Cloud-Aerosol-Precipitation Interactions (CAPI) Breakout Session

2012 ASR Science Team Meeting

15 March 2012

Agenda

- Ghan: FG efforts to address the large CAPI challenges
- Wood: Cloud effects on aerosol
- Feingold: Precip susceptibility
- Fan: Aerosol / deep convection interactions
- Liu: Ice nucleation
- Ovchinnikov/Shupe: Arctic aerosol / cloud interactions
- Jensen: Entrainment
- Kollias: Vertical velocity FG and Mixed-layer breakout
- Noone: Water isotopes
- McFarlane: CAPI VAP progress
- Ghan / Turner: General discussion: future CAPI efforts, IOPs, etc.

CAPI Challenges and Related Interest Groups

- Explain why climate models produce large AIE
  - New particle formation
  - Entrainment and vertical velocity
  - Precipitation susceptibility
  - Cloud effects on aerosol
- Understand aerosol effects on precipitation
  - Precipitation susceptibility
  - Aerosol / deep convection interactions
  - Isotopes
- Understand the catastrophic collapse of the CAPI system in boundary layer clouds
  - Precipitation susceptibility
  - Cloud effects on aerosol
- Understand ice nucleation and its impact on mixed-phase clouds
  - Ice nucleation
  - Ice physical and radiative processes
  - Arctic cloud/aerosol interactions
  - Aerosol / deep convection interactions

ASR
Atmospheric System Research

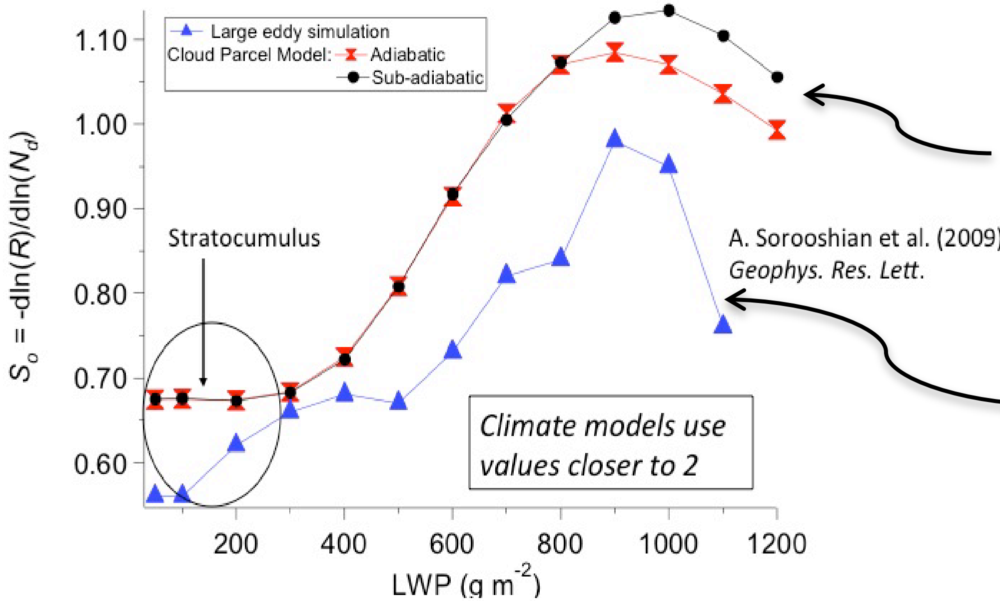
Azores breakout synthesis

- First ARM deployment to a marine low cloud environment
  - 20 months sampling revealing tremendous variability in clouds and associated thermodynamic environment, precipitation and aerosols.
  - Initial cloud classification completed
  - New drizzle retrievals
- New investigators
  - Several new teams have started, or are about to commence on analysis
- Model simulations
  - Dedicated forecast model simulations from NCAR and GFDL
- Graciosa chosen for next ARM fixed site
  - Suite of new measurements including precipitation radar, lidars (HSRL and Doppler), scanning Ka band radar, vertically pointing dual wavelength (W/Ka)

Cloud effects on aerosol: Synthesis

- Clouds exert major influences on the physical, chemical and optical properties of aerosols and are a major sink for aerosols. The presence of clouds complicates remote sensing of aerosols.
- Unique opportunities for ASR
- Presentations focused upon:
  - Dust aerosol scattering over the Atlantic increases in the vicinity of clouds but only if dust is < 2km
  - New ASR project to generate light absorbing aerosols via pyrolysis and combustion and examine properties at high RH (sub and supersaturated)
  - CAM model study showing improvements in low level Arctic BC through changes in aerosol scavenging
  - Insights into aerosol hygroscopic growth in the vicinity of low clouds using MODIS observations and a simple RH pdf approach to connect cloud cover with clear-sky RH between clouds

Susceptibility Breakout Session



Parcel models (entraining and adiabatic)

LES of RICO trade cumulus

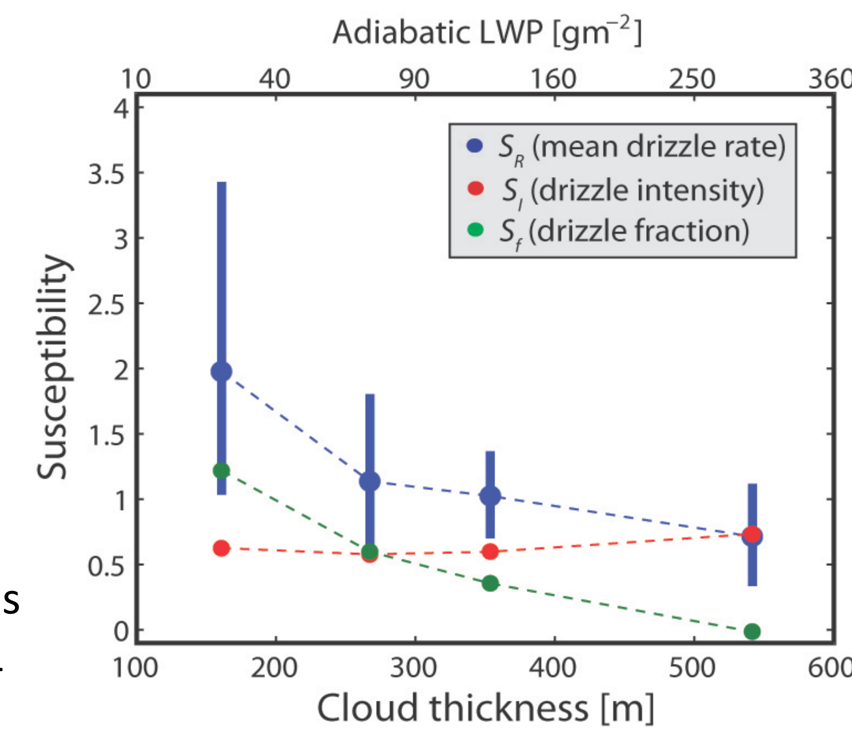
Finite range over which clouds exhibit significant precipitation susceptibility

$$S_o = -dlnR/dlnN_d$$

R = rainrate

N_d = drop (or aerosol) concentration

VOCALS stratocumulus
Terai et al. ACPD 2011



Speakers

1) G. Feingold (context and some new analysis)
Attempts to explain why the results show different
responses using collision-coalescence model (time is a rate-limiting factor)

2) S. Yuter (shipboard lidar measurements from VOCALS)
Boundary layer is often not well-mixed; surface aerosol does not necessarily represent aerosol feeding into cloud; confounding effects of wet scavenging

3) D. Rosenfeld (rain-Reff radius relationships from models)
Analysis of Wang et al. geoengineering simulations to show the threshold behavior of R at r_e > ~ 12 microns

4) H. Morrison (Precip susceptibility in CAM5)
Analysis of So in CAM5; So is the relative importance of autoconversion to accretion; model overestimates autoconversion and produces the wrong behavior vs. LWP; Use as a tool for diagnosing *why* autoconversion dominates. Probably because of diagnostic precipitation

Speakers

5) S. Ghan (Precip susceptibility in CAM5 and CAM5+MMF)
CAM5 overestimates dLWP/dN compared to CAM+MMF
Consider -dlnPOP/dlnN (observations from A-Train)
CAM5 and CAM5 + MMF *overestimate* –dlnPOP/dlnN and dlnLWP/dlnN

6) D. Noone (Use of isotopes to derive precip efficiency)
Water vapor isotopes vary with distance from ocean surface; use to determine entrainment and precipitation *efficiency* in Hawaii;
In future, consider sensitivity of precip efficiency to aerosol

7) A. Fridlind (SHEBA mixed phase clouds and their susceptibility to N_i)
SHEBA May 7 1998 case (very low LWP ~ 10 g/m2); simulations with different N_i; IN are entrained from above at much slower rate than ice falls; buffering; No sensitivity to N_a

Aerosol Deep Cloud Interaction (ADCI)

Lead: Zhanqing Li, Jiwen Fan, D. Rosenfeld

Focus Group's Objective

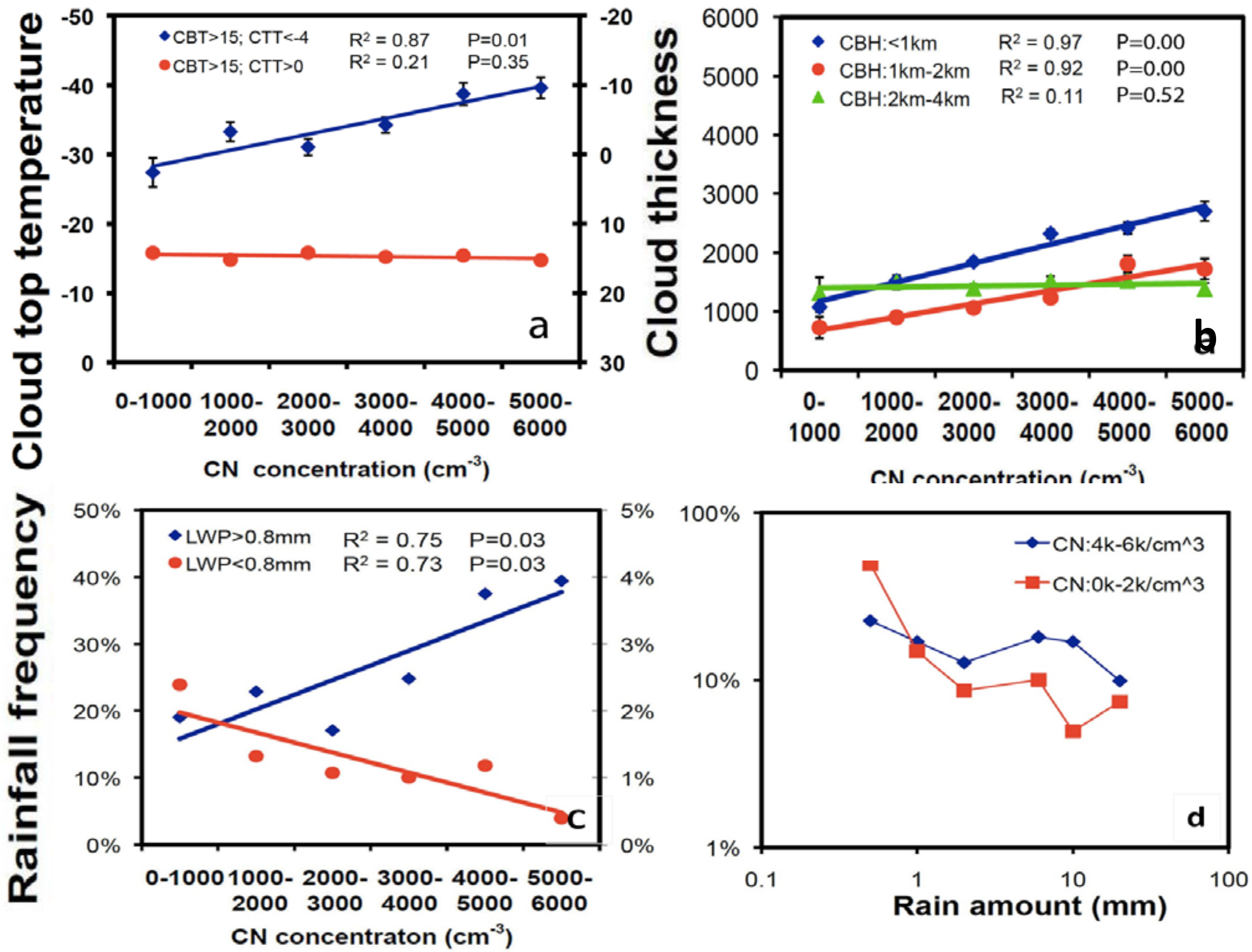
- **Identify, quantify, and simulate impact of aerosols on DCCs, energy budget, mass & hydrological cycles.**

Science Issues to Address

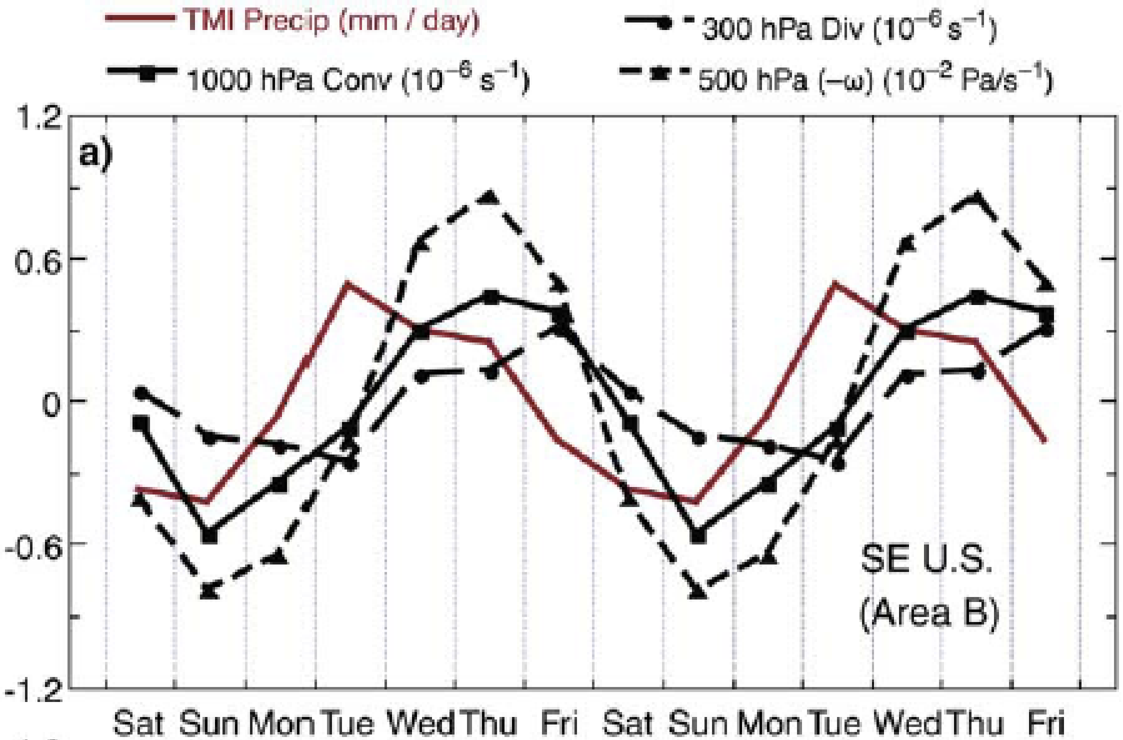
- Aerosol invigoration effects on thermodynamic forcing through changes of vertical profiles of latent heating (energy budget).
- Aerosol impacts on regional circulation system and beyond (mass budget)
- Impact on precipitation distribution in space and intensity (water cycle).
- Impact of CCN/IN on cloud anvils/cirrus (size, effective radius, and lifetime).
- Radiative forcing due to aerosol invigoration of clouds (modeling and observations), anvils and detrained vapor.

Observed Long-term Trends:

1. Influence on cloud geometry
2. Influence on rainfall frequency

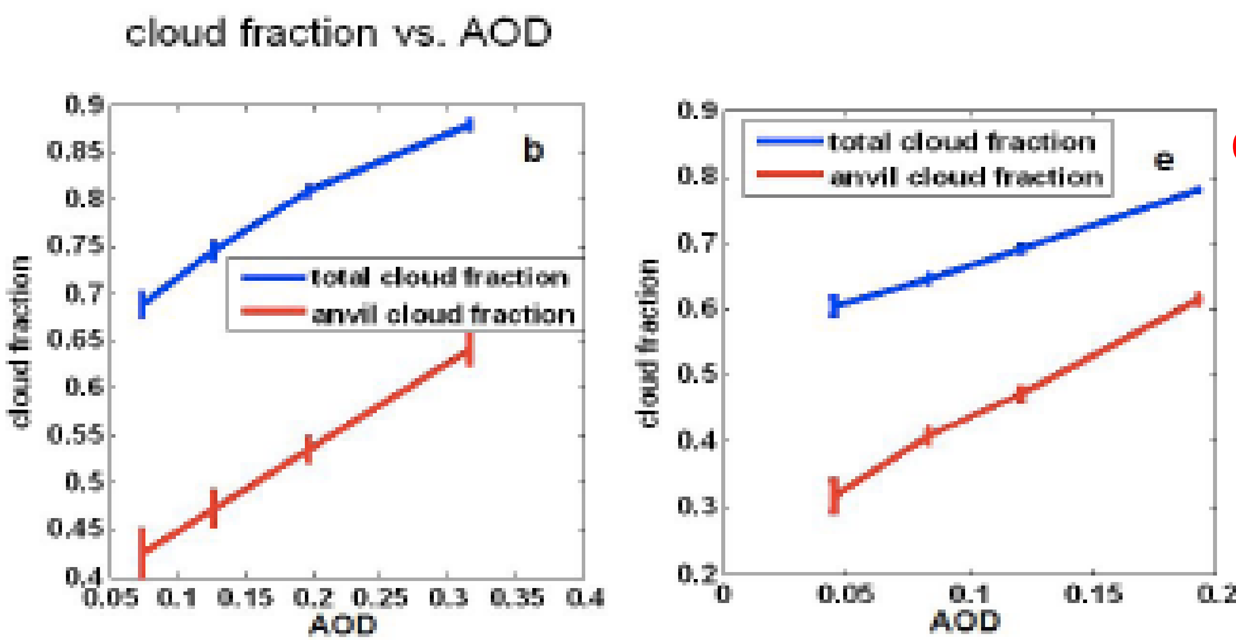


Li et al. (Nature-Geosci., 2011)



Lower-level convergence and precipitation

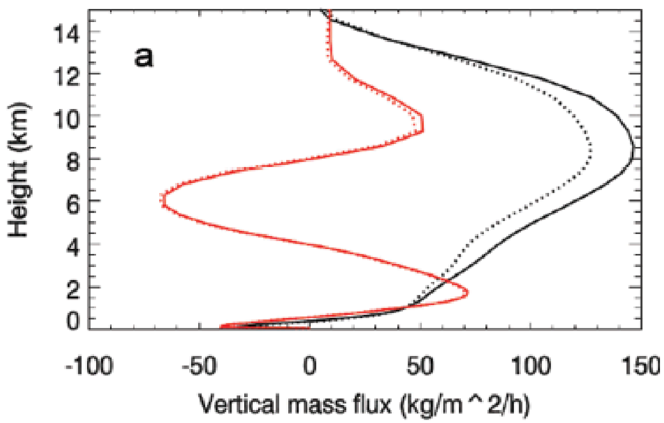
Bell et al., 2008

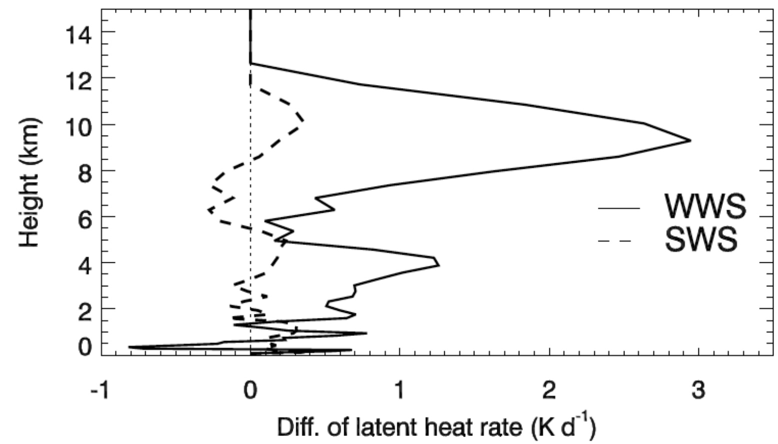


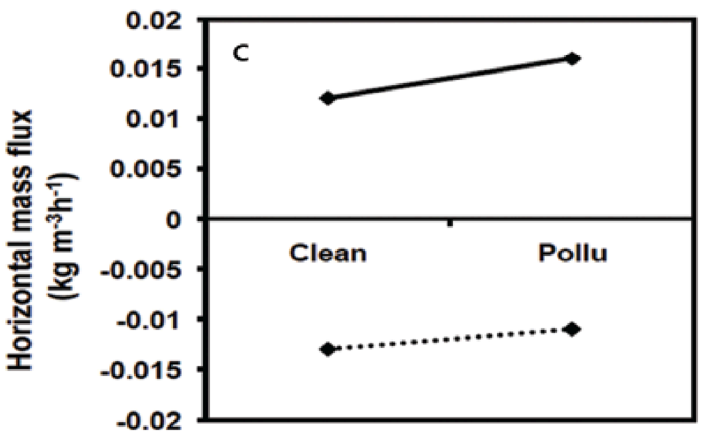
Cloud anvil area

Koren et al., *2010*

Circulation, latent heating and radiative forcing







		SW	+	LW	=	NET
TOA	(WWS)	-3.0		+6.6	=	+3.6
	(SWS)	-1.8		+3.9		+2.1
Atmosphere		-0.6		+6.2		+5.6
		-1.4		+4.0		+2.6
Surface		-2.4		+0.4		-2.0
		-0.4		-0.1		-0.5

Fan et al., *2012*

What ARM/ASR can do in measurements?

- CCN/IN (distribution and vertical profile with aircraft and Lidar)
- Vertical velocity retrievals in cloud, vertical profiles of cloud development (3-D cloud radar), and precipitation rate
- Field campaigns of box experiment with closure of energy and moisture fluxes/budgets at the scale of lifecycle of large cloud systems.

Our current focus

- Long-term model simulations to see if models can reproduce the observed long-term aerosol effects at SGP.
- Develop/improve parameterization for aerosol-deep convection interaction capabilities in the regional and global models.
- Document the impacts of aerosols on the mixed phase, anvils and detrained vapor of deep convective clouds.

“Ice Nucleation” breakout session

Tuesday, March 13, 1:00 p.m.–2:30 p.m.

1. Xiaohong Liu: Introduction to the session (5 mins)
2. Paul DeMott: Investigations of ice nuclei dependence on aerosol composition (10 mins)
3. Gourihar Kulkarni: Analyzing ice nuclei of dust and volcanic ash particles (10 mins)
4. Subhashree Mishra/David Mitchell: Ice nucleation and ice fall speeds in mid-latitude anvil cirrus - Results from SPARTICUS (10 mins)
5. Raymond Shaw: Is contact nucleation a thermodynamic effect? (10 mins)
6. Jiwen Fan: Dust effects on California winter clouds by serving as ice nuclei (IN) (10 mins)
7. Shaocheng Xie: Impact of heterogeneous ice nucleation on mixed-phase clouds and climate (10 mins)
8. Open Discussion/white paper 30 mins

Planned Activities in Next 5 years

1. Intercompare existing instruments with different designs and/or operational principles: organize a workshop in the laboratory and field (DeMott leads).
2. Propose dedicated IOPs on ice nuclei in a specific aerosol source regions (industrial pollution, fire, biogenic aerosol, soot and (NH4)2SO4).
3. Explore other opportunities for ice nuclei measurements in different locations (e.g., GOAmazon 2014+1); routine IN measurements at ACRF sites.
4. Propose an ACRF measurement in South America (Patagonian desert, ~50 S) would be a good place to study glaciation of mixed-phase clouds in SH storm track region and impact of dust on ice nucleation.
5. Participate in the intercomparison of IN effect on mixed-phase clouds in GCMs (AeroCom), used for IPCC AR5.

Arctic Clouds / ISDAC intercomparison

Arctic Aerosol-Cloud Interactions (AACI) interest group

Observational and modeling studies of Arctic clouds

- An update on the ISDAC Cloud Microphysics PI product (**Greg McFarquhar**)
- Microphysical and Radiative Properties of the ISDAC 26 April Mixed-phase Case (**Paul Lawson**)
- Modeling the effect of radiation on ice crystal spectrum in the Arctic (**Xiping Zeng**)
- ISDAC droplet closure study (**Michael Earle**)

ISDAC LES intercomparison

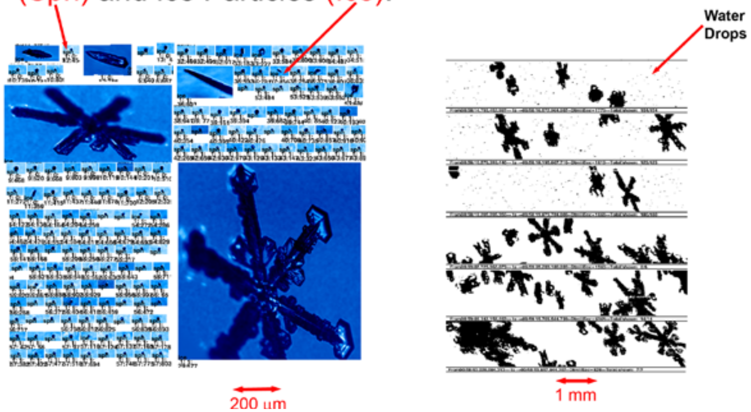
- Setup overview and preliminary results (**Mikhail Ovchinnikov**)
- Preliminary results from ISDAC intercomparison runs (**Jerry Harrington**)
- Discussion

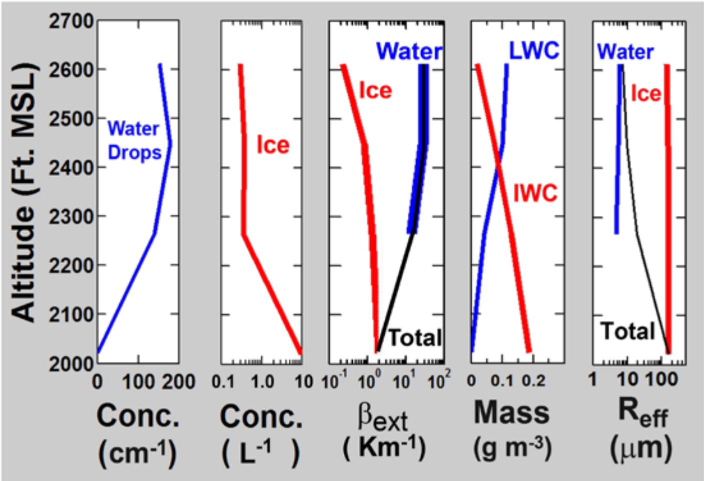
Microphysical Properties of the ISDAC 26 April Mixed-phase Case (Paul Lawson)

Methodology

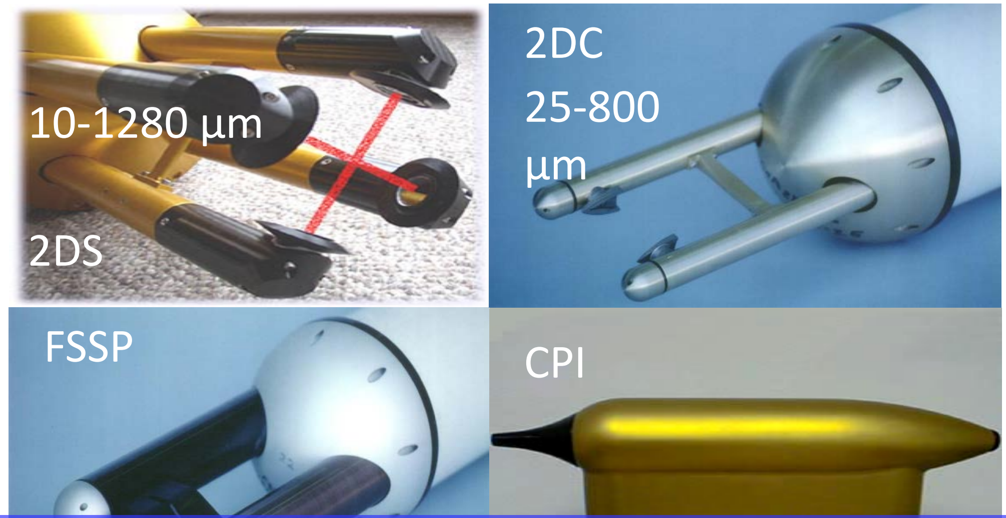
Automatically Sort CPI Images into Water Drops (Sph) and Ice Particles (Ice).

Apply Percentage of CPI Water and Ice to 2D-S Size Bins





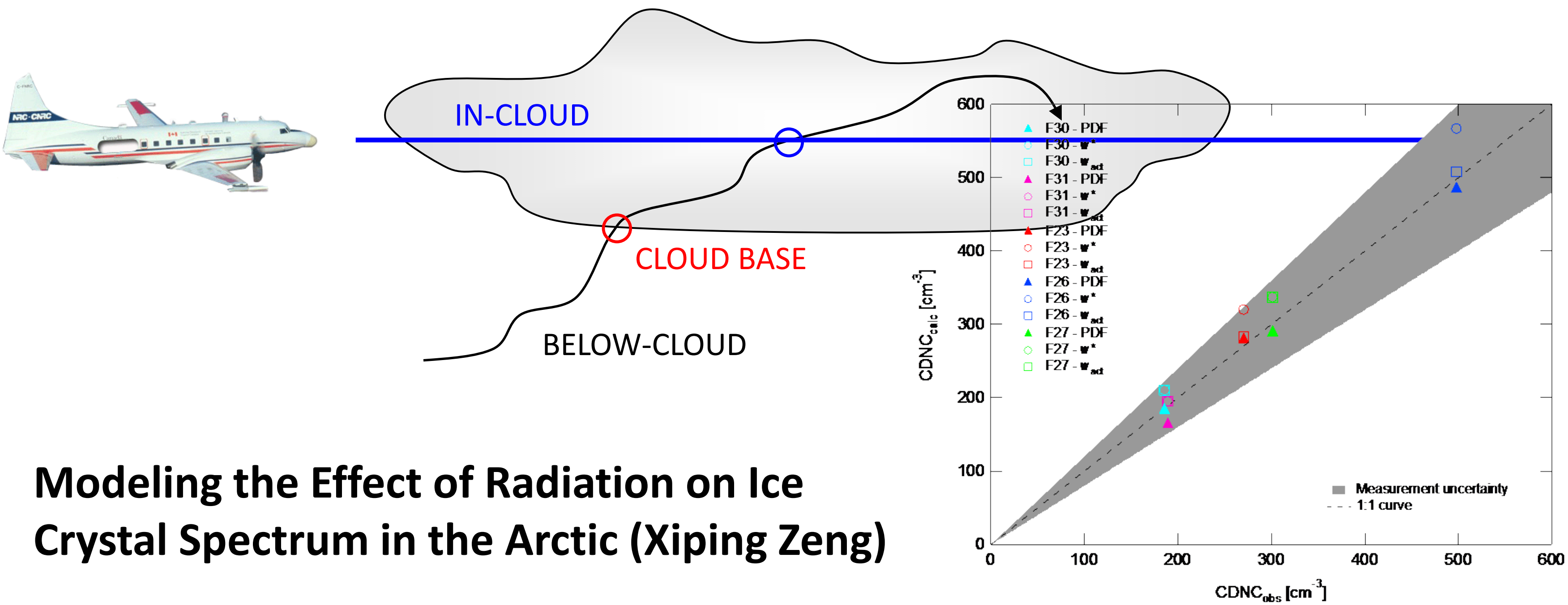
ISDAC Cloud Microphysics PI product (Greg McFarquhar)



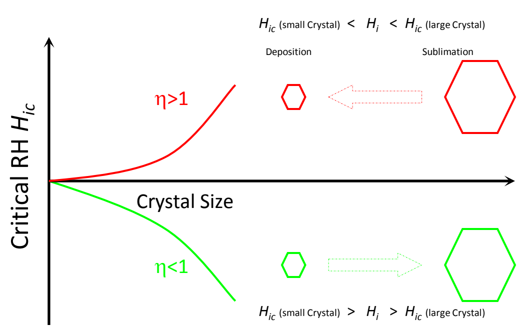
- Has been placed on ARM archive as PI product and gives best estimate of:
  - Number distribution function of liquid particles $N_w(D)$ 0 < D < 10000 µm
  - Number distribution function of ice particles Ni(D) 0 < D < 10000 µm
  - Liquid water content (LWC) & Ice water content (IWC)
  - Extinction of liquid drops $\beta_w(D)$ & ice crystals $\beta_i(D)$
  - Effective radius of liquid cloud drops r_{ew}
  - Effective radius of ice crystals r_{ei}
  - Median mass diameter of liquid drops D_{mml}
  - Median mass diameter of ice crystals D_{mmi}
  - Equivalent reflectivity of water Z_{ew} and ice Z_{ei}

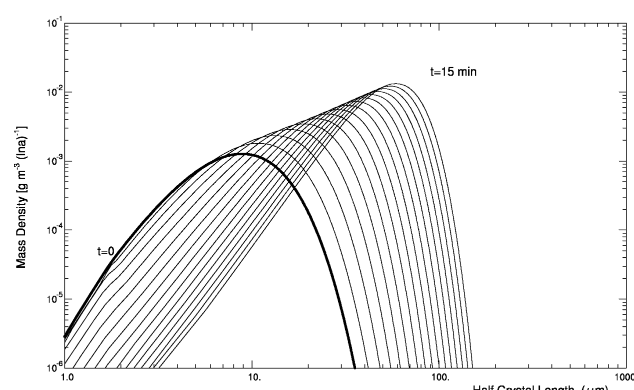
ISDAC droplet closure study (Michael Earle)

Use LES to guide model representations of updraft velocity for droplet activation



Modeling the Effect of Radiation on Ice Crystal Spectrum in the Arctic (Xiping Zeng)





ISDAC LES Intercomparison

- Ideas introduced at ASR STM 2011, refined at the working group meeting Sept 2011.
- Setup released (Dec. 1, 2011)
- First round of simulations (March 1, 2012) and ongoing.
- Additional simulations are likely, so

  … *IT'S NOT TOO LATE TO JOIN*

Setup details

- Based on ISDAC FLT 31
- Reductionist approach
- Constrained ice processes:
  - Nucleation (ice number)
  - Mass-diameter-capacitance relations
  - Mass-fall speed relation
- Unified radiation parameterization
- Runs: **ICE0**, **ICE1**, **ICE4** (N_i=0,1,4 L^{-1})

https://engineering.arm.gov/~mikhail/ISDAC_F31.html

ISDAC LES intercomparison

Preliminary results

(2 models x 3 runs)

DHARMA-2M (Andy Ackerman):

- 3D, two-moment microphysics

SAM-SBM (PNNL):

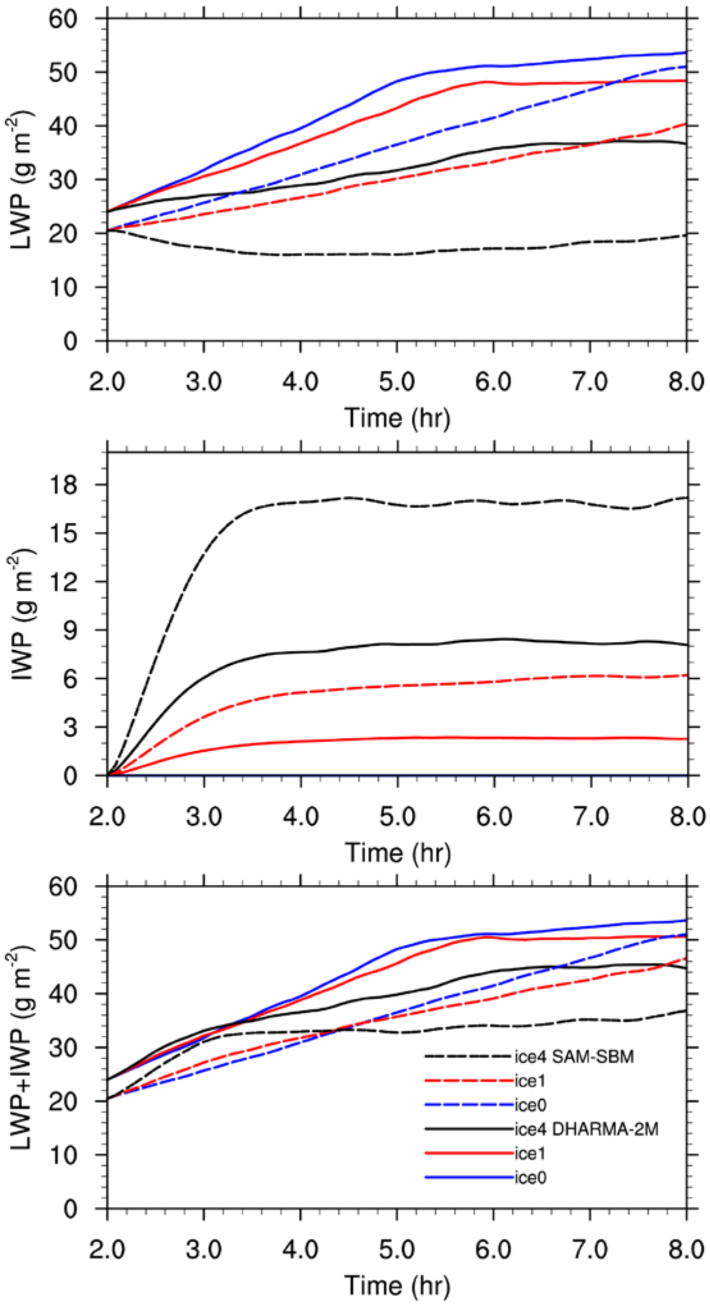
- 3D, size resolved (spectral bin) microphysics

Runs: ICE0, ICE1, ICE4

Differences in ICE0 runs after the spinup

(initialization, dynamics, entrainment, turbulence, etc.)

Sensitivities to *N*i are similar.



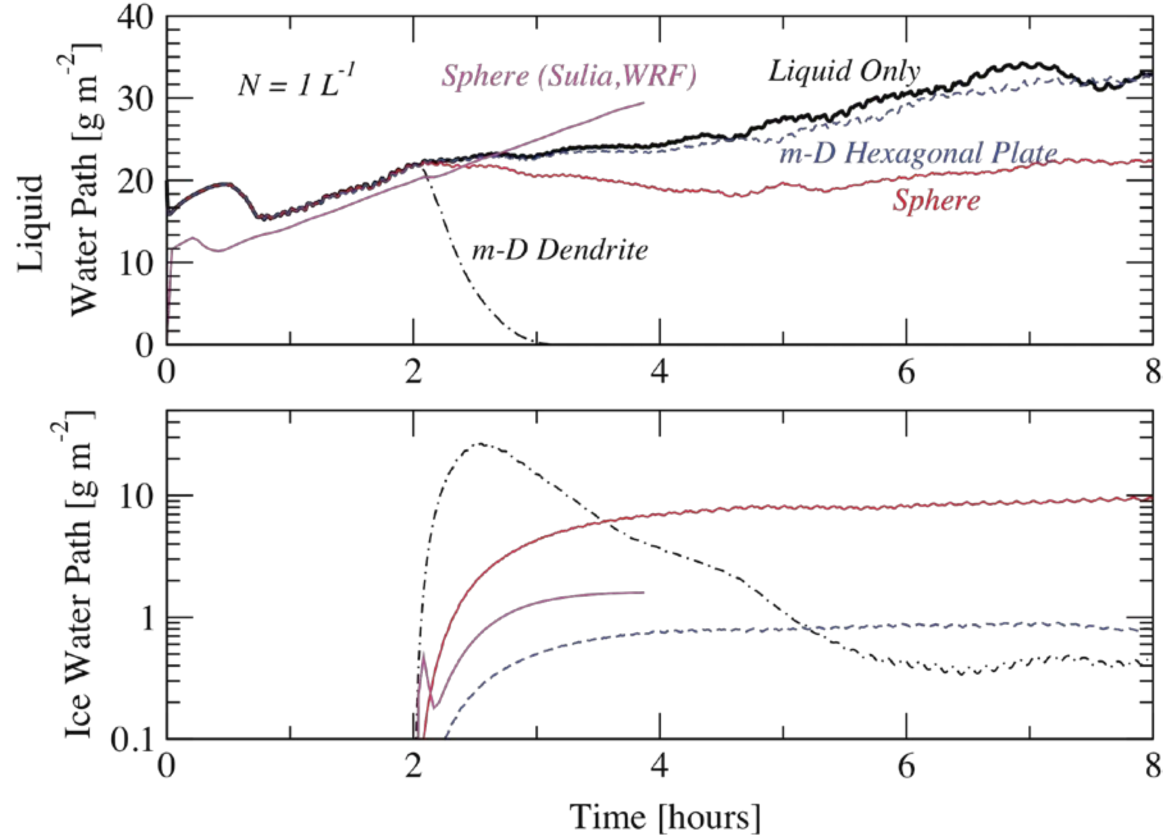
Preliminary results from ISDAC intercomparison runs

1. WRF LES (Kara Sulia)

- New Adaptive Habit Ice Growth Method
- Run with evolving habits and spheres

2. "RAMS" LES (Jerry Harrington)

- Mass-size relations
- 2-D ERM (3-D runs going)



Entrainment Breakout
Monday, March 12 7:30 – 9:00 PM

7:30 – 7:45 **Krueger** – Entrainment in Cumulus Ensembles: Cumulus Parameterization versus Giga-LES

7:45 – 8:00 **Lu** – A New Approach for Estimating Entrainment Rate in Cumulus Clouds

8:00 – 8:15 **Albrecht** – Estimating Entrainment Rates in Stratocumulus Clouds using MMCR Observations

8:15 – 9:00 **Jensen** – DISCUSSION: ASR Entrainment Focus Group and White Paper

From Entrainment FG White paper

(Contributions from Jensen, Krueger, Kollias, Liu, Vogelmann)

Approaches

1) Forward modeling of new (ARRA) remote sensing observations using existing LES results

2) Utilize existing long-term ARM measurements to retrieve cloud and environmental parameters relevant to entrainment

3) Model (LES/CRM) intercomparison in order to evaluate the robustness of representation of quantities that play important roles, or are impacted by, the entrainment process including the vertical profile of humidity, buoyancy reversal, and CDNC dependencies

4) Inter-comparison of GCM convective parameterization schemes

5) Propose and carry-out a coincident aircraft and surface-based remote sensing IOP targeting entrainment processes in shallow cumulus clouds

Vertical Velocity Focus Group

Progress Report & Recommendations*

Pavlos Kollias

*Include summary/recommendations from the PBL/Wind Profiler meeting

VV products

- **Kalesse (McGill):** Preliminary results from a long term (14-yr) climatology of vertical air motion from cirrus clouds at the SGP. Evaluation PI product will be submitted to the archive by June 2012.
- **Guo (PSU):** Vertical air motion retrievals in mixed-phase clouds. Preliminary application of the technique to NSA measurements look promising. Quality of the KAZR Doppler spectra very good.
- **North (McGill):** Discuss quality flags and vertical air motion uncertainty in deep convective clouds. Continue work with Collis to produce and submit to the archive the ConVVAP soon (May 2012).
- **Comstock (PNNL):** Presented re-processed (bias-corrected) in-situ vertical air motion data (AIMMS-20) from Sparticus. Preliminary comparison with ground-based sensors revealed differences associated with sampling issues and algorithm assumptions. Re-processed data will be submitted to the archive soon

VV & PBL Recommendations

- The VVFG needs to consider the development of a short-term and long-term validation strategy [e.g., aircraft campaign(s)] for a number of proposed Evaluation/VAP products.
- The VV/PBL groups strongly recommend the development of ARSCL-like products from the UHF profilers (UAZR). Initial results are very encouraging (Tridon, U. of Leicester).
- The VV/PBL groups strongly recommend the pairing of all KAZRs with UHF profilers (Darwin, Manus) with new UHF acquisitions or utilizing some of the SGP profilers.
- The VV/PBL groups agreed on developing an operational strategy for the UHF profilers that will address the needs of both the VV and PBL Focus Groups.

Entrainment at cloud boundaries

David Noone

Department of Atmospheric and Oceanic Sciences and CIRES,

University of Colorado, Boulder, USA

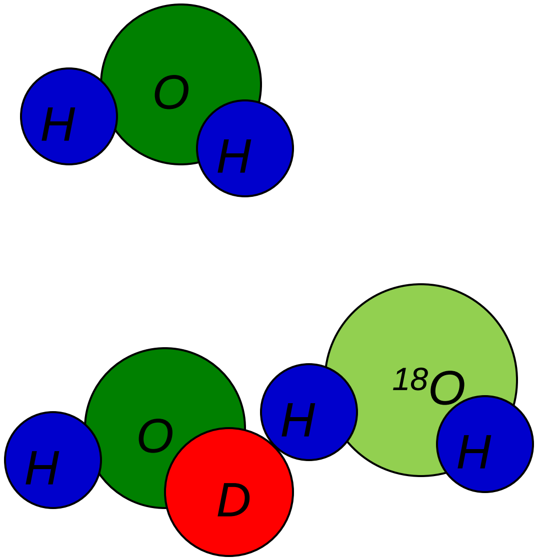
Max Berkelhammer (CU)
Camille Risi (CU, now at LMD)
Derek Brown (CU)
Adriana Bailey (CU)
Nicholas Buenning (now at USC)
Jesse Nusbaumer (CU)

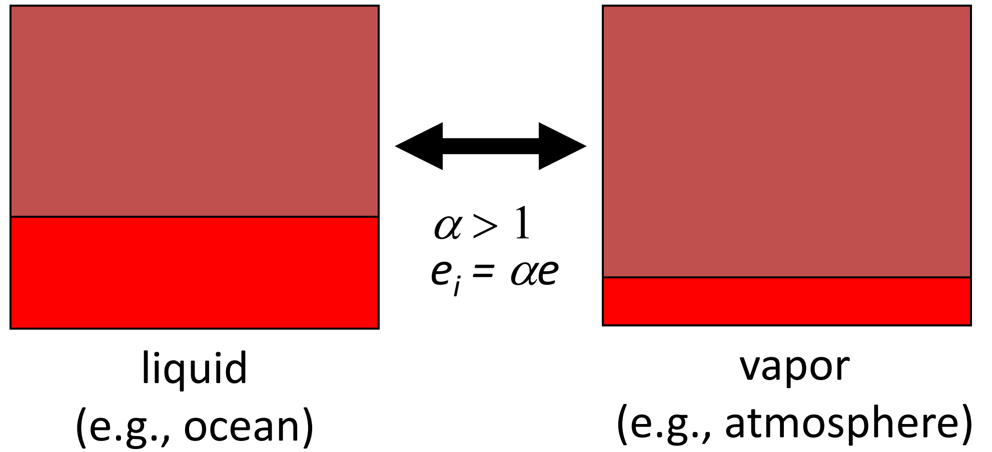
Naoyuki Kurita (IAEA/Jamstec)
John Worden (JPL)
Darin Toohey (CU)
Cynthia Twohy (OSU)
Chris Rella (Picarro)
Aaron van Pelt (Picarro)
Andrew Heymsfield (NCAR)
Zhengyu Liu (U Wisconsin)

CIRES
COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES

ATOC

Isotope physics





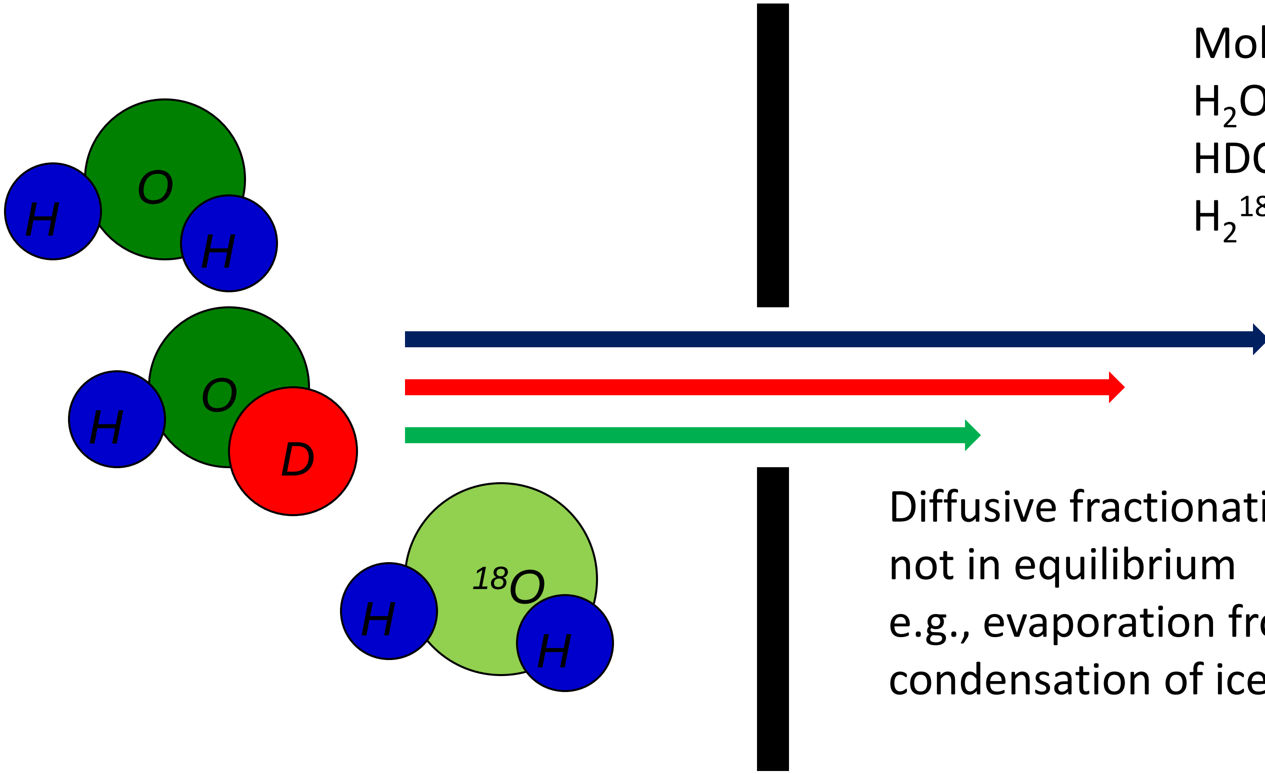
Condensation: heavier isotope preferentially removed, leaving vapor lighter

Evaporation: lighter isotopes preferentially removed, leaving liquid heavier

In a cloud, if some of the condensed liquid water remains as cloud, the rate at which heavy isotopes are removed is smaller. ***Thus a measure of precipitation efficiency***. (*when all water is retained, total water is conserved, and isotope ratios constant*)

Isotope physics 2: Kinetic fractionation

pressure 1 > pressure 2



Molecular weight
H_2O = 18
HDO = 19
$H_2{}^{18}O$ = 20

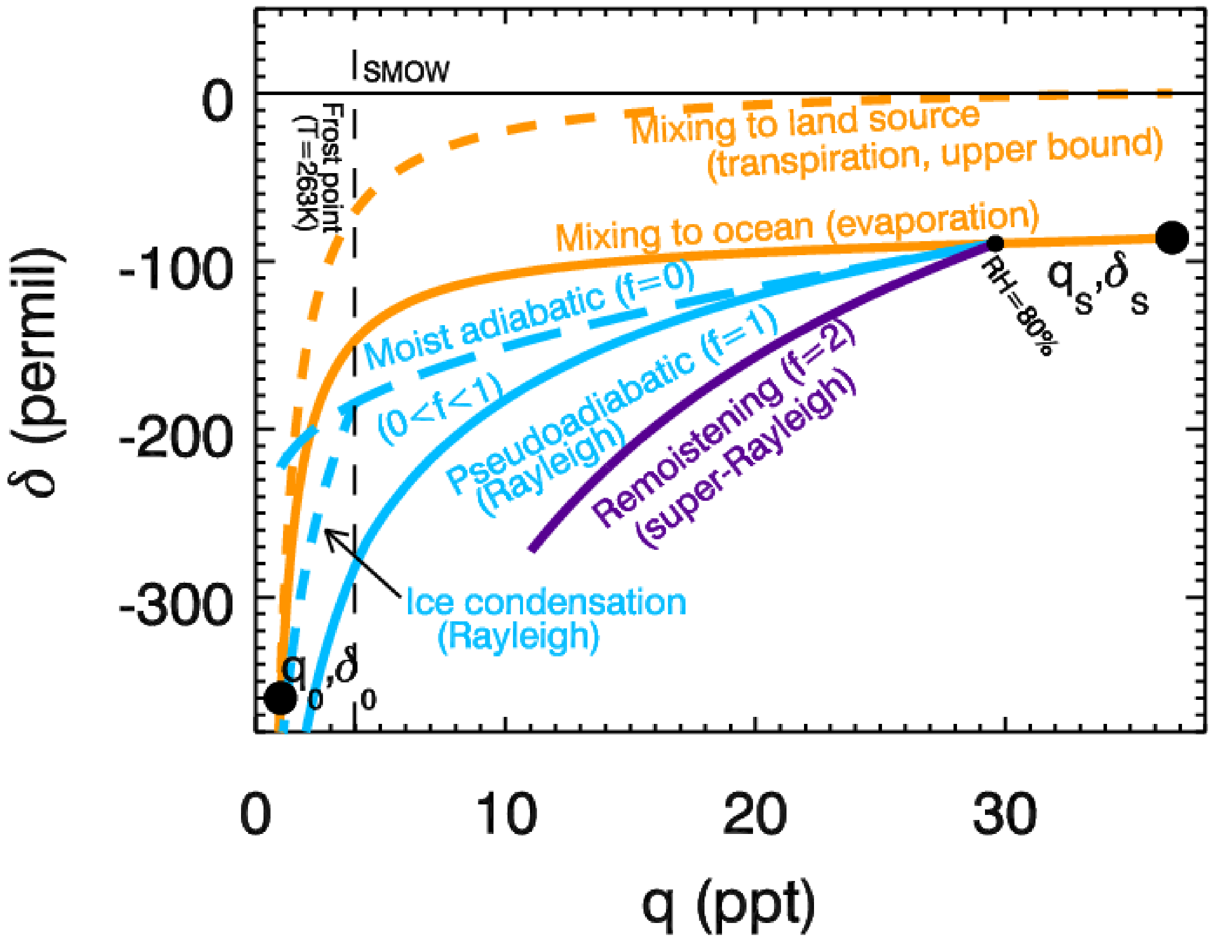
Diffusive fractionation seen when system not in equilibrium
e.g., evaporation from the ocean, condensation of ice in clouds…

Diffusion slower for the bigger molecules.

Differs from equilibrium which is stronger for ^{18}O because of asymmetry in the molecule.

Therefore, where HDO exceeds H218O, relative humidity < 100% in a cloud/etc.

Framework for interpreting HDO



(Noone, in press 2012)

"6 easy pieces"

Very powerful since isotope value can be different at same humidity.

Two things to worry about:

1) What is source composition? (end members, balance of sources)

2) What is *slope*? (rainfall efficiency, type of cloud)

Test isotope assumptions in the region of clouds

1. Are ascending plumes diluted?
2. Where does cloud condensate originate?
3. What are the conditions at ice formation?
4. Moistening of troposphere by condensate evaporation?

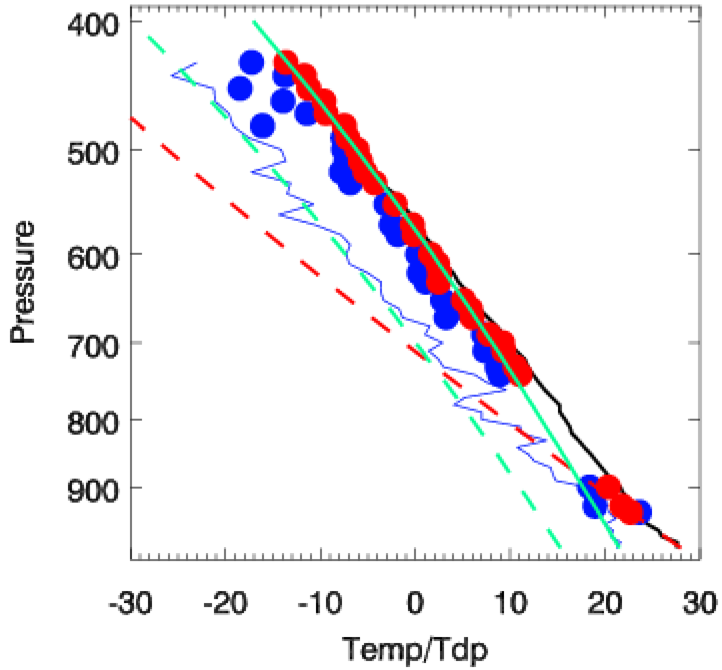
- Multiple aircraft profiles near St Croix on 13 days in July 2011
- Wavelength scanning cavity ring-down spectrometer, coupled to a counter-flow virtual impactor (CVI) inlet.

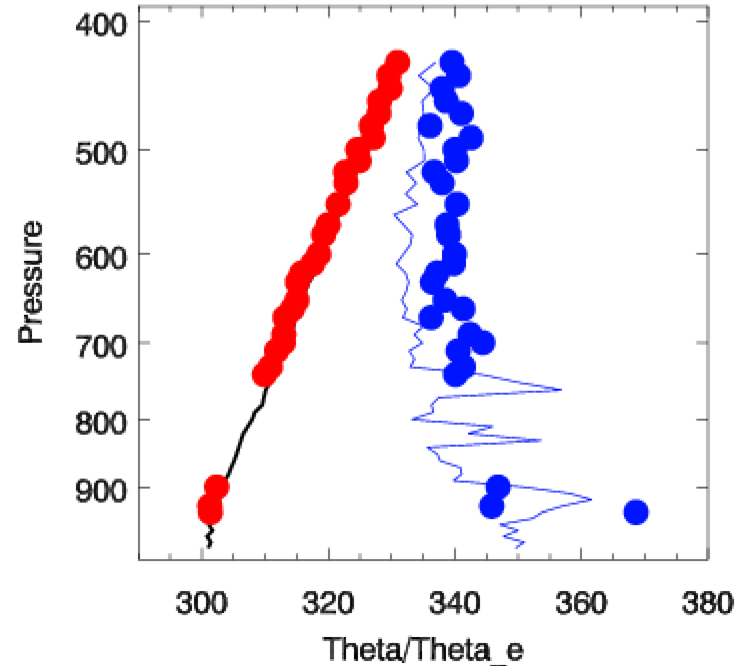
Measurements

- Measures ***clouds condensate***
- Manual valve to switch for **interstitial vapor**
- Instrument @5Hz, inlet response ~1 second
- Accuracy (δD: 2‰, δ^{18}O: 0.2‰, DXS ~ 3‰)
- Three-step calibration (great care needed!)
- Pre/post mission, "checked" every few flights.
- ***No inflight calibration***

Confirmation of quasi-equilibrium temperature profile

Average of 13 flights





— Environment temperature

— Environment dew point

● Cloud temperature

● Cloud dew point

— Dry adiabat

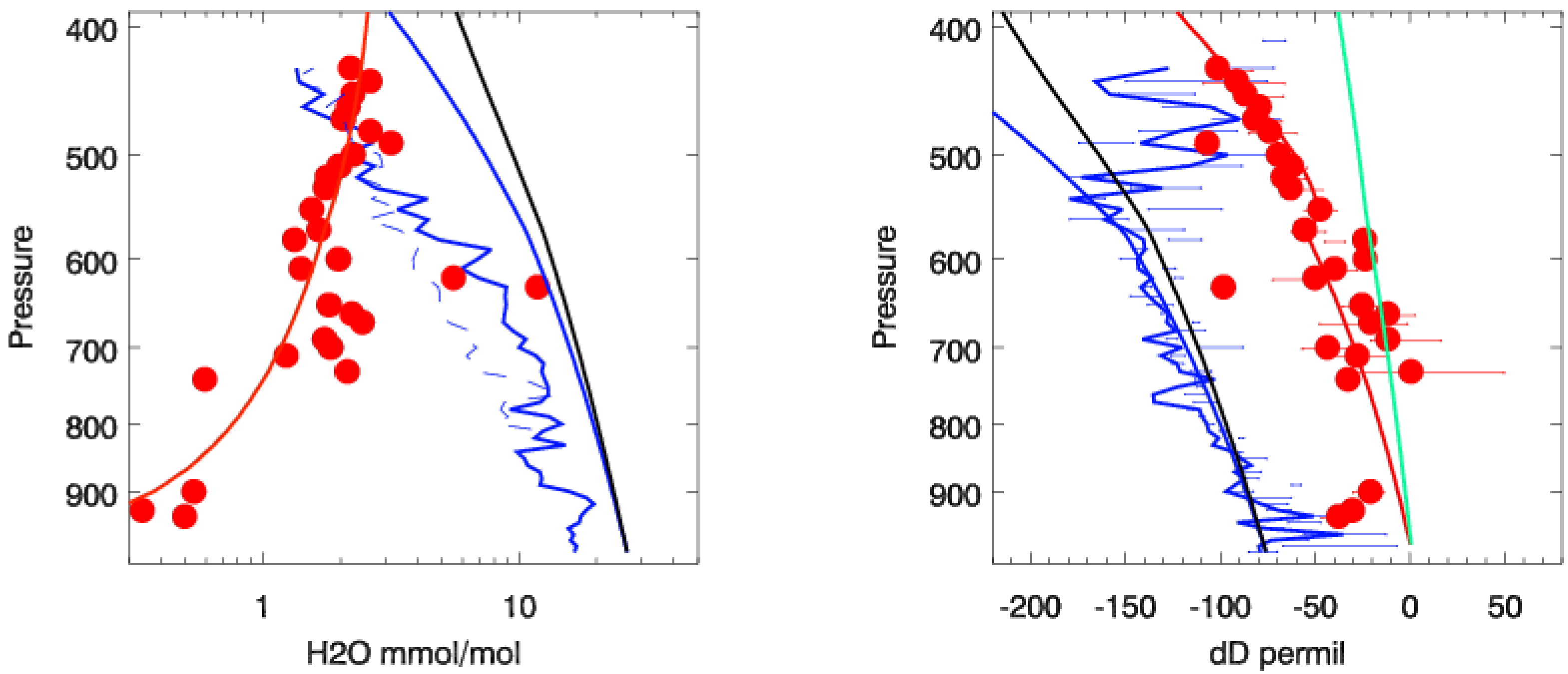
— Moist adiabat

Hypothesis testing:

- Data does not support dry stratification above LCL, so reject it (choose moist)
- Similarly moist not supported below LCL so reject it (choose dry).

Slopes matter! *They imply process.*

Hypothesis testing: multiple constraints



- Total water
- Cloud vapor
- Cloud condensate
- Detrainment/precip.
- Observed cloud condensate

Parameter estimation (*Goldilocks approach*)

1: Rayleigh model (ε=1): ***Reject***

No cloud water, δD too low above 600 hPa

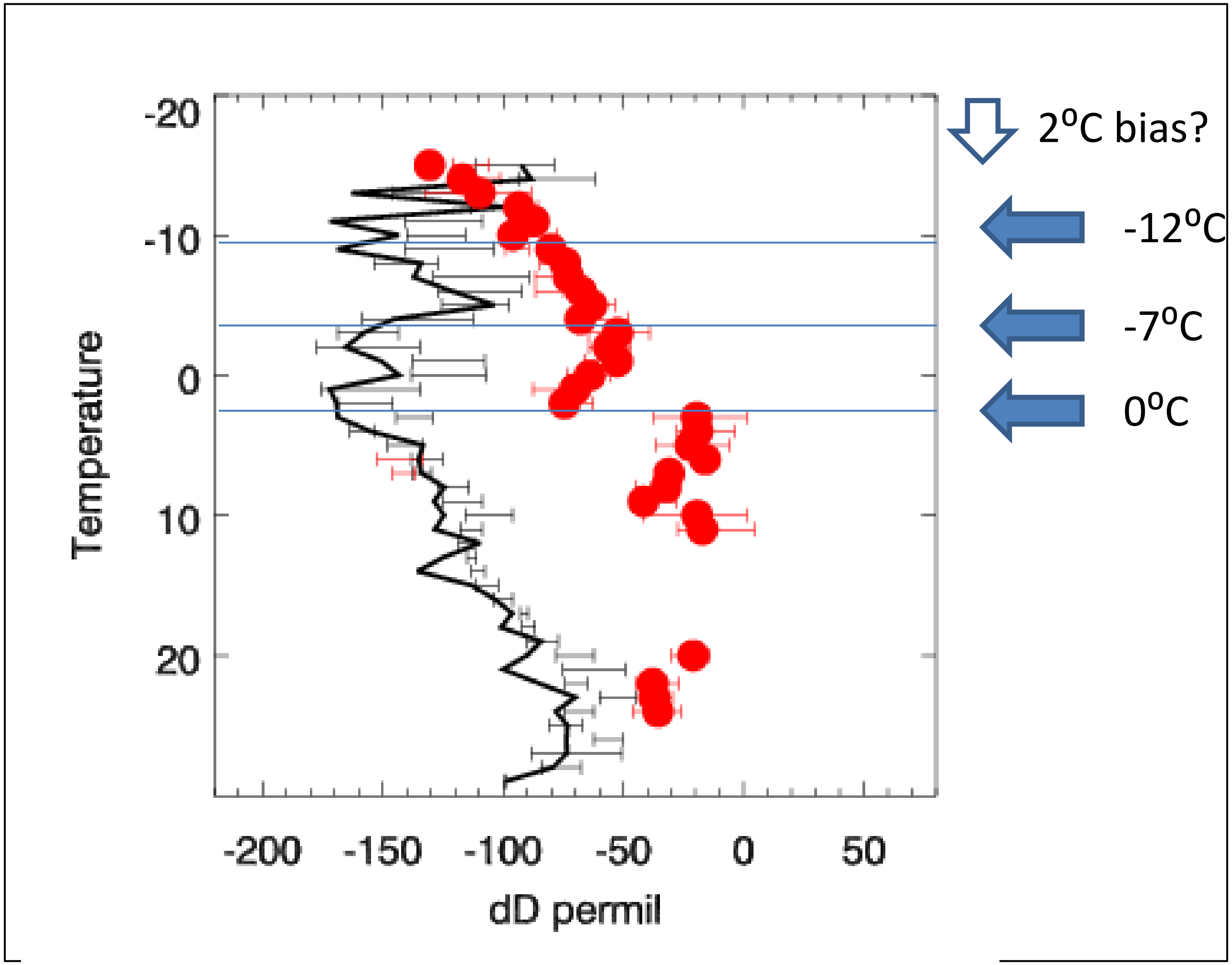
2: Moist adiabatic (ε=0): ***Reject***

Too much cloud water, δD too high above 600 hPa

3: Detraining model (ε=0.89): **Optimal** (just right!)

- Matches H_2O and δD constrains
- Predicts "kink" near freezing level

Evidence of glaciation



Ice Condensate

Mixed phase/
Bergeron process

Onset of glaciation

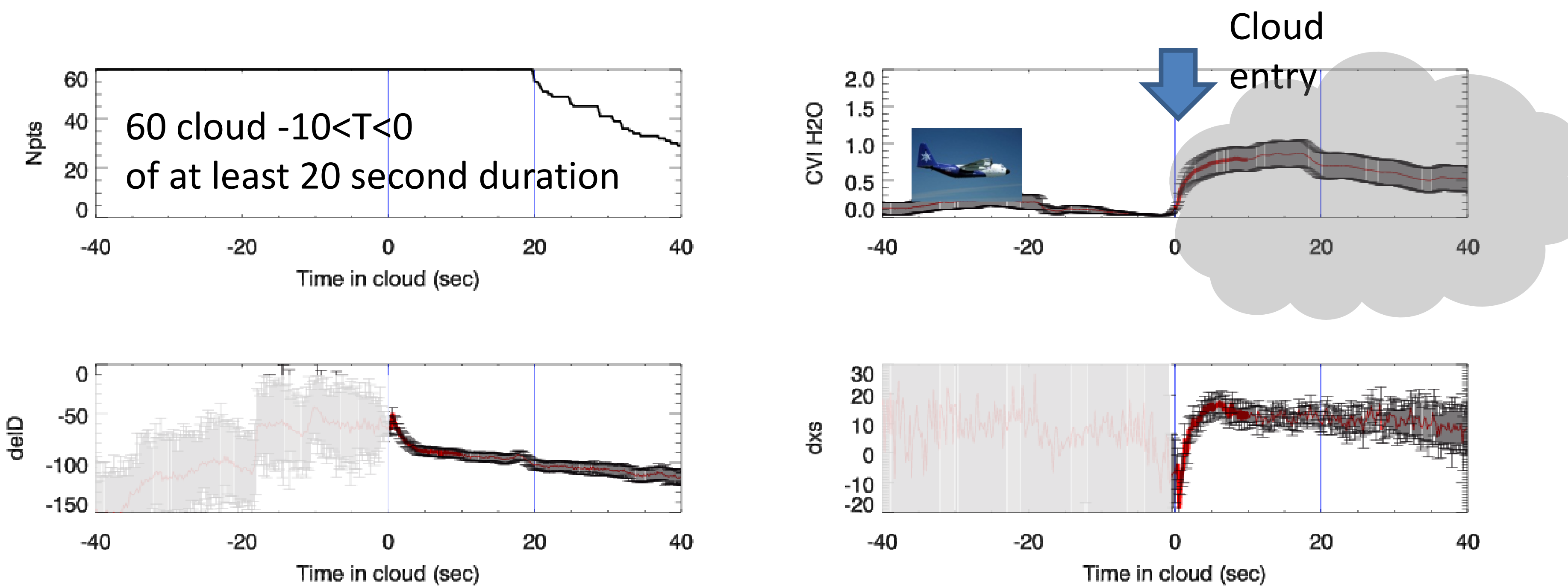
Liquid condensate

● Cloud condensate

— Cloud free/interstitial vapor

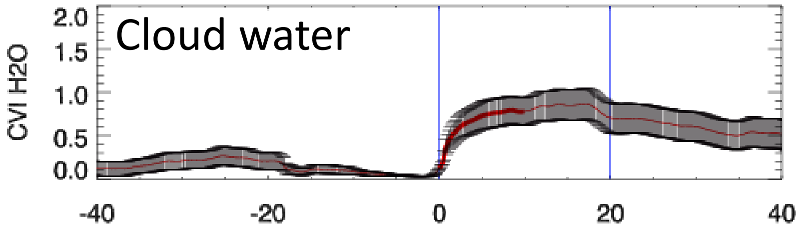
Binned by temperature.
(Notice negative scale, like height)

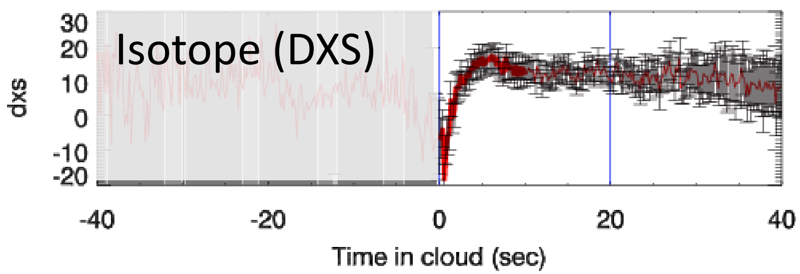
Entrainment and evaporation

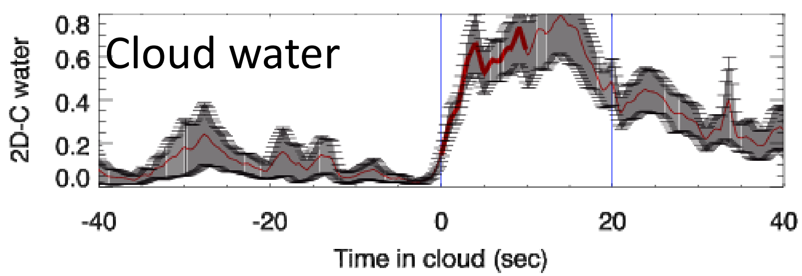


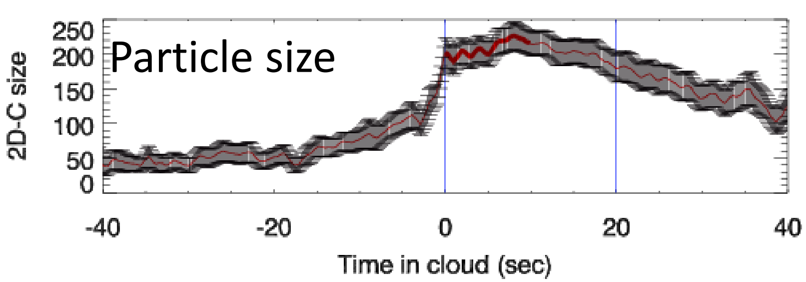
Imagine aircraft flying left to right.
20 second cloud. I trust first half, **so focus on time 0-10 seconds** Bold red)

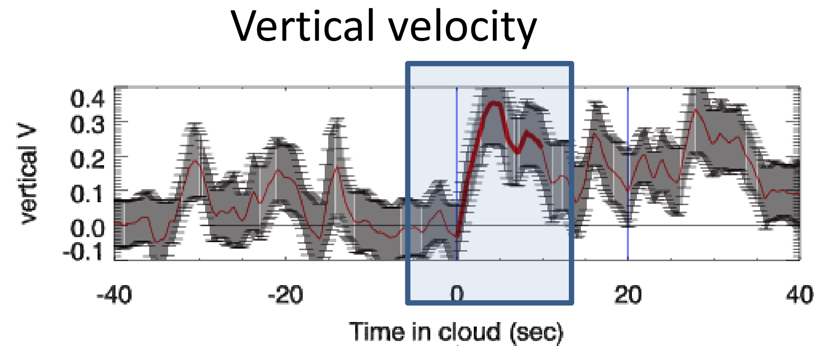
- Identify cloud entry when cloud water
- ~ 300 cloud penetrations over the 13 ICE-T flights. Some long, some short.
- Compute ensemble mean of multiple cloud passes (red line, error bars are S.E)
- Select cloud based on minimum and maximum duration and mean temperature:
- Cloud penetration> 20 seconds (and < 300), and mean temperature between -10 and 0 C





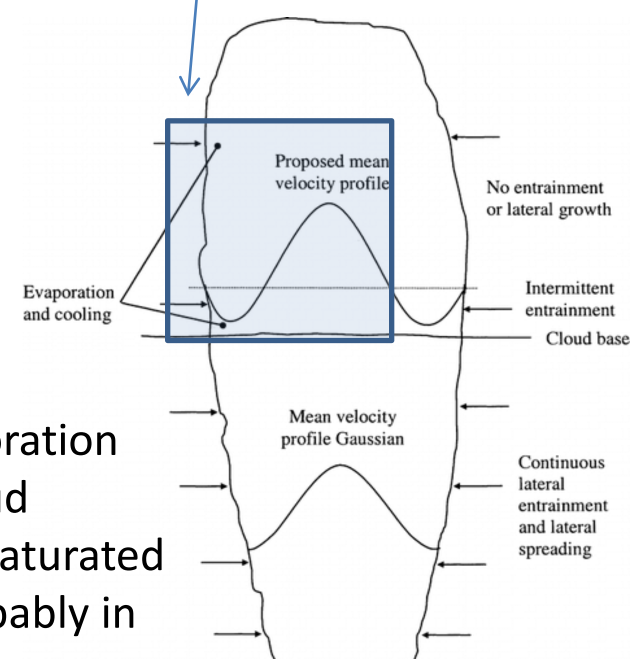






High updraft velocity in plume core.
Zero or weak subsidence near boundary.

Vertical velocityprofiles in convective plume: Agrawal (2005)



Exciting result: evaporation of cloud liquid at cloud boundary drives subsaturated downdrafts (and probably in agreement with a buoyancy sorting hypothesis)

Outcomes

- Estimate of precipitation efficiency in non-glaciated regions
- Direct measurement of evaporation at cloud boundaries
  - What is the length scale?
  - What is the effective humidity (entrainment rate)
  - Are new and old (upstream/downsteam) different?
  - Are poluted and clean clouds different?

CAPI VAP Updates

Sally McFarlane

Krista Gaustad, Laura Riihimaki, Chitra Sivaraman, Yan Shi, Tim Shippert

Over the past year work on Value Added Products (VAPs) for the Cloud-Aerosol-Precipitation Interactions (CAPI) working group has focused on three main areas:

1) Reprocessing historical data to fix errors and create consistent datasets
2) Extending existing VAPs to additional sites, including ARM Mobile Facility (AMF) deployments
3) Continued development of new and existing VAPs

Reprocessing

- Not exciting, but needs to be done periodically to correct errors, produce consistent dataset
- QCRad reprocessing to address:
  - previous end-to-end reprocessing of MFRSR data
  - small bugs in quality control flags
  - over-restrictive LW flag
  - correct global downwelling SW for IR loss
  - Create Data Quality Reports (DQRs) on data
- All data in archive by end of March

Extension of Existing VAPs to New Sites

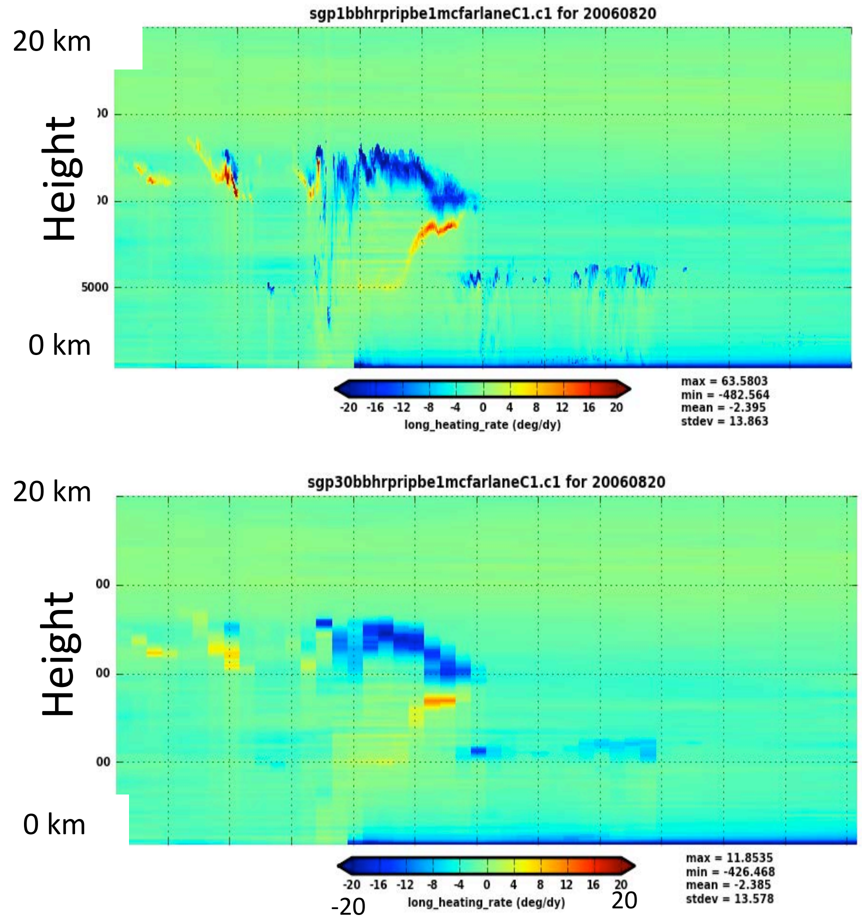
- Many VAPs originally developed for SGP, need testing or adjustment of limits, parameters, etc. for other sites. Additionally, AMFs may have slightly different instrumentation than fixed sites
- **MWRRET –** Updated to work with WACR-ARSCL data. Processed HFE and GRW data. Reprocessed historical AMF data.
- **MPLCMASK –** Updated to work with historical MPL datastreams and run operationally for AMF; processed all years at all sites
- **AERINF –** Updated to run operationally for current AMF sites; processed FKB, HFE, GRW
- **QCRad –** Initial AMF datasets at GAN and PGH processed. PGH data running operationally through remainder of deployment.
- **MFRSRCLDOD –** Updated to use MWRRET as input and run on SGP extended and boundary facilities; Will process all SGP data by end of May; move on to TWP and AMF sites this year.
- **MPLCOD –** Have analyzed effort to run operationally; will submit ECR and start work this summer.

Progress on Existing/New VAPs

- BroadBand Heating Rate Profile (BBHRP)
- Cloud Condensation Nuclei Profile (CCNProf)
- Planetary Boundary Layer Height (PBLHeight)
- Microwave Radiometer Retrieval for n-channel radiometers (MWRRET2)

RIPBE/BBHRP

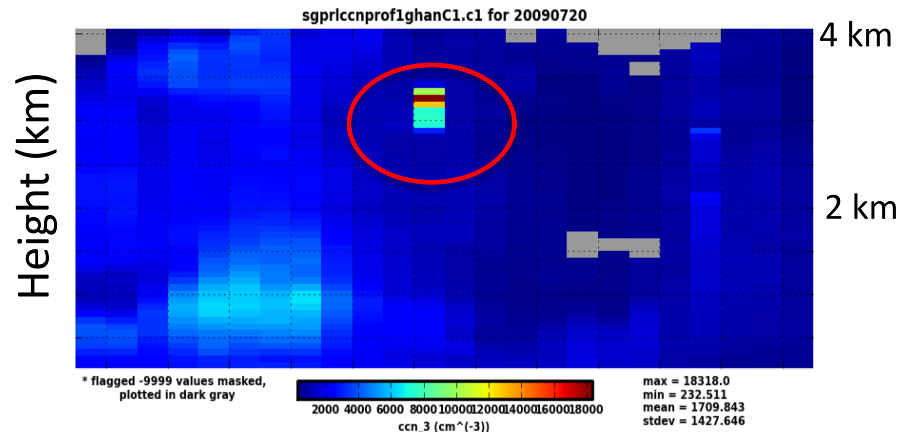
- Recent Work:
  - RIPBE code officially released; 2002-2007 SGP data in archive
  - BBHRP 1-min data processed for 2002-2007
- Current Efforts:
  - Prototype BBHRP-avg file for flux closure evaluation
- Next Steps:
  - Implement testbed – run BBHRP on ARM Cloud Retrieval Ensemble (ACRED) dataset at SGP
  - Expand to NSA and TWP sites

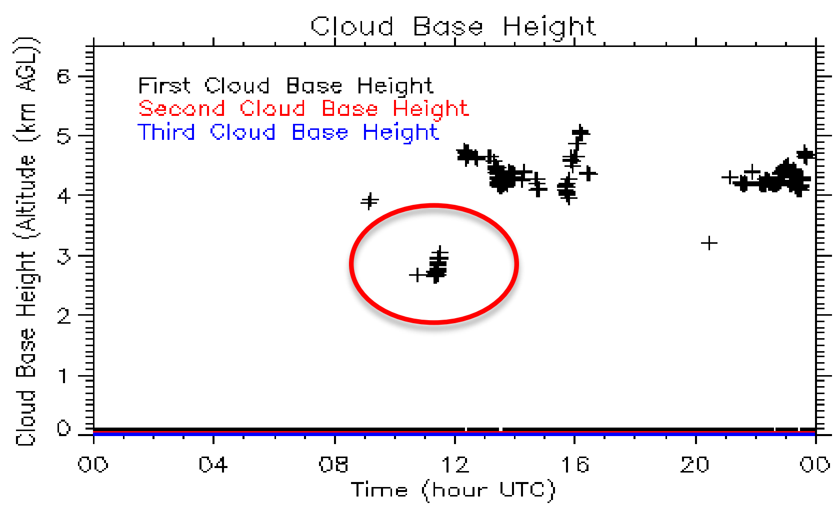


LW Heating Rate (K/day)

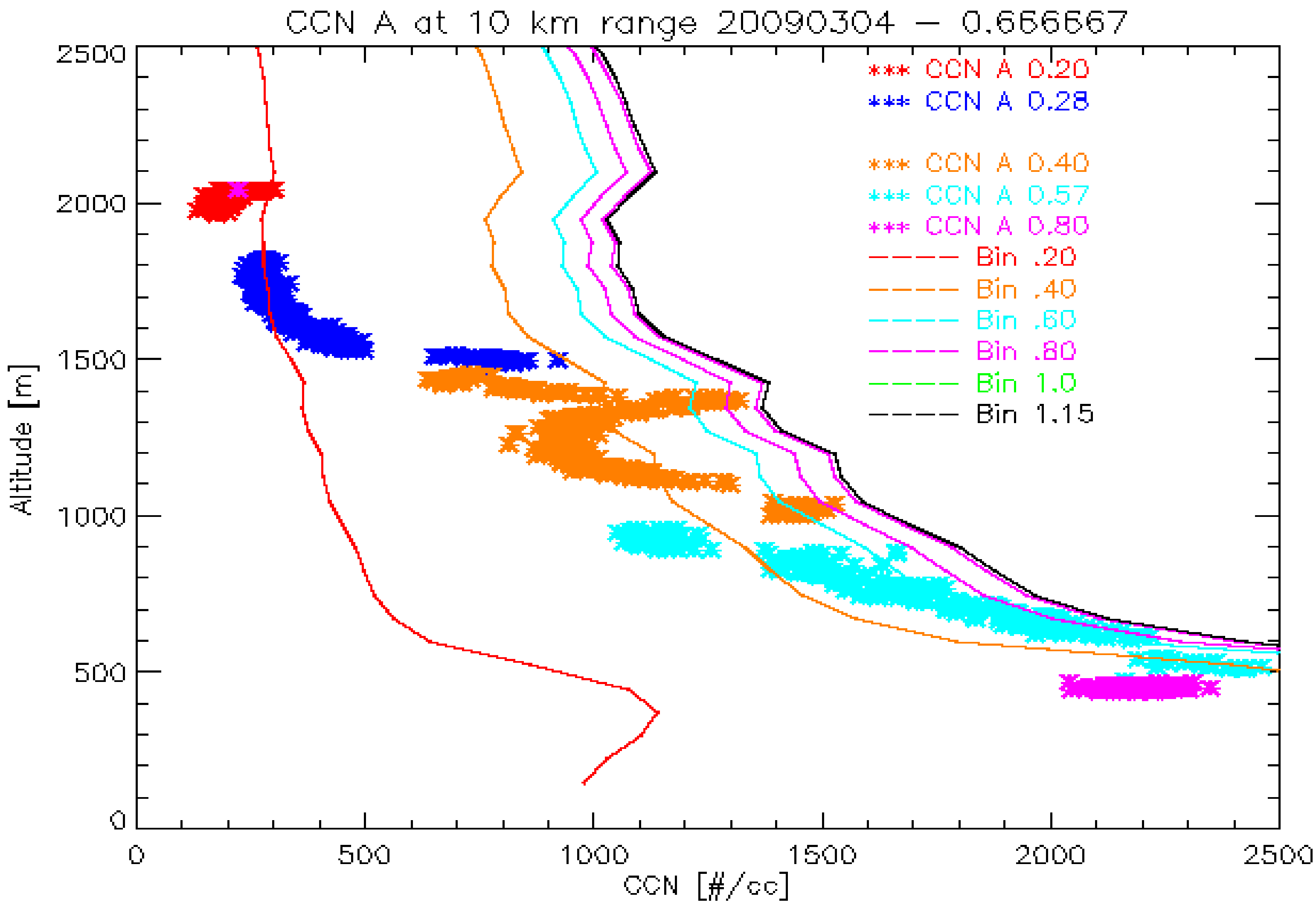
CCNProf

- Uses lidar exinction profile plus surface CCN and humidification factor to determine CCN spectrum profile up to cloud base following methodology of Ghan et al. 2006
- **Recent work** - Implemented algorithm; performed initial evaluation with aircraft data. Placed data in ARM Evaluation area.
- **Next Steps** - User feedback indicates cloudmask from Raman lidar does not adequately screen cloud contamination; will add higher temporal resolution cloud mask from ceilometer.
- **User feedback requested by June 1.**
- **Future Work –** Evaluate for Raman lidar at Darwin; apply to micropulse lidar data at SGP; extend to AMF sites w/ lidar and AOS measurements





http://www.arm.gov/data/eval/53

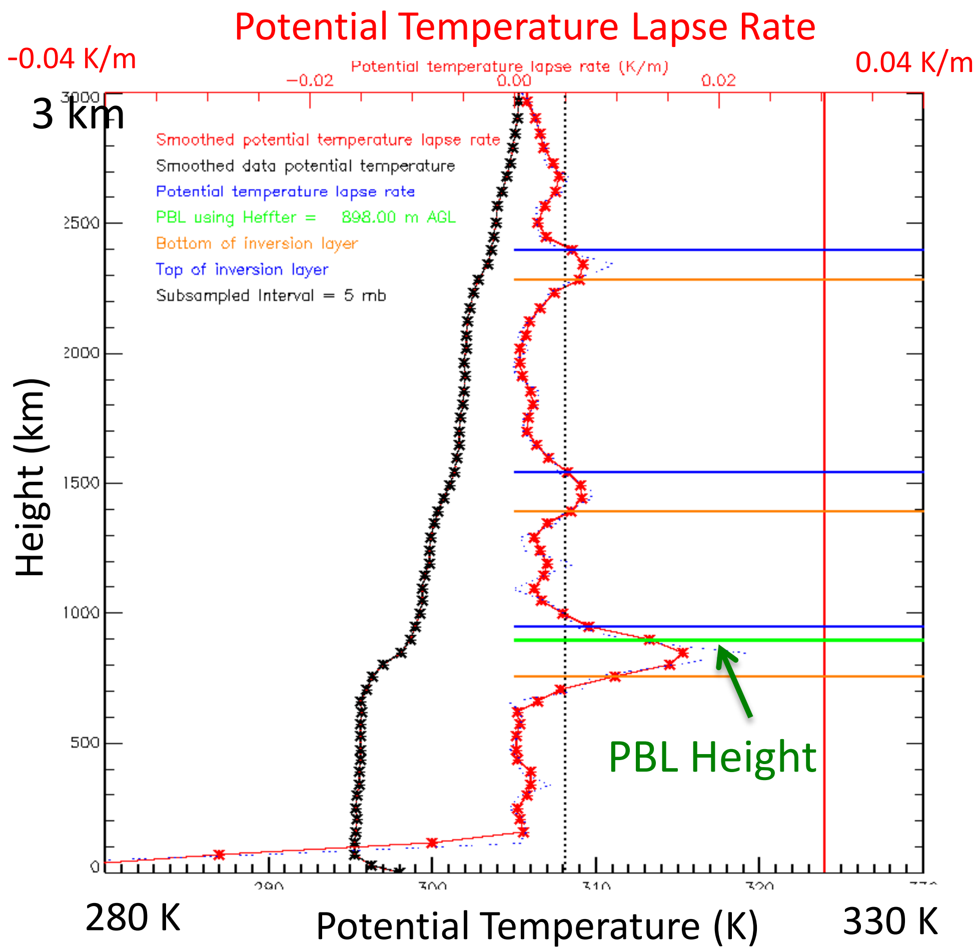

CCN A at 10 km range 20090304 – 0.666667
Altitude [m]
CCN [#/cc]
0
500
1000
1500
2000
2500
0
500
1000
1500
2000
2500
*** CCN A 0.20
*** CCN A 0.28
*** CCN A 0.40
*** CCN A 0.57
*** CCN A 0.80
Bin .20
Bin .40
Bin .60
Bin .80
Bin 1.0
Bin 1.15

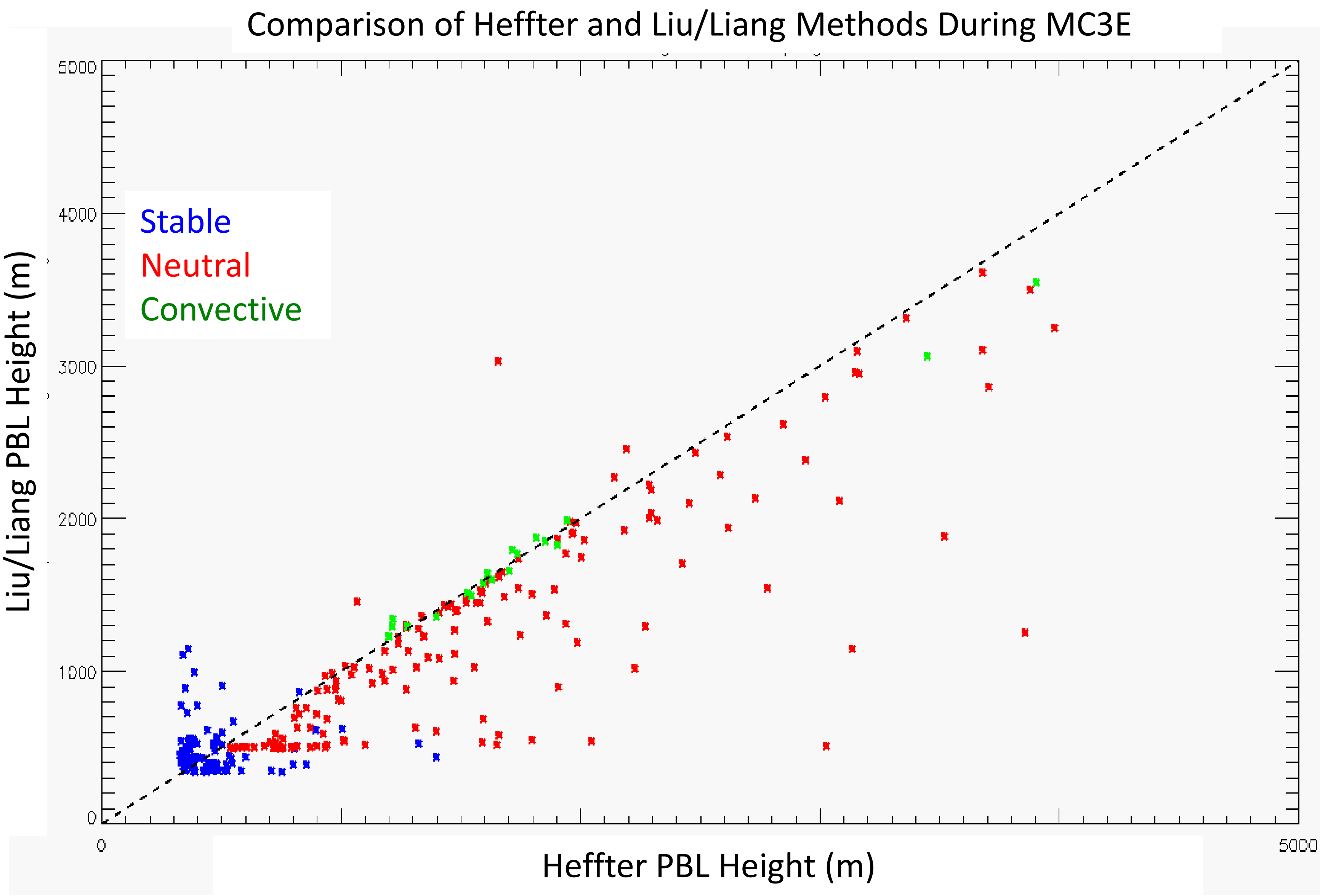
PBL Height

- Planetary boundary layer (PBL) depth important to wide range of atmospheric processes including cloud formation, aerosol mixing and transport, and chemical mixing and transport.
- VAP will implement estimates of PBL height from a range of instruments.
- Initial phase of development includes radiosondes, ceilometer, lidar as they exist at all sites.
- Future phase will include implementation of methods from more advanced instrumentation (radar wind profilers, Raman lidar, Doppler lidar etc.)
- Also, encouraging PIs to place their retrievals in archive

PBLHeight – Radiosonde Methods

- Implemented:
  - Heffter (1980), Liu and Liang (2010), Bulk Richardson
- Current work:
  - Adding qc
  - Understanding differences between methods
  - Exploring effects of sampling radiosonde data
  - Adding capability to output multiple layers (and characteristics of each layer)
- Next steps:
  - Place data in evaluation area; get user feedback

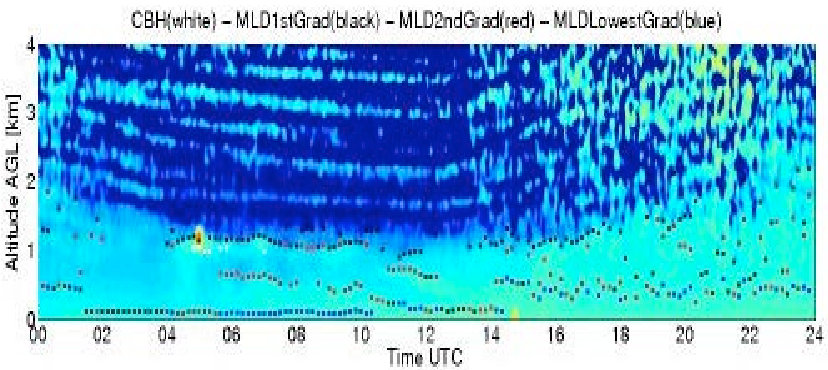



Comparison of Heffter and Liu/Liang Methods During MC3E
Liu/Liang PBL Height (m)
Heffter PBL Height (m)
Stable
Neutral
Convective
0
1000
2000
3000
4000
5000
0
5000

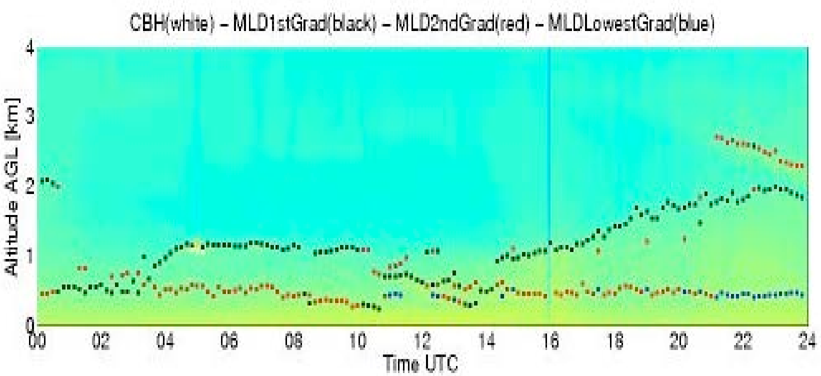
PBLHeight – Ceilometer/MPL Methods

- Plan to implement STRucture of the ATmosphere (STRAT-2D) method of Haeffelin et al. (2011)
- Mixing height detection using 2D gradient method
- Implementation delayed because IPSL releasing code as open source software which required modifications
- Initial analysis of one month of data processed by Haeffelin and Morille indicates:
  - low SNR of ceilometer may produce noisy results
  - MPL overlap issues restrict lowest height to ~200 m AGL

Ceilometer



MPL



The Multi-Frequency MWRRET (v2) Value Added Product: An Update

Dave Turner (NOAA)
Maria Cadeddu (ANL)

ASR Science Team Meeting
12-15 March 2012, Arlington VA

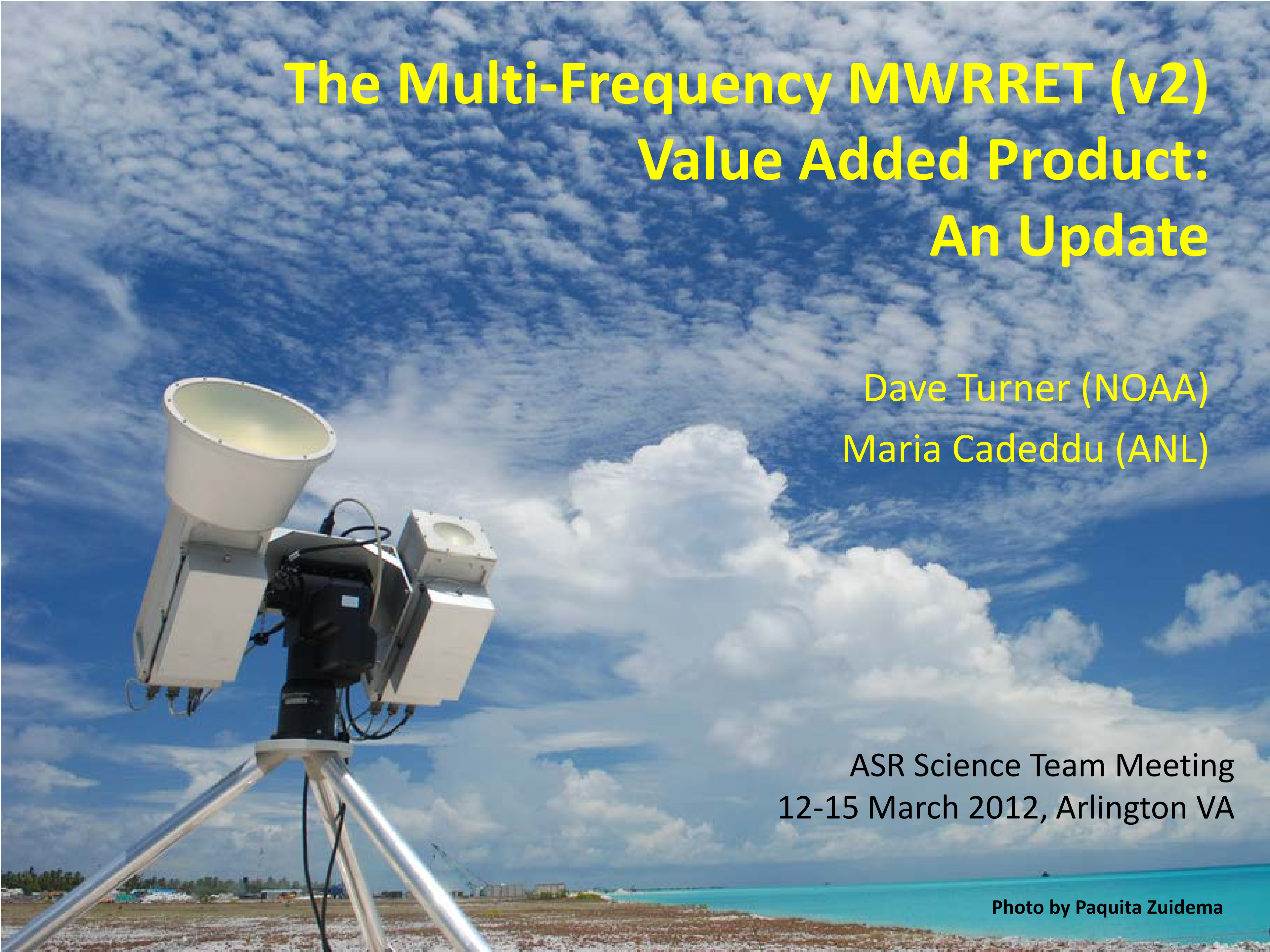


Photo by Paquita Zuidema

MWRRET Background

- Original "LOS" statistical retrievals had significant biases, especially in LWP
- MWRRET developed to perform physical retrievals to get the best possible estimates of PWV and LWP from the MWRs
  - Original algorithm designed for orig 2-ch MWRs (23.8 and 31.4 GHz)
  - Forward model is MonoRTM v3.0 (~2005)
  - Used T_b offsets to account for non-zero bias in LWP during clear sky conditions
  - Implemented for all ARM MWRs, data in archive, running operationally
  - Turner et al., TGRS 2007

- New MWR-3ch radiometers needed updated algorithm
- Desire to have updated algorithm use any combination of frequencies to retrieve PWV and LWP; e.g.:
  - New MWR-3ch radiometers
  - GVR and GVRP at Barrow
  - Combine channels from multiple radiometers (e.g., MWR-2ch and MWR-HF at Azores)

MWRRET v2 Status

- Initial version of new multi-frequency MWRRET (v2) developed
  - Updated forward model – MonoRTM v4.2 (Nov 2011)
    - Significant changes to H_2O continuum, H_2O line parameters (i.e., spectral widths), and N_2 continuum
- Evaluation datasets processed for:

  No T_b bias offsets applied to these datasets!

  - SGP MWR-3ch (23.8, 31.4, 89 GHz) — Nov-Dec 2011
  - AMF/Gan MWR-3ch (23.8, 31.4, 89 GHz) — Nov 2011
  - AMF/Azores MWR-2ch + MWR-HF (23.8, 31.4, 90 GHz) — Jan-Dec 2010
  - Summit HATPRO + MWR-HF (23.8, 31.4, 90, 150 GHz) — Jul 2010-Dec 2011
- Concerns / future
  - Need automated way to account to biases in some channel(s) ?
    - How to identify the channel(s) that need to have a bias applied to correct for a clear sky LWP bias
    - Need automated way to determine clear skies from only the MWR T_b data
  - The modeled temperature dependence of the liquid water absorption needs to be improved