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**Climate Variability and Predictability Program** 

**US CLIVAR** 

#### About US CLIVAR

**US CLIVAR** 

US Climate Variability and Predictability (CLIVAR) is a national research program with a mission to foster understanding and prediction of climate variability and change on intraseasonal-tocentennial timescales. Tarough observations and modeling with emphasis on the role of the ocean and its interac community and socie climate questions. T Change Research Pre Search

#### Predictability, Predictions, and Applications Interface Panel

The Predictability, Predictions and Applications Interface Panel's (PPAI) mission is to foster improved practices in the provision, validation and uses of climate information and forecasts through coordinated participation within the U.S. and international climate science and applications communities.



#### NEXT GENERATION EARTH SYSTEM PREDICTION

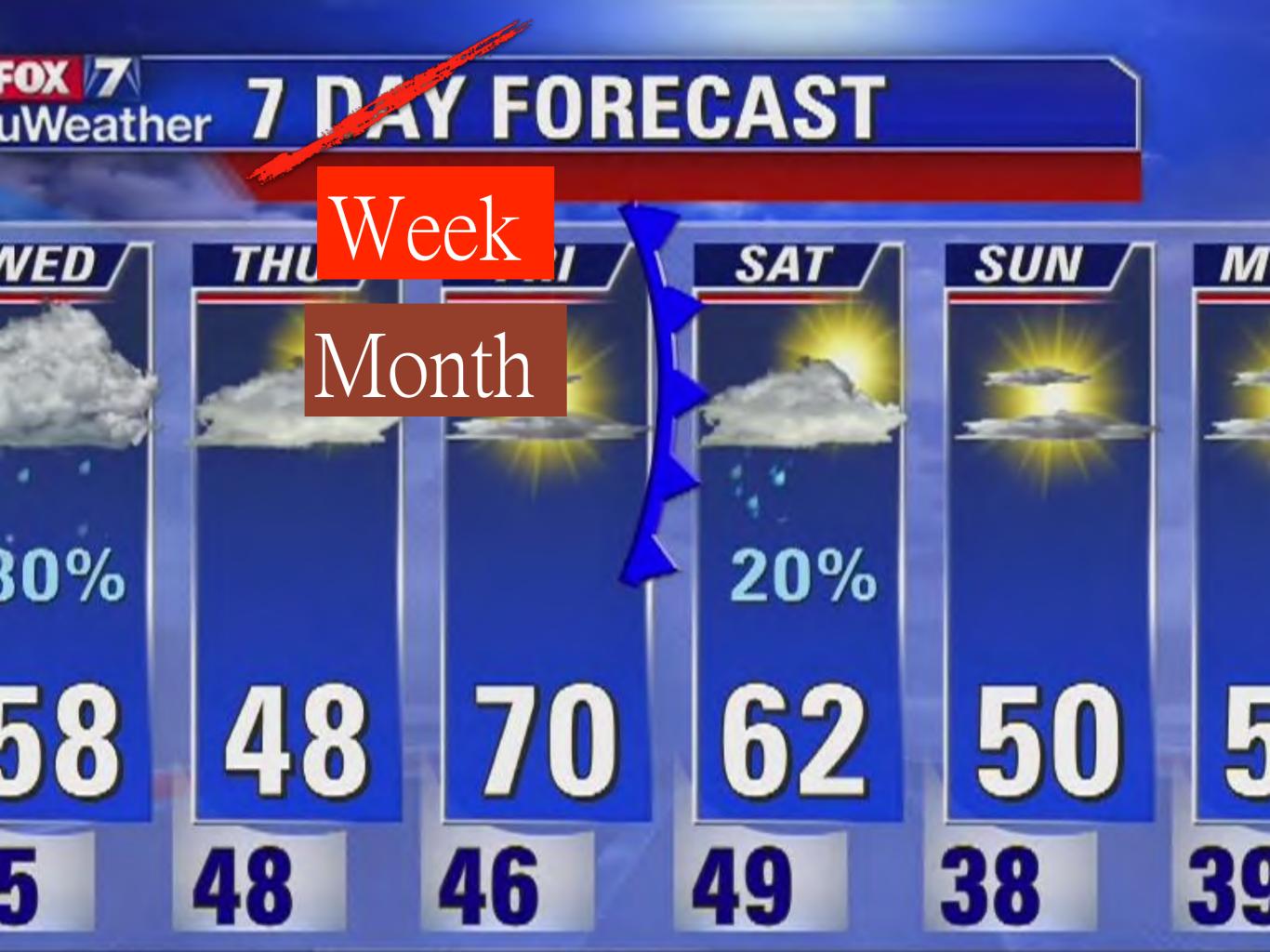
STRATEGIES FOR SUBSEASONAL TO SEASONAL FORECASTS

> The National Academies of SCIENCES • ENGINEERING • MEDICINE

# 291 pages

report





many critical decisions must be made several weeks to months in advance of favorable or disruptive environmental conditions...

e.g., it can take weeks or months to move emergency and disaster-relief supplies (or control disease outbreak)



*Pre-staging resources to areas that are likely to experience extreme weather or an infectious disease outbreak could save lives and stretch the efficacy of limited supplies* 

# FORECAST SKILLS AND THE **BREADTHSOF** VARIABIES

& PRODUCTS

# FOR THE NEXT DECADE

## RESEARCH STRATEGIES

- Engage Users in the Process of Developing S2S
   Forecast Products
   PPAI Interfacing!
- Increase S2S Forecast Skill
- Improve Prediction of Extreme and Disruptive Events and Consequences of Unanticipated Forcing Events
- Include More Components of the Earth System in S2S
   Forecast Models

### **RESEARCH STRATEGIES**

# CWB?

- Engage Users
- Forecast Skill
- Extreme Events
- Model Components



- Forecast Skill
- > Extreme Events
- > Model Components

uncover the specific **aspects of products** and make S2S products more useful to decision makers across multiple sectors.

—forecast variables, spatial and temporal resolutions, necessary levels of skill, etc.—



#### Forecast Skill

- > Extreme Events
- > Model Components

Better ObservationsData AssimilationAction ItemsModel OptimizationCalibration and Verification of S2S forecastsR2O

- > Engage Users
- > Forecast Skill
- > Extreme Events
- > Model Components

improve S2S forecasts to identify situations with high probabilities of disruptive consequences (~ 2-12 weeks)

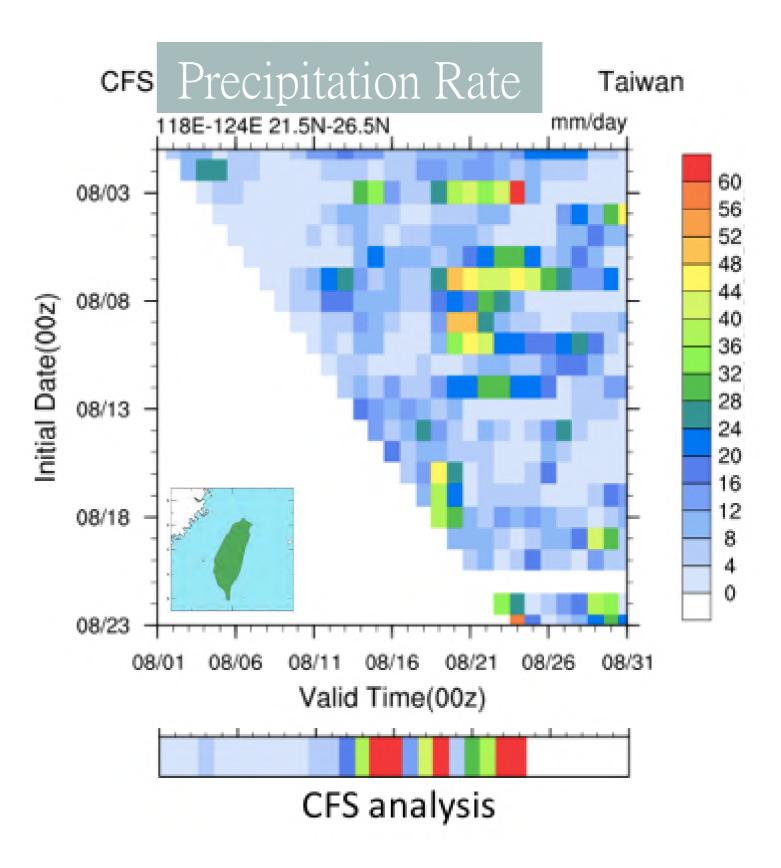
develop "forecasts of opportunity"— identifying windows in time when expected skill is higher than usual at a particular place

or certain interactions of climate modes, slowly-varying processes, and external forcing

predict the <u>consequences</u> of disruptive events caused by outside forces (volcanoes, meteor impacts, & human actions including aerosols, widespread fires, large oil spills, certain acts of war, or climate intervention)

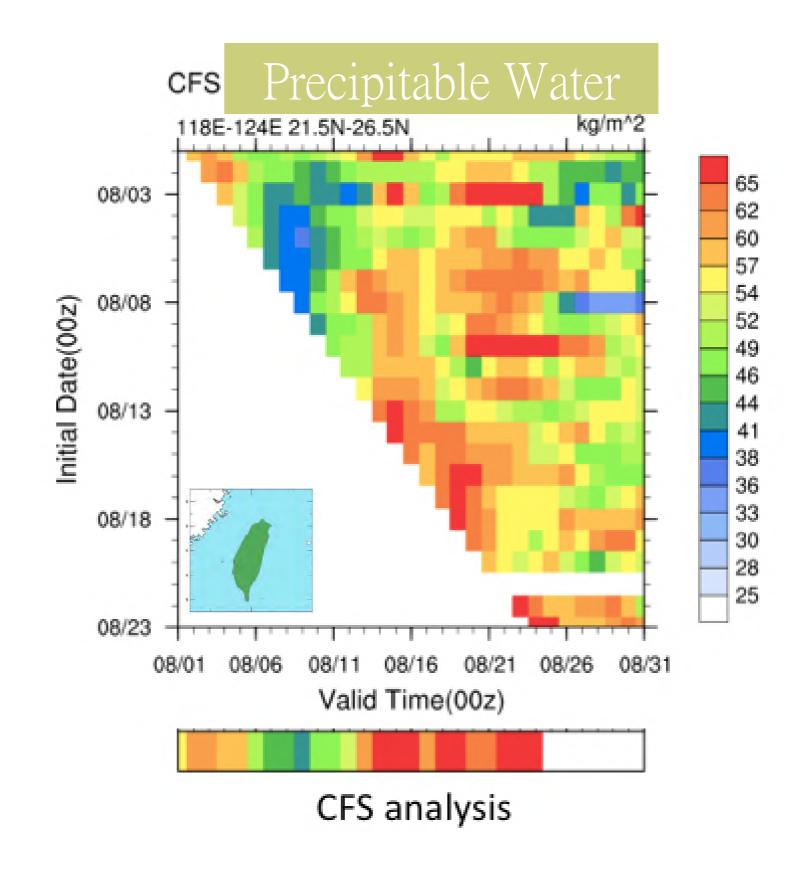
- > Engage Users
- Forecast Skill
- > Extreme Events
- Model Components



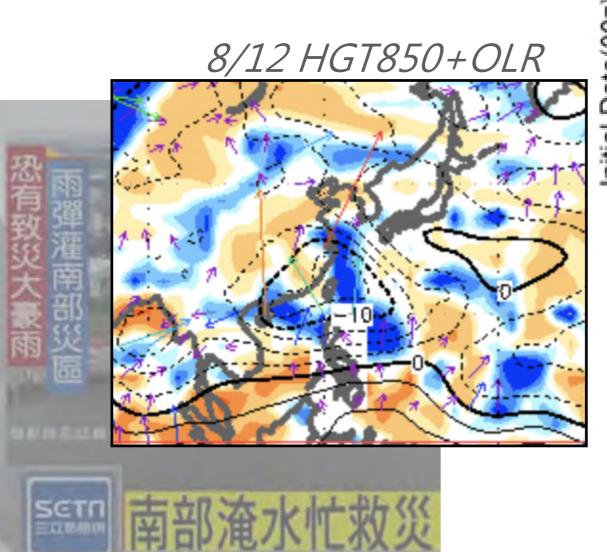


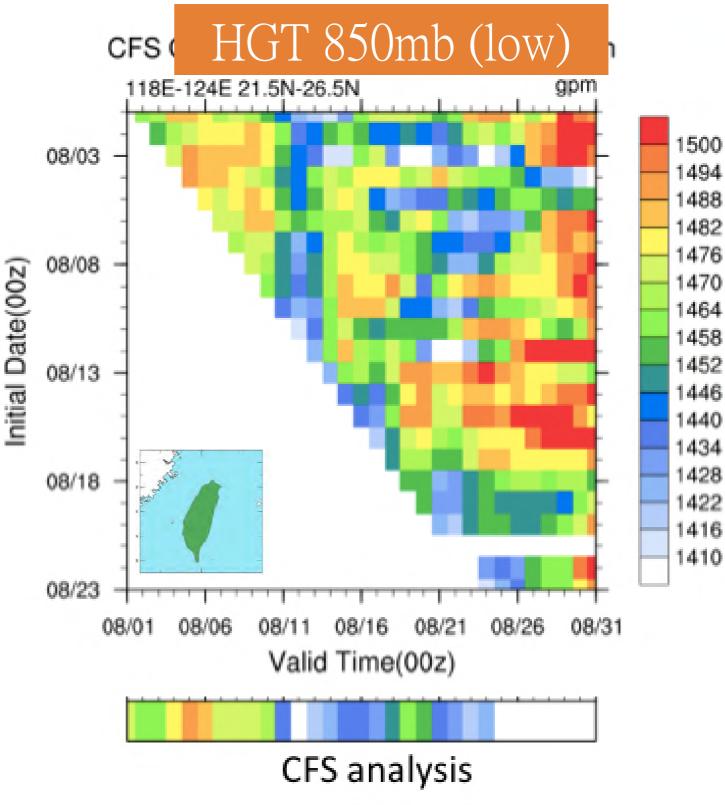
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- > Extreme Events
- > Model Components

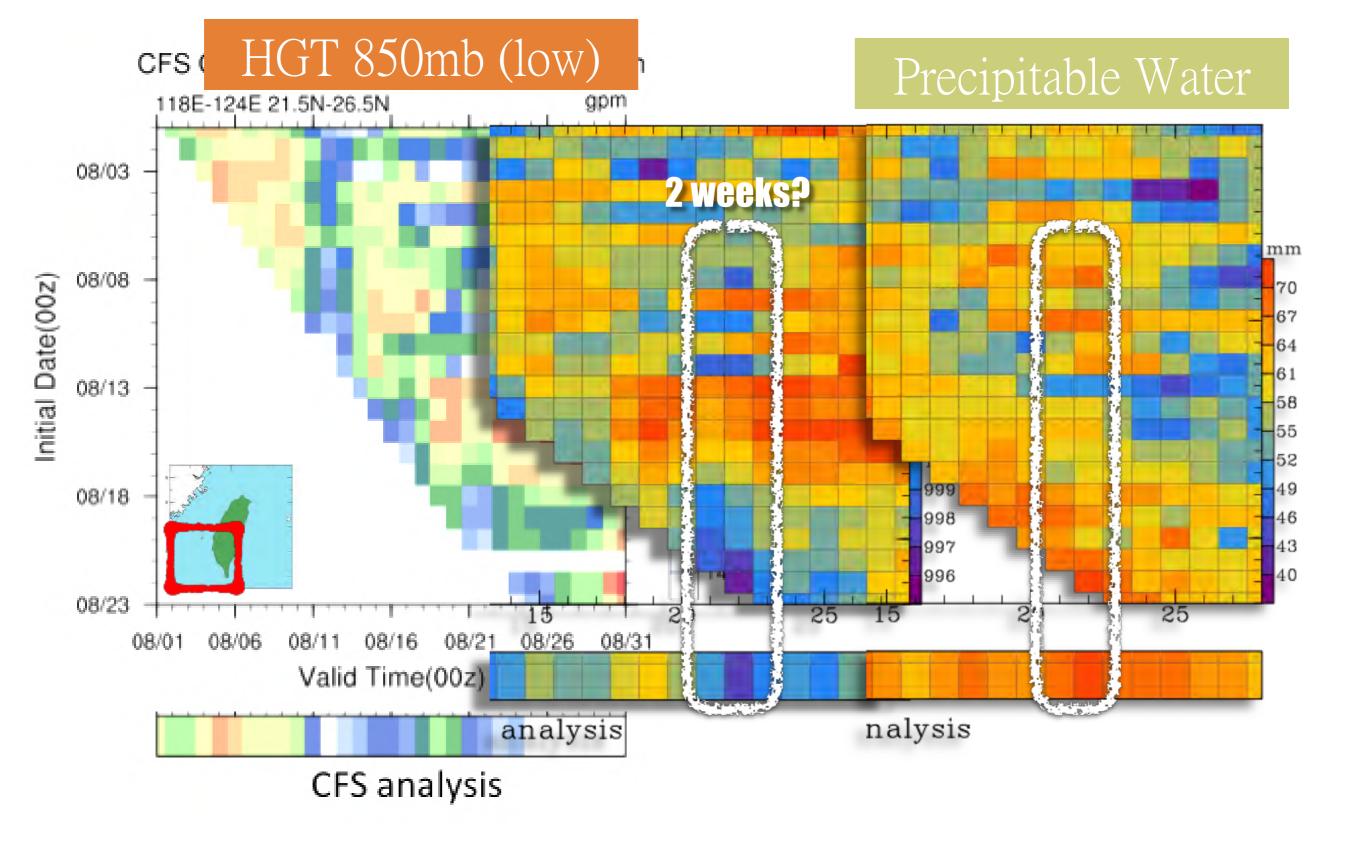




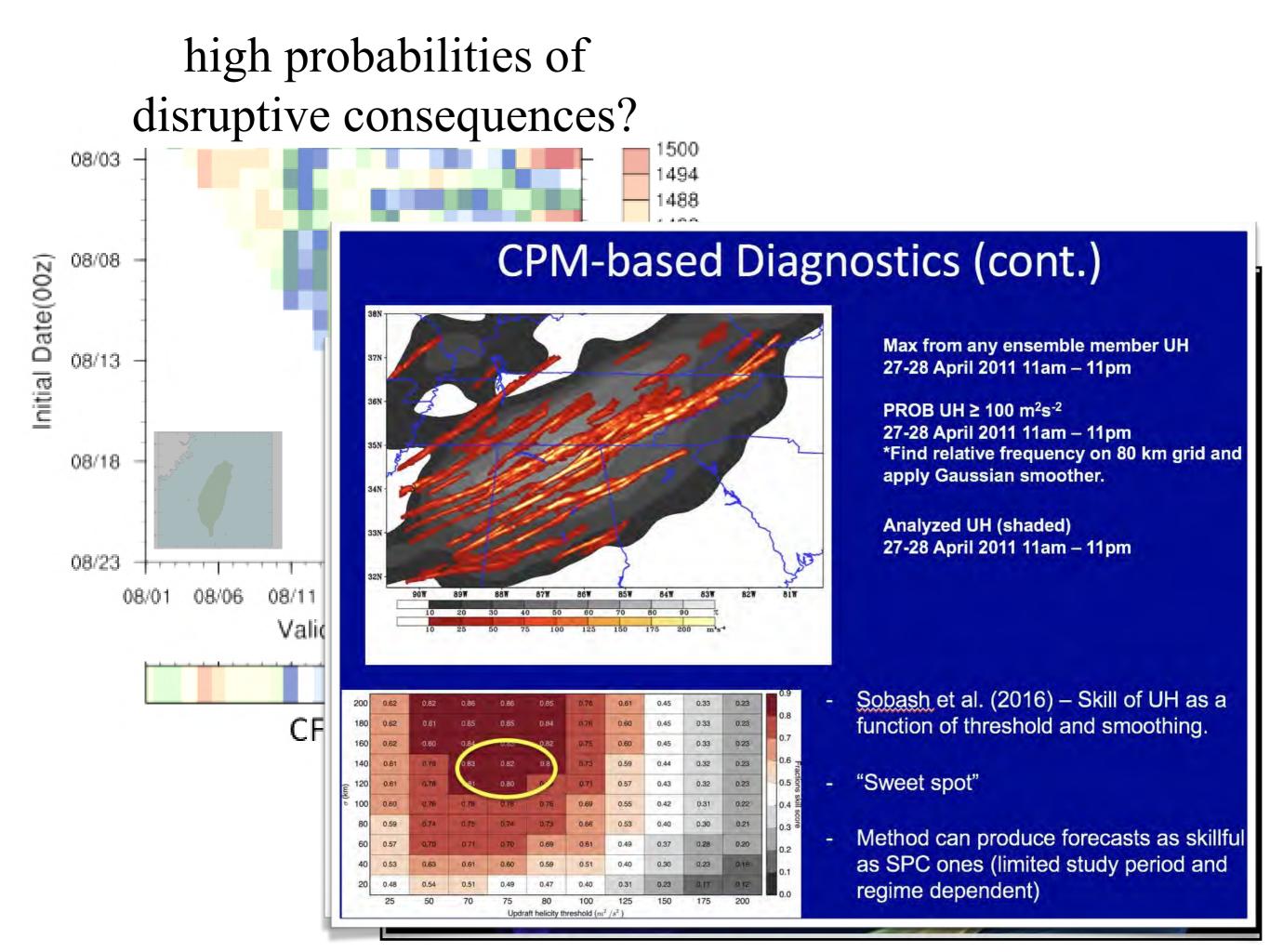
- > Engage Users
- Forecast Skill
- > Extreme Events
- Model Components







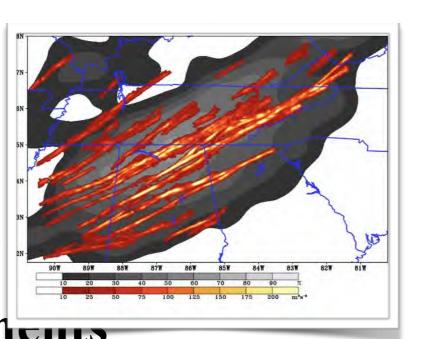
"forecasts of opportunity"?



- ➤ Engage Users
- Forecast Skill
- > Extreme Events
- Model Components

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understand which a interactions with th





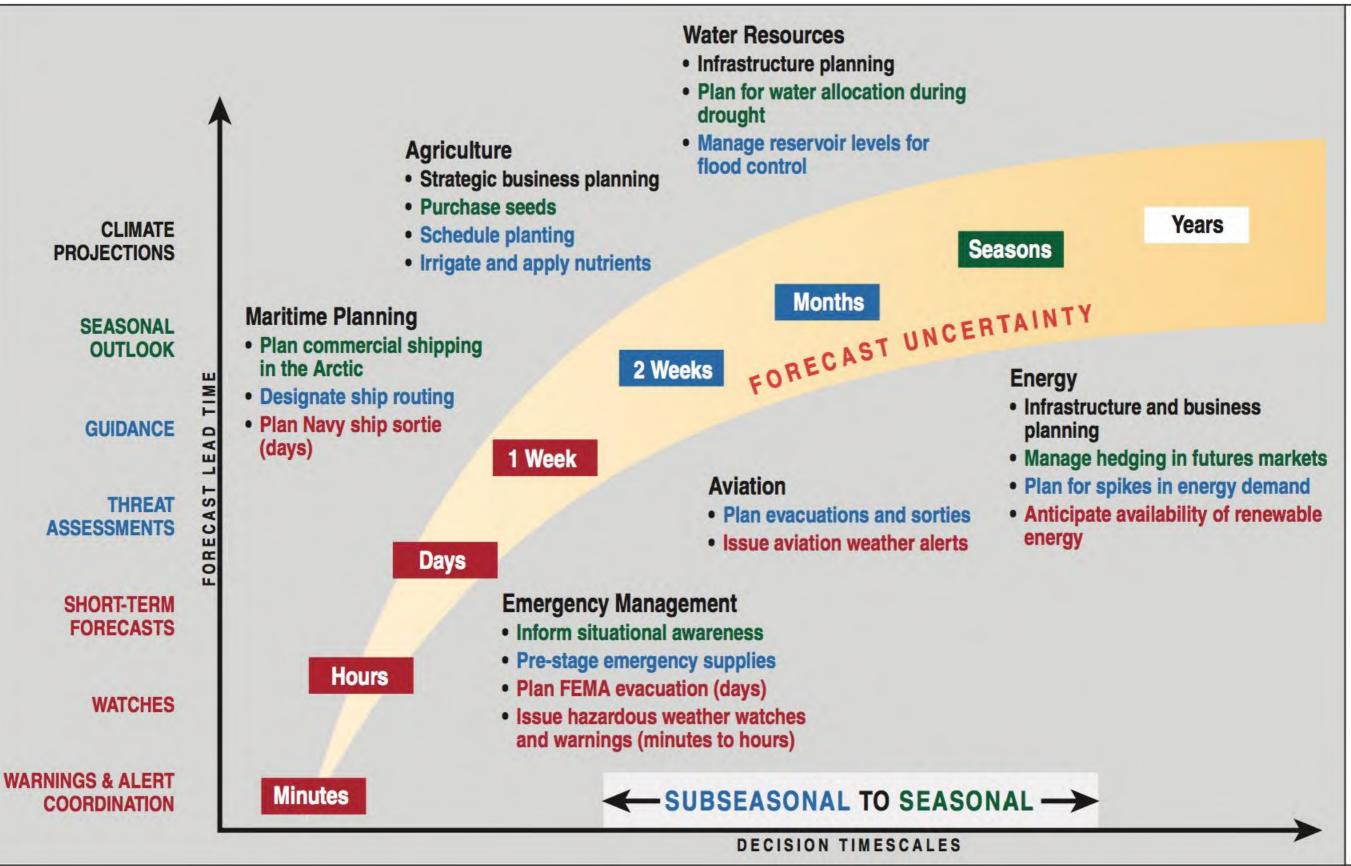
#### Future CPM applications (cont.)

NCAR's Model for Prediction Across Scales (MPAS)
 – Finalist for NGGPS (Next Generation Global Prediction System).



- Local grid-refinement with smoothly varying mesh.
- Scale dependent physics
- Has potential for climate modeling applications and can eliminate need for downscaling.
- 5-day forecasting with 3-km refined mesh tested during SFEs.

# ISI vs. S2S





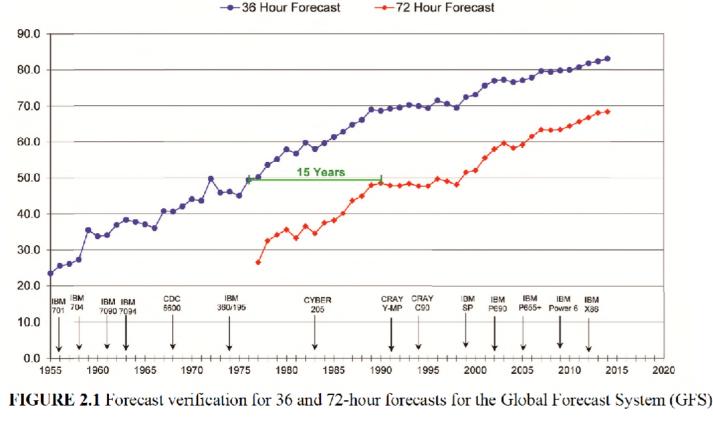
291 pages

## Chapter 2:

## History and Current Status of S2S Forecasting



[100 \* (1-S1/70) Method]



the prediction community now understands that the potential utility of forecasts is based on end-user decision support

probabilistic forecasts that include quantitative information regarding forecast uncertainty

# Chapter 2:

# History and Current Status of S2S Forecasting

billions-to-trillions of dollars sensitive to the weather

growing <u>recognition</u> that S2S predictions could play an important role in reducing society's exposure to weather, climate, and other environmental variability

Water Resources Management

Chapter 3:

Decision process:

Water supply management Hydropower scheduling Recreation budgeting

Water Resources Management -

Chapter 3:

Decision process:

Crop production Commodity trading Ranching Fisheries

Agriculture

Water Resources Management

Chapter 3:

Energy -

Agriculture

Decision process:

Power generation Operation Maintenance scheduling Energy trading

#### Water Resources Management

Chapter 3:

National Security Energy Agriculture Decision process:

Deployment for disruptive
(extreme) events
Food & water security
Tactical planning (fleets etc.)

#### Water Resources Management

Chapter 3:

Transportation, Construction, Business, Public Health...

**National Security** 

Energy

Agriculture

Water Resources Management

Chapter 3:

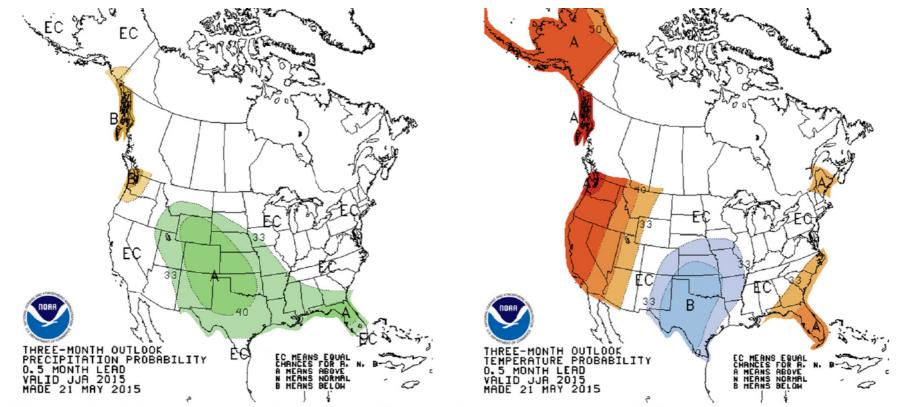


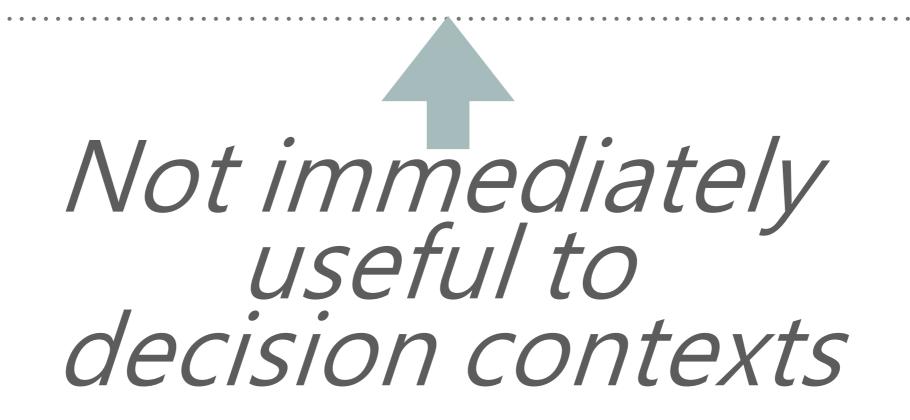
FIGURE 3.2 Three-month outlooks issued by the NOAA Climate Prediction Center for June-July-August 2015, issued 21 May 2015 (0.5 month lead time). Contours indicate probability of above (A) or

# Not immediately useful to decision contexts

## Forecast products need translation!

Decisions are based on discrete events at specific time & location

There is often a lack of understanding in (and trust of) forecasts



### Forecast products need translation!



out to 6 weeks



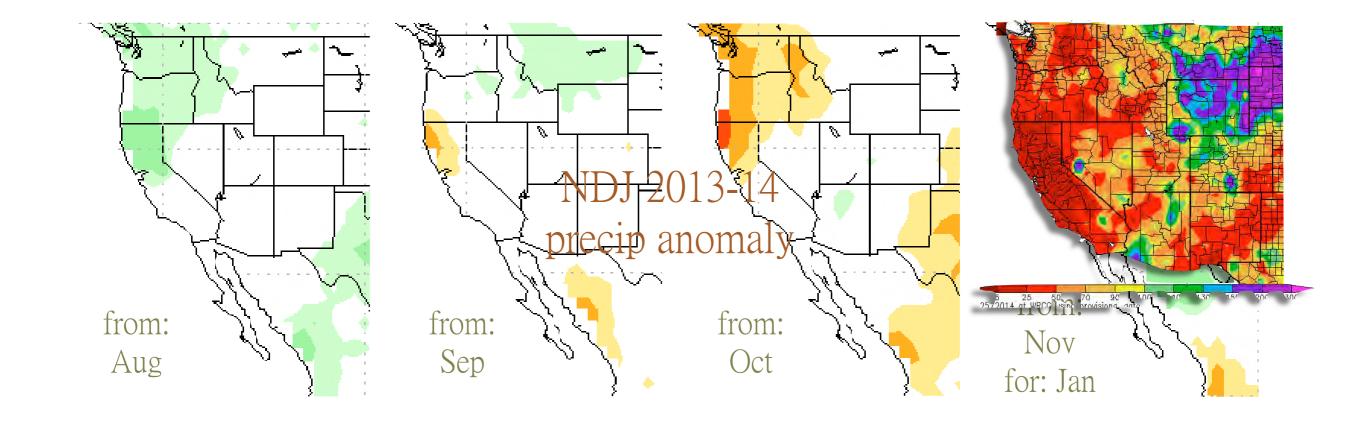
out to 4 weeks

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Chapter 3: Enhancing the Value and Benefits of S2S Forecasts

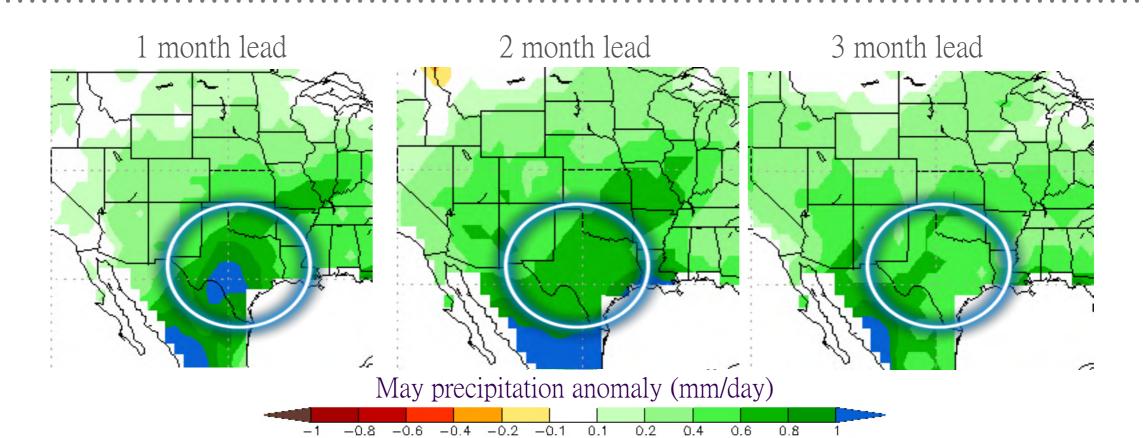


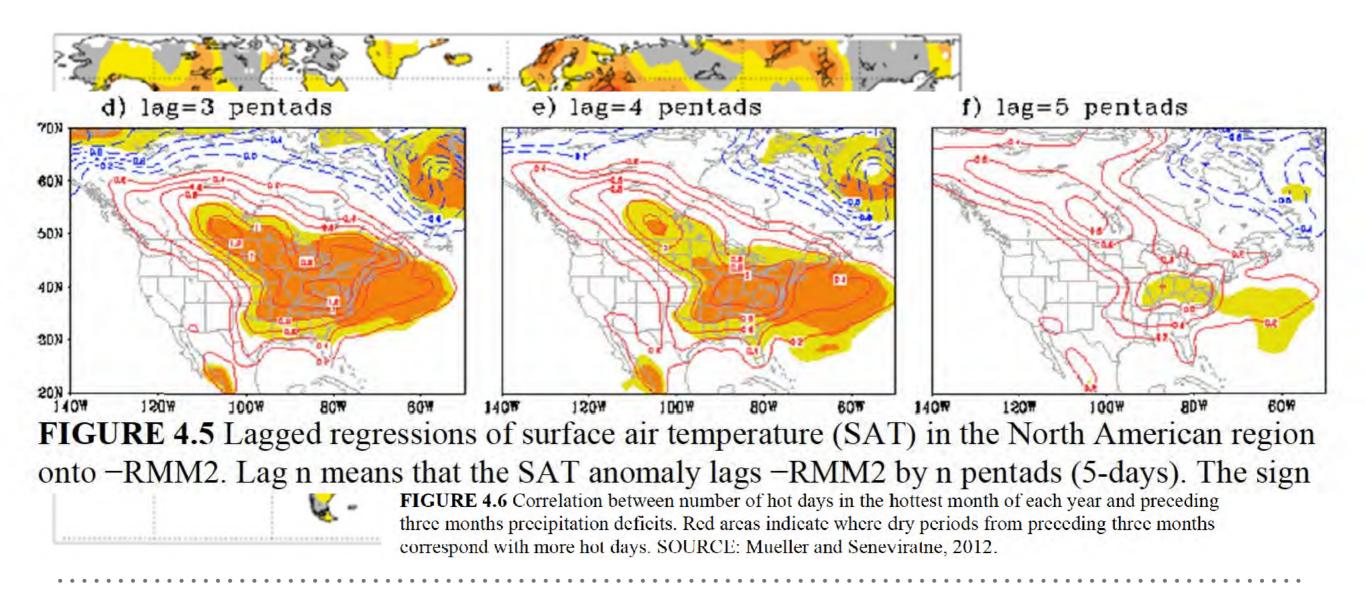
FIGURE 3.3 Recent drought has a severe impact on water availability in California, and water levels are





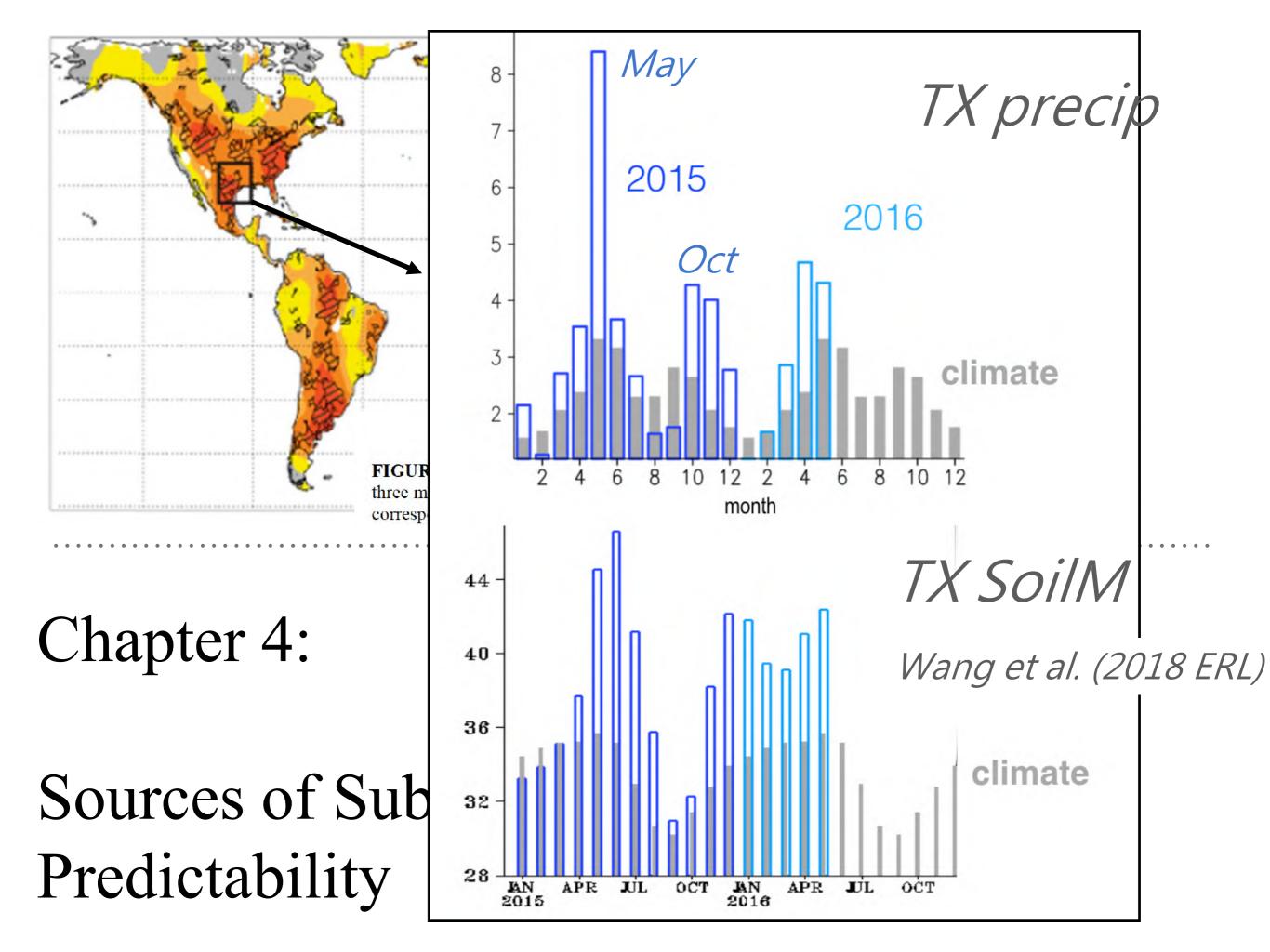
#### Texas floods: May & October 2015





#### Chapter 4:

# Sources of Subseasonal to Seasonal Predictability



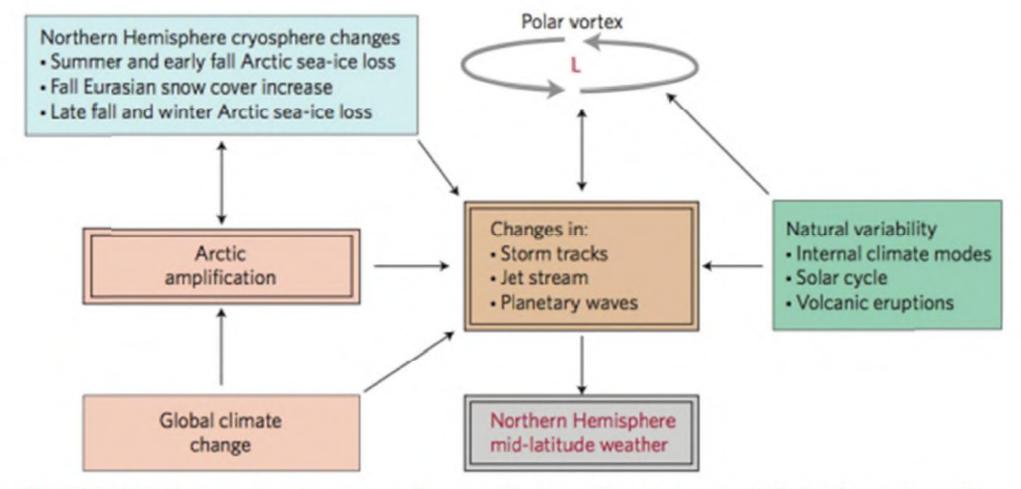
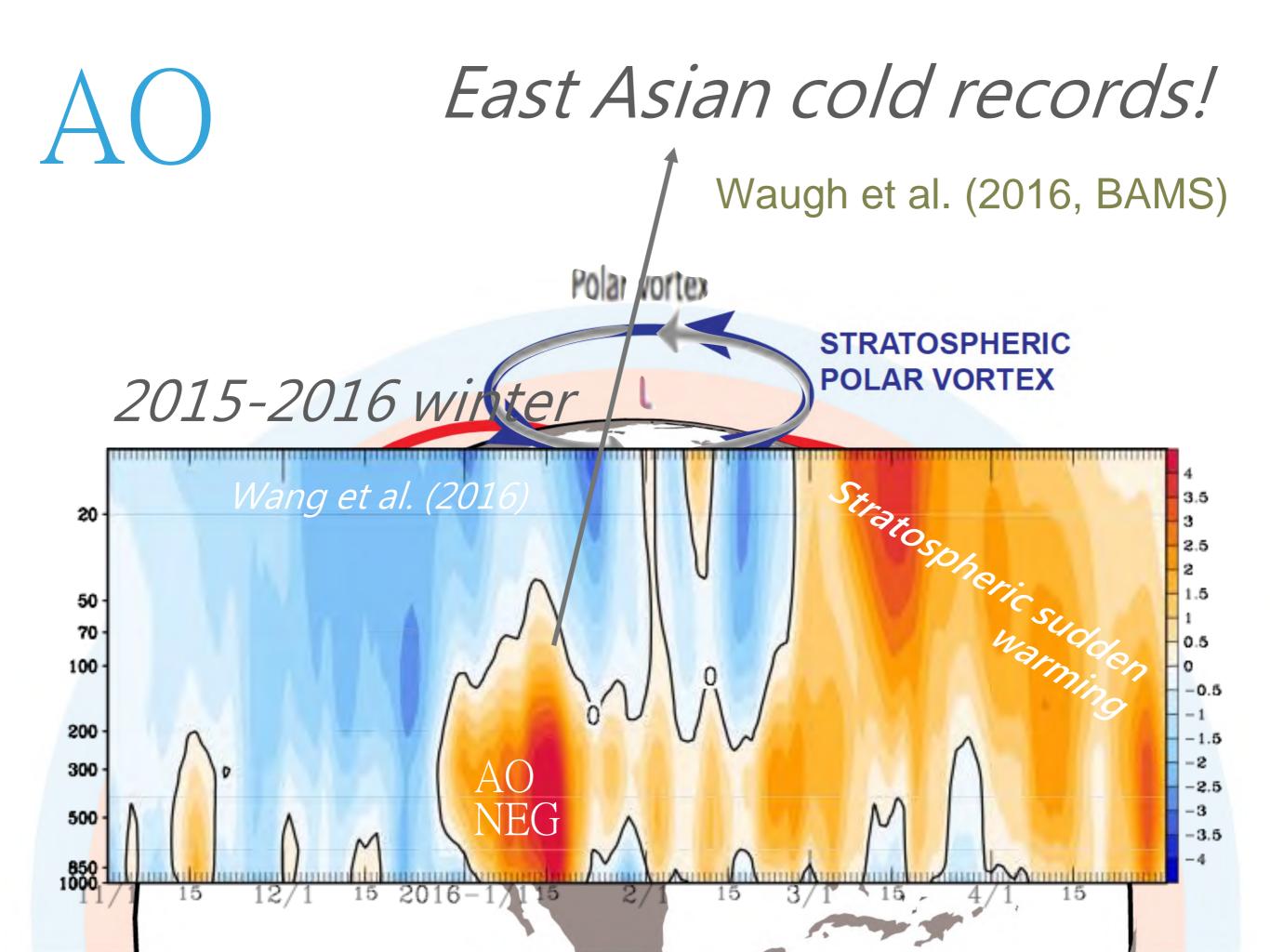
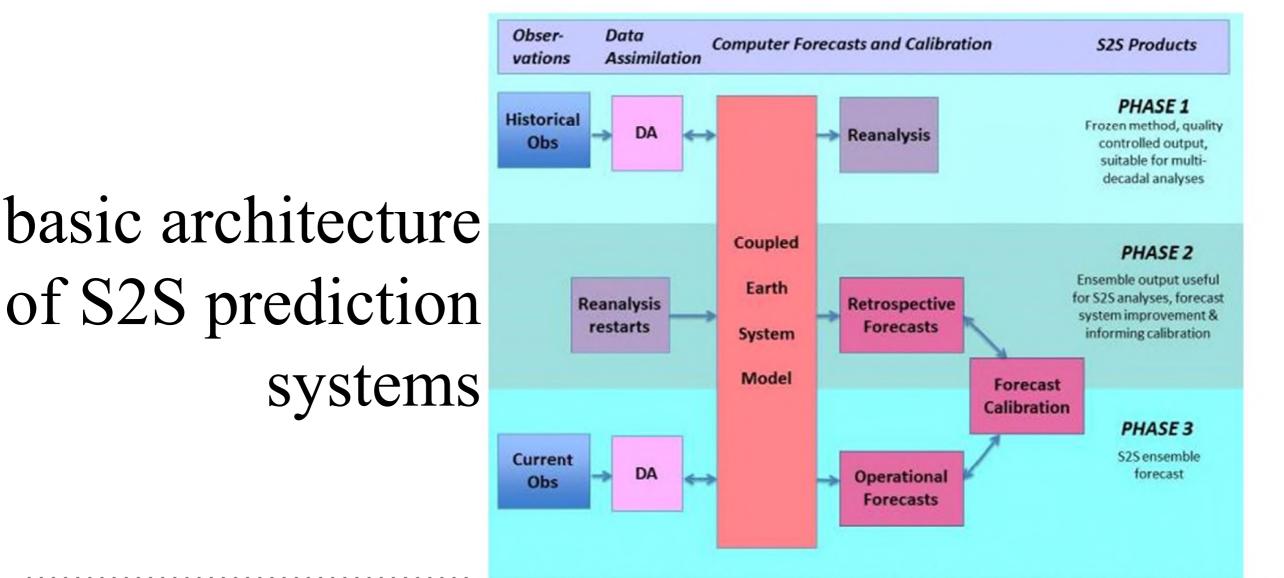


FIGURE 4.8: Schematic of ways to influence Northern Hemisphere mid-latitude weather. Three major

Chapter 4:

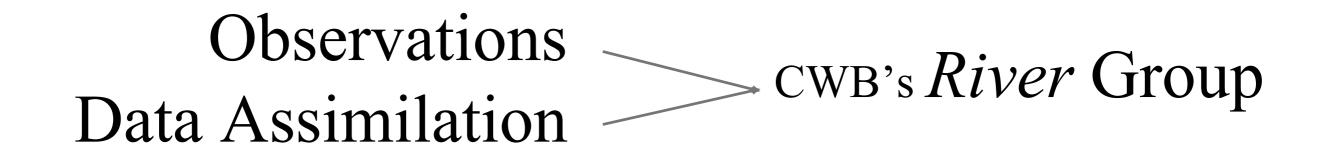
# Sources of Subseasonal to Seasonal Predictability





**FIGURE 5.1** The production of calibrated subseasonal and seasonal forecasts involves three separate processes. In the first phase, historical observations over a period of two or more decades are combined

## Chapter 5:



## Chapter 5:

- Model drifts
- > Parameterizations
- MODELS: > Tropical Convection
  - Cloud Permitting
  - ► Ocean models...

Chapter 5:

### **BOX 5.3—Feature-Based Verification**

Feature-based verification as proposed by Brown, et. al., 2002 has been heavily researched for mesoscale prediction over the past decade with several developed methodologies, including wavelet techniques, empirical orthogonal functions, and clustering (Gilleland et al 2010). A "feature" for mesoscale prediction can represent both temporal and spatial features that are recognizable and that have societally relevant consequences, such as a mesoscale cloud cluster, an area of heavy precipitation, or duration of extreme winds, or it may be a combination of these attributes. Conceptually, we understand a "hurricane" as a feature, but it can be defined as an area of cloud cover, rainfall, a radius of winds exceeding a threshold, or a moving point of maximum wind. For S2S, a "feature" might be an area of SST ar s the in both time and space (e.g. ENSO), an area of severe drought defined by rainfall, tempera le, area, temporal extent, or an area of sea ice coverage. Many indices discussed in the preceding dapters star as ENSO, PDO, MJO, etc., are roughly based on features. Feature-based verification havine advaring that it can "recognize" and verify a feature that may occur slightly earlier or late, may cover a smaller or larger area, may be more or less intense, may be of shorter or longer duration, etc., than policted. The enables more accurate quantitative evaluation of model performance in "near miss" situations and better refinement of model skill and reliability. Feature-based verification also has the advantage that is an aggregation of model variables in space and time and consequently has greater predictability that a single variable at a single grid-point (see also Chapter 2).

Chapter 5:

"There is a natural tension between the academic research community and the operational forecasting community."

Chapter 6:

MME research and demonstration efforts (e.g., ENSEMBLES, DEMETER, NMME, APEC Climate Center MME, Int. S2S, etc.)

there is inconsistency among the models in forecast start date, frequ

Chapter 6:

## R20 Strategies

for developments to be fully tested in the operational environment (operationalizing MMEs!) in order for the research community to use operational models for research, operational centers need to provide infrastructure support

## Chapter 6:

The Committee recommends that the nation should develop an R2O Strategies

## Establish Capability to Respond to Unanticipated Events

Chapter 6:

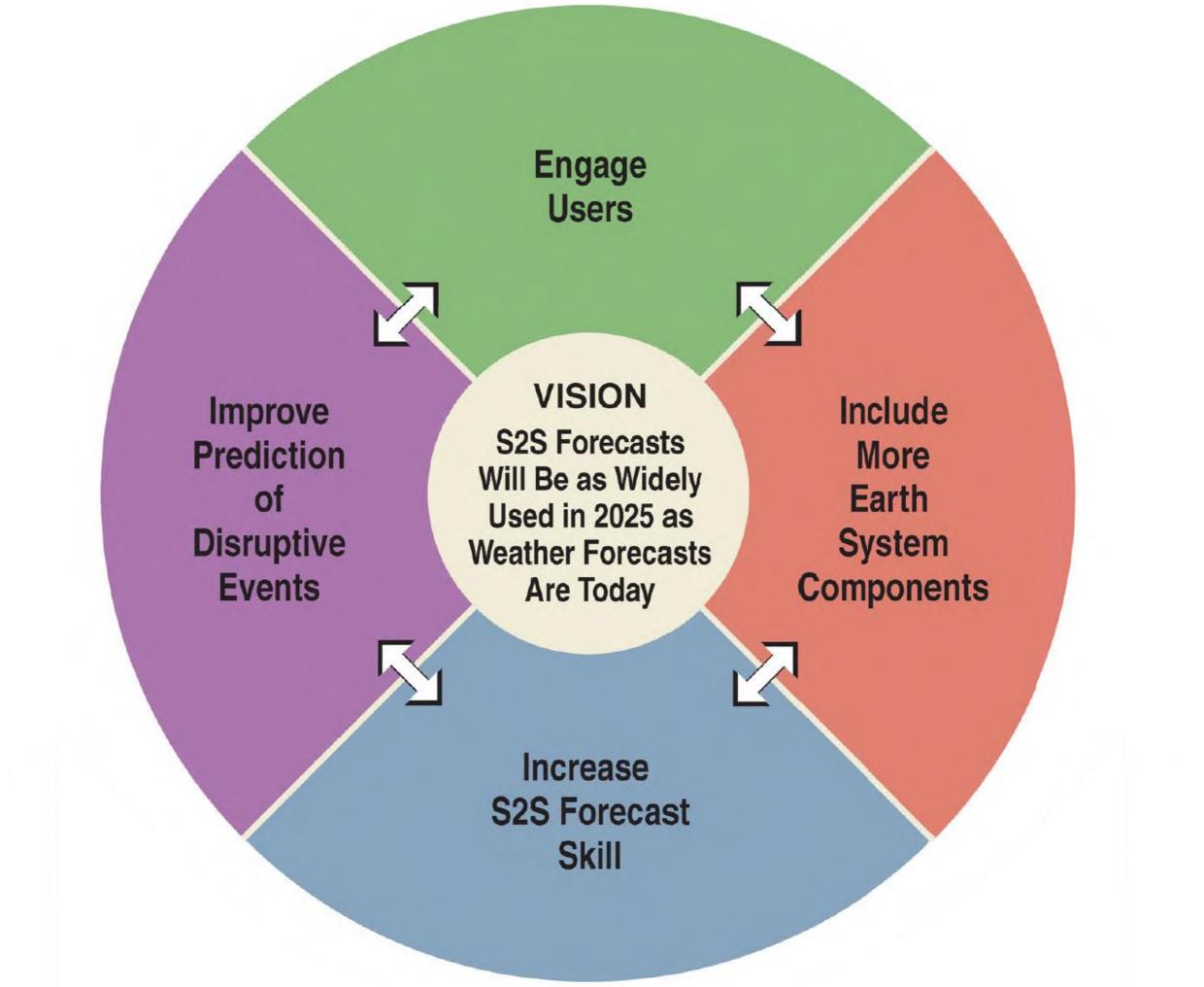
Typical Data Volumes from Today's S2S Prediction Forecasts

1 Terabyte per day

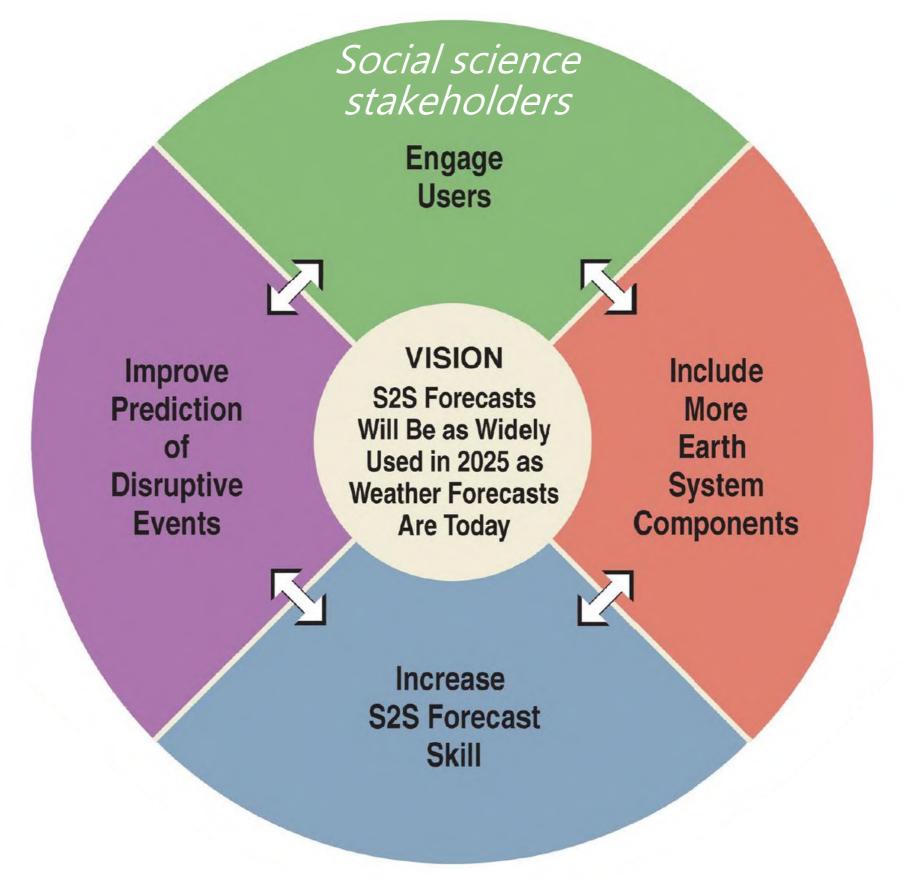
## can amount to hundreds of Terabytes per day

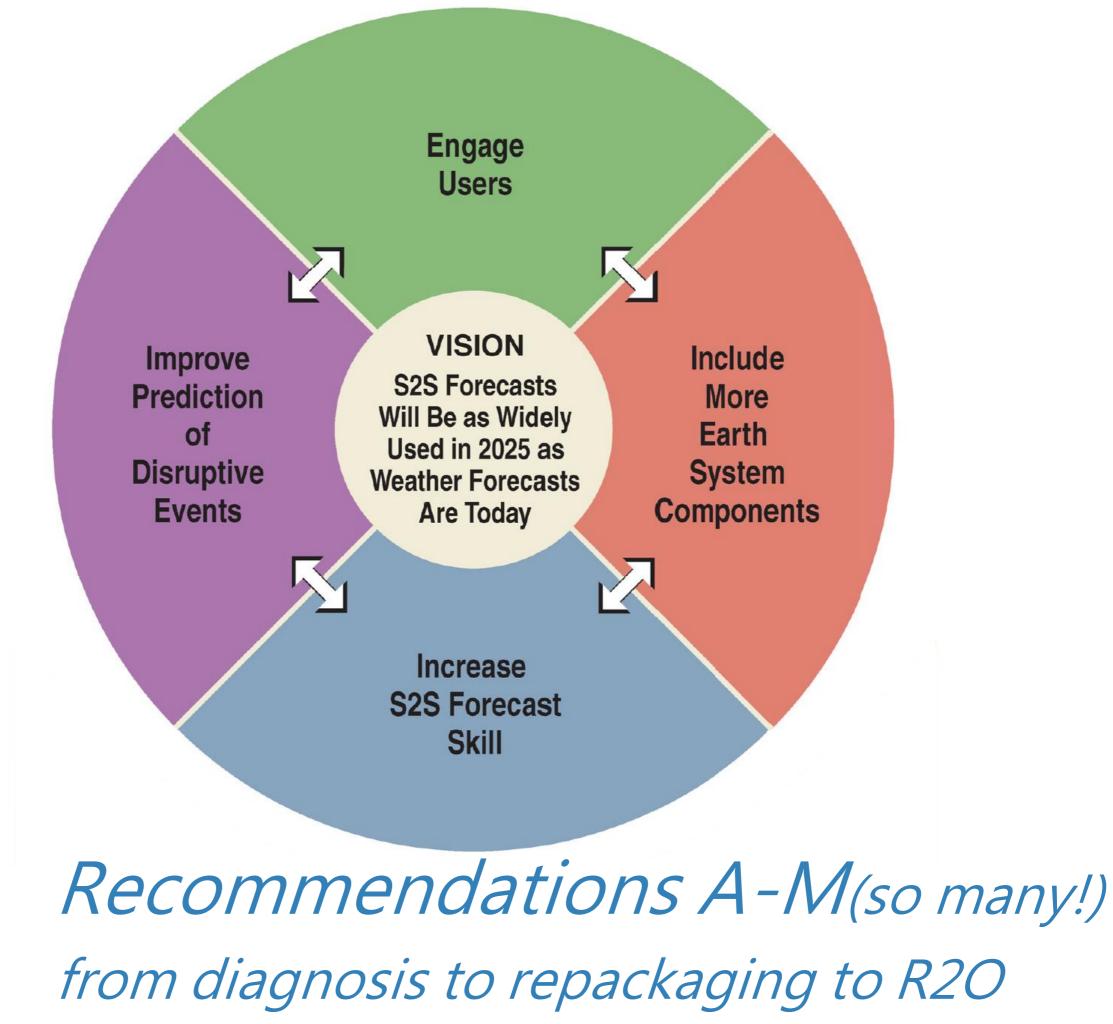
## Chapter 7:

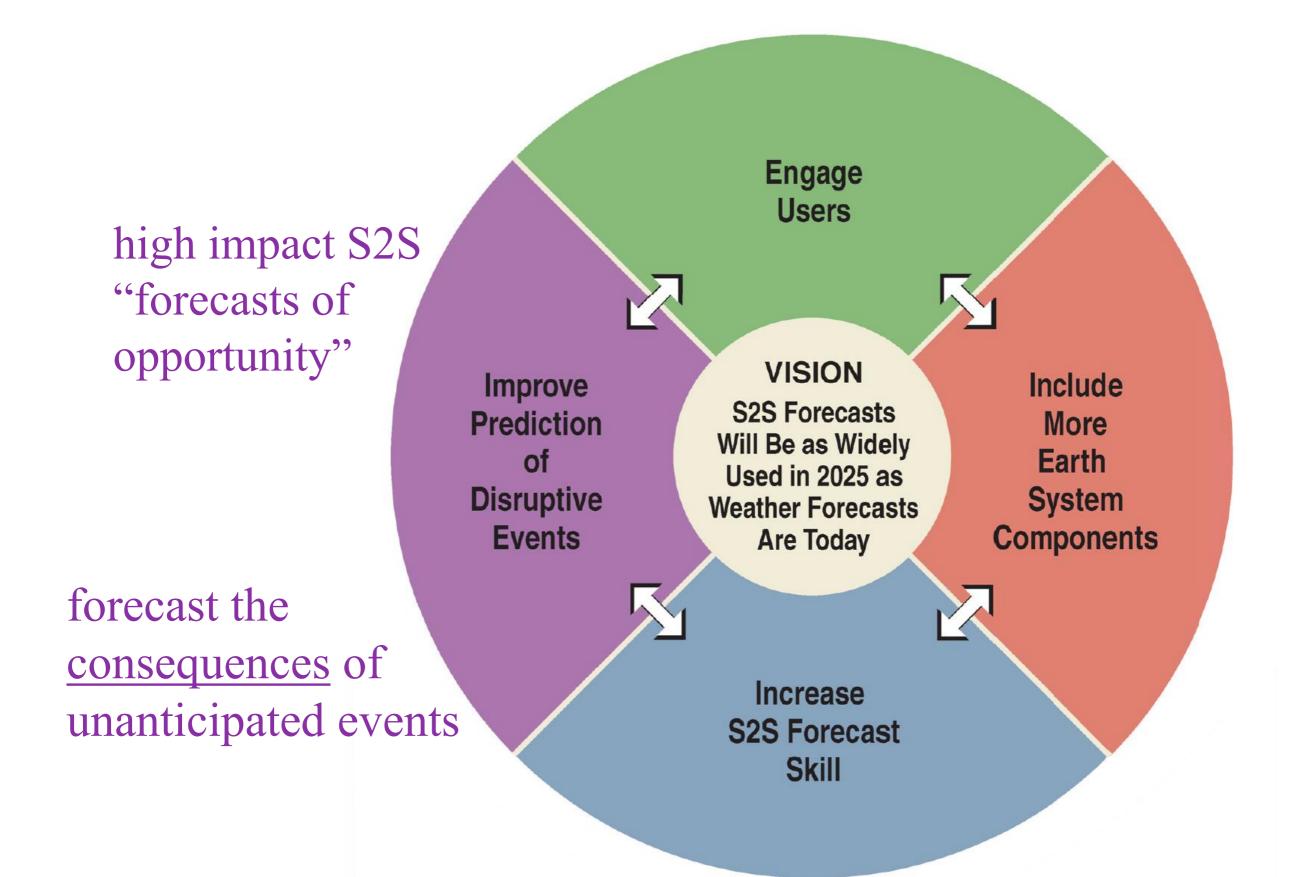
Cyberinfrastructure and Workforce Capacity Building

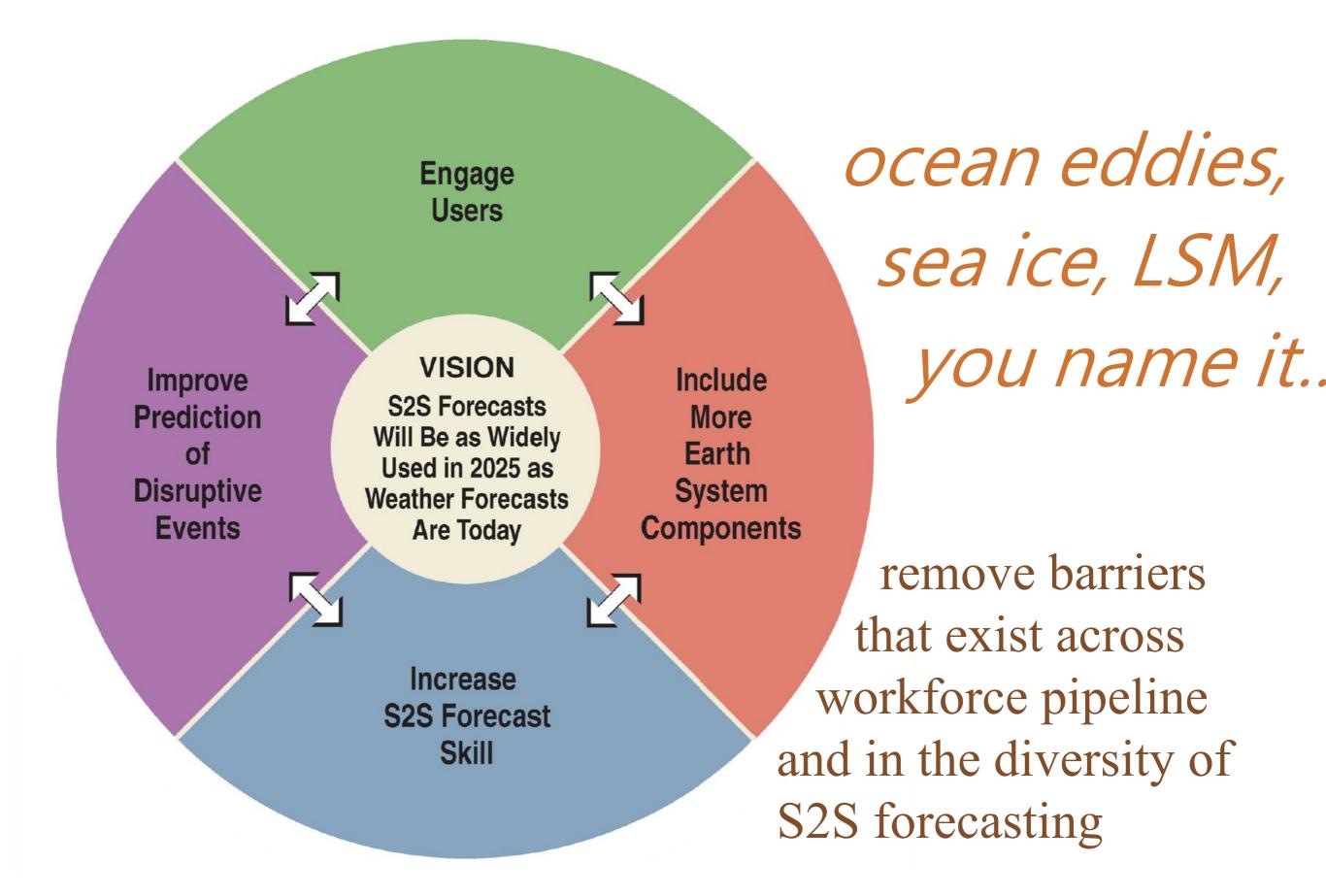


## Recommendations A, B









### Research Use of S2S Forecasts

Establish an Iterative Process to Engage Users

> Engage Users

Develop a National Capability for Unanticipated Forcing Events

Focus Attention on Disruptive and Extreme Events Improve Prediction of Disruptive Events

VISION S2S Forecasts Will Be as Widely Used in 2025 as Weather Forecasts Are Today

Increase S2S Forecast Skill

Characterize Natural Modes of Variability Maintain and Expand Observations

hrough Sensitivity Studies

Advance Strongly Coupled Data Assimilation Improve Model Parameterizations Pursue Feature-based Verification Explore S2S System Configurations Create Operational Multi-Model Ensemble Promote Collabo ation

Between Research and Operational Communities

Develop Next Generation Model Components

plore S2S System

Include

More

Earth

System

Components

## CONCLUSIONS

Next Generation Earth System Prediction Strategies for Subseasonal to Seasonal Forecasts

The scope of the research agenda will require (The report) sets forth a research agenda that describes will closer collaboration between federal agencies and international partners, better flow of ideas and data between the research and operational forecasting communities, and engagement of the entire weather and climate enterprise.

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Board on Atmospheric Sciences and Climate **Ocean Studies Board** 

**DIVISION ON EARTH AND LIFE STUDIES** 

## **Next Generation Earth System Prediction**

### **Strategies for Subseasonal to Seasonal Forecasts**



### REPORT IN BRIEF

### **Next Generation Earth System Prediction** Strategies for Subseasonal to Seasonal Forecasts

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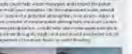
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**DIVISION ON EARTH AND LIFE STUDIES** 

## **Next Generation Earth System Prediction**

**Strategies for Subseasonal to Seasonal Forecasts** 





Connecting the two reports: Dealing with

# Questions?

**Next Generation Earth System Prediction** 

**Strategies for Subseasonal to Seasonal Forecasts** 

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