Cloud Life Cycle Working Group Breakout Session

DOE ASR Science Team Meeting
31 March 2011
San Antonio, TX

Overview of CLWG Translator activities and discussion

Objectives:

- Understand the infrastructure support for CLWG
- See future plans by translators
- Discussion of priorities/needs regarding data products (forcing data sets, new VAP efforts, new radar products)

Shaocheng Xie: Overview of LLNL activities in support of CLWG

Mike Jensen: Overview of BNL activities in support of CLWG

Scott Collis: Overview of ANL activities in support of CLWG

Potential Collaborative Research Areas of Focus

Objectives:

- Present ideas for broader research themes in CLWG and ASR
- Themes -> physical processes and/or high importance activities
- Groups might become FGs or sub-groups in CLWG depending on membership, organization, importance, progress, etc.

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Zhanqing Li: Cloud layering and overlap

Xiquan Dong: Deep convection life cycle

Zhien Wang: Life cycle of stratiform clouds

David Mitchell: Ice particle properties

Ismail Gultepe: Arctic snowfall processes

Shaocheng Xie: Quantifying retrieval uncertainty.

Yangang Liu: Quantifying uncertainty in cloud fraction & albedo.

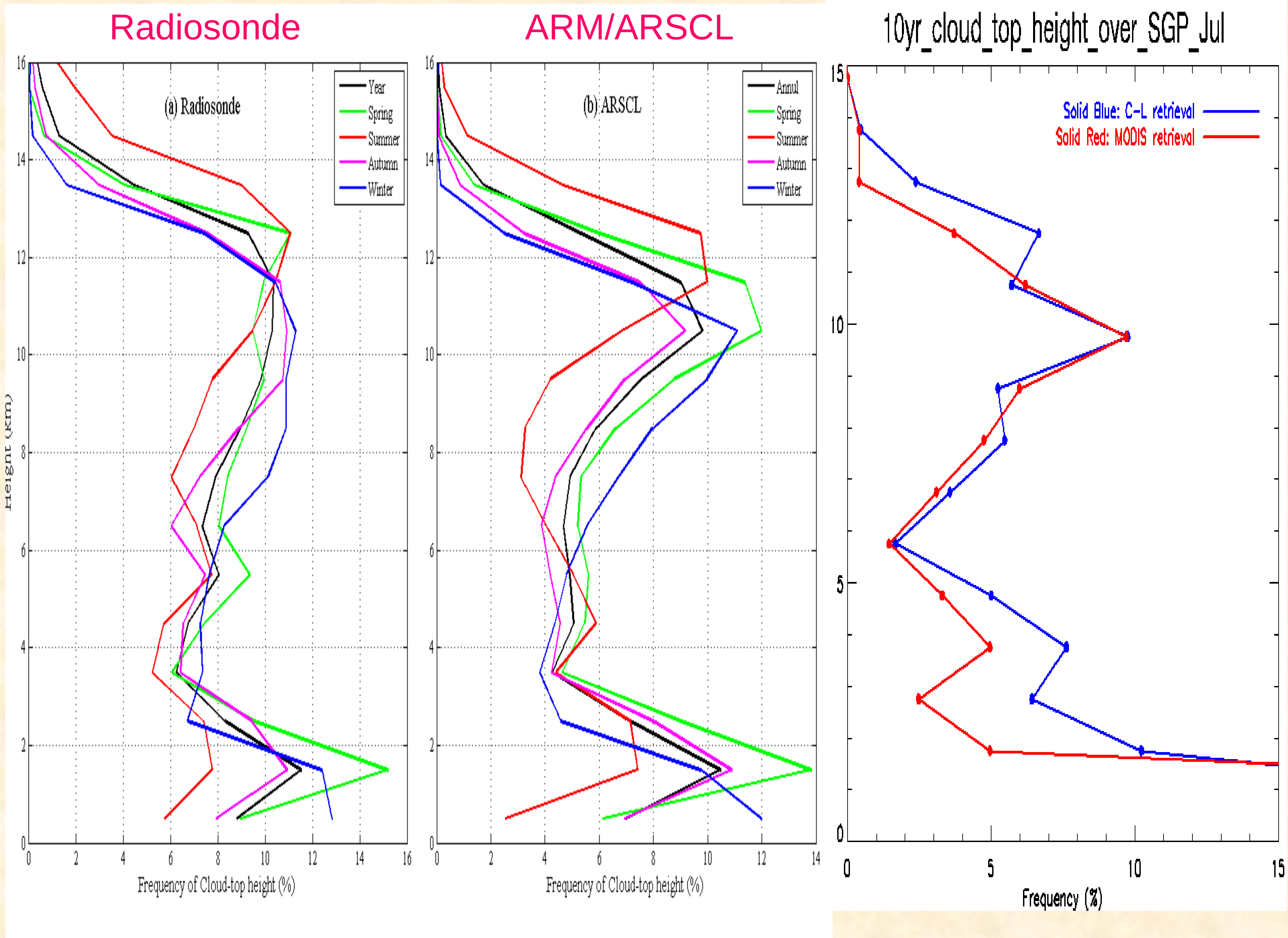
Ann Fridlind: Convective-Stratiform-Anvil Transition

Comparison & Integration of Cloud Layering and Overlapping Info from Ground-baed, Space-borne Sensors and Radiosonde

Zhanqing Li and Jinqiang Zhang

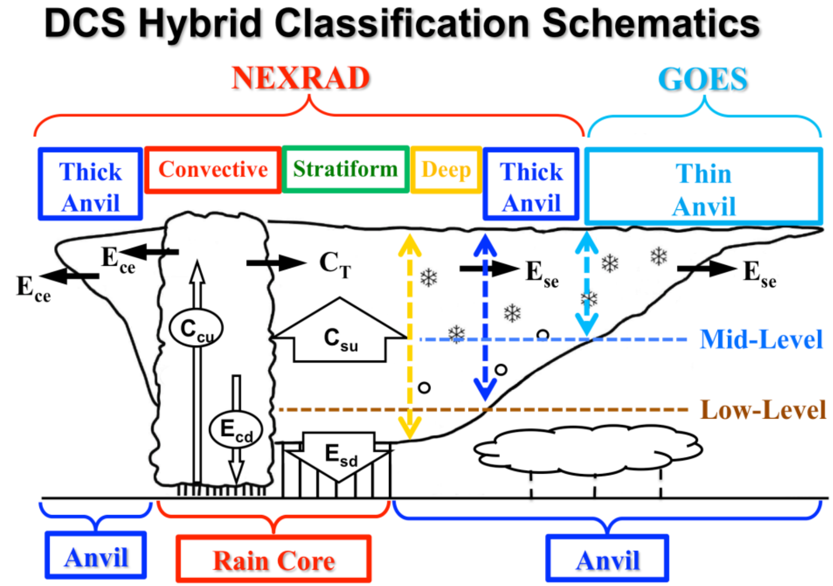
- Cloud veridical distribution and overlaping are key to climate studies
- Ground-based (especially ARM), and space-borne sensors (CloudSat/MODIS), and radiosonde observations all provide useful information, but with their limitations.
  - ARM – Single point, direct measure of cloud layers, but no direct measure of grid-scale overlapping
  - Radionsonde – longest global-scale data, but not a direct measure
  - Satellite – Global coverage, short-duration with inferring errors
- It is time to merge all three types of data to re-evaluate this important cloud problems in order to come up with the most sound approach for tackling it by models.

UNIVERSITY OF MARYLAND



Radiosonde
ARM/ARSCL
10yr_cloud_top_height_over_SGP_Jul
(a) Radiosonde
Year
Spring
Summer
Autumn
Winter
Height (km)
Frequency of Cloud-top height (%)
(b) ARSCL
Annul
Spring
Summer
Autumn
Winter
Frequency of Cloud-top height (%)
Solid Blue: C-L retrieval
Solid Red: MODIS retrieval
Frequency (%)

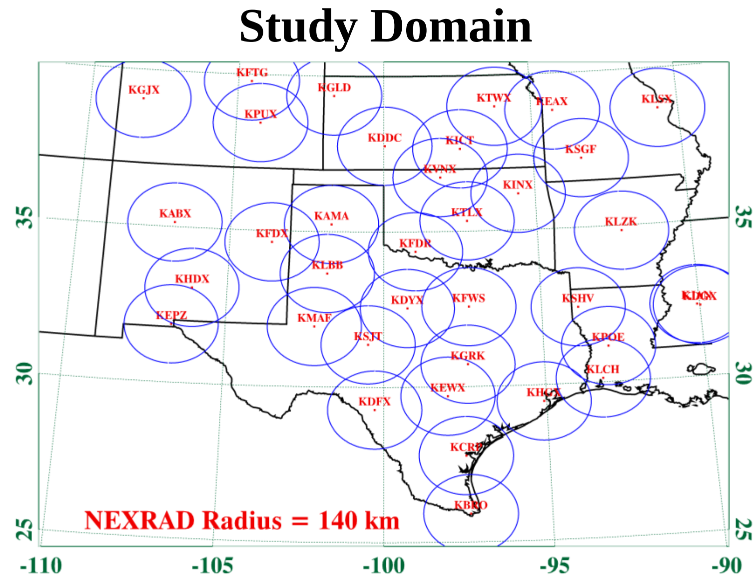
Deep Convection Life Cycle

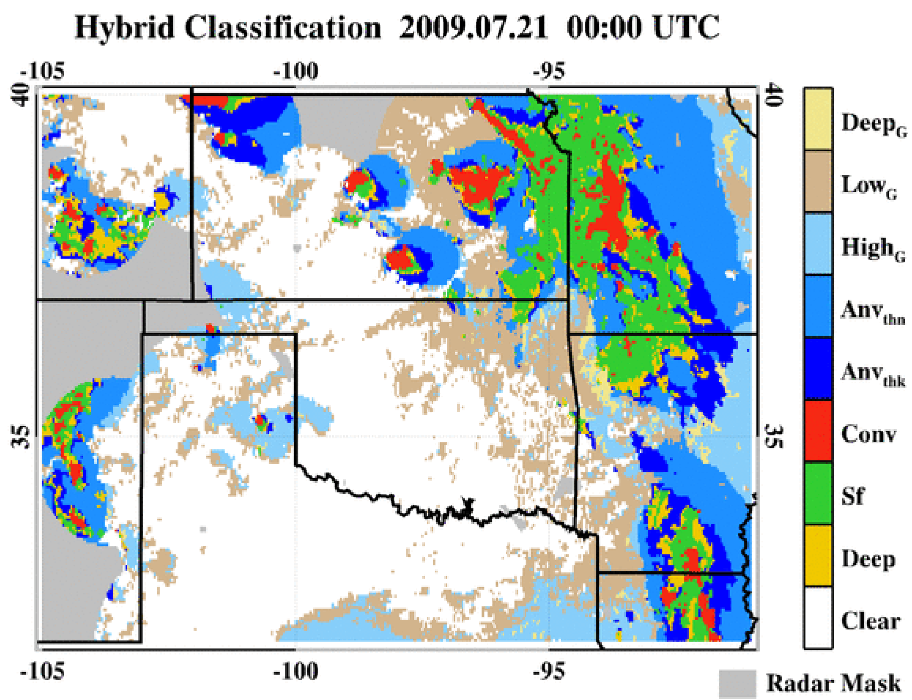


- DCS has two components:
  - *Rain core*: produce majority of warm season precipitation
  - *Anvil clouds*: important to radiative budget
- Simplistic representation in GCM, lack of observational constrain: mass flux detrained from convective to stratiform scheme forms anvil
- In reality their relationship changes with DCS size, strength, environment, and life cycle
- Difficult to observe and separate
  - Span large area, complicated 3D structure
  - Multi-instrument (radar, satellite) needed
- Requires collaboration between observation and modeling to improve our understanding and model representation

Collaboration

- Apply ***satellite tracking*** algorithm
  - Collaborate w/ Sally
- Get robust statistics on relationship between convective strength/precipitation with anvil production and associated cloud properties
- Collaborate w/ modelers to ***test these results with cloud resolving models***
  - Collaborate w/ Krueger





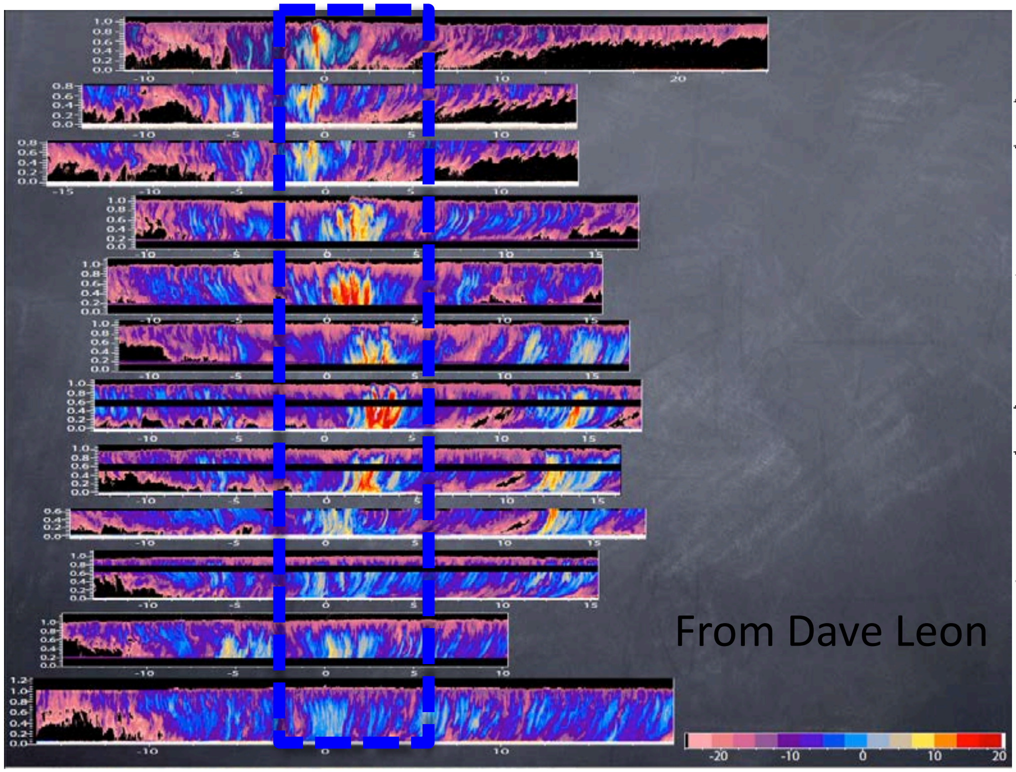
The dynamical, thermodynamical, microphysical control on stratiform cloud life cycle

Zhien Wang

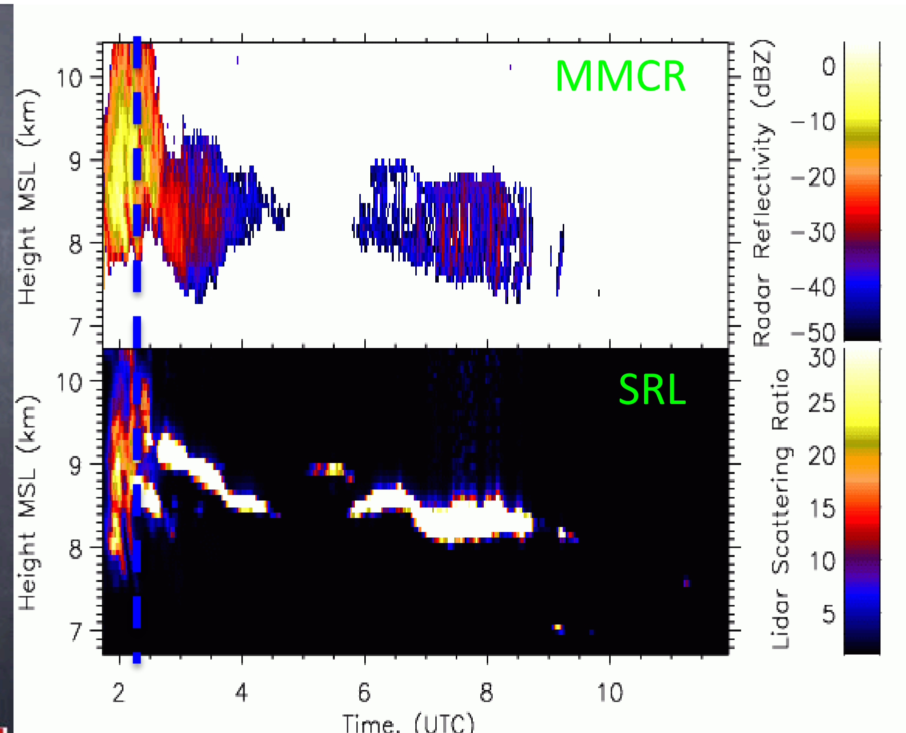
University of Wyoming

Stratiform (Ac, As, Sc, St) clouds have distinct lifecycles—impact their properties and radiative impacts

Strong interactions among dynamical, thermodynamical, microphysical processes.



Observed drizzling Sc cell (at scale of 30 km) evolution from Wyoming King Air with up and down radar.



The transition from ice (left) to mixed-phase clouds have significant different radiative forcing.

ASR and ACRF offer new capability to explore the lifecycle

- Scanning radars offer new data to study the lifecycle in these clouds– proper scanning strategies are needed.
- Airborne and satellite observations add additional capabilities.
- The team work of modelers and observers is needed to better understand the dynamical-thermodynamical-microphysical interactions in these clouds.
- Ultimate goal—better simulate these clouds in climate models.

Ice Particle Properties Focus Group

- **Motivation**

- A lack of observational constraints on ice particle properties (mass, D_{max}, A_{max}, aspect ratio, V_{fall}) is leading to substantial uncertainty in model results

- Ground-based and satellite remote sensing retrievals of ice cloud properties depend strongly on assumed ice particle properties (e.g. m-D, A-D expressions)

- **Activities**
  - CRM (Fridlind): Identify common ice particle property framework suitable for all model types
  - IOP data: extend analysis of existing single-particle data (e.g. CPI and optical probe data from SPARTICUS, ISDAC, TWP-ICE, M-PACE, CRYSTAL-FACE, SHEBA)

Ice Particle Properties Focus Group

- **Activities (continued)**
  - GCM (Lin): a general analytical framework for ice particle properties considering environmental conditions
  - Ice fall-speeds (Mitchell & Mishra): ice mass-weighted fall-speeds based on field observations and theory
  - Satellite (Mitchell & d'Entremont): radiation closure experiments using in situ data to evaluate these properties for models and retrieval algorithms.
  - Improve knowledge of Arctic ice properties (assisting Gultepe/Lubin focus group)

Polar Ice Clouds and Snow

I. Gultepe, D. Lubin, T. Kuhn, Z. Boybeyi, P. A. Kucera,
E. Girard, J. E. Cherry , J. Milbrandt, *Xiaohong Liu, D. Mitchell, and A. Fridlind*

MOTIVATIONS

- Surface snow measurements are highly inaccurate (>50%); error in PR of about 0.5 mm/hr=~10 W m-2.
- Arctic warming is very high e.g. 5-8C/50-100 years.
- Lack of understanding of the IWC conversion to PR in the Arctic e.g. snow density
- Role of inversion layers on the snow precipitation.
- Spectral radiances for ice crystal microphysics detection need to be improved
- IN acidification leading to radiative cooling and more precip.

Objectives/Outcomes

ISDAC 2008, NSA Barrow

- Better parameterization of the polar ice cloud microphysical properties e.g. IN/Ni and particle spectra (using ISDAC data)
- Obtain accurate snow PR and decide on an efficient instrument list for surface snow PR measurements (using FRAM&ISDAC data)
- Improve autoconversion processes from IWC to PR
- Use models and remote sensing retrievals with new algorithms to improve Arctic PR and ice cloud microphysical processes (coordinated with D. Mitchell/A. Fridlind focus group).

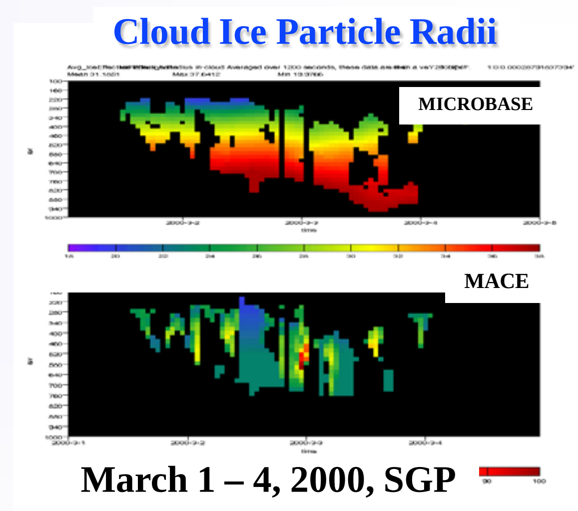
FRAM-ICE 2010-2011;

Yellowknife, NWT

Quantifying Uncertainty in ARM Cloud Retrievals

S. Xie, A. Protat, J. Comstock, Y. Lin, M. Jensen, J. Mace, S. McFarlane, S. Shen, C. Zhao

- **Issues**
  - **Uncertainty is large in the ARM retrieved cloud and cloud microphysical properties, but it has not been well addressed.**
  - **Uncertainty may come from**
    - **Measurement error**
    - **Instrument limitation**
    - **Algorithm deficiency (Insufficient knowledge)**
    - **Input and constraints (inconsistent)**
    - **Single point vs. GCM grid box average**



- **Why is it important to CLWG/ASR?**
  - **Cloud retrievals are the unique and key product produced by CLWG to support both cloud observation and cloud modeling studies**
  - **Quantifying uncertainty in ARM cloud retrievals is highly desired by the modeling community for better constraining climate models**

Quantifying Uncertainty in ARM Cloud Retrievals

- Ideas and activities
  - Create ensemble data products for cloud retrievals (need more VAPs!)
    - by using the available ARM cloud retrievals (e.g., CRED - ongoing)
      - Explore issues and provide a rough estimate
    - by perturbing key parameters or changing assumptions within a single retrieval method with the LLNL UQ analysis software (PSUADE)
      - Enable to do more in-depth uncertainty analysis: uncertainty assessment, sensitivity analysis, parameter estimation, calibration and optimization
  - Systematically evaluate the ensemble data using BBHRP and in-situ data
  - Conduct idealized test for uncertainty analysis (e.g., using simulators)
  - Implement advanced statistical methods to better quantify data uncertainty - e.g. Bayesian approach
- Products
  - A multi-year cloud retrieval ensemble dataset with the potential to produce a best estimate of cloud retrievals to the ASR community
- Collaborations
  - LLNL, BNL, PNNL ARM infrastructure teams, ASR experts in cloud retrievals and statistics.

Focus Group: UQ of Cloud Retrievals

Please let me if you are interested in joining us

xie2@llnl.gov

Quantifying Uncertainty of Cloud Fraction and Albedo

- Two cloud properties key to gaining cloud-radiative effects
- A large spread in observations (e.g., left panel next slide)
- A large spread in modeled cloud fractions (e.g., right panel next slide)
- A large spreads in modeled cloud abledo and fraction vs .albedo (e.g., right panel next slide)
- Less available data on cloud albedo than cloud fraction
- Model evaluation needs to know

-- observational spread vs. model spread, which is larger?

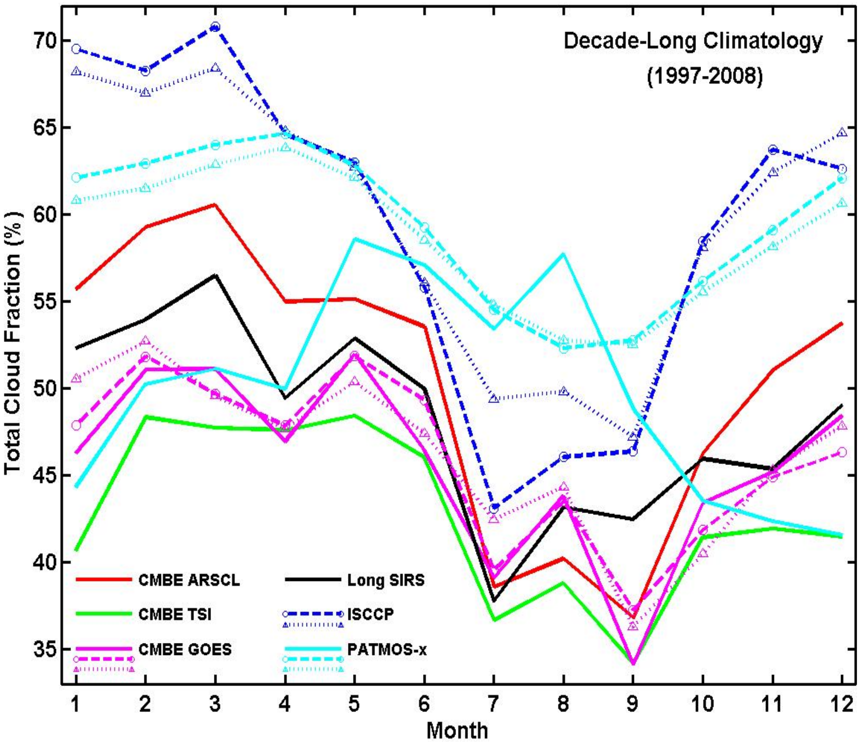
-- Physical/instrumental reasons for the spread/discrepancy?

  * Different instruments use different definitions
  * Different instruments have different sampling scales
  * Different models use different definitions
  * Consistency issue

➢ Activities: CMBE etc has a list of cloud fraction measurements, but less cloud albedos and UQ; FASTER is working on some issues, but not enough; need more interests and collaborations of all fronts from observations to models to parameterizations.

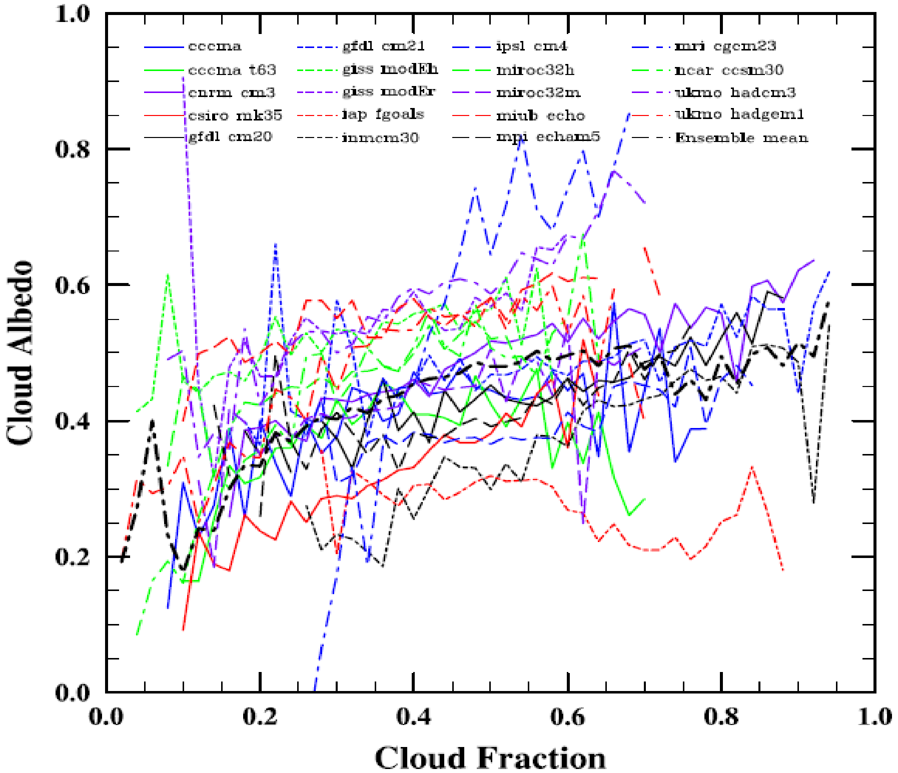
Motivating Examples at SGP

Monthly Observed Cloud Fractions



- Solid: surface or 0.5° satellite
- Dashed: 2.5° satellite
- Dotted: the entire SGP domain (32-42°N, 105-91°W)

Albedo vs. Fraction in AR4 Models



- 20 GCM results from grids near SGP CF
- Only examined surface and GOES Obs
- Inter-model difference much larger
  -- Obs better than models, or
  -- More independent measurements?

Echo the 1st slide: need more and focused activities on measurements of cloud fraction and cloud albedo, UQ them, and physical exploration!

Convective-STratiform-Anvil Transition (CSTAT)

- Motivation
  - large spread in convection-generated ice and rain microphysical properties across CRM/LAM/GCMs
  - convective ice properties and transition to stratiform are both challenging issues
  - transition to radiatively important anvil highly suspect
  - existing ASR focus on all-important (and hard) ice microphysics
  - need for ASR strength in observing boundary-layer processes
  - longstanding climate relevance

Convective-STratiform-Anvil Transition (CSTAT)

- Activities
  - required commitment to close collaboration between modelers and observationists
  - multi-observation approaches, including advanced forward calculations
  - IOP focus areas: TWP-ICE and MC3E
  - constrain dynamics, cold pools, hydrometeor size spectra, ice properties, condensation vs fusion latent heating, radiative fluxes under varying thermodynamic and aerosol states
  - constrain model parameterizations (CRM to GCM)
  - identify strong process relationships in observations and establish ability of models to reproduce them