Atmospheric Rivers in the Northwestern Pacific: Source Regions and Observation Impact

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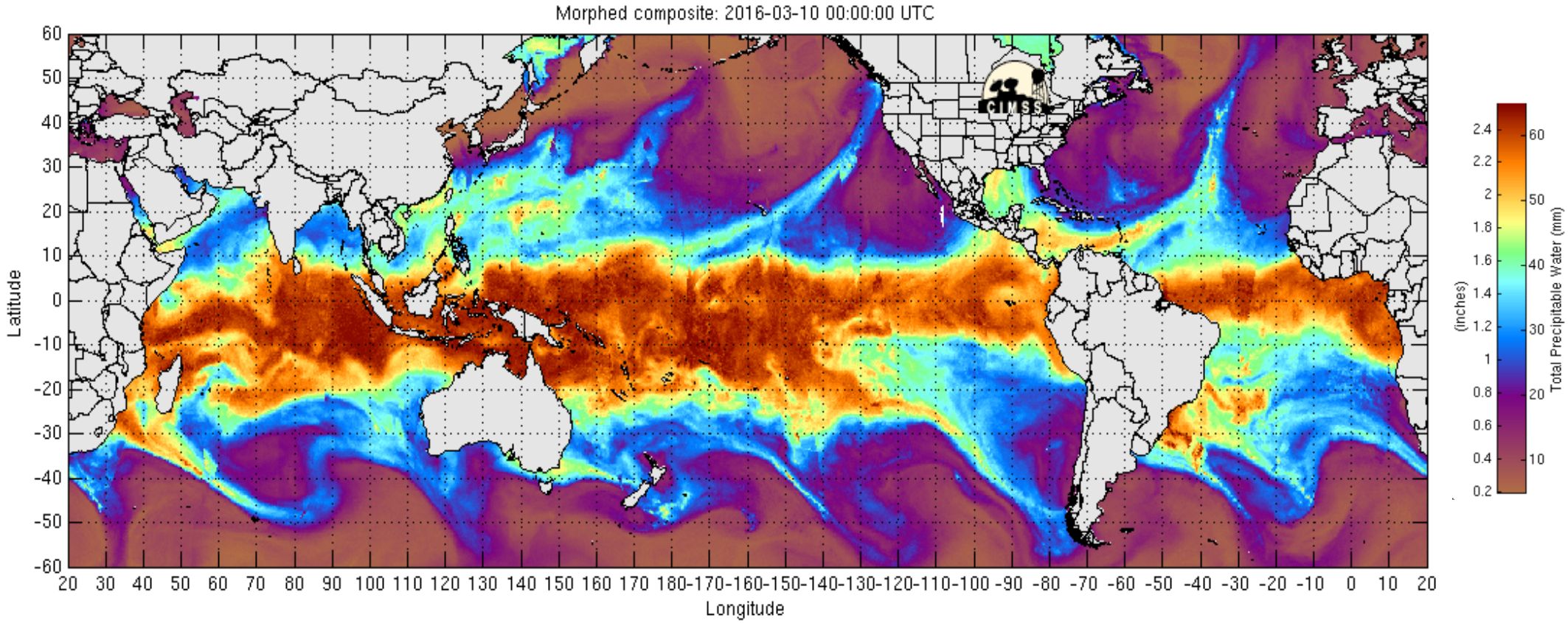
We acknowledge the support of the ONR Study of Air-Sea Fluxes and Atmospheric River Intensity (SAFARI) program and Multiscale Predictability of Atmospheric Rivers and Air-Sea Interaction project

AMS Annual Meeting, New Orleans, LA, 12-16 January 2025

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Background: What are Atmospheric Rivers (ARs)?

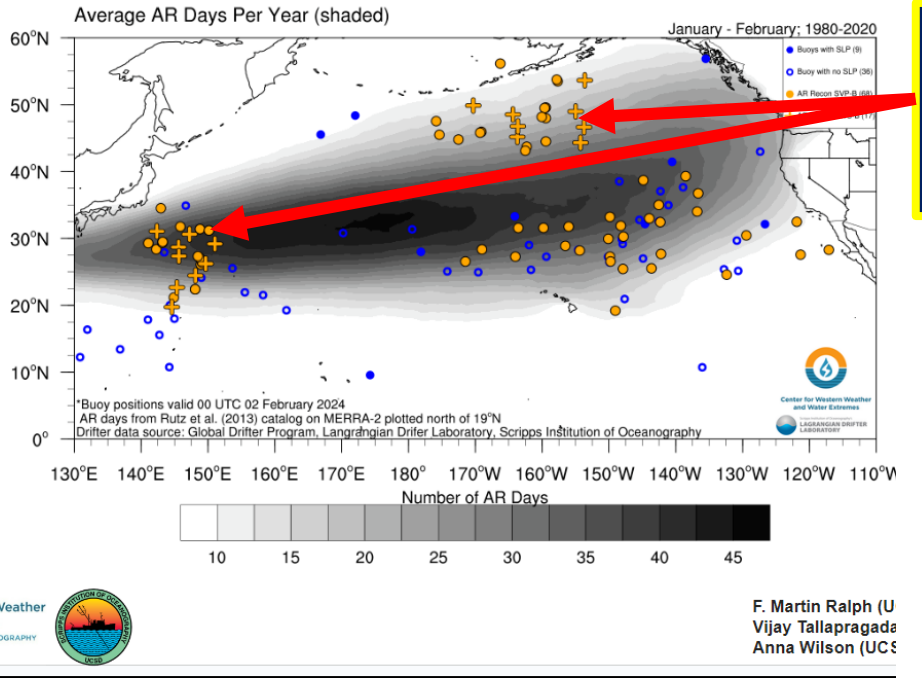
- ARs are long narrow *filaments* of very moist air. Moisture flux comparable to the Amazon (160 million kg/sec, Zhu and Newell 1998).
- Responsible for 95% of horizontal water vapor transport outside the tropics (only a few % of area): Key component of the global hydrological cycle, associated with beneficial impacts as well as hazards.



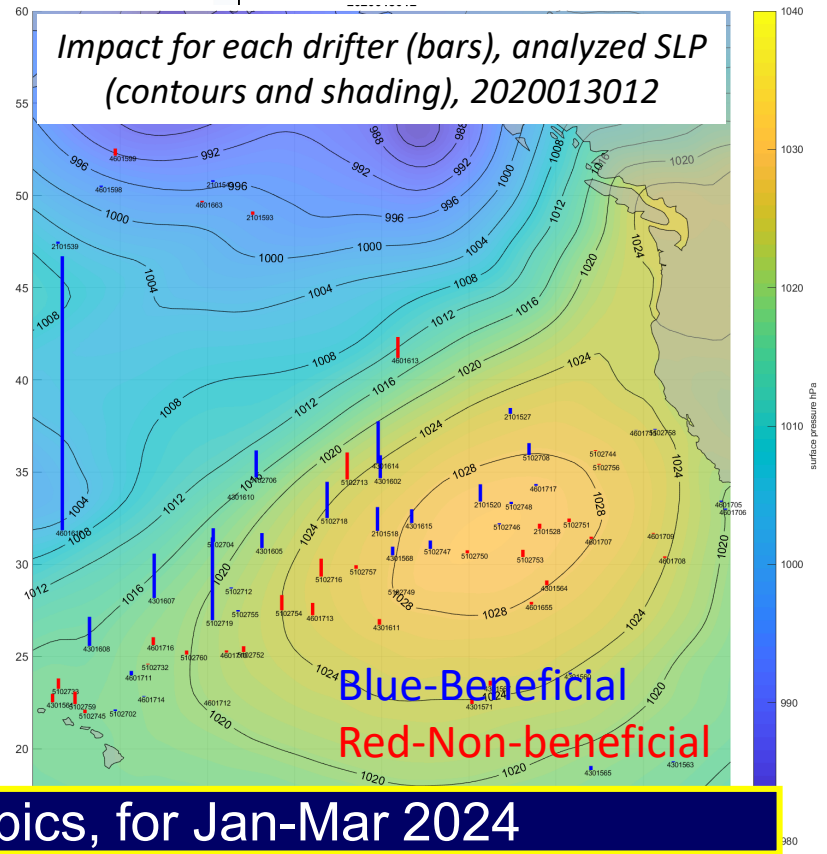
72-h morphed integrated microwave imagery of total precipitable water
Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison

AR RECON Deployed Buoys in EPAC and WPAC in 2024

AR Reconnaissance: Multi-organizational effort (led by CW3E) started in 2016 to take targeted observations (including dropsondes and drifting buoys) to improve forecasting of west-coast ARs and for basic & applied research



In 2024, AR RECON deployed drifters in WPAC out of Guam in addition to EPAC south of Alaska.



Previous Research: Surface pressure ob impact from Eastern Pacific drifting buoys in 2020 (*Reynolds et al., 2023, https://doi.org/10.1175/MWR-D-22-0124.1*) : Used adjoint-based ob impact and DA statistics from the NAVy Global Environmental Model (NAVGEM) to determine:

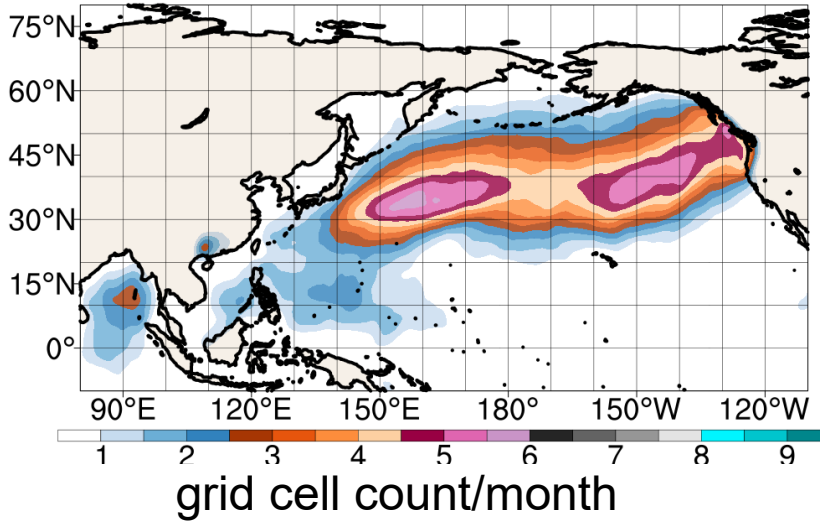
- Drifter obs most impactful when under high IVT, low pressures, large pressure gradients, relatively isolated
- NAVGEM low bias in subtropical high, leading to non-beneficial ob impact
- Obs of lower pressures are most beneficial later in DA window

This study – Extend analysis to entire N. Pacific, including tropics, for Jan-Mar 2024

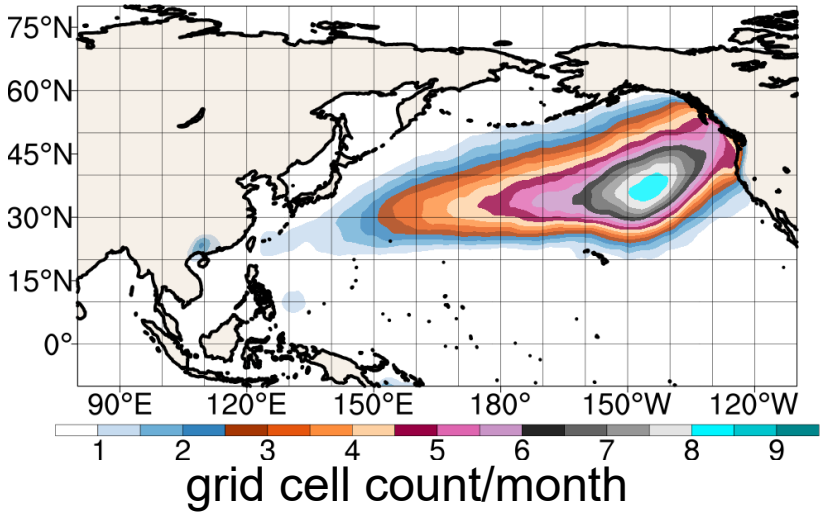
Climatology of ARs

Atmospheric River Frequency (1998-2022)
ERA5 meridional component of IVT ≥ 250 kg m^{-1} s^{-1}

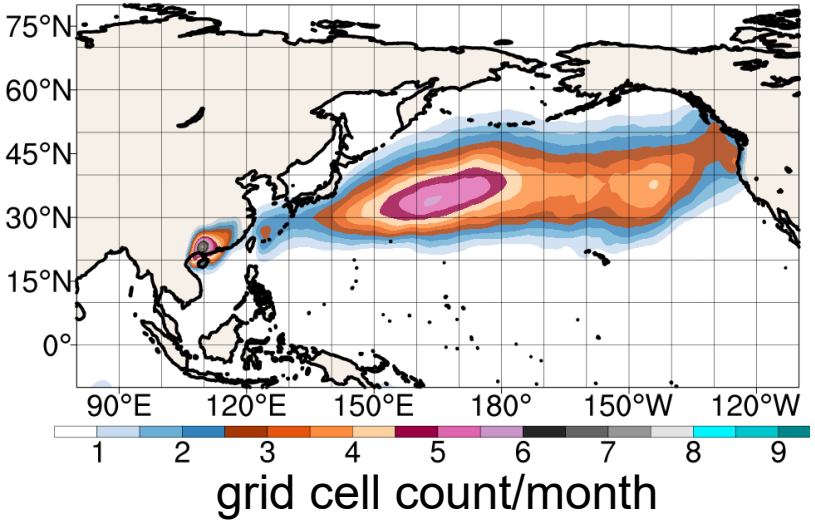
a) November



b) January

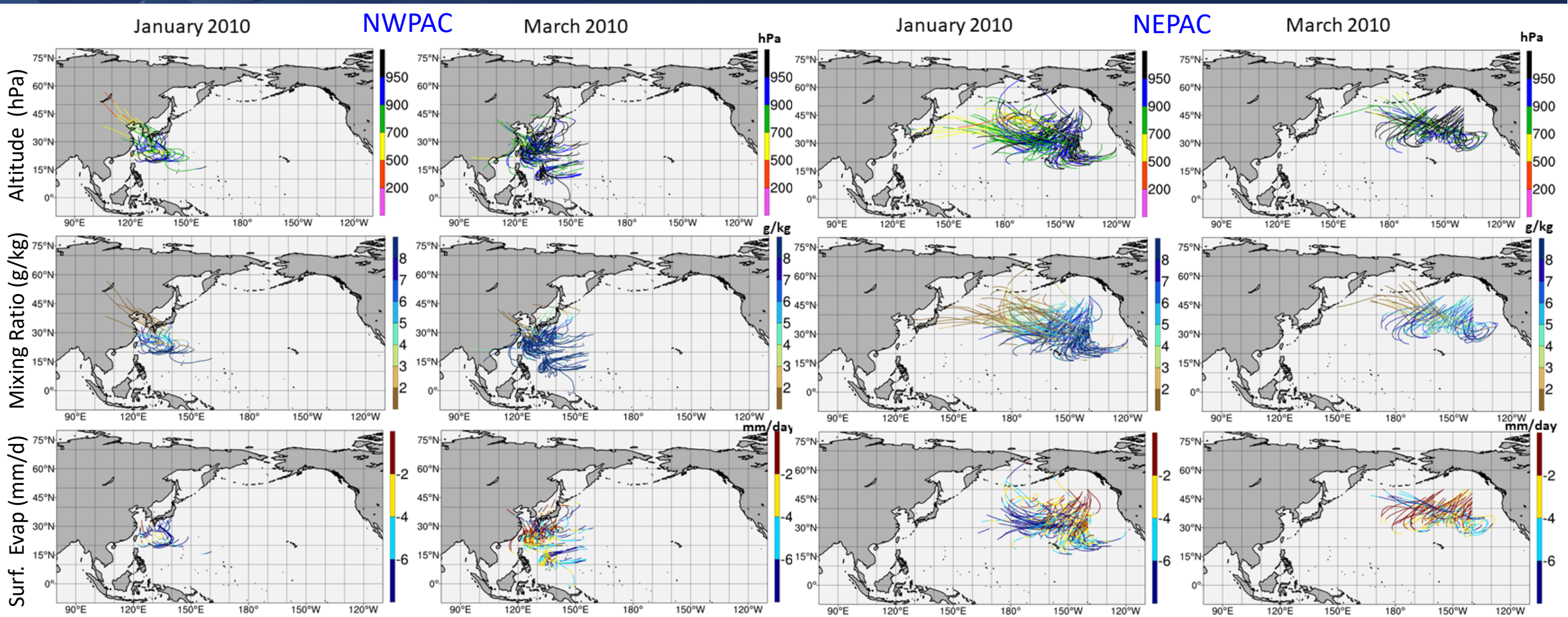


c) March



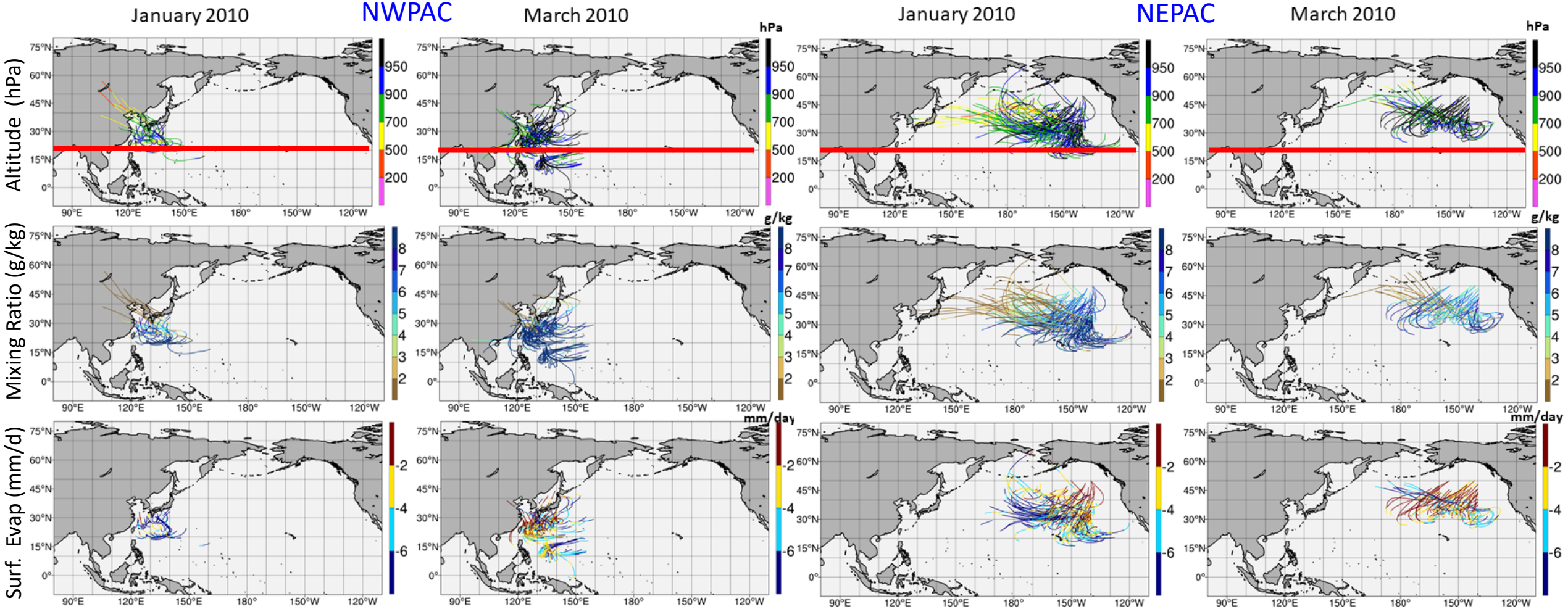
- In November, two maxima are apparent in the W. and E. Pacific basins
- In January, AR frequencies increase, with a max from the C. Pacific to the N. American coast
- AR frequencies decrease and shift westward in February-March
- Use trajectory analysis to identify how source regions shift as a function of region and time of year

AR Trajectory Analysis for Different Longitude Bands



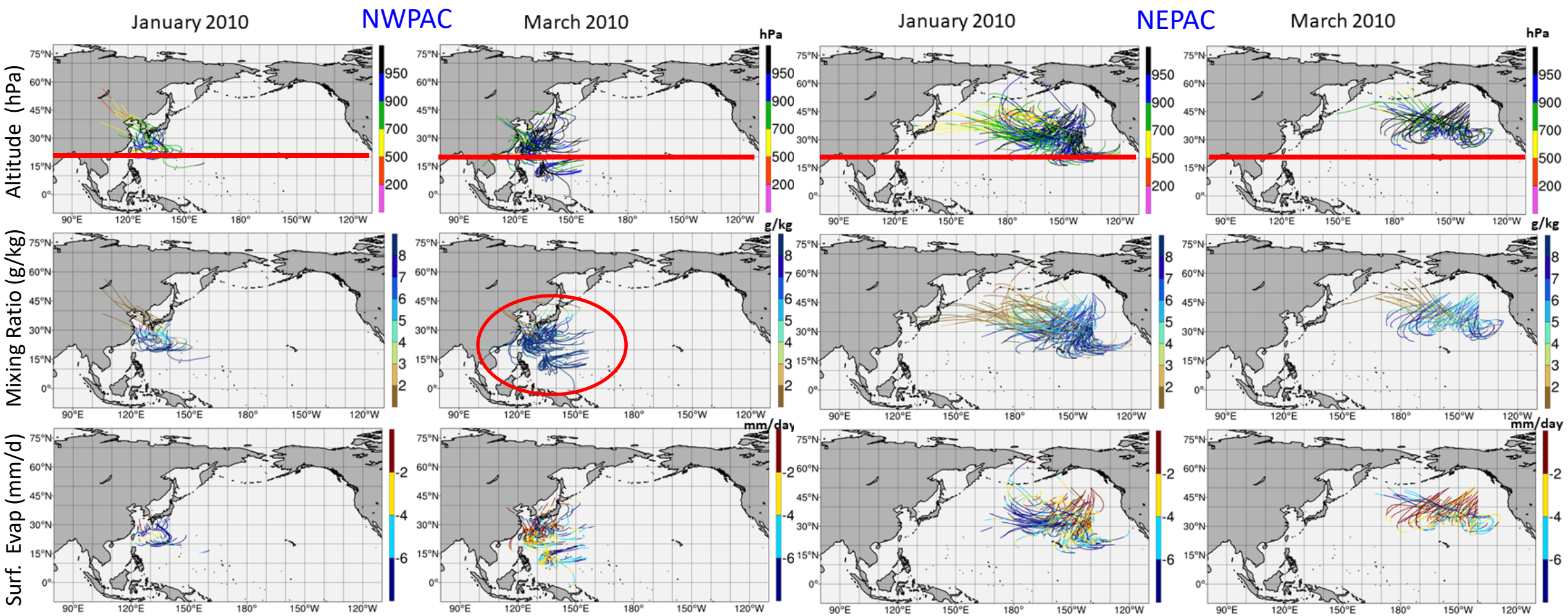
- 3-day back trajectories launched from max. meridional IVT between 12-50°N & 120-140°E (left) & 140-160°W (right)

AR Trajectory Analysis for Different Longitude Bands



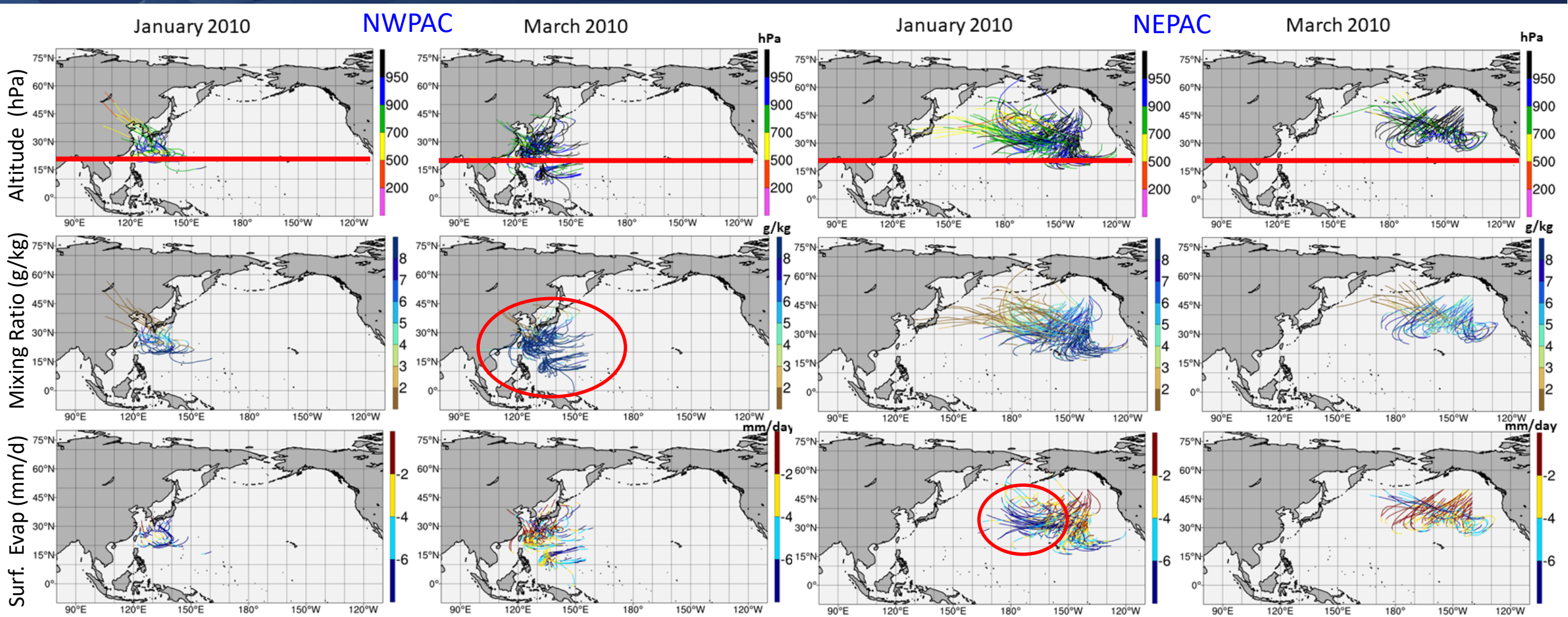
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- Trajectories extend to lower latitudes in WPAC compared to EPAC, especially in March

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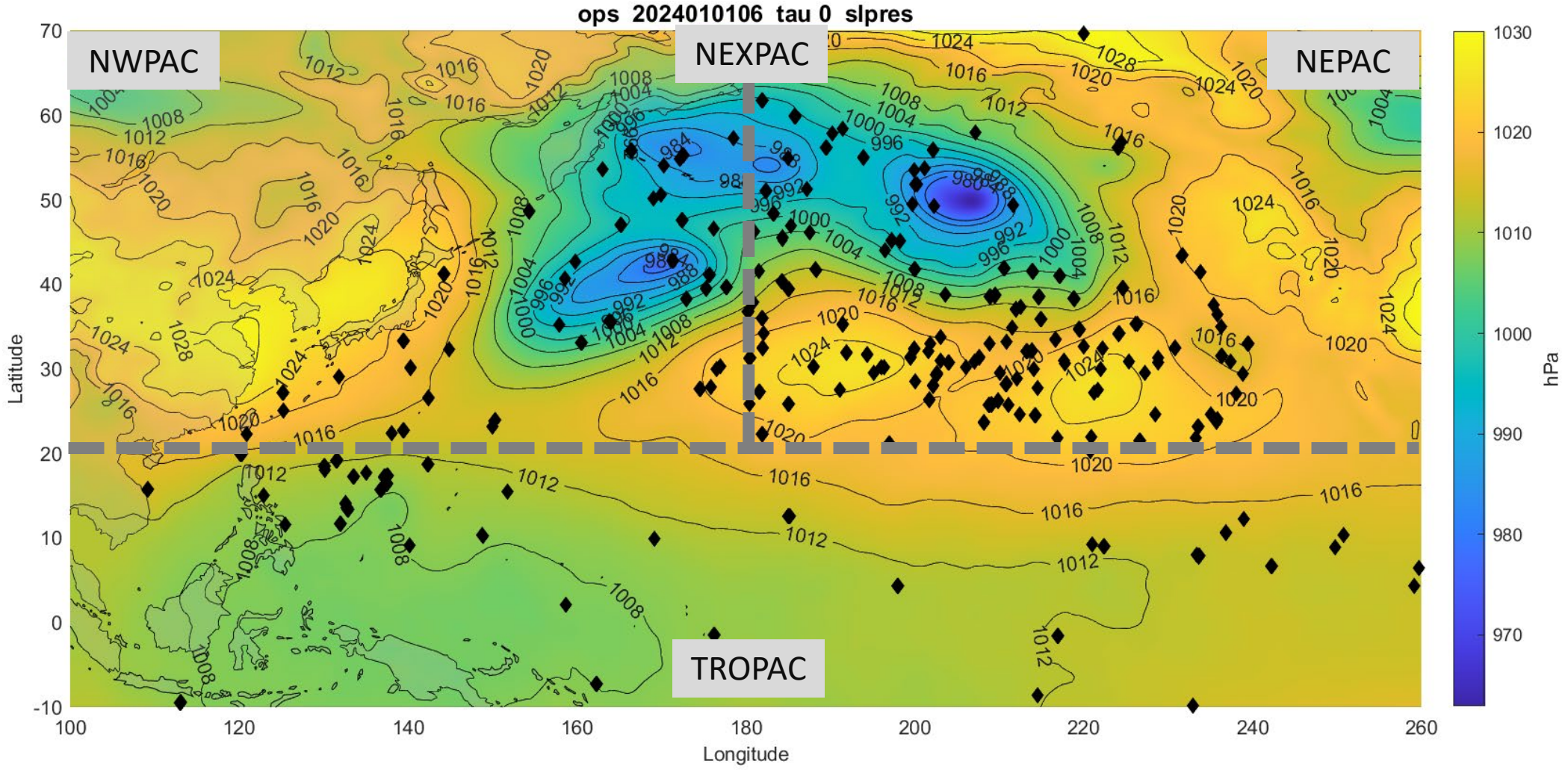
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- Moisture (mixing ratio) largest in WPAC in March (region of AR drifters deployed out of Guam)

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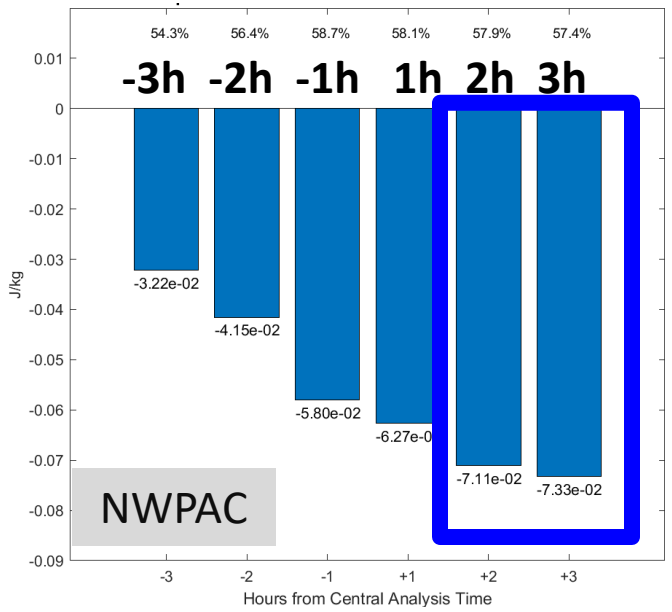
- 3-day back trajectories launched from max. meridional IVT between 12-50°N & 120-140°E (left) & 140-160°W (right)
- Trajectories extend to lower latitudes in WPAC compared to EPAC, especially in March
- Moisture (mixing ratio) largest in WPAC in March (region of AR drifters deployed out of Guam)
- Surface evaporation magnitude (for trajectories below 1 km) greatest in the C. Pacific in January

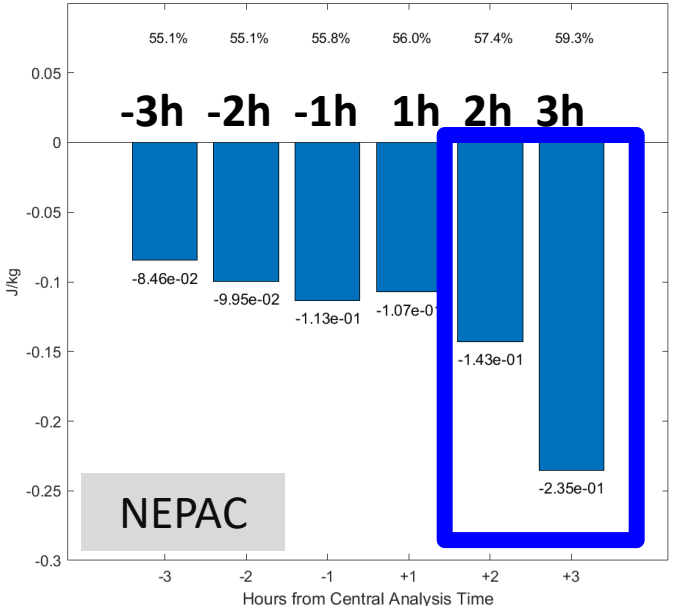
Drifter Regions



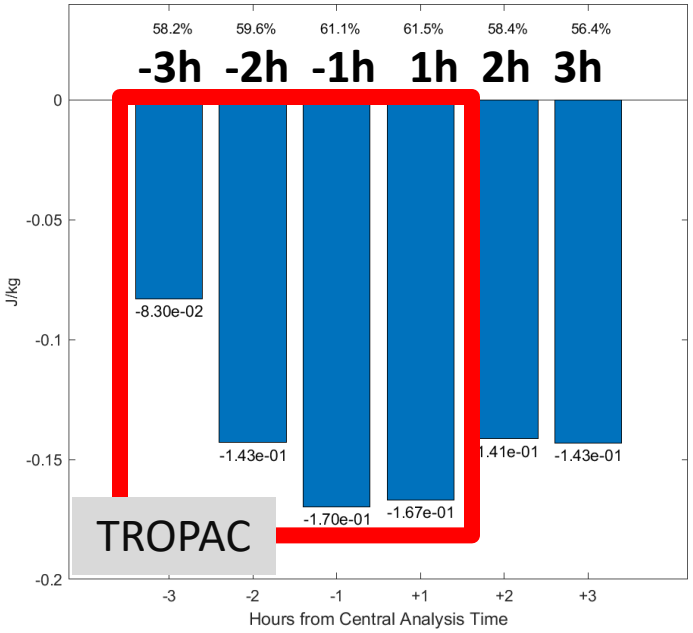
Separate drifter (black diamond) ob impact by region and by SLP (shaded); SLP gradient, IVT, and time within DA window

Ob Impact as a Function of Time in DA Window





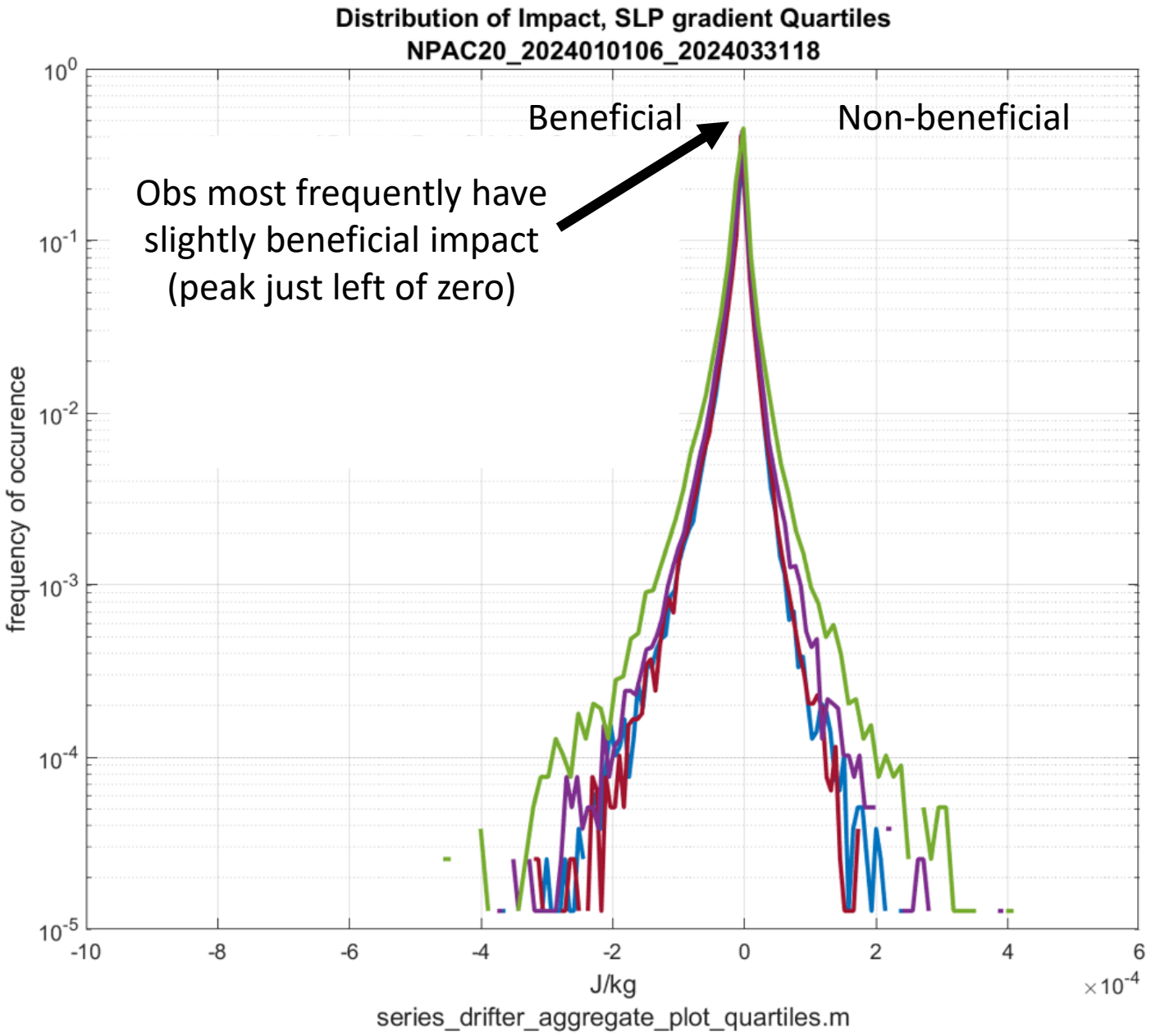
In both NWPAC and NEPAC, most benefit, on average, come from obs taken later in the DA cycle (similar to previous studies)



In TROPAC, obs in first hour still least beneficial, but average benefit similar for hours after that

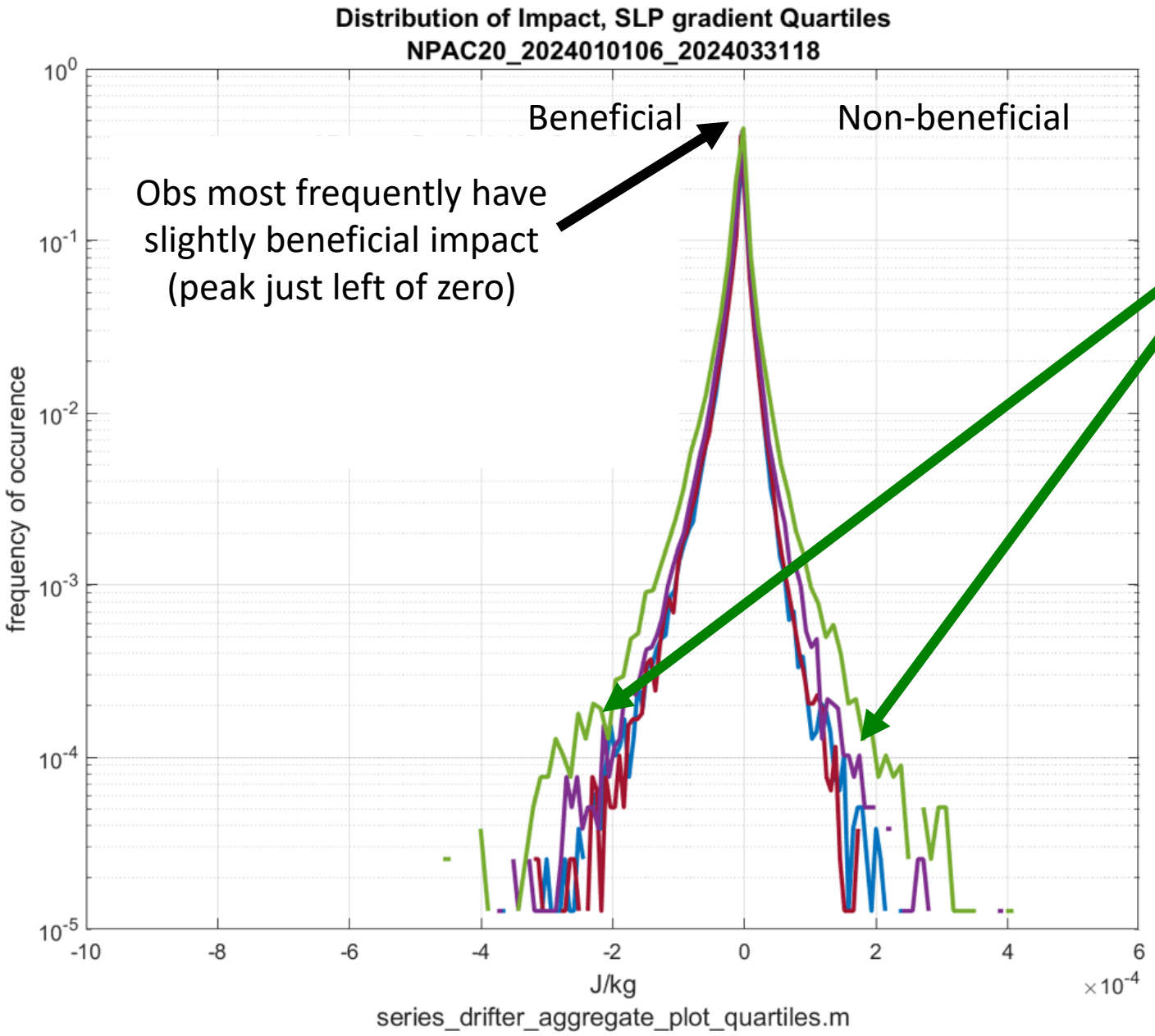
Reason for difference between tropics and extratropics subject for future work (related to adjoint covariance evolution in 4DVAR? Model bias?)

Ob Impact as a Function of Pressure Gradient: NEXPAC



impact distr for lowest quartile SLP gradient values
impact distr for second quartile SLP gradient values
impact distr for third quartile SLP gradient values
impact distr for top quartile SLP gradient values

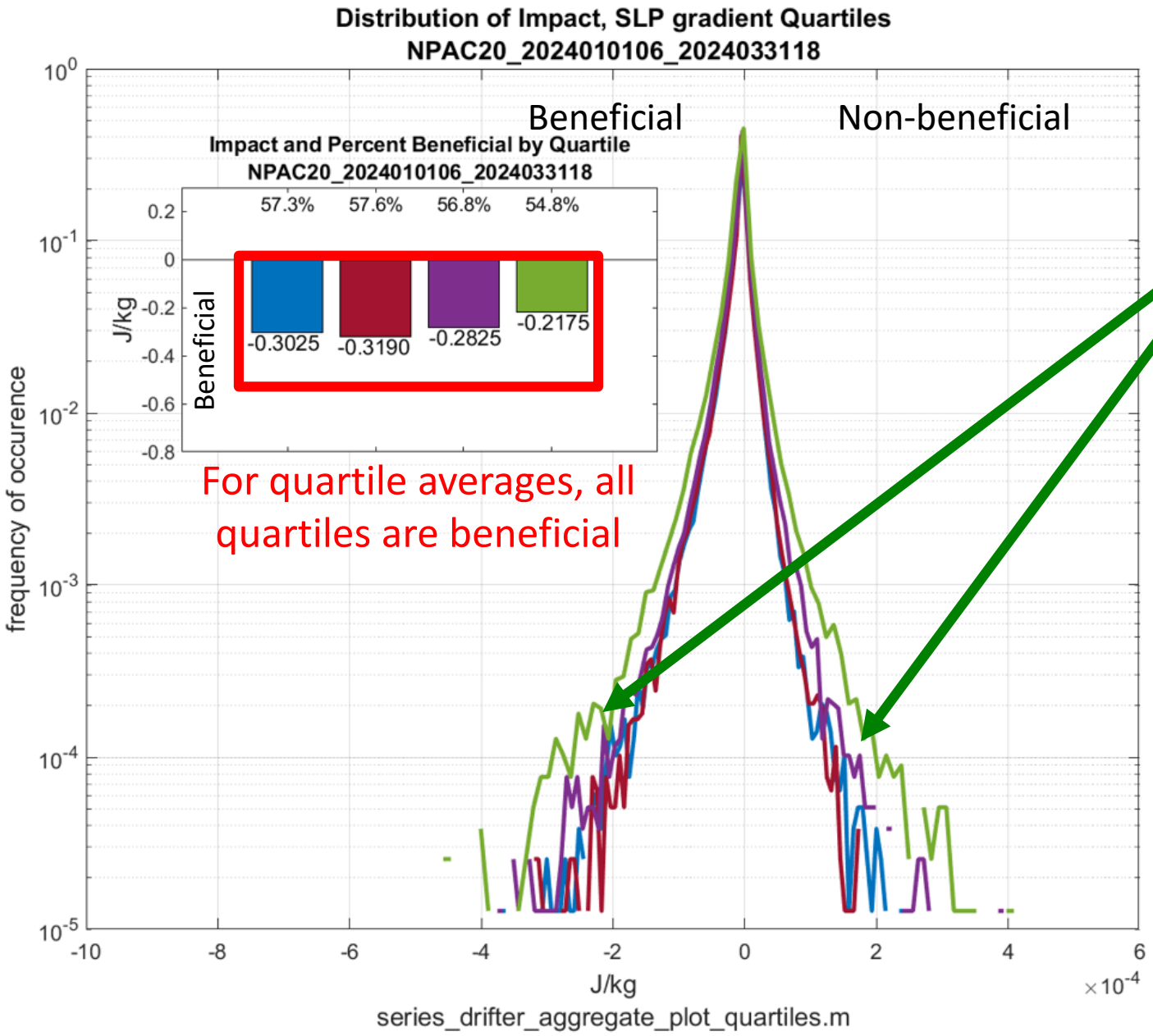
Ob Impact as a Function of Pressure Gradient: NEXPAC



Obs taken under strongest pressure gradient (highest quartile, in green), have the largest *magnitude* impact (both beneficial and non-beneficial)

- impact distr for lowest quartile SLP gradient values
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Ob Impact as a Function of Pressure Gradient: NEXPAC



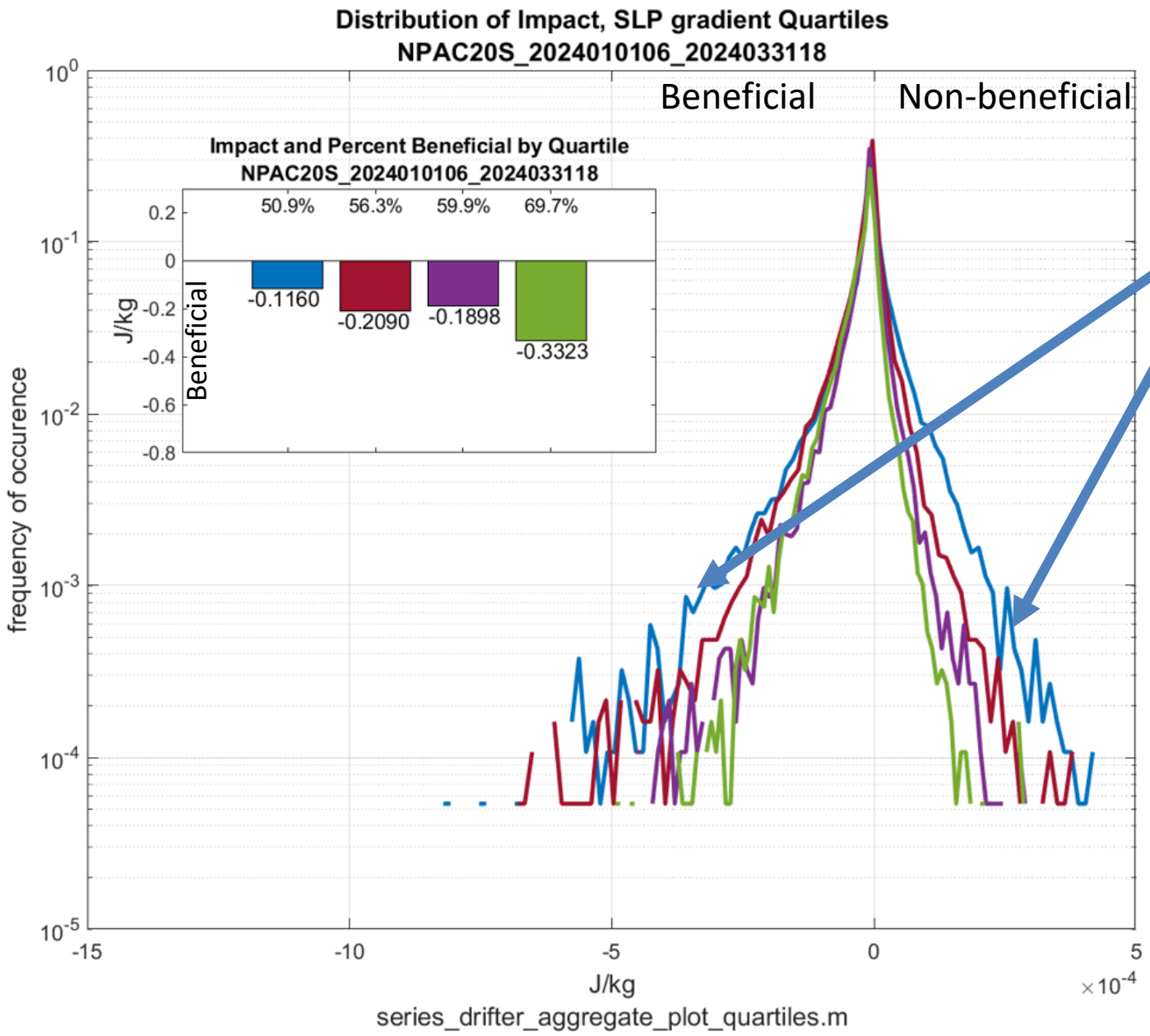
For quartile averages, all quartiles are beneficial

Obs taken under strongest pressure gradient (highest quartile, in green), have the largest *magnitude* impact (both beneficial and non-beneficial)

In NEXPAC, obs in *strong* pressure gradient regions have largest magnitude impact, similar to previous study, but all quartiles have beneficial average impact

- impact distr for lowest quartile SLP gradient values
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Ob Impact as a Function of Pressure Gradient: TROPAC

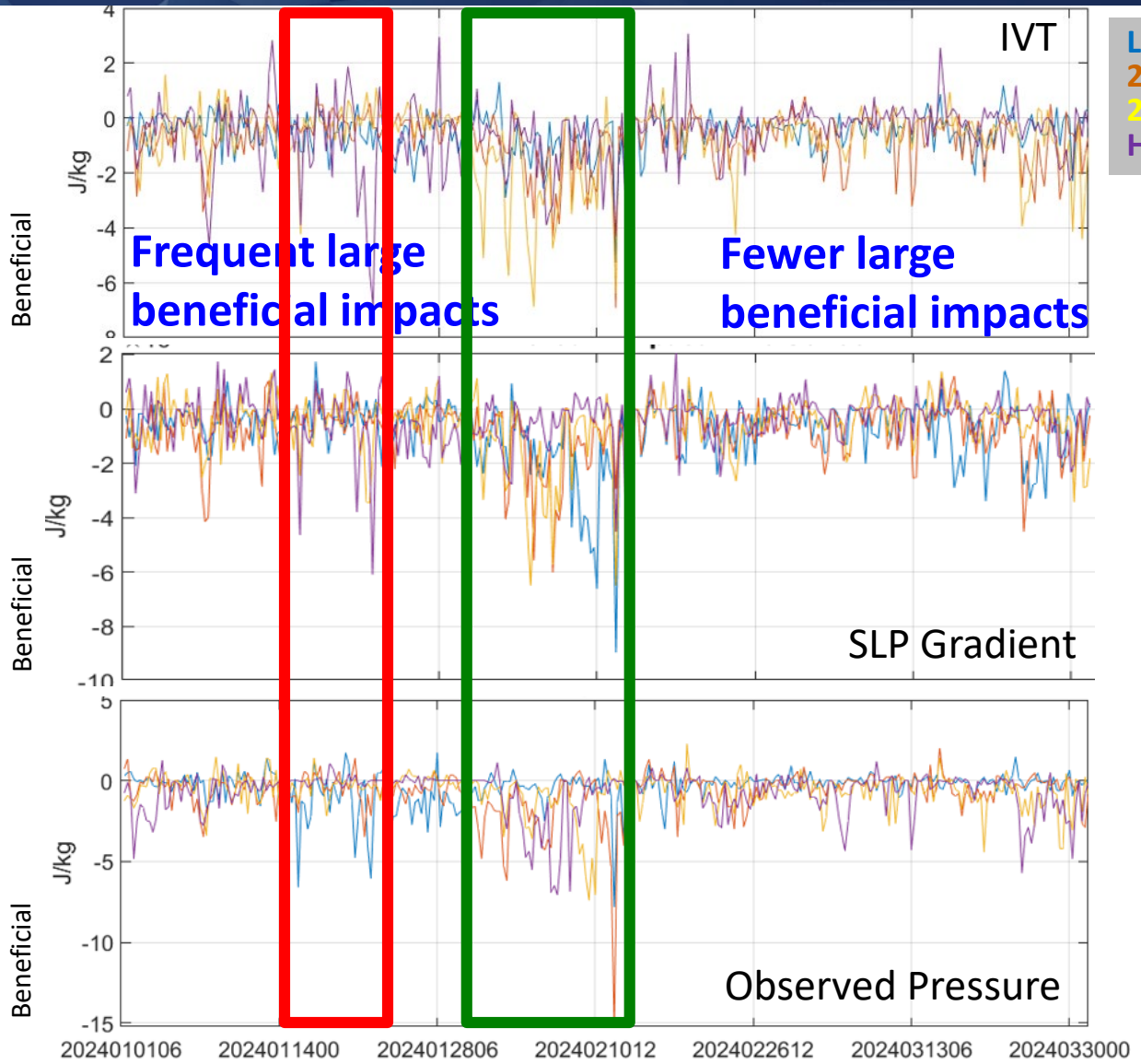


Obs taken in weakest pressure gradient (lowest quartile, in blue), have the largest *magnitude* impact (both beneficial and non-beneficial)

In TROPAC, obs in *weak* pressure gradient regions have largest magnitude impact – next step, examine case studies to link impact to processes

- impact distr for lowest quartile SLP gradient values
- impact distr for second quartile SLP gradient values
- impact distr for third quartile SLP gradient values
- impact distr for top quartile SLP gradient values

Ob Impact Varies on Many Timescales: NEPAC



Lowest Quartile
2nd Lowest Quartile
2nd Highest Quartile
Highest Quartile

Large beneficial impacts more frequent in January and early February than in late February or March

Benefits coming from obs under high IVT, in strong pressure gradients, and from low pressures

Benefits coming from obs under moderate IVT, weak to moderate pressure gradients, and moderate to high pressures

Next step – look at case studies

ARs in the Northwestern Pacific: Source Regions and Ob Impact

Summary

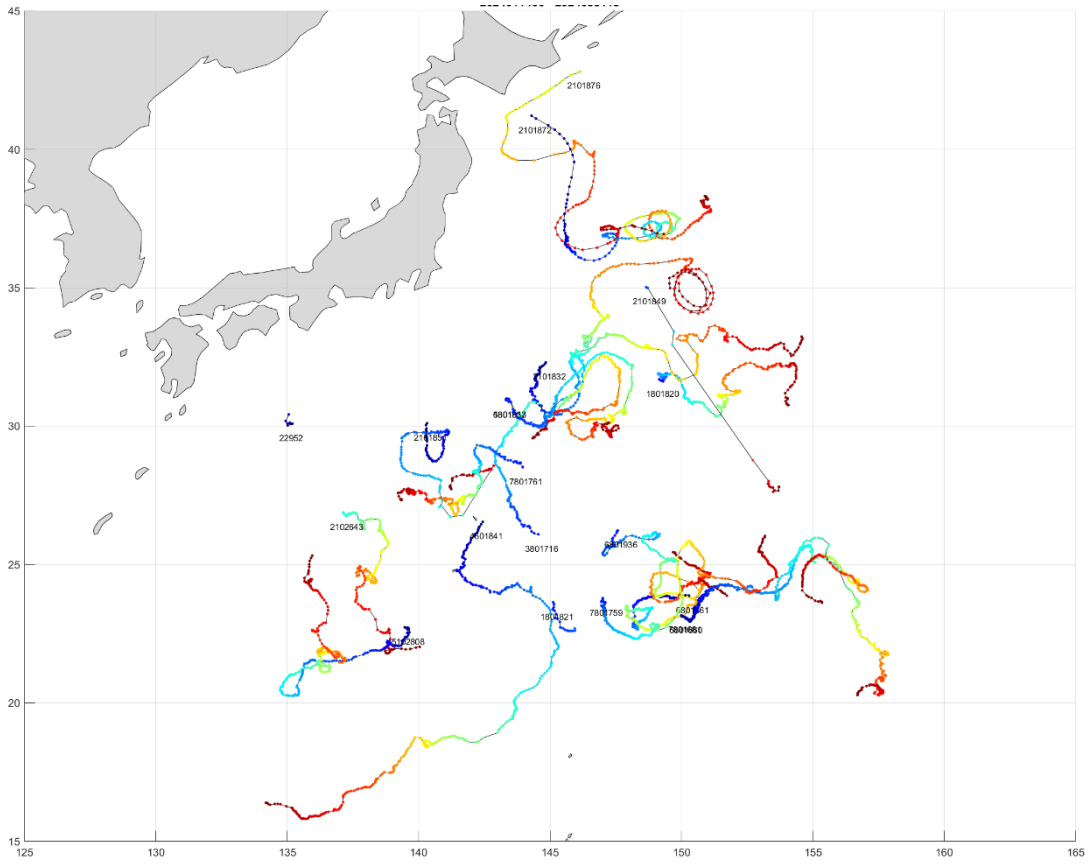
- AR trajectory characteristics modulated by month and longitude band
  - AR Recon drifters deployed from Guam in source region for WPAC ARs in March
- Drifter ob impact varies by region and time period
  - Largest impact comes in strongest pressure gradients in extratropics, but from weakest pressure gradients in tropics
  - In both tropics and extratropics, largest magnitude impact from obs under highest IVT and lowest surface pressures (extra slides)
  - Ob impact magnitude more sensitive to IVT in NEPAC and to pressure gradient in NWPAC (extra slides)
  - Large case-to-case and month-to-month variability in ob impact

Future Work

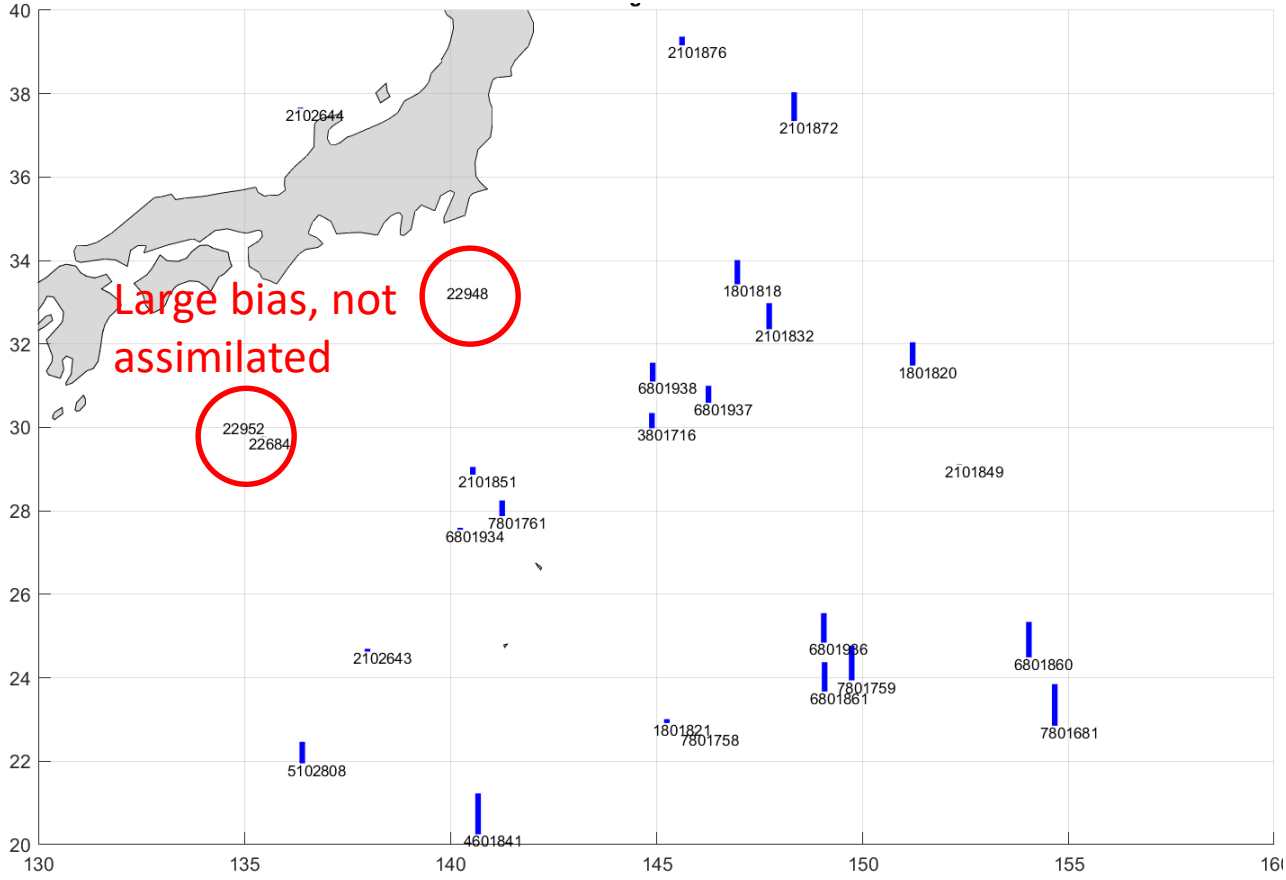
Consider case studies and relate AR trajectory analysis to surface fluxes and ob impact

Drifters N. of Guam

Drifter Location from 20240114 (blue) to 20240331 (red)



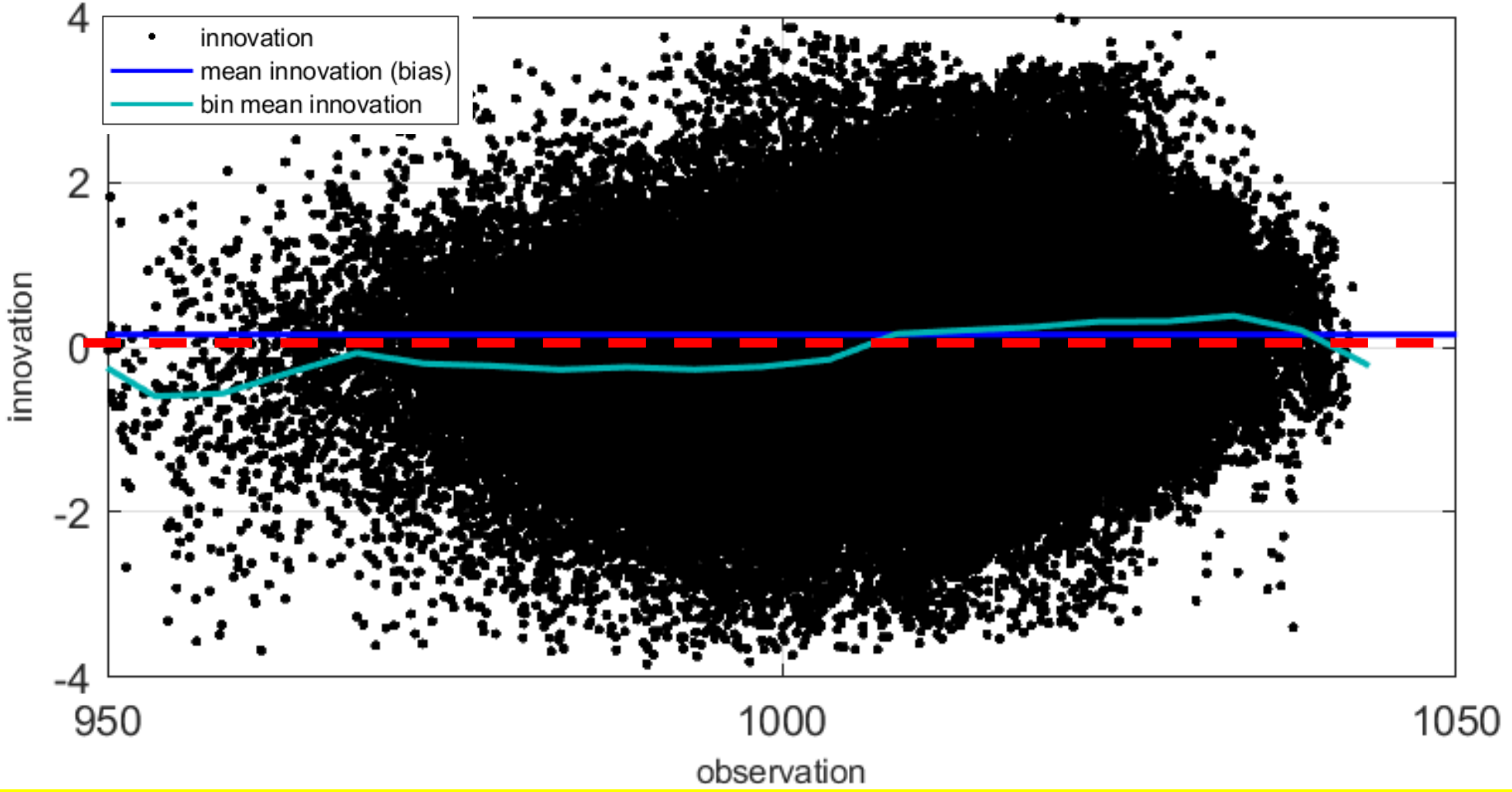
Cumulative Drifter Impact (blue-beneficial)



- AR Recon WPAC drifters in source region for WPAC ARs, particularly in March
- A few drifters (not AR Recon drifters) had large biases and were not assimilated
- All other drifters had cumulative beneficial impact (blue bars)

Using DA statistics to Examine Model Biases

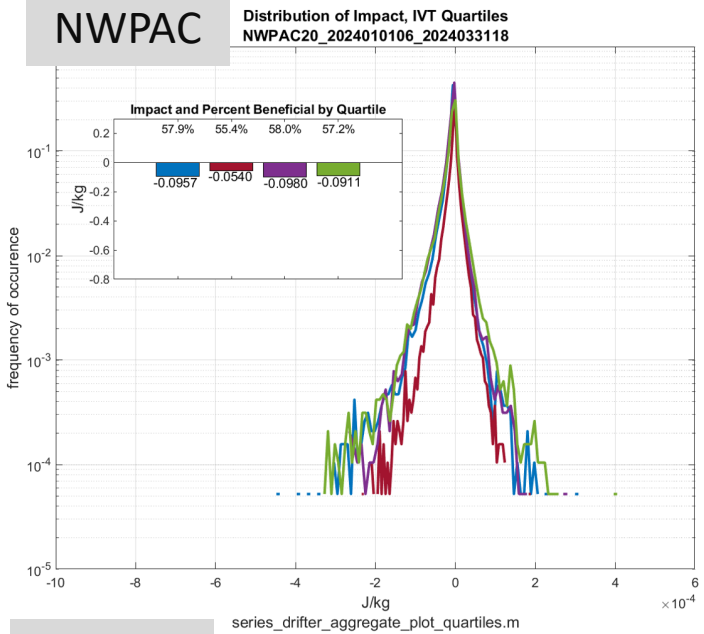
Innovation (Obs – background) vs Observation



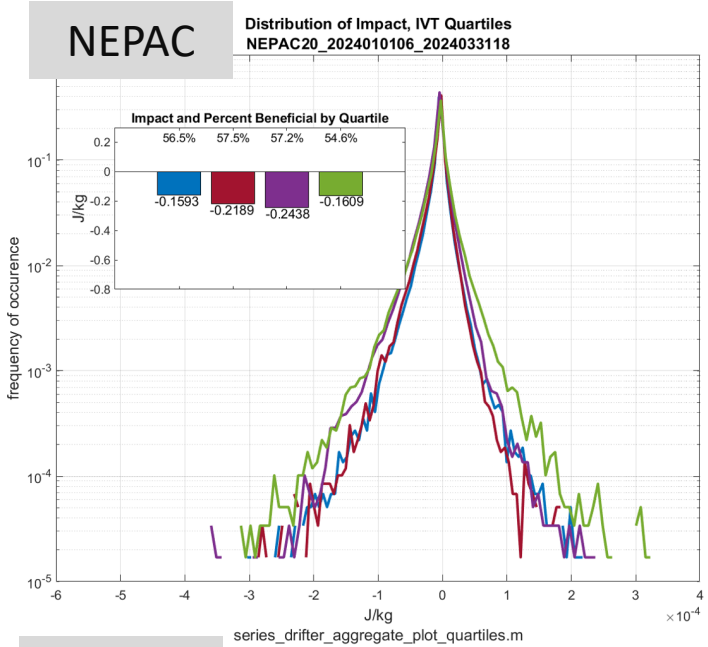
Low bias at high pressures and high bias at low pressures. Lowest pressure observations may be associated with tropical cyclones

Extra Slide: Impact Distributions by IVT quartile

NWPAC

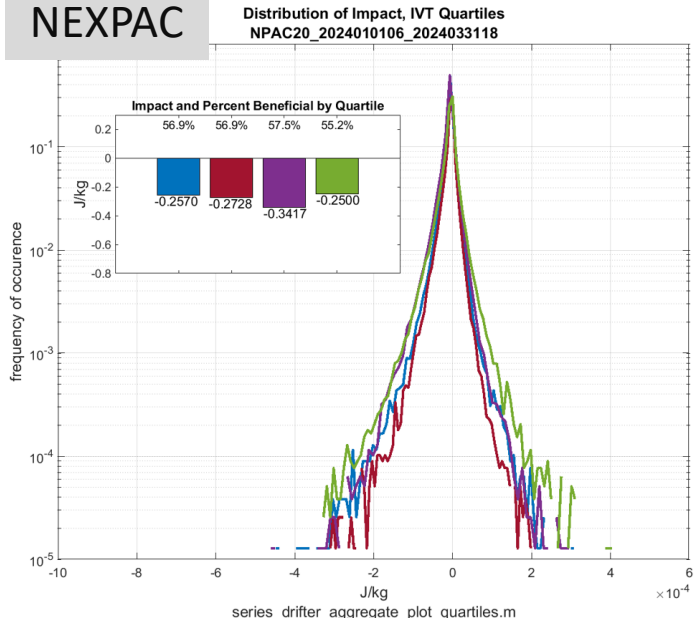


NEPAC

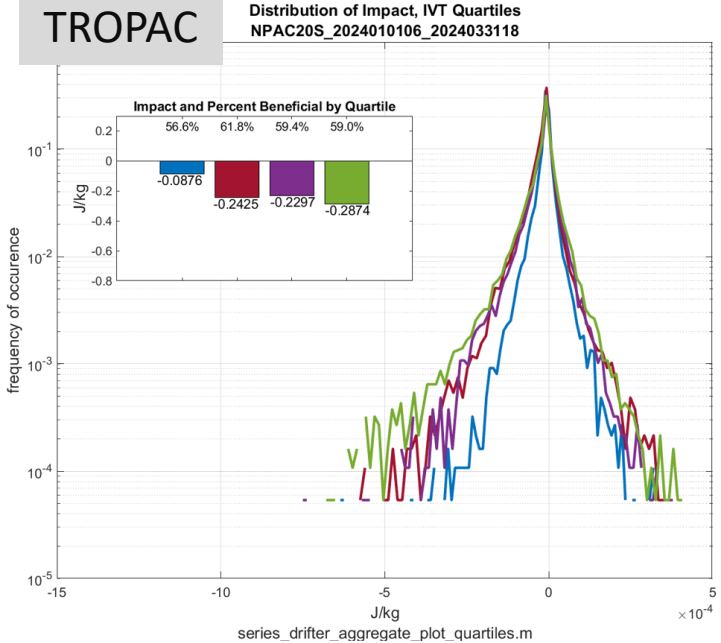


impact distr for lowest quartile IVT values
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NEXPAC

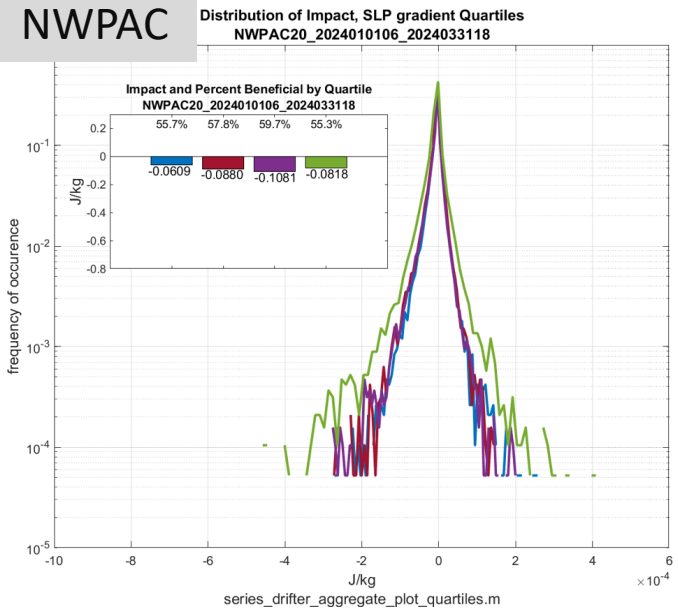


TROPAC

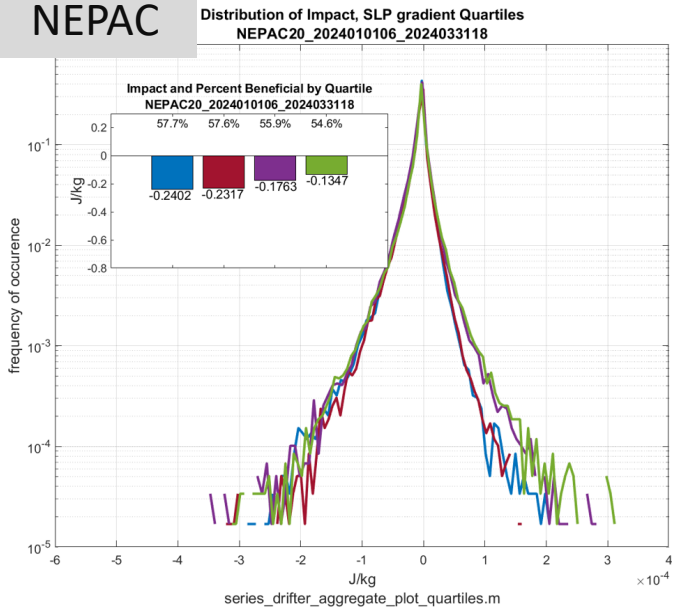


Extra Slide: Impact Distributions by SLP Gradient Quartile

NWPAC

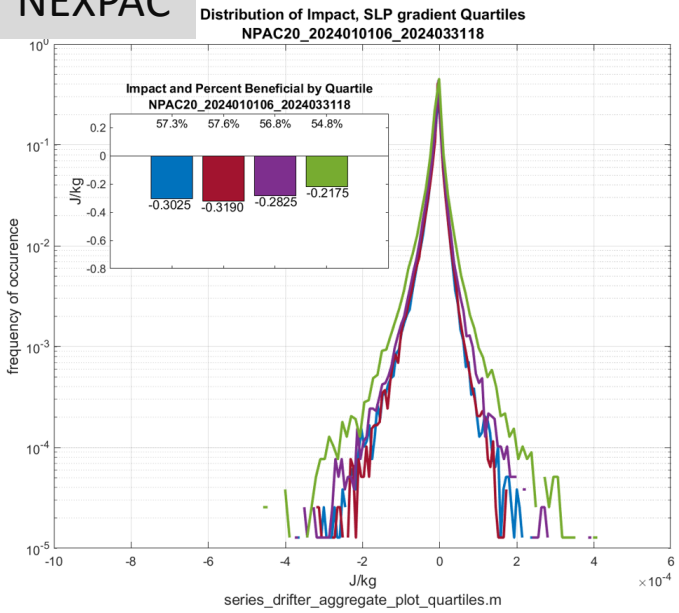


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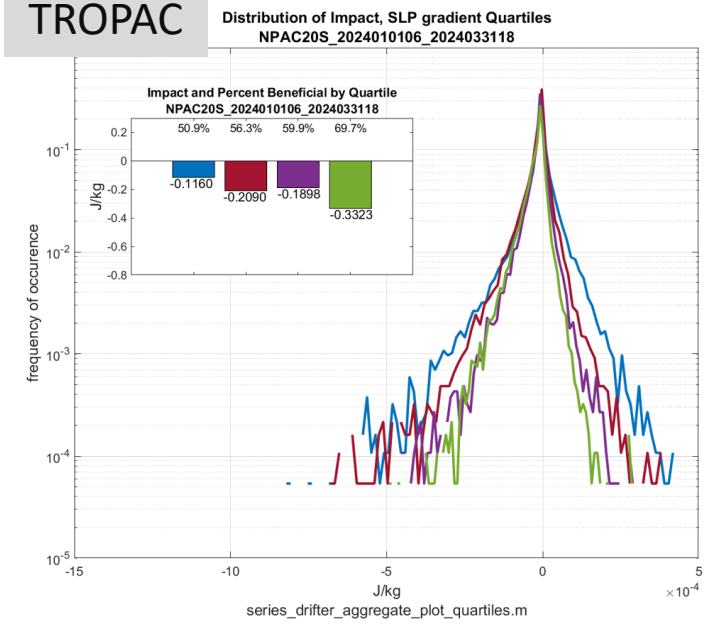


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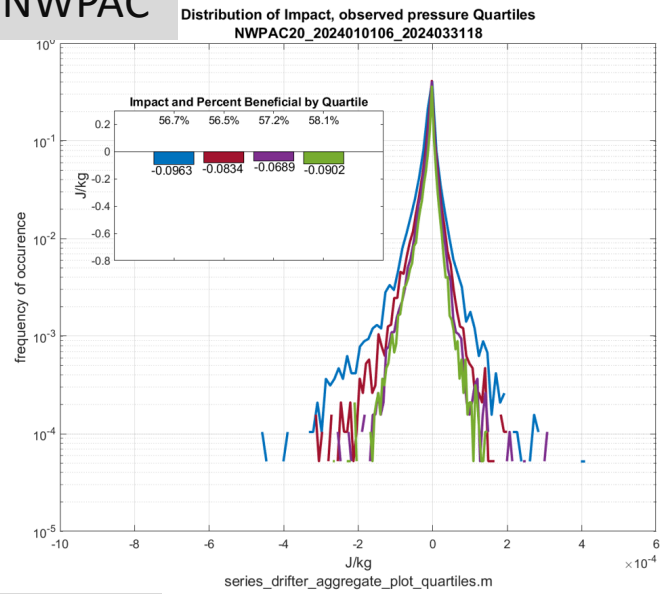


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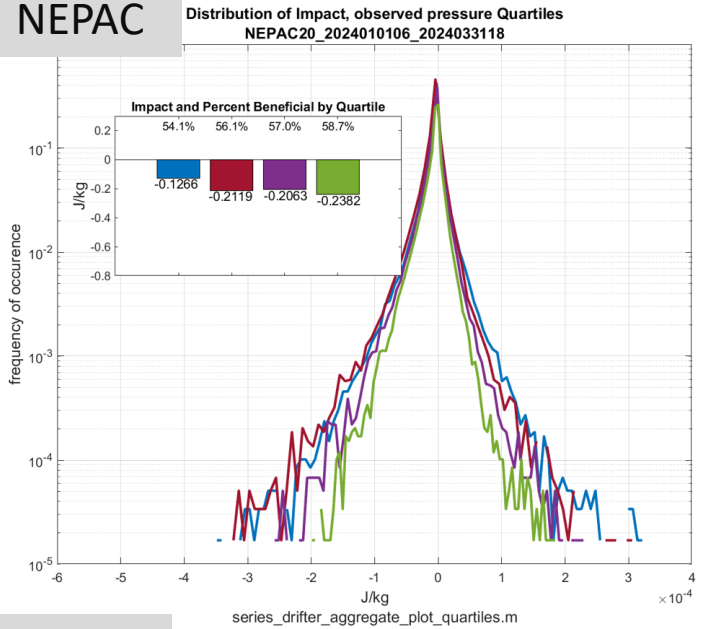


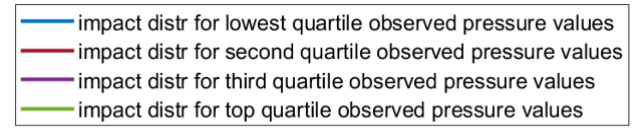
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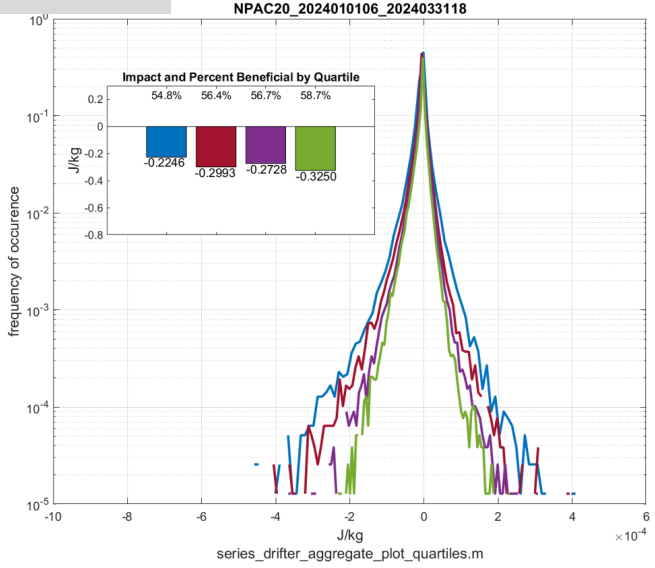


NEPAC





NEXPAC



TROPAC

