Using SAR to diagnose boundary layer stratification change at the ocean meso-to-submesoscale

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Abstract
One well known remote sensing tool for assessing surface wind changes on the ocean at spatial scales of less than 1km is synthetic aperture radar (SAR). Recently, our team has also shown that SAR data can also be used to quantify the presence or absence of several classes of coherent boundary layer structures (CS) that in turn reflect the basic state of the surface layer stratification, either neutral, near neutral, or unstable. Given the interest in how surface fluxes drive atmospheric and oceanic responses in conditions with large horizontal ocean temperature gradients, we propose that one potential diagnostic to explore is spatial/temporal transition in coherent boundary layer structures, and the attendant changes in thermal vs. shear control in the ABL. Basic machine learning methods developed for SAR data interpretation and supporting a recently-published global SAR stratification study will be reviewed. Global and regional scale examples of SAR-observed coherent structure transitions will be discussed. Such data could be used to assess how well numerical model parameterizations and their fluxes switch between observed CS regimes, if they address CS flux enhancements appropriately, and how well large eddy simulation models are able to predict these changes across conditions with large ocean temperature gradients.

Global Sentinel-1 C-band SAR Wave Mode (WV)

- Acquisitions
  - S-1A starting in 2016, S-1B in 2017
  - 20 × 20 km, 5 m spatial resolution, offshore only
  - Two incidence angles: 23° (WV1) & 36.5° (WV2)
  - Routine acquisition quasi-weekly
  - ~60,000 images/month/satellite

- Global coverage at a weekly-monthly timeframe

- Spatial gridded monthly average of Sentinel-1A WV2 acquisitions in 2016 and 2017. The color denotes # of SAR imageries in each 5° × 5° grid box

Example: Seasonal and spatial air-sea flux change across Arabian Sea and Tropical Indian Ocean

- North-Western Indian Ocean Basin
  - Bi-weekly averages show change from near neutral in winter to unstable in summer
  - Equatorial SST change in JJA clearly aligns with BL stratification and coherent structure change observed using SAR
  - Basin-wide patterns captured
  - Mostly WS JJA southerly flow (Summer)
  - Mostly MC in DJF northerly flow (Winter)

SAR-inferred BL coherent structures map to BL stratification

- 3 primary MABL states via CS:
  - MC: “(Warm) Streak”, “WV2” (wind streaks), “Rolly” = neutral
  - Nickel: “(No MABL) CS” = stable

- Stopa et al., 2022: GRL using Global Sentinel 1 SAR
  - Neural net image classifier (CMwv)
  - >600,000 highest-confidence WV2 images used
  - ERAS surface layer reference for stratification:
    - θi = 11°C
    - Ri = 10

SAR-observed Atm. Boundary Layer Change Across SST Gradients

- Eastern Tropical Pacific Example NECC
  - SAR imageries collected across NECC every 100 km along TAO buoy array (buoy latent heat flux and Ri time series at right)
  - South to north crossing of 8 deg. SST gradient
  - Evidence of latitudinal change in BL coherent structures (wind streaks to south and cellular in unstable northern region)

Summary and perspectives

Workshop question 4: What are key analysis approaches and diagnostics of air-sea coupling which could guide modeling and observational strategies, including time and space scale dependencies and specific variables and processes?

New ‘Routine’ Observational Tool:
- Satellite SAR detects boundary layer coherent structure (CS) type
- CS relates to state of surface layer stratification (unstable to stable)
- Spatial scales of 1-1000 km including seasonal mapping capability

Possible Discussion question:
Could such stratification information provide a new useful diagnostic for model/data comparisons and improved flux prediction?

Able to better assess/validate BL flux and BL parameterizations across SST gradients of SL stability, CS, within LES and high resolution coupled models?

References