Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

NCEP
NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION

A Research AND Operations Partnership

NOAA

NATIONAL WEATHER SERVICE

Operational Impact of Atmospheric Rivers Reconnaissance: Results that Matter

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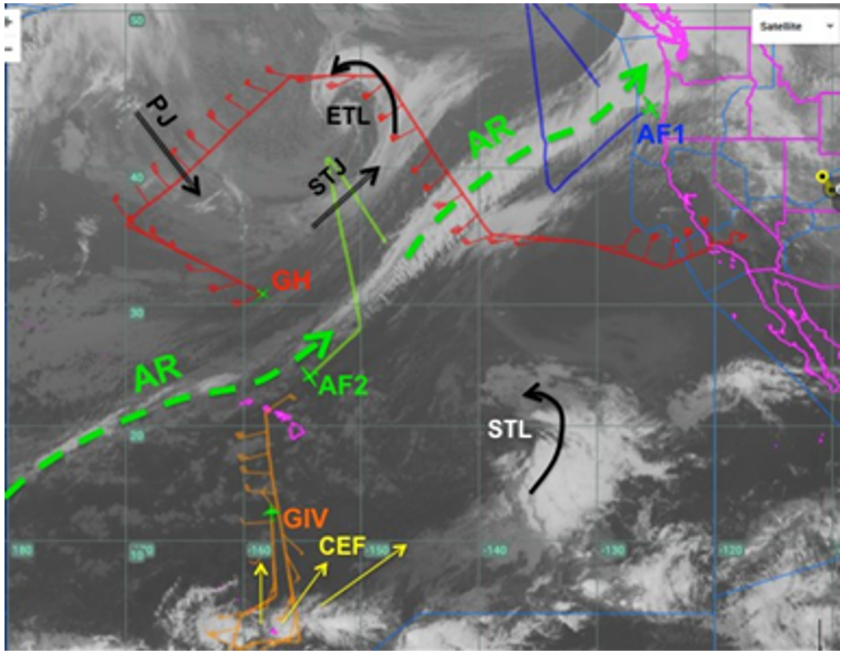
Seventh Annual Forecast Informed Reservoir Operations (FIRO) Workshop, August 4, 2020

Active regions of interest associated with Atmospheric Rivers (ARs)



AR Recon:

- Overarching goal: improve predictions of land-falling atmospheric rivers and their impacts in the western U.S.
- This program is a research AND operations partnership

An **AR**, **atmospheric jet features (black arrows)** associated with a **polar jet (PJ), subtropical jet (STJ), extratropical low (ETL), and subtropical low (STL),** and an area of upper-level **cross equatorial flow** (**CEF**; yellow arrows).

Improving NCEP Operational Global Model Forecasts using AR Recon Observations

Real-time planning for AR Recon sampling strategies:

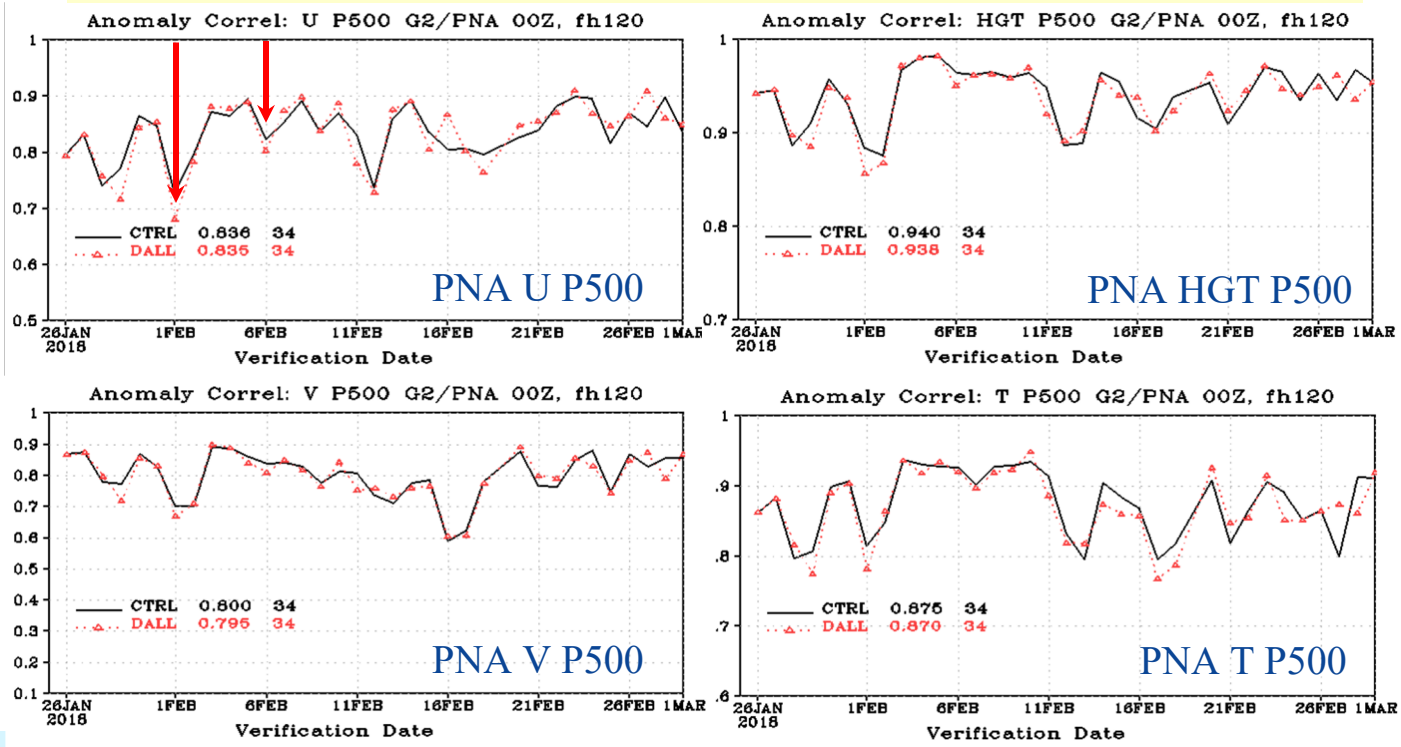
- Provide operational global model ensemble-based sensitivities representing model uncertainties
- Coordinate deployment of dropsondes from AR Recon flights to collect observations in a specific time period needed for real-time assimilation for Global Forecast System (GFS)
- Assimilation of dropsonde data in Global Data Assimilation System (GDAS)
- Conduct data denial experiments to document the impact of AR Recon observations

The Global Forecast System (GFS) is the cornerstone of NCEP's operational production suite of numerical model guidance.

Early Results: AR 2018: Pacific North American Region

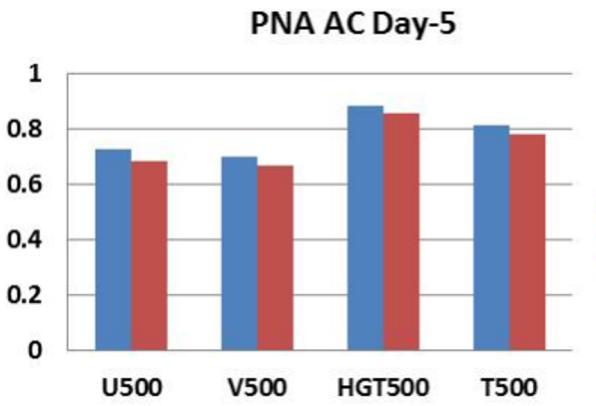
Operational GFS Control (CTRL) vs Denial all (DALL)

Positive impact with dropsondes

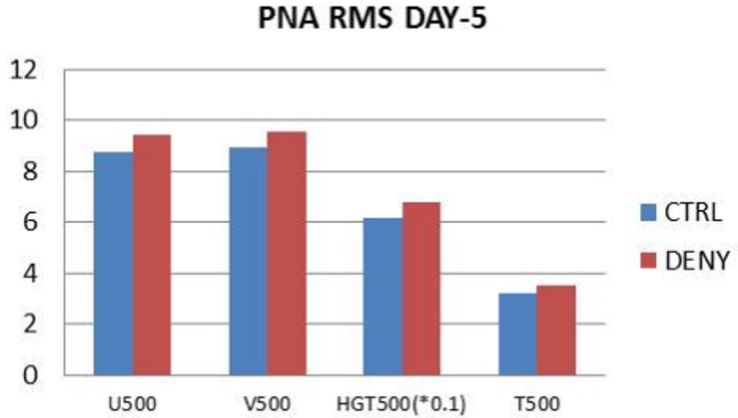


Dropout Case: Feb 1, 2018

AR 2018 Pacific North American (PNA) Region

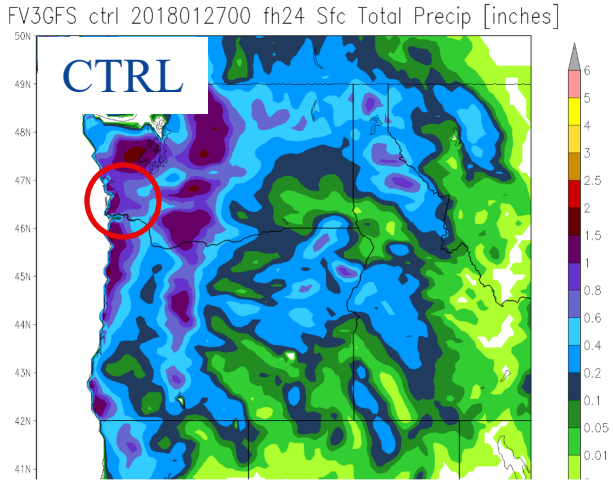


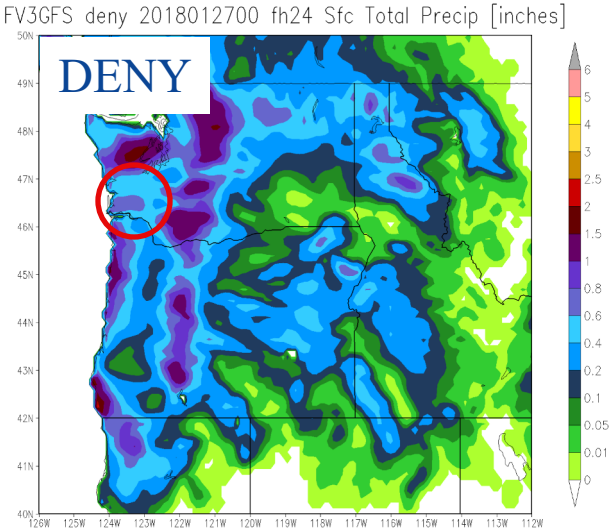
% of change U/6.6 V/4.4 HGT/3.0 T/4.0

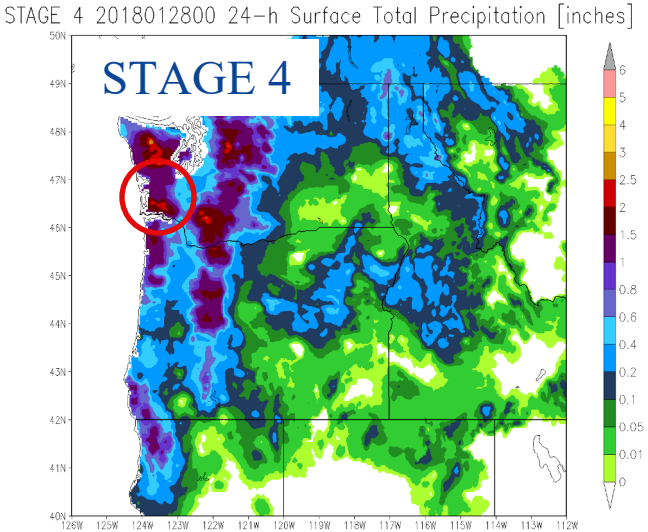


% of change U/7.8 V/6.6 HGT/10.0 T/8.1

6-10% improvement in large-scale forecasts for Pacific North American Region - indicative of data gaps in the North Pacific being addressed through AR Recon measurements







24-h forecast from 2018012700
24-h Total Precip

Positive impact with dropsondes for local precip

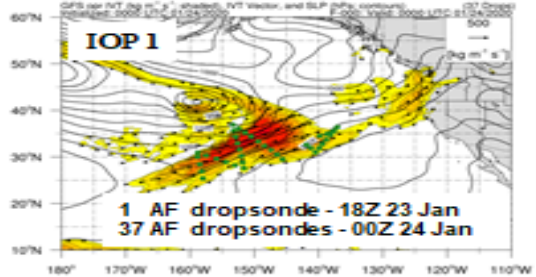
2019: Revisit AR Recon Data Impact Experiments

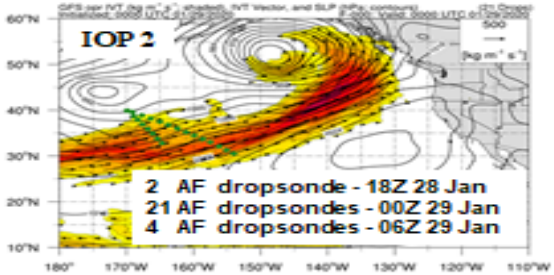
- **Control experiments based on Operational GFS**
  - 2016: Run FV3GFS with ENRR data
  - 2018: Run FV3GFS with both G-IV and C-130 data
  - 2019: Run FV3GFS with C-130 data
- **Data Denial Experiments**
  - Deny all ENRR/AR supplemental observations
- **Denial method:**
  - Flag specific observations by their SIDs in prepbufr files prior to analysis & forecast (the same as for GFS)
- Provide IC/BCs for CW3E WRF high-resolution modeling experiments

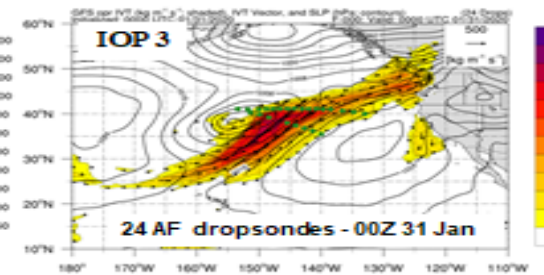
Summary of 2019 Data Impact Experiments

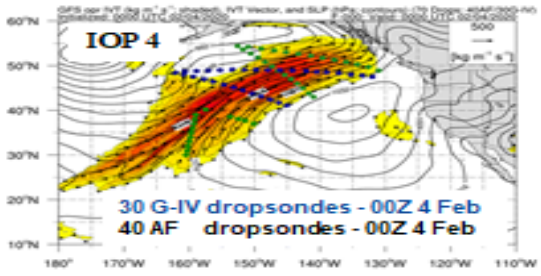
- **Positive impact on the GFS forecast skill for the Pacific-North American (PNA) region (180-320E 20-75N) overall.**
- **Data collected from the dropsondes helped to improve AR related precipitation forecasts and increase the 5-day anomaly correlation over PNA, including geopotential height, temperature, and wind.**
- **Data impact was greater when dropsonde observations from multiple aircraft (both C-130 and G-IV) were used. Data impact was also greater when sequential AR Recon missions were executed.**
- **The AR supplemental observations helped fill the data gaps needed for the data assimilation to provide better model initial conditions.**
- **Supplemental observations from AR had significant influence on local precipitation forecasts.**
- **Significant impact on wind analysis errors (17% improvement), was noted over the Pacific North American region**

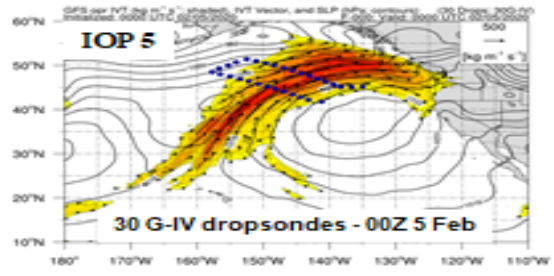
AR Recon 2020 IOP 1-9 (from 17 AR IOPs)

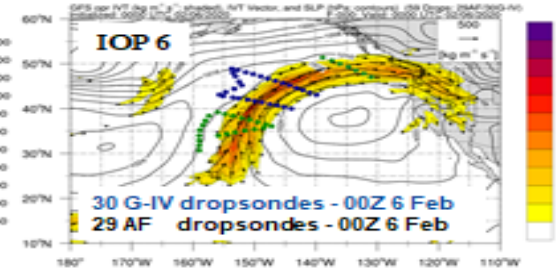


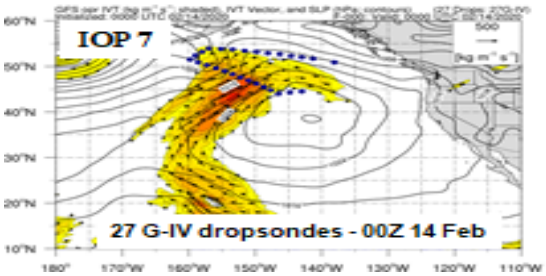


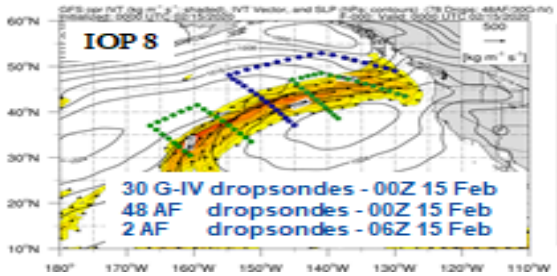


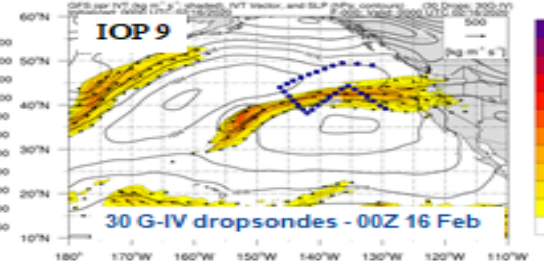




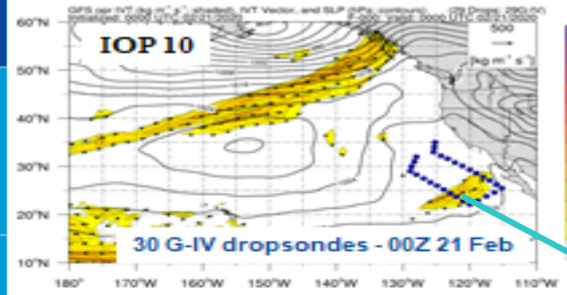


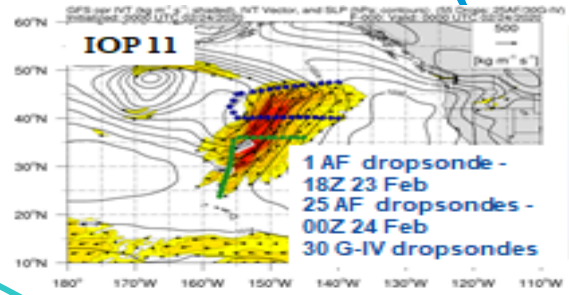


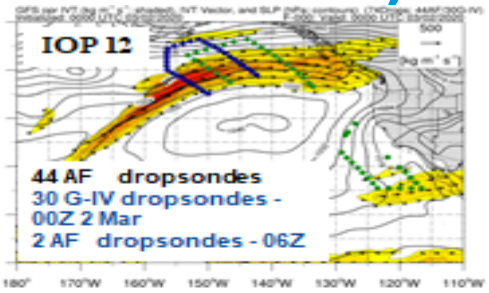


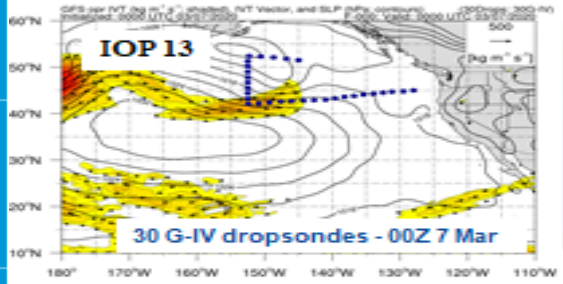


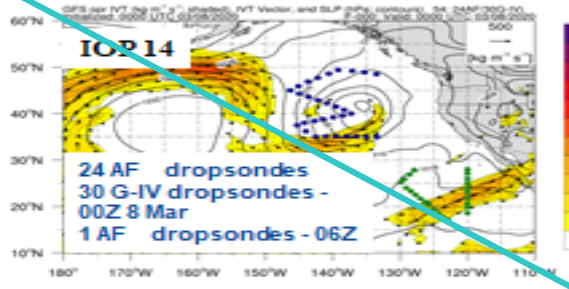
AR Recon 2020 IOP 10-17 (from 17 AR IOPs)

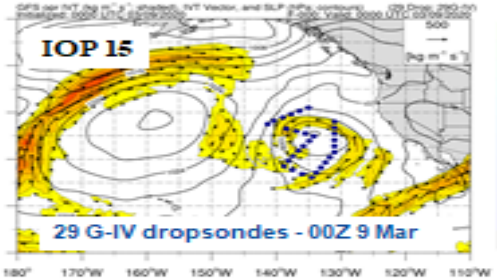


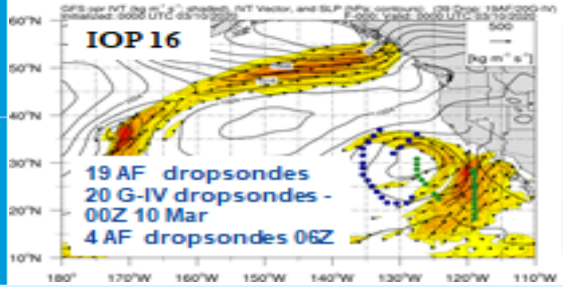


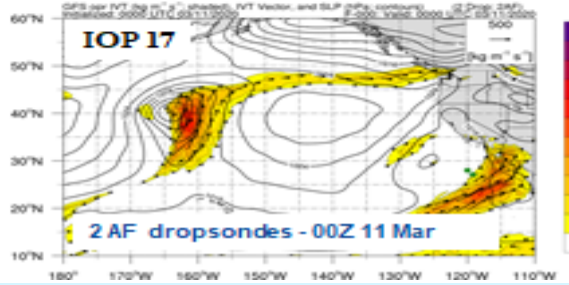










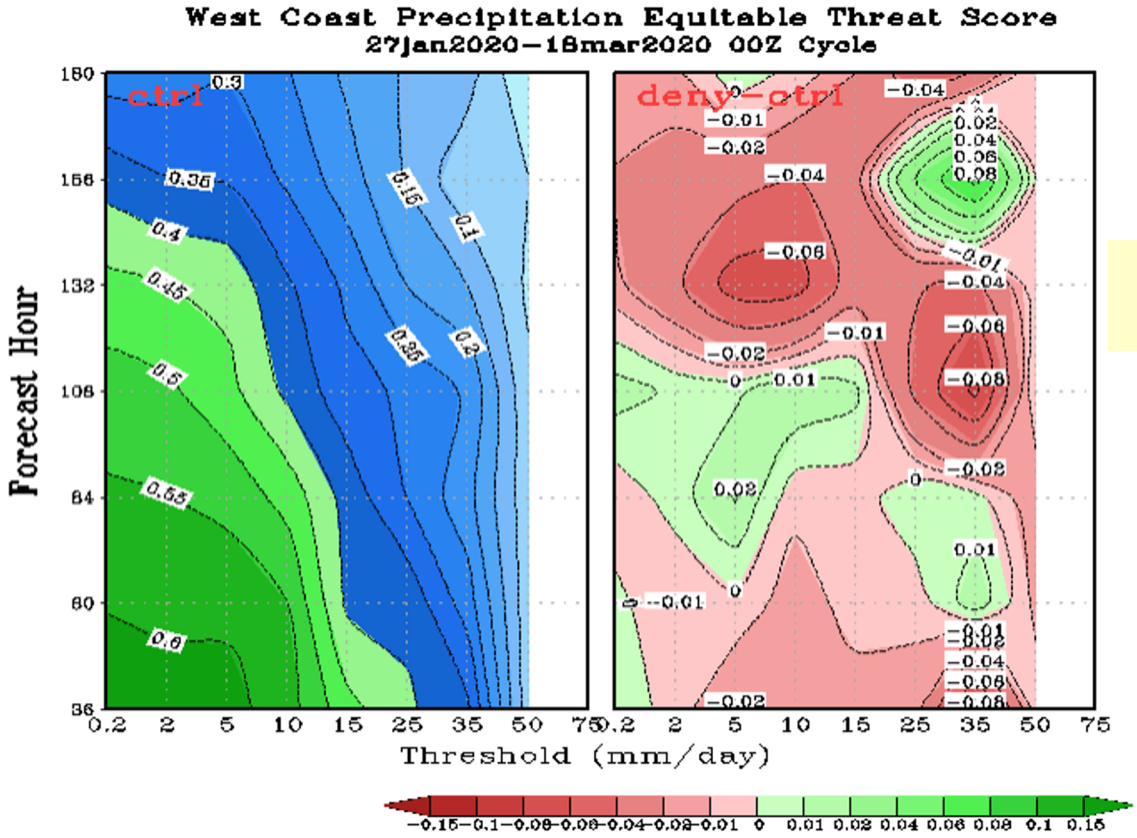


AR Recon 2020 Dropsondes Impact on Operational GFS

- Experiment period:
  - ➢ January 24 – March 18, 2020 (G-IV and C-130)
- Supplemental observation types to be denied:
  - ➢ Dropwindsonde - NOAA G-IV, C-130
- Modeling system: GFSv15
  - ➢ In operations June 12, 2019
  - ➢ Finite-Volume Cubed-Sphere Dynamical Core (FV3)
  - ➢ GFDL Microphysics Scheme with Multiple Prognostic Cloud Hydrometers
- **Focus on Regional Impacts**
  - ➢ **Comprehensive assessment of forecast improvements in the West Coast**
  - ➢ **Results that matter….**

West Coast PRECIP ETS Scores Jan-Mar 2020

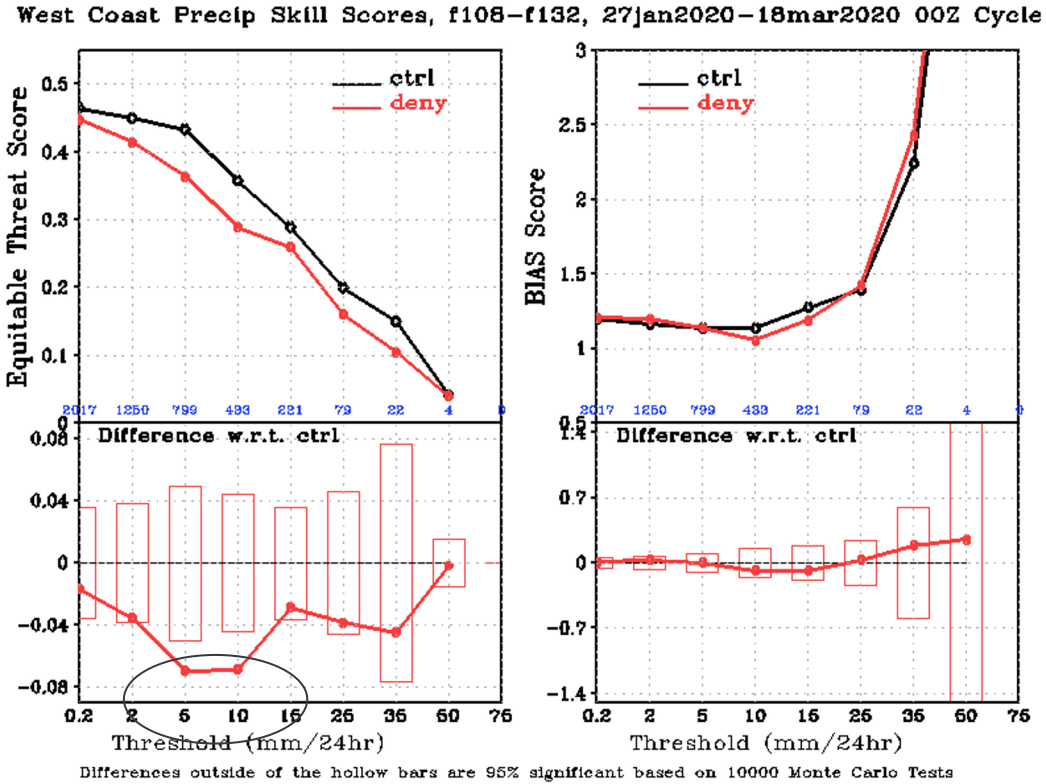
GFSv15 Control (ctrl) vs Denial (deny)



positive impact with dropsondes

West Coast 120 hr PRECIP ETS and BIAS Scores: Jan-Mar 2020

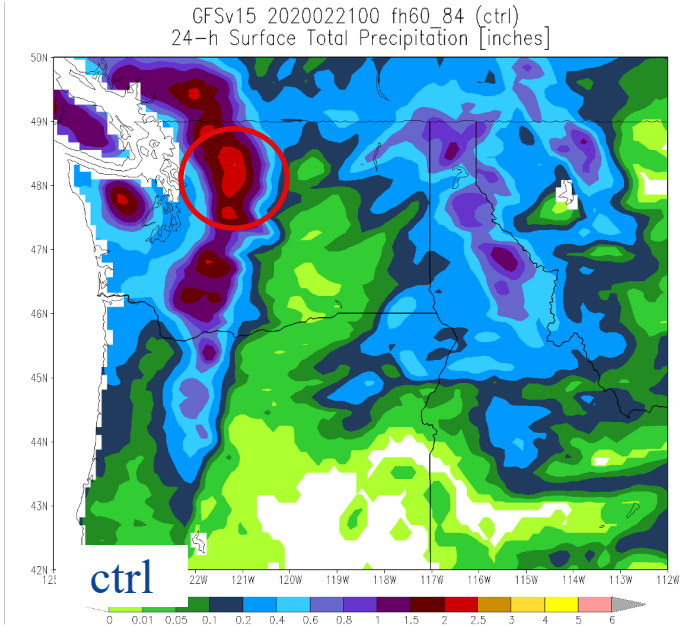
GFSv15 Control (ctrl) vs Denial (deny)

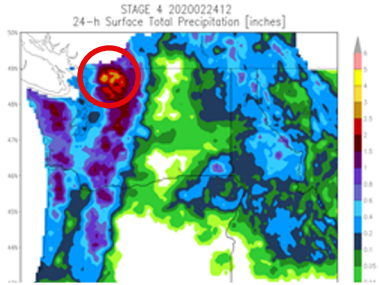


Significant Positive impact with dropsondes at day 5 (120-h)

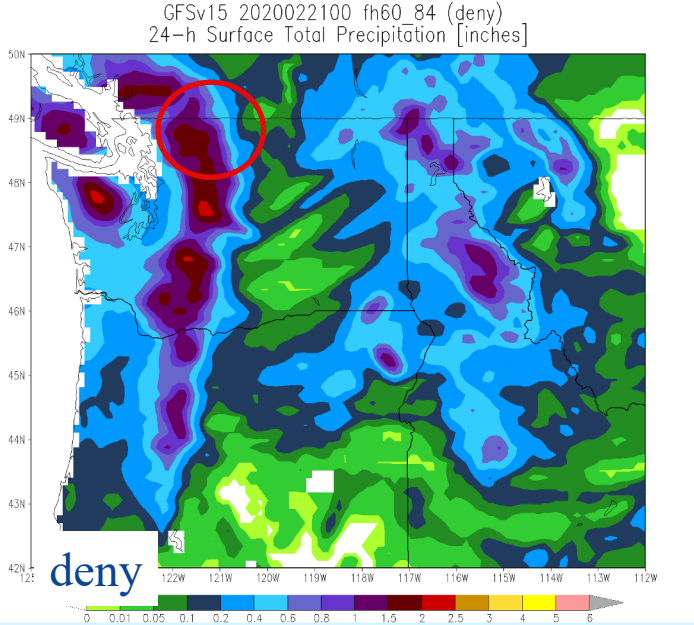
GFSv15 PRECIP: 72-hr Forecast

IC: 2020022100 (IOP 10)



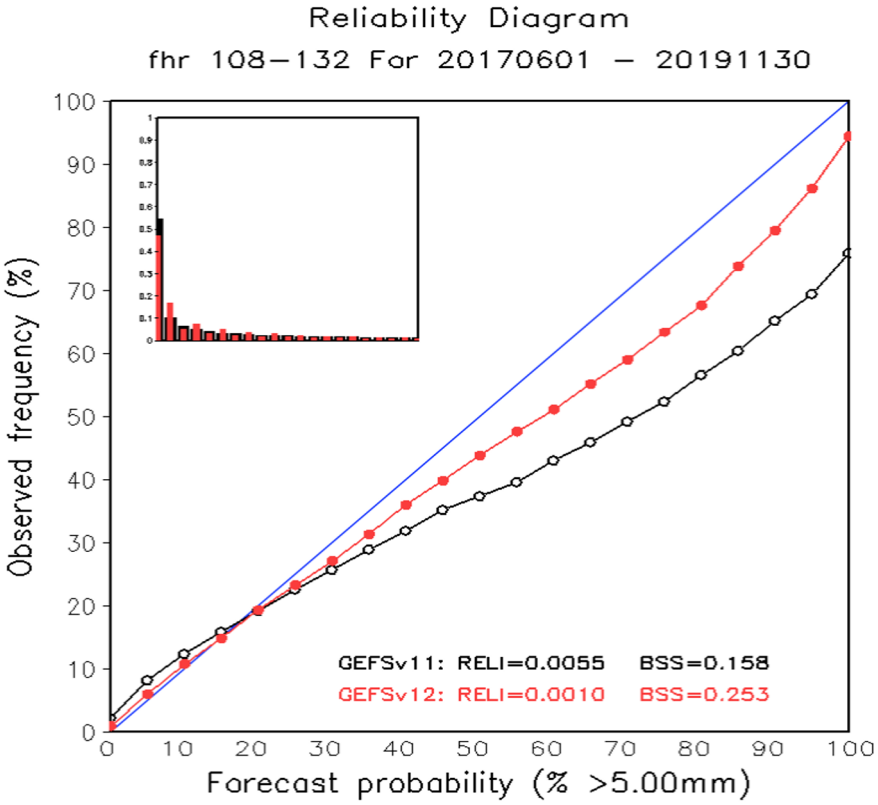


stage4

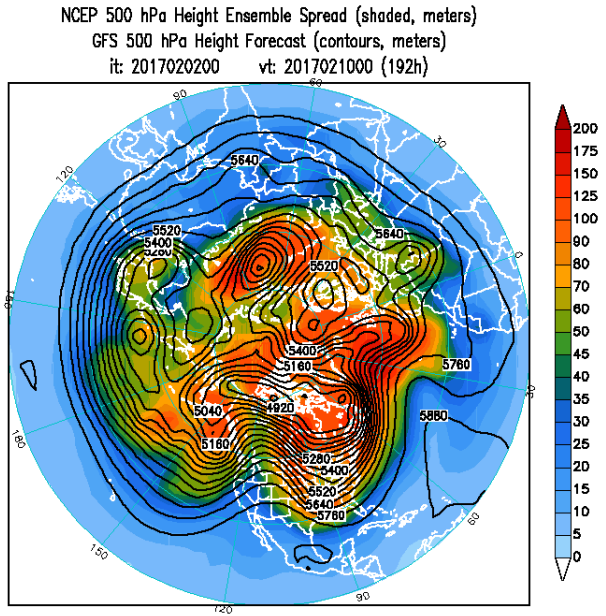


GFS captures intense precipitation amounts more accurately

Impact on Global Ensemble Forecast System (GEFSv12)



Much improved reliability of precipitation forecasts

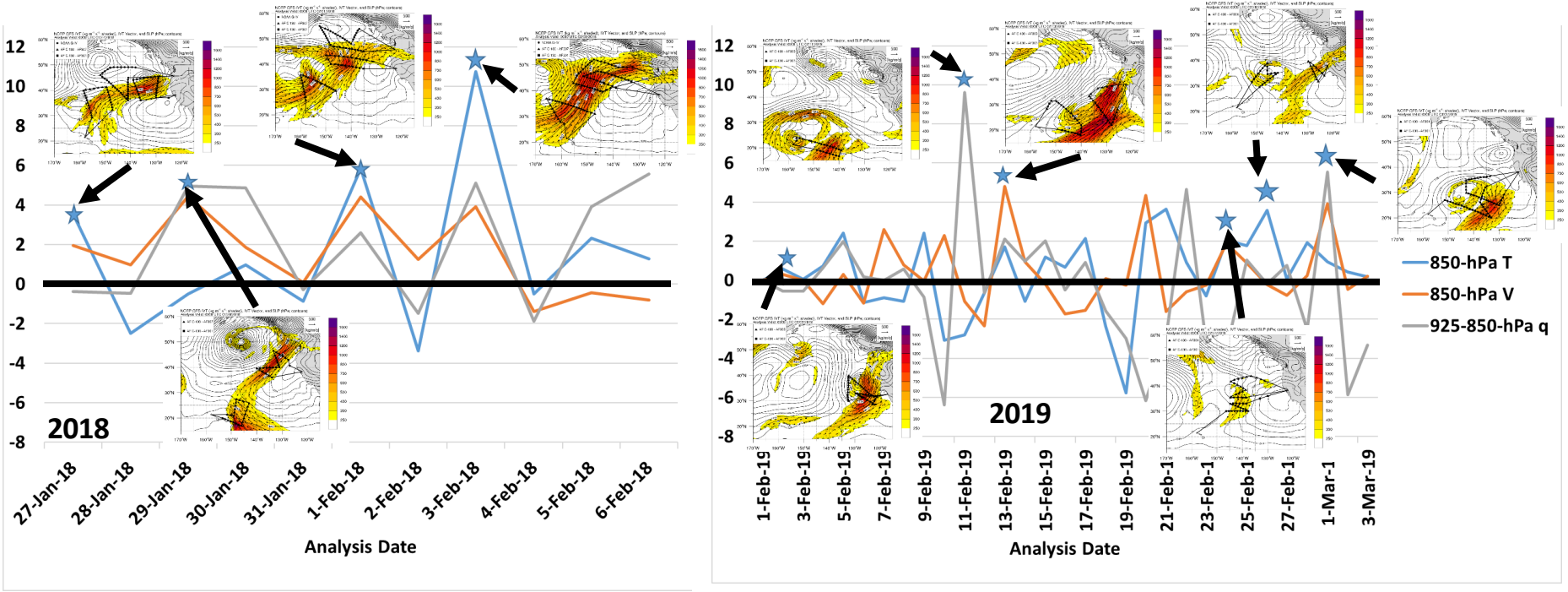


New Unified Forecast System (UFS) based sub-seasonal predictions from 31-member Global Ensemble Forecast System (GEFSv12, to be implemented in September 2020)

Collaborative AR Recon Research: NRL

FSOI Impact Studies: AR Recon Dropsondes and Buoys

% Reduction in RMS Difference between NAVGEM and ECMWF Analysis with RECON Data



- Some evidence that assimilation of RECON dropsondes draws analyses closer together, by as much as 11 %.
- No convincing evidence that the assimilation of dropsondes reduces standard error metrics over North America.
- Next steps: Large sample size (17 IOPs) in 2020, may help with sampling issue. Also consider precipitation and IVT metrics.

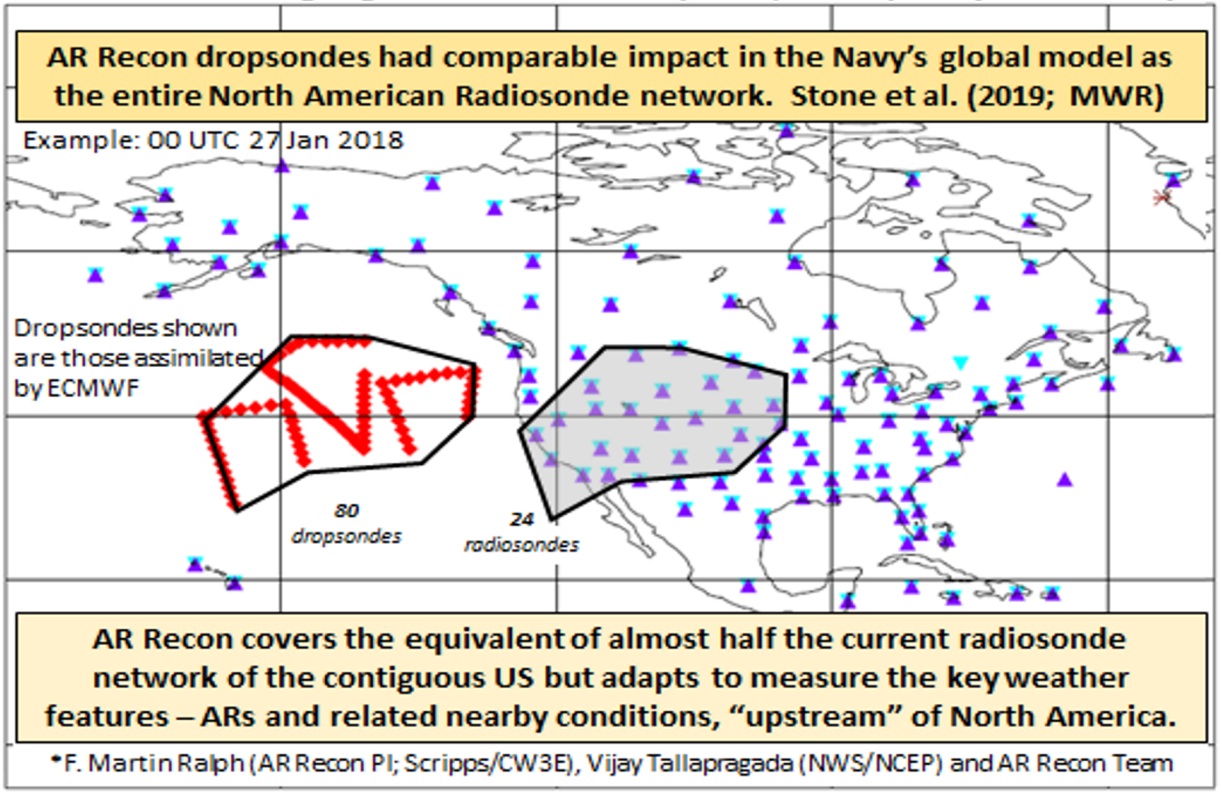
U.S. NAVAL RESEARCH LABORATORY

Collaborative AR Recon Research: NRL

Extent and impact of AR Recon Dropsondes comparable to the whole North American Radiosonde Network

Atmospheric River Reconnaissance* Aerial Coverage Compared to North American Radiosonde Network and Highlights of Stone et al. (2019, MWR) Navy-Model Impact Study

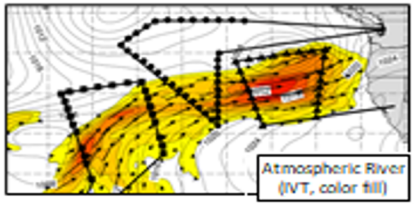
AR Recon dropsondes had comparable impact in the Navy's global model as the entire North American Radiosonde network. Stone et al. (2019; MWR)



AR Recon covers the equivalent of almost half the current radiosonde network of the contiguous US but adapts to measure the key weather features – ARs and related nearby conditions, "upstream" of North America.

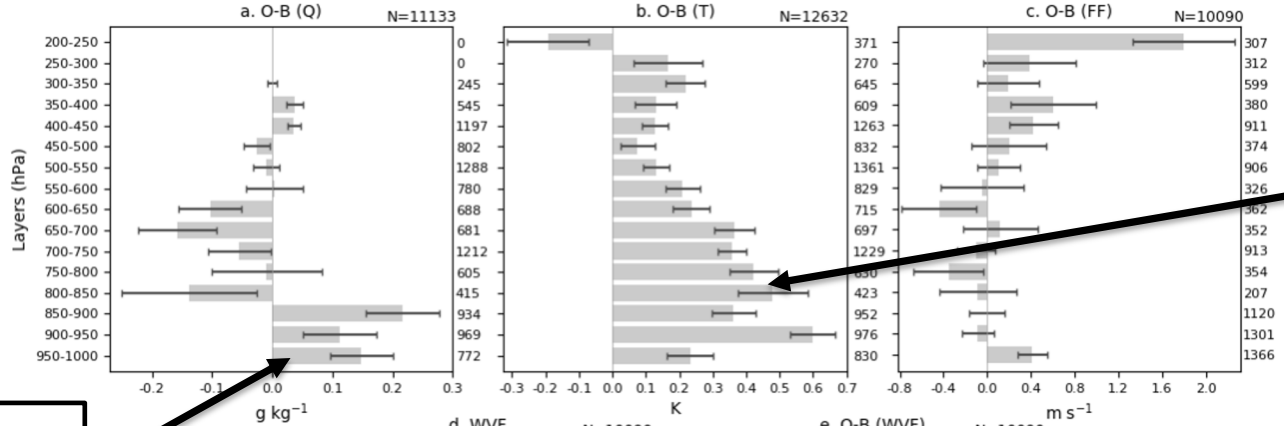
*F. Martin Ralph (AR Recon PI; Scripps/CW3E), Vijay Tallapragada (NWS/NCEP) and AR Recon Team

Slide by F.M. Ralph
Map courtesy of ECMWF



"The 24-h global forecast error reduction from the reconnaissance soundings can be comparable to the reduction from the North American radiosonde network for the field program dates that include at least two flights." (Stone et al. 2019; MWR)

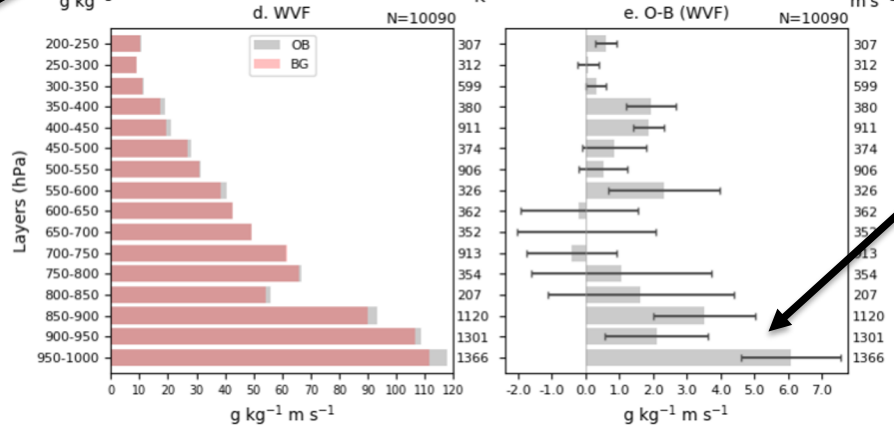
Collaborative AR Recon Research: ECMWF



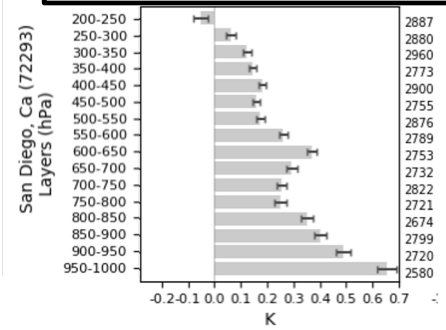
Cold bias - observations are warmer than the model.

Dry bias - observations have higher specific humidity.

Weaker model vapor fluxes below 850 hPa.



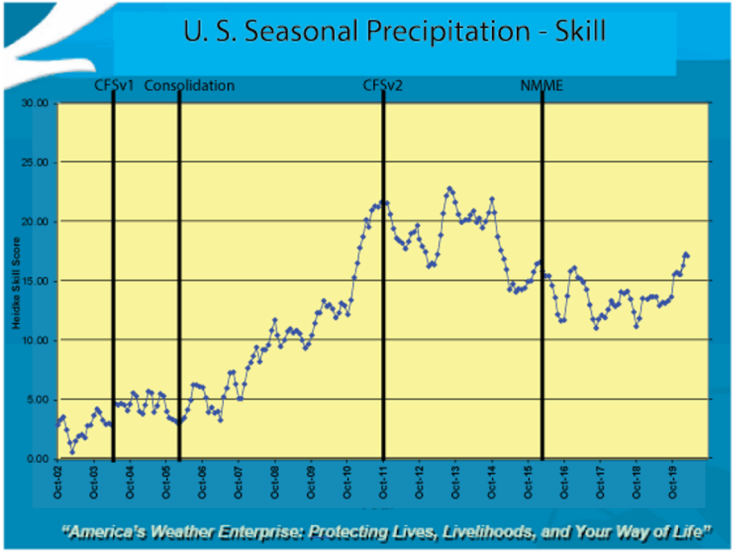
Temperature at land-based radiosonde site.

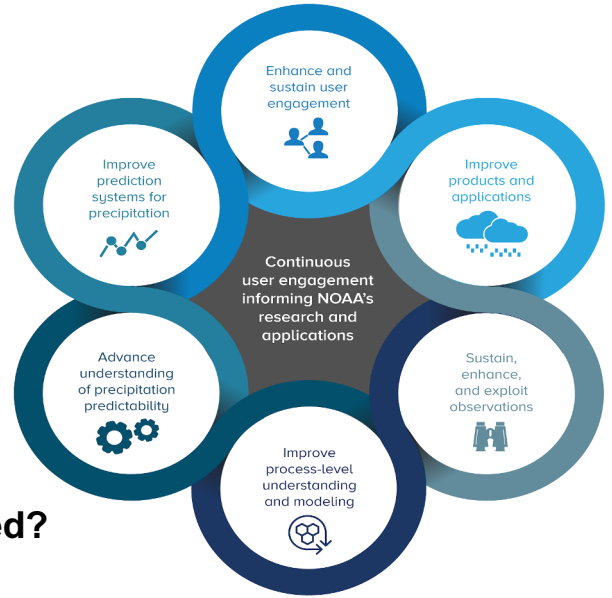


Observation-minus-Background (O-B)

Precipitation Prediction Grand Challenge

Strategic Goal: Provide more accurate, reliable, and timely precipitation forecasts across timescales from weather to subseasonal-to-seasonal (S2S) to seasonal-to-decadal (S2D) through the development and application of a fully coupled Earth system prediction model





What is needed?

- Integrated research-to-operations effort focusing on the weather-water-climate linkage
- Model improvements, observational enhancements, and research for improved forecast information from the end user community, especially those involved in water resource and emergency management.

Summary and Future Work

- Preliminary analysis indicates GFS forecast have improved for the PNA due to assimilation of AR Recon dropsondes.
- The AR supplemental observations helped fill the data gaps needed for the data assimilation to provide better model initial conditions.
- **There is positive impact on the GFS forecast skill for the precip along the West Coast.**
- **Next Steps:**
  - Continue to evaluate the impact of data on initial analysis and short-term error growth for selected AR cases.
  - Assimilate pressure and temperature from the AR drifting buoys and examine impact on GFS prediction.
  - Conduct case studies (e.g., cut-off lows) to identify sources of model errors that can be rectified in GFS.
  - Evaluate new and existing strategies for improving precipitation forecasts through enhanced use of dropsonde data.
  - Expand the data impact experiments using high-resolution stand-alone regional modeling system.
  - Develop operational ensemble sensitivity tool to provide real-time inputs and guidance for dropsonde deployment for AR Recon 2021 and beyond.