Atlantic weather regimes and poleward heat transport by transient eddies

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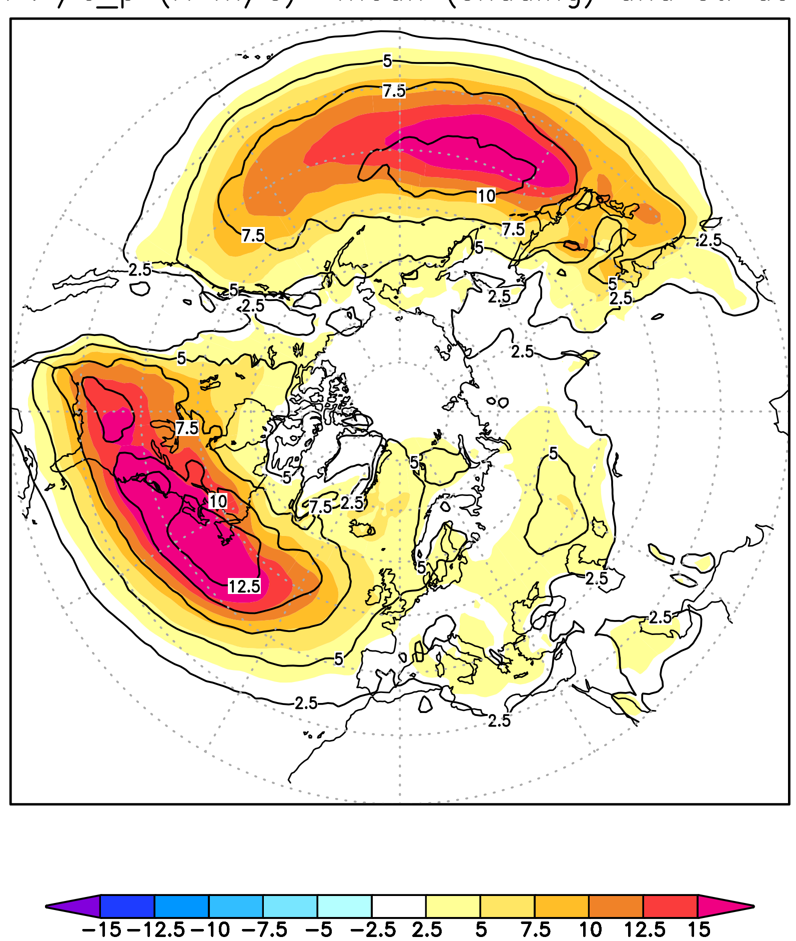
Overview

We investigate links between transient, poleward atmospheric heat transport and the atmospheric circulation in the North Atlantic sector.

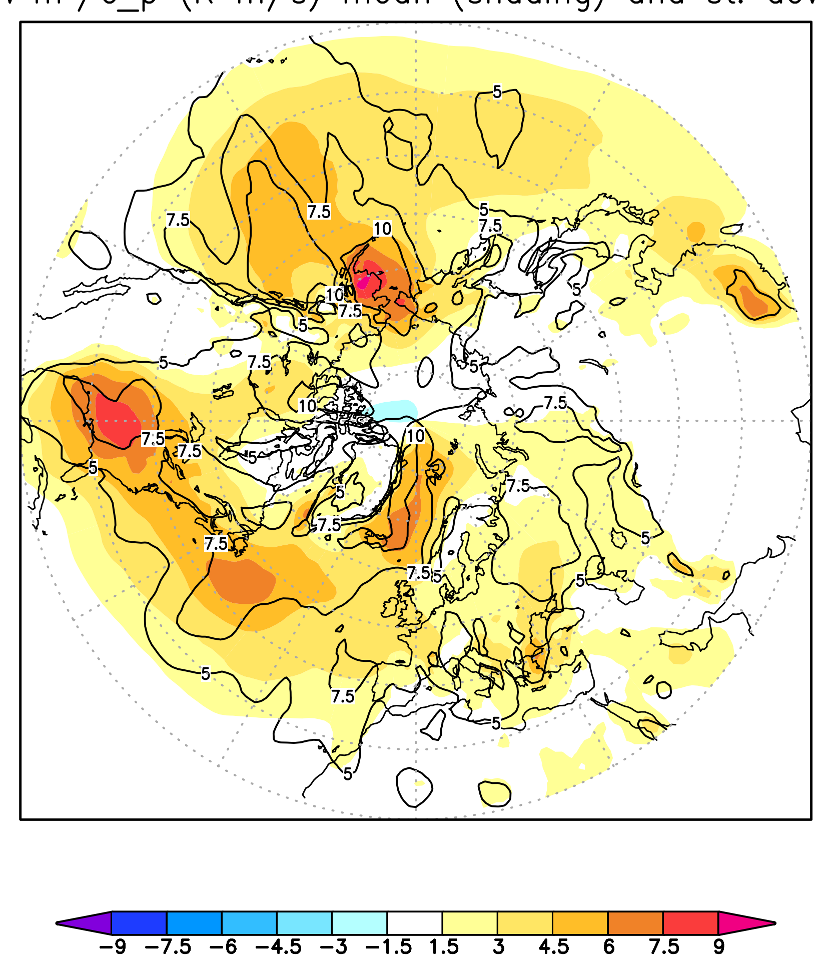
We look at the Northern Hemisphere but special emphasis is given to heat transport crossing the 70 °N wall.

Results are base on an atmospheric reanalysis, extended cold season.

m`V`/c_p (K m/s) mean (shading) and st. dev.



V`m`/c_p (K m/s) mean (shading) and st. dev.



Introduction

1) Heat transport performed by eddies is fundamental, transient eddies are a key (if not the dominant) component of AHT in the polar cap and its surroundings (Overland et al. 1990, Miletta et al. 2000).

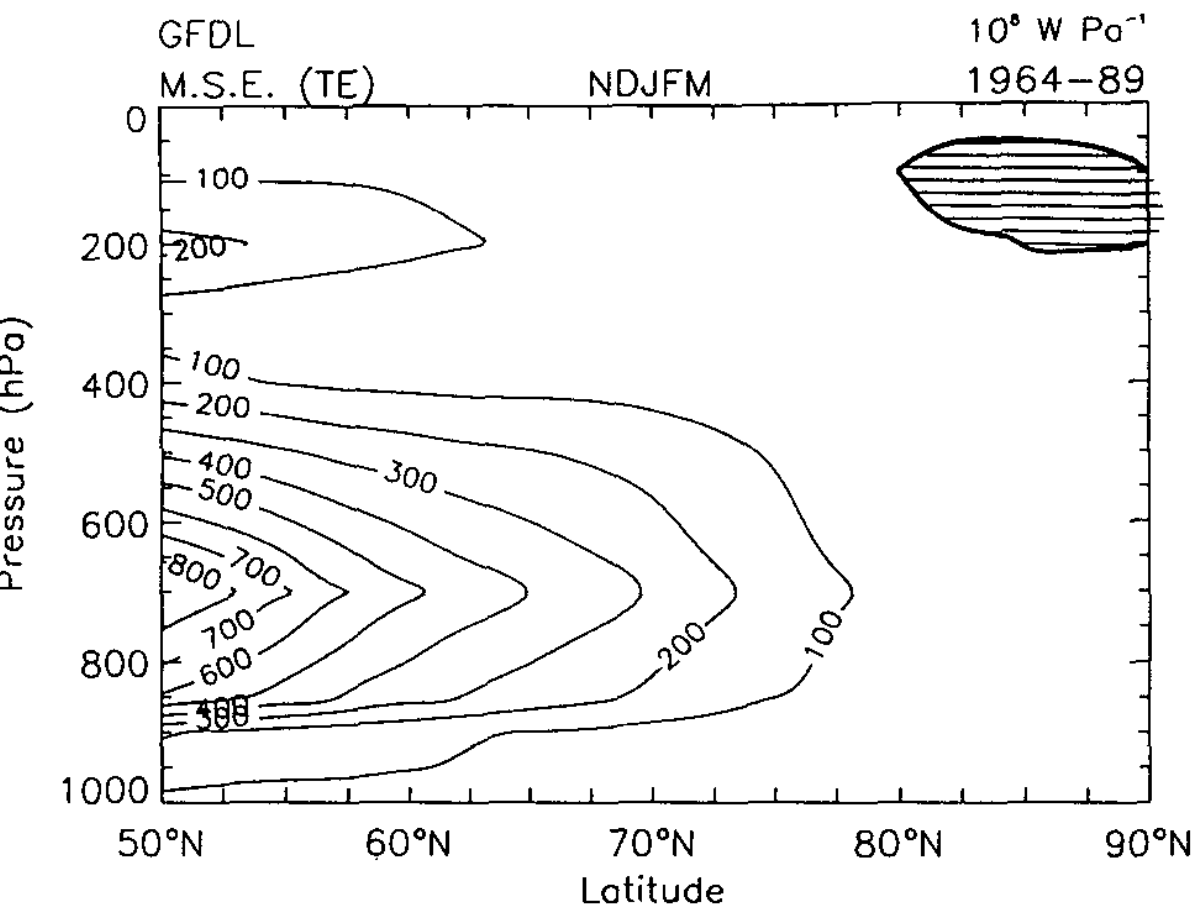


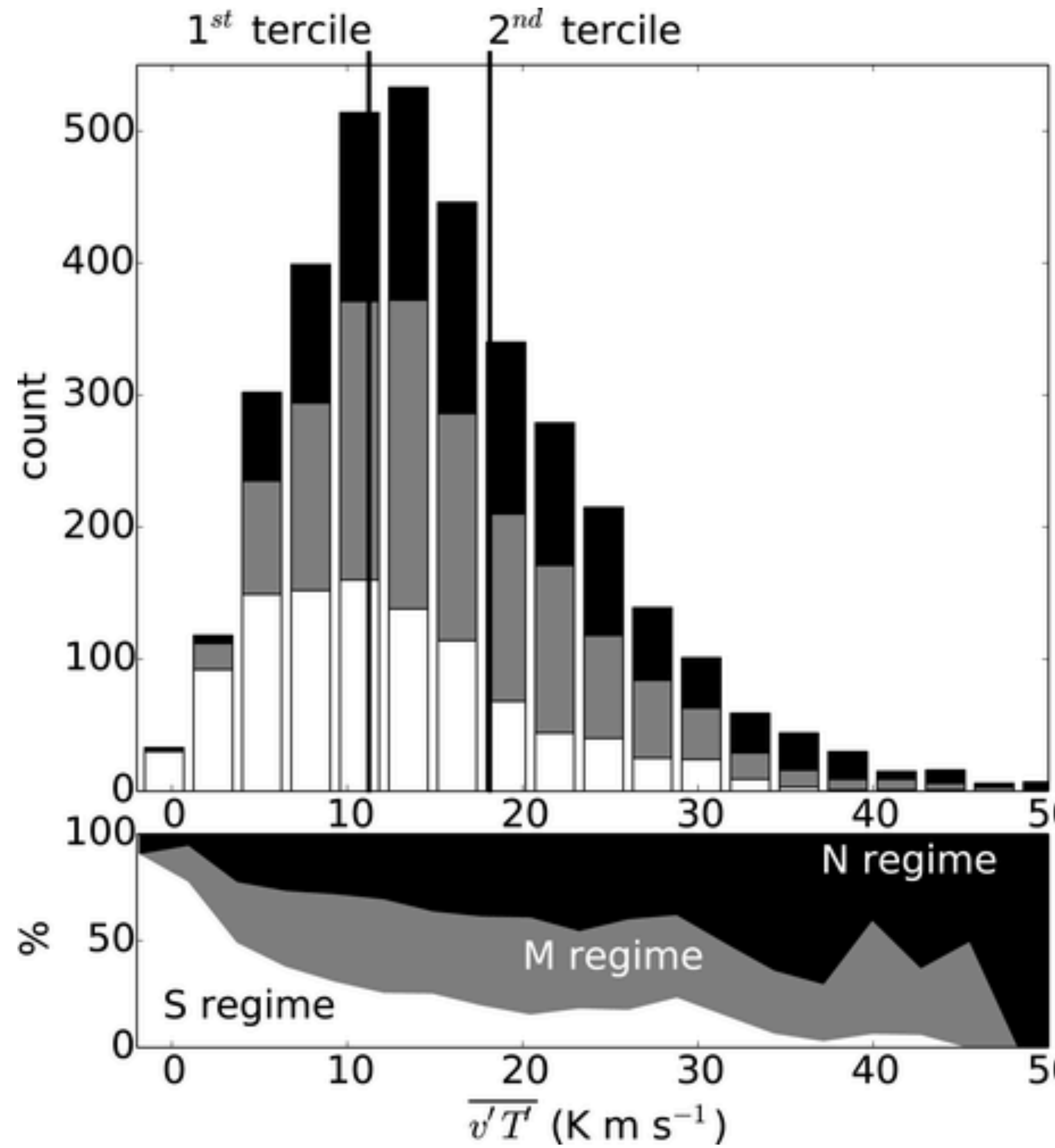
FIG. 5. Pressure–latitude cross section of the zonal-average poleward flux of MSE by transient eddies.

	Annual	DJF	NDJFM	JJA
F_{wall}	103	121	121	85
TE	56	58	58	53
SE	22	35	33	11
MMC	25	27	31	20
SH	44	68	63	21
TE	45	52	51	35
SE	19	33	31	8
MMC	−21	−17	−18	−22
GP	48	44	49	47
TE	−1	−1	−1	0
SE	0	0	0	0
MMC	48	45	50	48
LH	11	8	9	17
TE	12	7	8	18
SE	2	2	2	3
MMC	−3	−1	−1	−5

Overland et al . 1996

Introduction

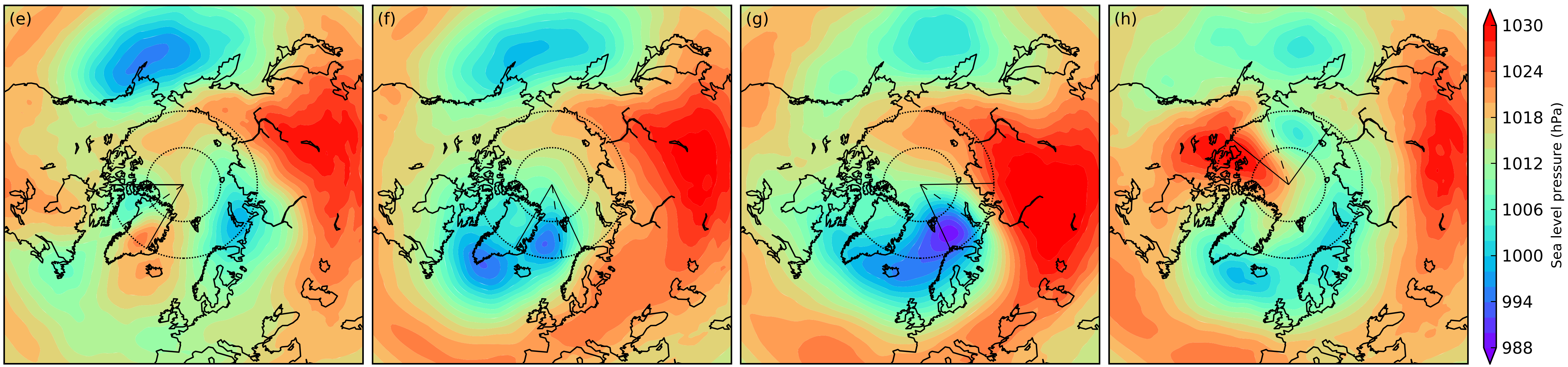
2) Storminess changes accordingly with the low-frequency, large-scale flow of the atmosphere. The variability of the storm track is largely ascribable to the alternating phases of the NAO/AO, but no clear evidence is found of any modulation (by the NAO) of high latitude transient eddy heat transport. (Miletta et al. 2000)



Novak et al . 2015

Introduction

3) There is emerging and growing evidence of impulsive and regional injections of heat and moisture into the Arctic. These phenomenon is deemed to be linked with the large scale circulation of the atmosphere and with poleward propagation of storms. (Messori and Czaja 2013, Woods et al. 2013)



Woods et al . 2013

Introduction

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Methodology

Data

Data used are obtained from ERA-Interim

6-hourly on a 1°x1° regular longitude-latitude grid

10 selected pressure levels (between 100 and 925 hPa)

Period: 1980-2017, extended cold season (NDJFM)

Methodology

Moist static energy:

$$m = c_p T + L_v Q + \Phi$$

c_p is specific heat of dry air, Lv latent heat of vaporisation

Transient eddy heat flux is defined as the product **V`m`**

Prime denotes a bandpass filter

Synoptic 2-9 days

Intra-seasonal 10-90 days

A 2d blocking index is based on Tibaldi and Molteni (1990)

A jet latitude index is computed following Woollings et al. (2010)

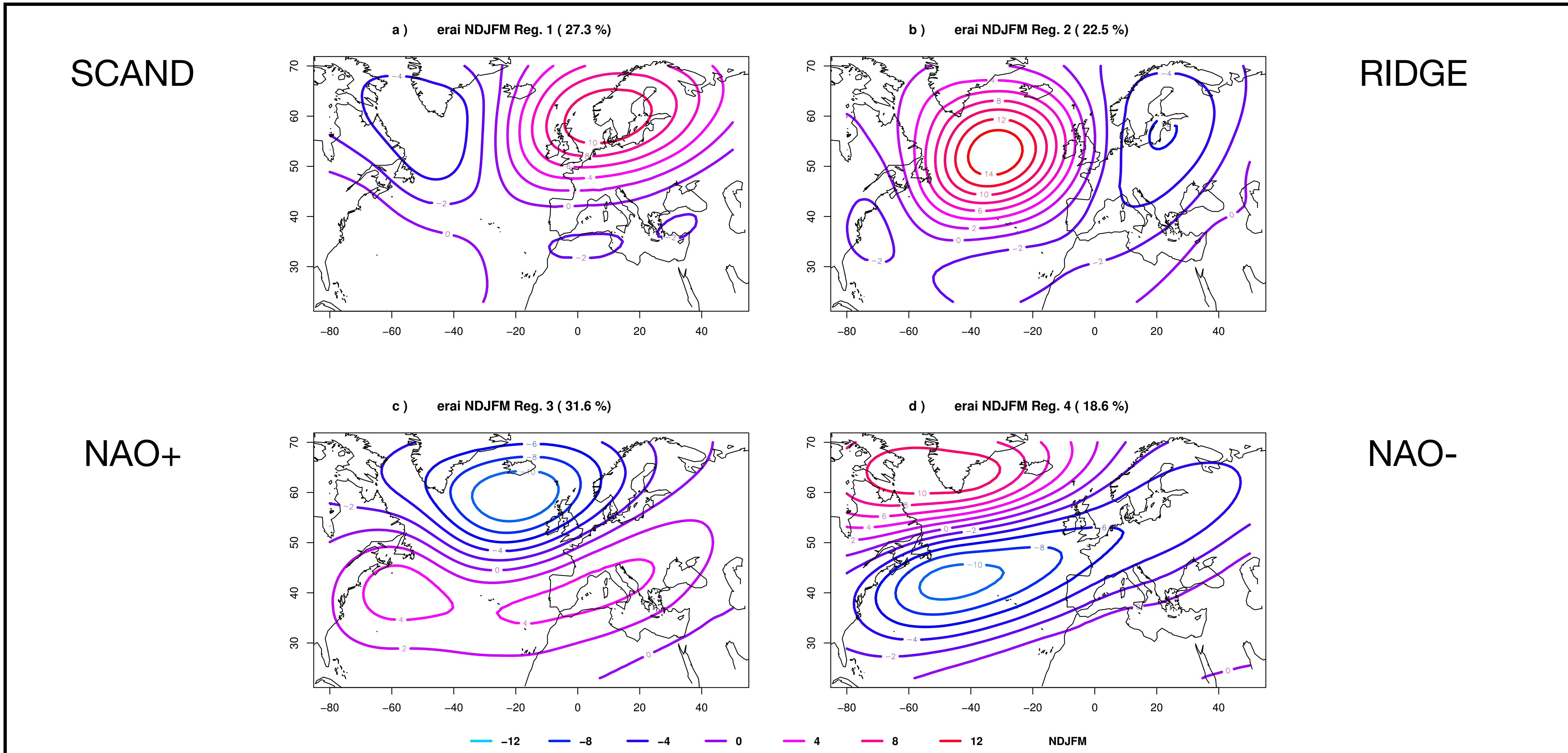
Methodology: Weather regimes

Weather regimes have been computed following the methods of Michelangeli et al. (1995) and Yiou et al. (2008).

The first ten Empirical Orthogonal Functions (EOFs) of Z at 500 hPa. A k-means algorithm is applied,

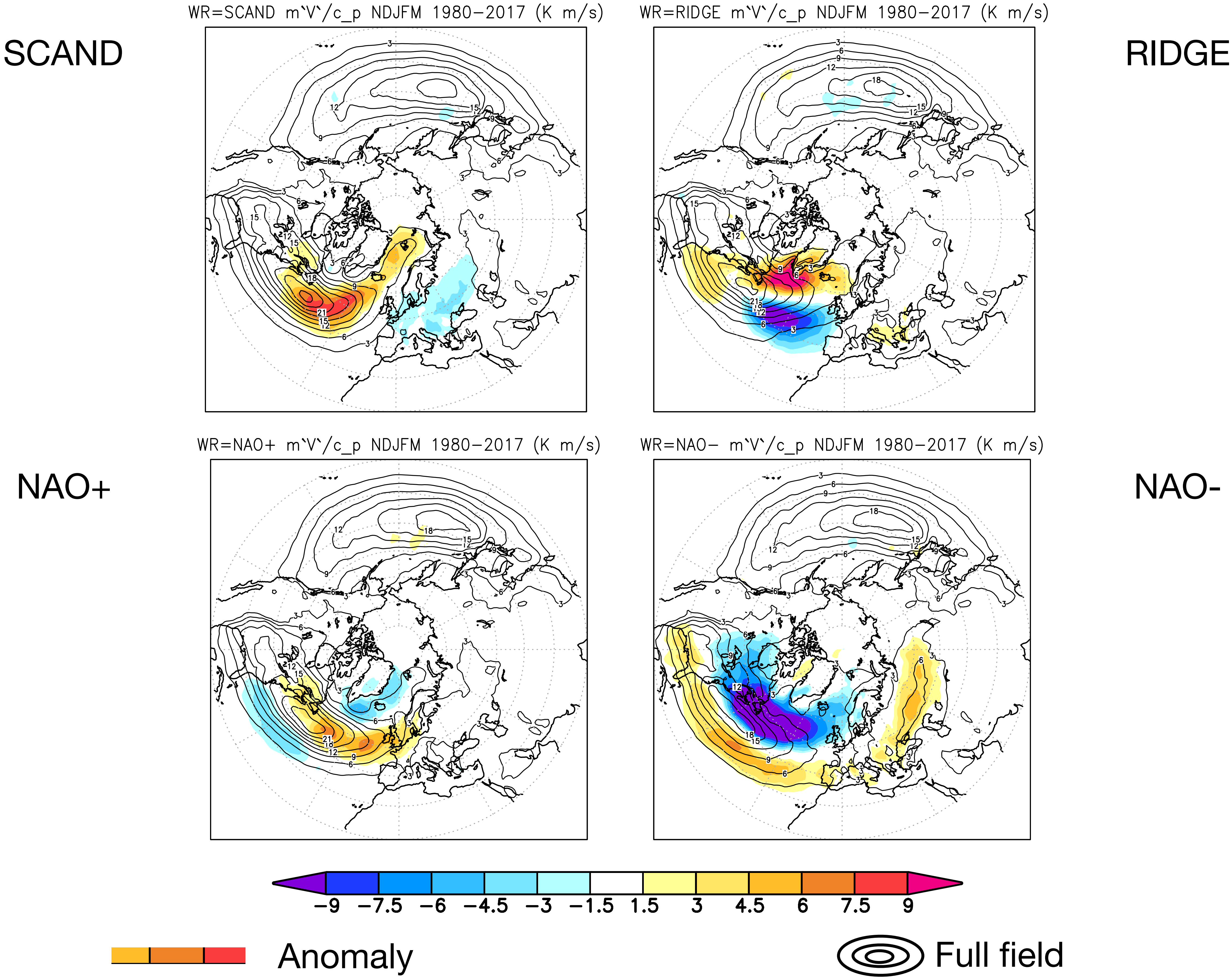
4 weather regimes, over the North Atlantic region [80°W - 50°E; 20 - 70°N] on daily data over the period 1980-2017, in NDJFM.

Daily data classifications are obtained by the minimum of the Euclidean distances to the centroids

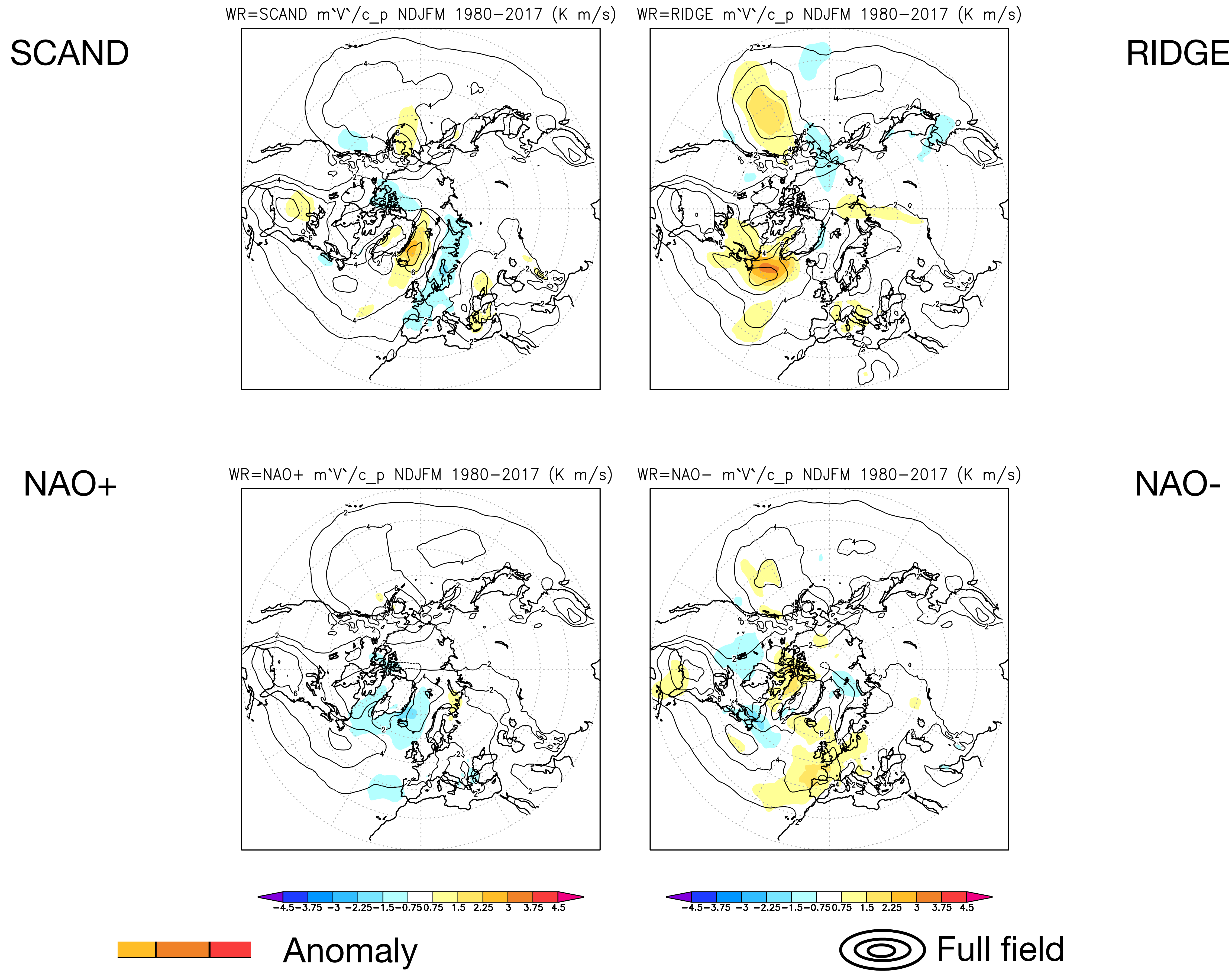


Results
Weather regimes

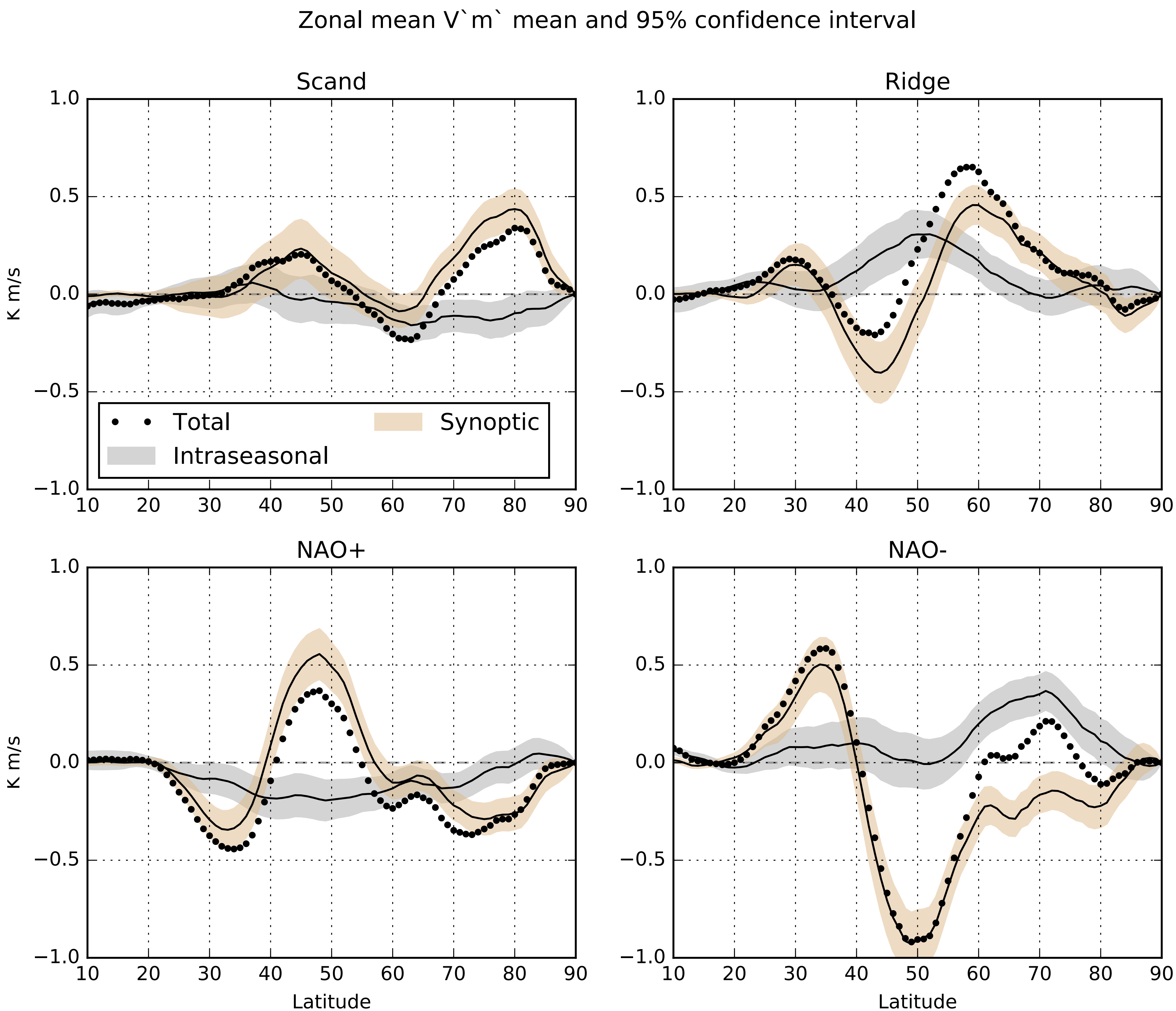
Synoptic eddies heat transport



Intra-seasonal eddies heat transport

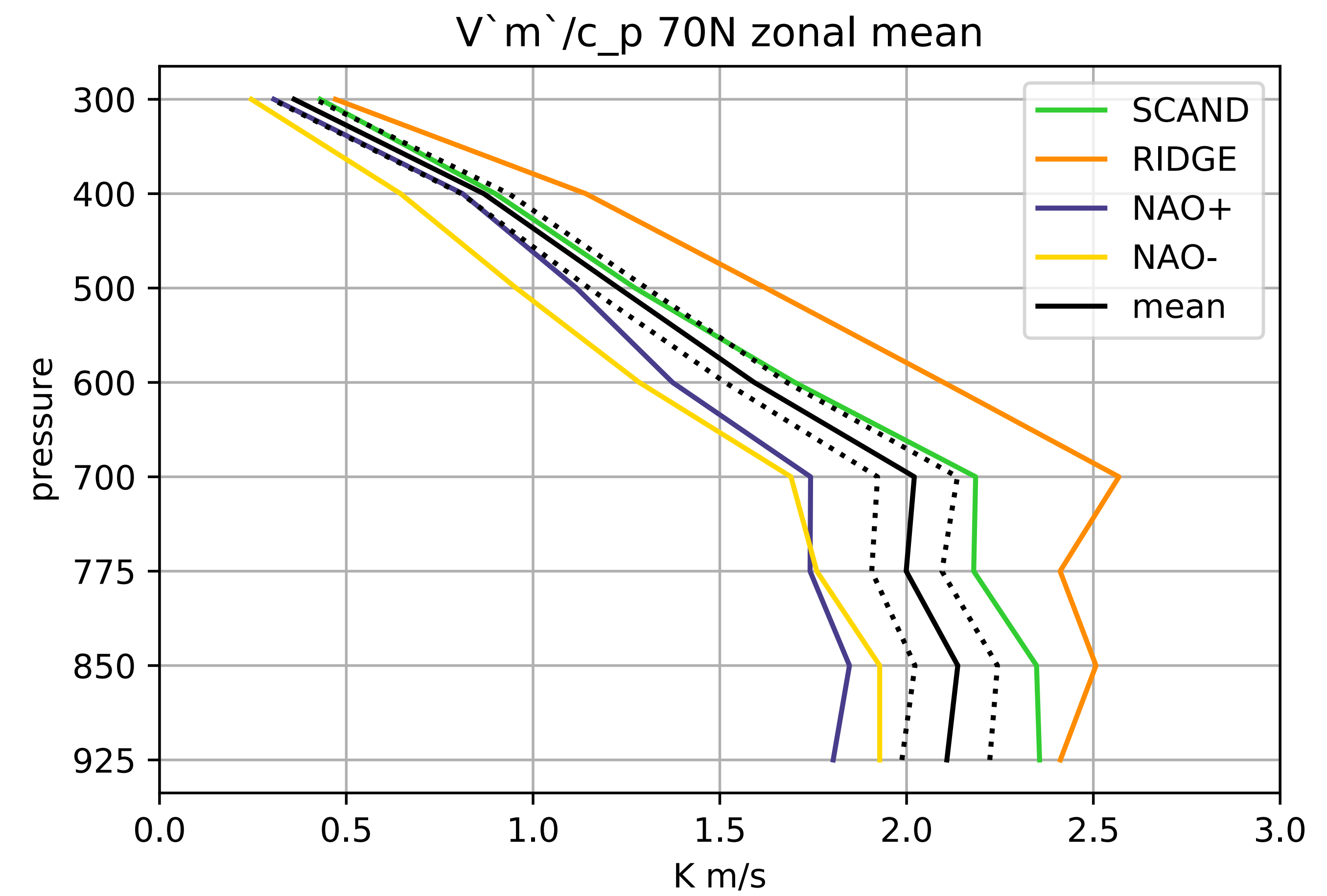


Zonal mean heat transport

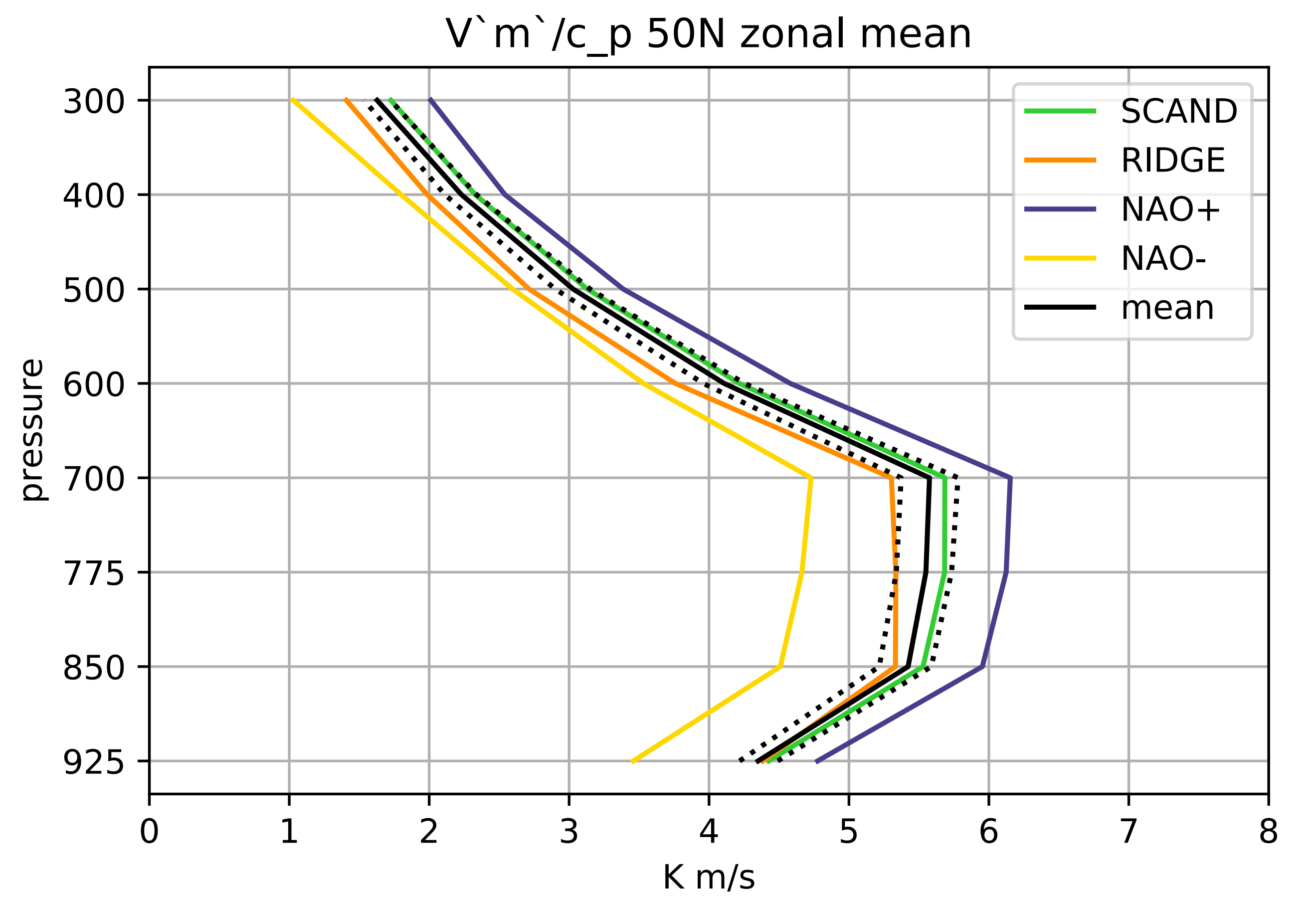


Vertical profile at 70 °N

70 °N Zonal mean
Both phases of NAO correspond to weak transport
Scand and Ridge to intensified transport



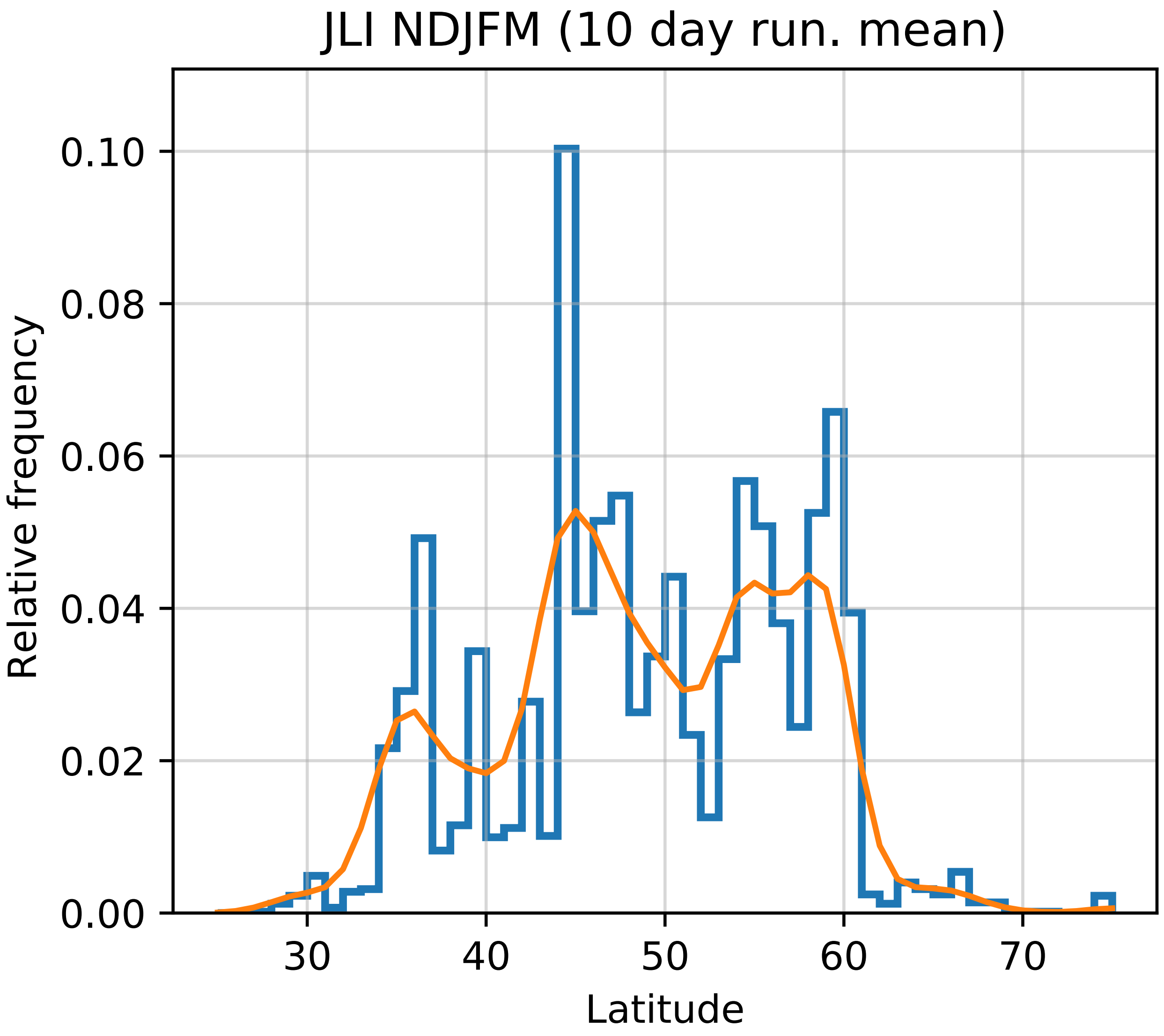
50 °N Zonal mean
Strong Modulation by the NAO with opposite sign in the subtropics.

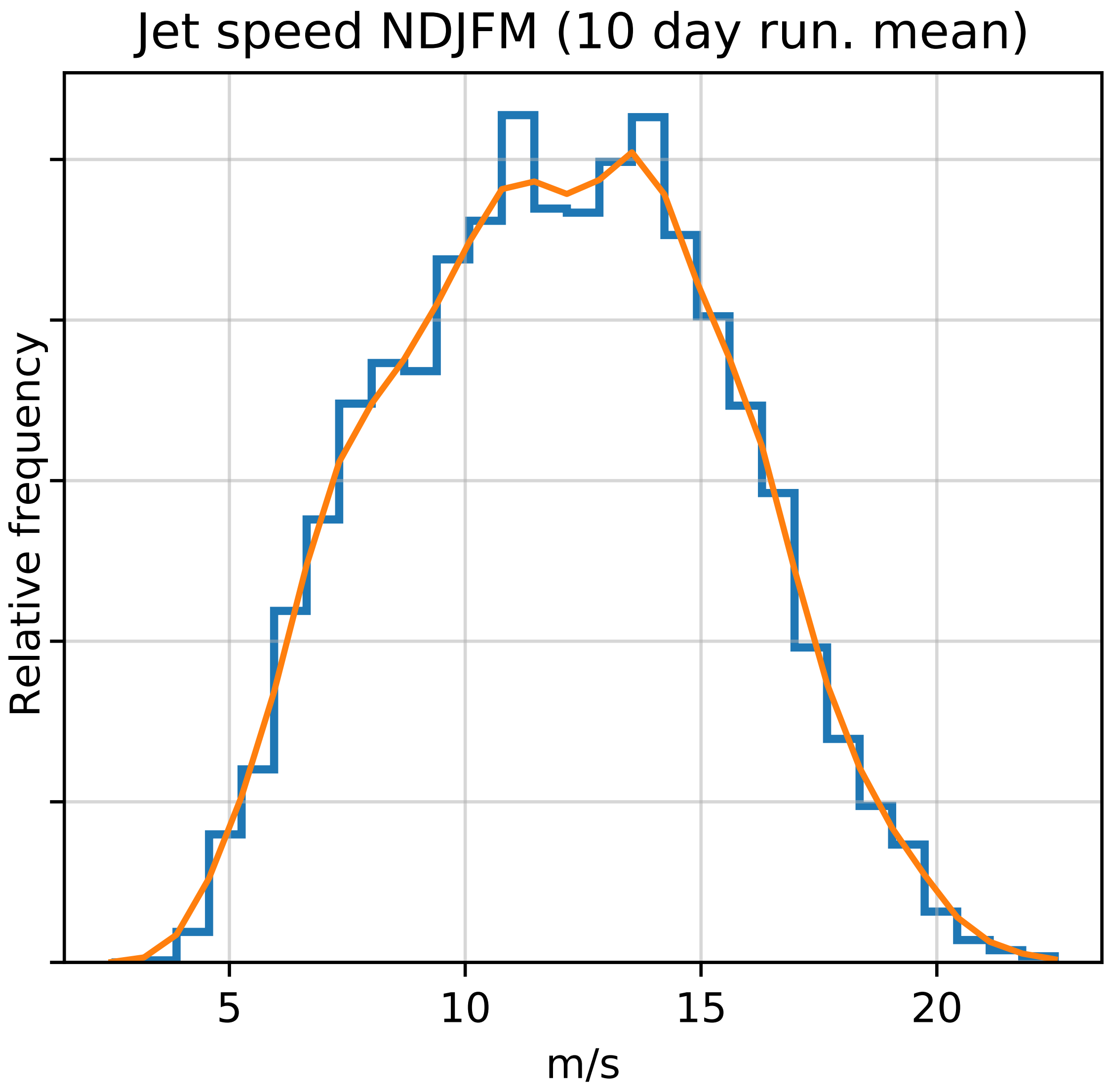


Results
Jet Latitude Index

Heat transport and Jet speed

Jet speed measured in the sector 60W-0 15-75N at 850 hPa





Heat transport and Jet speed

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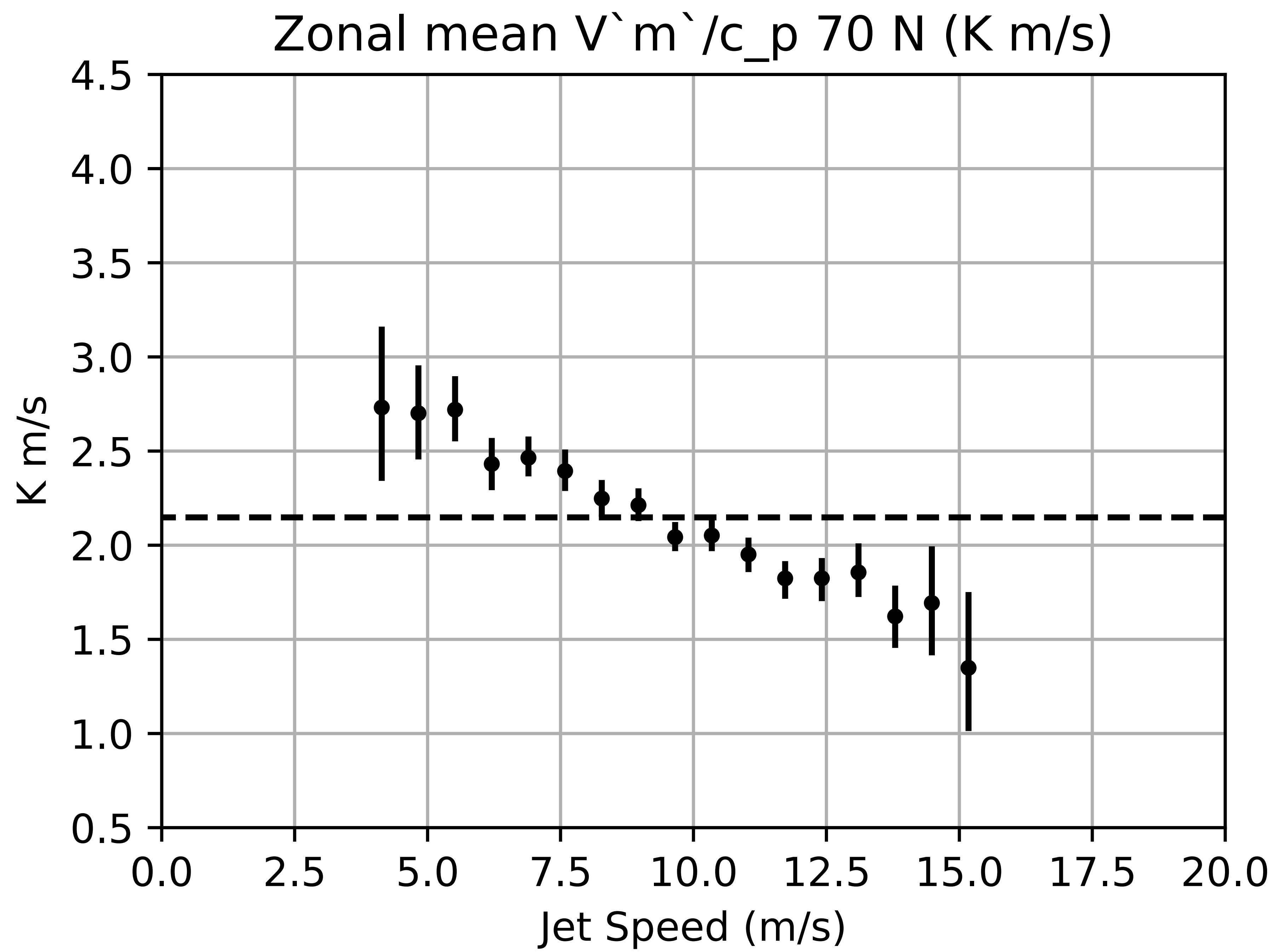
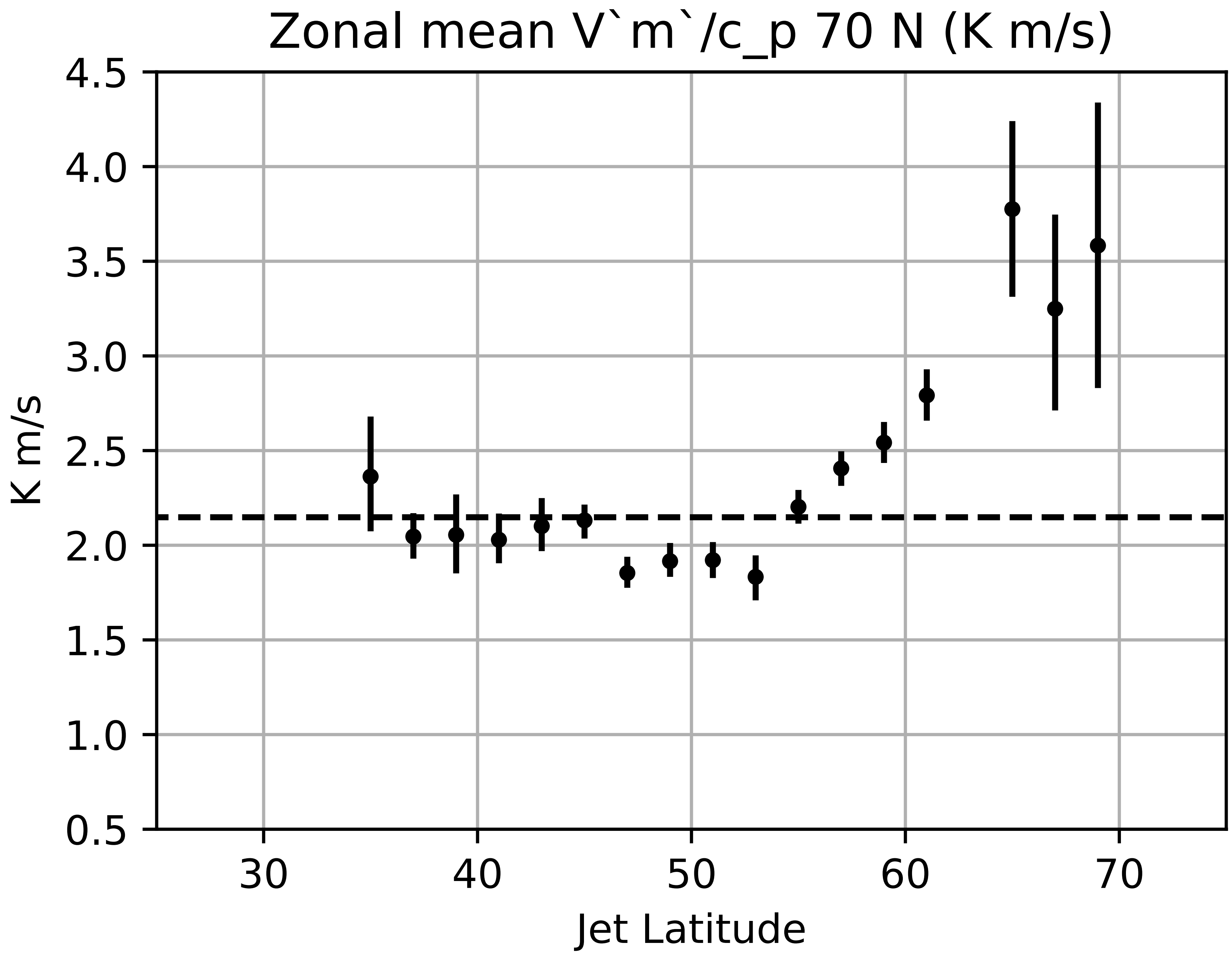


Heat transport decreases linearly with jet speed

Heat transport and Jet latitude

Jet latitude measured in the sector 60W-0 15-75N at 850 hPa
Trimodal distribution

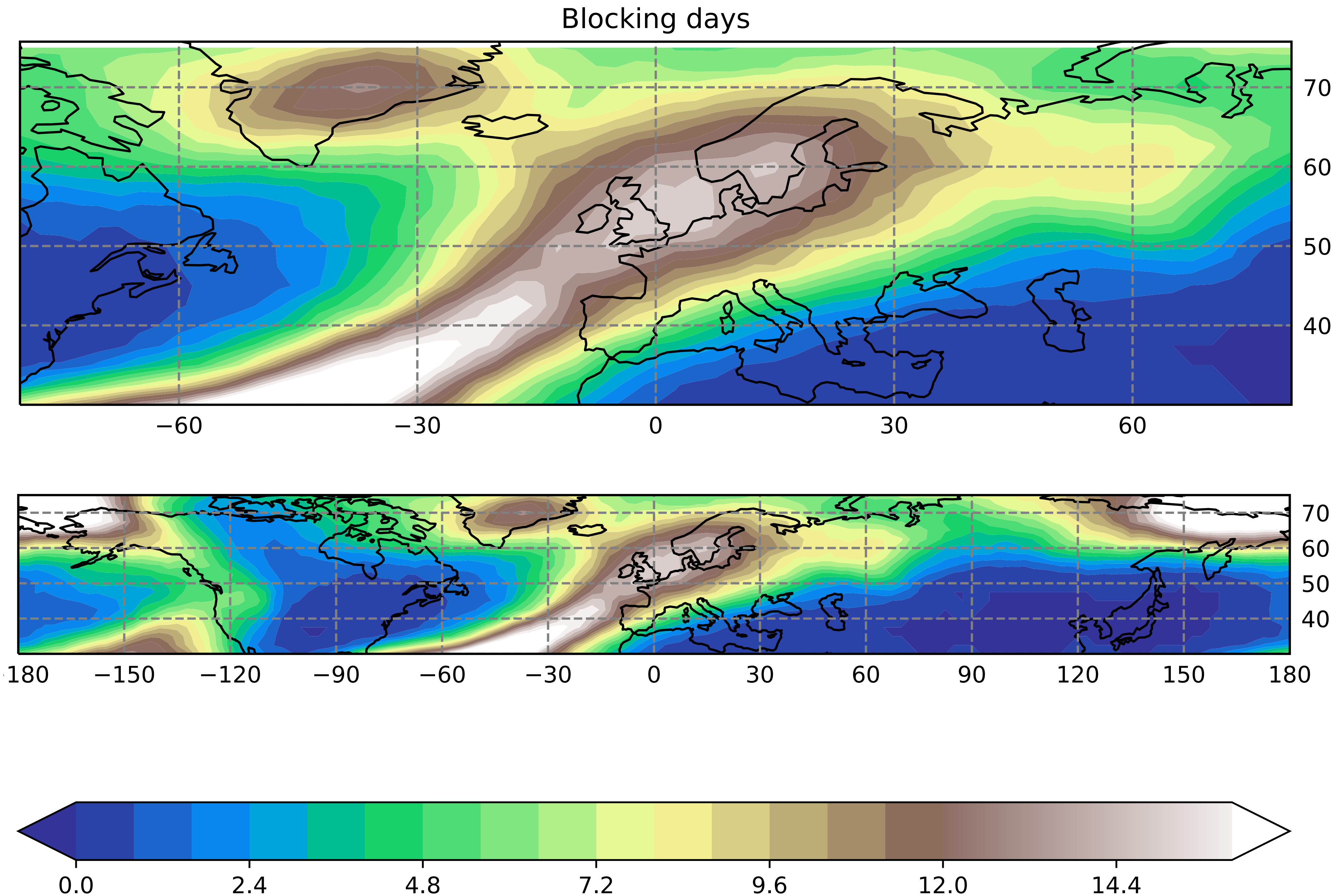


"Threshold" behaviour, strong HT with Northern regime

Results
Blocking Index

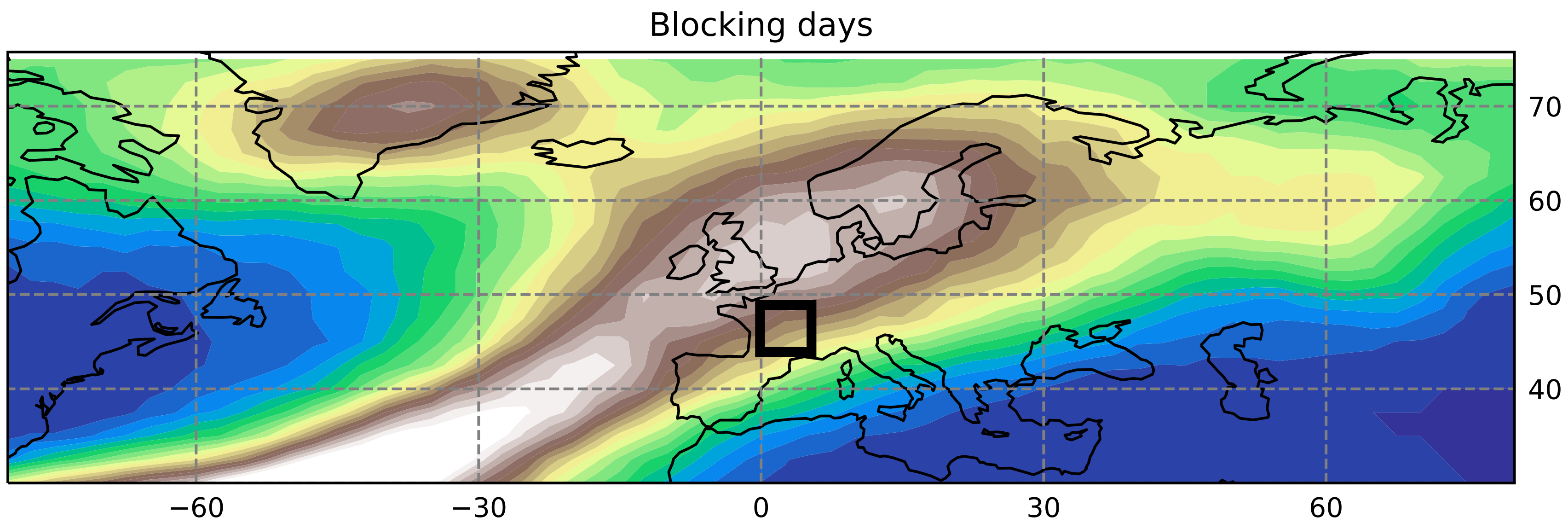
Blocking

Count of blocking days based on reversal of geopotential gradient

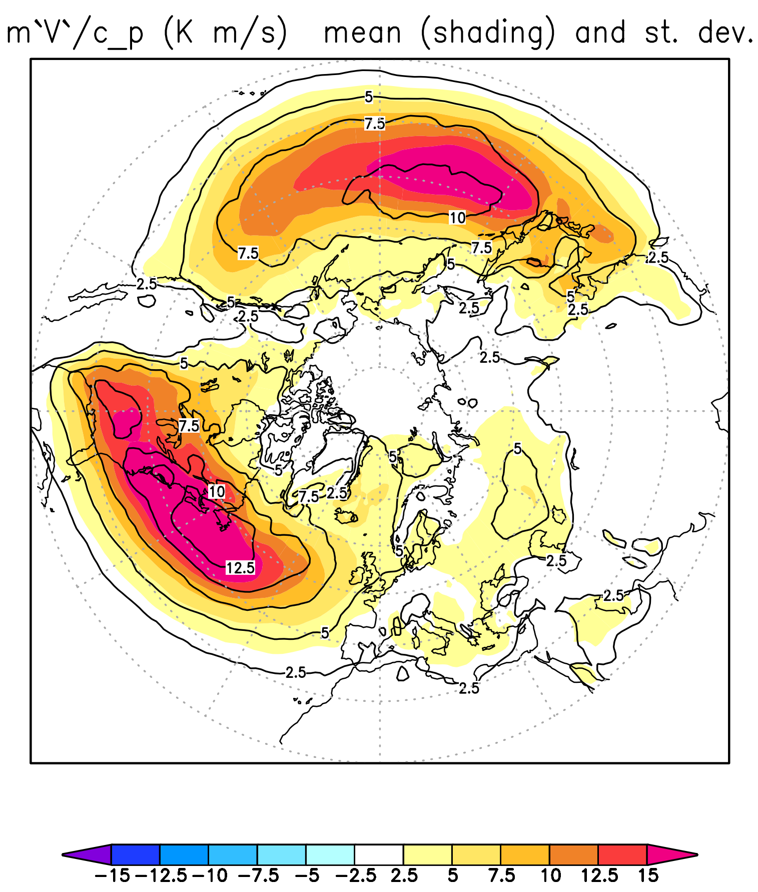


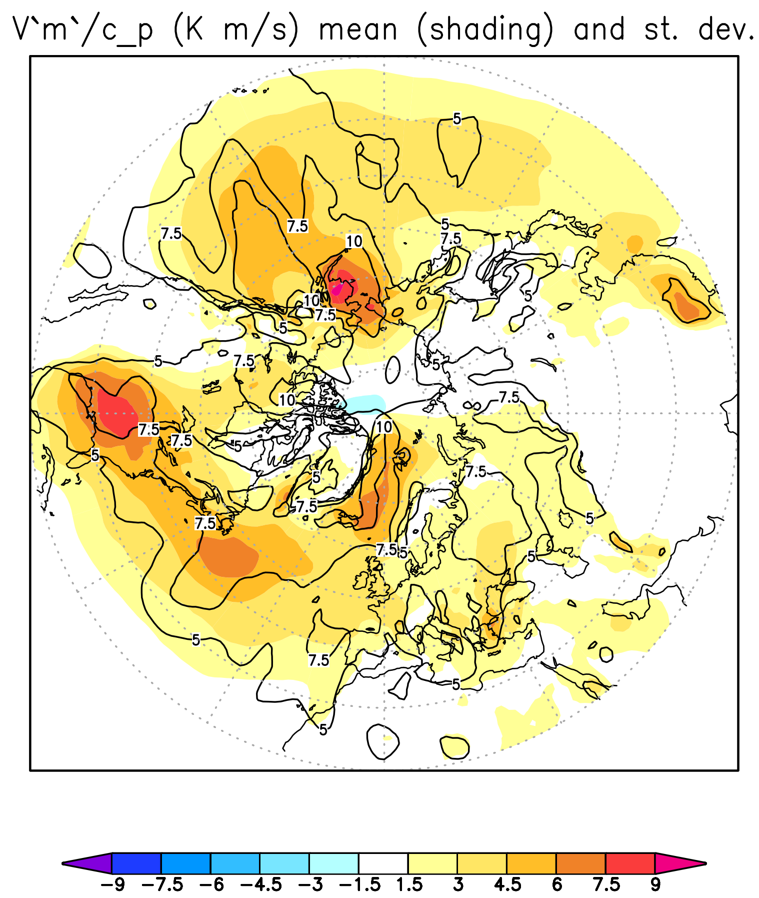
Blocking is a well known feature of extratropical circulation that comes with a perturbation of the jet

Heat flux associated with blocking



Identify days with blocked grid point in a 2.5°x2.5° grid

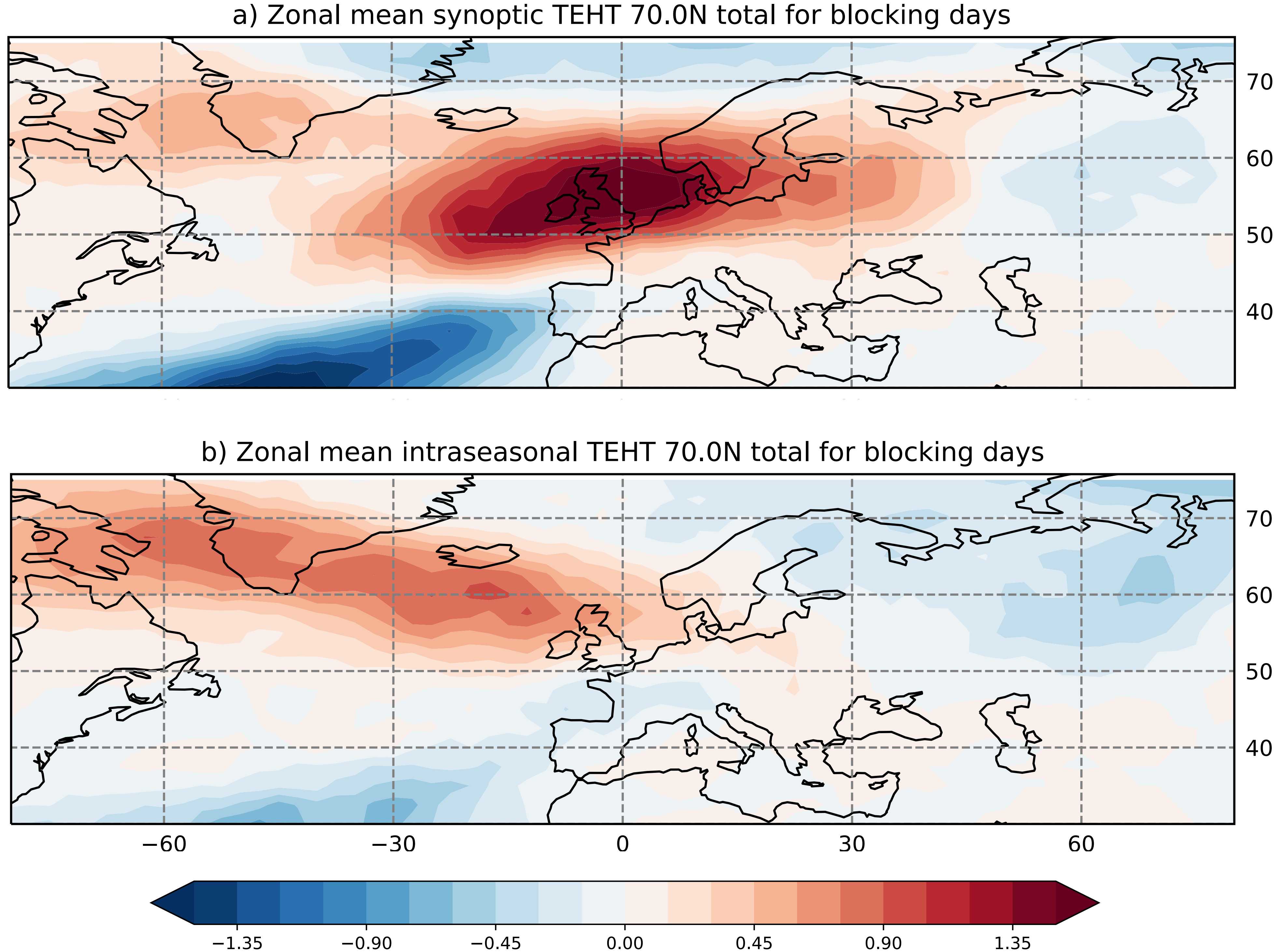




Average zonal mean V'm' at 70°N for identified days

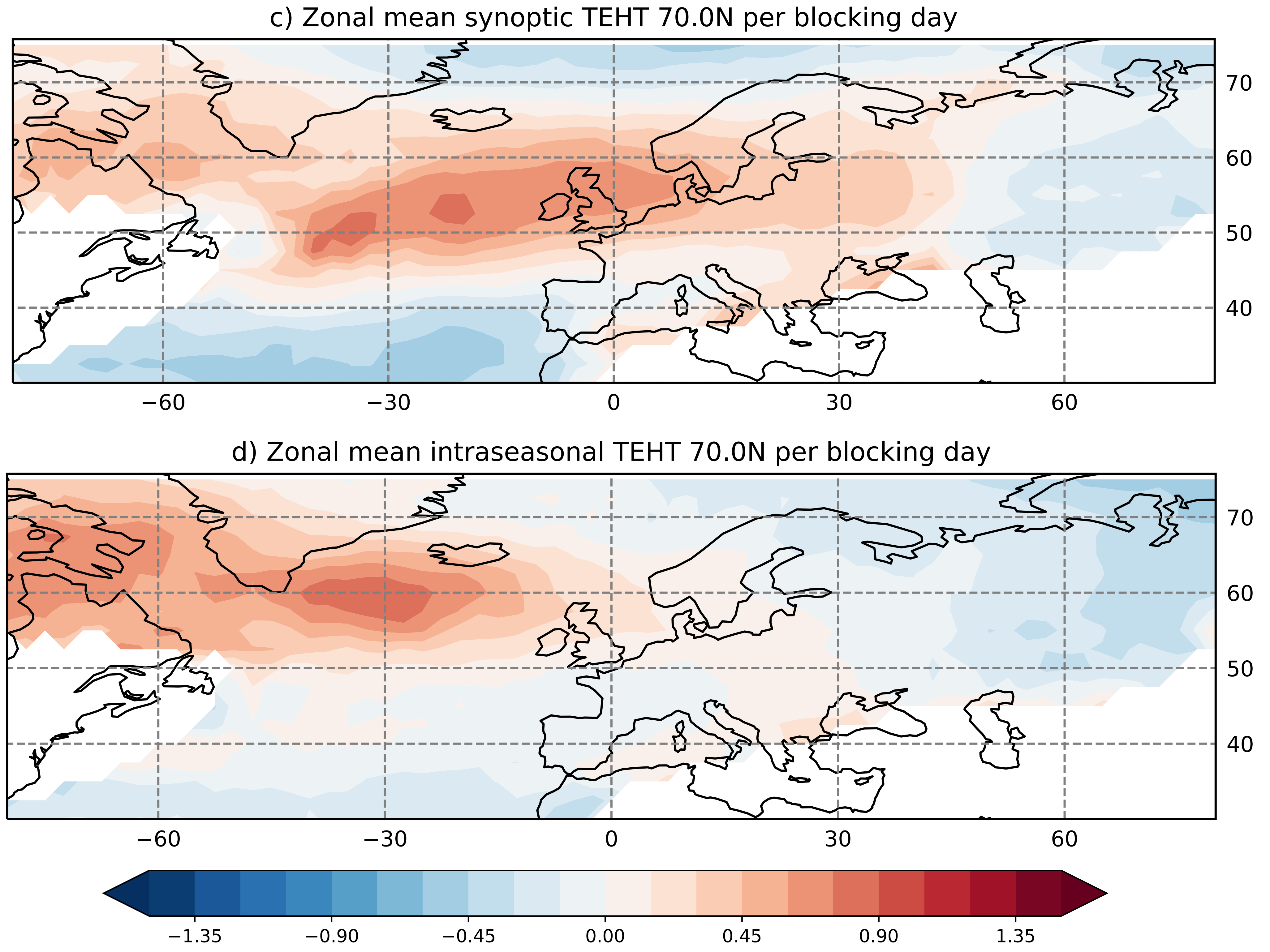
Synoptic and Intraseasonal frequencies

Blocking and heat flux



Total heat flux explained by blocked days

Blocking and heat flux



Heat flux per blocking day

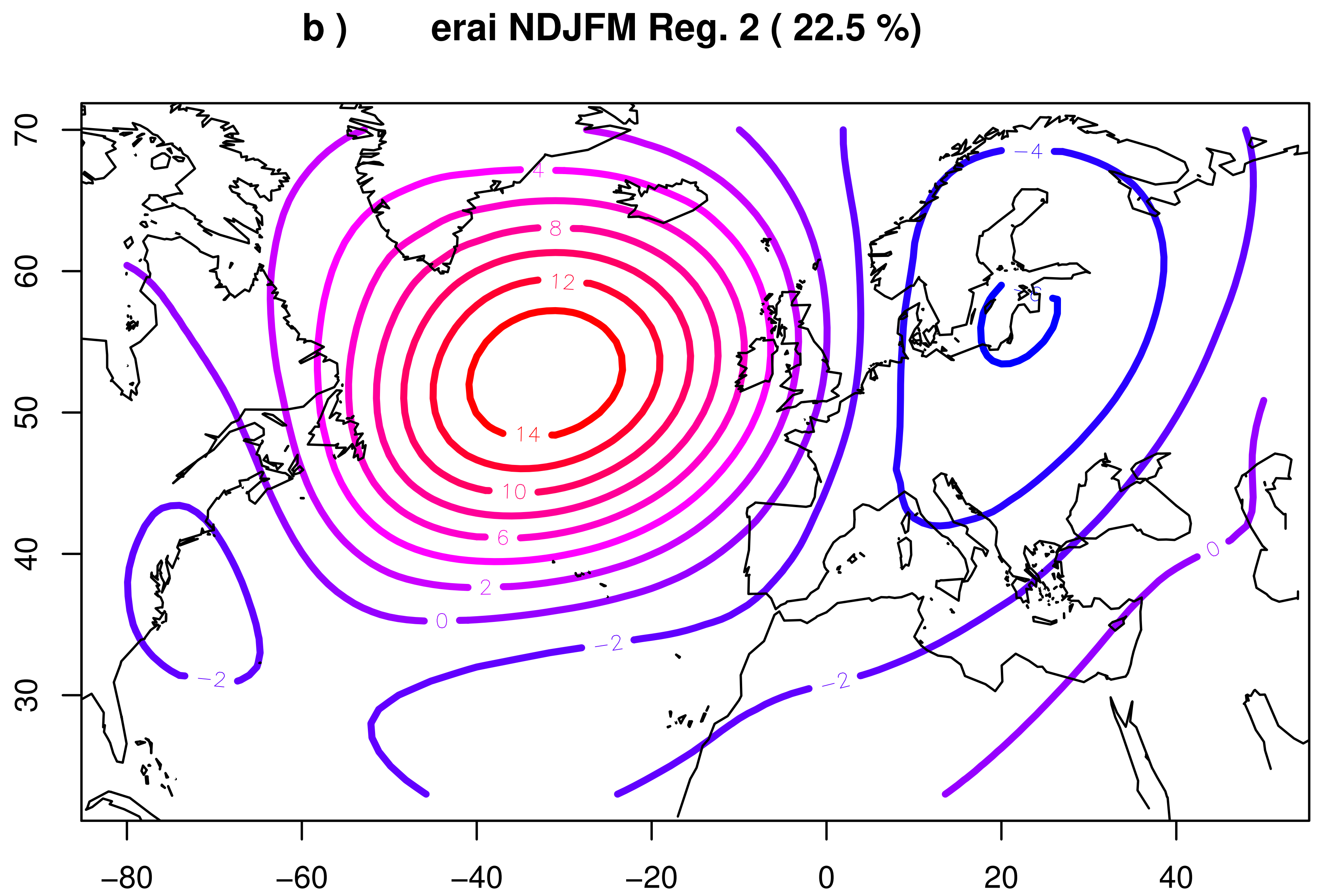
Summary

1) Transient eddy heat flux (TEHF) is substantially modulated by WRs on a regional scale.

2) Zonally average TEHF at 70°N is not significantly modulated by the phases of the NAO. It is on average stronger during Scand and Ridge and weaker in both phases of the NAO

3) TEHF at 70°N depends linearly on the North Atlantic jet speed. It also depends on jet latitude, being significantly large in the case of northern jet. This is associated with specific locations of blocking.

The winner is…



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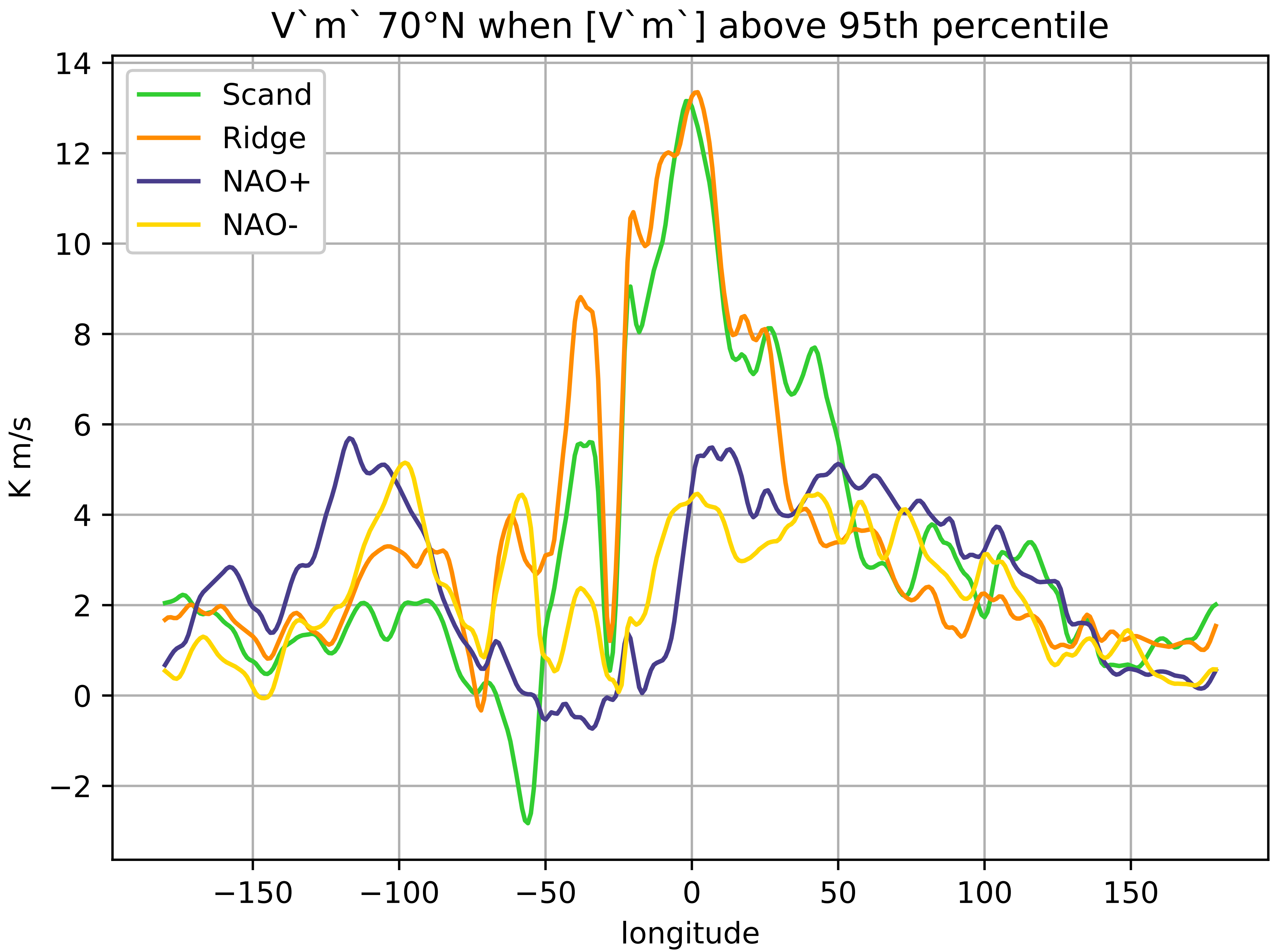
Thank you

Extremes

Longitudinal profile of synoptic eddy heat flux anomalies at 70° N in very strong zonally averaged



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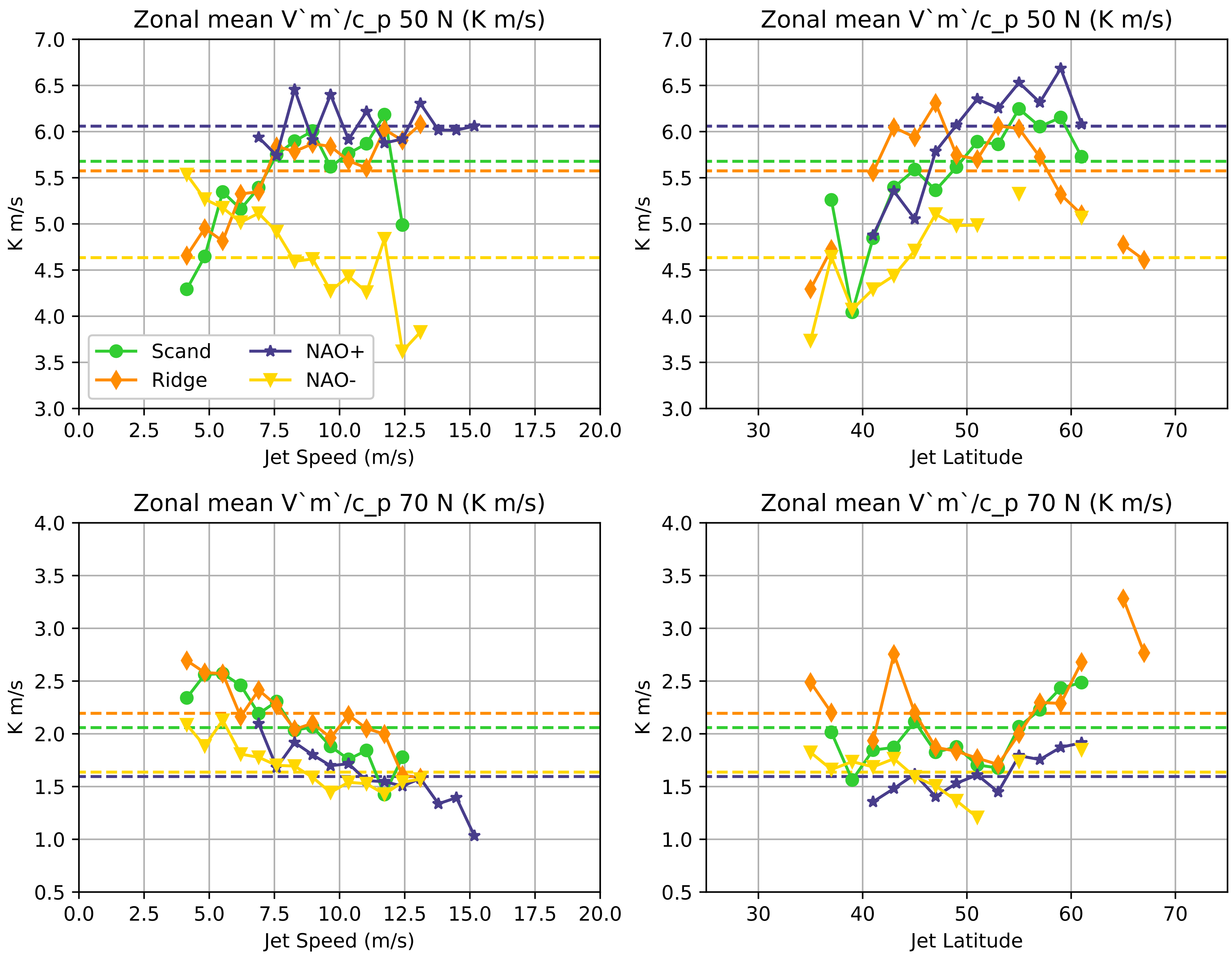
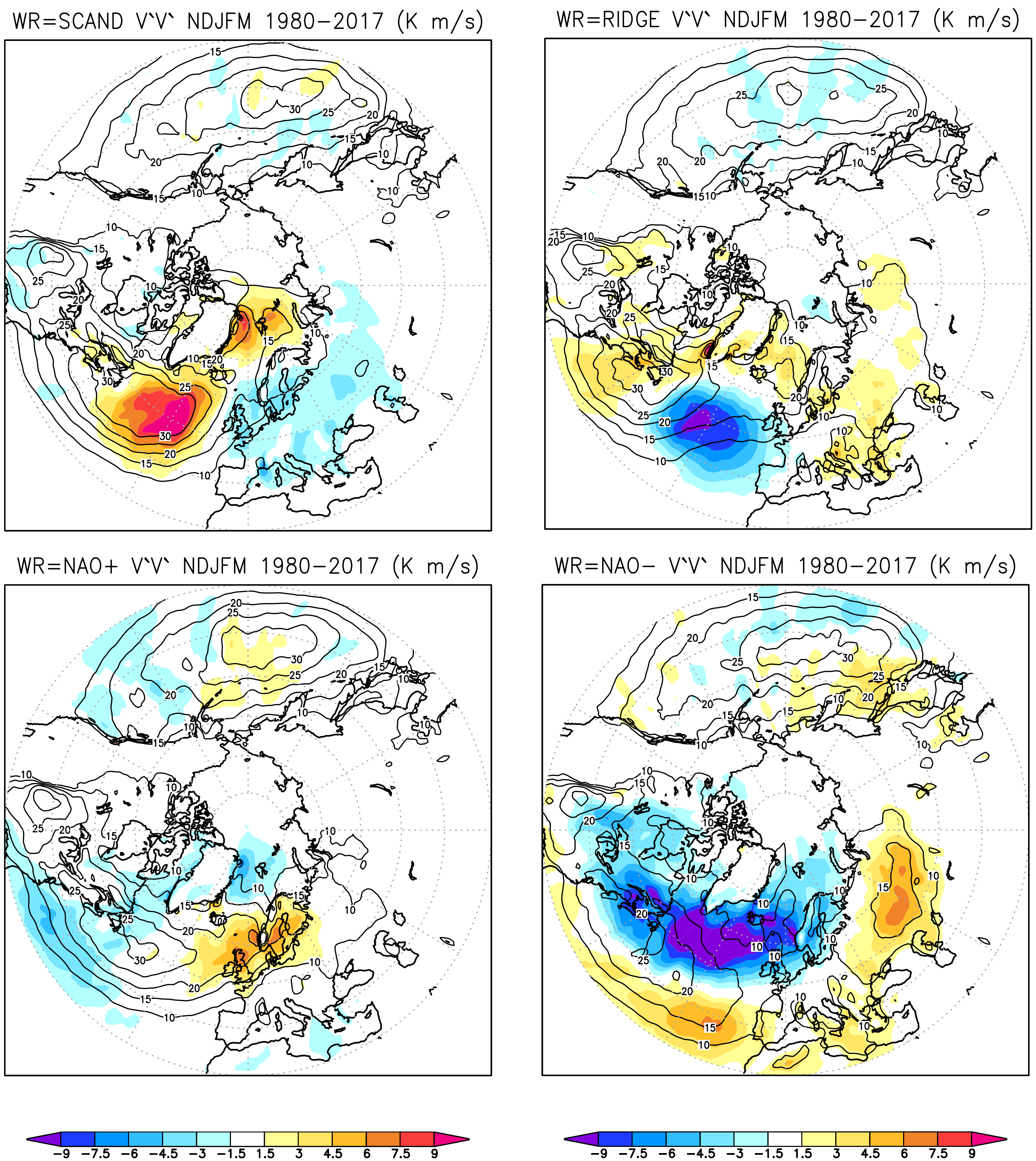
BLUE ACTION



Zonal mean V`m`/c_p 50 N (K m/s)
Zonal mean V`m`/c_p 50 N (K m/s)
Zonal mean V`m`/c_p 70 N (K m/s)
Zonal mean V`m`/c_p 70 N (K m/s)
K m/s
Jet Speed (m/s)
Jet Latitude
Scand
Ridge
NAO+
NAO-


WR=SCAND V`V` NDJFM 1980–2017 (K m/s)
WR=RIDGE V`V` NDJFM 1980–2017 (K m/s)
WR=NAO+ V`V` NDJFM 1980–2017 (K m/s)
WR=NAO– V`V` NDJFM 1980–2017 (K m/s)
–9 –7.5 –6 –4.5 –3 –1.5 1.5 3 4.5 6 7.5 9
–9 –7.5 –6 –4.5 –3 –1.5 1.5 3 4.5 6 7.5 9

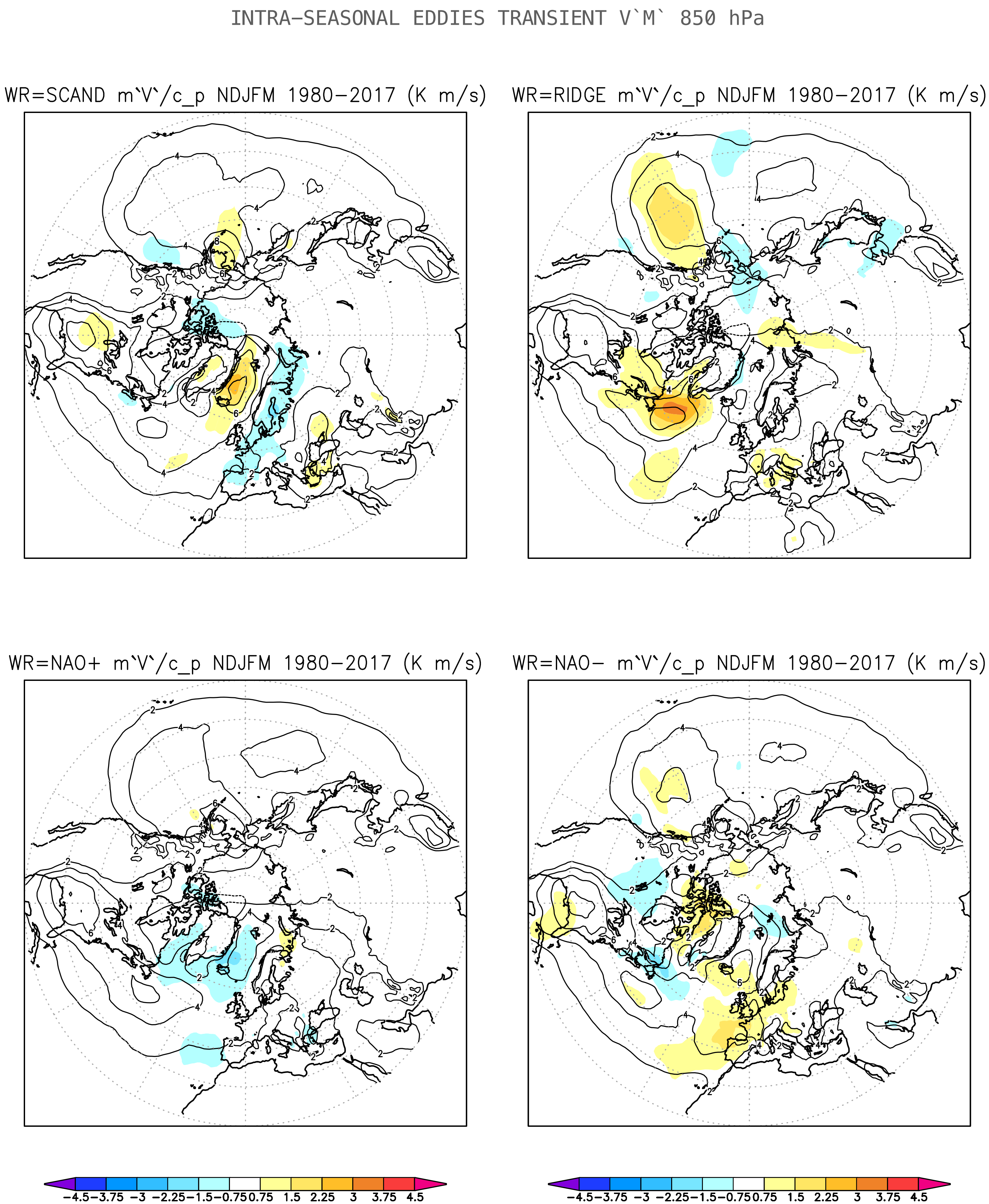
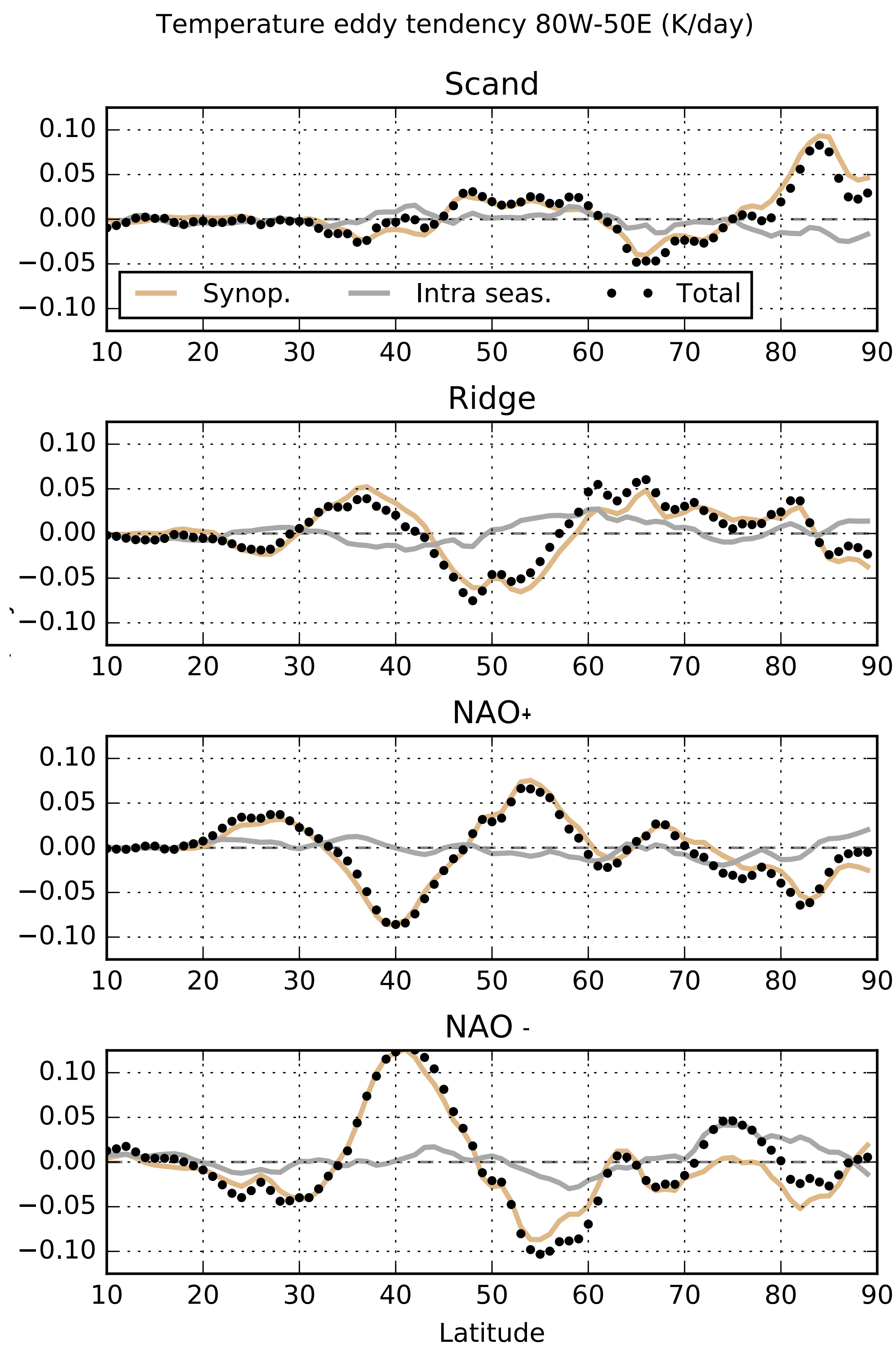
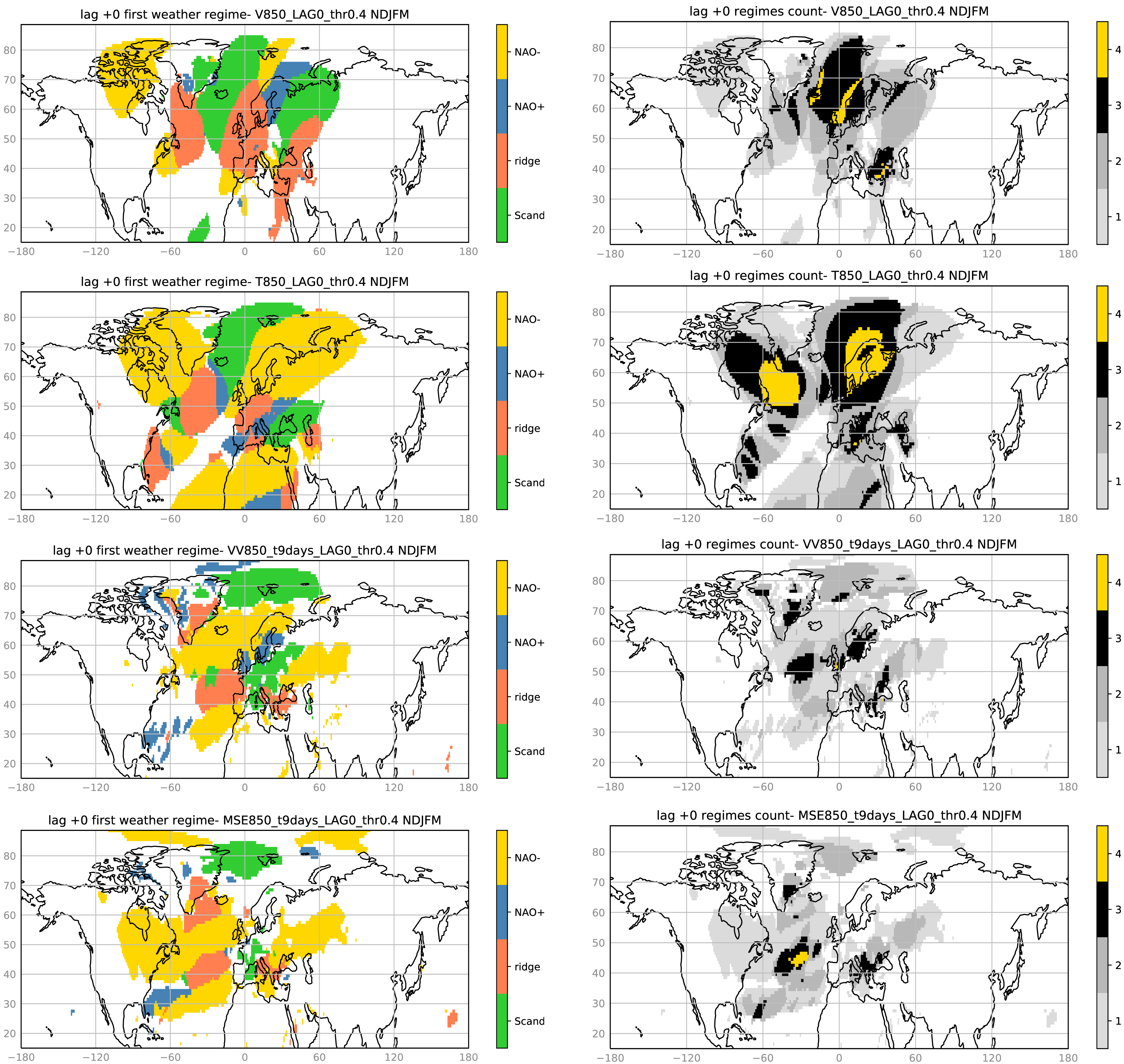


FIG. 7. As in figure 6 but for transient intra-seasonal eddies.



Temperature eddy tendency 80W-50E (K/day)
Scand
Synop.
Intra seas.
Total
Ridge
NAO+
NAO -
0.10
0.05
0.00
−0.05
−0.10
10
20
30
40
50
60
70
80
90
Latitude


lag +0 first weather regime- V850_LAG0_thr0.4 NDJFM
NAO-
NAO+
ridge
Scand
lag +0 regimes count- V850_LAG0_thr0.4 NDJFM
lag +0 first weather regime- T850_LAG0_thr0.4 NDJFM
lag +0 regimes count- T850_LAG0_thr0.4 NDJFM
lag +0 first weather regime- VV850_t9days_LAG0_thr0.4 NDJFM
lag +0 regimes count- VV850_t9days_LAG0_thr0.4 NDJFM
lag +0 first weather regime- MSE850_t9days_LAG0_thr0.4 NDJFM
lag +0 regimes count- MSE850_t9days_LAG0_thr0.4 NDJFM