Impact of Dropsonde Observations on the Predictability of Landfalling Atmospheric Rivers

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Introduction

Landfalling Atmospheric Rivers (ARs) provide between 30-50% of precipitation, but can also cause major flooding events in the western U.S. Accurate forecasts can improve water management decisions. Sparse observations over the Pacific have limited the improvement of forecast skills for the western U.S. due to the poor upstream initial conditions. While numerical weather predictions reap the benefits of satellite data over the oceans, those data poorly represent the low-level circulation and the vertical structure of water vapor in ARs.

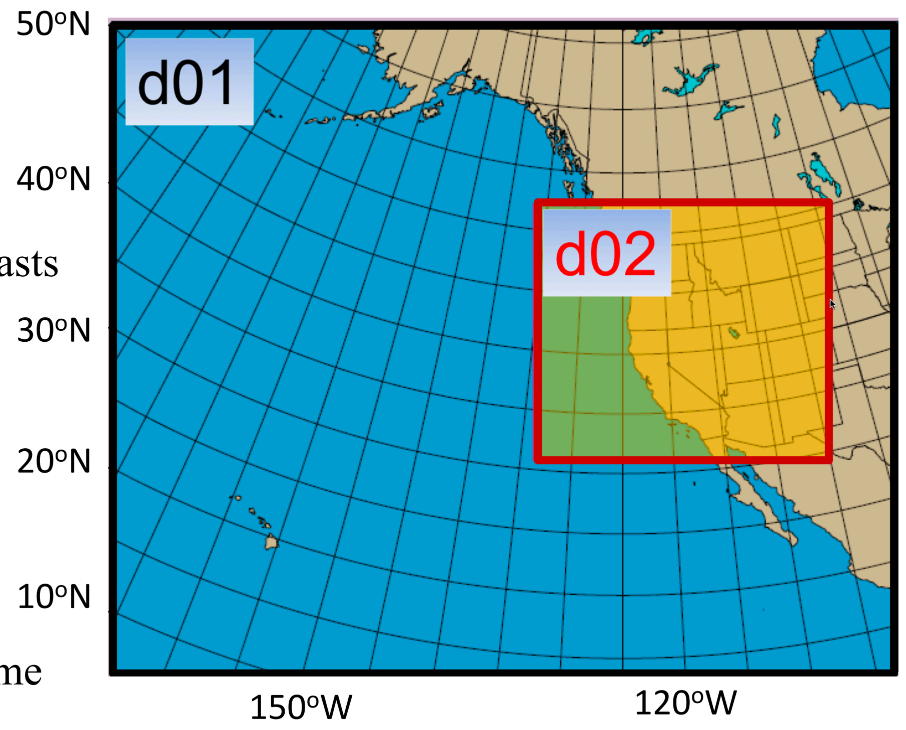
In the winters of 2016, 2018, and 2019, fifteen aircraft reconnaissance missions were carried out targeting AR conditions over the eastern Pacific. More than 900 dropsondes measured vertical profiles of wind, water vapor, temperature, and pressure. In this work, paired data assimilation experiments with and without these dropsondes are conducted using the Weather Research and Forecasting (WRF) model and the Community Gridpoint Statistical Interpolation (GSI) data assimilation system. The impact on the forecast skills of precipitation over the western U.S. is evaluated by comparing the simulations from paired runs for all fifteen Intensive Observation Periods (IOPs).

IOPs	Dates	IOPs	Dates
IOP1	02/14/2016	IOP9	02/28/2018
IOP2	02/16/2016	IOP10	02/02/2019
IOP3	02/22/2016	IOP11	02/11/2019
IOP4	01/27/2018	IOP12	02/13/2019
IOP5	01/29/2018	IOP13	02/24/2019
IOP6	02/01/2018	IOP14	02/26/2019
IOP7	02/03/2018	IOP15	03/01/2019
IOP8	02/26/2018		

A list of IOPs and the corresponding dates.

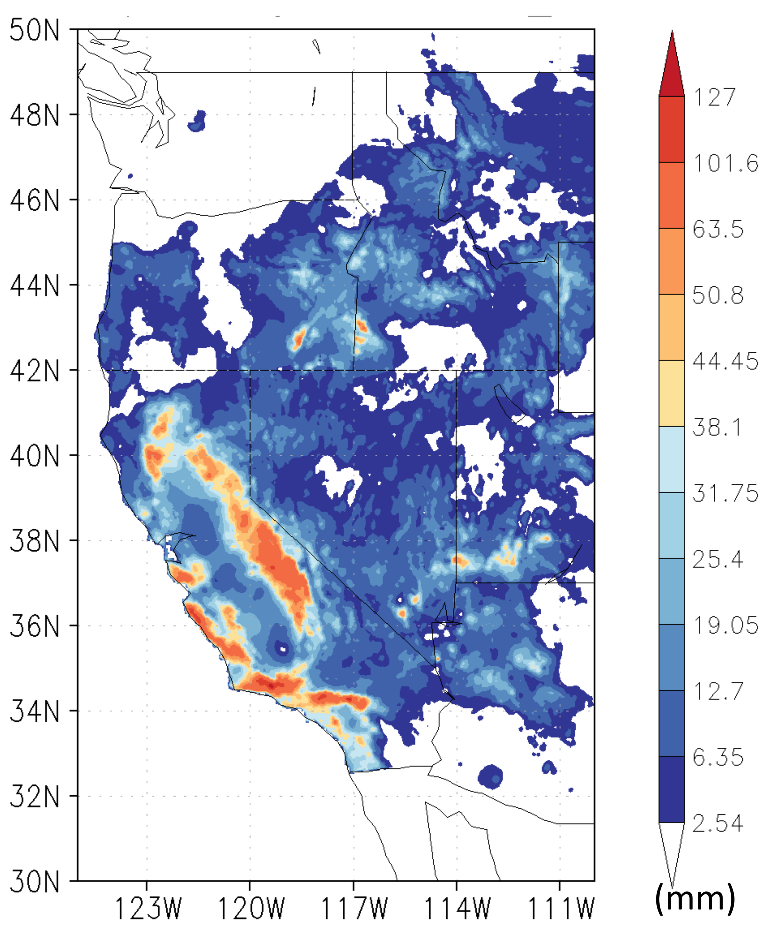
WRF Configuration

- Resolution
  - 9 (d01) / 3 km (d02), 48 levels, 10 hPa top
- Initial and boundary conditions
  - 6 hourly GFS 0.25 x 0.25 ° forecasts
- Physics
  - One-way nested
  - New Thompson scheme
  - Yosei University PBL scheme
  - Grell 3D cumulus scheme
  - RRTM long wave radiation
  - GSFC short wave radiation scheme
  - Two-hour digital filter



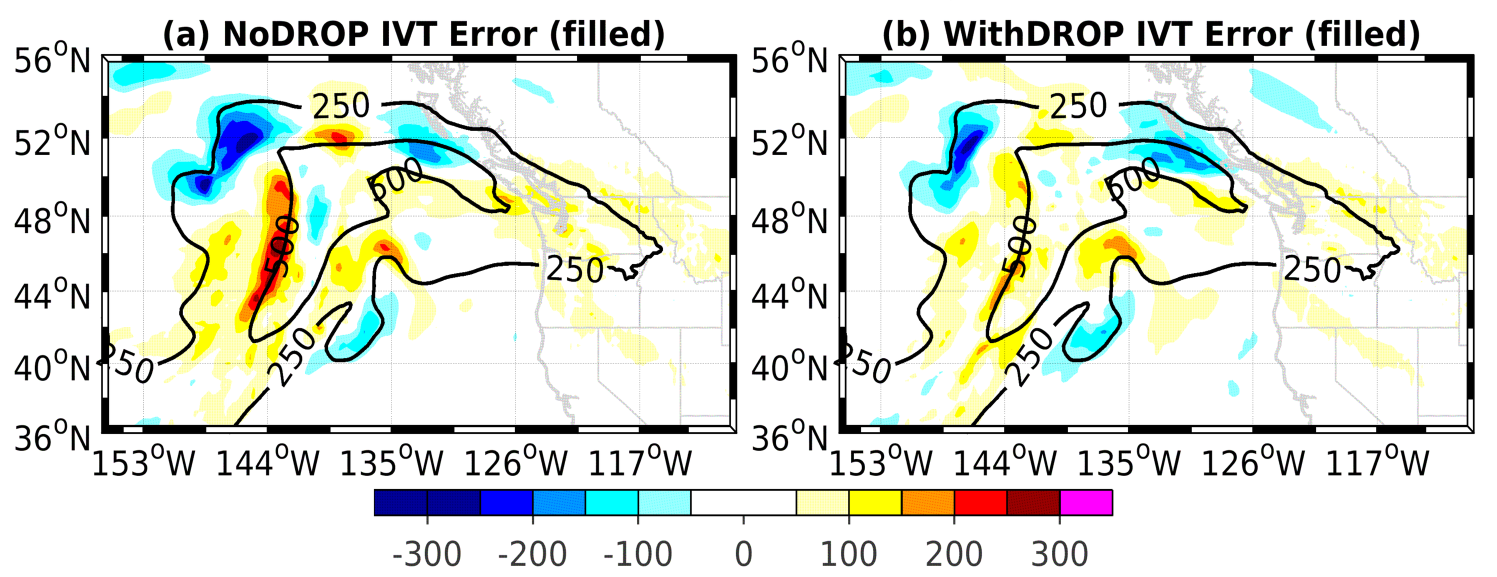
Data Assimilation Experiments Set-up

- GSI Hybrid 4DEnVar
  - Static background error covariance parameter: 0.25
  - Ensemble: downscaled 20-mem GEFS + 20-mem CMCE
  - Background: 9-hour forecast from WRF
- Assimilated Observations
  - Conventional data in NCEP PrepBUFR
  - Satellite derived wind in BUFR format
  - GPS RO refractivity in BUFR format
- Paired experiments
  - WithDROP: dropsondes assimilated
  - NoDROP: dropsondes not assimilated
- Verification domain and variables
  - Common domain: 20-50 ° N, 110-125 ° W
  - Accumulated 24-h precipitation using Stage IV 4-km data as the ground truth



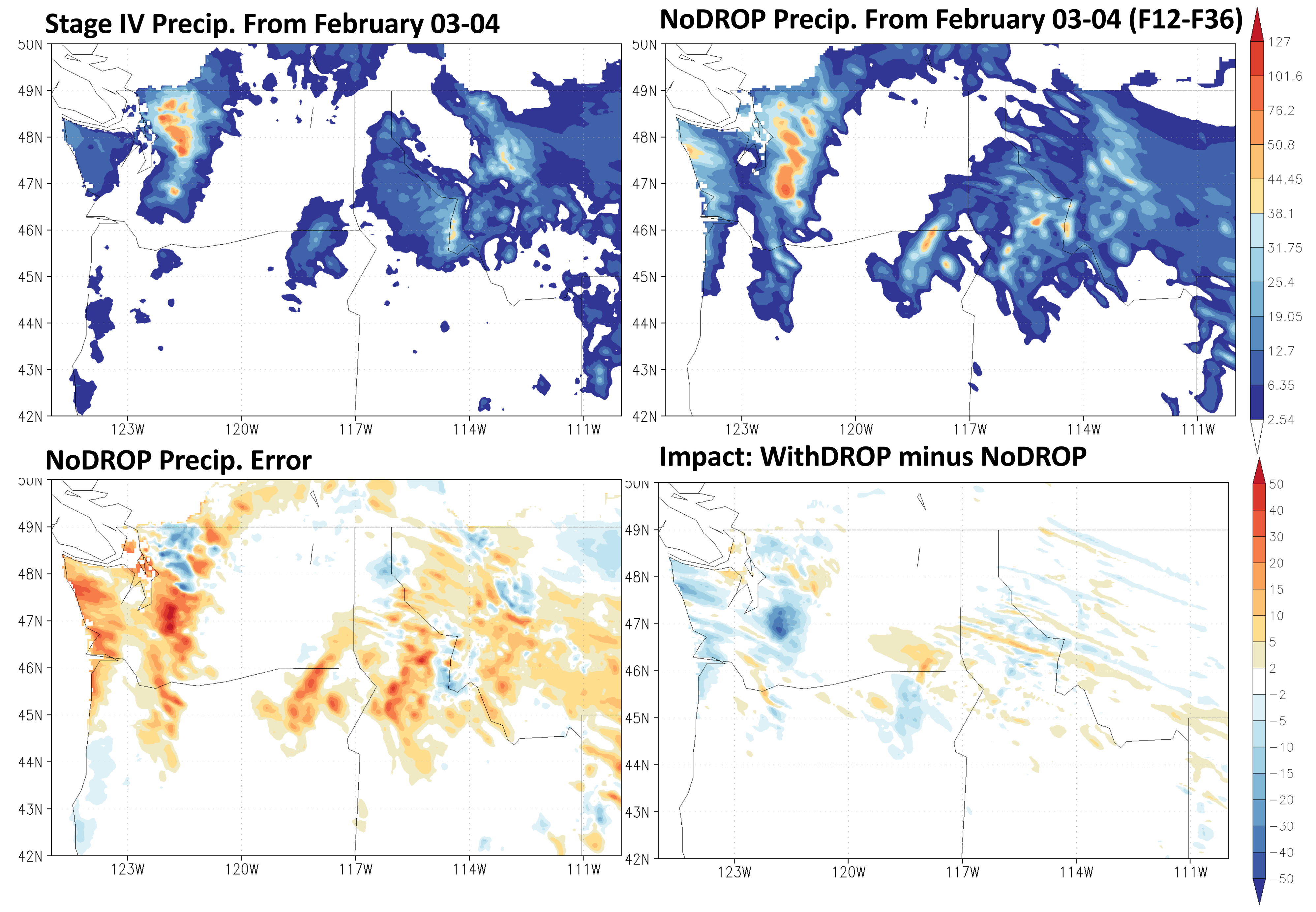
Stage IV 24-h precipitation over verification domain at 12Z, 3 February 2019.

Results for IOP7: IVT Differences

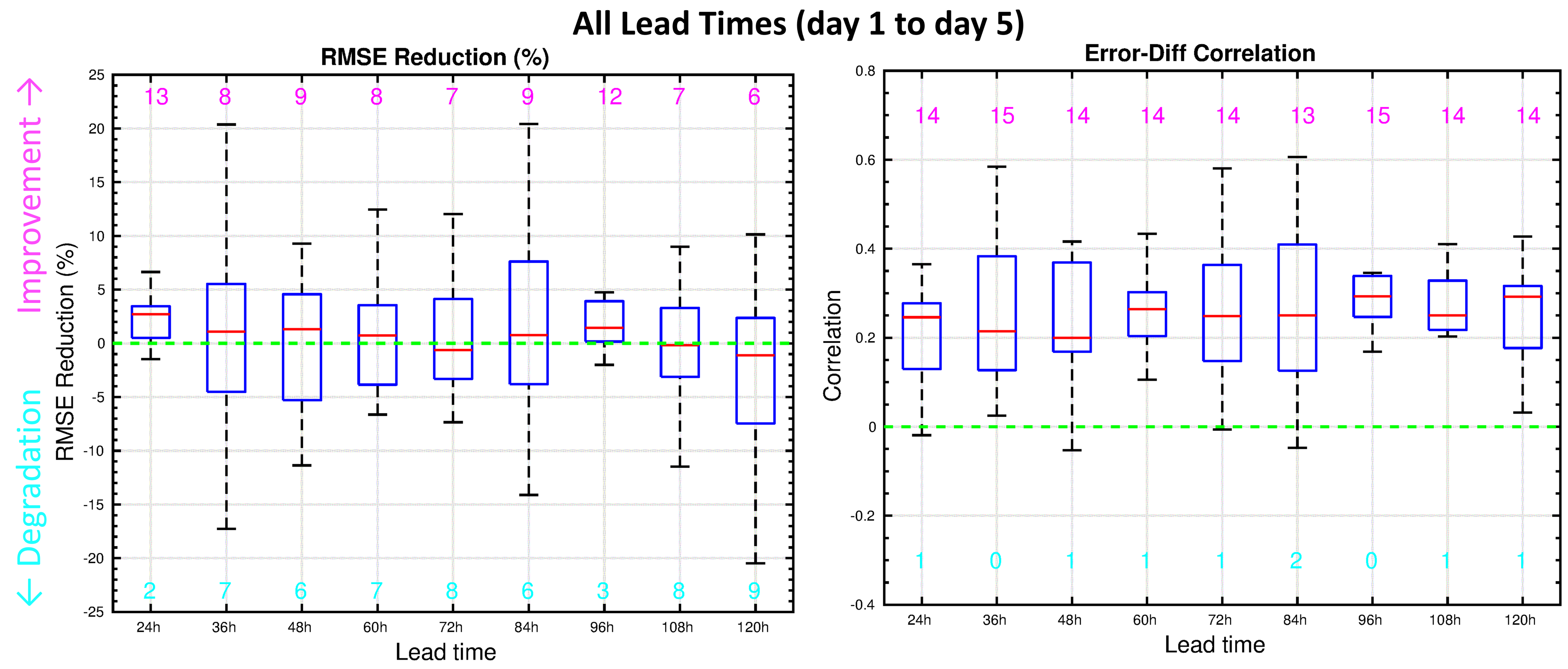


(a) Forecast error (filled, kg m^{-1} s^{-1}) of IVT in NoDROP run at 24-h forecast lead time. (b) Same as (a) but for WithDROP run. Black contours in (a) and (b) are analyzed IVT from ERA5 reanalysis data valid at 00Z, 4 February 2018.

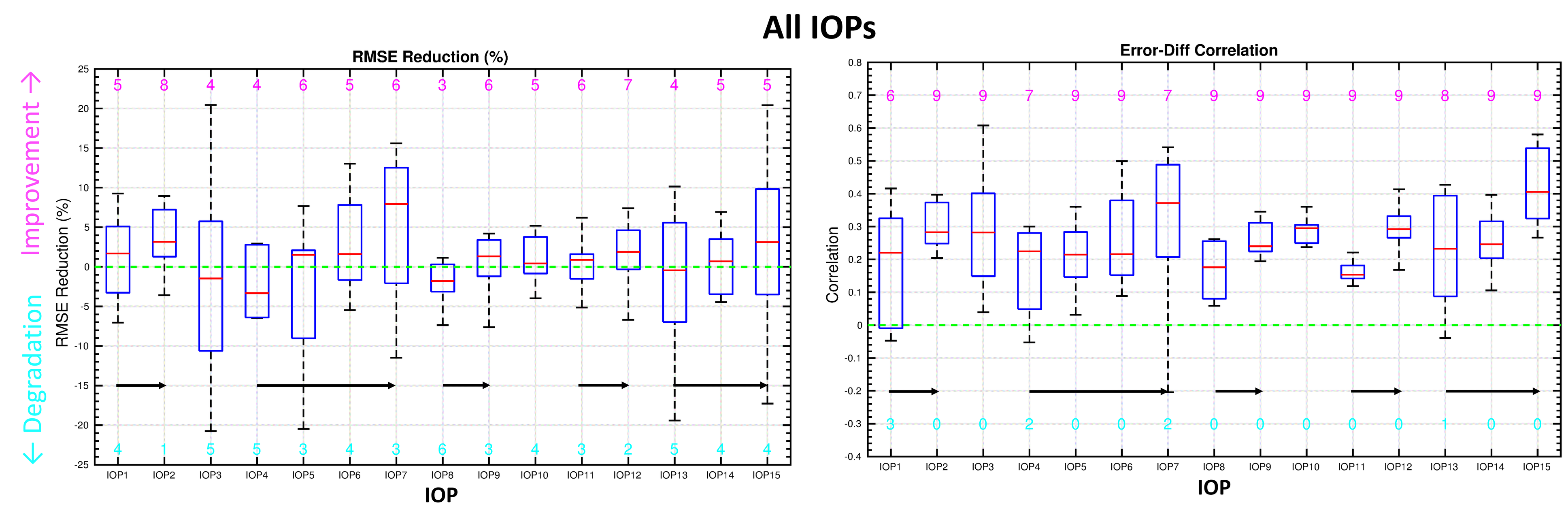
Results for IOP7: Precipitation Forecast Differences



Results for All IOPs: Impact on Precipitation Skills



RMSE reduction: RMSE of NoDROP minus RMSE of WithDROP. Positive: improved skill in WithDROP
Error-Diff Correlation: Correlation of NoDROP errors with NoDROP-WithDROP differences.
Positive: improved spatial correlation in WithDROP.



Note: IOPs are defined as consecutive cases if two adjacent IOPs are within 4 days. The Arrows in the above plots point from the first to the last IOP in a group of consecutive cases.

Conclusions and Future Work

Impact of dropsondes on precipitation skills over western U.S.

- The median RMSE reduction in WithDROP runs are positive for most of the lead times except for 72-h and 120-h. Precipitation RMSE skills are significantly improved at 24-h and 96-h lead times. The spatial correlation are significantly improved at all lead times.
- **Eleven out of fifteen IOPs show that the median value of RMSE at all lead times are improved. Fourteen out of fifteen IOPs show the spatial correlation at all lead times are significantly improved.**
- Larger improvements are consistently found after the first IOP of a group of consecutive cases, i.e., IOP2, IOP5-7, IOP9, IOP12, and IOPs 14-15.

Future work

- Evaluating the data impact with satellite radiance assimilated.
- Investigating the physical processes that might be associated with positive or negative impacts.
- Choosing different verification domains for IOPs not making landfall at western U.S., such as IOP3 and IOP8.

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