Observed Structure and Characteristics of Cold Pools over Tropical Oceans using Vector Wind Retrievals and WRF Simulations

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Motivation and Goals

- Precipitation falling in sub-saturated air creates surface **cold pools** (Feng et al., 2015), which are a variety of sizes and form in a variety of environments.
- Cold pools are important for convective initiation, development, and maintenance (Tompkins 2001) and can drastically modify air-sea exchange.
- Cold pools are poorly observed, especially over the global oceans.
- We cannot directly measure cold pool temperature properties from the satellites, but we hypothesize that we can detect cold pools at or above sensor resolution using remotely-sensed wind gradients.
- ***In this study, we present a new technique that identifies gradient features (GFs) as gradient-enclosed regions in EUMETSAT Advanced Scatterometer (ASCAT) 12.5 km wind products.***
- Wind gradients are calculated using the formula: $|\nabla\vec{V}| = \begin{bmatrix} \frac{\partial u}{\partial x} + \frac{\partial v}{\partial x} \\ \frac{\partial u}{\partial y} + \frac{\partial v}{\partial y} \end{bmatrix}$

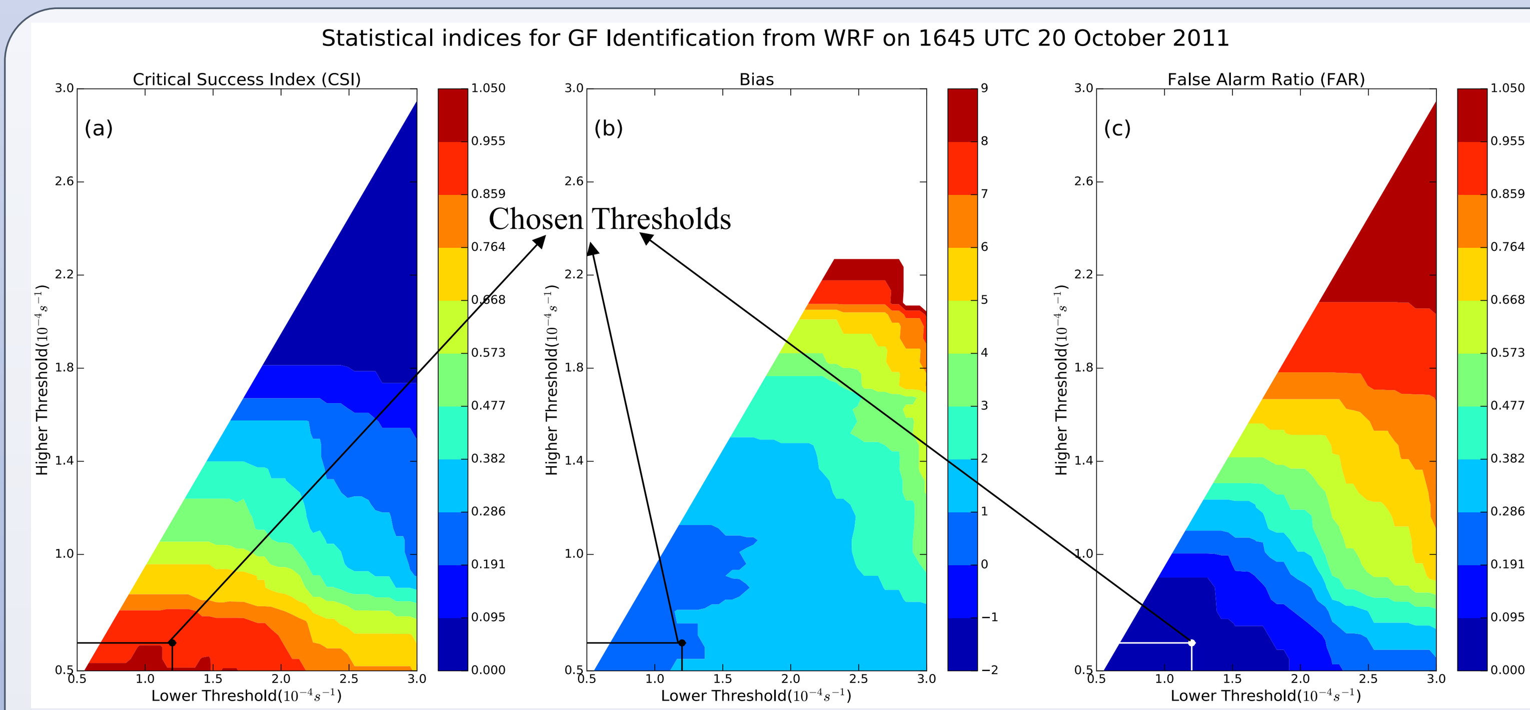
Evaluation Methodology

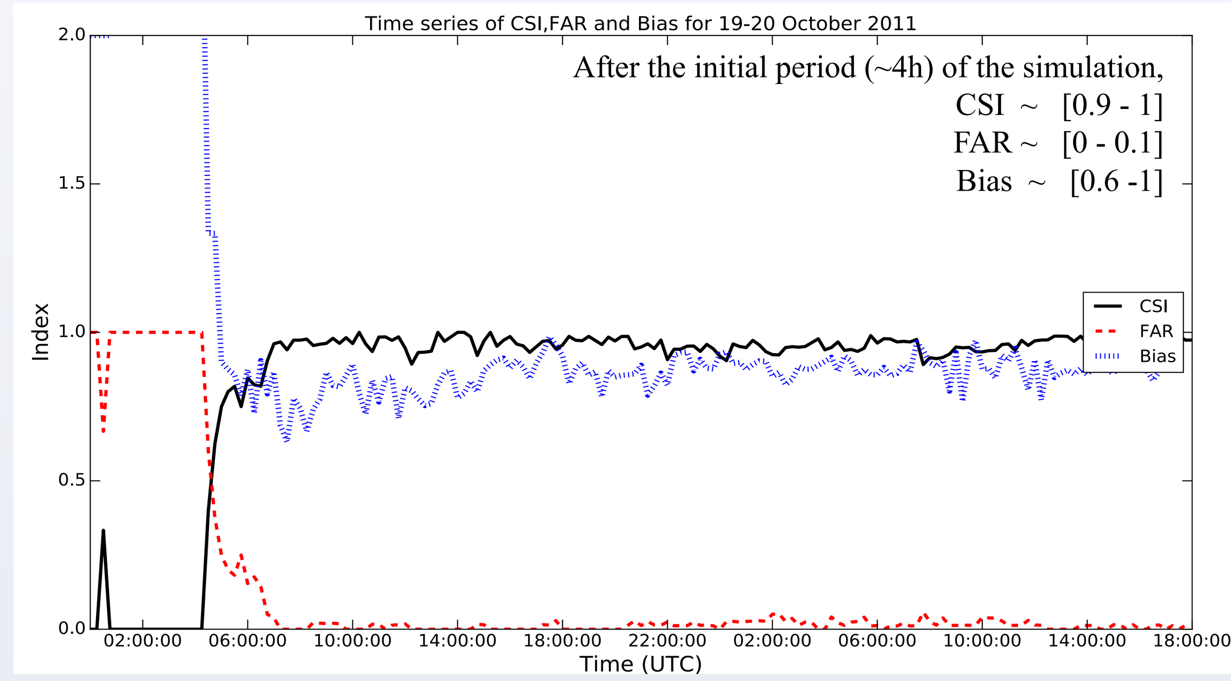
- ASCAT MetOp-A dataset from Remote Sensing Systems (REMSS) was used for the period of **2007-2015**.
- MERRA-2 reanalyses products were used to obtain background fields corresponding to ASCAT observed GFs.
- Python's scikit-image convex hull algorithm and Shapely feature was used to identify the perimeters of the **ASCAT GFs** with $|\nabla\vec{V}| \geq 1.2 \times 10^{-4}\ s^{-1}$.
- Sobel technique (Van der walt et al. 2014) was used for GF edge detection.
- WRF-ARW v3.8.1 was run on a nested grid of 27-9-3 km using initial conditions from GFS for 2 days (00UTC 19 October – 18UTC 21 October 2011) during the active phase of MJO-1 during DYNAMO.
- WRF's 3-km products were regridded to 0.125° lat-lon grid using a Gaussian weighting function similar to ASCAT footprint, and GFs were identified for the domain.
- Virtual temperature (T_v) anomaly was calculated by subtracting the ***Fast-Fourier Transform low-pass*** filtered T_v for each time period from the raw T_v values and the regions of anomaly **≤ -1.5 K** were identified as thermal cold pools (ground truth).
- To remove the bias in the WRF GFs due to lower gradient values, two-thresholds for gradient were applied by calculating statistical indices such as ***critical success index*** (CSI), ***false alarm ratio*** (FAR) and ***bias*** according to the following contingency table.

Gradient Feature (GF)

Virtual Temperature (T_v)	YES	NO
YES	A = Hits (Intersection of GF and T_v is >= 20% of area of T_v)	B = Missed events (Intersection of GF and T_v is < 20% of the area of T_v)
NO	C = False alarms (No intersection between GF and T_v).	D = Correct rejections (Both the parameters don't have a cold pool)

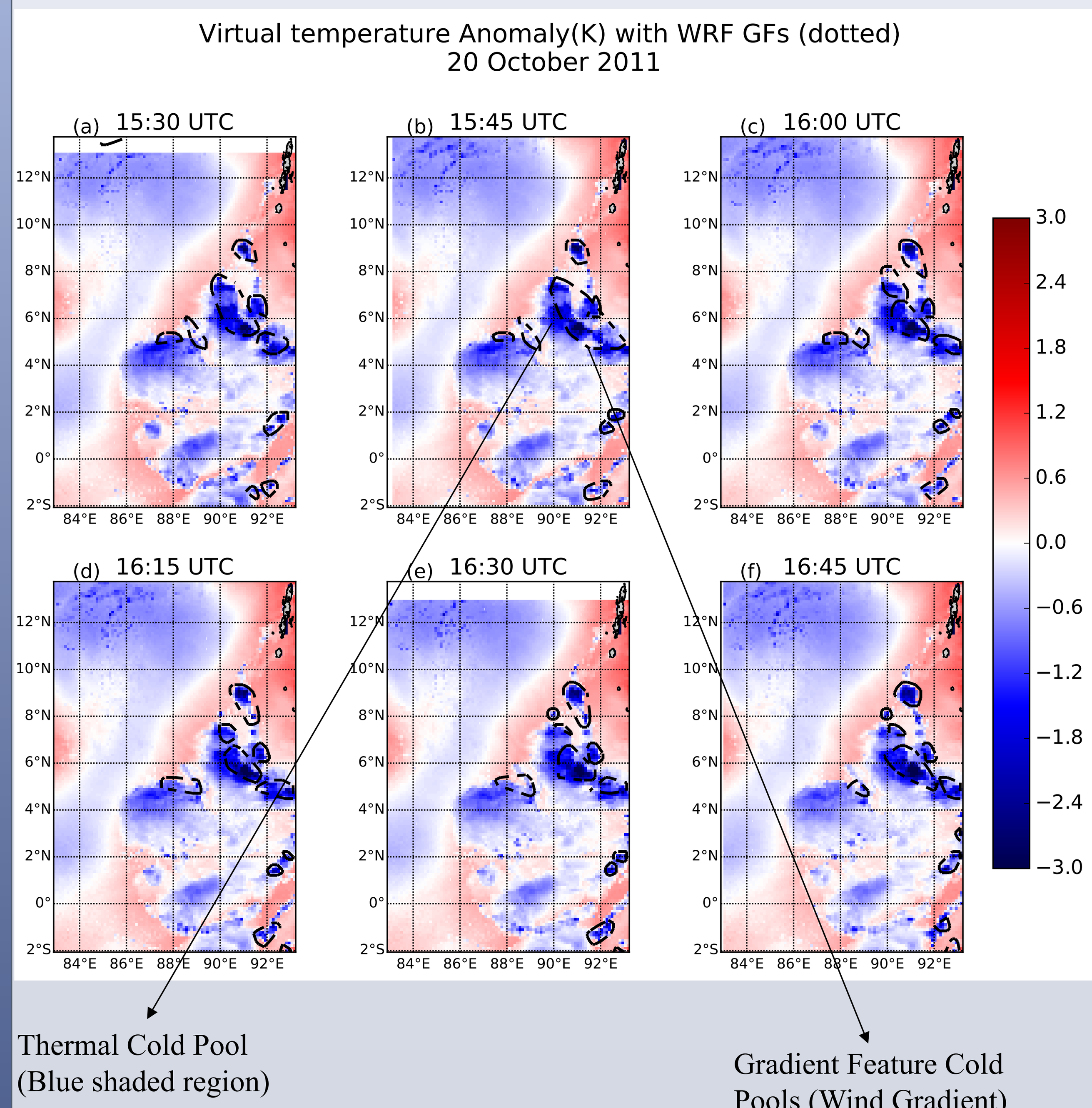
$$CSI = \frac{A}{(A+B+C)} \qquad Bias = \frac{(A+B)}{(A+C)} \qquad FAR = \frac{C}{(A+C)}$$



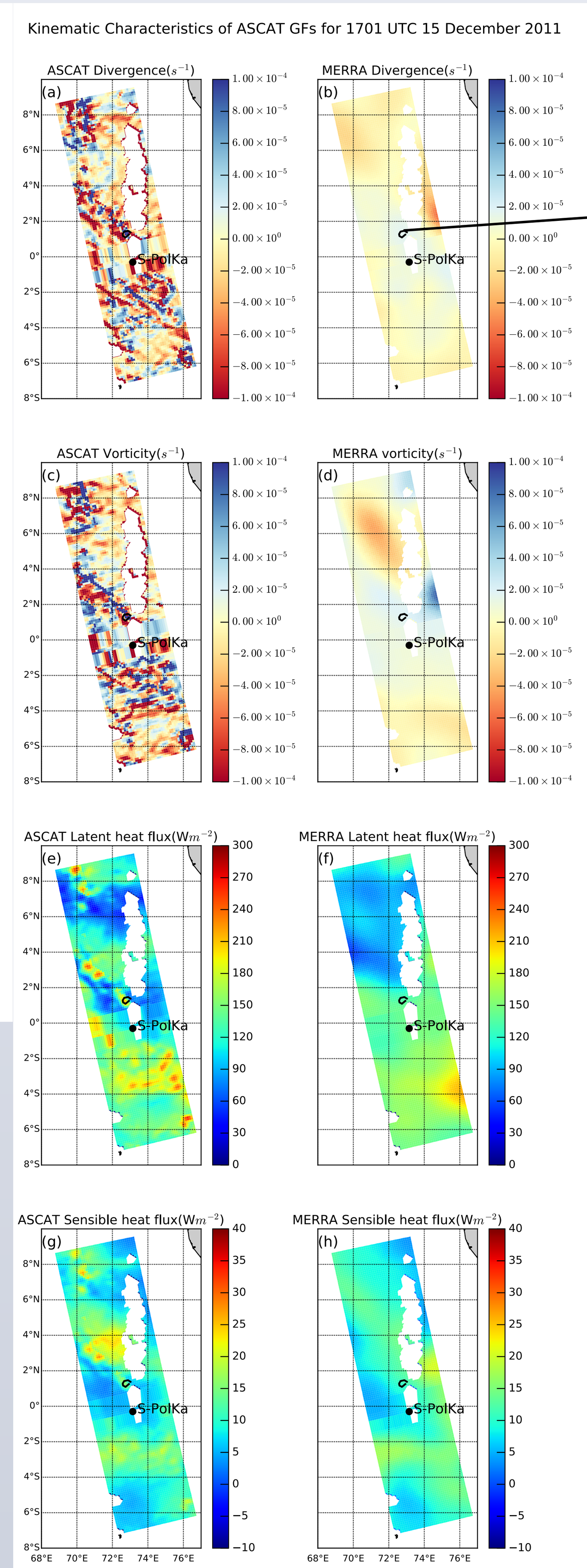


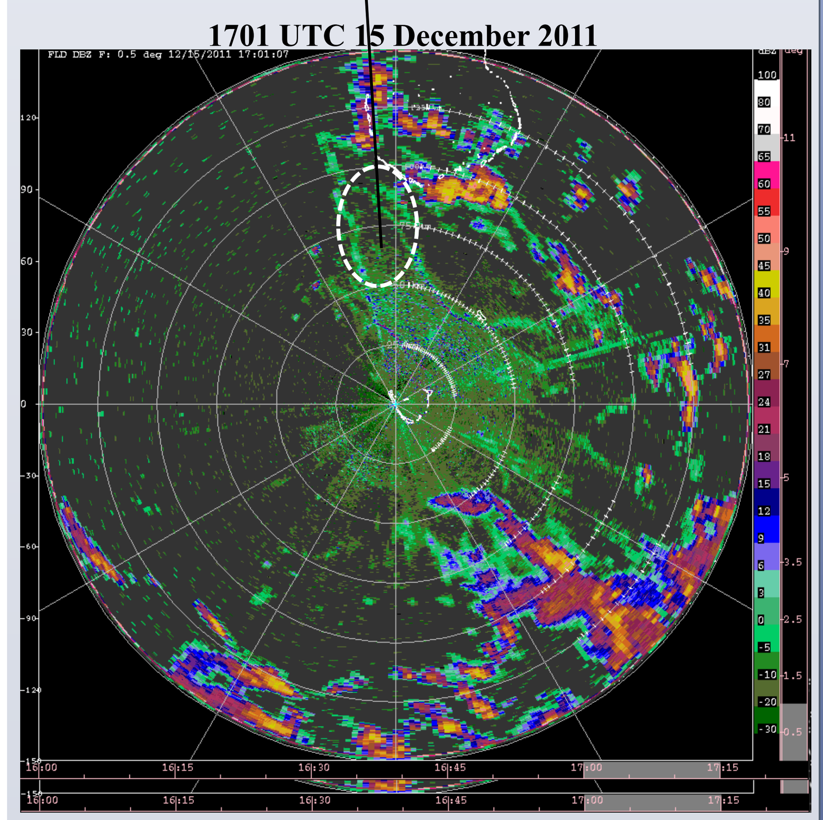
- ***This study uses a threshold of 6.8 x 10^-5^ s^-1^ and 1.2 x 10^-4^ s^-1^ for WRF simulated GFs since the CSI is maximum while bias and FAR are minimum at these thresholds.***

Results



- The correspondence of spatio-temporal evolution of thermal cold pool with wind gradient features from WRF for 20 October 2011 provides confidence in the hypothesis that what is being observed as GFs are cold pools essentially.
- ***The strength of the technique is that it is successful in identifying the isolated and intersecting cold pools over Indian Ocean.***

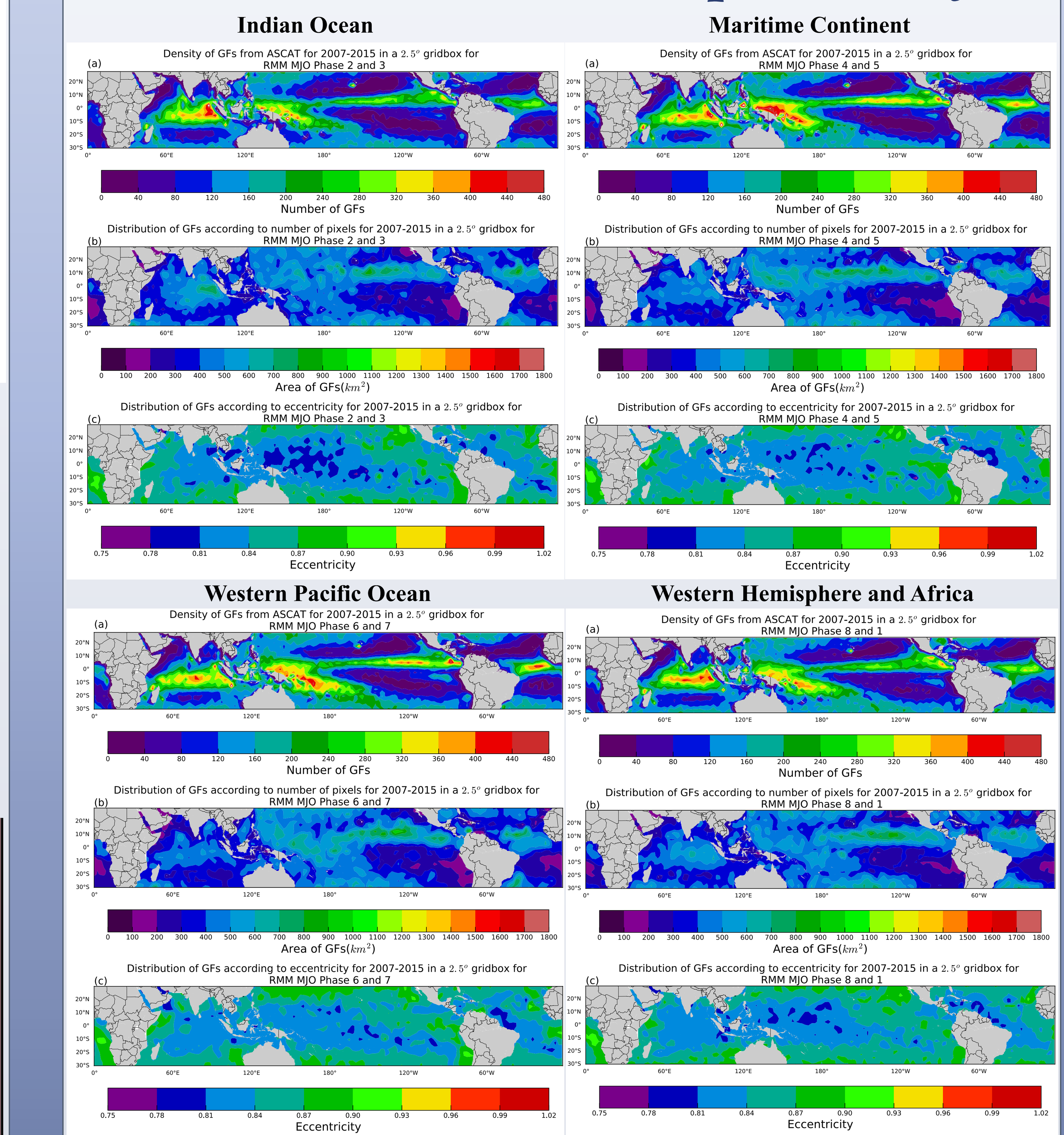


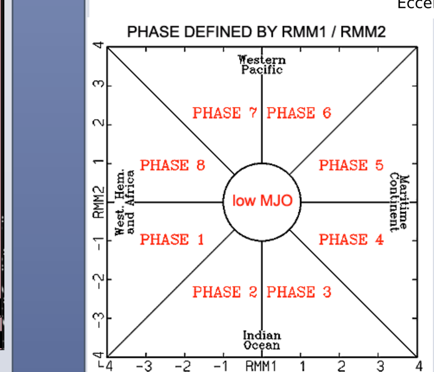


S-PolKa Radar (0.5° elevation) from DYNAMO

- The validation of the location of the cold pool from ASCAT with ground based radar from DYNAMO gives further validation to the identification technique.
- The evolution of surface sensible and latent heat fluxes using winds from ASCAT (e) as compared to the inherent fluxes from MERRA-2 tells us that the observation based cold pool fluxes aren't well represented in the model products, thus causing misrepresentation of convection due to errors in quantification of ocean-atmosphere exchange.

ASCAT Gradient Features Characteristics with respect to MJO





- This study has used **Wheeler-Hendon Index** to identify the phase and amplitude (Only outside the low MJO circle are considered) of MJO for the period of 9 years (2007-2015).
- We have divided these spatial plots according to the quadrants shown in the left hand side figure to visualize the evolution of cold pools as MJO propagates.

Conclusions

- The locations of virtual temperature (T_v) and WRF-GFs agree well in WRF, suggesting that these features are cold pools.
- ASCAT identified GF matches well in location with S-PolKa radar and provides an insight into the importance of wind-induced fluxes in the evolution of convection in the global model reanalyses (MERRA-2).
- The correspondence of ASCAT identified cold pools with the movement of MJO is fascinating and thus lays a groundwork for future work on linking these characteristics with different modes of tropical variability (MJO, BSISO etc).

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