



Intra-seasonal to Decadal Wind Variability from Satellite Observations

Lucrezia Ricciardulli, Carl Mears
Remote Sensing Systems, Santa Rosa, CA, USA

Outline:

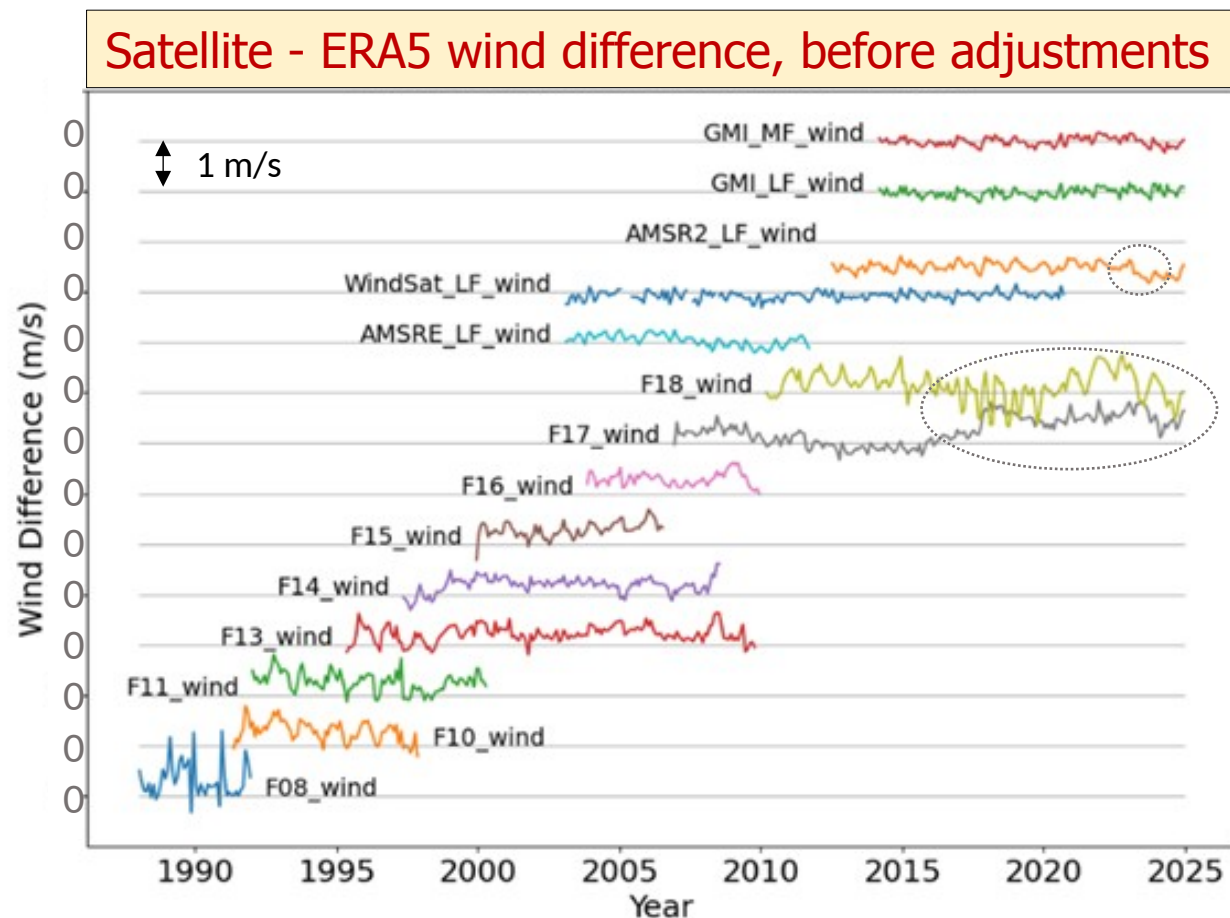
- Data products: Merged radiometers, QuikSCAT, ASCAT, ERA5, CCMP
- Methodology for merging radiometers
- Analysis of wind anomalies since 1988, and trend maps
- Similarities and differences with ERA5
- Discussions on “real signals” or “spurious effects”?
 - satellite drifts, RFI, uneven sampling of diurnal cycle, ERA5 inconsistencies
- Wind anomalies in ENSO events and Westerly Wind Bursts

RSS Merged Radiometer Winds

- Merges many radiometers 1988-present
- Radiometers' retrievals use same RTM
- 1-deg gridded monthly map timeseries <https://rems.com/measurements/wind/>
- Single data file: includes wind speed, anomalies, climatology, trend, and satellite used
- Occasional updates are needed to introduce/remove sensors, and correct for drifts.
- Used for annual AMS State of the Climate report

RECENT UPDATES (January 2025):

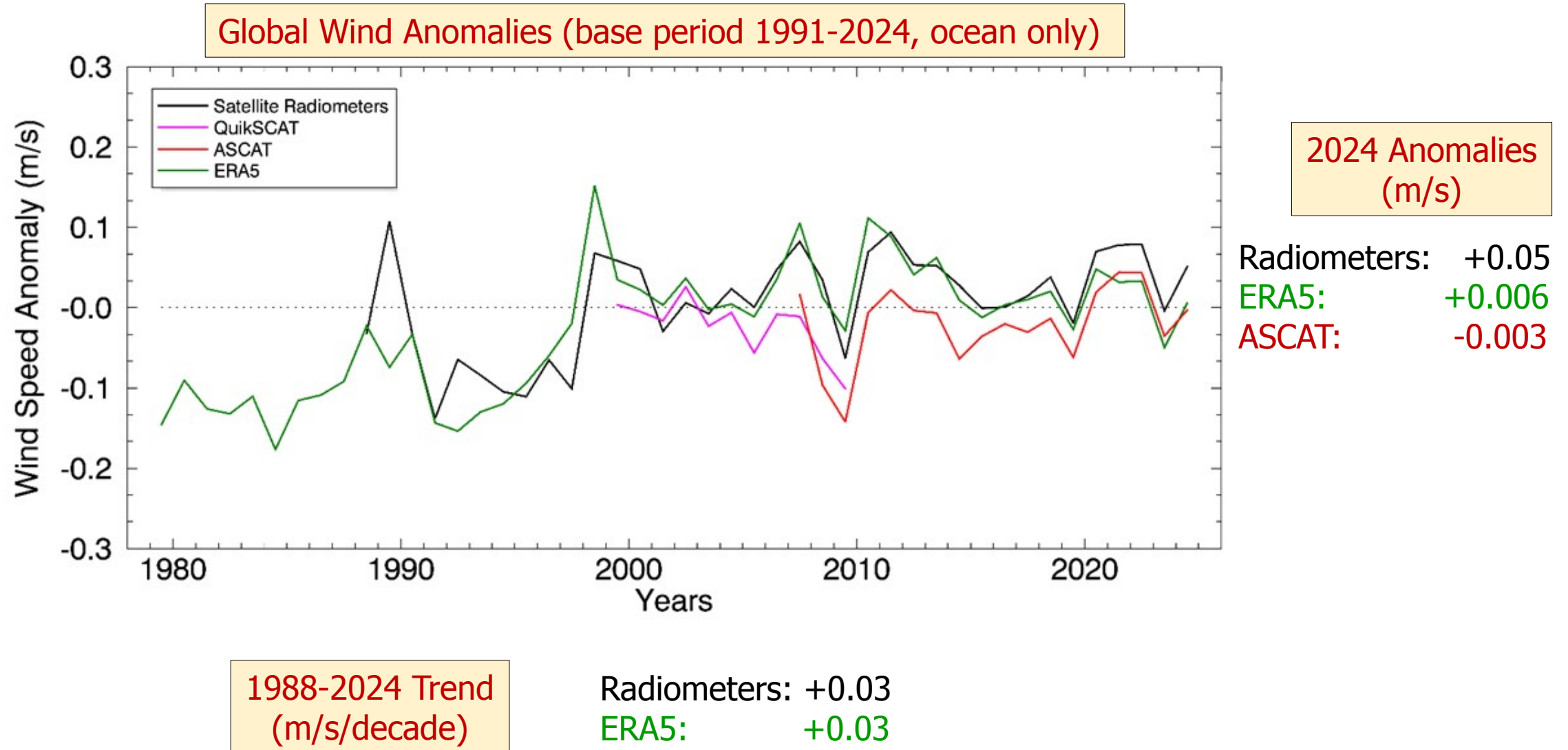
- GMI was introduced and used as “calibrator” due to its accuracy and stability.
- The following radiometers were “adjusted”:
 1. AMSR2: small drop ~ -0.2 m/s in 2023, small offset (diurnal)
 2. F17 and F18 large instabilities after 2017



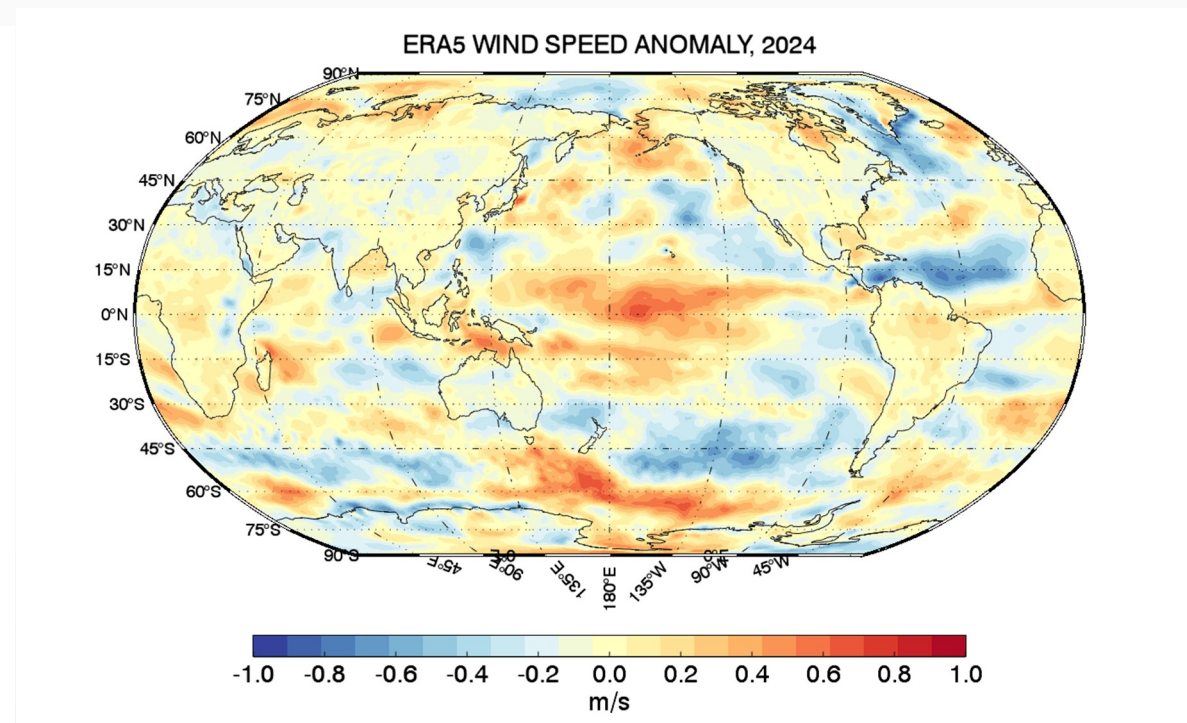
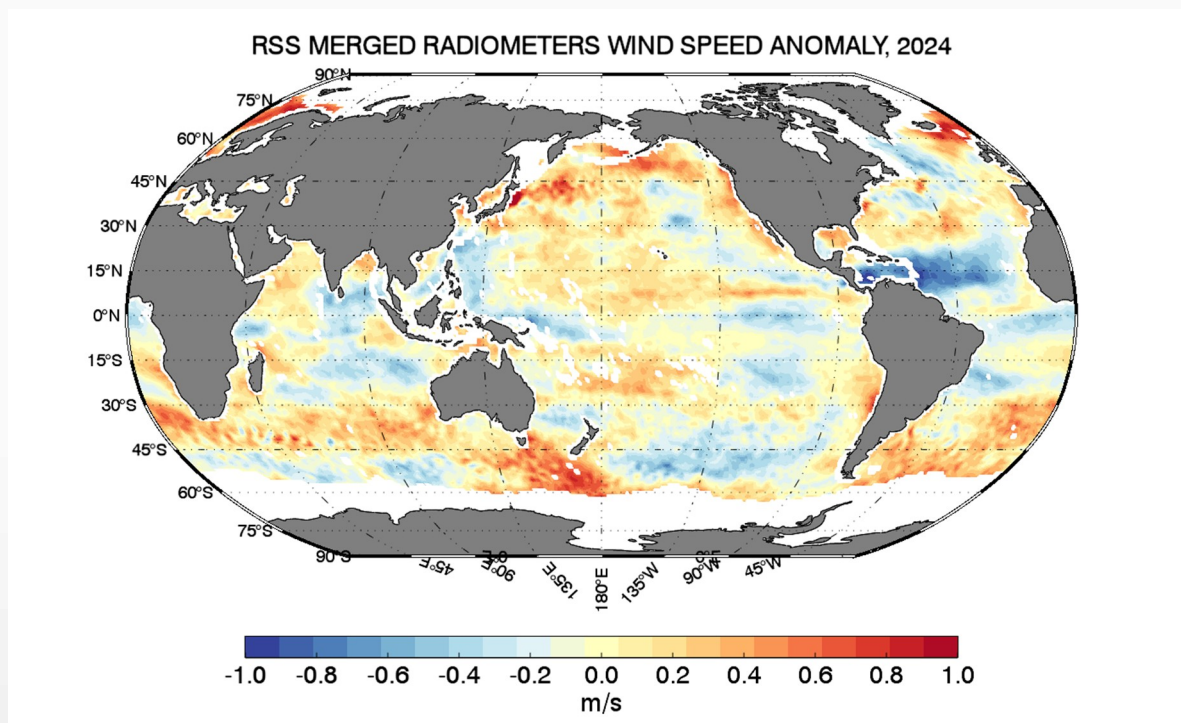
Wind LF: Low-frequency, 10 GHz channel

Wind MF: Moderate-frequency, 18 GHz channel (not included in merged)

Wind Anomaly Timeseries



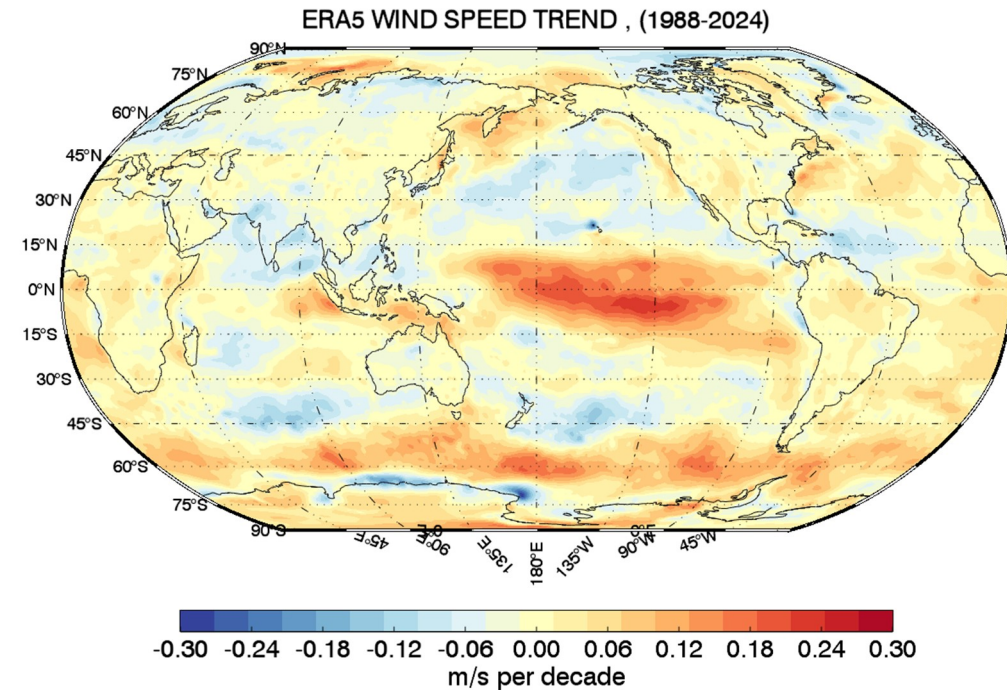
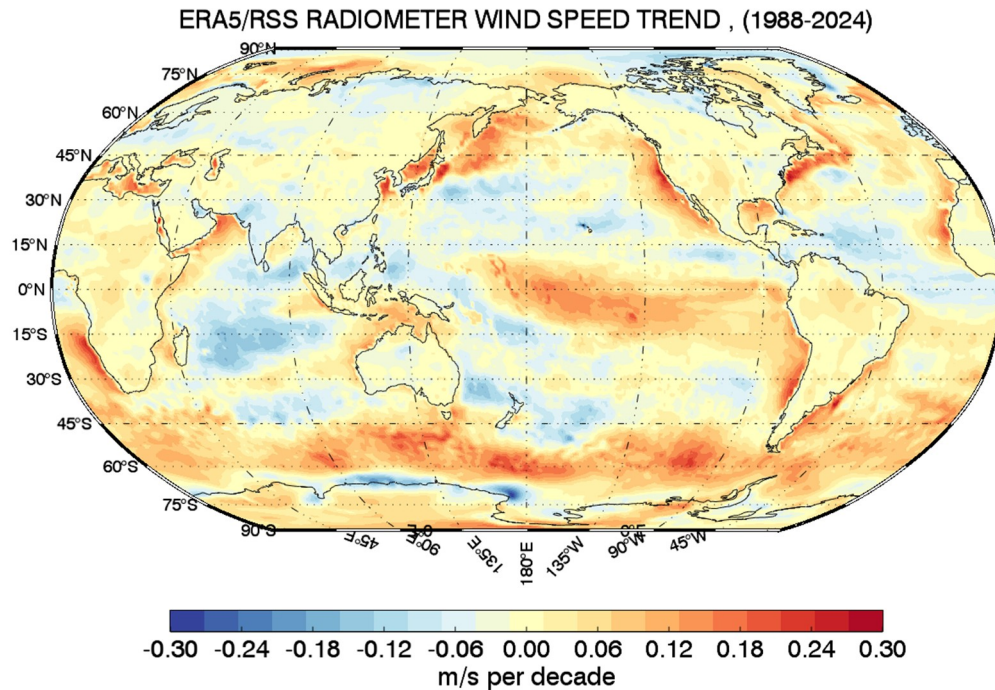
Wind Anomaly Maps for 2024



Notable regional features

- A large negative anomaly in the tropical Atlantic, slightly reduced compared to 2023.
- The Indian Ocean shows slightly negative wind anomalies.
- The Southern Ocean shows a moderate positive anomaly, except for the South-Eastern Pacific
- A positive anomaly in the tropical Pacific (note that 2024 was a transition year from El Nino to La Nina; a positive wind speed anomaly → La Nina)
- Central Tropical Pacific: ERA5 displays a much larger positive anomaly. Spurious?

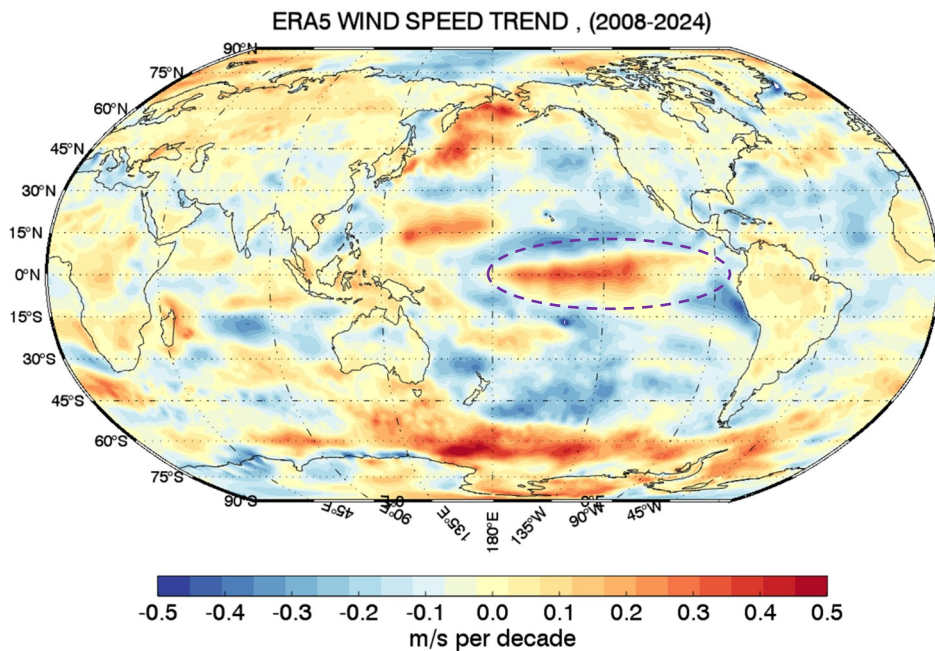
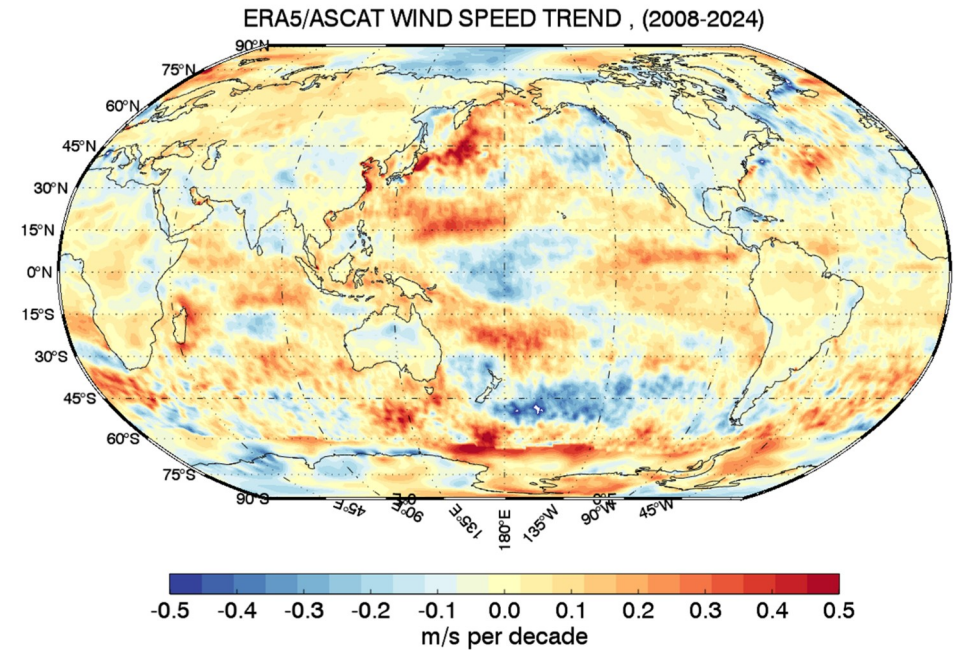
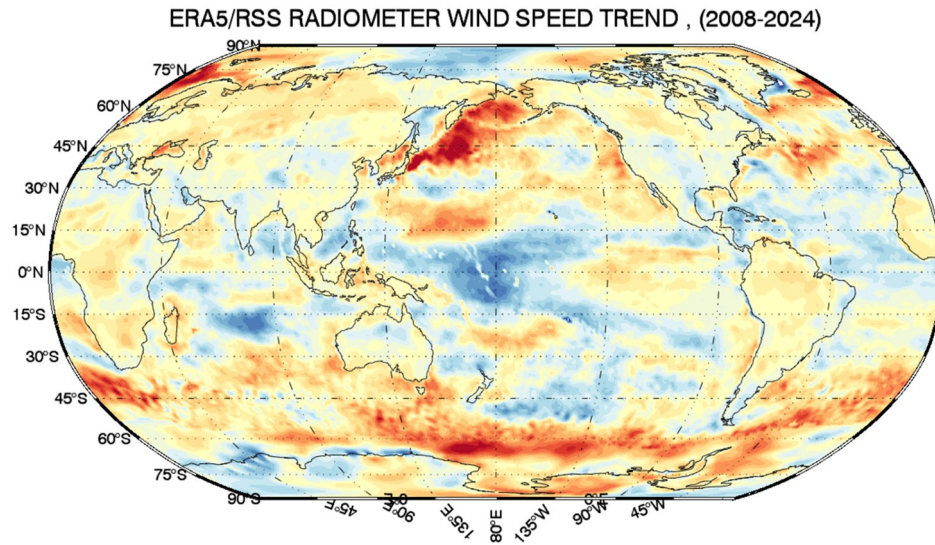
Wind Trend Maps (1988-2024)



Notable features

- Both Radiometers and ERA5 show negligible global trend of +0.03 m/s/decade (ocean only)
- Positive trend in the central Pacific, possibly due to effects of many La Nina years in the timeseries
- An increasing strengthening of the winds in the Southern ocean, feature consistently observed for many of the past years.
- In the radiometers: A "halo" of positive trend along the coastal waters. Spurious? More later
- In ERA5: Again, the central Tropical Pacific has a much larger signal. Spurious? More later

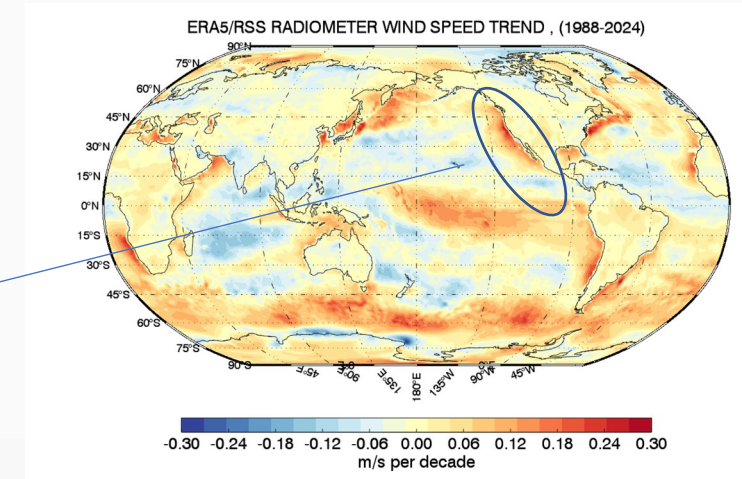
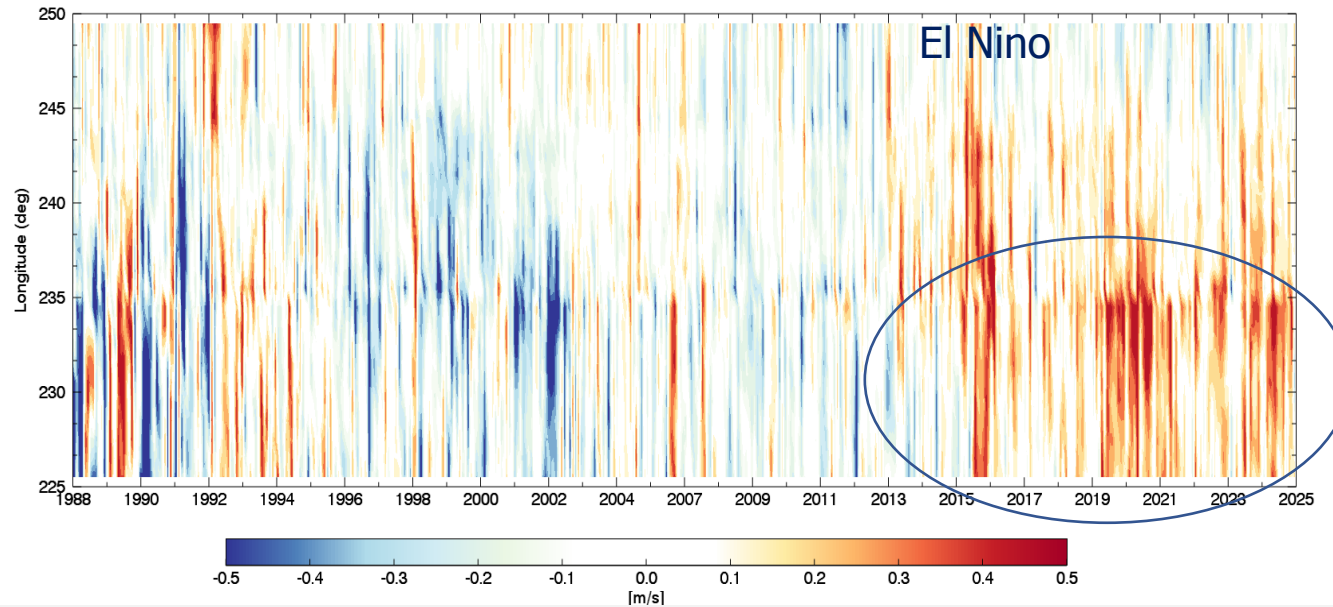
2008-2024 Wind Trends: ASCAT, Radiometers, ERA5



- ASCAT and Radiometers' trend very similar for overlapping period
- Less prominent halo in radiometer trend in this period (different colorbar range!)
- ERA5 very similar to satellites, but larger positive trend in Central/Eastern Equatorial Pacific: is it related to TAO spurious bias?

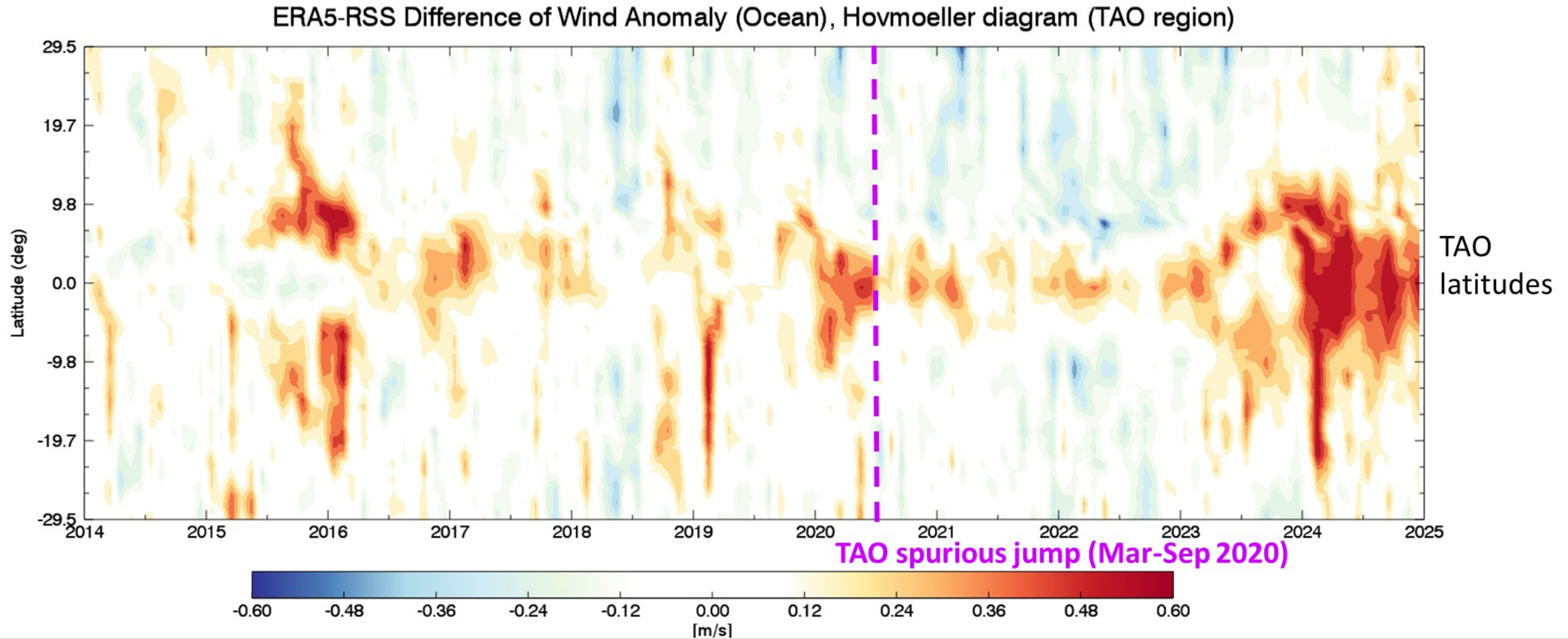
Issue 1: “Halo” along coastlines in Satellite trend

Radiometers–ERA5 wind difference for US West coast (25-45N)



- There seems to be an increase in positive anomalies off the US West coast in the last decade, especially after 2015 (“halo effect” in the trend map).
- This could be due to increasing Radio Frequency Interference (RFI, potentially in AMSR2 10 GHz channel).
- Another possibility is more weight from the 1:30 pm/am sampling (diurnal aliasing) into the merged data.
- Both factors require careful consideration when merging data.
- More investigation on this is under way.

Issue 2: ERA5-Radiometer Wind Anomaly, TAO region

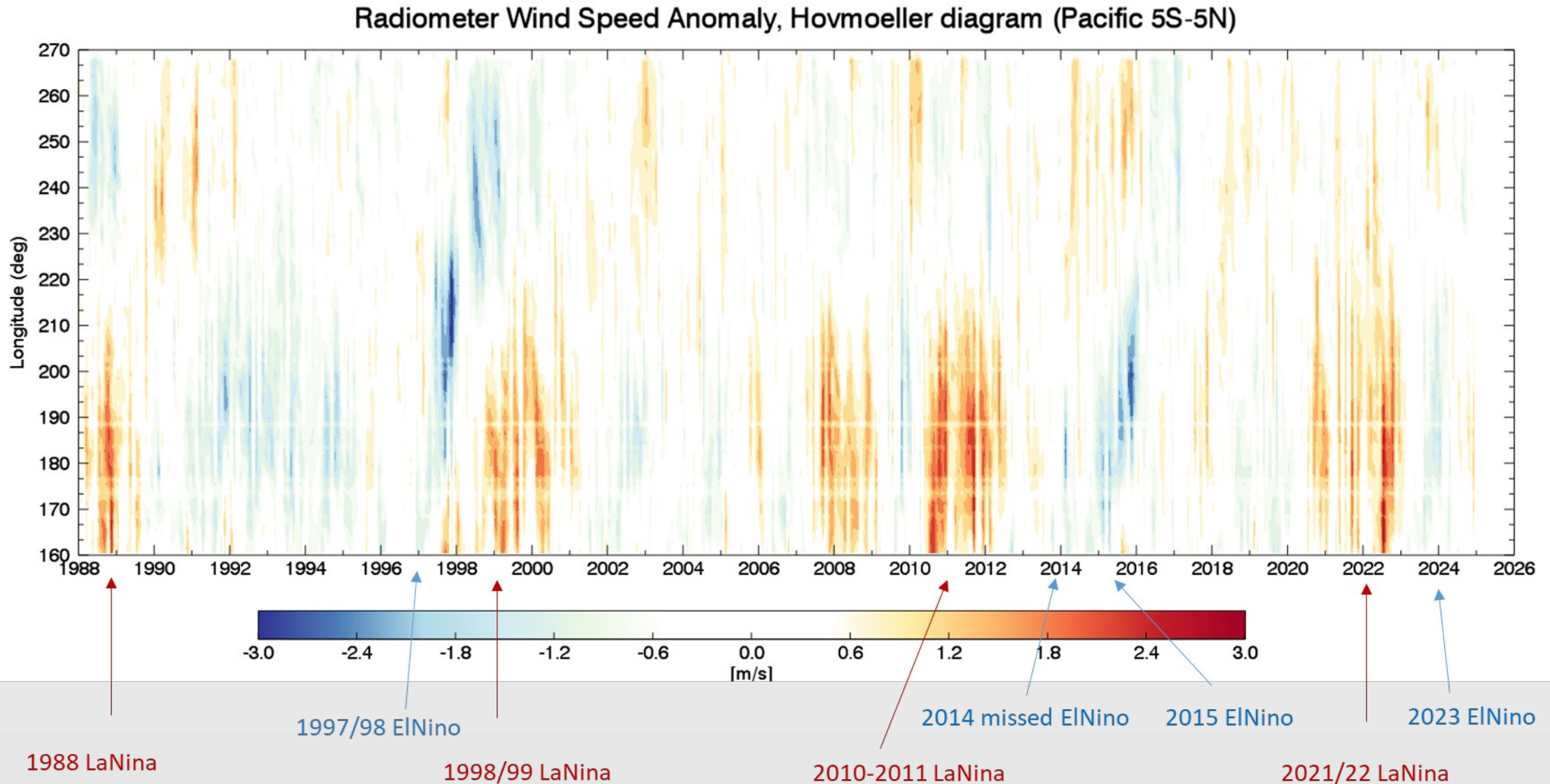


ERA5 and radiometer wind anomalies were more or less consistent until 2023. Then a large jump seems to occur in ERA5. Can this be related to assimilating TAO biased data?
Note that the TAO jump (0.5-0.8 m/s) started in mid 2020.

Tropical Wind Variability and ENSO events

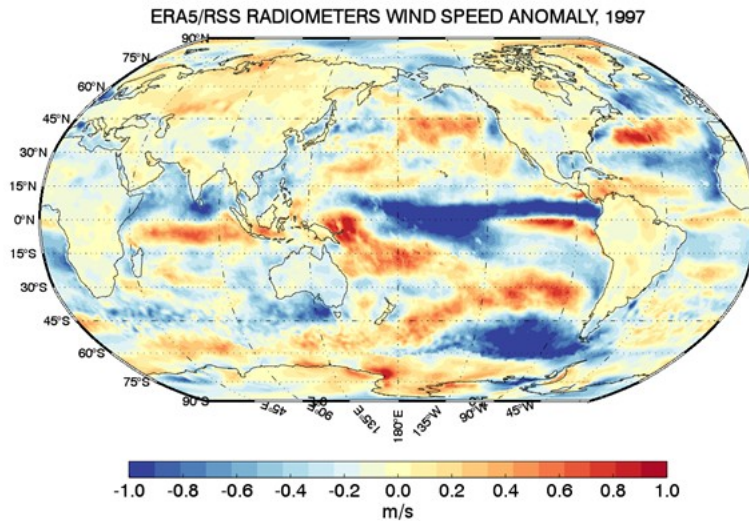


Tropical Wind Variability and ENSO events

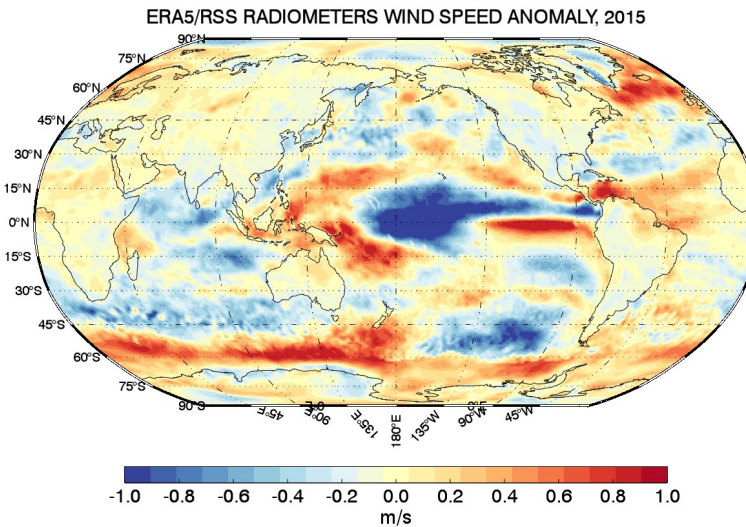


El Nino Years

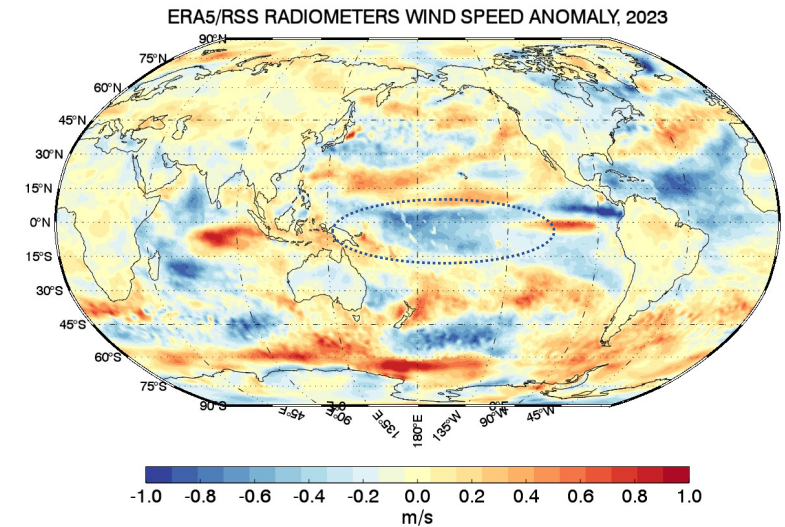
1997 EL NINO FORMING



2015 EL NINO FORMING



2023 EL NINO FORMING

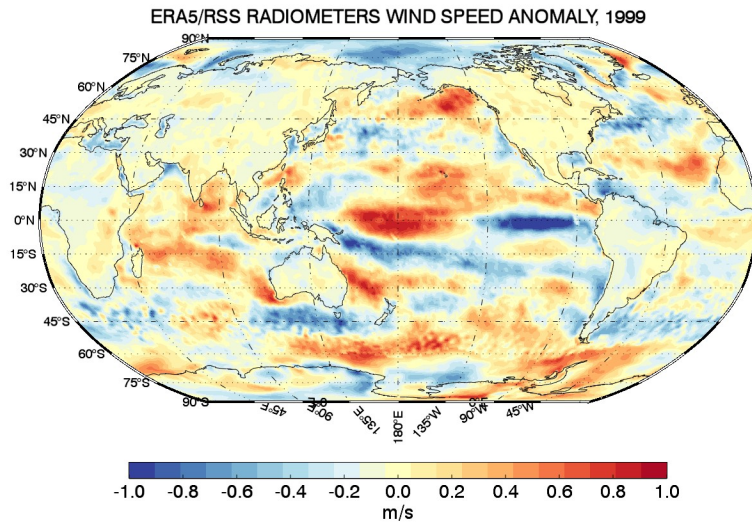


Weak Wind Anomaly
(but large SST anomaly!)

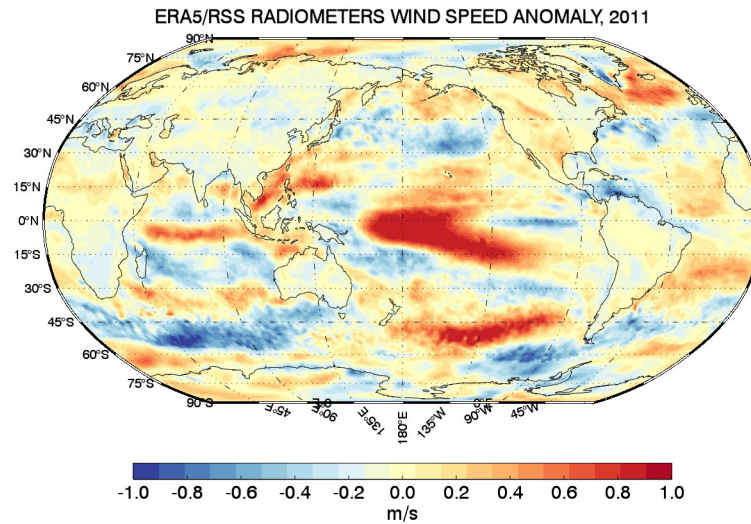
These are the forming years of three El Nino. 2023 El Nino wind anomalies are much weaker. Notice that unlike 1997 and 2015, the 2023 El Nino was preceded by a strong La Nina. Therefore, the background state was not neutral. See in the next slides how to account for that in the wind bursts analysis

La Nina Years

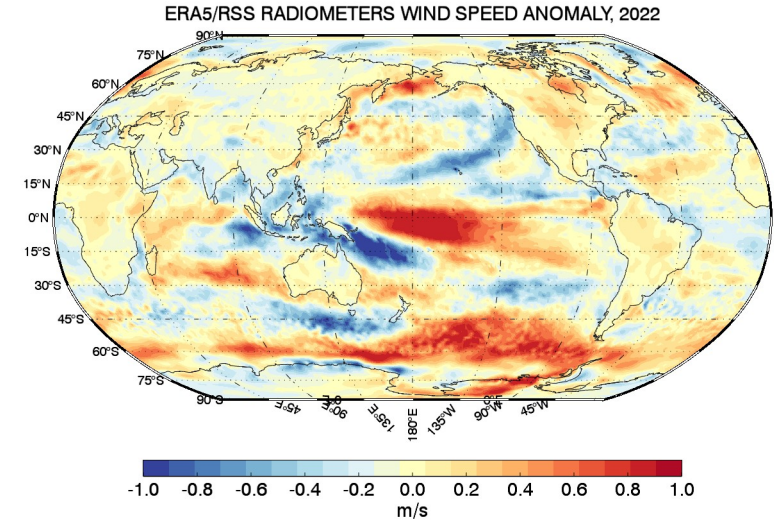
1999 LA NINA



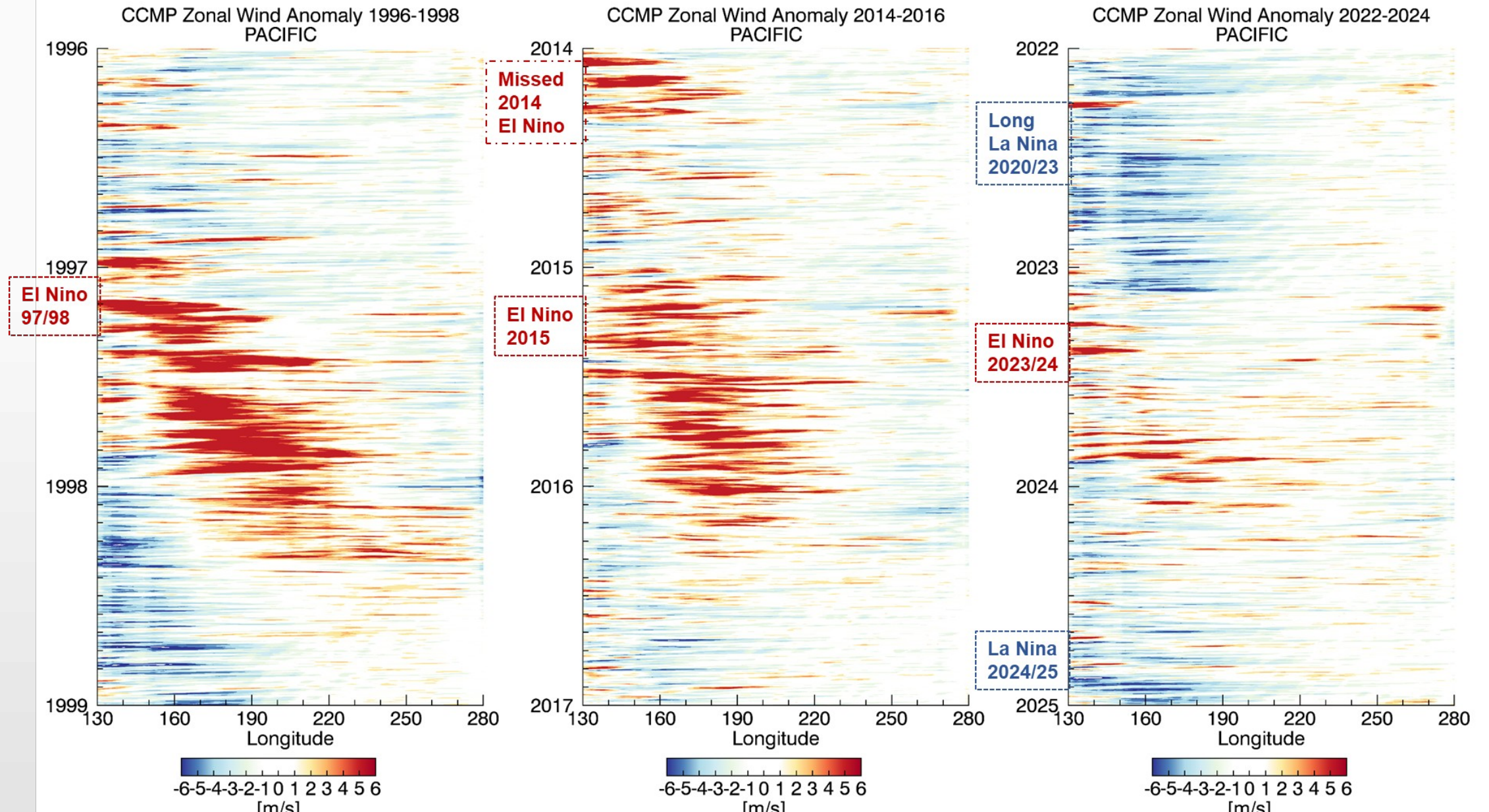
2011 LA NINA



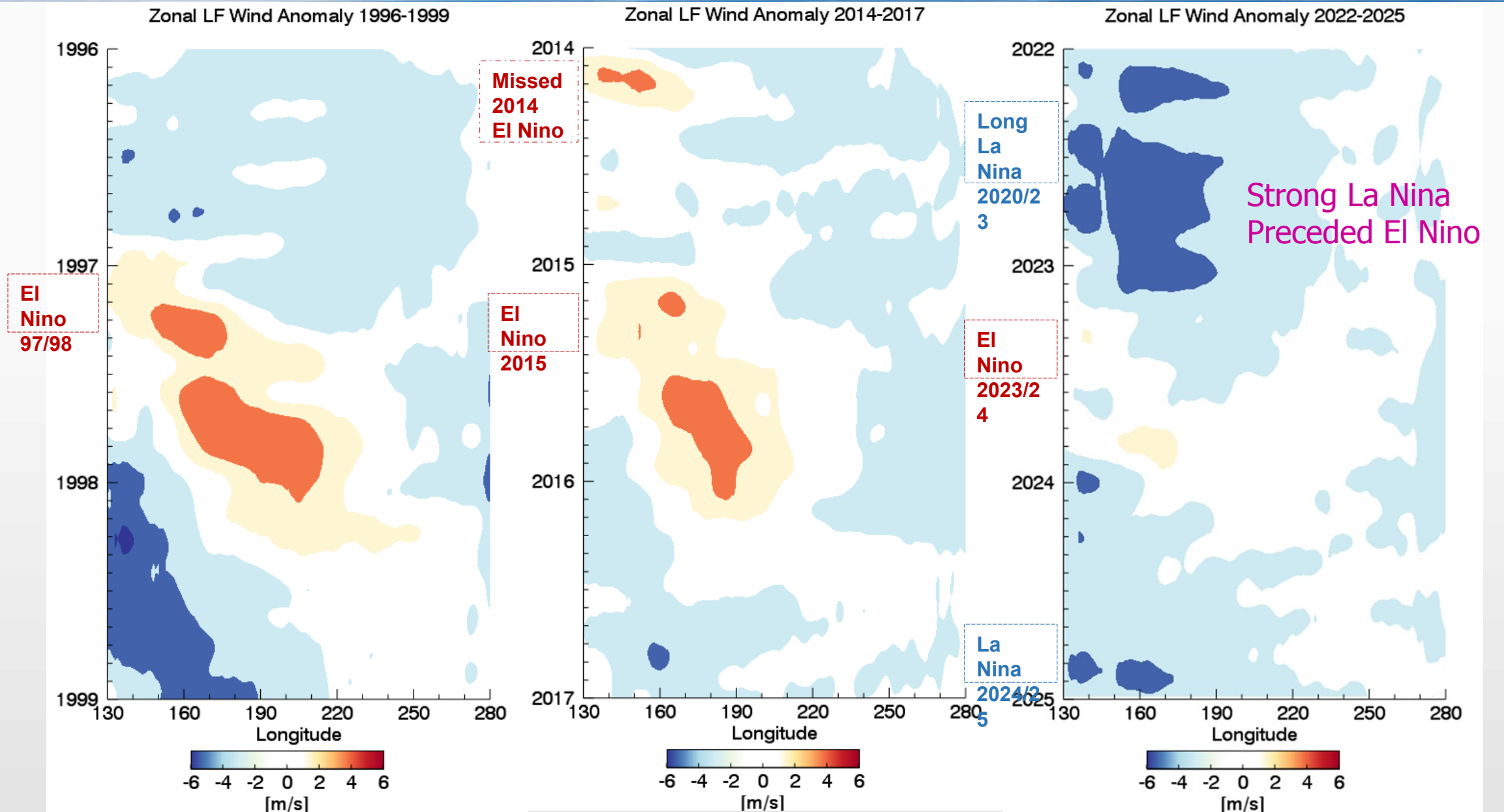
2022 LA NINA



Westerly Wind Bursts (WWB) Analysis (CCMP)



Background State (Low Frequency Component)



Summary and Topics for Discussion

- Cross-calibrated satellite wind data provide uninterrupted global coverage since 1988 (RSS Radiometers) and 1999 (RSS Scatterometers)
- Radiometers are merged in a monthly 1-deg gridded product used for AMS State of the Climate
- Global wind speed trend is negligible (0.03 m/s/decade)
- Global ocean wind anomaly varies over time, +/-0.2 m/s
- Larger variations for regional features, typically < 1m/s, but larger for ENSO years.
- El Nino: 1997 and 2015 very large negative anomaly in Central Pacific; 2023 much smaller
- La Nina: 1999, 2011, 2022 very large positive anomaly in Central Pacific;
- WWB: very intense activity at the onset of 1997 and 2015 El Nino, very weak for 2023 El Nino.

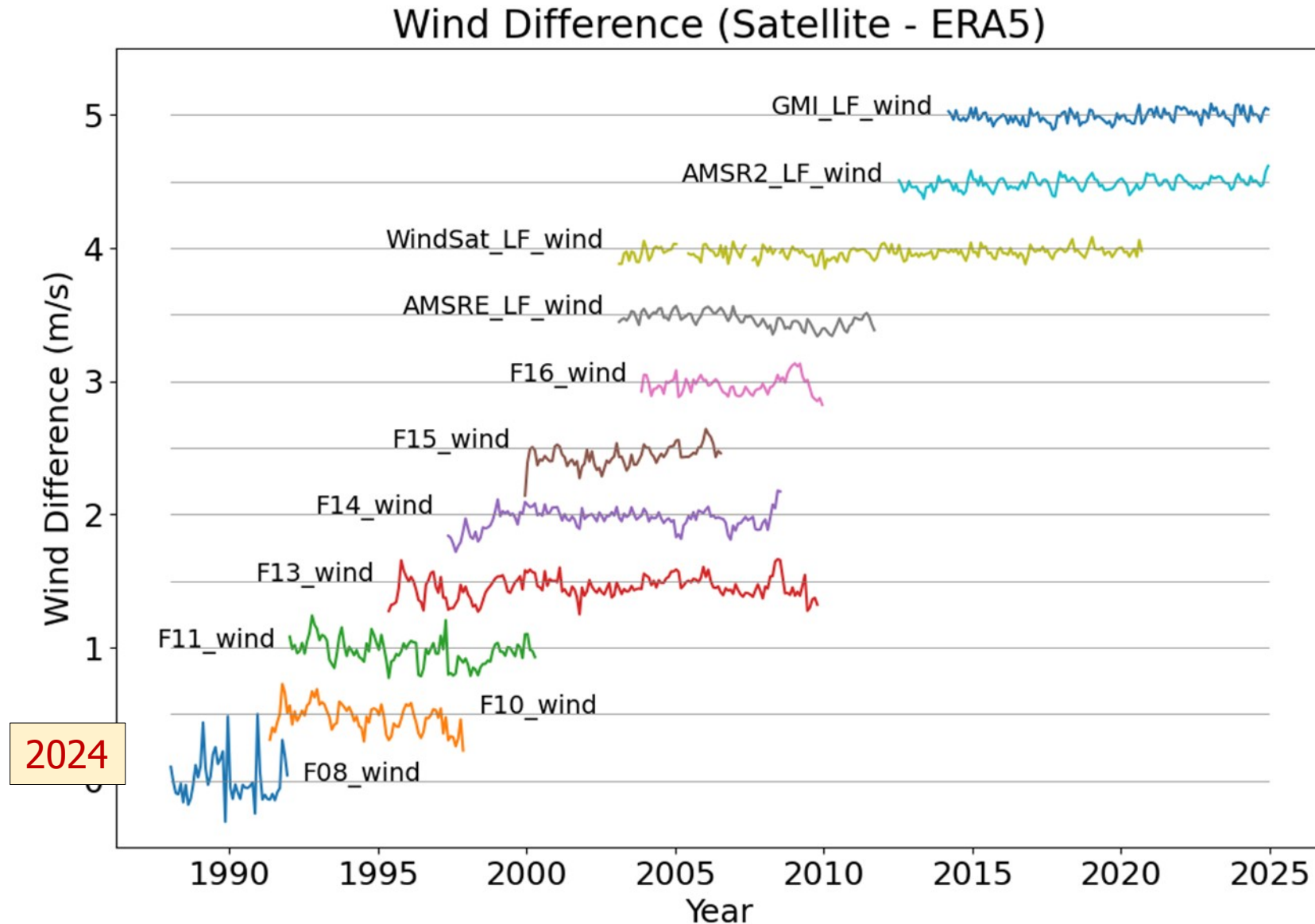
Open questions

- ERA5 and Satellite are overall consistent except for recent stronger wind anomalies in Tropical Pacific in ERA5. Spurious signal?
- Radiometers seem to show a "halo" of positive trend around the continents in the last decade. Spurious?

Extra Figures

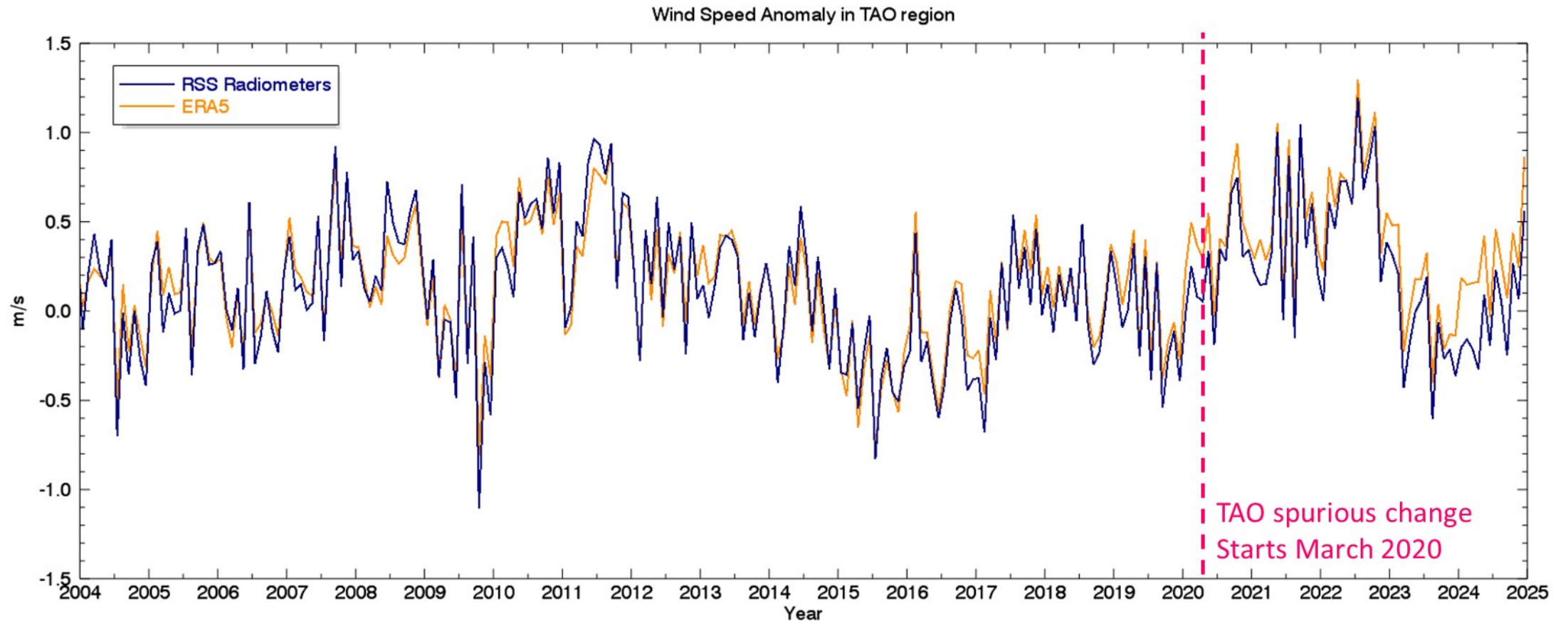


Radiometers included in merged dataset, after adjustment

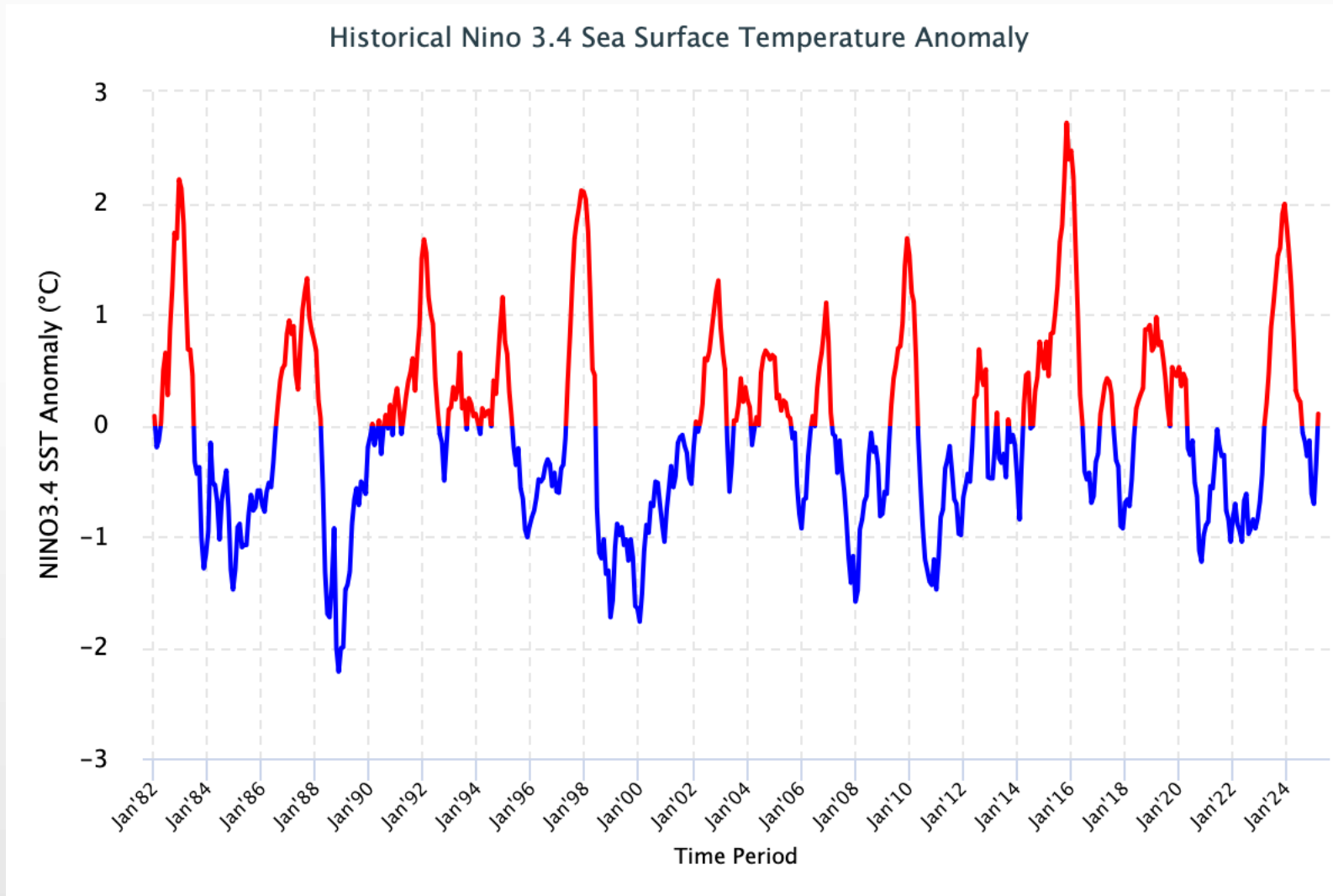


Wind Anomaly Timeseries in the TAO region, Sat vs ERA5

TAO region (8S-8N, 165-265E)



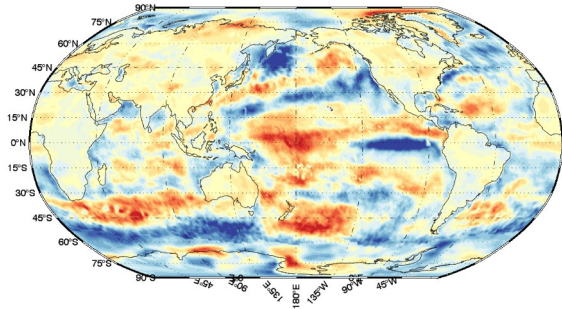
Nino 3.4 SST anomalies



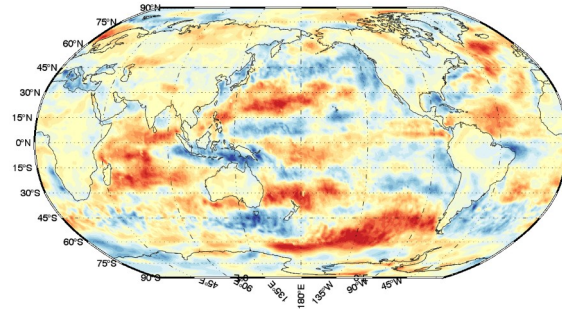
https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/?enso_tab=enso-sst_image

Yearly wind anomalies from merged radiometers (1988 to 2024)

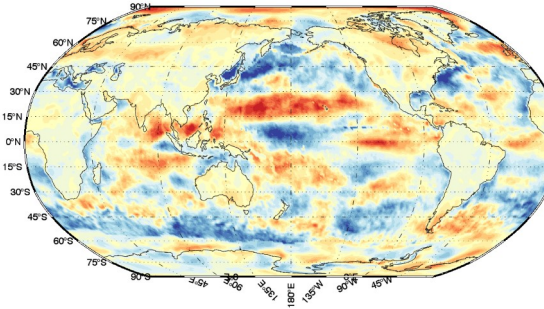
ERA5/RSS RADIOMETERS WIND SPEED ANOMALY, 1988



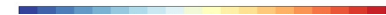
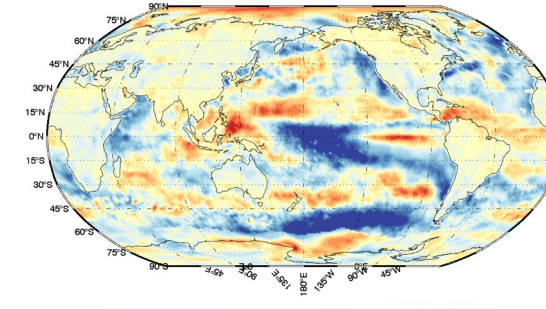
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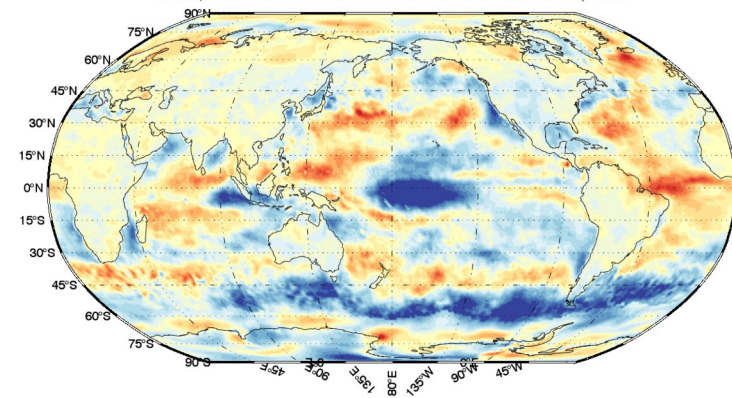
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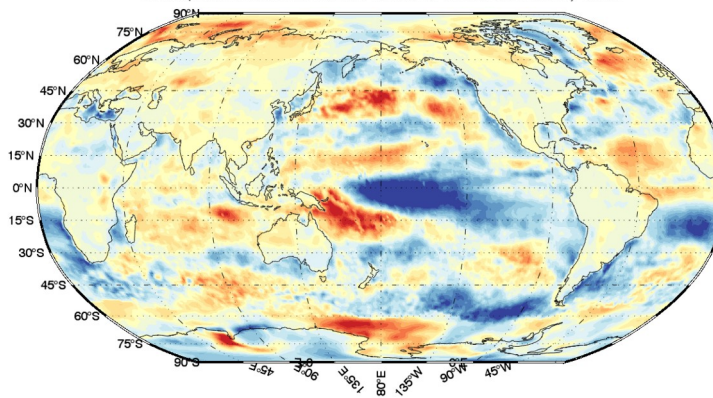
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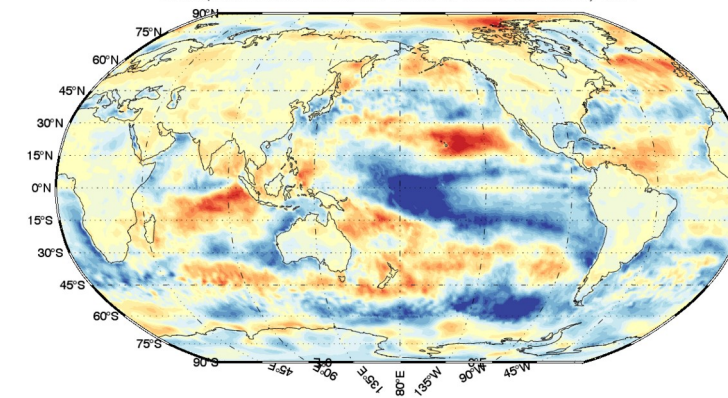
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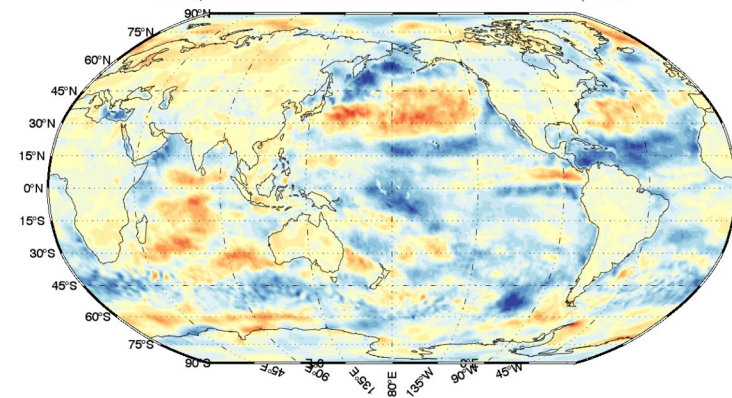
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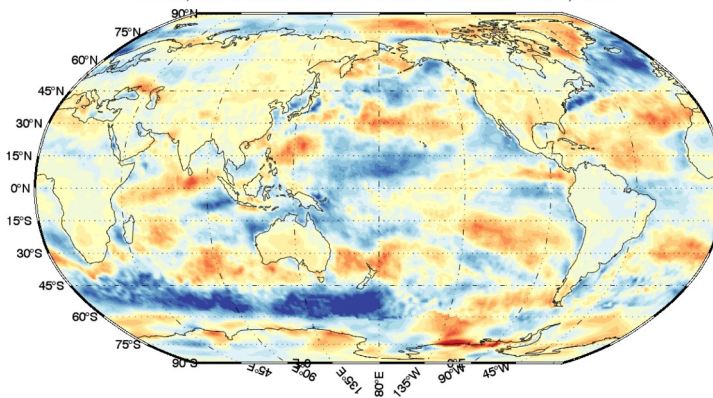
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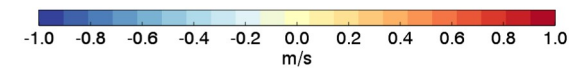
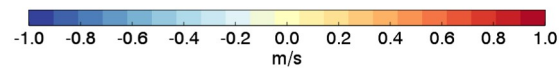
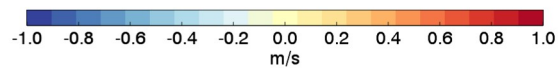
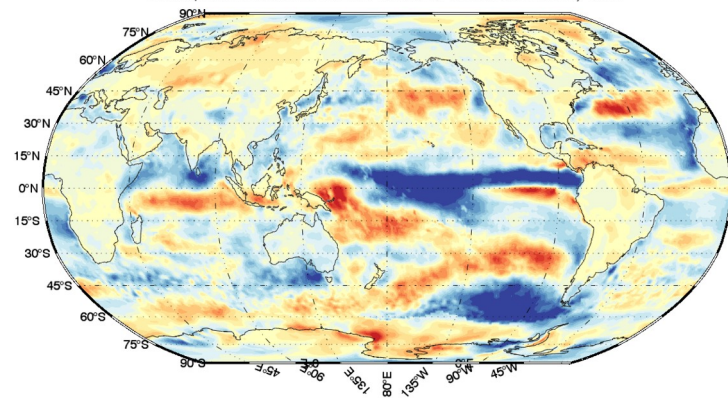
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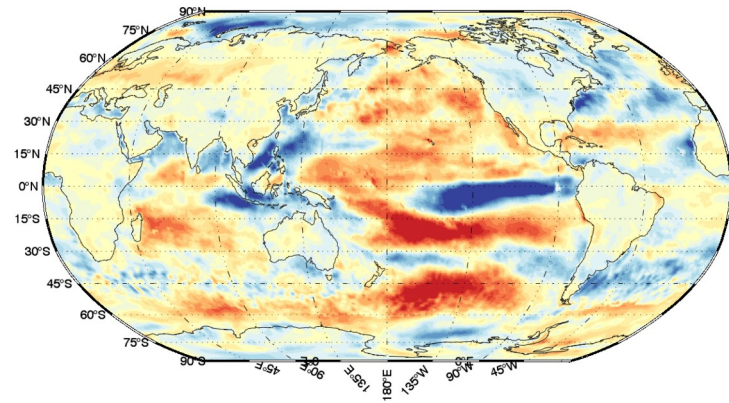
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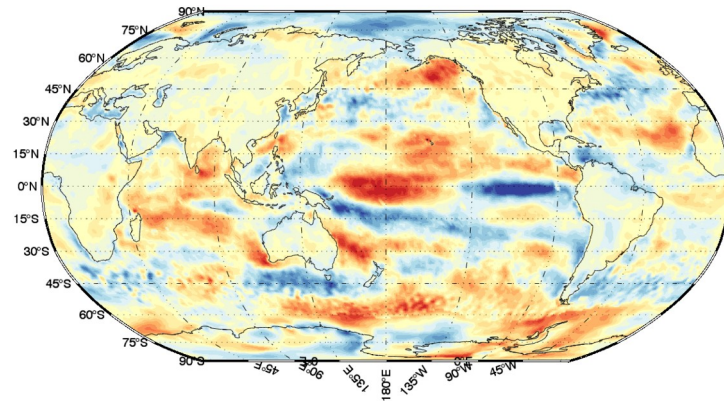
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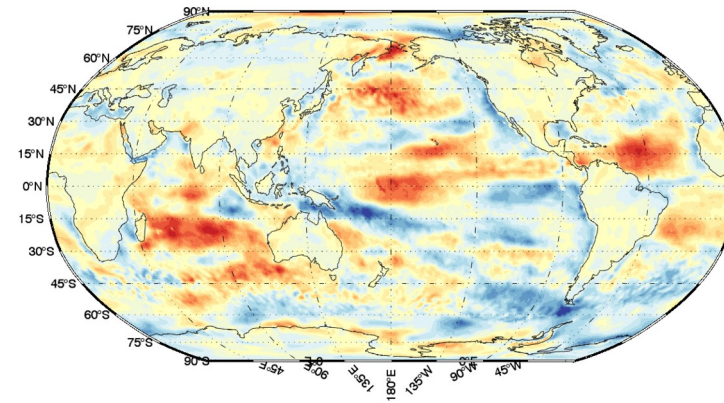
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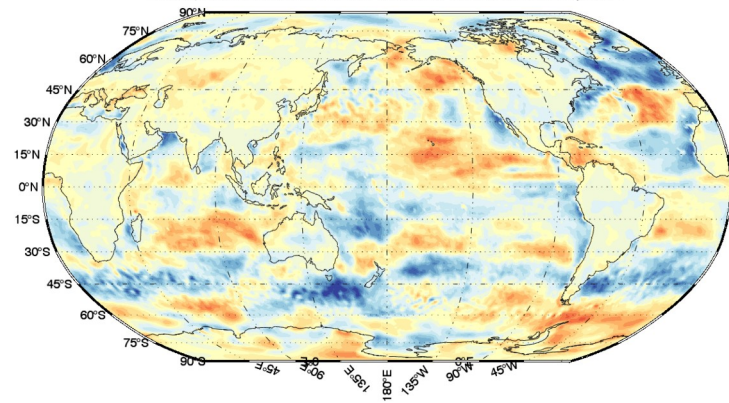
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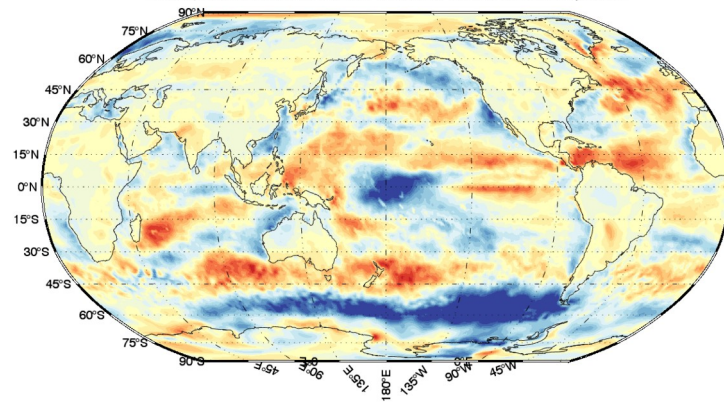
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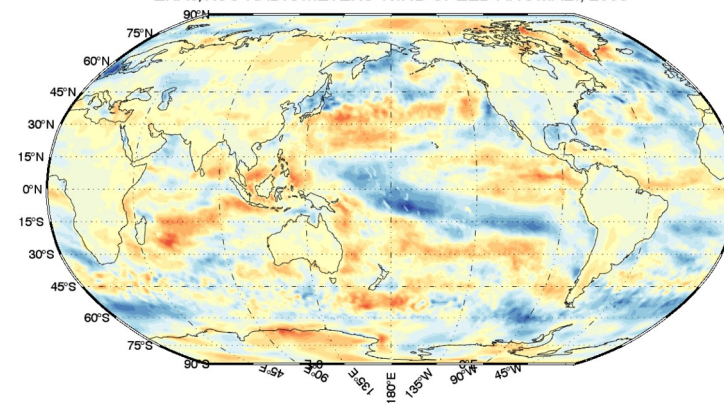
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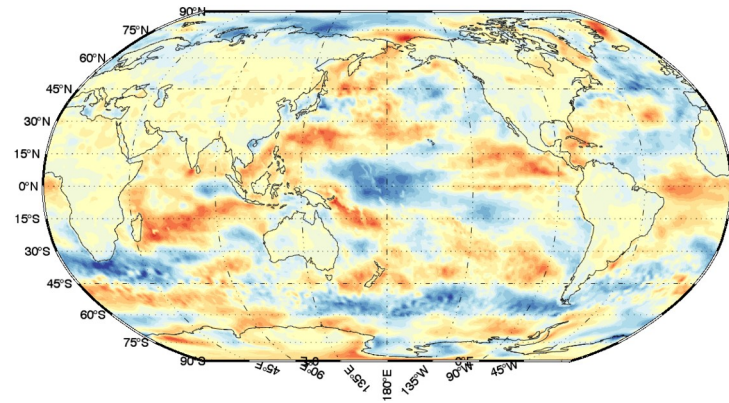
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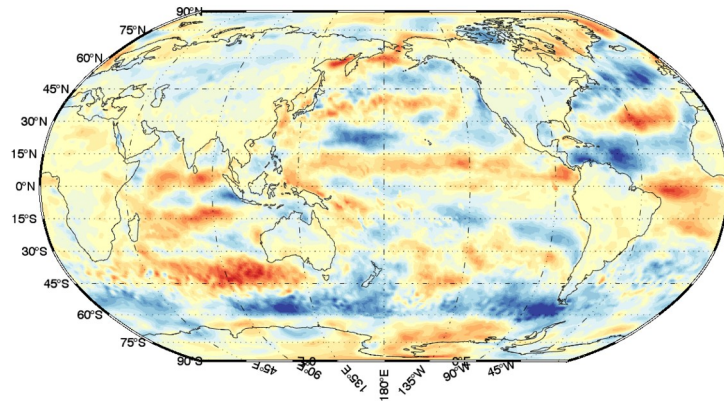
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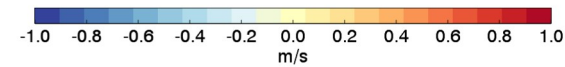
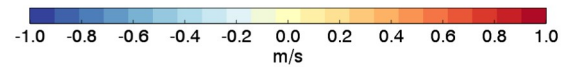
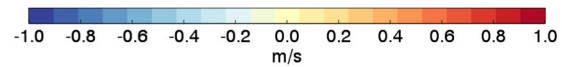
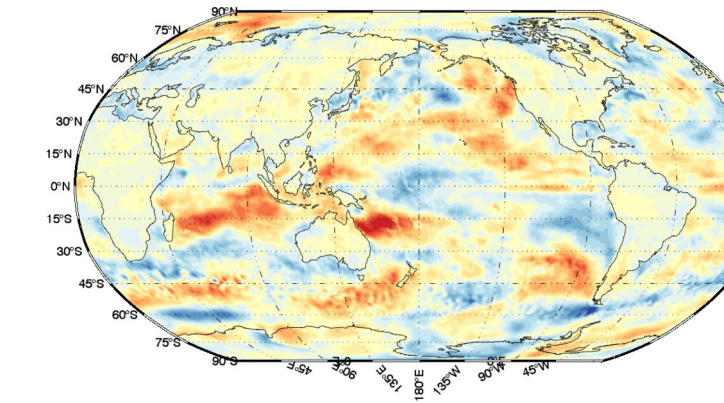
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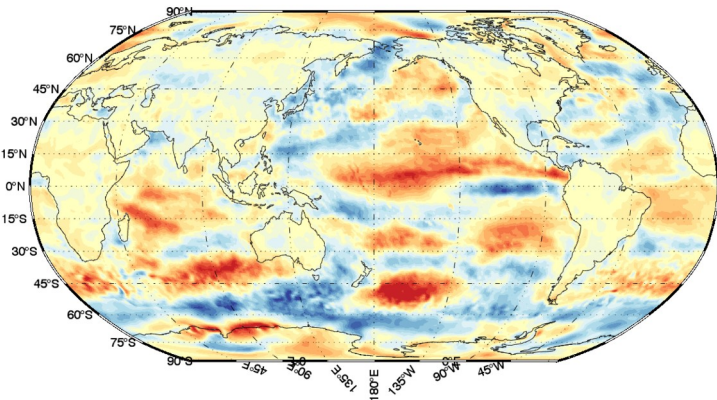
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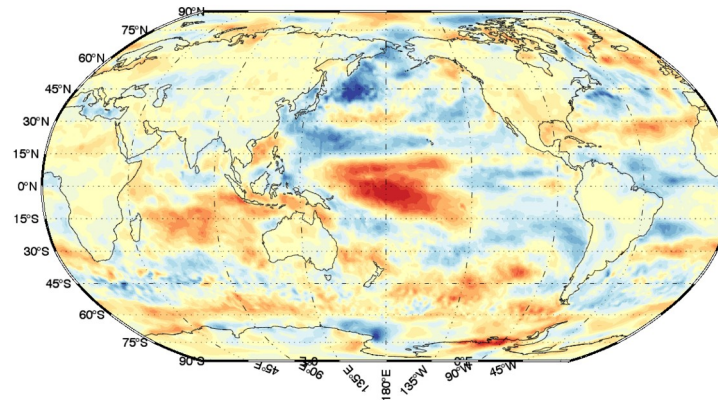
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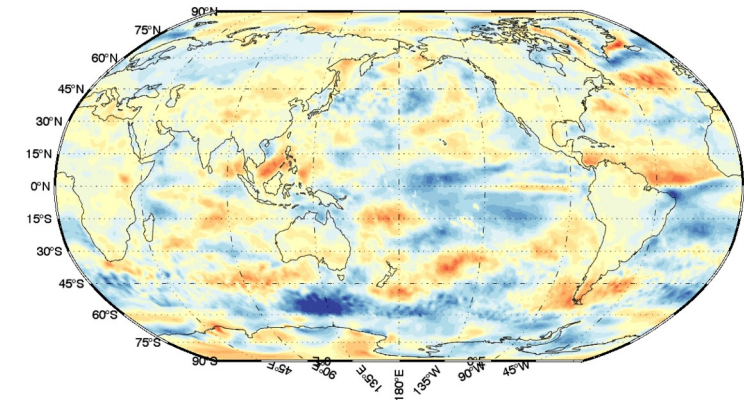
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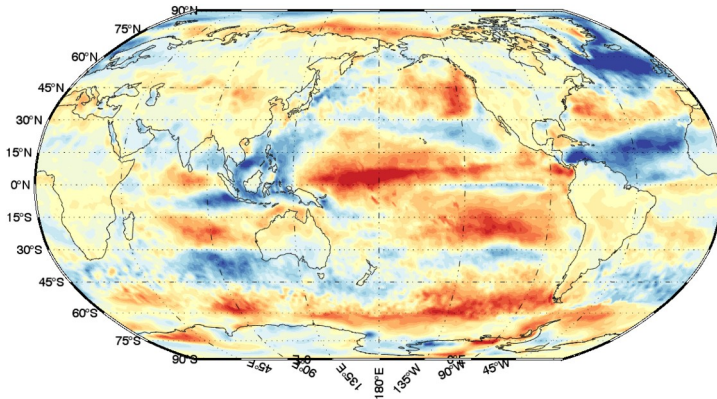
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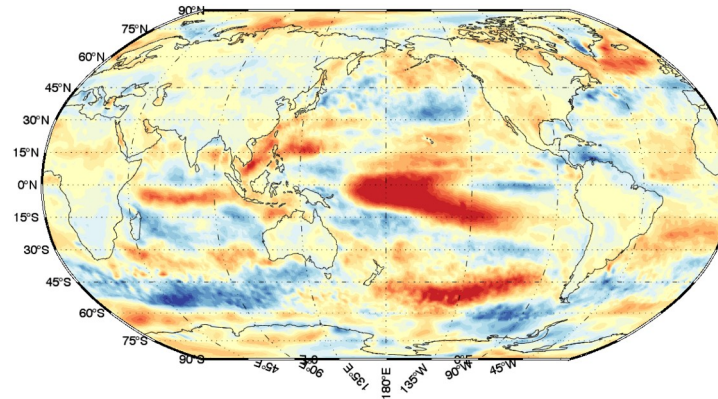
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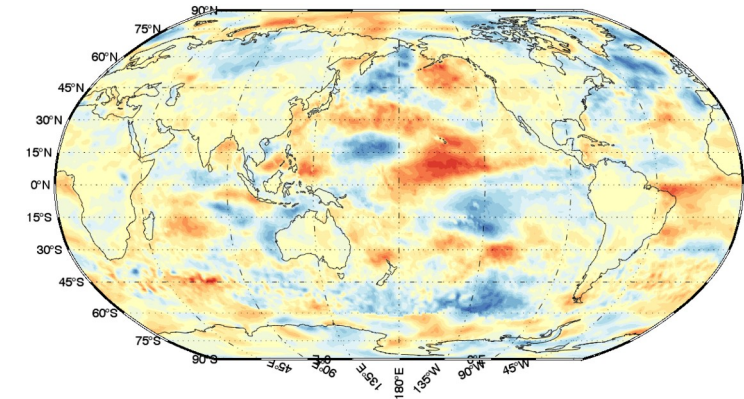
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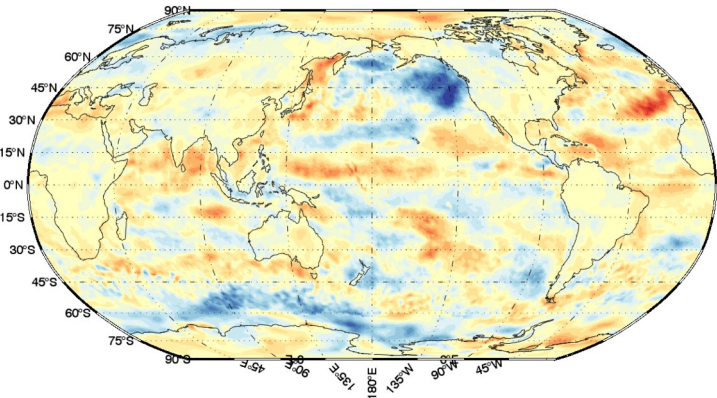
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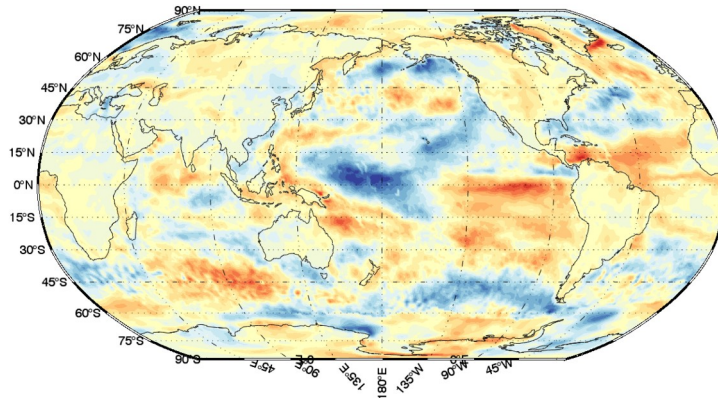
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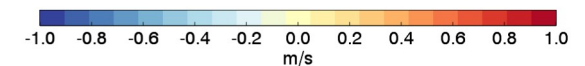
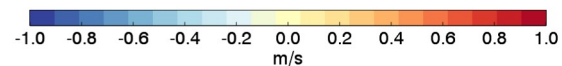
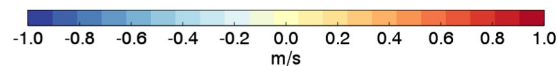
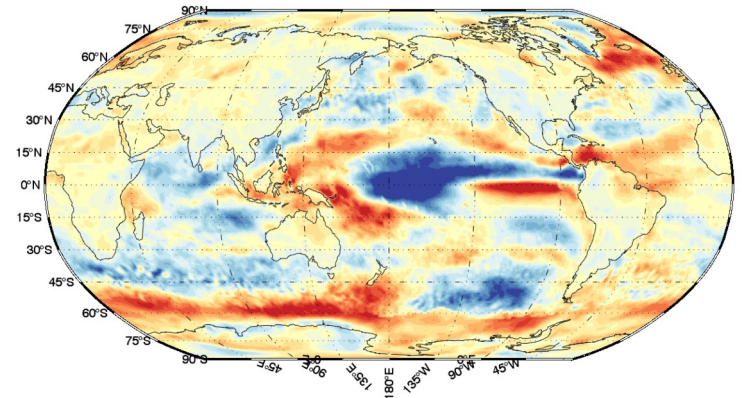
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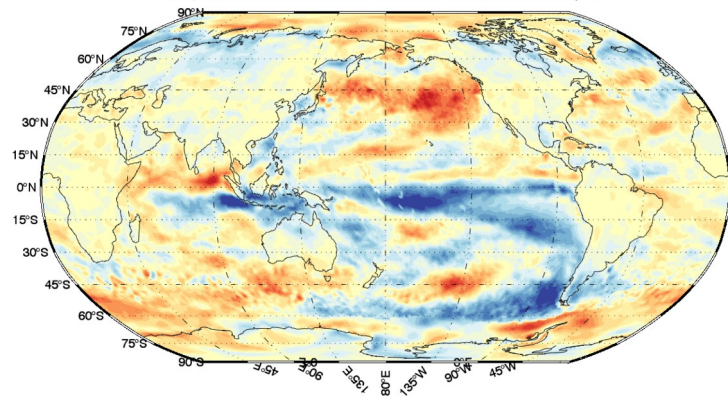
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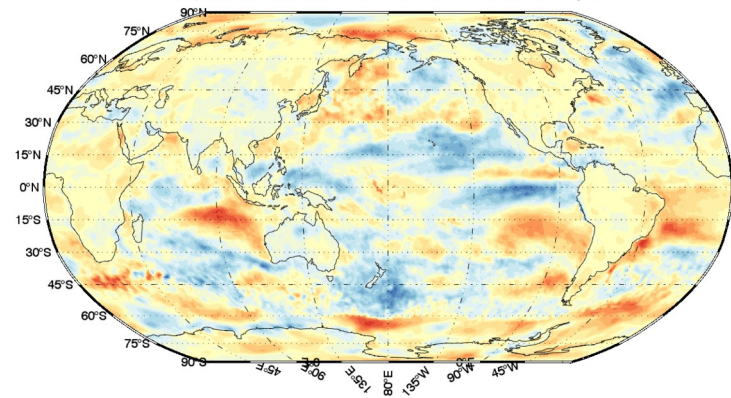
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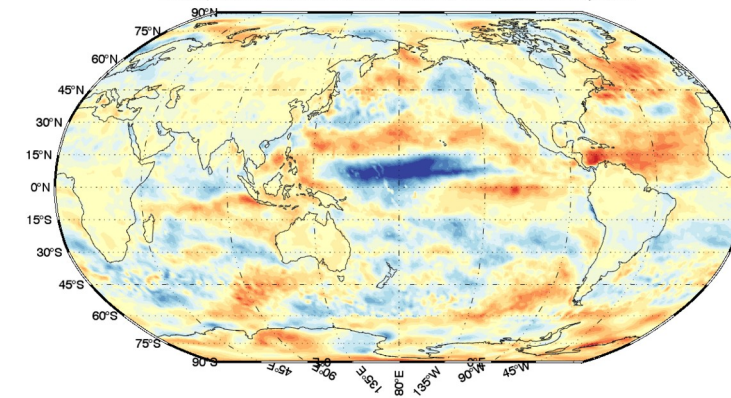
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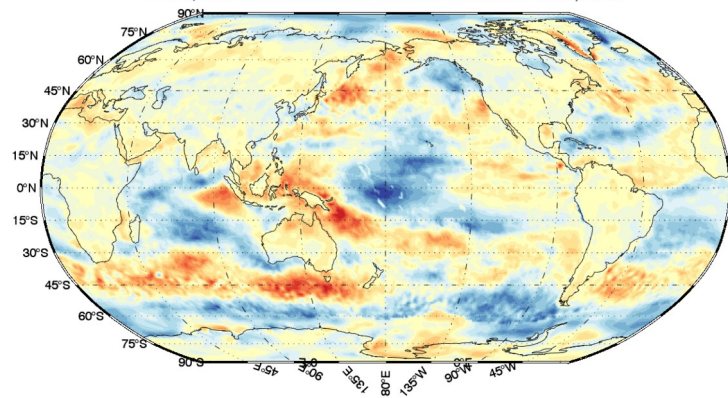
ERA5/RSS RADIOMETERS WIND SPEED ANOMALY, 2017



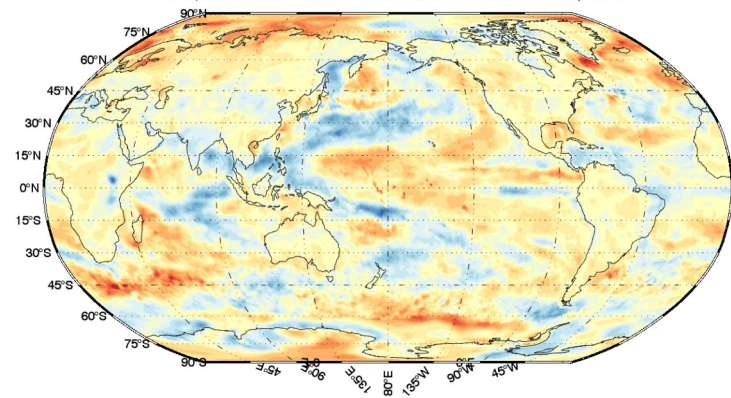
ERA5/RSS RADIOMETERS WIND SPEED ANOMALY, 2018



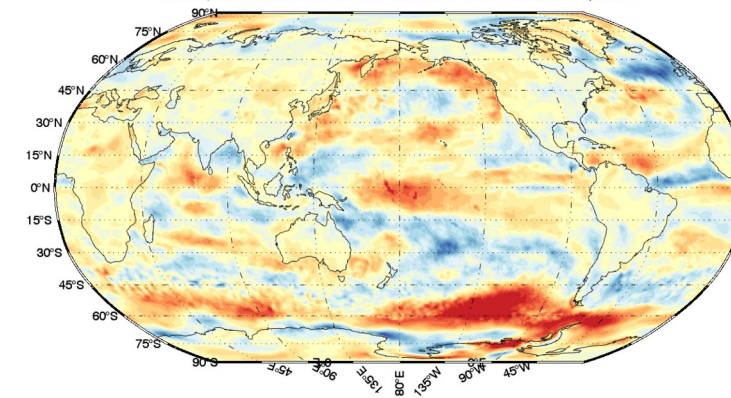
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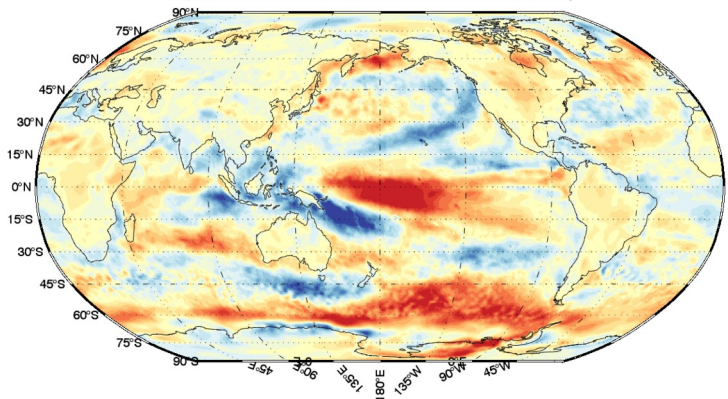
ERA5/RSS RADIOMETERS WIND SPEED ANOMALY, 2020



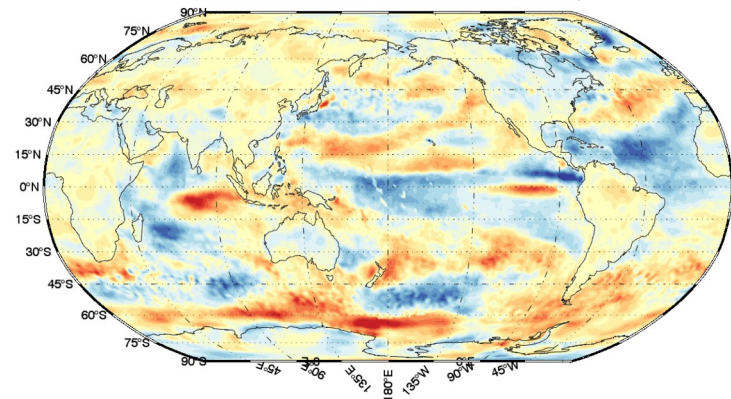
ERA5/RSS RADIOMETERS WIND SPEED ANOMALY, 2021



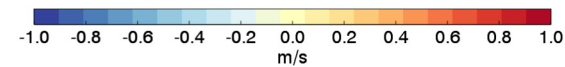
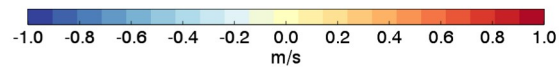
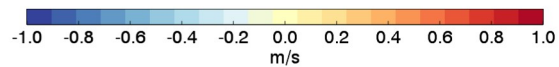
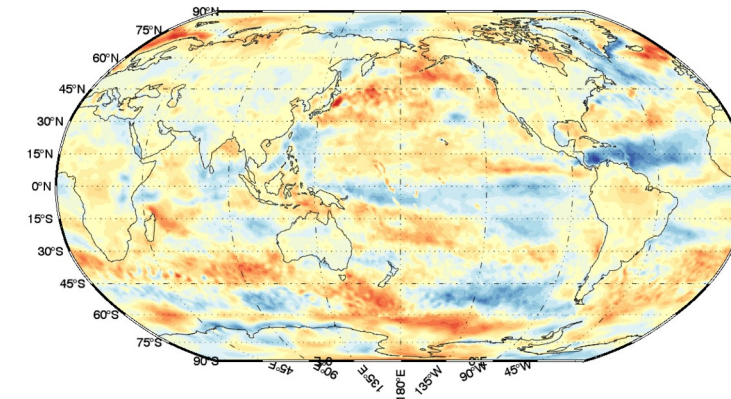
ERA5/RSS RADIOMETERS WIND SPEED ANOMALY, 2022



ERA5/RSS RADIOMETERS WIND SPEED ANOMALY, 2023



ERA5/RSS RADIOMETERS WIND SPEED ANOMALY, 2024



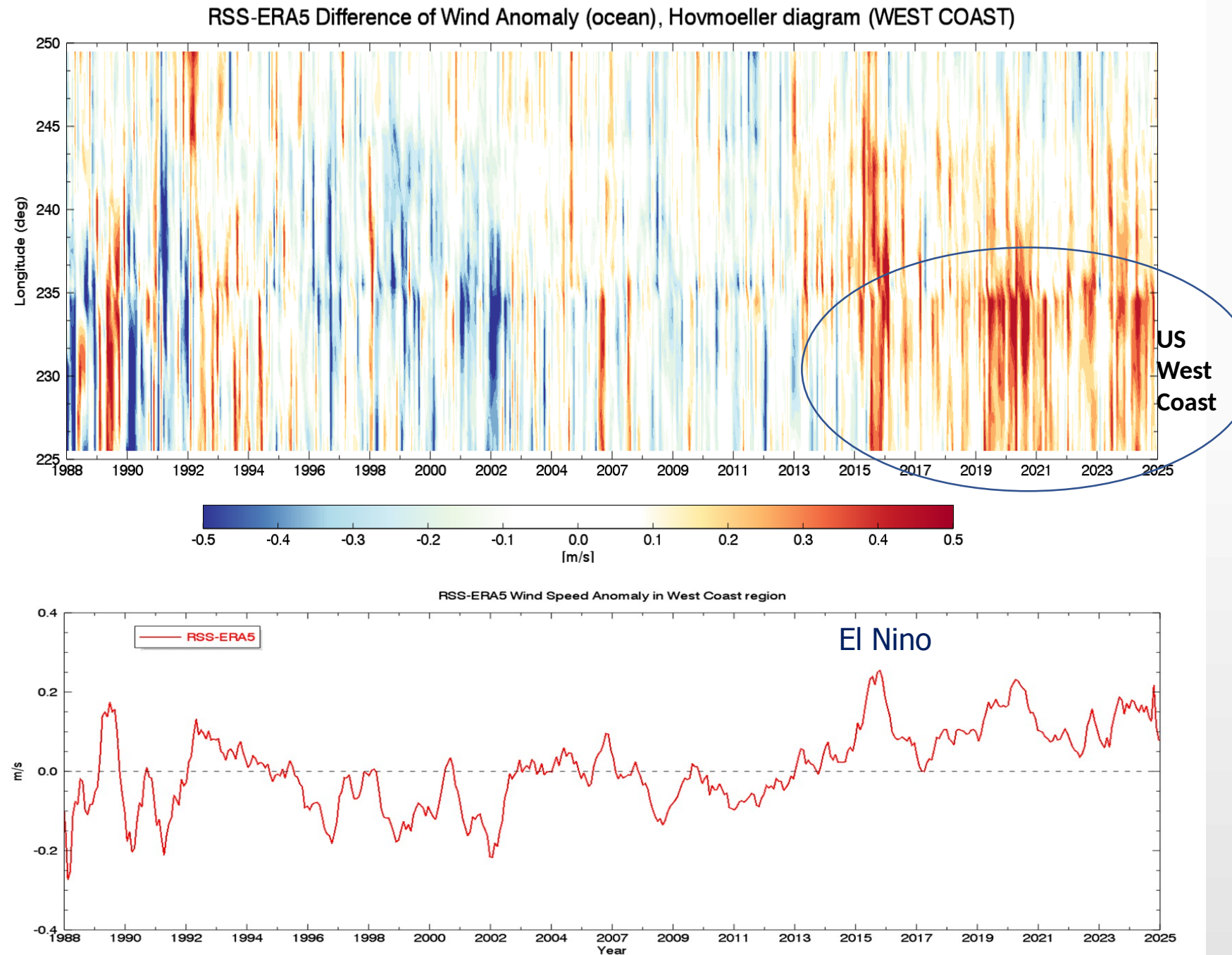
Variability off the US West Coast

Hovmoeller diagram for latitudes 25-45N, and off the US West coast (longitudes 225 to 250E).

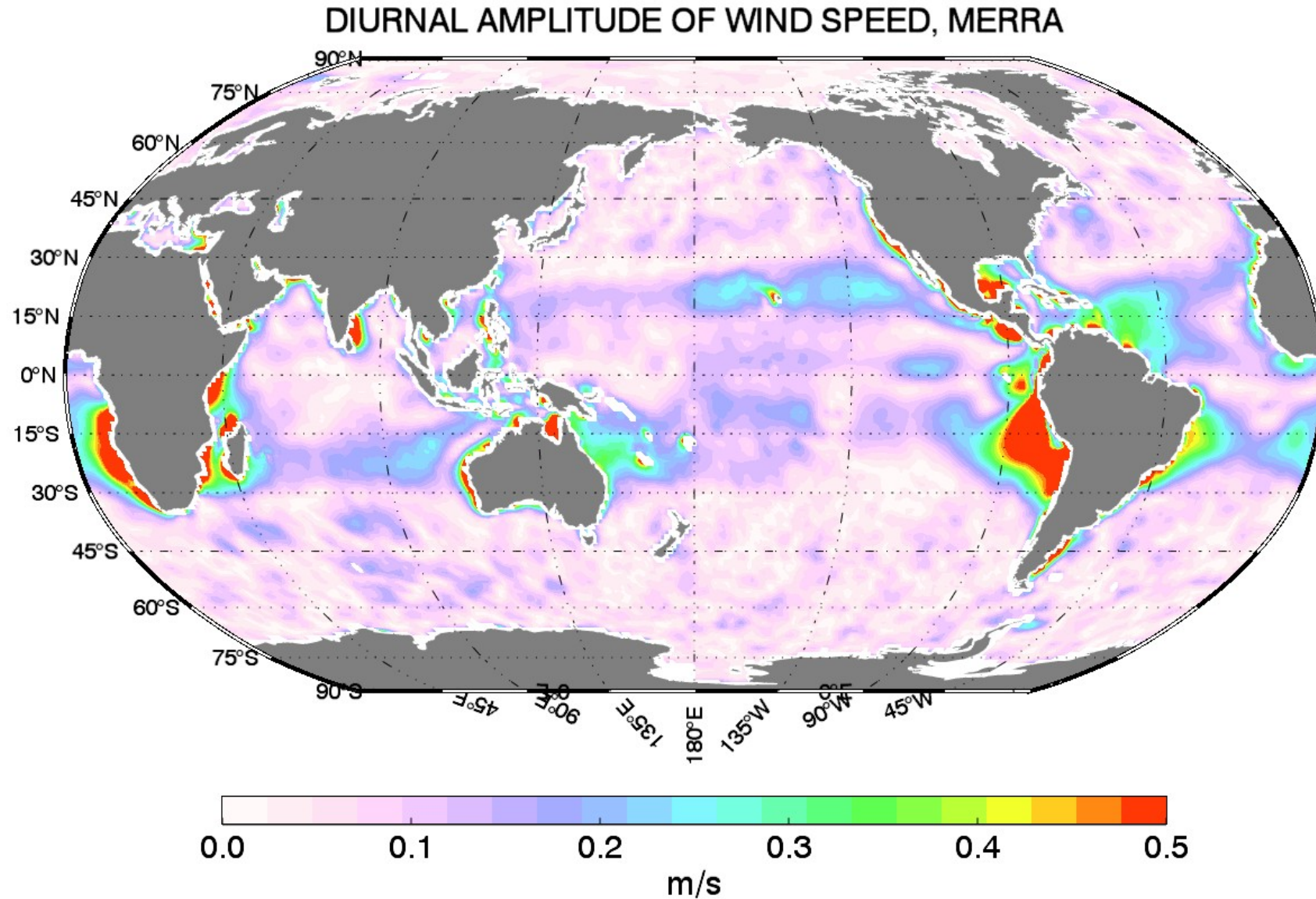
There seems to be a slope towards positive anomalies in the last decade, especially after 2019. (The “halo effect” in the trend map).

This could be due to increasing RFI (possibly in AMSR2 10 GHz channel), or to more weight from the 1:30 pm/am sampling (diurnal aliasing) into the merged data.

Needs more investigation



Wind Speed Diurnal Cycle (MERRA)



Local Time of Ascending Node

