Tropical-extratropical teleconnections: the role of midlatitude synoptic systems

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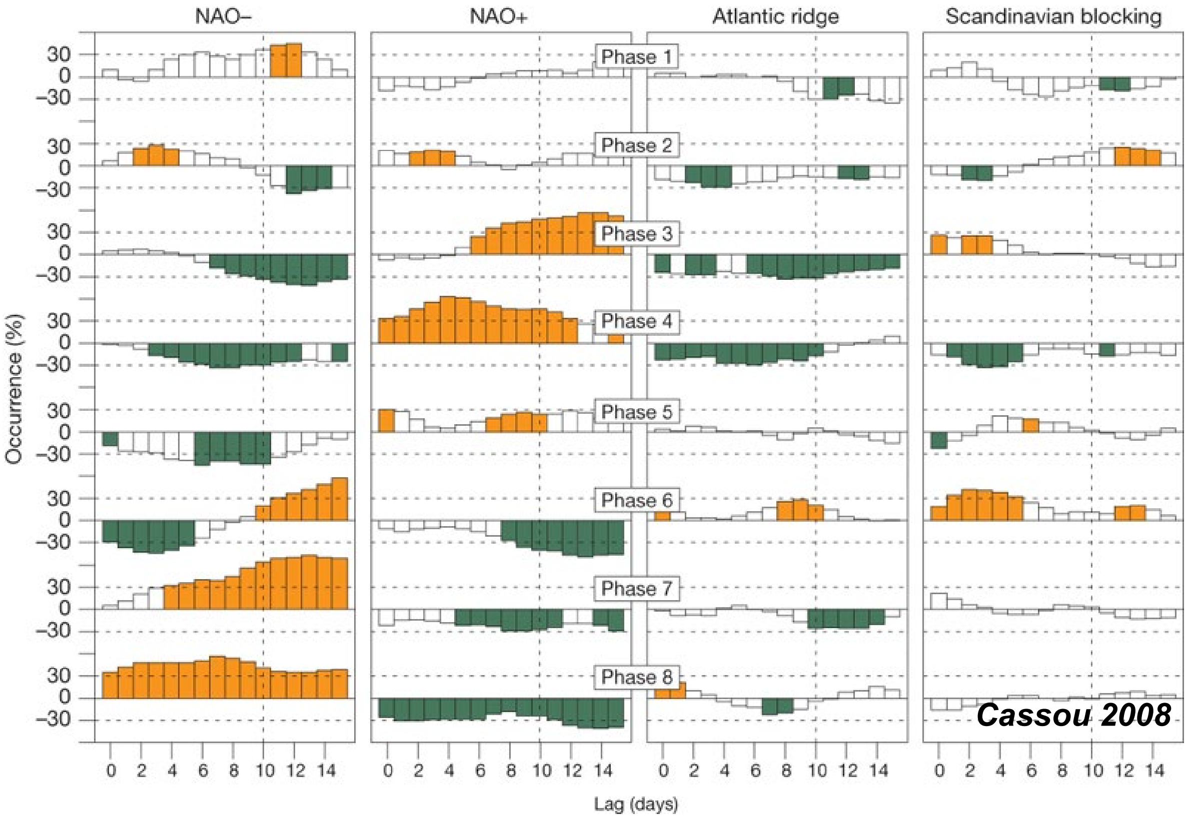
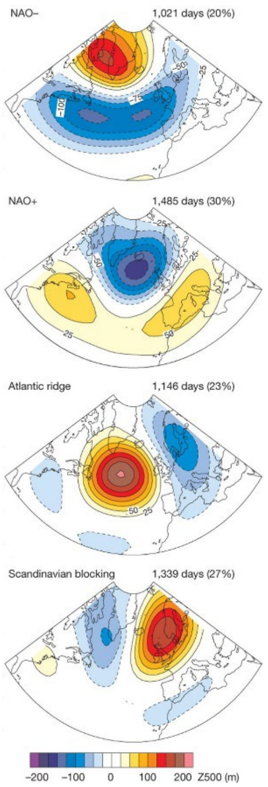
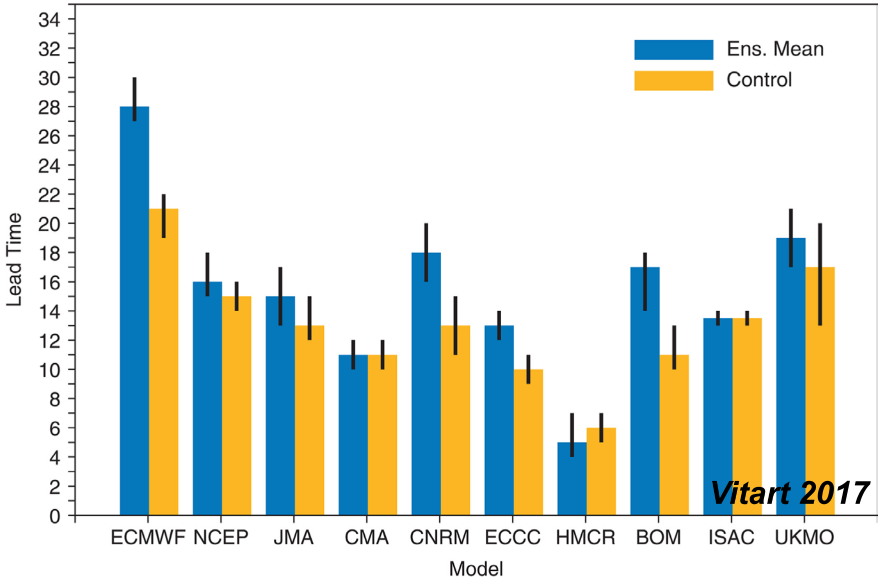
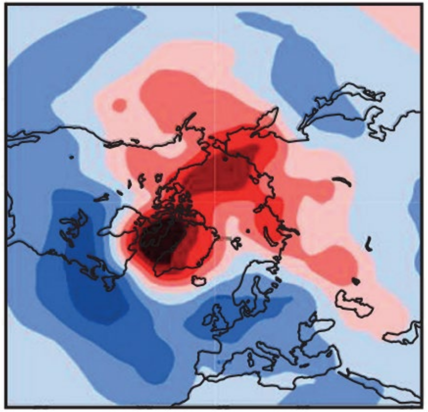
MJO affects occurrence frequency of North Atlantic weather regimes





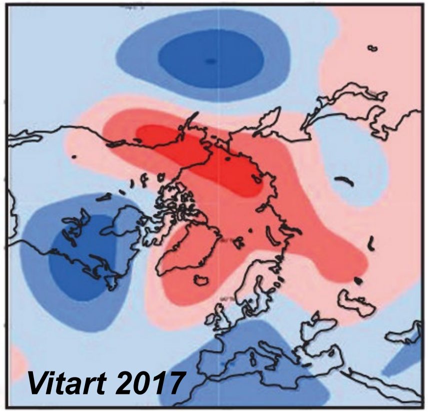
MJO – weather regime link underestimated in S2S models





Reanalysis

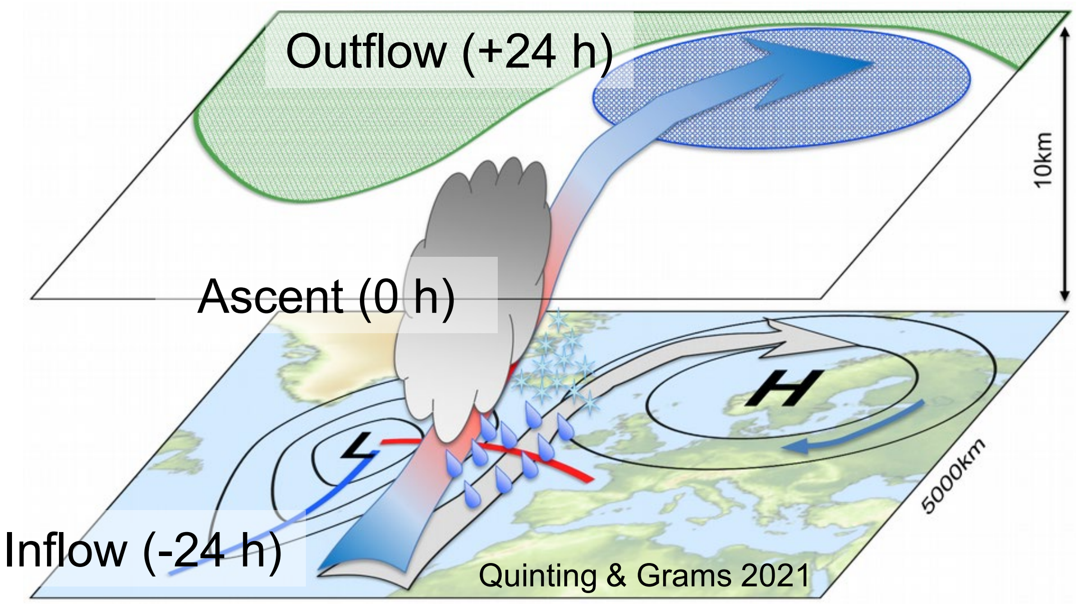
Z500 anomaly 11-15 days after phase 7



Reforecast

Z500 anomaly 11-15 days after phase 7

What role do midlatitude synoptic systems play?



WCBs contribute to intensification of cyclones
(e.g., Binder et al. 2016)

WCBs affect lifecycle of blocking anticyclones
(e.g., Pfahl et al. 2015)

WCBs are magnifier of forecast uncertainty
(e.g., Pickl et al. 2024)

What role do midlatitude synoptic systems play?

- What is the modulation of WCB activity by the MJO?
- How does WCB activity affect the MJO – weather regime link?
- How is modulation of WCB activity by MJO represented in S2S reforecasts?

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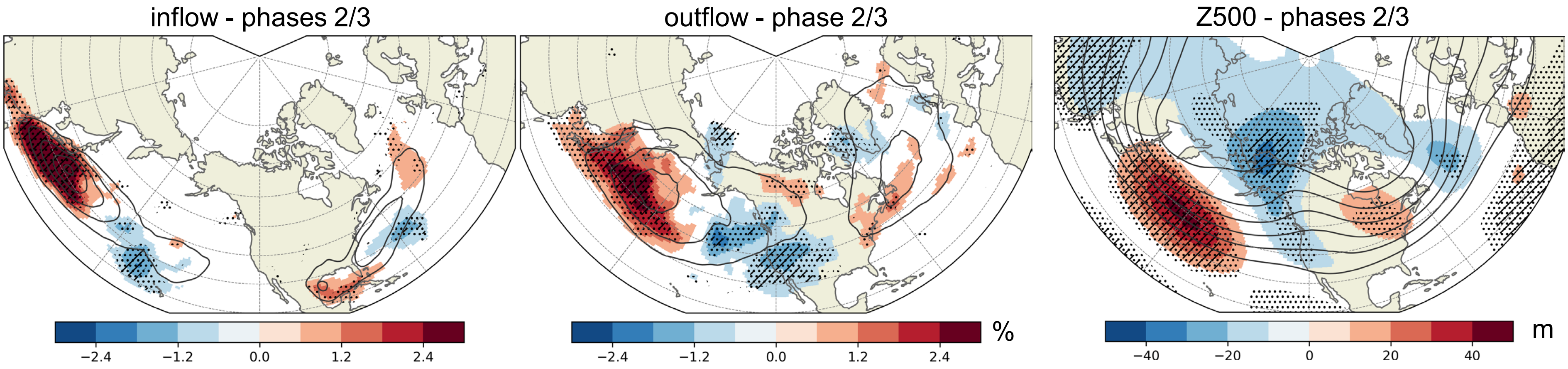
Warm conveyor belt activity over the Pacific: modulation by the Madden–Julian Oscillation and impact on tropical–extratropical teleconnections

- CNN-based WCB inflow and outflow objects (Madonna et al. 2014; Quinting & Grams 2022)
- ECMWF's S2S reforecast NDJFM 1997-2017 (Vitart et al. 2017)

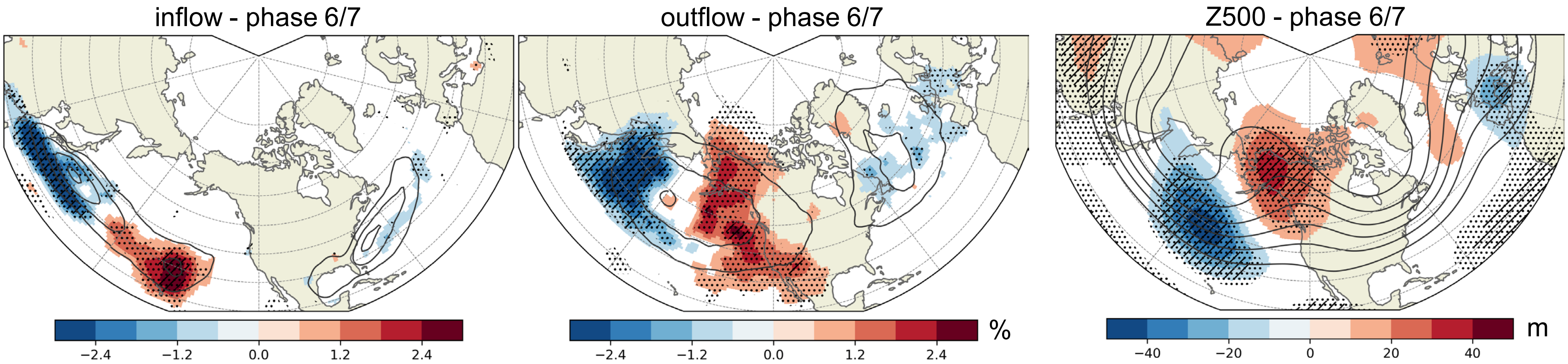
What is the modulation of WCB activity by the MJO?



WCB activity increases significantly over the western North Pacific during/after MJO phase 3 (cf. Guo et al. 2017)

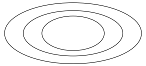
Anomalous ridging over Pacific (e.g., Moore et al. 2010)

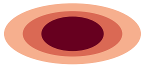
What is the modulation of WCB activity by the MJO?



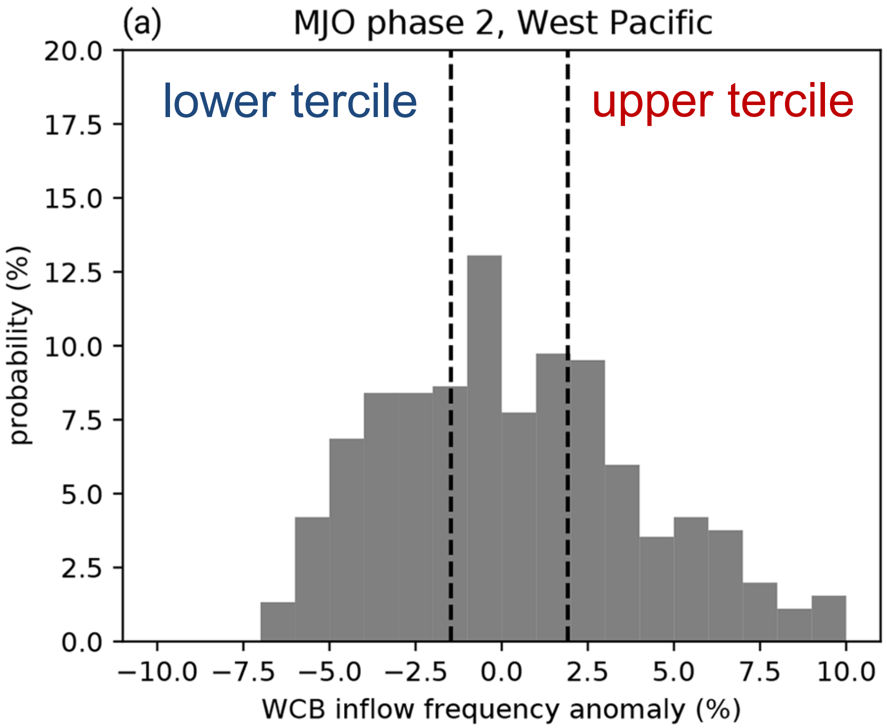
WCB activity increases significantly over the eastern North Pacific during/after MJO phase 7

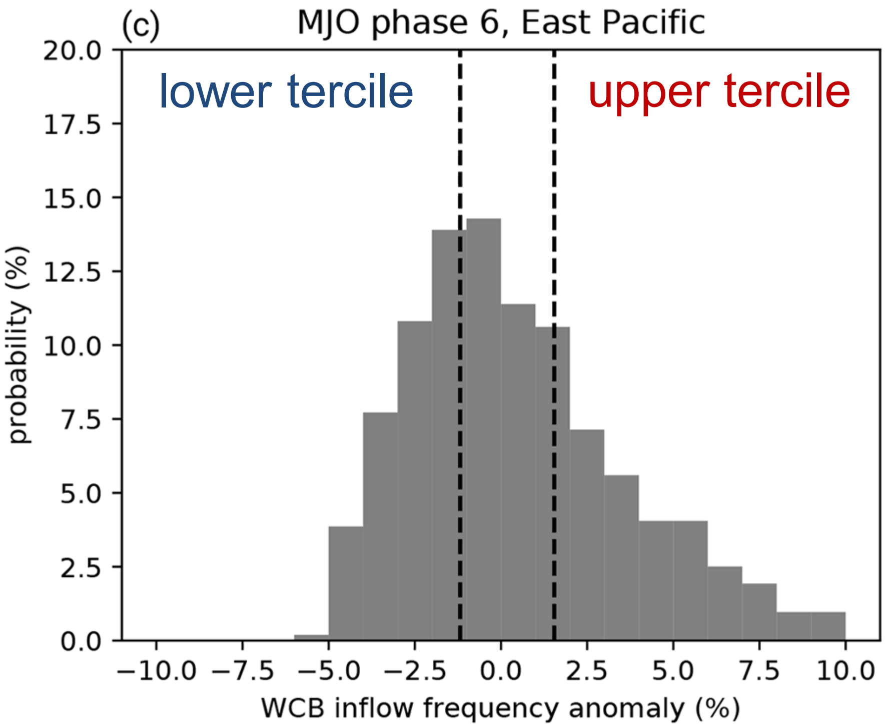
Anomalous ridging over Alaska (e.g., Henderson et al. 2016)


climatological frequency

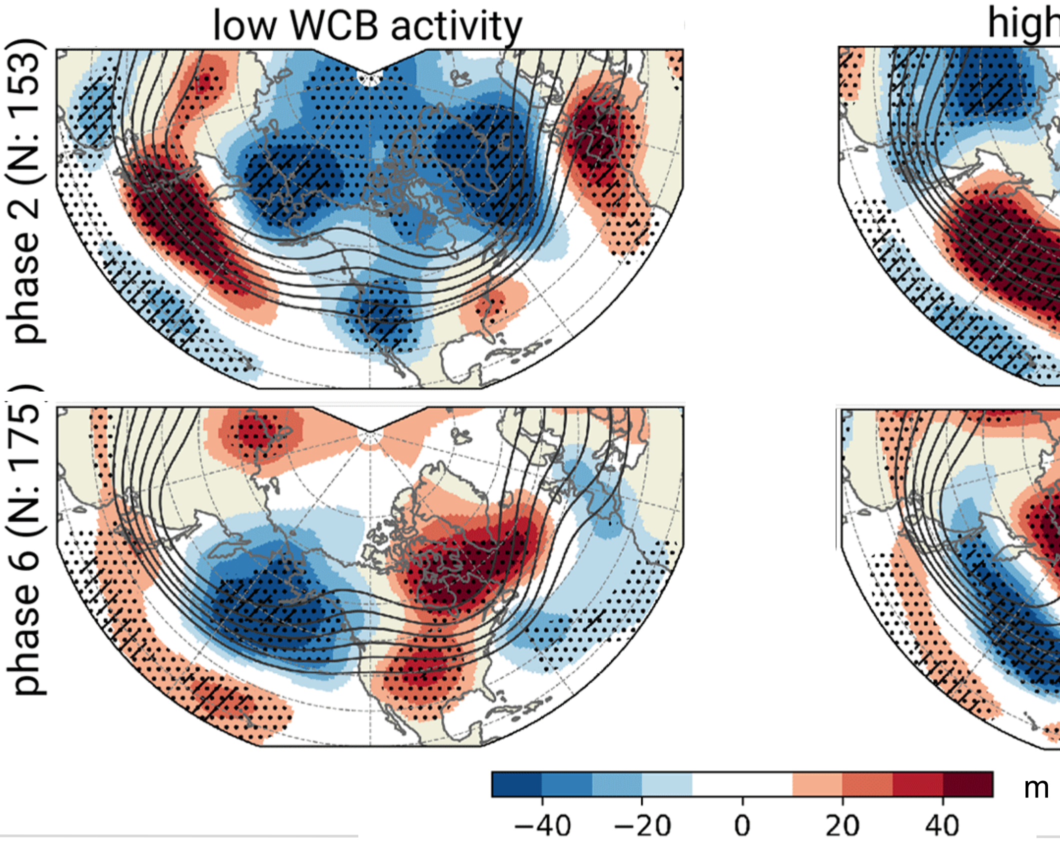

frequency anomaly (%)

What is the modulation of WCB activity by the MJO?

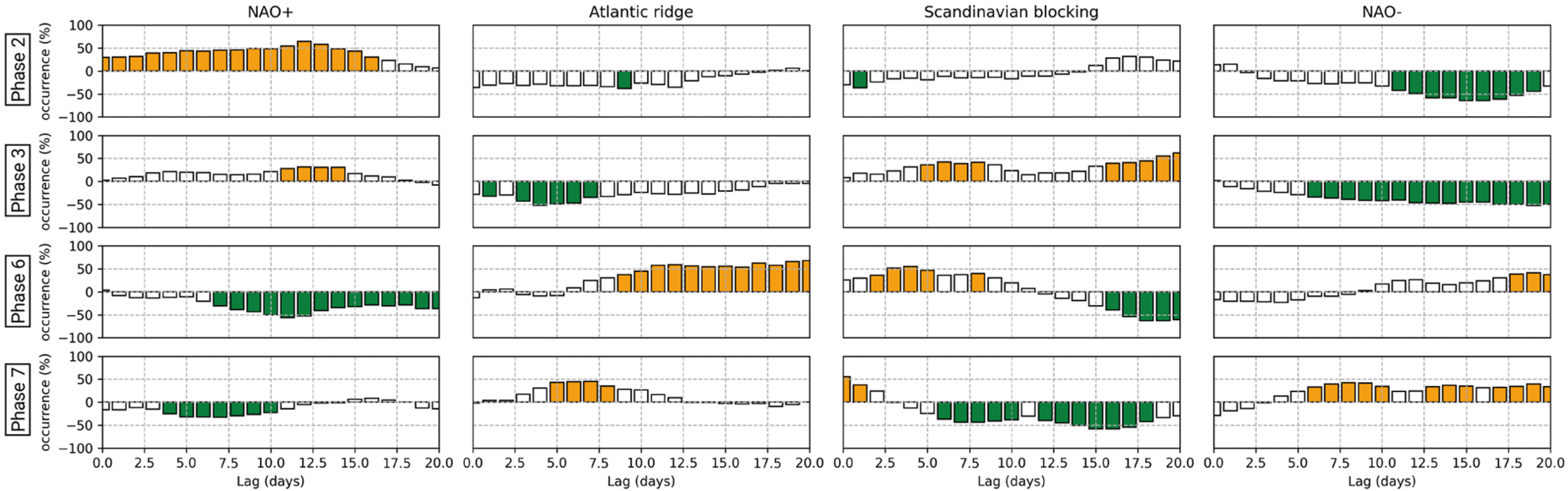




Impact of WCB activity on MJO – weather regime link

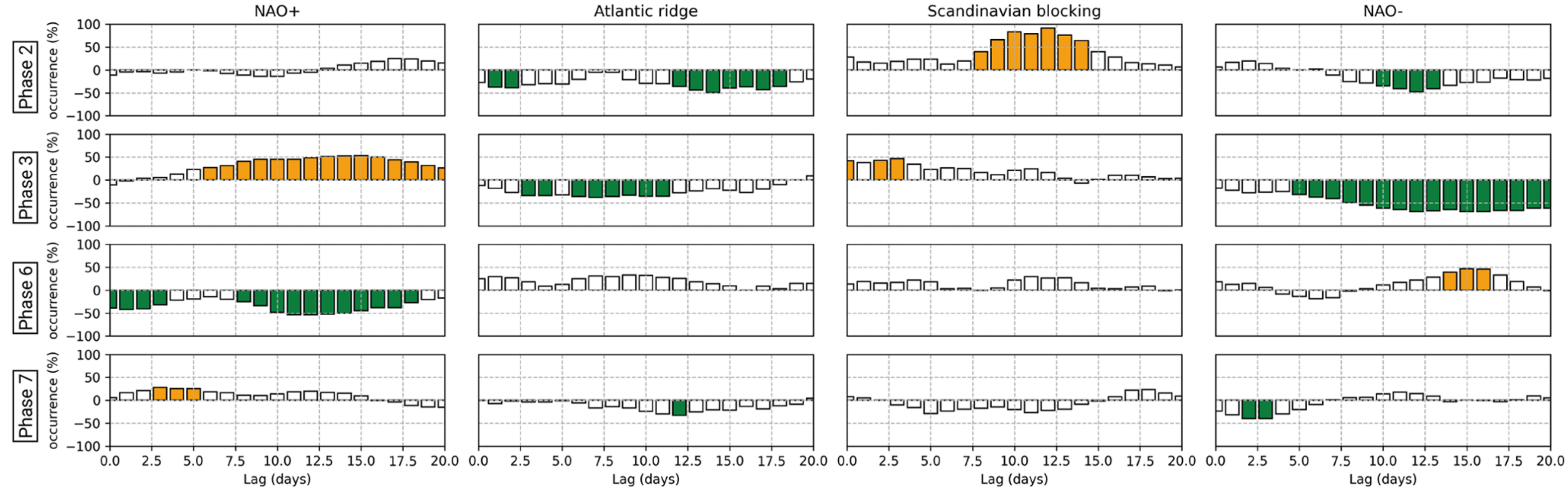


Impact of WCB activity on MJO – weather regime link



Known MJO – weather regime link **persists** after phases with anomalously **low** WCB activity

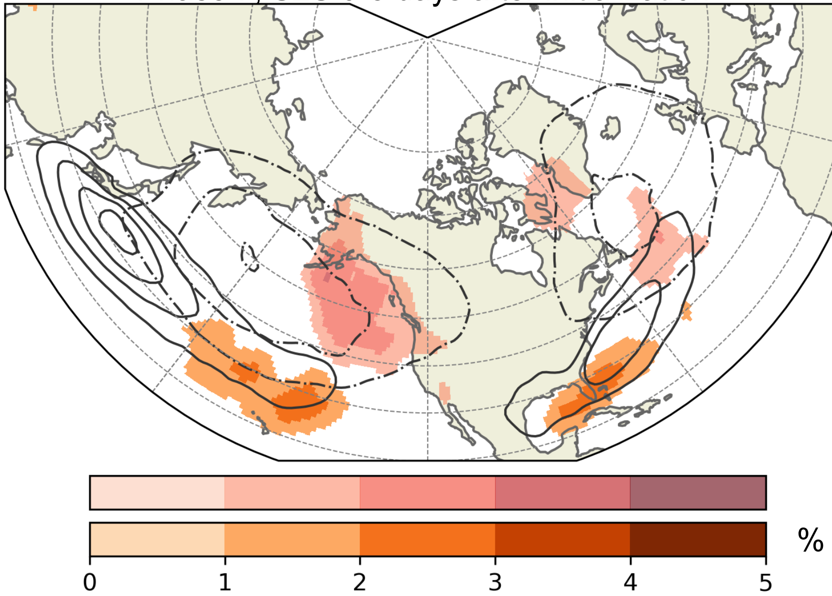
Impact of WCB activity on MJO – weather regime link



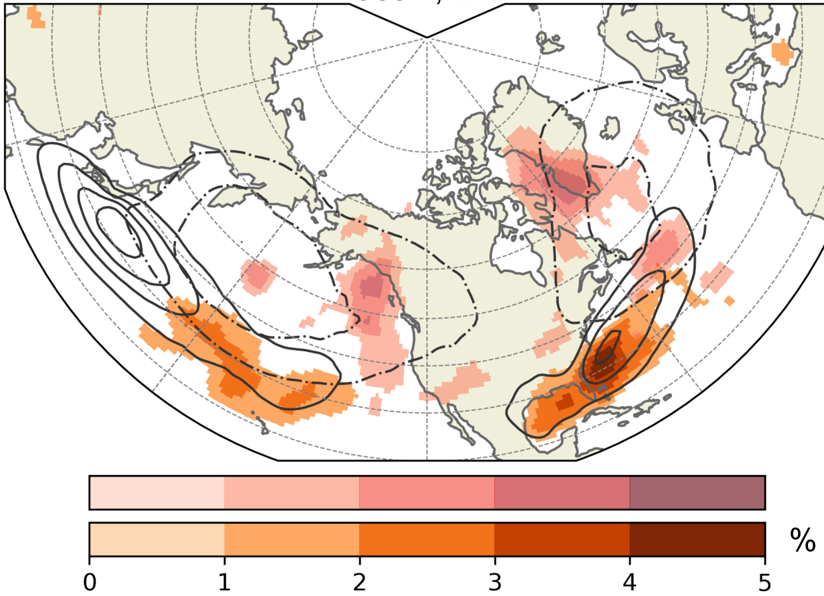
Known MJO – weather regime link **weakens** after phases with anomalously **high** WCB activity

Representation of WCB activity in S2S reforecasts

Phase 7; **S2S** 0-5 days after initialization



Phase 7; **ERAI**



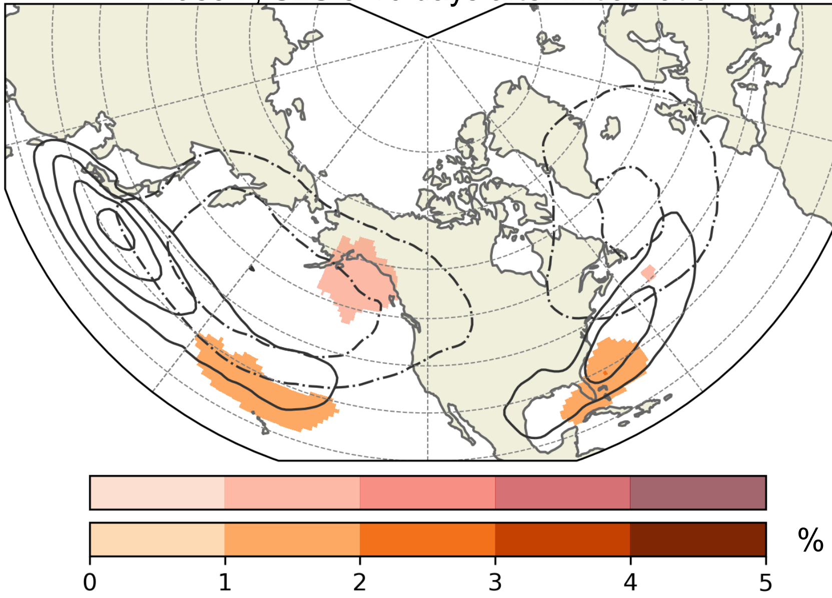
At early leadtimes ECMWF's S2S forecast represent WCB increase over eastern Pacific after phase 7

pos. inflow frequency anomaly

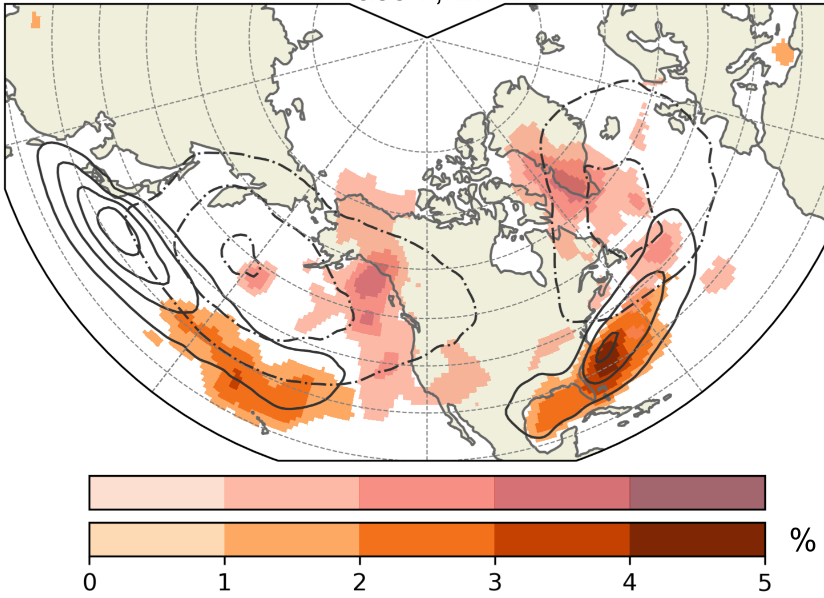
pos. outflow frequency anomaly

Representation of WCB activity in S2S reforecasts

Phase 7; **S2S** 5-10 days after initialization



Phase 7; **ERAI**

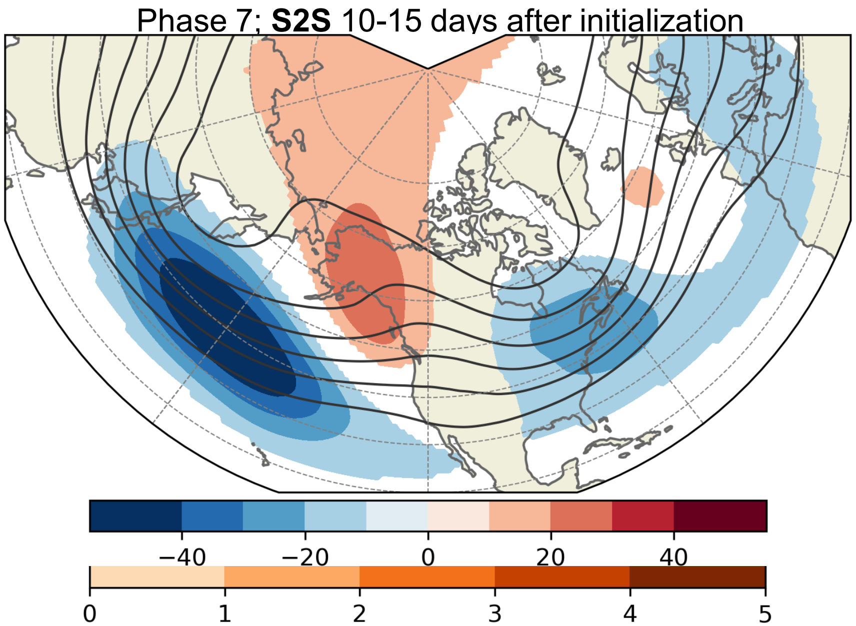


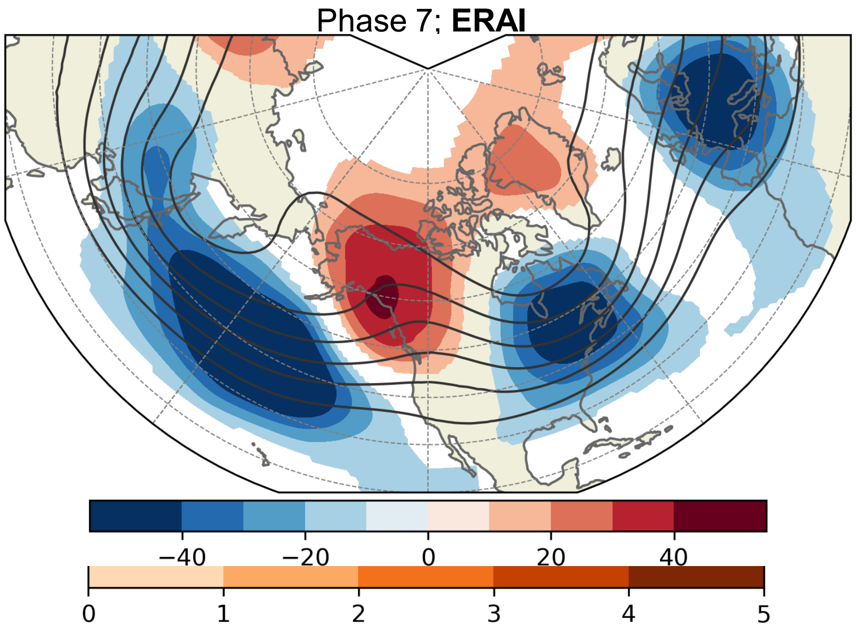
Anomalous WCB activity ceases in reforecasts after 5-10 days forecast lead time

pos. inflow frequency anomaly

pos. outflow frequency anomaly

Representation of WCB activity in S2S reforecasts





Anomalous outflow and ridge over western North America are underestimated. Coincidence or causality?

pos. inflow frequency anomaly

pos. outflow frequency anomaly

Take-home messages – Part I

- WCB activity over Pacific is modulated by MJO
  → in line with studies on ECs and ARs (Moore et al. 2010; Mundhenk et al. 2016; Guo et al. 2017)
  → how does this modulation affect the growth of forecast errors? (Pickl et al. 2024)

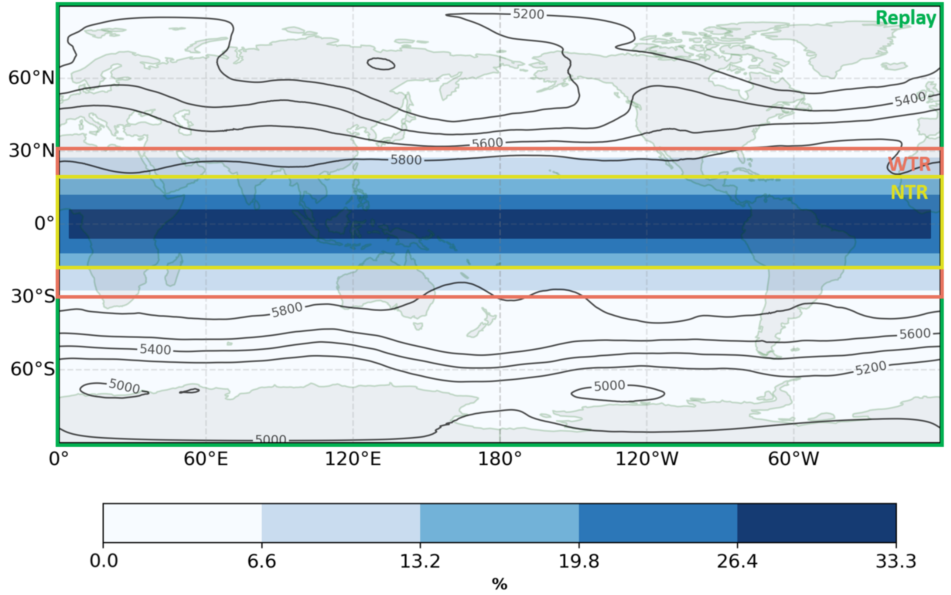
- latent heat release by WCBs affects the canonical MJO teleconnection pattern
  → effect of increased latent heat release by 20-27% in warmer climate? (Joos et al. 2023)

- modulation of WCB activity underestimated at lead times beyond 10 days
  → how is this modulation represented in other S2S models?
  → what are the sources of MJO teleconnection errors? (Vitart & Balmaseda 2024)

Relaxation experiments to identify source regions of forecast errors

$$\frac{\partial \mathbf{x}}{\partial t} = \mathcal{M}(\mathbf{x}) + \lambda(\mathbf{x}_{\mathrm{ref}} - \mathbf{x})$$

Jung et al. 2010
Dias et al. 2019



Three models:

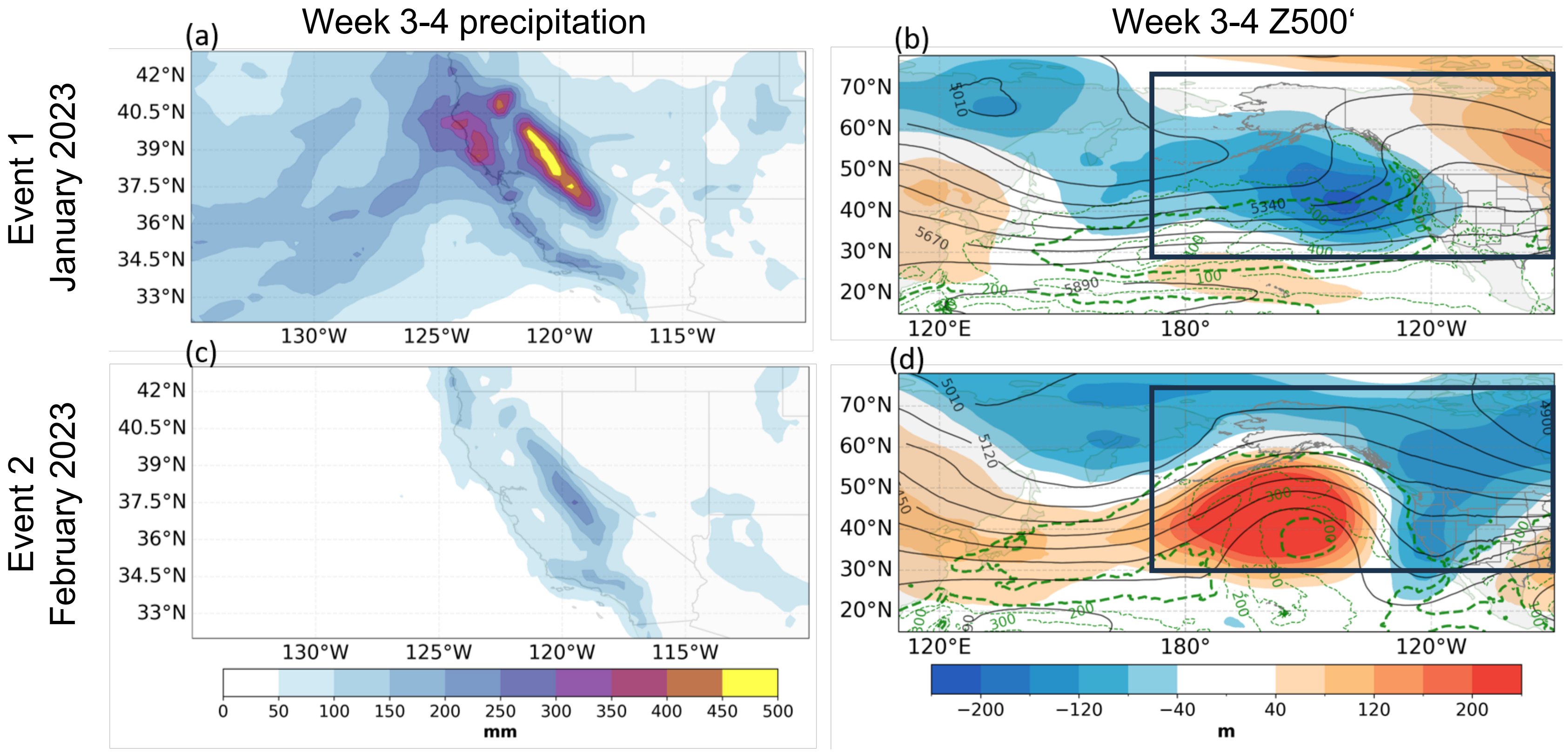
- Unified forecasting system
- NeuralGCM
- Pangu-Weather

Time-lagged ensemble (30 members)
Initialized from EDA members of ERA5

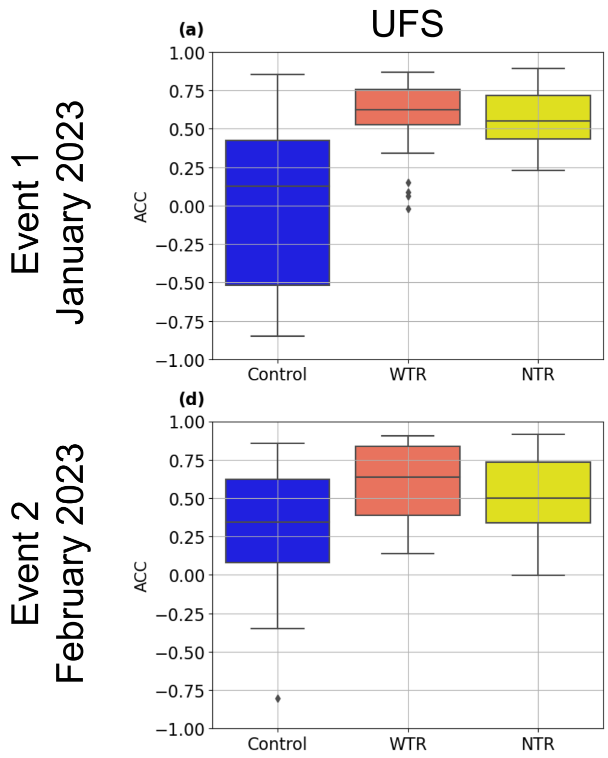
Leadtime: week 3-4

Focus on two MJO phase 7 events

Relaxation experiments to identify source regions of forecast errors



Relaxation experiments to identify source regions of forecast errors



Take-home messages – Part II

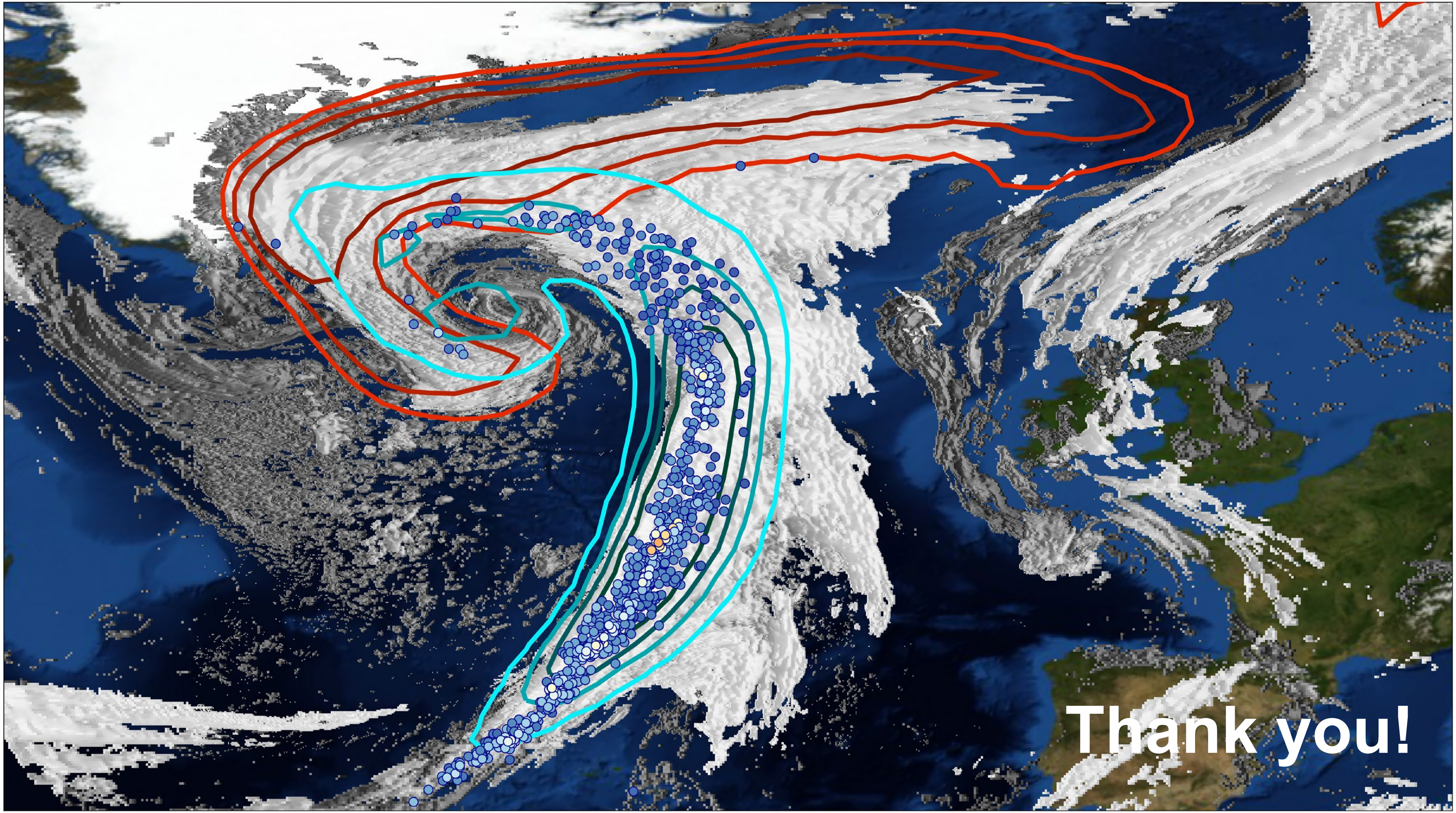
- Relaxation experiments technically possible with MLWP models
  → new opportunities for predictability/sensivity studies, **but** NWP forecasts needed to gain trust

- Two contrasting events indicate different role of tropics for forecast errors
  Event 1: significant forecast improvement in all three models with tropical relaxation
  Event 2: little improvement with relaxation in MLWP models
  → due to better representation of tropical waves?

Outlook

- Systematic analysis across different MLWP models needed

- Systematic variation of relaxation domain


Thank you!