Clouds, Aerosol, and Precipitation in the Marine Boundary Layer (CAP-MBL)

A proposal to the ARM Climate Research Facility (ACRF)

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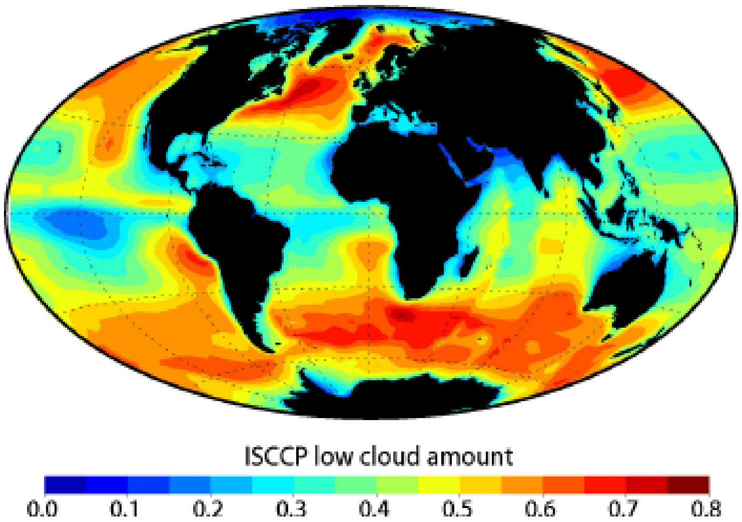
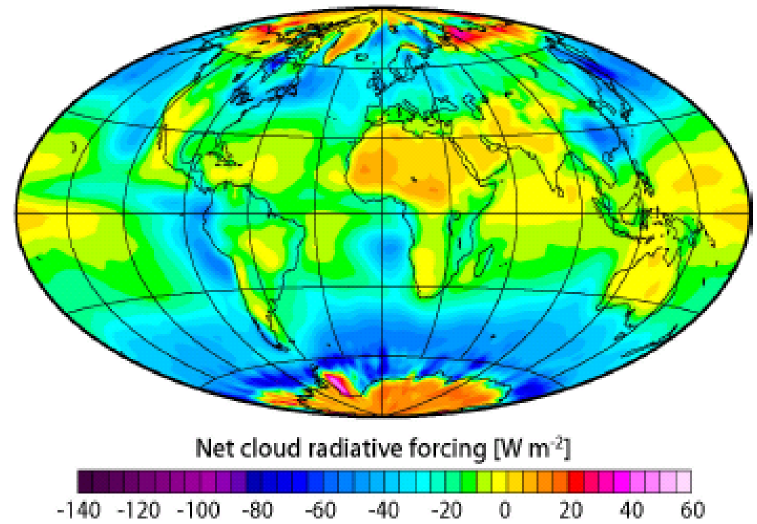
Date for proposed activities: **April-Dec 2009**

Proposed location: **Graciosa Island** (39.02°N, 27.97° W), **The Azores, NE Atlantic**





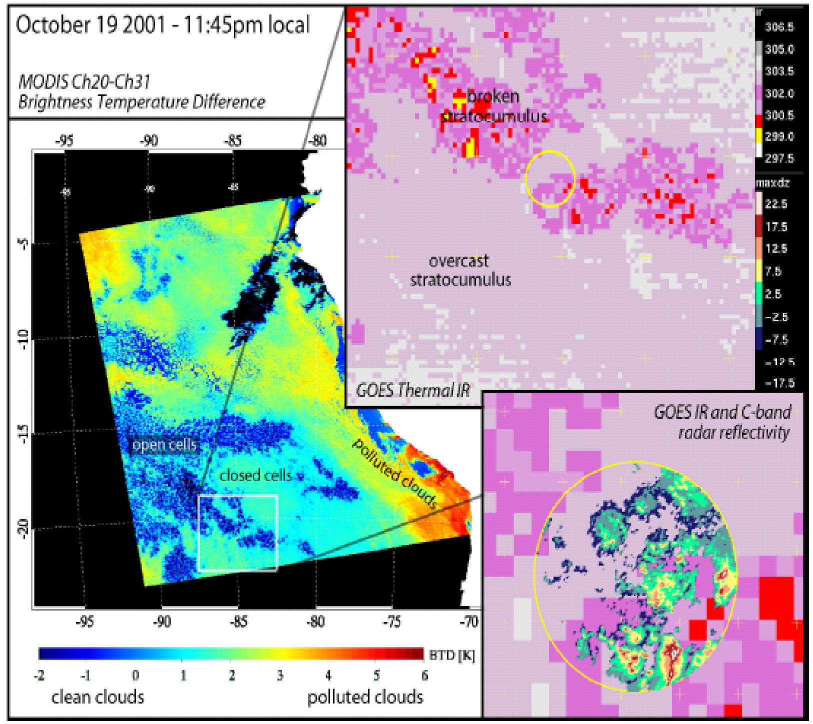
Importance of Low-Clouds for Climate

Imperative that we understand the processes controlling the formation, maintenance and dissipation of low clouds in order to improve their representation in climate models.

Aerosol-Cloud-Drizzle Interactions

Precipitation and its effects in the MBL over oceans

Figure 3 (RIGHT): MODIS satellite image from October 19 2001 during EPIC (main) showing night-time Ch20-Ch31 brightness temperature difference. Blues and reds indicate clouds with low and high cloud droplet concentration respectively. Open and closed cellular convection is also delineated. Upper inset shows GOES thermal infrared which can also be used to determine broken stratocumulus (open cells). Lower inset shows composite of shipborne C-band radar and GOES thermal infrared. In this case heavier drizzle is associated with the open cellular regions.



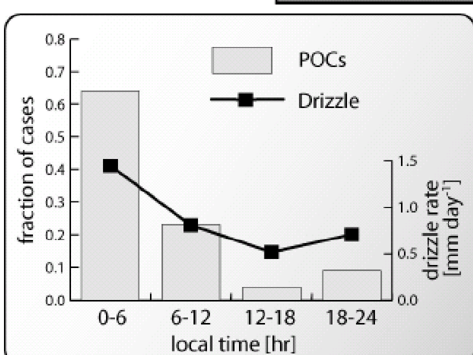


Figure 4: The diurnal cycle of the initial formation of pockets of open cells in otherwise overcast stratocumulus during Sep-Oct 2001. The data are from GOES over the SE Pacific subtropics (Wood et al. 2007). Also shown is the diurnal cycle of cloud base precipitation rate from EPIC 2001.

No long-term records exist that can be used to link cloud, precipitation, and aerosol microphysical variability in the remote-capped MBL.

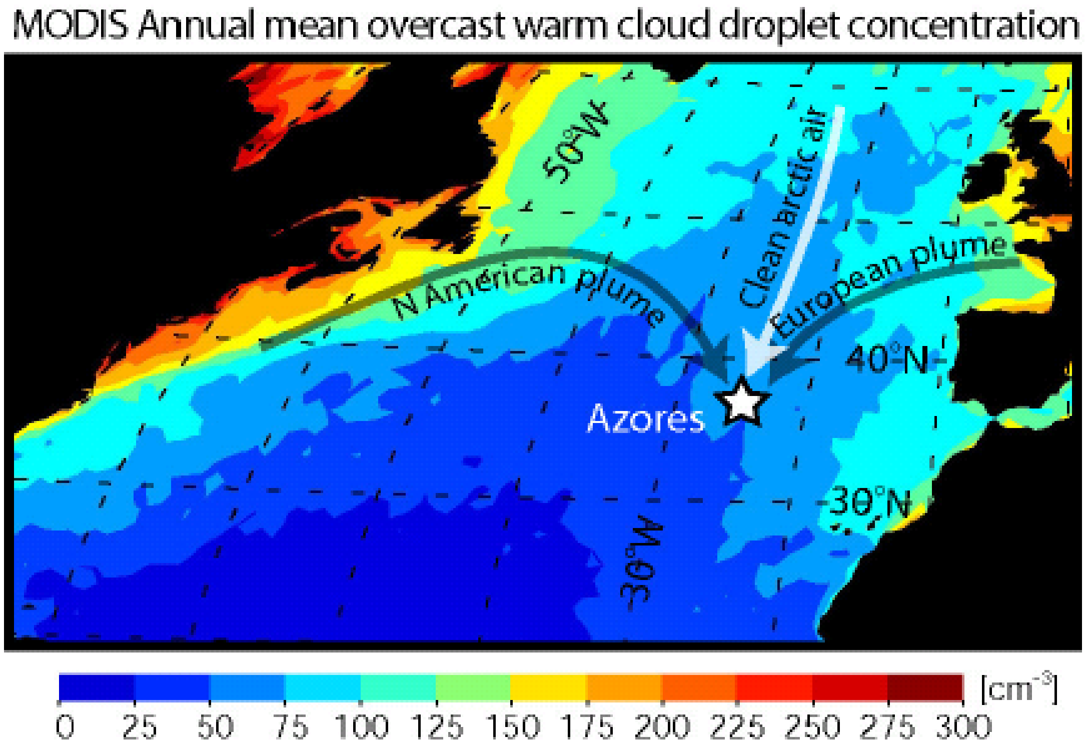


Figure 2: MODIS annual mean cloud droplet concentration for overcast warm clouds over the North Atlantic. The Azores typically experiences relatively clean conditions with northerly flow, but with periodic episodes of continentally-influenced polluted airmasses. The location is therefore ideal for capturing a wide range of aerosol conditions.

Scientific Goals of AMF Deployment to Azores

a) *Which synoptic-scale features dominate the variability in subtropical low clouds on diurnal to seasonal timescales over the NEA? Do physical, optical, and cloud-forming properties of aerosols vary with these synoptic features? How well can state-of-the-art weather forecast and climate models (run in forecast mode) predict the day-to-day variability of NEA cloud cover and its radiative impacts?*

b) *Can we find observational support for the Twomey effect in clouds over the NEA?*

c) *What is the variability in precipitation frequency and strength in the subtropical cloud-topped MBL on diurnal to seasonal timescales, and is this variability correlated with variability in aerosol properties?*

d) *Are observed transitions in cloud mesoscale structure (e. g. from closed cellular to open cellular convection) influenced by the formation of precipitation?*

Cloud Climatology for Azores

AMF Site: Graciosa Island in the Azores (28 ºW 39 ºN)

- Small Low Island
- No Direct Continental Influence
- MBL Depths 1-2 km

Avg Winds

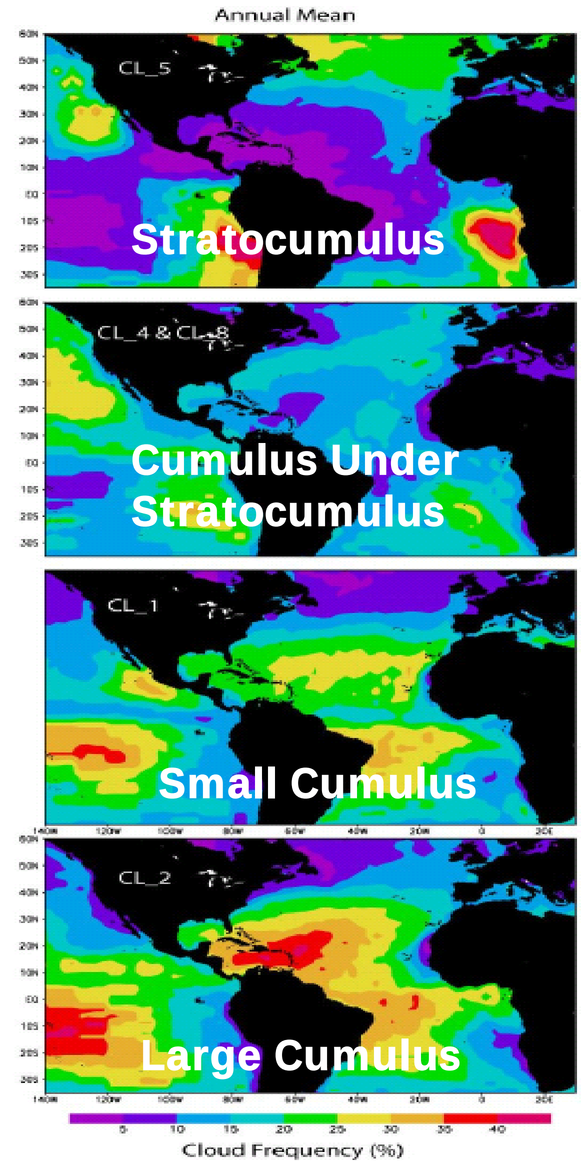


Figure 6: Annual mean frequency of occurrence of (from top) stratocumulus, stratocumulus with cumulus beneath or formed from spreading cumulus, small cumulus, and large cumulus

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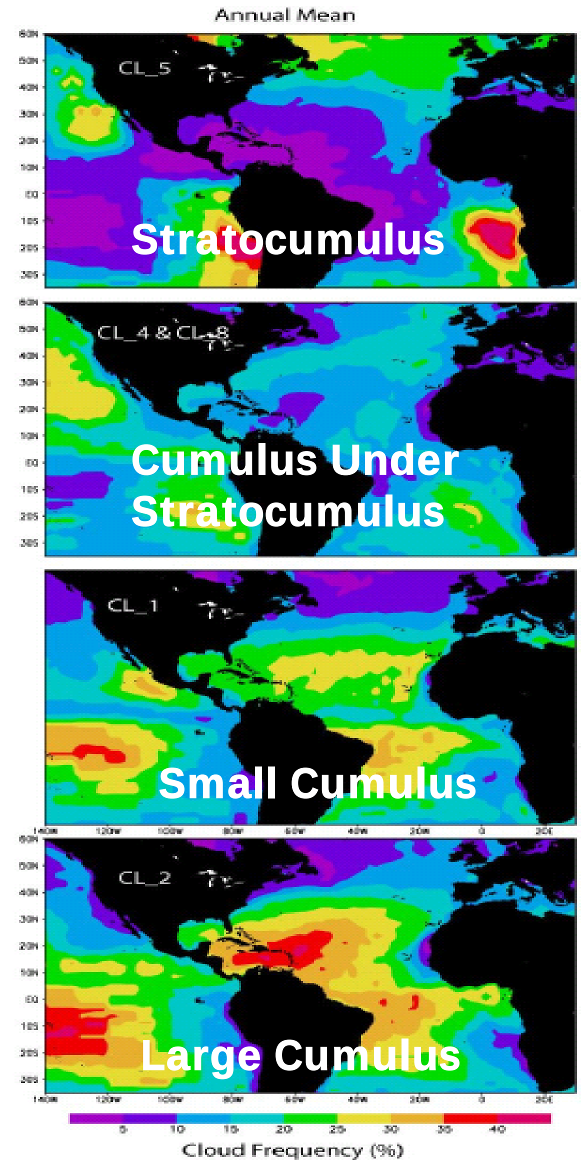

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Table 1: Key instrumentation requirments for the AMF deployment

Instrument	*Important derived parameters*
94 GHz Profiling Radar	(i) Cloud and precipitation vertical structure (ii) Cloud top height (iii) Drizzle drop size distribution using both Doppler spectral measurements (Frisch et al. 1995) and with MPL below cloud base (O'Connor et al. 2005)
Micropulse Lidar (MPL)	(i) Cloud occurrence, (ii) Precipitation profiling below cloud base (with radar) (iii) Aerosol properties in MBL and above MBL (clear skies)
Microwave Radiometer (MWR)	(i) Cloud liquid water path (ii) Column water vapor path
MultiFilter Rotating Shadowband Radiometer (MFRSR) and Narrow Field of View Radiometer (NFOV)	(i) Cloud visible optical thickness. Will be used to infer cloud microphysical properties (droplet concentration, effective radius) in combination with MWR (ii) Aerosol optical properties in clear skies
Marine Atmospheric Emitted Radiance Interferometer (MAERI).	Cloud liquid water path estimates for thin clouds (combined with MWR, following Turner 2007)
Total Sky Imager (TSI)	Cloud coverage and type
Ceilometer (VCEIL)	(i) Cloud base height (ii) Cloud cover
Balloon-borne Sounding System (BBSS)	(i) Atmospheric profile structure (ii) MBL depth (iii) Inversion strength
Eddy Correlation Systems (ECOR)	Surface turbulent fluxes of latent and sensible heat
Surface Meteorological Instruments	Surface temperature, humidity, pressure, winds
Sky Radiometers	Downwelling shortwave and longwave radiative fluxes used to constrain the surface energy budget
Surface aerosol observing system	Aerosol physical properties (total concentration, scattering and absorption), CCN characteristics

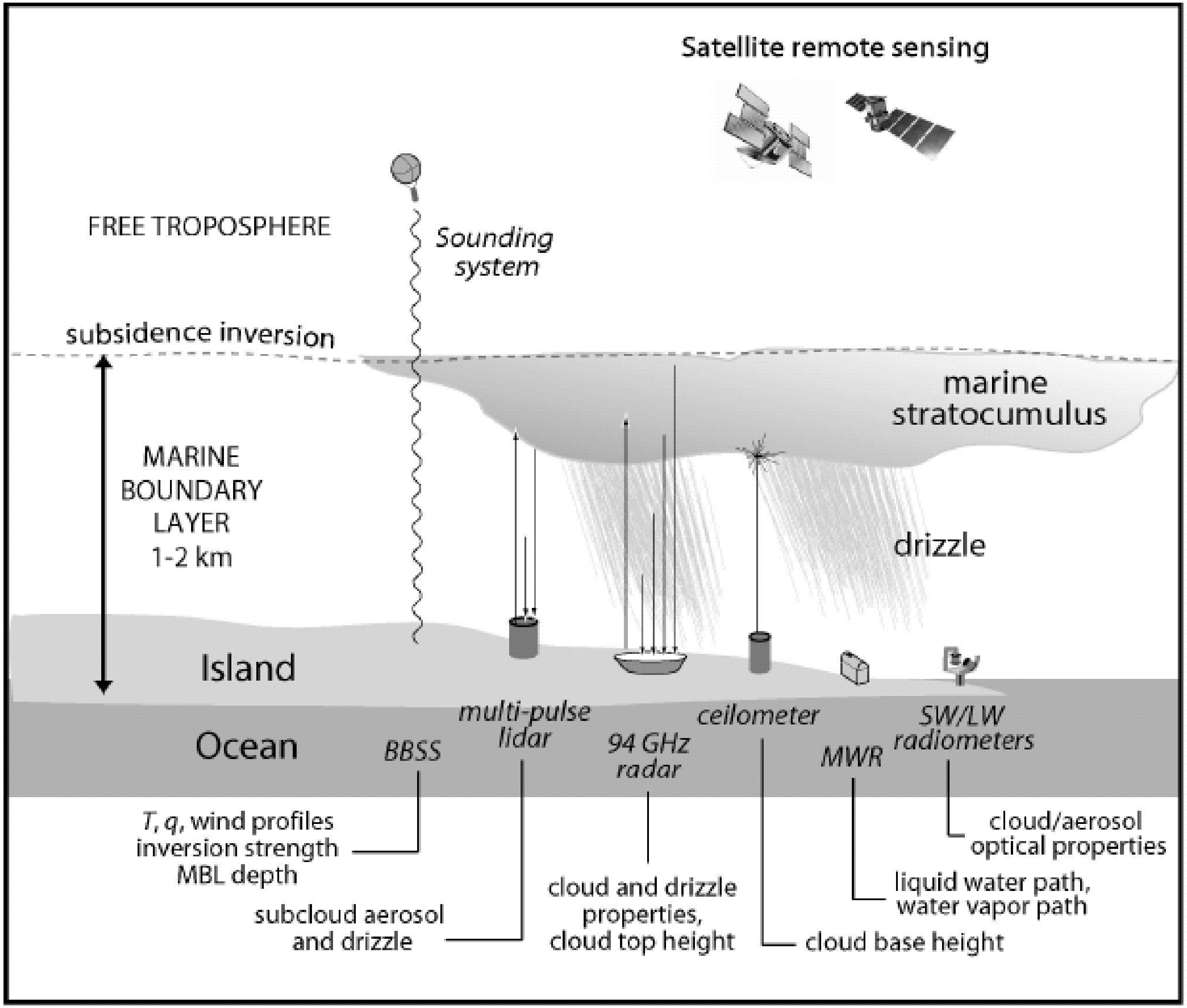

Figure 7: Schematic showing key instruments to be used in the AMF deployment.

Synergistic Activities

- PICO international Chemical Observatory, a component of the North Atlantic Regional Experiment (PICO-NARE)—Terceira, Pico
- Azores AERONET Site; Aerosols—Pico
- Satellite and Reanalysis Data Sets
  - Microphysical and MBL Retrievals (Aqua, Terra, CloudSat, CALIPSO etc.)
  - Cloud Morphology
- Modeling
  - LES
  - Single-column
  - Meso-scale and Global
- Aircraft Observations*

CAP-MBL Extension (Proposal in Preparation)

- Motivation
  - Extend record over one-annual cycle
  - Develop fully scanning radar capability for application in a marine, low-cloud environment
    - Deploy Scanning W-band WACR
    - Evaluate performance and scanning strategies in an environment with varied low cloud and drizzle conditions on a wide-range of scales
    - Provide 3-D cloud and drizzle fields upstream from island
  - Execute aircraft-based field program in coordination with surface-based AMF
    - Three aircraft—CIRPAS Twin Otter; DoE ASP G-1; UK *FAAM BAe-146*
    - Closure Studies—Aerosol, cloud microphysics and drizzle; entrainment; radiation