Impact of Two Different Flavors of ENSO on the Low Frequency Variation of the Southern Annular Mode

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Australian Government

Bureau of Meteorology

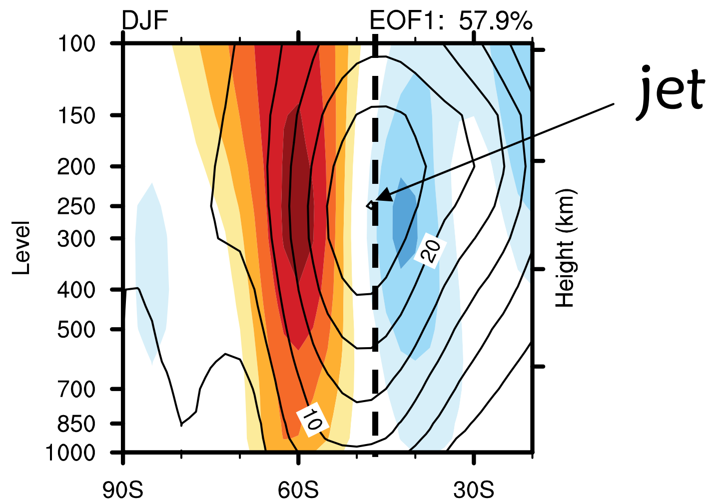
The Centre for Australian Weather and Climate Research

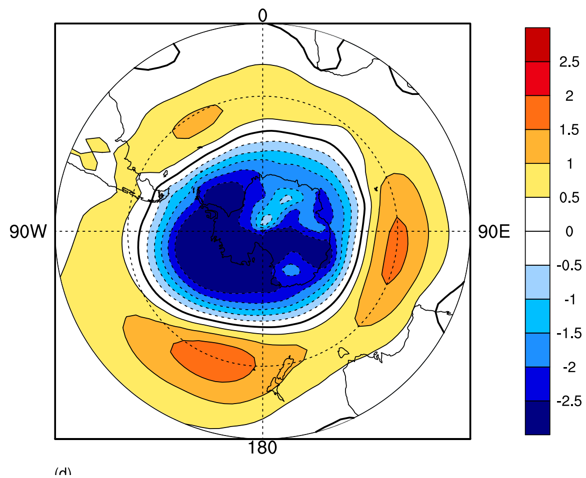
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

Southern Annular Mode (SAM)

- The most dominant mode of variability of the extratropical circulation in the SH in various time scales – from weeks to centuries
- Characterized by zonally symmetric north-south swing of the strength of the westerly jet in the extratropics
- Results in zonally symmetric north-south shifts of storm tracks that grow with the energy available from the vertical wind shear
- Projected onto an annular pattern of pressure/geopotential height anomalies with the opposite signs between the mid and high latitudes





Predictability of SAM

- SAM is driven by internal atmospheric dynamics – i) decorrelation time of < 2 weeks, ii) reproducibility in GCMs without SST forcing

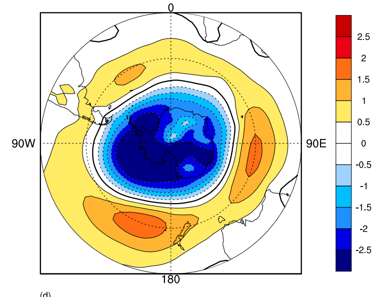
  → Thought to be unpredictable beyond a week

- However, seasonal SAM is associated with ENSO in austral spring to summer (e.g. Karoly 1989, Zhou and Yu 2004, L'Heureux & Thompson 2006)

  → **Predictability of SAM in a seasonal time scale!**

How does ENSO induce SAM?

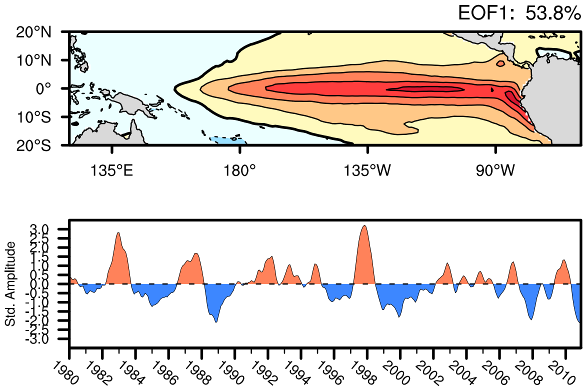
Data & Methodology



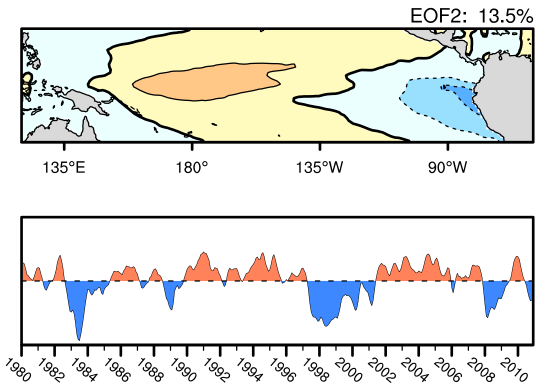
- **SAM index:** Difference of normalised zonal mean MSLP at 40°S and 65°S (Gong and Wang 1999)

- **Two different flavors of ENSO**
  (e.g. Hoerling et al. 1997, Ashok et al. 2007 , Wang and Hendon 2007, Kao and Yu 2009)

Traditional El Nino	Modoki El Nino
Eastern Pacific	Central Pacific
Cold-tongue	Warm-pool



SSTEOF1



SSTEOF2

Does this CP El Nino have any importance in regard to SAM?

Data & Methodology

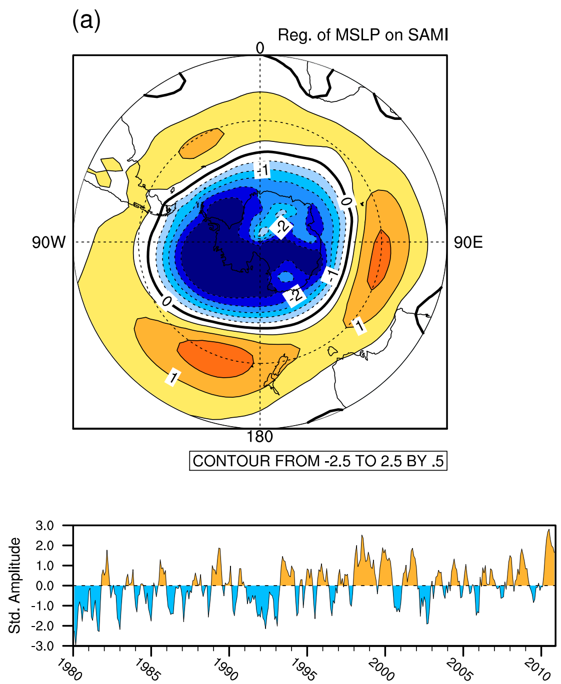
- Datasets

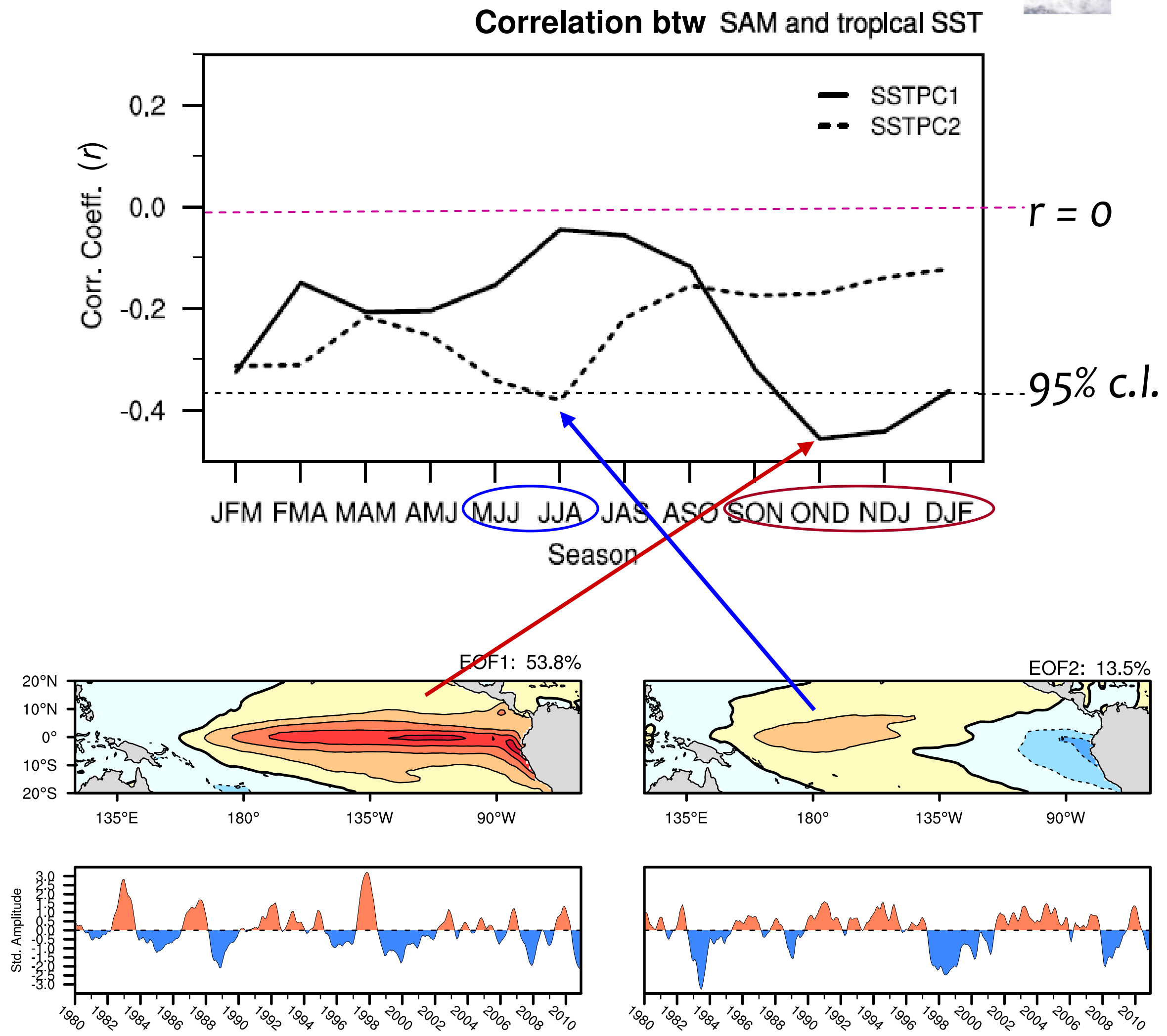
  - Hurrell et al (2008)'s SST analyses (a combined product of HadISST & Reynolds SST)

  - NCEP-NCAR reanalysis data for mslp (SAM index), u, v, T

- 3 month running average was applied to the monthly data over 1980-2010 before calculating correlation or regression

Results

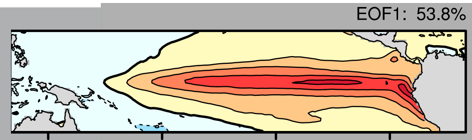




Mechanism of traditional ENSO to promote SAM in summer:

e.g.
Seager el al. 2003 J. Clim,
Lu et al. 2008 J. Clim

Traditional El Nino – negative SAM in summer

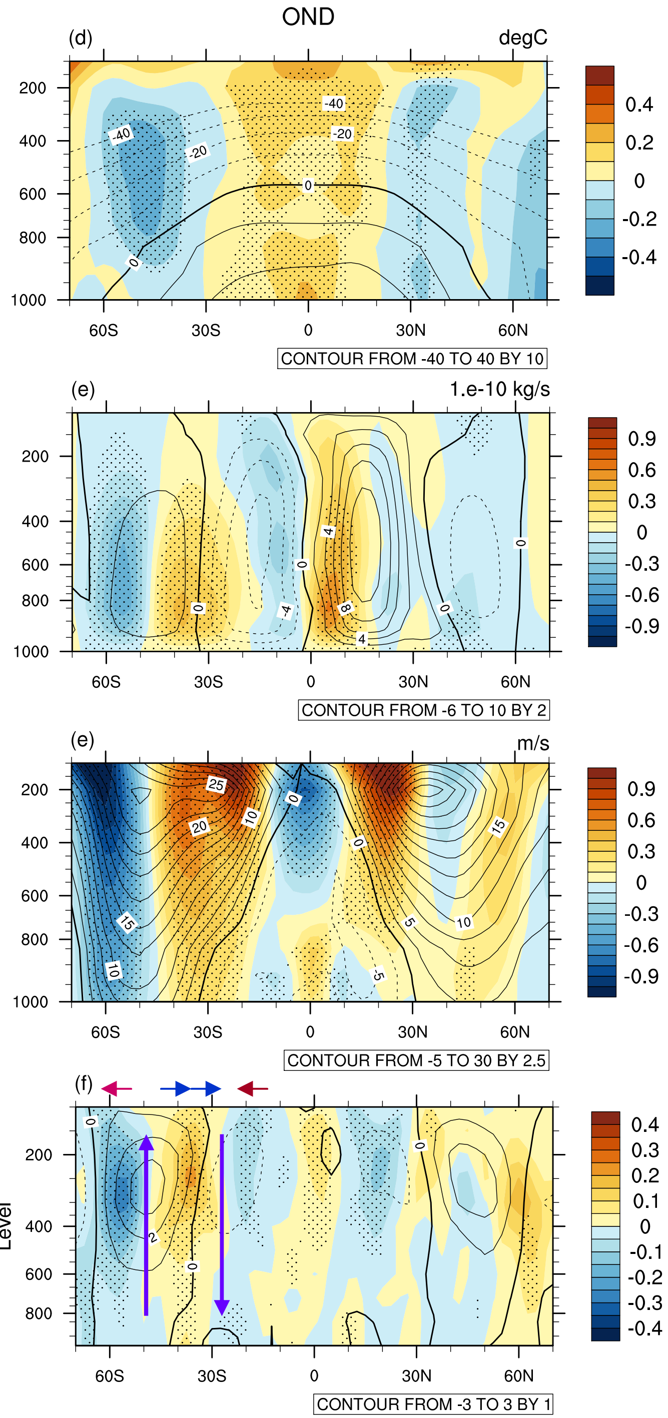


T

MMC

Uwind

Tran. Eddy Mom. Flux conv.



El Nino → Strong ***diabatic heating in the tropics***

Stronger ***Hadley circulation*** (HC) with latitudinal ***contraction***

Stronger westerlies in the ***subtropics*** driven by the poleward branch of contracted HC

Equatorward shift of baroclinic ***wave propagation***

Equatorward shift of ***momentum flux conv/div*** pattern

Downward motion & resultant ***adiabatic warming*** in the ***subtropics***

Increased ΔT and resultant increase of ***eddy activity*** in the ***midlatitudes***

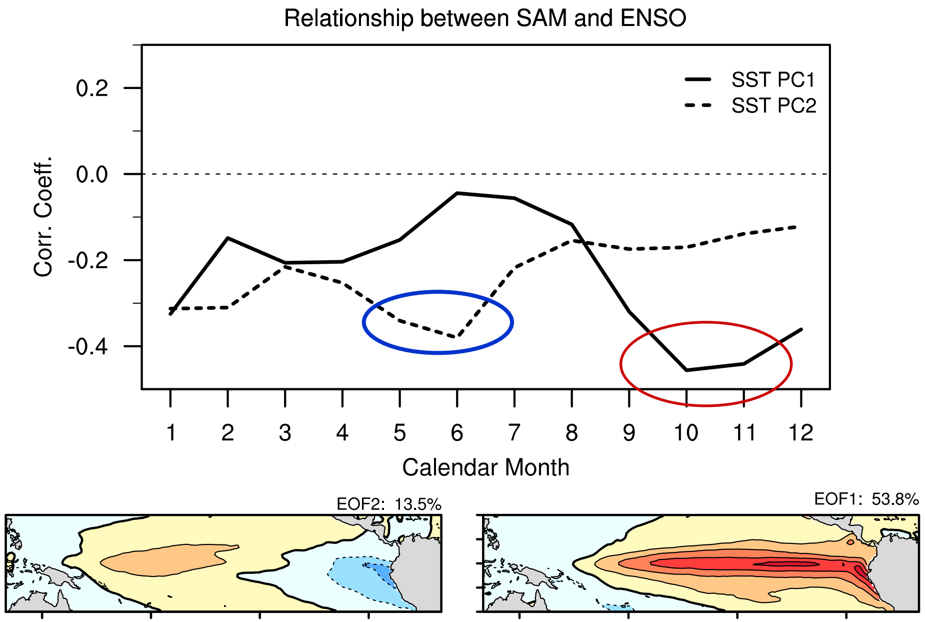
Eddy induced westerlies increase in the ***midlatitudes*** but decrease in the low & high lats

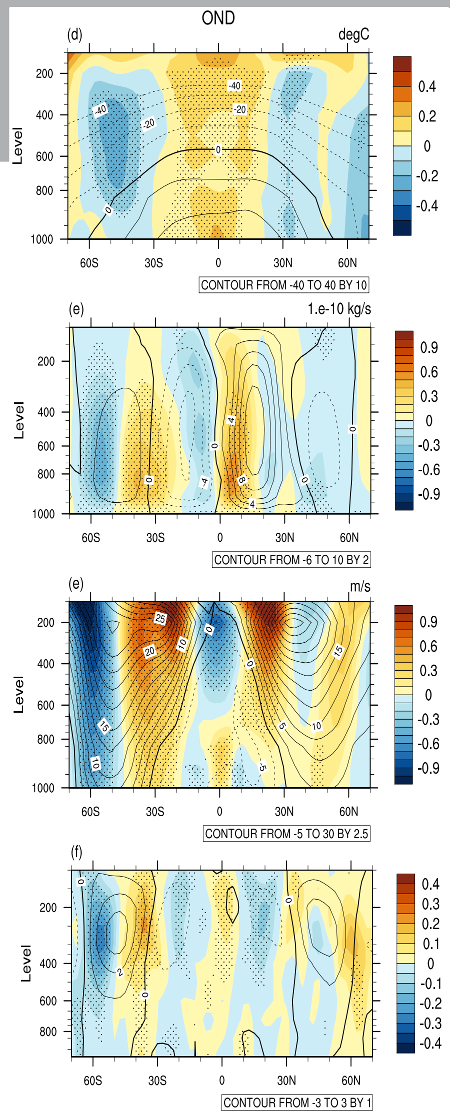
Upward motion & ***adiabatic cooling*** in the ***high latitudes***

Decreased ΔT and resultant reduction of ***eddy*** generation in the ***high latitudes***

→ Negative phase of SAM

Is the summer mechanism able to explain the winter relationship between SAM and central Pacific El Nino?





This chain of processes is favoured in ***October to February***

- ***mean structure*** of SH atmosphere is ***zonally symmetric***

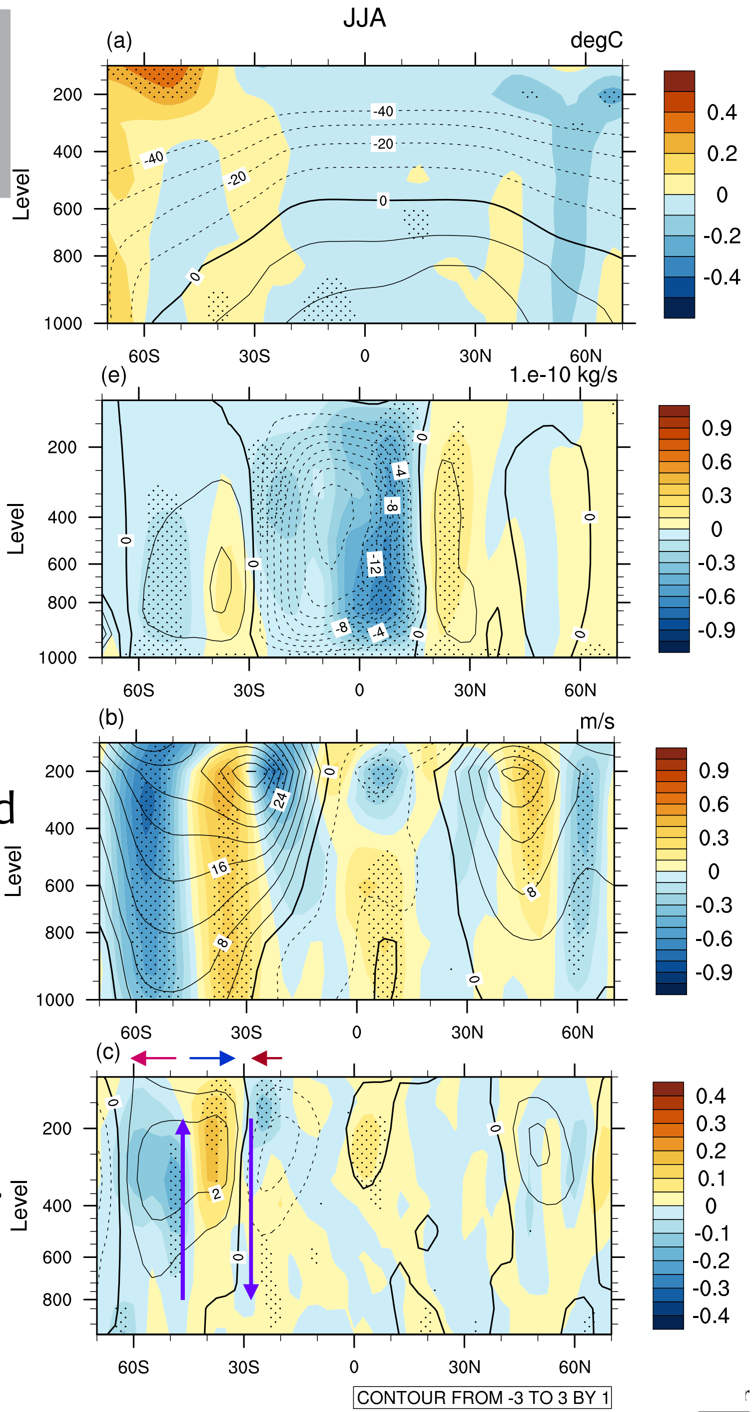
- ***north-south swing*** of the jet explains the largest proportion of ***zonal mean zonal wind variability***

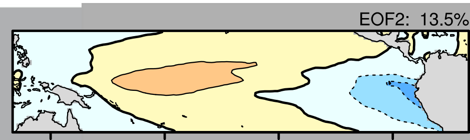
T

MMC

Uwind

Tran. Eddy Mom. Flux conv.





C. Pacific El Nino – negative SAM in winter

El Nino → an overall ***cooling*** in the tropics despite the warming in the central Pacific

Stronger **HC** with ***poleward expansion***

Stronger ***westerlies on the poleward side*** of the winter subtropical jet

→ ***La Nina-like tropical circulation*** → ~~***Positive SAM***~~

Winter subtropical jet provides ***vertical wind shear on the poleward side*** → ***baroclinic eddies*** can grow in the ***midlatitudes*** climatologically

Increase of ***westerlies*** on the subtropical jet ***due to CP El Nino*** → ***more eddies*** on its poleward side → ***more EMFC*** & resultant westerlies in the ***midlatitudes***

Downward motion & ***adiabatic warming*** in the ***subtropics*** but ***upward motion*** and ***adiabatic cooling*** in the ***high latitudes***

Increases of ΔT & ***eddy generation in the subtropics*** but ***decreases*** of them in the ***high latitudes***

→Negative phase of SAM

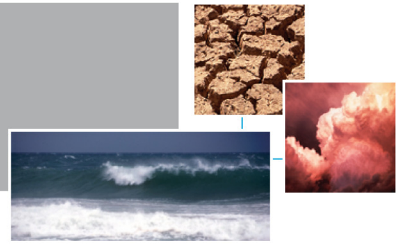
Summary

Traditional El Nino – negative SAM in warm seasons	Central Pacific El Nino – negative SAM in cold seasons
Tropical heating	Tropical cooling
Hadley Circulation contraction	Hadley Circulation expansion
Increased westerlies in the low latitudes	Increased westerlies in the midlatitudes
Shift wave breaking equatorward	Promote eddy generation in the midlats

Traditional and Central Pacific ENSO can be an important source of predictability of SAM in the SH warm and cold seasons, respectively

Further details – Lim et al. (2013) Seasonal Predictability of the Southern Annular Mode due to its Association with ENSO accepted in J. Clim.

Data & Methodology



- Zonally averaged momentum eq

$$\frac{\partial[\bar{u}]}{\partial t} = f[\bar{v}] - \frac{\partial}{\partial y}[\overline{u'v'}] + F$$

→ increase of westerlies with time = Coriolis' Torque + Eddy Momentum Flux convergence + Friction

$$-f[\bar{v}] \sim -\frac{\partial}{\partial y}[\overline{u'v'}]$$

→ Eddy momentum flux convergence/divergence can induce *v* (meridional winds)

- Continuity eq

$$\frac{\partial[\bar{v}]}{\partial y} = \frac{\partial[\bar{w}]}{\partial z}$$

→ Div of *v* winds induces upward motion

- Thermal wind equation

$$f\frac{\partial[\bar{u}]}{\partial z} \sim -\frac{1}{\rho[\theta]}\frac{\partial[\theta]}{\partial y}$$

→ Vertical shear of westerlies ~ meridional temperature gradient – important source of growth of eddies