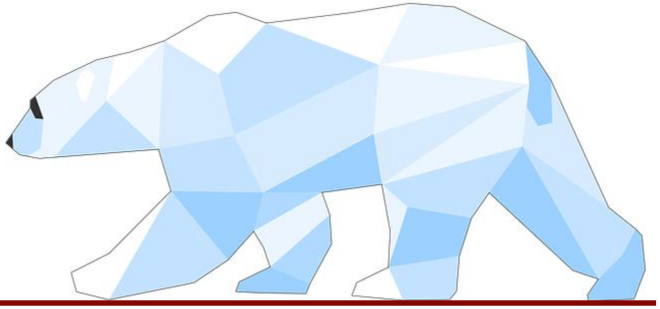
Wintertime temperature extremes in the high Arctic



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Warm and Cold Spells in the Arctic

- Warm spells: meridional circulation, moisture intrusions.
- Cold spells: Arctic isolated from mid-latitudes, zonal circulation.

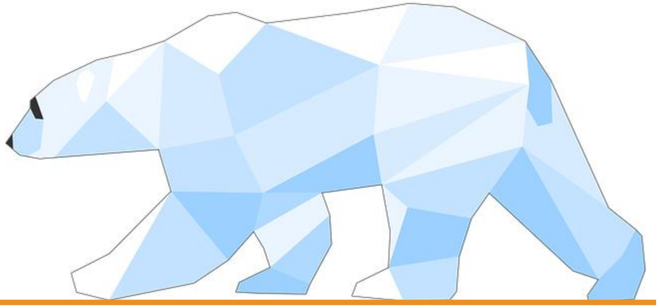
Role of Cyclones

- Favour penetration of moisture across Arctic basin.
- Cyclone relay rather than single tracks from North Atlantic.

Return Values

- Non-trivial to estimate return values of these events.
- Need to account for their spatial structure.

WARM AND COLD SPELLS IN THE ARCTIC

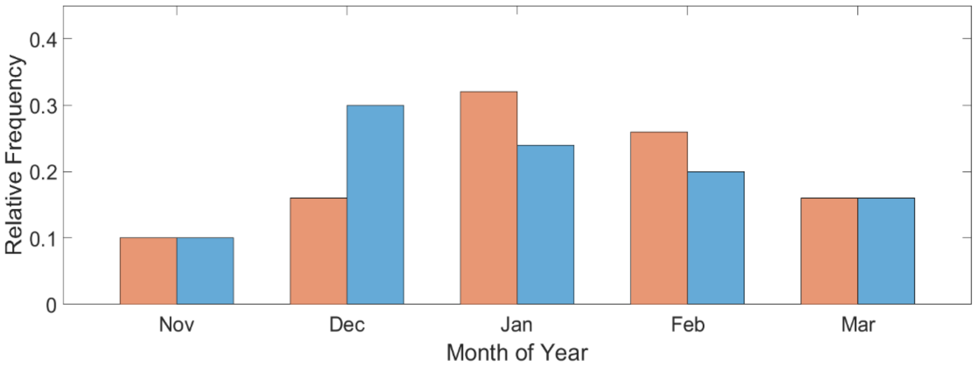


Based on Messori *et al.*, *J. Clim.* (2018)

CLIMATOLOGY

Analyse 50 warmest/coldest NDJFM spells: based on **domain-averaged t2m anomalies** above 80˚ N in ERA-Interim.

Event selection domain

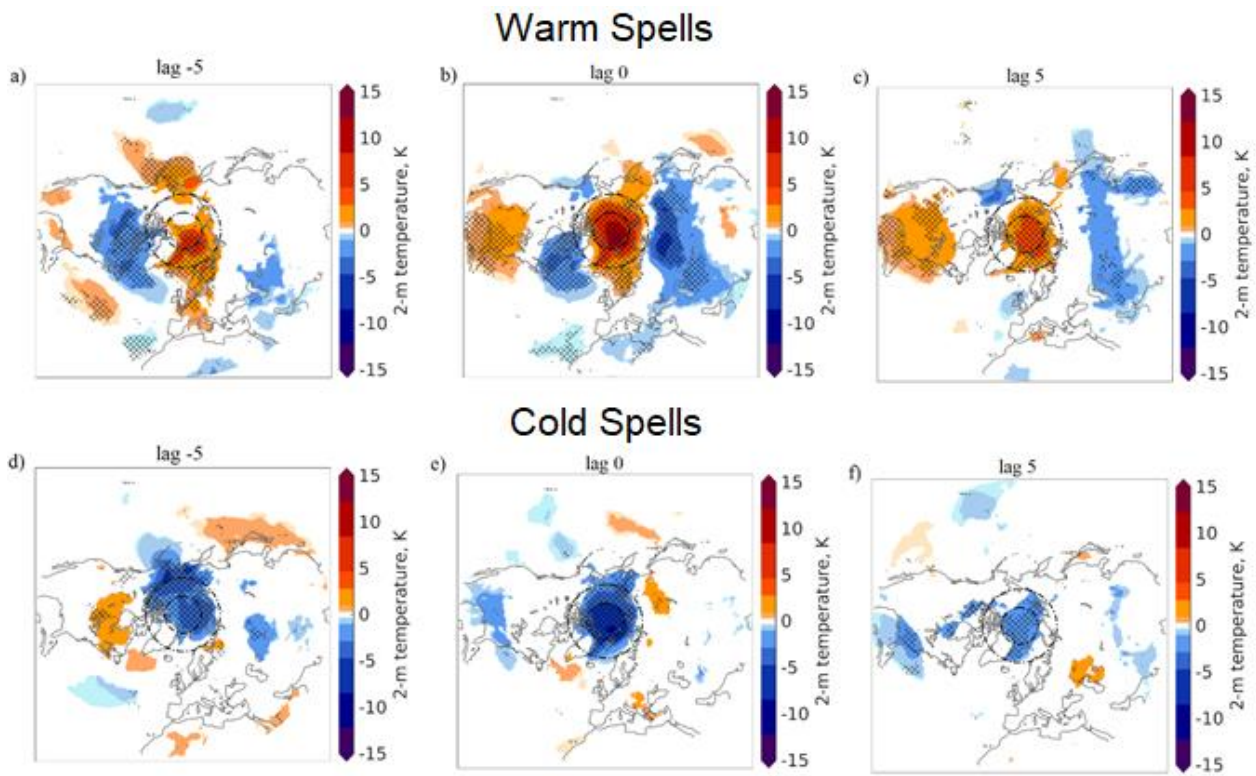


Warm/cold spell frequency in NDJFM

Climatology

Both warm and cold spells show **long persistence** (> 1 week):

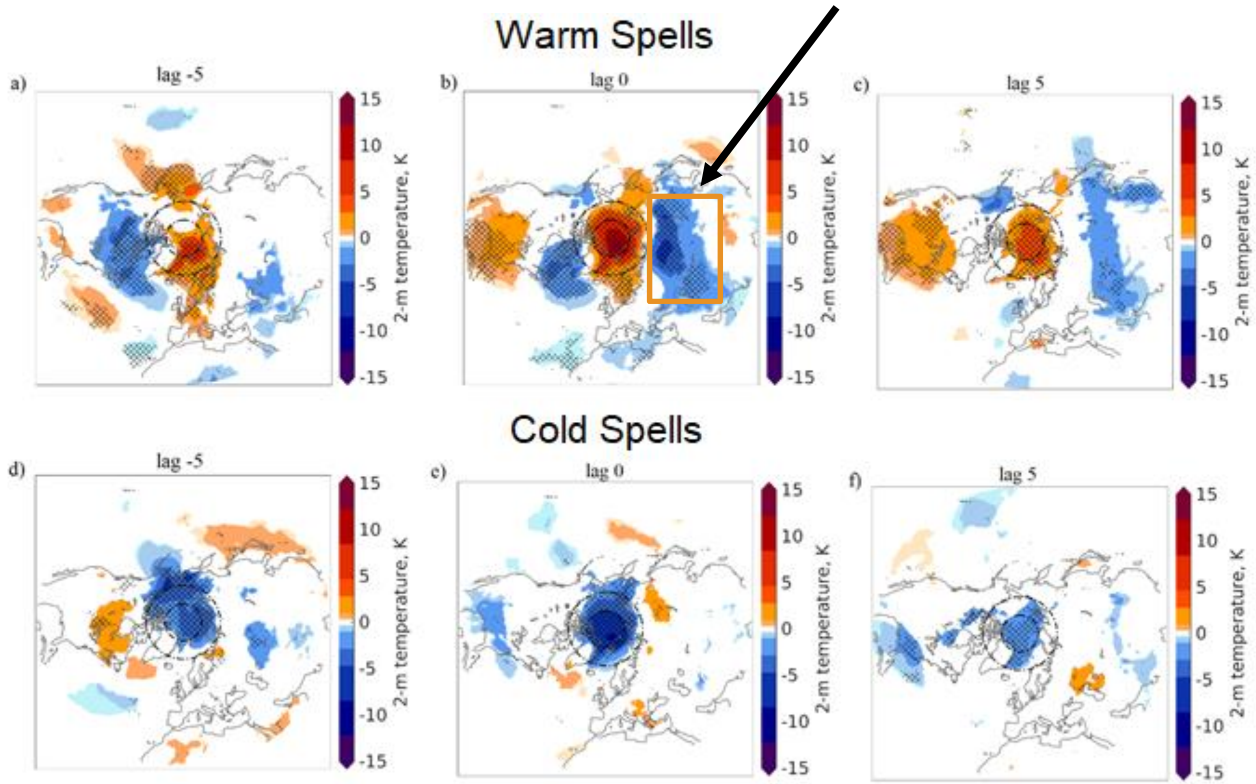
t2m composites at lags of -5 to +5 days relative to peak anomalies



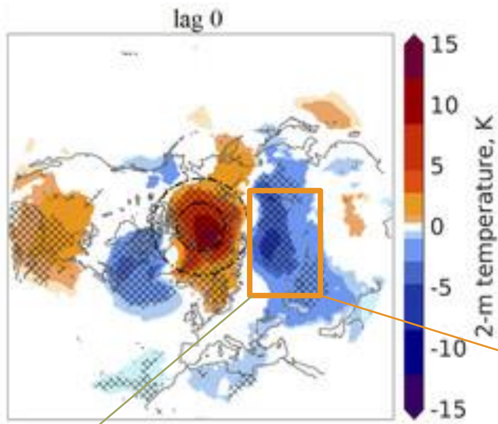
CLIMATOLOGY

Ample literature on **Warm Arctic – Cold Eurasia** (WACE) pattern on seasonal or longer timescales (e.g. Mori *et al.*, 2014).

t2m composites at lags of -5 to +5 days relative to peak anomalies

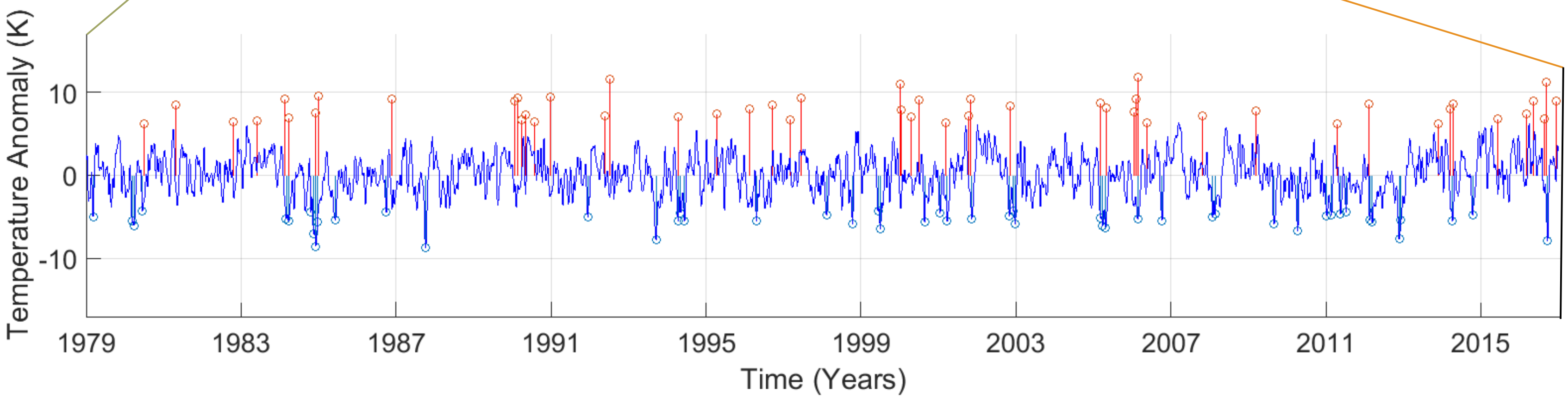


CLIMATOLOGY



We find repeated match between **Warm Arctic and Cold Eurasia** also on synoptic timescales.

t2m composite at peak warm Arctic spells

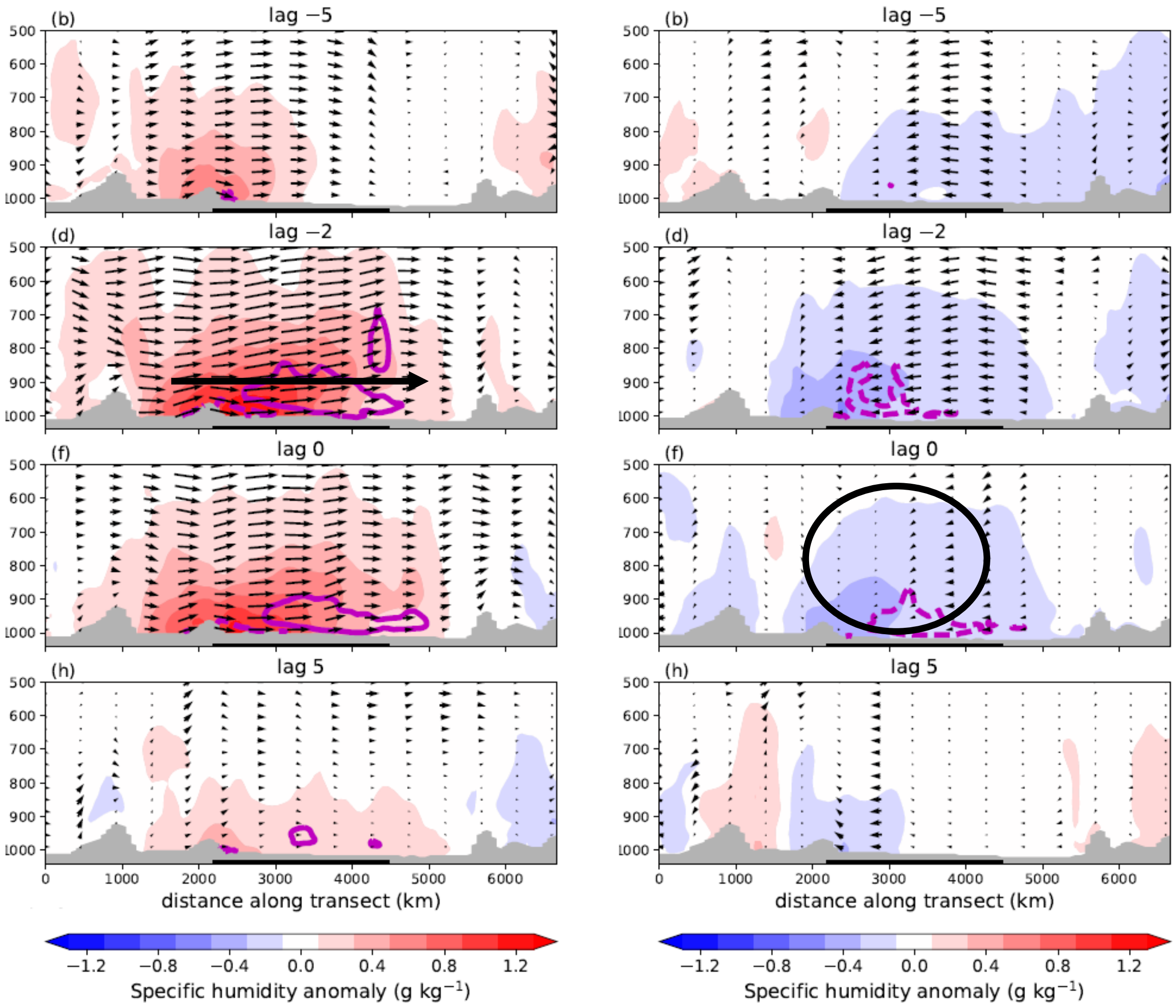


Temperature anomalies in northern-central Eurasia (blue line), coldest 50 days there (blue circles) and warmest 50 days in the high Arctic (red circles)

CLIMATOLOGY

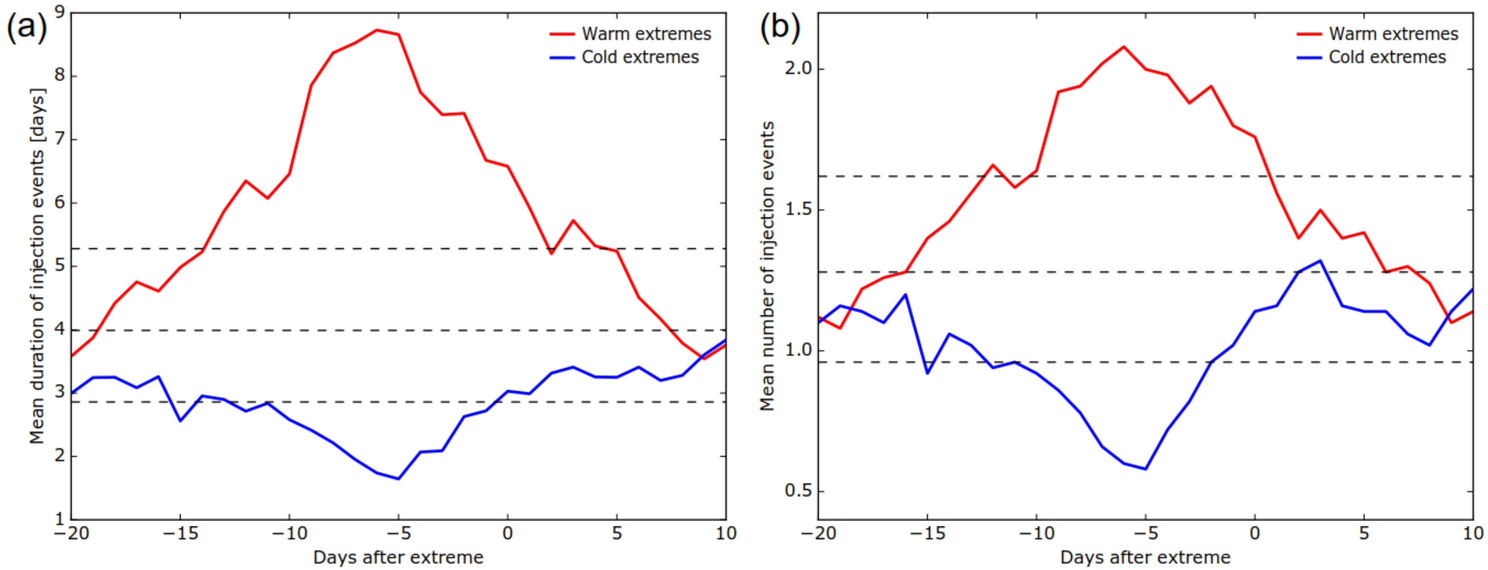
Warm spells preceded by arrival of moist airmasses from the Atlantic:

Wind and humidity composites at lags of -5 to +5 days relative to peak anomalies.
The transect is from Scandinavia to Alaska.



MOISTURE INTRUSIONS

Moisture intrusions: **intense, persistent and zonally extended** moisture flux across 70 °N.



Mean intrusion duration and number relative to peak Arctic temperature anomalies

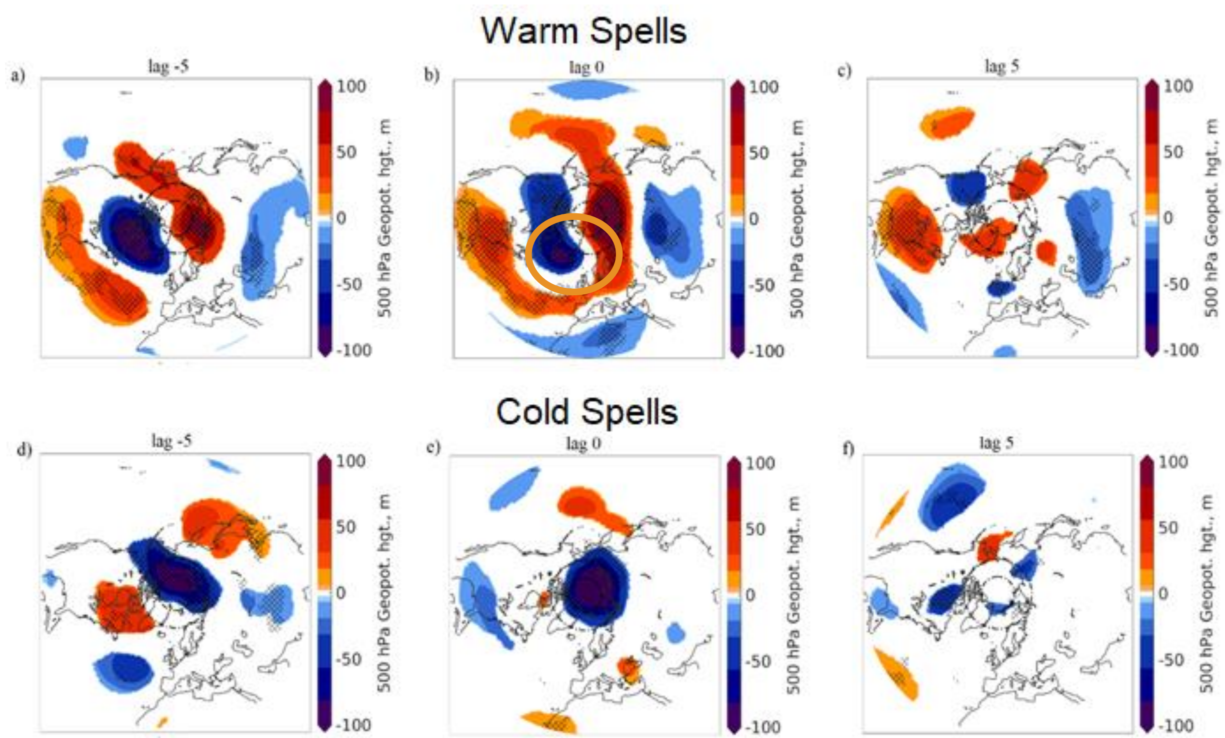
Moisture intrusions: **clear link** with warm and cold spells.

LARGE-SCALE CONTEXT

Warm spells: clear **“Atlantic corridor”** for moisture intrusions.

Cold spells: strengthened **zonal circulation**.

Z_{500} composites at lags of -5 to +5 days relative to peak anomalies



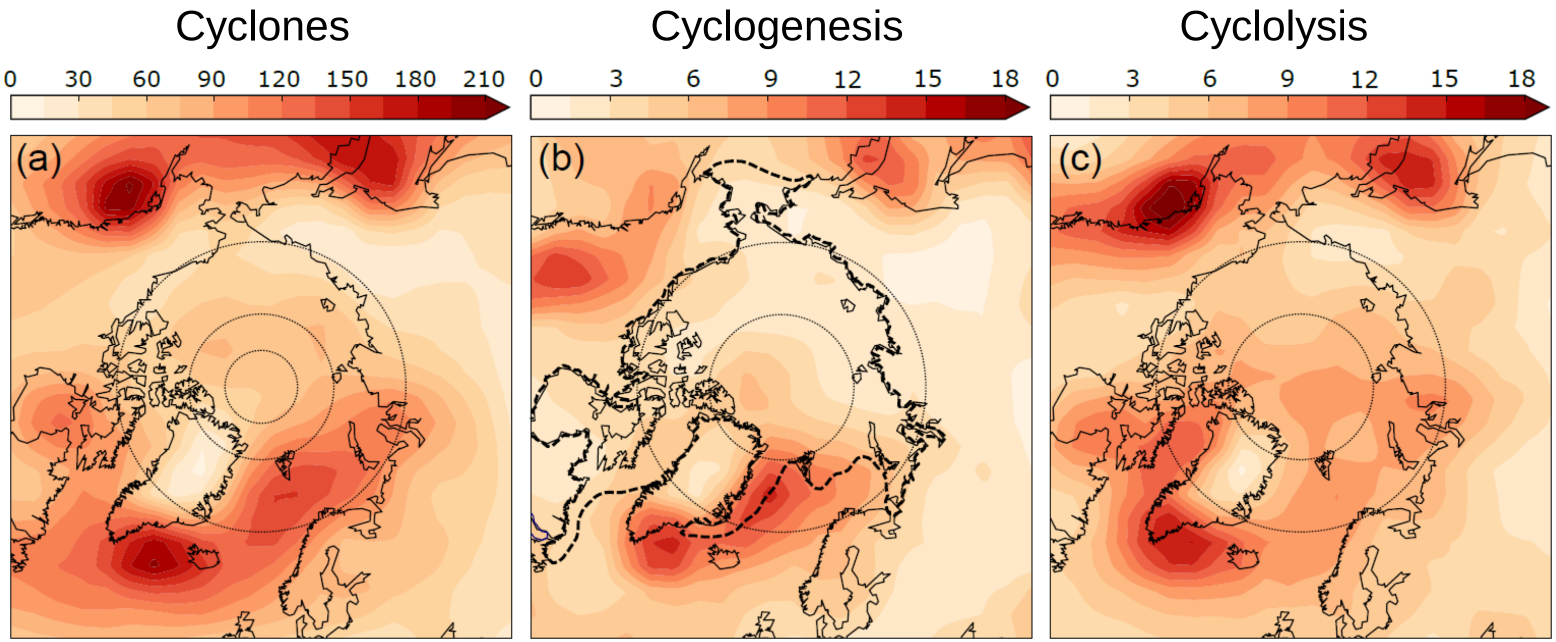
Warm and Cold Spells in the Arctic

- Mid-latitude airmasses/moisture intrusions → warm Arctic extremes.
- Systematic large-scale configuration favouring moisture intrusions and extremes.
- Cold spells → high latitudes isolated from mid-latitudes.

ROLE OF CYCLONES

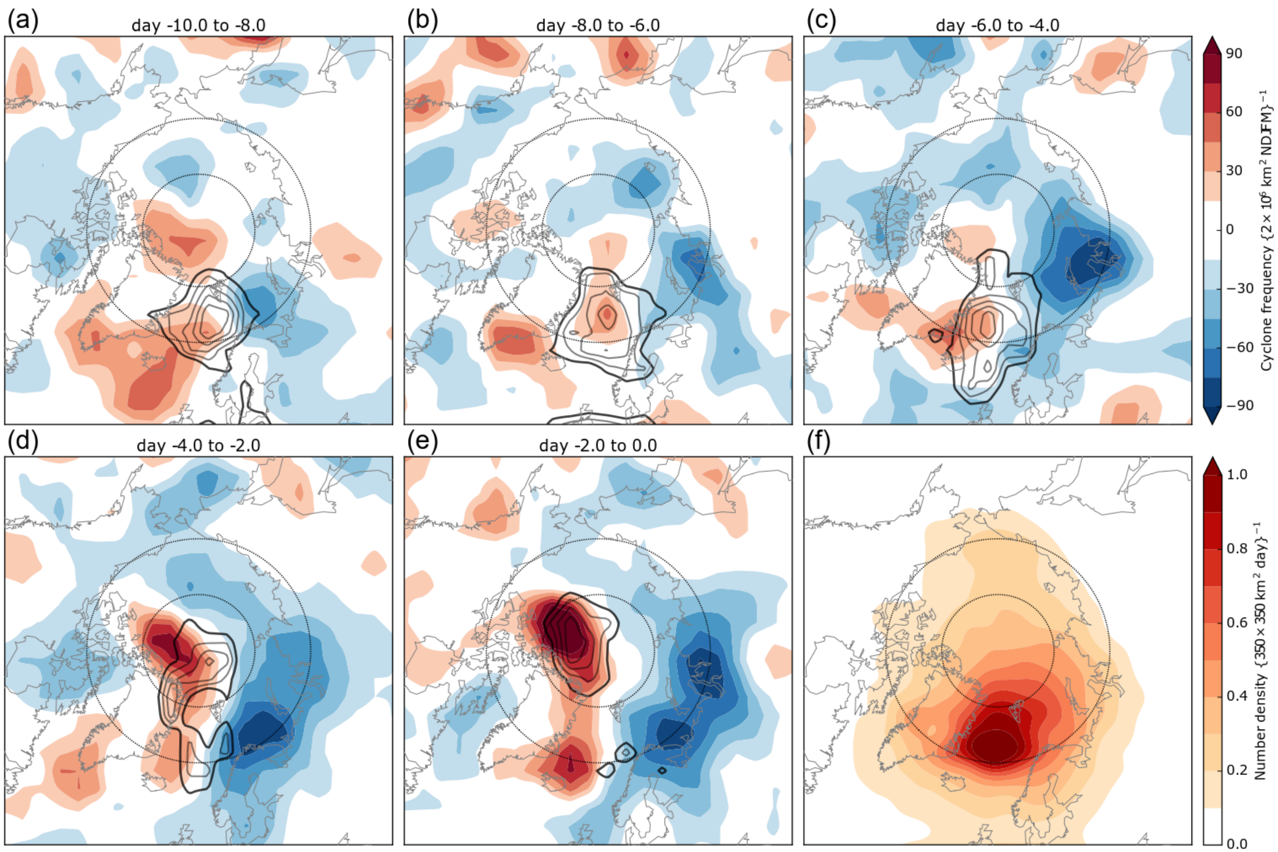
ROLE OF CYCLONES

Cyclone climatology (units [2 × 10^6 km^2 NDJFM]$^{-1}$):



Role of Cyclones

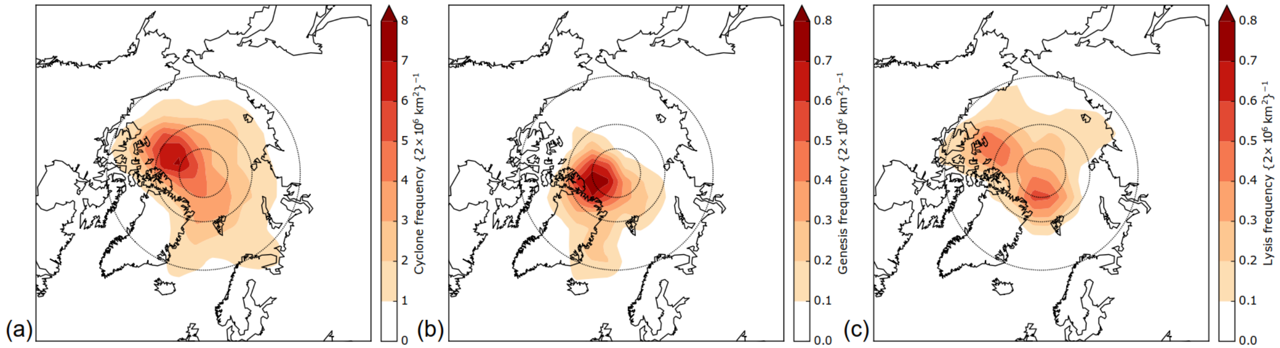
Cyclone anomalies prior to warm spells favour **moisture intrusions**:



Anomalies in frequency of cyclones (colours) and density of moisture intrusions (contours) prior to warm spells.

ROLE OF CYCLONES

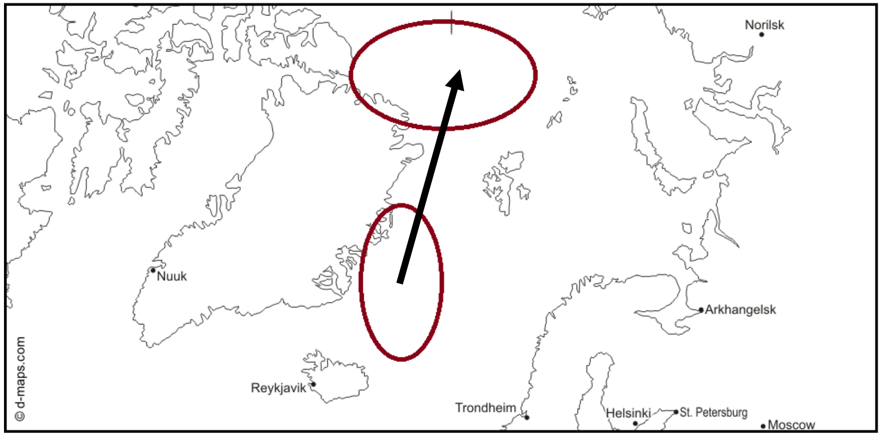
Cyclones **north of 80° N** during warm spells do not come from the North Atlantic:



Frequency, genesis and lysis for cyclones that existed north of 80°N prior to warm spells.

→ Local life-cycle?

→ Cyclone relay?



Role of Cyclones

- Clear anomalies in cyclone activity preceding warm spells.
- Contribute to northward progression of moisture intrusions together with large-scale configuration.
- Challenges picture of continuous tracks from North Atlantic.

RETURN VALUES OF WARM ARCTIC EXTREMES

Based on Messori *et al.*, *Q. J. R. Meteorol. Soc.* (2020)

Return Values of Warm Extremes

Aim:

Estimate temperature return values over long times from short observational data series, using Extreme Value Theory (EVT).

Challenge:

Warm extremes have a relatively narrow footprint, being associated with moisture intrusions → naïve application of EVT gridpoint-by-gridpoint gives noisy, physically unrealistic picture.

RETURN VALUES OF WARM EXTREMES

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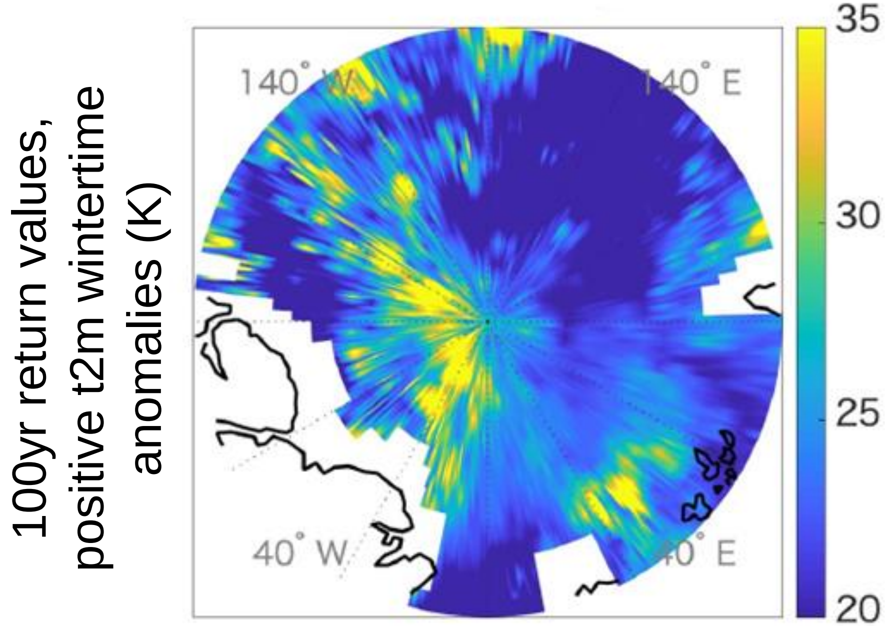


STM–E Model

STM–E Model:

Two-part model: Space-Time Maxima (STM) and Exposure (E)

STM: extract the locations of the maximum values during each extreme event.

E: a value normalized in [0, 1] for each event, in the form of a geographical map.

Assuming that the distributions of STM and E are independent, the two may be multiplied to derive the STM-E extreme behavior estimate at each location.

STM–E Model

Define STMs:

Select maximum for each physical event (e.g. cyclone)

$\{s\}_{i=1}^{n}$, n being the number of events

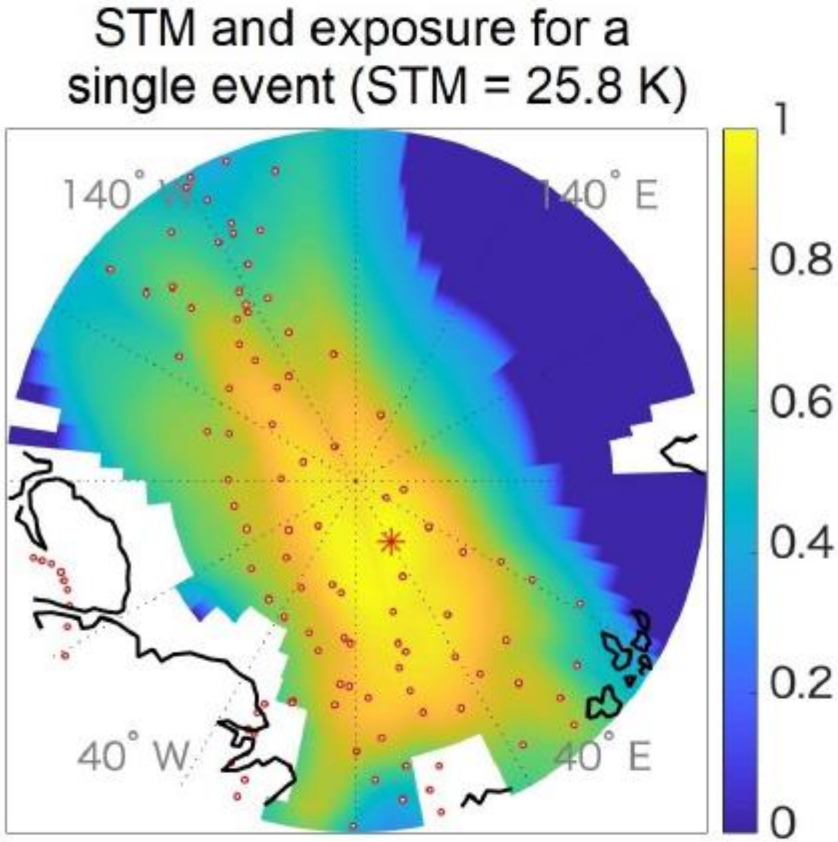
Can then use standard EVT to compute conditional distribution of threshold exceedances.

Define Es (N.B. sloppy notation for conciseness):

$e_{i,j} = \max\left(\frac{h(j,t)}{s_i}\right)$, *j* being an index over spatial locations, and t being an index over timesteps for which the event lasts.

STM–E Model

Example of STM (red asterisk) and E (colours) for a single warm spell:



STM–E MODEL

Combine to obtain STM–E:

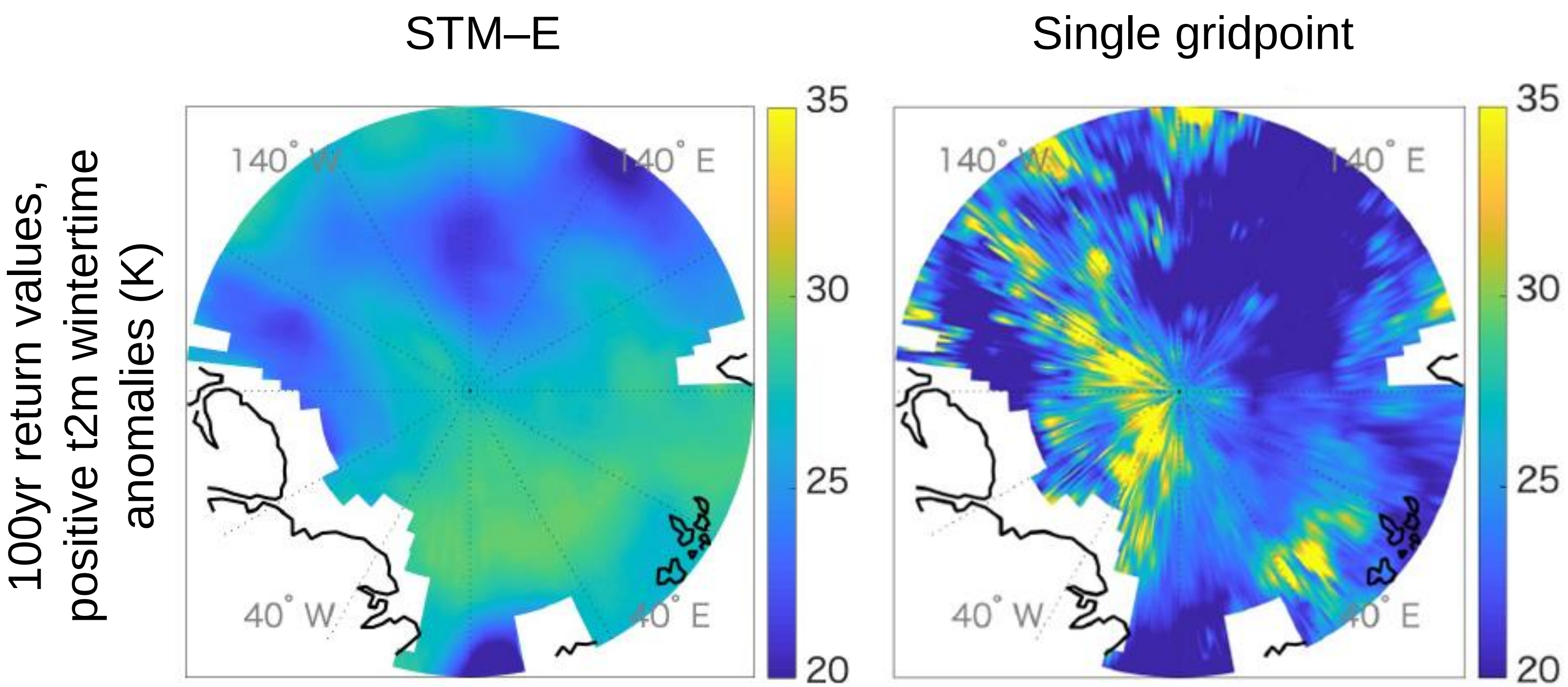
Event severity at a location *j* is $H_j = E \times S$, *E* and *S* random variables for STM and Exposure.

Can then obtain the cumulative distribution of H_j.

N.B. We have thus «pooled» STMs so that all physical events contribute to the set $\{s_i\}$.

Return Values of Warm Extremes

STM-E (Space-Time Maxima – Exposure) Model results in improved estimates of return values:



Return Values of Warm Extremes

- Arctic warm extremes: example of geophysical extreme where a naïve EVT approach fails.
- The STM–E model seems to provide sensible estimates.
- Possible in the future to include non-stationarity in the STM–E framework?

Thank You!

Messori G.*, Wada R.*, Woods, C. (*equal contribution; 2020). A spatial model for return values of warm extremes in the high Arctic. *Q. J. R. Meteorol. Soc.*

Messori G., Woods C., Caballero R. (2018) On the drivers of wintertime temperature extremes in the High Arctic. *J. Clim*.

Woods, C., & Caballero, R. (2016). The role of moist intrusions in winter Arctic warming and sea ice decline. *J. Clim*.

Mori, M., Watanabe, M., Shiogama, H., Inoue, J., & Kimoto, M. (2014). Robust Arctic sea-ice influence on the frequent Eurasian cold winters in past decades. *Nature Geosci.*