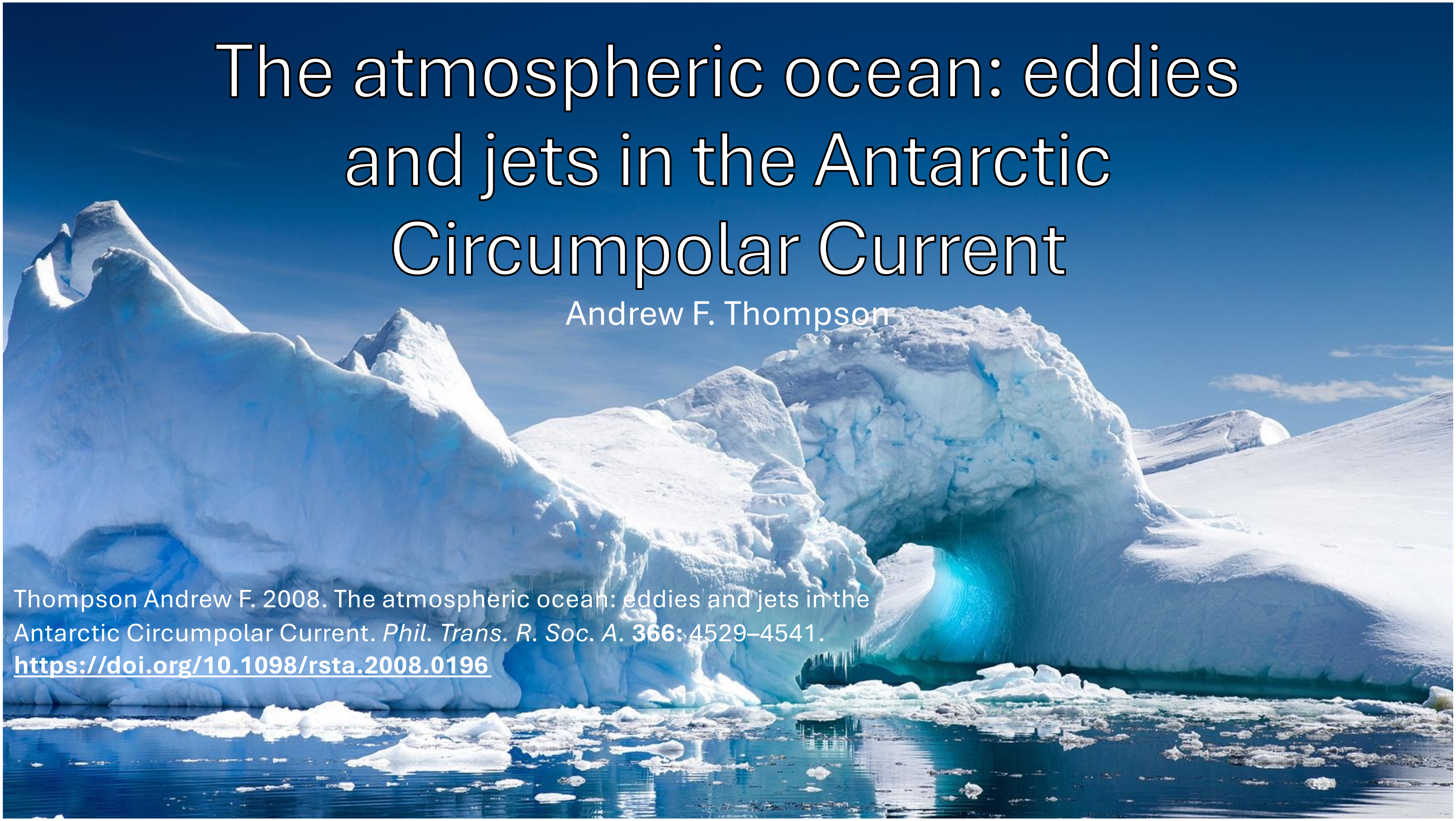


The atmospheric ocean: eddies and jets in the Antarctic Circumpolar Current

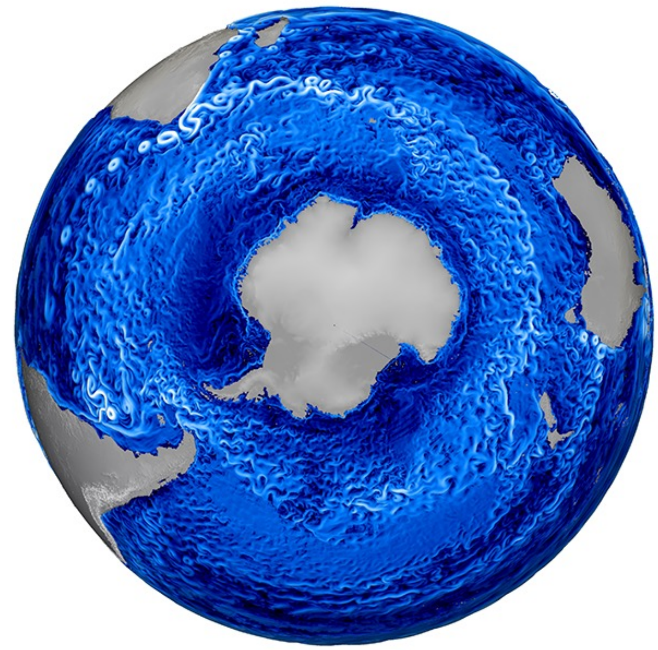
Andrew F. Thompson

Thompson Andrew F. 2008. The atmospheric ocean: eddies and jets in the Antarctic Circumpolar Current. *Phil. Trans. R. Soc. A.* **366:** 4529–4541.
https://doi.org/10.1098/rsta.2008.0196

Overview

- How can global climate models be improved to better represent the circulation of the ACC?
- How can global climate models depict eddies and jets?
- Large-scale models cannot show eddies and jets, so scientists work on incorporating their effects through increased wind stress
- 2009 launch of DIMES Project

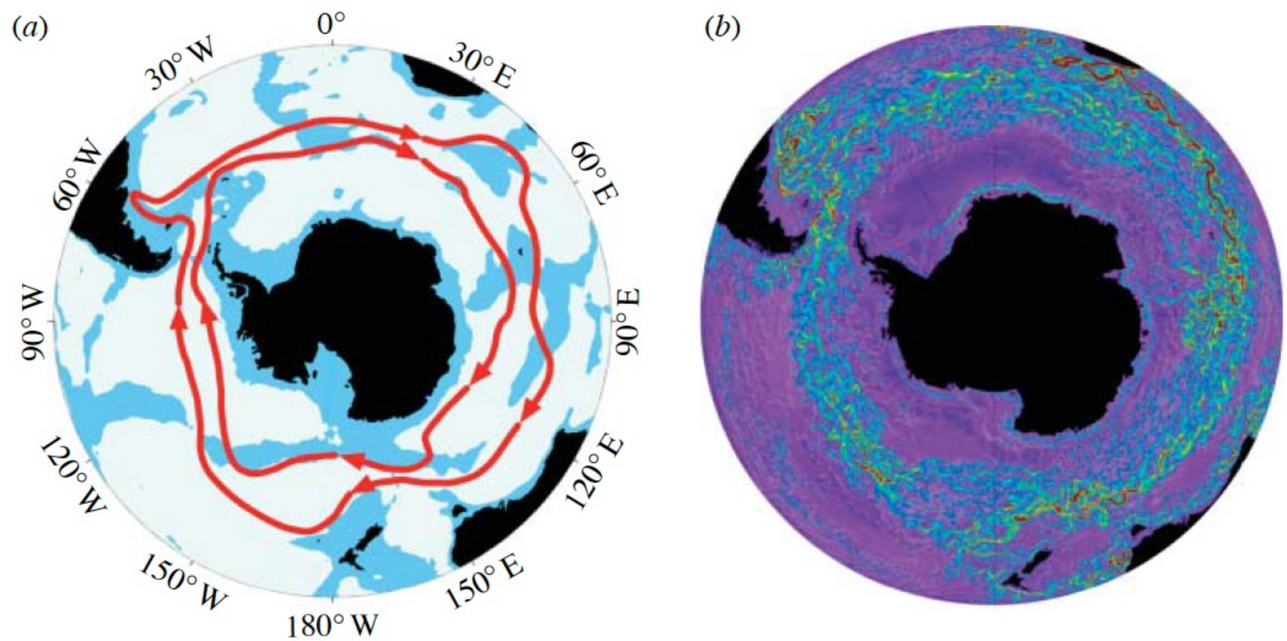
Antarctic Circumpolar Current



Antarctic Circumpolar Current (ACC)

- Longest and strongest ocean current globally with a volume transport of 130 Sverdrup, spanning 24,000 km
- No continental barriers which allows it to close in a circumpolar loop, flowing clockwise
- Most important ocean current in the climate system due to linking multiple ocean basins

Antarctic Circumpolar Current (ACC)



ACC Properties

- Ekman transport on surface due to wind stress and friction
  - Transport is perpendicular to the wind motion
  - Variations in east- west wind velocities create areas of convergence and divergence
- Unlike ocean basins, the ACC is NOT geostrophic meridionally
  - Very little meridional flow
  - The pressure gradient is due to a sloping sea surface height and no meridional boundaries
  - A mean meridional flow may occur, but only below sill depth (~2500m)

ACC Properties

- The zonal component exceeds the meridional component
  - Allows the current to flow circumpolar
- The presence of mesoscale eddies and jets allow for meridional transport of heat and density
  - Occur above sill depth (consider the surface layer)
  - Eddy: vortex-like structures present in the current → like atmospheric storms
  - Jet: Concentration of eddies in a zonal band

Meridional Circulation

Meridional Circulation: Mesoscale Eddies

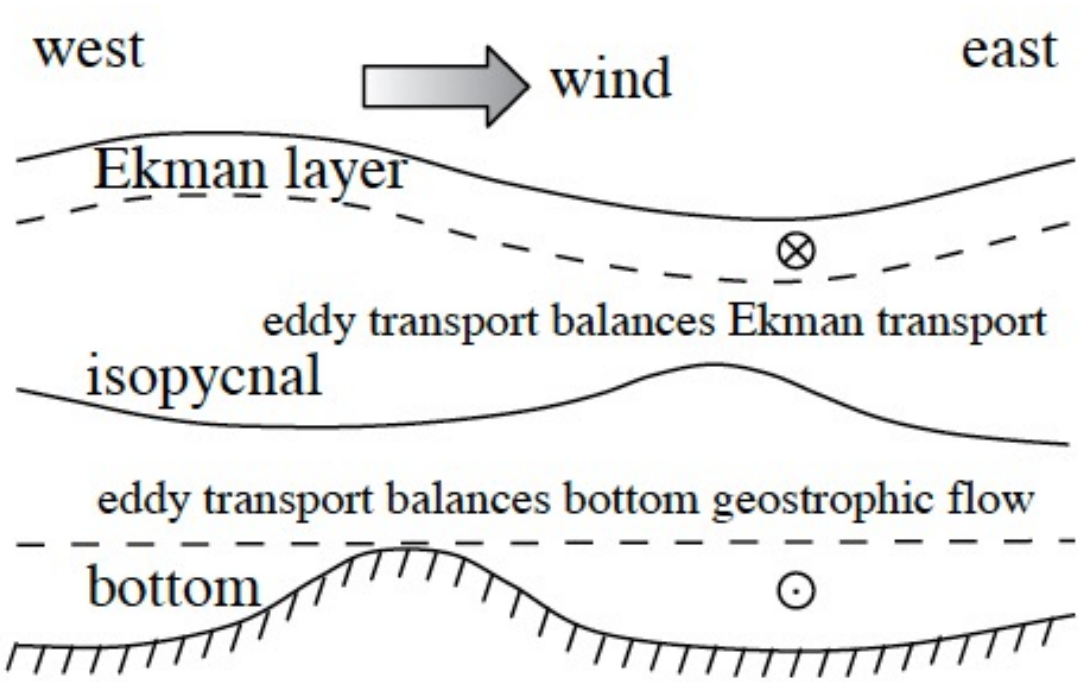
- Time-mean Eulerian circulation with transient eddies:
  - $\overline{h\boldsymbol{u}} = \overline{(h+h')(\boldsymbol{u}+\boldsymbol{u}')} = \overline{h\boldsymbol{u}} + \overline{h'\boldsymbol{u}} = \overline{h}(\boldsymbol{u}+\boldsymbol{u}^*)$
  - $\boldsymbol{u}^* = \overline{h'\boldsymbol{u}}'/\overline{h}$ → eddy induced velocity (bolus velocity)
  - Equation gives the eddy transport

Meridional Circulation: Mesoscale Eddies

- Steady State Zonal Momentum Balance
  - $-\rho f\overline{V_1} = \overline{-h'p'_x} + \overline{\tau^x}$ (upper layer)
  - $-\rho f\overline{V_2} = \overline{-h'p'_x} + \overline{Hp'_x}$ (lower layer)
  - Balance of surface wind stress and bottom stress from topographic caused pressure gradients

Meridional Circulation: Mesoscale Eddies

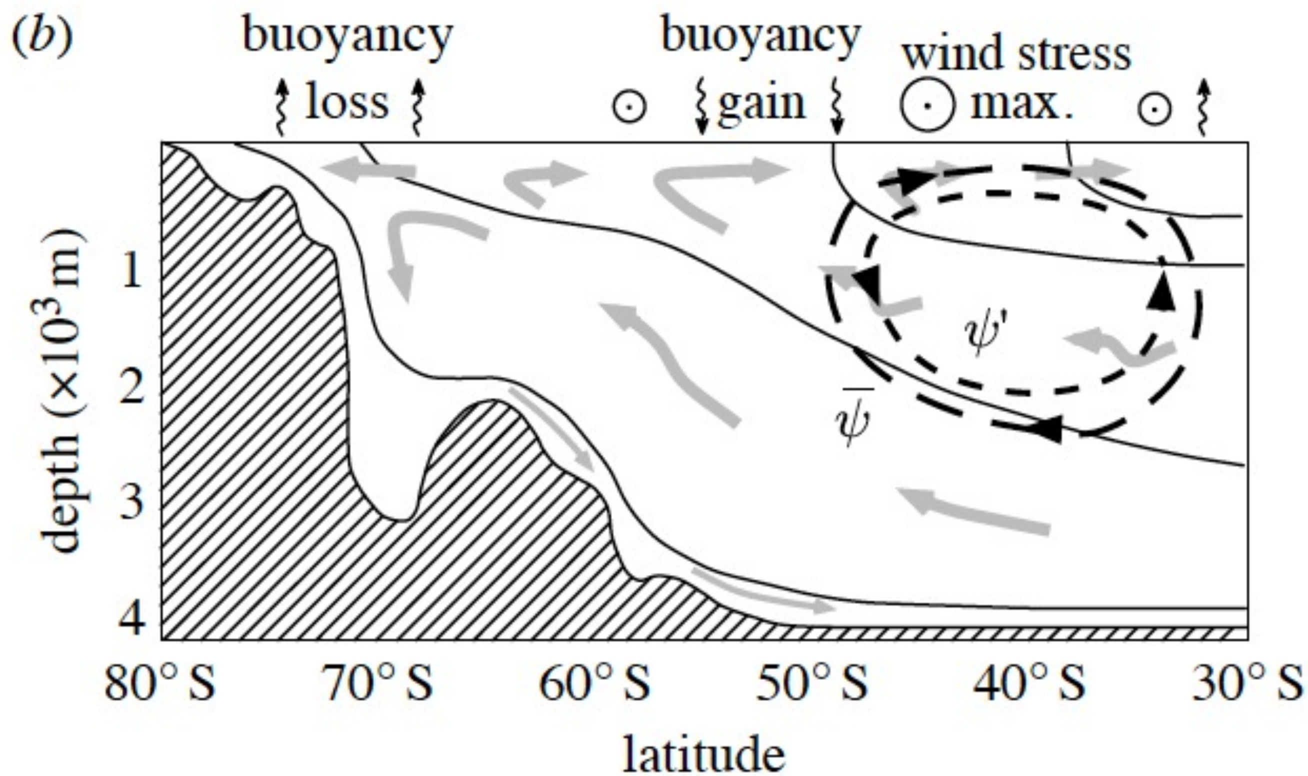
(a)



Meridional Circulation: Mesoscale Eddies

- Further assume no mixing between layers
  - $\overline{V_1} = \overline{V_2} = 0$
  - $p'_x \approx \rho_0 f v' \rightarrow \overline{h' p'_x} \approx \rho_0 f \bar{h} v^*$
  - Upper layer Ekman transport and wind stress become balanced by eddies
  - Eddies allow for transport of momentum between layers

Meridional Circulation: Mesoscale Eddies



Meridional Circulation: Meridional Overturning

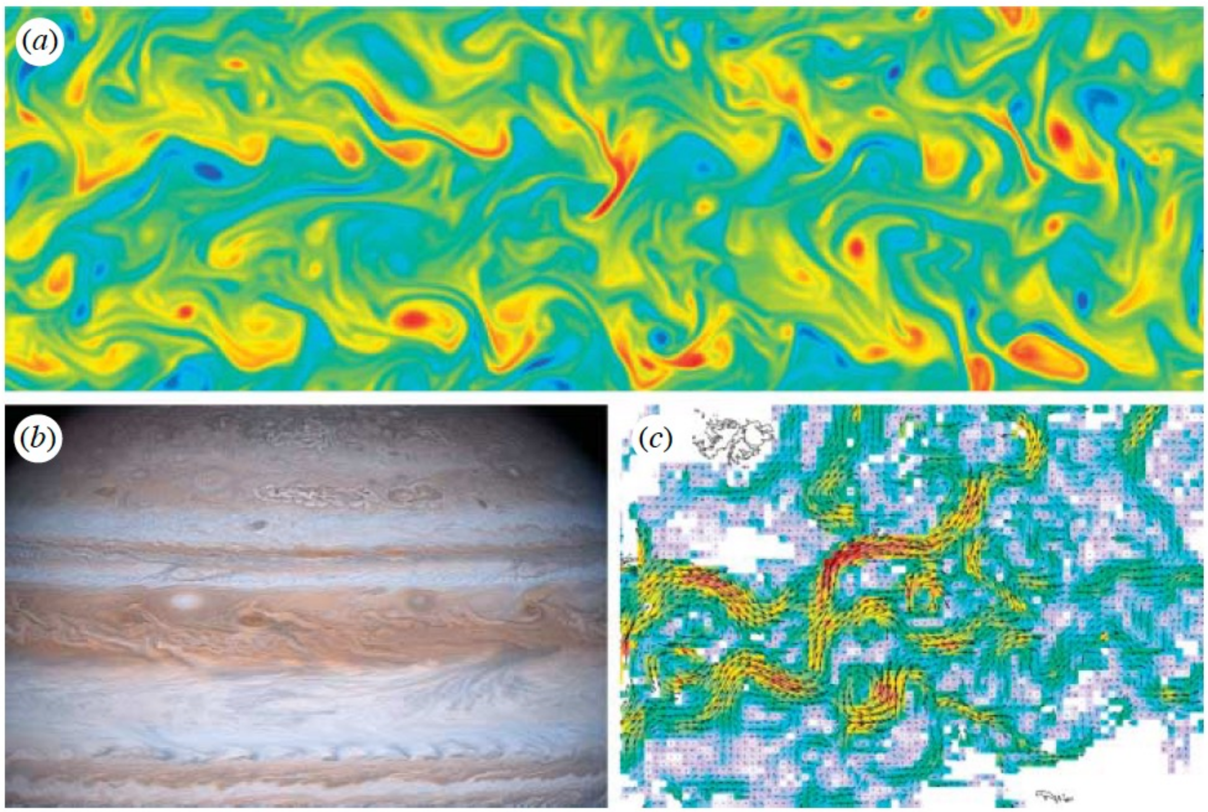
- Assume a steady-state meridional overturning
- Residual mean theory
  - ψ: circumpolar-mean residual overturning
  - $\bar{\psi}$: Eulerian cell mean overturning
    - Tilts isopycnals
  - ψ': eddy cell induced overturning
    - Involves factors of baroclinic instability
    - “flattens” isopycnals
  - Overturning not included in above values is responsible for density variation in the ACC

Meridional Circulation: Meridional Overturning

- $\psi' = k|s|s$
- Allows for eddies to be more easily picked up by model
- Mimics increased wind stress
- Major issues in the model due to the inability to use strong vertical mixing and density variations

Jets in the ACC

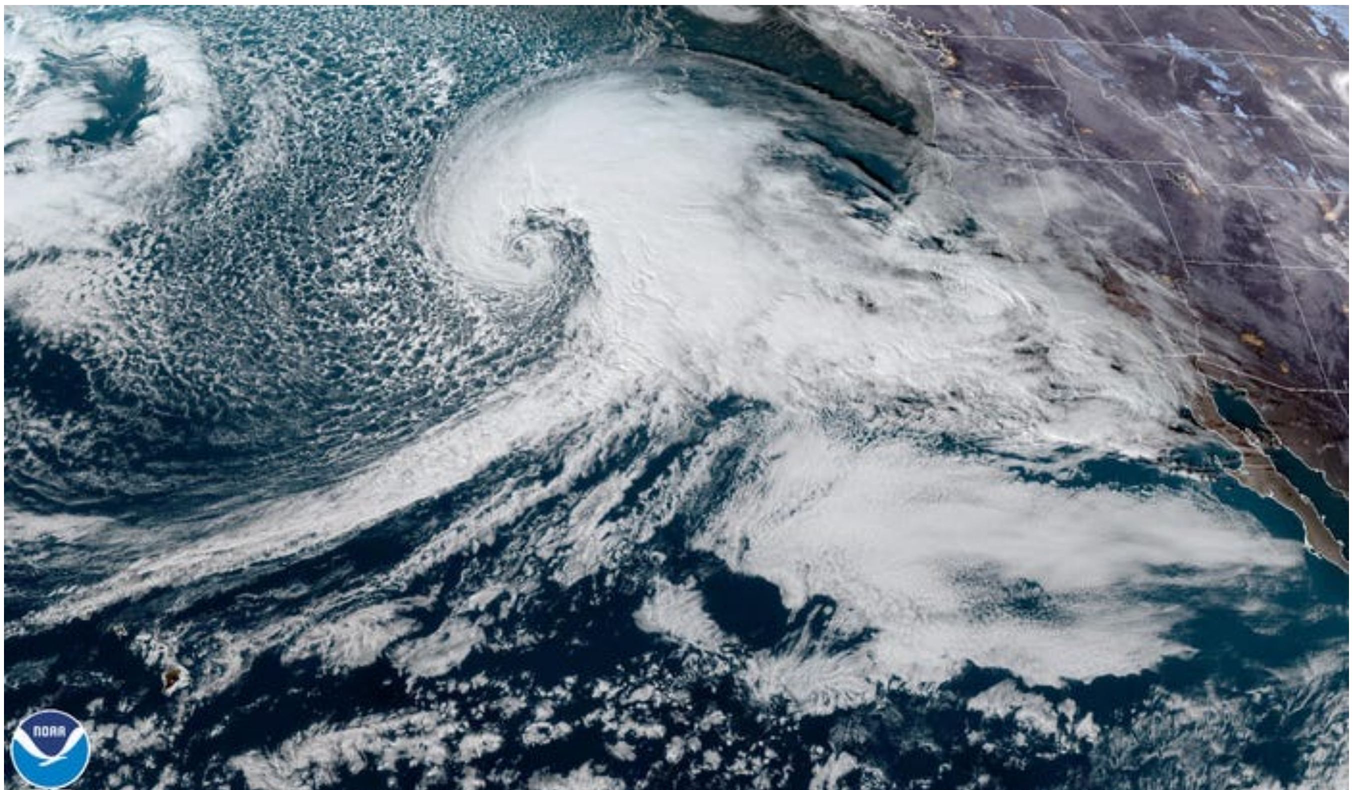
Jets in Atmospheres and Oceans



Jets in Atmospheres and Oceans

- Potential Vorticity in jets
  - $Q = \frac{\zeta + f}{h}$
- Rhines Scale: $\ell_R \sim \sqrt{\frac{U}{\beta}}$

Similarities to the Atmosphere



03 Jan 2023 23:36Z - NOAA/NESDIS/STAR GOES-West - GEOCOLOR Composite - Day(0.47 um - blue, 0.64 um - red, and 0.86 um – near IR)

The ACC and Global Climate

Global Climate

- ACC is a huge part of the global overturning circulation by linking major basins
- Meridional density causing tilted isopycnals increases carbon uptake and mixing between surface and middle waters
  - Changes in this process affects strength and frequency of eddies
- Climate change is creating further unpredictability in an already complicated system that is hard to model

Questions?