MJO-teleconnection in UFS prototype 5 and 6 in the troposphere: impact of vertical model levels

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The work has been submitted to Climate Dynamics

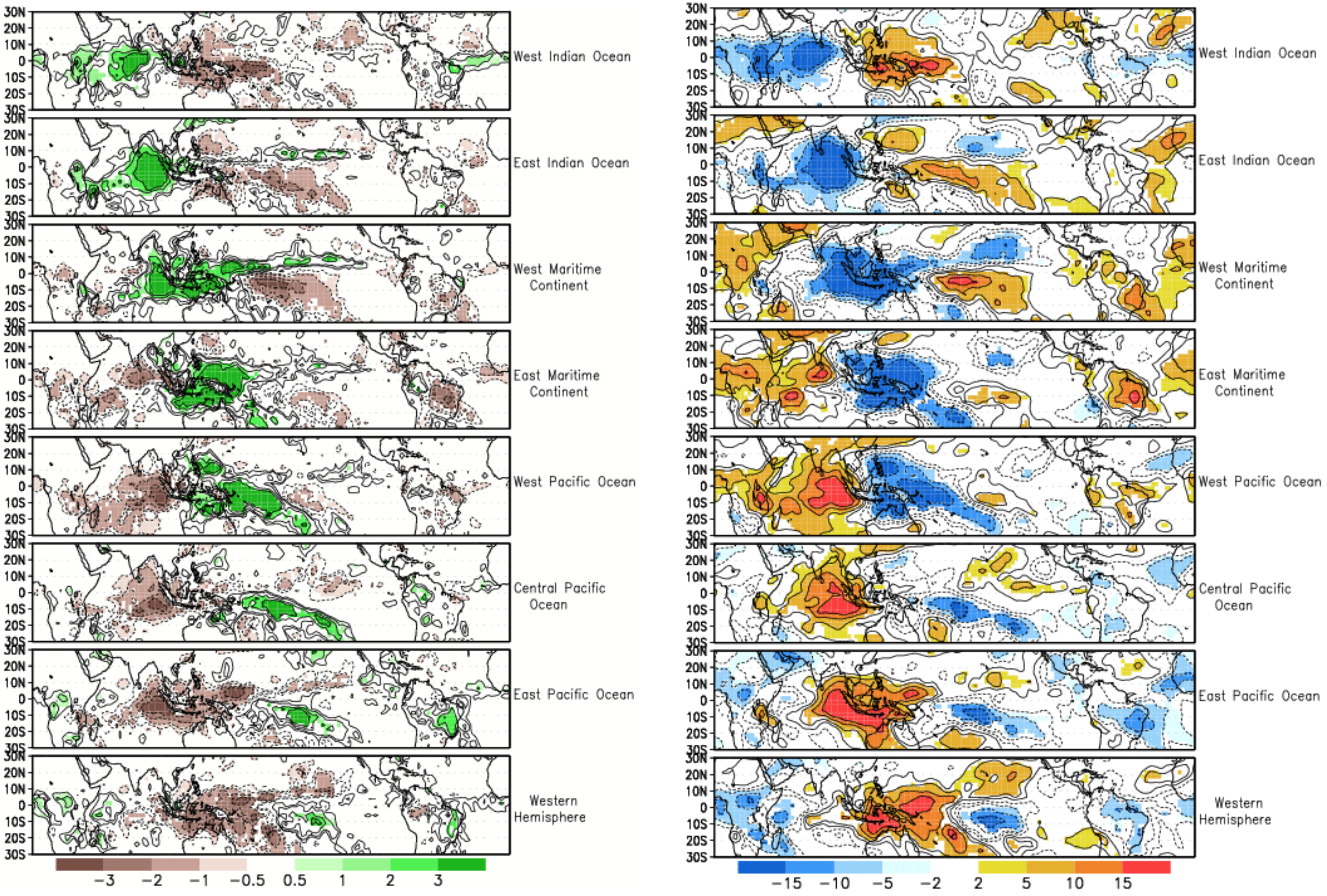
Madden Julian Oscillation (MJO, 30-80 days)

Dominant mode of tropical intrapersonal variability

RMM index

Realtime Multivariate MJO index (Wheeler and Hendon 2004)

Multivariate-EOF of OLR, U850 & U200



Phase 2

Phase 3

Phase 4

Phase 5

Phase 6

Phase 7

Phase 8

Phase 1

Precipitation anomalies

OLR anomalies

from CPC website

Madden Julian Oscillation (MJO, 30-80 days)

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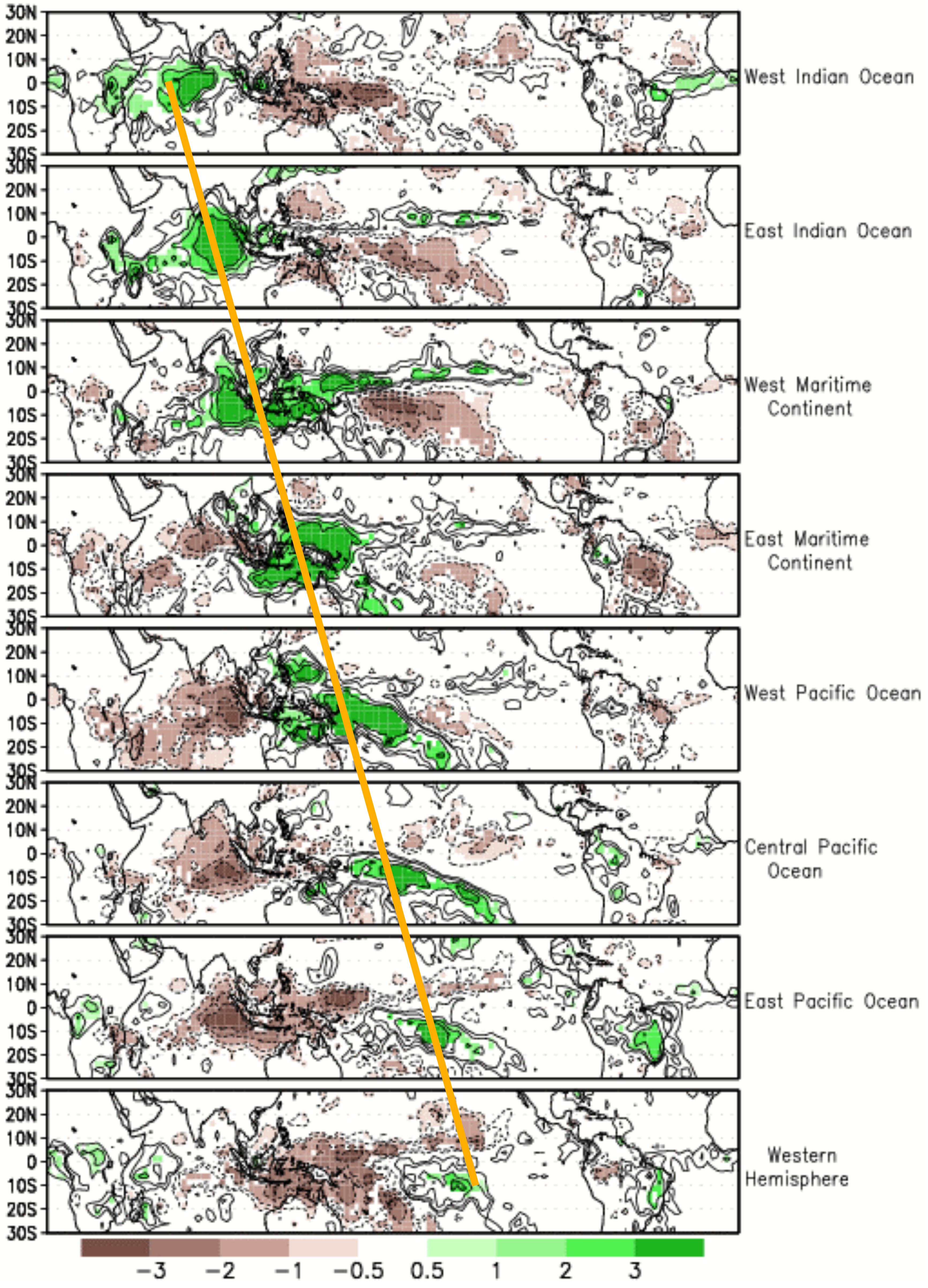

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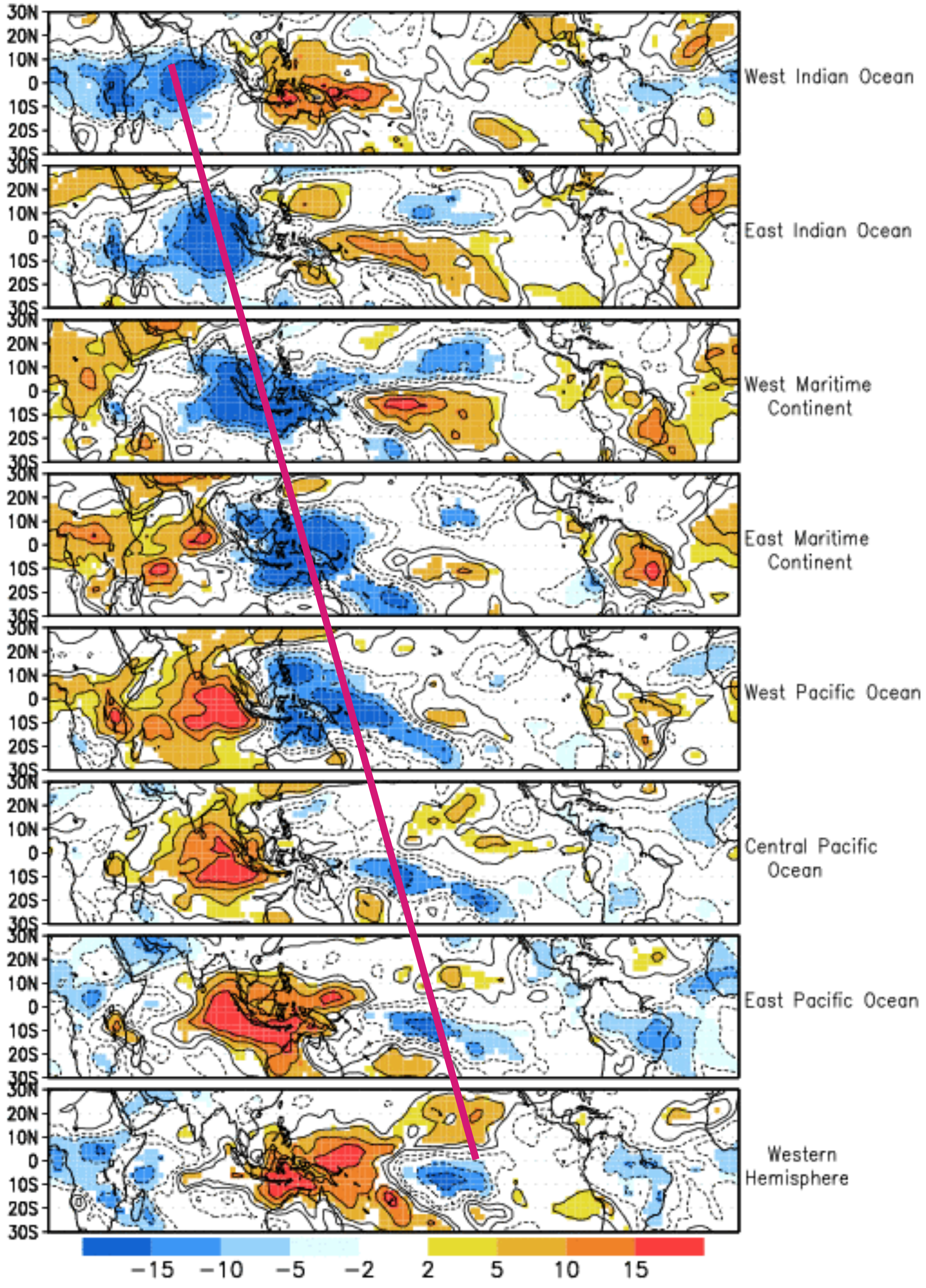

OLR anomalies

RMM index
Phase 2
Phase 3
Phase 4
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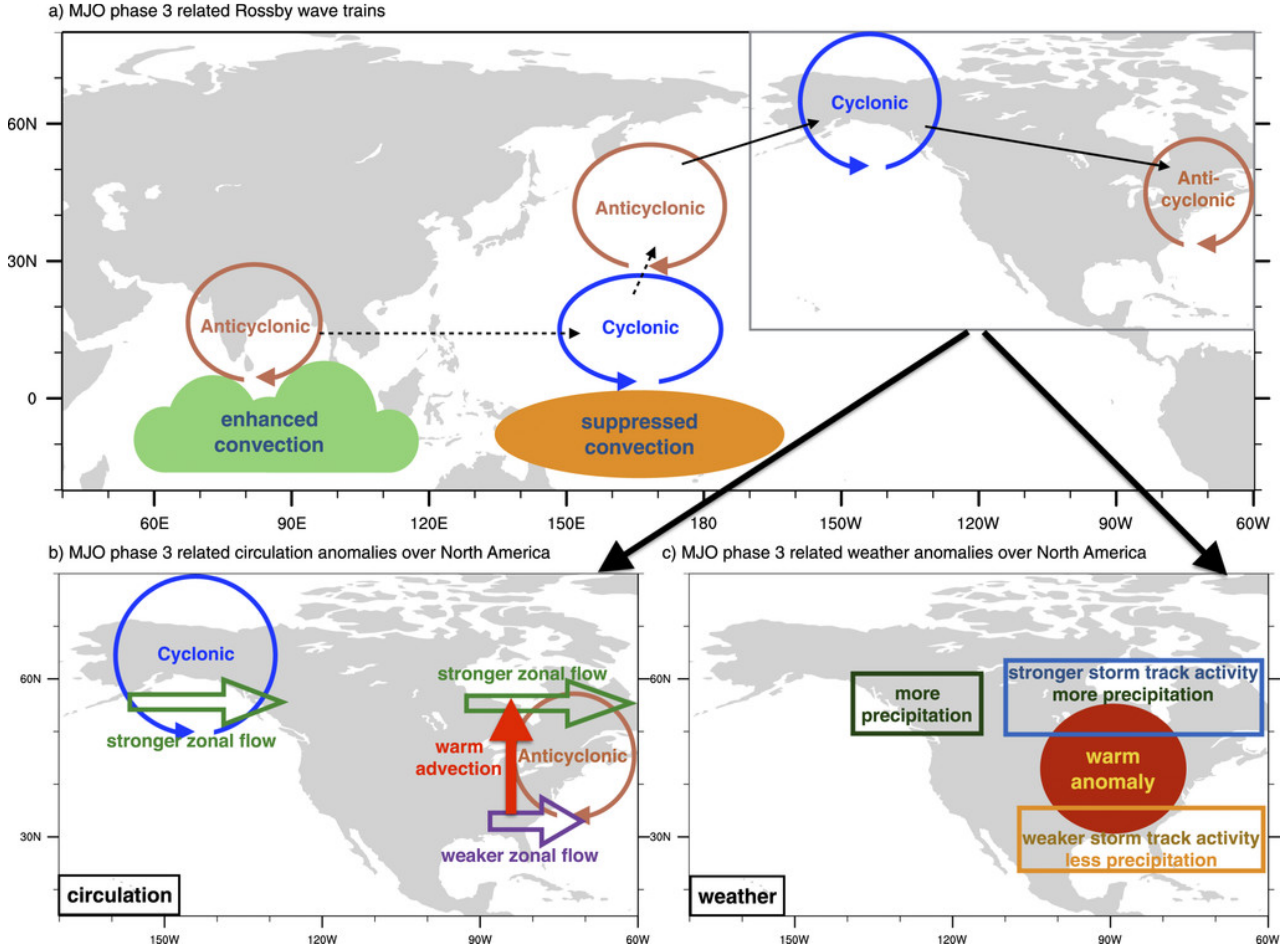
MJO teleconnection

North America



Zheng et al., (2018)

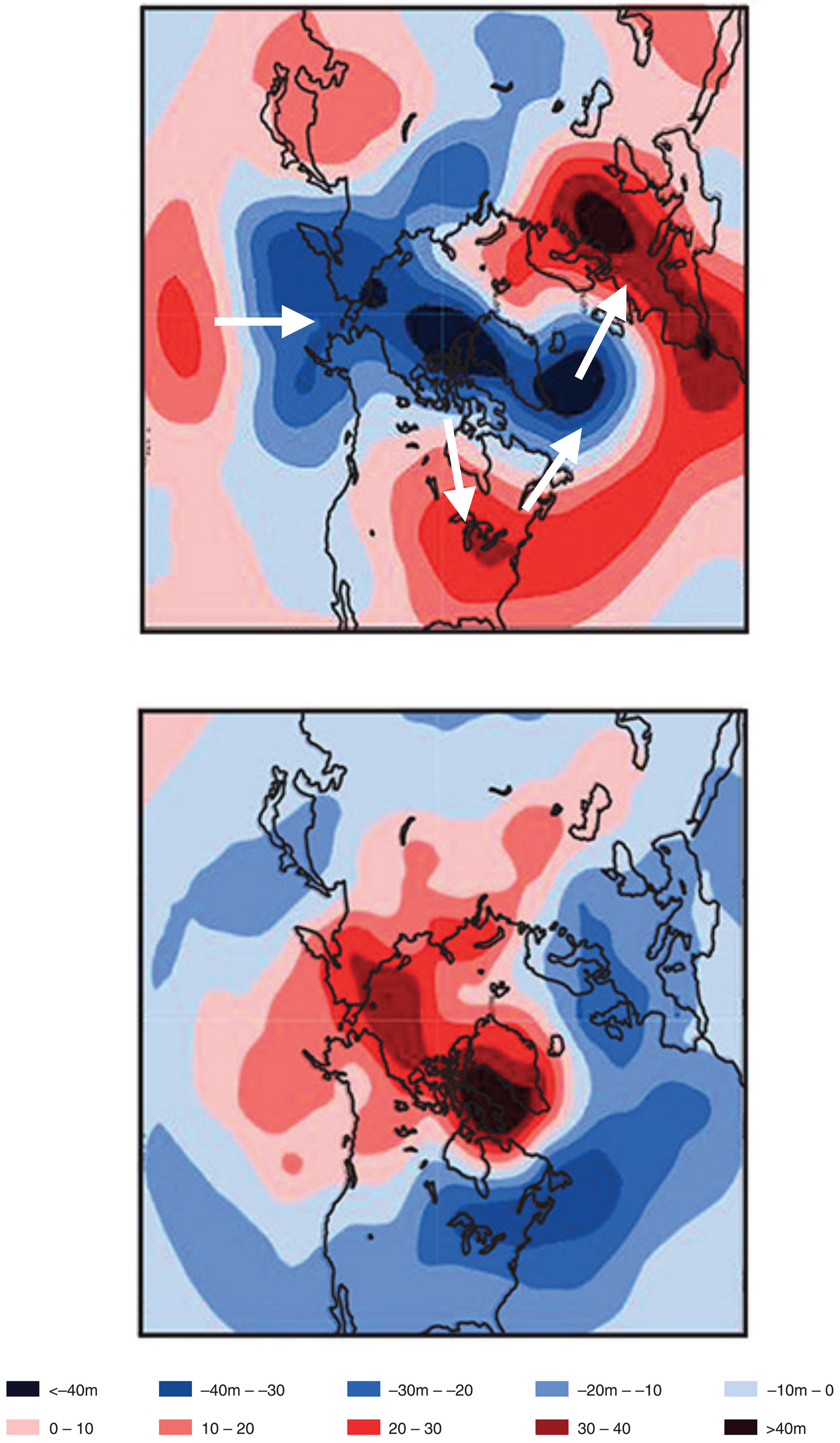
MJO teleconnection

Z500
Day 11-15

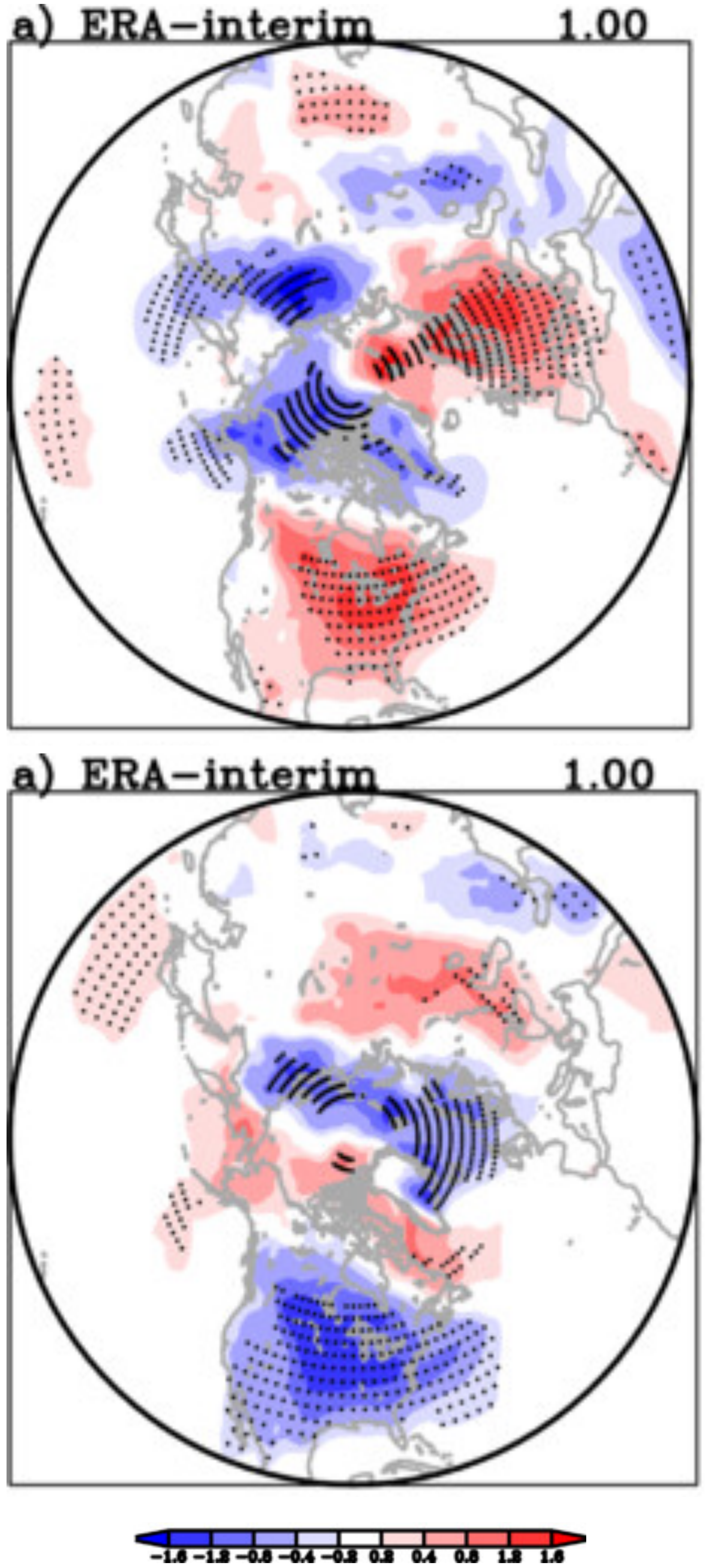
T2m
week 3

Phase3

Phase7



Vitart (2017)



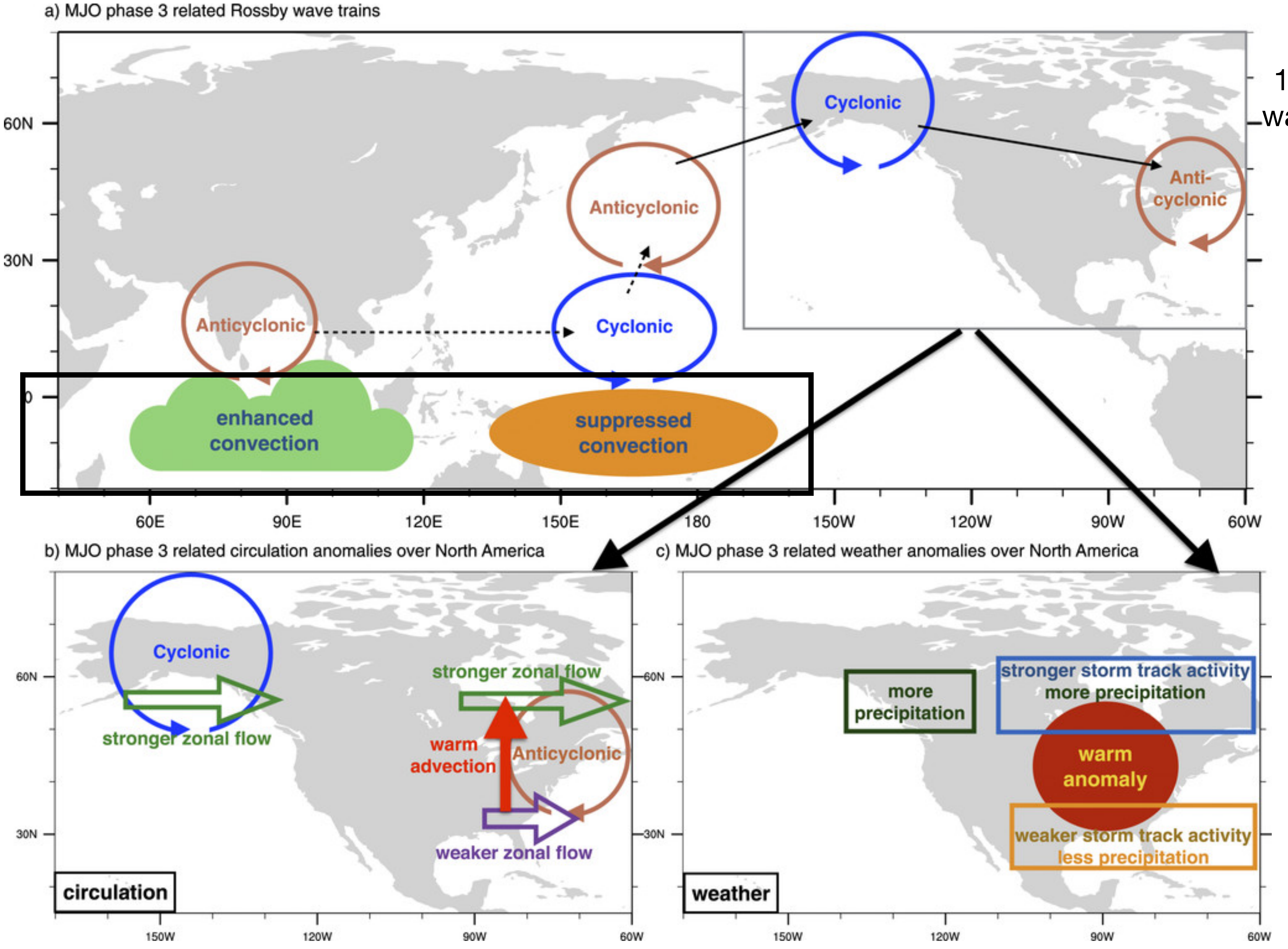
Stan et al., (2022)

NAO
Signal

MJO teleconnection

North America

MJO
Skillful prediction:
3~4 weeks



1~2 weeks for Rossby wave propagation in the extratropics

Zheng et al., (2018)

Evaluation of MJO teleconnection in UFS

Large scale circulation: ***Z500***

Surface Weather: ***T2m, precip***

Evaluation of MJO teleconnection in UFS

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Surface Weather: ***T2m, precip***

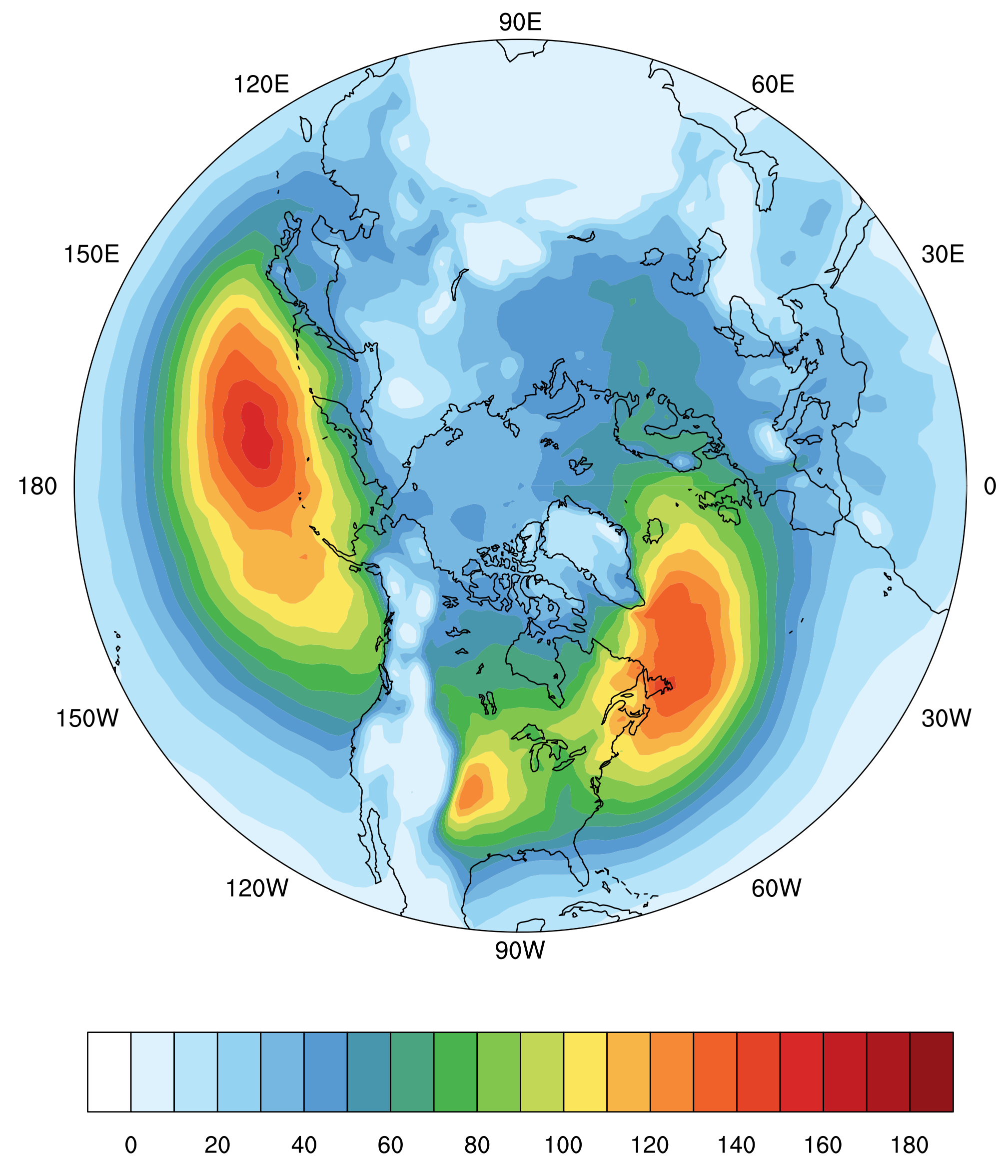
Extratropical cyclone activity: ***EKE850***

$$\mathrm{eke850}(t)=\frac{1}{2}\left\{\overline{\left[\mathrm{U850}(t+24\,\mathrm{h})-\mathrm{U850}(t)\right]^{2}}+\overline{\left[\mathrm{V850}(t+24\,\mathrm{h})-\mathrm{V850}(t)\right]^{2}}\right\},$$

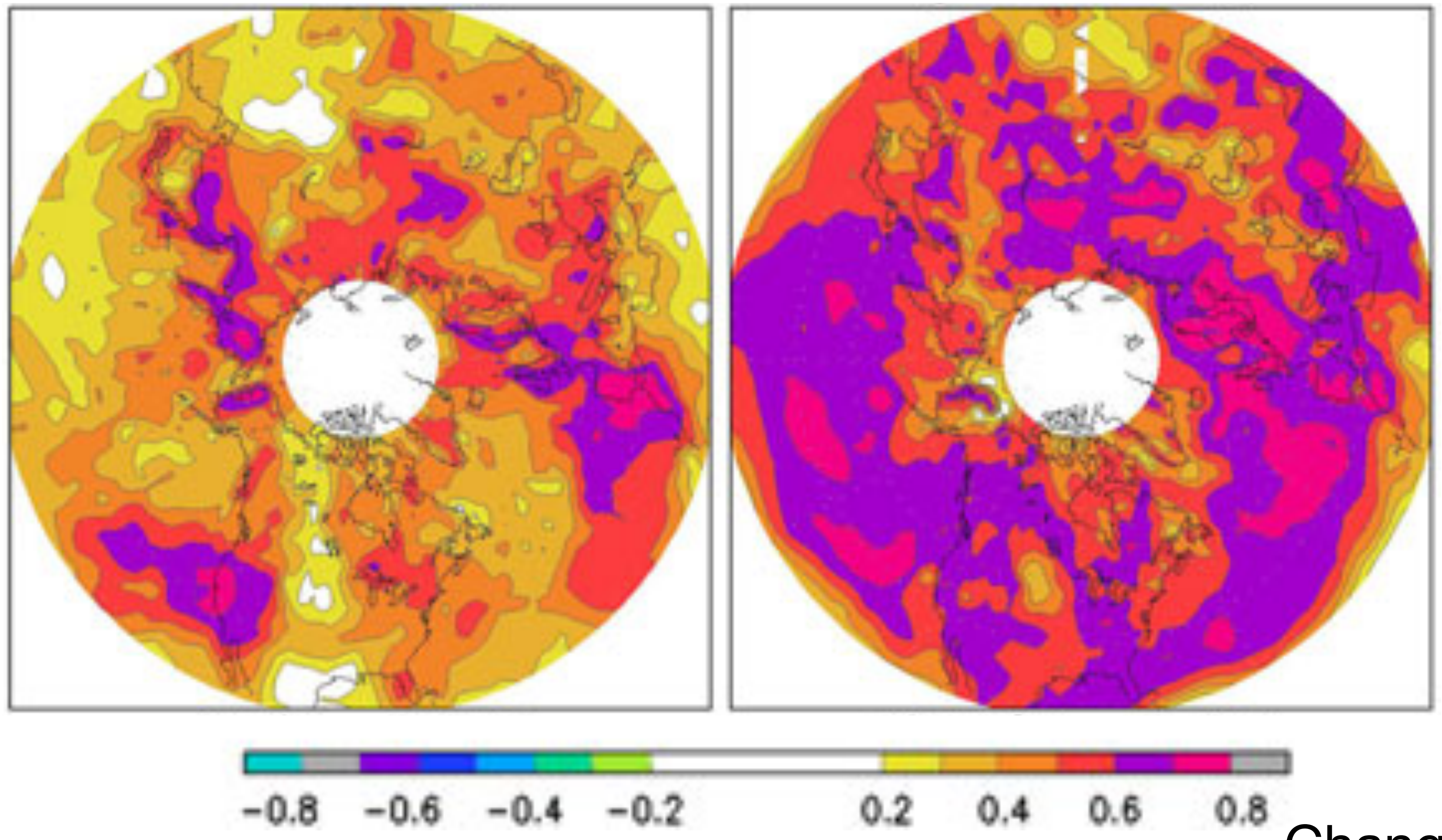
24-h difference filtered eddy kinetic energy at 850-hPa

highlights synoptic scale variability

EKE850 Winter climatology



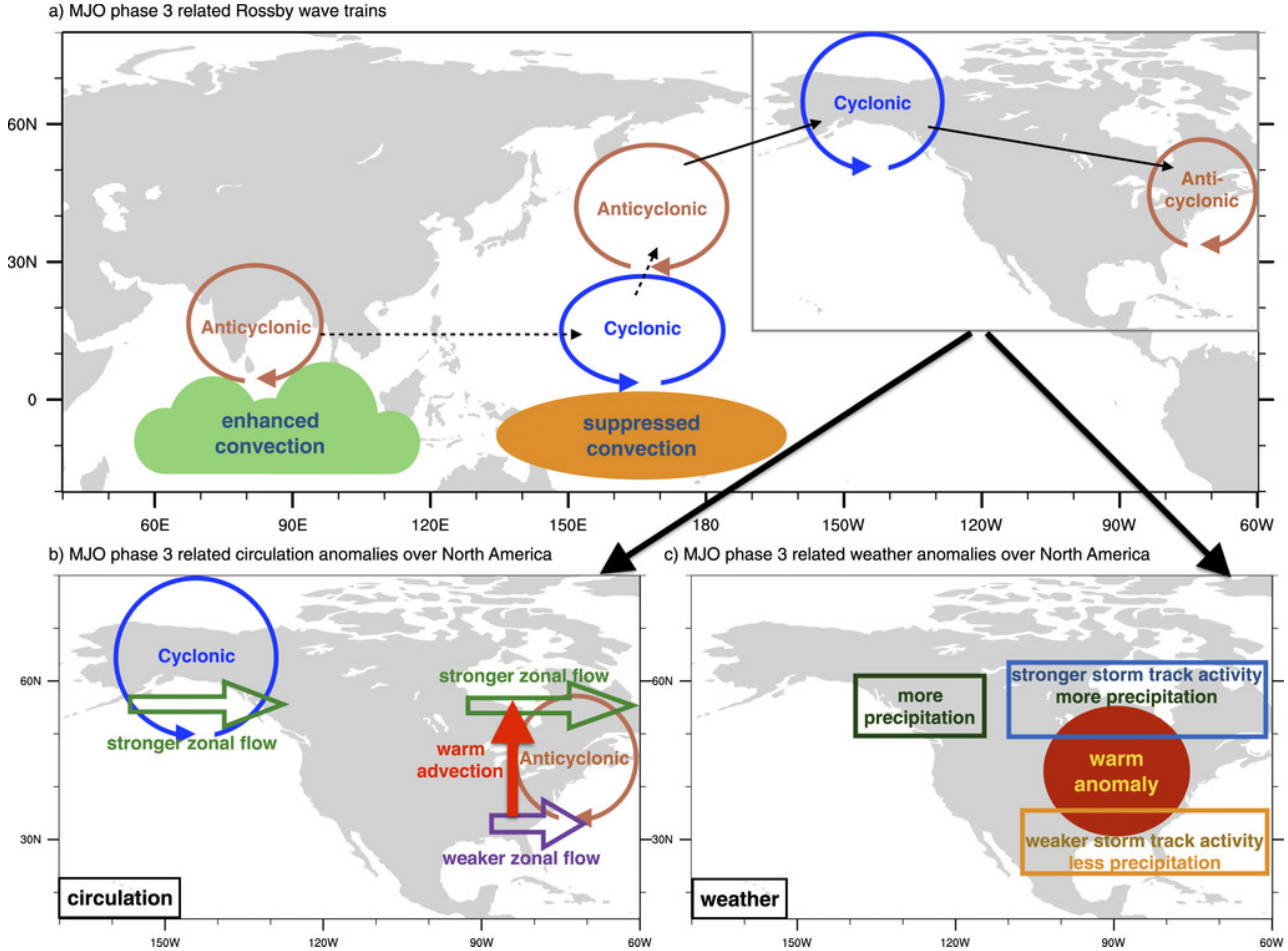
Correlation between EKE850/SLPvar
And
precip high wind events



Chang et al., (2022)

Evaluation of MJO teleconnection in UFS

North America



Large scale circulation drives anomalies in extratropical cyclone activity in sub-monthly time scales

Zheng et al., (2018)

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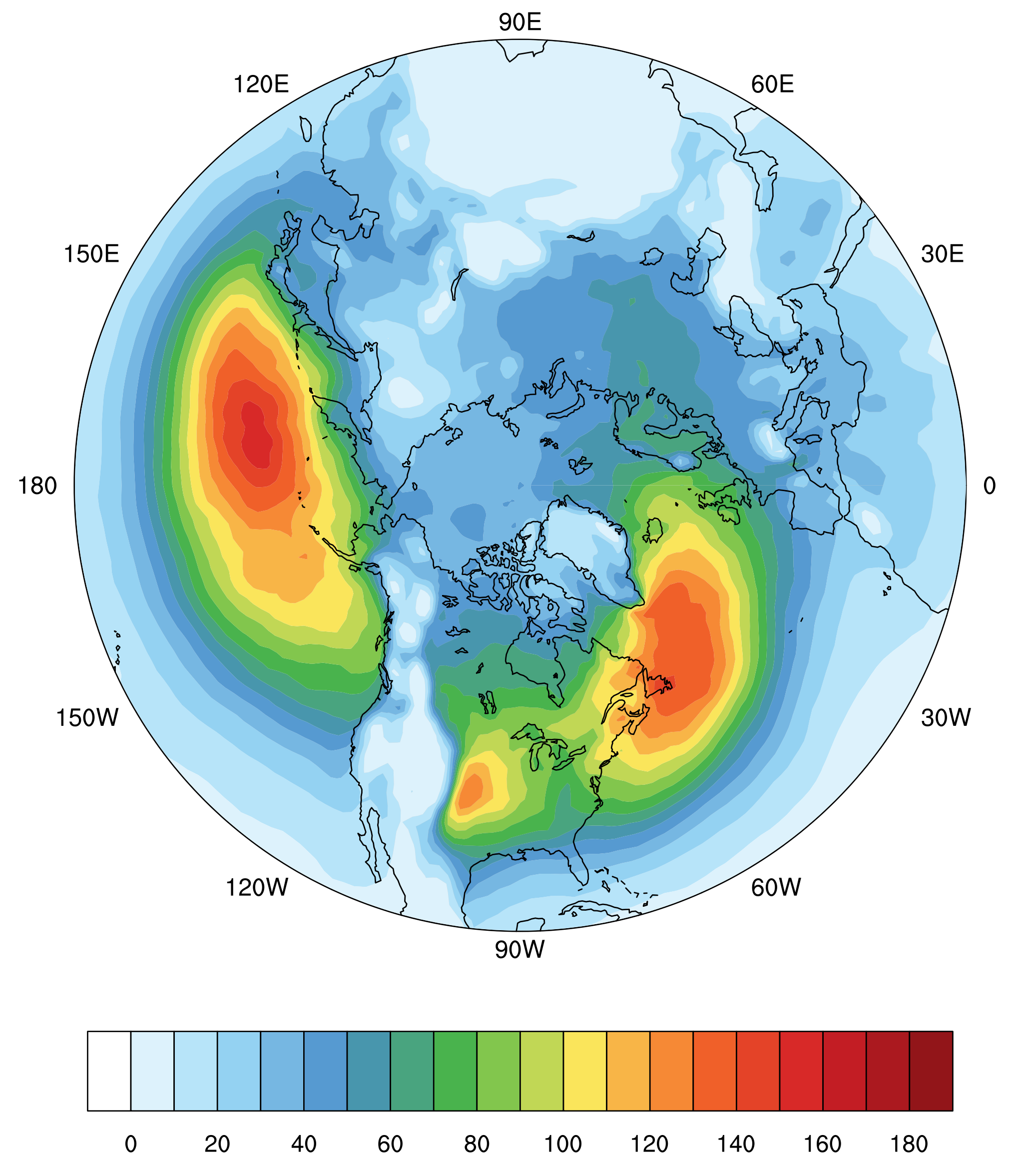

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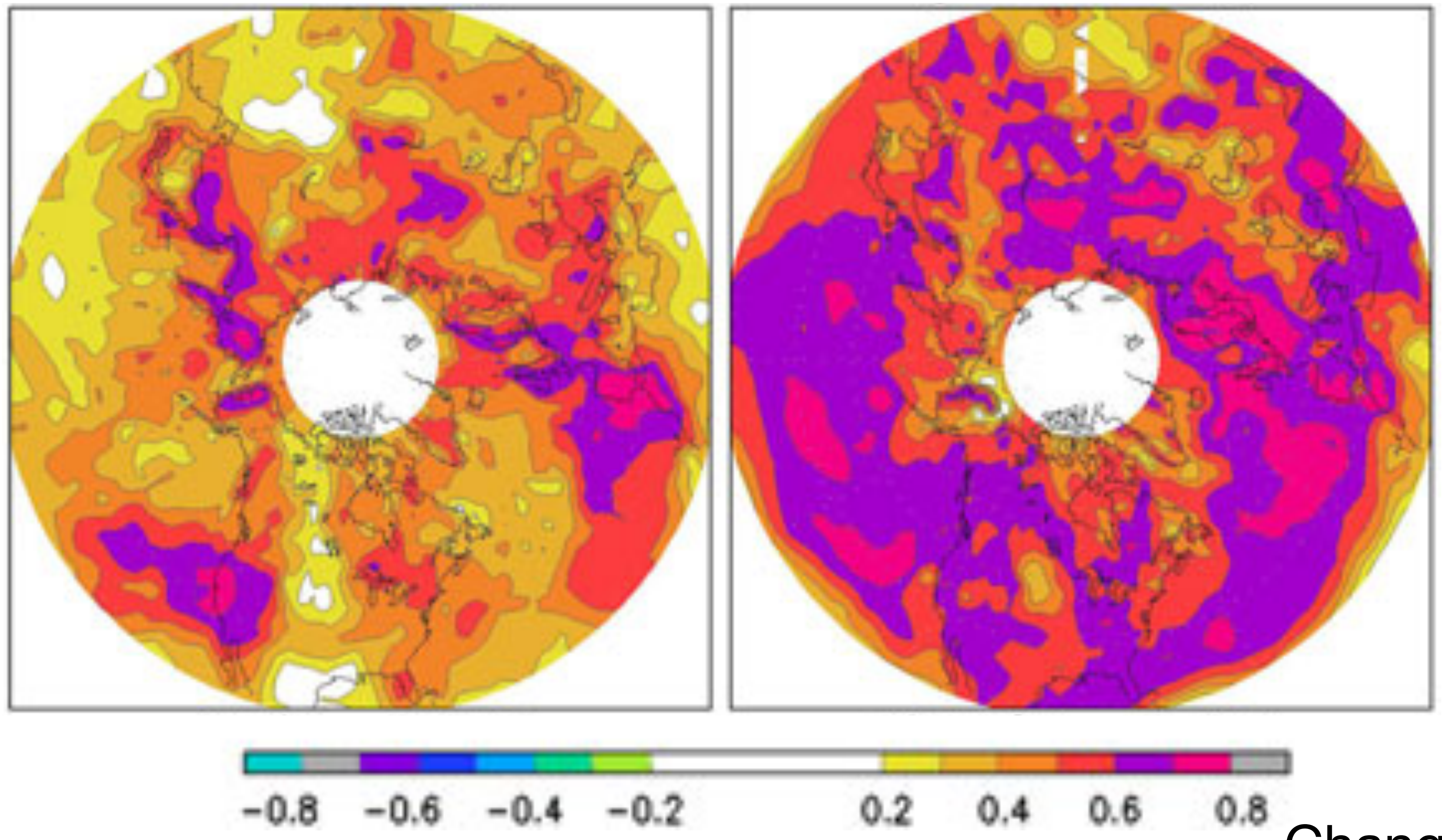

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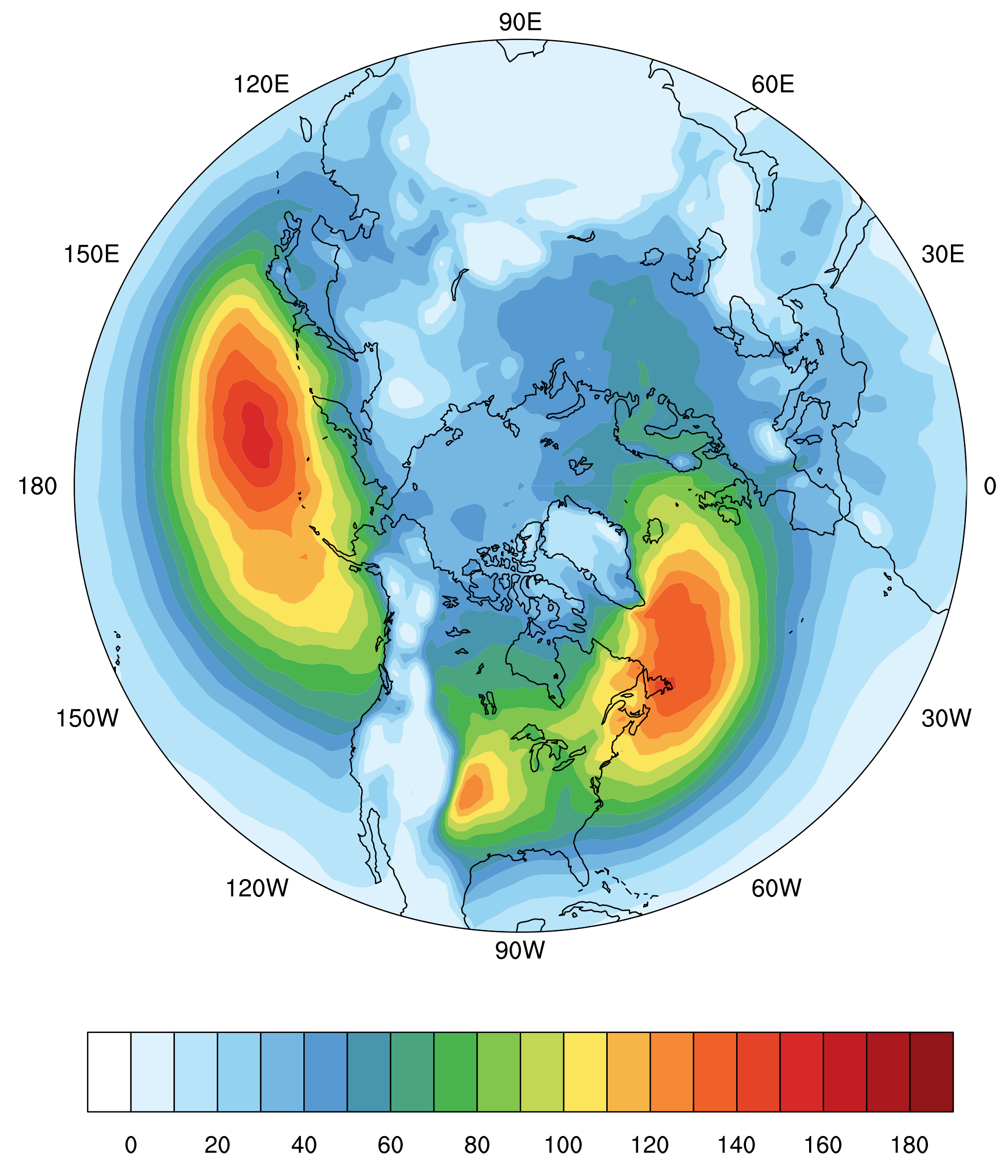
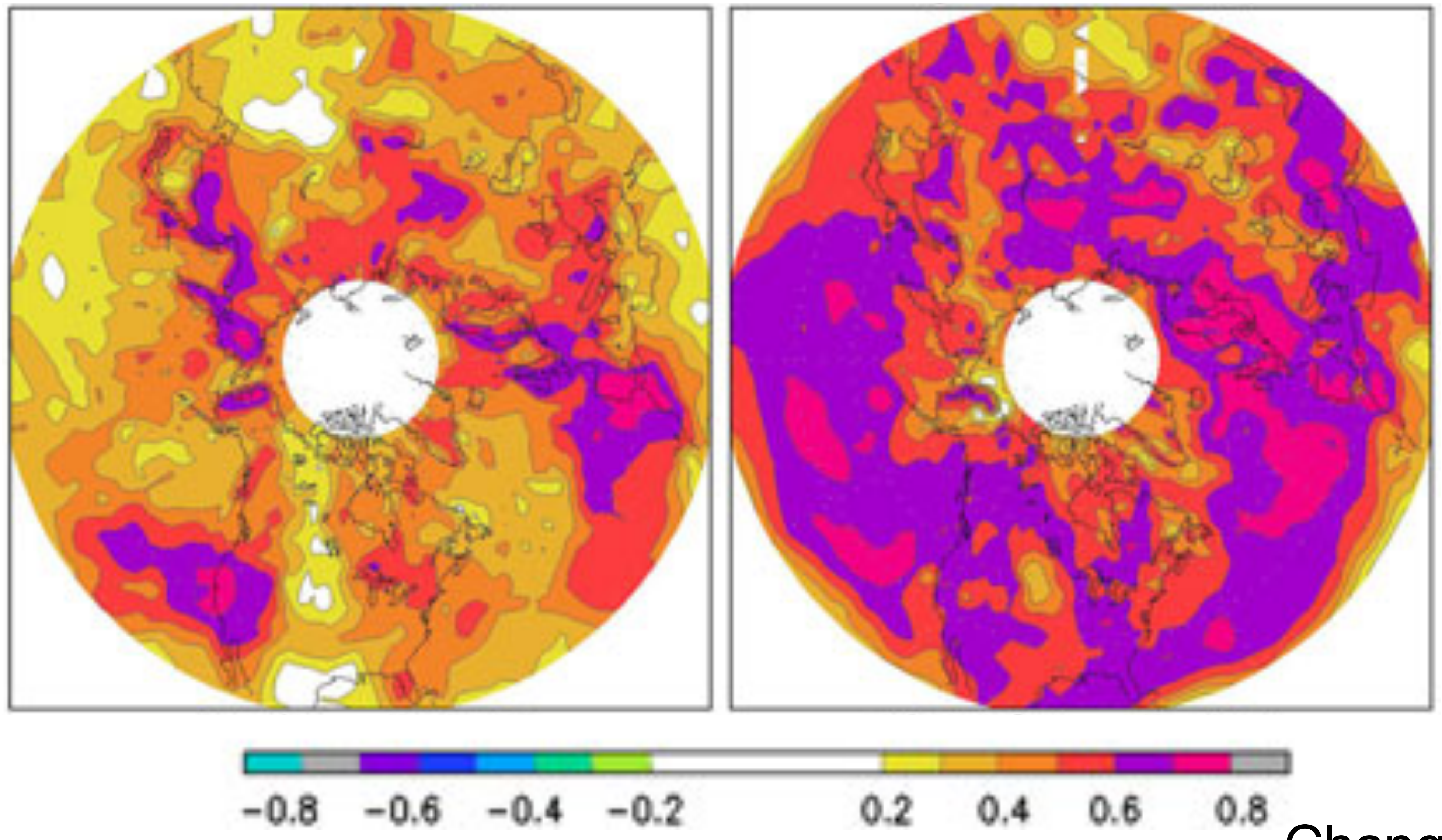


Evaluation Methods

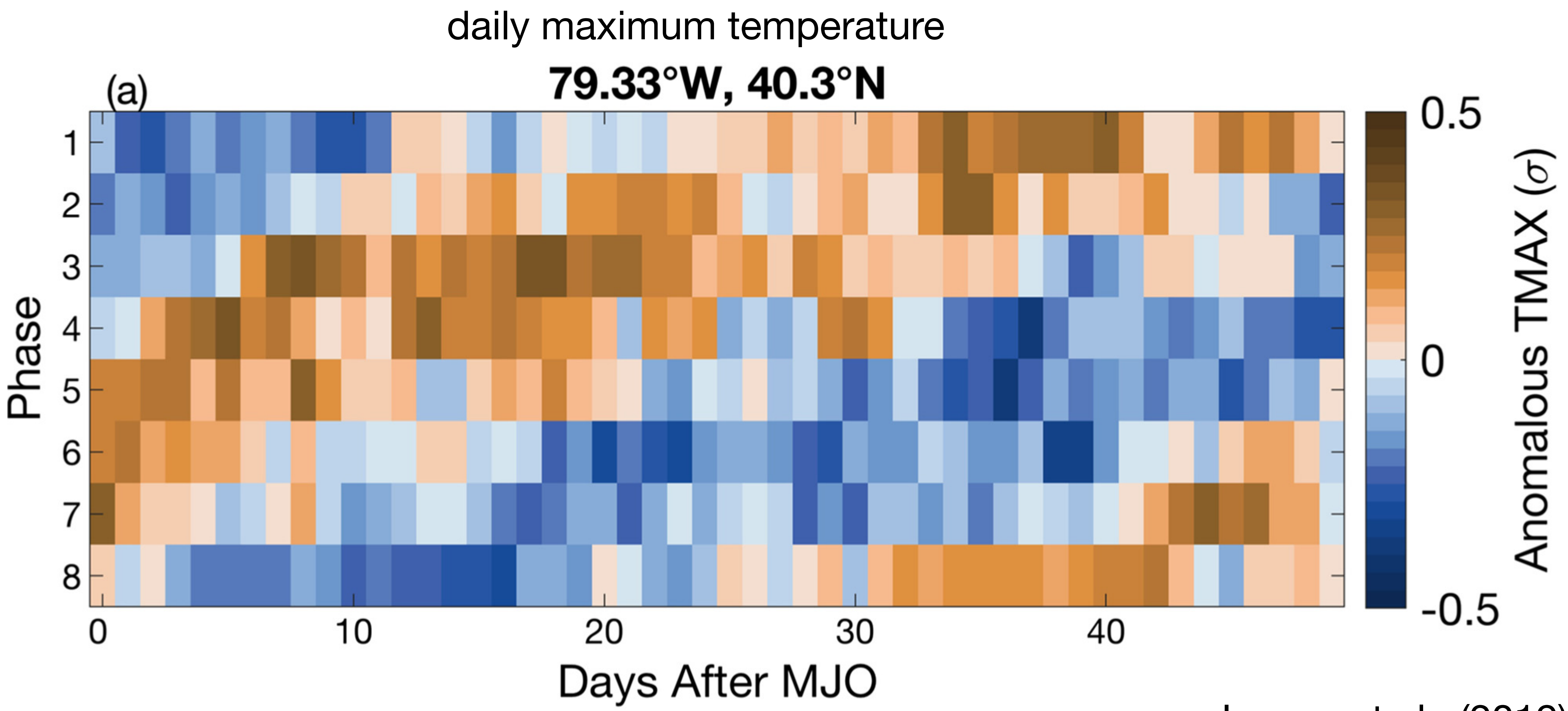
a) Composite analysis: Anomalies after specific MJO phases
b) STRIPES index (Jenney et al., 2019)

Correlation between EKE850
And
precip high wind events



Chang et al., (2022)

STRIPES index



Jenney et al., (2019)

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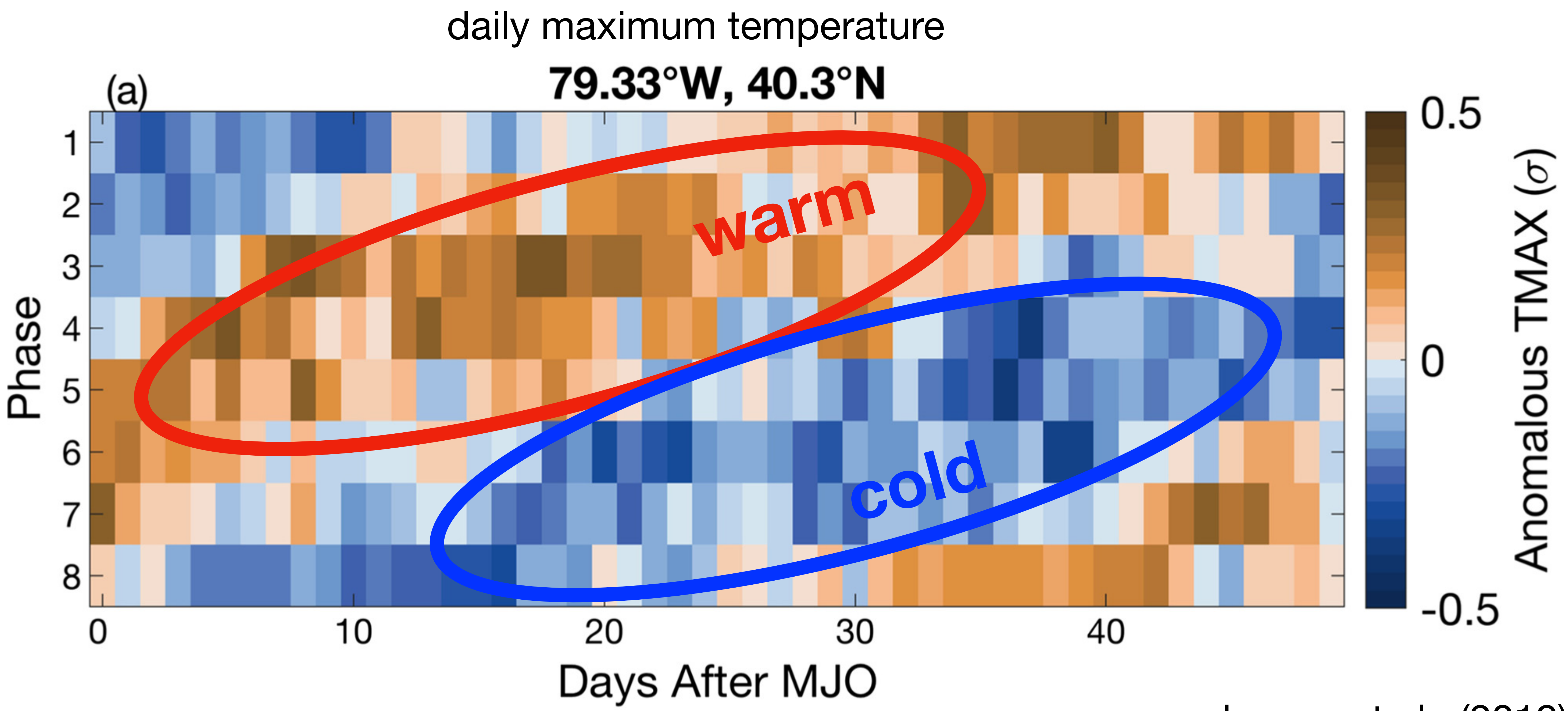


Jenney et al., (2019)

STRIPES index: The oscillation (amplitude) of variables (z500, precip, etc) associated with different MJO phases and lag time

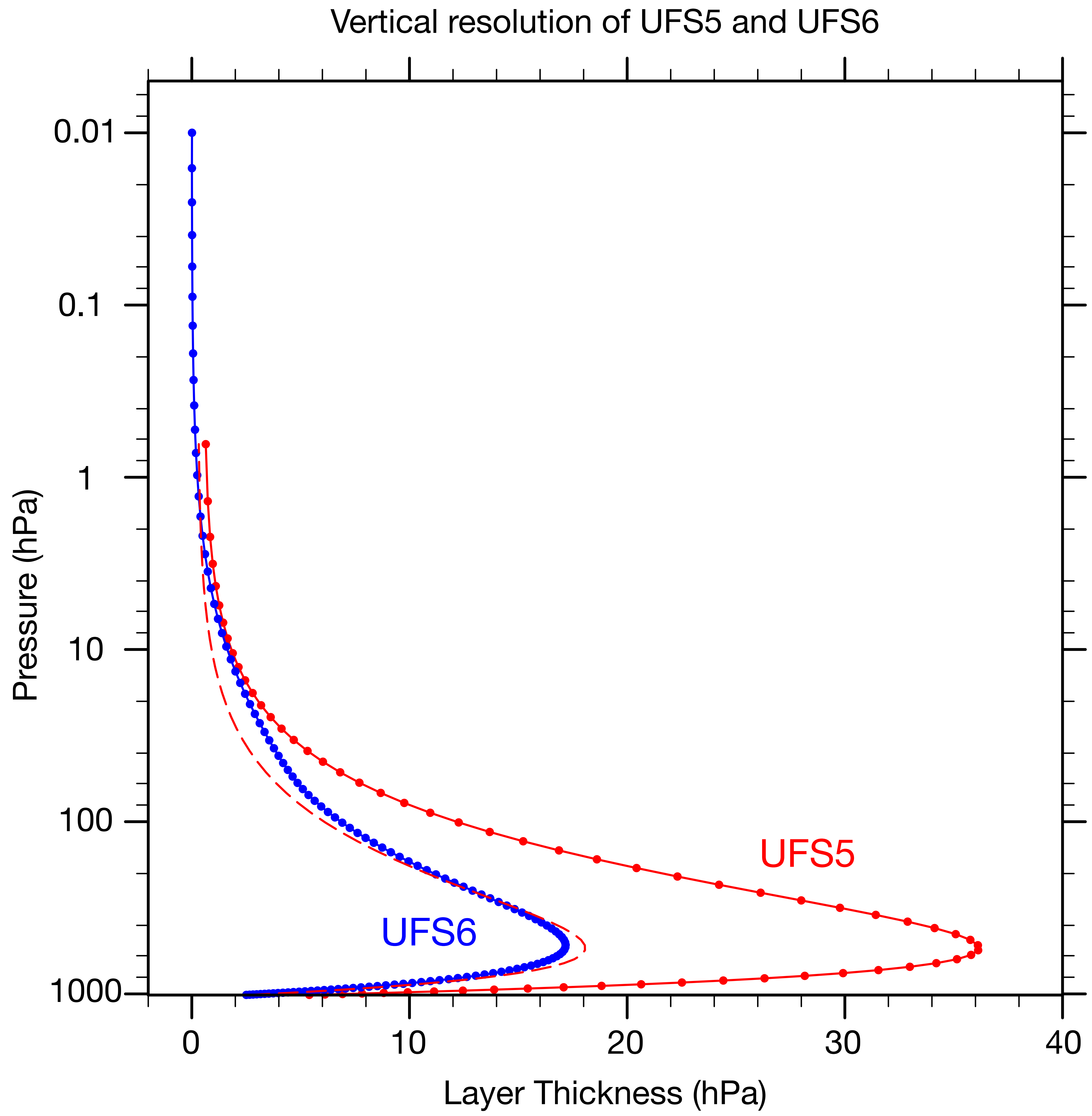
UFS

Prototype 5 & 6:

Reforecast from Apr 2011 to Mar 2018

168 reforecast runs in total

Proto type	Atmospheric Model C384 (~0.25 degree) horizontal resolution			Ocean Model Tripolar ~0.25 degree horizontal resolution	Wave Model Regular lat/lon 0.5 degree grid	Ice Model Tripolar ~0.25 degree horizontal resolution	Mediator
	Dynamical Model	**Physics Settings & Driver**	**Land Model**				
UFS5	FV3 64 layers, Non-Fractional grid (model top at 54km)	GFSv15.2, CCPP driver	Noah LSM	MOM6	Wavewatch III	CICE6 (Mushy thermodynamics not turned on)	CMEPS
UFS6	FV3 127 layers, Fractional grid (model top at 80km)	GFSv16, CCPP driver					



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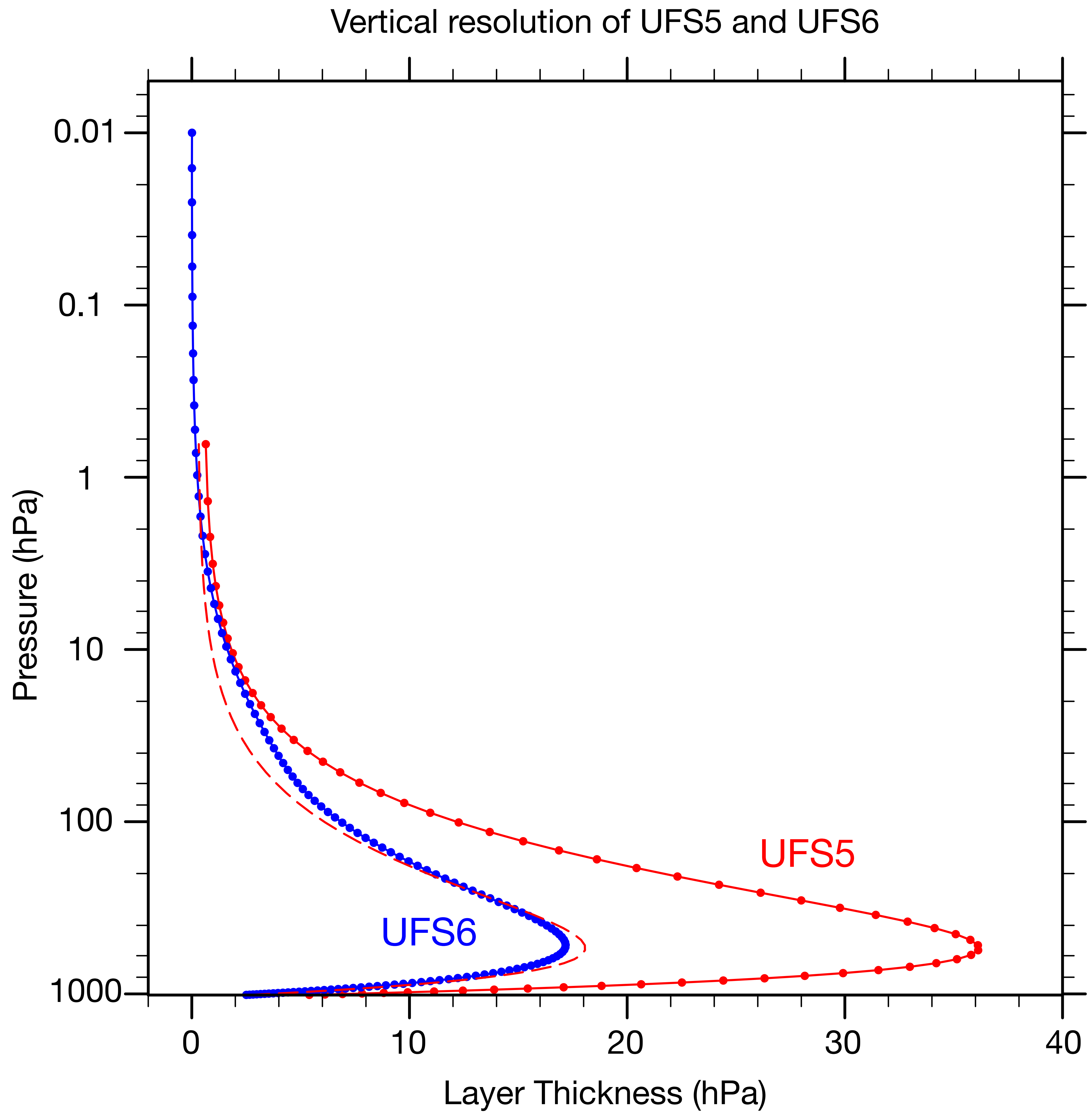


UFS

MJO itself and MJO teleconnection in UFS prototype 5 and 6:

Extended boreal winter: NDJFM (70 reforecast runs)

MJO phases defined by “observed” RMM index at reforecast initialization

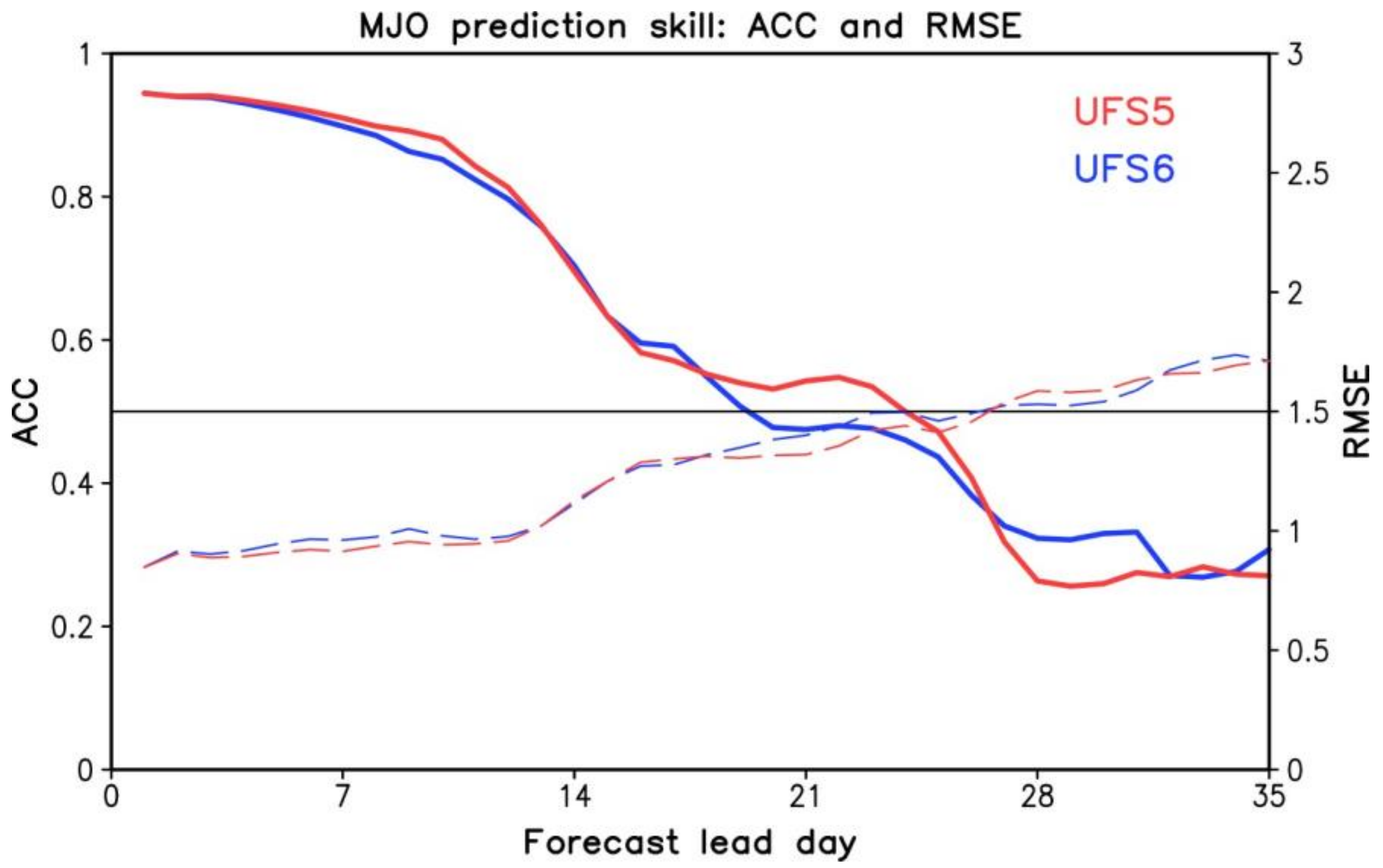
MJO events: RMM index amplitude > 1 at initialization

Climatology (as a function of lead time): average of reforecast runs that are initialized at the same month and day across different years

Forecast anomalies: deviation from the climatology

Verification dataset: ERA-interim & IMERG(percip), NOAA OLR

UFS: Prediction of the MJO



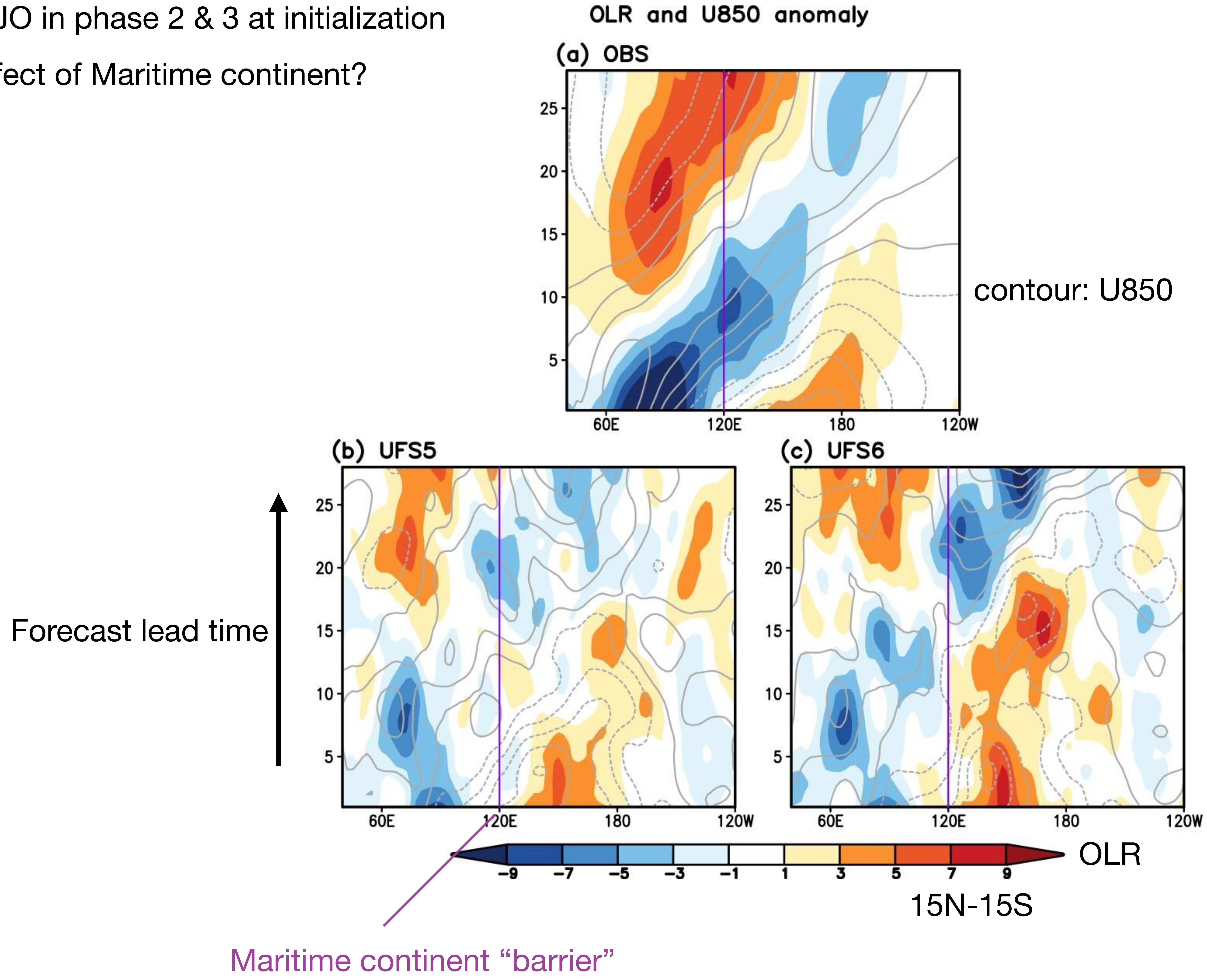
UFS5 is slightly better in week 3

Performance not as good as the top performed S2S models in predicting MJO

UFS: Prediction of the MJO

MJO in phase 2 & 3 at initialization

Effect of Maritime continent?



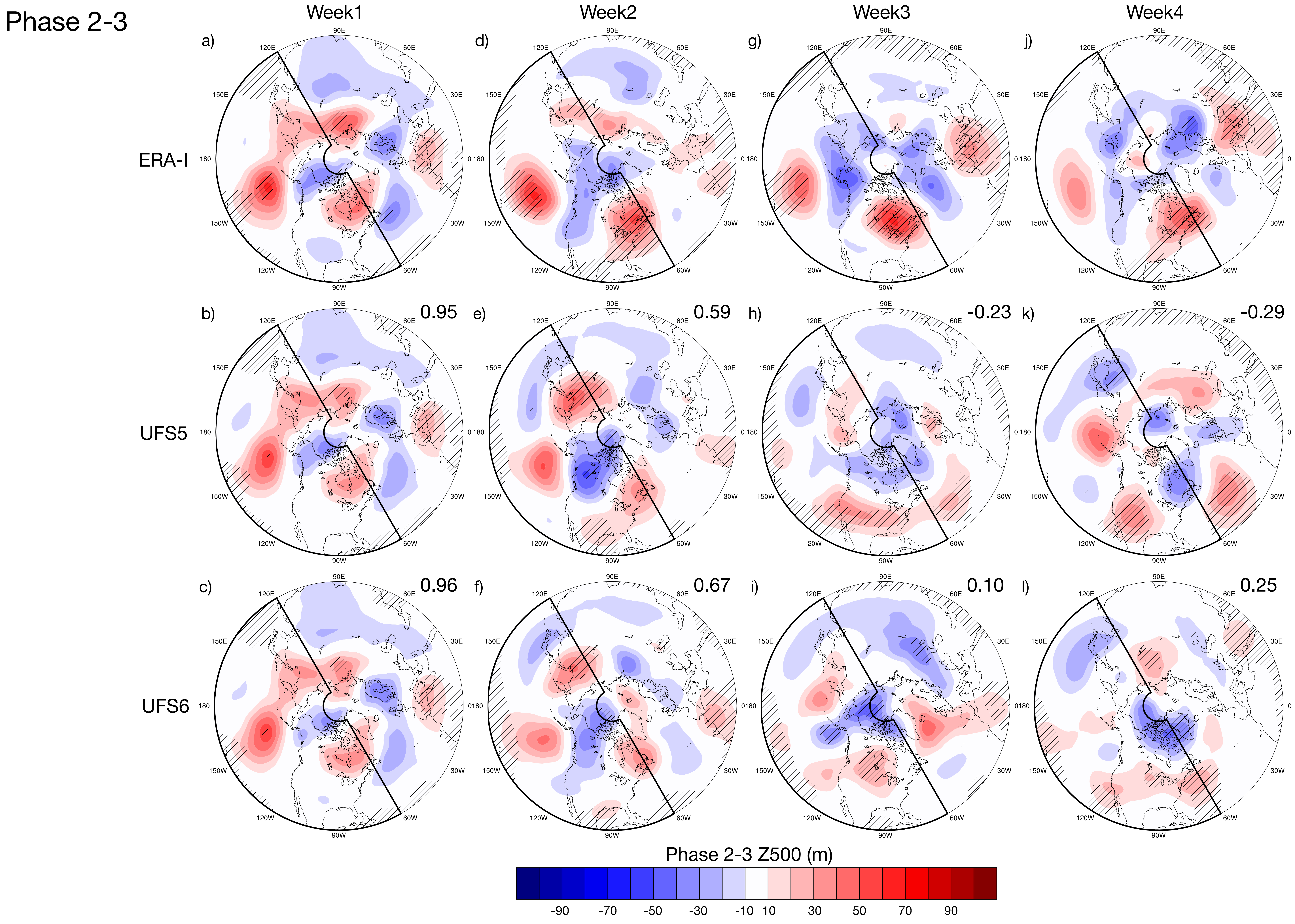
UFS5: OLR signal is too weak;

u850 continues propagating in week 2

UFS6: stronger OLR signal compared with UFS5

propagation speed too slow

MJO teleconnection (z500)



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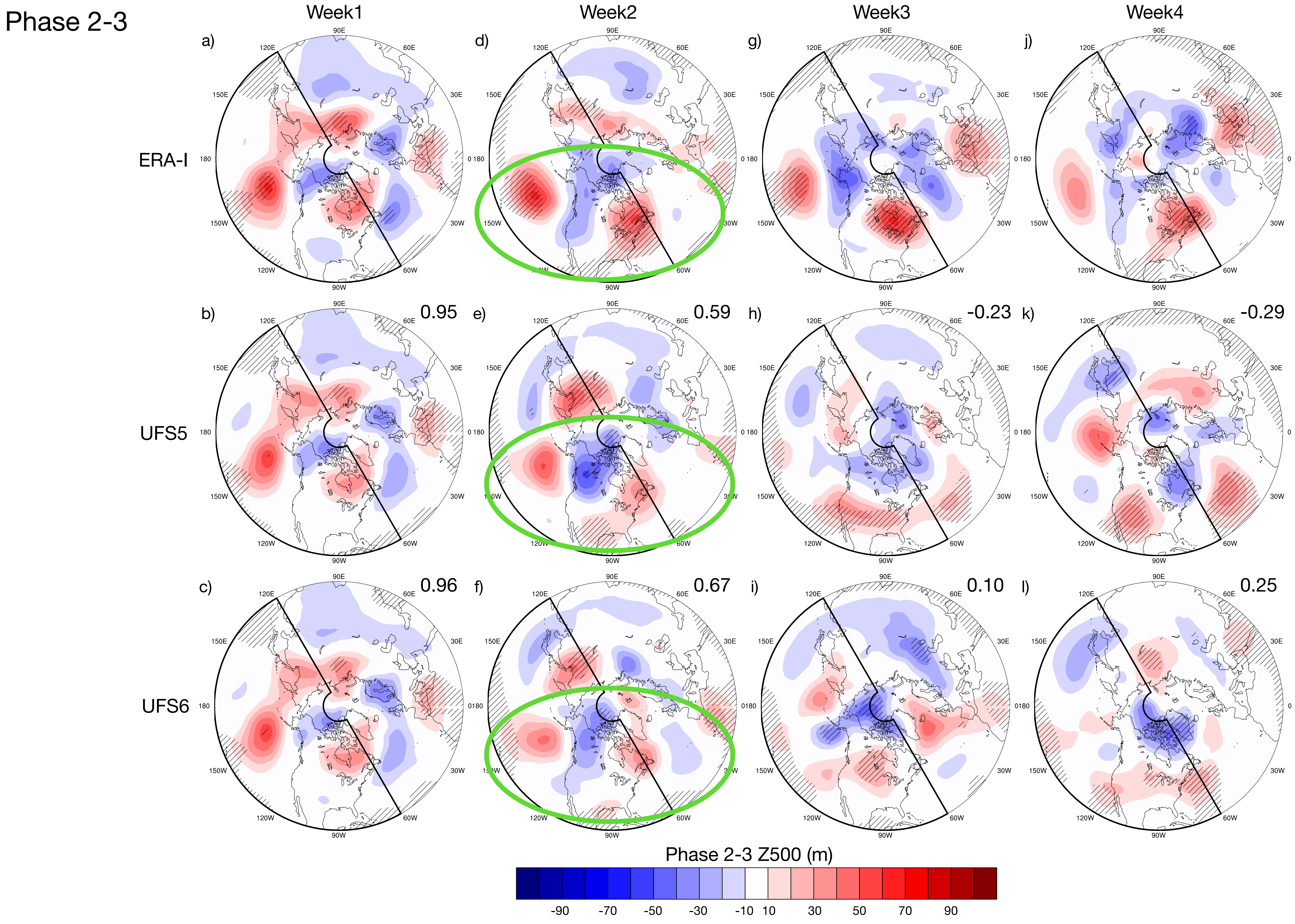
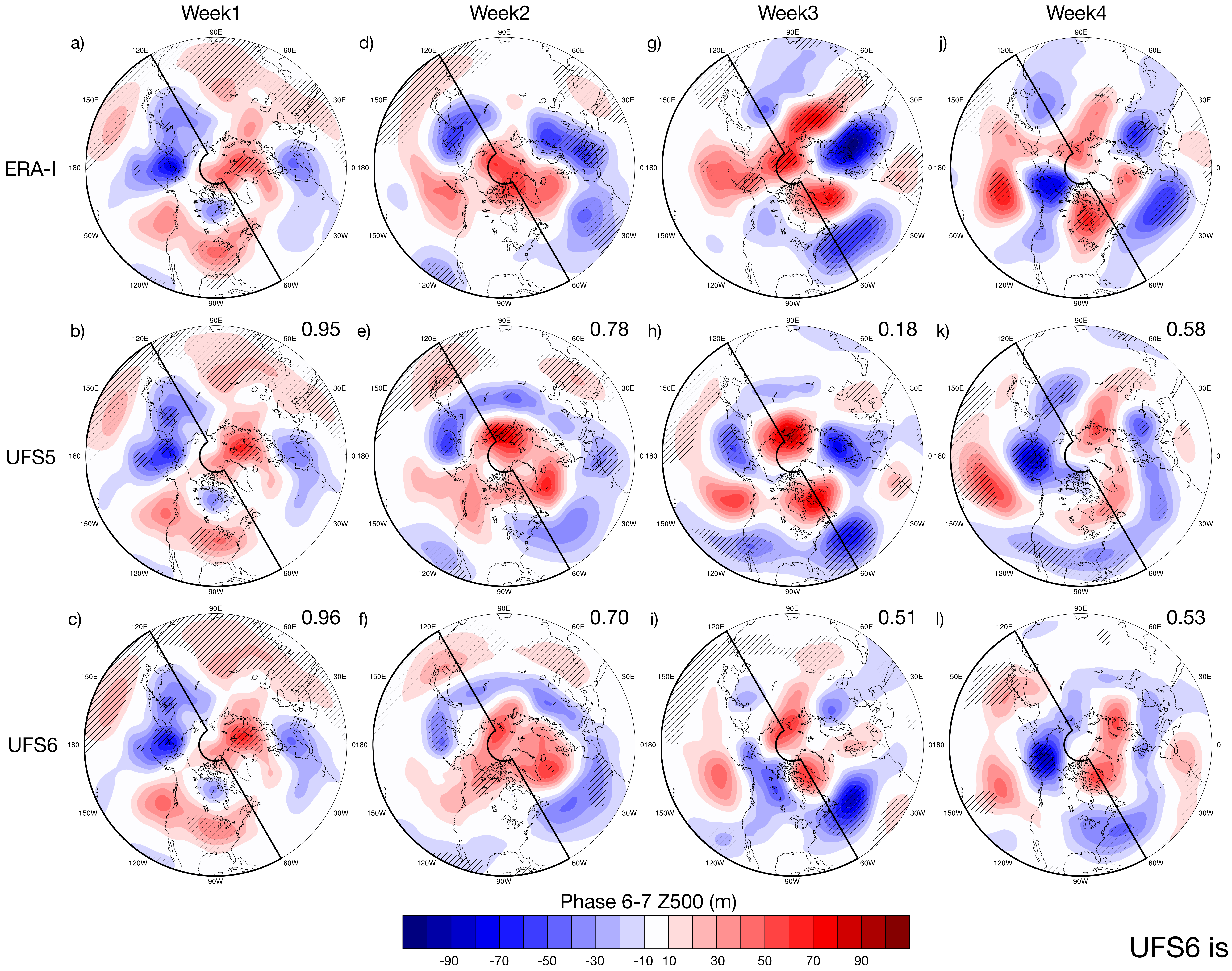


MJO teleconnection (z500)

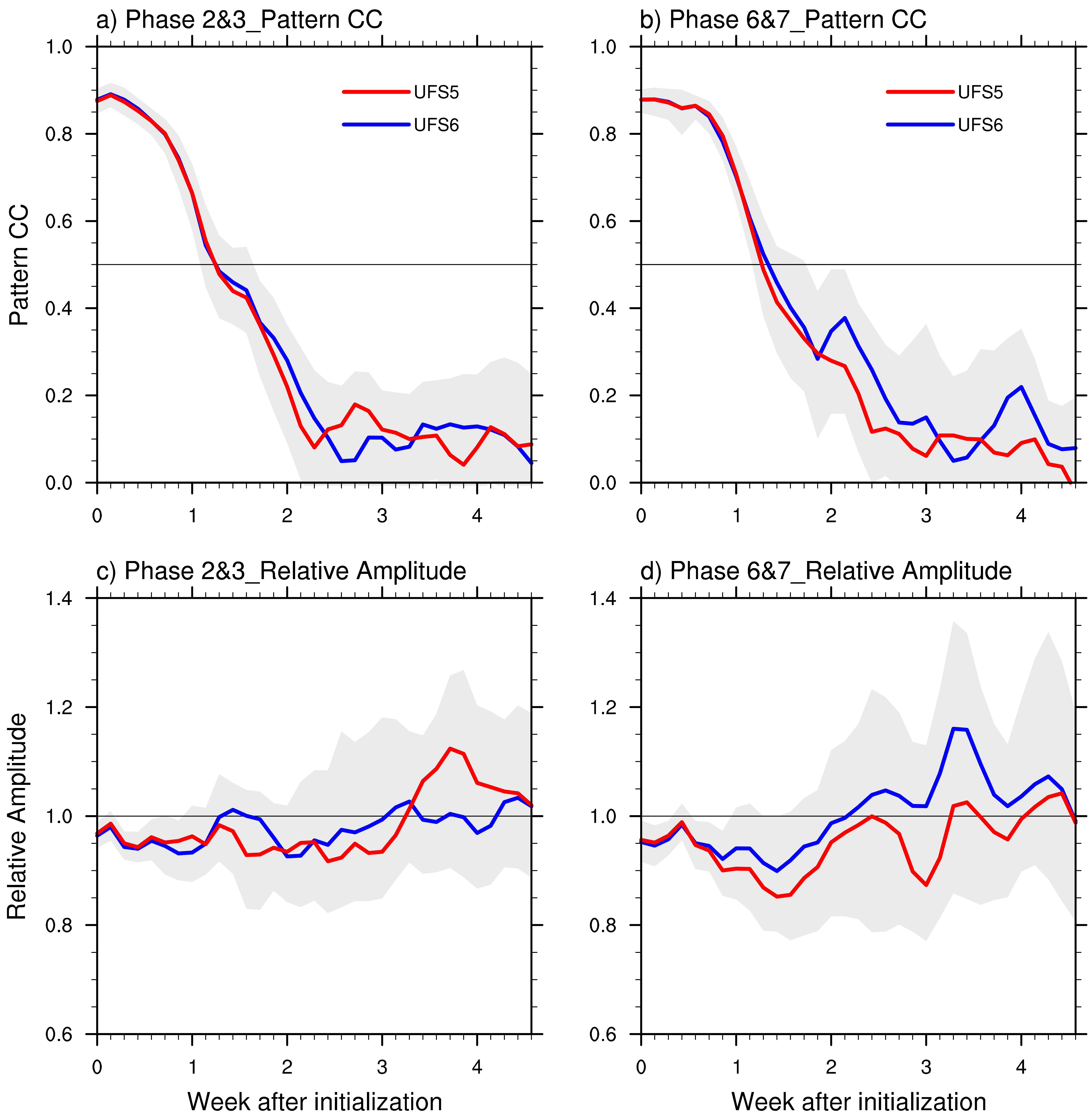
Phase 6-7



UFS6 is slightly better than UFS5

MJO teleconnection (z500)

Over the PNA region



Average of pattern correlation for individual reforecast runs

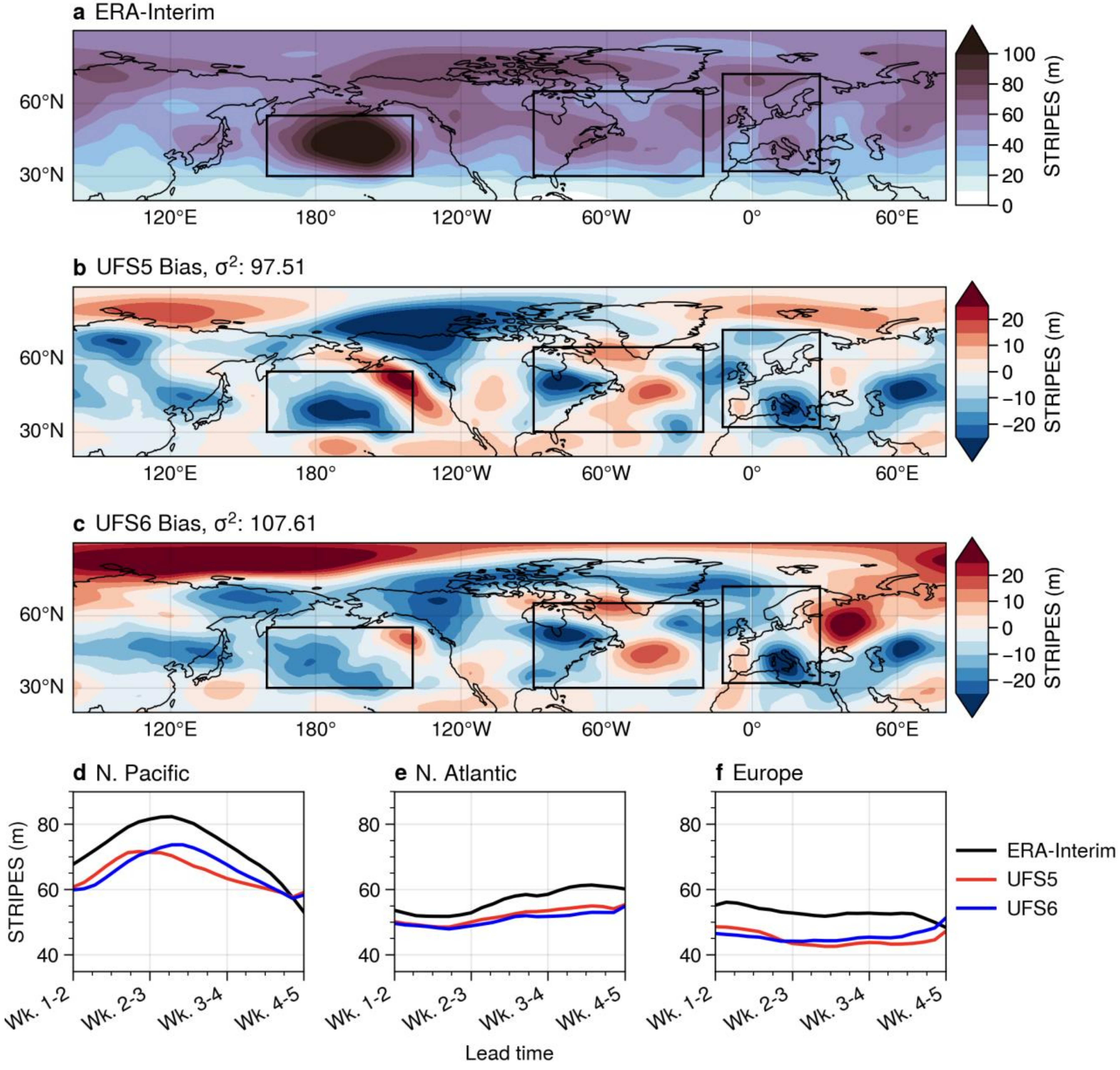
Amplitude of teleconnection

UFS6 is slightly better?

MJO teleconnection (z500)

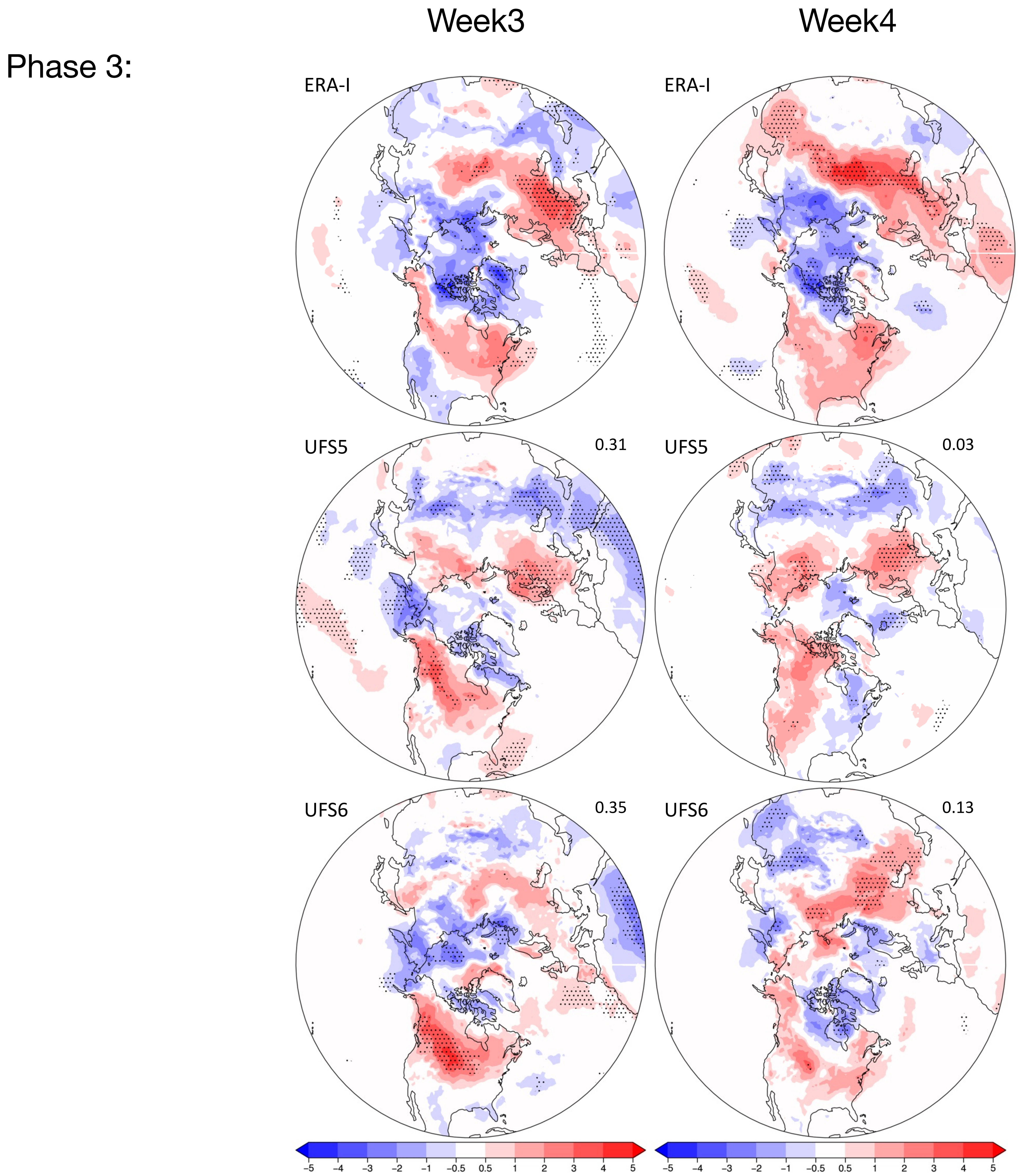
STRIPES index:

Oscillation of z500 associated with different MJO phases and lead time



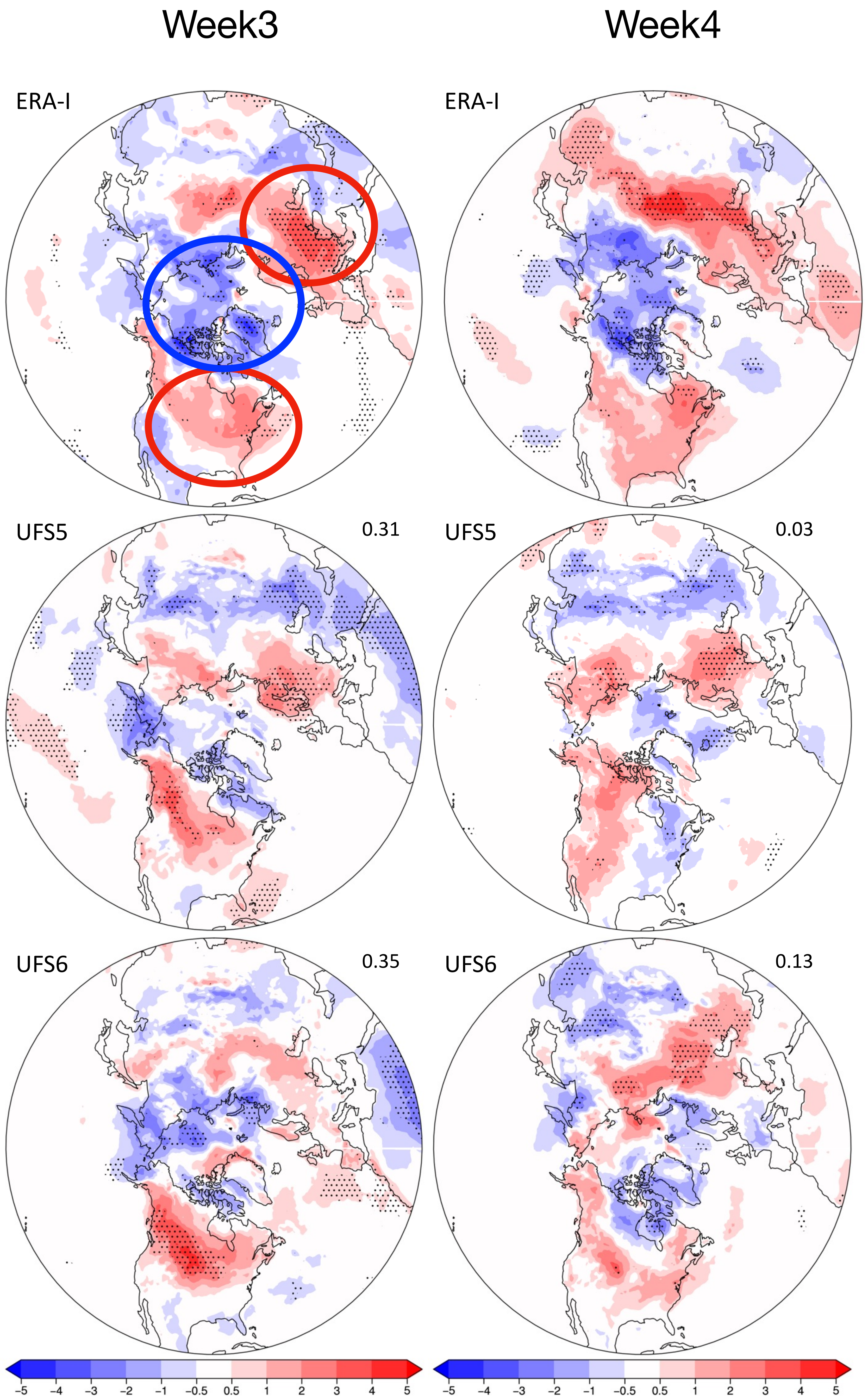
Both UFS5 and UFS6 underestimates the oscillation associated with the MJO

MJO teleconnection (T2m)



MJO teleconnection (T2m)

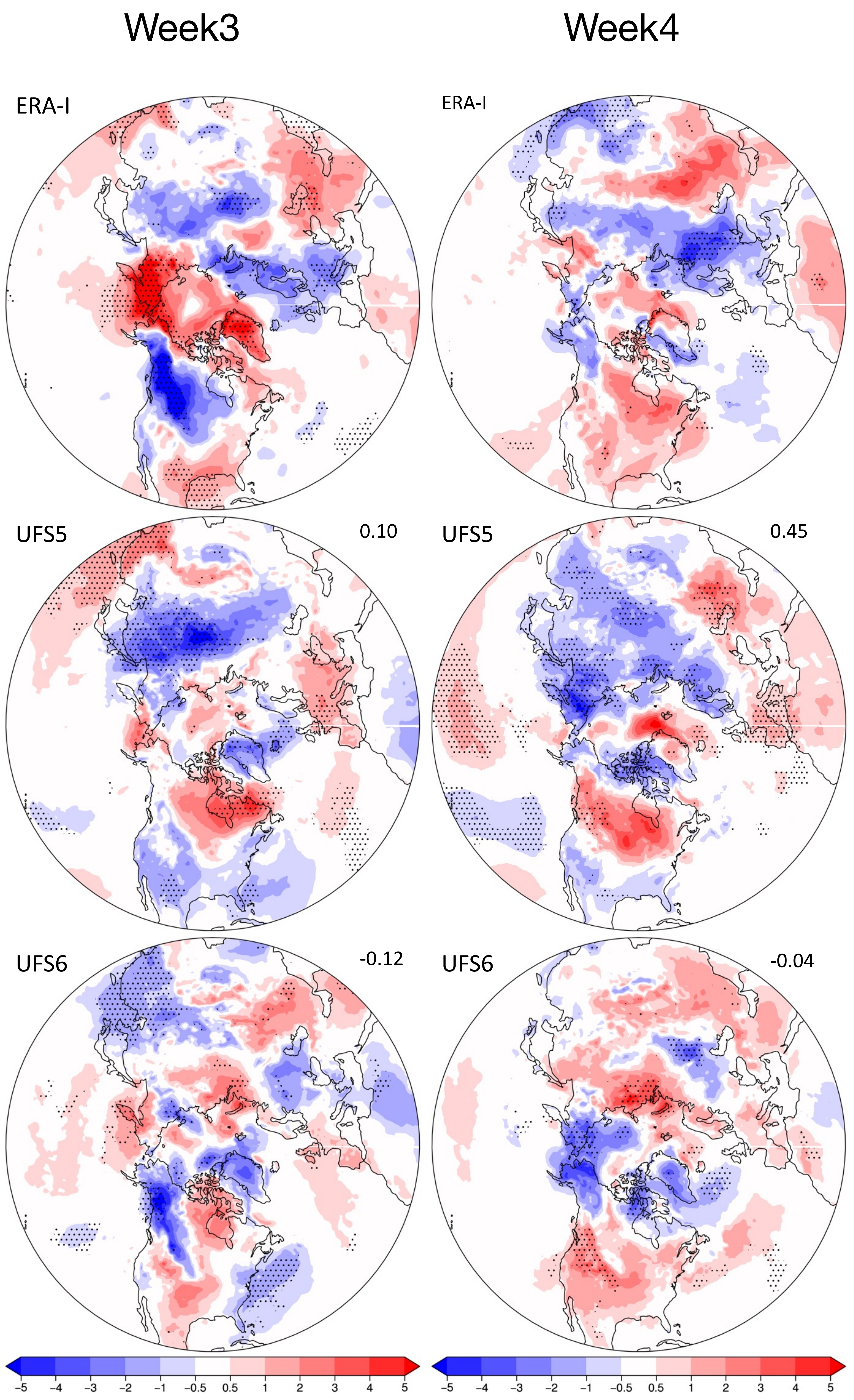
Phase 3:



Both prototypes capture the signal in week 3

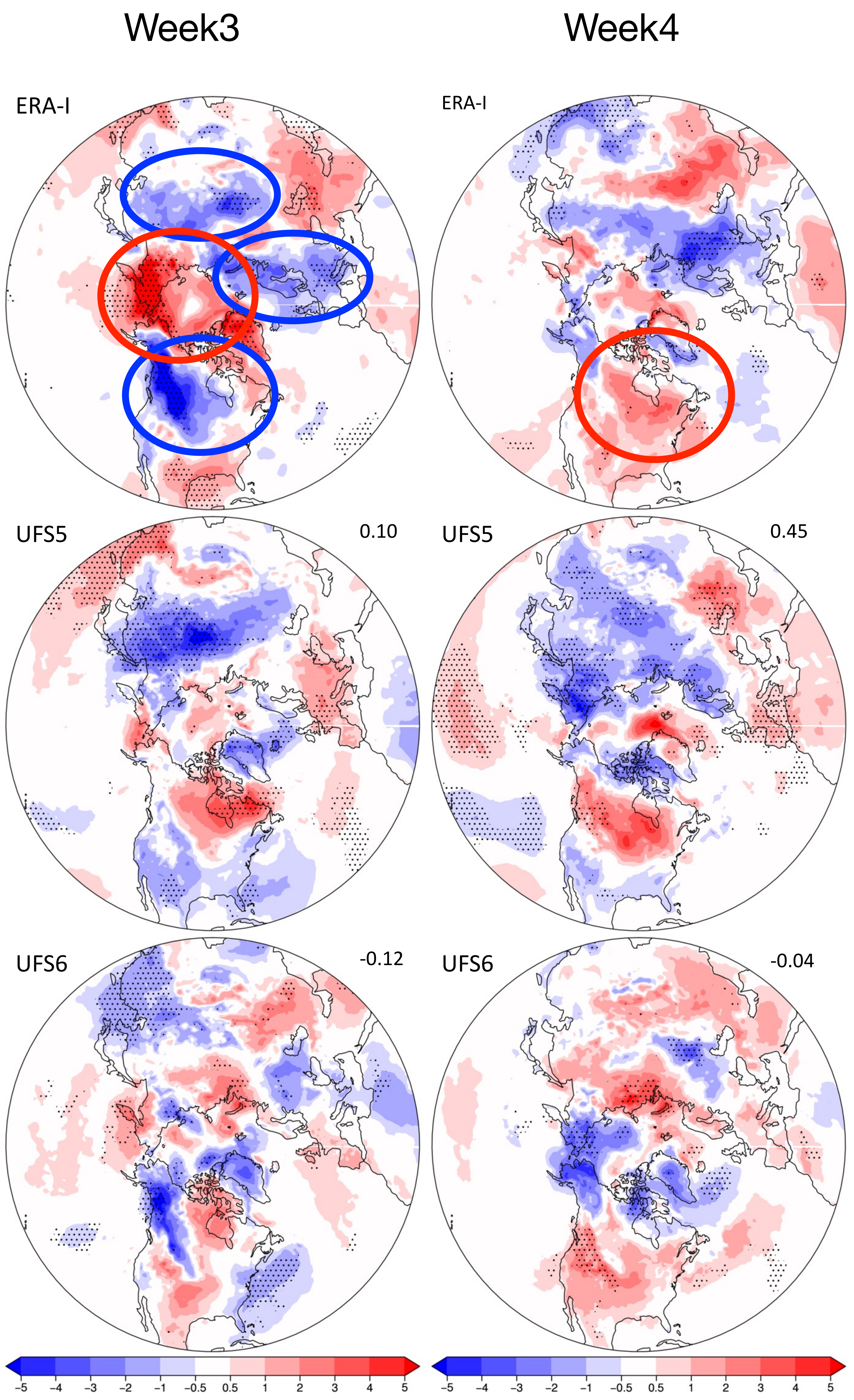
MJO teleconnection (T2m)

Phase 7:



MJO teleconnection (T2m)

Phase 7:

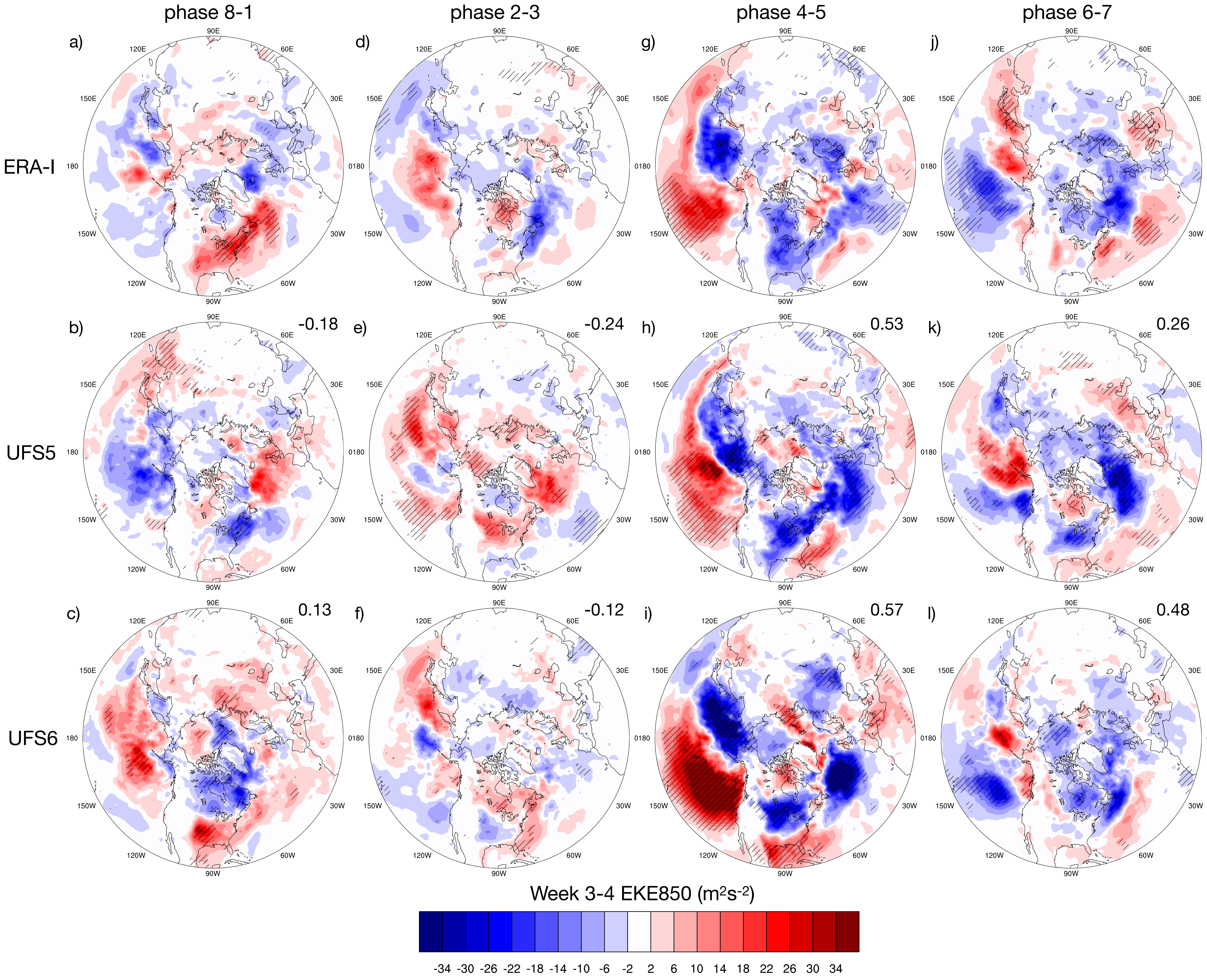


Two prototypes cannot capture the sign reversal from week 3 to 4

UFS5 better captures the cold anomalies over Eurasia

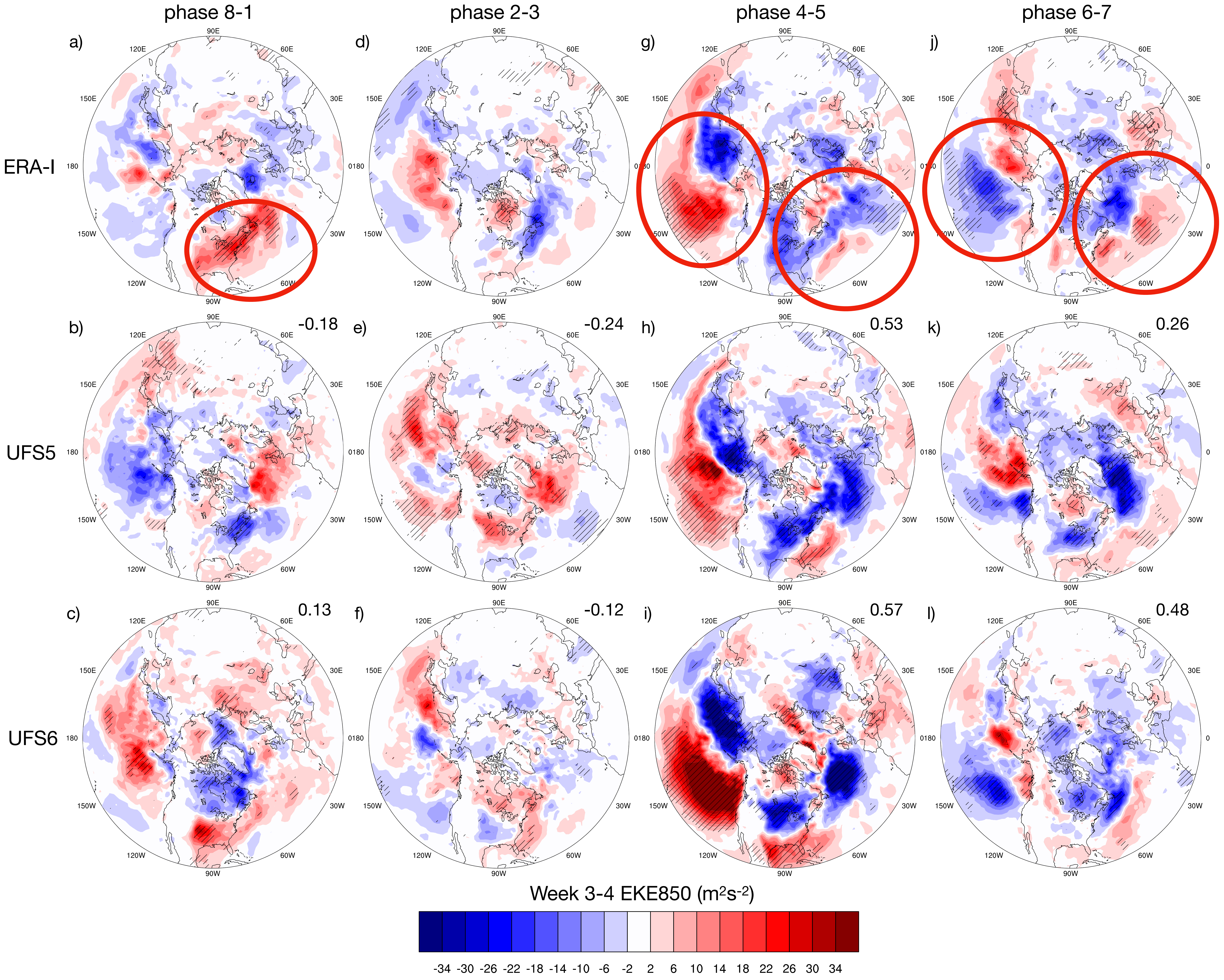
MJO teleconnection (Extratropical cyclone activity)

Week 3-4



MJO teleconnection (Extratropical cyclone activity)

Week 3-4



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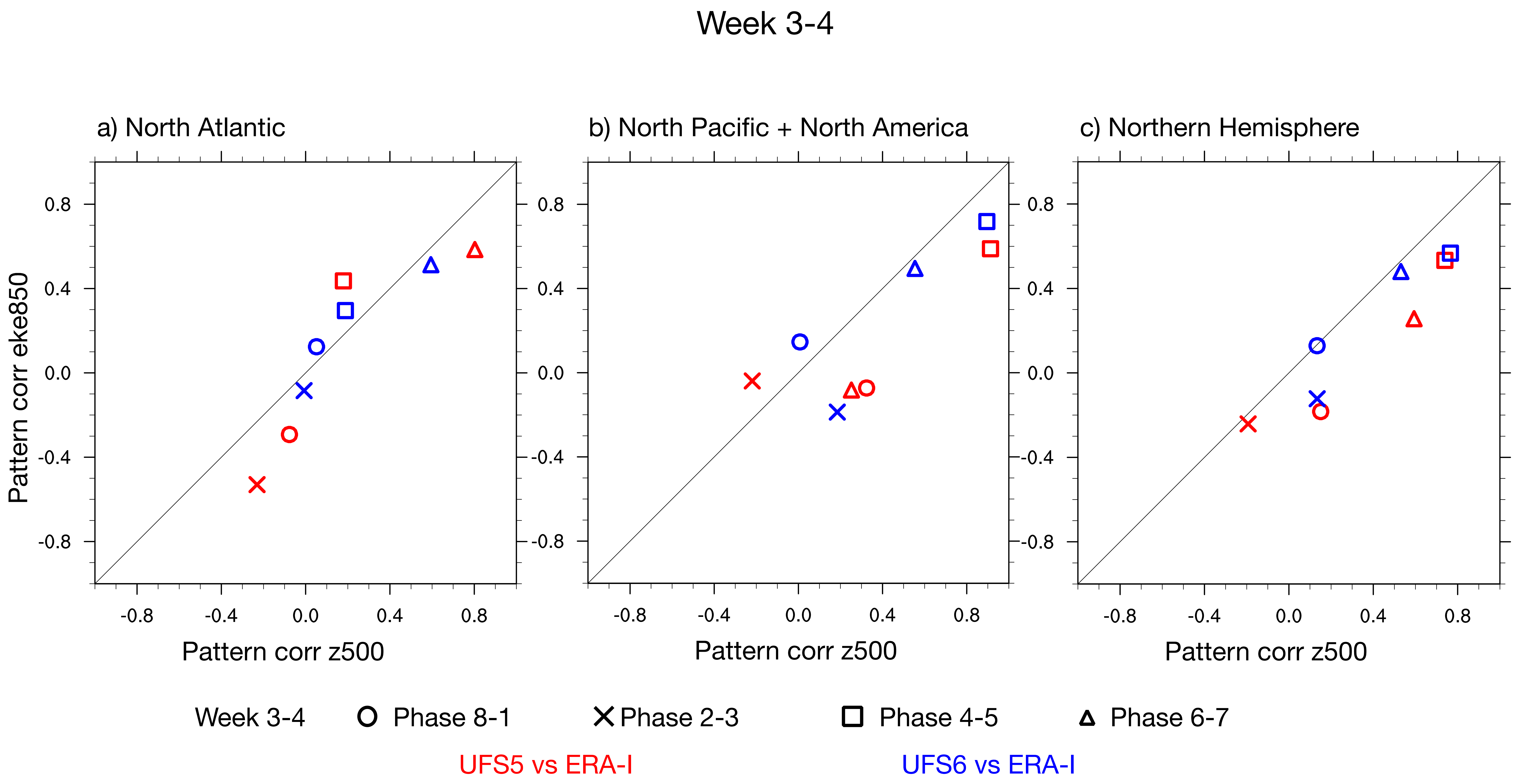

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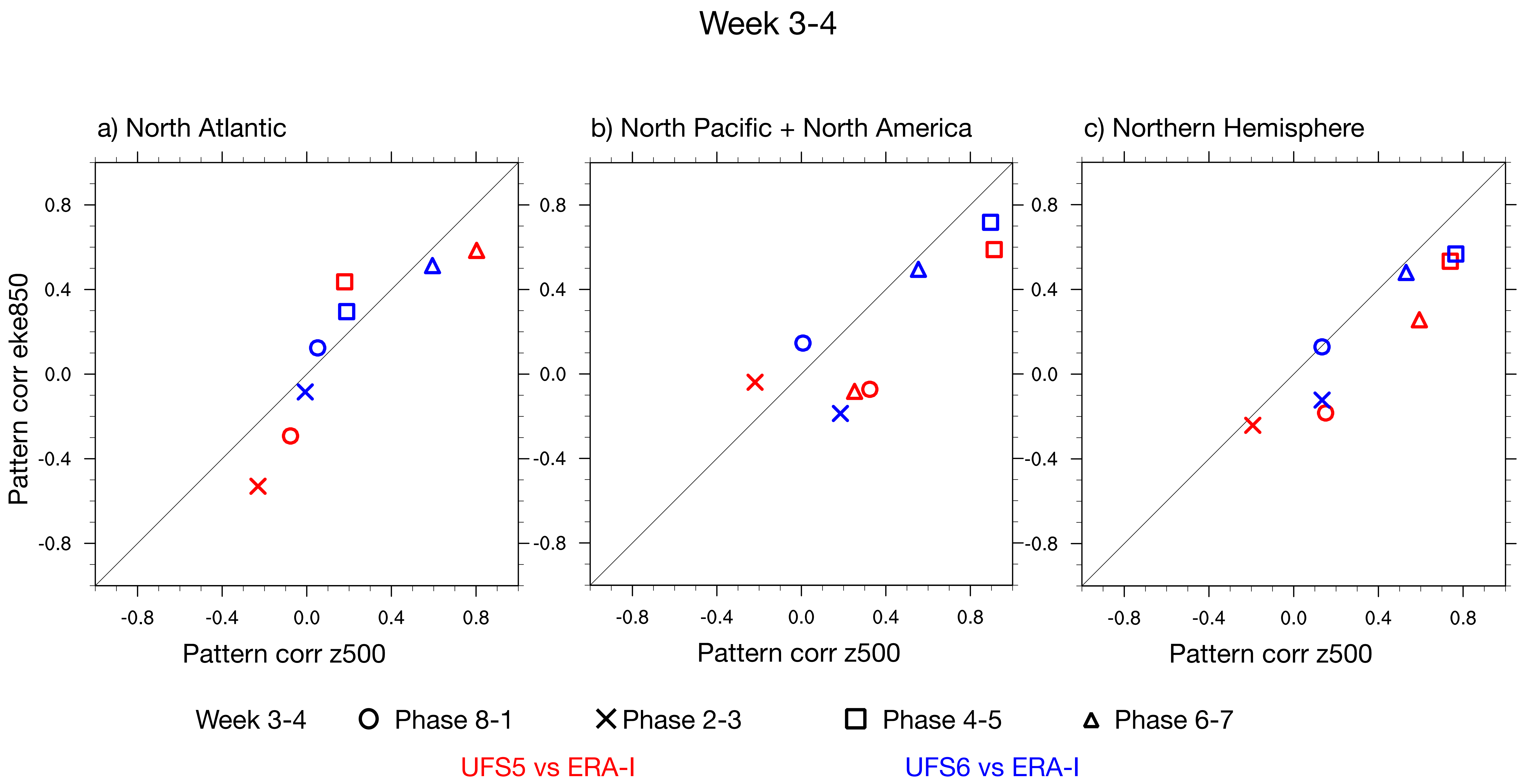


Better capture of large scale circulation—> better capture of extratropical cyclone activity

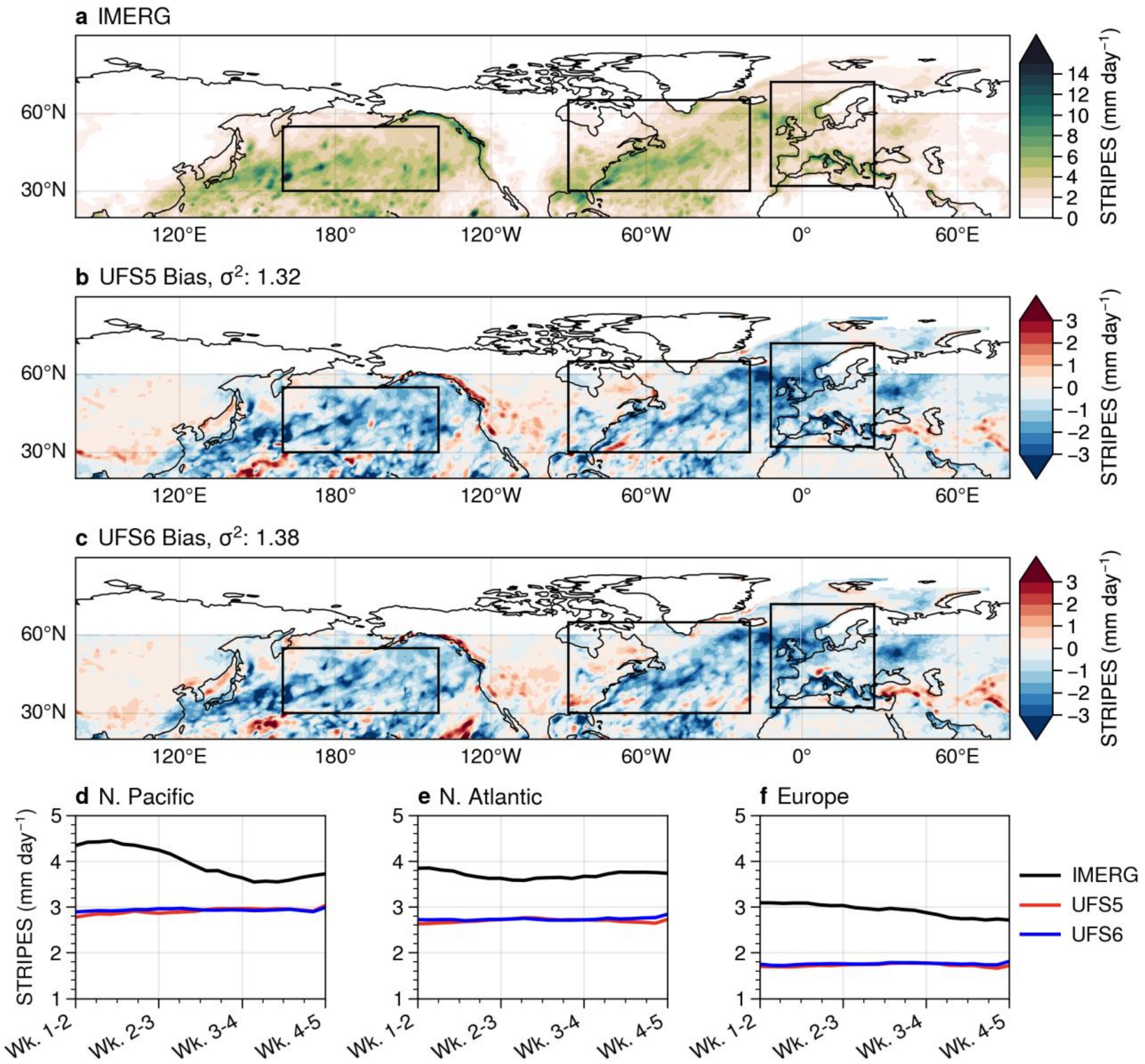
Prototype 5 & 6 performs better/worse in different MJO phases and regions

MJO teleconnection (precip)

STRIPES index:

Oscillation of precip associated with different

MJO phases and lead time



Conclusion

Prediction of the MJO: UFS5 skill is slightly better than UFS6 in week 3, but not comparable to most recent forecast models.
Both prototypes still have difficulties in propagating the MJO across the Maritime Continent.

Large scale circulation (Z500): UFS6 is slightly better than UFS5; both prototypes show similar biases (underestimate the oscillation/variability associated with the MJO)

Precipitation: Both prototypes underestimate the variability associated with the MJO

Extratropical cyclone activity: Both prototypes capture the MJO-related signal in phase 6-7 over the North Atlantic, and in phase 4-5 over the North Pacific; extratropical cyclone activity anomalies are better captured when large scale circulation is better captured by the prototypes

T2m: Both prototypes forecast the sign, amplitude, and approximate locations of temperature anomalies over the mid-to-high latitude continents for RMM phase 3. For phase 7, both prototypes fail to capture the sign reversal over North America from week 3 to in the reanalysis, while cold anomalies over Eurasia are better captured by UFS5 than UFS6.

Overall, two prototypes show similar performance in predicting MJO-teleconnection.
The increase in vertical levels and the upgrades in model physics does not show large benefits in predicting the MJO-teleconnection in the troposphere.

Caveats/Limitation

Limited number of reforecast (twice a month; 1 ensemble member; during 7 years):

Only 70 reforecast runs during extended boreal winter (NDJFM);
About ~46 runs with active MJO (RMM amplitude>1) at initialization

Difficult to get statistical significant differences between p5 and p6;
Difficult to compare with other S2S models;
Difficult to isolate MJO-related signal from other variability

Caveats/Limitation

Week 3-4

Extratropical cyclone activity:

phase 4-5: large anomalies over the North Pacific

Only 6 reforecast initialized in RMM phase 4-5

3 of the 6 runs initialized in winter 2015-16, a strong El Niño event

—> phase 4-5 composite is largely contributed by ENSO signal

—> high correlation between model and reanalysis in phase 4-5 is not necessarily due to model well capturing MJO-teleconnection; but rather due to model capturing ENSO-teleconnection