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

ADVANCES IN PRECIPITATION FORECAST ACCURACY SUPPORTED BY ATMOSPHERIC RIVER RECONNAISSANCE: PROGRESS & FUTURE DIRECTIONS

Presented by: Anna Wilson, Center for Western Weather and Water Extremes, UC San Diego/Scripps Institution of Oceanography, AR Recon Coordinator

On behalf of the entire AR Recon team

Marty Ralph, CW3E/Scripps/UCSD (PI); Vijay Tallapragada, NOAA/NCEP/EMC (Co-PI)

9th Annual Forecast Informed Reservoir Operations Workshop
3 August 2022

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AR RECON - RESEARCH AND OPERATIONS PARTNERSHIP

- **AR Recon began as a pilot study in 2016**
- **Became Operational in 2020 when it was called for in the Interagency "National Winter Season Operations Plan"**
- **Better weather observations over the Pacific help AR landfall predictions and associated precipitation, water supply and flooding**
- **Advances scientific understanding, enables forecast improvements via multiple pathways**
- **International, Interagency Steering Committee (SC) Coordinates Modeling and Data Assimilation efforts**

Key Partners: NCEP/NWS, ECMWF, NRL, NCAR, CU Boulder, Plymouth State Univ., SUNY Albany, NWS Western Region, NOAA AOC, Air Force, Northern Ill. Univ.

F. Martin Ralph, PI
(UC San Diego/SIO/CW3E)
Vijay Tallapragada, Co-PI
(NOAA/NWS/NCEP)

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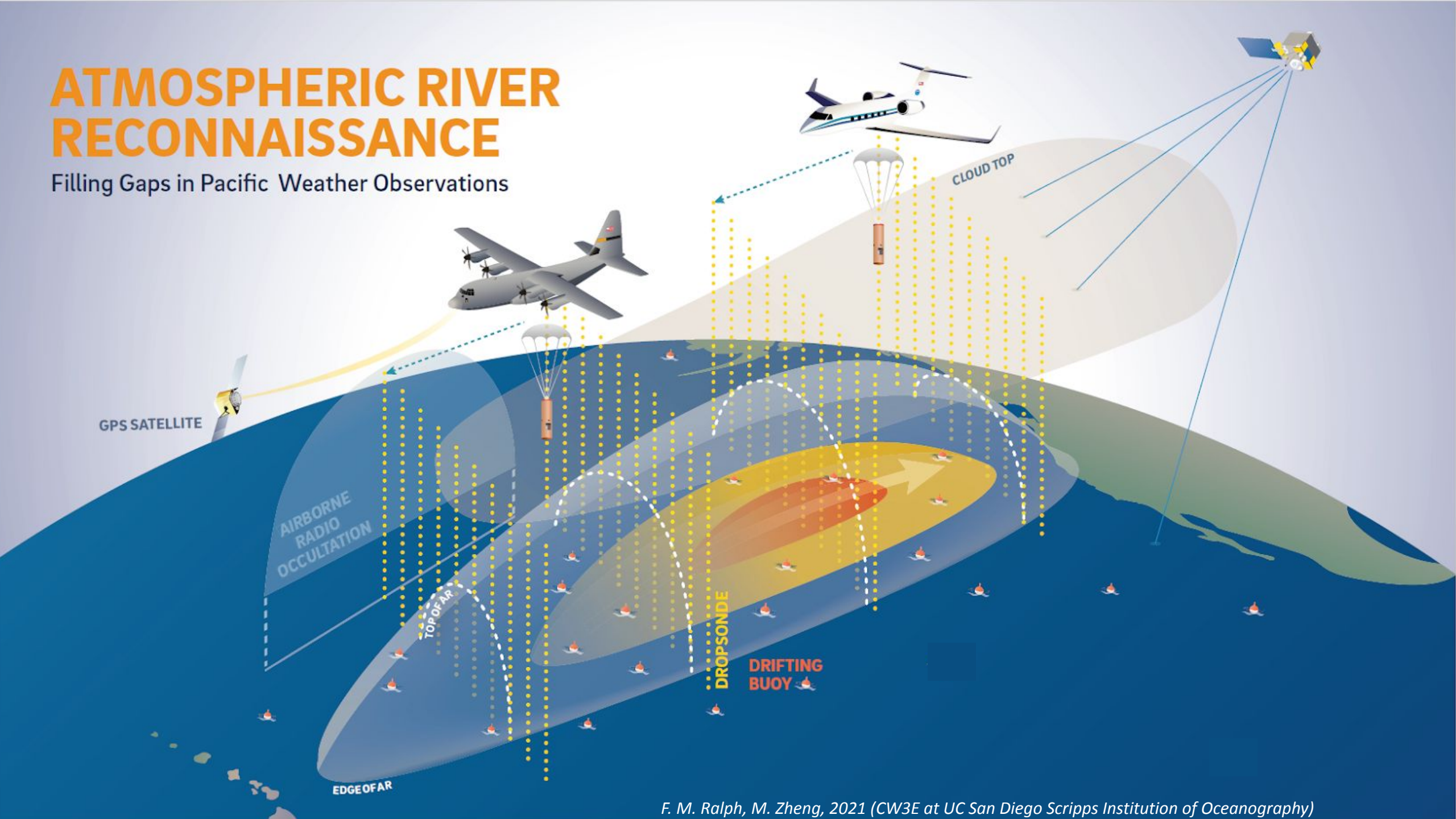
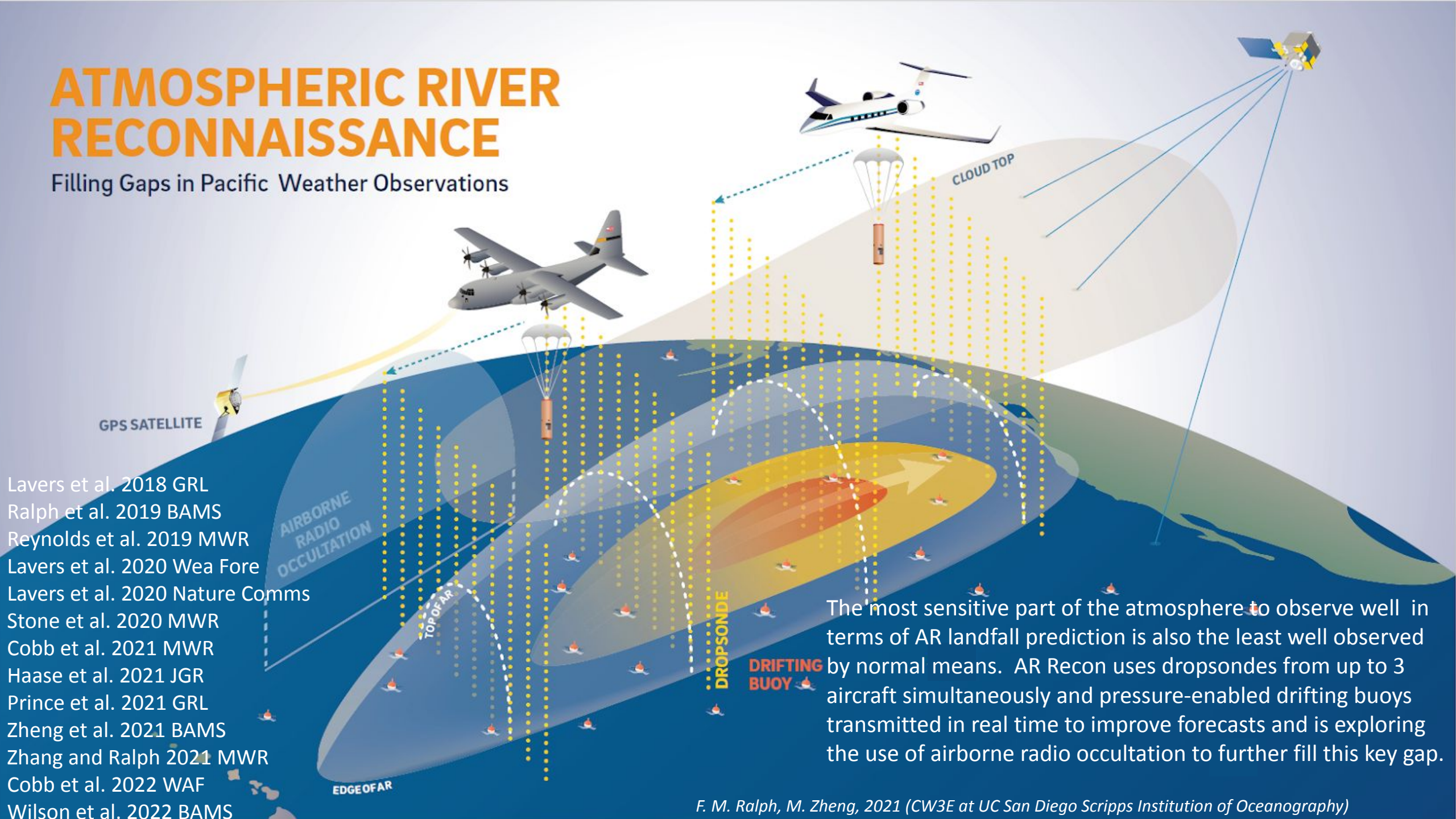


F. M. Ralph, M. Zheng, 2021 (CW3E at UC San Diego Scripps Institution of Oceanography)

ATMOSPHERIC RIVER RECONNAISSANCE

Filling Gaps in Pacific Weather Observations



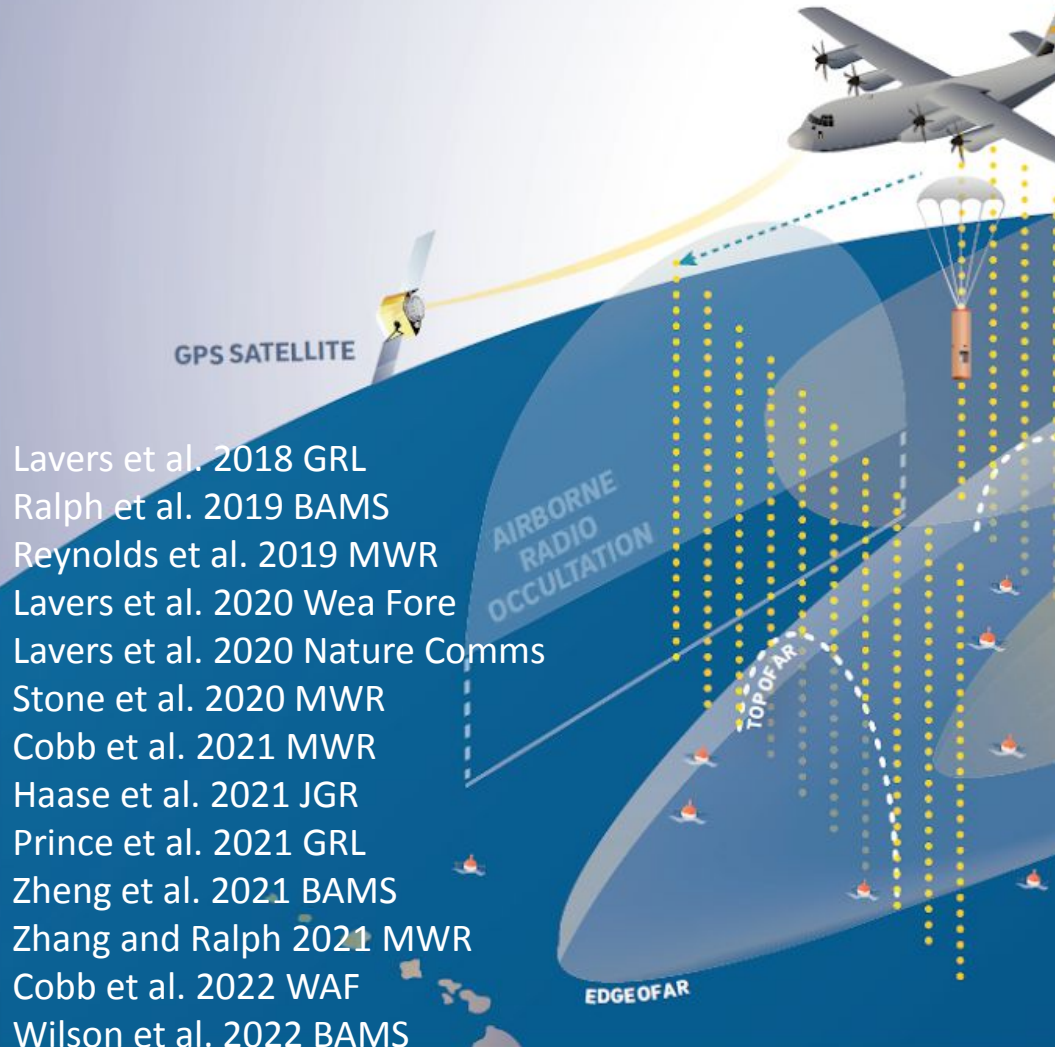
Lavers et al. 2018 GRL
Ralph et al. 2019 BAMS
Reynolds et al. 2019 MWR
Lavers et al. 2020 Wea Fore
Lavers et al. 2020 Nature Comms
Stone et al. 2020 MWR
Cobb et al. 2021 MWR
Haase et al. 2021 JGR
Prince et al. 2021 GRL
Zheng et al. 2021 BAMS
Zhang and Ralph 2021 MWR
Cobb et al. 2022 WAF
Wilson et al. 2022 BAMS

The most sensitive part of the atmosphere to observe well in terms of AR landfall prediction is also the least well observed by normal means. AR Recon uses dropsondes from up to 3 aircraft simultaneously and pressure-enabled drifting buoys transmitted in real time to improve forecasts and is exploring the use of airborne radio occultation to further fill this key gap.

F. M. Ralph, M. Zheng, 2021 (CW3E at UC San Diego Scripps Institution of Oceanography)

ATMOSPHERIC RIVER RECONNAISSANCE

Filling Gaps in Pacific Weather Observations



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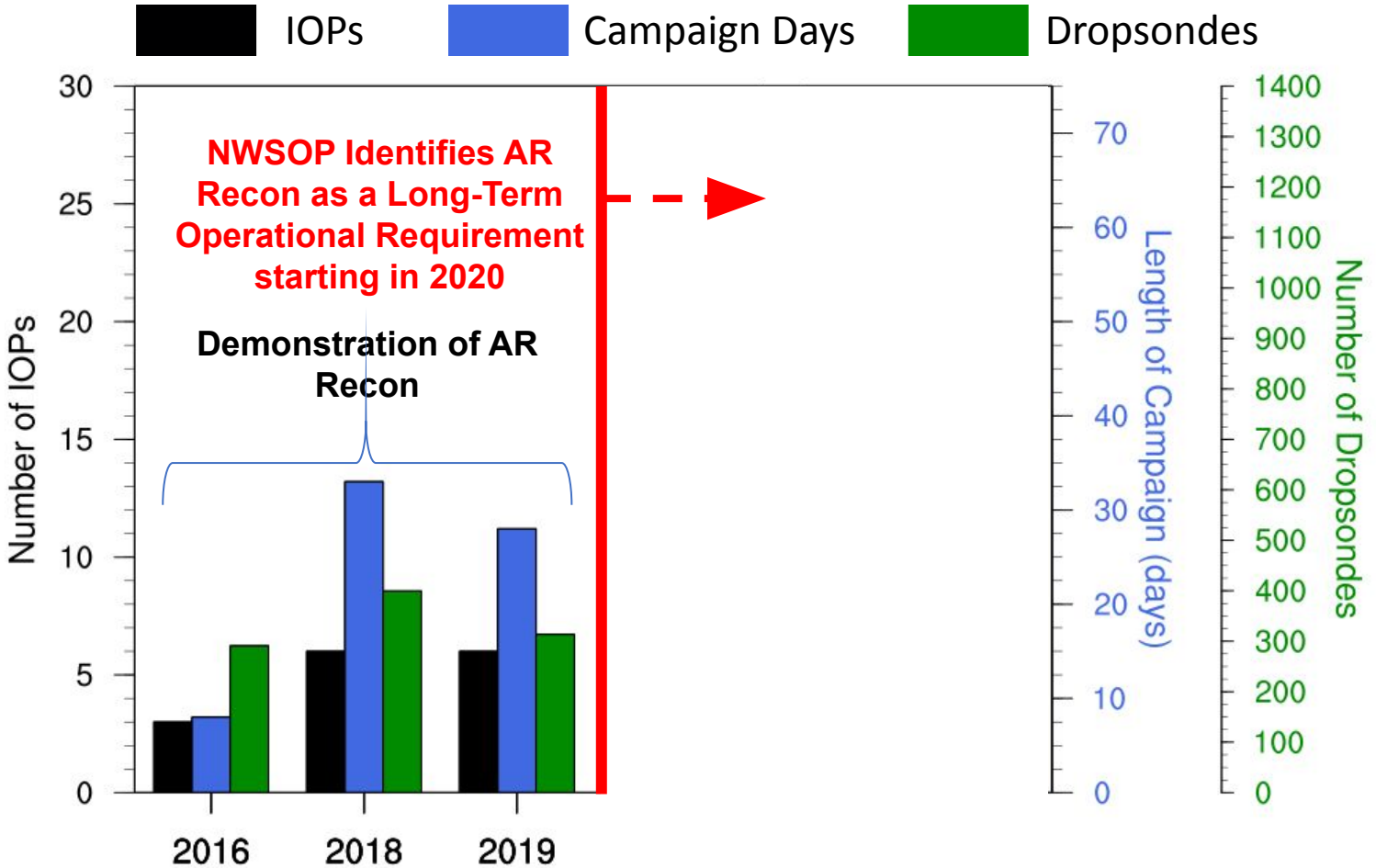
Wilson et al. 2022 BAMS

Atmospheric River Reconnaissance: Growth from Demonstration to Operations



AR Recon –2022 Flight Operations Planning and Execution

NWS Co-PI
V. Tallapragada (NCEP) – Co-PI

AR Recon PI and Mission Director
F.M. Ralph (SIO/CIMEC & CW3E)
Alternates –V. Tallapragada, J. Rutz, J. Cordeira, A. Wilson, J. Haase, C. Davis
Coordinators: A. Wilson (CW3E), A. Cobb, K. Paulsson

Flight Directors
Lt Col R. Rickert (AF C-130s)
A Lundry (NOAA G-IV)

C-130 and G-IV Crews; CARCAH

AR Core Target Planning
Two C-130s
J. Rutz (NWS WR) – Lead
AR Core Target - Team
J. Cordeira (Plym. St); A. Michaelis (NIU)

iterate

Flight Track Assessment
AF Navigators (rotating)
NOAA (A. Lundry)
Coordinator: A. Cobb, C. Hecht, B. Downing, S. Roj, J. Ludtke (CW3E)

iterate

Secondary Target Planning
NOAA G-IV
J. Cordeira (Plym. St) - Lead
Secondary Target - Team
C. Davis (NCAR); J. Rutz (NWS WR); L. Bosart (SUNY Albany); A. Michaelis (NIU)

Key dates
Dec 7: forecasting dry run

5 Jan – 19 Mar: Flight operations IOP takeoff dates in PT; e.g. TO 16 Jan is flight 00Z 17 Jan

Ensemble Sensitivity Team
R. Torn (Albany) – Co-Lead; X. Wu (NCEP) – Co-Lead; M. Zheng (CW3E), K. Wu, S. Lord, T. Elless (NCEP), A. Michaelis (NIU), L. Delle Monache (CW3E)

Daily Forecasts, Flight Summaries and Planning Time 0800 PT*

**Attended by the designated lead for the day from each group*

Moist Adjoint Team
C. Reynolds (NRL)-Lead; J. Doyle (NRL); M. Zheng (CW3E), A. Michaelis (NIU), L. Delle Monache (CW3E)

Flight Operations Resources

Two C-130s available for storm flts from Mather

One G-IV available for storm flts from Hawaii

Ocean Drifter Team
L. Centurioni (SIO)-Lead; A. Wilson; D. Lavers; A. Subramanian

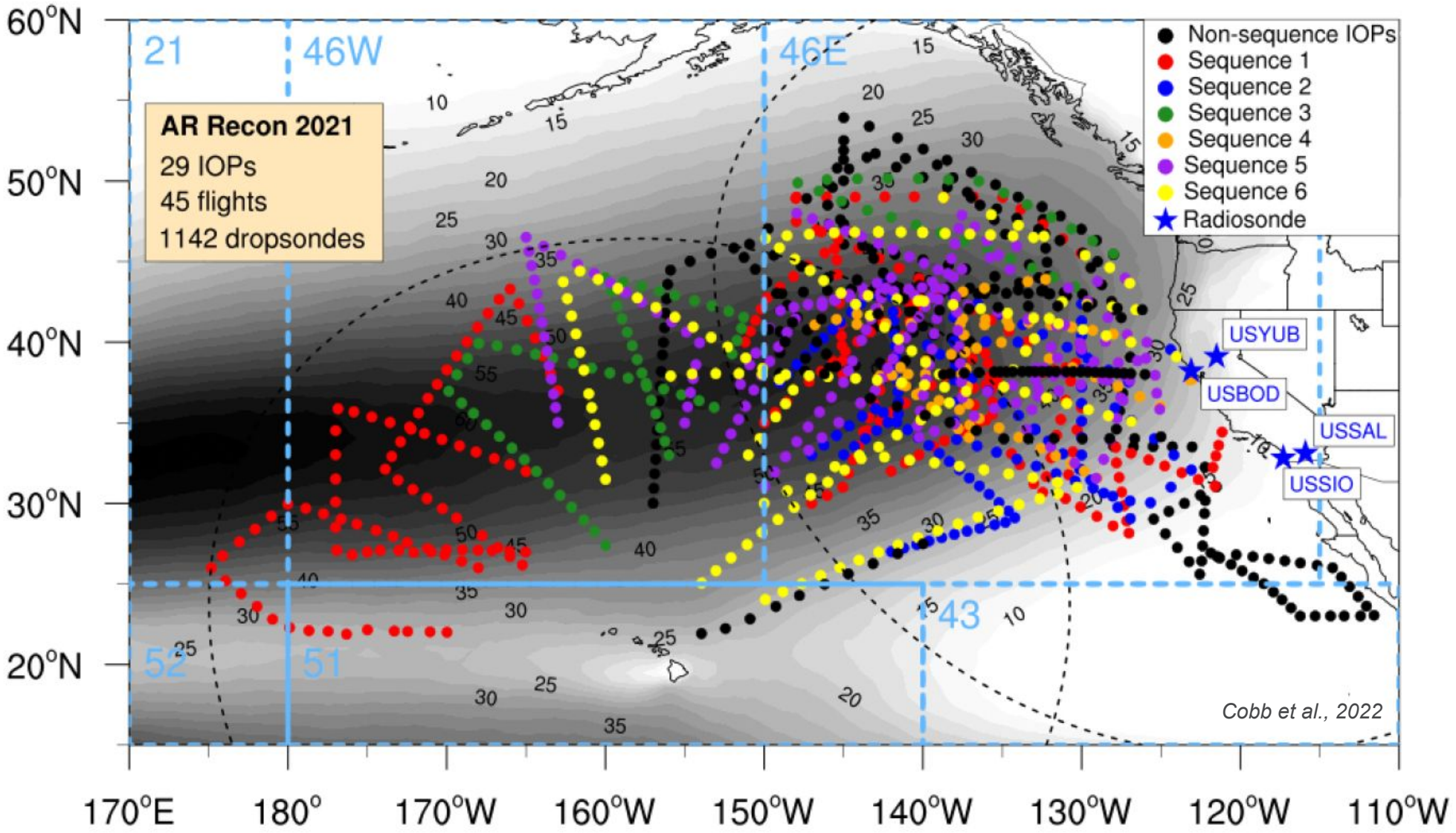
AR Recon Forecasting Team
C. Hecht (SIO/CW3E) – Lead; B. Kawzenuk (CW3E); A. Michaelis (N. Illinois U.); C. Castellano (CW3E), M. DeFlorio (CW3E), A. Cobb (CW3E), L. Odell (CW3E)

ARO Team
J. Haase (SIO)-Lead; M. Murphy; B. Cao (SIO)

Modeling and Data Assimilation (SC = Steering Committee)
M. Ralph (CW3E, SC Co-Chair); V. Tallapragada (NCEP, SC Co-Chair); J. Doyle (NRL, SC Member); F. Pappenberger (ECMWF, SC Member); C. Davis (NCAR, SC Member); C. Reynolds (NRL, SC Member); A. Subramanian (CU Boulder, SC Member); L. Delle Monache (CW3E, SC Member); D. Lavers (ECMWF); M. Zheng, M. Murphy, J. Haase, (CW3E)

Real Time Data Denial Runs and Assessment/Flight Summaries
V. Tallapragada, X. Wu (NCEP), A. Cobb, A. Wilson, M. Zheng (CW3E), D. Lavers (ECMWF), A. Subramanian (CU Boulder)

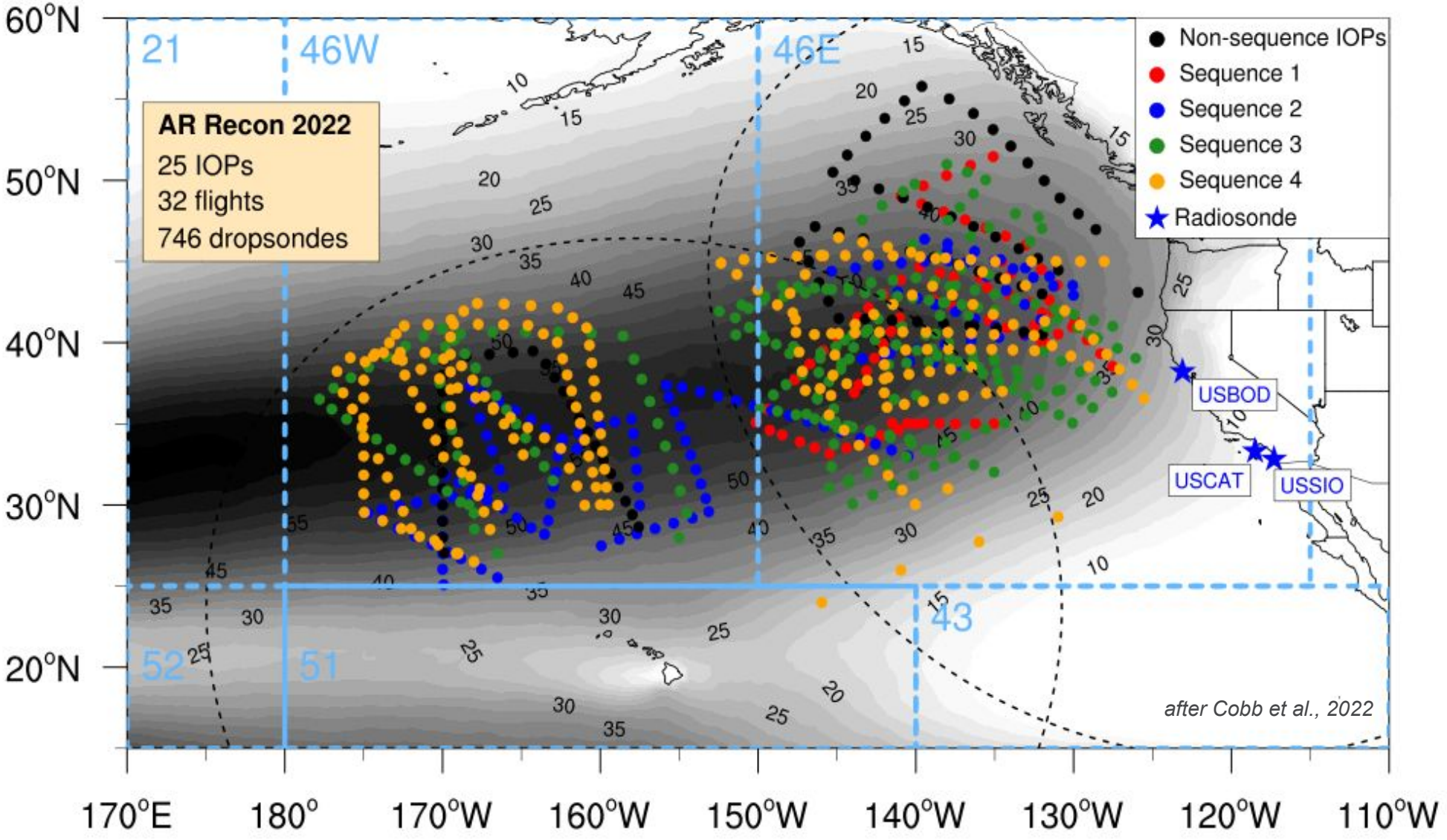
NORTHEAST PACIFIC DROPSONDE COVERAGE – AR RECON 2021



Center for Western Weather and Water Extremes

AR Recon:
F. Martin Ralph, PI,
(UC San Diego/SIO/CW3E)
Vijay Tallapragada, Co-PI,
(NOAA/NWS/NCEP)

NORTHEAST PACIFIC DROPSONDE COVERAGE – AR RECON 2022



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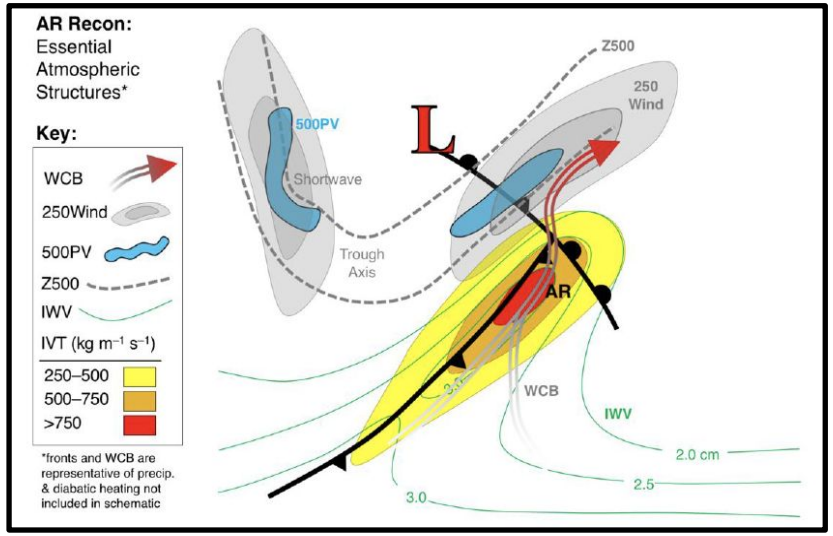
Vijay Tallapragada, Co-PI,
(NOAA/NWS/NCEP)

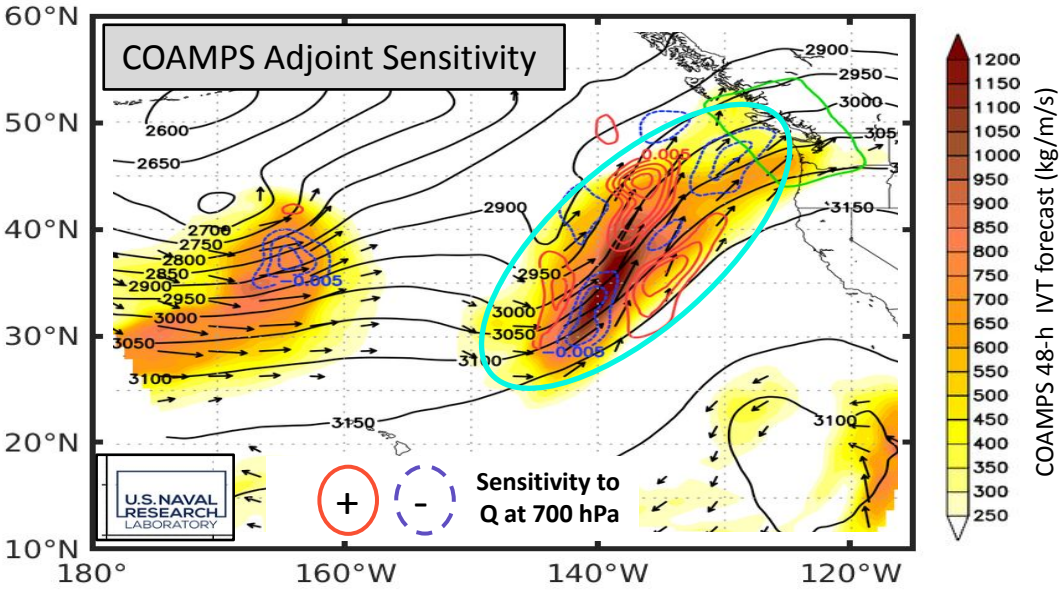
An overview of flight track design methods used during AR Recon planning

AR Recon Targets **Essential Atmospheric Structures**



Schematic by J. Cordeira, Wilson et al. 2022

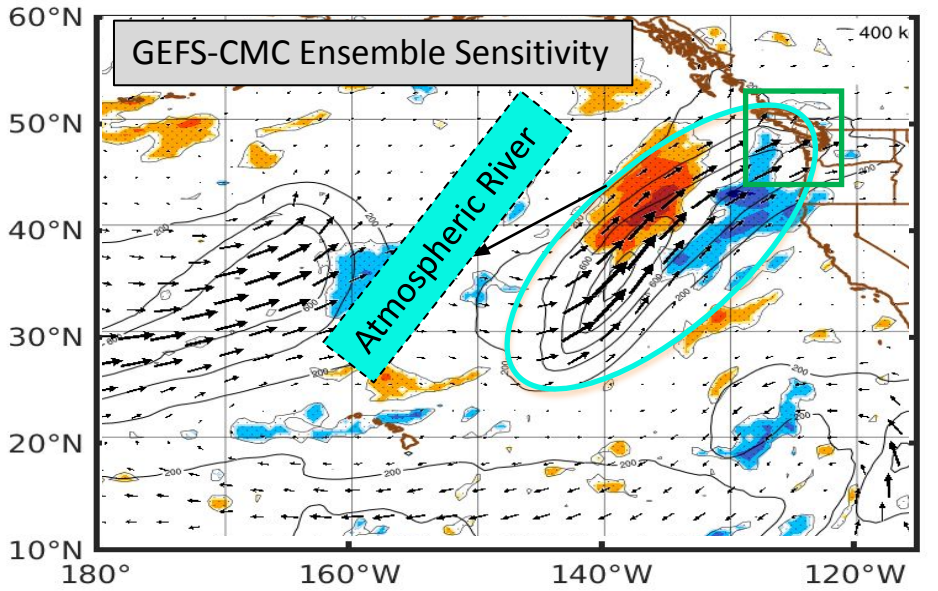
IOP2: Flight time: 00Z 12 Jan 2022; **Forecast initial time**: 00Z 10 Jan. 2022



Precip. Validation Box

Forecast Metrics:
24-h precip.
12Z 1/12–
12Z 1/13

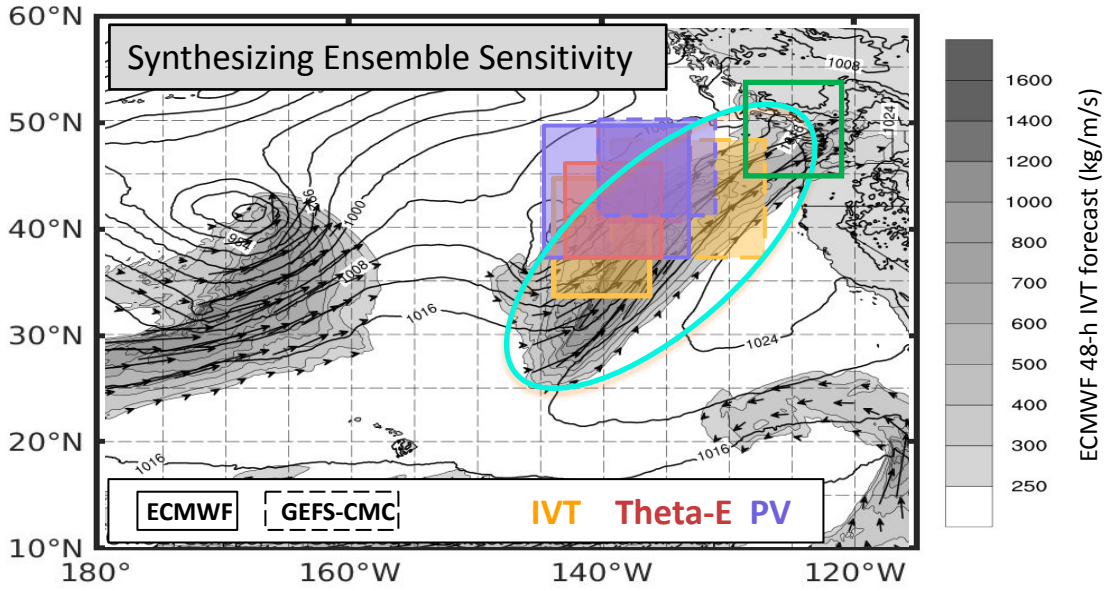
IOP2: Flight time: 00Z 12 Jan 2022; **Forecast initial time**: 00Z 10 Jan. 2022



Precip. Validation Box

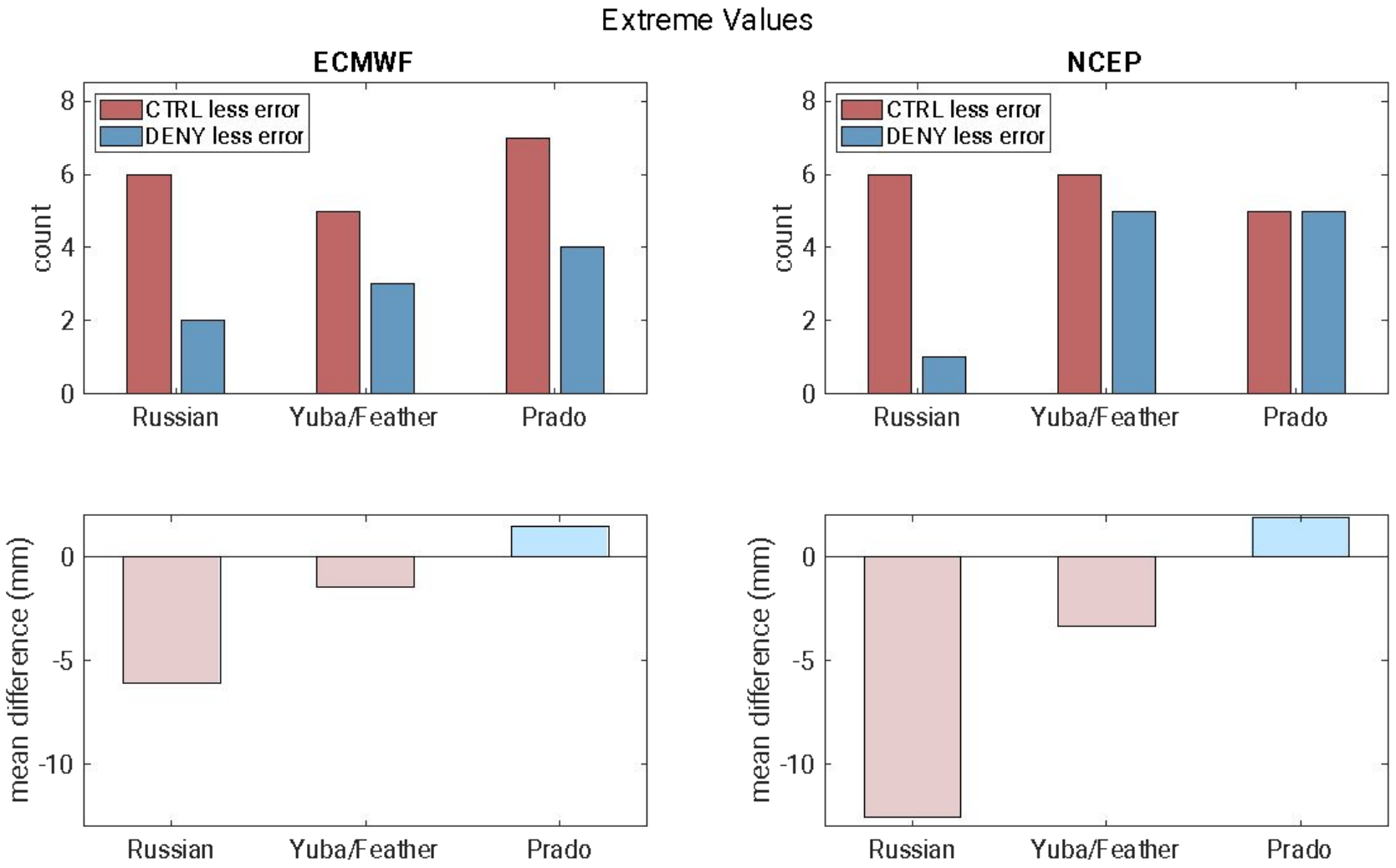
Forecast Metrics:
PC of EOF1 for precip.

Validation time:
12Z 1/12–
12Z 1/13



Prepared by M. Zheng & F. M. Ralph at CW3E

What is the impact of the collected data?

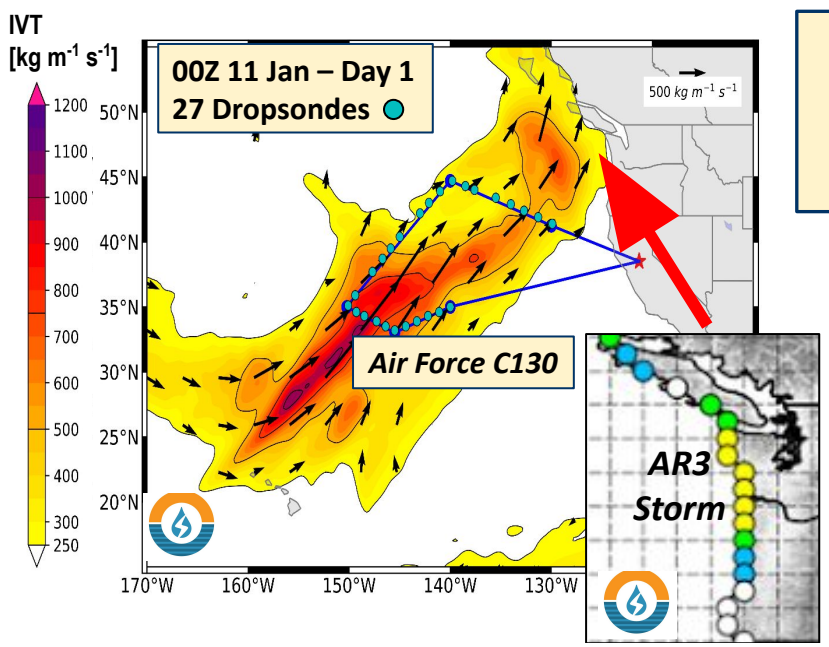


Error in 90th percentile precipitation for 3 California watersheds.

From DeHaan et al., in prep

Atmospheric River Reconnaissance 2022

Preliminary Assessment of Impact on Heavy Precipitation Forecast in GFS During the Sequence of 3 days of AR Recon flights from 11-13 Jan 2022



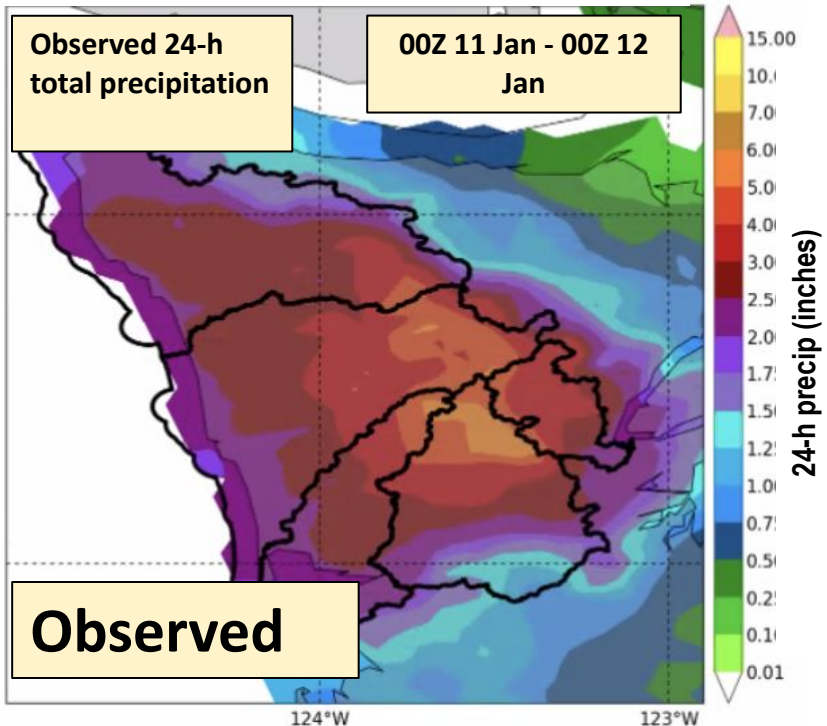
AR Recon flight substantially reduced errors in the 1-2-day lead-time forecast of heavy precipitation from an AR3 storm

The region had been experiencing flooding already this winter, and WA had requested a Presidential Disaster Declaration for earlier AR storms that had hit in Nov-Dec 2021, before AR Recon season began on 11 Jan 2022.

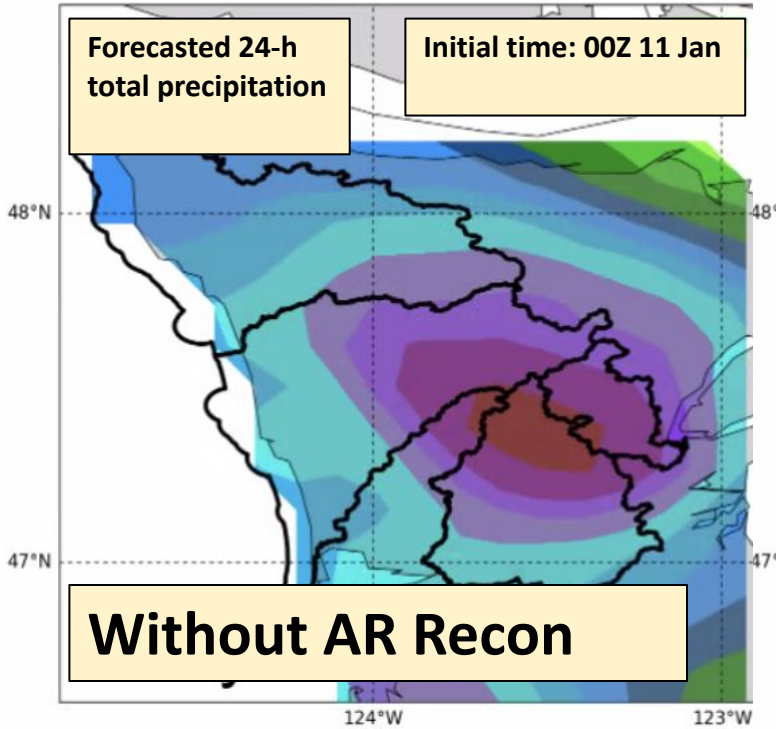
Center for Western Weather and Water Extremes

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

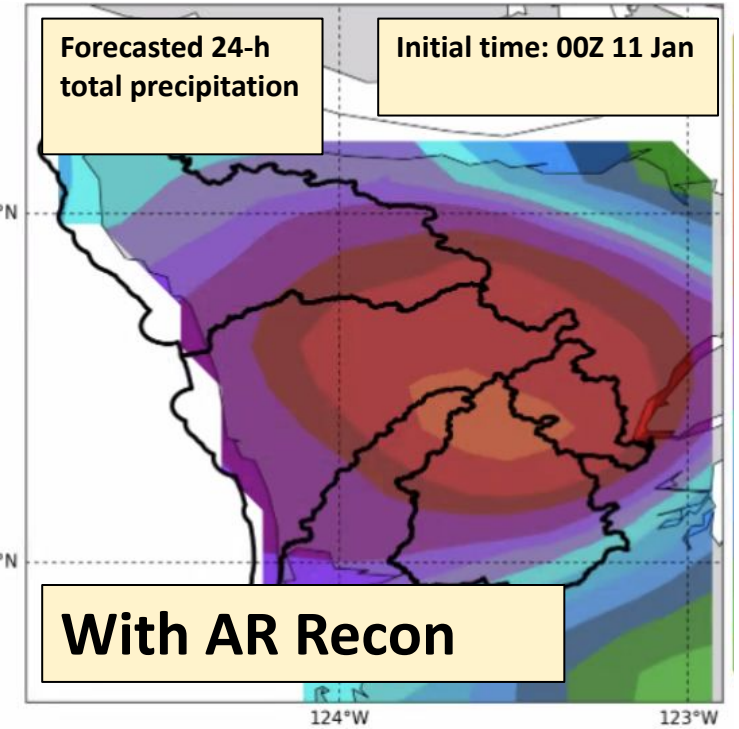
Max > 6 inches in 1 day



Max < half what was observed



Max > 5 inches in 1 day
Close to what was observed



Presidential Major Disaster Declarations for Washington State in 2020-2021

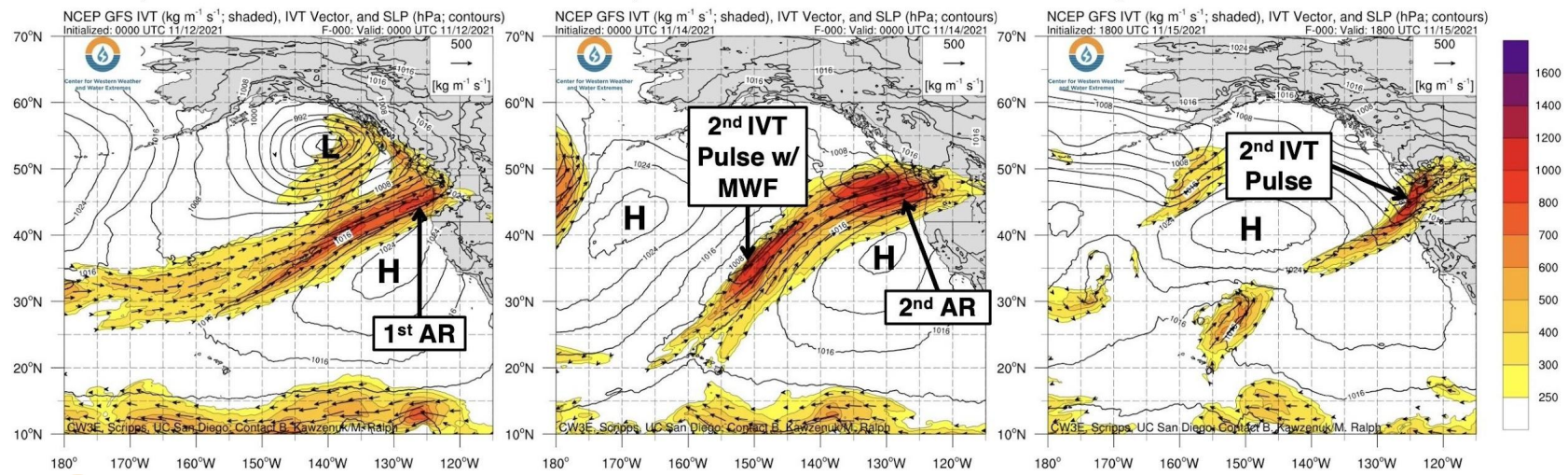
"…multiple damaging Atmospheric River events over a short period of time, with several occurring back-to-back. This brought severe overlapping impacts to communities in Western Washington."

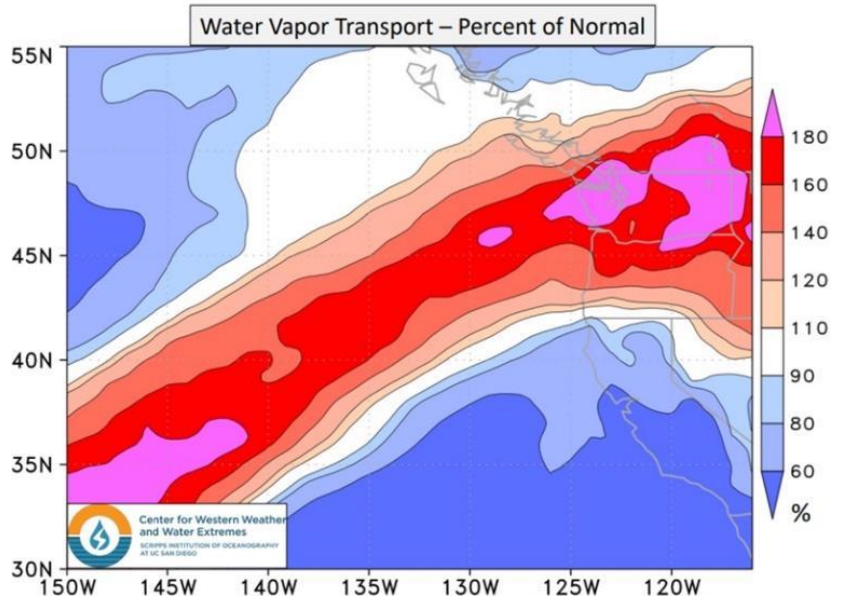
– Washington State Request for Major Disaster Declaration (Nov 5 – Dec 2, 2021)

Atmospheric rivers play a key role in the declared major disasters of severe winter storms and flooding in 2020–2021 in Washington state.

WA declared major disasters of severe winter storms in 2020-2021: (1) Jan 20, 2020 – Feb 10, 2020; (2) Dec 29, 2020 – Jan 16, 2021; (3) Nov 5, 2021 – Dec 2, 2021.

GFS IVT & SLP Analyses for 11–15 Nov 2021





Water vapor transport during 11–16 Nov 2021 as a percentage of normal conditions based on CFSR.

Center for Western Weather and Water Extremes

Prepared by Z. Zhang & F. M. Ralph at CW3E

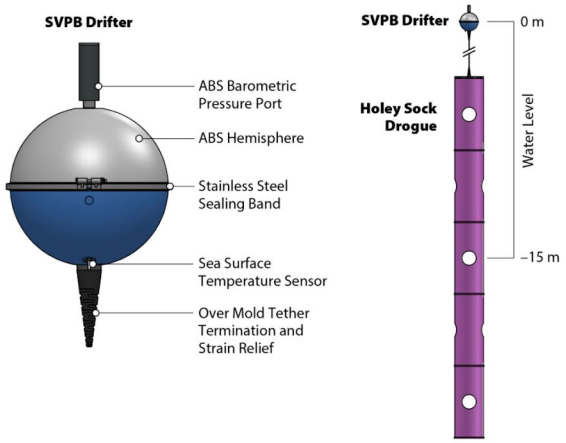
History of CW3E/LDL Drifting Buoy Deployments

Water Year	SVP-B - Air	DWS-B - Air	SVP-B – Ship	DWS-B - Ship
2019 – NE Pac	32	0	0	0
2020 – NE Pac	16	8	32	8
2021 – NE Pac	20	10	0	0
2022 - NE Pac	20	10	20	6
2023 and on – *proposed – NE Pac*	20	10	28	6
2023 and on – *proposed – NW Pac*	20	10	28	6

2023 will the be the fifth year in a row with buoy deployment collaboration between NOAA's 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***)

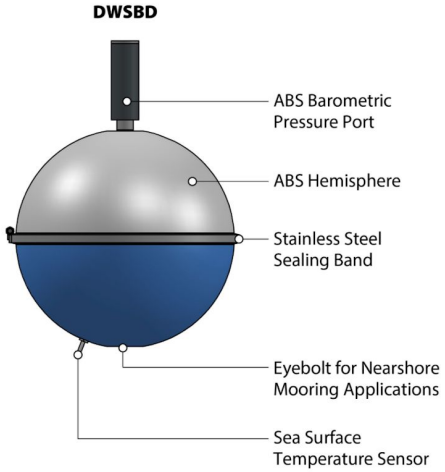
SURFACE VELOCITY PROGRAM BAROMETER (SVPB) DRIFTER

- Sea surface temperature
- Sea level barometric pressure

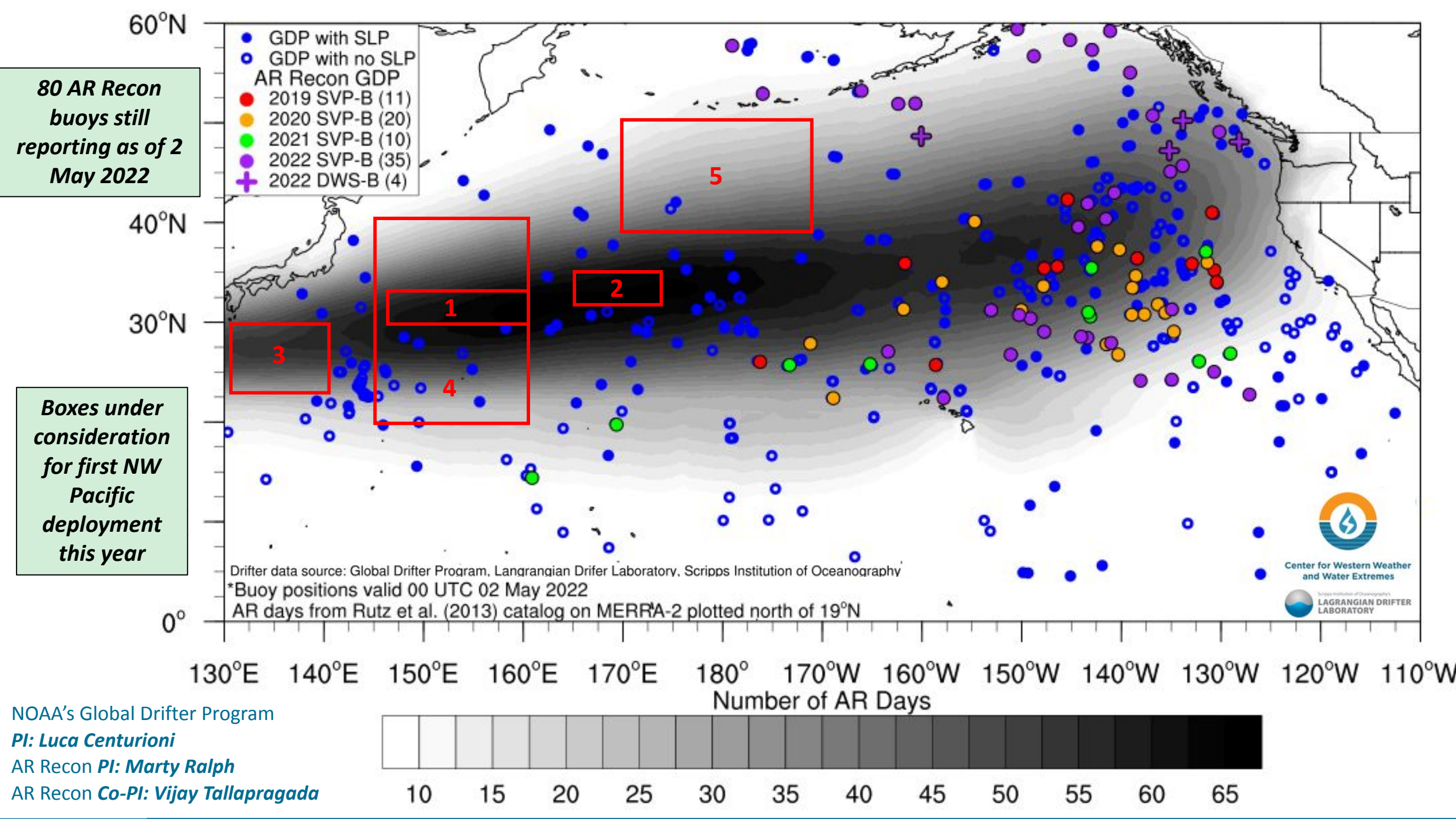


DIRECTIONAL WAVE SPECTRA BAROMETER DRIFTER (DWSBD)™

- Sea surface temperature
- Sea level barometric pressure
- Wave spectra



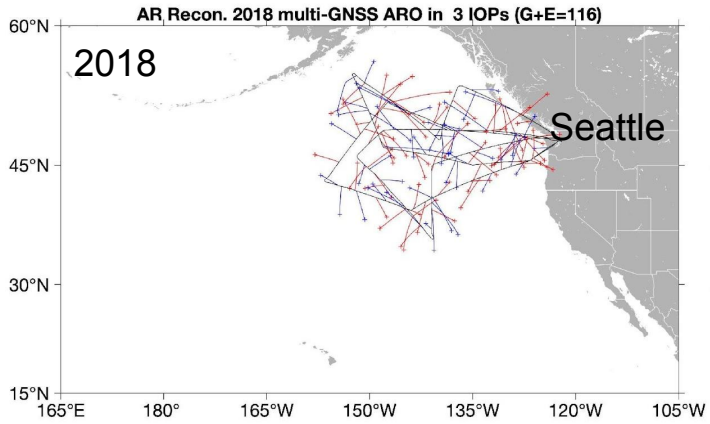
Sponsored by California's Atmospheric Rivers Research, Mitigation, and Climate Forecasting Program Managed by CA DWR, led by CW3E

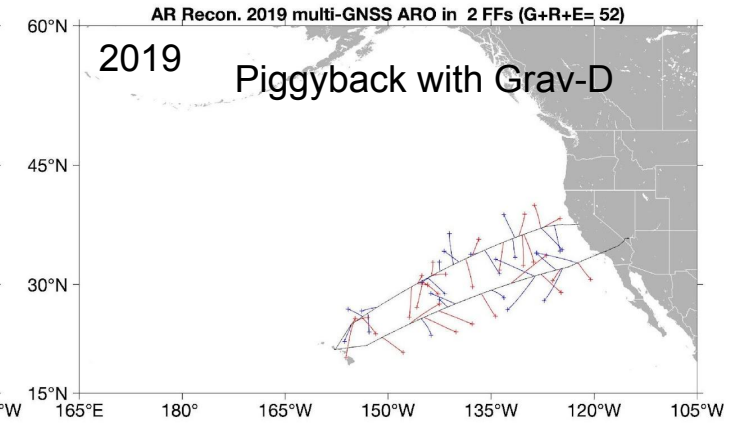


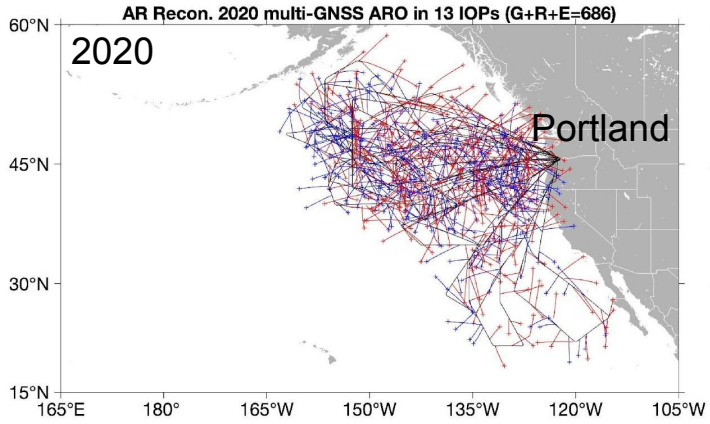
80 AR Recon buoys still reporting as of 2 May 2022

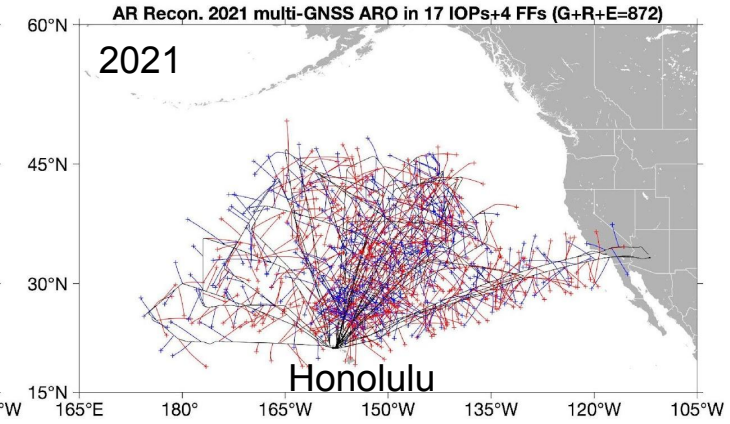
Boxes under consideration for first NW Pacific deployment this year

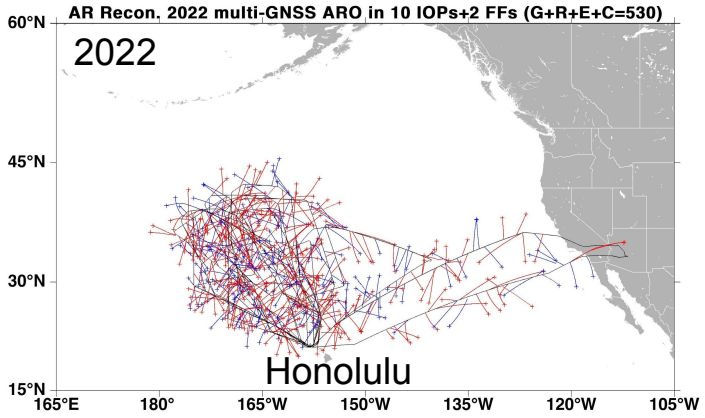
NOAA's Global Drifter Program
PI: Luca Centurioni
AR Recon ***PI: Marty Ralph***
AR Recon ***Co-PI: Vijay Tallapragada***











ARO in AR Recon. from 2018-2022 on NOAA G-IV

Ferry flights over the Pacific are included.

Year	Total	Avg per flight	Notes
2018	116	**38**	GPS+Galileo
2019	52	**26**	GPS+Galileo+GLONASS
2020	686	**50**	GPS+Galileo+GLONASS
2021	872	**42**	GPS+Galileo+GLONASS new antenna
2022	494	**45**	GPS+Galileo+GLONASS+Beidou new antenna

2022 Instrumentation Status:

NOAA G-IV: ARO with near real time raw transmission; Lower troposphere recording

AF C-130s: post-flight delivery and analysis - experimental

Bing Cao and Jennifer Haase, SIO / UCSD

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TARGETED OBSERVATIONS TO IMPROVE FORECASTS - SUMMARY

- ***Partnerships are crucial***
- Observations of key quantities allow for precipitation forecast improvements via multiple paths
- Uses both widely accepted technology (buoys, dropsondes, radiosondes) and novel technology (airborne radio occultation)
- Continuous evaluations lead to expansions, even greater potential improvements