US CLIVAR

Climate Variability and Predictability Program

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About 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-to-centennial timescales, through observations and modeling with emphasis on the role of the ocean and its interac d to serve the climate community and soci esearch on outstanding climate questions. T e broader US Global Change Research Pr esearch within the US to

氣象/氣候服務
氣象/氣候服務

Predictability, Predictions, and Applications Interface Panel

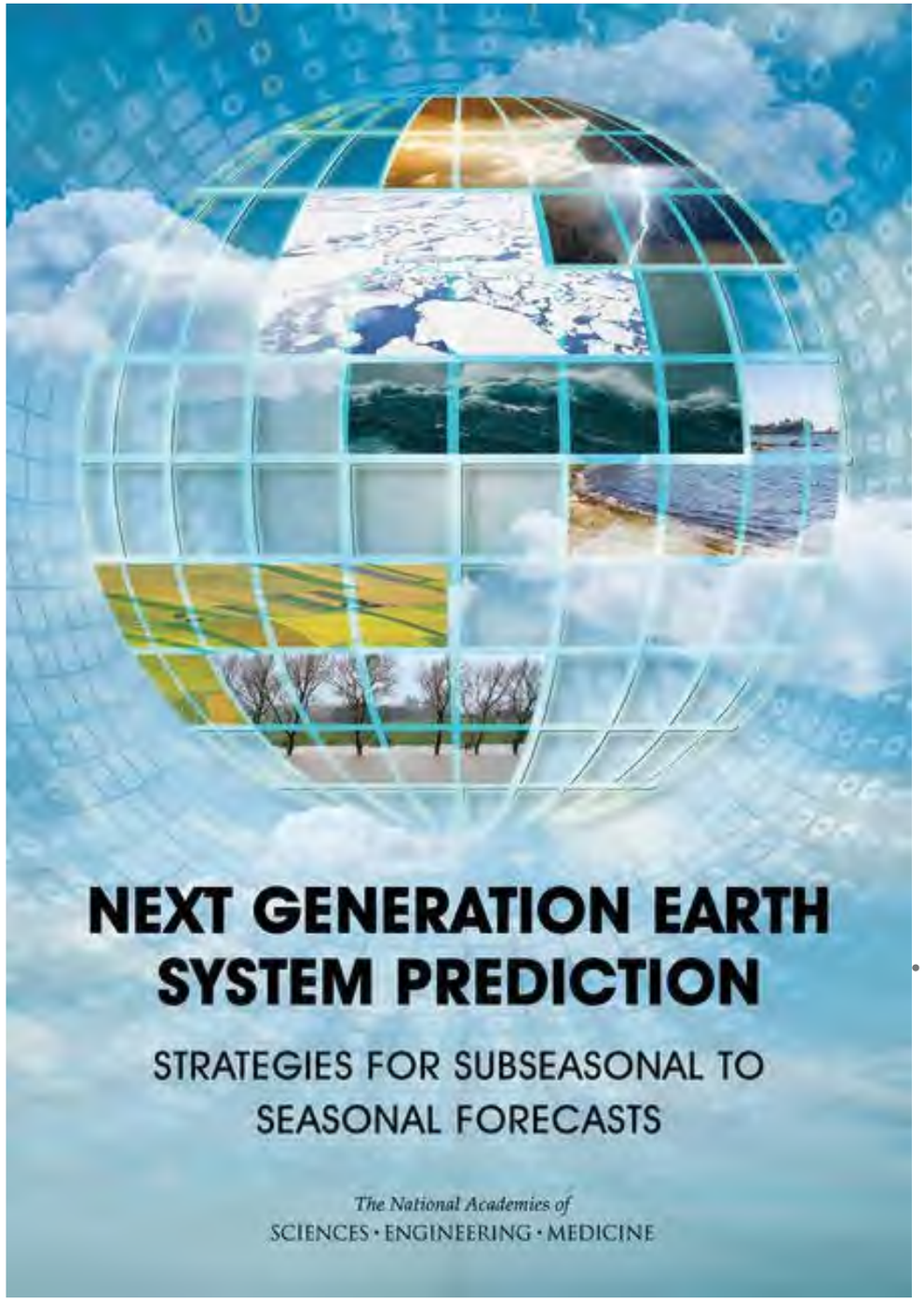
The Predictability, Predictions and Applications Interface Panel's (PPAI) mission is to foster improved practices in the provision, validation and uses of climate information and forecasts through coordinated participation within the U.S. and international climate science and applications communities.

Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts

下一代地球系統模擬 REVIEW

THE NATIONAL ACADEMIES PRESS

report



291 pages

report

FOX 7
uWeather

7 DAY FORECAST

Week

Month

WED | THU | SAT | SUN

30%

20%

58 | 48 | 70 | 62 | 50

5 | 48 | 46 | 49 | 38

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 BREAKDOWN OF SKILLS VARIABLES & PRODUCTS

STRATEGIES 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

- **Engage Users**
- 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.—

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

Better Observations

Data Assimilation

Model Optimization

Calibration and Verification of S2S forecasts

R2O

Action Items

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

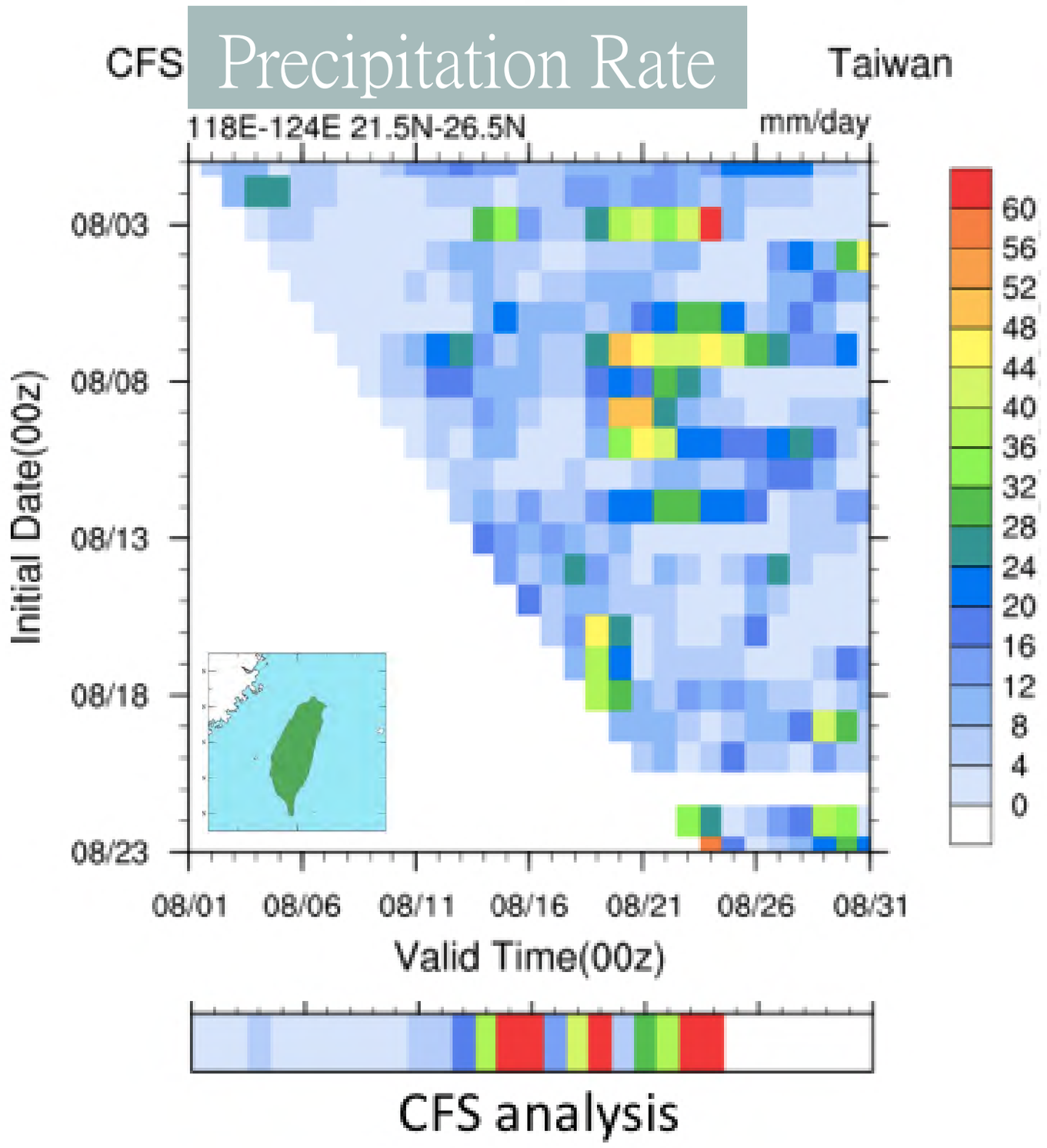
improve S2S forecasts to identify situations with high probabilities of disruptive consequences (~ 2-12 weeks)

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

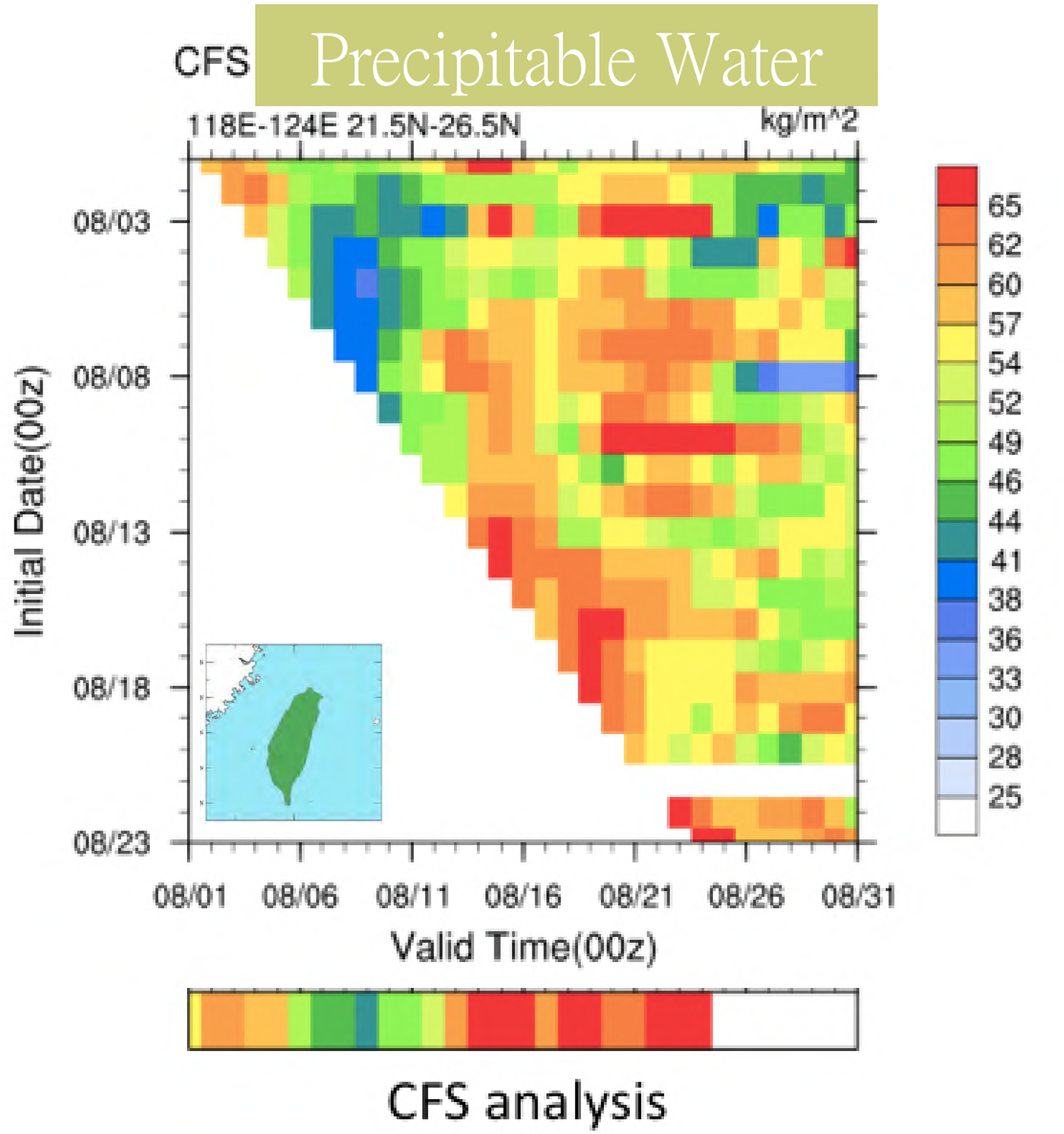
or certain interactions of climate modes, slowly-varying processes, and external forcing

predict the consequences 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

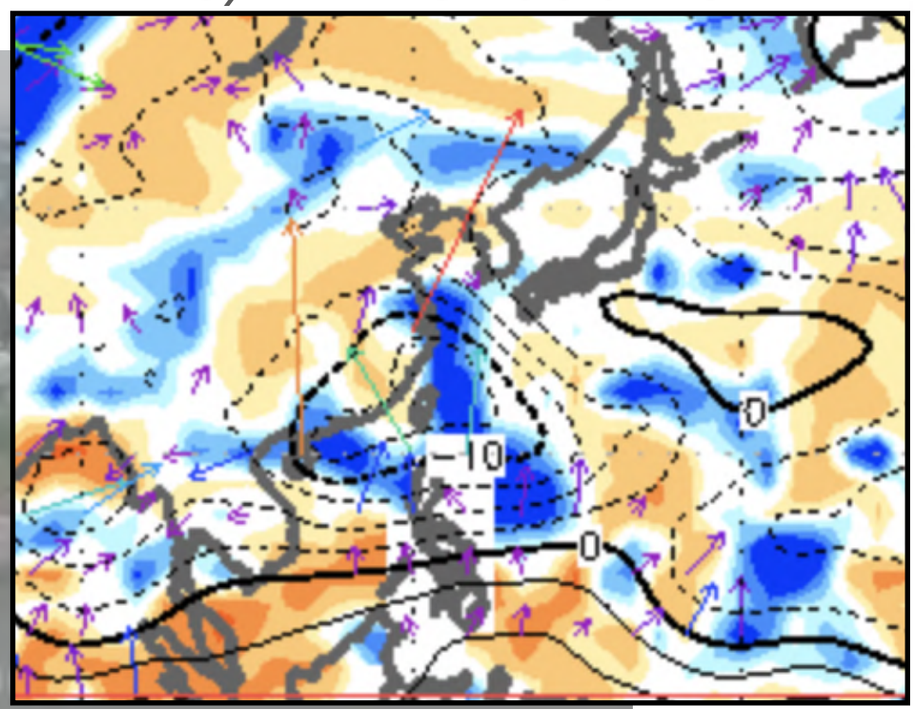


- Engage Users
- Forecast Skill
- **Extreme Events**
- Model Components

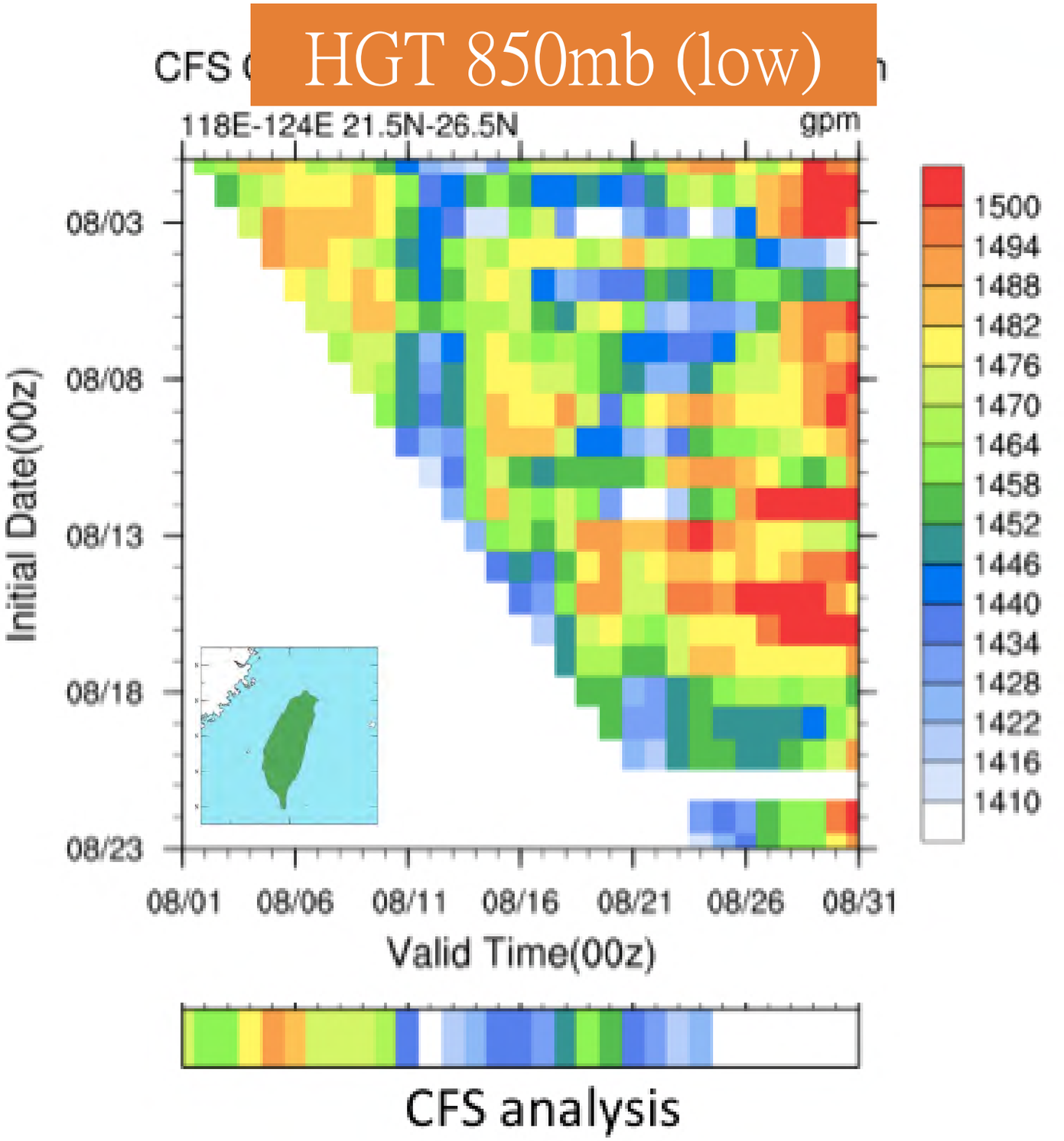


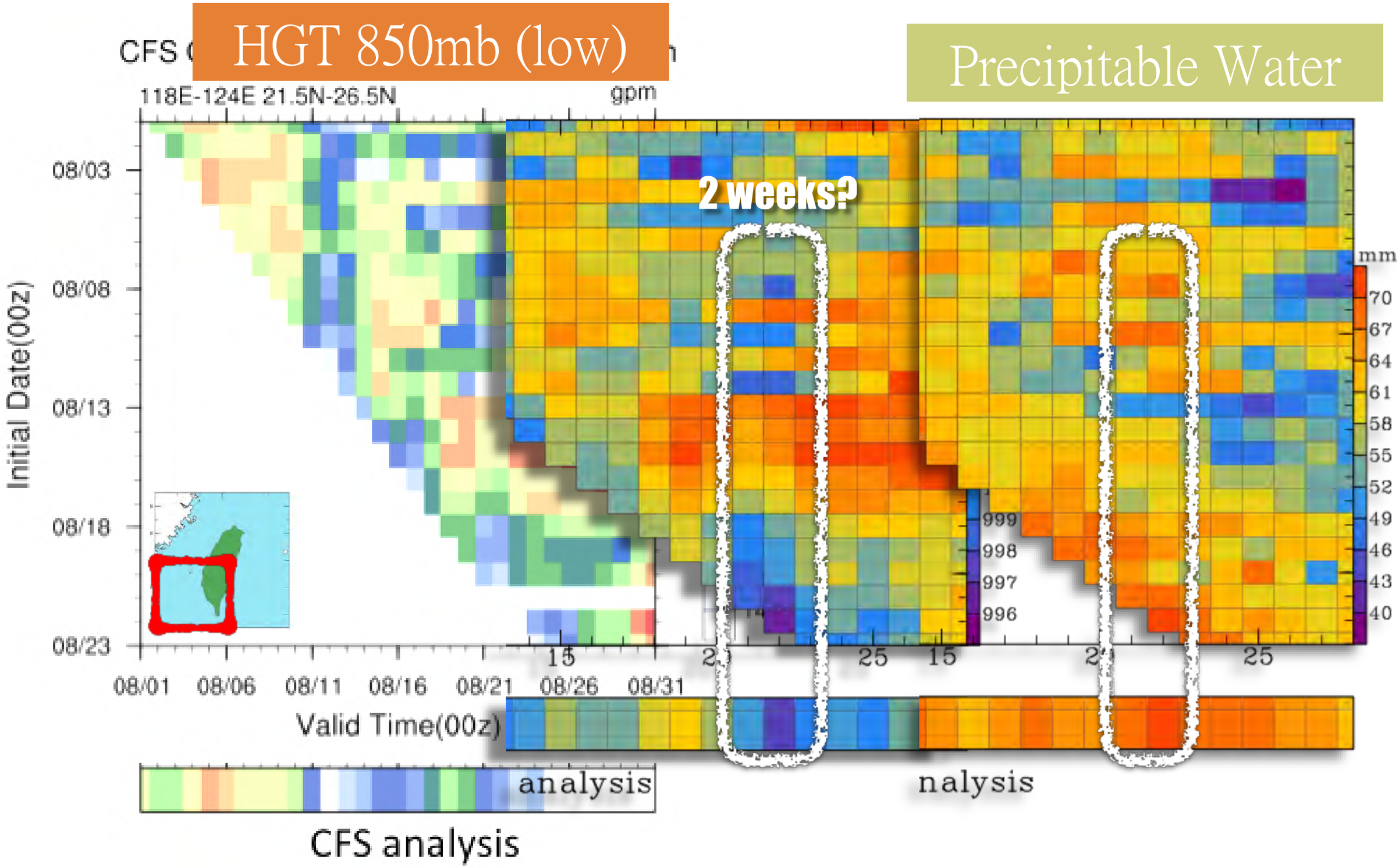
- Engage Users
- Forecast Skill
- **Extreme Events**
- Model Components

8/12 HGT850+OLR



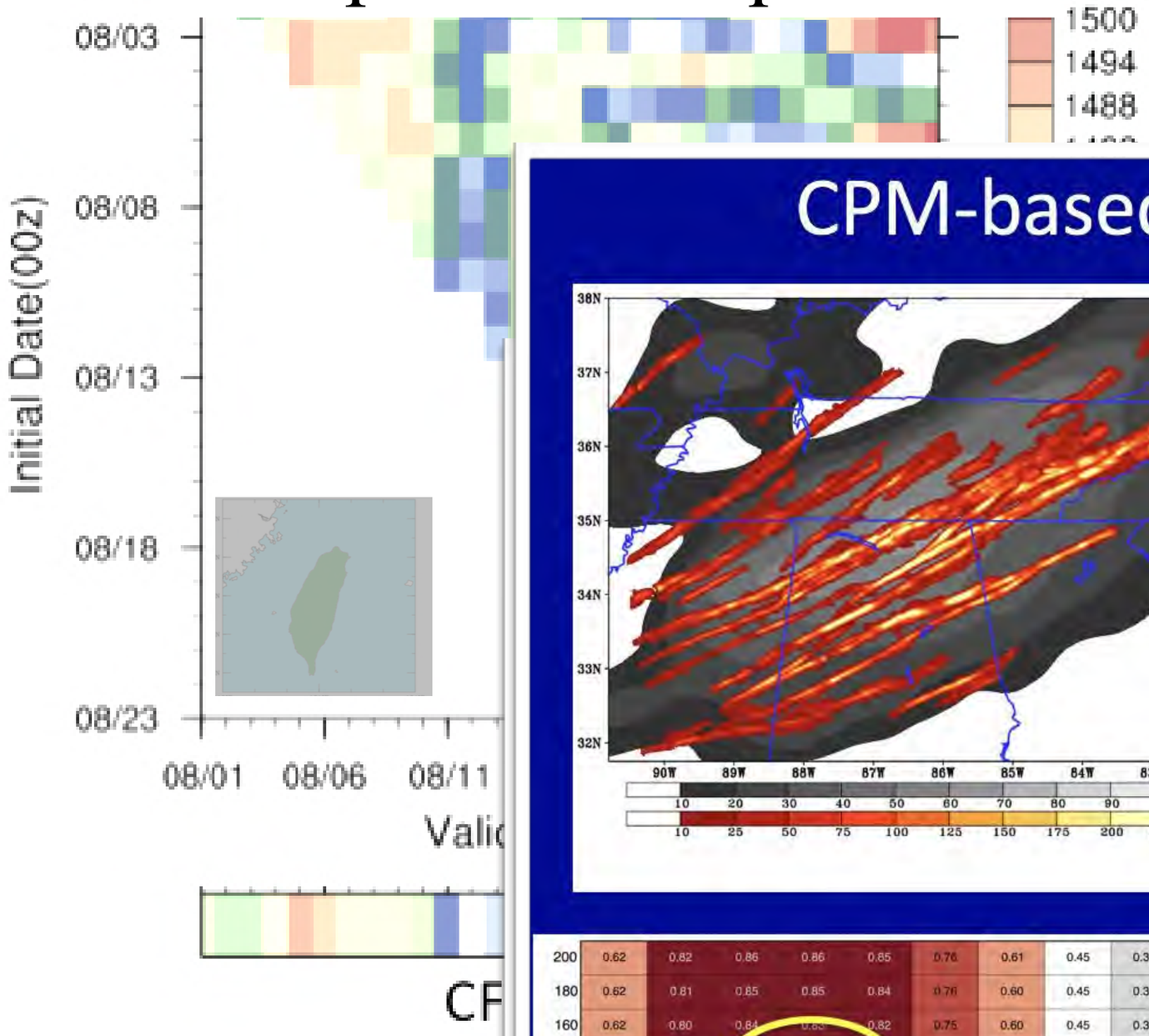
HGT 850mb (low)





“forecasts of opportunity”?

high probabilities of disruptive consequences?

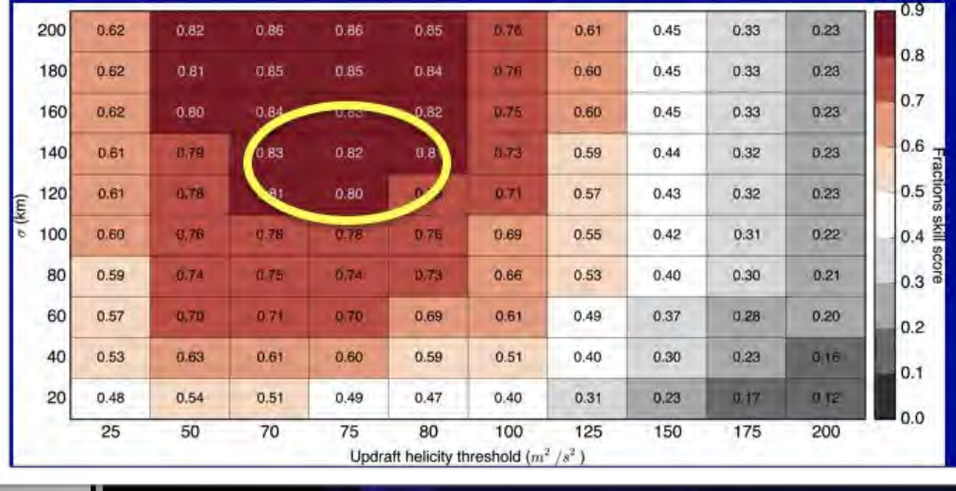


CPM-based Diagnostics (cont.)

Max from any ensemble member UH
27-28 April 2011 11am – 11pm

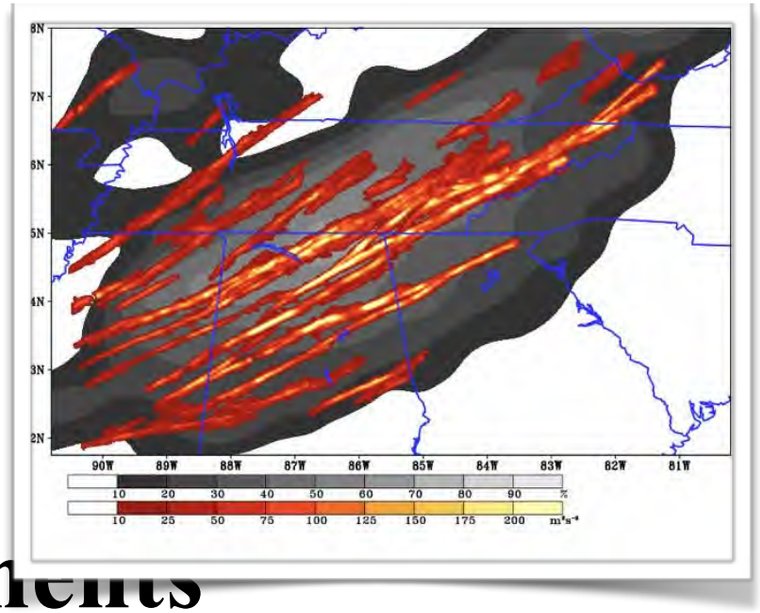
PROB UH ≥ 100 m^2s^{-2}
27-28 April 2011 11am – 11pm
***Find relative frequency on 80 km grid and apply Gaussian smoother.**

Analyzed UH (shaded)
27-28 April 2011 11am – 11pm



- Sobash et al. (2016) – Skill of UH as a function of threshold and smoothing.
- "Sweet spot"
- Method can produce forecasts as skillful as SPC ones (limited study period and regime dependent)

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



advance ocean, s
capability within
capability in atm
(e.g., eddy-resolving reso
better representation of se

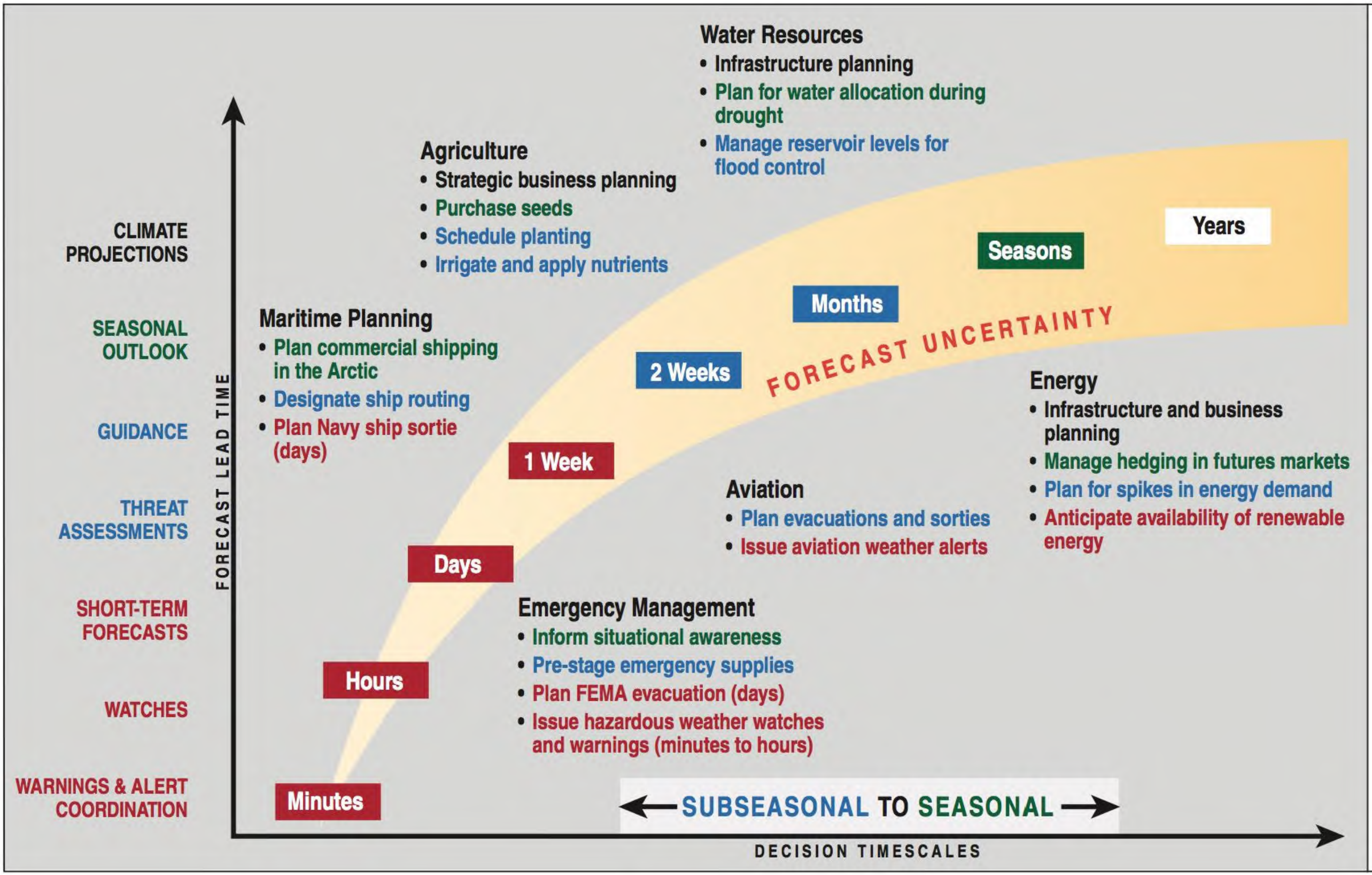
understand which a
interactions with th

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


Water Resources
• Infrastructure planning
• Plan for water allocation during drought
• Manage reservoir levels for flood control
Agriculture
• Strategic business planning
• Purchase seeds
• Schedule planting
• Irrigate and apply nutrients
Years
Seasons
Months
2 Weeks
1 Week
Days
Hours
Minutes
FORECAST UNCERTAINTY
Maritime Planning
• Plan commercial shipping in the Arctic
• Designate ship routing
• Plan Navy ship sortie (days)
Energy
• Infrastructure and business planning
• Manage hedging in futures markets
• Plan for spikes in energy demand
• Anticipate availability of renewable energy
Aviation
• Plan evacuations and sorties
• Issue aviation weather alerts
Emergency Management
• Inform situational awareness
• Pre-stage emergency supplies
• Plan FEMA evacuation (days)
• Issue hazardous weather watches and warnings (minutes to hours)
CLIMATE PROJECTIONS
SEASONAL OUTLOOK
GUIDANCE
THREAT ASSESSMENTS
SHORT-TERM FORECASTS
WATCHES
WARNINGS & ALERT COORDINATION
FORECAST LEAD TIME
SUBSEASONAL TO SEASONAL
DECISION TIMESCALES

291 pages

Chapter 2:

History and Current Status of S2S Forecasting

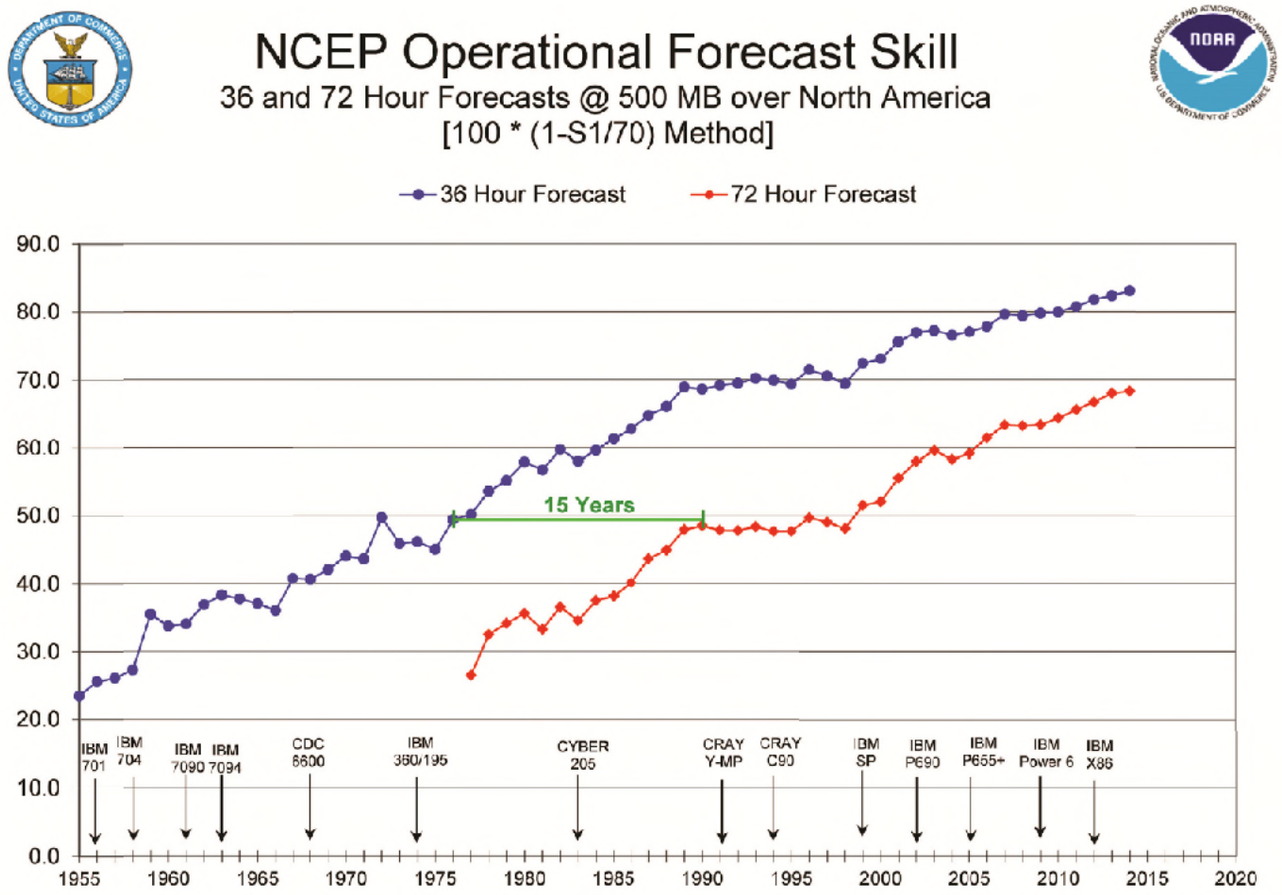


FIGURE 2.1 Forecast verification for 36 and 72-hour forecasts for the Global Forecast System (GFS)

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 recognition 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:

Enhancing the Value and Benefits of S2S Forecasts

Decision process:

Water supply management
Hydropower scheduling
Recreation budgeting

Water Resources Management

Chapter 3:

Enhancing the Value and Benefits of S2S Forecasts

Decision process:

Crop production
Commodity trading
Ranching
Fisheries

Agriculture

Water Resources Management

Chapter 3:

Enhancing the Value and Benefits of S2S Forecasts

Decision process:

Energy → Power generation
Operation
Maintenance scheduling
Energy trading

Agriculture

Water Resources Management

Chapter 3:

Enhancing the Value and Benefits of S2S Forecasts

National Security

Energy

Agriculture

Water Resources Management

Decision process:

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

Chapter 3:

Enhancing the Value and Benefits of S2S Forecasts

Transportation, Construction, Business, Public Health…

National Security

Energy

Agriculture

Water Resources Management

Chapter 3:

Enhancing the Value and Benefits of S2S Forecasts

CHALLENGES TO THE USE OF S2S PREDICTIONS

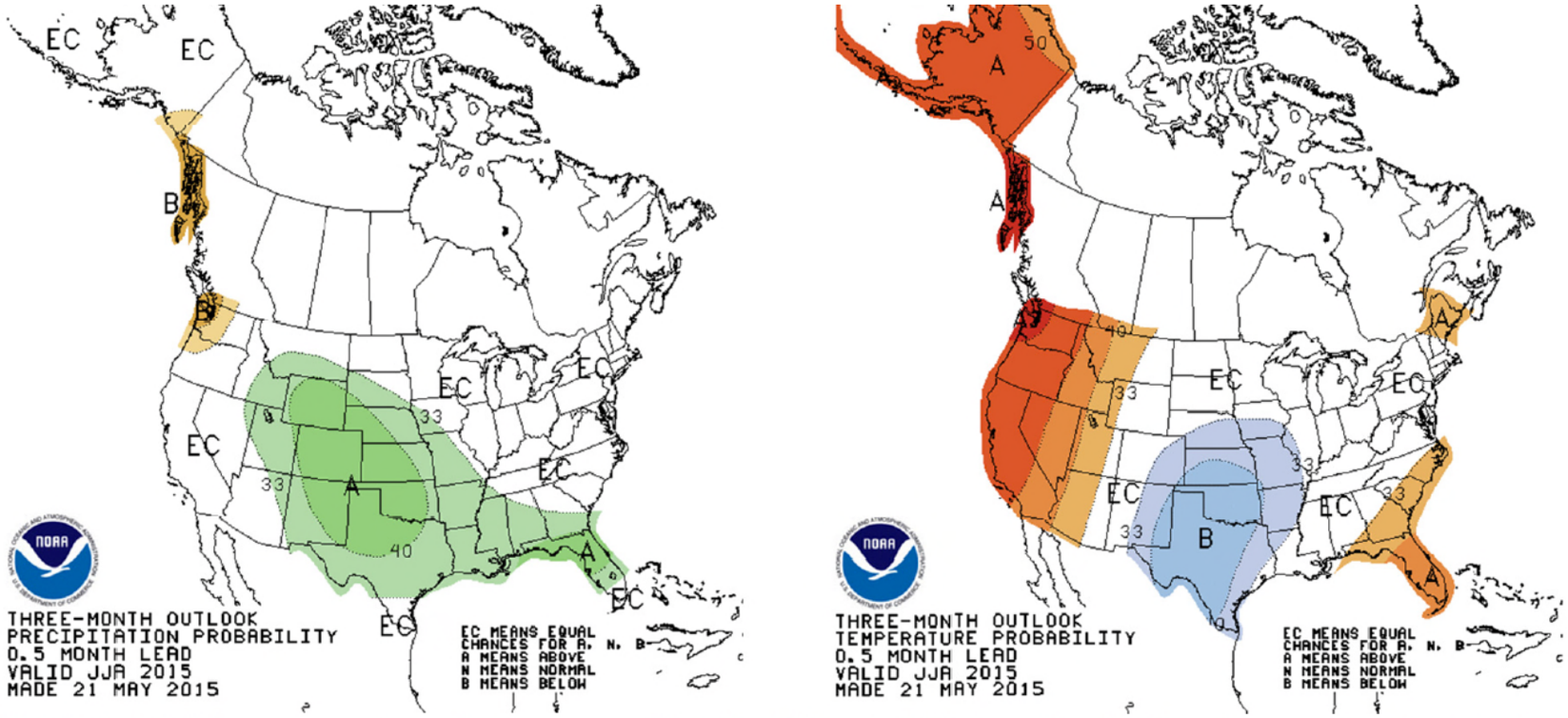


FIGURE 3.2 Three-month outlooks issued by the NOAA Climate Prediction Center for June-July-August 2015, issued 21 May 2015 (0.5 month lead time). Contours indicate probability of above (A) or

Not immediately useful to decision contexts

CHALLENGES TO THE USE OF S2S PREDICTIONS

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

Not immediately useful to decision contexts

Forecast products need translation!

ST200 short waves

Mean T700

CFSv1

v2

Spring Snowmelt

First Fall Freezes

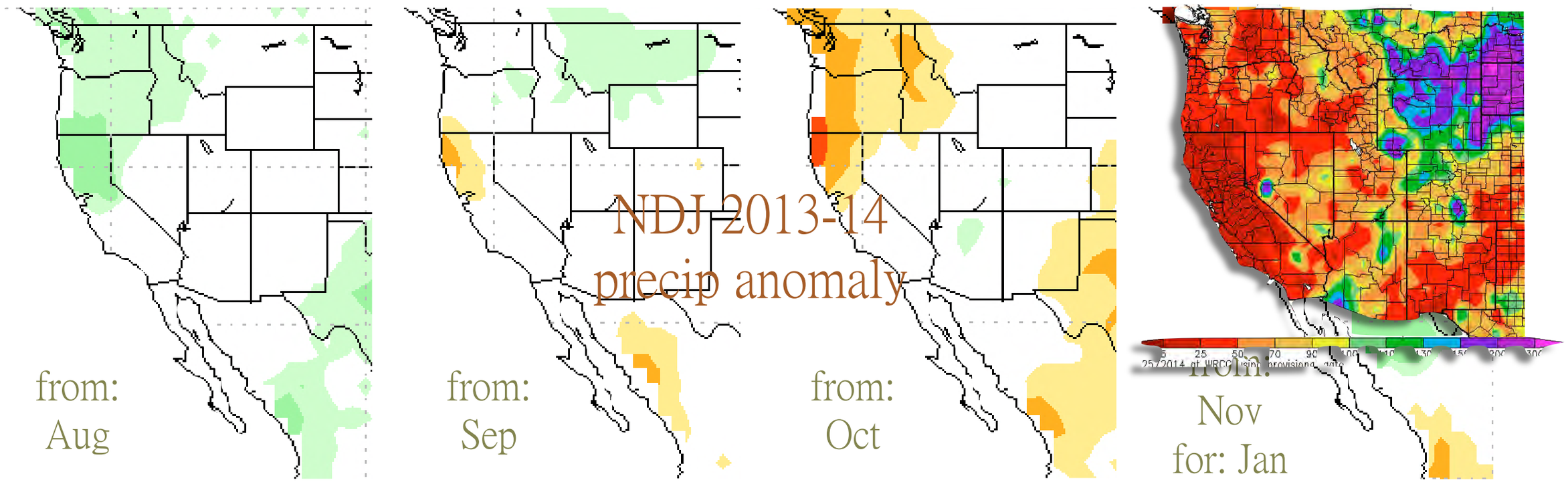
out to 3-4 weeks

out to 6 weeks

Winte rsions

out to 4 weeks

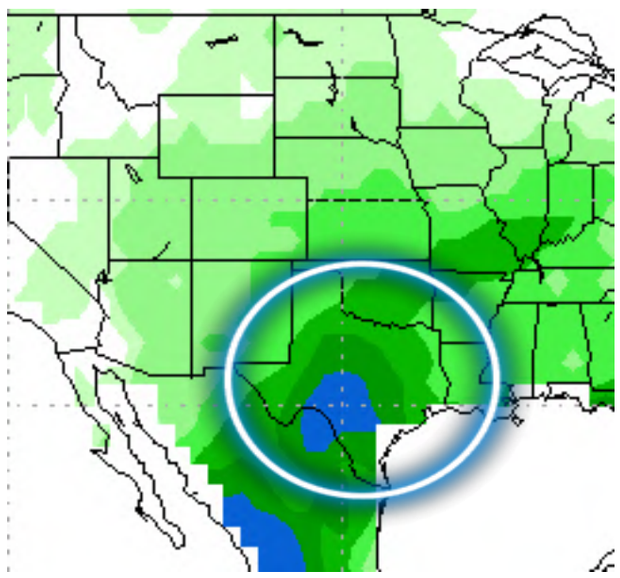
FIGURE 3.3 Recent drought has a severe impact on water availability in California, and water levels are



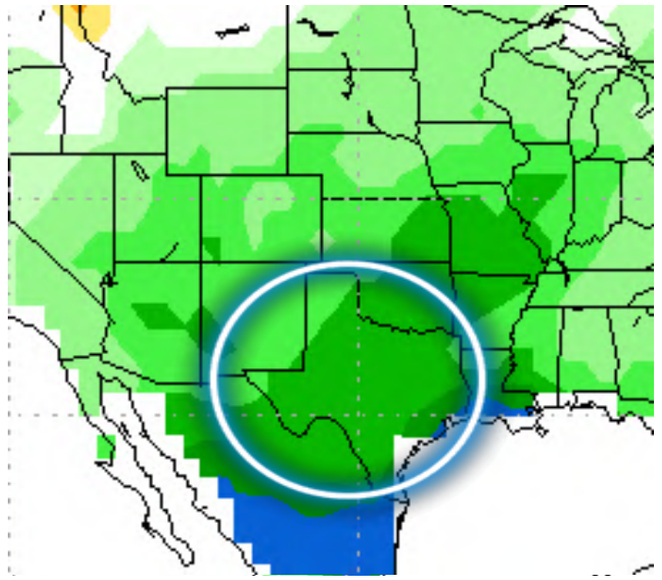
CHALLENGES TO THE USE OF S2S PREDICTIONS

Texas floods: May & October 2015

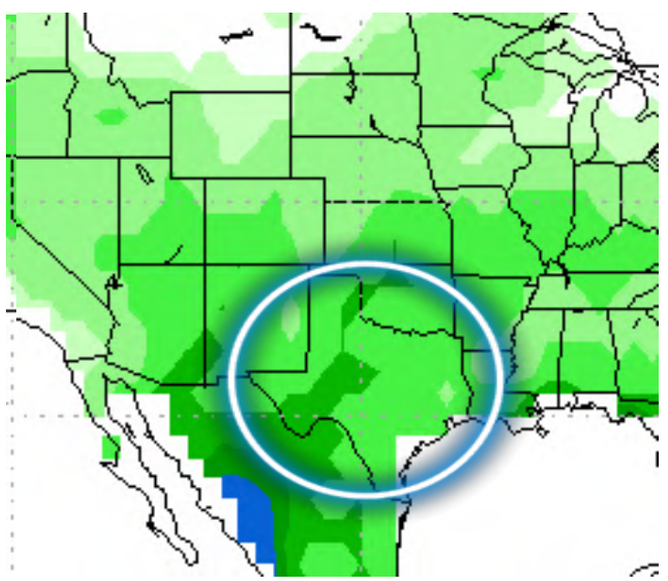
1 month lead



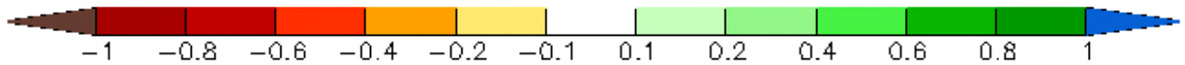
2 month lead



3 month lead



May precipitation anomaly (mm/day)



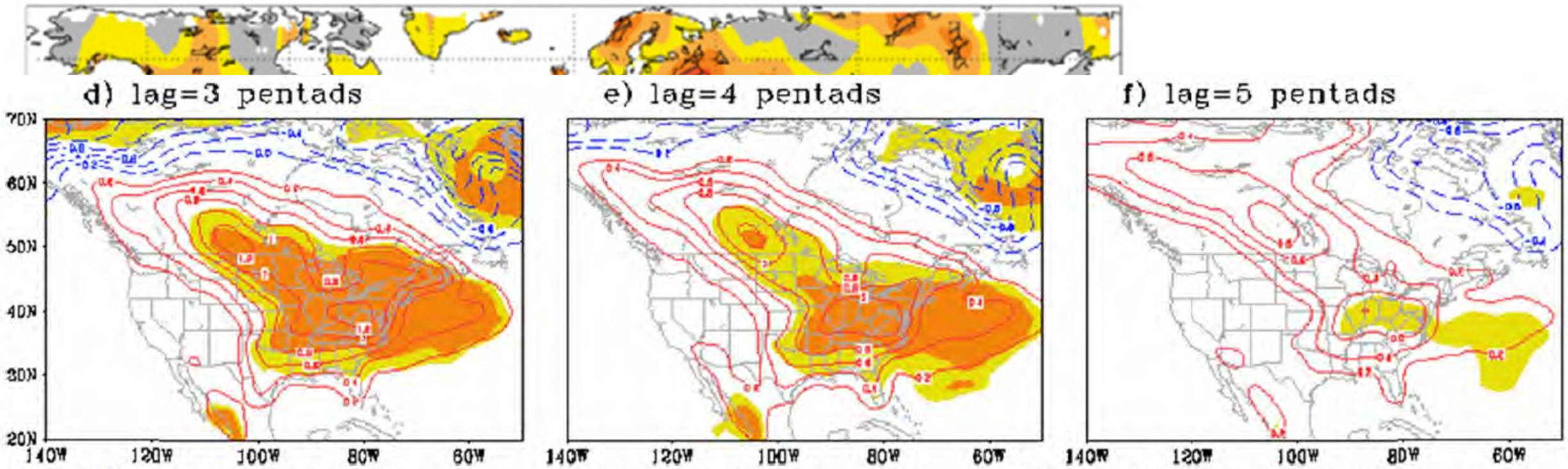
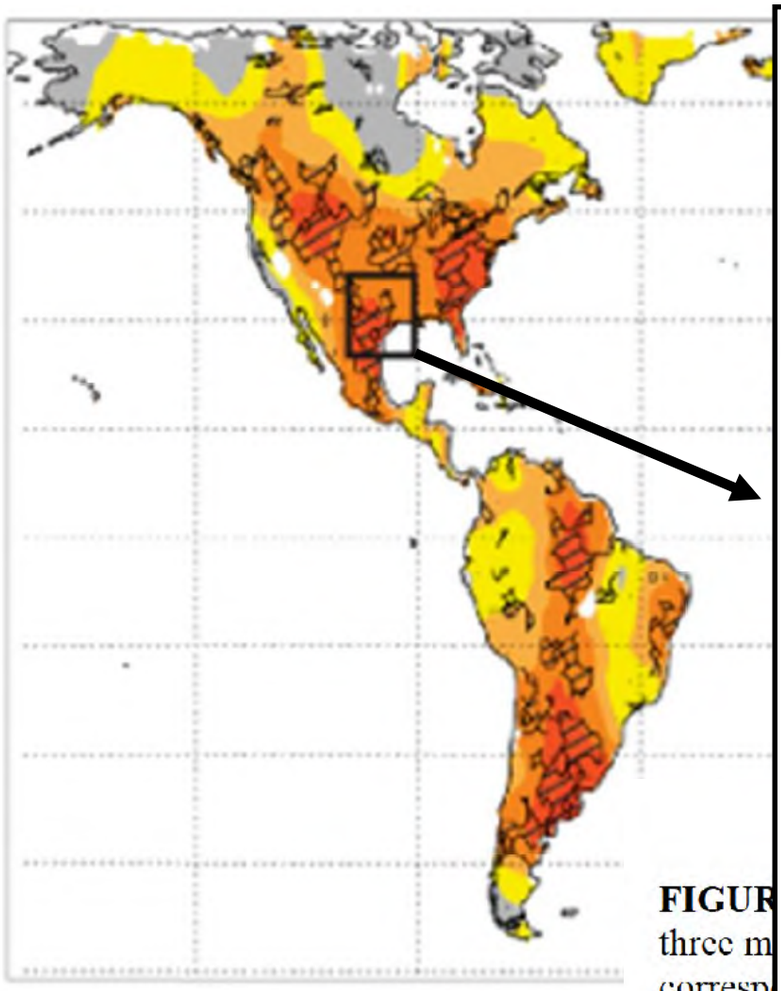


FIGURE 4.5 Lagged regressions of surface air temperature (SAT) in the North American region onto −RMM2. Lag n means that the SAT anomaly lags −RMM2 by n pentads (5-days). The sign

FIGURE 4.6 Correlation between number of hot days in the hottest month of each year and preceding three months precipitation deficits. Red areas indicate where dry periods from preceding three months correspond with more hot days. SOURCE: Mueller and Seneviratne, 2012.

Chapter 4:

Sources of Subseasonal to Seasonal Predictability



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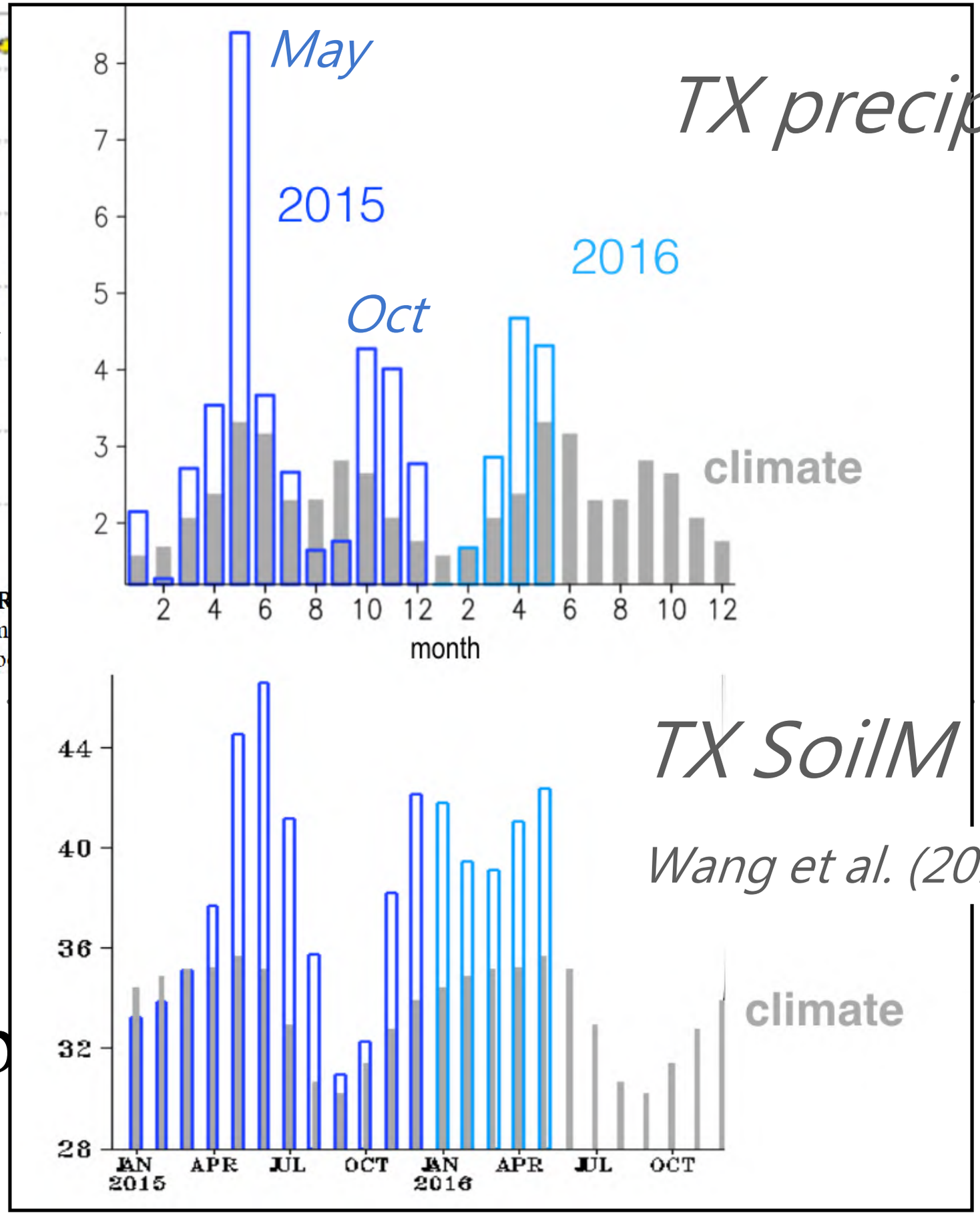


Chapter 4:

Sources of Sub
Predictability

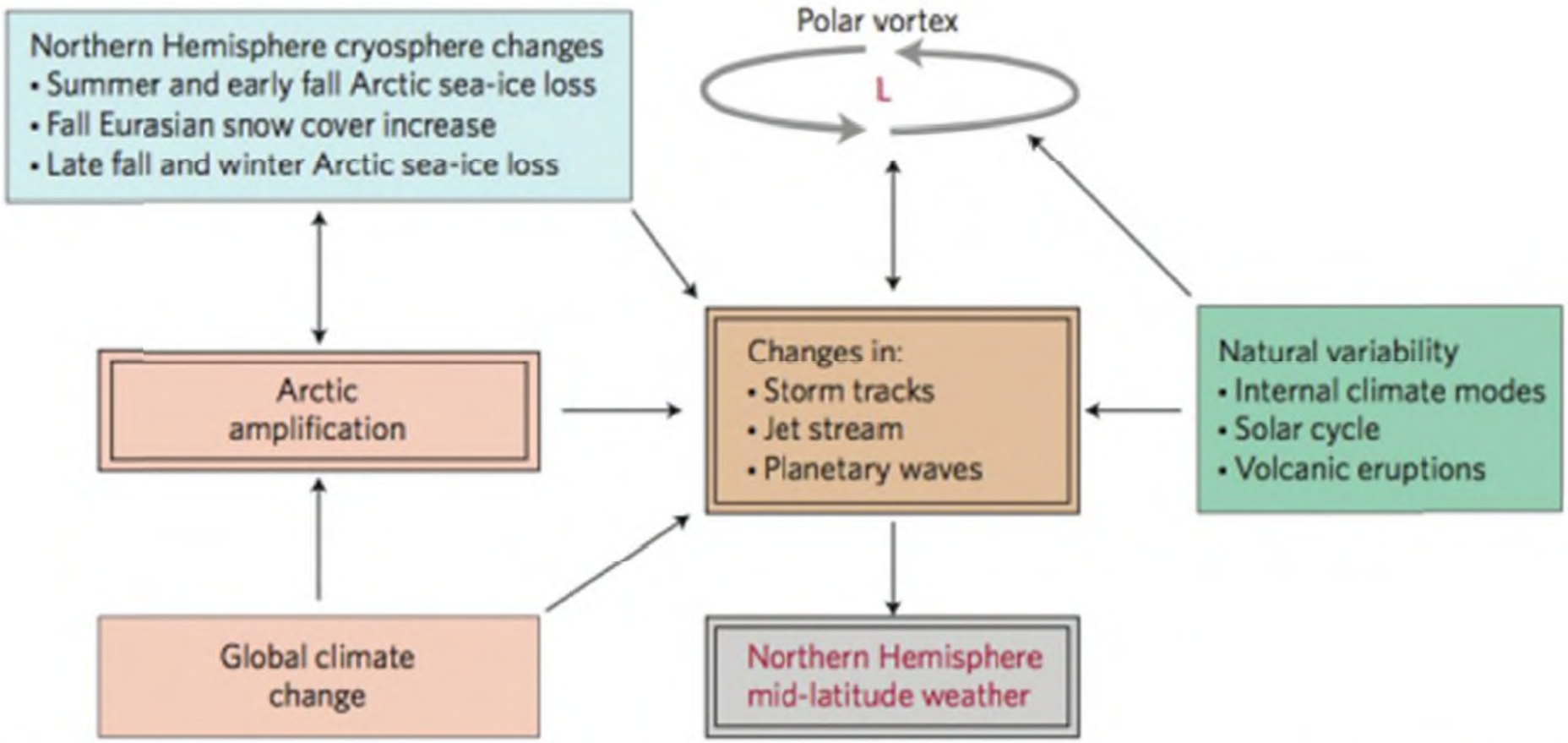


FIGURE 4.8: Schematic of ways to influence Northern Hemisphere mid-latitude weather. Three major

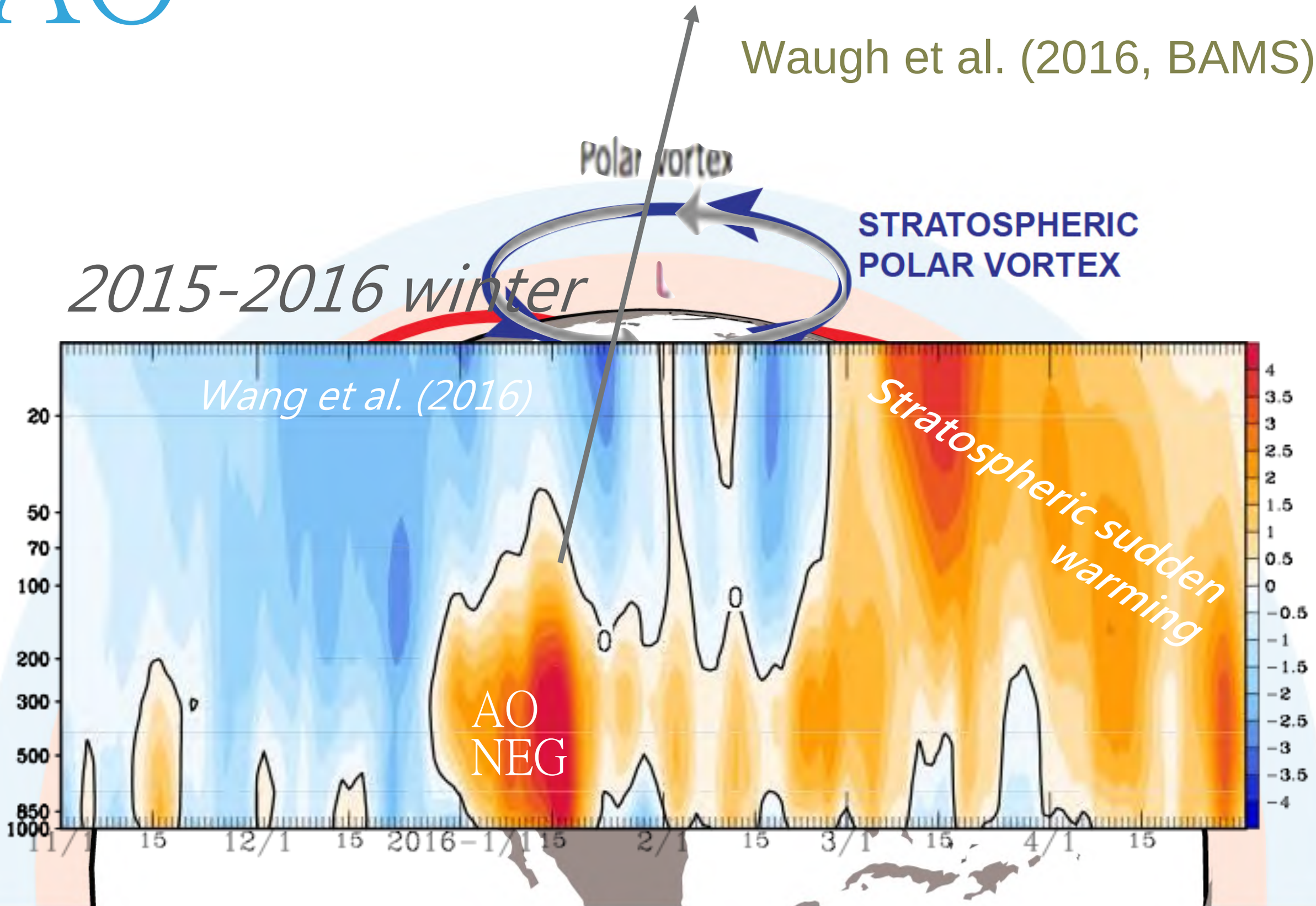
Chapter 4:

Sources of Subseasonal to Seasonal Predictability

AO

East Asian cold records!

Waugh et al. (2016, BAMS)



basic architecture of S2S prediction systems

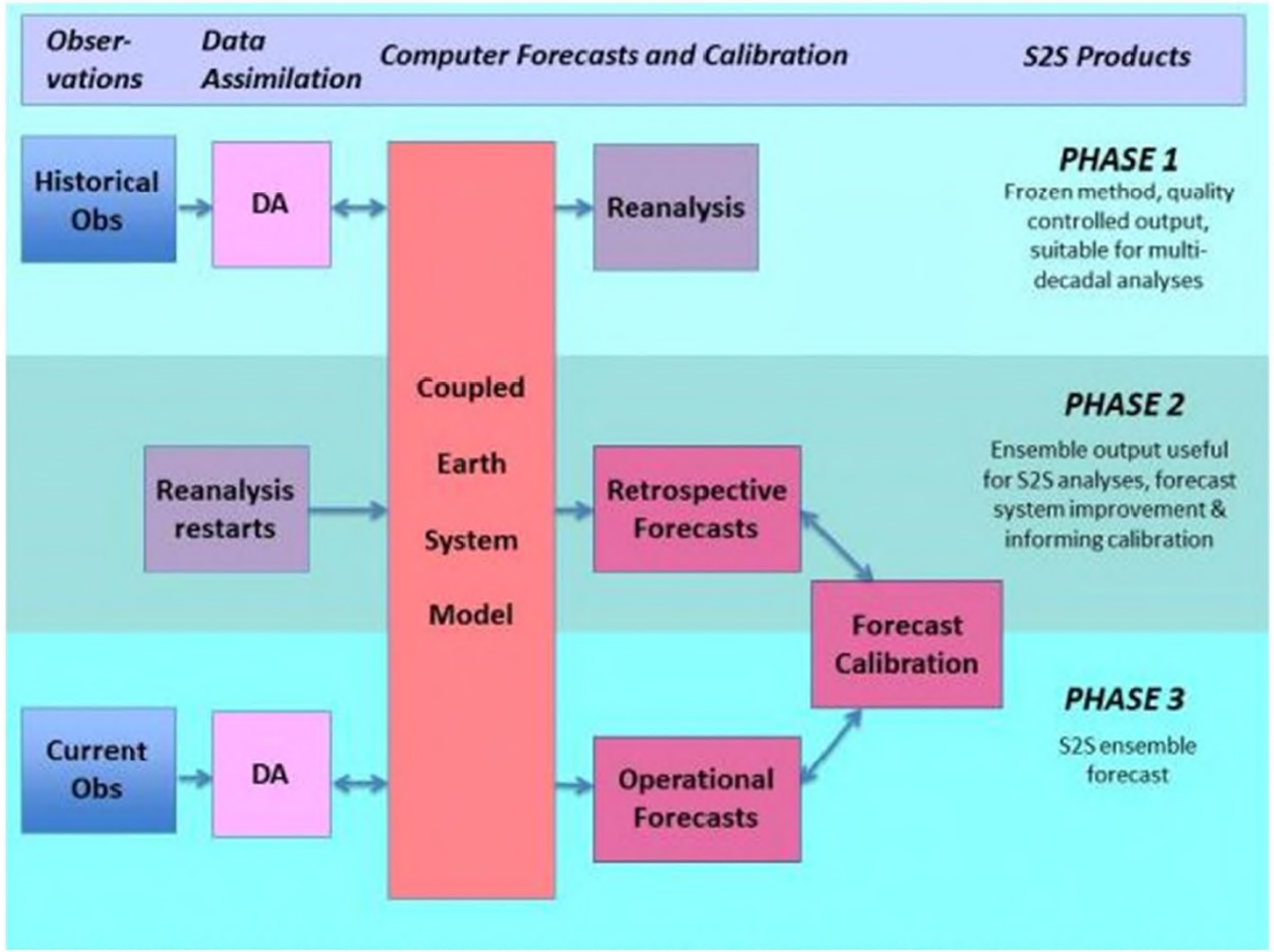
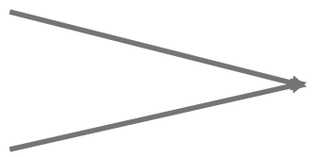


FIGURE 5.1 The production of calibrated subseasonal and seasonal forecasts involves three separate processes. In the first phase, historical observations over a period of two or more decades are combined

Chapter 5:

S2S Forecast Systems: Capabilities, Gaps, and Potential

Observations
Data Assimilation



CWB's *River* Group

Chapter 5:

S2S Forecast Systems: Capabilities, Gaps, and Potential

MODELS:

- ➢ Model drifts
- ➢ Parameterizations
- ➢ Tropical Convection
- ➢ Cloud Permitting
- ➢ Ocean models…

.....

Chapter 5:

S2S Forecast Systems: Capabilities, Gaps, and Potential

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 anomalies that persists in both time and space (e.g. ENSO), an area of severe drought defined by rainfall, temperature, area, and temporal extent, or an area of sea ice coverage. Many indices discussed in the preceding chapters such as ENSO, PDO, MJO, etc., are roughly based on features. Feature-based verification has the advantage 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 predicted. This 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:

S2S Forecast Systems: Capabilities, Gaps, and Potential

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

Chapter 6:

Interface Between Research and Operations

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:

Interface Between Research and Operations

R2O 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:

Interface Between Research and Operations

The Committee recommends that the nation should develop an

R2O Strategies

Establish Capability to Respond to Unanticipated Events

Chapter 6:

Interface Between Research and Operations

Typical Data Volumes from Today's S2S Prediction Forecasts

1 Terabyte per day

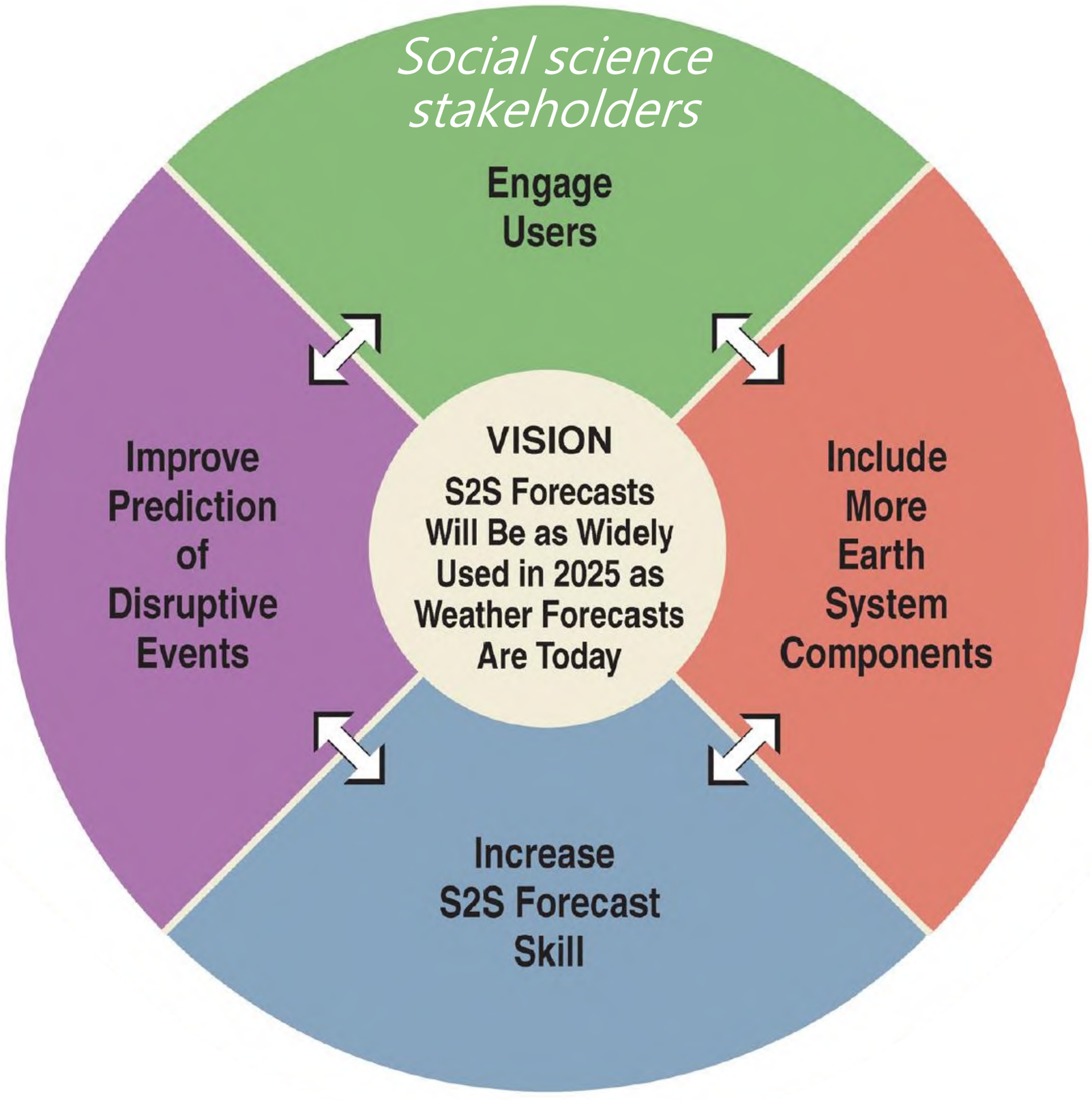
can amount to hundreds of Terabytes per day

Chapter 7:

Cyberinfrastructure and Workforce Capacity Building


Engage Users
Include More Earth System Components
Increase S2S Forecast Skill
Improve Prediction of Disruptive Events
VISION
S2S Forecasts Will Be as Widely Used in 2025 as Weather Forecasts Are Today

Recommendations A, B

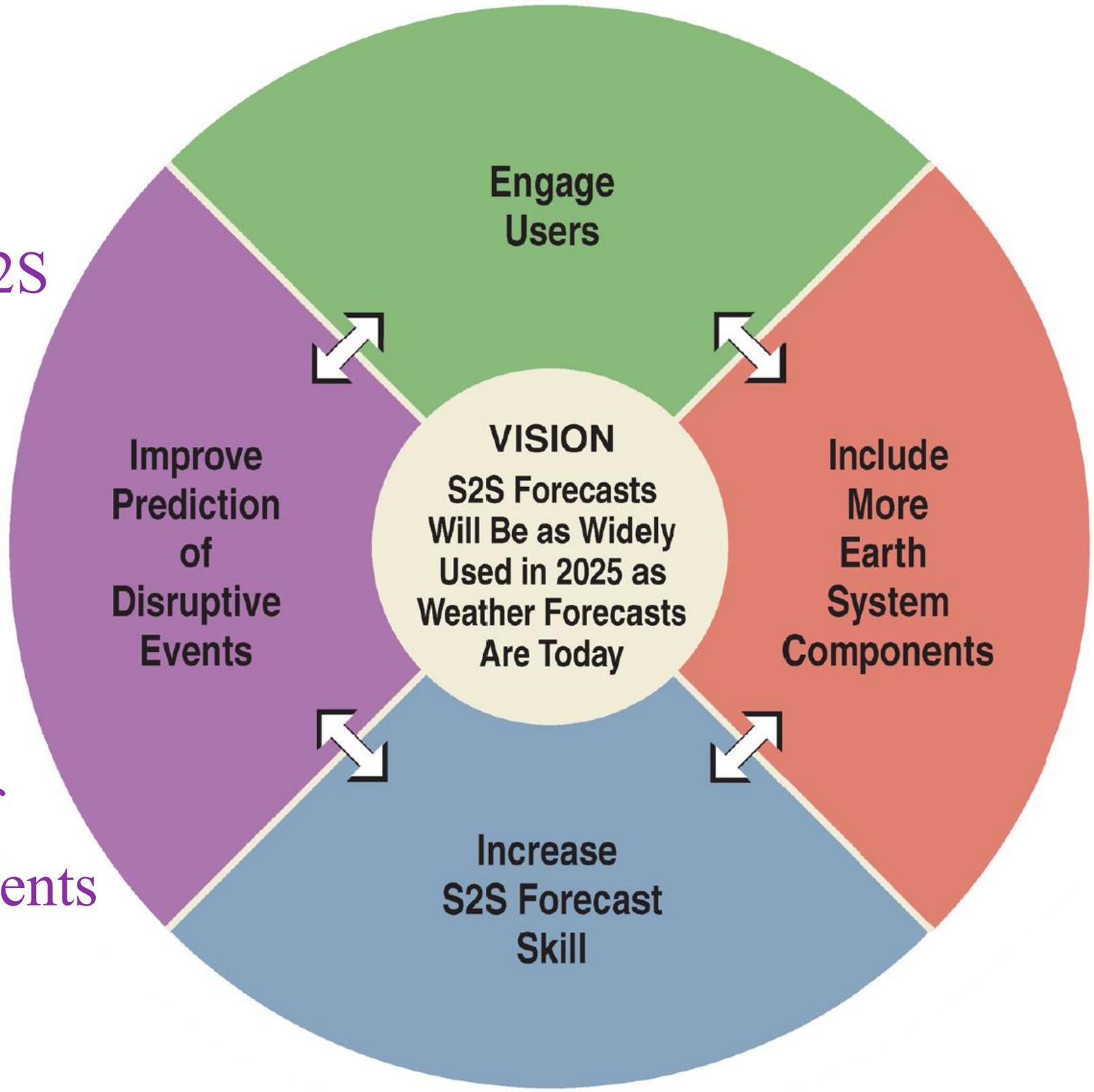


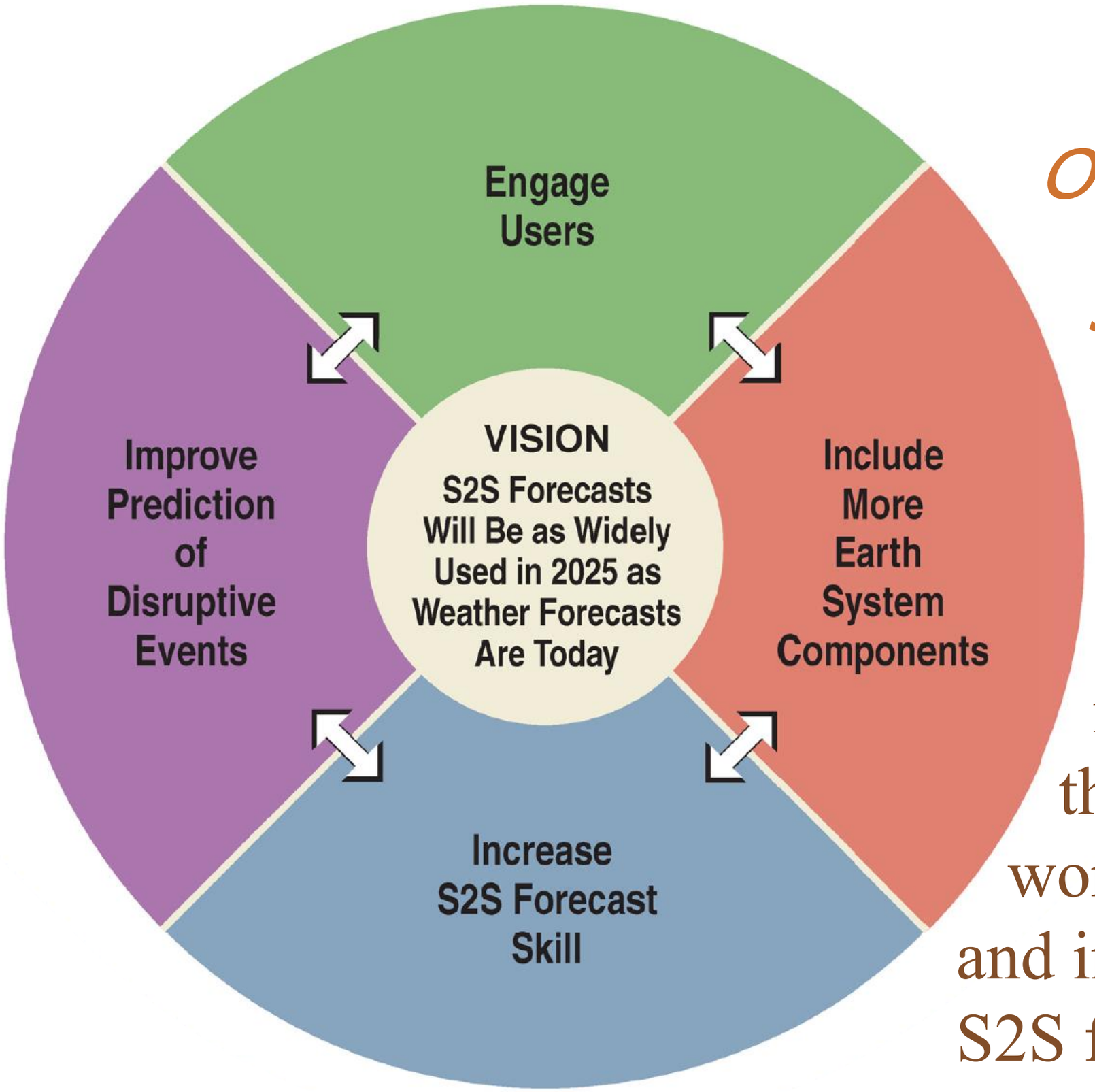
Recommendations A-M(so many!)

from diagnosis to repackaging to R2O

high impact S2S "forecasts of opportunity"

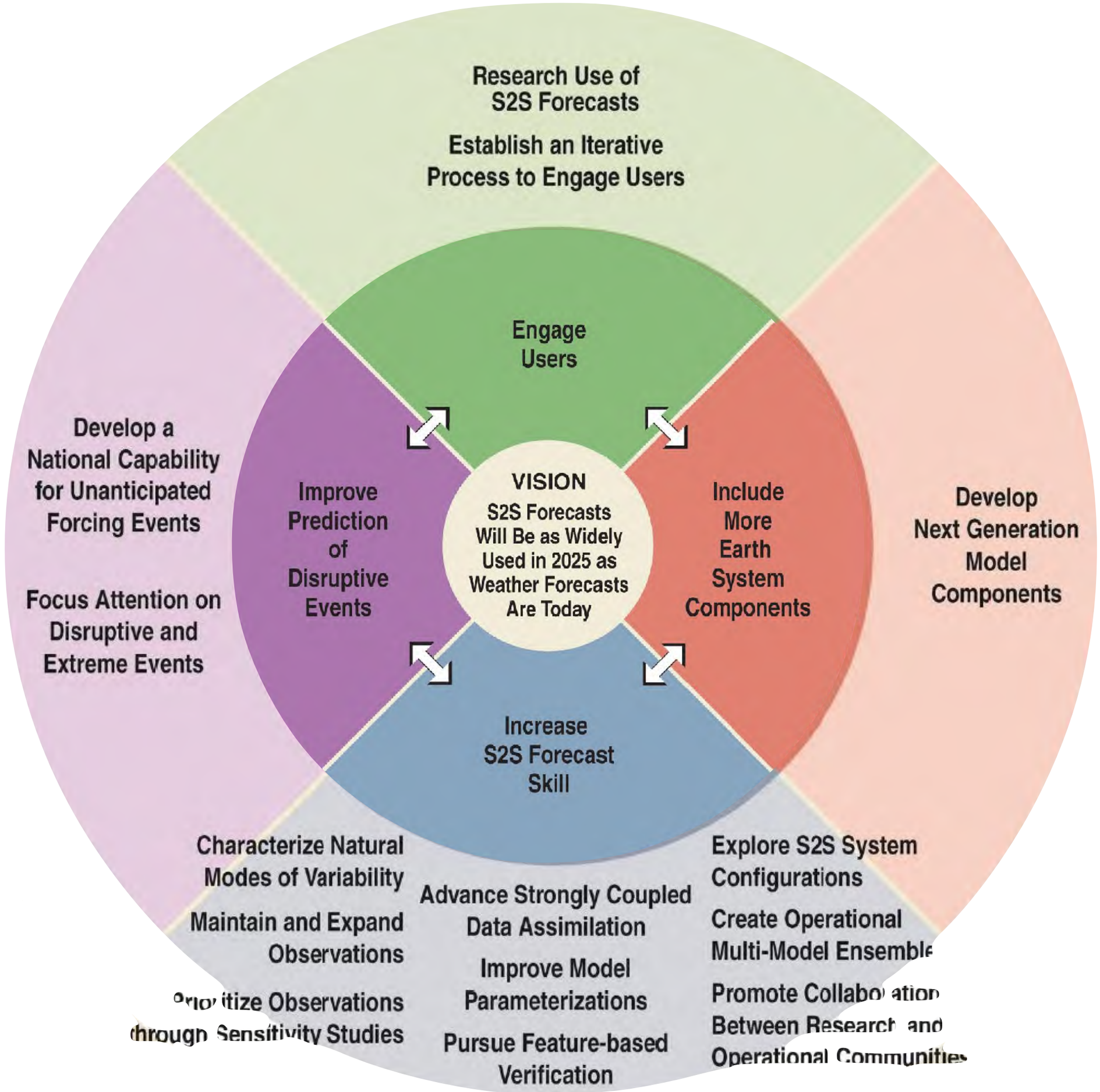
forecast the consequences of unanticipated events





ocean eddies, sea ice, LSM, you name it..

remove barriers that exist across workforce pipeline and in the diversity of S2S forecasting


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
Include More Earth System Components
Develop Next Generation Model Components
Increase S2S Forecast Skill
Characterize Natural Modes of Variability
Maintain and Expand Observations
Prioritize Observations through Sensitivity Studies
Advance Strongly Coupled Data Assimilation
Improve Model Parameterizations
Pursue Feature-based Verification
Explore S2S System Configurations
Create Operational Multi-Model Ensemble
Promote Collaboration Between Research and Operational Communities

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 wh
closer collaboration between federal agencies and
international partners,
PPAI
better flow of ideas and data between the research and
operational forecasting communities, and
engagement of the entire weather and climate enterprise.

REPORT IN BRIEF

March 2016

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
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Board on Atmospheric Sciences and Climate
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Next Generation Earth System Prediction

Strategies for Subseasonal to Seasonal Forecasts

CWB climate service

Connecting the two reports: Dealing with

Questions?

Next Generation Earth System Prediction

Strategies for Subseasonal to Seasonal Forecasts

RAYMOND J. BAN (Chair), Ban and Associates, LLC, Marietta, GA
CECILIA M. BITZ, University of Washington, Seattle
ANDY BROWN, UK Met Office, FitzRoy Road, Exeter, UK
ERIC CHASSIGNET, Florida State University, Tallahassee
JOHN A. DUTTON, Prescient Weather Ltd., State College, PA
ROBERT HALLBERG, NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ
ANKE KAMRATH, National Center for Atmospheric Research, Boulder, CO
DARYL KLEIST, University of Maryland, College Park
PIERRE F.J. LERMUSIAUX, Massachusetts Institute of Technology, Cambridge
HAI LIN, Environment and Climate Change Canada, Dorval, Quebec
LAURA MYERS, University of Alabama, Tuscaloosa
JULIE PULLEN, Stevens Institute of Technology, Hoboken, NJ
SCOTT SANDGATHE, University of Washington, Seattle
MARK SHAFER, University of Oklahoma, Norman
DUANE WALISER, NASA Jet Propulsion Laboratory, Pasadena, CA
CHIDONG ZHANG, University of Miami, FL