Diagnosing Sources of Forecast Model Errors in Tropical-Extratropical Interactions

Juliana Dias,
G. Kiladis, M. Gehne and S. Tulich
It is well known that tropical weather and climate influence extra-tropical weather and climate.

The details of the wave patterns and their paths depend on interactions between the horizontal and vertical distribution of the tropical heat source due to precipitation and the large-scale basic state flow. [Sardeshmukh and Hoskins 1988; Grimm and Silva Dias 1995; Newman and Sardeshmukh 1998, Branstator 2014]


Do extra-tropical forecasts draw skill from the tropics?
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Relaxation types of experiments* have shown that a reduction of tropical forecast errors improves medium to extended range skill scores particularly over the North Pacific, North America, and the North Atlantic.

Blue shading indicates regions where forecast errors are reduced when nudging SST to observations (middle row) and nudging the tropics to analysis (bottom row).


Do extra-tropical forecasts draw skill from the tropics? Yes...

Relaxation types of experiments have shown that a reduction of tropical forecast errors improves medium to extended range skill scores particularly over the North Pacific, North America, and the North Atlantic.


Blue shading indicates regions where forecast errors are reduced when nudging SST to observations (middle row) and nudging the tropics to analysis (bottom row)
But, short to medium range forecasts tend to be worse in lower latitudes

Are current tropical forecasts good enough for the extratropics to draw this skill? What are the sources of model errors that influence the midlatitude response to tropical forecasts?

* Figure from Dias et al. 2018: *Equatorial waves and the skill of NCEP and ECMWF numerical weather prediction systems*
Diagnostics of S2S precipitation reforecasts with global verification against TRMM to address the following two questions:

- To what extent are N.H. medium to extended range forecasts associated to tropical skill at earlier lead times?
- Is this relationship mediated by the MJO and or other tropical phenomena?
Why NCEP and ECMWF systems in particular?

Conditional skill analysis: to what extent are N.H. forecasts associated to tropical skill at earlier lead times?

To look at conditional skill we chose dates where tropical skill is above/below model specific thresholds at each lead time
Conditional skill analysis

(a) Tropics (10°S-10°N)

(b) 2d2d QPF skill distribution (10°S-10°N)

"poor" forecast days

"good" forecast days

0.1 0.2 0.3 0.4 0.5 0.6 0.7
APC

NCEP x TRMM
ECMWF x TRMM

Q_l Q_l Q_u Q_u
Conditional skill: Tropics (10°S-10°N) - 1d1d

(a) Tropical APC

![Graph showing tropical APC with labels for good and poor 1d1d tropical forecast]
Conditional skill: Tropics (10°S-10°N) - 1d1d

(a) Tropical APC

(b) N.H. APC

ECMWF $\langle \text{APC} \mid \text{Qu}_{1\text{d1d} - 30\text{N}-50\text{N}} \rangle / \langle \text{APC} \rangle$

ECMWF $\langle \text{APC} \mid \text{QI}_{1\text{d1d} - 30\text{N}-50\text{N}} \rangle / \langle \text{APC} \rangle$

NCEP $\langle \text{APC} \mid \text{Qu}_{1\text{d1d} - 30\text{N}-50\text{N}} \rangle / \langle \text{APC} \rangle$

NCEP $\langle \text{APC} \mid \text{QI}_{1\text{d1d} - 30\text{N}-50\text{N}} \rangle / \langle \text{APC} \rangle$
Conditional skill: N.H (30°N-50°N) - 1d1d

(a) Tropical APC
- good 1d1d NH forecast
- poor 1d1d NH forecast

(b) N.H. APC
- good 1d1d NH forecast
- poor 1d1d NH forecast

- ECMWF \( \langle \text{APC} \mid \text{Qu}_{1d1d-10S-10N} \rangle \) / \( \langle \text{APC} \rangle \)
- ECMWF \( \langle \text{APC} \mid \text{Ql}_{1d1d-10S-10N} \rangle \) / \( \langle \text{APC} \rangle \)
- NCEP \( \langle \text{APC} \mid \text{Qu}_{1d1d-10S-10N} \rangle \) / \( \langle \text{APC} \rangle \)
- NCEP \( \langle \text{APC} \mid \text{Ql}_{1d1d-10S-10N} \rangle \) / \( \langle \text{APC} \rangle \)
Conditional skill: Tropics (10°S-10°N) - 1d1d

(a) Tropical APC

(b) N.H. APC

- ECMWF $\langle APC | Qu_{1d1d - 30N-50N} \rangle / \langle APC \rangle$
- ECMWF $\langle APC | Qi_{1d1d - 30N-50N} \rangle / \langle APC \rangle$
- NCEP $\langle APC | Qu_{1d1d - 30N-50N} \rangle / \langle APC \rangle$
- NCEP $\langle APC | Qi_{1d1d - 30N-50N} \rangle / \langle APC \rangle$
Conditional skill: Tropics (10°S-10°N) - 2d2d

(a) Tropical APC

- good 2d2d tropical forecast

- poor 2d2d tropical forecast

(b) N.H. APC

- ECMWF \( \langle APC | Qu_{2d2d - 10S-10N} \rangle / \langle APC \rangle \)
- ECMWF \( \langle APC | Qi_{2d2d - 10S-10N} \rangle / \langle APC \rangle \)
- NCEP \( \langle APC | Qu_{2d2d - 10S-10N} \rangle / \langle APC \rangle \)
- NCEP \( \langle APC | Qi_{2d2d - 10S-10N} \rangle / \langle APC \rangle \)
In both systems, a better (worse) tropical short range forecast is associated with better (worse) N.H. week 1 and beyond skill, but the NCEP conditional skill is more sensitive.
Does tropical-extratropical conditional skill depend on the tropical initial state?

- **El Niño** years are associated with higher tropical anomaly pattern correlation

- **MJO** also modulates tropical anomaly pattern correlation

*Fig. shows box plot of 2d2d precipitation APC*
Does tropical-extratropical conditional skill depend on the MJO?

○ The MJO is weak in the NCEP model
○ ECMWF subseasonal variability is overall in better agreement with observations

Figure from Janiga, M.A. et al, 2018: Subseasonal Forecasts of Convectively Coupled Equatorial Waves and the MJO: Activity and Predictive Skill. MWR.

○ Is the conditional skill sensitive to the MJO?
○ Does it matter if the system can produce an MJO?
Does tropical-extratropical conditional skill depend on the tropical initial state?

- The timing of the changes in the NCEP N.H conditional skill is not sensitive to the MJO, but the amplitude is.
- In contrast, there is a shift in the timing of the ECMWF N.H conditional skill (week 2 -> week 3-4)

*Active/Inactive based on the OMI index amplitude*
Does tropical-extratropical conditional skill depend on the tropical initial state?

(a) Active MJO*

(b) Inactive MJO*

* Active/Inactive based on the OMI index amplitude
Does tropical-extratropical conditional skill depend on the tropical initial state?

- MJO initial state affects the amplitude of the NCEP ratios, but not the timing;
- ECMWF ratio peaks at week 3-4 when week 1 tropical forecast is good;
- ECMWF longer lead time N. H. conditional forecasts are more sensitive to week 1 tropical skill when the MJO is inactive;
Are tropical waves (e.g. Kelvin Waves, easterly waves) sources of deterministic <week 1 predictability?

Tropical-extratropical QPF skill relationship might depend on other tropical processes

~65% of “good” 2d2d forecast days are associated with active MJO or El Niño

- Are tropical waves (e.g. Kelvin Waves, easterly waves) sources of deterministic <week 1 predictability?
Summary:

○ NCEP N.H forecasts tend to be more sensitive to short to medium range tropical skill than the ECMWF;

○ The pickup in N.H. skill depending on <week1 tropical skill occurs during inactive MJO periods and also neutral ENSO conditions, suggesting that other tropical processes (e.g. easterly waves, Kelvin Waves) are also important.

Conclusions

○ The imprint of tropical processes in conditional skill might be a useful diagnostics tool to characterize sources and propagation of tropical forecast errors;

○ Aside from looking at other models, precipitation forecast skill is a high bar for testing model performance. Some initial testing shows that northern hemisphere z500 and upper level winds skill are also increased depending on tropical precipitation skill.