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Impacts of a Midlatitude Oceanic Frontal Zone on the Southern Baroclinic Annular Mode

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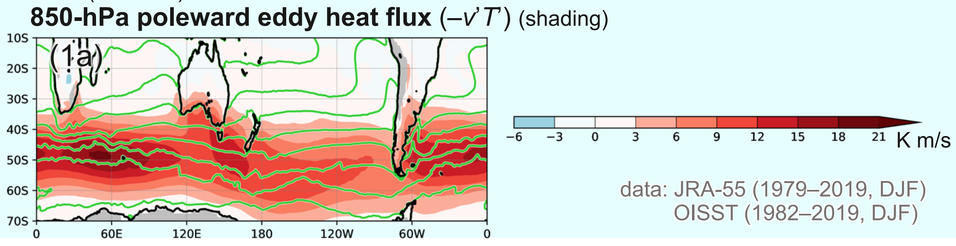
1. Introduction

■ **Midlatitude oceanic frontal zone**: tight meridional SST gradient

- Energizes & thereby anchors storm-track activity & eddy-driven jet by efficiently maintain near-surface baroclinicity & supporting recurrent development of baroclinic eddies

e.g., Nakamura et al. (2004; 2008)

Climatological-mean
SST (contours)
850-hPa poleward eddy heat flux $(-v'T')$ (shading)



data: JRA-55 (1979–2019, DJF)
OISST (1982–2019, DJF)

2. Analysis

We assess storm-track activity & its BAM-associated variability in atmospheric reanalysis data & AGCM experiments

- Extract **transient disturbances** with **8-day high-pass filtering** (noted with primes)
  - ➢ Measure storm-track activity with eddy statistics (such as tEKE=$(u'u'+v'v')/2$)
  - ➢ Assess BAM variability by defining **BAM index** as PC1 of [tEKE]

EOF domain: 925–200 hPa, 20–70ºS [ ] : zonal mean

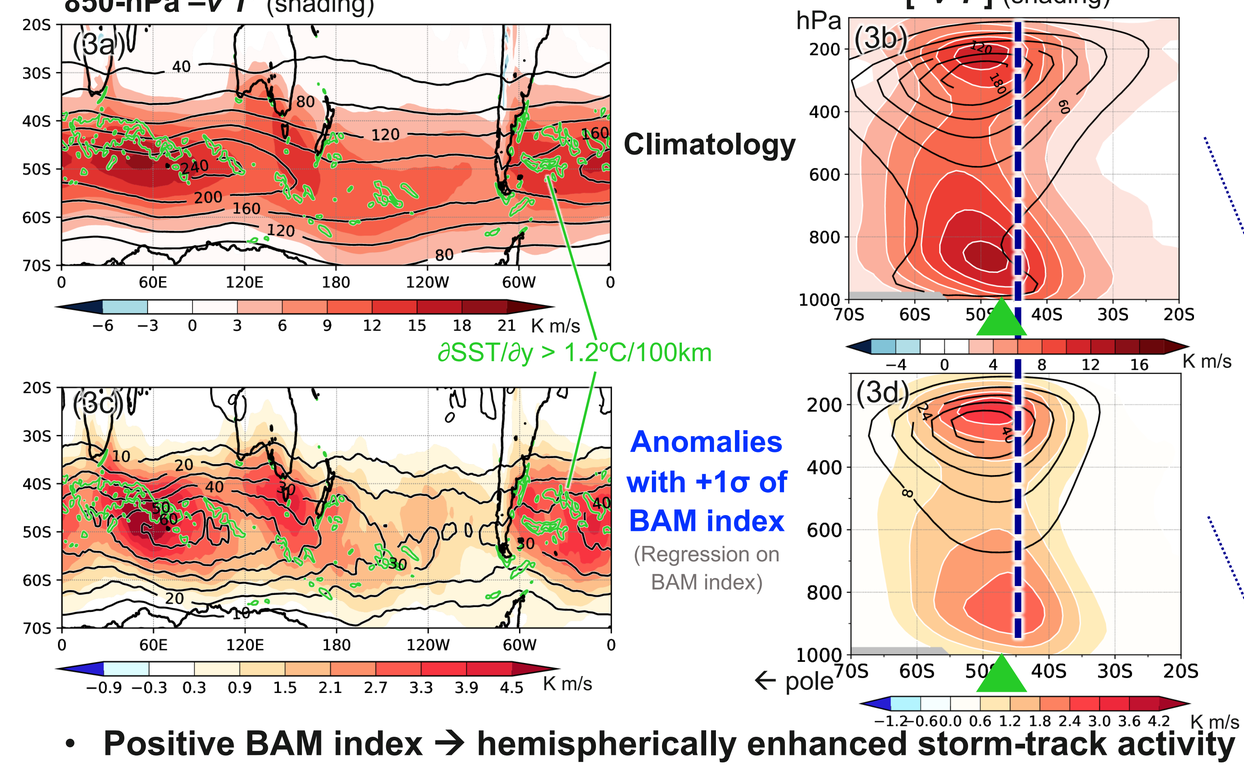
3. BAM signature in the Southern Hemisphere

- **JRA-55 atmospheric reanalysis** (Kobayashi et al. 2015)
  - Analysis period: 1979–2019 (41years) - 1.25º × 1.25º

300-hPa tEKE (contour, m^2/s^2)
850-hPa $-v'T'$ (shading)

JRA-55 (summer; DJF)

[tEKE] (contour, m^2/s^2)
[$-v'T'$] (shading)



Climatology

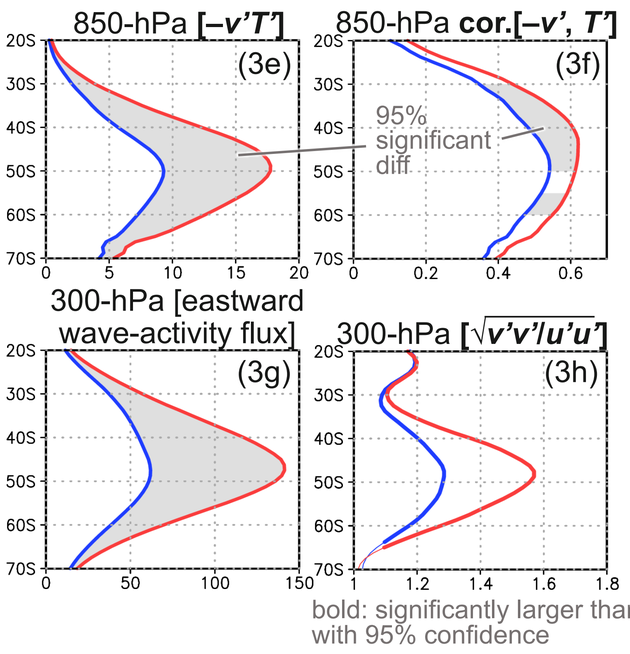
Anomalies with +1σ of BAM index
(Regression on BAM index)

- **Positive BAM index → hemispherically enhanced storm-track activity**

● **As important dynamical characteristic, we found BAM-associated structural modulations of transient disturbances**

Nakayama et al. (2023, *J. Clim.*)

Composites for **positive** & **negative** phases of BAM (results for all months)
BAM index>+1 BAM index<−1



bold: significantly larger than 1 with 95% confidence

In positive phase of BAM,

- Transient disturbances exhibit **more distinct baroclinic structure** (higher cor.[$-v'$, T'])

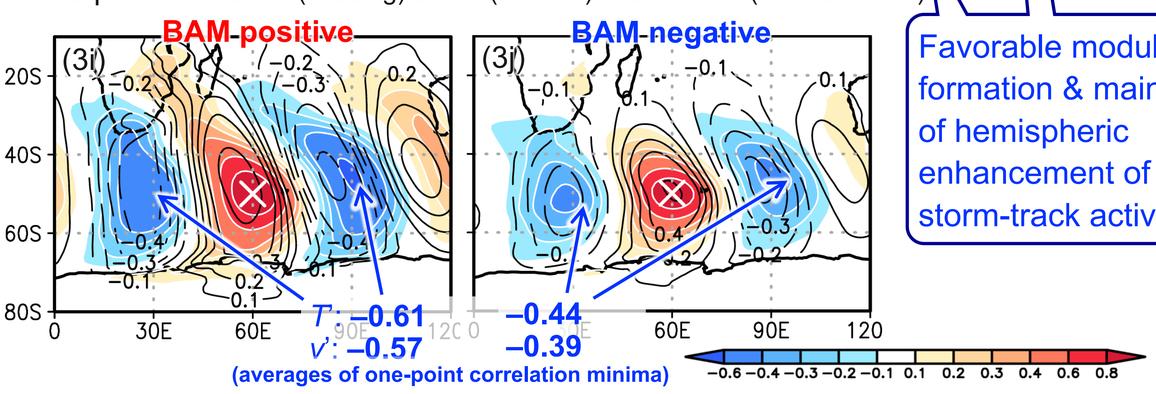
→ **More efficient baroclinic growth**

- Transient disturbances exhibit **more meridionally elongated structure** (higher [$\sqrt{v'v'/u'u'}$])

→ **More efficient downstream development** (eastward energy propagation)

→ Yield further baroclinic growth downstream

One-point corr of T' (shading) & $-v'$ (contour) based on T' (all at 850 hPa)



T': **−0.61**
v': **−0.57**
(averages of one-point correlation minima)

−0.44
−0.39

Favorable modulations for formation & maintenance of hemispheric enhancement of storm-track activity!

Conclusions

Nakayama, Nakamura & Ogawa (2021, *J. Clim.*)
Nakayama, Nakamura & Ogawa (2023, *J. Clim.*, accepted)

- With **midlatitude oceanic frontal zone**, **BAM variability is significantly amplified & thereby anchored**
  - Efficient restoration of near-surface baroclinicity
- BAM is found to be associated with **structural modulations of transient disturbances** (baroclinic structure, meridional elongation), which is **more significant with oceanic frontal zone**, due to **more coherent & organized baroclinic wave packets**

Motivation

■ Impacts of oceanic frontal zone on storm-track variability remain to be shown

- **Baroclinic annular mode (BAM)** was recently discovered
  Dominant variability in extratropical eddy activity representing its **hemispheric-scale pulsing** at period of ~25 days
  Thompson & Woodworth (2014)
  Thompson & Barnes (2014)
- Seen in both hemispheres, but more distinct in Southern Hemisphere
  Thompson & Li (2015)

△ Mechanism of BAM remains unclear

Purpose

■ **To assess impacts of oceanic frontal zone on BAM**
(spatial structure, dynamics, …)

4. Impacts of Oceanic Frontal Zone on BAM

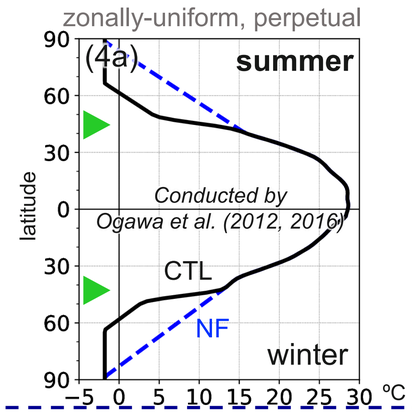
Nakayama et al. (2021, *J. Clim.*)

- **Aqua-planet experiments with & without oceanic frontal zone are compared**

CTL	**SST front at 45º lat** Observed SST in South Indian Ocean
NF	**SST front is artificially relaxed** by raising SST in high latitude

- Run with AFES (AGCM for Earth Simulator)
- T79L56 (~150 km grid int, top=0.09 hPa)
- Run for 3600 days

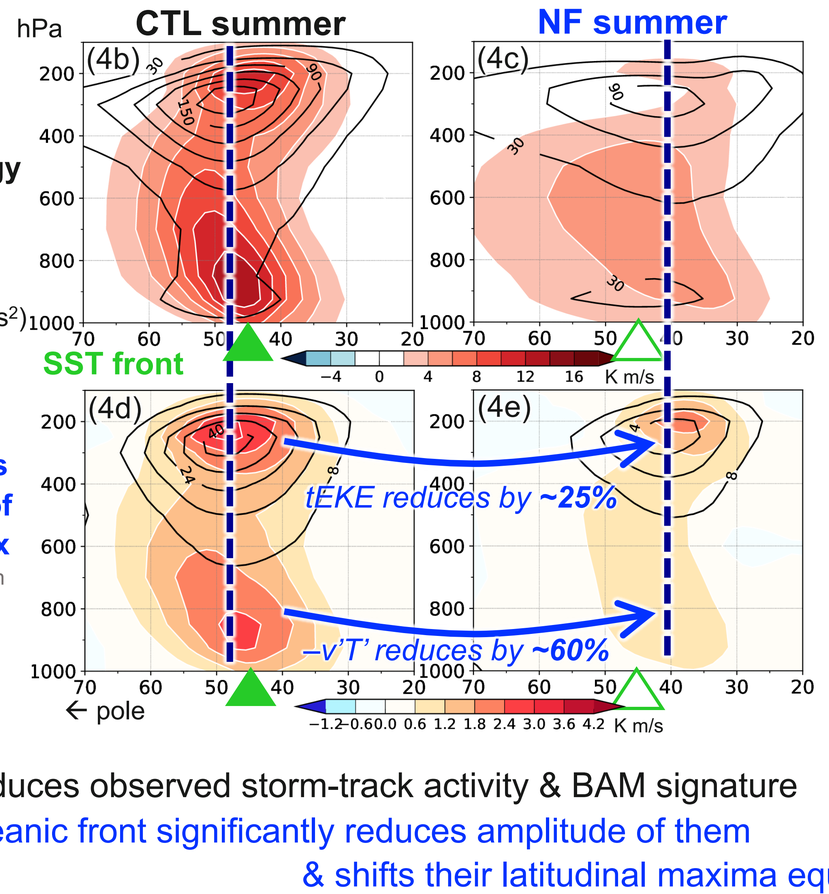
Prescribed SST
zonally-uniform, perpetual



Climatology

[tEKE] (contour, m^2/s^2)
[$-v'T'$] (shading)

Anomalies with +1σ of BAM index
(Regression on BAM index)

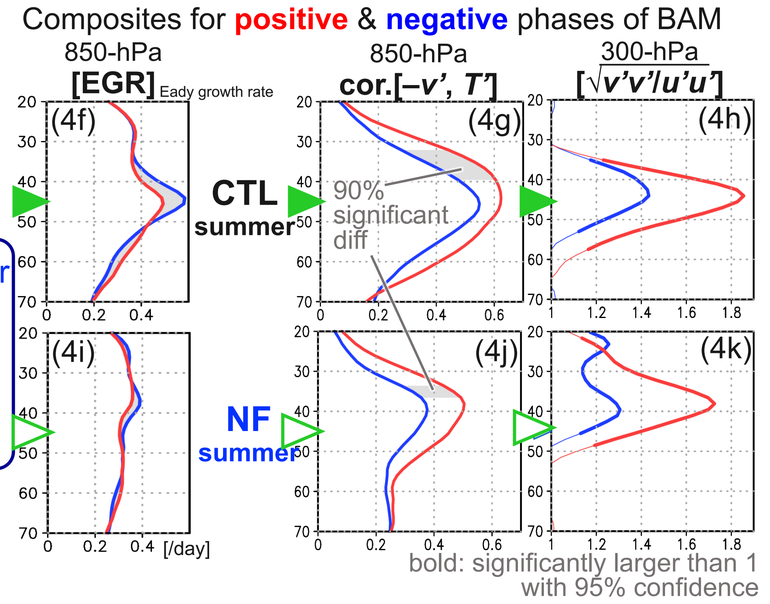


- CTL well reproduces observed storm-track activity & BAM signature
- Removal of oceanic front significantly reduces amplitude of them & shifts their latitudinal maxima equatorward

● BAM-associated structural modulations in aquaplanet

Composites for **positive** & **negative** phases of BAM

Nakayama et al. (2023, *J. Clim.*)



bold: significantly larger than 1 with 95% confidence

- BAM-associated structural modulations of transient disturbances in both CTL & NF
  → Manifestation of atmospheric internal dynamics
- Higher cor.[$-v'$, T'] in CTL (90% significant)
  → More distinct baroclinic structure of disturbances with oceanic front
- More significant modulations of cor.[$-v'$, T'] in CTL