Decomposing Atmospheric Response to Mesoscale Eddies: Roles of Thermal Gradients and Air–Sea Temperature Contrast

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Mesoscale eddies

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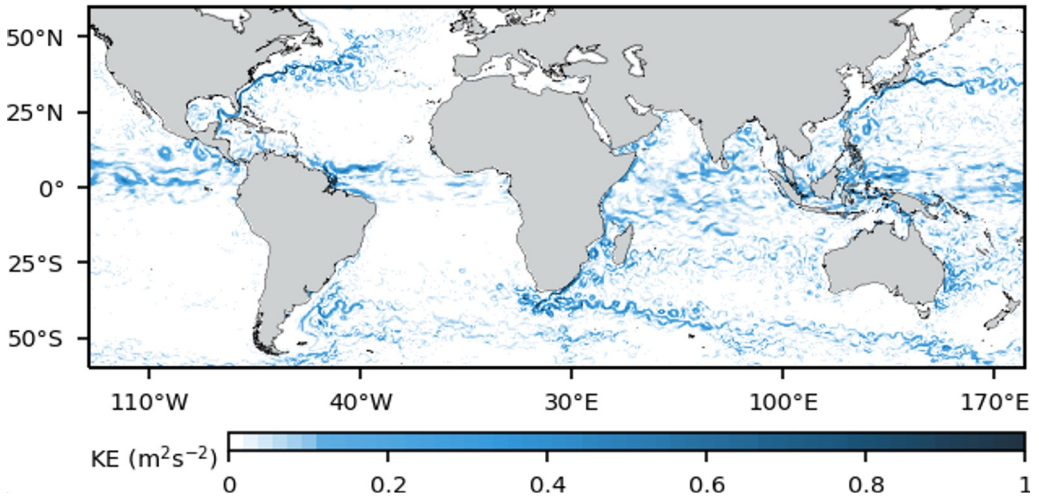
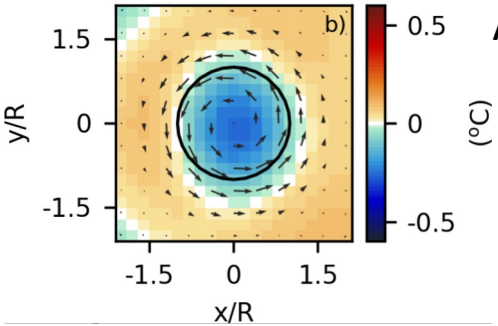
- Diameter: 40 to 200 km
- Lifetime: weeks to several months
- Associated surface currents: 0.1 to 1 m/s



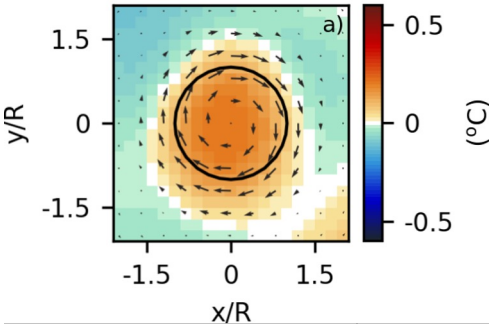
Cyclonic eddies

- Cold-core
- Negative sea level anomaly
- Positive vorticity



Anticyclonic eddies

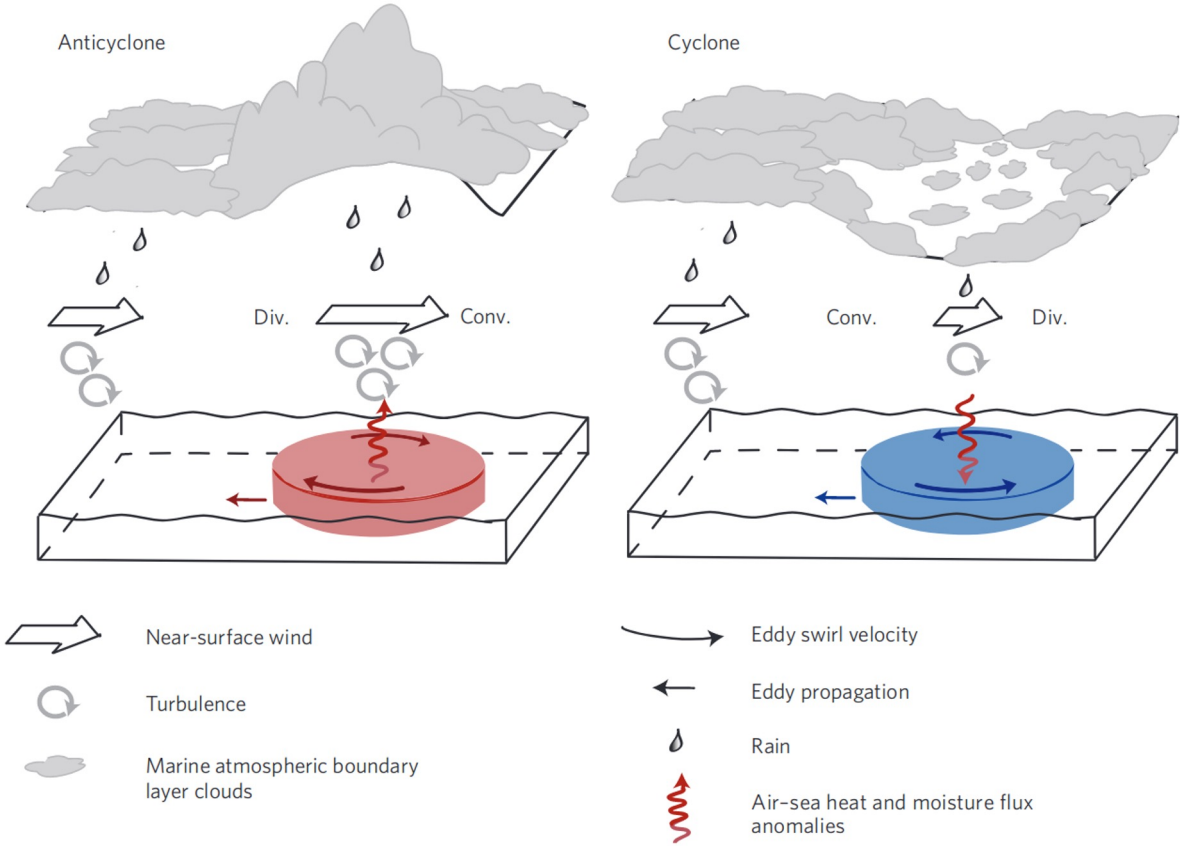
- Warm-core
- Positive sea level anomaly
- Negative vorticity



The thermal feedback to the atmosphere

Mesoscale eddies:

- Drive turbulent heat fluxes anomalies between the ocean and the atmosphere
- **Important implications in the atmosphere**
  - Heat and moisture fluxes
  - Turbulence
  - Clouds coverage
  - Precipitation
- Coupling coefficients
  - Divergence: Stronger slopes
  - Curl: Weaker slopes



Modified from Frenger *et al.*, 2013

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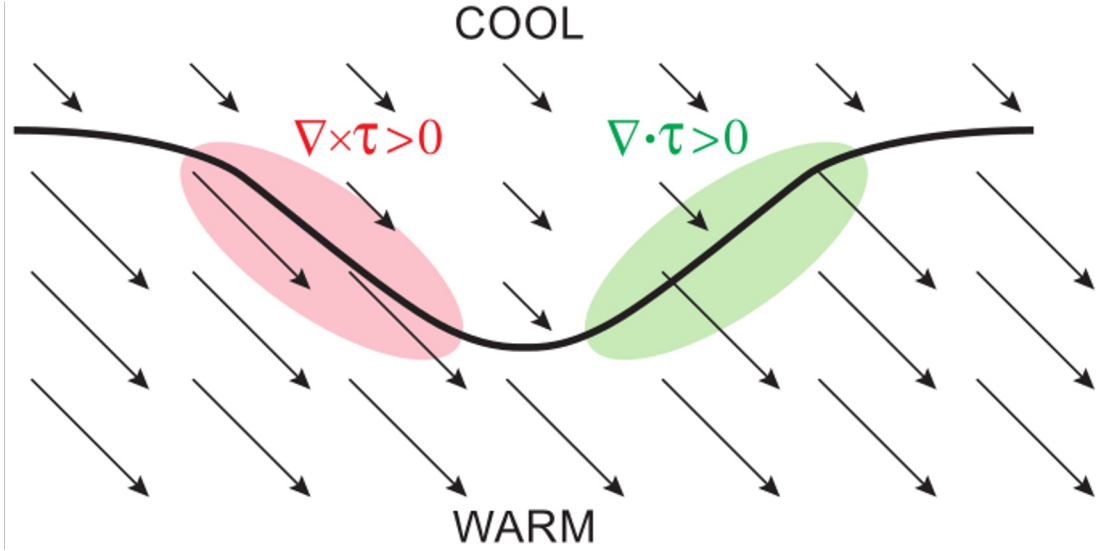

Chelton *et al.*, 2014

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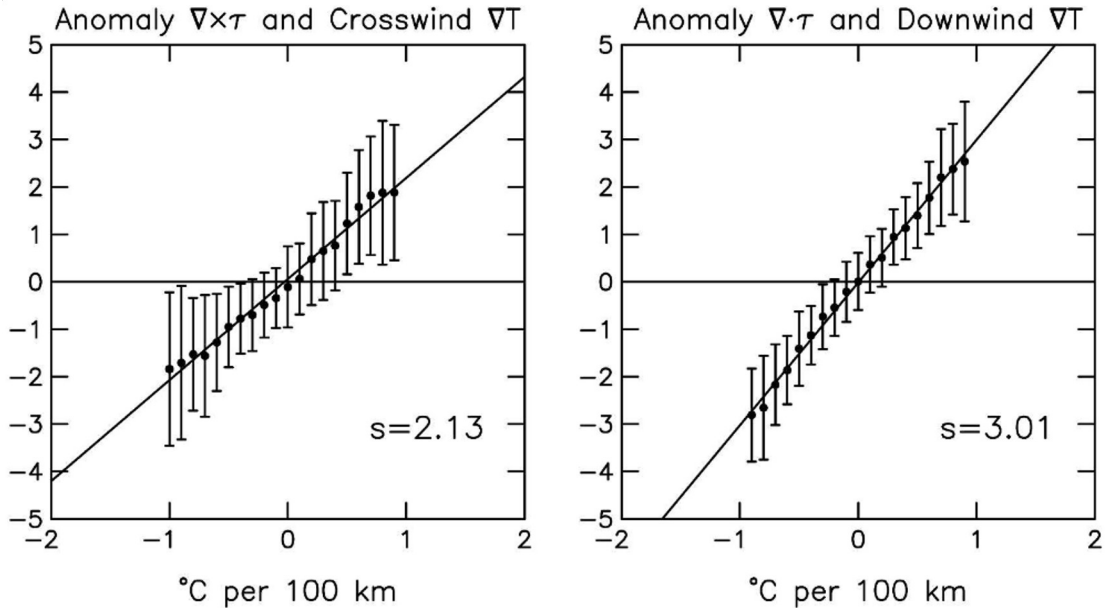

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The current feedback to the atmosphere

The current feedback modulates the energy transfer between the atmosphere and the ocean through the wind work (WW)

$$\mathrm{WW} = \frac{1}{\rho_0}(\overline{\tau_x}\,\overline{u_g} + \overline{\tau_y}\,\overline{v_g}) + \frac{1}{\rho_0}(\overline{\tau_x' u_g'} + \overline{\tau_y' v_g})$$

$$\tau = \rho_a C_d |U_r| U_r$$

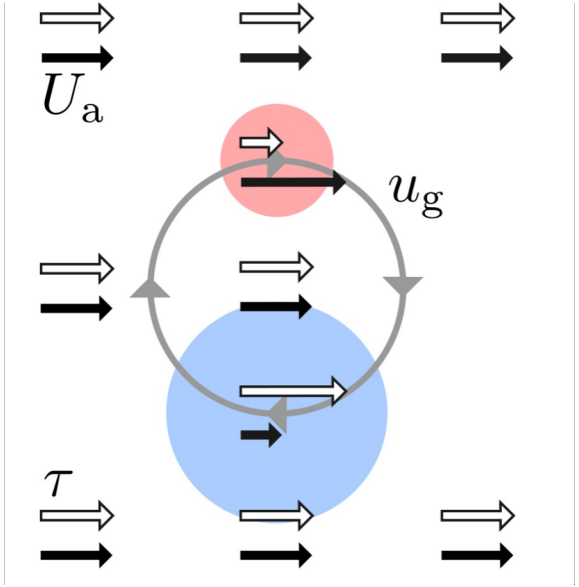
$$U_r = U_a - u_g$$

Wind-aligned currents:

- Wind stress: Negative anomalies
- Energy flux: Atmosphere to ocean currents
- **Stronger currents**

Wind-opposite currents:

- Wind stress: Positive anomalies
- Energy flux: Ocean currents to atmosphere
- **Weaker currents**



Bye, 1985; Renault *et al.*, 2016a, 2016b, 2017b

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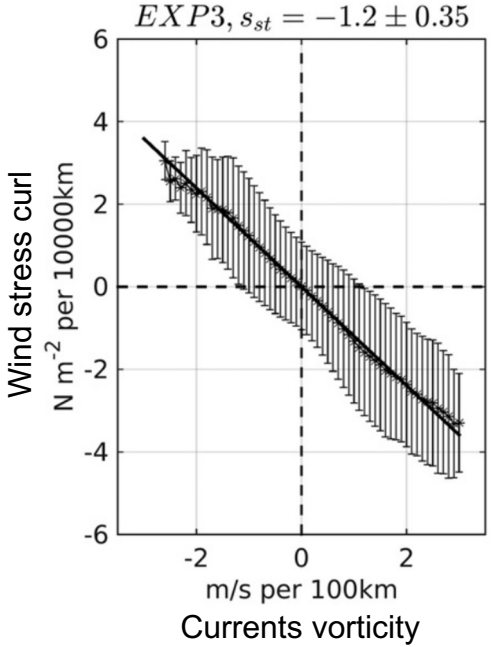

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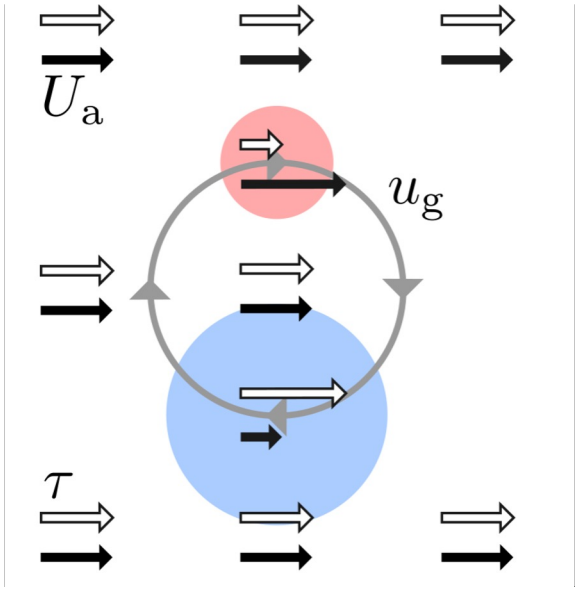

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Objective and methods

Main objectives:

- Relative contributions of thermal drivers to wind stress curl and divergence over mesoscale eddies:
  - Along-winds thermal gradient
  - Across-winds thermal gradient
  - Temperature difference between the Atmosphere and the Ocean
- Are these thermal responses contaminated by surface currents?

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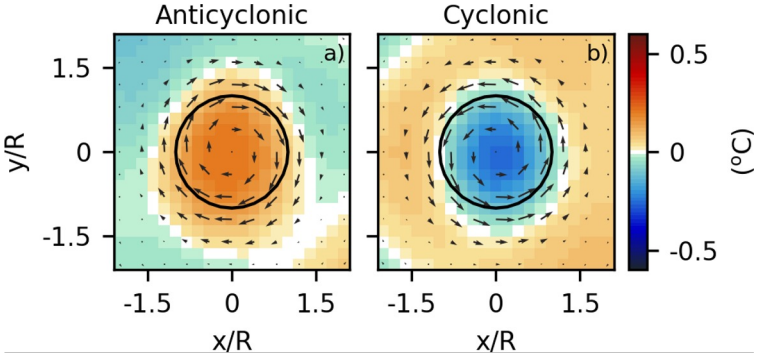

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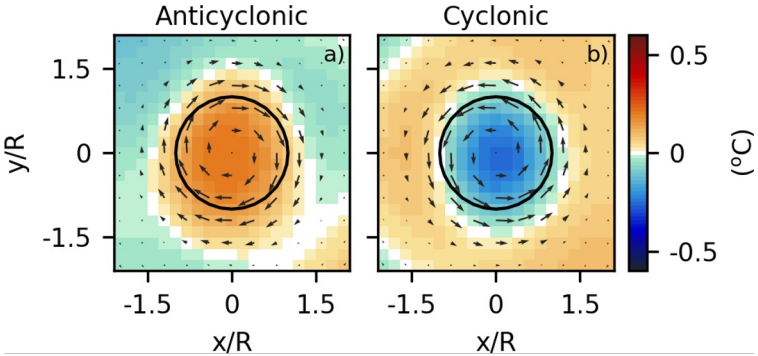

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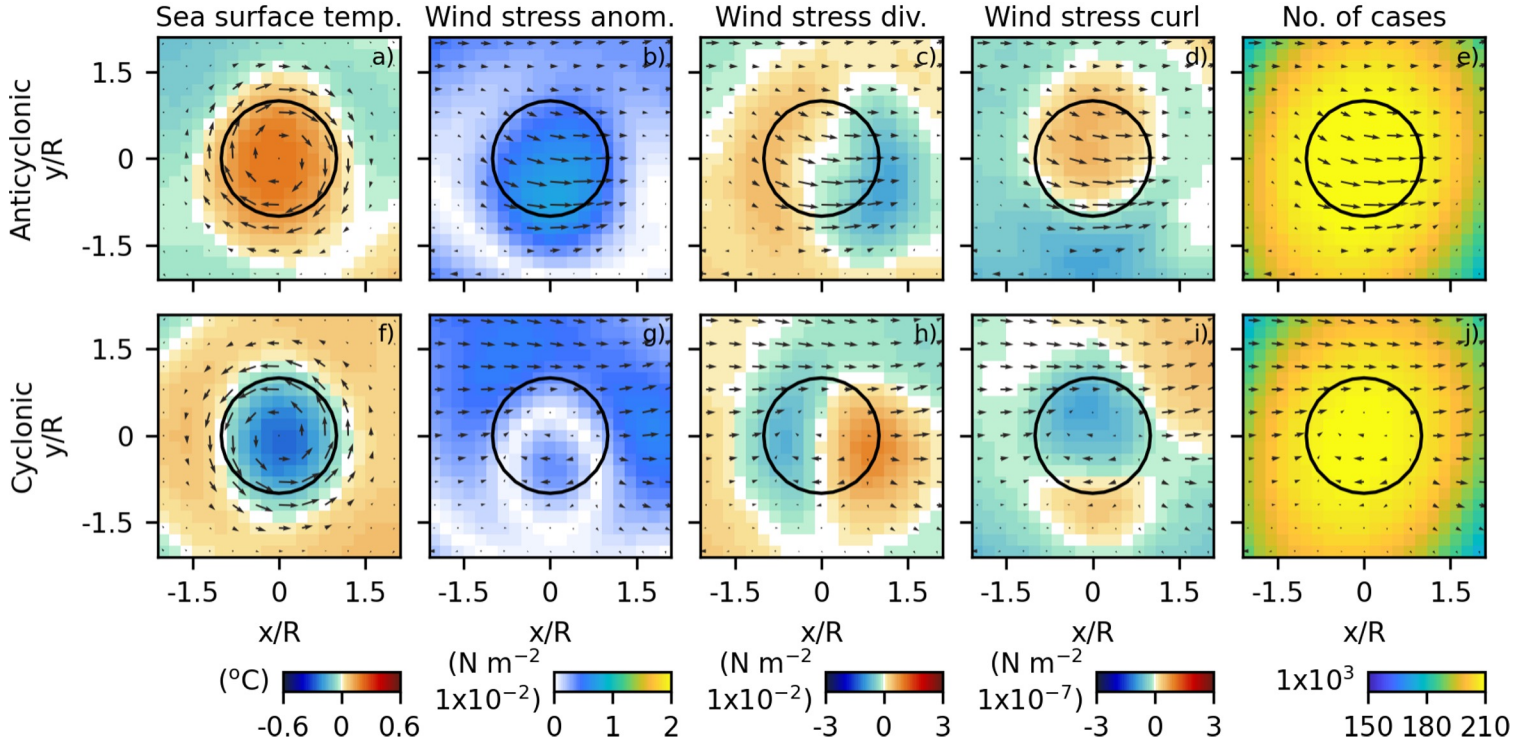
- Linear regression:

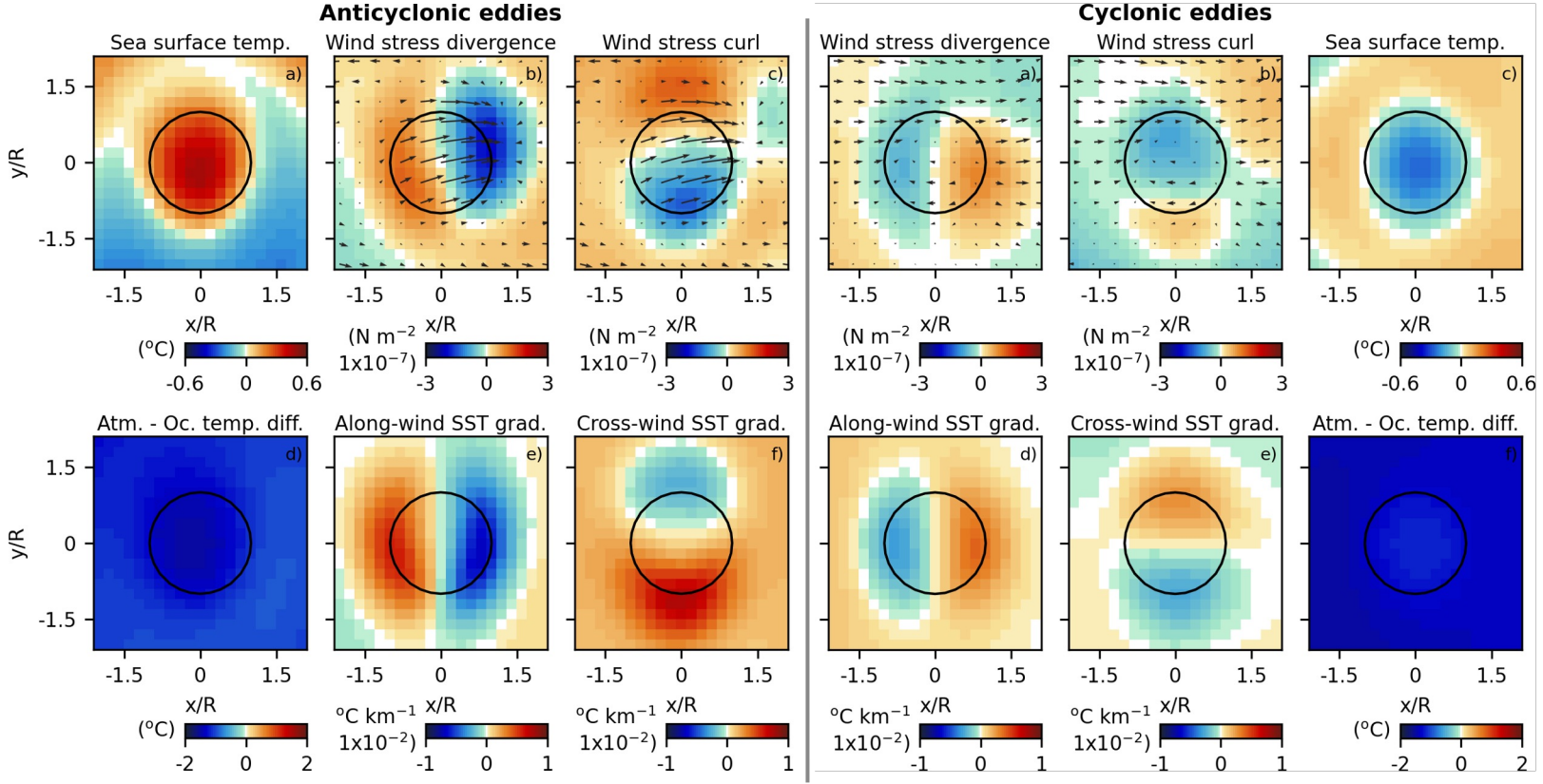
$$\nabla \times \tau = \alpha_{||} \nabla \mathrm{SST}_{||} + \alpha_{\perp} \nabla \mathrm{SST}_{\perp} + \alpha_{a-o} \Delta \mathrm{T}_{a-o} + \varepsilon$$

$$\nabla \cdot \tau = \alpha_{||} \nabla \mathrm{SST}_{||} + \alpha_{\perp} \nabla \mathrm{SST}_{\perp} + \alpha_{a-o} \Delta \mathrm{T}_{a-o} + \varepsilon$$

Mean conditions over warm- cold-core mesoscale eddies



Mean conditions and predictors over warm- cold-core mesoscale eddies



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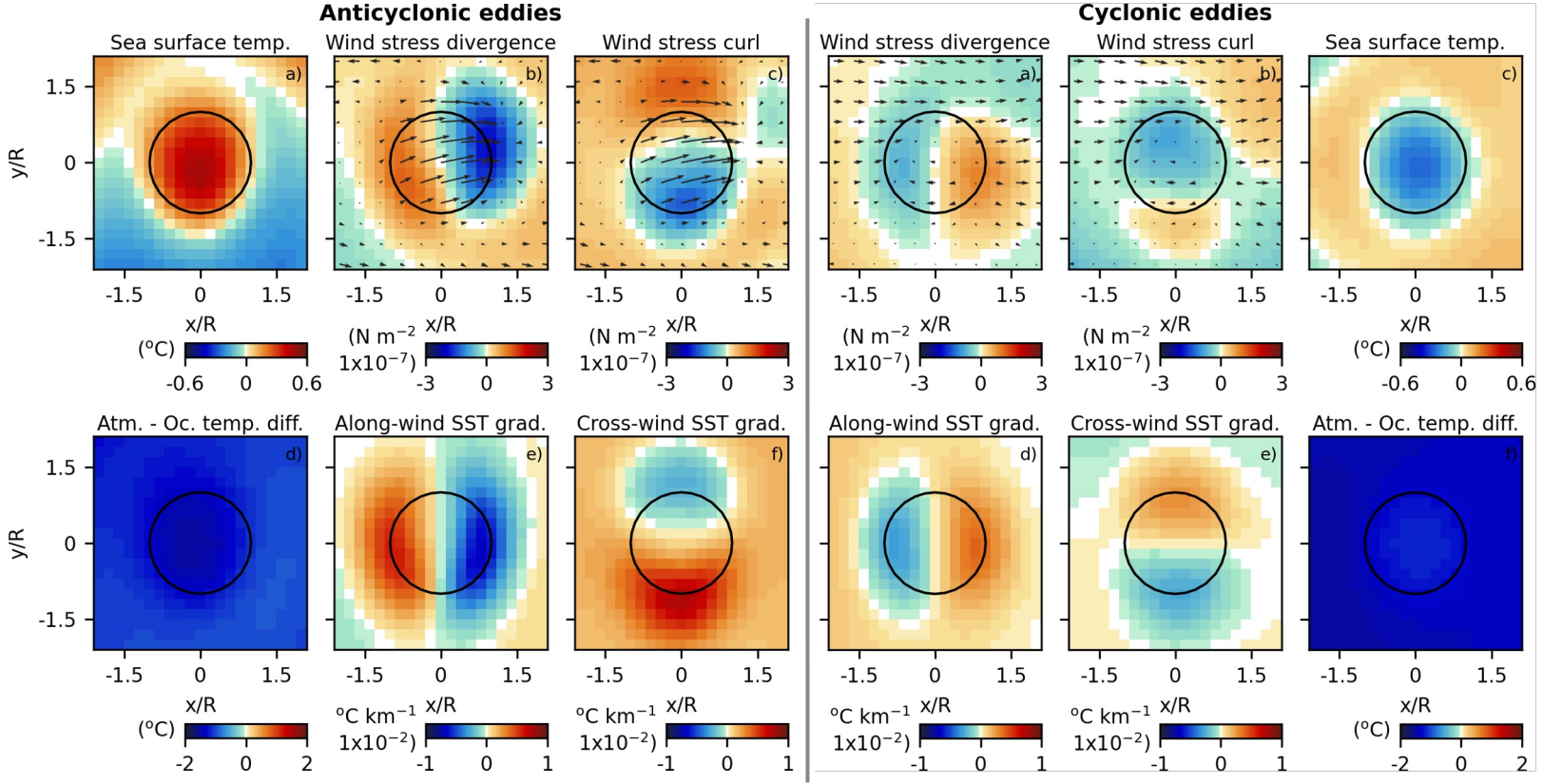

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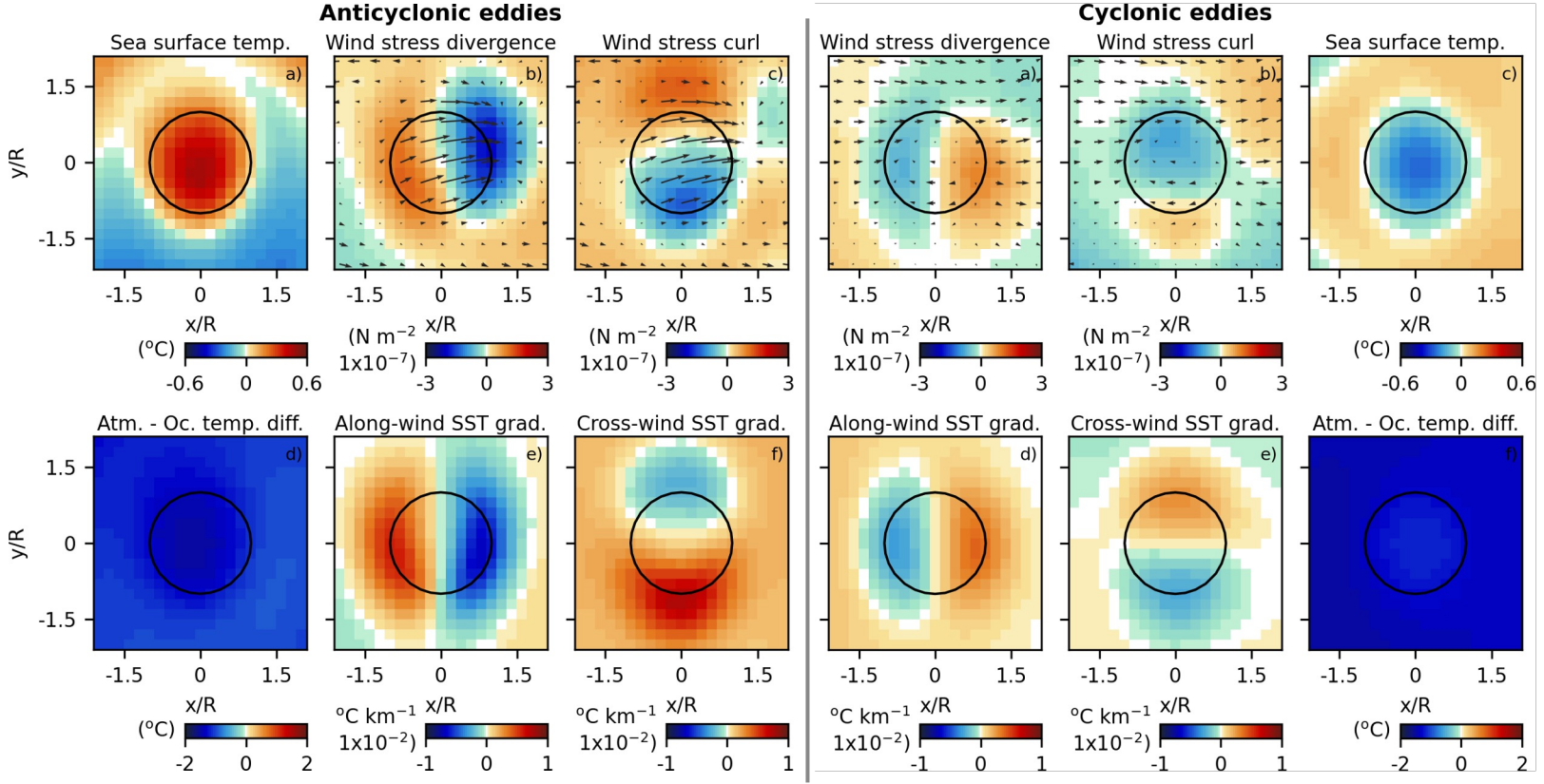

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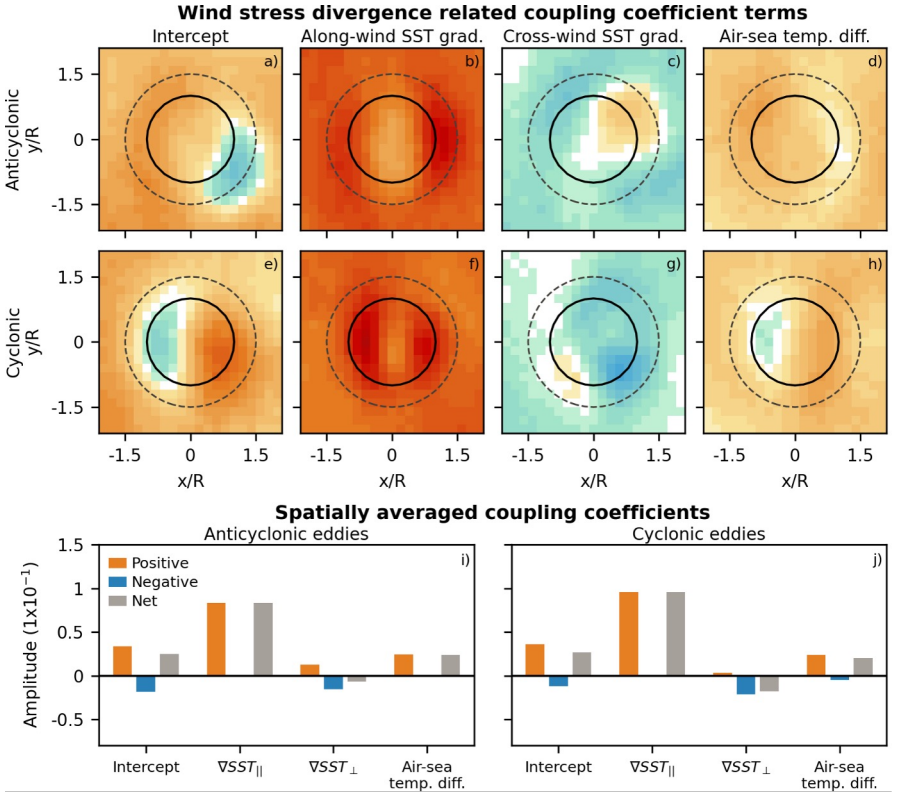
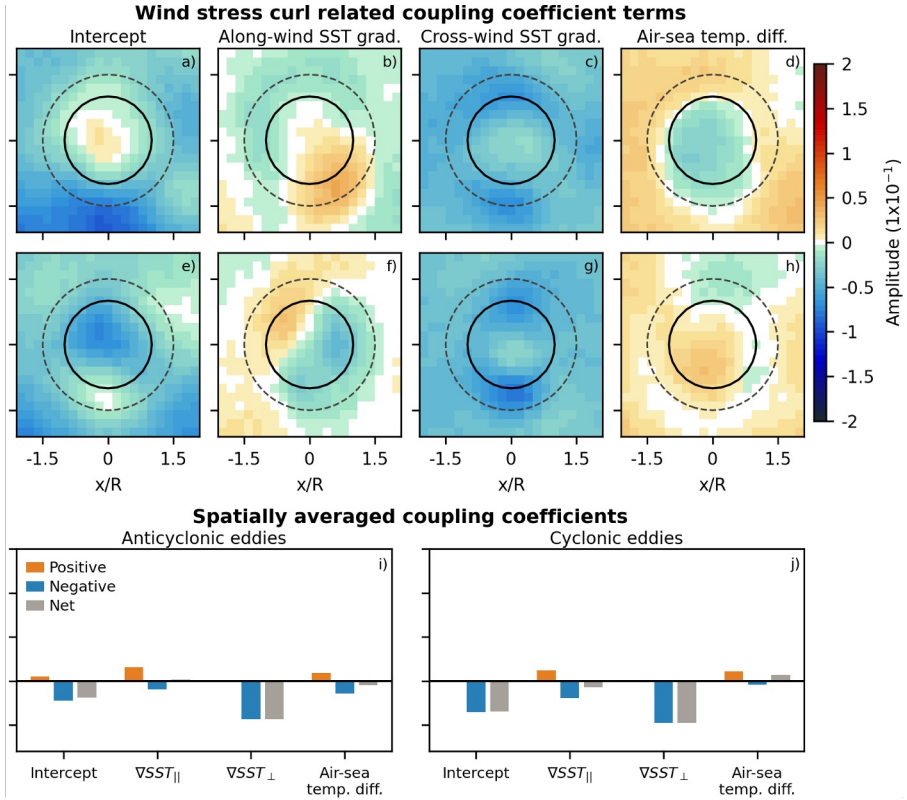
Coupling coefficients





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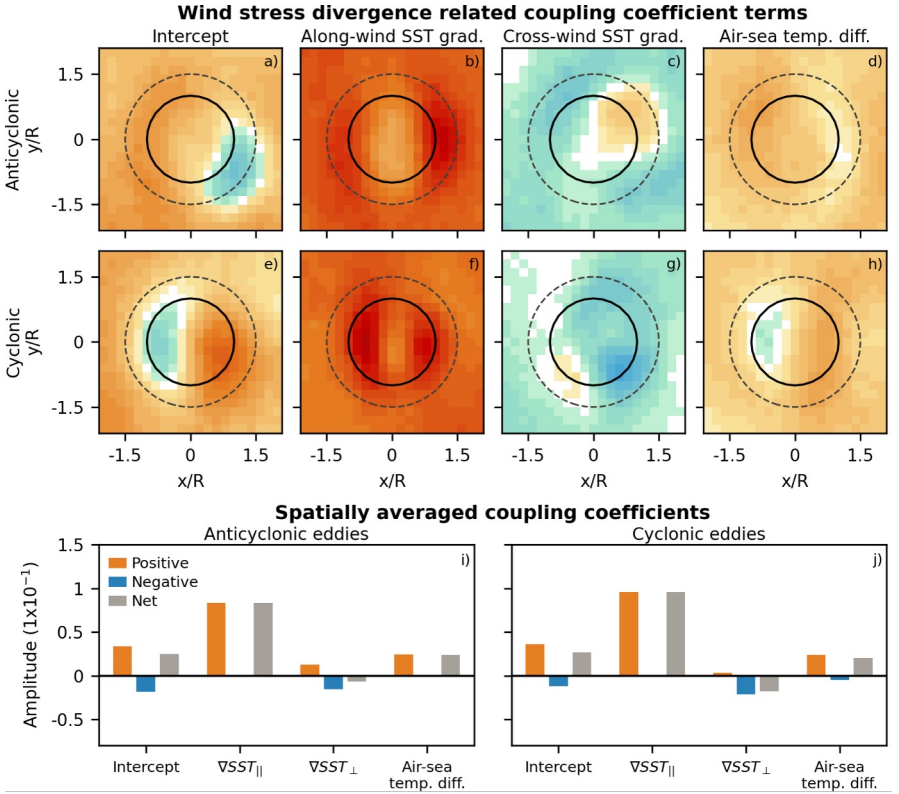

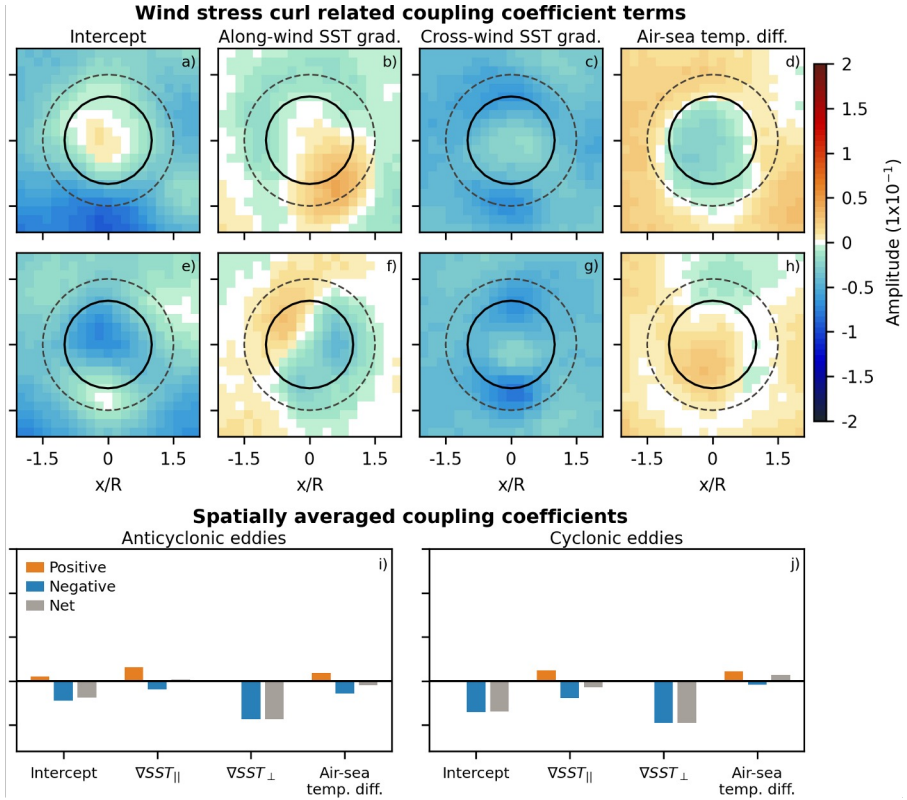

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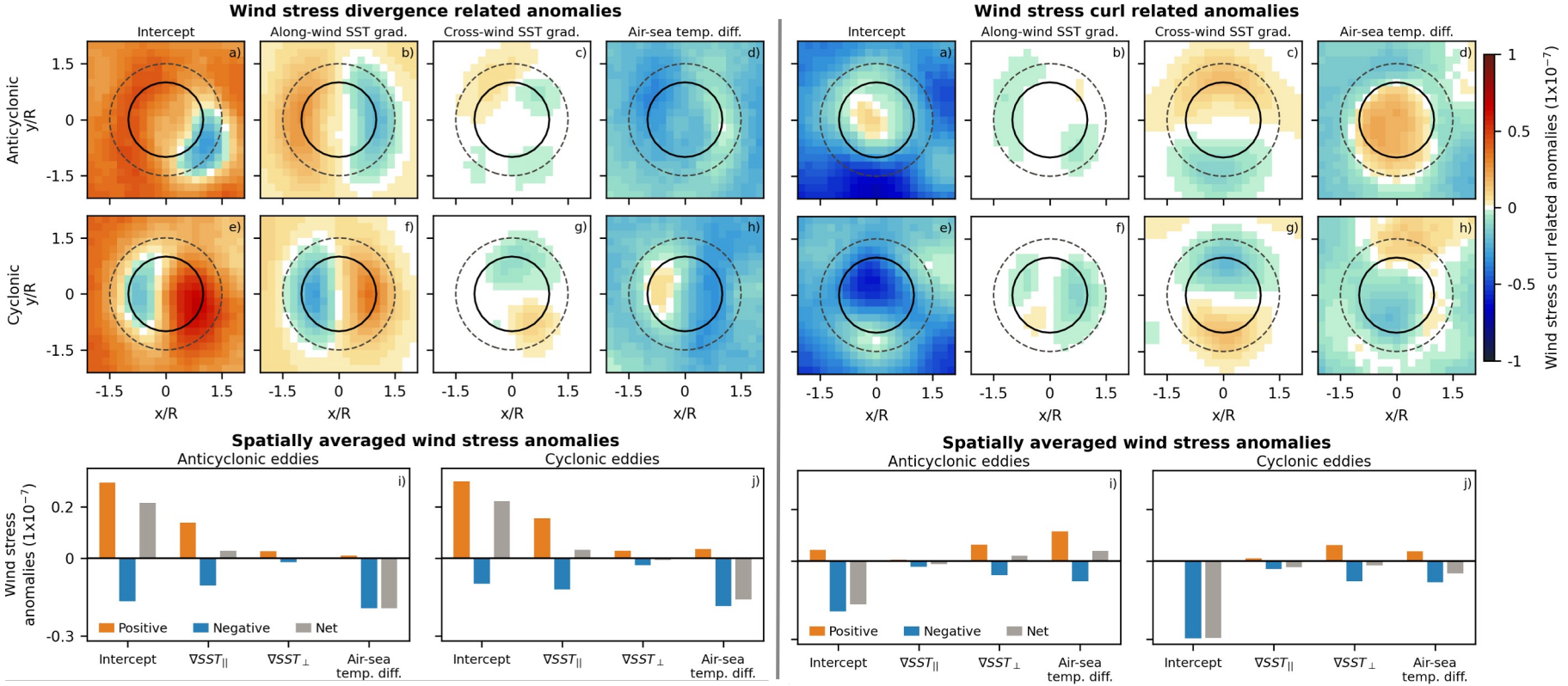
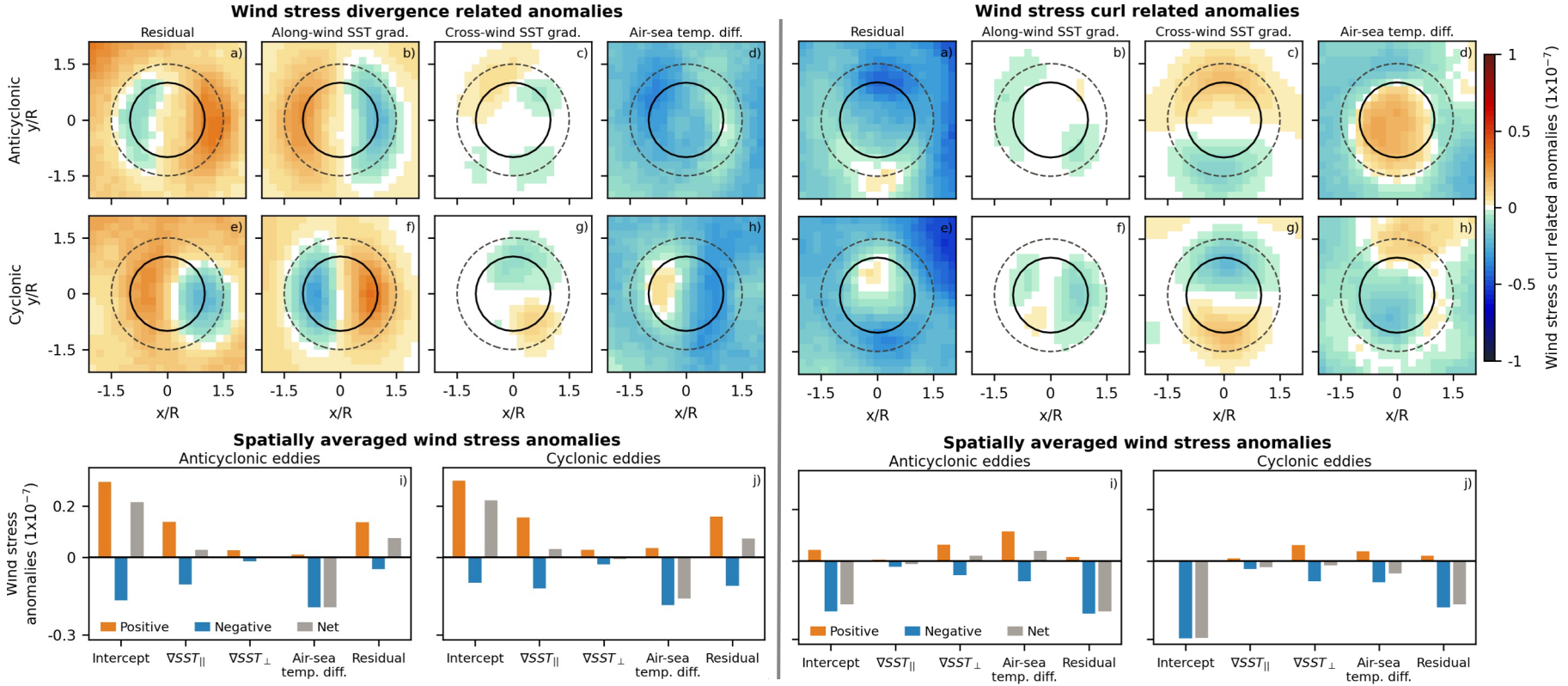
Reconstructed wind stress



Reconstructed wind stress
Residual



Summary and next steps

- Accounting for the **intercept** and **air–sea temperature contrast** improves the reconstruction of the thermal contribution to wind stress divergence and curl.

- **Current feedback can contaminate the wind stress curl response to thermal feedback.**
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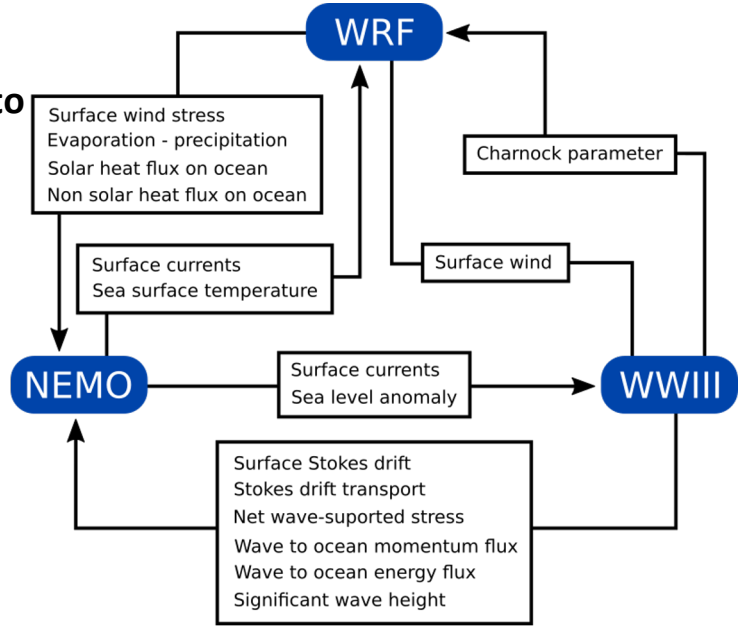
  - **Coupled numerical simulations**



Larranaga *et al.*, 2022 and 2026