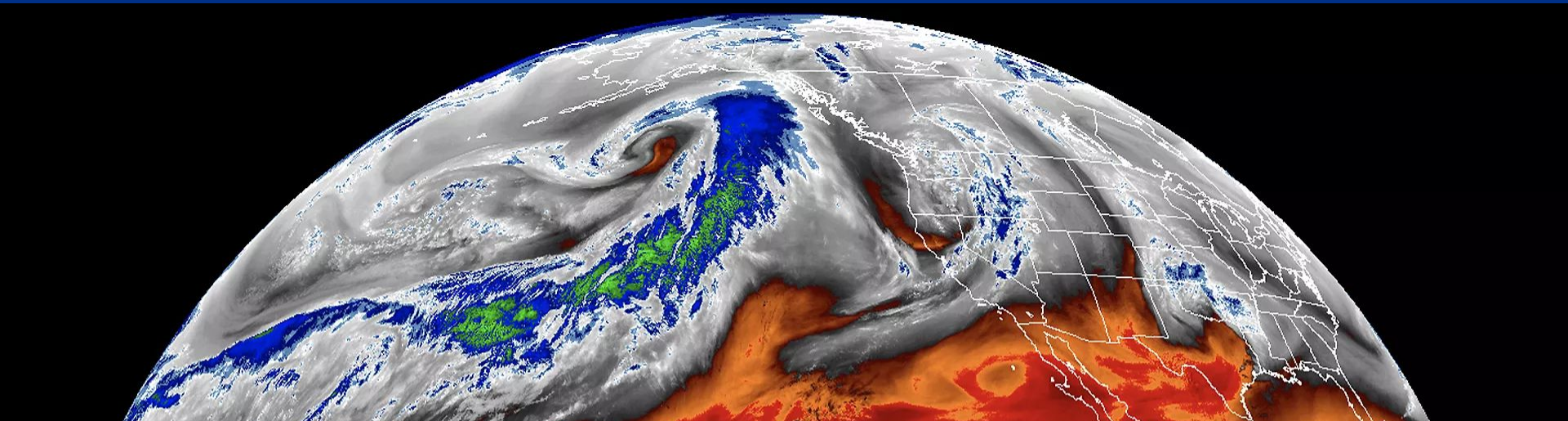
NOAA and the Weather Program Office Subseasonal to Seasonal Program

Mark Olsen, Dorothy Koch, Jessie Carman

NOAA OAR Weather Program Office

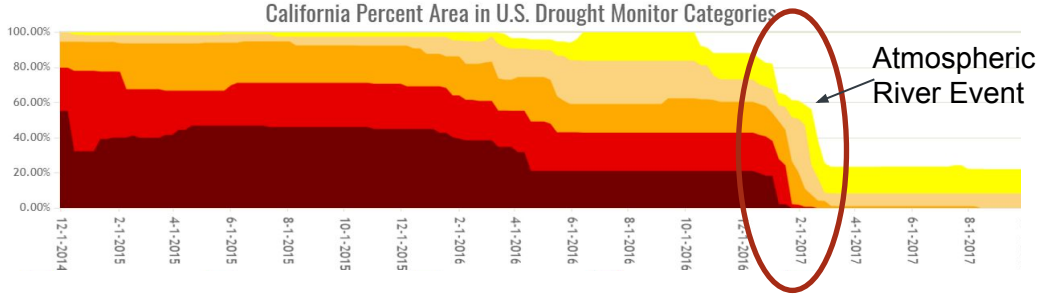
September 22, 2023



Improved Precipitation Forecasts are Vital to Our Economic, Environmental and National Security

Historic rainfall, flooding in Kentucky

Flash drought in California, ended by an atmospheric river

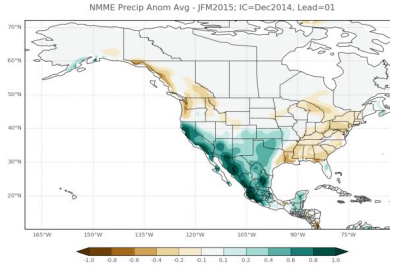


Historic flooding, landslides in Puerto Rico

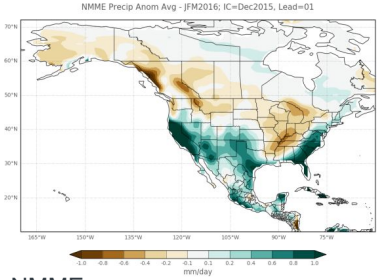
Record low flows on the Colorado River

We have the scientific and technological opportunity to do better

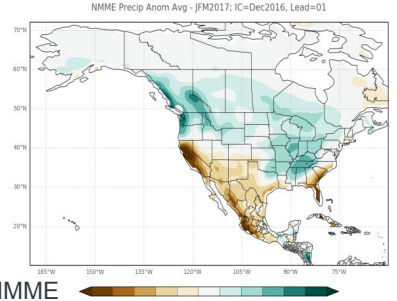
Seasonal precipitation prediction skill is poor



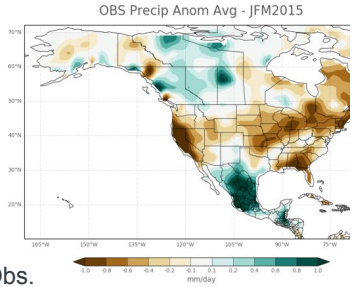
NMME 2015



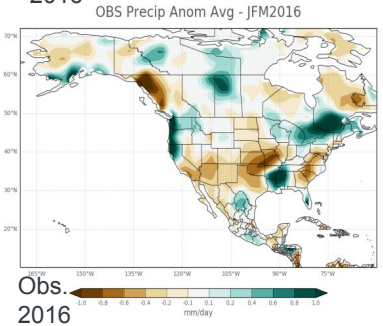
NMME 2016



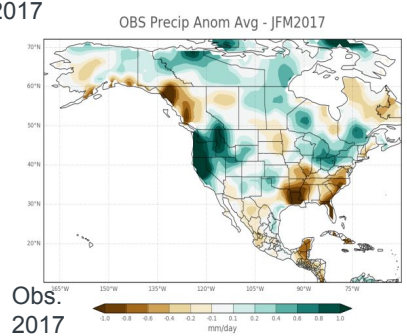
NMME 2017



Obs. 2015



Obs. 2016

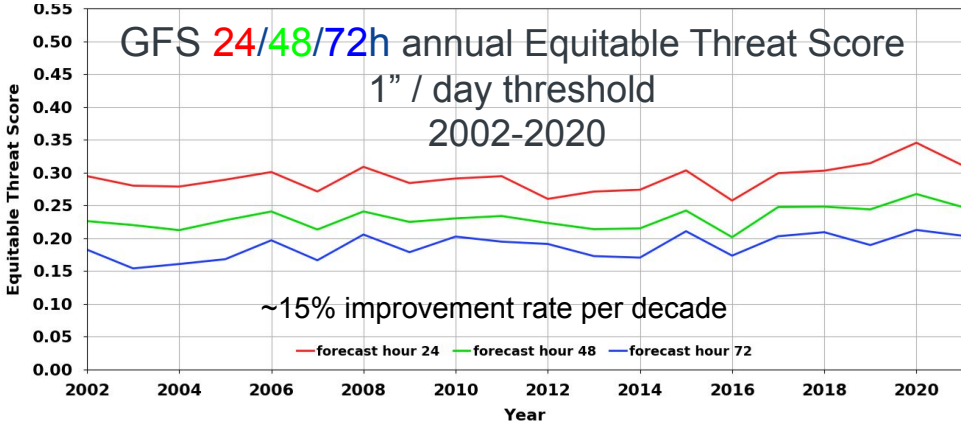


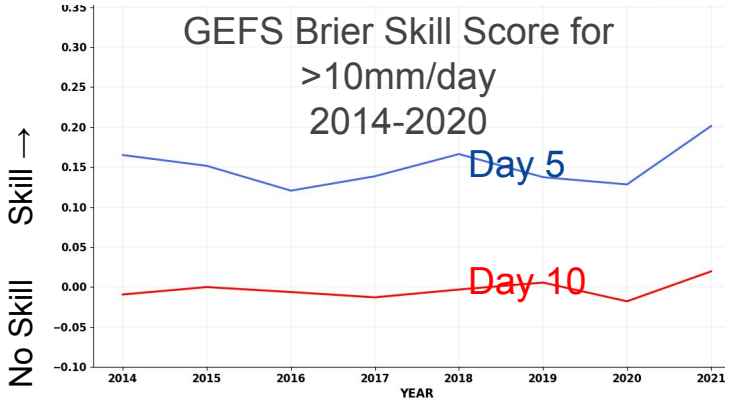
Obs. 2017

State of the art first season precipitation forecasts for winters of 2014-2017 were consistently of wrong sign over California and most of the west. Is this due to a limit in predictability, or missing or misrepresented physical processes?

Imperative to Improve Precipitation Forecasts

Painfully slow improvement in past ....





Priorities for Weather Research Report

"Unfortunately, precipitation forecast skill has not improved substantially over decades and remains one of the major technical challenges in atmospheric sciences.

Poor prediction skill for flood and drought has an inordinate impact on disadvantaged communities"

Common Model Systematic Errors in both Weather and Climate Models

- Underestimation of heavy rain & overestimation of light rain
- The diurnal cycle of precipitation, with maxima too early in the day
- Initiation of convective precipitation, often due to errors in representation of boundary layer & convective parameterizations
- Slow or non-physical propagation of convection
- Phase speed of mid-latitude troughs
- Sub-seasonal tropical variability (MJO representation)

Precipitation Prediction Grand Challenge (PPGC) Targets

Increase lead time, enhance resilience, and deliver new information for communities.

Better forecasts of extreme events (e.g., catastrophic precip & flooding events)

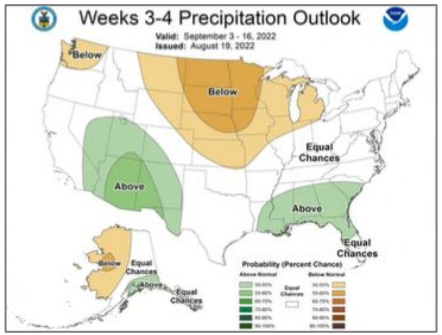
Improved week 3&4, monthly and seasonal forecasts

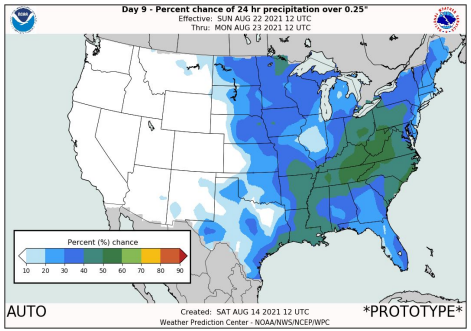
Improved atmospheric forcings leading to more accurate hydrologic forecasts across time scales (flash flooding to water supply)

Improved drought early warning

Enhanced skill for prediction of atmospheric rivers (e.g., for FIRO)

New tools based on reforecasts - such as the Extreme Forecast Index and AI-powered applications





Precipitation products to be improved and implemented with PPGC

PPGC Connection to Hydroclimatology

Continued advances in PPGC will:

- Accelerate R2O and lead to a transformational advance in the skill of atmospheric forecasts used in hydrologic models to predict streamflow across all time scales
- Improve precipitation forecasts for water management in the U.S., including through regional pilots:
  - “Winter S2S Precipitation Forecasts for Water Management in the Western U.S.”
  - “Spring and Summer S2S Precipitation Forecasts for Agriculture for the Central U.S.”
- Enable multi-decadal forecasts of water resources availability in the western U.S.

FY23 Congressional Appropriations for NOAA

Subseasonal to Seasonal (S2S) Weather Prediction - $12M
Water in the West - $12M

$5.0M
National Weather Service (NWS)

- ***Develop Seasonal Forecast System (SFS)***

$7M
Oceanic & Atmospheric Research (OAR)

- ***Weather Program Office's S2S Research Program***

$12M
Other synergistic activities

- ***Water in the West Initiative***
- ***Used in FY23 to develop an Atmospheric River forecast model***

- **NOAA is also encouraged to pursue a pilot project for S2S precipitation forecasts supporting water management in the western U.S.**
- **Develop an Innovative Climate Testbed**

NOAA's S2S Goals: In Development

Goals:

- **Improve S2S forecast skill**
- **Enhance S2S products for stakeholders**

Develop UFS Seasonal Forecast System (SFS) v1

Improve prediction & predictability; address model biases

Operational forecast goals

Post-processing

Improve communication of seasonal forecasts and uncertainty

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Improve communication of seasonal forecasts and uncertainty

- **Improve data assimilation (DA), especially coupled DA**
- **Conduct Reanalysis/reforecast for extended range**
- **Component developments, especially land, atmospheric chemistry and physics, ocean, and ice**

NOAA's S2S Goals: In Development

Goals:

- **Improve S2S forecast skill**
- **Enhance S2S products for stakeholders**

Develop UFS Seasonal Forecast System (SFS) v1

Improve prediction & predictability; address model biases

- **E.g. MJO propagation**
- **QBO**
- **Tropical SST patterns**

Operational forecast goals

Post-processing

Improve communication of seasonal forecasts and uncertainty

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Improve prediction & predictability; address model biases

Operational forecast goals

- **Temperature**
- **Precipitation**
- **Storm outlook**

Post-processing

Improve communication of seasonal forecasts and uncertainty

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- **Improve S2S forecast skill**
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Develop UFS Seasonal Forecast System (SFS) v1

Improve prediction & predictability; address model biases

Operational forecast goals

Post-processing

- **Diagnostic and verification tools**
- **Innovative hybrid dynamic-statistical techniques**
- **Include AI/ML**

Improve communication of seasonal forecasts and uncertainty

NOAA's S2S Goals: In Development

Goals:

- **Improve S2S forecast skill**
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Improve prediction & predictability; address model biases

Operational forecast goals

Post-processing

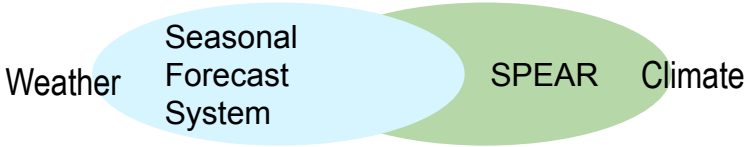
Improve communication of seasonal forecasts and uncertainty

- **Gather Stakeholder requirements**
- **Jointly establish metrics of forecast skill**
- **Communication of forecast uncertainty**
- **Co-Develop forecast products**

NOAA Landscape for S2S Precipitation

NOAA Activities in S2S forecasting and prediction include

- Operational forecasts
  - **National Weather Service (NWS)**: Climate Prediction Center (CPC; forecasts) and Environmental Modeling Center (EMC; modeling) and Office of Science and Technology Integration (OSTI; program office)
- Research
  - **Oceanic and Atmospheric Research (OAR)**: Weather Program Office (WPO) and Climate Program Office (CPO); OAR Laboratories, e.g. Physical Sciences Laboratory (PSL) and Geophysical Fluid Dynamics Laboratory (GFDL)
- Three primary modeling tools
  - Unified Forecast System's (UFS) Seasonal Forecast System (SFS): Weather to Seasons
  - GFDL's SPEAR model: Seasons to Climate
  - North American Multi-Model Ensemble (NMME)

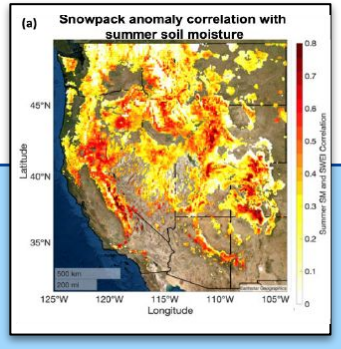


Research highlights: Community projects

Examples of WPO S2S Program funded research with strong ties to hydrology to improve forecast models:

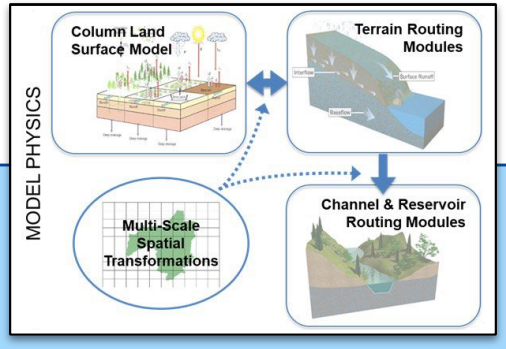
Assessing the impact of dynamic vegetation on drought forecasts
(Otkin - U. Wisconsin)

GOAL: UFS vegetation treatments and effects on flash drought



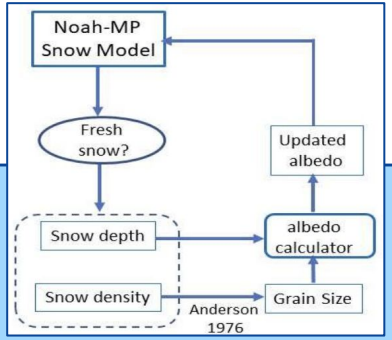
Enhancing NOAA UFS subseasonal to seasonal predictions of precipitation and drought via improved representation of snowpack processes
(He - NCAR)

GOAL: Aerosols, vegetation effects on snowpack in UFS



Integrated surface physics for coupled hydrometeorology in the UFS for S2S prediction
(Gochis - NCAR)

GOAL: Land hydrology developments



Exploring concerted integration of alternative snow parameterization and novel interactive vegetation phenology to improve UFS S2S predictions of snowpack and drought termination over the western US
(Zhang - UTA)

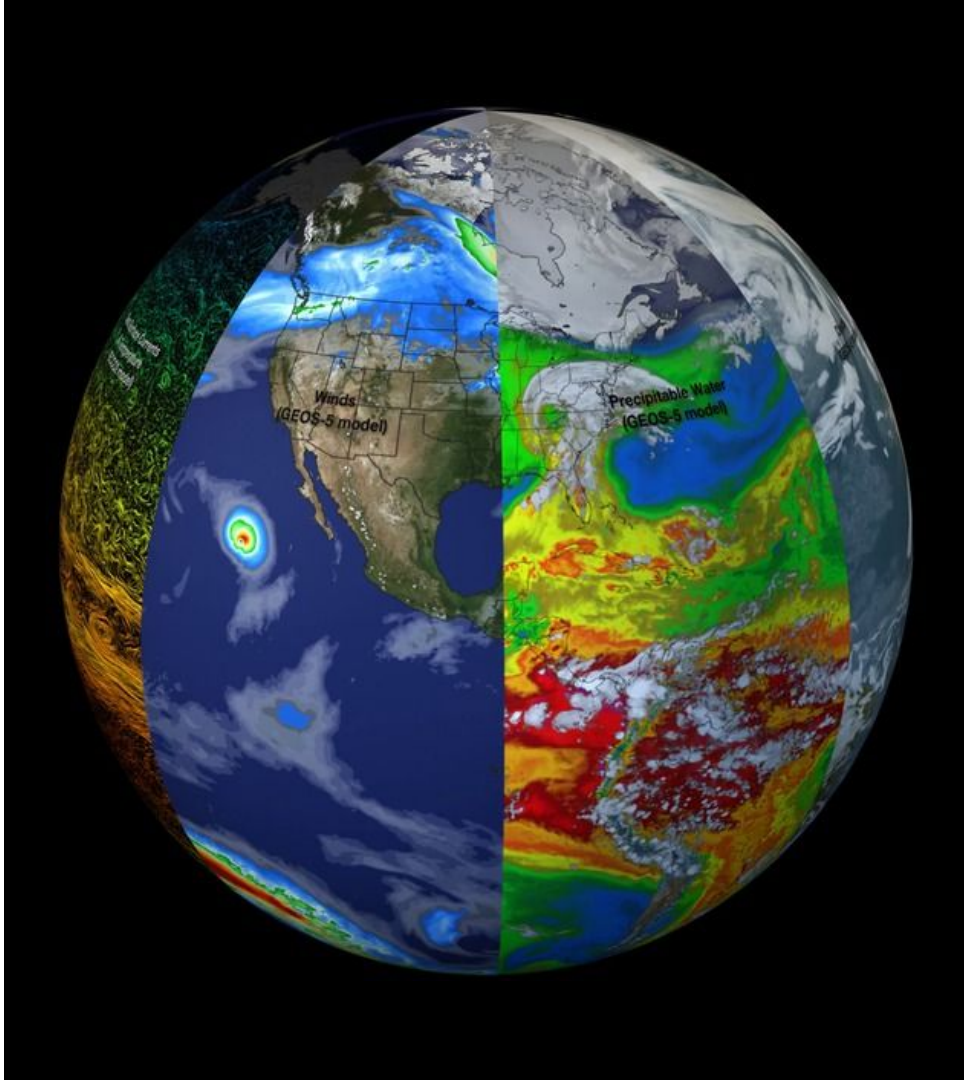
GOAL: Enhance/Improve NOAH-MP

NOAA SFS Development Plan

Seasonal Forecast System (SFS) is an extension of NOAA's current medium range forecast system (the Global Forecast System; GFS); based on the Unified Forecast System (UFS)

UFS Development GOALS:

1) Initialize model across interfaces
2) Minimize systematic drift from initial conditions
3) Estimate uncertainties using ensemble forecasts
4) Reduce systematic biases and improve forecast skill
5) SFS infrastructure
    a) Testing and evaluation
    b) SFS will use cloud computing
    c) Provide to community through the Earth Prediction Innovation Center (EPIC)

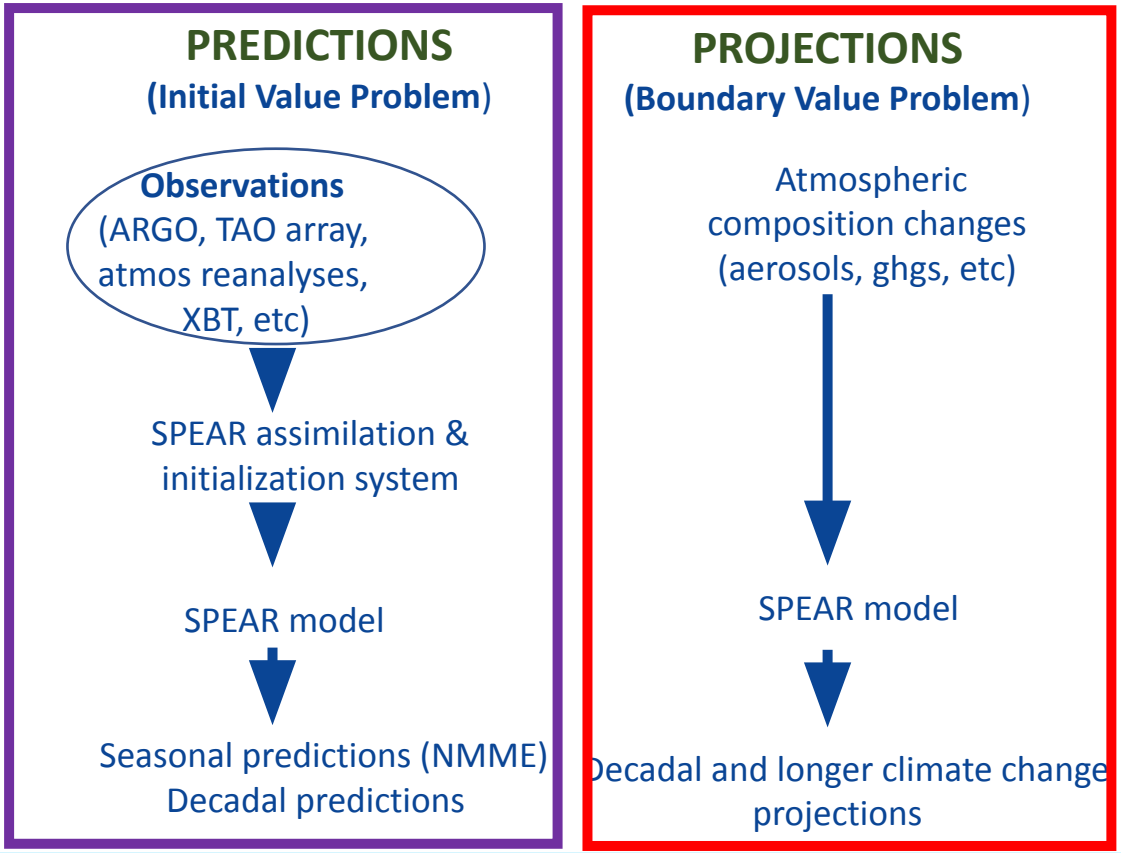


Research: GFDL's SPEAR model

(**S**eamless system for **P**rediction and **EA**rth system **R**esearch)

- SPEAR is based from GFDL's Earth System (Climate) models
- Focus is seasonal to decadal
- Can run initialized with observations (prediction-mode) or driven by forcings (projection mode)
- **Contributes to National Multi-Model Ensemble (NMME)**

Delworth et al., JAMES (2020),
Lu et al., JAMES (2020)



Multi-Model Ensembles (MMEs)

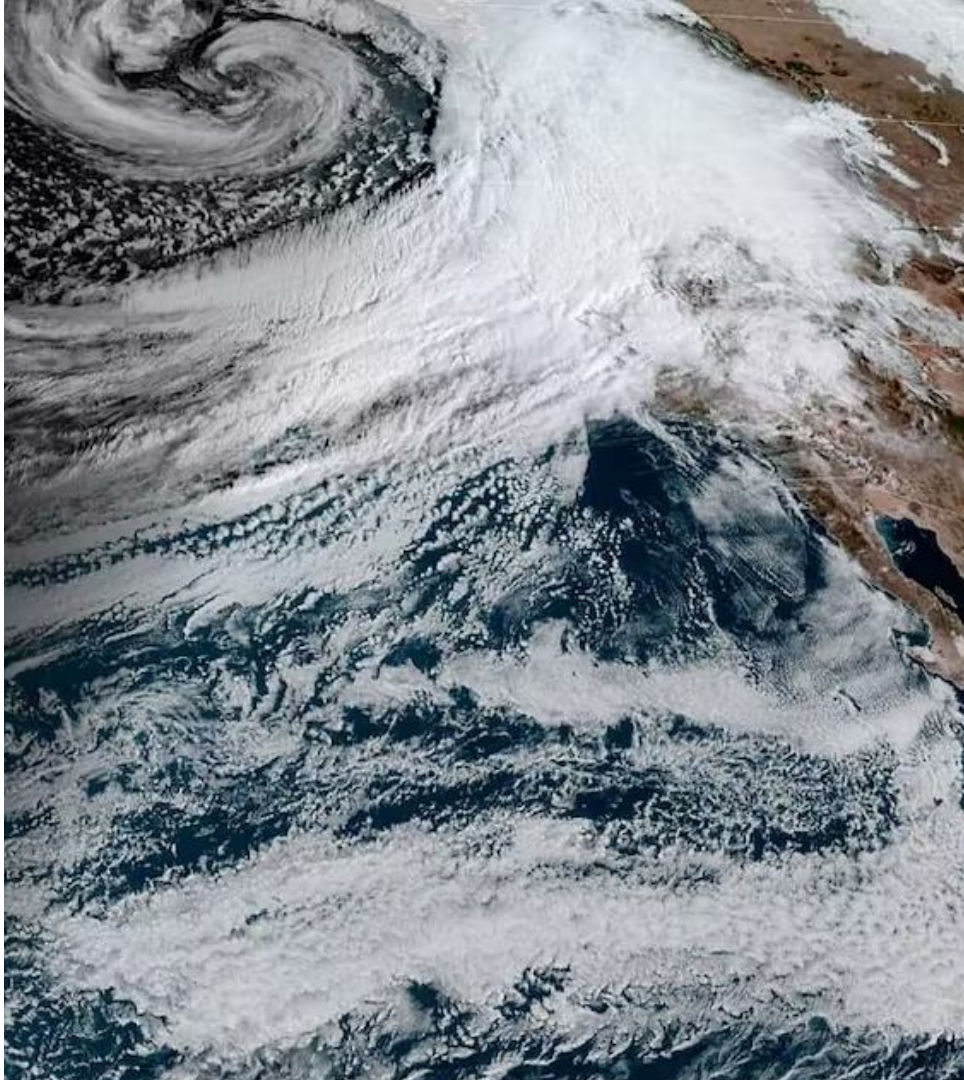
Real-time, updating, multi-model ensembles over the S2S timescale pull greater unified benefit from multiple investments.

Subseasonal Experiment (SubX)

- Discontinued in FY23 due to limited funds

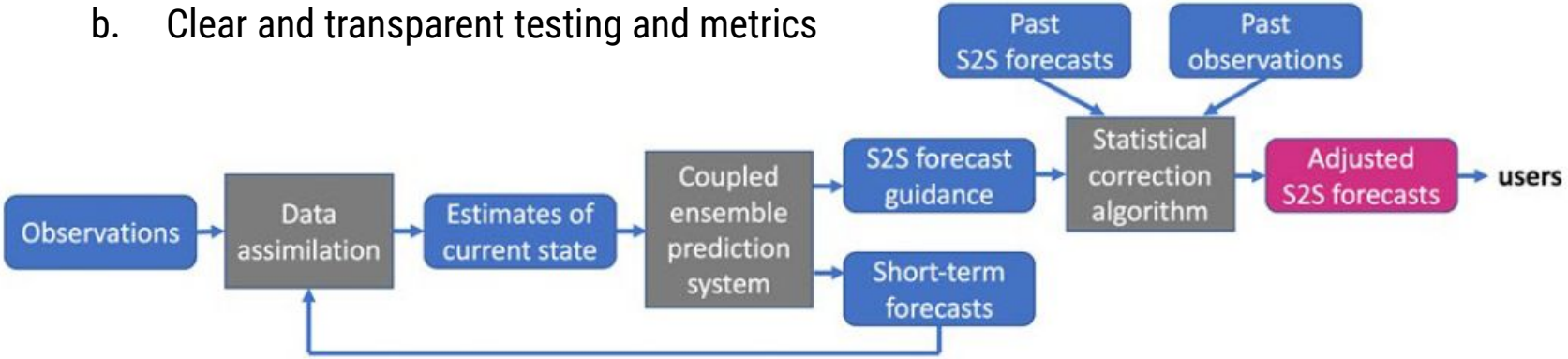
North American Multi-Model Ensemble (NMME)

- June 2023 workshop (report pending)
  - Potential data and product needs for research and decision support
  - Required infrastructure to support data and product needs



Path Forward: S2S (Precipitation) Forecast Improvement strategy

1. **Establish Forecasting Goals and Metrics of success:**
   a. Stakeholders, modelers and forecasters work together on: i) what is ultimate aim and ii) what is feasible right now
   b. For S2S, include underlying phenomena targets (e.g. MJO, blocking, QBO)?
2. **Assess where effort/improvements are most needed:**
   a. Where to focus for improvements: observations, models, products, communication
   b. High Performance Computing (HPC) requirements
3. **Team approach:**
   a. Co-develop products (stakeholders, modelers, forecasters)
   b. Clear and transparent testing and metrics



Path Forward

- Support UFS SFS development
- External competitions/community support; Internal competitions/NOAA support
- Infrastructure support furthering community use/access, including EPIC and cloud
- Engage stakeholder, agency and international partners

Workshop planned for further planning with S2S community *(tentatively Spring 2024)*

We invite and welcome any collaboration/coordination!

Contact:
Dr. Mark Olsen (OAR): mark.olsen@noaa.gov
Dr. Yan Xue (NWS): yan.xue@noaa.gov

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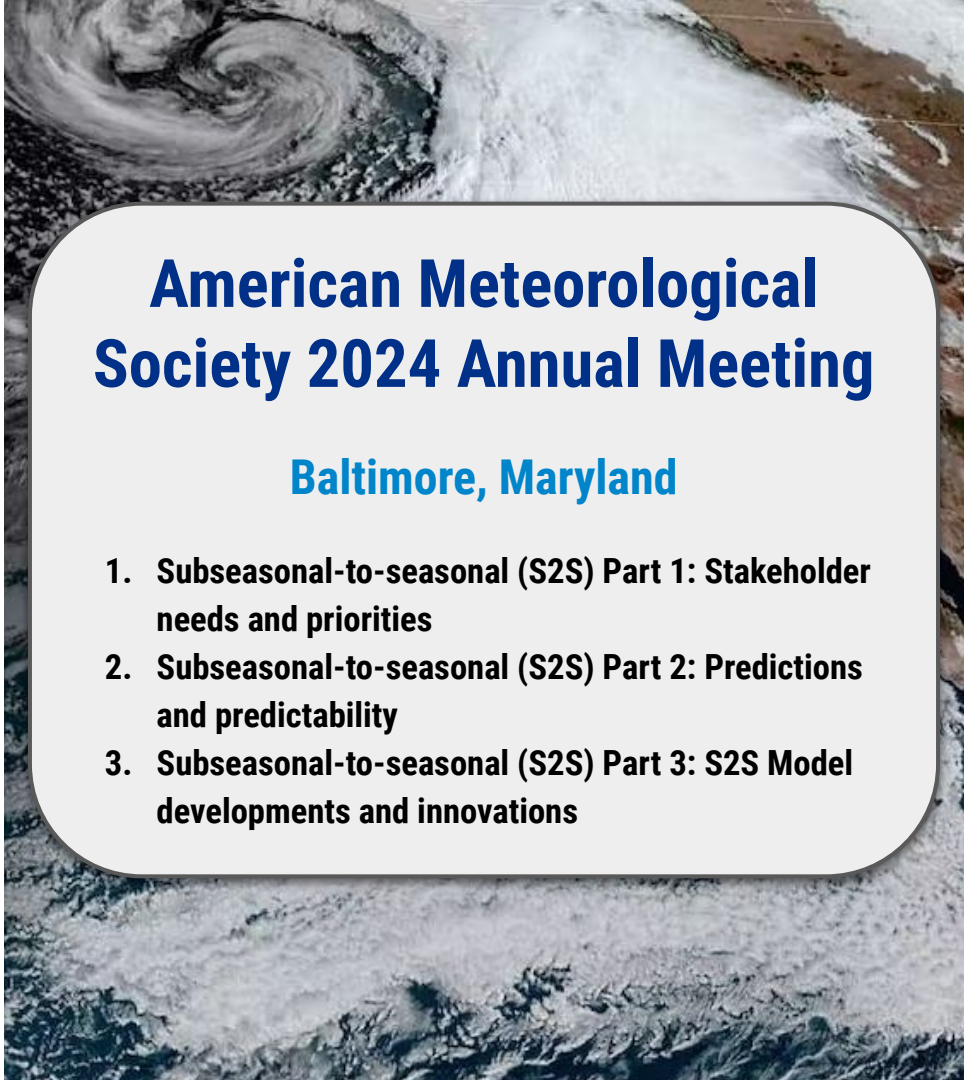

American Meteorological Society 2024 Annual Meeting

Baltimore, Maryland

1. **Subseasonal-to-seasonal (S2S) Part 1: Stakeholder needs and priorities**
2. **Subseasonal-to-seasonal (S2S) Part 2: Predictions and predictability**
3. **Subseasonal-to-seasonal (S2S) Part 3: S2S Model developments and innovations**

NOAA WEATHER PROGRAM OFFICE

THANK YOU

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Backup Slides

7. Bridging the Gap to Decisions

Western U.S. Hydrology

- Congressional appropriations provided first directed funding in FY22
- FY23 appropriations specified an increased focus

Western U.S. Hydroclimatological Study

- Congressional directive to conduct a study of hydroclimatological changes in major river basins of the western U.S. over the next 30 years

MME efforts

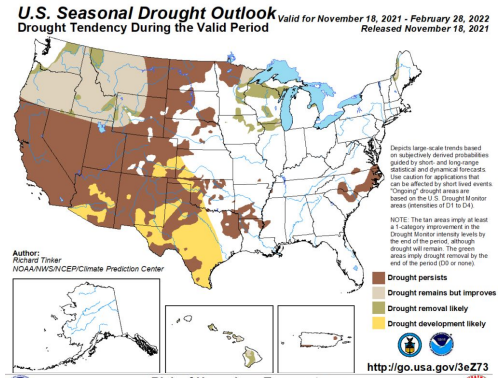
- Partnerships with other agencies
- Provide multiple research and operational benefits over these timescales

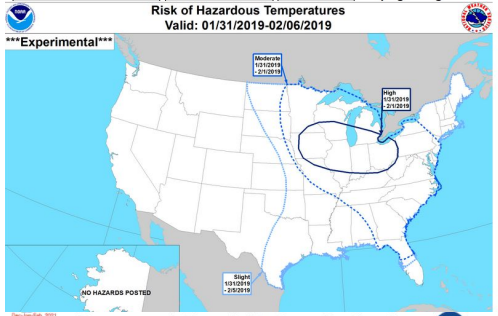
2. NWS Subseasonal-to-Seasonal Forecasts

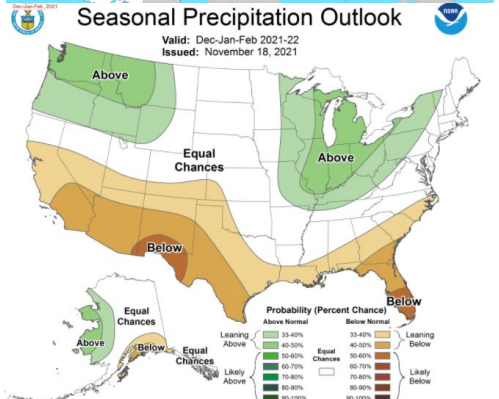
- **Temperature and Precipitation Outlooks** (CONUS, AK, HI)
  - Week 2, Week 3-4, Monthly, and Seasonal
- **Monthly and Seasonal Drought Outlooks** (CONUS, AK, HI)
- **US Hazards Outlook**
  - Week 2 extremes of temperature, precipitation, and wind
- **Global Tropics Hazard Outlook**
  - Weeks 2-3 extremes of temperature and precipitation, and potential of tropical cyclones
- **Seasonal Hurricane Outlook**
- **ENSO Prediction**
- **Arctic Sea Ice Prediction**
  - Weeks 1-6, Monthly, and Seasonal

S2S forecast products are based on combination of:

- Forecast models that are now extending from weeks to months
- Statistical tools that merge models and historical data





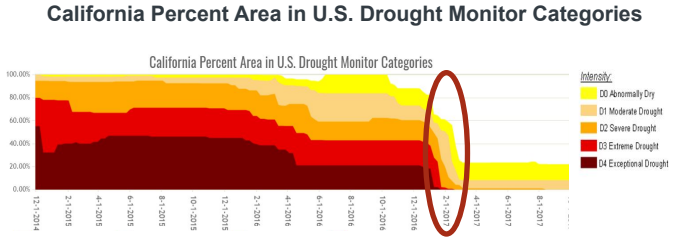


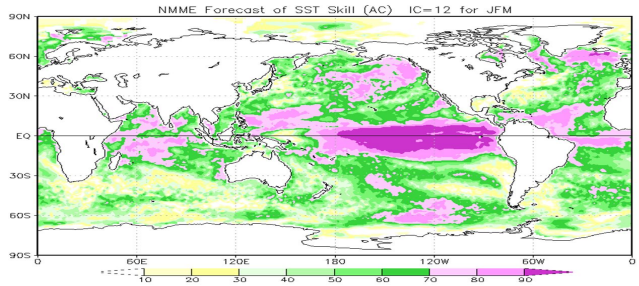
Forecast challenges

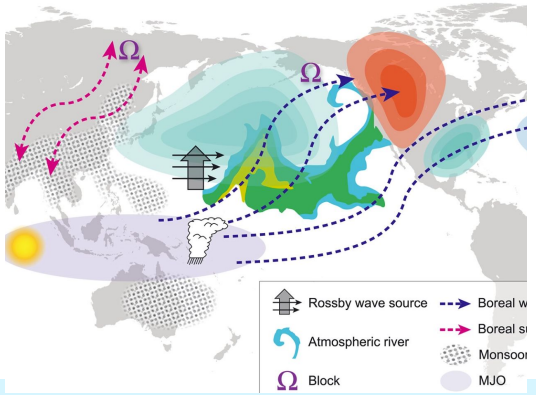
1. **Drought Amelioration** for example the termination of drought conditions by atmospheric rivers in 2017 and in 2022 was not predicted.
2. **Drought onset**, regime shift cannot be predicted beyond 1 week
3. **Monthly variability,** which months will be dry/rainy
4. **Tropical precipitation mean (double ITCZ) and variability**
5. **Tropical SST variability,** including for ENSO

Where we might focus to gain skill:

- MJO (propagation)
- QBO (stratospheric circulation)
- Blocking evolution







Weather, Subseasonal, & Seasonal Forecast Systems

Global Coupled Unified Forecast Systems (UFS)

Current Systems

GFS v16 (since March 2021)
Weather (0-14 days), deterministic,
no coupling with ocean/ice

GEFS v12 (since September 2020)
Subseasonal (0-35 days), ensemble,
no coupling with ocean/ice

CFS v2 (since March 2011)
Seasonal (0-9 months), ensemble,
coupled with ocean/ice.

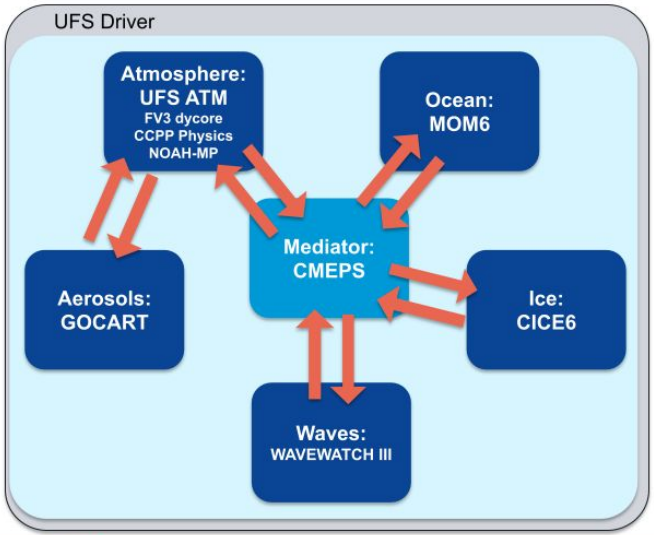
Future UFS Systems

GFS v17

GEFS v13

SFS v1

UFS System Configuration



8. Discussion on Extended Range (weeks and beyond)

1. Tell us what you need:
   a. Timescale of interest
   b. Spatial scale of interest
   c. How good is good enough?

2. Where do you get your information now?
   a. Products

3. Is there interest/capacity in co-development with NOAA of:
   a. Success targets and metrics?
   b. Products and sustained iteration toward useful information?