Atmospheric Front Shaping the Surface Wind Convergence Over the Southern Ocean: Observational Case

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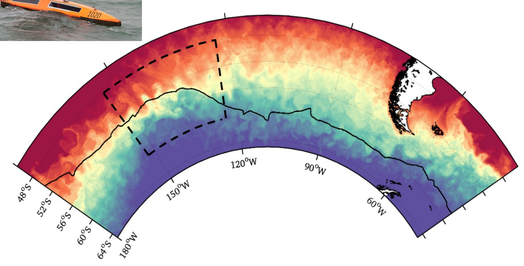
1. Research questions

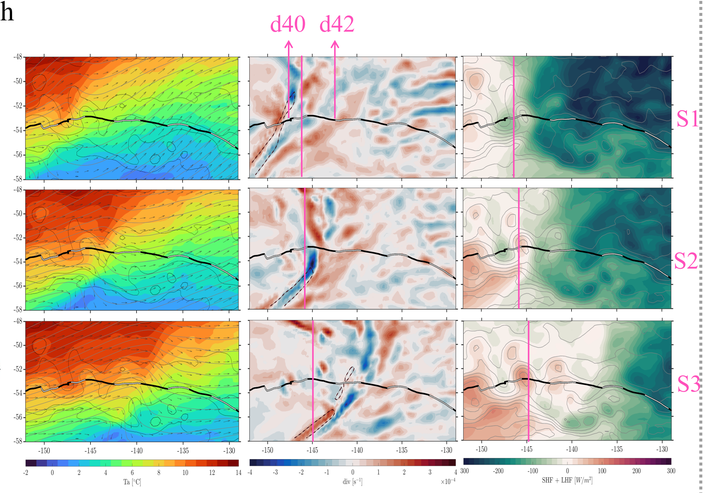
- **The marine atmospheric boundary layer (MABL) is mainly modulated by SST through vertical mixing and pressure adjustment mechanisms. Which mechanism dominates the processes during the atmospheric front (AF) passage? Can the AF strengthen or weaken the SST-MABL coupling?**
- **How to extract submesoscale air-sea interaction info from the uncrewed surface vehicle observations? Can the mesoscale air-sea coupling mechanism be applied to the oceanic submesoscale regime? Will AF affect submesoscale air-sea coupling?**

2. Data and Method

- Saildrone observation in the Southern Ocean: O(100 m), 1 min; COARE 3.5 bulk algorithm
- ERA5 reanalysis products: 0.25°×0.25° × 1h
- Gaussian spatial filter: 250 km

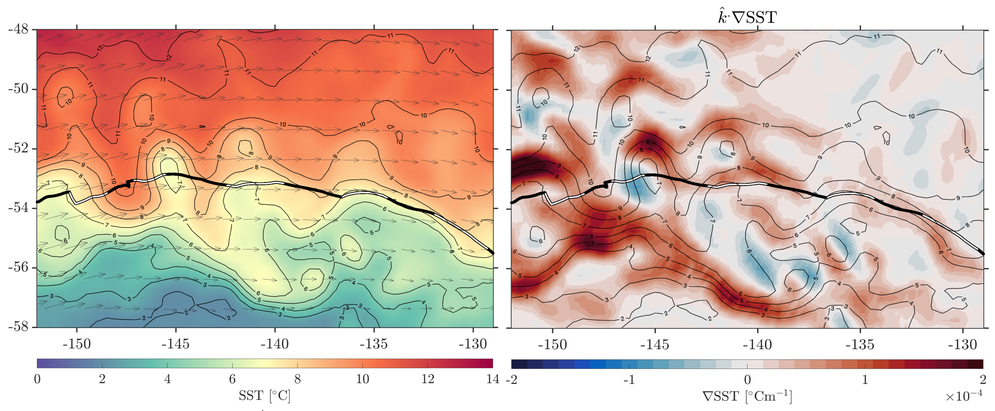
- Front detection: $\mathcal{F} = \frac{\zeta_p |\nabla(T_p)|}{f|\nabla(T_0)|}$





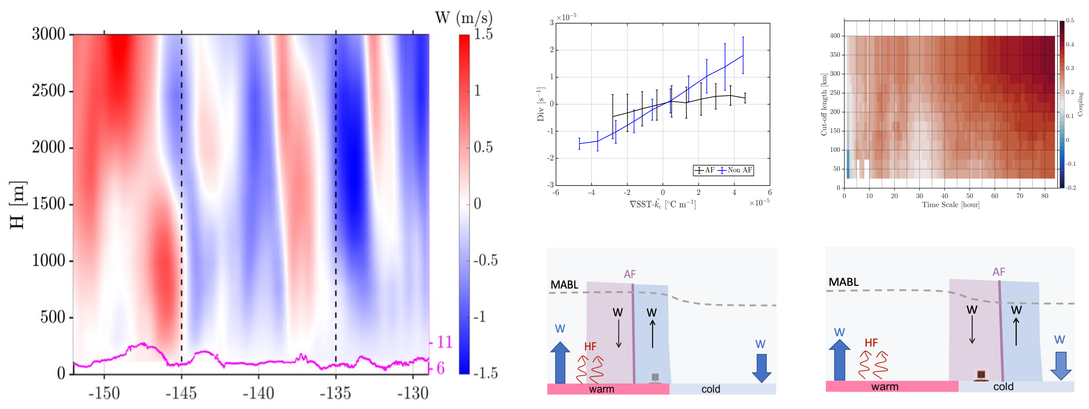
- Numerous SST meanders exist in the Southern Ocean (SST snapshot on Feb 10, 2019)
- The atmospheric front moves eastward at ~5 m/s (snapshot at each 6 h)

3. Results: mesoscale air-sea coupling



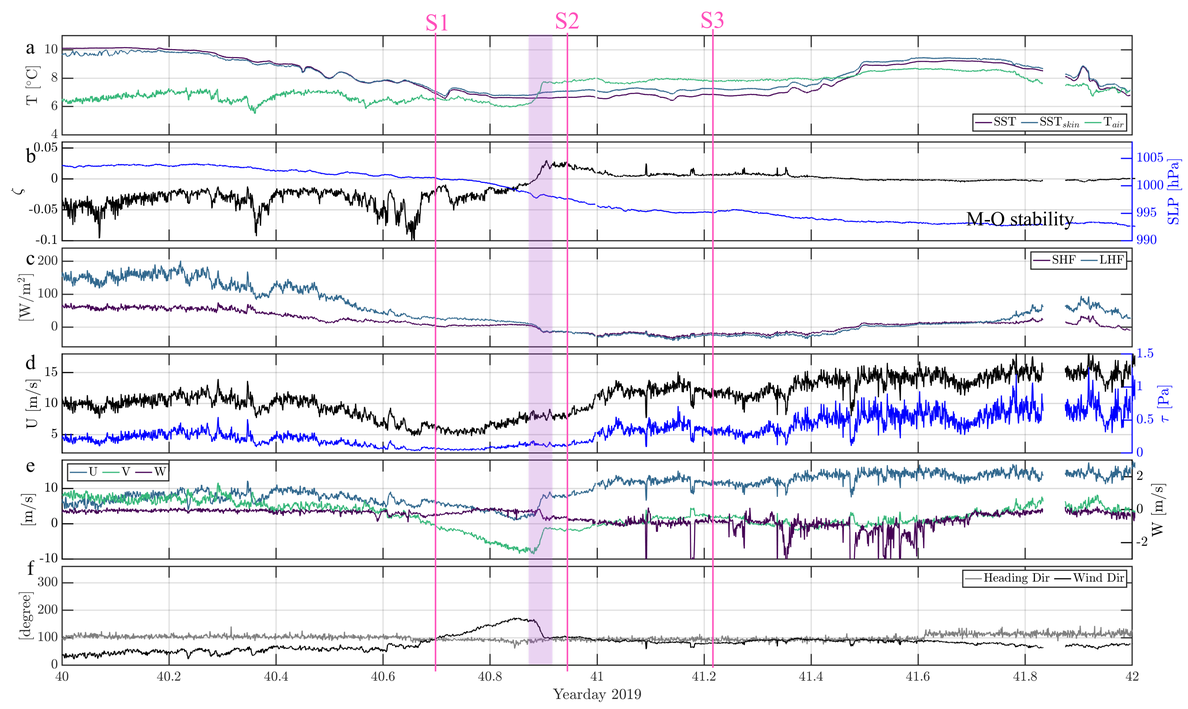
DMM PA

- Daily averaged SST, wind, downwind SST gradient, surface wind divergence
- Downwind SST gradient is correlated with surface wind divergence, not the Laplacian of air temperature → Downward momentum mixing (DMM) dominates at the daily averaged time scale, not the pressure adjustment (PA) mechanism as expected



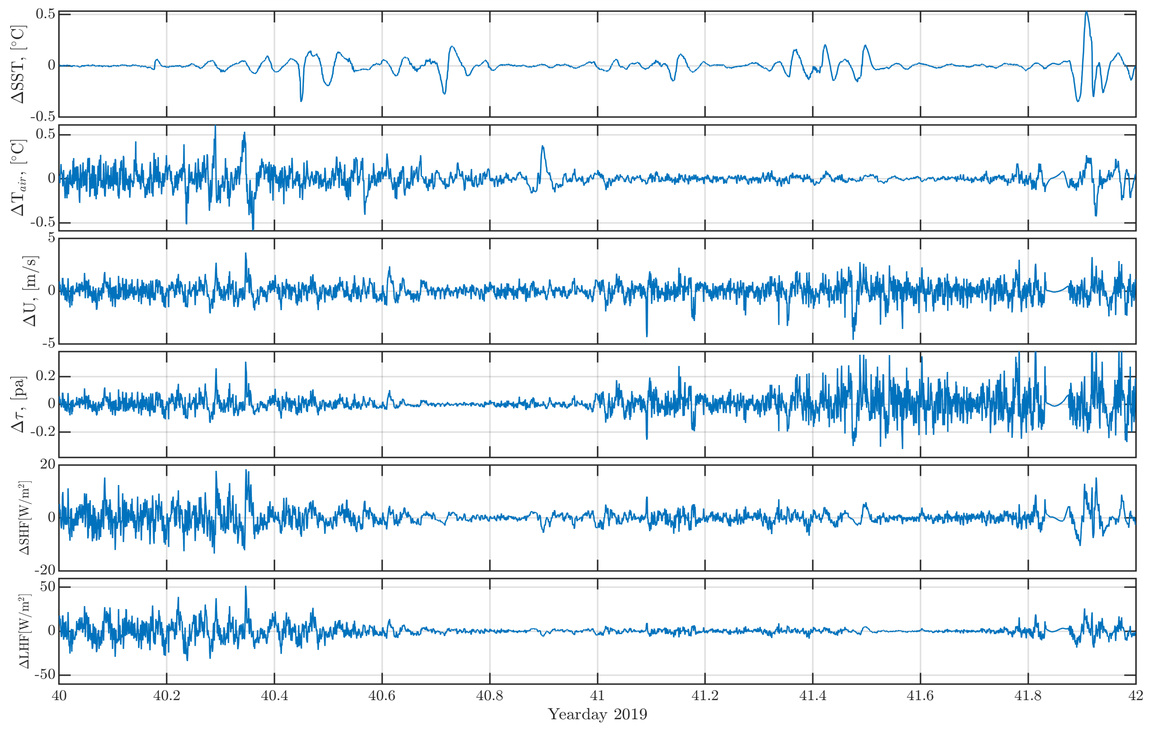
- Daily averaged vertical velocity (52S to 54S) is related to the SST gradient
- Daily averaged air-sea coupling coefficient **decreases** when the atmospheric front passed by
- The air-sea coupling coefficient is influenced by the spatial filter cutoff scale and time average length scale → adapted filter is needed
- The vertical motion near the SST gradient is 'balanced' by the atmospheric front circulation→ weakening air-sea coupling

4. Results: Submesoscale air-sea coupling

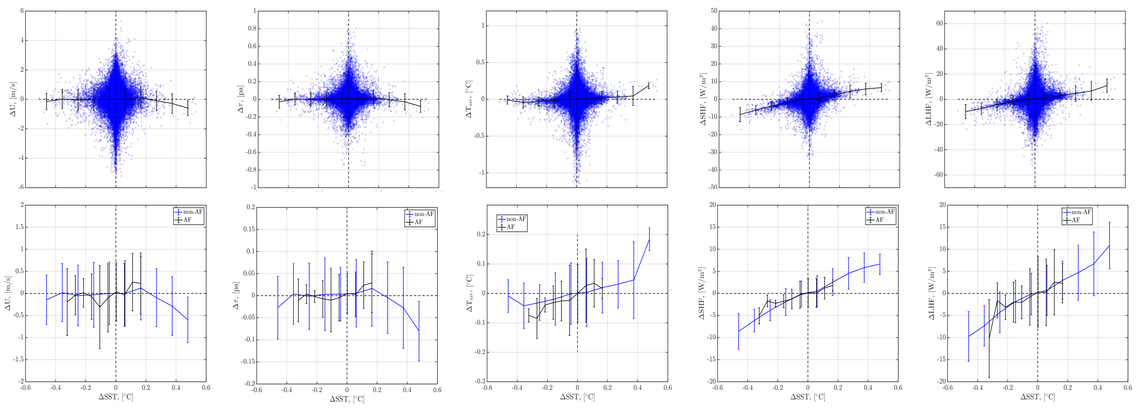


- Saildrone recordings of air-sea variables during the atmospheric front passage
- Shadow region is where the saildrone met the atmospheric front interface → air temperature/MABL stability/heat fluxes/surface winds/ changed
- ERA5 products overestimate Ta and heat fluxes during the atmospheric front passage

Extracting air-sea interactions at oceanic submesoscale



- 1-D filter cutoff scale: 2 h (~16 km), oceanic submesoscales, deformation radius
- Large perturbations at the warm SST side and cold flank of the atmospheric front



- A positive linear relationship between SST and heat flux perturbation at submesoscale
- The relationship between SST and surface wind perturbation is not obvious

5. Summary and discussion: multiscale air-sea coupling

- The DMM dominates at a daily time scale as expected. The atmospheric front can weaken the daily scale time-mean mesoscale air-sea coupling. The spatial filter matters.
- Can a proper filter extract submesoscale air-sea interactions from point measurements? These recordings exhibit an entanglement of temporal and spatial variations.
- Similarities and differences between air-sea coupling mesoscale and submesoscale:
  - Ocean-driven MABL variations dominate in both regimes
  - A positive linear relationship between SST and heat flux perturbation in both regimes
  - The surface wind variations at the submesoscale are more complex

References: Parfitt et al, GRL, 2016, 2017; Fourssard et al, JAS, 2019; Shao et al (in revision); etc.