Ocean surface and subsurface measurements for AR Recon and subseasonal AR predictability

Aneesh Subramanian, Tim Higgins, Donata Giglio, Bruce Ingleby, Anna Wilson, David Lavers, Brian Kawzenuk, Minghua Zheng, Jim Doyle, Carolyn Reynolds, Vijay Tallapragada, Luca Centurioni, Luca Delle Monache, Marty Ralph
with contributions from many others

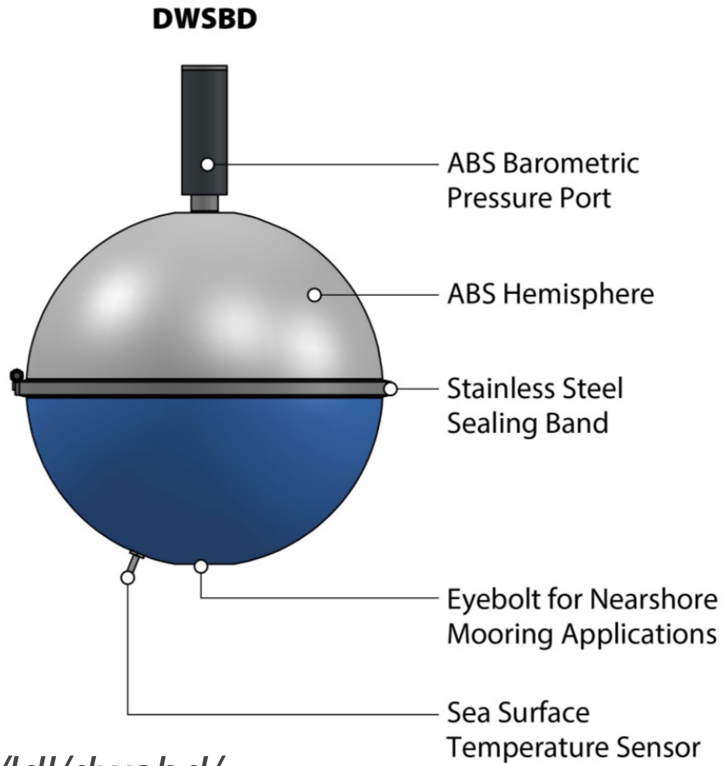
AR Recon Workshop, 28 June 2023

DIRECTIONAL WAVE SPECTRA BAROMETER DRIFTER (DWSBD)™

Technical Description

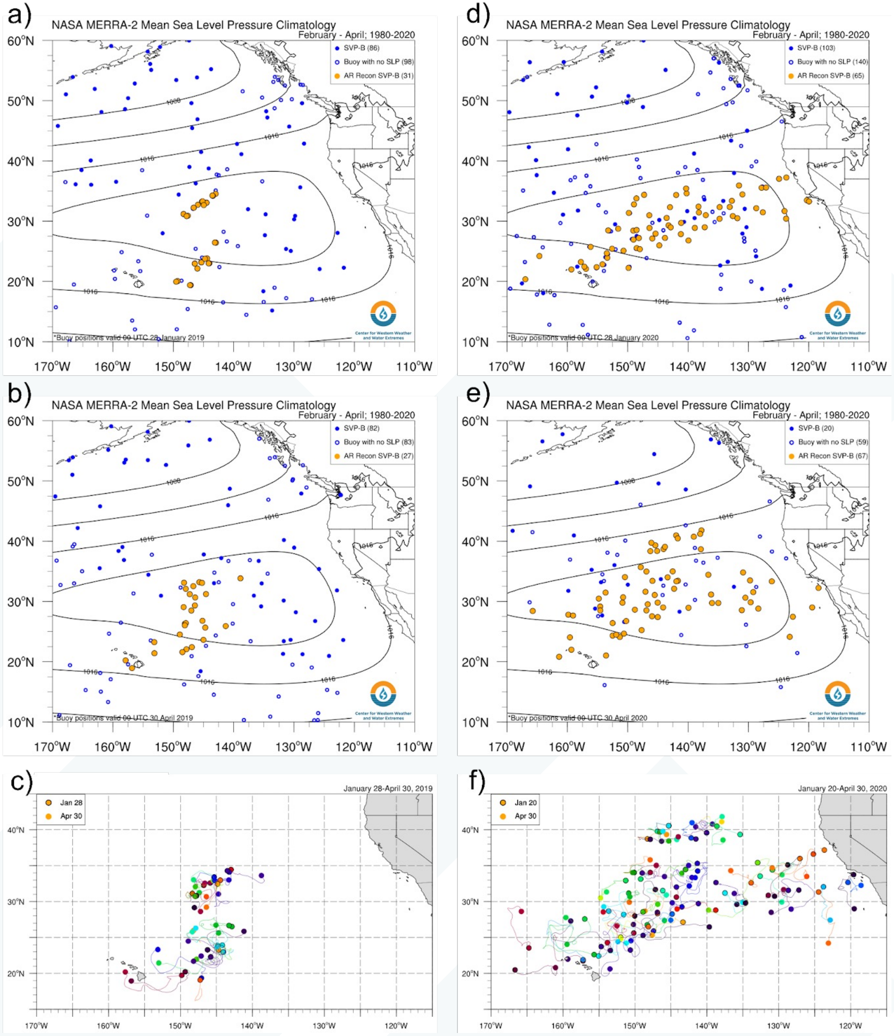
- 35 cm sphere surface float
- GPS-based tracking and wave engine
- Iridium Short Burst Data (SBD) telemetry
- Onboard datalogger with up to 16 GB of storage
- Fourier coefficients a0, a1, b1, a2, b2
- 1/256 Hz bandwidth from 0.03–0.50 Hz
- Sea level barometric pressure sensor (±0.4 hPa accuracy)
- User-programmable sampling window
- Sea surface temperature (±0.05 K accuracy)
- Freely drifting or restrained mooring configurations
- One-year lifespan

> Download technical illustration (312 KB pdf)



https://gdp.ucsd.edu/ldl/dwsbd/

AR Recon 2019-20 – Surface Pressure over NE Pacific



Buoys were deployed to fill a gap in SLP observations over the NE Pacific after feedback from a meeting of the AR Recon Steering Group at ECMWF in Fall 2018.

The drifters span a large region over the season. Initial deployment is along a line dropped from flights or ships of opportunity.

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

Figure courtesy Brian Kawzenuk

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

Data Denial Experiments with and without AR Recon Buoys: 2019 & 2020

Control experiment: All observations including SLP from buoys were assimilated prior to forecast initialization

Denial experiment: Buoy SLP data were withheld from assimilation

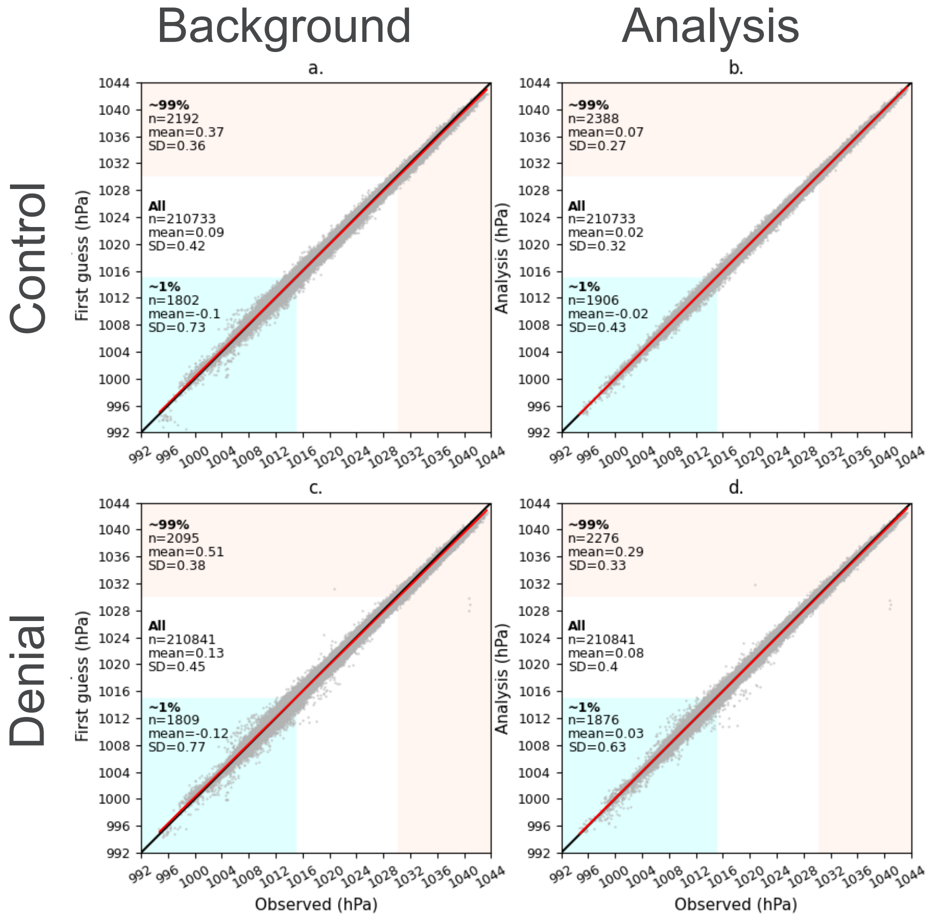
Medium range forecasts were run (10 days)

Observation – Background (1 and 99 %)

The mean(O-B) is significantly improved in the Control experiment compared to the denial experiment.

Control (99%):
Mean error for background = 0.37

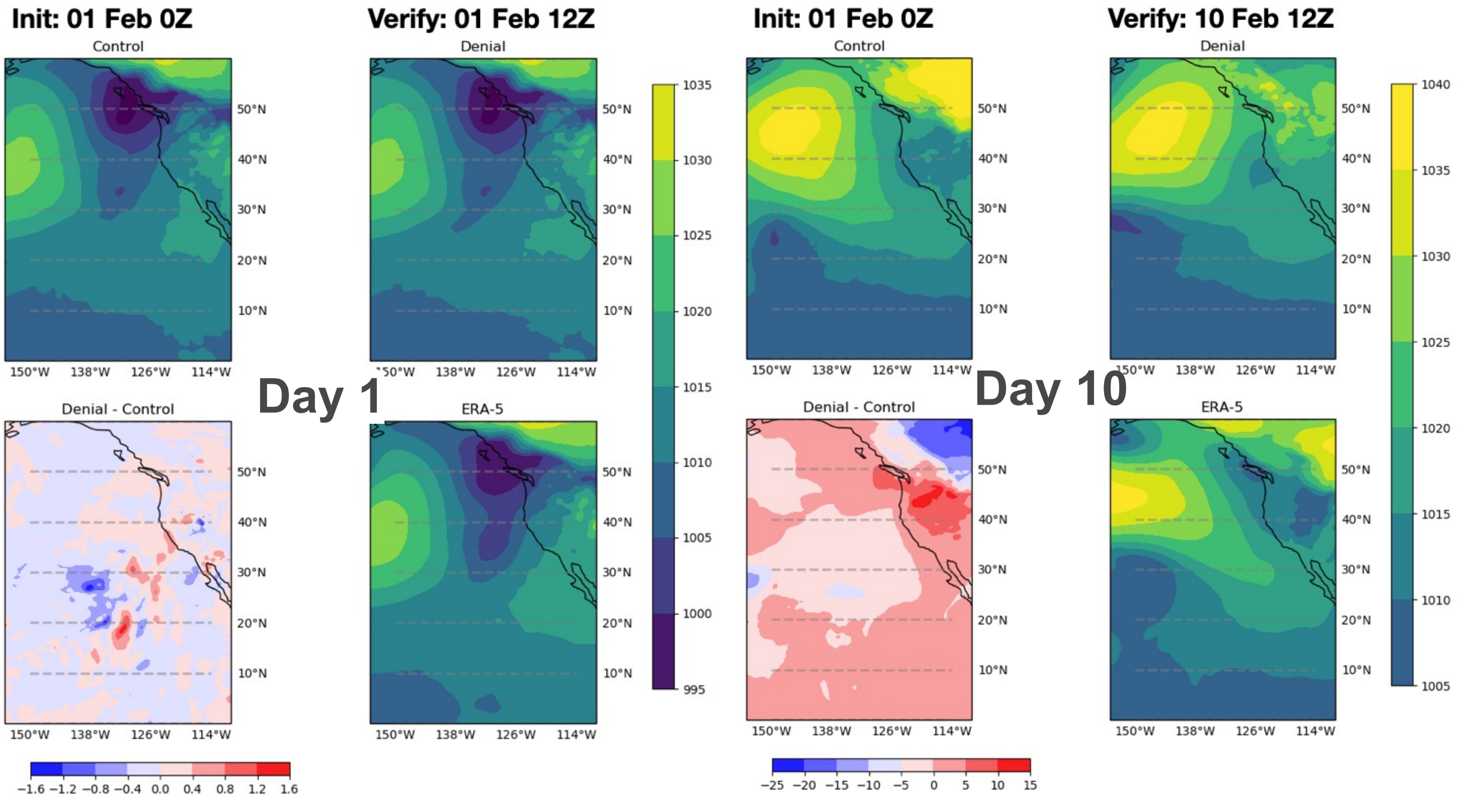
Denial (99%) :
Mean error for background = 0.51



Forecast error : Mean Sea Level Pressure

Forecast differences are initially large in the region near the buoy locations.

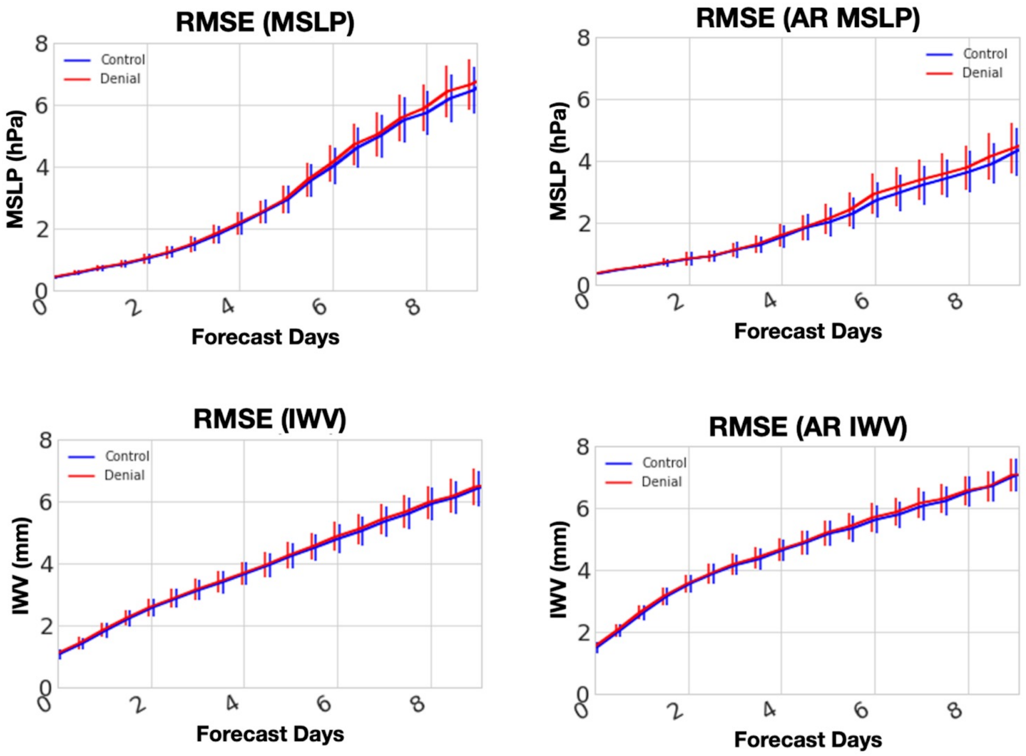
The errors grow downstream with increased lead time.



Forecast errors - AR Recon Buoys: 2019 & 2020

RMSE for Mean Sea Level Pressure and the Integrated Water Vapor over the Northeast Pacific Domain (AR masked variables on the right)

No significant difference between the two experiments over 10 day forecast lead time.



Buoy Impacts and Future Plans

- Ocean surface buoy observations of SLP in a data sparse region has an impact on analysis of MSLP and surface variables
- Changes in surface pressure can impact the mid-latitude low pressure system and atmospheric river dynamics/thermodynamics
- Continue efforts to assess effectiveness of buoy observations for multiple years and other forecast/DA systems

Atmospheric river impacts on the upper ocean: a study using Argo floats

Donata Giglio[1]

Collaborators:

Lauren Hoffman [2], Bill Mills[1], Sarah Purkey [2], John Gilson [2], Aneesh C. Subramanian[1], Brian Kawzenuk [2], Anna Wilson [2], Marty Ralph [2]

[1]University of Colorado, Boulder, Colorado, USA

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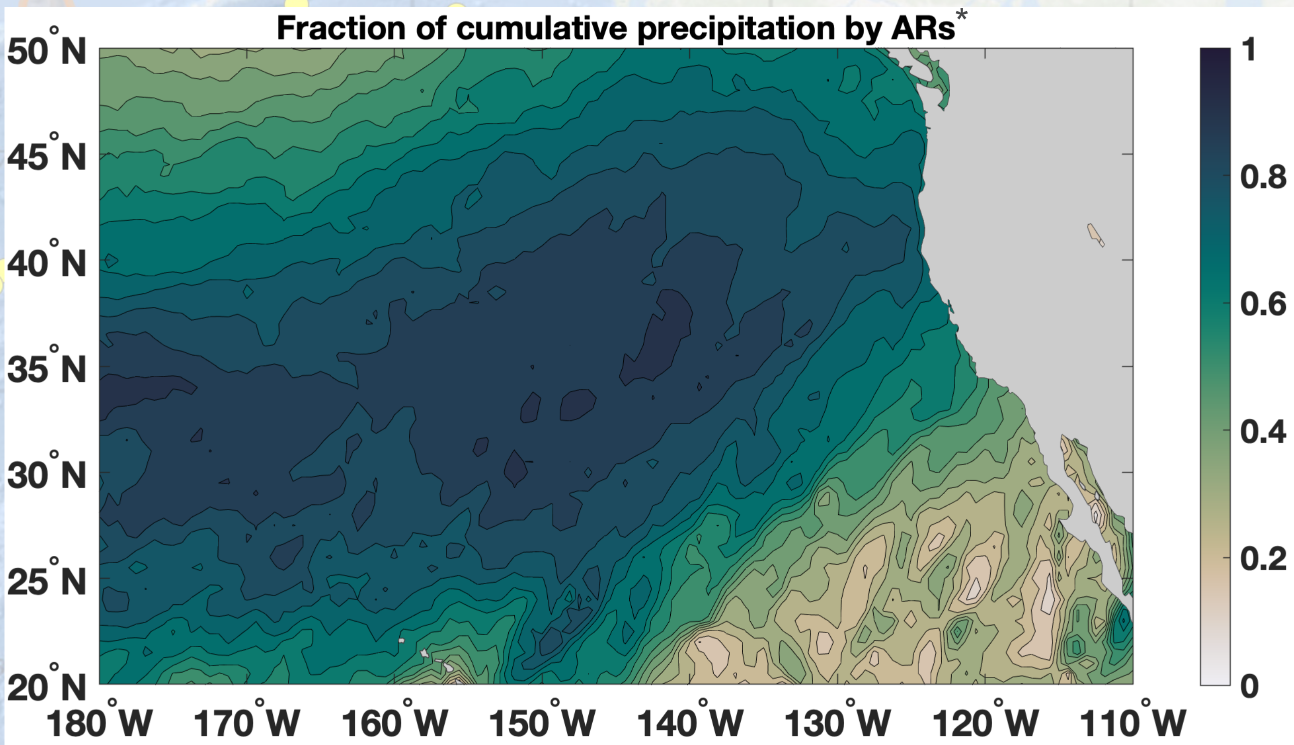
University of Colorado Boulder

Why are we studying Atmospheric River impacts on the upper ocean?

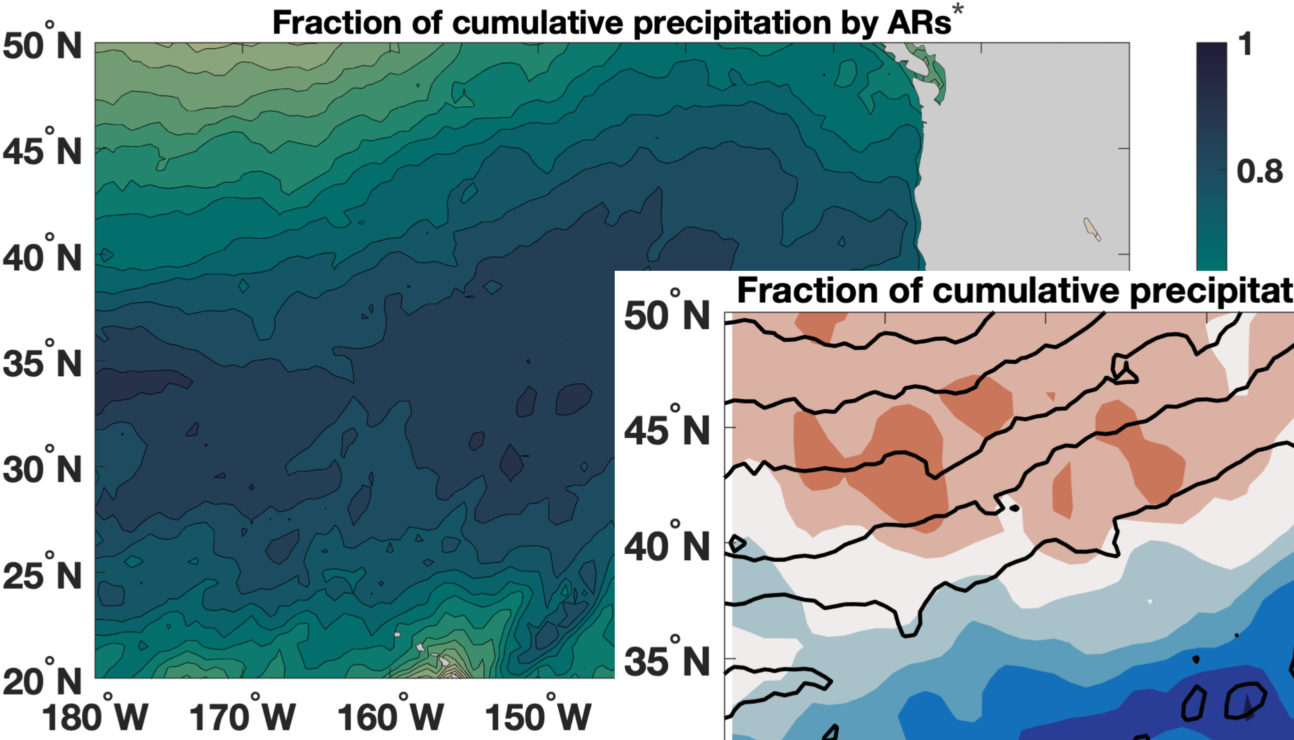
To understand relevant processes and possible implications for air-sea interactions.

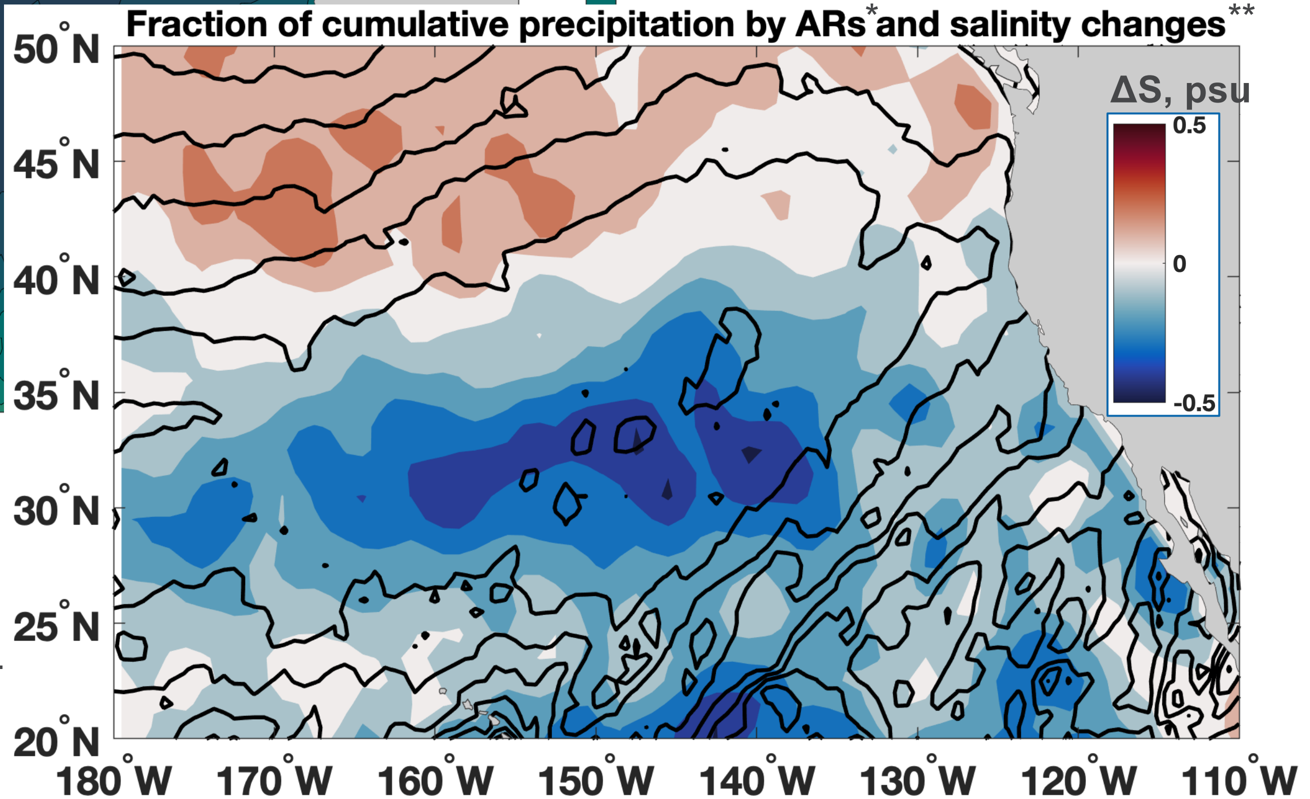
Why are we studying Atmospheric River impacts on the upper ocean?

Atmospheric rivers can account for a large fraction of the rainfall over the open ocean.



* for DJF, during the years 2005-2021 (GPM and SIO AR climatology)



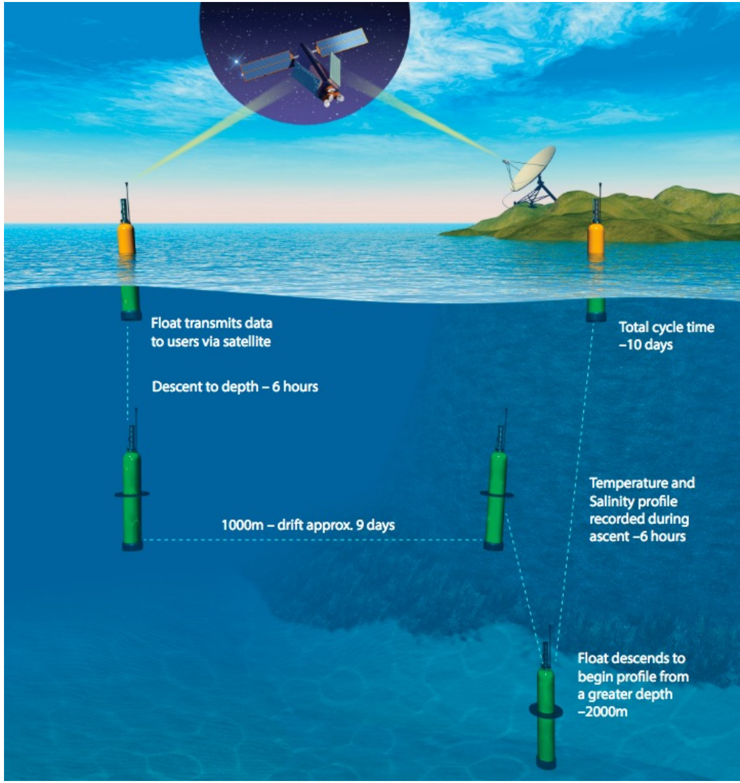


* for DJF, during the years 2005-2021 (GPM and SIO AR climatology)

** March – November, during 2005-2021 (Roemmich and Gilson product)

Pilot experiment in the North Pacific: datasets

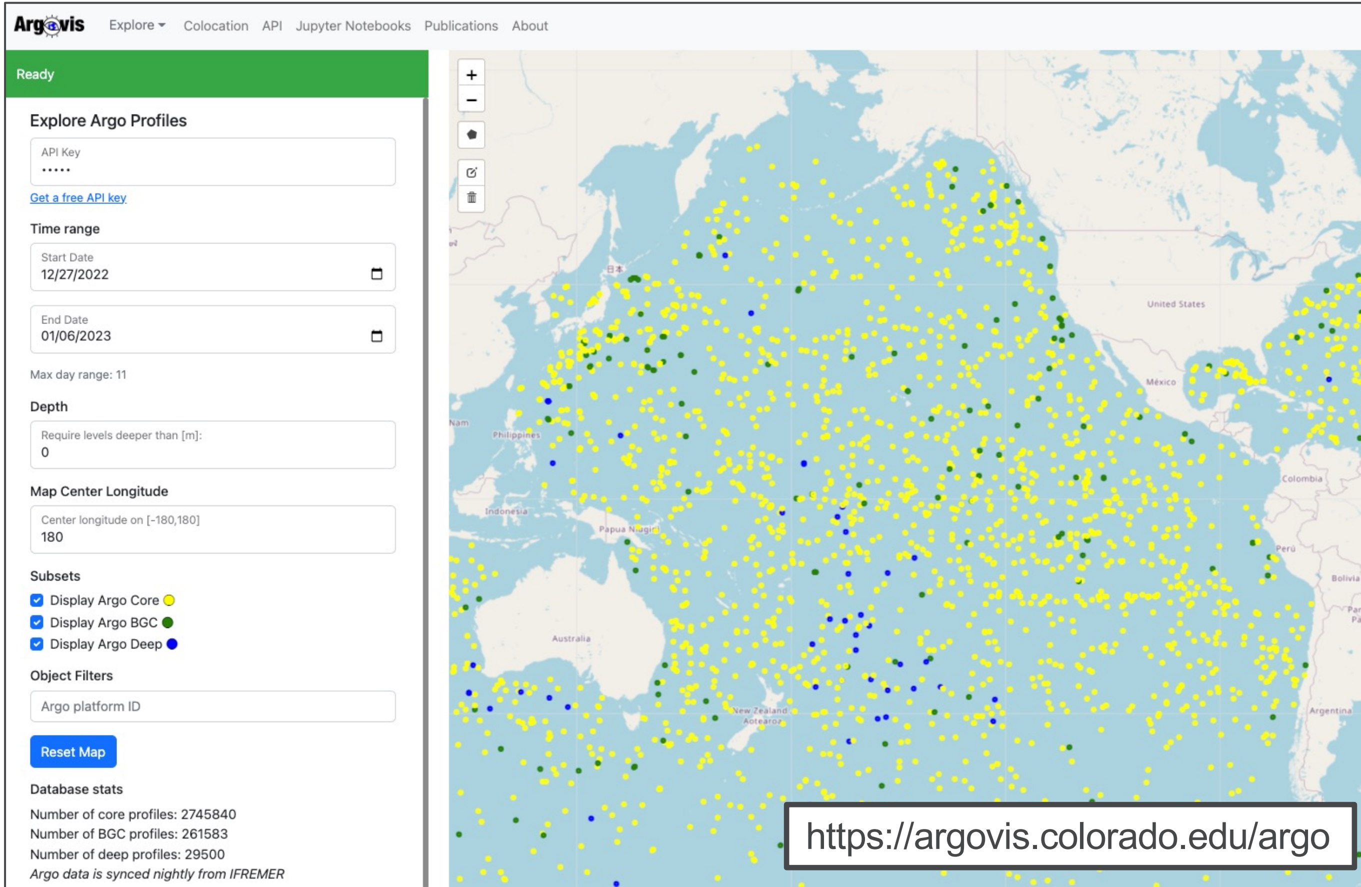
- Argo floats
  - custom sampling for selected floats likely to be co-located with precipitation from an atmospheric river



- ERA5 Reanalysis, e.g. winds, IVT
- GPM precipitation

Pilot experiment in the North Pacific: Argo sampling

Argo floats : sampling to 500m continuously during an AR-event, 1 profile every ~4-5 hours, instead of every ~10 days



Near-surface ocean freshening during AR precipitation events

- Measured by Argo floats during a pilot experiment

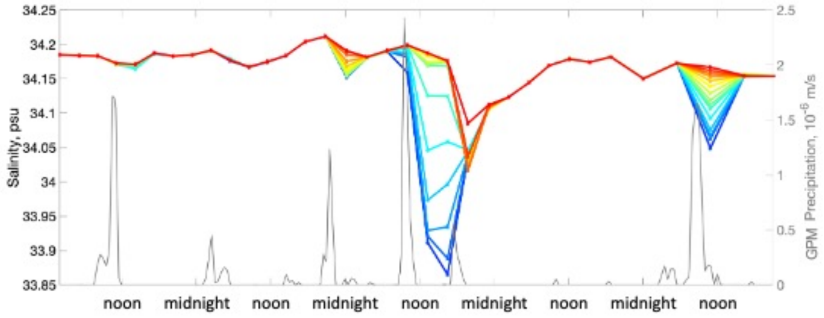


Fig. 4 Salinity during AR passage (lines colored by pressure level, left y-axis); GPM precipitation (gray line, right y-axis).

Pressure levels (dbar): 1.5 3.5 5.5 7.5 9.5 11.5 13.5 15.5 17.5 19.5 21.5 23.5 25.5

- Stronger signal for weaker wind speed

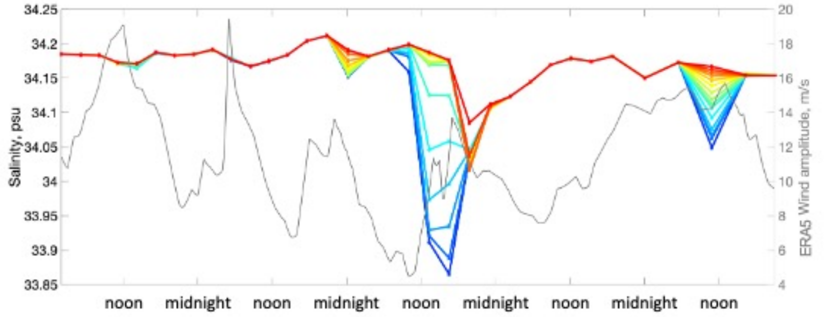
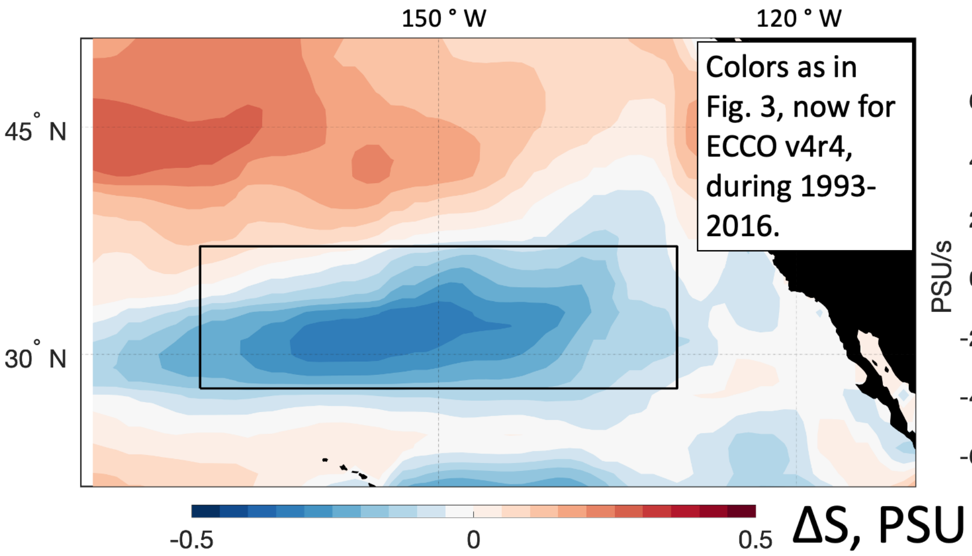
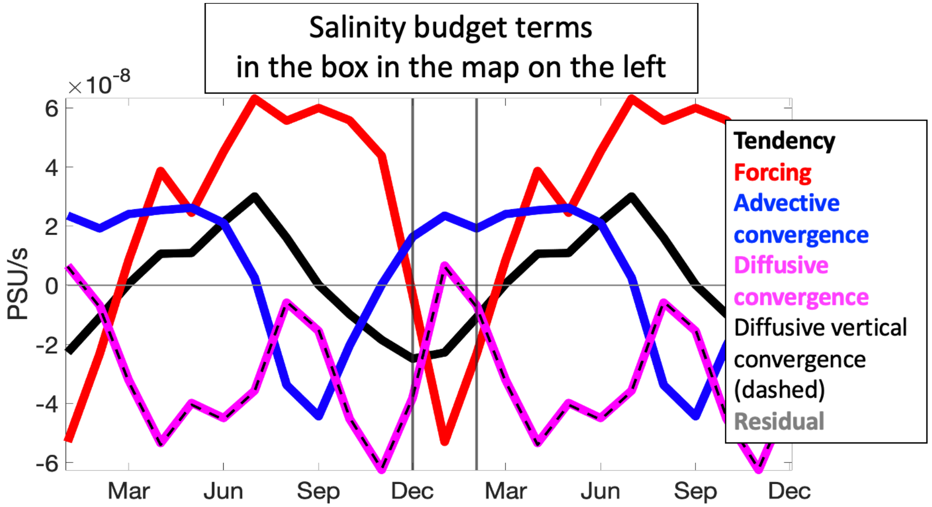


Fig. 5 As in Fig. 4, yet ERA5 wind amplitude is shown on the right y-axis (gray line).

- Captured by 1D General Ocean Turbulence Model (not shown)

ECCO Ocean State Estimate captures freshening





ECCO (Estimating the Circulation and Climate of the Ocean; v4r4) captures freshening and shows air-sea exchanges and vertical diffusion contribute to it.

Summary

- Rainfall from atmospheric rivers contributes to a seasonal near-surface ocean freshening with implications for air-sea interactions and seasonal predictions

- Atmospheric river events produce salinity anomalies that are detectable by ocean instruments and were measured by Argo floats
  - Wind regulates salinity response to AR
  - Near-surface freshening lasts several hours
  - Implications for air-sea interactions

Thank you!

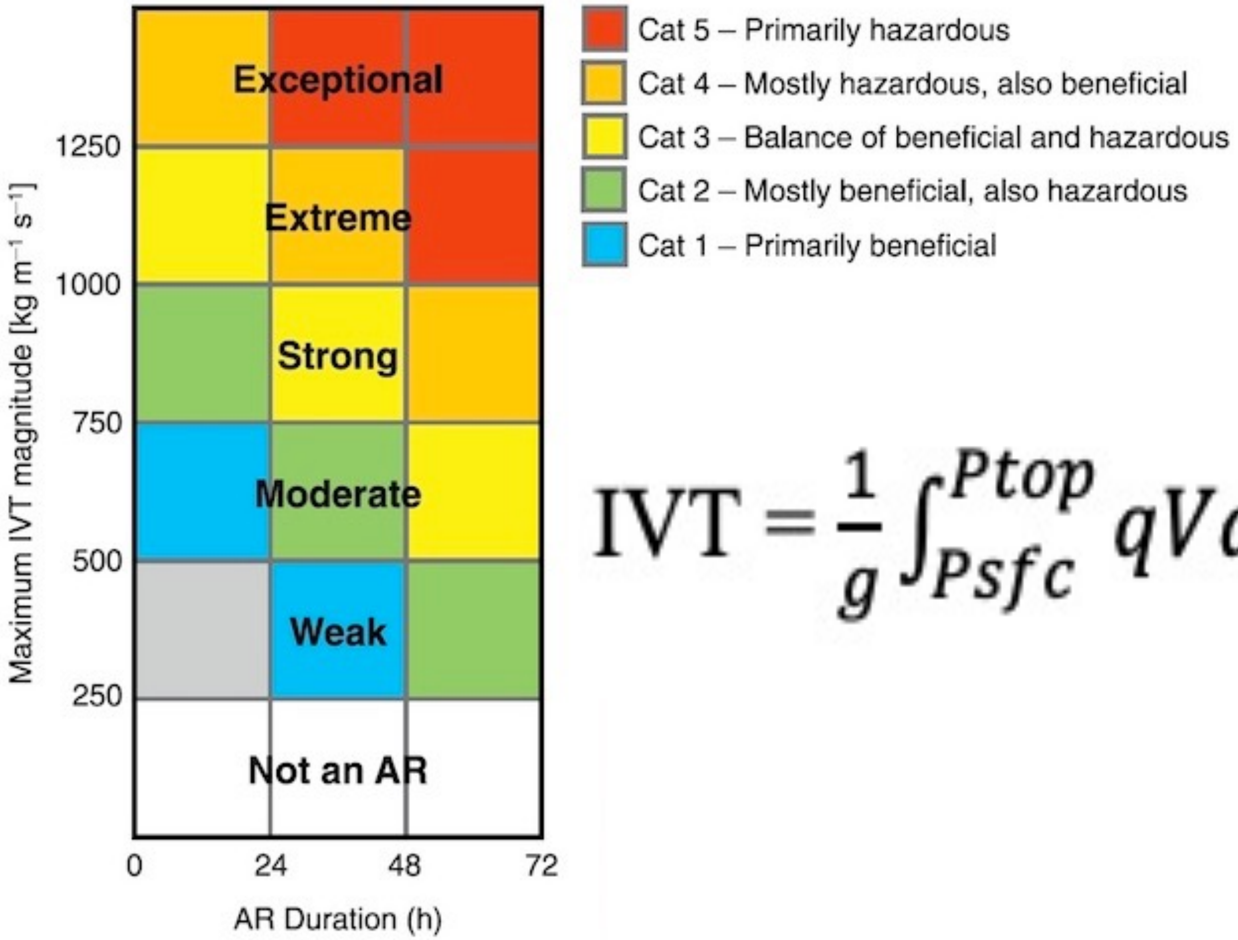
Subseasonal Potential Predictability of Horizontal Vapor Transport and Precipitation Extremes in the North Pacific

Tim Higgins

Aneesh C. Subramanian, Will Chapman, David Lavers, Andrew Winters

Project Goal

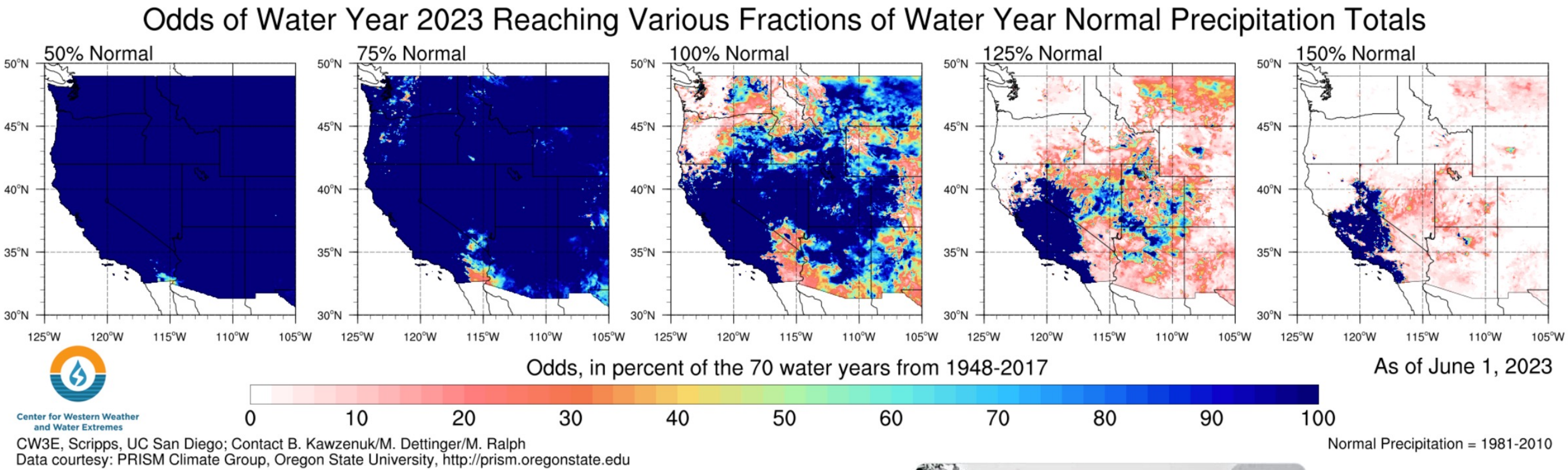
Demonstrate differences between potential predictability of integrated vapor transport (IVT) and precipitation at subseasonal to seasonal (S2S) lead times



$$IVT = \frac{1}{g}\int_{Psfc}^{Ptop} qV\,dP$$

Source: Ralph et al. 2019

Winter 2022-2023



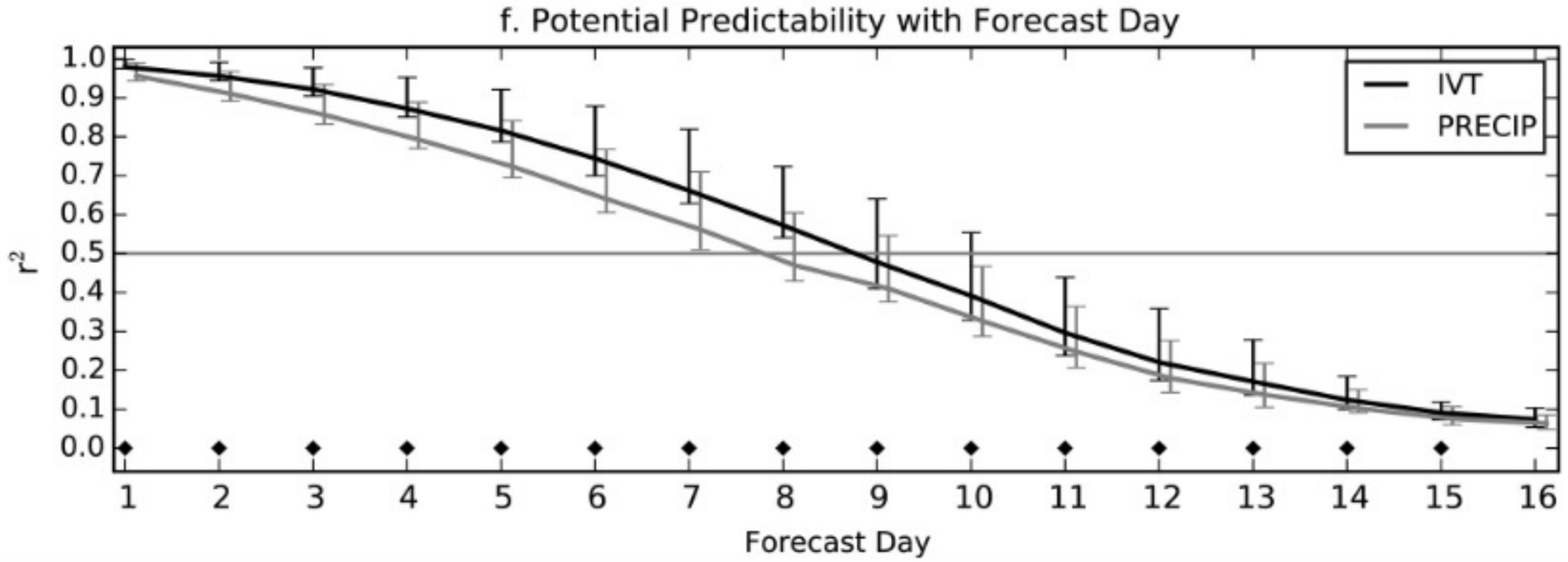
UC Berkeley Central Sierra Snow Lab, 2023

Tahoe, CA, 2023

Motivation

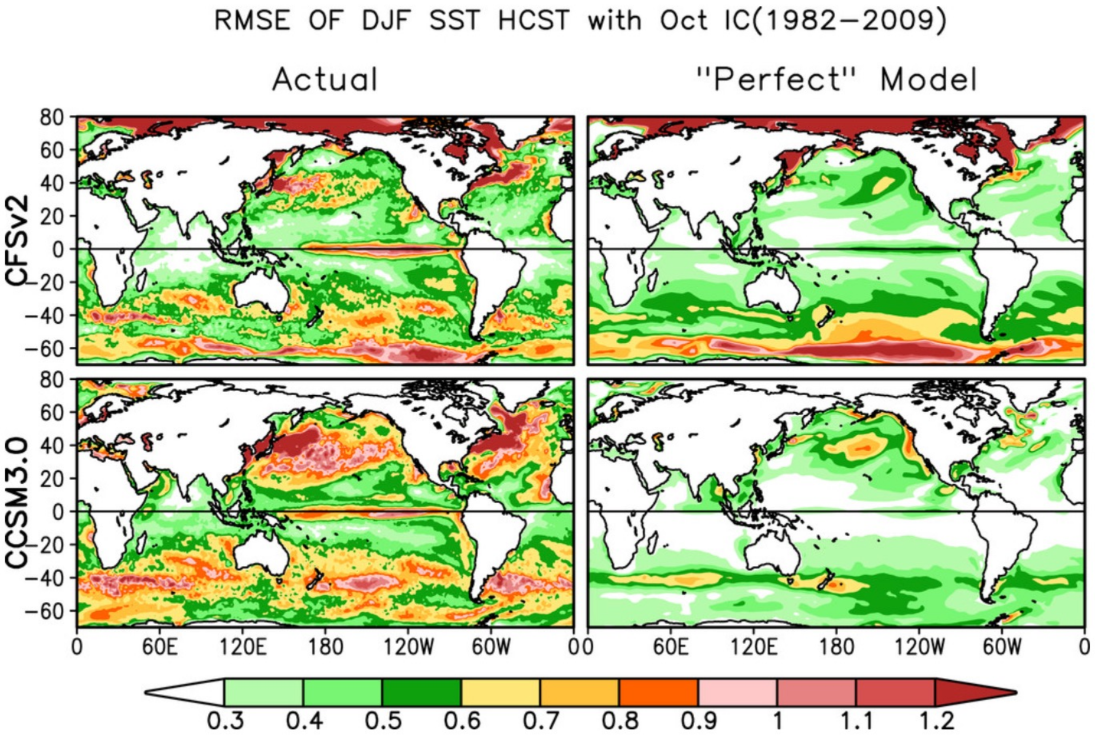
Previous work showed IVT to have greater forecast skill than precipitation at medium-range lead times

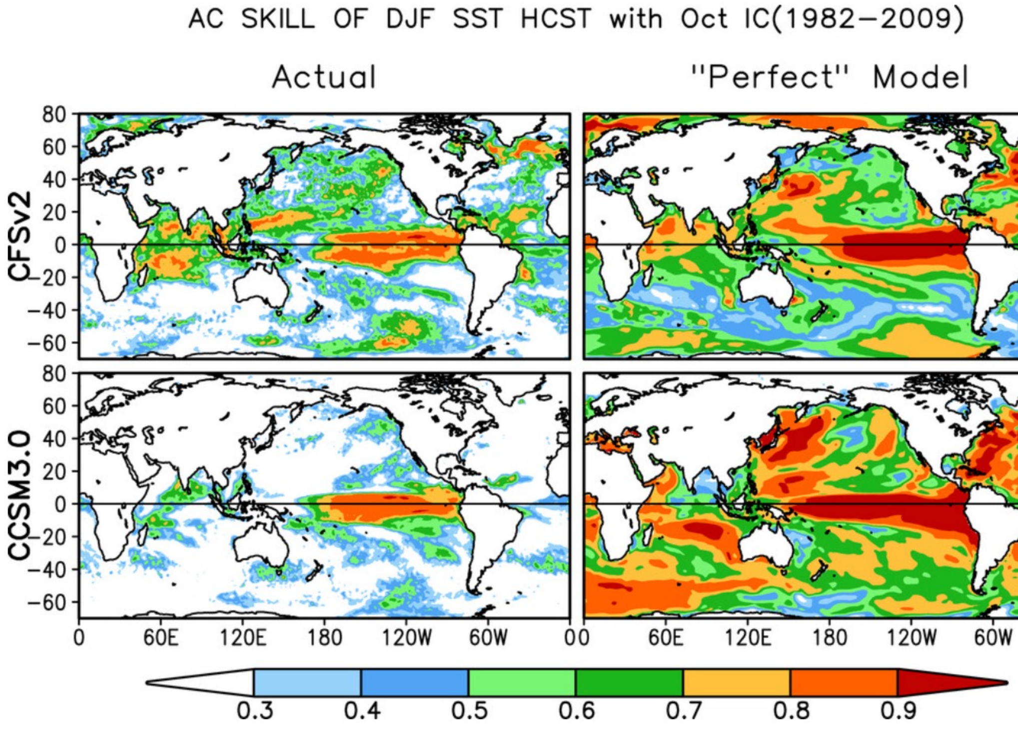
The same relationship has not been demonstrated in the S2S range



Source: Lavers et al. 2016

Potential Predictability





Source: Kumar et al. 2014

Data

- 20 years of ECMWF S2S reforecasts initialized during DJF months (N=500)
- Lead times at intervals of 24-hours, initialized at 0000 UTC
- Reforecasts initialized 3-4 days apart
- 11 Ensemble members
- 1.5° x 1.5° horizontal grid resolution spanning entire globe
- Anomalies calculated from weekly climatology in the model

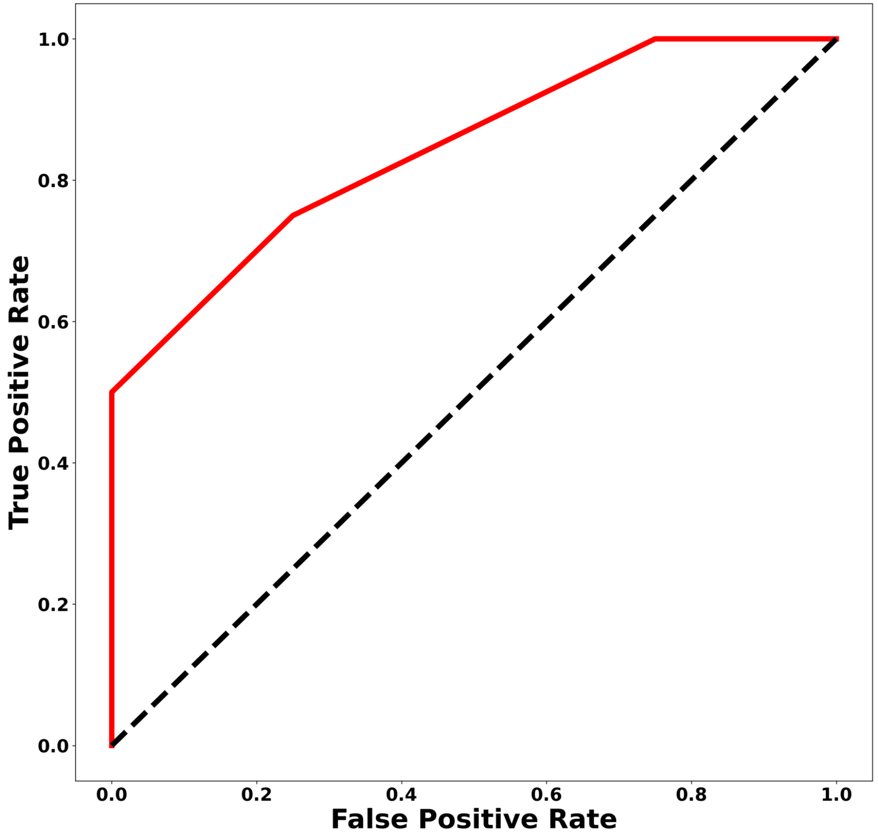
ECMWF

ROC Scores

$$A = 1 - \frac{1}{e'e}\sum_{i=1}^{e} f_i - \frac{1}{2e'e}\sum_{i=1}^{e}(f_i' - f_i)$$

A = area under the curve
e = number of events
e’ = number of non-events
f = number of non-events having a higher forecast probability than the current hit
f’ = number of non-events having a forecast probability greater than or equal to that of the current hit

Forecast Date	Probability of 90th Percentile IVT	Observed 90th Percentile IVT (1), <90th Percentile IVT (0)
2/8	0.6	1
2/1	0.5	1
1/14	0.4	1
1/4	0.4	0
1/11	0.4	0
1/21	0.3	1
1/7	0.3	0
1/25	0.3	0
1/28	0.3	0
1/18	0.2	0
2/4	0.2	0

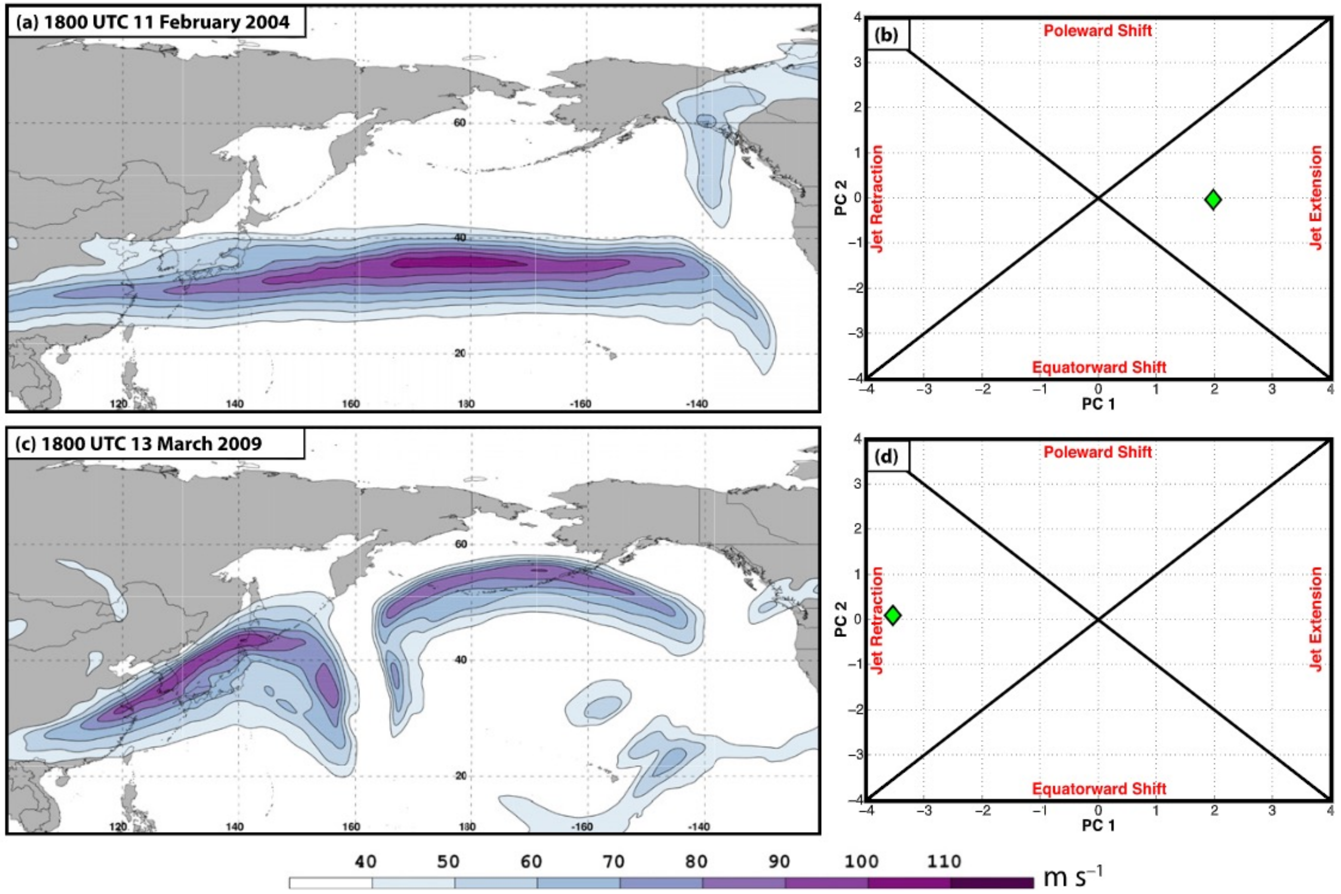


North Pacific Jet Regimes

EOFs are calculated from zonal wind velocity anomalies at 300 hPa

Leading EOF: Extension/Retraction of North Pacific Jet (NPJ)

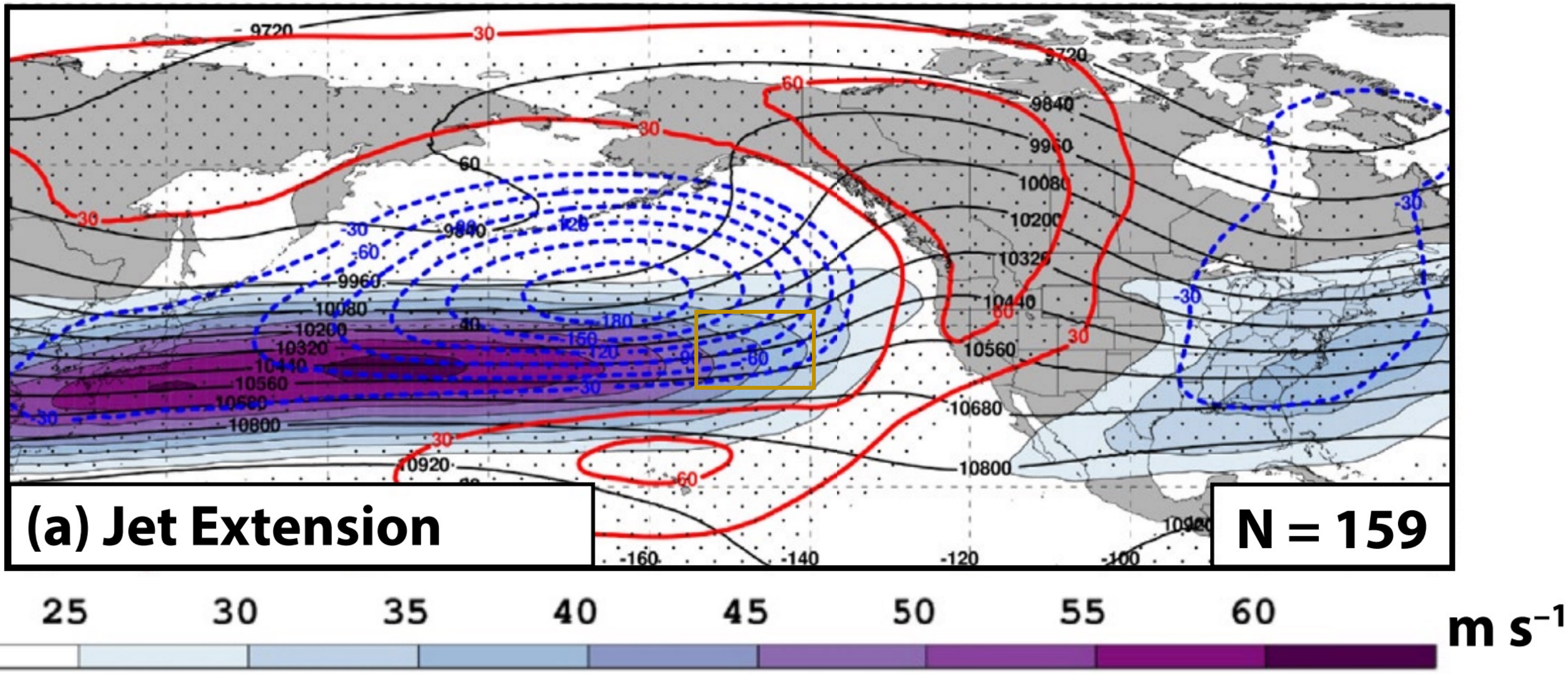
Second leading EOF: Poleward/Equatorward shift of NPJ



Source: Winters, Keyser, and Bosart (2019)

Jet Exit Region

Source: Winters, Keyser, Bosart (2019)



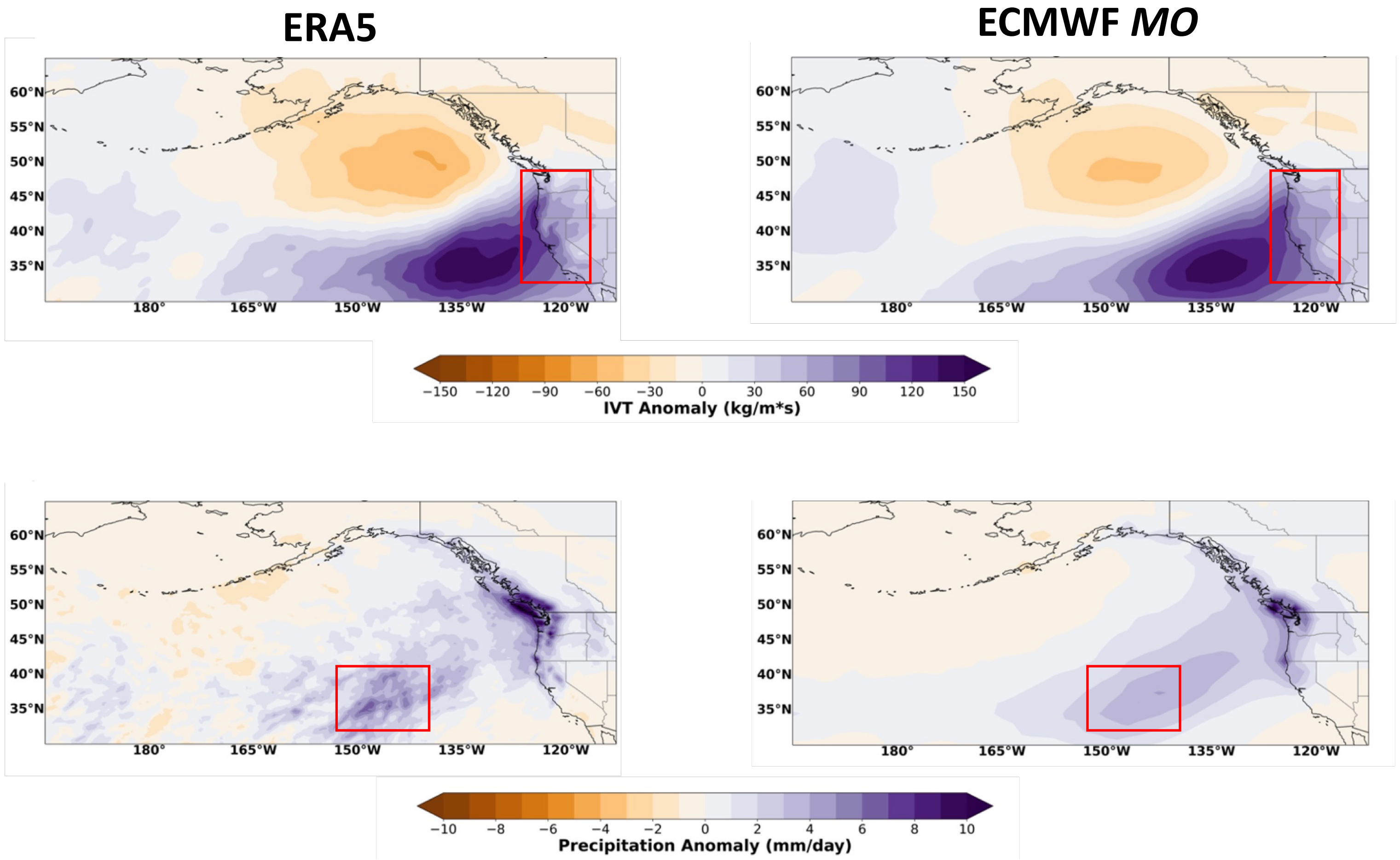
250 hPa geopotential heights – black contours
250 hPa geopotential height anomalies – colored contours: red (positive), blue (negative)
Wind speed – shaded

Introduction | Data | Methods | Results | Conclusion

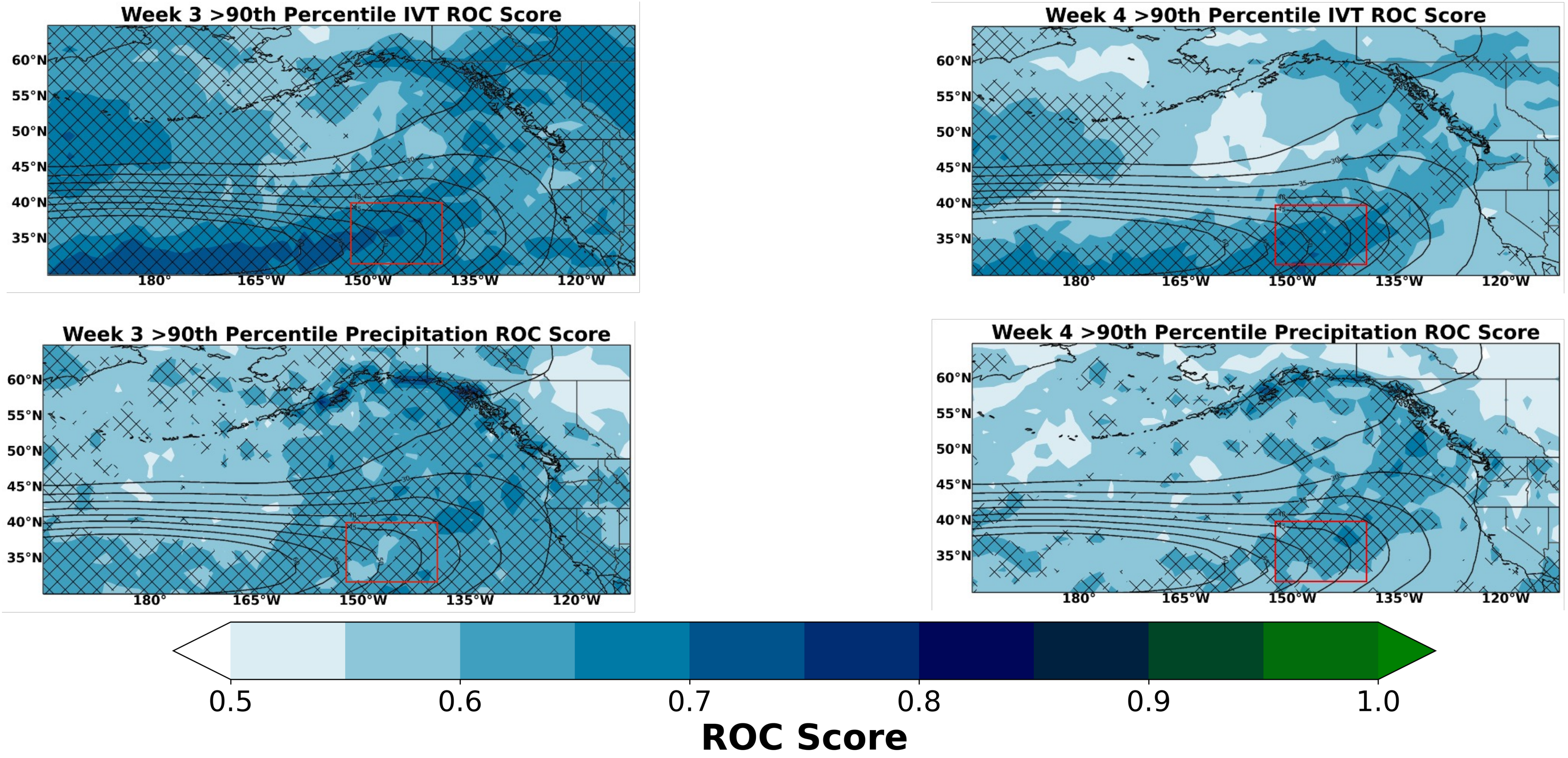
Importance of Predicting Jet Exit

>90th Percentile Coastal Precipitation

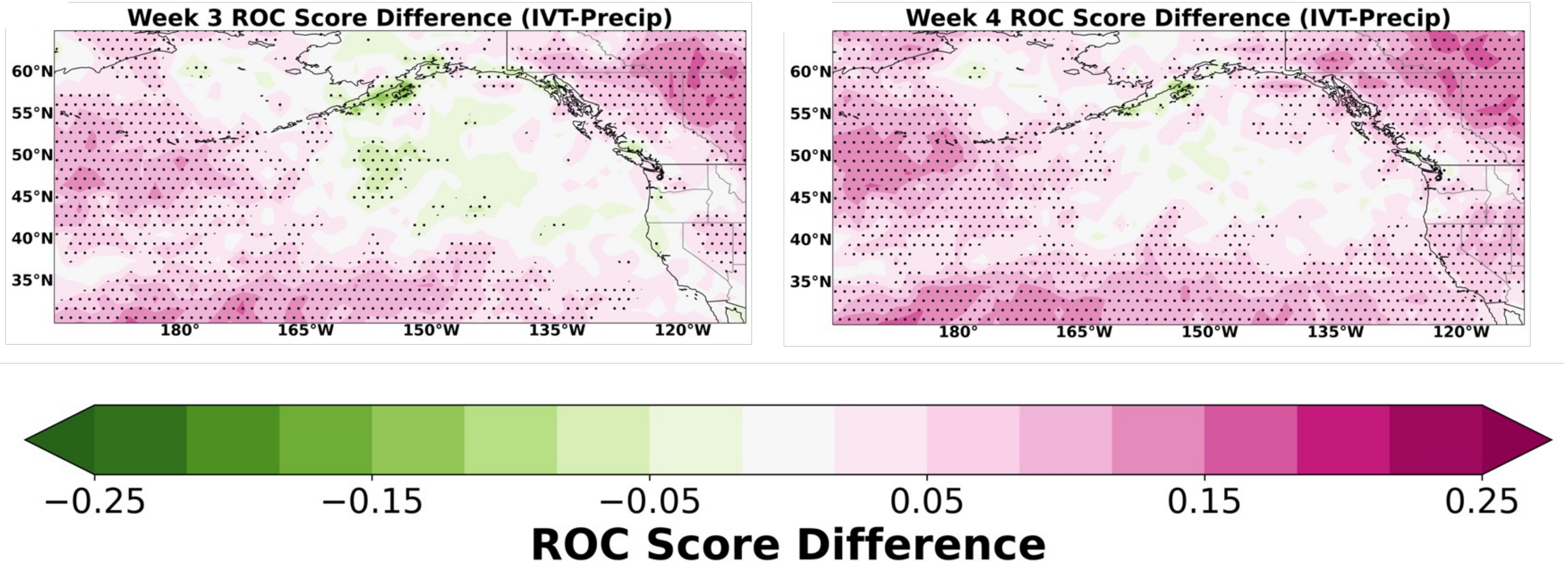
>90th Percentile Jet Exit IVT



Week 3 and 4 ROC Scores



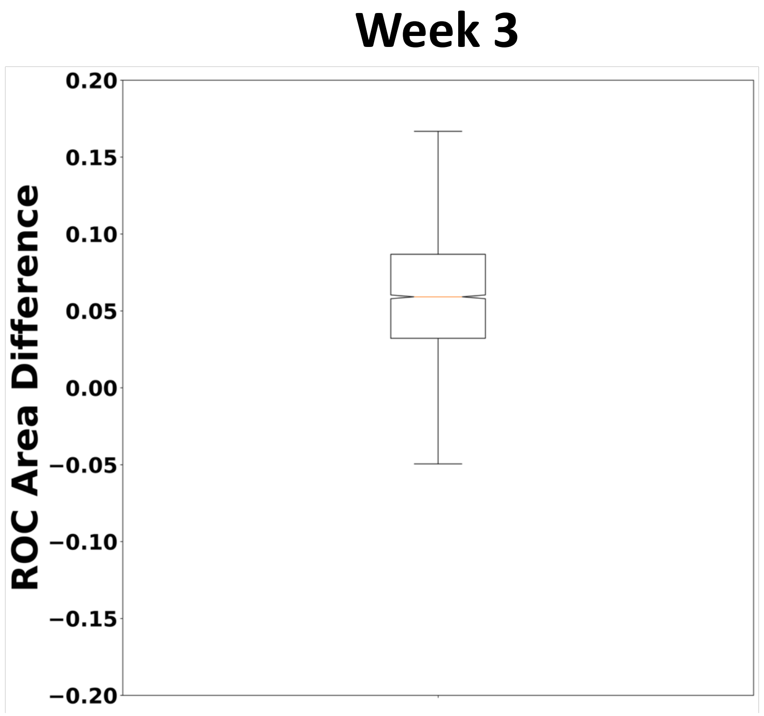
Week 3 and 4 ROC Score Differences

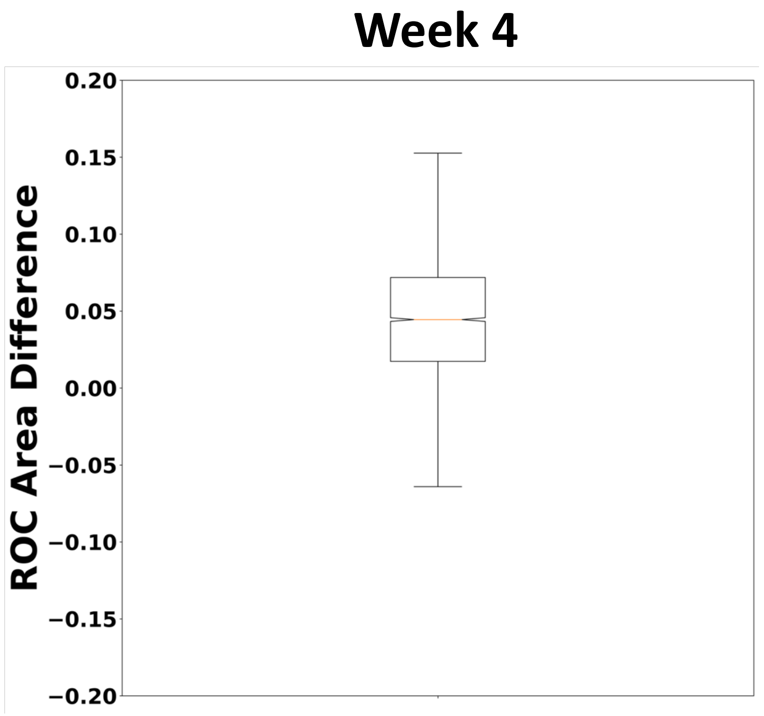


Change in Jet Exit ROC Scores (IVT-Precip)

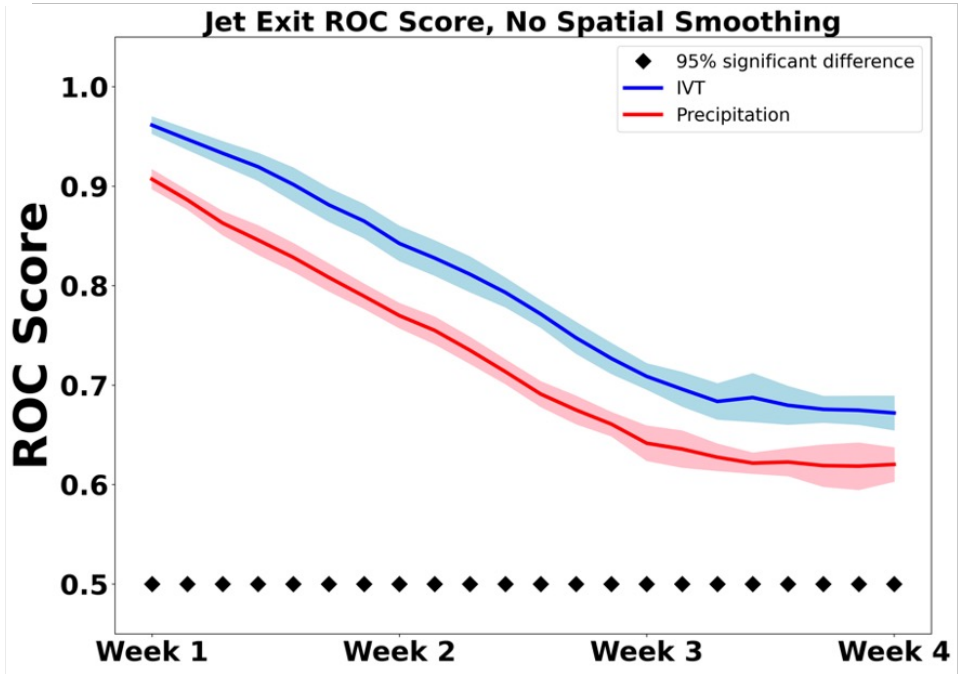
5000 Bootstraps

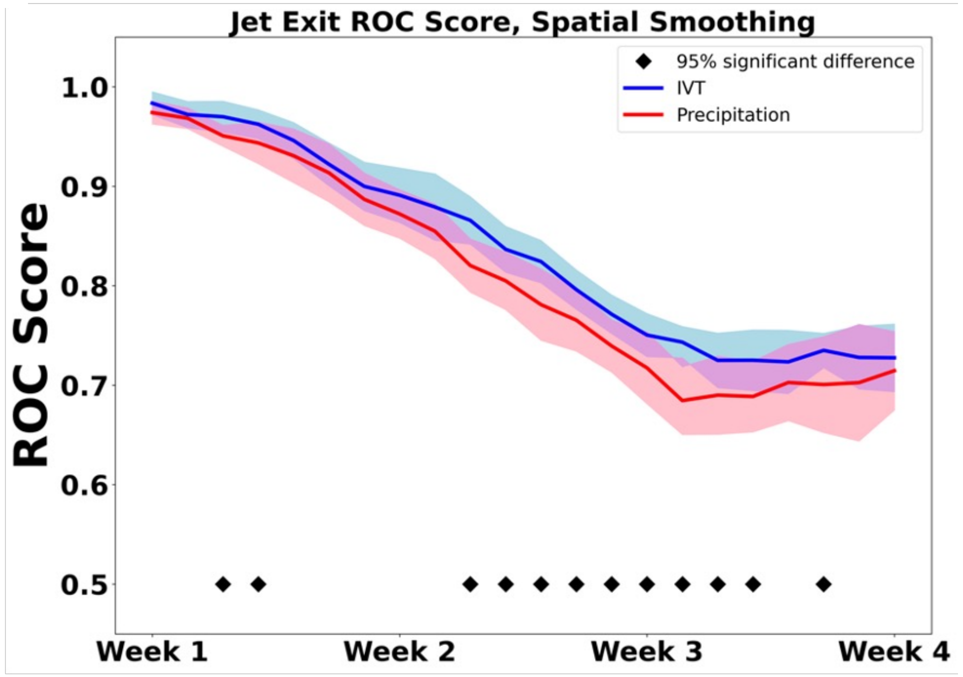
1000 Samples



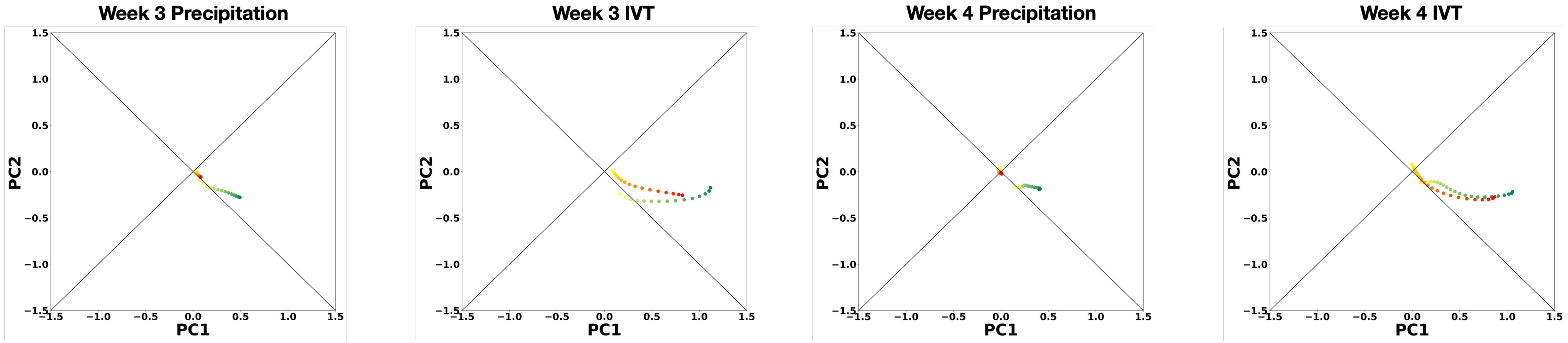


Impact of Smoothing Spatially



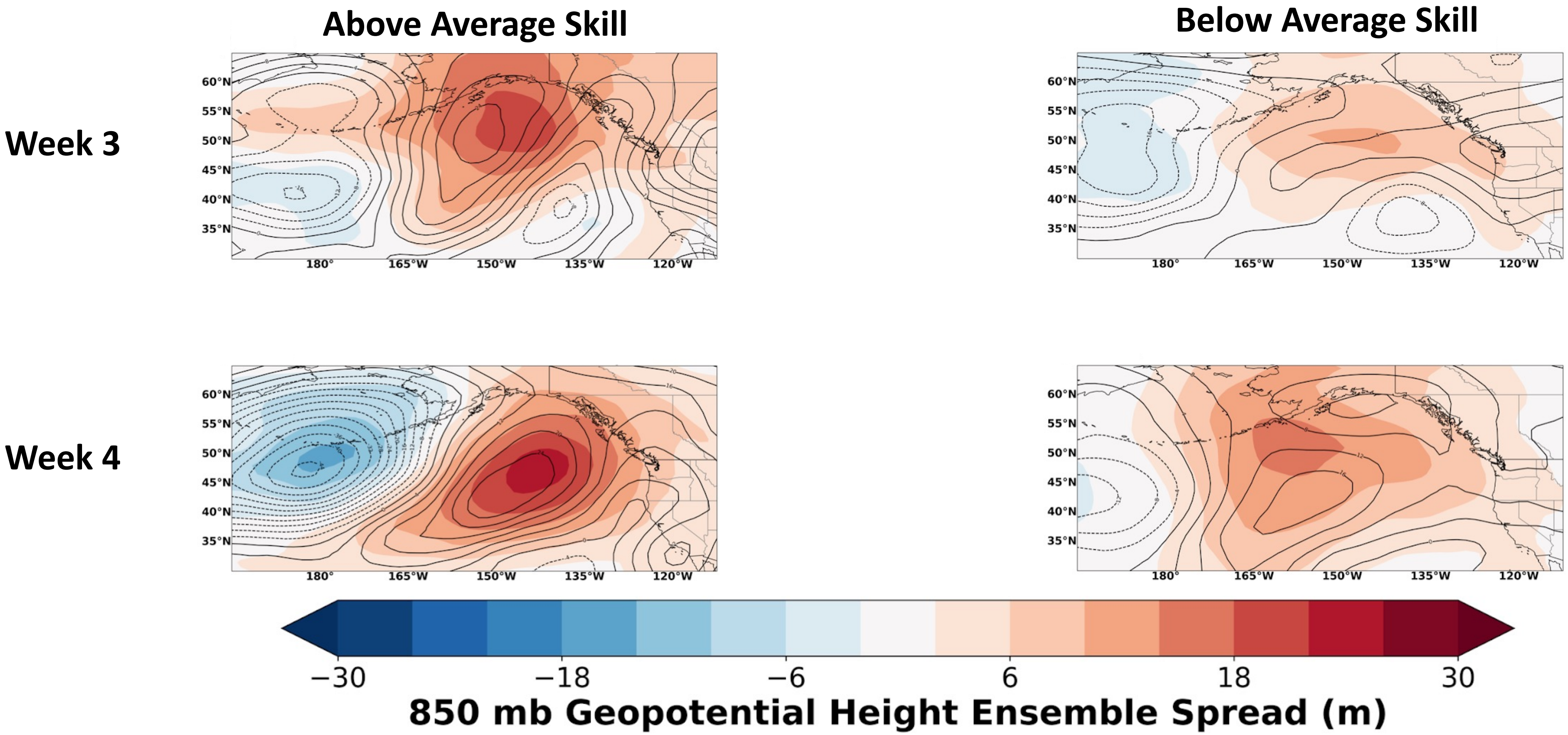


MO NPJ Regimes during *MO* >90th Percentile Conditions



Red = below average skill forecasts
Green = above average skill forecasts
Darker shades = longer lead times

Anomalous Ensemble Spread of 850 mb GPH (shaded) and 300 mb GPH (contours) during *MO* >90th Percentile Jet Exit IVT



Main Conclusions

There is some potential predictability of both >90th percentile IVT and precipitation weeks exists out to week 4 in the jet exit region

IVT generally has more forecast skill than precipitation does over the North Pacific at subseasonal lead times

Local variability cannot fully explain differences in forecast skill

The strength of the NPJ can have a significant impact on the predictability of both IVT and precipitation in the S2S range