U.S. NAVAL RESEARCH LABORATORY

# Using analysis corrections to represent systematic and stochastic model error

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# Analysis Correction-based Additive Inflation

- **Goal: decrease model bias and increase spread in ensemble forecasts**

  - Compute $\delta x_m^F = \overline{\delta x^a} + \alpha\left[\delta x_m^a - \overline{\delta x_e^a}\right]$

Seasonal (3-month) average analysis correction; address bias same for all ensemble members

stochastic component; address ensemble spread randomly sampled from same 3-month period as $\overline{\delta x^a}$ different for each ensemble member ($m$)

- **Incrementally add $\frac{\delta x_m^F}{T}$ at each time step ($T$ = time steps/6-hr forecast) to T,U,V,Q,P**

- **Compute/add a new $\delta x_m^F$ over each 6-hr period of the forecast**

- **Sample from a 1-year archive of analysis corrections**

$\delta x^a =$ analysis correction (or increment)

$$\delta x^a = x^a - x^f$$

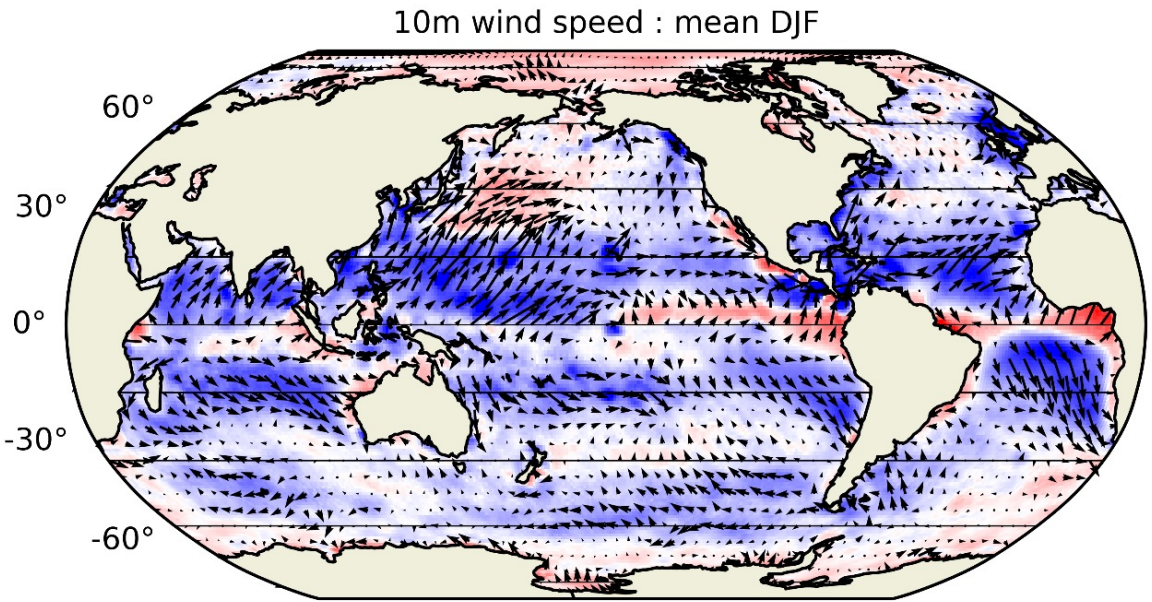
analysis - forecast

*Crawford et al. 2020 MWR; Bowler et al. 2017 QJRMS*

# Structure of average analysis corrections

$$\delta x_m^F = \overline{\delta x^a} + \alpha\left[\delta x_m^a - \overline{\delta x_e^a}\right]$$

- **Example of the mean analysis correction to wind speed**
- **Illustrates how the DA system is systematically adjusting the background**
- **In the tropics, represents a slowing of the trade winds**

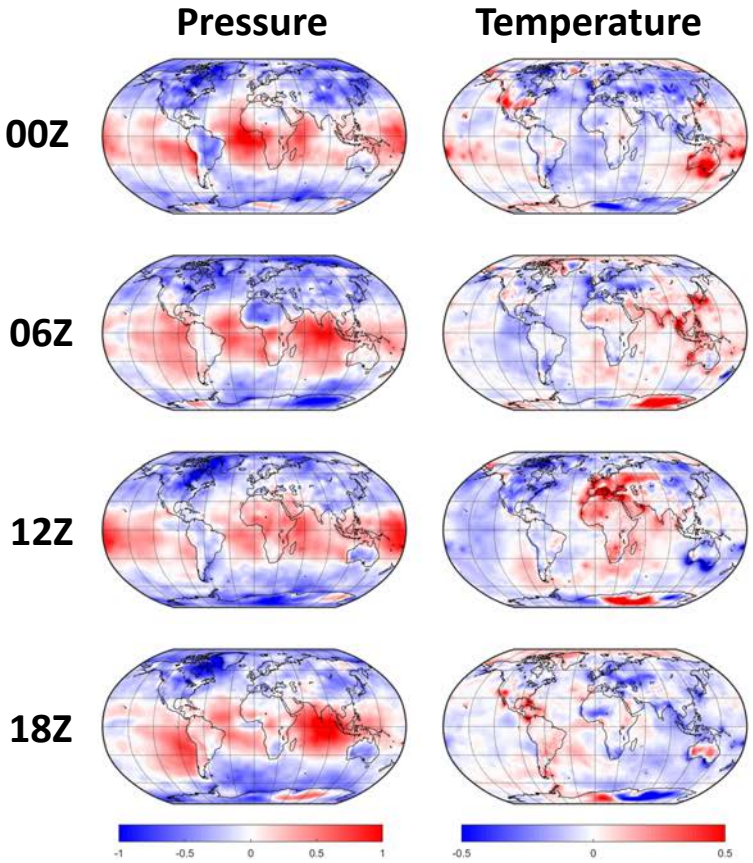



Mean analysis correction to 10m wind speed

*Crawford et al. 2020*

# Structure of average analysis corrections

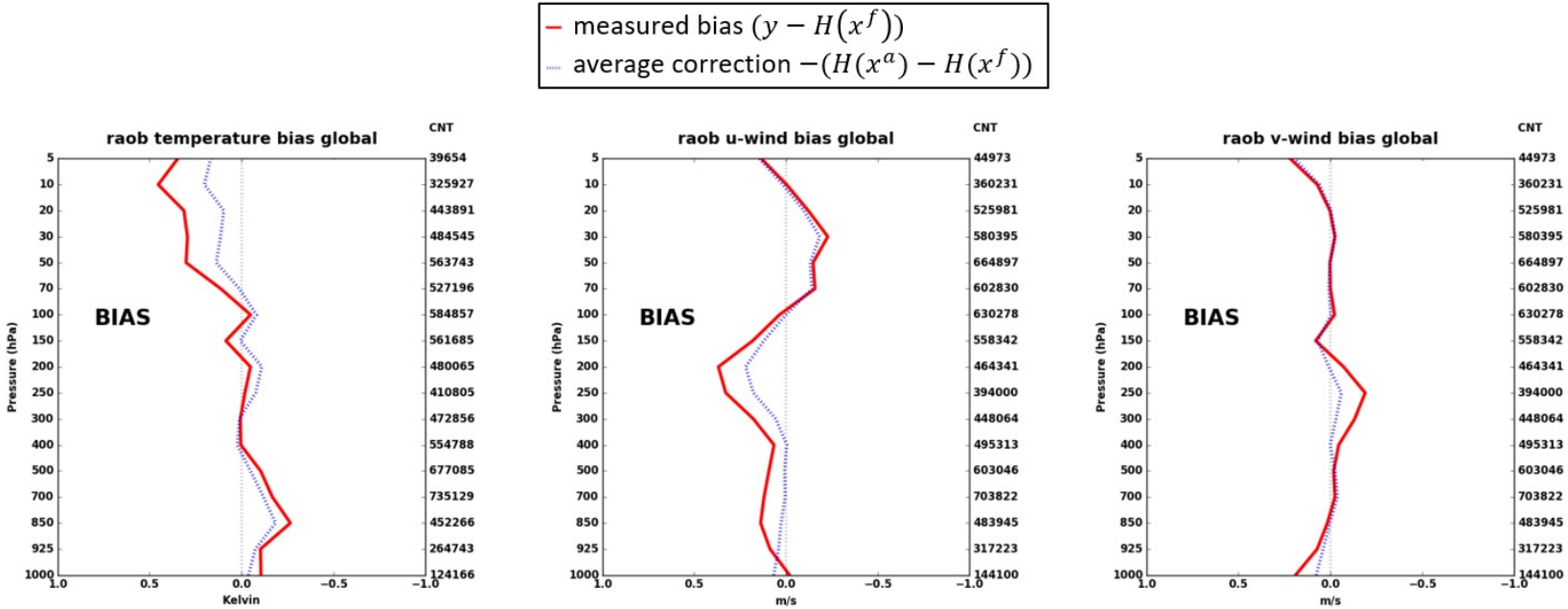
- Mean analysis corrections to surface pressure (left) and temperature (right)
- Large dependence on time-of-day
- Average corrections show a clear migration westward between 00Z and 18Z
- We now use analysis corrections relative for the forecast time-of-day to produce the perturbations




*Crawford et al. In prep.*

# Comparison to true estimate of the bias

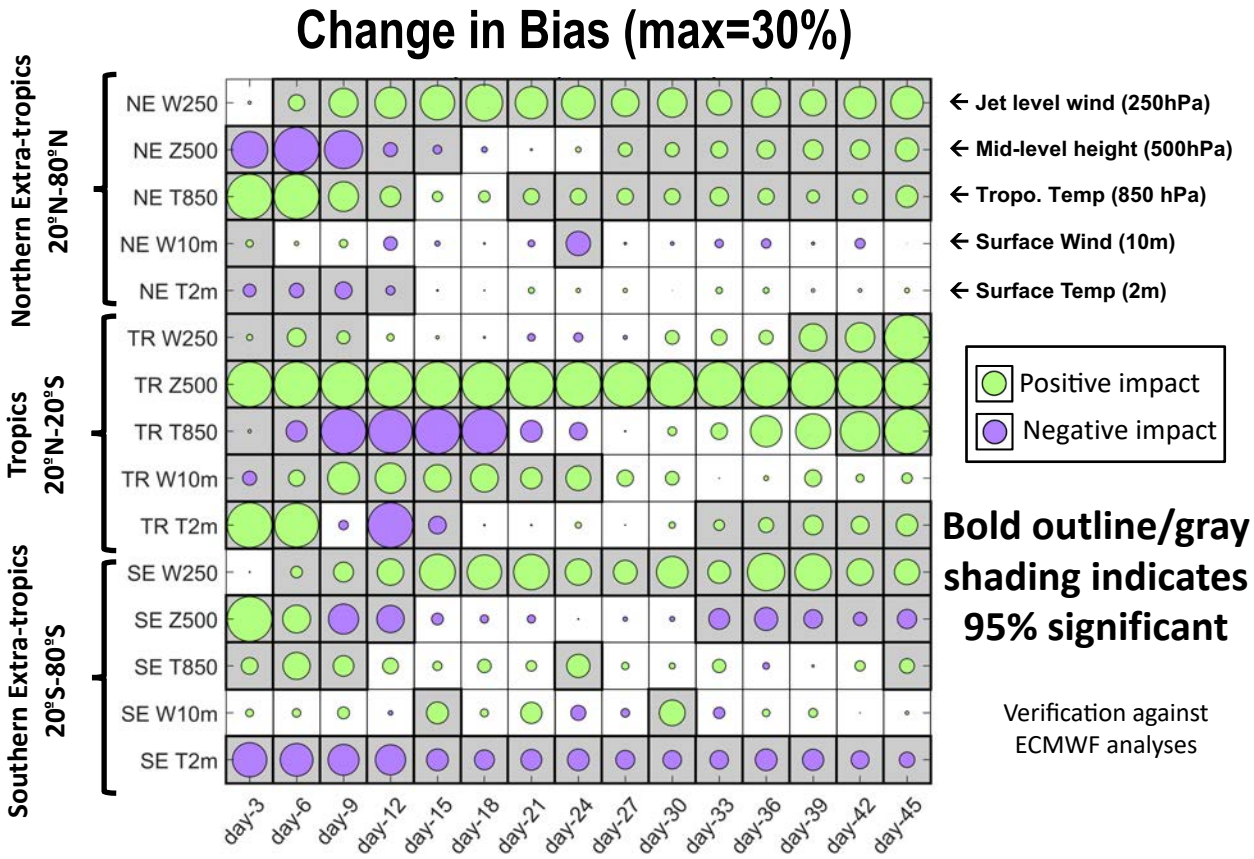
- Average analysis corrections (blue) verify well against observation based estimates of the bias (red)
- Though corrections tend to be an underestimate of the true bias




*Crawford et al. 2020*

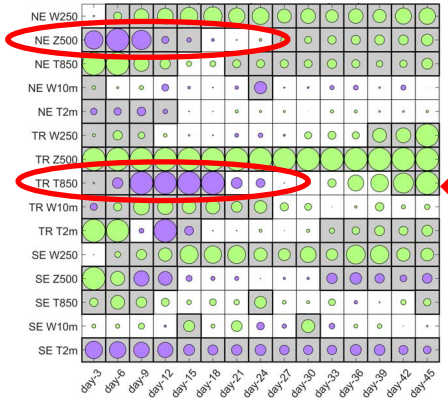
# Application to Navy ESPC Ensemble

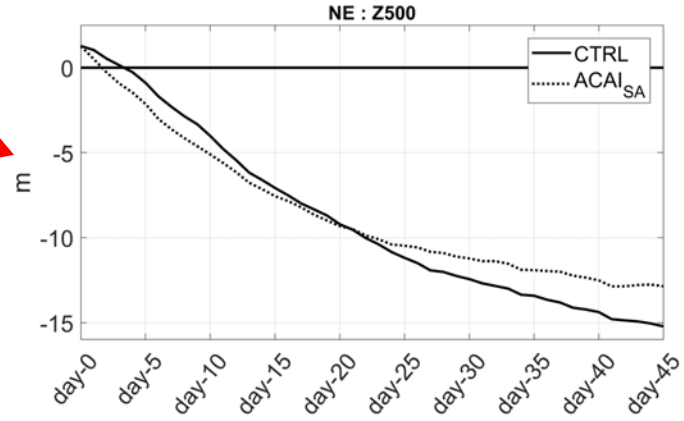
- 1-year of 45-day ensemble forecasts run once per week (total of 52 forecasts) using Navy ESPC system (Barton et al. 2021)
- Bias scorecard illustrates a largely positive impact to the forecast bias, especially in NE and TR

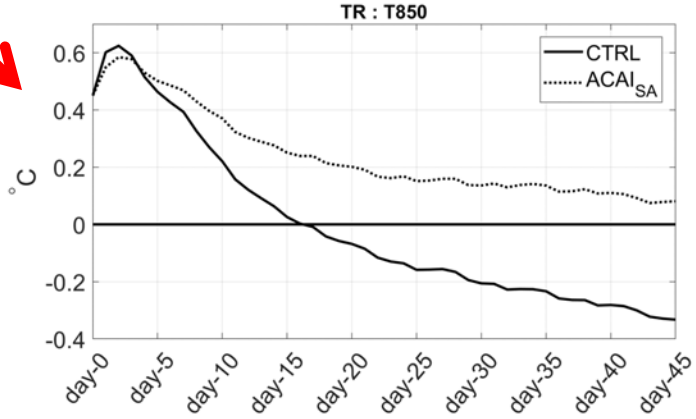



*Crawford et al. In prep.*

# Application to Navy ESPC Ensemble




- **While both cases appear degraded, the true biases illustrate that ACAI is able to slow the negative trends**

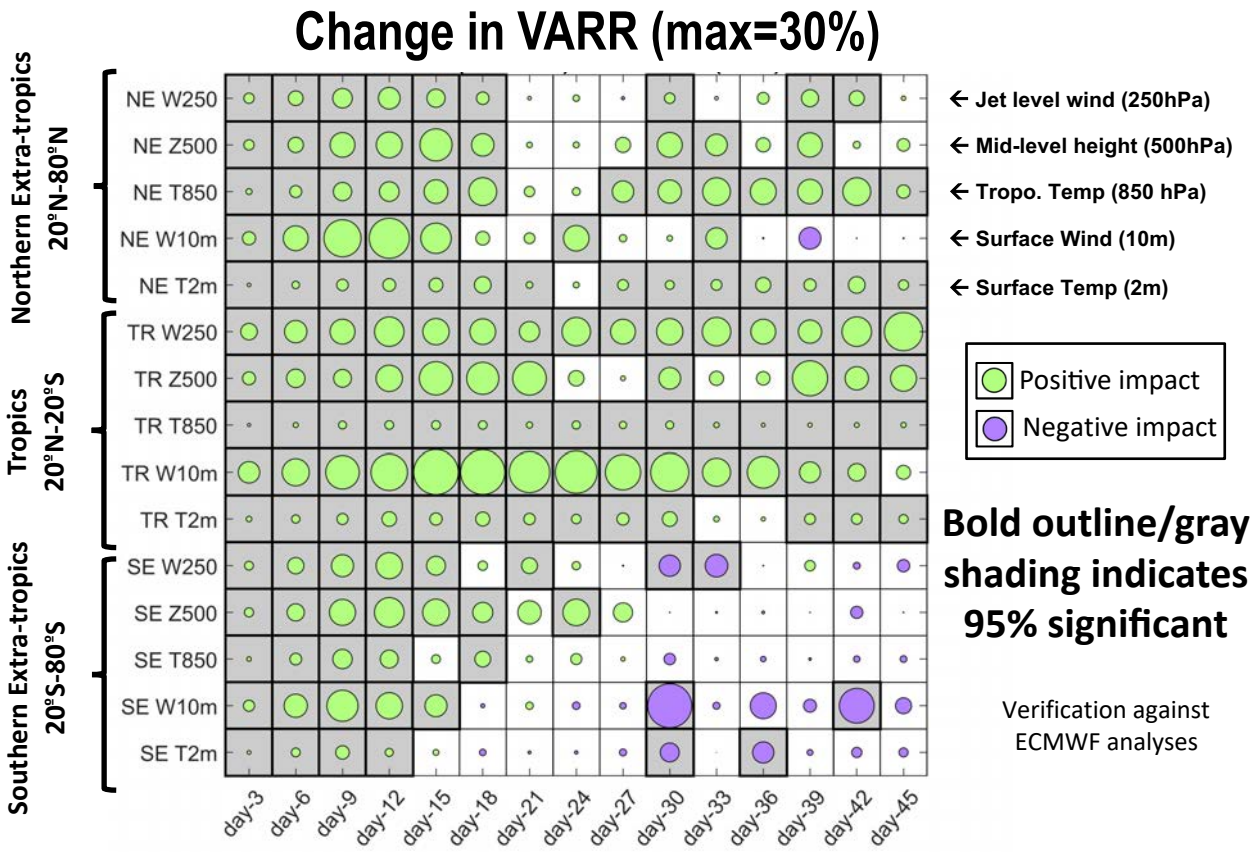
- **Though in Z500 (top-right) ACAI tends to over correct the bias at first causing the degradation in the scorecard**

*Crawford et al. In prep.*

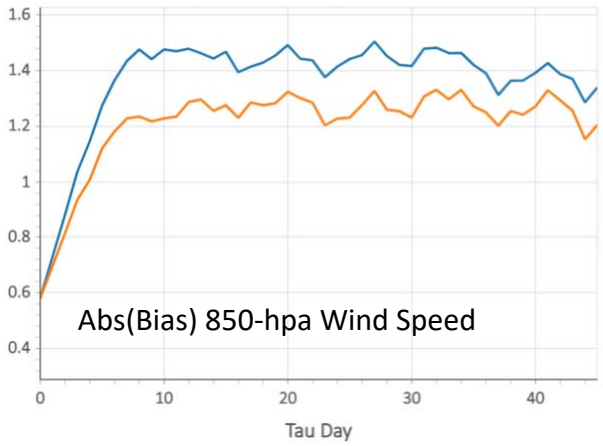
# Application to Navy ESPC Ensemble

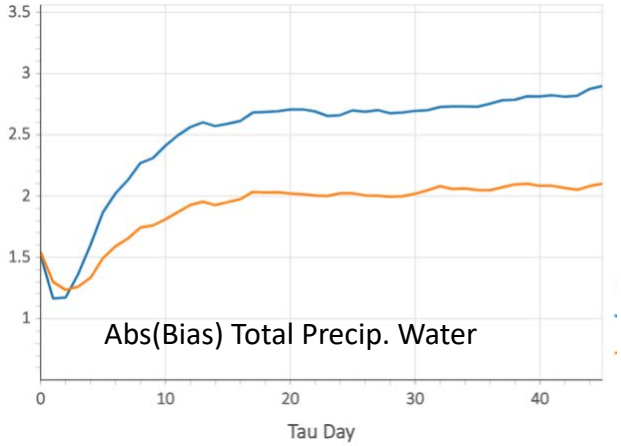
- Scorecard of spread-skill shows a near across the board improvement in first 3-weeks, with continued improvement in NE and TR out to 45 days
- Some neutral or degraded performance in southern extra-tropics at later leads

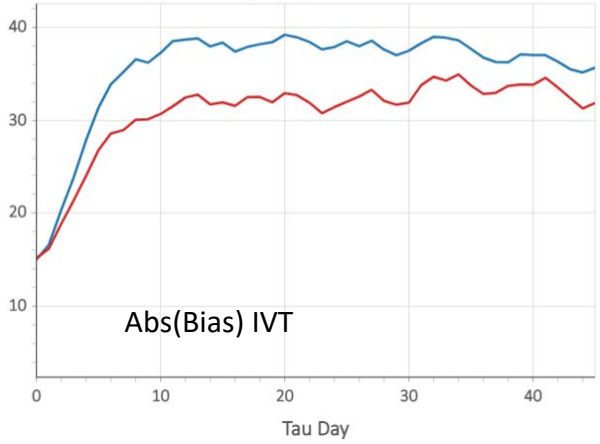



*Crawford et al. In prep.*

# Impact to Integrated Vapor Transport Bias



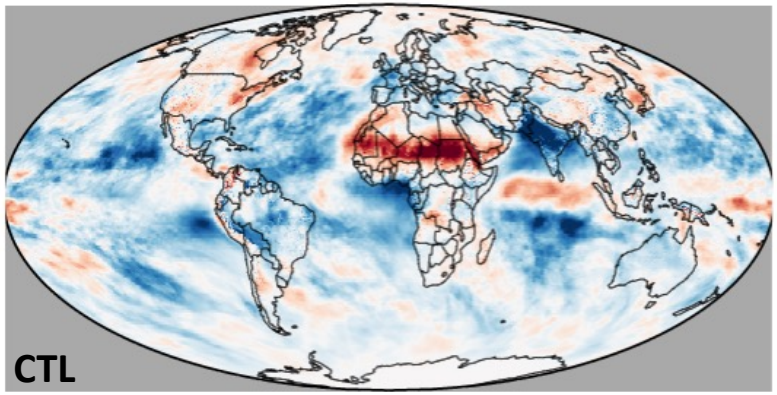



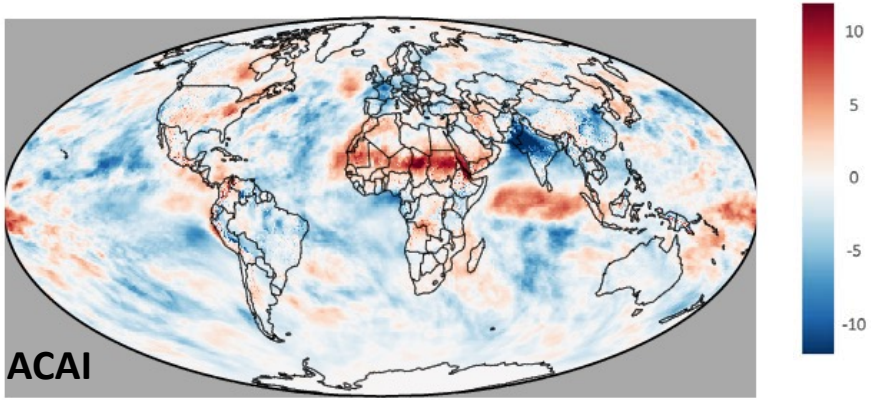

- **Top figures show the reduction of bias in wind speed and moisture by including ACAI in coupled forecasts.**
- **Results in a significant reduction of IVT bias (bottom)**

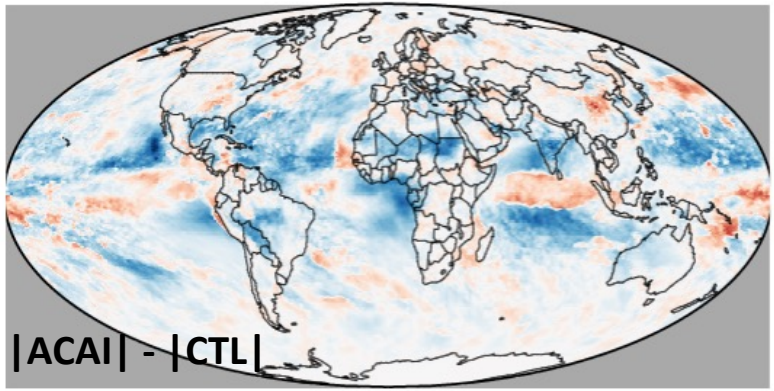
*Reynolds et. al., 2022 MWR*

# Impact to Integrated Vapor Transport Bias

JJA TPW Bias (mm) for 14-day Forecasts for CTL, ACAI, and |ACAI| - |CTL|



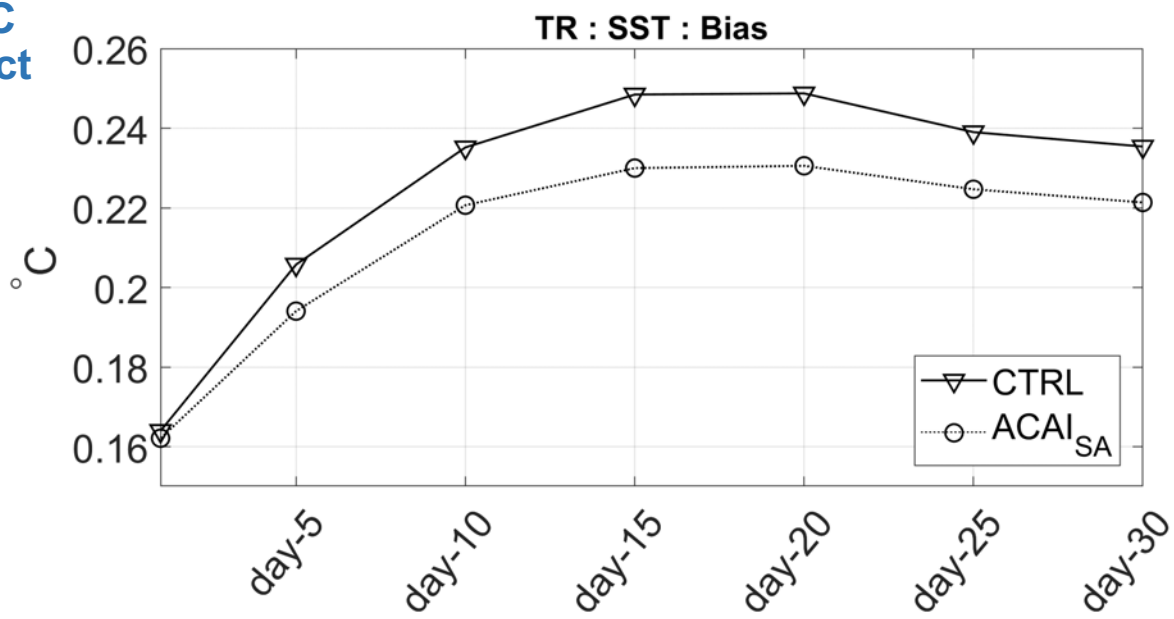

- **ACAI's reduction in positive TPW bias over Sahel and negative TPW bias over tropical Atlantic.**
- **In contrast, ACAI has little (slightly negative) impact over western-central tropical Pacific and tropical Indian Ocean.**

*Reynolds et. al., 2022 MWR*

# Impact to Ocean SST Bias

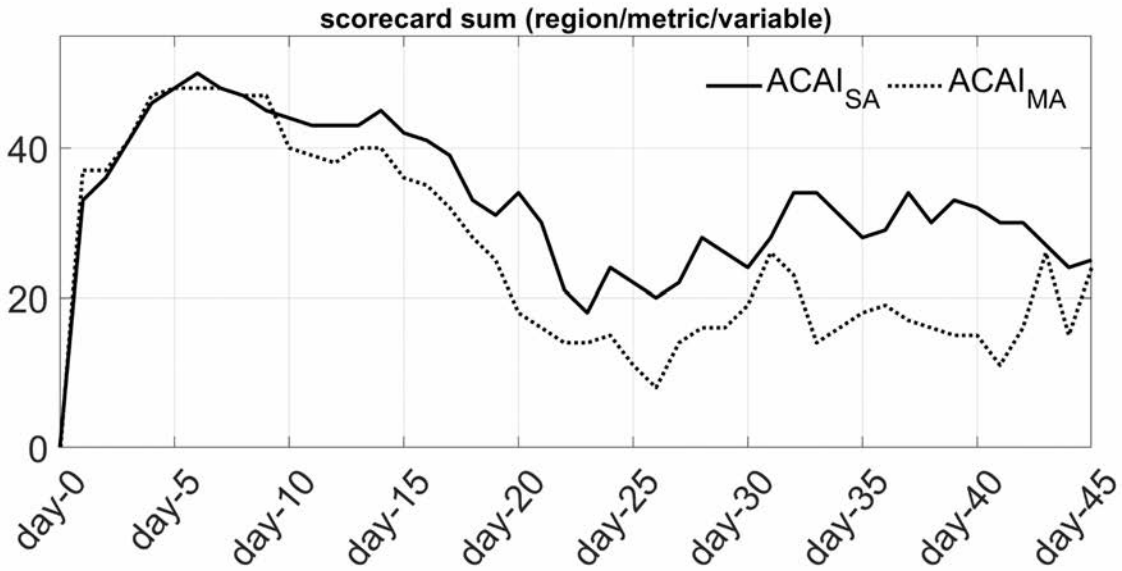
- **Hourly coupling in the Navy ESPC will allow cross-component impact of model error techniques**

- **Tropical SST biases are reduced by the application of the ACAI perturbation to the atmospheric component (NAVGEM)**




*Crawford et al. In prep.*

# Static vs. Moving Archive of Increments




- Have also explored the use of a moving archive (MA) of analysis corrections vs. a static archive (SA)
- Both methods present a significant improvement over the baseline system, but larger improvement from ACAI$_{SA}$ after ~week-2
- ACAI$_{MA}$ is beneficial in that one does not need to generate a new archive when upgrades are made to the DA or forecast system

*Crawford et al. In prep.*

# Thanks!