



Center for Western Weather
and Water Extremes

SCRIPPS INSTITUTION OF OCEANOGRAPHY
AT UC SAN DIEGO

UC San Diego



The Global Atmospheric River Reconnaissance Program

F. Martin Ralph, Director of CW3E
Principal Investigator, AR Recon
Principal Investigator, Global AR Recon Program

AR Recon Workshop

European Centre for Medium-Range Weather Forecasts

1 Jul 2026

Outline

- 1 – Background
- 2 – GARRP Demo 2026 - Planning
- 3 – GARRP Demo 2026 – Done!
- 4 – Future Strategy



White House
Office of Science and
Technology Policy (OSTP)

EARTH SYSTEM PREDICTABILITY
RESEARCH AND DEVELOPMENT
STRATEGIC FRAMEWORK AND ROADMAP

A Report by the
FAST TRACK ACTION COMMITTEE ON EARTH SYSTEM
PREDICTABILITY RESEARCH AND DEVELOPMENT
of the
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

October 2020

Executive Summary

From predictions of individual thunderstorms to long-term global change, enhanced Earth system predictions are crucial to inform societal resilience to extreme events such as droughts and floods, heat waves, wildfires and coastal inundation. However, in some cases, there is still a lack of clear understanding of whether, or under which conditions, extreme meteorological events and their cascading events are predictable and why. A better understanding of Earth system predictability (ESP) would help the Federal Government target investments to improve predictions and increase public benefit. To help address this gap, and facilitate Federal coordination, the National Science and Technology Council (NSTC) created a Fast Track Action Committee (FTAC) on ESP in February 2020. It was charged with identifying barriers to progress, as well as prioritizing opportunities for activities that could improve our understanding of ESP. Subsequently, the FTAC engaged with the public and the interagency prior to developing an R&D Strategic Framework and a Roadmap to guide the initial R&D activities that address urgent prediction needs within the framework.

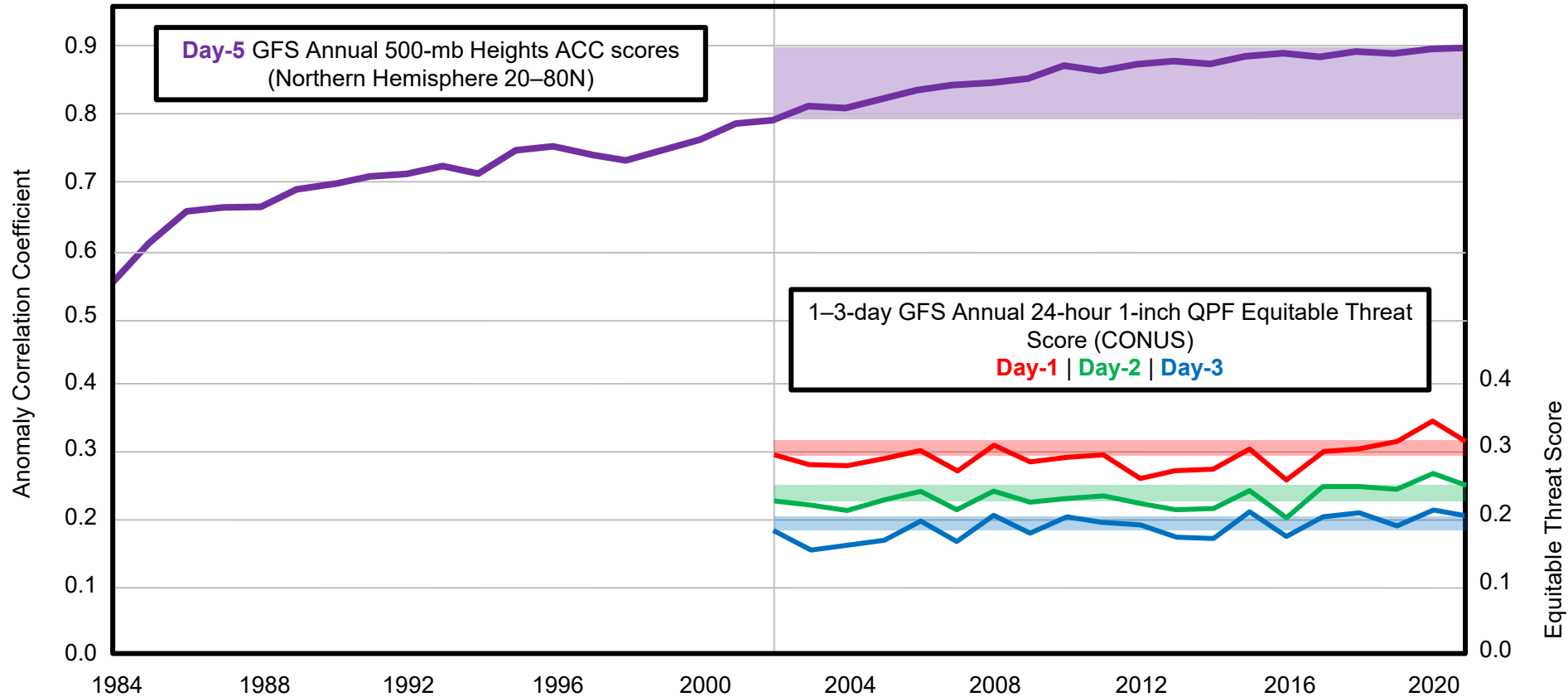
The R&D Strategic Framework aims to increase the understanding of ESP to improve predictions through three primary goals that connect theory with observations, process research, and modeling. An additional four cross-cutting goals address these thrusts as well as emphasize advanced technologies, enhanced collaborations, partnerships, and training the next generation of talent. The Roadmap identifies five areas of R&D opportunity focusing on the predictability of Earth's water cycle and precipitation extremes and associated biosphere and human interactions. **strategically advance the ESP R&D priority. The goal of this R&D is to attain high-resolution predictions and projections of high impact water cycle events, their cascading impacts across the Earth system, and their coupling to human, ecological, and biogeochemical systems.**



The goal of this R&D is to attain high-resolution predictions and projections of **high impact water cycle events, their cascading impacts*** across the Earth system, and their coupling to human, ecological, and biogeochemical systems.

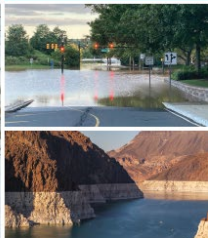
***Cascading impacts:** “Such as droughts, floods, hurricanes, extratropical cyclones, atmospheric rivers, and wildfires”

Moving the needle of QPF Skill



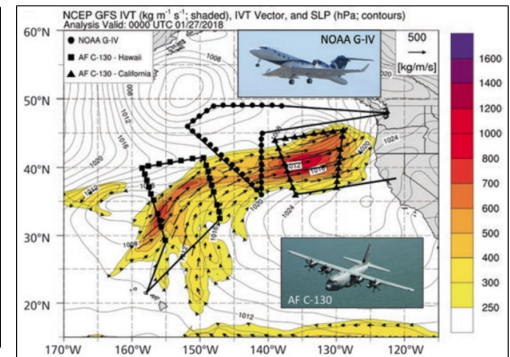


DECEMBER
2021



PWR Report Recommendations on Atmospheric Rivers

- Expand AR Obs' and DA
- Use RAOP approach
- Create AR forecast metrics



Following Direction from US Congress, NOAA/SAB convened an extensive process to identify formal recommendations to NOAA to improve weather research and prediction over the next decade (over 150 experts provided inputs)

• **One of the key recommendations of this 2021 report was expansion of AR Recon and related AR research and predictions**

improve flood
require better
prediction skill has
them Prediction
needed to better
atmospheric river

casting of ARs
should build
improve forecasts
and mixed layer

A REPORT
**Priorities for
Weather Research**
NOAA SCIENCE ADVISORY BOARD

All images depict weather events and impacts from 2021

OD-8.2. Adopt a research and operations partnership approach, including engagement of the international and academic communities.

OD-8.3. The program development and implementation should create new forecast skill metrics targeting extreme precipitation prediction in the west and the phenomenon, ARs, that produces it. It should target socio-economic impact considerations including for use in reservoir operations to mitigate drought and flood impacts.

In June 2023 US Senator Padilla introduced the “Atmospheric Rivers Reconnaissance, Observations and Warning Act” (ARROW)

Key clauses of the ARROW Act, introduced in the US Senate in June 2023 by Senator Padilla:

- “Conduct of Winter Season Reconnaissance of Atmospheric Rivers...”
- “...over the eastern, central and western north Pacific Ocean, the Gulf of Mexico and the western Atlantic Ocean...”
- “Participate in the research and operations partnership that guides flight planning and uses research methods to improve and expand the capabilities of weather reconnaissance over time...”

- **Can we move the needle on week 2 (Day 8-14) forecasts?**

Atmospheric Rivers Reconnaissance, Observations and Warning Act

Senator Padilla’s atmospheric river forecasting amendment passed as part of the 2023 NDAA is based on his [Atmospheric Rivers Reconnaissance, Observation and Warning Act](#), which will improve the accuracy and timeliness of West Coast Atmospheric River (AR) forecasts by directing the Air Force and NOAA to provide the necessary aircraft, personnel, and equipment to meet AR mission requirements during the winter season in the West Coast. As the frequency and intensity of AR storms increase — which Californians saw firsthand earlier this year — AR reconnaissance flights are increasingly critical for anticipating the landfall and severity of ARs, enabling communities to prepare for and mitigate damage from storm events, while and conserving water for future droughts.

IN THE SENATE OF THE UNITED STATES

Mr. PADILLA introduced the following bill; which was read twice and referred to the Committee on _____

A BILL

To require the conduct of winter season reconnaissance of atmospheric rivers on the West Coast of the United States, and for other purposes.

- 1 *Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,*
- 2
- 3 **SECTION 1. SHORT TITLE.**
- 4 This Act may be cited as the “Atmospheric Rivers
- 5 Reconnaissance, Observation, and Warning Act” or the
- 6 “ARROW Act”.

Senator Padilla describing the Atmospheric River Reconnaissance, Observations and Warnings Act

Congressional Briefing on
Forecasting for Extremes

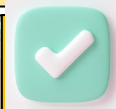


Senator Padilla
California

J. Zimmerman
NOAA/NWS/OWP

R. Colosimo
USACE DASA

F. M. Ralph
UCSD/SIO/CW3E



22 Dec 2023

**Approved by Pres. Biden as
part of the NDAA passed by
the US Senate and House**



At the Capital Visitors Center
7 November 2023

The ARROW Act was enacted upon President Biden's signature on 22 December 2023 as part of the 2024 National Defense Authorization Act after approval by the US Senate and House

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.



Atmospheric Rivers River Reconnaissance, Observations and Warnings Act: Enacted upon President Biden’s signature on 22 December 2023 as part of the 2024 National Defense Authorization Act after approval by the US Senate and House

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

<https://www.noaa.gov/news-release/noaa-orders-second-high-altitude-jet-for-hurricane-and-climate-research>; Artist concept of NOAA G550 courtesy Gulfstream. (Image credit: Gulfstream)

Outline

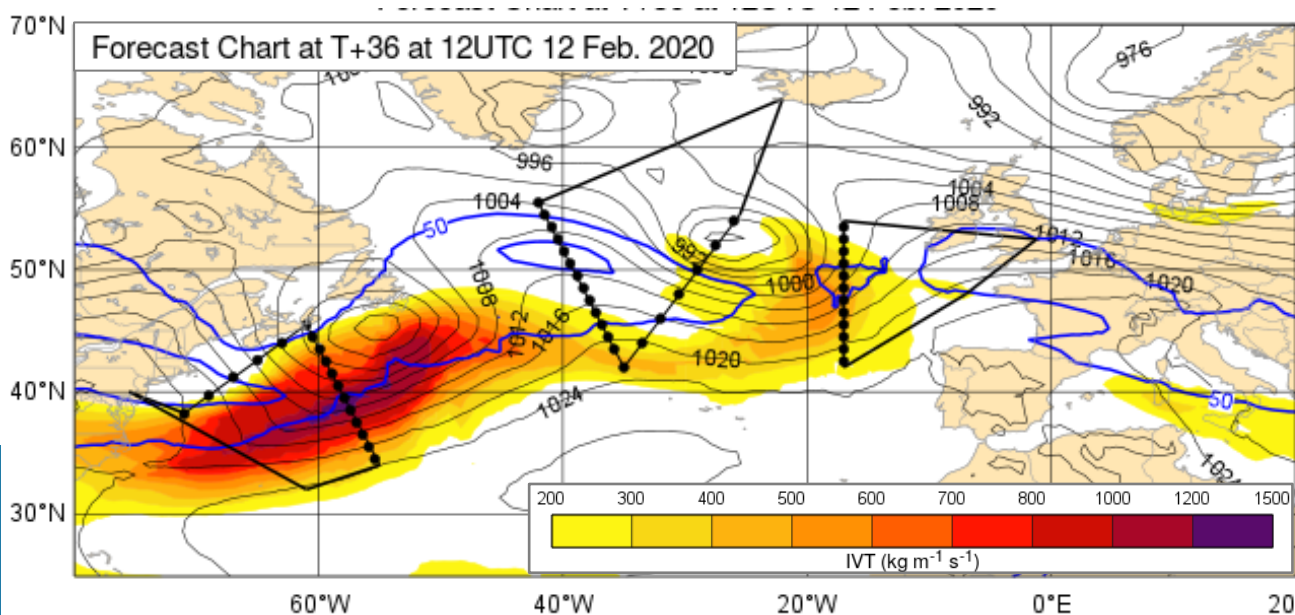
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Improved forecasts of atmospheric rivers through systematic reconnaissance, better modelling, and insights on conversion of rain to flooding

Lavers, D.A., F.M. Ralph, D.S. Richardson and F. Pappenberger (*Communication Earth Environ*, 2020)

Proposes a joint European–American observational campaign building on AR Recon and NAWDEX

NWP modelling improvements including use of extra observations. Investigate how river basin properties affect the rainfall to river discharge conversion.



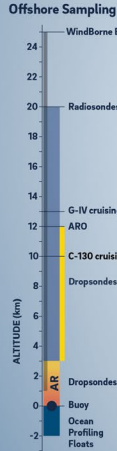
CW3E



ECMWF

Atmospheric River Reconnaissance

GARRP:
**Can we move the needle on
week 2 (Day 8-14) forecasts?**



GPS SETTING SATELLITE

ARO

TOP OF AR

EDGE OF AR

DROPSONDE

ATMOSPHERIC RIVER

DRIFTING BUOY

OCEAN PROFILING FLOATS

7km depth

0km

Ralph et al. 2020
(Bull. Amer. Meteorol. Soc.)
AR Recon Overview

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

Research and Operations Partnership

- Data consistently shows significant positive impact on forecasts, leading to expansions:
- 2024/2025 in the West Pacific

GARRP Demos

- 2026 – 2029 (with GPEX)
- 2030 and beyond: GARRP Operational?

Key Partners: CW3E/UC San Diego, NCEP/NWS, NOAA Aircraft Operations Center, US Air Force, ECMWF, Naval Research Laboratory, National Center for Atmospheric Research, Universities

Global Precipitation EXperiment (GPEX)

A 10-year program started in 2024

The future of the global water cycle among the frontiers of climate research precipitation...

GPEX provides a unique opportunity to study precipitation and to accelerate progress...

The GPEX/YoP will include coordinated observations of **mesoscale convective systems** and **extremes** as well as changes in precipitation seasonality.

GPEX Selects AR Recon/GARRP as its First “Anchor Project”

ability for humans around the world remain Sustainable Development Goals. Especially the prediction of

understanding phenomena and processes critical to climate change...

storm types (**atmospheric rivers**, **mesoscale convective systems**) and the prediction of precipitation events, **including extremes**.

Primary Working Group: Global Field Campaign Planning

Primary Storm Types: Monsoons, Hurricanes, Mesoscale Convective Systems, Atmospheric Rivers

Co-Chairs:

- F. Martin Ralph (UCSD/Scripps Institution of Oceanography)
- Samson Hagos (DOE/Pacific Northwest National Laboratory)

From <https://www.wcrp-climate.org/gpex-overview>

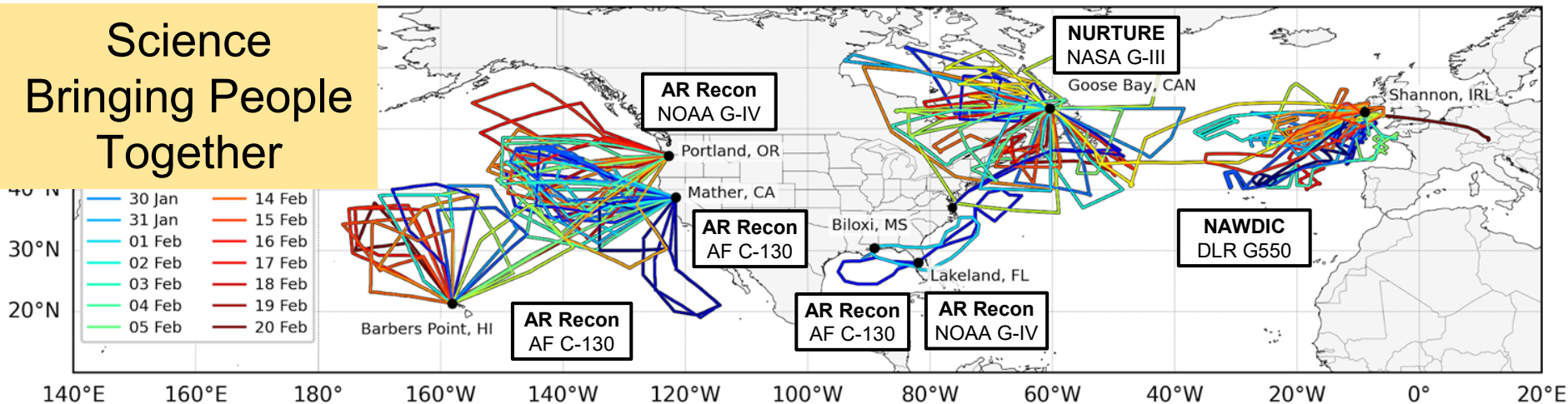
Global Atmospheric River Reconnaissance (GARRP) 2026 Demo

F. M. Ralph, GARRP PI, Vijay Tallapragada GARRP Co-PI

GARRP-Demo 2026 Aircraft IOPs

22 Jan–20 Feb 2026

Science
Bringing People
Together



AR Recon: Atmospheric River Reconnaissance

NURTURE: North American Upstream Feature-Resolving and Tropopause Uncertainty Reconnaissance Experiment

NAWDIC: North Atlantic Waveguide, Dry Intrusion, and Downstream Impact Campaign

Total number of flights: 72

Total deployed dropsondes: 1151



San Diego



AR Recon – Close Coordination with ONR’s SAFARI DRI

SAFARI (Sea-Air Fluxes and AR Initiation), an Office of Naval Research Departmental Research Initiative, has begun close coordination with AR Recon and other campaigns.

SAFARI adds capacity (observations, modeling, advanced techniques) to transform process-based understanding of AR life-cycles - **leveraging and enhancing AR Recon observations**. There are currently over 15 PIs from 7 institutions.

OVERARCHING GOAL: Improve predictability of high impact weather associated with ARs at time scales up to 2 weeks, by improving understanding of AR “headwaters” processes and evolution over the ocean.

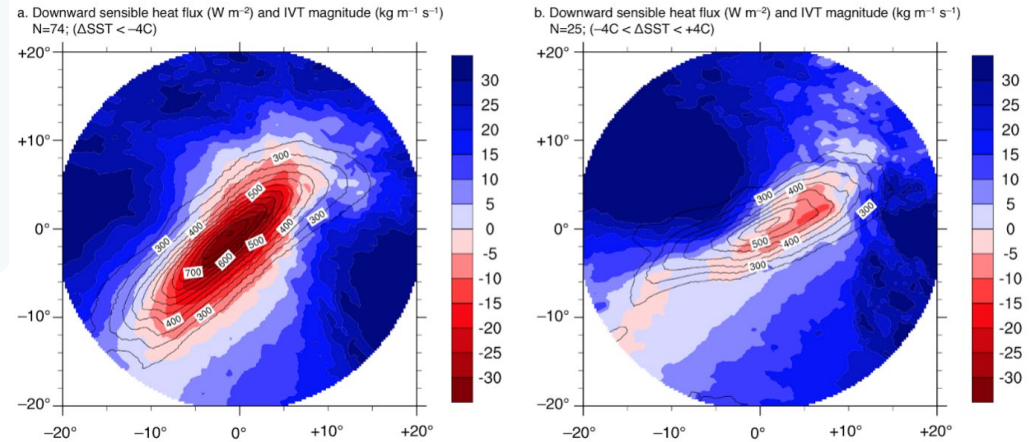


Figure from Ralph et al. (2024) showing the difference in sensible heat flux strength in strong (left) vs weak (right) boundary layer decoupling regimes



AR Recon: Partnership with NAWDIC

- **January 13th through February 20th, 2026**
- HALO (and other) aircraft sampled relevant features over the North Atlantic
- Key Questions: Can we better characterize interactions and transitions between ARs and dry intrusions? Regions of intense moisture uptake into ARs?
- Embedded CW3E/AR Recon scientists in person throughout campaign



North Atlantic Waveguide, Dry Intrusion and Downstream Impact Campaign



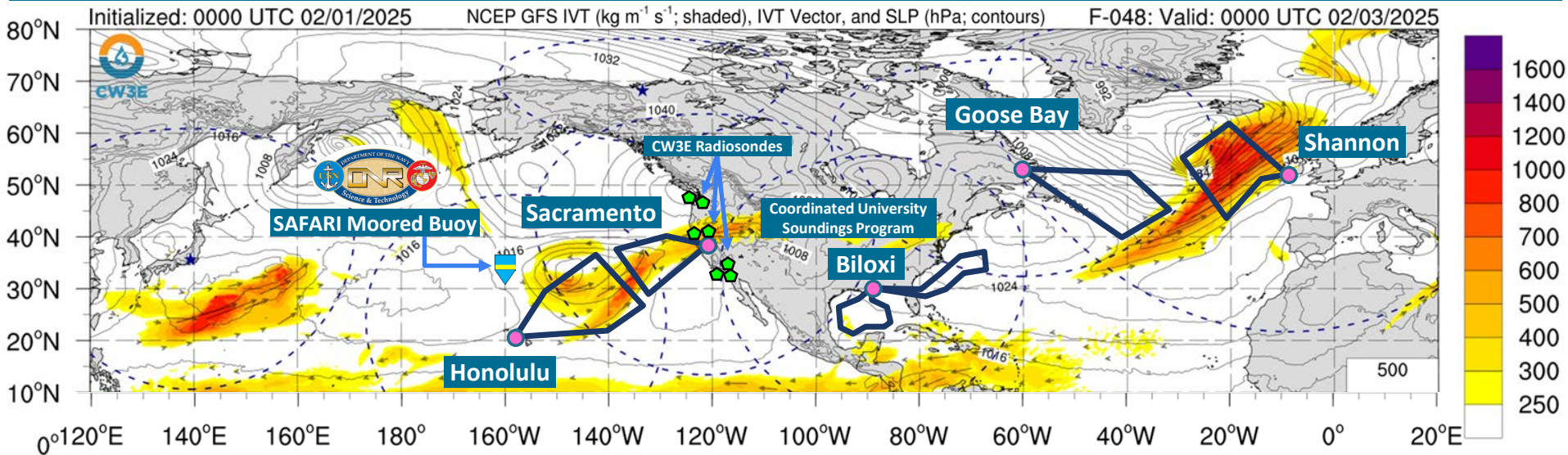
AR Recon: Coordination with NURTURE

- **January 26th through February 20th, 2026 (2027 dates ~Jan 15 – Mar 1)**
- Field campaign aims to further understand the atmospheric processes that lead to extreme high-impact weather events during the winter.
- NASA used the GIII in 2026 and will transition to the new B777 in 2027.
- Multiple AR Recon scientists engaged with this campaign



Global Atmospheric River Reconnaissance Program (GARRP) 2026 Demo - PLAN

F. M. Ralph, GARRP PI, V. Tallapragada, GARRP Co-PI



AR Recon: Atmospheric River Reconnaissance

NURTURE: North American Upstream Feature-Resolving and Tropopause Uncertainty Reconnaissance Experiment

NAWDIC: North Atlantic Waveguide, Dry Intrusion, and Downstream Impact Campaign

AR Recon

NE PAC (G-IV)
2 Feb – 24 Mar
Portland, OR

W ATL (G-IV)
6 Jan – 5 Feb
Lakeland, FL

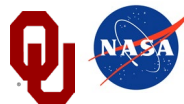


C PAC (C-130)
10 Jan – 4 Mar
Barbers Point, HI

E PAC (C-130)
8 Jan – 5 Feb
Mather, CA

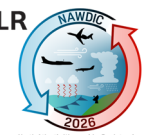
W ATL (C-130)
1 Nov – 31 Mar
Biloxi, MS

NURTURE



NW Atlantic (G-III)
26 Jan – 20 Feb
Goose Bay, Canada

NAWDIC



NE Atlantic (HALO)
13 Jan – 20 Feb
Shannon, Ireland

North Atlantic Waveguide, Dry Intrusion and Downstream Impact Campaign

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Global Atmospheric River Reconnaissance Program

Goal: Test methods to improve forecasts 8-14 days ahead for the entire Northern Hemisphere

First GARRP Demo

22 Jan – 20 Feb 2026 (30 days)

Aircraft Missions/Dropsondes

AT LEAST ONE FLIGHT EACH DAY

- 64 flights (1, 2, 3 or 4 per day)
- 1131 dropsondes (avg 38/day)

and SLP (hPa; contours)

Aircraft: Dropsondes and Airborne Radio Occultation*

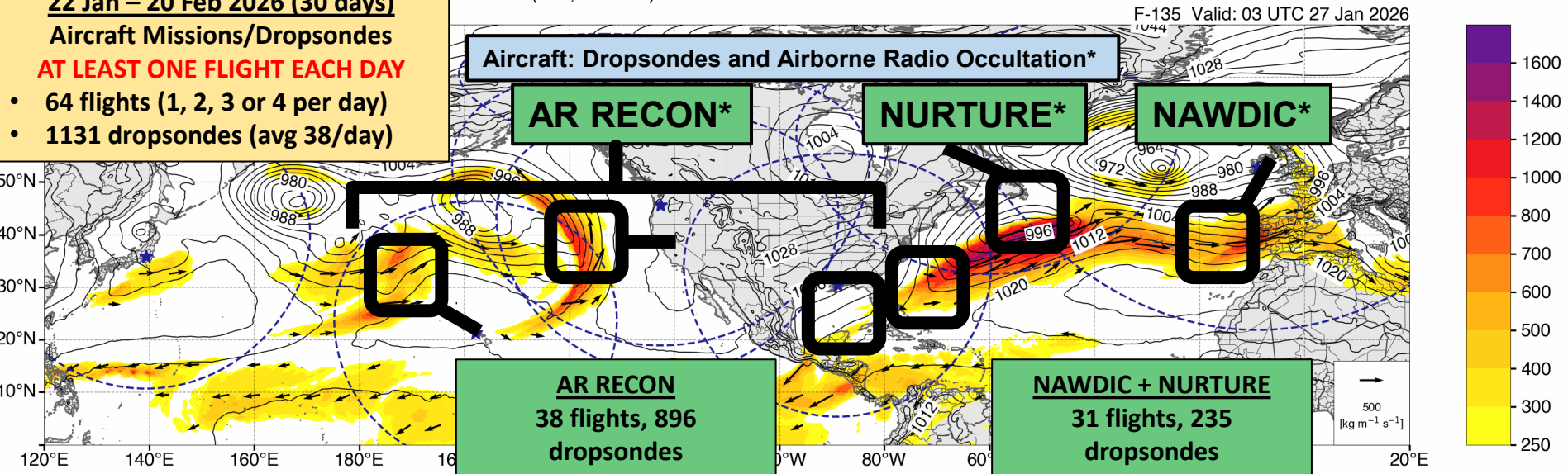
AR RECON*

NURTURE*

NAWDIC*

AR RECON
38 flights, 896
dropsondes

NAWDIC + NURTURE
31 flights, 235
dropsondes



GARRP Co-Leads

F. Martin Ralph, UCSD/SIO/CW3E, V. Tallapragada, NOAA/NWS

*Leads: AR Recon (Ralph/Tallapragada); NAWDIC (Quinting/Ramos/Raveh-Rubin/Oertel), NURTURE (Cavallo), Airborne Radio Occultation (Haase)

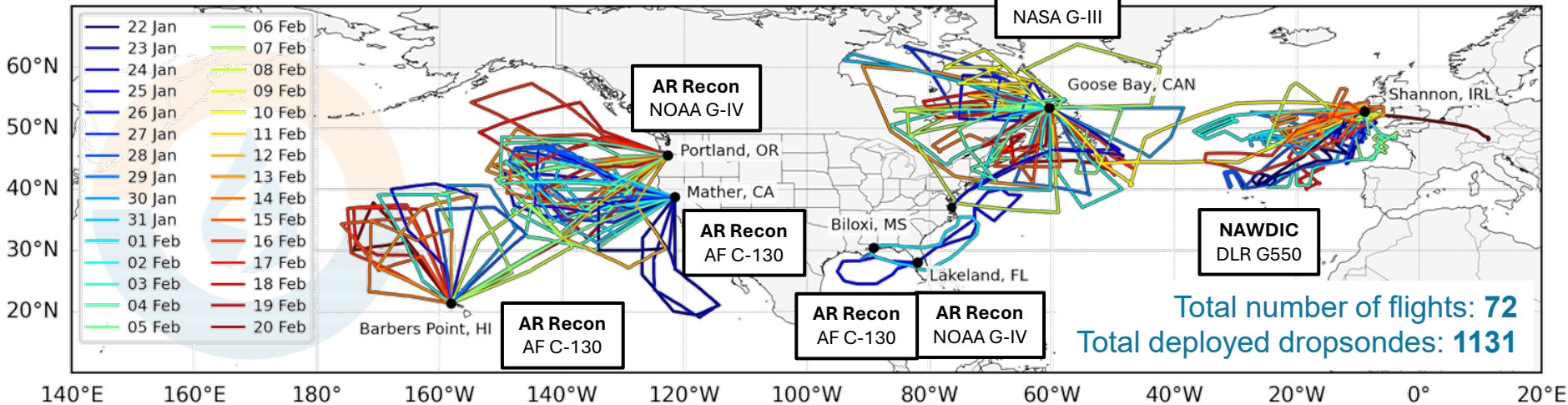
Global Atmospheric River Reconnaissance (GARRP) 2026 Demo

F. M. Ralph, GARRP PI, Vijay Tallapragada GARRP Co-PI



GARRP Demo Aircraft IOPs

Demo: 22 Jan–20 Feb 2026



Slide provided by P. Capute

Notes: A few NURTURE tracks are estimated; does not include buoys or additional CUSP-ARR, CW3E, WindBorne, E-ASAP, EUROP radiosondes (798 total)

AR Recon: Atmospheric River Reconnaissance

NURTURE: North American Upstream Feature-Resolving and Tropopause Uncertainty Reconnaissance Experiment

NAWDIC: North Atlantic Waveguide, Dry Intrusion, and Downstream Impact Campaign

AR Recon

NE PAC (G-IV)
2 Feb – 24 Mar
Portland, OR

W ATL (G-IV)
6 Jan – 5 Feb
Lakeland, FL



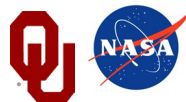
C PAC (C-130)
10 Jan – 4 Mar
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E PAC (C-130)
8 Jan – 5 Feb
Mather, CA

W ATL (C-130)
1 Nov – 31 Mar
Biloxi, MS



NURTURE



NW Atlantic (G-III)
26 Jan – 20 Feb
Goose Bay, Canada



NAWDIC



NE Atlantic (HALO)
13 Jan – 20 Feb
Shannon, Ireland



Northern Hemispheric GARRP Demo (22 Jan – 20 Feb 2026, 30 days)

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



1131 drop - sondes

867 radio - sondes

Flights w/ Drops	2	1	4	3	3	2	3	2	3	3	3	3	4	2	2	2	3	2	1	1	1	2	3	2	3	2	1	3	1			
Number of Drops	30	10	49	73	59	31	72	32	57	51	44	62	62	36	36	18	63	29	6	4	5	30	38	50	34	51	23	5	46	25		
Mather, CA	25		23	25	21	22	31	25	24	25	26	25	20			10												10				
Barbers Point, HI				29			25		23			29						25	25										25			
Portland, OR													30	30	30		30					30	30	35	30	30		30				
Biloxi, MS									10	10	10																					
Lakeland, FL		10	10	19	29																											
Shannon, IRE	5		6			16	16	16	16	8	8	8	8			4	4	4	4	4	4	8	8	15	18							
Goose Bay, CAN			10		9	9	7			8		4	6	6	8	8		6	4	5			7	4	6	5	5	6				
WindBorne	59	51	62	40	51	61	59	67	97	86	76	73	79	83	106	113	115	114	116	129	142	144	167	156	143	143	147	155	167	172		
CUSP-ARR	12	32	28	13	1	3	7			1			13	40	35	19	2	3	1	2			13	36	27	31	29	16	8	15		
CW3E	1						8	8	8	1							5	4								6	2	2				
E-ASAP Ships	7	8	10	9	10	11	11	7	8	7	6	7	6	7	8	10	9	8	4	8	8	11	12	11	12	10	10	9	9	10		
EUROP	12	9	2		2	15	3	13	5	6	3		13	5	5	7		2	5	2	5	14	2	15	4	1	10	3		9		
Total Observations	32	49	40	22	13	29	29	28	21	15	9	7	32	52	48	36	16	17	10	12	13	25	27	62	43	48	51	30	17	34		
	Jan 21	Jan 22	Jan 23	Jan 24	Jan 25	Jan 26	Jan 27	Jan 28	Jan 29	Jan 30	Jan 31	Feb 01	Feb 02	Feb 03	Feb 04	Feb 05	Feb 06	Feb 07	Feb 08	Feb 09	Feb 10	Feb 11	Feb 12	Feb 13	Feb 14	Feb 15	Feb 16	Feb 17	Feb 18	Feb 19	Feb 20	Feb 21

AR RECON

NAWDIC

NURTURE

Slide provided by P. Capute

AR Recon

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2 Feb – 24 Mar
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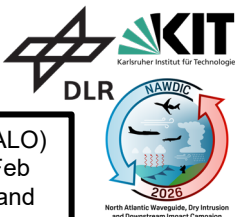
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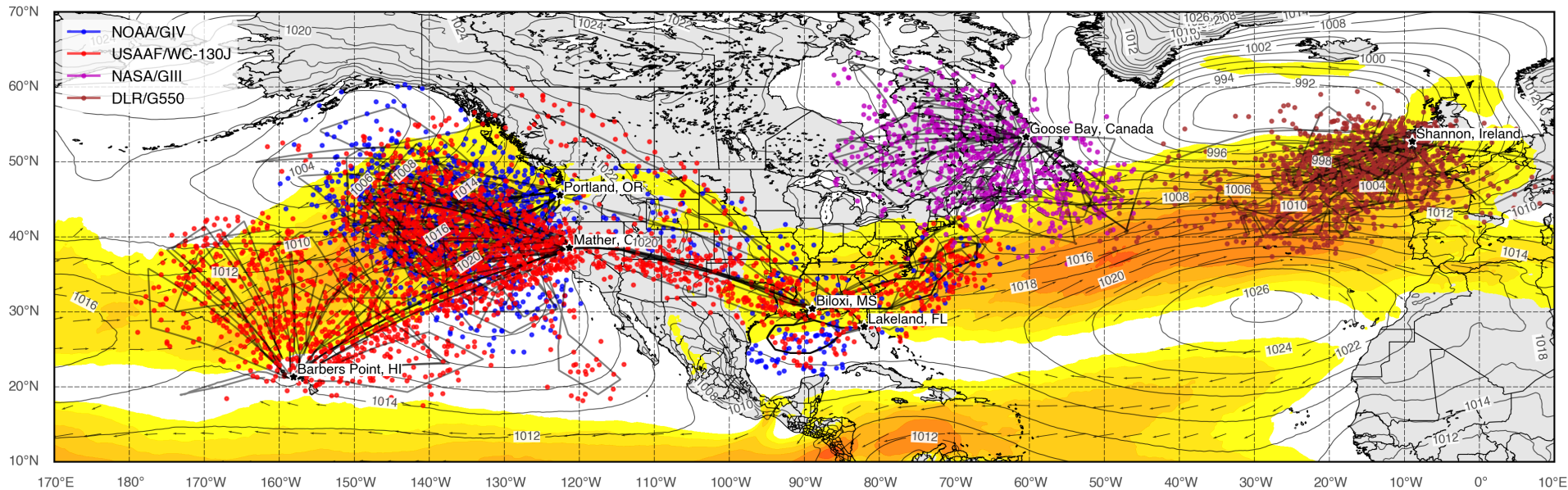
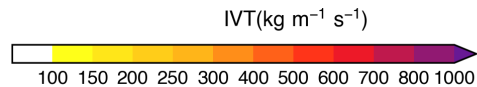
NAWDIC



NE Atlantic (HALO)
13 Jan – 20 Feb
Shannon, Ireland

North Atlantic Waveguide, Dry Intrusion and Downstream Impact Campaign

GNSS ARO (final, colored dots), mean GFS IVT($\text{kg m}^{-1} \text{ s}^{-1}$; shaded), IVT Vectors, and mean SLP(hPa; contours)
 Flights were executed by NOAA/USAF/NASA/DLR aircraft in AR Recon 2026 (incl. NURTURE/NAWDIC) field campaign



Disclaimer: final results, but might be slightly different from released files due to QC procedures. The map might not include all flights due to delays in data recovery! Flights: 121, Occs: 5882
 Contact: J. Haase/B. Cao/N. Barton/K. Loo/ARO team, in partnership with the UC San Diego/Scriptts Institute Oceanography/Center for Western Weather and Water Extremes

	AR Recon 2025	AR Recon 2026
Aircraft w/ ARO	NOAA G-IV 10 USAF WC-130s	NOAA G-IV 10 USAF WC-130s 1 NASA G-III 1 DLR G-550
Total flights	20 G-IV + 49 C-130 = 69	23 G-IV + 57 C-130 + 19 G-III + 18 G-550 = 117
Total profiles	3271	5882

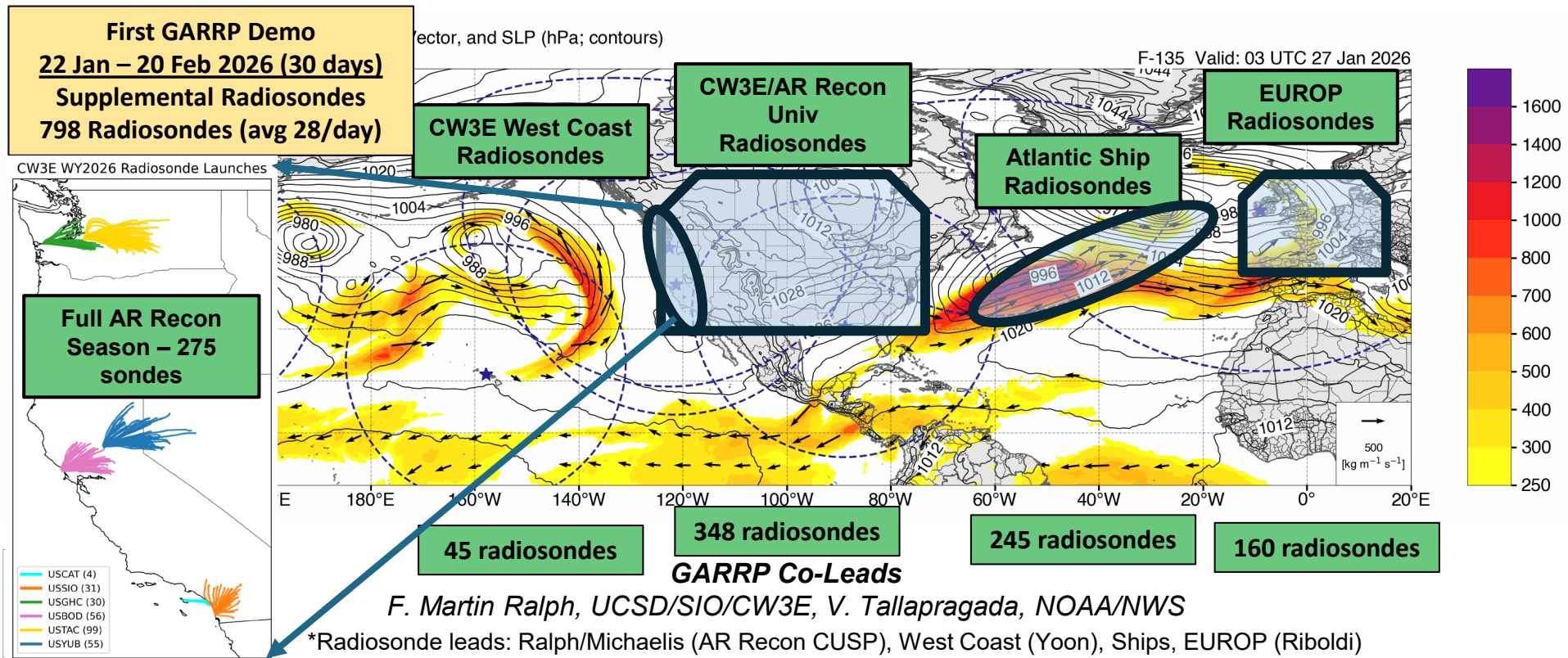


PI: J. Haase, SIO

Slide Provided by: B. Cao,
 N. Barton, K. Loo, the
 ARO team at IGPP/SIO

Global Atmospheric River Reconnaissance Program

Goal: Test methods to improve forecasts 8-14 days ahead for the entire Northern Hemisphere



Global Atmospheric River Reconnaissance Program

Goal: Test methods to improve forecasts 8-14 days ahead for the entire Northern Hemisphere

First GARRP Demo
22 Jan – 20 Feb 2026 (30 days)
Drifting Buoys
~175 buoys with sea level pressure

ector, and SLP (hPa; contours)

Drifting buoys with barometers from AR Recon/GARRP*

F-135 Valid: 03 UTC 27 Jan 2026

Pacific Drifting Buoys

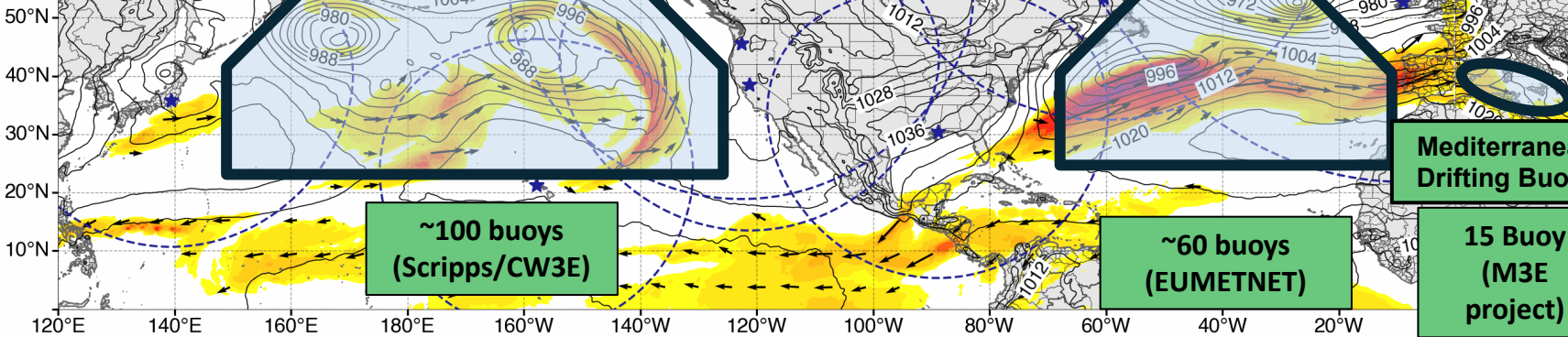
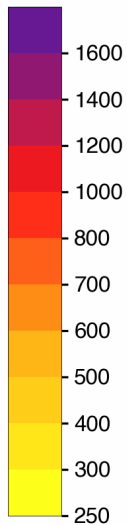
Atlantic Drifting Buoys

Mediterranean Drifting Buoys

~100 buoys (Scripps/CW3E)

~60 buoys (EUMETNET)

15 Buoy (M3E project)



GARRP Co-Leads

F. Martin Ralph, UCSD/SIO/CW3E, V. Tallapragada, NOAA/NWS

*Buoy leads: Luca Centurioni (Scripps), David Lavers (ECMWF), M3E Project Leads



Global Atmospheric River Reconnaissance Program

Goal: Test methods to improve forecasts 8-14 days ahead for the entire Northern Hemisphere

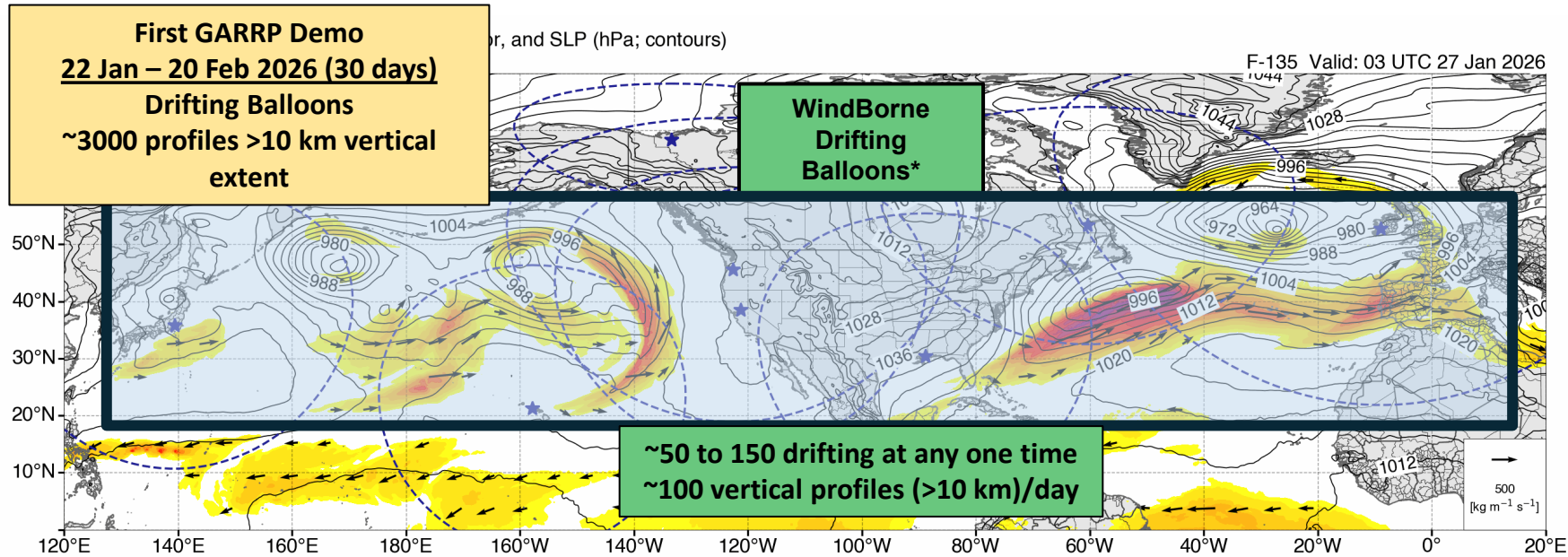
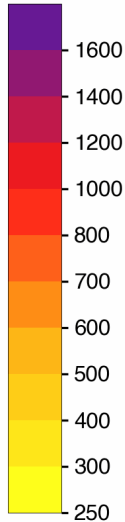
First GARRP Demo
22 Jan – 20 Feb 2026 (30 days)
Drifting Balloons
~3000 profiles >10 km vertical extent

or, and SLP (hPa; contours)

**WindBorne
Drifting
Balloons***

F-135 Valid: 03 UTC 27 Jan 2026

~50 to 150 drifting at any one time
~100 vertical profiles (>10 km)/day



GARRP Co-Leads

F. Martin Ralph, UCSD/SIO/CW3E, V. Tallapragada, NOAA/NWS

*Drifting balloons lead: Todd Hutchinson (WindBorne)



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GARRP Demo-2027

- AR Recon Pacific and Gulf dropsondes and Airborne Radio Occultation
- NURTURE Northwest Atlantic
- Possible AR Recon Northeast Atlantic?
- Drifting buoys enabled with barometers (NOAA adding 60 to Pacific)
- CW3E West Coast Radiosonde Program
- AR Recon – Coordinated University Sounding Program – (NASA doubling)
- EUROP – Coordinated GARRP Sounding Program – envisioned
- More Northern Hemis soundings – Asia, West Pac, Caribbean (GPEX?)
- Atlantic ship sondes – TBD
- Commercial shipping – opportunity to expand on developing program
- WindBorne soundings – major expansion in GARRP Demo 2026, Next?
- Selected Southern Hemisphere radiosondes - idea



GARRP Demonstrations

- 2026 - done
- 2027 – expansion of 2026 across the Northern Hemisphere
- 2028 – add southern hemisphere initial demo, with GPEX
 - S Hemis: WindBorne, barometer-enabled drifting buoys and Univ. soundings
- 2029 – year- 1 of GPEX Global AR Precipitation Campaign
 - S Hemis: Expansion from 2028 to include Circum-Antarctic soundings
- 2030 – year- 2 of GPEX Global AR Precipitation Campaign
 - Add other field programs as part of GARRP and GPEX
- GARRP becomes operational as a Research And Operations Partnership

GARRP Structure and Working Groups

Leadership

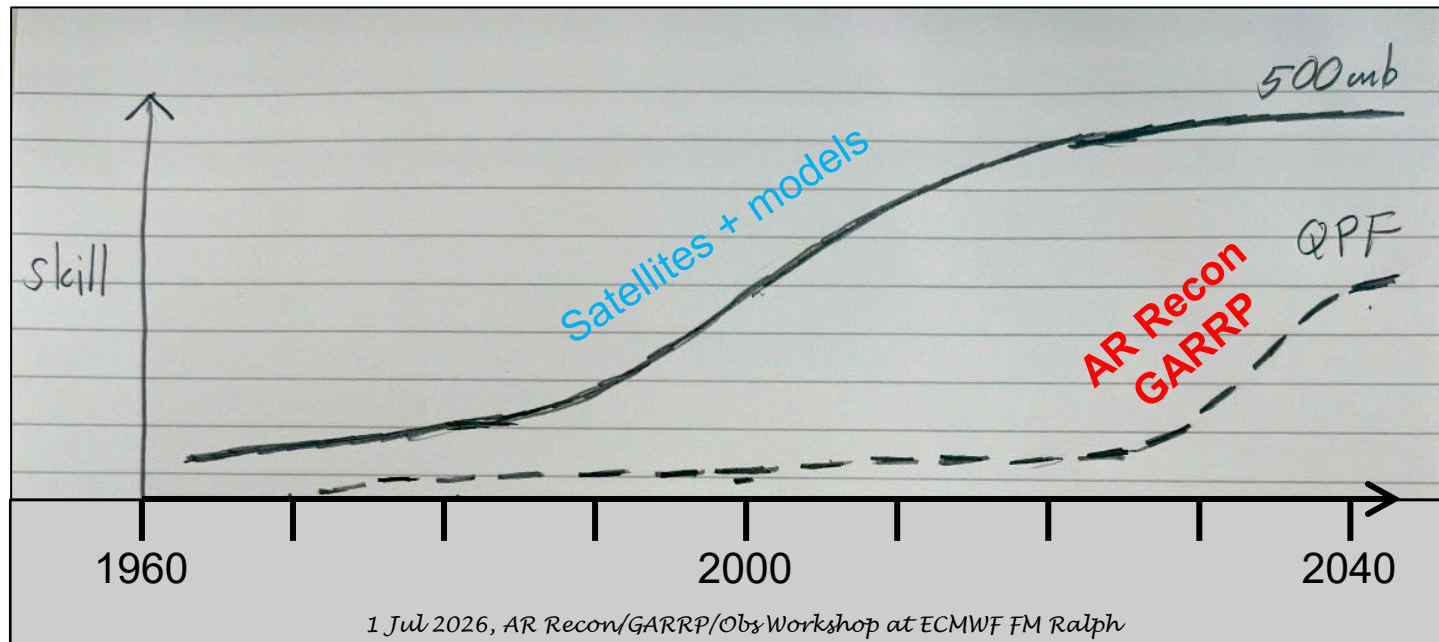
- F. Martin Ralph (PI)
- Vijay Talapragada (Co-PI)

Working Groups

- Observations
 - Anna Wilson
 - Jia Wang
- Modeling/Data Impacts
 - David Lavers
 - Minghua Zheng
- Physical Processes
 - Carolyn Reynolds
 - Aneesh Subramanian



Vision for AR-Recon/GARRP Impact on Forecast Skill



Summary

- GARRP: Demonstration Research And Operations Partnership will be ongoing for the coming years
- Will continue to partner with other campaigns of opportunity, private sector, academia, government agencies, and more
- Welcoming involvement, coordination, collaboration and partnerships



Dropsonde tube
on the WC130-J



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

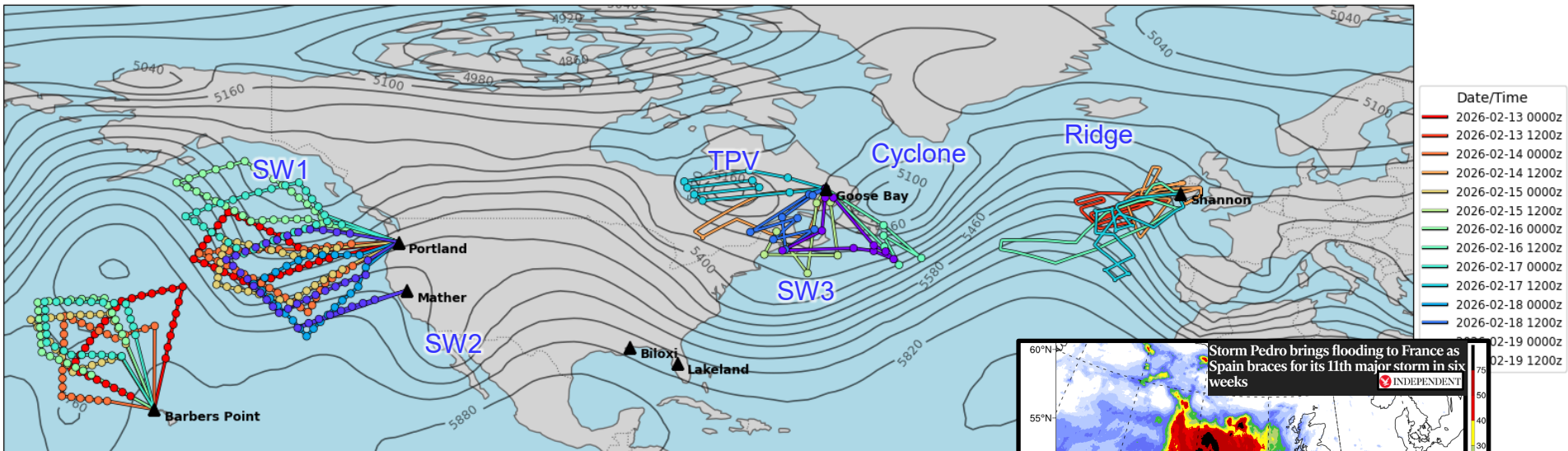
UC San Diego



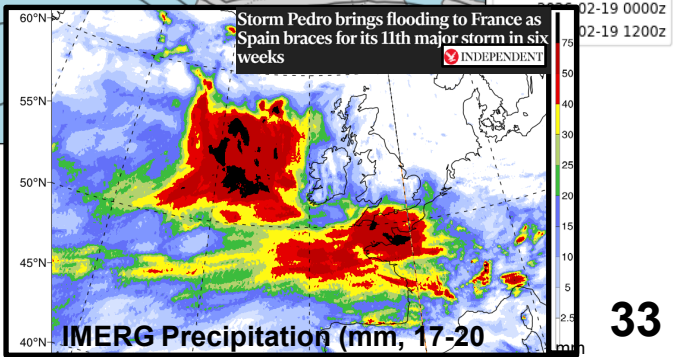
SCRIPPS INSTITUTION OF
OCEANOGRAPHY

Flight Tracks during Storm Pedro Time Period

AR Recon, NAWDIC, NURTURE Flight Tracks (13-19 Feb. 2026)
1800 UTC 13 Feb. 500-hPa Geopotential Height Analysis



- Storm Pedro: Flooding in France(100-200 mm) & UK impacts
- During 13-19 Feb. 20+ research flights and many dropsondes
- Excellent case to examine in the context of GARRP goals

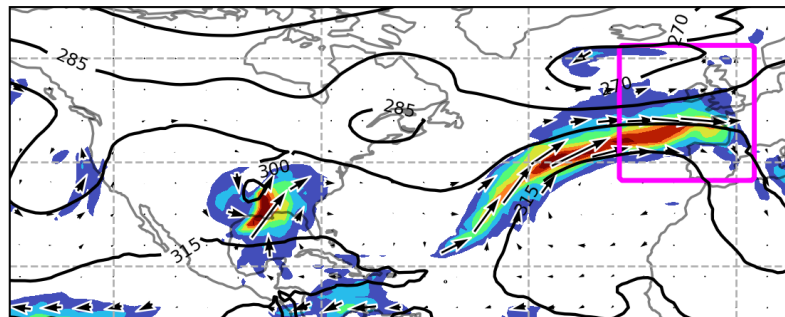
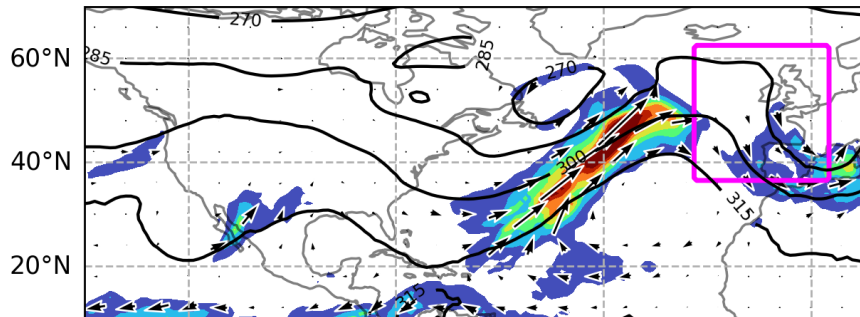


Synoptic Overview

IVT Vectors and Magnitude (shading, $\text{kg m}^{-1} \text{s}^{-1}$) and 700-hPa Geopotential Height (black, dam)

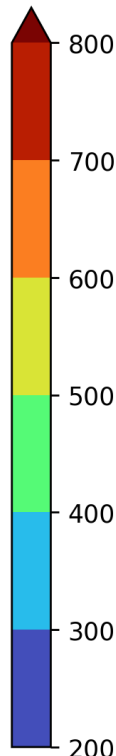
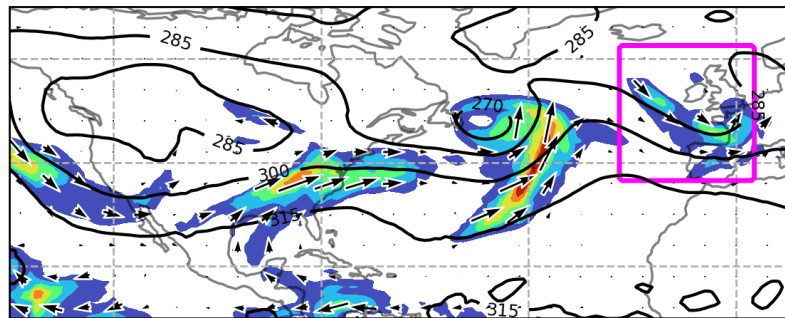
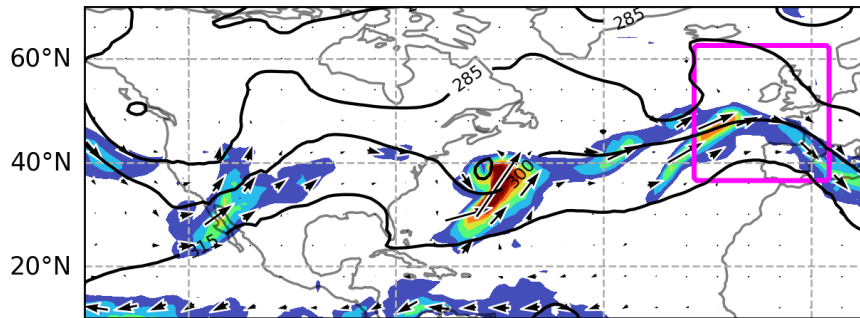
(a) 1800 UTC 13 Feb 2026 ($t = 0$ h)

(b) 0600 UTC 15 Feb 2026 ($t = 36$ h)



(c) 0600 UTC 17 Feb 2026 ($t = 84$ h)

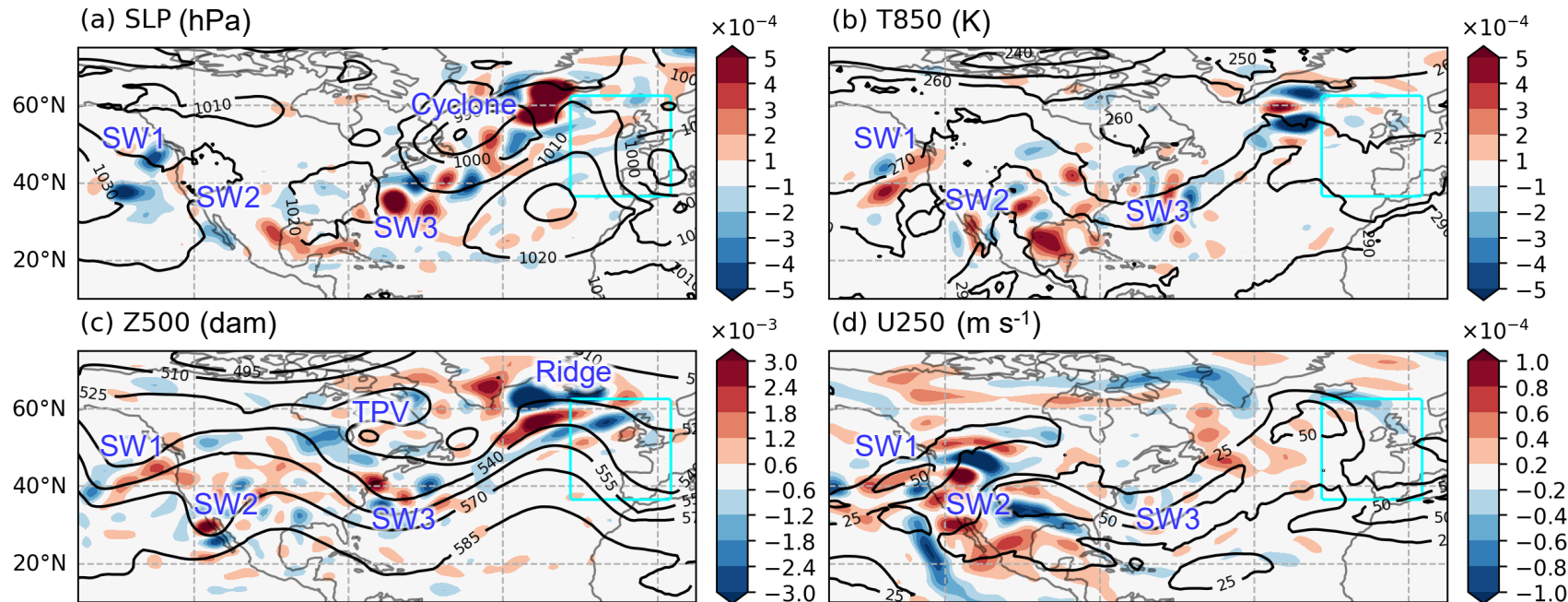
(d) 1800 UTC 18 Feb 2026 ($t = 120$ h)



Multiple Atmospheric rivers were present in the East Pacific and Atlantic

Sensitivity of 5-day ML Forecast Error to Initial Conditions

5-day ML Sensitivity (shading) and Initial Conditions from ERA5 (black) Valid at 1800 UTC 13 Feb. 2026



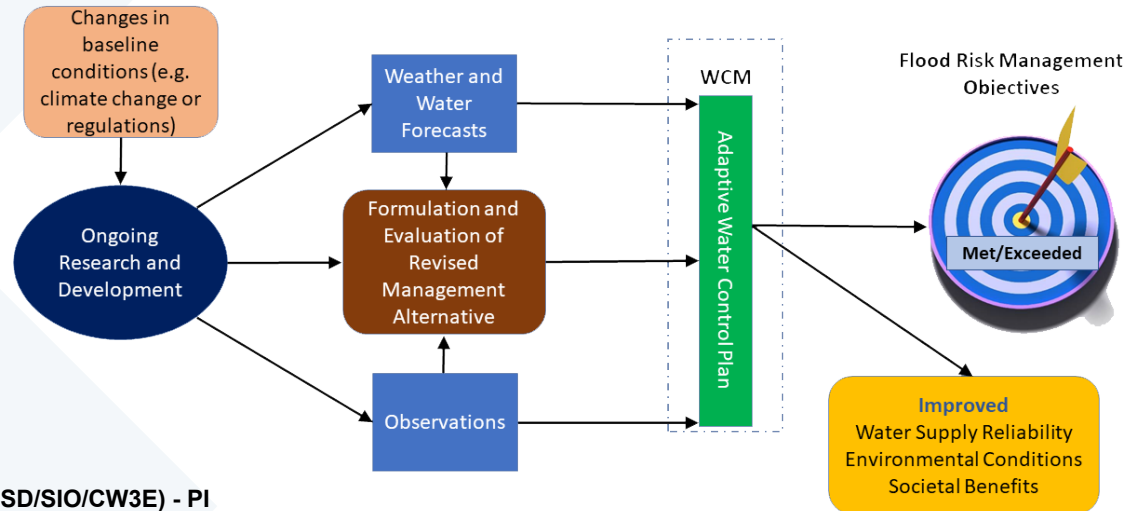
- GraphCast ML sensitivities highlight role of multiple shortwaves, ARs, and TPV
- Sensitivities are tilted upstream with altitude similar to adjoints (correlation between NWP and ML sensitivities ~ 0.7 for more than 100 cases)

AR Recon: A World Weather Research Programme 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 with CW3E and other partners to advance their goals of **using improved AR prediction to inform water and infrastructure management** (e.g., for Forecast Informed Reservoir Operations – FIRO).

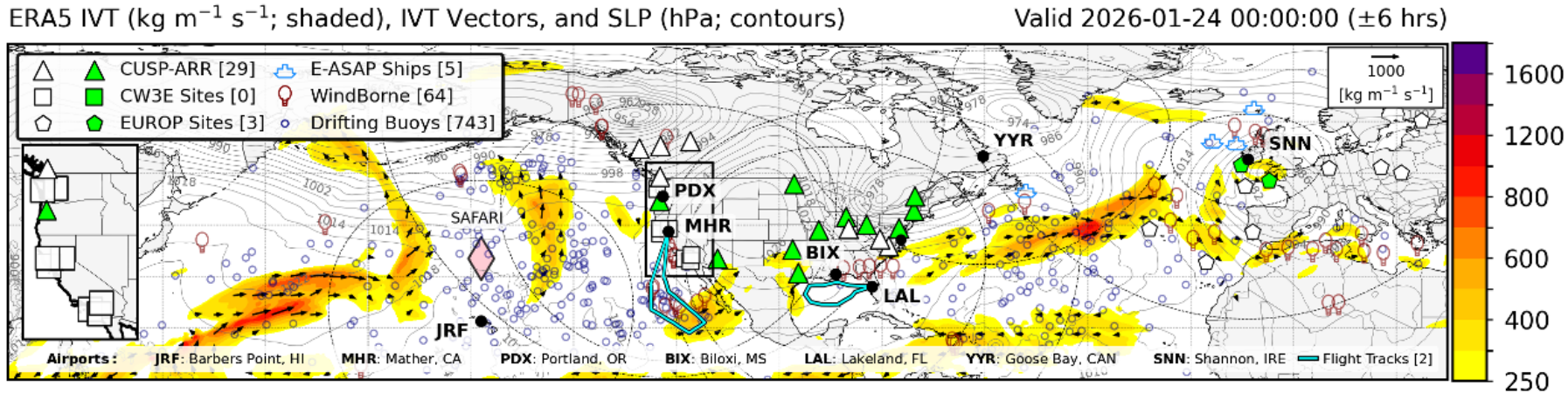
FIRO Model for Adaptive Water Control Manuals



Global Atmospheric River Reconnaissance Program

Goal: Test methods to improve forecasts 8-14 days ahead for the entire Northern Hemisphere

Example of observations from one day – 24 Jan 2026



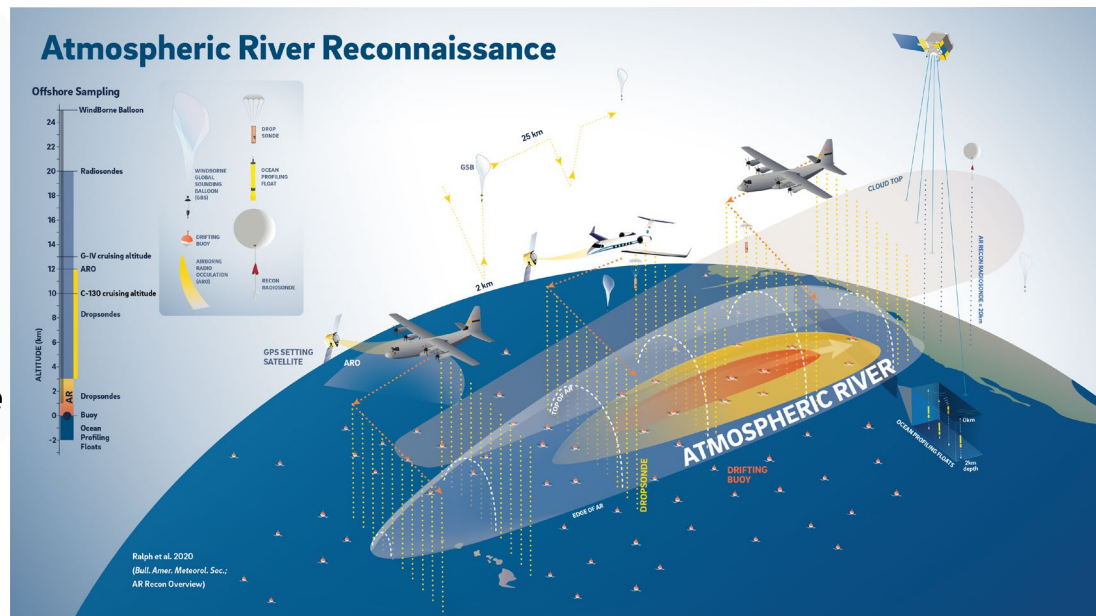
GARRP Co-Leads

F. Martin Ralph, UCSD/SIO/CW3E, V. Tallapragada, NOAA/NWS

AR Recon – GPEX Anchor Project

*“InPRHA aims to integrate **advanced forecasting systems** into early warning and action mechanisms to enhance resilience to natural and societal hazards.”*

*“AR Recon develops and tests targeted airborne and buoy observations over the Northeast Pacific to improve 1–5 day forecasts of AR landfall and impacts on the U.S. West Coast. It supports scientific research and operations to advance understanding of precipitation processes, improve extreme **precipitation forecasts**, and inform **water management** and **flood alerts**.”*



Atmospheric River (AR) Recon
PI: F. Martin Ralph, Co-PI: Vijay Tallapragada

AR Recon advances AR science, serving as an anchor project supporting the WCRP Global Precipitation Experiment (GPEX)