Aerosol-Cloud-Precipitation: Airborne plans and discussion

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many contributors

Outline

- Aircraft and payloads
- Flight Plans
- Multi-platform synergies

Aircraft and payloads

The aircraft

NSF C-130

CIRPAS Twin Otter

DoE ASP G-1

UK FAAM BAe-146

NSF C-130 Payload

- **Standard instruments**: Microphysics, Turbulence, Thermodynamics suite
- **Remote sensing**: Wyoming Cloud Radar (zenith+nadir+slant), Cloud Lidar (zenith), Microwave radiometer (183 GHz, zenith), MODIS Airborne Simulator (MASTER, nadir), BBRs
- **Chemistry/aerosols/clouds**: LDMA, RDMA, ToF Mass Spec, nephelometer, PSAP, CN counters (+ultrafine), CCN, CVI, Cloud water collector, gas phase chemistry, Impactors, PDPA, 2D-S, fast FSSP
- **Dropsondes**

What will the C-130 measure?

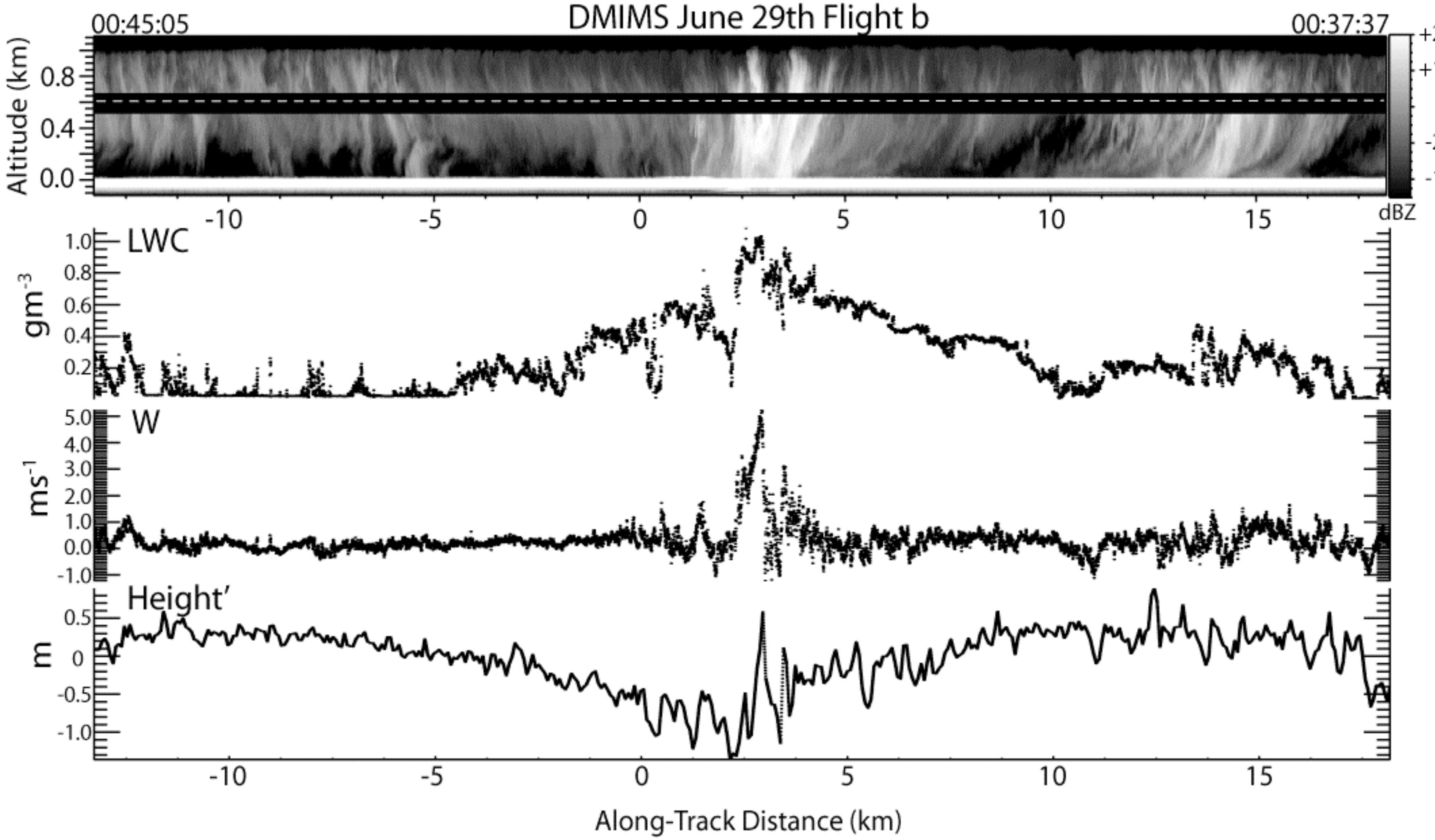
C-130 Measurables

- <u>Boundary layer structure:</u>
  - vertical profiles (dropsondes), T, q, u, v
  - *in-situ* mean state and turbulence ⇒ entrainment
  - cloud mesoscale circulations (WCR)
  - mesoscale horizontal variability (differential GPS)
  - inversion base height (WCR)

C-130 Measurables

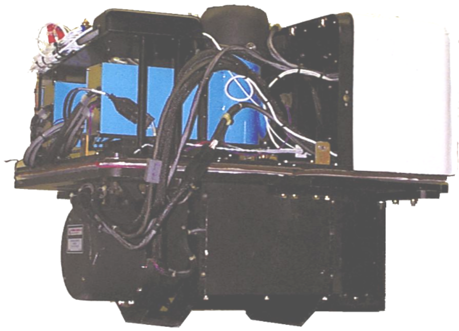
- Cloud and precipitation (remotely sensed):
  - high resolution vertical and horizontal cloud and precipitation structure (WCR)
  - cloud base height, from below (WCL)
  - LWP, from below (183 GHz radiometer)
  - cloud optical properties (BBRs, MASTER from above)

Drizzle, LWC, w, and pressure perturbations in stratocumulus



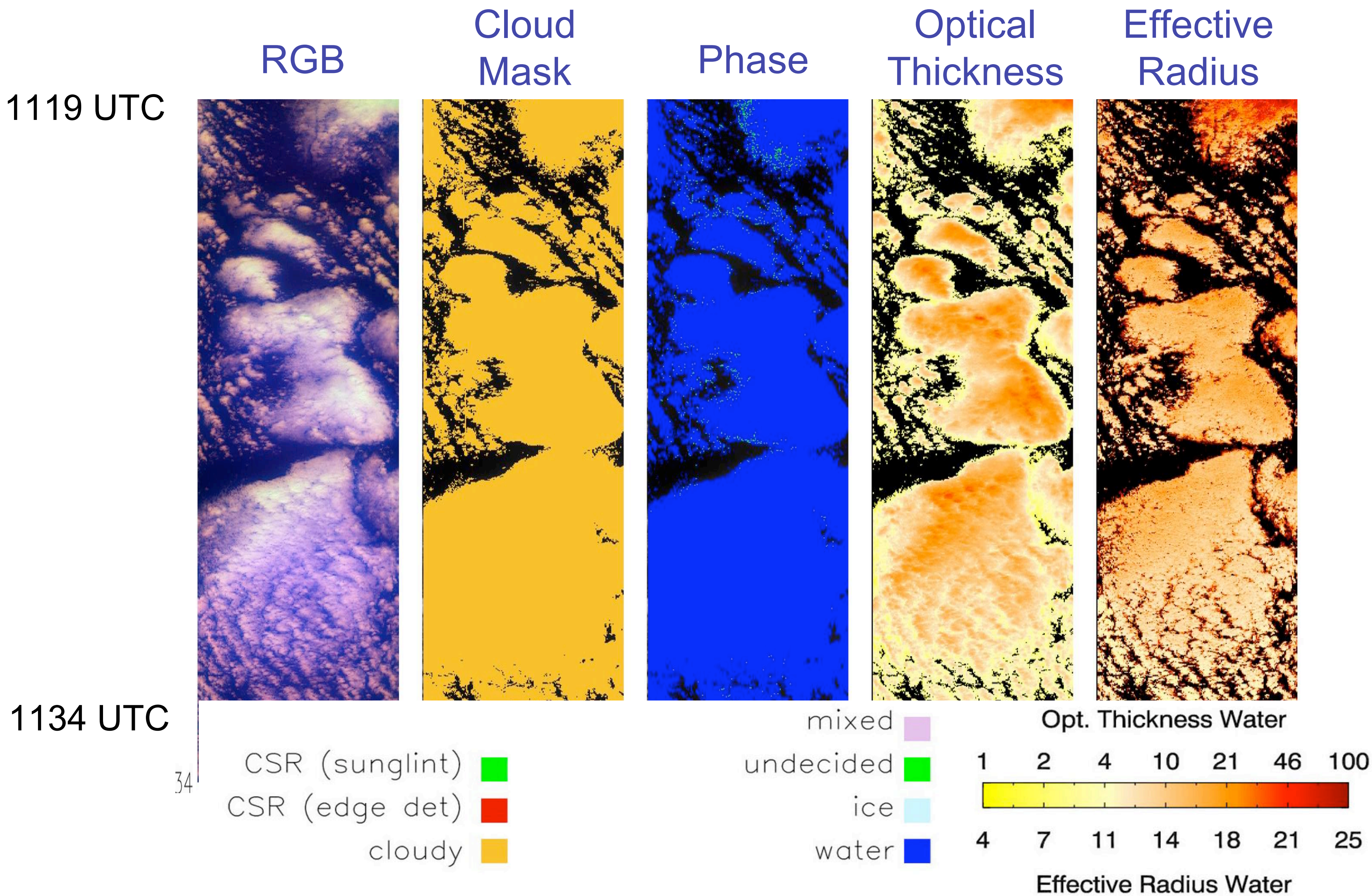
MODIS/Aster Airborne Simulator (MASTER)

(*mas.arc.nasa.gov*, *masterweb.jpl.nasa.gov*)



- 50 spectral channels from VIS to IR, 50 m spatial resolution (from 20 km altitude), 16 bit data system
- MASTER: VIS to 12 µm, variable scan speed for different a/c altitudes, flown on B200 King Air, ER-2, WB-57, DC-8
- NASA Facility instrument supported by the Ames Airborne Sensor Facility (J. Myers)
  - Engineering and maintenance
  - Field support and data processing (L1B)
  - Calibration/Characterization Lab: radiometric cal (light sources, integrating spheres, diffusers, NIST traceability), spectral cal from UV to IR, environmental test chamber
- Level-2 products provided by PI investigators only

SAFARI-2000, 14 Sept 2000, ER-2 Flight Track 10
northern part of track off Angola

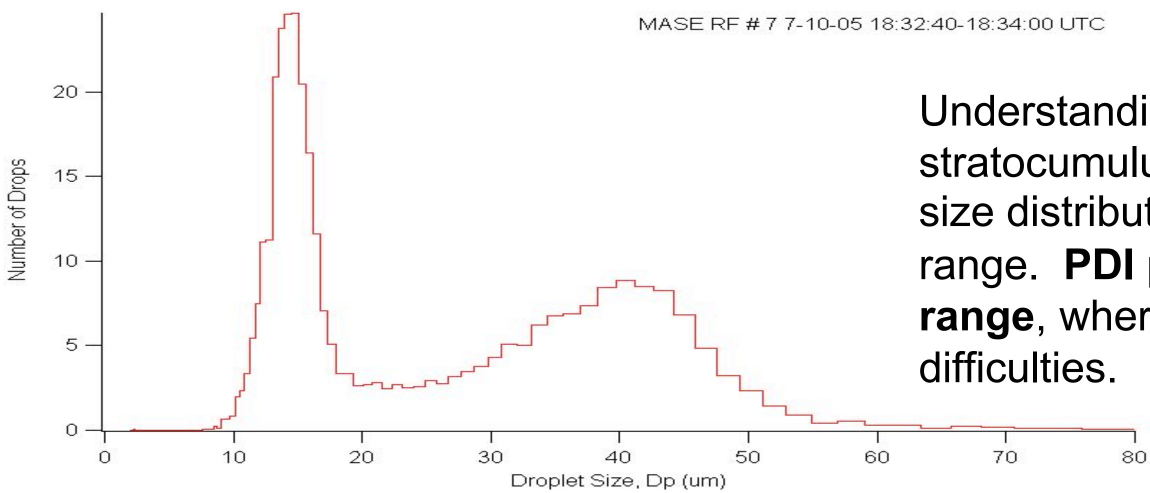


C-130 Measurables

- Cloud and precipitation (in-situ):
  - importance of redundancy in measurements
  - cloud/precipitation size distribution (1-400 μm)
  - cloud liquid water content (Gerber PVM)
  - new state-of-the-art probes
    - drizzle sampling (2D-S, SPEC Inc.)
    - cloud/drizzle boundary (PDPA, UCSC)
    - fast FSSP (Meteo France)

UC Santa Cruz @ VOCALS?

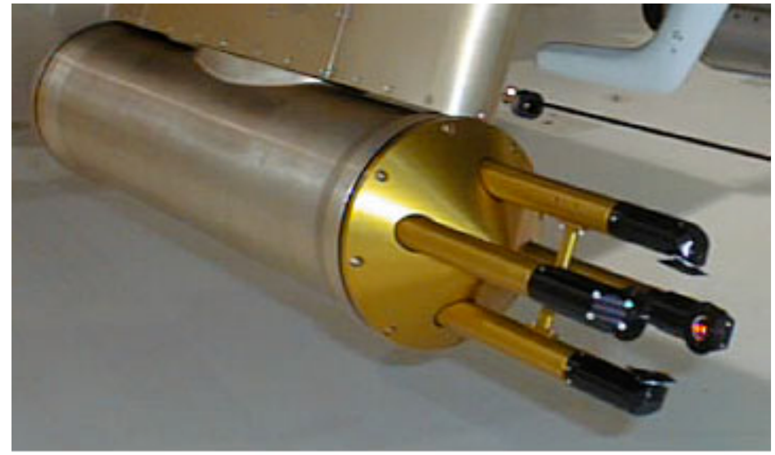
- PI: Patrick Chuang
- **Phase-Doppler Interferometer (PDI)** has been developed for airborne measurements.
- Measures single cloud drop:
  - *size*
  - *velocity*
  - *inter-drop spacing*
- Size range: 3 to 150 um

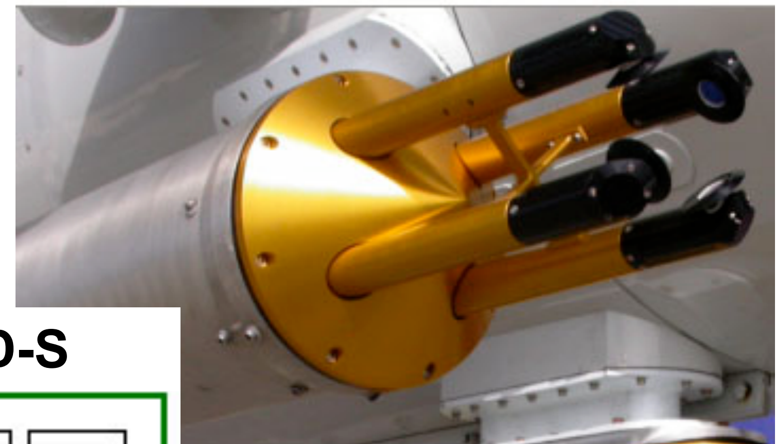


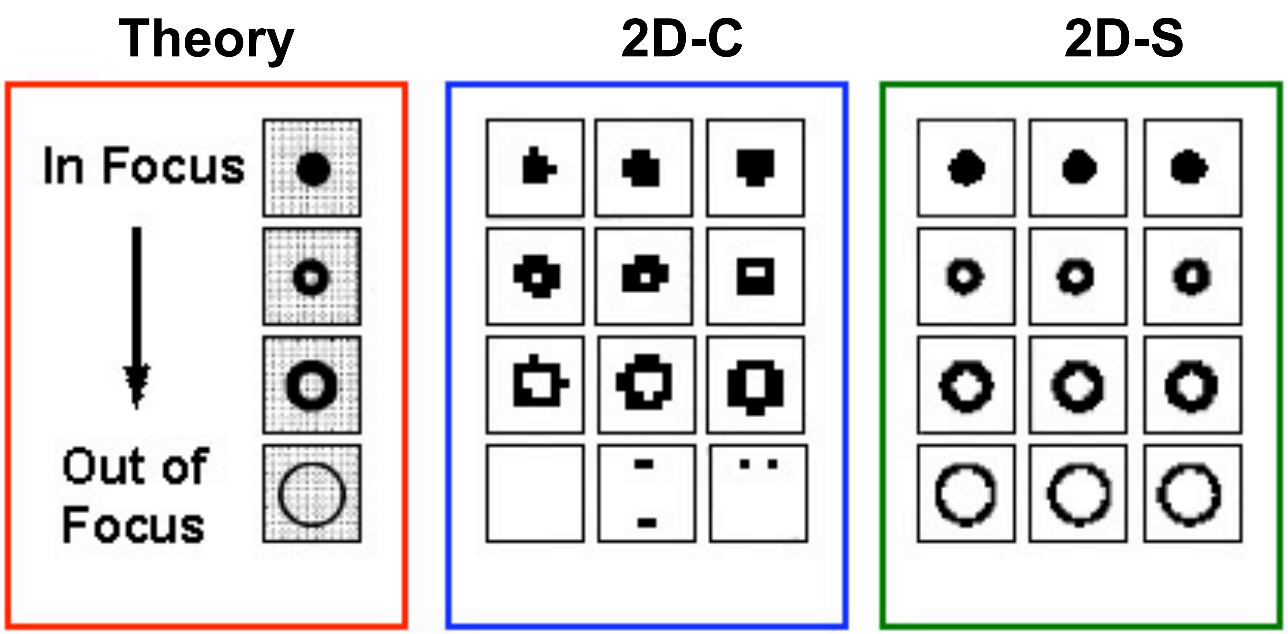
Understanding the **development of drizzle** in stratocumulus requires measurement of drop size distribution in the **30 to 100 μm** diameter range. **PDI performs very well in this size range**, whereas other instruments often have difficulties.

2D-S Probe (SPEC Inc.)

- Faster response time than 2D-C
- Small particles can be imaged (5-10 microns)
- Improved sample volume characterization for small drops

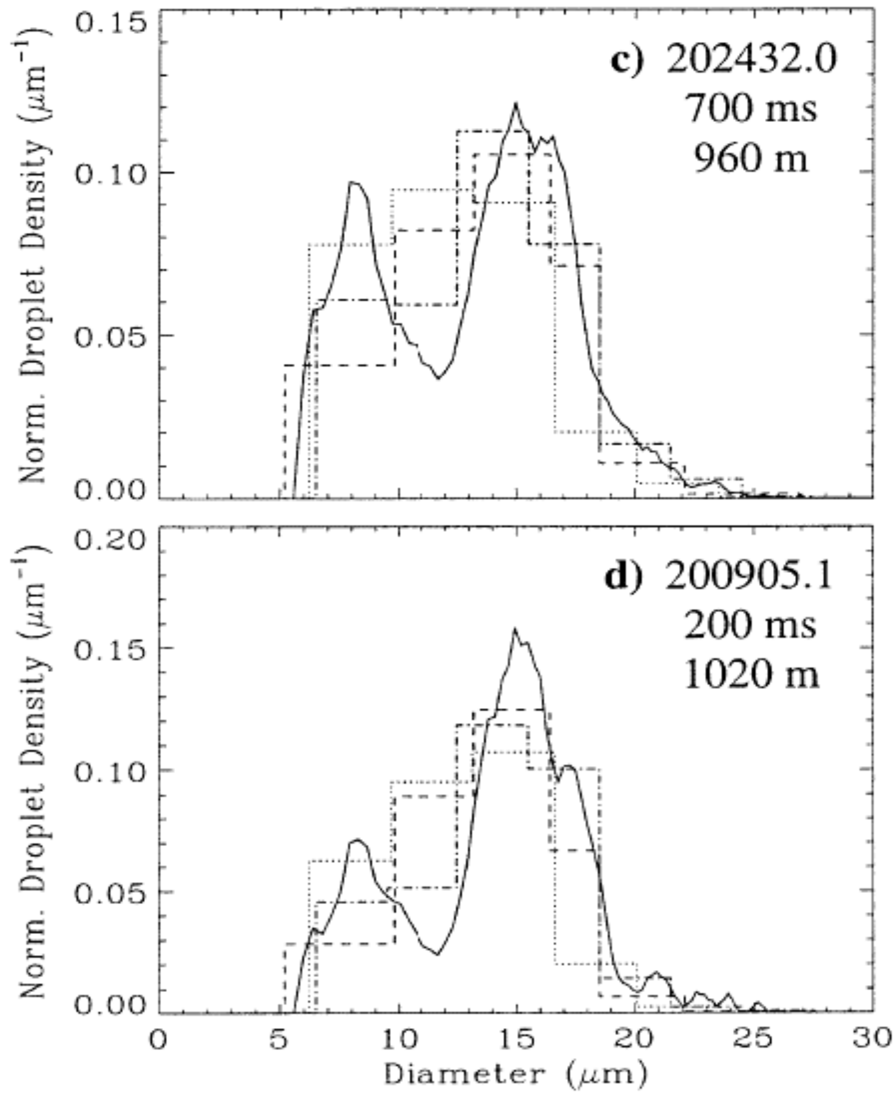






Fast-FSSP

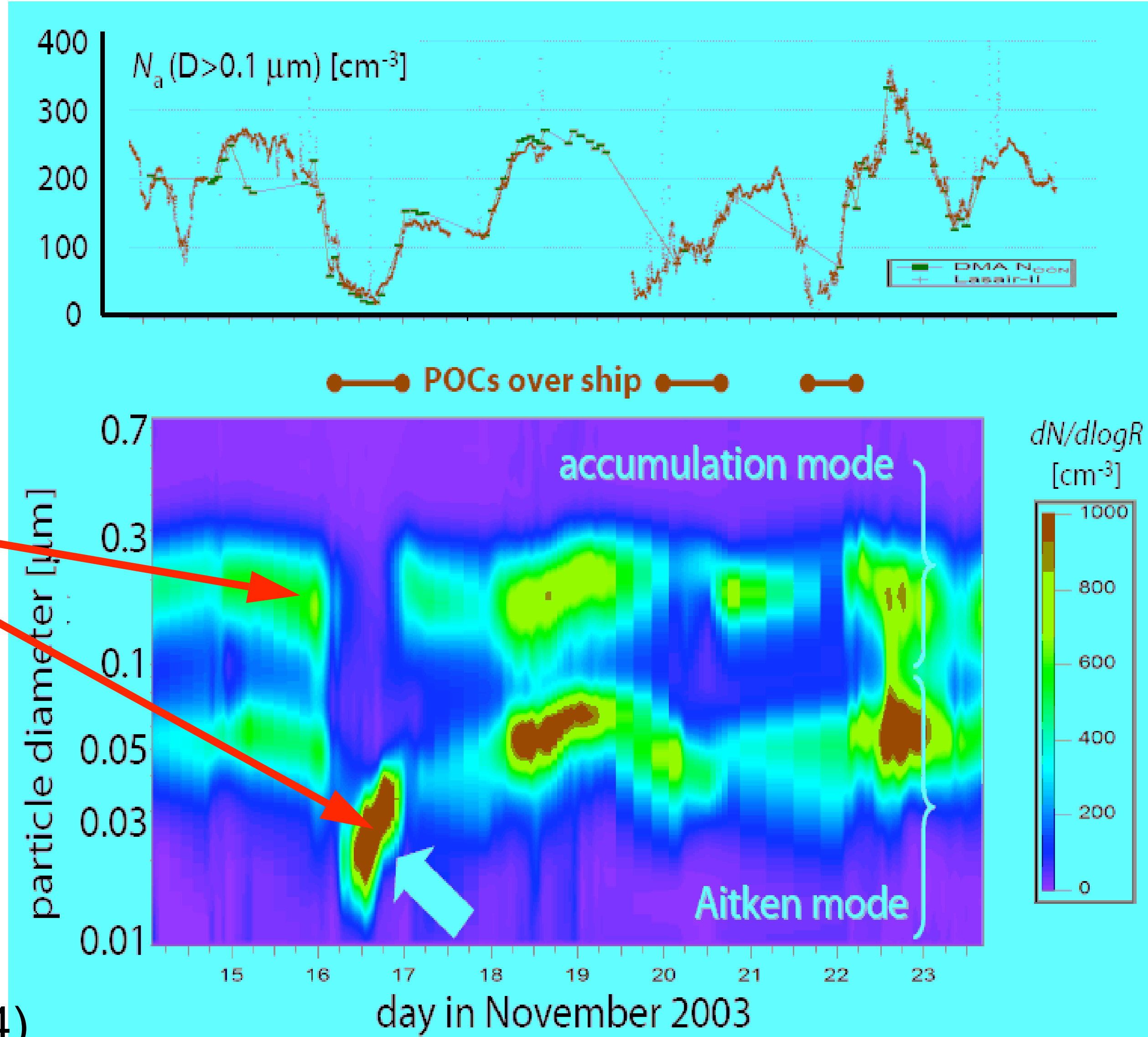
- No dead time
- Higher resolution spectra than standard FSSP
- Auto-calibrating using Mie scattering



C-130 Measurables

- Aerosols:
  - aerosol size distribution (10 nm-10 μm)
    - LDMA/RDMA, PCASP, giant nucleus impactor
  - size-resolved aerosol speciation
    - impactors, streakers, aerosol mass spectrometer
  - cloud condensation nucleus spectrum
  - ultrafine aerosol (CPCs)
  - cloud droplet residual aerosol chemistry (CVI)
  - bulk chemistry of cloud LWC
  - aerosol radiative properties (scattering/absorption)

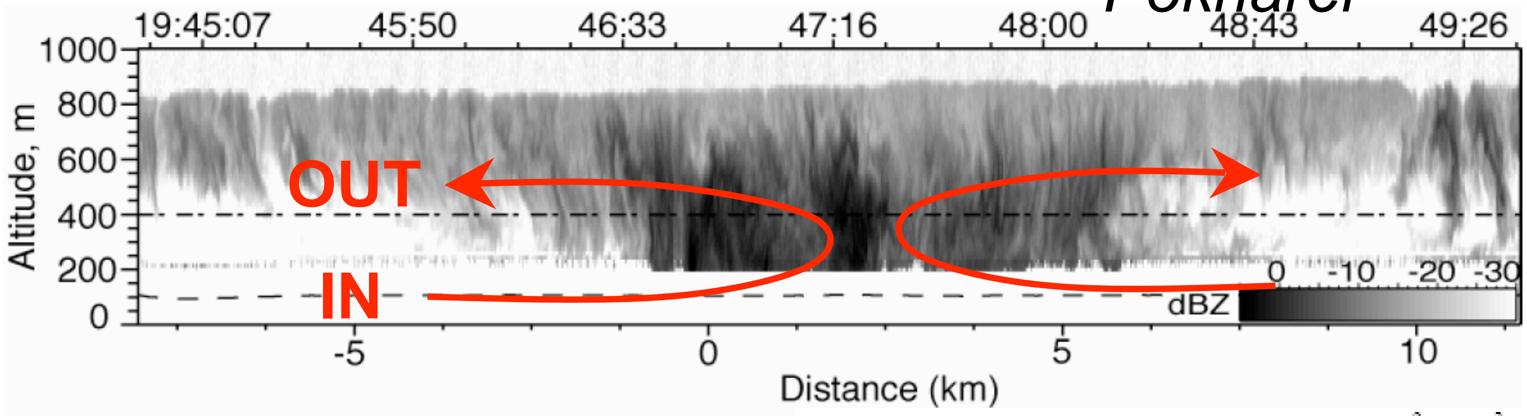
Chemistry?

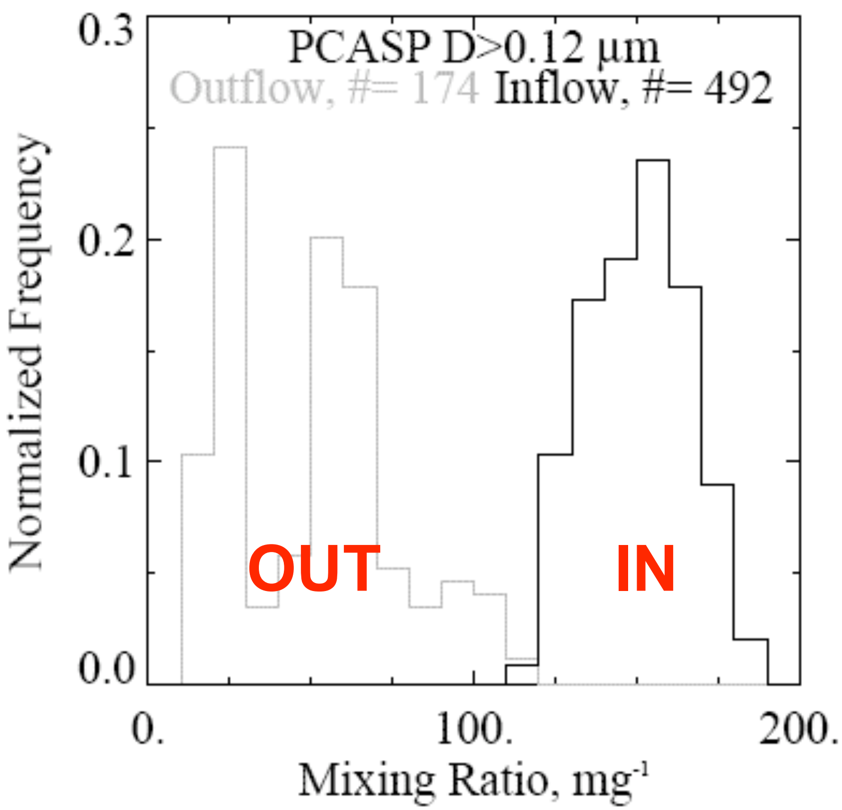


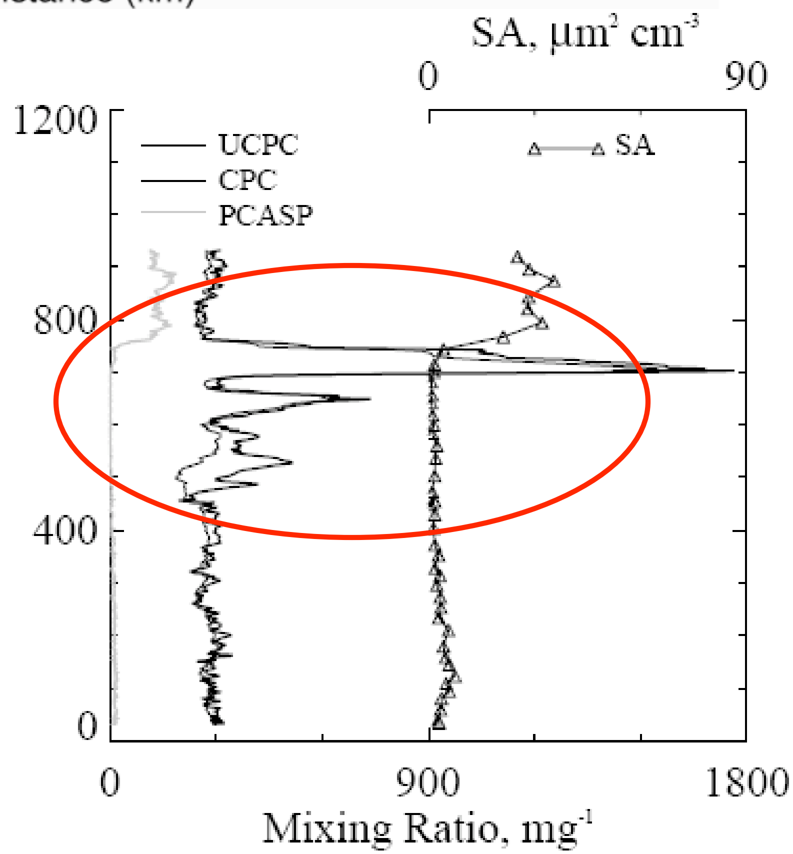
from Kollias et al. (2004)
measurements by
Don Collins, Texas A&M

Drizzle and aerosol processes

Snider and Pokharel







C-130 Measurables

- Gas phase chemistry:
  - – SO_2 and DMS concentrations at high frequency
  - – CO, fast O_3

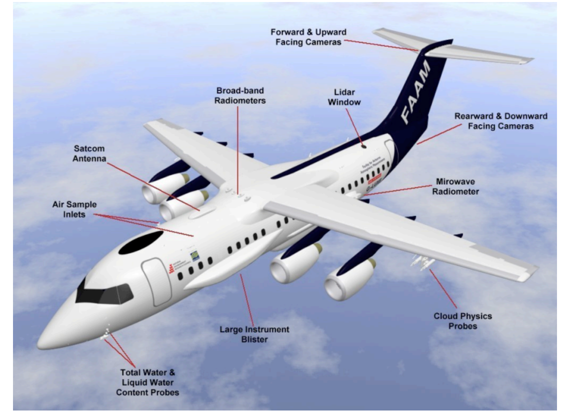
CIRPAS Twin Otter Payload

- **Standard instruments**: Microphysics (PDPA, FSSP, CIP), Turbulence, Thermodynamics suite
- **Remote sensing**: 94 GHz FMCW radar, chaff dispenser
- **Chemistry/aerosols/clouds**: PCASP, 2 CPCs, DMA/TDMA, CCN, SP2 (black carbon)
- **Towed platform (optional)**

DoE ASP G-1 Payload

- **Standard instruments**: Microphysics, Turbulence, Thermodynamics suite
- **Chemistry/aerosols/clouds**: Aerosol size distribution/conc (PCASP, FIMS, CPC), composition (PILS, ToF aerosol mass spectrometer), CCN, nephelometer, aethelometer, O_3, CO, SO_2, DMS/organics

FAAM BAe-146 payload



- **Standard instruments**: Microphysics, Turbulence, Thermodynamics suite
- **Remote sensing**: Microwave Radiometer (MARSS), Shortwave Spectrometer (SWS), Spectral Hemispheric Irradiance Measurement (SHIM), BBRs, Heiman, Airborne Research Interferometer Evaluation System (ARIES)
- **Chemistry/aerosols/clouds**: CCN, CPC, Aerosol mass spectrometer, SP2 (black carbon), filters, CVI, nephelometer (dry/wet), PSAP

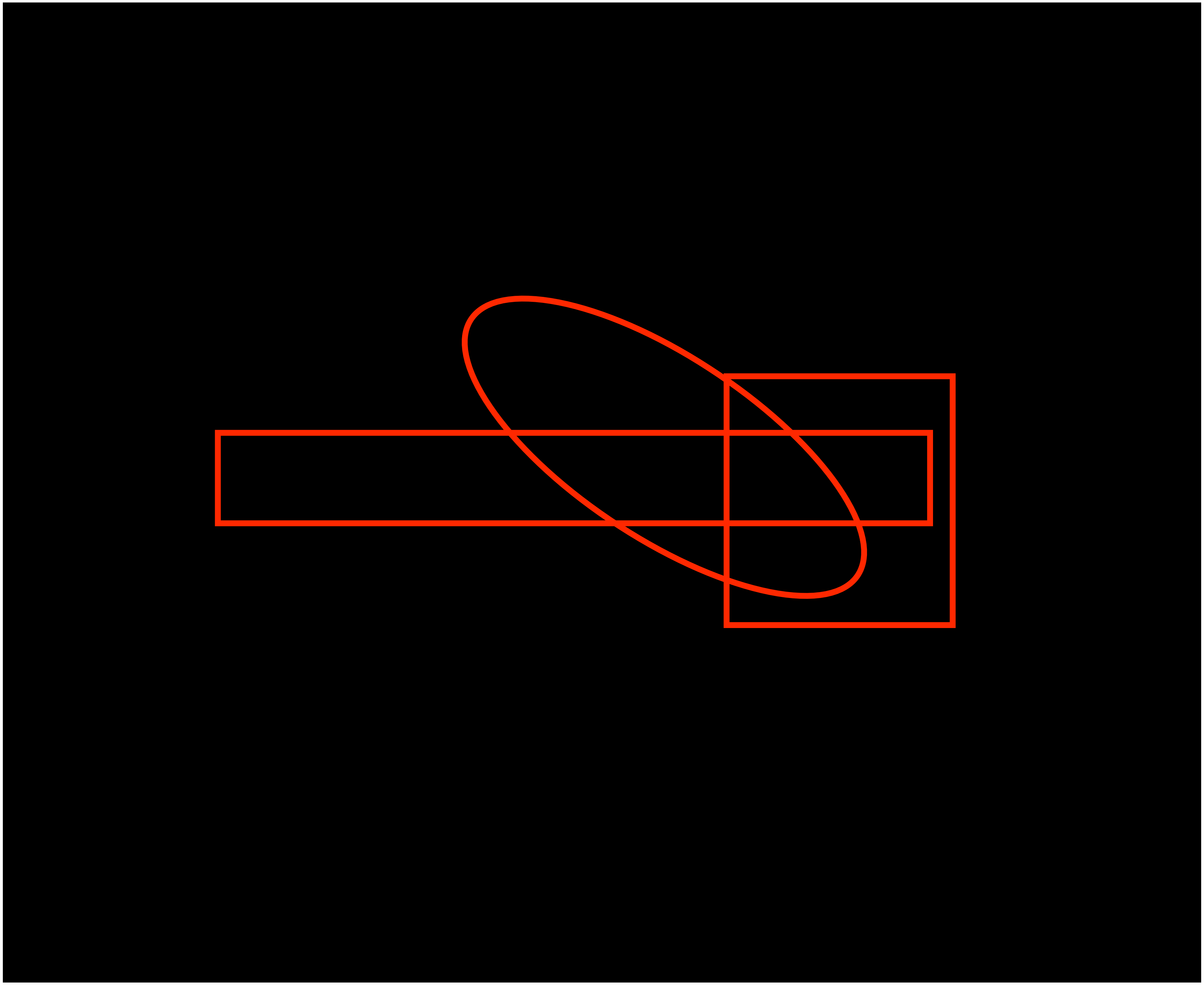
When will the C-130 deploy?

Nominally Oct 15- Nov 15

Mainly during Phase 2 of ship sampling (Oct 22-Nov 11)

More on aircraft payloads and plans in Breakout C, Tuesday 08:30-10:30

Flight Plans



Cross section flights

C-130 Cross-Section Sampling

- GOAL: Repeatable characterization of lower tropospheric structure, clouds, aerosols/chemistry, surface fluxes along 20°S
- Probably 5 flights with this plan
- Same time of day? Depart at 03 hr local, return 12 hr.

C-130 Cross-Section Sampling

below cloud: LWP, subcloud aerosol/chemistry, MBL turbulence, WCR, cloud base

in cloud: microphysics/turbulence/chemistry, WCR

above cloud: WCR, MASTER, FT aerosols

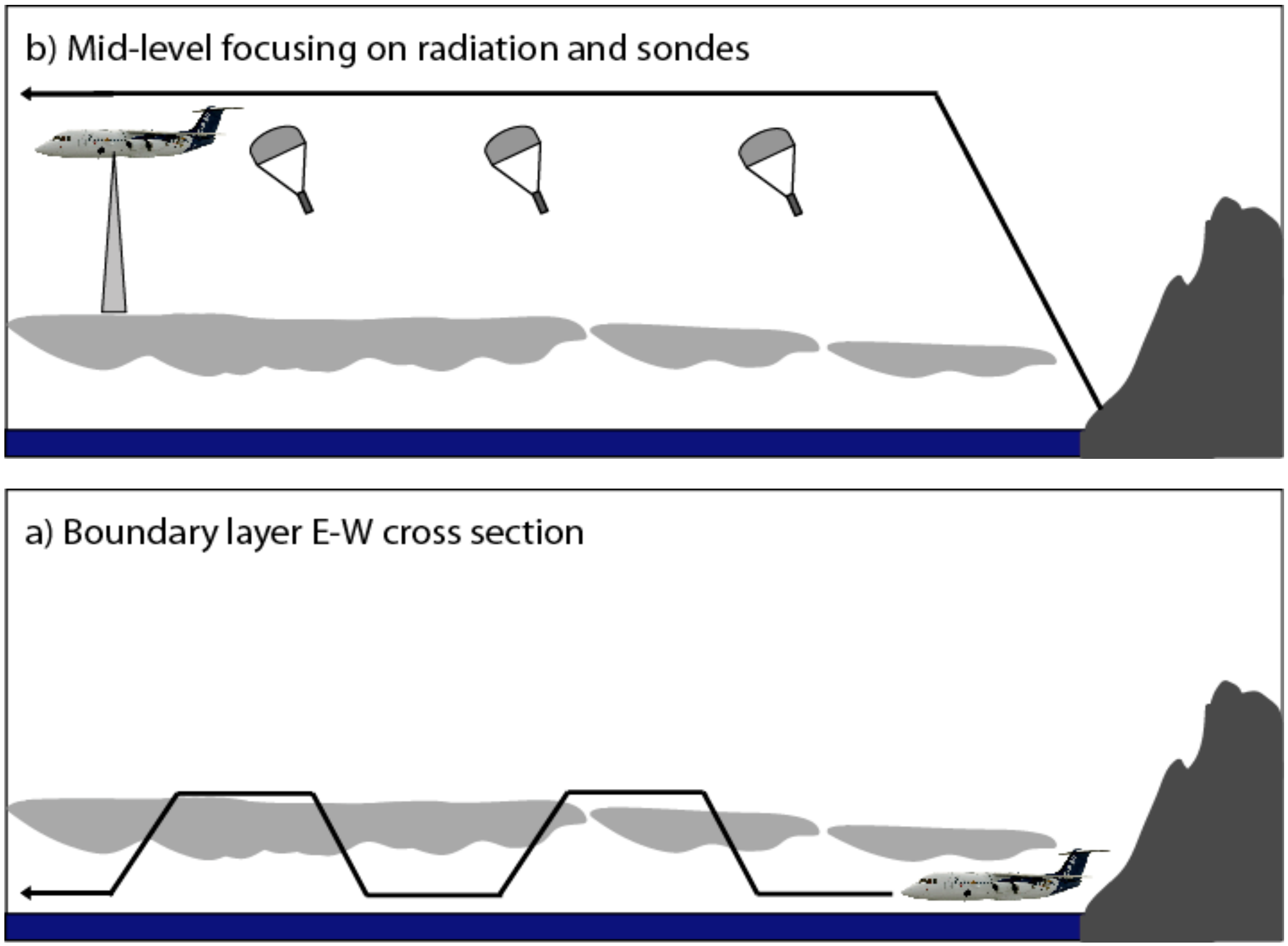
Cross-section flights

aerosol-cloud-precipitation hypothesis testing

- H1a – influence of aerosols upon precipitation
  - systematic evaluation of aerosol gradients and precipitation
- H1b – precipitation and POCs
  - do we see regions of open cells *without* drizzle?
- H1c – small r_e anthropogenic or natural?
  - in-situ and remotely sensed cloud microphysics and subcloud aerosol speciation and attribution

FAAM 146 Cross section

- Complement C130 measurements with focus on radiation (mid-level) and aerosol-cloud (low-level)



POC-drift flights

POC-Drift missions (C-130 + others)

below cloud: LWP, subcloud aerosol/chemistry, MBL turbulence, WCR, cloud base

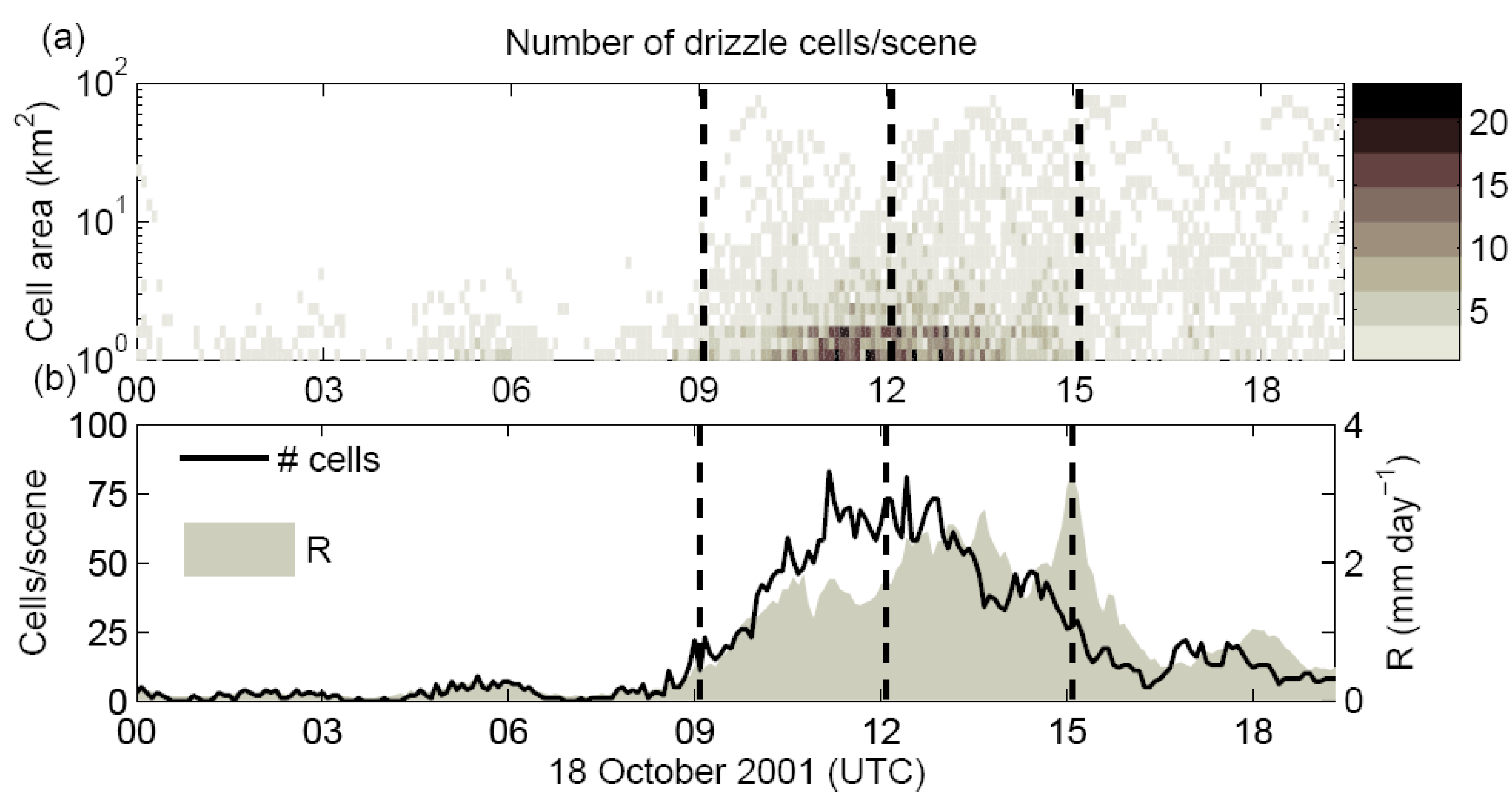
in cloud: microphysics/turbulence/chemistry, WCR

above cloud: WCR, MASTER, FT aerosols

POC-Drift missions (probably 4/5 flights)

- 100 km long runs (16 minutes) crossing boundary between open and closed cells, drift with the mean wind
- Three stacks: legs below cloud, cloud base, in cloud, cloud top, above cloud (100 mins including profile)
- Profiles after each stack at least 1 or 2 in clear sky if possible
- Synergy with ship
- Multi-flight, multi-aircraft sampling (Lagrangian), possible RHB synergy
- Some during day, some night

Prolific production of drizzle cells at boundary between closed and open cellular structure



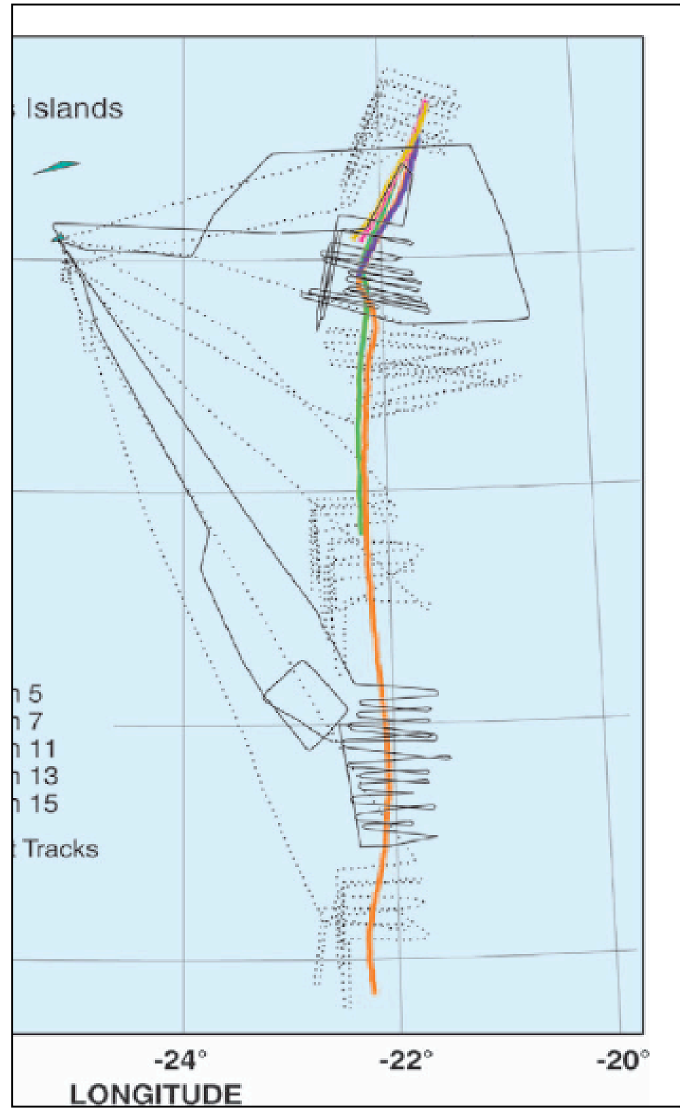
Closed cellular← Transition →Open cellular

Comstock et al. (2007)

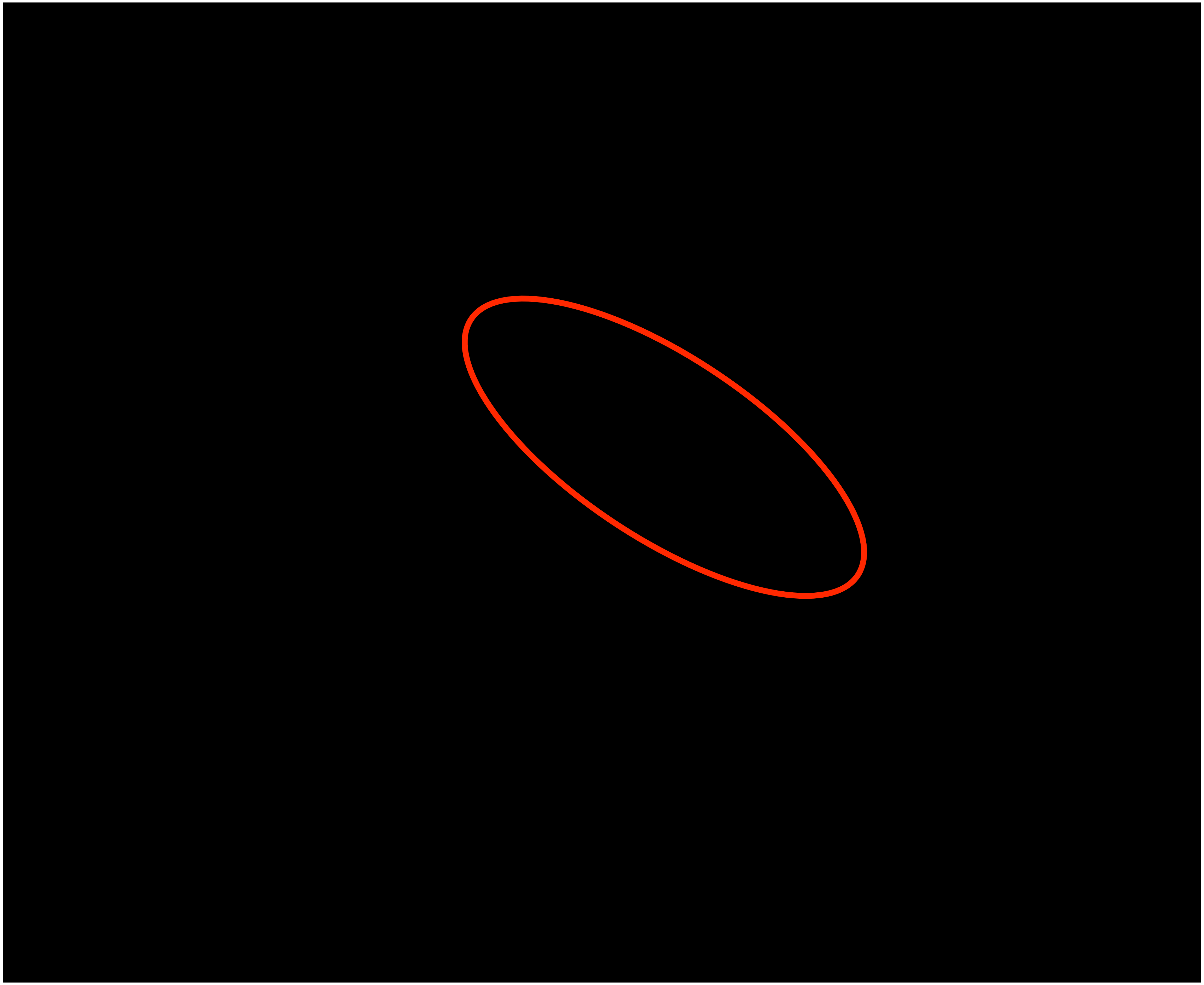
Strawman: multi-flight Lagrangian

- Daily pattern modeled on POCs-drift mission
- Track airmass using satellites (POCs) and model trajectories
- e.g. Night: C-130 ⇒ Day: G-1 or 146 ⇒ Night C-130

- Can track POCs or evolution of polluted MBL



ASTEX Lagrangian 2, Azores, 1992 (Businger et al. 20



POC-drift/lagrangian flights
aerosol-cloud-precipitation hypothesis testing

- H1a – influence of aerosols upon precipitation
  - quantification of aerosol and precipitation characteristics across POC boundary
- H1b – precipitation and POCs
  - detailed mesoscale structure and dynamics of precipitating stratocumulus
- H1c – small r_e anthropogenic or natural?
  - in-situ and remotely sensed cloud microphysics and subcloud aerosol speciation and attribution
  - lagrangian evolution of entrained air
- H1d – coal. scavenging needed to maintain POCs
  - evolution/budgets of aerosol distribution in and near POCs

Hypothetical C-130 flight calendar

- Oct 15-18, 3 test flights (**daytime**) [12]
- Oct 19-25, **day flights**, 1 POC drift, 1 polluted lagrangian (2 flights) [27]
- Oct 26-31, **night flights**, 3 X-section flights [27]
- Nov 1-Nov 7, **day flights**, 2 POC drift [18]
- Nov 7-Nov 15, **night flights,**
  2 cross section flights, 1 POC drift, 1 SST [36]

TOTAL HOURS: 120

Coastal Airborne Sampling

- Exploration of gradients in cloud microphysical properties
- **MORE in BREAKOUT GROUP C from**
  - **Bruce Albrecht (Twin Otter)**
  - **Pete Daum (G-1)**
  - **Steve Abel (FAAM 146)**

Synergy between platforms

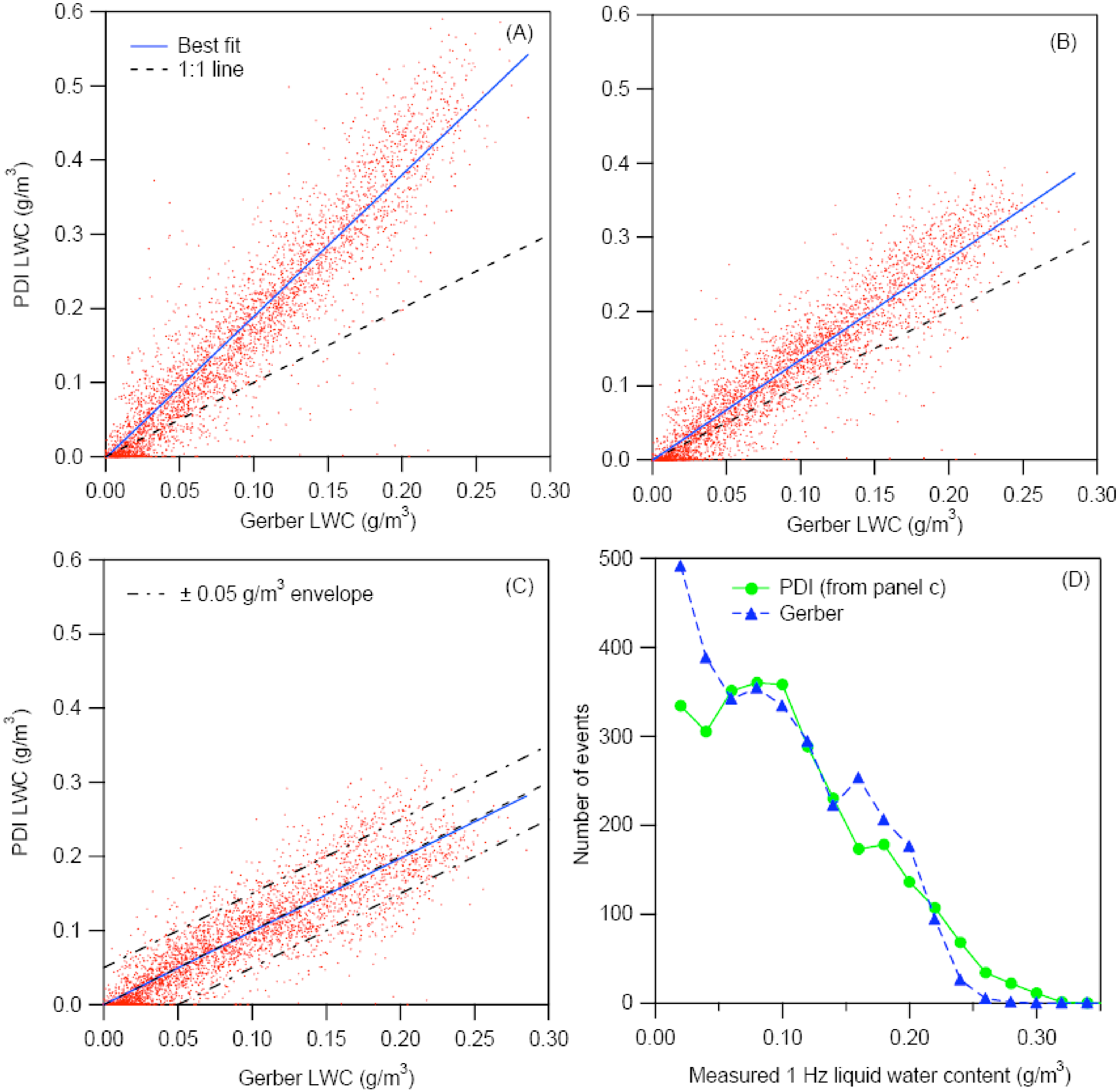
- Cross section
- Lagrangians
- Aircraft-aircraft intercomparisons
- C-130 cross section near coastal sampling

RHB/C-130 Co-sampling
During POC-drift and Cross-section missions

Additional slides

Aircraft sampling along POC boundaries

- Aircraft sampling is needed within transition region between closed and open cellular regions
- EPIC Sc data showed that transition region has
  - Prolific drizzle cell development (number of small drizzle cells increases by a factor of 5)
  - Highest rain rates preferentially occur within transition region
- Need detailed joint microphysics, aerosol and kinematic measurements within transition region to untangle feedbacks



Comparisons of PDI and Gerber derived LWC.

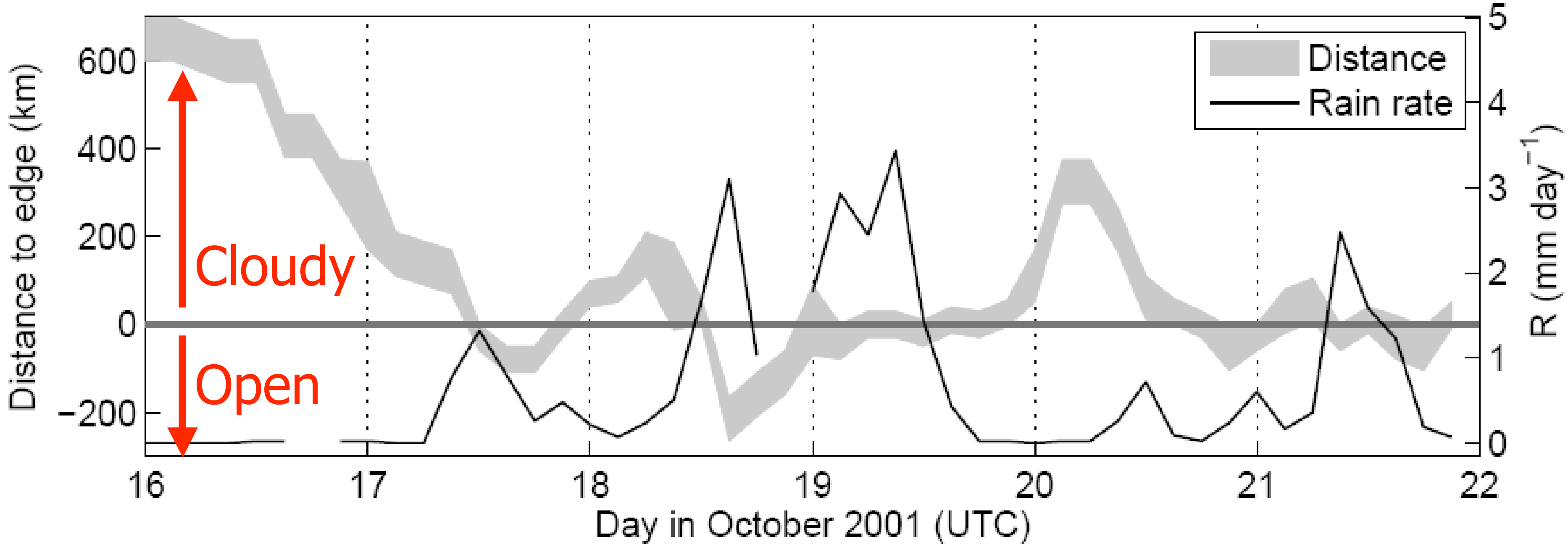
(A) No roll-off correction applied to Gerber data.

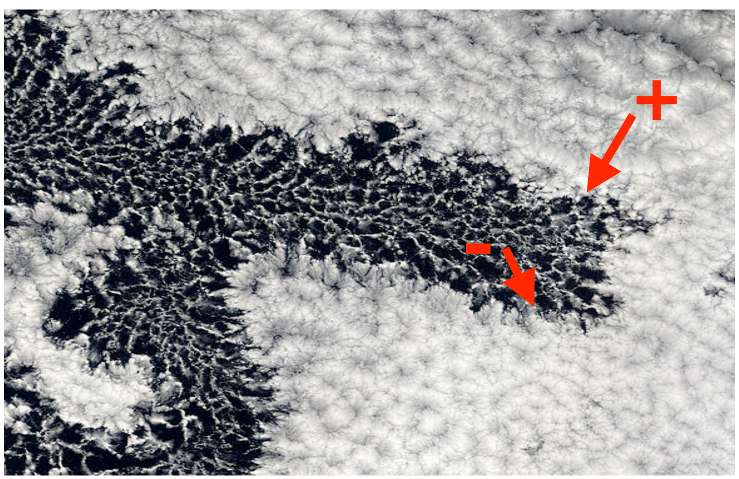
(B) Normal roll-off correction.

(C) Roll-off shifted by 7 um (towards smaller sizes)

(D) PDF of 1 Hz LWC data during MASE.

Rain rates and transitions

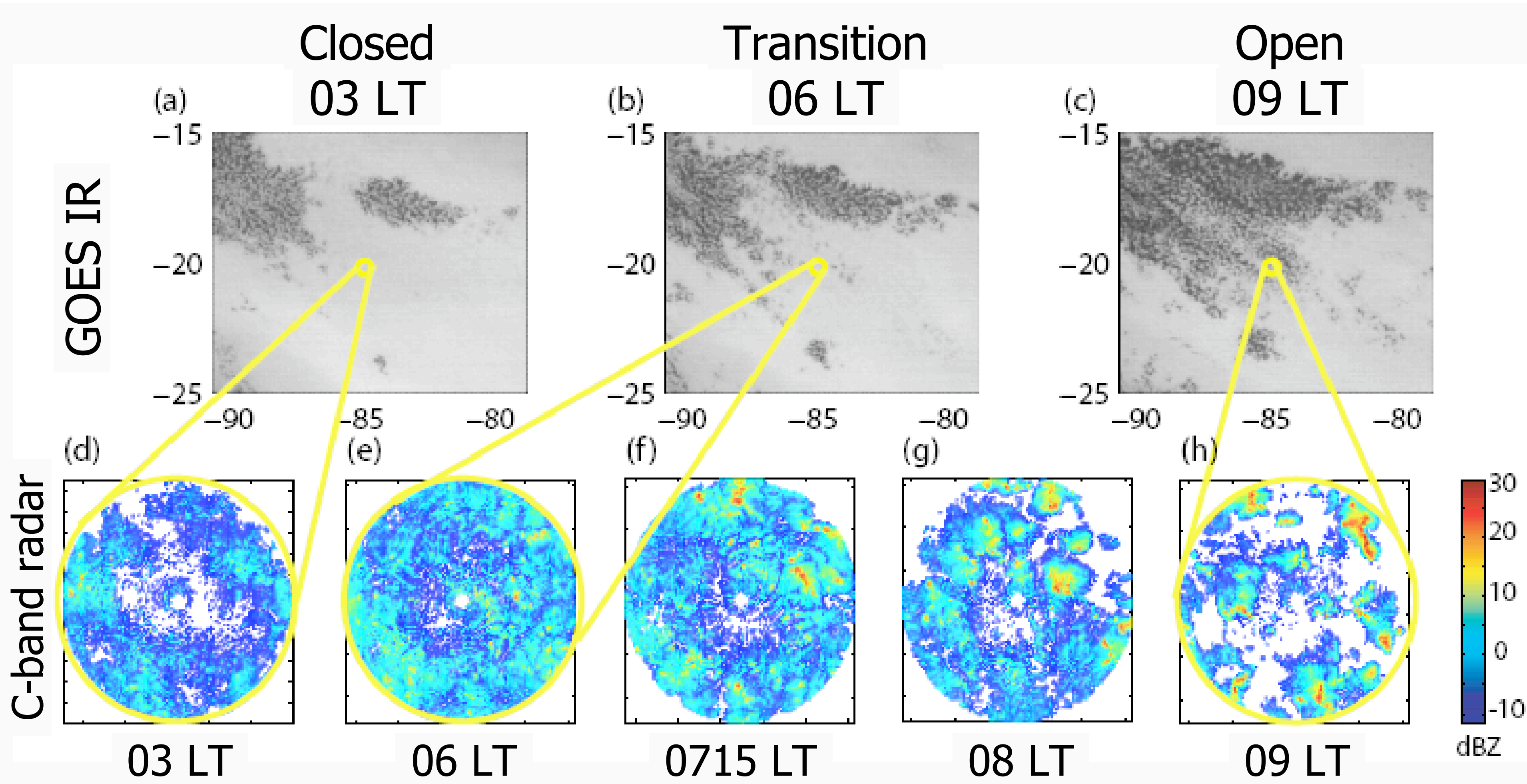




Comstock et al. (2007)

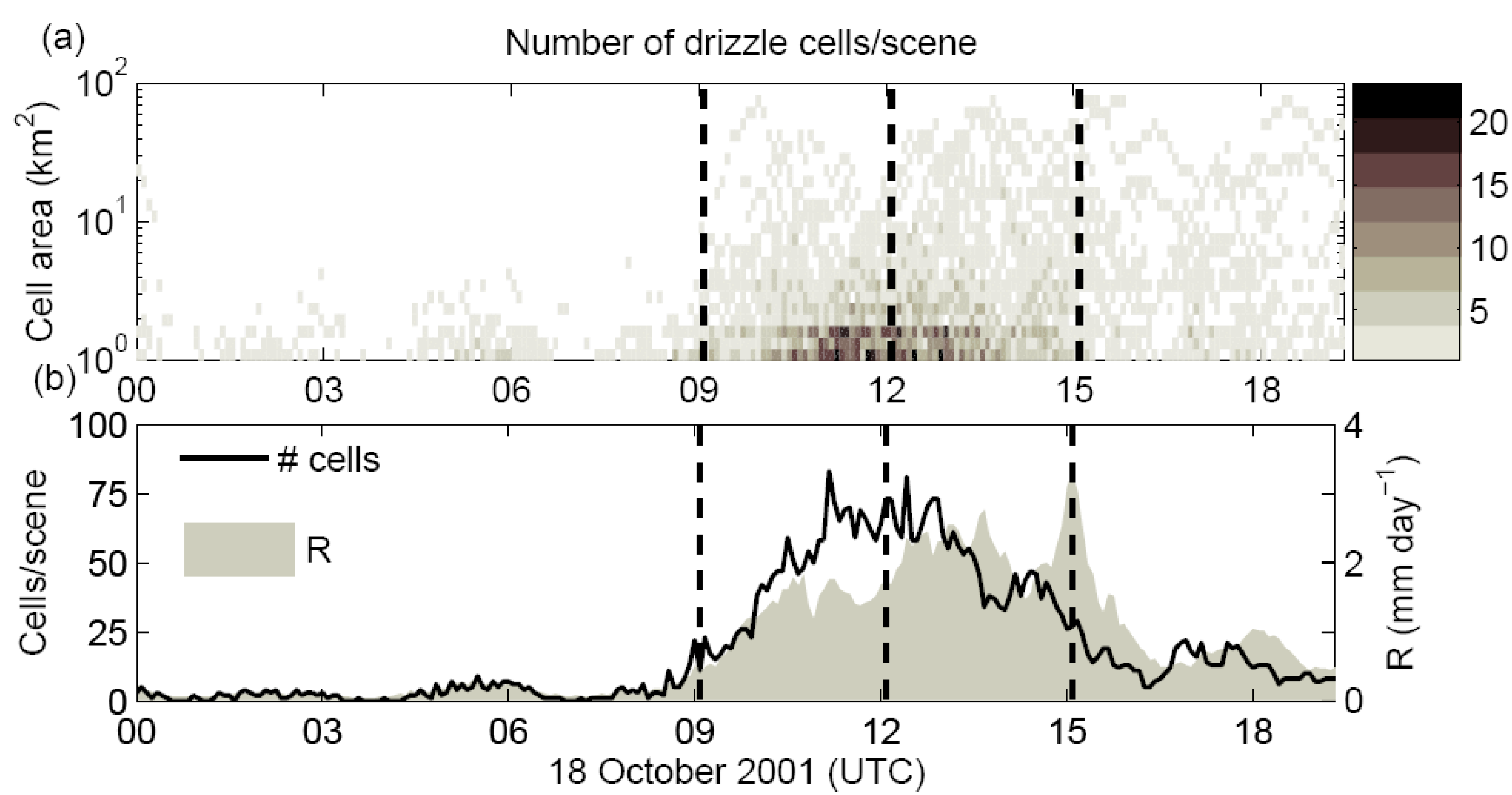
Positive distance = cloudy
Negative distance = open-cellular

Transition: Closed to open-cellular



Comstock et al. (2007)

Prolific production of drizzle cells at boundary between closed and open cellular structure



Closed cellular← Transition →Open cellular

Comstock et al. (2007)

Additional slides

VOCALS—CIRPAS Twin Otter

Instrument	**Observations/Purpose**
Standard met	Winds, temp, dewpoint, cloud liquid water, sfc temp, turbulence
Towed-Platform (Optional)	Turbulence near surface
94 GHz Doppler FMCW radar	Cloud properties; in -cloud turbulence
Chaff Dispenser (with radar)	Track air movements — entrainment, sub -cloud cloud layer coupling, large eddies
CPCs	Ultrafine aerosols
PCASP	Aerosols 0.1 -3 _m
FSSP	Clouds 2 -40 _m
CIP	Drizzle 25 -1500 _m
DMA/TDMA (?)	Aerosols, hygroscopicity
N-Mass	5 channel CN, fast response
CCN-200	CCN (fast -2-point; slow -6 points)
Phased Doppler Interferometer	Cloud -drizzle 2 -600 _m
SP2-Black Carbon	BC mass and ratio to total particles