Airmass transport and dynamical drivers of an extreme wintertime Arctic warm event

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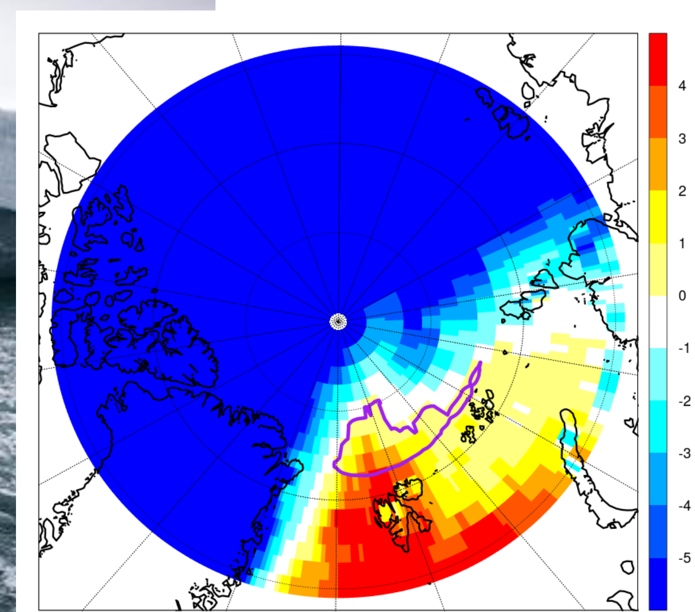
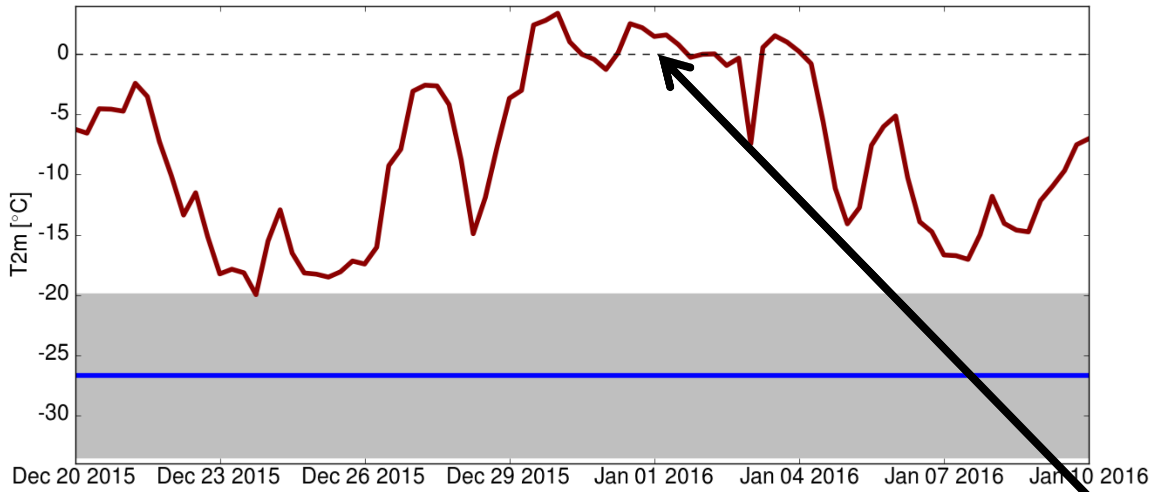
[1]ETH Zurich, Switzerland [2]KIT, Germany [3]FU Berlin, Germany

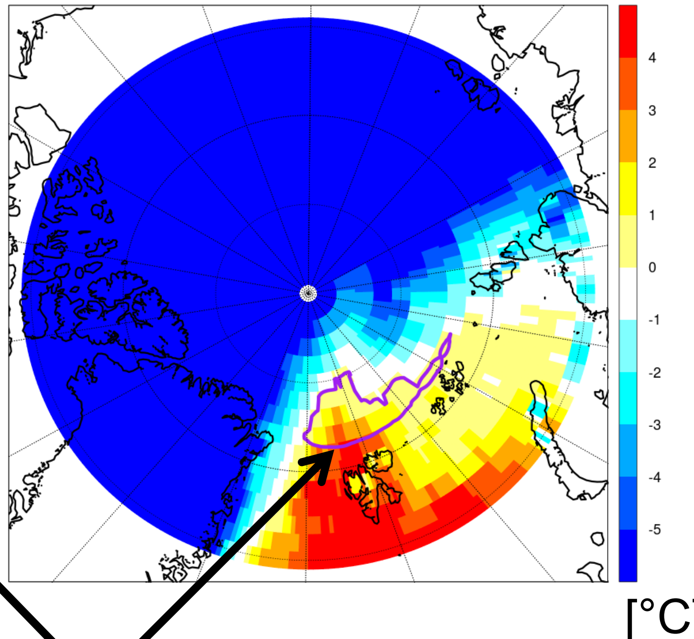


An extreme Arctic heat and melt event in Dec/Jan 2015/16

Arctic surface temperature (T2m)
(≥ 82°N, 120°W – 120°E)



Maximum T2m between
30 Dec 2015 – 4 Jan 2016



— Domain max. T2m in Dec/Jan 2015/2016

— Winter climatological mean: -27°C
±1 standard deviation

max. T2m > 0°C around
Svalbard & over the Kara Sea

see also Boisvert et al. 2016,
Moore 2016, Kim et al. 2017

An extreme Arctic heat and melt event in Dec/Jan 2015/16

Change in Arctic sea-ice thickness between 28 Dec 2015 and 4 Jan 2016

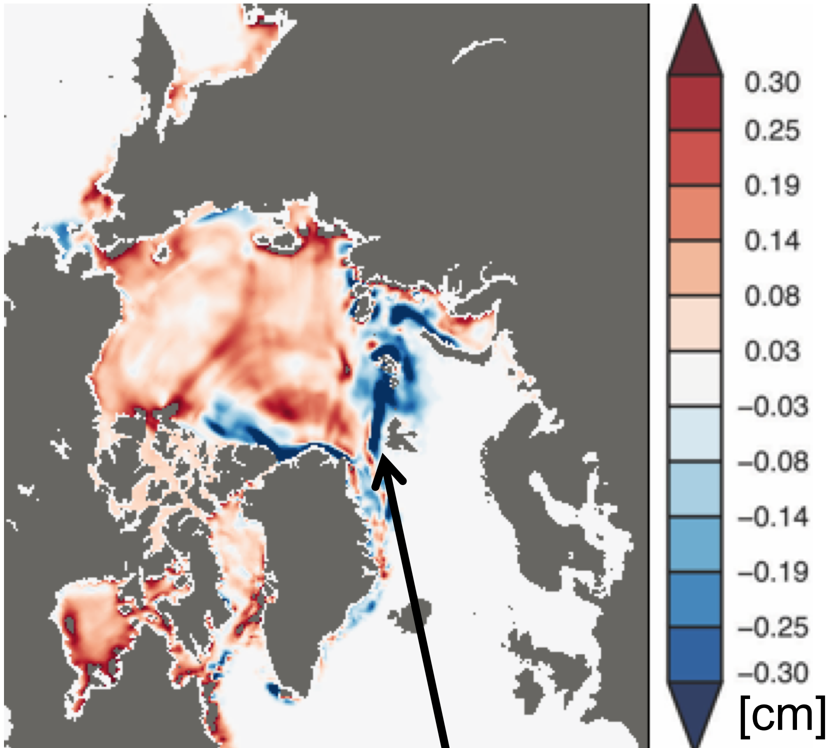
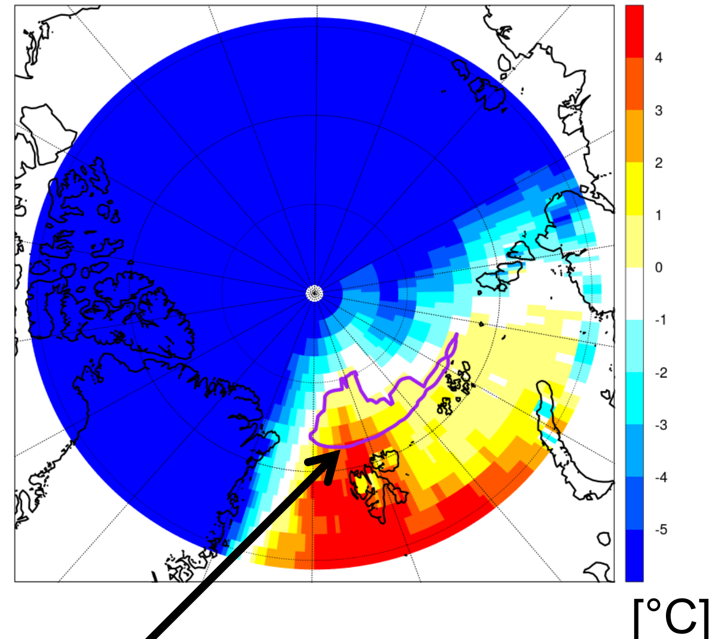


Image credit: NSIDC, courtesy PIOMAS

Extreme sea-ice thinning in the middle of the cold season

Maximum T2m between 30 Dec 2015 – 4 Jan 2016



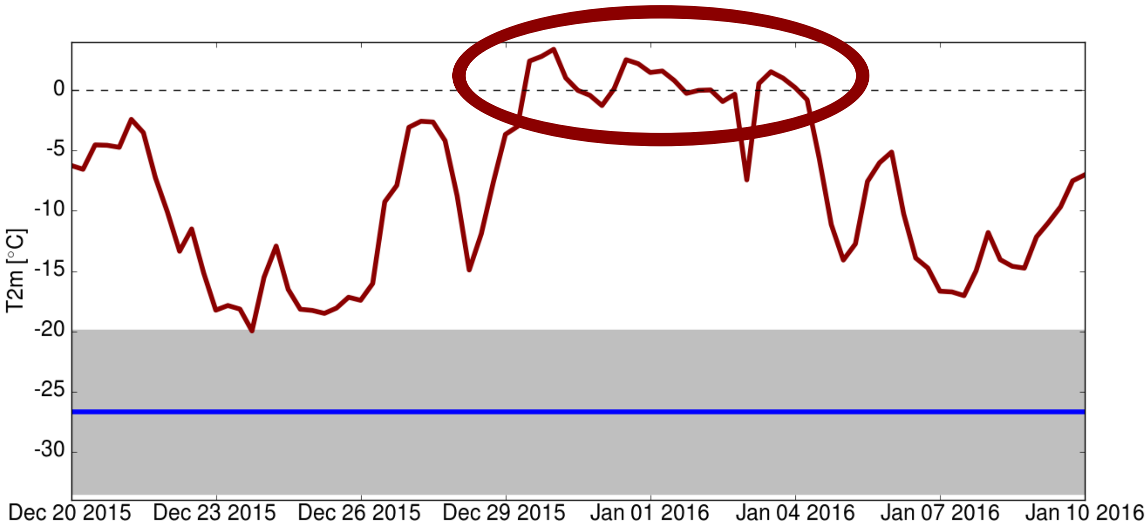
max. T2m > 0°C around Svalbard & over the Kara Sea

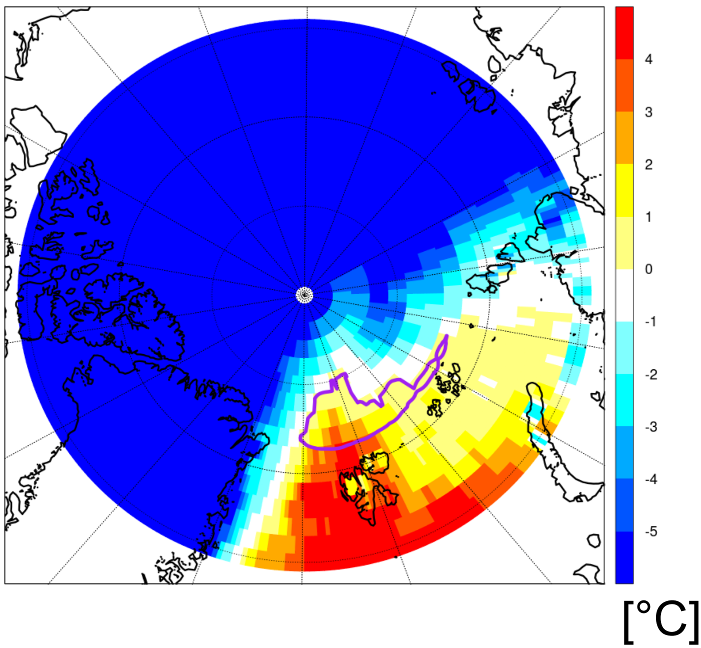
see also Boisvert et al. 2016, Moore 2016, Kim et al. 2017

Research questions

1) Which meteorological processes led to the extreme Arctic warm event?

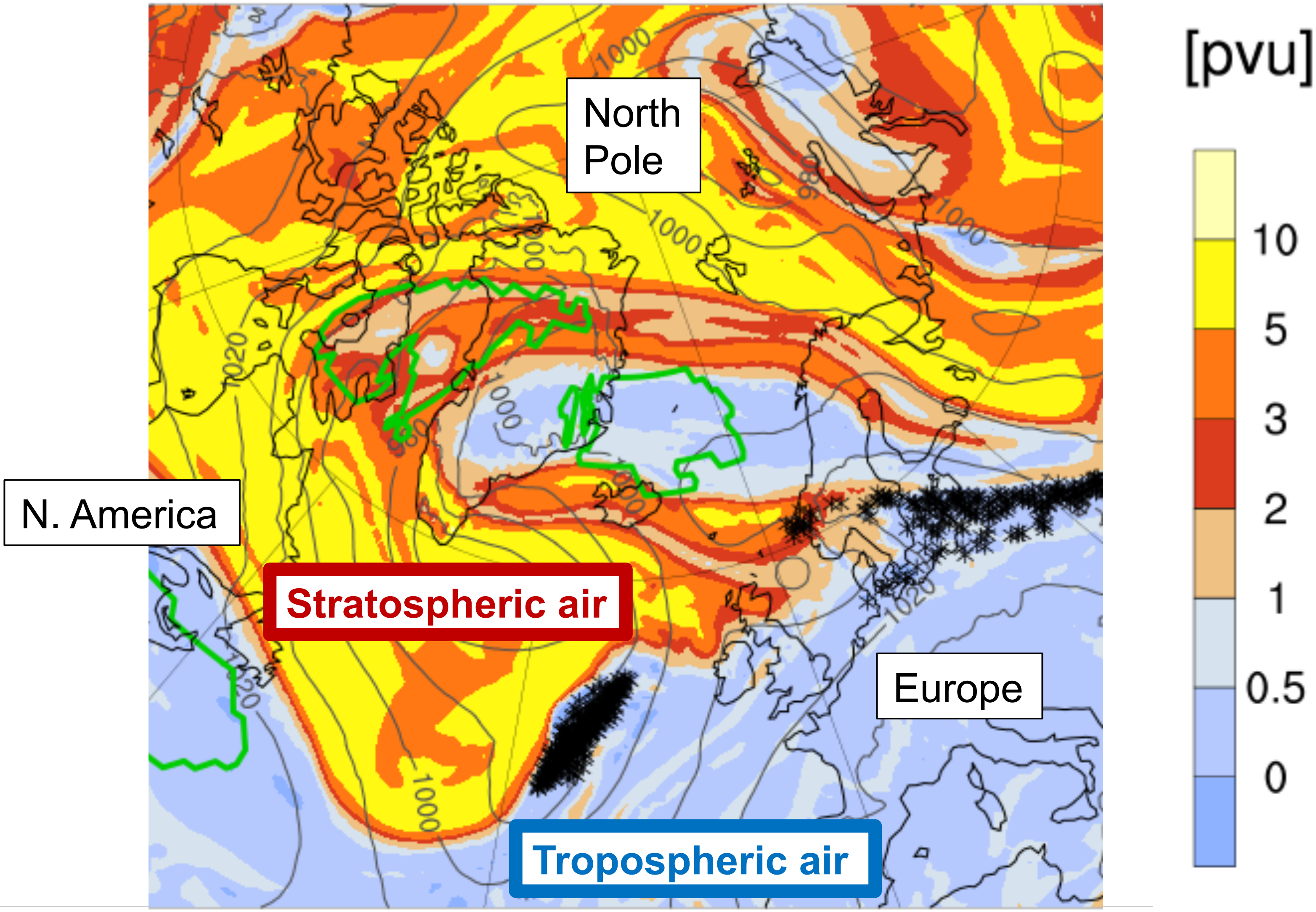
2) Where originated the warm air masses that arrived in the Arctic?





Part 1) Synoptic evolution: 06 UTC 27 Dec 2015

Colors: Isentropic PV on 310K —— SLP (every 10hPa)
* WCB intersections with 310K —— Blockings (Schwierz et al. 2004)



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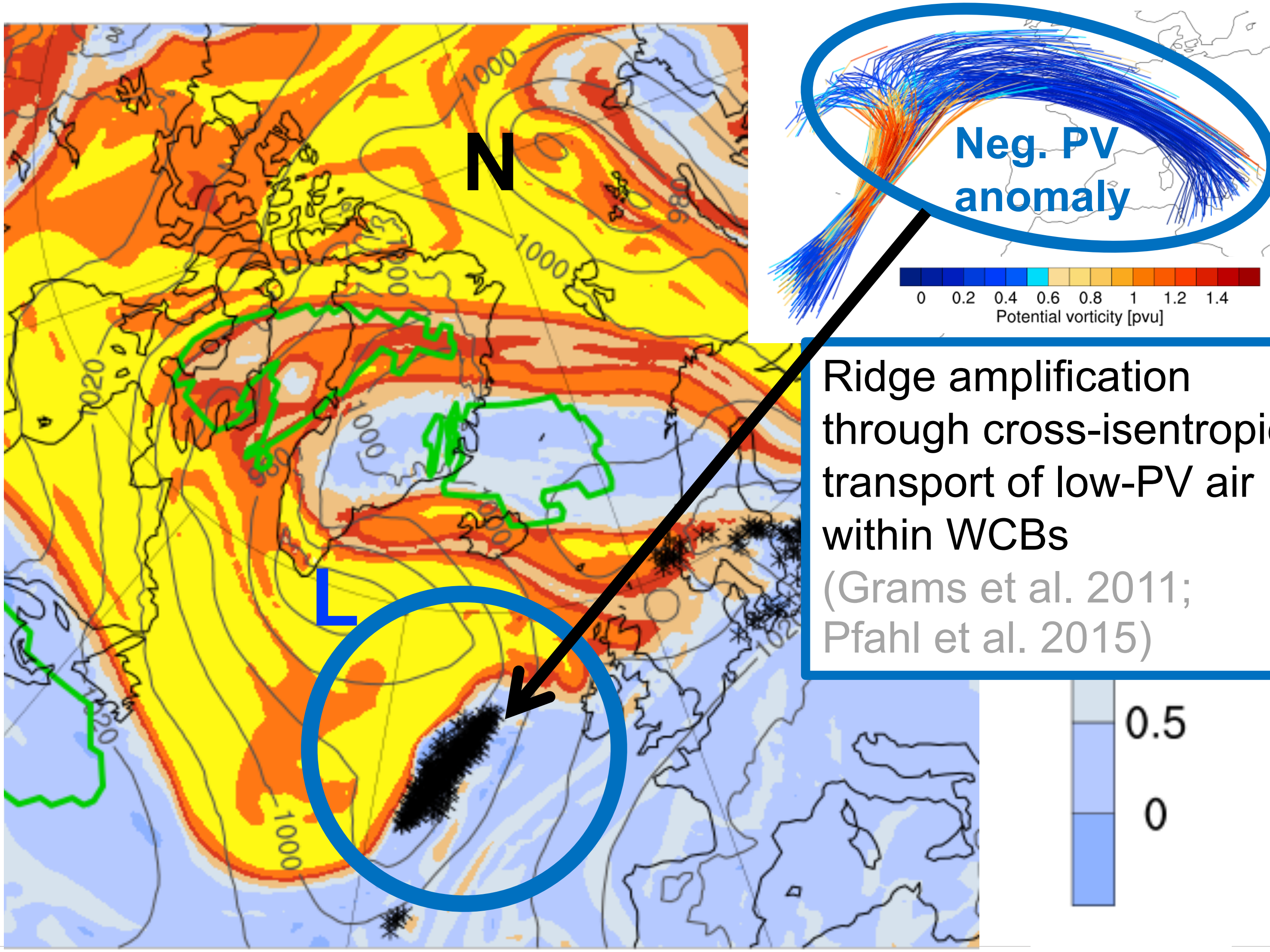

Ridge amplification through cross-isentropic transport of low-PV air within WCBs (Grams et al. 2011; Pfahl et al. 2015)

Synoptic evolution: 12 UTC 27 Dec 2015

Colors: Isentropic PV on 310K —— SLP (every 10hPa)
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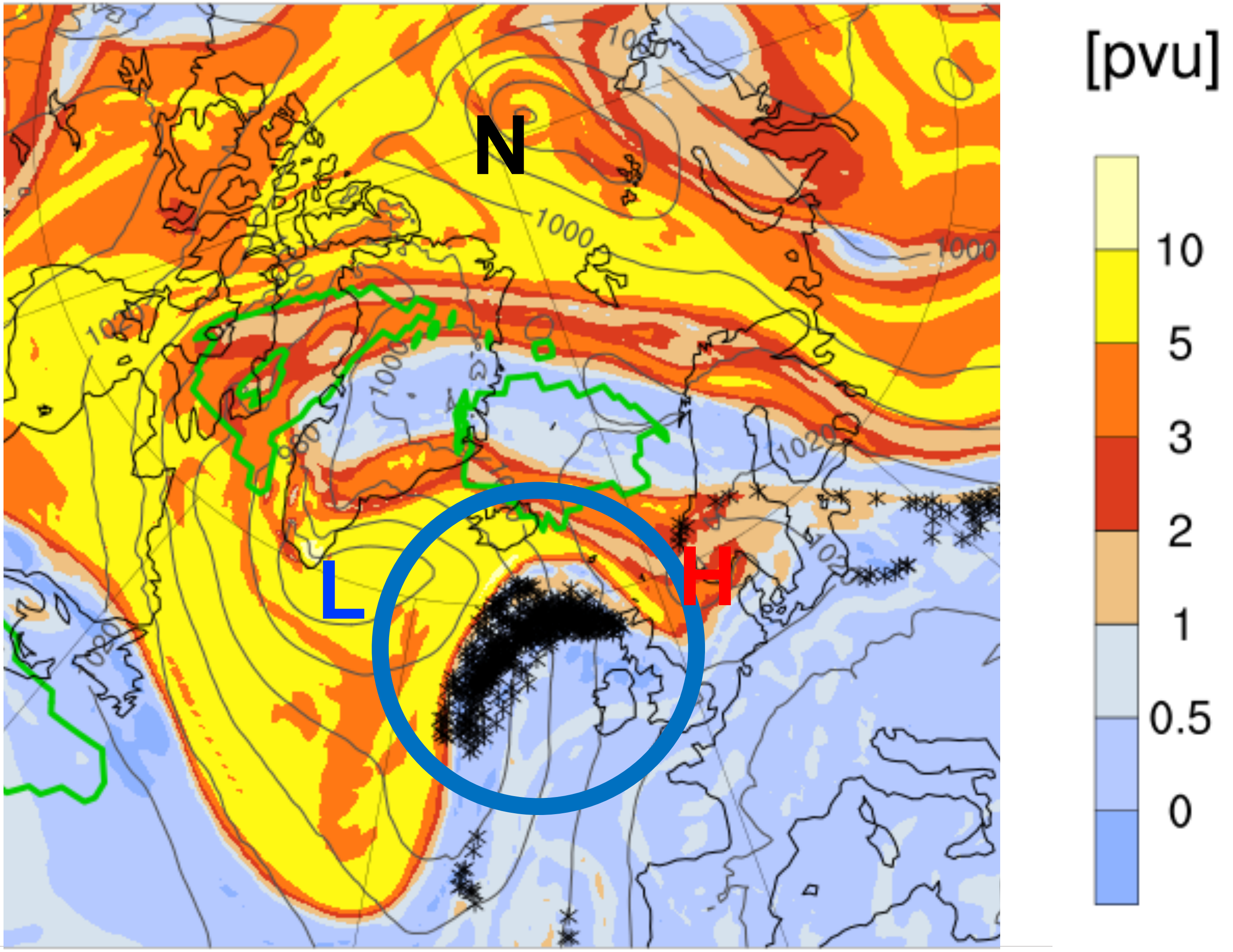

Synoptic evolution: 18 UTC 27 Dec 2015

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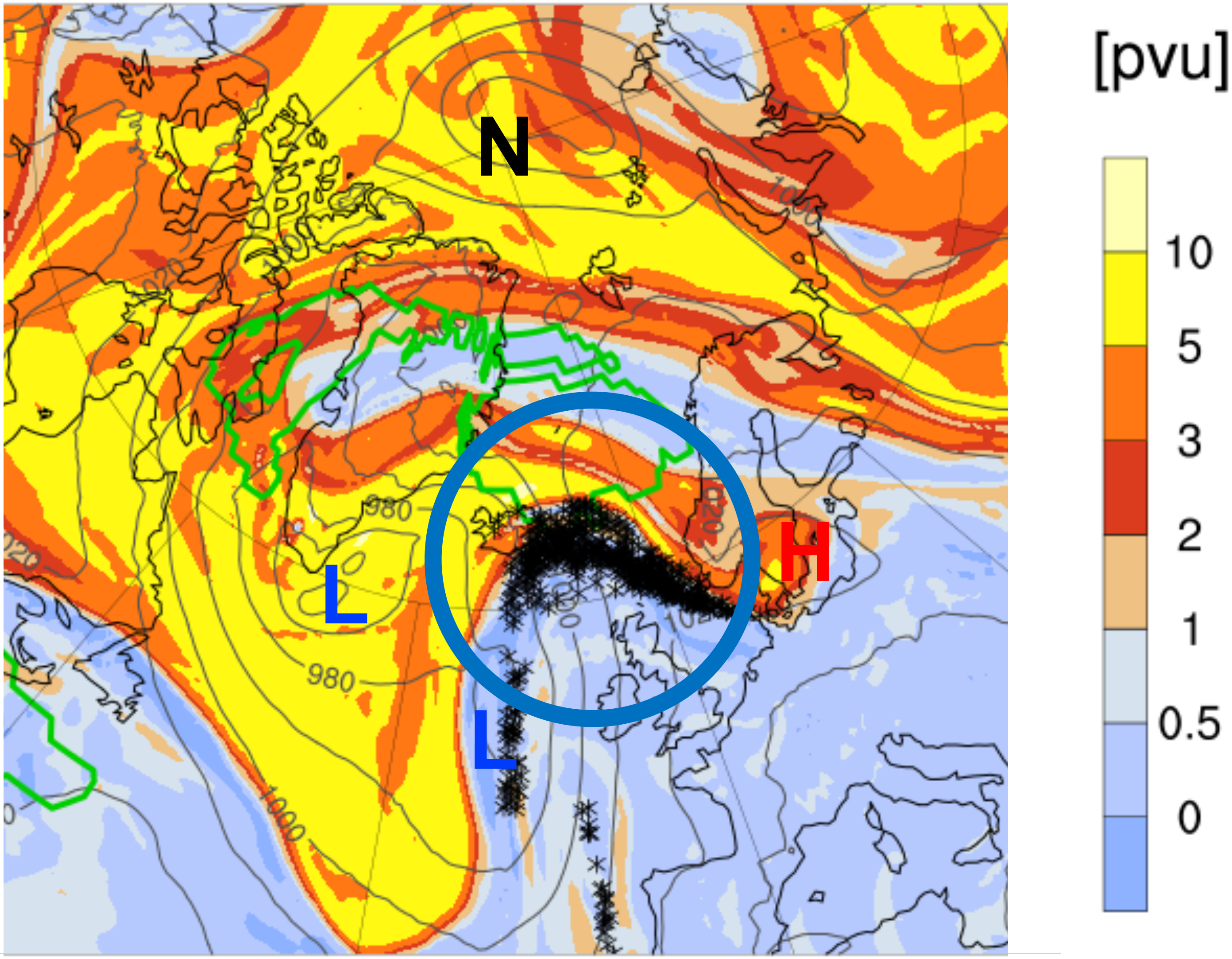

Synoptic evolution: 00 UTC 28 Dec 2015

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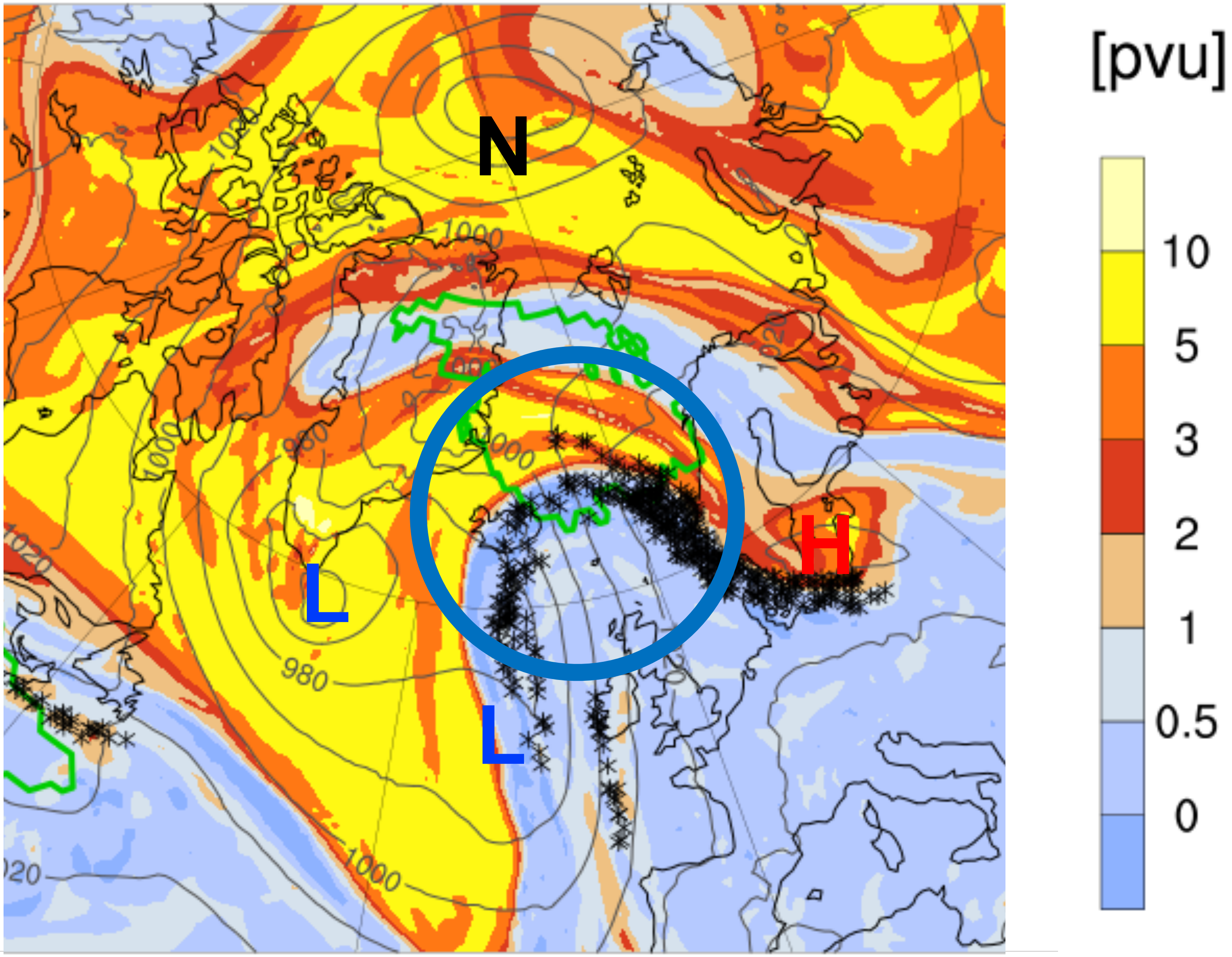

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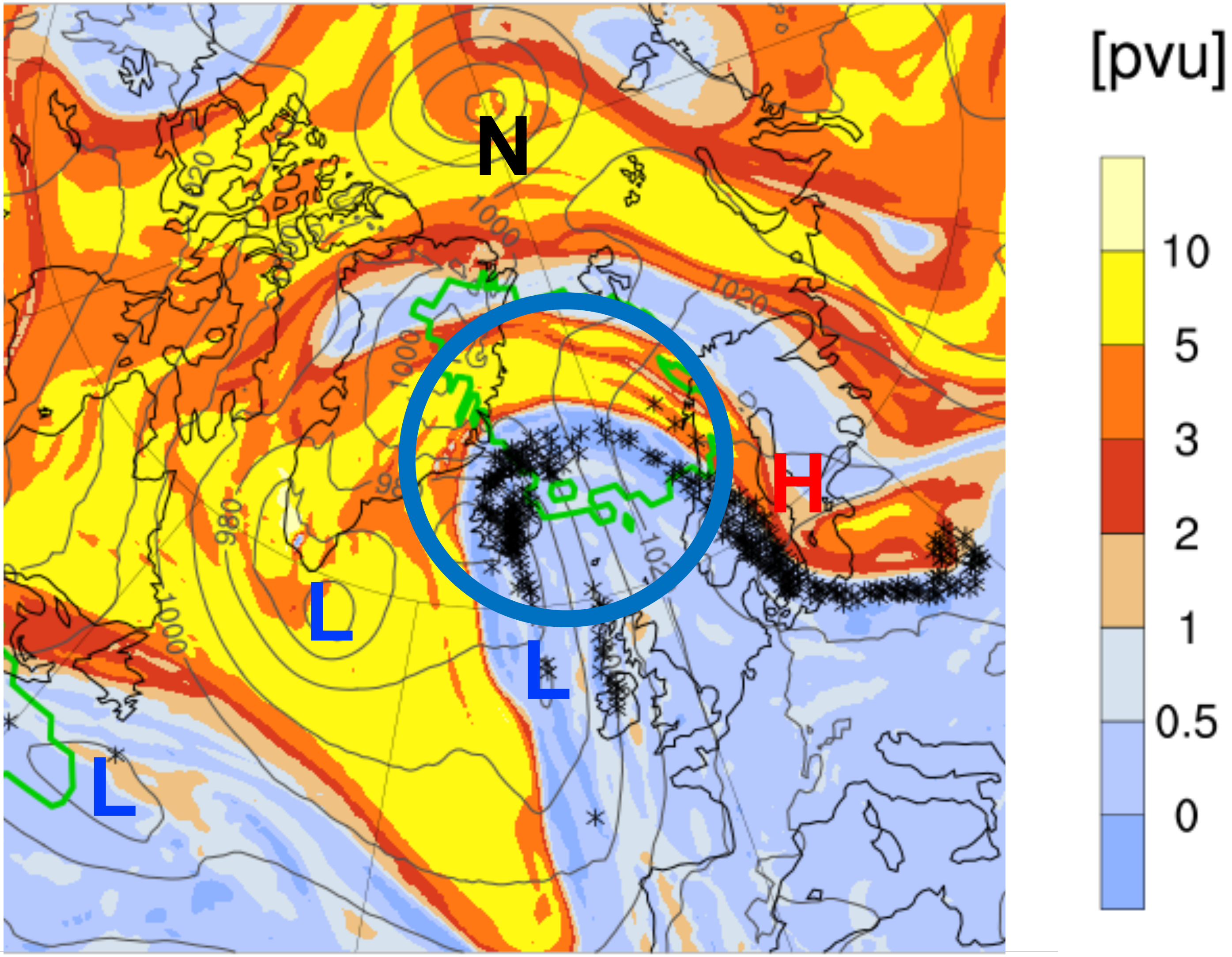

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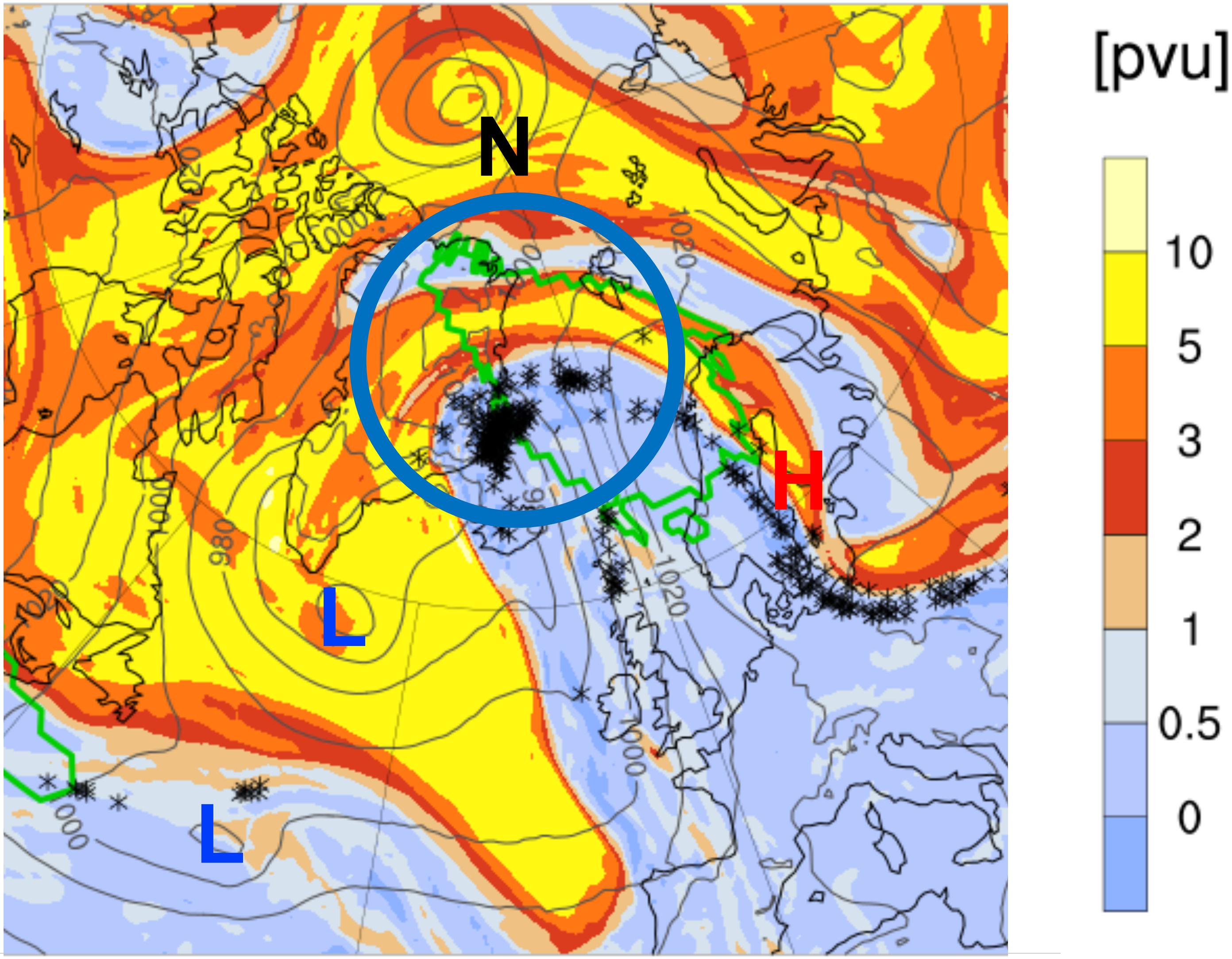

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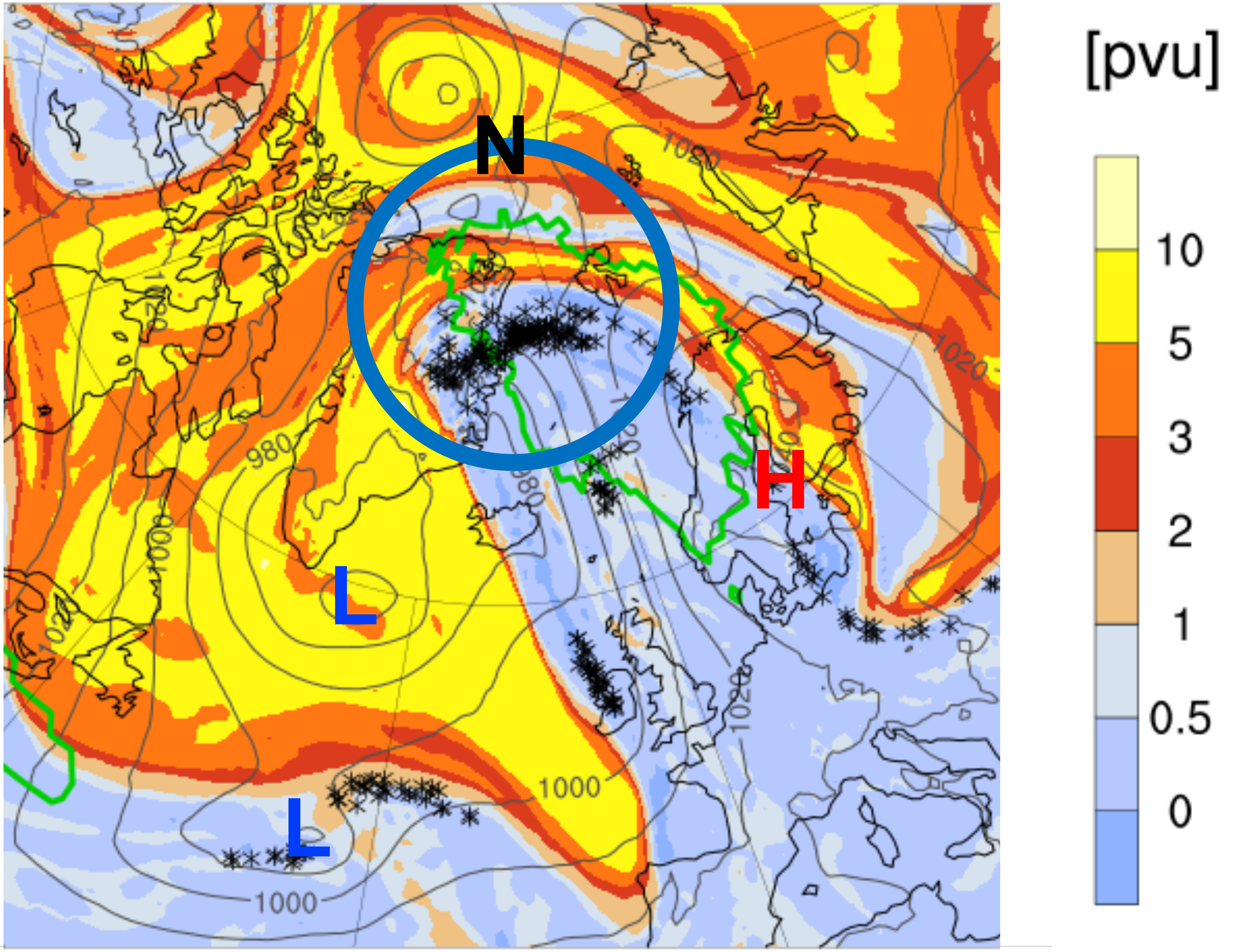

Synoptic evolution: 00 UTC 29 Dec 2015

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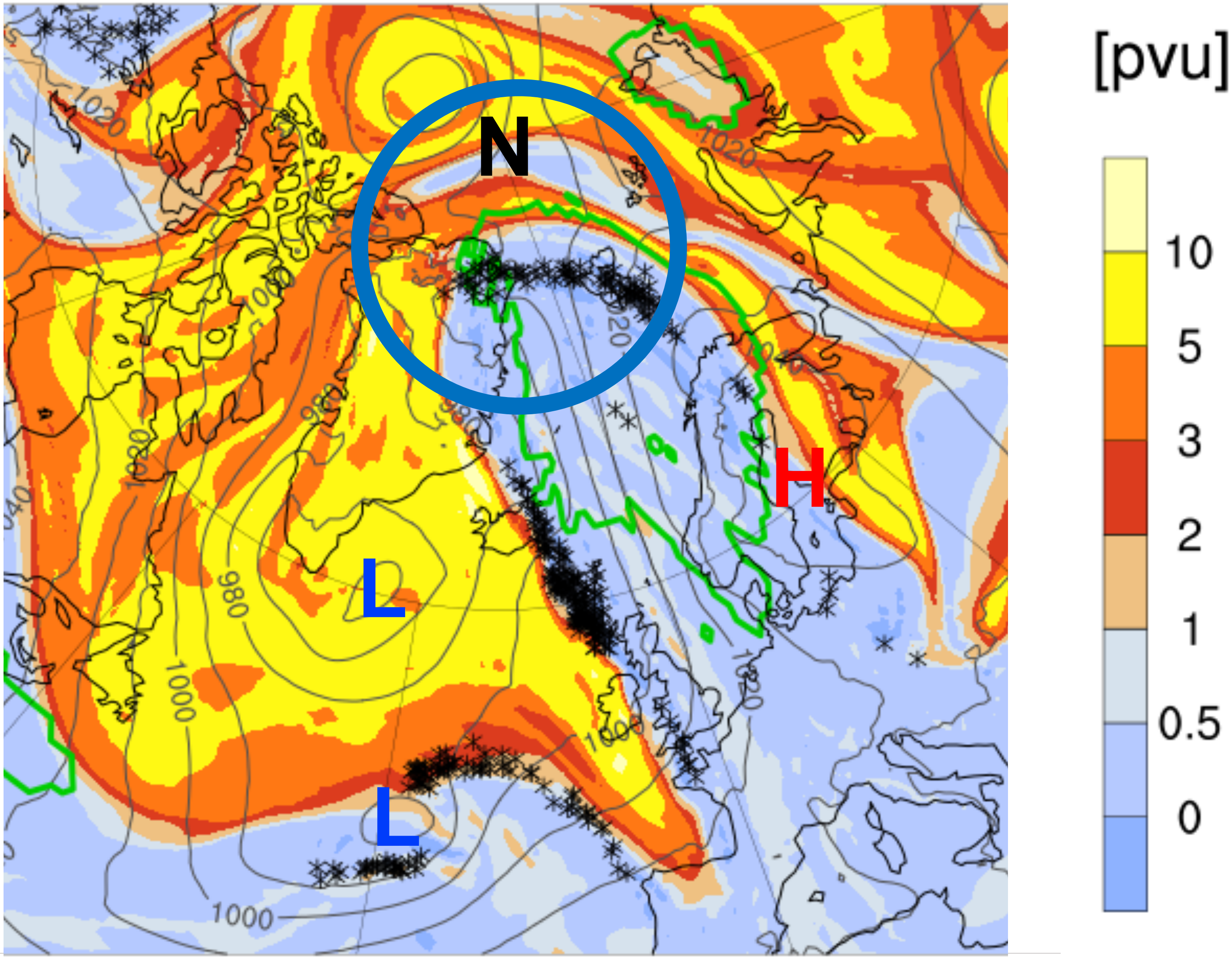

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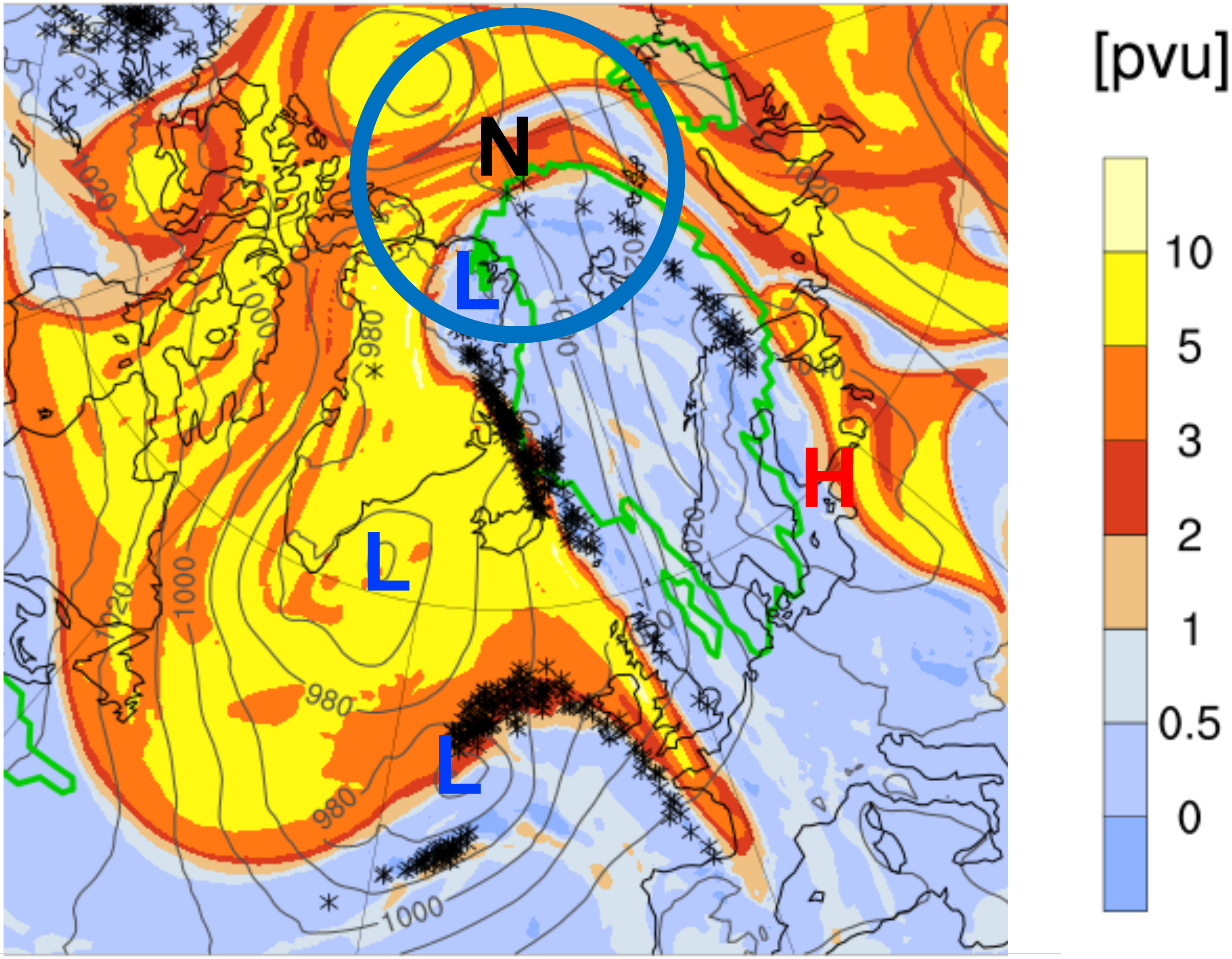

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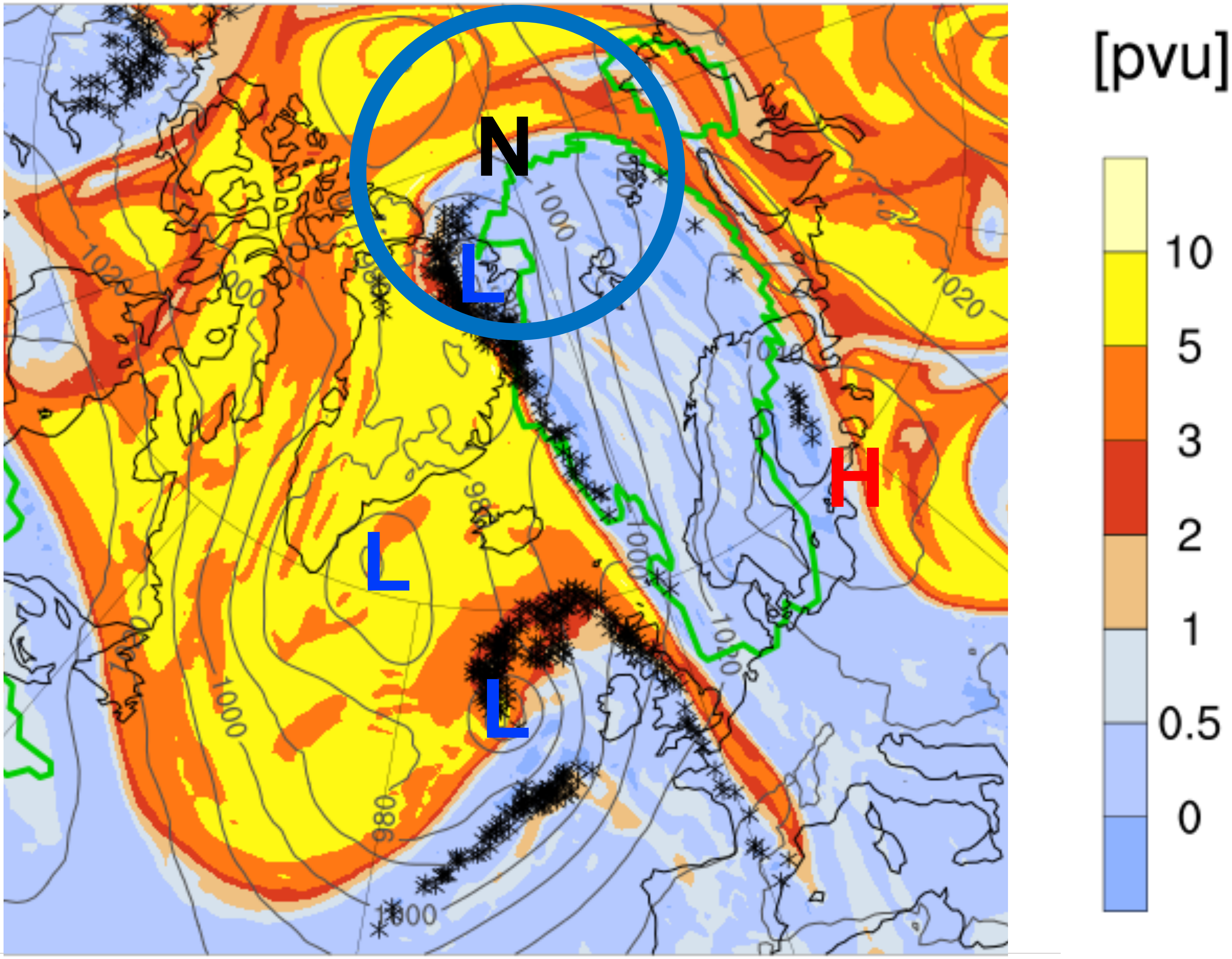

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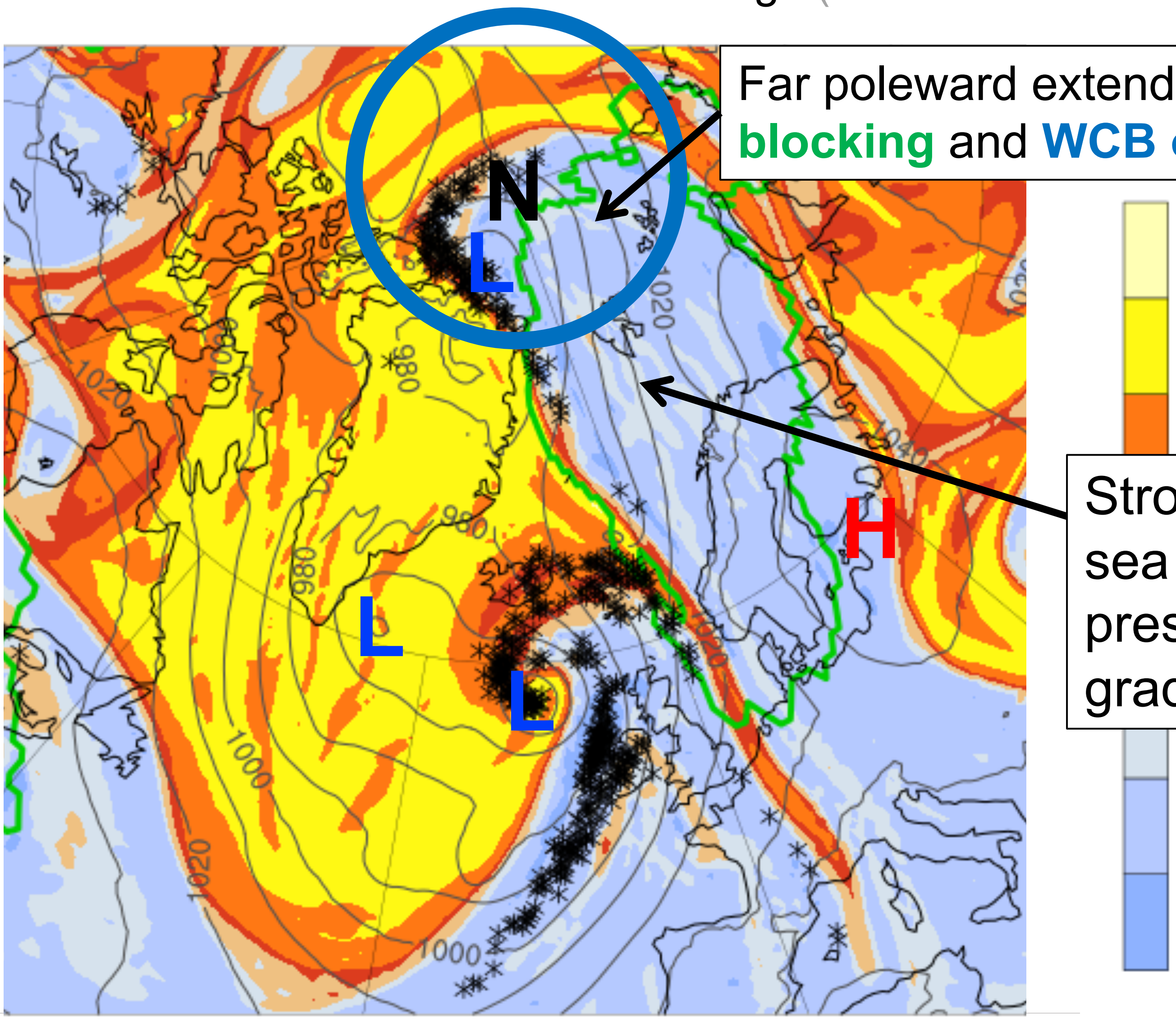
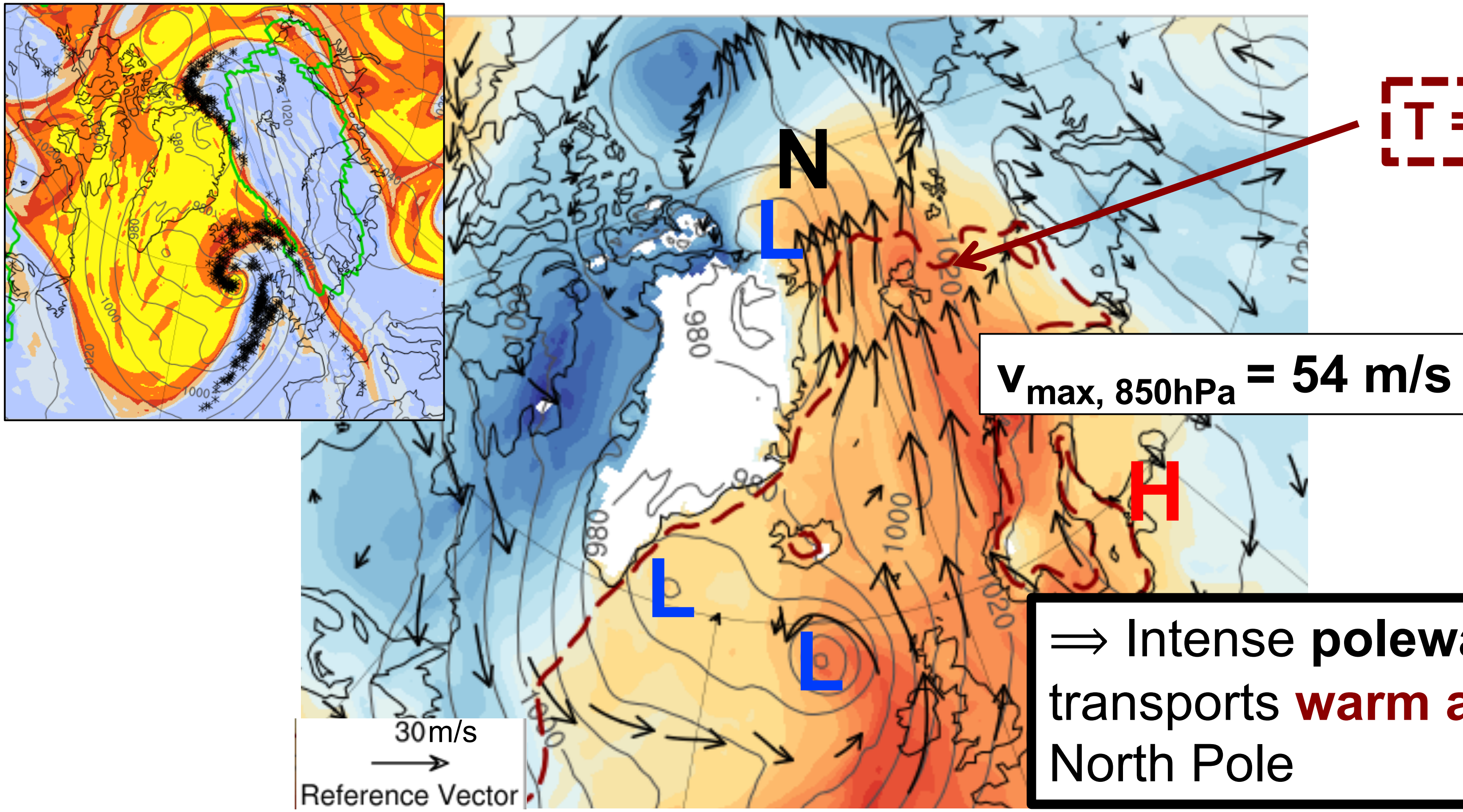


Far poleward extending **blocking** and **WCB outflow**

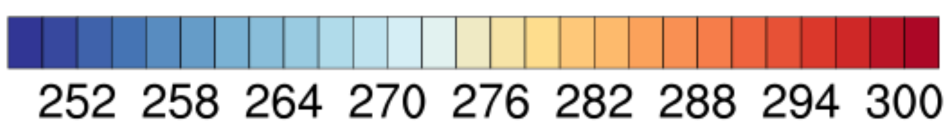
Strong sea level pressure gradient

Synoptic evolution: 18 UTC 29 Dec 2015

T2m = 0°C — SLP (every 10 hPa) — Wind vectors at 850 hPa



⟹ Intense **poleward jet** transports **warm air** to the North Pole

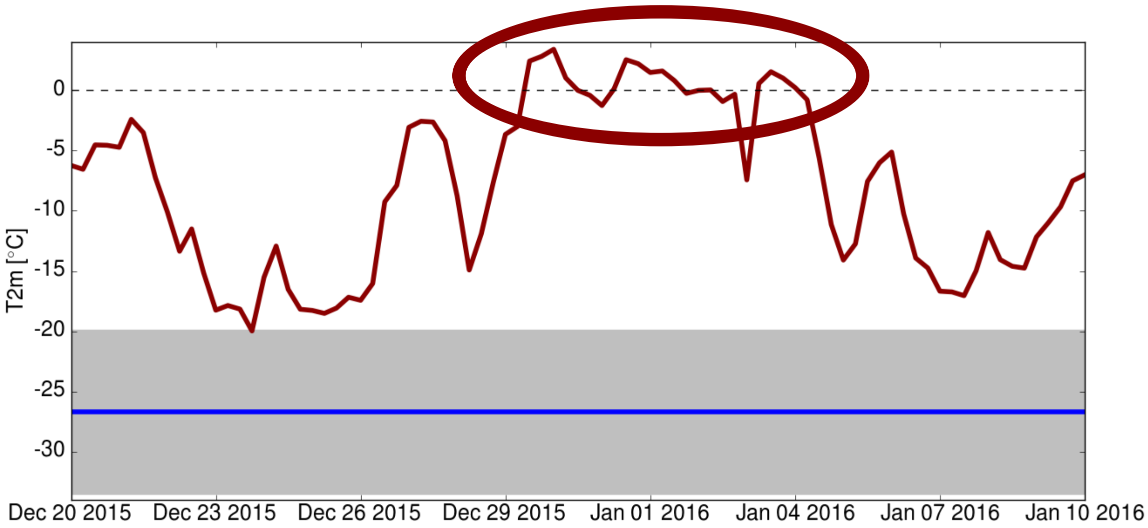


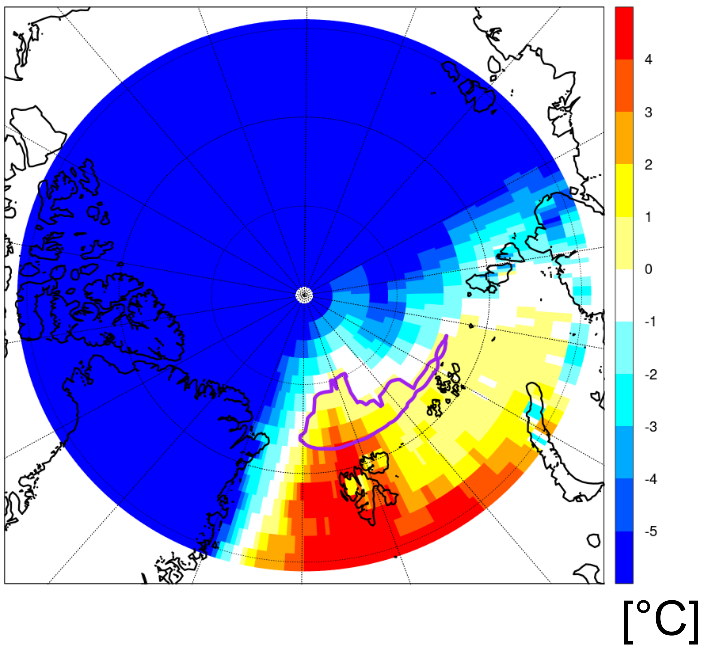
850-hPa Potential temperature [K]

Research questions

2) Where originated the warm air masses that arrived in the Arctic?

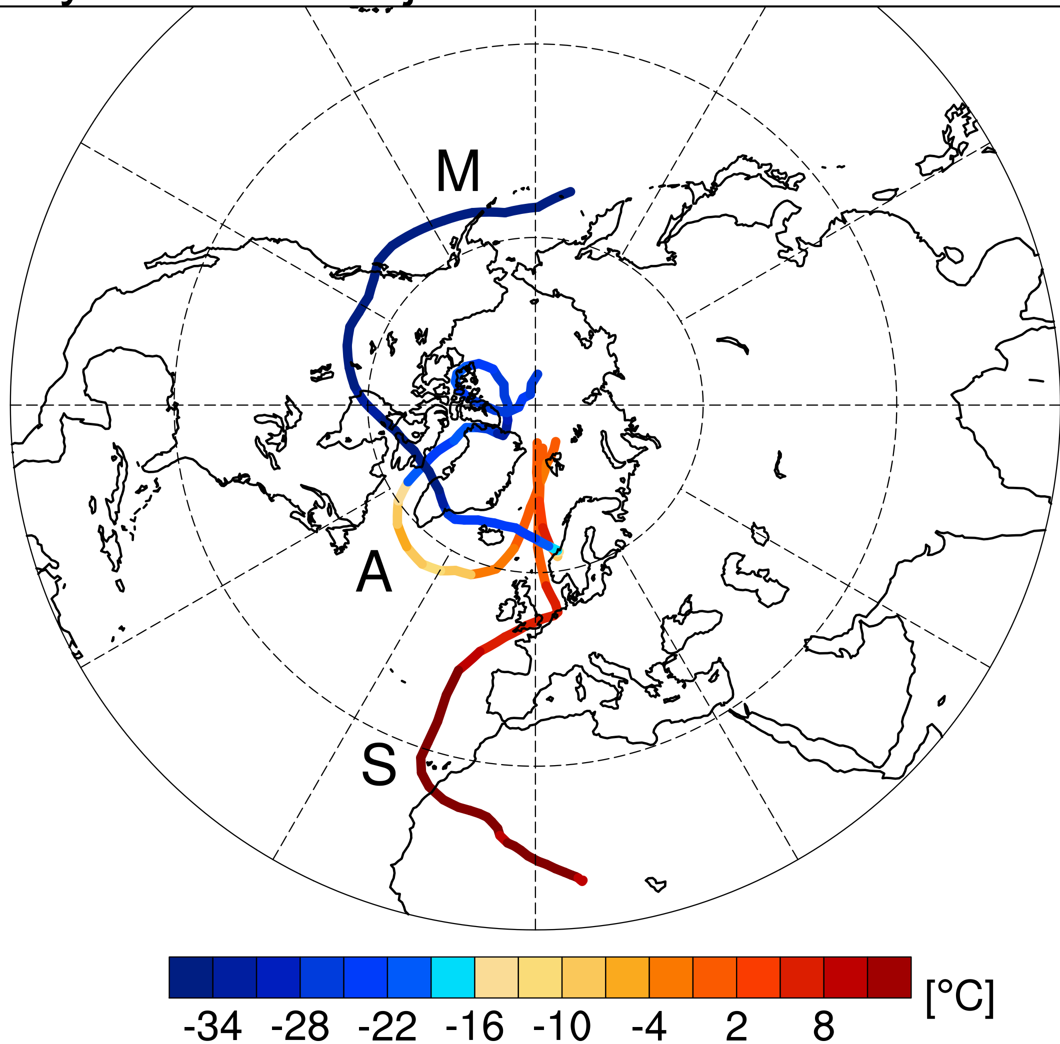
➢ Calculation of 10-day backward trajectories from all grid points ≥ 82°N with T2m > 0°C in ECMWF high-resolution op. analyses

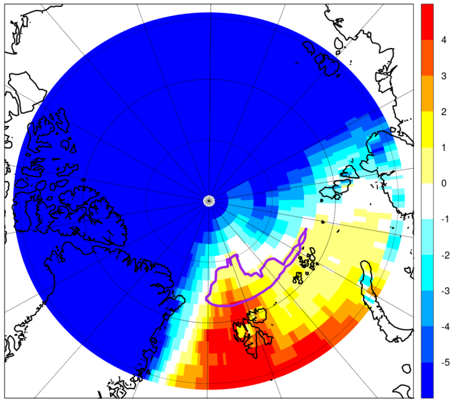




Part 2) Origin of the warm air masses

Temperature evolution along three representative 10-day backward trajectories from the warm event





3 source regions:

S) Subtropics
A) Arctic
M) Midlatitudes

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T & θ changes of air parcels before arriving in the Arctic

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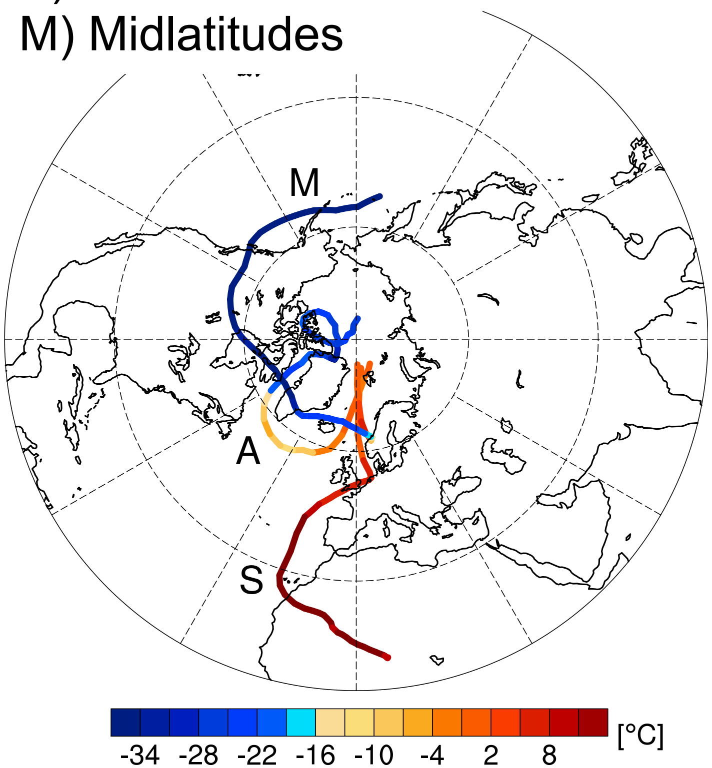

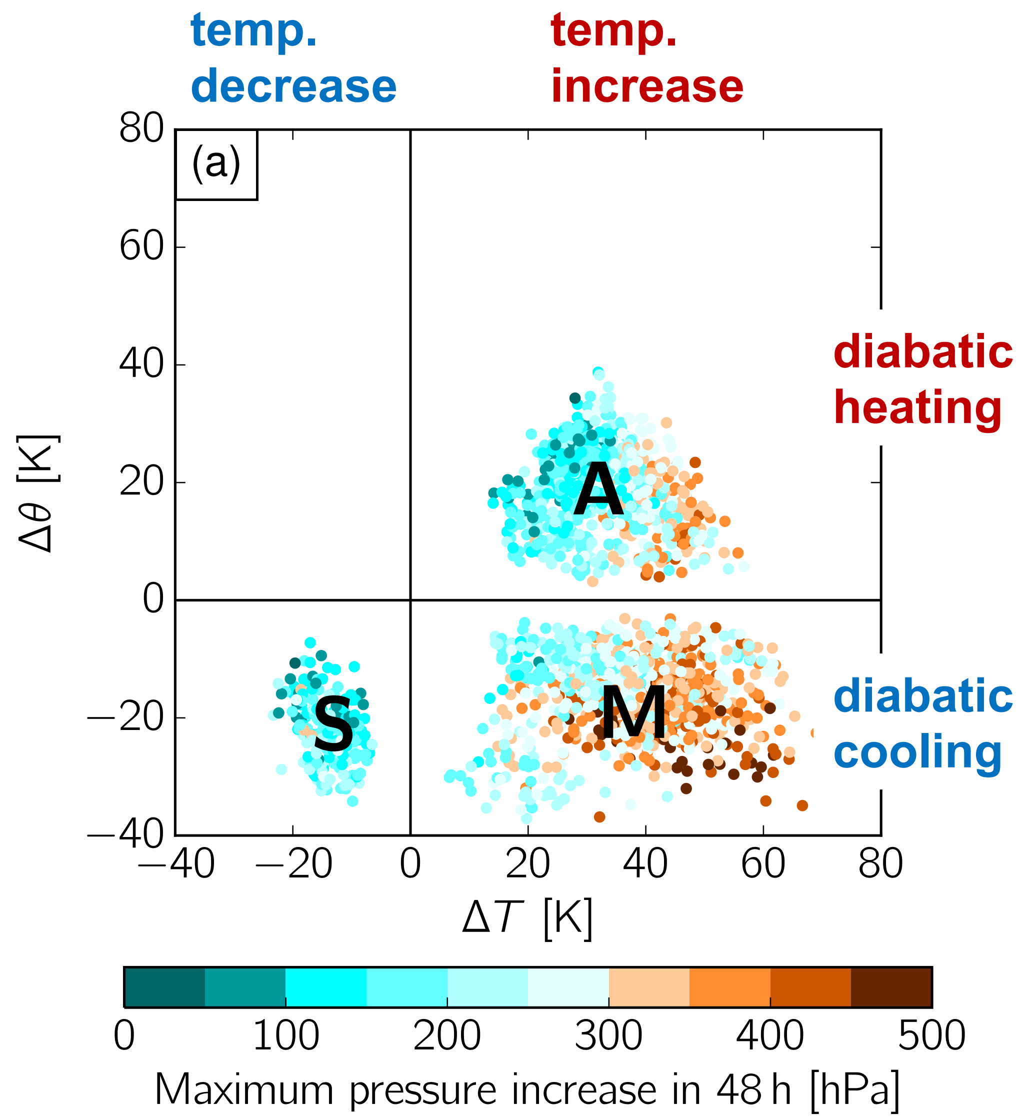

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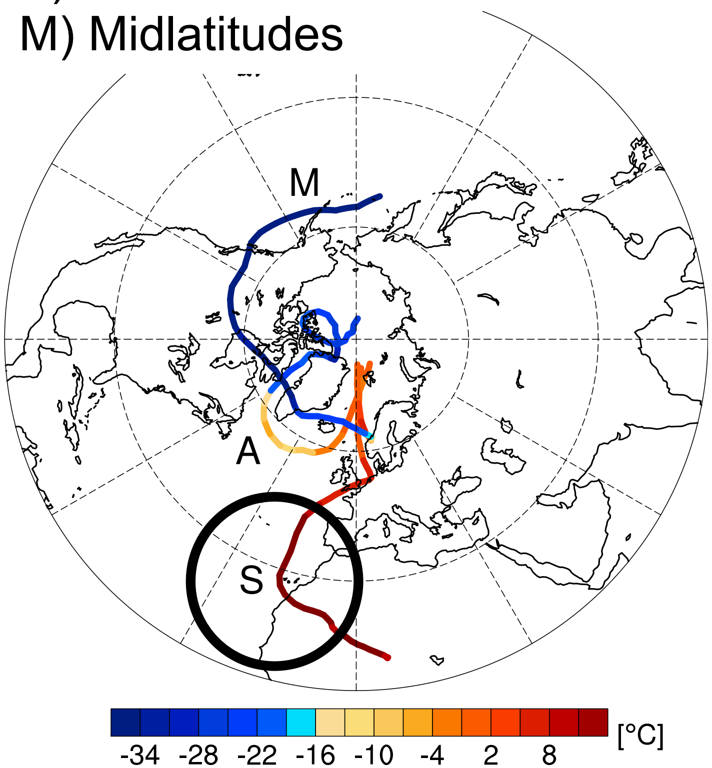
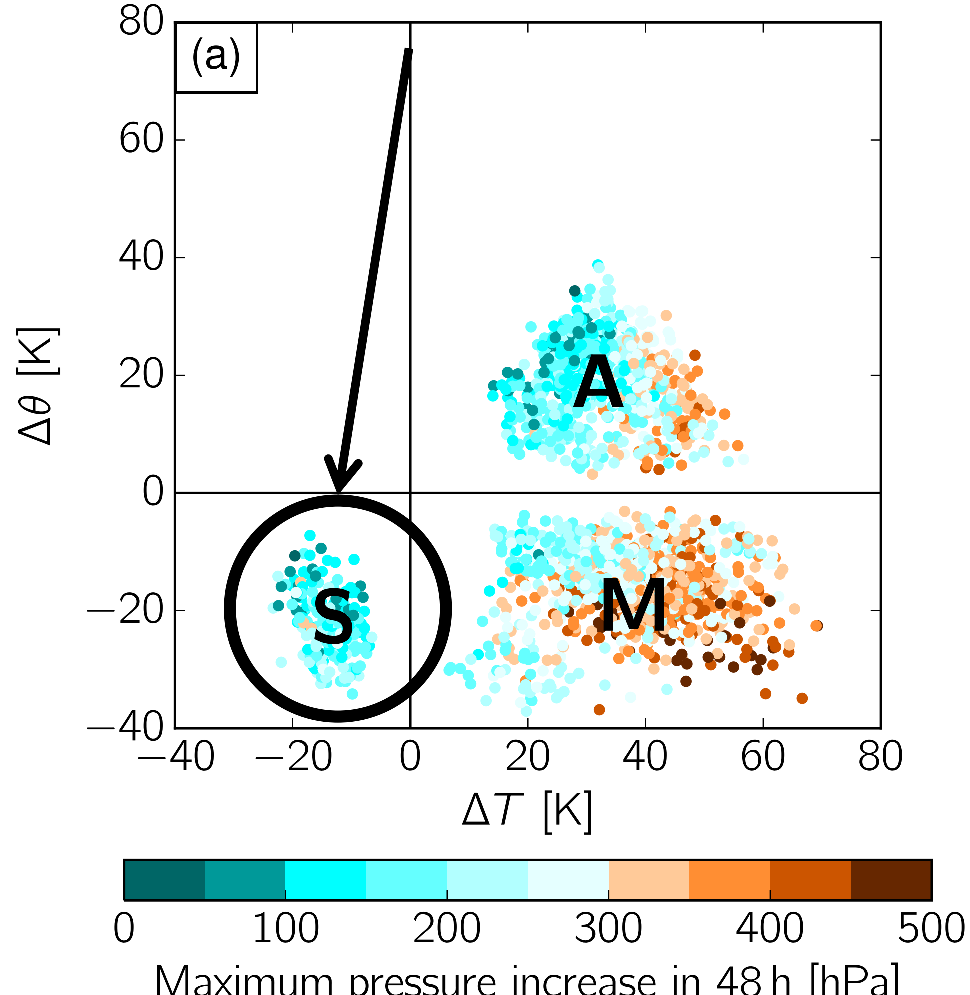


T decrease & diabatic cooling

by surface fluxes during **poleward transport of warm subtropical air**



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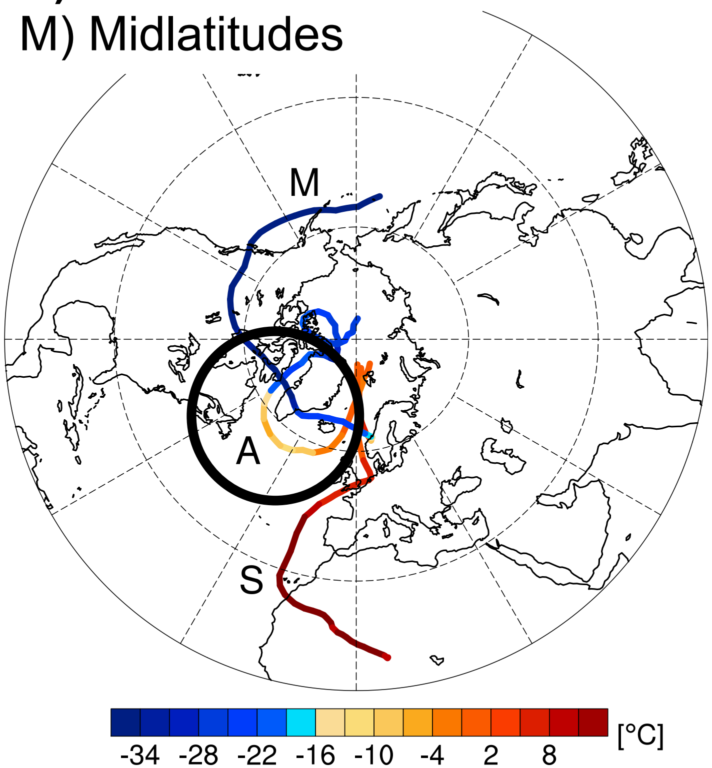
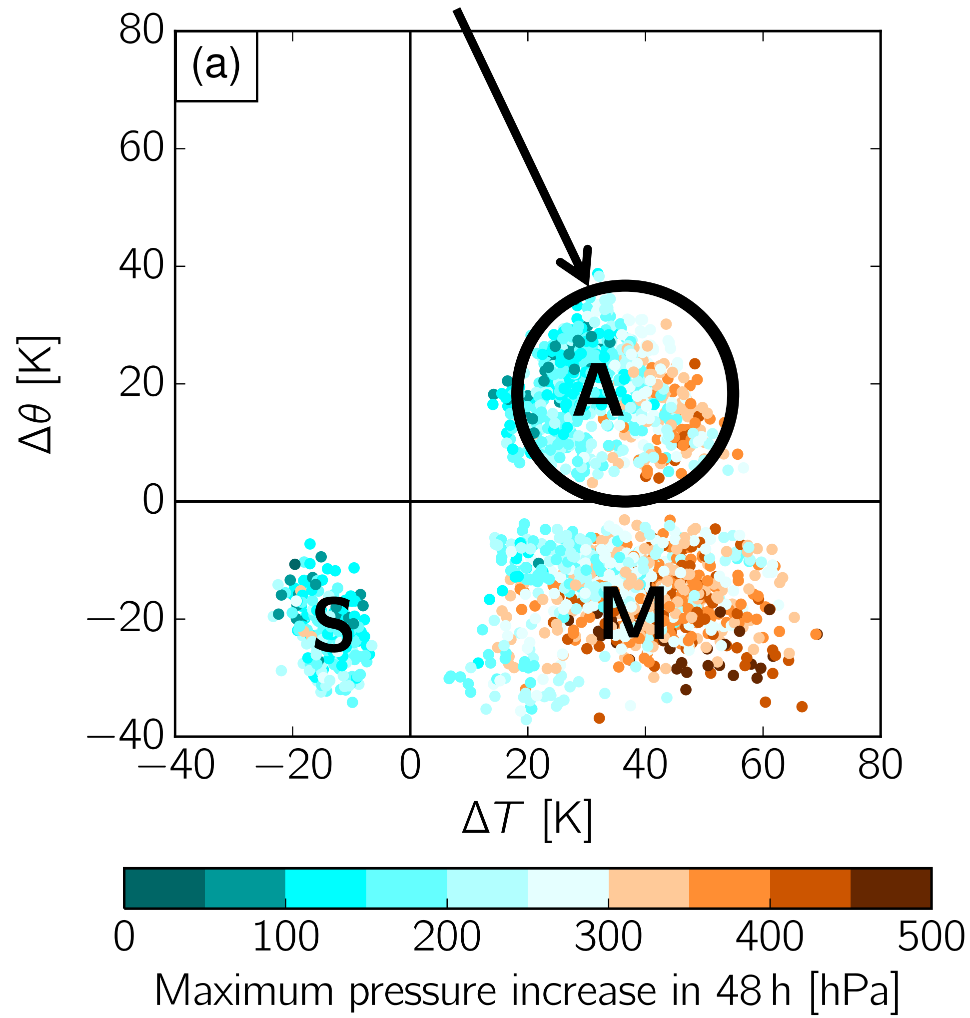


T increase & diabatic heating of cold Arctic air by **surface fluxes from the warm ocean**



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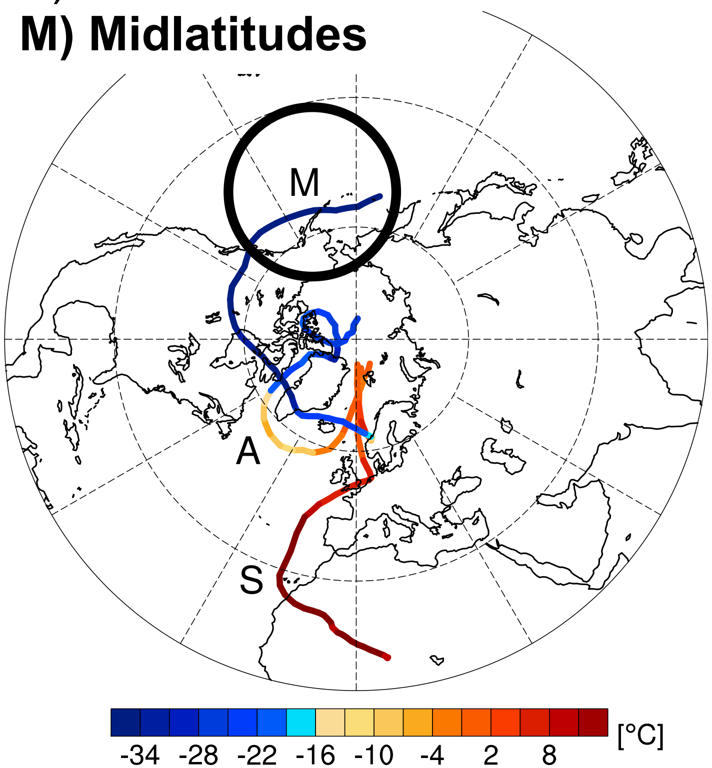
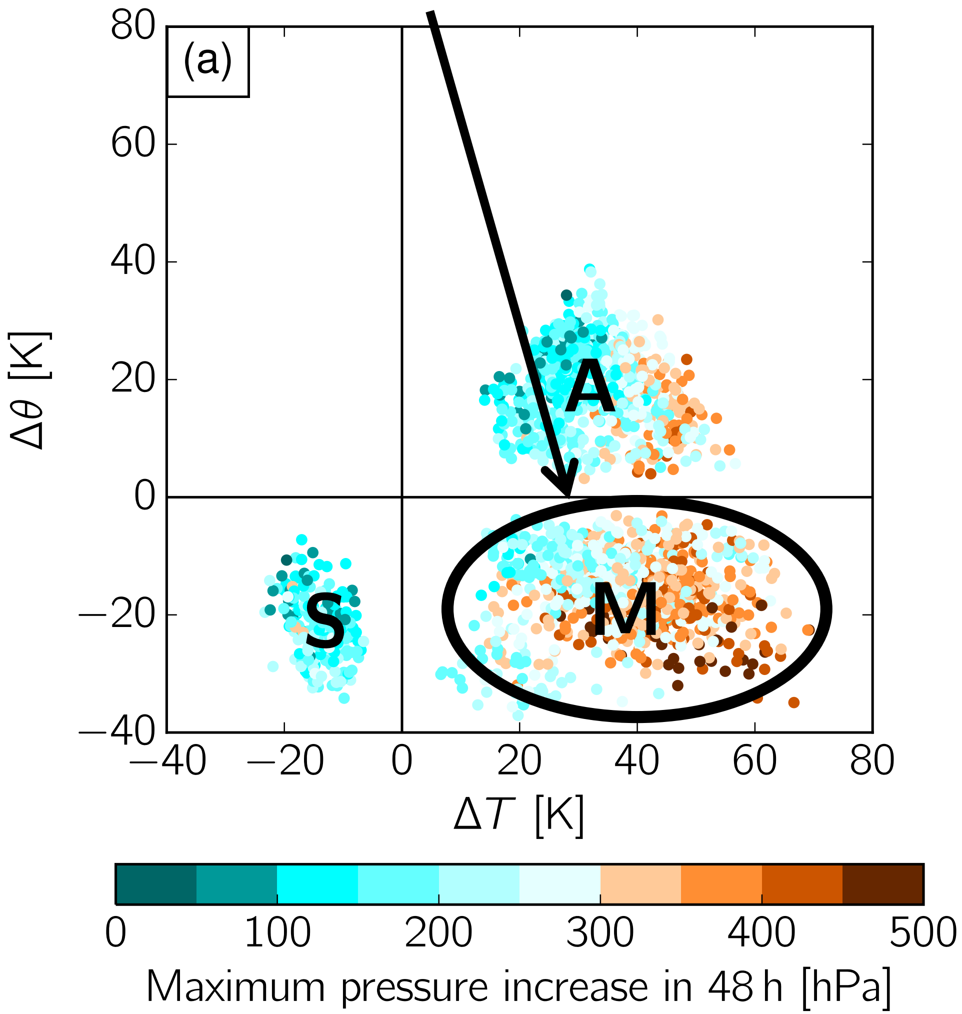


T increase & **diabatic cooling during descent** from upper troposphere



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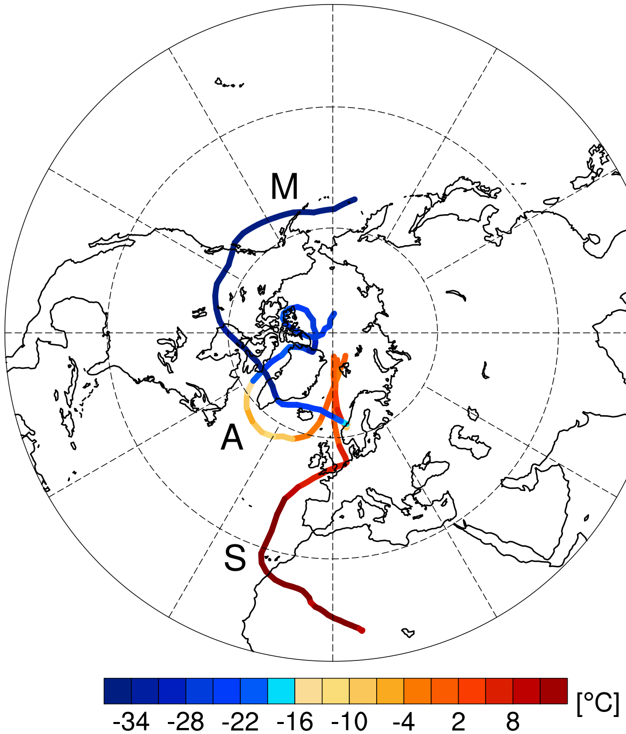
Summary part 2) Origin of the warm air masses

3 fundamentally different airstreams contributed to the record-high Arctic temperatures in late Dec 2015:

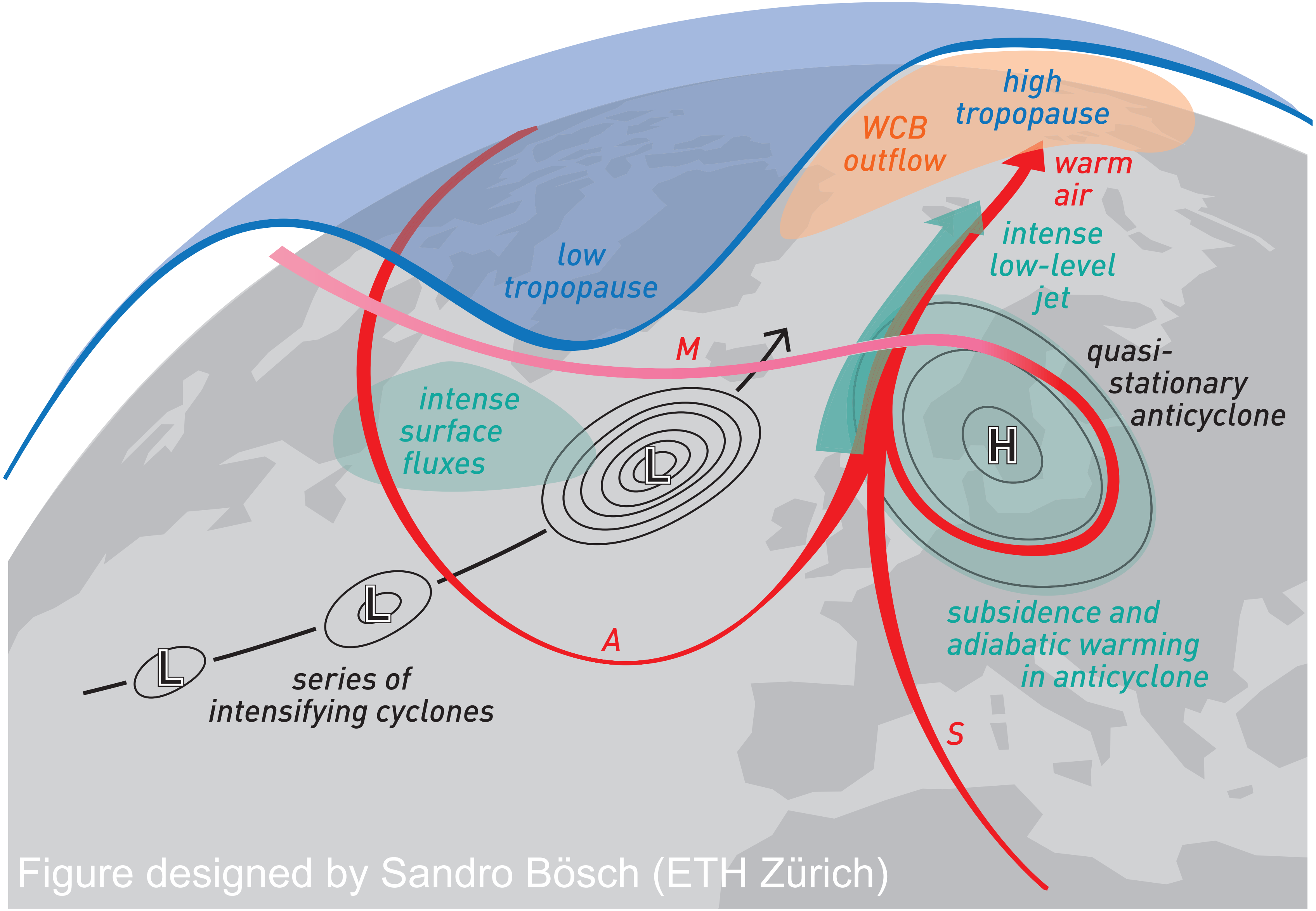
S) Warm low-level air of subtropical origin

A) Initially cold low-level air of polar origin heated over the warmer ocean

M) Initially cold upper-tropospheric air heated adiabatically during descent



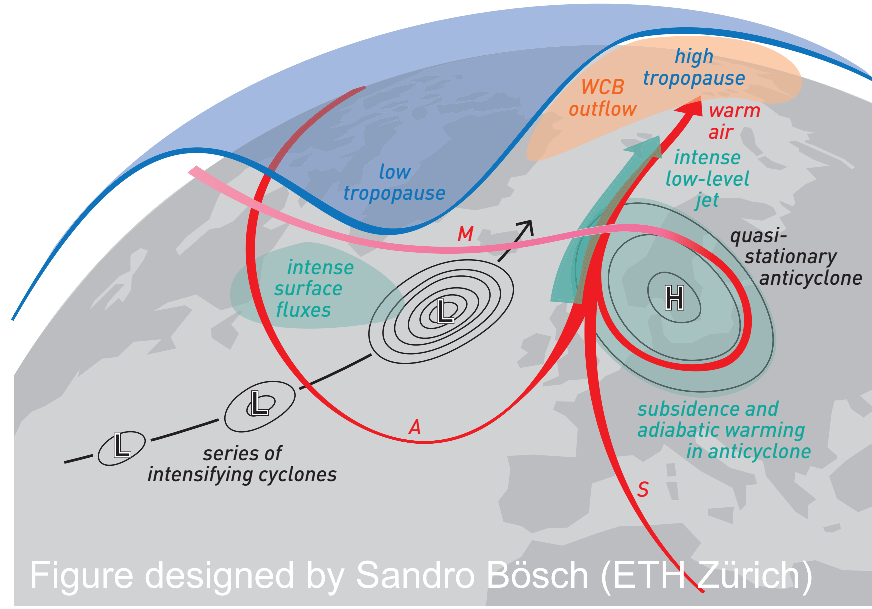
Processes that led to the extreme Arctic heat and melt event



Binder et al. 2017, *Geophysical Research Letters*

Summary and main findings

- The extreme Arctic heat and melt event in late Dec 2015 resulted from a complex chain of unusual processes.



Binder, H., Boettcher, M., Grams, C. M., Joos, H., Pfahl, S., & Wernli, H. (2017). Exceptional air mass transport and dynamical drivers of an extreme wintertime Arctic warm event. *Geophys. Res. Lett*.

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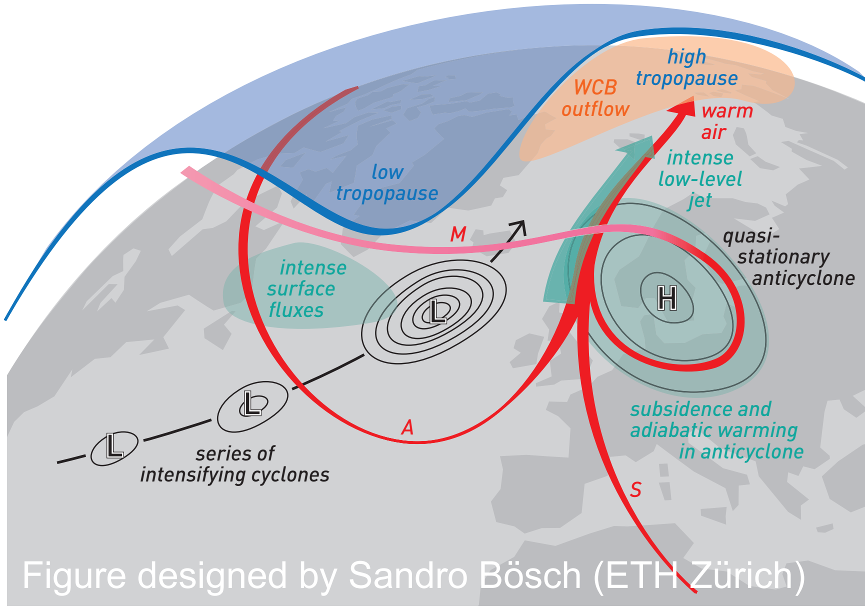
- The extreme Arctic heat and melt event in late Dec 2015 resulted from a complex chain of unusual processes.

- Strong WCB activity contributed to the setup of a complex 3-D configuration that allowed for the fast poleward transport of warm air.



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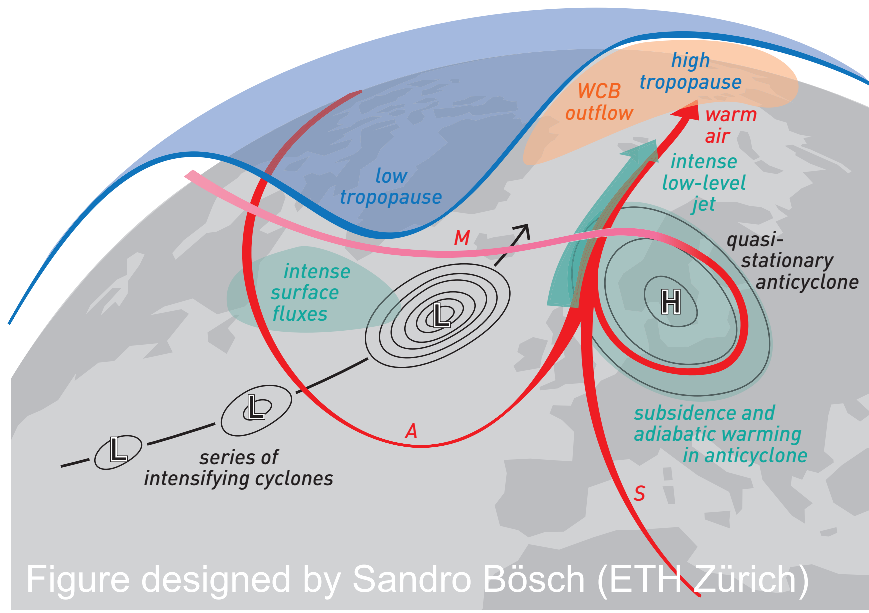

- 3 fundamentally different airstreams were responsible for the high Arctic temperatures:

  S) Warm low-level air of subtropical origin
  A) Initially cold low-level air of polar origin heated over the warmer ocean
  M) Initially cold upper-tropospheric air heated adiabatically during descent

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