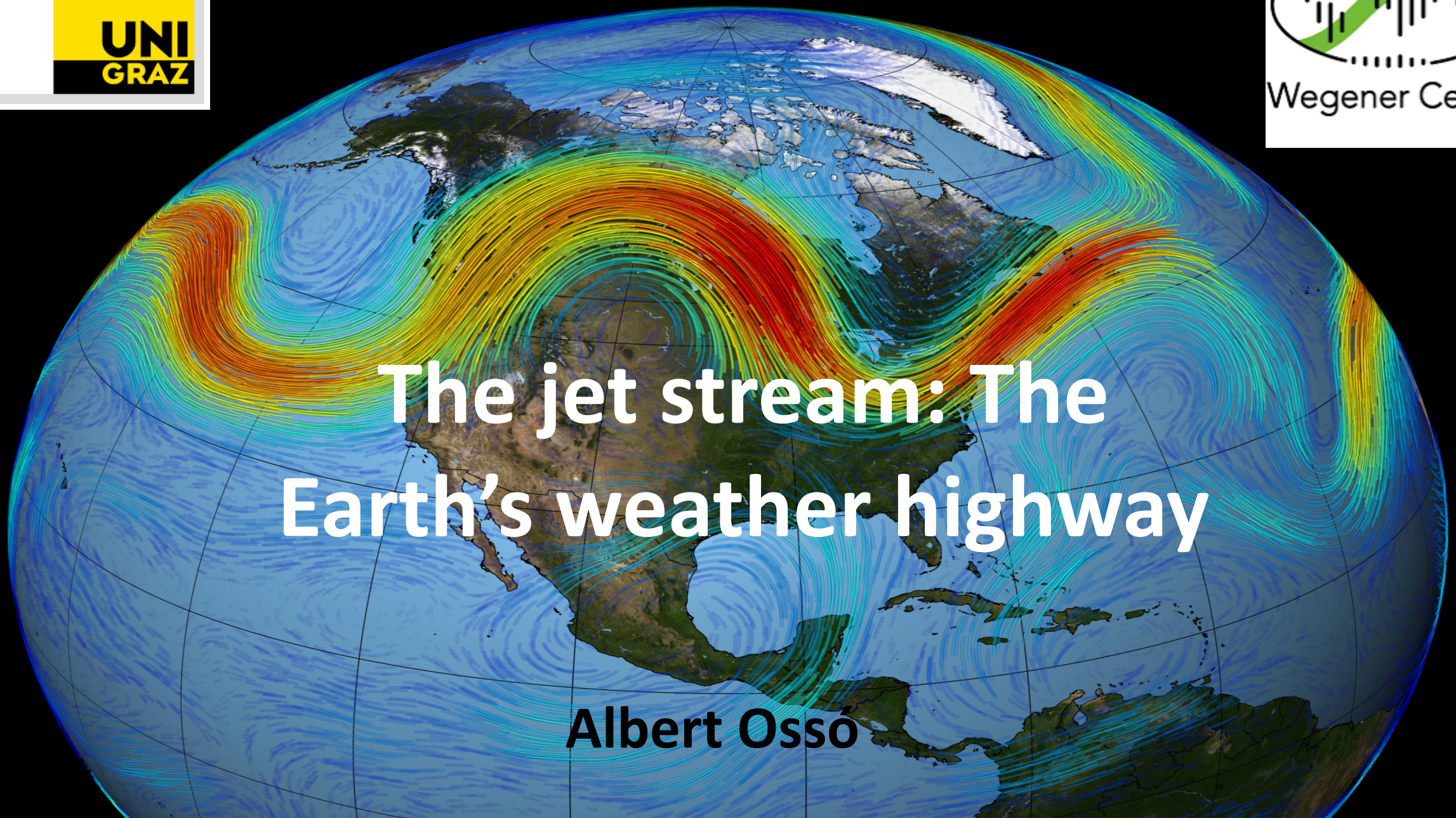


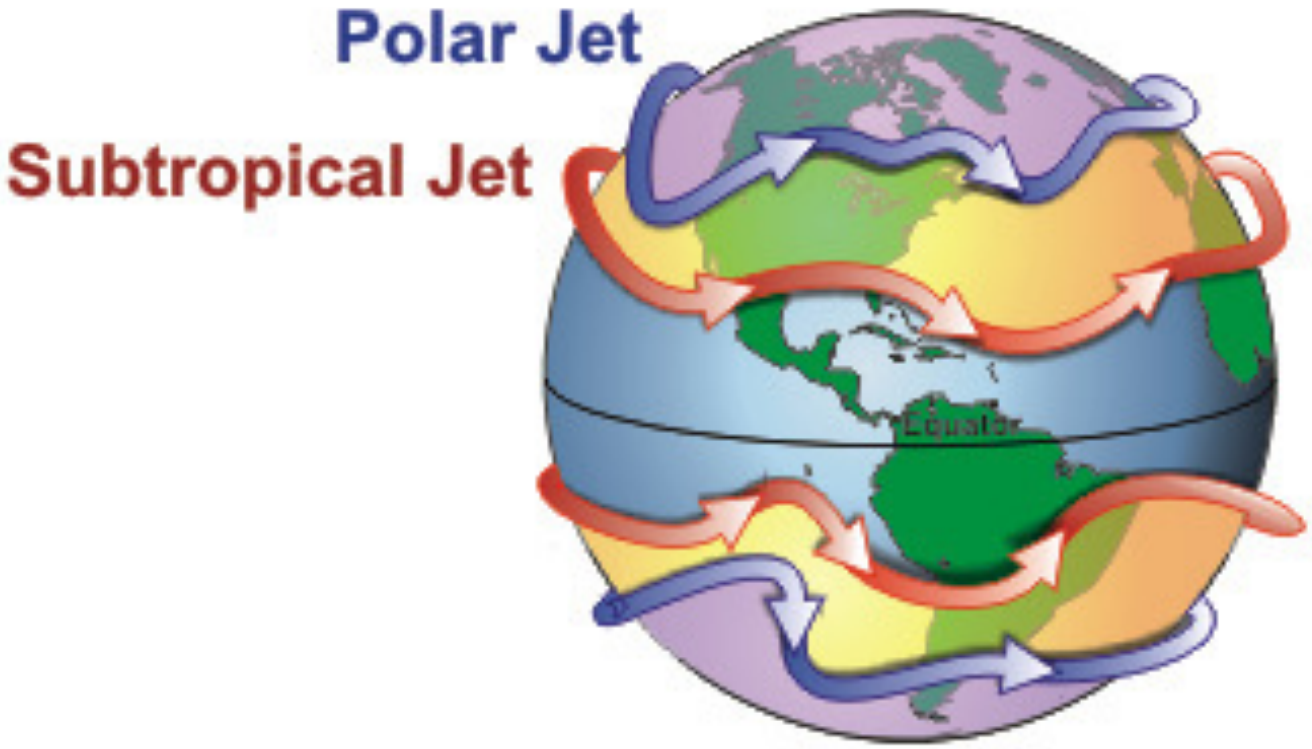
The jet stream: The Earth's weather highway

Albert Osso

Outline

- What is the jet stream?
- The discovery of the jet stream
- How does it form?
- Why does it matter?
- Jet response to increased greenhouse gases
- Conclusions

What is the Jet Stream?



➢ Jet streams are fast-flowing, narrow air currents in the Earth's atmosphere.

Wasaburo Ooishi, Japanese Discoverer (1920s)

Dec2, 1924: measurements at Japan upper air observatory in Tateno (60km from Tokyo)

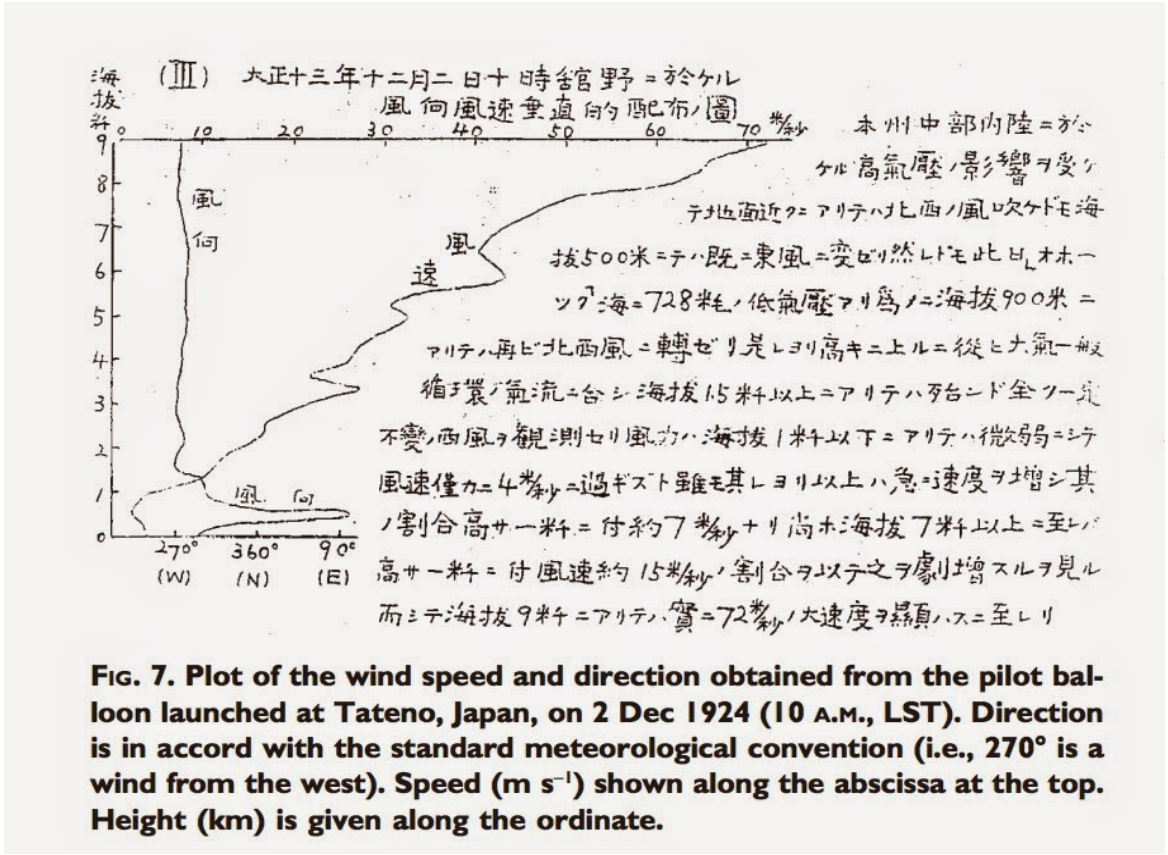
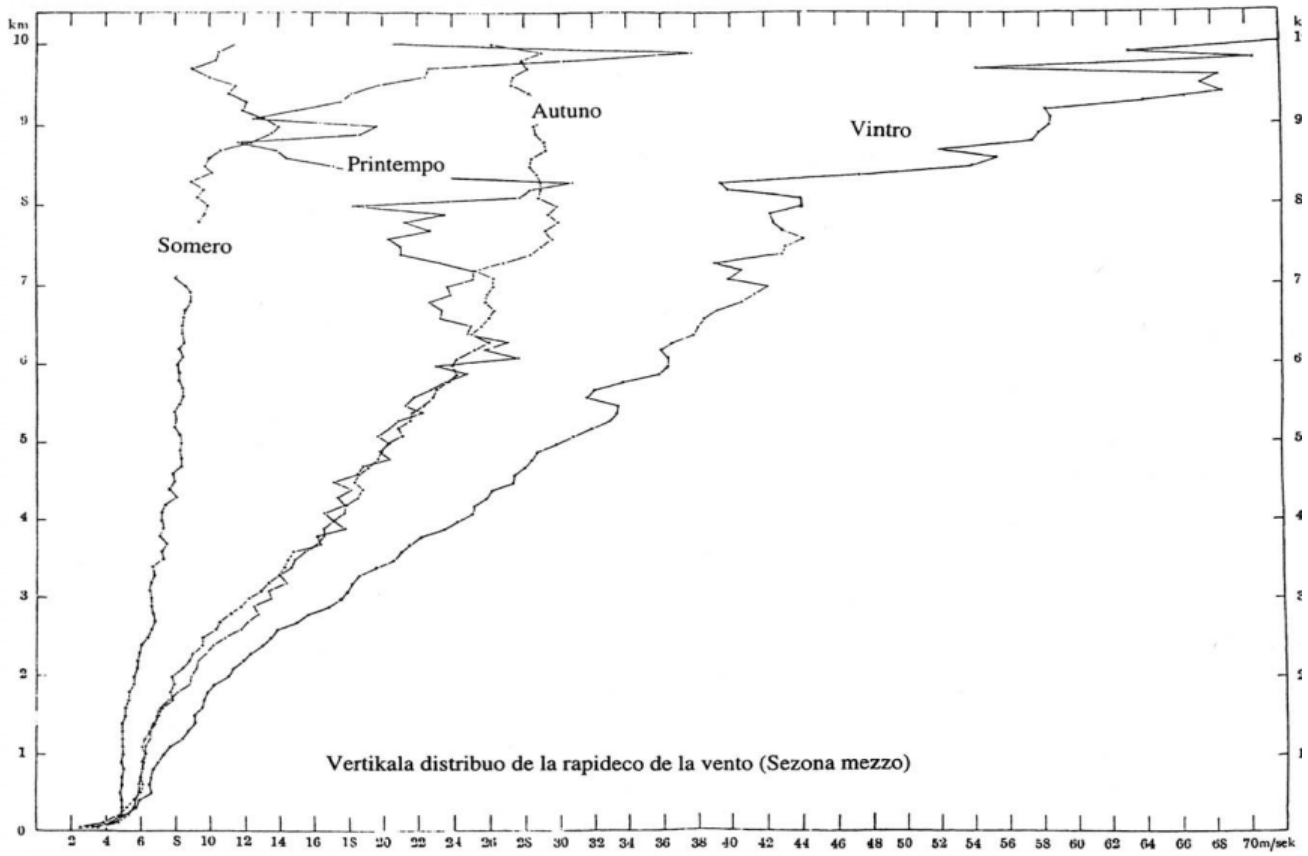


FIG. 7. Plot of the wind speed and direction obtained from the pilot balloon launched at Tateno, Japan, on 2 Dec 1924 (10 A.M., LST). Direction is in accord with the standard meteorological convention (i.e., 270° is a wind from the west). Speed (m s^{-1}) shown along the abscissa at the top. Height (km) is given along the ordinate.

Lewis (2003;BAMS)

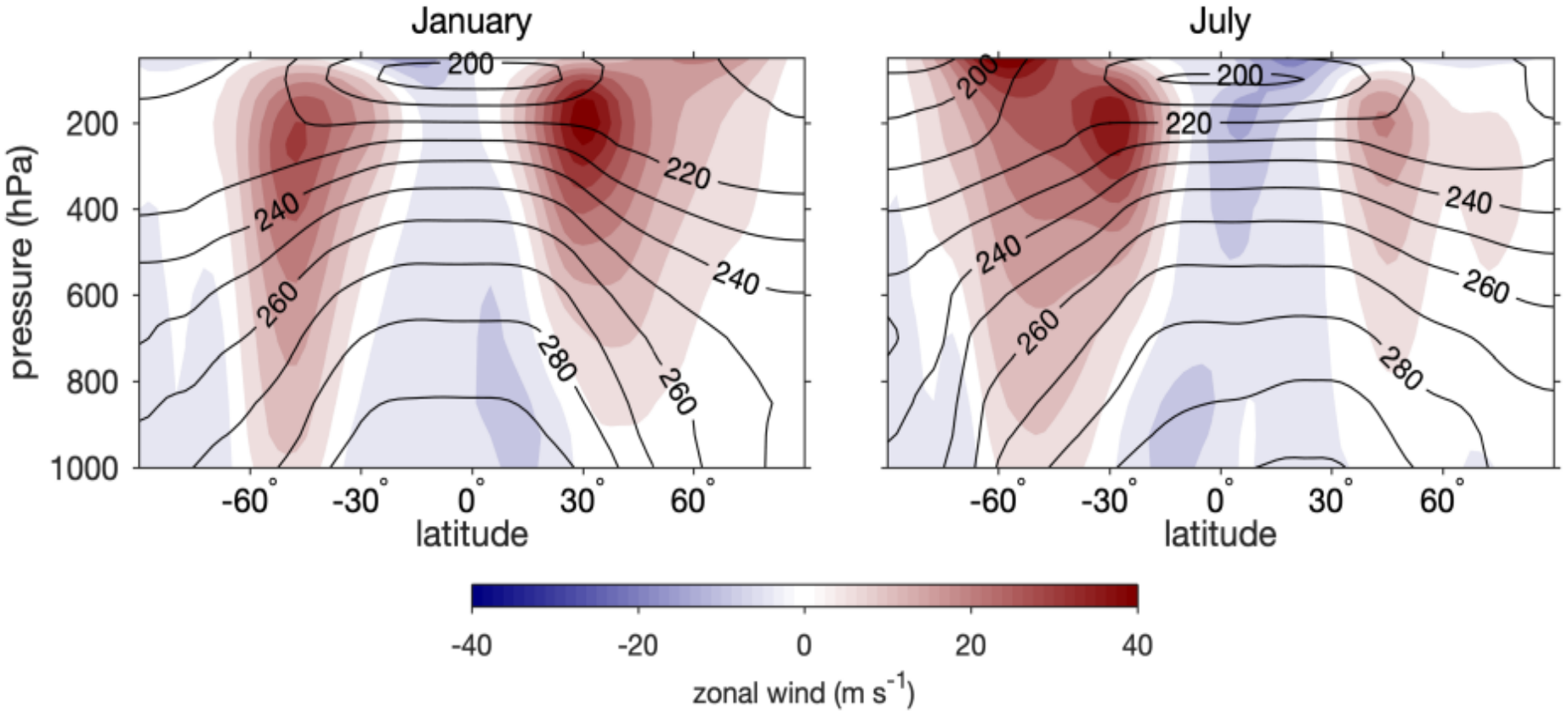
3 years of data (1924-26)



But the paper was largely unnoticed…

Lewis (2003;BAMS)

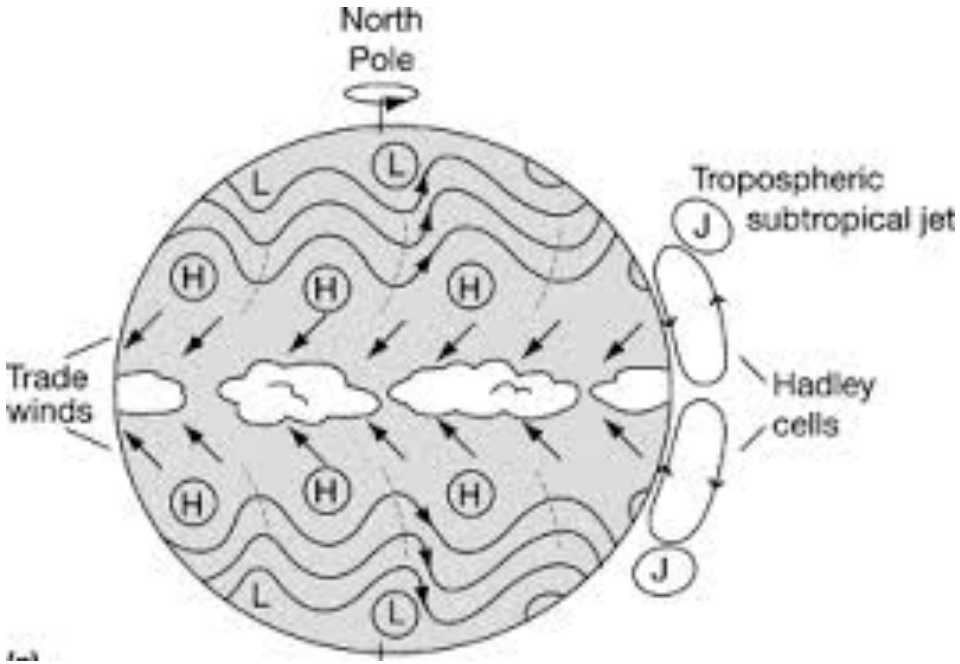
Vertical profiles of the zonal-mean zonal wind



NCEP-DOE reanalysis for the years 1981-2010

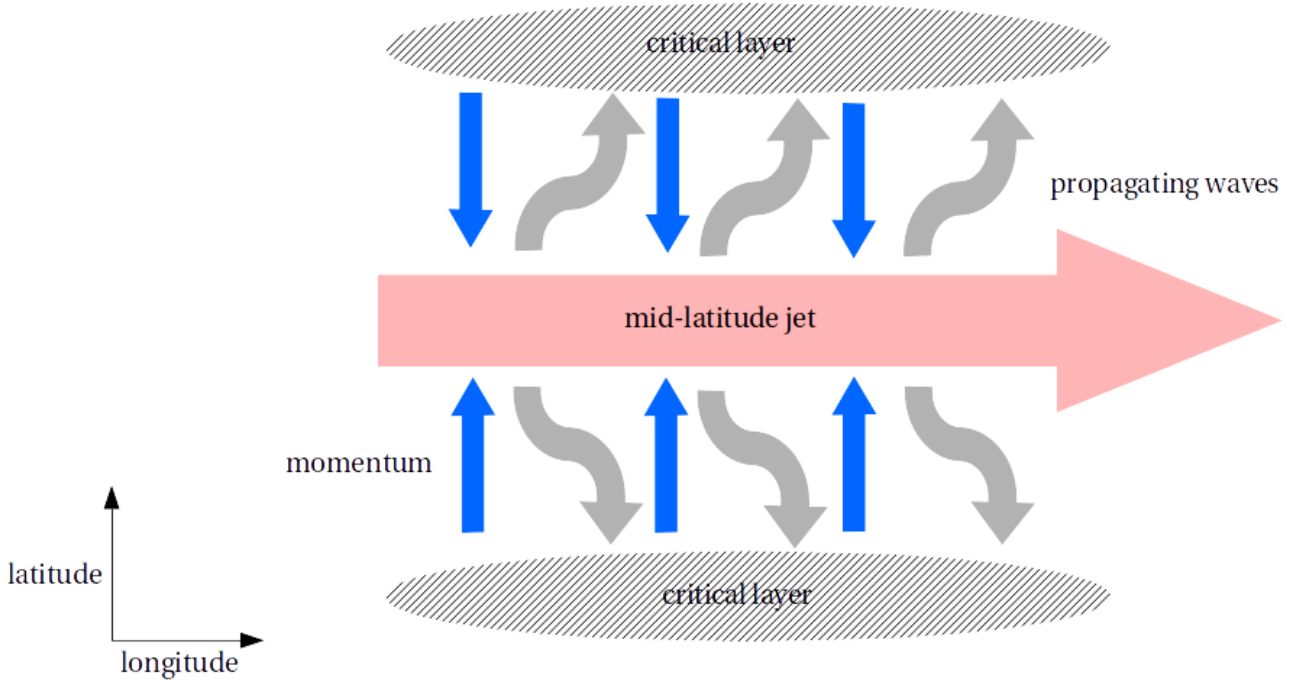
How does it form?

There are two fundamental ingredients: **Planet rotation** and **differential meridional heating**.

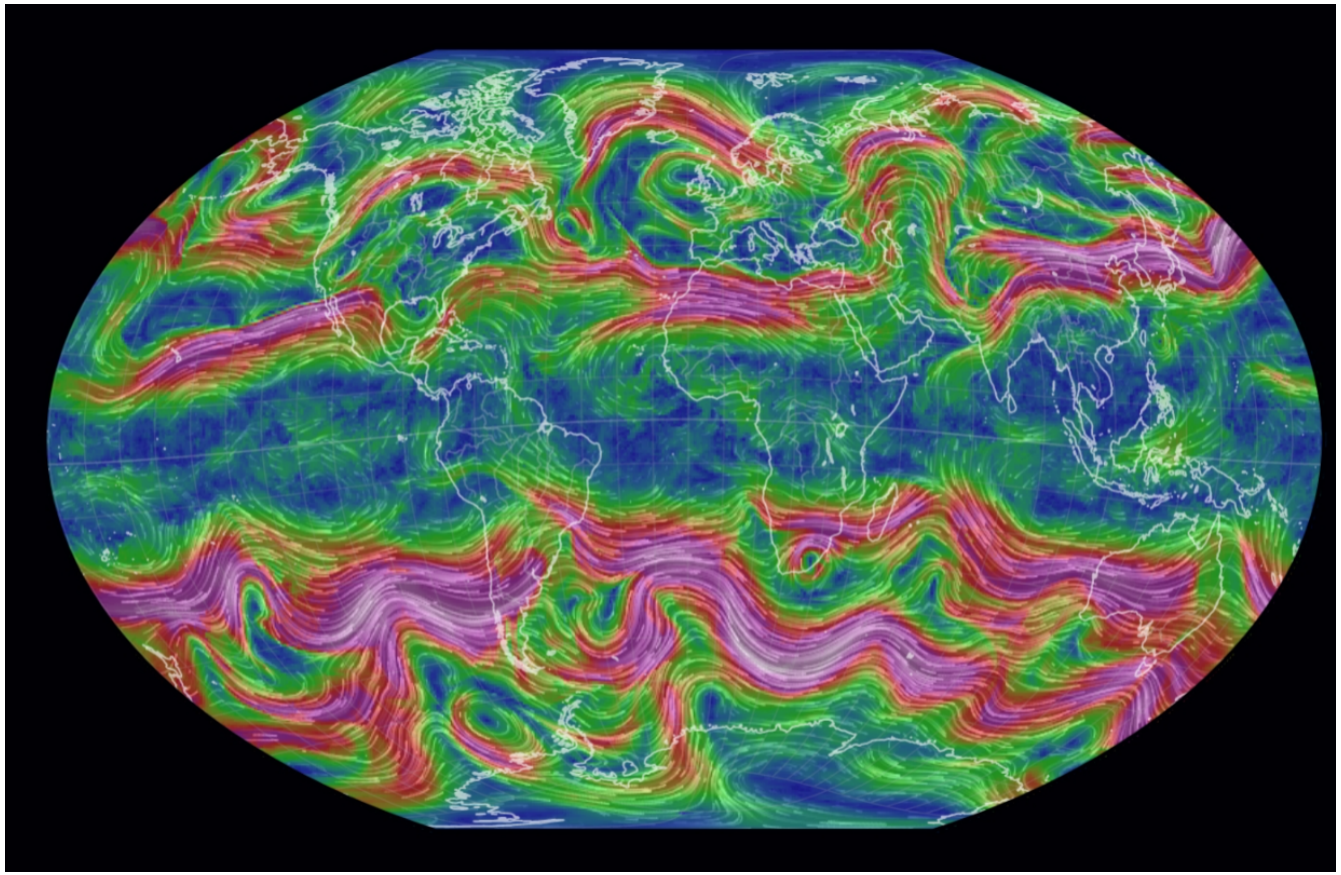


- **Held and Hou, 1980:** The “thermally driven jet” results purely from conservation of angular momentum (in the absence of eddies).

➢ **Panetta, 1992:** The “eddy-driven” results solely due to momentum flux convergence by transient eddies (neglecting advection of angular momentum).



However, in the real world…

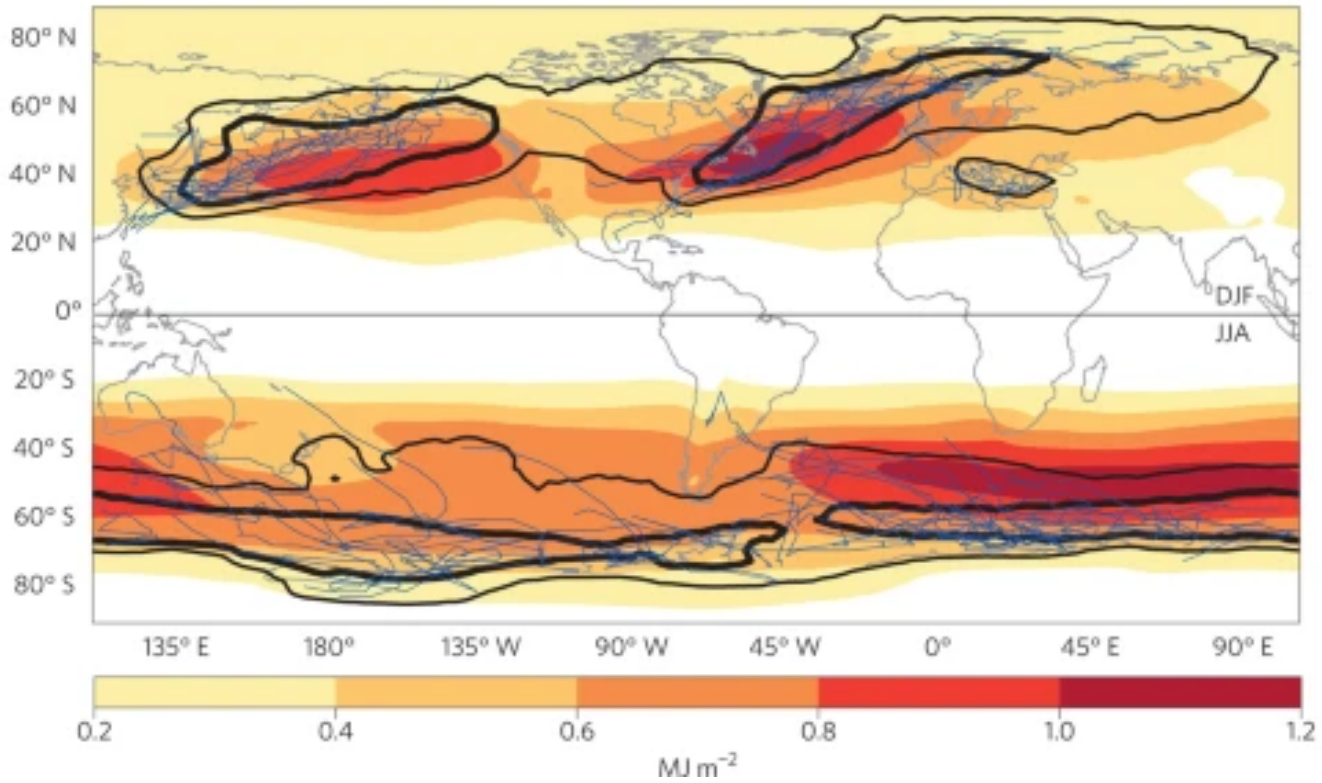


- In reality, the two driving processes interact, and the jets can mutually influence each other. Moreover, in many instances, the jets merge into a single structure.

- Zonal asymmetries such as the distribution of land and ocean, the presence of mountain ranges, tropical convection and east–west midlatitude SST gradients contribute to the formation of distinct regional jet streams.

Why It Matters?

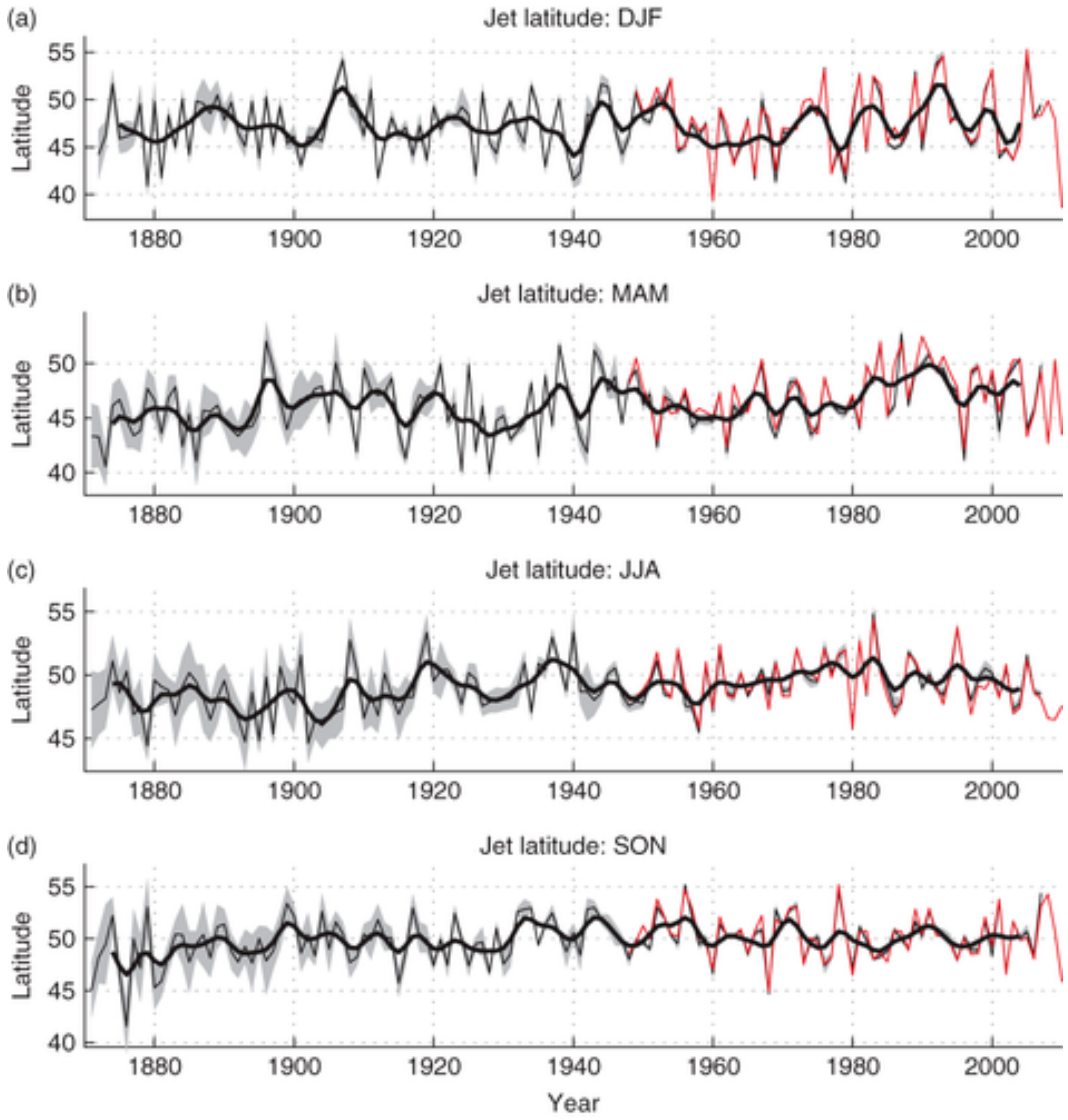
Climatological Cyclone Density



Shaw et al. 2016

- The jet stream acts like a weather highway. At the midlatitudes, the jet stream guides storms towards the west coasts of the continents via relatively narrow paths over the oceans called storm tracks, which **strongly determine the regional hydroclimate and storminess.**

Jet stream temporal variability

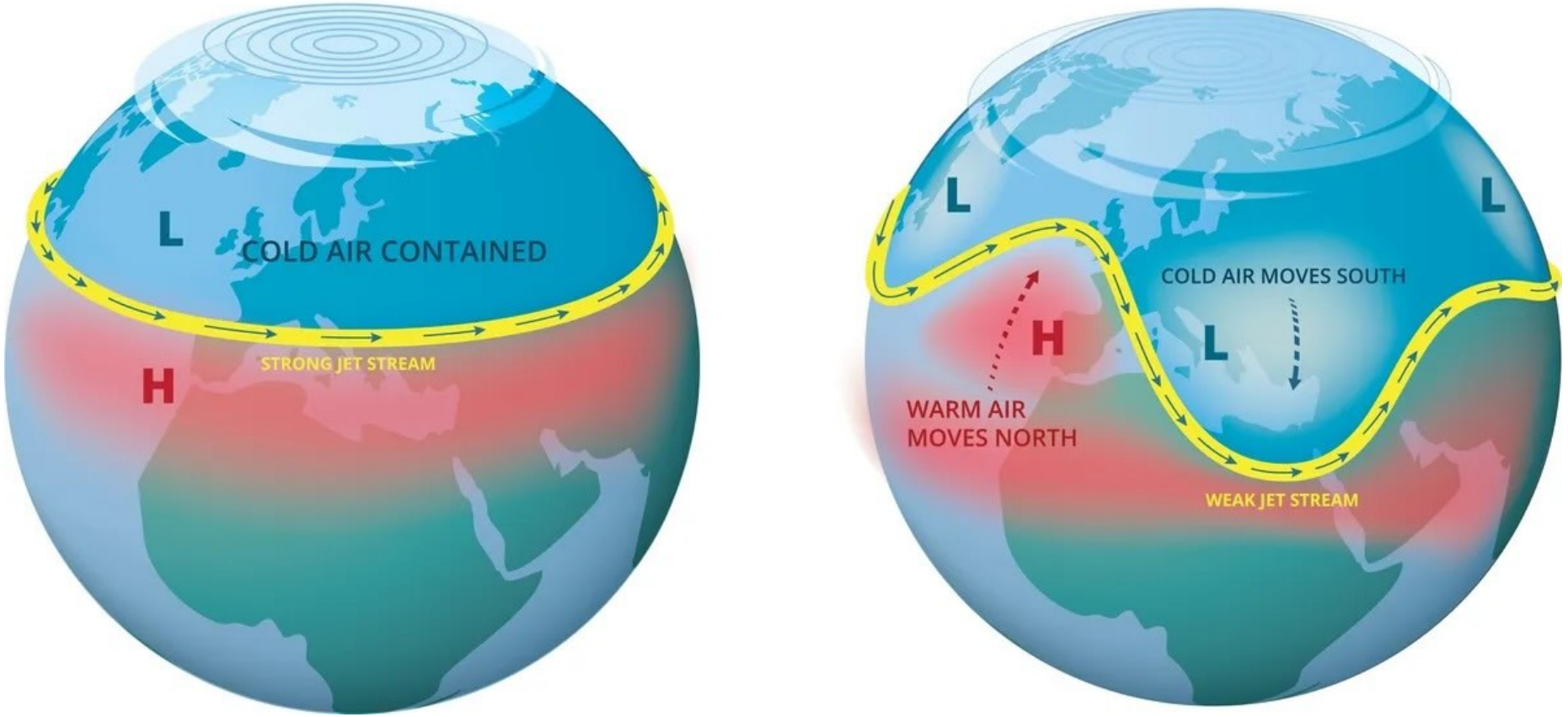


- Observational and modelling evidence shows that the position and intensity of the jet streams vary on timescales ranging from days to centuries, accounting for a large fraction of the regional climate variability in the extratropics.

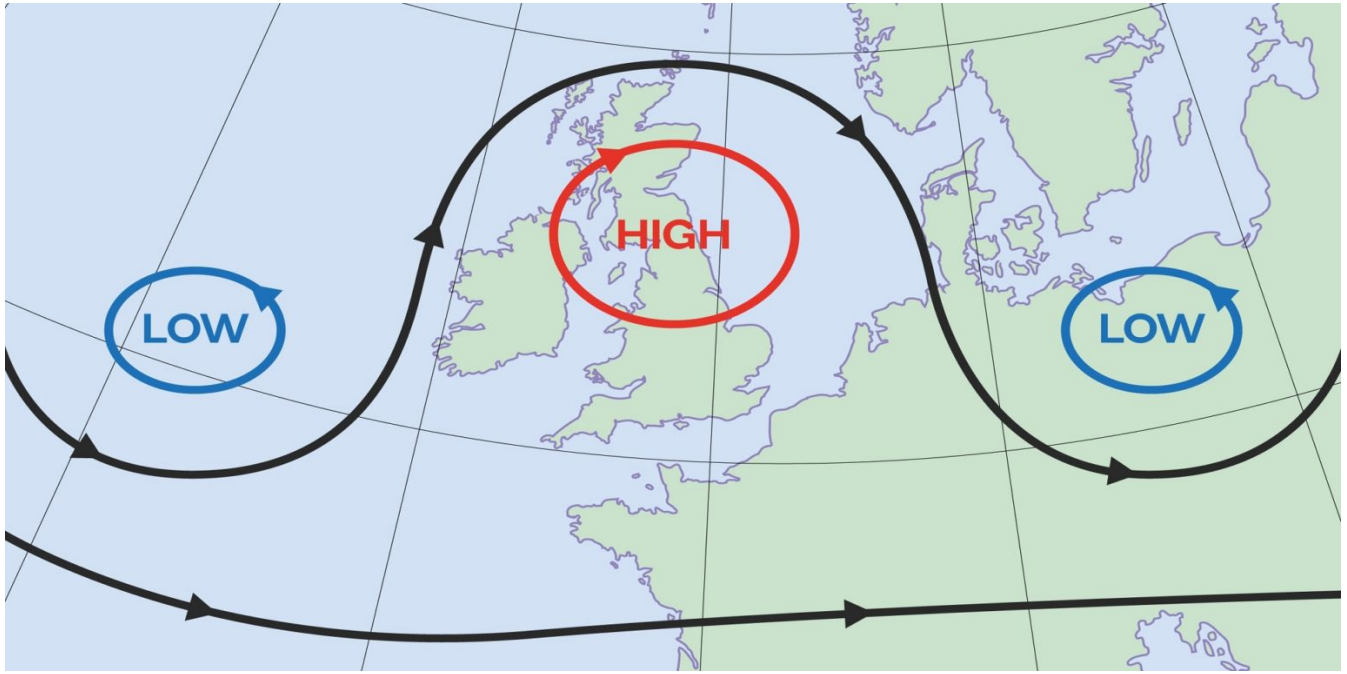
Woollings et al. 2013

Extreme events: Heatwaves & Floods

➢ A wavy jet can ‘lock’ weather in place.

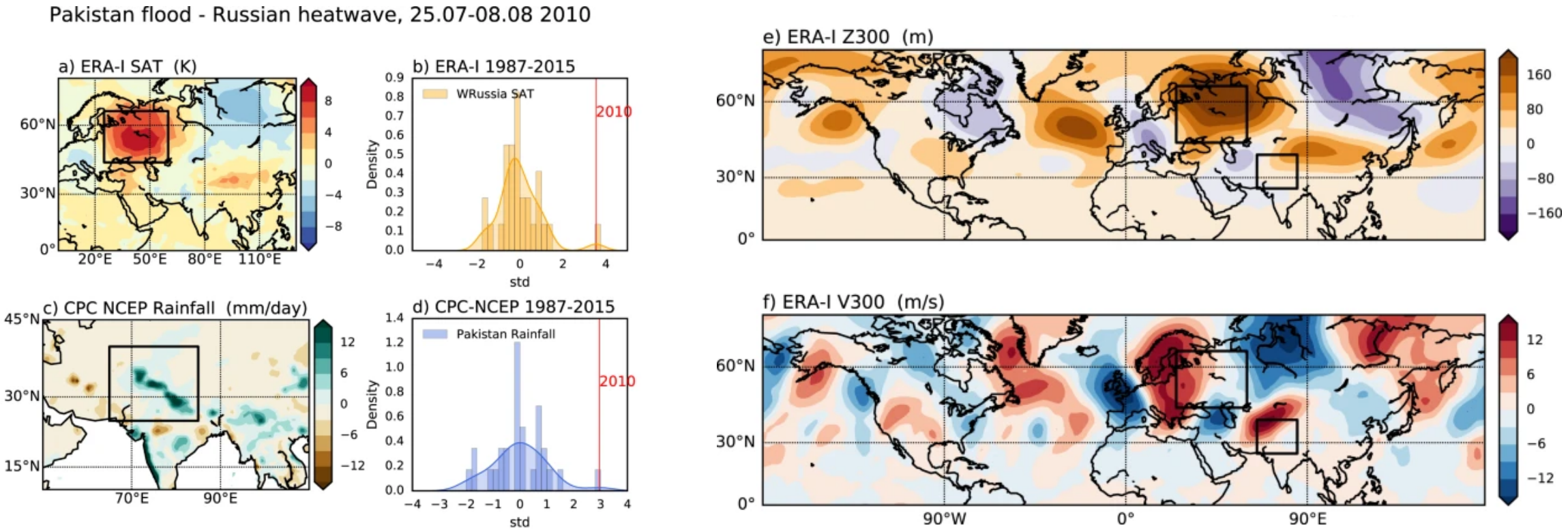


Omega Block



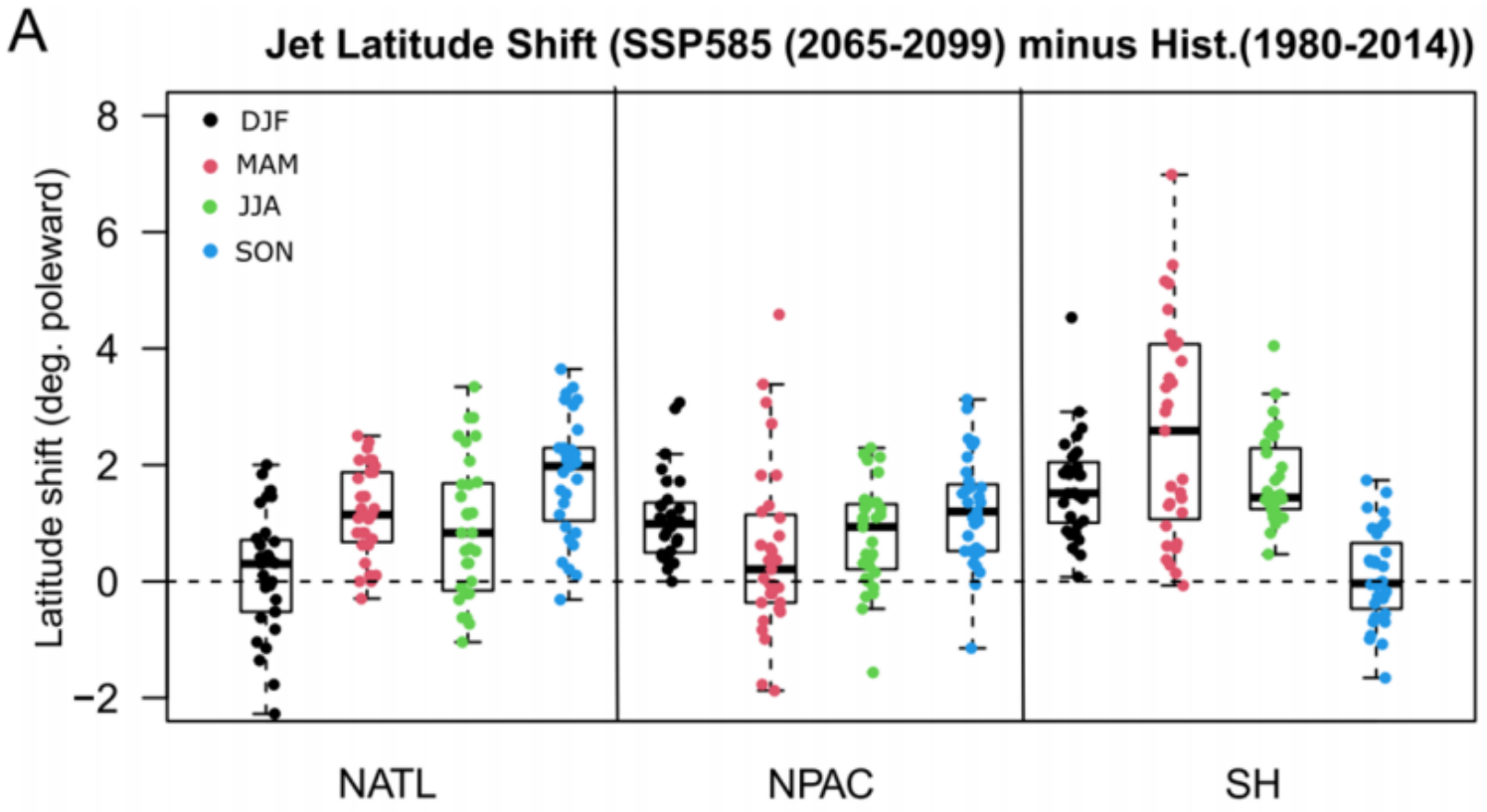
2010 summer

➢ In summer 2010, a strongly meandering jet stream connected two simultaneous extreme weather events, the Russian heatwave, and the Pakistan flood, leading to severe societal impacts.



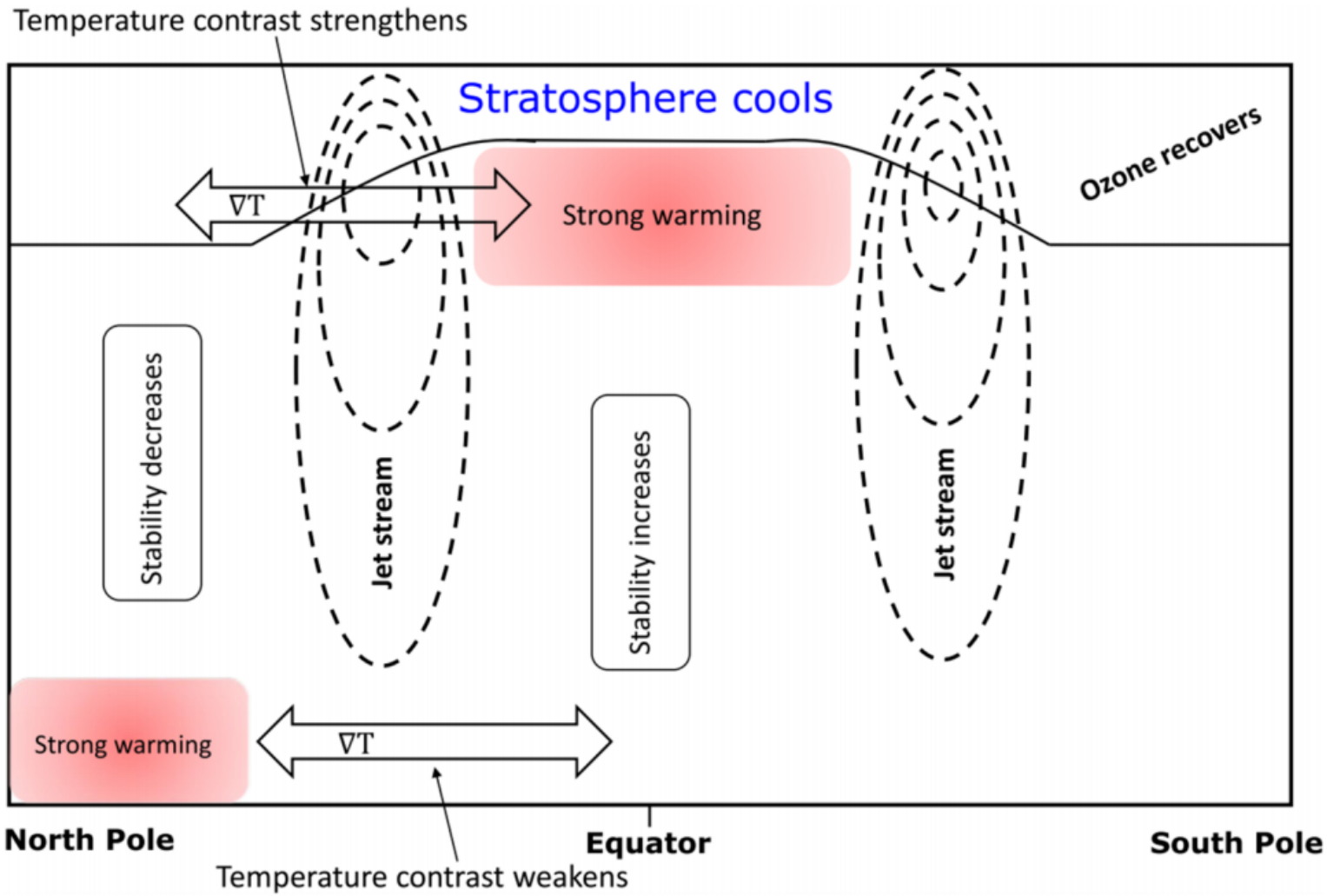
Di Capua et al., 2021

Jet response to increased greenhouse gases

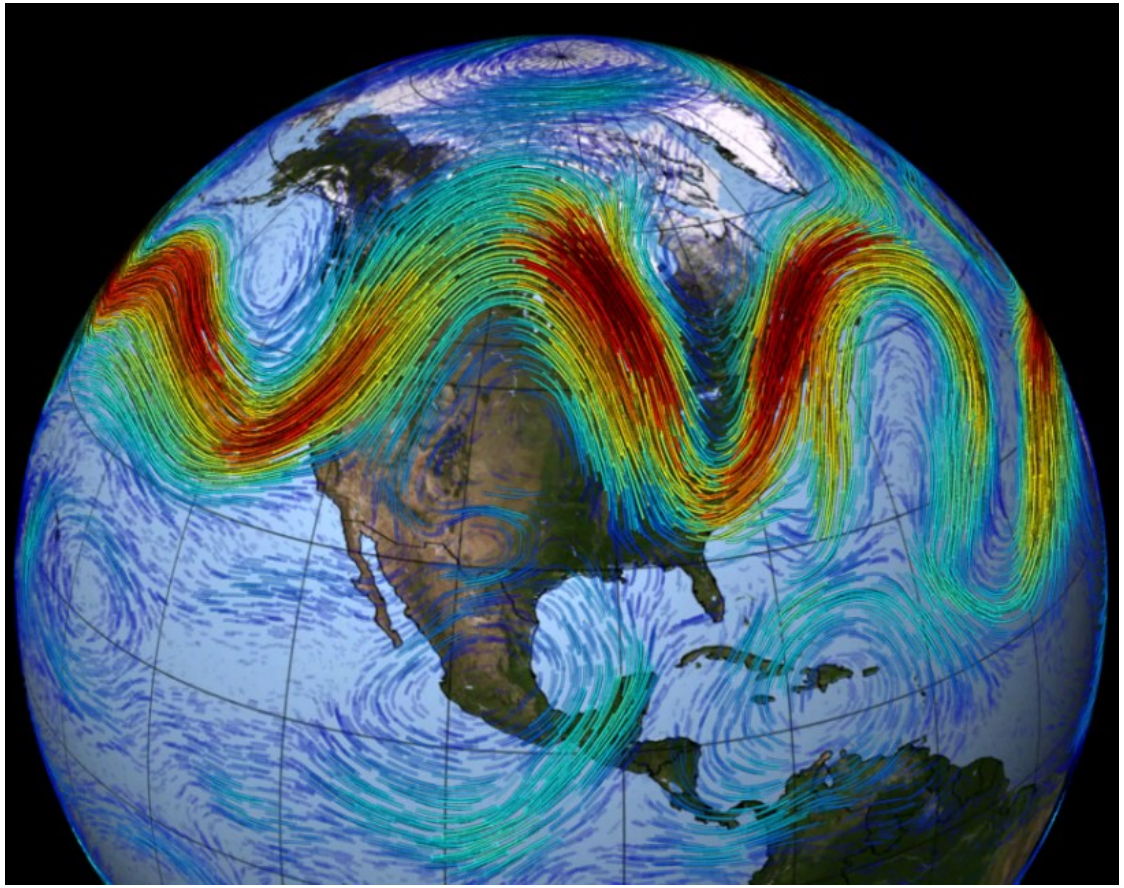


Ossó et al., 2024

Mechanisms mediating the mean jet response to increasing GHG concentrations



Changes in the jet variability: A more wavy or persistent jet?



- Several studies have suggested that the NH eddy-driven jet has become “wavier” and associated weather patterns have become more persistent in recent decades.

- However, the mechanims linking global warming and jet waviness are unclear, and modelling evidence has conflicting results.

Concluding remarks

We have made significant progress

- Thanks to improved observations from satellites, radiosondes, and other sources, as well as the use of increasingly powerful numerical models, we have gained an unprecedented understanding of the jet stream phenomena.

- The overall response of the jet stream to climate change is beginning to emerge from the background of internal variability. Yet, many regional aspects of this response remain highly uncertain.

- Models robustly project an overall poleward shift of the zonally-averaged upper and low-level zonal winds in response to rising concentrations of GHGs. However, these shifts vary significantly depending on the region and season.

We still have a lot to learn

- There is a significant spread in projected jet changes, not only in terms of the magnitude but even the sign.

- Recent evidence suggests that models underestimate the jet stream response to anthropogenic forcing during the historical period, raising the possibility that the future jet response is also underestimated.

- Crucially, there is no consensus on the relative importance of the physical mechanisms driving the jet's forced response, nor is there a complete understanding of the mechanisms themselves. Both limitations make it difficult to develop constraints to reduce the uncertainties in the jet projections.

What are we doing at the WEGC and elsewhere?

- We are developing new conceptual and numerical models to improve our understanding of the jet stream variability and its response to climate change.
- We are developing new tracking algorithms and standardising output to ensure the comparability of results across studies.
- We work with impact modellers to provide better and more reliable regional projections.

Better understanding = better preparation.

Hopefully…

Questions?