Air-sea interaction and the value of ocean observations for S2S*
(*sub-seasonal to seasonal prediction)

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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.
Taking the analogy WAY too far...

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

Weekly Average SST

2017/06/11 - 2017/06/17

NOAA/ESRL/PSD

°C
NASA PO.DAAC Physical Oceanography Distributed Active Archive Center

MUR L12 ("1km")

Snapshot of Gulf Stream high-resolution SST
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
El Niño: warm water moves east, storms move south...maybe

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)

- 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.
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

National contributions - 3945 Operational Floats
Latest location of operational floats (data distributed within the last 30 days)

Argentina (2)  Australia (377)  Brazil (6)  Bulgaria (1)  Canada (75)  China (115)  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)  Spain (7)  USA (2174)
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](http://gdp.ucsd.edu/ldl_drifter/index.html)