GAPS IN OCEAN OBSERVATIONS TO SUPPORT FORECASTING

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Western States Water Council May 22 2019

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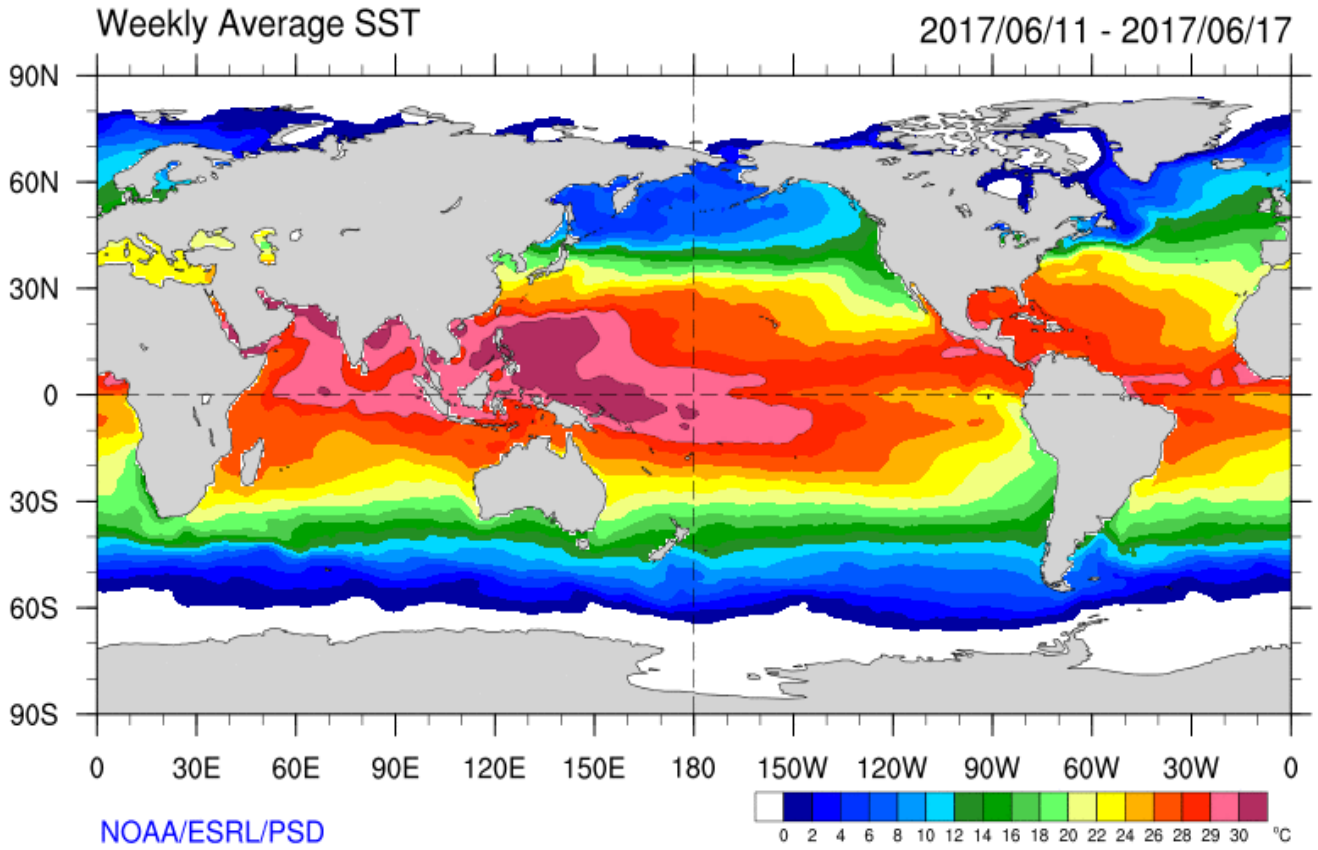
Why care about ocean observations

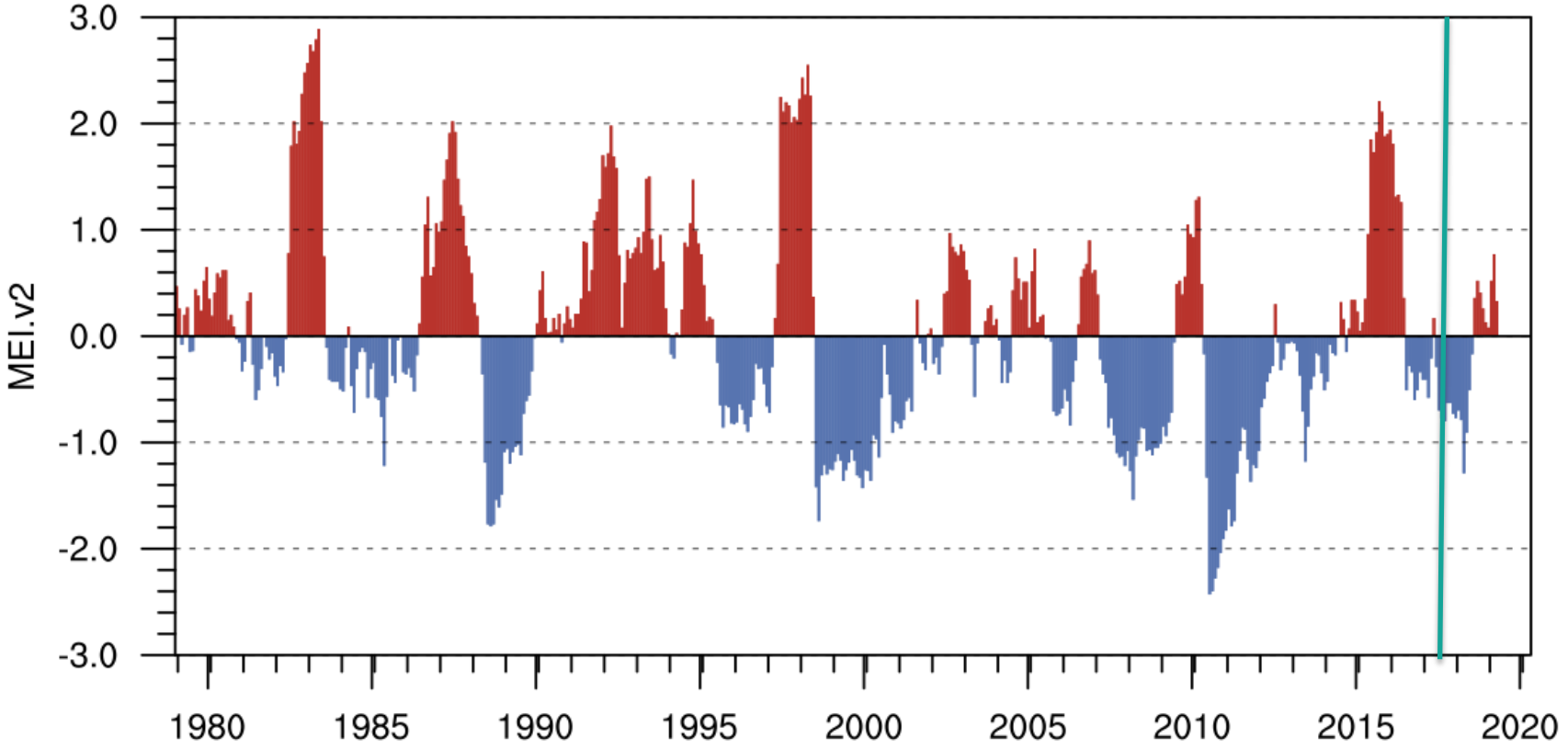
- Water (on land and in the ocean) is important for climate and weather.
- Heat is important, not just land or sea surface temperature (SST).
- The ocean evolves more slowly than the atmosphere and has longer prediction times.
- I will review examples of ocean influence on sub-seasonal to seasonal forecasting (S2S), and evidence that it can be important after a few days, but much is left to be done.
- I will finish by discussing a few measurement programs

The top three meters of the ocean can hold as much heat as the entire atmosphere

Smoothed Sea Surface Temperature (SST) from NOAA



NOAA EL NINO – SOUTHERN OSCILLATION (ENSO) INDEX. + = EL NINO



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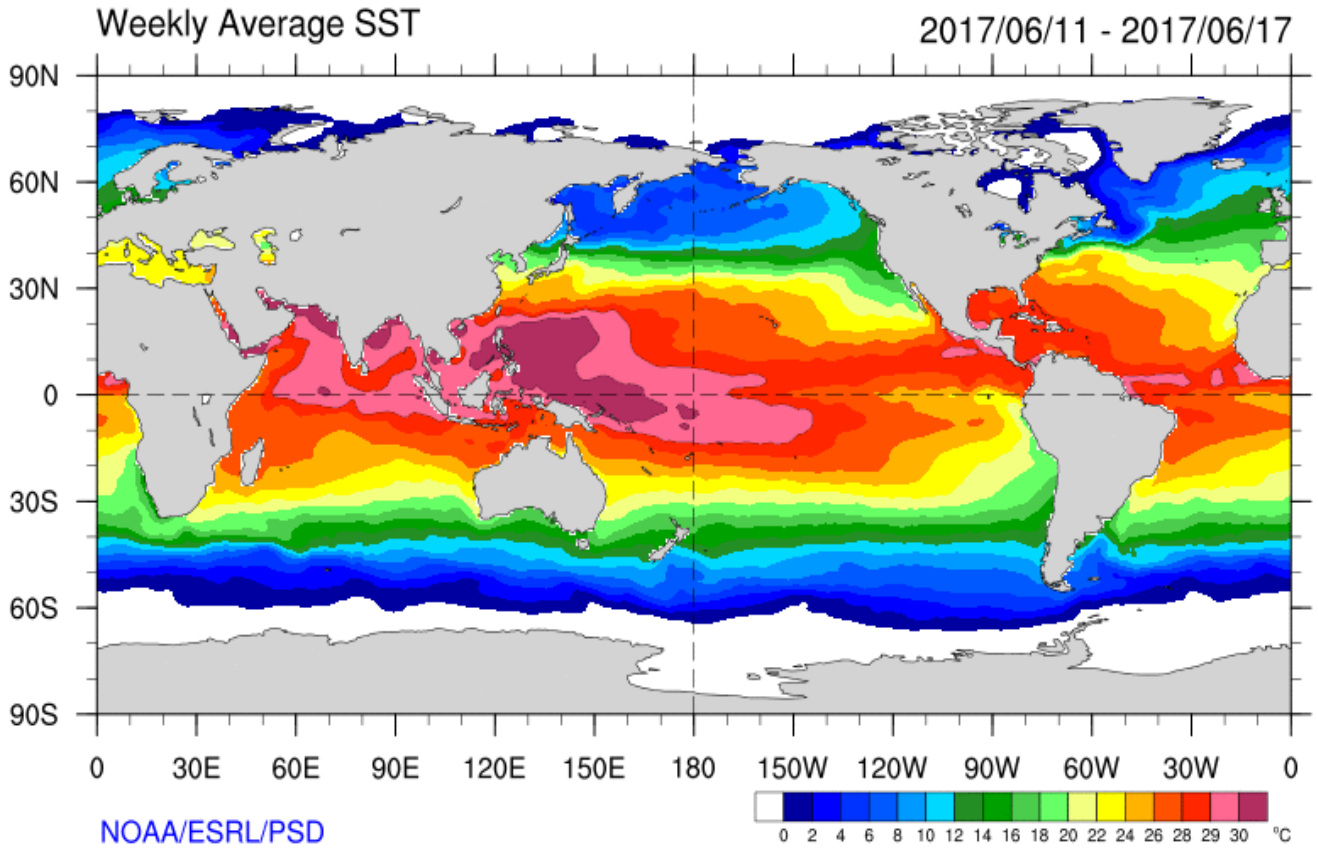
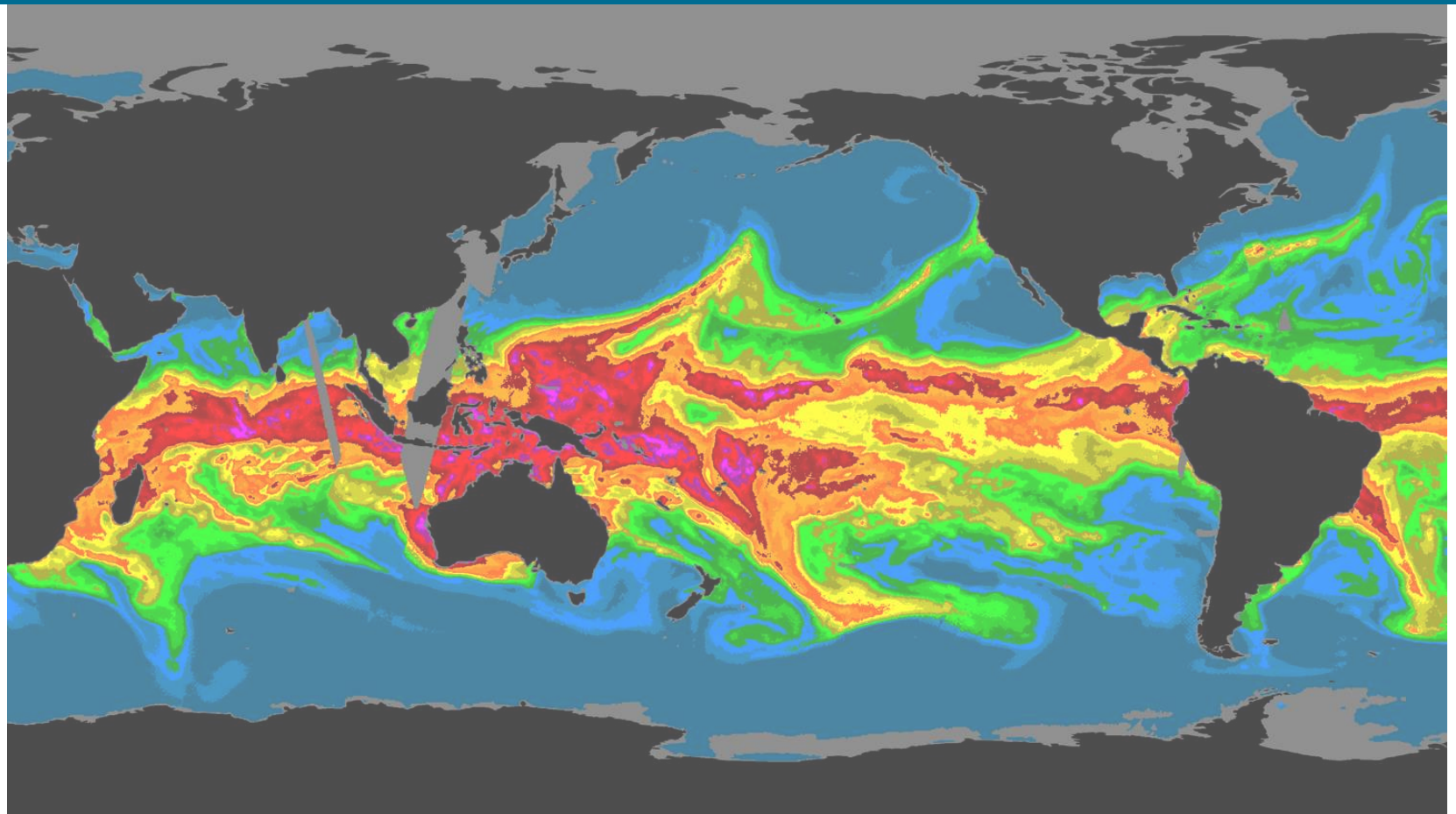
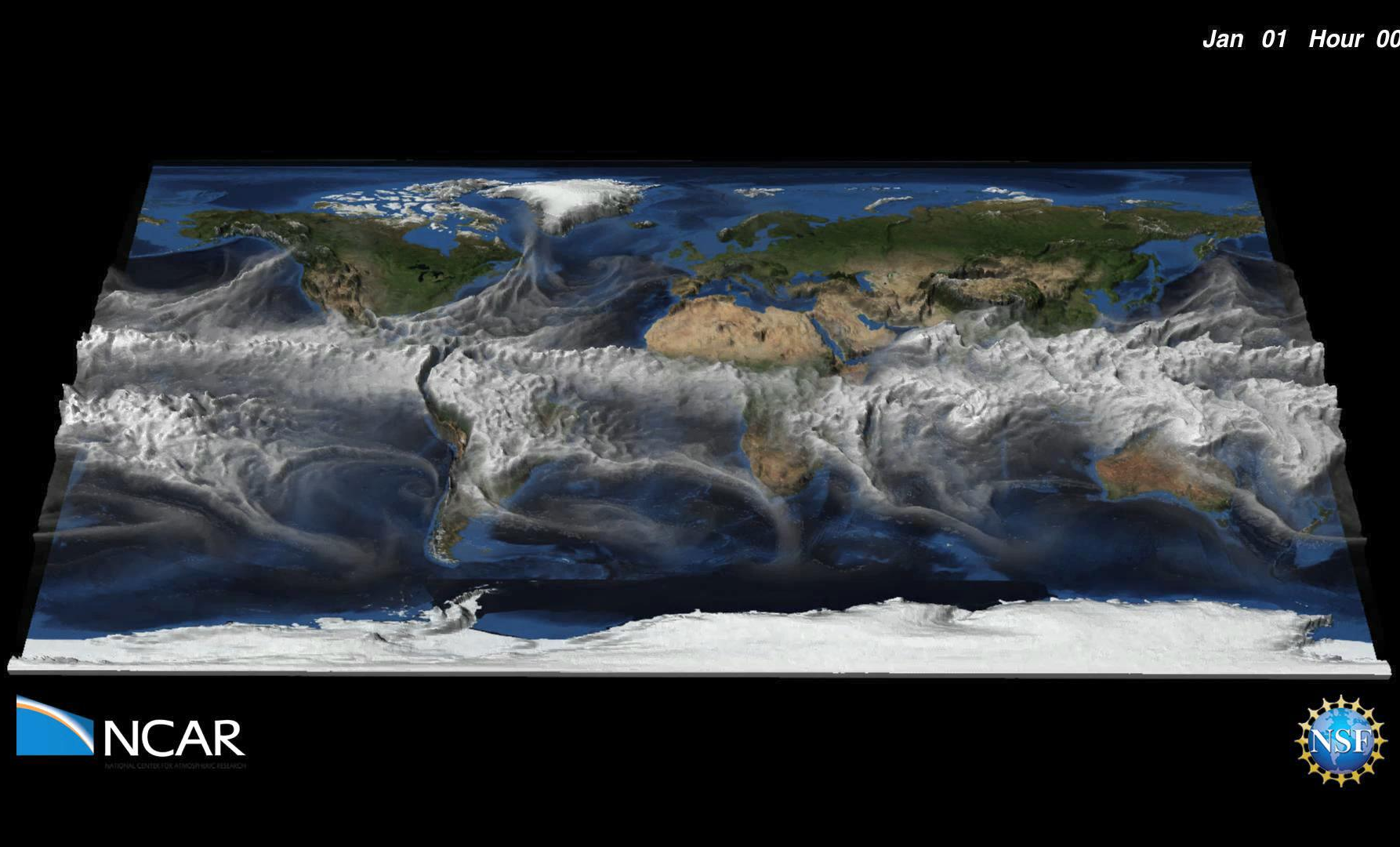
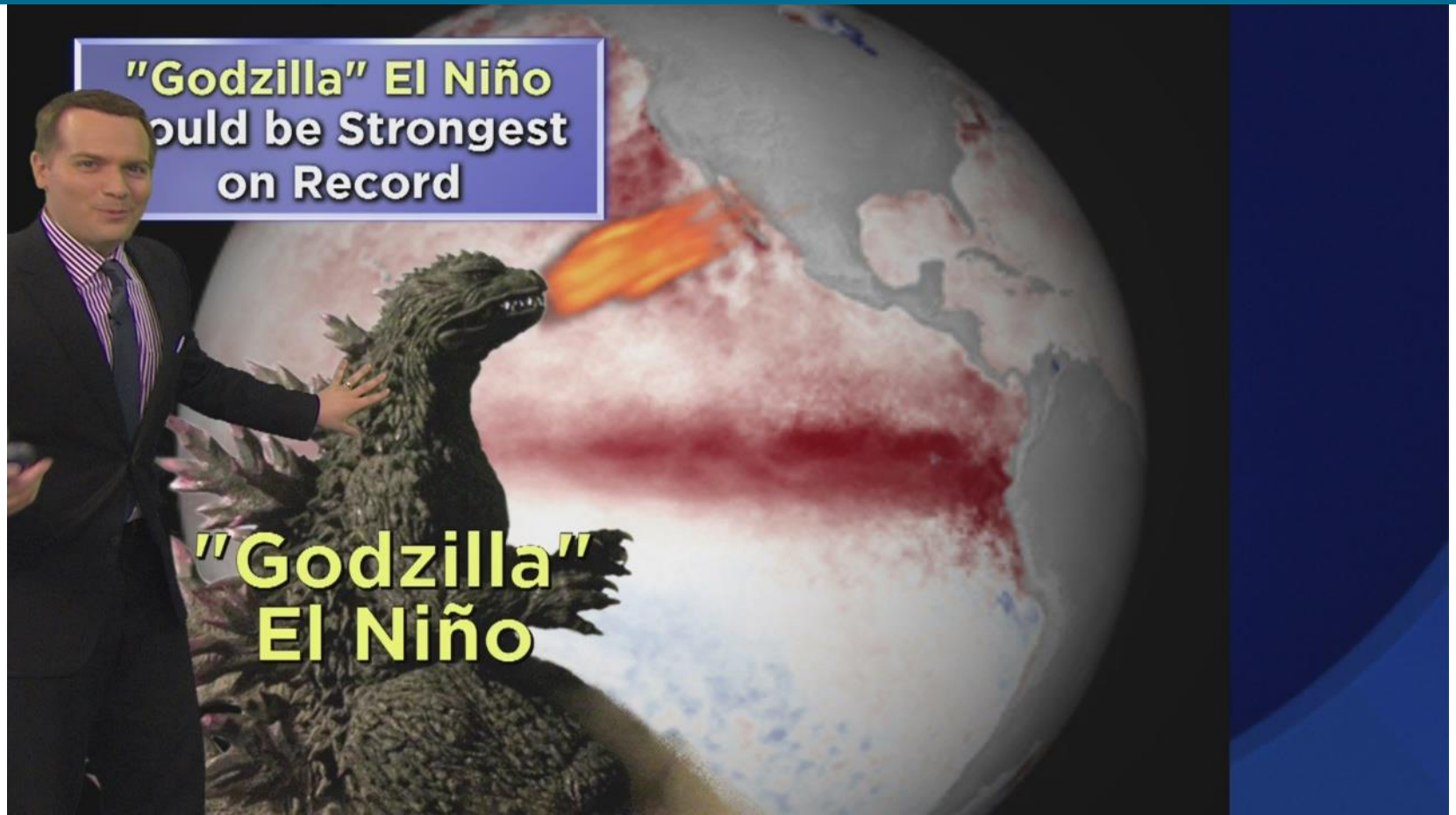


Snapshot of vertically integrated water vapor in the atmosphere




Jan 01 Hour 00
NCAR
NSF

Wide Acceptance of the Ocean's Role in 2015-2016 El Niño and "The Blob"



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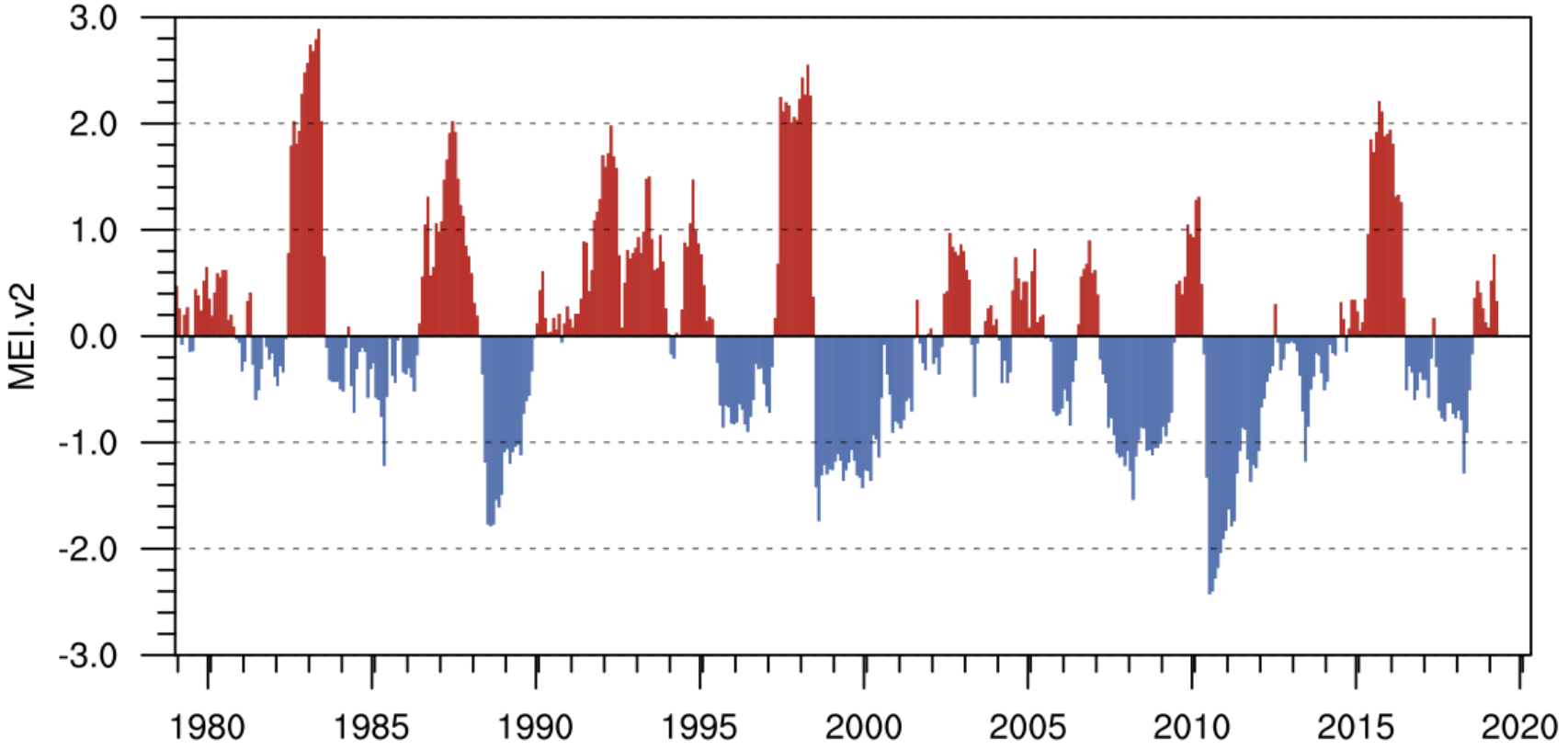
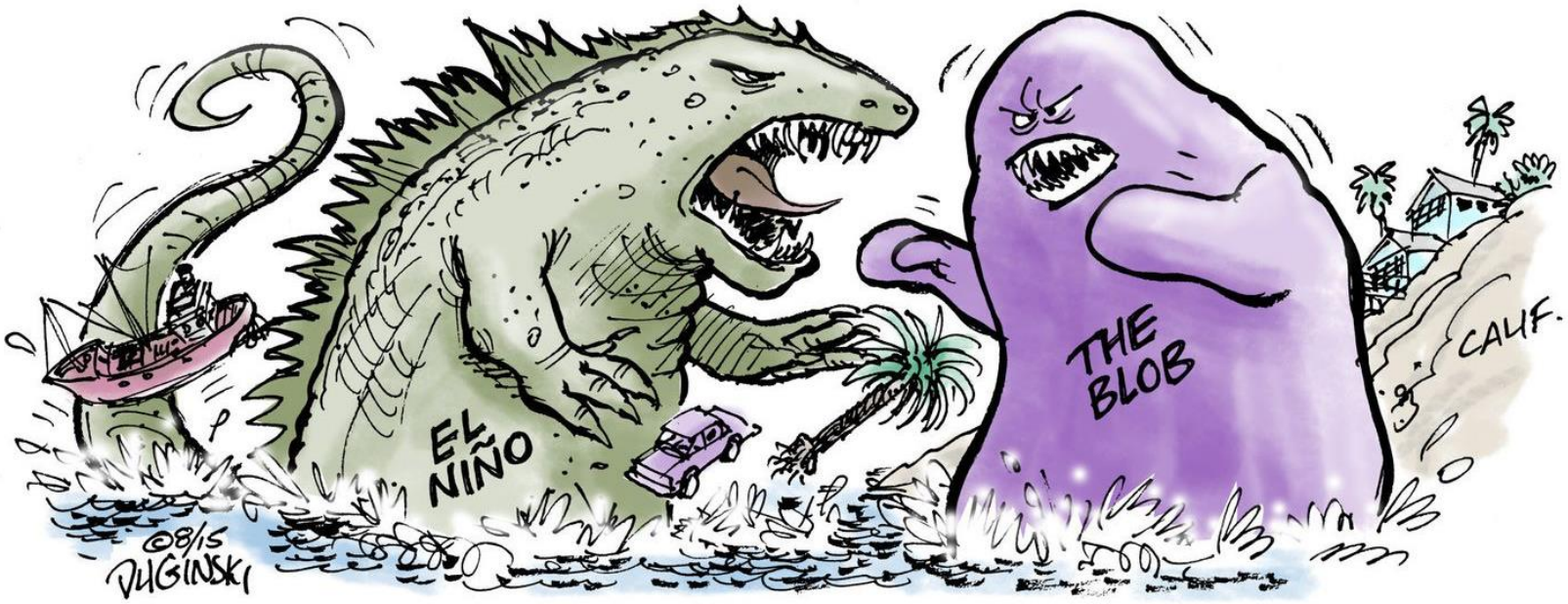


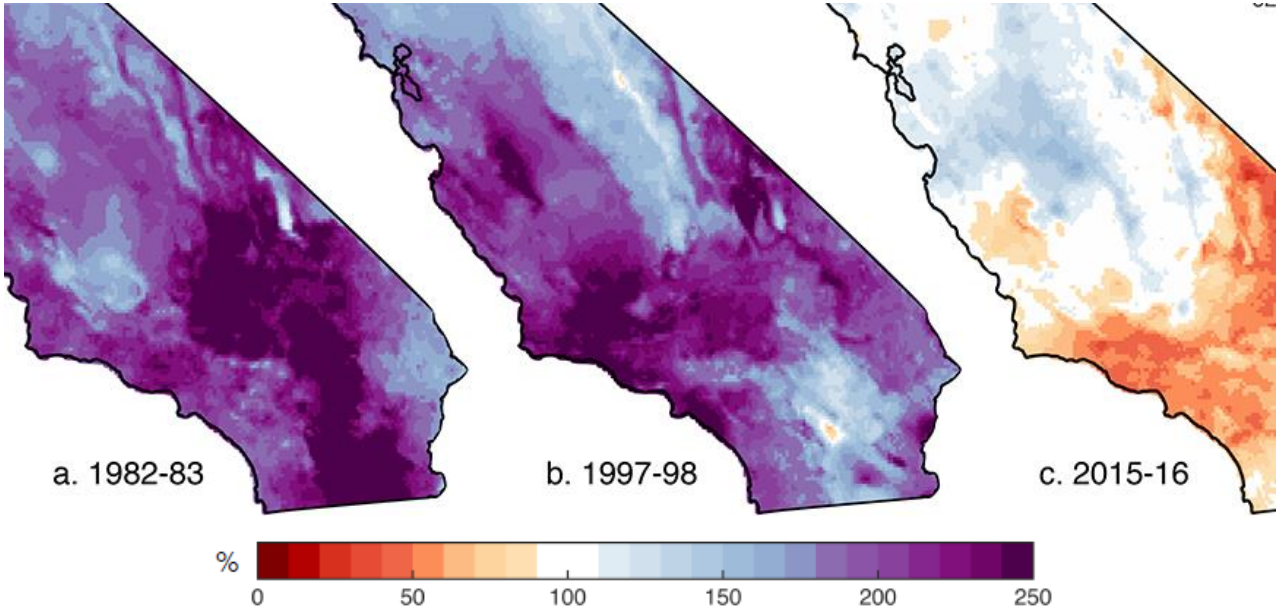
When strong El Niño rains didn't materialize, it was blamed on "The Blob"



Research has turned up less cartoon-ready reasons

Tropical Ocean Contributes to Dry El Niño in 2015-2016

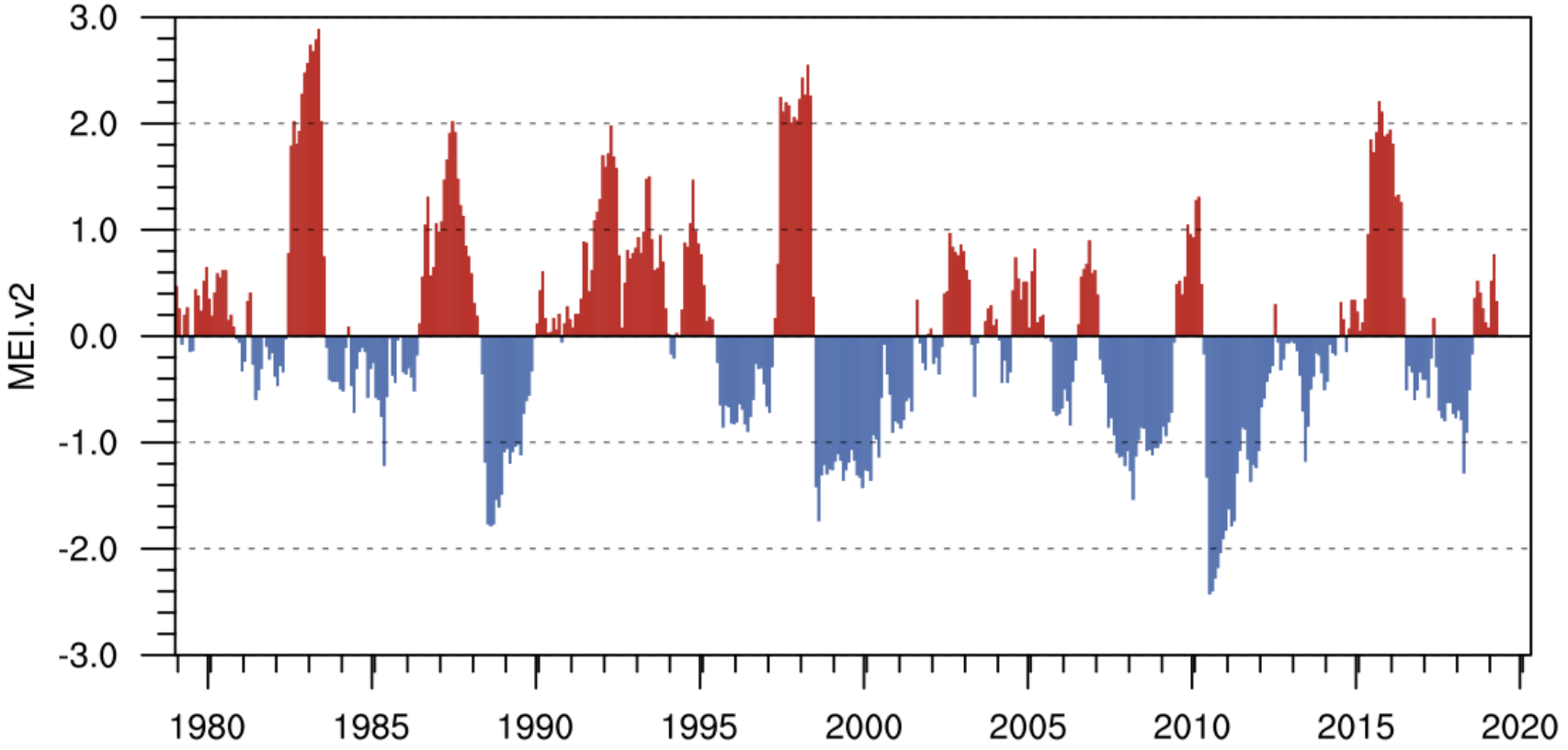
Observed Precipitation Anomaly (%)



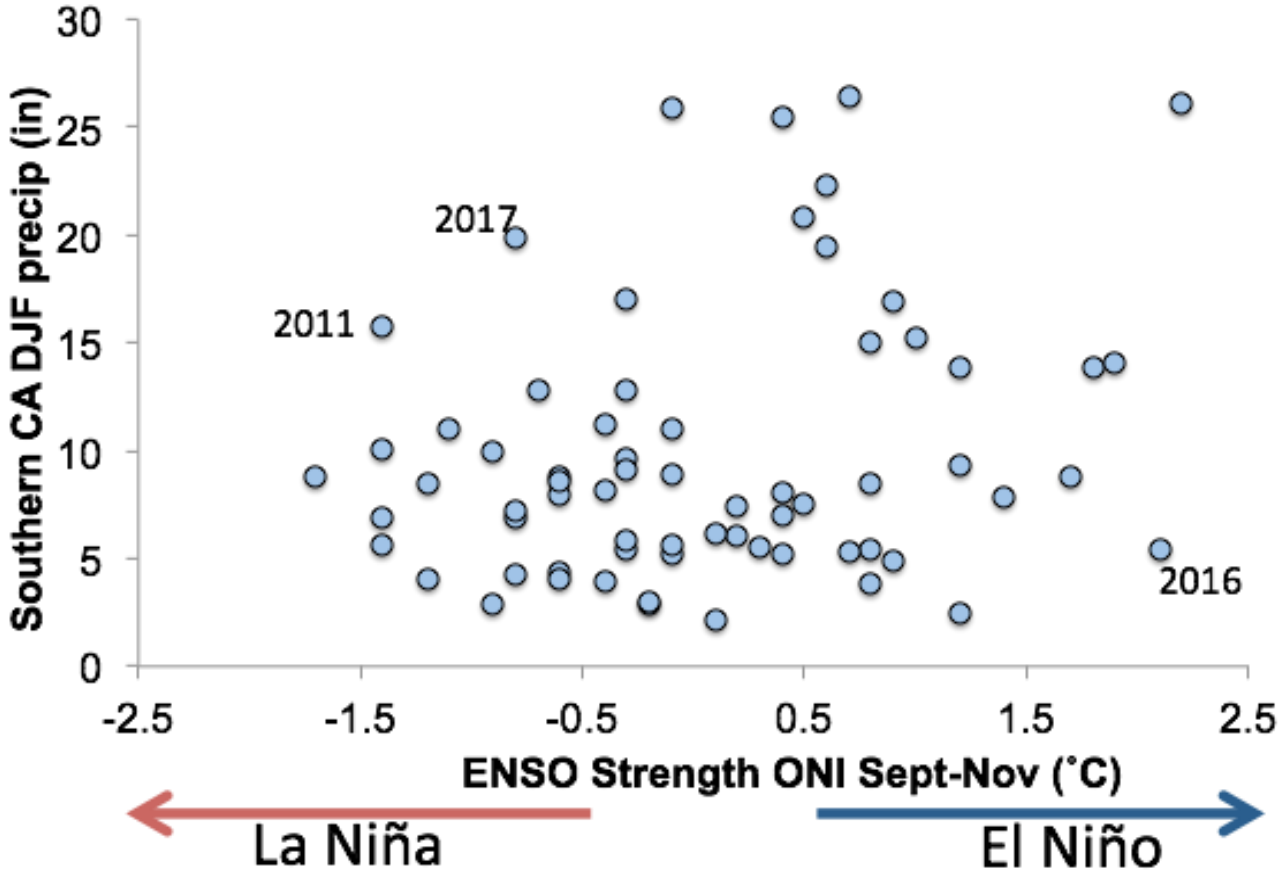
Atmospheric simulations indicate that the difference in California rainfall among major El Ninos is related to an SST anomaly pattern in the Indo-western Pacific.

N. Siler, S.-P. Xie, Y. Kosaka & X. Li (2017, *J Climate*)

NOAA EL NINO – SOUTHERN OSCILLATION (ENSO) INDEX. + = EL NINO



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



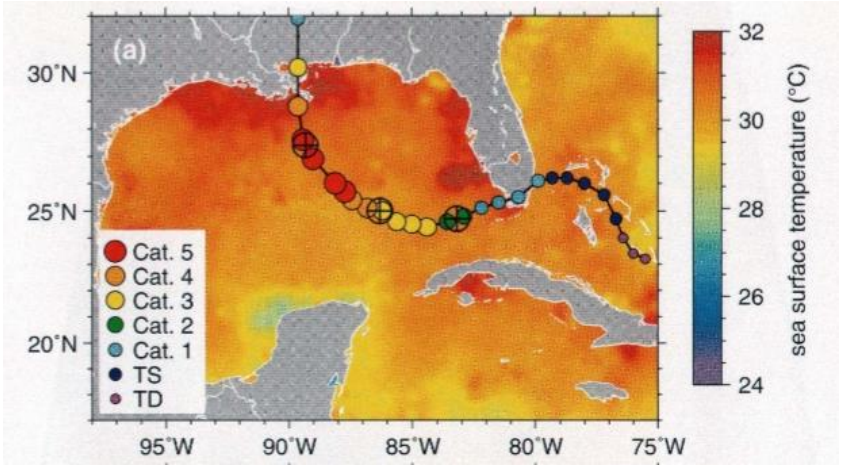
Southeast Asian Monsoons

Southeast Asian Monsoons

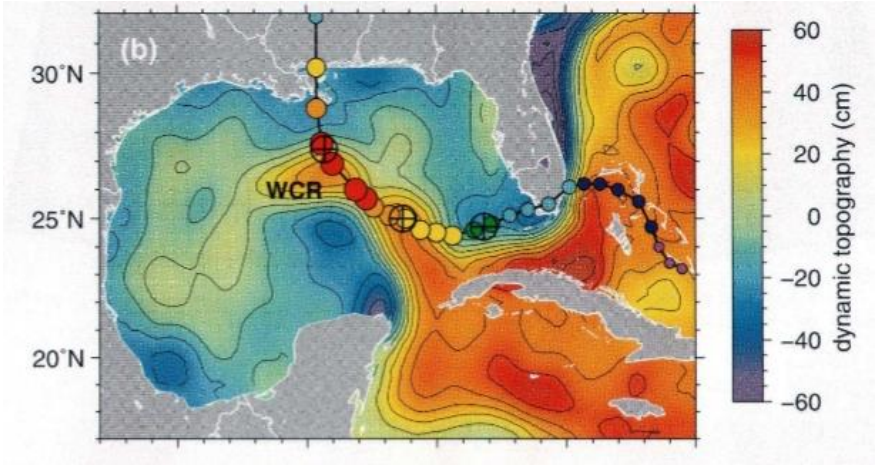
- Navy-funded studies in the western Bay of Bengal
- Understanding how the ocean influences monsoon pattern and rainfall
- Hypothesis – Understanding the ocean can improve monsoon prediction

Upper ocean heat influences hurricanes (not just SST)

Hurricane Katrina - Intensification correlated with ocean heat content



Sea Surface Temperature



Ocean Heat Content

So we have the ocean being seen as important for ENSO, monsoons, and hurricanes.
How about weather and S2S?

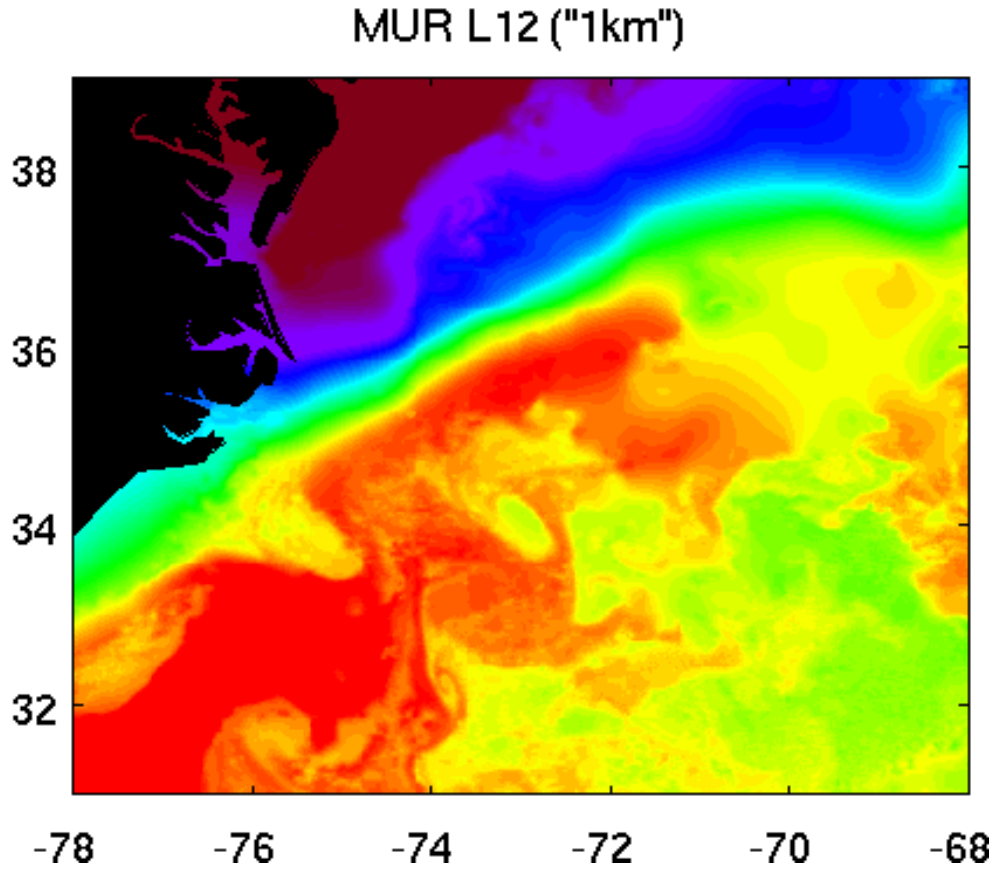
Gulf Stream also affects weather and S2S further north

A 2008 study found the Gulf Stream affects the entire troposphere.

The current anchors a tall wall of atmospheric upward motion that penetrates into the upper troposphere and supports deep raining clouds.

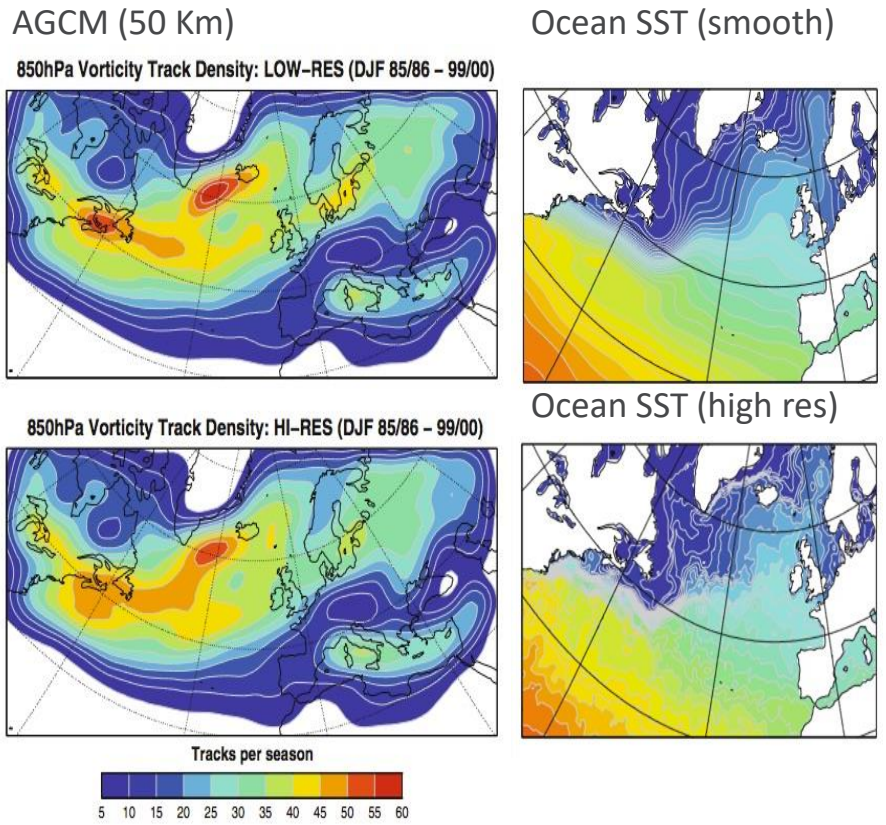
Provides a pathway by which the Gulf Stream can affect local sub-seasonal to seasonal processes, and possibly processes in remote regions via an effect on planetary wave propagation.

Zoomed-in look at 1km resolution SST in Gulf Stream



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

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

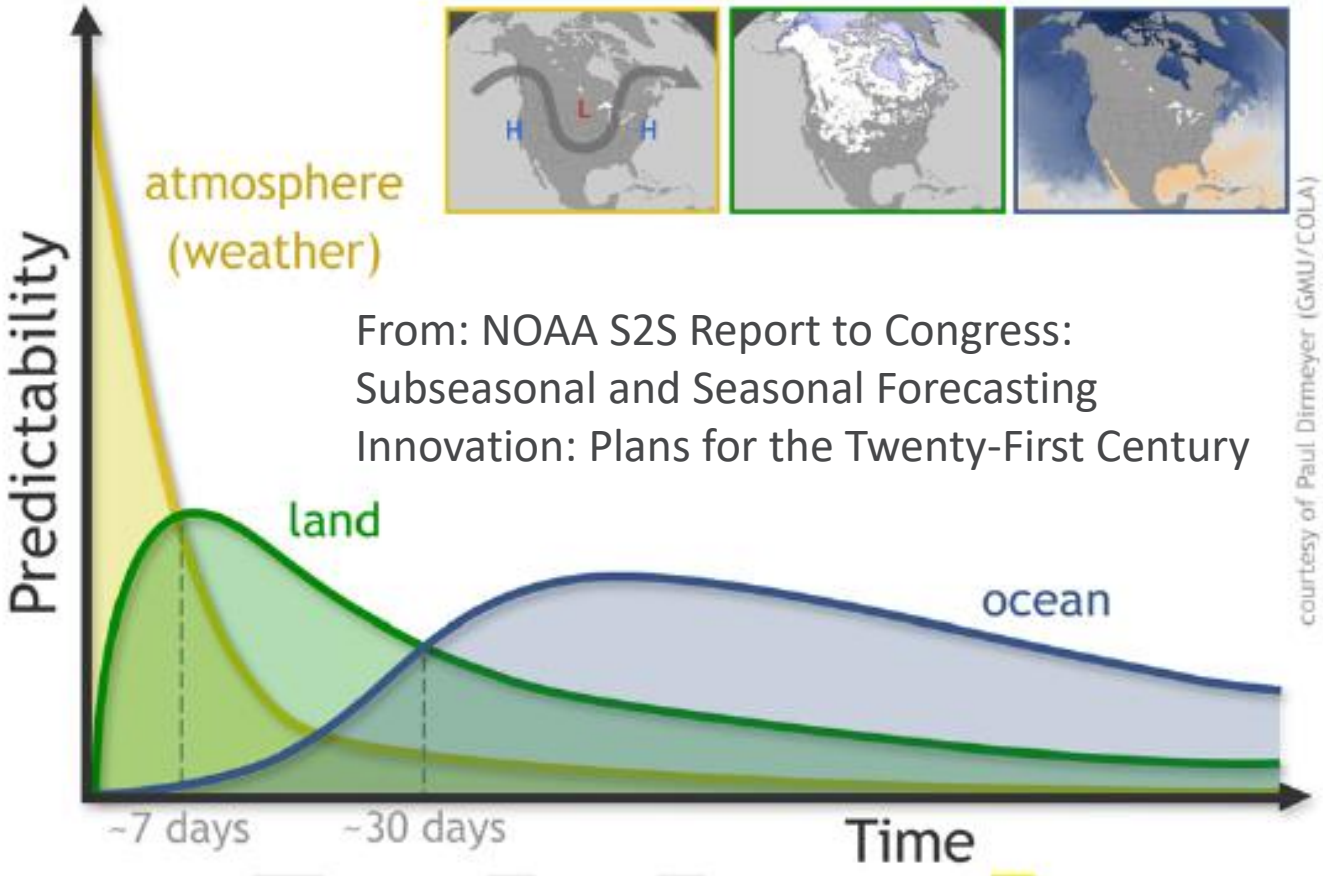


Weather research & forecasting innovation act of 2017

- Requires NOAA to develop and improve sub-seasonal to seasonal temperature and precipitation forecasts
- Timescales are two weeks to three months (sub-seasonal) and three months to one year (seasonal)
- Emphasizes forecasts on national and regional levels
- Encourages prioritization of forecast needs to enhance national security

NOAA joining in where the US Navy and ECMWF have been working already.

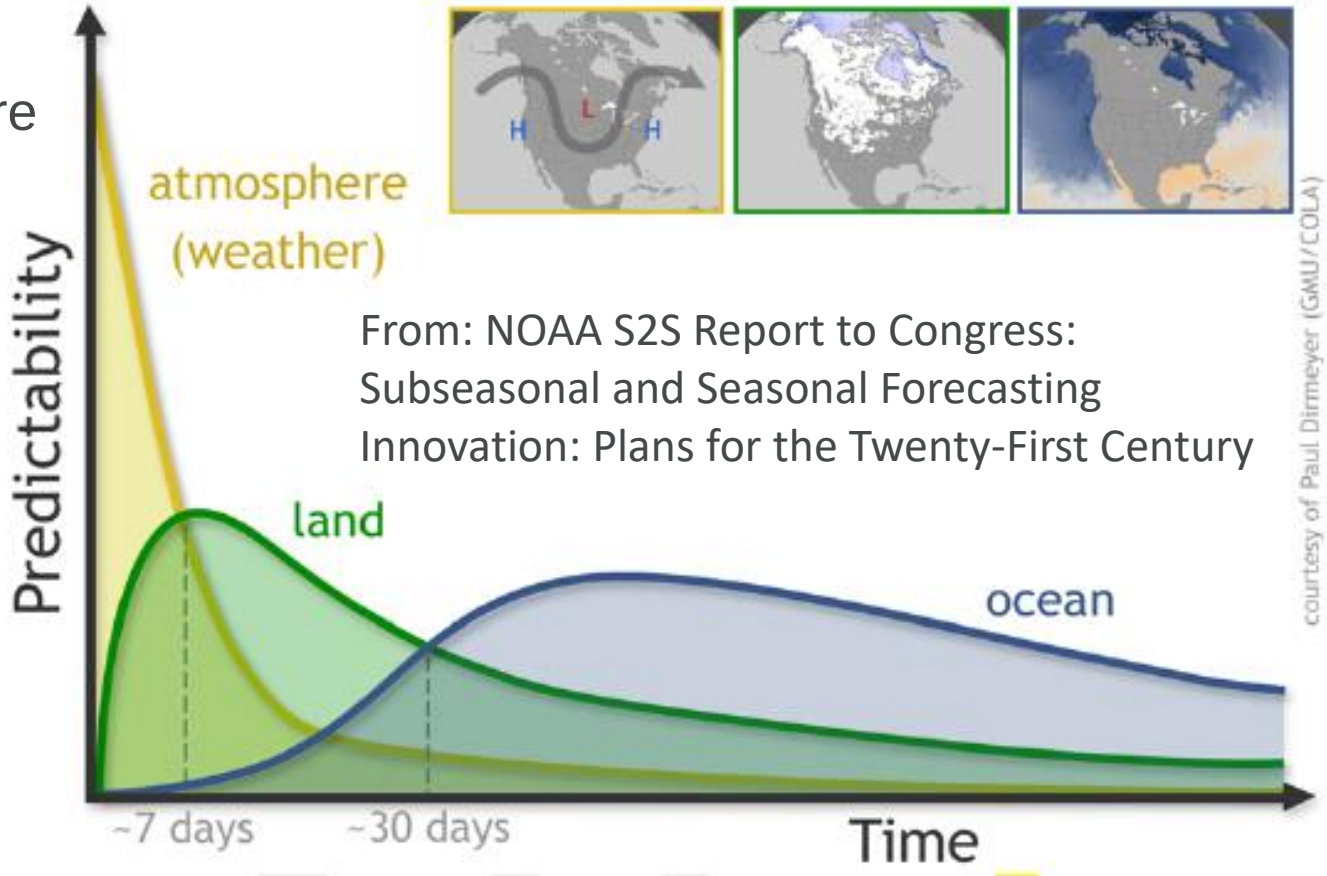
NASA and NOAA Sketch of sources of S2S Predictability



From: NOAA S2S Report to Congress:
Subseasonal and Seasonal Forecasting
Innovation: Plans for the Twenty-First Century

NASA and NOAA Sketch of sources of S2S Predictability

Drawn by a Soil moisture Person!!



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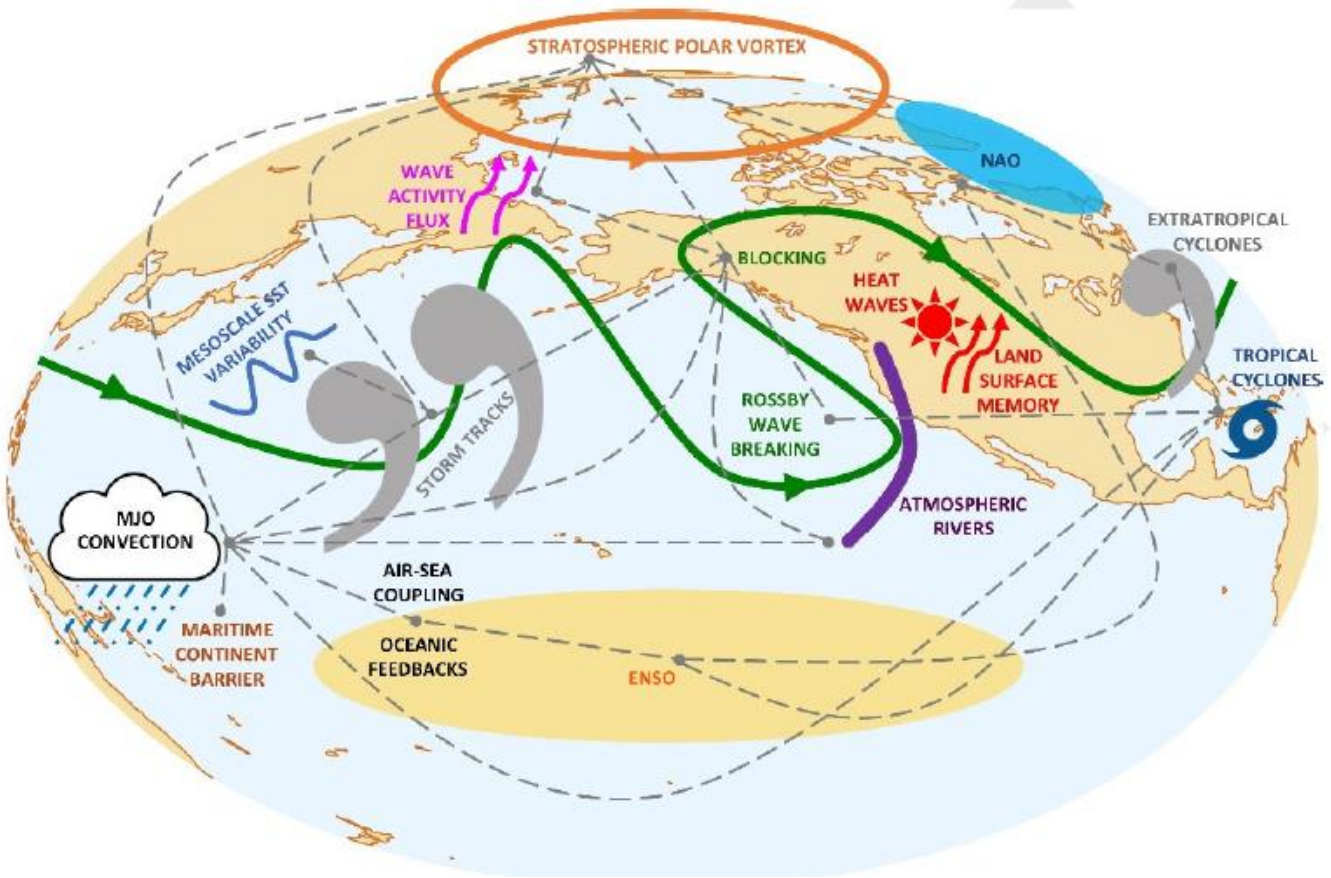
NOAA sketch of S2S Mechanisms



What Ocean Knowledge Is Necessary For Prediction?

- Small scales matter
- Upper ocean is the focus (top ~100 meters)
- More observations
- Better models, tested and fed by the observations

Improving predictions

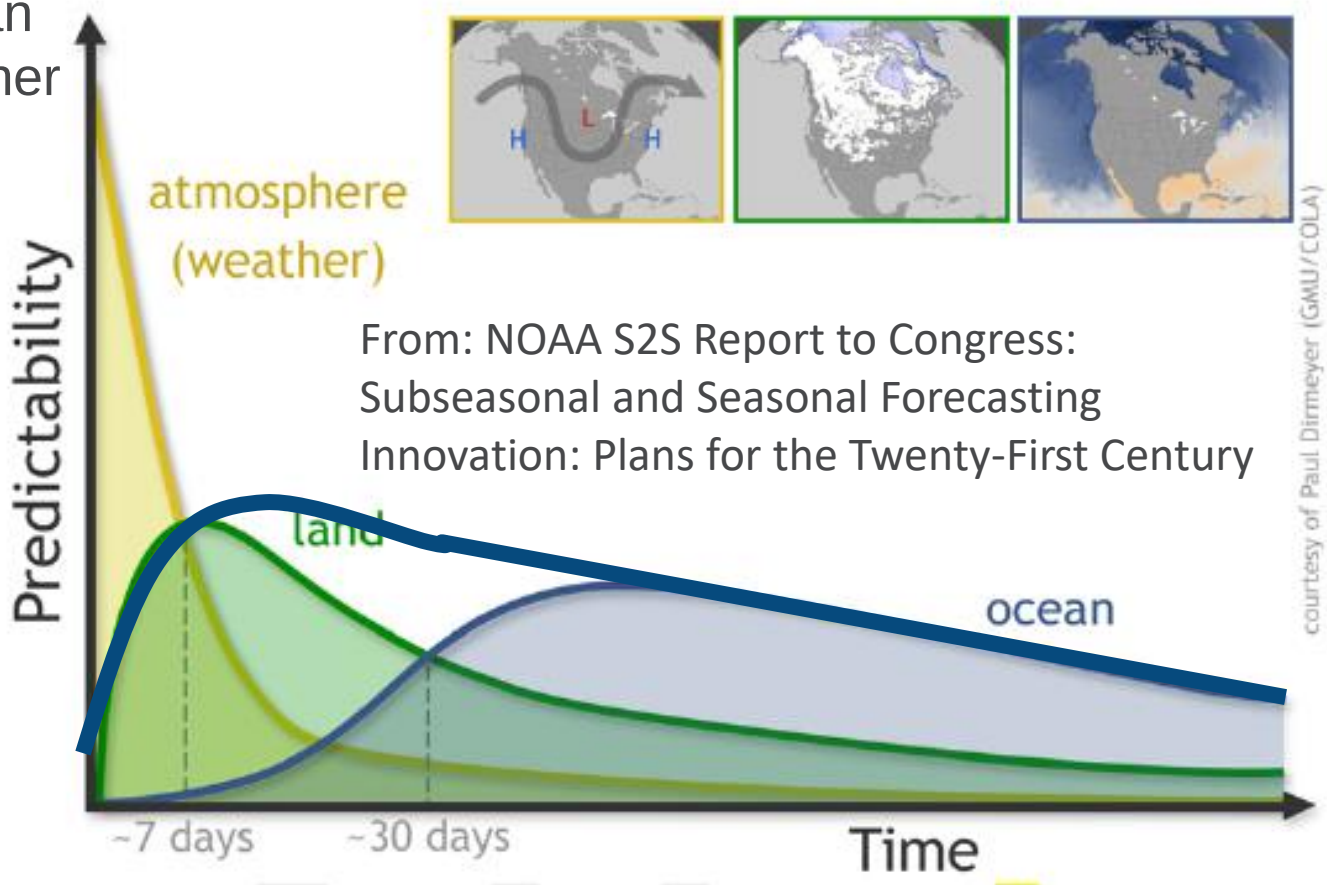
- The atmosphere, land, and ocean work together to create weather and climate.
- Weather has been forecasted without the ocean, except for monsoons, hurricanes, but that is changing.
- S2S is still a research topic, but the ocean plays a role, and we can’t make progress if we don’t study it.

What can be predicted beyond a few days?

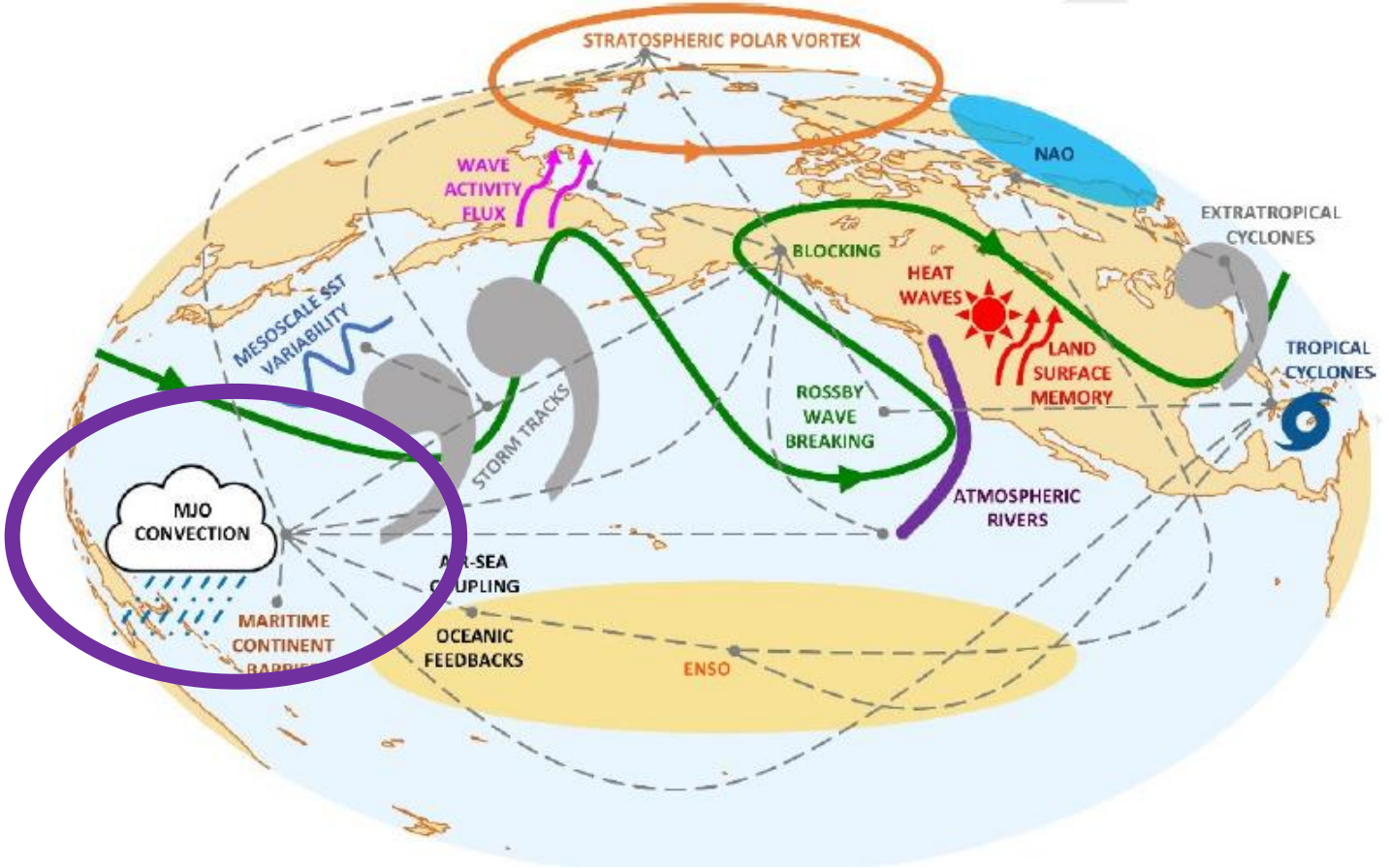
- The atmosphere is “chaotic”, At longer lead times it will be a challenge to supply useful information
- What CAN we predict, and how do we make it actionable?

Revised cartoon for S2S predictability for the West

Defaced by an Oceanographer

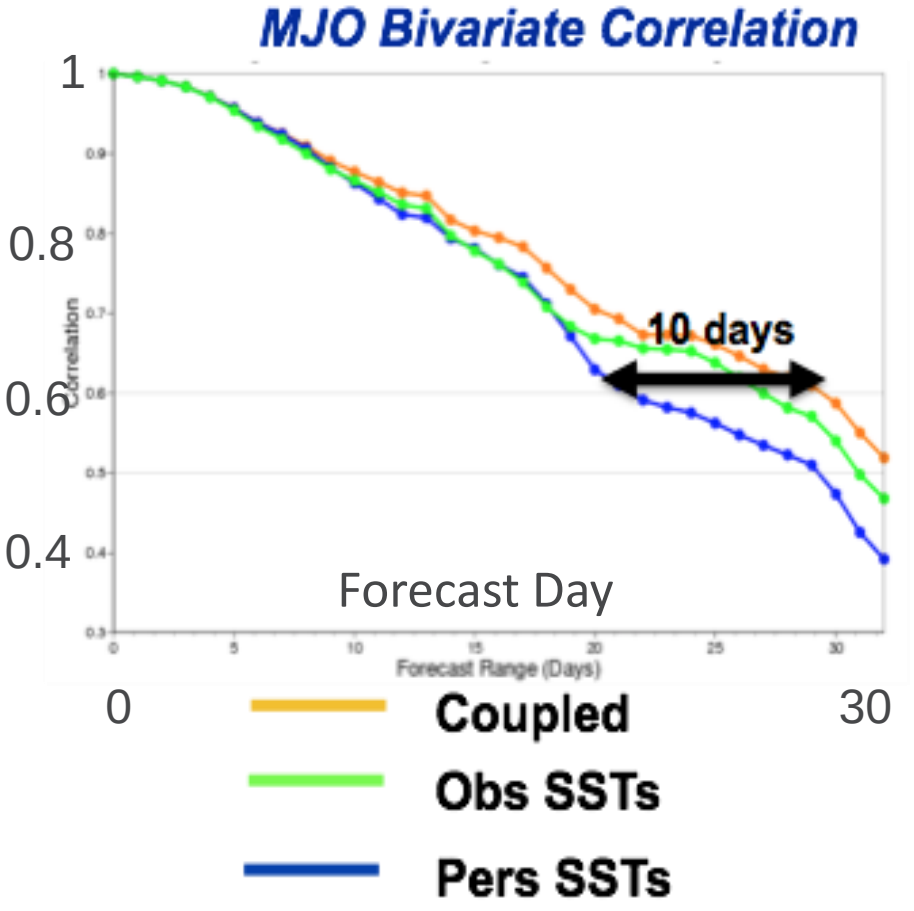


Look at the Madden-Julian Oscillation (MJO): Rivaling ENSO?

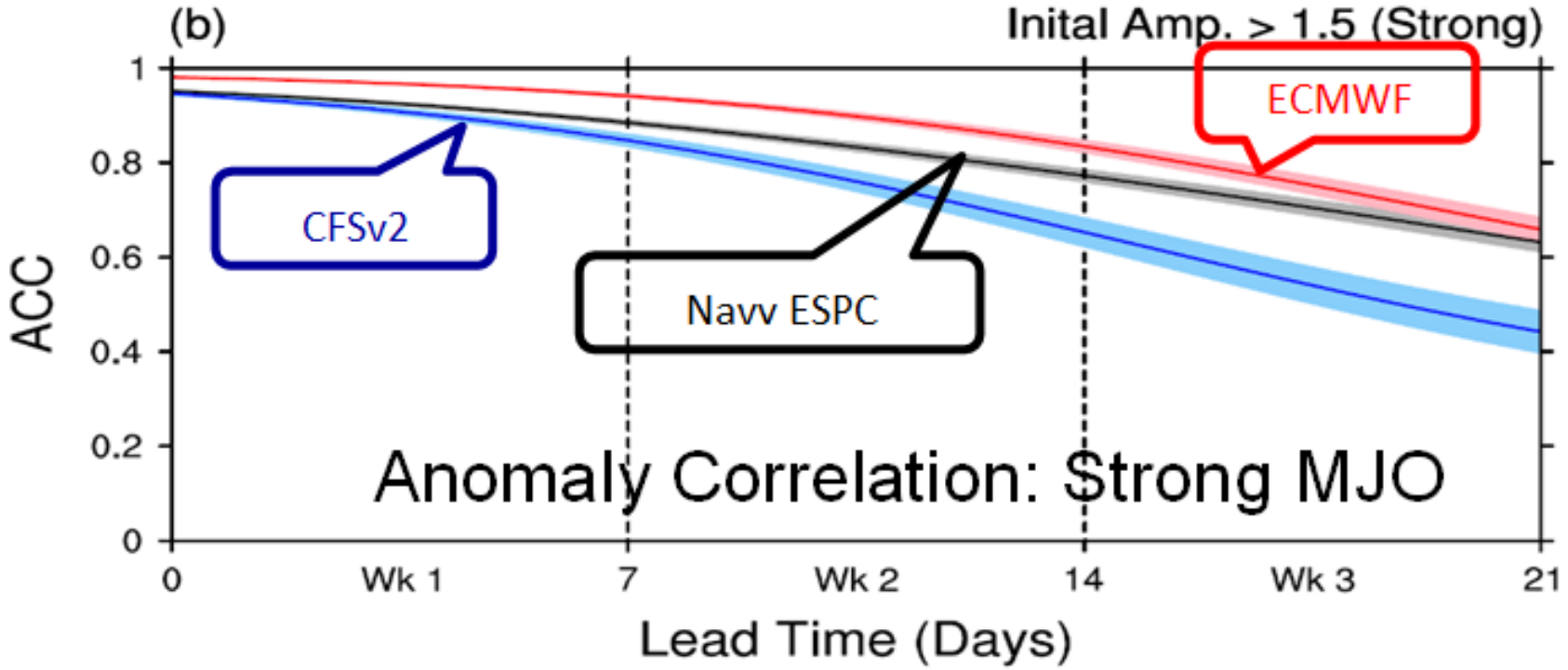


ECMWF global coupled forecasting skill

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



US Navy global coupled MJO forecasting skill



Courtesy of Sergey Frolov, Naval Research Lab Monterey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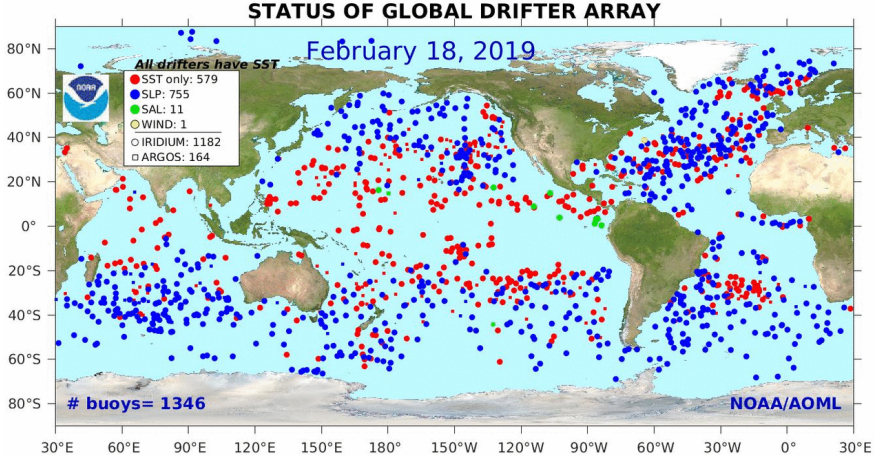
The Global Drifter Program

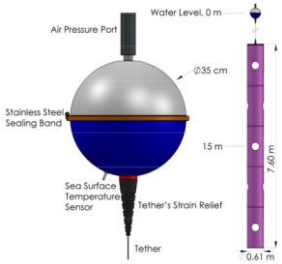
The Only Global In-Situ Ocean Observing Network for Making Observations at the Air-Sea Interface



***Overarching Goals*:**

Maintain global 5ºx5º array of surface drifting buoys to meet the needs for an accurate and globally dense set of in-situ observations: **SST**, **mixed layer currents, atmospheric pressure**, winds, and salinity

Work with the international community to maintain the array



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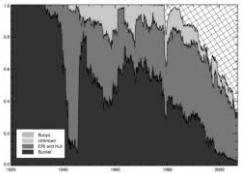
GLOBAL DRIFTER PROGRAM
National Oceanic and Atmospheric Administration

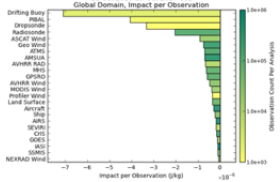
Main Critical Impact Areas



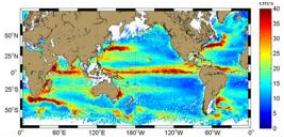
SST From Space Cal/Val

Left: Fractional contribution of SST data by platforms (buoys refers primarily to drifters, that provide more SST data than all the other sources combined). From Kennedy et al, 2011, JGR. Drifters provide X100 daily SST obs than Argo.

SLP for NWP and Climate Indices



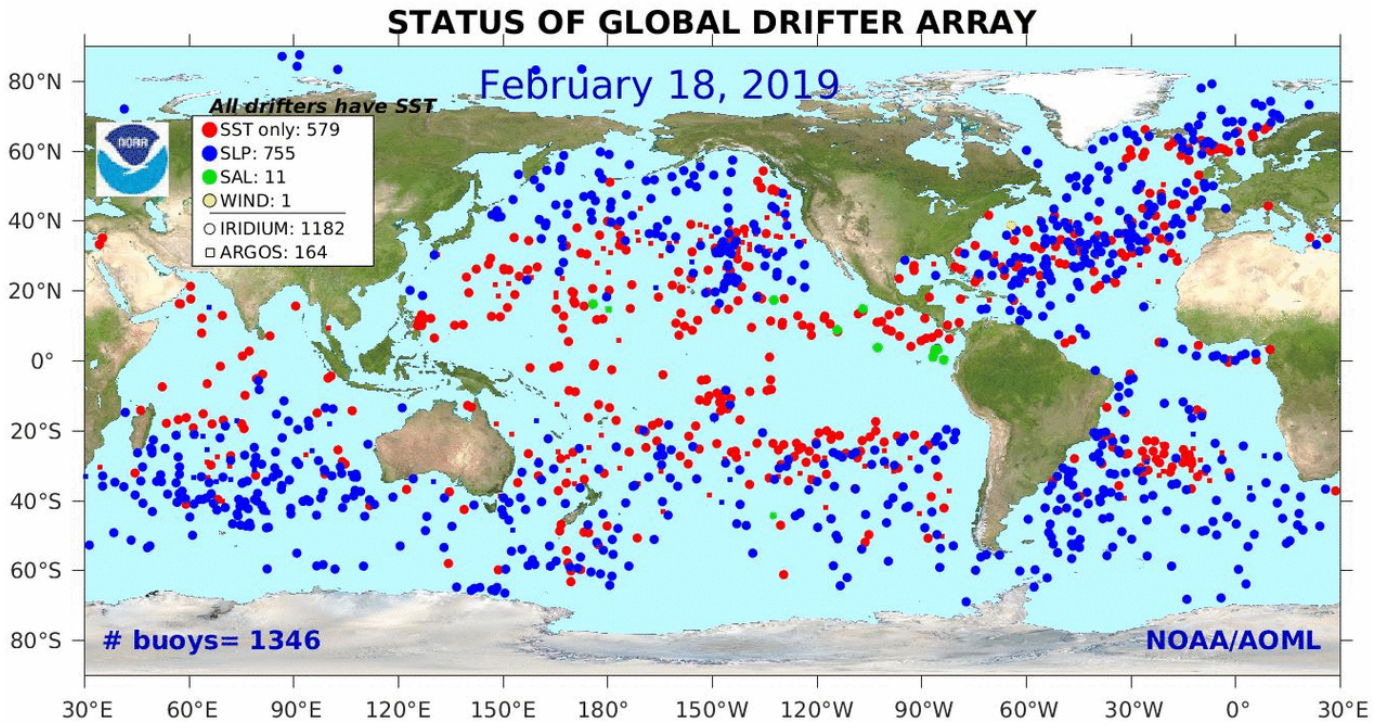
Left: Drifters SLP data have the largest positive impact per observations (Centurioni et al. 2016, BAMS). Both forecasting and climate studies benefit from drifter data, especially in the southern ocean where the drifters are essentially the only source of in-situ SLP data.



Science

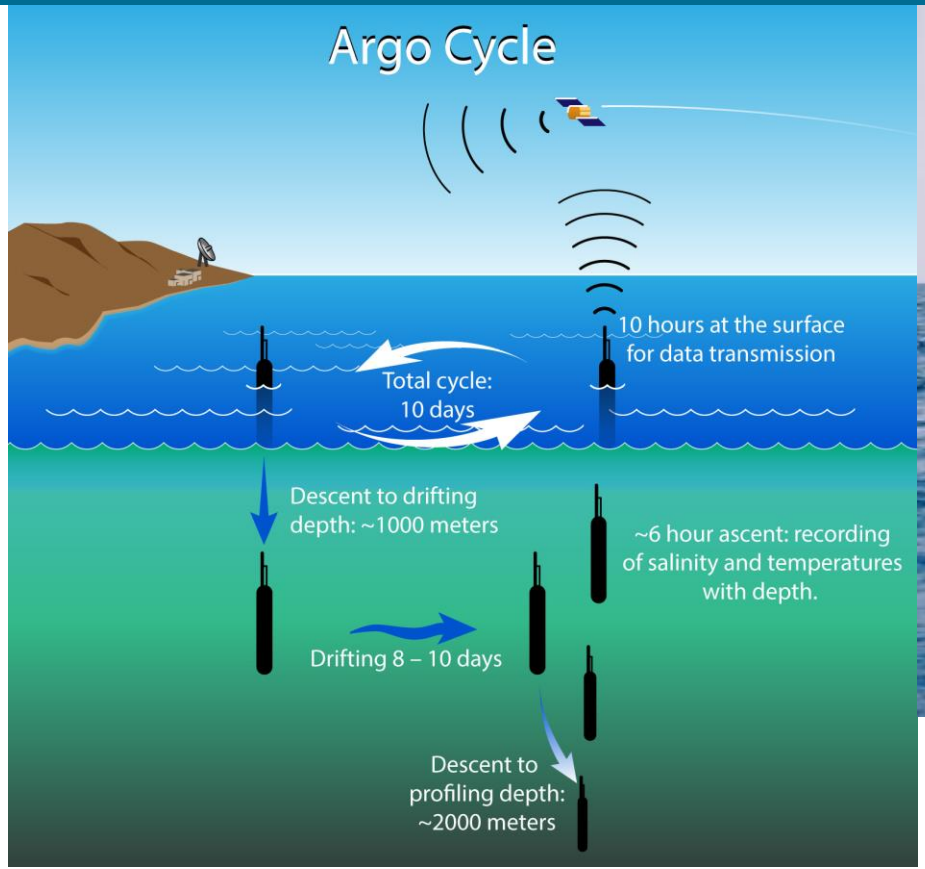
Over 1,100 paper published to date use drifter data directly

Global Drifter Array



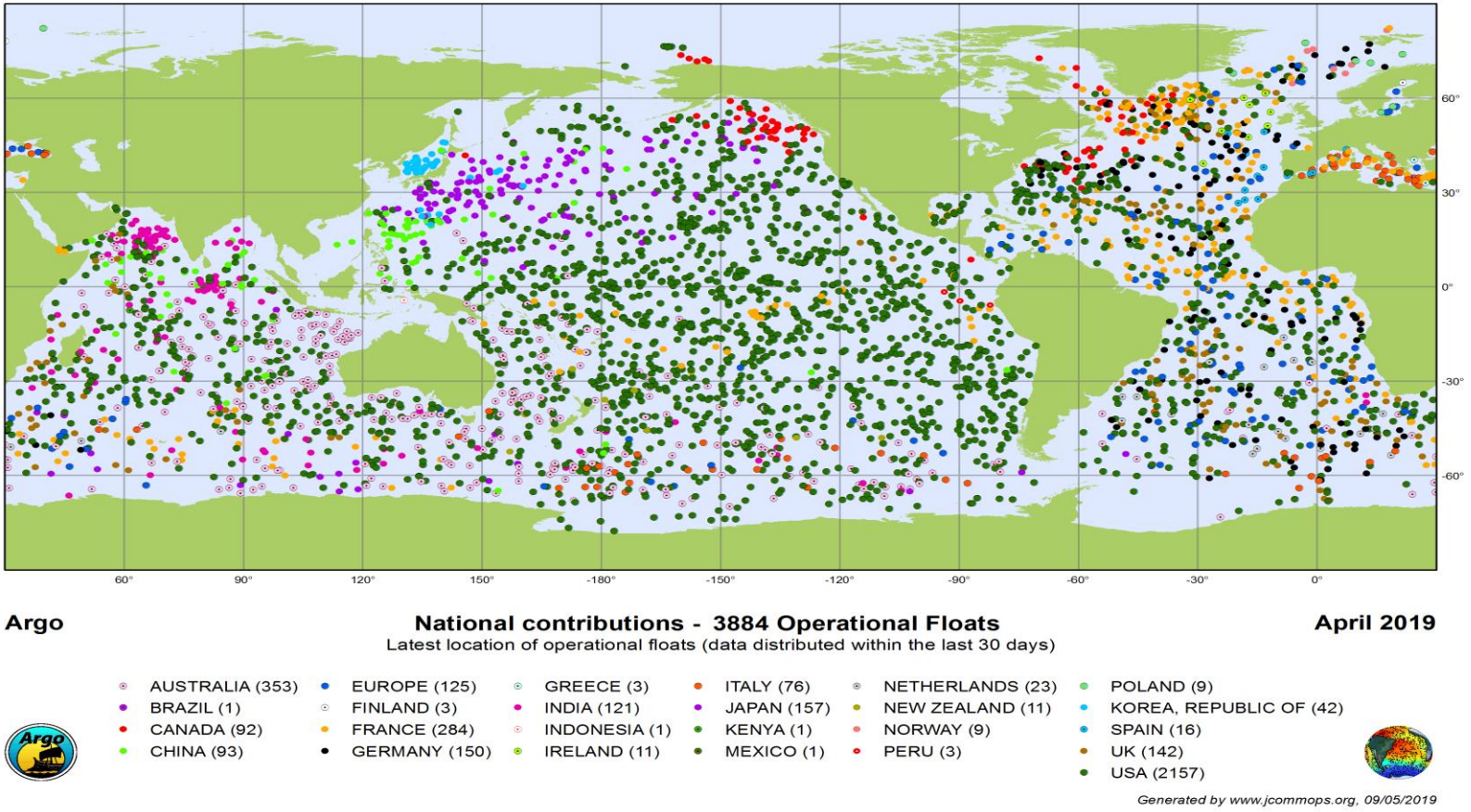
Blue drifters measure Sea Level Pressure as well as SST and currents

Argo Floats (NOAA)

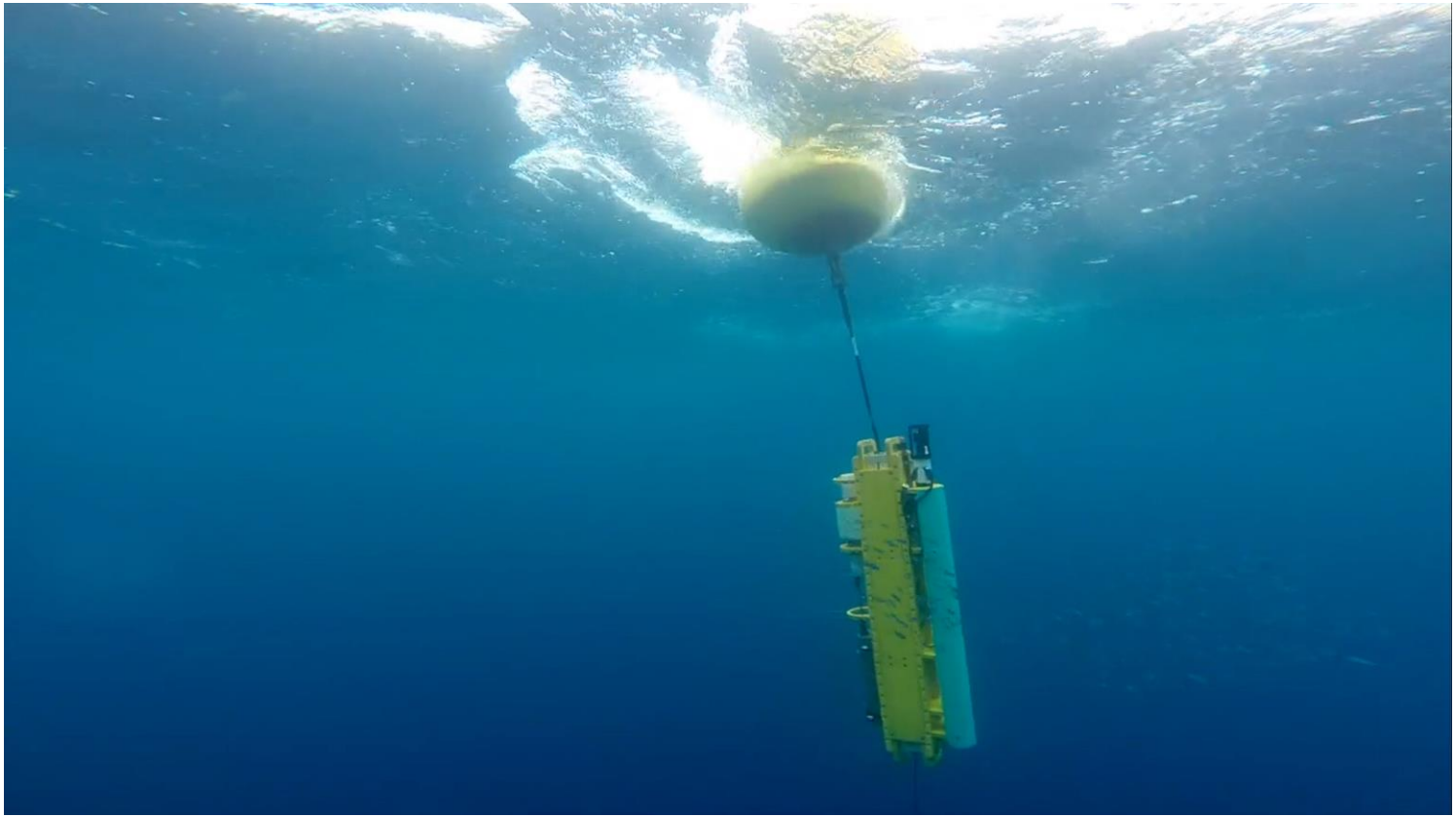


Deployed from ships, research and commercial

Argo Float Positions 4/19



Wirewalker



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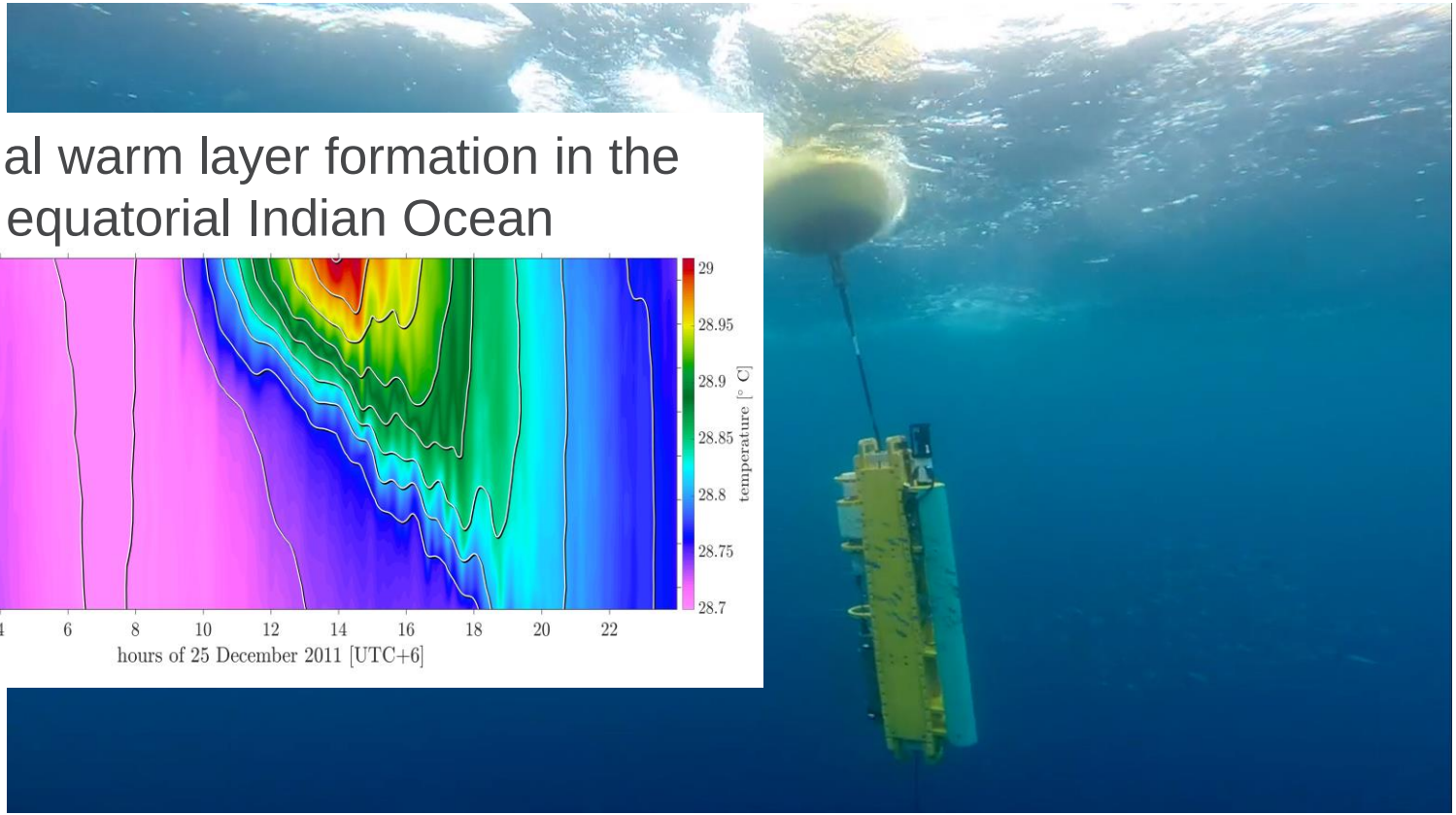
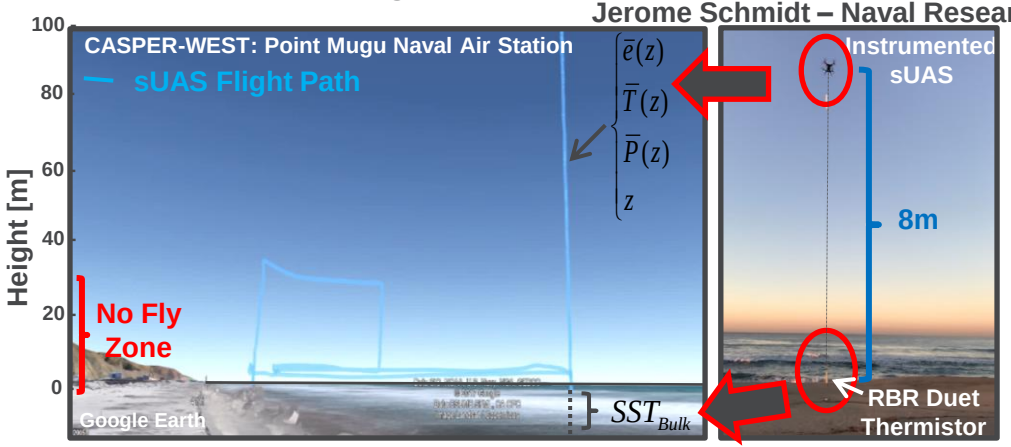
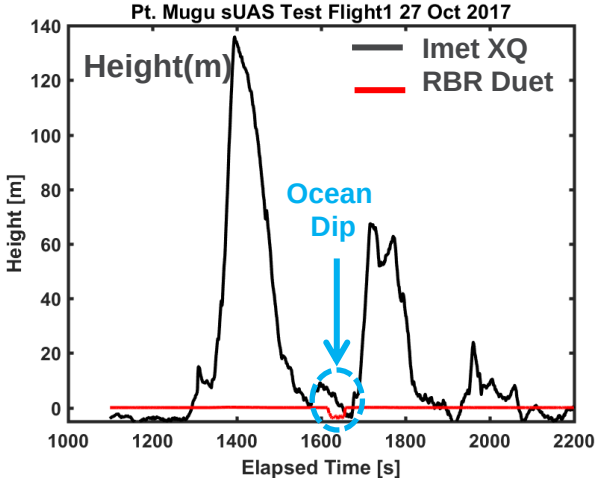


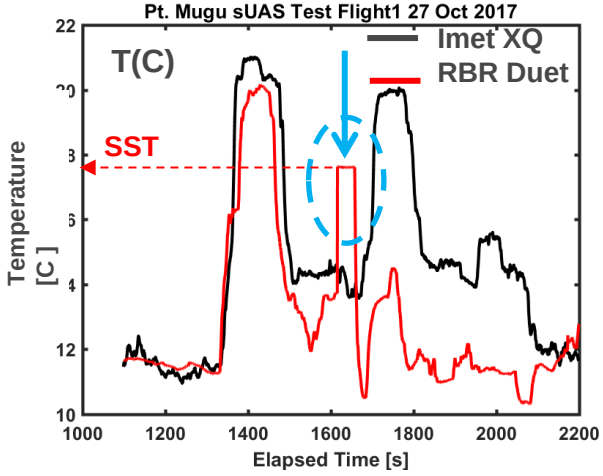
Diurnal warm layer formation in the equatorial Indian Ocean

Atmospheric and oceanic structure using drones
CASPER-WEST (2017): Test Flight 1

Piotr Flatau – Scripps Institution of Oceanography
Jerome Schmidt – Naval Research Laboratory







NOAA Research Funding

- NOAA Operations and Research funding - $3.7 billion
- Over $1.4 billion dedicated to meteorological, hurricane, weather and satellite research, observations, and operations
- Sustained Ocean Observations - $43 million
  - ARGO
  - Global Drifter Program (GDP)
  - Moorings
  - Tide Gauges
  - Oceanographic and Weather Observing Buoys
  - Expendable Bathythermograph (XBT)

NOAA Ocean Observations

- Cost effective solution to increase predictive capabilities of extreme weather and sub-seasonal and seasonal (S2S) forecasts.
- Vital to calibrating and validating satellite observations.
- Funding for Ocean Observations stagnant over a decade while costs have increased – resulting in inflationary cuts
  - Materials
  - Ship Time
  - Lab Costs
  - Data Processing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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.

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

So, Where are the S2S predictions?

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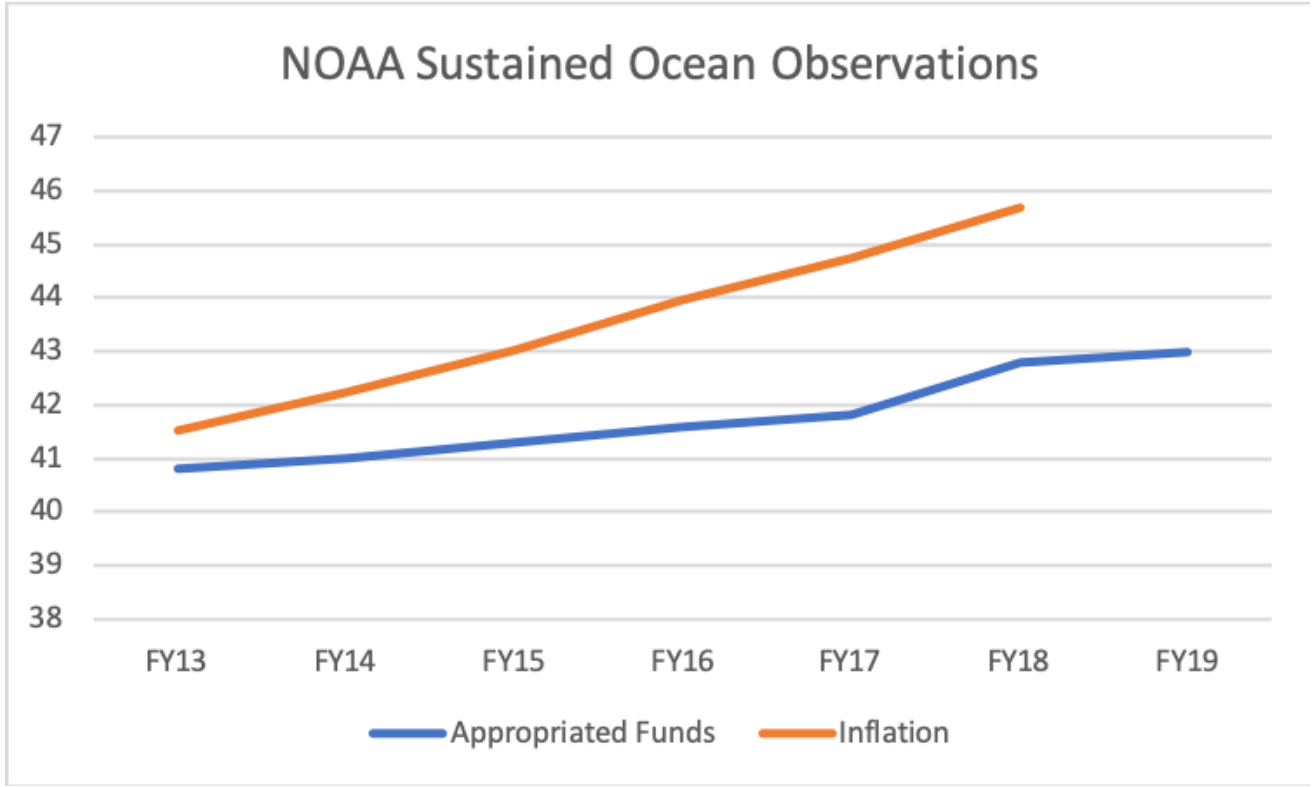
NOAA Ocean Observations



Two weeks of Satellite Altimetry Sea Surface Anomaly

NASA PO.DAAC Physical Oceanography Distributed Active Archive Center