A Lagrangian Study of Factors Associated with Transitions in Marine Mesoscale Organization

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Mesoscale Cellular Convection (MCC)

- Marine low clouds can organize into cells on a scale of 10-40 km.
- A few dominant, repeating cellular structures sustained by different processes:
  - **Closed cells** are driven by cooling at cloud-top, with descending air creating thin spots between cells.
  - **Open cells** are more convective, likely driven by colliding cold pools causing updrafts.
  - **Disorganized cells** may not be driven by a single mechanism, and tend to be spatially irregular.
Mesoscale Cellular Convection

- Closed cells tend to form along the west coasts of the continents and advect westward and equatorward in the trade winds.

- Closed cells tend to break into either open cells or disorganized cells, and are eventually replaced by trade Cu. Transition regions studied here are shown below in red.
Why MCC?

- Cloud amount does not tell the whole story concerning albedo.
- Different cellular organizations behave differently.
- Open cells have a lower albedo for an equivalent % cloud cover.
  - This is due to the presence of thin veil (detraining shallow convection) clouds surrounding the thick convective cores of open cells.
  - For GCMs to accurately represent albedo, cellular structures need to be better represented.

MCC Classifier

• Using a human-trained machine learning algorithm.

• Three classifications:
  • Closed (1)
  • Open (0)
  • Disorganized (3)

• Classified in ~256km ‘oversampled’ square boxes.

• Based on L2 MODIS LWP data during the day only.
Precipitation and MCC

• Differing cellular organizations show distinct differences in precipitation rate and distribution.
• Closed cells are associated with broad areas of light drizzle.
• Open cells have more intensely drizzling cores, but less expansive precipitation overall.
• A core question: Is precipitation involved in the transition between closed and open MCC?
  • Does precipitation drive the process?
  • Is precipitation just a ‘side-effect’ of the transition process?
• We can use our new Tb-derived rain rate estimates to test this, along with other variables.
Precipitation from CloudSat and AMSRE Tb

• Using co-located observations to determine the relationship between AMSR/E 89 GHz Tb and rain rate.

• After binning for confounding variables (SST, wind, column water vapor, ice clouds), we can estimate rain statistics from Tb:
  • Rain probability
  • Mean rain rate
  • Mean rain rate when raining
  • Maximum rain rate
Cloud Variables and Environmental Predictors Associated with MCC Transitions

• Cloud Variables
  • Cloud Cover (CC, %, MODIS)
  • Cloud Liquid Water Path (LWP, AMSR/E)
  • Drizzle rate (AMSR/E & CloudSat)
  • Droplet Concentration (Nd, MODIS, daytime only, Grosvenor...)
  • PBL Depth (MODIS & CALIPSO)

• To assess whether cloud properties differ before and during different types of transitions.

• Environmental predictors (ERA5)
  • Humidity above the PBL
  • Wind speed at the surface
  • Lower Tropospheric Stability
    • Theta 700 – Theta 1000
  • Sea Surface Temperature (SST)
  • 700 hPa subsidence

• Compare the meteorological conditions associated with transitions.
Lagrangian Approach

• Sample the same cloud scene as it advects and evolves in time and space.
• Trajectories are sampled every 12 hours as the A-train flies overhead.
  • Sample radius of 200km for MCC classifiers.
  • Roughly 160,000 48-hour trajectories are computed for 2007-2010
MCC Sample Histograms

- MCC classifiers are sampled every 24 hours during the day.
- Histograms of MCC are established for each 200 km-radius sample.
- A sample is considered to be an MCC type if a majority (>50%) of one MCC type is present.
- Trajectories that transition from a majority closed MCC to majority open or disorganized are considered ‘transitioned’.
Results: Cloud Variables

- CC declines most going from closed to disorganized.

- Closed-Open transition shows significantly lower Nd, more precipitation, and higher LWP.

- Closed-Disorganized occurs in deepest closed PBLs.
Results: Predictor Variables

- Humidity above the PBL and LTS is much higher in closed-closed cases, while SST is lower.
- Wind speed is significantly higher in closed-open cases.
- Subsidence is lowest in Closed-Disorganized cases.
Locations of Transitions Differ

- MCC stays closed closer to the coast, except in E Indian.
- Are differences in cloud and predictor variables simply due to geography?
- Converting variables to deseasonalized anomalies will minimize biases associated with different geography.
Results: Anomalies

• For closed-open trajectories, the LWP and droplet concentration anomalies are still significantly different than for the other sets.
  • LWP is higher
  • $N_d$ is much lower, indicating a reduction in cloud drops is a strong predictor of closed-open versus closed-closed.

• Closed-disorganized transitions tend to occur in significantly deeper PBLs
Results: Anomalies

- Closed-open transitions are associated with significantly stronger wind speeds.
- Closed-disorganized transitions are associated with warmer SSTs, a drier troposphere above the PBL, lower LTS, and less subsidence.
Next project phase: Global Lagrangian Analysis

- Using a similar framework, but for MCC classifications between 65N and 65S.
- ~50,000 Trajectories per year have been run for years 2003-2011.
- Beginning on clusters of similar MCC classifiers, run 48 hours forward and back.
- To look at global climatologies and differing mechanics in different regions.
Conclusions

• Transitions from closed-open differ from other transitions in several ways:
  • Stronger precipitation overnight.
  • Significantly lower droplet concentrations prior to transition.
  • Greater LWP.
  • Stronger wind speed.

• Transitions from closed to disorganized are driven by differing mechanisms:
  • Deep PBL
  • Lower LTS
  • Warmer SST
  • Less subsidence
  • Drier free troposphere

• Trajectories that remain closed tend to be associated with:
  • Higher LTS
  • Less precipitation
  • Greater humidity in the free troposphere