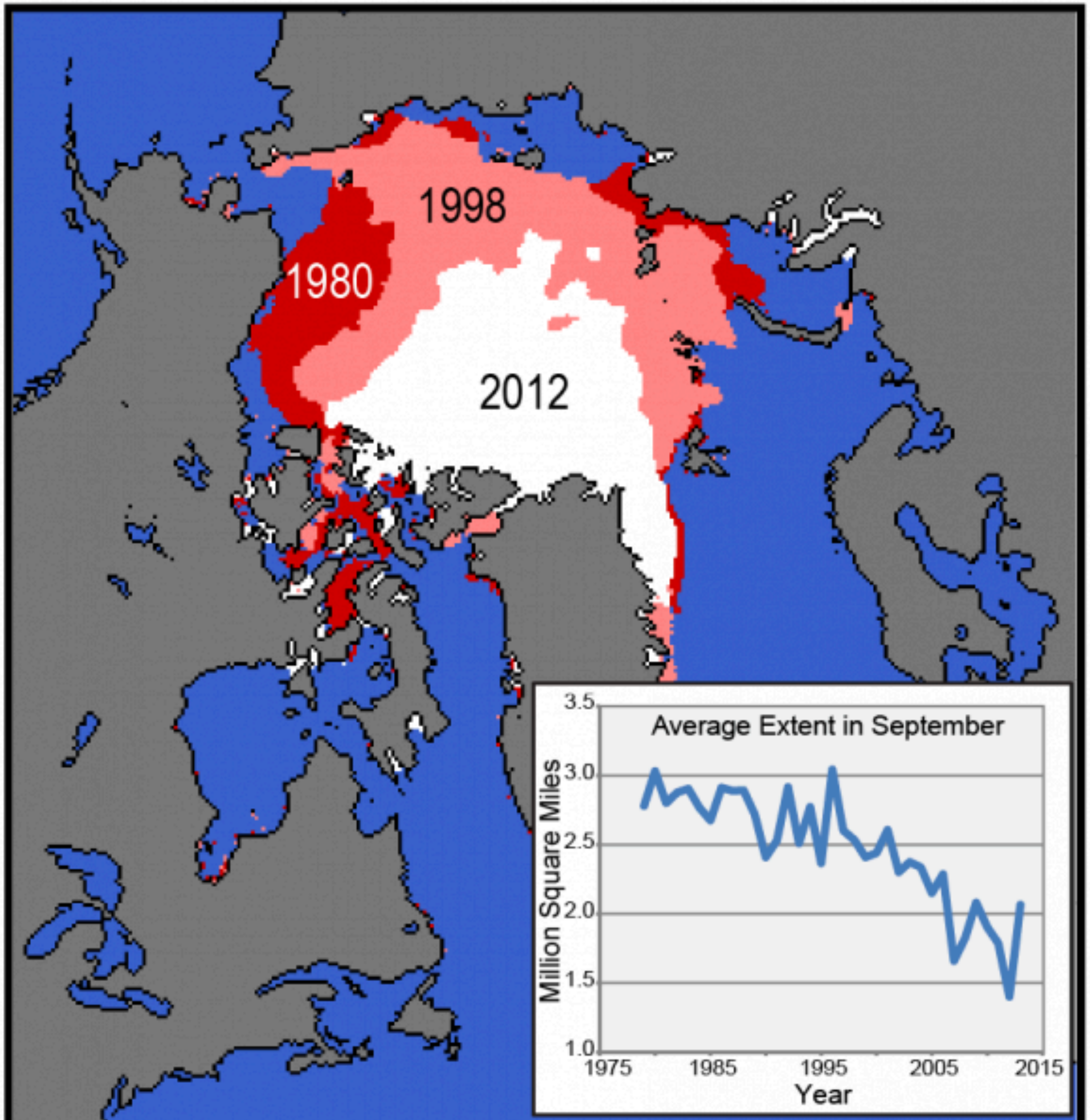
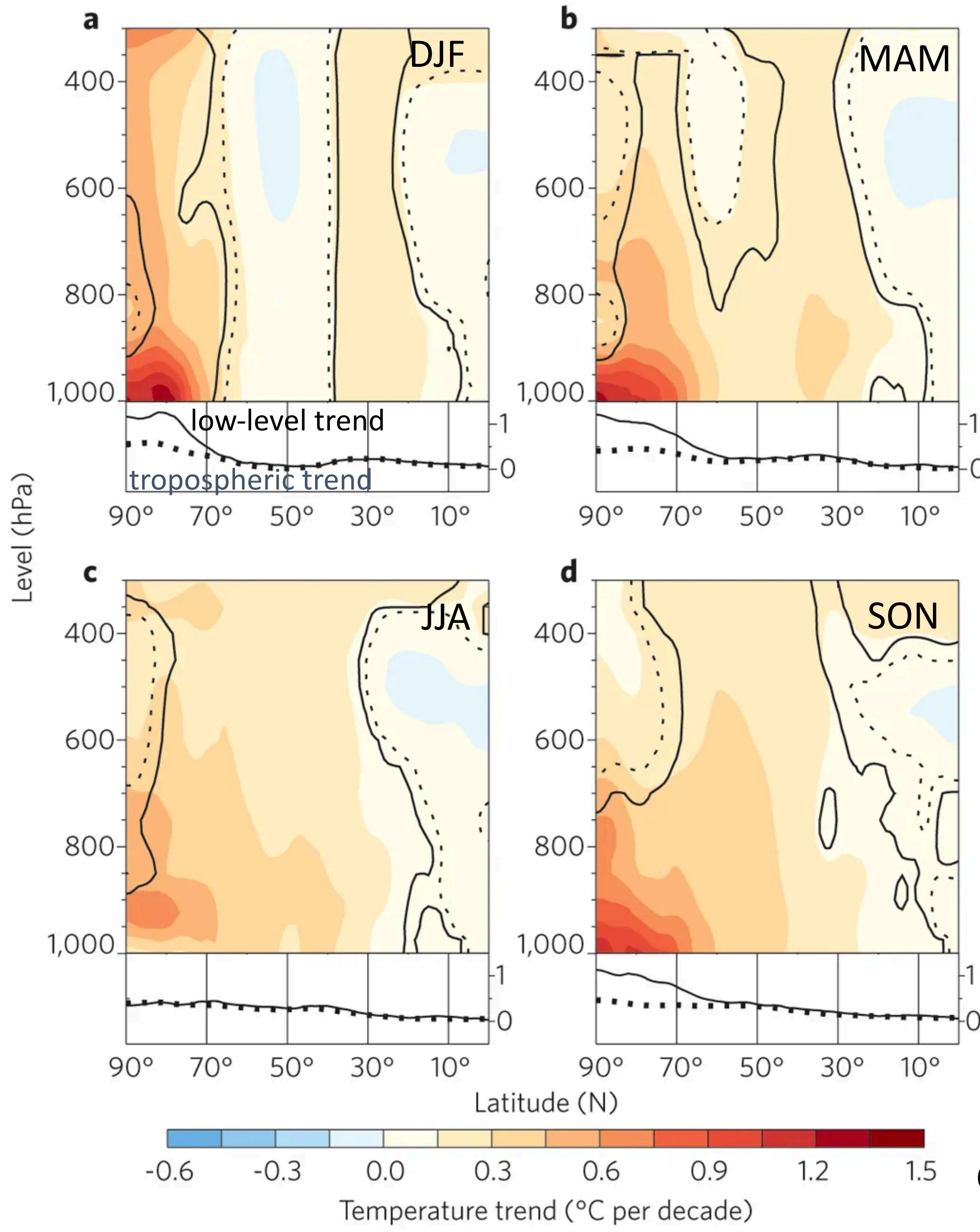
ATM 622
General Circulation

9. Arctic amplification and jet waviness

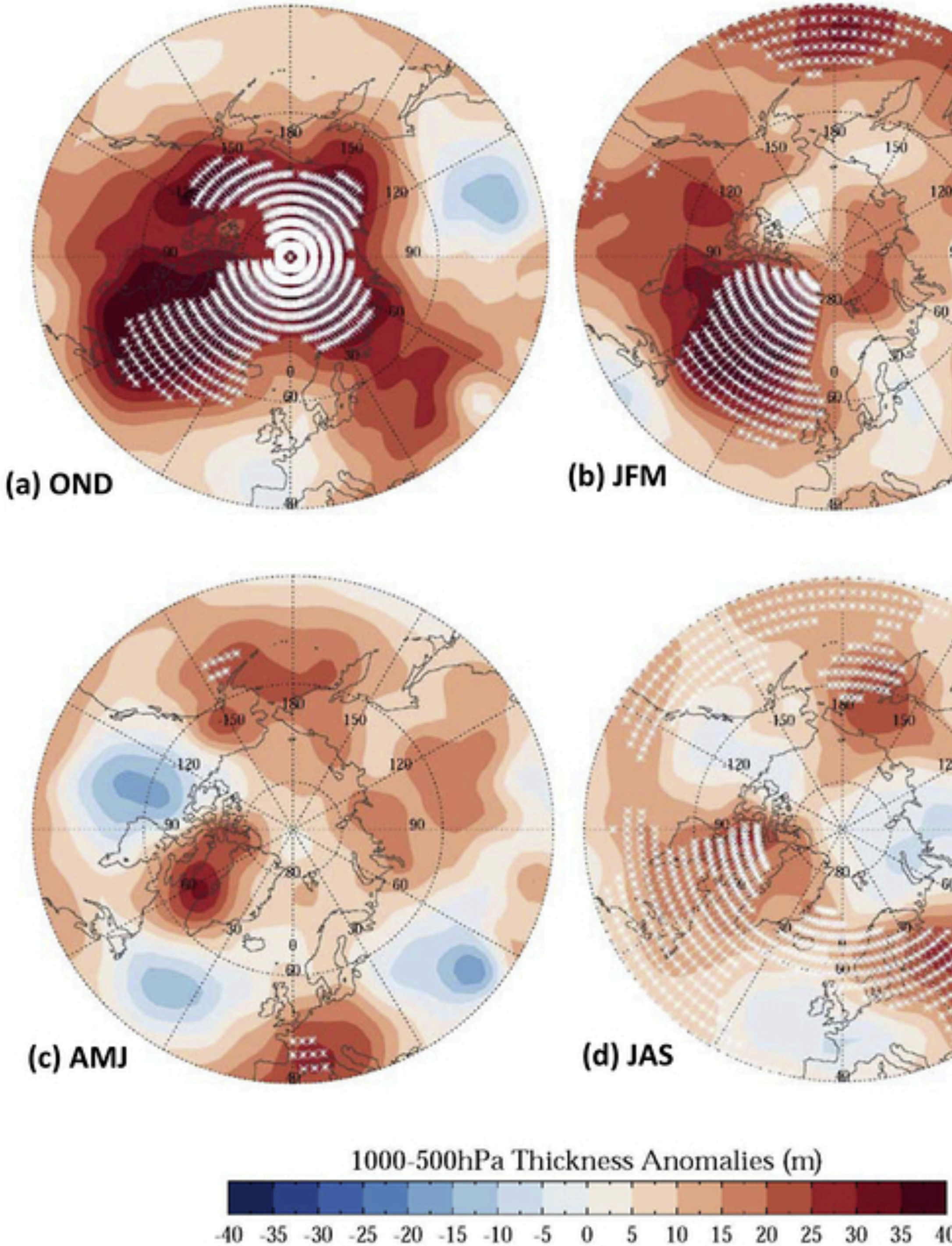
Declining Sea Ice Extent



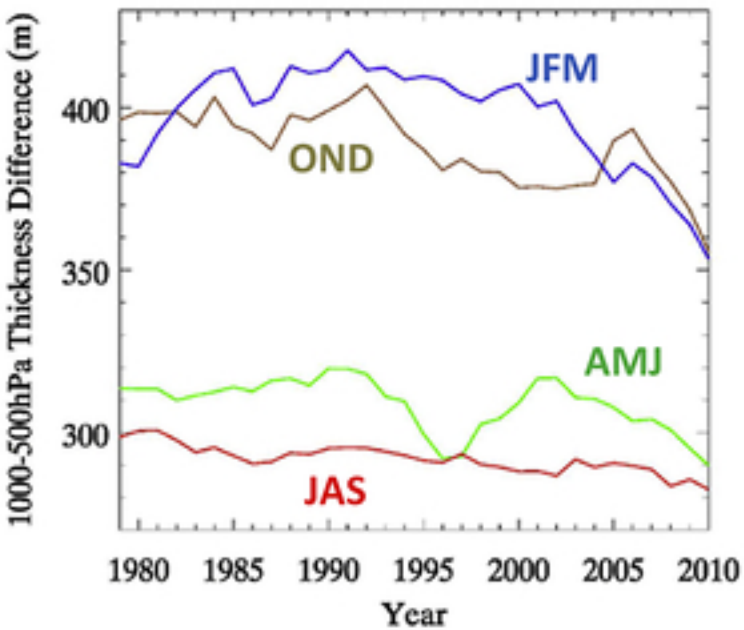
NSIDC (2012)

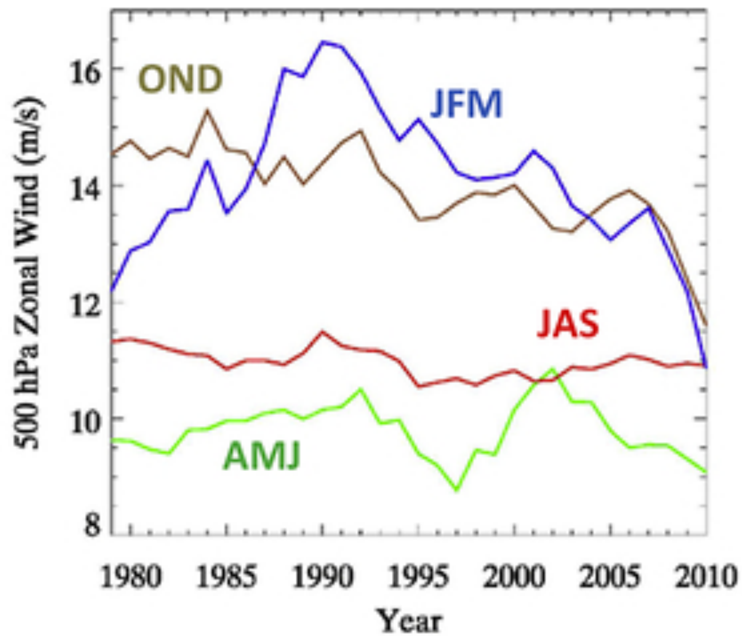


Cohen et al. (2014)

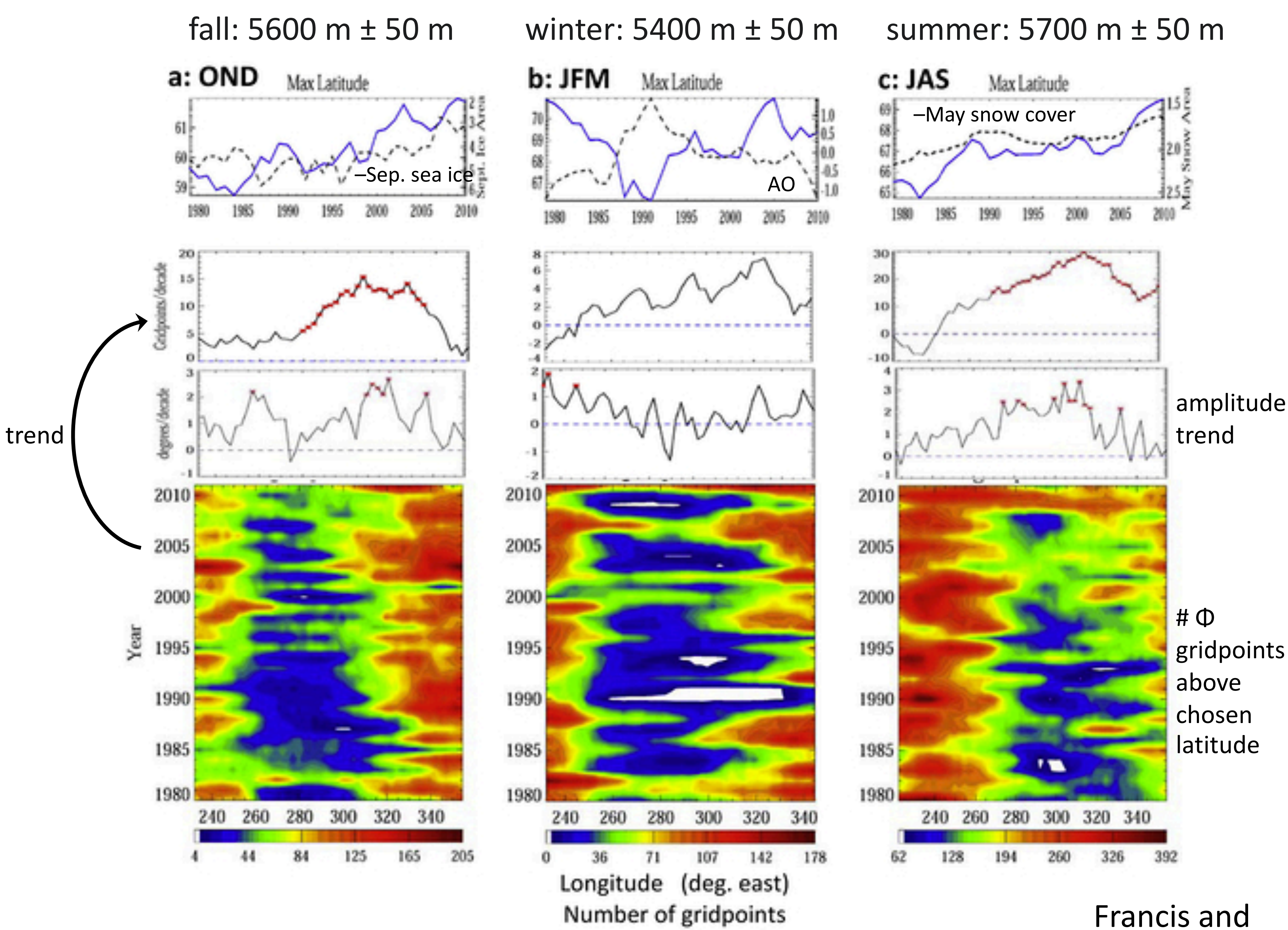


Francis and Vavrus (2012)

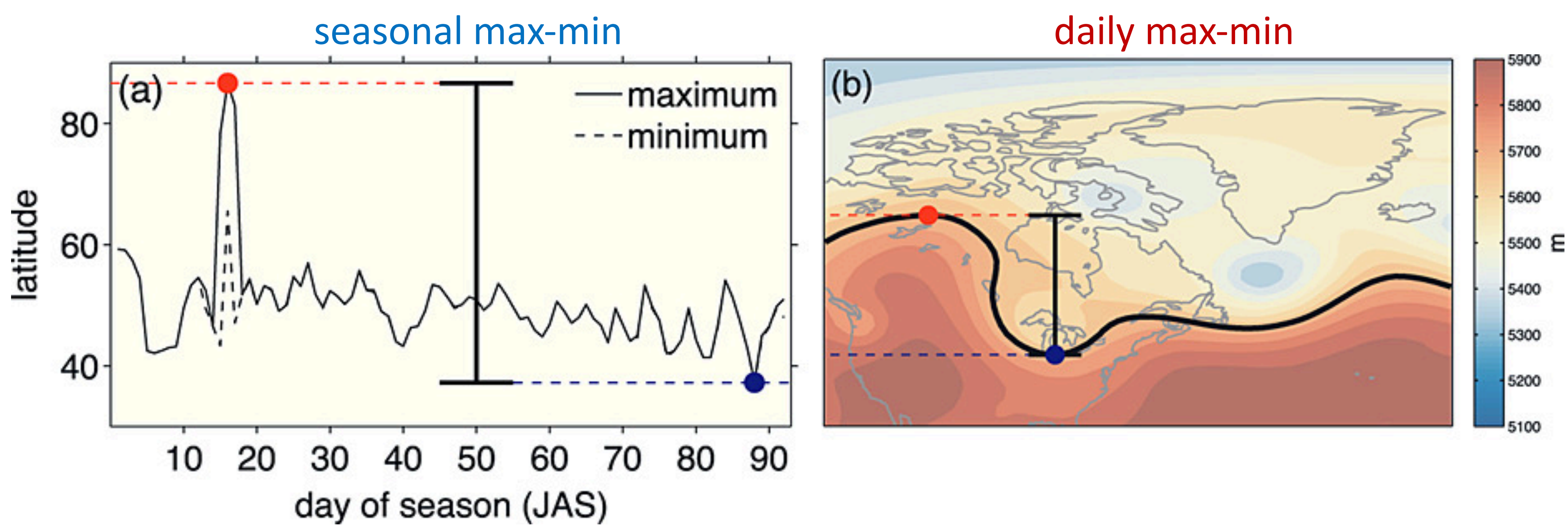


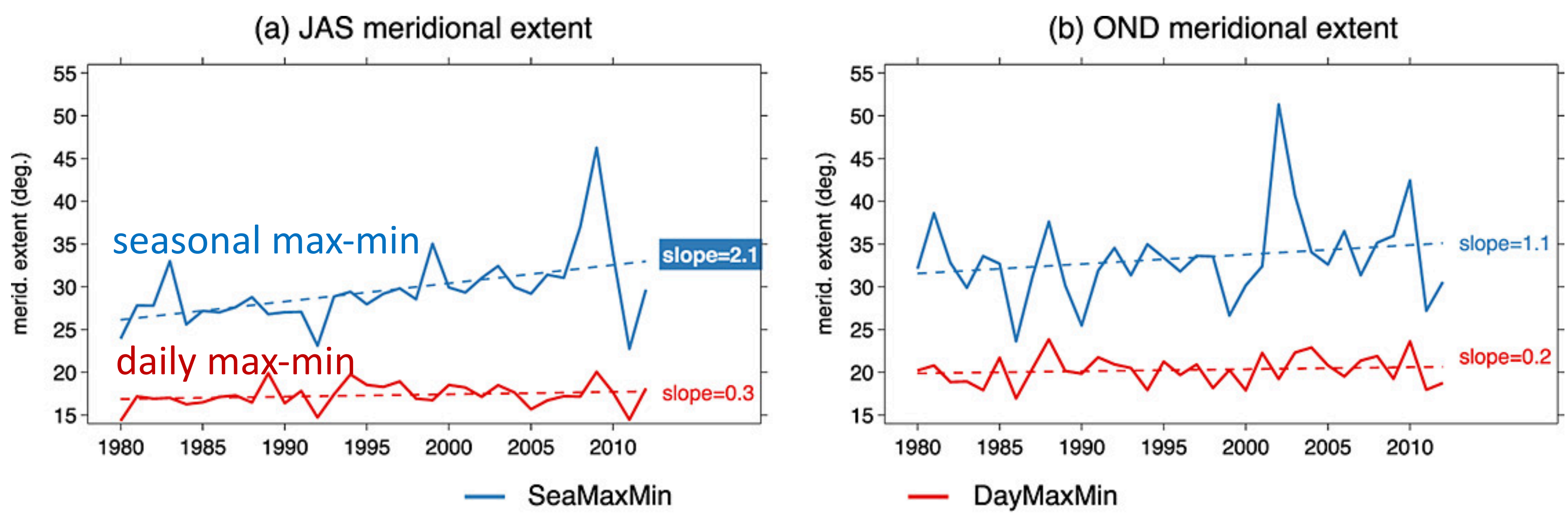


Francis and Vavrus (2012)

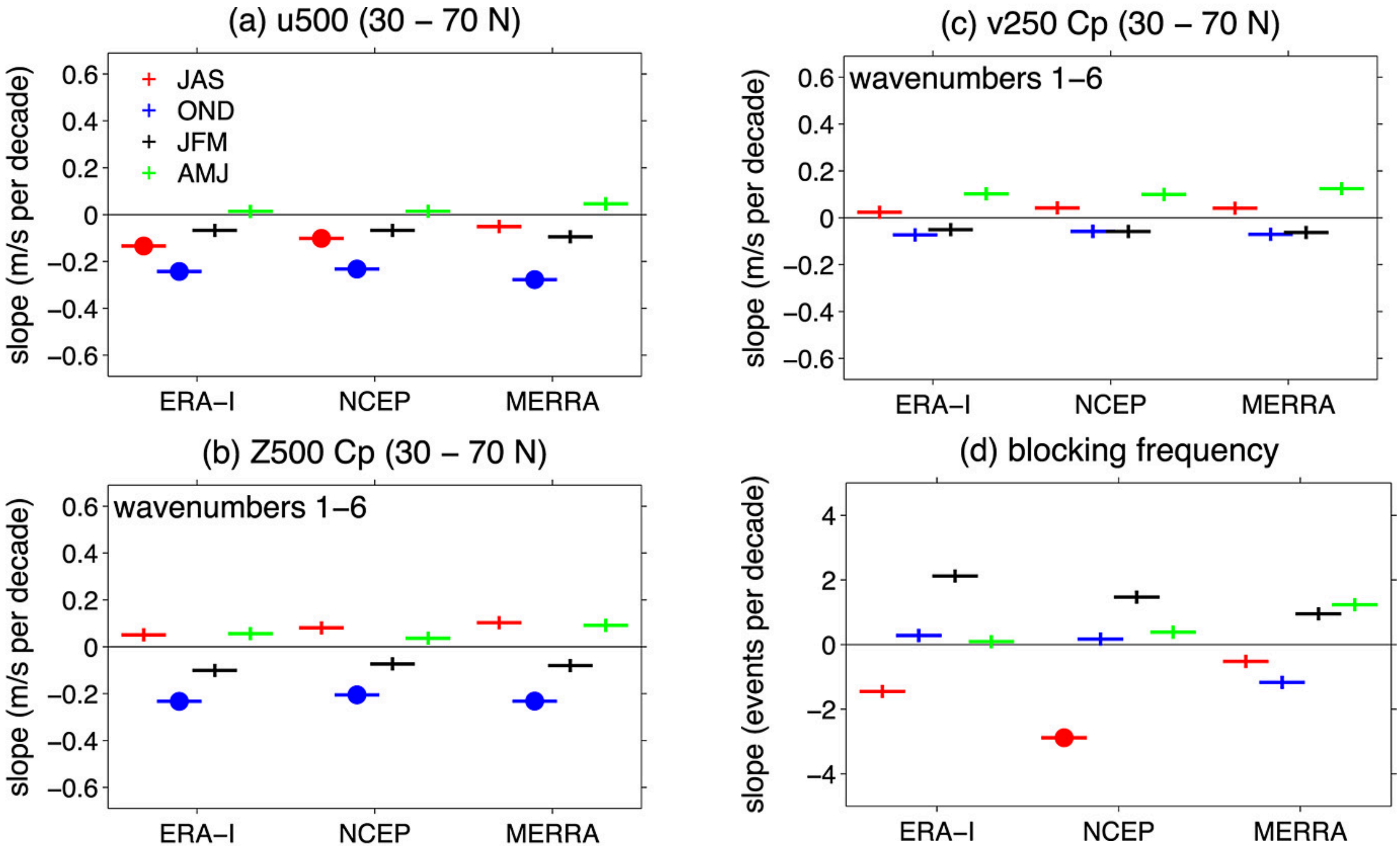


Francis and Vavrus (2012)


seasonal max-min
daily max-min
(a)
maximum
minimum
latitude
day of season (JAS)
(b)
m

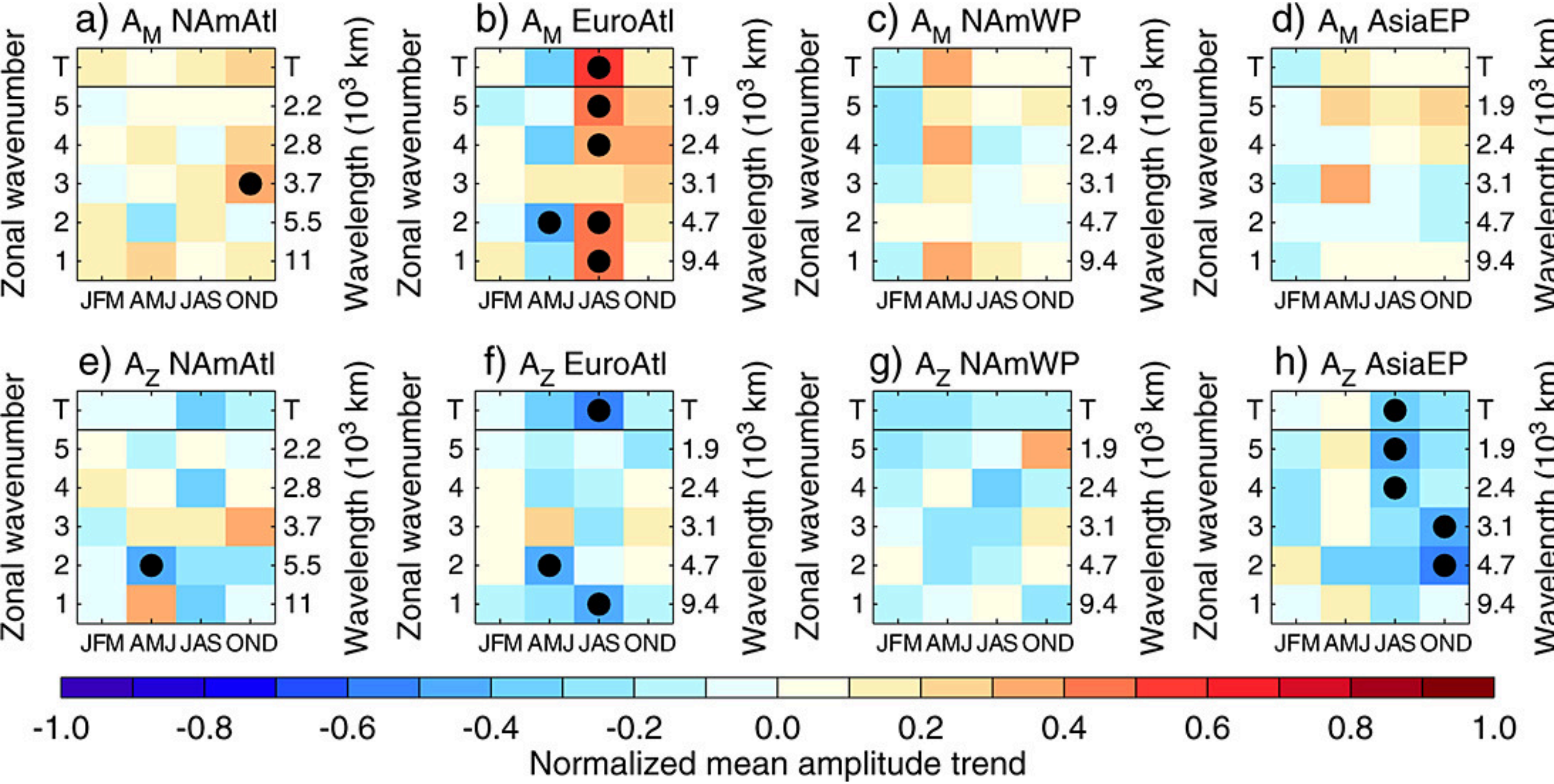

(a) JAS meridional extent
(b) OND meridional extent
merid. extent (deg.)
seasonal max-min
daily max-min
slope=2.1
slope=0.3
slope=1.1
slope=0.2
SeaMaxMin
DayMaxMin

Barnes (2013)



(a) u500 (30 – 70 N)
JAS
OND
JFM
AMJ
slope (m/s per decade)
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
ERA−I
NCEP
MERRA
(c) v250 Cp (30 – 70 N)
wavenumbers 1−6
slope (m/s per decade)
(b) Z500 Cp (30 – 70 N)
wavenumbers 1−6
slope (m/s per decade)
(d) blocking frequency
slope (events per decade)
4
2
0
−2
−4

Barnes (2013)



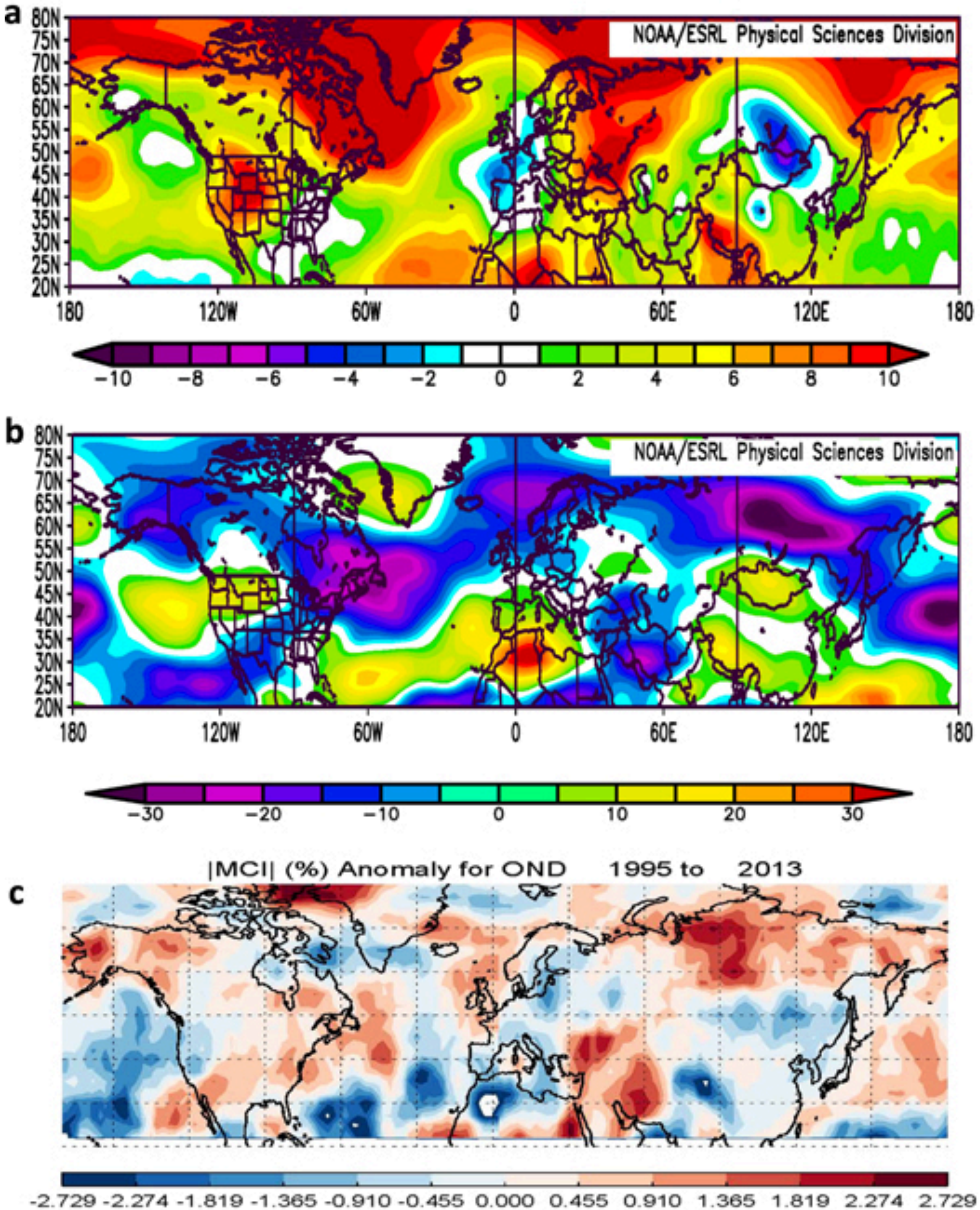
Screen and Simmonds (2013)

Fall (OND)

1000–500-hPa thickness anom.

500-hPa zonal wind anom.

Meridional Circulation Index anom.



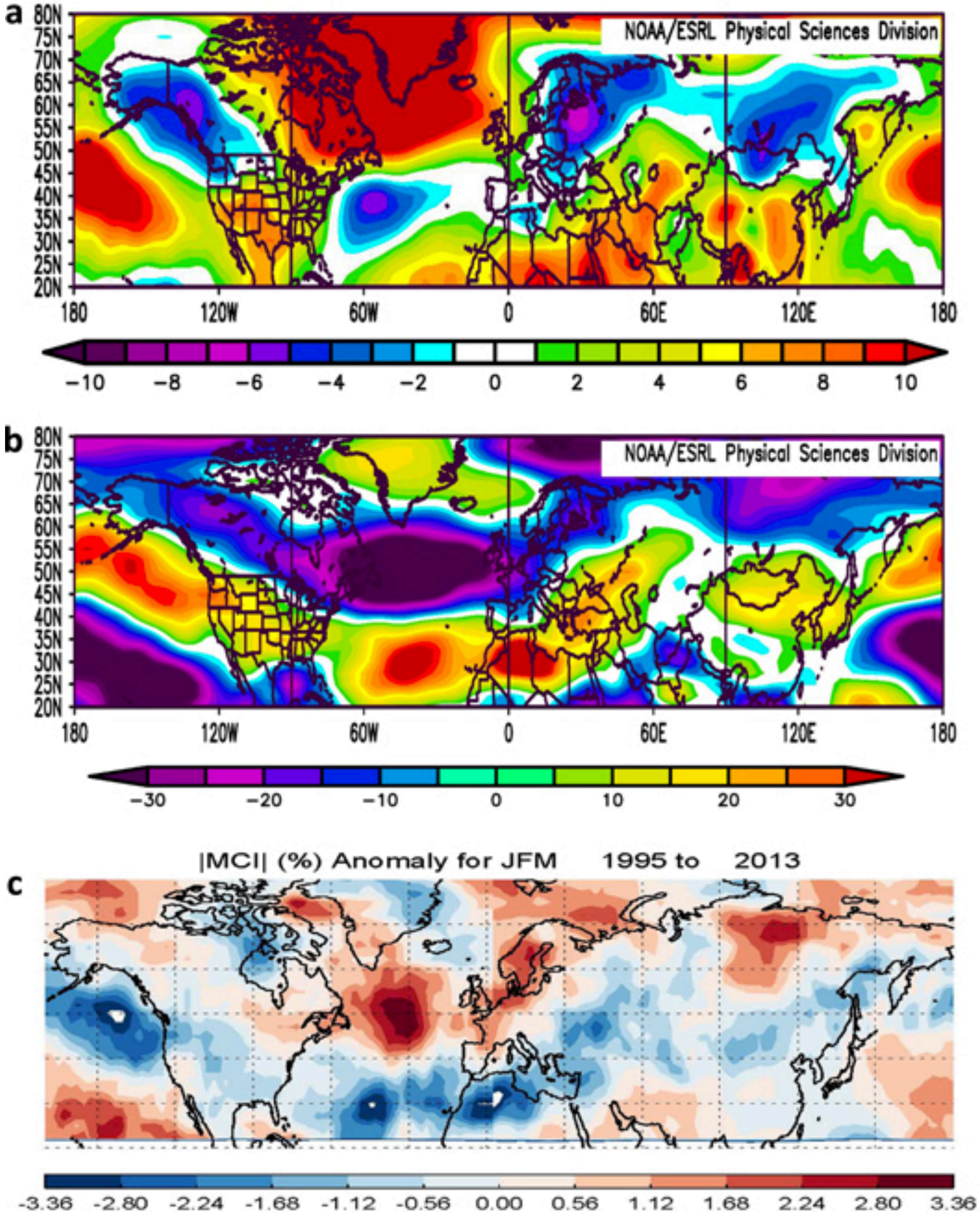
Francis and Vavrus (2015)

Winter (JFM)

1000–500-hPa thickness anom.

500-hPa zonal wind anom.

Meridional Circulation Index anom.



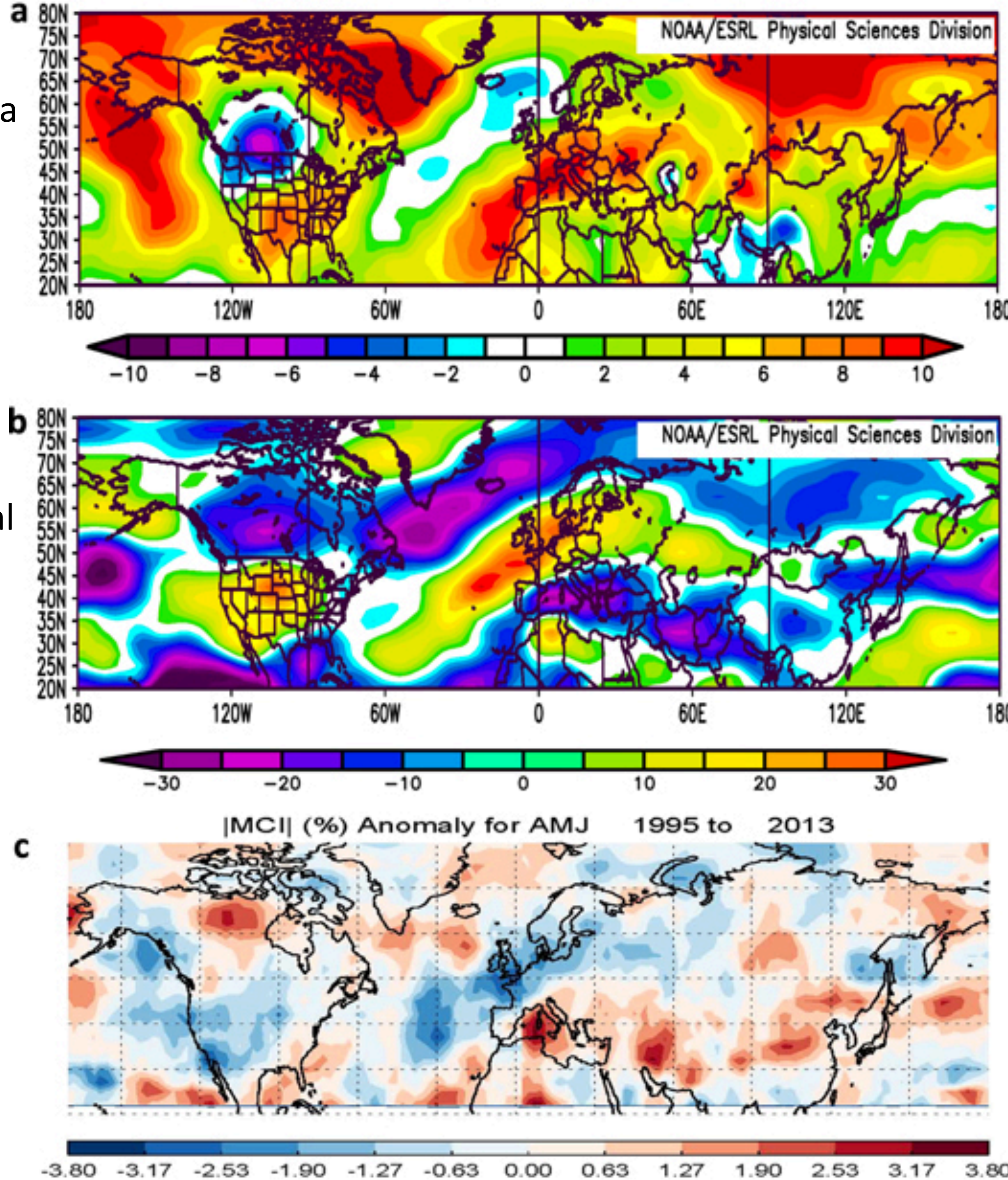
Francis and Vavrus (2015)

Spring (AMJ)

1000–500-hPa thickness anom.

500-hPa zonal wind anom.

Meridional Circulation Index anom.



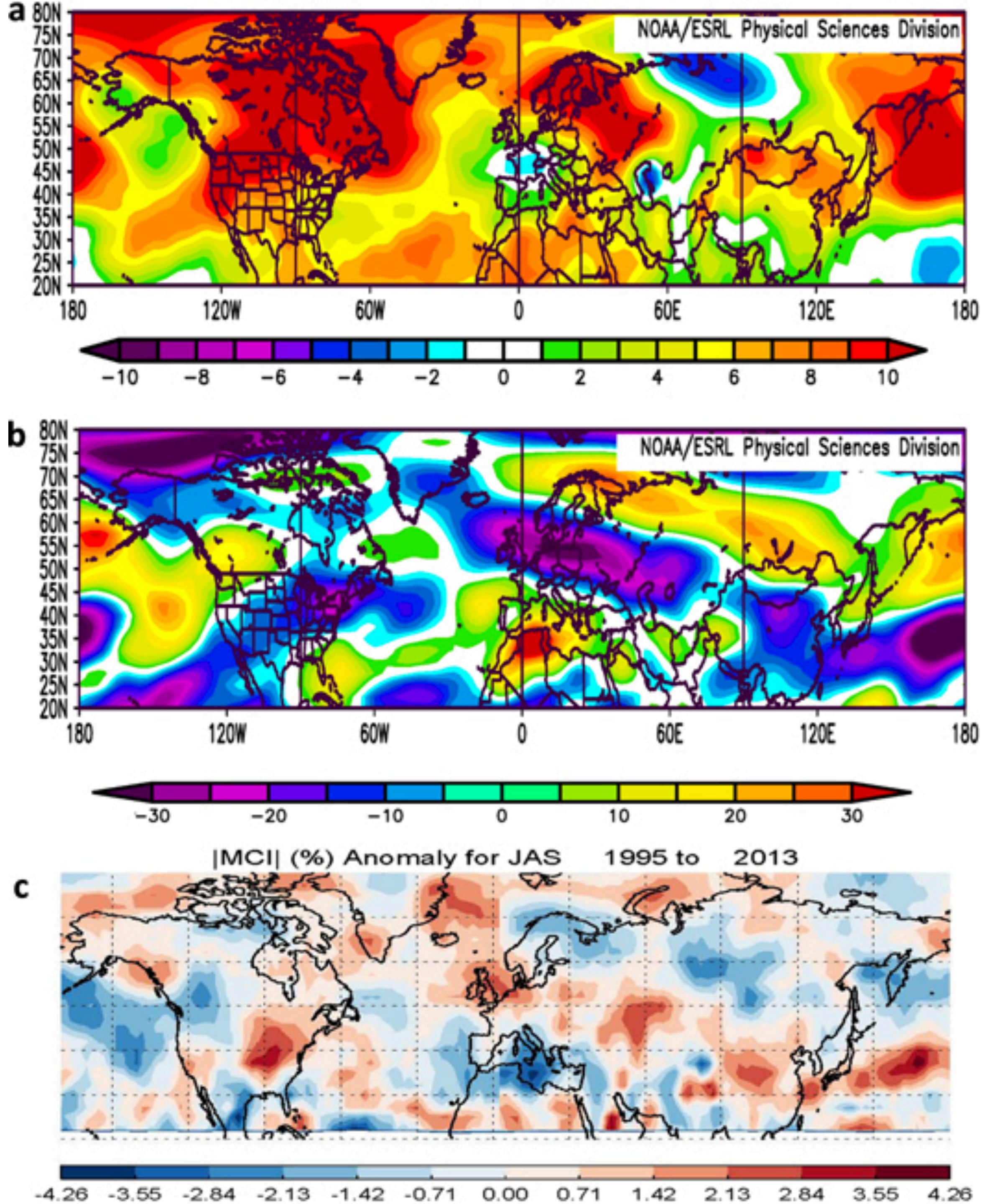
Francis and Vavrus (2015)

Summer (JAS)

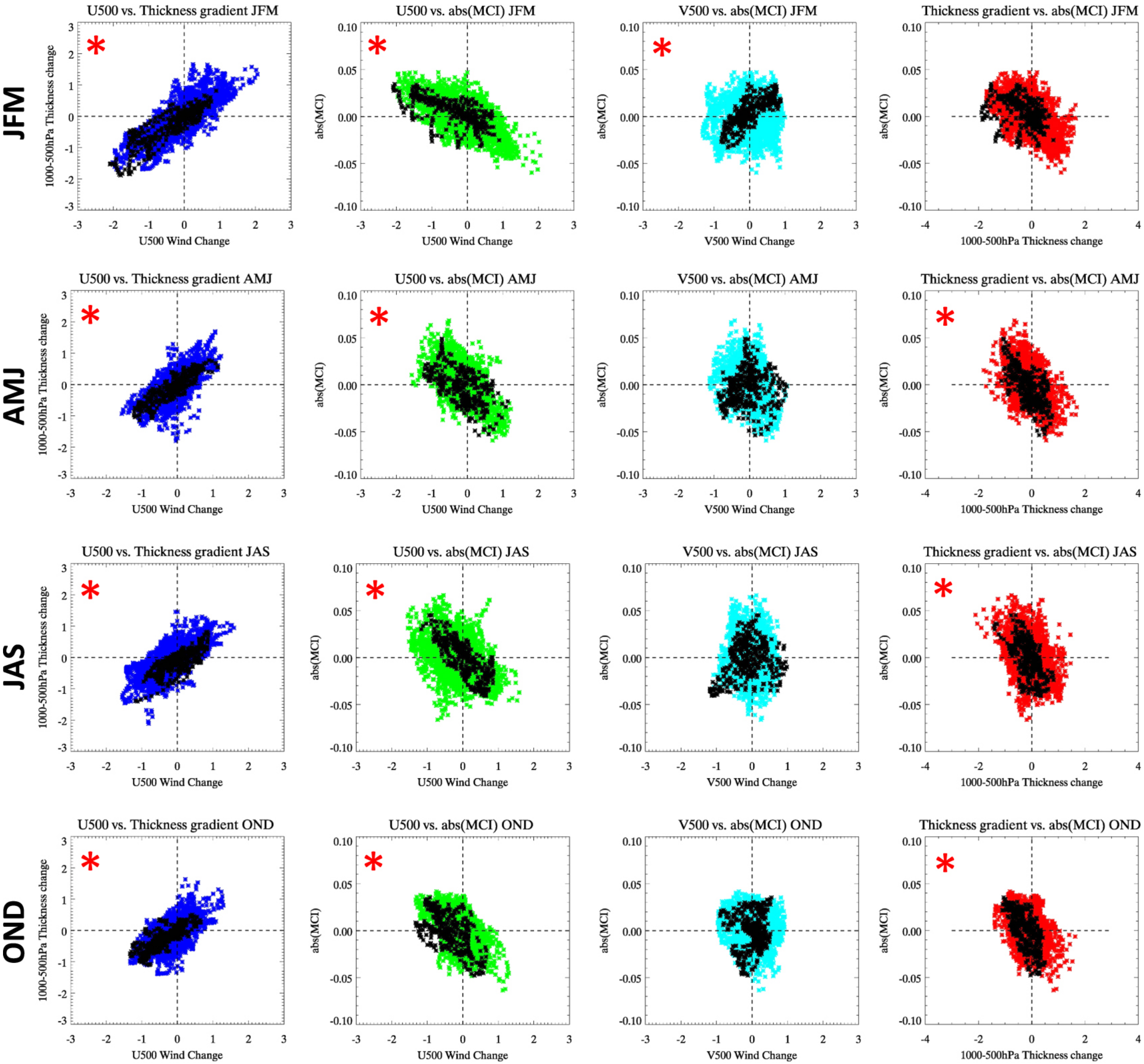
1000–500-hPa thickness anom.

500-hPa zonal wind anom.

Meridional Circulation Index anom.



Francis and Vavrus (2015)

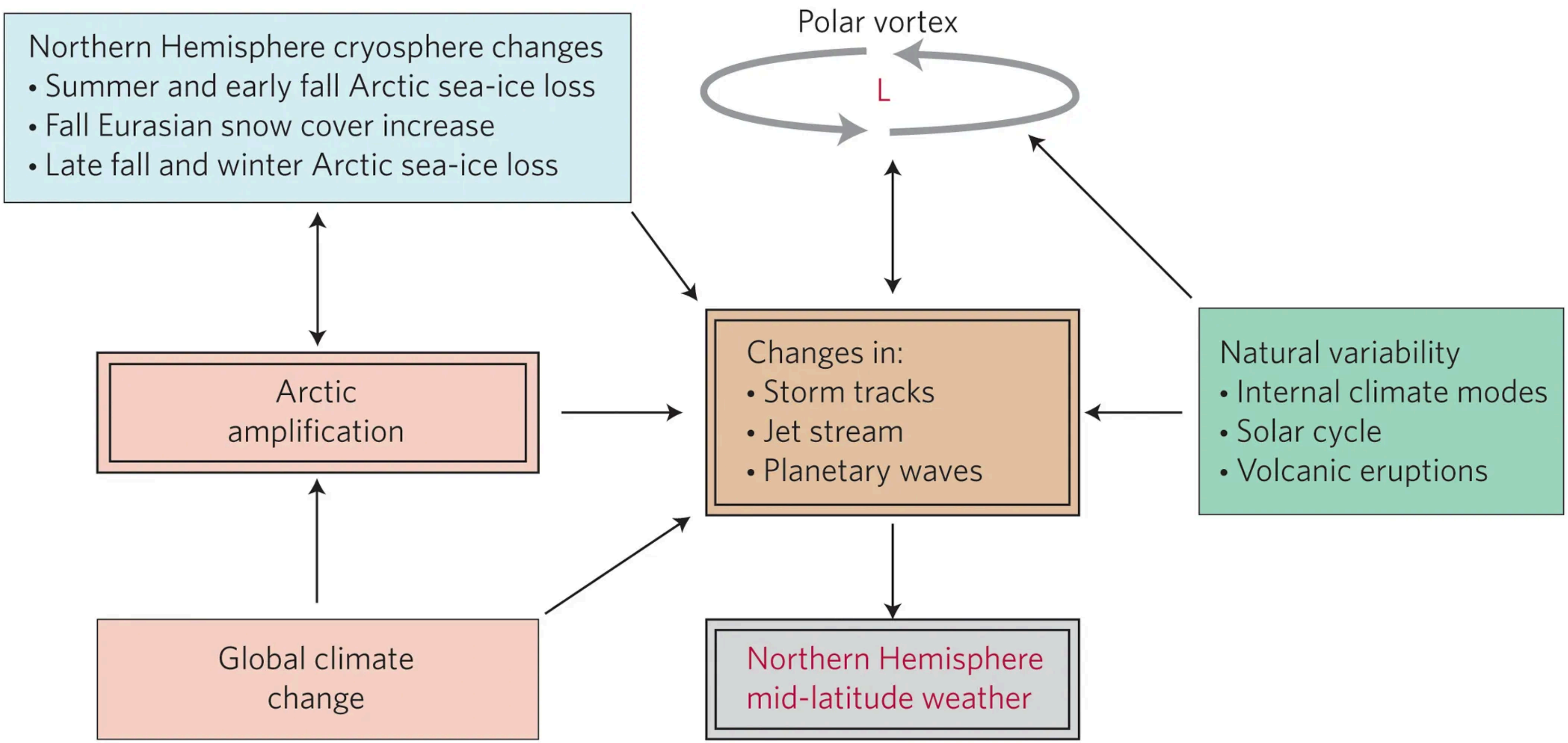


Francis and Vavrus (2015)

Region	JFM			AMJ			JAS			OND		
Atlantic 285 – 60E	16	19	30	10	5	15	25	57*	58*	23	47*	70*
North America 220 – 290E	14	18	27	13	12	18	33	59*	65*	-5	23	20
Europe -15 – 45E	3	1	-3	7	3	14	-8	6	0	1	17	40*
Asia 30 – 150E	4	4	5	12	1	18	-15	-15	-24*	15	65*	103*
Pacific 150 – 240E	-4	-18	-14	18*	12	24*	-3	-3	-9	2	25	13
Northern Hemisphere	4	-6	-5	3	1	3	-7	-5	-11	7	16	25*

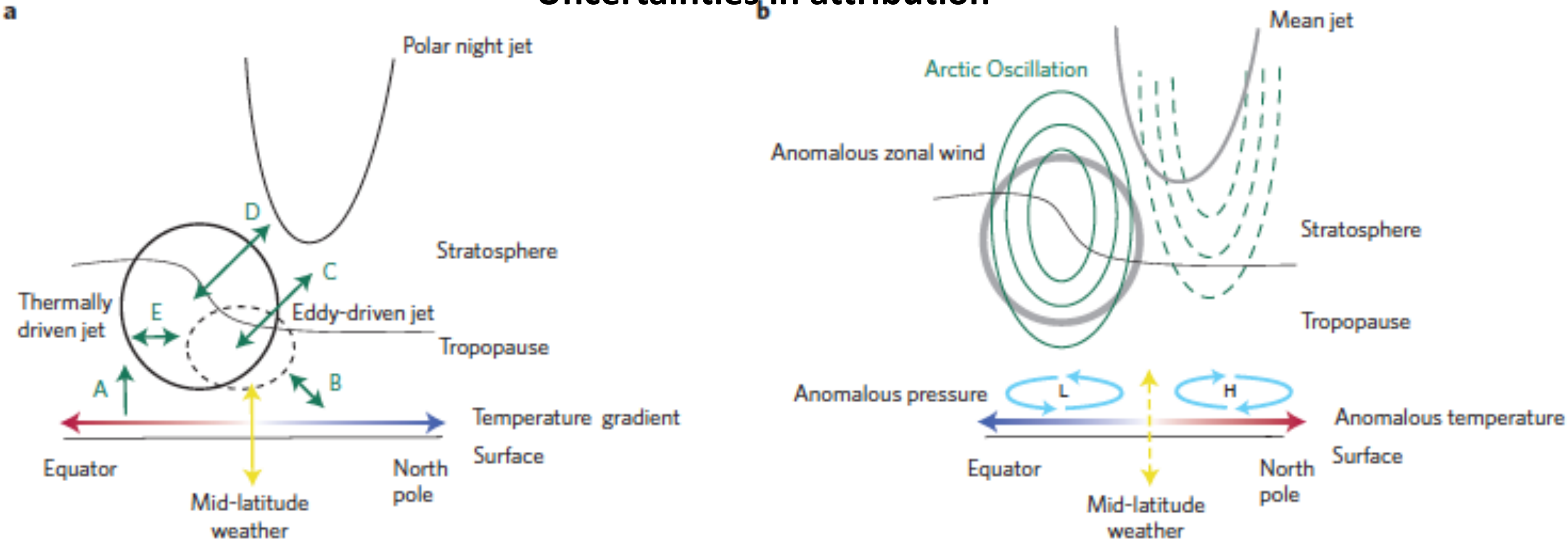
< -40%	-39 to -30%	-29 to -20%	-19 to -10%	-9 to 0%
0 to 9%	10 to 19%	20 to 29%	30 to 39%	> 40%

Francis and Vavrus (2015)



Cohen et al. (2014)

Uncertainties in attribution

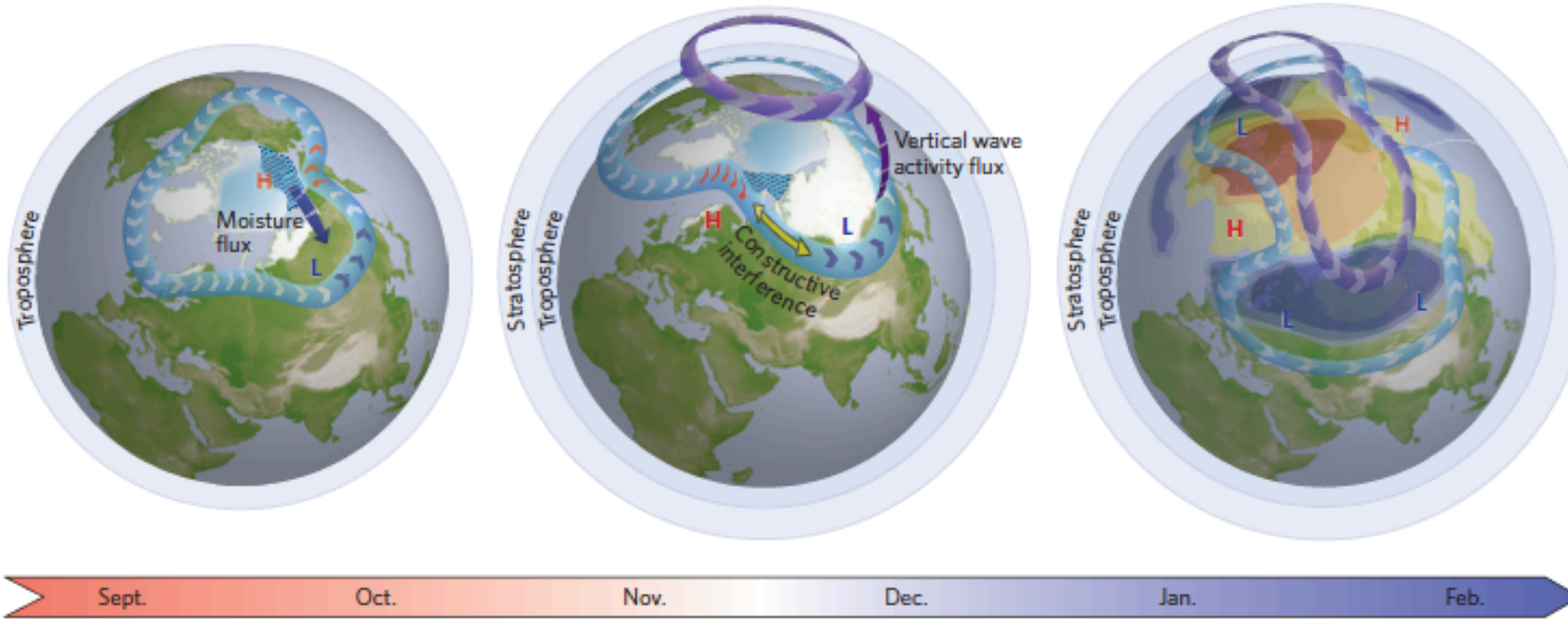


A. The temperature gradient, in this definition, influences the thermally driven jet (black solid circle) via the thermal-wind balance (in combination with boundary conditions). B. The temperature gradient influences the eddy-driven jet (black dashed circle) via changes in baroclinicity. The eddy-driven jet influences the temperature gradient via horizontal heat fluxes. C. The eddy-driven jet affects stratospheric winds (black U shape) via vertical wave propagation. Stratospheric winds affect the eddy-driven jet by altering the vertical wave-guide. D. The thermally driven jet affects stratospheric winds via generation of orographically forced waves. Stratospheric winds affect the thermally driven jet by altering the vertical wave guide. E. The thermally driven jet affects the eddy-driven jet by acting as a wave guide (the role of baroclinicity here directly associated with the temperature gradient). The eddy-driven jet affects the thermally driven jet via energy fluxes.

Positive (negative) zonal wind anomalies associated with the negative NAO/AO are superimposed on the jet shown by a green solid (dashed) line. Also shown are the temperature changes with warmer temperatures in the Arctic (red) and colder temperatures in the mid-latitudes (blue), increased high-latitude blocking (represented by clockwise flow around a high) and a southward shift in the storm tracks (represented by an anticlockwise flow around a low), and increased meridional flow.

Cohen et al. (2014)

One possible chain of mechanisms



Reduced sea ice favors an increase in mid-tropospheric heights in the Barents and Kara seas region in winter] with downstream troughing over Eurasia. Warming of the atmosphere due to increased heating from newly ice-free ocean causes geopotential heights to increase in the mid-troposphere, which suppresses the jet stream southward over east Siberia (Arctic Dipole).

The extensive snow cover over Siberia in October and November and the sea-ice loss over the Barents and Kara seas in November and December produce same-signed mid-tropospheric geopotential height patterns over Eurasia. This planetary wave configuration is favourable for increased vertical propagation of Rossby waves from the troposphere into the stratosphere.

Increased vertical propagation of Rossby wave energy from the troposphere to the stratosphere weakens the polar vortex, resulting in a stratospheric warming event. These circulation anomalies resemble those associated with the negative phase of the NAO/AO.

Cohen et al. (2014)