1. Background

Atlantic Tradewind Ocean-Atmosphere Mesoscale Interaction Campaign (ATOMIC):

- Campaign region: lower branch of the northeasterly trade wind (see Fig. 1.1).
- SST spatial variation in 0°C.
- Oceanic dynamical regime: transition from mesoscale O(V<10 ms-1) to submesoscale O(V>10 ms-1).

Shallow Trade Cumulus:

- Cloud top capped by the trade wind inversion (2km~3km).
- Mainly organized into four different mesoscale patterns.
- Cooling effect on the eastern equatorial trade wind (see Fig. 2.2).
- Cool out planet and resilient to global warming, at the heart of long-standing uncertainties in climate models.

Questions and Objectives:

Q1: Does the relatively weak and fine-scale spatial variation of sea surface temperature (SST) affect shallow cumulus cloudiness?

- Seek evidence from observations. (This poster).

Q2: If so, does it play a role in the formation of any of the mesoscale organizations in the ATOMIC region?

- Obtain process-level understanding from cloud-resolving Large Eddy Simulations (ongoing work).

2. Data & Methods

I. Data:

- A. ATOMIC field data from RHB and wave gliders:
  - 10-minute surface wind speed (U10).
  - 10-minute sea surface temperature (SST).

- B. Satellite data:
  - 5-km daily GOES-POES blended L4 SST product.
  - 2-km hourly GOES-16 L3C cloud mask.
  - 5-hm daily averaged cloud cover fraction.

- C. ERA Reanalysis (daily, 0.25°):
  - Surface wind speed (U10).
  - Potential temperature profiles (θ).
  - Low-Tropospheric Stability (θ<sub>500</sub> - θ<sub>850</sub>).

II. Methods:

- A. Wavelet coherence analysis on field data:
  - Follow recipes developed in [5].
  - Assumption: SST and surface wind along transects represent mainly spatial variation.

- B. Statistical analysis on satellite data:
  - 1. Relationship between daily cloud cover fraction anomalies and effective downwind SST gradient (if -SST).
  - 2. Feature-based composite analysis:
    - Object-based feature detection method based on connectivity (dow w.r.t. transect).
    - Two types of features: warm (<0°C), cold (<0°C).
    - SST spatial anomaly: SST(x,y) - <SST><p(x,y)>.<p(x,y)>
    - Composite in a feature-centered, normalized and surface wind aligned coordinate.

3. Results

I. Local coherence between surface wind and SST

- Figure 3.1 Covariation of SST and surface wind.
  - Left panel: An wavelet coherence example on Jan 9, 2020 where two warm features were captured along the RHB transect.
  - Middle panel: Surface wind and SST correlates well at 14 km and 26 km on average.
  - Right panel: The significant coherence regions at the two characteristic length scales roughly have two different phases:
    - 30°, positive correlation, with surface wind lags SST by a phase of 30° (downward mixing mechanism).
    - ~180°, surface wind is out of phase from SST (wind forces the ocean or pressure adjustment mechanism in play).

II. Relative change in cloudiness in different atmospheric regimes and its relationship with SST gradients

- Figure 3.2 Cloudiness (occurrence frequency) during the 2-month data period.
  - White-dashed contours: 2-month mean large-scale SST.
  - Assumption: Influence of the fine-scale SST-variability on cloudiness is assumed to be weak in this 2-month mean state.
  - Overall, we see that the cloudiness increases from northeast (~0.3) to southeast (~0.5).

- Figure 3.3 Relative change of cloudiness relative to the reference state in four atmospheric regimes.
  - The first level of the thick black contours: 95% confidence level for positive fractional change.
  - Cloudiness hotspots: significant localized increases in cloudiness; an indication of inhomogeneity in the environment (e.g., influence from SST warm anomalies).

- Figure 3.4 Relative change of daily-mean cloudiness from the 2-month “climatology” as a function of effective downwind SST gradients.

- Figure 3.5 Composites of cloudiness and its anomalies over warm and cold features in the gravel-favored atmospheric regime.

4. Summary

- Over scales of 14 km and 26 km, surface wind and SST are mostly out of phase along 15 RHB and wave glider transects.
- On average, daily cloud fraction increases relative to the 2-month “climatology” for strong SST gradients, regardless of the sign.
- Composite analysis shows that in the gravel regime (U10>8m/s, LST<15K), 5-10% spatial anomalies in cloudiness occur within 1 equivalent radius of both warm and cold features.
- These results together suggest that atmospheric response to the weak SST gradients in ATOMIC sampling region is likely different from that in region with strong SST gradients. (Hypothesis: pressure adjustment mechanism > downwind momentum mixing mechanism in ATOMIC.)