


Evidence Linking Arctic Amplification with Changing Weather Patterns in Mid-Latitudes

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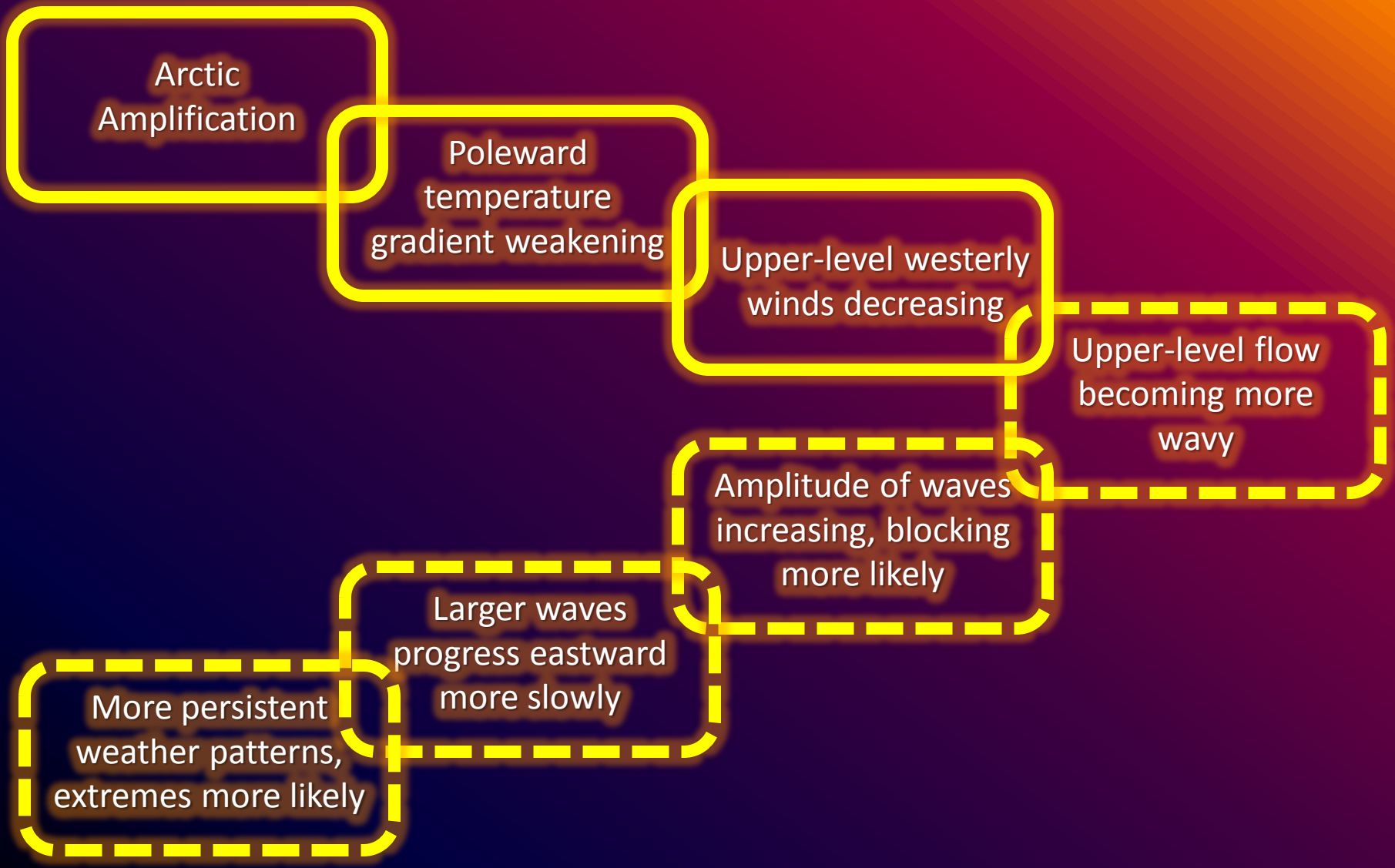
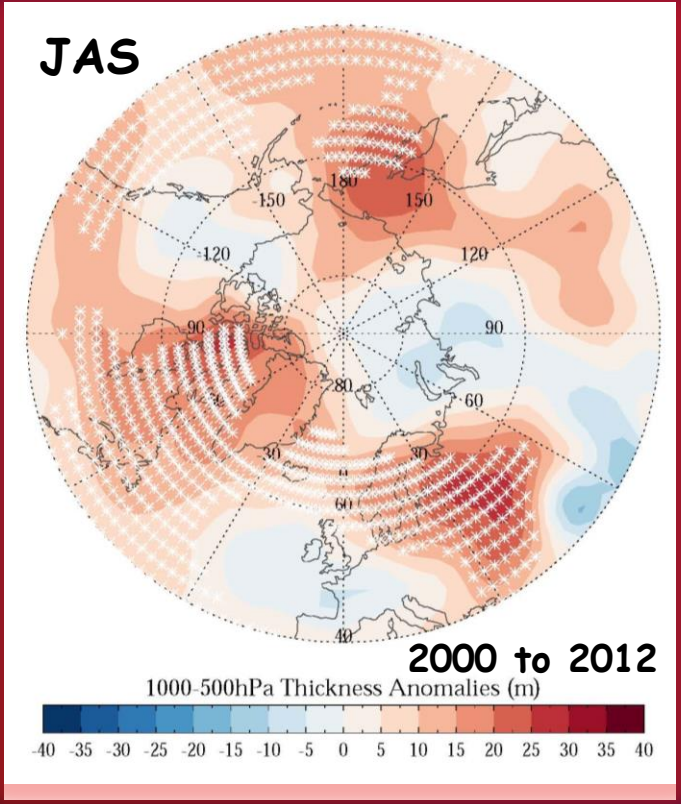
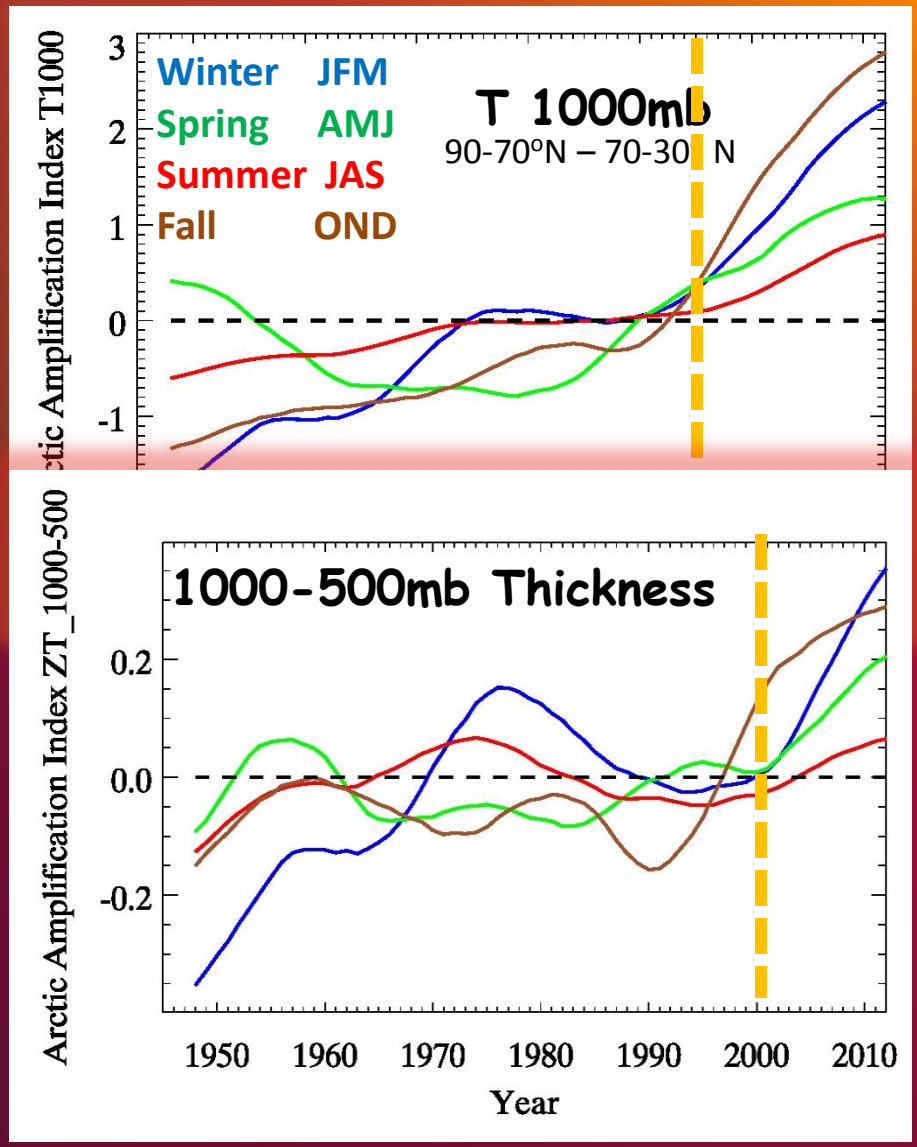
Chain of Events Linking Arctic Amplification (AA) with Increased Extreme Weather in Mid-Latitudes

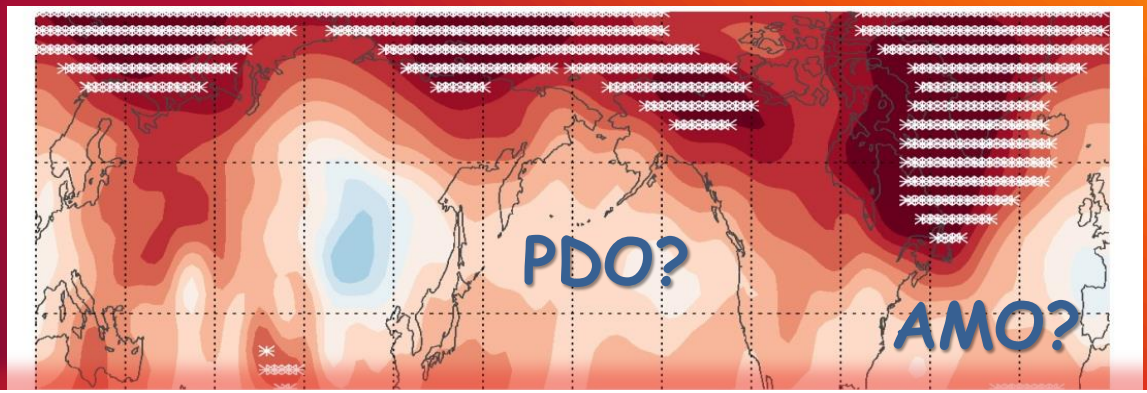


1 Arctic Amplification



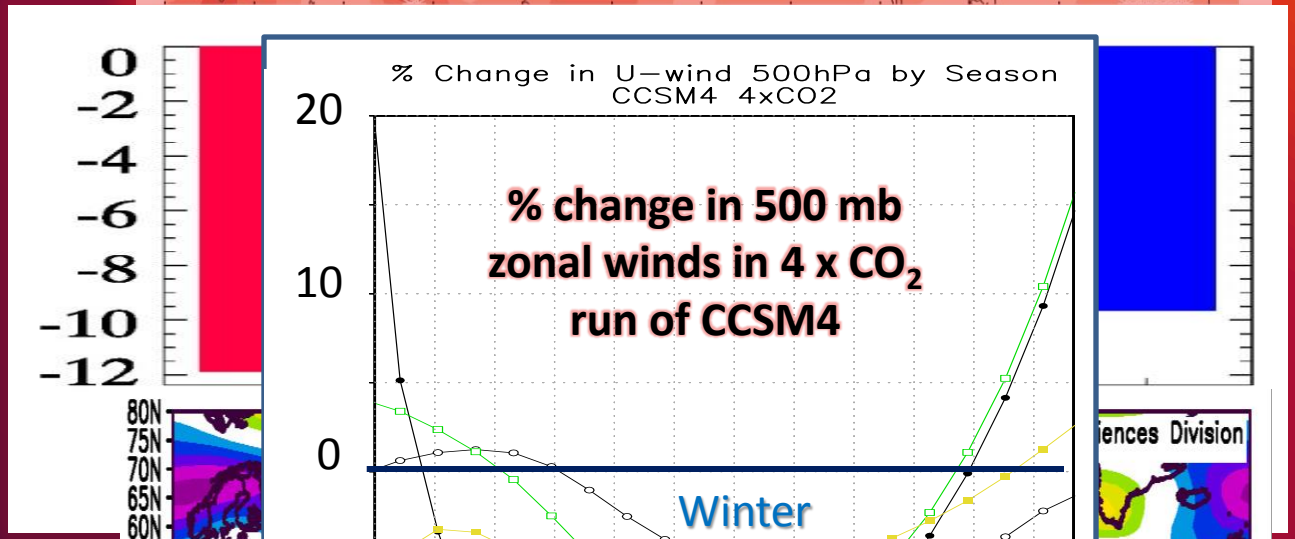


2 Poleward temperature gradient weakening



OND

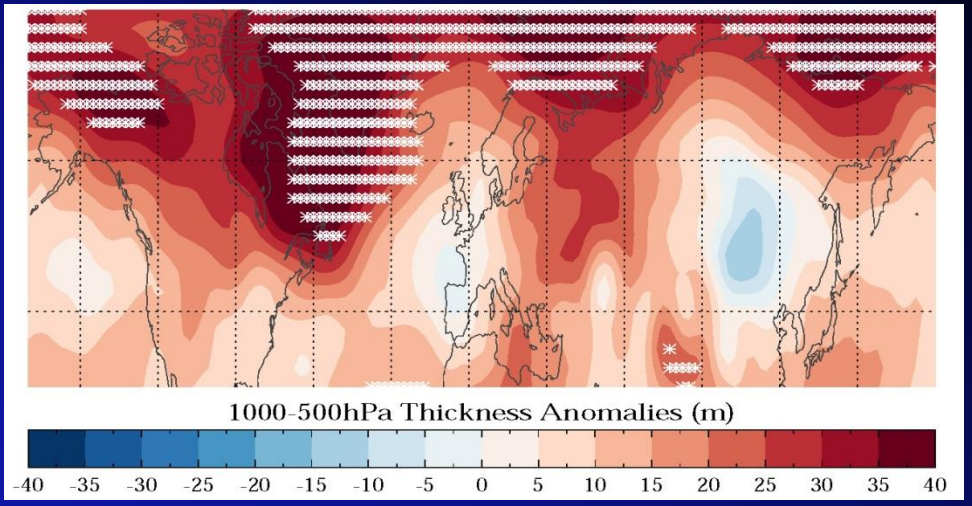
Trends in poleward thickness gradient (1000-500 hPa) from 1979 to 2012



3 Zonal winds decreasing where gradient weakens

4

Upper-level flow becoming more meridional



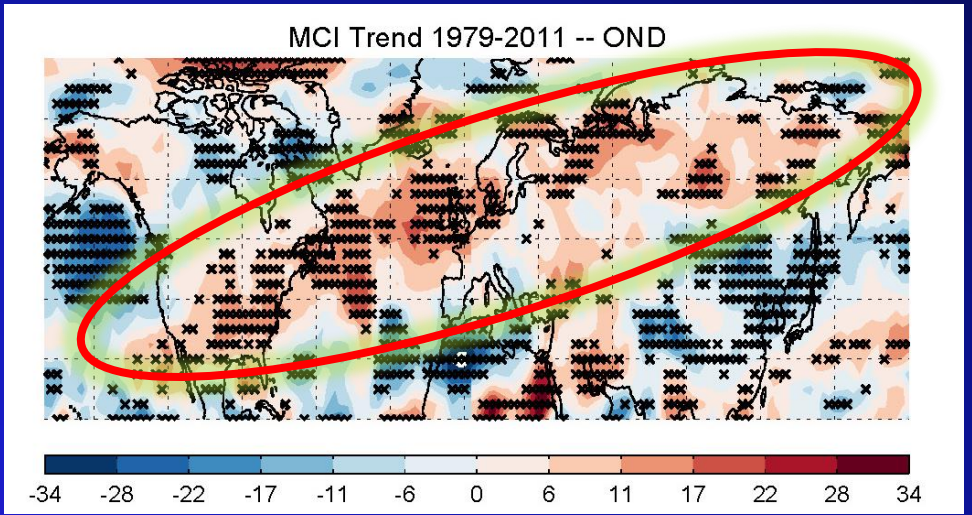
OND

CCSM4 4 x CO_2

Change in Meridional Wind Fraction @45°N

Trends in meridional component of the 500 hPa wind (1979 to 2011)

Winter	+33%
Spring	+21%
Summer	+21%
Fall	+19%



5

Amplitude of waves increasing, blocking more likely

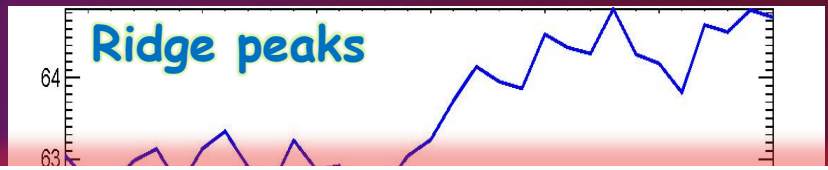
Francis and Vavrus, GRL 2012

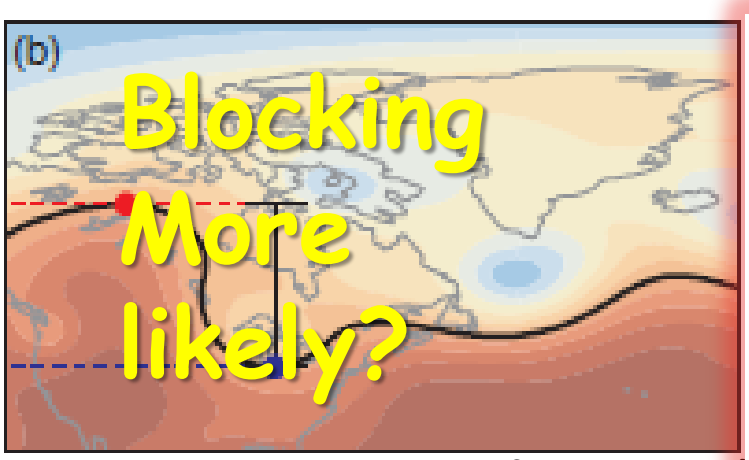
5

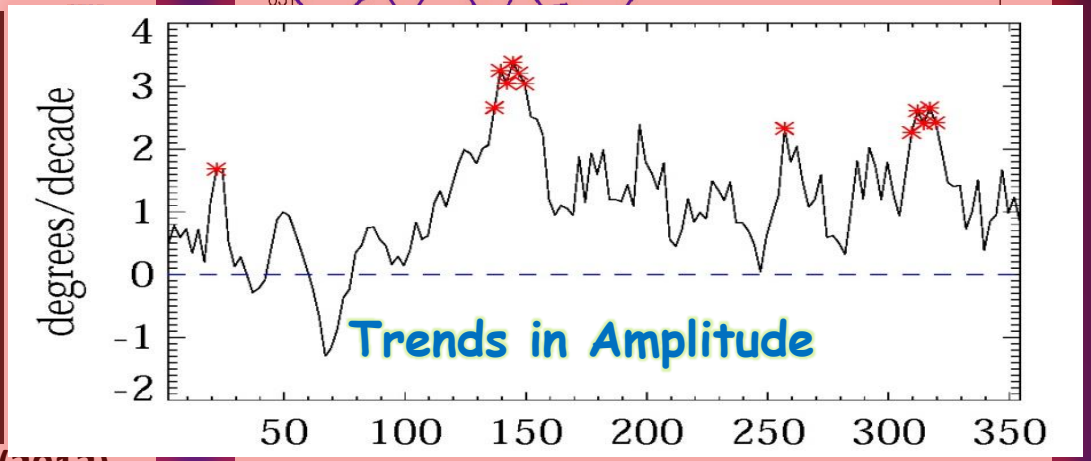
Amplitude of waves increasing, blocking more likely

OND

Northern Hemisphere

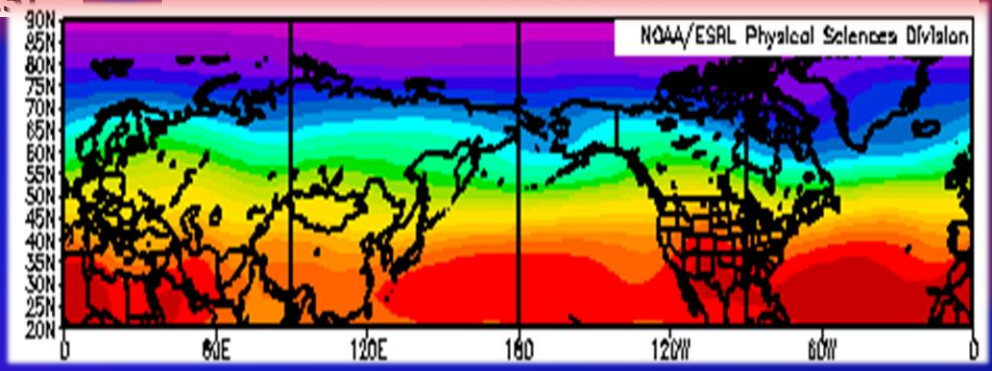






from Barnes (2013)

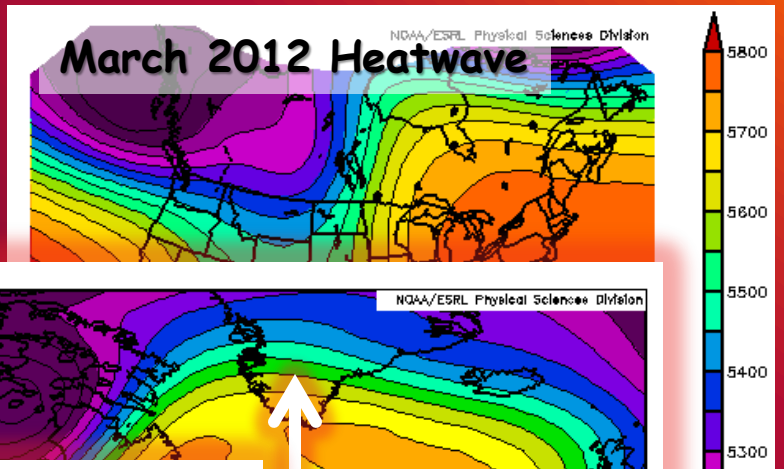
500mb heights
2000-2012

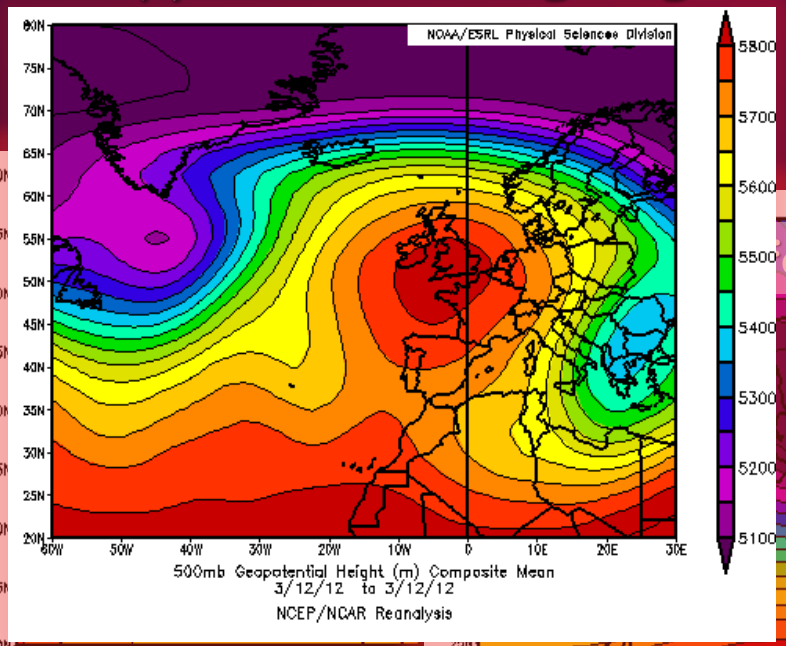


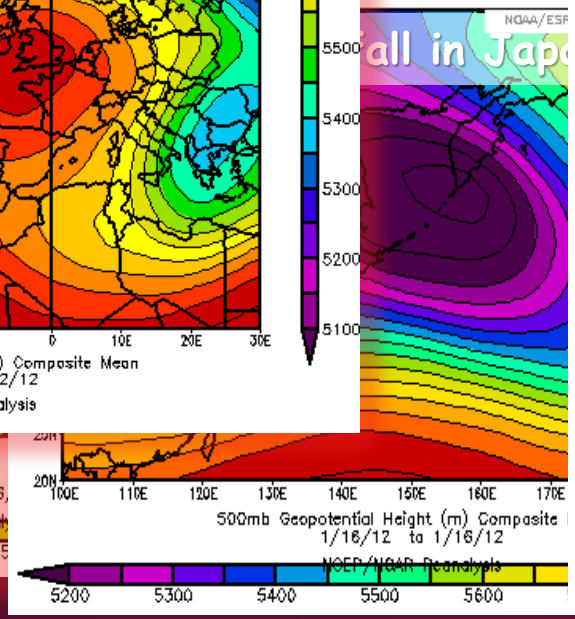
5

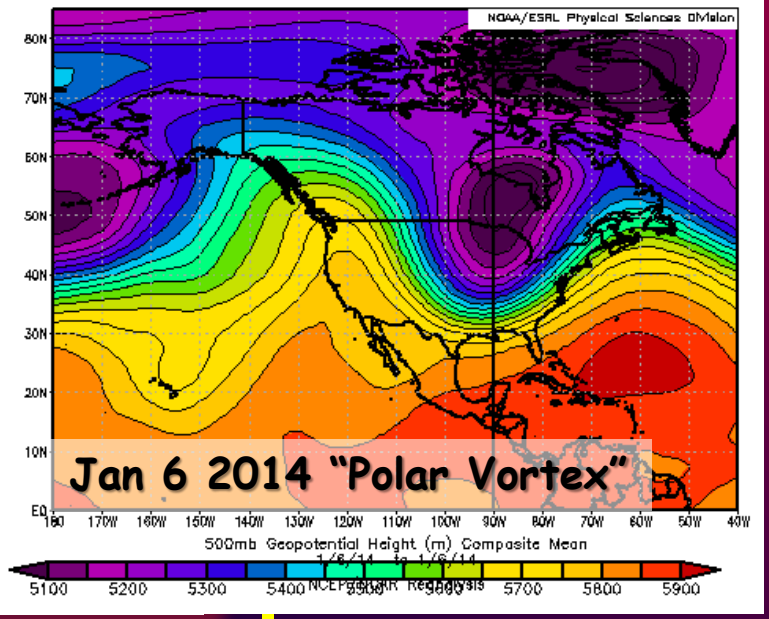
Amplitude of Rossby waves increasing, blocking more likely

Blocking => "Extreme Waviness"
A typical blocking high

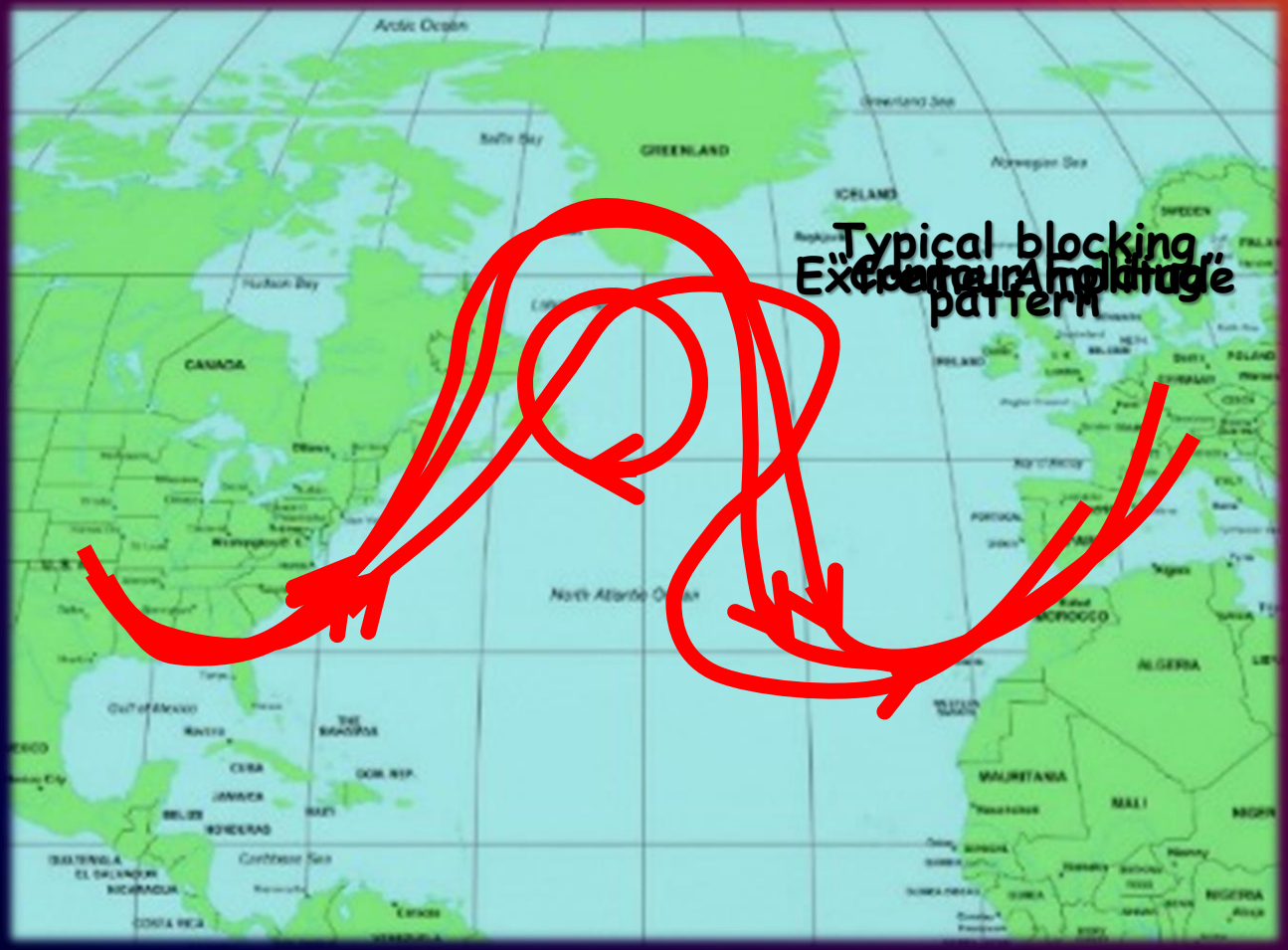








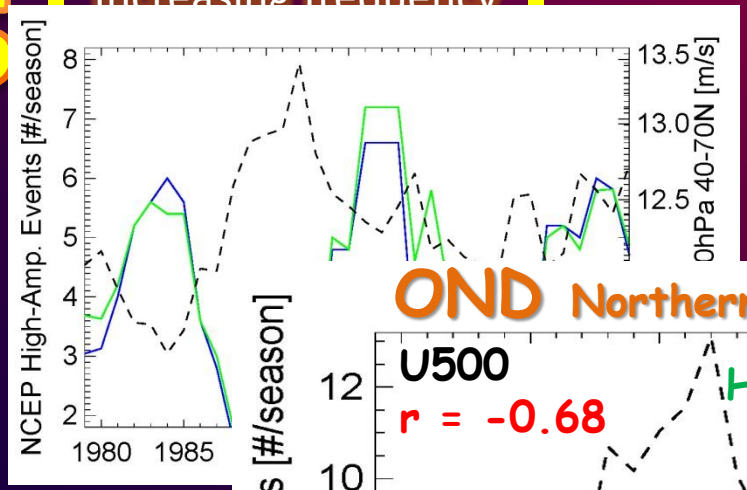
Types of "Extreme Waviness"

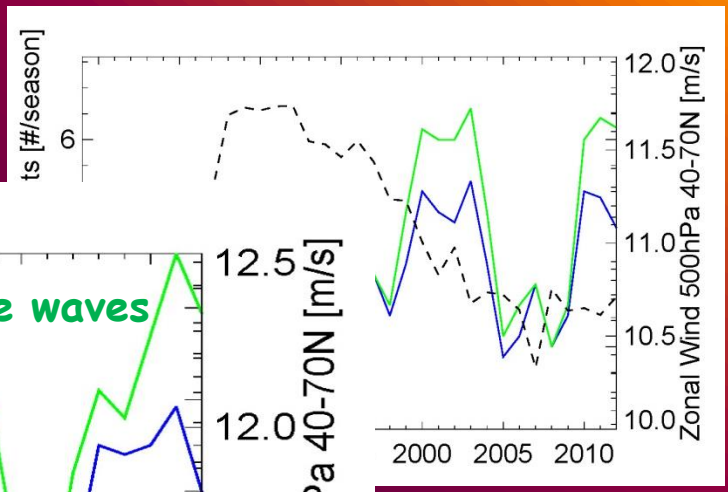


Count "extreme waves" exceeding 40° latitude

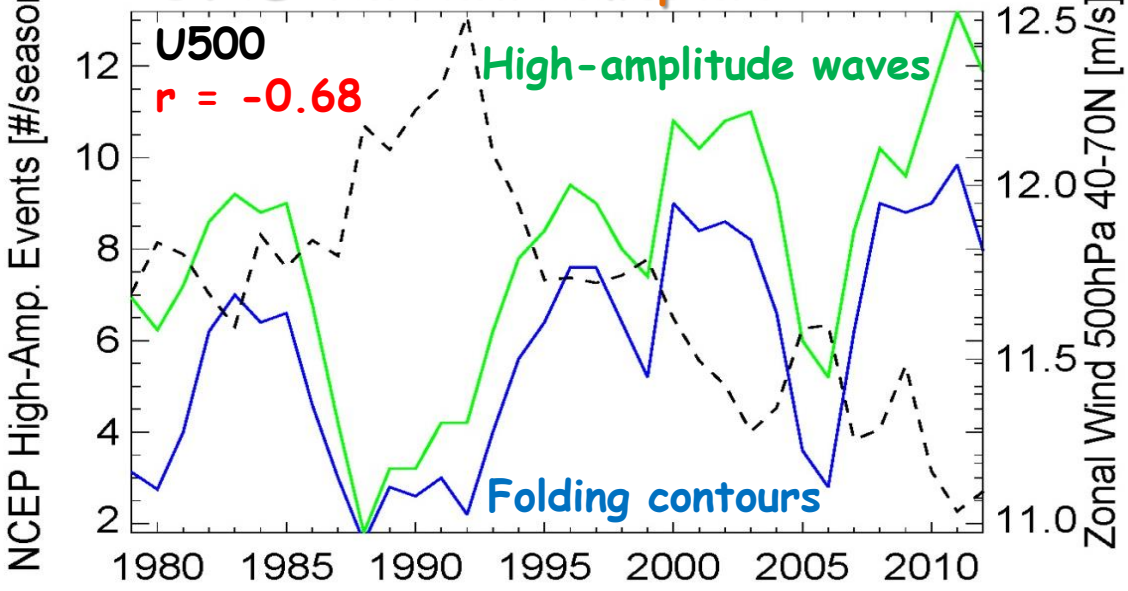
5

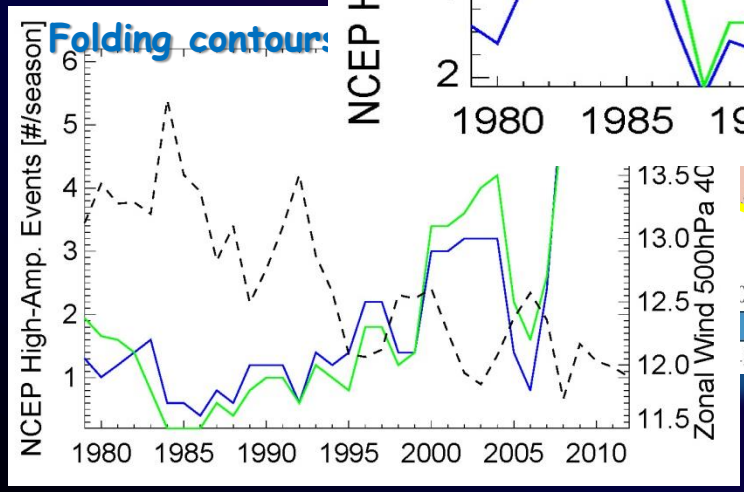
Increasing frequency

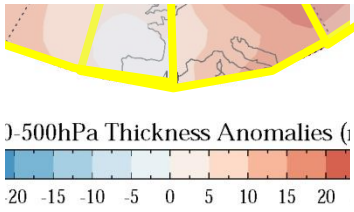


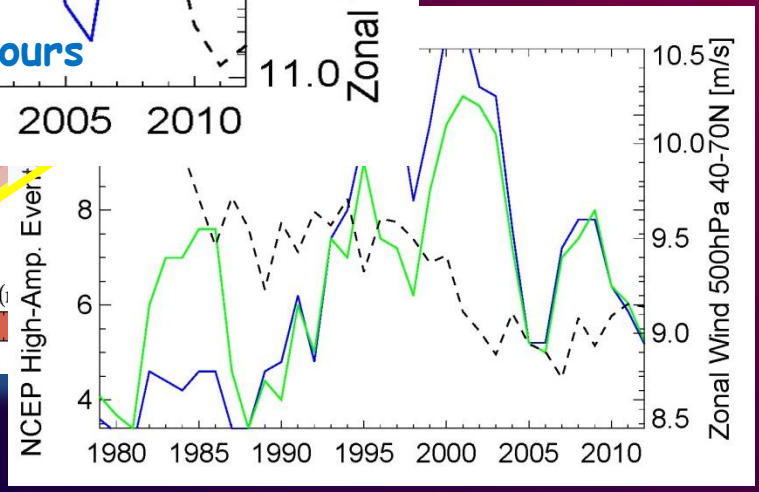


OND Northern Hemisphere



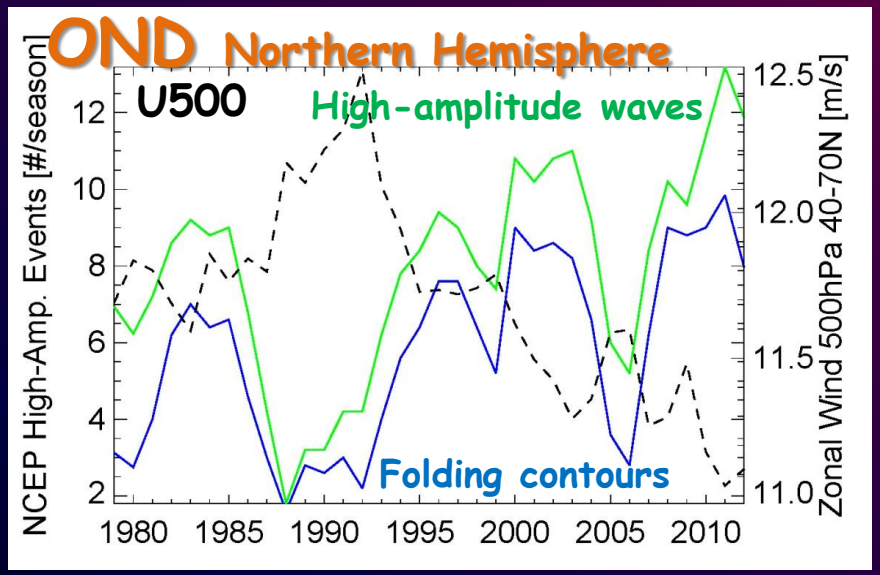


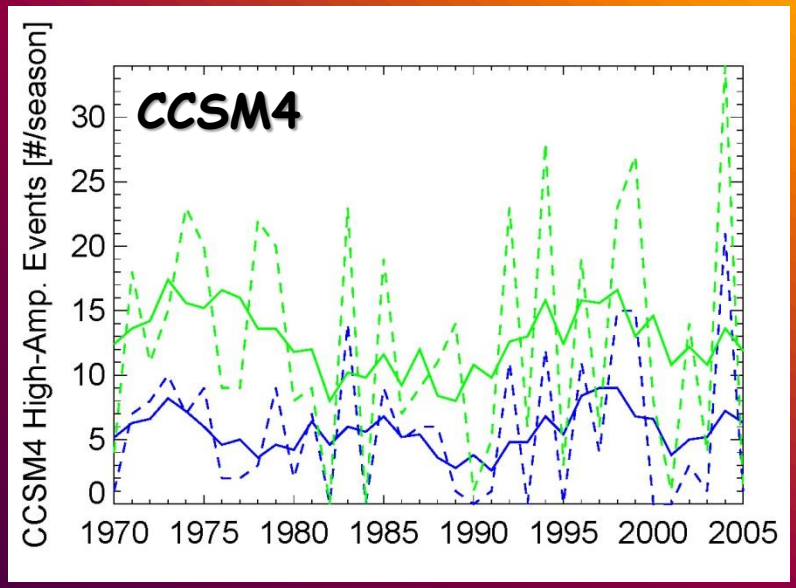


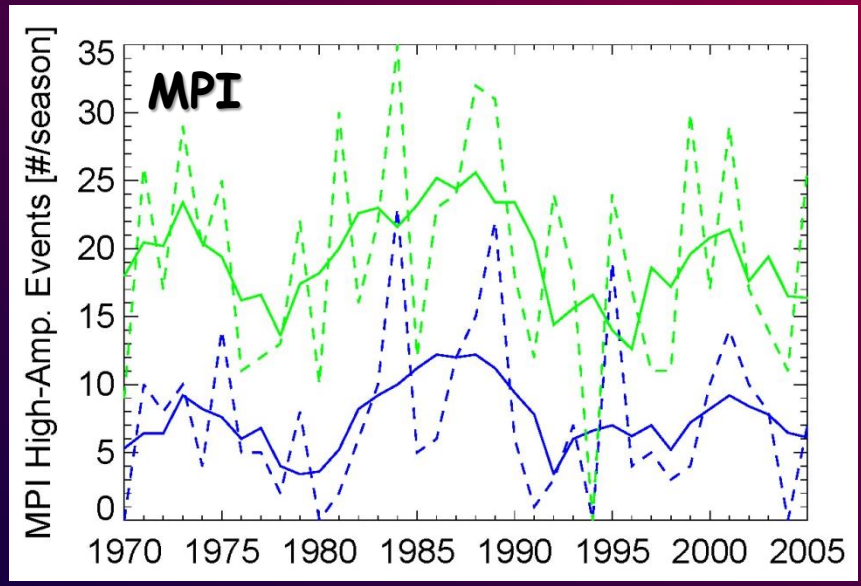


5 Increasing frequency of large waves

Do GCMs capture this behavior?
=> 4 members of CMIP5:

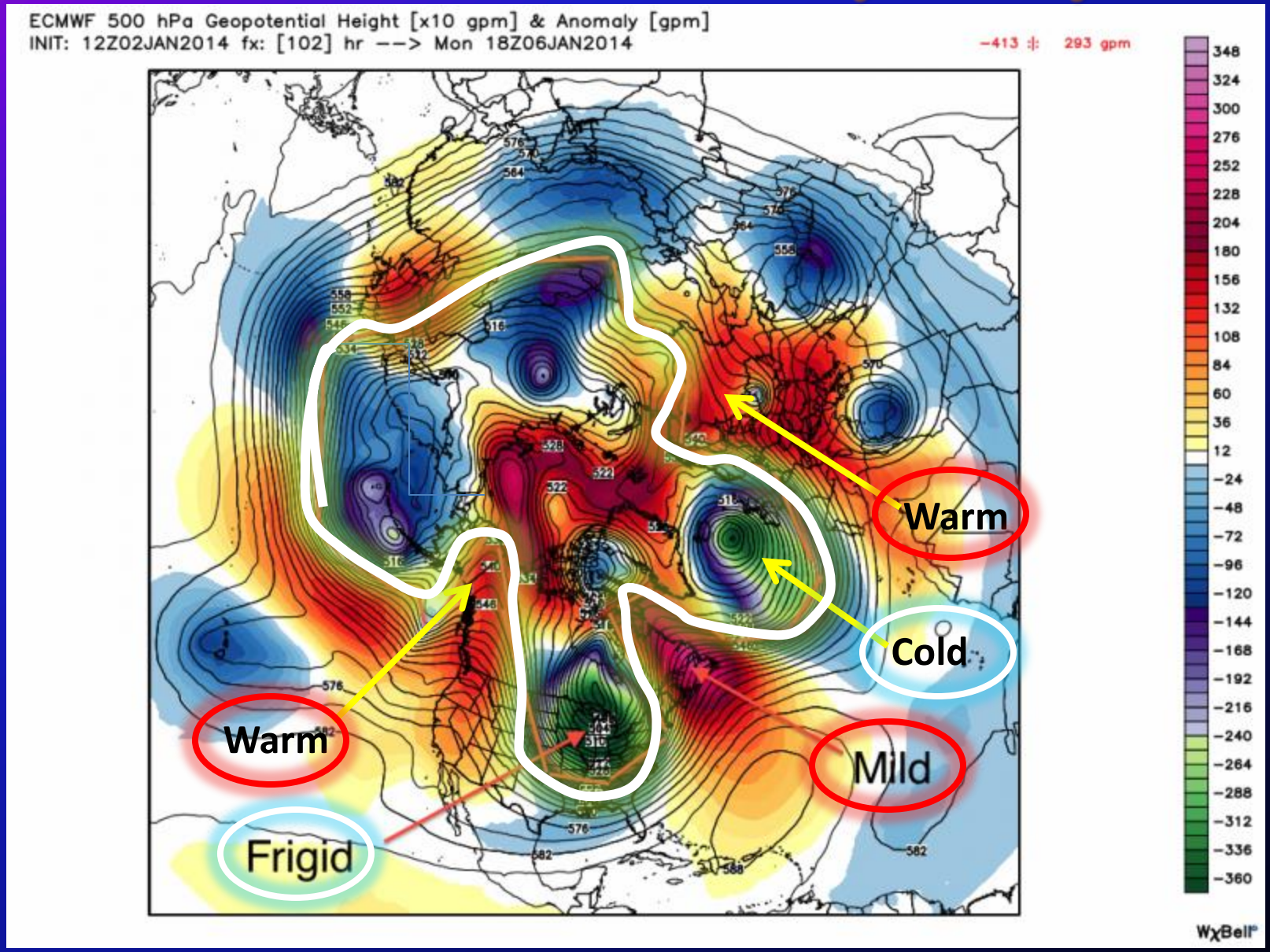






Models seem to capture about the right number, some have increasing trends, some not.

Attack of the Polar Vortex – Early January 2014



Summary

- Some links in the chain are solid:
  - AA is emerging in all seasons, strongest in fall and winter
  - Poleward gradients weakening, but seasonally and spatially variable
  - Where gradients weaken, upper-level zonal winds decrease, flow becomes more meridional (wavy)
- Others not so much:
  - Changing amplitude and propagation speed of large-scale waves, mechanism linking to AA unconfirmed
  - Changing frequency of persistent weather patterns?
  - Interactions among AA and other large-scale influences (ENSO, PDO, NAM, PNA, stratosphere, etc.)?

Thank-you!

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Extras

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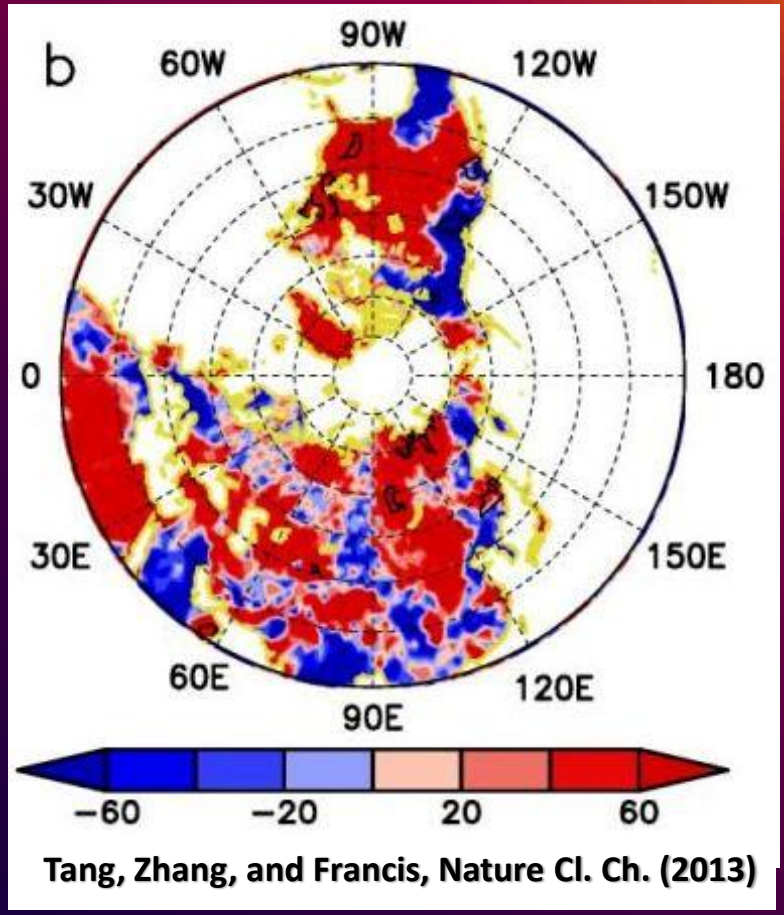
More persistent weather patterns, extremes more likely

Summer heat waves

Enhanced loss of sea-ice and snow cover associated with heat wave influence of ice influence is stronger



Tang, Zhang, and Francis, Nature Cl. Ch. (2013)

4

Upper-level flow becoming more meridional

OND

CCSM4 4 x CO_2

Change in Meridional Wind Fraction @45°N

Trends in meridional component of the 500mb wind (1939 to 2011)

Winter	+39%
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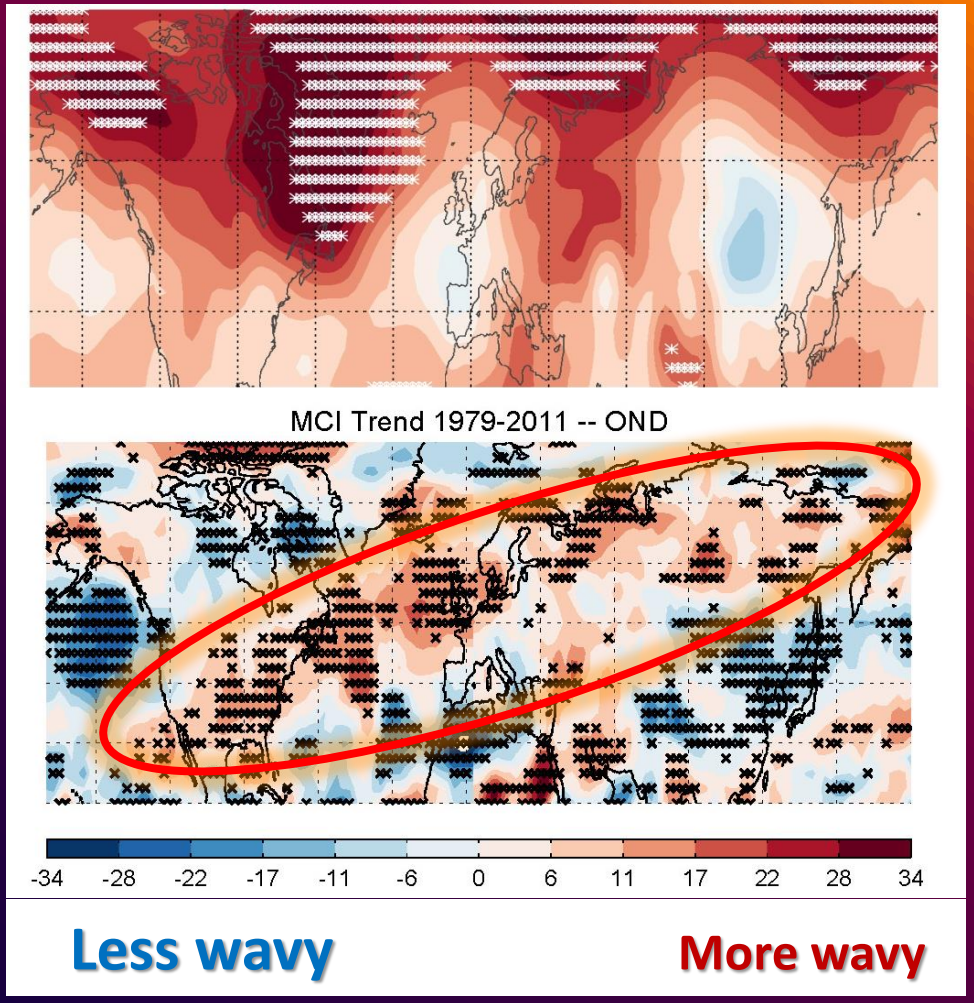
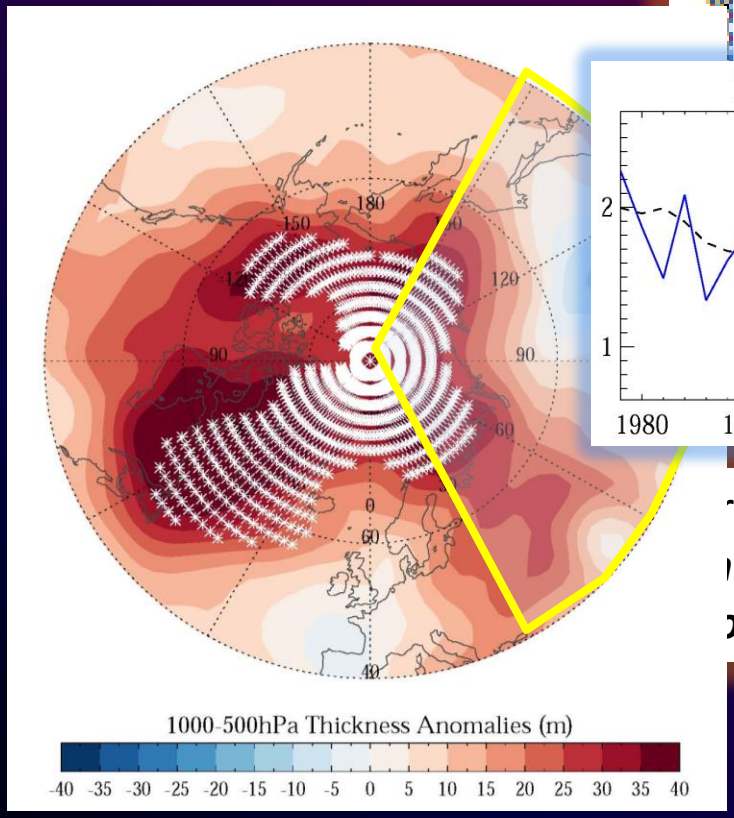
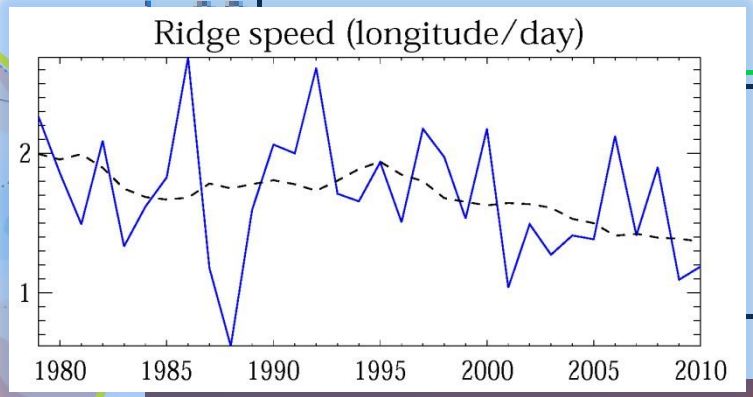


6

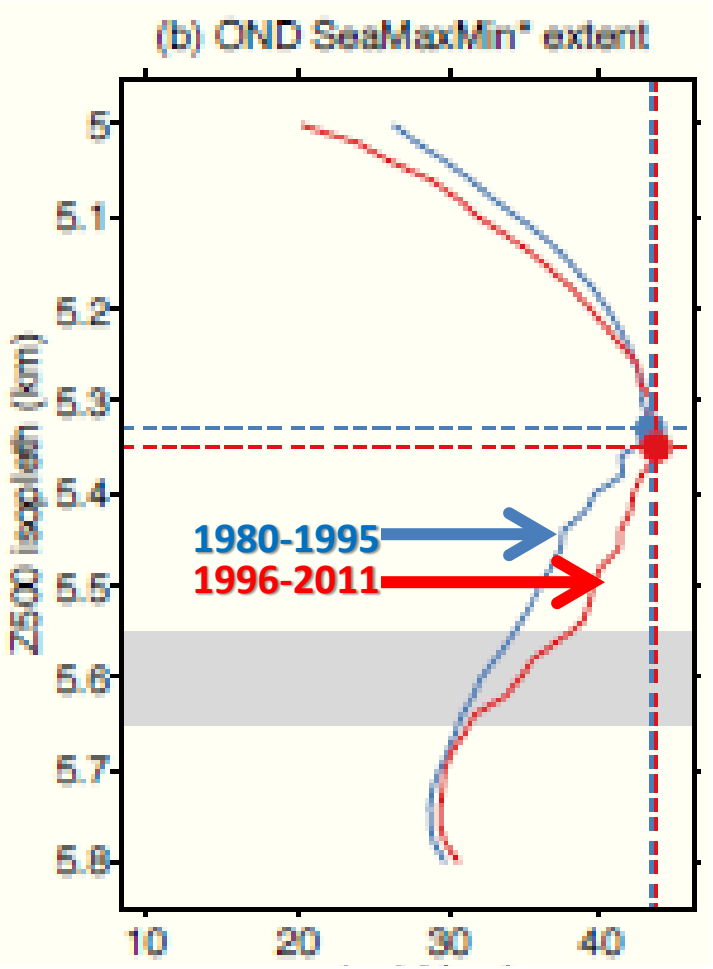
Large-scale waves progress more slowly eastward





om Barnes (2013) ***"We find a robust decrease wave phase speeds in OND, which is onsistent with the u500 reductions."***

An Artifact of the Methodology?

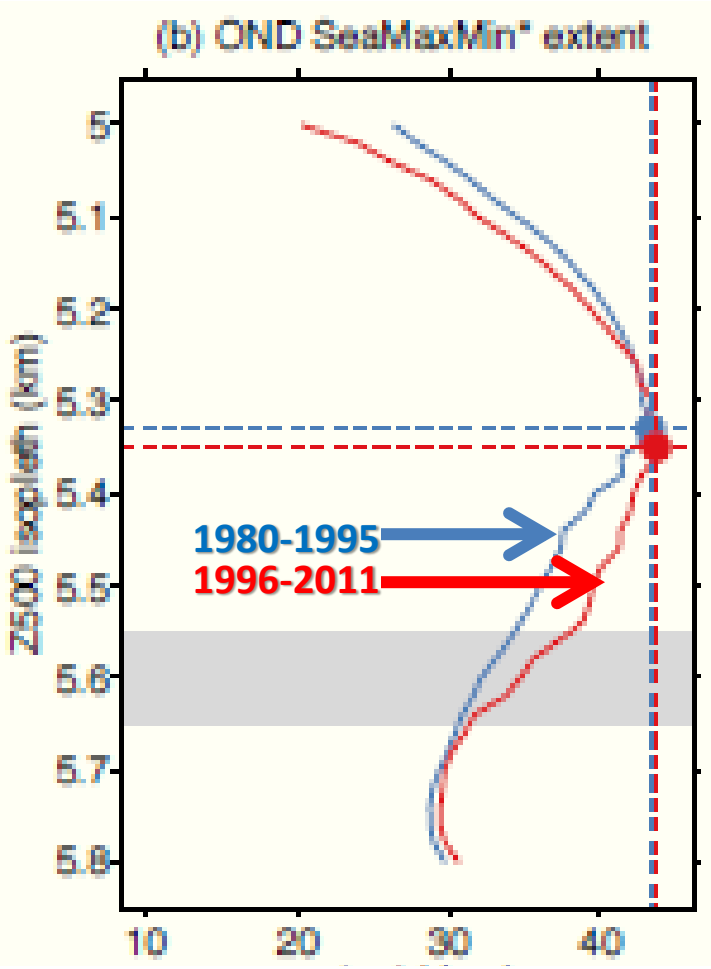


Wave amplitude (deg. latitude)
from Barnes (2013)

500 mb height with maximum waviness

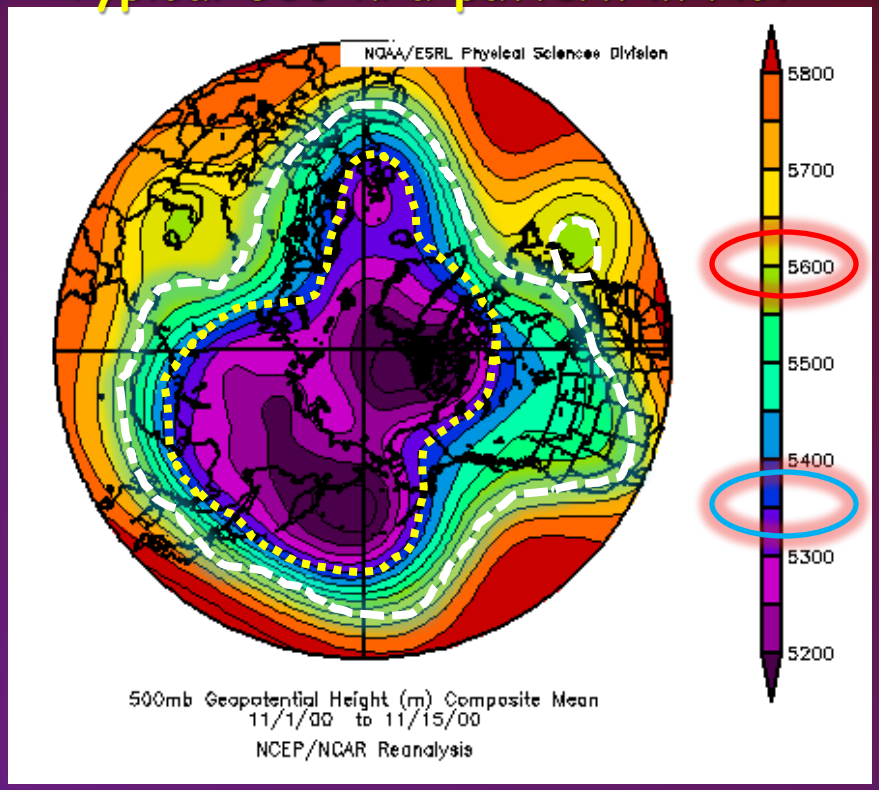
500 mb height contour used in FV12

An Artifact of the Methodology?



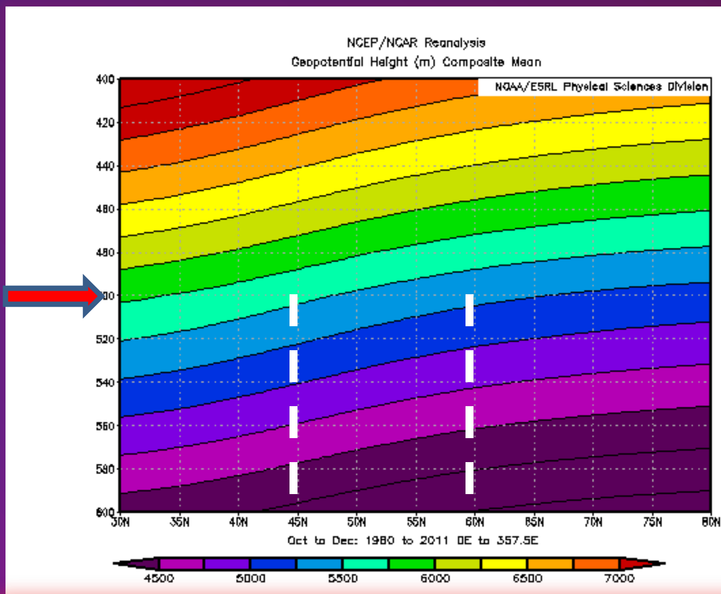
Wave amplitude (deg. latitude)
from Barnes (2013)

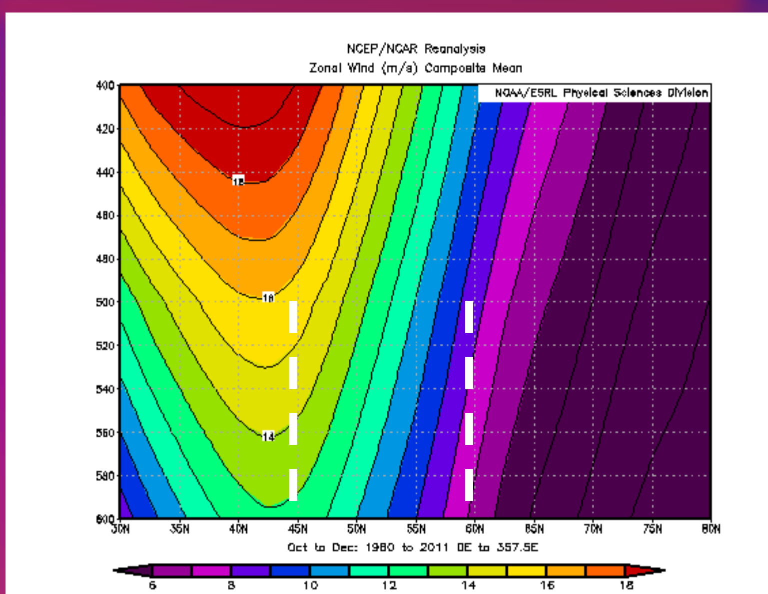
Typical 500 hPa pattern in Nov

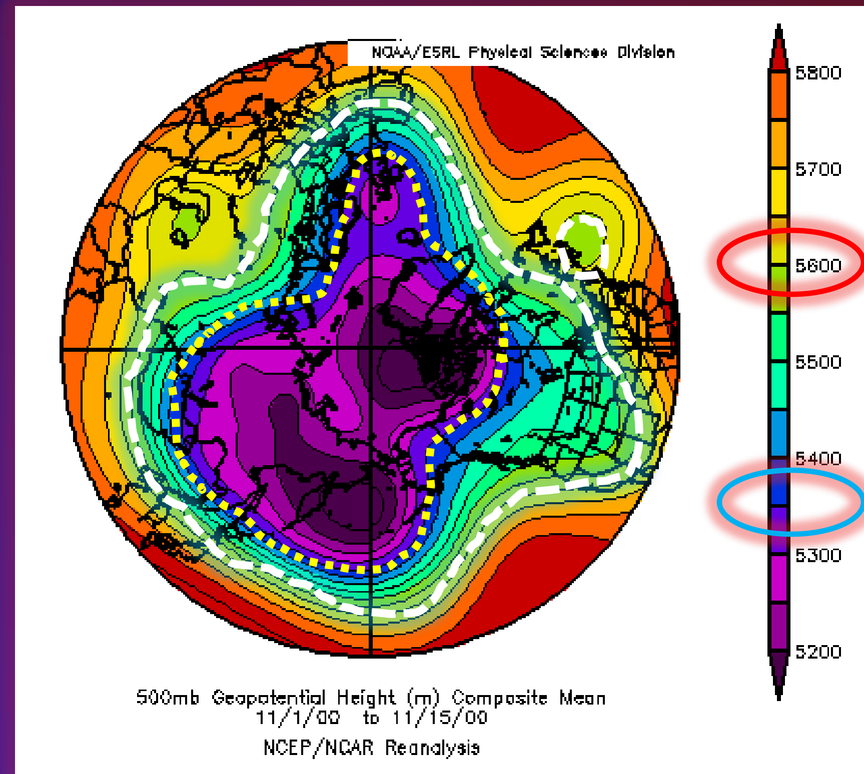


Contour with max waviness has different shape from FV12's contour in max gradient

An Artifact of the Methodology?

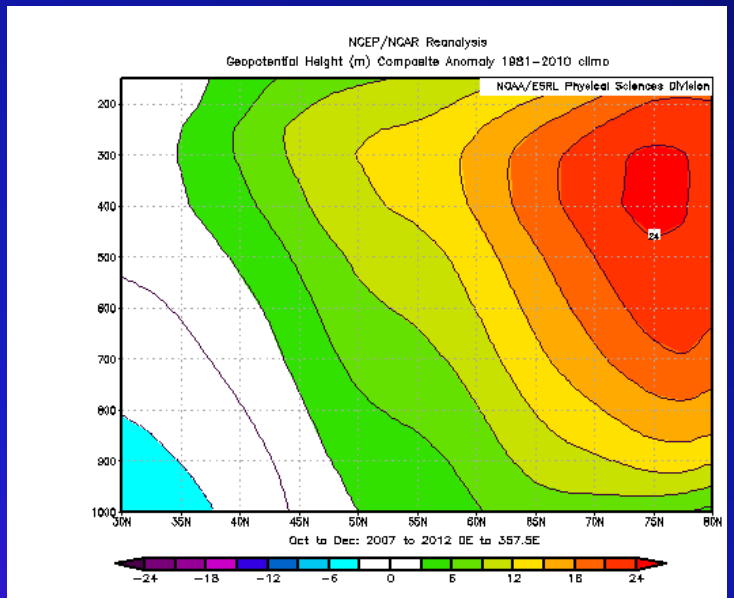


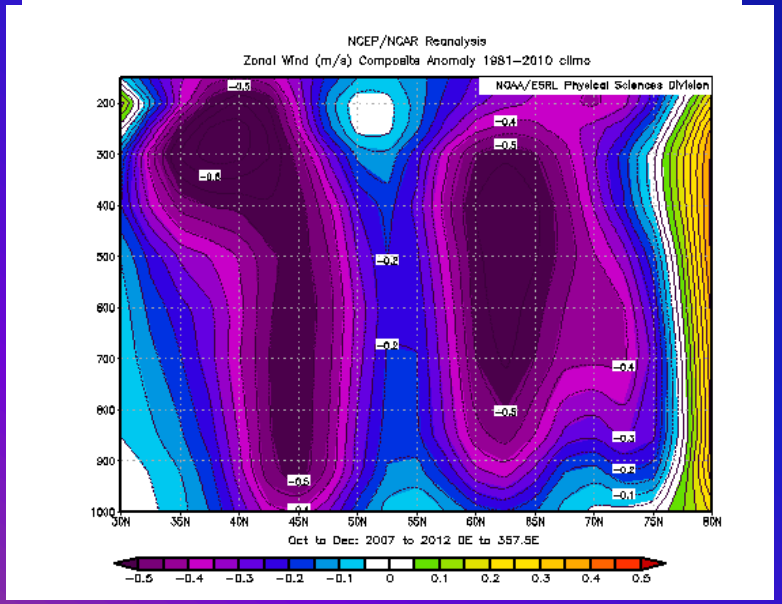


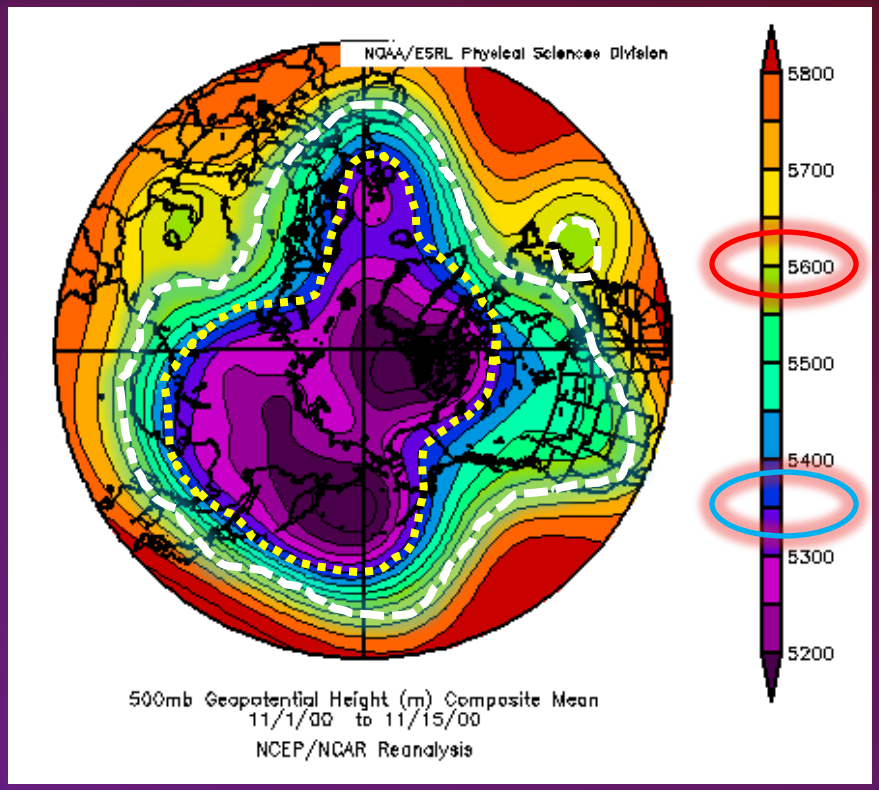


Contour with max waviness has 15° farther north from max wind zone, not representative of jet stream trajectory.

Contour with max waviness is a different shape from FV12's contour gradient.







Anomalies in zonal-mean heights and zonal winds for OND 2007-2012