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.

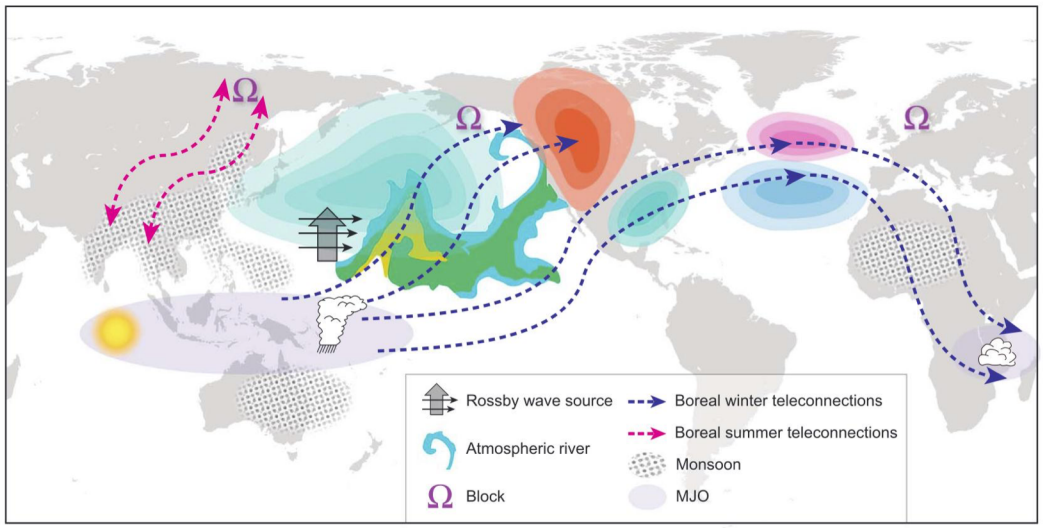

Figure: Schematic of tropical-NH interactions from ***Stan, C. et al. (2017).*** *Review of tropical-extratropical teleconnections on intraseasonal time scales. Rev. of Geoph., 55, 902–937.*

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.

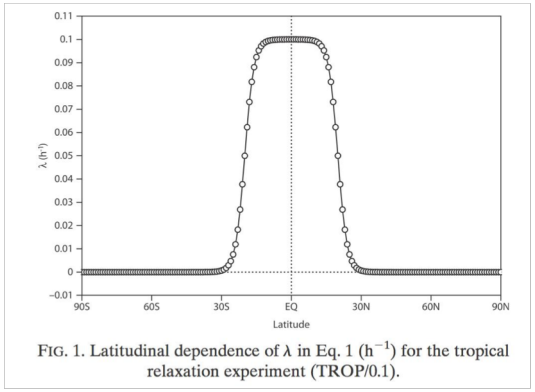


FIG. 1. Latitudinal dependence of λ in Eq. 1 (h^{-1}) for the tropical relaxation experiment (TROP/0.1).

[*Haseler 1982, Klinker 1990, Ferranti et al 1990, Jung et al. 2010a, Hansen et al. 2016]

Figures from Jung, T. et al., 2010: Diagnosing the Origin of Extended-Range Forecast Errors. Mon. Wea. Rev.

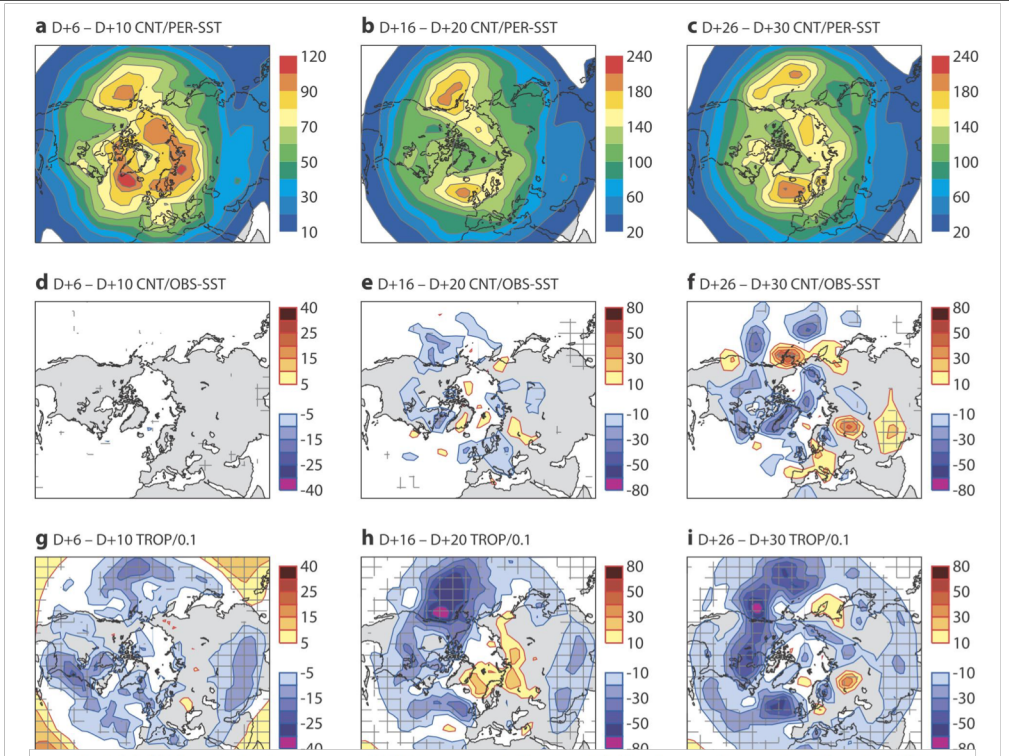
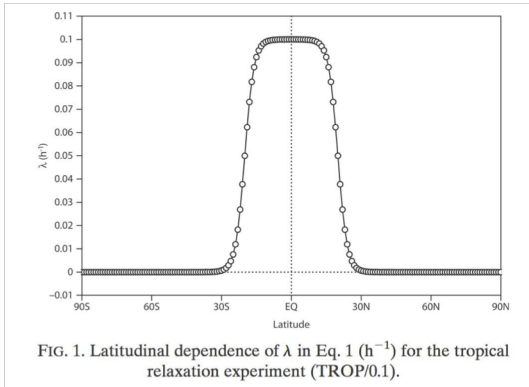


FIG. 6. (a)–(c) Mean absolute forecast error of 500-hPa geopotential height field (m) for the control integration with persisted SST/sea ice (CNT-PER). (d)–(f) Difference in mean absolute forecast error for Z500 between the control integration with observed (CNT-OBS) and persisted (CNT-PER) SST/sea ice. (g)–(i) As in (d)–(f), but for the difference between TROP/0.1 and CNT-PER. (j)–(l) As in (d)–(f), but for the difference between NH-S/0.1 and CNT-PER. Results are shown for 5-day-averaged data: (left) D+6 to D+10, (middle) D+16 to D+20, and (right) D+26 to D+30. Differences significant at the 95% confidence level (two-sided *t* test) are hatched.

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.



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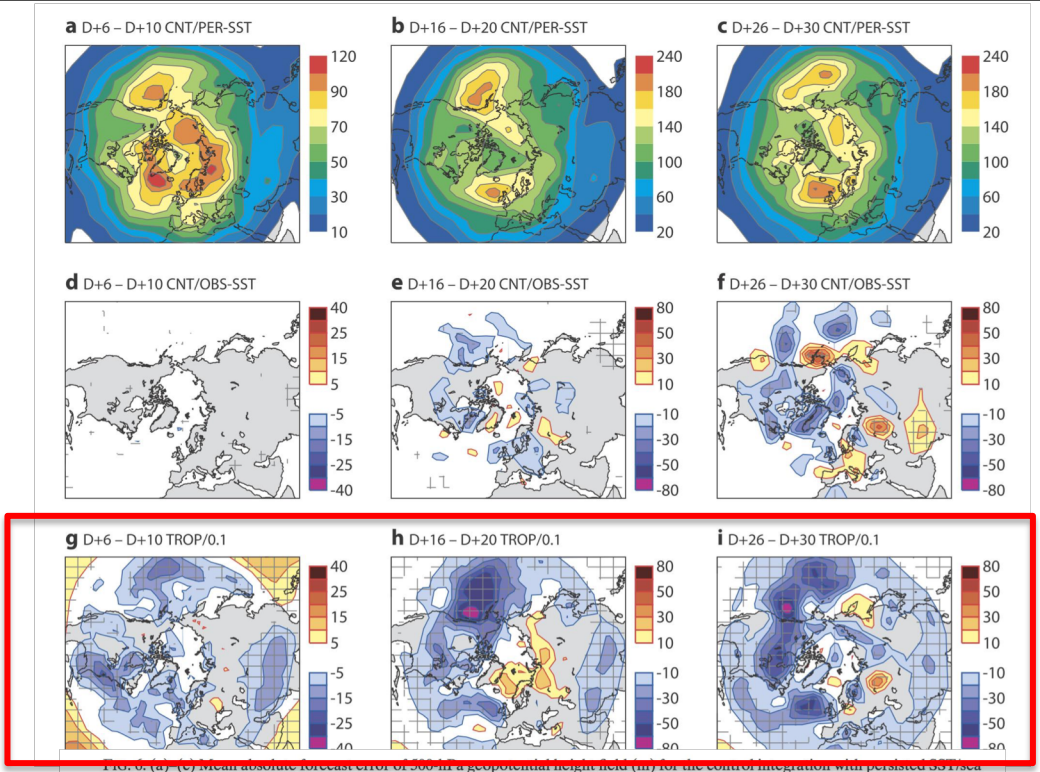

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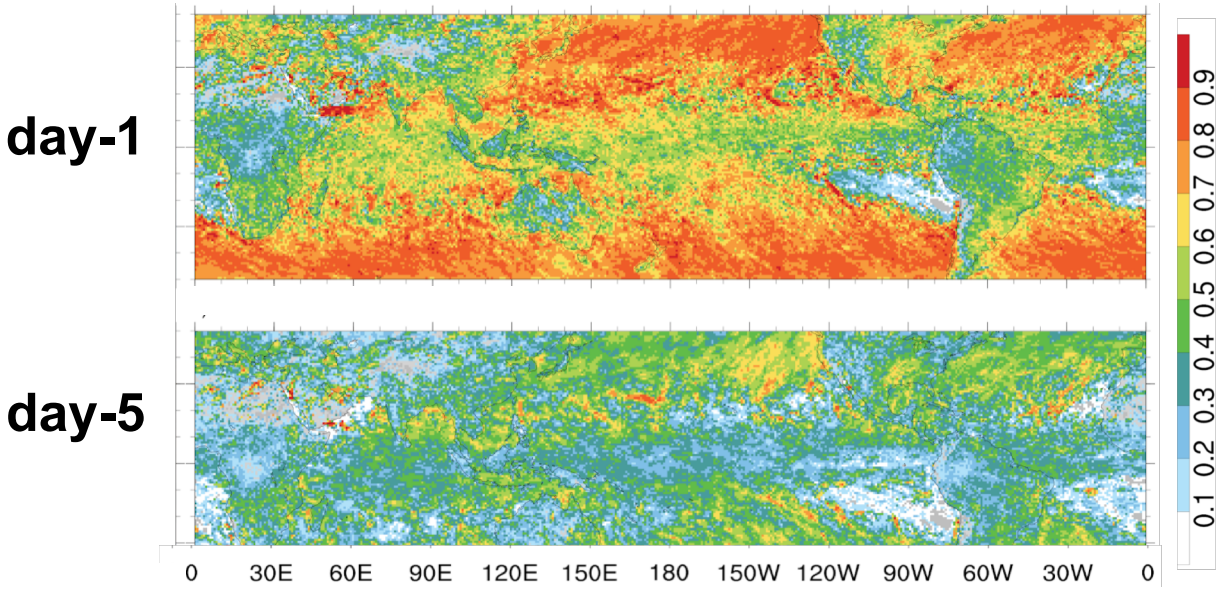
But, short to medium range forecasts tend to be worse in lower latitudes

Grid point correlation: ECMWF forecast precipitation x obs. (CMORPH)*



Are current tropical forecasts good enough for the extra-tropics 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*

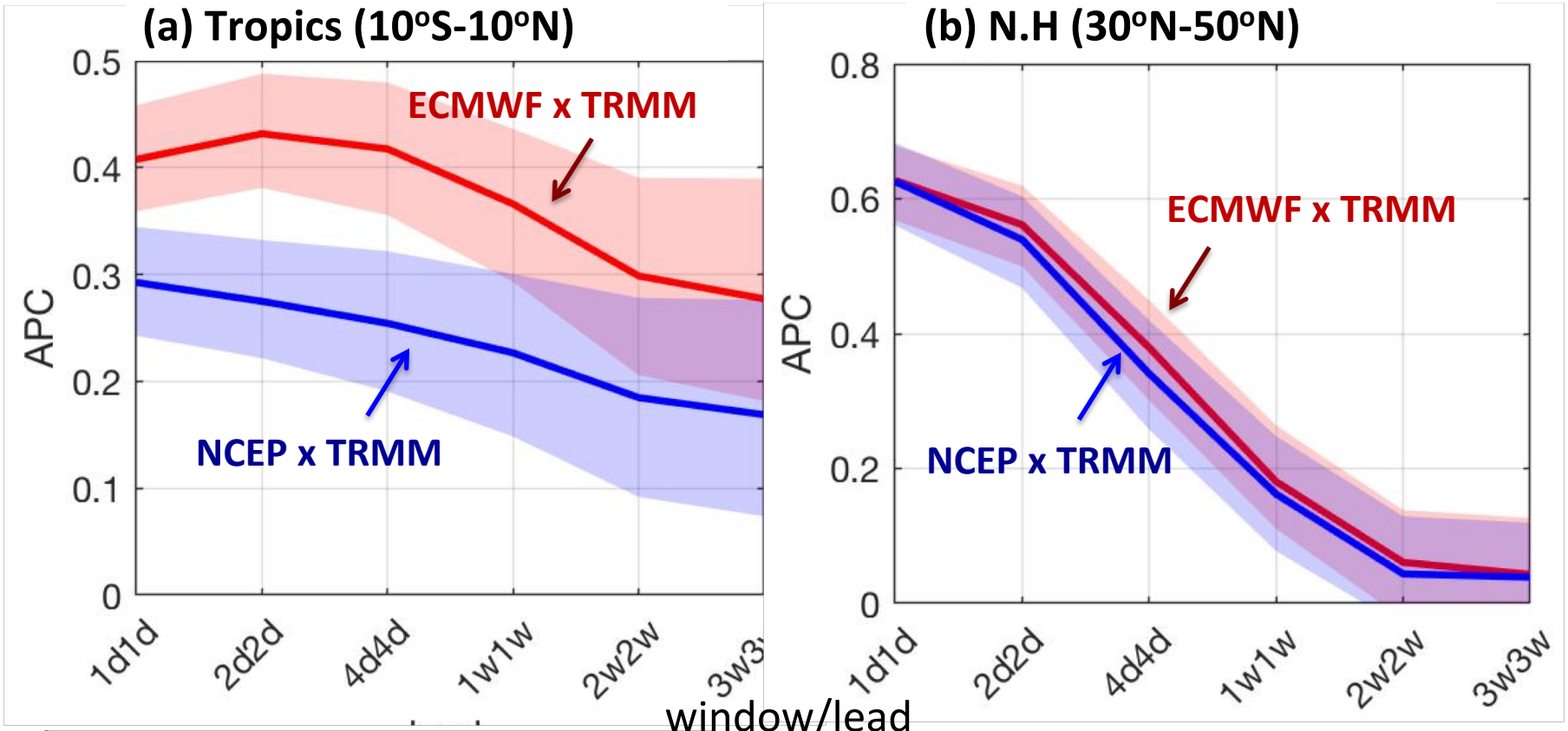
Today's talk

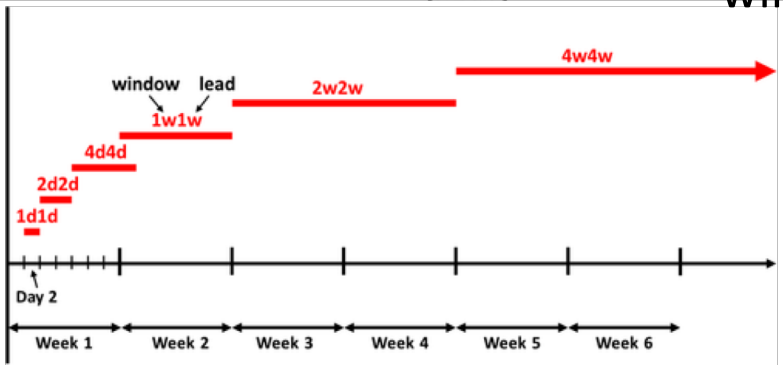
Diagnostics of S2S precipitation reforecasts with global verification against **TRMM** to address the following two questions:

- **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?**

Status on 5th January 2018	Time range	Resolution	Ens. Size	Frequency	Re-forecasts	Rfc length	Rfc frequency	Rfc size	Volume of real-time forecast per cycle	Volume of reforecast per update
BoM (ammc)	d 0-62	T47L17	3*11	2/week	fix	1981-2013	6/month	3*11		6 TB
CMA (babj)	d 0-60	T106L40	4	daily	fix	1994-2014	daily	4		
CNR-ISAC (isac)	d 0-32	0.75x0.56 L54	41	weekly	fix	1981-2010	every 5 days	5		
CNRM (lfpw)	d 0-32	T255L91	51	weekly	fix	1993-2014	4/month	15		6.6 TB
ECCC (cwao)	d 0-32	0.45x0.45 L40	21	weekly	on the fly	1995-2014	weekly	4		
ECMWF (ecmf)	d 0-46	Tco639/319 L91	51	2/week	on the fly	past 20 years	2/week	11		
HMCR (rums)	d 0-61	1.1x1.4 L28	20	weekly	on the fly	1985-2010	weekly	10		
JMA (rjtd)	d 0-33	TI479/TI319L100	50	weekly	fix	1981-2010	3/month	5	3.8 GB	900 GB
KMA (rksl)	d 0-60	N216L85	4	daily	on the fly	1991-2010	4/month	3		
NCEP (kwbc)	d 0-44	T126L64	16	daily	fix	1999-2010	daily	4		
UKMO (egrr)	d 0-60	N216L85	4	daily	on the fly	1993-2015	4/month	7		

Why NCEP and ECMWF systems in particular?



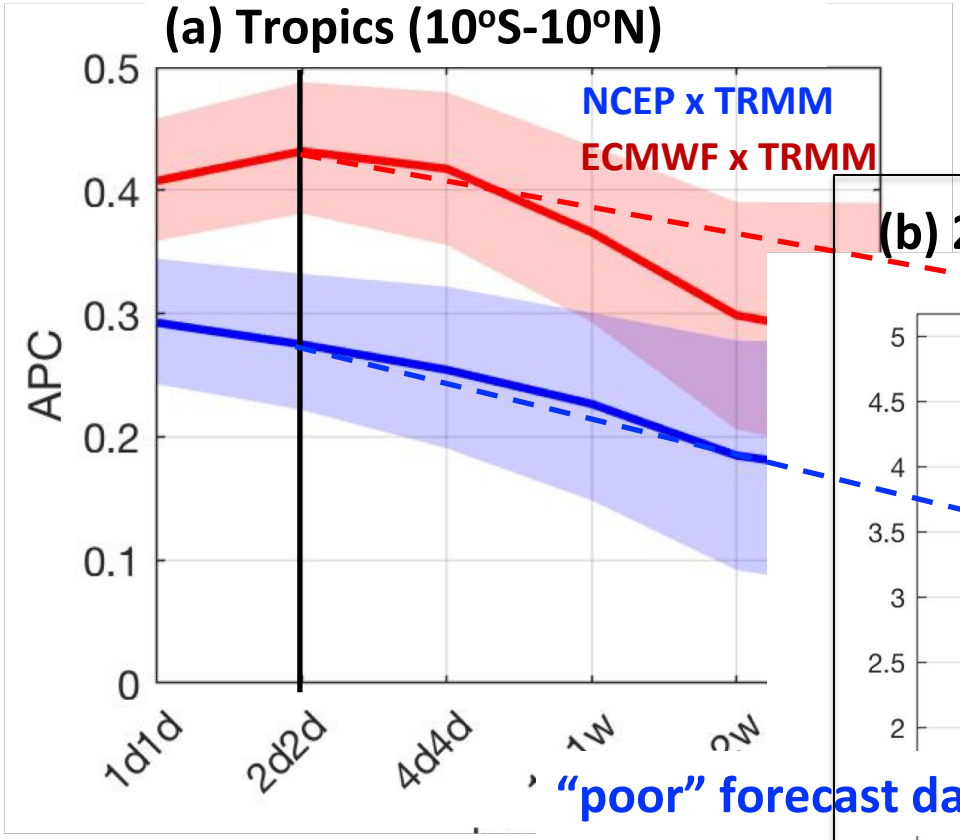


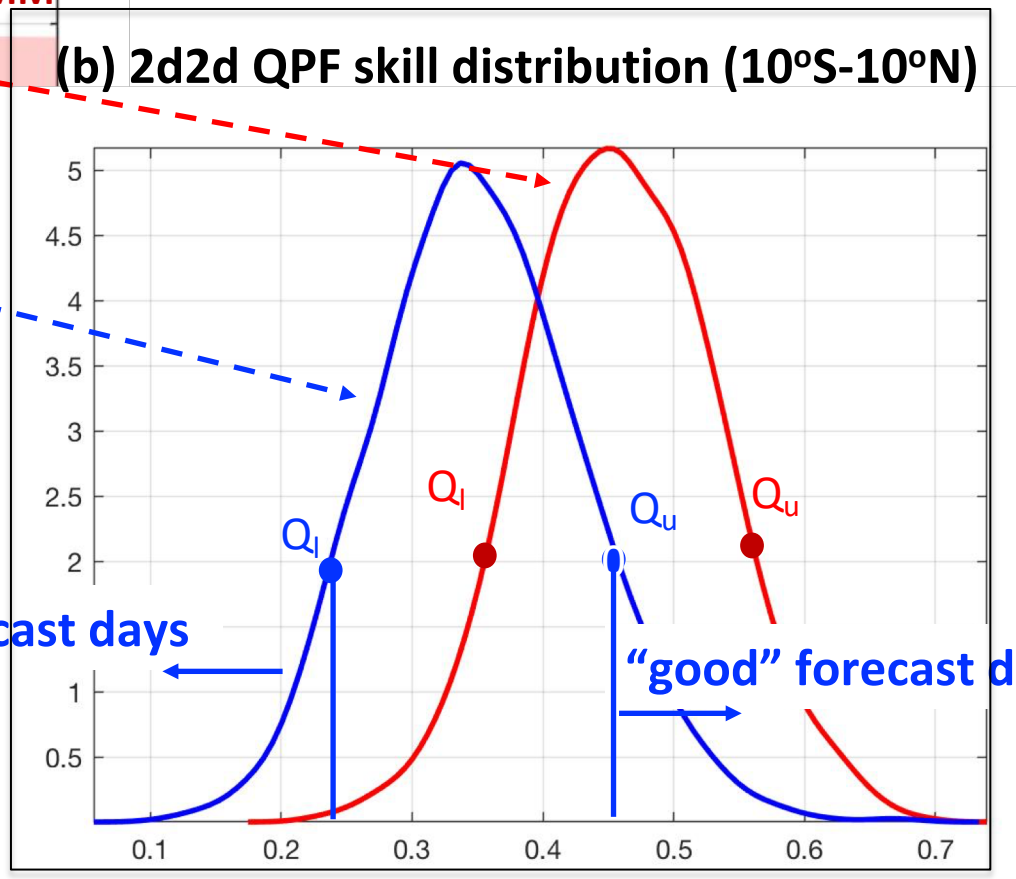
Zhu and Wheeler, 2014: Seamless Precipitation Prediction Skill in the Tropics and Extratropics from a Global Model. MWR

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

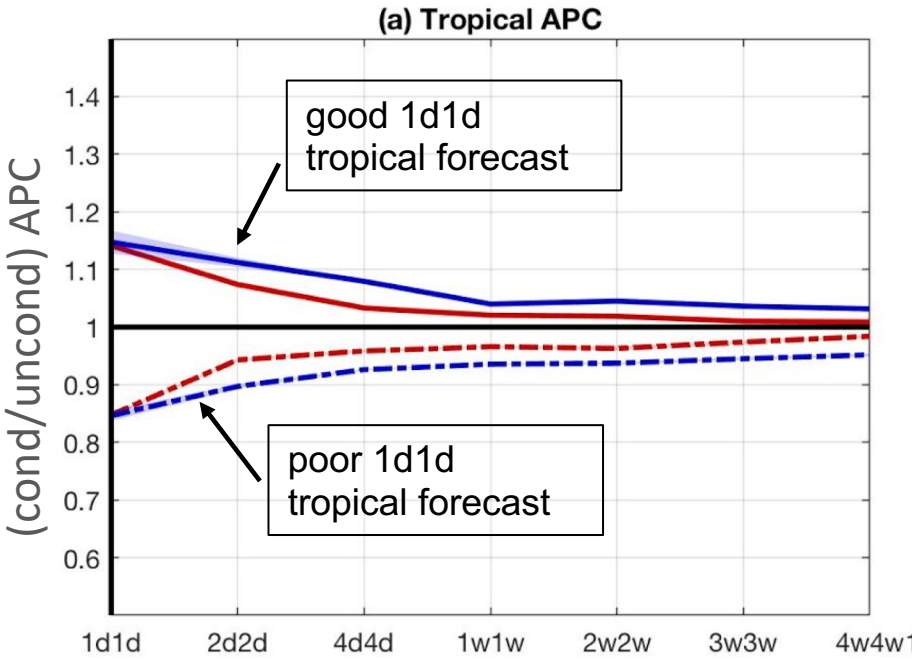
To look at conditional skill we chose dates where tropical skill is above/below model specific thresholds at each lead time

Conditional skill analysis





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



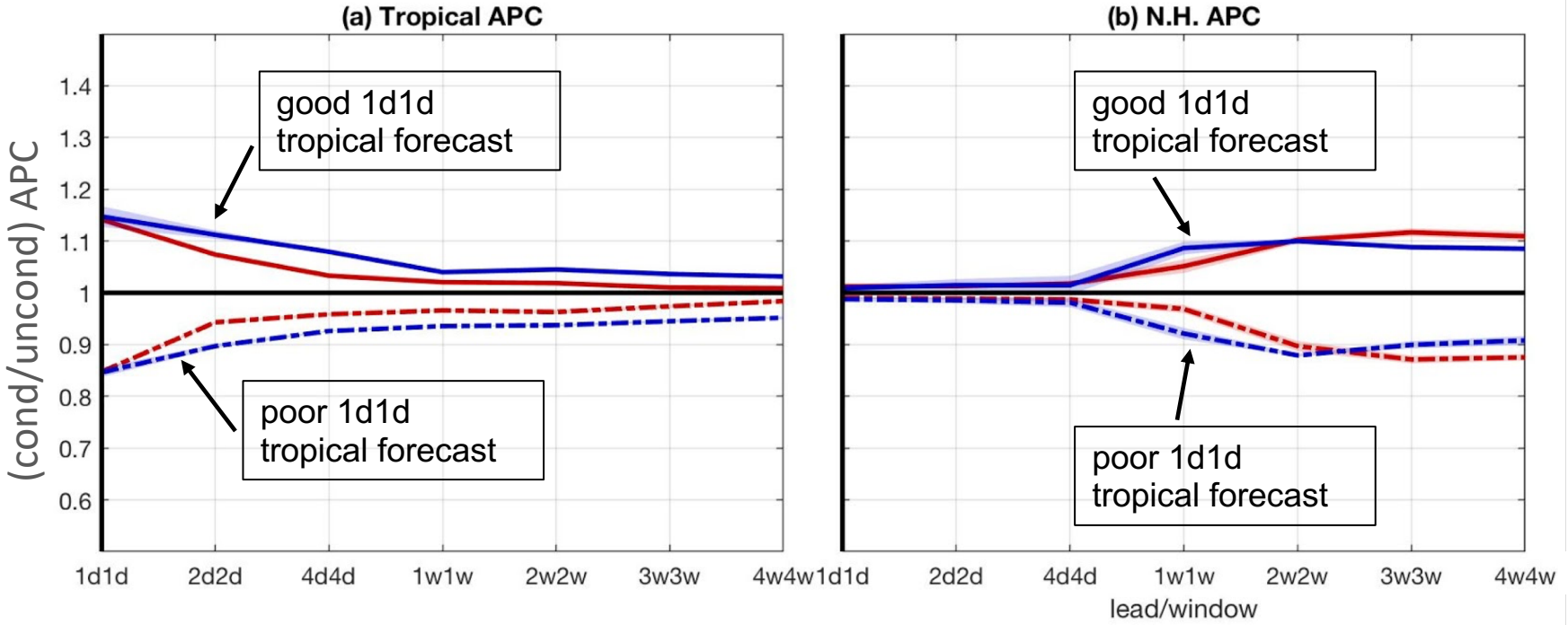
ECMWF ⟨**APC**|Qu $_{1d1d\ –\ 10S\text{-}10N}$ ⟩ / ⟨APC⟩

ECMWF ⟨**APC**|Ql $_{1d1d\ –\ 10S\text{-}10N}$ ⟩ / ⟨APC⟩

NCEP ⟨**APC**|Qu $_{1d1d\ –\ 10S\text{-}10N}$ ⟩ / ⟨APC⟩

NCEP ⟨**APC**|Ql $_{1d1d\ –\ 10S\text{-}10N}$ ⟩ / ⟨APC⟩

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



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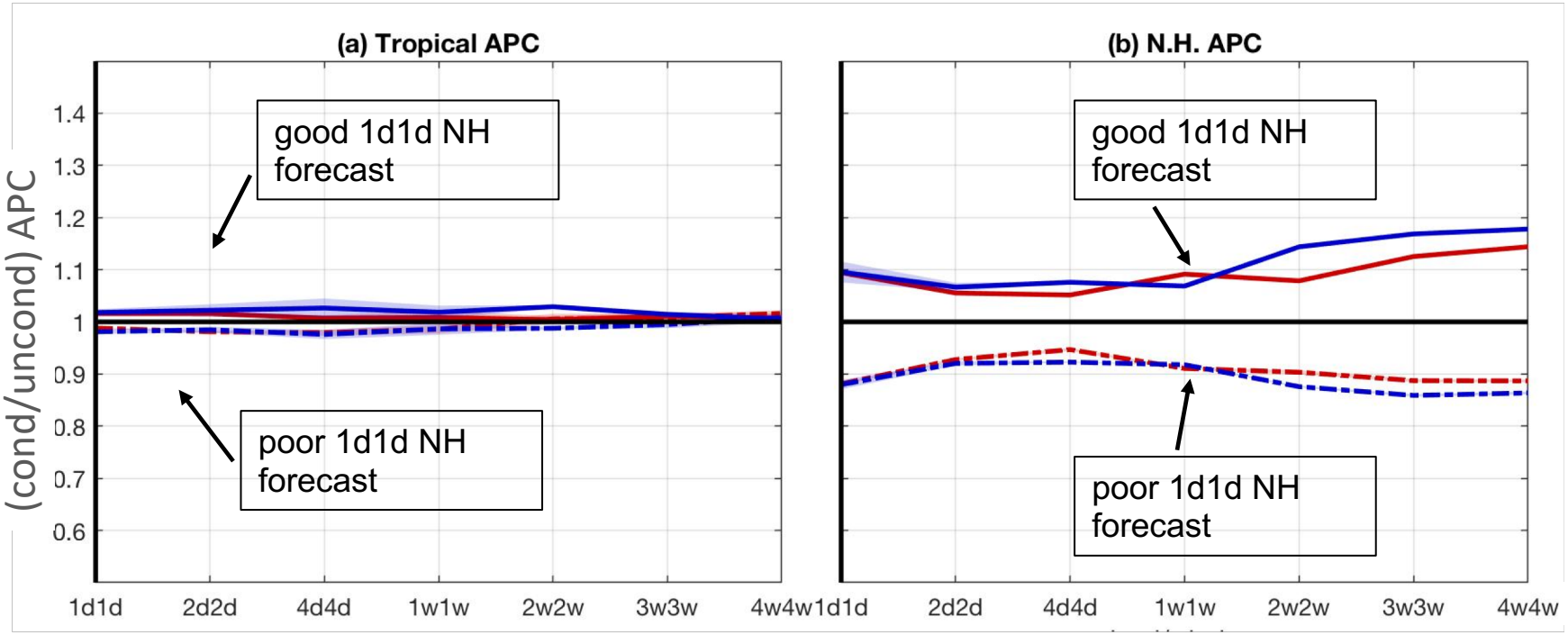
Conditional skill: N.H (30°N-50°N) - 1d1d



ECMWF ⟨**APC**|Qu $_{1d1d\ –\ 10S\text{-}10N}$ ⟩ / ⟨APC⟩

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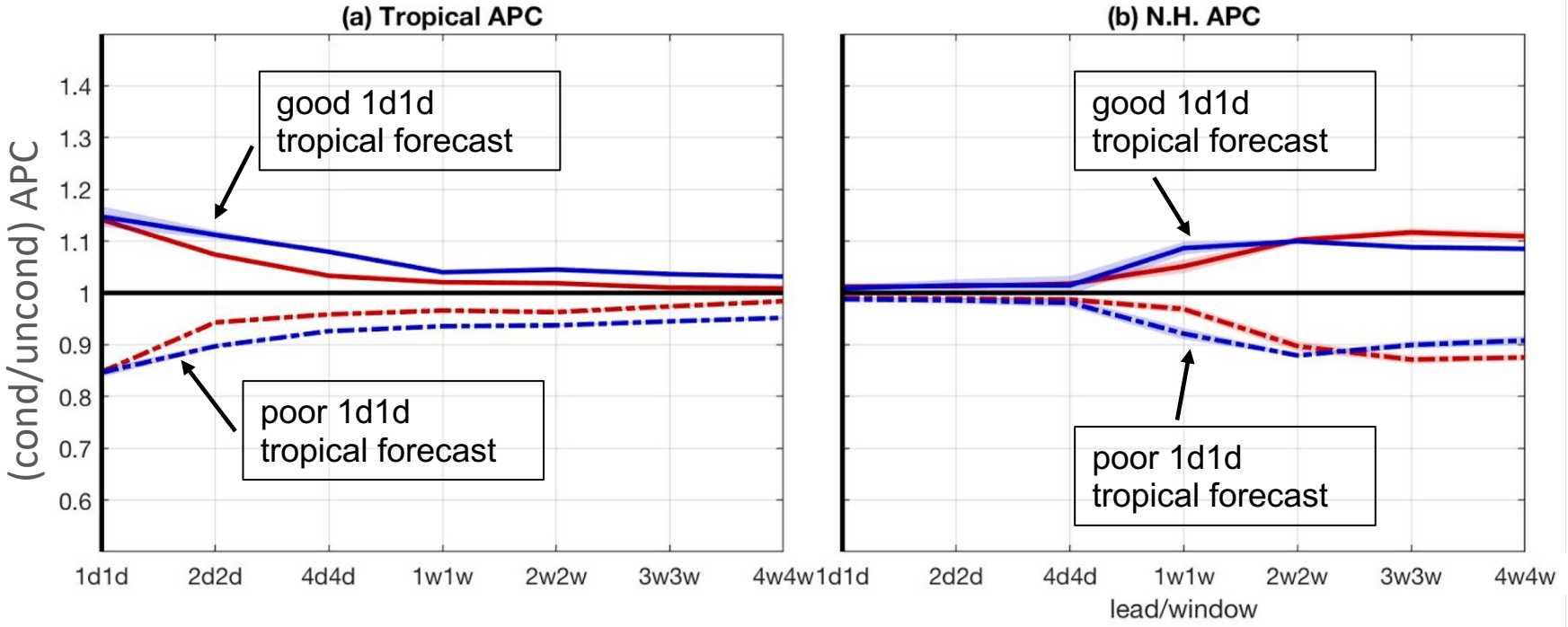
Conditional skill: Tropics (10°S-10°N) - 1d1d



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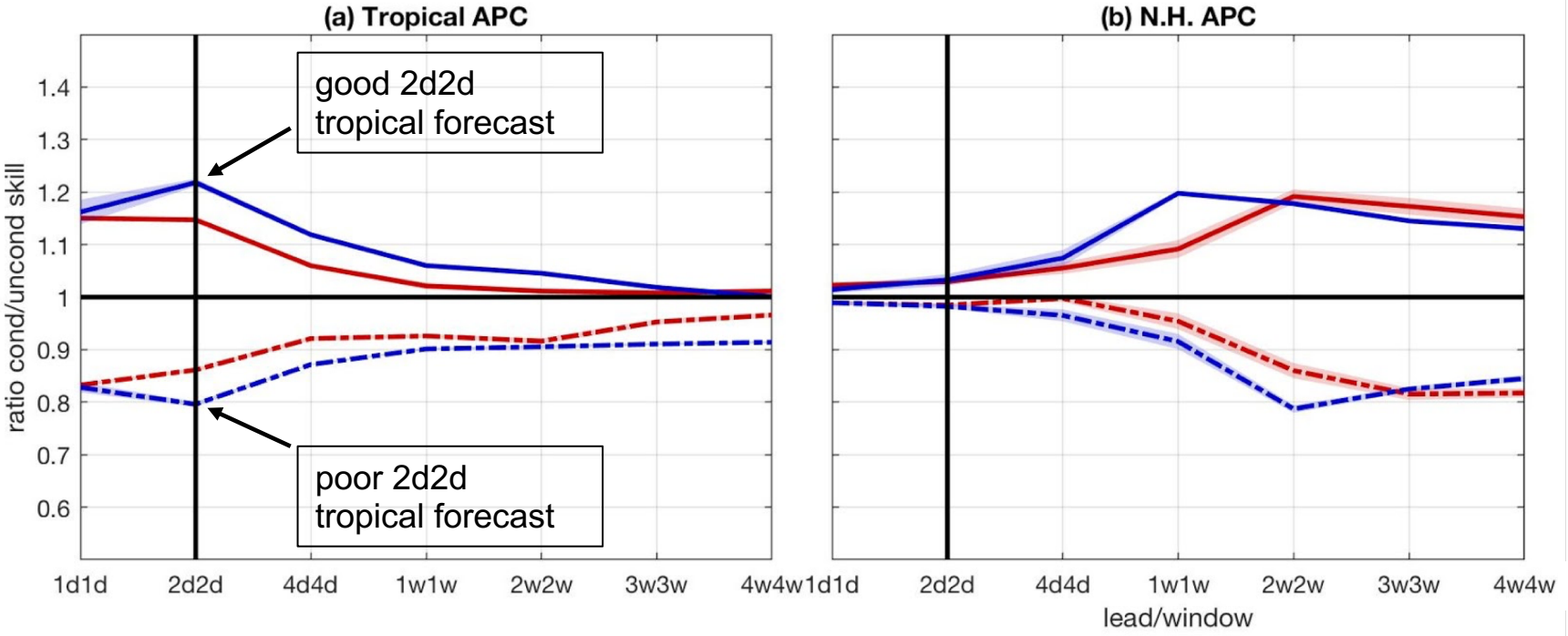
Conditional skill: Tropics (10°S-10°N) - 2d2d



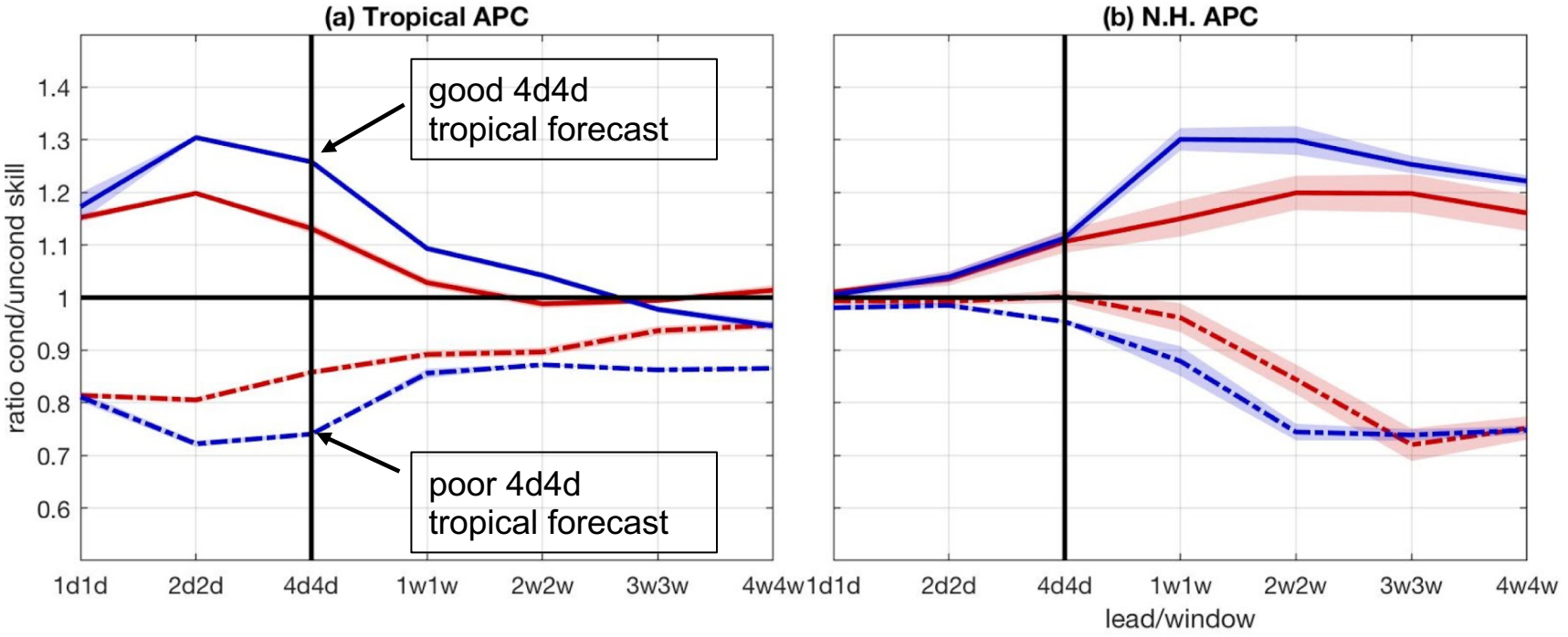
ECMWF ⟨**APC**|Qu $_{2d2d\ –\ 10S\text{-}10N}$ ⟩ / ⟨APC⟩

ECMWF ⟨**APC**|Ql $_{2d2d\ –\ 10S\text{-}10N}$ ⟩ / ⟨APC⟩

NCEP ⟨**APC**|Qu $_{2d2d\ –\ 10S\text{-}10N}$ ⟩ / ⟨APC⟩

NCEP ⟨**APC**|Ql $_{2d2d\ –\ 10S\text{-}10N}$ ⟩ / ⟨APC⟩

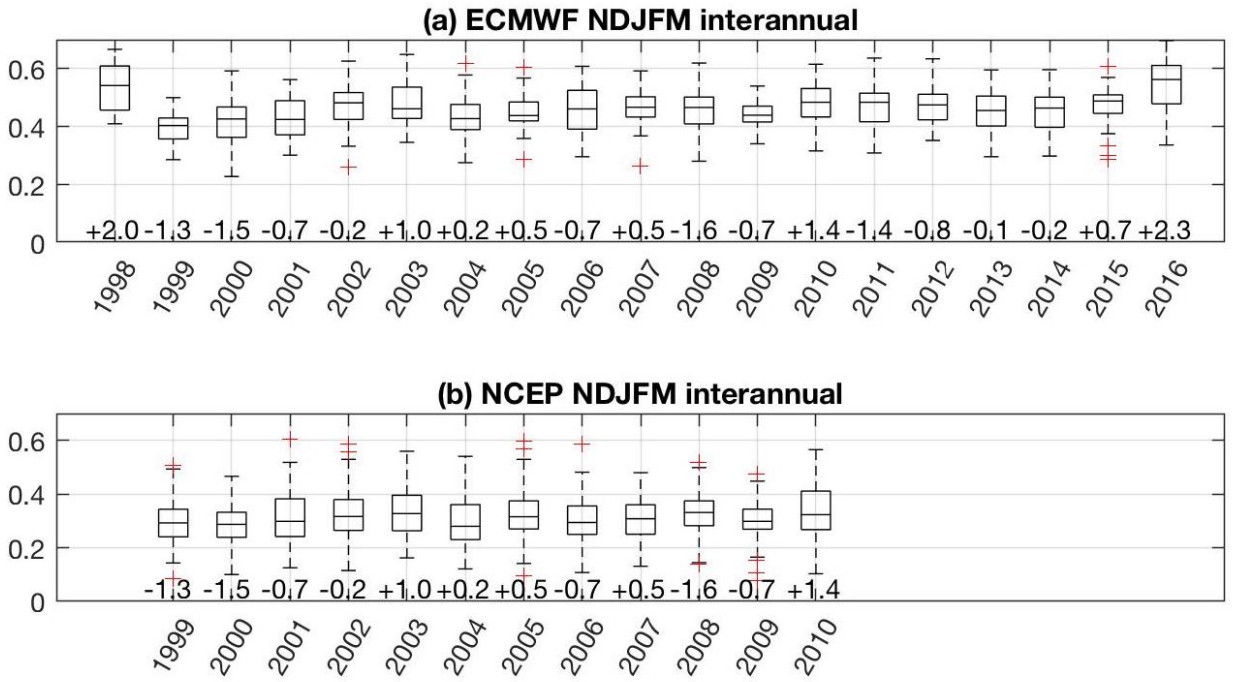
Conditional skill: Tropics (10°S-10°N) - 4d4d



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

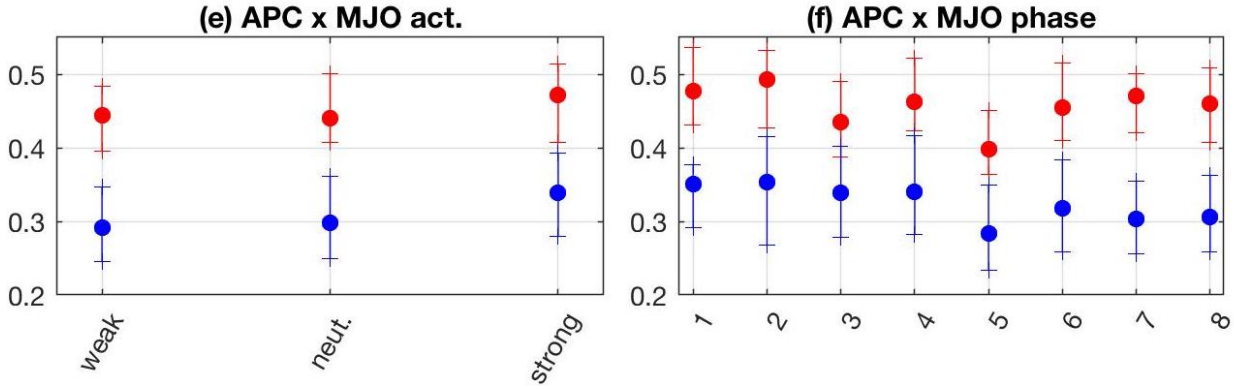


**Fig. shows box plot of 2d2d precipitation APC*

Does tropical-extratropical conditional skill depend on the MJO?

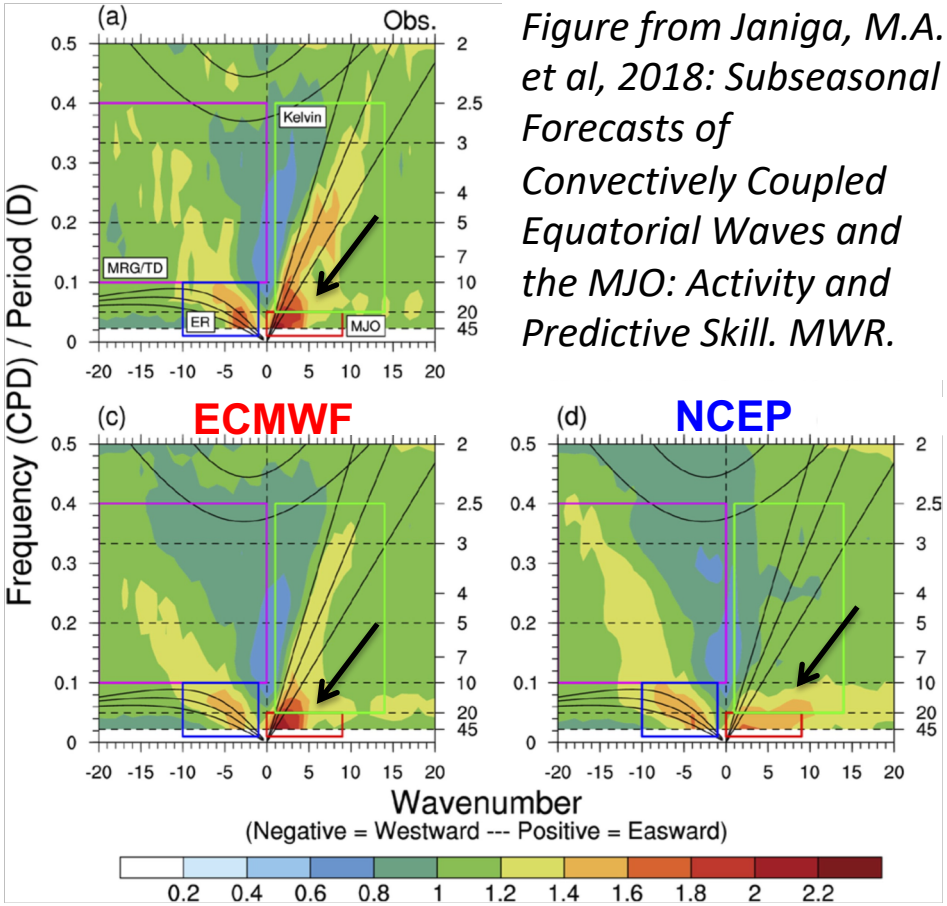
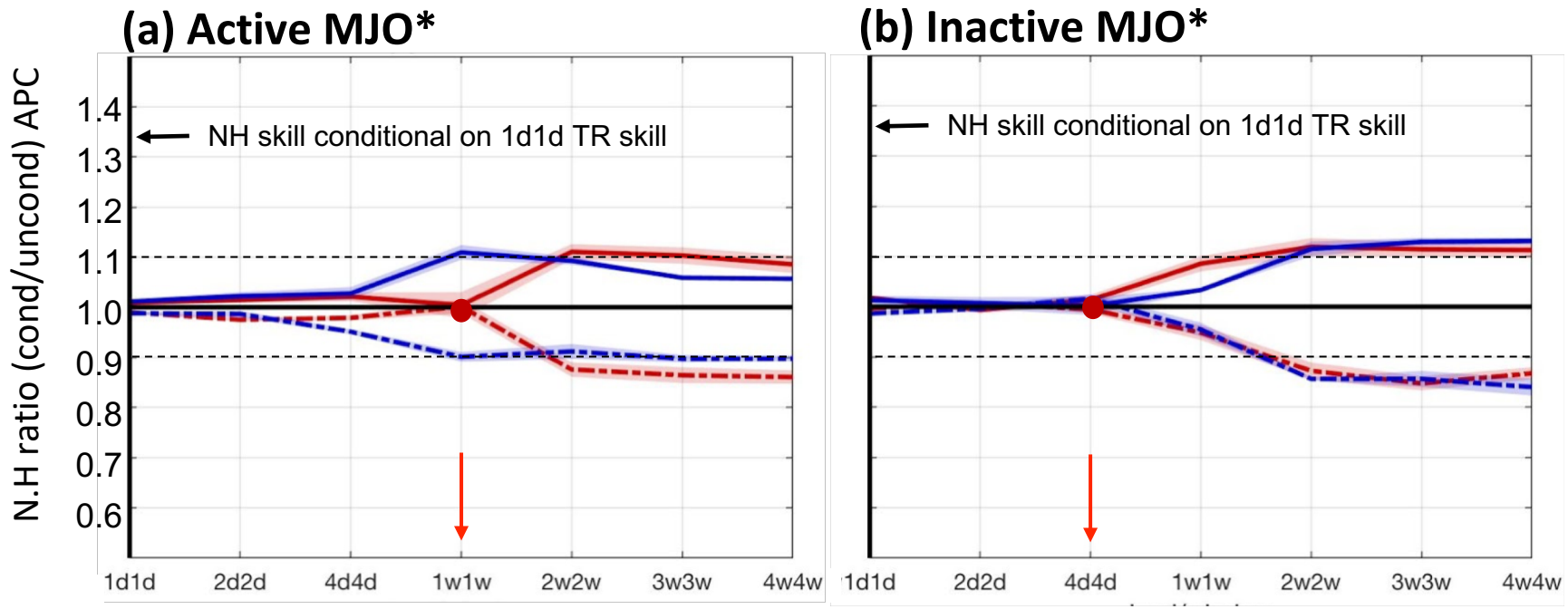


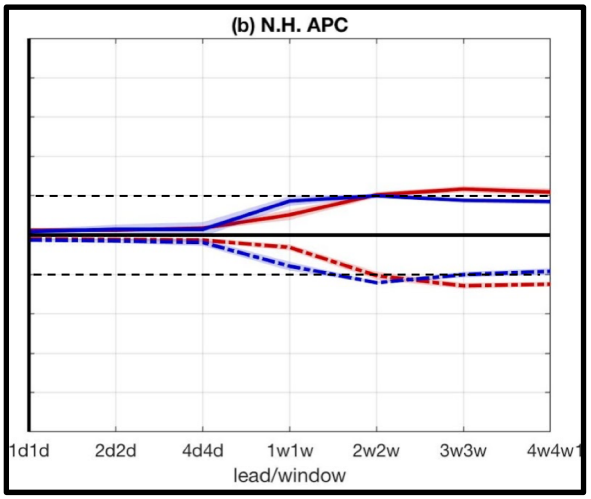
Figure from Janiga, M.A. et al, 2018: Subseasonal Forecasts of Convectively Coupled Equatorial Waves and the MJO: Activity and Predictive Skill. MWR.

- Is the conditional skill sensitive to the MJO?
- Does it matter if the system can produce an MJO?

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

Does tropical-extratropical conditional skill depend on the tropical initial state?

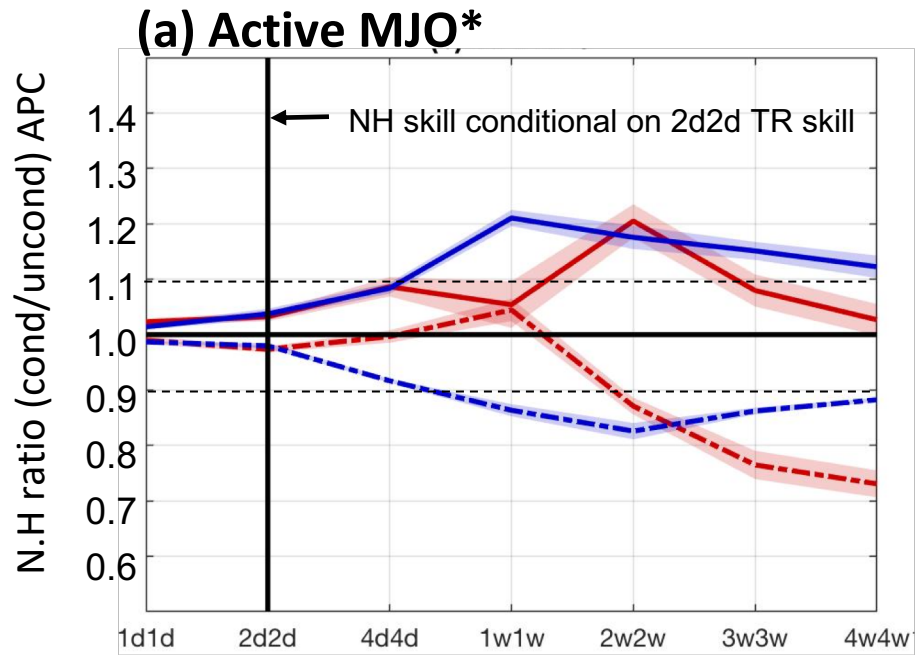


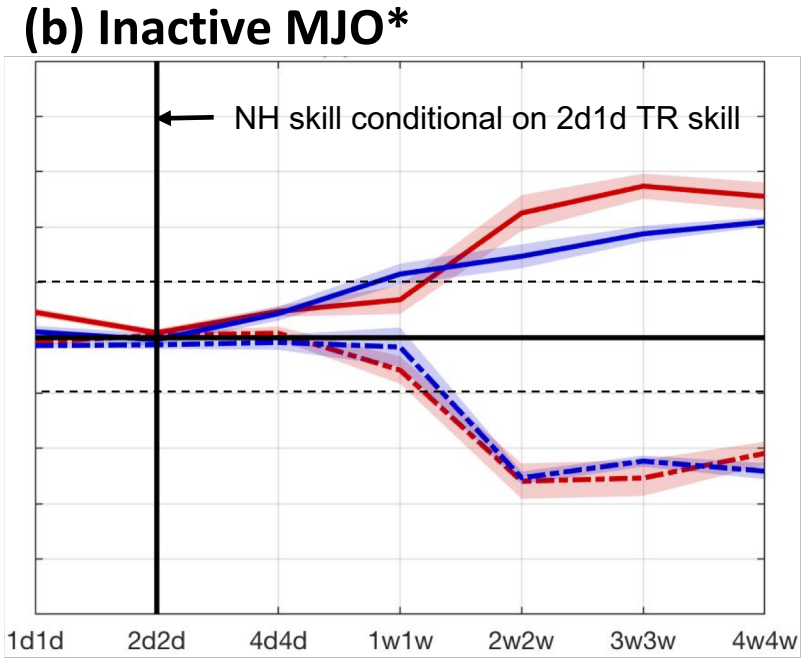


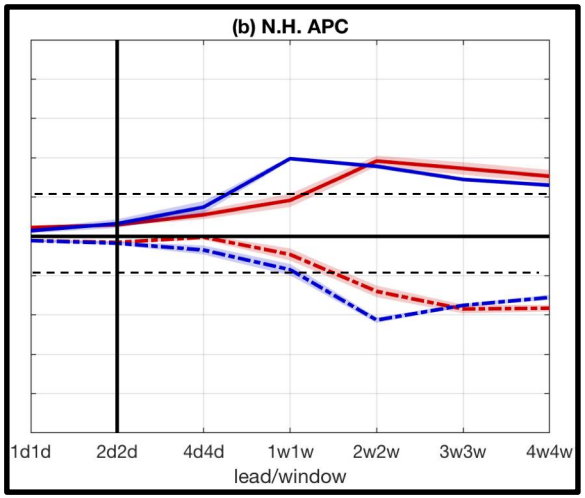
- The timing of the changes in the **NCEP** N.H conditional skill is not sensitive to the MJO, but the amplitude is.
- In contrast, there is a shift in the timing of the **ECMWF** N.H conditional skill (week 2 -> week 3-4)

** Active/Inactive based on the OMI index amplitude*

Does tropical-extratropical conditional skill depend on the tropical initial state?







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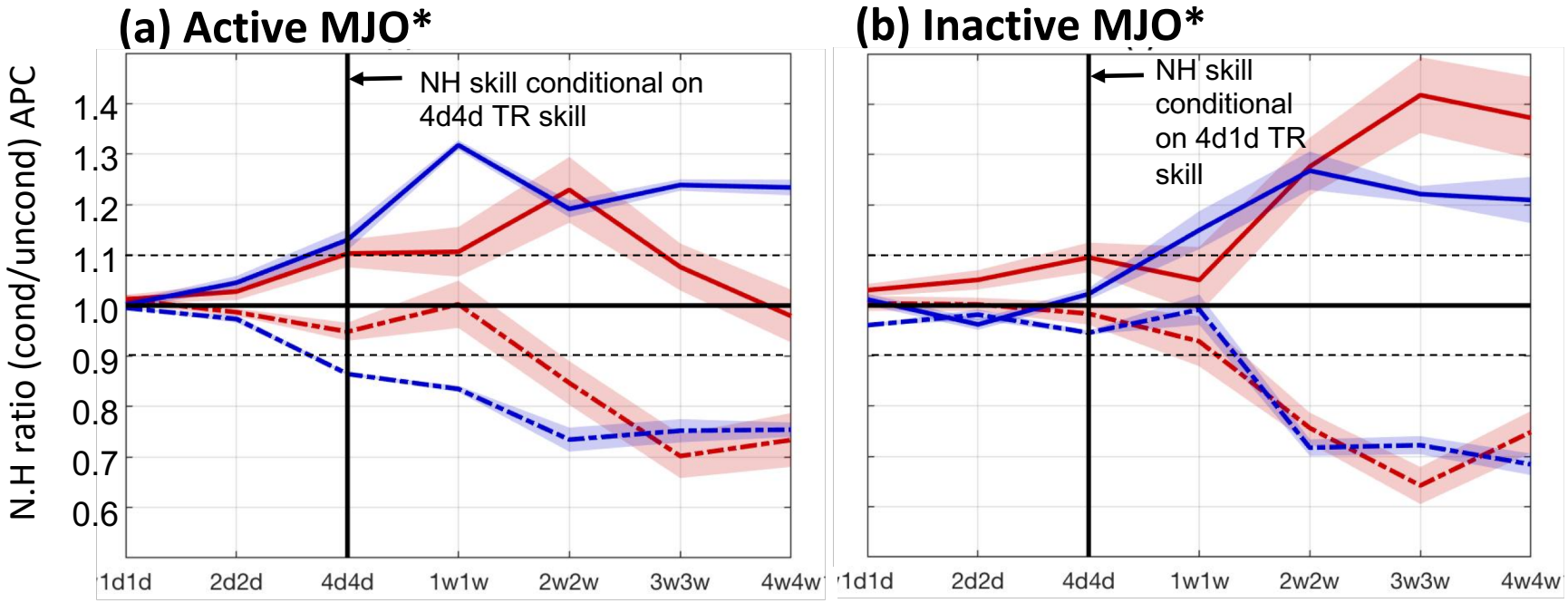
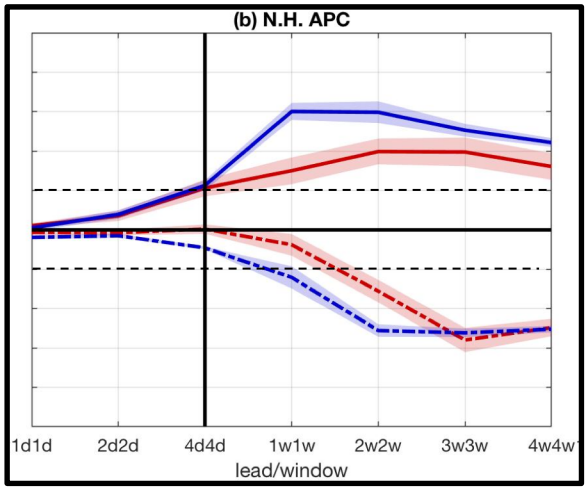
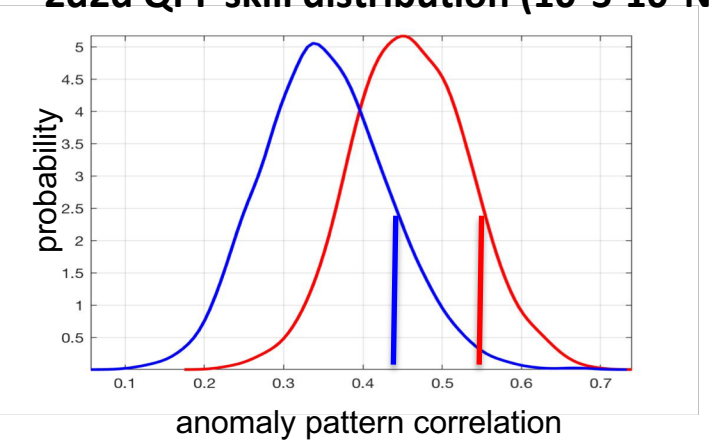




- MJO initial state affects the amplitude of the NCEP ratios, but not the timing;
- ECMWF ratio peaks at week 3-4 when week 1 tropical forecast is good;
- ECMWF longer lead time N. H. conditional forecasts are more sensitive to week 1 tropical skill when the MJO is **inactive**;

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

2d2d QPF skill distribution (10ºS-10ºN)



~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.