Discussion on CPMSG metrics and decadal plan

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Boundary layer structure & Shallow cloud microphysics

- **Goal**

  Develop and maintain a public list of measurement or analysis gaps that require either specific additional investments or integration of PI or external data sets or codes, as well as a method for gauging community support.

- **Matrix**

  Science question

  Problem & Roadblock

  Impact

  Research Elements

  Maturity/Readiness [Low, Medium, High]

  Solution and Recommendation [Timeline]

  Roadmap to Modeling

Summary of the Workshop

- **Date**

  March 23-24, 2020

- **Report**

  https://drive.google.com/file/d/192OY2zAqFlwwb9T2FbLll6wALiREF1pj/view?usp=sharing

- **Action plans for implementation**

  Solicit input from breakout sessions during the upcoming PI meeting, e.g., the lidar group for characterizing boundary layer structure and obtaining 3D structure and spatial context

  Solicit input from working groups to clarify/identify barriers and recommendation, e.g., surface inhomogeneity, the need of ocean measurements at ENA, adaption/development of remote sensing techniques for high-latitude sites.

Problem & Roadblocks – Shallow cloud microphysics

- **Lack of robust**
  - Droplet number concentration retrieval
  - Joint cloud and drizzle property retrieval
  - Observations for clouds with low liquid water path
  - Observations for clouds with large liquid water path
  - Observations of vertical velocity from cloud base to in-cloud
  - Observations of small-scale turbulence, entrainment and mixing

- **Issues about**
  - Difficulty in constraining large-scale vertical motion, divergence, latent heating, advective tendencies of hydrometeors
  - Quality and availability of aerosol measurements
  - Site representativeness in terms of sampled aerosol conditions, possible CCN data quality issue, the degree of coupling with boundary layer

Problem & Roadblocks – Boundary Layer Structure

- **Main issues**
  - Difficulty in characterizing PBL height and (internal) structure robustly
  - 3D structure and spatial context and important on the km scale

- **Unclear issues**
  - MBL analysis at ENA requires ocean surface properties
  - Continuation and harmonization of datasets

Other topics discussed in the Cloud & Precipitation Measurement and Science Group (CPMSG)

- **Convection and cirrus (Mike Jensen); Mixed-phase and ice process (Matt Kumjian)**
- **Regime Classification (Scott Giangrande)**
- **Short-term measurement (Scott Collis)**

  having flexible short measurement modes was an important new area for ARM to pursue for the more complex instrumentation (LIDAR, Radar)
- **High-volume data reduction (Rob Newsom)**

  Doppler spectra (either radar or lidar) potentially contain a wealth of information relevant to cloud and precipitation research, but because of the sheer size of these datasets and the small user base, the information content has not been fully explored.
- **Open source and community codes (Adam Theisen)**
- **Joint exercise with ARM data (Ann Fridlind)**

Shallow Cloud Microphysics (1)

Science question(s):	• What processes and interactions determine the precipitation formation, rate, frequency, structure and evolution of low-topped warm clouds? • How do these interactions influence cloud dynamics, cloud microphysical and optical properties, and their response to climate change?				
Problems & Roadblocks	**Impact**	**Research Elements**	**Maturity/Readiness**	**Solution/Recommendation**	**Roadmap to Modelling Goals**
• Lack of robust droplet number concentration retrievals [***2.1***]*	• Lead to more robust analyses in quantifying aerosol impacts on cloud microphysical properties, and precipitation rate and probability, since cloud droplet number concentration is one of the most important (and wanted) variables in aerosol-cloud interaction studies.	• Microwave radiometer • Shortwave radiometer • Cloud radar (with/without Doppler spectrum info) • Lidar or ceilometer	• NDROP should work rather well for relatively overcast clouds [***High***], but based on the adiabatic assumption • Several retrieval methods have been developed, but extensive evaluations and comparisons are missing [***Medium***]	• Prioritize NDROP VAP for ENA and SGP [***6 months***] • Needed for NSA, but some development is needed due to the nature of mixed-phase clouds [***12 months***]	• Model evaluations can be performed in different ways – simply evaluating cloud droplet number concentration, or evaluating "relationships" instead, e.g., precipitation vs liquid water content and cloud droplet number concentration
• Lack of robust joint cloud and drizzle property retrievals [***2.4, 2.6, 2.10, 2.11***]*	• Lead to better observational constraints and statistics across scales for understanding and representation of warm cloud microphysical processes (specifically, autoconversion and accretions).	• Microwave radiometer • Shortwave radiometer • Cloud radar (with/without Doppler spectrum info) • Lidar or ceilometer • In-situ cloud probe measurements for evaluation	• Joint cloud and drizzle retrieval exist from vertically pointing cloud radars [***Medium***] • In principle, spatial distribution and co-variability of cloud and drizzle properties can be quantified using scanning cloud radars [***Medium***]	• ***Calibrate Lidar and ceilometer backscatte***r, required for characterizing drizzle properties in the sub-cloud layer and for retrieving in-cloud drizzle properties. • ***Analyze ACE-ENA in-situ cloud measurements***, providing an excellent opportunity and some golden cases for better identifying strengths and deficiencies for each retrieval method. • ***Record Doppler signals***	• These detailed retrievals can be used to evaluate parameterizations of autoconversion and accretion, and to quantify the enhanced factor due to sub-grid variability.

Shallow Cloud Microphysics (2)

Problems & Roadblocks	Impact	Research Elements	Maturity/Readiness	Solution/Recommendation	Roadmap to Modelling Goals
• Lack of robust observations for clouds with **low** liquid water path	• Lead to better prediction in Earth radiation budget both at TOA and at the surface, considering they are the most frequent cloud type. • Lead to better understanding of the role that shallow convection plays in preconditioning the environment to allow deep convection • Lead to better quantification of their interactions with the boundary layer structure and surface.	• AERI • Dual-frequency cloud radar • Scanning cloud radar • **Aircraft capability**	• AERIoe retrieval techniques are mature [***High***]. • Dual-frequency cloud radar retrieval principle is straightforward, but requiring beams are aligned well. [***High***]. • Techniques from scanning cloud radar are mature, but ideally, clouds need to be located within 2.5 km.	• AERIoe retrievals is part of VAP and is available for all sites. However, since it is computationally expensive, priority needs to be identified. •	•
• Lack of robust observations for clouds with **large** liquid water path	•	• MWR	• Develop MWR capability to measure LWP under heavy precipitation case [***challenging***].	•	•
• Measurements of vertical velocity (from cloud base to in-cloud) [***newly added***]	•	•	•	•	•
• Observations of small-scale turbulence, entrainment, and mixing • [***newly added***]	•	•		•	•

Shallow Cloud Microphysics (3)

Problems & Roadblocks	Impact	Research Elements	Maturity/Readiness	Solution/Recommendation	Roadmap to Modelling Goals
• Difficulty in constraining large-scale vertical motion, divergence, latent heating, advective tendencies of hydrometeors	•	• Wind profiler • Doppler radar • X-band radar • Analysis data	• ARM data assimilation system being developed at SBU by integrating the ARM 3DVAR into the NCEP WRF GSI assimilation system [***High***]. • 4DVAR techniques developed in DYNAMO [***???***]. • Convergence of wind and moisture, given by wind profilers and Raman lidars at either a ring or four corners of a quadrilateral domain through the variational analysis [***Not available currently]***.	•	•
• Quality and availability of aerosol measurements [***2.7,2.8,2.9***]	•	• Aerosol observation systems • Raman lidar • High Spectral Resolution Lidar • MPL	• Vertical distribution of aerosol backscatter and extinction profiles, humidity profiles [***7.1.2; limited***] •	•	•
• Site representativeness in terms of sampled aerosol conditions, possible CCN data quality issue, the degree of coupling with boundary layer [***1.1, 2.3***]	•	• AERI • Dual-frequency cloud radar	• Analyses from various sites and campaigns should help cover a wider range of aerosol conditions.	•	•

Boundary Layer Structure (1)

Science question(s):	• What processes determine the boundary layer structure and its interactions with cloud dynamics, microphysics and underlying surface?				
Problems & Roadblocks	**Impact**	**Research Elements**	**Maturity/Readiness**	**Solution/Recommendation**	**Roadmap to Modelling Goals**
• Difficulty in characterizing PBL height and (internal) structure robustly [***1.2, 1.3***]	•	• Temperature, moisture, wind profiles at high resolution from Doppler and Raman lidars • Tethered balloon system (TBS)	• PBL height VAP is available, based on sounding data [***Medium-High***], but need better temporal resolution. • PI product (wind and boundary layer properties) from Doppler Lidar [***High***] • TBS offers wind, moisture, pressure, temperature profiles below/in clouds. • Moisture flux with Doppler and Raman lidar [***High***]; temperature flux may be more difficult to do. No radiation flux in clouds is available. • AERI provides temperature and water vapor profiles [***High***]. Compared to lidar methods, the key advantage is the capability for near-surface measurements (though near-surface WV remains challenging)	• •	•

Boundary Layer Structure (2)

Problems & Roadblocks	Impact	Research Elements	Maturity/Readiness	Solution/Recommendation	Roadmap to Modelling Goals
• 3D structure and spatial context are important on the km [***1.6***]	•	• Scanning Doppler lidar (DP) performs full-360 deg Plan-Position-Indicator (PPI) scans once every hour (?) • According to the handbook, DP also performs Range-Height-Indicator (RHI) scans, but these scans don't seem to be in the current data stream?	• LAFE has 2D scans for wind, temperature and WV at 3-m resolution from RHI scans) [***High***]; ENA has 3D • Scanning Doppler lidar can get TKE profiles [***not quite developed***]	•	•
• MBL analysis at ENA requires ocean surface properties [***1.7***]	•	• SST measurements at high resolution, and ideally, wind fields as well	•	•	•
• Continuation and harmonization of datasets [***1.4, 1.5***]	•	•	•	•	•