A role for barotropic eddy-mean flow feedbacks in the zonal wind response to sea ice loss and Arctic Amplification

BRYN RONALDS

CVCWG FEB. 27TH 2019

Eddies increase jet speeds in response to sea ice loss

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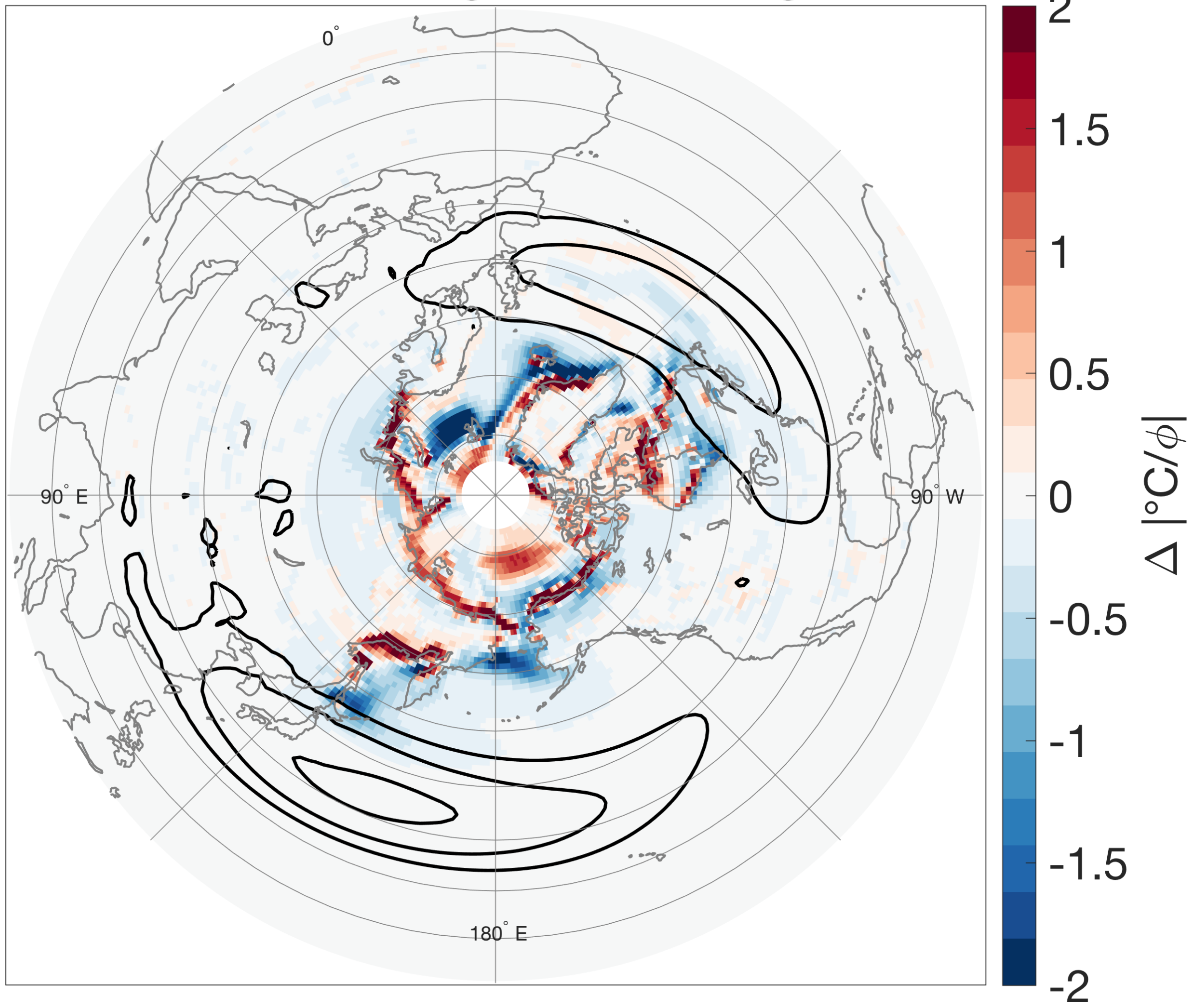
Background

In response to Arctic amplification and sea ice loss:

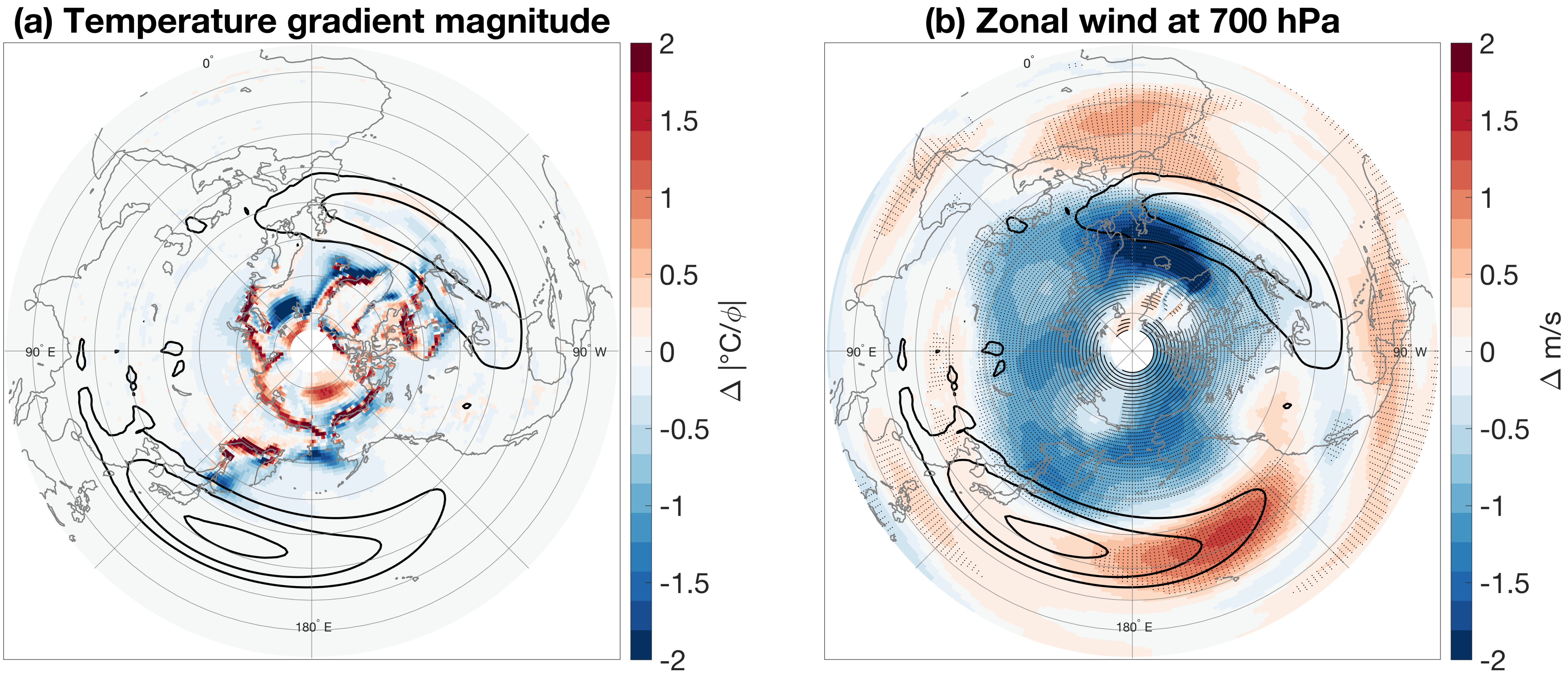
- Zonal mean eddy-driven jet stream weakens & shifts equatorward
- Big regional & seasonal differences
- North Atlantic jet generally weakens, but North Pacific jet strengthens

CCSM4: LOWICE - CONTROL

(a) Temperature gradient magnitude



CCSM4: LOWICE - CONTROL



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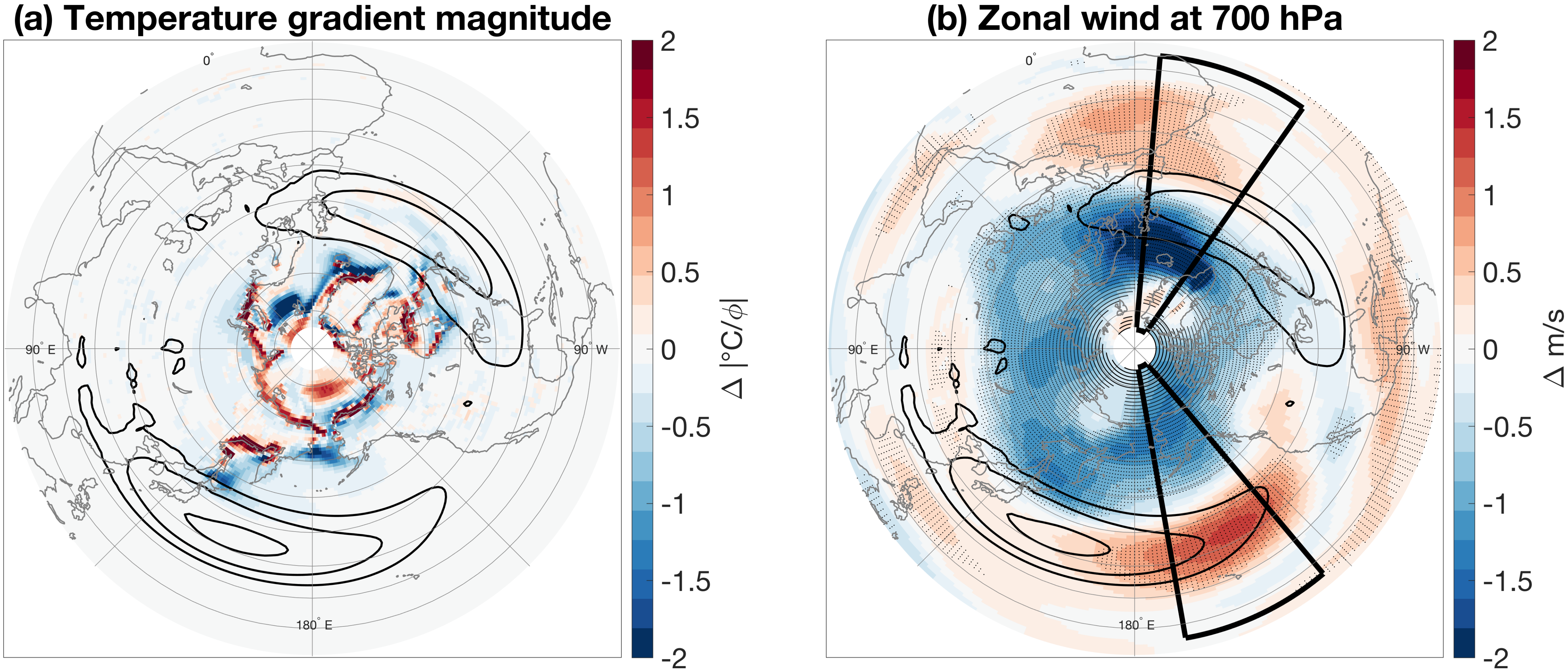
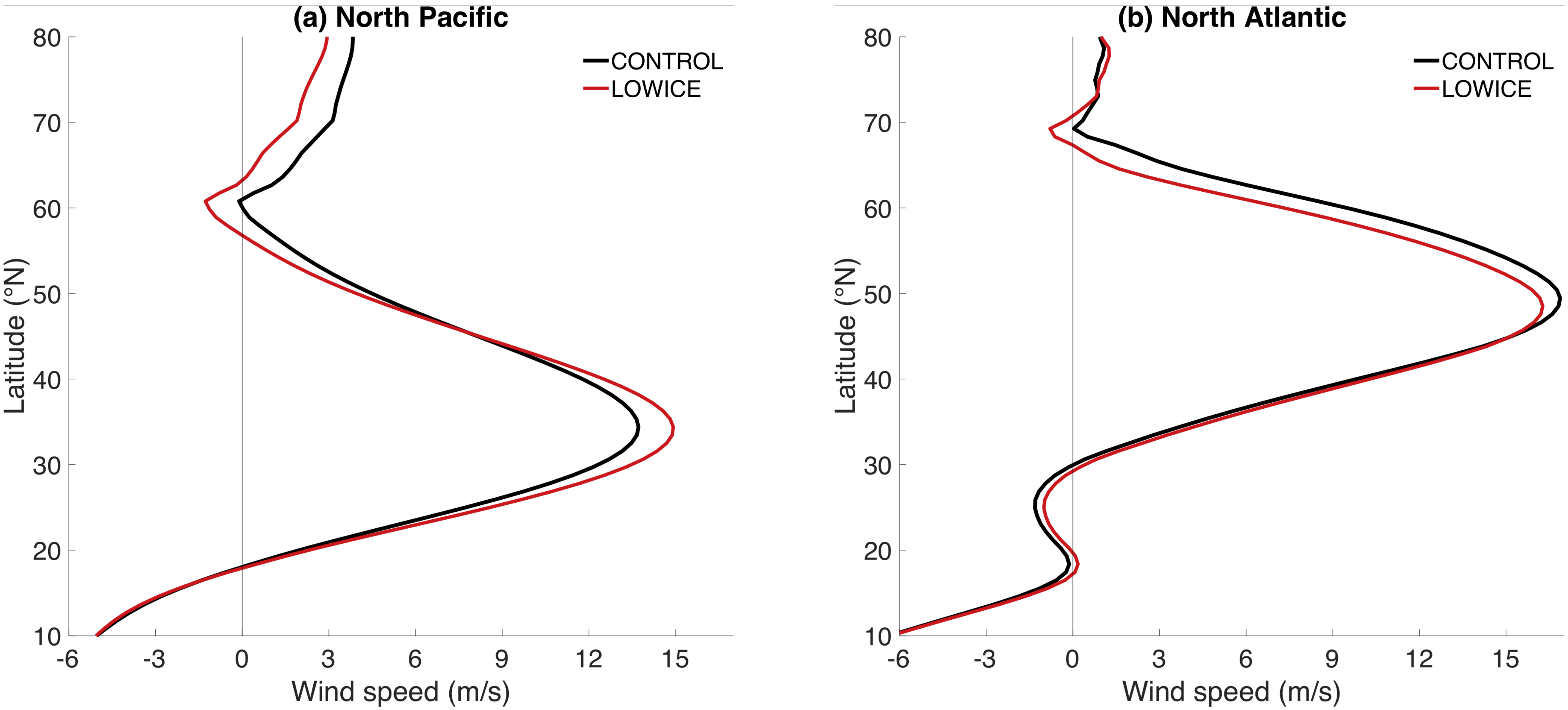


CCSM4: Zonal mean U at 700 hPa



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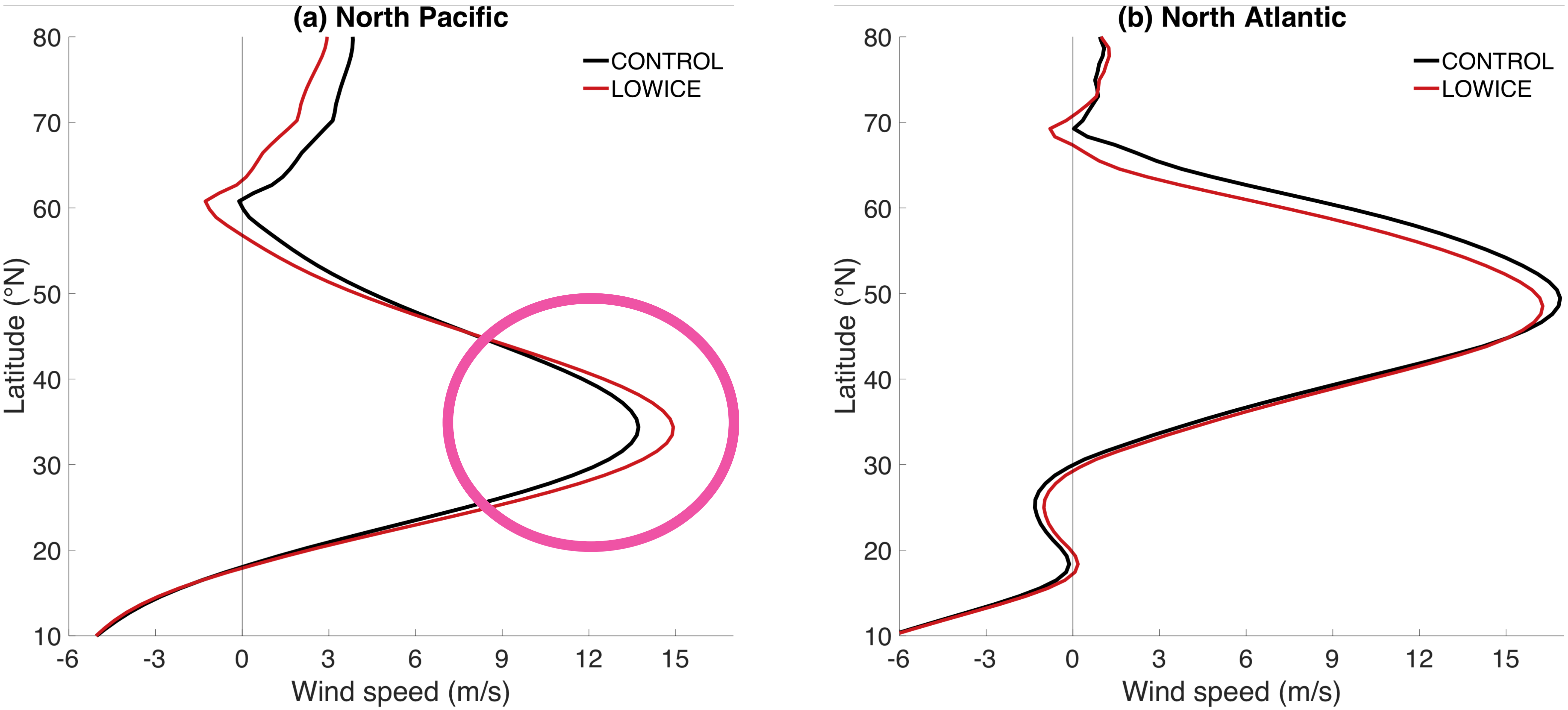

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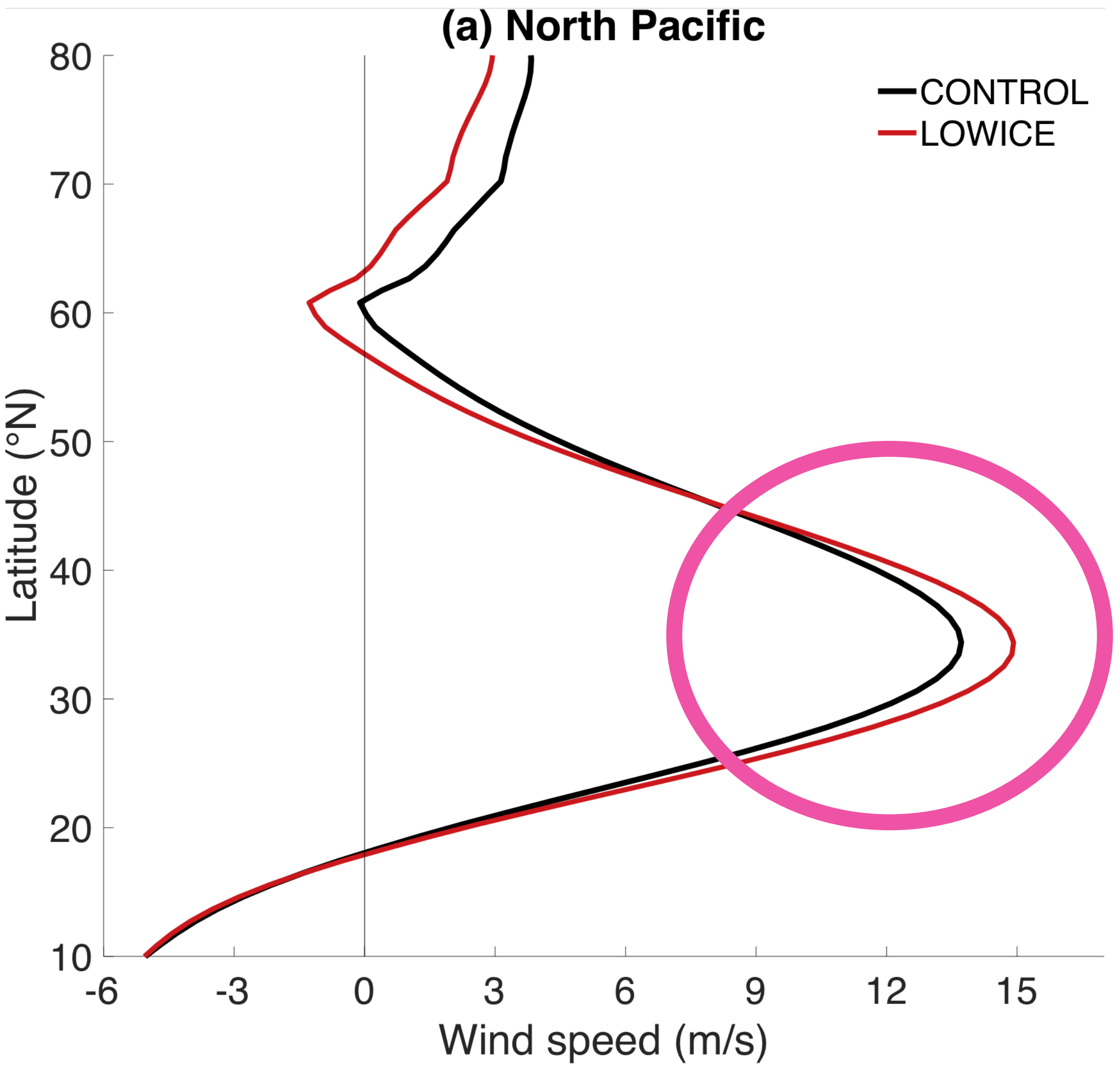

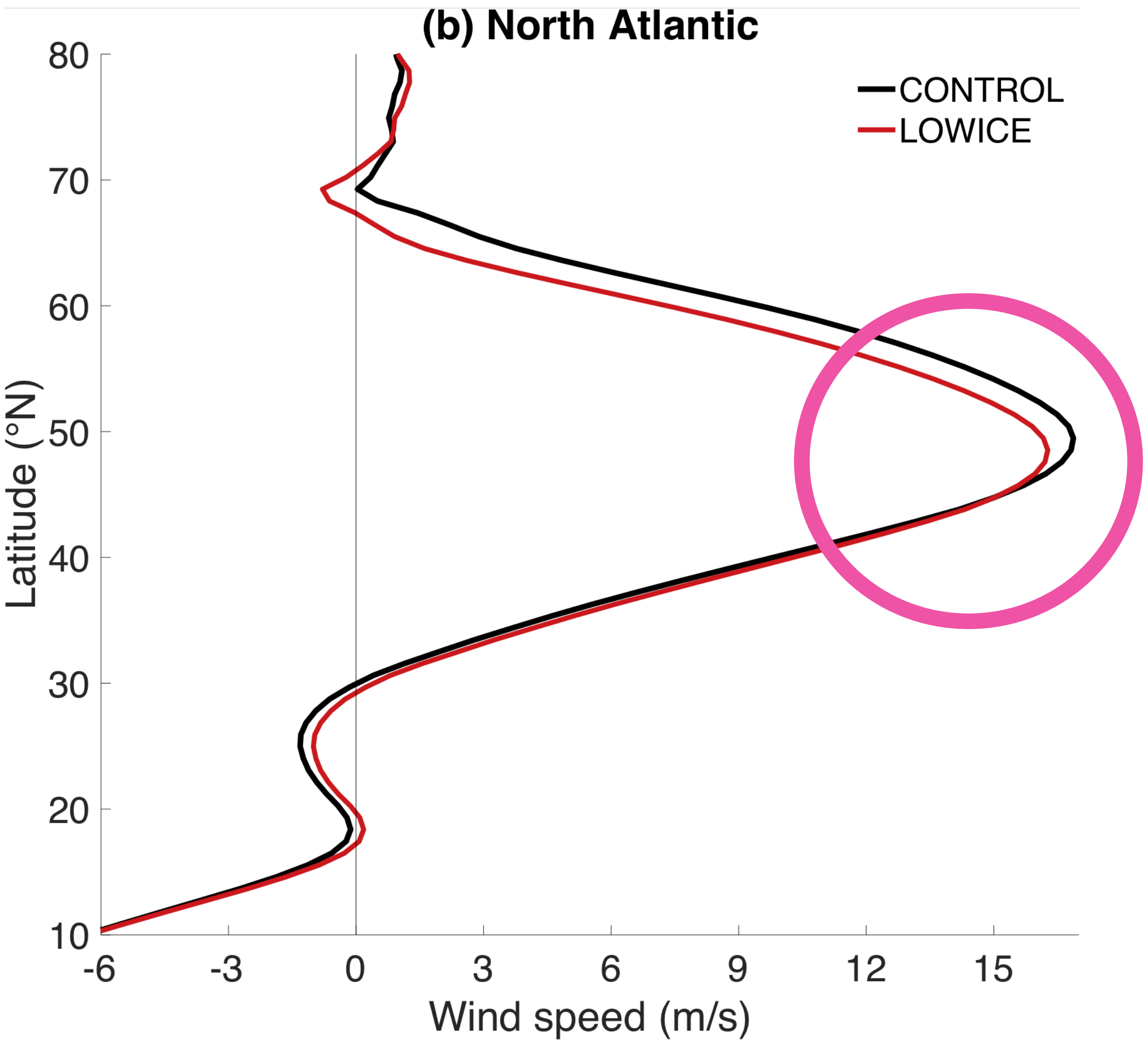

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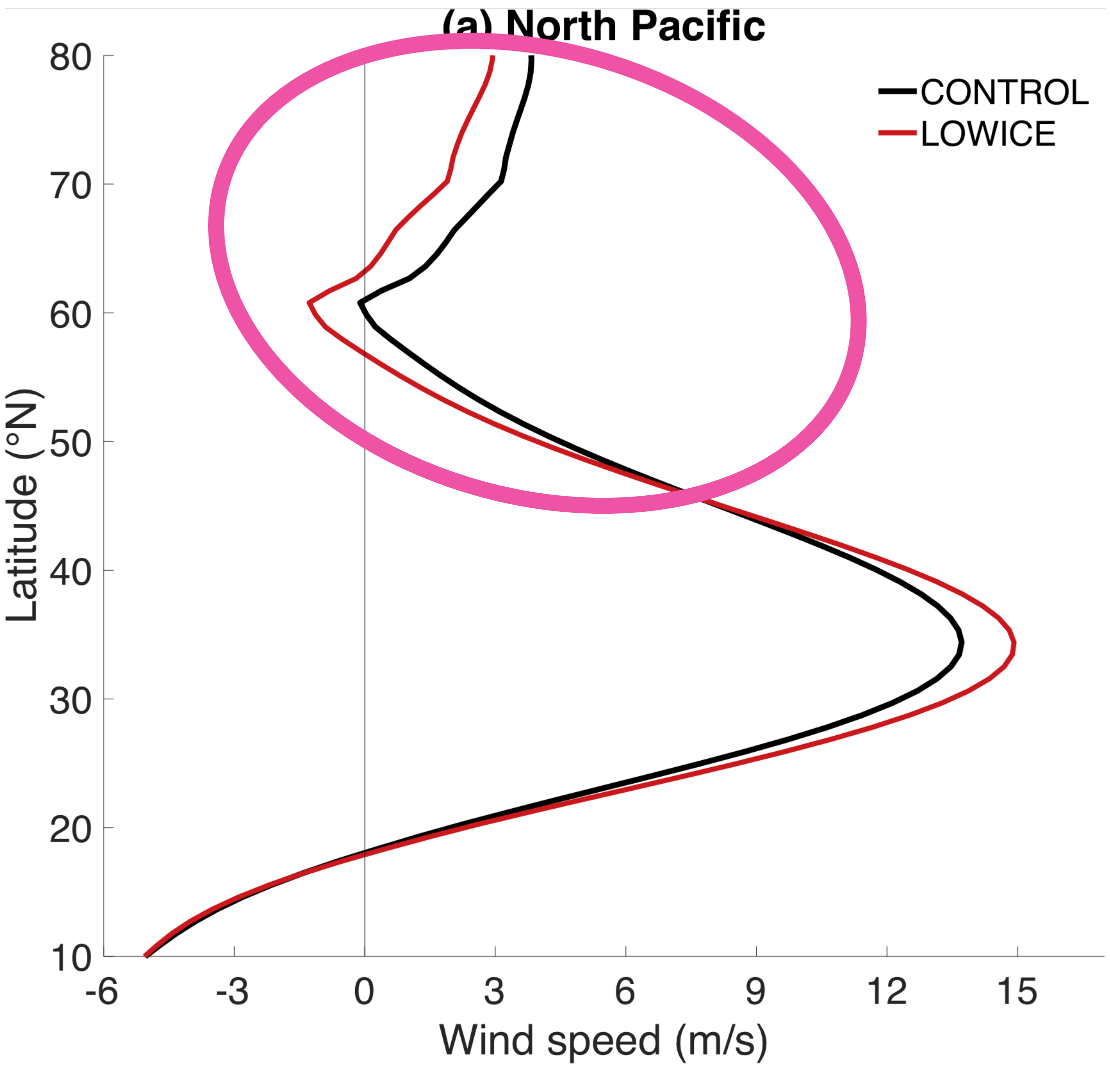
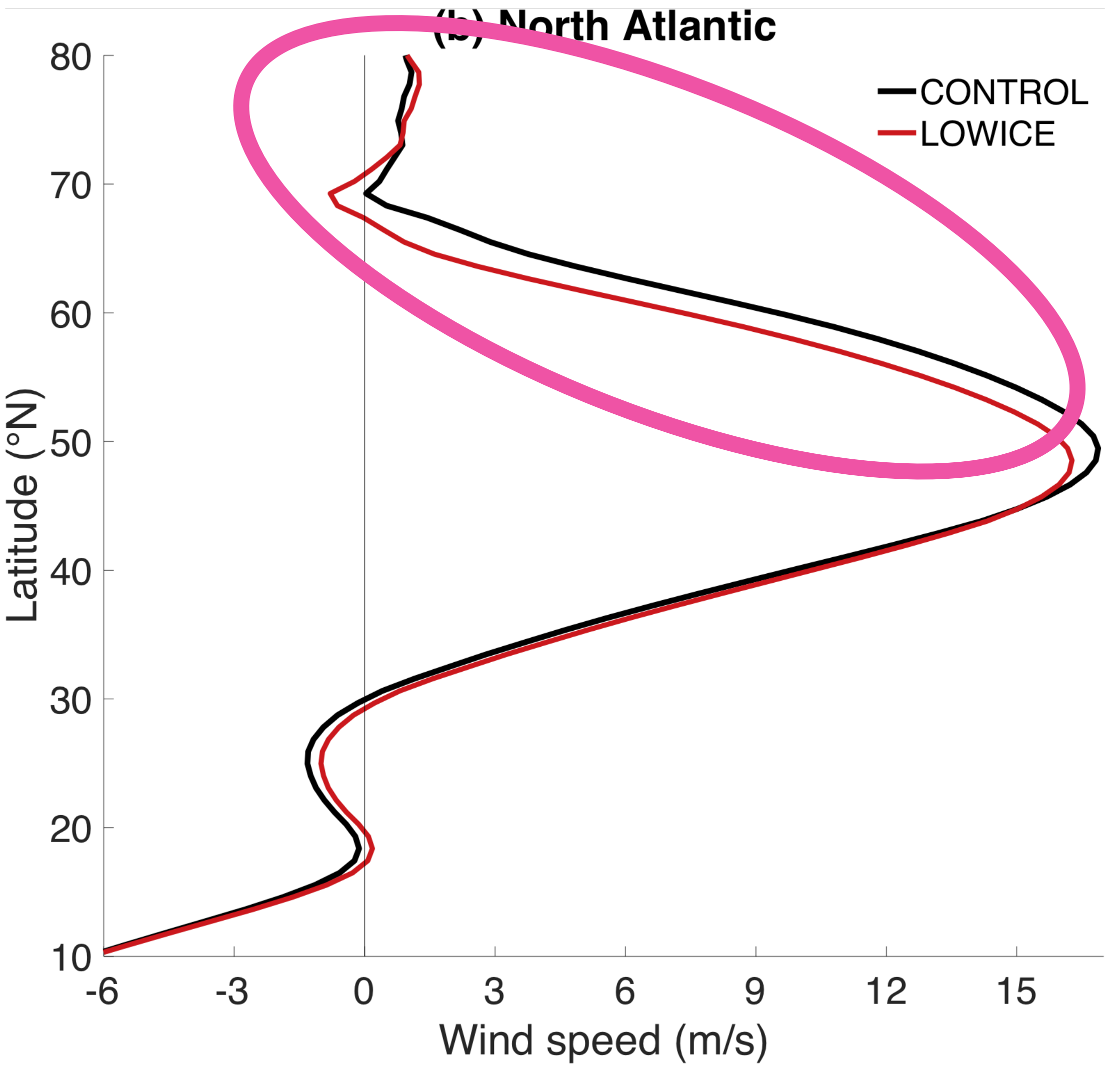
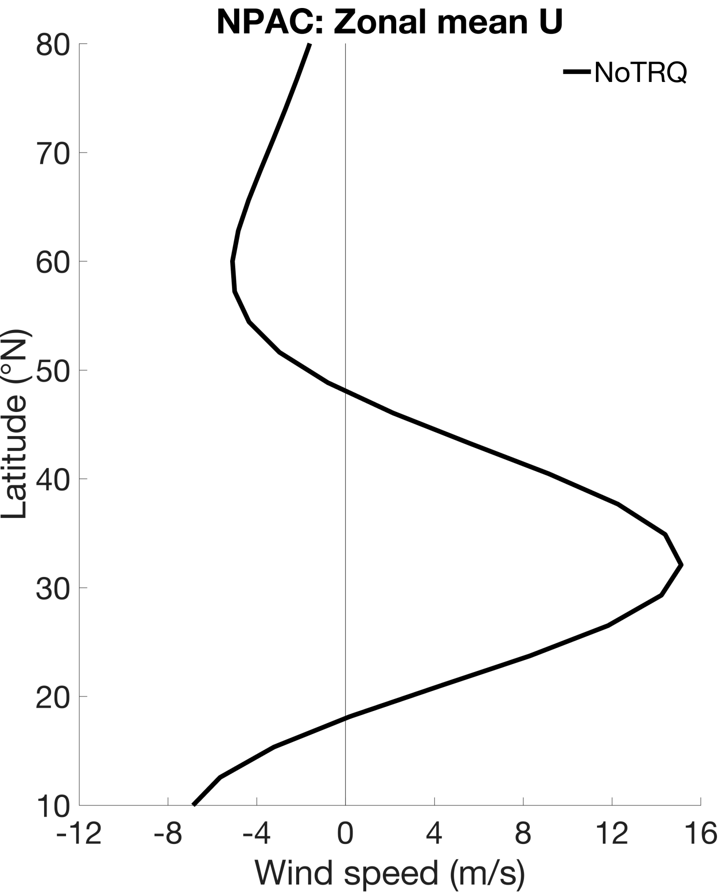




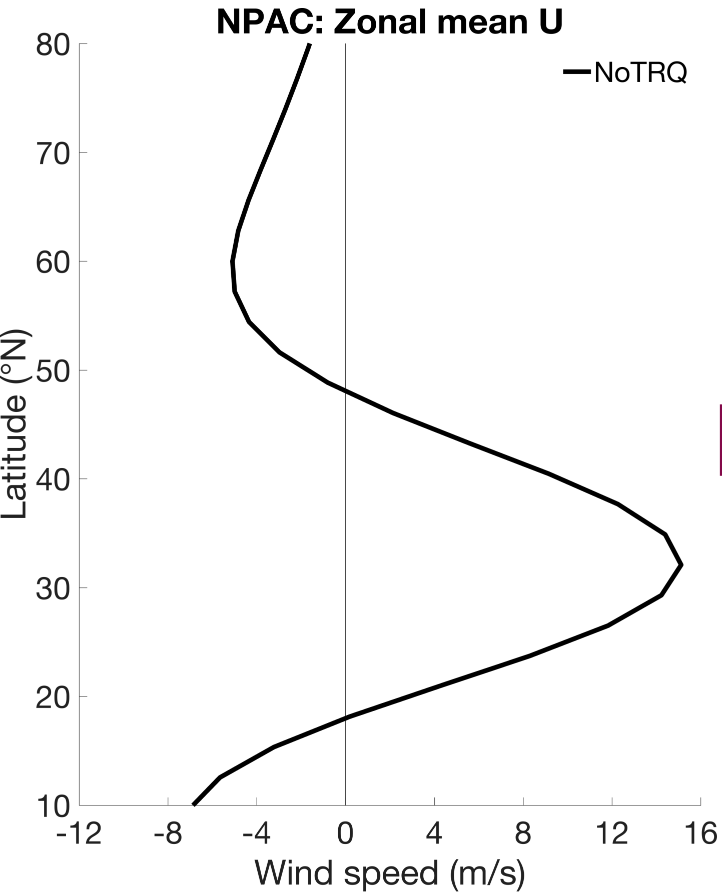
Idealized model experiment

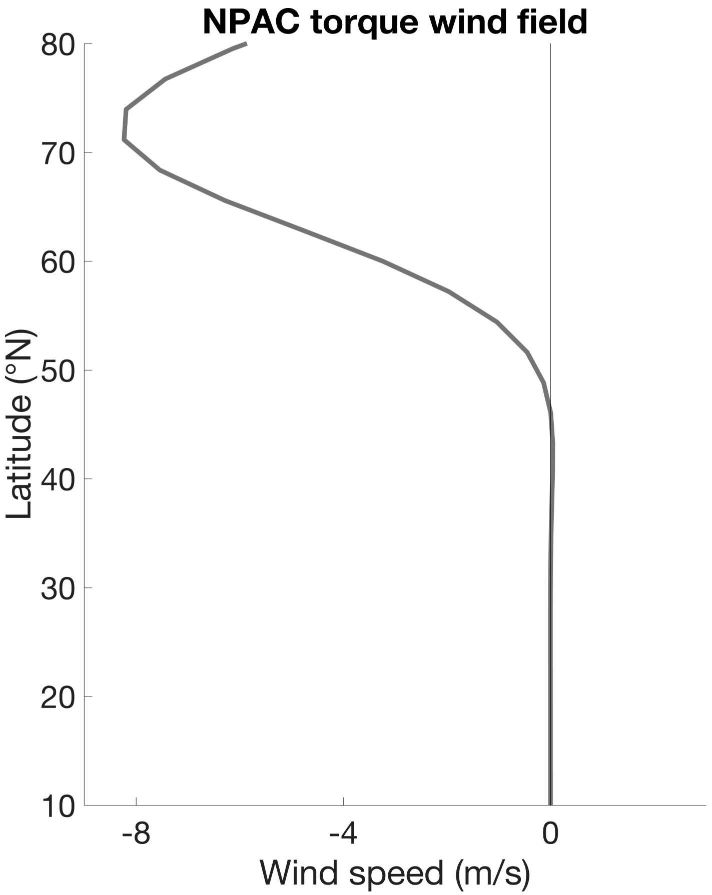
- **Local easterly wind anomalies due to thermal wind balance** ✓
- Approximate this as an easterly torque (previous work)
- Go in the barotropic model and create two experiments:
  - North Pacific (stirring 30N, torque 72N)
  - North Atlantic (stirring 45N, torque 60N)

Direct response



Direct response





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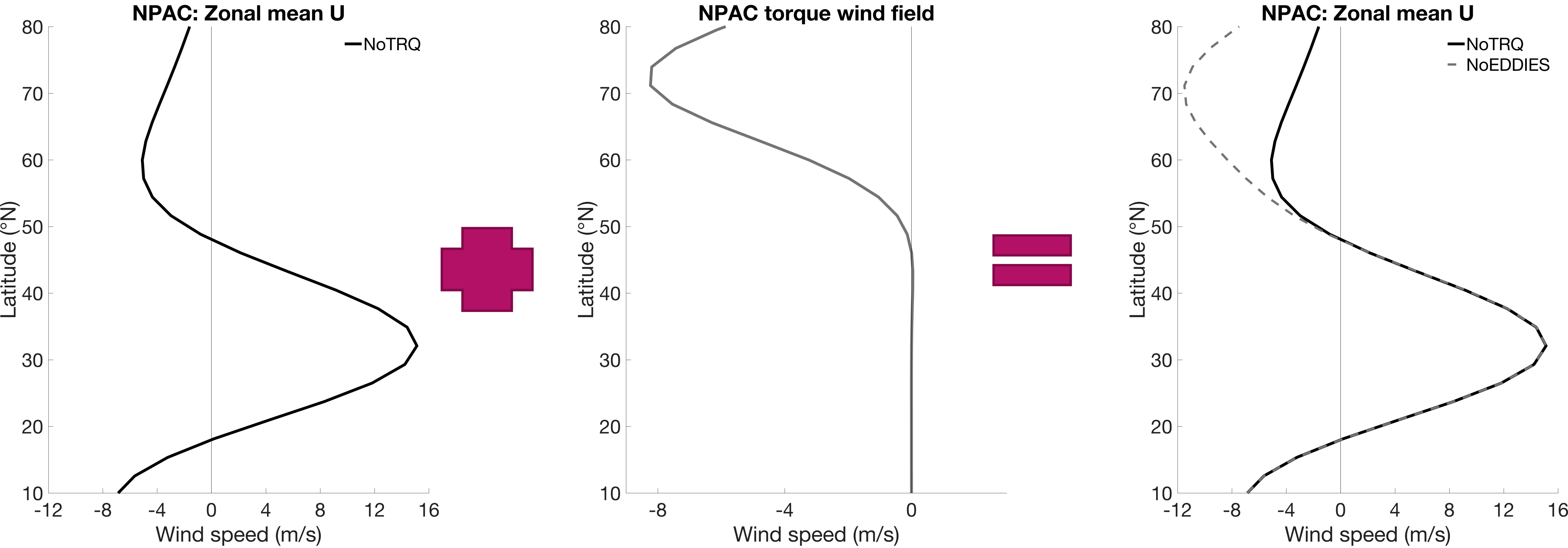
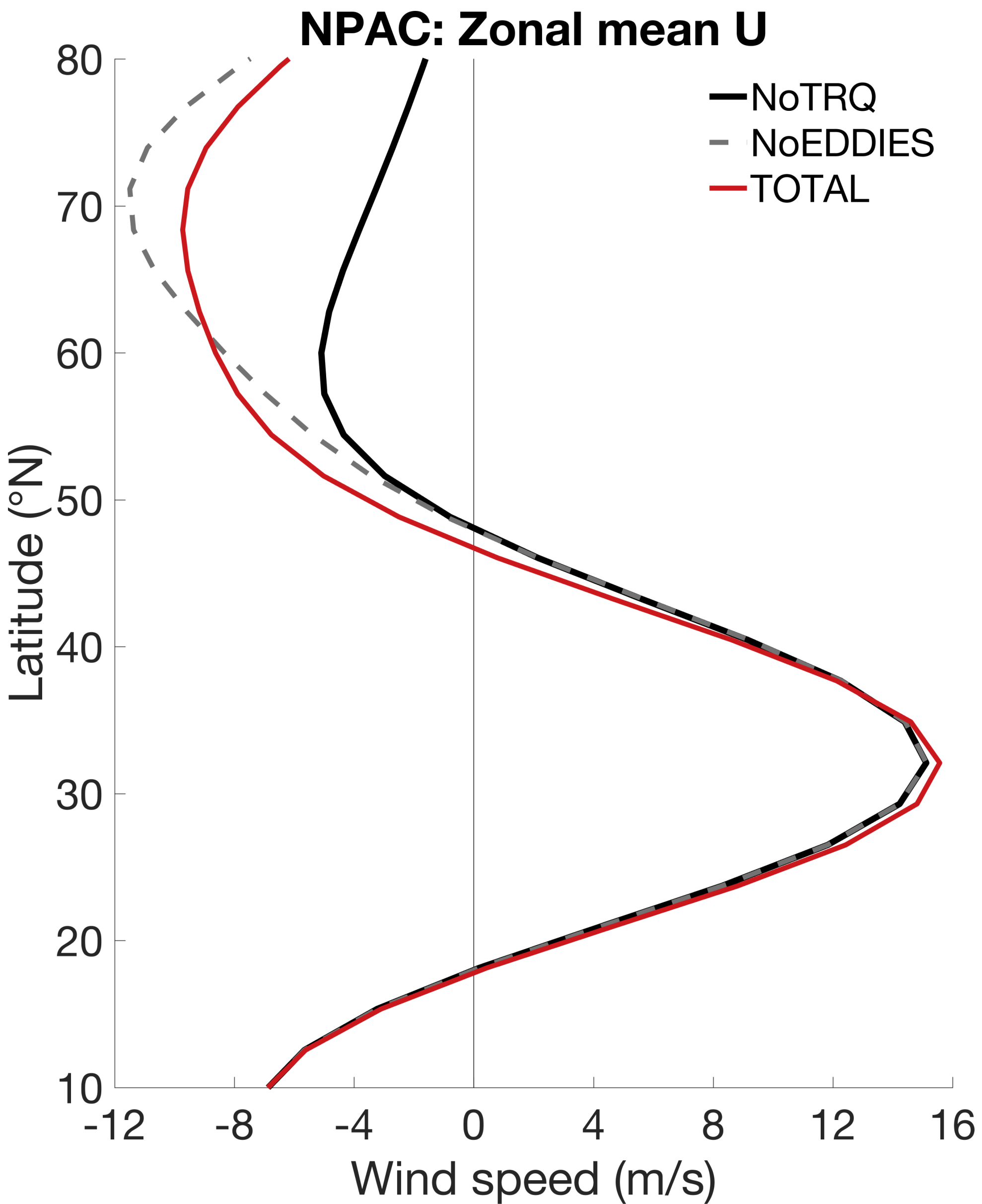
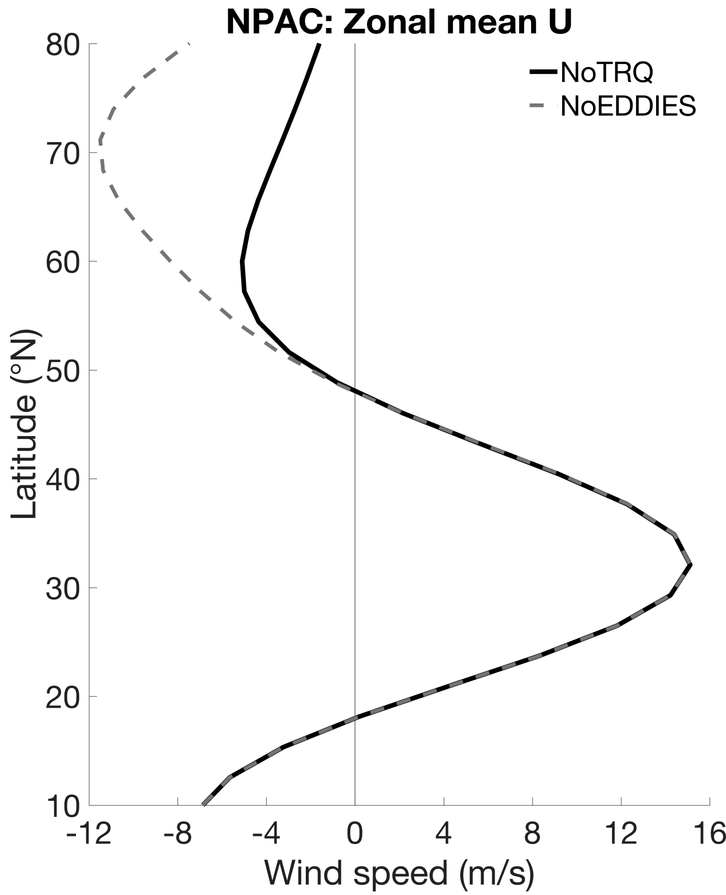


Direct response + eddy feedbacks





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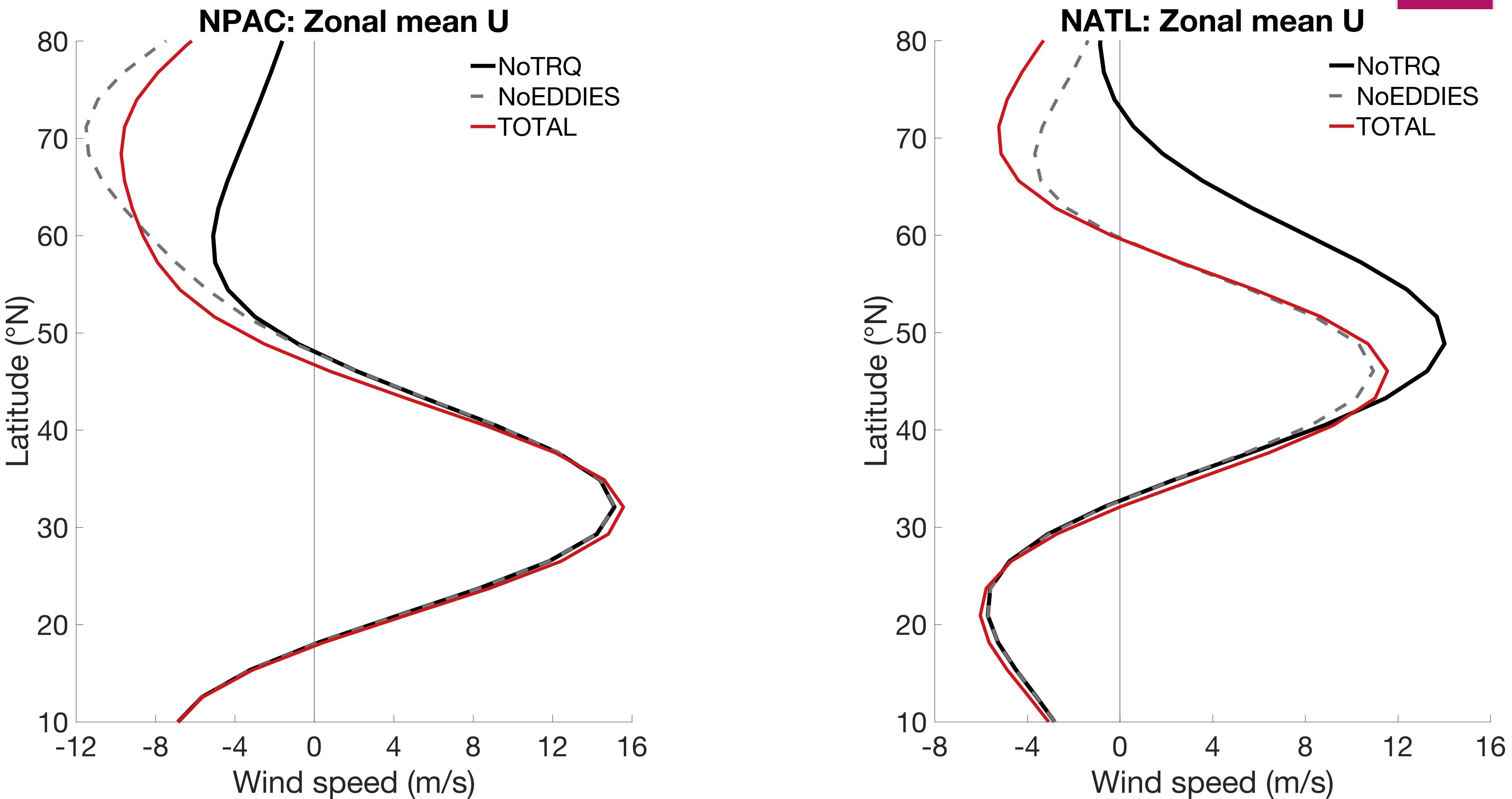

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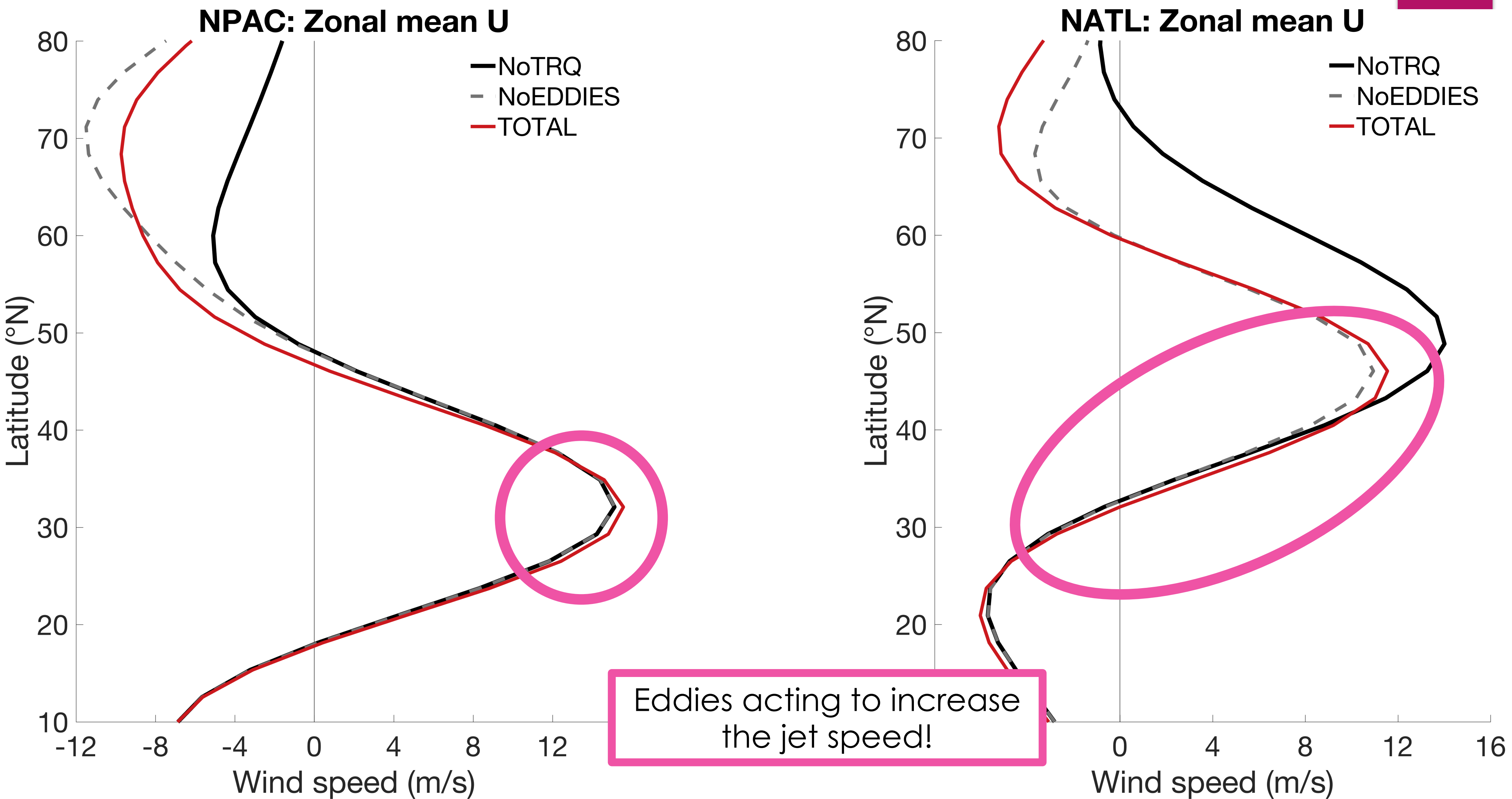
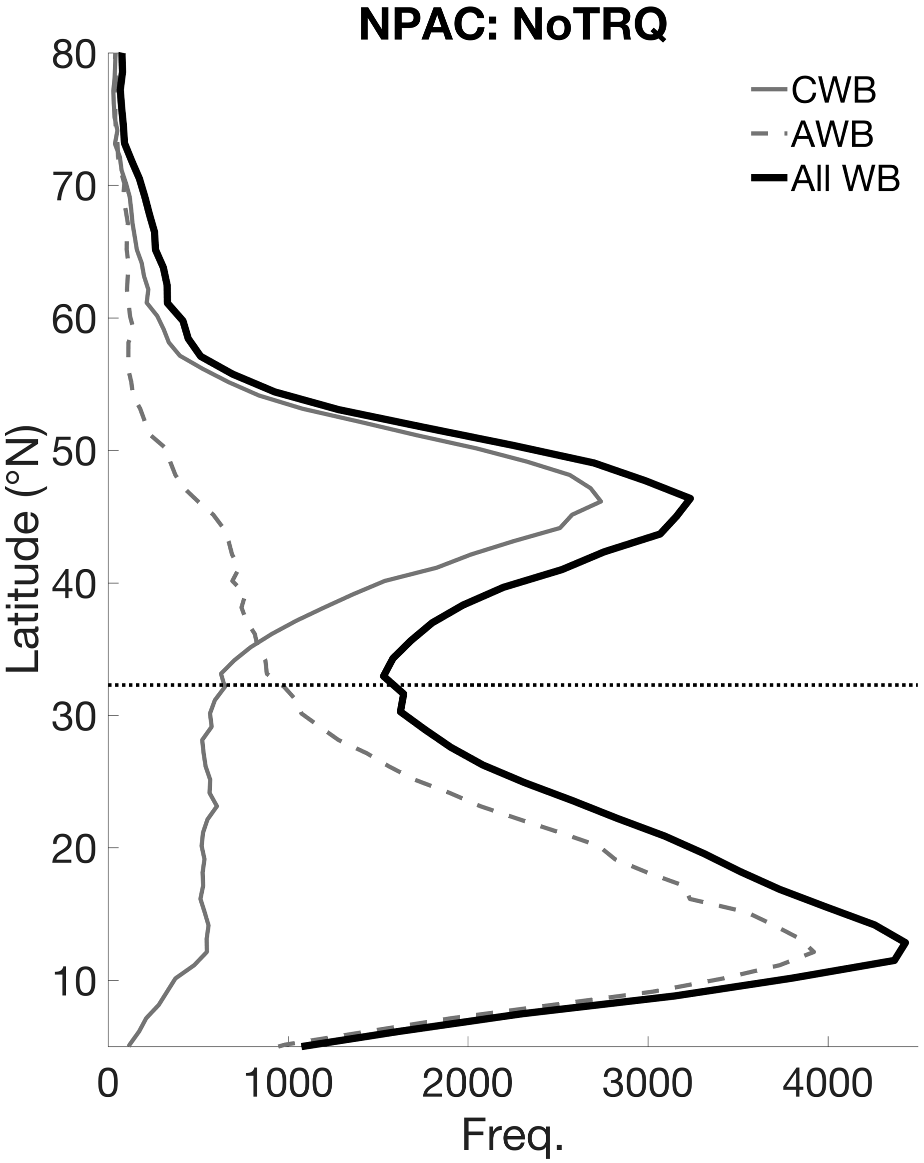


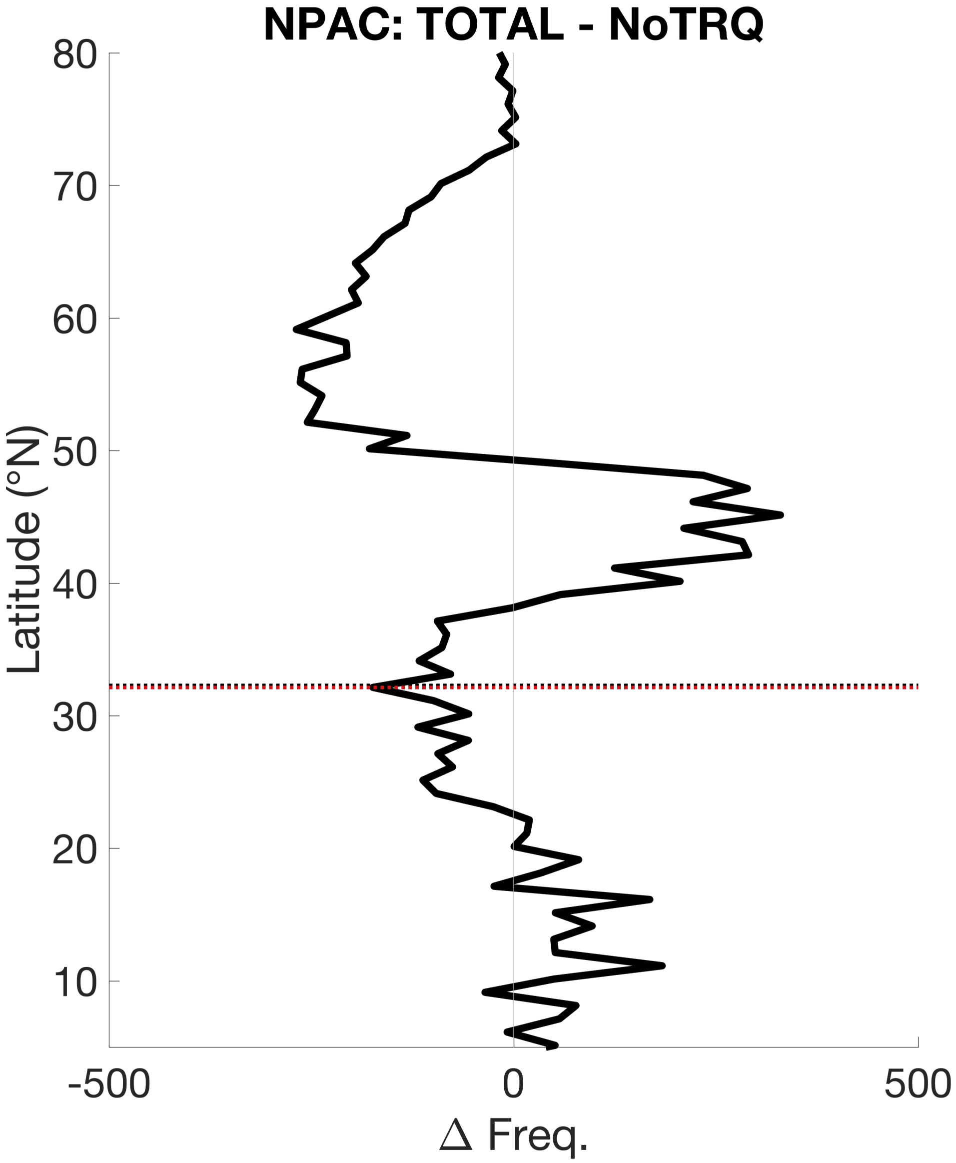
Eddies acting to increase the jet speed!

Eddies act to increase jet speed

- HOW?
- Eddies influence the mean flow via wave breaking
- i.e. eddy momentum flux convergence into the jet core
- So let’s take a look at the wave breaking

Wave breaking frequencies





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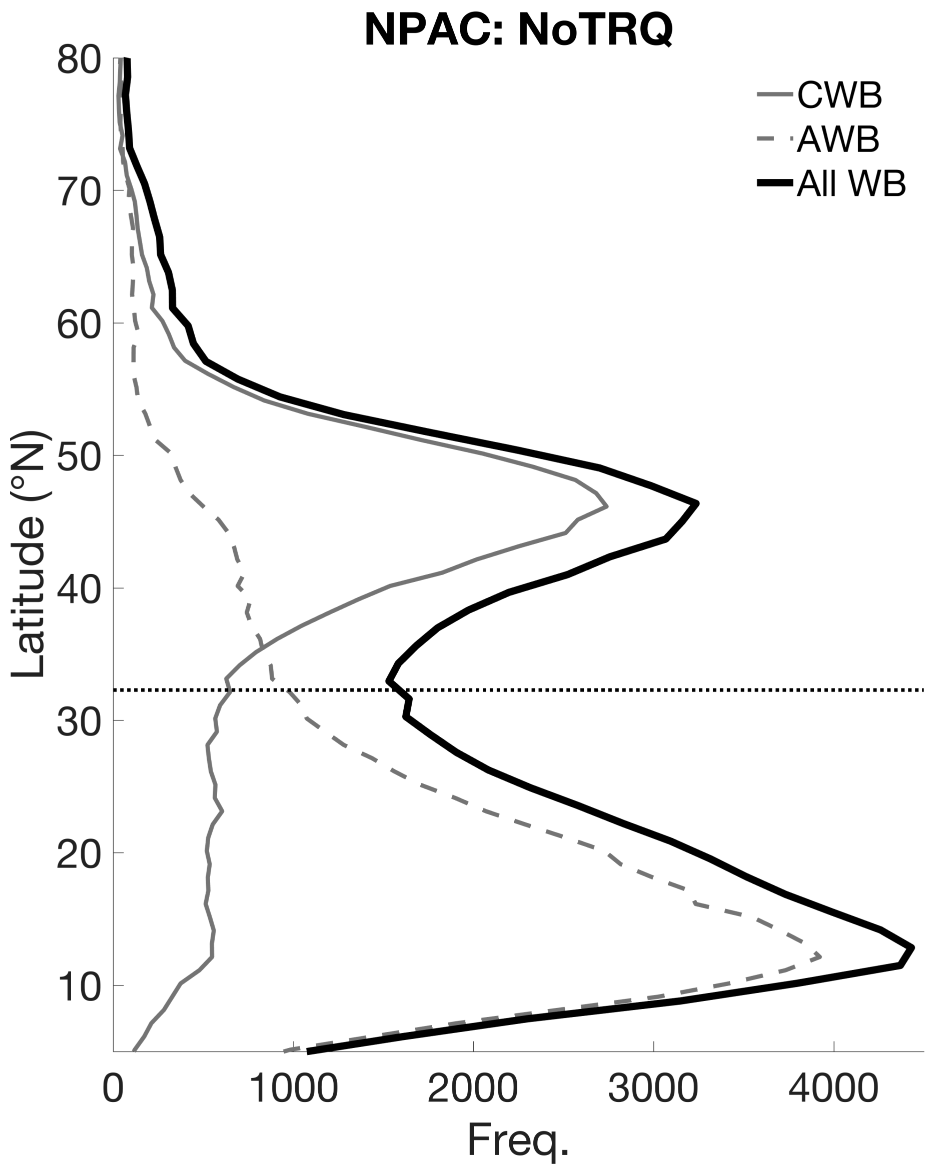
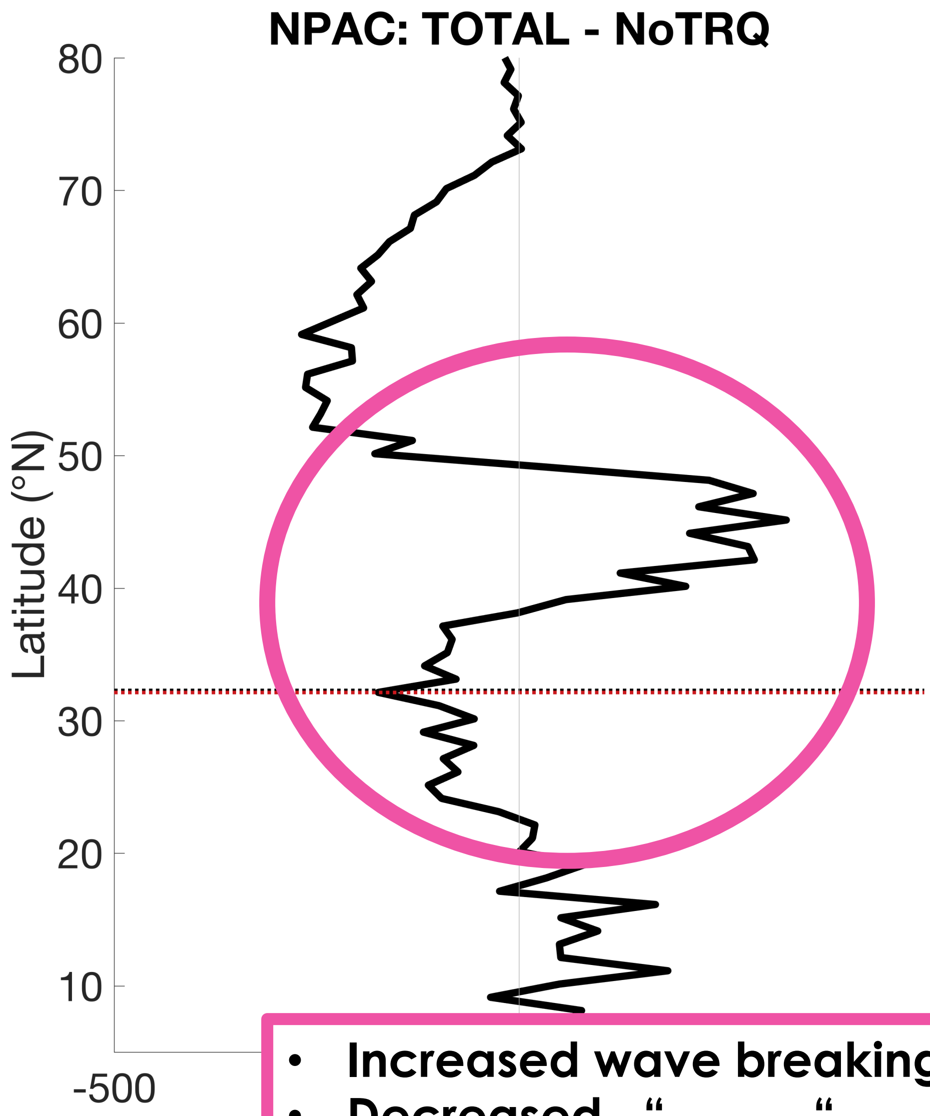
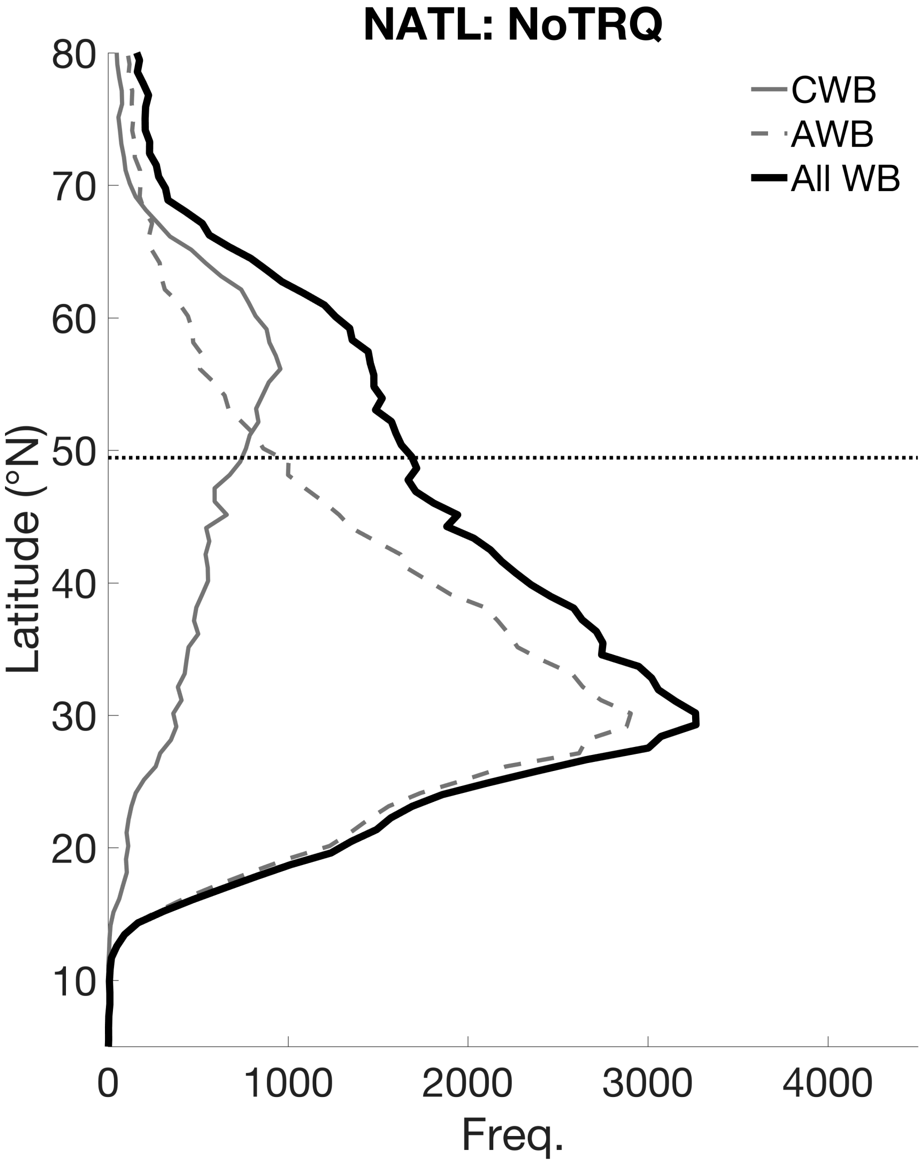
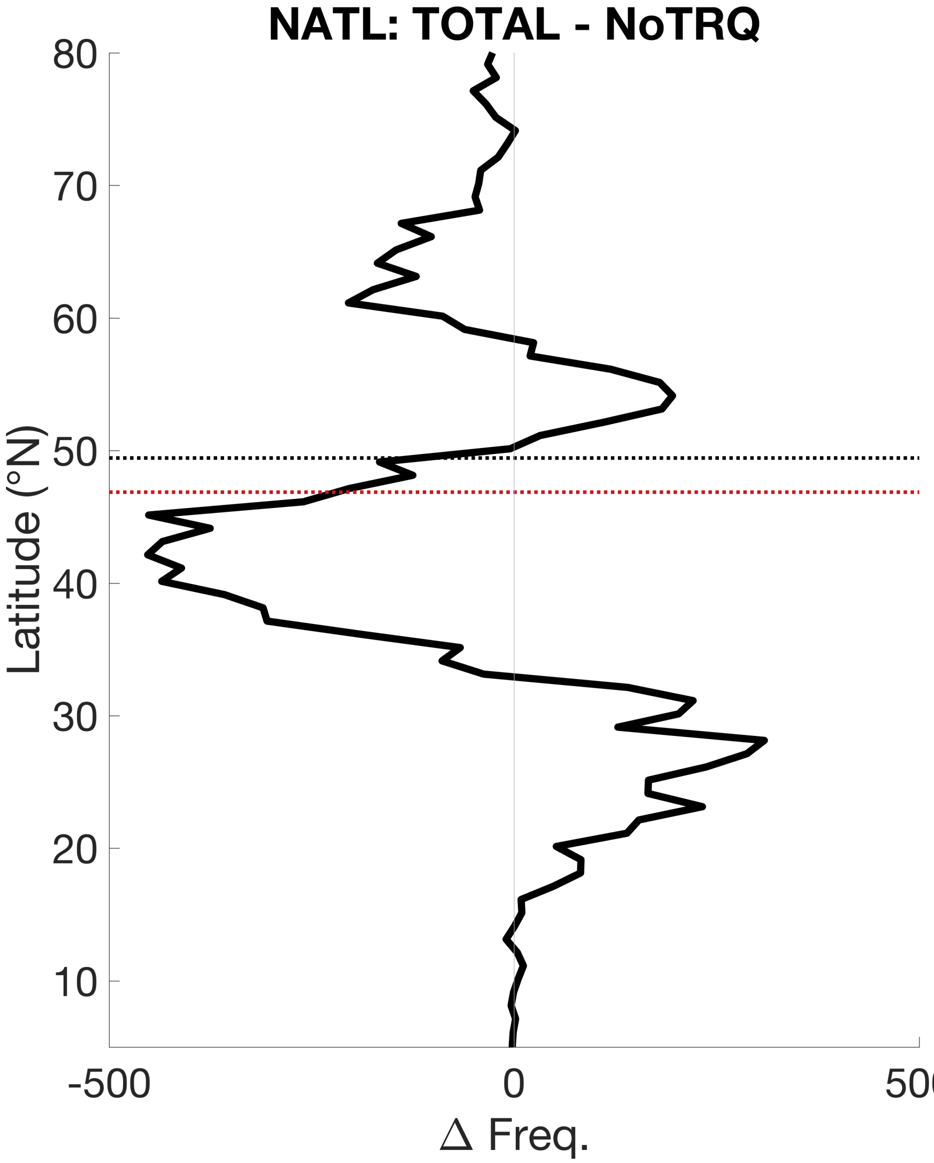




- Increased wave breaking poleward flank
- Decreased “ “ in the jet core
- → BOTH lead to increased jet speeds

Wave breaking frequencies





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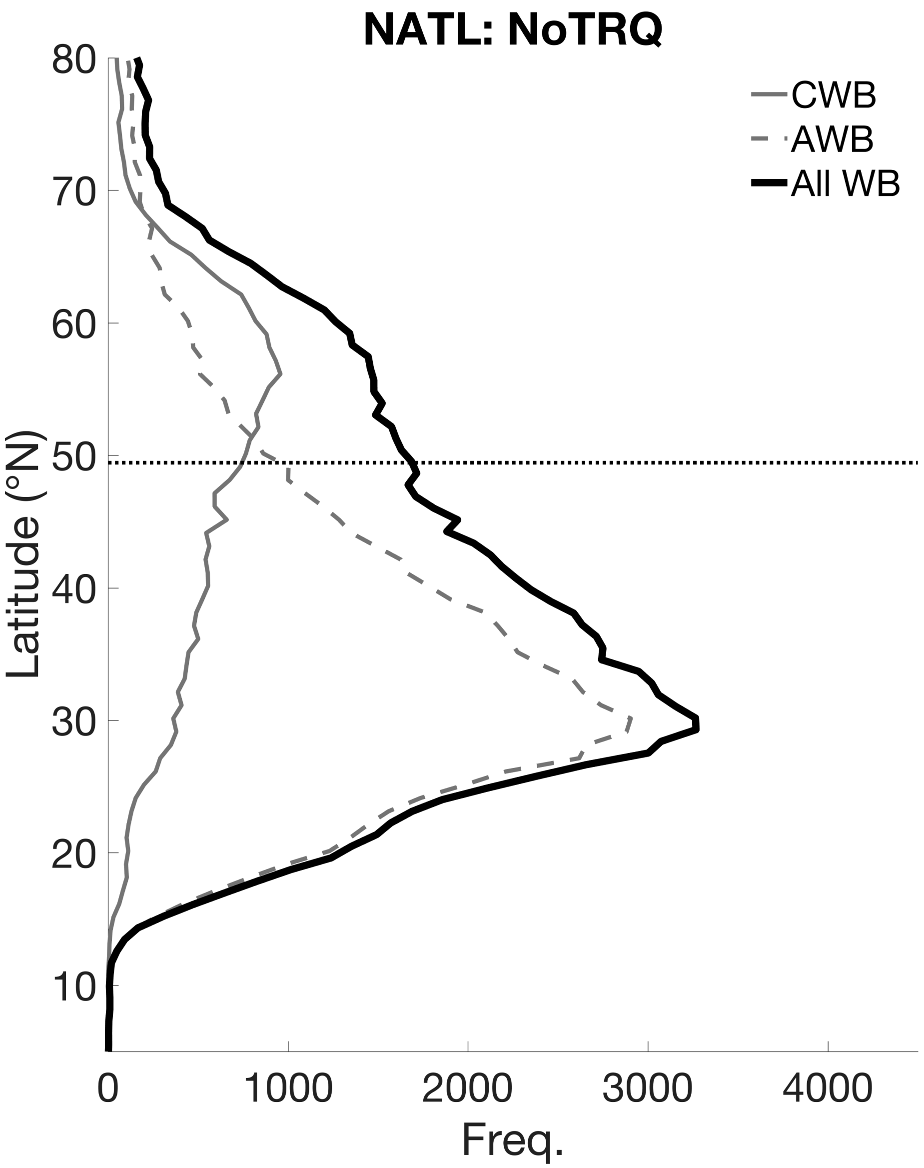
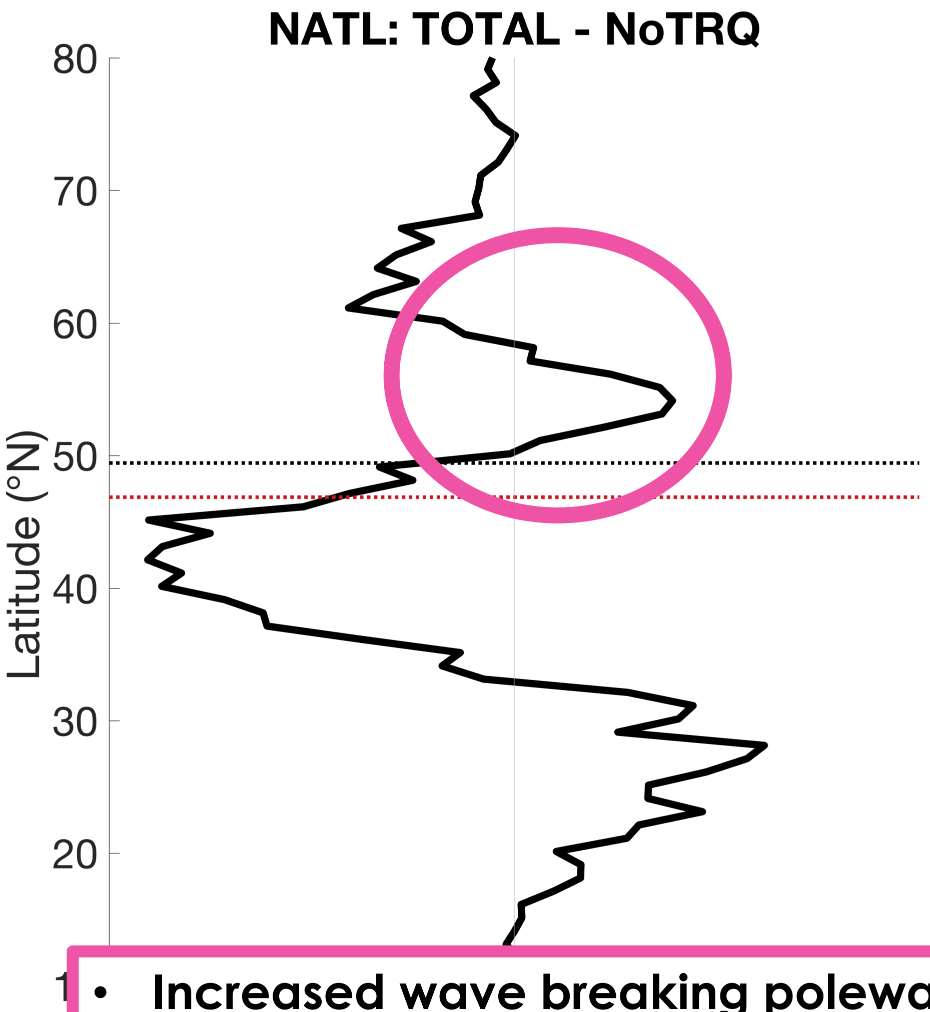
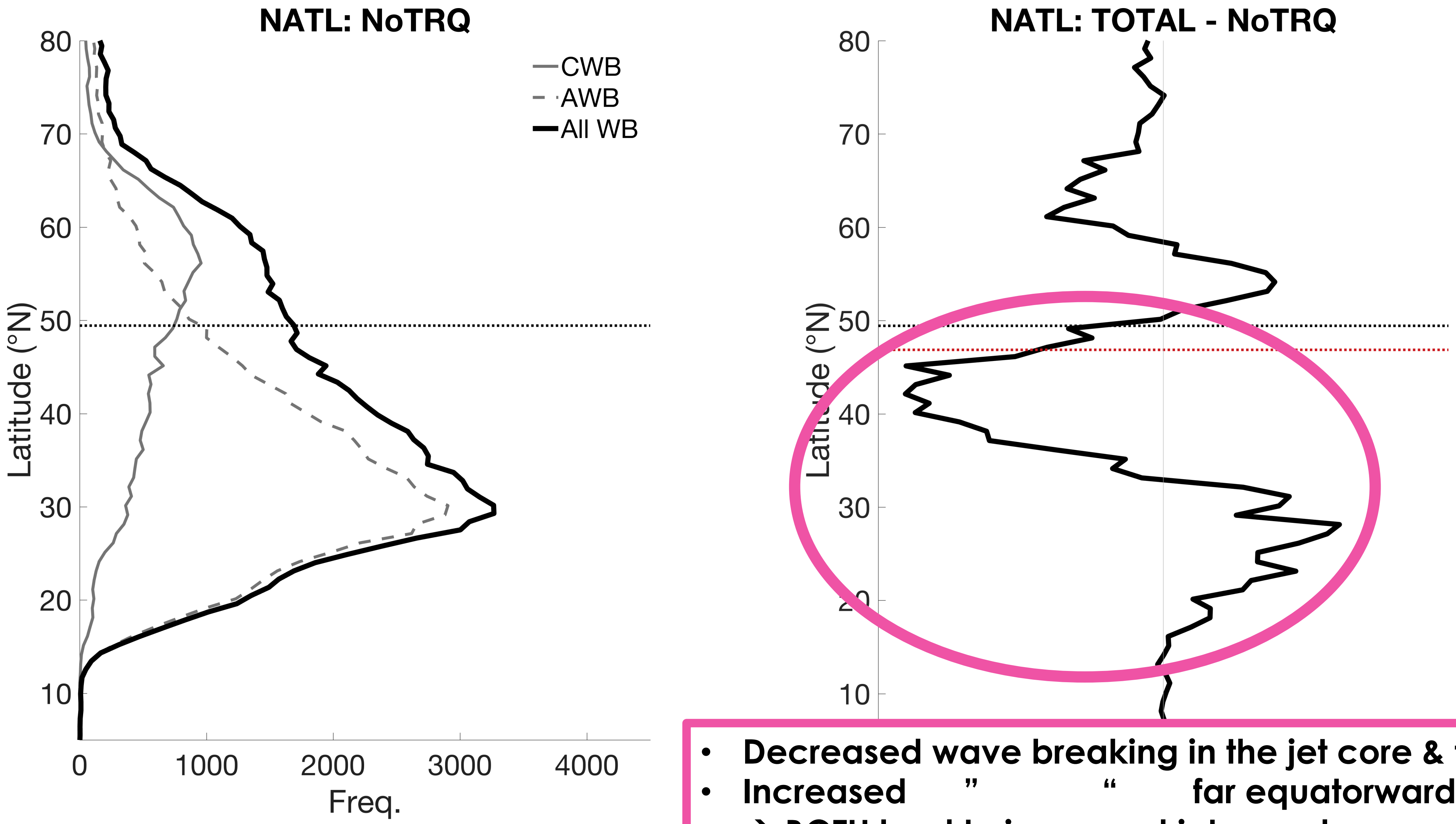




- Increased wave breaking poleward flank
- BUT very close to jet core
- -> cancellation momentum
- -> decreased jet speeds in TOTAL

Wave breaking frequencies



- Decreased wave breaking in the jet core & to the south
- Increased " " far equatorward flank
- → BOTH lead to increased jet speeds

But why these changes?

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Meridional shear of planetary vorticity + relative vorticity

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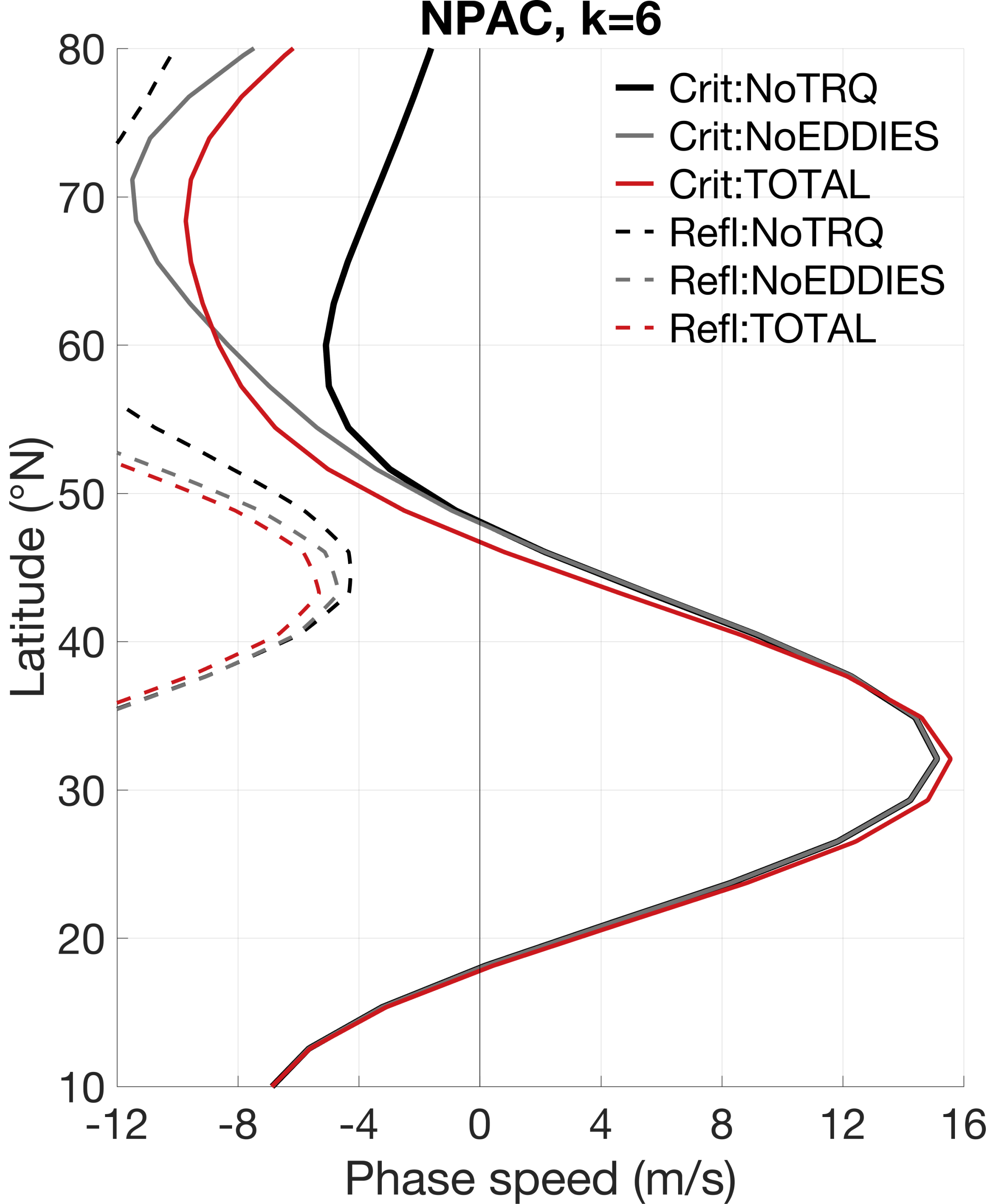
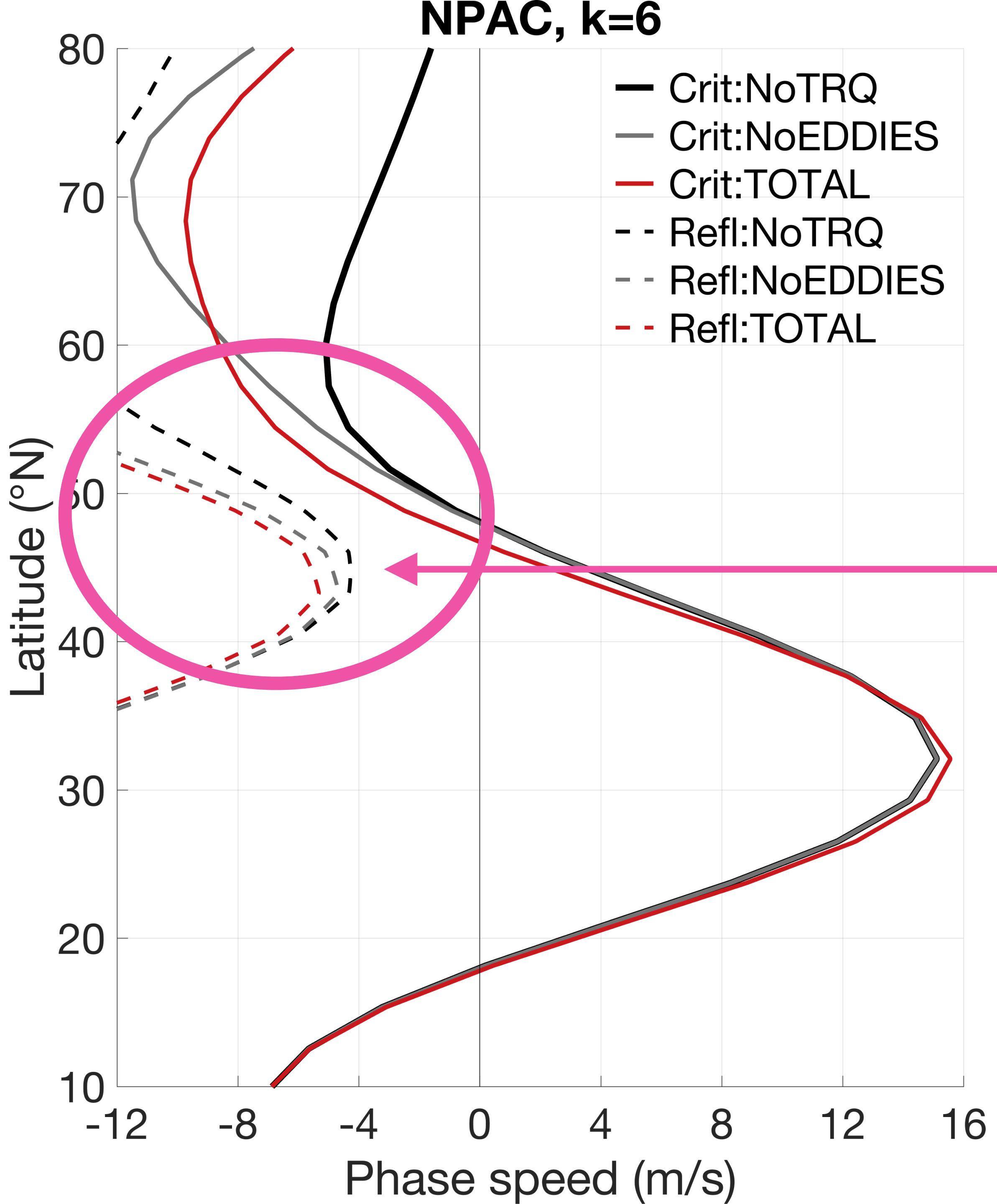
Meridional shear of planetary vorticity + relative vorticity

Zonal wavenumber
(pick this and plot c)


NPAC, k=6
Crit:NoTRQ
Crit:NoEDDIES
Crit:TOTAL
Refl:NoTRQ
Refl:NoEDDIES
Refl:TOTAL
Latitude (°N)
Phase speed (m/s)
80
70
60
50
40
30
20
10
-12
-8
-4
0
4
8
12
16



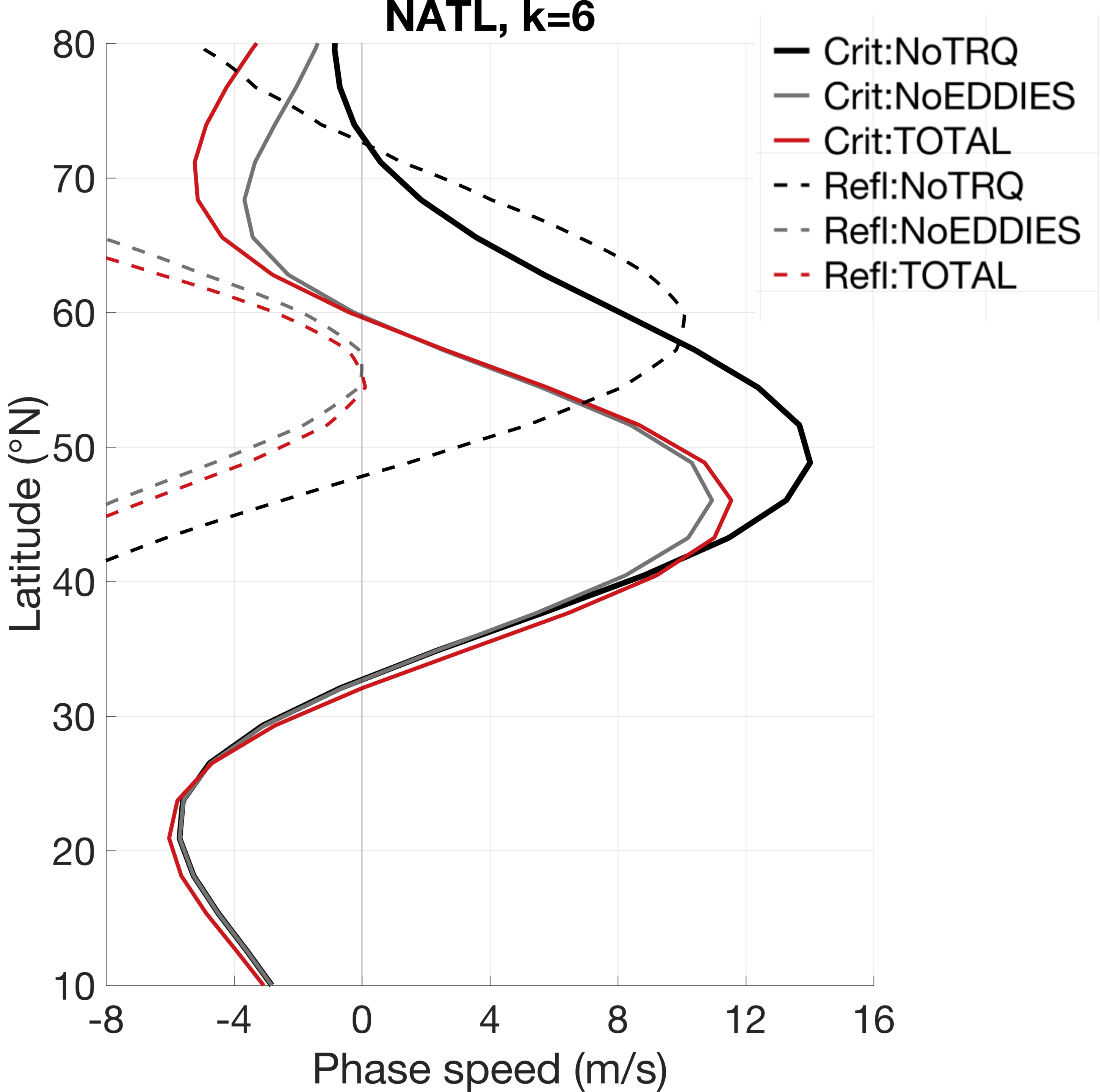
Changes in reflective profiles due to torque:

Waves can reach critical latitude on P-flank in TOTAL

= increased wave breaking on P-flank

Some of the waves that were reflected in NoTRQ broke in the jet core

= decreased wave breaking in jet core


NATL, k=6
Crit:NoTRQ
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80
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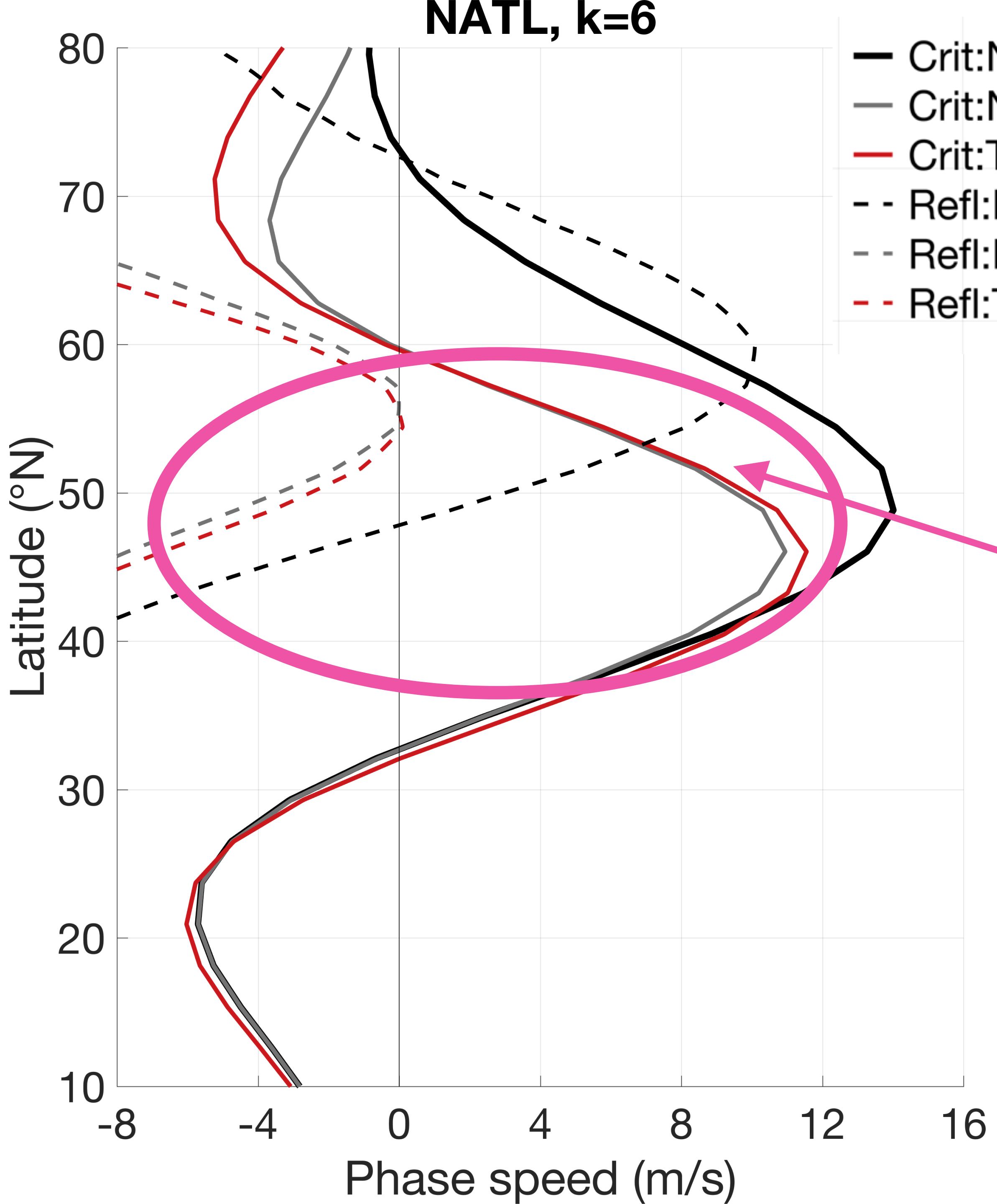
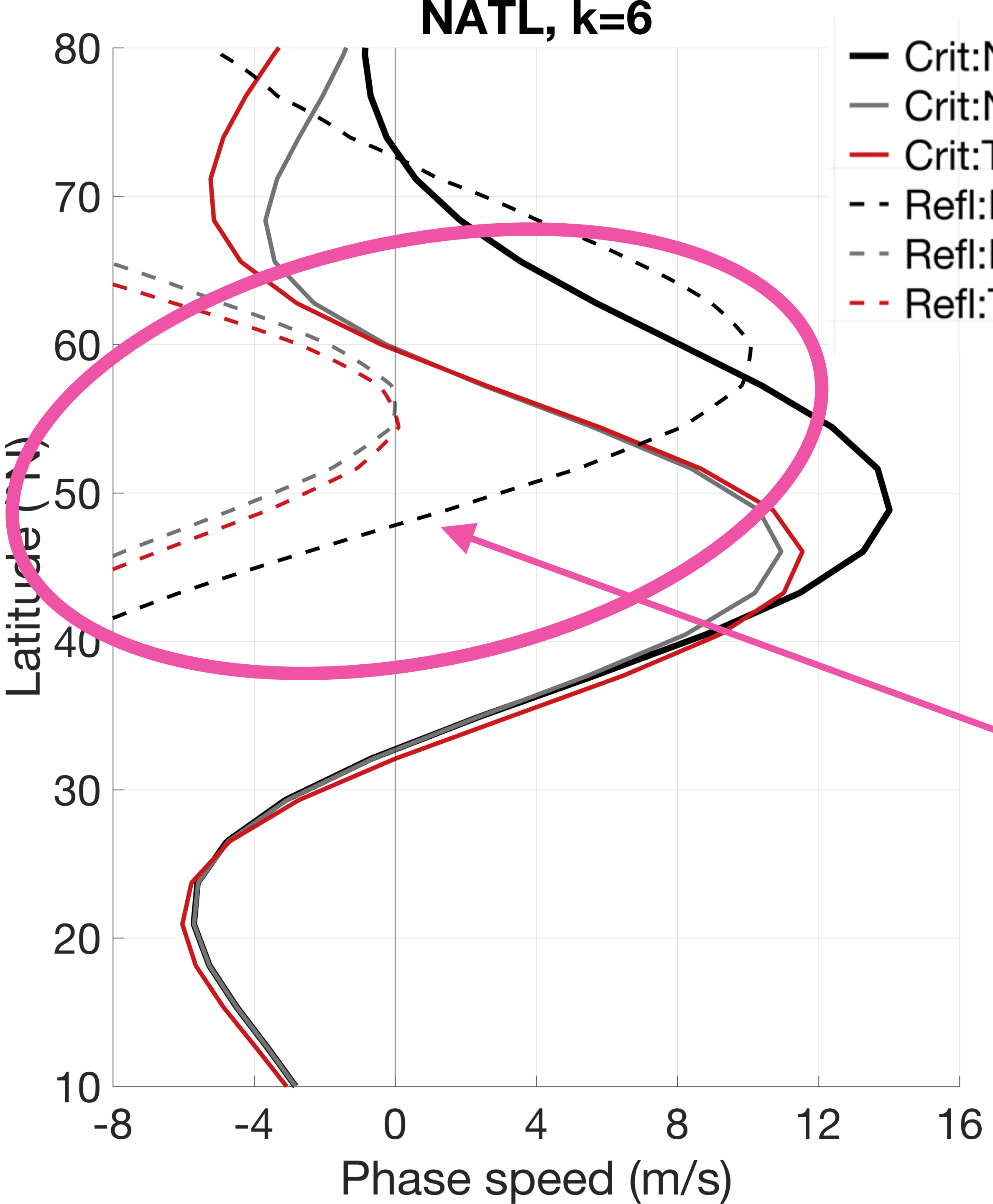
30
20
10
-8
-4
0
4
8
12
16



Changes in critical profiles due to torque:

Critical latitude is closer to jet core/wave source region



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Waves that were trapped in NoTRQ can propagate in TOTAL

= increased wave breaking on EQ-flank

Summary

Using zonally symmetric barotropic model:

- Direct impact of sea ice loss = weaken $\nabla_y T$ = easterly wind anomalies
- Apply easterly torque in model
- Separate direct response of winds to the torque versus the eddies
- Two experiments:
    1. North Pacific jet: strengthens b/c eddies
    2. North Atlantic jet: weakens b/c direct response, eddies still try to strengthen