Impact of Atmospheric River Reconnaissance Dropsonde Data on NCEP Operational GFS Forecasts

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HMT Seminar Series (PEAR and WWE)
February 11, 2025

NATIONAL WEATHER SERVICE

Key Messages for Mid-February Atmospheric River

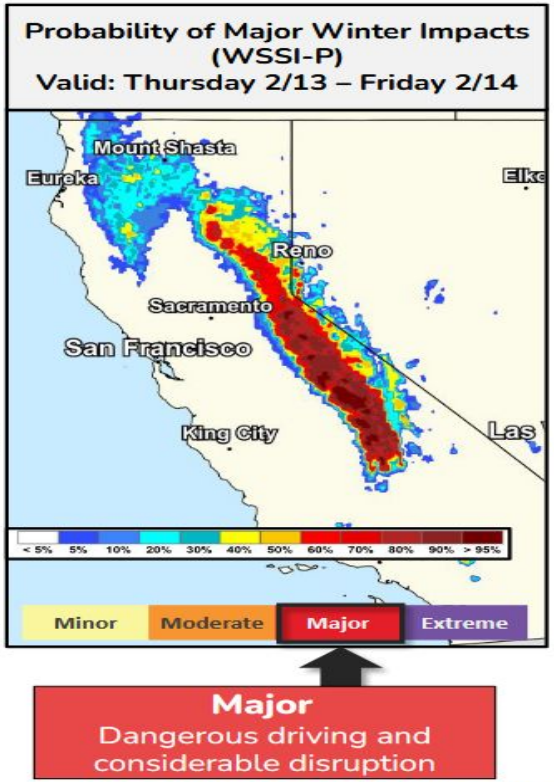
Updated Feb. 10, 2025
12:30 PM PST

Periods of heavy rainfall and snow to impact much of California later this week

- **Flooding Potential to Increase with Atmospheric River Rainfall**
  A new atmospheric river arriving Wednesday night will bring heavy and impactful rains to central and southern California going through Thursday night. There is a Slight Risk of excessive rainfall from the coastal ranges into the Central Valley and the Sierra Nevada foothills.

- **Dangerous Burn Scar Flash Flooding and Debris Flows Possible**
  Very sensitive burn scar areas of southern California in particular will be at risk for dangerous flash flooding including debris flows with this event.

- **Significant Mountain Snow**
  Heavy snow will fall over the Sierra Nevada and northern California terrain Thursday into Saturday. Snow levels will rise through the event, but heavy snow is likely to cause dangerous travel at many of the area passes due to snow-covered roads and low visibility.

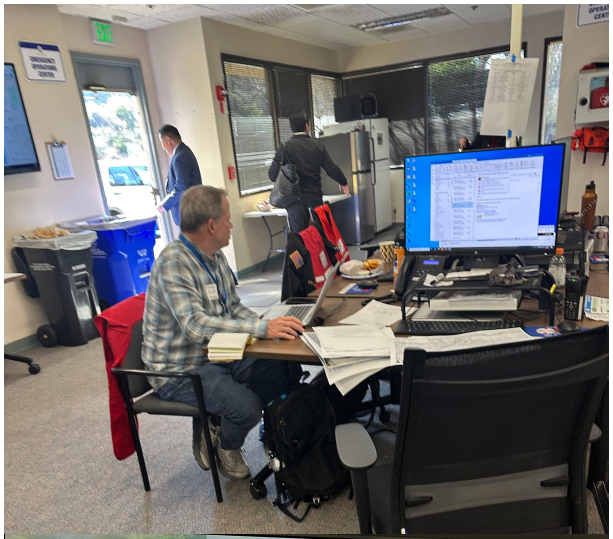


National Oceanic and Atmospheric Administration
U.S. Department of Commerce

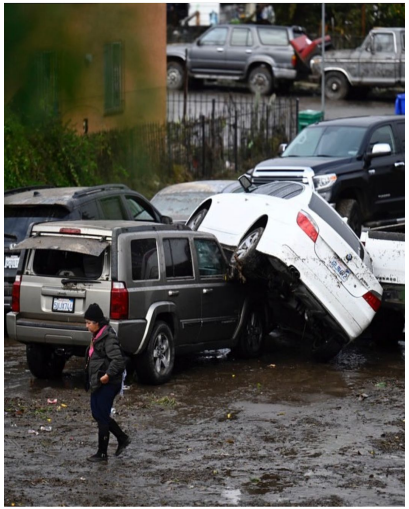
For more information go to:
www.wpc.ncep.noaa.gov and www.weather.gov

Weather Prediction Center
College Park, MD

Atmospheric River Impacts San Diego County January 22, 2024 with 1000-Year Flood



fox5sandiego

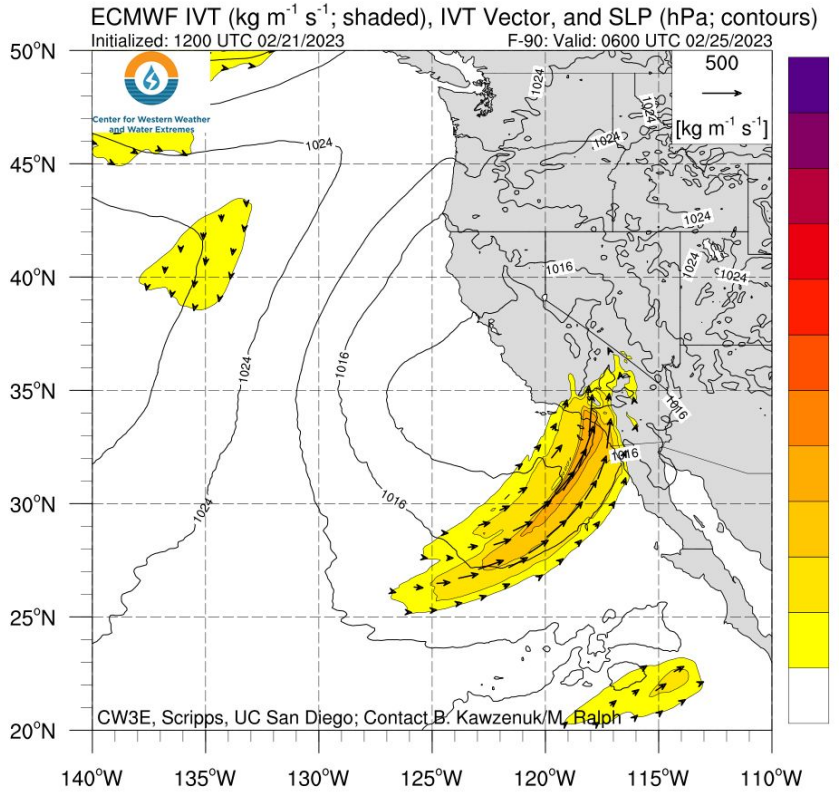


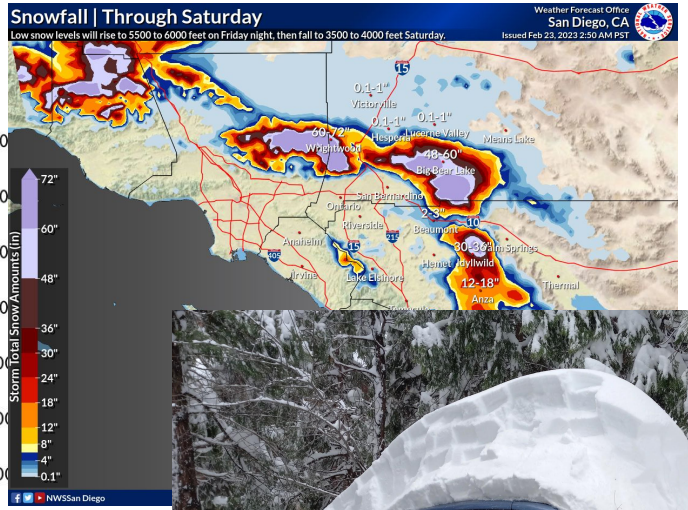
5,946 likes

fox5sandiego STORM DAMAGE 🌧️ Heavy rain and flooding on Monday in the San Diego area caused serious damage to vehicles, homes and roads More on the aftermath via the link in our bio. 📷: @apnews Denis Poroy/ Gregory Bull #fox5sandiego #storm #rain #flooding

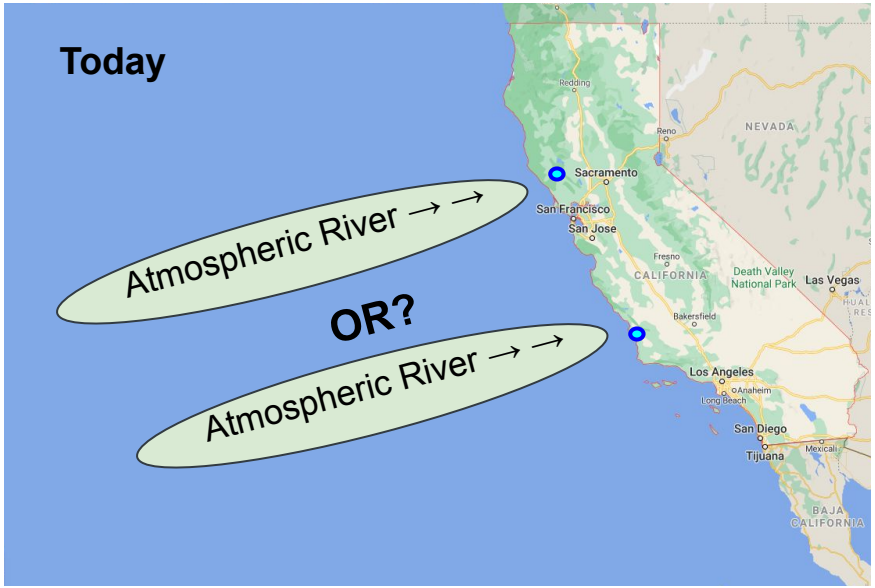
Atmospheric River Impacts LA County: February 4-6, 2024

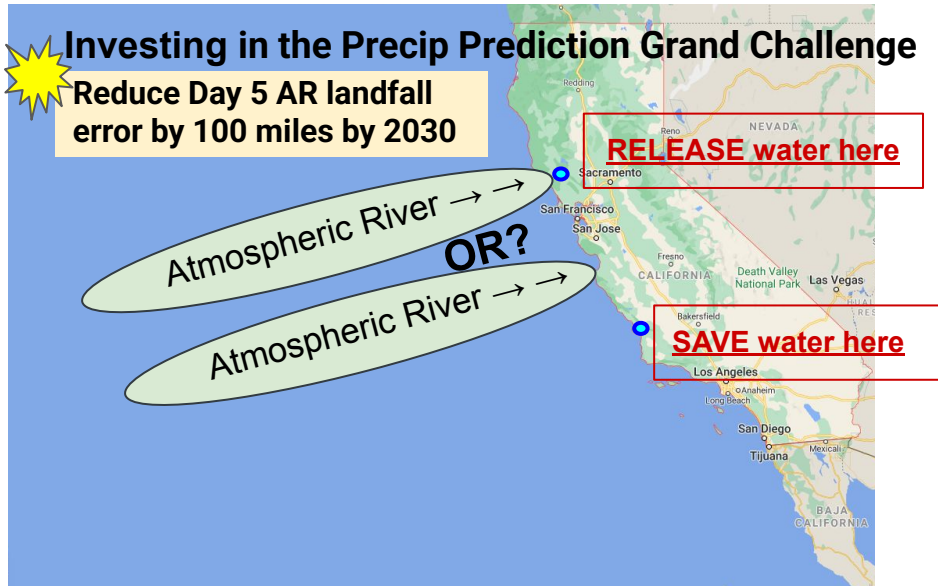
Feb 2023: First Ever Blizzard Warning in Southern California!





Priorities: Improve AR Predictions for US West Coast





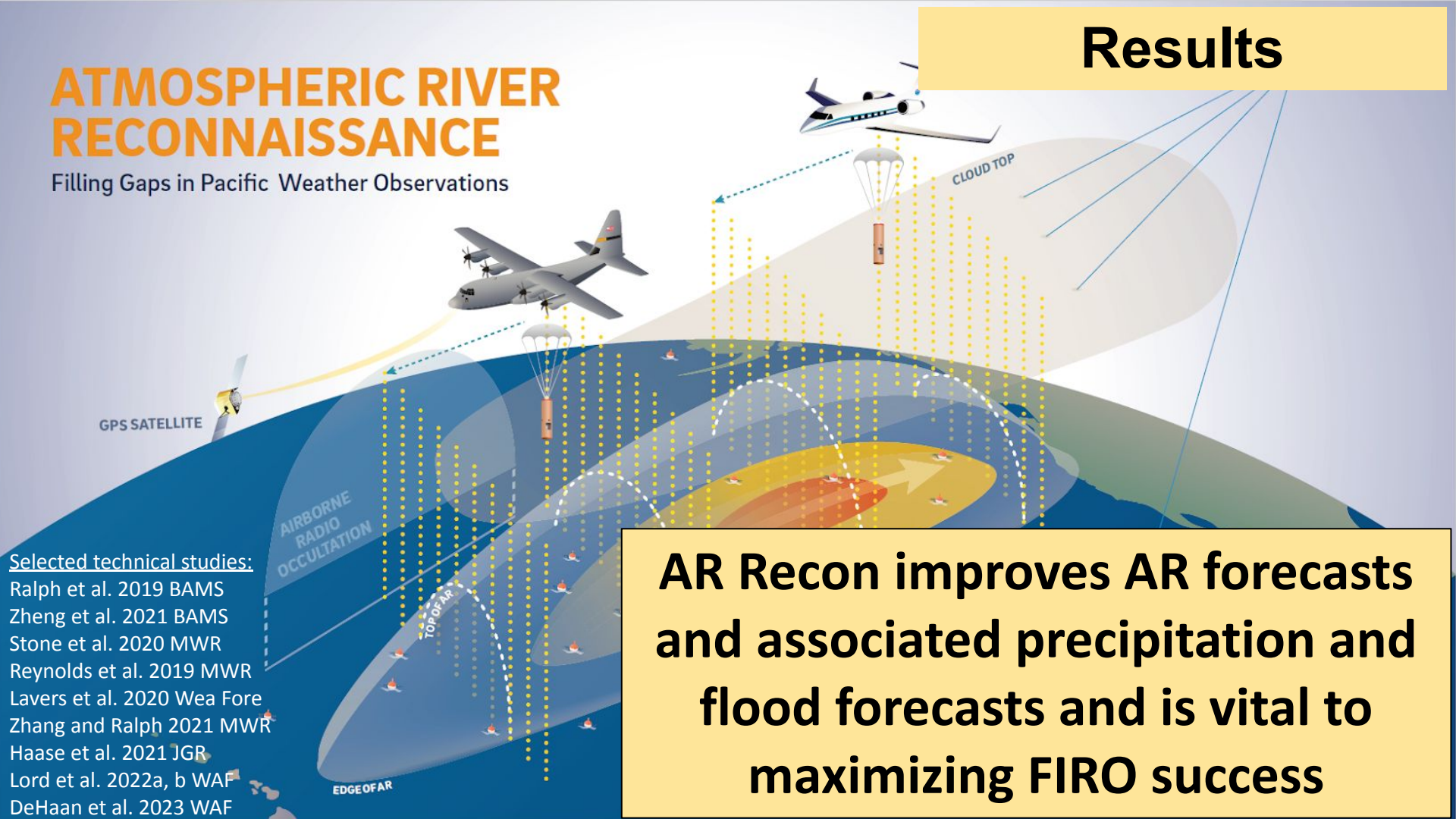
Actions?

- Not really sure where to pre-position resources
- Decision makers simply WAIT to act

Actionable information

- The State pre-deploys assets to San Francisco
- Emergency Operations Center activates
- The Lake Medocino Reservoir *releases* water to avoid catastrophic flood
- The Twitchell Reservoir *saves* water - enough to serve water to 10,000 households / yr

Results



Selected technical studies:
Ralph et al. 2019 BAMS
Zheng et al. 2021 BAMS
Stone et al. 2020 MWR
Reynolds et al. 2019 MWR
Lavers et al. 2020 Wea Fore
Zhang and Ralph 2021 MWR
Haase et al. 2021 JGR
Lord et al. 2022a, b WAF
DeHaan et al. 2023 WAF

AR Recon improves AR forecasts and associated precipitation and flood forecasts and is vital to maximizing FIRO success

Operational Goals for AR Recon at NCEP

- Overarching goal: improve operational predictions of land-falling atmospheric rivers and their impacts in the western U.S.
- Enhance the use of aircraft observations in modeling and data assimilation
- Design and develop ensemble based objective sampling strategies
- Run (near) real time data denial experiments
- Improve verification techniques

Outline

- Overview of AR Reconnaissance
- Research and Operations Partnership for AR Recon
- AR recon is official through NWSOP
- Data Gaps associated with ARs
- Ensemble and adjoint based sampling strategies
- Impact of dropsonde data on NCEP operational GFS
- Multi-agency collaborations
- Current progress and future work

Lessons learned from Hamill et al. 2013

- Hamill et al. 2013 resulted in suspension of Pacific Recon since then. Using 2011 recon data, Hamill et al. suggested statistically insignificant impact on global forecasts and hence recon is not a cost-effective way to improve forecasts.
- Cited reasons include denser observations, improved modeling and DA methods, incomplete sampling due to limitations etc.
- The current AR Recon Program revisits these issues, analyzes the data gaps, employs better sampling strategies using operational ensembles and adjoint methods, and directly uses operational models to evaluate the forecast impacts of dropsonde data.

Atmospheric River Reconnaissance Background (2016-2024+)

AR RECON
Research And Operations Partnership

OVERARCHING GOAL

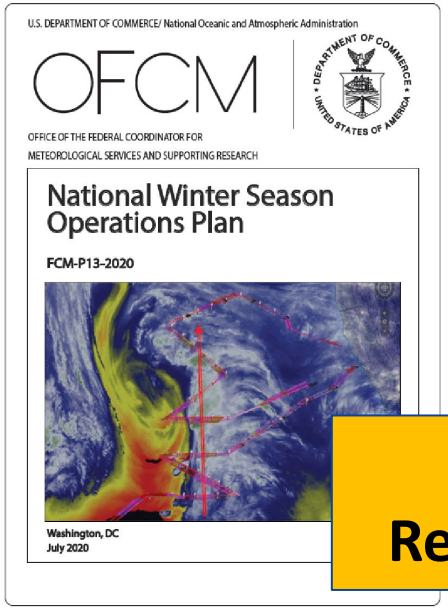
Atmospheric River Reconnaissance Strives to Improve Predictions of Land-falling Atmospheric Rivers and Their Associated Impacts in the Western U.S.

- Has transitioned from field demonstration to an **operational requirement through NWSOP**
- Organized and led as a **Research And Operations Partnership**
- Uses Air Force C-130s and the NOAA G-IV; uses dropsondes, flight level data, airborne radio occultation, pressure-enabled drifting buoys
- Flight planning and calling of missions is carried out by a diverse team of scientists and forecasters
- "Steering committee for modeling and data assimilation" enables multi-agency impact assessments
- Robustness of results are established through scientific peer-review

F. Martin Ralph (UCSD/SIO/CW3E) - PI
Vijay Tallapragada (NWS/NCEP) - Co-PI
Anna Wilson (UCSD/SIO/CW3E) - Coordinator

National Winter Season Operations Plan Includes AR Reconnaissance Off the U.S. West Coast Starting in 2020

In Spring 2019, the interagency group that develops the NWSOP approved incorporation of AR Recon as a leading priority for addressing gaps in west coast storm prediction, specifically targeting ARs and their vicinity over the Pacific with NOAA and Air Force Recon capabilities.


U.S. DEPARTMENT OF COMMERCE/ National Oceanic and Atmospheric Administration

OFCM

OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

National Winter Season Operations Plan

FCM-P13-2020

Washington, DC
July 2020

Cover Image: AR Recon tracks (AFRC/53 WRS WC-130J aircraft) from 24 February 2019 on GOES-17 water vapor imagery (warm colors delineate dry air and white/green colors delineate cold clouds). White and brown icons indicate dropsondes. The red arrow indicates the AR axis.

Foreword

The purpose of the National Winter Season Operations Plan (NWSOP) is to coordinate the efforts of the Federal meteorological community to provide enhanced weather observations of severe Winter Storms impacting the coastal regions of the United States. This plan focuses on the coordination of requirements for winter season reconnaissance observations provided by the Air Force Reserve Command's (AFRC) 53rd Weather Reconnaissance Squadron (53 WRS) and NOAA's Aircraft Operations Center (AOC).

The goal is to improve the accuracy and timeliness of severe winter storm forecasts and warning services provided by the Nation's weather service organizations. These forecast and warning responsibilities are shared by the National Weather Service (NWS), within the Department of Commerce (DOC) and the National Oceanic and Atmospheric Administration (NOAA); and the weather services of the United States Air Force (USAF) and the United States Navy (USN) , within the Department of Defense (DOD).

Within the organizational infrastructure of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM), the Working Group for Winter Season Operations (WG/WSO) is responsible for maintaining the plan. This year marks the 35th edition of the National Winter Season Operations Plan (NWSOP).

The national winter season mission is a team effort, and as we strive to be a "Weather-Ready Nation," the effective coordination of the Federal agencies involved, local emergency managers

AR Recon represents a Research And Operations Partnership

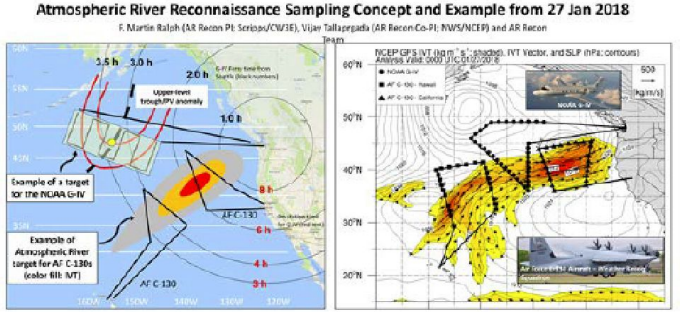


Figure 1-1. Atmospheric river reconnaissance targeting concept and example using 3 aircraft, executed on 27 Jan 2018. In addition, moist adjoint method is used to identify regions of large initial condition error impacts, which largely match the location of the AR.

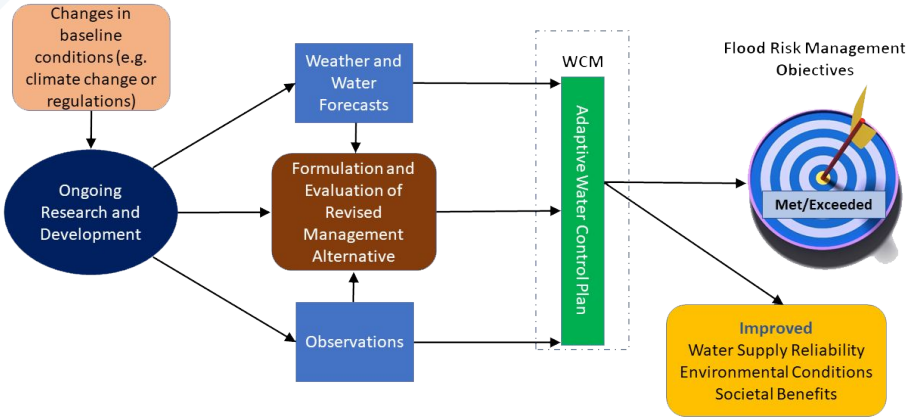
raft operations may begin as early as five days prior
ndfall. The frequency of flights during operations is
eeds of forecast models, however, may include up to
ture centered around 0000 UTC. During operations,
or at UCSD/SIO/CW3E identifies important AR
nd data collection requirements via either the NWS
ector, EMC representative or WPC representative to
EP Central Operations. CARCAH works with the SDM to determine the ability of reconnaissance units to meet requirements, considering the availability of resources with mission requirements and incorporates tasked requirements into the Winter Season Plan of the Day (WSPOD).

AR RECON: A WORLD WEATHER RESEARCH PROGRAM (WWRP) ENDORSED PROJECT

AR Recon has developed the tools and network necessary to incrementally **improve the warning process for extreme weather events** and **reduce prediction uncertainty**.

Key sponsors include the U.S. Army Corps of Engineers and the California Department of Water Resources, who are working to advance their goals of **using improved AR prediction to inform water and infrastructure management.**

FIRO Model for
Adaptive Water Control Manuals



West Coast Forecast Challenges and Development of AR Recon

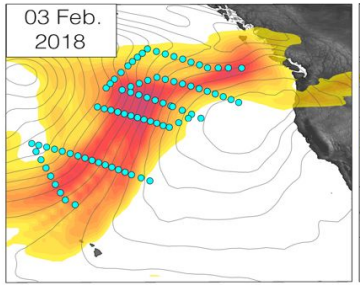
*Bull. Amer. Meteorol. Soc. (in press 2020)**

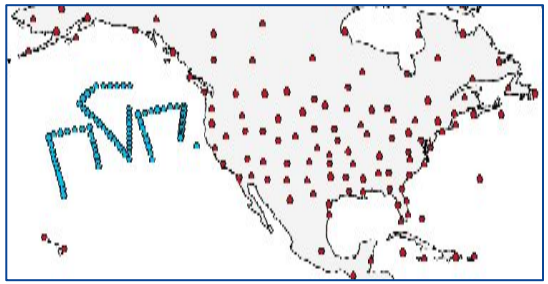
Capsule Summary: Atmospheric River Reconnaissance is a multi-year research and operations partnership to evaluate the potential of targeted airborne observations over the Northeast Pacific to improve forecasts of atmospheric river impacts on the U.S. West Coast at lead times of less than five days.

Major Milestones in developing AR Recon

Table 4. Major milestones in the development of AR Recon

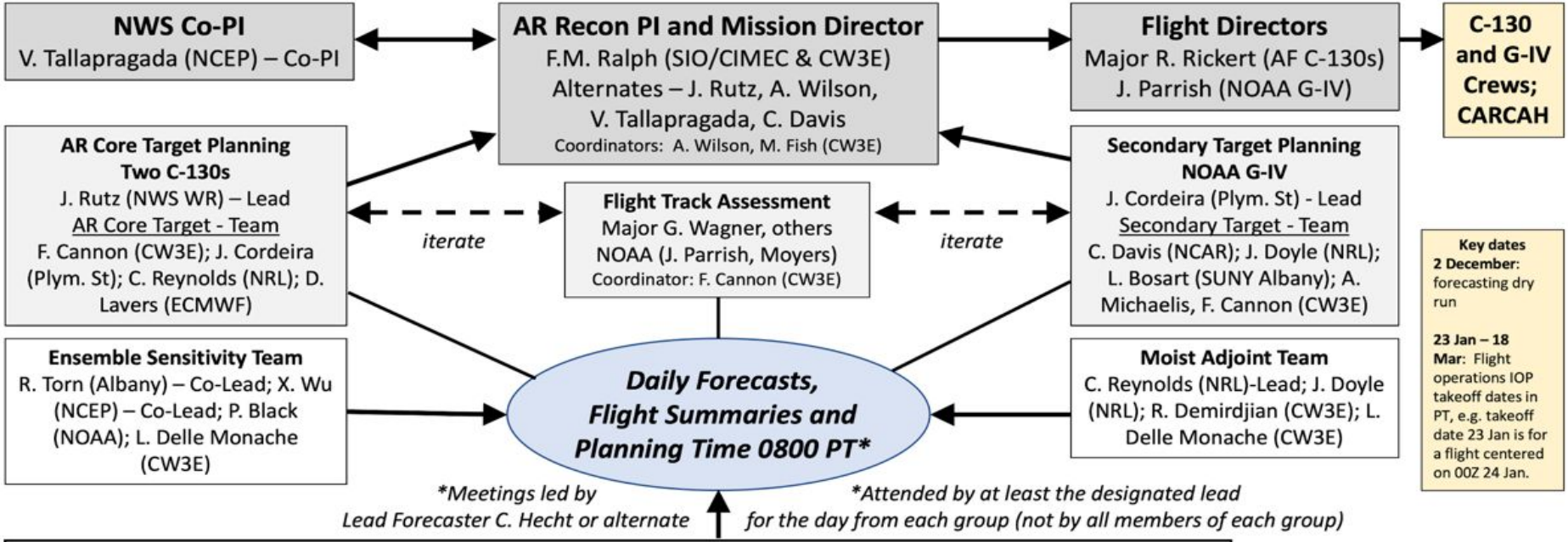
Milestones	2016	2017	2018	2019	2020
U.S. Army Corps of Engineers begins support of AR Recon through the CW3E Forecast Informed Reservoir Operations Program	X				
1st dedicated AR Recon flights in partnership with NCEP, with 2 USAF C-130 aircraft. 6 total flights and 272 dropsondes released	X				
Assessment of lessons learned in 2016, and planning for 2018 season		X			
AR Recon 2016 data help define AR dynamics and kinematics in the American Meteorological Society Glossary (Ralph et al. 2018)		X			
California Department of Water Resources begins support of AR Recon through the CW3E AR Research Program		X			
2nd AR Recon season, including support from the NOAA G-IV aircraft and 2 USAF C-130s. 13 total flights and 361 dropsondes released			X		
AR Recon Modeling and Data Assimilation Steering Committee formed			X		
Use of NRL COAMPS adjoint model to inform flight targeting			X	X	X
GPS-Radio Occultation deployment on NOAA G-IV or USAF C-130			X	X	X
Interagency workshops at ECMWF, NCEP, CW3E			X	X	X
Publication using dropsonde observations to document errors in ECMWF data assimilation first guess fields in AR conditions (Lavers et al. 2018)			X		
3rd AR Recon Season, with 2 C-130s. 9 total flights and 291 dropsondes				X	
Deployment of drifting buoys with partners at Scripps and ECMWF				X	X
Data denial runs completed at NRL, ECMWF, NCEP, NCAR and CW3E, and preliminary assessment of AR Recon forecast impacts				X	X
AR Recon called for in OFCM's National Winter Season Operations Plan				X	
Congress appropriates funds in NOAA for AR Recon G-IV and NCEP				X	X
Stone et al. (2020) found impact of AR Recon in the NAVGEM forecast model was similar to that of entire North American Radiosonde network					X
Congress appropriates funds in Air Force for AR Recon					X
4th AR Recon Season. Two C-130s and the NOAA G-IV flew 17 IOPs and released a total of 733 dropsondes					X
Planned: AR Recon 2021 from 8 January to 31 March, 3 aircraft					





*Ralph, Cannon, Tallapragada, Davis, Doyle, Pappenberger, Subramanian, Wilson, Lavers, Reynolds, Haase, Centurioni, Ingleby, Rutz, Cordeira, Zheng, Hecht, Kawzenuk, Delle Monache

AR Recon – 2020 Flight Operations Planning and Execution



Key dates

2 December: forecasting dry run

23 Jan – 18 Mar: Flight operations IOP takeoff dates in PT, e.g. takeoff date 23 Jan is for a flight centered on 00Z 24 Jan.

Flight Operations Resources

Two C-130s available for 12 storm flts from Hawaii, Travis AFB or San Diego

One G-IV available for 12 storm flts from Portland

AR Recon Modeling and Data Assimilation Steering Committee

Formed in April 2018 to coordinate across agencies and partners in assessment of data impacts
Adopted this Terms of Reference that identified goals, members, strategies, process and outcomes

Steering Committee

- F. Martin Ralph – (UCSD/Scripps/CW3E) - AR Recon PI and AR DA SC Co-Chair
- V. Tallapragada (NOAA/NWS/NCEP) – AR Recon Co-PI and AR DA SC Co-Chair
- J. Doyle (NRL)
- A. Subramanian (UCSD/Scripps/CW3E)
- C. Davis (NCAR/MMM)
- F. Pappenberger (ECMWF)
- L. Delle Monache (CW3E)

The AR DA Steering Committee will develop a multi-year (~5 years) work plan that lays out specific goals and a technical approach to achieve them. The AR DA SC will develop the work plan outline, conduct a workshop to garner broader input, and then approve the plan.

AR DA Goals:

1) Assess the impact of AR Recon dropsondes on weather forecasts, specifically
   a. Extreme precipitation on the U.S. West coast in cool season
   b. AR landfall and inland penetration (strength, duration, orientation)
   c. Snow level in the Western U.S.
   d. Central and eastern U.S. storms during the cool season
   e. Large scale flow patterns across CONUS, especially related to low skill forecasts
2) Develop data assimilation (DA) methods optimized for use of dropsondes (and other observations when feasible, e.g., radio occultation, drifting buoys, cloud tracked winds)

AR DA Goals

Assess the impact of AR Recon dropsondes on cool-season weather forecasts

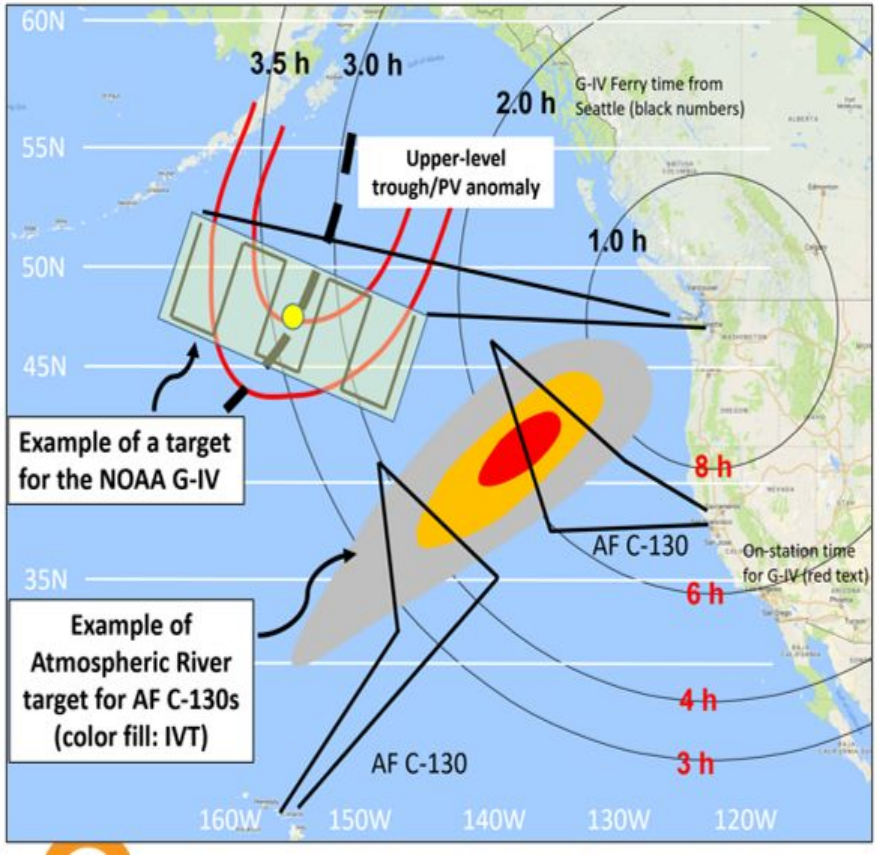
- Extreme precipitation - U.S. West coast
- AR landfall and inland penetration
- Snow level in the Western U.S.
- Central and eastern U.S.
- **Large scale flow patterns across CONUS, especially related to low skill forecasts**
- **Develop data assimilation (DA) methods optimized for use of dropsondes (and other obs' when feasible, e.g., radio occultation, drifting buoys, cloud tracked winds)**
- Develop forecast skill performance metrics for west-coast ARs and extreme precipitation (applicable to North America, Europe, South America etc…)

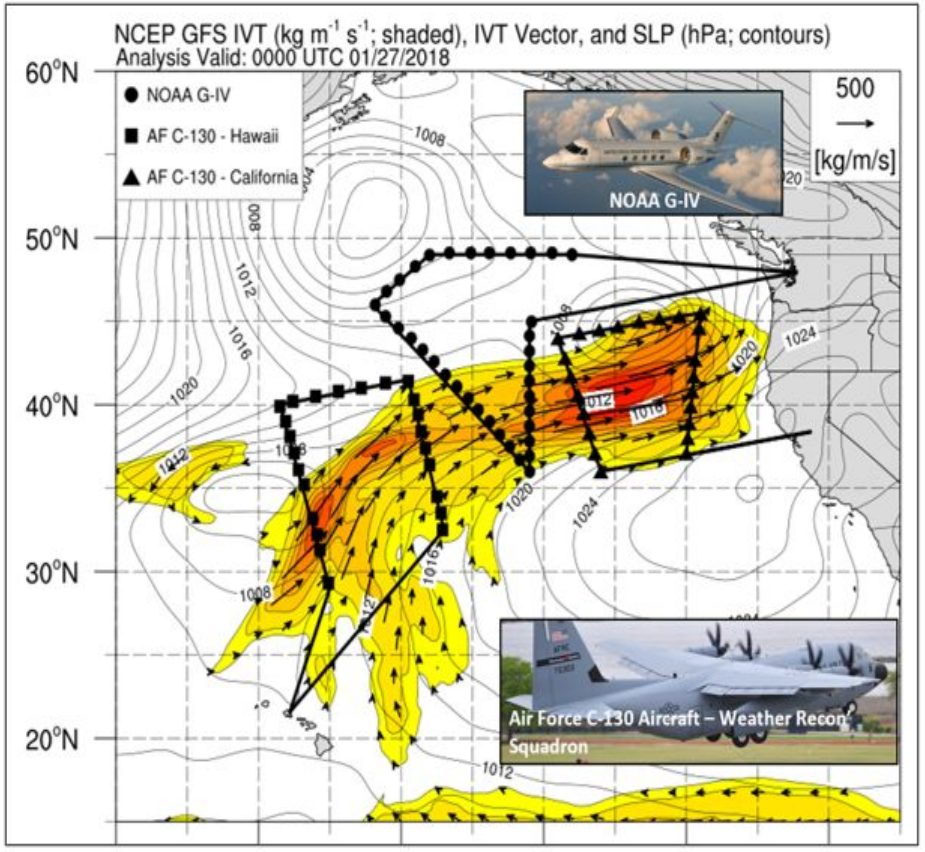
Anticipated Outcomes

- **Improved DA methods for dropsonde data assimilation**
- Quantification of the impact of dropsonde DA on the analysis and the degree to which the data can be fit by the model
- Quantification of the impact of dropsonde DA on short- and medium-range forecasts
- Potential improvements in parameterizations in models that reduces errors in AR analyses and forecasts
- Development of effective strategies for future sampling of ARs through ensemble based forecast sensitivity experiments

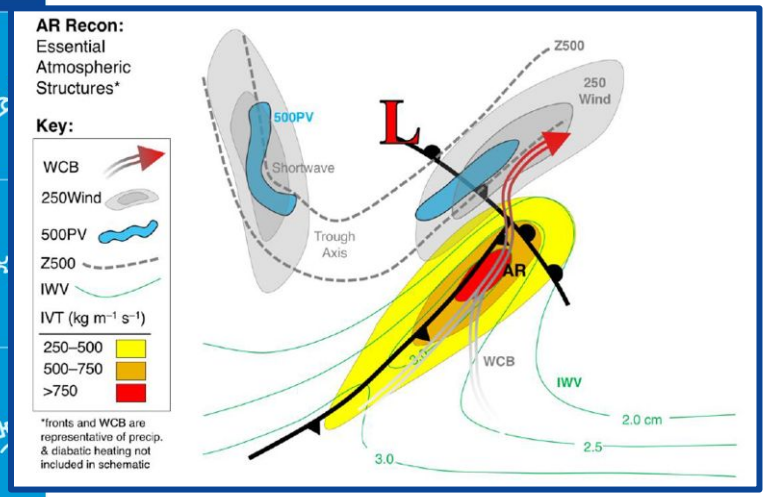
analyses and forecasts
- Development of effective strategies for future sampling of ARs through ensemble based forecast sensitivity experiments

Atmospheric River Reconnaissance Sampling Concept and Example from 27 Jan 2018

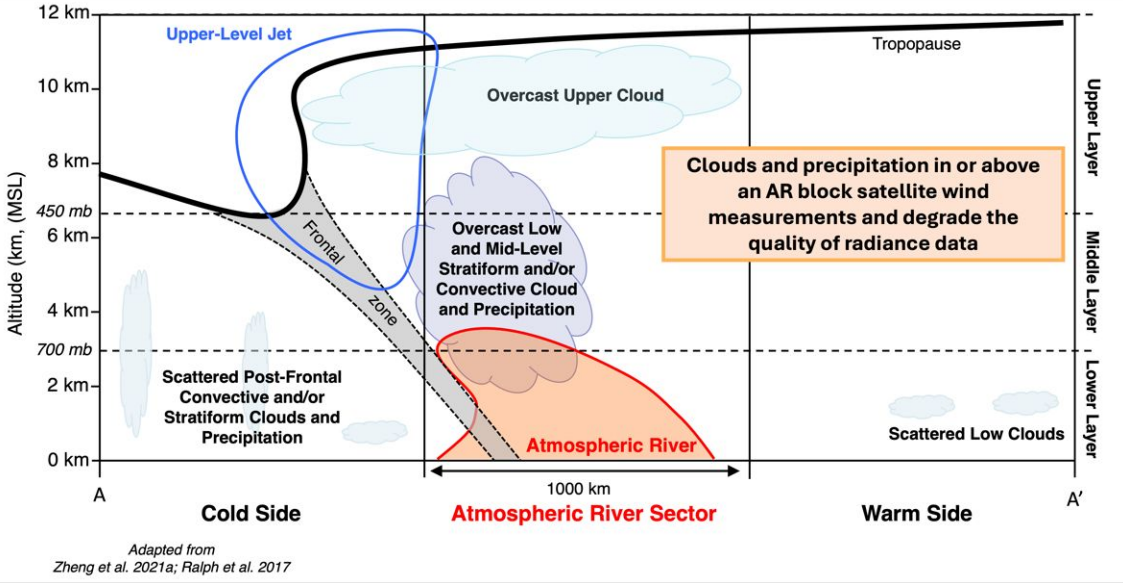




AR Recon: Flight Track Design



Schematic Lead: J. Cordeira
Wilson et al. 2022



Adapted from
Zheng et al. 2021a; Ralph et al. 2017

How do we determine where to fly and where to drop?

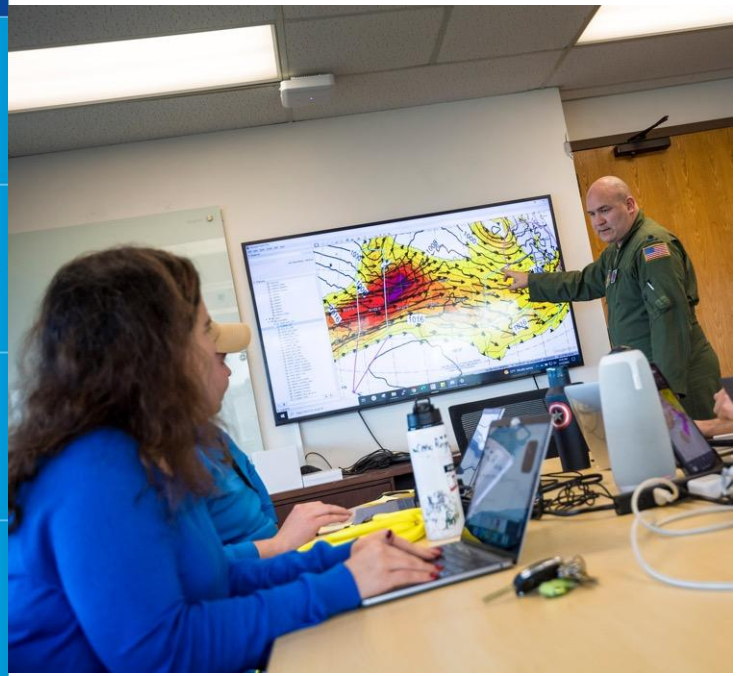
Fundamental physics knowledge, Adjoint model sensitivity (NRL),
Ensemble sensitivity (U Albany, NCEP)

Close coordination with the Flight Directors, including the 53rd and AOC on-site

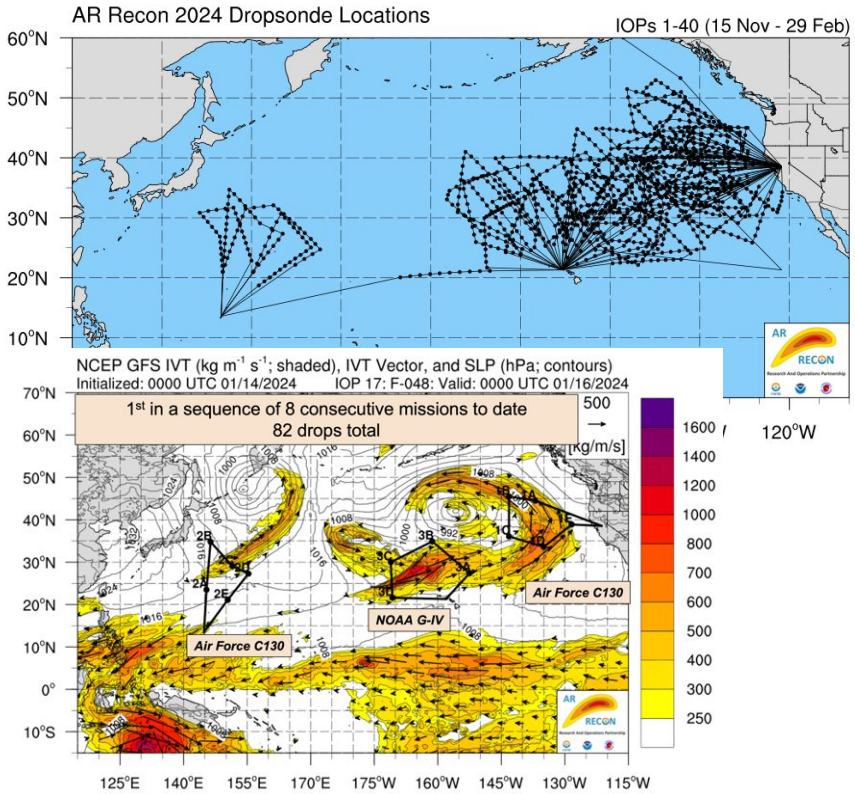
Vijay Tallapragada, Co-PI (NOAA/NWS/NCEP)

F. Martin Ralph (UCSD/SIO/CW3E) - PI
Vijay Tallapragada (NWS/NCEP) - Co-PI

AR Recon: Flight Track Design

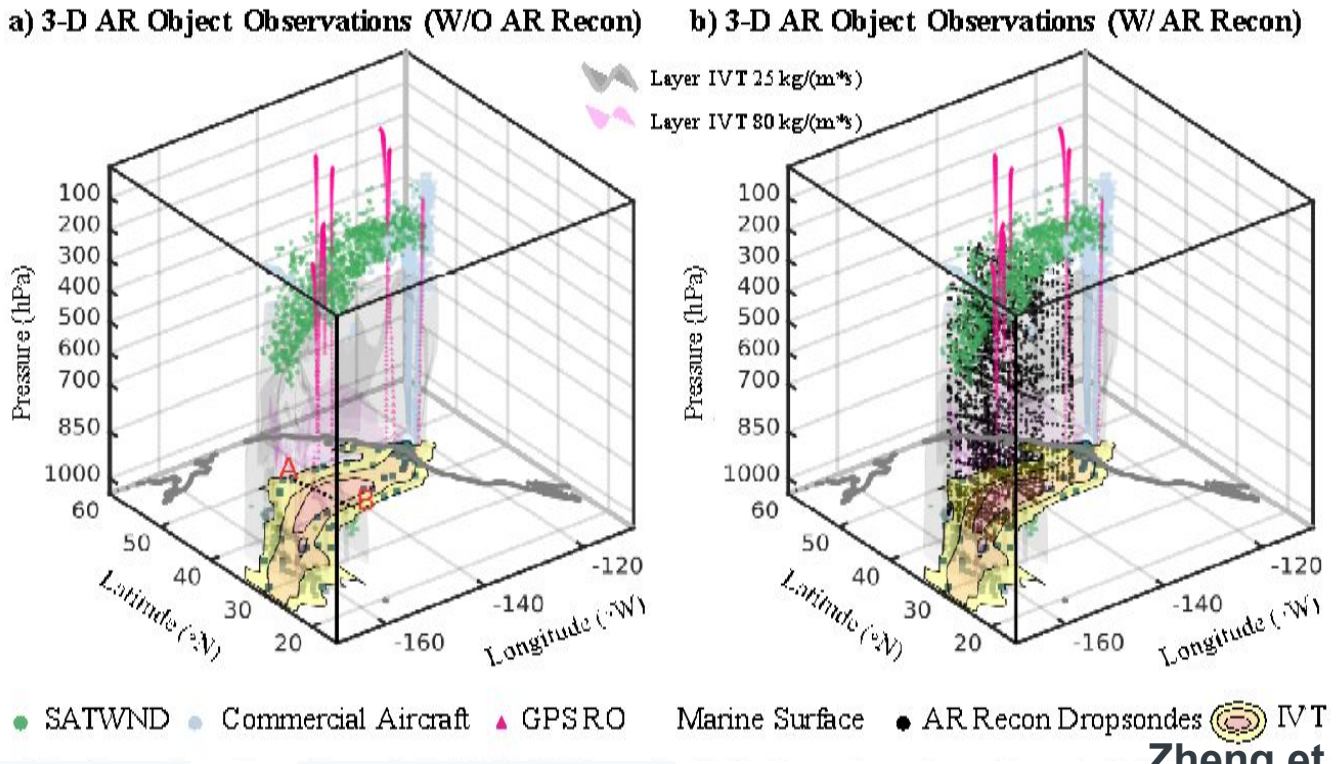


Lt. Col. Ryan Rickert, Chief Meteorologist, embedded at Scripps Institution of Oceanography to work closely with CW3E researchers to coordinate reconnaissance flights. Image: Erik Jepsen/UC San Diego.



DATA GAPS FOR AR: OBSERVATION DENSITY ANALYSIS

AR RECON
Research And Operations Partnership

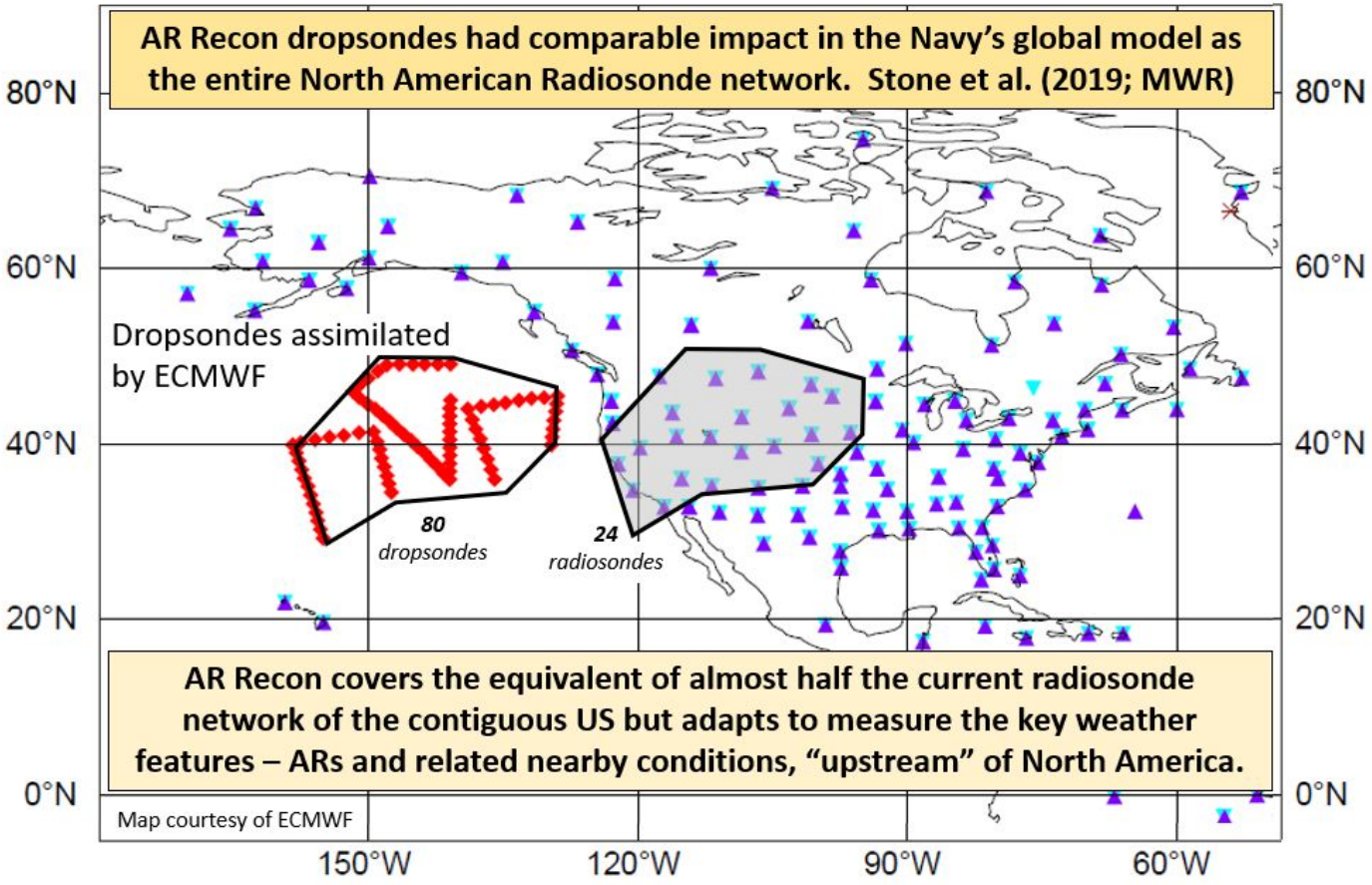


Zheng et al. 2020 (BAMS)

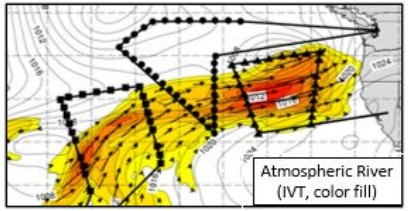
Atmospheric River Reconnaissance Example– 2018 (0000 UTC 27 Jan)

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

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

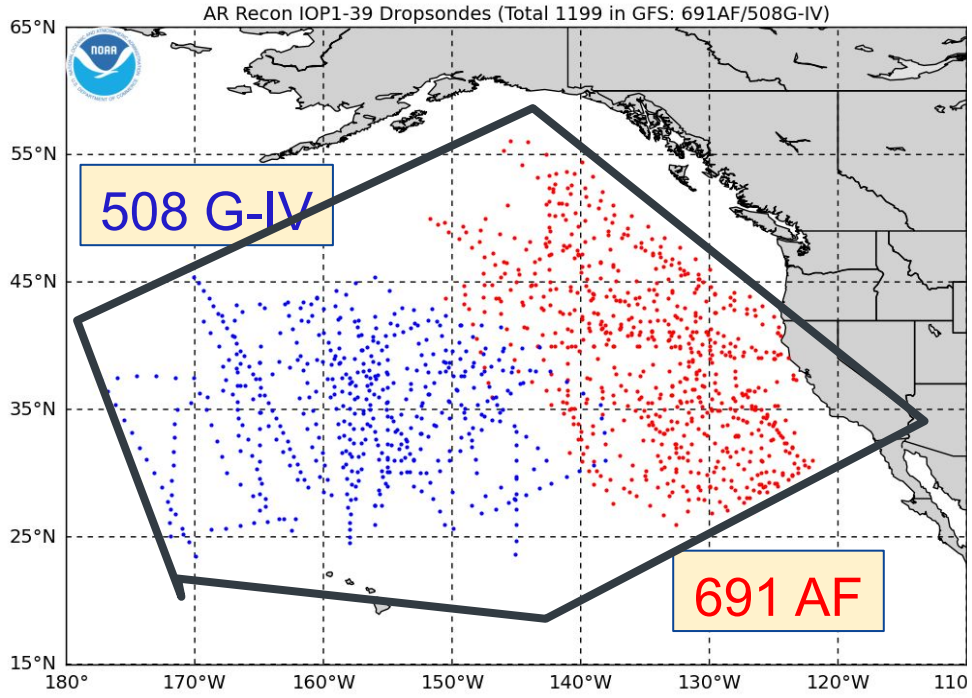


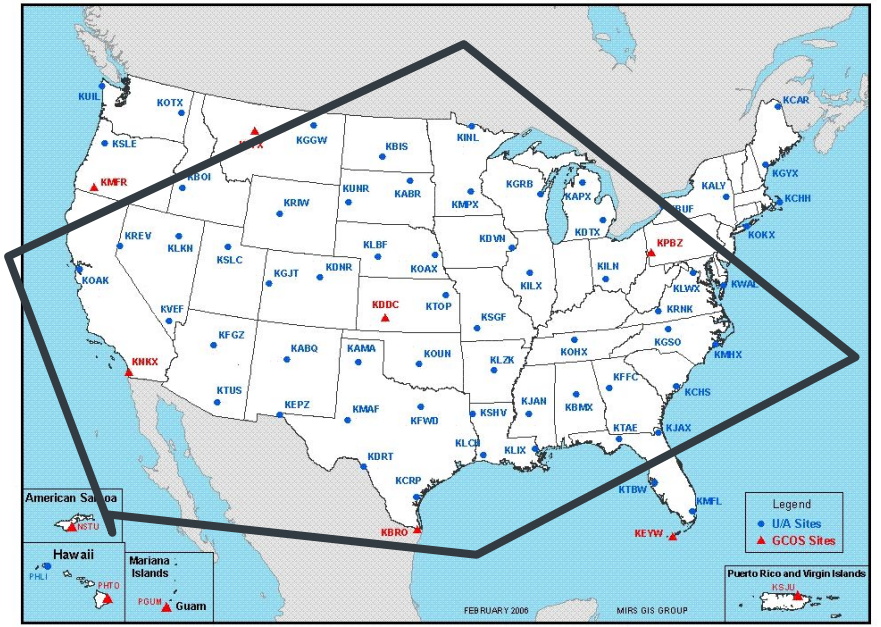
AR Recon covers the equivalent of almost half the current radiosonde network of the contiguous US but adapts to measure the key weather features – ARs and related nearby conditions, "upstream" of North America.



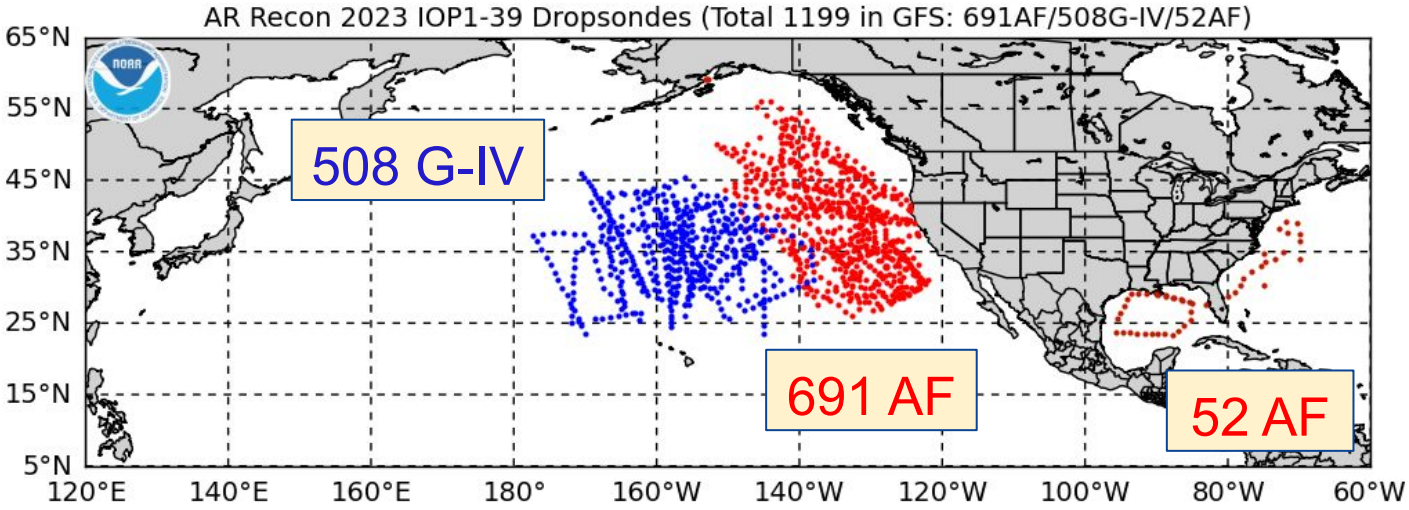
"The 24-h global forecast error reduction from the reconnaissance soundings can be comparable to the reduction from the North American radiosonde network for the field program dates that include at least two flights."
(Stone et al. (2019; MWR)

2022-2023 AR Recon IOP 1-39 dropsondes

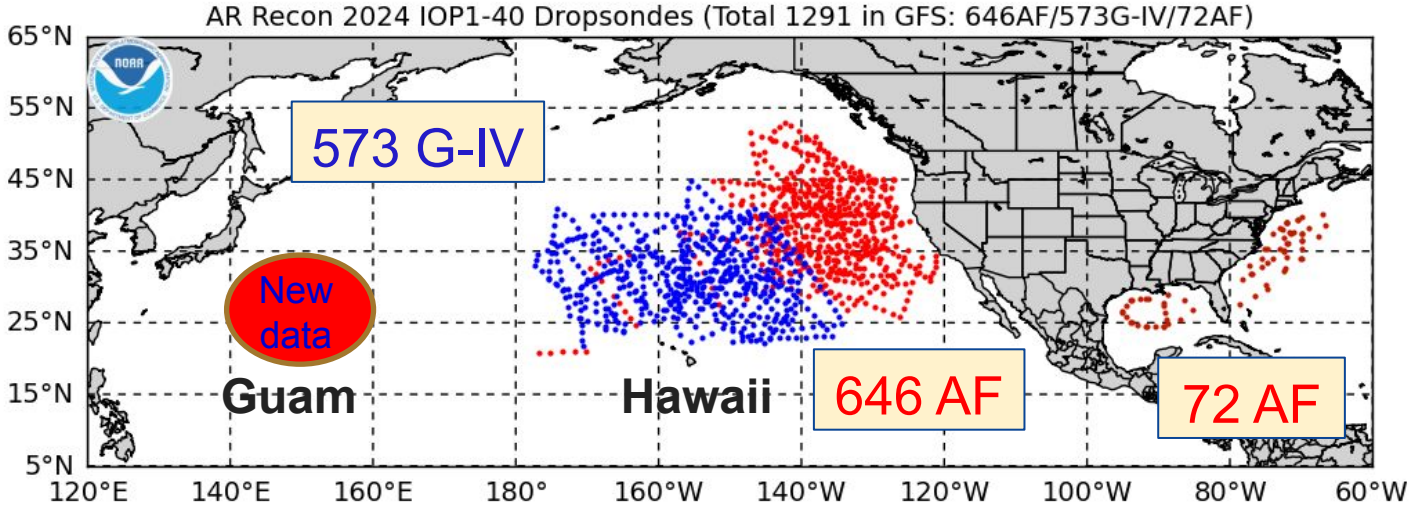




AR Recon 2023 Dropsondes 39 missions 5 Nov 2022 - 14 Mar 2023

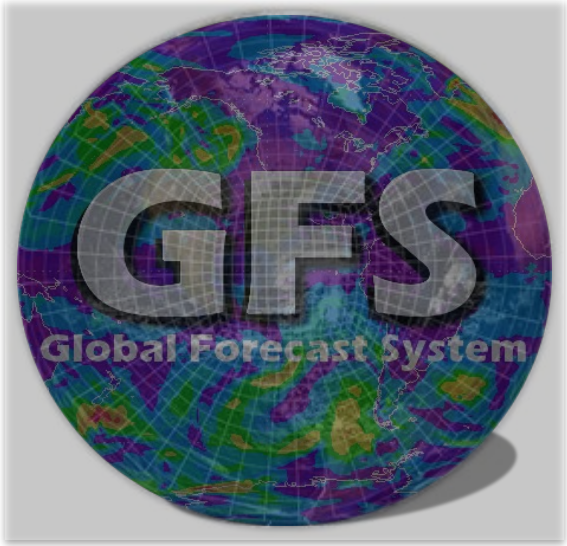


AR Recon 2024 Dropsondes 40 missions 11 Nov 2023 - 14 Mar 2024



Motivation: Improving NCEP Operational Global Model Forecasts using AR Recon Observations

- NWS' Senior Scientist & Modeling Chief (Co-PI) guides the overall AR Recon effort with CW3E Director FM Ralph (PI)
- Use US' leading weather models (GFS and GEFS) to provide input on where data are needed
- NWS/NCEP and NWS/Western Region Coordinate with CW3E on calling for flights
- Assimilate AR Recon data into the GFS and other major operational global models across the world
- Assess impact of AR Recon obs' on forecasts
- Develop future strategies for global and **regional** forecast improvements



The Global Forecast System (GFS) and the Global Ensemble Forecast System (GEFS) are the cornerstones of NCEP's operational production suite of numerical model guidance.

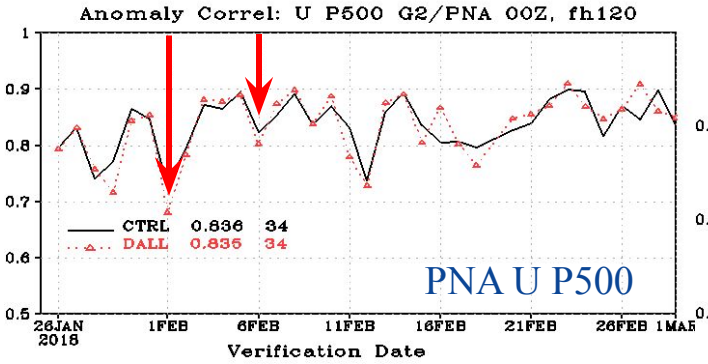
Near Real-Time Data Denial Experiments with NCEP Operational GFS

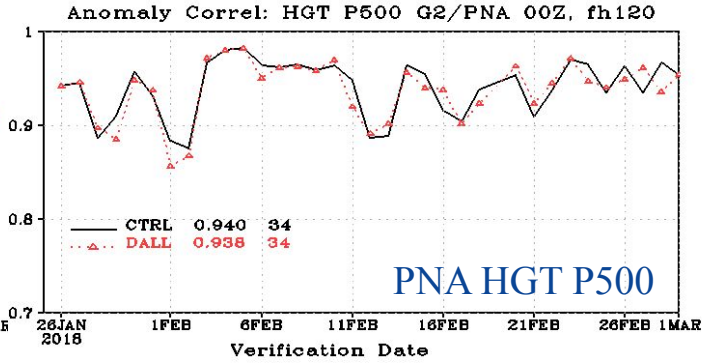
- ARR near real-time data denial:
- CTRL – operational GFS, assimilate dropsonde and HDOBs data
- DENY – the same setting as operational GFS, but deny dropsonde and HDOBs data

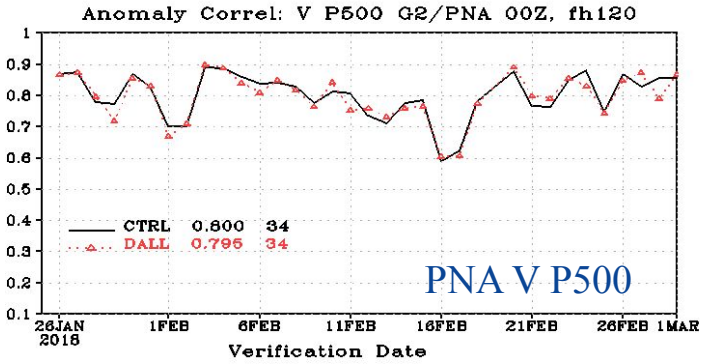
Early Results: AR 2018: Pacific North American Region

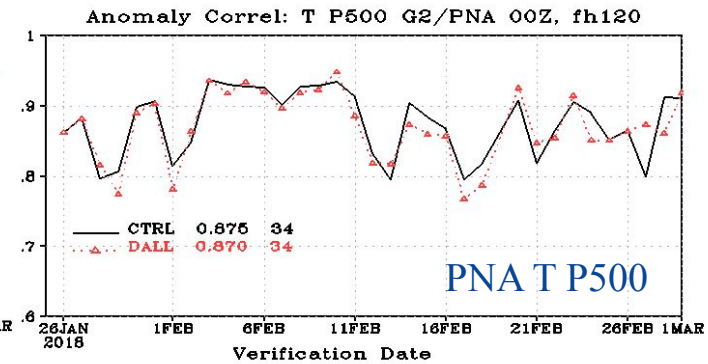
Operational GFS Control (CTRL) vs Denial all (DALL)

Positive impact with dropsondes



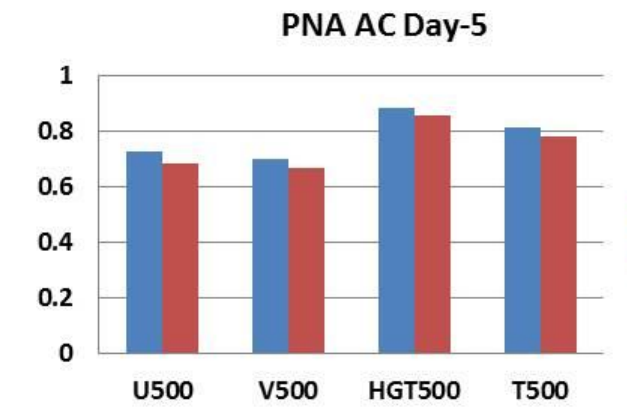




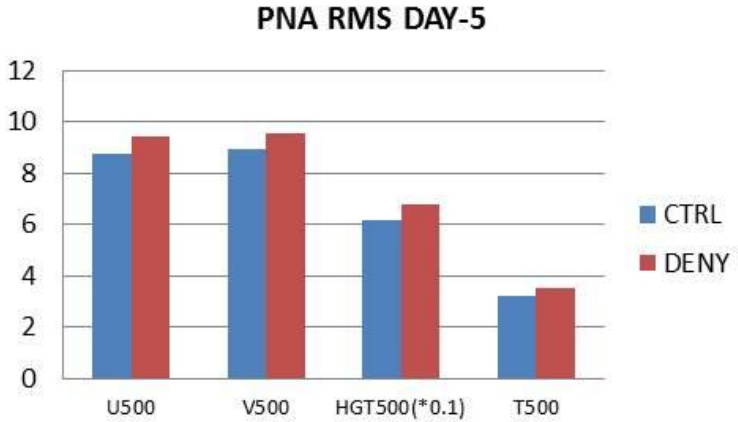


Dropout Case: Feb 1, 2018

AR 2018 Pacific North American (PNA) Region



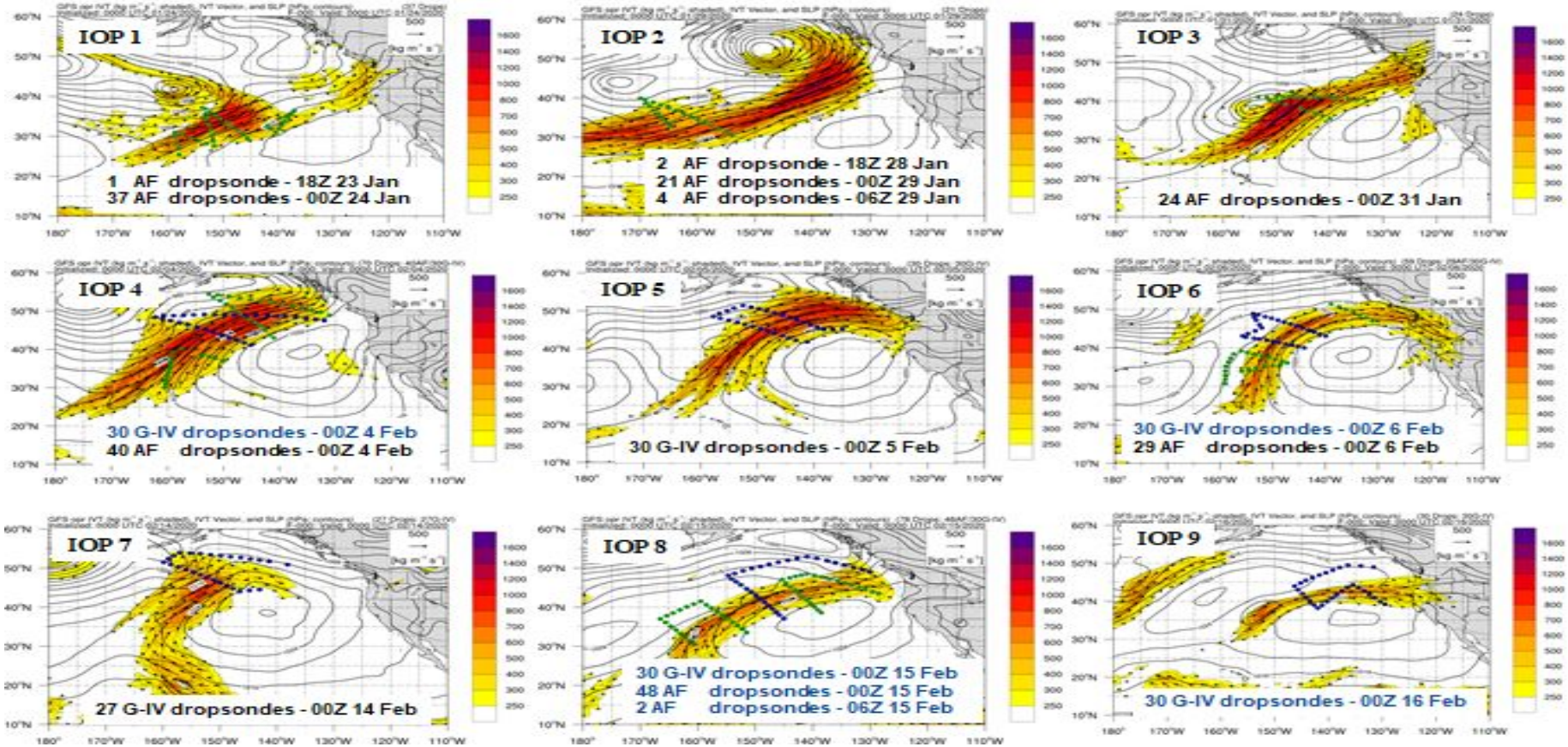
% of change U/6.6 V/4.4 HGT/3.0 T/4.0



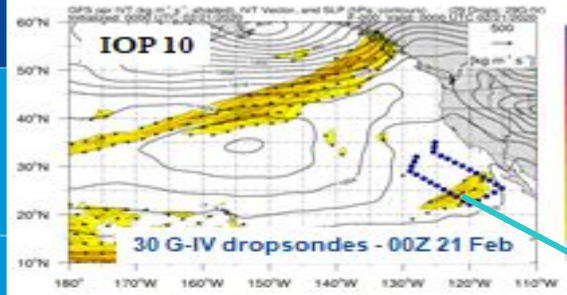
% of change U/7.8 V/6.6 HGT/10.0 T/8.1

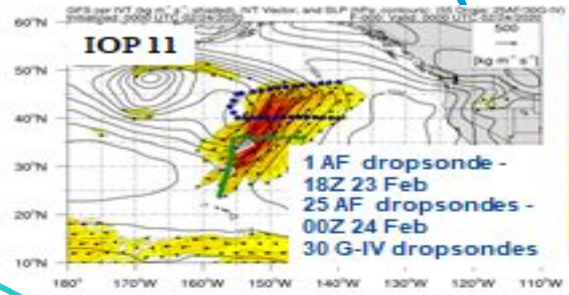
6-10% improvement in large-scale forecasts for Pacific North American Region - indicative of data gaps in the North Pacific being addressed through AR Recon measurements

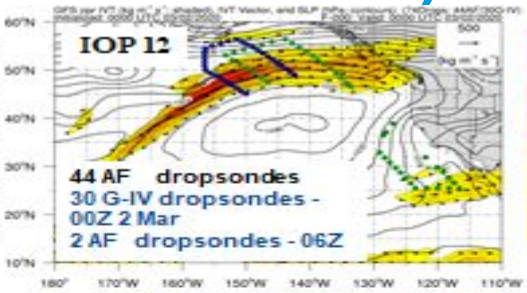
AR Recon 2020 IOP 1-9 (from 17 AR IOPs)

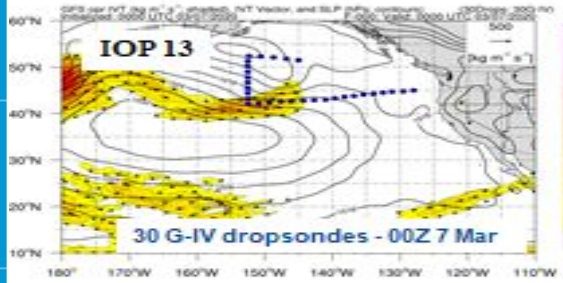


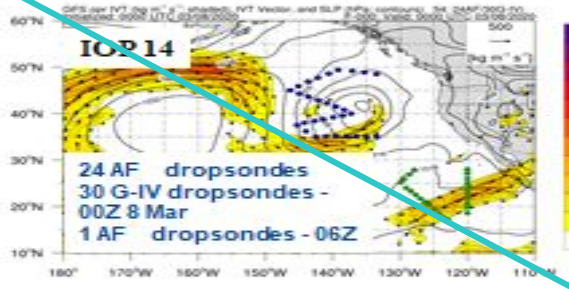
AR Recon 2020 IOP 10-17 (from 17 AR IOPs)

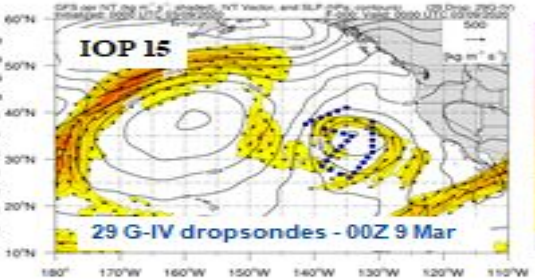


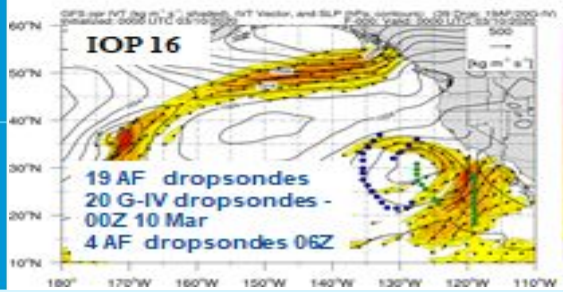


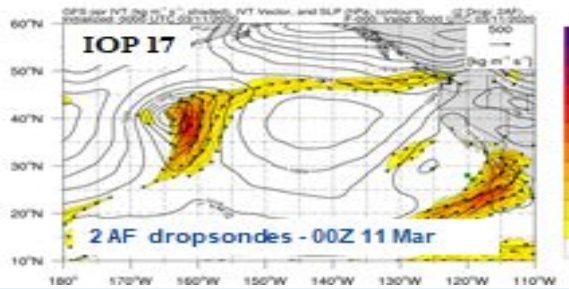










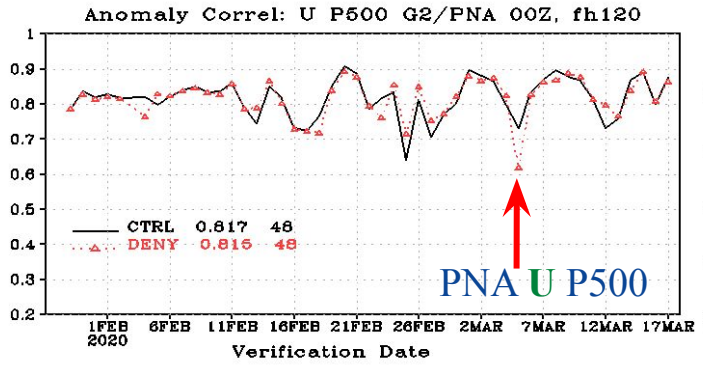


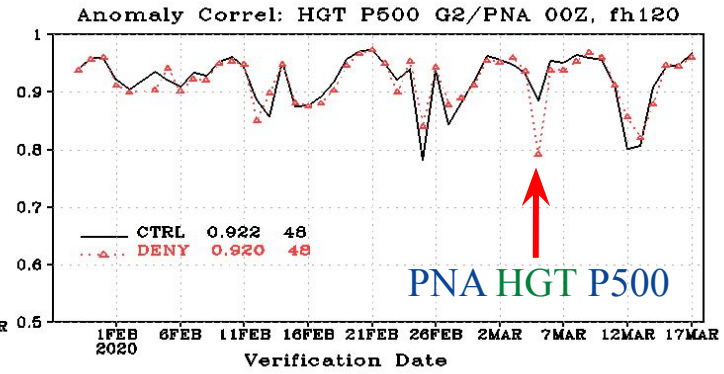
PNA P500 U/V/HGT/T

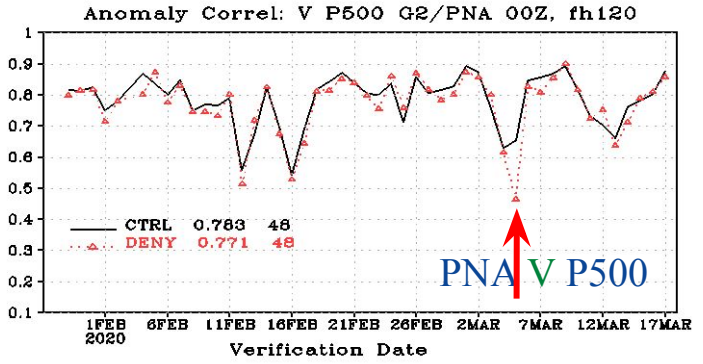
GFSv15 Control (CTRL) vs Denial (DENY)

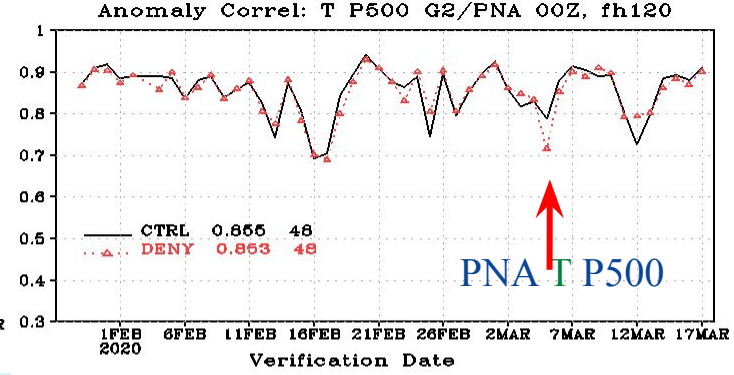
https://www.emc.ncep.noaa.gov/gc_wmb/wd20xw/vsdb/ar2020

Very small positive impact with dropsondes over PNA (180E-320E, 20N-75N)

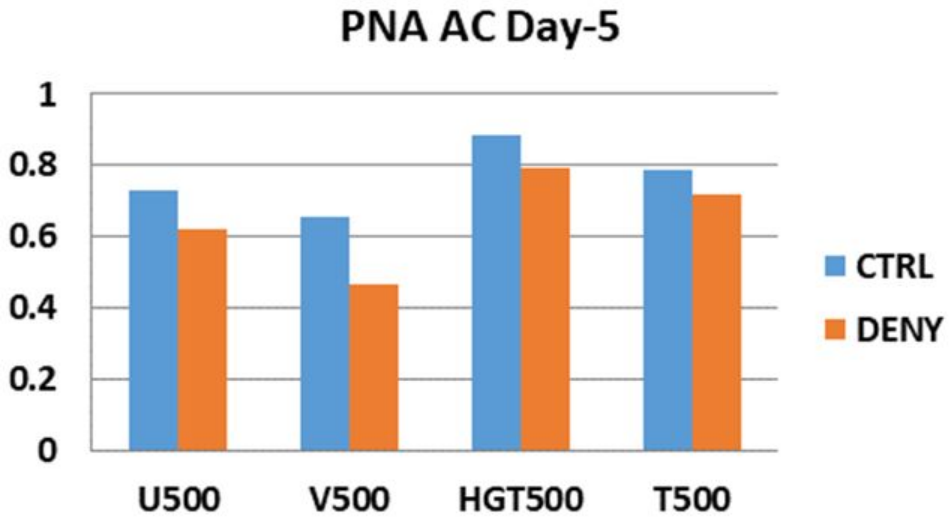








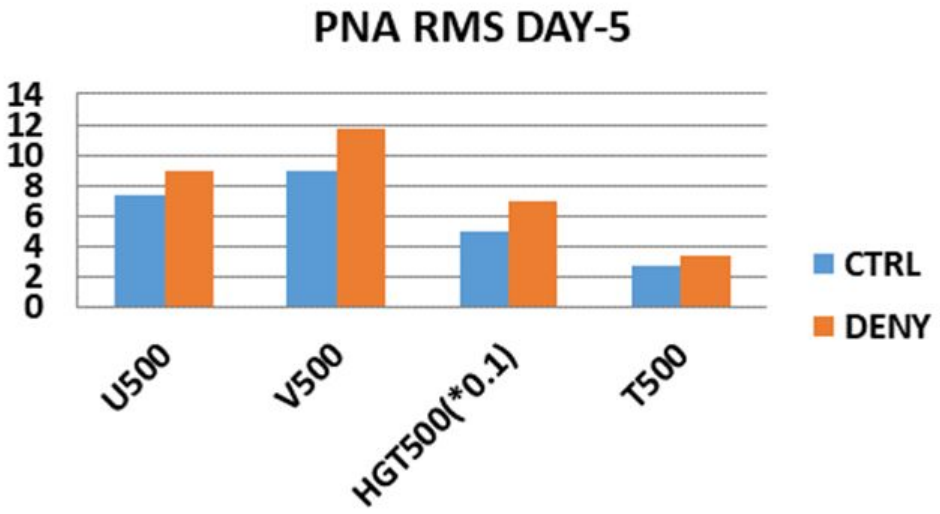
Dropout Case: Feb 29, 2020 5-day Forecast for Mar 5
PNA P500 **U/V/HGT/T** AC



% of change U/15.6 V/29.1 HGT/10.5 T/9.1

Dropout Case: Feb 29, 2020 5-day Forecast for Mar 5

PNA P500 **U/V/HGT/T** RMS

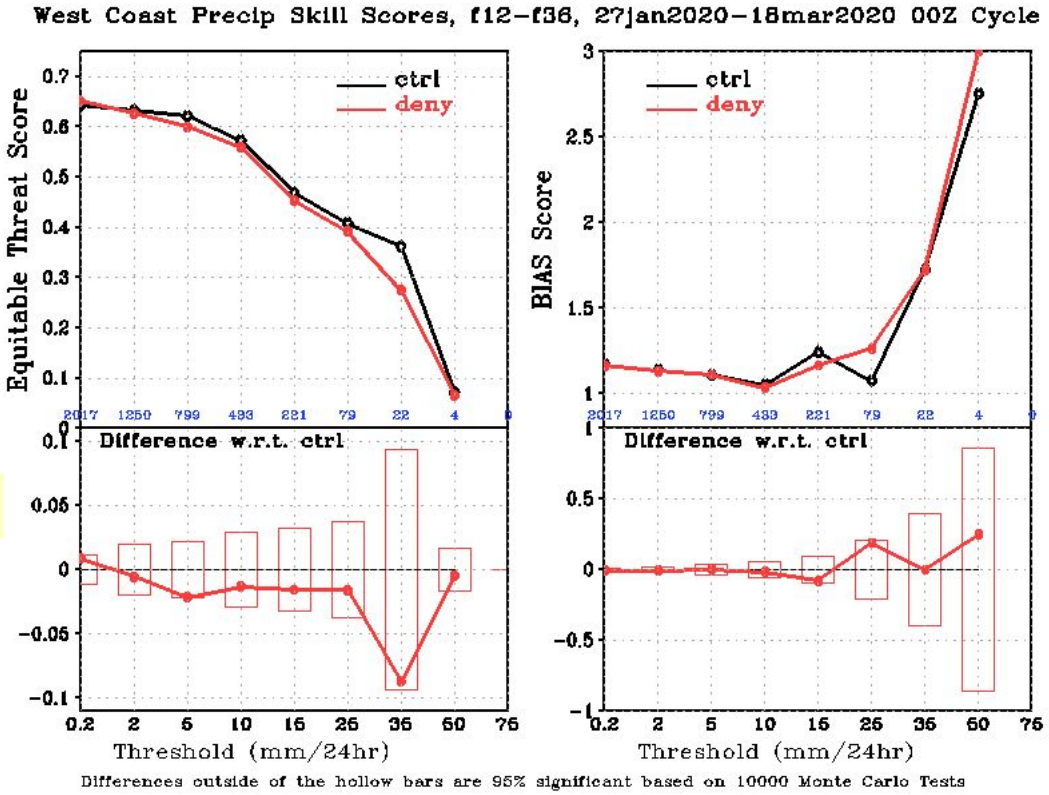


% of change U/21.2 V/31.4 HGT/28.5 T/20.2

West Coast 24 hr PRECIP ETS and BIAS Scores: Jan-Mar 2020

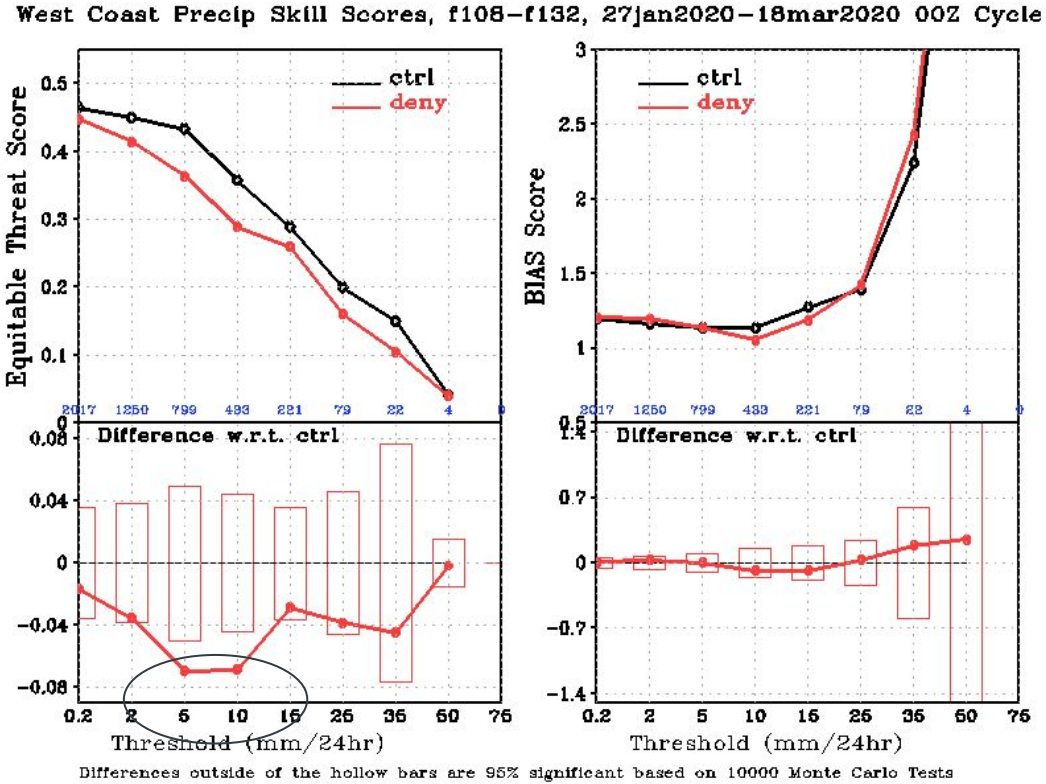
GFSv15 Control (ctrl) vs Denial (deny)

Small positive impact with dropsondes at day 1 (24-h)



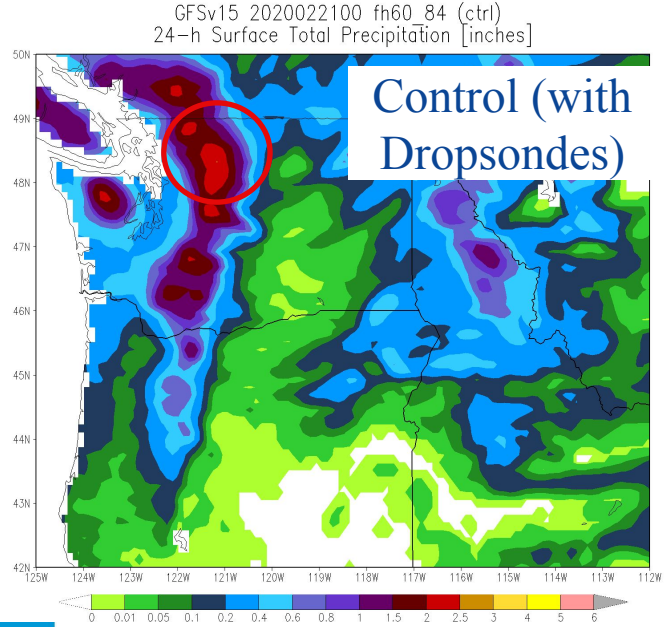
West Coast 120 hr PRECIP ETS and BIAS Scores: Jan-Mar 2020

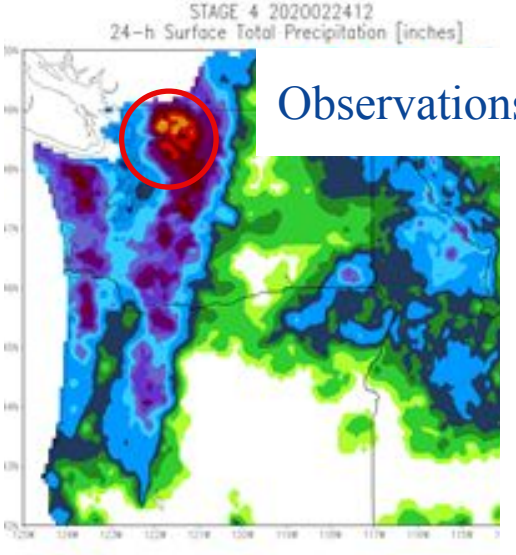
GFSv15 Control (ctrl) vs Denial (deny)

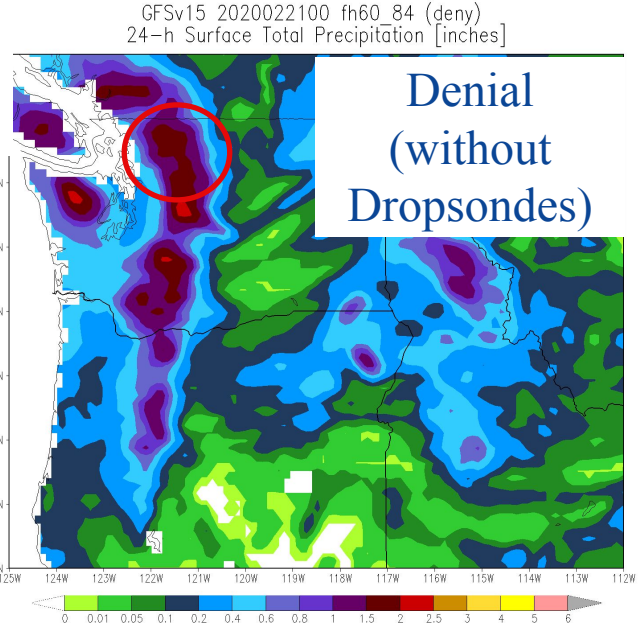


Significant Positive impact with dropsondes at day 5 (120-h)

GFSv15 PRECIP: 24-h total – 2020 February 23 12Z-February 24 12Z (72-hr forecast)





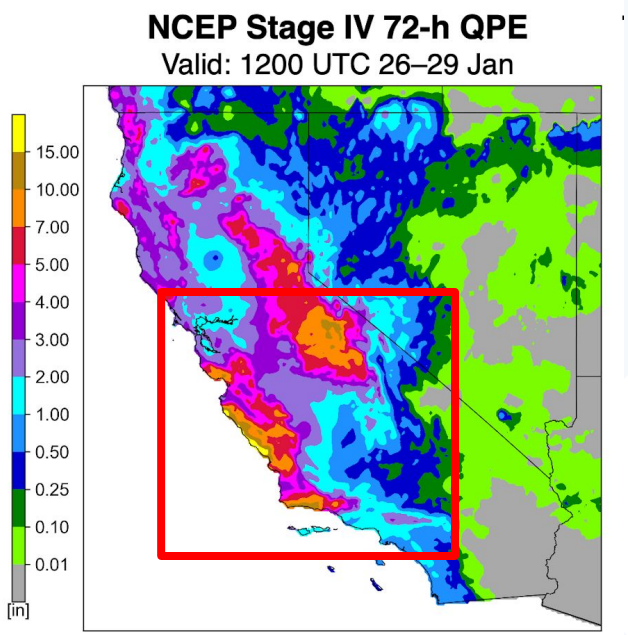


AR Recon helped better predict the intense precipitation amounts

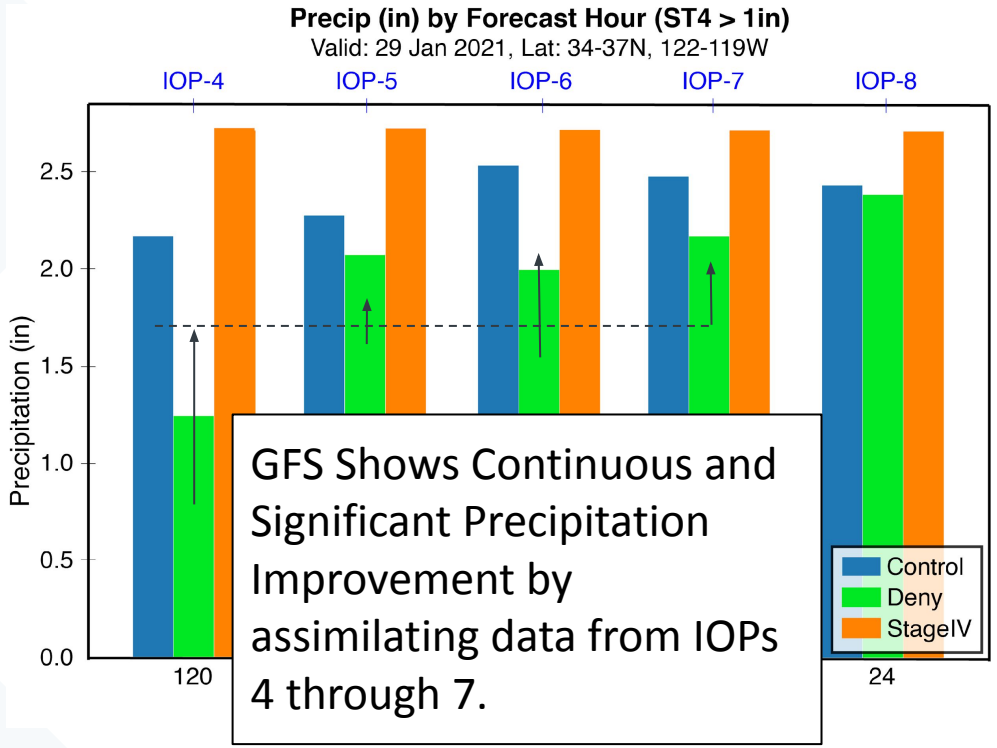
AR Recon 23-28 Jan. 2021 Sequence: *Example of Impact*

AR Recon Data Denial Experiments

V. Tallapragada, F.M. Ralph, X. Wu, M. Zheng



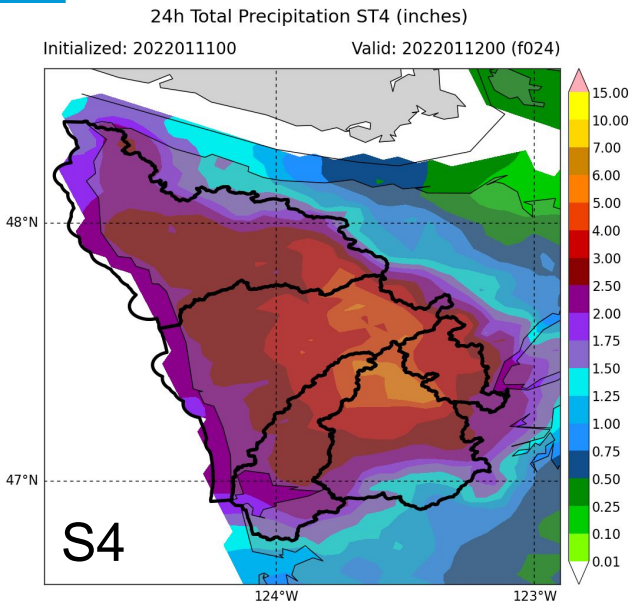
GFS precipitation forecast error at 120h (5-day) lead time *with drops* is equivalent to the 48h (2-day) error without drops.

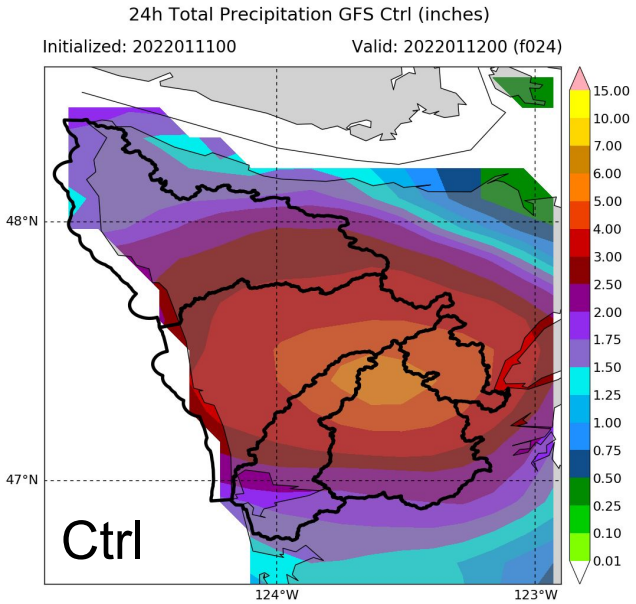


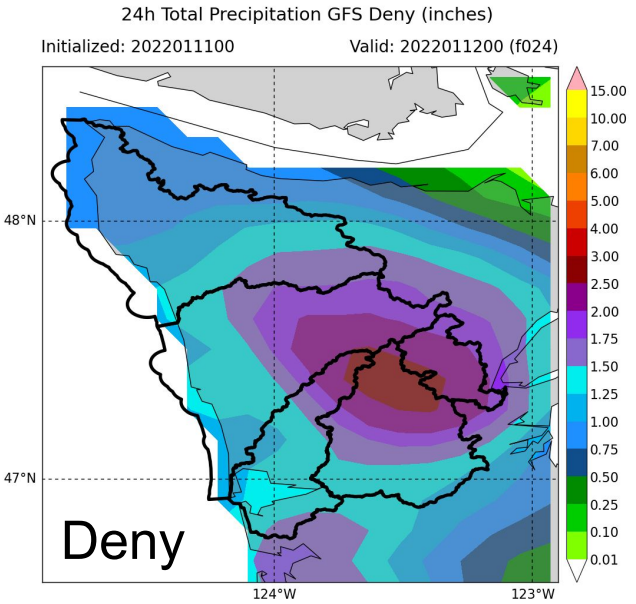
GFS Shows Continuous and Significant Precipitation Improvement by assimilating data from IOPs 4 through 7.

ARR 2022 IOP 1 (Jan 11) Impact from GFSv16 Forecast

24-h precipitation 00Z Jan 11 to 00Z Jan 12

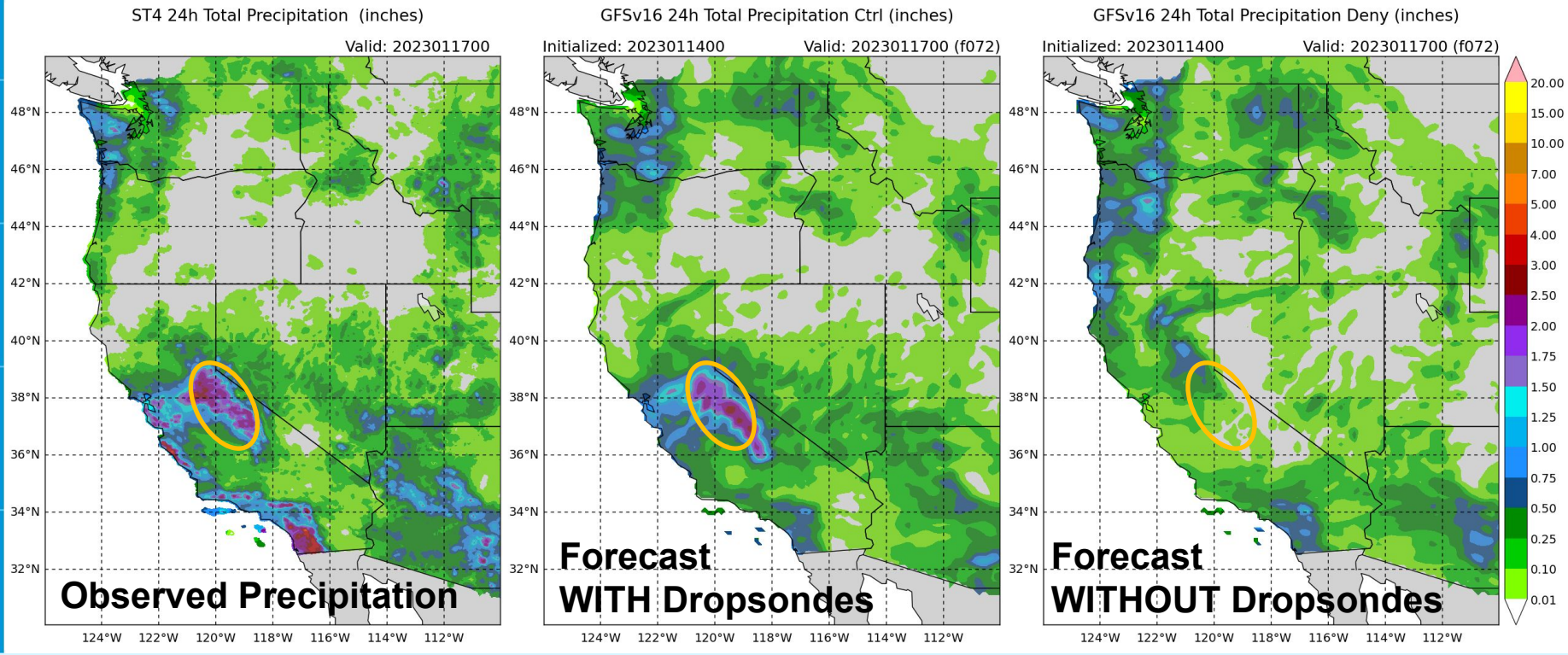






AR Recon flight substantially reduced errors in the 24-48 hours lead-time forecast of heavy precipitation (in WA). The maximum precipitation in the data denial experiment is less than half of the observed maximum precipitation (~6 inches) in this case.

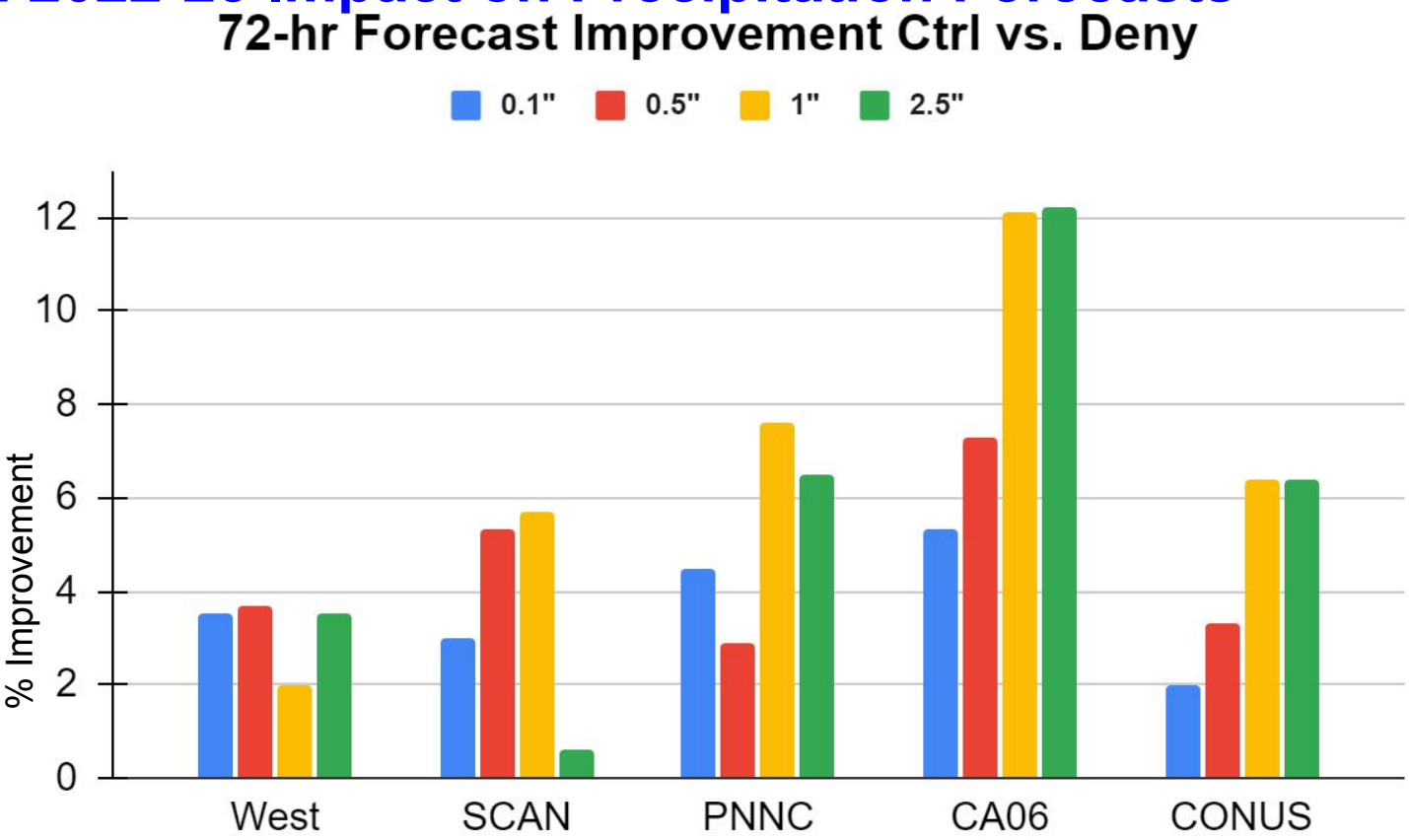
Case Study: IOP 14 (00Z Jan 14 2023)
72-hour forecast, verify at 00Z Jan 17



AR Recon 2022-23 Impact on Precipitation Forecasts

Largest improvements over the California Domain for the heavier precipitation amounts

On average, **12% improvement equates to skill expected 8 years in the future.**

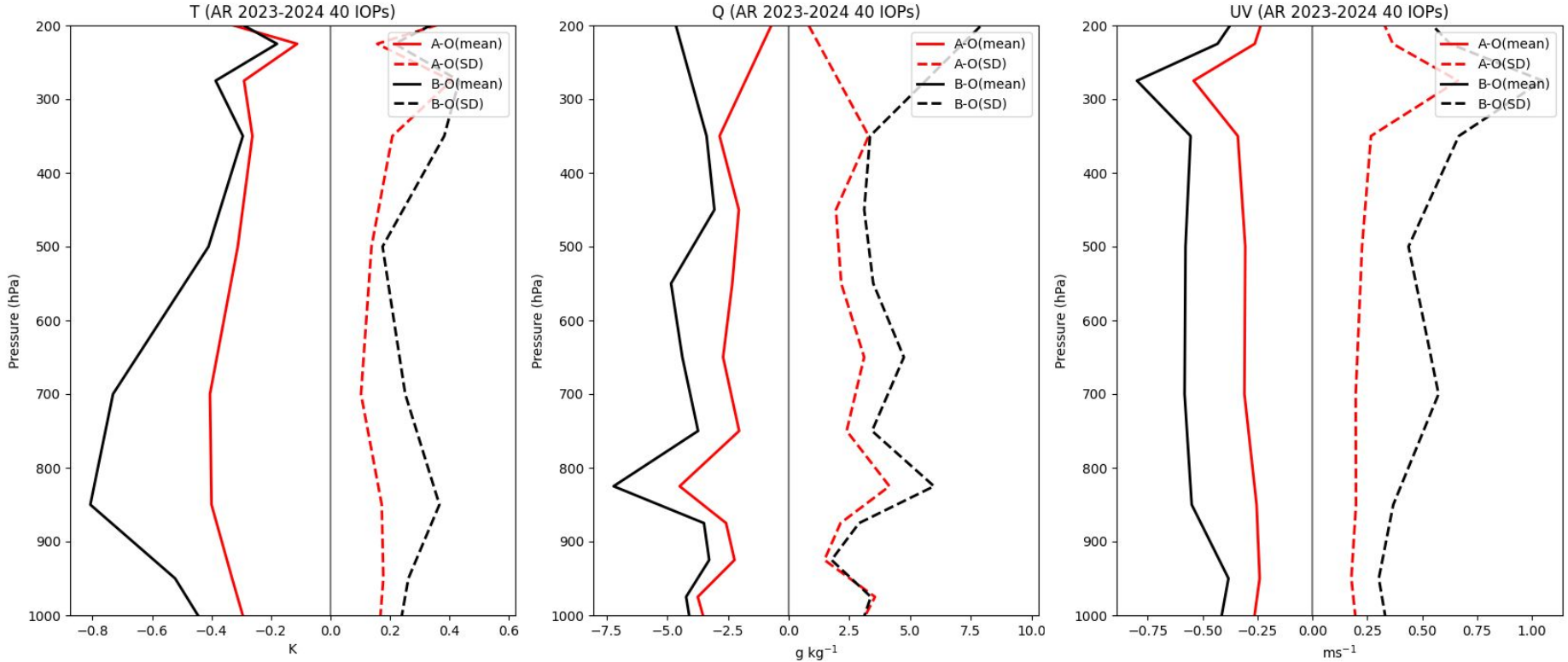


Near Real-Time Data Denial Experiments with NCEP GFSv16

- ARR near real-time data denial: Starting from Nov 15, 2023 (IOP 1)
  - CTRL – operational GFS, assimilate dropsonde and HDOBs data
  - DENY – the same setting as operational GFS, but deny dropsonde and HDOBs data

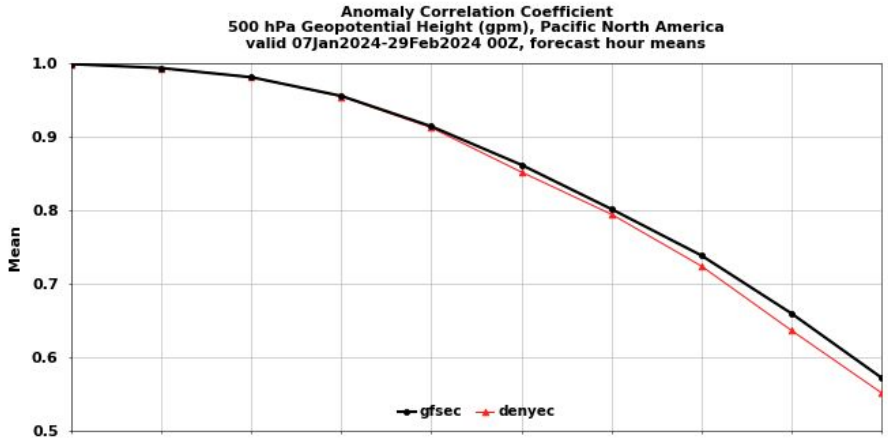
GFS DA with Dropsondes data (40 IOPs)

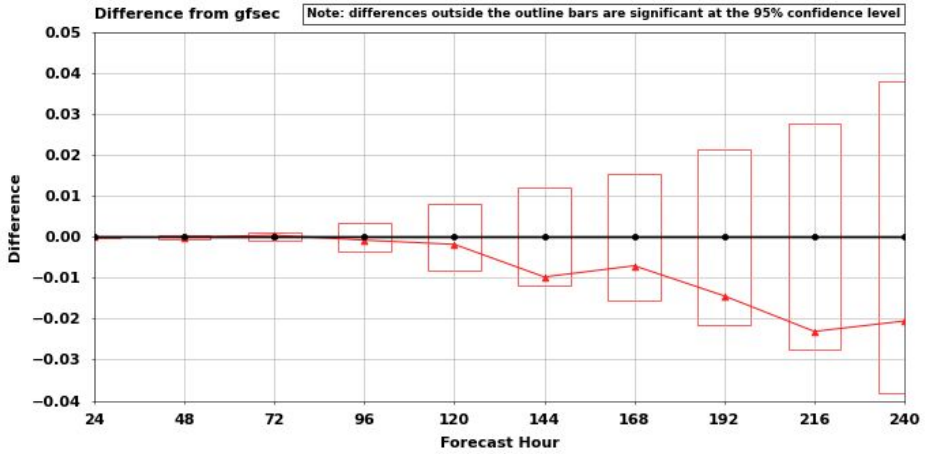
Mean of (A-O) and (B-O) for T, Q and UV during 2023 Nov 15 and 2024 Feb 29 from GFS



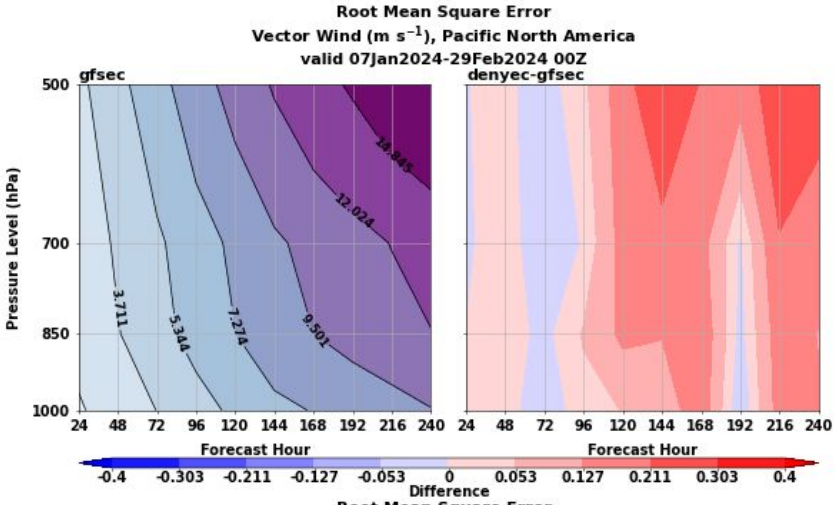
Improved analysis in T/Q/UV with dropsonde obs

Z 500 hPa ACC 120-hr: PNA

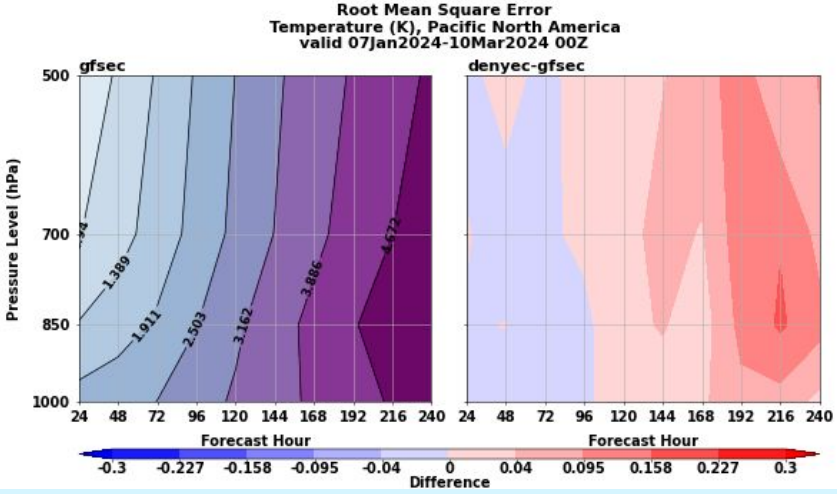




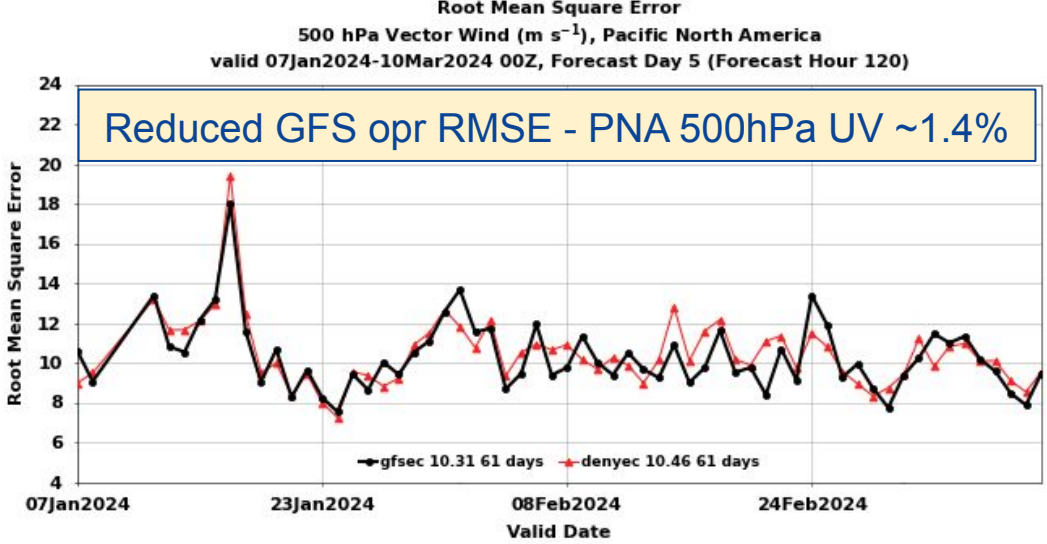
Wind and Temperature RMS PNA



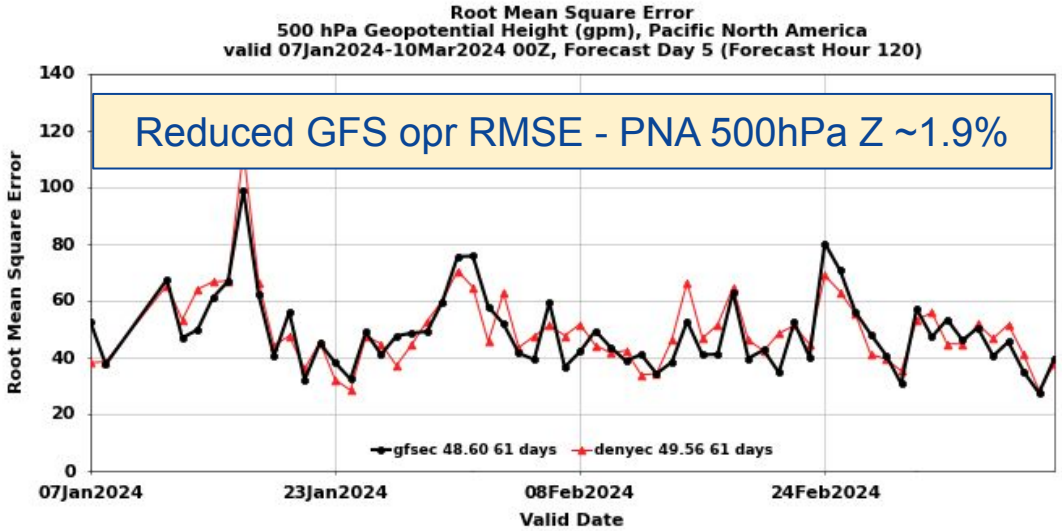
UV



T

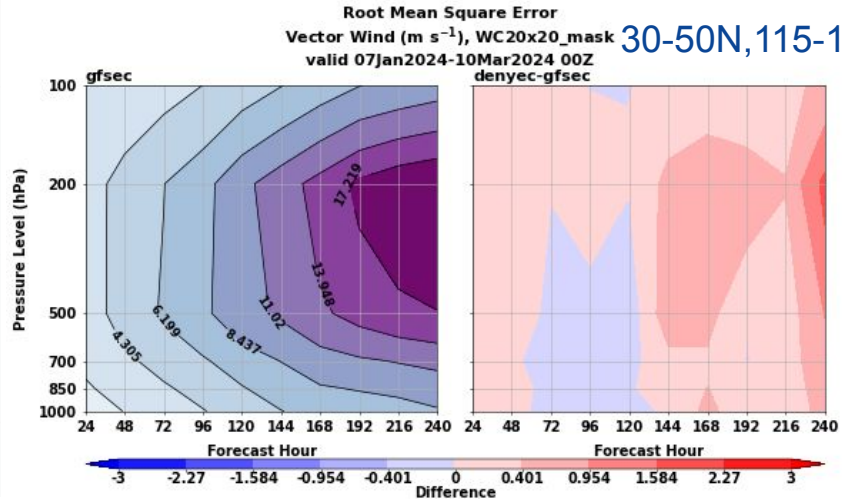


PNA 120-h RMSE
500 hPa UV (10.31/10.46)

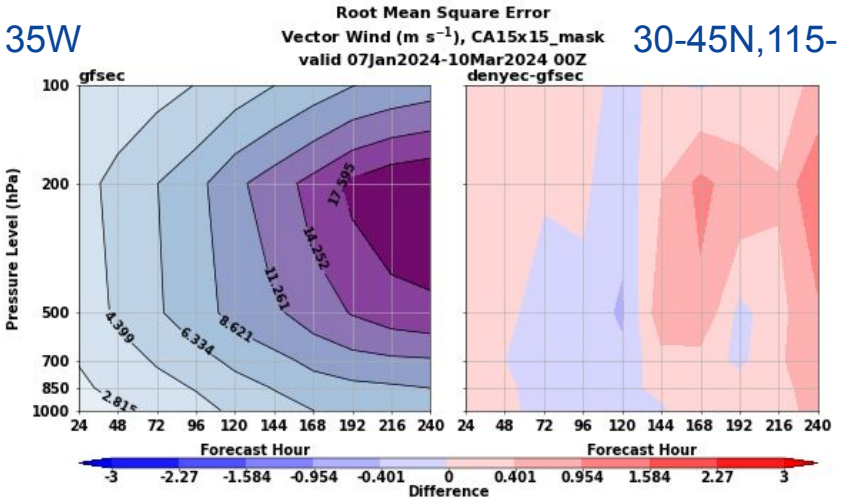


PNA 120-h RMSE
500 hPa Z (48.60/49.56)

Wind and Temp RMS 24-240-hr: WC20/CA15 - Jan 7 – Mar 10

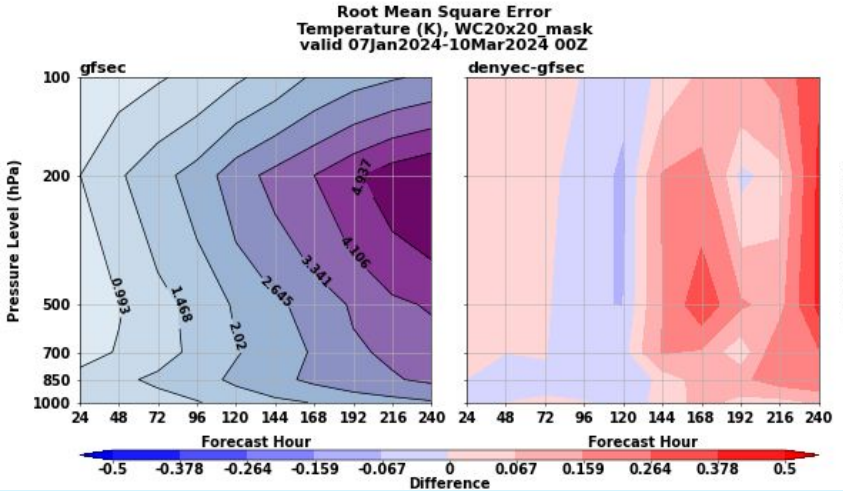


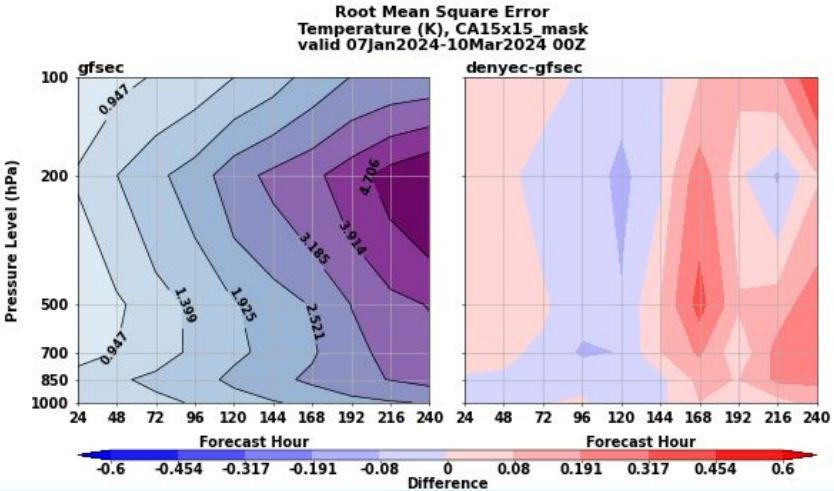
30-50N,115-135W



30-45N,115-130W

UV





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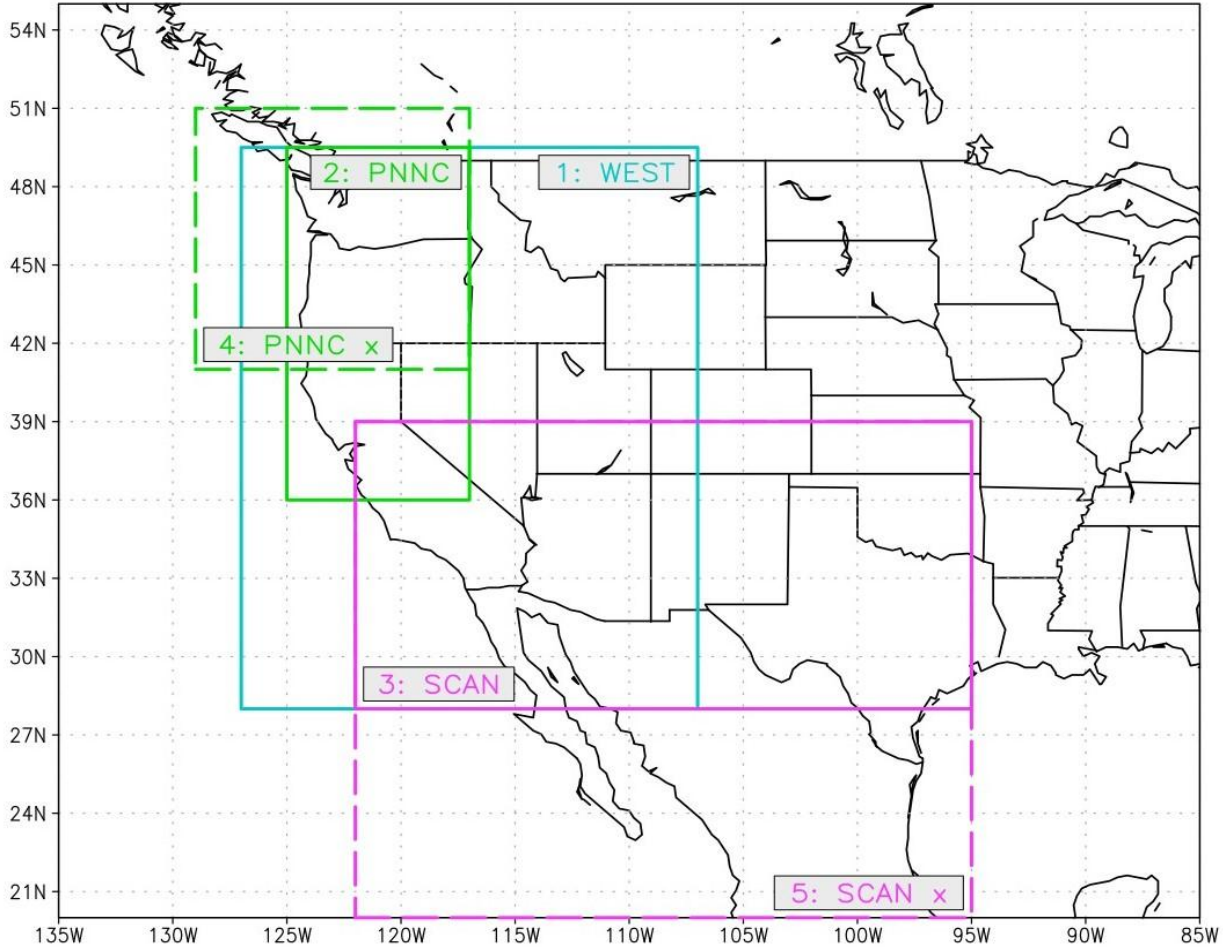


Spatial domains for precipitation verifications

(Lord et al. 2023. WAF)

West Coast
WEST: **107-127 W, 28-49.5 N**

Pacific Northwest and Northern California
PNNC: **117-125 W, 36-49.5 N**

Southern California, Arizona, New Mexico
SCAN: **95-122 W, 28-39 N**

AR Recon Recap: Better observations Improved Forecast Skill (WY23)

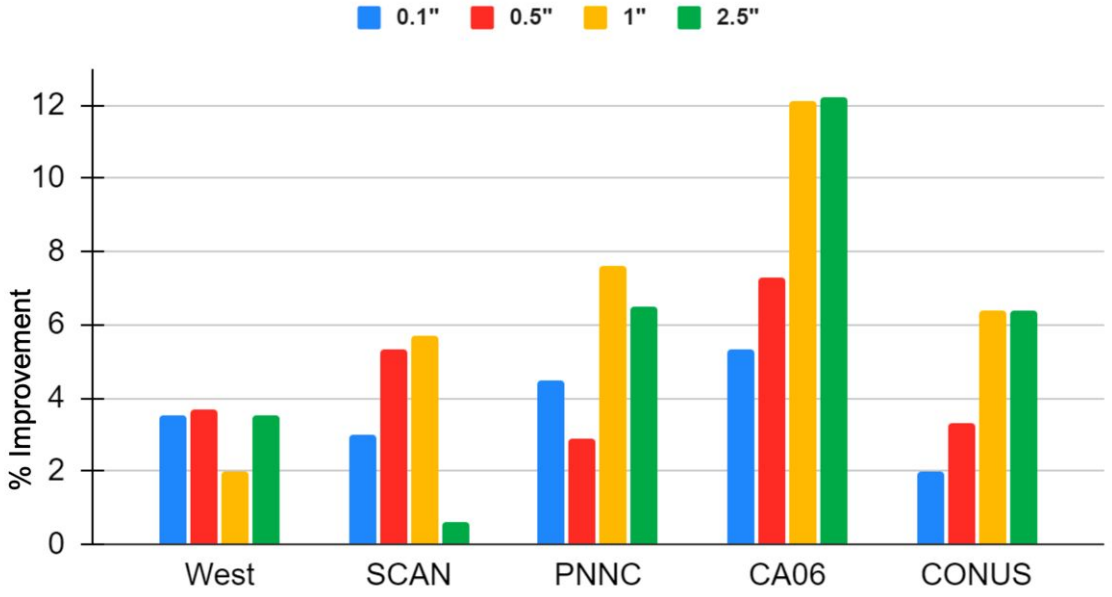
Presentation
by V. Tallapragada

AR Recon Workshop
June 2023
@ECMWF

Not only is skill improved over West Coast, but also over western U.S. and CONUS! Regionally upwards of 12% improvement!

AR Recon 2022-23 Impact on Precipitation Forecasts

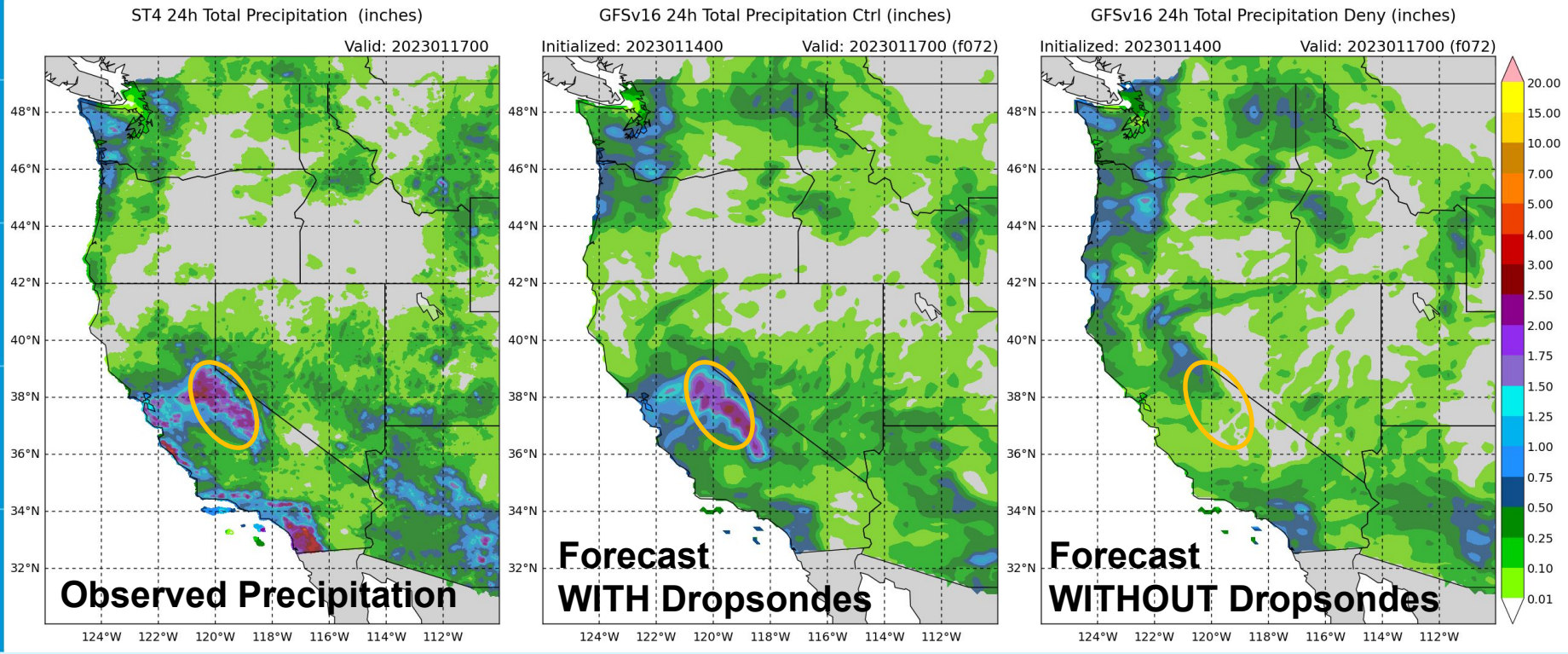
72-hr Forecast Improvement Ctrl vs. Deny



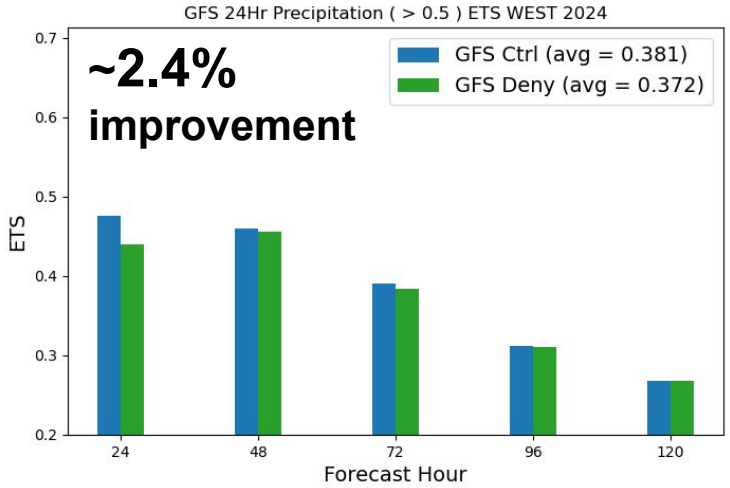
Largest improvements over the California Domain for the heavier precipitation amounts

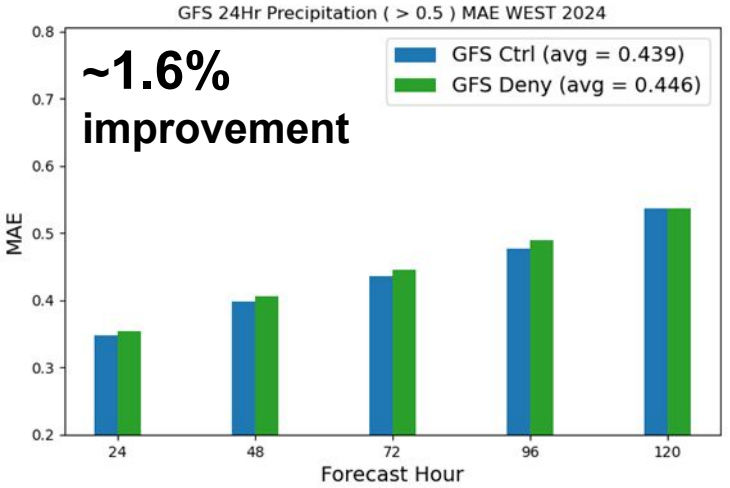
On average, **12% improvement equates to skill expected 8 years in the future.**

Case Study: IOP 14 (00Z Jan 14)
72-hour forecast, verify at 00Z Jan 17

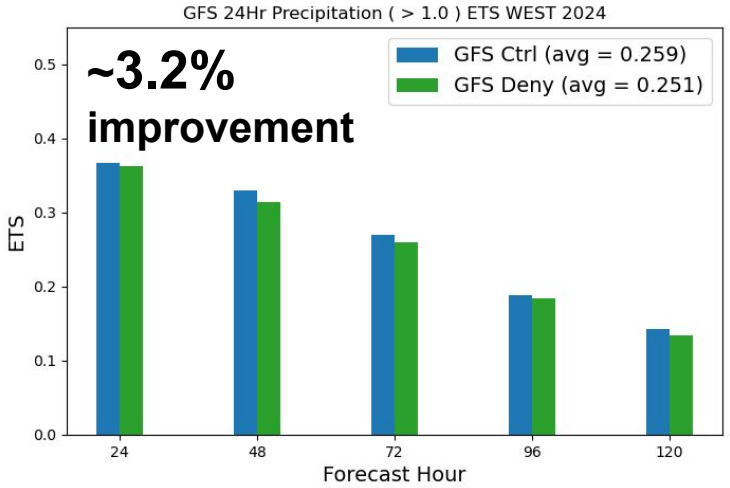


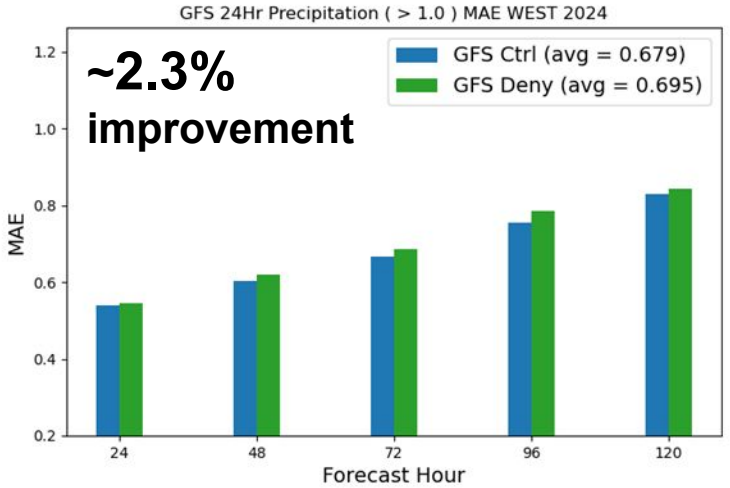
AR Recon precipitation (>0.5 in)





AR Recon precipitation (>1.0 in)



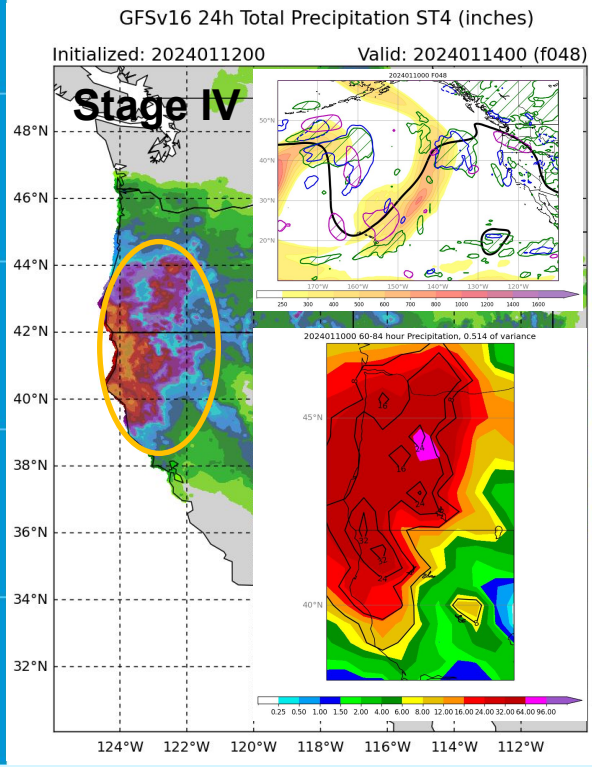


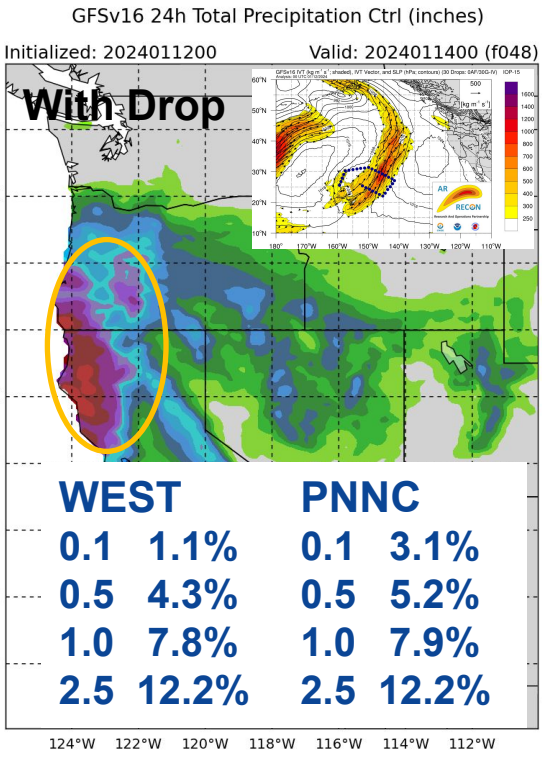
2023-2024 ARR 40 IOPs WEST

ETS

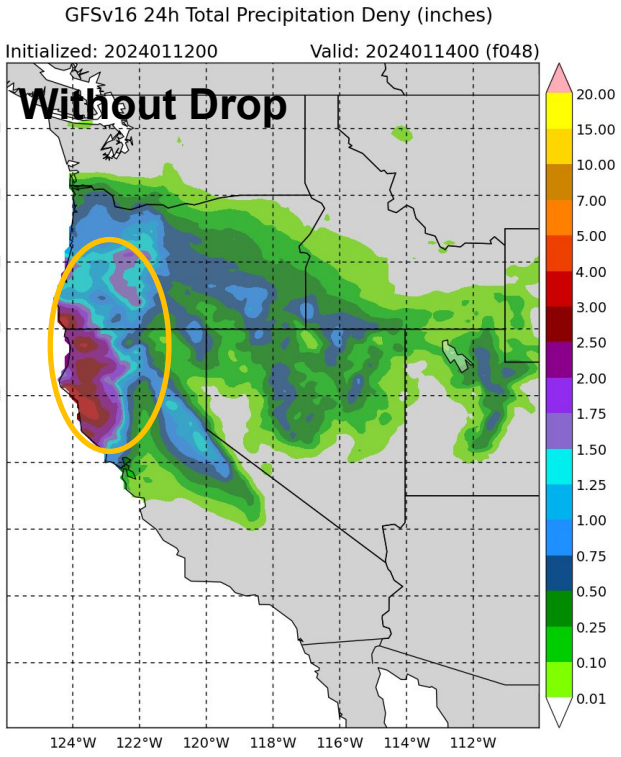
MAE

Case Study: IOP 15 (00Z Jan 12)
48-hour forecast, verify at 00Z Jan 14, 2024

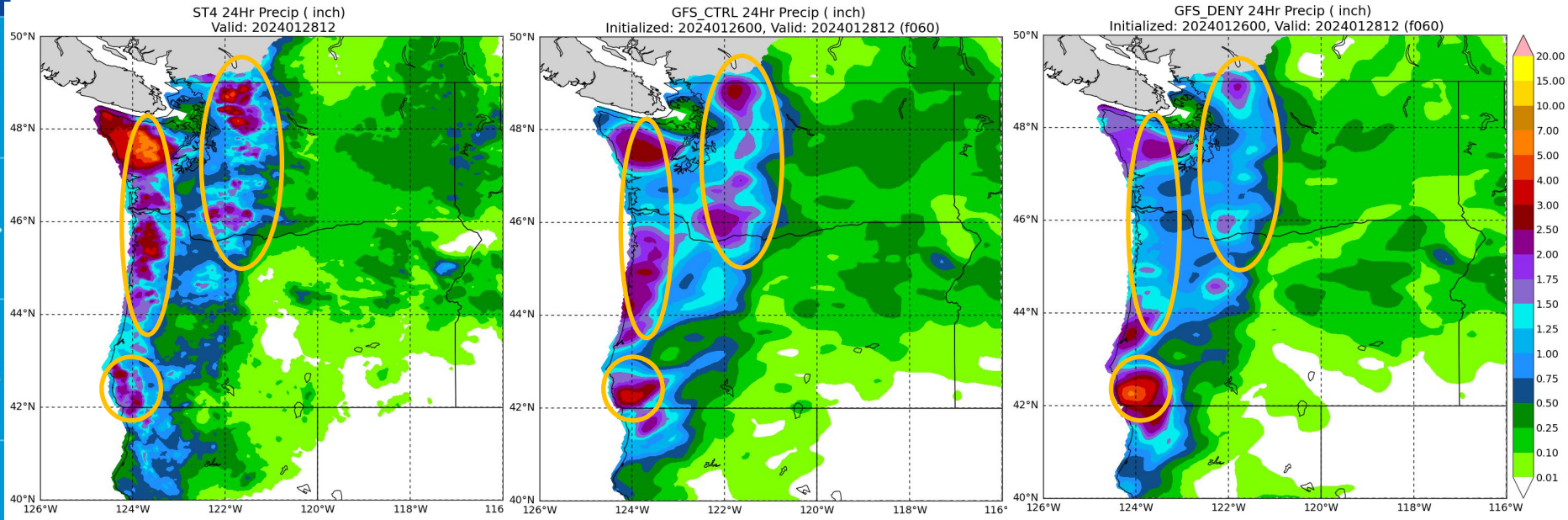




WEST		PNNC	
0.1	1.1%	0.1	3.1%
0.5	4.3%	0.5	5.2%
1.0	7.8%	1.0	7.9%
2.5	12.2%	2.5	12.2%



Case Study: IOP 26 (00Z Jan 26)
60-hour forecast, verify at 12Z Jan 28, 2024



Stage IV Obs | **With Drop** | **Without Drop**

Positive dropsonde impact for GFS precipitation forecast

AR Recon - Water Year 2025

Pacific Observations:

53rd Weather Reconnaissance Squadron:

- Drifting buoy deployments have begun – 80 new buoys to be deployed from California and Japan
- Resources permitting for flights Nov/Dec/Mar
- On station and available for flights January 8 – March 5
- ~2 weeks with extra aircraft based in Japan

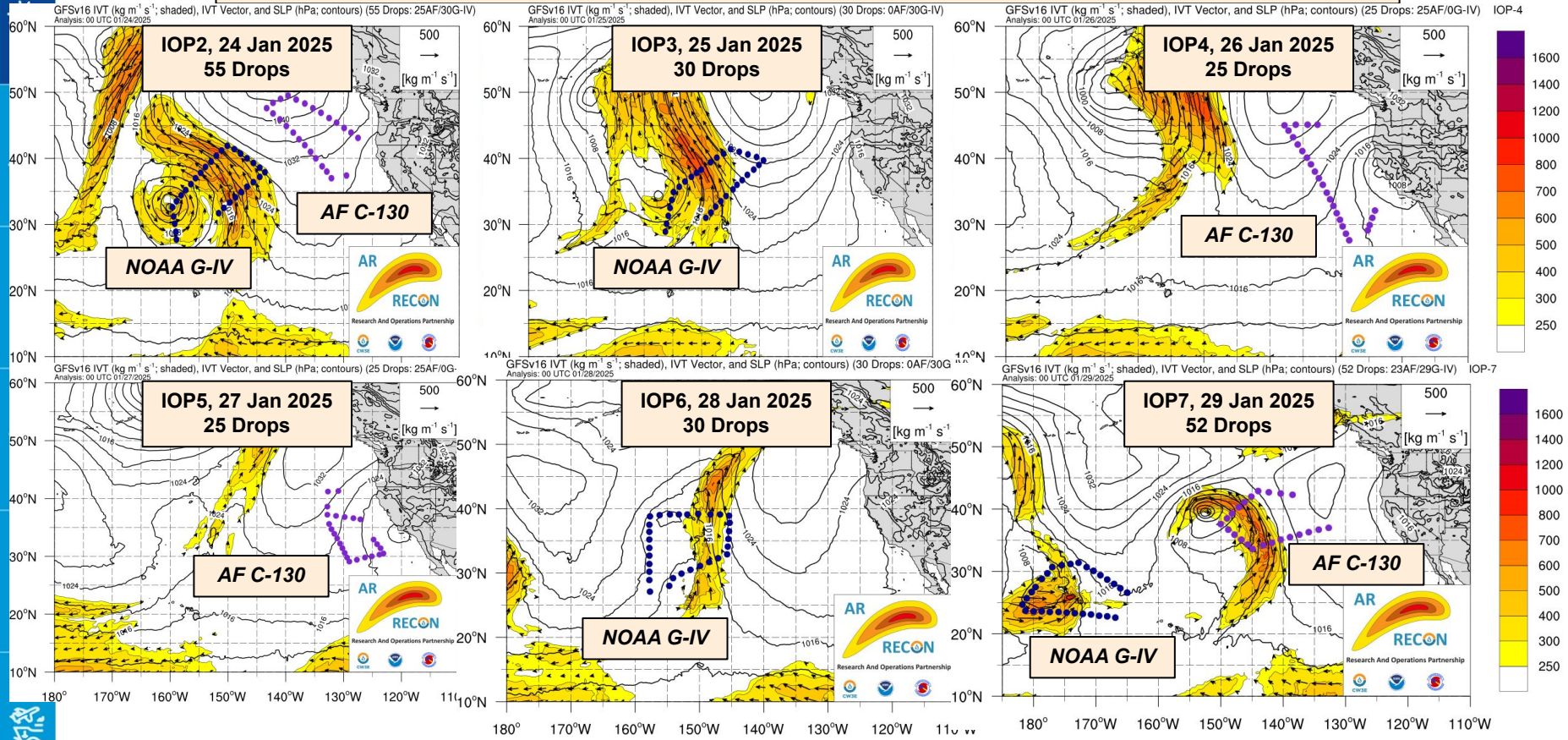
NOAA Aircraft Operations Center:

- Jan 6-Mar 13, based out of Honolulu, Hawaii
- 175 hours of flight time

Tech. Sgt. Larry Banks checks the dropsonde prior to use during an Atmospheric River mission Jan. 12, 2022. Credit: Senior Master Sgt. Jessica Kendziorek).

A pallet of three weather buoys parachutes to the Pacific Ocean after being released by the Air Force Reserve's 53rd Weather Reconnaissance Squadron Hurricane Hunters Dec. 15, 2021. Credit: US Air Force.

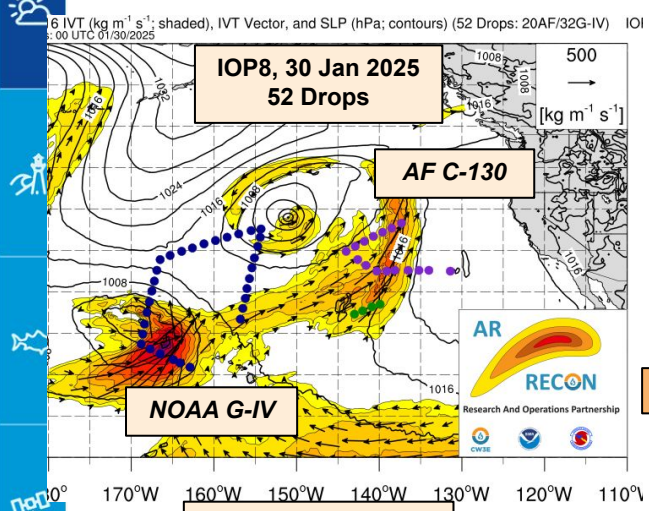
Atmospheric River Reconnaissance 2024-2025 Sequence-1 (Active)

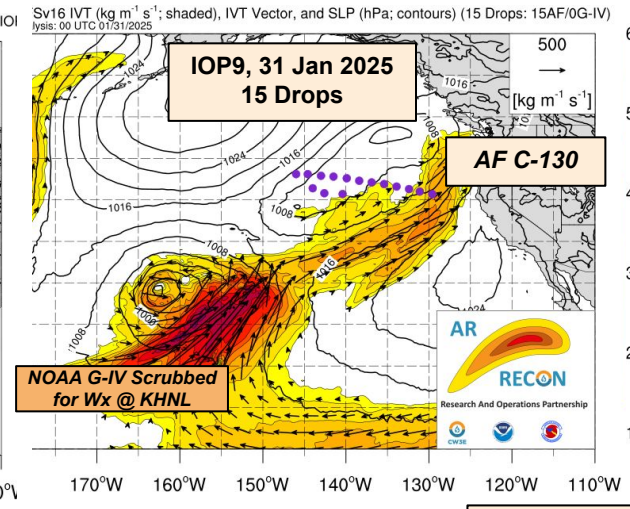


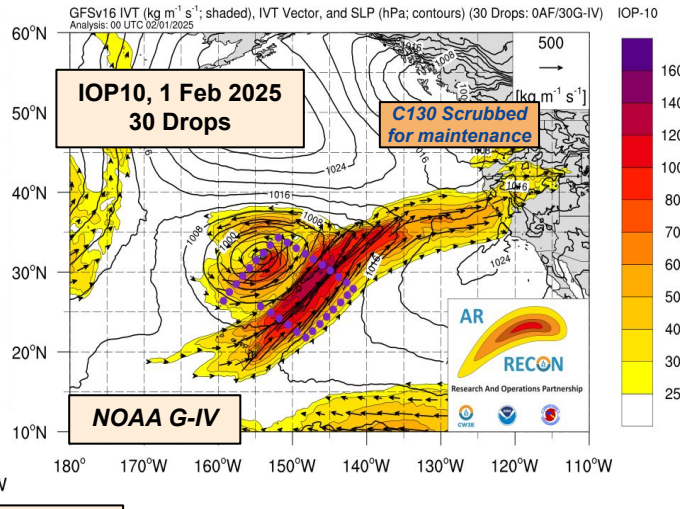
Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

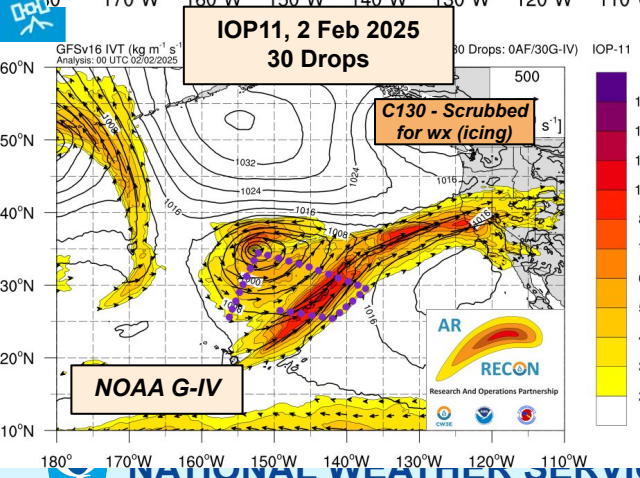
F. Martin Ralph (UCSD/SIO/CW3E) - PI
Vijay Tallapragada (NWS/NCEP) - Co-PI
Anna Wilson (UCSD/SIO/CW3E) - Coordinator

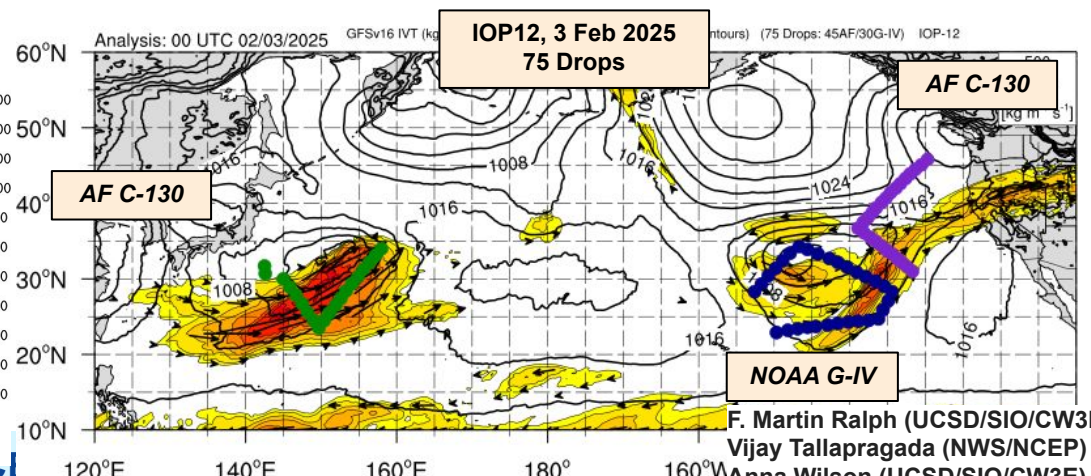
Atmospheric River Reconnaissance 2024-2025 Sequence-1 (Active)











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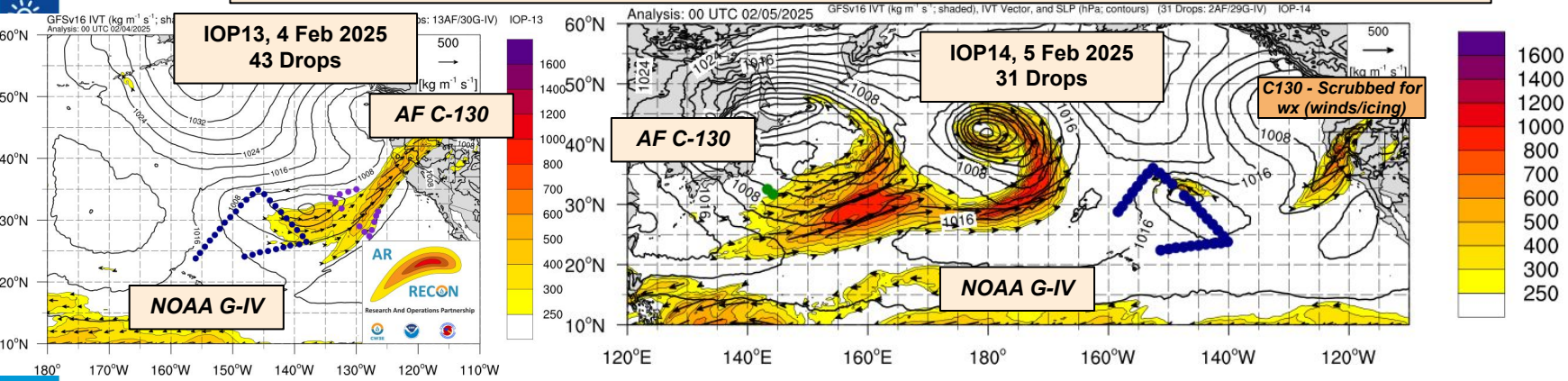

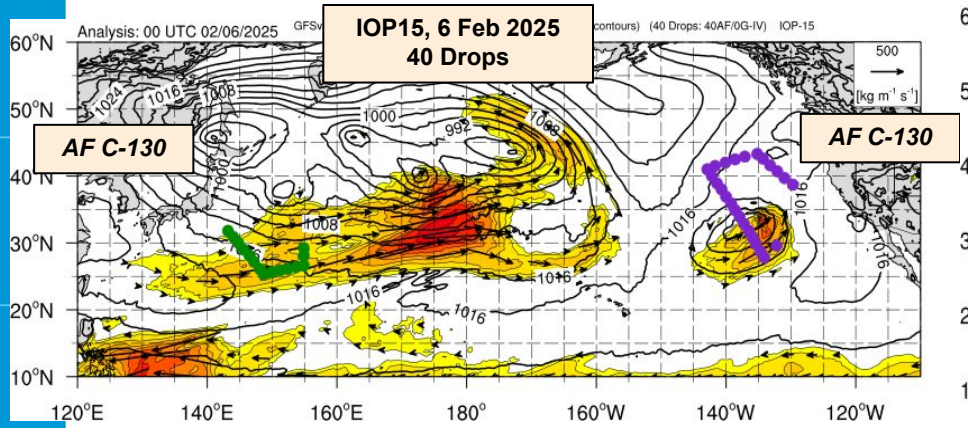

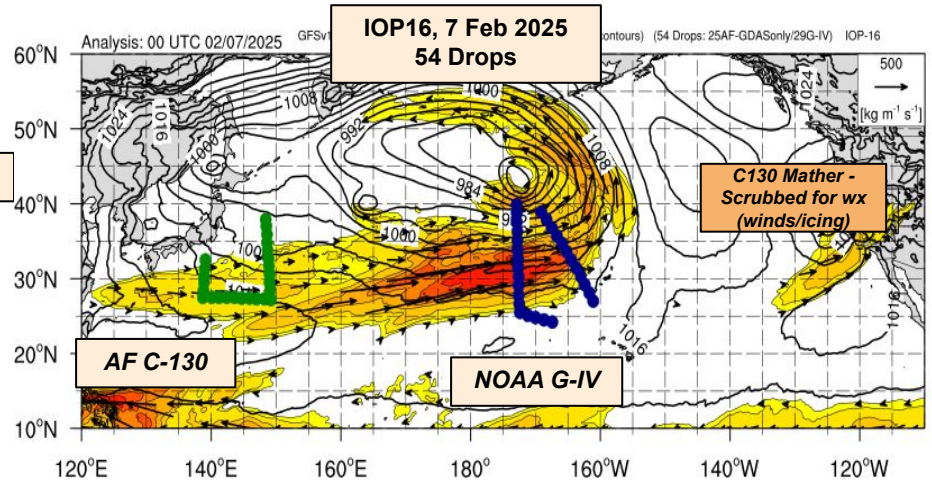

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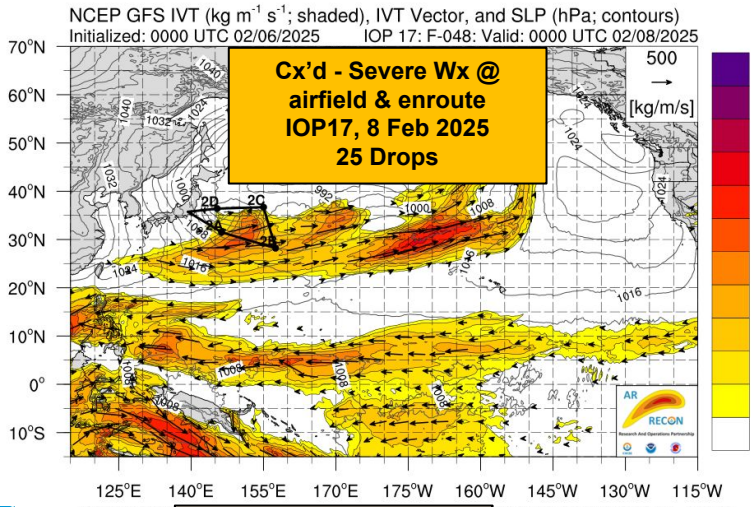

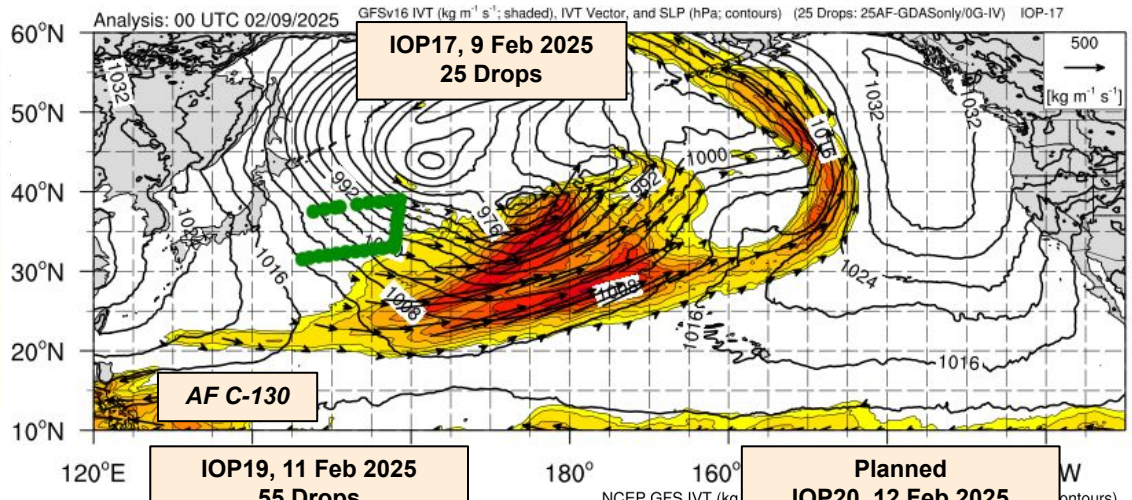

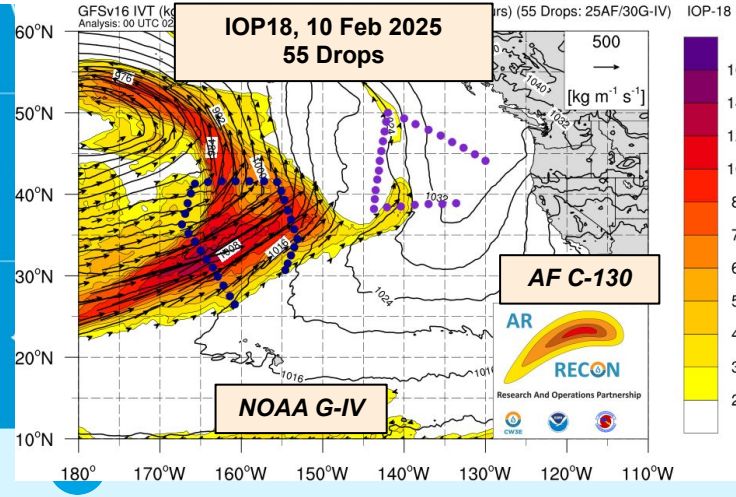

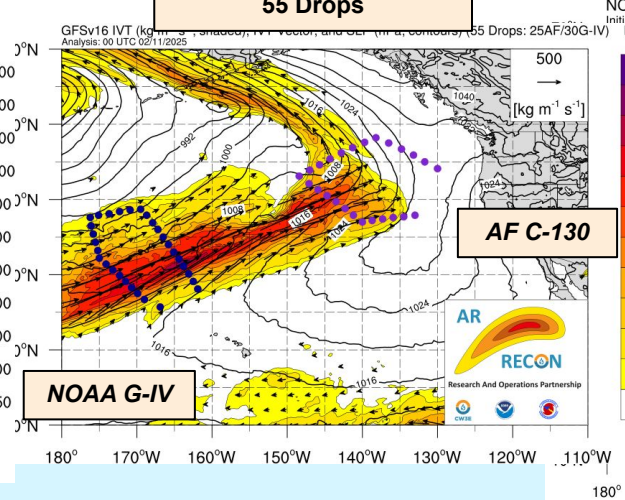

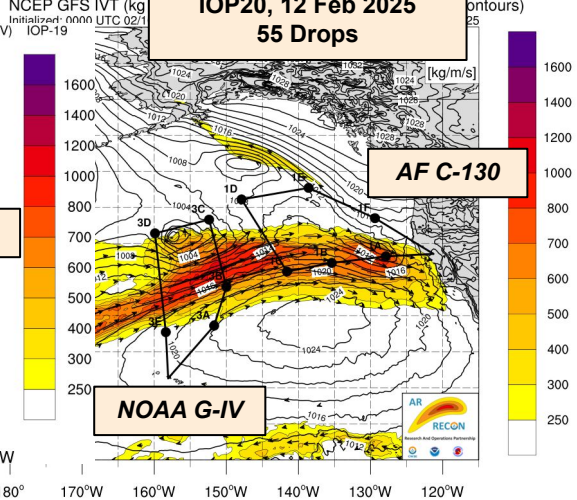

00Z 3 Feb 2025

AR Recon 2024-2025 Season
Northern Hemispheric GARRP* Demo

F. M. Ralph, AR Recon PI, Vijay Tallapragada Co-PI

AR RECON
Research And Operations Partnership

West Pac | Cent/East Pac | East Coast/Gulf | High Latitude | East Atlantic

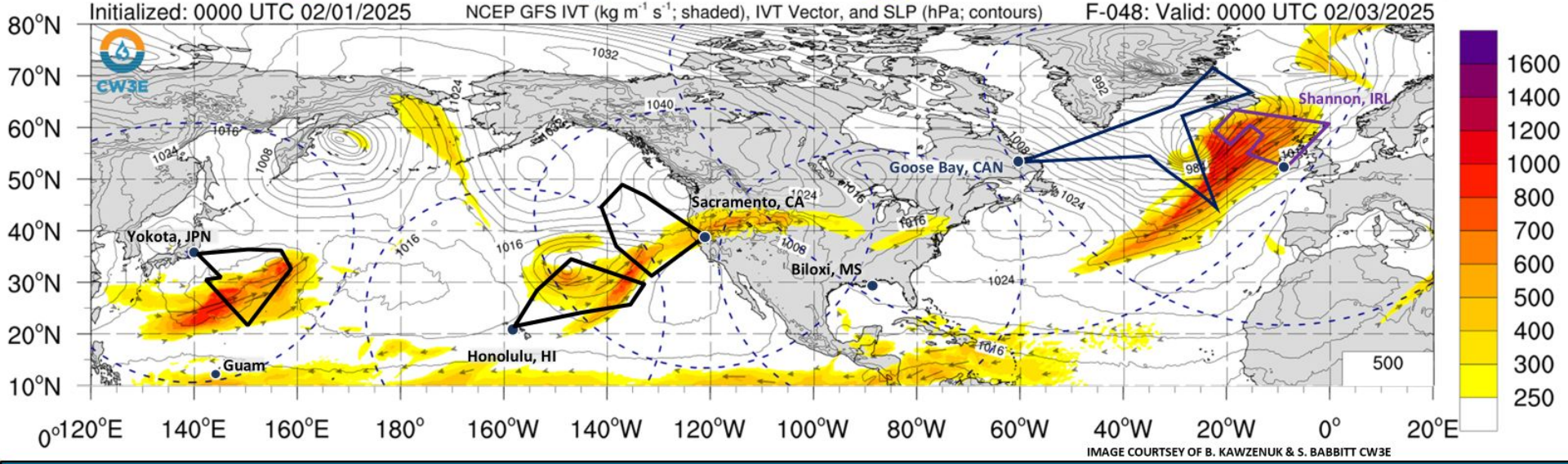

IMAGE COURTSEY OF B. KAWZENUK & S. BABBITT CW3E

Command Center
La, Jolla, CA

CW3E

West Pac	Central/East Pac	East/Gulf Coast
Jan 2024 Guam Jan 2025 Yokota, JPN	1 Nov – 31 Mar 4 • AF C-130 Sacramento • NOAA G-IV Hawaii	On Request Dec-Feb • AF C-130 Biloxi

Command Center

KIT Karlsruher Institut für Technologie

High Latitude	Atlantic
NASA Nurture 2027 Op • NASA 777, Gander, CAN	NAWDIC 27 Jan – 7 Feb 2025 Dry Run 12 Jan – 20 Feb 2026 Op G550 & ATF42 Shannon, IRL

(*Global Atmospheric River Reconnaissance)

00Z 4 Feb 2025

AR Recon 2024-2025 Season
Northern Hemispheric GARRP* Demo

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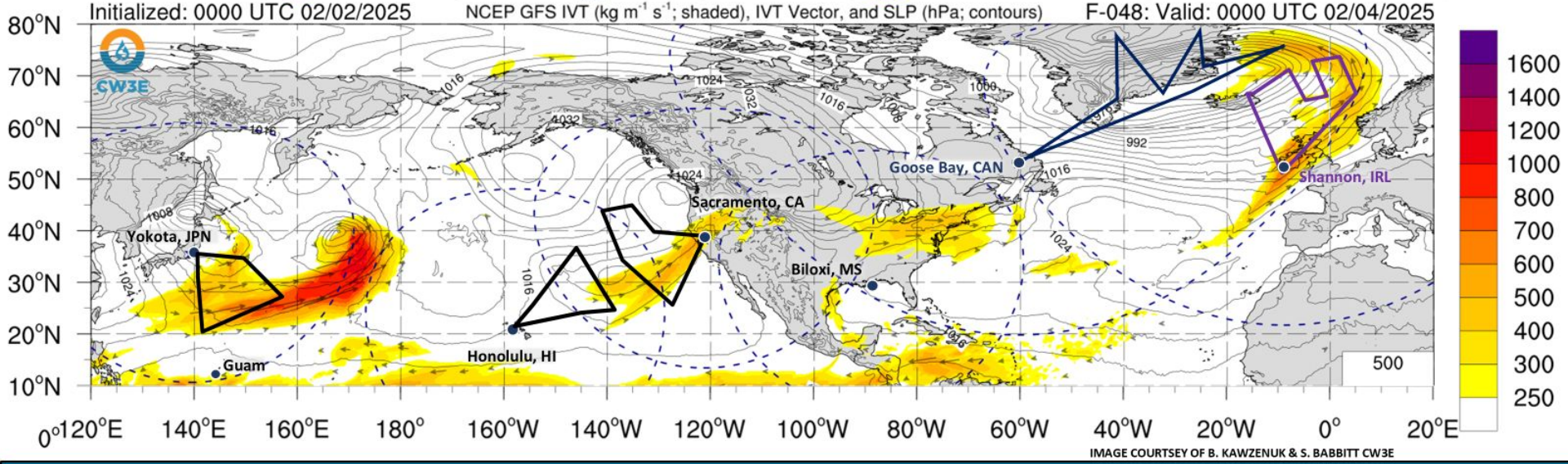

IMAGE COURTSEY OF B. KAWZENUK & S. BABBITT CW3E

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00Z 6 Feb 2025

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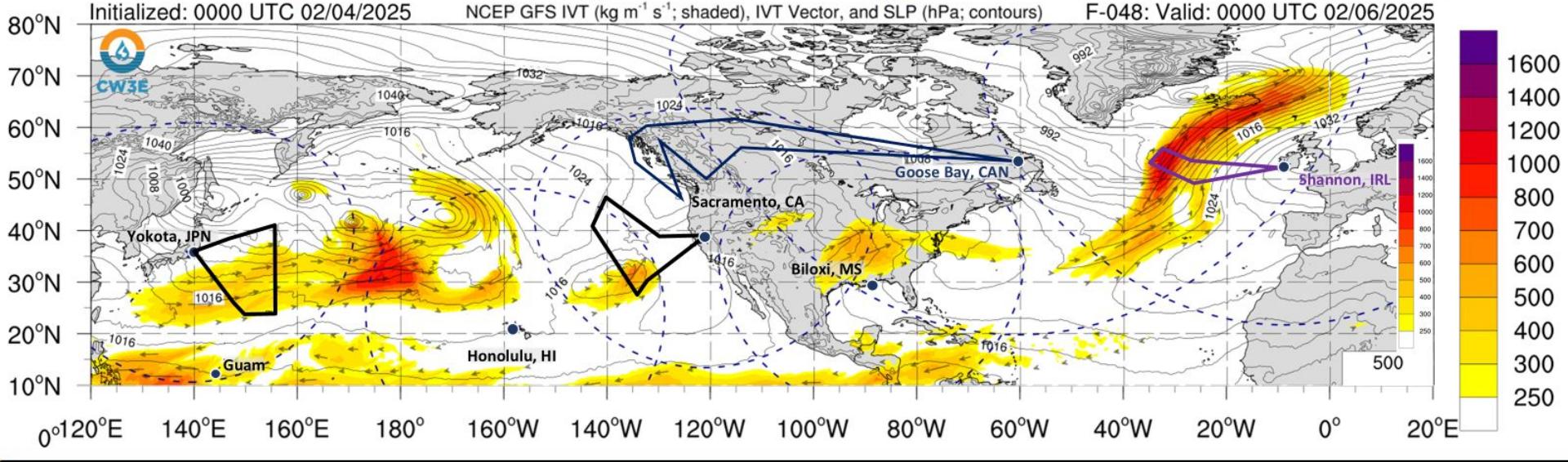

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00z 7 Feb 2025

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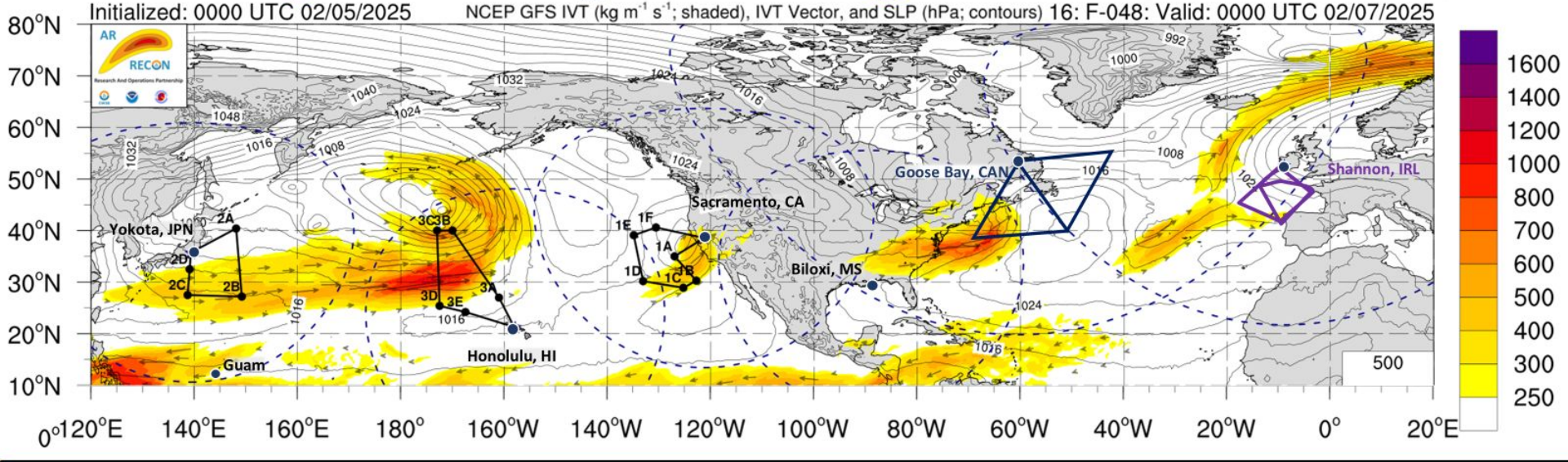

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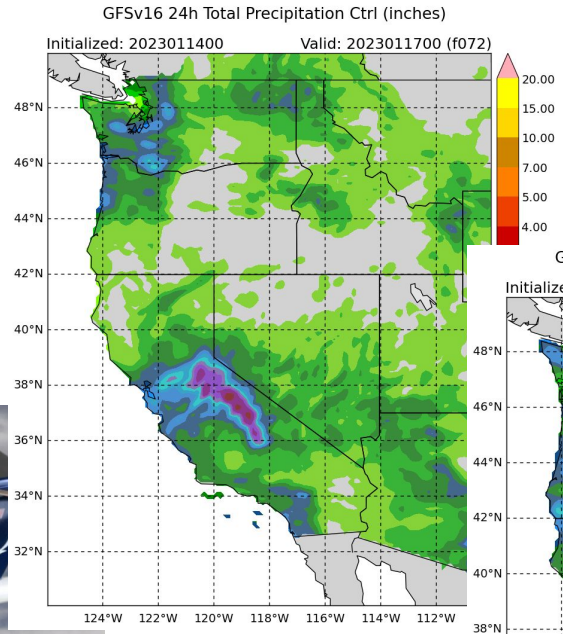
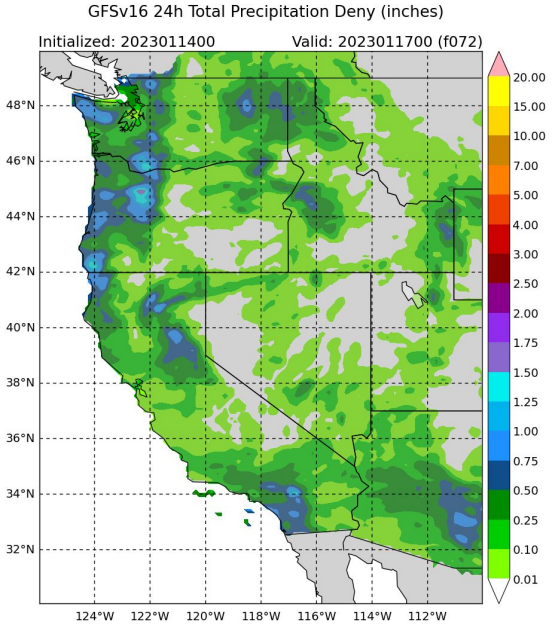
AR Recon Program: Now and the Future





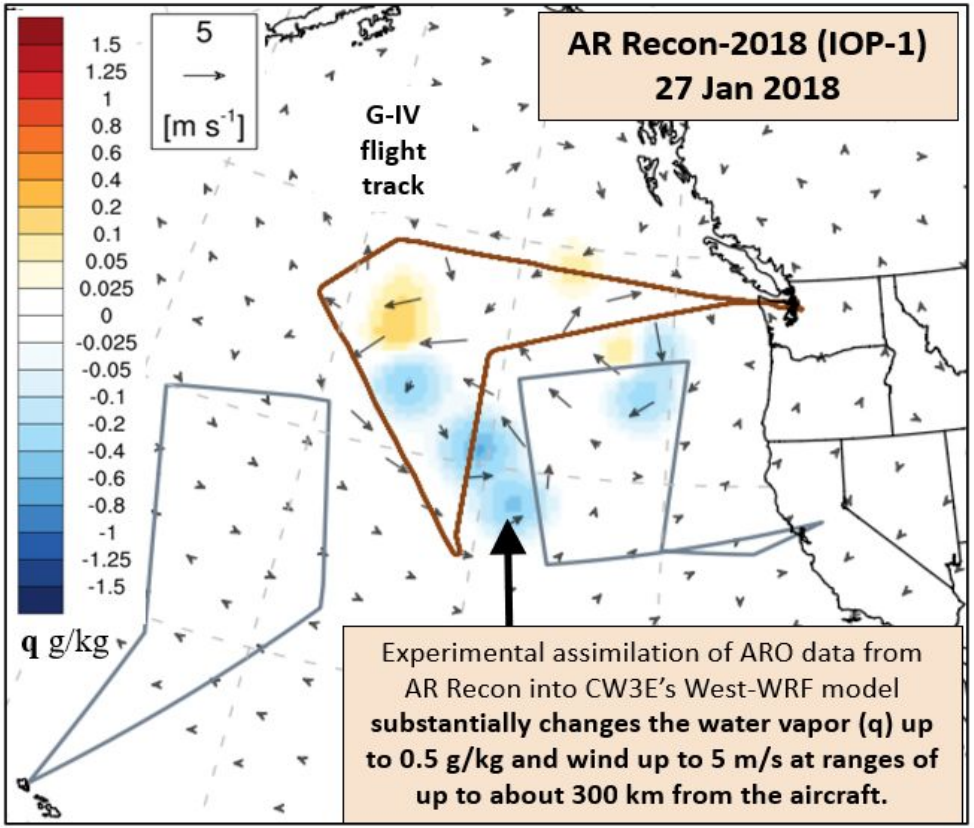
New NOAA Aircraft Enhance AR Reconnaissance

"These new state-of-the-art aircraft will greatly enhance NOAA's ability to gather data critical to hurricane research and forecasting, **atmospheric river research and forecasting**, climate studies and other missions. Infrastructure investments like this protect both lives and livelihoods." - NOAA Administrator Rick Spinrad, Ph.D (NOAA press release 7/15/24).

2 new aircraft (G550s) will replace NOAA's aging GIV. The new aircraft can fly faster, higher, and longer.

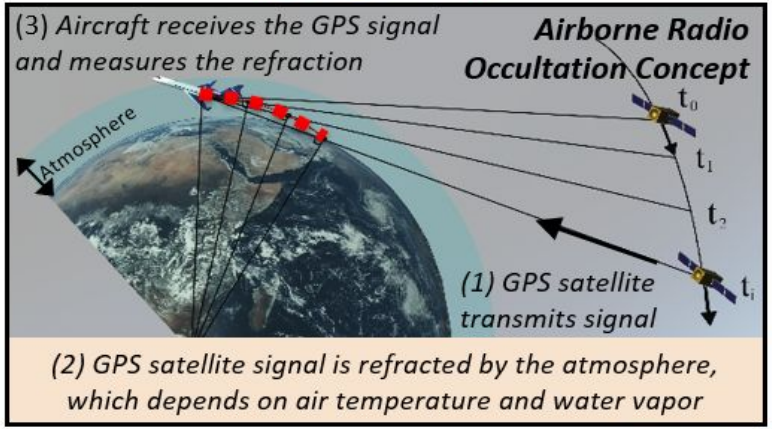
Artist concept of NOAA (Image credit: Gulfstream)

Emerging Technology Testing in AR Recon: Airborne Radio Occultation (ARO)



ARO Lead: Jennifer S. Haase (SIO/UCSD)

jhaase@ucsd.edu



AR Recon - 2020 deployment

- 3 aircraft with standard ARO
- 1 aircraft experimental dual-pol ARO hydrometeor information

CW3E NASA NSF

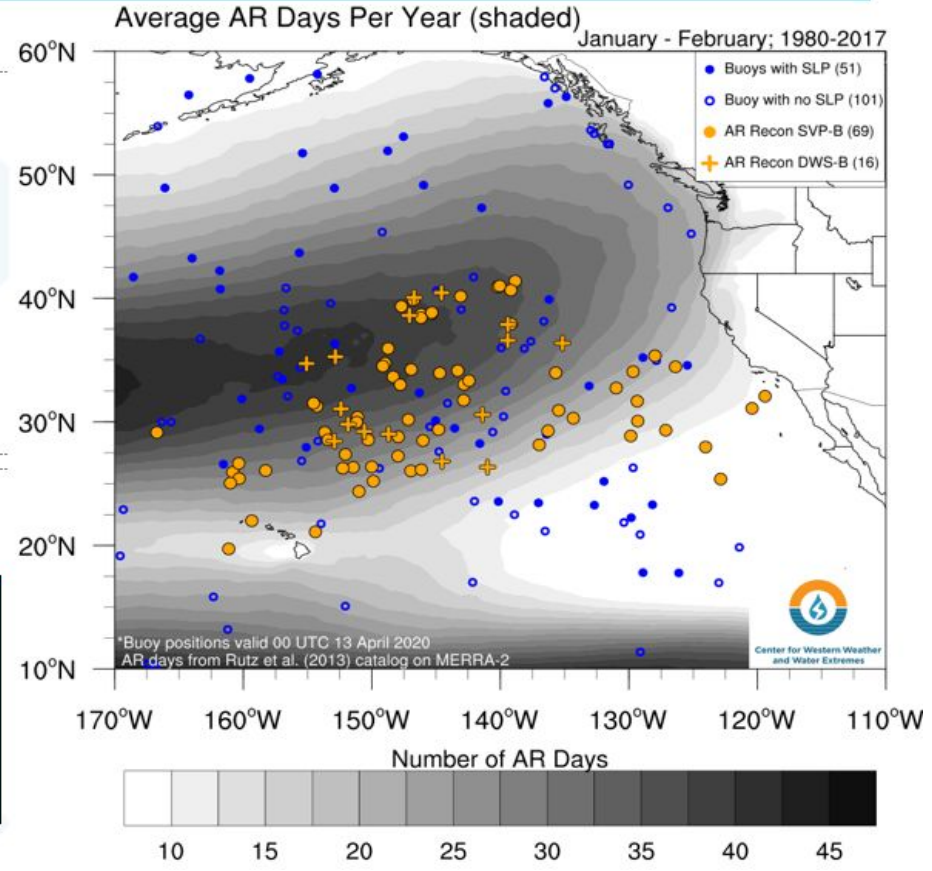
ROC2 Receiver

DRIFTING BUOY WITH PRESSURE SENSORS – AR RECON DEPLOYMENT

- Second year in a row with buoy deployment collaboration between NOAA Global Drifter Program (***PI: Luca Centurioni***), Scripps/CW3E AR Recon (***PI: Marty Ralph***) with planning support from the AR Recon Modeling and DA Steering Committee (***Scripps/CW3E, NCEP, ECMWF, NRL, NCAR, CU Boulder***)

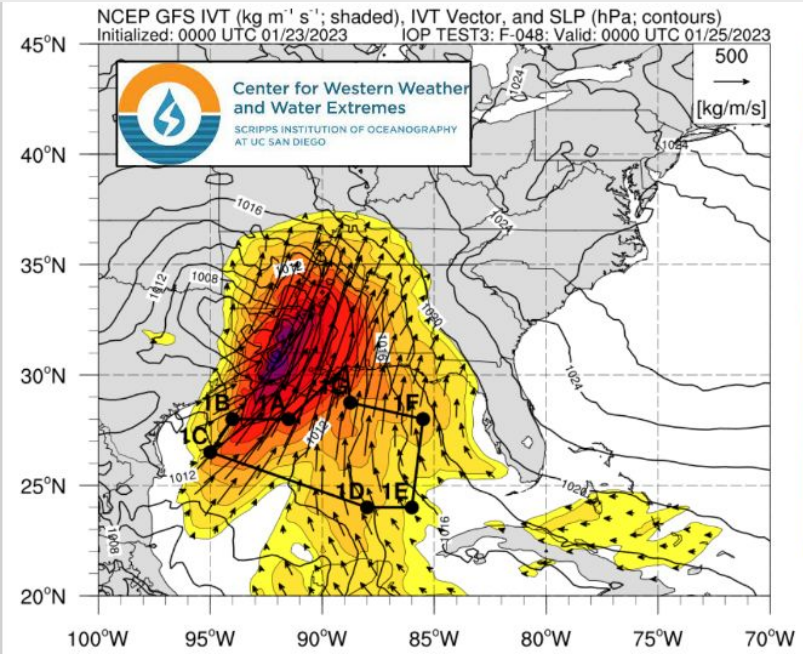
- 2019: 32 buoys air-deployed by Air Force
- 2020: 64 buoys – 40 deployed via ship of opportunity; 24 deployed via Air Force
- Evaluation ongoing

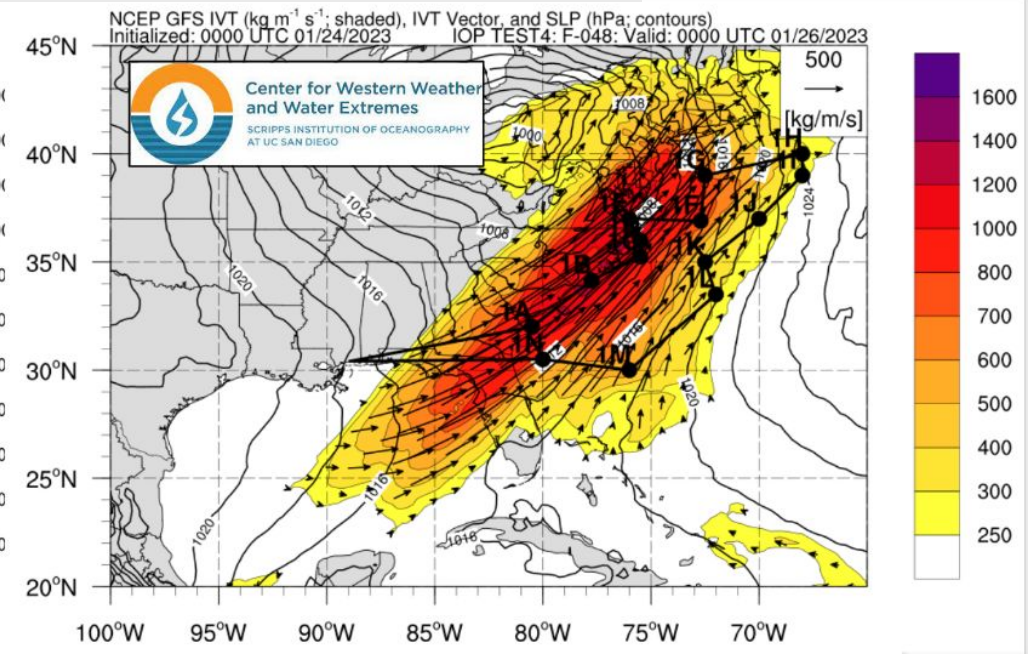
Leverages federal investments by upgrading instrumentation provided through NOAA's Global Drifter Program



AR Recon Milestones – Flight Plans for the Gulf of Mexico and Atlantic Ocean

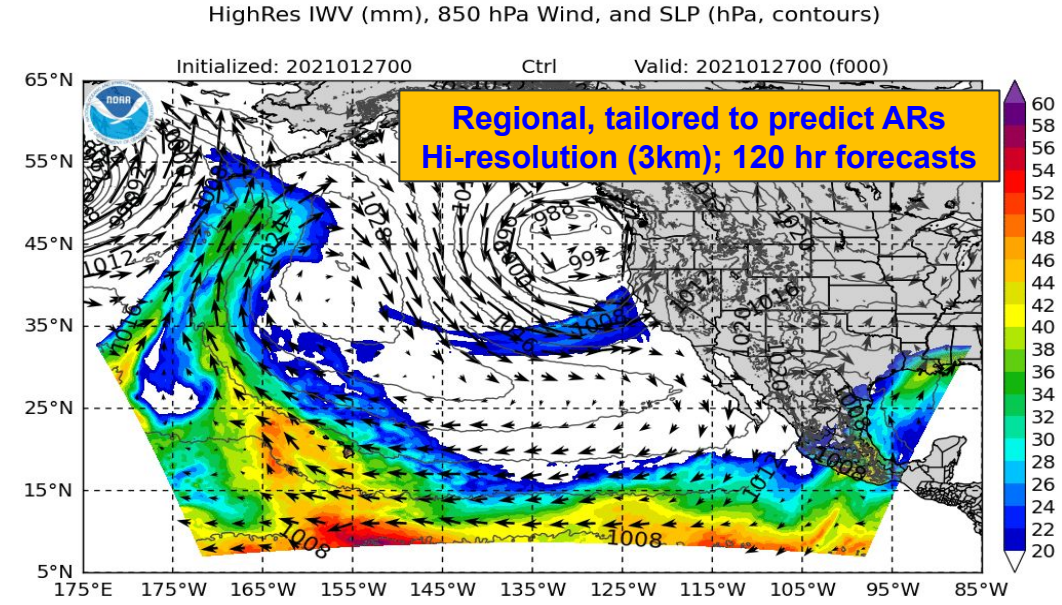
January 25, 2023



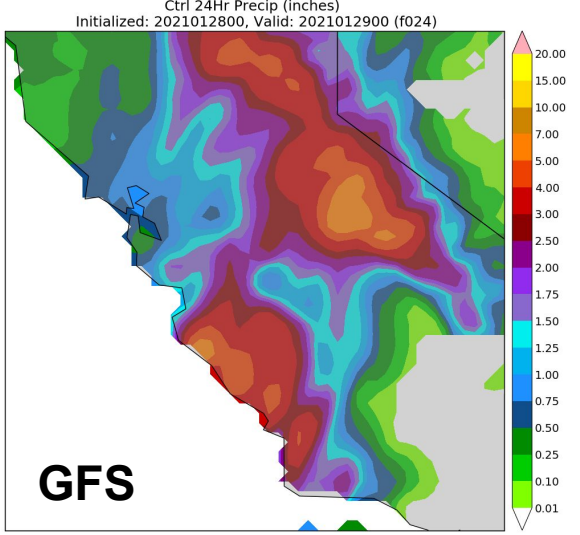


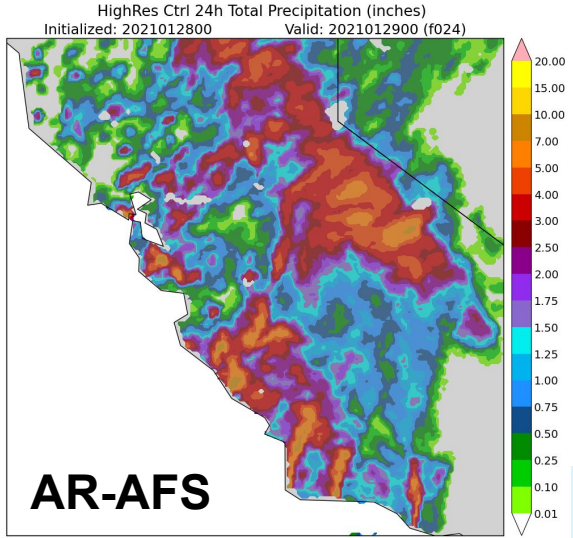
High Resolution UFS Regional Model for Atmospheric Rivers (AR-AFS)

Designed in partnership with CW3E
builds on lessons from CW3E's West-WRF model & the successful paradigm of HFIP & HAFS



24-h precipitaion forecasts





Summary and Future Plans

- AR dropsonde data help improve GFS forecasts over the PNA (180-320E, 20-75N) due to improvement in GFS analysis.
- There is a positive impact on the GFS forecast skill for the precip over the U.S. West Coast, along with improved analysis and forecast of moisture, wind, and AR landfall.
- Data gaps associated with ARs can be addressed with targeted AR Recon field campaigns which provide vital observations for improving precipitation forecasts.
- Continue evaluating the impact of AR Recon data (including those from Guam) on GFS operational forecasts.
- Optimize the use of AR Recon data and other innovative observations.

Thanks for your attention

Questions?