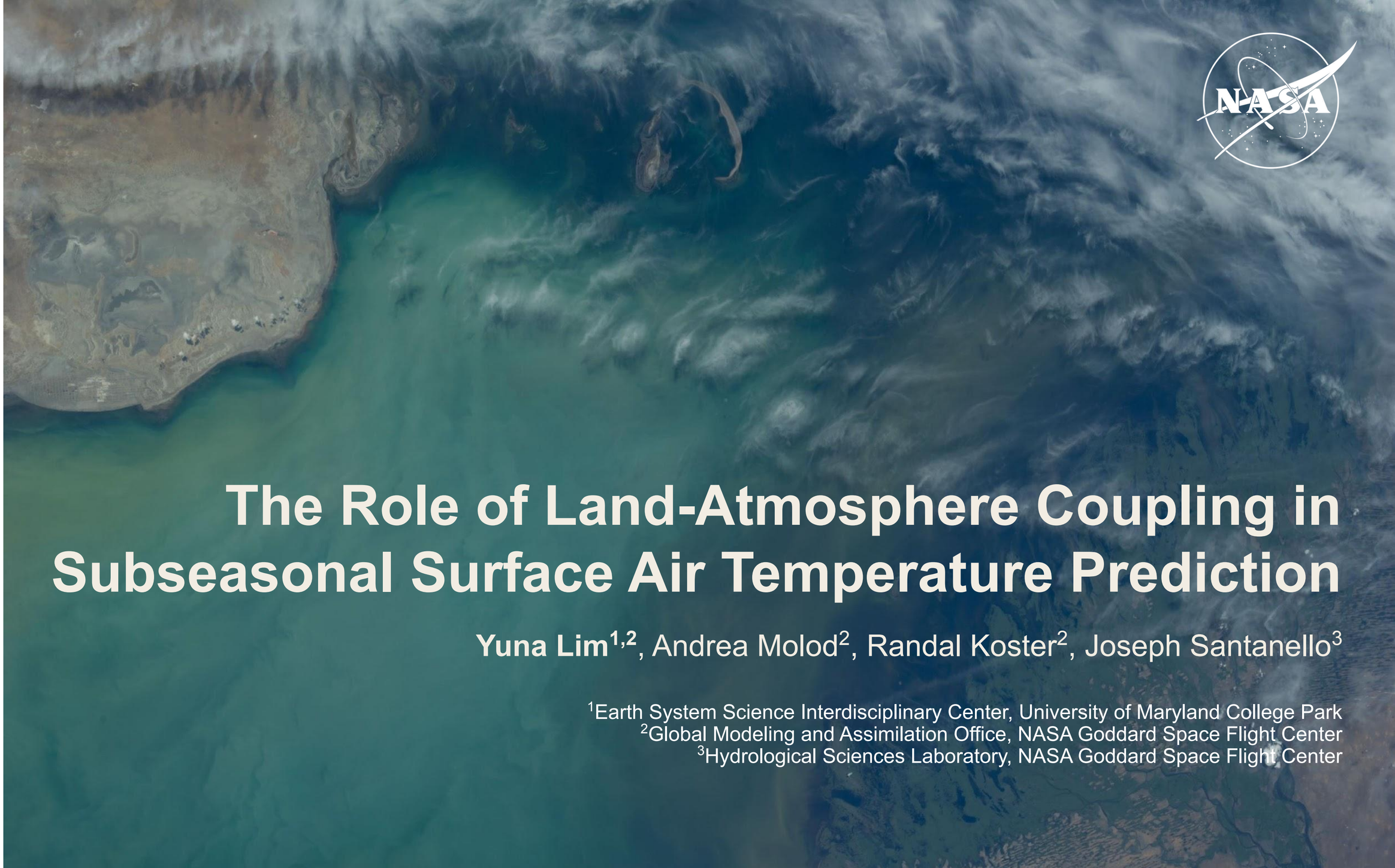
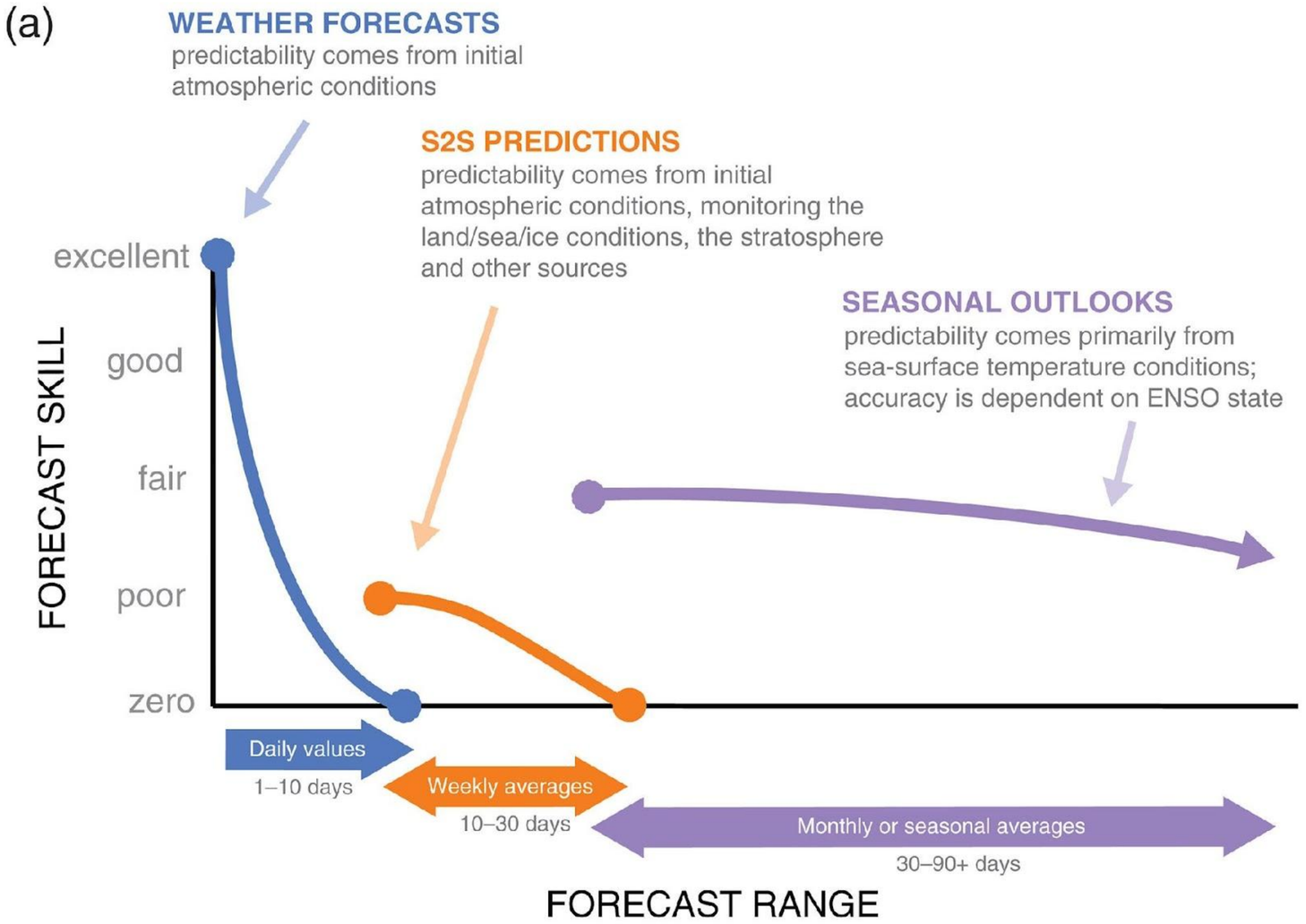


The Role of Land-Atmosphere Coupling in Subseasonal Surface Air Temperature Prediction

Yuna Lim[1,2], Andrea Molod[2], Randal Koster[2], Joseph Santanello[3]

[1]Earth System Science Interdisciplinary Center, University of Maryland College Park
[2]Global Modeling and Assimilation Office, NASA Goddard Space Flight Center
[3]Hydrological Sciences Laboratory, NASA Goddard Space Flight Center

Subseasonal Prediction



(White et al. 2017)

Prediction skill on longer time scales can leverage specific climate phenomena or conditions for a predictable signal. These conditions can provide windows of opportunity for skillful forecasts.

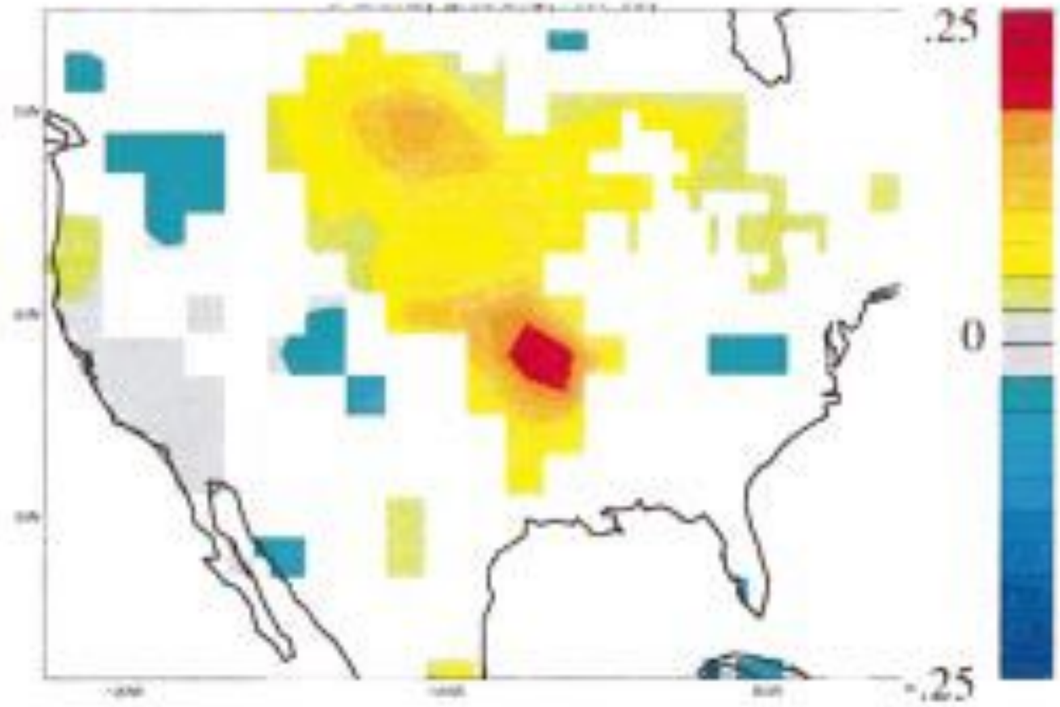
- Mariotti et al. (2021, BAMS)

GODDARD EARTH SCIENCES

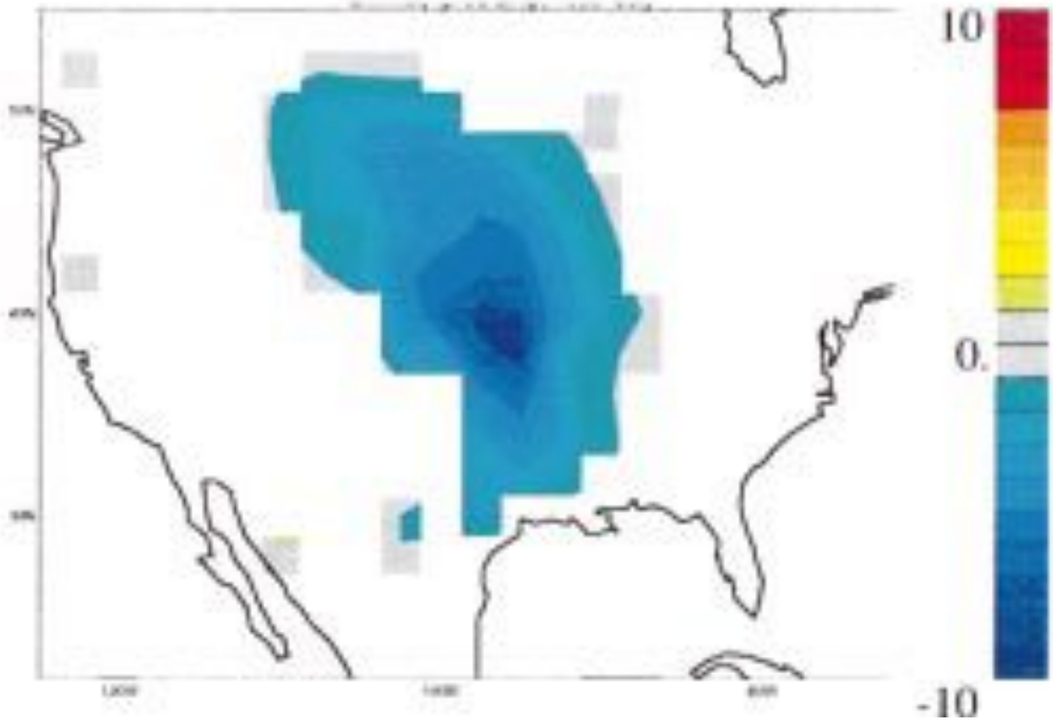
Sources of Subseasonal Prediction: Land

AMIP with soil moisture initialization - AMIP

Soil Moisture

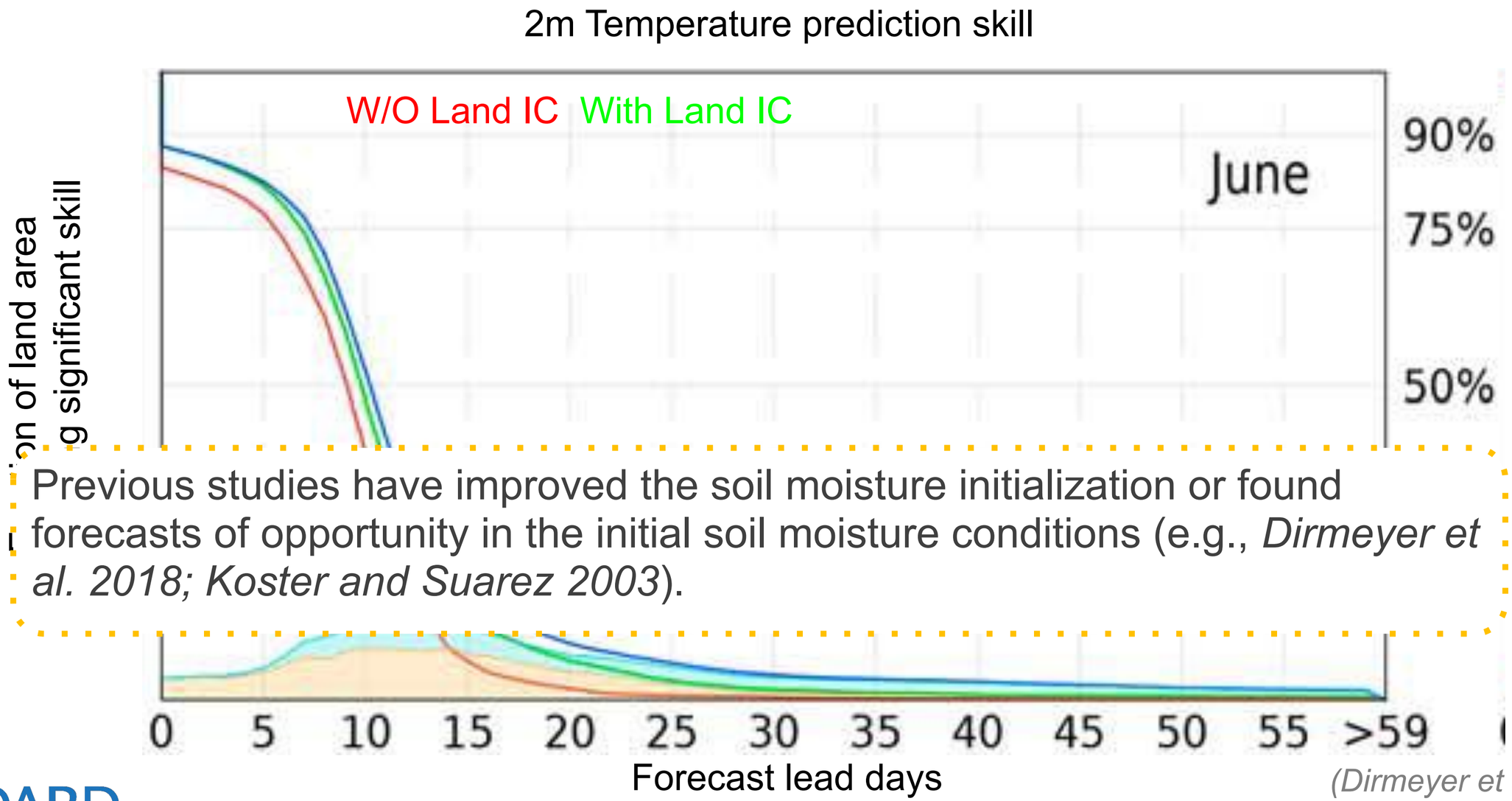


2m Temperature [K]



(Koster and Suarez 2003)

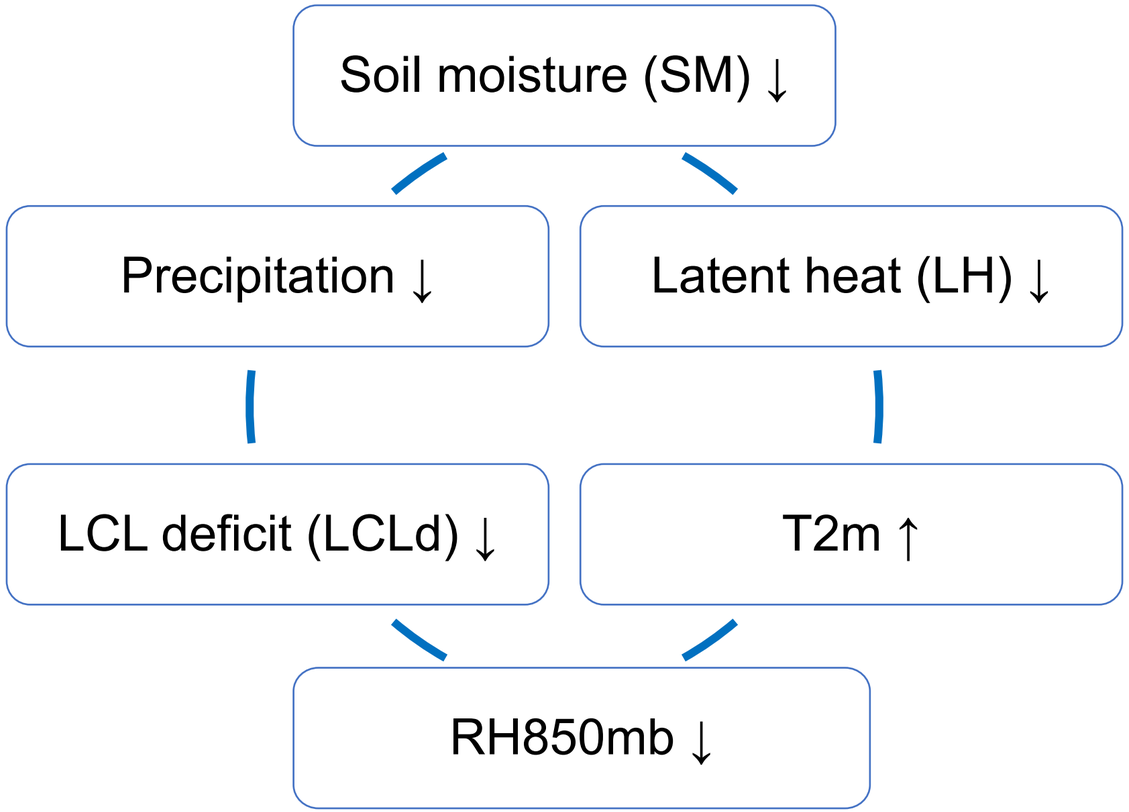
Sources of Subseasonal Prediction: Land



Previous studies have improved the soil moisture initialization or found forecasts of opportunity in the initial soil moisture conditions (e.g., *Dirmeyer et al. 2018; Koster and Suarez 2003*).

(Dirmeyer et al. 2018)

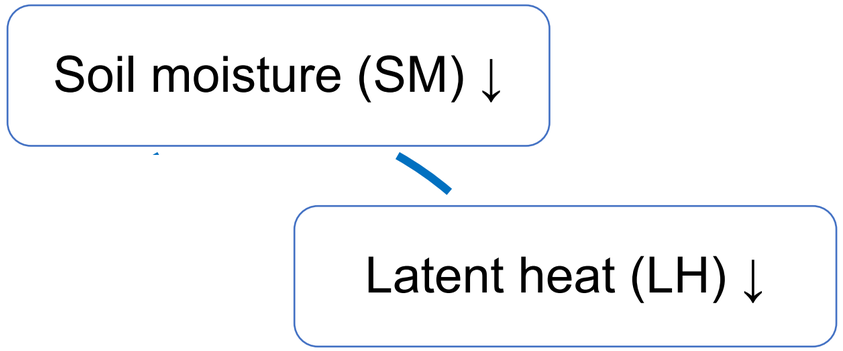
Land-Atmosphere (L-A) Coupling



(Molod et al. 2004)

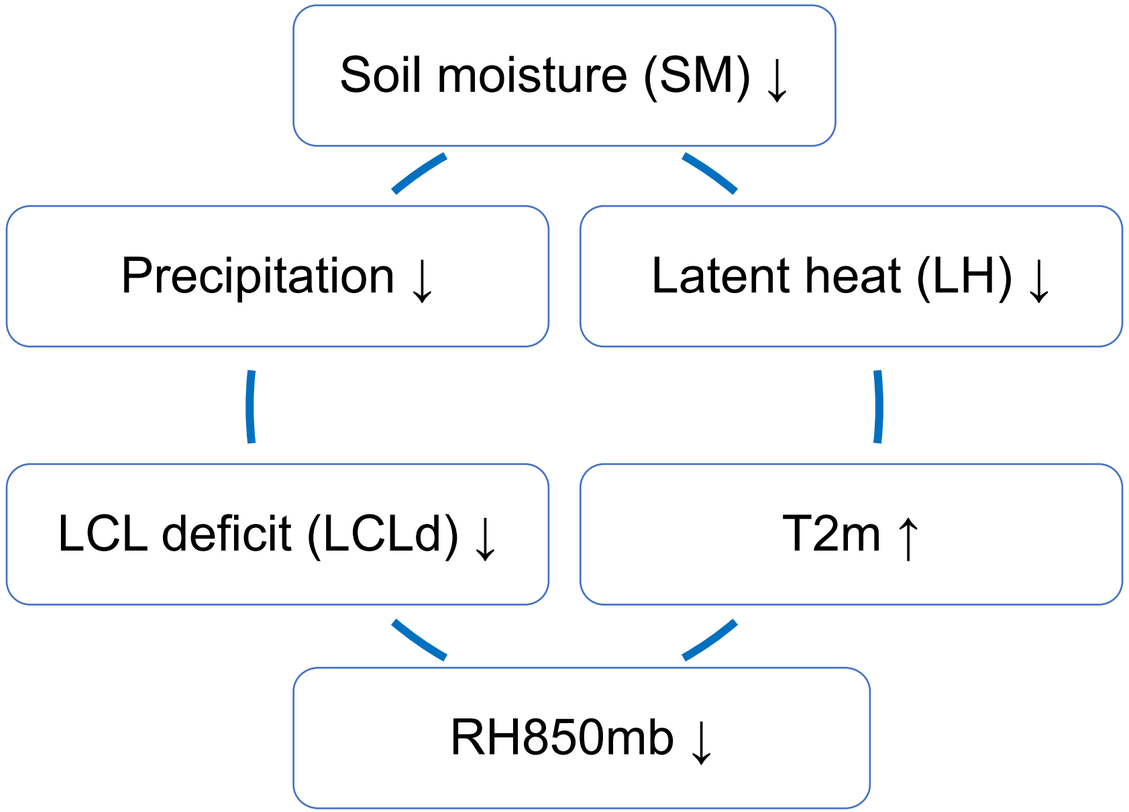
GODDARD EARTH SCIENCES

Land-Atmosphere (L-A) Coupling



(Molod et al. 2004)

Land-Atmosphere (L-A) Coupling



(Molod et al. 2004)

Scientific Questions:

- Does a strong L-A coupling increase T2m prediction skill?
- Does prediction skill increase with deeper coupling across multiple metrics?

GODDARD EARTH SCIENCES

Data and Methods

- Reforecasts in NASA's GEOS-S2S-2, initialized from 1999 to 2022 during boreal summer (June-August).

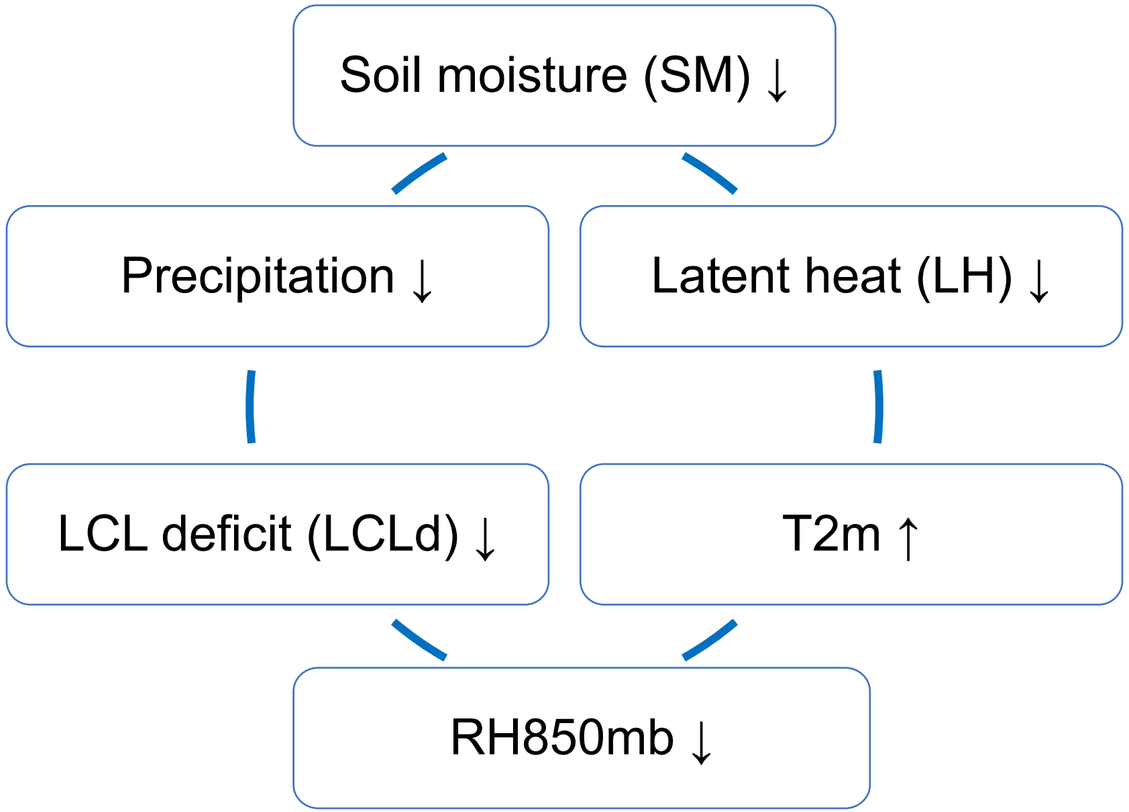
	Reforecast Period	Reforecast Frequency	Number of Reforecasts	Ensemble Size
GEOS-S2S-2	1999-2022	5-day interval	414	4

- The anomaly correlation coefficient (ACC) is used to evaluate the prediction skill of 2m temperature (T2m). It is compared to ERA5 data.

$$ACC(\tau) = \frac{\sum_{t=1}^{N} M(t,\tau)O(t)}{\sqrt{\sum_{t=1}^{N} M(t,\tau)^2}\sqrt{\sum_{t=1}^{N} O(t)^2}}$$

N: Number of reforecasts, $O(t)$: observed T2m anomalies at time t,
$M(t,\tau)$: T2m anomalies of the reforecasts at lead time τ

L-A Coupling Metrics



(Molod et al. 2004)

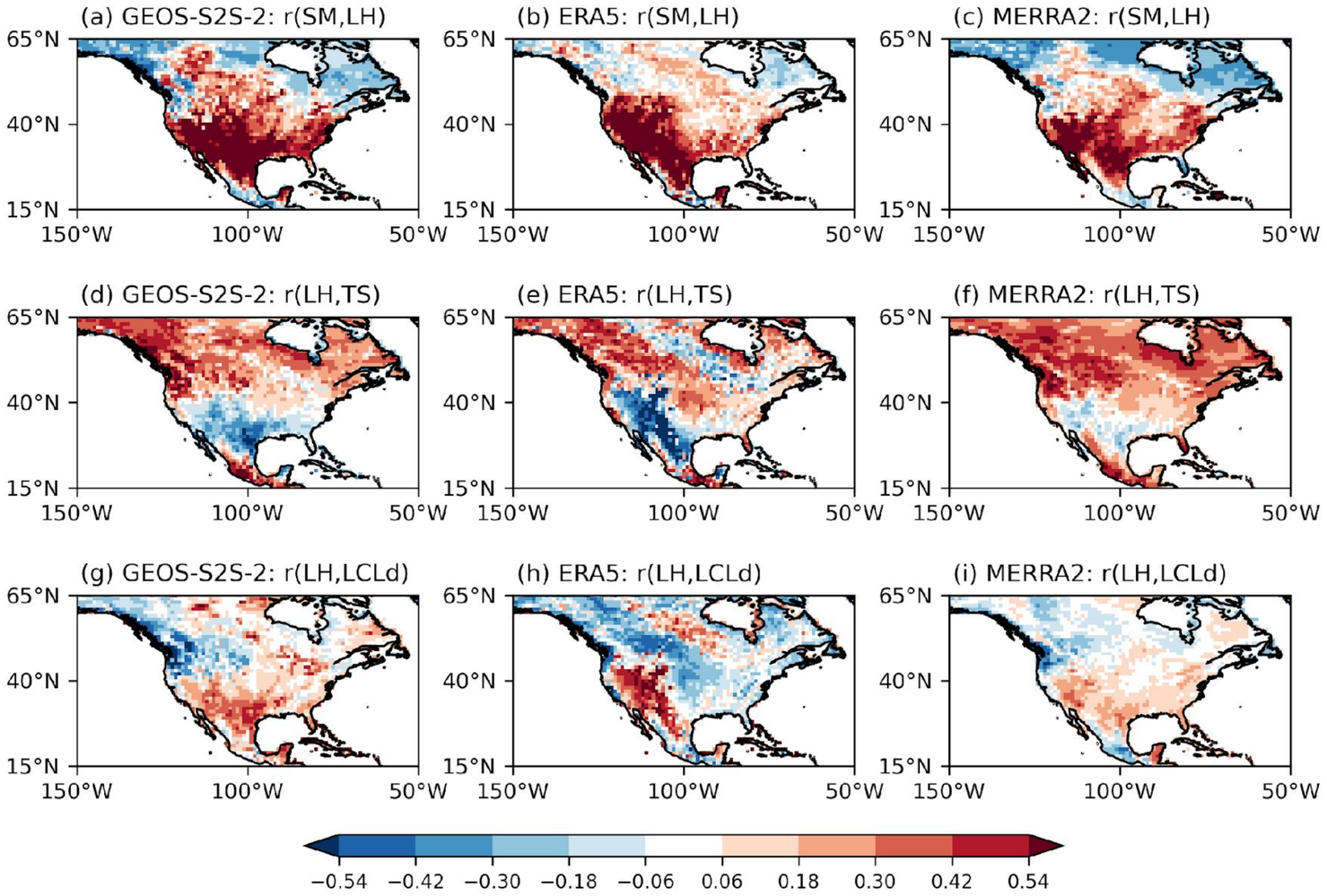
$$r(SM,LH) = \frac{\sum_{ens=1}^{4}\sum_{\tau=15}^{28}(SM'LH')}{\sqrt{\sum_{ens=1}^{4}\sum_{\tau=15}^{28}SM'^{2}}\sqrt{\sum_{ens=1}^{4}\sum_{\tau=15}^{28}LH'^{2}}}$$

$$r(LH,TS) = \frac{\sum_{ens=1}^{4}\sum_{\tau=15}^{28}(LH'TS')}{\sqrt{\sum_{ens=1}^{4}\sum_{\tau=15}^{28}LH'^{2}}\sqrt{\sum_{ens=1}^{4}\sum_{\tau=15}^{28}TS'^{2}}}$$

$$r(LH,LCLd) = \frac{\sum_{ens=1}^{4}\sum_{\tau=15}^{28}(LH'LCLd')}{\sqrt{\sum_{ens=1}^{4}\sum_{\tau=15}^{28}LH'^{2}}\sqrt{\sum_{ens=1}^{4}\sum_{\tau=15}^{28}LCLd'^{2}}}$$

When all three indices indicate the strong L-A coupling based on the 50th percentile, the reforecast is defined as having strong coupling.

Evaluation of L-A Coupling in GEOS-S2S-2

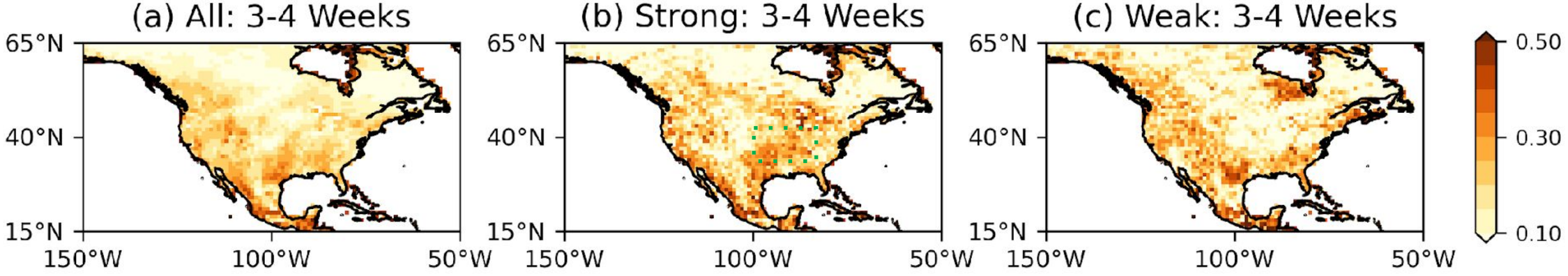


- The overall distributions of maxima and minima in GEOS-S2S-2 closely resemble those in ERA5 and MERRA2.

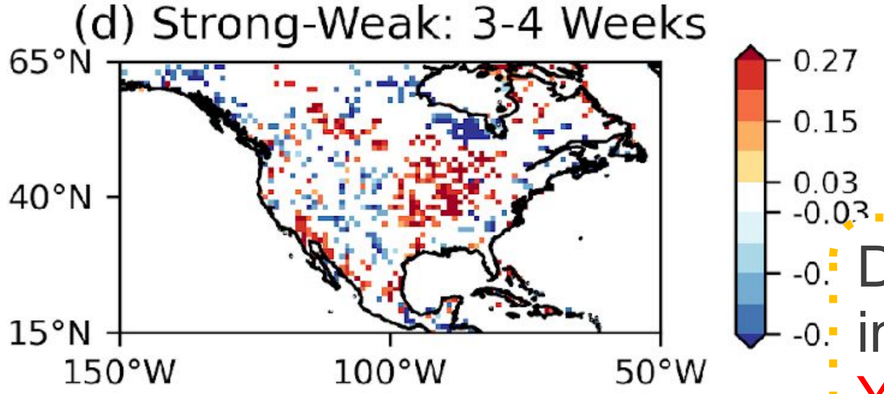
(Lim et al.; in revision)

Impact of L-A Coupling on Subseasonal Temperature Prediction Skill

ACC



(Lim et al.; in revision)

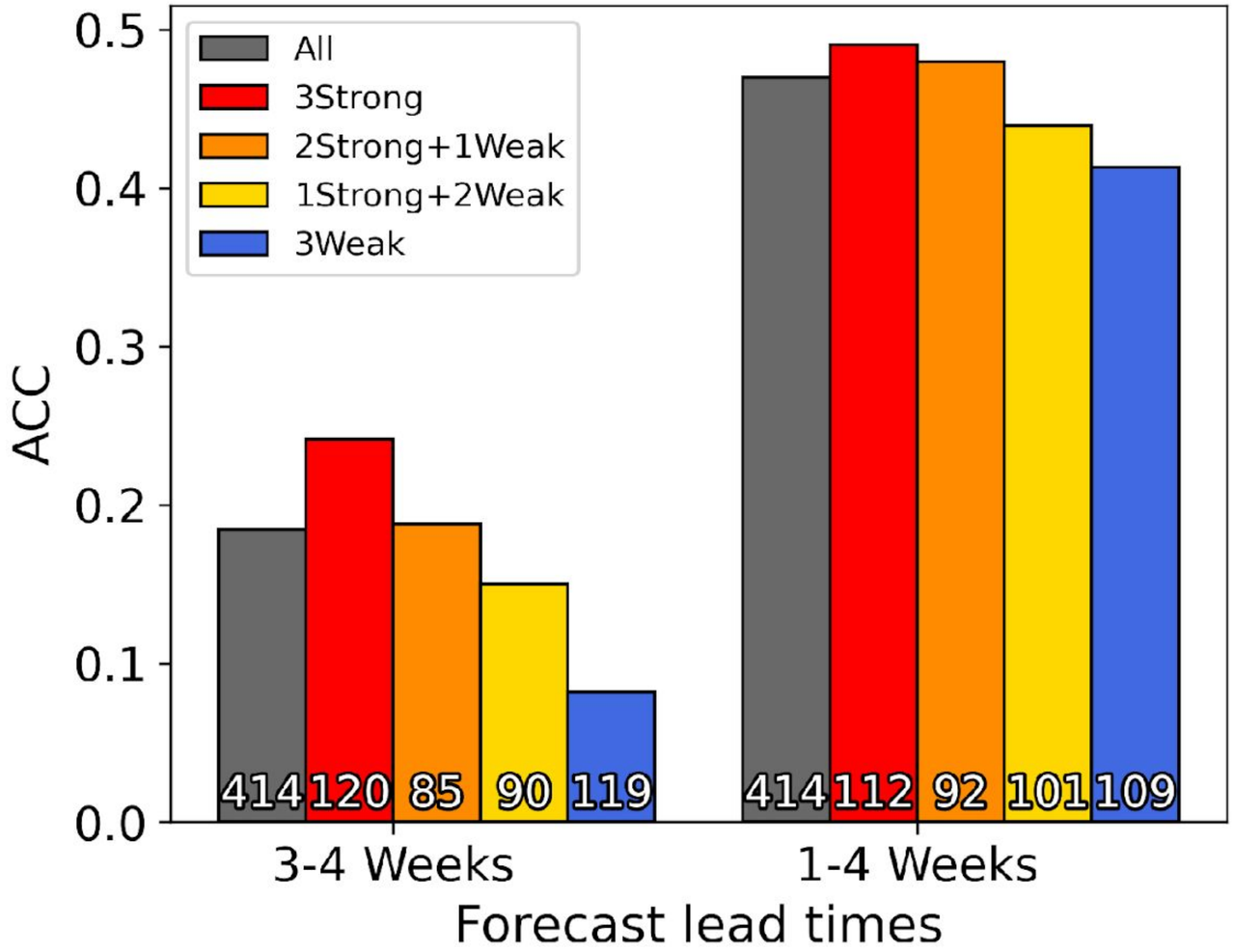


- The prediction skill for surface air temperature

Does a strong L-A coupling increase T2m prediction skill?
Yes!

GODDARD EARTH SCIENCES

Impact of L-A Coupling on Subseasonal Temperature Prediction Skill

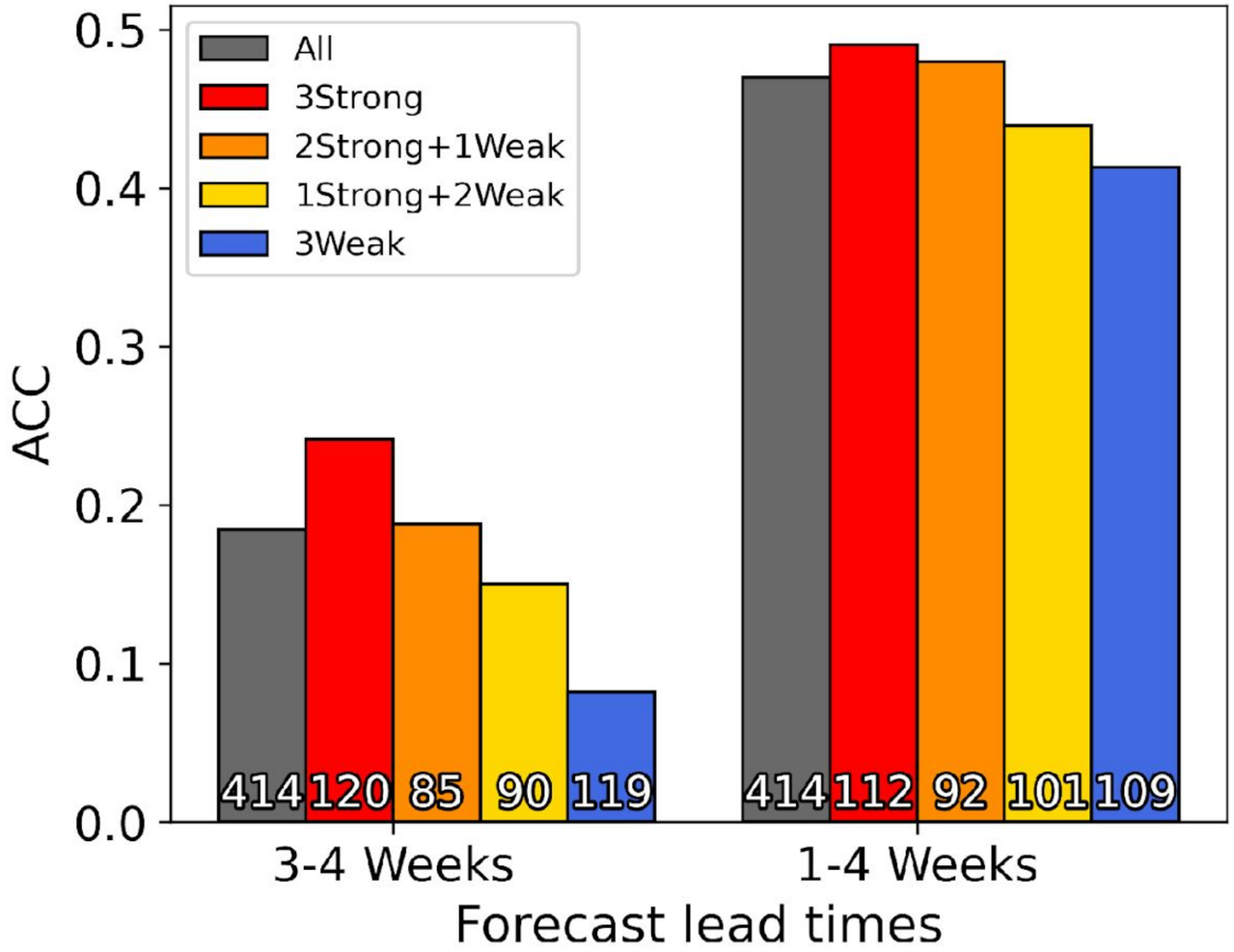


(Lim et al.; in revision)

Does prediction skill increase with deeper coupling across multiple metrics?

GODDARD EARTH SCIENCES

Impact of L-A Coupling on Subseasonal Temperature Prediction Skill



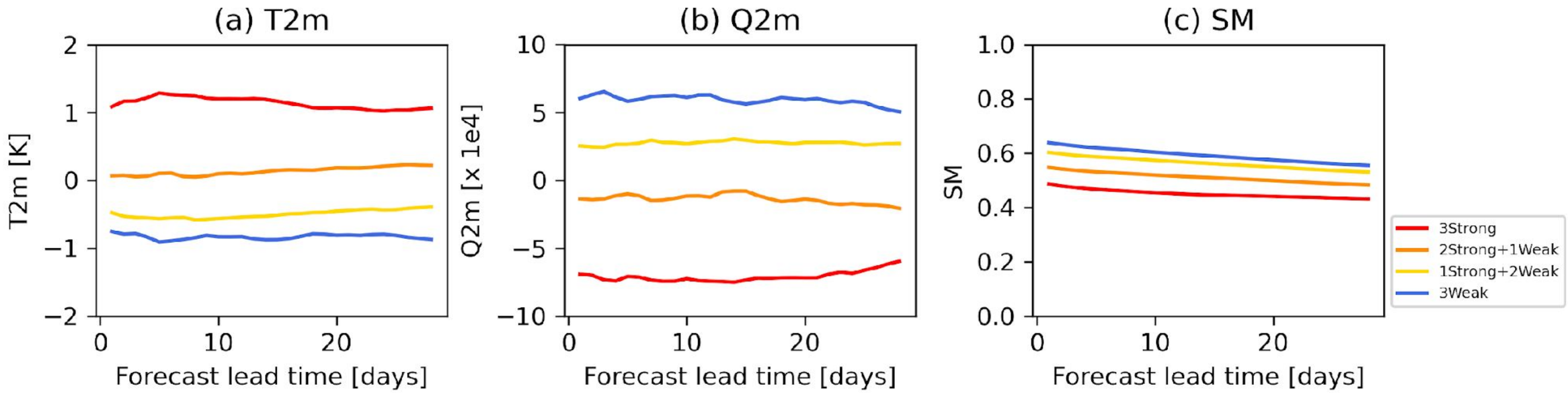
(Lim et al.; in revision)

Does prediction skill increase with deeper coupling across multiple metrics?

⇒ When the L-A coupling is deeply connected from the soil to the free troposphere, the prediction skill significantly increases.

GODDARD EARTH SCIENCES

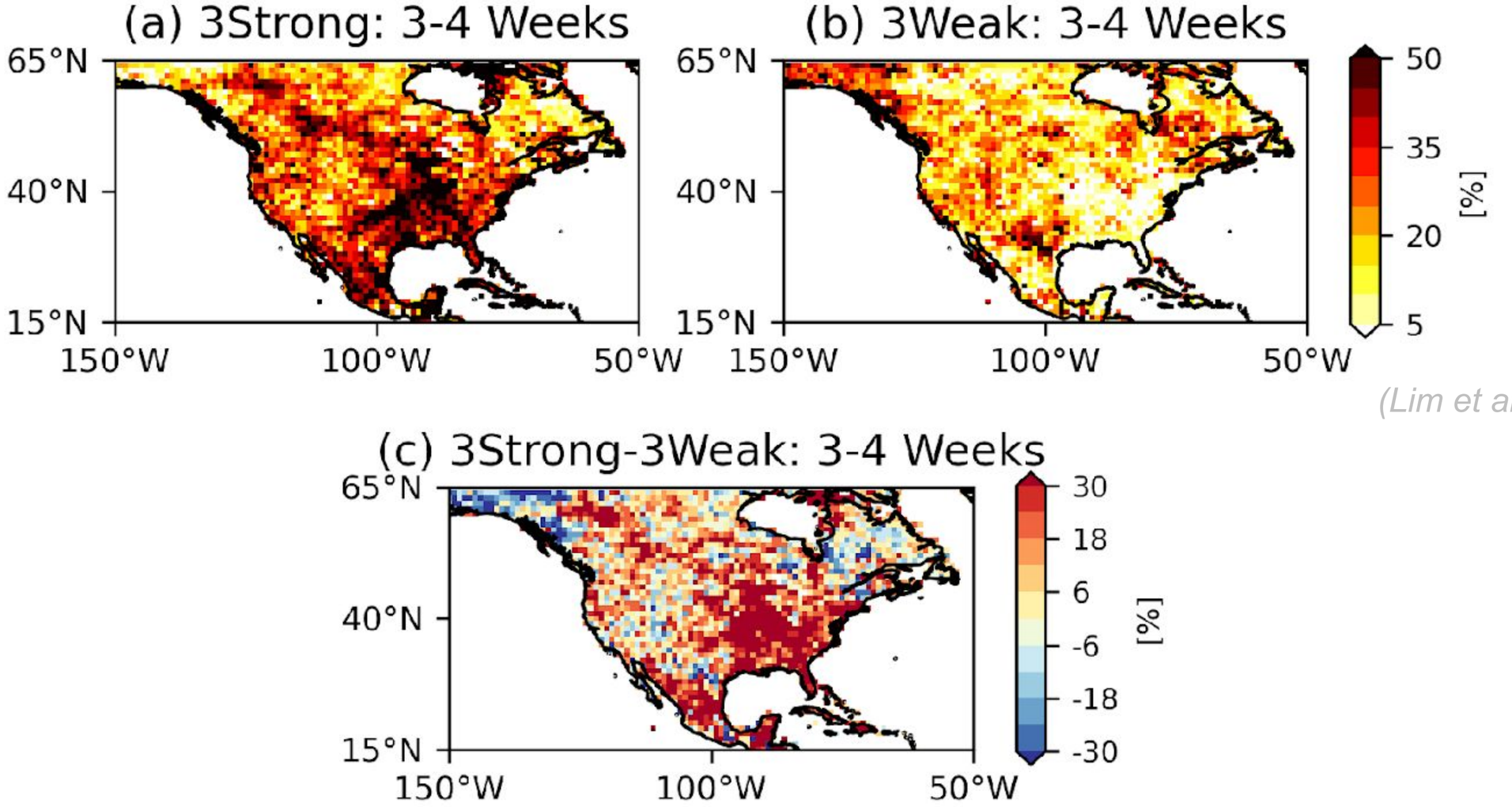
Characteristics of Strong L-A Coupling Events



(Lim et al.; in revision)

- Regions experiencing strong L-A coupling tend to exhibit warm and dry anomalies

Prediction Skill of Abnormally Warm Events



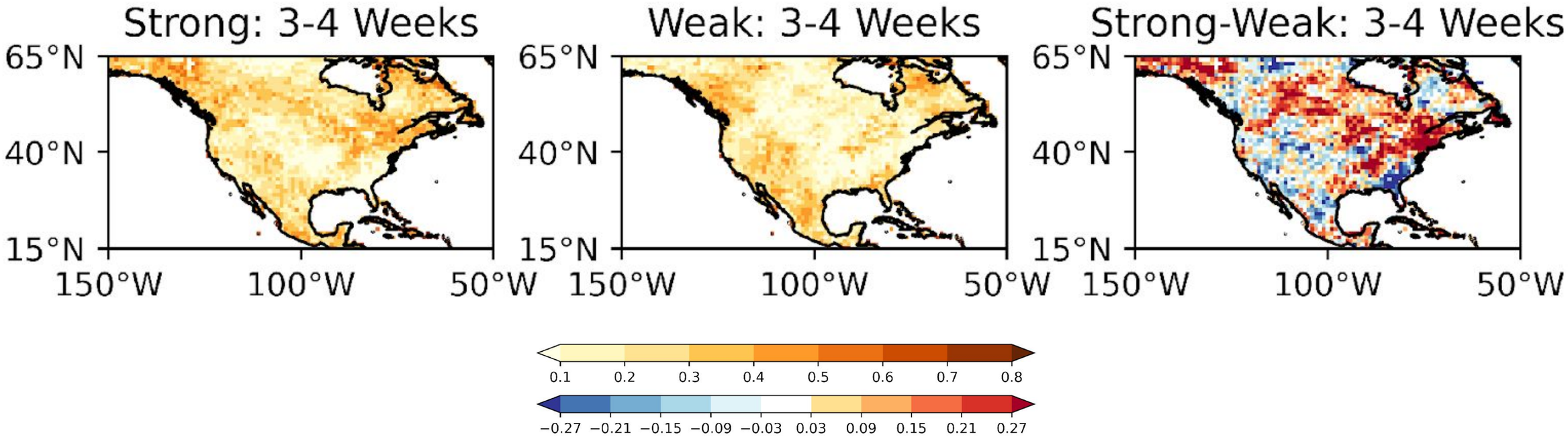
(Lim et al.; in revision)

Summary

- When strong L-A coupling is detected at 3-4 week forecasts, the prediction skill for 2-m temperature is enhanced across the Midwest and northern Great Plains at this forecast lead time.

- Regions experiencing strong L-A coupling tend to exhibit warm and dry anomalies, leading to improved predictions of abnormally warm events.

Ongoing Work - Sensitivity Test: Spring



Summary

- When strong L-A coupling is detected at 3-4 week forecasts, the prediction skill for 2-m temperature is enhanced across the Midwest and northern Great Plains at this forecast lead time.

- Regions experiencing strong L-A coupling tend to exhibit warm and dry anomalies, leading to improved predictions of abnormally warm events.

Contact: Yuna Lim (yu-na.lim@nasa.gov)

GODDARD EARTH SCIENCES