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

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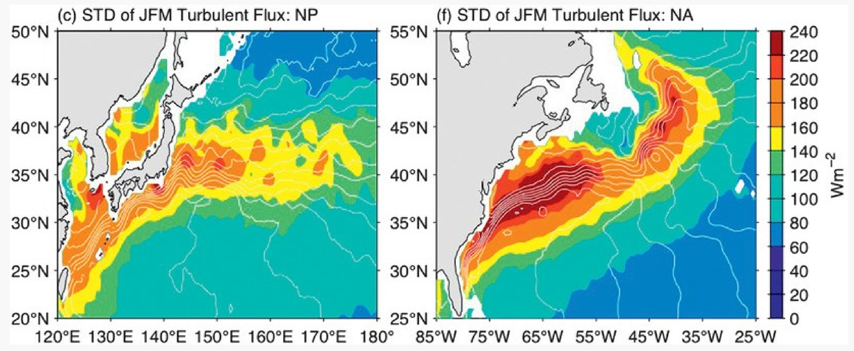
Motivation

- **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*1 (Okajima et al. 2021)

$$\kappa_2 \equiv \frac{1}{R_s} = \frac{1}{V^3}\left(-uvu_x + u^2v_x - v^2u_y + uvv_y\right)$$

850-hPa curvature*2 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 (Kuwano-Yoshida and Minobe 2017)

- T239(0.5°), 20-year (1981-2001) for control (realistic fronts) & smth (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

$$\epsilon \equiv (q\mathbf{v}') \cdot \frac{\nabla\kappa_2}{|\nabla\kappa_2|}$$ (Positive: acyc -> cyc)

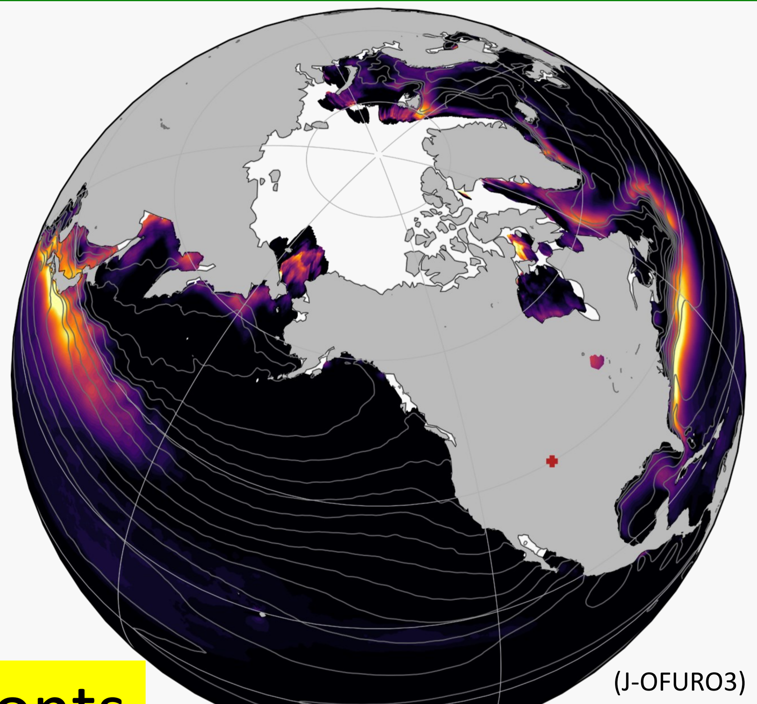
is calculated as a measure of moisture exchange.

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.

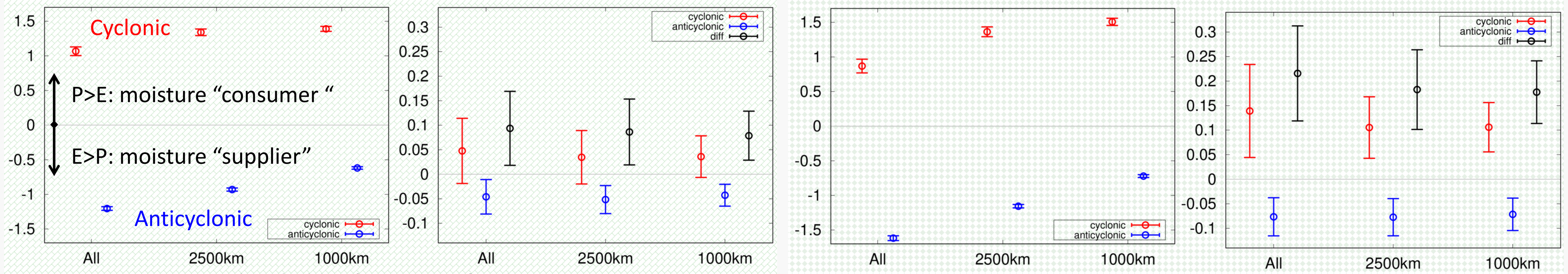


(J-OFURO3)

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

Whiskers: std err
Assuming Lq = 2500 J/kg

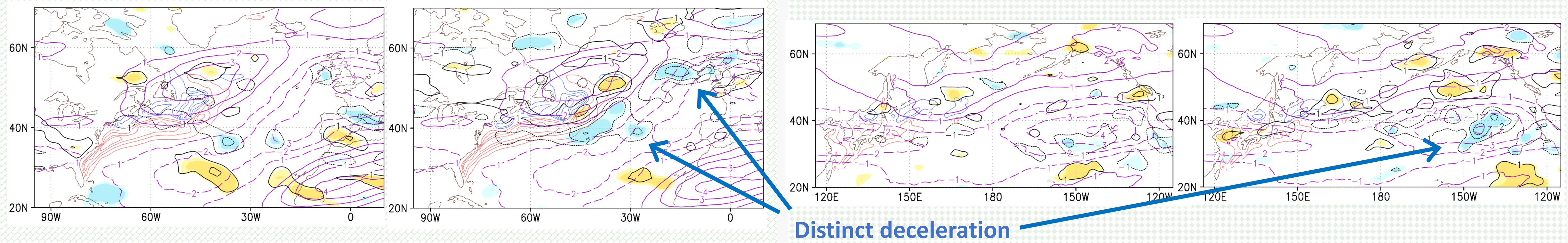
Climatology (control) | Response to fronts (control – smth) | Climatology (control) | Response to fronts (control – smth)



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

Shading: 90/95% significance
Purple contour: U_{300} response

Cyclonic | Anticyclonic | Cyclonic | Anticyclonic



North Atlantic Gulf Stream front

North Pacific Kuroshio Extension/Oyashio fronts

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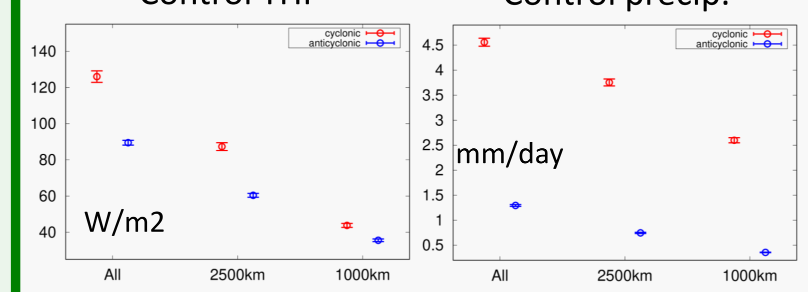
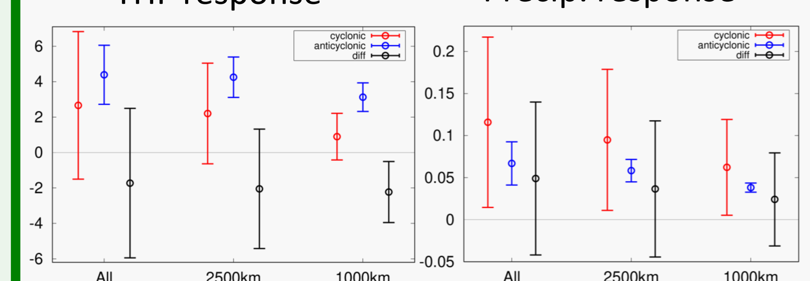
Additional results (for NA)

Control THF | Control precip.



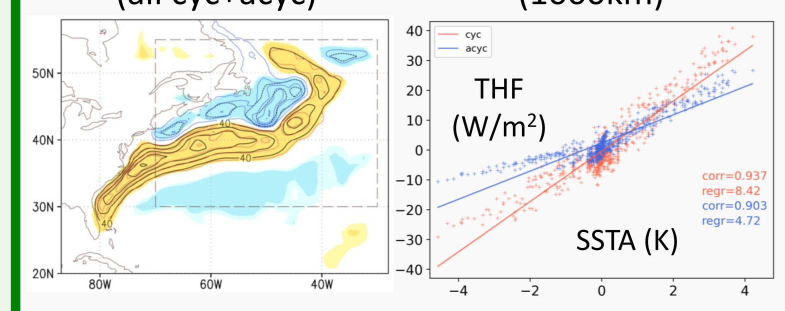
Climatologically*3, anticyclonic contribution accounts for ~40% of THF, while much less for precip.

THF response | Precip. response



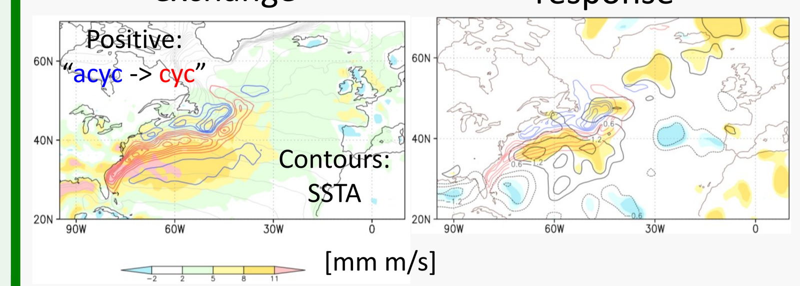
THF enhancement is greater over anticyclonic domains, while precip increases mainly within cyclonic domains.
(In line with Tsopouridis et al. 2021)

THF response (all cyc+acyc) | THF response vs SSTA (1000km)



THF response well corresponds to local SSTA.
THF weakening is suppressed within anticyclonic domains.

Clim. moisture exchange | Moisture exchange response



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-55CHS (Masunaga et al. 2018)
- Future change

*1 include both high- and low-freq. components. *2 Similar results are obtained with 925-hPa κ_2. *3 Results in "control" are qualitatively the same as in JRA-55.

Acknowledgements

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