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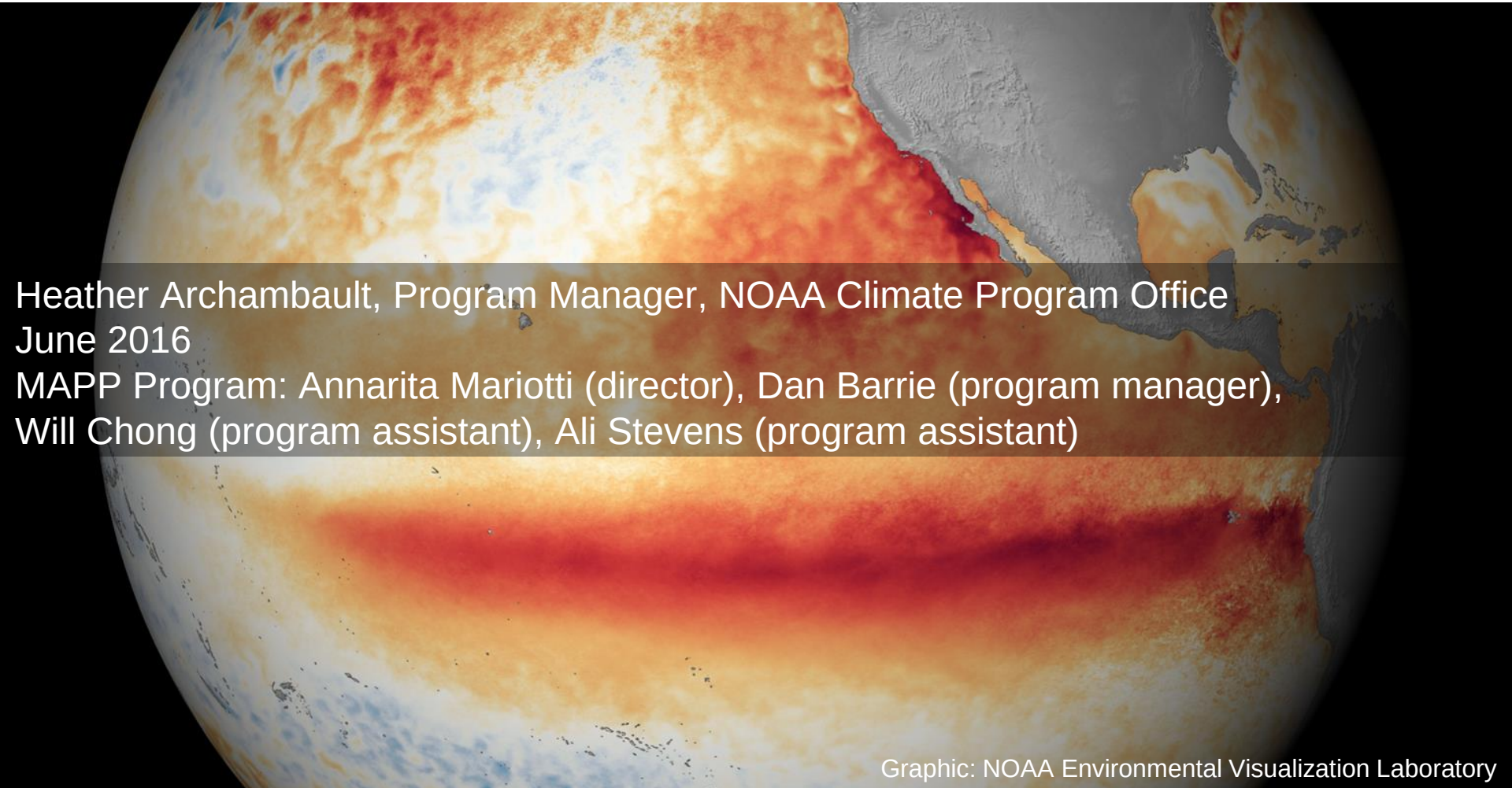
Modeling, Analysis, Predictions, and Projections

OAR/Climate Program Office

Subseasonal-to-Seasonal Prediction Initiatives and Scientific Opportunities in High-Resolution Modeling



Heather Archambault, Program Manager, NOAA Climate Program Office
June 2016
MAPP Program: Annarita Mariotti (director), Dan Barrie (program manager), Will Chong (program assistant), Ali Stevens (program assistant)

Graphic: NOAA Environmental Visualization Laboratory

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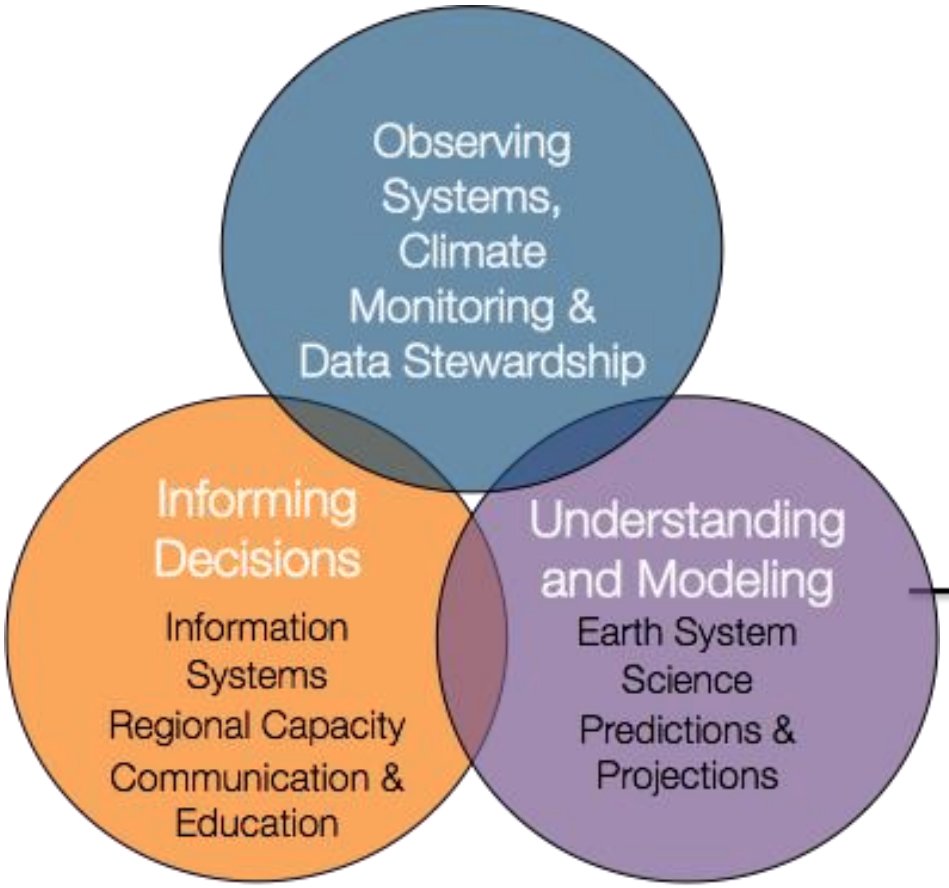
MAPP's Role within NOAA

CPO Focus Areas



Oceanic & Atmospheric Research (OAR)

↓

CPO

↓

MAPP

A mission-oriented competitive research program at interface between science and services

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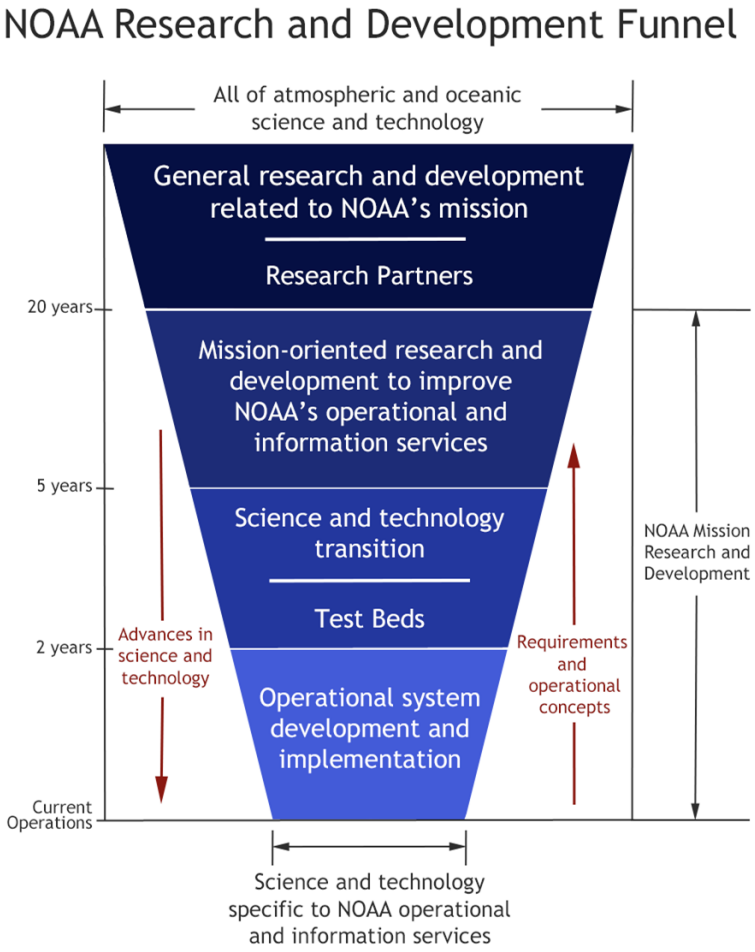
Observations → Processes → Models→ Predictions

The Climate Program Office's MAPP and Climate Variability and Predictability (CVP) programs have long supported seasonal prediction research.

Concept of CVP–MAPP research connection

CVP: Support for DYNAMO field campaign for airborne measurements → improved understanding and modeling of basic processes that influence MJO initiation

MAPP: MJO model improvements → better simulations and predictions of MJO and its impacts on US circulation pattern → better NWS predictions of US precipitation



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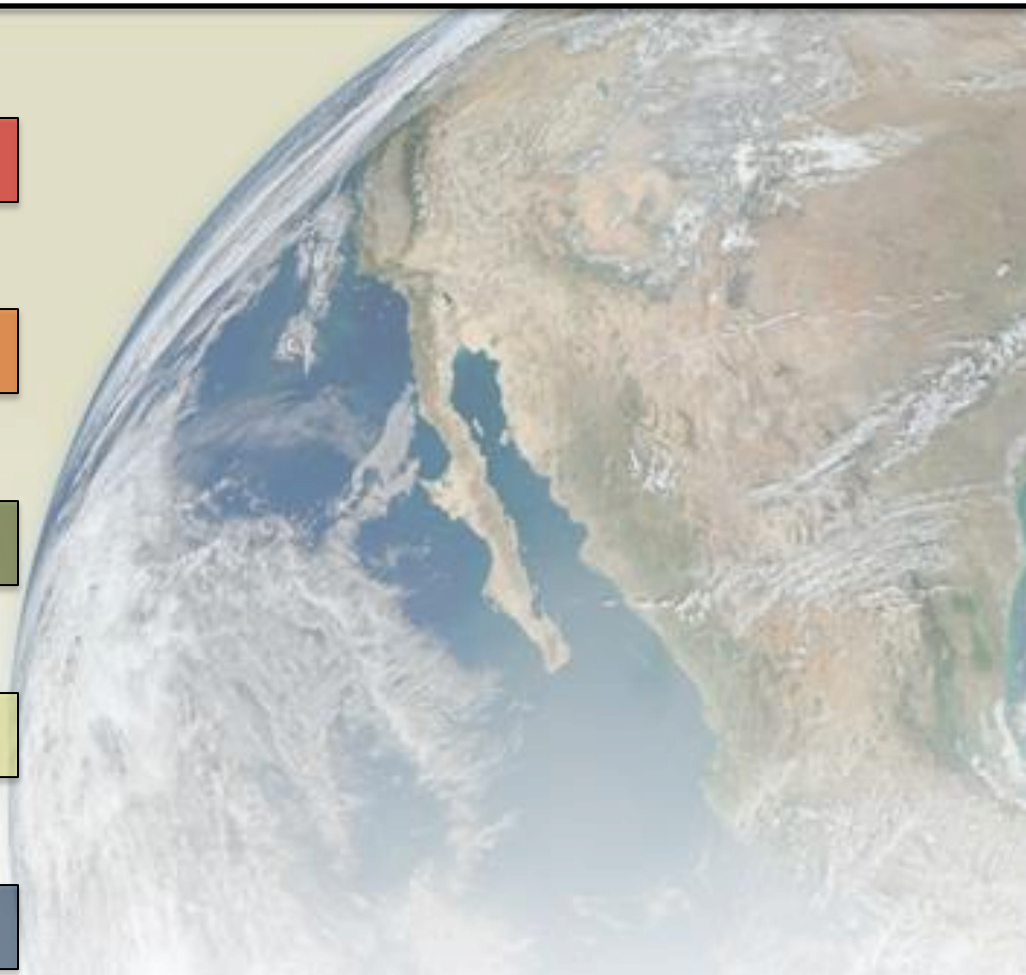
MAPP Focus Areas



- Prediction
- Climate Reanalysis
- Climate and Earth System Modeling
- Drought and Other Applications
- Climate Projections

- Through annual competitions, MAPP Program supports 5 focus areas
- “Climate Competitive Research” NOAA/OAR Budget Line

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Researcher-led Task Forces

Prediction	➢ Subseasonal to Seasonal Prediction*
Climate Reanalysis	➢ Climate Reanalysis
Climate and Earth System Modeling	➢ Climate Model Development
Drought and Other Applications	➢ Drought
Climate Projections	➢ Model Diagnostics

*planned

- MAPP task forces allow for a sustained, coordinated research effort by MAPP investigators

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MAPP, CVP partnerships relevant to prediction work

Within NOAA:

noaaresearch

Office of Weather and Air Quality

Earth System Prediction Capability (ESPC)

Labs: GFDL, ESRL

National Weather Service

Office of Science and Technology Integration: NGGPS Program, Weeks 3-4 Program

With other Federal agencies through:

National ESPC
Earth System Prediction Capability

US CLIVAR

GlobalChange.gov
U.S. Global Change Research Program

Interagency Group on Integrative Modeling

Internationally:

World Meteorological Organization
Weather • Climate • Water

WCRP

WWRP
World Weather Research Programme

Subseasonal to Seasonal (S2S) Prediction Project

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MAPP activities to improve predictions

- Development and demonstration of NMME
- Development of Climate Forecast System, v2
- Drought Task Force – NIDIS link
- Climate Prediction Task Force
- Climate reanalysis research
- Data assimilation techniques
- Predictability and prediction research at Center for Ocean-Land-Atmosphere (George Mason University)

New in FY 2016:

- **$3M+** in subseasonal to seasonal (S2S) prediction research investments, including transition to operations work. With co-support from NWS NGGPS, NESDIS, NASA and Navy
- Targeted improvements to model physics

Evaluation of soil moisture biases at increasing lead times in CFSv2 reforecasts
Dirmeyer 2013, CFSv2 Topical Collection

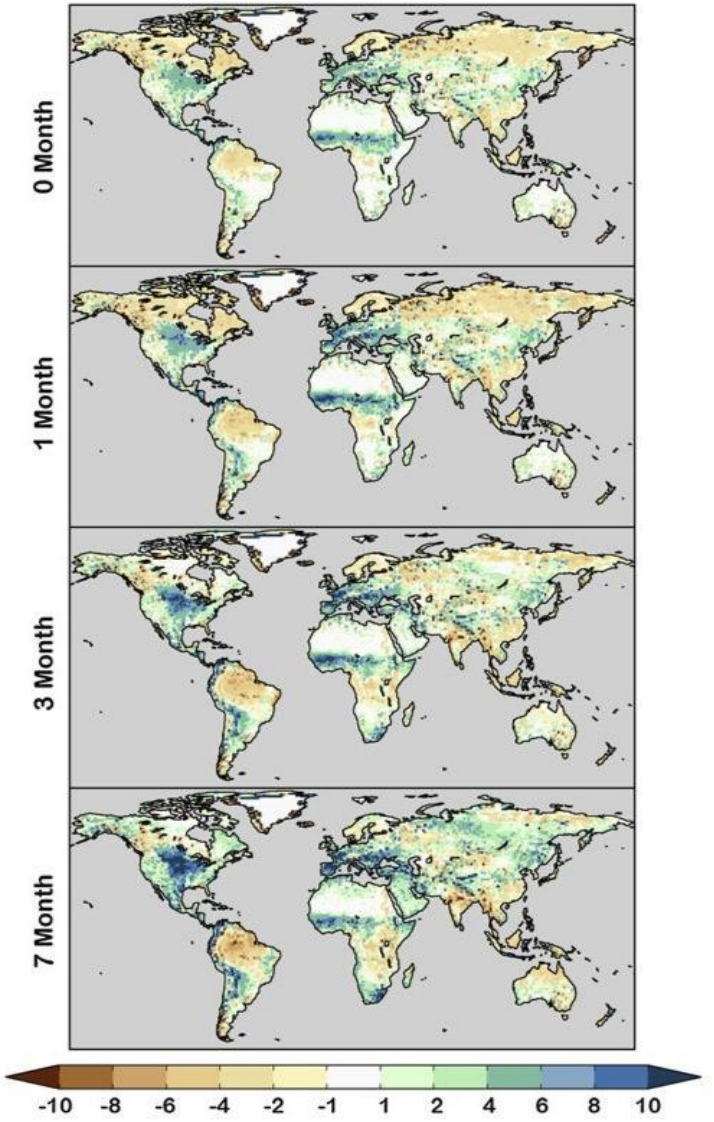
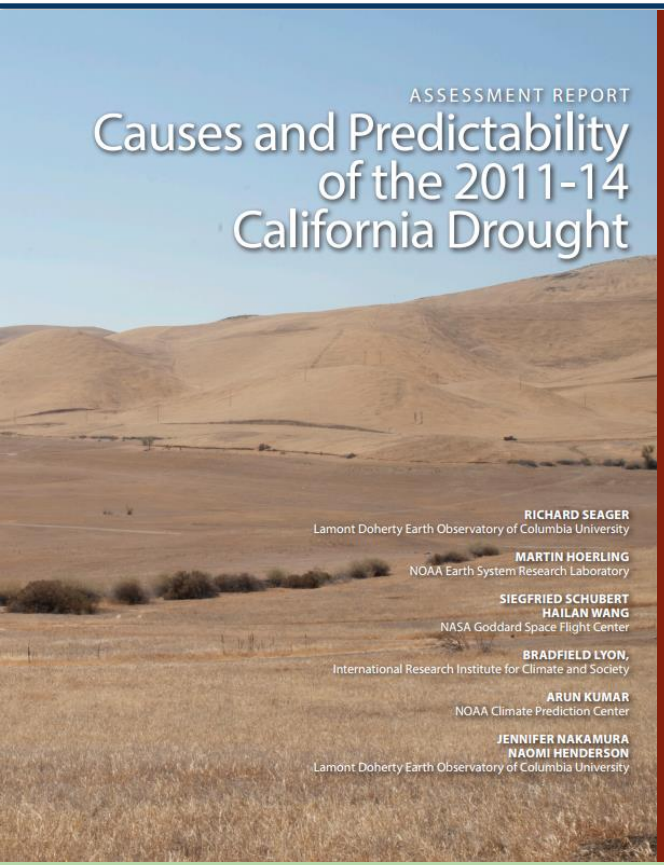


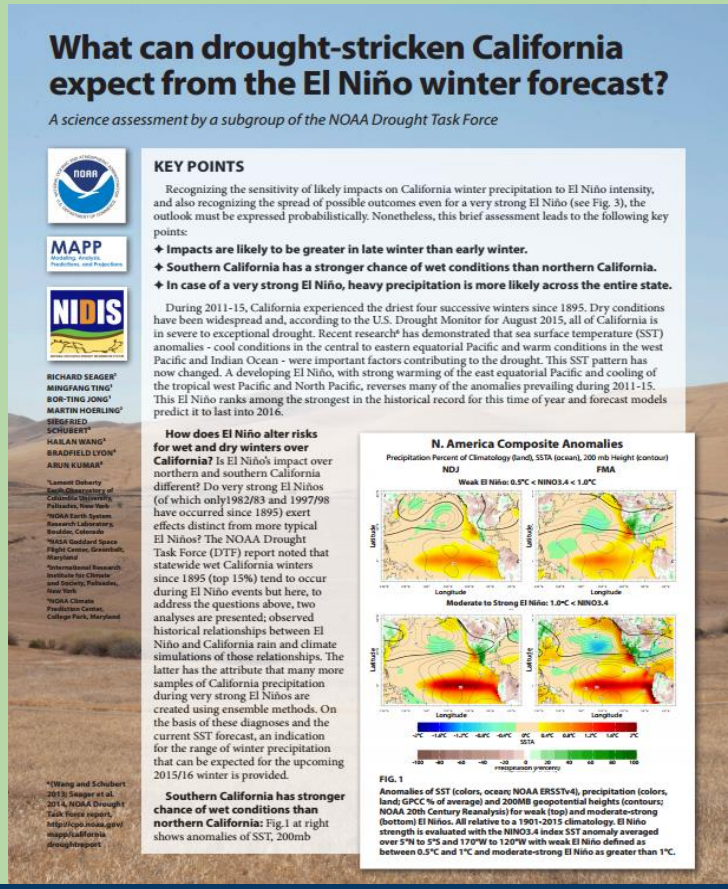
Fig. 3 As in Fig. 2 for JJA volumetric soil moisture (10–40 cm layer) forecast errors relative to CFS reanalysis

Drought Task Force: A California Focus



Scientific assessment of causes of 2011–2014 drought:

- Persistent high pressure off West Coast diverted storms
- Response to SST forcing
- La Nina in first year, then continued ocean influence



What can drought-stricken California expect from the El Niño winter forecast?

A science assessment by a subgroup of the NOAA Drought Task Force

RICHARD SEAGER, MINGFANG TING, BOR-TING JONG, MARTIN HOERLING, SIEGFRIED SCHUBERT, HAILAN WANG, BRADFIELD LYON, ARUN KUMAR

KEY POINTS

Recognizing the sensitivity of likely impacts on California winter precipitation to El Niño intensity, and also recognizing the spread of possible outcomes even for a very strong El Niño (see Fig. 3), the outlook must be expressed probabilistically. Nonetheless, this brief assessment leads to the following key points:

- **Impacts are likely to be greater in late winter than early winter.**
- **Southern California has a stronger chance of wet conditions than northern California.**
- **In case of a very strong El Niño, heavy precipitation is more likely across the entire state.**

During 2011-15, California experienced the driest four successive winters since 1895. Dry conditions have been widespread and, according to the U.S. Drought Monitor for August 2015, all of California is in severe to exceptional drought. Recent research* has demonstrated that sea surface temperature (SST) anomalies - cool conditions in the central to eastern equatorial Pacific and warm conditions in the west Pacific and Indian Ocean - were important factors contributing to the drought. This SST pattern has now changed. A developing El Niño, with strong warming of the east equatorial Pacific and cooling of the tropical west Pacific and North Pacific, reverses many of the anomalies prevailing during 2011-15. This El Niño ranks among the strongest in the historical record for this time of year and forecast models predict it to last into 2016.

How does El Niño alter risks for wet and dry winters over California? Is El Niño's impact over northern and southern California different? Do very strong El Niños (of which only1982/83 and 1997/98 have occurred since 1895) exert effects distinct from more typical El Niños? The NOAA Drought Task Force (DTF) report noted that statewide wet California winters since 1895 (top 15%) tend to occur during El Niño events but here, to address the questions above, two analyses are presented; observed historical relationships between El Niño and California rain and climate simulations of those relationships. The latter has the attribute that many more samples of California precipitation during very strong El Niños are created using ensemble methods. On the basis of these diagnoses and the current SST forecast, an indication for the range of winter precipitation that can be expected for the upcoming 2015/16 winter is provided.

Southern California has stronger chance of wet conditions than northern California: Fig.1 at right shows anomalies of SST, 200mb

N. America Composite Anomalies
Precipitation Percent of Climatology (land), SSTA (ocean), 200 mb Height (contour)
NDJ FMA
Weak El Niño: 0.5°C < NINO3.4 < 1.0°C
Moderate to Strong El Niño: 1.0°C < NINO3.4
Latitude Longitude
SSTA
Precipitation (percent)

FIG. 1
Anomalies of SST (colors, ocean; NOAA ERSSTv4), precipitation (colors, land; GPCC % of average) and 200MB geopotential heights (contours; NOAA 20th Century Reanalysis) for weak (top) and moderate-strong (bottom) El Niños. All relative to a 1901-2015 climatology. El Niño strength is evaluated with the NINO3.4 index SST anomaly averaged over 5°N to 5°S and 170°W to 120°W with weak El Niño defined as between 0.5°C and 1°C and moderate-strong El Niño as greater than 1°C.

*(Wang and Schubert 2013; Seager et al. 2014; NOAA Drought Task Force report, http://cpo.noaa.gov/mapp/california droughtreport

Current Drought Task Force foci:

- Why was the winter 2015–2016 precipitation forecast for western U.S. a bust?
- What are impacts of temperature and evapotranspiration, relative to precipitation deficits, on drought?

Research assessment of typical El Niño impacts on California winter precipitation

- El Niño impacts are typically greater in late winter than early winter
- Southern California has higher odds of wet than Northern California

Transition of Research to Operations: Climate Test Bed

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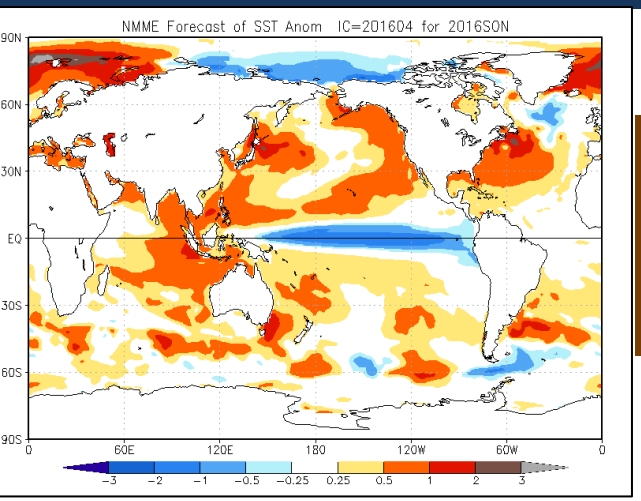
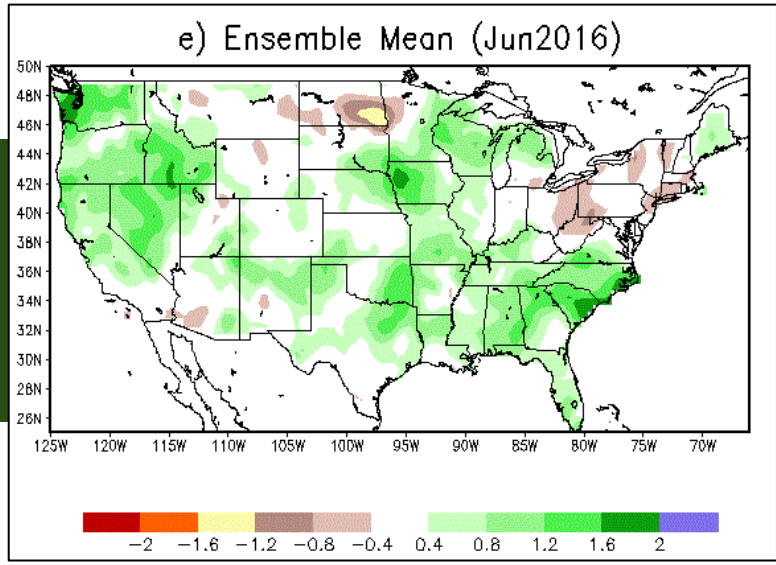
The **NOAA Climate Test Bed** is a joint effort of NWS and OAR/CPO to advance operational climate monitoring, models, and prediction capabilities by accelerating transition of research into operations

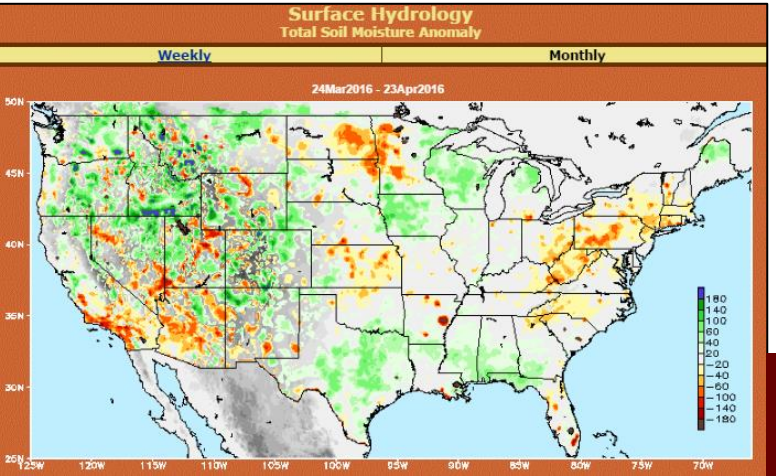


North American Multi-Model Ensemble System

The Climate Test Bed fosters a key service–science link between NOAA and outside scientific community.



Standardized Precipitation Index forecasts derived from NMME



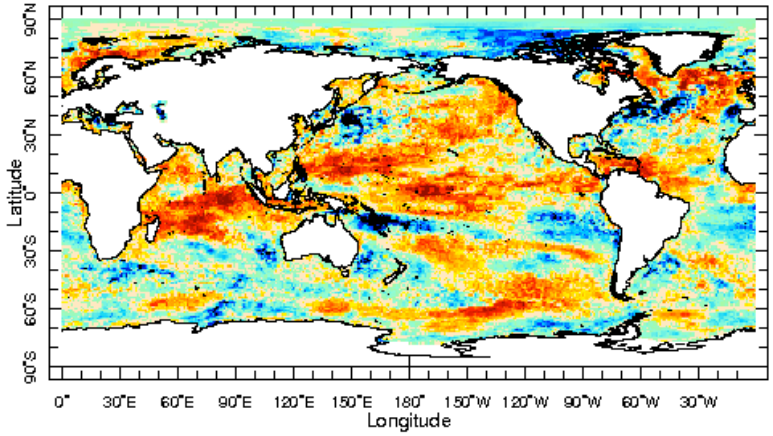
North American Land Data Assimilation System

The North American Multi-Model Ensemble: Now Operational

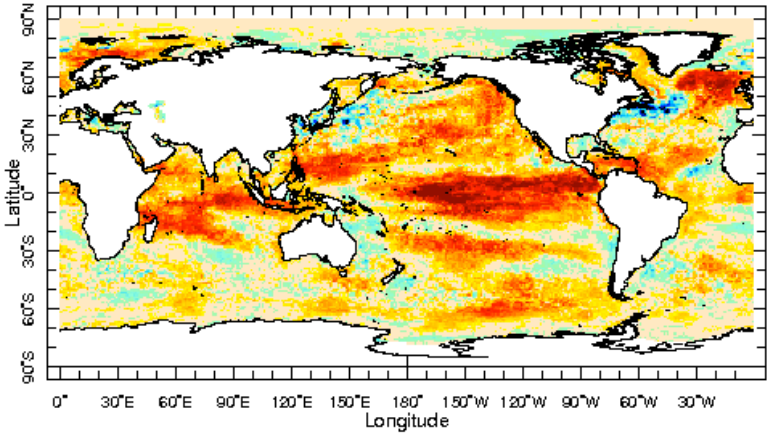
MAPP Modeling, Analysis, Predictions, and Projections

- Concept: on average, can achieves superior forecast skill relative to any single-model prediction system by combining predictions from leading climate models
- Through Climate Test Bed, with support from NASA, DOE, and NSF, NMME was developed and demonstrated as ready to be transitioned into operations
- NMME completed transition to NWS operations in May 2016
- Largest seasonal prediction dataset publicly available provides a platform for prediction and applications research projects
- Research to improve NMME continues: NMME Special Issue in *Climate Dynamics* open for submissions through Sep 2016

CFSv2 forecast skill



NMME forecast skill



Ranked probability skill scores of 6.5-month sea surface temperature forecasts

lead 6.5 months S2 Jul

Warmer colors = greater skill

A MAPP–CTB-developed Empirical Subseasonal Prediction Tool

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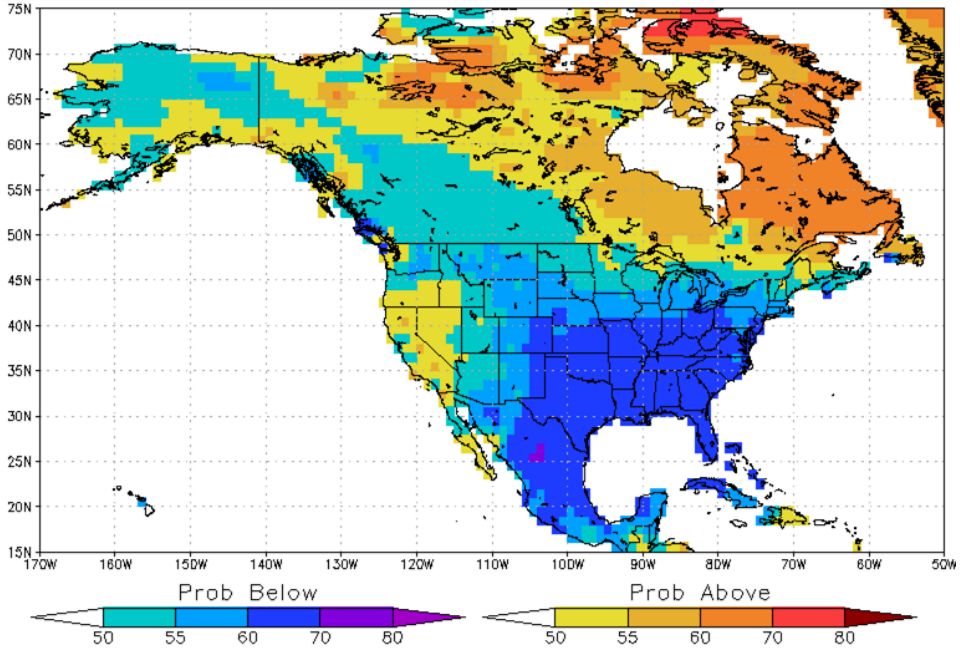
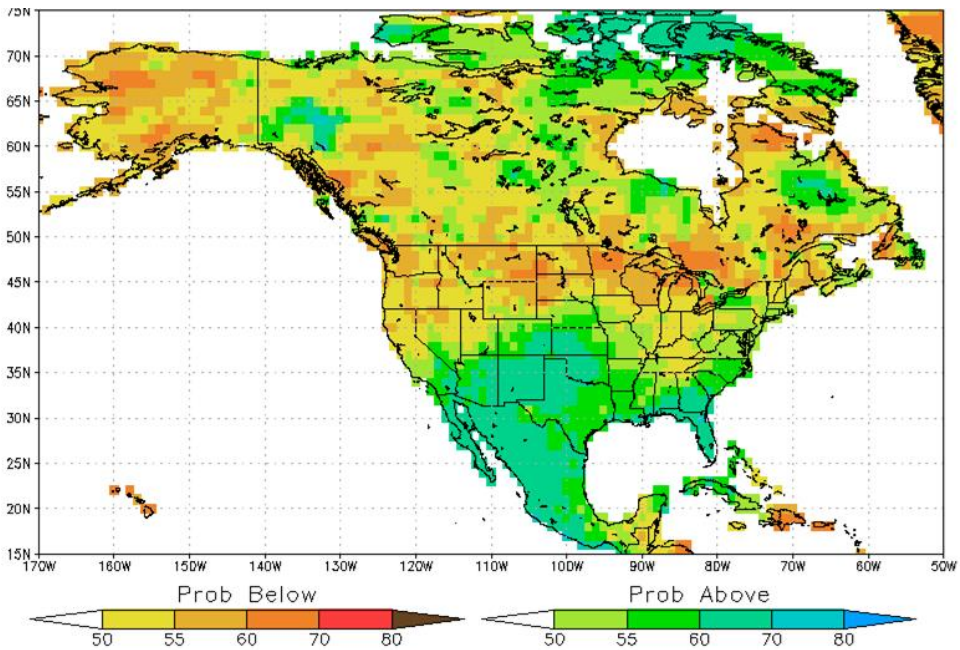
Forecast Tools for CPC Experimental Week 3–4 Outlooks

Principal Investigators: Nat Johnson and Shang Ping Xie
CPC Investigators: Michelle L'Heureux and Steven Baxter

El Niño and MJO Phase 7, January



Probability of Above/Below 2-m Temp.



Probability of Above/Below Precip.

Generates probabilistic forecasts by leveraging information about current states of ENSO and Madden-Julian Oscillation (and for temperature, trend information)

Example of NMME research – Atmospheric River Prediction

Hyemi Kim and Yang Zhou, Stony Brook University

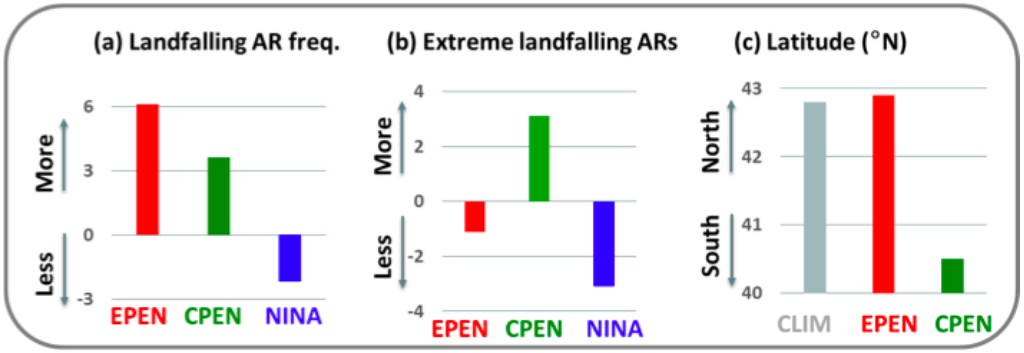
Research questions:

- How does ENSO phase (EP and CP El Nino, and La Nina) impact atmospheric rivers (ARs) and moisture transport?
- How well do current ensemble prediction systems in NMME database predict AR activity?

Approach:

- Examine AR activity (frequency, intensity, landfall location) in ENSO phases
- Examine causes of change in seasonal moisture transport related to ENSO
- Evaluate AR–ENSO prediction in NMME reforecasts

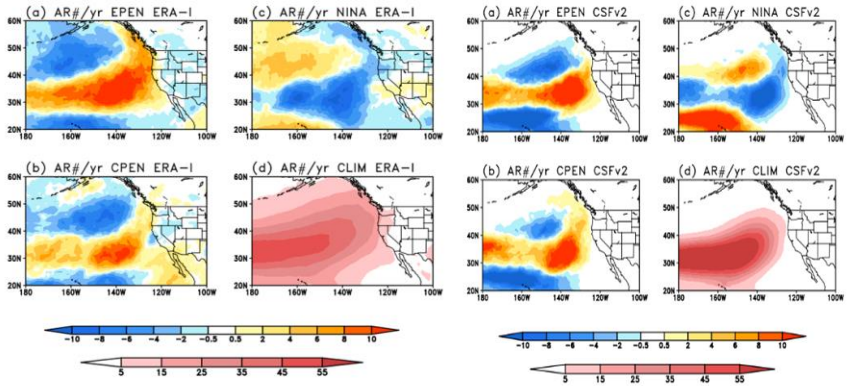
Landfalling ARs: Vertically integrated moisture flux ≥ 250 kg/m/s
Extreme landfalling ARs: Vertically integrated moisture flux ≥ 450 kg/m/s



ERA-Interim:
6-hourly data from 1979/80-2015/16, Dec–Feb

Atmospheric River Frequency

ERA-Interim CFSv2



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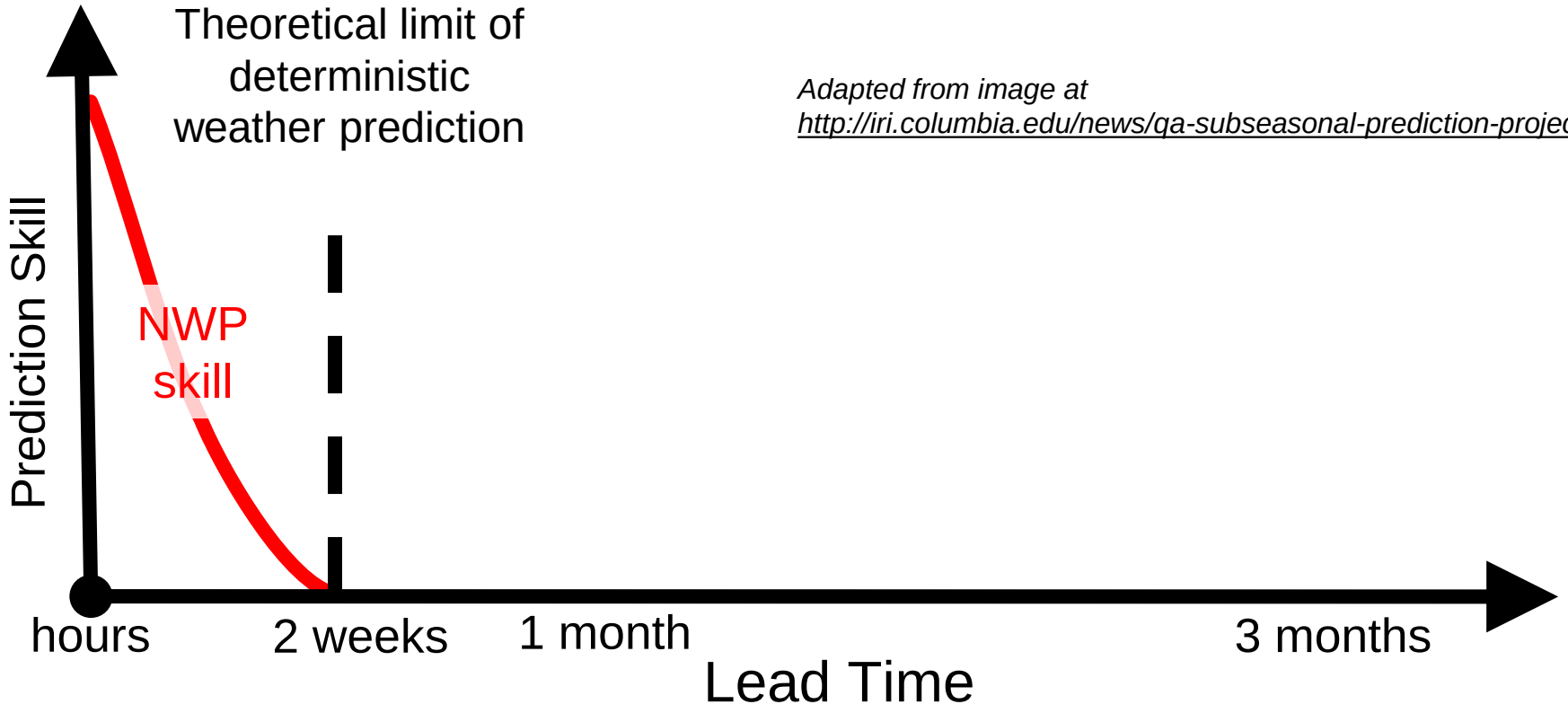
Challenge of Prediction for Lead Times Between Weather and Climate



Adapted from image at
http://iri.columbia.edu/news/qa-subseasonal-prediction-project/

Weather predictability:

Arises from atmospheric initial conditions and atmospheric processes

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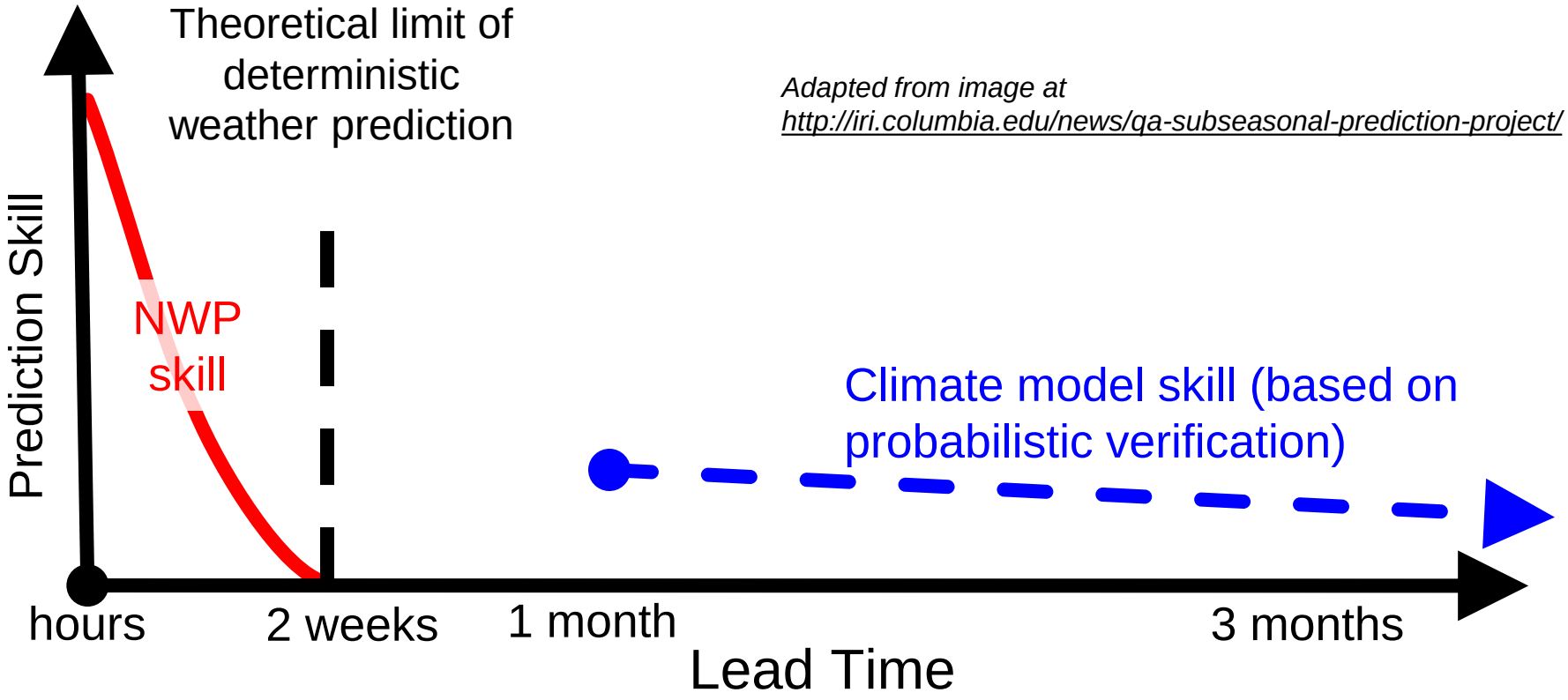
Challenge of Prediction for Lead Times Between Weather and Climate



Weather predictability:

Arises from atmospheric initial conditions and atmospheric processes

Climate predictability:

Arises from natural modes of variability in coupled Earth system, slowly-varying processes, and trends

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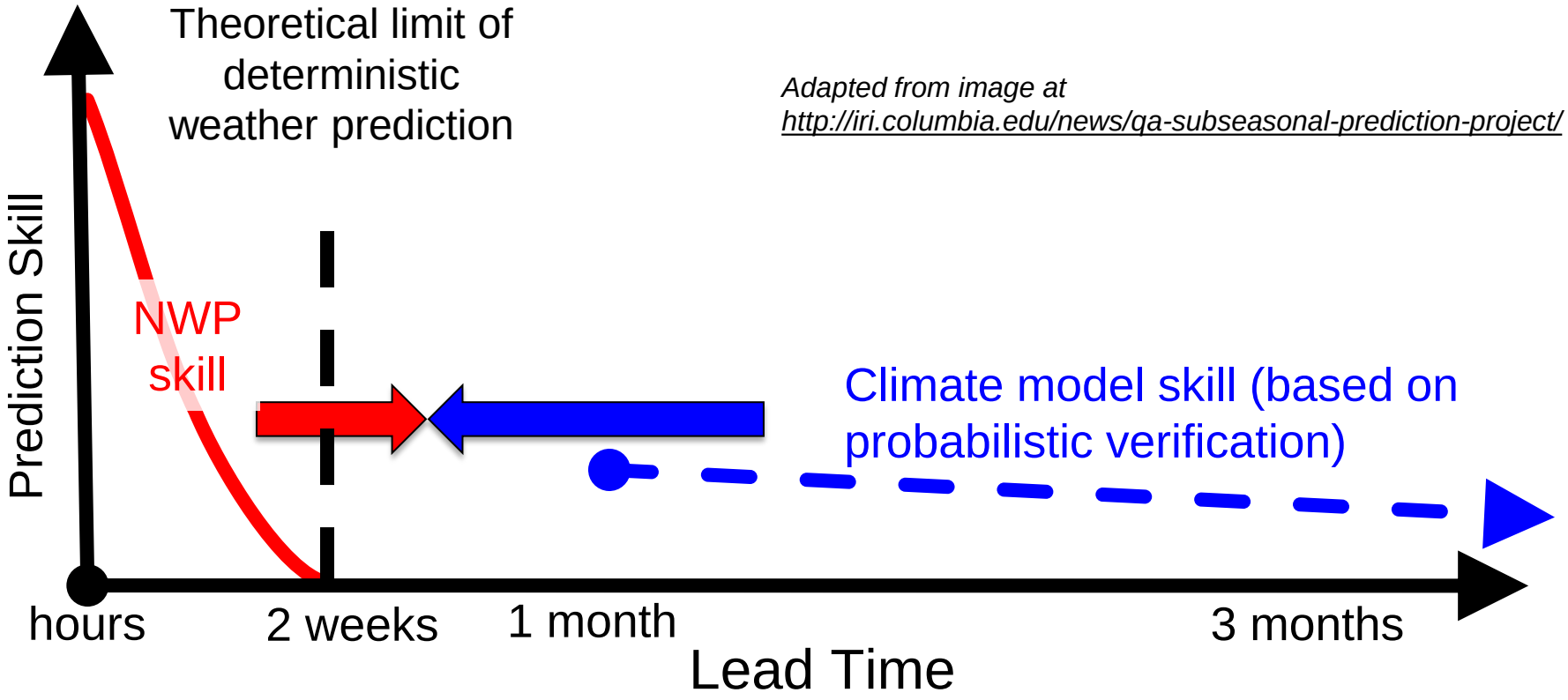
Challenge of Prediction for Lead Times Between Weather and Climate



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Weather predictability:
Arises from atmospheric initial conditions and atmospheric processes

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Strategy to Advance S2S Prediction Capability

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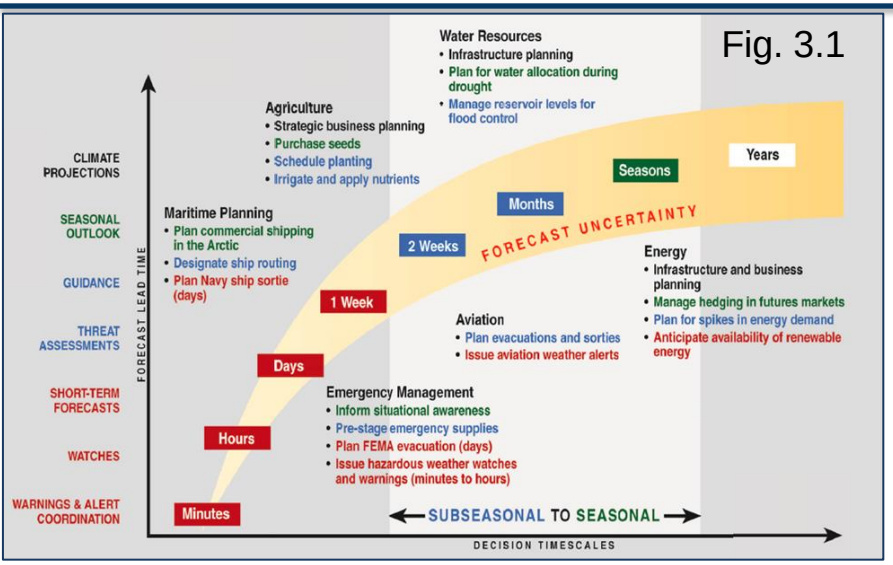

Fig. 3.1

MAPP's strategy in supporting new S2S research and transition projects:

1. Test prediction tools via Climate Test Bed (R2O; targets short-term advances)
2. Understand how to improve prediction systems' representation of predictability sources (research; targets medium-term advances)

>$3M planned starting FY16

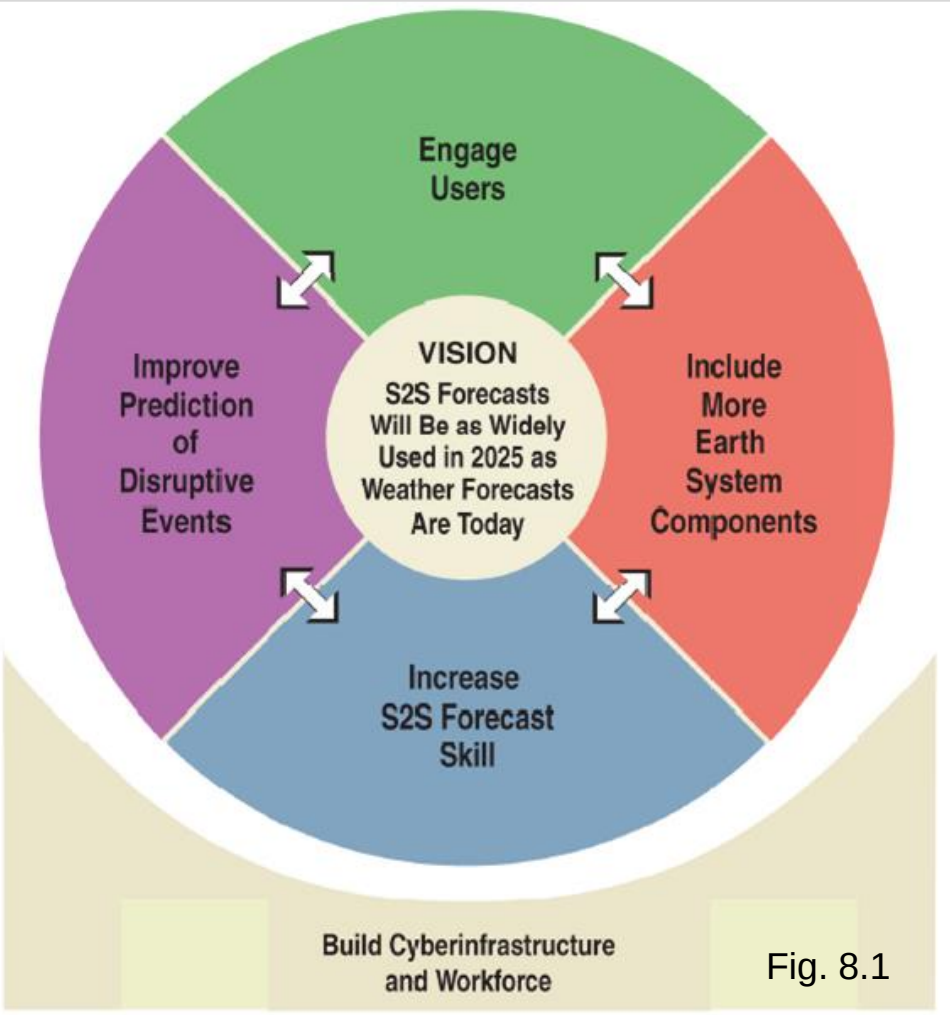

Fig. 8.1

Next Generation Earth System Prediction Strategies for S2S Forecasts (NAS, 2016)

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Strategy to Advance NOAA's S2S Prediction Capability

1: "Climate Test Bed - Transition of Research to Operations"

- SubX (Subseasonal Prediction Experiment) will test experimental subseasonal prediction systems
- Projects on land surface models and data assimilation for better representation of snow and other biases
- Statistical techniques to improve prediction of teleconnection response over North America
- New drought products tailored to water managers

Co-support: NWS/NGGPS program, ONR, and NESDIS

Fig. 3.1, NAS S2S report: Lake Oroville in California on July 20, 2011 (left) and January 16, 2014 (right). Source: CA Dept. of Water Resources

Strategy to Advance NOAA's S2S Prediction Capability

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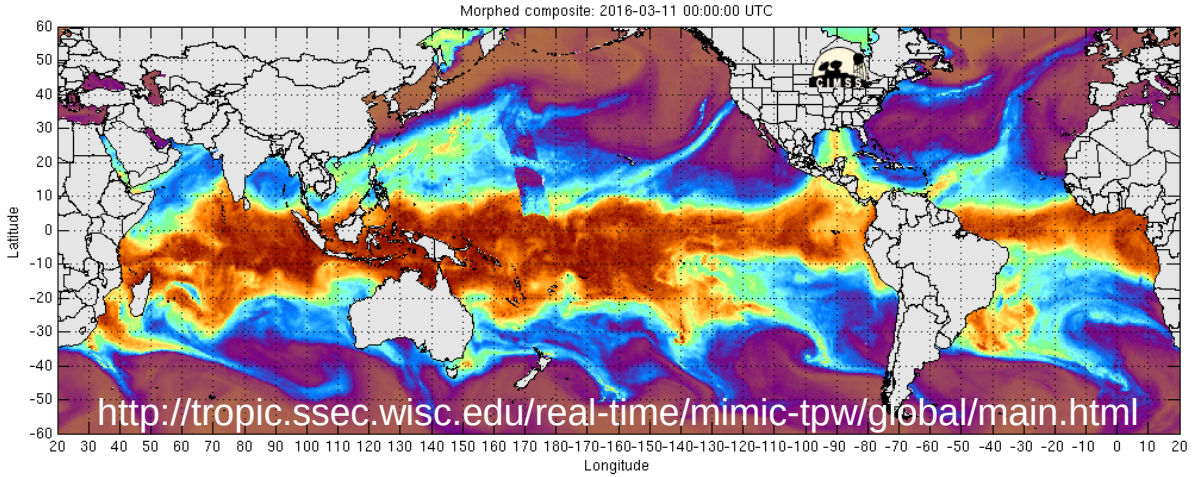
2: "Research to Advance Prediction of S2S Phenomena"

- 3-year projects to examine how prediction of S2S phenomena (sources of predictability) is influenced by prediction system set up
- Examining statistical, other approaches to find less-expensive sources of improved forecast information
- Projects include work on prediction of connection between tropical forcing and midlatitude blocking/atmospheric rivers
- Improvements in NA precipitation prediction from multi-model data
- Contribute to a broad, coordinated research effort that connects to WMO S2S Prediction Project via a **new S2S Prediction Task Force**

Co-support: NWS/NGGPS program



Total precipitable water loop for March 11–14, 2016, showing two atmospheric rivers making landfall along U.S. West Coast.

Scientific Opportunities in High-Resolution Modeling

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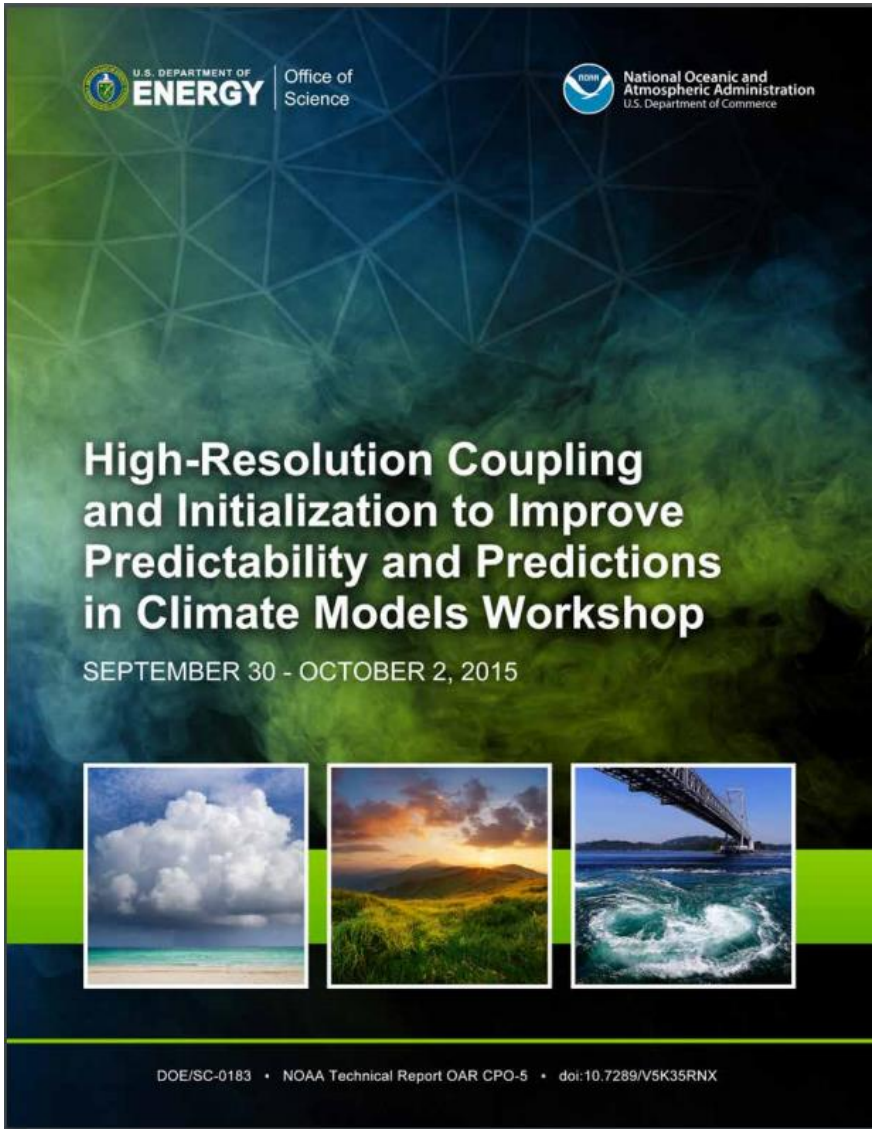
Recent NOAA-DOE sponsored workshop to explore opportunities

Brought together two groups: one focused on S2S prediction and the other interested in climate model improvement

Workshop themes:

1) seamless S2S predictions
2) frameworks for diagnosing biases in coupled systems
3) initialization at high resolution and uncertainty sampling for S2S prediction



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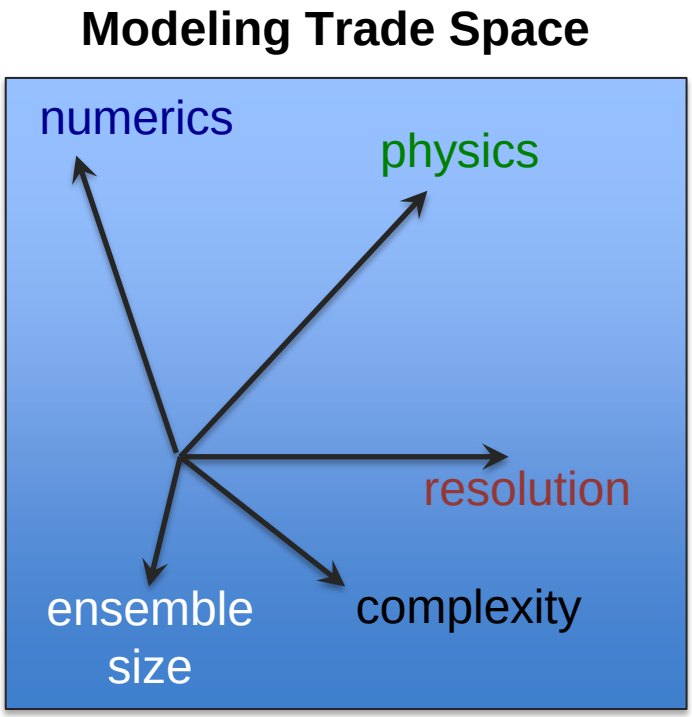
Scientific Opportunities in High-Resolution Modeling

Outcomes:

- Global high-resolution in coupled models, together with adequate process physics, has potential to significantly improve models and S2S predictions, as it helped for NWP
- However, a systematic experimentation and assessment of benefits in the “modeling trade space” is currently lacking due to costs
- Requires substantial investments in research and computing infrastructure, with benefits from coordination between the S2S predictions and climate modeling communities



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Summary

- MAPP and CVP programs' research and transition have been key to improving seasonal predictions
- New FY 2016 MAPP initiatives are aimed at closing the weather-climate prediction gap – pioneering on select activities recommended in the S2S NAS report
- These new initiatives represent only tip of iceberg of what NOAA could do to advance S2S prediction (see, e.g., NAS S2S report)
- Increasing resolution for global coupled models may improve predictions in many respects; work is needed to systematically explore trade offs between resolution and other aspects of modeling