

CLIMATE CHANGE AND THE LESSONS OF 2020, 2021 AND 2022

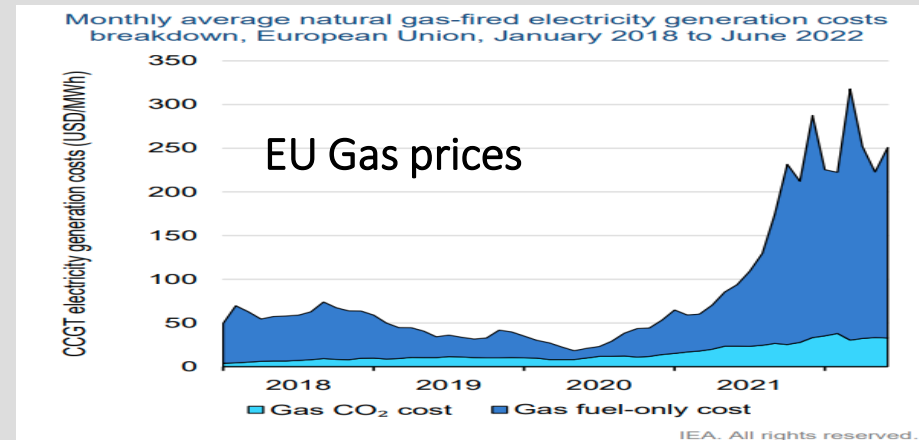
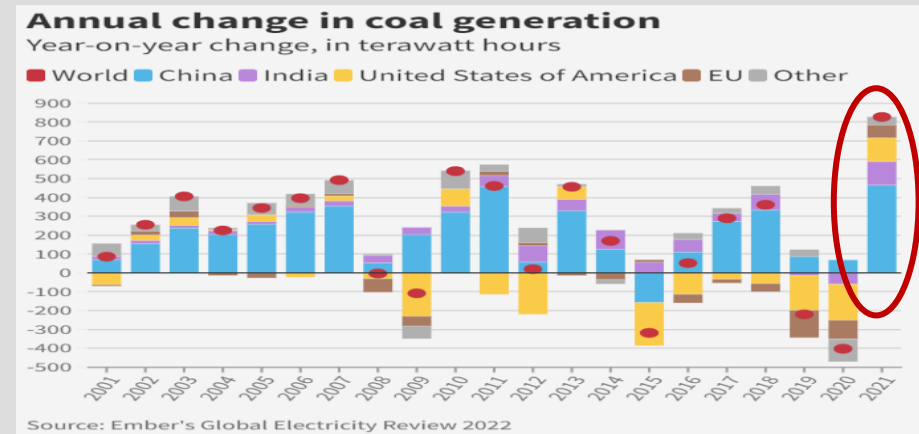
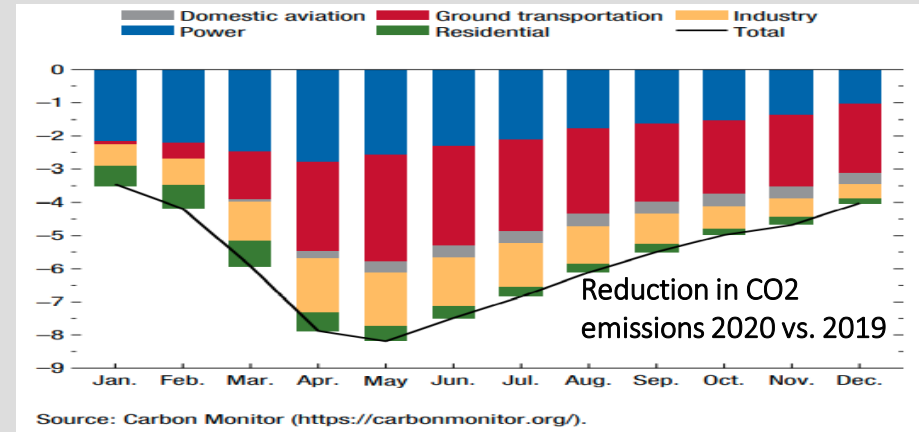


Ray Leonard

Linden Energy Holdings

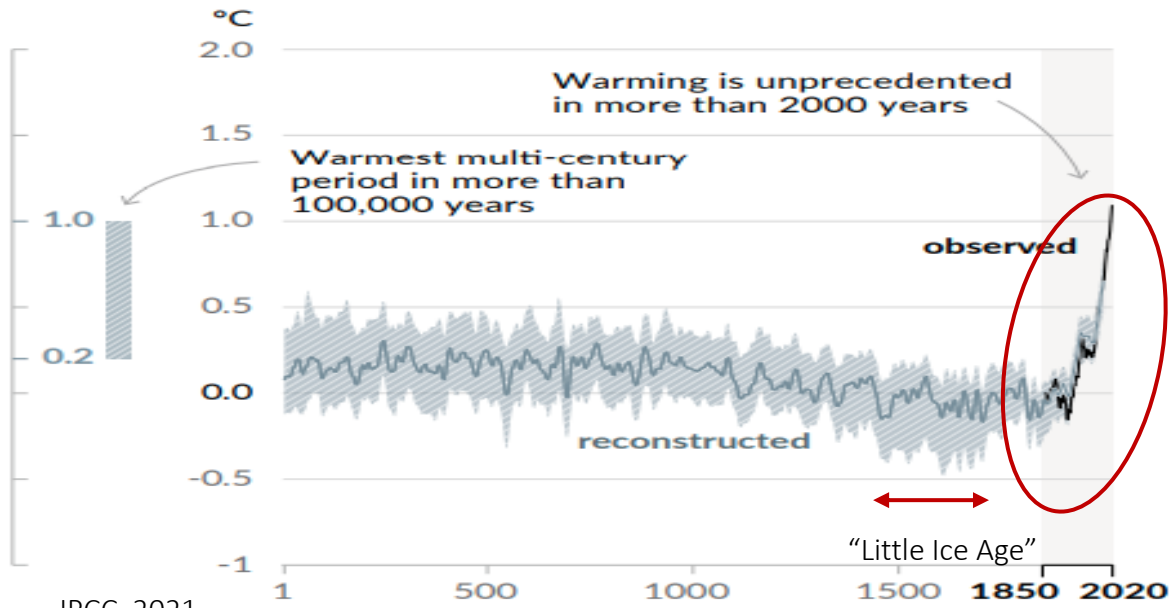
July 29, 2022

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Many factors have contributed to temperature change

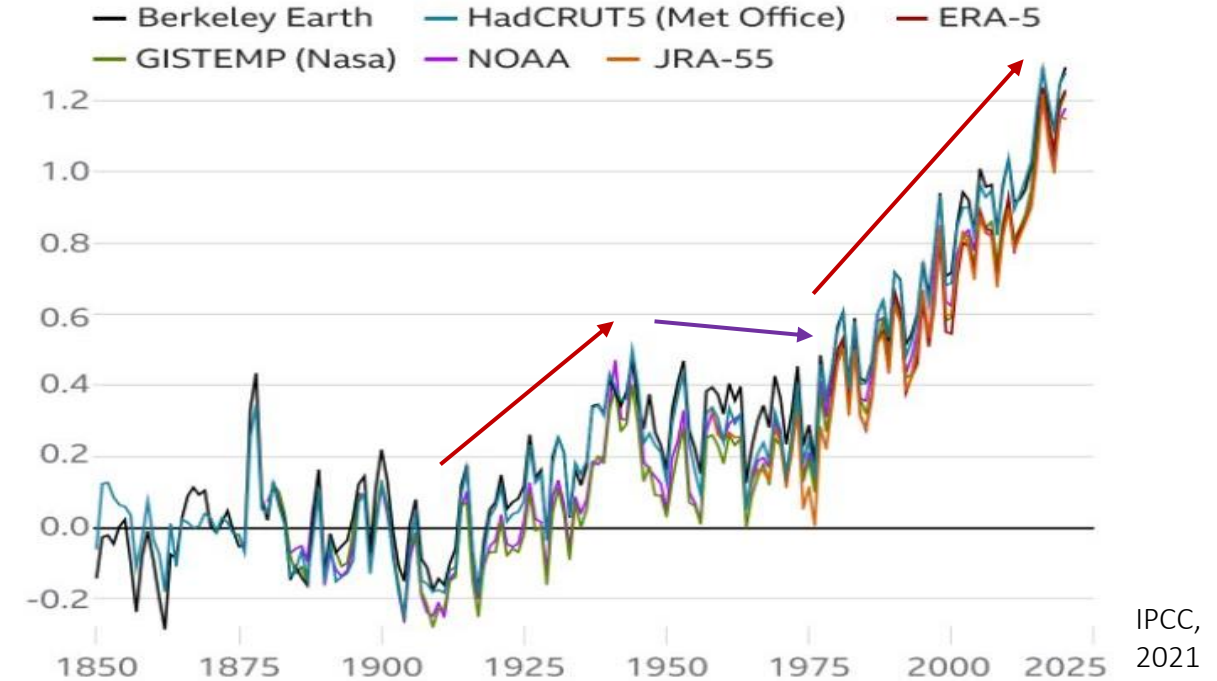
a) Change in global surface temperature (decadal average) as reconstructed (1-2000) and observed (1850-2020)



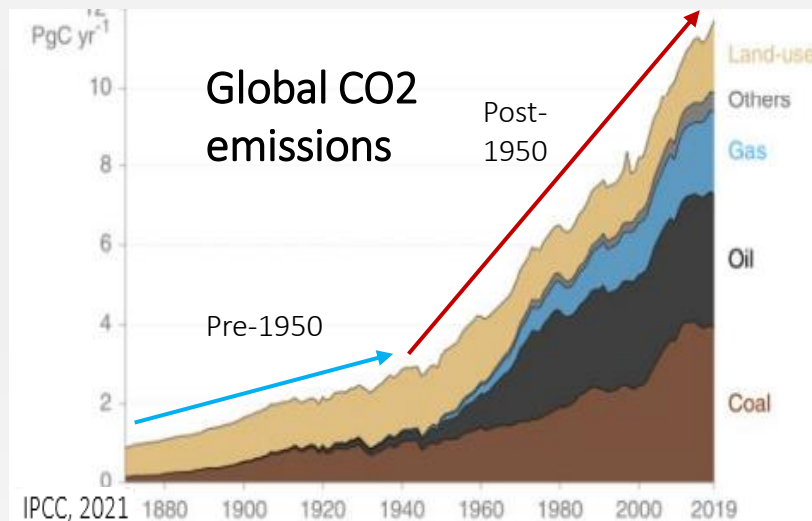
IPCC, 2021

- ❖ Normal temperature variations can be 0.5 deg C/year
- ❖ Temperatures dropped over a 300-year period (1400-1700, or “Little Ice Age”) due to reduced solar radiation
- ❖ Temperature rise of 1 deg C in past 40 years is far outside normal range of historical time

Global mean temperature change from pre-industrial levels, °C



IPCC,
2021



Global temperatures in past 100 years have followed 3 trends:

- 1910-1950: increase of 0.5 deg. C
- 1950-1980: temperature flat or slightly decreasing
- 1980-2020: increase of 1 deg. C

This is not consistent with CO2 emissions, which began rapid increase in 1950

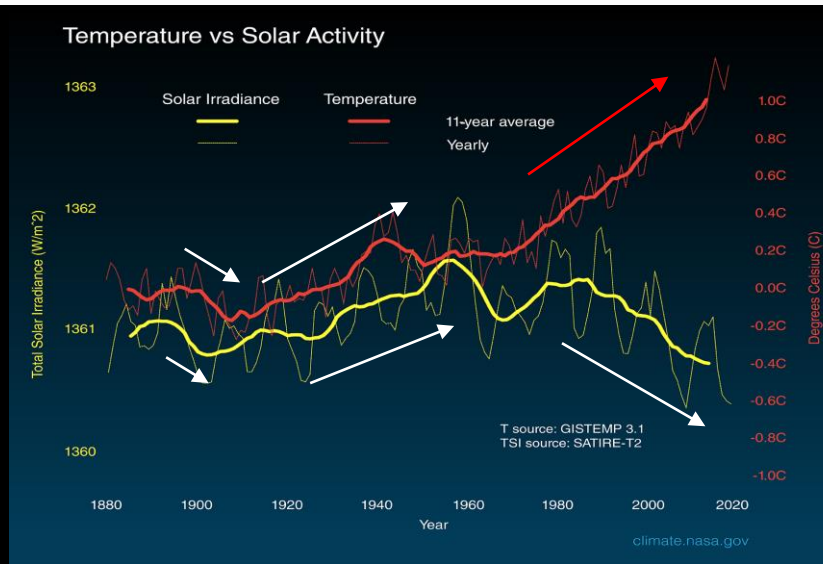


Natural causes of temperature variation: Solar radiation

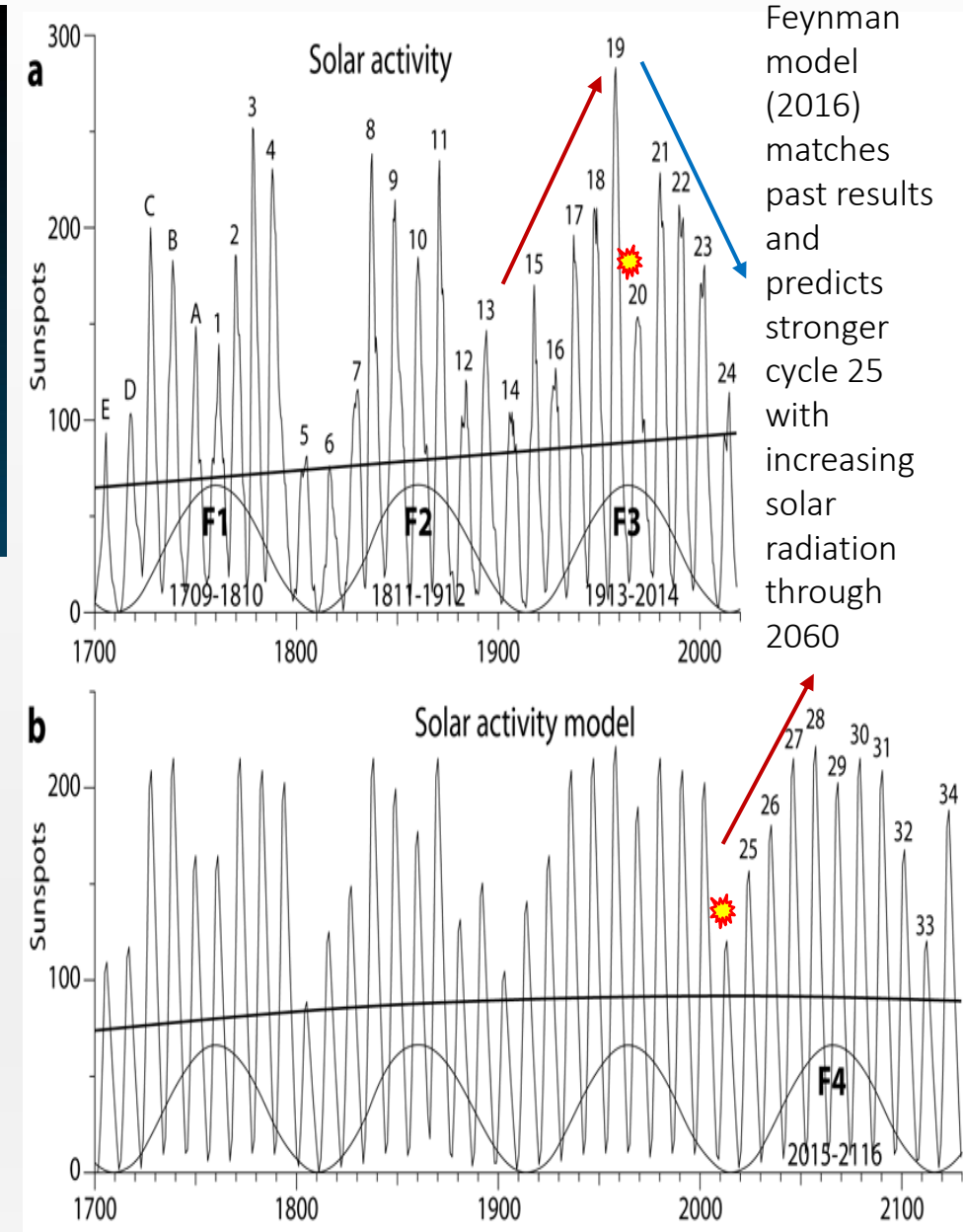
SOLAR MINIMUM

SOLAR MAXIMUM

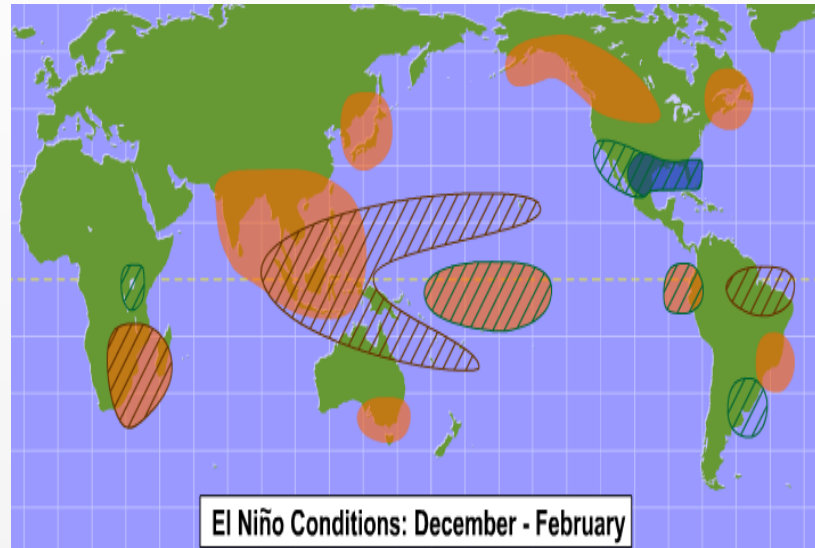
NASA



- Solar radiation varies by about 1 watt.m³ (0.13%) in 22-year cycles, enough to make a significant difference.
- There is a 0.1-0.2 deg. C impact on annual temperature from top to bottom of cycle depending on strength of cycle.
- These cycles vary over 100-year periods. Cycles are strengthening since end of “Little Ice Age”.
- The strengthening cycles from 1910-1950 was a factor in the 0.5 deg. temperature increase during this period
- The 1 deg. C increase since 1980 is not connected with solar activity, in fact, decreased solar activity likely reduced the amount of temperature rise
- We are at the bottom of the 100-year cycle. Increased solar activity will potentially add to the temperature increase in the 2020-2060 period.

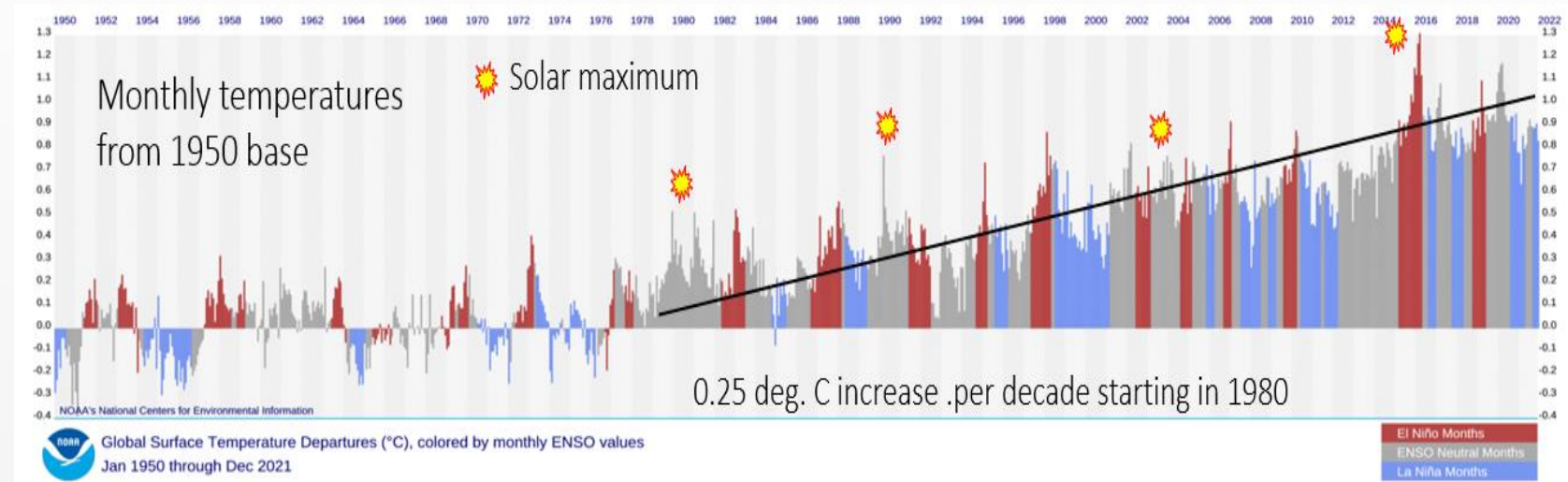
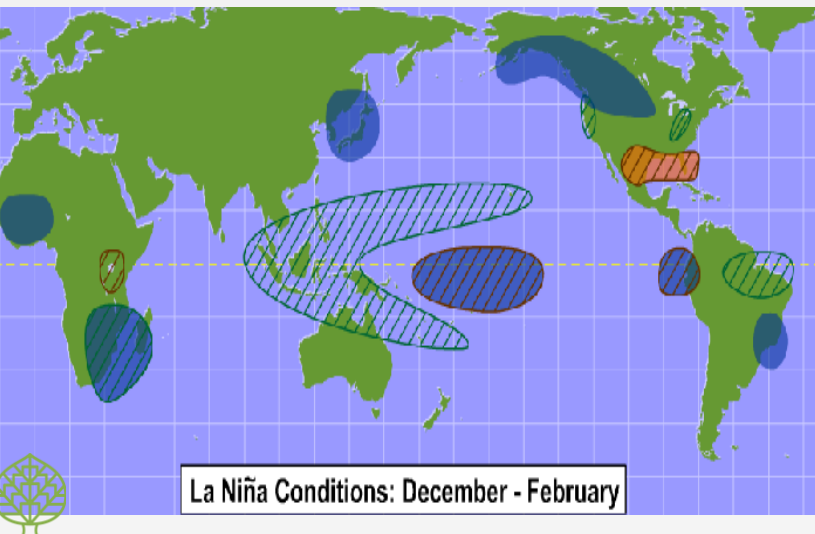


Natural causes of temperature variation: Ocean Currents

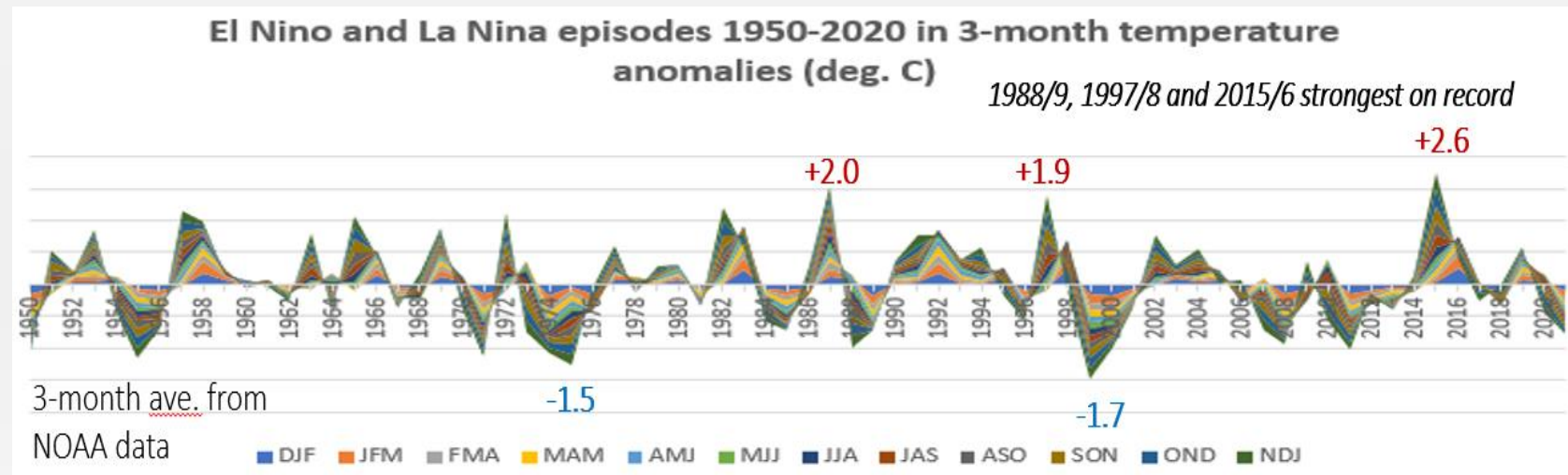


■ warm
 ■ cool
 dry
 wet

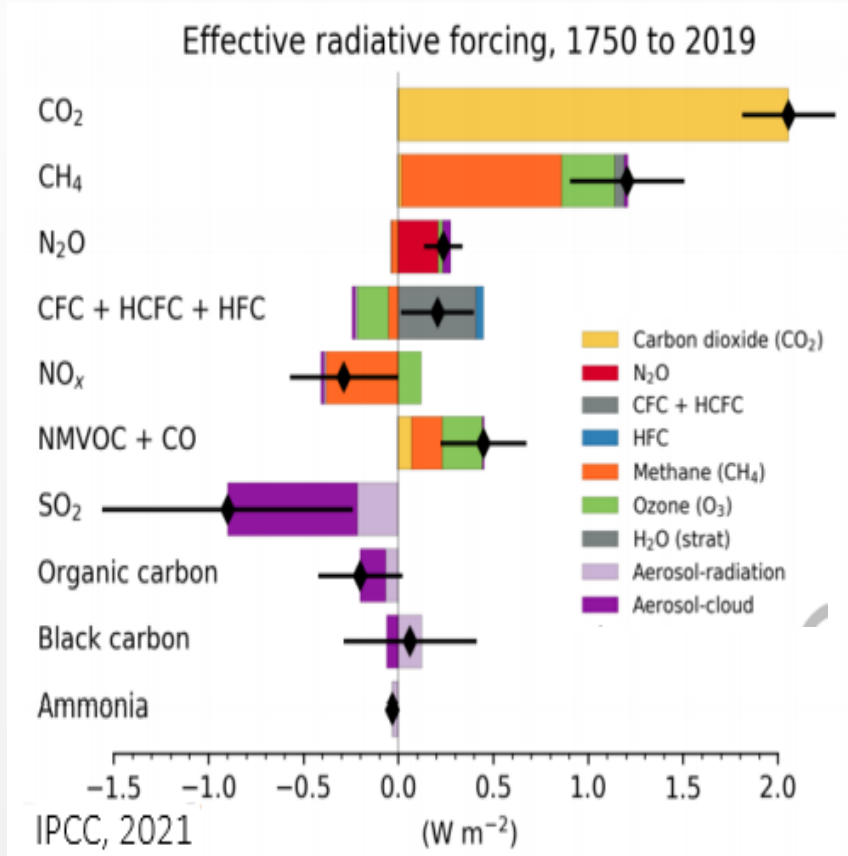
Penn State, NOAA



El Nino and La Nina occur at irregular periods and varying strengths. El Nino adds approximately +.15 deg C global temperature per 1 deg. C strength while La Nina subtracts the same amount.

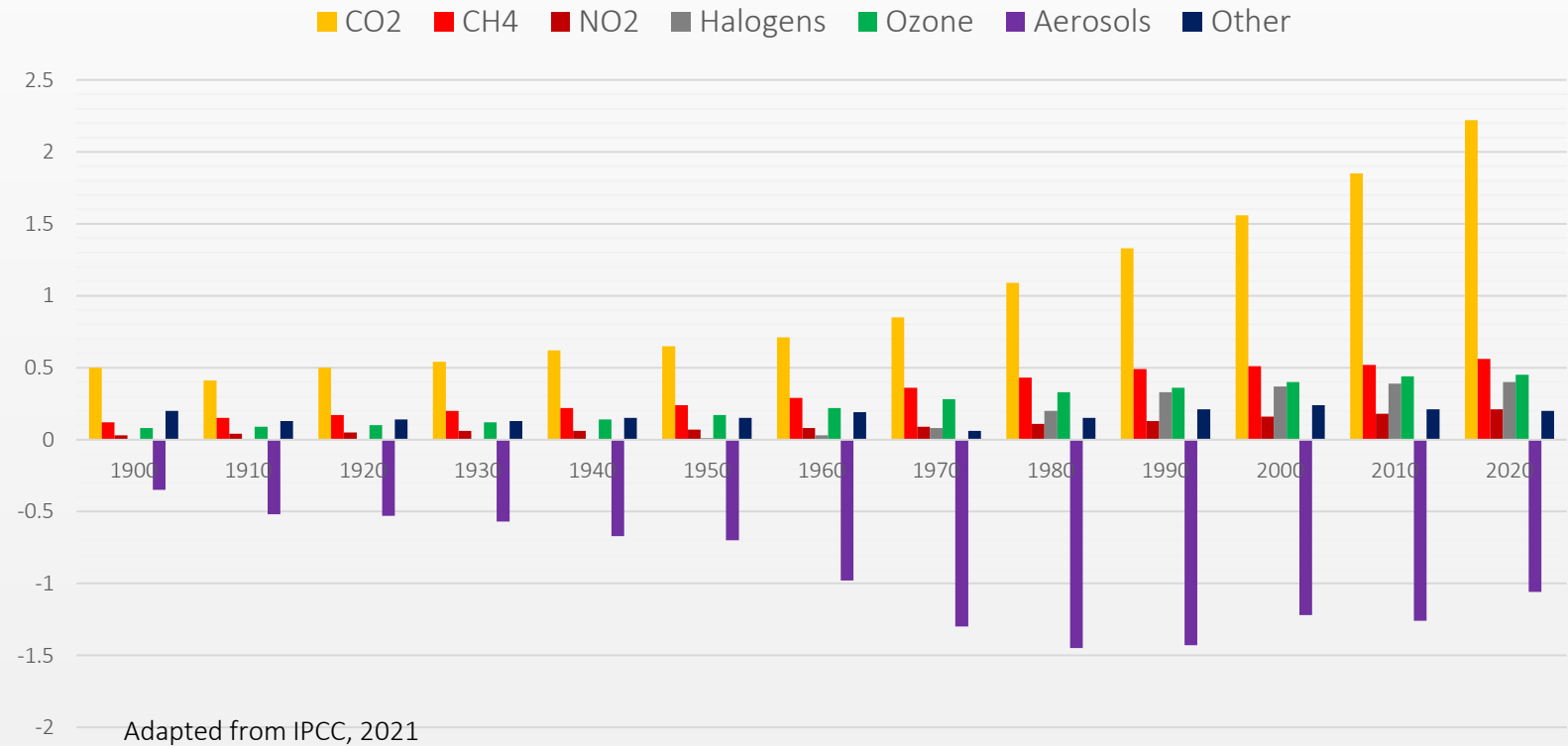


Greenhouse gases and the Atmosphere: It's not just about CO₂



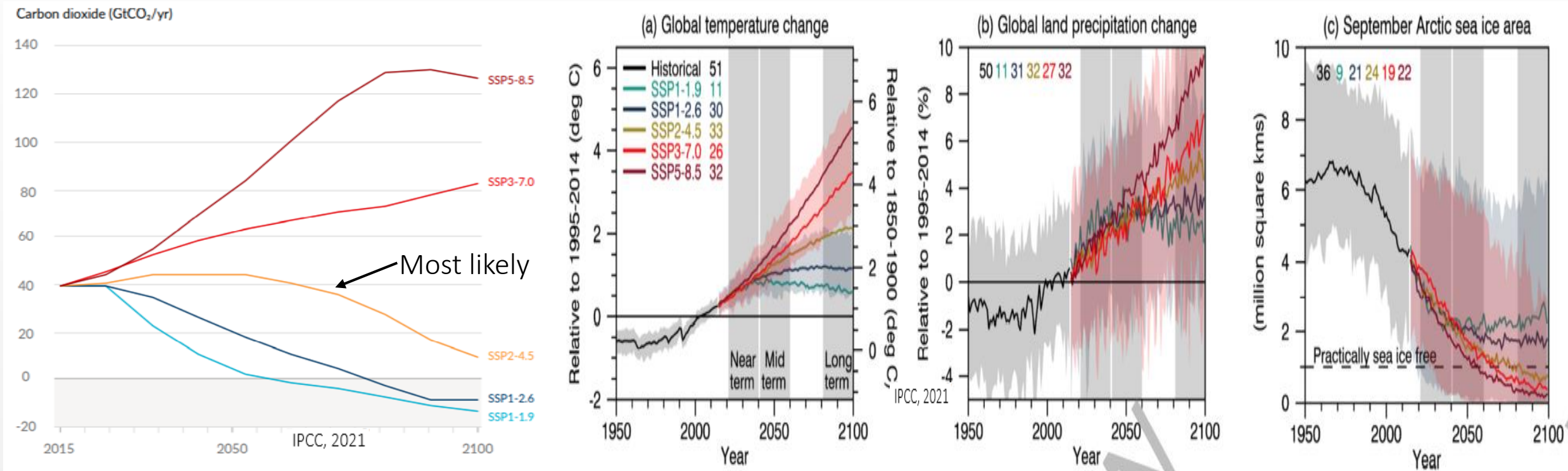
Radiative forcing (RF) is the change in energy flux in the atmosphere due to natural or human caused climate change in watts/meter. RF increase of 1750-2020 is +2.79.

Radiative Forcing of GHG 1900-2020



- ❖ The most important factors have been addition of CO₂ in the atmosphere (+) mostly due to combustion of fossil fuels and aerosol pollution (-) from the same process
- ❖ From 1900-1990, these two factors largely cancelled each other out
- ❖ Increase in other GHG's increase 250% from 1950-1990
- ❖ After 1990, pollution (aerosol emission) dropped in Europe and USA replaced in part by pollution in Asia

The 2021 IPCC report presents five potential scenarios for the rest of the 21st century, however, not all are realistic



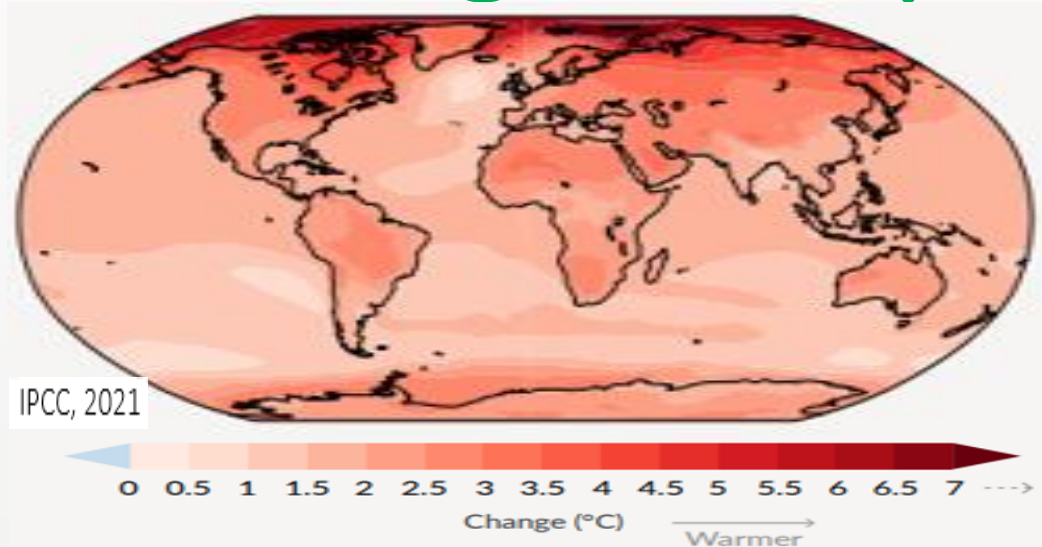
The IPCC admits in the report that the two high and low scenarios are unlikely. In fact, being able to move from the constant increase in carbon emissions to a plateau then decline after 2050 would be a significant achievement. Moving the decline closer to the present (beginning 2025) in SSP1-2.6 is a “stretch” goal.

Under most likely scenario (SSP2-4.5) the following would occur:

- ❑ Global temperature would rise to 2 deg. C relative to 1900 around 2040 and 3 deg. C by end of century
- ❑ It will be a wetter world in general, precipitation will rise 3% in first half of century, 5% by 2100
- ❑ The arctic will be mostly ice free by late summer by 2050
- ❑ **Through 2040, SSP1-2.6 and SSP2-4.5 have virtually identical results**

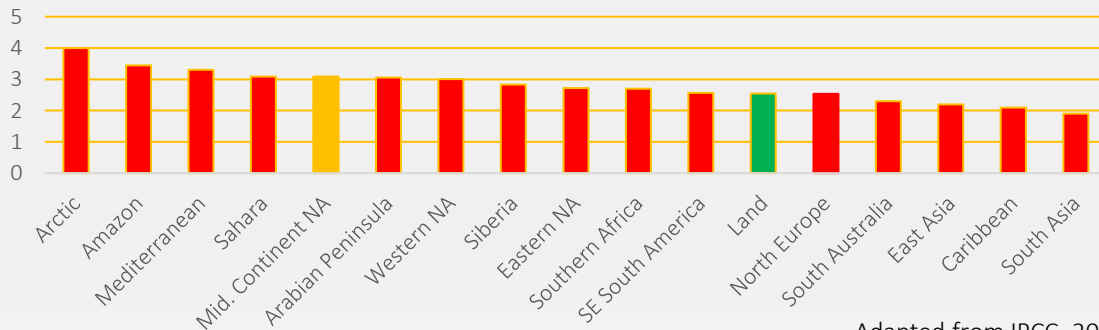


What will the world be like in 2050, with 2 deg. C temperature increase?



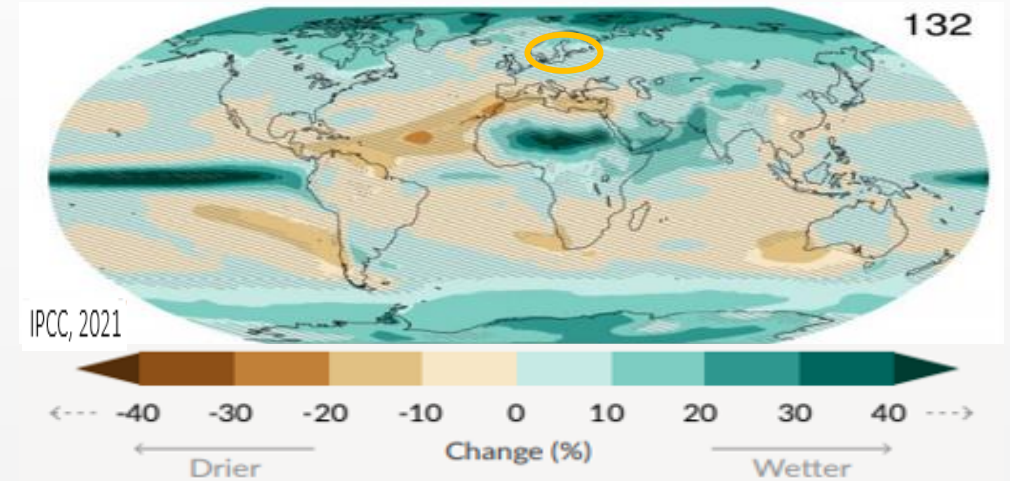
Temperature change at 2 deg warming

Temperature with global 2 deg C increase

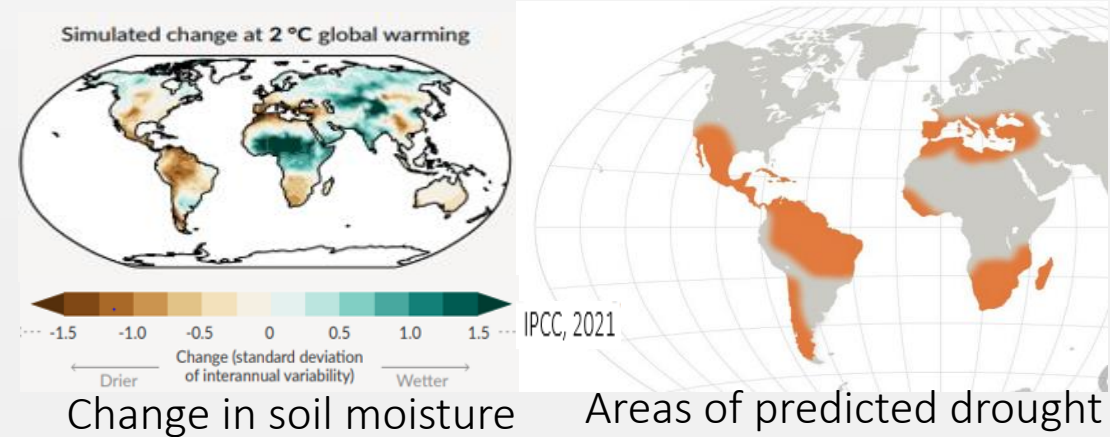


Adapted from IPCC, 2021

While land will average +2.55 deg C and ocean +1.64 C, the Arctic will warm the fastest



Precipitation change at 2 deg C warming

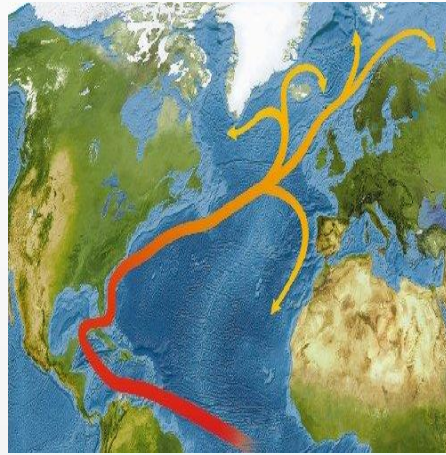


Change in soil moisture

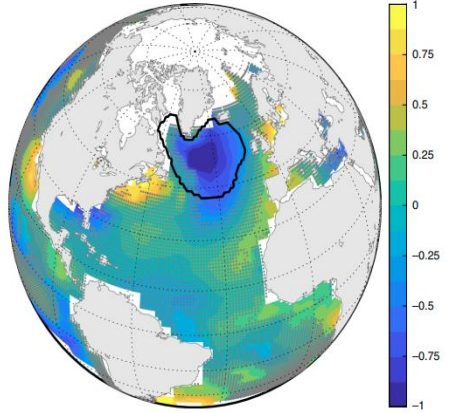
Areas of predicted drought

Combination of temperature increase and reduced precipitation will lead to serious drought

What are potential tipping points that could cause “catastrophic change” in this century?



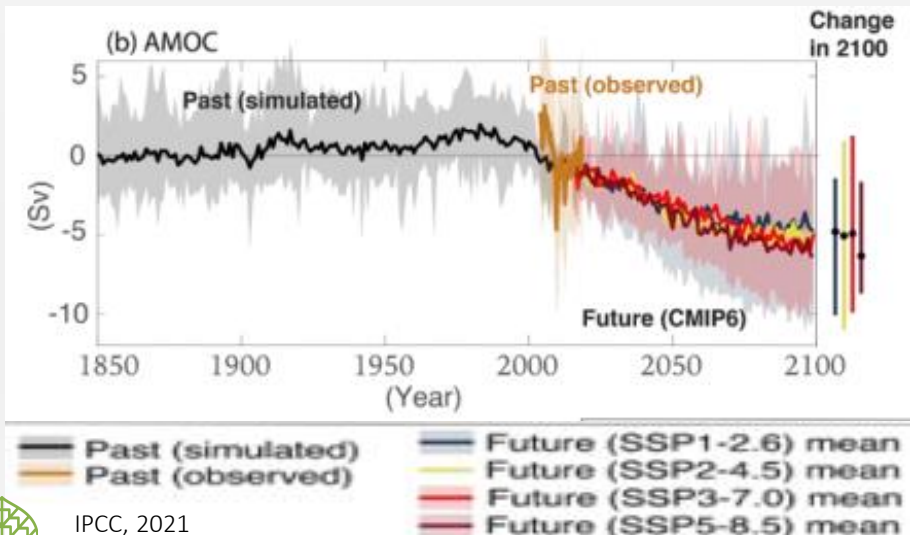
Gulf Stream Wikipedia



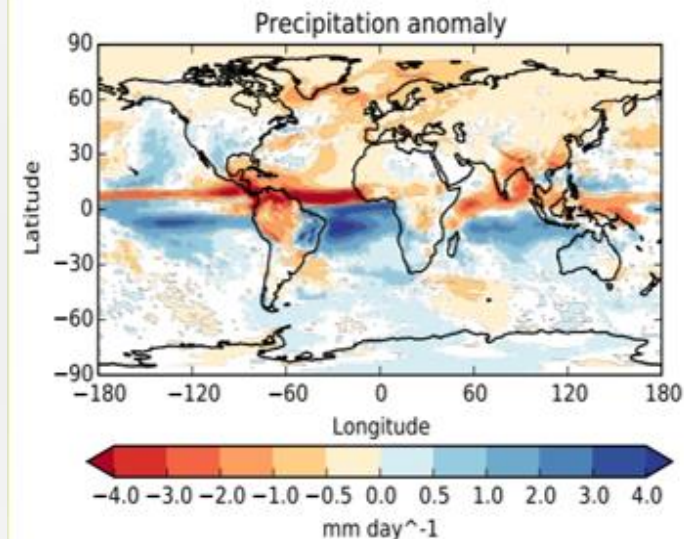
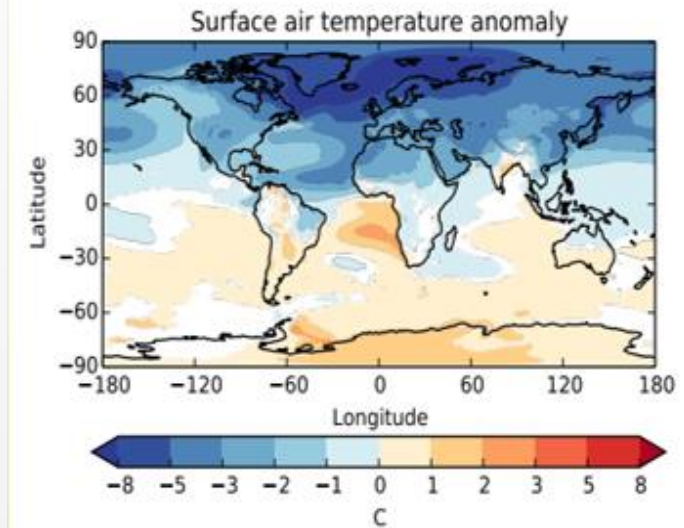
Trends in sea surface temperature
1909-2018 Deg. C (HadISST and Kaplan)

Overturning of Atlantic Meridian (Gulf Stream):

- Increasing freshwater melt from Greenland and Arctic has weakened Gulf Stream by 15%
- This will accelerate under all scenarios and if it reaches 35-40% may overturn, radically changing global climate
- Heat transfer will slow, cooling N Hemisphere, warming S Hemisphere. Effects will be worldwide, especially precipitation.
- This occurred about 13,000 years ago (Dryas event) dropping temperatures in NW Europe and Greenland 5 deg C in 30 years



IPCC, 2021

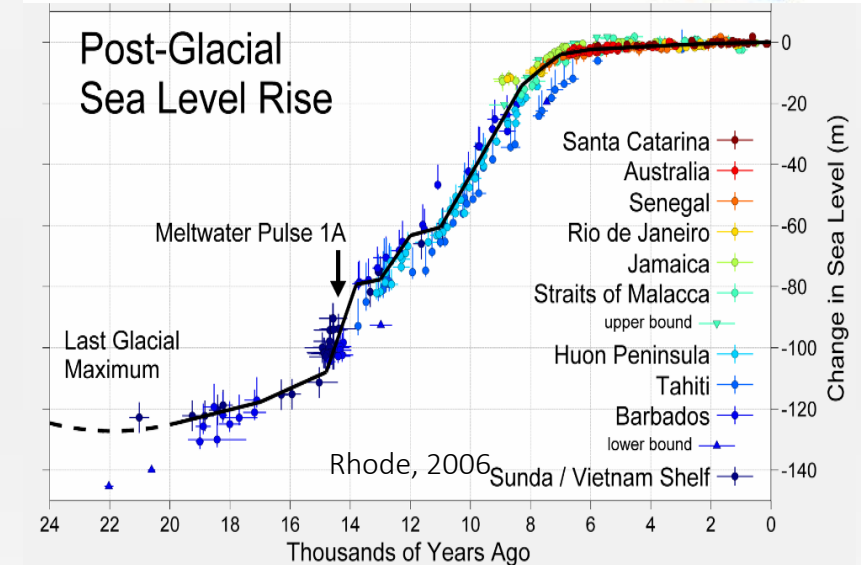
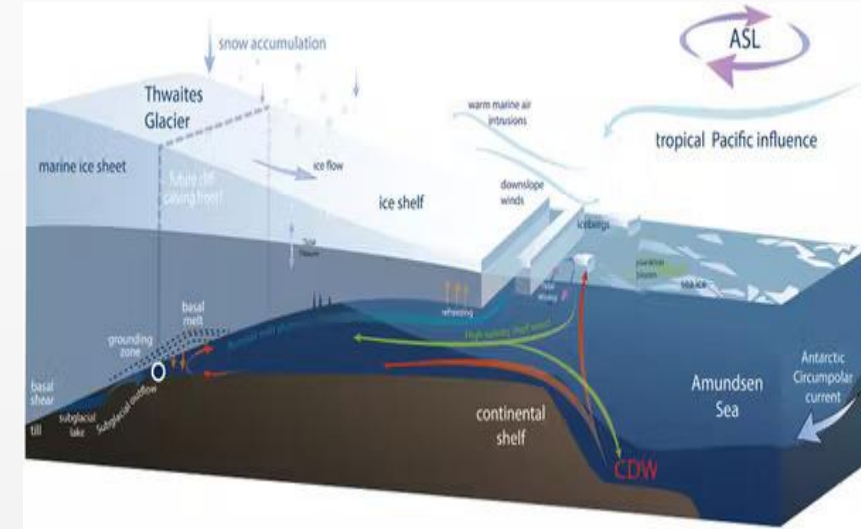
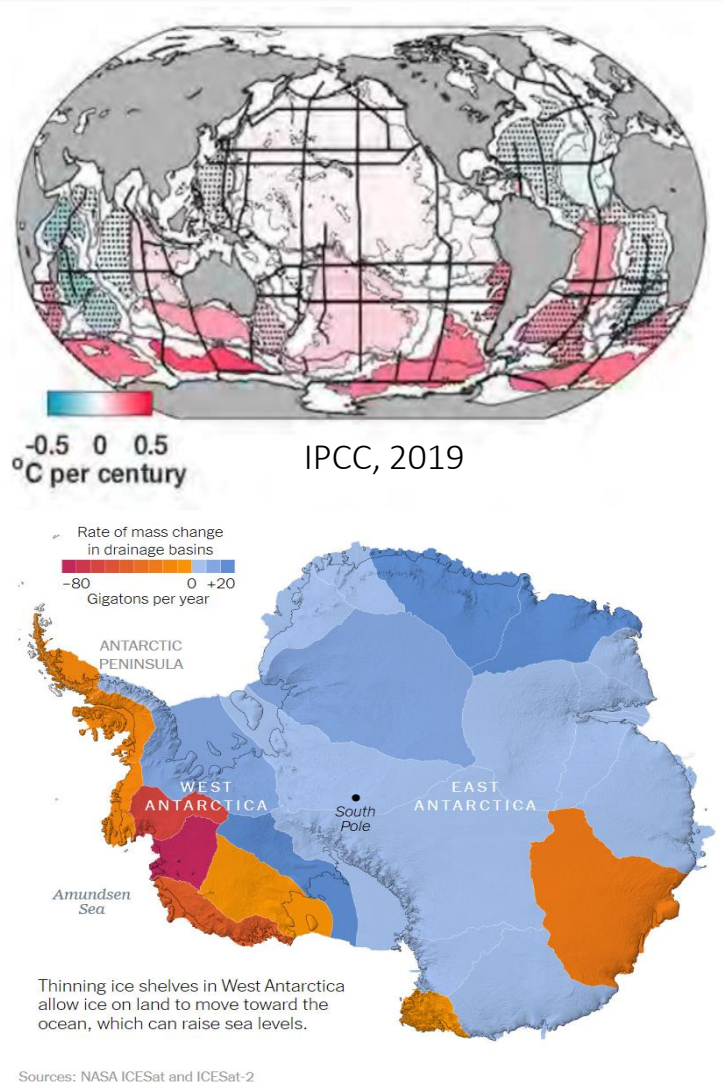


Jackson et al. 2015

What are potential tipping points that could cause “catastrophic change” in this century?

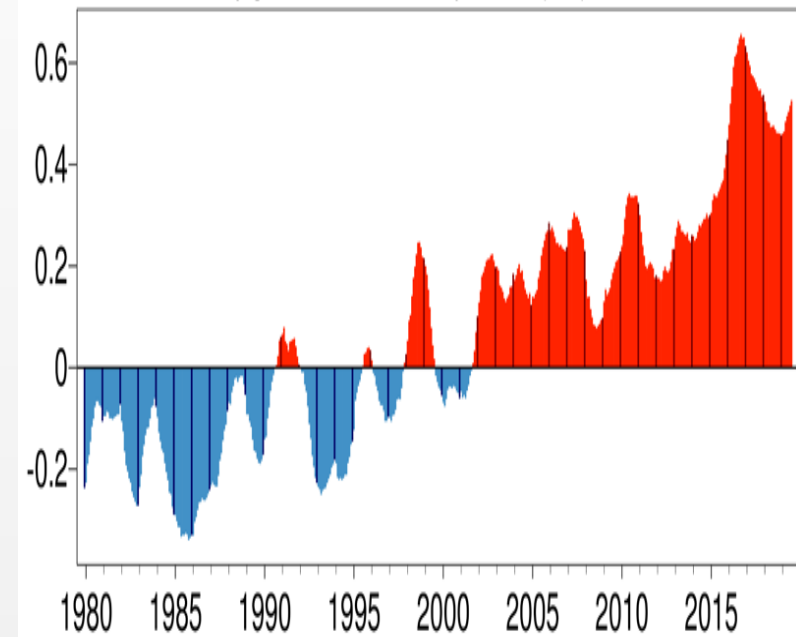
Breaking off of West Antarctic ice sheet:

- Much of increased ocean heat is transferred by currents to southern ocean surrounding Antarctica
- Most of Western Antarctica is ice
- Melting due to increased air temperatures and warm currents are making West Antarctic glaciers increasingly unstable
- Breaking off of ice sheets could cause magnitude increase in rate of level rise as happened 14,600 years ago, raising sea level 18 meters in 500 years (one meter/28 years)

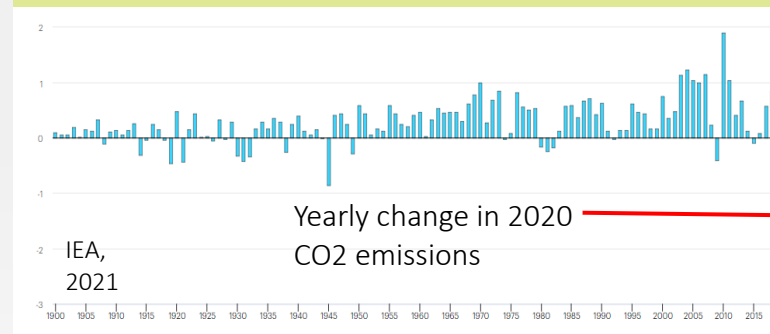
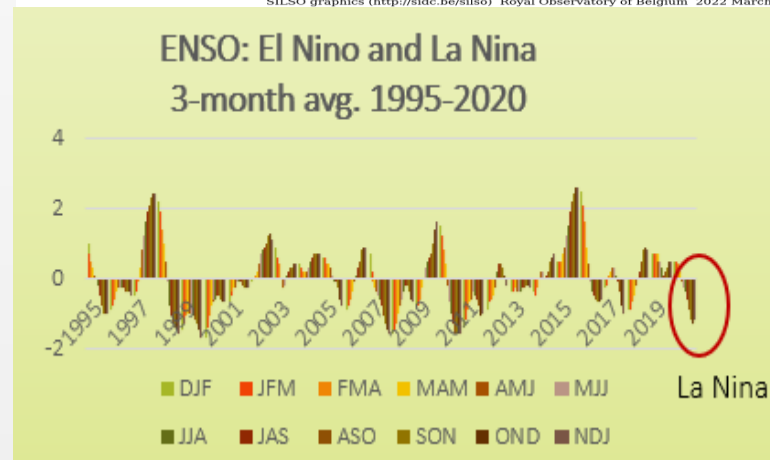
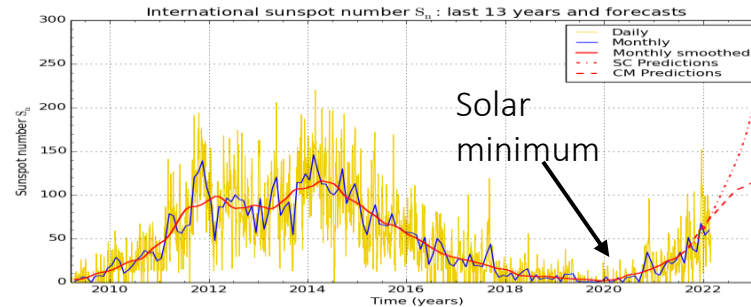


2020 demonstrated the effect aerosols (or lack of) have on temperatures

12month-anomaly global surface air temperature (°C) relative to 1981-2010



After the record shattering 2016, temperatures dropped in 2017-2019 by 0.2 deg. C.



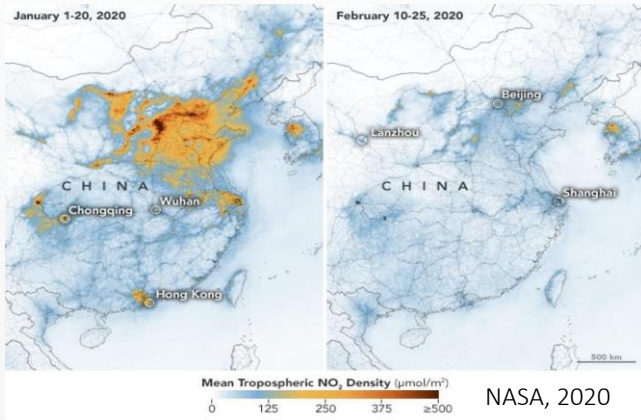
2020 should have been a cool year

- The sun was at the minimum of its cycle
- The ocean current was La Nina
- CO 2 emissions had the one-year greatest drop since records have been kept



2020 tied 2016 as warmest year in historic time!

During 1H 2020, due to Covid lockdowns, world stopped polluting!

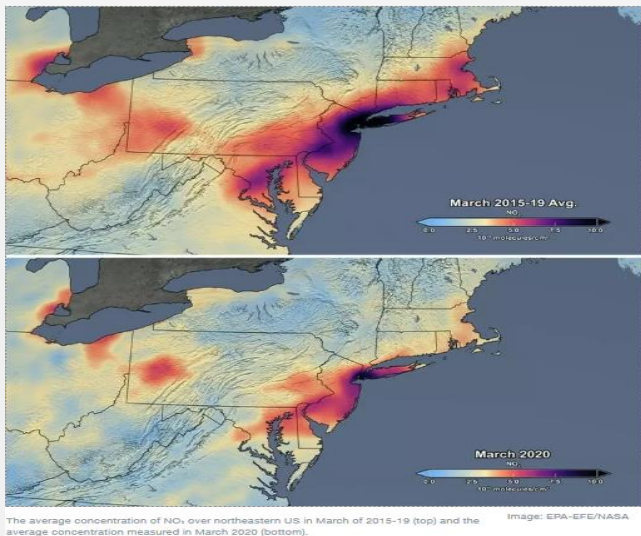
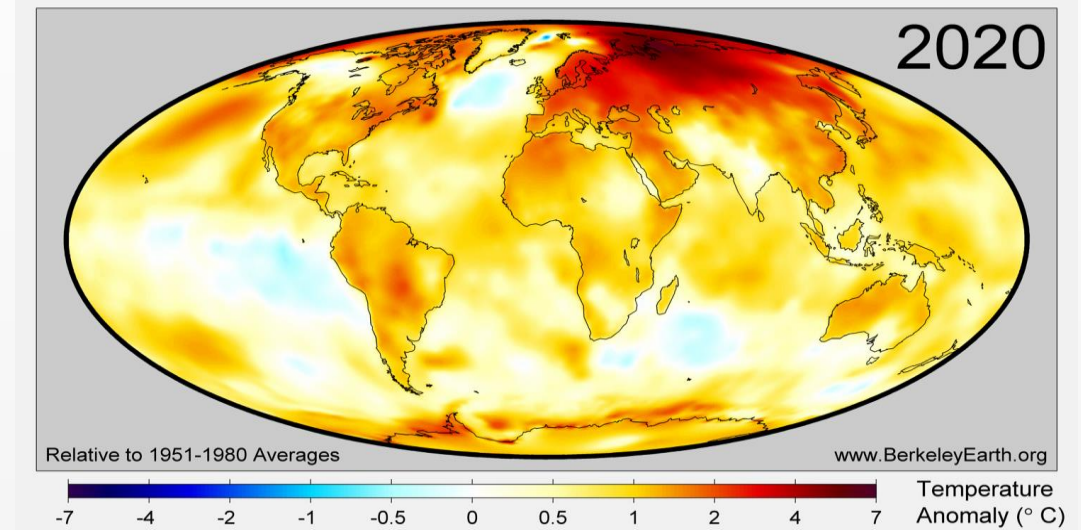


CHINA Jan 2020 vs Feb 2020

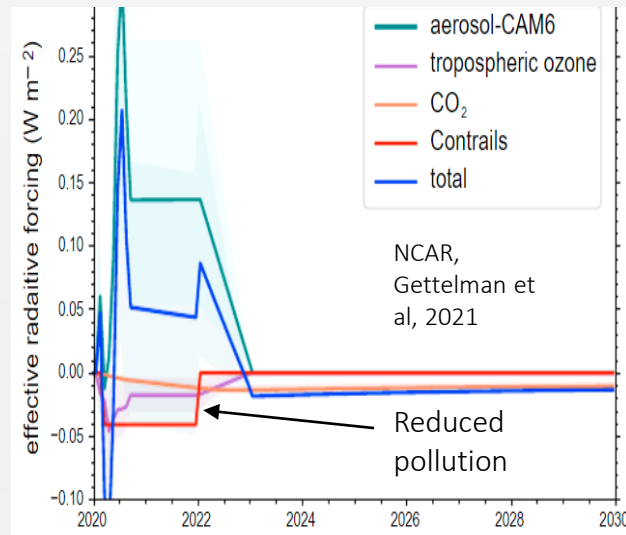


Reuters,
2020

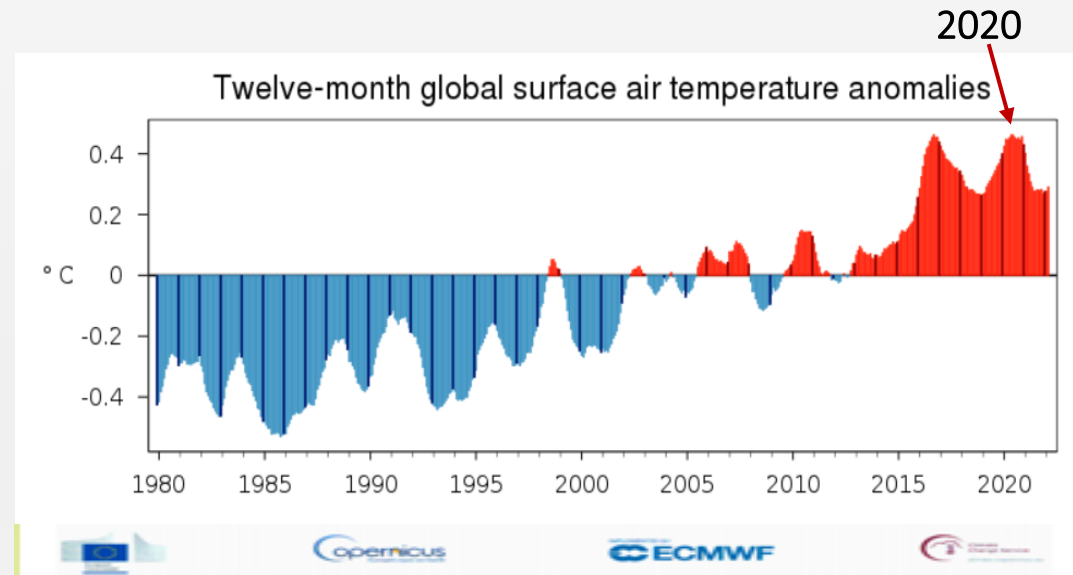
INDIA New Delhi
Jan 2020 vs Feb 2020



Northeast USA:
March 2019 vs March 2020



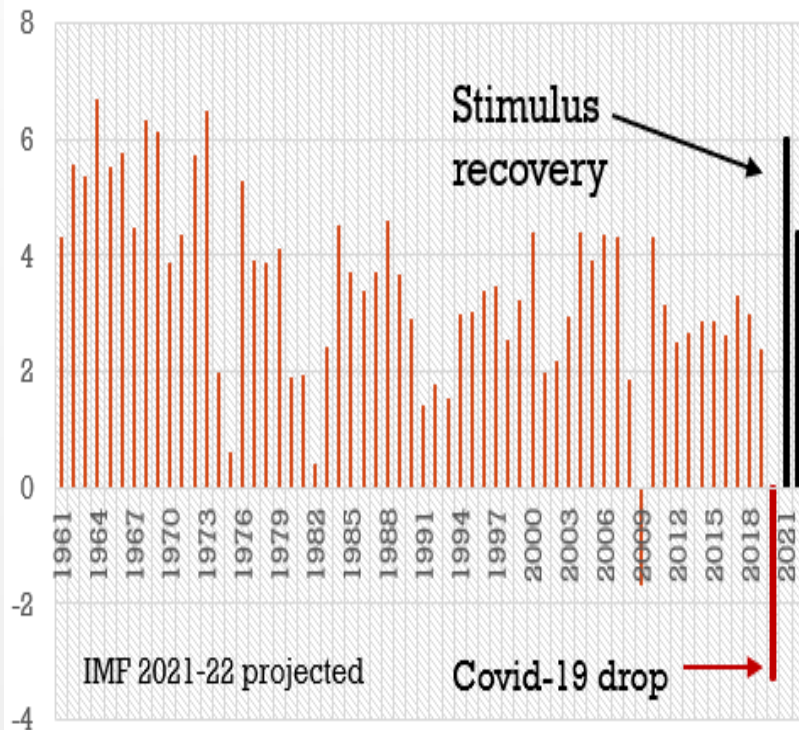
Increased RF due to lack
of pollution



Record high temperatures, especially 1H 2020.
Temperatures dropped in 2021

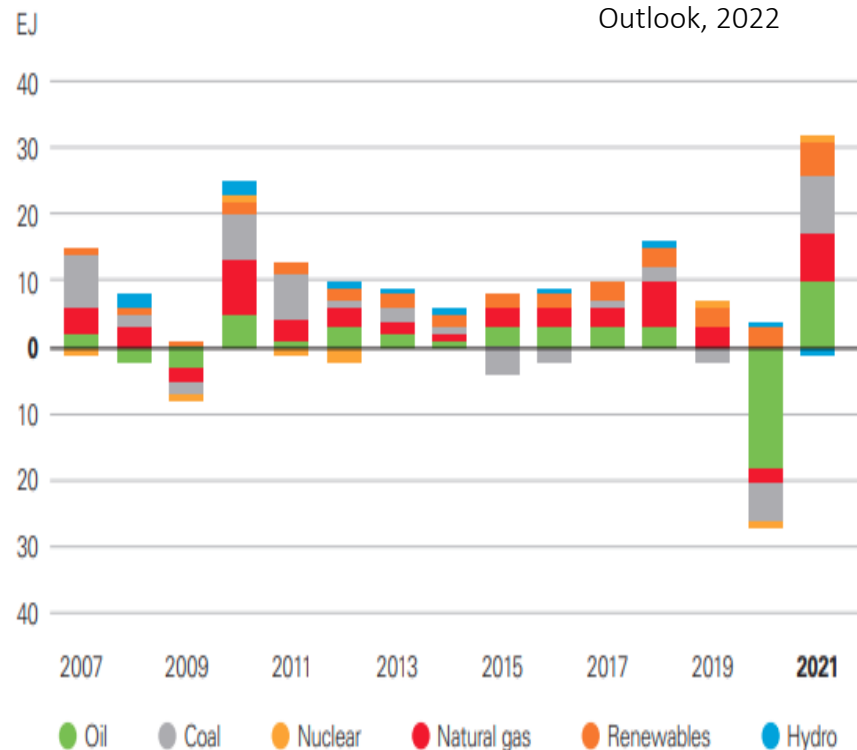
Massive Economic stimulus is 2021 resulted in global economic recovery and record increase in energy demand

World GDP Growth (%)



With massive stimulus, world economic growth of 2021 resulted in 6.1%, the highest percentage rise in 50 years

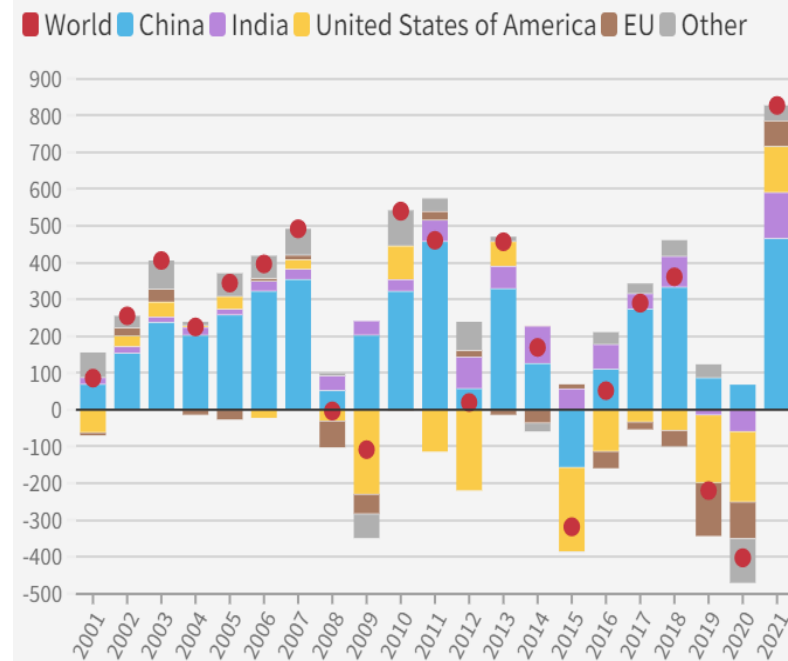
Change in primary energy by fuel



Not surprisingly, this growth resulted in greatest rise in energy use ever recorded, 80% from fossil fuels. Energy supplied by hydro power actually declined, due to drought.

Annual change in coal generation

Year-on-year change, in terawatt hours



Source: Ember's Global Electricity Review 2022

The annual increase in coal generation was the greatest ever recorded. 56% of the increase came from China.

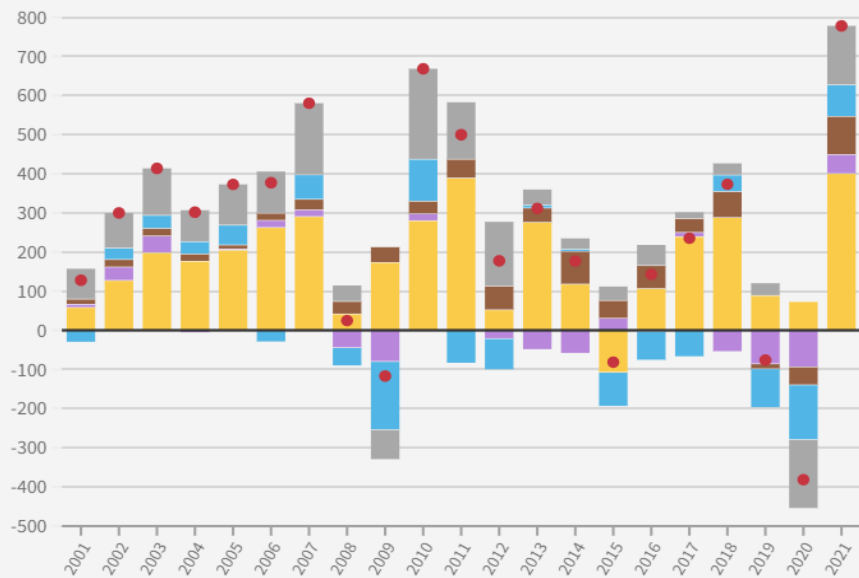


This had two results: increase in CO2 emissions and increased fossil fuel prices

Global change in emissions

Year-on-year change (MtCO₂)

■ World ■ China ■ EU ■ India ■ United States of America ■ Other



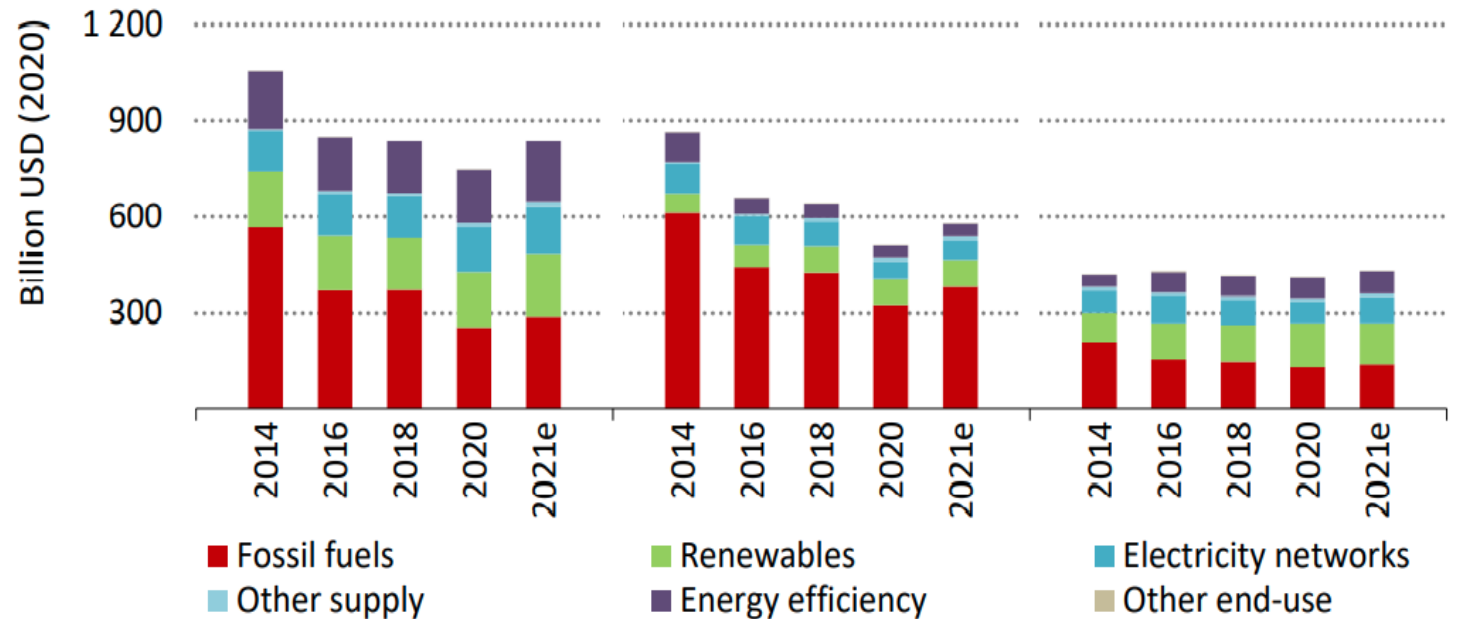
Source: Ember's Global Electricity Review 2022

CO2 emissions from electricity generation increased by 800 Mt, double the decrease from 2020, making the 2030 CO2 reduction goals more difficult to be met.

Advanced economies

Emerging market and developing economies

China



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From 2014-2020, annual investment in fossil fuels had declined by >50% from USD\$1350 billion to \$650 billion. Despite some increase in 2021, demand outpaced supply. Renewable investment increase during that period was statistically higher, from \$300 billion to \$450 billion, but would not be enough to meet the 2021 demand increase.



The result has been a major price rise in energy, contributing to worldwide inflation, as happened 50 years ago

After two years of decline, coal prices rebound to all-time highs

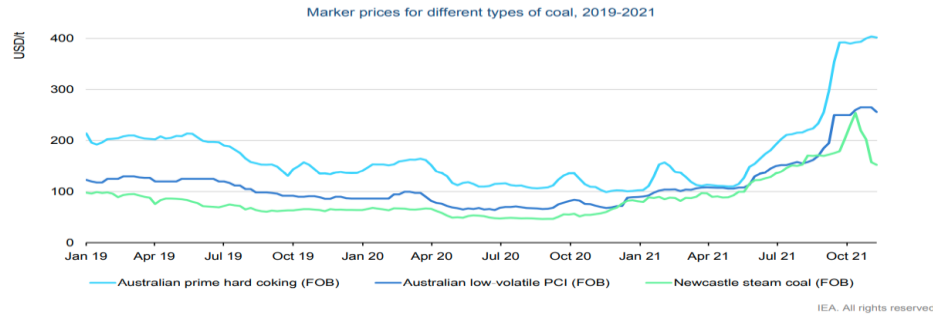


Figure 1. Crude oil front-month futures prices dollars per barrel

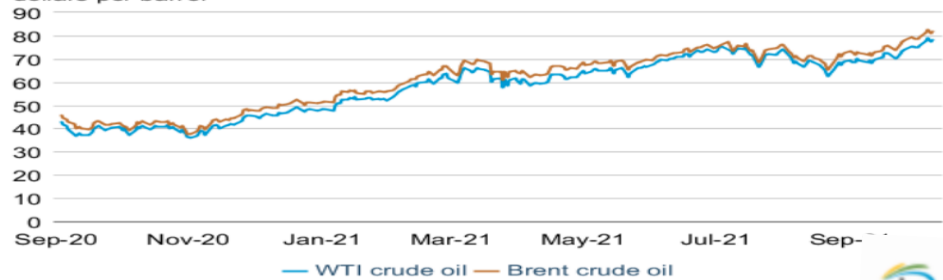
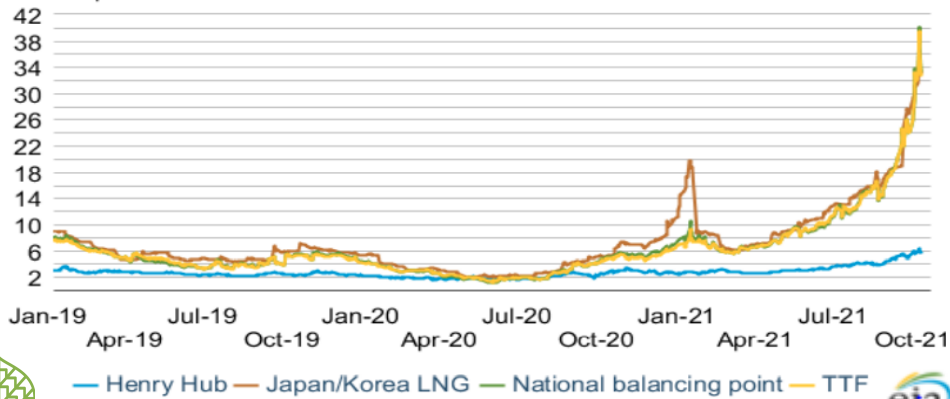
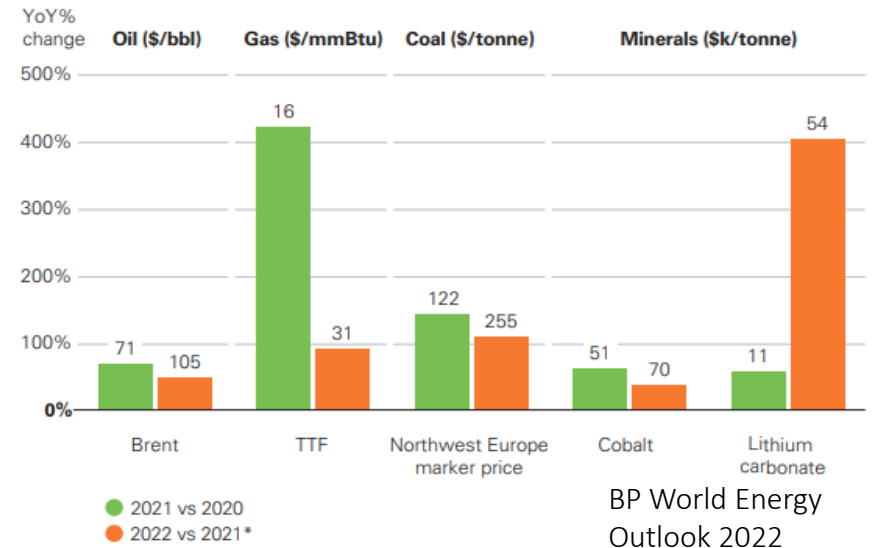


Figure 10. International natural gas prices dollars per million British thermal units



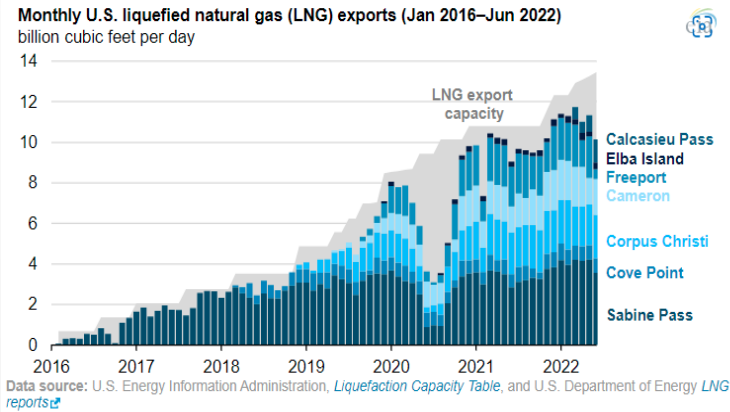
- Coal prices tripled beginning in 2H 2021
- Crude oil doubled from \$40 to \$80/bbl. in 2021
- Natural gas rose in price 250% USA and 400% for LNG in Europe and Asia in 2021

Energy and mineral prices increased in 2021 and continue to do so in 2022

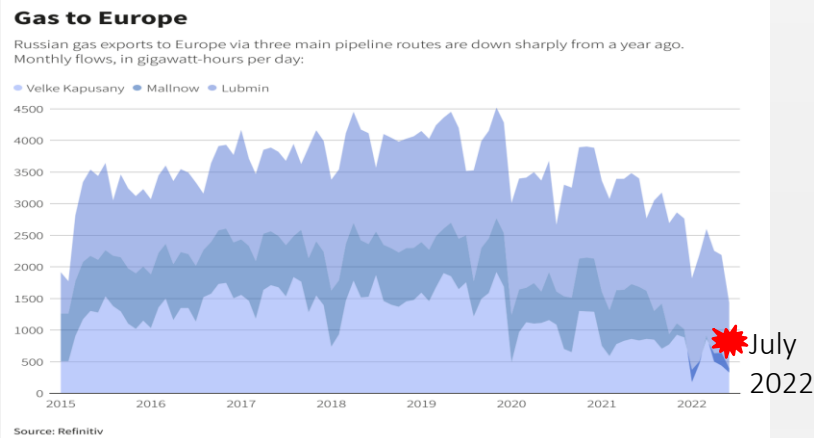


In addition to the rise in fossil fuel prices, the downward trend in cost of renewables has reversed due to inflation and shortage of critical minerals. Prices have risen of cobalt (70%) and lithium (400%), key to batteries have risen sharply.

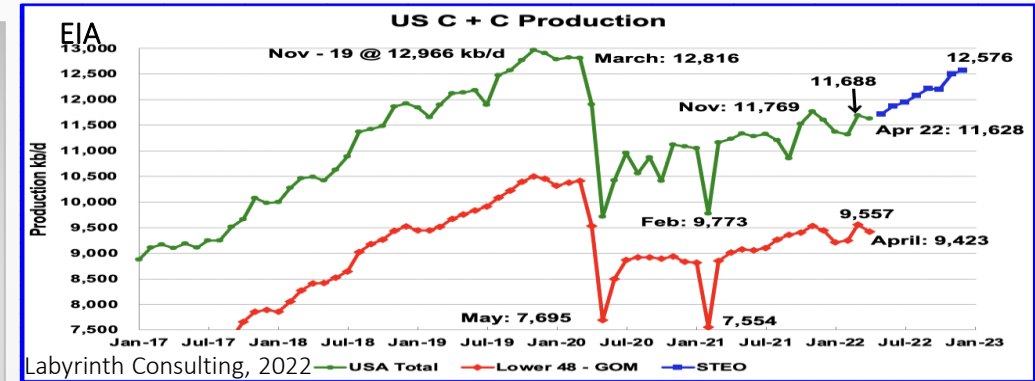
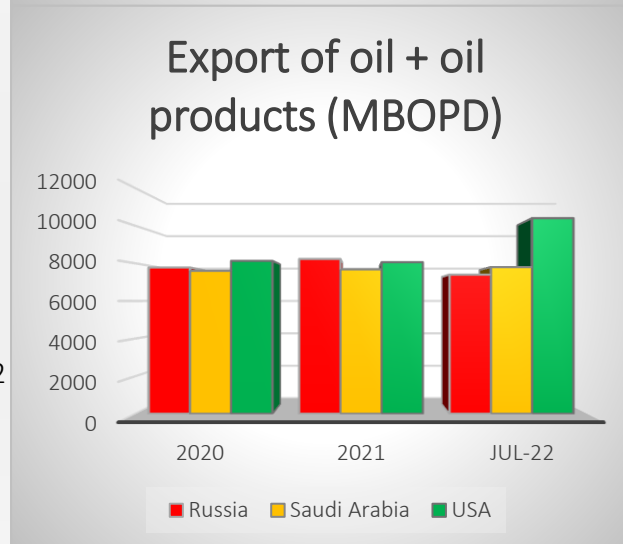
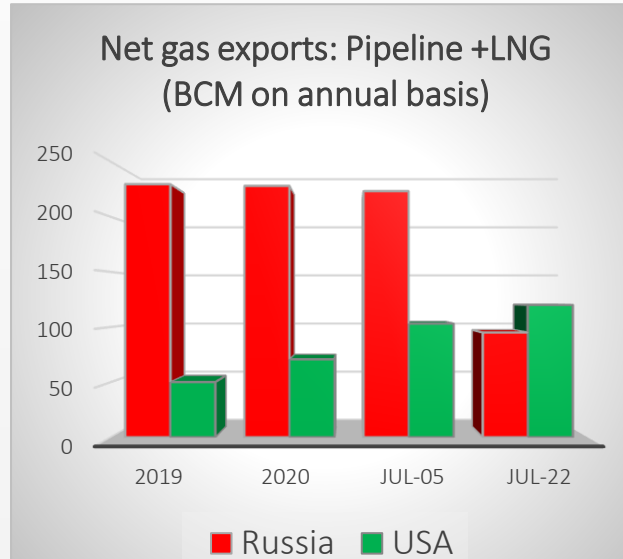
In 2022, the Russian invasion of Ukraine disrupted world energy markets: the US is stepping in to fill the gap



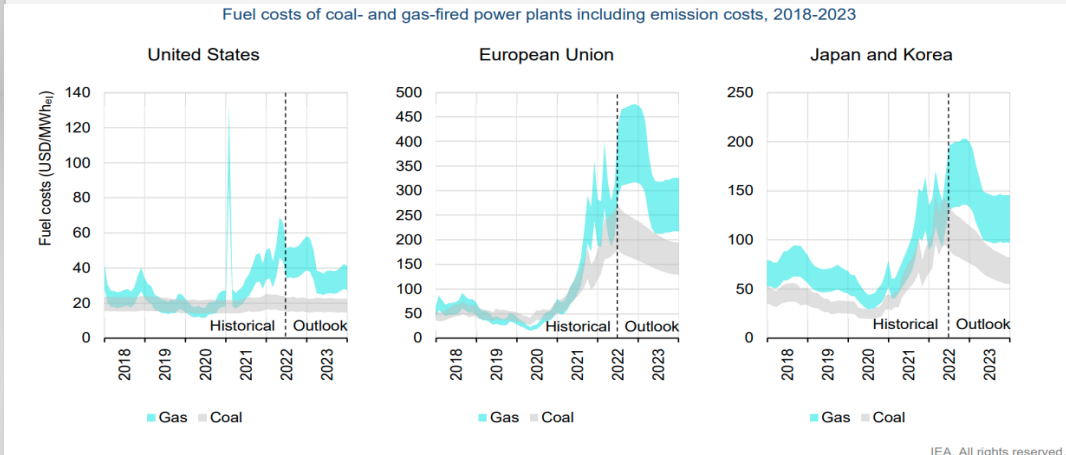
The US rose from zero to the world #1 LNG exporter in a six-year period



By July 2022, Russian gas to Europe dropped by 80% from 2020 peak

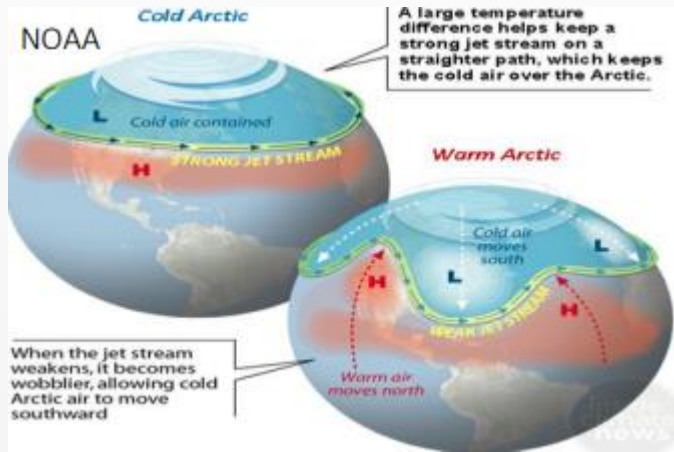


US Crude production, #1 in world, will recover to pre-pandemic level by January 2023

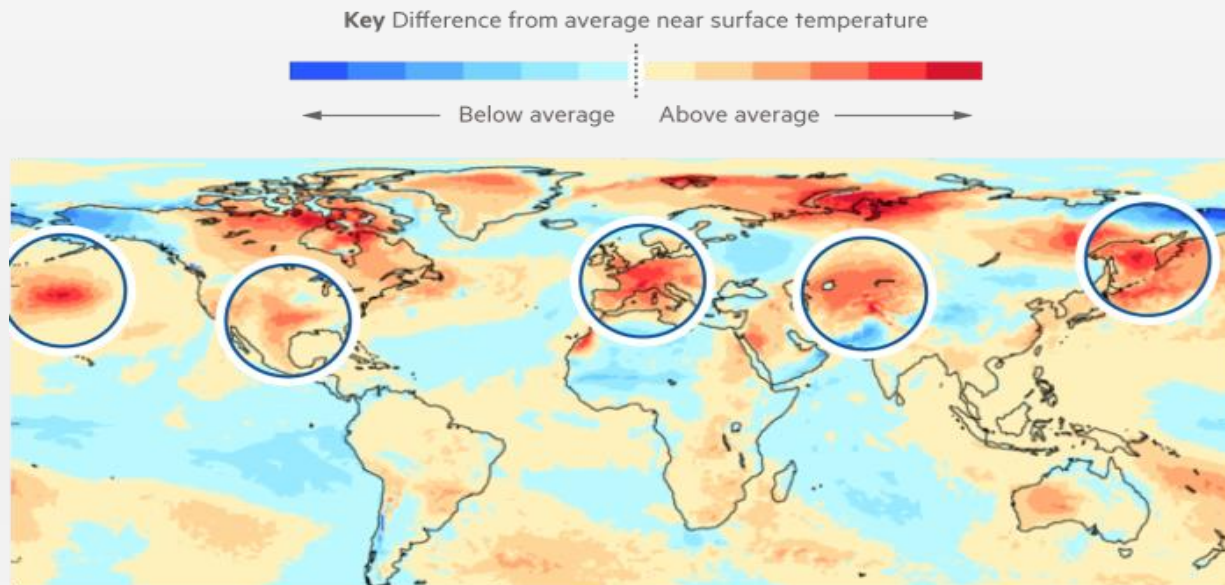


Meanwhile, fossil fuel prices increased further with the invasion and will remain at a high level through 2023

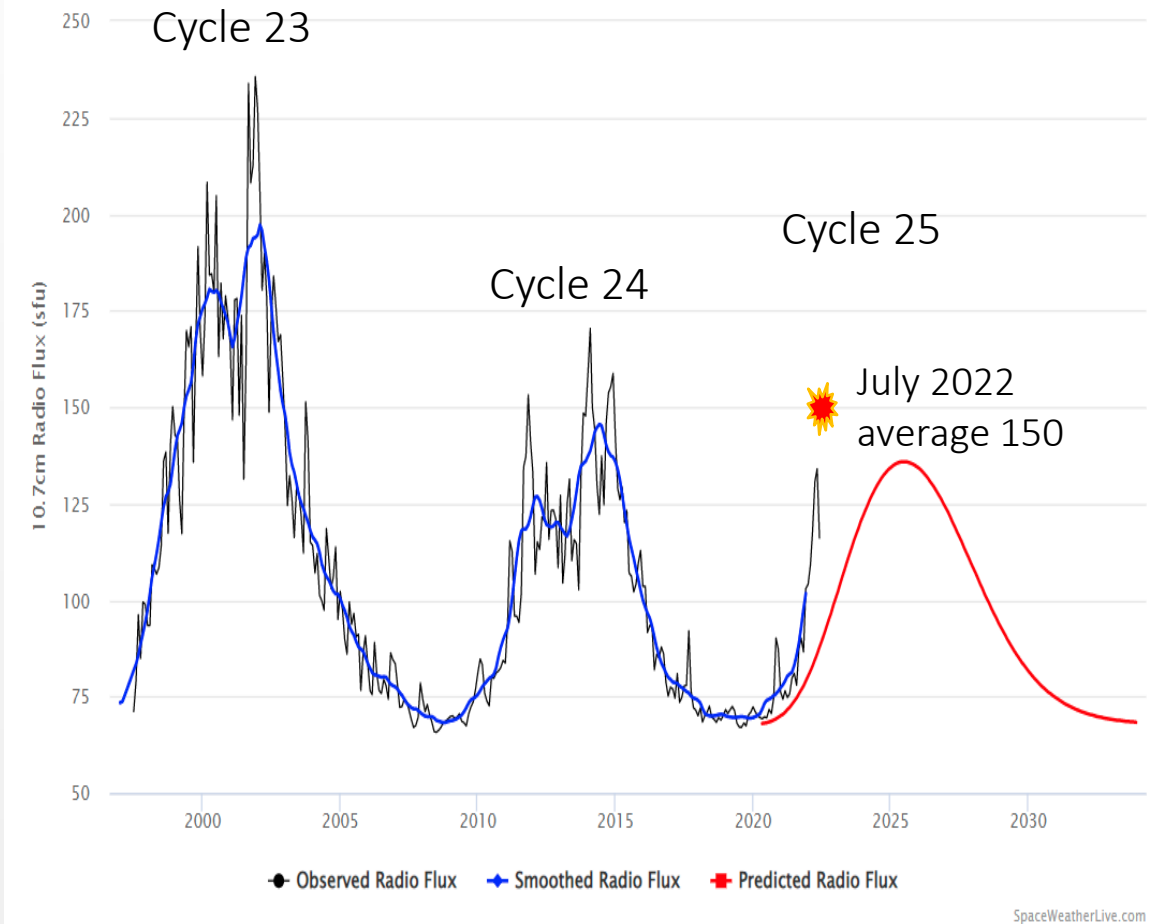
The climate in mid-2022 is heating up



As the jet stream weakens, heat domes in northern hemisphere are becoming more common. During week of July 18, 2022 multiple occurrences.

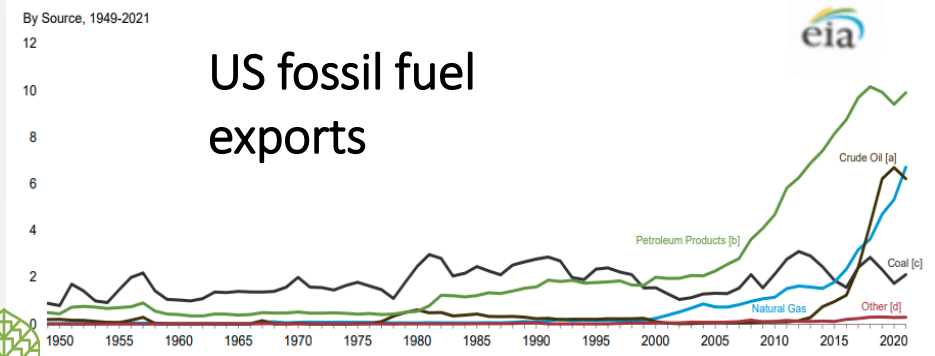
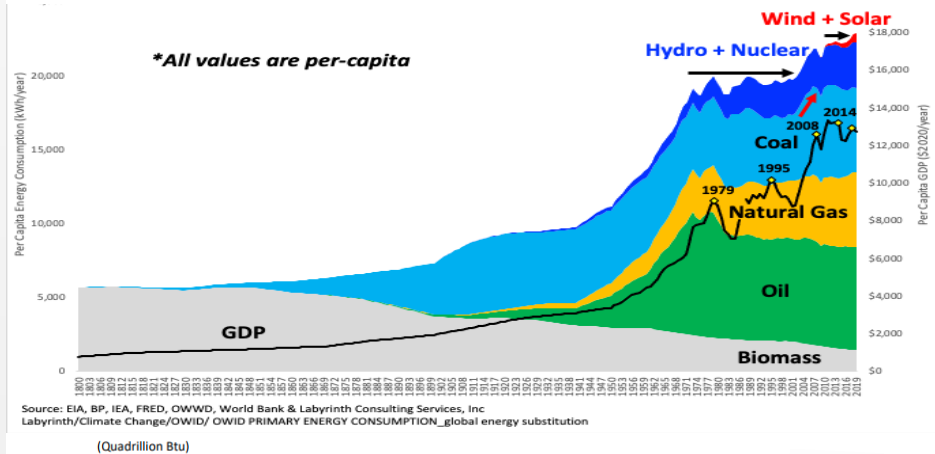
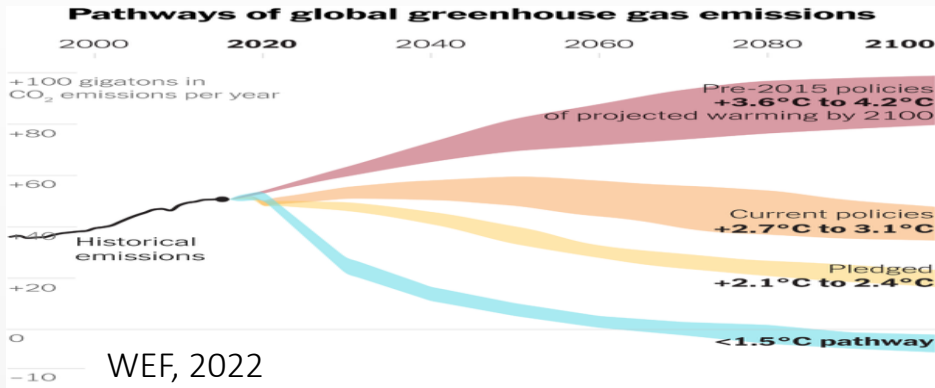


Graphic: Ian Bott
© FT
Source: Met Office



Solar cycle 25 is on track to resemble Cycle 23, rather than 24, which may begin having an impact on increasing temperatures

Summary and Conclusions: What is most likely future?



- The world will reach 2.0 degree C above pre-industrial temperature by 2050. There is no realistic alternative. Under current world policies, we are heading for a temperature close to 3 degrees C by the end of the century. The chance of reaching a climatic tipping point late in the century is significant.
- Despite the intensive efforts of the past decade, only about 15% of energy comes from non-fossil fuel sources. Coal, the fuel with the highest CO₂ emissions, will see a continued rise in use in the next few years due to the inability of renewables to meet rising energy demand.
- The world will be facing an energy shortage and high prices in the near term due to lack of investment and over-reliance on renewables. Plans for a rapid “energy transition” are unrealistic and will not take place, especially outside the US and EU.
- Due to invasion of Ukraine, the world energy market is shifting as US replaces Russia as #1 oil+oil products and natural gas exporter.