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Synthesizing Cloud Field Complexity over Ascension Island and Beyond

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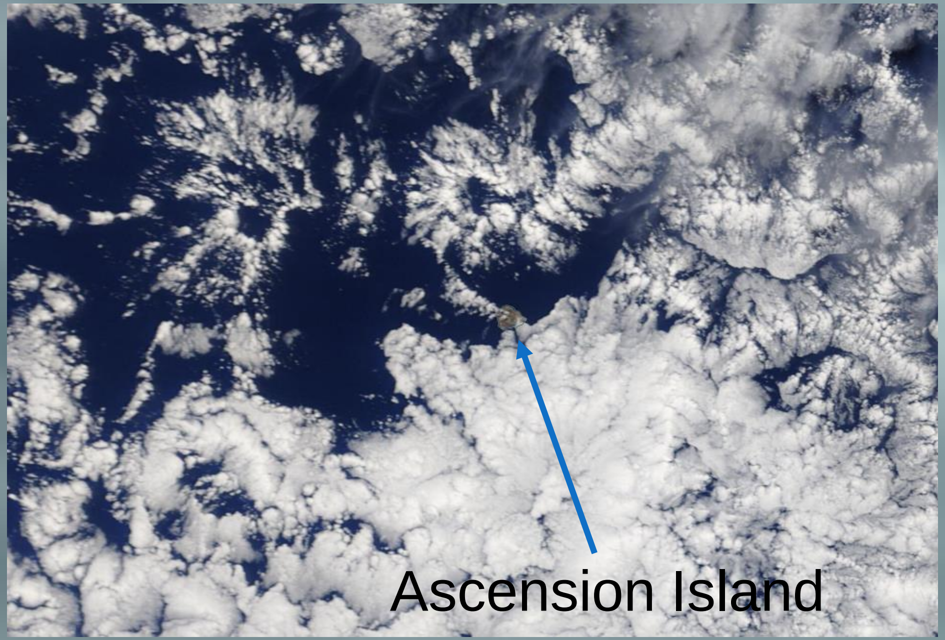

Marine boundary layer clouds, which reside in the lower 3-km of the marine atmosphere, cover a large portion of the Earth's surface, are critical components of the Earth's energy budget, and are challenging to represent in models.

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Introduction and Motivation

- Marine Boundary Layer (MBL) clouds
  - structurally complex consisting of mixtures of different cloud types that often produce light precipitation
  - cloud morphology at a given time and place depends upon large-scale meteorological conditions and cloud-to-cloud interactions
  - Marine cloud structure is highly variable and often changes every few hours.
- We are experimenting with machine learning techniques to efficiently categorize and quantify the complexity of these cloud fields.
- Detailed measurements of MBL clouds have become recently available from the ARM program at locations such as Ascension Island (ASI), which is in the South-Central Atlantic Ocean.
- Remote sensors at ASI provide structural measurements of the overlying clouds every two seconds and radiosondes (balloon-borne sensors) measure the profiles of temperature, humidity, and pressure several times per day.

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Goals and Objectives

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- Quantify the MBL cloud morphology in 6-hour increments using data collected from Ascension Island (ASI) during the Layered Atlantic Smoke Interactions with Clouds (LASIC)
  - Use machine learning to classify cloud morphology
- Identify specific features of the clouds at ASI that may be associated with the steep island coastline
- Contrast the cloud morphology over the South Central Atlantic with that observed over Eastern North Atlantic (ENA).
- Continue to develop methods to classify MBL cloud structure at all ARM marine deployment locations

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Quantifying Complex Cloud Morphology

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- We are applying a machine learning algorithm known as K-Means to ASI cloud measurements
  - K-Means is a method of quantization that aims to partition a collection of observations into "clusters" in which each observation belongs to the cluster with the nearest mean.
  - Each 6-hour period of cloud observations from ASI and ENA are assigned to a cluster that indicates different cloud morphology
  - Three inputs describing the physical attributes of the cloud field are used as inputs to the K-Means algorithm:
    - ✓ A Thickness Index (TI) : $TI = \frac{1}{N}\sum_{j=1}^{N}\left[\left(\sum_{i=i_b}^{i=i_t} k_i \cdot \Delta z\right)/z_{max}\right]_j$ $\quad \begin{cases} k_i = 1 & Z > -35\ dBZ \\ k_i = 0 & Z < -35\ dBZ \end{cases}$
    - ✓ A Drizzle Index (DI) : $DI = \frac{1}{N}\sum_{j=1}^{N}\left[10\left(\left(\bar{Z}_{\Delta h_{DD}} + 35\right)/45\ dBZ\right)\left(\Delta h_{DD}(m)/z_{max}\right)\right]_j$
    - ✓ A Complexity Index (CI) : $CI = \frac{h_{c\_max}(m) - h_{c\_min}(m)}{z_{max}}$
  - These indices represent measures of the total cloud depth, rainfall intensity, and geometric variations in the cloud field.

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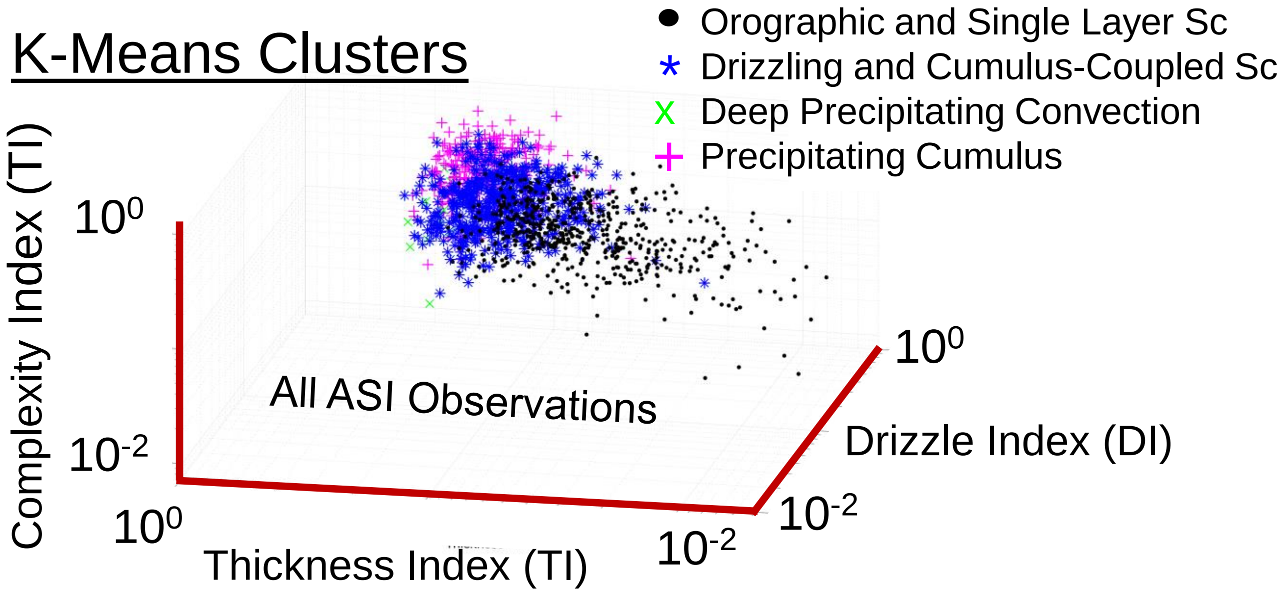
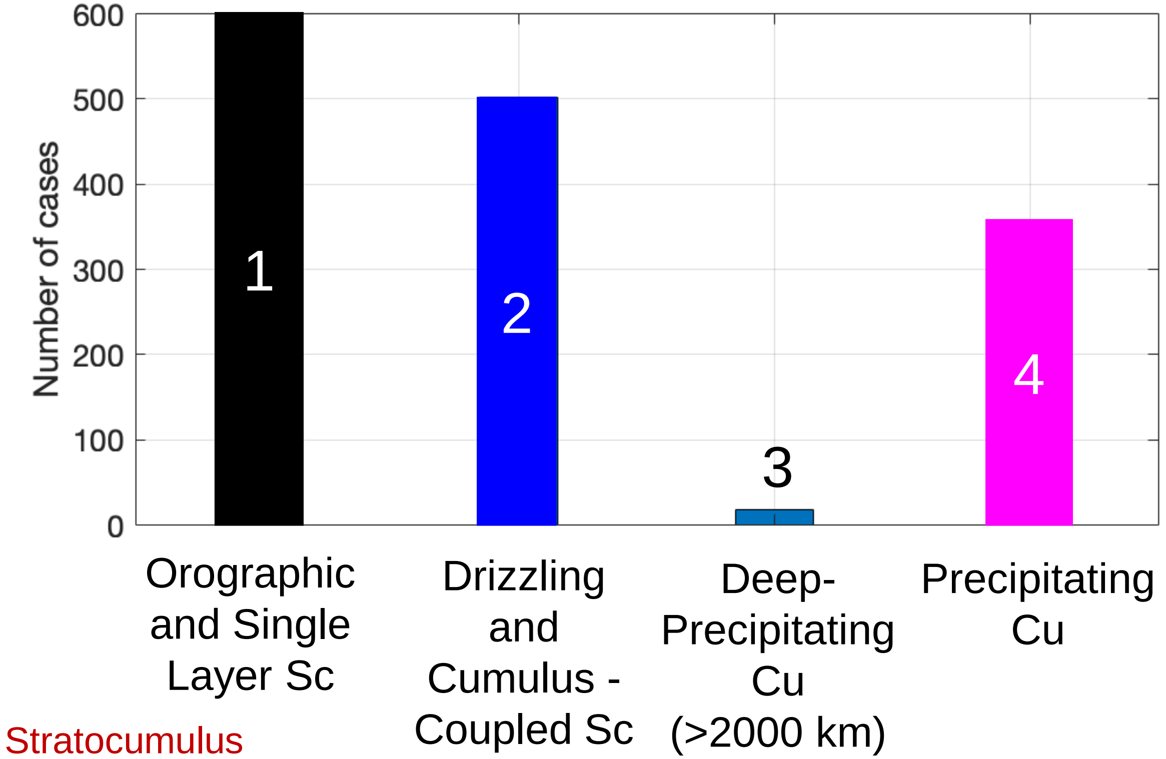
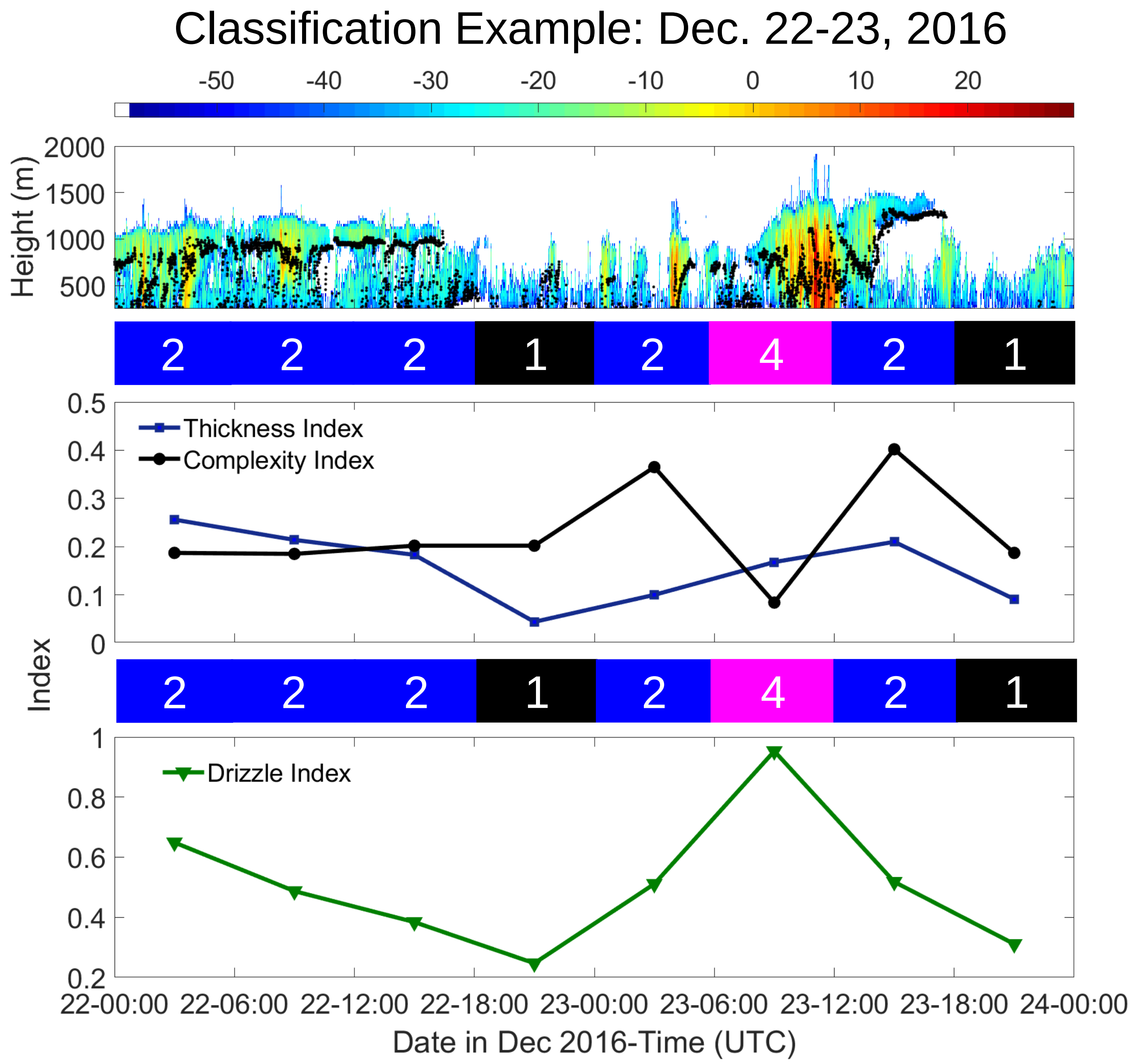
Classifications for Ascension Island







Sc: Stratocumulus
Cu: Cumulus

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Summary

- One year of ASI cloud measurement were subjected to a K-Means clustering algorithm based upon three indices that quantify different aspects of the cloud morphology, which was originally applied to data from the ARM Eastern North Atlantic (ENA) Observatory.
- Cloud morphology at ASI includes a combination of marine boundary layer and orographic clouds and K-Means showing success in differentiating.
- ASI/ENA cloud morphology is similar in most classifications

Site	Single Layer and Orographic* (%)	Drizzling and Cu-Coupled Sc (%)	Deep Convection (%)	Precipitating Cu (%)
ASI (1 year)	41*	34	1	24
ENA (4 summers)	47*	25	5	23

* Orographic clouds primarily at ASI, single layer Sc primarily at ENA