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U. S. Navy Earth System Prediction Capability (ESPC) Global Coupled Subseasonal Forecast System: Overview and Impacts of Including Analysis Correction-based Additive Inflation (ACAI)

U. S. Navy Earth System Prediction Capability Team (Marine Meteorology, Ocean Sciences, Remote Sensing, and Space Science Divisions)

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Ensemble ESPC: V1 vs V2

ESPC Version Number	Time Scale, Frequency	Atmosphere NAVGEM	Ocean HYCOM	Sea Ice CICE	Waves[1] WW3	Land Surface LSM	Aerosol[2]
V1	0-45 days weekly 16 members	T359L60 (37 km) 60 levels	1/12° (9 km)[3] 41 layers	1/12° (3.5 km)[4] CICE V4		Module within NAVGEM	
V2	0-45 days (2x) weekly 16 members[5]	T681L100 (19 km) L143 HA	1/12° (9 km)[3] 41 layers Tides	1/12° (3.5 km)[4] CICE V6	1/4° (28 km)	Module within NAVGEM	Module within NAVGEM

[1] One-way coupling to waves only.

[2] Atmosphere-aerosol coupling only.

[3] Horizontal resolution at the equator.

[4] Horizontal resolution at the North Pole.

[5] The exact configuration determined by operational resources available.

Navy ESPC V1 Description: Barton, N., et al. 2020: The Navy's Earth System Prediction Capability. Earth and Space Science. e2020EA001199. doi.org/10.1029/2020EA001199

- **Goal: decrease model bias and improve spread-skill**

- 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 δx_m^F over each 6-hr period of the forecast**

- **Use a 1-year archive of analysis corrections from the weakly coupled DA system**

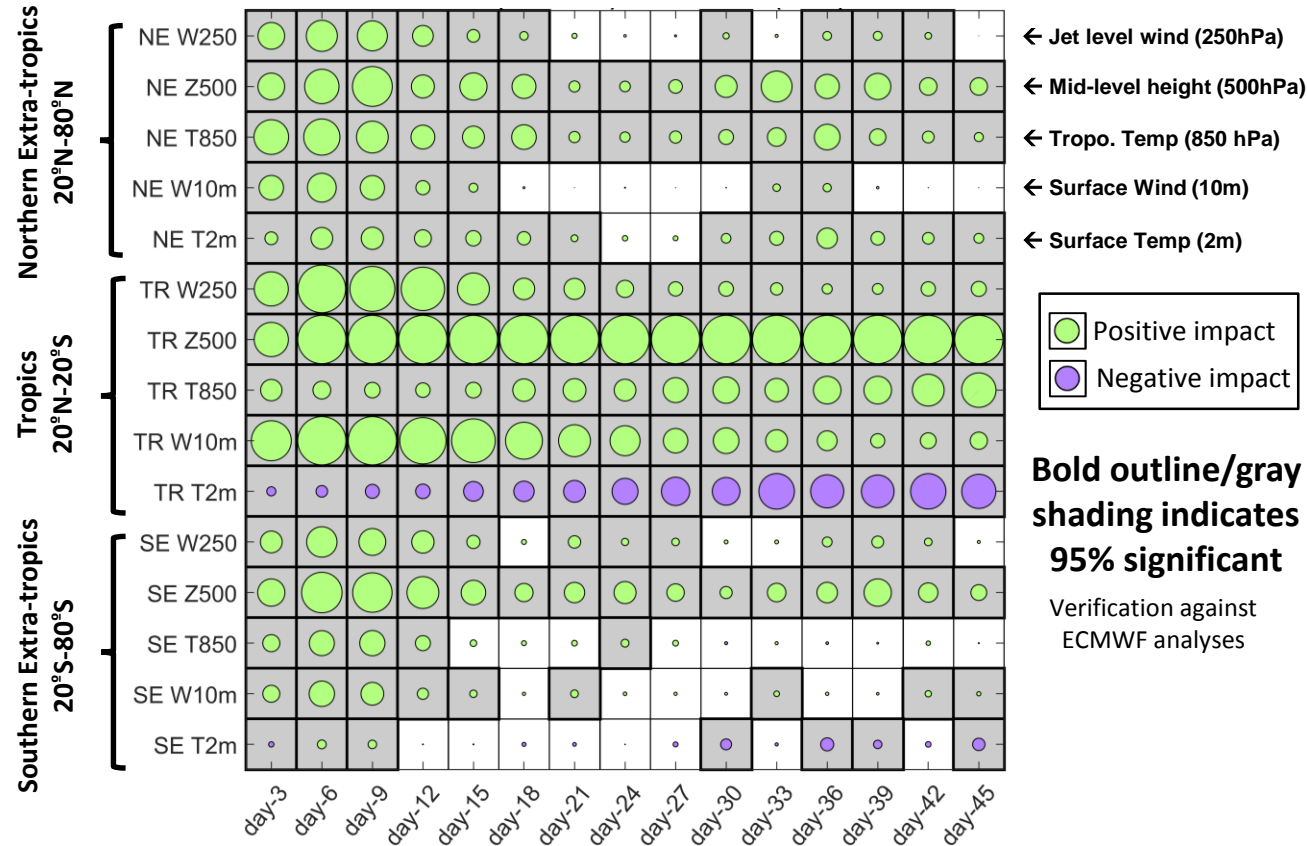- **What do the $\overline{\delta x^a}$ (or bias) terms look like (extra slide)?**

δx^a = analysis correction (or increment)
$$\delta x^a = x^a - x^f$$
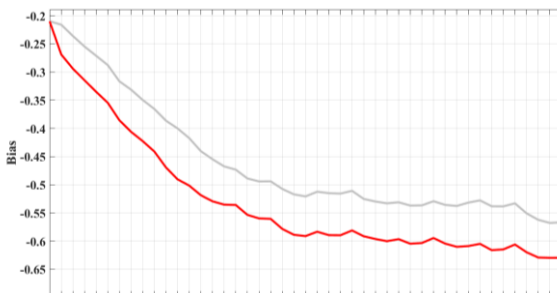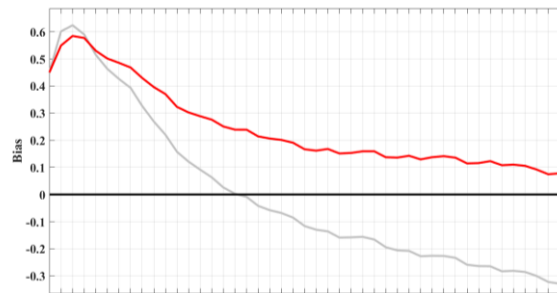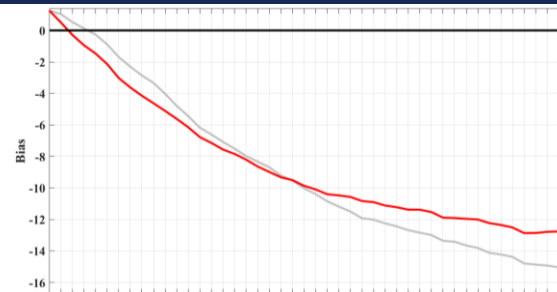analysis - forecast

Crawford et al., 2020 (Similar to Bowler et al., 2017)

- **Similar improvement to CRPS, though we do see more positive impact to the extra-tropics**

- **Largest impact in tropics, especially 500mb height**

- **Oddly, tropical 2m air temp is degraded**

Change in CRPS (max=10%)

← Jet level wind (250hPa)
← Mid-level height (500hPa)
← Tropo. Temp (850 hPa)
← Surface Wind (10m)
← Surface Temp (2m)

Positive impact
Negative impact

Bold outline/gray shading indicates 95% significant

Verification against ECMWF analyses

Crawford et al., in prep

Change in Bias (max=30%)

Baseline
ACAI

Crawford et al., in prep

Summary
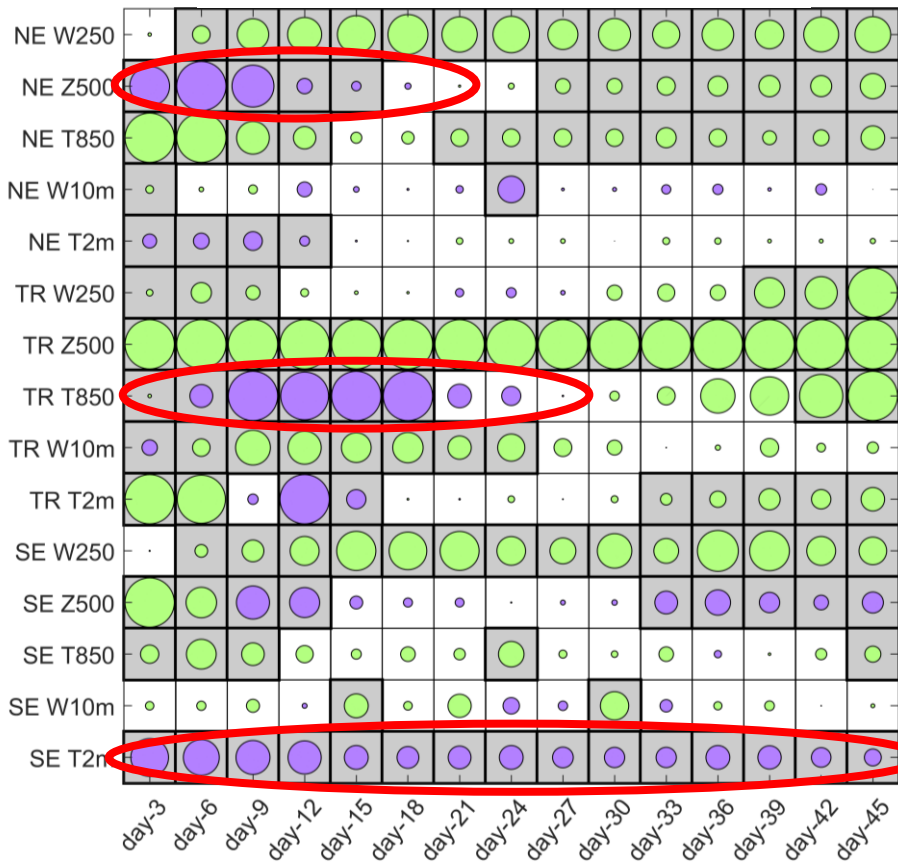
- We have implemented analysis correction-based additive inflation (ACAI) in Navy ESPC to address model error during forecast integrations, under consideration for transition to operations.

- ACAI presents substantial improvement for many standard skill metrics out to 45-days using both a static and moving archive of analysis corrections

- We also see improvement by including SKEB in the coupled system and hope the two methods (ACAI and SKEB) will prove additive in their benefits

- In addition to standard skill metrics, we see improvement to moist processes including total precipitable water and MJO biases

- Some issues remain to be sorted out (enhanced SST biases in some regions).

- **Large dependence on time-of-day in the structure of the average analysis corrections**

- **Average corrections to pressure and temperature show a clear migration westward between 00Z and 18Z**

- **In ACAI we use analysis corrections relative for the forecast time-of-day to produce the perturbations**

Crawford et al., 2020

Impact of ACAI on coupled ensemble
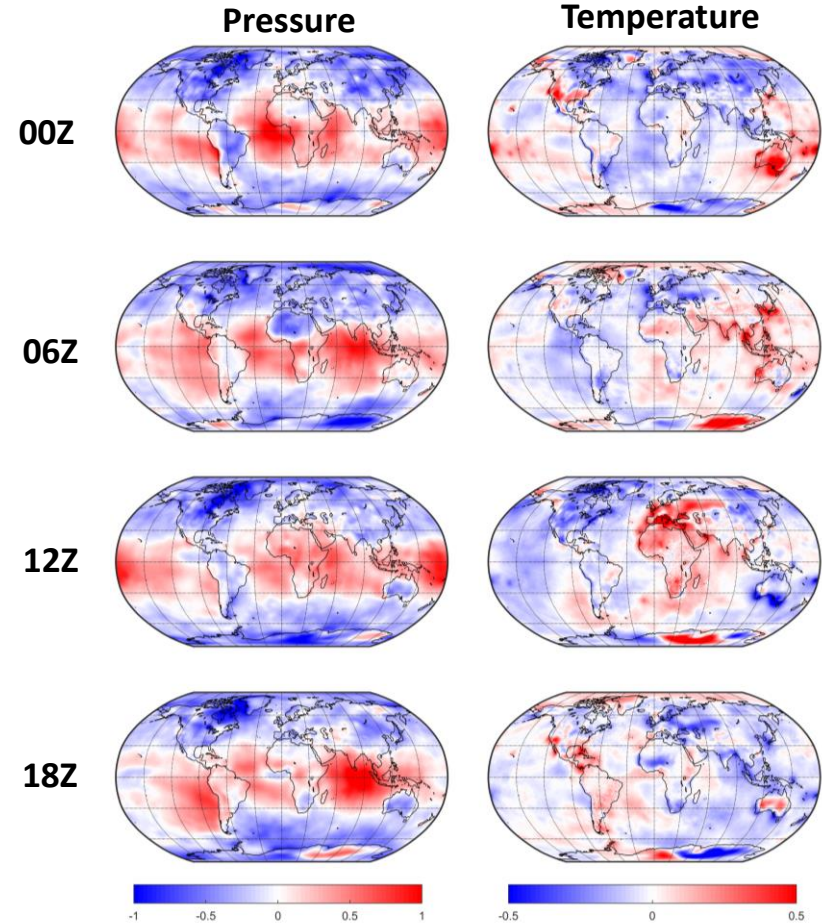
- **Almost across the board improvement to RMSE**

- **Largest impact in tropics, especially 500mb height**

Crawford et al., in prep

Change in spread-skill (30%)
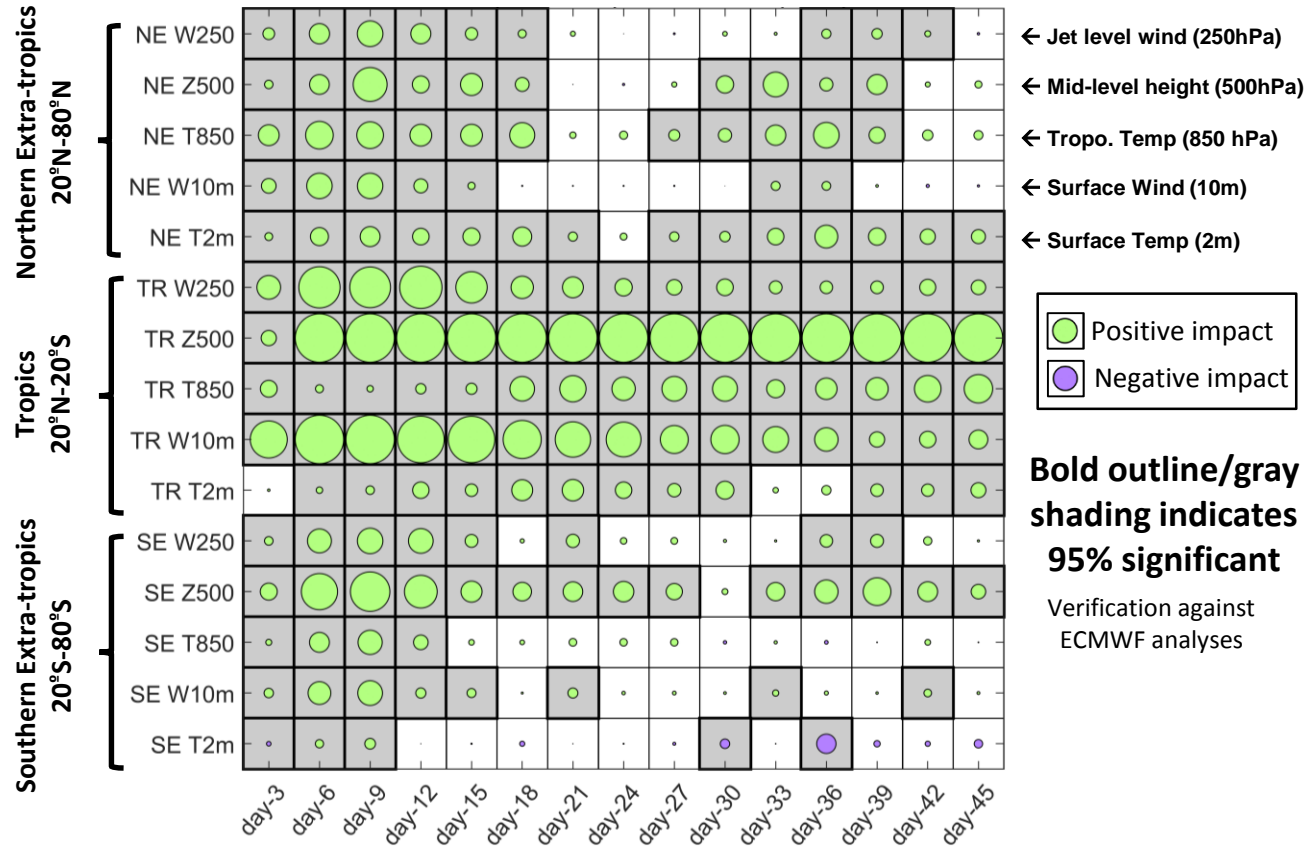
- **Scorecard presenting changes to baseline (v1) system by applying ACAI**
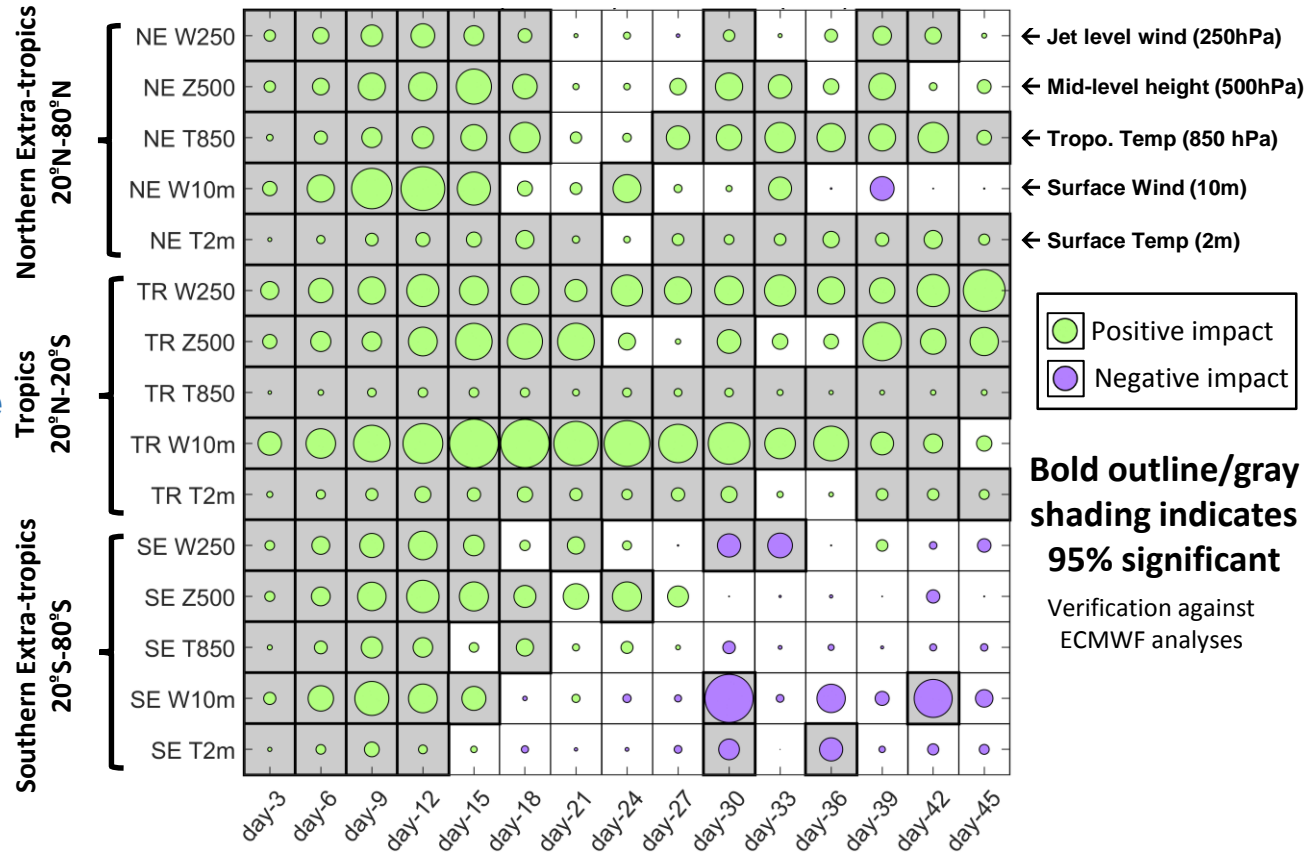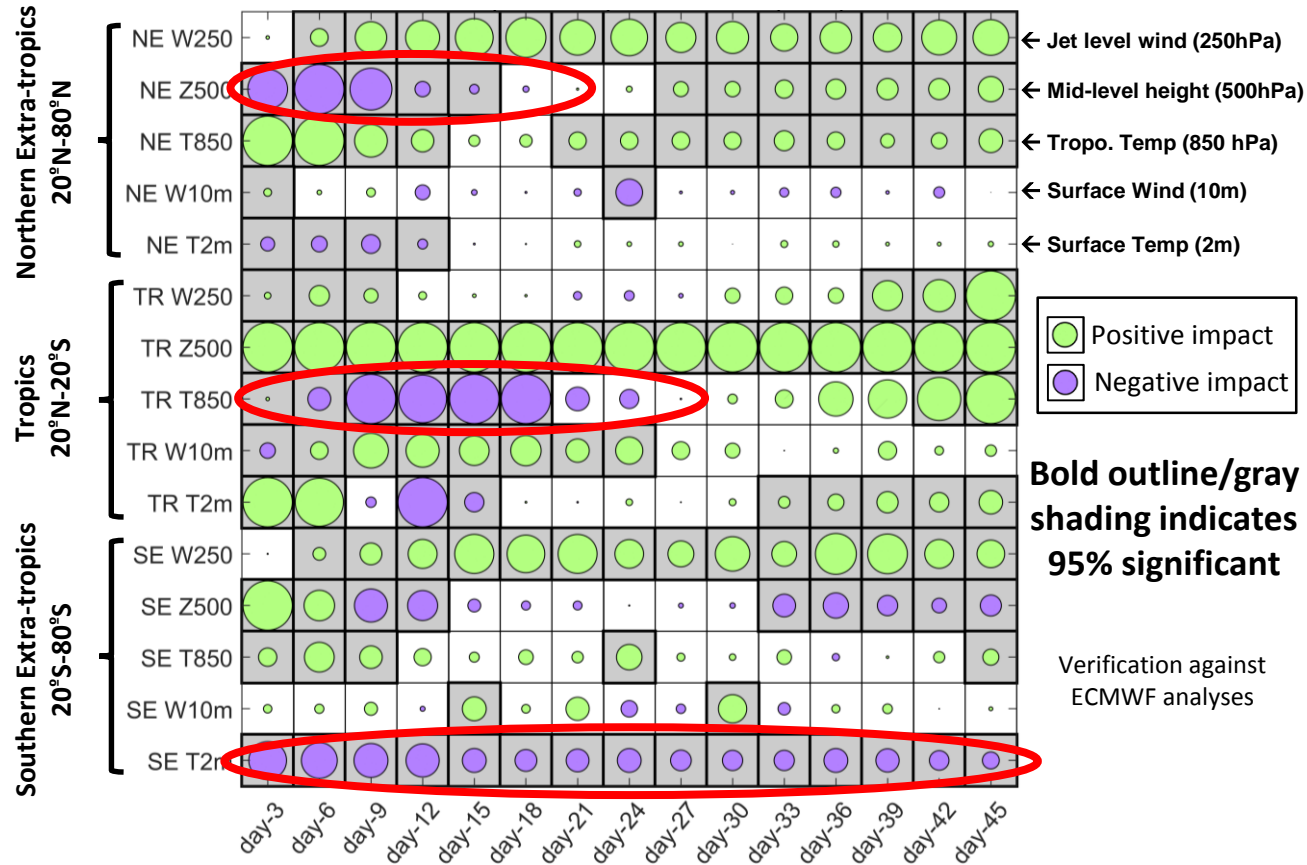
- **Changes in spread-skill (ratio of ensemble mean squared error to ensemble spread)**

- **Substantial improvement to NE and tropics; neutral impacts to SE at later lead times**

Legend:
- Green: Positive impact
- Purple: Negative impact

Bold outline/gray shading indicates 95% significant

Verification against ECMWF analyses

Row labels (left axis):
- Northern Extra-tropics 20°N-80°N: NE W250, NE Z500, NE T850, NE W10m, NE T2m
- Tropics 20°N-20°S: TR W250, TR Z500, TR T850, TR W10m, TR T2m
- Southern Extra-tropics 20°S-80°S: SE W250, SE Z500, SE T850, SE W10m, SE T2m

Right axis labels:
← Jet level wind (250hPa)
← Mid-level height (500hPa)
← Tropo. Temp (850 hPa)
← Surface Wind (10m)
← Surface Temp (2m)

X-axis: day-3, day-6, day-9, day-12, day-15, day-18, day-21, day-24, day-27, day-30, day-33, day-36, day-39, day-42, day-45

Crawford et al., in prep

Change in Bias (max=30%)

- **Scorecard presenting changes to baseline (v1) system by applying ACAI**

- **Scorecards highlight 5 variables in 3 regions**

- **Substantial improvement to the bias of many variables out to 45-days**

Jet level wind (250hPa)
Mid-level height (500hPa)
Tropo. Temp (850 hPa)
Surface Wind (10m)
Surface Temp (2m)

Positive impact
Negative impact

Bold outline/gray shading indicates 95% significant

Verification against ECMWF analyses

Crawford et al., in prep