Air-sea interaction and the value of ocean observations for S2S*

(*sub-seasonal to seasonal prediction)

Bruce Cornuelle and Aneesh Subramanian
Scripps Institution of Oceanography, UCSD

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A commercial message on behalf of ocean observations

- Preamble: settled science vs intuition/ideology
- Introduction: simple review of how the climate/weather system works and why water is key
- Recent work on S2S showing the influence of the ocean
- Discussion of ocean observations leading to show and tell

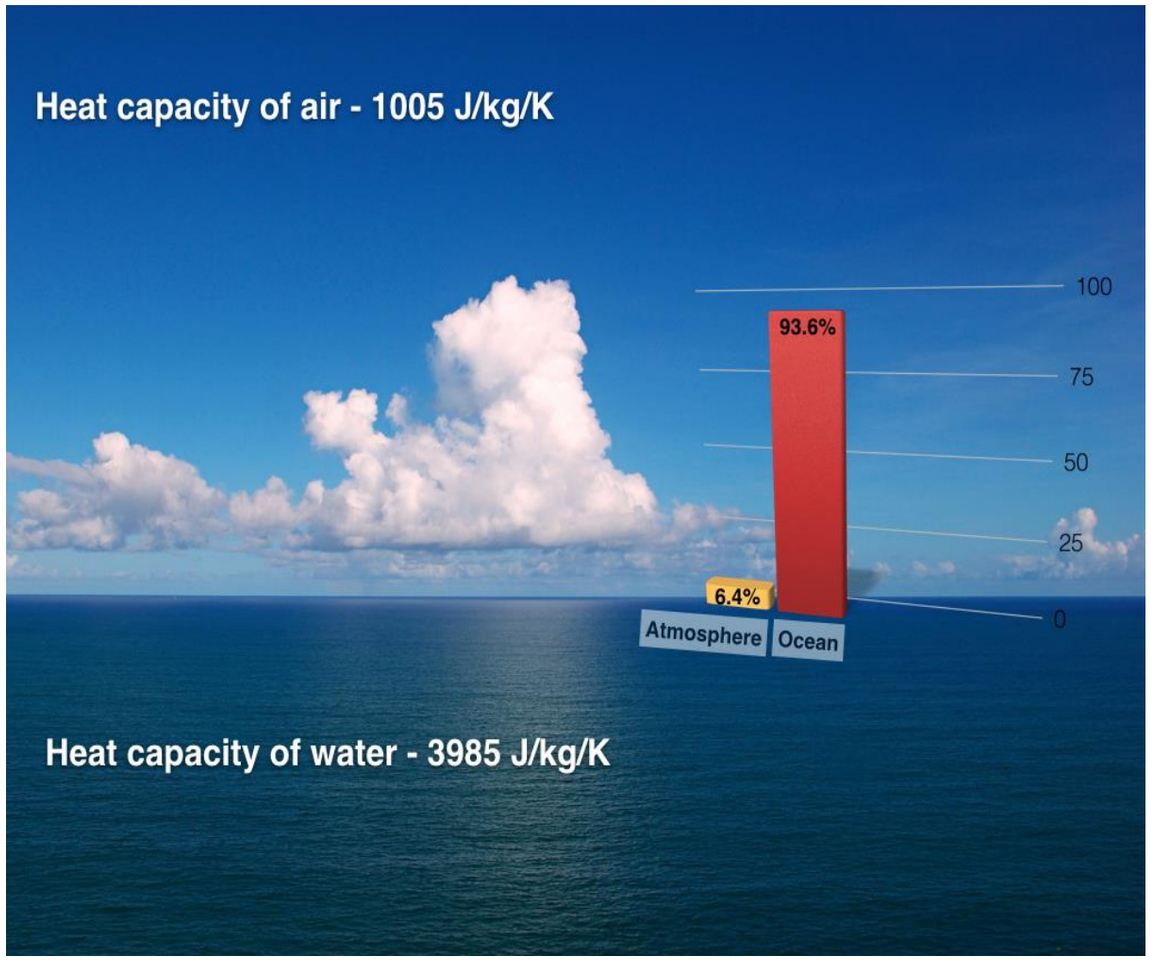
Why does the ocean matter?

The heat capacity of water per unit volume is >3000 times that of air at sea level.

The ocean heat capacity is about 1000 times that of the atmosphere. Evaporating and condensing water is a very efficient way to move heat.

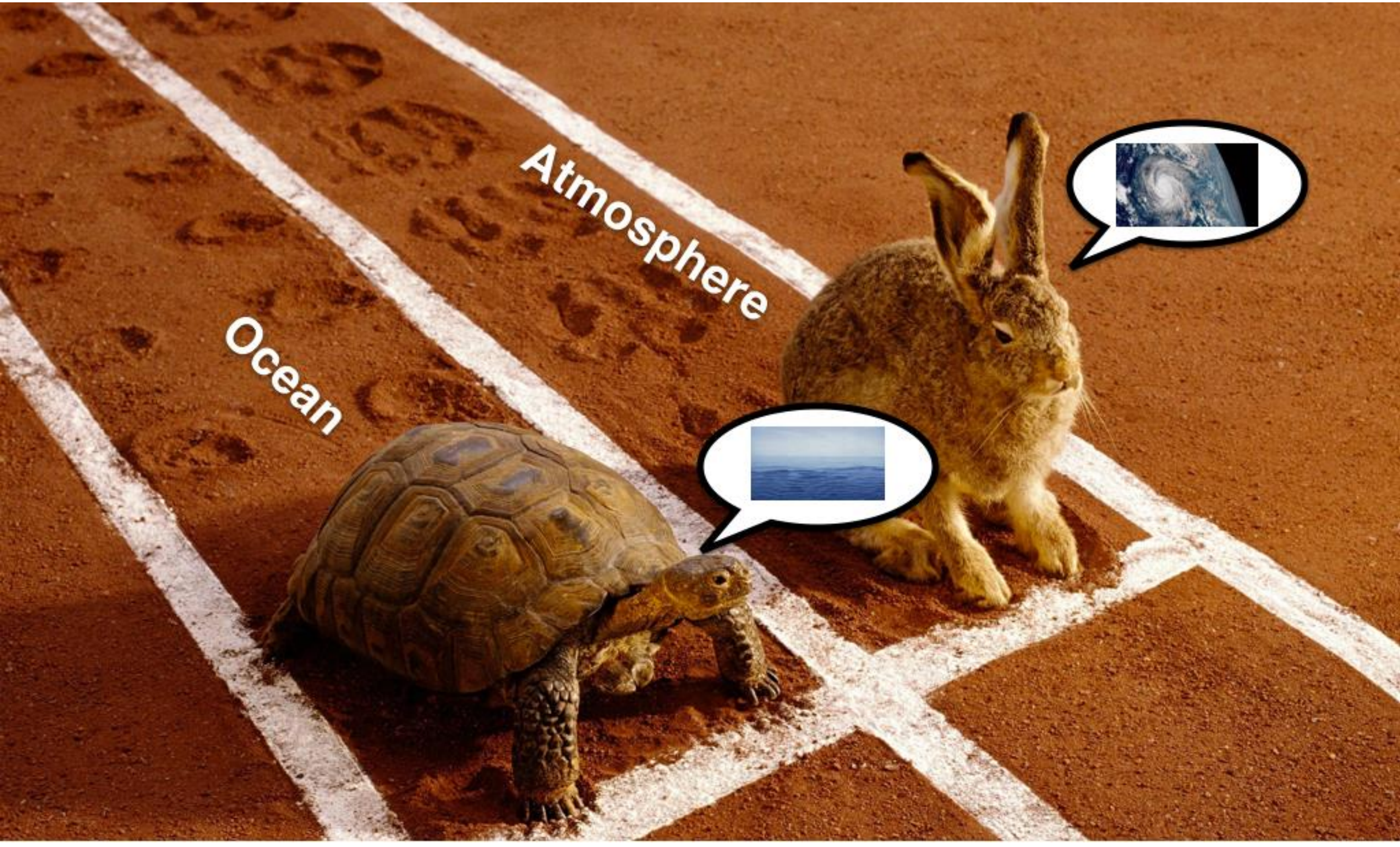
The upper 3m of the ocean can hold more heat than the atmosphere. Soil moisture and surface water are also important!

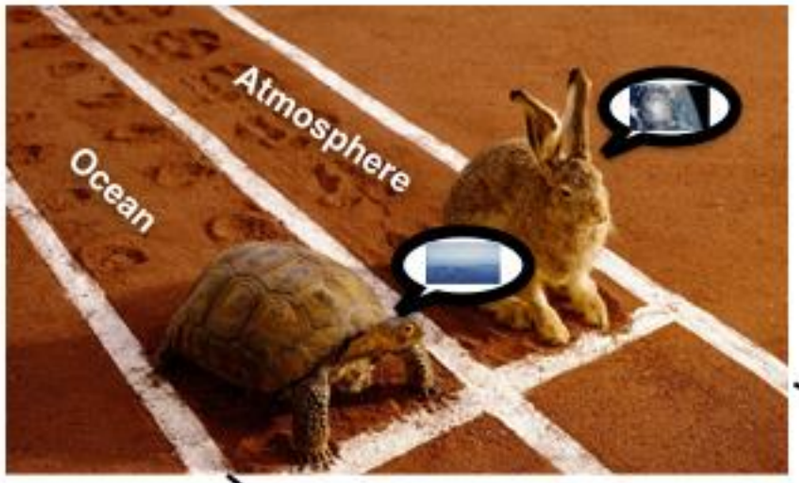
The increase of heat held in the ocean over the last 50 years is more than 30x larger than in the atmosphere. The oceans have absorbed about 93% of the new heat over that time.



The “hiatus” in global warming was due to confusing surface temperature for global heat content
The heat was in the ocean

Oceanographer ideology:
The atmosphere is mercurial and forgets what it's doing.
The ocean has a long memory and moves slowly.





Weather

Taking the analogy WAY too far…

...and taking advantage of the implied (unfair) value judgement against the Hare

Subseasonal-Seasonal

Climate

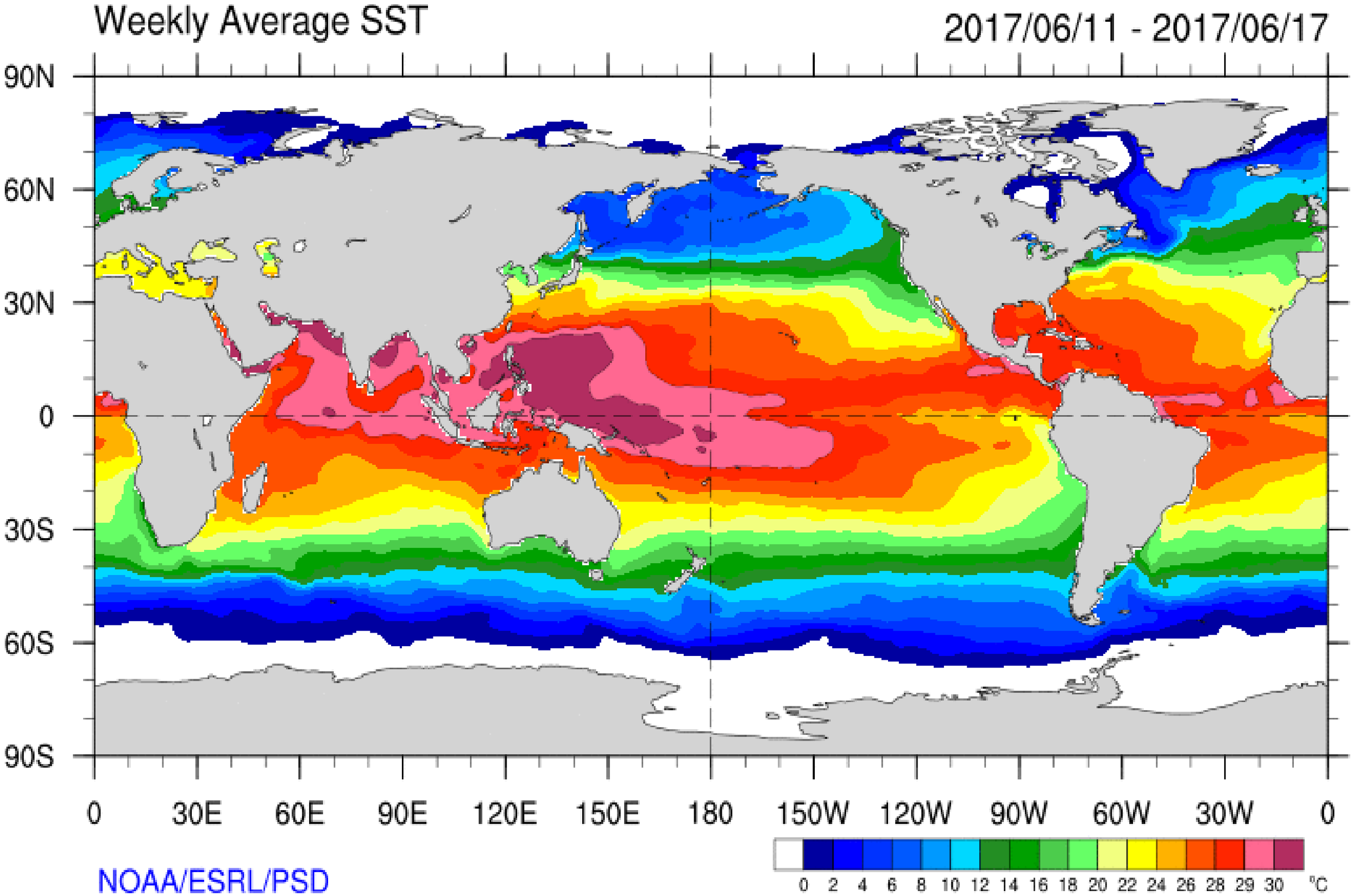
Understanding at different timescales: science vs intuition/ideology

The time-mean state is broadly understood: atmosphere and ocean work together to create the climate. Small scales remain difficult, but can be parameterized in some cases

Short time-scales up to 5-10 days can be forecasted: the atmosphere evolves and the ocean stays fixed

For S2S it is still being learned. Turbulence randomizes the atmosphere, and the connection with the ocean is inconveniently complicated.

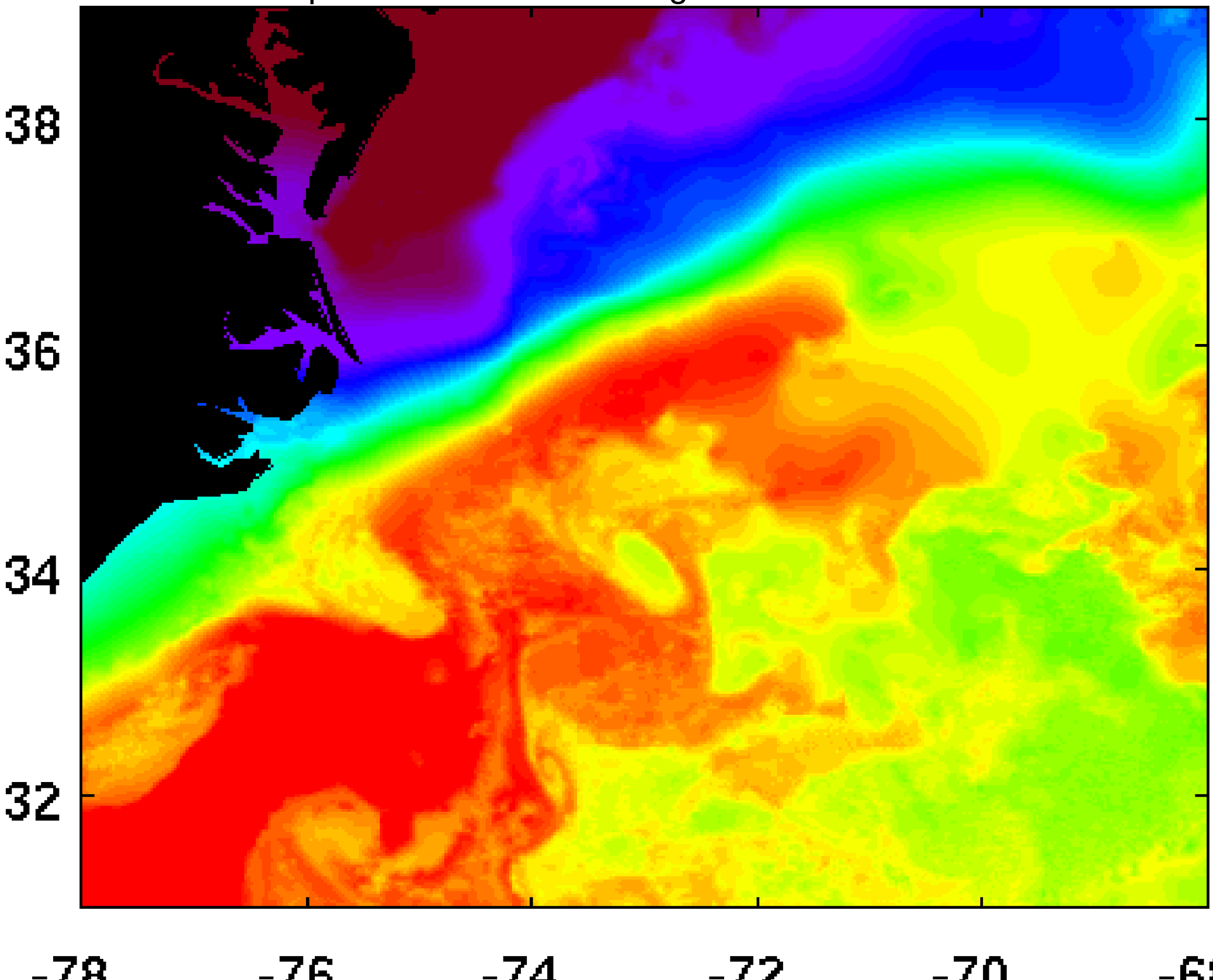
Smoothed Sea Surface Temperature (SST) from NOAA

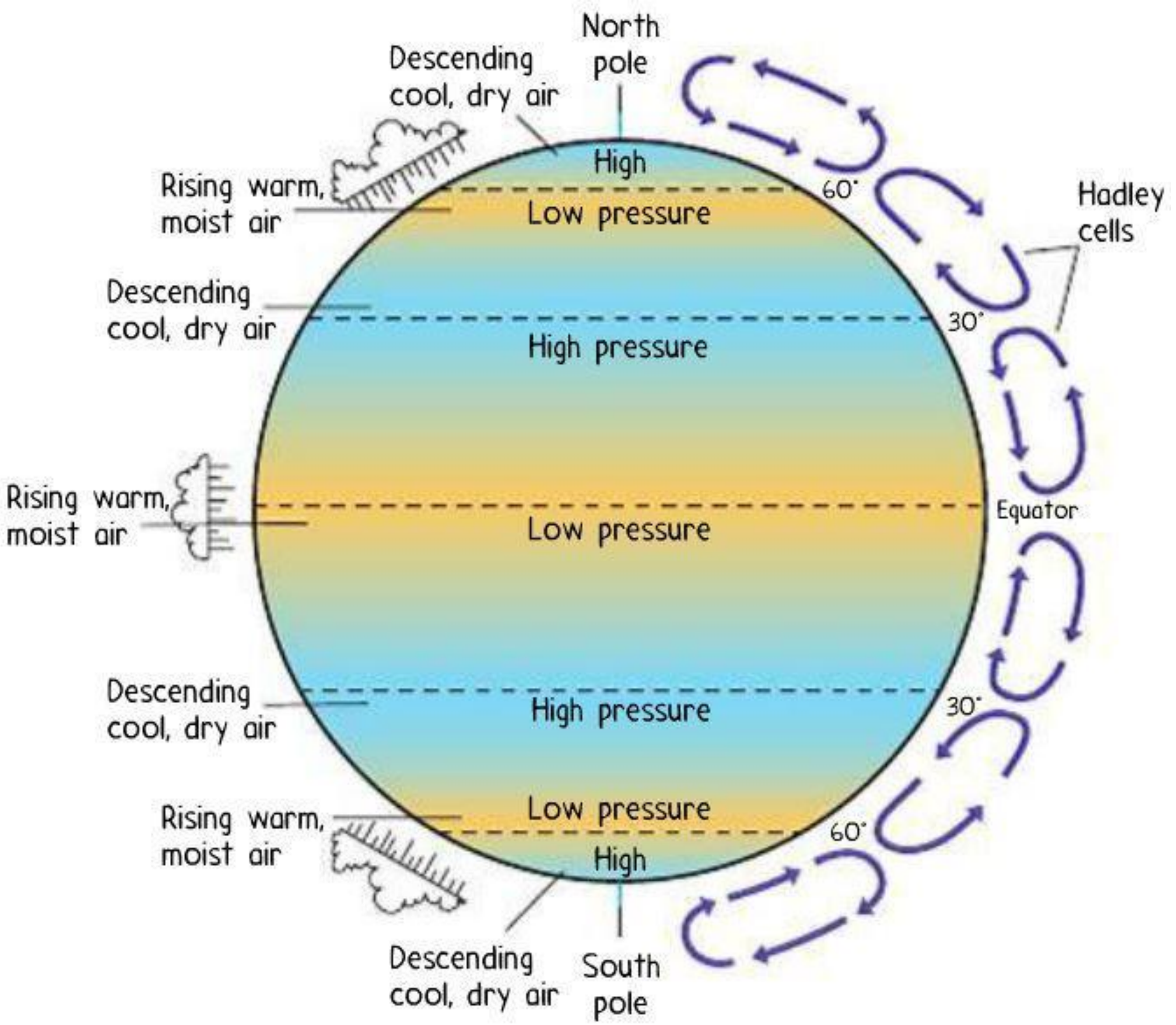


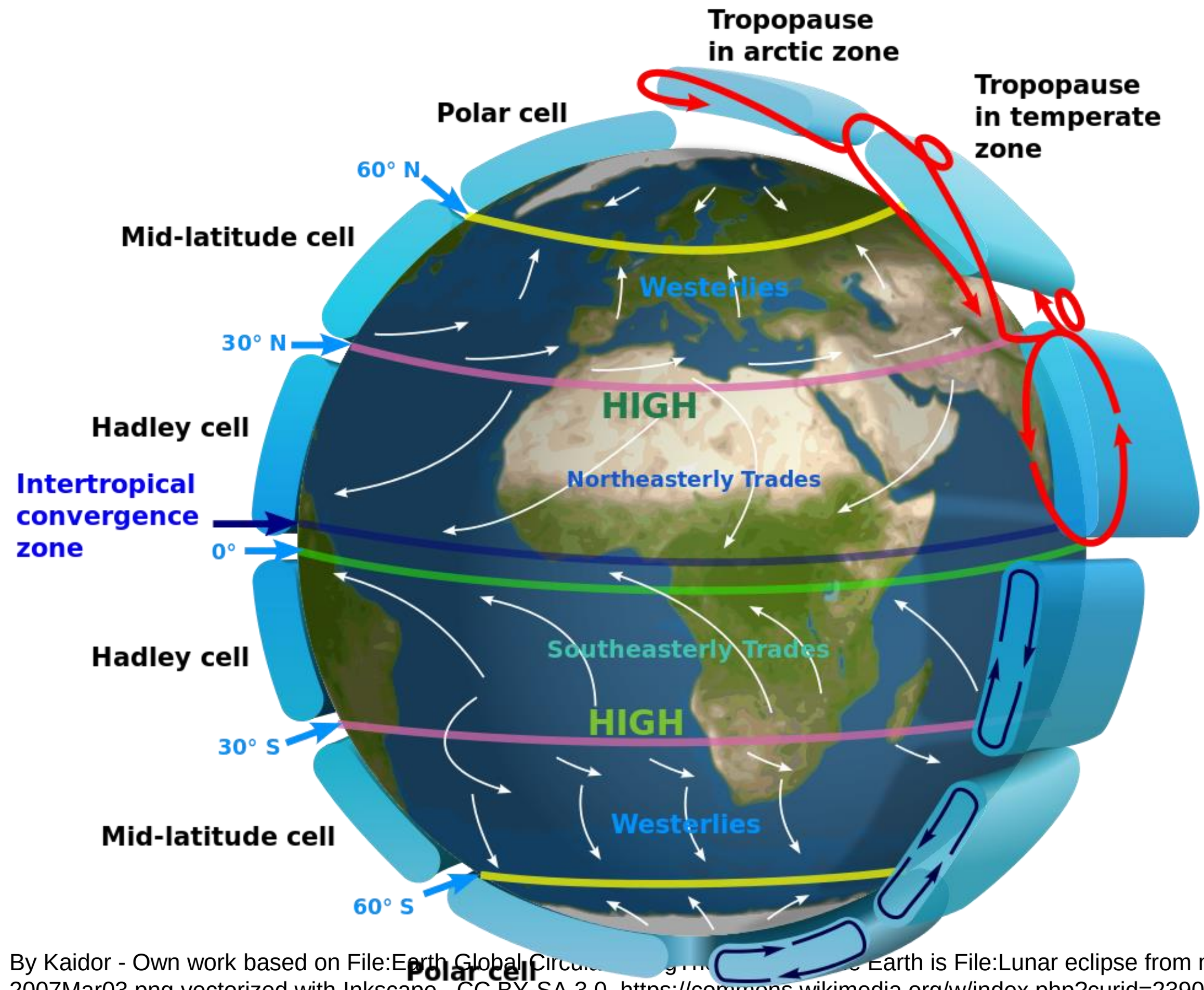
NASA PO.DAAC Physical Oceanography Distributed Active Archive Center

MUR L12 ("1km")

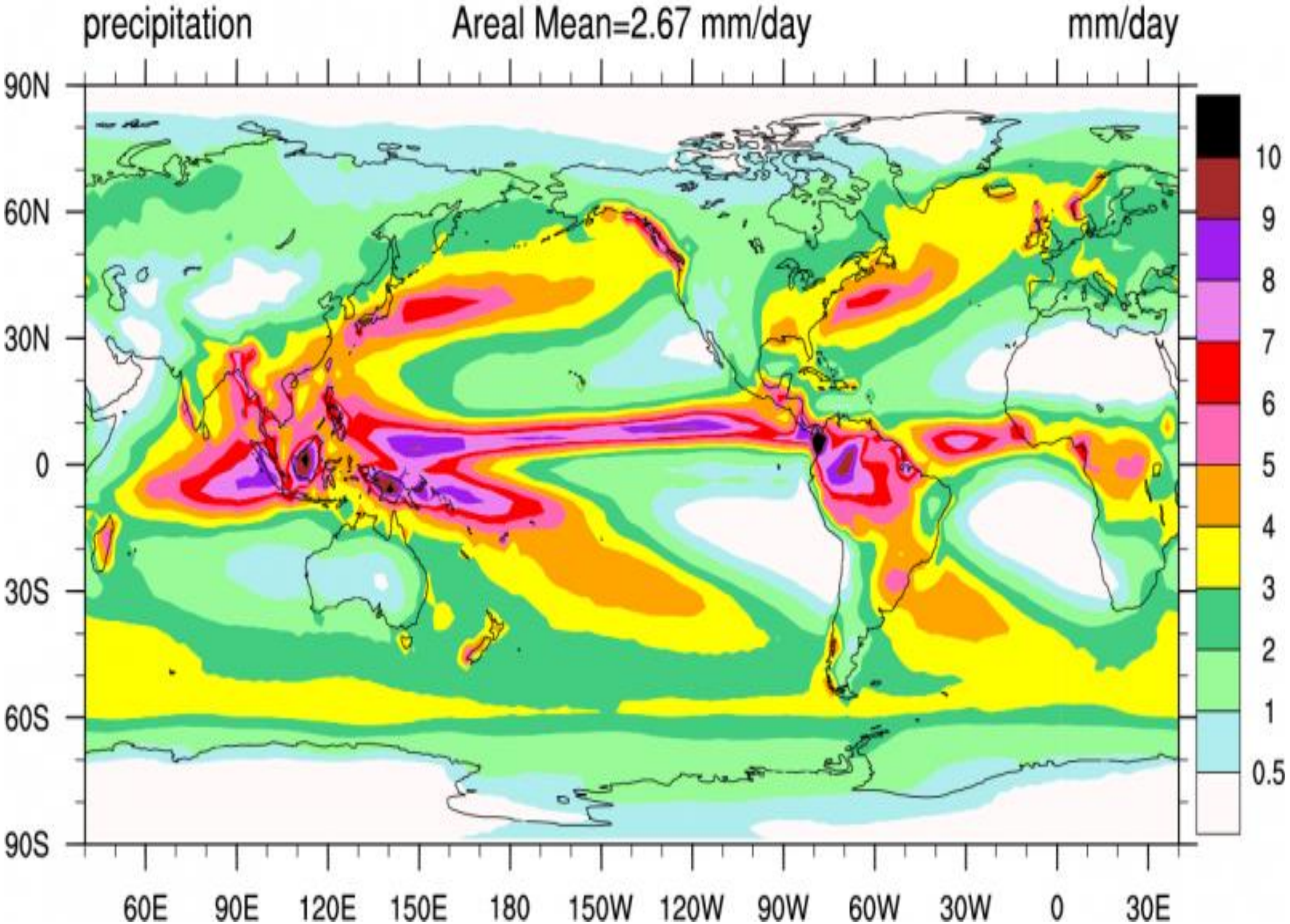
Snapshot of Gulf Stream high-resolution SST




North pole
Descending cool, dry air
High
Rising warm, moist air
60°
Low pressure
Hadley cells
Descending cool, dry air
30°
High pressure
Rising warm, moist air
Equator
Low pressure
Descending cool, dry air
High pressure
Low pressure
Rising warm, moist air
60°
High
Descending cool, dry air
South pole



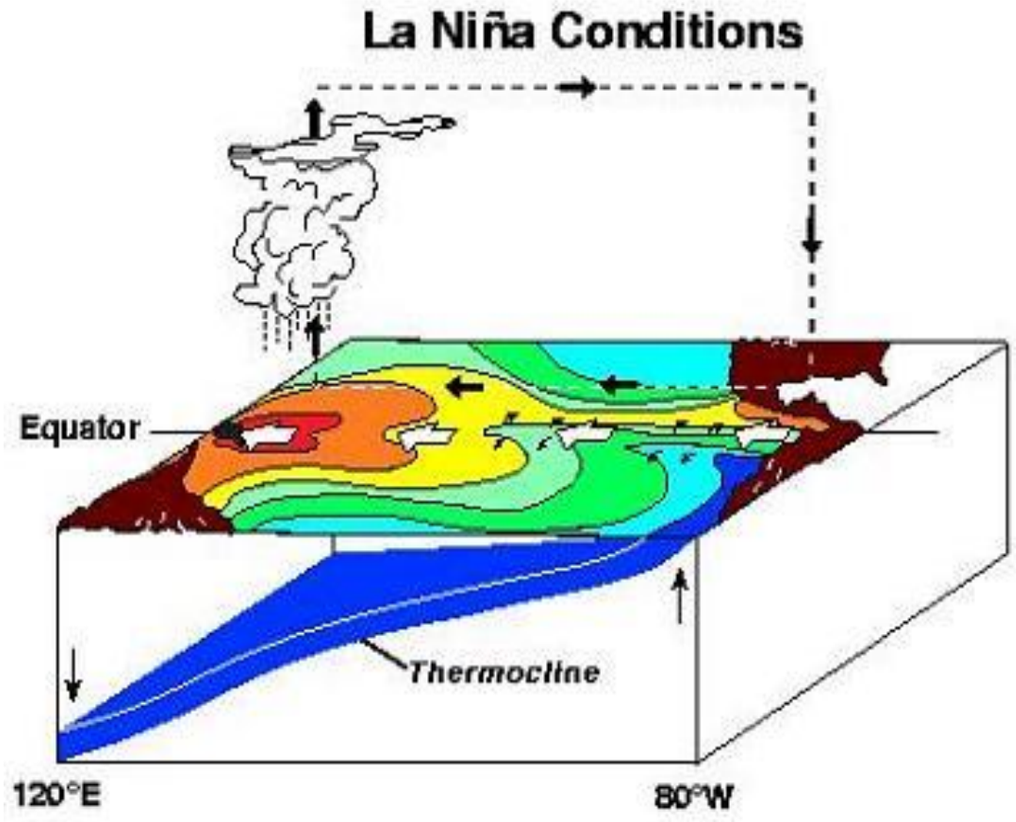
TRMM GPCP: 1979-2010

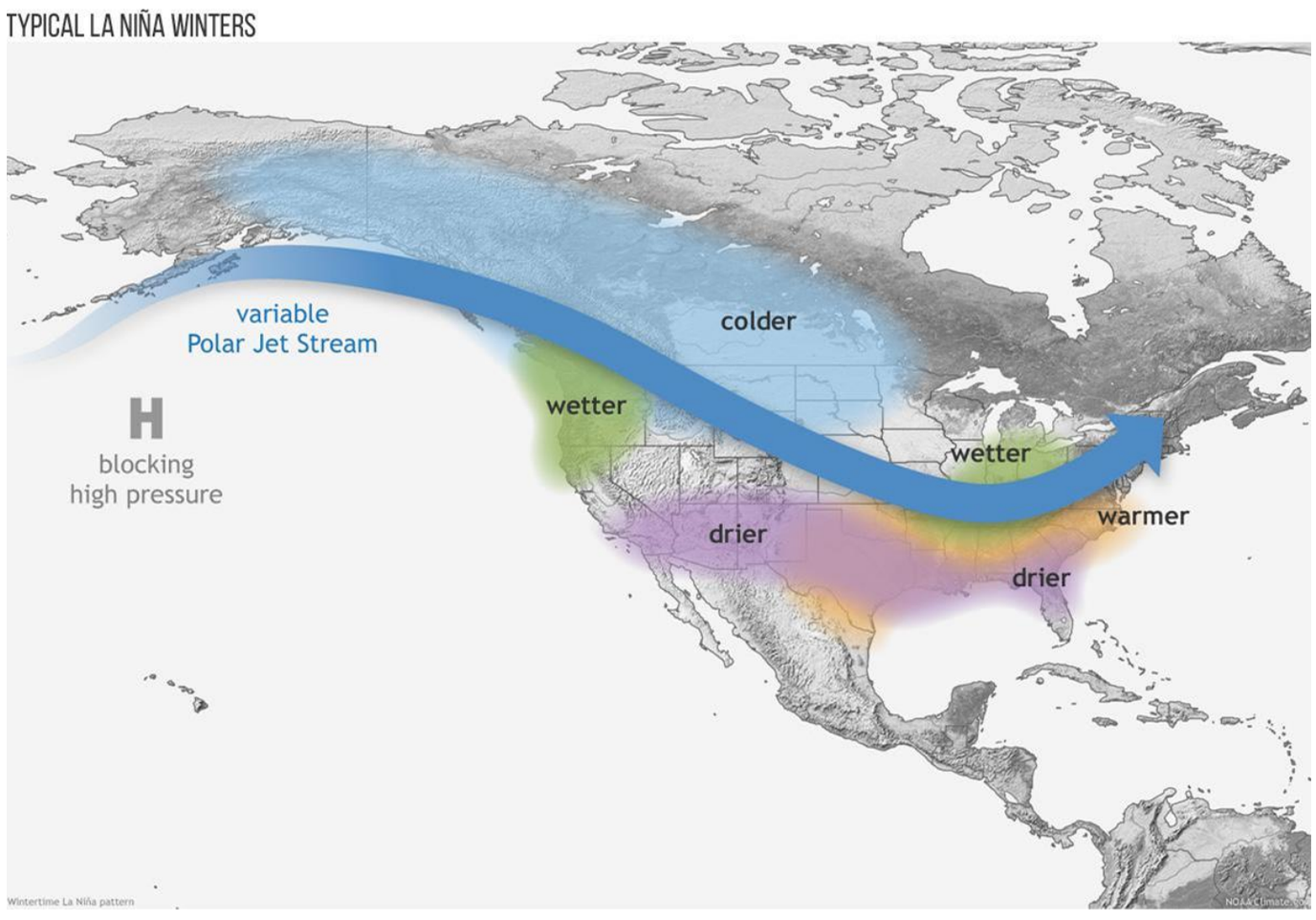


Seasonal Outlooks

- ENSO is the most studied source of predictability on seasonal timescales.
- Yet, in the recent decade (or two) ENSO teleconnections into the mainland US have not been representative of the canonical teleconnection patterns
- Researchers are exploring other sources of predictability such as regional ocean state (e.g.: upper ocean heat content in Northeast Pacific, storm track variability)

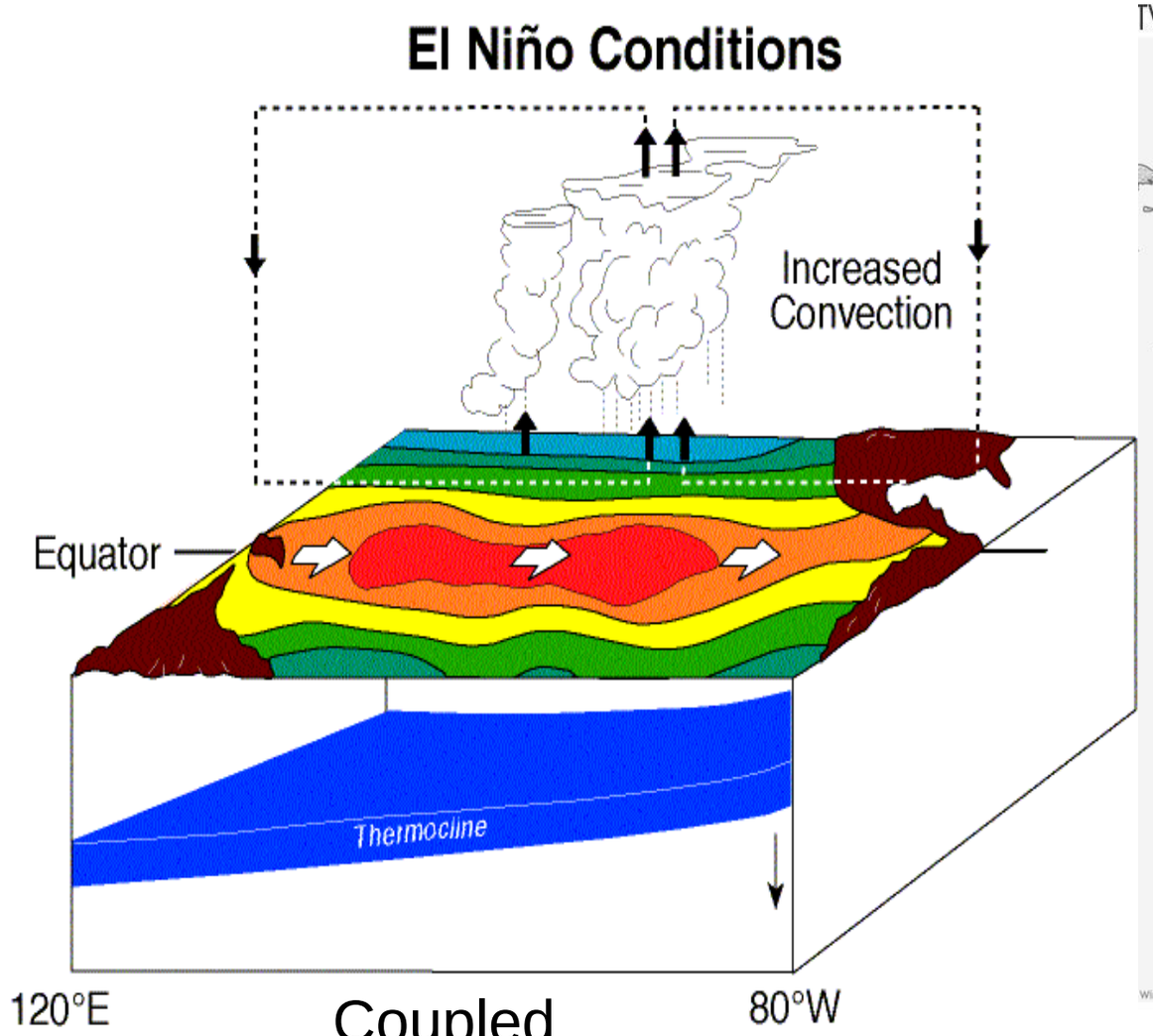
La Nina: warm water moves west, storms move north…maybe



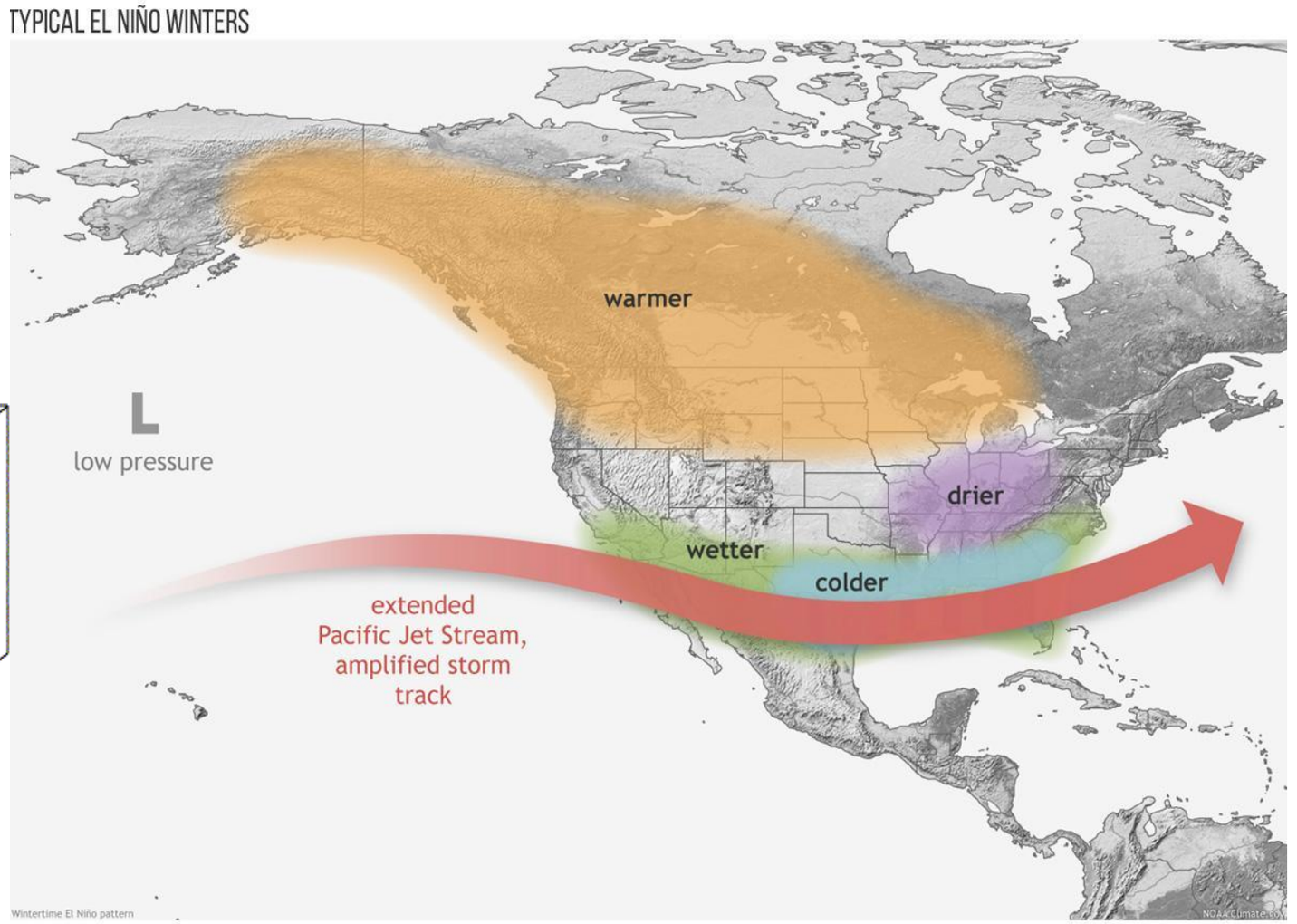


Coupled phenomena

El Nino: warm water moves east, storms move south…maybe



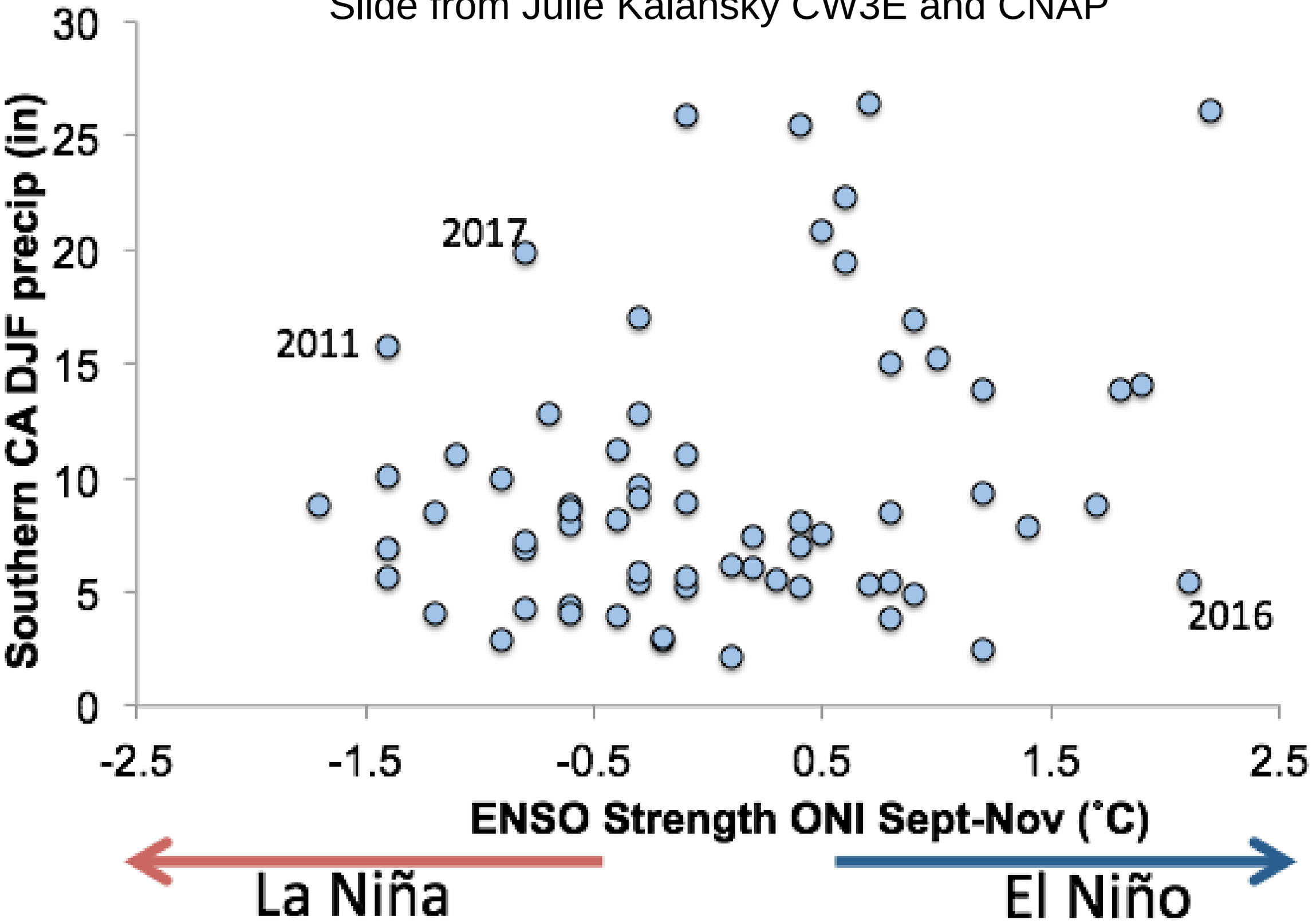
Coupled phenomena



Source: NOAA

Are the ENSO teleconnections to Southern CA rainfall changing? (or just complicated?)

Slide from Julie Kalansky CW3E and CNAP



Recent work shows evidence of the importance of the ocean, but…

- Small scales seem to matter, making the observation and computation problems harder.

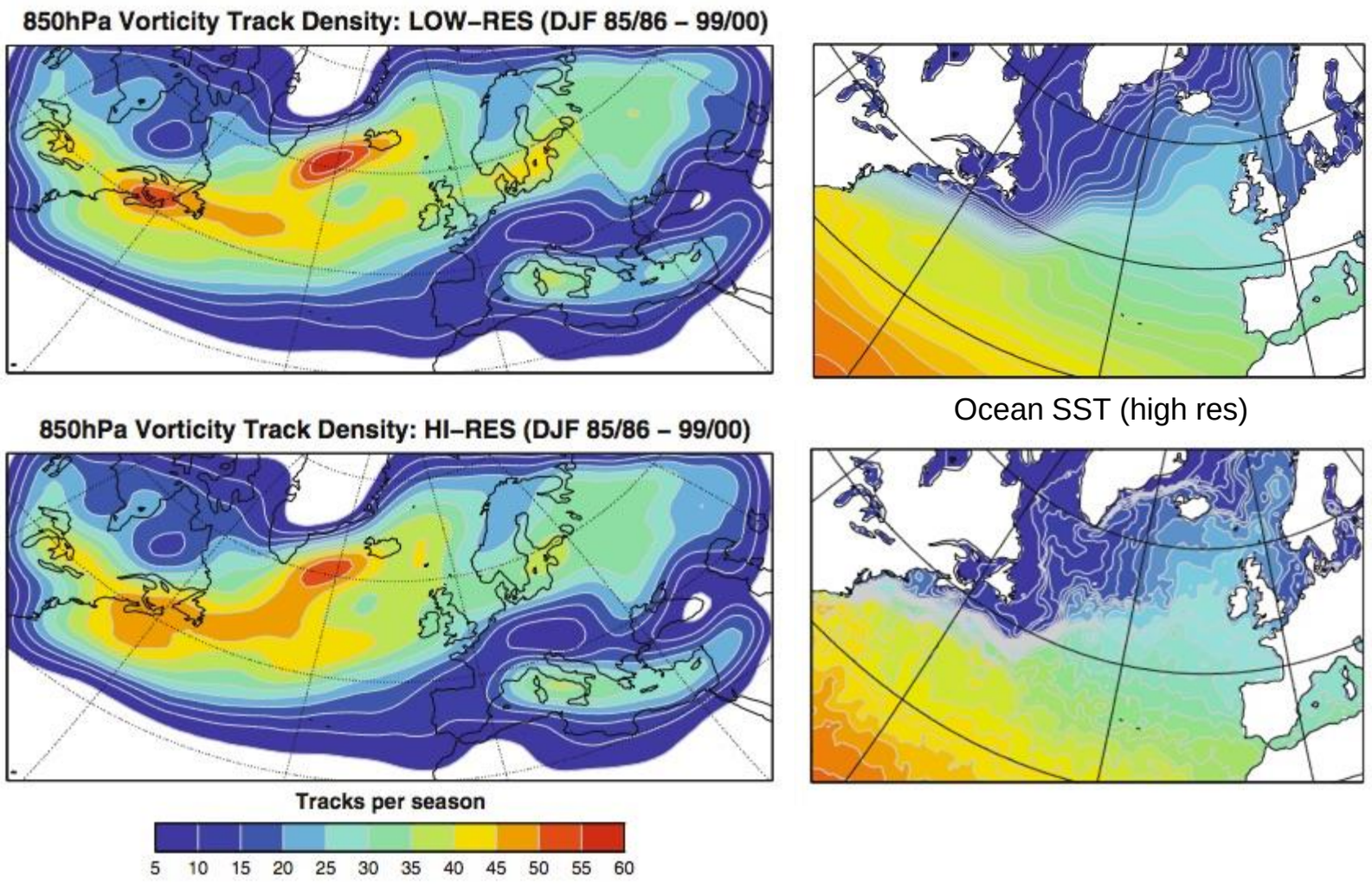
- Coupling involves turbulent fluxes which are still poorly understood.

- The surface boundary layer is very complicated, with surface waves playing a role.

Impact of increasing ocean horizontal resolution (Woolings et al. 2010)

AGCM (50 Km)

Ocean SST (smooth)

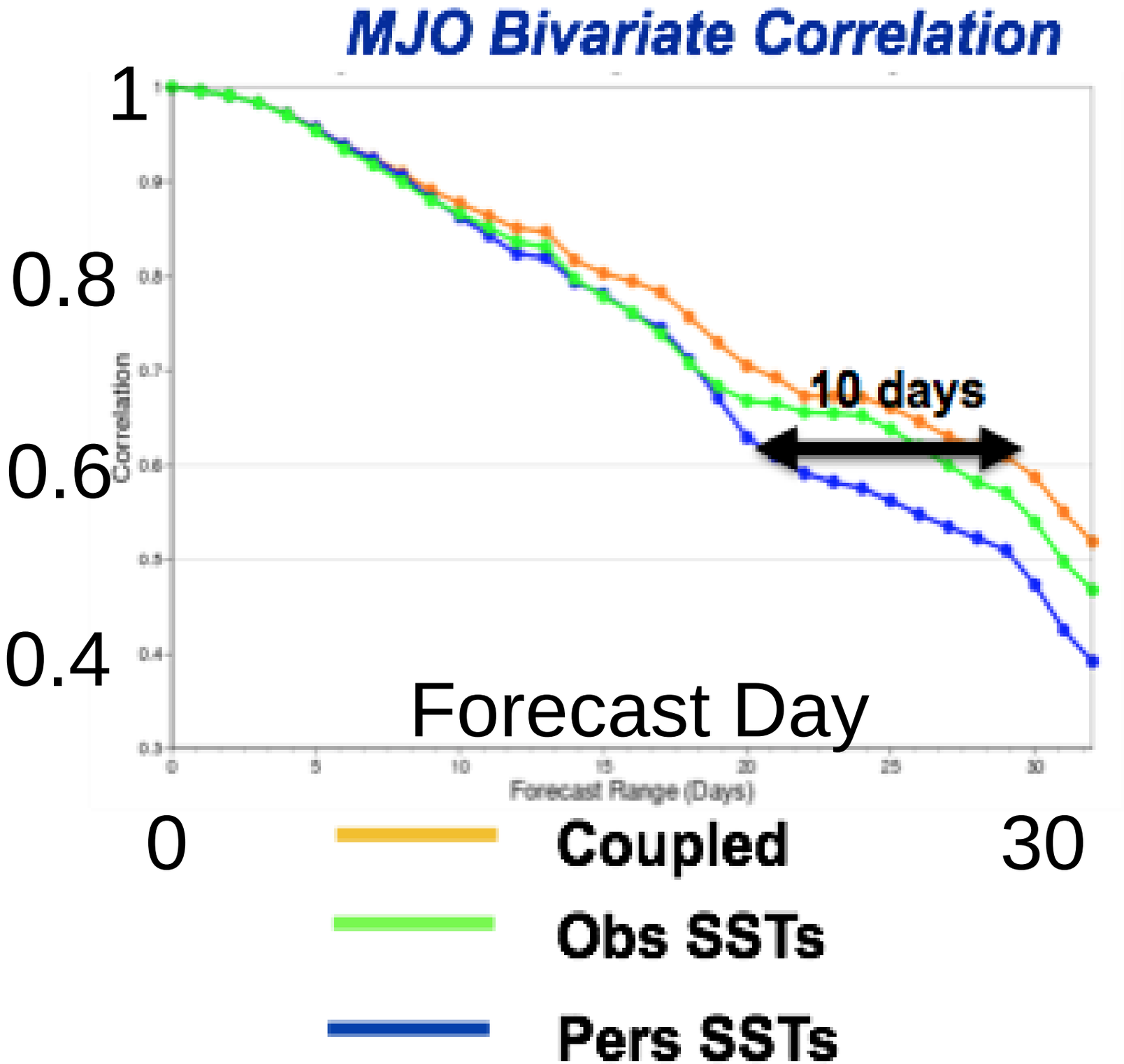


Ocean SST (high res)

- High resolution ocean changes storm track density in coupled seasonal model hindcasts
- Ocean changes storm track – Possible impact on teleconnections

ECMWF coupled forecast experiments

Coupled model forecasts Improved Madden-Julian Oscillation prediction by 10 days compared to atmosphere-only forecasts



The Navy is funding a large program to use ocean measurements to improve predictions of the Monsoon in collaboration with the Indian weather service

Code 32

All Programs

Division 321

Division 322

- **Physical Oceanography**
- Early Student Support
- **MISO-BOB DRI**
- North Arabian Sea Circulation
- Flow Encountering Abrupt Topography
- Waves, Langmuir Cells and the Upper Ocean Boundary Layer
- Planning Letter Submission
- Annual Reports FY12
- Annual Reports FY13
- Annual Reports FY14

Oceanic Control of Monsoon Intra-seasonal Oscillations in the Tropical Indian Ocean and the Bay of Bengal (MISO-BOB)

An Air-Sea Interaction Initiative: This Initiative is Fully Subscribed

Our current predictive skill of the monsoon is poor on weekly to monthly timescales, yet improved prediction would benefit the billions of people that inhabit the nations bordering the northern Indian Ocean as well as the safety of ships at sea that work in or transit through this area. The upper ocean stratification in the Bay of Bengal is strongly controlled by the salinity structure, resulting in complexities in the upper ocean temperature and heat content distribution. The heat content and stratification impacts the air-sea fluxes, thus coupling the atmospheric and Oceanic boundary layers at multiple-scales. Previous work has shown that coupling with the oceans in coupled models improves weather predictions, but the mechanisms and the required coupling approach are yet to be identified. This new proposed observational and modeling work is timely both in terms of our current state knowledge and overlap with funded atmospheric and oceanic measurement programs in India.

The active and break cycles determined by Monsoon Intra-seasonal Oscillations (MISO) strongly modulate rainfall, sea surface temperature, heat fluxes and winds and (presumably) surface currents in the northern Indian Ocean. The northern Indian Ocean (Bay of Bengal and Arabian Sea) show strong coupling at 10-90 day time scales. Currently, the MISO represents a primary challenge to sub-seasonal weather prediction and accurate simulation of upper ocean temperature and salinity structure. Coupled regional climate models have shown that the ocean plays an important role in setting the propagation speed and intensity of the MISO; but our current in situ knowledge of the MISO in the sub-surface ocean is comprised of coarse resolution information from the ARGO float program and the RAMA mooring array in the Bay of Bengal. These data show clear signatures of MISO in both salinity and currents in the Northern Indian Ocean. Further, taken together with results from coupled regional ocean-atmosphere models, they lead to a number of important unanswered questions that ultimately effect predictability of weather and the upper ocean temperature and salinity structure.

No predictions yet, but ocean observations are important

Research:

- Understand the ocean surface mixed layer structure and heat content.
- Understand the air-sea interactions
- Understand the physics of the evolution of the mixed layer
- Better computational capability

Forecasts:

- Know the upper ocean structure at the start of the forecast

What are the ocean observations and how much do they cost?

Argo Floats: $10M/yr for US

Surface drifters: $7M (?)

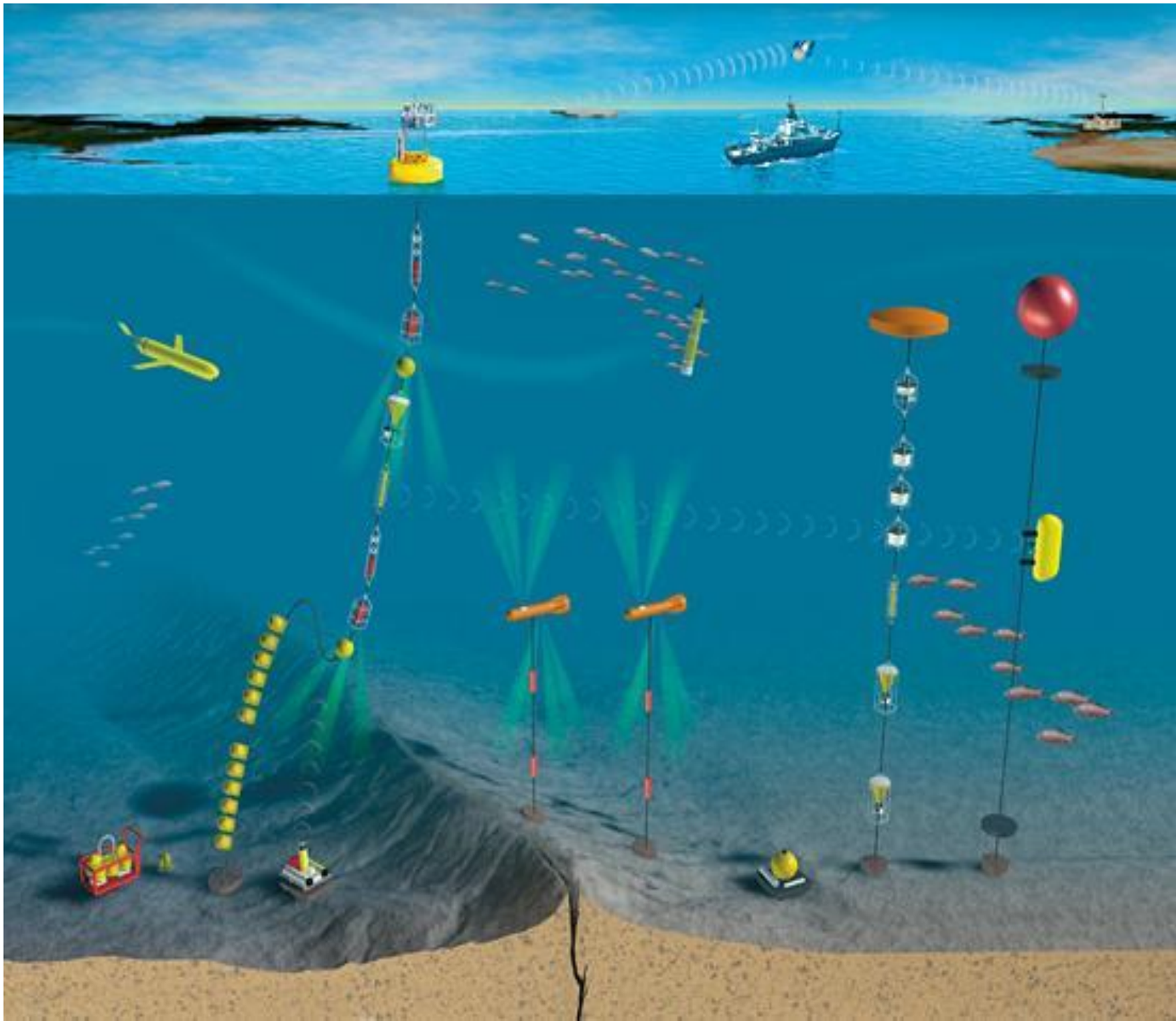
TAO $20M (??) (need to count shiptime, etc.)

Expendable temperature measurements from thips: (XBTs) $7M (?)

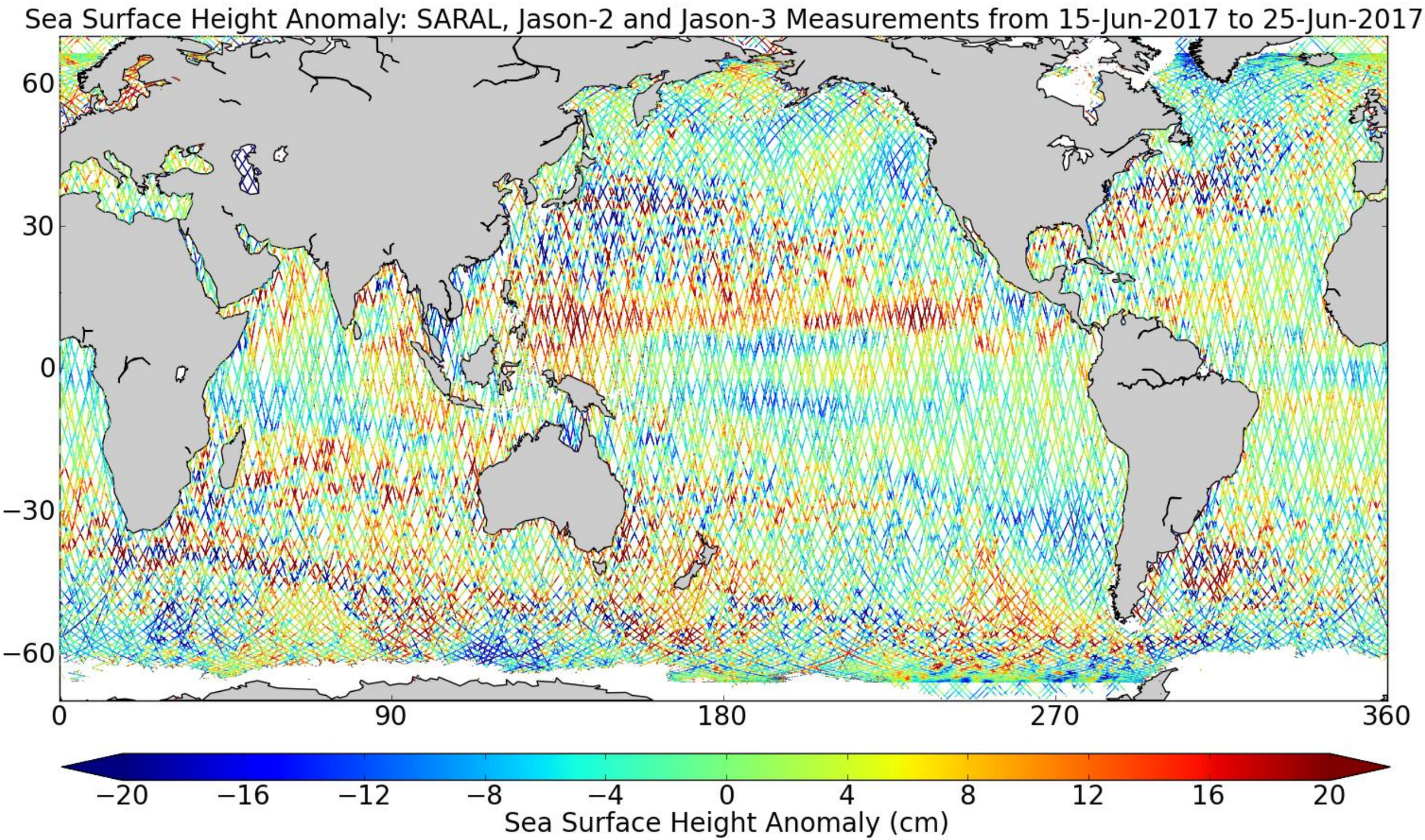
Other obs. $15M (?)

Acad. Research $50M (??)

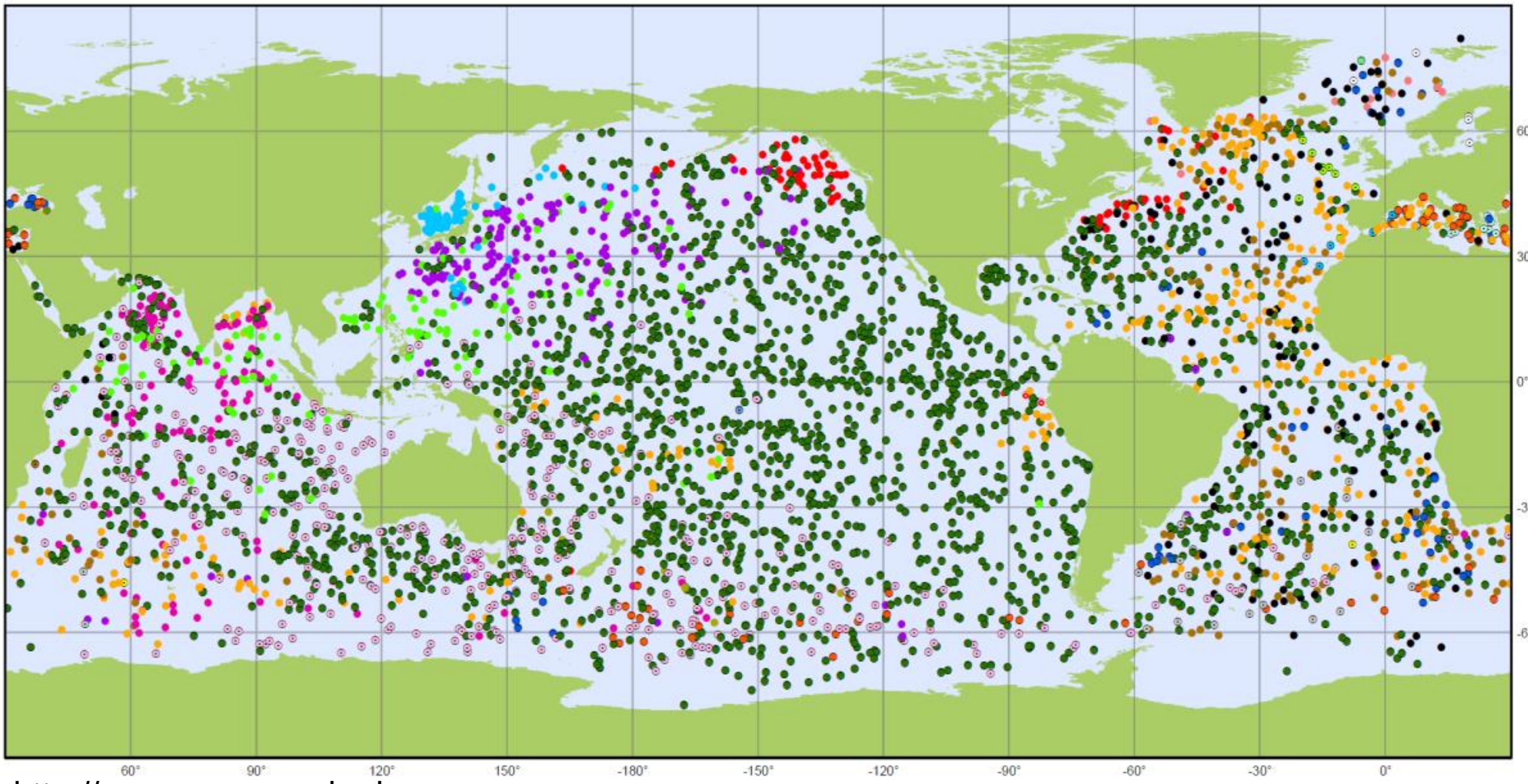
Satellites: $3B (??)



Two weeks of Satellite Altimetry Sea Surface Anomaly
NASA PO.DAAC Physical Oceanography Distributed Active Archive Center



The Argo Program: Systematic observations of the global ocean



http://www-argo.ucsd.edu

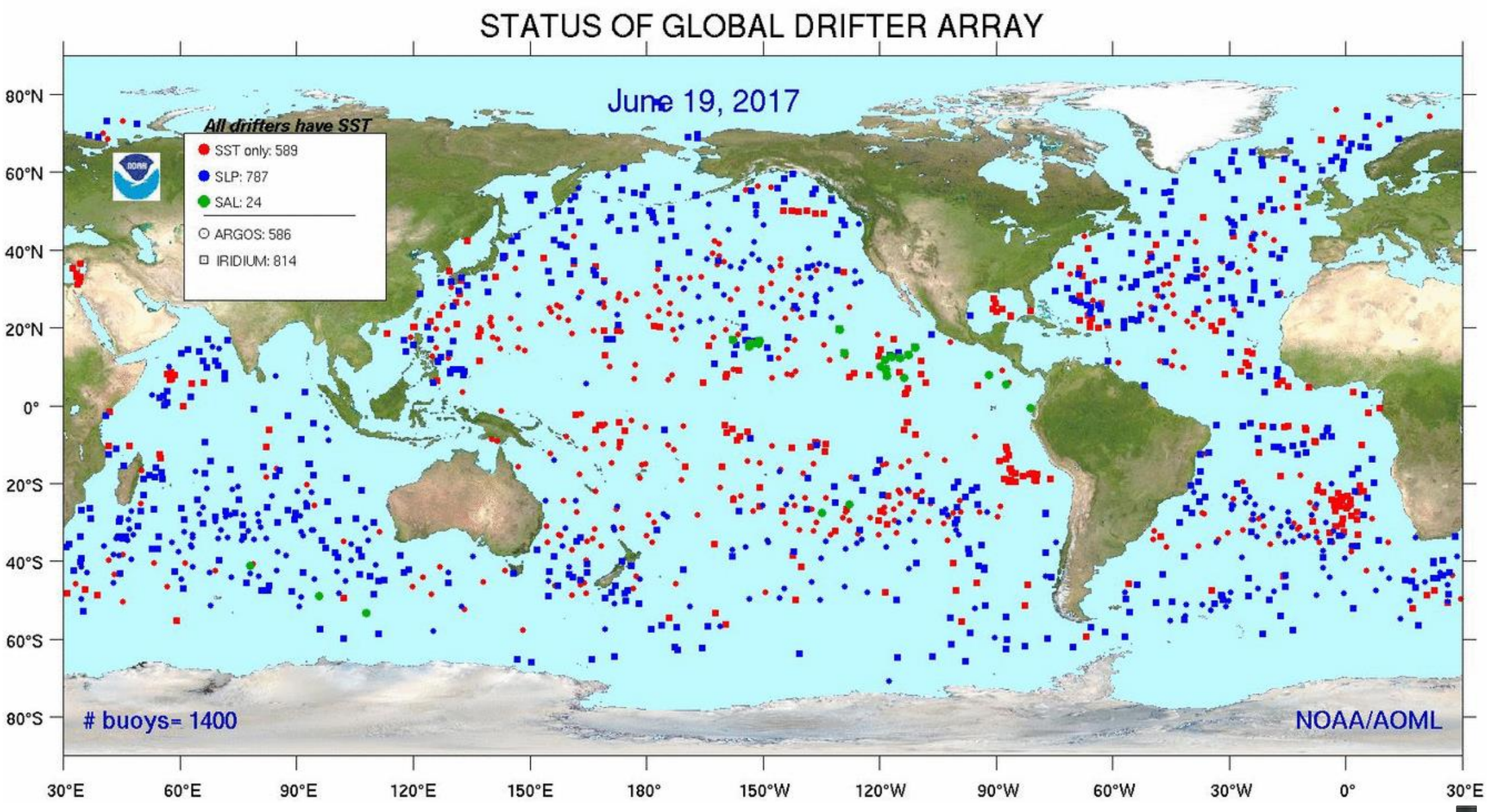
Argo **National contributions - 3945 Operational Floats** **April 2017**

Latest location of operational floats (data distributed within the last 30 days)

- ARGENTINA (2)
- AUSTRALIA (377)
- BRAZIL (6)
- BULGARIA (1)
- CANADA (75)
- CHINA (116)
- ECUADOR (1)
- EUROPE (57)
- FINLAND (6)
- FRANCE (327)
- GERMANY (141)
- GREECE (8)
- INDIA (128)
- IRELAND (11)
- ITALY (73)
- JAPAN (167)
- KENYA (1)
- MAURITIUS (1)
- MEXICO (2)
- NETHERLANDS (26)
- NEW ZEALAND (7)
- NORWAY (10)
- PERU (3)
- POLAND (2)
- KOREA, REPUBLIC OF (61)
- SPAIN (7)
- UK (155)
- USA (2174)

The Global Drifter Program (GDP)

"Global Measurements of Surface Velocity, SST, SSS, Winds and Atmospheric Pressure"



The NOAA funded GDP is a global array array of surface drifters that measure **Essential Climate Variables, including** near-surface ocean currents (15 m depth), **sea surface temperature, sea surface salinity**, **sea-level air pressure, and directional wave spectra.**

- (http://gdp.ucsd.edu/ldl_drifter/index.html)