Online ISSN : 2249-4626
Print ISSN : 0975-5896
DOI : 10.17406/GJSFR

Global Journal

of Science Frontier Research: H

Environment & Earth Science

Global Warming - Make it Rain

Development of Strong Convection

Highlights

International Environmental Laws

Methane Explosion Characteristics

Discovering Thoughts, Inventing Future

VOLUME 22 ISSUE 2 VERSION 1.0

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Volume 22 Issue 2 (Ver. 1.0)

Open Association of Research Society

Incorporation No.: 0423089
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250 USD (B/W) & 350 USD (Color)

Contents of the Issue

Global Journal of Science Frontier Research: H
Environment & Earth Science
Volume 22 Issue 2 Version 1.0 Year 2022
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

To Bring an End to Global Warming - Make it Rain

By William Van Brunt

Abstract- Over the last 40 years, the average global temperature has risen by 1°C and the catastrophic storm risk has tripled, as the latent heating power of the atmosphere grew, driven by the 15% increase in the average global concentration of the primary greenhouse gas, water vapor. Global warming and the catastrophic storm risk only worsen as the average global concentration of water vapor continues to increase at 0.4% $yr.^{-1}$ driving the average global temperature up at 0.2°C per decade. As the latent heating power of the atmosphere rose, the annual number of catastrophic, weather-related events increased to over 750, by 2019, 525 above the 1980 baseline of 225 annual events. Since 1980, these weather-related catastrophic events have taken tens of thousands of lives, wiped out whole communities while wreaking 4.6 trillion dollars in cumulative worldwide weather-related destruction, of which 2.4 trillion dollars is the result of global warming driven increasing atmospheric latent heating power, as shown by the close correlation of major weather-related events with the average global temperature record (correlation coefficient 0.84).

Keywords: climate change, global warming, carbon dioxide, water vapor, water vapor primary greenhouse gas, relationship of concentration of water vapor to average global temperature, latent heating, increasing latent heating power, global warming driven, major, weather-related, catastrophic events, limiting and reversing global warming, concentration of co_2 *cannot be reduced, precipitation, evaporation, reducing concentra-tion of water vapor, water vapor heating, crisis, existential threat, catastrophic damages, destruction, billion, trillion.*

GJSFR-H Classification: DDC Code: 150.195 LCC Code: BF408

TOBRINGANENDTOGLOBALWARMINGMAKEITRAIN

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To Bring an End to Global Warming - Make it Rain

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Keywords: *climate change, global warming, carbon dioxide, water vapor, water vapor primary greenhouse gas, relationship of concentration of water vapor to average global temperature, latent heating, increasing latent heating power, global warming driven, major, weather-related, catastrophic events, limiting and reversing global warming, concentration of co_2 cannot be reduced, precipitation, evaporation, reducing concentration of water vapor, water vapor heating, crisis, existential threat, catastrophic damages, destruction, billion, trillion.*

I. Introduction

Increasing precipitation to reduce the average global concentration of water vapor, can:

A. Reduce the rate of increase of and, if sufficient, reverse greenhouse heating; and,
B. Reduce the annual occurrence of massive weather-related disasters, lives lost and weather-related economic losses.

II. Background

- Earth is heated by the sun and the greenhouse gases, GHG. The main greenhouse gases are CO_2 and water vapor, the primary greenhouse gas.
- As the concentration of greenhouse gases grow, greenhouse heating and global warming increase.
- Between 1976 and 2019, as the result of an increasing concentration of greenhouse gases, the heating of the planet increased significantly, by 2.4%, increasing the average global temperature by 1°C, escalating the rates of evaporation, convection, precipitation and the rate of release of the potential energy (the "latent heat") of water vapor.
- Compared to the increase of ~ 0.2°C from 1880 to 1976, a period of 96 years, an increase of 1°C since 1976, in less than half that time, is significant. The average rate of increase in global temperature during this 45-year period is ten times the average rate of increase for the prior 96 years and there is nothing to suggest that it is slowing.
- Since 1976, the concentration of CO_2 increased by 82 ppmv, an increase in the atmospheric concentration, of 0.008%.
- What is generally ignored in the IPCC and related climate change literature is that the atmospheric concentration of water vapor, which accounts for 97% of greenhouse heating,[1] increased by 15%,

an increase in the atmospheric concentration of water vapor of 0.15%.

- This15%, increase, in parts per million, is 18 times greater than CO_2. When compared on a molecule-to-molecule basis, a molecule of H_2O has a heating efficiency 40 times greater than a molecule of CO_2. [2], Fig. 3(a)] Together, in terms of heating power, this is a water vapor increase at least 700 times greater than that of CO_2.
- This atmospheric concentration of water vapor is driven primarily by changes in sea surface temperatures in the Eastern Equatorial Pacific El Niño-Southern Oscillation, or "ENSO" region (5°N–5°S, 170°–90°W) and autonomous feedback, not by changes in the concertation of CO_2.
- While evaporative and precipitative rates are essentially equal, there are slight differences. When the rate of evaporation exceeds the precipitative rate, the atmospheric concentration of water vapor increases and vice versa.
- The year over year changes in the average global temperature correlate closely with changes in the average global concentration of water vapor. However, it is not the changes in temperature that are the direct near-term concern. It is the indirect effects.
- As the average global temperatures rise, the rate of evaporation increases. As water vapor condenses into droplets, the energy absorbed at evaporation, its "latent heat," is released, heating the surrounding air, causing the moist air to rise. Increases in the evaporative rate drive increasing latent heating power. This release of latent heat plays a major role in the formation of thunderstorms and hurricanes.
- Since precipitation and evaporation are essentially equal, the precipitative rate and therefore the latent heating power also rise, increasing the intensity and number of catastrophic weather events.
- Since 1980, major weather-related loss events have more than tripled, driven by a 10% increase in latent heating power.
- Since 1980, increasing greenhouse warming and resultant latent heating power increases fueled 9,000, additional, catastrophic storms, above the baseline of 8,800 such events. These global warming driven events increased each year at a rate of $11.8 yr.^{-1}$, taken thousands of lives, wiped-out whole communities, wreaking nearly 2.4 trillion dollars in cumulative worldwide destruction by 2019. The number of annual weather related catastrophic events tripled with 525 additional annual events, 130 billion $dollarsyr.^{-1}$over the 1980 baseline.
- The global effort to eliminate carbon dioxide, CO_2 emissions, cannot reduce the concentration of CO_2. CO_2 does not breakdown nor does it react with other atmospheric gases. Reducing CO_2 emissions can only limit the rate of increase in the concentration of CO_2. Today, the concentration of CO_2 continues to increase at 2 ppmv yr^{-1}. If carbon emissions were wholly eliminated, CO_2 will remain at or close to the highest level reached to that date. Any meaningful net, natural reduction in the concentration of CO_2 would take decades to centuries.
- With this realization, a number of novel and massive geo-engineering "concepts," which are briefly summarized in the Appendix, to reduce the concentration of CO_2 and/or solar heating, none of which have been shown to be feasible, much less workable and environmentally sound, but if one were, it is still unclear:

a. How effective it would be;
b. How long would it take to fully implement;
c. Whether it would it be difficult to control and terminate;
d. What investments would be required; and,
e. What the ongoing costs are likely to be.

when multiple ways to increase precipitation are well-known and practiced, suggestions to reduce the concentration of water vapor have not been set out.

- With respect to efforts focused on the reducing the concentration of CO_2:

a. The atmospheric concentration ofcarbon dioxide, CO_2, continues to increase at two parts per million, ppmv, annually. That is an increase of 23 billion metric tons of CO_2 each year.
b. CO_2 is well mixed in the atmosphere, with an average concentration today less than 0.05%. This means that, if removal were possible, it would be a slow process because for every ton of CO_2 eliminated, 2,000 metric tons of air, would have to be processed or for 2 ppmv that would be 46 trillion tons.

Thus, any suggestion that a significant reduction in the concentration of CO_2 can be achieved within a reasonable period of time is wholly unrealistic.

- However, as shown below, the concentration of water vapor can be reduced by increasing precipitation and if water vapor reductions are effected, the worsening global problem that is global warming, the immediate catastrophic weather threat and an existential climate change threat to the populations of ever-expanding regions of the globe, can be limited and reversed.

III. Variations in Global Temperature

As noted above, between 1880 and 2019, as the result of an increasing concentration of greenhouse gases, the average global temperature increased by 1ºC as is shown in Figure 1. Also set out in Figure 1 are the yr./yr. changes in the average global temperature.

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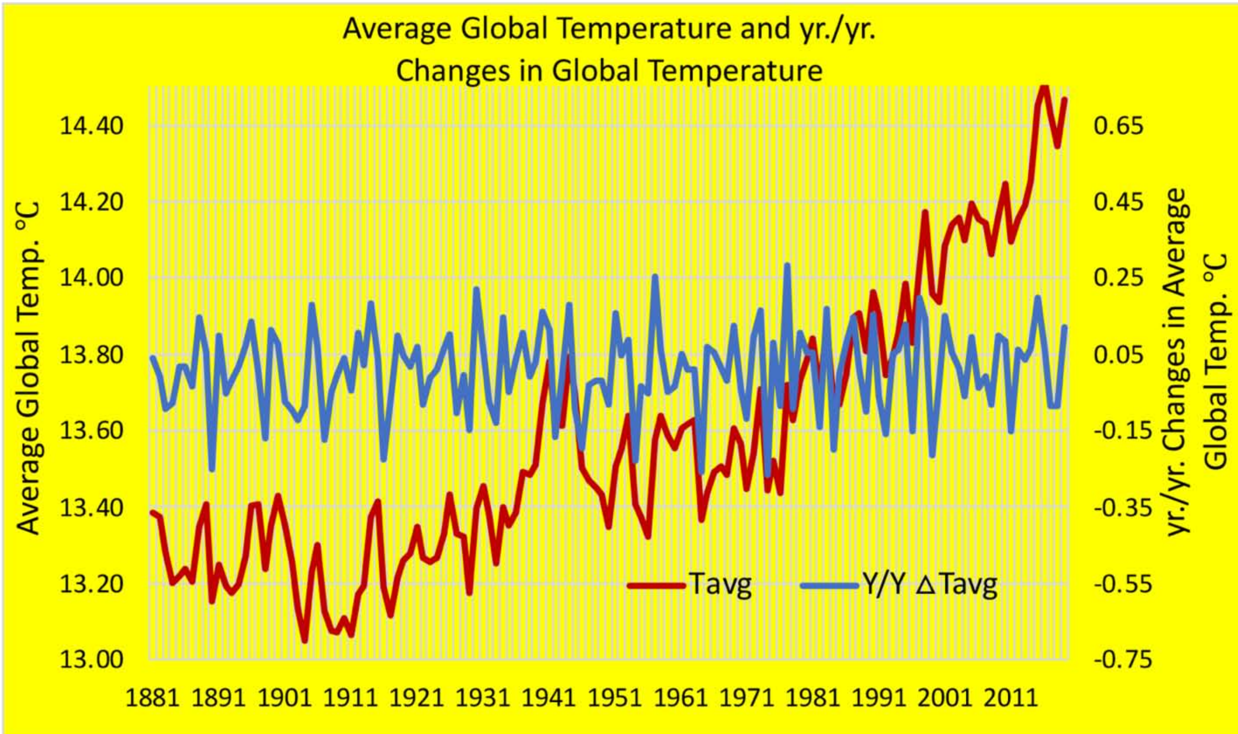

Figure 1: From NOAA Data [3-4] - Average Global Temperature, T_{Avg} plotted against the left vertical axis and yr./yr. changes in the Average Global Temperature plotted against the right vertical axis from1881 to 2019 shown on the Same Scale

While the focus is, as it should be, on the trend in the average global temperature since 1976, the year over year changes in temperature, as much as 0.28 ºC in a single year, 28% of the total change in the average global temperature over this period, are significant.

The question is – what drives the year over year changes in the global temperature shown in Figure 1?

IV. Calculating Changes in the Concentration of and Resulting Changes in Average Global Temperature[1]

Current climate change forecast models, based on the assumption that the increasing concentration of CO_2 drive climate change, when applied retroactively, "hind cast", and compared to the historical temperature record do not, cannot, replicate this record. Given that:

- From 1880 to 2019, there are 140 measurements or estimates of the average annual global temperature, the average annual global temperatures of land and the seas and the average global concentration of CO_2;
- While the 1°C increase in the average global temperature since 1976 is a very serious problem, the annual changes in average global temperature are small, reflecting an increase of only 0.02°C ~ 0.008%/yr., on average, (See Figure 2 setting out the average global absolute temperature from Figure 1 for the period 1880 to 2019); and,

[1] Note: The assumptions underlying and the derivations of this and the other two Principles and all of the data underlying this work appear in the Tables and in the Supplementary Materials, which are too lengthy to repeat here and are also all fully set out in [5].

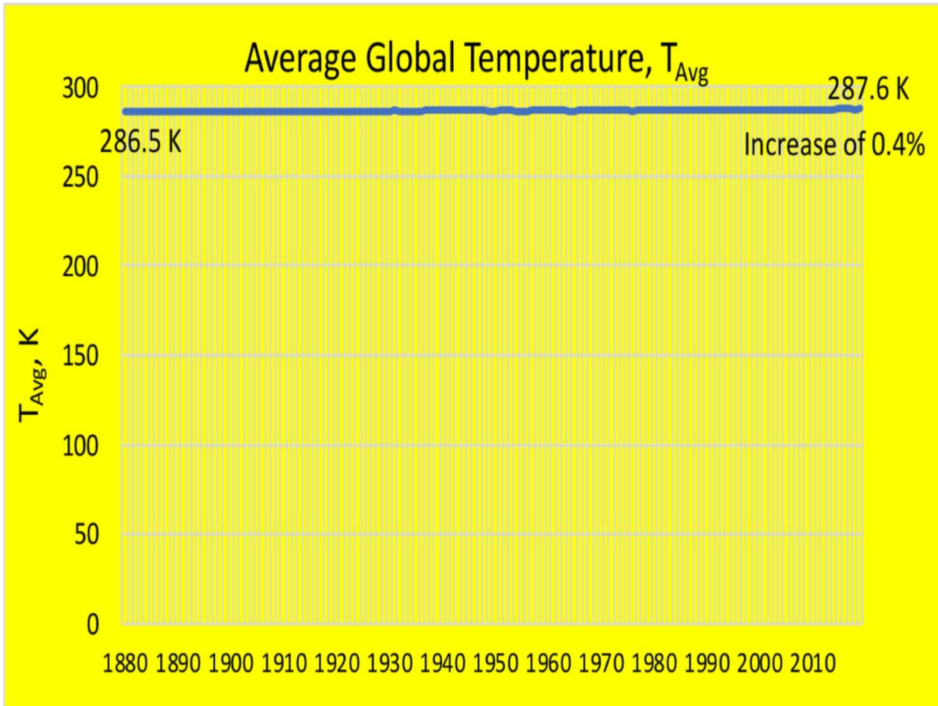

Figure 2: Average Global Absolute Temperature from Figure 1, K

- Changes in the annual average global net absorbed GHG heating, the energy available after the energy absorbed by evaporation and convection, that drove those changes were, therefore, also small, hence, the annual average global temperature determinations clearly represent equilibrium temperatures and calculating the average global net absorbed heating from greenhouse gases at the surface of each of the land and sea, for each year, is straightforward, identifying the key drivers of changes in the average global temperature and precisely determining the annual changes in the average global concentration of water vapor and the effect of these changes on average global temperature can be achieved through the application of the following three basic principles of atmospheric physics.

V. The First Principle – Determining Changes in the Concentration of Water Vapor

As greenhouse heating escalates, sea surface temperatures rise, evaporation increases and the average global concentration of water vapor, TPW, grows.

There are two major factors affecting average global evaporation and changes in the concentration of water vapor:

1. Average global, steady state, sea surface temperature, SST; and,
2. Changes in average global total heating, since for the seas, ~ 64% of the increase in average global total heating is absorbed in driving evaporation.[5]

This is captured by the First Principle- the change in the average global concentration of water vapor, ΔTPW resulting from a change in evaporation in response to a change in a) sea surface temperature, SST and b) total heating, TH, is proportional to the change in total heating,ΔTH and an exponential function of the change in the average global Sea Surface Temperature, ΔSST. [5]

$$\Delta TPW = 0.157\Delta TH + 17.5\left\{e^{[0.0686(SSTo + \Delta SST) - 288)]} - e^{[0.0686(SSTo) - 288)]}\right\} \text{ kgm}^{-2} \quad (1)[5]$$

Where, ΔTH is the change in annual average Global total heating, W m^{-2}

ΔSST is the change in the average Global Sea Surface Temperature, ^{o}C

Applying this formulation, percentage changes in the average global concentration of water vapor from 1880 are plotted in Figure 3 against percentage changes in the average global temperature measured in Kelvin.

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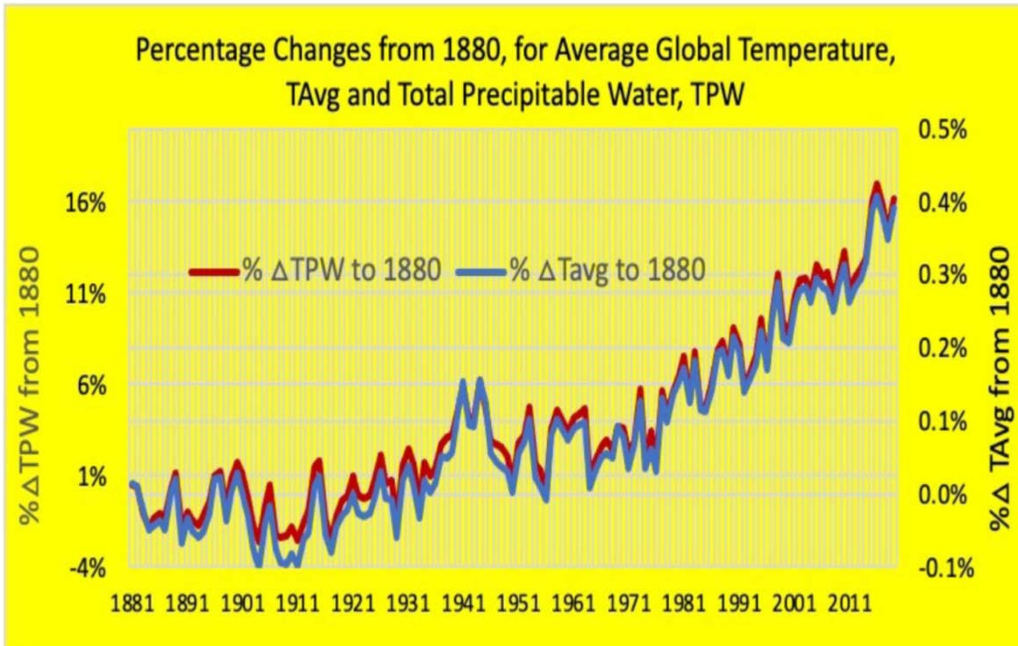


Figure 3: Percentage Changes in the Average Global Temperature, K, % ΔT_{Avg} Compared to Percentage Changes in The Concentration of Water Vapor, %ΔTPW, over 1880

Figure 3 shows the annual percentage changes from 1880 in the absolute average global temperature, ΔT_{Avg} and the calculated concentration of water vapor %ΔTPW. The correlation coefficient is 0.998.

VI. Comparing Calculated Changes in the Concentration of Water Vapor to the Data

From Eqn. 1, the average global concentration of atmospheric water vapor is calculated to have been 18.4 kg/m² in 1880. The results of the application of this Principle to NOAA data for 1996 – 2007, in g cm^{-2} (10 kg m^{-2} = 1 g cm^{-2}) is set out in Table 1.[5]

That this is accurate is shown in Figure 4.

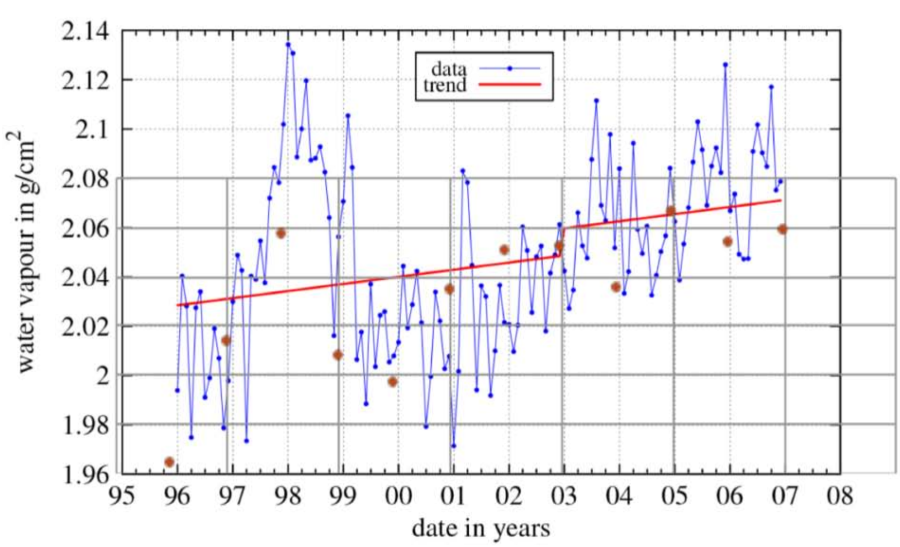


Table 1

Year	TPW gcm-2
1996	1.964
1997	2.013
1998	2.056
1999	2.008
2000	1.997
2001	2.034
2002	2.050
2003	2.052
2004	2.035
2005	2.066
2006	2.053
2007	2.058

Figure 4: Changes in the Concentration of Water Vapor[6]

The calculated average annual results for each year are shown as red dots and can be compared to the monthly global concentration of water vapor concentration data from satellite measurements along with their trendline (red line), in Figure 4. On average this trendline is within 1% of the trendline of the calculated TPW values, thus, demonstrating the validity of the First Principle, Eqn. 1.

These changes in the average global concentration of water vapor, △TPW drive changes in water vapor heating, △WV.

$$\Delta WV = 73.3 \ln(1 + \Delta TPW/TPW_o) \quad Wm^{-2.} \qquad [5]$$

How these changes in water vapor heating drive changes in the average global temperature is shown, below.

VII. The Second Principle – The Relationship between Average Global Temperature and the Concentration of Water Vapor

The effect of changes in the average annual concentration of water vapor, from Eqn.1on the annual average global temperature is set out as Figure 5 showing the average global temperature, T_{Avq} and concentration of water vapor, TPW, each for the same year.

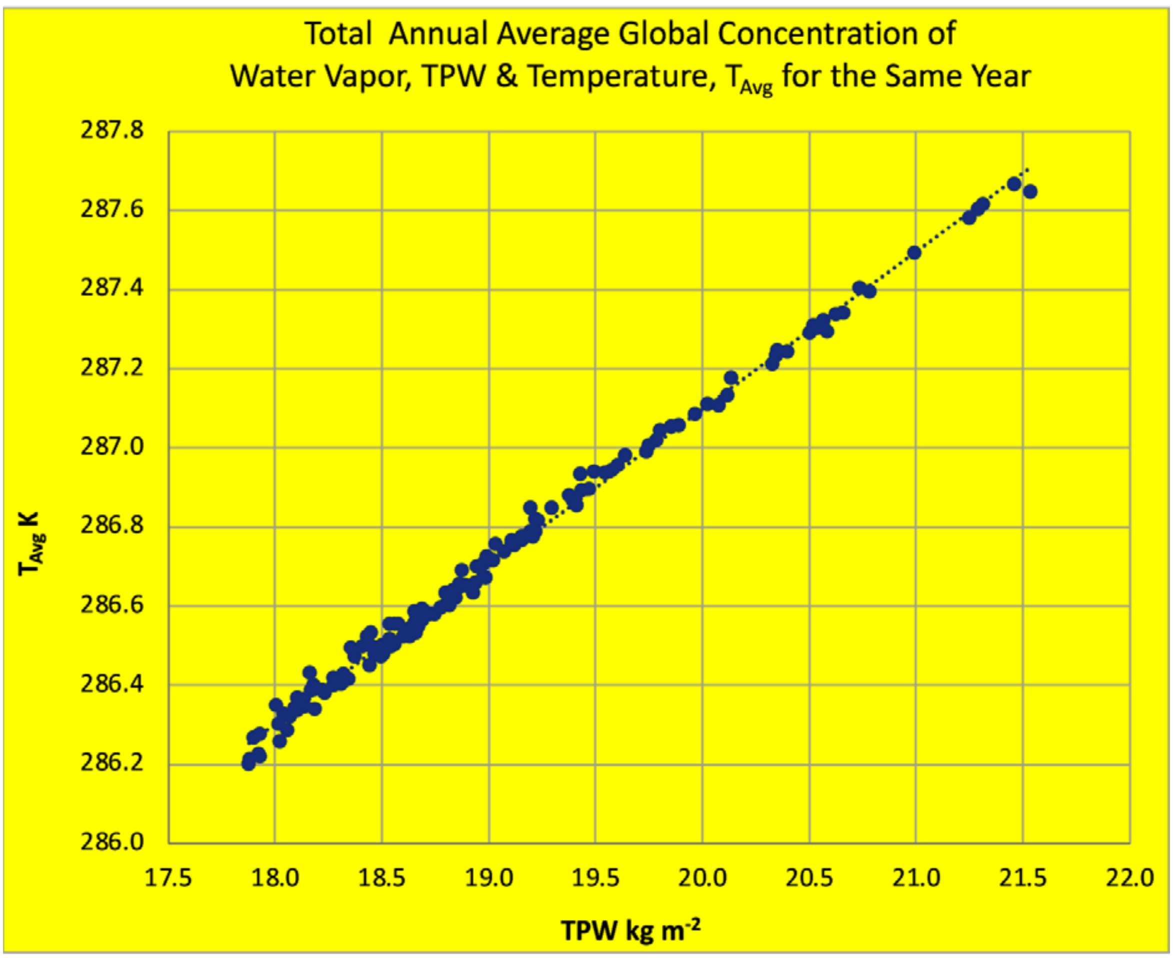


Figure 5: Annual Average Global Temperature, T_{avg} and Concentration of Water Vapor, TPW

The slope of the trendline set out in Figure 5 is 0.39 T_{Avg}/TPW with an R^2 of 0.995. The effect of the concentration of water vapor, TPW in kg m^{-2} on average global temperature, $T_{Avg,}$ K, is therefore:

$$T_{Avg} = 0.39\ TPW + 279.1 \qquad (2)$$

Eqn. 2 is the new Second Principle.

This principle of atmospheric physics is a data-based discovery, the validity of which is demonstrated by the correlation coefficient of average global temperature, T_{Avg}, to the calculated concentration of water vapor, TPW, of 0.998.

Eqn. 2 shows that a reduction in the concentration of water vapor will result in a reduction in average global temperature.

VIII. The Third Principle - Changes in the Concentration of Water Vapor are not Just Responsive To, These Changes Can Initiate and Drive Changes in the Average Global Temperature

From Eqn. 1, the year over year percentage change in the concentration of water vapor, △TPW, along with year over year percentage change in the average global absolute temperature, [1-3] for the period 1880 to 2019, is set out in Figure 6.

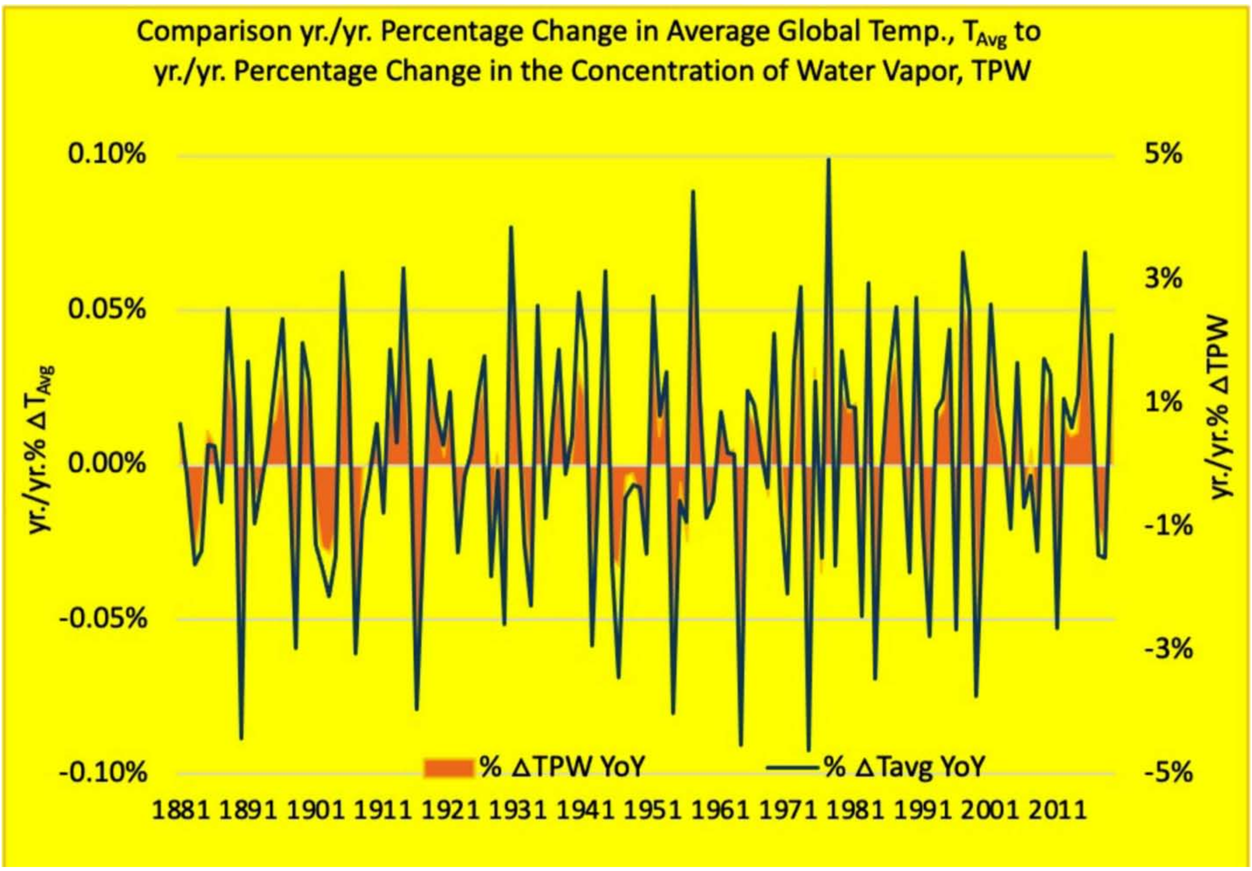


Figure 6: From Eqn. 1 yr./yr. Percentage Changes in the Annual Average Global Temperature, Tavg, Measured in Kelvin, compared to yr./yr. Percentage Changes in the Concentration of Water Vapor, TPW

The correlation coefficient of yr./yr. percentage changes in the average global temperature and yr./yr. percentage changes in the concentration of water vapor is 0.98.

A plot of the change in the Annual Average Global Temperature, ΔT_{Avg}, against the change in the average annual global concentration of water vapor, △TPW, each for the same year. is set out as Figure 7.

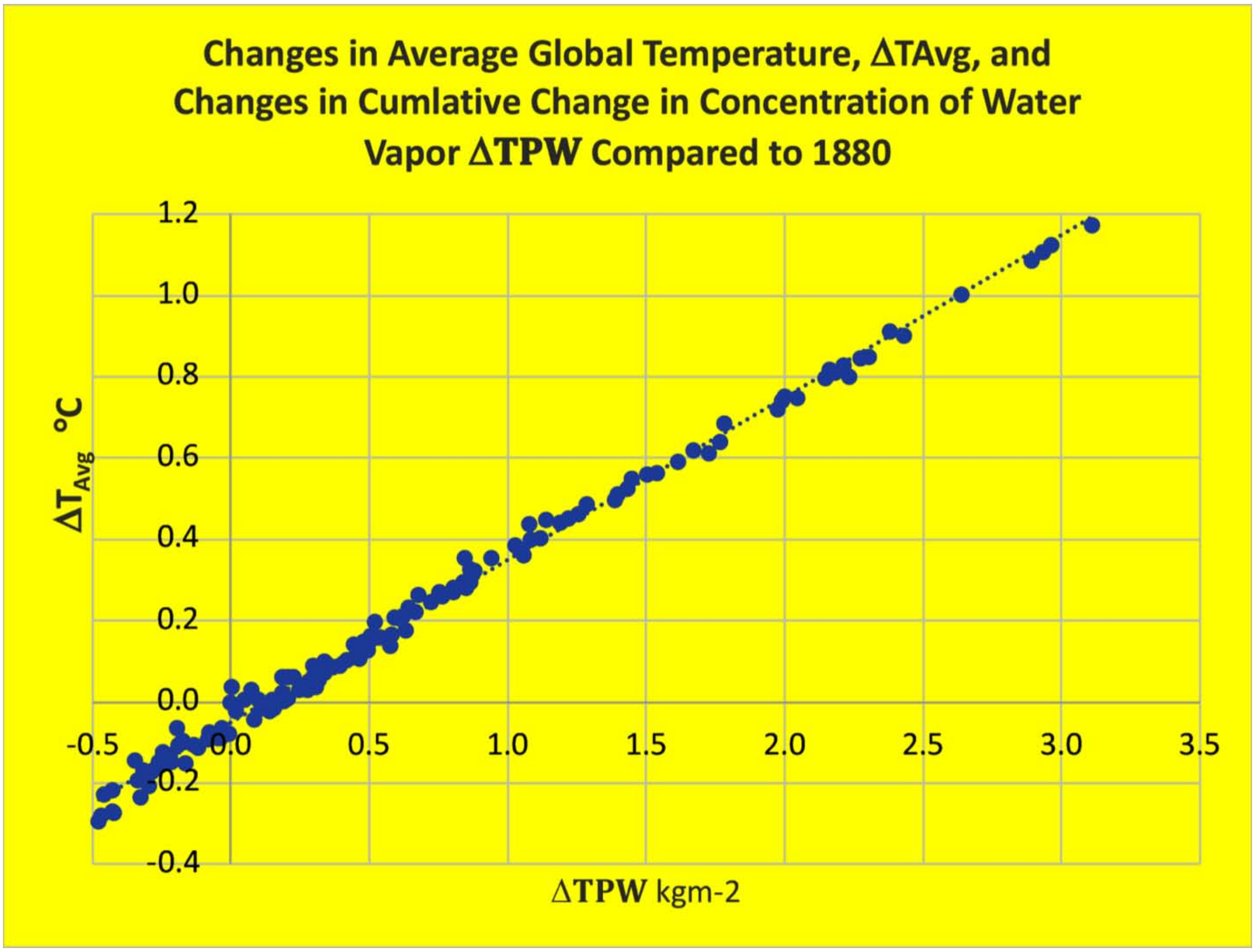


Figure 7: Changes in the Average Global Temperature ΔT_{avg} and in the Average Global Concentration of Water Vapor, ΔTPW Applying Eqn. 1 For Each Year Compared To 1880

The slope of the trend line shown in Figure 7, with an R^2 of 0.9953 and the effect of changes in the concentration of water vapor, ΔTPW in kg m^{-2} on changes in the average global temperature, ΔT_{Avg} in Celsius, is therefore:

$$\Delta T_{Avg} = 0.39\, \Delta TPW\ °C \qquad (3)[5]$$

For these small changes, this is an accurate approximation of the first derivative of Eqn. 2, in Figure 7, with an R^2 of 0.9953 and the effect of changes in the concentration of water vapor, ΔT_{Avg} / in Figure 7, with an R^2 of 0.9953 and the effect of changes in the concentration of water vapor, ΔTPW = 0.39.

Eqn. 3 is the Third Principle.

Because this formulation is a data-based discovery, it takes into account the effects of changes in cloud cover and all other GHG.

The correlation coefficient of the computed ΔT_{Avg} with actual is 0.998. This precise replication of the temperature data validates Principles 1- 3.

IX. Changes in the Average Concentration of Water Vapor are Not Driven by Changes in The Concentration of CO_2

In response to the contention that it is changes in the concentration of water vapor that drive climate change; based on the assumption that CO_2 is the sole driver, the assertion is made that changes in the concentration of water vapor are driven by changes in CO_2 heating, with water vapor heating a feedback effect of the changes in CO_2 heating.

Applying Eqn. 1, changes in the average global concentration of water vapor between 1976 and 2019 are set out in Figure 8.

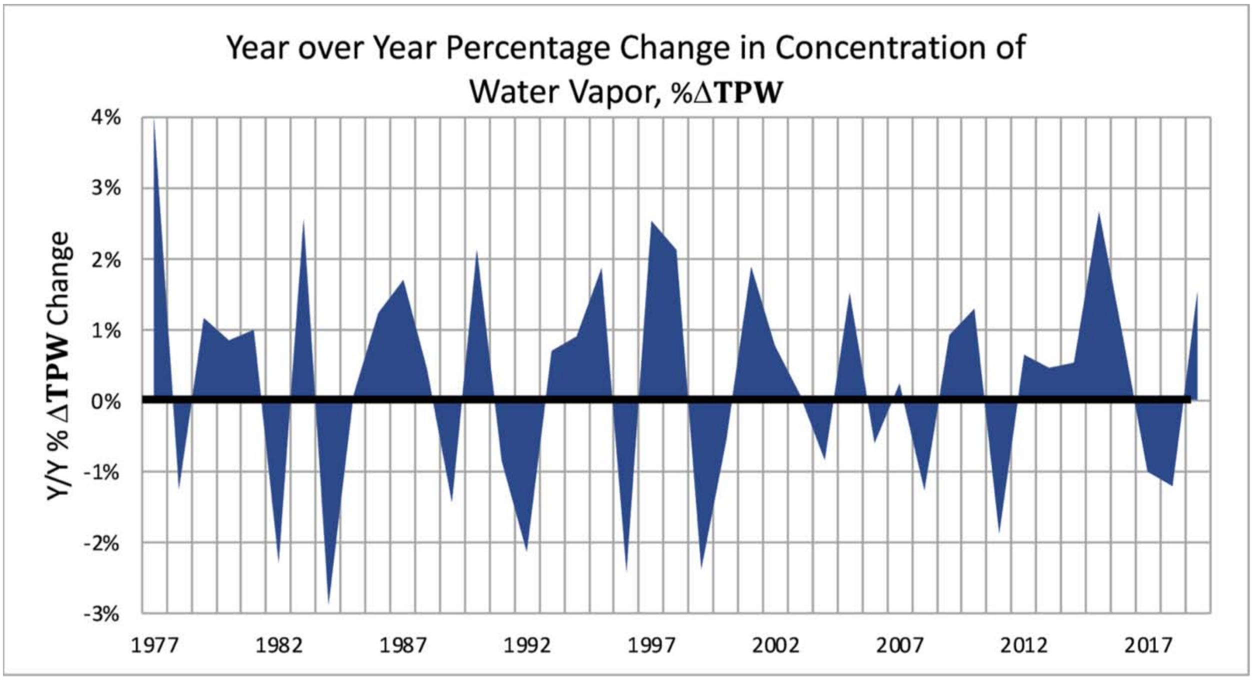


Figure 8: Year over percentage changes in the Global concentration of Water Vapor, % ΔTPW

A change in the concentration of water vapor simply requires a difference between the average change in evaporation, ΔEV and the average change in precipitation ΔPR, for the same time period.

$$\Delta TPW = \Delta EV - \Delta PR \quad (4)$$

Thus, changes in precipitation relative to the changes in evaporation or changes in evaporation stemming from changes in surface temperature unrelated to changes in GHG heating can both drive changes in the concentration of water vapor.

X. Changes in the ENSO Drive Changes in the Concentration of Water Vapor

For example, El Niño driven increases in the Eastern Equatorial Pacific El Niño-Southern Oscillation, or “ENSO” region (5°N–5°S, 170°–90°W) ENSO region Sea Surface Temperatures drive local changes in evaporation and the concentration of water vapor in this region.

These changes in the local concentration of water vapor and water vapor heating disseminateas water vapor and water vapor heating spread outside the ENSO region through large, positive, vertically integrated, water vapor transport anomalies, peaking globally four months later[2]. [7]

Figure 9 is Figure 8 including year over year percentage change in the average Enso region SST for the 12-month period commencing September of prior year.

[2] It has been found that that the rainfall evolution in the tropical Pacific associated with the ENSO SST anomalies lags one season followed by an atmospheric lag in associated weather events outside the ENSO region of 1–3 months. [13]

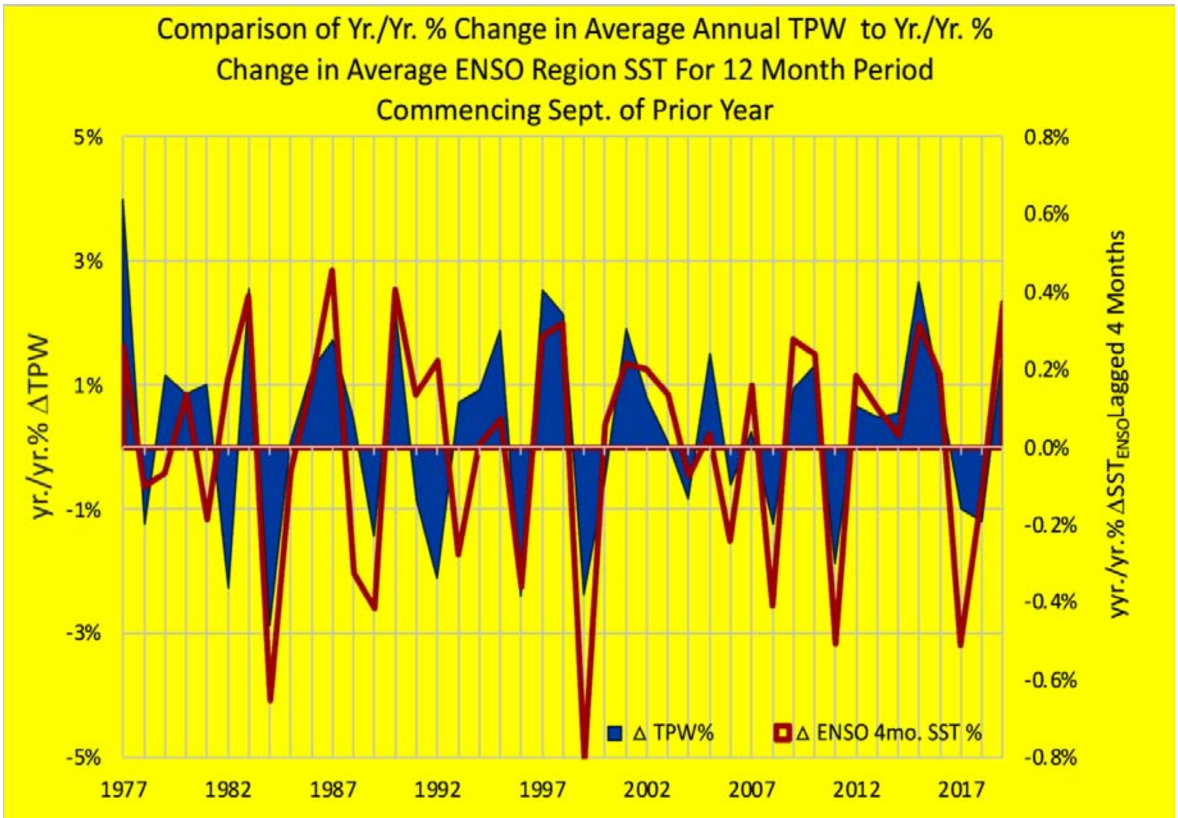


Figure 9: Year Over Year Percentage Change in the average Annual TPW Applying Eqn. 1, Plotted Against the Right Vertical Axis to Year Over Year Percentage Change in the Average ENSO Region SST for the 12 Month Period Commencing September of Prior Year[3] Plotted Against the Right Vertical Axis

As shown in Figure 9, there is a strong correlation between changes in the global concentration of water vapor and changes in Sea Surface Temperatures in the ENSO region lagged four months to capture the effects of water vapor as it rises from and spreads beyond this region. The correlation coefficient is 0.7.

Thus, as shown in Figure 9, it is clear that the year-to-year variations in the average global concentration of water vapor and therefore temperature, are largely the result of ENSO driven changes in the concentration of water vapor.

XI. ENSO SST Changes Arise Independently of Changes in GHG Heating

Changes in the ENSO region SST arise independently of changes in greenhouse heating. See Figure 9.

[3] Note: The changes in the concentration of water vapor, changes in total precipitable water, ΔTPW, shown in Figure 4 are determined solely from the NOAA data. The ENSO SST data comes from the monthly Oceanic Niño Index (ONI). [14]

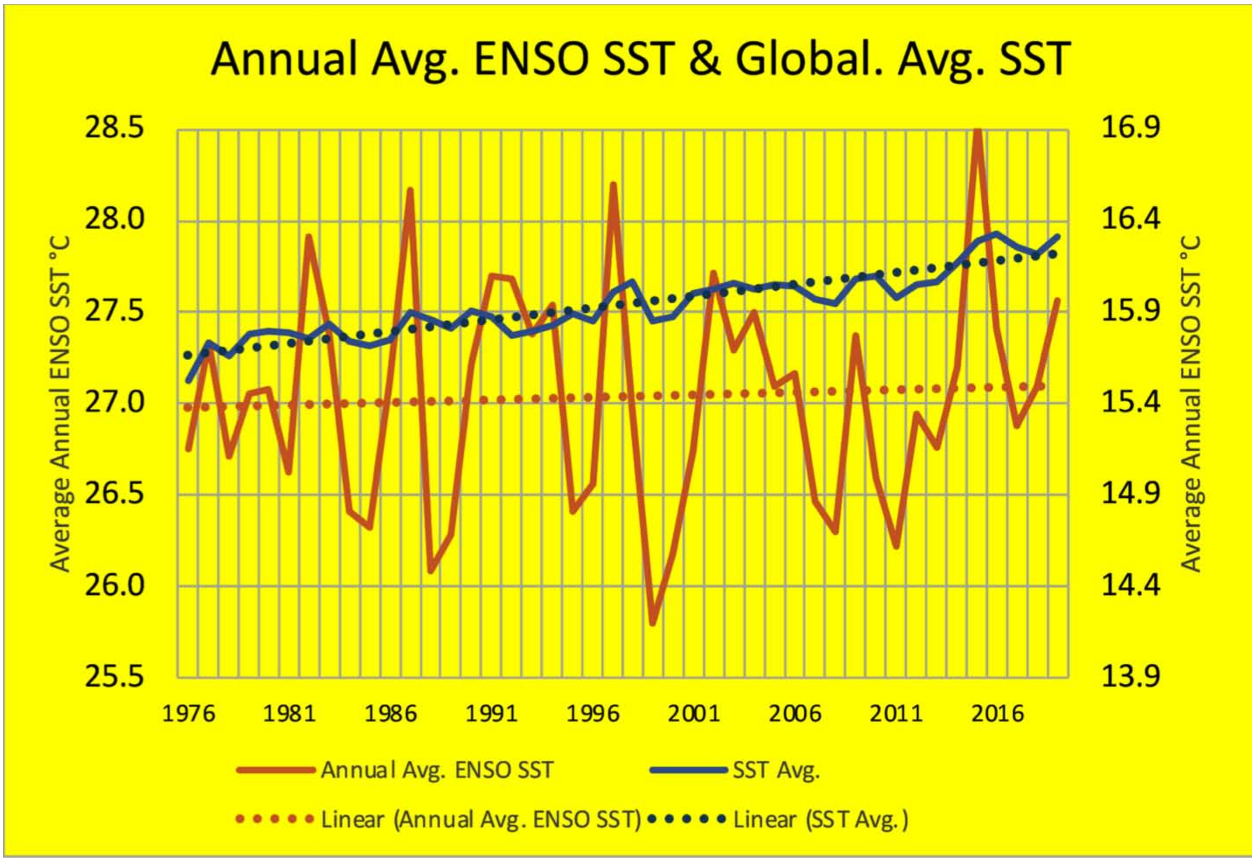


Figure 10: Annual Average Global SST & ENSO SST

There is no correlation between the SST record for the ENSO region shown in orange and the average global SST record, shown in blue, which reflects changes in greenhouse heating. The scales are the same. There is no correlation between changes in the global SST and the ENSO SST.

The trendline for the global SST is 0.13°C yr^{-1} with an R^2 of 0.83. The trendline for the ENSO SST is 0.003°C yr^{-1} with an R^2 of 0.0035, essentially flat. There is no correlation. The correlation coefficient for these two temperatures is 0.28.

Thus, changes in the ENSO region SST arise independently of and are not directly or indirectly driven by or related to changes in the average global temperature.

XII. Other Changes in Water Vapor Heating Can Arise Autonomously, Independently of Changes in the Concentration of CO_2

As a general matter, it is accepted that increases in the concentration of water vapor increase greenhouse warming.

While climate experts agree that increases in the concentration of water vapor require an increase in surface temperature; a position wholly in line with Eqn. 1, the assertion is made that changes in surface temperature are initiated or driven solely or primarily by changes in heating resulting from changes in the concentration of CO_2.

This certainly does not explain reductions in temperature and as to increases, is clearly not the case with El Niño driven changes. To the extent that the position is maintained that the increasing surface temperature is initiated or driven by an increase in the concentration of $CO_2$and the resultant increase in CO_2 heating, it cannot be science based. The relationship between climate change and changes in the concentration of CO_2 and water vapor can be summed up as follows:

The correlation coefficient of yr./yr. percentage changes in the average global temperature and yr./yr. percentage changes in the concentration of water vapor is 0.98.

If increases in the concentration of CO_2 drove the increases in the average global temperature, the year over year changes in the concentration of CO_2 would correlate with the year over year changes in the average global temperature. See Figure 10.

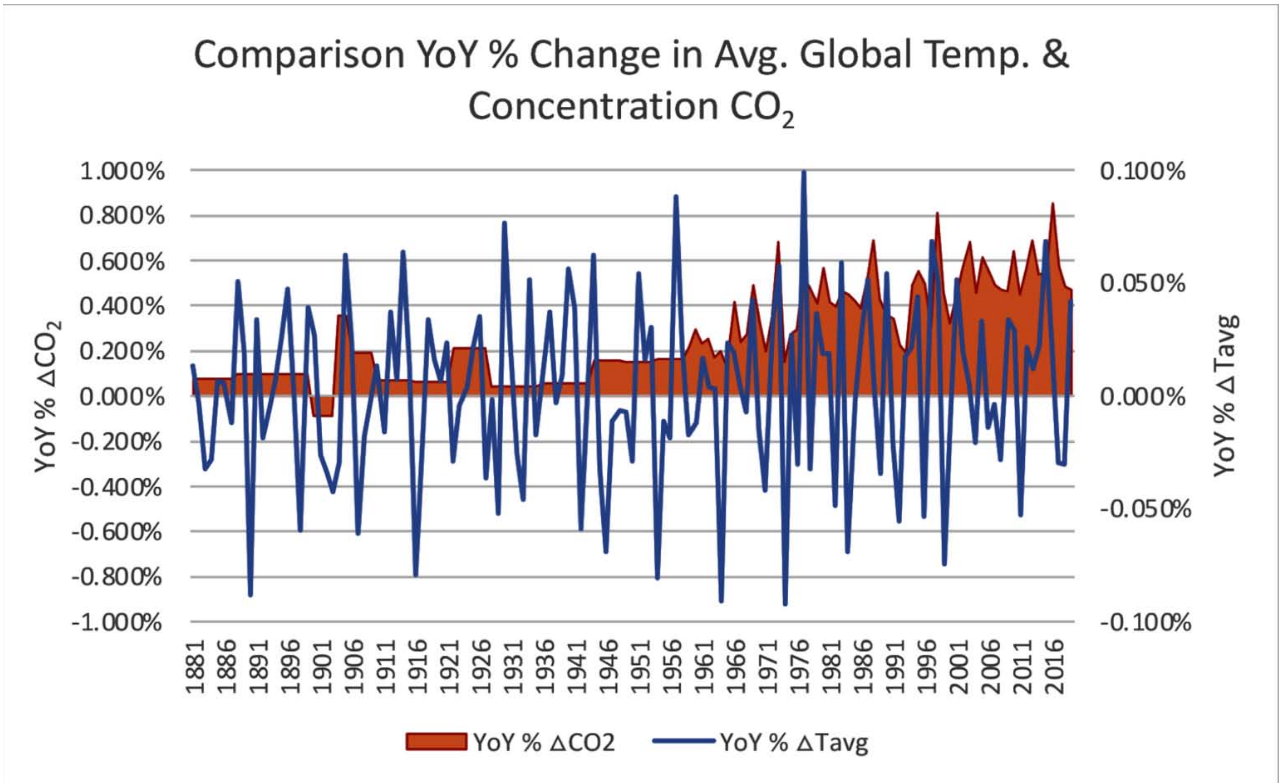


Figure 10: Comparison of yr./yr. percentage changes in concentration of CO_2shown in orange as gauged by the left vertical axis to yr./yr. percentage changes in average global temperature shown in blue and plotted against the right vertical axis

There clearly is no correlation between percentage changes in average global temperature and percentage changes in the concentration of CO_2 as confirmed by the correlation coefficient of 0.16 – no correlation.

Moreover, CO_2 based Climate Change Models [8] cannot accurately replicate the historical temperature record. In many cases, the 95% envelope for calculations of past temperatures from the CO_2 based forecast models is roughly ± 0.3°C, 60% of the increase in the average global temperature since the mid-seventies. Those models to which this confidence level applies do not accurately replicate the data. Therefore, the theories underlying them are invalid.

There is no correlation between changes in the concentration of CO_2 and changes in the average global temperature. Changes in average global temperature arise independently of and not driven by changes in the concentration of CO_2.

Nor, for the same period, is there a correlation between the year over year changes in the global concentration of water vapor and changes in the concentration of CO_2. Changes in the concentration of water vapor, ΔTPW, which some presume to be driven by changes in temperature resulting from changes in the concentration of CO_2 are also wholly unrelated to changes in the concentration of CO_2.

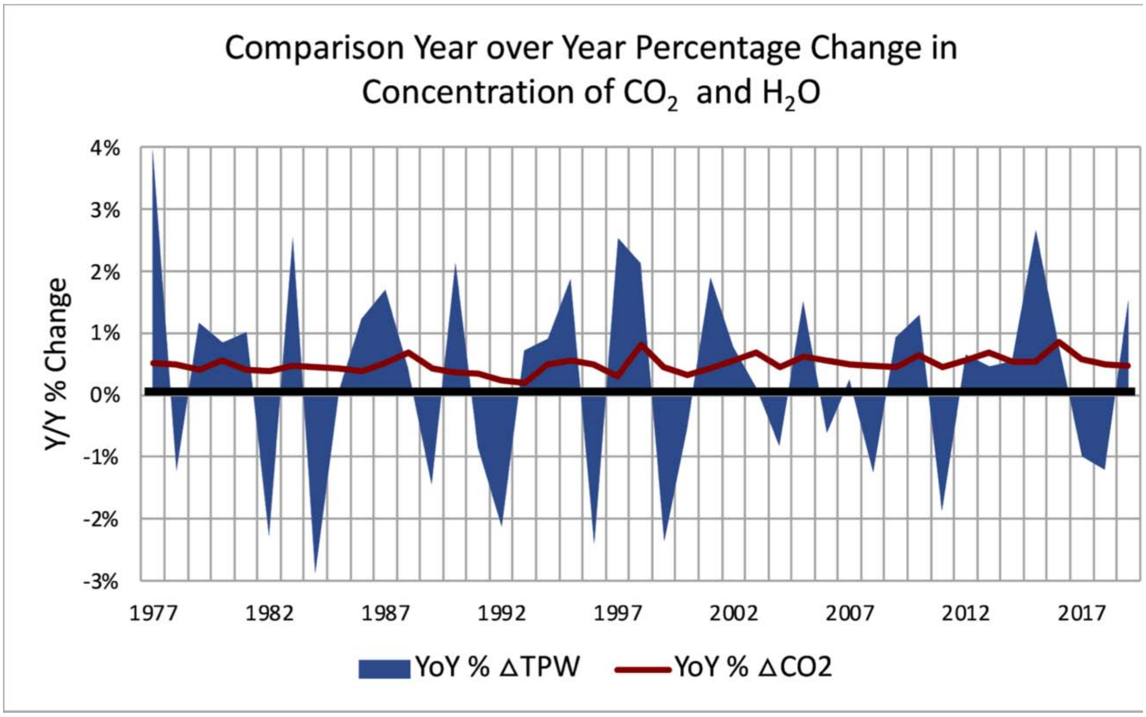


Figure 11: Comparison of year over percentage changes in the global concentration of water vapor, $\Delta\mathrm{TPW}$, and carbon dioxide, ΔCO_2

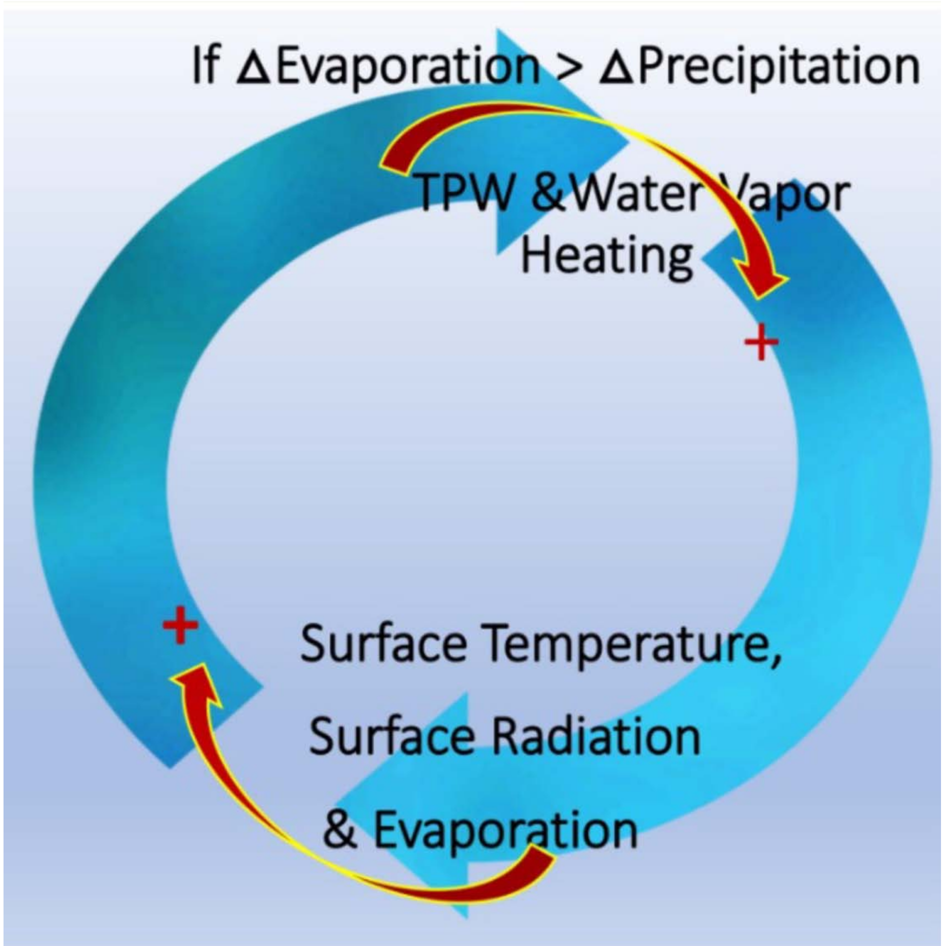
Figure 11 is a comparison of year over percentage changes in changes in the global concentration of CO_2, $\%\Delta CO_2$, shown in red, between 1977 and 2019 and the global concentration of water vapor, $\%\Delta\mathrm{TPW}$, shown in blue, calculated in accordance with Eqn.1, as a function of annual changes in average global total heating and average global sea surface temperature. There is no correlation. The correlation coefficient is 0.21.

In terms of the physics, since 1977, 20% of the yr./yr. changes in the concentration of water vapor were negative while the changes in the concentration of CO_2 were all positive. Increases in the concentration of CO_2 cannot drive reductions in the concentration of water vapor.

On the other hand, when compared to the to the historical temperature record, as shown in Figure 3, the average global temperature determined using Eqns. 1 & 2 has a correlation coefficient of 0.998 with the greatest temperature difference being 0.11°C.

Proof of a theory lies in the data. Here, the match is nearly perfect.

In addition to there being no correlation between changes in the concentration of CO_2 and ENSO effects, changes in the average global concentration of water vapor, changes in the average global concentration of water vapor can arise independently of and not be driven by changes in the concentration of CO_2.



Self-Sustaining Increase in Heating

As shown in this illustration, evaporation and water vapor heating can be in an autonomous, positive feedback loop. As the concentration of water vapor increases, water vapor heating and evaporation increase. If the rate of evaporation exceeds precipitation, the concentration of water vapor increases; on and on.

A characteristic of positive feedback loops is that absent external intervention, they continue. Therefore, to the extent evaporation exceeds precipitation, this continues. Only increases in precipitation, which occur, break this wholly autonomous cycle.

XIII. The Need to Increase Precipitation

In any event and regardless of the cause of the continuing increase in the concentration of water vapor, Eqn. 3 is correct; reductions in the global concentration of water vapor will reduce the rate of increase in the average global temperature and can reverse the increase. A sufficient increase in precipitation will do just that.

But while the above shows the role played by, effects of and the underlying causes in the annual variability in the concentration of water vapor, this has likely gone on for centuries without driving the global warming currently being experienced since 1976. The question is – what is driving this?

The average increases in precipitation are less than the average increases in evaporation, since 1976. Why?

To go from water vapor to the formation of raindrops necessary for precipitation generally requires a catalyst in the form of microscopic aerosol particles or molecules of air ionized by cosmic rays.

When present at an altitude at which the atmospheric temperature is below the dew point, water vapor condenses on these particles/molecules which are referred to as cloud condensing nuclei, CCNs, to form raindrops.

Between 1911 and 1941 the average global temperature increased at a slightly greater rate. This warming trend ceased in 1944, when in 1945, precipitation exceeded evaporation.
Then why wouldn't this repeat?

It might, but there is likely a significant difference between 1944 and the years since 1976 - a diminished concentration of aerosols and a resulting increase in the concentration of water vapor.

Possible causes:

- Clean Air Act - Since the advent of the Clean Air Act in the 70's and similar efforts in Europe, the average concentration of aerosols over land has declined; between 2003 and 2012, by more than 7%, while over the oceans, there was only a slight increase. The result a slight net decline, globally, during this period;[9]
- The incidence of atmospheric penetration of ionizing cosmic rays and resulting cloud condensing ionized air molecules may have also declined.[10]

But whatever the cause of the average global evaporation >average precipitation imbalance since 1976, what should occur is the testing of practical and controllable mechanisms to appropriately increase the atmospheric concentration of iWilliam Van Brunt Page 15 3/17/22) ionized air molecules and ii) environmentally safe aerosol particles, such as ice crystals at the right times in the right locations.

If this is successful, and the average global precipitative rate can be maintained in balance with the average global evaporative rate, increases in the average global temperature will be halted.

Moreover, by driving just a slight increase in annual global precipitation relative to evaporation, the rate of increase in global warming cannot only be reduced, it can be reversed, even to the point of returning the planet to the average global temperatures last seen in the mid-seventies.

If this can be shown to be feasible, the economics would have to be examined, but one advantage is that the location and the periods of operation can be selected. Therefore, the effects can be monitored and controlled.

Between 1976 and 2019, the average global temperature rose by 1.03 °C. To effect this reduction the average global concentration of water vapor would have to be reduced by:

$$\Delta \mathrm{TPW} = 2.5 \times 1.03 = 2.64 \text{ kg m}^{-2} \text{ or mm m}^{-2}$$

The physics, Eqn. 3, shows that if the average global precipitation can be increased, just slightly, from 985 to 988 mm, which is only 0.3% more than average annual precipitation, or an average increase of 0.008 mm/day, for one year, the concentration of water vapor, thus water vapor heating, will be reduced to the point that the average global temperature will revert to the average global temperature for 1976, 13.5°C. This temperature reduction will be maintained, if, thereafter, the rate of precipitation compared to the rate of evaporation remain or can be kept substantially in balance.

In terms of timing and geography one region that could be considered for increasing precipitation is the ENSO region during El Niño events, which as shown in Figure 9, are the primary drivers of yr./yr. increases in the average global temperature. This has the added benefit of reducing the likelihood of flooding. A global average of 2.9 mm yr.-1,is the equivalent 0.4 m yr.-1 increase in precipitation, for the Enso region, which isroughly equivalent to quarterly precipitation anomalies for major areas within the ENSO region.[11]

XIV. Latent Heating & Major Weather Events

Every year the insurance industry publishes data on losses from natural disasters, worldwide, including major meteorological, climatological and hydrological losses, weather-related losses.

Set out in Figure 13 are the annual numbers of major, natural, catastrophic events.

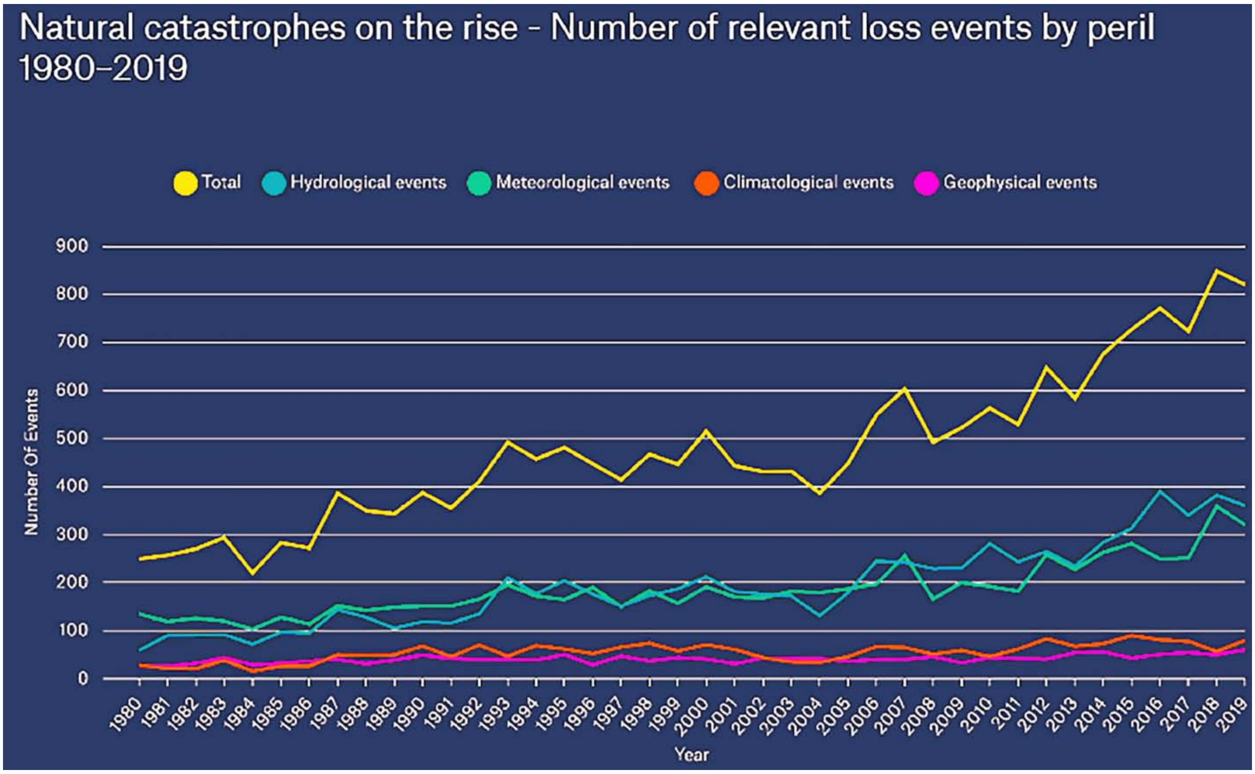


Figure 13: Annual Number and Type of Natural Catastrophes by year 1980 – 2019 [12]

Figure 13, deducting the geophysical events, the annual major weather-related loss event are set out in Table 1A and Figure 14.

Table 1A

Year	No. Major Weather-Related Events
1980	225
1981	250
1982	260
1983	250
1984	180
1985	250
1986	230
1987	250
1988	300
1989	300
1990	340
1991	300
1992	350
1993	450
1994	400
1995	440
1996	450
1997	350
1998	410
1999	390
2000	460
2001	400
2002	370
2003	360
2004	350
2005	400
2006	450

2007	550
2008	450
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2010	500
2011	520
2012	550
2013	600
2014	550
2015	600
2016	670
2017	725
2018	790
2019	750

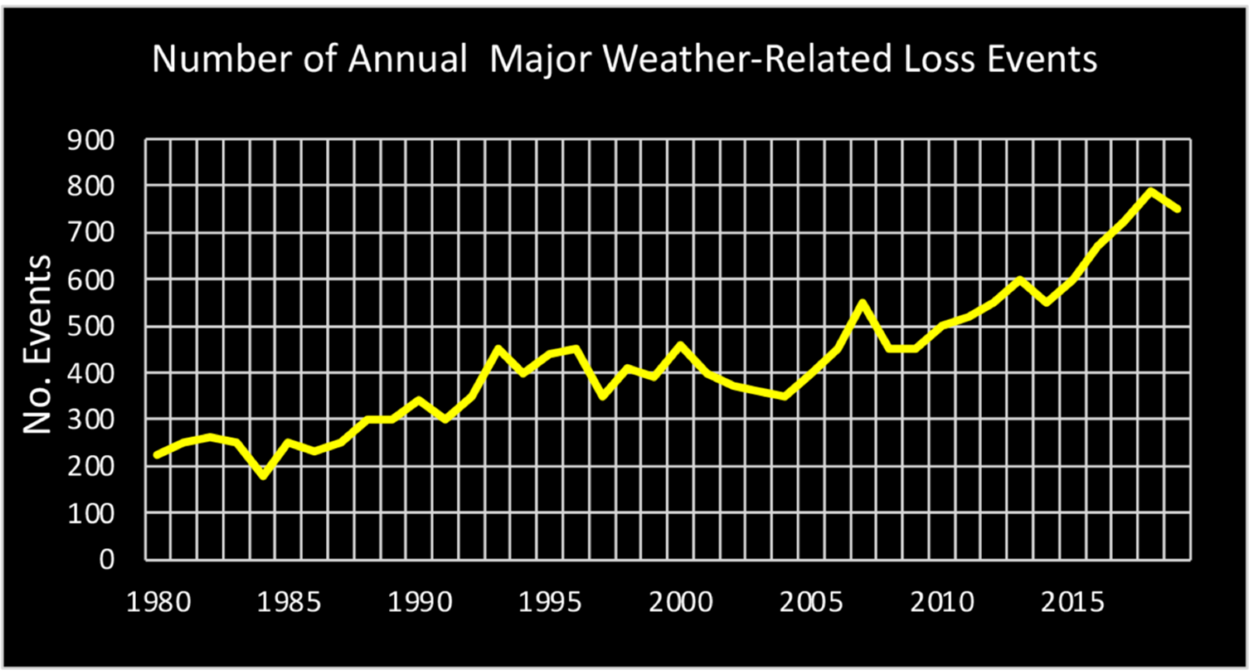

Figure 14: Number of Major Weather-Related Loss Events each Year

In terms of major weather-related losses, global warming is already a calamity, a calamity which continues to increase.

By 2019 major weather-related loss events had more than tripled. That year, there were 575 major weather-related disasters, above the1980, 225 event baseline.

XV. The Data Shows - Global Warming Drives these Catastrophic Storms

While some deny it, much is made, at least anecdotally, about, worsening weather and global warming. This is real and it is driven by the increasing global temperature.

- When water vapor condenses, the energy absorbed as it evaporated is released, heating the surrounding air which causes the moist air to rise and plays a major role in the formation of thunderstorms and cyclonic storms. This energy is termed “latent heat”.
- Because it is released upon condensation, the latent heating power of water vapor is proportional to the rate of precipitation. Given that the average global evaporative and precipitative rates are the same and changes in the evaporative rate are proportional to changes in the average global temperature, changes in the average global temperature are used as a proxy for the latent heating rate in Figure 15.

The relationship of changes in average global temperature to major weather-related loss events is shown in Figure 15.

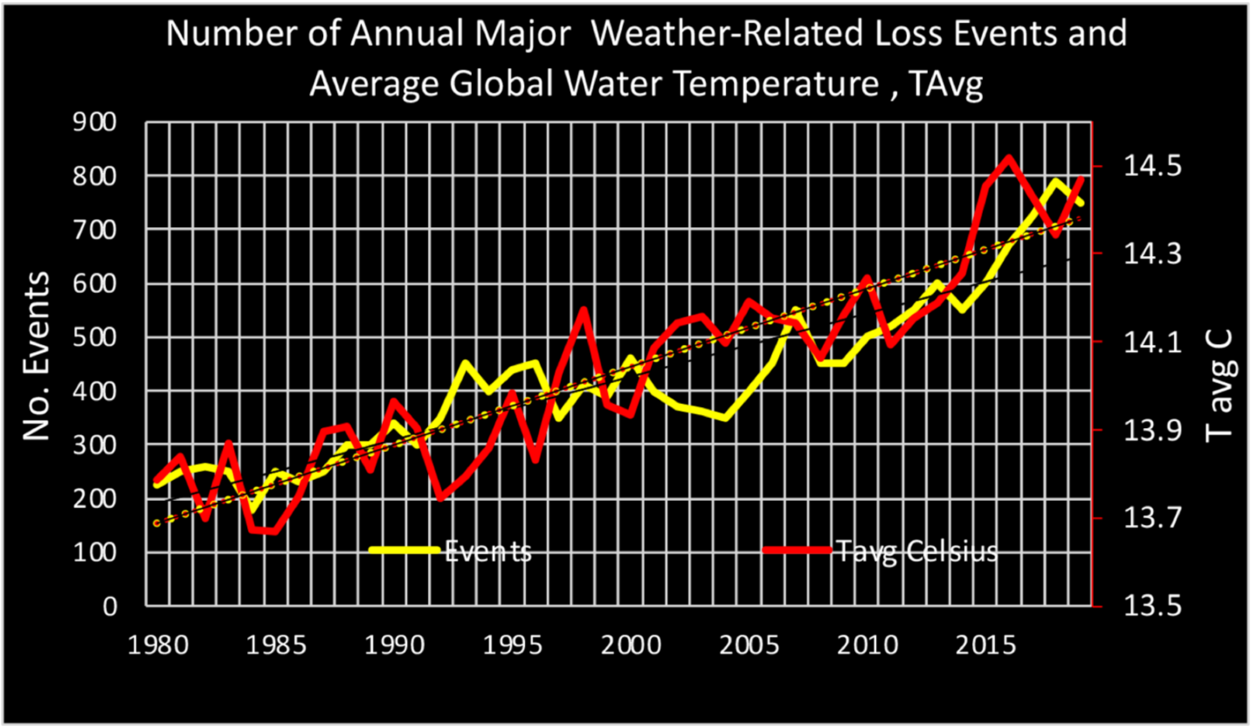

Figure 15: This is Figure 14 with annual loss events shown in yellow and the average global temperature from Figure 1, in red

That the increasing latent heating power is the cause of the growth in catastrophic weather-related events, is shown by the clear correlation between changes in average global temperature in red, and major weather-related loss events in yellow. The correlation coefficient is 0.84.

These increasing major loss events were clearly driven by global warming.

Assuming the loss events in 1980 were not impacted by increases in global warming and taking that as a base, this data shows that for every 0.1°C increase in average global temperature there were roughly an additional 67weather-related loss events.

While the individual events are not global, the damage these major events wreak in a single year has significant and widespread economic impact.

The Munich Re natural disaster loss report [12] shows that from 1980 through 2019, total cumulative economic loss from natural disasters was 5.2 trillion dollars. Averaging this over the estimated total number of events, 17,700 and, subtracting the 2,000 geophysical events, roughly 4.6 trillion of these losses were weather-related. This breaks down to 15,700 weather-related events of which 6,700 were in excess of the 225 event 1980 baseline.

Since 1980, as latent heating increased by 10%, weather-related losses grew at an average rate of \$3.1 billionyr.$^{-1}$. By 2019 the cumulative economic loss from global warming driven catastrophic events above baseline totaled 2.4 trillion dollars.

Not only is the rate of major weather-related loss events increasing, due to the increasing atmospheric latent heating power, the weather can be more severe.

Today, global warming, alone, accounts for loss of lives in the thousands, annually and well over \$100billion dollars in annual economic loss. This crisis is immediate.

Global warming must be reduced, now.

XVI. Solution

- There is no question that greenhouse heating, which continues to increase has already accounted for loss of life in the tens of thousands and damages in the Trillions.
- Knowing the desired reduction in the average global temperature, the goal for the reduction in the global concentration of water vapor can be determined from Eqn. 3.
- This reduction must be monitored and can be achieved by increasing the global precipitative rate to slightly exceed the average global evaporative rate.
- Because changes in latent heating power follow changes in evaporation, reducing the rate of evaporation by reducing the concentration of water vapor and water vapor heating, also reduces the risk of extreme changes in local climate and catastrophic weather.
- Eqn. 3, shows that an increase in the average global rate of precipitation to slightly exceed the average

global evaporative rate, by an average of 0.003 mm d-1 for a year or 1 mm yr-1 will reduce the average global temperature by 0.4 °C, or through an average reduction of 0.0081 mm d^{-1} for a year or 2.9 mm yr^{-1}, the average global temperature will return to the temperatures of the mid-seventies.

- This is the only practicable means of limiting and reversing global warming and reducing the atmospheric latent heating power.

Reducing the atmospheric concentration of the primary greenhouse gas, water vapor, through increasing precipitation to slow the rate of and reverse the increase in the average global temperature must be undertaken.

In Sum: The Solution to Global Warming is Simple make it Rain

Abbreviations and Definition of Terms

Nomenclature

Conv - heating flux that drives thermal convection, Wm^{-2}
ΔT - change in temperature, °C
Eff - heating efficiency - the fraction of total heating remaining after the deduction of evaporative and convective losses, and for the seas, subsurface warming

$$Eff = 1 - (Evap + Conv)/\ TH$$

Evap - heating flux absorbed by evaporation, Wm^{-2}
GHG - Greenhouse Gases
IR - Infrared Radiation
NaH - net absorbed heating flux, that fraction of total radiative heating remaining, after deducting the power driving evaporation and convection, Wm^{-2}

$$NaH = TH - Evap - Conv = Eff \cdot TH$$

OLR - Outgoing Long wave Radiation
Power - heating flux per square meter, Wm^{-2}
Ppmv - parts per million, volume
Rad_U - Radiant Emittance, Wm^{-2}
ΔTH_{CO2} - Back-radiation flux solely from CO_2, Wm^{-2}
σ - Stefan–Boltzmann constant, 5.67 x10^{-8} Wm^{-2} K^{-4}
Sol - Heating flux from solar radiation, Wm^{-2}
SST - Sea Surface Temperature
T - absolute temperature, K
TH - total radiative heating flux, including WV, Wm^{-2}
WV - total heating flux from water vapor feedback effect, Wm^{-2}

Subscripts
Avg - average global
CO_2 - indicates a factor driven solely by CO_2
ENSO - Eastern Equatorial Pacific El Niño-Southern Oscillation, "ENSO" region (5°N–5°S, 170°–90°W)
L - land
N - new
o - original or initial
O - ocean
Tot - total
U - up
WV - water vapor

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Appendix

Geo-Engineering Concepts Put Forward to Reduce Global Warming

These are some of the geo-engineering concepts that have been put forward to address this problem:

- Albedo enhancement. *Increase the reflectiveness of clouds or the land surface so that more of the Sun's heat is reflected into space.*
- Space reflectors. *Block a fraction of sunlight before it reaches the Earth, such as by using trillions of tiny spacecrafts to form a sunshade a million miles from Earth in perfect solar orbit.*
- Stratospheric aerosols. *Introduce small, reflective particles into the upper atmosphere such as sulfur dioxide into the stratosphere to reflect a fraction of the sun's rays back into space.*
- Forestation. *Engage in a global-scale tree planting effort.*
- Biochar. *Instead of burning it, "Char" biomass and bury it so that its carbon is locked up in the soil.*
- Ambient Air Capture. *Build large machines that can remove carbon dioxide directly from ambient air and store it elsewhere.*
- Ocean Fertilization. *Fertilize the oceans, with iron for example, to encourage the growth of marine phytoplankton that would pull carbon out of the atmosphere.*
- Enhanced Weathering. *Expose large quantities of minerals that will react with carbon dioxide in the atmosphere and store the resulting compound in the ocean or soil.*
- Ocean Alkalinity Enhancement. *Grind up, disperse, and dissolve rocks such as limestone, silicates, or calcium hydroxide in the ocean to increase its ability to store carbon.*

If workable, to be effective in the near term, these projects would likely have to be massive, difficult of control and not easily terminated.

Global Journal of Science Frontier Research: H
Environment & Earth Science
Volume 22 Issue 2 Version 1.0 Year 2022
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Experimental Study on Methane Explosion Characteristics in Different Atmospheres

By He Jie, Zhuang Chunji, Dai Yifan, Cao Zaorui & Li Hua

Abstract- Today, with the rapid development of petrochemical industry, petrochemical products are more and more indispensable in our life, and chemical fiber products have entered thousands of households. With the construction of a large number of gas storage facilities, the probability of gas and oil tank accidents is also increased, and once an explosion accident occurs, the consequences are often very serious. To prevent its explosion and reduce its explosion risk, the key is to deeply study and master its explosion characteristics. At present, many scholars at home and abroad have studied the explosion characteristics, but most of them are the explosion instrument, explosion suppression gas, single gas and so on.

Keywords: CH_4, premixed gas, explosion limit, explosion pressure.

GJSFR-H Classification: DDC Code: 333.82330973 LCC Code: HD9579.M4

EXPERIMENTALSTUDYONMETHANEEXPLOSIONCHARACTERISTICSINDIFFERENTATMOSPHERES

Strictly as per the compliance and regulations of:

Experimental Study on Methane Explosion Characteristics in Different Atmospheres

不同气氛中甲烷爆炸特性实验研究

He Jie [α], Zhuang Chunji [σ], Dai Yifan [ρ], Cao Zaorui [Ѡ] & Li Hua [¥]

¥摘要：在石化行业快速发展的今天，生活中越来越离不开石化产品，化纤产品走进千家万户。在大批贮气设施建设的同时，也增大了气、油罐事故概率，且一旦发生爆炸事故，后果往往非常严重。防止其爆炸及降低其爆炸危险性，其关键是深入研究并掌握其爆炸特性。现在过内外许多学者都对爆炸特性进行过研究，但大多是研究爆炸仪器、抑爆气体、单一气体等，对多种气体形成的预混气体的爆炸特性的研究比较少。

本文利用HY12474B型可燃气体爆炸极限实验装置进行实验研究，对甲烷、乙烷与丙烷单烷烃进行实验测量；再经过两两组合进行预混气体实验测定； 通过对三种气体形成的二元预混以及三元预混气体的爆炸特性进行实验测定，得出爆炸极限，爆炸压力图以及爆炸最大压力图像；在预混气体中加入不同浓度的氮气和氧气，继续进行爆炸特性实验，对实验结果进行分析，得出非可燃气体对甲烷预混气体的影响程度；最后总结归纳，甲烷在不同气氛环境下的爆炸特性的区别，以及产生这种区别的原因，归纳出如下规律：

1) 在对三种单烷烃爆炸极限测定后，所得数据符合 Le Chatelier理论公式，基本确定实验的准确性符合要求，在二元与三元预混气体中，爆炸极限和爆炸域宽都是存在一定规律，基本时随着*C*原子组分含量的增加，爆炸极限都降低，而且*C*原子组分占比越高，爆炸极限越低；爆炸域宽也是随*C*原子组分占比增高降低。
2) 通过对单烷烃、二元气态烷烃和三元气态烷烃的爆炸压力和最大爆炸压力进行对比，得出不同烷烃与甲烷形成预混气体 时，对甲烷预混气体的爆炸危险性的影响能力：$C_3H_8>C_2H_6+C_3H_8>C_2H_6>CH_4$。随着预混气体中 *C* 原子组分所占比例的下降，爆炸压力也有一定程度的降低。
3) 不可燃气体对CH_4预混气体的影响能力也与*C*原子的含量有同样的关系，但O_2的加入可以释放*C*原子的爆炸危险性，加入 O_2 后，*C* 原子含量高的预混气体产生的最大爆炸压力较其他气体，最大爆炸压力最大；N_2 等抑爆气体会抑制预混气体的爆炸能力，整体降低预混气体爆炸极限与爆炸压力。

关键词：CH_4；预混气体；爆炸极限；爆炸压力.

Abstract- Today, with the rapid development of petrochemical industry, petrochemical products are more and more indispensable in our life, and chemical fiber products have entered thousands of households. With the construction of a large number of gas storage facilities, the probability of gas and oil tank accidents is also increased, and once an explosion accident occurs, the consequences are often very serious. To prevent its explosion and reduce its explosion risk, the key is to deeply study and master its explosion characteristics. At present, many scholars at home and abroad have studied the explosion characteristics, but most of them are the explosion instrument, explosion suppression gas, single gas and so on.

In this paper, the explosion limits of methane, ethane and propane were measured by hy12474b combustible gas explosion limit experimental device; Then, the premixed gas was measured by pairwise combination; Through the experimental measurement of the explosion characteristics of binary premixed gas and ternary premixed gas formed by three kinds of gases, the explosion limit, explosion pressure diagram and maximum explosion pressure image are obtained; Different concentrations of nitrogen and oxygen were added into the premixed gas, and the explosion characteristics experiment was continued. The experimental results were analyzed, and the influence degree of non combustible gas on methane premixed gas was obtained; Finally, the differences of explosion characteristics of methane in different atmospheres and the reasons for the differences are summarized as follows.

(1) In binary and ternary premixed gases, the explosion limit and the width of explosion range have certain rules. Basically, with the increase of the content of C atom, the explosion limit decreases, and the proportion of *C* atom is higher, The lower the explosion limit is; The width of explosion domain also decreases with the increase of the proportion of C atom. (2) By comparing the explosion pressure and maximum explosion pressure of single alkanes, binary gaseous alkanes and ternary gaseous alkanes, it is concluded that when different alkanes and methane form premixed gas, the influence ability on the explosion risk of methane premixed gas is C_2H_6 + $C_3H_8>C_3H_8>C_2H_6>CH_4$. With the decrease of the proportion of *C* component in the premixed gas, the explosion pressure also decreases to a certain extent. (3) The influence ability of non combustible gas on CH_4 premixed gas has the same relationship with the content of *C* atom, but the addition of O_2 can release the explosion risk of C atom. After the addition of O_2, the maximum explosion pressure of premixed gas with high content of *C* atom is higher than that of other gases, and the maximum explosion pressure is the largest; N_2 and other explosion suppression gases can inhibit the explosion ability of premixed gas and reduce the explosion limit and explosion pressure of premixed gas as a whole.

Keywords: CH_4, *premixed gas, explosion limit, explosion pressure.*

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I. 引 言

a) 研究背景

自1867年法国发生城市煤气管道爆炸以来，许多学者都 对气体爆炸进行了研究工作， 随着石油化工的兴起， 大批运输油气设施的建设与维修，直接导致油、气爆炸事故的频繁发生。当前我国优化能源结构的主 要方式是：降低煤炭消费比重，提高天然气消费比重，而天然气本身的物理和化学性质与瓦斯相近，在发生泄漏 时，极易与空气形成爆炸性混合气体[1]，在生产生活 中，难免会发生或大或小的爆炸事故， 事故一旦发生，其后果往往不堪设想，人们在预防事故发生上，一度下了很大的功夫，通过前人研究，发现降低爆炸危险性关键，是从根本上掌握其爆炸特性。可燃气体爆炸极限、爆炸压力、爆炸火焰等都是物质危险性评估以及安全操作方法确定的重要参考依据之一[2]，气体的爆炸特性是由许多因素决定的，具体包括气体自身属性，预混气体自身所处环境、起爆温度、点火压力等条件；我们在日常生活想做到对爆炸事故的预防，可以通过控制气体浓度，或加入部分惰性气体：氮气、氦气等来抑制可燃气体的爆炸

b) 研究现状

国内外学者已对预混气体爆炸特性进行了大量研究:任常兴、V. Schröde、李润之[3-5]等研究发现爆炸极限主要由气体本身的燃爆特性决定，在高温高压的状态下，气体的爆炸上限都会出现剧增现象；但也与实验测定装置、初始温度、压力和湿度、点火源的类型和能量等因素有关。

焦枫媛[6]等设计了喷射流混合器和静态混合器组成的2级混合器，并通过自身研究，设计了新的爆炸特性测试装置，分别对比了气体在不同混合器条件下爆炸特性的变化。事实证明在二级混合器条件下，爆炸上限增加，下限减少，他们做出大胆猜测，混合物的均匀性会影响气体的爆炸特性。

罗振敏[7]等人就C_2H_6、C_2H_4、CO、H_2 气体分别与CH_4 气体组成的双组份可燃气体的爆炸极限进行了实验。其结果虽然与公式存在误差但总体而言，Le Chatelier定律均适用于计算；武丽娜等人[4]觉得Le Chatelier公式计算爆炸极限时可以运用于大量的可燃气体混合物计算，确认了公式的可行性；李海奎等[5]认为Le Chatelier定律不但可以用于单一物质爆炸极限的计算，而且可以计算其他各种爆炸特性，如：活化能、克分子燃烧热、反应速率相近的混合气体的爆炸极限，并通过实验测定验证了结论的可行性。

Jie. Liu等[8]对H2/CO/O2/CO2/H2O混合物的压力-温度爆炸极限进行了计算和理论分析。结果表明，随着H2O和CO2摩尔分数 的增加，三种爆炸极限附近的爆炸温度均升高。分析表明，第一次爆炸极限主要由添加惰性气体后氧浓度的变化控制；二次爆炸极限的变化是由H+O2（+M）反应速率的变化引起的 → ho2（+M），它是通过第三体复合反应的伴随效率间接实现的， 而惰性气体的加入对第三体爆炸极限的影响主要是由氢气浓度的变化引起的。

A.Lidor等[9] 基于燃料氧化剂混合物热力学稳定性分析的概念，对爆炸极限现象提出了一种新的解释。通过对H2-O2 系统爆炸极限的详细统计热力学分析，证明了这一概念。结果表明，虽然分子数的相对波动幅度很小，但反应物在爆炸极 限处接近其热力学稳定极限，从而导致自燃的发生;并通过热力学方法进行了分析证明。

S. Kondo[10]等对由九种不同化合物制备的各种二元和三 元混合物的可燃极限进行了测量。处理过的化合物有甲烷、丙烷、乙烯、丙烯、甲醚、甲酸甲酯、1,1-二氟乙 烷、氨和一氧化碳。结果表明，可燃性上限的观测值与计算值的偏差主要集中在较低的浓度上。

C. V. Mashuga等[11]为了估算甲烷和乙烯混合物的爆炸极限，并在其中加入N2，他选用了1200K 的火焰温度，在绝热条件下进行实验测定，最后估算出爆炸极限基本符合理论值。

综上所述，可燃气体混合物爆炸特性研究仍是目前国内外研究的热点之一，研究甲烷预混气体爆炸特性具有重要的现实意义。

c) 研究内容

从目前的研究现状来看，甲烷预混气体爆炸特性还有很多研究方面，对我们日常生活也有一定必要性。本文在前人研究的基础上，以甲烷为研究对象，开展甲烷预混气体爆炸特性实验，利用HY12474B 型可燃气体爆炸极限实验装置，研究甲烷预混气体在如下气氛环境：乙烷、丙烷、氧气和氮气等不同气氛环境下得爆炸特性。拟开展以下实验研究。

1) 在学习了解实验室现有的HY12474B型可燃气体爆炸极限实验装置的基本原理上，通过设计制作单烷烃的爆炸特性实验方案，检验其准确性和实用性；
2) 探究以甲烷为主要成分，分别加入乙烷、丙烷单烷烃通过改变组分配比，进而研究甲烷在单种可燃气体气氛环境中的爆炸特性；
3) 探究以甲烷为主要成分，加入乙烷丙烷混合物通过改变三种组分配比，利于HY12474B型可燃气体爆炸极限实验装置，进而研究甲烷在不同组分的二元可燃气体气氛环境中的爆炸特性；
4) 探究以甲烷为主要成分，加入乙烷、丙烷、氧气和氮气通过改变各组分配比，研究甲烷在复杂气氛环境中的爆炸特性。

II. 爆炸特性影响因素

a) 爆炸极限的影响因素

可燃气体与空气在一定浓度范围内按一定比例浓度混合，会形成混合物，在遇到点火源或温度较高的物体，会产生燃烧，甚至爆炸，这个浓度我们称之为爆炸极限。

爆炸极限一般分为爆炸上限和爆炸下限；在气体可以爆炸的范围内，气体能达到的最大浓度，这个浓

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度就成为爆炸上限；相反，能引起气体爆炸的最小浓度，我们就称之为爆炸下限。不管爆炸上限还是下限，都是研究气体能否爆炸的重要爆炸特性因素。

而影响气体爆炸极限的因素有很多：起爆前的爆炸环境、爆炸点火能力、爆炸环境的压力等都会影响爆炸极限；起爆中爆炸混合物本身的属性、爆炸混合均匀度、混合方式也会影响爆炸极限；所以爆炸极限的影响因素时多种多样的。

i. *温度对预混气体爆炸极限的影响*

温度是影响分子运动的重要条件，当温度升高，分子运动变快，很大几率会增加气体的爆炸概率；由于空气中分子运动变快，碰撞变激烈，当他们与空气中的氧气分子发生碰撞，从而发生反应，就会使混合气体的爆炸风险变高，在爆炸条件形成时，发生爆炸。

Zabrtakis[12]的研究表明，爆炸极限本身可变性比较高，当周围温度不稳定的时候，爆炸上下限都会发生变化，尤其在社会生活与生产中，经常会将一些原料混合起来，在理论上他们的浓度和比例是不会爆炸，但当温度发生变化时，他们会变为可燃甚至会产生爆炸。

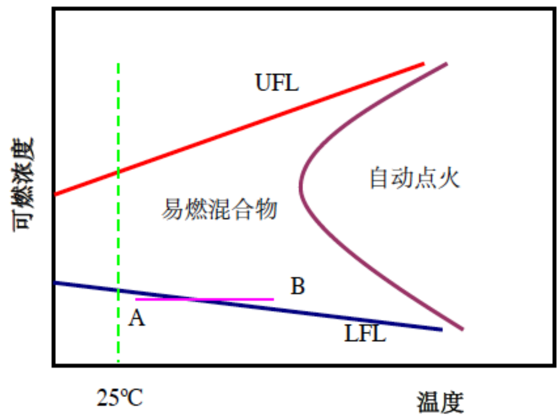

图2-1: 温度对爆炸极限的影响

孙彦龙[13] 等人为了测试温度对爆炸极限的影响，他们以M15，M50，M85 甲醇汽油为研究对象，在考虑了温度阶梯的设定后，他们选择选用不同的初始温度来进行实验，他们冲25℃开始，逐渐升高温度，从开始25℃升高至40℃ 到后来递增20 ℃ 进行实验；实验测得爆炸下限都发生一定变化，其中M50和M85 甲醇汽油都有少许下降，而且他们还发现，在改变甲醇体积时，对下降速度也会有影响，体积分数越大，下降越明显；但M15对反应变化的敏感度就比较低，爆炸下限变化较小。

ii. *压力对预混气体爆炸极限的影响*

气体的的初始压力会影响气体很多的特性，当然也会影响气体混合物的爆炸极限，在其他学者的研究我们得知，当爆炸压力变大，　爆炸上限会发生明显变化，爆炸上限在压力增大时会明显增大；但在爆炸下限时，影响就没那么明显；但在压力减小时，爆炸上限和下限都会变化，最后形成闭合图像，气体不在发生爆炸。

图2-2时天然气爆炸极限对初始压力做出反应的曲线图，由图可以看出，爆炸上限会随着压力的增加，变化显著。爆炸下限基本趋于一条直线，在压力增大时，爆炸下限有一点下降，基本可以验证我们前面所说，爆炸压力对上限影响较大，下限影响一般[14]。

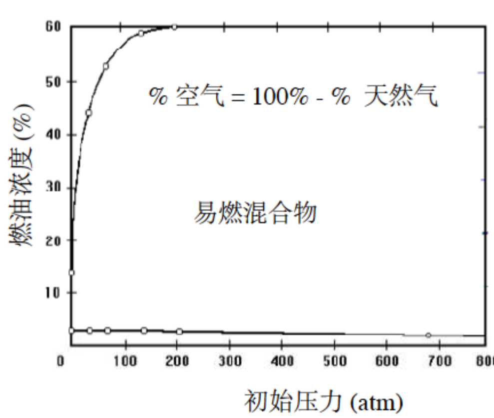

图2-2: 初始压力对28℃天然气可燃性极限的影响

郭丹彤[15] 认为初始爆炸压力对爆炸极限的影响较大，他通过进行改变初始压力的实验出来测量爆炸极限，其中他主要采用控制变量法，测试了气体在1atm和5atm的压力下的最大爆炸压力，结果发现在不同初始压力的条件下，最大爆炸压力各不相同，在1atm时为0.63 MPa，而在5atm时为3.25MPa。她大胆预测是因为初始压力的改变，影响了气体爆炸过程产生的链式反应；通过实验研究，她还对密度对爆炸压力的影响做了推测，最终她认为，气体密度增加也会增强爆炸强度。

喻健良[16]选用了乙烷作为研究对象，探究温度和压力对爆炸极限的影响，他自己设计搭建了高温高压实验装置，在改变了初始温度以及初始压力的条件下，进行乙烷爆炸极限的测量，旨在测出温度和压力双重作用下乙烷爆炸极限变化的规律；实验表明，在初始温度和初始压力增大时，乙烷的爆炸上限和下限都会扩大，爆强度也会变大。

iii. *气体组分对预混气体爆炸极限的影响*

张增亮[17]研究角度与他人不同，他想从不同浓度可燃气体下手，研究其最大允许氧浓度的规律，最终通过实验分析的方式，分析爆炸极限与最大允许氧浓度含量之间的关系；进而总结出两者在不同方面的对爆炸极限的影响，继续界定了可燃气体的爆炸范围与爆炸强度。

Besnard[18]的报告为惰性气体对爆炸极限的影响提供了一个很好的例子。他研究发现，在系统中加入抑爆气体组分，会在一定程度上降低系统的爆炸能力，他们加入各种惰性气体，通过实验，最后对爆炸系统分析发现，抑爆气体可以明显降低系统的爆炸范围。

姜程山[19]也通过加入抑爆气体来探究组分对爆炸极限的影响，在他看来，多心气体抑爆原理主要是：稀释了气体浓度、隔绝了氧气、还有部分气体可以起到冷却作用；通过这些假设，他认为主要是抑爆气体通过化学反应动力学来影响爆炸，通过抑制爆炸反应，来降低爆炸极限。

孙俊芳[20] 等通过设计一种新式的爆炸极限估算方式，旨在进行不同组分的气态混合物爆炸极限的计算；他们为了获得甲烷在不同混合物中的爆炸极限，对甲烷不同预混气体进行了实验研究，通过对对CH_4/N_2和CH_4/CO_2这2种二元混合气体进行实验测得，还分别进行了不同比例的组合，测出爆炸极限；最终实验得到爆炸极限与他们设计公式估算结果基本相同，证明了他们设计实验的可行性。

路长[21] 也为研究不同组分对爆炸极限的影响做出贡献，他通过研究H_2和CO_2的反应与爆炸现象，得出CO_2对H_2和CH_4的影响；他自行设计了爆炸平台，通过加入不同体积的预混气体，然后再加入不同配比的 H_2，进行爆炸实验，通过对实验后的爆炸压力，火焰传播速度进行分析，得出CO_2不仅有物理惰性和稀释可燃混合气等作用,在爆炸时还会进行爆炸反应，进而消耗部分H_2，反应生产CO会继续影响爆炸过程。

b) *爆炸压力影响因素*

在混合气体爆炸时，　必然会伴随着压力的上升，而不同的环境条件、点火装置、点火源位置都会影响爆炸时的压力。通常为了方便数据收集，我们通过研究爆炸时的最大爆炸压力、爆炸压力曲线、爆炸上升速率来反映爆炸产生的威力。

爆炸压力是指在气体发生爆炸后，在局部受限空间不断膨胀，对容器造成巨大压力，一般我们选用在常温常压下容积为8　升的球形容器进行爆炸压流测定，由于容器形状不同、材质不同测得的爆炸压力也不尽相同。

影响爆炸压力的因素也是多种多样的：点火源位置与能量不同，会直接影响爆炸压力的大小；而且气体状态的不同也会引起爆炸压力的变化；气体的混合系不同，混合系的材质混合系的组分占比都会影响爆炸压力。

i. *点火源对预混气体爆炸压力的影响*

混合物在发生爆炸会有很多前提条件，点火源是一个重要条件，只有当点火源达到了发生爆炸的最低要求能量值，气体或混合物才会发生爆炸；当然点火源能量越大，发生爆炸的几率也越大。

而点火源由于它的形状、点火方式、点火能量、点火面积等因素也各不相同，所有不同的点火源也会直接影响到爆炸物的爆炸特性。

Bradley等[22]在实验过程中将点火源安置在容器口中心，通过实验，他认为最危险的点火位置为球形容器的中心；但HPhylaktou等[23]在实验时发现将点火源放置在容器底部时，爆炸更加剧烈，他在对比了放在容器中心的实验结果，认为放在容器底部比容器中心爆炸更剧烈；Kasmani等[24]却与他们的结论都不同，他认为是放在容器底部时压力最大。

郭丹彤[25] 认为爆炸压力的不同很大程度时由于点火源位置的不同，他在实验牙就肿，分别将点火源位置放置在不同高度，测量爆炸压力。他选用距离封闭段不同的位置进行实验，先选取1m然后将点火源移动至2.5m处；实验结果显示在俩处的爆炸压力不同，分别为0.91MPa和0.27MPa；说明由于点火源位置的不同，爆炸压力有明显变化。

综上所述，选用什么样的点火源、在什么位置放置点火源、点火源能量设置都会直接或间接影响爆炸压力和爆炸极限。

ii. *湍流状态对预混气体爆炸压力的影响*

湍流反映的是一种气体流动状态，当气体流动达到一定速度时，气体流层间就会产生相对滑动和混合，导致流体的运动不规则[26-27] 在实际生产场所内的空气　往往是非静态的，所以实际生产空间内的气体大都呈湍流状态。

黄代民[28]通过实验分析得出，湍流条件下甲烷爆炸极限浓度附近的爆炸压力相差明显，如图3-1，　由于湍流加快了甲烷气体的传质和传热。

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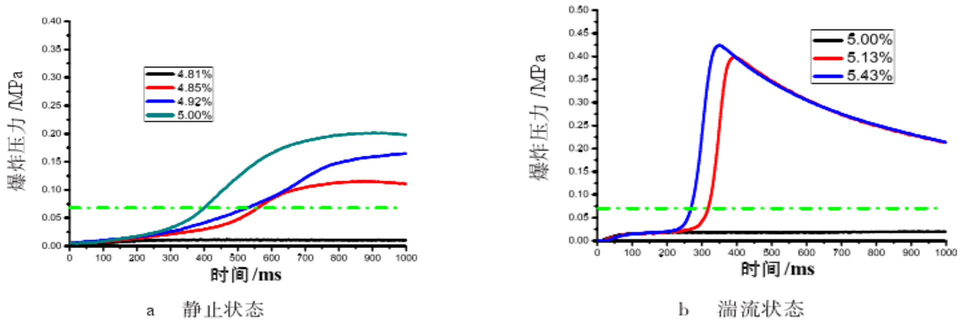


a）静止状态下甲烷爆炸下限附近压力曲线　b）湍流状态下甲烷爆炸下限附近压力曲线

图2-3: 静止与湍流状态下甲烷爆炸下限附近压力曲线对比

由图可得，在湍流状态下，甲烷爆炸极限压力发生变化，在湍流状态下，压力升高明显，而且爆炸达到最大爆炸压力迅速，在短时时间内，产生巨大的爆炸压力，比起静止状态，湍流状态的爆炸压力会大许多。

陈爱平[29]利用 DBZ-1 型爆炸实验装置进行实验测定，通过实验测定得出管道内流动气体流量增大,爆炸强度提高。由于在管道内流量的变化导致气体反应程度不同，由于流动状态的变化直接影响到爆炸极限，通过继续对爆炸极限范围的研究，发现流动状态不单单会影响爆炸极限的大小，还会影响爆炸极限范围的变化，在流动状态下下爆炸极限范围明显气比体处于静态时的爆炸极限范围窄。

韦一[30] 通过实验获得了宏观静止和流动状态下丙酮和正庚烷蒸气的爆炸特性参数,并对比分析了流动状态对两种蒸气爆炸特性的影响。分别在宏观静止和流动状态下对不同浓度丙酮和正庚烷蒸气的爆炸特性参数进行测量。结果表明,随着浓度的增加，两种状态下丙酮和正庚烷蒸气的爆炸压力及其上升率均呈现先增大后减小的趋势；此外,流动状态下丙酮和正庚烷蒸气的最大爆炸压力均小幅增加,最大爆炸压力上升率和爆炸指数则显著提高。

谭迎新[31] 探究了动态条件对爆炸下限的影响，他选用三种气体作为实验对象，通过比较他们在动态和静止条件下的爆炸极限，探究不同条件对爆炸极限的影响；他还自己设计了爆炸测定实验装置，通过实验测得数据显示在动态条件下爆炸上限会变大，爆炸下限也有一定升高；还发现动态条件下爆炸范围会变小的实验现象。

事实证明，爆炸物在不同的流动或存 在状态下自身的特性会发生变化，在流动状态下爆炸极限和爆炸压力会变大，在湍流状态下也会加快气体爆炸强度。

c) *气体组分对预混气体爆炸压力的影响*

在混合物组分不同时，由于各组分爆炸特性不同，所以产生的爆炸压力也不同，直接反应在爆炸中的爆炸威力不同。通常我们用气体爆炸大最大爆炸压力来来反映他们爆炸产生的危险度。在甲烷与丙烷组分配比不同的情况下，分别取不同浓度时产生的最大爆炸压力，结果如图3-2所示：

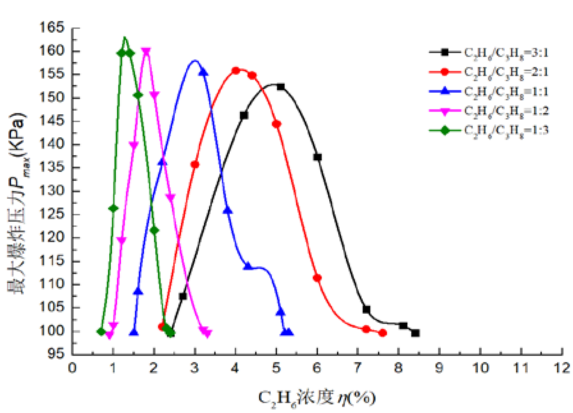


图2-4: CH_4、C_3H_8不同浓度的最大爆炸压力曲线图

可以看出图像变化从右向左靠拢，而且爆炸压力峰值也逐渐身高，但爆炸域宽却变小了，我们大胆猜测，是C原子的作用使得气体本身的可爆范围转化为最大爆炸压力。

朱熹[32]采用多功能球形气体/粉尘爆炸实验装置，进行氟化酮、七氟丙烷抑制甲烷爆炸实验。他通过对两个研究对象的爆炸特性进行研究，在同意甲烷浓度下，探究两个研究对象对甲烷的影响规律，主要从爆炸压力、爆炸极限、爆炸压力上升速率来进行研究，结果表明氟化酮对甲烷有明显的抑制作用，在爆炸极限和爆炸压力上都表现明显。

薛少谦[33]为寻找既环保又能抑制瓦斯爆炸的气体抑爆介质，解决瓦斯输送过程中的爆炸安全问题,分析了七氟丙烷作为抑爆介质的抑爆机理。他通过研究甲烷预混气体的爆炸特性，采用了20L爆炸特性测试系统，在爆炸系统中加入了不同体积分数的七氟丙烷，通过实验探究甲烷预混气体的爆炸压力和最大爆炸压力，以及压力上升速率，结果表明，在体积分数增大时，最大爆炸压力上升，爆炸压力上升速率也变大。

d) 爆炸火焰的影响因素

火焰速度是进行燃烧过程中，我们可以看到的火焰前沿移动速度的快慢，通常会收到火焰前面气流以及管道形状的影响；火焰传播速度使我们通常研究火焰的一个重要特征要素，可以直接反应燃烧和爆炸的危害和强度；火焰速度往往受很多因素影响，燃烧物资本身的特性、空气中的氧含量、管道的压力、管道的温度、燃烧物的存在状态等

在爆炸进行的整个过程中，燃烧速度受到环境等原因导致难以测量，数据也不够准确，而测量火焰速度则相对容易得多，数据也准确，所以在研究过程中普遍选用火焰速度来描述爆炸反应过程中火焰传播的运动状况[34]。

冯若尘[35] 以火焰传播速度以及爆炸压力峰值变化等特征参数为研究对象,分析了在障碍物的影响下，以及浓度梯度的设定对爆炸压力和火焰 传播速度的影响。他通过爆炸激波管试验平台，对不同浓度甲烷和不同障碍物进行组合实验，得出不同浓度的甲烷在不同管状空间爆炸对火焰传播速度的影响：在均匀浓度下火焰传播速度基本一致，在设置梯度浓度变化下，火焰传播速度也会呈上升趋势。

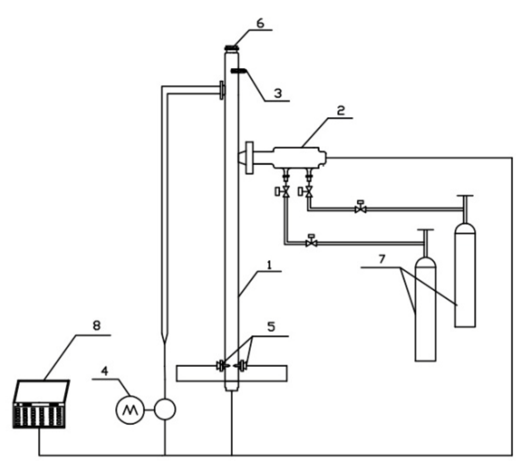
王涛[36]运用XKWB-S型气体爆炸火焰传播特性测试系统和专业气体爆炸模拟软件FLACS进行实验，想通过模拟，得出甲烷在燃烧时的火焰长度和传播速度的关系，而且在加入了CO2后他们是否会发生变化；他通过结合可燃性气体爆炸传播相关机理，通过数值模拟发现：当甲烷接近当量浓度时，它的火焰长度和传播距离都会变成，而且CO2的加入不但会降低他的传播速度，还会降低火焰的亮度和火焰强度；在火焰传播过程中，还会受到一定的湍流影响，导致火焰不稳定。

杨鹏[37]想通过模型模拟来预测单一体系和混合体系的爆炸下限，通过模拟三种烷烃在绝人条件下的燃烧实验，利用CHEMKIN软件的绝热燃烧相平衡模型探究火焰的变化，得出随着体积分数的增加绝热温度和压力都会升高，他们通过继续实验，最终建立了绝人燃烧相平衡模型。

III. 实验装置及试验方案

a) 试验装置

本实验选用HY12474B型可燃气体爆炸极限实验装置，设计依据符合国家标准GB/T 12474-2008《空气中可燃气体爆炸极限测定方法》。装置如图5-1所示，首先将石英管内抽真空，接下来在气泵的运行下进气，进气结束后自动进行气体搅拌与空气配平，在点火延时120s后电火花进行点火放电，可以在石英管内看到一团上升火焰，可能会伴随不同程度的爆炸声，通过传感器将压力温度信息传至计算机，然后通过泄压装置将管道内压力释放，本实验装置可自动进样，配气精度也可达到0.1%。



1石英管；2进气口；3压力温度传感器；4气泵；5点火装置；6压力释放处；7气瓶；8计算机

图3-1: 实验装置示意图

b) 试验方案

实验进行时，事先调整好实验前数据，实验大气压处于空气大气压，温度全部设定为17.5℃，实验环境湿度调整为63.2%RH，采样时间为1s，实验设备灵敏度为50，搅拌时间统一设定为120s，点火1s，在真空度为3.2KPa的条件下进行实验。

实验先测定单烷烃气体爆炸极限，我们选用CH4、C2H6、C3H8 为第一组实验对象，实验结束后，我们分别加入不同浓度的氮气和氧气如（如表 3-1、3-2所示），通过数据处理的到爆炸压力曲线和最大爆炸压力曲线。可燃预混气体爆炸特性的实验方案

本实验以甲烷为主要研究对象，并加入可燃性烷烃气体乙烷和丙烷，研究其对甲烷爆炸极限、爆炸压力、最大爆炸压力的影响。实验围绕气体种类、气体组分配比这两个变量对甲烷进行实验设计。实验开始前先将甲烷、乙烷和丙烷存放在实现准备的气囊中，然后将气囊接入到HY12474B 型可燃气体爆炸极限实验装置进气口，通过电脑软件远程控制进气浓度，按照如（表3-1）实验方案，进行甲烷乙烷丙烷配比实验。实验进行条件进气浓度、实验环境监测、实验温度、 点火时间、搅拌时间、实验压力等设定全部通过电脑软件设定，在实验设定结束后，等待实验装置进行进气，搅拌，空气配平后，进行点火， 点火结束后软件自动进行数据采集，爆炸压力图像处理，然后进行管道清洗，继续进行下一组实验。

本实验首先测定甲烷、 乙烷和丙烷爆炸极限，通过与理论计算值进行对比，验证实验可行性和实验装置的准确性；然后进行甲烷与乙烷混合气体爆炸实验，通过改变甲烷乙烷配比不同，分别进行实验，得出甲乙烷预混气体爆炸极限，爆炸压力以及最大爆炸压力的数据与图像；紧接着进行甲烷与丙烷混合气体爆炸实验，与甲烷乙烷爆炸方案相同；最后我们进行甲烷乙烷丙烷三种混合气体爆炸实验，分别进行了27组不同配比的实验，最后得出一系列数据，通过数据分析处理得出甲烷在混合烷烃气氛环境下的爆炸极限、爆炸压力和最大爆炸压力的变化。通过实验数据，分析出通过改变可燃气体气氛和混合气体组分配比对甲烷爆炸特性的影响。

表 3-1: 预混气体比例配比表

组分 比例	甲烷：乙烷	甲烷：丙烷	甲烷：乙烷：丙烷	甲烷：乙烷：丙烷	甲烷：乙烷：丙烷
	1:1	1:1	1:1:1	2:1:1	3:1:1
	1:2	1:2	1:1:2	2:1:2	3:1:2
	1:3	1:3	1:1:3	2:1:3	3:1:3
	2:1	2:1	1:2:1	2:2:1	3:2:1
	2:2	2:2	1:2:2	2:2:2	3:2:2
	2:3	2:3	1:2:3	2:2:3	3:2:3
	3:1	3:1	1:3:1	2:3:1	3:3:1
	3:2	3:2	1:3:2	2:3:2	3:3:2
	3:3	3:3	1:3:3	2:3:3	3:3:3

本实验方案（表 3-2）测量非可燃气体对预混气体爆炸特性的影响，实验首先测量了甲烷，乙烷和丙烷加入氮气和氧气的爆炸特性，验证了实验设备的精确度。由于时间以及考虑材料成本问题，我们紧接着只进行甲烷：乙烷=1:1、甲烷：丙烷-1:1、甲烷：乙烷：丙烷=1:1:1实验加氮气、氧气实验，每一种组分配比分别加入2.5%、5.0%、7.5%、10%氧气和10%、20%、30、40%氮气。通过对比甲烷和甲烷乙烷预混气体，甲烷和甲烷丙烷预混气体在氧气和氮气影响下的爆炸特性，总结归纳氧气，氮气对甲烷以及甲烷预混气体的影响能力，通过甲烷：乙烷：丙烷 =1:1:1 预混气体分别加氮气和氧气，我们可以探讨甲烷在复杂气氛环境下爆炸特性的变化。

表 3-2: 非可燃气体与预混气体比例配比

组分 非可燃气体	氧气				氮气			
甲烷	2.5	5.0	7.5	10	10	20	30	40
乙烷	2.5	5.0	7.5	10	10	20	30	40
丙烷	2.5	5.0	7.5	10	10	20	30	40
甲烷：乙烷=1:1	2.5	5.0	7.5	10	10	20	30	40
甲烷：丙烷=1:1	2.5	5.0	7.5	10	10	20	30	40

组分 非可燃气体	氧气				氮气			
甲烷：乙烷：丙烷=1:1:1	2.5	5.0	7.5	10	10	20	30	40

IV. 甲烷预混气体混合物的危险性测定

a) 甲烷预混气体爆炸极限测定

i. 单烷烃爆炸极限的测定

分别对三种单烷烃气体（CH_4、C_2H_6、C_3H_8）进行爆炸极限测定，所测实验数据与《石油化工可燃气体和有毒气体检测报警设计规范》（GB50493—2009）中的数据进行比较，如表 4-1所示。

表 4-1: 单烷烃爆炸极限表

气体种类	爆炸下限LEL（%）		爆炸上限UEL（%）	
	实测值	文献值	实测值	文献值
CH_4	6.1	5.0	15.1	15.0
C_2H_6	3.7	3.0	12.7	15.5
C_3H_8	2.5	2.1	9.7	9.5

由表4-1可以的看出，在单烷烃爆炸极限的测定中，实验测定结果与文献值还存在一定误差，爆炸上限平均误差为21%，爆炸下限误差较低，平均误差为7%；我们在分析了实验现象与结果认为主要原因为：（1）实验室气体纯度没有达到文献值要求，（2）实验仪器的精确度只能达到0.1%，不够文献值要求（3）实验室环境不恒定，实验过程中，实验室环境也会有各种变化，温度，湿度都有所差异[18]。

图 4-1为圆柱石英爆炸管内CH_4燃烧爆炸火焰时序图。从图中能够观测到不同浓度下CH_4火焰在管内传播过程中形成的球形或指形火焰，随着CH_4浓度的增加爆炸火焰颜色由浅变深再变浅[19]。在整个爆炸过程中火焰变化明显，在爆炸下限我们观察到一朵淡蓝色蘑菇状火焰缓慢上升，而在甲烷浓度处于爆炸极限中间位置，火焰表现为上升迅速而且颜色明显，且尾部伴随着淡红色的火焰，并伴有火焰由下往上在管道内传播的爆炸声音；当浓度增大到爆炸上限附近时爆炸火焰又变为和爆炸下限时的缓慢淡蓝色火焰状态。

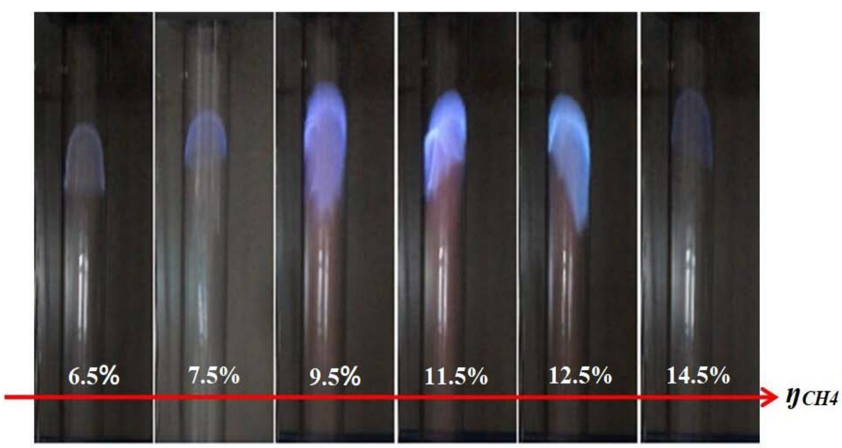


图 4-1: 甲烷燃烧爆炸火焰时序图

ii. 甲烷预混气体爆炸极限的测定

本实验采用Le Chatelier公式（4-1）进行理论值计算，通过计算值我们设定进气浓度，按照比例设定混合，通过实验测定爆炸极限，预混气体爆炸极限实验测定结果如表（4-2、4-3）所示。

$$Lm = 100 \div \left(V_1 \div L_1 + V_2 \div L_2 + \ldots + Vn \div Ln\right) \quad (4\text{-}1)$$

式中Lm——混合气体爆炸极限，%；

L_1、L_2、L_3——混合气体中各组分的爆炸极限，%；

V_1、V_2、V_3 —— 各组分在混合气体中的体积分数，%。

爆炸极限域宽（公式 4-2 所示）也是研究爆炸极限危险性的重要指标，域宽越大，气体其所能爆炸的爆炸浓度范围越广。

$$L = UEL - LEL \quad (4\text{-}2)$$

式中L——爆炸极限域宽，%；

UEL——爆炸上限，%；

LEL——爆炸下限，%。

根据表4-2可以看出，在变换不同比例的甲烷乙烷比例和甲烷丙烷比例时，爆炸极限有不同程度的变化，而且域宽也发生了变化。

整体变化呈大致规律，在丙烷占比上升时，爆炸极限就有明显下降，爆炸极限的域宽也随丙烷占比增大而降低。

表 4-2: 二元甲烷预混气体不同组分爆炸极限表

组分 \ 比例		1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
CH_4/C_2H_6	LEL(%)	4.6	4.2	4	5.1	4.6	4.5	5.2	4.8	4.6
	UEL(%)	13.6	13.2	12.8	14.1	13.6	13	14.4	13.3	13.6
	L(%)	9.0	9.0	8.8	9.0	9.0	8.5	9.2	8.5	9.0
CH_4/C_3H_8	LEL(%)	3.8	3.3	3.2	4.5	3.8	3.3	4.8	4.2	3.8
	UEL(%)	12.2	11.1	10.8	12.9	12.2	10.3	13.2	11.2	12.2
	L(%)	8.4	7.8	7.6	8.4	8.4	7	8.4	7	8.4

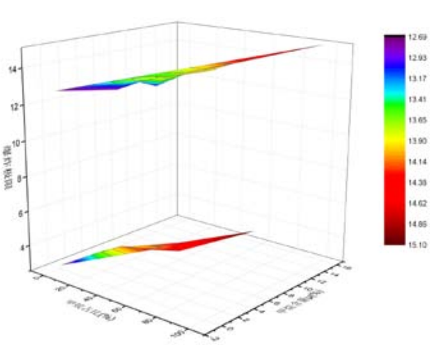
根据表 4-2可以看出，$CH_4/C_2H_6/C_3H_8$为 1:1:1、1:1:2、1:1:3时爆炸极限都呈下降趋势；由表可以看出在*C* 原子占比变大的情况下，爆炸极限都是呈下降趋势，而且随着*C* 原子占比含量变大下降趋势也逐渐变大。

在表中可以看出，随着组分比的变化，也就是*C*原子占比的变大，爆炸上限与下限的差值，我们称之为域宽，也在逐渐变小，说明随着*C*原子占比的增加，不单单会影响爆炸极限的变化，还会影响爆炸的域宽。

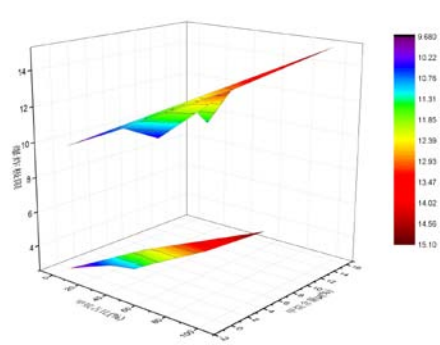
表 4_3: 三元甲烷预混气体不同组分爆炸极限表

组分 \ 比例		1:1:1	1:1:2	1:1:3	1:2:1	1:2:2	1:2:3	1:3:1	1:3:2	1:3:3
$CH_4/C_2H_6/C_3H_8$	LEL(%)	3.9	3.6	3.5	4	4	3.17	3.54	3.34	3.21
	UEL(%)	12.5	11.2	10	12	11	11.25	12.46	11.87	11.48
	L(%)	9.9	7.6	6.5	8.4	7	8.08	8.92	8.53	8.27
		2:1:1	2:1:2	2:1:3	2:2:1	2:2:2	2:2:3	2:3:1	2:3:2	2:3:3
	LEL(%)	4.4	4.5	3.37	4.5	3.9	3.39	3.8	3.36	3.4
	UEL(%)	12.4	11.5	11.43	12.5	13.8	11.64	12.79	12.21	11.81
	L(%)	8	7	8.06	8	9.9	8.25	8.99	8.85	8.41
		3:1:1	3:1:2	3:1:3	3:2:1	3:2:2	3:2:3	3:3:1	3:3:2	3:3:3
	LEL(%)	4.5	3.84	3.59	4.1	3.79	3.58	4	3.56	3.9
	UEL(%)	14	12.27	11.8	13.02	12.39	11.95	13.03	11.92	13.8
	L(%)	9.5	8.43	8.21	8.92	8.6	8.37	9.03	8.36	9.9

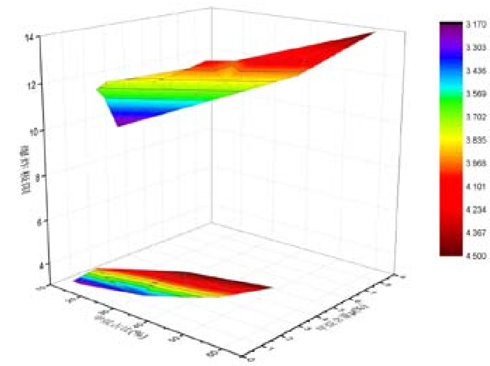
经计算，爆炸极限测量值与理论值基本一致，其误差产生的原因可能是由实验仪器精度造成，因此实验所得数据符合Le Chatelier理论公式。根据上表可以得到二元，三元预混气体的爆炸极限三维图，如图4-2所示：



a）甲乙烷爆炸极限三维图



b）甲丙烷爆炸极限三维图



c）甲乙丙烷爆炸极限三维图

图 4-2: 甲烷不同预混气体爆炸极限三维图

从爆炸极限三维图中，我们可以看到，不管是甲烷乙烷预混气体、甲烷丙烷预混气体还是甲烷乙烷丙烷预混气体，他们都是呈向右上角增长的趋势，从图4-2可以看出爆炸极限三维图呈一个锥形图，主要是因为甲烷占比变大，*C*原子组分占比变小，直接导致爆炸极限升高；右上角三维图面积变小也是因为在甲烷占比越来越大的时候，爆炸极限变化的幅度也增大。

b) ***甲烷预混气体爆炸压力测定***

分别测出不同组分比下的二元，三元预混气体在爆炸极限范围内的最大爆炸压力值，如表 4-4、4-5所示。

表 4-4: 二元甲烷预混气体最大爆炸压力测定表

比例 / 烷烃混合物	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
CH_4/C_2H_6	147.1	149.9	152.2	146.5	149.9	146.3	152.2	143.4	147.1
CH_4/C_3H_8	148.9	149.8	154.5	149.0	149.8	145.9	154.8	141	148.9

由表 4-4 可以看出，在二元甲烷预混气体最大爆炸压力测定中，甲乙1:3和3:1时的爆炸压力最大，都为152.2.在甲乙3:2时的爆炸压力最小，仅为 143.4；而甲丙预混气体最大爆炸压力时在甲丙3：1时取到最大值，为154.8，在甲丙3:2时取到最小值，为141。可以看出在组分不同二元预混气体中，最大爆炸压力最大与最小值的取值点都是相同的，在3:1时取到最大值，在3:2时取到最小值。我们推测是由于H原子占比的变大会提高最大爆炸压力。

表 4-5: 三元甲烷预混气体最大爆炸压力测定表

比例 / 烷烃混合物	1:1：1	1:1:2	1:1:3	1:2:1	1:2:2	1:2:3	1:3:1	1:3:2	1:3:3
$CH_4/C_2H_6/C_3H_8$	147.5	144.1	147.4	147.5	148.5	142.9	145.5	139.3	150.7
	2:1：1	2:1:2	2:1:3	2:2:1	2:2:2	2:2:3	2:3:1	2:3:2	2:3:3
	150.6	142.2	145.1	150.7	147.5	153	142.2	143.3	138.6
	3:1：1	3:1:2	3:1:3	3:2:1	3:2:2	3:2:3	3:3:1	3:3:2	3:3:3
	144	143	151.7	146.3	137.7	145.3	142.8	145.1	147.5

由表 4-5 可以看出，在三元甲烷预混气体最大爆炸压力测定中，最大爆炸压力的最大值时在甲烷：乙烷：丙烷=3:1:3时取到，为 151.7，比起二元预混气体最大值要稍微低一点。而最小值是在甲烷：乙烷：丙烷=2:3:3时取到，仅为 138.6，是比甲乙预混气体最小值低，但是高于甲丙预混气体最小值，主要是因为预混气体中*C*原子在总体里含量的占比影响了爆炸压力的大小，*C* 原子含量高的预混气体，爆炸压力会低一些，反之亦然。

分别测出不同组分比下的二元、三元气态烷烃混合物爆炸极限范围的爆炸压力值，如表 4-6、4-7、4-8、4-9、4-10所示。

表 4 6: 二元甲烷预混气体爆炸压力测定表

$CH_4:C_2H_6$=1:1		$CH_4:C_2H_6$=1:2		$CH_4:C_2H_6$=1:3		$CH_4:C_2H_6$=2:1		$CH_4:C_2H_6$=2:2		$CH_4:C_2H_6$=2:3		$CH_4:C_2H_6$=3:1		$CH_4:C_2H_6$=3：2		$CH_4:C_2H_6$=3:3	
CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)
2.3	100.1	1.5	100	0.9	101.4	3.5	100	2.3	100.1	1.8	99.8	3.6	101.3	2.9	99.8	2.3	100.1
2.8	115	1.7	122.5	1.1	121.5	4.2	125	2.8	115	2.1	122	6	137.5	3.5	117	2.8	115
3.9	145.5	2	135	1.4	142	5.6	145.5	3.9	145.5	3.4	146.3	7.6	142.5	4.5	128	3.9	145.5
4.6	142.5	2.5	150	2	148	7	121.5	4.6	142.5	4	130	9	120	5.3	143.4	4.6	142.5
5.8	115	3.4	117.5	2.4	122.5	8	114	5.8	115	4.7	123	10.5	101.3	6.5	122	6.8	100
6.8	100	4.4	100	3	105	9.5	100	6.8	100	5.2	99.8	10.6	100	7.8	99.8	2.3	100.1

表 4-7: 二元甲烷预混气体爆炸压力测定表

$CH_4:C_3H_8$=1:1		$CH_4:C_3H_8$=1:2		$CH_4:C_3H_8$=1:3		$CH_4:C_3H_8$=2:1		$CH_4:C_3H_8$=2:2		$CH_4:C_3H_8$=2:3		$CH_4:C_3H_8$=3:1		$CH_4:C_3H_8$=3：2		$CH_4:C_3H_8$=3:3	
CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax(kPa)	CH_4浓度（%）	Pmax (kPa)
2	100.1	1	100	0.8	100	3	101.3	2	100.1	1.3	99.8	4	100	2.52	99.8	2	100.1
2.5	124.7	1.1	109	0.9	110	4.2	142.5	2.5	124.7	1.8	125	5	130	3	116	2.5	124.7
3.5	147.8	1.5	124.1	1	127.9	6	145	3.5	147.8	2.8	145.9	6.5	147.5	4.1	132	3.5	147.8
4.0	133.4	2	148.5	1.5	151.7	7.1	112.5	4.0	133.4	3.3	131	7.6	135	4.8	141	4.0	133.4
4.5	119.5	2.5	132.3	2	120.6	7.5	102.5	4.5	119.5	3.8	117	9	105	5.5	127	4.5	119.5
5.5	100	3	108	2.5	100	8.5	99.5	5.5	100	4.1	99.8	10	100	6.7	99.8	5.5	100

表 4-8: 三元甲烷预混气体爆炸压力测定表

CH_4:C_2H_6:C_3H_8=1:1:1		CH_4:C_2H_6:C_3H_8=1:1:2		CH_4:C_2H_6:C_3H_8=1:1:3		CH_4:C_2H_6:C_3H_8=1:2:1		CH_4:C_2H_6:C_3H_8=1:2:2		CH_4:C_2H_6:C_3H_8=1:2:3		CH_4:C_2H_6:C_3H_8=1:3:1		CH_4:C_2H_6:C_3H_8=1:3:2		CH_4:C_2H_6:C_3H_8=1:3:3	
CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)
1.3	99.8	0.8	100	0.7	99.8	1	100	0.8	100	0.6	99.8	0.7	99.8	0.56	99.8	0.45	99.8
1.8	131	1.1	112	0.9	118	1.5	124	1	115	0.8	115	1.0	121	0.8	116	0.6	122
2.2	145.3	1.4	125	1.1	132	2	147.5	1.3	134	1	125	1.3	135	1.1	124	0.8	131
2.8	135	1.7	144.1	1.3	147.4	2.2	135	1.5	148.5	1.2	142.9	1.7	145.5	1.4	137.3	1.1	150.7
3.5	121	2.1	128	1.5	120	2.6	114	2	121	1.5	130	2.1	125	1.7	122	1.3	126
4.1	99	2.8	99.3	2	100	3	99.8	2.2	99.8	1.9	99.8	2.5	99.8	2	99.8	1.64	99.8

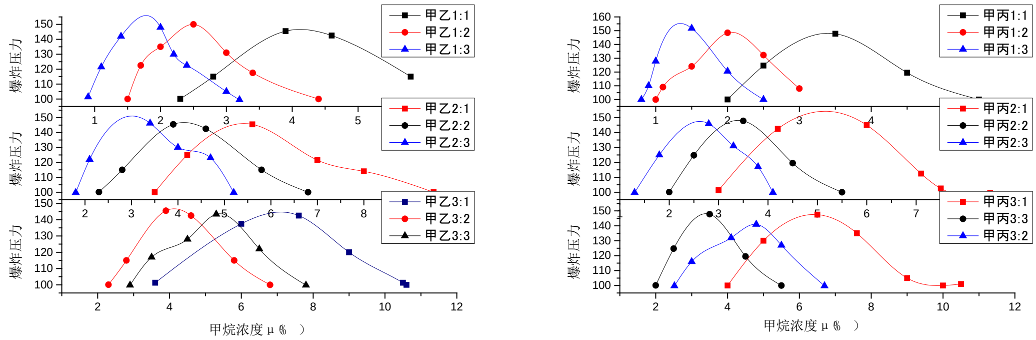
表 4-9: 三元甲烷预混气体爆炸压力测定表

CH_4:C_2H_6:C_3H_8=2:1:1		CH_4:C_2H_6:C_3H_8=2:1:2		CH_4:C_2H_6:C_3H_8=2:1:3		CH_4:C_2H_6:C_3H_8=2:2:1		CH_4:C_2H_6:C_3H_8=2:2:2		CH_4:C_2H_6:C_3H_8=2:2:3		CH_4:C_2H_6:C_3H_8=2:3:1		CH_4:C_2H_6:C_3H_8=2:3:2		CH_4:C_2H_6:C_3H_8=2:3:3	
CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)
2.2	100	1.8	99.8	1.12	99.8	1.8	100	1.3	99.8	0.97	99.8	1.3	99.8	0.96	99.8	0.85	99.8
3.1	127	2.3	128	1.5	115	2.1	113	1.8	131	1.3	121	1.8	126	1.5	115	1.1	115
4.2	150.6	3.1	142.2	2	132	3.3	150.7	2.2	145.3	1.8	133	2.5	134	2	125	1.5	125
5	131	3.6	135	2.5	145.1	3.7	139	2.8	135	2.2	153	3	142.2	2.2	143.3	1.9	138.6
5.7	116	4.0	120	3.1	122	4.2	120	3.5	121	2.7	135	3.8	129	3.1	120	2.4	122
6.2	100	4.6	100	3.81	99.8	5	100	4.1	99	3.3	99.8	4.3	99.8	3.8	99.8	3	99.8

表 4-10: 三元甲烷预混气体爆炸压力测定表

CH_4:C_2H_6:C_3H_8=3:1:1		CH_4:C_2H_6:C_3H_8=3:1:2		CH_4:C_2H_6:C_3H_8=3:1:3		CH_4:C_2H_6:C_3H_8=3:2:1		CH_4:C_2H_6:C_3H_8=3:2:2		CH_4:C_2H_6:C_3H_8=3:2:3		CH_4:C_2H_6:C_3H_8=3:3:1		CH_4:C_2H_6:C_3H_8=3:3:2		CH_4:C_2H_6:C_3H_8=3:3:3	
CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)	CH_4浓度（%）	Pmax (kPa)
2.7	99.8	1.92	99.8	1.5	99.8	2.1	99.8	1.6	99.8	1.3	99.8	1.7	99.8	1.3	99.8	1.3	99.8
3.5	124	2.2	121	1.9	121	2.8	121	2.1	115	1.9	121	2.1	121	1.8	123	1.8	131
5.6	144	3.5	133	2.5	134	3.5	131	3.1	126	2.5	133	3.1	133	2.4	136	2.2	145.3
6	130	3.9	143	3.4	151.7	4.2	146.3	3.6	137.7	2.8	145.3	3.7	142.8	2.8	145.1	2.8	135
7.1	120	5.4	126	4.5	126	5.5	126	4.3	122	3.5	127	4.5	122	3.4	124	3.5	121
8.4	99.8	6.1	99.8	5.1	99.8	6.5	99.8	5.31	99.8	4.5	99.8	5.6	99.8	4.47	99.8	4.1	99

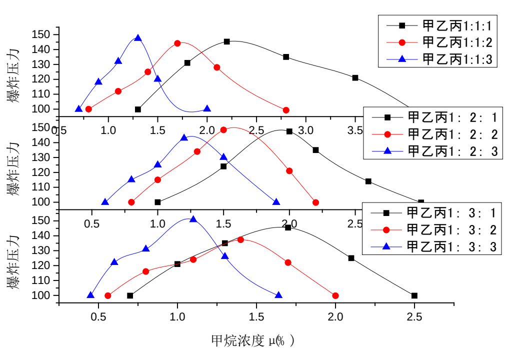
由上表作出图4-3、4-4：

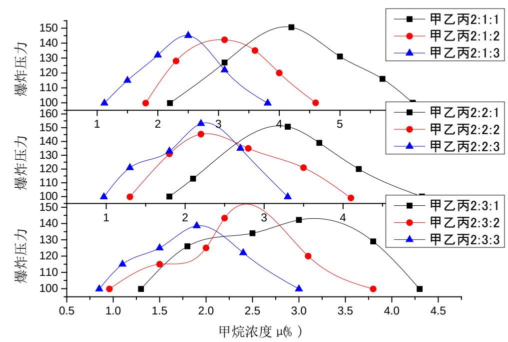


a）甲乙烷爆炸压力对比图　*b*）甲丙烷爆炸压力对比图

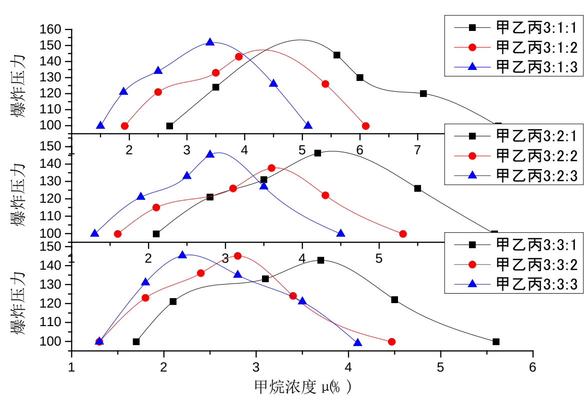
图4-3: 二元预混气体爆炸压力对比图

从图4-3中可以看出，各组分比的最大爆炸压力曲线的趋势基本相同，均随预混气体混合物浓度的升高先增大后减小[38]；在甲乙混合物与甲丙混合物中，能够取到最大的爆炸压力时，气体的组分比为2:1和1:3。不同比例的爆炸曲线最大压力存在差异，但压力曲线走势基本相同，在*C*原子占比小的时候，曲线的横坐标跨度较小，但最大值较大；反之亦然。





a）甲烷比值恒定为1，混入不同比例乙烷/丙烷的爆炸压力曲线图　*b*）甲烷比值恒定为2，混入不同比例乙烷/丙烷的爆炸压力曲线图



b）甲烷比值恒定为2，混入不同比例乙烷/丙烷的爆炸压力曲线图

图4-4: 三元预混气体爆炸压力对比图

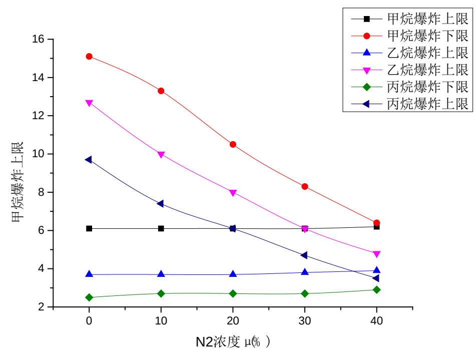
从图4-4中可以看出，各组分比的最大爆炸压力曲线的趋势也是基本相同，均随预混气体混合物浓度的升高先增大后减小；在爆炸极限范围内最大爆炸压力峰值出现在爆炸范围的中间位置范围；由于实验设备精确

度的问题，部分爆炸压力曲线会存在误差，但还是可以看出当丙烷在预混气体中占比变大时，爆炸压力曲线呈细高状，证明当丙烷占比增大时，爆炸压力会变大，但可爆范围会变小，即预混气体中，甲烷浓度很低就可以发生爆炸，而且爆炸压力会很大。

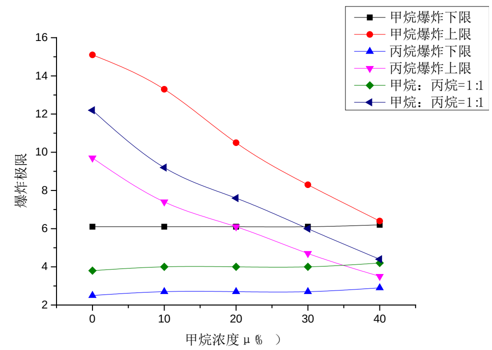
V. 非可燃气体对甲烷预混气体危险性的影响

a) N_2对混合可燃气体危险性影响的测定

i. *N_2对甲烷预混气体爆炸极限影响的测定*



a）单烷烃混合不同浓度N_2爆炸极限曲线图



b）多烷烃混合不同浓度N_2爆炸极限曲线图

图5-1: 单烷烃、多烷烃混合不同浓度N2爆炸极限曲线图

由图 5-1 （*a*）可以看出在形成甲丙预混气体后，加入一定量N_2后，甲丙预混气体的爆炸极限变化趋势和单烷烃气体变化趋势大致相同；而且爆炸极限一致保持在甲烷与丙烷爆炸极限之间。而由图 5-1（*b*）可以看出，预混气体加入N_2的爆炸极限变化趋势都是大致相同的；其中甲丙预混气体的爆炸极限最低，甲乙丙烷预混气体的爆炸极限最高。在加入大量N_2后，最后预混气体的爆炸极限上下限重合，不再爆炸。

ii. *N_2对单烷烃爆炸极限影响的测定*

实验就分别对三种单烷烃气体（CH_4、C_2H_6、C_3H_8）加入不同浓度的氮气对其爆炸极限进行测定，测量结果如表 5-1所示。

表5-2: 单烷烃混合不同浓度N_2爆炸极限测定表

N_2浓度(%)	0	10.1	20	30.1	40	N_2浓度(%)	0	10.2	20.1	30.1	40.1
甲烷爆炸上限(%)	15.1	13.3	10.5	8.3	6.4	甲烷爆炸下限(%)	6.1	6.1	6.1	6.1	6.2
N_2浓度(%)	0	10.1	20.1	30	40	N_2浓度(%)	0	10.1	20	30	40
乙烷爆炸上限(%)	12.7	10.0	8.0	6.1	4.8	乙烷爆炸下限(%)	3.7	3.7	3.7	3.8	3.9
N_2浓度(%)	0	10.1	20	30	40	N_2浓度(%)	0	9.9	20	30	40
丙烷爆炸上限(%)	9.7	7.4	6.1	4.7	3.5	丙烷爆炸下限(%)	2.5	2.7	2.7	2.7	2.9

由表5-1可以看出，在加入不同浓度N_2 后，单烷烃的爆炸极限都会发生变化，　　而且都随着N_2浓度的增加，爆炸上限明显降低，爆炸下限基本没有变化。

由表5-1可以做出图5-2，从图5-2 可以看出在加入N_2后，N_2的抑制效果明显，单烷烃的爆炸上限急剧下降，在N_2浓度达到 35%-40% 时，爆炸上下限基本相同，此时气体不会再发生爆炸。

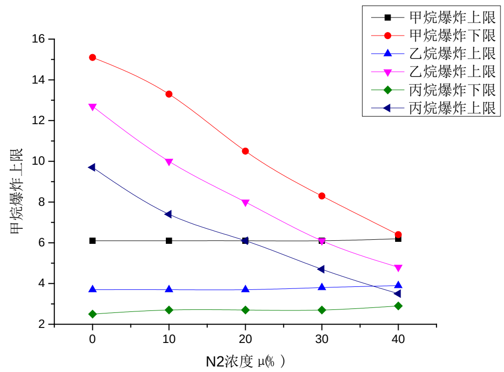


图 5-2: 单烷烃混合不同浓度N_2爆炸极限曲线图

与上限不同的是爆炸下限的变化很小，图像基本处于一条直线；在加入N_2后，乙烷的爆炸上下限处于甲烷与丙烷之间，而且甲烷爆炸极限下降趋势最大，乙烷其次，丙烷最小。我们可以推测N_2对单烷烃爆炸极限的影响强度为$CH_4>C_2H_6>C_3H_8$。

iii. **N_2对甲烷预混气体爆炸压力曲线的影响**

通过实验数据，我们做出加入N_2预混气体最大爆炸压力曲线对比图（5-3）：

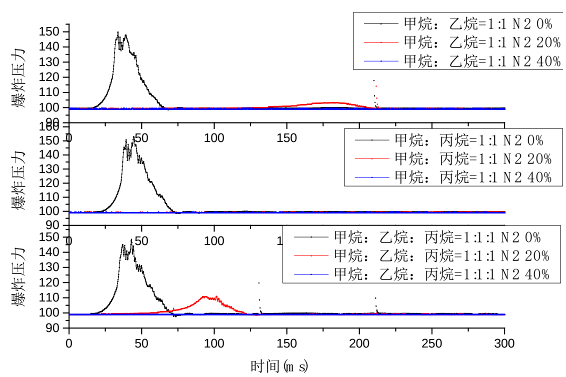


图 5-3: 加入N_2预混气体最大爆炸压力曲线对比图

由图5-3可以看出在加入N_2后单烷烃或预混气体的 最大爆炸压力都有明显降低；在没有加入N_2时，不同比例的预混气体的有明显的爆炸压力曲线，二元预混气体都在大约25Ms的时刻达到最大爆炸压力，而三元预混气体达到最大爆炸压力的时刻要稍微延后一些。在加入20%N_2后，甲乙预混气体还有一点爆炸压力显示在图上，当N_2浓度增加到40%的时候，就没有爆炸压力了，是因为N_2浓度太高抑制了预混气体的爆炸特性，从而不在爆炸。而甲丙与甲乙丙预混气体则在加入20%N_2的时候，爆炸压力就基本趋于0，从前面我们研究可以推测是因为，随着C原子占比的增加，预混气体本身的爆炸特性就会降低，当加入N_2惰性气体后，导致爆炸特性急剧下降，最终无法爆炸。

b) *O_2对混合可燃气体危险性的影响测定*

i. **O_2对单烷烃爆炸极限影响的测定**

O_2 对混合烷烃爆炸极限影响的测定采用的是两种不同烷烃加 O_2 构成三元混合物的进行爆炸极限的试验，试验结果如表 5-2所示。

表 5-3: 烷烃气体混合O_2爆炸极限表

O_2浓度(%)	0	2.6	5.0	7.6	10.1	O_2浓度(%)	0	2.6	5.2	7.6	10
甲烷爆炸上限(%)	15.1	17.6	20.7	23.6	26.7	甲烷爆炸下限(%)	6.1	5.9	5.9	5.9	5.9
O_2浓度(%)	0	2.6	5.0	7.4	10.1	O_2浓度(%)	0	2.5	5.1	7.6	10
丙烷爆炸上限(%)	9.7	10.1	11.9	13.5	15.3	丙爆炸下限(%)	2.5	2.5	2.5	2.5	2.5
O_2浓度(%)	0	2.6	5.0	7.6	10.1	O_2浓度(%)	0	2.5	5.1	7.7	10.2
CH_4:C_3H_8=1:1 UEL(%)	12.2	12.8	14.6	17.2	18.8	CH_4:C_3H_8=1:1 LEL(%)	3.8	3.8	3.8	3.8	3.8

从上表中，可以看出烷烃爆炸上限随着 O_2 浓度的增加呈上升趋势，爆炸下限虽然呈下降趋势但下降幅度很小[17]。在加入O_2后爆炸极限明显变大，最大值为26.7，时当CH_4加10%O_2的爆炸上限，我们推测在加入更多O_2，其爆炸极限还会上升，但由于实验风险变大，我们暂时停止继续加O_2的实验。最小值为丙烷不加O_2，即使全部加入2.5%O_2也依旧时丙烷爆炸上限最低，主要原因还是由于C原子的含量太高，导致气体本身的爆炸能力变低。

在O_2浓度一样时，在甲烷里加入乙烷形成混合气体时，发现预混气体还是处于甲烷与丙烷之间，这个结果与我们推测结果一样，依旧是C原子占主要原因，最终影响了爆炸极限的变化。

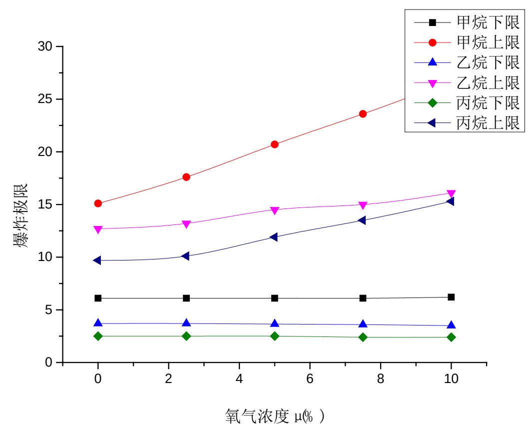


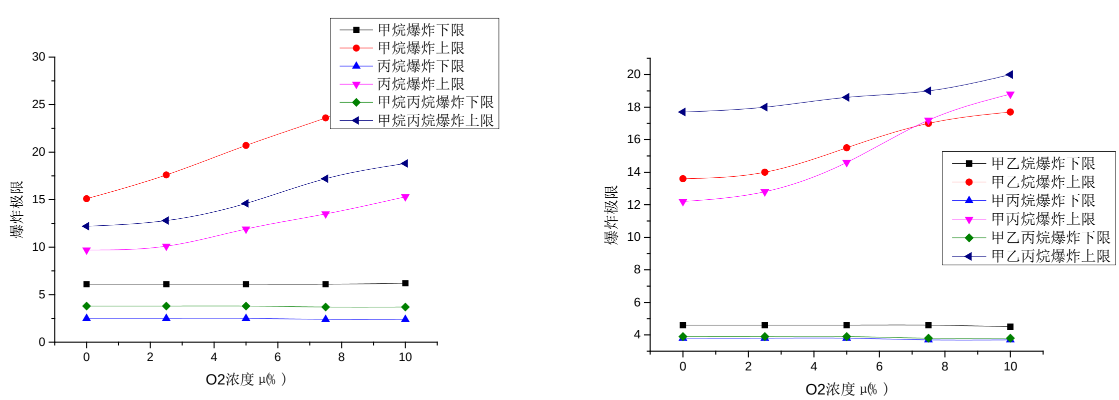
图5-4: 单烷烃混合O_2爆炸极限曲线图

从上图中可以看出，氧气对单烷烃有一定的活化能力，导致单烷烃的爆炸极限都有不同程度的增加。由图可以看出 O_2 对单烷烃的活化能力大小为：甲烷>乙烷>丙烷。由于C原子数的增加，会降低单烷烃本身的爆炸特性，也会降低氧气的活化能力。

在图中显示，在加入O_2 后整体图像呈喇叭状，可以看出依然是甲烷的爆炸极限增长剧烈，乙烷次之，丙烷最小；但在之后的图像走势可以看出丙烷的爆炸上限可能会超过乙烷的爆炸上限，可能是实验数据存在一定误差，但整体我们可以看出乙烷和丙烷也都是呈上升趋势，而且是逐渐变缓。

ii. ***O_2对甲烷预混气体爆炸极限影响的测定***

通过实验数据，我们作出单烷烃、多烷烃混合不同浓度O_2爆炸极限曲线图（5-5）：



a）单烷烃混合O_2爆炸极限曲线图 *b*）多烷烃混合O_2爆炸极限曲线图

图5-5: 单烷烃、多烷烃混合不同浓度O_2爆炸极限曲线图

由图 5-5（*a*）可以看出在形成甲丙预混气体后，加入一定量O_2后，甲丙预混气体的爆炸极限变化趋势和单烷烃气体变化趋势大致相同；而且爆炸极限一致保持在甲烷与丙烷爆炸极限之间。而由图5-5（*b*）可

以看出，预混气体加入O_2的爆炸极限变化趋势都是大致相同的；其中甲丙预混气体的爆炸极限最低，甲乙丙烷预混气体的爆炸极限最高，我们大胆推测是由于C 原子数的增加，O_2的影响能力降低了，但预混气体本身随含C量的增高，本身的爆炸潜力也随之变大。我们推测会有一个临界点，使得甲丙预混气体的爆炸极限变为最大值。

iii. O_2对甲烷预混气体爆炸压力曲线的影响

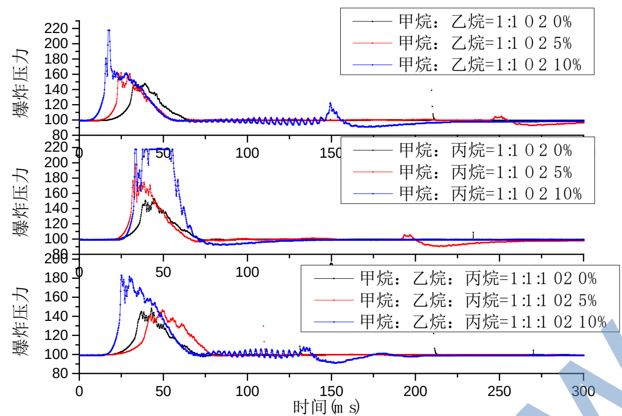


图5-6: 加入O_2最大爆炸压力曲线对比图

由图5-6 可以看出加入不同浓度O_2的甲烷预混气体的最大爆炸压力曲线，在加入 0% O_2 时，不同比例的甲烷预混气体都有明显的爆炸压力；在加入 5% O_2 时，爆炸压力顶峰有明显上升，而且，起爆时刻也由 25ms 提前到10-15ms；在加入10%O_2时， 可以看出甲乙与甲丙预混气体的最大爆炸压力已经突破测量范围，尤其甲丙预混气体的最大爆炸压力乙远远超过了 217.5kPa，而且起爆时间被再次提前。可以看出在加入O_2后，会明显提高甲烷预混气体的最大爆炸压力，还会将起爆时间提前，当O_2浓度足够高时候，基本上可以做到在点火的一瞬间就达到最大爆炸压力的程度。而且，随着 C 原子组分占比的增加，我们可以发现在O_2的活化作用下，激发了C原子的爆炸威力，导致C原子组分占比高的预混气体产生的最大爆炸压力相较其他气体要高出许多。当我们在平时的可燃气体隐患排查时，一定要注意环境中O_2的含量，O_2会全面的提高可燃物的爆炸危险度，包括爆炸极限、爆炸域宽、爆炸压力以及起爆时间等。

VI. 不同气氛中甲烷爆炸特性对比

a) 甲烷预混气体爆炸极限测定

整理甲烷在不同气氛下形成各种预混气体的爆炸极限，作出表6-1：

表6-1: 甲烷预混气体爆炸极限表

组分 / 爆炸极限	CH_4	CH_4:C_2H_6=1:1	CH_4:C_3H_8=1:1	CH_4:C_2H_6:C_3H_8=1:1:1	CH_4 5%O_2	CH_4:C_2H_6=1：15% O_2	CH_4:C_3H_8=1:1 5%O_2	CH_4:C_2H_6:C_3H_8=1:1:15%O_2	$CH_4$20%N_2	CH_4:C_2H_6=1:120%N_2	CH_4:C_3H_8=1:120%N_2	CH_4:C_2H_6:C_3H_8=1:1:120%N_2
爆炸上限	15.1	13.6	12.2	12.5	20.7	15.5	14.6	18.6	10.5	9	7.6	10.5
爆炸下限	6.1	4.6	3.8	3.9	5.9	4.6	3.8	3.9	6.1	4.6	4.6	3.9

由表6-1可以看出，CH_4加入5%O_2爆炸上限限最大，为20.7，最小为CH_4:C_3H_8加20%N_2，为7.6，因为在O_2的活化作用下，CH_4爆炸极限明显升高，而在N_2的抑制作用下本来爆炸极限就偏低CH_4:C_3H_8预混气体，就要稍微低一点。由表6-1作出图6-1：

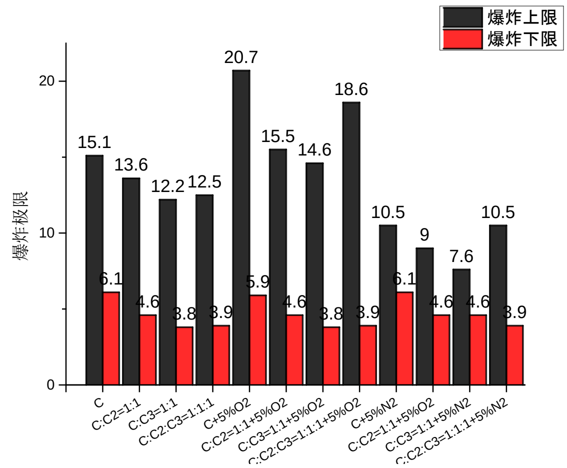


图6-1: 甲烷预混气体爆炸极限图

由图6-1可以看出CH_4的不同预混气体，爆炸　下限波动较小，但爆炸上限波动频繁，在加入5%O_2后的预混气体的爆炸上限明显比其他气氛环境下打的多。在加入20%N_2后，爆炸上限也稍微降低了。爆炸上限最大差值达到了13，而爆炸下限最大差值仅为2.3。

b) 甲烷预混气体爆炸压力测定

将不同预混气体爆炸压力整理得到图6-2：

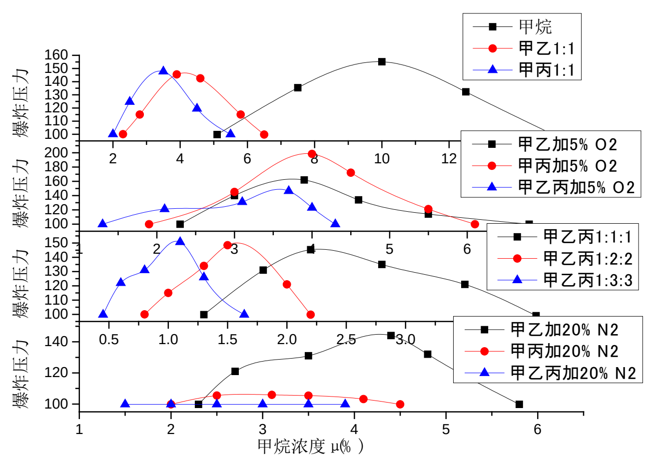


图6-2: 甲烷预混气体爆炸压力图

由图6-2可以看出，甲烷在不同气氛环境中爆炸压力各不相同，甲烷与可燃气体或抑爆气体形成的预混气体爆炸压力曲线都有明显降低，爆炸域宽会稍微扩大，我们可以通过加入可燃烷烃气体或抑爆气体来防止甲烷预混气体的爆炸。当甲烷与活化气体形成预混气体时，爆炸压力会有明显上升，而且爆炸域宽也会变大，也可以发现甲烷：丙烷=1:1时加入氧气爆炸压力最大，是因为C原子组分占比的增大，在氧气的活化作用下，激发了预混气体的爆炸能力，使得爆炸压力变大。

c) 甲烷预混气体最大压力爆炸测定

将不同预混气体最大爆炸压力整理得到图6-3：

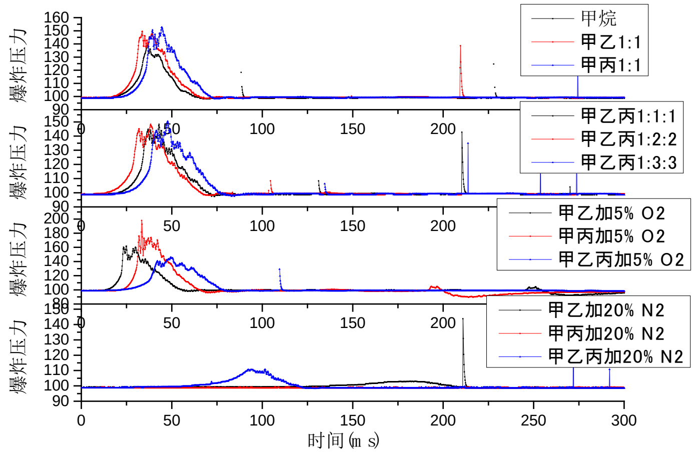


图6-3: 甲烷预混气体最大爆炸压力图

由图6-3可以看出，当 *C* 原子组分占比偏大时，爆炸压力图像顶峰最高，但起爆时间会有一点延后；在加入氧气后，最大爆炸压力的顶峰明显升高，而且起爆时间也稍微提前；相反，在加入抑爆气体氮气后，不单爆炸压力顶峰降低很多，而且起爆时间延后，爆炸时长也变窄。

d) 小结

综上，我们可以看出甲烷在不同气氛环境中的爆炸特性各不相同，不同的气氛环境对甲烷的影响强度与机理也不尽相同，可燃烷烃气体虽然会降低预混气体的爆炸极限，但当*C* 原子占比变大时，会使得最大爆炸压力变大；活化气体则会全面活化预混气体的爆炸特性，增大爆炸极限、提高爆炸压力、提前起爆时间、延长爆炸时长；惰性气体可以全方面抑制预混气体的爆炸能力，降低爆炸极限、降低爆炸压力、延后起爆时间等，但惰性气体本身带有一定的危险性，我们在使用惰性气体抑制爆炸时要注意惰性气体在空气中的浓度，谨防窒息危害。

VII. 结论

本文利用HY12474B型可燃气体爆炸极限实验装置，开展了甲烷不同气氛环境爆炸特性的实验研究，得出了以下结论：

不可燃气体对CH_4预混气体的影响能力也与*C*原子的含量有同样的关系，但O_2的加入可以释放*C*原子的爆炸危险性，加入O_2后，*C* 原子含量高的预混气体产生的最大爆炸压力较其他气体，最大爆炸压力最大。希望本文的以为CH_4爆炸特性研究提供参考价值。

1) 在对三种单烷烃爆炸极限测定后，所得数据符合Le Chatelier 理论公式，基本确定实验的准确性符合要求，在二元与三元预混气体中，爆炸极限和爆炸域宽都是存在一定规律，基本时随着*C* 原子组分含量的增加，爆炸极限都降低，而且*C* 原子组分占比越高，爆炸极限越低；爆炸域宽也是随 *C* 原子组分占比增高降低。
2) 通过对单烷烃、二元气态烷烃和三元气态烷烃的爆炸压力和最大爆炸压力进行对比，得出不同烷烃与甲烷形成预混气体时，对甲烷预混气体的爆炸危险性的影响能力：$C_3H_8 > C_2H_6+C_3H_8 > C_2H_6 > CH_4$。随着预混气体中*C*研制组分所占比例的下降，爆炸压力也有一定程度的降低。
3) 不可燃气体对CH_4预混气体的影响能力也与*C*原子的含量有同样的关系，但O_2的加入可以释放*C*原子的爆炸危险性，加入O_2后，*C*原子含量高的预混气体产生的最大爆炸压力较其他气体，最大爆炸压力最大；N_2等抑爆气体会抑制预混气体的爆炸能力，整体降低预混气体爆炸极限与爆炸压力。

VIII. 致谢

在将近三个月的时间的论文写作过程中，我遇到了无数的困难和障碍,但都在同学和老师的帮助下度过了，尤其要强烈感谢我的论文指导老师庄春吉讲师，他对我进行了无私的指导和帮助，不厌其烦的进行论文的修改和改进。庄老师严谨的治学态度、渊博的学术知识、诲人不倦的敬业精神以及宽容的待人风范使我获益颇多。

其次，感谢学院为我提供了良好的实验环境，才使得我得以完成这篇毕业论文。

同时，也感谢这篇论文所涉及到的各位学者。本文引用了数位学者的研究文献，如果没有各位学者的研究成果的帮助和启发,我将很难完成本篇论文的写作。

再次感谢每一位参与实验与论文过程的老师和同学，在他们的帮助下，我才能安全进行实验，认真完成论文。

最后，感谢我的爸爸妈妈，养育之恩，无以回报，是你们不求回报的付出才有了今天的我，谢谢你们！

由于我的学术水平有限，所写论文难免有不足之处，恳请各位老师和学友批评和指正。

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Global Journal of Science Frontier Research: H
Environment & Earth Science
Volume 22 Issue 2 Version 1.0 Year 2022
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Development of Strong Convection in the Inner Core of Tropical Cyclones during Intensification

By Jeff Callaghan

Abstract- Recent intensifying tropical cyclones around the globe are analysed to examine the observed winds structure in their inner core. The winds in sectors with strong bands of thunderstorms were observed from computer model analyses to turn in an anticyclonic fashion from the 850hPa level up to the 500hPa level. This wind structure resembles Quasi-Geostrophic warm air advection and from Hysplit Trajectory analysis was in areas of ascending air currents suitable for the initiation of thunderstorms.

GJSFR-H Classification: DDC Code: 551.116 LCC Code: QE509.4

Development of Strong Convection in the Inner Core of Tropical Cyclones during Intensification

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Abstract- **Recent intensifying tropical cyclones around the globe are analysed to examine the observed winds structure in their inner core. The winds in sectors with strong bands of thunderstorms were observed from computer model analyses to turn in an anticyclonic fashion from the 850hPa level up to the 500hPa level. This wind structure resembles Quasi-Geostrophic warm air advection and from Hysplit Trajectory analysis was in areas of ascending air currents suitable for the initiation of thunderstorms.**

I. Introduction 1

Decades of observations have shown us in the Northeast Australian Region that the convection (thunderstorms) in the inner core of tropical cyclones initially develops in an asymmetric pattern which under the right conditions may form an axisymmetric ring of convection as it reaches peak intensity. Researchers (see below) believe that the axisymmetric model of tropical cyclone structure fails to explain convection initiation in the inner core. The concept on Vortical Hot Towers(VHTs) has been developed to understand how this convection can develop. In this paper the roles of winds turning in an anticyclonically fashion between the 850hPa level up to 500hPa is presented as an explanation of the structure of VHTs.

II. Generation of Vortical Hot Towers in the Inner Core of Tropical Cyclones 2

The term Hot Towers has been applied to tall cumulonimbus clouds that are horizontally small with their greatest extent is in the vertical, reaching altitudes as high as 18 km. They can efficiently transport heat from the lower troposphere to the stratosphere. When they are thought to form within areas of rotation in rotating updrafts and are known as Vortical Hot Towers(VHTs).The role of hot towers in tropical weather was first formulated by the legendry scientist Joanne Simpson(nee Malkus) in (Riehland Malkus1958).

We have looked at the role of a certain wind structures producing these VHTs. In Section 3 of Callaghan (2021) is a detailed review (including climatology) of how winds turning anticyclonic from the 850hPa level up to the 500hPa level are associated with tropical cyclone intensification and extreme rainfall both in the tropics and in higher latitudes. Due to this wind structure, being like Quasi Geostrophic warm air advection (Holton 2004), for brevity we call it Warm Air Advection (WAA). Examples of this wind structure causing extreme rainfall and being associated with tropical cyclone intensification are shown in Tory 2014, Callaghan and Tory 2014, Callaghan and Power 2016 and Callaghan 2017a, 2017b, 2018, 2019a, and 2019. Such WAA has a wind structure that produces streamwise vorticity (Davies-Jones 1985) encouraging rotating updrafts which separate updrafts from the destructive effects of downdrafts. The opposite structure of winds turning cyclonic through this layer can cause convection with rotating updrafts when in an environment of low static stability but mostly this wind structure suppresses convection and here is called cold air advection (CAA).

The common summer wind pattern off the Northeast Australian Coast is a CAA wind structure which contributes to convective suppression. This was illustrated in Figure 2 of Callaghan (2021) which shows the winds turning clockwise (cyclonic) with height over the area on average through January, February, and March. The rainfall associated with this pattern is light rain with the heavy rain further north in the monsoon trough across the Gulf of Carpentaria and Cape York. The author spent the active La Nina 1973/1974 summer on Willis Island Meteorological station in the Coral Sea and with monotonous regularity the radar balloon flight showed low level southeast winds turning clockwise with height through southerly winds up to south-westerly at 500hPa. During this time only light rainfall was observed. It was only when a vortex developed, or an upper trough system extended up into the tropics (see example Appendix I Callaghan 2021) that a pattern conducive to heavy rainfall was observed. In those cases, because the most common 850 to 500hPa vertical wind shear was westerly a dipole structure was produced with WAA and ascent in the east and CAA and descent in the west.

In the Queensland Severe Weather Section of the Bureau of Meteorology a diagnostic for heavy rain and TC intensification was developed using 850hPa, 700hPa and 500hPa winds from the European Model. This became possible from the 1990s when computer forecasting models became freely available. This clearly showed to us the relationship between WAA and heavy

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rain and TC intensification. Callaghan and Tory 2014 used data from Holland (1984) to show that intensifying tropical cyclones in the Australian/southwest Pacific region had an asymmetric convective structure associated with WAA when considering the climatological winds at 850hPa and 500hPa.

From Callaghan 2017b the most rapid intensification cases had asymmetric inner core convection early in a six- hour period where the Central Pressure dropped 29hPa. The more intense TCs developed an axisymmetric convective pattern at peak intensity and an example of this is shown with Hurricane Michael (Callaghan 2019a).From this study an important case examined which models could not forecast the RI of was severe tropical cyclone Marcia as recently as February 2015. In this case throughout the RI convection was formed more vigorously on the western flank under the influence of a warm air advection process and this needs to be understood on its influence on the model failures. Below we present two recent forecasting failures involving Super Typhoon Rai.

III. Eliassen Vortex 3

Eliassen (1951) derived an equation for an axisymmetric vortex circulation The Primary circulation refers to the tangential or swirling flow rotating about the central axis, and the secondary circulation refers to the "in-up-and-out circulation" (low and middle level inflow, upper-level outflow).

If the vortex is axisymmetric and in approximate gradient wind and hydrostatic balance, Eliassen derived an equation for the circulation in a vertical plane obtaining a diagnostic expression for mass-flow in the radius-height plane. From Willoughby (1988) the secondary circulation controls the distribution of hydrometeors and radar reflectivity. The ascending motion occurs in numerous individual convective updraft cores. These cover 10% of the area in the vortex core and 60% of the eye wall. The vertical velocities in the strongest 10% of the updraft cores averages 3.5m/s.

Smith and Montgomery (2008) found from these axisymmetric models that in an intensifying tropical cyclone (TC) the azimuthally averaged field has negative unbalanced buoyancy, which they defined here as buoyancy relative to the reference density of the balanced state. Therefore, they concluded it could not support an intensifying circulation by itself. As a result, they decided that this circulation must be driven by VHTs. Nguyen et al. (2008) examined tropical-cyclone intensification and predictability in the context of an idealized three-dimensional numerical model and in the prototype amplification problem starting with a weak axisymmetric tropical storm-strength vortex, they showed that the emergent flow becomes highly asymmetric and is dominated by deep convective vortex structures, even though the problem as posed is axisymmetric. They also referred to these structures as VHTs.

The above studies concluded that there was a fundamental difference between the axisymmetric paradigm for tropical-cyclone intensification and the asymmetric paradigm, in which the VHTs are key elements of the evolution. Indeed, they found that these VHTs are the only coherent structures that have positive local buoyancy. As a result, it was concluded that this circulation must be driven by the local buoyancy in the VHTs. Hence WAA plays a crucial role in the intensification of TCs via its development of VHTs.

IV. Data 4

- Much of the data comes from The Bureau of Meteorology website bom.gov.au however the following web sites were used to obtain data after the event: -
- Archived synoptic weather observations from www.meteomanz.com/?l=1 ;
  Archived upper wind observations from the University of Wyoming web site: - at weather.uwyo.edu/upperair/sounding.html.
- Ocean Heat Content (OHC) data was obtained from RAMMB: TC Real-Time: Currently Active Tropical Cyclones (colostate.edu).
- The NOAA HYSPLIT model for air parcel trajectory analyses using he Global Data Assimilation System (GDAS) 0.5degree global model September 2007 to June 2019 at the following site: - https://www.ready.noaa.gov/HYSPLIT.php
- Numerical Model upper wind analyses were obtained from the Weathernerds web site at: - Weathernerds

These provided the source of the events which had the wind structure to generate inner core convection on Tropical Cyclones (TCs). This wind structure (winds turning anticyclonic from 850hPa through 700hPa to 500hPa) could be assessed by a series of 850hPa, 700hPa and 500hPa wind charts and then highlighting the 700hPa wind charts which fell into this category. An easier way was to overlay the 850hPa winds on the 500hPa winds. The advantage of this latter chart was it was much easier to determine whether the wind backed or veered. However, it slightly exaggerated the anticyclonic turning area of winds from 850hPa to 500hPa as in a few cases there was no anticyclonic turning between the 700hPa up to the 500hPa levels. We present both methods here but mostly used the charts showing the 850hPa to 500hPa shear.

V. Examples of Tropical Cyclones with WAA in the Inner Core 5

a) *Severe tropical cyclone Batsirai 5.1*

Batsirai is the first of a series of recent tropical cyclones making landfall with very destructive winds. It is shown in these examples how the WAA in the inner core was associated with ascent enabling convection to develop there. Hysplit trajectory analysis are employed to validate the ascent observed WAA. The trajectories are those taken by air parcels whereas some of these parcels will be involved in the development of convection and will circulate around the centre of the cyclone.

TC Batsirai struck Madagascar on 5 February 2022. According to the Madagascar National Disaster Management Agency this resulted in 121 fatalities with19,000 homes being destroyed (8,364), flooded (7,098) or damaged (3,236). The main wind damage and thirty-four fatalities caused by Batsirai was concentrated around the coastal town of Mananjary while eighty-seven people died following landslides in the mountainous district of Ikongo to its south-southwest.

By examining Figure 1 (left frame) it can be seen, that at 0600UTC 2 February 2022 WAA (from 850hPa winds turning anticyclonic up to 500hPa) in the inner core of Batsirai was associated with ascent from the Hysplit trajectory analysis (Figure 2). This ascent existed from the 1500metre elevation up to 4500metres elevation in one hour or just under 1m/s vertical velocity. The trajectories (not shown) reached the outflow layers (above 200hPa) after 5hours. Trajectory from 500m elevation rose to just over 3000m elevation in one hour so the whole low-level layer was lifted. Trajectories (not shown) starting at 1500km east northeast of the centre at this time show little ascent from 1500km elevation as would be expected from the lack of WAA advection in that segment. In time the trajectories would differ from the movement of individual convective cells which develop in the rising motion provided by the WAA. For instance, after 4 hours the air parcels were moving in easterly winds in the outflow layer at 200hPa.

From Black et al 1996, studying seven Atlantic Hurricanes using Doppler radar data, more than 70% of the vertical velocities range from -2 to 2 m s^{-1}. The broadest distribution of vertical motion is in the eye wall region where around 5% of the vertical motions are >5 m s^{-1}. Averaged over the entire dataset, the mean vertical velocity was upward at all altitudes. Mean downward motion occurred only in the lower troposphere of the stratiform region.

The top left microwave image in Figure 3 at 0950UTC 2 February was when from Dvorak analysis near peak intensity with a small compact eye and by the next image at 0409UTC 4 February it had a much larger eye having just gone through an eye wall replacement cycle. By 1243UTC 4 February 2022 (top right frame Figure 3) the eye has slowly reduced in size as the eye wall contracts to complete the cycle. From the first three lower frames in Figure 3 convection weakens in the northern sector near the eye of Batsirai as CAA take hold there (see left frame in Figure 4 where a large area of CAA had developed north of the centre by 0000UTC 5 February 2022. By 1350UTC 5 February 2022 bands of strong convection (red areas) wrapped around the centre onto the coast over Mananjary and south of southwest of the town. The eye had contracted by then indicating intensification at landfall. Coincident with this intensification WAA at 1200UTC 5 February 2022 (right frame Figure 4) dominated the circulation with little CAA present.

Hysplit trajectory analysis at this time (Figure 5) shows ascent from 1500m elevation up to just under 4000m elevation near Mananjary. Observations (winds read from an anemometer) were available from Mananjary around this time at: -

- 1200UTC 5 February Average wind from the south at 70knots mean sea level (msl) pressure 987.0hPa 54mm of rain past 6hours.
- 1500UTC 5 February Average wind from the south at 90knots msl pressure 976.9hPa 81mm of rain past 6hours.

Sea surface temperatures (SSTs) were around 27^{0}C leading up to landfall while the Ocean Heat Content (OHC) was around 15-35 kJ/cm^2 (where greater than 50 kJ/cm^2 have been shown to promote greater rates of intensity change).OHC data was obtained from RAMMB: TC Real-Time: Currently Active Tropical Cyclones (colostate.edu).

The worst of the wind damage and loss of life from the wind occurred in the Mananjary area while the second rain band further south is associated with the large loss of life from landslides in the mountainous district of Ikongo.

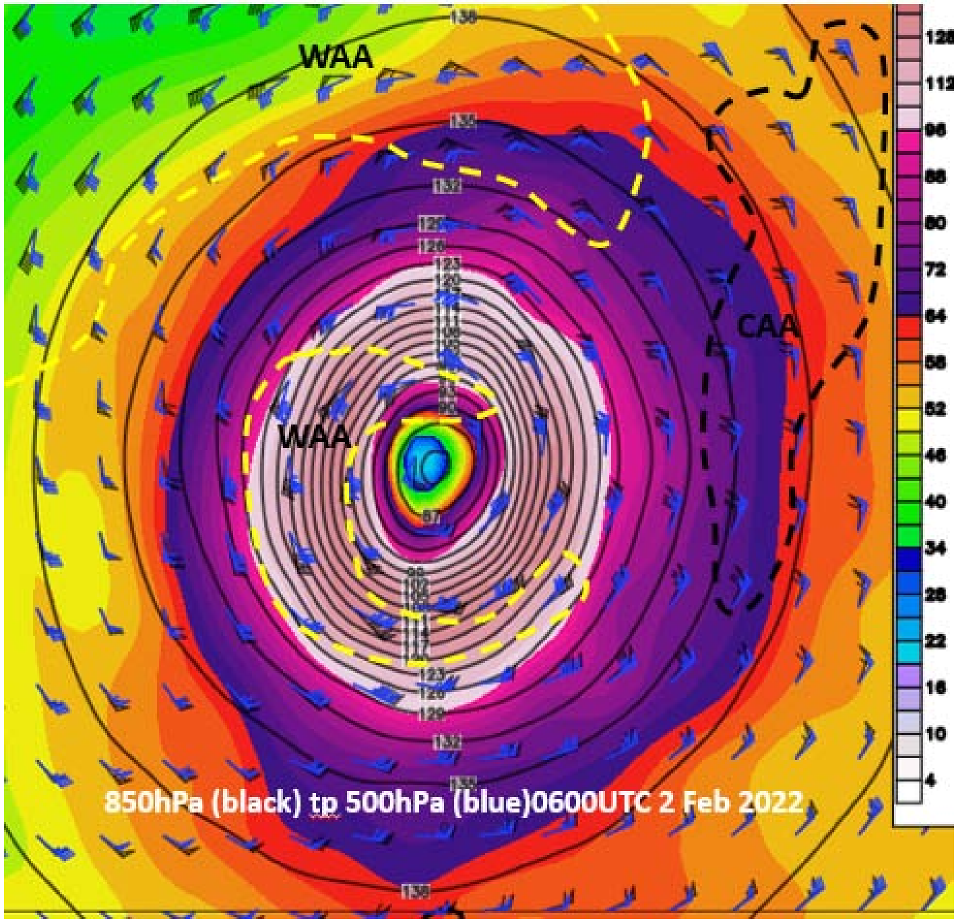


Figure 1: GOES 850hPa wind analysis (black plots) 500hPa analysis blue plots with yellow dashed line highlighting where 850hPa winds turned anticyclonic rising to 500hPa (WAA) and where they turned cyclonic highlighted by black dashed line (CAA) for 0600UTC 2 February 2022.

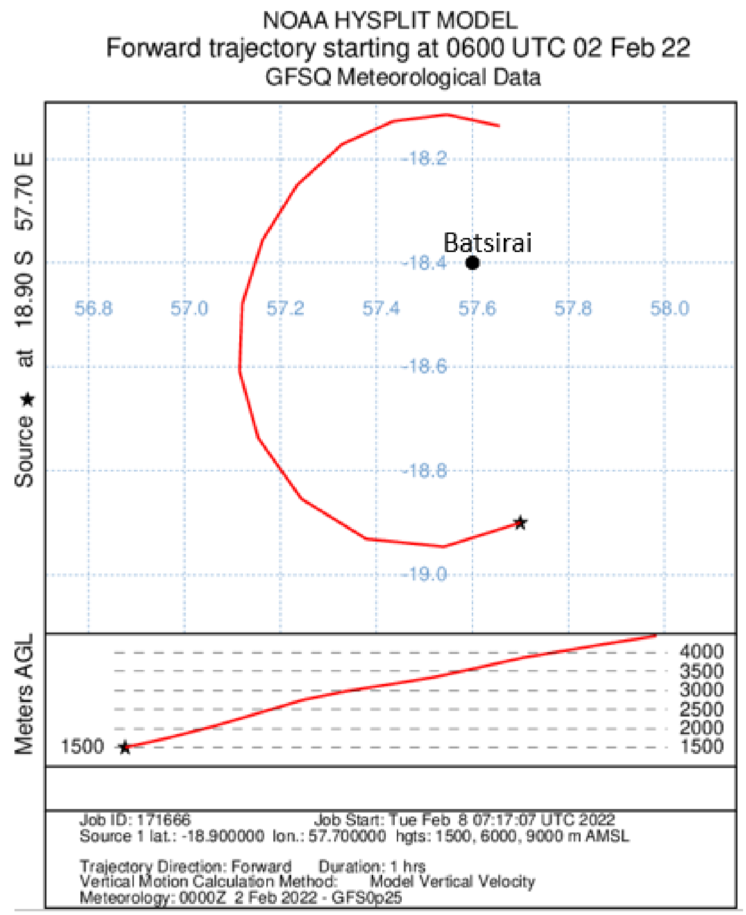
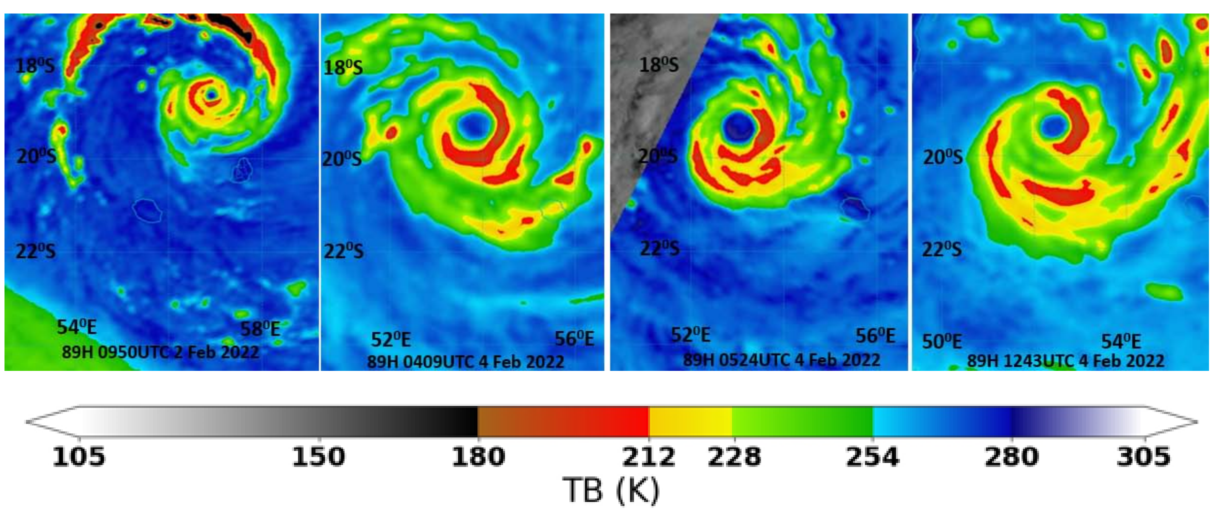


Figure 2: Hysplit trajectory analysis starting 0600UTC 2 February 2022 for tropical cyclone Batsirai



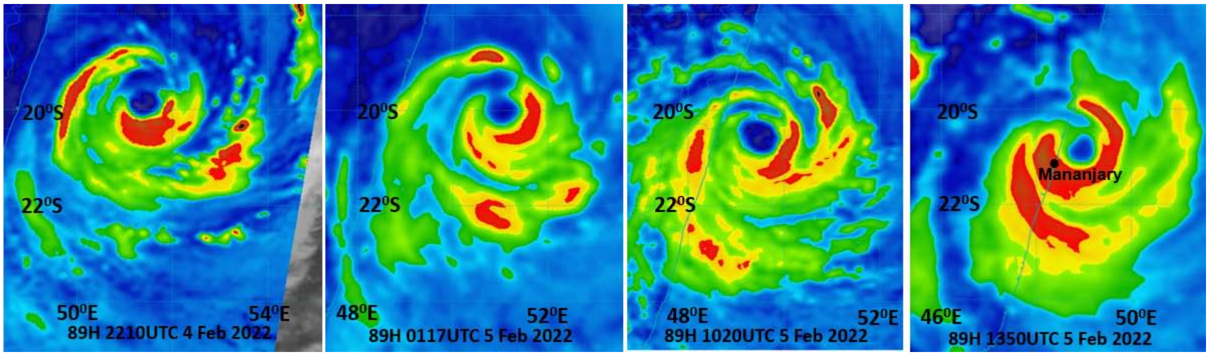


Figure 3: 89H Microwave images (Courtesy NRL Monterey) for 0950UTC 2 February to 1350UTC 5 February 2022

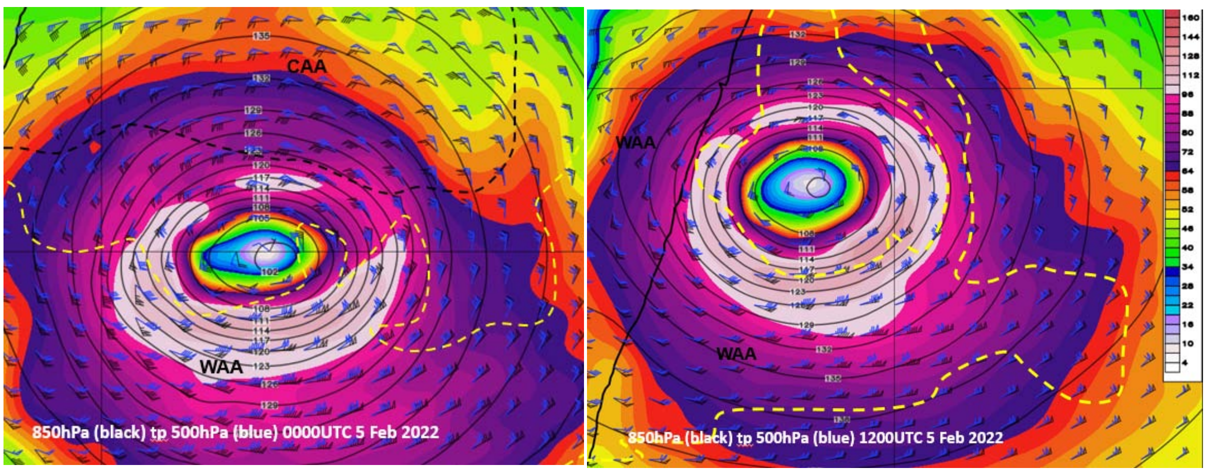


Figure 4: GOES 850hPa wind analysis (black plots) 500hPa analysis blue plots with yellow dashed line highlighting where 850hPa winds turned anticyclonic rising to 500hPa (WAA) and where they turned cyclonic highlighted by black dashed line (CAA) for 0000UTC 5 February 2022 (left frame) and 1200UTC 5 February (right frame).

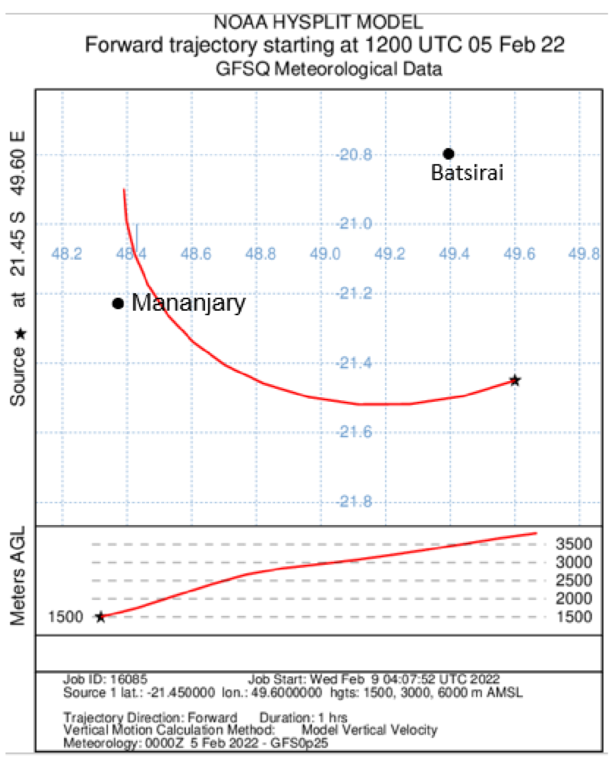


Figure 5: Hysplit trajectory analysis starting 1200UTC 5 February 2022 for tropical cyclone Batsirai

b) Severe tropical cyclone Seroja 5.2

Seroja despite making landfall on the sub-tropical coast it remained a very destructive storm as it crossed the coast. It followed a tongue of warmer water onto the coast(Figure 6) with Ocean Heat Content (OHC) of 19kJ/cm^2.

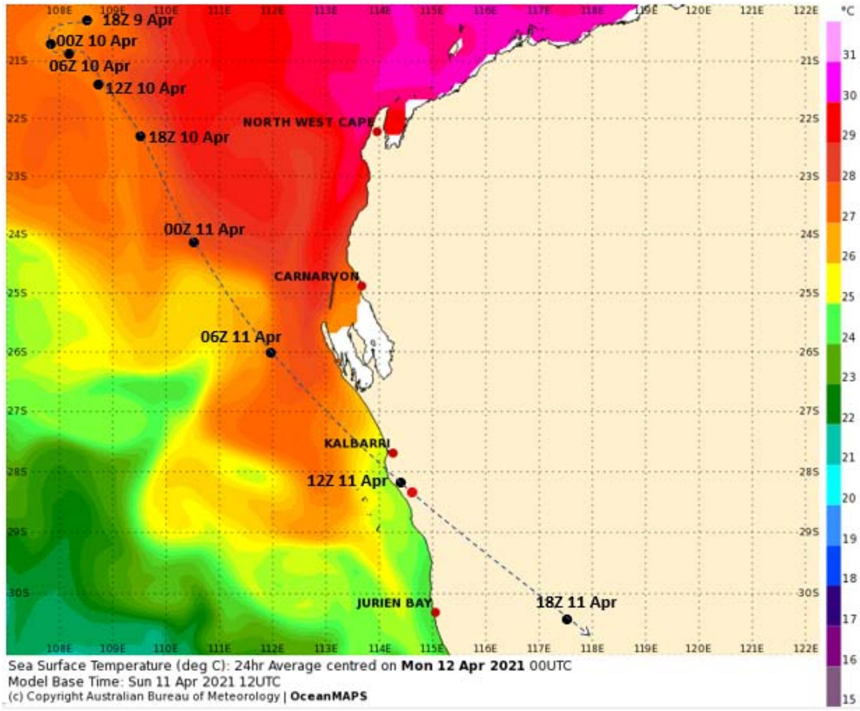
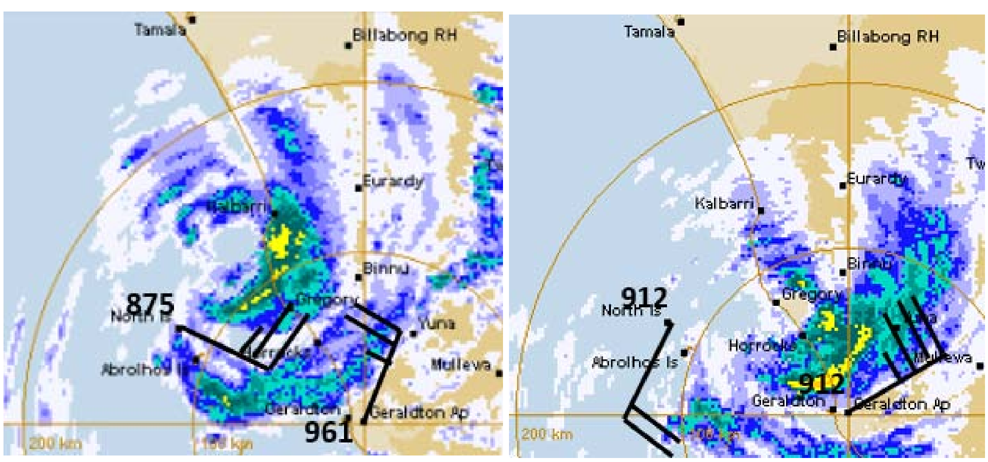


Figure 6: Track of Seroja on map of sea surface temperature distribution



1100UTC 11 April 2021 1200UTC 11 April 2021

Figure 7: Geraldton radar images (radar rings every 100km) and wind and pressure observations (last three digits to one decimal place) for 1100UTC 11 April 2021 (left) and 1200UTC 11 April 2021 (right)

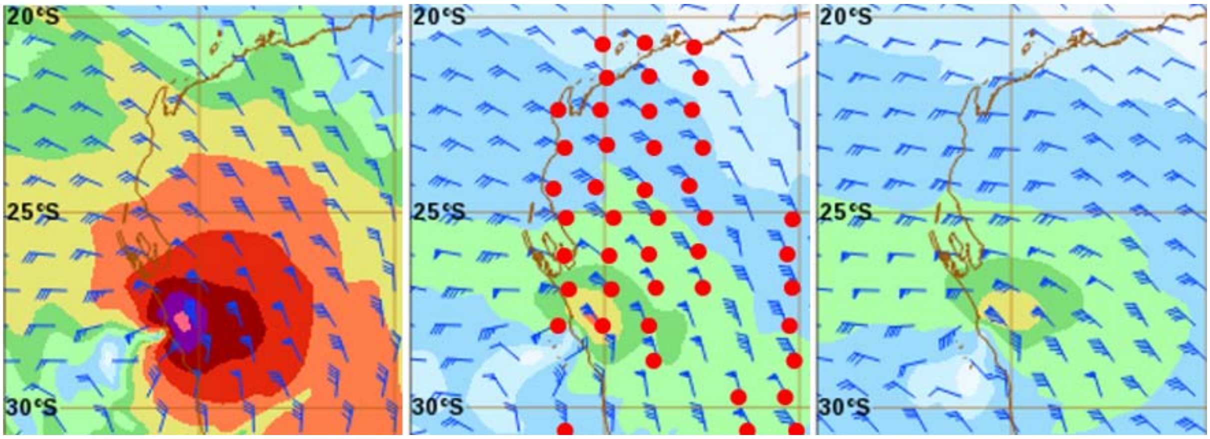


Figure 8: Winds at 1200UTC 11 April 2021 in left frame has 850hPa winds, centre frame 700hPa winds with red dots where the winds turned anticyclonic from 850hPa through 700hPa up to 500hPa and right frame 500hPa winds

The radarimages of Seroja at landfall show Kalbarri under the eyewall in Figure 7 (left frame) while town of Northampton lay under the eyewall north of Geraldton in the right frame of Figure 7. In Figure 8 are the 850hPa, 700hPa and 500hPa wind analyses with red circles highlighting where winds turned anticyclonic from the 850hPa level through 700hPa up to 500hPa that is WAA for 1200UTC 11 April 2021.

Impacts at Kalbarri and Northampton were severe with around 70% of buildings sustaining severe damage, mostly consisting of lost roofs but with many structures destroyed. Many locations recorded maximum wind gusts more than 125km/h with the highest being 170km/h from Meanarra Tower near Kalbarri. Trajectories of air parcels from WAA near Seroja (Figure 9) show areas of strong ascent over both Kalbarri and Northampton.

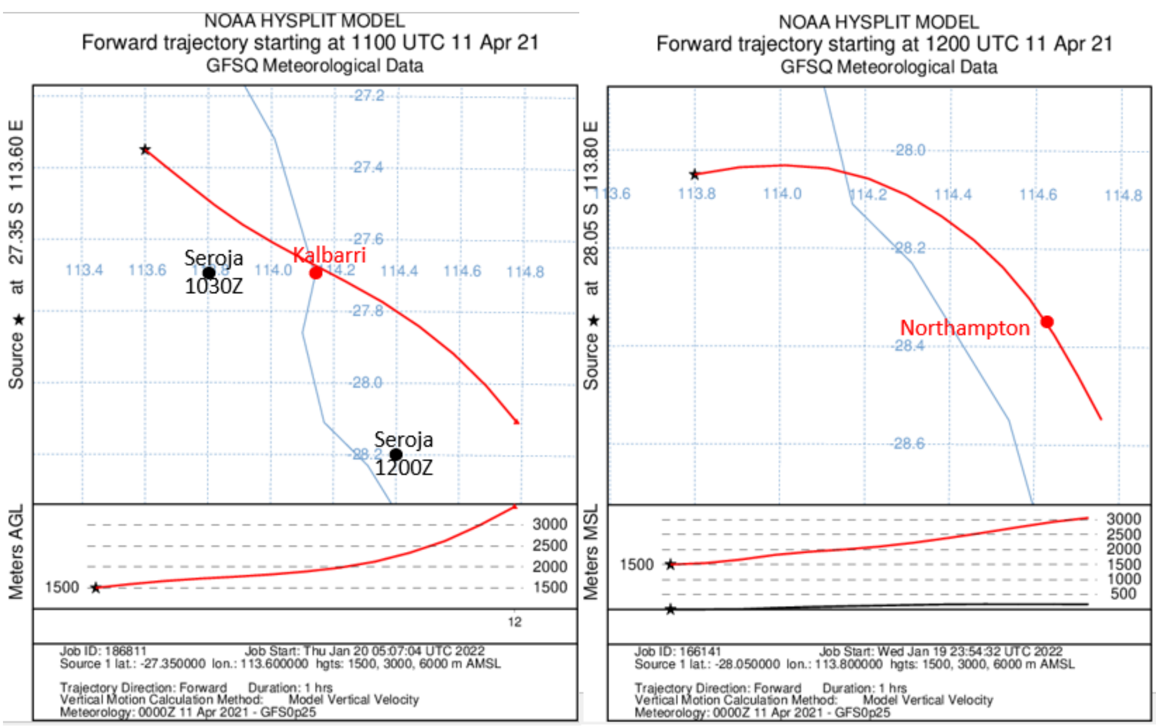


Figure 9: Hysplit trajectory analysis starting 1100UTC 11 April 2021 and 1200UTC 11 April 2021 tropical cyclone Seroja

c) Severe Tropical Cyclone Harold 5.3

Harold at 0000UTC 4 April 2020 with the circulation dominated by strong WAA over much of its western inner core and beyond(Figure 10). By 1200UTC 4 April 2020 the central pressure decreased from 967hPa to 950hPa. The Intensity then halted briefly before reaching peak intensity 924hPa at 1200UTC 6 April over Vanuatu where widespread severe structural damage was experienced around Luganville and Pentecost Island. The trajectories resulting from this strong WAA are shown in Figure 11. The trajectories after 1hour (left frame) show air parcels at 1500m elevation lifted to 5000m with parcels lifted even after 6hours up to 13,500m and above. With different starting elevations and therefore different wind directions (due to the anticyclonic turning of the wind) the trajectories showed a strong upper outflow pattern.

As it moved towards Luganville it passed over waters with strong Ocean Heat Content (OHC) of 50-100kJ/cm^2.

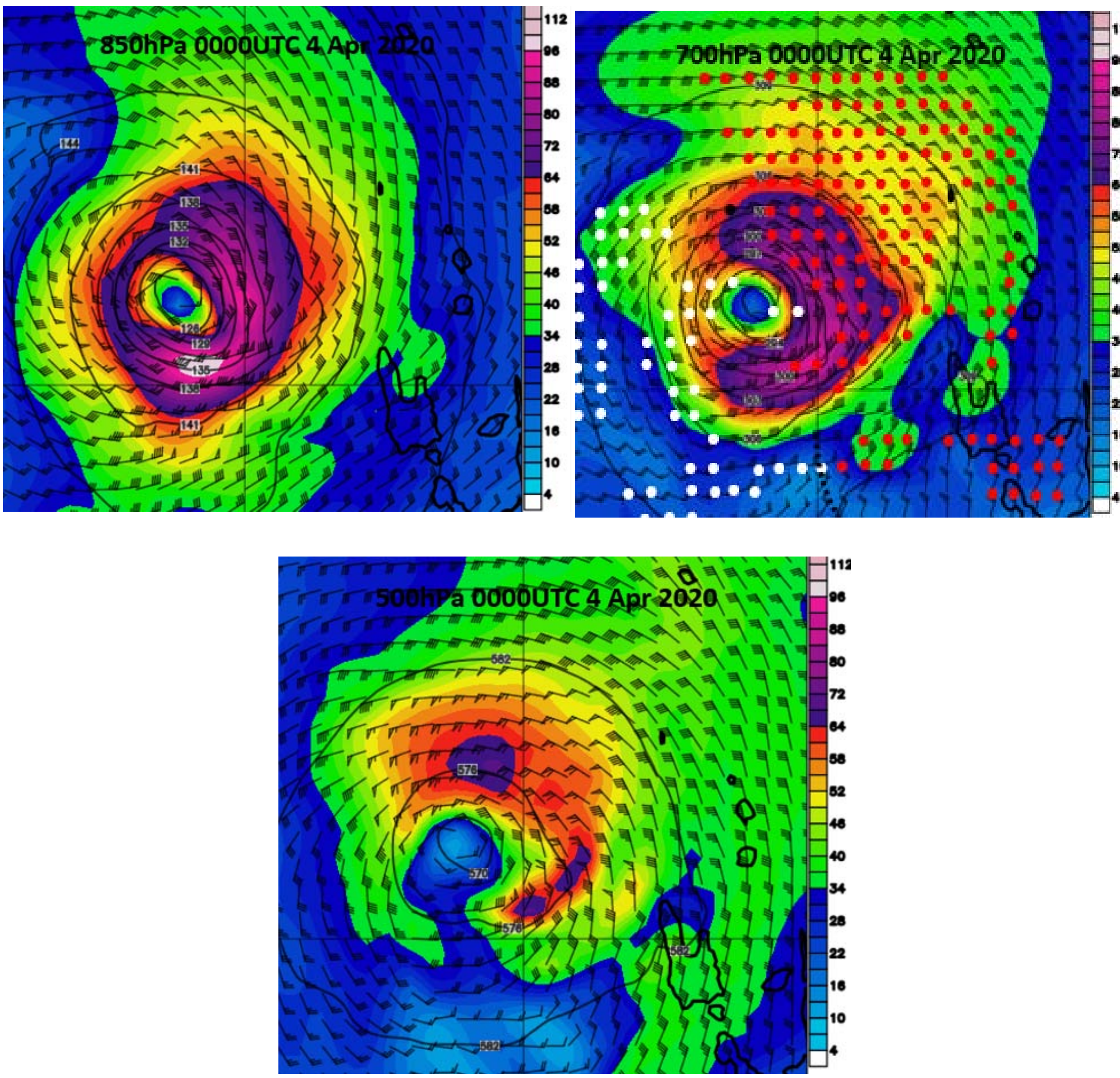


Figure 10: Top left frame is 850hPa winds top right 700hPa winds and lower left 500hPa winds for 0000UTC 4 April 2020 where red circles are the wind plots at 700hPa where the winds turned anticyclonically coherently from 850hPa through 700hPa up to 500hPa. Similarly, the white plots are where the winds turned cyclonically

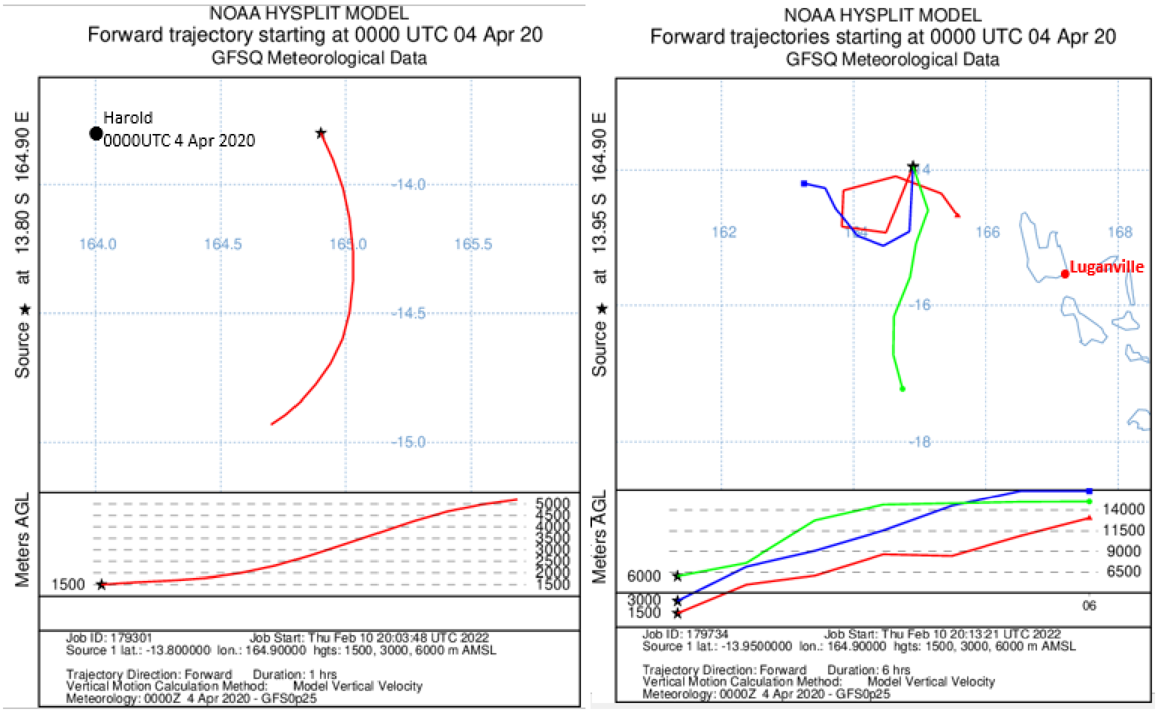


Figure 11: Hysplit trajectories from 0000UTC 4 April 2020 over one hour (left) and over 6 hours (right)

d) *Super Typhoon Rai 5.4*

Typhoon Rai caused severe and widespread damage throughout the Southern Philippines, killing at least 409. Rai unexpectedly underwent rapid intensification on December 15. The Joint Typhoon Warning Centre (JTWC) forecast from 1200UTC 15 Dec 2021 had 75knot peak average winds for Rai as it approached the northern tip of Mindanao in the Philippines at 1200UTC 16 Dec. Their analysis at 1200UTC 16 Dec had peak winds of 130knots as Rai was about to make landfall (see JTWC forecasts at NRL Monterey). On December 16, the typhoon made landfall over Surigao Island in the province of Surigao del Norte 1:30 PM local time (05:30UTC).

From Figure 12 WAA at 1200UTC 15 December 2021 was located mostly north and west in the inner core of Rai. From Figure 13 this caused ascent to just over 3500m from the 1500m level in one hour. By 0000UTC 16 December the WAA extended right around the southern semicircle of the inner core of Rai (Figure 12) with Hysplit (Figure 13) showing ascent up to 5,500m in one hour around to the northeast of the centre as convection becomes strong in the northeast quadrant (red to black area in Figure 14) and therefore wraps around the eye (Figure 14) to completely enclose it.

As Rai moved towards Surigao Island it passed over waters with strong OHC of 35-75kJ/cm^2.

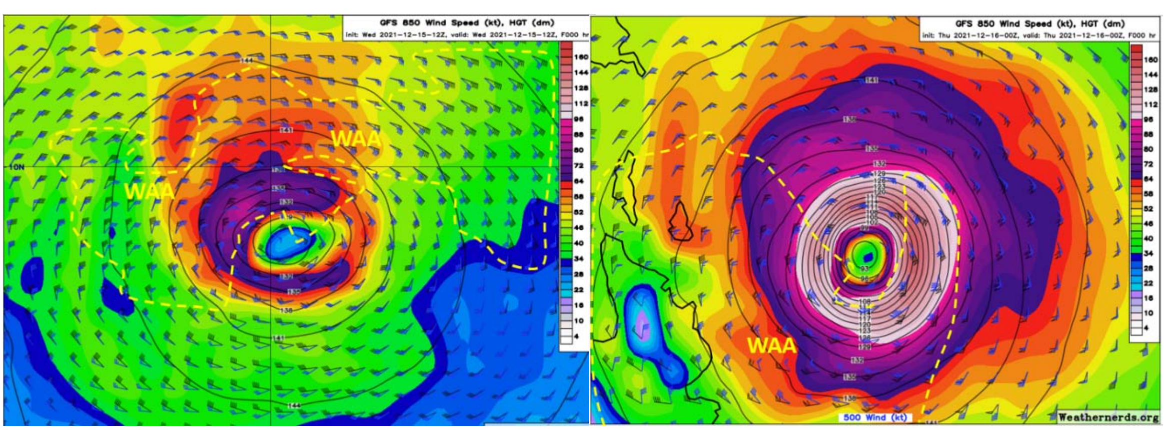


Figure 12: GOES 850hPa wind analysis (black plots) 500hPa analysis blue plots with yellow dashed line highlighting where 850hPa winds turned anticyclonic rising to 500hPa (WAA) and where they turned cyclonic highlighted by black dashed line (CAA) for 1200UTC 15 December 2021 (left frame) and 0000UTC 16 December 2021 (right frame)

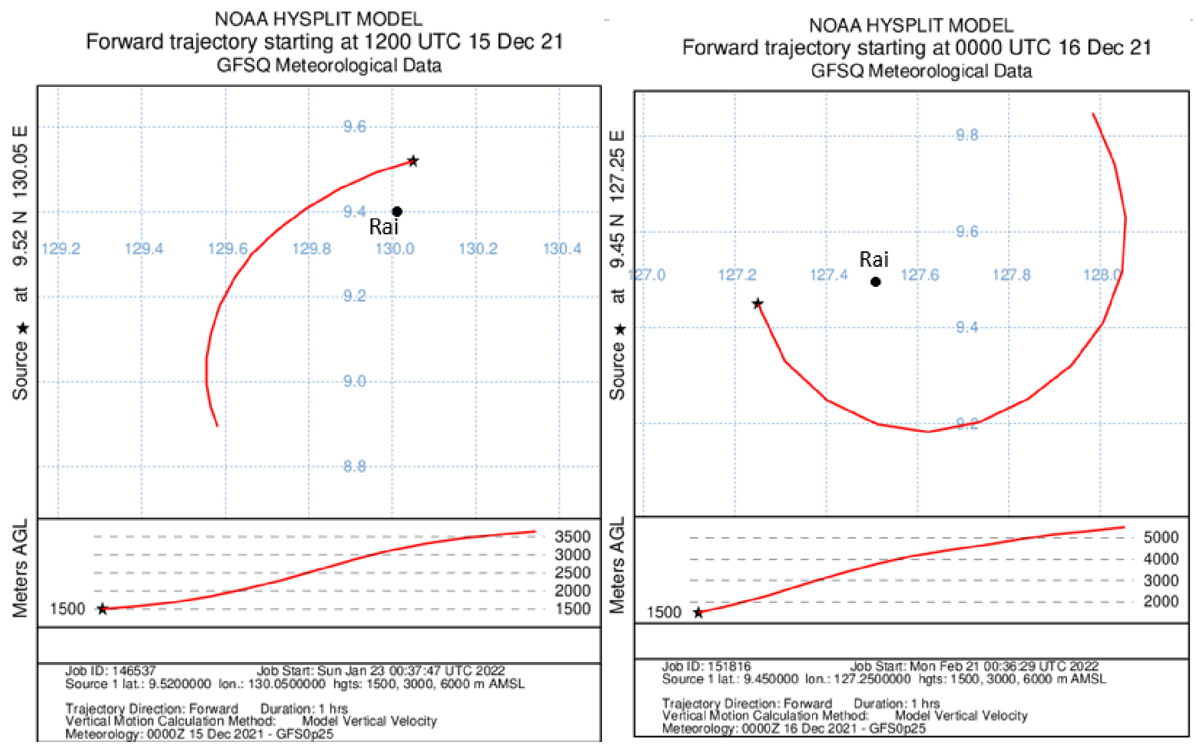


Figure 13: Hysplit trajectories over one hour from 1200UTC 15 December 2021 (left) and over one hour from 0000UTC 16 December 2021 (right)

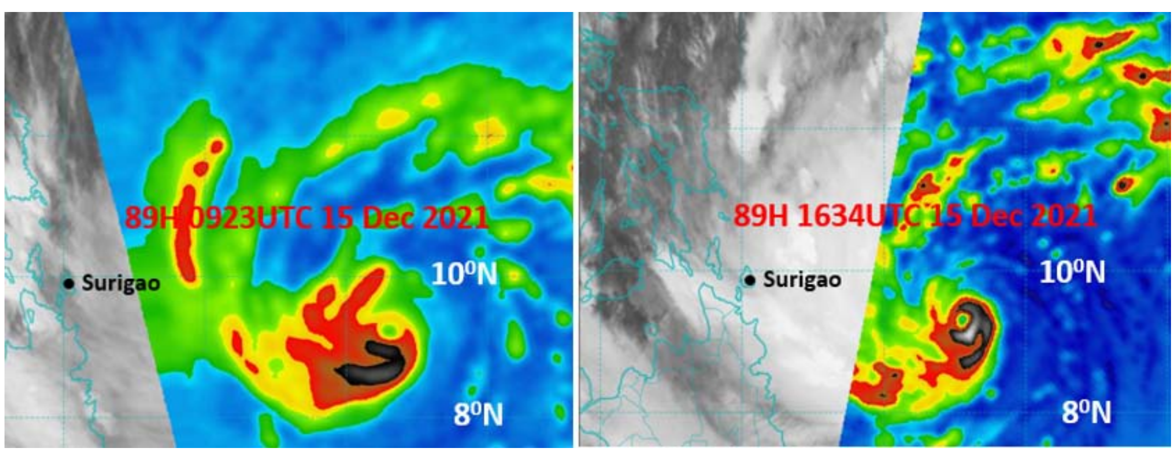


Figure 14: 89H Microwave images (Courtesy NRL Monterey) for 0923UTC 15 December 2021 to 1634UTC 15 December 2021

Rai crossed over the Philippine Archipelago weakening as it did so and with the expectation from computer models and the JTWC it would move into the South China Sea and moved northwards as a much weaker system. However, it underwent rapid intensification in the South China. At 1800UTC 18 December it was analysed by the JTWC to have a peak sustained winds of 145knots whereas earlier at 1200UTC 17 Dec it was forecast by JTWC to have a peak wind speed of 95knots in this area.

From Wikipedia Rai wreaked havoc across Vietnamese-held isles in the Spratly Islands. An observation tower in Southwest Cay recorded sustained winds up to 180 km/h (110 mph) and a gust of 200 km/h (120 mph) during the afternoon of December 18 before being knocked down. The storm destroyed five hundred square meters (5,400 sq ft) of civilian house tiles, twenty-seven solar batteries, four hundred square meters of farmland, and knocked down 90% of the trees on the island; no casualties were reported there. As it passed seawards of Vietnam Rai began to batter the Central Vietnamese coast, with severe winds and rainfall up to 300mm. On December 19, one person (fisherman) was reported dead in Tuy Phong, five ships were capsized, and three others were damaged off the coast.

Over this period microwave images (Figure 15) show the intensification of Rai where an elongated eye at 2316UTC 17 December 2021 (left frame) contracts into a circular compact eye by 2030UTC 18 December 2021 (right frame). At 1200UTC 18 December 2021 (halfway between these two images) GOES analyses (Figure 16) shows a large area of WAA occupying the northwest inner core semicircle of Rai while a smaller area of CAA was located around the southeast semicircle. Hysplit trajectories (Figure 17) show strong ascent in the WAA area from 1500m elevation up to 4000m in one hour.

As Rai moved out into the South China Sea it passed over waters in the first 12 hours with small Ocean Heat Content (OHC) of 0-15kJ/cm^2 and then over waters with negligible OHC.

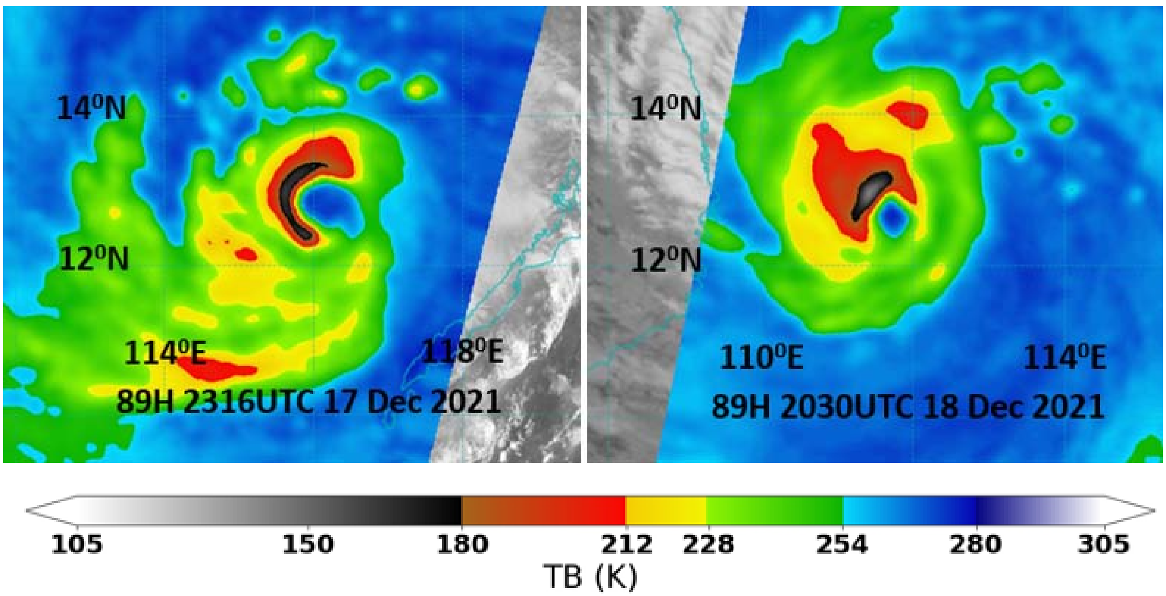


Figure 15: 89H Microwave images (Courtesy NRL Monterey) for 2316UTC 17 December 2021 to 2030UTC 18 December 2021

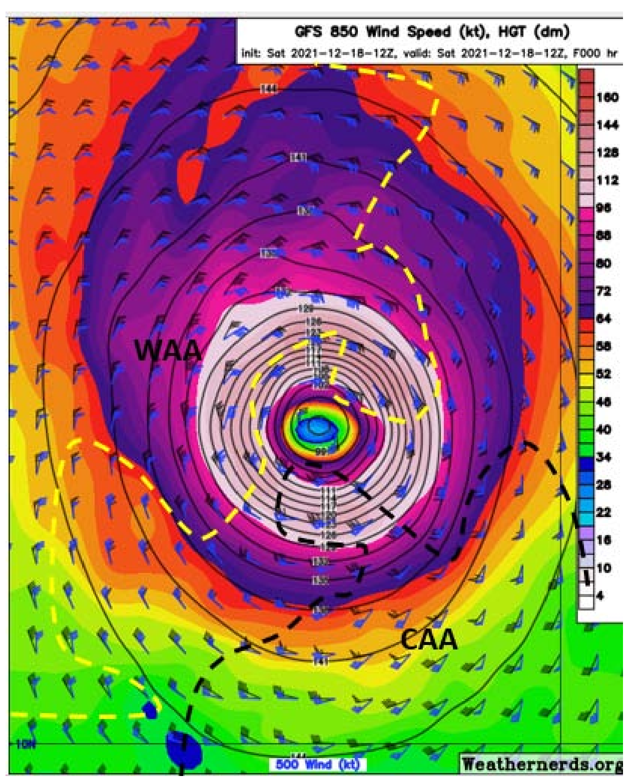


Figure 16: GOES 850hPa wind analysis (black plots) 500hPa analysis blue plots with yellow dashed line highlighting where 850hPa winds turned anticyclonic rising to 500hPa (WAA) and where they turned cyclonic highlighted by black dashed line (CAA) for 1200UTC 18 December 2021

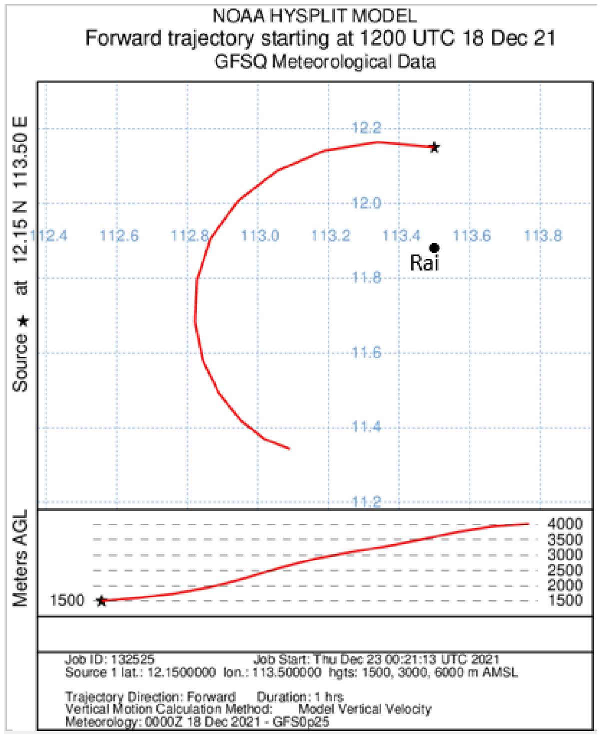


Figure 17: Hysplit trajectories over one hour from 1200UTC 18 December 2021

e) Michael 5.5

Reconnaissance aircraft measured a central pressure of 955hPa in Hurricane Michael at 2307UTC 9 October 2018 while it was moving north towards the Florida Panhandle. By 1309 10 October 2018 the aircraft calculated it had deepened to 934hPa and then it made landfall east of the Tyndall Airforce Base which recorded a mean sea level pressure of 922.4hPa at 1720UTC 10 October 2018 and measured a gust of 208km/h (Bevan et al 2019). Mexico beach area, 28 km southeast of Tyndall felt the full force of Michael and suffered the greatest loss of the thirty-nine lives so far accounted for as having been lost in the United States. Mexico Beach is a small town (population of only 1,072 in the 2010 census).

Michael developed extensive WAA areas at 2355UTC 9 Oct 2018 and 1205UTC 10 October 2018 Figure18. These are taken from Callaghan 2019a where the winds are analysed between1km and 5km to determine the turning winds. Hysplit trajectories for both cases show strong ascent with the circulation rising from an elevation of around 1300m up to well above 4000m. Though not shown in both cases over longer periods (9 and 6 hours) the trajectories from three levels rise well above 12km into the outflow area of Michael. As Michael approached the coast it moved through water with OHC of15-35kJ/cm^2.

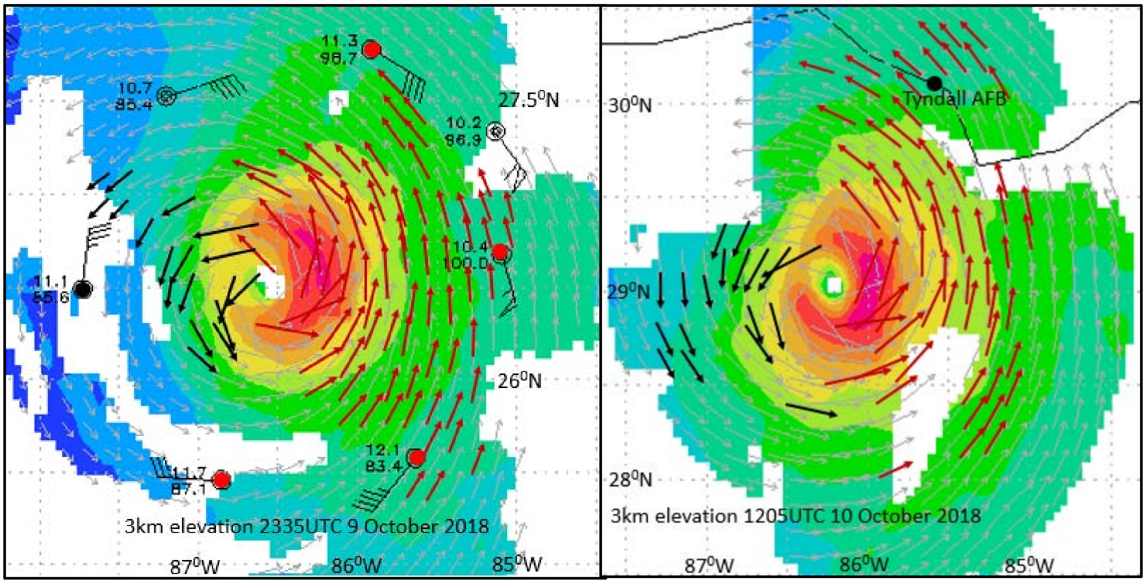


Figure 18: Horizontal plots of a composite two real time Doppler radar analyses for Hurricane Michael at 3km elevation at 2335UTC 9 October 2018 (left) and 1205UTC 10 October 2018 (right). Red wind plots denote ascent (wind directions turning in an anticyclonic direction from 1km to 3km to 5km) and black plots indicate descent (wind directions turning in a cyclonic direction from 1km to 3km to 5km.) The large wind plots in the left frame are from dropsondes and those marked with a bold red circle denote ascent (anticyclonic turning) and those with a bold black circle denote descent (cyclonic turning)

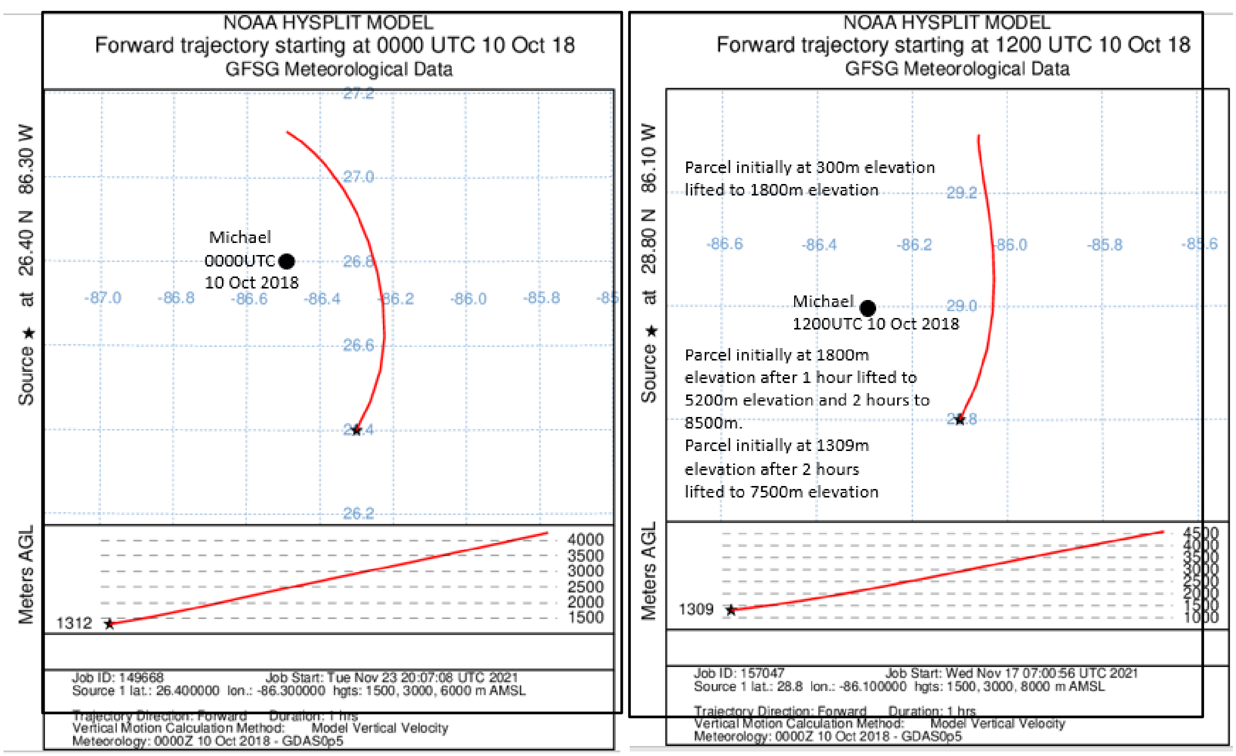


Figure 19: Hysplit trajectories over one hour from 0000UTC 10 October 2018 (left) and from 1200UTC 10 October 2018 (right).

f) Dorian 5.6

A WAA region about the inner core of Hurricane Dorian at 2322UTC 31 August 2019 is displayed in Figure 20. At the time Dorian was moving west towards the Bahamas with a central pressure of 939hPa and peak winds of 135knots. Twelve hours later it had a central pressure of 927hPa and peak winds of 155knots (1minute average winds) (Avilla et al 2020).

WAA areas at 2322UTC 31 August 2019 were less extensive than with Michael and in the first hour Hysplit trajectories (Figure 21) show weaker ascent with the circulation rising from an elevation of around 1500m up to about 2900m. After 12hours the trajectories from the three levels rose above 12kmelevation into the outflow area of Dorian which is not shown. As Dorian approached the Bahamas it moved through waters with OHC of 50-75kJ/cm^2. Comparing this with Michael the weaker ascent supplied by the WAA was compensated by the much stronger OHC.

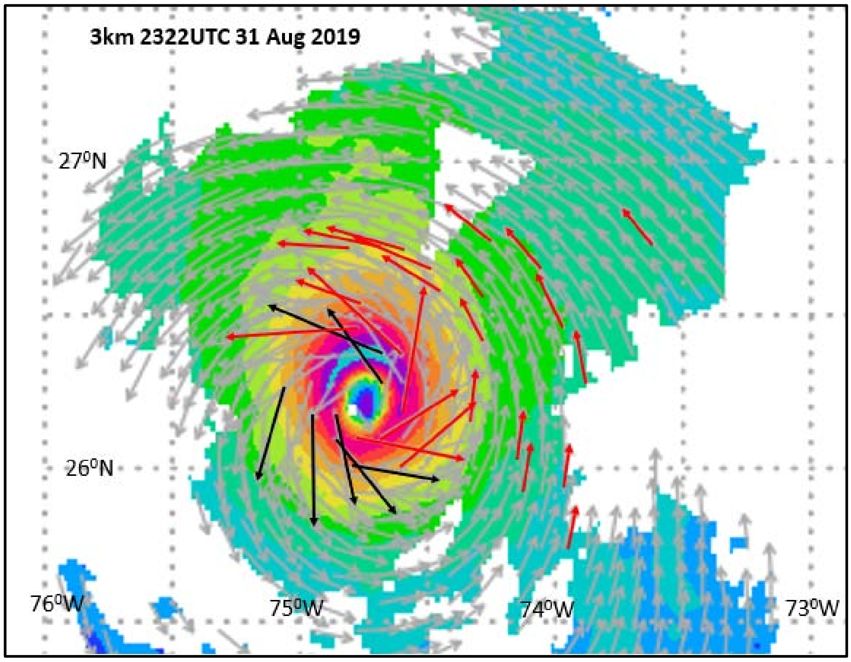


Figure 20: 3000metre elevation winds from Doppler Radar700hPa winds for 2322UTC 31 August 2019 where red arrows are the wind plots where the winds turned anticyclonically coherently from 1km elevation through 3km elevation up to 5km elevation. Similarly, the black plots are where the winds turned cyclonically

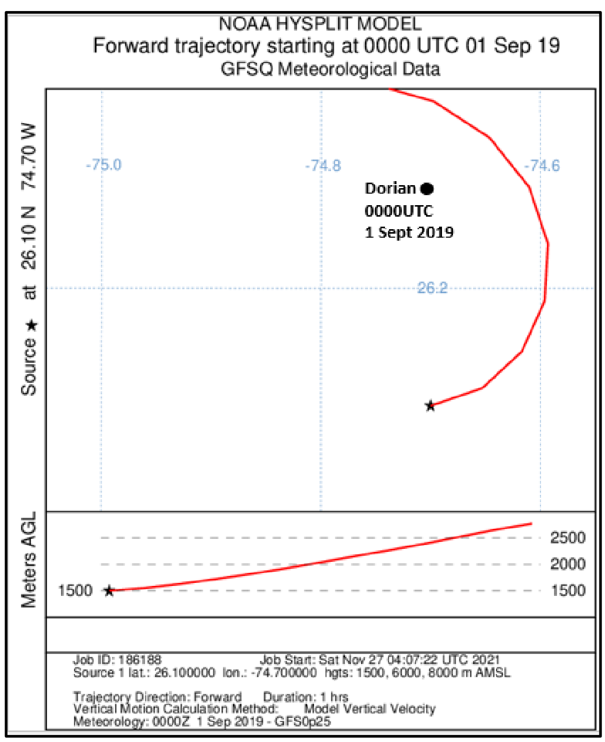


Figure 21: Hysplit trajectories from 0000UTC 1 September 2019 over one hour (left) and right over 12hours with dashed line showing 12hr track of Hurricane Dorian

g) Laura 5.7

In Figure 22 strong WAA is evident in the inner core of Hurricane Laura at 0000UTC 27 August 2020 approaching landfall when the peak wind speed was 130knots having increased from 100knots over the previous 12 hours. The strength of the hurricane levelled off for a few hours before landfall, and the well-defined eye of this devastating category four hurricane crossed the coast near Cameron, Louisiana, around 0600 UTC 27 August (Pasch 2021). Laura was the strongest hurricane to strike Louisiana since Hurricane Camille of 1969 (which produced category five conditions over the southeastern part of the state).

Hysplit trajectories from this strong WAA area rose from 1500m elevation up to above 6000m (Figure 23). After 6hours the trajectories from the three levels rose above 12km elevation into the outflow area of Laura. As Laura approached landfall it passed over waters with OHC 35-50 kJ/cm^2 with small area 15-35 near the coast.

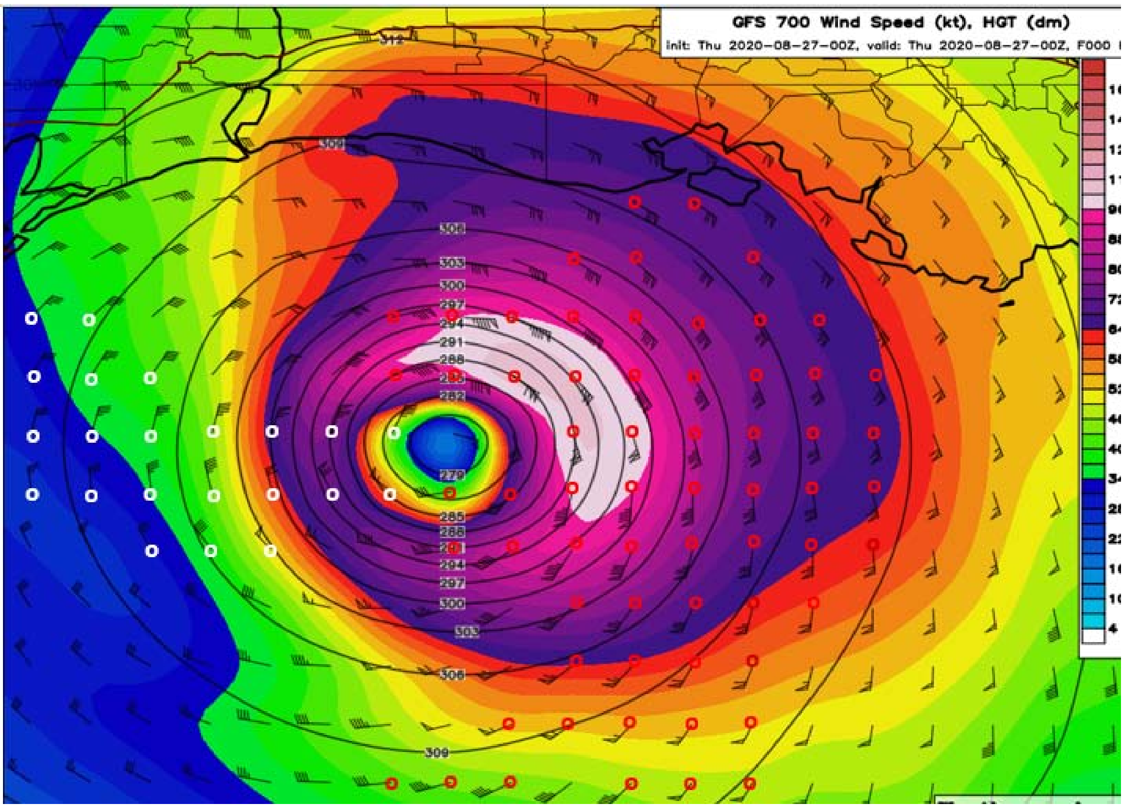


Figure 22: 700hPa winds at 0000UTC 27 August 2020 with red circle denoting where winds turn anti-cyclonically from 850hPa through 700hPa to 500hPa and white circles denote these winds turning cyclonically

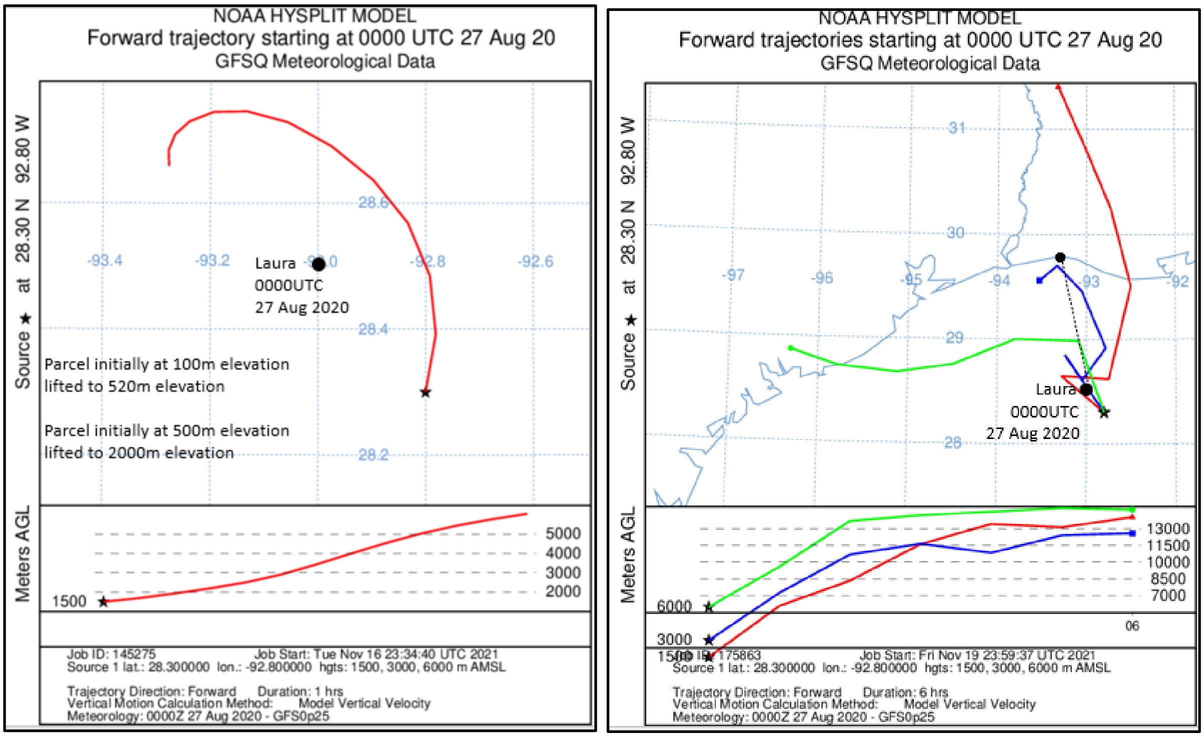


Figure 23: Hysplit trajectories from 0000UTC 27 August 2020 over one hour (left) and right over 6 hours with dashed line showing 6hr track of Hurricane Laura

h) Hurricane Ida 5.8

The National Hurricane Centre (NHC) reported at 1755UTC 29 August 2021 that Hurricane Ida made landfall as an extremely dangerous category four hurricane near Port Fourchon Louisiana with maximum sustained winds of 130knots (242km/h) and a minimum central pressure of 930hPa. NHC assessed it reached this intensity at 1200UTC 29 August 2021 having intensified from 100knots at 0600UTC 29 August and 89knots at 0000UTC 29 August 2021. Reconnaissance Aircraft 0bservations over this period are shown in Table 2.

Table 2: Reconnaissance Aircraft 0bservations of Hurricane Ida.

Time Date	Central Pressure	Flight level winds
0035UTC 29 August 2021	967hPa	700hPa level 91knots
0613UTC 29 August 2021	950hPa	700hPa level 133knots
1018UTC 29 August 2021	936hPa	700hPa level 145knots
1047UTC 29 August 2021	936hPa	700hPa level 146knots
1156UTC 29 August 2021	932hPa	700hPa level 138knots
1224UTC 29 August 2021	932hPa	700hPa level 138knots
1410UTC 29 August 2021	933hPa	700hPa level 136knots
1602UTC 29 August 2021	931hPa	700hPa level 127knots
1650UTC 29 August 2021	932hPa	700hPa level 127knots

Throughout its path of destruction in Louisiana, more than a million people in total had no electrical power. Widespread heavy infrastructural damage occurred throughout the southeastern portion of the state, as well as extremely heavy flooding in coastal areas. There was also substantial plant destruction in the state. As of September 15, the following deaths were confirmed in relation to Ida in the United States with thirty-three deaths in Louisiana, thirty in New Jersey, eighteen in New York, five in Pennsylvania, three in Mississippi, two in Alabama, two in Maryland, one in Virginia, and one in Connecticut.

GFS WAA winds in the inner core of Ida (Figure 24) turning anticyclonically from 850hPa to 500hPa in the southern eye wall of Ida at 12Z 29 August approaching landfall.

In Figure 25 the Hysplit trajectories show the WAA forcing strong ascent from 1500metres over one hour up to around 5000m elevation.

Microwave imagery(Figure 26) shows a decrease in eye size from 2349UTC 28 August 2021 to form a small compact just before landfall at 1511UTC 29 August 2021. The effect of the strong WAA convection on the southern side at 1200UTC 29 August 2021 can be seen from the red areas developing there.As Ida approached landfall it passed over waters with OHC 35-50 kJ/cm^2 with small area 15-35 near the coast. This was like Laura as was the strong ascent generated by the WAA convection in the inner core in both cases.

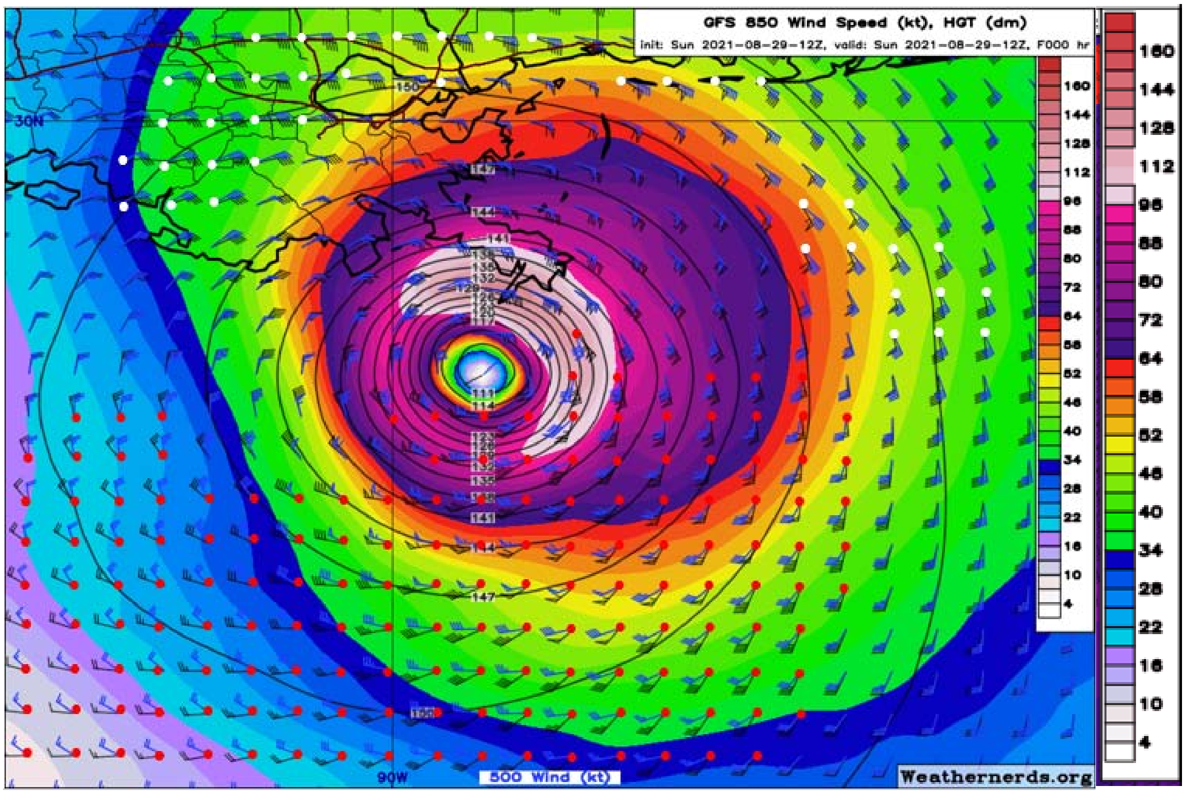


Figure 24: GFS850hPa (black plots) and 500hPa (blue plots) wind analyses 1200UTC 29 August 2021. Red circles are the wind plots where the winds turned anticyclonically from 850hPa up to 500hPa. Similarly, the white circles are where the winds turned cyclonically

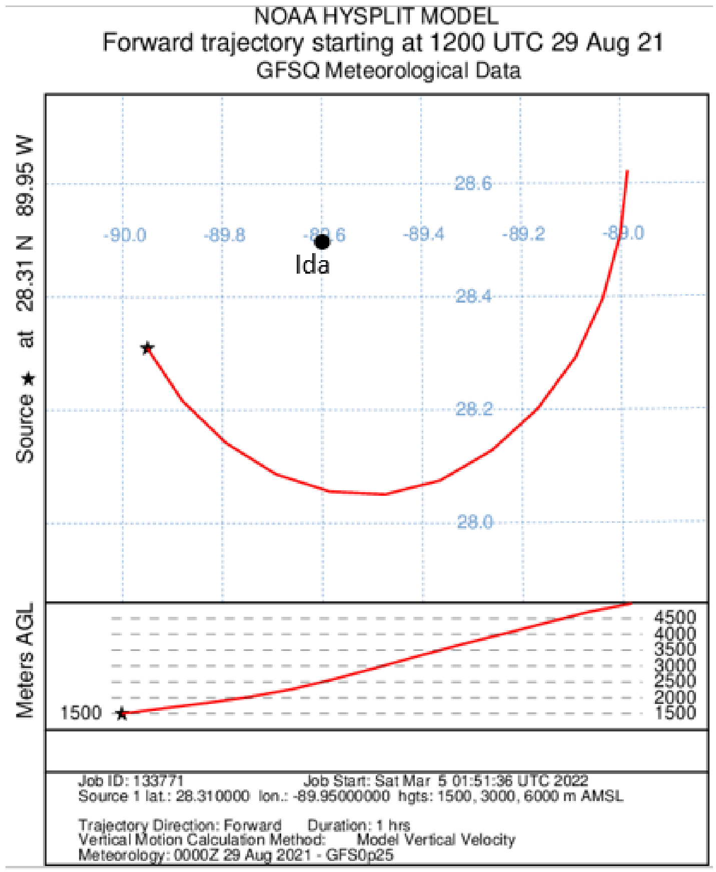


Figure 25: Hysplit trajectories from 0600UTC 29 August 2021 left over one hour and right over 12hours with dashed line showing 12hr track

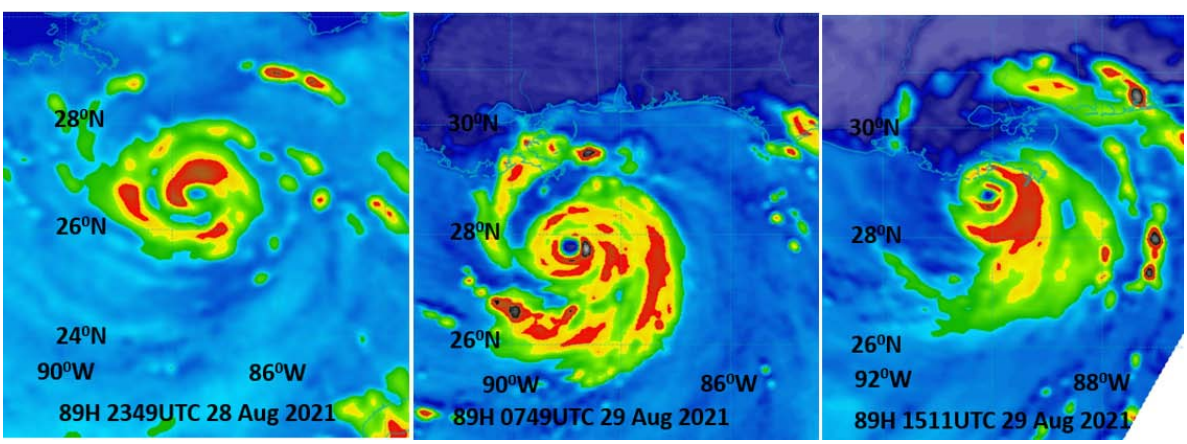


Figure 26: Microwave images (Courtesy of NRL Monterey) approaching landfall from 2349UTC 28 August 2021 to 1511UTC 29 August 2021

Acknowledgement 6

Permission from Matt Onderlinde to use Computer weather charts from the Weathernerds site is greatly appreciated.

VI. Conclusion 7

Recent very destructive tropical cyclones approaching landfall around the Globe have been examined. Sectors of the inner core of these cyclones were surveyed to identify pronounced regions of low to mid-level WAA. These regions were then analysed for evidence of ascent using Hysplit trajectory analysis. The results showed that regions of WAA produced ascent in the core where convection developed verified by microwave data. Little ascent was evident in other areas away from the WAA.

Two identical hurricanes which devastated the same part of Louisiana were compared. Both Hurricanes approached landfall over oceans with similar OHTs. The WAA with Laura produced strong ascent reaching 6000m after one hour while with Ida the ascent was strong but a little less reaching 5000m elevation. However, the whole structure of Ida had less CAA in the inner core circulation making the potential for intensification up to landfall similar.

All cyclones examined had WAA producing moderate to strong ascent in the inner cores and four which had strong ascent from WAA were Super Typhoon Rai, Severe tropical cyclone Batsirai, Hurricane Michael and severe tropical cyclone Harold. Comparing two US Category Five Hurricanes, Michael and Dorian, Michael had much stronger inner core WAA and ascent however Dorian passed over waters with much stronger OHC.

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Global Journal of Science Frontier Research: H
Environment & Earth Science
Volume 22 Issue 2 Version 1.0 Year 2022
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Determination of Explosive Properties of $CH_4/C_2H_6/C_3H_8$ Binary Gaseous Alkane Mixture

By He Jie, Zhuang Chunji, Dai Yifan, Cao Zhaorui & Li Hua

Ningbo Institute of Technology

Abstract- In this paper, HY12474B flammable gas explosion limit experimental device was used to study the explosion characteristics of the three kinds of binary gaseous alkane mixtures, which were the mixture of CH4, C2H6 and C3H8 with different composition ratio respectively. The experimental results showed that the velocity of flame at both ends of explosion limit of the binary gaseous alkane mixtures relatively slow, and the flame is also not so apparent. The composition ratio of binary gaseous alkane mixture has a greater impact on explosion limit, three kinds of mono alkane can be ranked by their influence as CH4>C2H6>C3H8 in turn. When the composition ratio of gaseous alkane mixtures decreased, the explosion limit range is reduced, but the maximum explosion pressure peak is increased.

Keywords: *gaseous alkane; explosion flame; explosion limit; maximum explosion pressure.*

GJSFR-H Classification: *DDC Code: 628.9222 LCC Code: TH9446.5.P45*

DETERMINATIONOFEXPLOSIVEPROPERTIESOFCHCHCHBINARYGASEOUSALKANEMIXTURE

Strictly as per the compliance and regulations of:

Determination of Explosive Properties of $CH_4/C_2H_6/C_3H_8$ Binary Gaseous Alkane Mixture

$CH_4/C_2H_{6/}C_3H_8$二元气态烷烃混合物爆炸特性测定

He Jie [α], Zhuang Chunji [σ], Dai Yifan [ρ], Cao Zhaorui [Ѡ] & Li Hua [¥]

摘　要： **本文采用HY12474B型可燃气体爆炸极限实验装置，将CH_4、C_2H_6和C_3H_8按不同组分比两两混合，研究三类二元气态烷烃混合物的爆炸特性。结果表明：二元气态烷烃混合物的爆炸极限处火焰传播速度较缓慢，火焰较不明显；二元气态烷烃混合物组分比对爆炸极限影响较大，三种单烷烃对爆炸极限的影响能力依次为CH_4＞C_3H_8＞C_2H_6；当气态烷烃混合物组分比下降时，其爆炸极限范围缩小，最大爆炸压力峰值增大。**

*关键词：*气态烷烃；爆炸火焰；爆炸极限；最大爆炸压力

Abstract- In this paper, HY12474B flammable gas explosion limit experimental device was used to study the explosion characteristics of the three kinds of binary gaseous alkane mixtures, which were the mixture of CH4, C2H6 and C3H8 with different composition ratio respectively. The experimental results showed that the velocity of flame at both ends of explosion limit of the binary gaseous alkane mixtures relatively slow, and the flame is also not so apparent. The composition ratio of binary gaseous alkane mixture has a greater impact on explosion limit, three kinds of mono alkane can be ranked by their influence as CH4＞C2H6＞C3H8 in turn. When the composition ratio of gaseous alkane mixtures decreased, the explosion limit range is reduced, but the maximum explosion pressure peak is increased.

Keywords: gaseous alkane; explosion flame; explosion limit; maximum explosion pressure.

I. 引 言

随着现代化工业的不断发展，煤炭等不可再生资源的使用比例逐步降低，以可燃性气体为主的清洁型能源得到了飞速发展，并已在生产生活中占据了重要地位[1] 。很多情况下可燃气体中会含有其他气体成分，如天然气、液化石油气以及某些反应所需的混合气等，生产、储存、运输以及使用等环节过程一旦操作不当，很容易引发可燃气体燃烧爆炸灾害事故。可燃气体爆炸极限是物质危险性评估以及安全操作方法确定的重要参考依据之一[2]，主要由气体本身的燃爆特性决定，但也与实验测定装置、初始温度、压力和湿度、点火源的类型和能量等因素有关[3-5] 。国内外学者已对多元可燃气体 混合物爆炸极限进行了大量研究，A. Lidor等[6]基于燃 料氧化剂混合物热力学稳定性分析 的概念，对爆炸极限现象提出了一种新的解释，并通过热力学方法进行了分析证明；S. Kondo 等[7] 对九种可燃气体混合物进行了燃 烧极限的测定，表明混合物的爆炸下限测定值与Le Ch-atelier公式计算值吻合较好；C. V. Mashuga等[8]选取 1200K作为绝热火焰温度对甲烷 乙烯与氮气混合物的爆炸极限进行了估算；焦枫媛等[9] 研究了混合气体均匀性对甲烷爆炸特性影响的实验研究，并由此设计了混合器；J. Liu等[10]研究了H_2O和CO_2的摩尔分数变化对爆炸极 限的影响。综上所述，可燃气体混合物爆炸特性研究仍是目前研究的热点之一。本文通过对CH_4、C_2H_6和C_3H_8三种气态烷烃进行两两混合形成二元气态烷烃混合物，利用HY12474B 型可燃气体爆炸极限实验装置，研究气态烷烃混合物组分比对二元气态烷烃混合物爆炸特性的影响，望能为气态烷烃混合的事故预防和安全防控提供参考。

II. 实验装置与实验方法

a) *实验装置*

本实验选用 HY12474B 型可燃气体爆炸极限实验装置，该装置主要由抽真空、进样、循环搅拌、电火花点火、爆炸管、泄压装置、恒温控制、数据处理和计算机等几部分组成，其中爆炸管为3.4 L圆柱石英爆炸管，爆炸管底部安装了 300 J 高能脉冲电火花装置，顶部安装了压力传感器，样品通过自动进样系统精确进样，配气精度可达到0.1%。实验装置如图1所示。

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Fund Project: Funded by Ningbo Natural Science Foundation (2018A610122), Student Science and Technology Innovation Fund of Ningbo Institute of Technology (2018042), Funded by Ningbo Institute of Technology Annual School Research Project (2018005).

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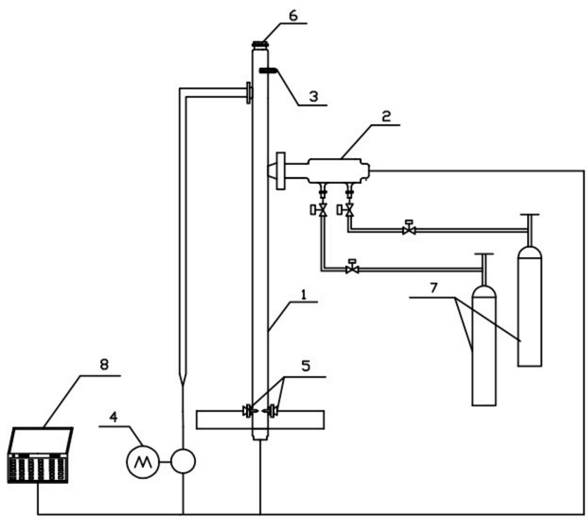

1爆炸管；2进样口；3压力传感器；4真空泵；5放电电极；6泄压阀；7气瓶；8计算机

图1 实验装置示意图

Fig. 1: Experimental device schematic

b) 实验方法

本实验选用纯度为99.9%CH_4、99.9% C_2H_6和99.9% C_3H_8三种气态烷烃作为实验研究对象，通过将其按照不同组分比进行两两混合，研究二元气态烷烃混合物的爆炸极限和最大爆炸压力。本实验参照《空气中可燃气体爆炸极限测定方法》GB/T 12474-2008），在大 气压 为99.1kP，环境温度为17.5℃，环境湿度为63.2%RH的条件下进行实验。实验操作以单甲烷的爆炸极限测定为例进行介绍，首先在抽气阀上连接真空泵，启动真空泵并将爆炸管抽真空至0.5kPa，将纯CH_4样品接入进气接口，打开空气接口，按照设定浓度自动进样；然后进行无油封闭循环搅拌，搅拌时间设为120s，使CH_4与空气充分混合；接着启动高能脉冲电火花进行点火，通过观察石英玻璃爆炸管内火焰和计算机控制界面显示，综合判定CH_4与空气混合气体是否发生燃烧爆炸，并保存实验数据；最后实验结束后对爆炸管进行清洗。实验过程中对实验样品的进样控制，应根据放电电极点火后甲烷/ 空气混合气体是否发生爆炸，逐步减小或增加CH_4体积分数重复实验，直至爆炸和不爆炸之间有一个最小体积分数差，本实验要求最小体积分数差≤0.1%。

c) 实验方案

本文首先对三种烷烃气体分别单独进行实验，测出三种气体烷烃各自的爆炸上下限，将实验结果与标准值进行对比，验证实验结果的可靠性；然后将其按照不同组分比进行两两混合，对二元气态烷烃混合物的爆炸特性参数进行测定；最后对实验结果进行总结分析，研究气态烷烃混合物组分比对其爆炸特性参数的影响。

III. 实验结果与分析

a) 单烷烃可燃气体爆炸极限测定

分别对CH_4、C_2H_6和 C_3H_8 三种气态烷烃的爆炸上下限单独进行测定，所测实验数据与《石油化工可燃气体和有毒气体检测报警设计规范》（GB50493—2009）中的数据进行比较，如表1所示。

表1: 三种气态烷烃爆炸极限值

Table 1: The explosion limit of three gaseous alkanes

物质种类	实测值		文献值	
	LEL/%	UEL/%	LEL/%	UEL/%
CH_4	6.1	15.1	5.0	15.0
C_2H_6	3.7	12.7	3.0	15.5
C_3H_8	2.5	9.7	2.1	9.5

通过表1可以看出，所测CH_4上下限与文献值的最大相对误差分别为0.6%和22.0%，误差平均值为11.3 %；所测C_2H_6上下限与文献值的最大相对误差分别为22.0%和18.0%，误差平均值为15.0%，所测C_3H_8上下限与文献值的最大相对误差分别为9.0%和16.0%，误差平均值为为13.4%。分析误差产生的原因主要是由于三种气态烷烃的纯度不够以及环境温度较低、大气压力、环境湿度、实验器材精度等因素引起[11]。总体而言，本实验测试结果基本符合要求，能为二元气态烷烃混合物的爆炸特性测定提供可信的实验数据。

图2为圆柱石英爆炸管内CH_4燃烧爆炸火焰时序图。从图中能够观测到不同浓度下CH_4火焰在管内传播过程中形成的球形或指形火焰，随着CH_4浓度的增加爆炸火焰颜色由浅变深再变浅[12]。在浓度为爆炸下限附近时，爆炸火焰安静缓慢上升；随着浓度的增加，火焰上升速率逐渐加快，且尾部伴随着淡红色的火焰，并伴有火焰由下往上在管道内传播的声音；当浓度升高到爆炸上限附近时，火焰慢慢恢复到了淡蓝色。

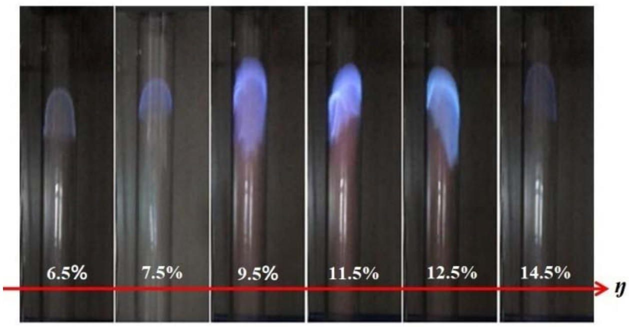

图2: CH_4燃烧爆炸火焰时序图

Fig. 2: Timing diagram of CH_4 combustion explosion flame

b) ***二元气态烷烃混合物爆炸特性测定***

i. ***烷烃组分比对爆炸极限的影响***

在开始对二元气态烷烃混合的爆炸极限测定前，采用夏特尔公式对该混合物的爆炸极限进行估算[13]，在此基础上按照设定配比进行混合，逐步测得爆炸极限值。二元气态烷烃混合物爆炸极限测定实验结果如表 2 和图3所示。

由表2可以算出，随着气态烷烃混合物组分占比的下降，二元气态烷烃混合物的爆炸上下限都有不同程度的减小，爆炸极限宽度呈逐渐缩小。CH_4/C_2H_6的爆炸上下限的平均减小速率都为0.024；CH_4/C_3H_8 的爆炸上下限的平均下降速率分别为0.036和0.054；C_2H_6/C_3H_8的爆炸上下限平均下降速率分别为0.012和0.020。由表2区域内CH_4/C_2H_6和CH_4/C_3H_8的爆炸极限数据比较可以得出C_3H_8对爆炸极限的影响大于C_2H_6，由表2区域内CH_4/C_3H_8和C_2H_6/C_3H_8的爆炸极限数据比较可以得出 CH_4 对爆炸极限的影响大于C_2H_6，由表2区域内CH_4/C_2H_6和C_2H_6/C_3H_8的爆炸极限数据比较可以得出CH_4对爆炸极限的影响大于C_3H_8。由此可得，对二元气态烷烃混合物的爆炸极限影响能力：CH_4＞C_3H_8＞C_2H_6。

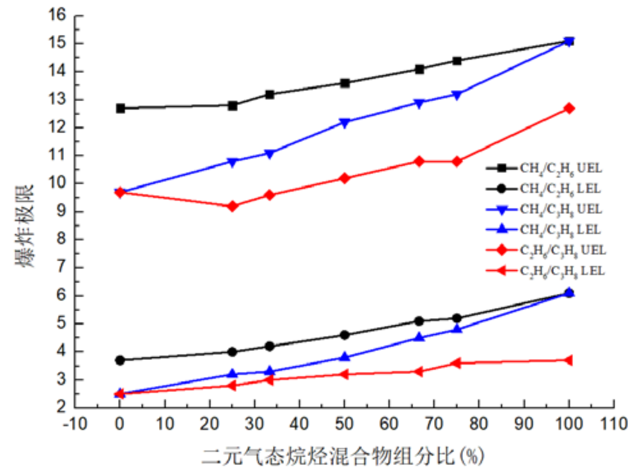

图3: 二元气态烷烃混合物爆炸极限趋势图

Fig. 3: Explosion limit trend of the binary gaseous alkane mixtures

根据表2得到二元气态烷烃混合物的爆炸极限图，如图 3所示。从图中可以看出， CH_4/C_3H_8 的爆炸极限变化最为明显，CH_4/C_2H_6和C_2H_6/C_3H_8的变化次之；CH_4/C_3H_8爆炸上下限处于CH_4/C_2H_6和C_2H_6/C_3H_8之间。

ii. ***烷烃组分比对爆炸压力的影响***

分别测出不同组分比下的二元气态烷烃混合物爆炸极限范围的最大爆炸压力值P_{max}，如表3所示。表2

表2: 二元气态烷烃混合物爆炸极限测定值

Table 2: Determination of explosion limit of the binary gaseous alkane mixtures

混合物组分占比		1：0	3：1	2：1	1：1	1：2	1：3	0：1
CH_4/C_2H_6	爆炸下限LEL（%）	6.1	5.2	5.1	4.6	4.2	4	3.7
	爆炸上限UEL（%）	15.1	14.4	14.1	13.6	13.2	12.8	12.7
	爆炸极限宽度L_z	9.0	9.2	9.0	9.0	9.0	8.8	9.0
混合物组分占比		1：0	3：1	2：1	1：1	1：2	1：3	0：1
CH_4/C_3H_8	爆炸上限LEL（%）	6.1	4.8	4.5	3.8	3.3	3.2	2.5
	爆炸下限UEL（%）	15.1	13.2	12.9	12.2	11.1	10.8	9.7
	爆炸极限宽度L_a	9.0	8.4	8.4	8.4	7.8	7.6	7.0
混合物组分占比		1：0	3：1	2：1	1：1	1：2	1：3	0：1
C_2H_6/C_3H_8	爆炸上限LEL（%）	3.7	3.6	3.3	3.2	3	2.8	2.5
	爆炸下限UEL（%）	12.7	10.8	10.8	10.2	9.6	9.2	9.7
	爆炸极限宽度L_a	9.0	7.2	7.5	7.0	6.6	6.4	7.0

表3: 二元气态烷烃混合物爆炸特性测定表

Table 3: Determination of explosion characteristics of the binary gaseous alkane mixtures

	烷烃组分比 / 烷烃混合物	1:0	3:1	2:1	1:1	1:2	1:3	0:1
最大爆炸压力 P_{max}(kPa)	CH_4/C_2H_6	147.2	145.4	146.5	147.1	149.9	152.2	152.2
	CH_4/C_3H_8	147.2	147.5	149.0	148.9	149.8	154.5	154.8
	C_2H_6/C_3H_8	152.2	153.3	156.1	158.2	158.6	163.2	154.8

从表3可以看出，随着二元气态烷烃混合物组分比的下降，各组分下的爆炸极限范围内的最大爆炸压力峰值逐渐变大。相同组分比下C_2H_6/C_3H_8的最大爆炸压力峰值均比CH_4/C_2H_6和CH_4/C_3H_8要大，且在C_2H_6/C_3H_8=1:3的条件下峰值达到了最大值163.2kPa，而在CH_4/C_2H_6=3:1的条件下峰值达到了最小值145.4kPa，由此可知C_3H_8燃烧爆炸可产生了较大的爆炸压力。

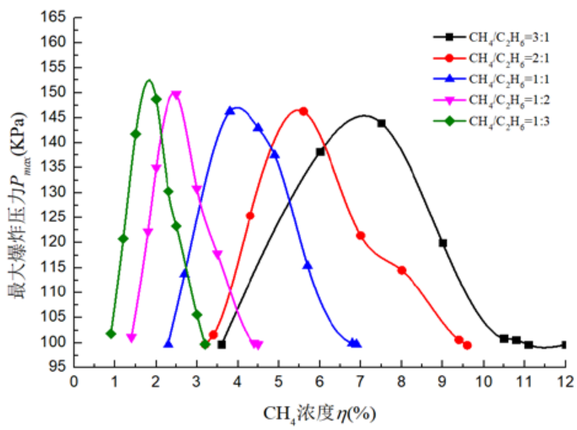

图4: 不同组分CH_4/C_2H_6在爆炸极限范围内最大爆炸压力曲线图

Fig. 4: Maximum explosion pressure curve of CH_4/C_2H_6 with different component ratio in the explosion limit range

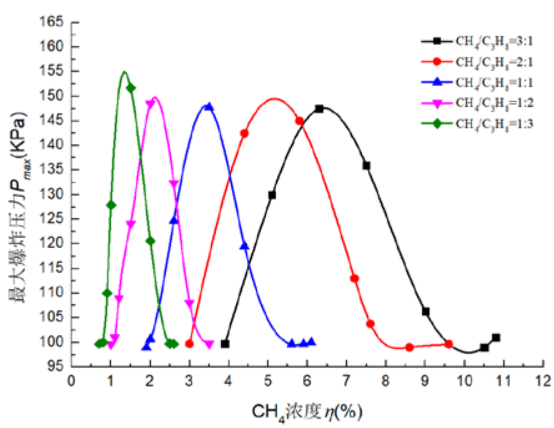

图5: 不同组分CH_4/C_3H_8在爆炸极限范围内最大爆炸压力曲线图

Fig. 5: Maximum explosion pressure curve of CH_4/C_3H_8 with different component ratio in the explosion limit range

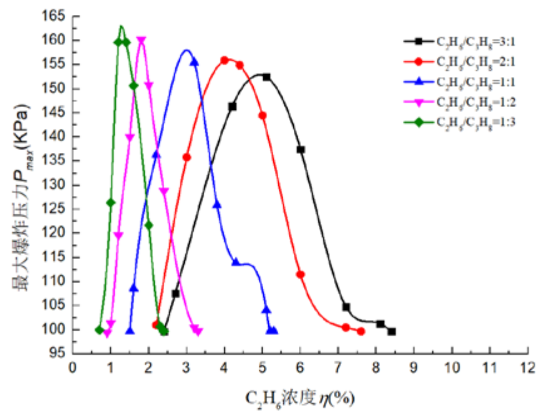

图6: 不同组分C_2H_6/C_3H_8在爆炸极限范围内最大爆炸压力曲线图

Fig. 6: Maximum explosion pressure curve of C_2H_6/C_3H_8 with different component ratio in the explosion limit range

三类二元气态烷烃混合物随组分浓度变化，其爆炸火焰时序图与单烷烃基本相似。在爆炸极限范围内最大爆炸压力曲线分别见图4，图5和图6。从图中可以看出，各组分比的最大爆炸压力曲线的趋势基本相同，均随气态烷烃混合物浓度的升高先增大后减小[14]；在爆炸极限范围内最大爆炸压力峰值出现在爆炸范围的中间位置范围；当三种二元气态烷烃混合物的组分比均为1:3 时，在最大爆炸压力曲线图上能取得最大爆炸压力的最大峰值，且最大爆炸压力曲线图也变的最窄，最大爆炸压力曲线图呈现由右向左逐渐聚集的趋势。由此可得，随气态烷烃混合物组分比的下降，二元气态烷烃混合物的爆炸极限范围缩小，而其最大爆炸压力峰值增大。

IV. 结 论

本文利用可燃气体爆炸极限实验装置，开展了二元气态烷烃混合物的爆炸特性的实验研究，得出了以下结论：

1) 对三种气态烷烃的爆炸极限分别进行测定，验证了本实验研究的可行性，通过观察CH_4的爆炸火焰时序图 发现了在爆炸上下限处火焰传播速度较缓慢，火焰较不明显。
2) 通过测定二元 气态烷烃混合物组分比对爆炸极限，得出三种气态烷烃的对爆炸极限的影响能力依次为：$CH_4>C_3H_8>C_2H_6$。

3) 随气态烷烃混合物组分比的下降，二元气态烷烃混合物的爆炸极限范围缩小，而其最大爆炸压力峰值增大。

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Global Journal of Science Frontier Research: H
Environment & Earth Science
Volume 22 Issue 2 Version 1.0 Year 2022
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Covid-19 the Global Pandemic; where is the Law of Polluters Pay and International Environmental Laws

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Abstract- SARS-CoV-2 otherwise known as COVID-19 is one of resent brand of the coronaviruses that has ravaged the whole world at a pandemic scale. It is the second deadly virus originating from China that has over 7,344,220 confirmed infested cases in 213 countries and a death toll of over 414,140 as of June, 2020. Socio-economically, the pandemic forces the whole world to a stand-still for months thereby eroding the hitherto economic gains over the years. This study therefore uses secondary data through the search engine to examine the origin and mutation of the coronaviruses transmission to human and the wet market, the impacts of the pandemic and the Chinese government responses. The study further examines the existing environmental laws, the polluters-pay-principle, the Tort law and principles of Due Diligence that can be applied to pandemic cases. The study revealed Coronalviruses do not just jump to human, that the inaction of the global bodies like WHO in the trading and consumption of wild animals that has trans-boundary implications since the outbreak of SARS in 2002 and negligence in early warning are responsible for the pandemic.

Keywords: *COVID-19, coronaviruses, virus mutation, polluters-pay, wet market, tort law.*

GJSFR-H Classification: *DDC Code: 344.046 LCC Code: K3585*

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Strictly as per the compliance and regulations of:

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I. Introduction

The onset of COVID-19 in Wuham, China, home to 11 million people and the capital of the Hubei Province was like a rivulet that turnout to be a mighty devastating disastrous river flood. According to Huang et al. (2020) and Shen, et al (2020), the whole phenomena initially were seen as unexplained cases of pneumonia with cough, dyspnea, fatigue, and fever as the main symptoms have occurred in Wuhan, China in a short period of time since December 2019. And that China's health authorities and CDC quickly identified the pathogen of such cases as a new type of coronavirus, which the World Health Organization (WHO) later named COVID-19 in January, 2020. As of 29 February 2020, COVID-19 has spread to 60 countries and territories, of which the World Health Organization (WHO) published the number of cumulative cases in 54 Member States on 29 February 2020, as well as Hong Kong, Macao and Taiwan.

The new condition of life emanating from the globally pandemic actually popup some agitating questions like: 'are we really at the end of the capitalist system and its hedonistic forms, are the teachings of the holy books on global plagues replicating again, or are we simply at a stage of societal transformation? This is not the first that humanity is forced to face or probably the last. The people infected by the COVID-19 in the world today (WHO data, May 2020) are over 5 million confirmed cases including 326,459 deaths and still counting. Yet Wuhan, China, the epicentre of the pandemic was said to have removed all the barriers erected since January 23 2020. Their isolation has ended, roads, sea, rail, and air links reopened, while America and Europe that are worst affected and other continents are still stuck in the pandemic quagmire.

Globally, there is presently an economic catastrophe, countries that are hitherto described as economic giants are being threaten economically, while those who are in economic recession are plunging into more and more recession. For instance, according to Alessandro (2020) quoting the former Italian Minister of Economy, Pier Carlo Padoan, that "Eurobond and Mes have become "toxic words", now unmanageable. It would be better to get rid of them and then start discussing again using a new vocabulary" (Padoan, interview on the Foglio).

At the beginning of March, the OECD warned that the world economy would grow by half compared to forecasts if the coronavirus crisis gets longer and worse. As a worst-case scenario, the global economy is expected to grow by 1.5% in 2020, compared to 3.2% last year (OECD data, March 2020). It is becoming obvious that the COVID-19 crisis will persist longer than many investors suspected and that the economic damage will be deeper and potentially more long-lasting. Some management analysts (Lazard Frères, March 2020) predict that the economic impact will be extremely violent as it combines a shock of both demand and supply. For instance, the Small and Medium Enterprises (SME) services index in Europe is falling to the lowest standard (from 52.6 in February to 28.4, compared to the previous low of 39.2 in February 2009, (OECD 2020).

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Meanwhile, in the United States, weekly unemployment claims have risen to 3.2 million, and going by the speed of this crisis, US GDP could drop by 30% in the second quarter of the year 2020. Unemployment has already risen to 12-13% due to the coronavirus pandemic and the economy is amid a shocking decline that is still not reflected in the data, (Yellen, 2020). As for the coronavirus, a vaccine will probably emerge soon, but who will produce the vaccine for the new globalized economic crisis? For instance, according to the International Air Transport Association (IATA), Air France-KLM and Qantas groups in Australia are facing financial blow. Qantas claimed that the coronavirus could reduce profits for the fiscal year ending June 30 to $66 million, with losses of around $30 million, while Air France-KLM estimated a profit loss of $216 million between February and April this year (Alessandro, 2020).

Structurally for instance, the major oil- and gas-producing states (the Gulf Cooperation Council member states, Iran, Iraq, Libya, Algeria), the pandemic's impact is revealing, once again, the dangers of being over reliance on hydrocarbons for economic growth, (Chloe and Asmaa, 2020). Global oil prices are currently oscillating between $20 and $30 a barrel that mean sustained low oil prices and a deep global recession is looming if not already here. Moreover, the tourism industry, a major part of several countries' economies (the United Arab Emirates, Saudi Arabia, Israel, Egypt, Turkey, Jordan, and more), has also nosedive substantially with severe impacts on employment and government revenues, (Andrew and Heba, 2020)

Going by the above global pandemic and its origin, pertinent questions as to the level of Chinese government negligence of International Environmental Law and effectiveness of their existing emergency response, negligence in the operation of their wild animal market, the level of human induced factor in the SARS-CoV-2 virus mutation, and the invocation of the existing inter-territorial environmental laws in mitigating future re-occurrence of pandemic that could lead to global standstill from any part of the world, are calling for investigation. It is for this reasons that this study aimed at examining the gaps in the coronavirus onset management

II. Relevant Literature

A review of the history of scientific taxonomy and nomenclature of emerging virus and infectious disease according to Jones (2020) observed that as far back as 1966, an International Committee on Nomenclature of Viruses (ICNV) was established with the mission of introducing some degree of order and consistency into the naming of viruses. And that in 1973, the ICNV became the International Committee on Virus Taxonomy (ICTV), a global authority on the designation and naming of viruses like WHO that is responsible for the naming of new human infectious diseases.

Studies revealed in retrospect that, virologist Anthony Peter Waterson (1923 – 1983) and his colleagues can be said to have coin the neologism "coronavirus" (Waterson and Wilkinson, 1978), and also in 1968, eight distinguished virologists proposed the term "coronaviruses" in a brief annotation of Nature (Almeida et al, 1968). In humans, there are 7 spectrums of human coronaviruses (HCoVs) known to cause the common cold as well as more severe respiratory disease. Out of these, human coronaviruses HCoV-229E, HCoV-NL63, HCoV-OC43 and HCoV-HKU1 are routinely responsible for mild respiratory illnesses like the common cold but can cause severe infections in immune compromised individuals. But three of them are known to have caused deadly outbreaks, which are: SARS-CoV, MERS-CoV, and the newly identified coronaviruses now known as SARS-CoV-2 (Gorbalenya et al 2020).

These cases were soon determined to be caused by a novel coronavirus that was later named SARS-CoV-2 (Niederberger,; 2020). Coronaviruses are a group of viruses that are common in humans and are responsible for up to 30% of common colds (Mesel-Lemoine et al, 2012). Corona is Latin for "crown" – this group of viruses is given its name due to the fact that its surface looks like a crown under an electron microscope .Two outbreaks of new diseases in recent history were also caused by coronaviruses – SARS in 2003 that resulted in around 1,000 deaths and MERS in 2012 that resulted in 862 deaths (Smith, 2006; Erasmus, 2020).

The first cases of COVID-19 outside of China were identified on January 13 in Thailand and on January 16 in Japan. On January 23rd the city of Wuhan and other cities in the region were placed on lockdown by the Chinese Government. Since then COVID-19 has spread to many more countries – cases have been reported in all regions of the world. One can see the latest available data in the dashboards of cases and deaths which are kept up-to-date by Johns Hopkins University. By projection, if COVID-19 affects half the world's current population over the course of a year with a 1 percent fatality rate, the death toll would be 35 million. By comparison, the Spanish flu infected an estimated 500 million people and killed 50 million worldwide in 1918-19.

In an effort to defend the stigmatization of the Chimes in relation to the 2019 virus name tag, Zhiwen (2020) opine that: as the earlier nomenclature practices, the neologism "coronavirus" came due to the misjudgements of its debut in textbooks and that the portfolio of full-fledged official names would duly discourage the spread of regional stigmatization and racial discrimination. Perceptual bias in the perception of natural origin of COVID-19 is part of the reason for negative behavioural propensities in specific regions, rather than the degree of infection in their territories.

III. Covid-19; Virus Mutation or Genetically Engineered

Generally when it comes to virus mutation, coronaviruses are usually host specific: they attach to hosts with the spike protein and its particular shape normally fits only one host. The shape of the spike protein is determined by the S gene. Therefore, the S gene must have changed if a coronavirus jumps to a new host. This change cannot be a small set of point mutations as different animal species require quite different spike proteins. Consequently we find a larger change in the S gene in each three cases of coronaviruses (SARS-CoV, MERS-CoV and SARS-CoV-2) that have recently jumped from an animal host to humans. There are two possible reasons for this larger change which are Recombination (a natural process) and Genetic Engineering.

One general problematic characteristic of coronaviruses is its common repeat infections, and this may be because the immune response against these viruses is not complete or it is short living. It is also possible that the spike protein changes over time so that antibodies do not give complete protection, (Almeida et al 1978). The spike protein is also the part of the virus that antibodies try to disable. This phenomenon can be noticed not only with SARS-CoV-2 but with all three. For instance, Hamzah et al, (2016) revealed that camels that were given a vaccine expressing the spike protein of MERS showed antibodies and a significant reduction of excreted infectious virus. That is, they were still infectious even after being vaccinated, which means that coronaviruses activities should not be underestimated. The phylogeny flow network shows an initial emergence in Wuhan, China, in Nov-Dec 2019, followed by sustained human-to-human transmission at a global level which also shows clear genetic relationships through the transmission patterns of "A – D" as in Figure 2.

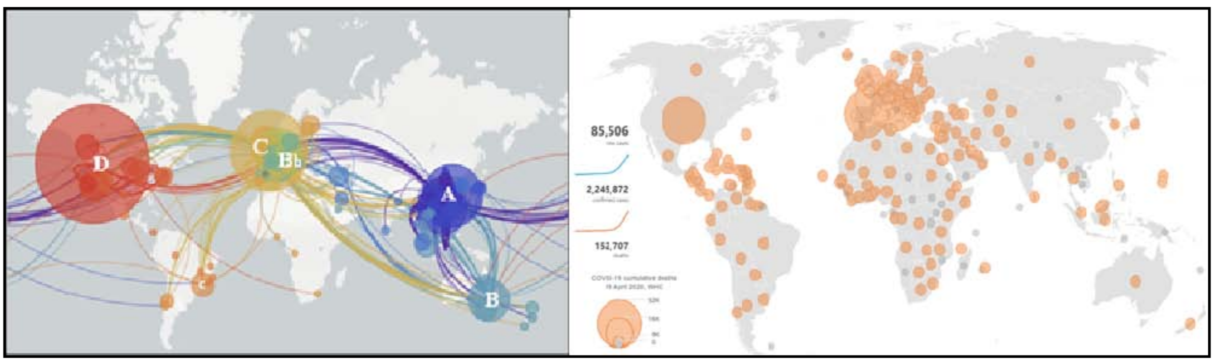

Figure 2: Global Phylogeny evolutionary of SARS-CoV-2 viruses and COVID-19 death as at April 2020.
Source: nextstrain.org, 2020

Since 2002, three new serious human coronaviruses (SARS-CoV, MERS-CoV and SARS-CoV-2) have appeared. It is thought provoking to observe that SARS-CoV found in 2002 (called SARS) also originated in Guadong, China. SARS-CoV originates in bats and the intermediate host is likely to be a civet. Himalayan palm civet CoVs in a live-animal market in Guadong had nearly identical (99.8%) genomes to the human SARS-CoV (Guan et al, 2003). SARS-CoV did not just arise from a civet CoV, It is either as a result of recombination events, as claims, or it was engineered.

MERS-CoV that was found in 2012 was endemic in dromedary camels in East Africa and Middle East. Hamzah et al, (2016) suggests that the original reservoir of MERS-CoV was bats, as bats are the main reservoir for many types of coronaviruses. Between 2009 and 2011, there were series of studies on bats that revealed that out of ten tested bats in Ghana only one, Nycteris bat, had 2c-beta coronavirus (i.e., of the type of MERS-CoV). One third of Nycteris bats had the virus. 14.7% of Pipistrellus bats from four European countries had 2c-beta coronavirus. Both 2c-beta coronaviruses are close to MERS-CoV. Archived serum samples from camels also revealed that the virus was already common in camels in the early 1980s in Sudan and Somalia.

Coronaviruses are RNA viruses, as is the Ebola virus, found in 1976. The phylogenetic tree drawn by Holmes et al, (2016) so that recombination is not a major behaviour of this virus, but there has been a case of recombination in Zaire Ebola virus, described by Wittman et al, (2007). A recombinant event between two lineages between 1996 and 2001 was found to have caused a series of Ebola outbreaks between 2001 and 2003. Phylogenetic trees of traditional DNA viruses, like variola (smallpox) and the measles virus seem to be trees, (Furuse et al, 2011).

The natural recombination explanation does not hold in the pangolin CoV: in the recombination explanation, a pangolin would have been infected with two CoV viruses, one from a bat with an S gene that does not infect humans, and the other from some other animal that has an S virus that can infect humans before the RNA of these viruses would recombine. But there seem no such other virus and assuming such will only complicate the problem further. The contending issue then is that mere random viruses mutations might not just produce enough changes to create a significantly different S gene because a virus population is very large, and this cannot be explain off genetically.

It is therefore suspicious that three new deadly coronaviruses appeared in such a short time. There had to be a significantly large change in the genome of the virus over a reasonable period of time for it to migrate into humans. Thus, there must be a more convincing proof that Covid-19 was not genetically engineered or the age long wild life Wet Market incubated the transmission to man and that WHO and UN-Habitat need to decode the genetic black box of the COVID to the world.

It is no longer news globally that there is leadership tussle among the G7 and G20 measured by the level of national resilience to any global challenge. Unlike after the 2008 financial crisis, the G7 and G20 meetings have been perfunctory, with every country looking after itself and taking measures to stop the spread of COVID-19 domestically, (Mathew and Peter, 2020).. The bottom line is that the coronavirus pandemic may end up reinforcing Chinese President Xi Jinping and the Communist Party of China's authoritarian tendencies. Obviously, it will require the United States and the EU taking more decisive responsibility for the developing world's predicaments in countering the loyalty pendulum swinging to China's Belt and Road Initiative.

IV. The Law of Polluters Pay Principle (PPP) and Covid-19

The polluter pays principle (PPP) was first mentioned in the recommendation of the EU Organization for Economic Cooperation and Development (OECD) of 26th May 1972 and reaffirmed in the recommendation of 14th November 1974. In Rio 1992, PPP was laid down as Principle 16 of the UN Declaration on Environment and Development. The European Community took up the OECD recommendation in its first Environmental Action Program (1973-1976) and then in a Recommendation of 3 March 1975 regarding cost allocation and action by public authorities on environmental matters.

Since 1987, the principle has also been enshrined in the Treaty of the European Communities and in numerous national legislations world-wide. PPP is highly recognised by the International court of Justice under Article 38 and applied under the "General principles of law recognized by civilize nations" Art. 38 1 (c) One of the main functions of PPP is that the polluter should bear the expense of carrying out the measures "decided by public authorities to ensure that the environment is in an acceptable state (OECD, 1972). Since its first appearance in 1972, the PPP is today understood in a much broader sense, not only covering pollution prevention and control measures but also covering liability, e.g. costs for the clean-up of damage to the environment, (OECD 1989 and 1992). Also, the field of application of PPP has been extended in recent years from pollution control at the source towards control of product impacts during their whole life cycle (LCA = Life Cycle Assessment). The PPP has a curative function, which means that the polluter has to bear the clean-up costs for damage already occurred.

The polluter pays principle does not only apply if there is a "real" pollution in terms of harm or damage to private property and/or the environment. Most legal orders go beyond this interpretation: In the light of the precautionary principle, environmental legislation may also provide for measures which are taken to minimise risks – even in cases where there is a lack of scientific knowledge and scientific cause–effect relationships cannot fully be established, (Petra, 2014).

The term "polluter" refers to a polluting, harmful activity and but also those who are (only) causing risks for the environment and where pollution has not (yet) occurred. The fact that SARS-CoV found in 2002 and COVID-19 both originated from China with human inducement factor (i.e Wet Market figure 3) that becomes global pandemic and keeping the whole world standstill, then the principle of PPP should be apply.

Source: Getty Images

Figure 3: Images of wild life, Wet Market in Myanmar and public protest against it in US.

V. Trans-Boundary Environmental Impact Assessment and Covid-19

In contemporary public international law, the concept of absolute territorial sovereignty is no longer recognized. Consequently, the scope for discretionary action arising from the principle of territorial sovereignty is determined by such principles and adages as 'good neighbourliness' and *sic utere tuo ut alienum non laedas* (you should use your property in such a way as not to cause injury to your neighbour's) as well as by the principle of State responsibility for actions causing trans-boundary damage, and more importantly, the prohibition of the abuse by a State of the rights enjoyed by it by virtue of international law. The fact that this concept is deeply embedded in contemporary international law is evident in the jurisprudence of international law.

State sovereignty cannot be exercised in isolation because activities of one nation often bear upon those of others and, consequently, upon their sovereign rights. Oppenheim (1912) noted that nation in spite of its territorial supremacy, is not allowed to alter the natural conditions of its own territory to the disadvantage of the natural conditions of the territory of a neighbouring country. It has also been argued that the application of national Environmental Impact Assessment (EIA) legislation to trans-boundary impacts complies with the 'non-discrimination principle' whereby foreign stakeholders should have a right to participate in the EIA procedure of the origin nation on an equal footing with domestic stakeholders

Thus, the principle of territorial sovereignty finds its limitations where its exercise touches upon the territorial sovereignty and integrity of other country. Consequently, the scope for discretionary action arising from the principle of sovereignty is determined by such principles and adages as 'good neighbourliness' and *sic utere tuo ut alienum non laedas* (you should use your property in such a way as not to cause injury to your neighbour's) as well as by the principle of State responsibility for actions causing trans-boundary damage. The strongest support for these principles and their implications can be found in the jurisprudence of international case law.

Under the principles of international law, no State has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another or the properties or persons therein, when the case is of serious consequence and the injury is established by clear and convincing evidence. The Rio Declaration (1992), adopted in a non-binding form by the United Nations Conference on Environment and Development (UNCED), provides in Principle 2 that States shall prevent trans-boundary damage: States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national The UN Declarations on environment commencing with the Stockholm Declaration of 1972 and over a 150 international instruments which followed, provided ample evidence of State obligations in regard to Environment Law. Justice Weeramantry in his dissenting Opinion on the Use of Nuclear Weapons, (ICJ-Advisory Opinion of 8 July 1996) at the request of World Health Organization (WHO), outlined how these obligations had accrued. He observed:

> *From rather hesitant and tentative beginnings, environment law has progressed rapidly under the combined stimulus of over more powerful means of inflicting irrevocable environmental damage and an ever-increasing awareness of the fragility of global environment. Together these have brought about a Universal concern with activities that may damage global environment which is the common inheritance of all nations, great and small. (ICJReports1996 p. 258.)*

It is therefore of necessity that the G7, G20, WHO, and UN-Habitat should come out of their global politics shell by calling a-spade-a-spade and seek for justice in the present pandemic.

VI. Case Reviews in International Law of Negligence and Covid-19

Negligence (Lat. negligentia) is a failure to exercise appropriate and or ethical ruled care expected to be exercised amongst specified circumstances. The area of tort law known as negligence involves harm caused by failing to act as a form of carelessness possibly with extenuating circumstances. The core concept of negligence is that people should exercise reasonable care in their actions, by taking account of the potential harm that they might foreseeably cause to other people or property, (Feinman, 2010; Deakin et al, 2003)).

This subsection examines how the common law tort of negligence as developed in the United Kingdom can offer a meaningful guidance for deconstructing the practice of positive human rights obligations. It shows how the common law tort of negligence, as developed by the national courts, can provide a helpful guidance for elucidating some of the disparate analytical elements that are subsumed under the umbrella of positive human rights obligations.

In tort law, the question of whether there is a duty of care is often asked prior to the question whether this duty has been breached. This logical sequence is related to the fact that an omission is at the heart of the analysis, which raises the question as to the standard

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against which any omission is to be measured for finding liability. Not only is the question of the duty of care central to tort law, but the existence of a duty is not presumed, there is thus no prima facie duty of care as in the case of Michael and Others v the Chief Constable of South Wales police (2015). In English tort law, the approach of instrumentalism has been applied, which implies drawing analogies with established categories of liability when asking the question whether duty exists. If such analogies cannot be established, the case will be regarded as novel and it needs to be determined whether a duty should be imposed, (Booth and Squires, 2019). This question implies an inquiry as to whether 'as a matter of law liability in negligence is countenanced in this category of case, (Donal, 2013).

In determining the existence of duty in the common law tort of negligence according to Vladislava (2019), a three-part test is applied that consists of asking the following questions:

1. Was the harm that the claimant suffered a foreseeable consequence of the defendant's negligence;
2. Were the claimant and the defendant in a relation of proximity, i.e. were they connected in terms of time, space and relationship (Carl, 2012); and
3. Is the imposition of a duty 'fair, just and reasonable', i.e. should a duty be imposed, as a matter of public policy as in the case of Caparo Industries plc v. Dickman (1990).

These elements can be respectively framed as foresee ability, proximity and reasonableness. The elements have to be cumulatively fulfilled, which means, for example, that a duty cannot be established on the basis of 'fairness, justice and reasonableness' alone. Questions concerning foresee ability, proximity and reasonableness are also asked to determining whether the obligation has been breached.

In term of the proof of causation, the tort law of negligence requires the claimant to demonstrate that the breach of the duty caused the harm. There needs to be accordingly a causal relationship between the breach of duty and the loss suffered by the claimant. For this purpose, a 'but for' test has been utilised: the claimant must establish that 'but for' the negligence of the defendant, he or she would not have suffered the harm for which compensation is sought which have to be established on the balance of probabilities, Sandy (2015).

The principles of 'Due Diligence' or 'Due Care' with respect to the environment and natural wealth and resources are among the first basic principles of environmental protection and preservation law. They take root in ancient and natural law as well as in religion. Apart from continuous auditing and monitoring, there is an increasing emphasis on the duty of States to take preventive measures to protect the environment. The notion of precaution is an attractive one that can be taken to mean a parental attitude towards the environment, protecting it from potential harm by acting on foresight and avoiding unacceptable risks. It appears that the Precautionary Principle (PP) has had a meteoric rise in the international law arena and now being incorporated into treaties with more clearly defined objective principles, (Roderick, 2011). The PP is included in the Rio Declaration, Principle 15 which states:

Where there are threats of serious of irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

In a more realistic approach, when it is matter of foreseeable harm prevention, threshold of proof of responsibility for actual harm lowered. While still entailing some element of foresees ability, this would require measures of prevention at an earlier stage, when there is still some room for uncertainty. Expressions such as 'reasonably foreseeable' or 'significant risk' allow both the magnitude of harm and the probability of its occurrence to be taken into account. Three levels of State responsibility have been identified by scholars in relation to the environment: The most traditional one is that related to responsibility on the basis of fault or lack of due diligence. At the intermediate level, one finds the objective or strict responsibility, which is related to an obligation of result; the obligation not to damage the environment and the violation of which will engage responsibility regardless of fault. The most stringent level, referred to as absolute responsibility, concerns liability for acts not prohibited by international law irrespective of fault or of the lawfulness of the activity in question, (Stapleton, 2011).

The issue of environmental impact litigation and redress is not new with series of national and international decided court cases. The major advantages of court reviewed cases even at ICJ levels is for States to be weary of the Precautionary Principle in the exercise of their sovereignty in the use of environmental resources .For instance, in the Island of Palmas Case (United States v. The Netherlands, award in 1928) the Tribunal concluded, more generally, in what no doubt constitutes its best-known paragraph:

- The state have obligation of mutual respect and protection of the environment (1974, Nuclear Tests) and not to allow their territory to be used for activities violating rights of other states (1949, Corfu Channel).
- There is also a general obligation to ensure that any activity under the state's jurisdiction and control respects environment of other states or area beyond control. (1996, Advisory Opinion on use of Nuclear Weapons).

Also in the Erika oil spill case, the European Court of Justice held in 2008, based on Art. 15 of the EU Waste Framework Directive (2006), that the producer of hydrocarbons which became waste due to an accident at sea, could be held liable for the clean-up costs. In accordance with the polluter pays principle, however, such a producer is not liable unless he or she has contributed through his or her conduct to the risk of pollution stemming from the shipwreck.

VII. Human Right and Covid-19

Human right principles are key in shaping the present pandemic response for both the public health and the broader impact on people's lives and livelihoods. Responses that are shaped by and respect of human rights result in better outcomes in beating the pandemic, ensuring healthcare for everyone and preserving human dignity and that human rights are obligations which States must abide by. (UN, 2020).

Observing the crisis and its impact through a human rights lens puts a focus on how it is affecting people; particularly the most vulnerable and what can be done about it now, and in the long term. Historic underinvestment in health systems has weakened the ability to respond to this pandemic as well as provide other essential health services. COVID-19 is showing that Universal Health Coverage (UHC) must become an imperative.

The coronavirus can infect and kill the young, as well as the old, the rich, the poor, or those with underlying health conditions. It does not respect race, colour, sex, language, religion, sexual orientation or gender identity, political or other opinion, national, ethnic or social origin, property, disability, birth or any other status. COVID-19 is creating a vicious cycle whereby high levels of inequalities fuel its spread, which in turn deepens inequalities. Many of the people most severely impacted by the crisis are those who already face enormous challenges in a daily struggle to survive. According to UN (2020), for more than 2.2 billion people in the world, washing their hands regularly is not an option because they have inadequate access to water, and for 1.8 billion who are homeless or have inadequate, overcrowded housing, physical distancing is a pipe dream. Poverty itself is an enormous risk factor.

VIII. Discussion

The coronavirus has take its toll all over the world, but when an individual or a nation falls, there is usually a need take a cursory look at the root cause of the fall. Global politics seem to becloud or deaden the sense of examining the circumstances that surround the movement of the SARS-CoV2 to human that is not unconnected to the wet Market in China. When SARS that originated in Guadong, China came out in 2002 and claimed over 1,000 lives, nothing was done to unravel the root cause and neither was there any invocation of legal ordinances to curtail the reoccurrence.

Globally, there is discuss on space debris management and the need for space debris tax for correction and clean up. In the year 2007, China deliberately causes space collision that lead to about one thousand debris in the outer space to the detriment of others with impunity seemingly. The space tax is to operate on the principle of the common good as in the environmental law of polluters-pay-principle.

Again, a critical look at what is currently happening at the Indian sea where China has dominated with war ammunition vessels with the sole aim of territorial expansion, it's becoming obvious that anther world war or global lord is in making. Is it out of place at this juncture to conclude that coronavirus is genetically engineered as a miniature of biological weapon that is begging for investigation outside the present global politics within the G5 and G20 where African nations are part of the grasses in the arena.

Although World Health Organization (WHO) Director General has called for solidarity, not stigma, it is notable that to date WHO and other related bodies have not issued any substantive statement on how countries can take public health measures that achieve health protection and mitigation future reoccurrence while respecting human rights (Alicia-Ely and Roojin, 2020; Ghebreyesus, 2020).

Although communicating uncertainty and risk while addressing public concerns can be a challenge, failure to do so can lead to a range of outcomes, including a loss of trust and reputation, economic impacts and, in the worst case, a loss of lives. It is not therefore a surprise that the US president (Donald Trump) is pulling out of a body like WHO.

IX. Conclusion and Recommendations

The world is again been faced with more grievous virus outbreak at a pandemic scale of which over 414,140 people have died so far from the COVID-19 outbreak as of June 10, 2020 with currently over 7,344,220 confirmed cases in 213 countries and territories while still assessing the fatality rate. Socio-economically, the world is at stand still for months thereby eroding the hitherto economic gains over the years. In fact, another laboratory has been created for the sociologist and psychologist in terms of the anomalies in social system and spatial human interaction.

COVID-19 has manifested itself in an increasingly worrying way in some of the most polluted areas in the world, a reason that could justify the high number of infected in the Italian Region of Lombardy, one of the most industrialized areas in Europe where the concentration levels of particulates (Pm10) are among the highest not only in Europe but in the world as well; this situation has persisted for too many years.

There is an urgent need for global bodies like WHO, UN-Habitat, Global Watch, and Human right activist to invoke the environmental laws like the PPP, EIA, and the Tort law through the ICJ against Chinese government. The Environmental Conservationist are clamouring for more stringent laws against the poachers of wild animals that are near extinct worldwide and in China in particular. Mere closure of those Wet Markets in China is not enough; they should be treated as suspect at the ICJ for possible compensation and remediation globally. Where there is no sentence against evil did, the heart of men will be set to continue in more evil. The safety of the global health should not be mortgaged for the politics of supremacy among the G5 and G20.

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A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Science Frontier Research Paper

Techniques for writing a good quality Science Frontier Research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation)
by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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ISSN 9755896