Using Northeastern Pacific Buoy Surface Pressure Observations to Learn About Model Error

U.S. NAVAL RESEARCH LABORATORY

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Background and Experimental Design

SURFACE PRESSURE OBSERVATIONS

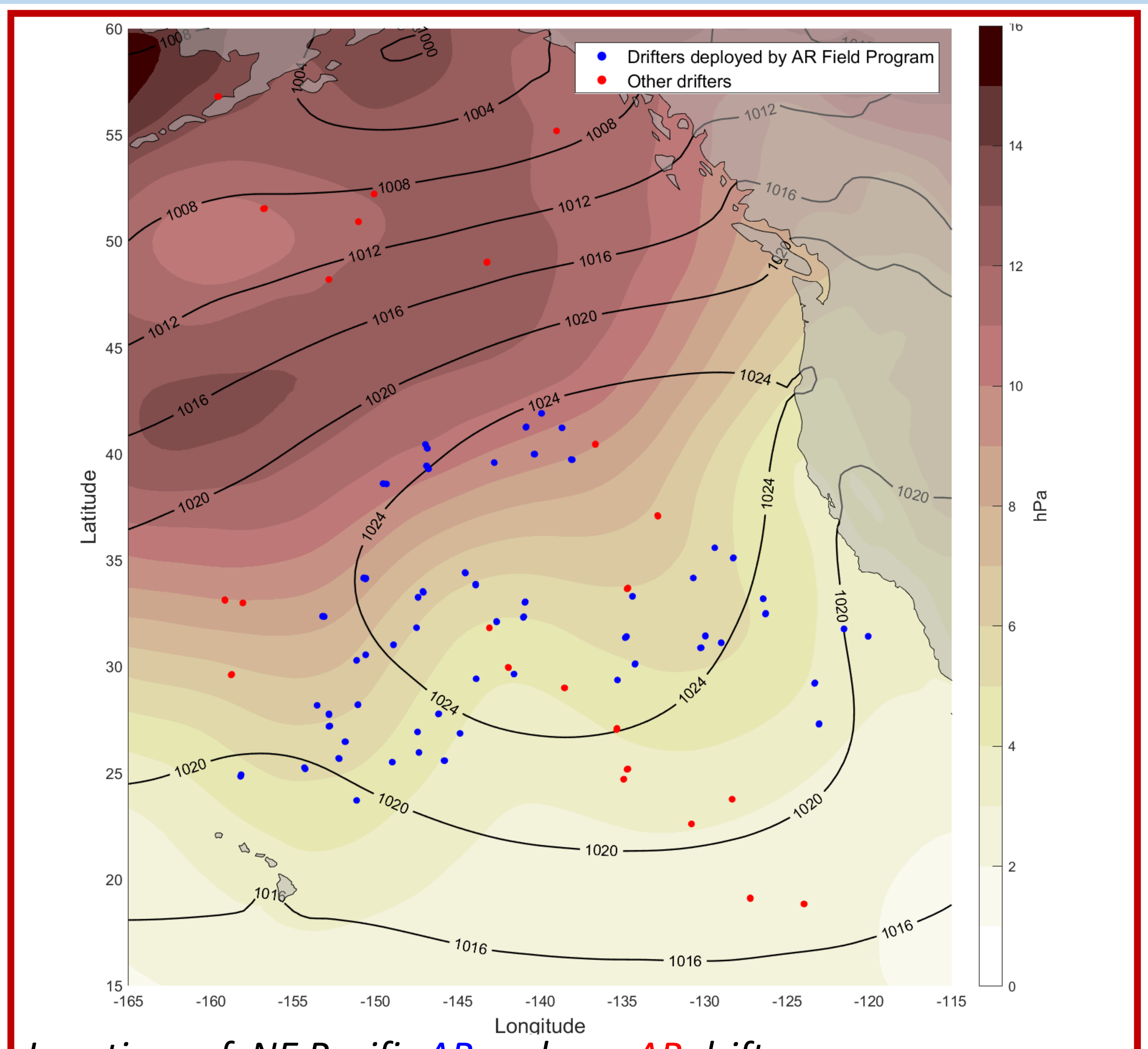
- Surface pressure obs are impactful - provide information on mass of atmospheric column, reflect synoptic-scale variability, influence tropospheric circulation through DA (e.g., 20th Century Reanalysis Project, Compo et al. 2011; Slivinski et al. 2021).
- Drifter obs are impactful - often in regions with few other in-situ obs (e.g., Ingleby and Isaksen, 2018; Centurioni et al. 2017; Horanyi et al. 2017).
- Eyre and Reid 2014 cost-benefit studies for ob impact: Best are aircraft obs, 2nd best are drifter obs.

ATMOSPHERIC RIVER RECONNAISSANCE PROJECT

- Multi-Organizational effort to take targeted observations to improve forecasting of west-coast ARs (Cobb et al. 2022; Ralph et al. 2020).
- Deploy both dropsondes and drifting buoys in the NE Pacific.
- Impact of AR observations in NRL global system for Dropsondes (Stone et al. 2020) and drifters (Reynolds et al. under review).

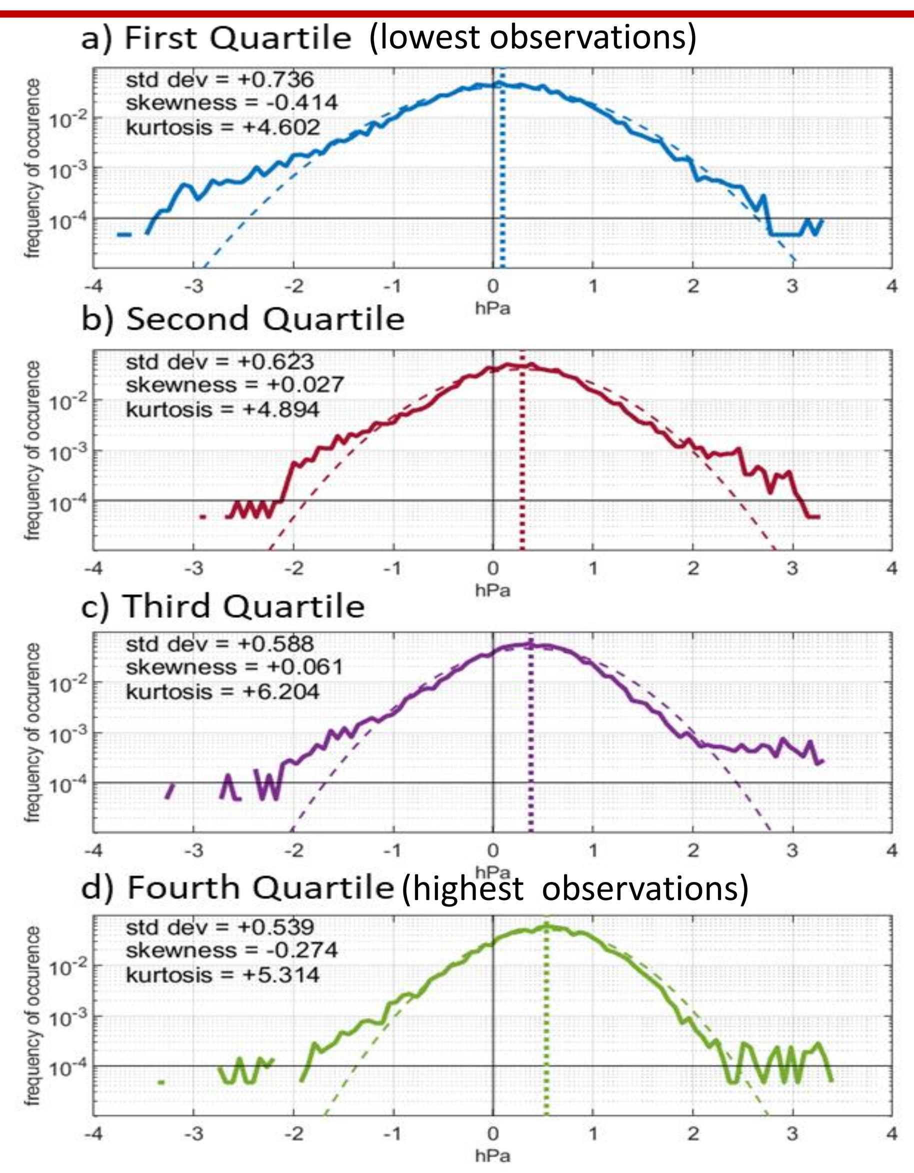
EXPERIMENTAL DESIGN

- Use the Navy Global Environmental Model (NAVGEM) to examine impact of AR-RECON and non-AR RECON drifter surface pressure obs on analyses and short term forecasts.
- Forecast Sensitivity/Observation Impact (FSOI, Langland and Baker 2004): Uses adjoints of forecast model and 4-d VAR DA to calculate impact of each ob on 24-h forecast error.
  - Model – 31 km res; DA increments -100 km res.
  - Global moist total energy error metric.
  - 2020 AR Recon Season: 2020012200-2020031300.
- Data Denial Studies were also performed (please see manuscript for additional information).



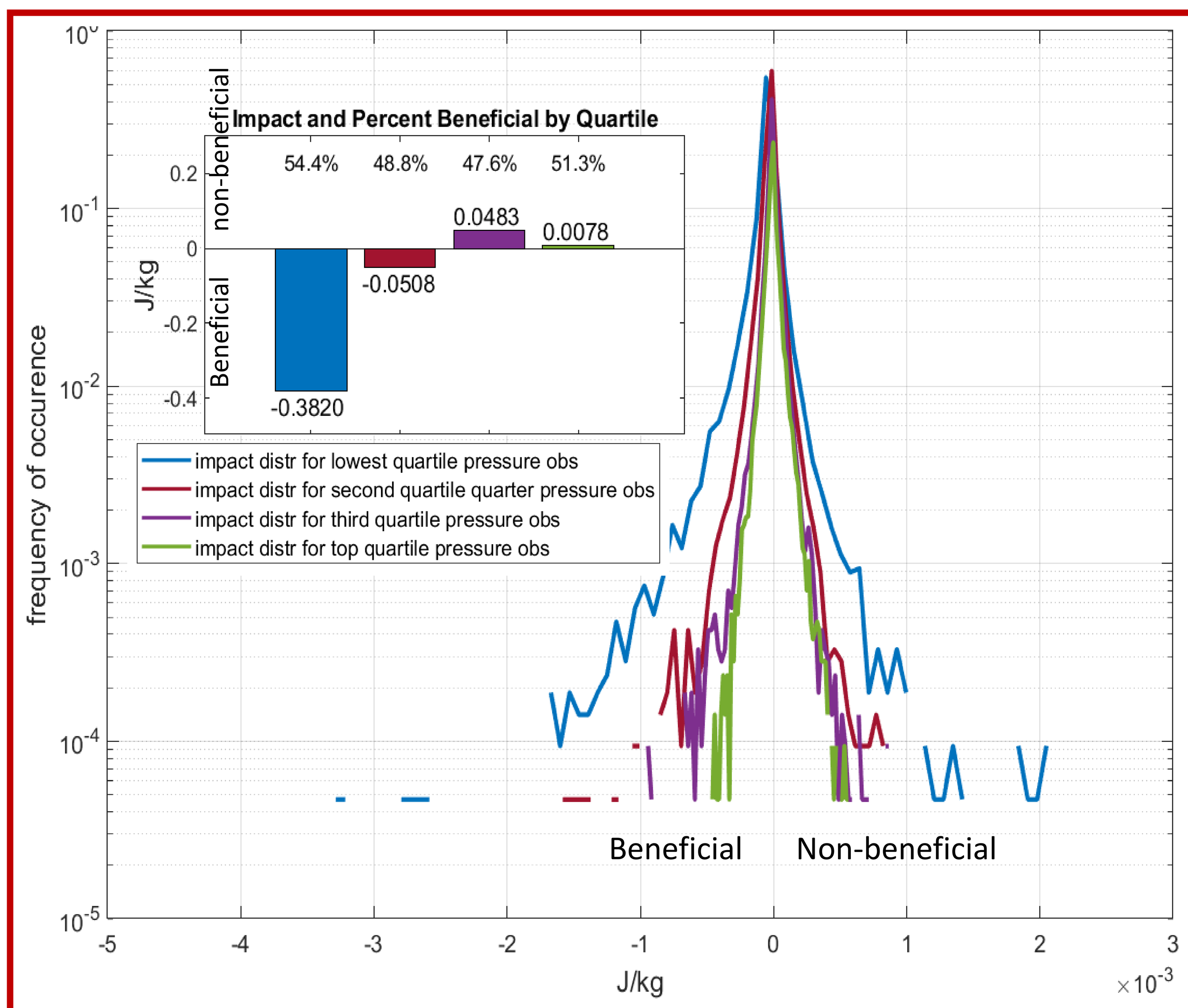
Locations of NE Pacific AR and non-AR drifters on 2020031300. NAVGEM analyzed SLP (hPa) average (contours) and std. dev (shading) from 2020012200-2020031300.

Innovations and Impacts by Observation Value Quartile



Innovation (observation – background, hPa) distributions (solid line) and Gaussian distributions with same variance (dashed lines). Dotted straight line shows mean. Quartiles determined by observation value with lowest observations in first quartile and highest observations in forth quartile.

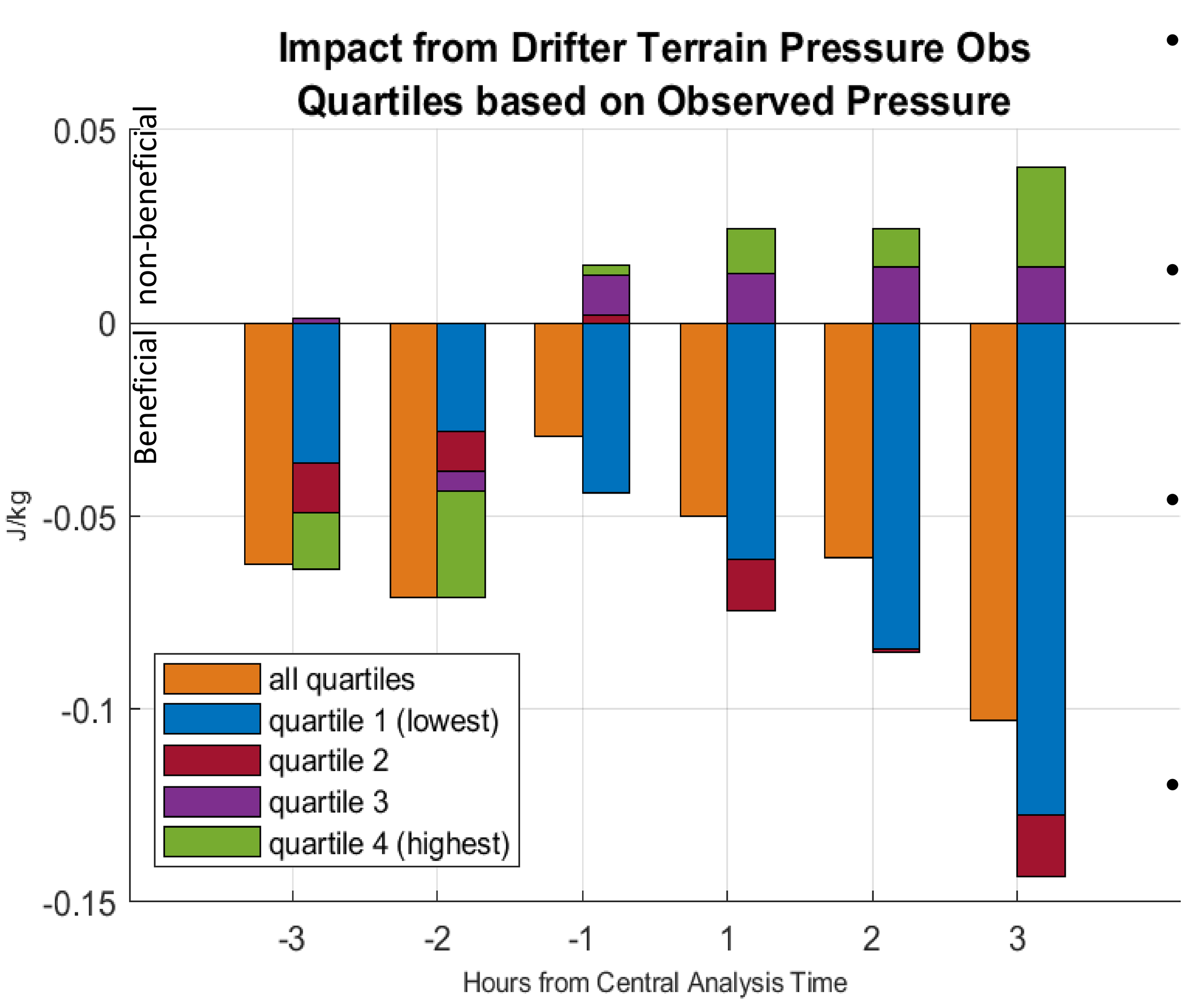
- NAVGEM has a conditional bias – mean innovation becomes more positive as quartiles include higher observed values (model has low bias for high observations).
- This effect becomes more pronounced for obs taken later in DA window (not shown).
- How might this bias affect FSOI?



Frequency distribution of drifter surface pressure observation impact (J kg^{-1}) for the different observation quartiles. Inset shows aggregate impact for each quartile. Negative values are beneficial (reduce forecast error) and positive values are non-beneficial (increase forecast error).

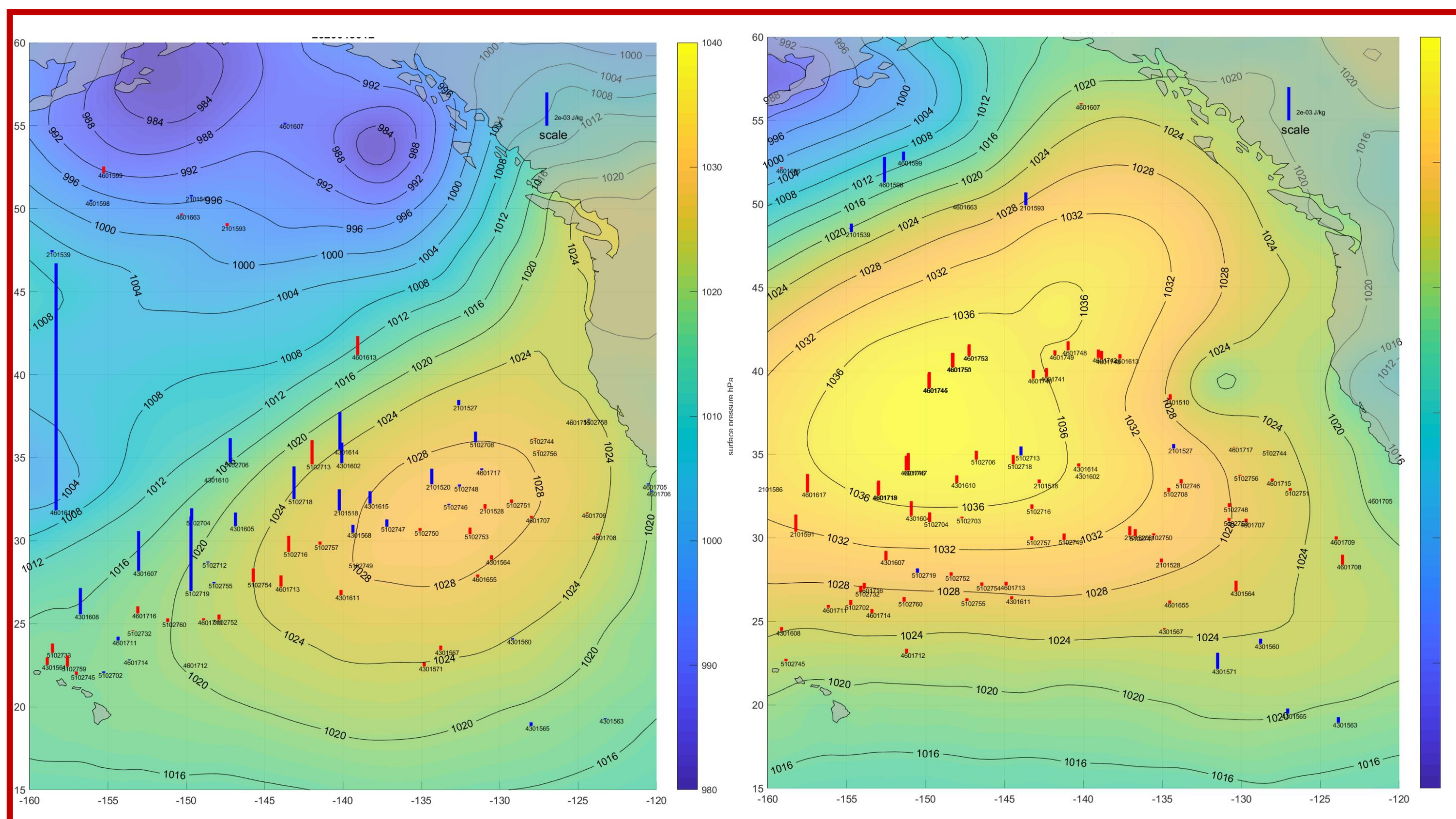
- The obs in lowest quartile (blue) have largest magnitude impact, largest beneficial average impact, and largest fraction of beneficial obs.
- The obs in the other quartiles have smaller magnitude impacts and close to neutral impact on forecast error reduction.
- McNally (2018) showed that satellite obs later in the DA window are more beneficial than obs earlier in the DA window. Similar for drifters?
- Bigger impacts from observations in "dynamically active" regions?

Observation Impact by Observation Quartile, Time in DA Window, Synoptic Environment



Total impact from all NE Pacific drifter surface observations (orange) as a function of hour within the six-hour data assimilation cycle. Impact is also broken out by surface pressure ob quartile.

- Lowest quartile obs most beneficial, larger benefits in 2nd half of window.
- Obs in upper quartiles are beneficial in first 2 hours, non-beneficial later in the window.
- Plausible that model bias at high pressures makes it difficult for DA system to use these obs effectively.
- Minimum impact in middle of window results from beneficial + non-beneficial cancellations.



Impact for each drifter (bars), analyzed SLP (contours and shading), for the case with the largest beneficial impact (2020013012, left panel), and the case with the largest non-beneficial impact (2020030100, right panel).

- For beneficial case (left), biggest impact from obs along the front. Obs under the high are near-neutral.
- For non-beneficial case (right), aggregate non-beneficial impact results from cumulative impact of small non-beneficial impacts of obs under the high.

Summary, References, and Acknowledgments

- DA statistics show that NAVGEM is biased low for high pressures.
- Drifter surface pressure FSOI becomes non-beneficial for high pressure obs later in DA window - consistent with model error (which is larger later in the DA window) inhibiting effective use of obs.
- Currently using strong constraint DA system – in future should test with weak constraint.
- Most beneficial obs; from lowest pressure quartile and taken later in DA window.
- Obs relatively more beneficial when taken in regions of strong pressure gradients, in regions of high integrated vapor transport, and when relatively isolated (see Reynolds et al. for more info).

Details on this work: Reynolds, et al., 2022: Impact of Northeastern Pacific Buoy Surface Pressure Observations. Mon. Wea. Rev. (under review).

Details on Dropsonde Impacts: Stone et al., 2019: Atmospheric River Reconnaissance Observation Impact in the Navy Global Forecast System. Mon. Wea. Rev., 148, 763-782.

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