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Updates on the Navy Global Atmospheric Ensemble System

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Summary

- We are evaluating a new method to account for systematic and stochastic model error within our global atmospheric ensemble forecast system, NAVGEM
- The method uses analysis corrections from the data assimilation system to estimate model bias and as a representation of stochastic model error
- We refer to this method as analysis correction-based additive inflation (ACAI), Crawford et al. 2020, *MWR*.
- Will present results from two sets of experiments using different formulations of ACAI

Analysis Correction-based Additive Inflation (ACAI)

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

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

Multi-month average analysis correction; address bias same for all ensemble members

stochastic component; address ensemble spread randomly sampled from same 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 δx_m^F over each 6-hr period of the forecast

- Sample from an archive of analysis corrections from an independent year or trailing period

δx^a = analysis correction (or increment)

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

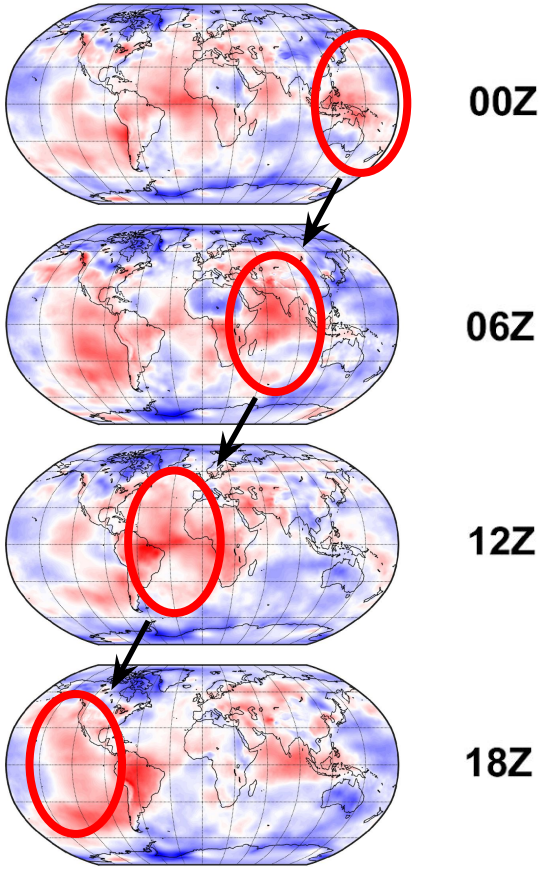
analysis - forecast

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

Structure of average analysis corrections

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

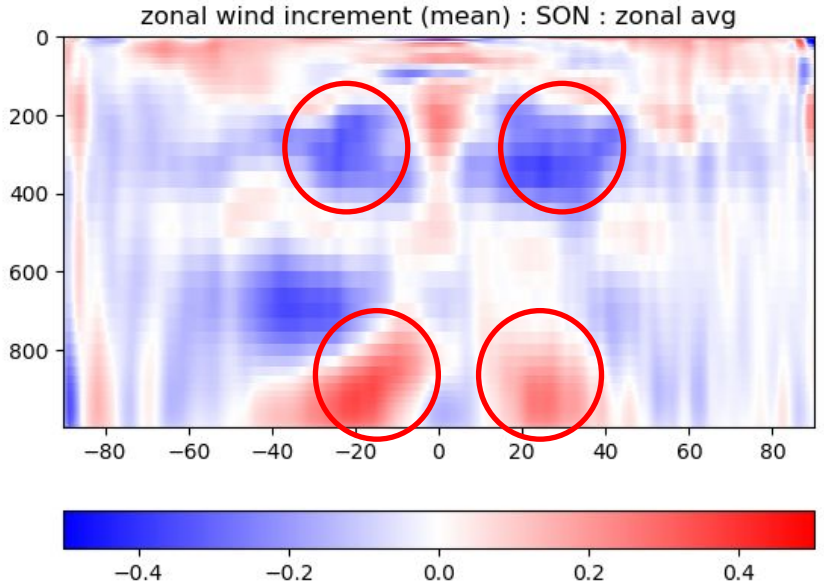
- Mean analysis corrections to surface pressure as a function of Z (right)
- Large dependence on time-of-day
- Average corrections show a clear migration westward between 00Z and 18Z
- We now use analysis corrections relative for the forecast time-of-day to produce the ACAI perturbations



Structure of average analysis corrections

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

- Zonal average of mean correction to u-wind
- Represents a systematic *reduction* in the magnitude of surface level trade winds and jet wind speed



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Experiments

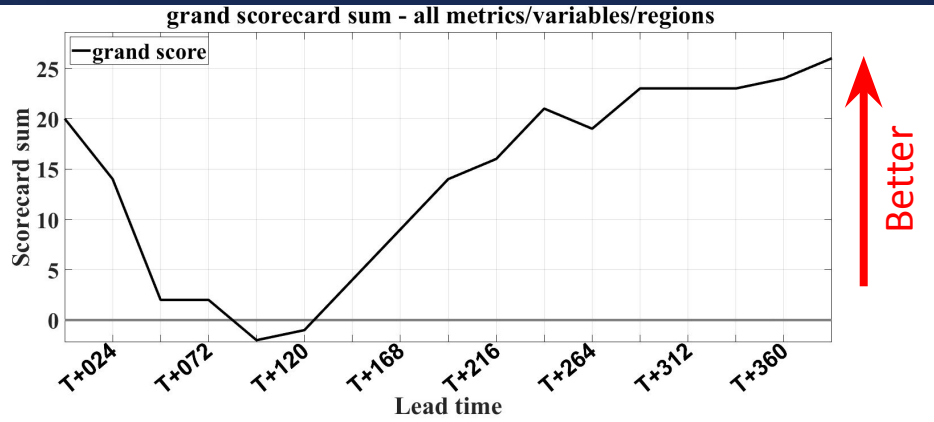
- All experiments run with an updated version of NAVGEM (v2.1); most notably an updated TLM/adjoint.

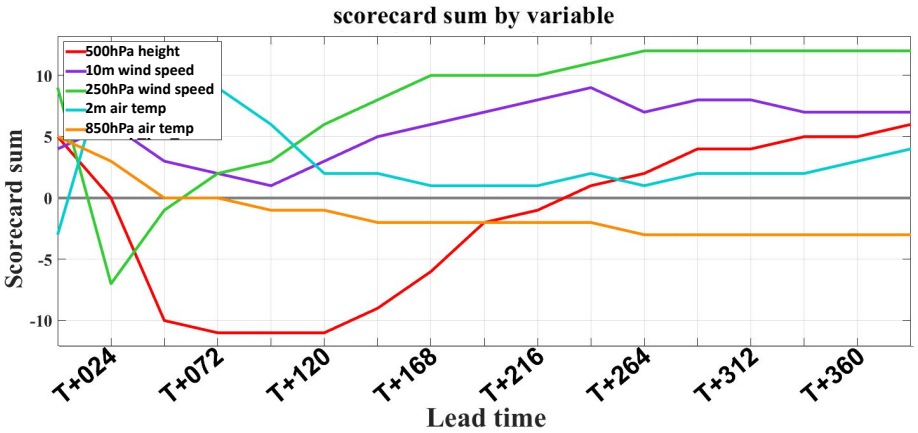
- Baseline simulation: T359 (37km) NAVGEM, 60 vertical levels
  - 20-member ensemble based on ET; 16-day forecast every 0Z and 12Z
  - One month of forecasts; January 1, 2021 - January 31, 2021
  - Ensemble centered on control analysis
  - Includes SKEB, No ACAI

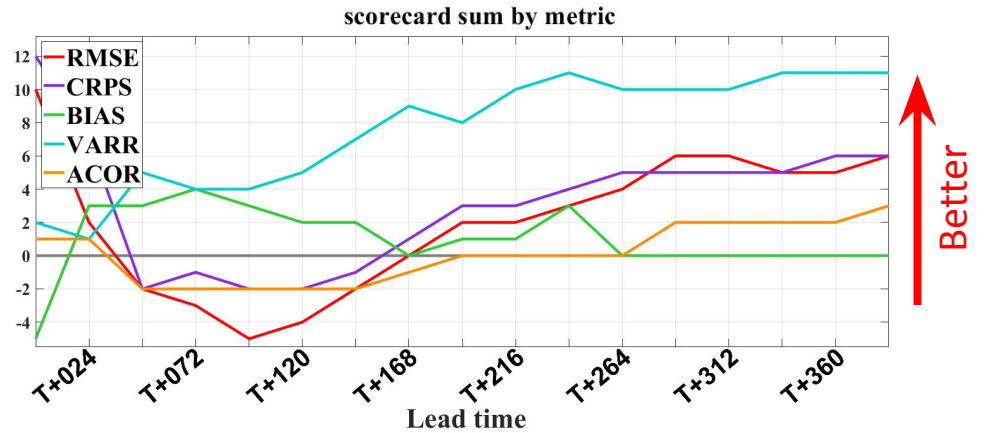
- ACAI experiments
  - $\delta x_m^F = \overline{\delta x^a} + \alpha\left[\delta x_m^a - \overline{\delta x_e^a}\right]$
  - ACAI Trailing Archive (TA)
    - Same as Control with ACAI using a trailing archive of analysis corrections from prior 60-days
    - $\overline{\delta x^a}$ computed over 60-day period prior to the day of the forecast
    - δx_m^a is randomly drawn for each member from the same period as used to compute $\overline{\delta x^a}$
  - ACAI Static Archive (SA)
    - Same as Baseline with ACAI using a static archive of analysis corrections from independent year
    - $\overline{\delta x^a}$ computed over 3-month period centered on day of the forecast
    - δx_m^a is randomly drawn for each member from the same 3-month period as used to compute $\overline{\delta x^a}$

Experiment comparison
Baseline vs. ACAI w/ Trailing Archive

- Comparison of the Baseline system to ACAI with trailing archive (ACAI-TA)
- Overall, considerably positive impact on baseline system (right)
- Some degradation of 500 hPa geop. ht. between tau-48 and tau-216 (bottom left)



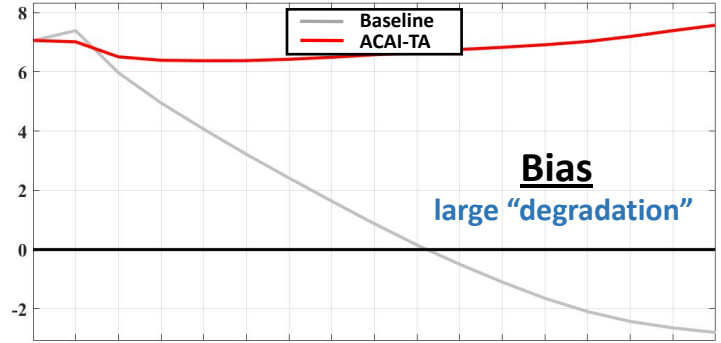


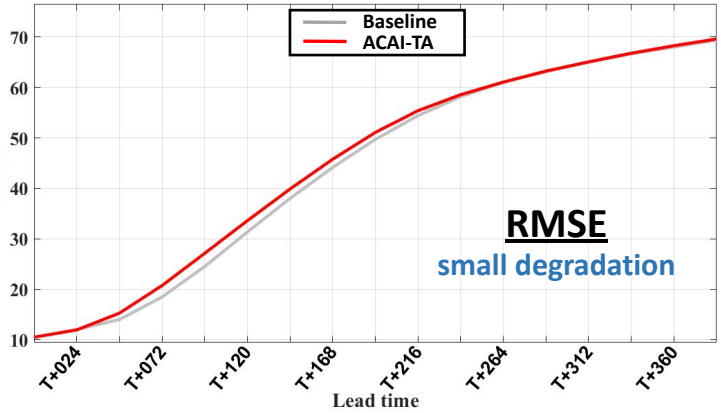


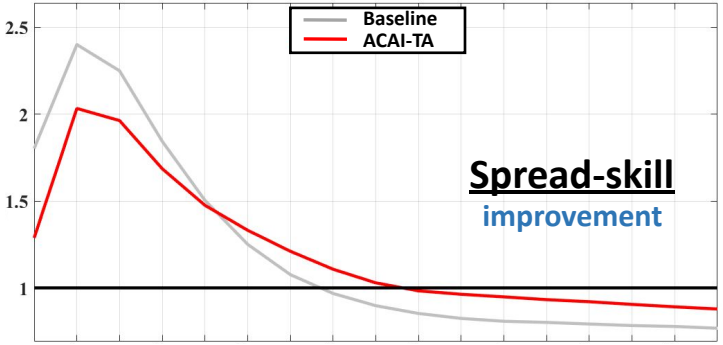
Experiment comparison
500 hPa performance

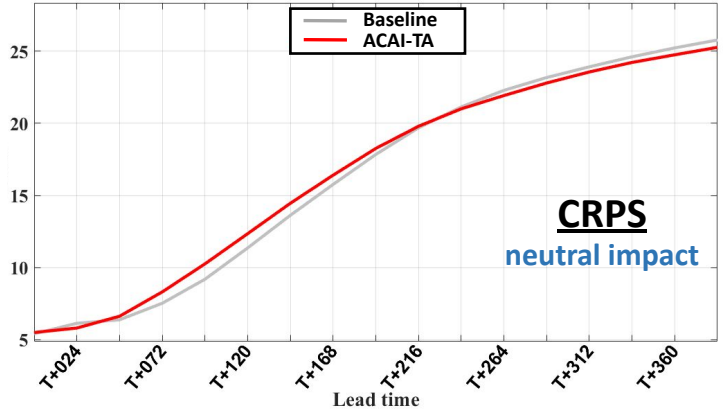
What causes degradation in 500hPa height on scorecard?

Mostly attributed to a stabilization of the bias (ACAI removes the negative trend; top left)



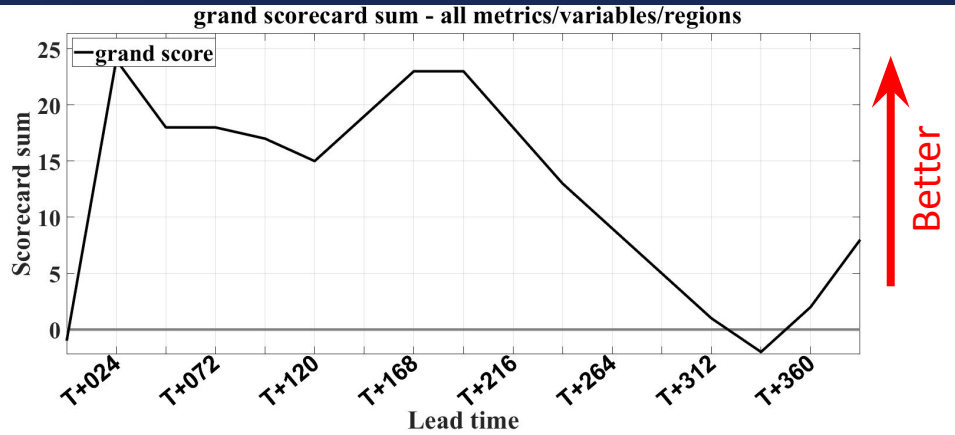


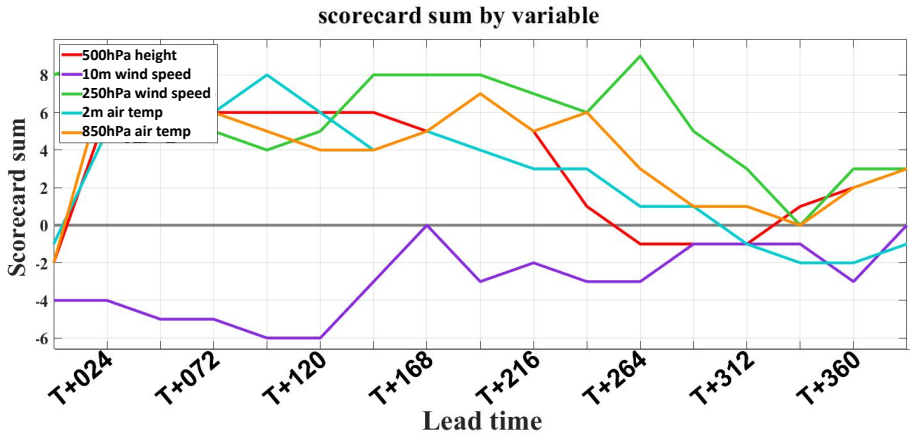


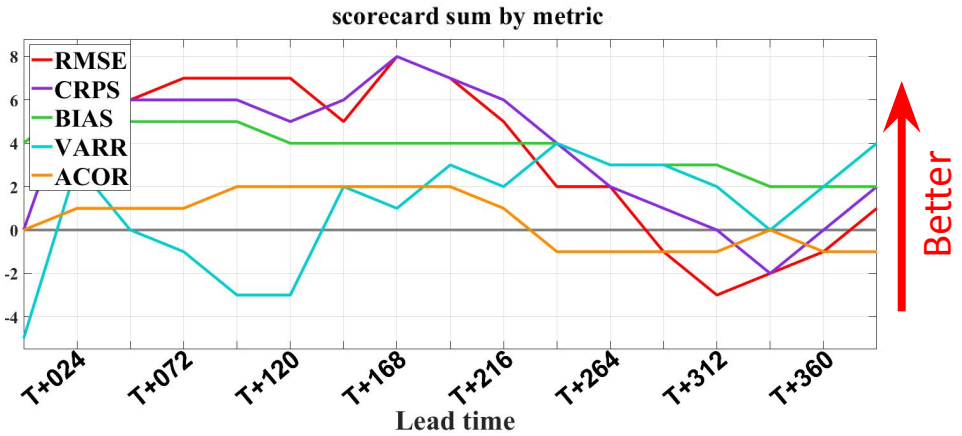


Experiment comparison
Static vs. Trailing Archive

- Comparison of ACAI with static archive vs trailing archive
- Static archive considerably outperforms trailing archive (right)
- However, we do see degradation in 10m wind speed. Most notably from tau-0 and tau-168 (bottom left)

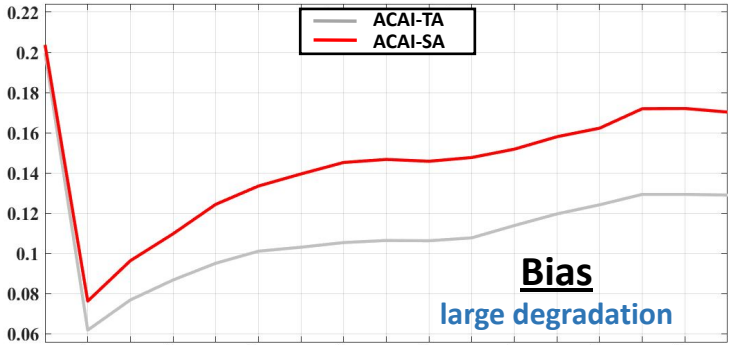


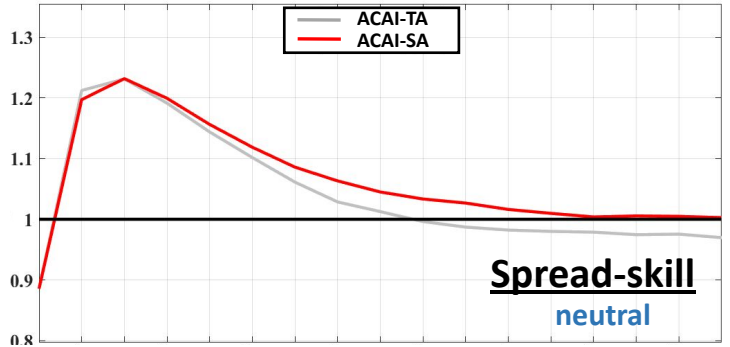


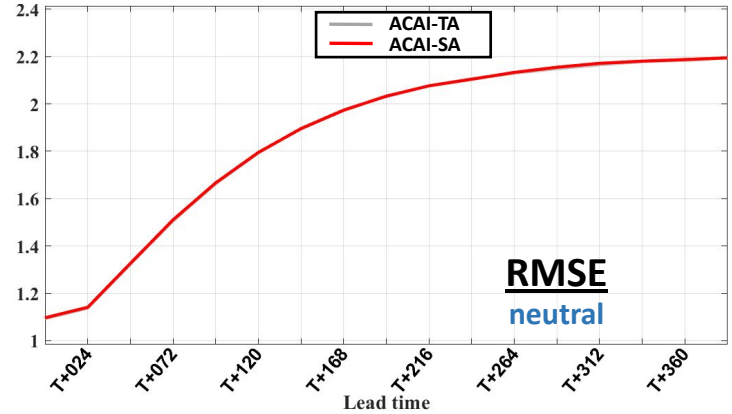


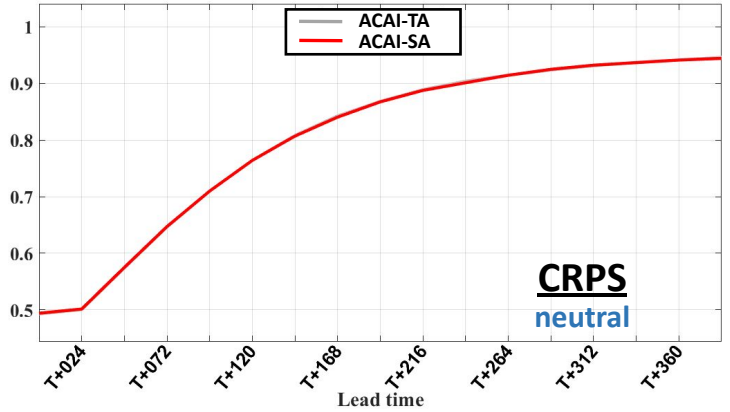
Experiment comparison
10m wind speed performance

Degradation in 10m wind speed driven mostly by increase in bias (top left), but also in a slight degradation in spread-skill (top right)



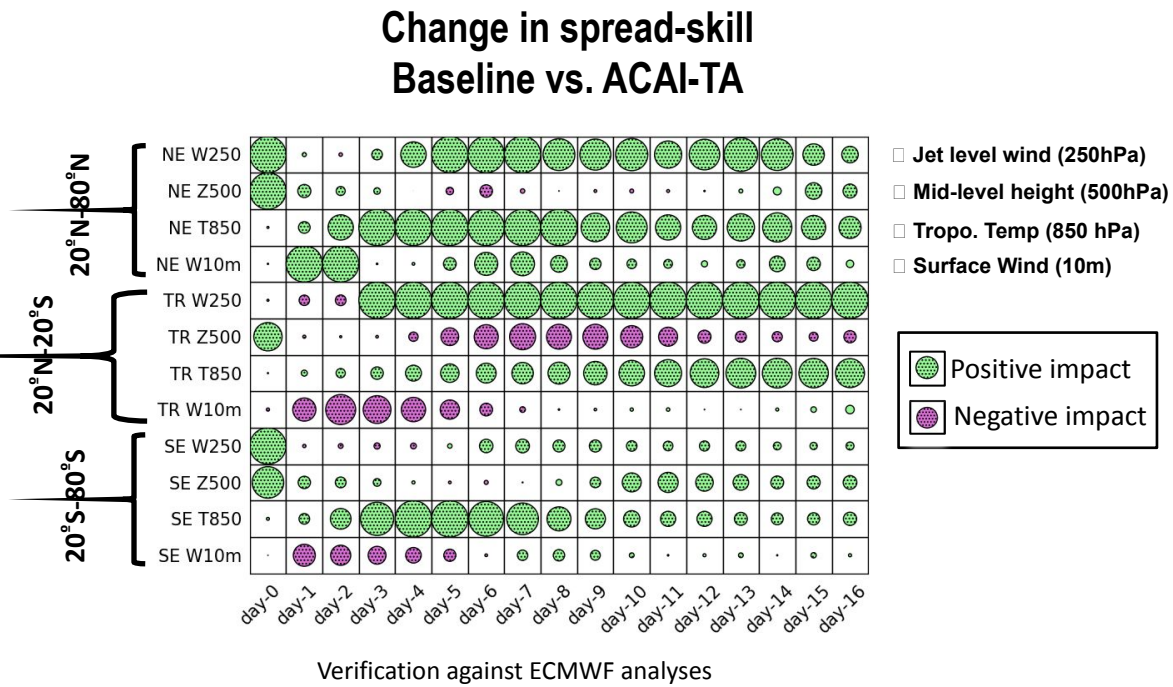






Experiment comparison spread-skill scorecard

- Scorecard of spread-skill (ratio of ensemble spread to ensemble mean squared error) separated by region and variable
- Shows a near across the board improvement beyond day-7
- Degradations driven mostly by ACAI making ensemble over-dispersive



Verification against ECMWF analyses

Conclusions

- Multi-month averages of analysis corrections capture interesting structures of model bias
- Using ACAI with a 60-day trailing archive of analysis corrections provides substantial improvement over the Baseline NAVGEM
- However, ACAI based on a static archive of analysis corrections outperforms the trailing archive formulation
- This may be due to the static formulation using a centered mean with a more robust representation of the seasonal average.
- ACAI provides particularly good improvement to ensemble spread-skill
- Hope to transition updates to the operational ensemble later this year.