Relationship of Precipitation and Marine Atmospheric Boundary Layer (MABL) states as Observed by SAR over the Subtropical Ocean

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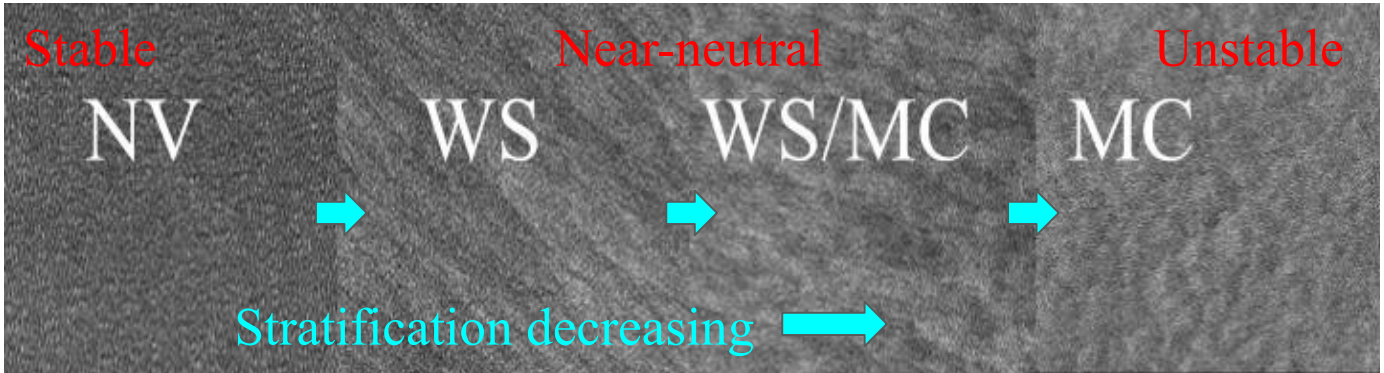
Is there coupling between the distribution of coherent structures within the sub-cloud MABL and the overlying mesoscale precipitation & cloud fields?

Results

1) **[Method]** Ocean surface textures observed by imaging radars can be used to infer the boundary layer state (at global/regional and seasonal scales) and indicate presences of rain columns and cold pools

2) **[Result 1]** Rain-impacted textures (cold pools, air-mass boundaries, rain cells) are rainer than others

3) **[Result 2]** Mixed rolls/cells have less rain than pure rolls or pure cells;
Uncertain if rolls or cells are rainer! →suggests MABL states relate to air-sea fluxes…



1) Methods: Textures→*Ri*

$$Ri = \frac{g}{T_{10v}} \frac{z_{10}\left(T_{10v} - SST_v\right)}{U_{10N}^2}$$

CS=coherent structure = cells & rolls

●SAR detection using the sea-surface texture
1) Microscale Convection (MC) - unstable (UBL)
2) Wind Streaks (WS) - near neutral (NNBL)
3) Negligible Variability (NV) - stable (SBL)
maps to *Ri* from ERA5

We define implicit CS bands based on (a)
1) **UBL: *Ri*<-0.012**
2) **NNBL: -0.012≤*Ri*<0.001**
3) **SBL: *Ri* ≥0.001**

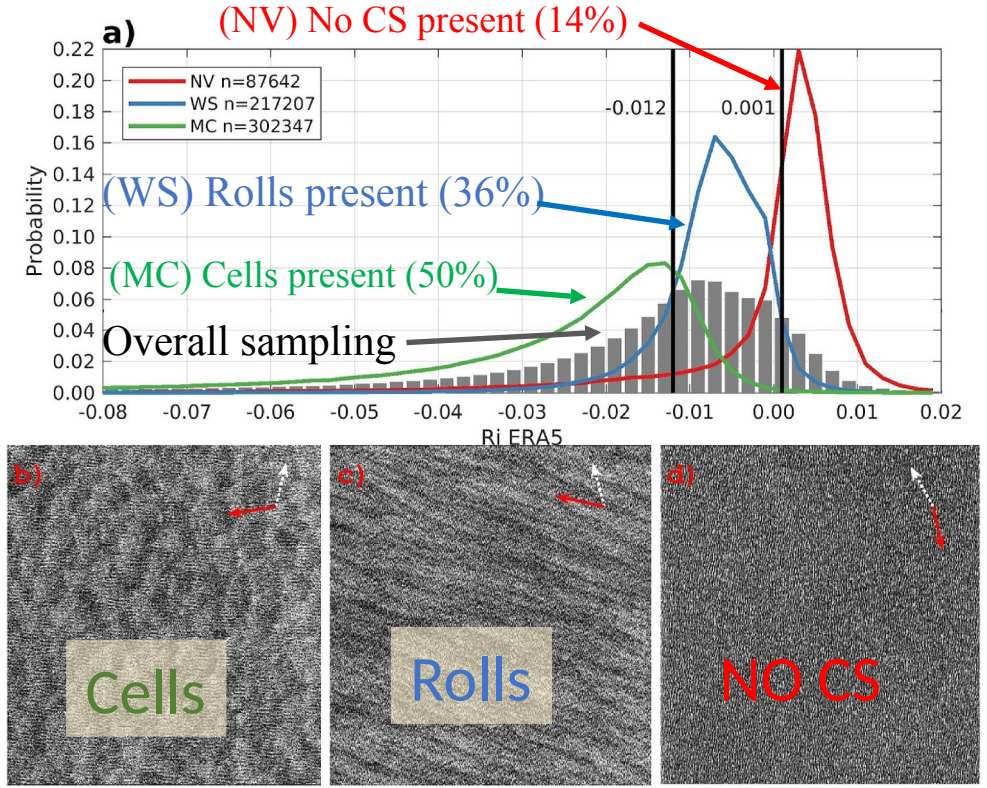
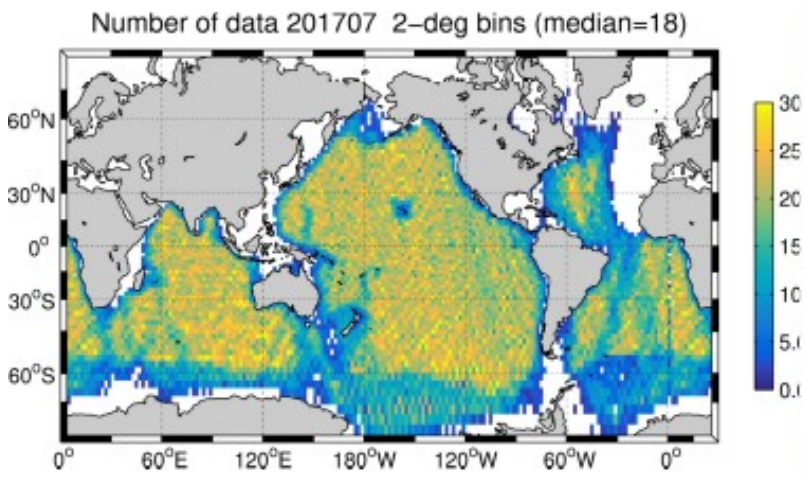


Figure 1. (a) PDFs of MABL *Ri* estimated from ERA5 for cells (unstable), streaks (near stable), and negligible atmospheric variability (stable) detection from SAR. The shaded gray PDF denotes the entire WV2 population. Representative SAR images for (b) unstable $Ri = -0.032$, $U_{10}^N = 5.3$ ms^{-1}, $\Delta T_v = -2.81°$, (c) near-neutral $Ri = -0.006$, $U_{10}^N = 9.8$ ms^{-1}, $\Delta T_v = -1.74°$, and (d) stable $Ri = 0.005$, $U_{10}^N = 7.6$ ms^{-1}, $\Delta T_v = 0.84°$ MABL states. The white dashed arrow points north and the red solid arrow is the ERA5 wind direction.

Stopa et al., GRL 2022

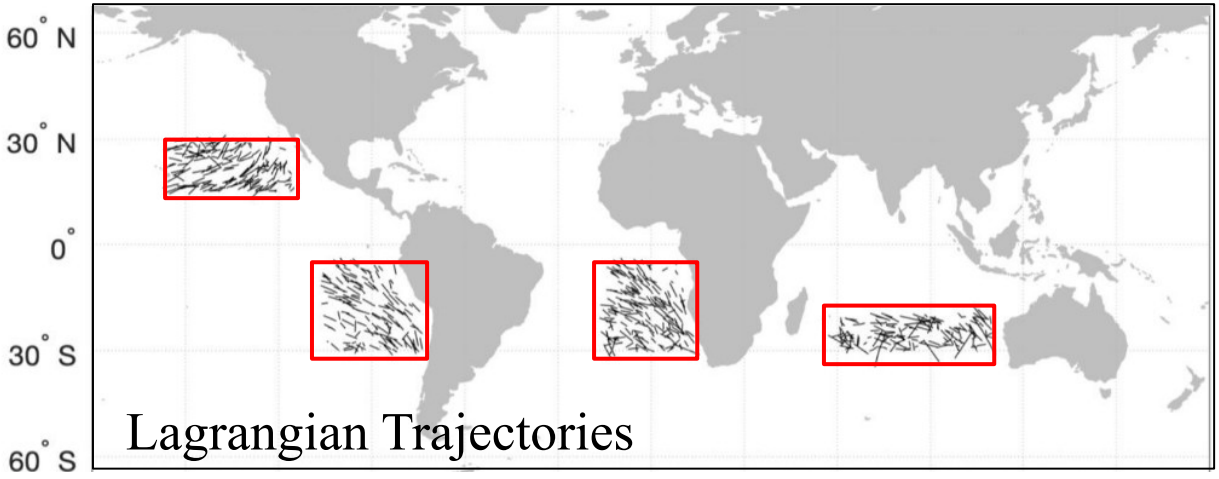
1) Methods - Sentinel-1



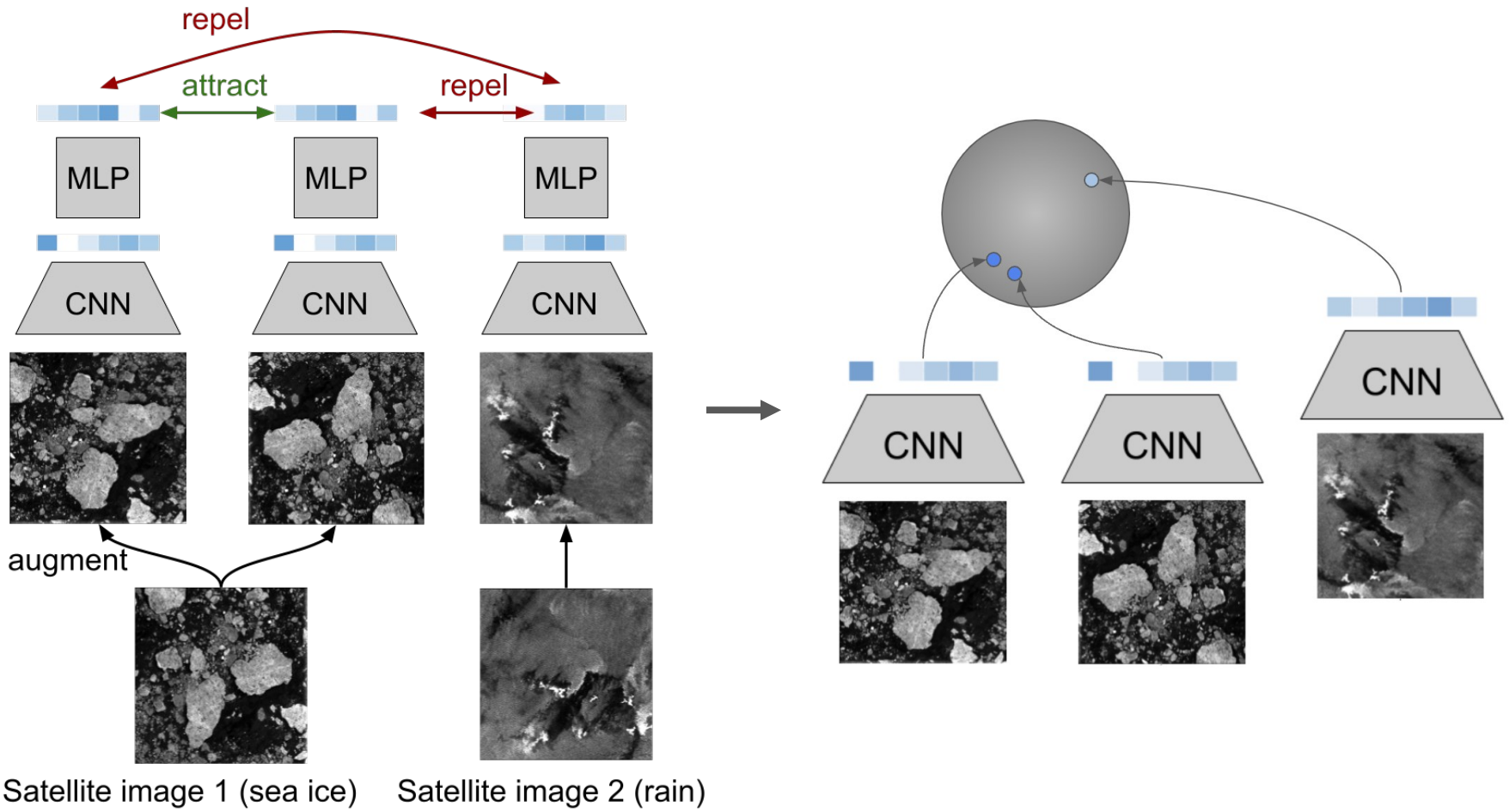
●S-1A/B/C – launched Apr 2014, May 2016, Dec 2024
Operated by ESA, managed by Copernicus

<u>Wave Mode (WV):</u>
●Global coverage; 20x20 km @ 5m resolution
●S-1A/B 120K images per month
●Two incidence angles: WV1~23° WV2~37°
●WV Archive has >11 million images ~1 Pb!
→Automation is needed

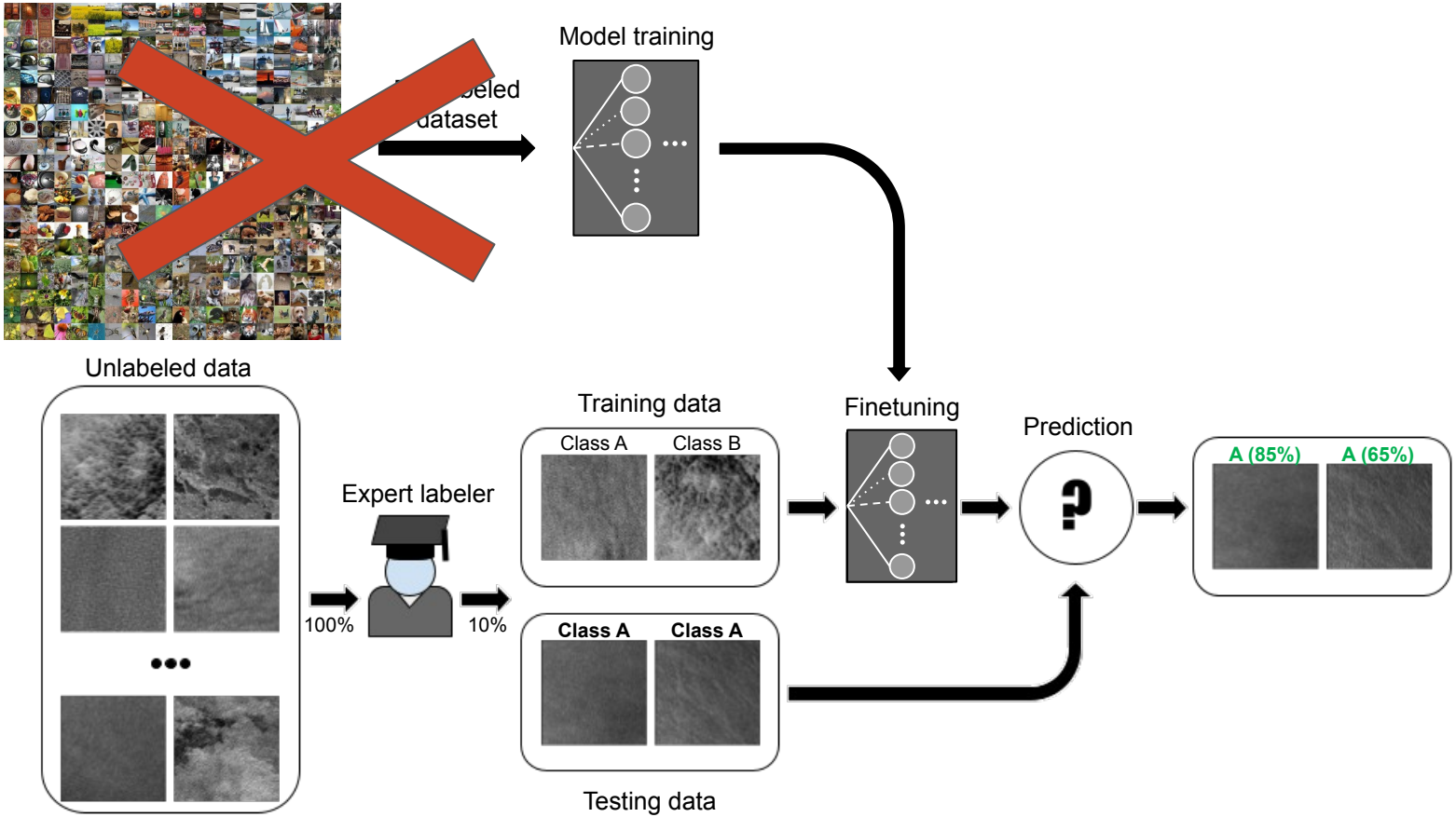
<u>Areas of interest</u>
●Subtropical Ocean
●All regions are analyzed together



1) Methods - WVNet contrastive model



1) Methods - WVNet - a foundational SAR model



2) S-1/WINDSAT

NP, SP, SA, IO trade wind regions
~293K matchups
sufficient sample size for 4-11 m/s

- RI - high H20, vapor, RR
- WM - rolls/cells - low H20, vapor, RR

- MC - cells - high H20 & RR
  when U10N<7 m/s, high vapor
  when U10N>7 m/s, low vapor

- WS - rolls - average H20 & RR
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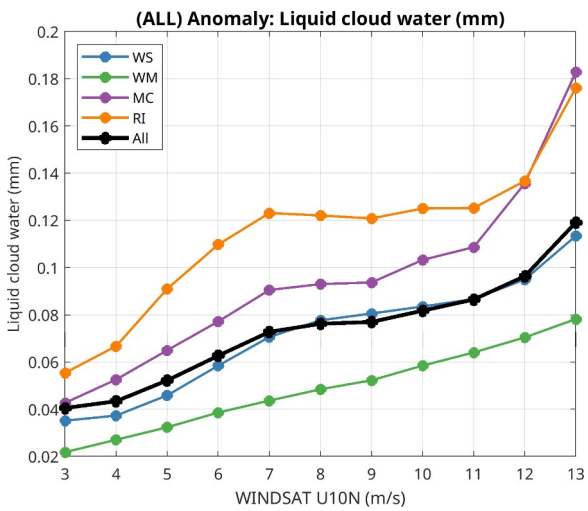

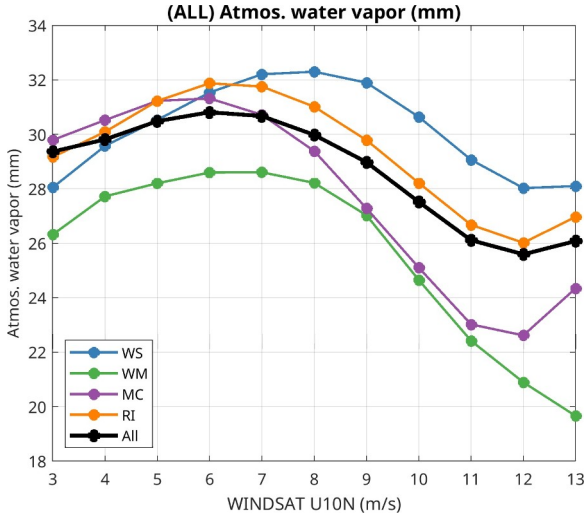

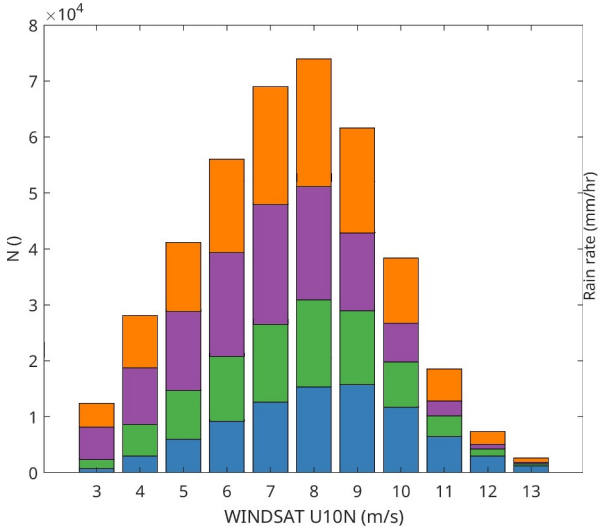

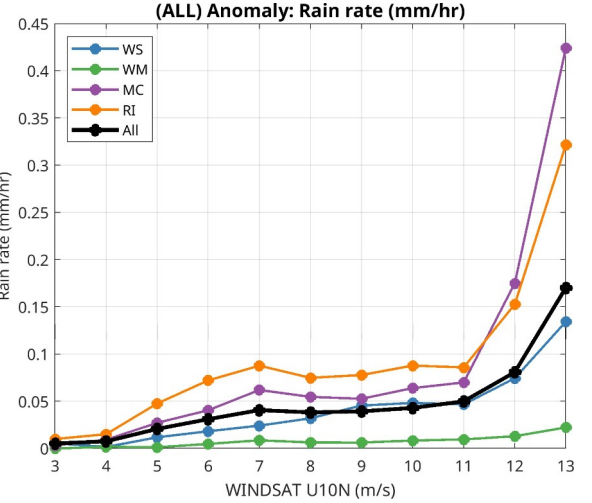

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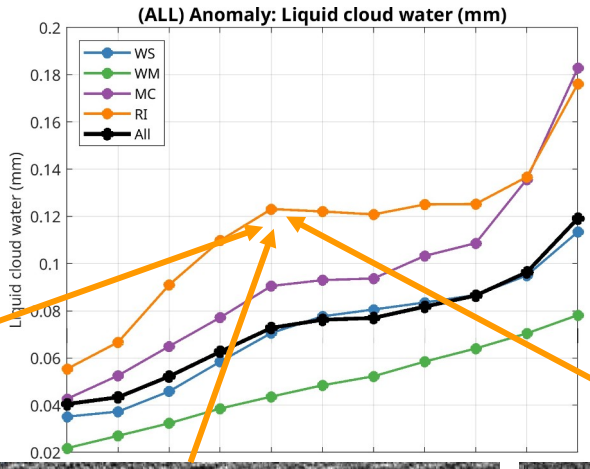

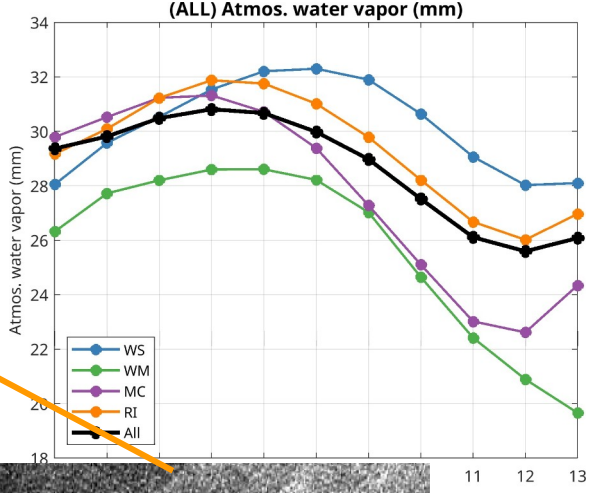

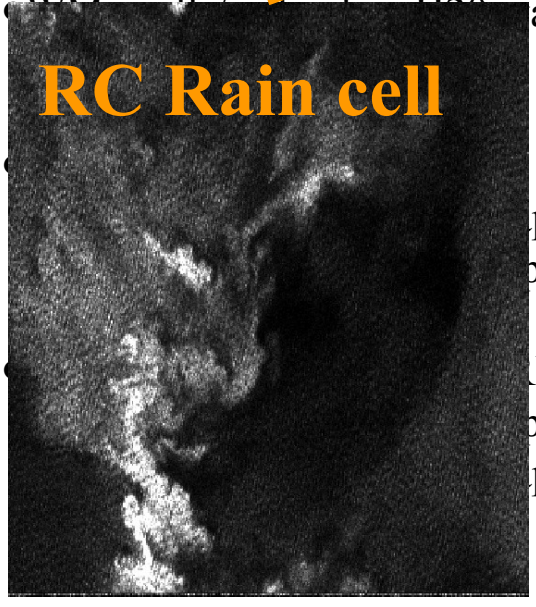

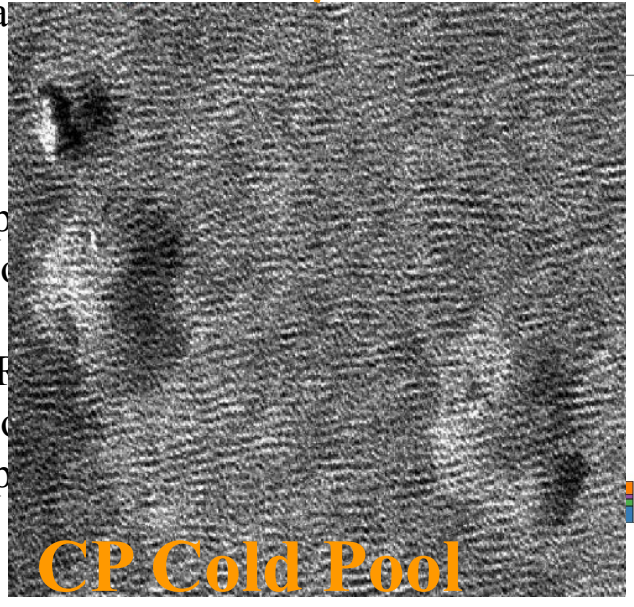

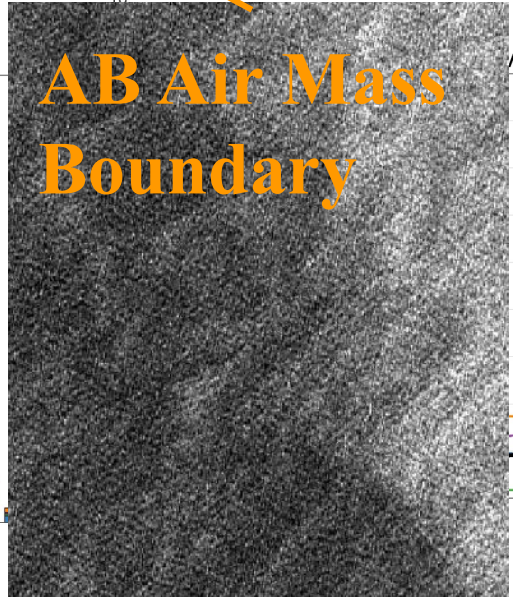

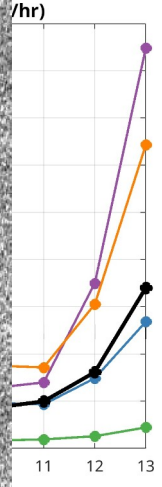

2) S-1

NP, SP, SA
~293K ma
sufficient

- RI - high
- WM - ro
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- MC - ce
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- WS - ro
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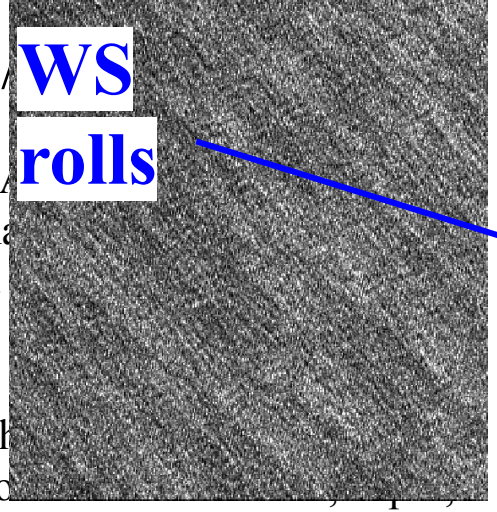

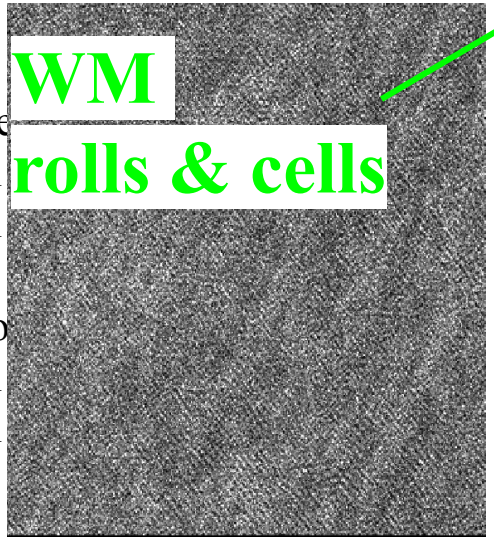

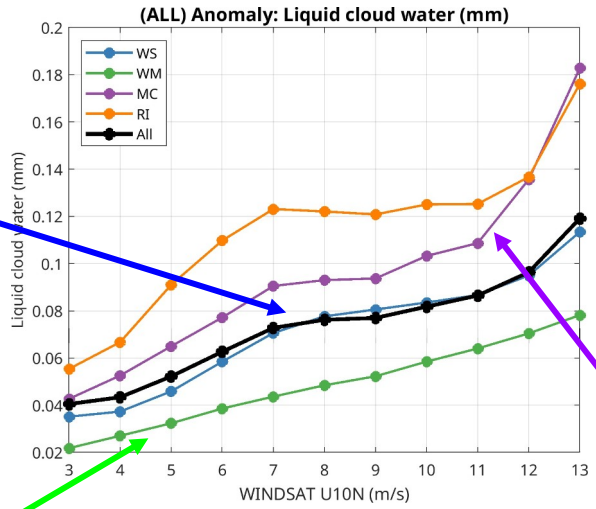

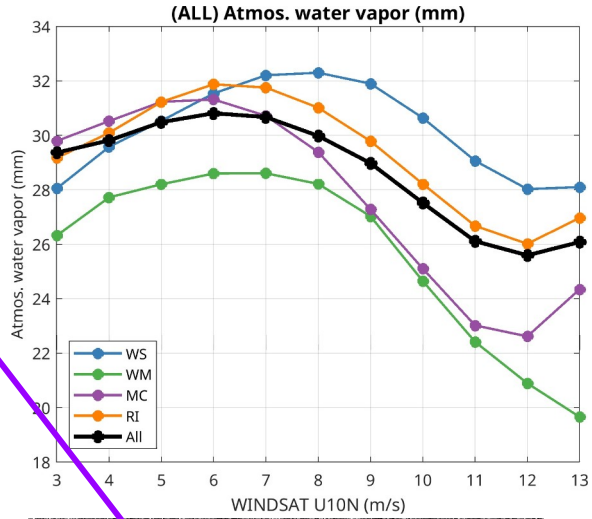

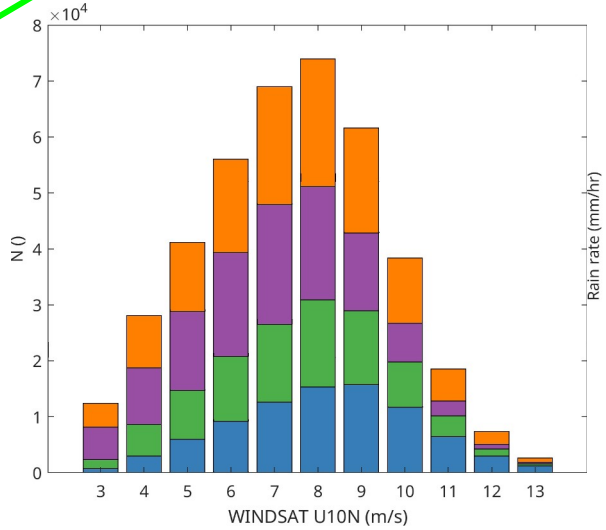

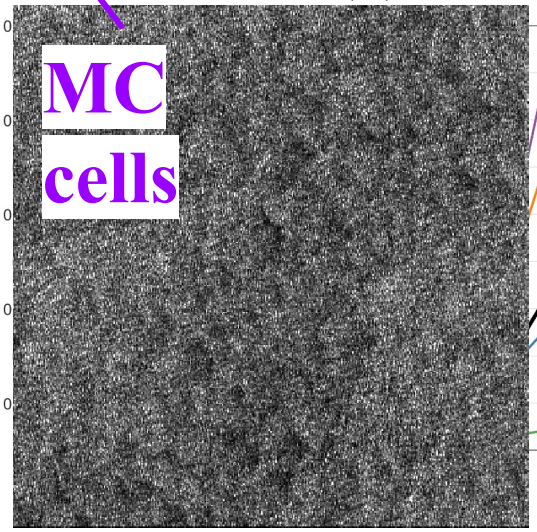

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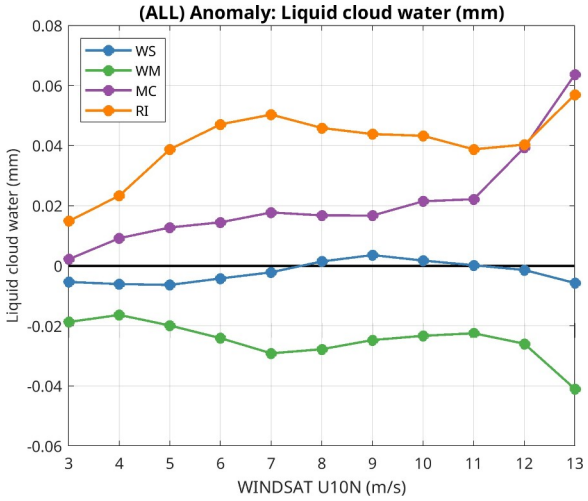
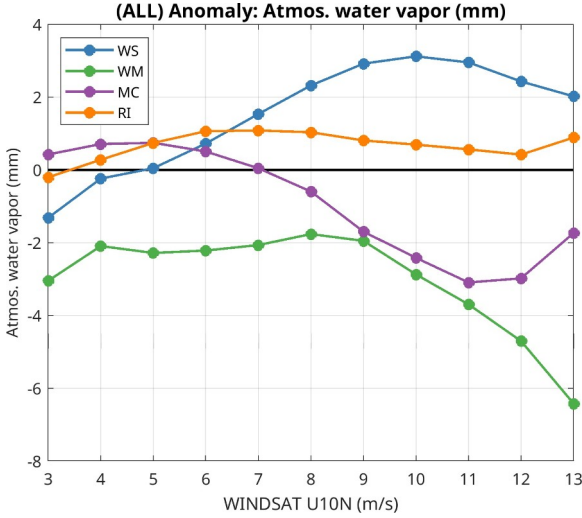
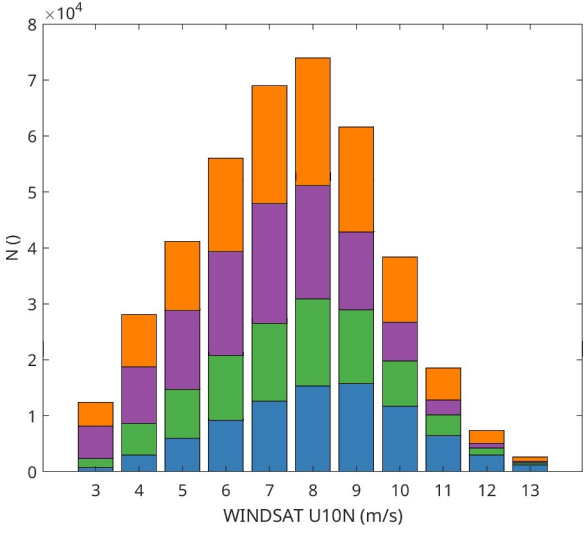
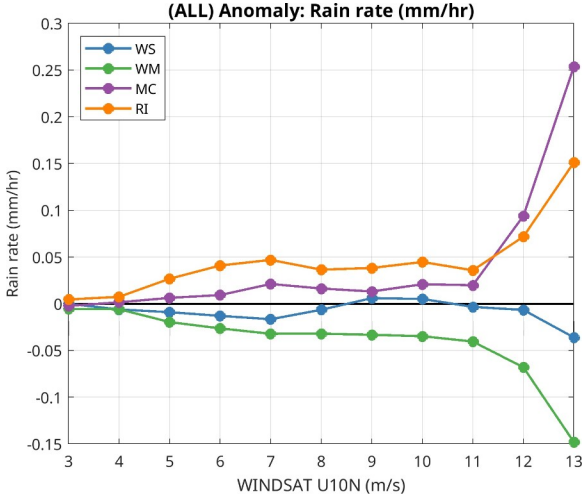








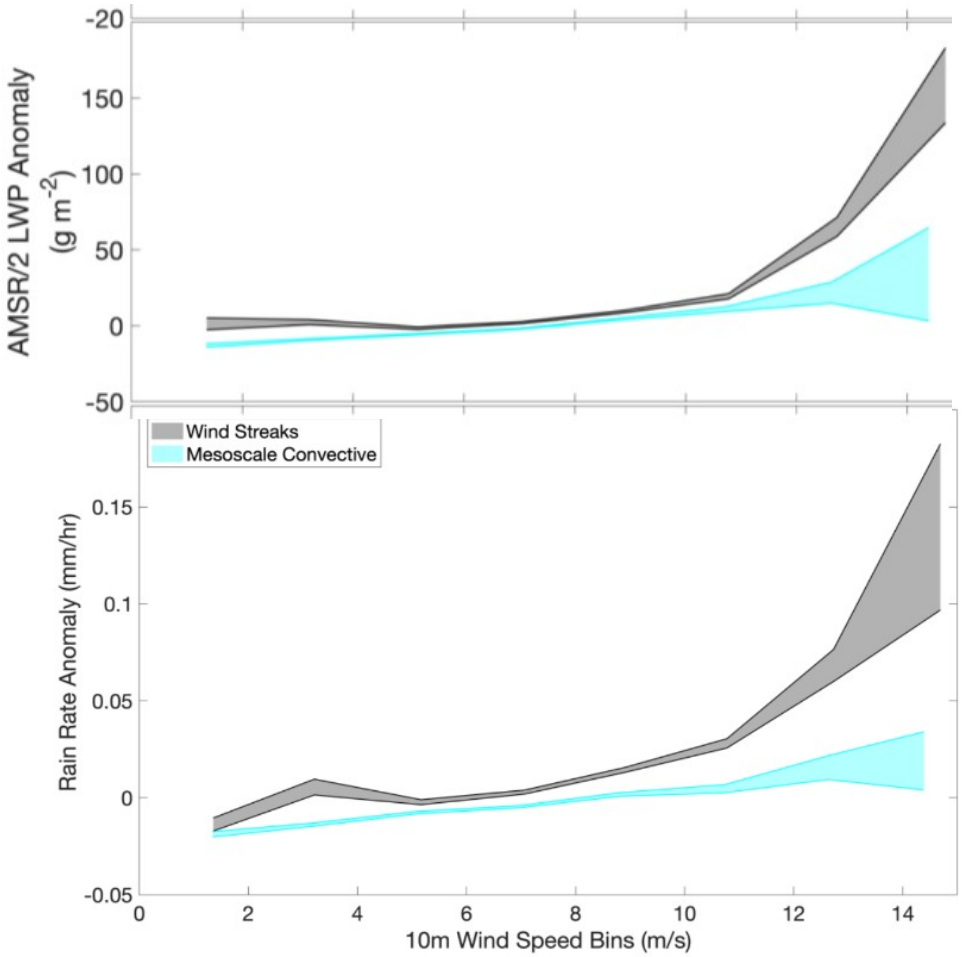
2) S-1/AMSR/2

-AMSR/2 has 1:30 AM/PM passes
-forward/backward trajectories propagate the observations so they match
-LWP ~ liquid cloud water

- RI events are rainier (not shown)

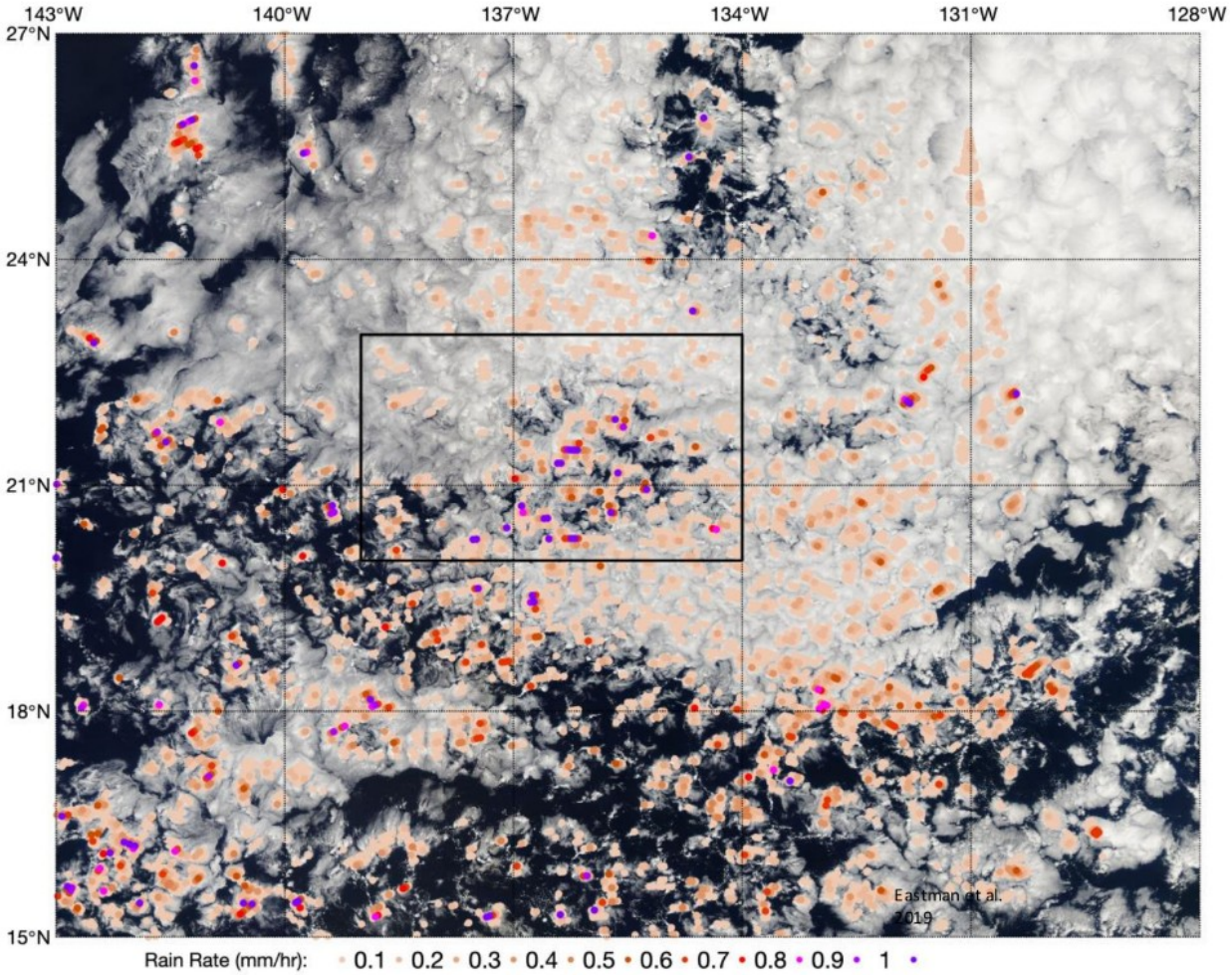
- MC - low RR & low LWP
- WS - high RR & high LWP
- Opposite result compared to S-1/WINDSAT!

- Are the trajectories representative of the raining condition?
- WINDSAT (~40 km footprint) too coarse?



2) S-1/AMSR2

- AMSR/2 - 89GHz channel can estimate light warm rain in shallow clouds
- High spatial variability!



3) Results and outlook

Results

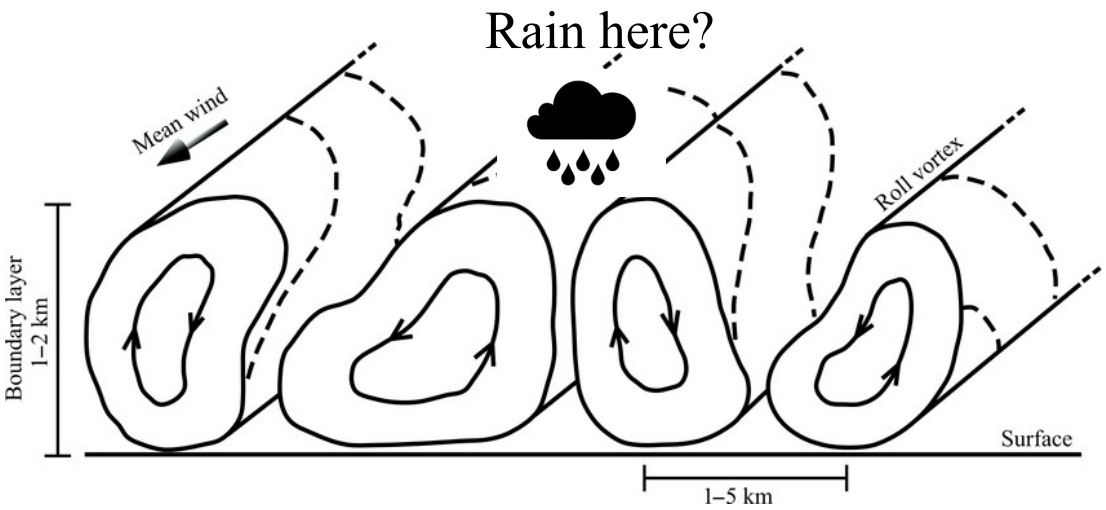
1) Ocean surface textures observed by imaging radars can be used to infer the boundary layer states and presence of rain signatures
2) Rain-impacted textures (cold pools, air-mass boundaries, rain cells) are rainer than others
3) Mixed rolls/cells have less rain than pure rolls or pure cells (consistent)

Short-term outlook

- Rolls or cells - rainier???
  - COWVR 2022 matches - show similar results as WINDSAT… adding more years
  - Analyze other precipitation datasets to confirm (GOES, GPM, TRMM, etc.)
- Analyze extratropics… clouds processes are very different than tropics.

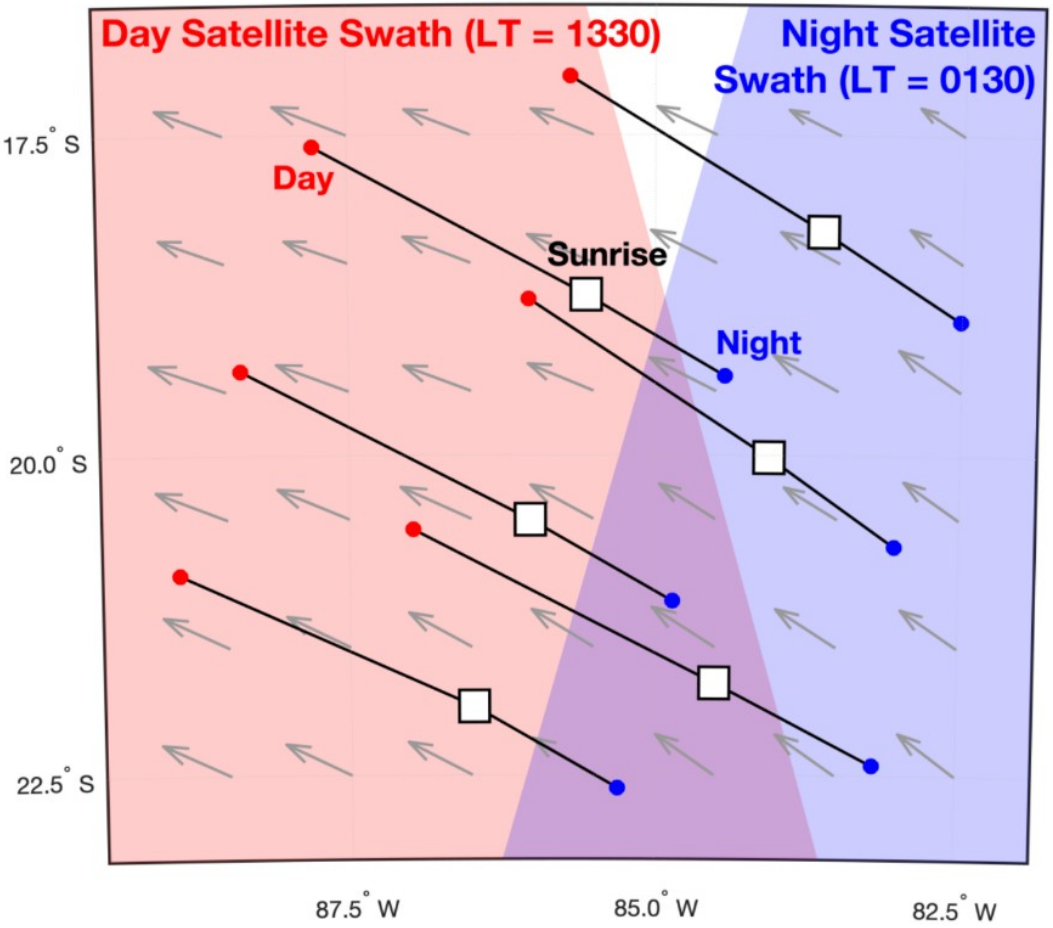
Thank you!

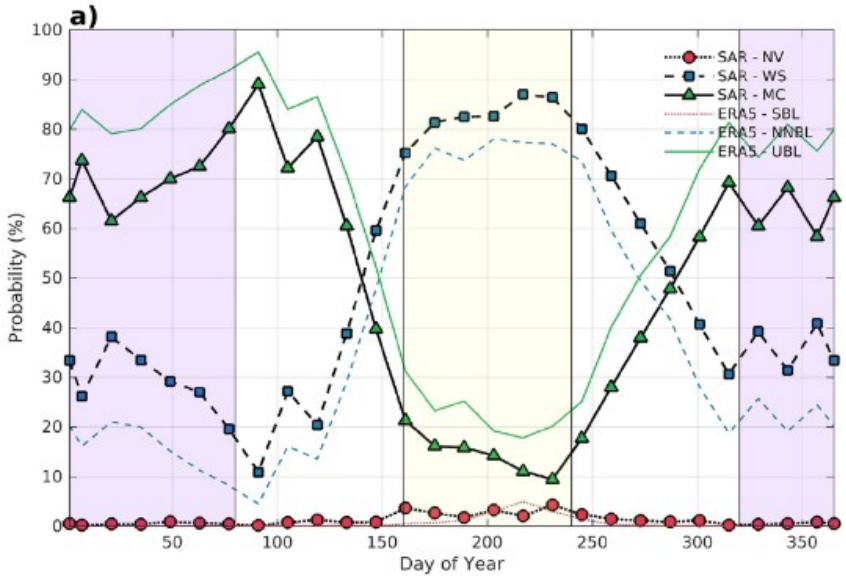
EXTRA

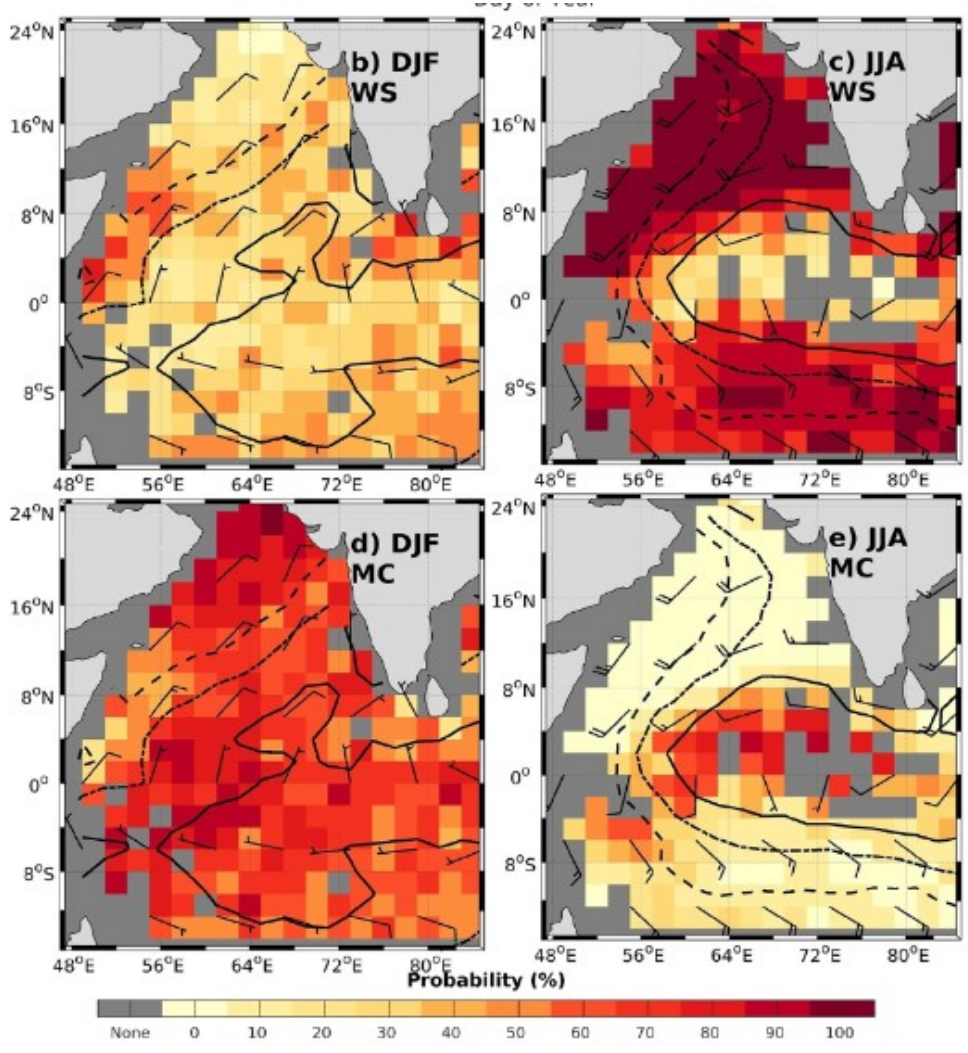

Rain here?
Mean wind
Roll vortex
Boundary layer
1–2 km
Surface
1–5 km

Tying SAR Observations to Rain Observations

- PBL Trajectories link SAR obs to rain obs, both before and after.
- SAR obs are 'bracketed' by rain information, ~5-7 hours removed.
- Trajectories built using ERA5 winds at 925 hPa.



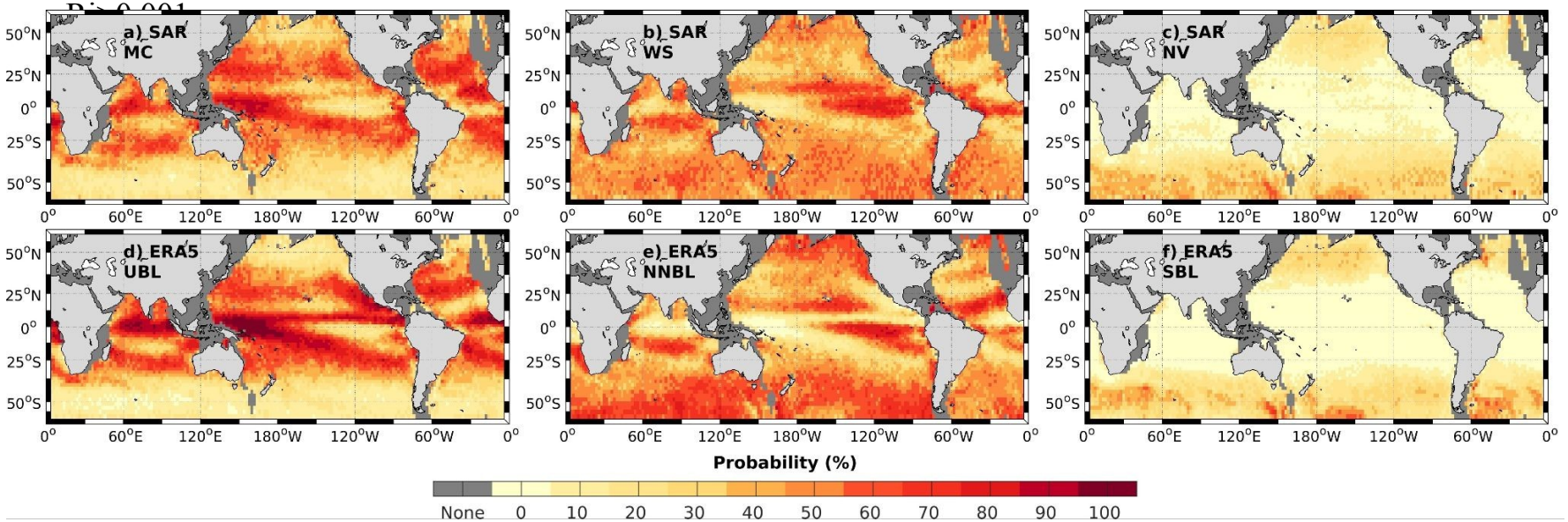




Relative occurrence rates between SAR-detected MC and WS images in the western Indian Ocean. (a) is biweekly regional averages. The maps in 2° bin-averaged seasonal WC and MC rates from DJF and JJA monsoon periods. The surface wind vectors are given as the barbs (direction from) where a full barb is 10 knots. The SSTv 27, 28, and 29°C contours are given as the dotted lines, dash-dot, and solid, lines. These wind and SSTv information are from over our larger overall WV2 data set and not the 27% of selected images to show the climatology.

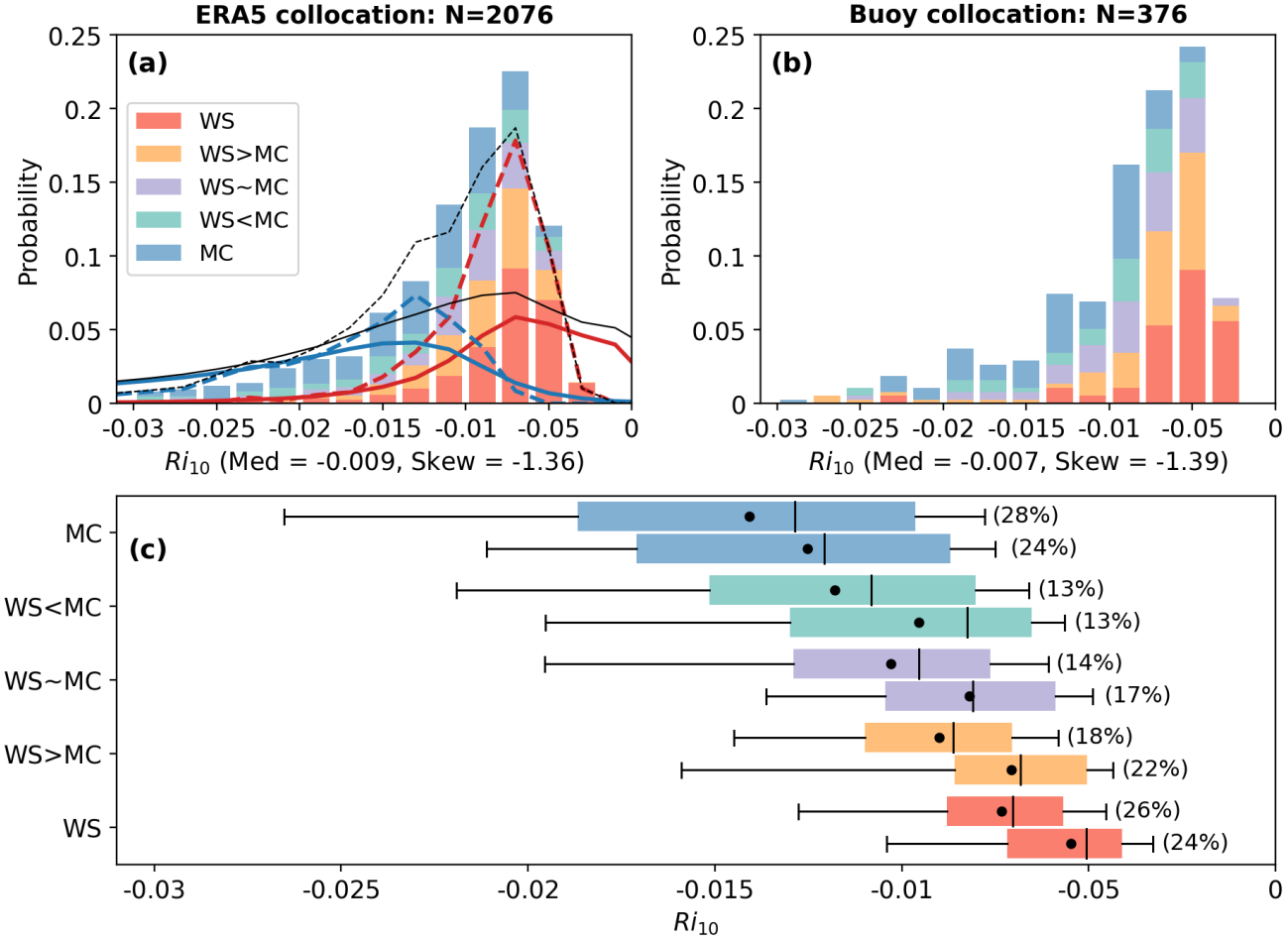
3) Extra - Applications

UBL - Ri<-0.012 NNBL -0.012<Ri<0.001 SBL



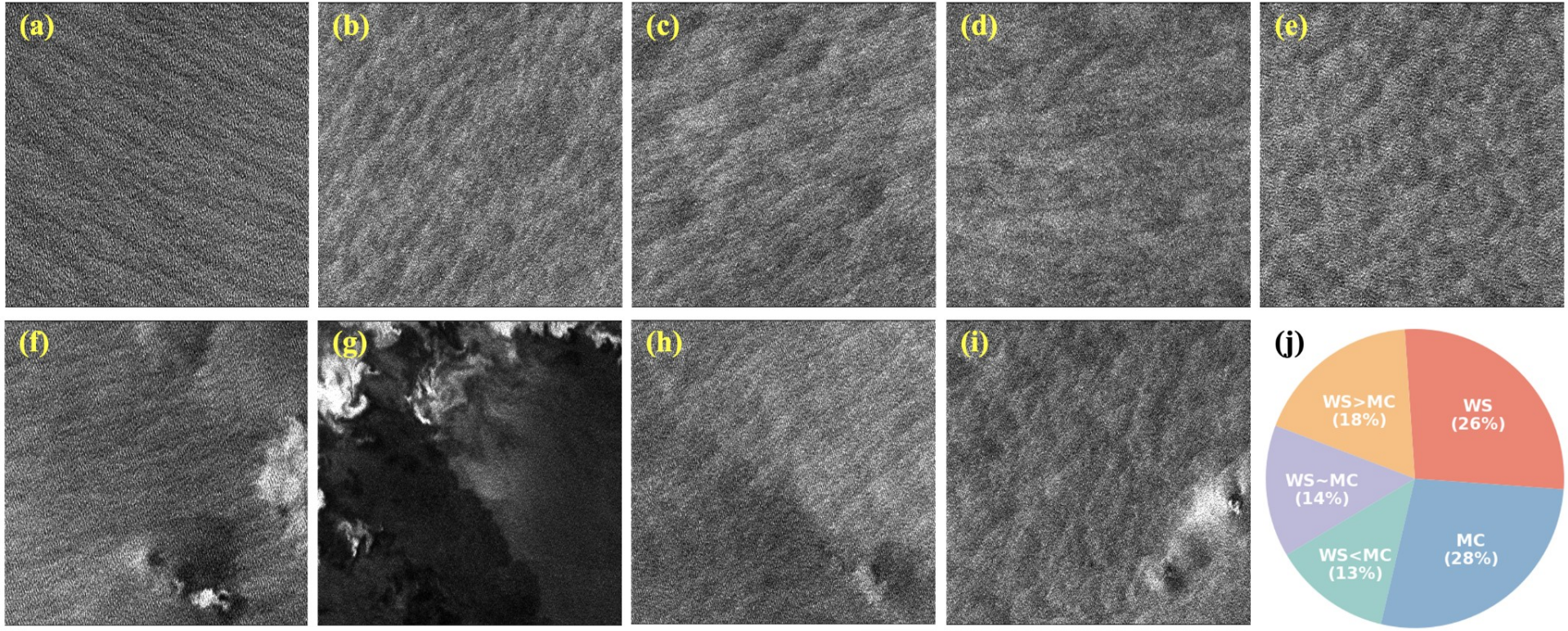
- SAR and ERA5 sampling is the same, all grid points (2-deg bins) add to 100%
- Relative occurrence rate between SAR-detected MC, WS, and NV events, top panels (a-c), using S-1
- Panels d-f show ERA5: UBL, NNBL, and SBL based on *Ri* criteria.

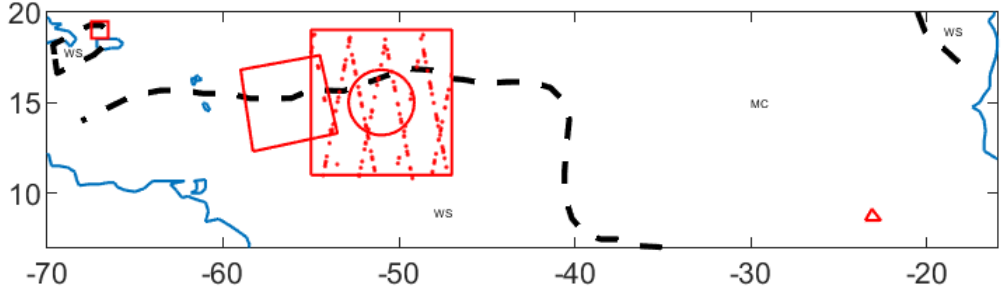
- Regional patterns are similar! The method can be used to map these events spatially.



Our results confirm Grossman (1982)

- Continuous transition from WS to MC as Ri↓
- Small range of Ri
- Results are similar between ERA5 and NTAS buoy





99% of images have the imprint of MABL CS during dry months Jan-Jun in NW Atlantic

- Approximate equal distribution between
  - WS
  - Mixed MC/WS
  - MC