Earth Sciences Department

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Forecast Briefing

April 2025

Climate Services Team (CST)

Earth System Services (ESS)

Barcelona Supercomputing Center (BSC)

Tuesday 22nd Apr 2025

Outline

I. Recent state of the climate

II. Seasonal forecasts

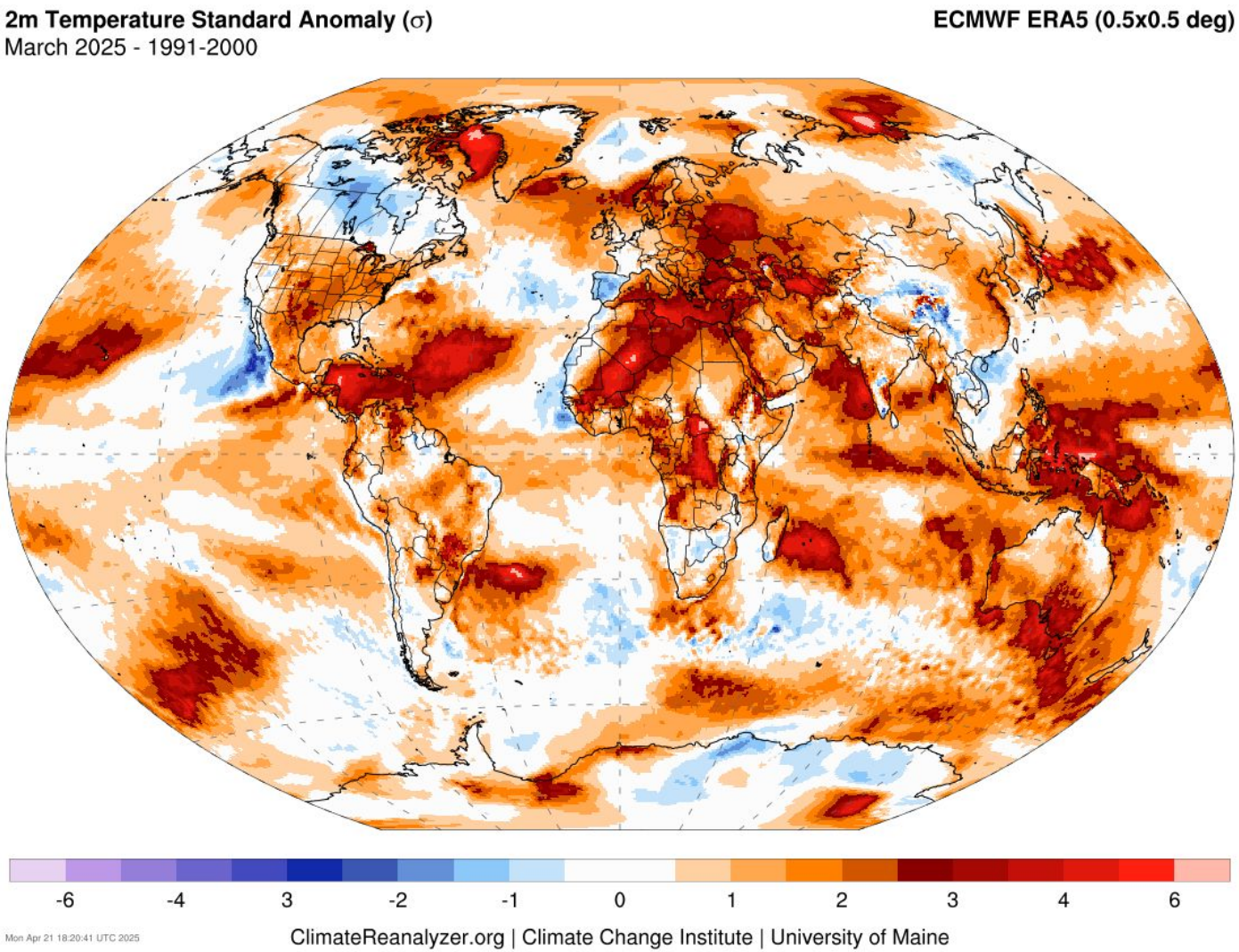
III. Intra-seasonal forecasts

IV. Discussion

I. Recent state of the climate

I. Recent state of the climate

Temperature



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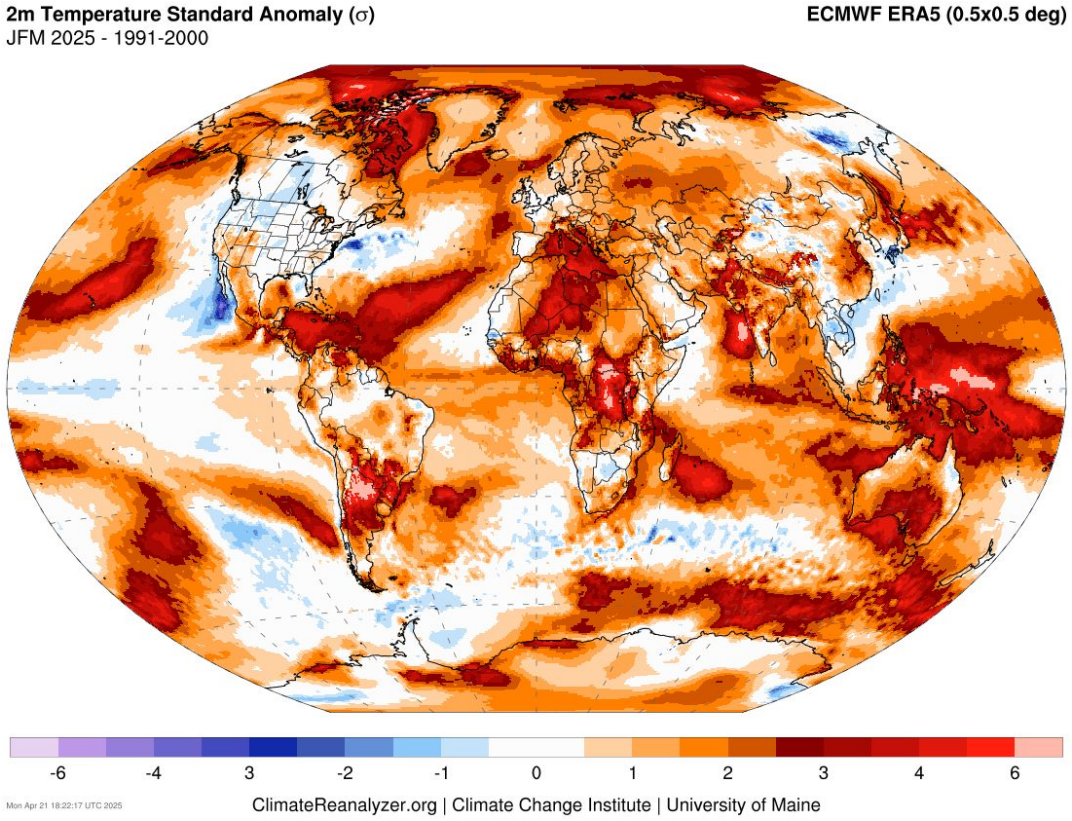
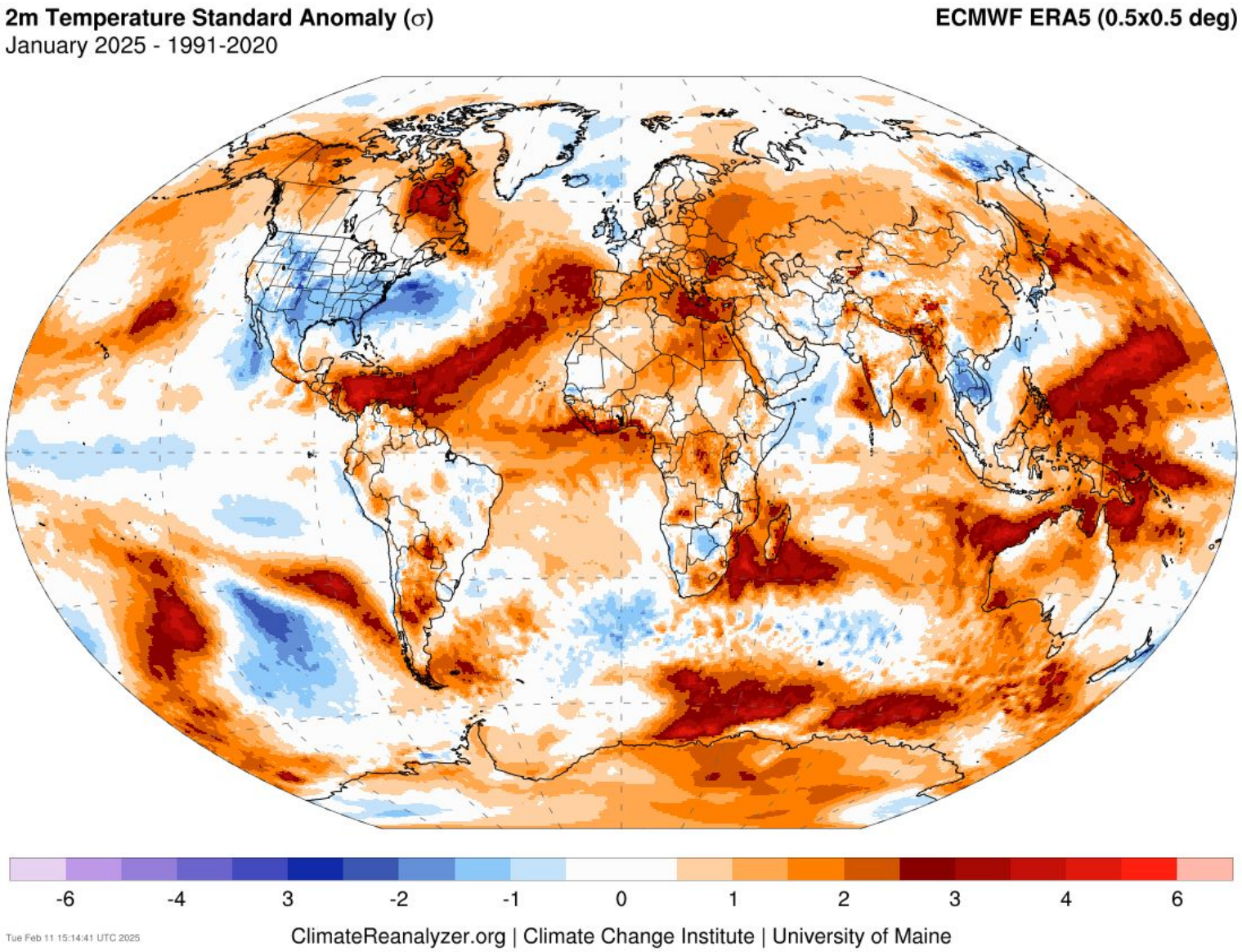
- March's signal has similarities to JFM but the anomalies are smaller at multiple regions:
  - The Arctic ocean, central Canada, Alaska, Argentina, Antarctic ocean and Antarctica, Iberian peninsula, western Russia, Australia
- There are some regions where the anomalies are higher for March than for JFM such as some parts of the USA and the coast of Chile.



Source: https://climatereanalyzer.org/research_tools/monthly_maps/



- The standardized anomaly gives a measure of how large an anomaly is compared to the climatological (i.e. typical) variability. It is measured in number of ***σ*** (i.e. number of standard deviations)

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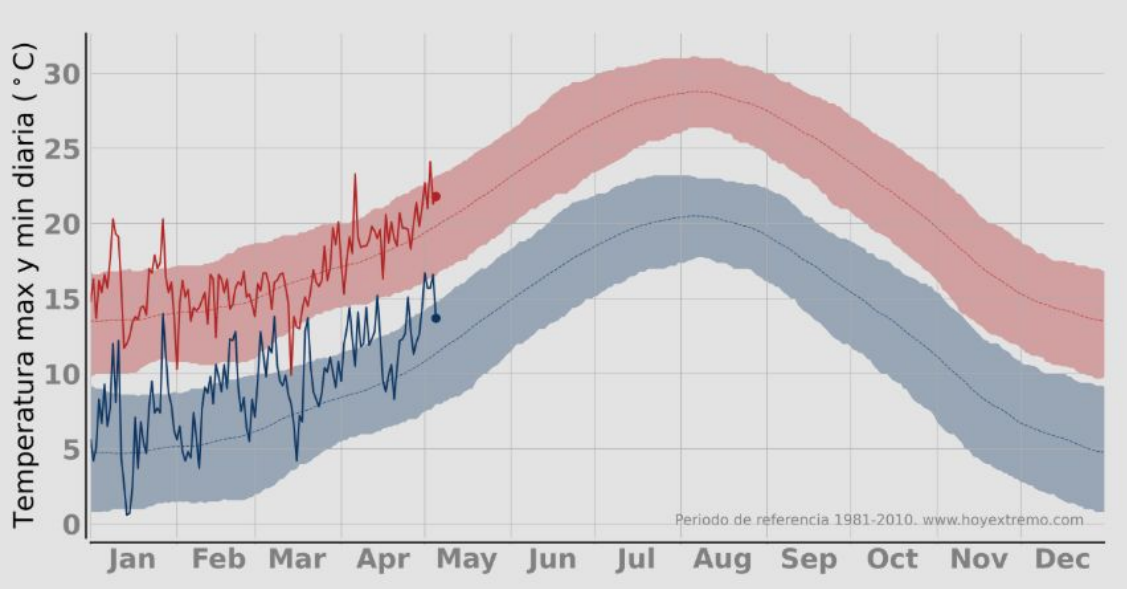
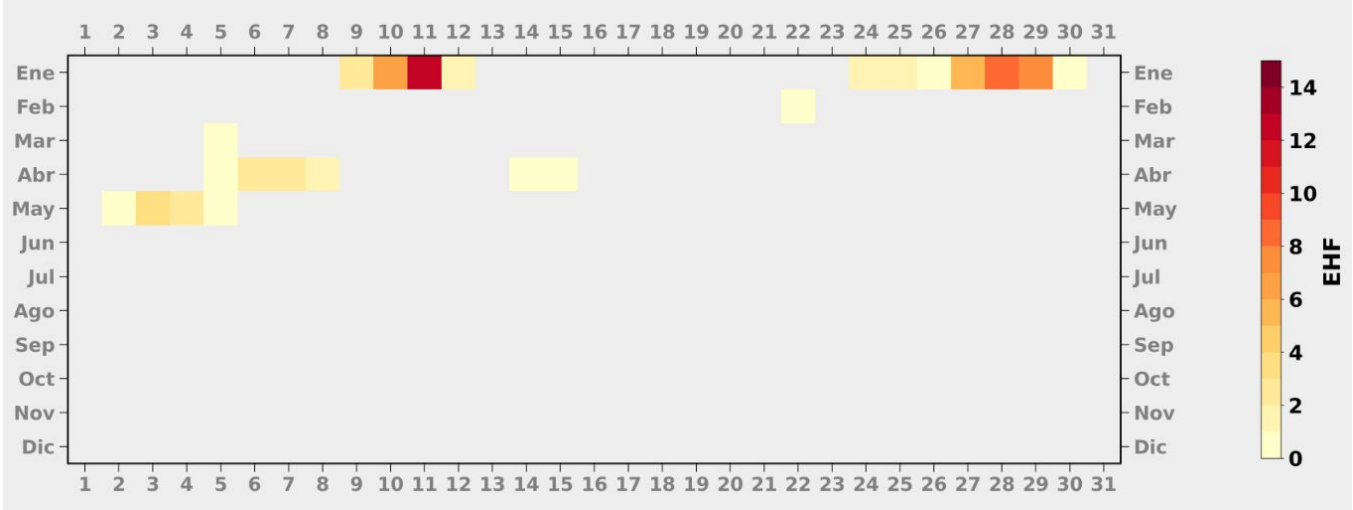
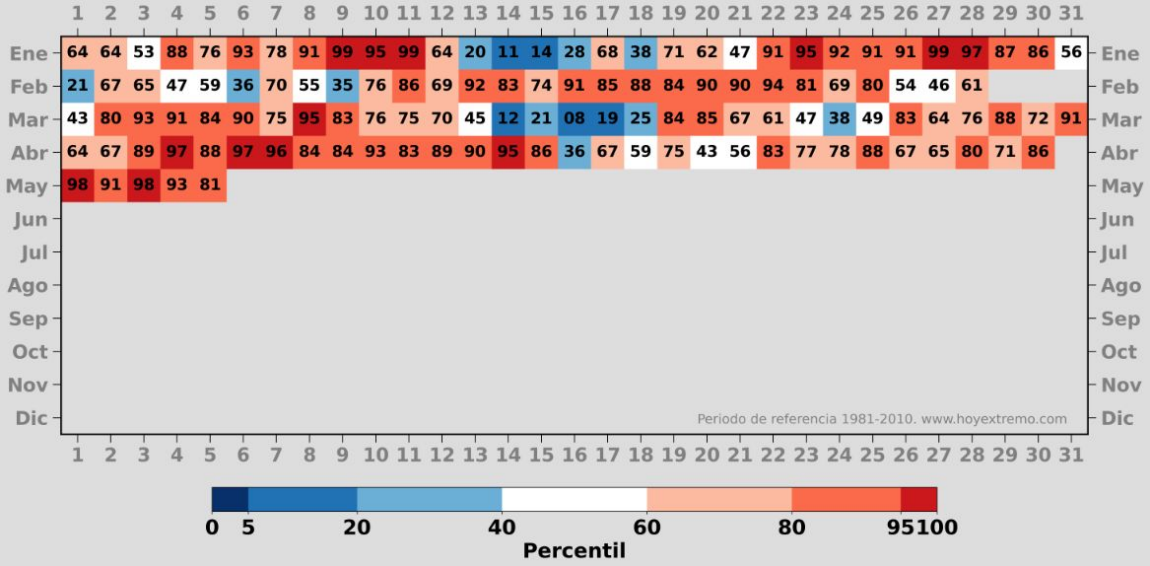
Source: https://climatereanalyzer.org/research_tools/monthly_maps/

I. Recent state of the climate

Barcelona







➢ **Excess Heat Factor (EHF)**: Temperature-based index that allows to monitor the extension, duration and intensity of a heat wave.

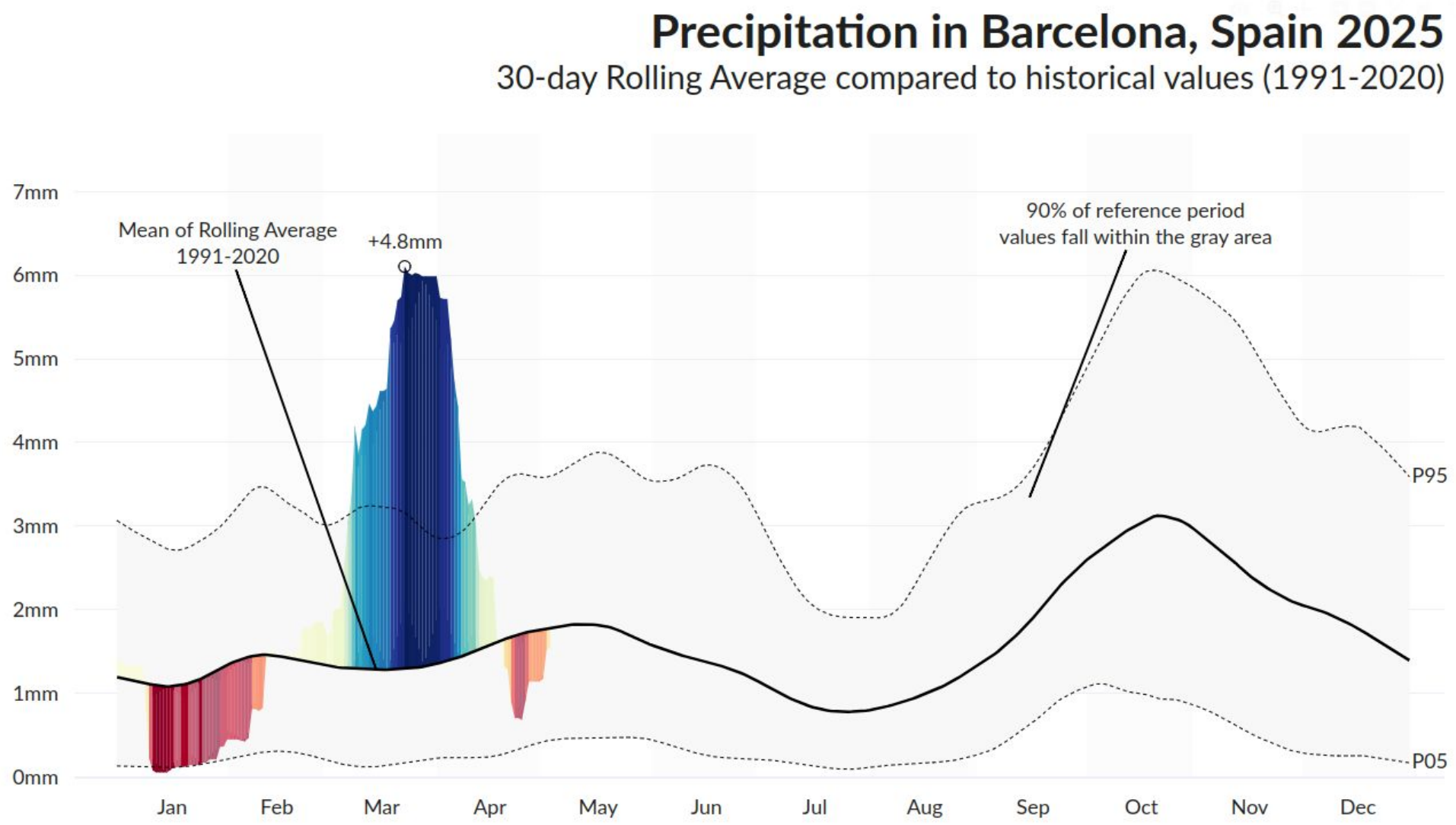
$$EHI_{\text{sig}} = (T_i + T_{i+1} + T_{i+2})/3 - T_{95}$$

$$EHI_{\text{accl}} = (T_i + T_{i+1} + T_{i+2})/3 - (T_{i-1} + \ \ldots \ + T_{i-30})/30$$

$$EHF = EHI_{\text{sig}} \times \max(1,\ EHI_{\text{accl}})$$

Source: https://hoyextremo.com/city_pages/barcelona/#summary

Barcelona



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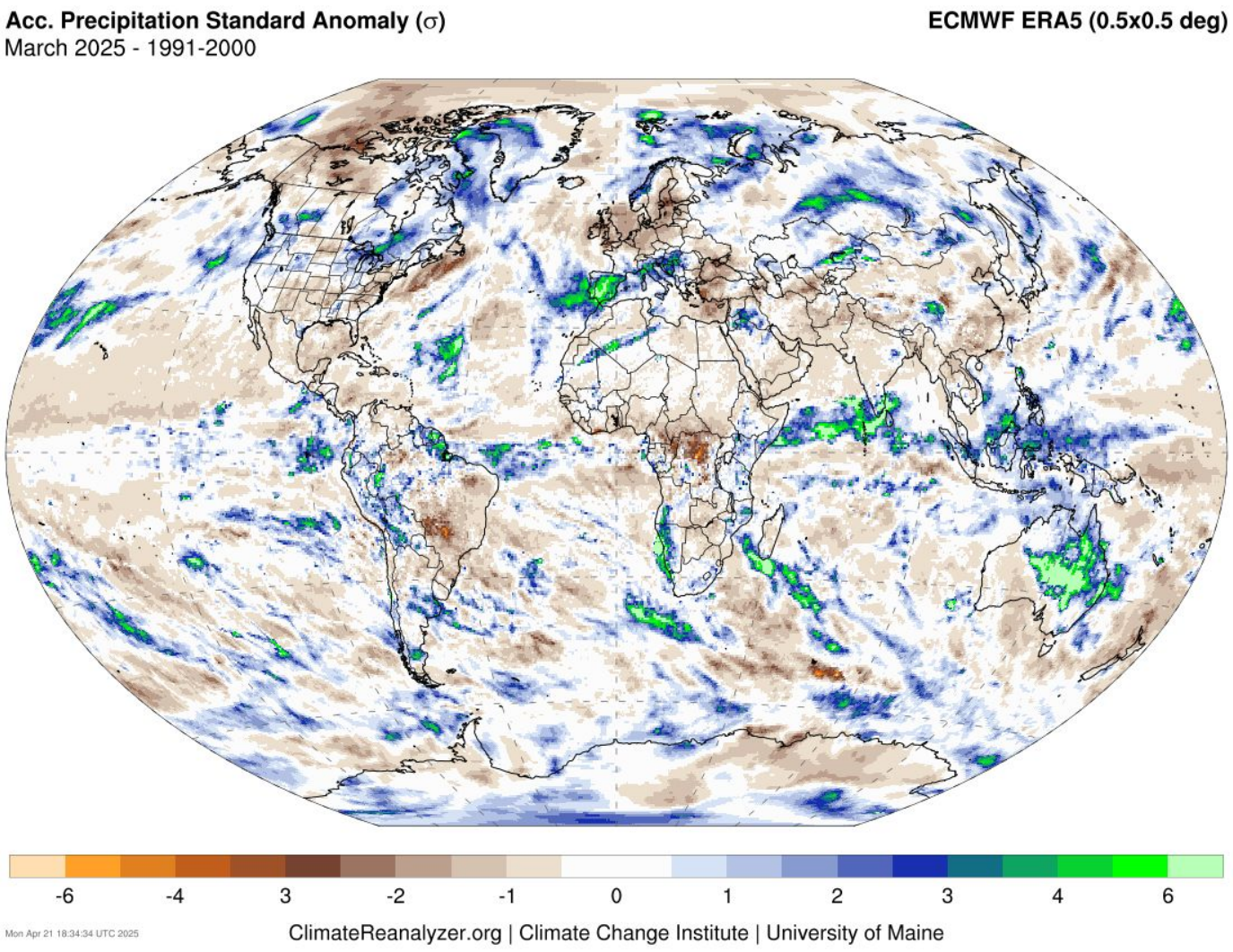
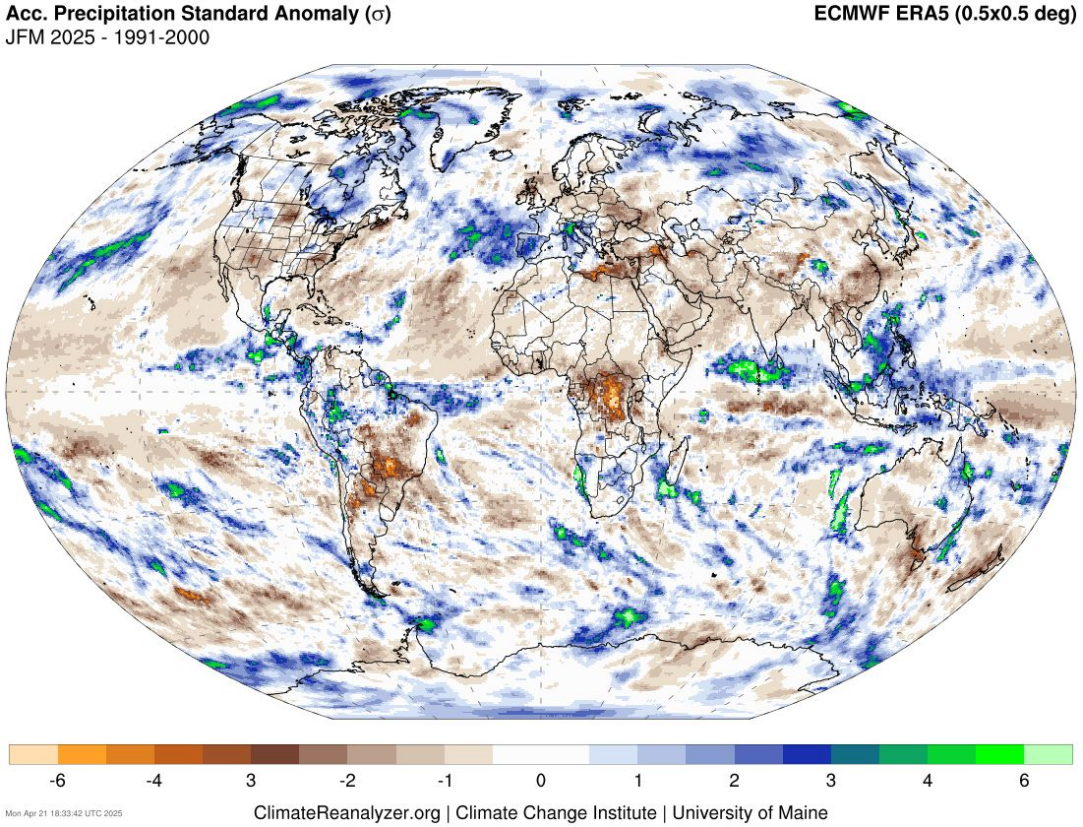
Source: https://yotka.org/meteo-hist

I. Recent state of the climate

Precipitation



- High precipitation over some points of the Atlantic, the Iberian peninsula, parts of the ITCZ (Indic ocean, Indonesia, Guyanas), southern Africa and Madagascar, Australia, some regions of Russia.
- Dryness over East coast of the USA, central Europe, southern Brazil, Congo and western Turkey.



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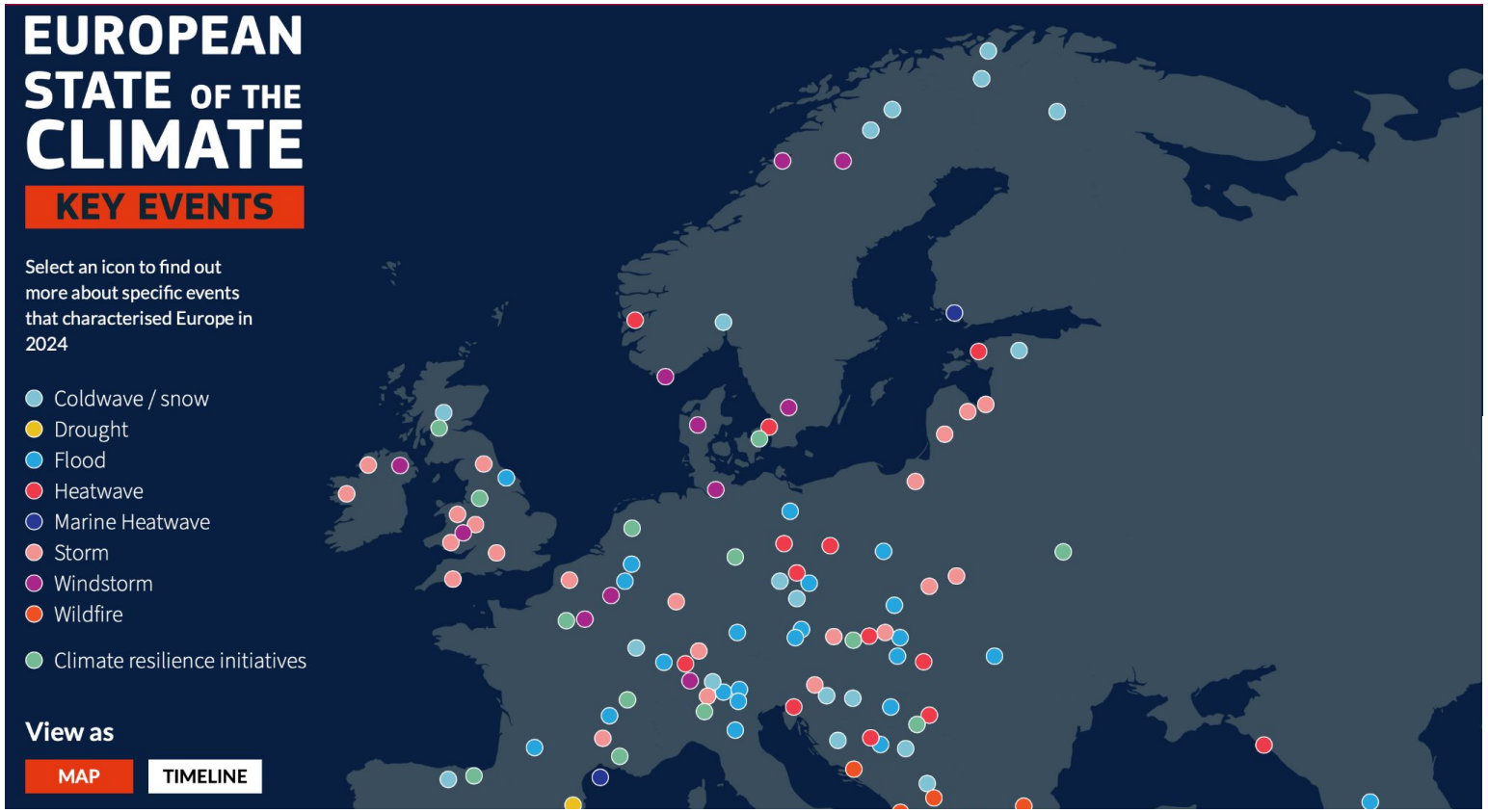
Source: https://climatereanalyzer.org/research_tools/monthly_maps/

I. Recent state of the climate

ESOTC



Source: https://climate.copernicus.eu/esotc/2024/key-events

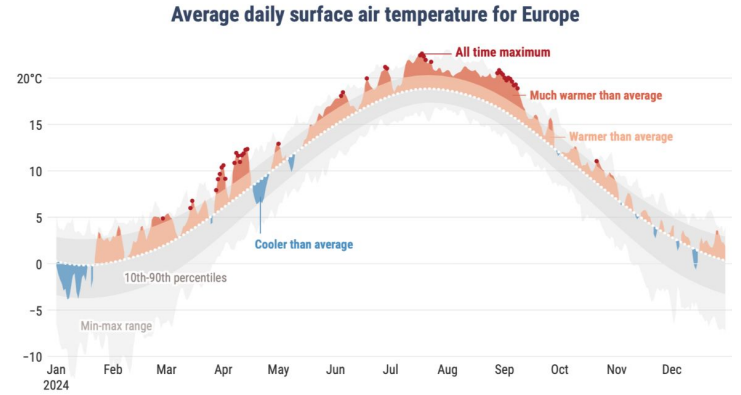


Figure 3.2. Average daily surface air temperature (°C) for European (as defined by C3S) land for 2024, showing warmer-than-average (orange shading), much-warmer-than-average (red shading) and all-time maximum (red dots) temperatures, and cooler-than-average (blue shading) temperatures, alongside the 10th and 90th percentiles (outside of which temperatures are considered to be much below/much above average) (grey shading) of the daily surface air temperature for 1991–2020 and the average (median, dashed line). Data: E-OBS. Credit: C3S/ECMWF/KNMI.

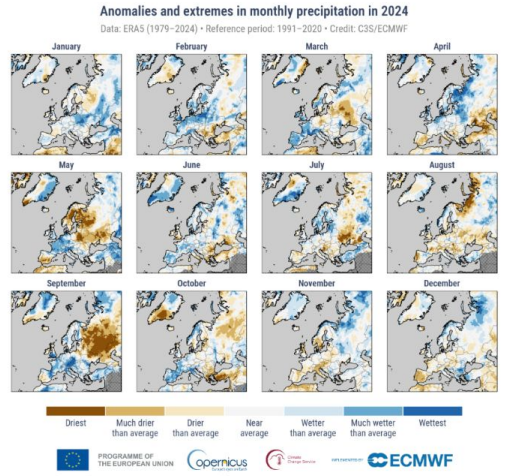
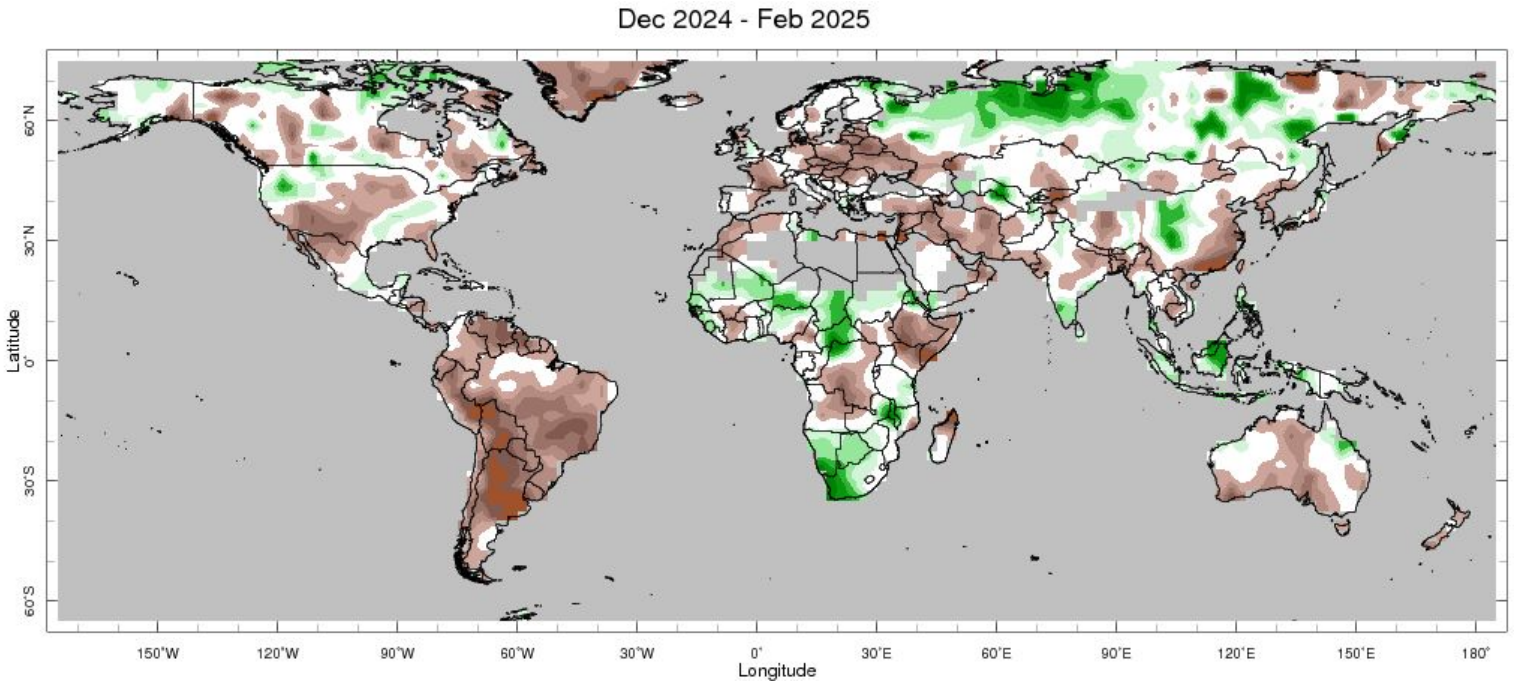


Figure 7.2a. Anomalies and extremes in monthly precipitation in 2024. The extreme categories ('wettest and 'driest) are based on rankings for 1979–2024. The other categories describe how precipitation compares to the distribution during the 1991–2020 reference period. 'Much wetter/drier than average' - wetter/drier than 90% of precipitation values. 'Wetter/drier than average' - than 66% of precipitation values. 'Near average' - within the middle 33%. Data: ERA5. Credit: C3S/ECMWF.

Standardized Precipitation index (SPI)

SPI-3



Grey = Regions with an annual average precipitation of less than 0.2 mm/day have been "masked" from the plot.

Other information: 2.5º lat/lon grid, 1979-present climatological base period

➢ SPI

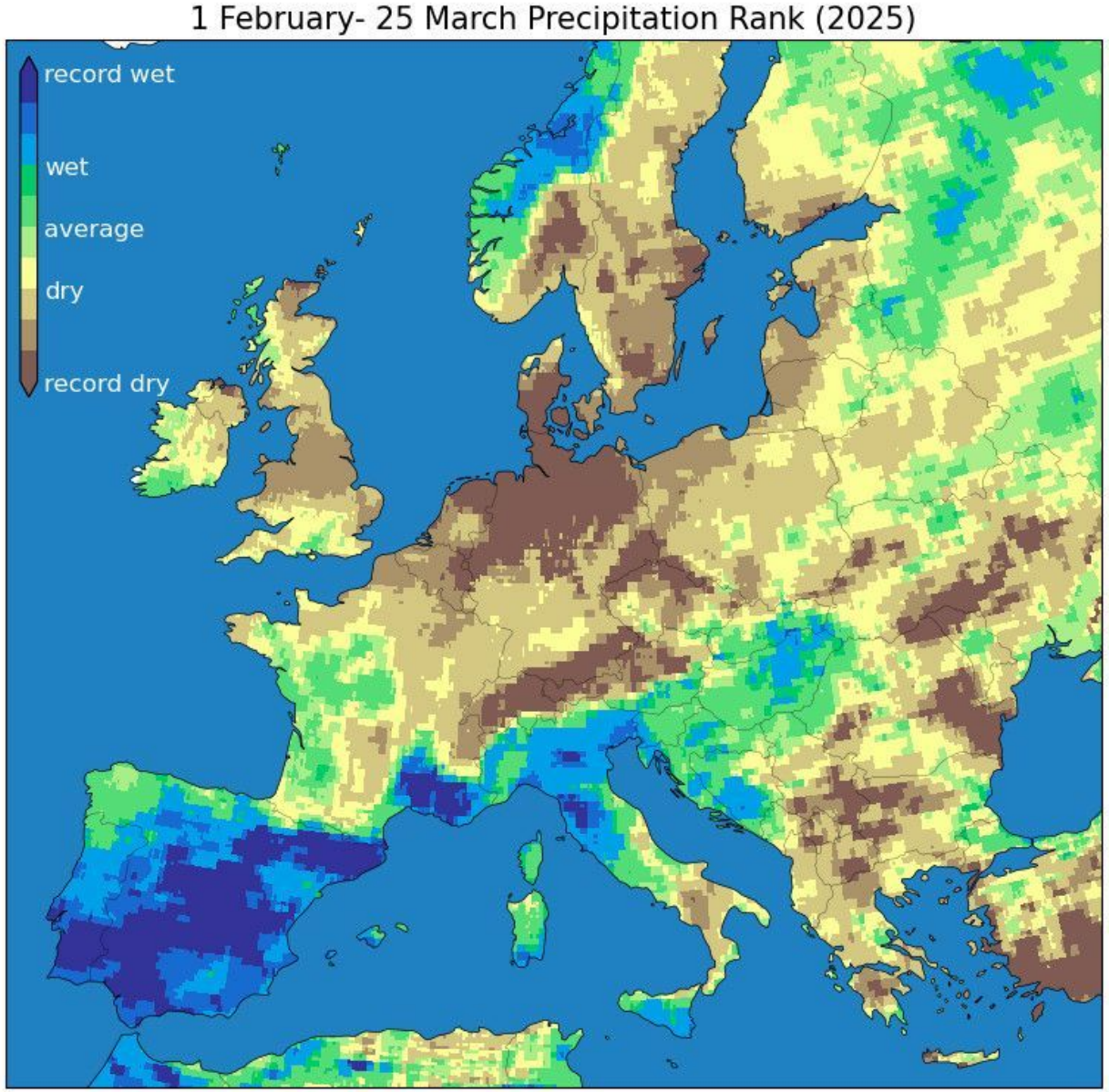
The Standardized Precipitation Index (SPI; McKee 1993) is the number of standard deviations that observed cumulative precipitation (over x number of months) deviates from the climatological average.

- SPI-x:
  Cumulative distribution over x-months.
- Shorter SPI values (SPI-1, SPI-3):
  Respond quickly to rainfall changes, useful for early warning systems.
- Longer SPI values (SPI-6, SPI-12, SPI-24):
  Reflect cumulative precipitation trends, useful for long-term water resource management.

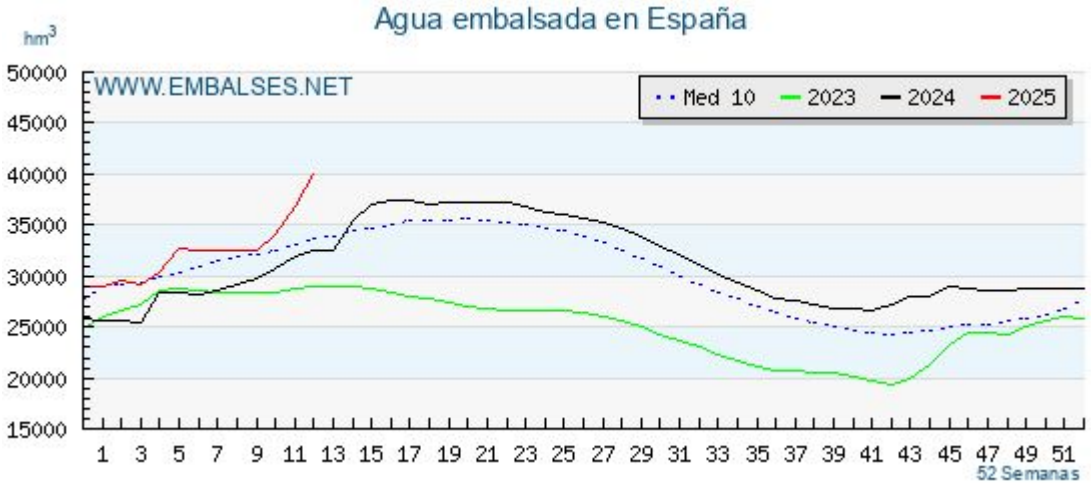
Source: https://iridl.ldeo.columbia.edu/maproom/Global/Precipitation/SPI.html?var=.SPI-CAMSOPI_3-Month

I. Recent state of the climate

Precipitation



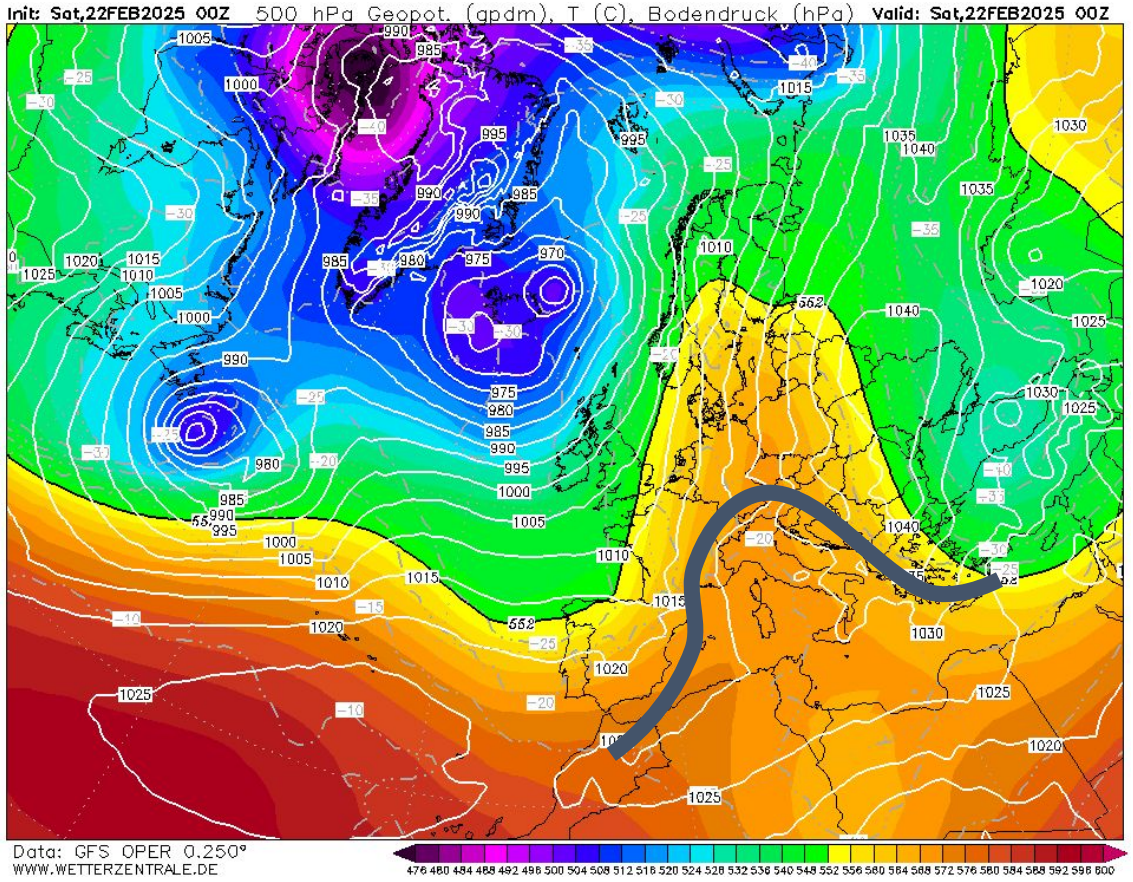
- Record wet in most of the Iberian Peninsula (since 1940; ERA5), south of France and north of Italy.
- Record dry in north of Germany, Denmark, Netherlands, the Alps and parts of the Scandinavian Peninsula.
  - Turkey also shows a relevant negative rank.

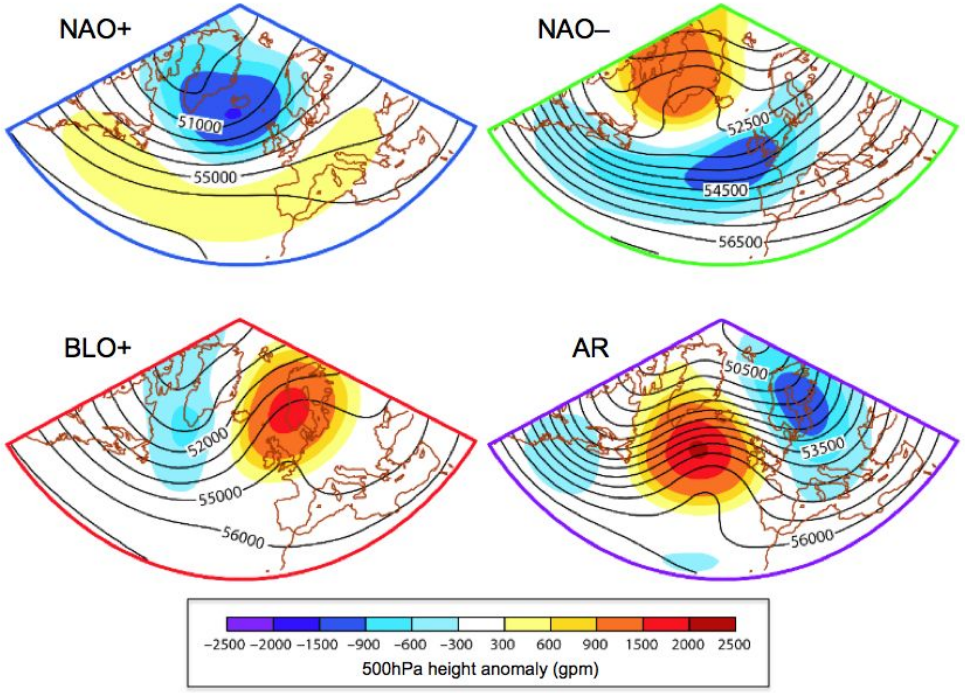


Source: https://www.embalses.net/

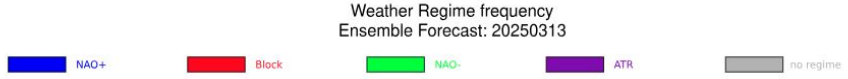
I. Recent state of the climate

Weather regimes





- GFS analysis

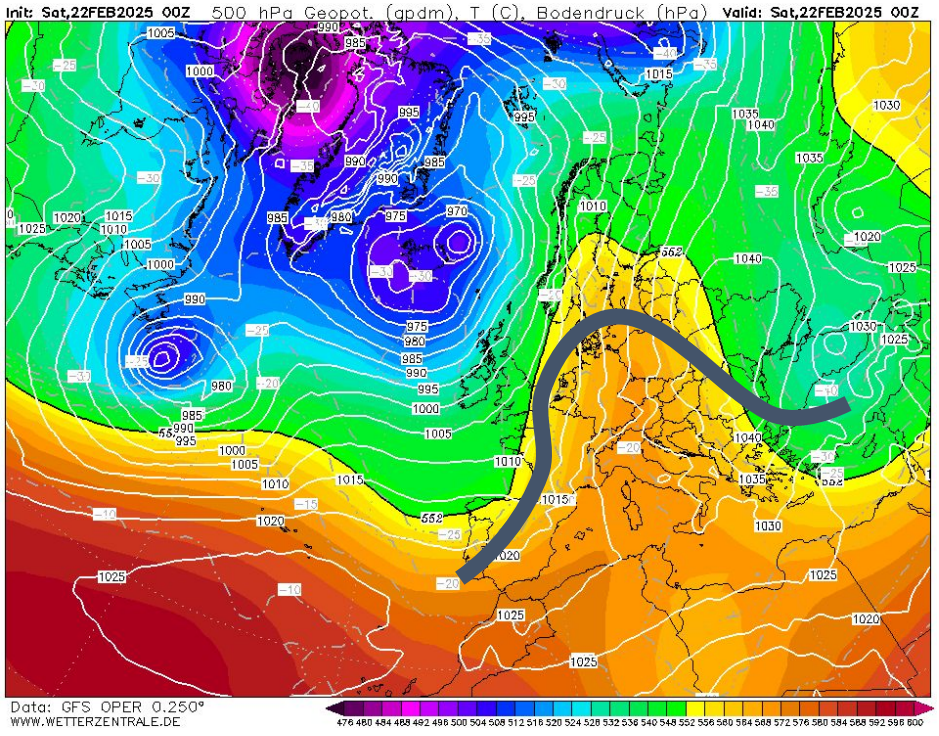


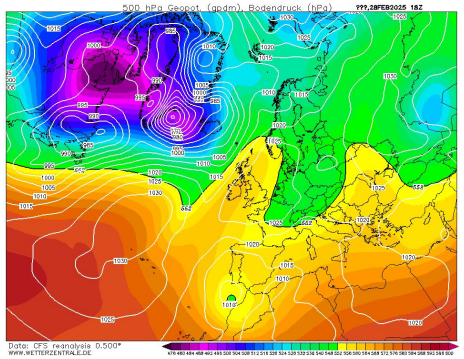
- **Blocking:** Onset through anticyclonic wave breakings over Europe in the upper troposphere (Michel et al., 2012). Two main precursors of Euro-Atlantic blocking events are a retrograding high-latitude planetary-scale wave and an enhanced baroclinic wavetrain across the North Atlantic (Michelangeli & Vautard, 1998)

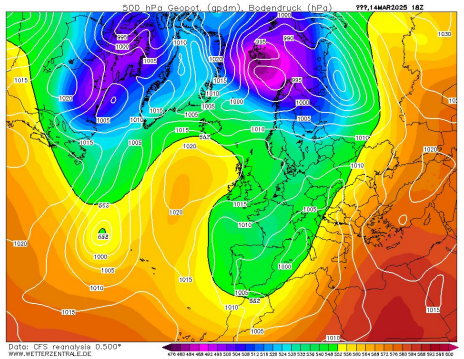
- Future tool on evaluation of weather regimes.

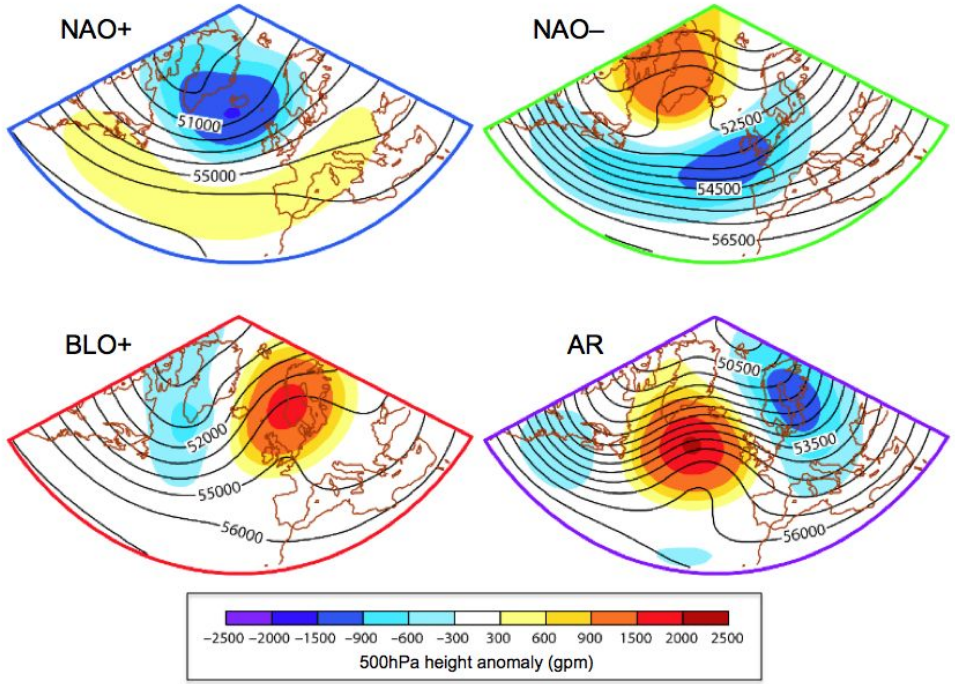
Source: https://www.wetterzentrale.de/reanalysis.php?map=1&model=avn&var=2&jaar=2025&maand=3&dag=26&h=0&nmaps=64

I. Weather regimes









GFS analysis

Future tool on evaluation of weather regimes

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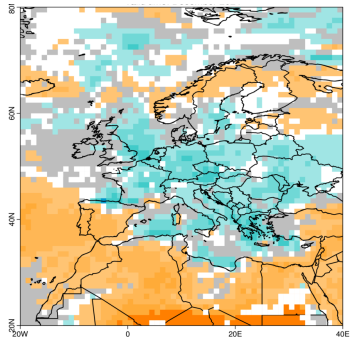
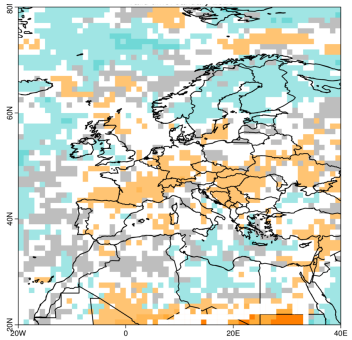
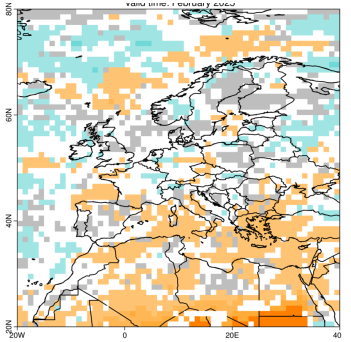
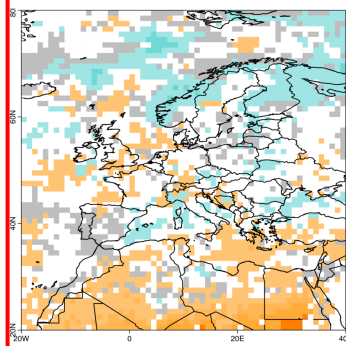
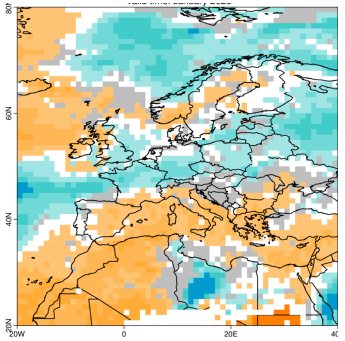
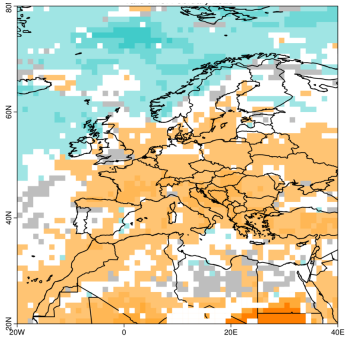
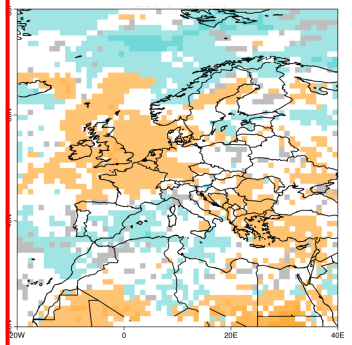
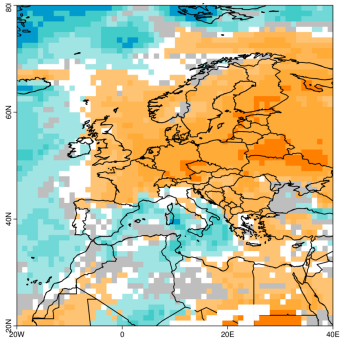
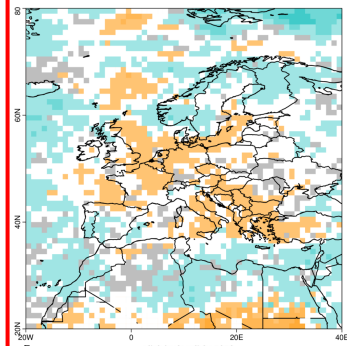
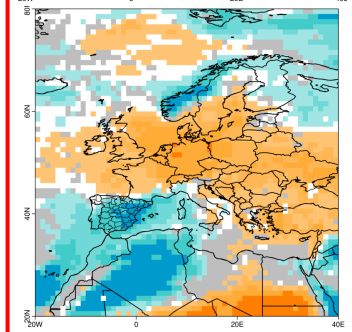
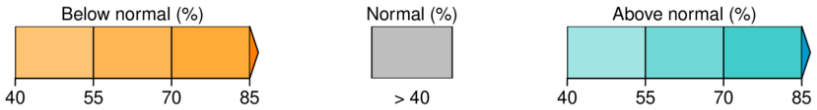
Source: https://www.wetterzentrale.de/reanalysis.php?map=1&model=avn&var=2&jaar=2025&maand=3&dag=26&h=0&nmaps=64

Did we anticipate above normal precipitation in Iberia?

Forecast month →

Start date ↓

	December	January	February	March
December '24 →				
January '25 →				
February '25 →				
March '25 →				



A bit!

Since January

Calibrated seasonal forecast ECMWF System5 with SUNSET

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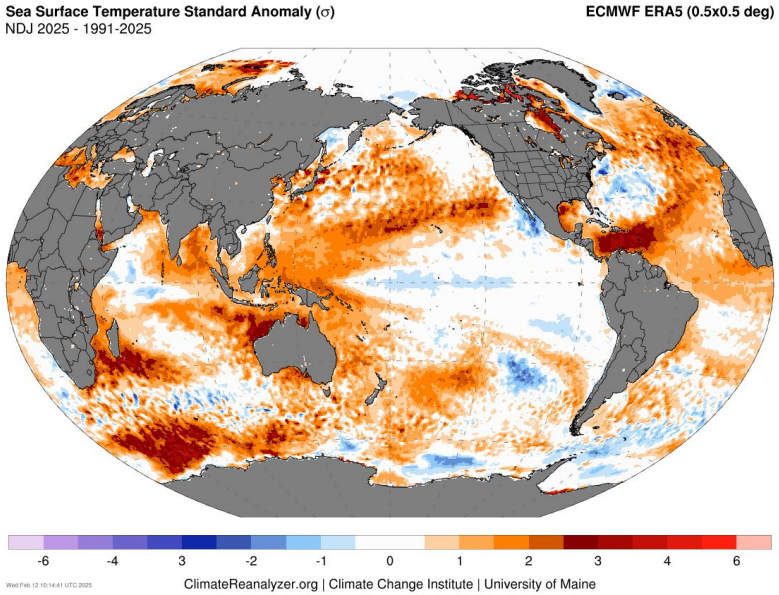
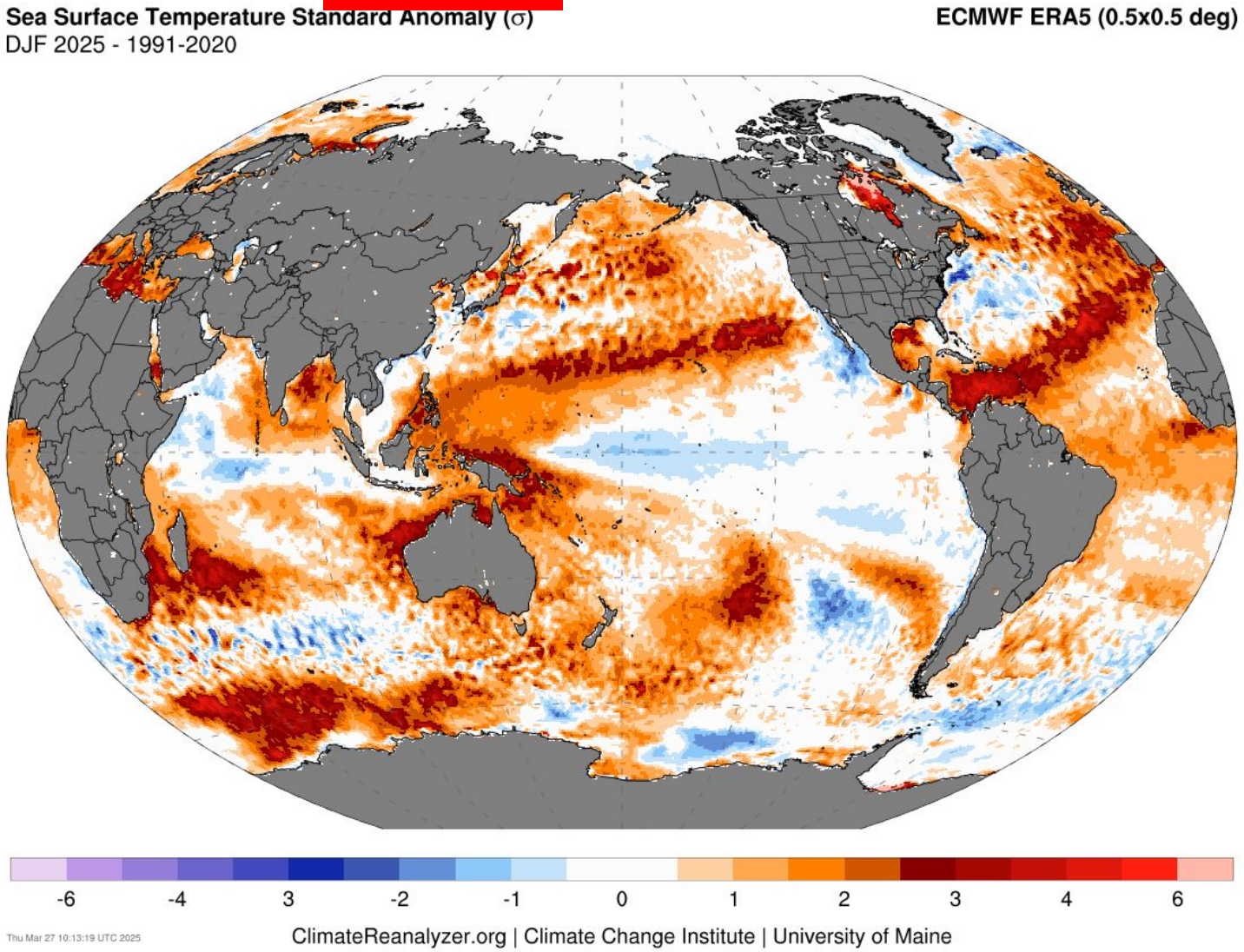


UPDATE



Source: https://climatereanalyzer.org/research_tools/monthly_maps/

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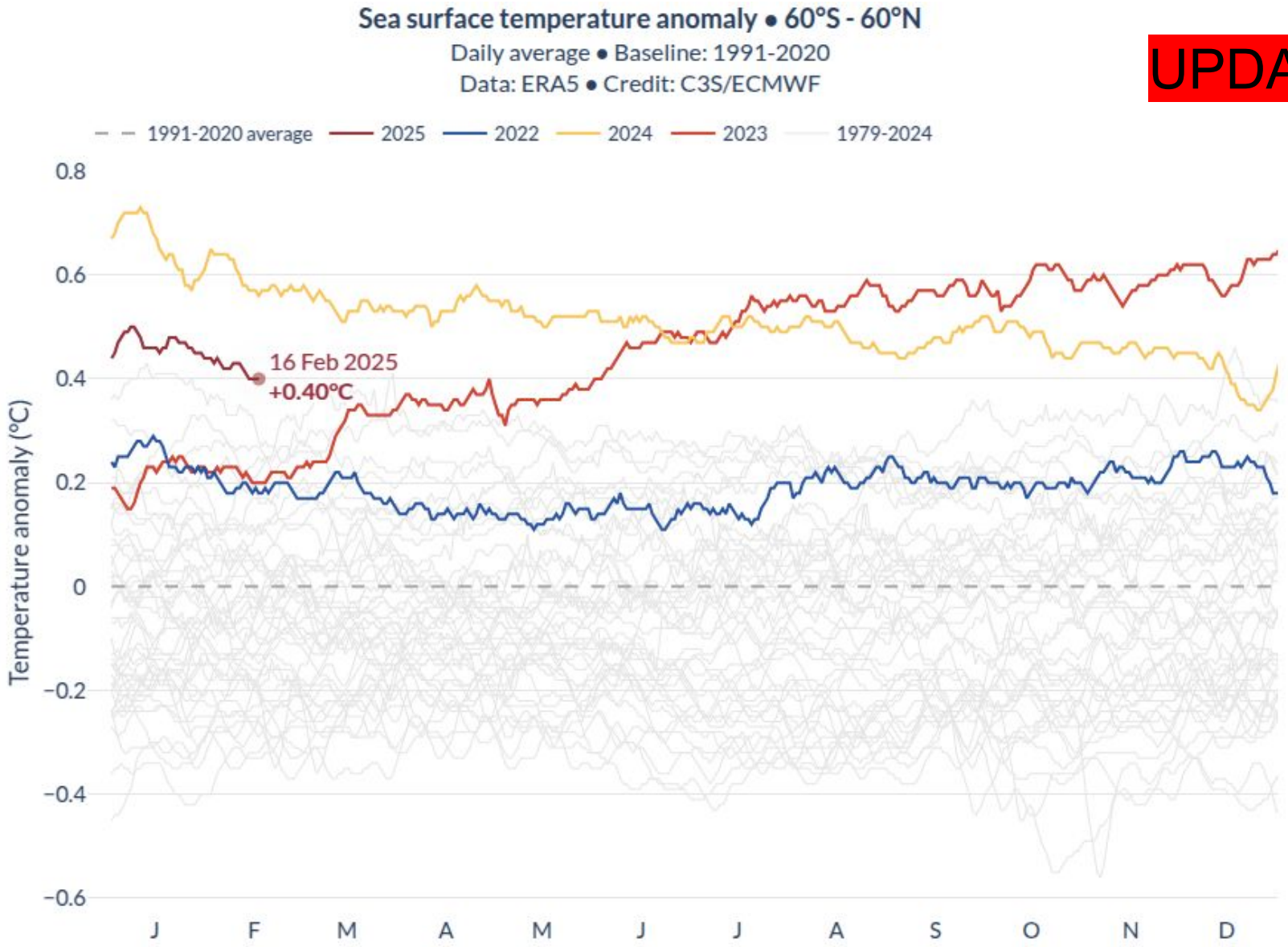


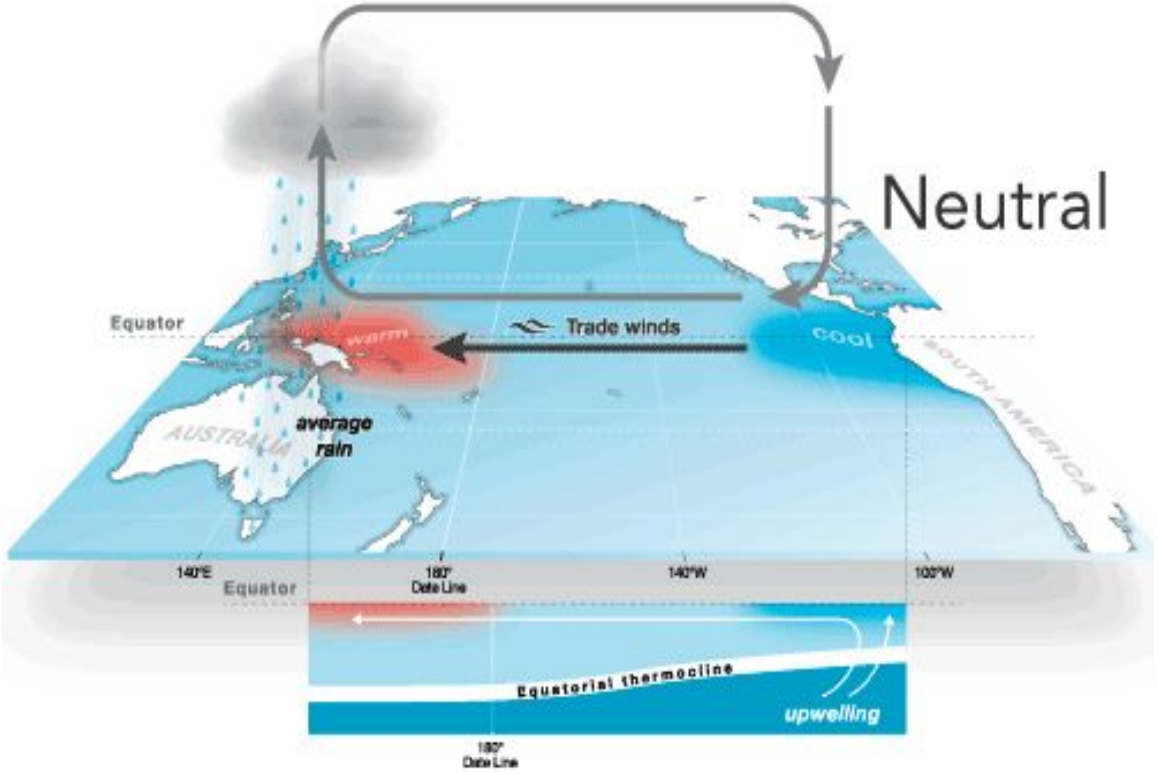
UPDATE

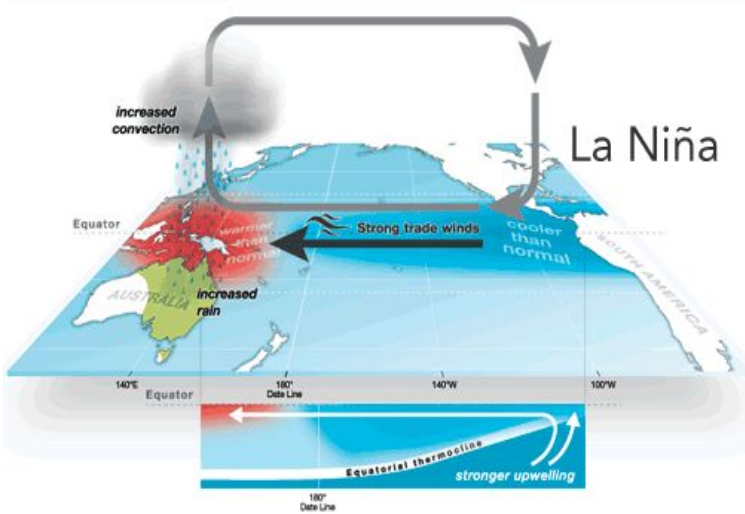
- Since mid-2023, global SST anomalies have increased significantly compared to previous years, remaining above +0.4 ºC throughout all seasons (except for December 2024).

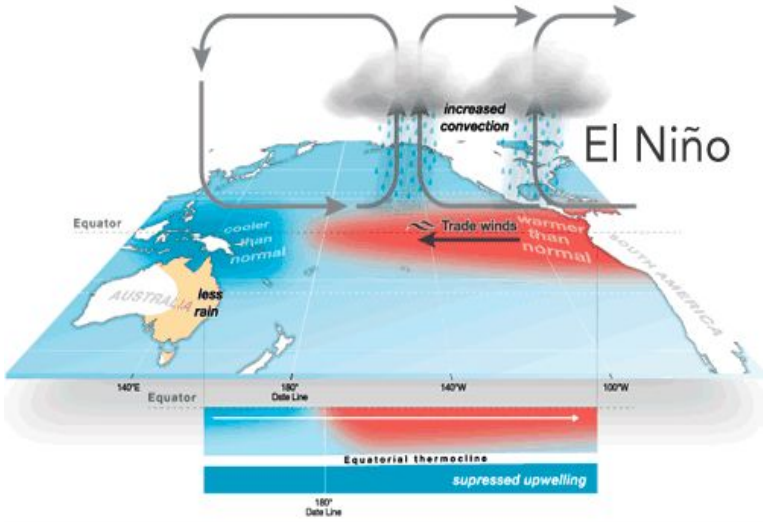
Source: https://pulse.climate.copernicus.eu/

El Niño-Southern Oscillation (ENSO)

➢ ENSO is the leading mode of natural variability at seasonal to interannual (S2I) time scales and is considered as an internally occurring coupled ocean-atmosphere phenomenon.







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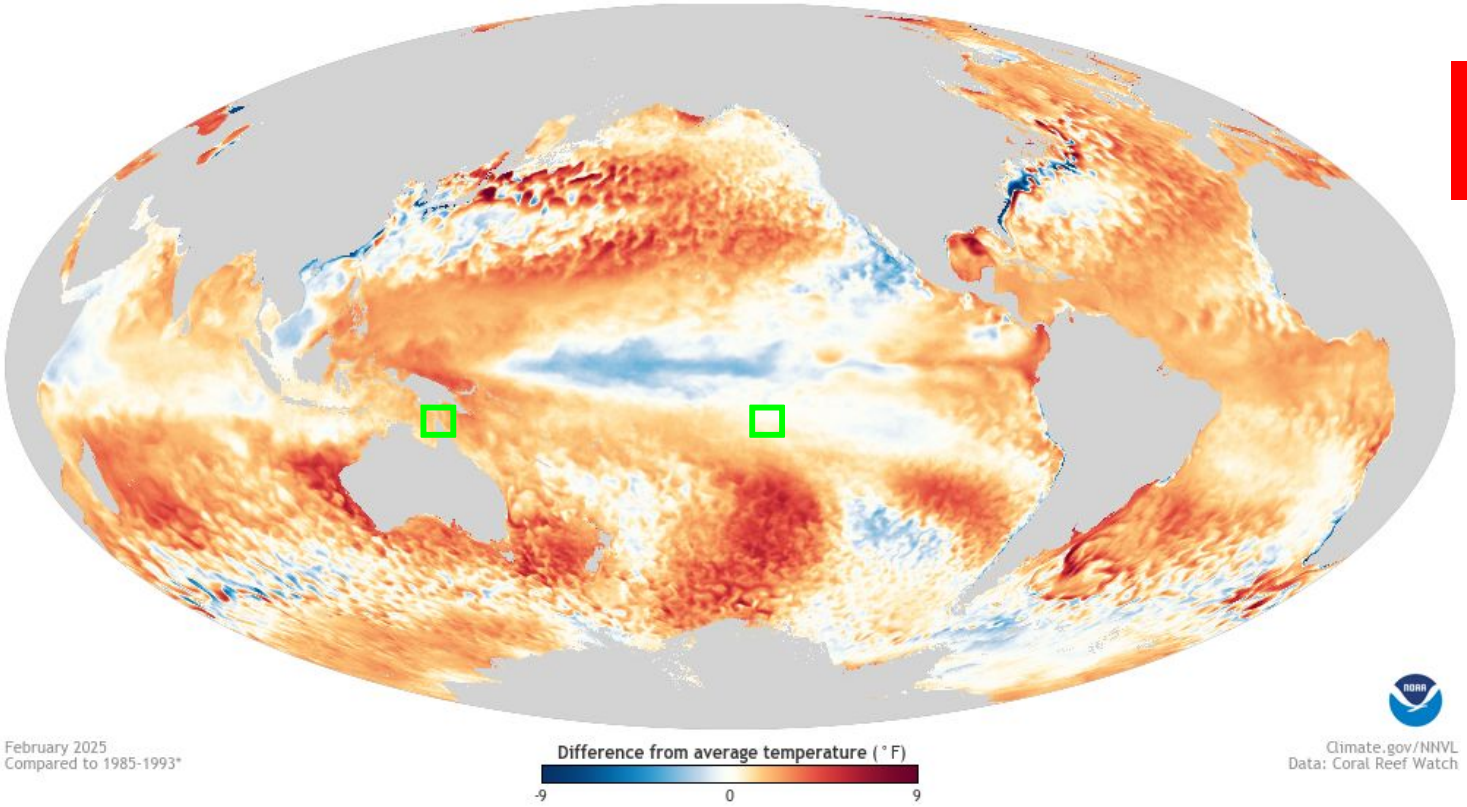
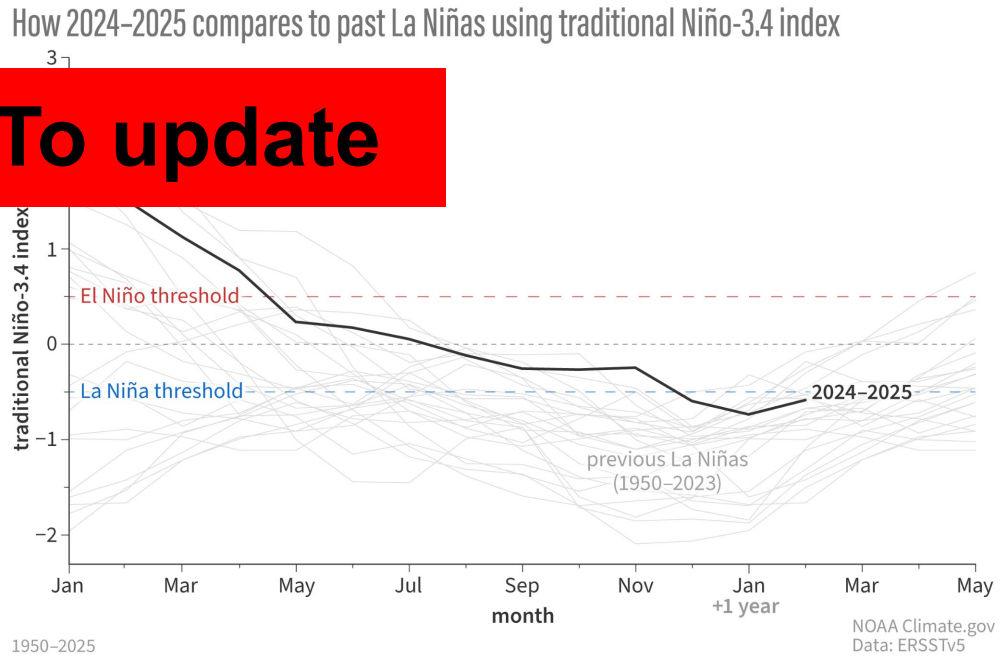
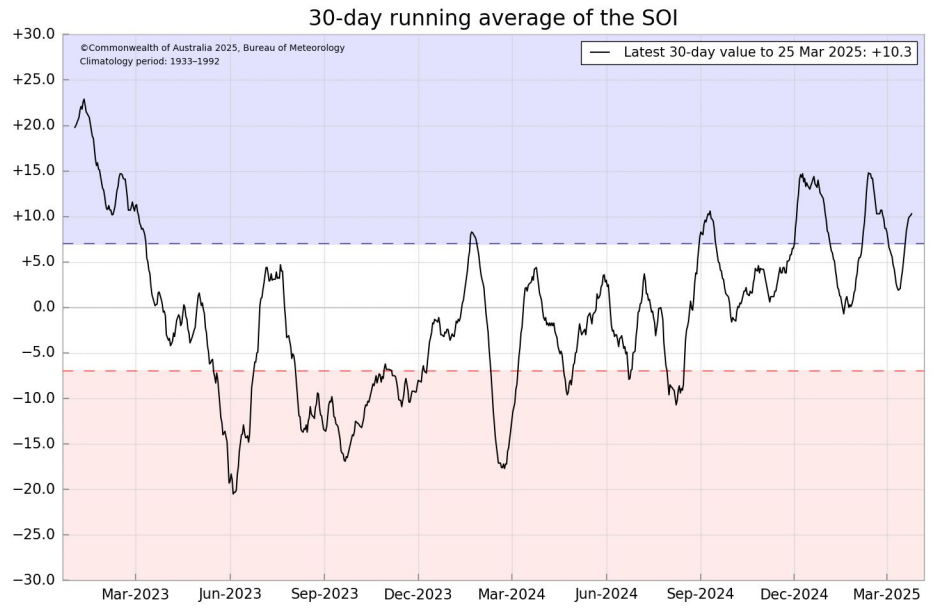




To update



- ENSO status is traditionally diagnosed by looking at SST anomalies in the Niño 3.4 region, known as the Oceanic Niño Index (ONI), and the difference in mean sea level pressure between Darwin and Tahiti, known as the Southern Oscillation Index (SOI).

- ENSO alert system status: **La Niña Advisory**

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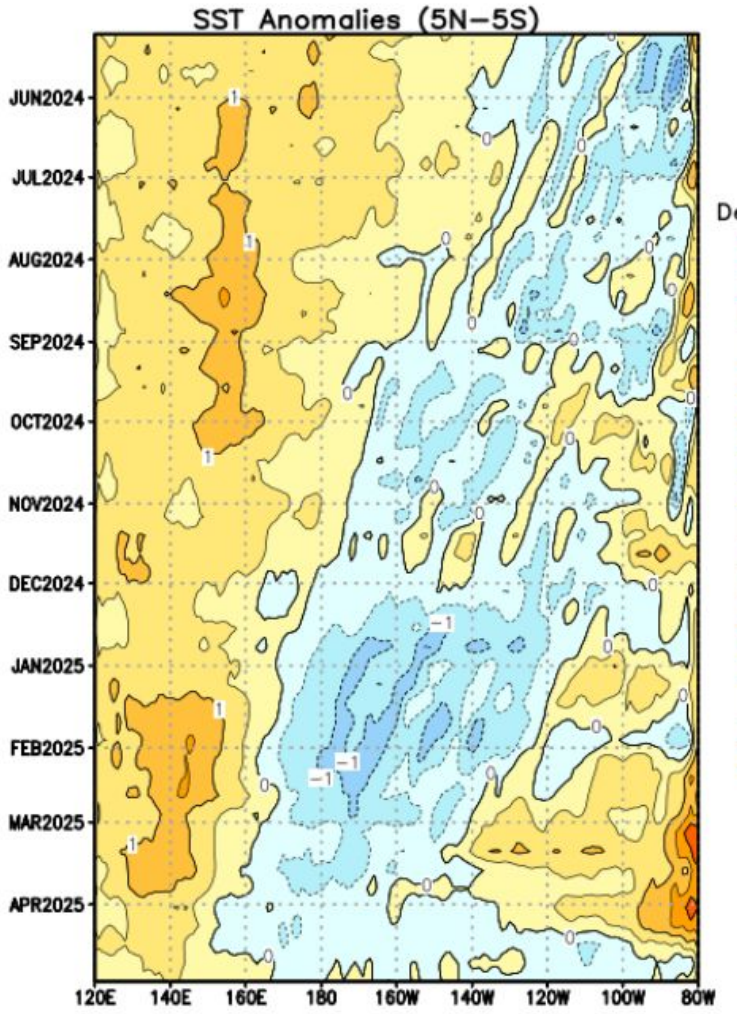
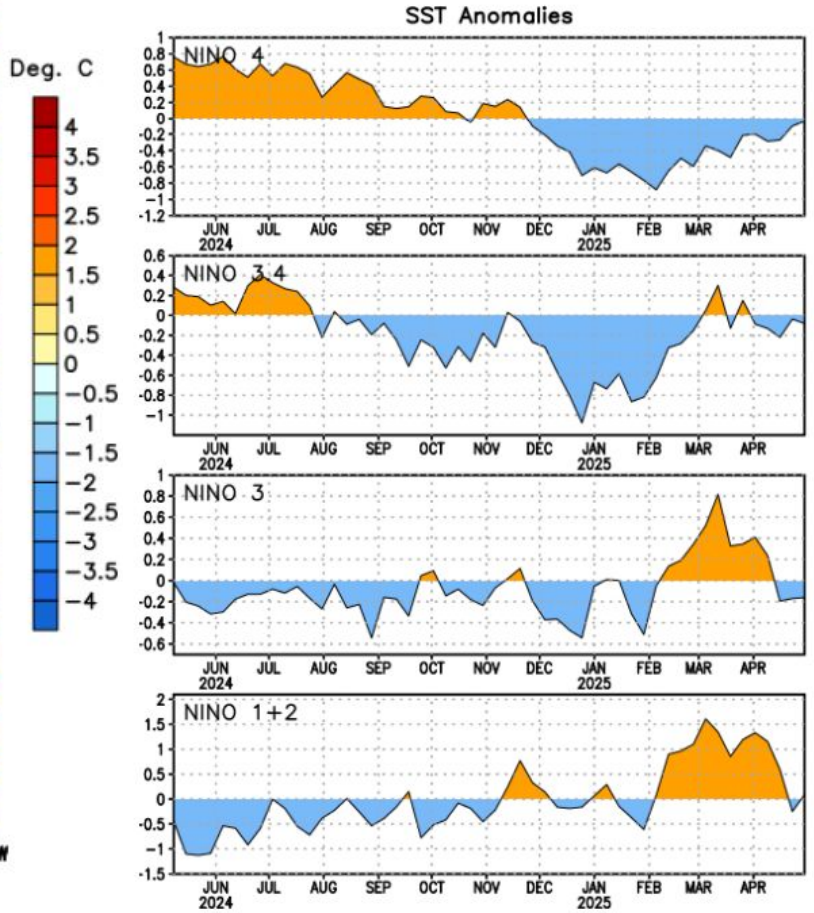
Source: https://www.climate.gov/news-features/blogs/enso / http://www.bom.gov.au/climate/enso/?ninoIndex=nino3.4&index=nino34&period=weekly#tabs=Pacific-Ocean&pacific=SOI

El Niño-Southern Oscillation (ENSO) - **The ocean**

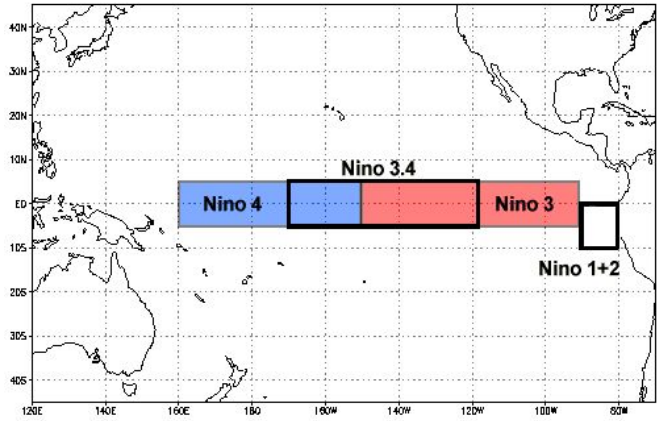
ENSO Alert System Status: Final La Niña Advisory

ENSO-neutral conditions are present.*





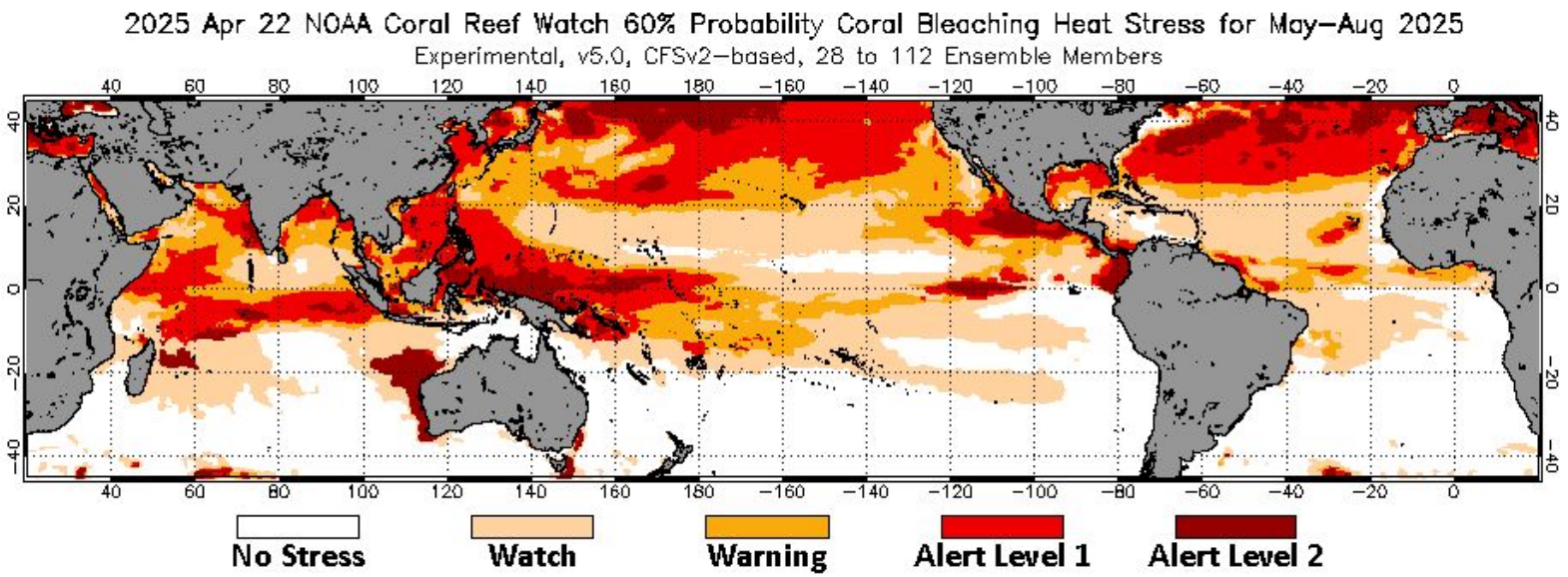
➢ Monitoring regions



➢ La Niña has disappeared. Warm anomalies in the Niño 1+2 region: **Coastal El Niño**

Source: https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf / https://www.pmel.noaa.gov/gtmba/assorted-plots

El Niño-Southern Oscillation (ENSO) - The ocean



Before and after of coral bleaching on Lizard Island, The Great Barrier Reef, Queensland.
Photo credit: The Ocean Agency

Warning	Possible bleaching
Alert level 1	Bleaching likely
Alert level 2	Mortality likely

- 60% of ensemble members probability of coral **bleaching** from May to August.
- Based on daily SSTs from NCEP CFSv2.
- Coral bleaching can be predicted up to 4 months in advance.

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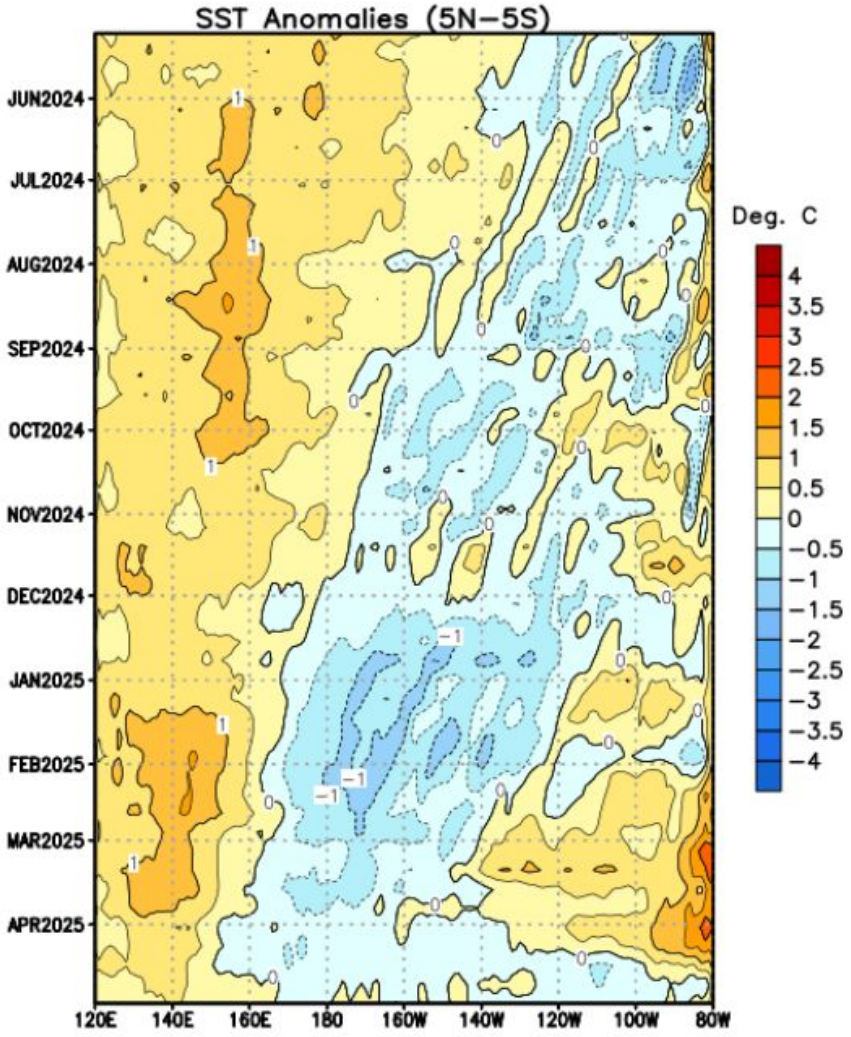
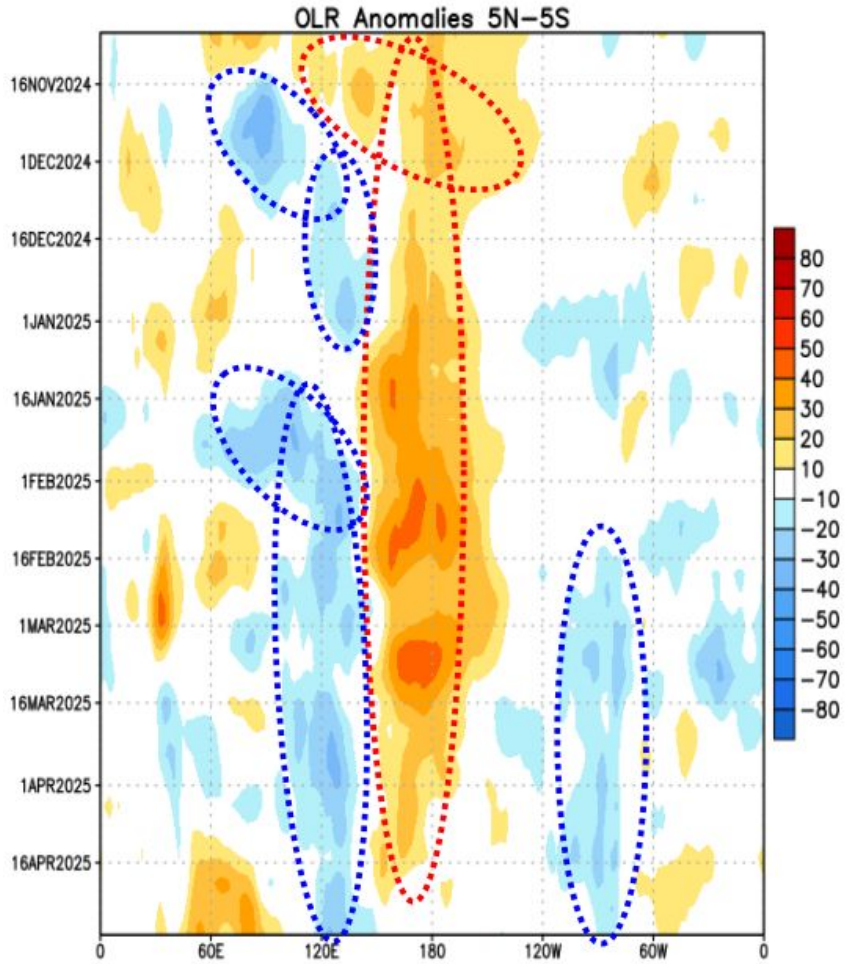
Source: https://coralreefwatch.noaa.gov/

El Niño-Southern Oscillation (ENSO) - **The atmosphere**





- While **La Niña**-related SSTs have gotten weaker and weaker, the atmosphere still shows evidence of a **stronger Walker circulation**, with negative (upwelling) OLR anomalies over the Maritime continent and **positive** (subsidence) anomalies in the central Pacific, now fading.

- **Upward air motion** anomalies have appeared since mid-February possibly triggered by the **positive SST anomalies** off the coast of Peru.

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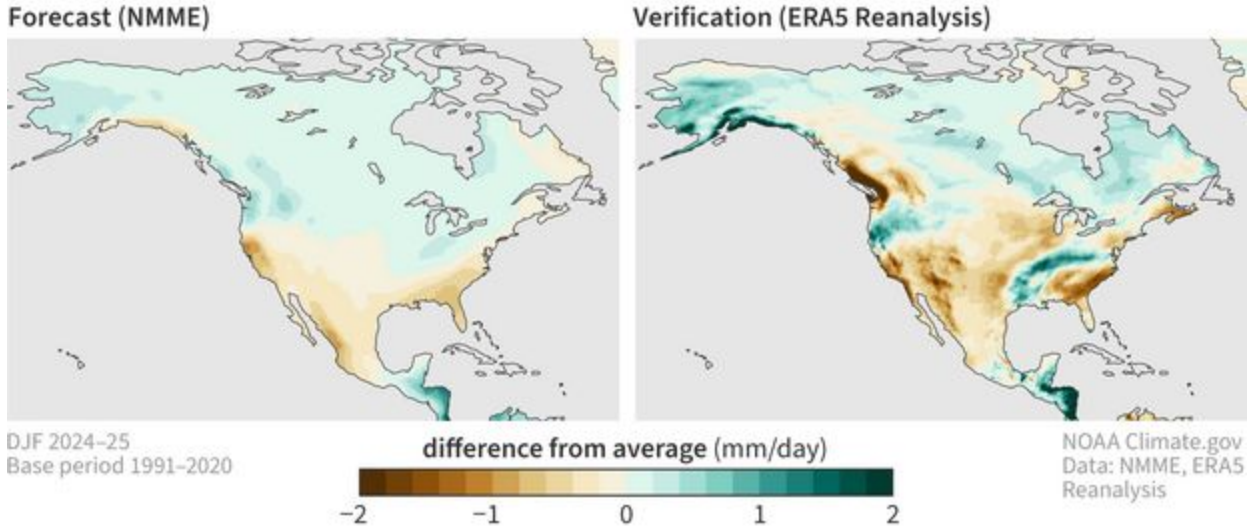
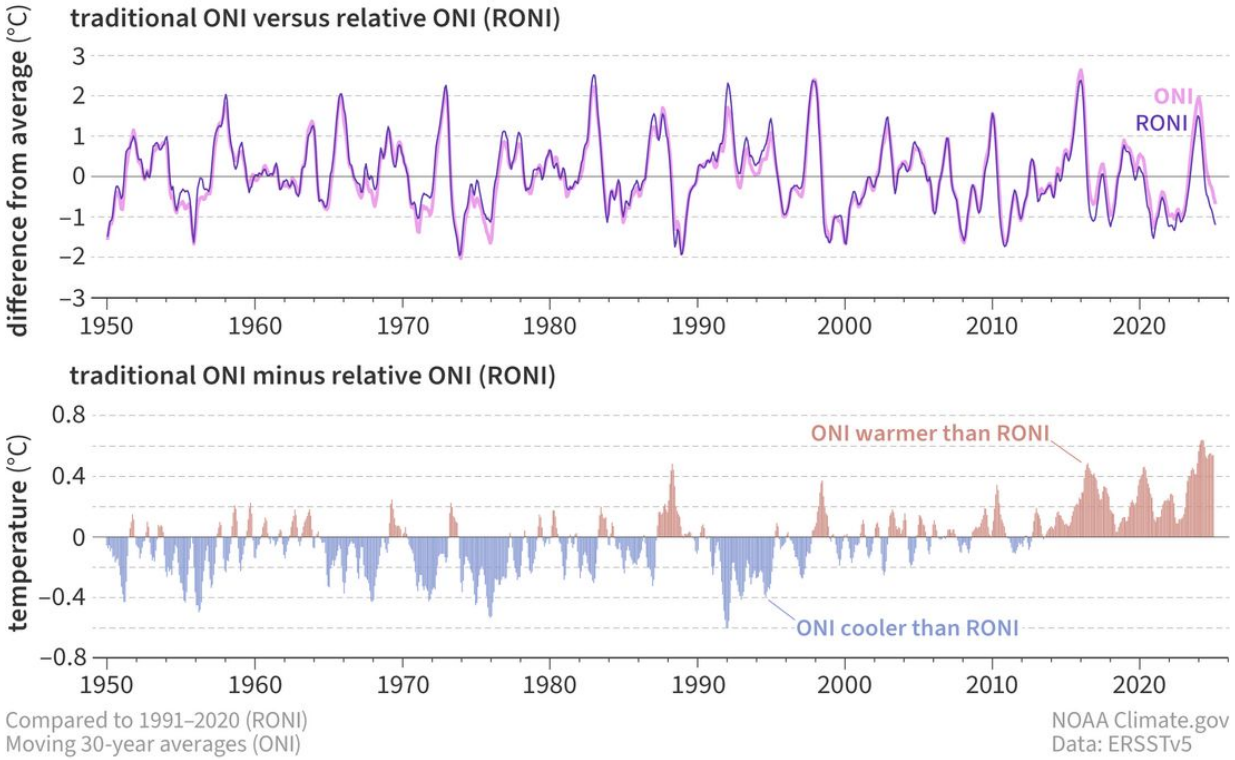
Source: https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf / https://www.pmel.noaa.gov/gtmba/assorted-plots

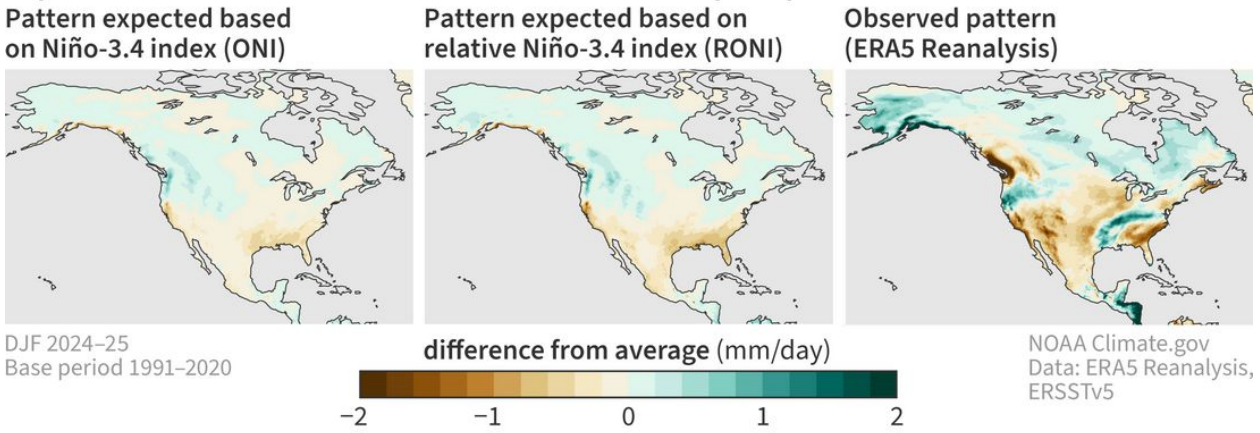
Winter 2024–25 precipitation forecast and verification



Traditional ENSO-monitoring index has been higher than relative index in recent years



Expected La Niña influence on the winter 2024–25 precipitation



- ONI has been consistently higher than RONI during the past 15 years (climate change signal).
- The observed anomaly pattern is much stronger than the one forecasted by NMME.

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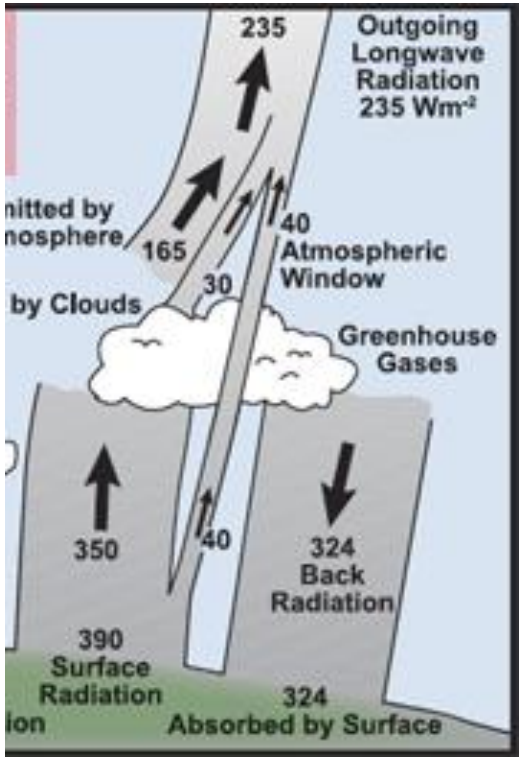
Source: https://www.climate.gov/news-features/blogs/enso/winner-or-bust-did-la-nina-shape-north-american-precipitation-winter

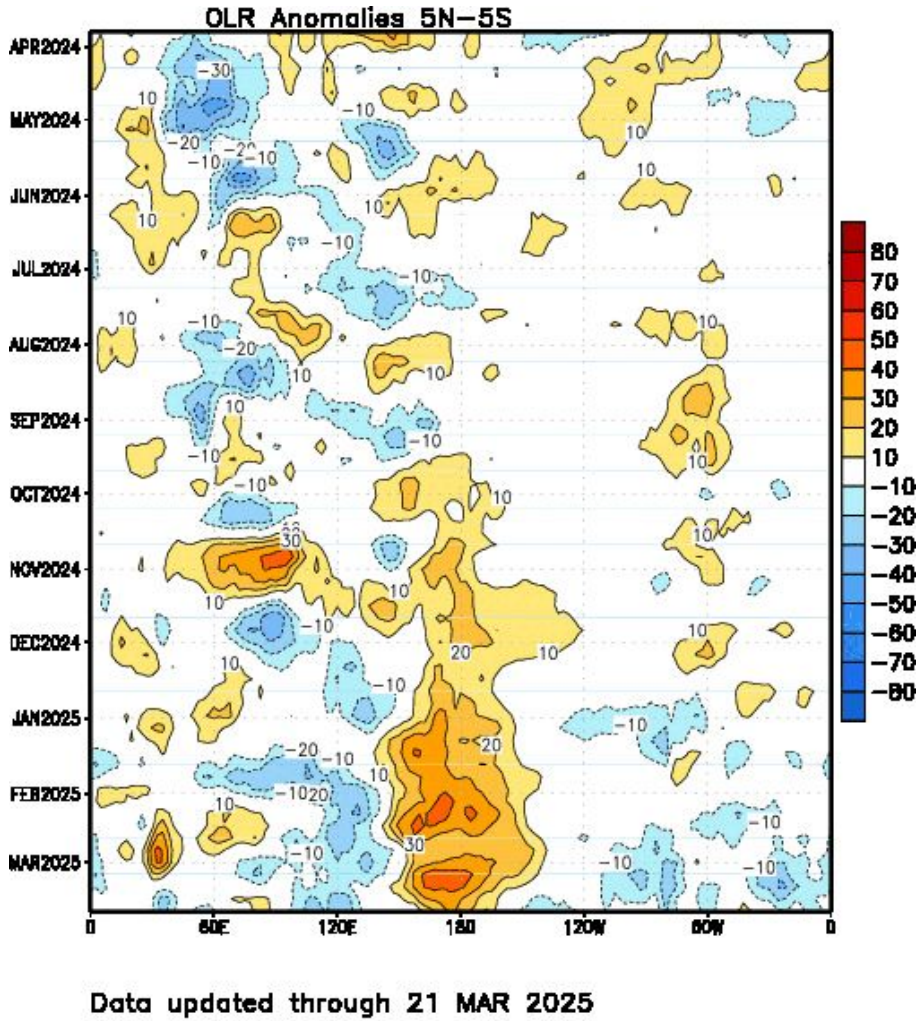
➢ Negative OLR anomalies:

Enhanced convection =

High and deep clouds =

Their top is cold and emits less emission of longwave radiation back to space.





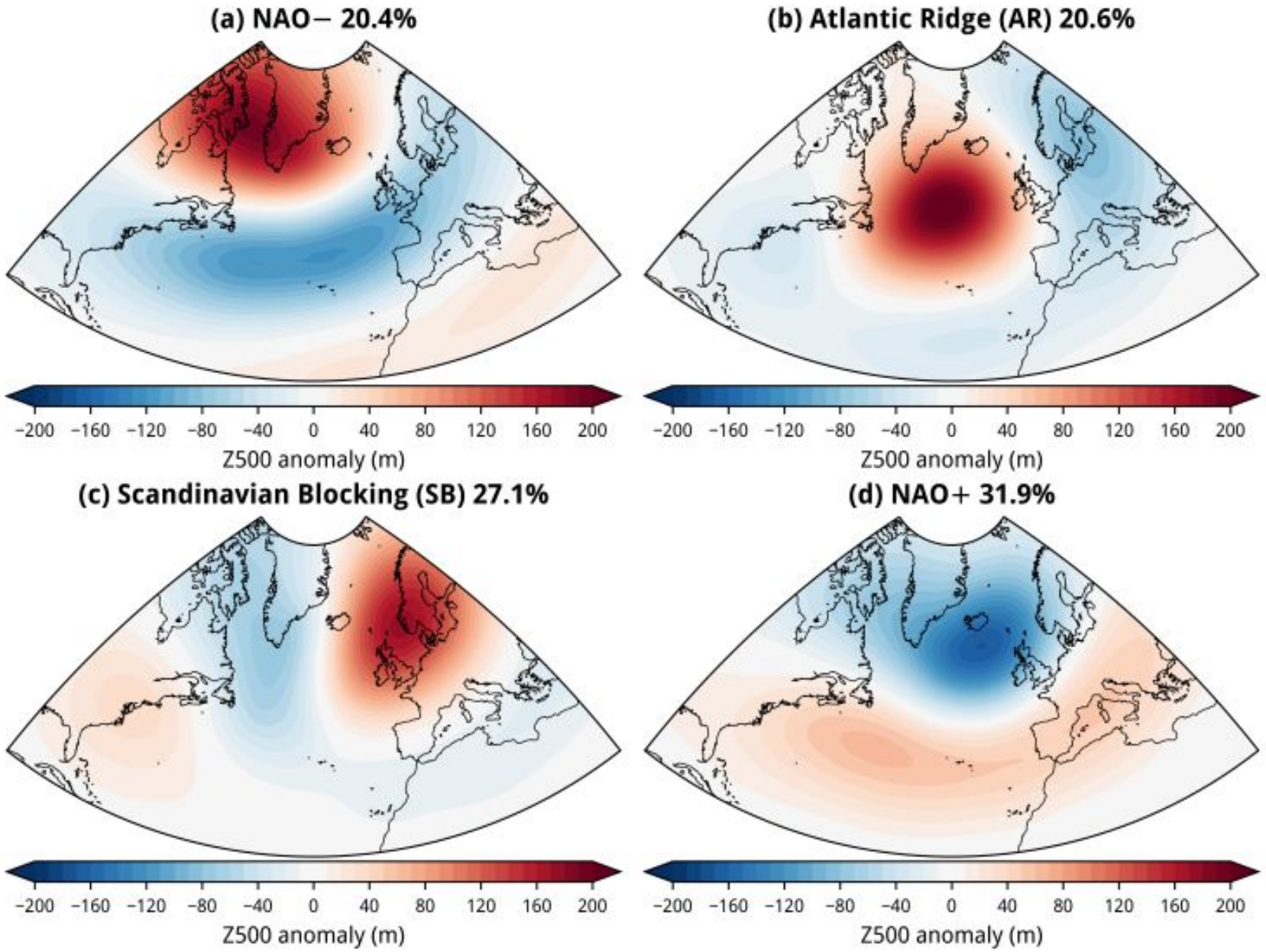
➢ Positive OLR anomalies:

Suppressed convection over the central Pacific is associated with La Niña.

Subsidence (orange/red shading)

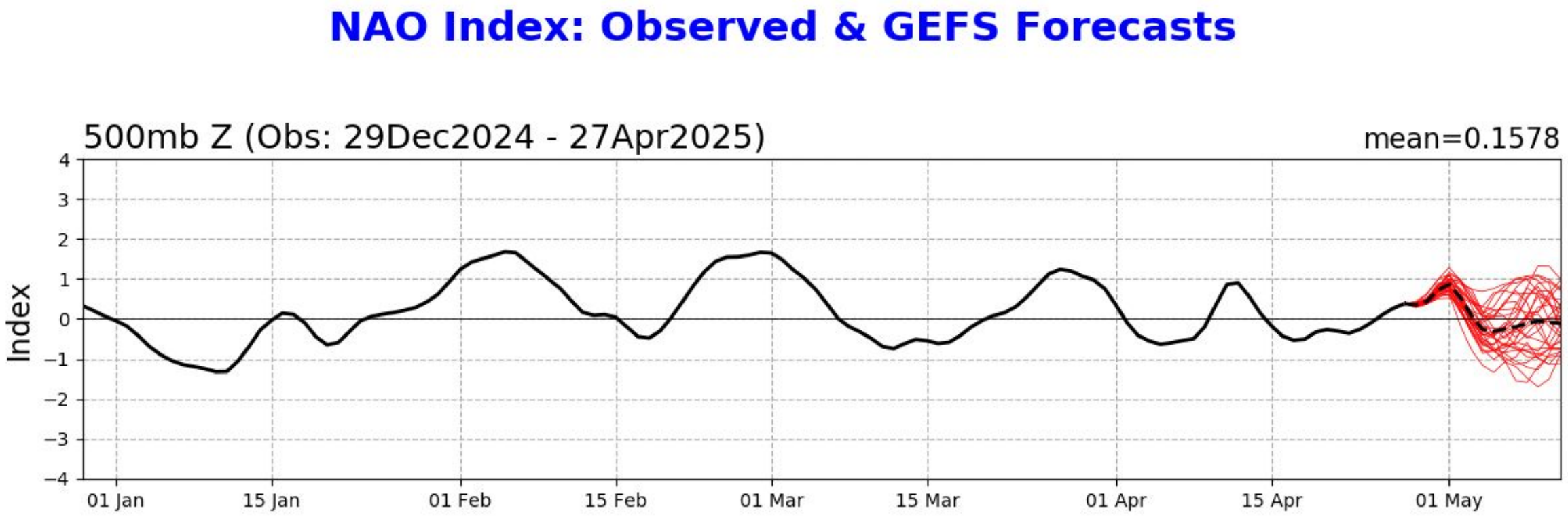
Enhanced convection (blue shading)

Source: https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf



Source: https://simonleewx.com/north-atlantic-wintertime-weather-regimes/

NAO forecast



Source: https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao_index_ensm.shtml

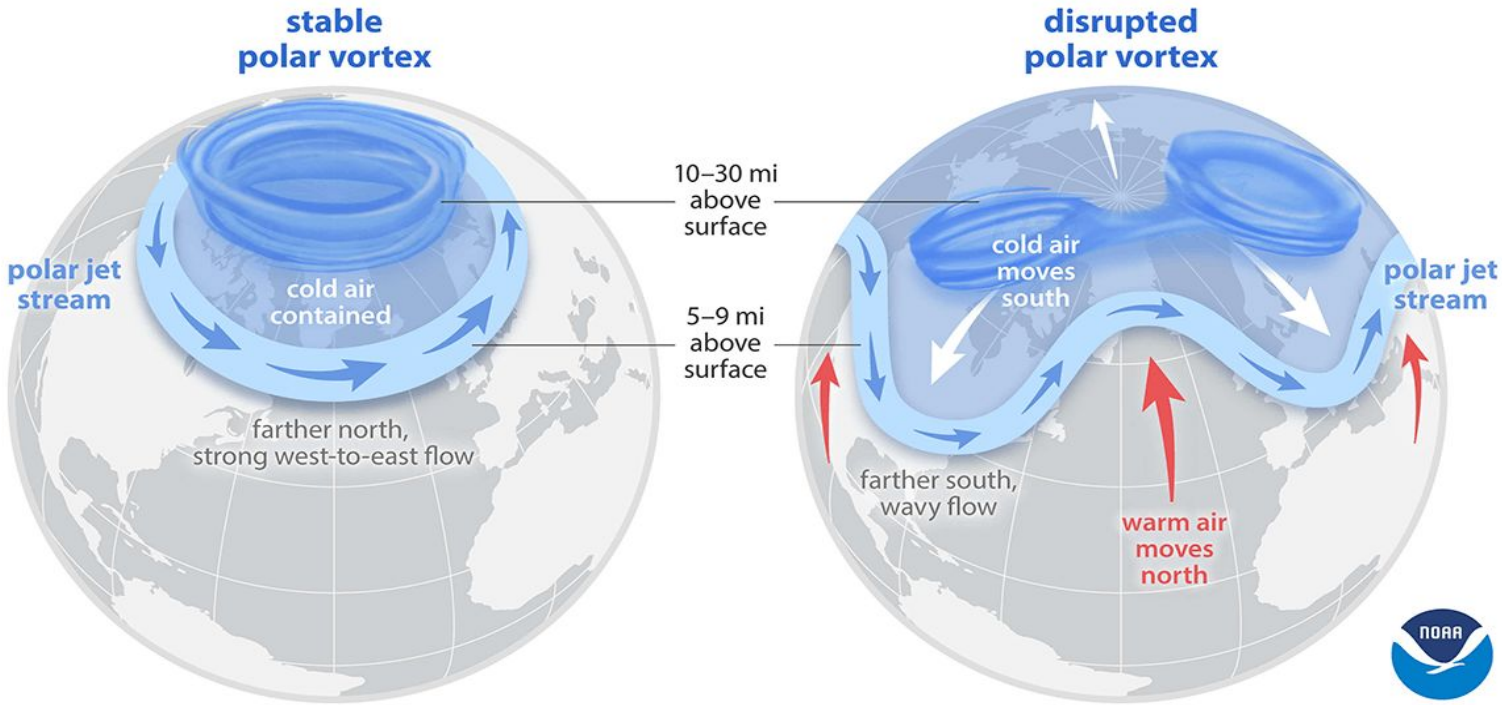
Polar Vortex

Understanding the polar vortex

The Arctic polar vortex is a strong band of winds in the stratosphere, surrounding the North Pole 10–30 miles above the surface.

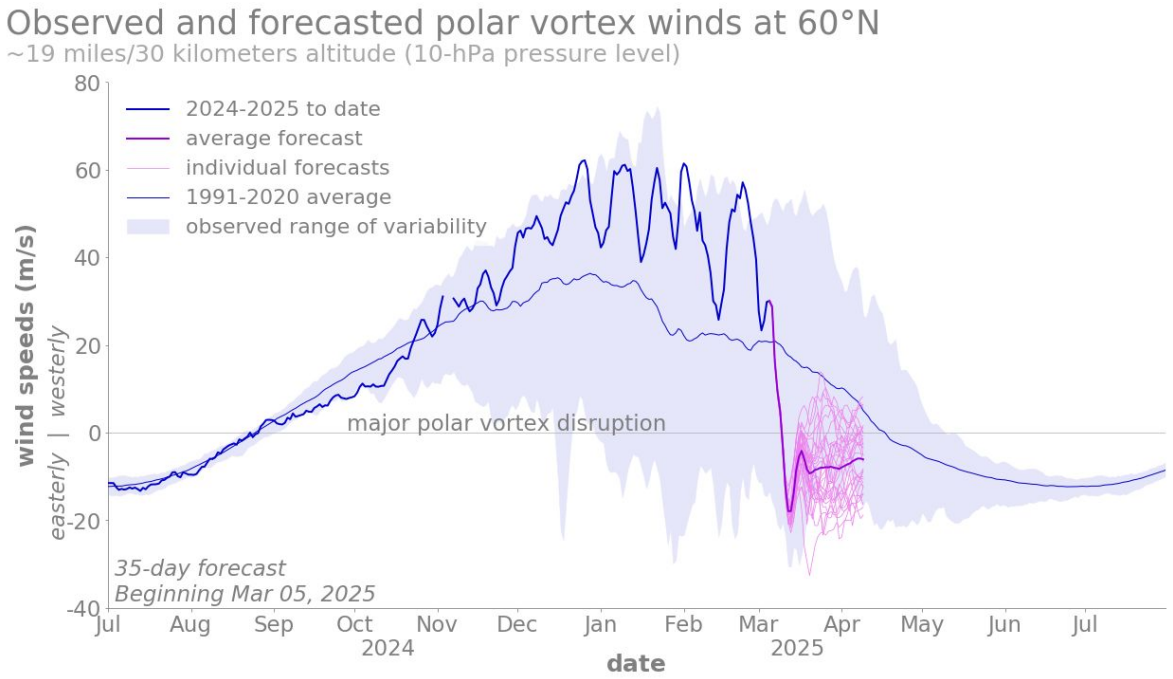
The polar vortex is far above and typically does not interact with the polar jet stream, the flow of winds in the troposphere 5–9 miles above the surface. But when the polar vortex is especially strong and stable, the jet stream stays farther north and has fewer "kinks." This keeps cold air contained over the Arctic and the mid-latitudes warmer than usual.

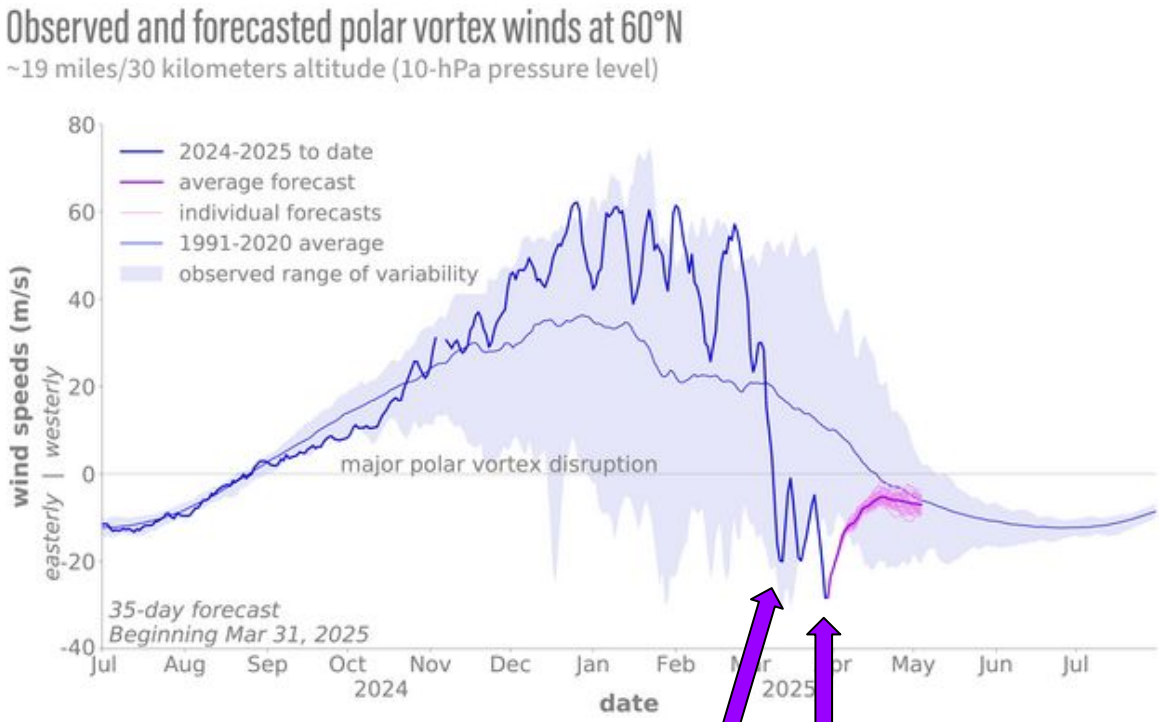
Every other year or so, the Arctic polar vortex dramatically weakens. The vortex can be pushed off the pole or split into two. Sometimes the polar jet stream mirrors this stratospheric upheaval, becoming weaker or wavy. At the surface, cold air is pushed southward to the mid-latitudes, and warm air is drawn up into the Arctic.



I. Recent state of the climate

Polar Vortex forecasts





- A vortex disruption was forecasted at the beginning of March.
- **And it happened on March 9!** Then winds tried to go back to westerly (3 times) but did not success.
- During the last attempt it reached a minimum of -28 meters per second, which are the most strongly "opposite" polar vortex wind speeds at 10 hPa recorded for this time of the year since 1991.

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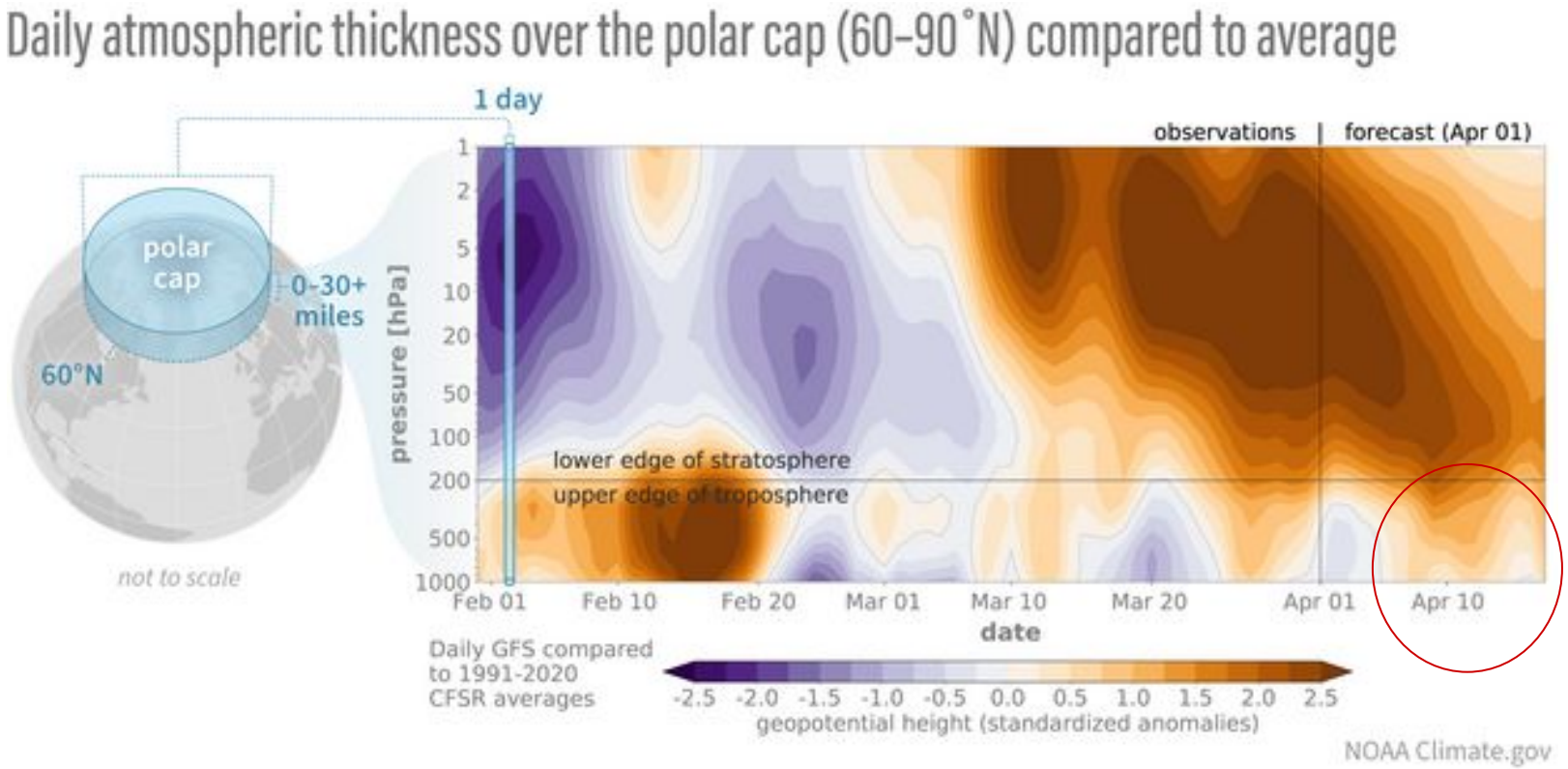
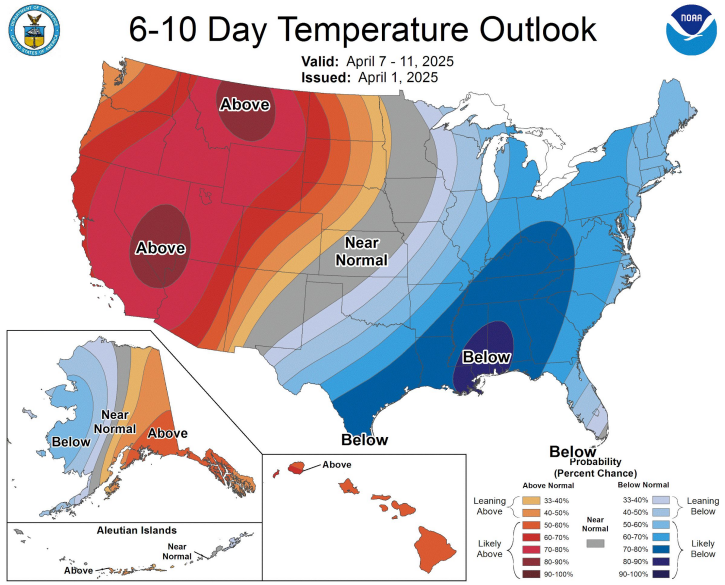
Source: https://www.climate.gov/news-features/blogs/polar-vortex/early-interesting-end-2024-25-polar-vortex-season

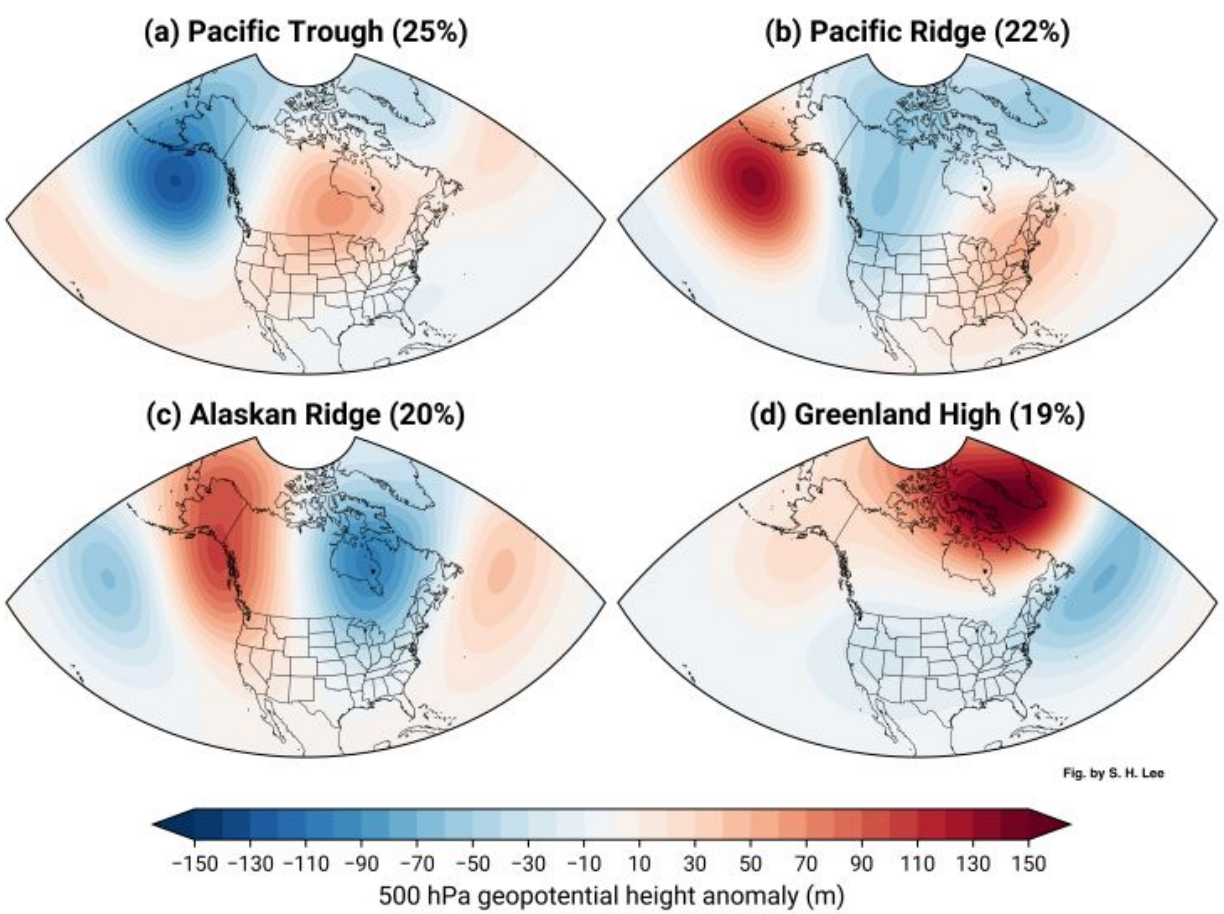
Stratosphere-troposphere coupling

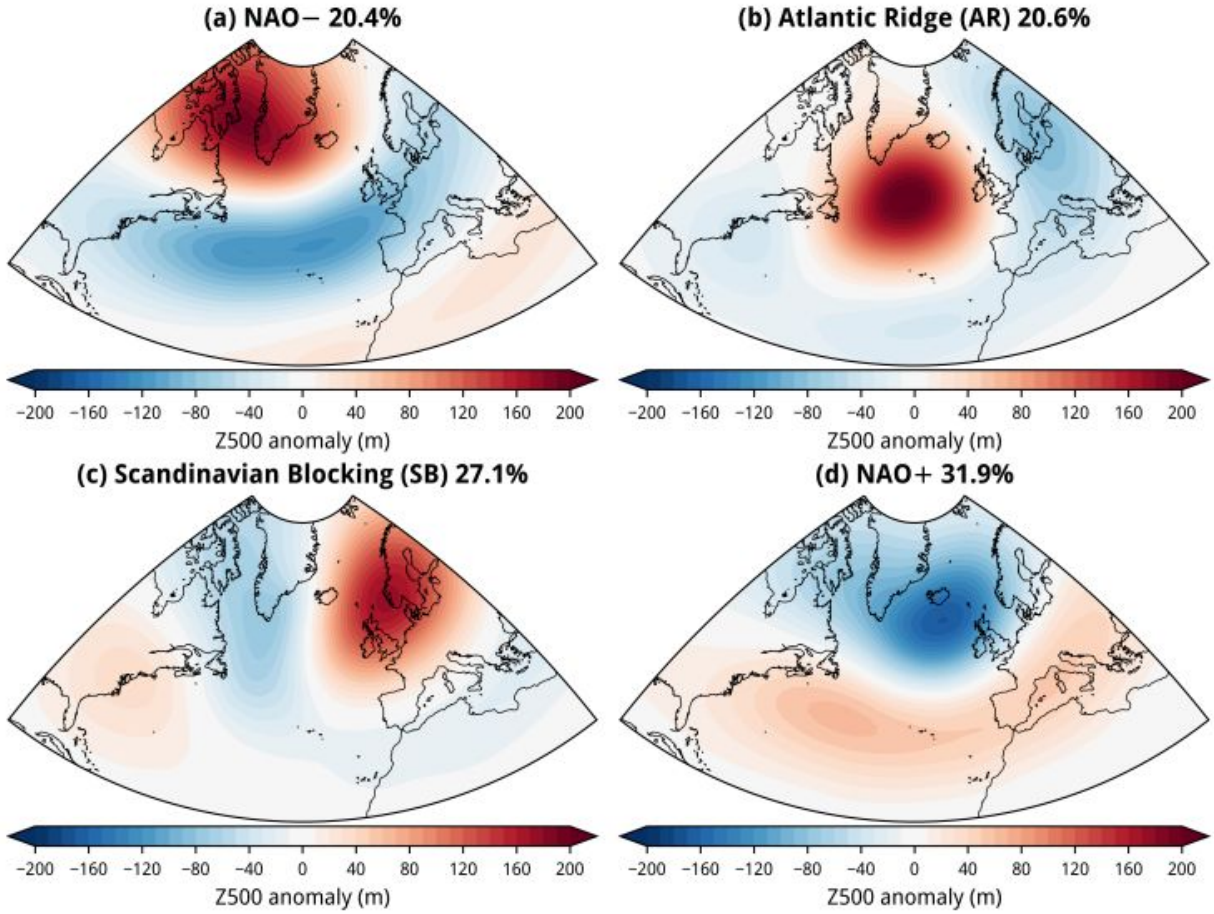




➢ Downward propagation of positive geopotential height anomalies increase the likelihood of cold weather in North America and northern Europe.

Source: https://www.climate.gov/news-features/blogs/polar-vortex/early-interesting-end-2024-25-polar-vortex-season





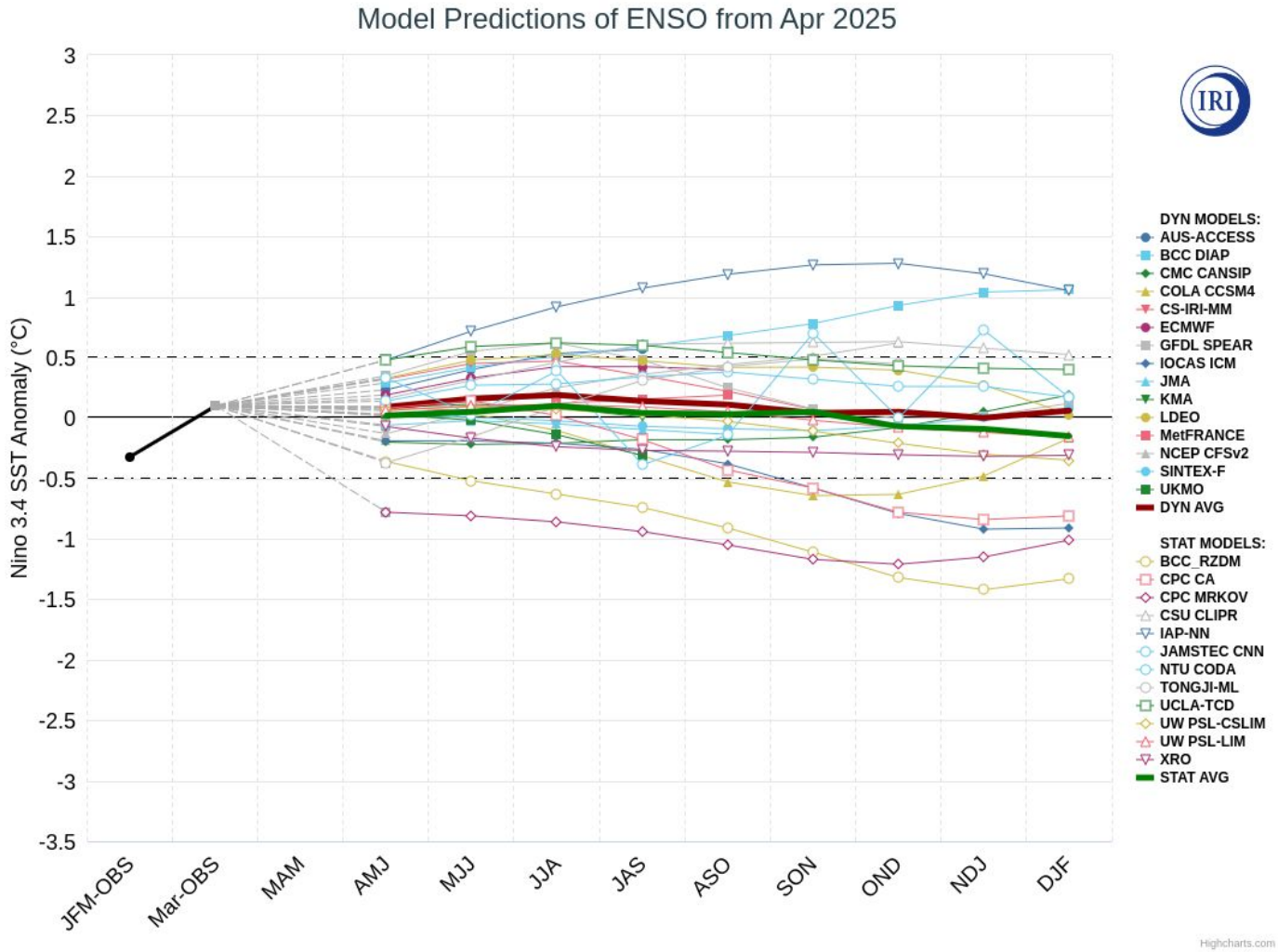
Source: https://simonleewx.com/north-atlantic-wintertime-weather-regimes/

I. Recent state of the climate

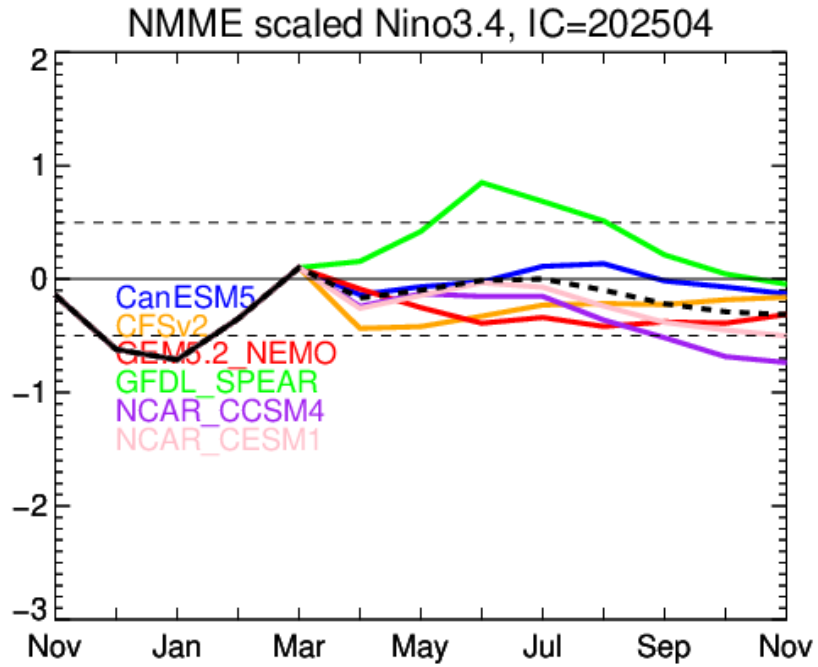
II. Seasonal forecasts

II. Seasonal forecasts

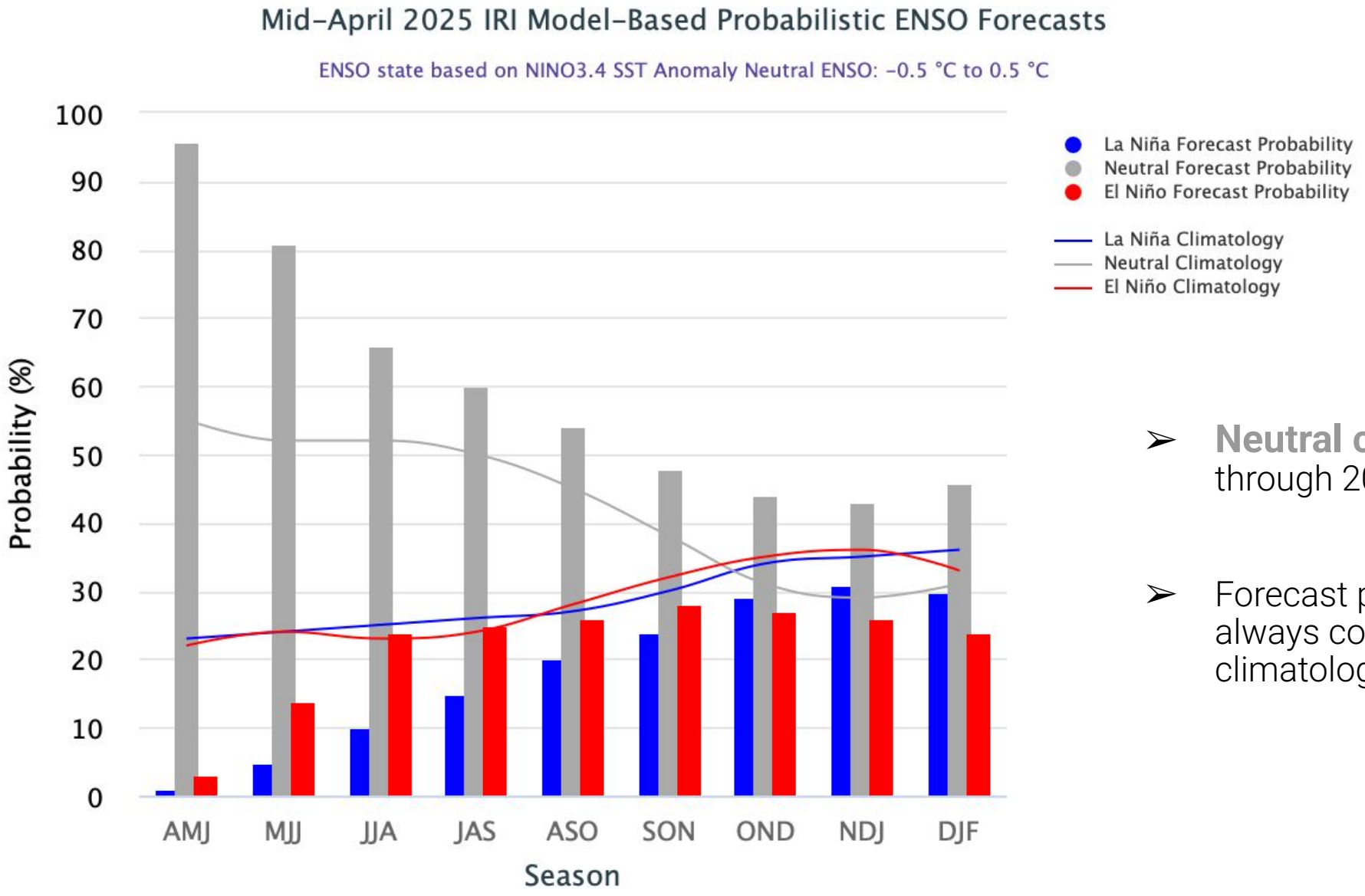
ENSO forecasts



➢ **ENSO-neutral** conditions are now present and expected to last through 2025.



Source: https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/?enso_tab=enso-sst_table / https://www.cpc.ncep.noaa.gov/products/NMME/current/plume.html

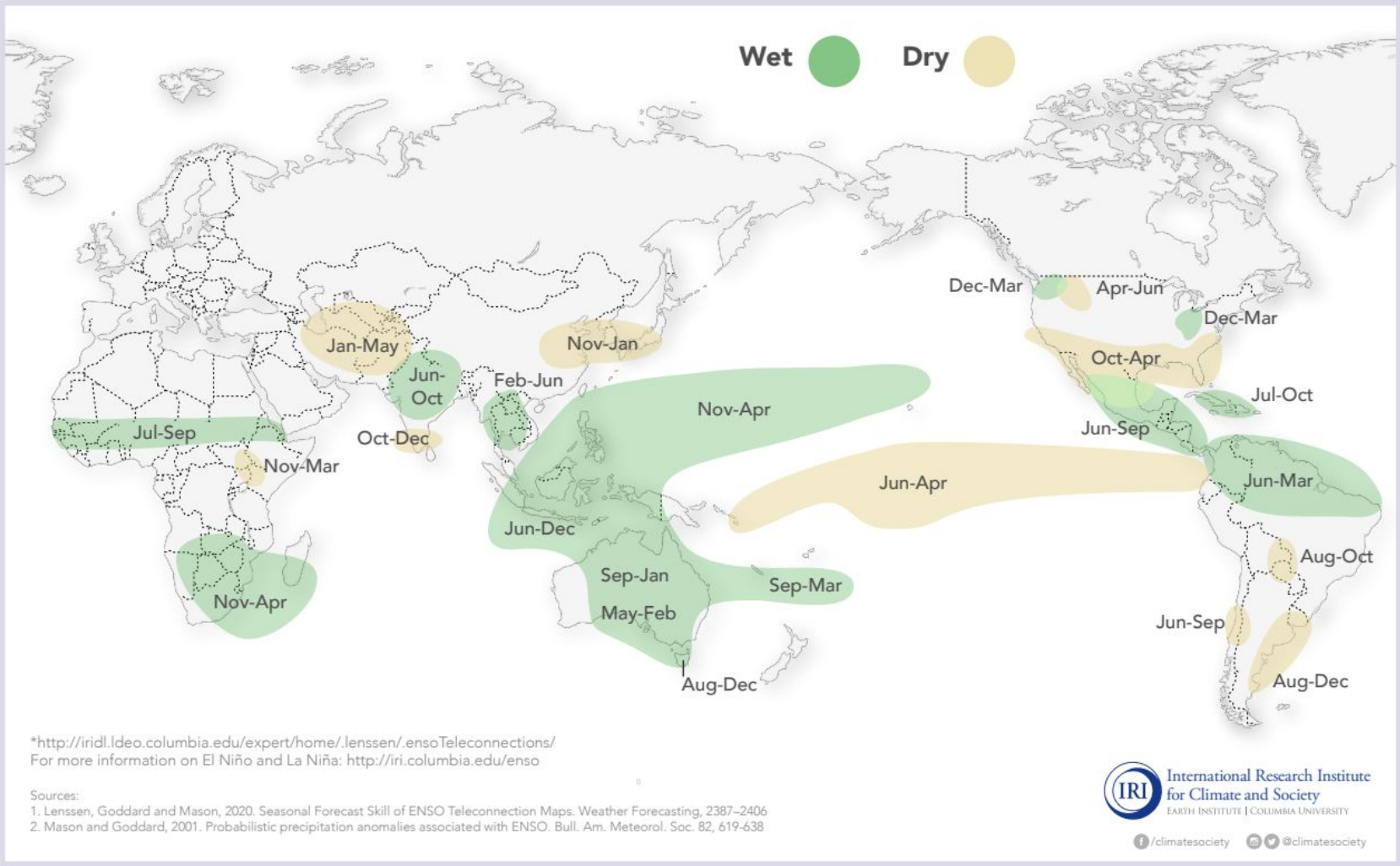


- **Neutral conditions** expected through 2025.
- Forecast probability needs to be always compared against climatological probability.

Source: https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/

La Niña and Rainfall

La Niña conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. The regions and seasons shown on the map below indicate typical but not guaranteed impacts of La Niña. For further information, consult the probabilistic information* that the map is based on.

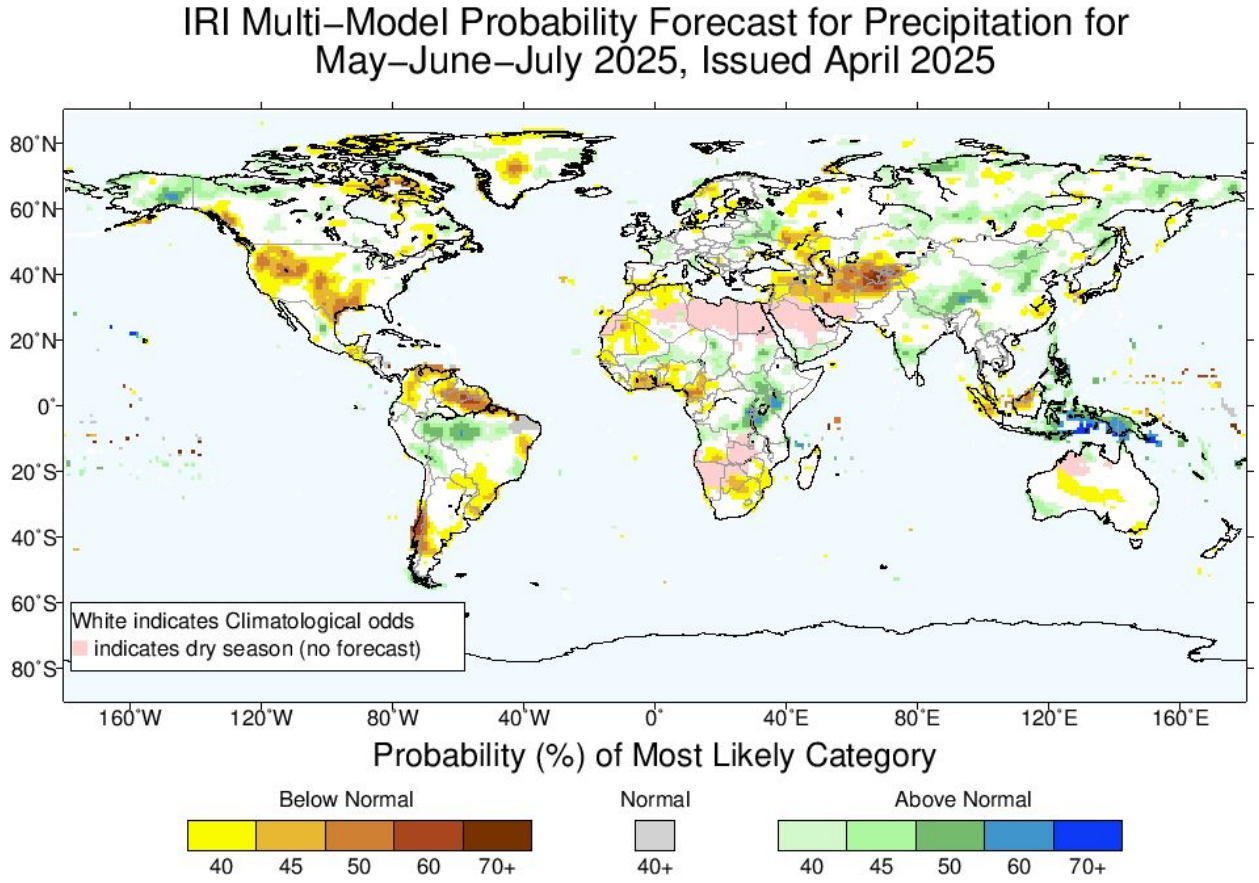


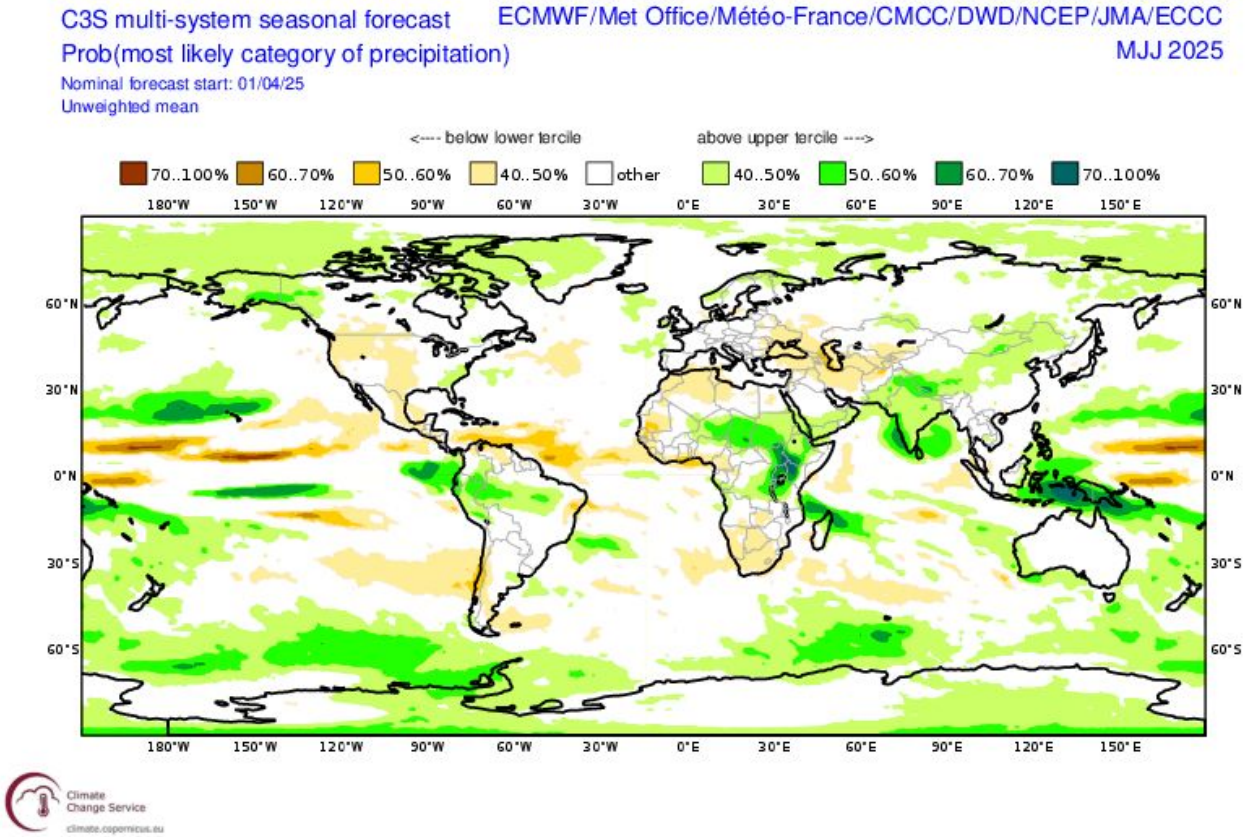
- Canonical La Niña impacts on rainfall patterns across the globe.
- For MAM drier anomalies are expected in:
  Parts of US and Mexico, parts of eastern Africa, parts of central Asia
- Wetter anomalies are expected in: northern South America, Southeast Asia, Philippines, Eastern Pacific, southern Africa, parts of Australia, Great Lakes area

Source: https://iridl.ldeo.columbia.edu/maproom/IFRC/FIC/laninarain.html

II. Seasonal forecasts

Precipitation



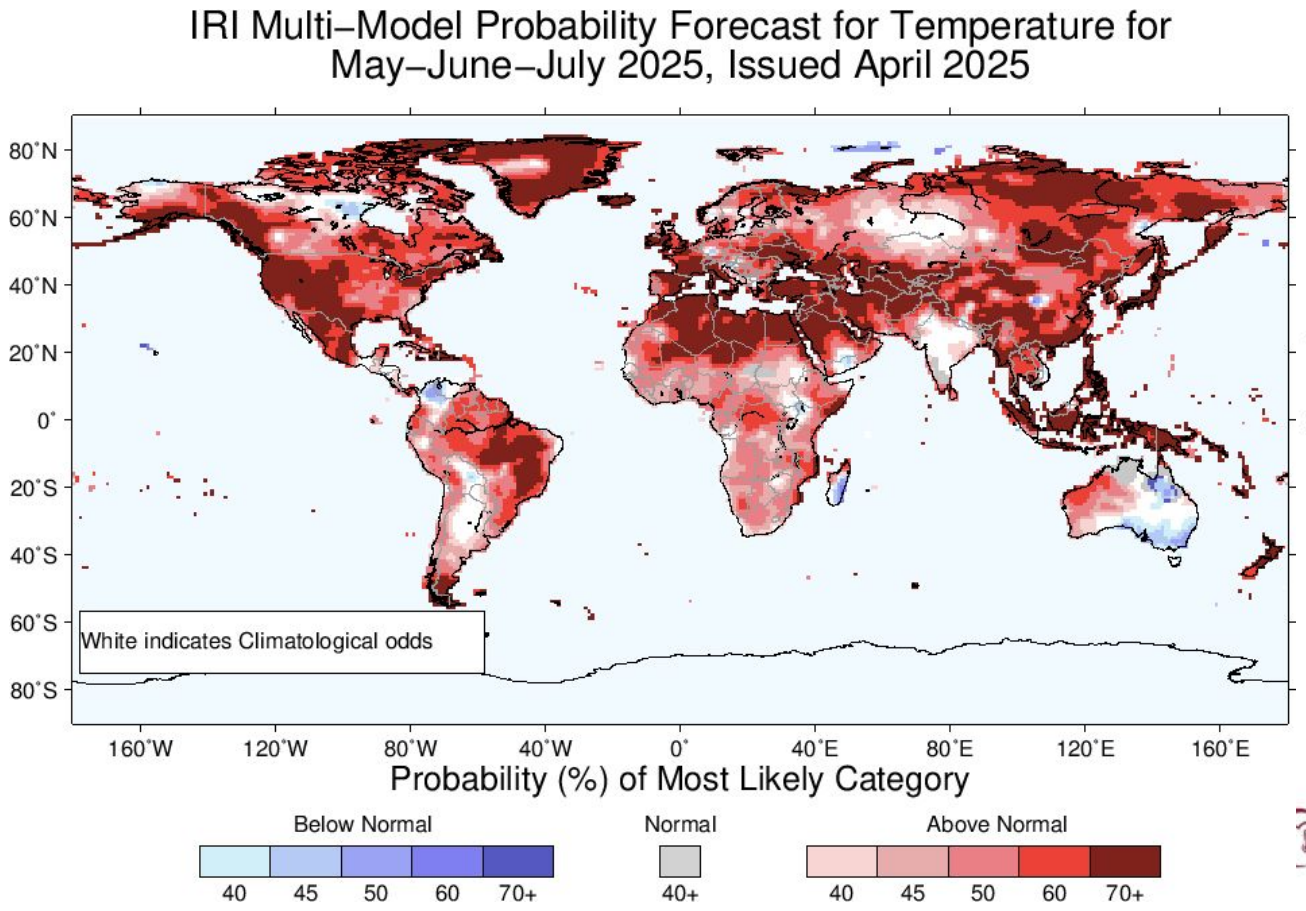


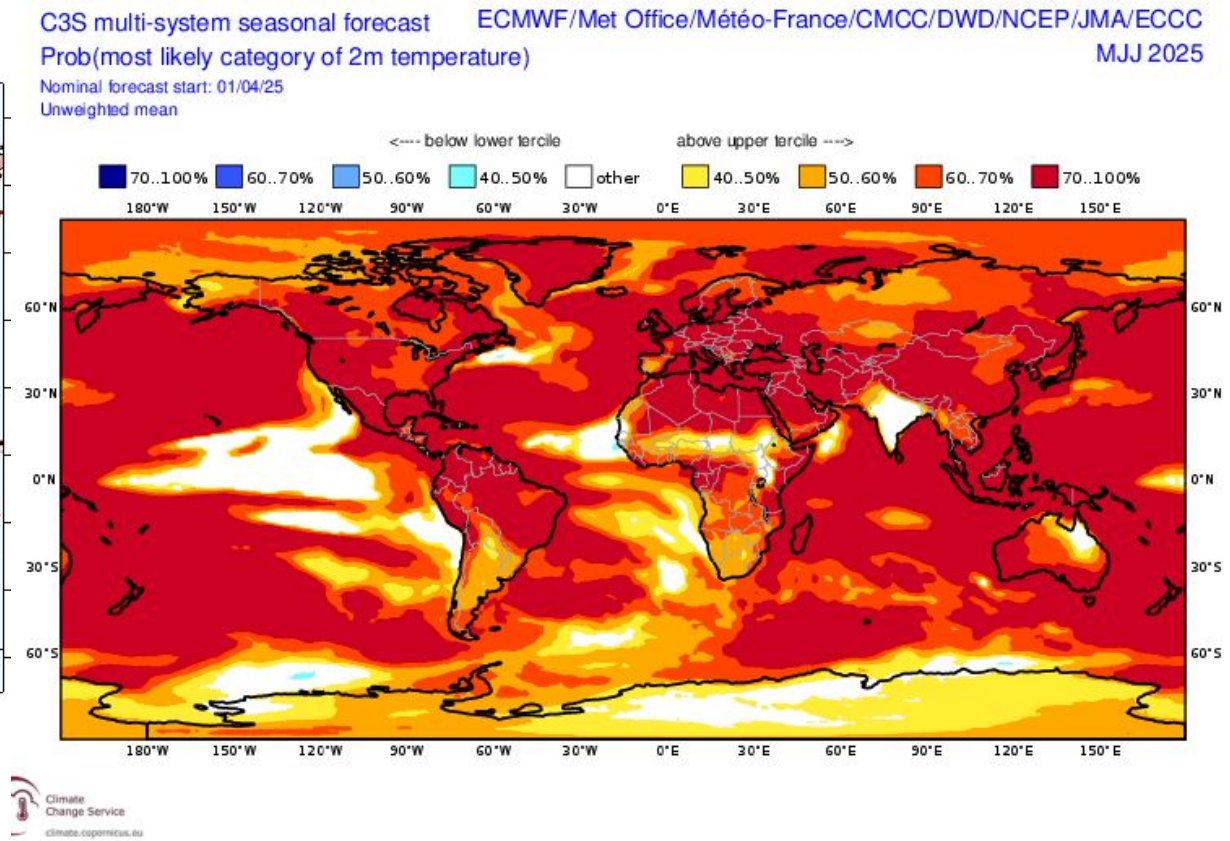
➢ Positive anomalies in Eastern Africa, India, Maritime Continent, parts of China, parts of South America.

Source: https://climate.copernicus.eu/charts/packages/c3s_seasonal/ / https://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/

II. Seasonal forecasts

Temperature





- Typical global warming signal.
- Parts of North Atlantic, Southern sea, Indochinese peninsula with cooler anomalies. Northern North America, southern South America, India and southern Africa with less warm signals.

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Source: https://climate.copernicus.eu/charts/packages/c3s_seasonal/ / https://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/

I. Recent state of the climate

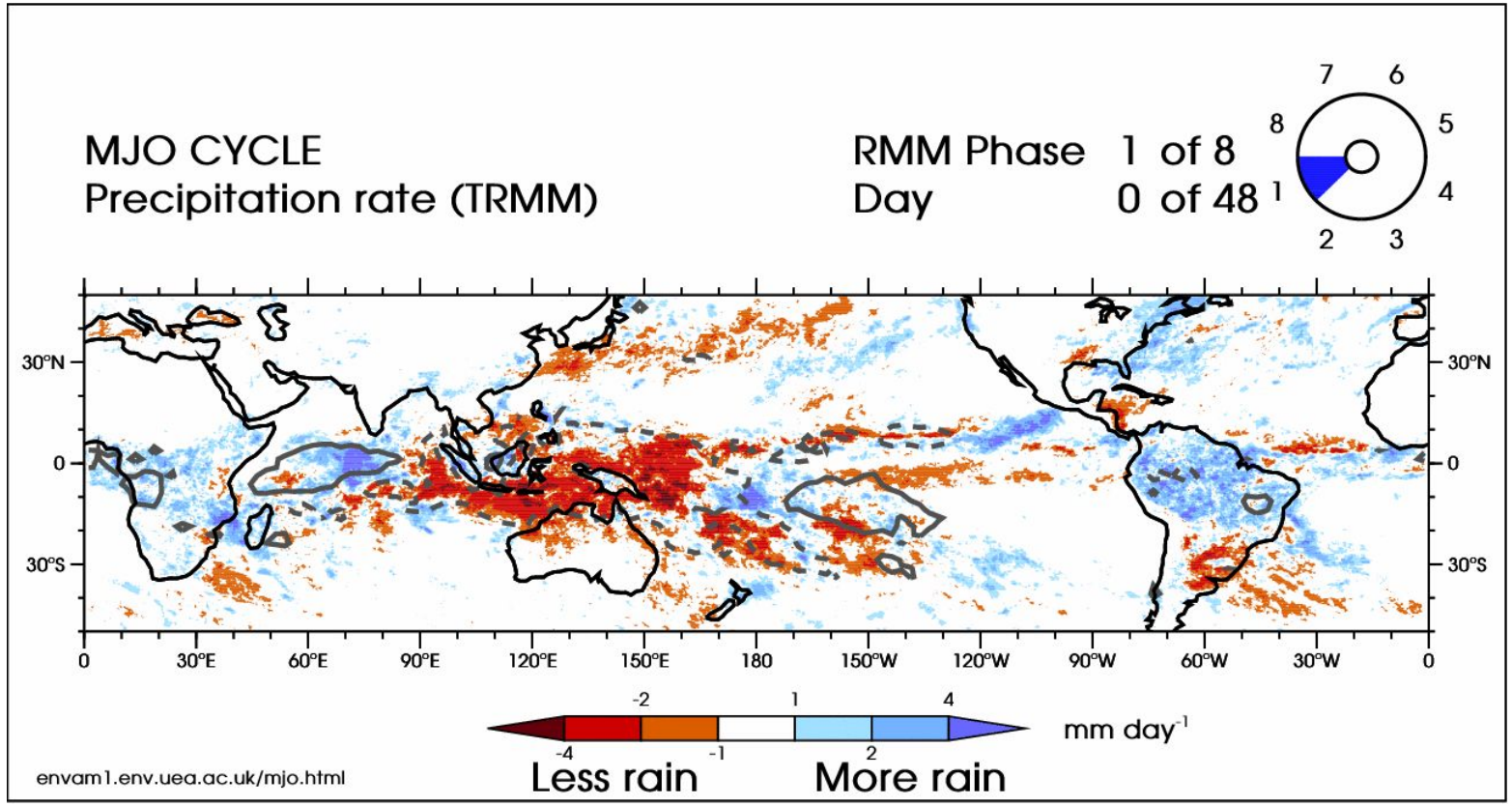
II. Seasonal forecasts

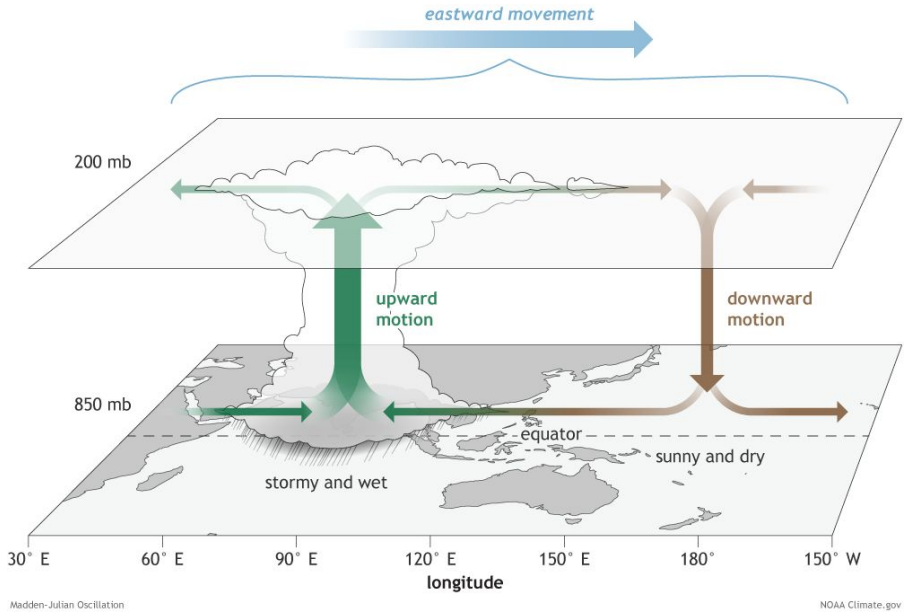
III. Intra-seasonal forecasts

III. Intra-seasonal forecasts

Madden-Julian Oscillation (MJO)

➢ The MJO is the leading mode of tropical intra-seasonal variability with a 20–90 days time scale. It is an important source of regional climate variability and predictability across the globe at intra-seasonal time scales.





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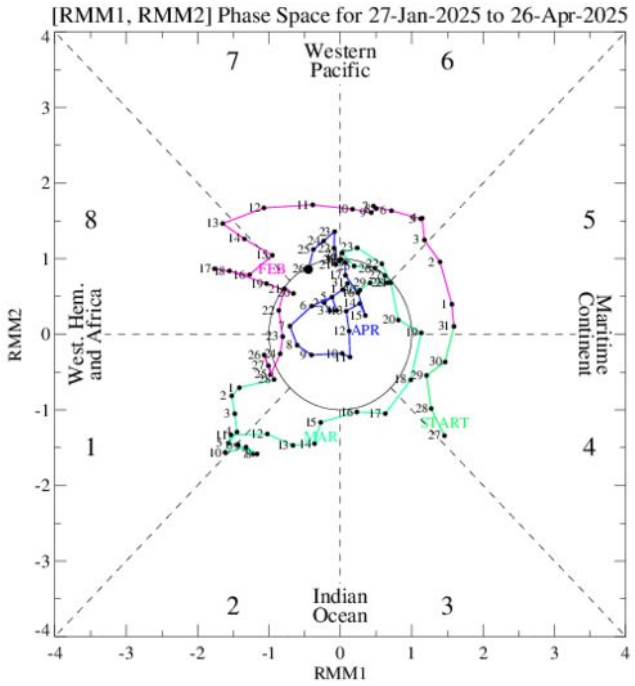
Source: https://www.climate.gov/news-features/blogs/enso/what-mjo-and-why-do-we-care

III. Intra-seasonal forecasts

MJO phase status

➢ RMM phase diagram for the latest 90 days



➢ **RMM index**

RMM = Real-time Multivariate MJO Index

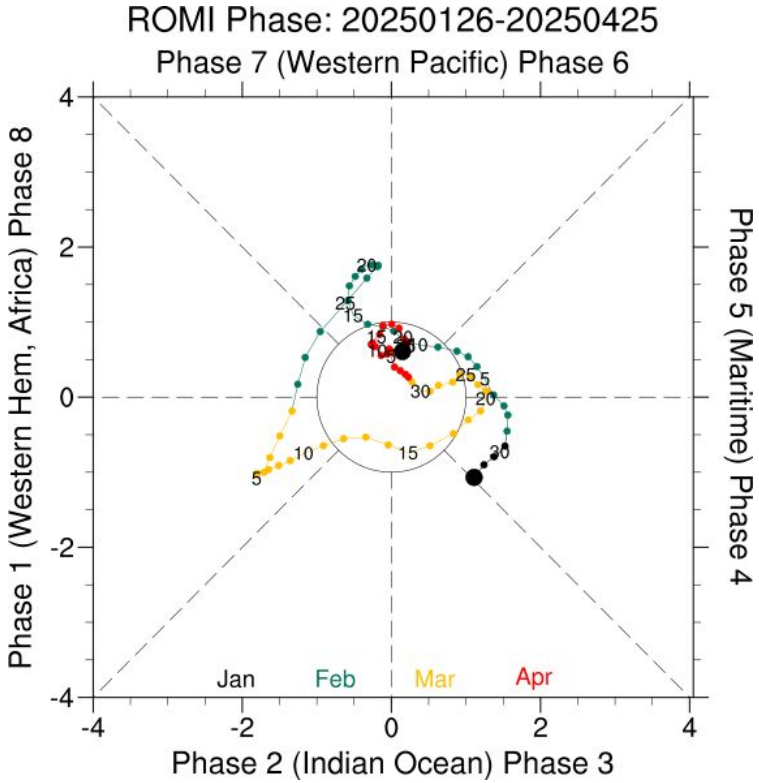
Developed by Matthew Wheeler and Harry Hendon (2004).

A multivariate index that combines:

- **Outgoing Longwave Radiation** (a proxy for convection/cloudiness)
- **Zonal winds at 850 hPa** (low-level winds)
- **Zonal winds at 200 hPa** (upper-level winds)

Projects these variables onto two principal components (RMM1 and RMM2) to define the MJO's location and intensity in an 8-phase diagram.

➢ ROMI phase diagram for the latest 90 days



➢ **ROMI index**

ROMI = Real-time OLR MJO Index

Developed as a simpler alternative to RMM.

Based only on OLR data.

Uses empirical orthogonal function (EOF) analysis of OLR to define MJO phases.

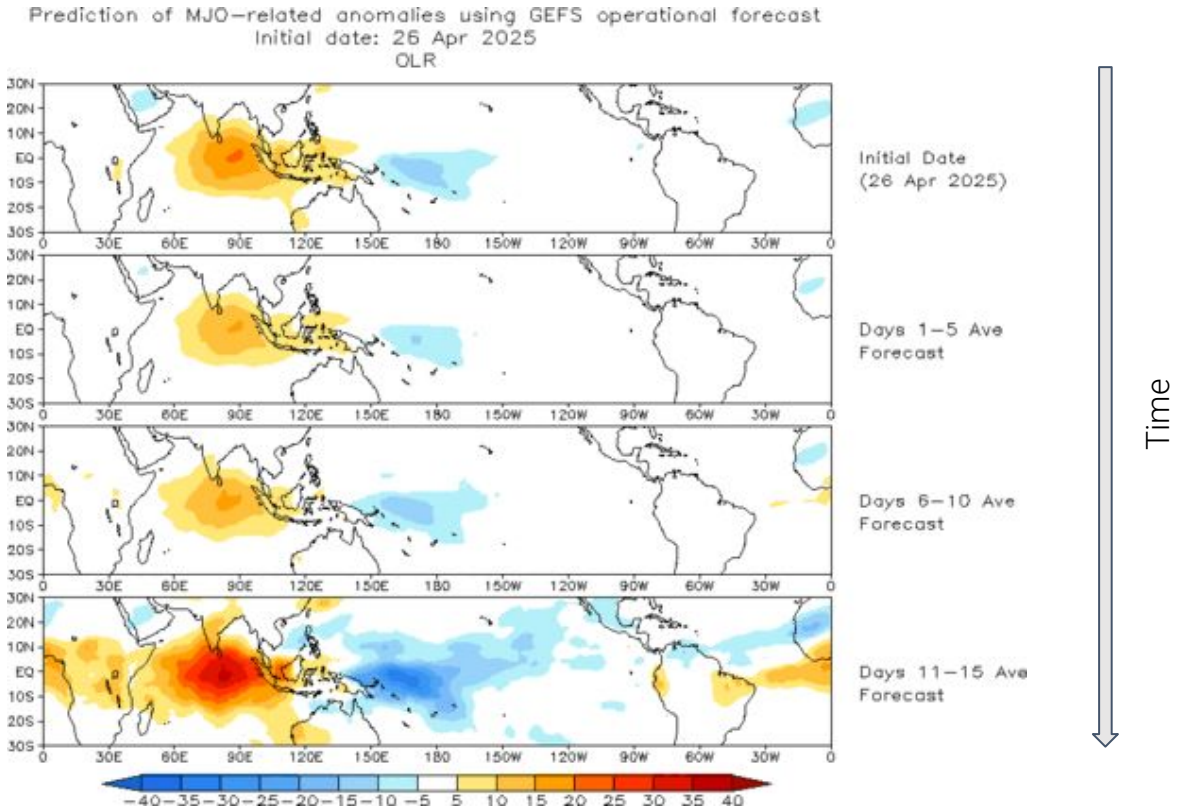
➢ During March, the MJO transitioned from phases 1-2 to be inactive. It remained inactive for much of April.

Source: https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/whindex.shtml / https://psl.noaa.gov/mjo/

III. Intra-seasonal forecasts

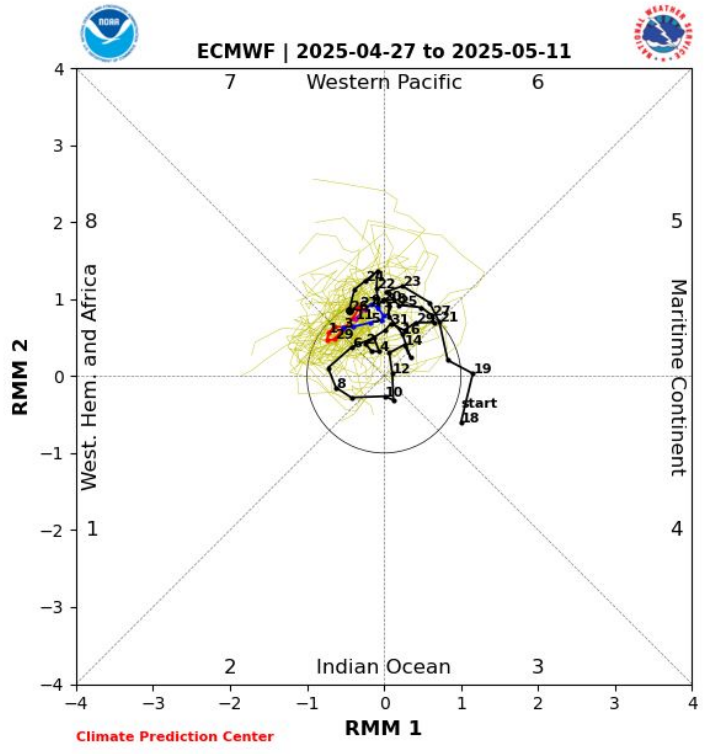
MJO forecasts

➢ OLR anomalies [W/m2] (ensemble mean GEFS)



Low OLR (enhanced convection) / High OLR (suppressed convection)

➢ Evolution of last 40 days of observations + ensemble forecast



Mean forecasts: 1-7 day, 8-14 day, >= 15 days

➢ MJO is expected to stay in the Western Pacific, although with large uncertainty.

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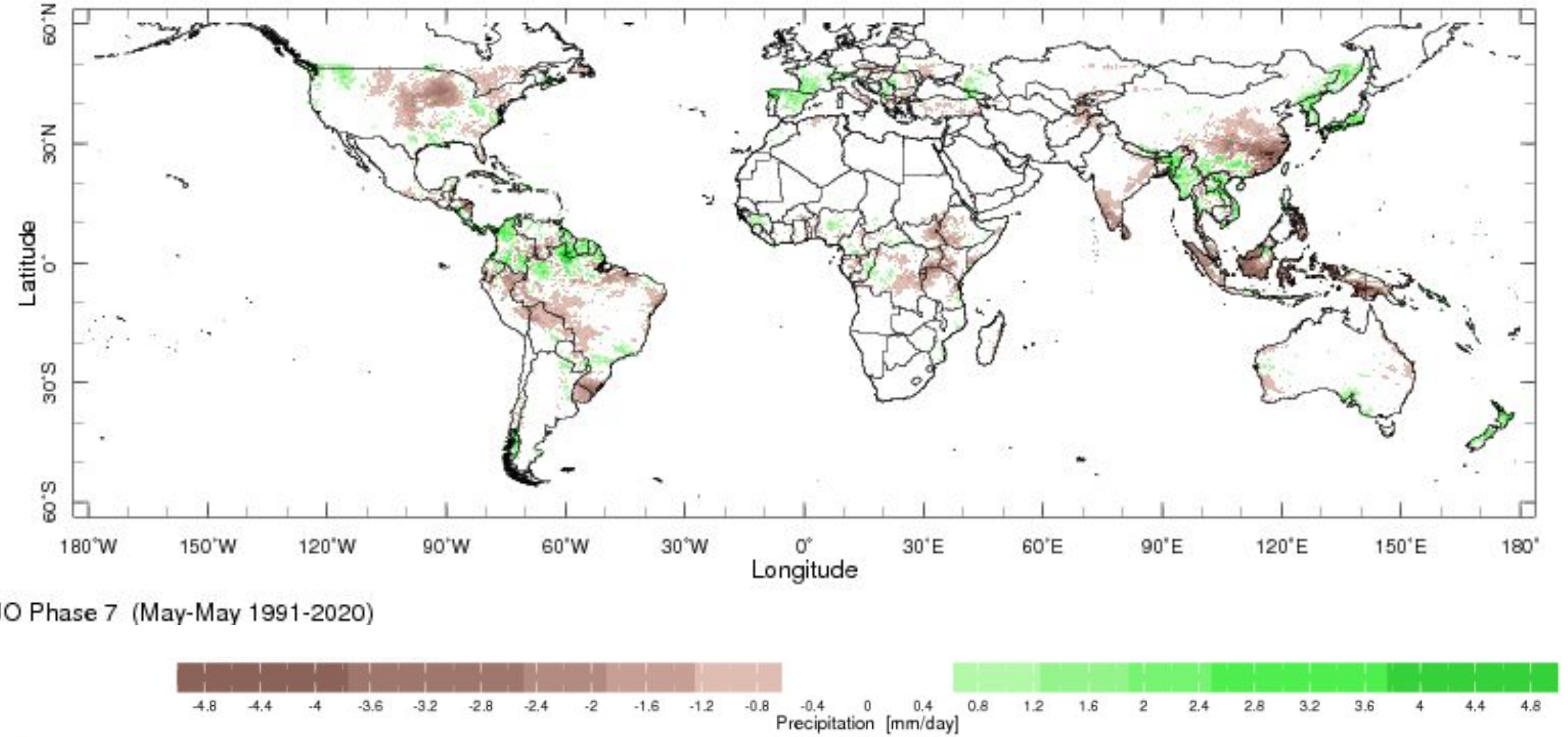
Source: https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/foregfs.shtml / https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/ecmf.shtml

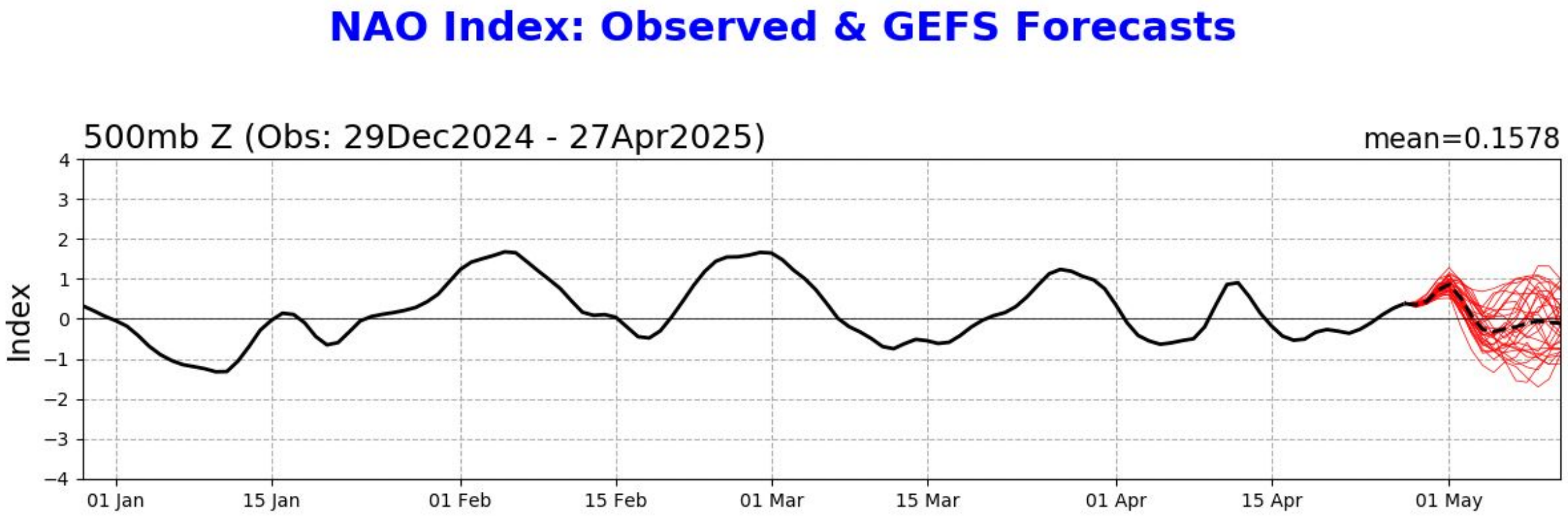
➢ Precipitation composite during MJO Phase 7 in May

Composite = average pattern



Source: IRI link

NAO forecast

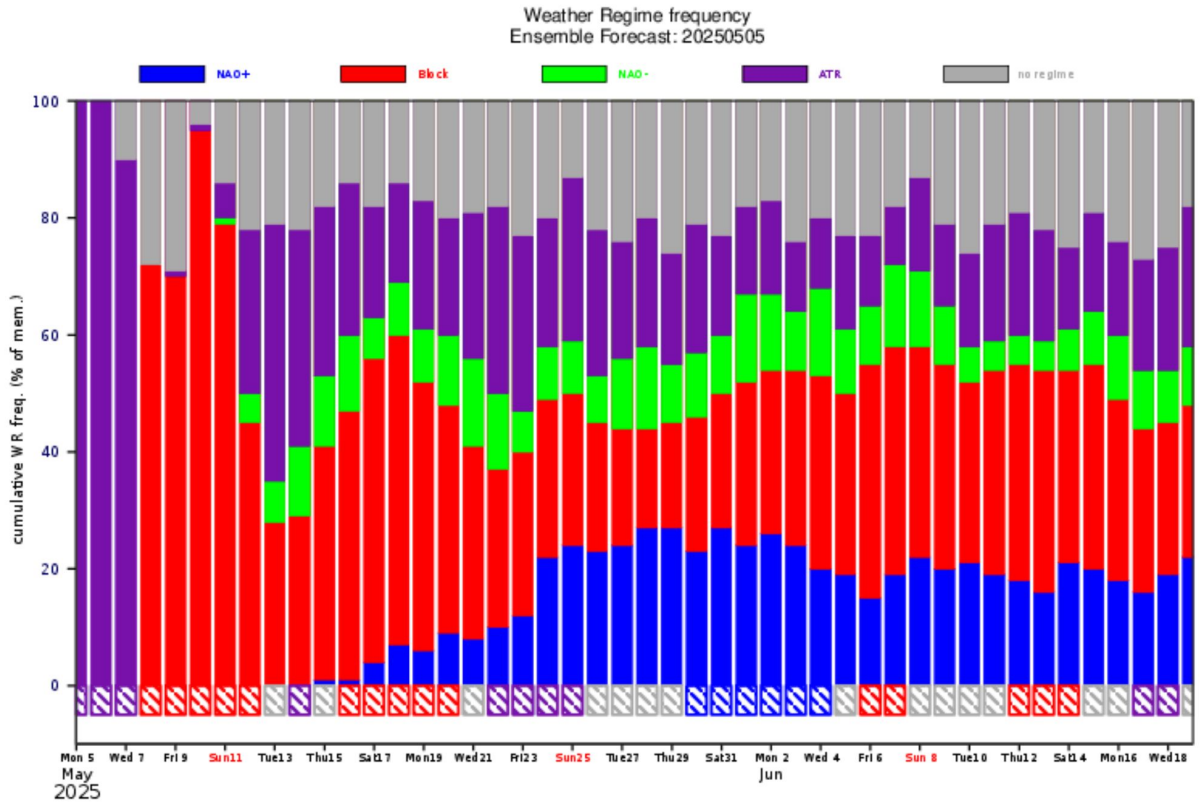


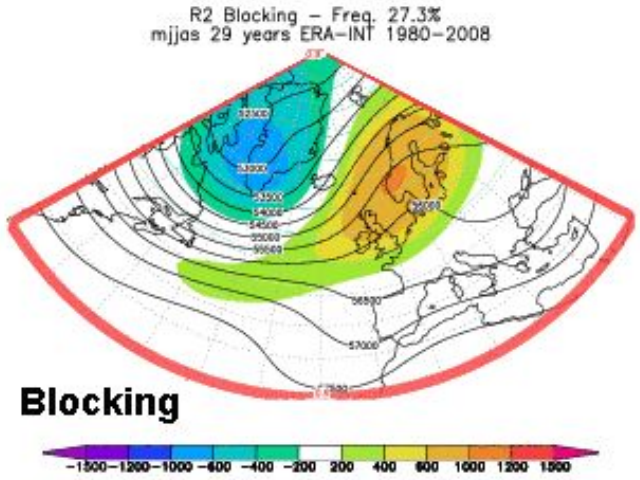
Source: https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao_index_ensm.shtml

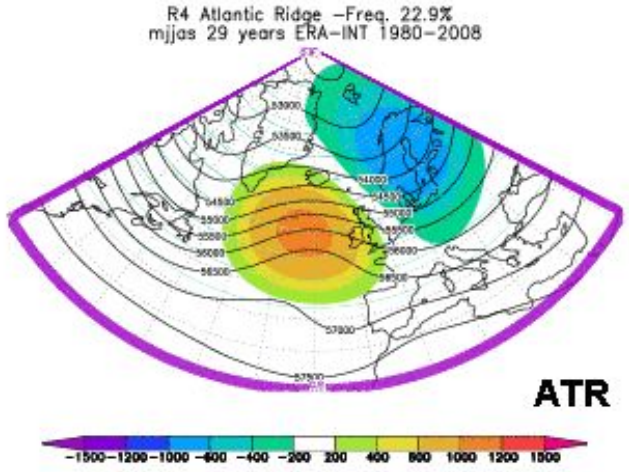
III. Intra-seasonal forecasts

Weather regimes

Weather regimes probabilities - Extended range forecast







ECMWF

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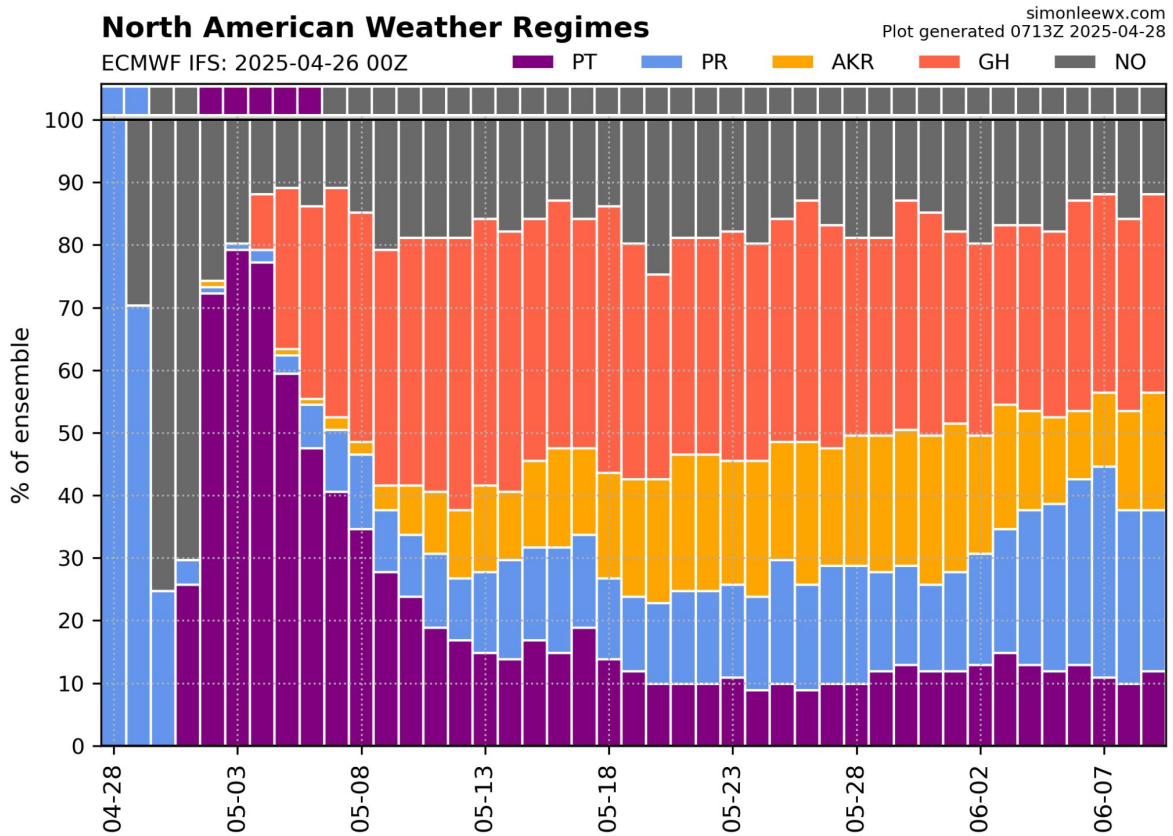
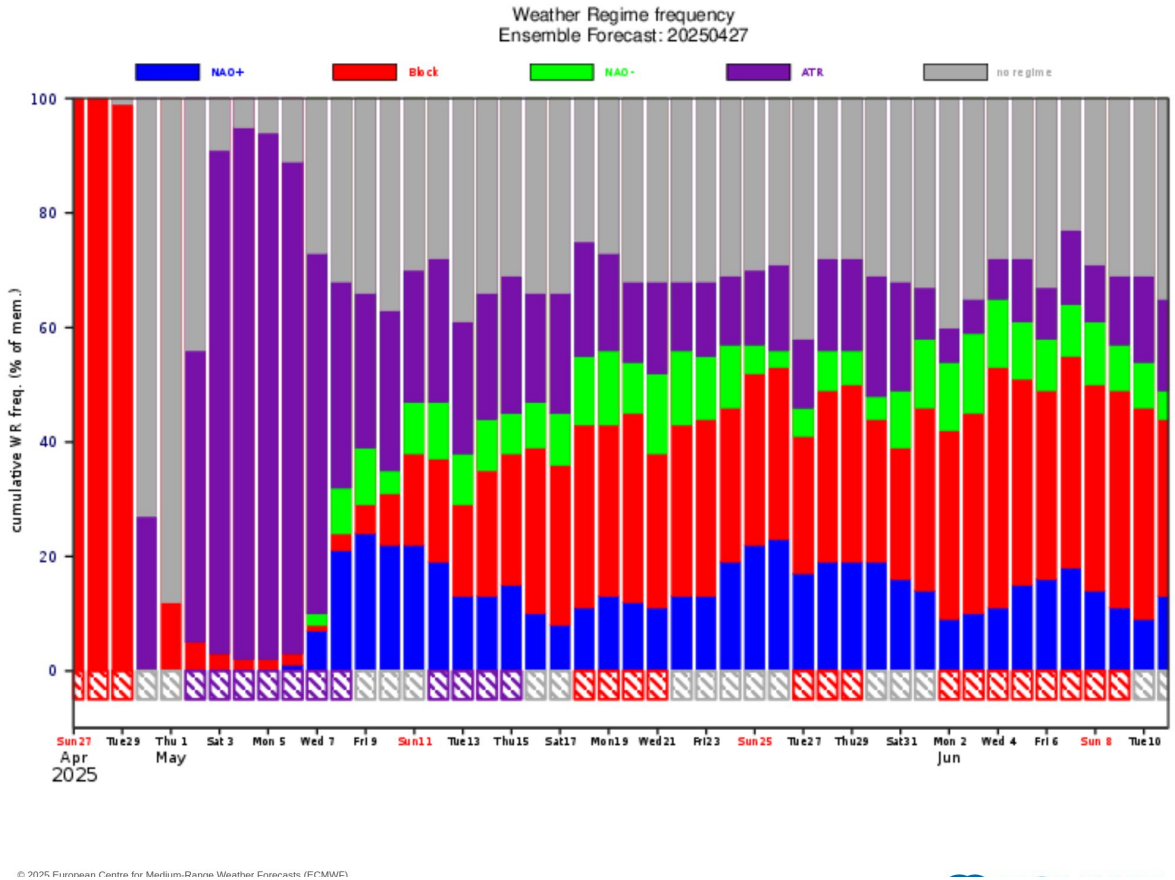
Source: https://charts.ecmwf.int/products/extended-regime-probabilities?forecast_from=latest





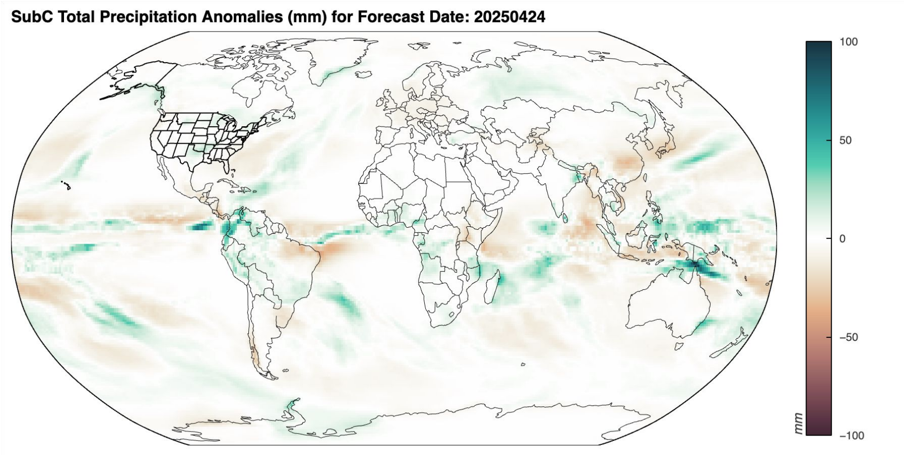
- Increased likelihood of GH (in Europe NAO+, Messori et al., 2023) as expected in the North American regimes.
  - But we don't observe an increased likelihood of any regime in the ECMWF S2S forecast?

Source: https://simonleewx.com/ecmwf_north_america_regimes/

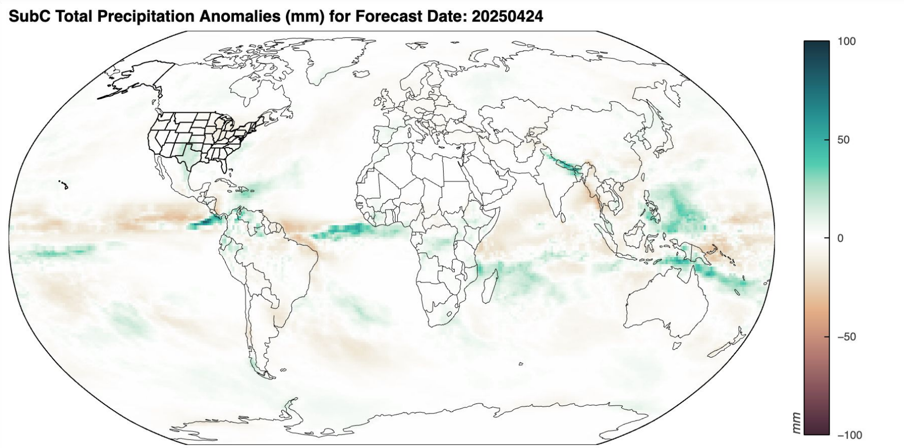
III. Intra-seasonal forecasts

Precipitation

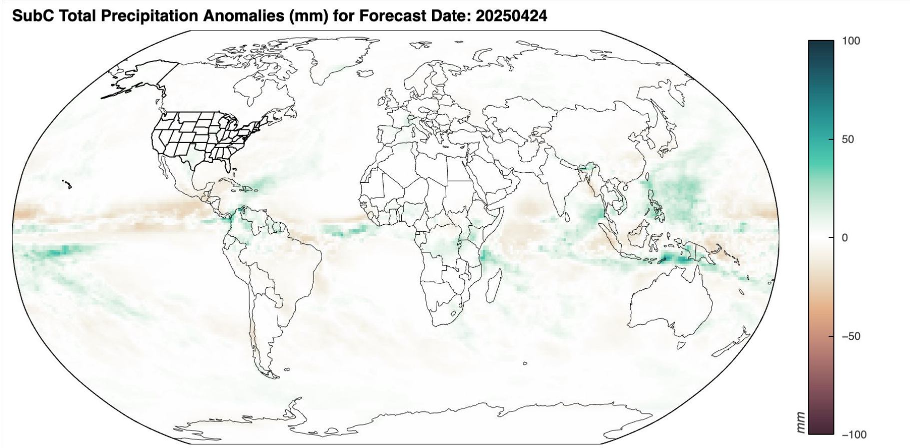
Week 1



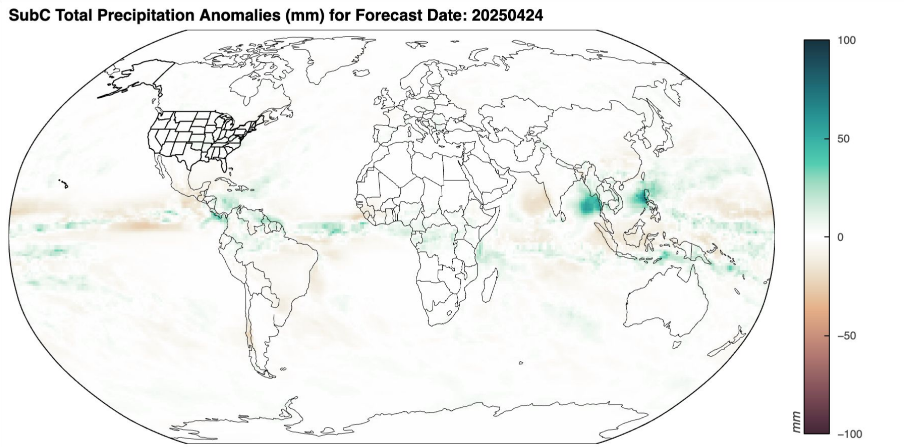
Week 2

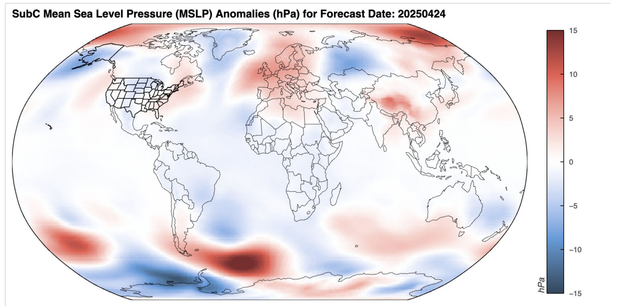


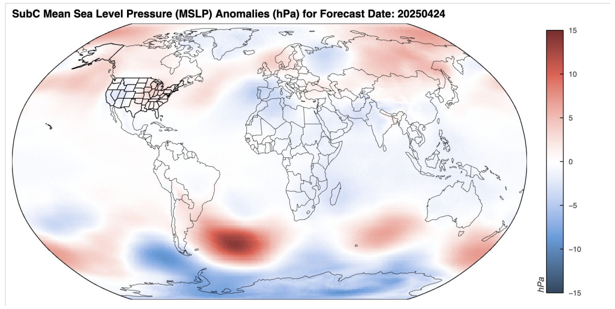
Week 3

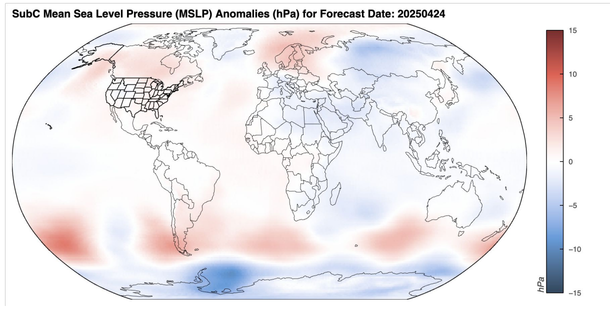


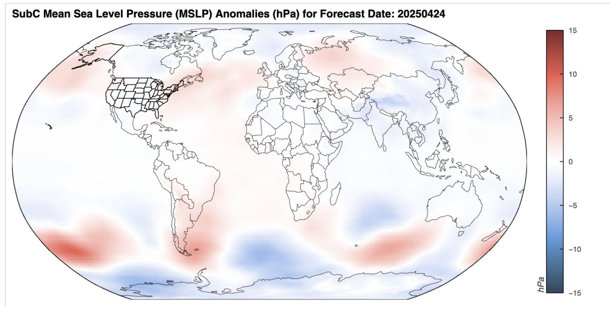
Week 4











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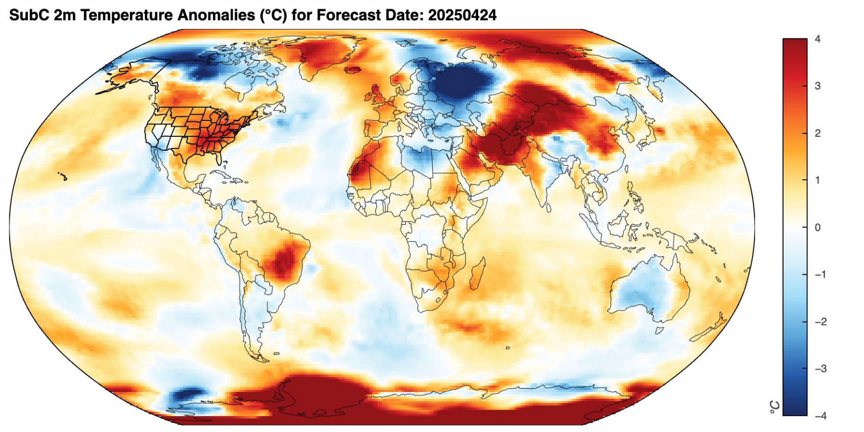
Source: http://weather.ou.edu/~kpegion/subc/forecasts/images/Latest/Interactive.html

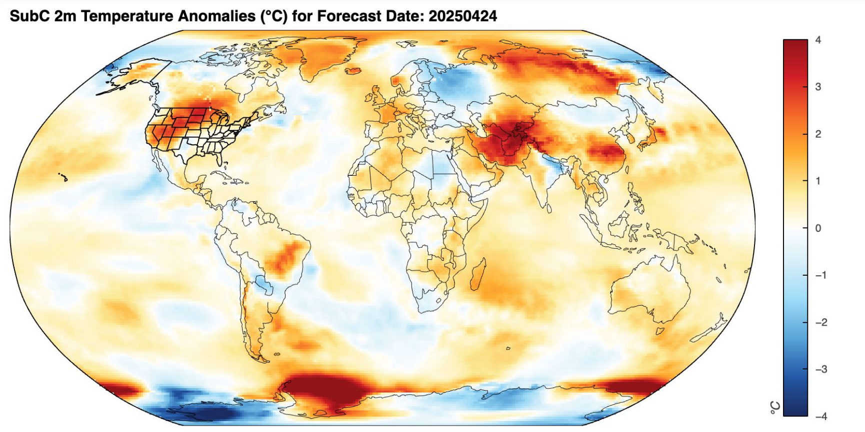
III. Intra-seasonal forecasts

Temperature

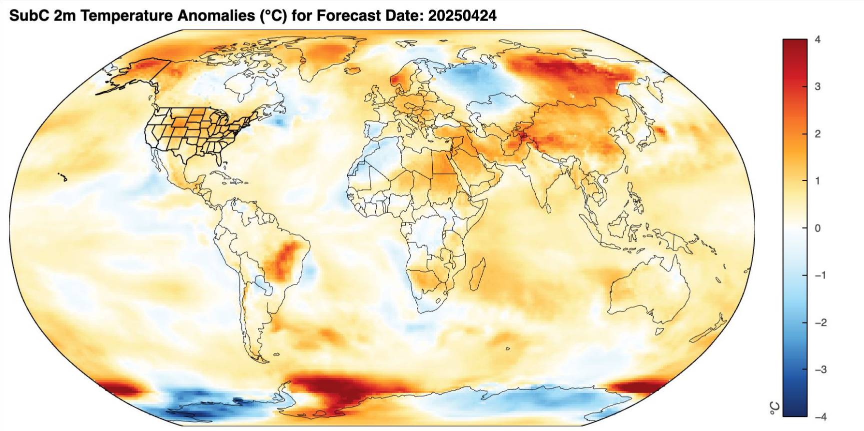
Week 1



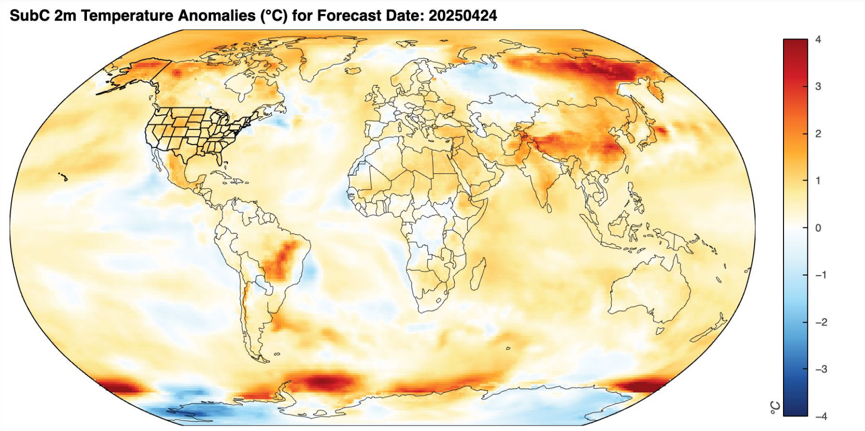
Week 2

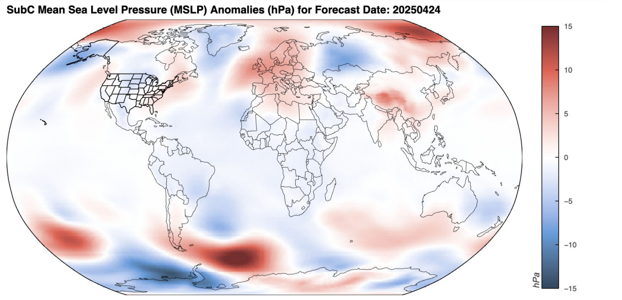


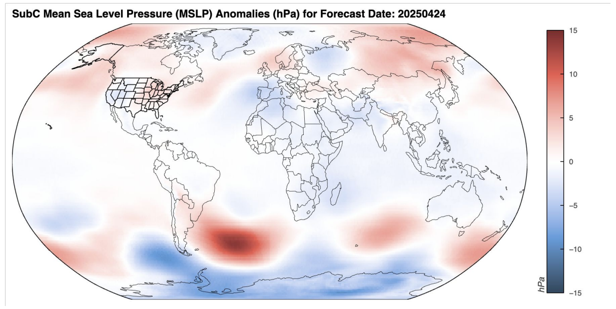
Week 3

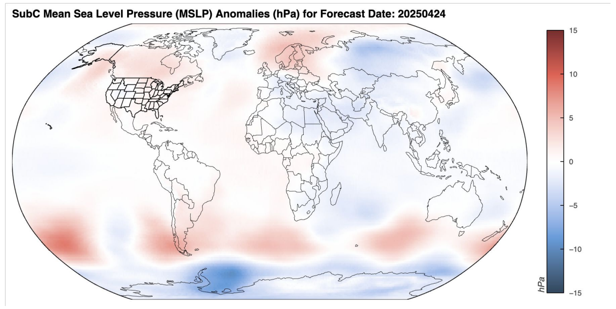


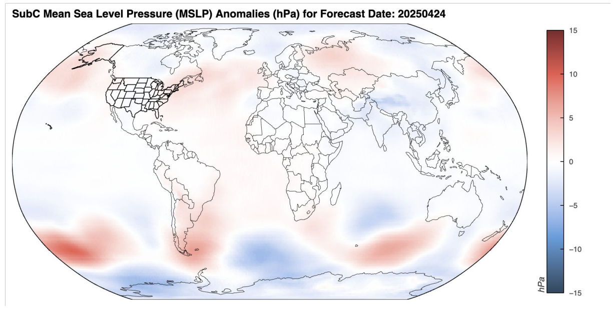
Week 4











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Source: http://weather.ou.edu/~kpegion/subc/forecasts/images/Latest/Interactive.html

I. Recent state of the climate

II. Seasonal forecasts

III. Intra-seasonal forecasts

IV. Discussion

Summary

Recent state of the climate

- Persistent observed dry anomalies in most of the Americas, the Guinean coast, Congo, central Asia, parts of Australia, most of Europe, Southeast Asia, eastern China, Madagascar, eastern Siberia, parts of India and Australia.

- Both record wet (Iberian peninsula, south of France, parts of Italy) and dry in central-north Europe (North of Germany, Alps, etc.).

- Persistent weak **la Niña** with warm anomalies in the Niño 1+2 region (Coastal El niño).

- Sudden stratospheric warming (likely final event) starting around the 12th of March with likelihood of mild conditions over europe in the upcoming weeks.

- During February MJO avoided phase 8 due to strong subsidence in the CP. It became active at the beginning of March (phases 1 and 2) and has since then become inactive.

Summary

Seasonal forecasts

- High likelihood of return to neutral conditions during MAM 2025.
- Apart from southern Africa, anomalies in precipitation could be consistent with a La Niña.
- Typical global warming signal in seasonal temperature forecasts. Parts of North Atlantic, Southern sea, Indochinese peninsula with cooler anomalies. And northern North America, southern South America, India and southern Africa with less warm signals.

Summary

Intraseasonal forecasts

- High likelihood of inactive MJO for the forthcoming weeks.
- Increased likelihood of mild conditions over europe in the upcoming weeks, in-line with SSW impacts and ECMWF forecast.
  - Increased likelihood of GH in the US.

Discussion

- What lead to the anomalous rainfall in the Iberian peninsula?
- What impacts will the final stratospheric warming have?
- Inconsistencies between ENSO forecasts and seasonal predictions.

Earth Sciences Department

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Forecast Briefing

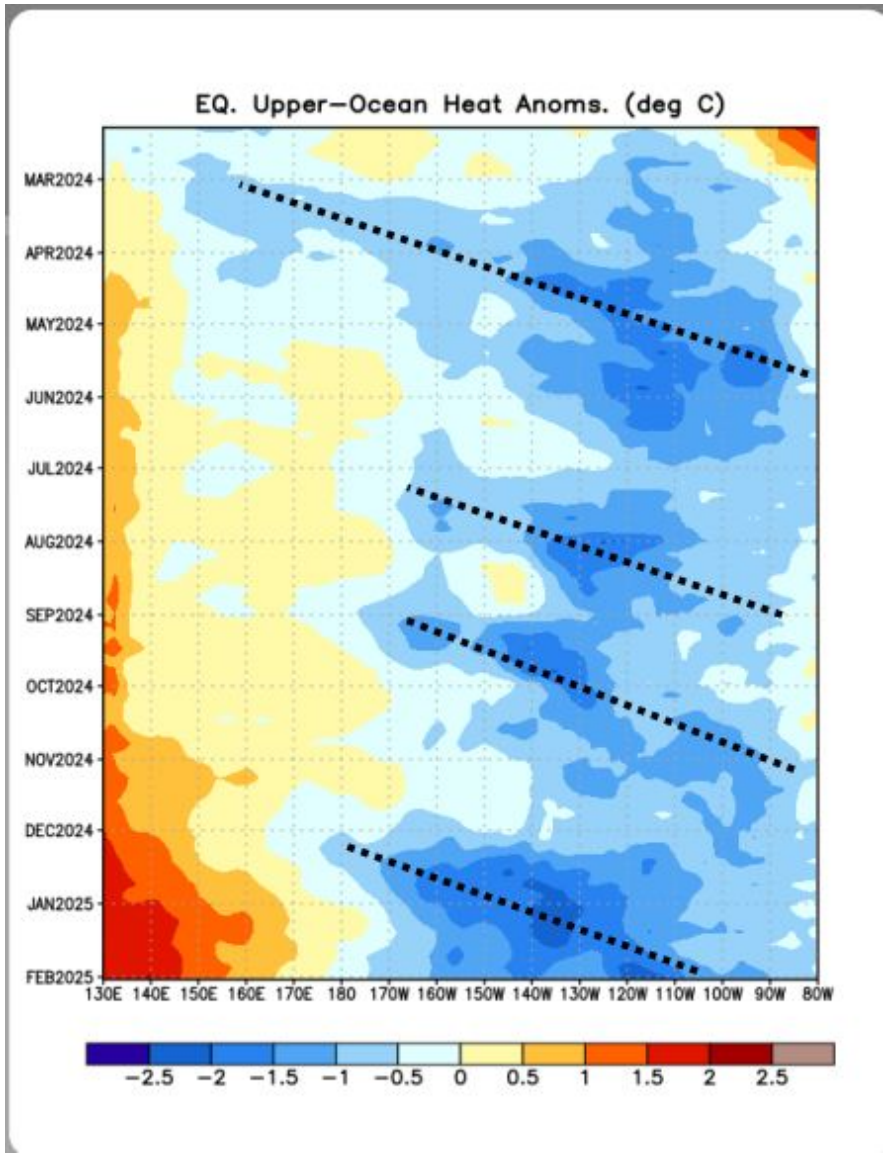
April 2025

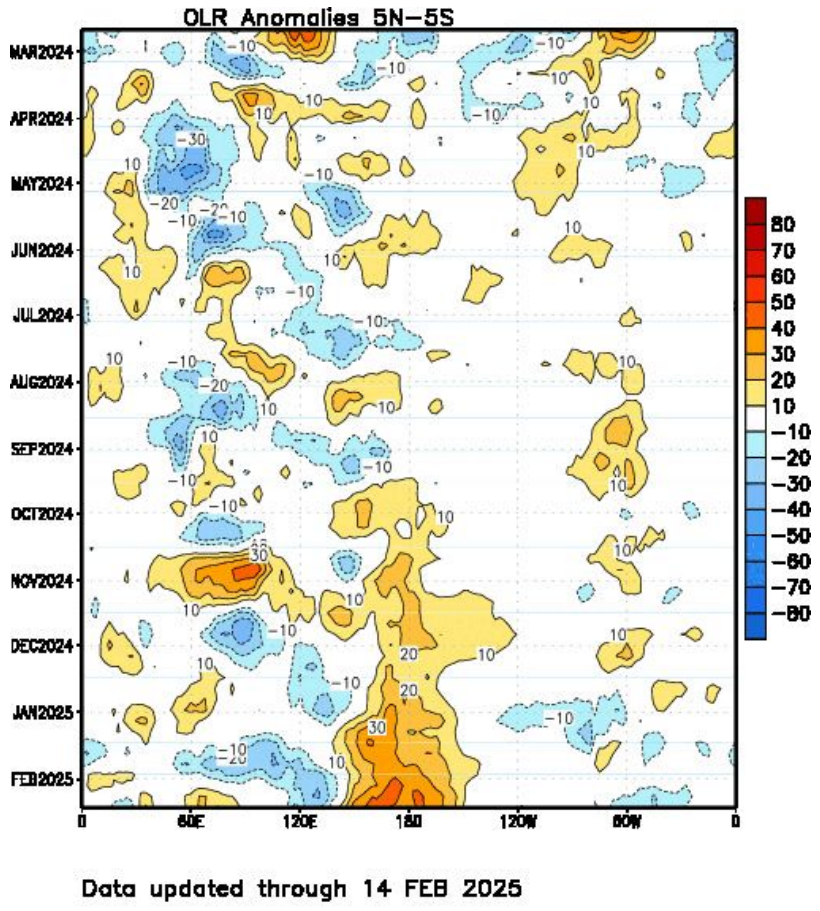
Climate Services Team (CST)

Earth System Services (ESS)

Barcelona Supercomputing Center (BSC)

Tuesday 22nd Apr 2025





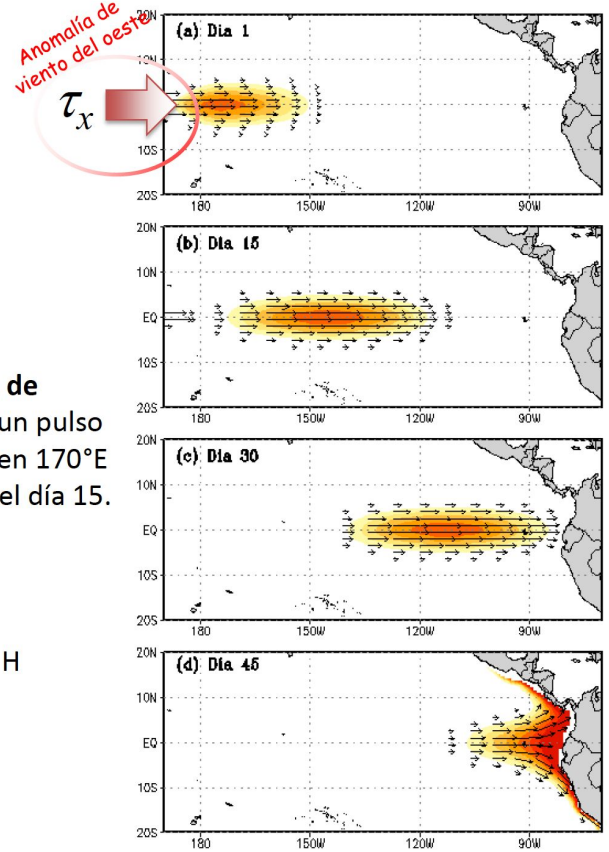
- Since mid-September 2024, positive OLR anomalies (suppressed convection/ rainfall) have persisted near the Date Line.
- Since early December 2024, negative OLR anomalies (enhanced convection/ rainfall) have emerged over Indonesia.

Drier-than-average conditions (orange/red shading)

Wetter-than-average conditions (blue shading)

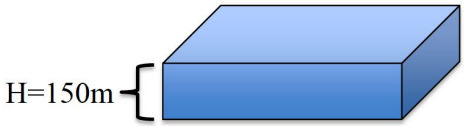
Source: https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

¿Cómo se forma una onda Kelvin cálida?



Simulación numérica de la propagación de una onda Kelvin Ecuatorial forzada por un pulso de viento del oeste ecuatorial centrado en 170°E durante 30 días con un pico máximo en el día 15.

Océano de profundidad H

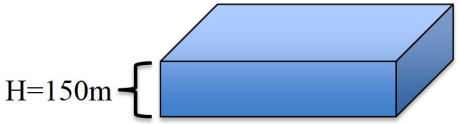


Mosquera (2014)

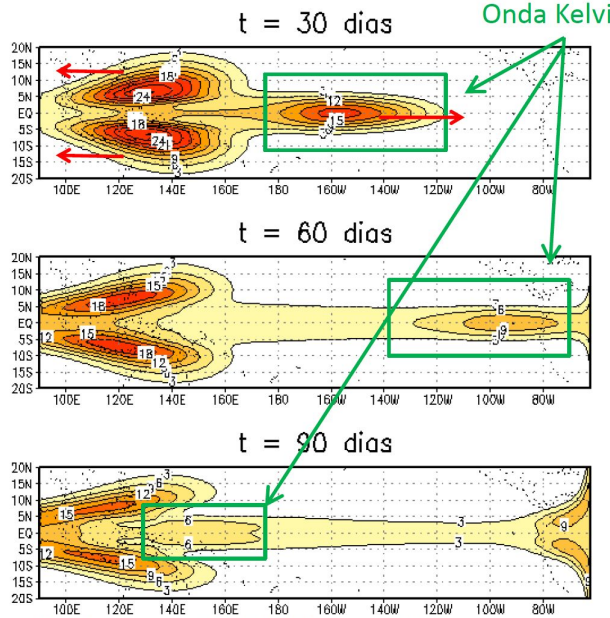
¿Cómo se forma una onda Kelvin cálida?

Como consecuencia de la reflexión de la onda Rossby en la frontera occidental

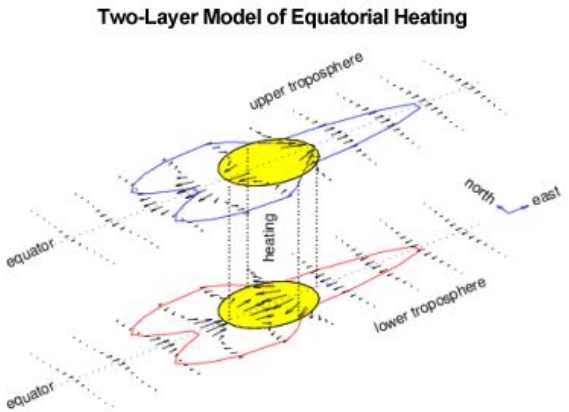
Océano de profundidad H



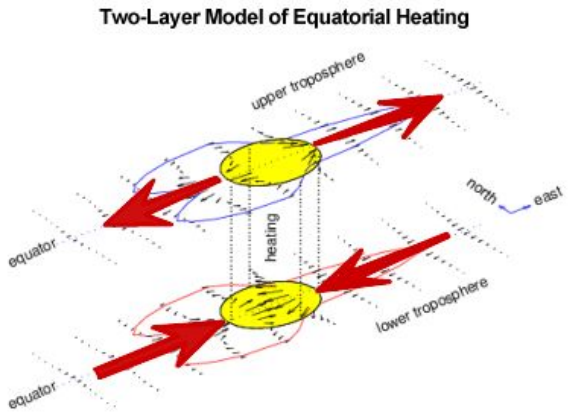
Nivel del mar



Simulación con LOM-IGP (Mosquera, 2009)



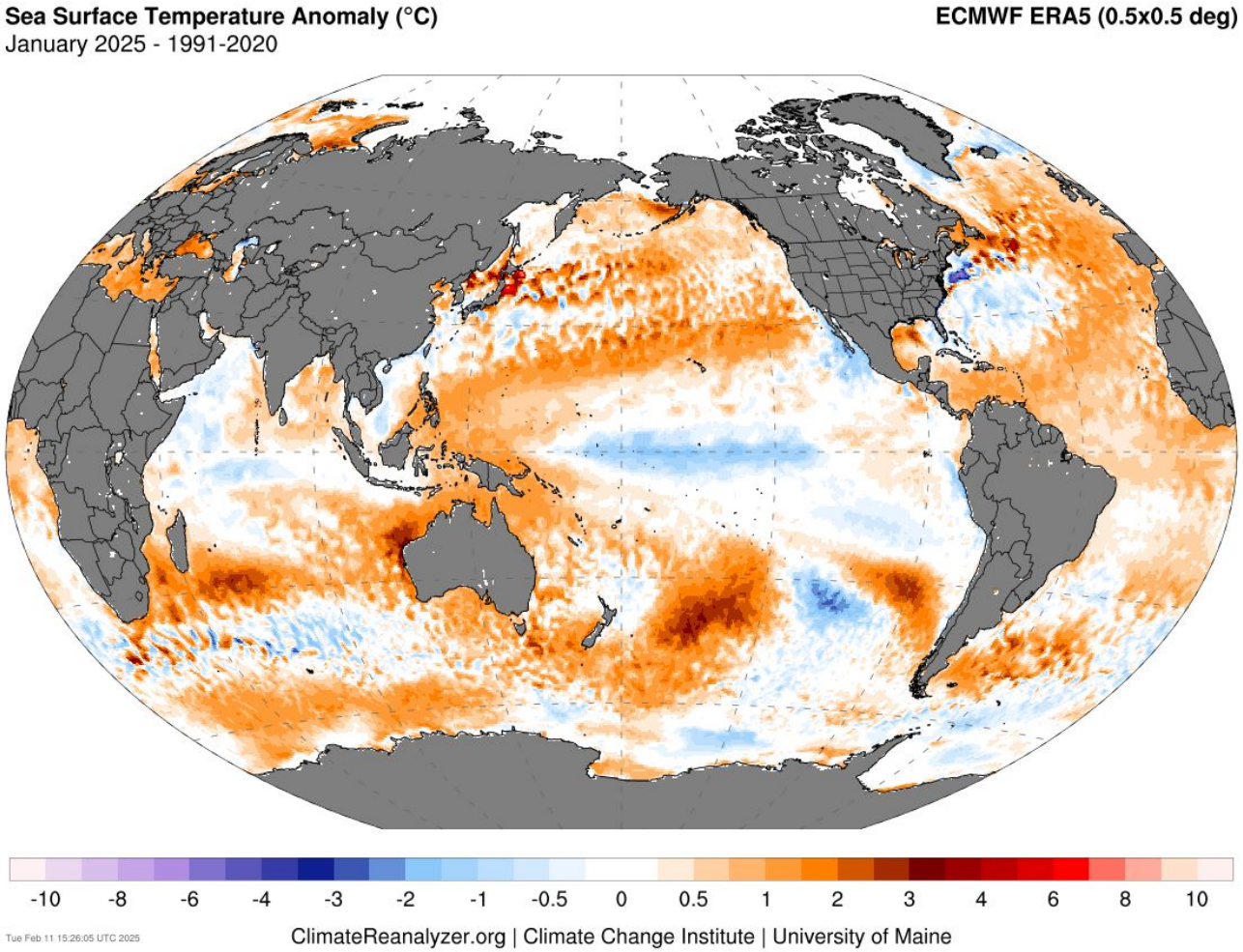
Gill, 1980: Q

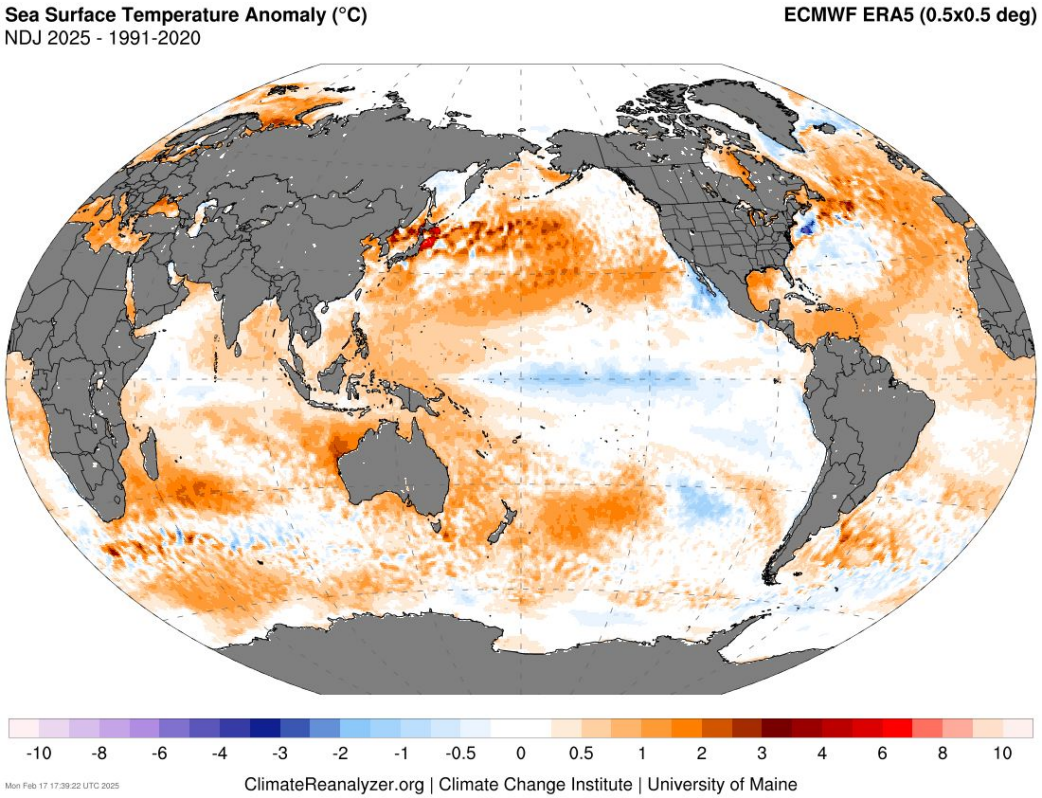


Gill, 1980: QJRMS

I. Recent state of the climate

Sea surface temperature (SST)





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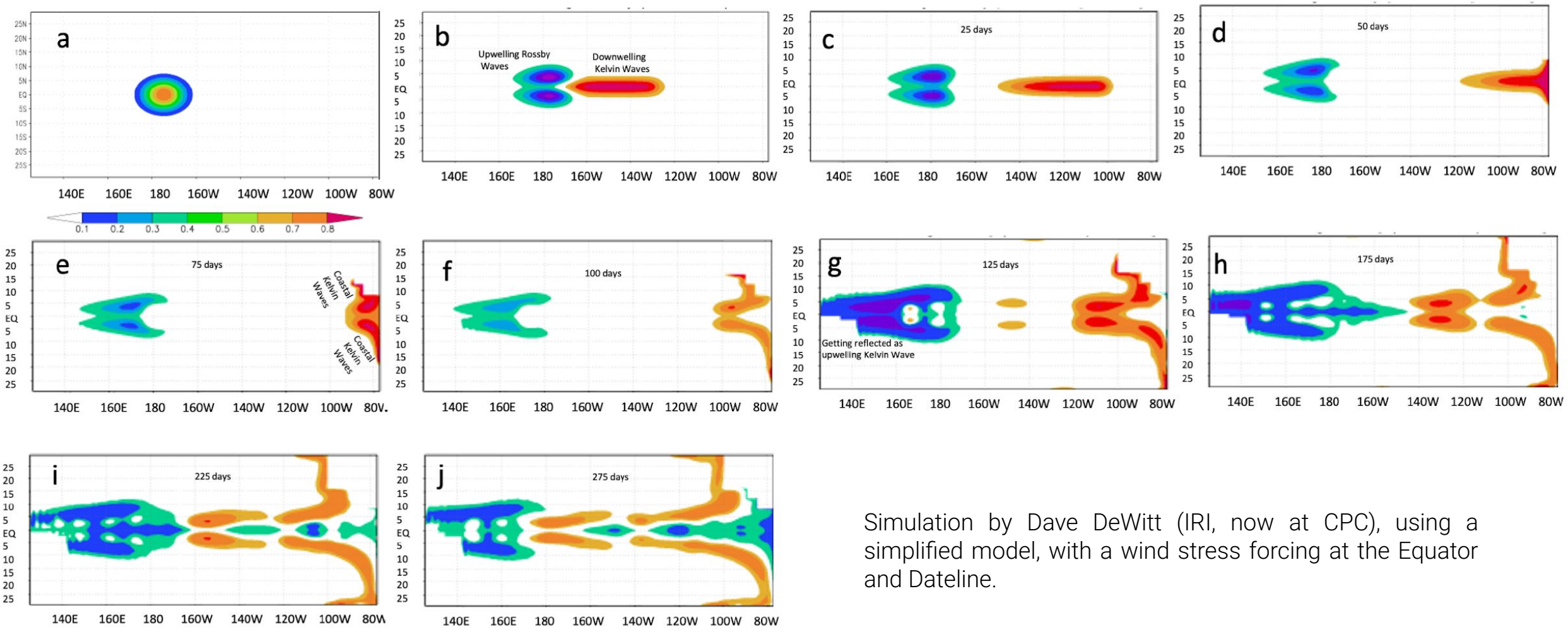
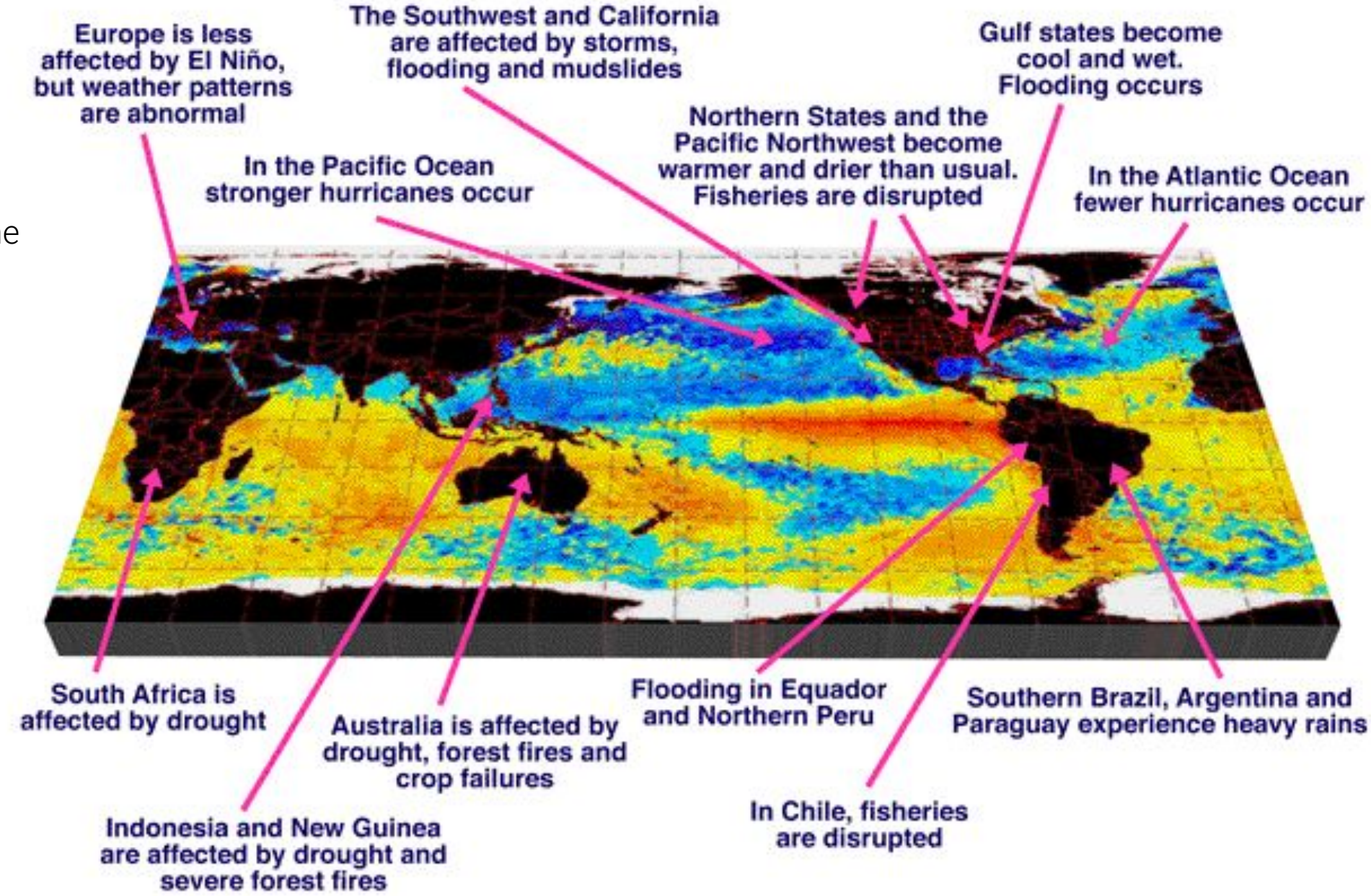
Source: https://climatereanalyzer.org/research_tools/monthly_maps/



Simulation by Dave DeWitt (IRI, now at CPC), using a simplified model, with a wind stress forcing at the Equator and Dateline.

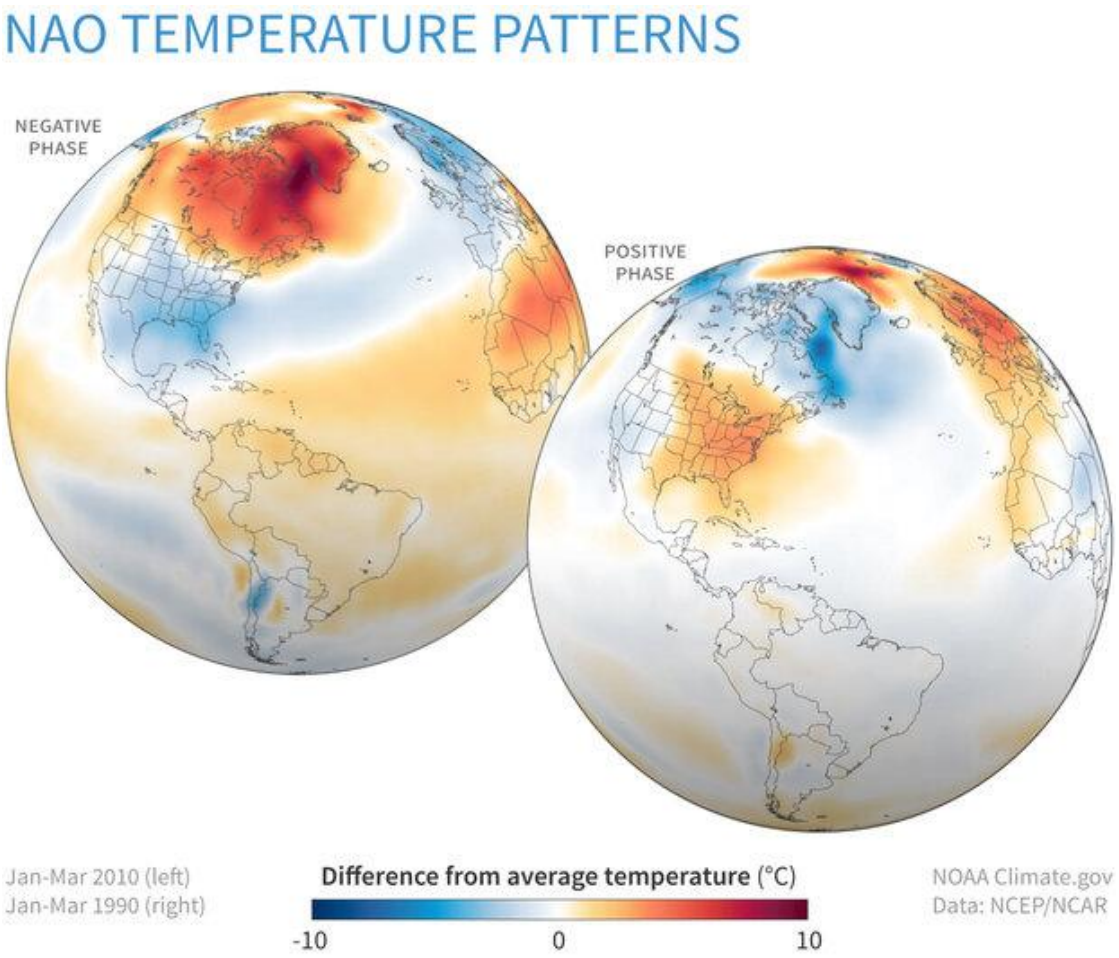
- Canonical El Niño impacts across the globe.

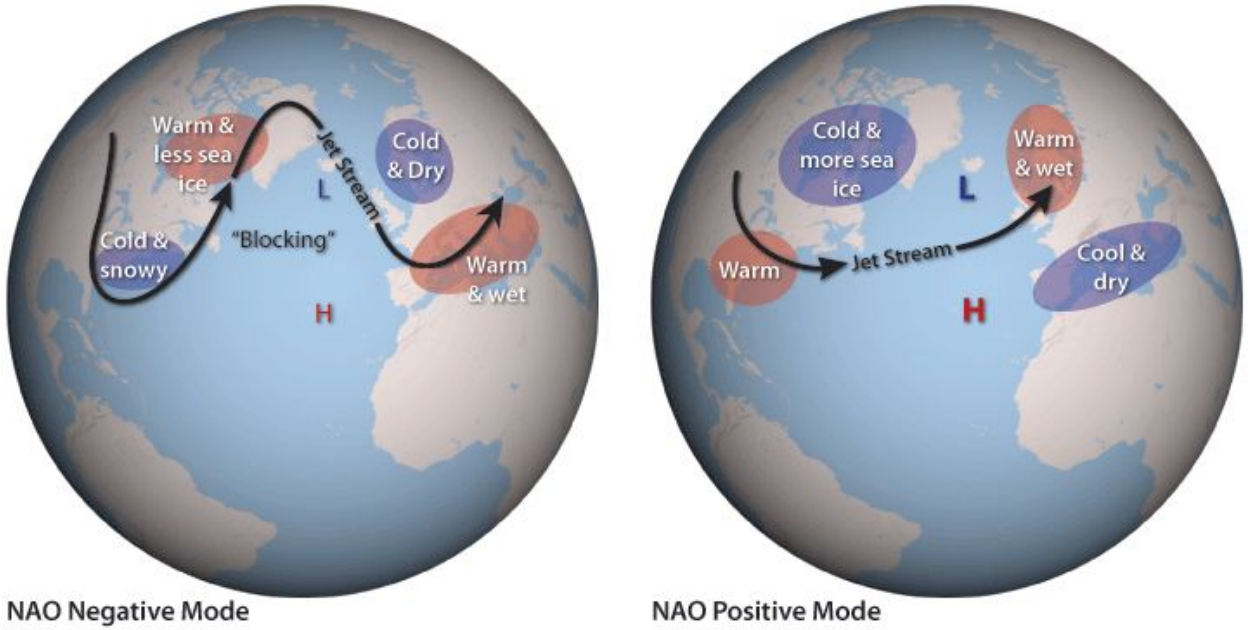


I. Recent state of the climate

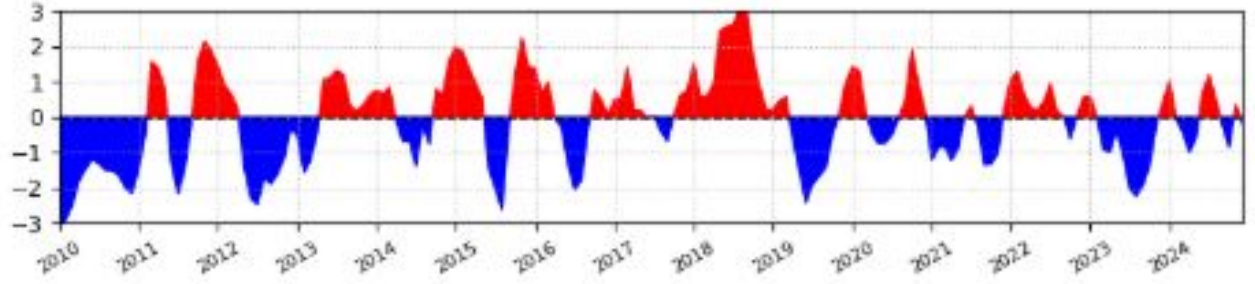
North Atlantic Oscillation (NAO)

➢ The North Atlantic Oscillation (NAO) is the leading mode of large-scale atmospheric variability in the North Atlantic basin.





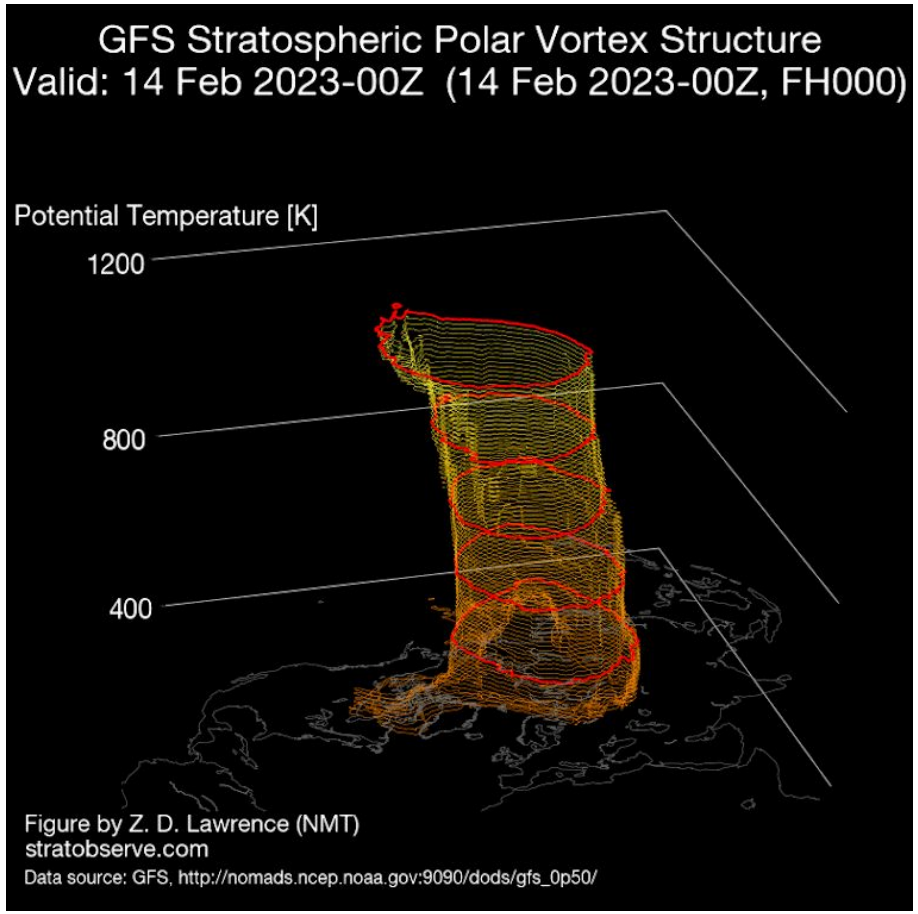
NAO index: Standardized 3-month Running Mean Index (through Jan 2025)

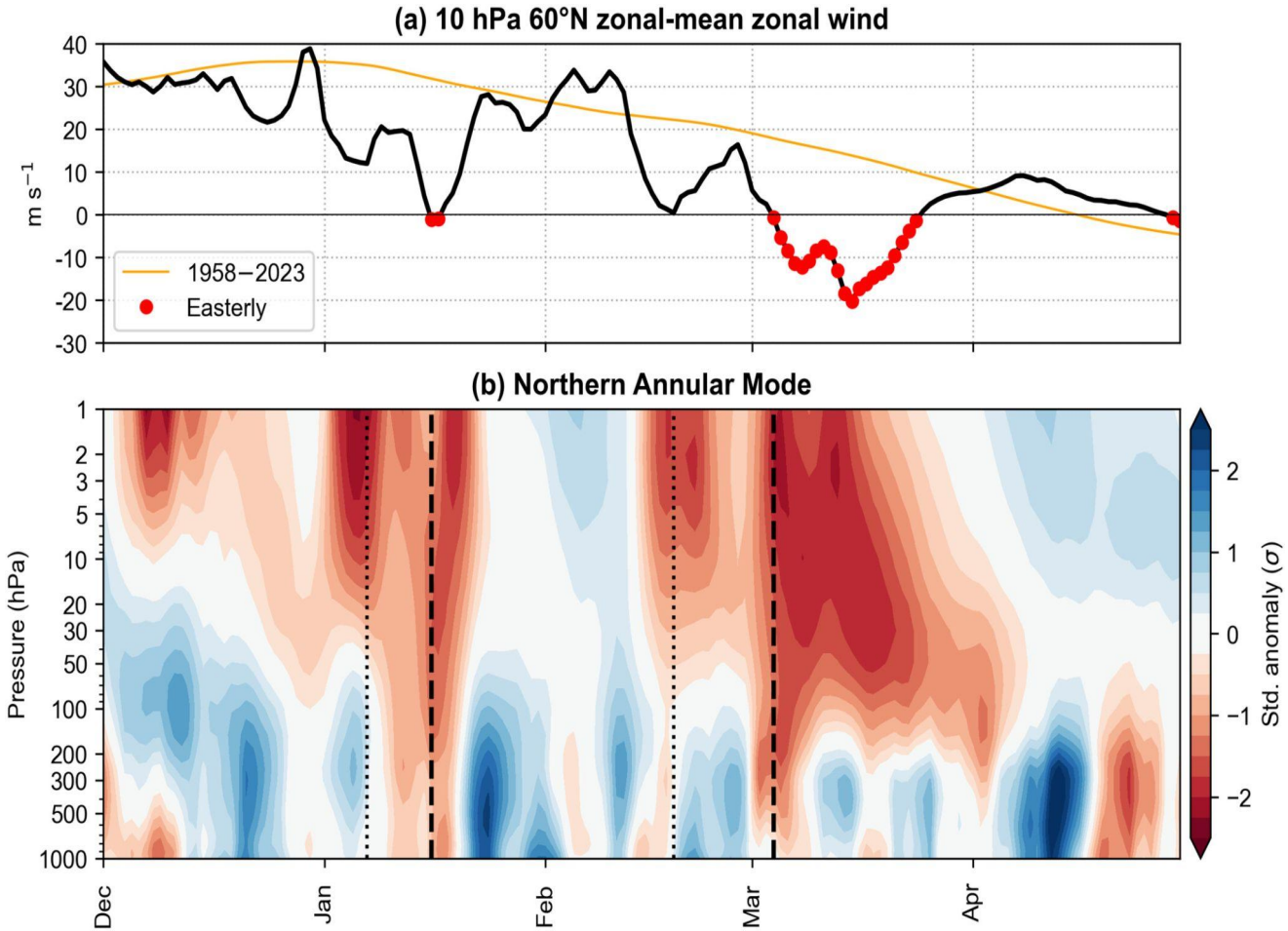


Source: https://www.cpc.ncep.noaa.gov/data/teledoc/nao_ts.shtml

Sudden stratospheric warmings (SSWs)

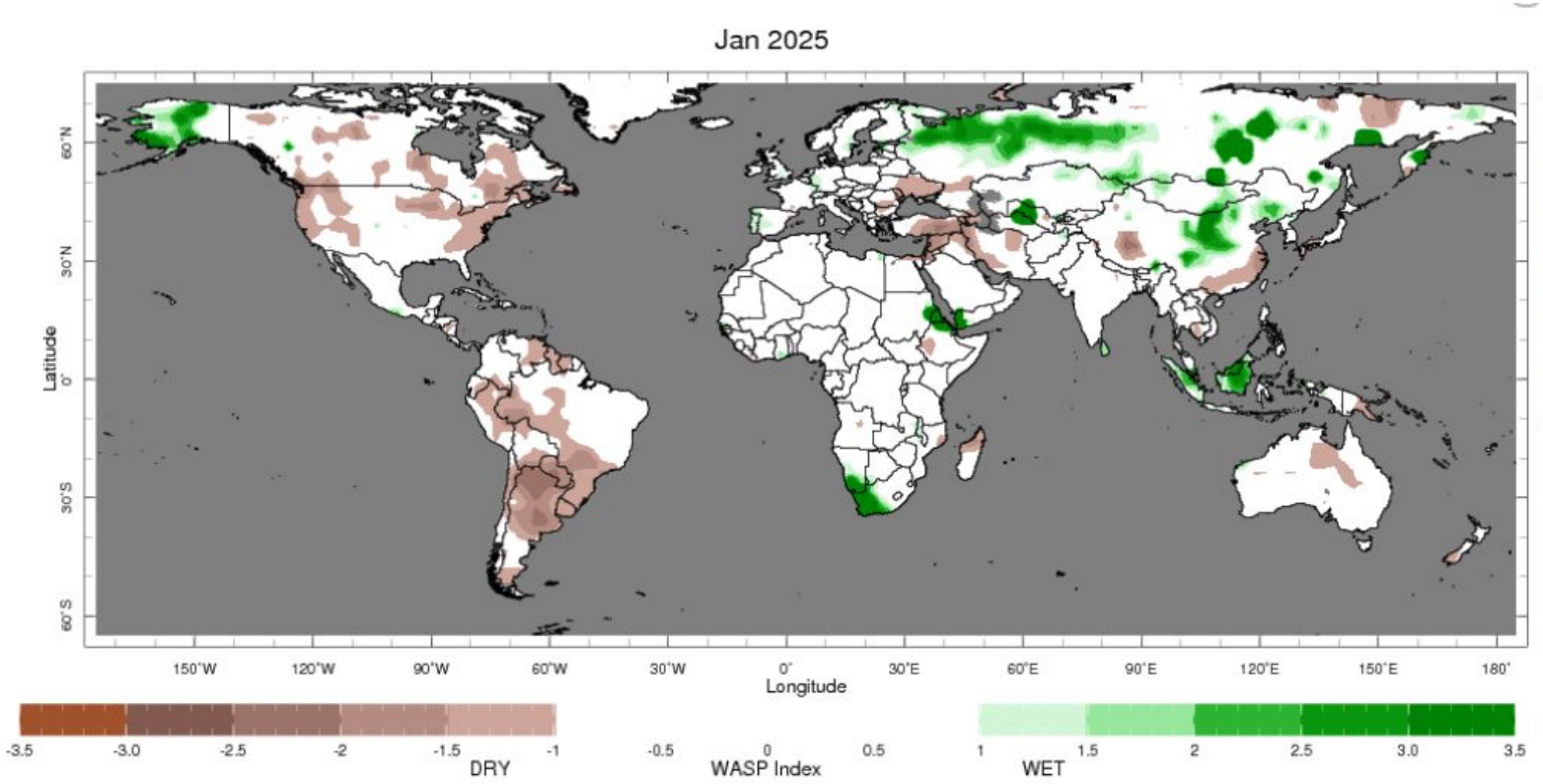
➢ A sudden stratospheric warming can reach the surface and drive very cold anomalies in northern Europe.

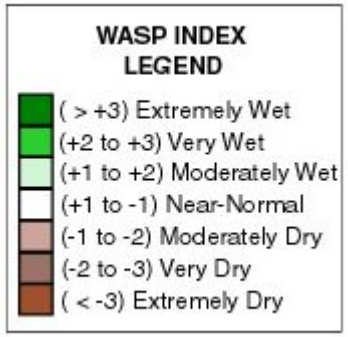


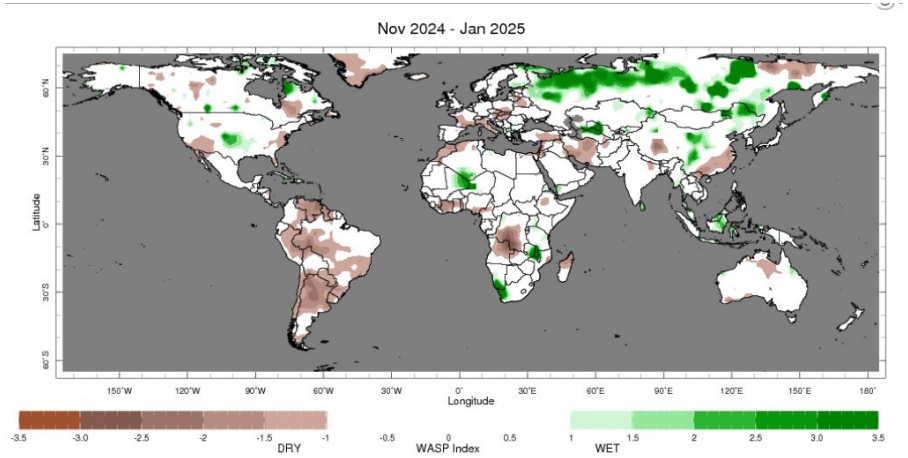


Source: Lee et al. (2024)
https://doi.org/10.1002/wea.7656

WASP index







Source: https://iridl.ldeo.columbia.edu/maproom/Global/Precipitation/WASP_Indices.html