Cyclonic and anticyclonic contributions to air-sea interactions around midlatitude oceanic frontal zones

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Motivation

- The Kuroshio-Oyashio Extension and Gulf Stream frontal zones are vitally important for midlatitude air-sea interactions and the maintenance of storm-tracks & westerly jets.
- Synoptic-scale fluctuations play a pivotal role in the air-sea interaction.

STDEV of daily THF (Kelly et al. 2010)

Around NH frontal zones, subweekly THF fluctuations are prominent.

- However, specific processes related to the interaction have not been sufficiently understood, esp. their contributions to climatological means.

Methods

Evaluation of cyclonic and anticyclonic contributions:

Identification of cyclonic and anticyclonic domains is based on local curvature of the unfiltered winds (Okajima et al. 2021)

\[
\Gamma = \frac{1}{2} \left( \sin \phi \frac{d^2 U}{dy^2} + \cos \phi \frac{d^2 V}{dy^2} \right)
\]

850-hPa curvature is used for 2-D variables (e.g., THF)

Atmospheric reanalysis:

JRA-55 (Kobayashi et al. 2015), 1958/59-2017/18

Assessment of the frontal impacts:

Through AGCM experiments with realistic/smoothed frontal zones (Kawano-Yoshida and Minobe 2017)
- T239(0.5°), 20-year (1981-2001) for control (realistic fronts) & smith (smoothed only over NP or NA) experiments using AFES3

Moisture exchange b/w cyclonic and anticyclonic domains:

Moisture flux projected onto the upgradient direction of local curvature

\[ \frac{\partial q}{\partial x} \] (Positive: anticyc - cyc)

is calculated as a measure of moisture exchange.

Transient eddy feedback forcing onto westerly jets:

Based on the 3-D height tendency equation with responses of Eulerian eddy statistics from 8-day high-pass fields (Okajima et al. 2021)

Key takeaways:

- Climatologically, moisture is transported as a net from anticyclonic domains to cyclonic domain.
- Oceanic fronts reinforce the “acyc -> cyc” moisture transport.
- Anticyclonic domains are the key for westerly wind deceleration feedback response to realistic oceanic fronts.

Precipitation – Evaporation (mm/day; DJF-mean)

Responses of \( dU_{300}/dt \) by transient eddies (cnt; m/s/month; DJF)

North Atlantic
Gulf Stream front

North Pacific
Kuroshio Extension/Oyashio fronts

Shading: 90/95% significance
Purple contour: \( U_{300} \) control

Cyclonic
Anticyclonic
Cyclonic
Anticyclonic

Additional results (for NA)

- Climatologically", anticyclonic contribution accounts for "40% of THF, while much less for precip.

- THF enhancement is greater over anticyclonic domains, while precip increases mainly within cyclonic domains.

The moisture exchange evaluation supports the climatological "acyc -> cyc" moisture transport and its enhancement by oceanic fronts.

Implications & Future studies

- The quantification of the contributions to THF/precip. leads to a better understanding of the formation mechanism for seasonal SST anomalies due to modulated storm-track activity
- The sensitivity of a basin-scale atmospheric response to midlatitude SST anomalies to the resolution of AGCMs
- Relationship between the enhanced THF and the upper-level jet response
- Comparison between JRA-55C and JRA-55S
- Future change

References


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*1 include both high- and low-var. components. *2 Similar results are obtained with 925-hPa u. *3 Results in "control" are qualitatively the same as in JRA-55.

*4 Additional results (for NA)

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