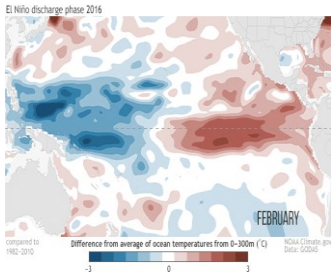
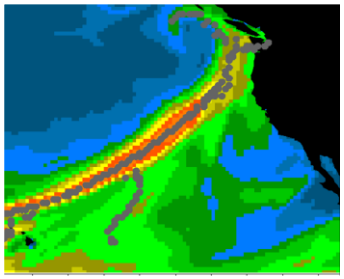
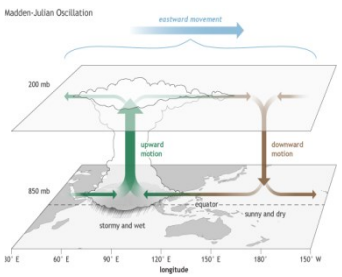
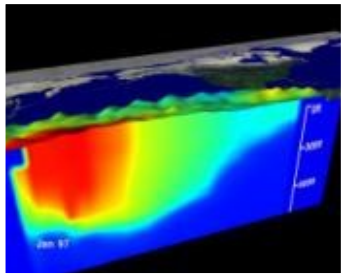
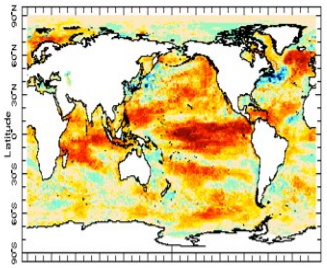
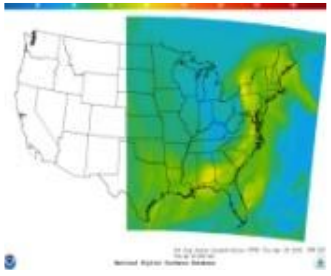
Improving Subseasonal-to-Seasonal Prediction: A Critical Timescale for Drought Early Warning

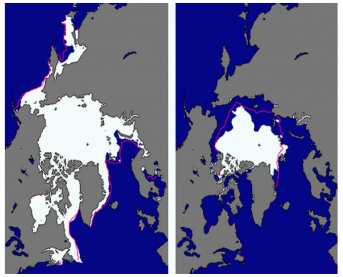
Office of Oceanic & Atmospheric Research (OAR)



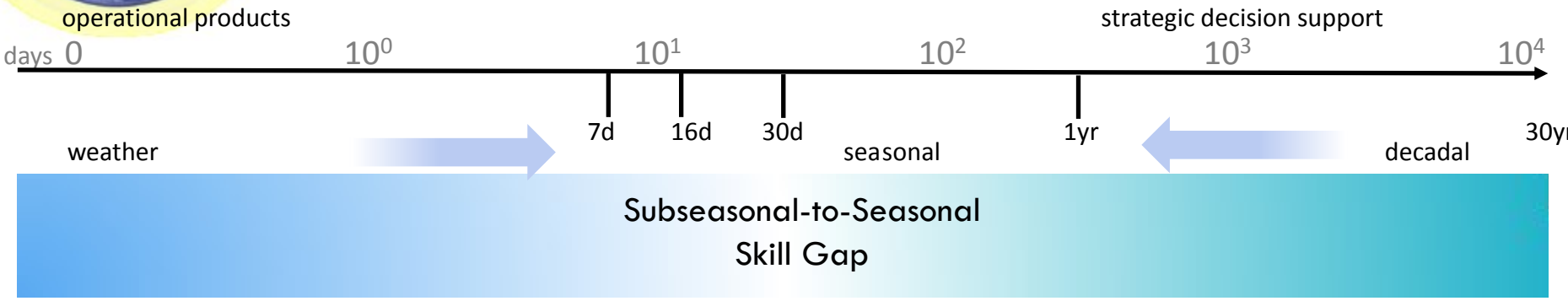



Wayne Higgins
Director, Climate Program Office
November 16, 2016

Co-Authors: Jin Huang, John Cortinas, Jessie Carman, Annarita Mariotti, Heather Archambault, Dan Barrie, Sandy Lucas, Jeremy Mathis, David Legler, Roger Pulwarty, Claudia Neirenberg, Hunter Jones

- Bridging the Gap Between Weather & Climate Prediction
- NOAA Oceanic and Atmospheric Research (OAR) Strengths
- Climate Program Office (CPO) Contributions to Subseasonal-to-Seasonal Prediction
  - Observations & Research
  - Direct Contributions
  - Integrated Information Systems



- To bridge the skill gap between Weather & Climate Prediction:
  - Fully coupled air-ocean-land-ice modeling systems
  - Improved data assimilation
  - Improved process representation and higher resolution
  - Reanalysis and reforecasts
  - Multi-model ensembles

- Needed across time scales:
  - Better utilization of High Performance Computing
  - Common model architectures
  - Uncertainty depiction; metrics
  - Product creation

<u>OAR Labs</u>: Advance core capabilities

Examples:

- **GFDL:** High-resolution modeling system for Wx & Cx Prediction (FV3 for NCEP/Unified Global Coupled System)
- **ESRL:** Medium-range modeling; attribution for extremes
- **ARL:** Monitoring (e.g. chemistry) supporting predictions

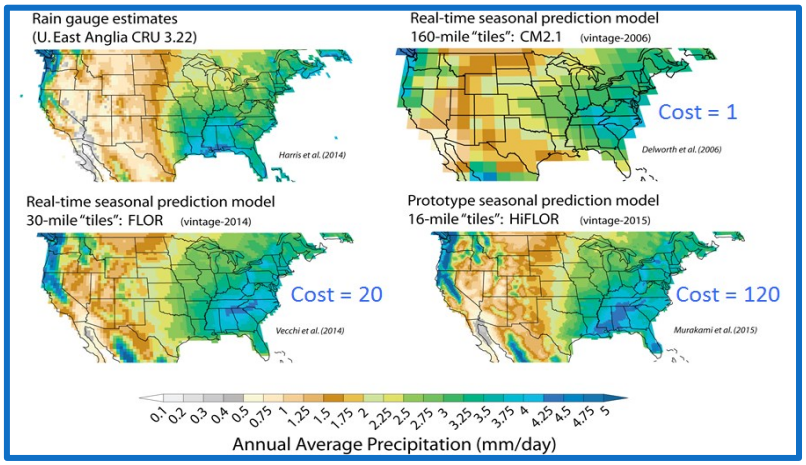
<u>OAR Programs</u>: engage the broad internal / external community

OWAQ → ← **CPO**

- Support foundational research; process studies; transition activities; etc.

ESRL-led El Niño Rapid Response Field Campaign 2015-16

- Goal: Improve understanding, modeling, and prediction of El Niño and the midlatitude response
- Outcome: Unprecedented data set of tropical conditions and the midlatitude response

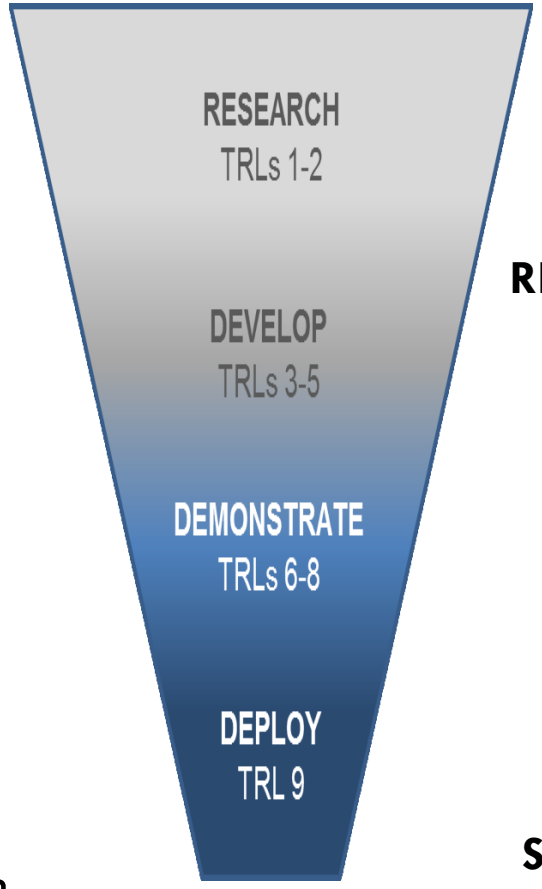


GFDL Advances in High-Resolution Modeling

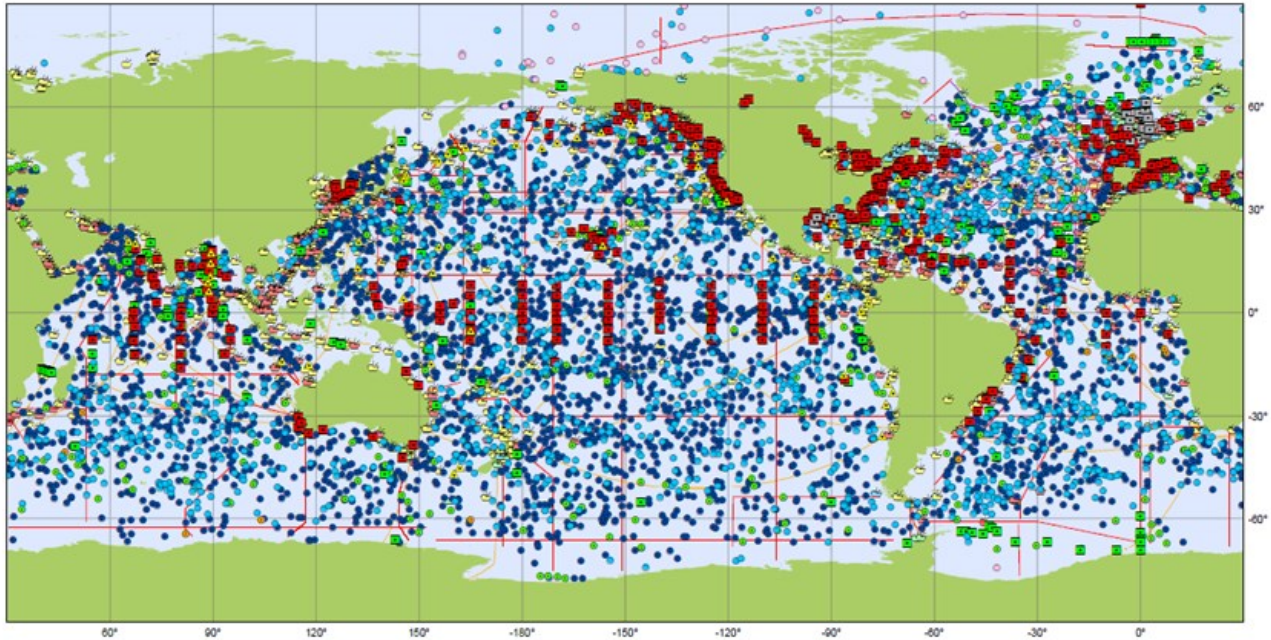
- New capabilities to predict extremes such as tropical cyclones and heavy precipitation on subseasonal – to-seasonal timescales

- Atmospheric Chemistry, Carbon Cycle and Climate (AC4)
- Climate Variability and Predictability (CVP)
- Modeling Analysis Predictions & Projections (MAPP)
- Regional Integrated Sciences & Assessments (RISA)
- Sectoral Applications Research Program (SARP)
- Coastal and Ocean Climate Applications (COCA)
- National Integrated Drought Information System (NIDIS)

- **Observations & Research**
  - Global Ocean Observations
  - Madden Julian Oscillation
  - Atmospheric Rivers
  - Drought
  - Arctic
  - Atlantic Meridional Overturning Circulation
- **Direct Contributions**
  - North American Multi Model Ensemble
  - Sub-seasonal Experiment
  - Climate Forecast System
- **Integrated Information Systems**
  - National Integrated Drought Information System
  - National Integrated Heat Health Information System

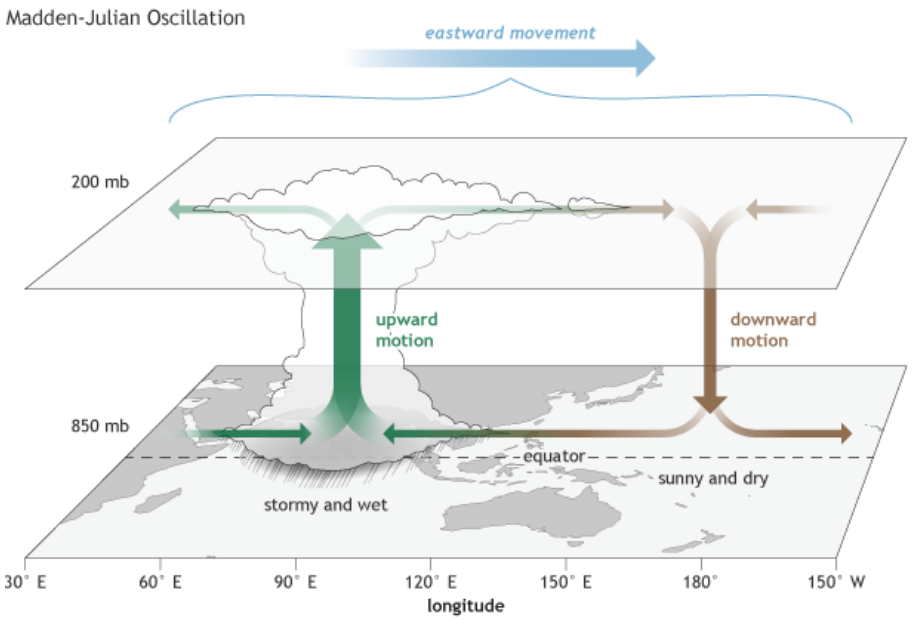


- Contributions to major global ocean observing systems (e.g. Argo, Global Drifters, RAMA, PIRATA, Oceansites, ocean gliders, etc.)
- Supports JCOMM infrastructure to deliver ocean data
- Collaborates with partners to advance the global in situ observing system (e.g. TPOS 2020 for ENSO monitoring and prediction).



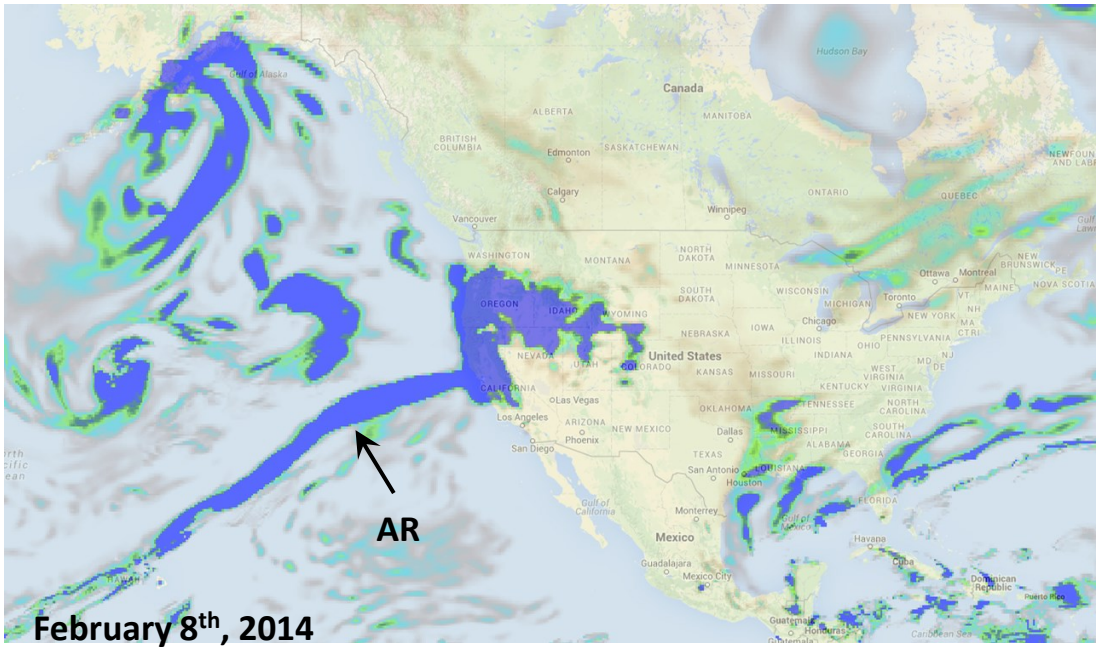
DYNAMO (Dynamics of the Madden-Julian Oscillation) field campaign was supported with a series of research competitions.

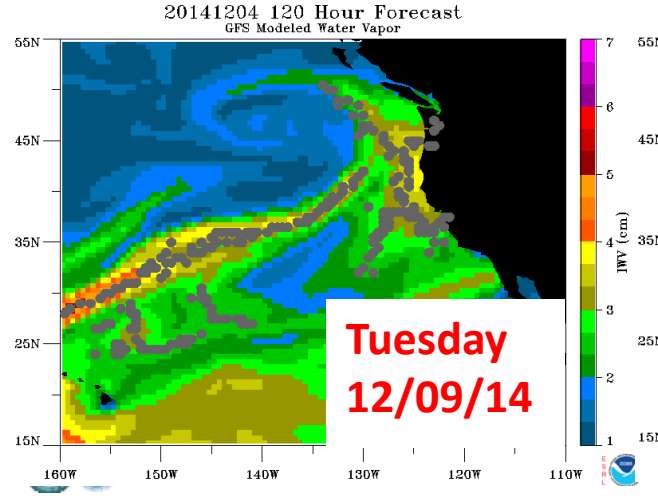
- FY11 – Observations and process understanding
- FY13 – Analysis and modeling of results.
- FY15 – Climate Process Teams to improve MJO representation and S2S prediction skill in NCEP and GFDL models.
- FY17 – Join ONR and NASA campaign to understand the role of the maritime continent in MJO propagation.

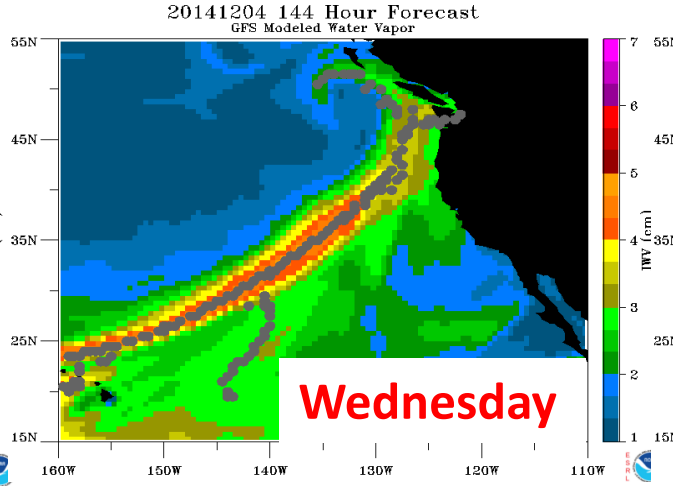


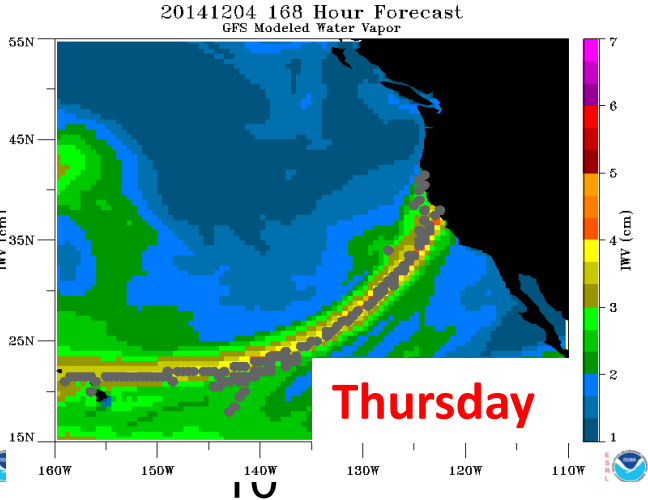
http://cpo.noaa.gov/dynamo-webinars

- ARs are narrow corridors of enhanced winds and water vapor transport with low pressure systems
- ~ 40-70% of the drought breaks in the west since 1950 are due to ARs
- ARs can cause major flooding
- Currently: looking at seasonal prediction of AR's in CFSv2







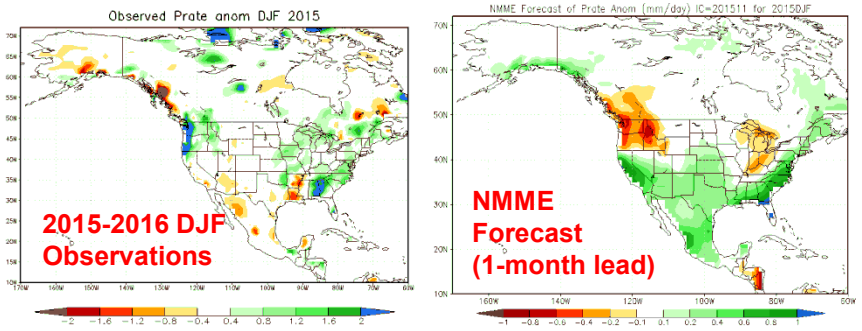


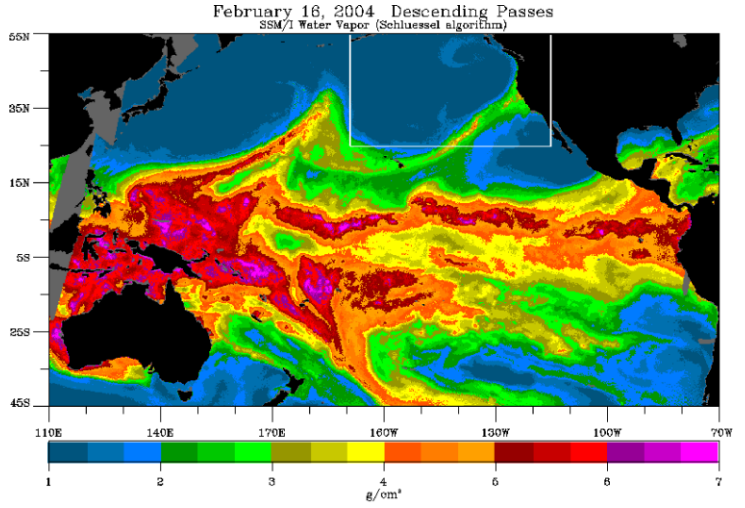
Goal: *to make targeted improvements in the skill of seasonal precipitation forecasts through user- and operations-driven advances in understanding, models, and products*

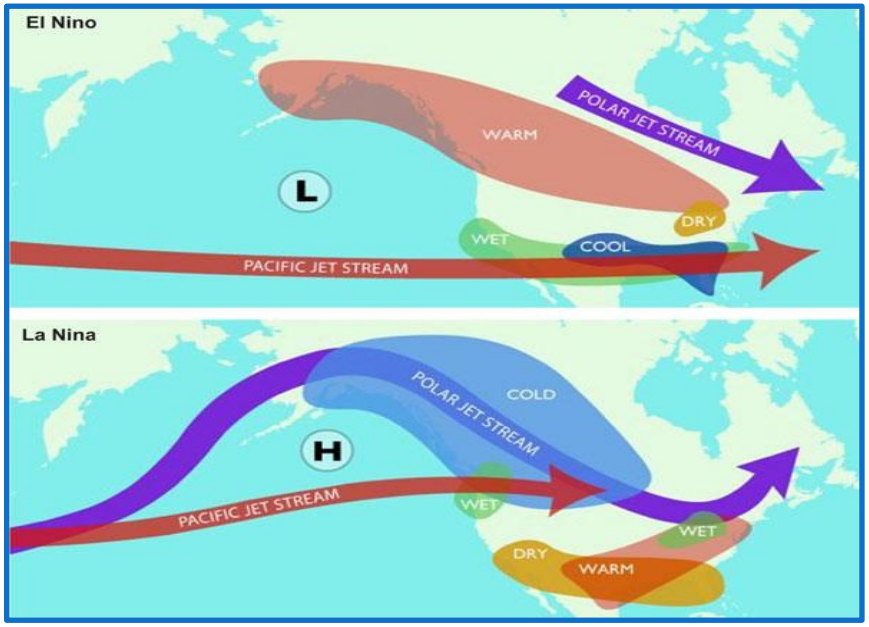
- **Motivation: skill of seasonal precipitation forecasts remains low while user need for improved information remains high**

- Focal areas
  - Tropical convection in models
  - Tropical-extratropical interactions
  - Sources of predictability
  - Improve forecast building blocks – data assimilation, models, observations

- Partners:
  - NOAA operational centers, laboratories, cooperative institutes
  - Research community

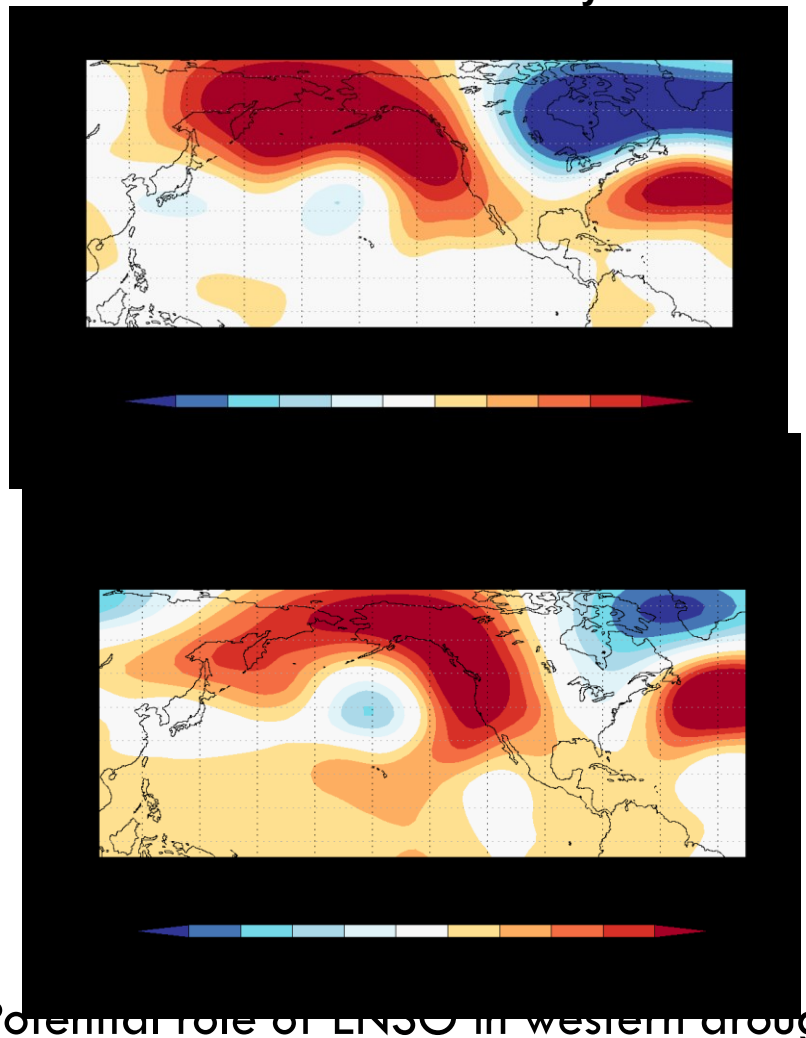






Typical weather & atmospheric circulation patterns over North America during El Nino (top) & La Nina (bottom)

November 2013 - February 2014



- 2016-2018 term; based on new MAPP S2S-focused projects
- Leadership: Elizabeth Barnes (lead), Paul Dirmeyer, Andrea Lang, Edmund Chang

Goals:

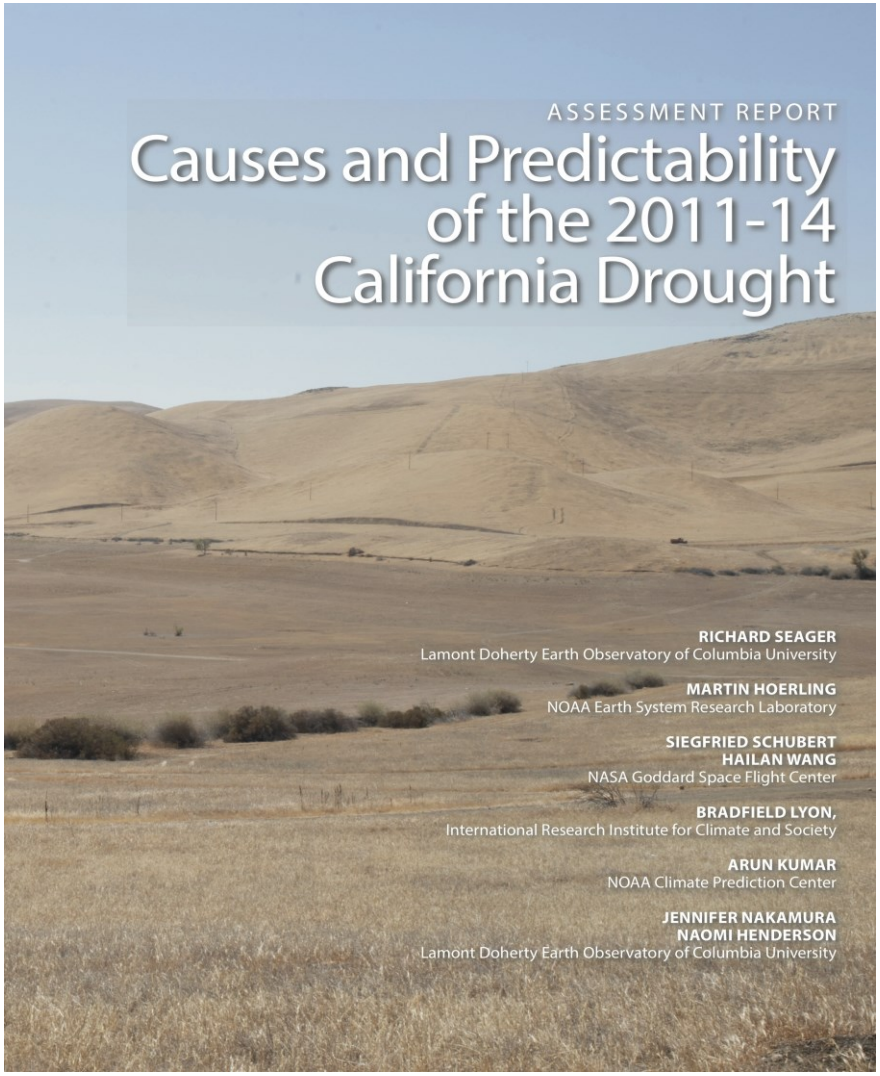
- Advance capability to model and predict sources of S2S predictability to help close gap in prediction skill and products between traditional weather and seasonal lead times
- Coordinate and focus MAPP-funded S2S research and transition activities (e.g., SubX)
- Facilitate connections with other national and international S2S research efforts (e.g., WWRP/WCRP S2S Prediction Project)

Subseasonal-to-Seasonal S2S Prediction Project

The **Drought Task Force seeks** to achieve significant new advances in the ability to understand, monitor, and predict drought over North America.

Task Force Assessment Activity

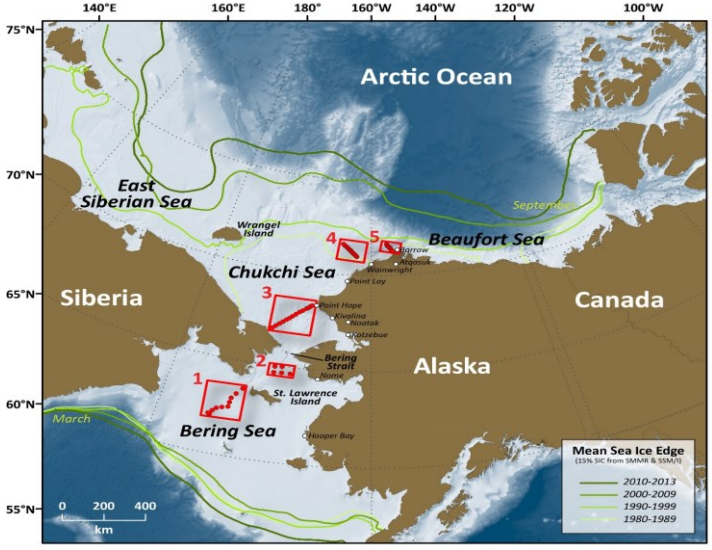
- Assessments of recent or current droughts
- Collaborative, focused activity bringing together a diverse group of researchers
- California Drought: caused by high pressure off the U.S. West Coast itself caused by anomalous Sea Surface Temperatures



OBSERVATIONS

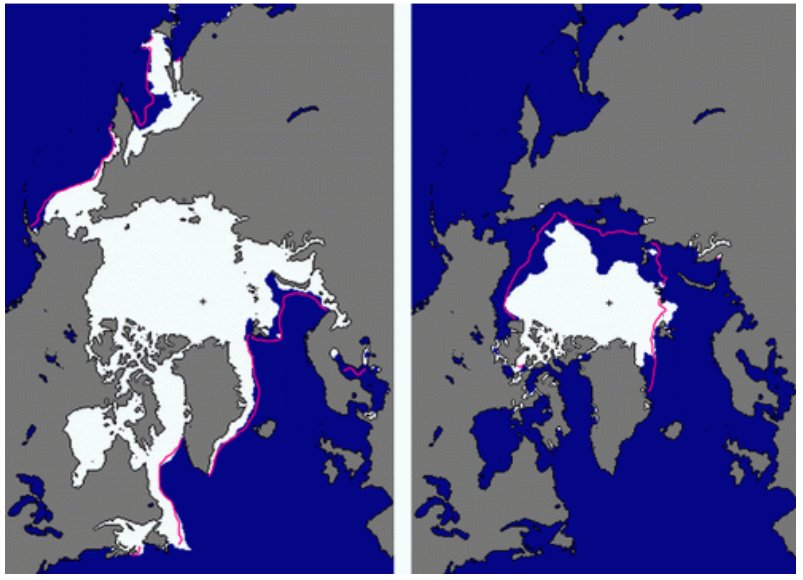
Distributed Biological Observatory (DBO)
http://www.arctic.noaa.gov/dbo

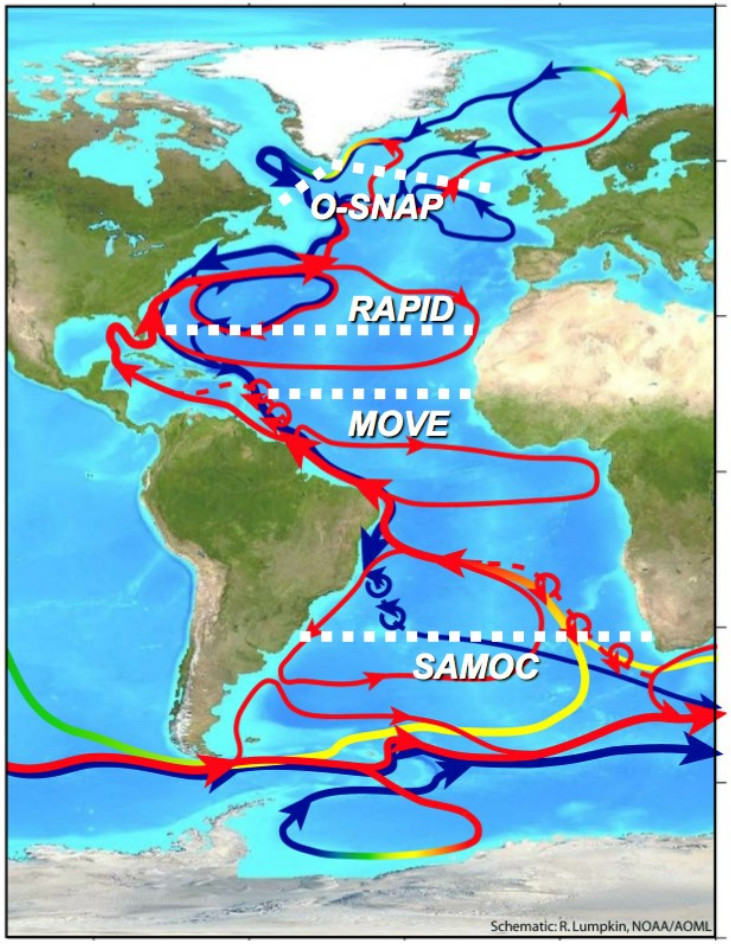
- Serves as a *change detection array*, via sampling of biophysical processes



RESEARCH & MODELING

To determine how the Arctic system is changing, particularly the consequences that the loss of sea ice may have on Arctic ecosystems, coastal management, economic development and severe weather events.



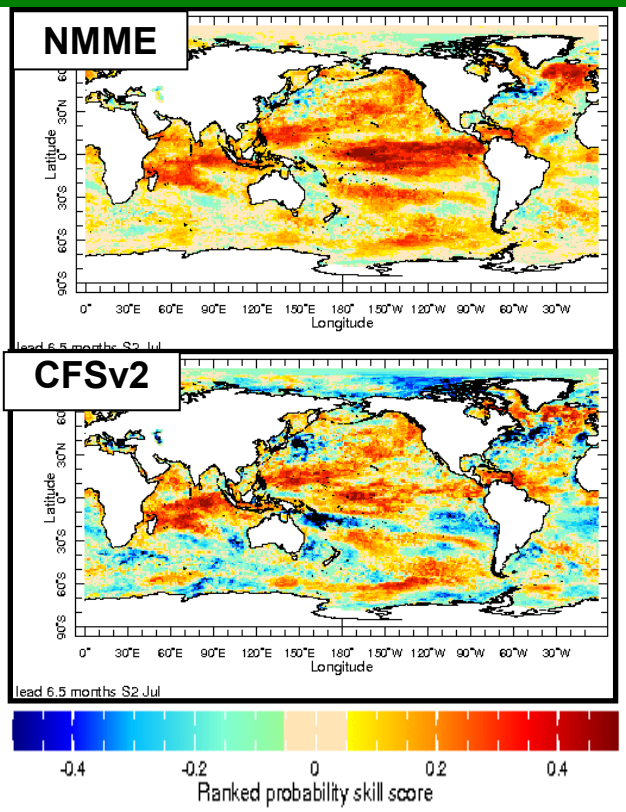


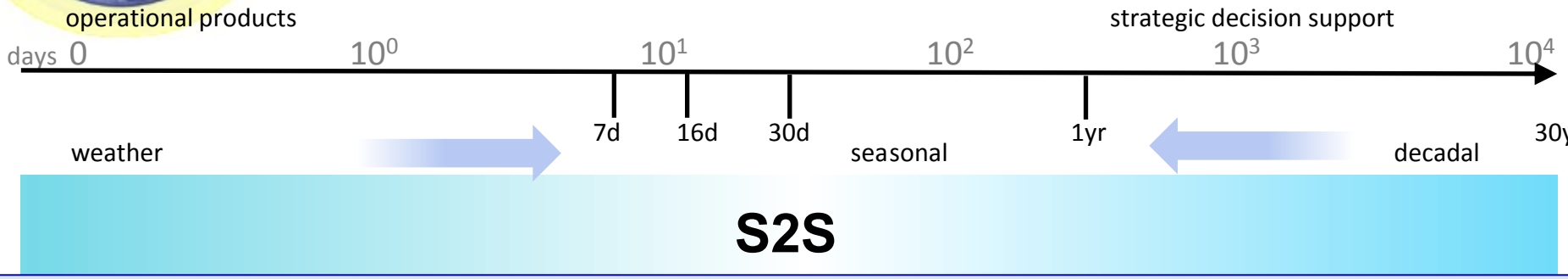
- The Atlantic Ocean drives long-term global ocean circulation by cold, salty water sinking at high latitudes
- The North-South movement of heat and currents is collectively called the AMOC (Atlantic Meridional Overturning Circulation)
- The AMOC cycle takes about 60 years.
- Understanding and predicting the AMOC cycle can help predict multi-decadal climate variability
- **Understanding AMOC can help build an experimental multi-decadal prediction system**

NMME Goal: *improve subseasonal to interannual predictions based on an ensemble of major US and Canada models*

- 2011: Experimental system initiated (CTB)
- 2011-present: Supported by CPO with contributions from NSF, DOE and NASA.
- 2011-present: Evaluated real-time forecast reliability based on 30-year hindcasts
- 2015: NMME **Seasonal** Forecast System becomes operational at NCEP
- **Currently: The most comprehensive seasonal prediction dataset for research and applications**

Comparison of Skill: NMME vs CFSv2





SubX Goal: *Address gaps in NOAA and ESPC operational prediction capabilities at sub-seasonal to seasonal (S2S) timescales*

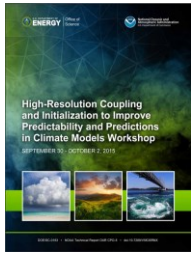
- **Current Status:** testing real time sub-seasonal MME prediction system
- **6 Models:** CFS, GEFS, Navy, NASA/GEOS5, NCAR/CCSM, Canada
- **SubX Protocol** for hindcasts and real-time forecasts

Goal: support improvements to NCEP Climate Forecast System for operational seasonal to interannual prediction and climate monitoring

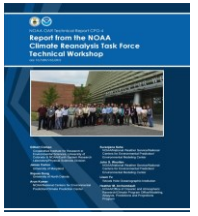
- Assess benefits of high-resolution modeling
- Test new physical representations in models via Climate Process Teams
- Coupled data assimilation
- Process level diagnostics for model improvement (Model Diagnostics Task Force)
- Modeling software infrastructure (NEMS) and data access (NCMA)

Earth System Processes

Resolution

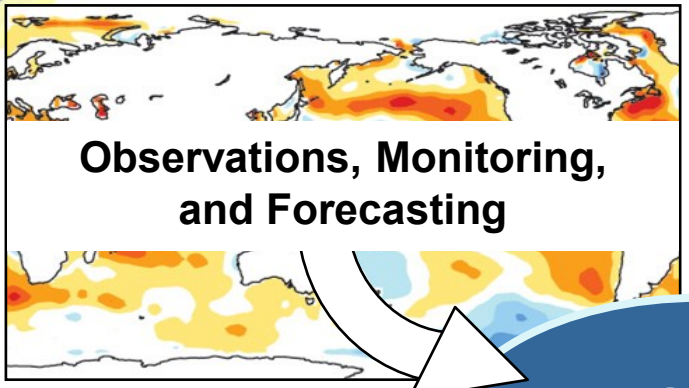


Infrastructure



Assimillation

MAPP Modeling, Analysis, Predictions, and Projections



Observations, Monitoring, and Forecasting

Earth System Science and Modeling

INTEGRATED INFORMATION

Communication, Education, and Engagement

Societal Outcomes

A systematic collection, analysis, and communication of information about and coming from areas of impending risk to (i) anticipate risk and opportunities, and (ii) inform development of strategic responses.

Science Service

Pioneered within CPO, the IIS concept has grown to be NOAA-wide.
IIS's are interfaces between CPO-supported research & societal outcomes.

CPO Programs:

AR | OCO | CM | CVP | AC4 | MAPP | RISA | SARP | COCA | IRAP | CEE

Integrated Information Systems:

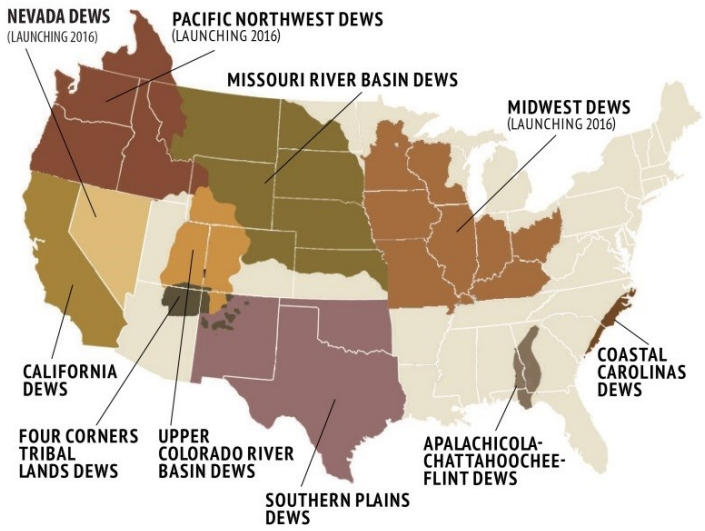
CPO	CPO	NOS	OAR	NMFS	NOAA
NIDIS	NIHHIS	NICFIS	IG3IS	?	??
Drought and Water Resources	Weather and Climate Extremes	Coasts and Climate Resilience	Atmospheric Composition	Sustainability of Marine Ecosystems	Arctic

Outcomes:

NOAA envisions a future in which communities and business are better prepared for water resource challenges.	Scientific expertise brought to bear on climate and weather extremes to reduce exposure, improve resilience and early warning and save lives.	NOAA envisions a future with a strong economy and thriving coastal communities and ecosystems.	Observing, monitoring and informing the US and the world as we choose the future of our shared atmosphere.	Science and marine resource mgmt. for climate-smart communities: identifying and managing risks to marine ecosystems and their services.

Linking intelligence to users to enhance resilience

NIDIS Drought Early Warning Systems



- State drought planning
- RISA networks
- NWS Forecast Offices
- Tribal Engagement

Observations, Monitoring and Forecasts

Drought Impacts, Assessments, & Scenarios

Integrated Information System

Drought Risk Management and Adaptation

Communication & Outreach

Engaging Preparedness & Adaption

NIDIS

National Integrated Drought Information System

NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM

Na

NIHHIS Website: http://toolkit.climate.gov/nihhis/

The activities described here are a unique federal investment in end-to-end capabilities to improve the global observing system, advance understanding, improve coupled modeling and prediction, and enable decision support services.

These activities are foundational to NOAA Goals to meet the U.S. Federal need for Earth System Prediction products & services, including drought

Integrated Information Systems knit these investments together to address key societal challenge priority areas for our stakeholders:

- Extremes (NIHHIS)
- Drought/Water Resources (NIDIS)
- Coastal Flooding (NICFIS)

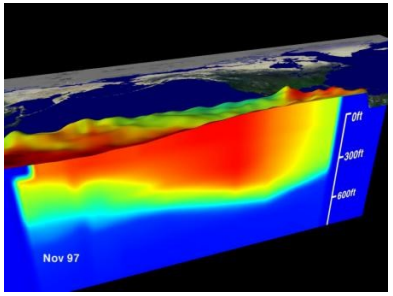
- Marine Ecosystems
- Arctic
- Atmospheric Composition

} We don't have an IIS structure for these yet

SST anomalies → **Global-Scale Atmospheric Changes** → **Regional Forcing and Land Feedbacks** → **Local Impacts, Info needs**

Key Phenomena, variables

ENSO, PDO, AMO, warm pool variability, Global Warming, etc

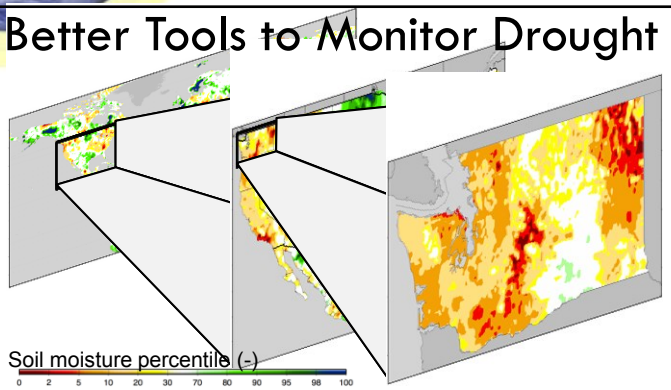


Planetary waves, hydrological cycle, monsoons, Hadley Cell, Walker Circulation

Precipitation, soil moisture, snow, low level jets, dust, vegetation, changes in weather

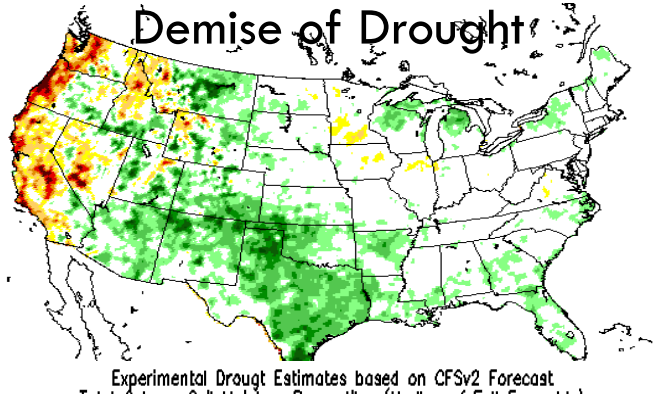
Soil moisture, stream flow, precipitation, ground water, lakes, reservoirs

Better Tools to Monitor Drought



Soil Moisture over the Western U.S.

Predicting Onset, Evolution, and Demise of Drought



Monitoring – use new observations (soil moisture; snowpack), increase resolution, communicate uncertainties, objective information

Predictability – identify sources of predictability on timescales of weeks to decades and better understand physical drivers of drought

Prediction – improvements in systems including using using multiple models, improving model initial conditions, and moving to higher resolution

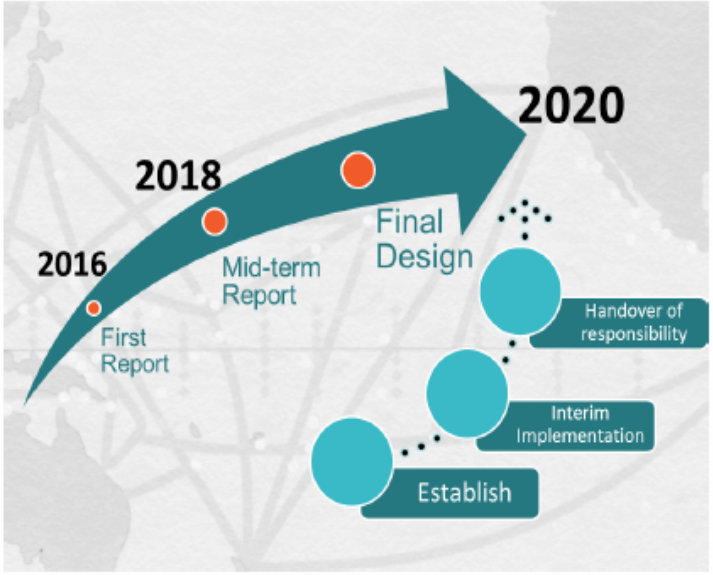
Projections – refining projections of future conditions

TPOS 2020: an international project under GOOS/IOC

Goals

- To redesign and refine the T.P.O.S. to observe ENSO and advance understanding of its causes
- To determine the most efficient and effective observational solutions to support prediction systems for ocean, weather and climate services
- To advance understanding of tropical Pacific physical and biogeochemical variability and predictability.

Timeline



TPOS 2020 Tropical Pacific Observing System