Impact of Analysis Correction-based Additive Inflation on Integrated Vapor Transport

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Introduction and Experimental Design

Background:

- High-fidelity analyses and forecasts of integrated vapor transport (VT) central to study of hydrological cycle & high-impact phenomena (monsoons, atmospheric rivers).
- This has motivated several studies investigating errors and biases in IVT (e.g., Lavers et al., 2018; Cobb et al., 2021; Nardi et al., 2018; Xue et al., 2010) and Monsoon biases (e.g., Sahana et al. 2018; Meynadier et al., 2010).
- Stochastic forcing can improve ensemble forecast performance on many timescales (Berner et al. 2017).
- We apply Analysis Correction-based Additive Inflation (ACAI, Crawford et al., 2020) to the Navy ESPC global coupled ensemble forecast system to investigate the impact of ACAI on IVT and its wind and moisture components.
- We recalculate IVT forecast bias and error substituting in reanalysis winds or moisture to quantify impacts of each component on IVT biases and errors.

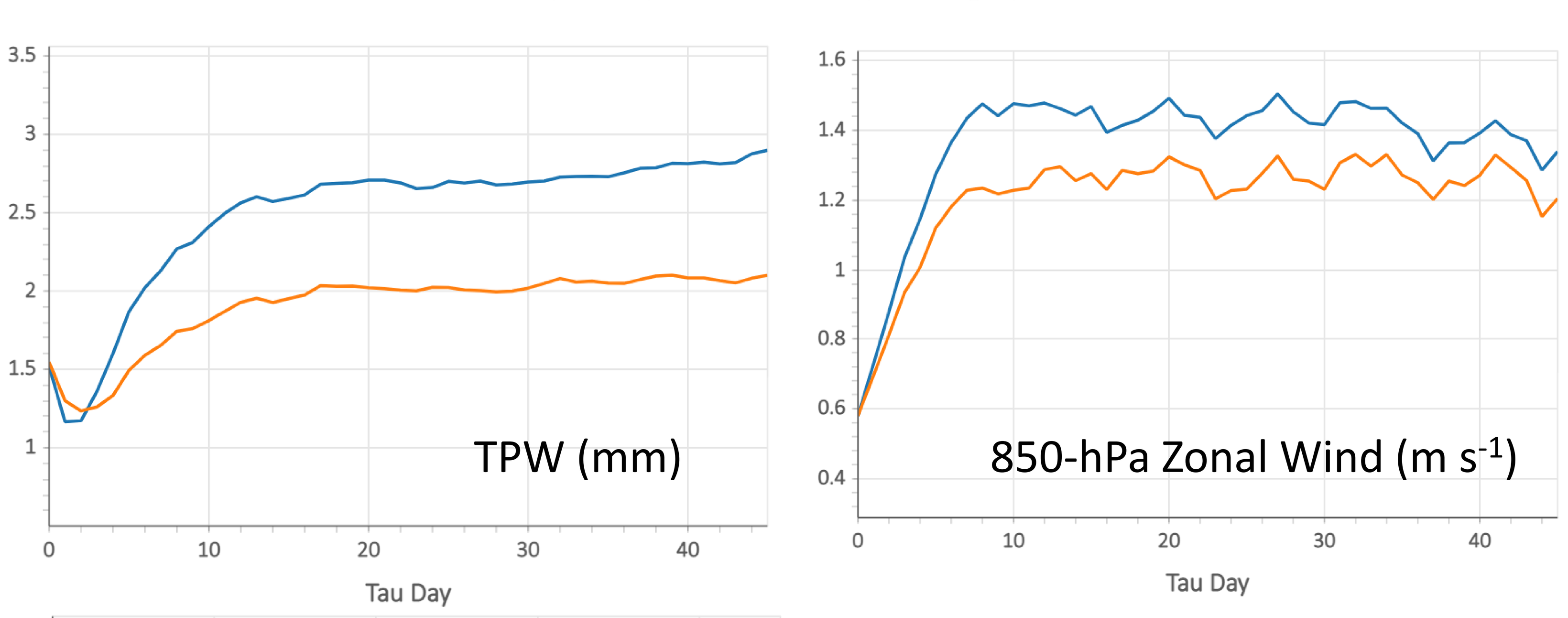
Experimental Design

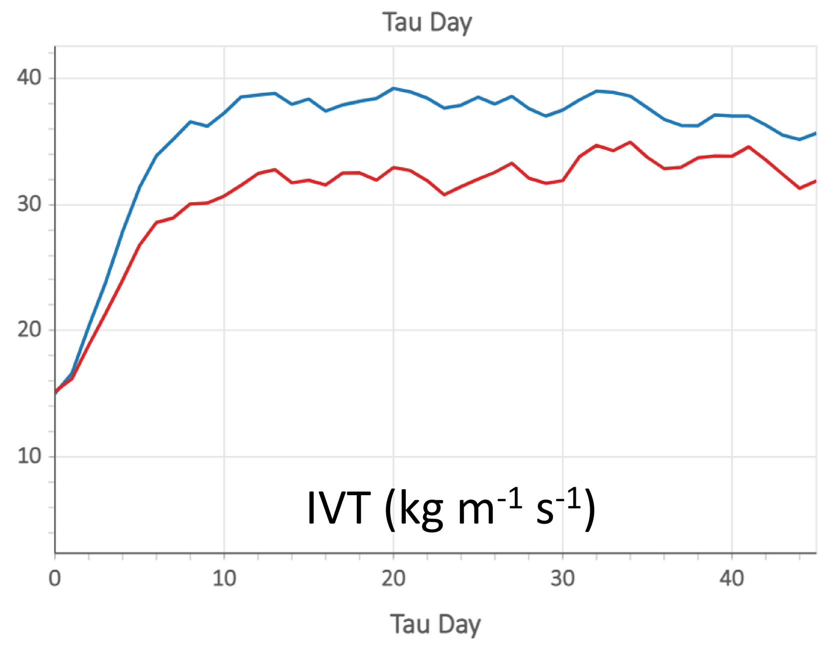
- Navy Earth System Prediction Capability (Navy ESPC; Barton et al. 2020).
  - NAVGEM (37 km), HYCOM (1/12°), CICE (1/12°) 45-day 16-member weekly forecasts, became operational at Fleet Numerical Meteorology and Oceanography Center on 31 August 2020 (also participating in the NOAA SubX project).
  - Initial perturbations produced using an Ensemble of Data Assimilation methodology.
  - Weakly-coupled DA using NCODA (HYCOM-CICE) and Hybrid NAVDAS-AR (NAVGEM).
- Experiments:
  - NAVGEM 37km, HYCOM and CICE reduced to ¼° for computational reasons.
  - 7-member 45-day ensembles once per week from 1 Feb 2017 through 31 Jan 2018.
  - Control Ensembles: No model uncertainty .
  - ACAI Ensembles: same initial conditions as CTL, but uses analysis-background differences to correct for biases (time-mean term) and account for model uncertainty (random term). Details in Will Crawford's presentation.
  - ERA5 analyses are used as verification, also substituted for forecasted winds or specific humidity to determine how each component is impacting the IVT bias.

	Model Uncertainty	Winds	Specific Humidity
CTL	None	Navy ESPC	Navy ESPC
CTL_ERAMOIST	None	Navy ESPC	ERA5
CTL_ERAWIND	None	ERA5	Navy ESPC
ACAI	ACAI	Navy ESPC	Navy ESPC
ACAI_ERAMOIST	ACAI	Navy ESPC	ERA5
ACAI_ERAWIND	ACAI	ERA5	Navy ESPC

Impact of ACAI on Biases

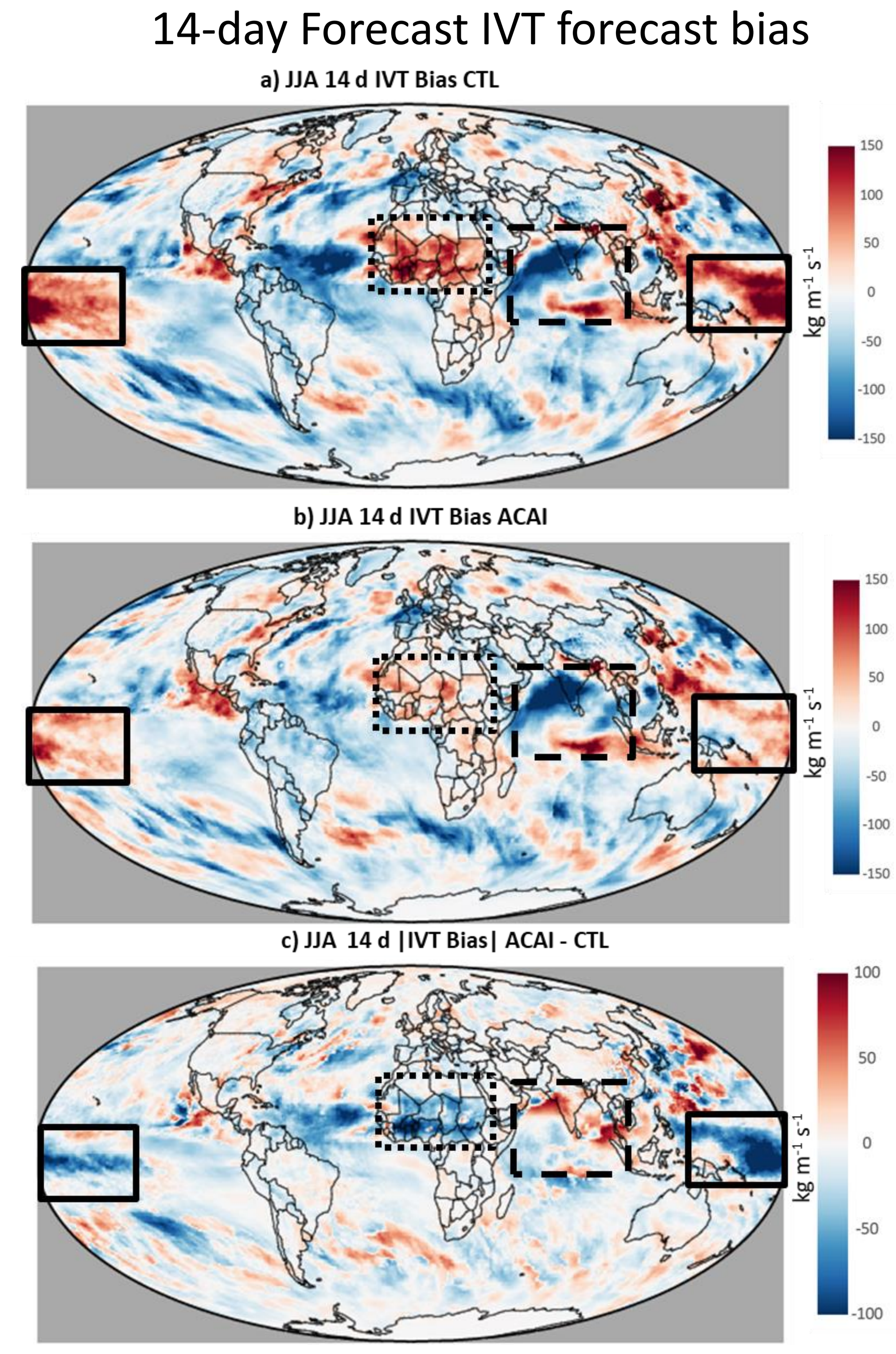
Global Average JJA Bias Magnitude as a function of forecast lead time for CTL (blue) and ACAI (orange)





- Bigger improvement from ACAI for Total Precipitable Water (TPW) than for low-level winds.
- Improvement to IVT similar to that for low-level winds. Is IVT bias dominated by wind bias?
- Results for other seasons are similar but magnitude of improvement slightly smaller.

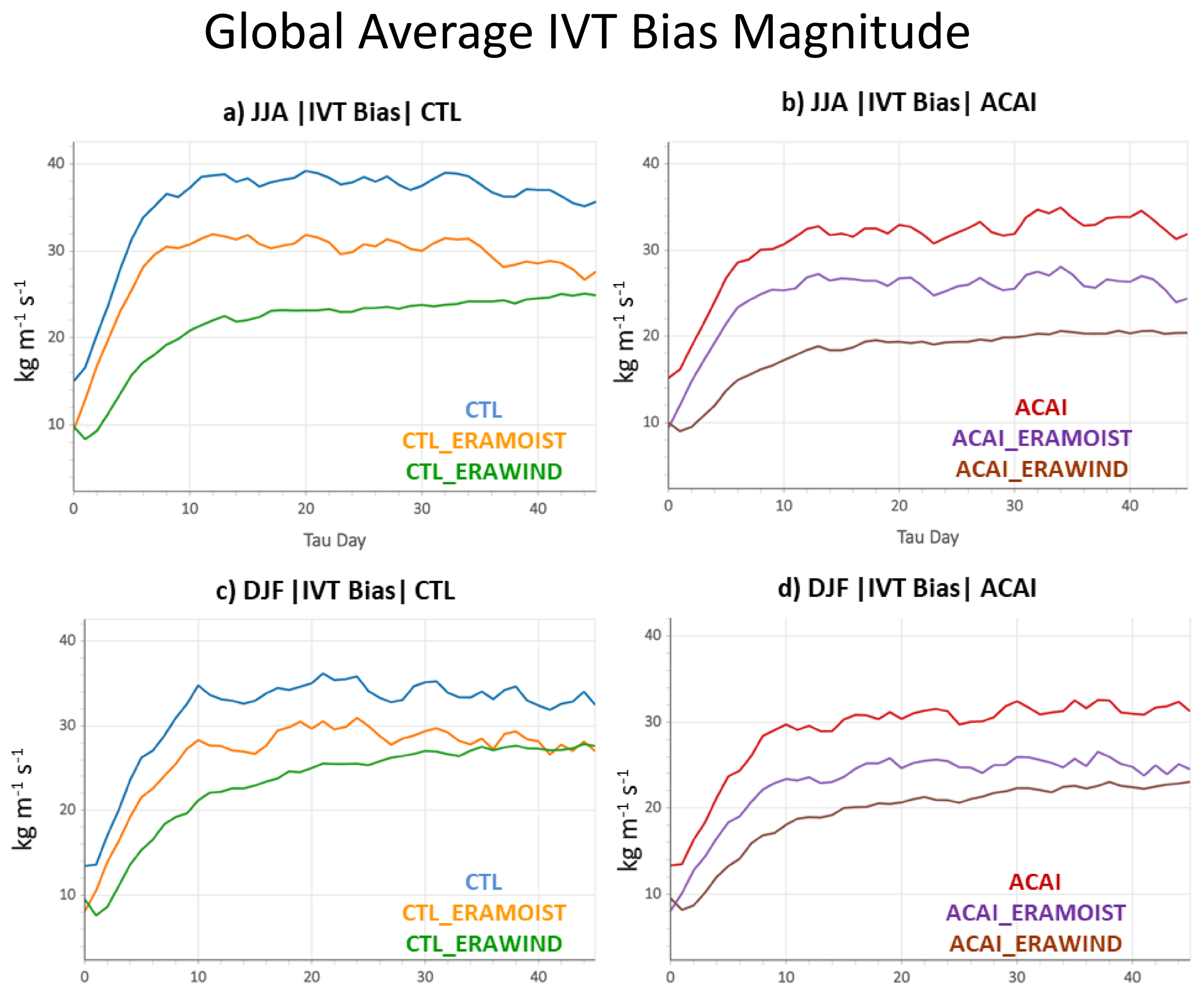
14-day Forecast IVT forecast bias



- For ACAI and CTL, IVT low bias over many ocean basins, high bias over some tropical continental areas, tropical Indian Ocean, tropical West and Central Pacific.
- ACAI reduces positive and negative biases in many regions but increases biases in some regions, like the South Asian Monsoon (SAM).
- The regions where ACAI increases bias are also regions where the bias changes sign/character with forecast time (not shown).

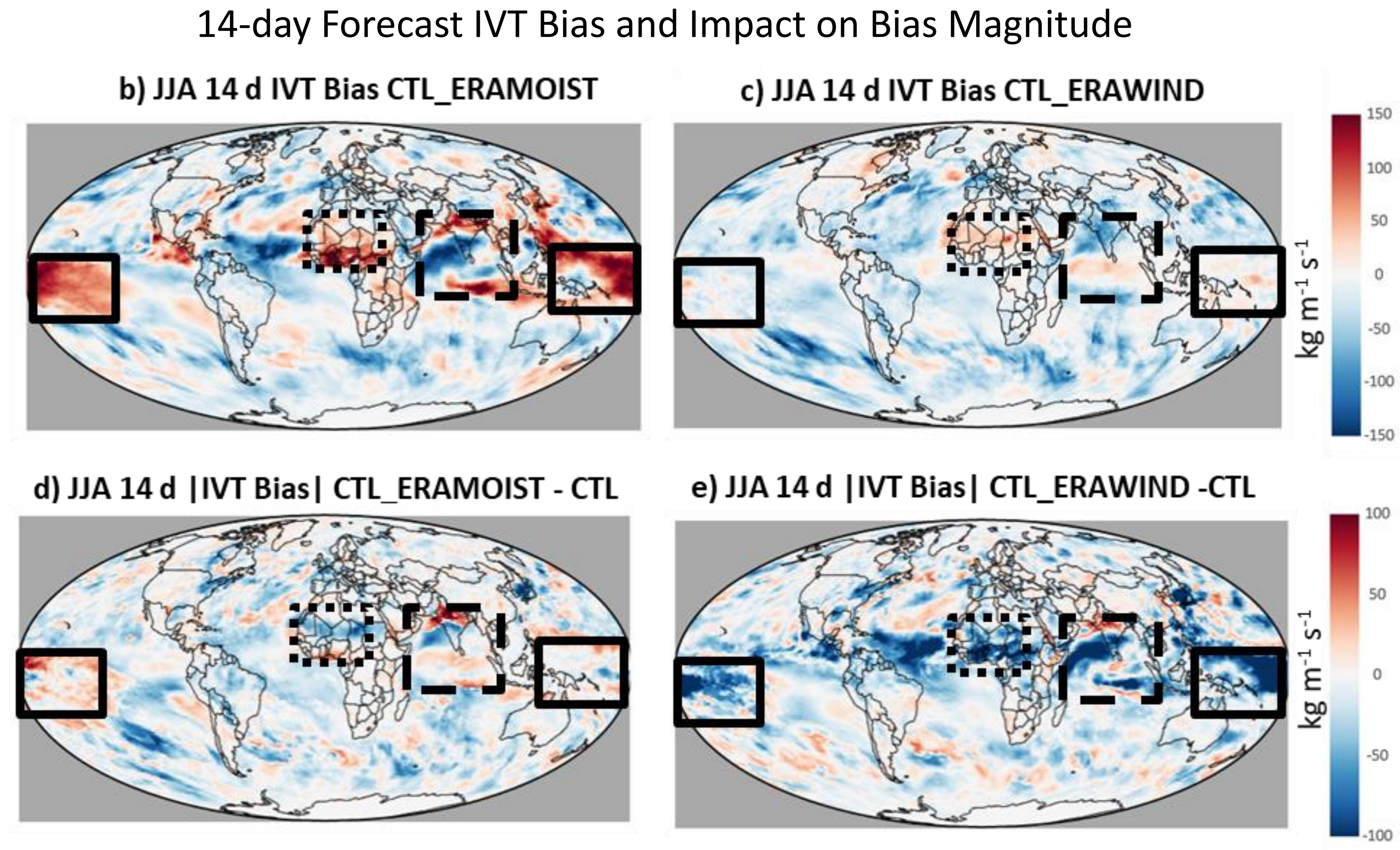
Substituting ERA5 Analyses for forecast winds or moisture in the IVT Bias Calculation

Global Average IVT Bias Magnitude



- In both summer and winter, and in both the CTL and ACAI runs, using analyzed winds in the bias calculation reduces the bias magnitude about twice as much as using the analyzed moisture for the first few weeks of the forecast.
- This indicates that errors in winds are dominating the IVT biases in a global sense.

14-day Forecast IVT Bias and Impact on Bias Magnitude



- In the Tropical Western Pacific, the IVT bias is dominated by wind errors.
- In the West African Monsoon (WAM), both moisture and wind errors contributed to IVT biases, although wind errors dominate.
- In Northern Arabian Sea and over Northern India, subbing in either analyzed winds or moisture actually increases the bias, pointing to compensating errors.

Summary, References, and Acknowledgments

- ACAI is effective at reducing global average bias magnitude.
  - By forecast day 10, global average absolute value of bias reduced by over 30% for moisture and over 20% for IVT and 850-hPa zonal winds.
  - Bias reductions are substantially higher in some regions, particularly the tropics.
  - Impact of ACAI is location dependent, does not work well where the bias changes with forecast lead time (e.g., over northern Arabian Sea and India).
  - ACAI also reduces RMSE throughout the forecast (by about 5%, not shown).
- Wind errors dominate IVT biases out to three weeks, but this is location dependent.
- Using ERA5 winds reduces IVT MAE twice as much as using ERA5 moisture (not shown).
- In some regions, substituting analyzed winds or moisture in for the forecast fields increases biases and errors, indicating compensating errors.

Details on this work: Reynolds, et al., 2022: Analysis of integrated vapor transport biases. Mon. Wea. Rev., Early Online Release.
Details on ACAI: Crawford, et al., 2020: Using analysis corrections to address model error in atmospheric forecasts. Mon. Wea. Rev., 148, 3729-3745.
Details on Navy ESPC: Barton, et al., 2021: The Navy's Earth System Prediction Capability. Earth and Space Sciences, e2020EA001199.

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