ARM/GCSS/SPARC TWP-ICE CRM Study

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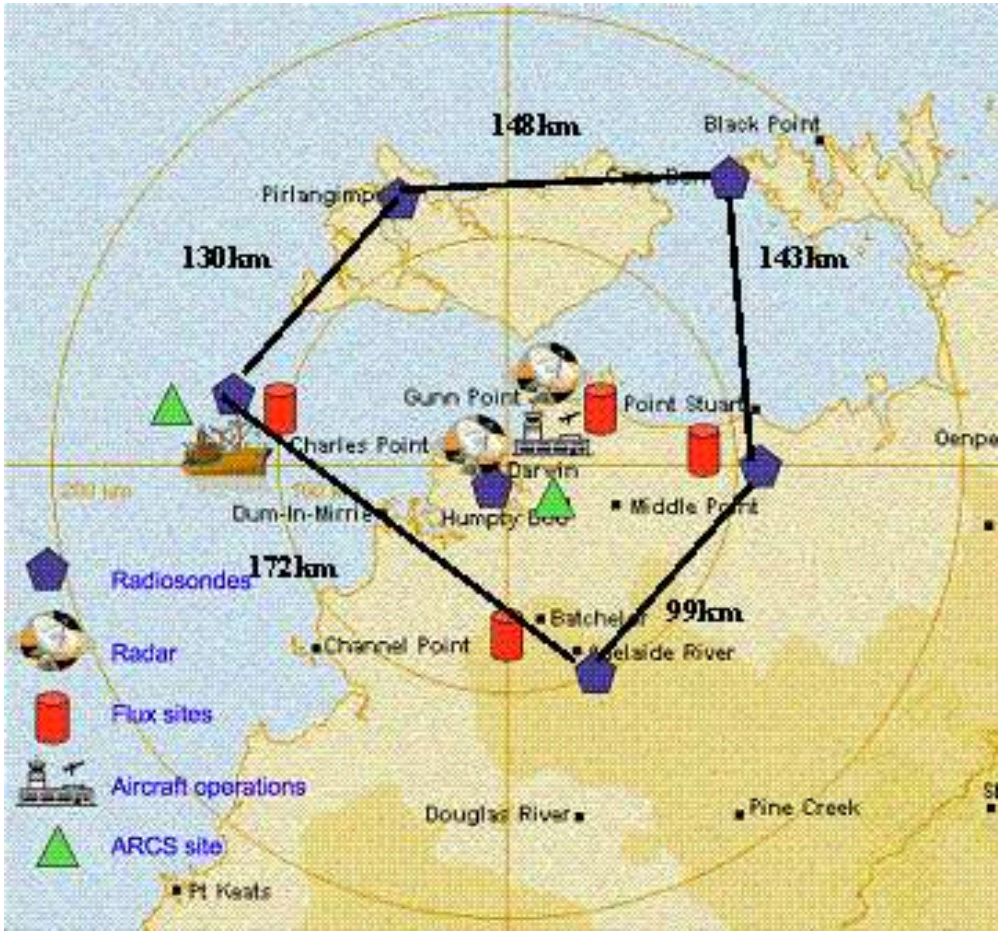
Dave Turner • University of Wisconsin
Guosheng Liu • Florida State University

Cloud Modeling Working Group Meeting • 20 November 2008

Experiment domain

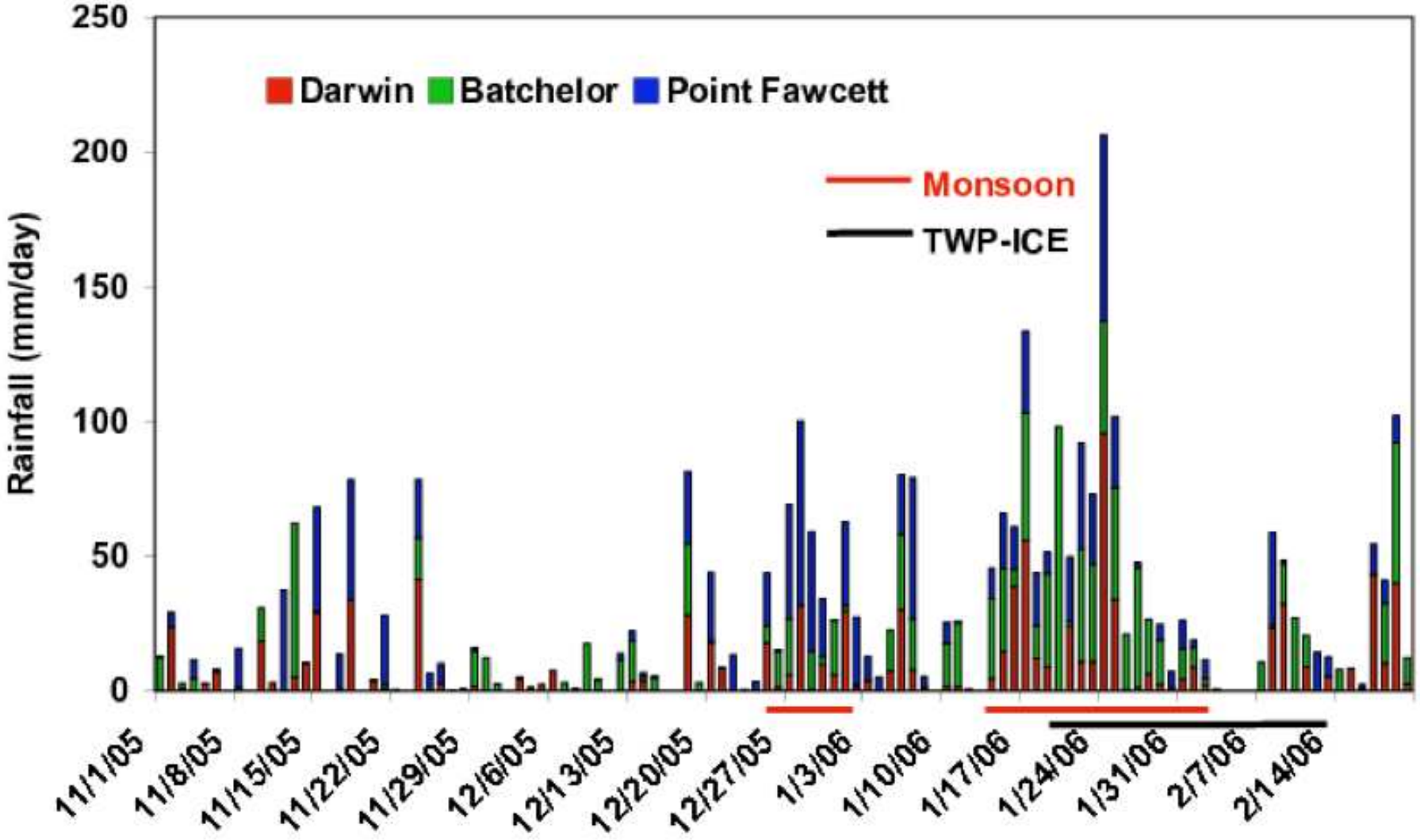


Source: *Shaocheng Xie, LLNL*

Experiment goals

- make detailed measurements of cirrus microphysics and their relationship to storm structure and intensity
- characterize and document evolution
  - microphysical properties
  - large-scale environment
  - convective boundary layer
  - dynamical and radiative impacts
- verify remote-sensing data
- provide data for forcing models

Conditions encountered



Source: *Lori Chappel, Australian BOM*

Model intercomparison studies

- interlocking studies - Jon Petch
  - Global Energy and Water cycle EXperiment (GEWEX) Cloud System Study (GCSS) - Precipitating Cloud Systems
  - Stratospheric Processes And their Role in Climate (SPARC)
- cloud-resolving models (CRMs) - Ann Fridlind
  - 16 days
- single-column models (SCMs) - Christian Jakob/Laura Davies
  - 26 days
- limited-area models (LAMs) - Maria Russo
  - several days

CRM study goals

- evaluate models
  - simulations and data agree?
  - data sufficient to evaluate models?
  - additional data needed?
  - methodology sufficient?
- quantify convective transport to the tropopause
  - CRM predictions consistent with measurements and theory?
  - temporal and spatial characteristics of vertical mass transport?
  - influence on water vapor near the tropopause?
  - primary uncertainties in simulations and data?

CRM study participants

- Ann Fridlind, NASA GISS
- Jon Petch, UK MetOffice
- Wojtek Grabowski, NCAR
- Yi Wang, PNNL
- Xiaohong Liu, PNNL
- Charles Seman, GFDL
- Annica Ekman, Stockholm University
- Axel Seifert, German Weather Service
- Virginie Marécal, University of Orléans/CNRS
- Jean-Pierre Chaboureau, University of Toulouse/CNRS

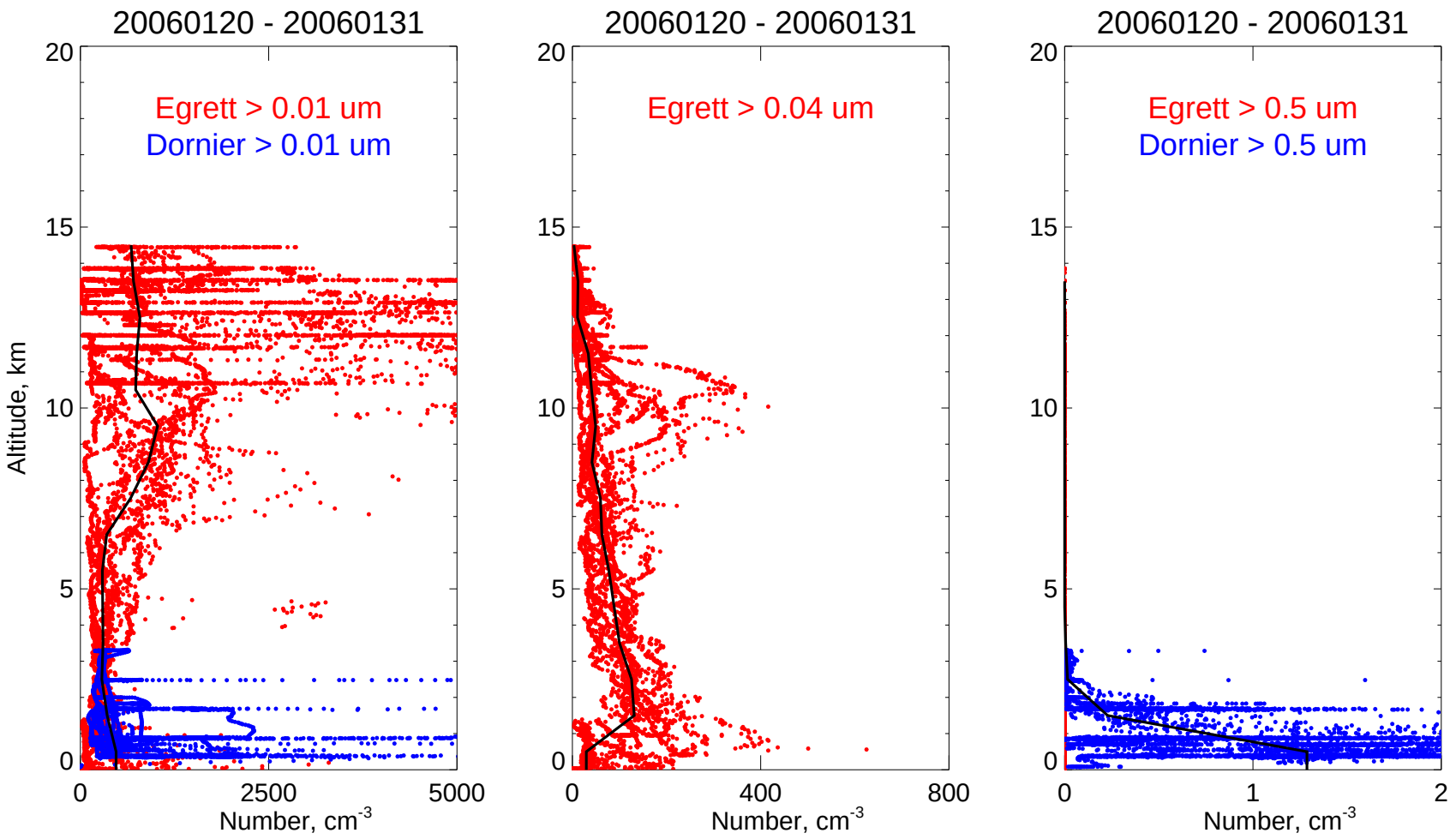
GISS simulations

- general
  - horizontal domain size = 176 x 176 km (or 72 x 72 km)
  - periodic boundary conditions (idealized marine)
  - fixed SST = 29°C
  - interactive surface fluxes
  - large-scale forcings from variational analysis
  - baseline and sensitivity test
    - nudge Θ, water vapor at $Z > 13$–15 km, $\tau = 6$ h
    - nudge at $Z > 0.5$–1 km, $\tau = 6$ h
- example
  - vertical domain size = 24 km
  - horizontal grid = 1 km (or 125 m)
  - vertical grid = 100–250 m (or 62.5–125 m)
  - bulk microphysics (Grabowski, 1999)
    = cloud liquid, rain, fluffy ice, dense ice
  - 2-stream radiative transfer, 44 bands, size-resolved Mie

Aerosol specification

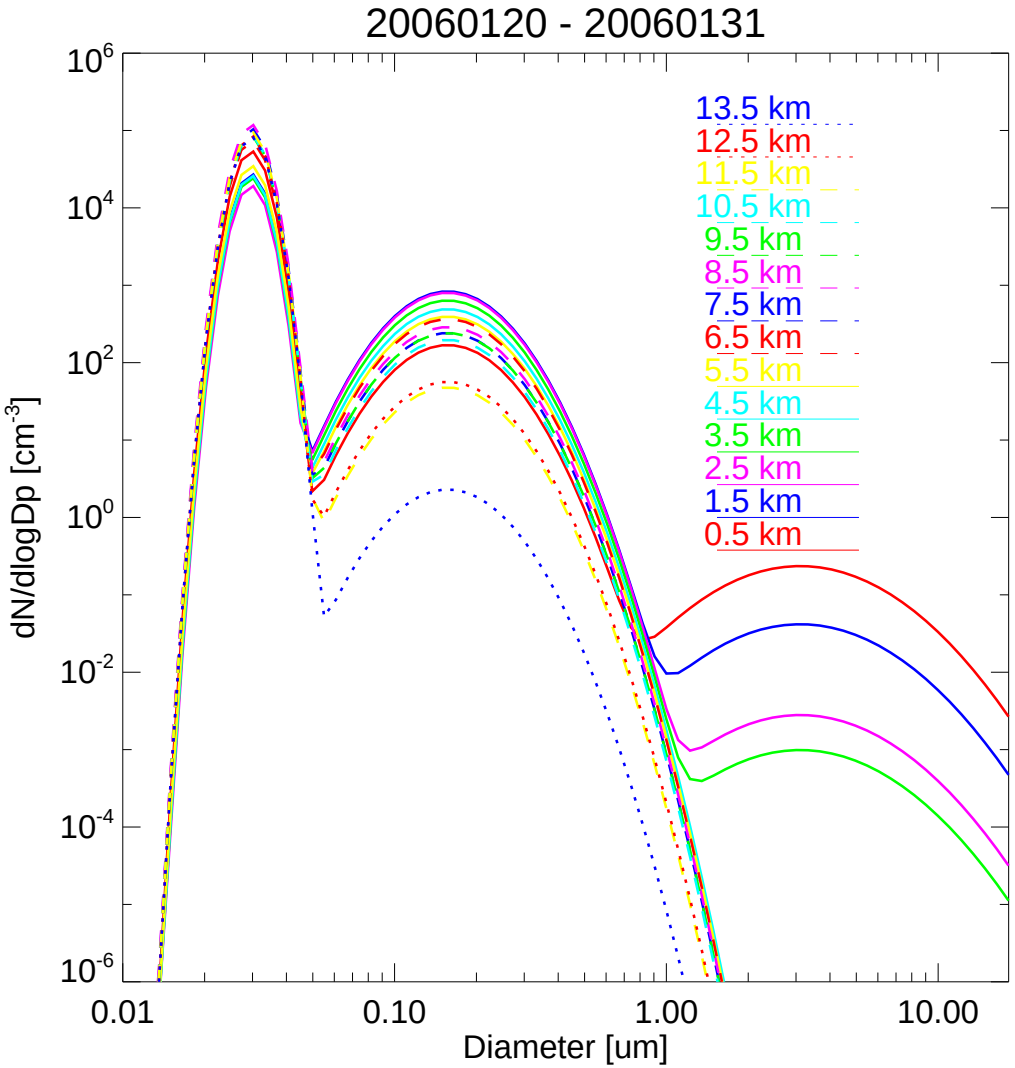
- Aerosol and Chemical Transport in tropIcal conVEction (ACTIVE)
  - funded by the UK Natural Environment Research Council
  - http://cloudbase.phy.umist.ac.uk/field/active
- bulk mass composition [*Allen et al., 2008*]
  - 80% ammonium sulfate
  - 20% organics
- number size distribution profiles
  - three lognormal modes [*Allen et al., 2008*]
    - diameter = 0.03, 0.18, 4.4 microns
    - standard deviation = 1.12, 1.45, 1.8
  - profiles of number concentration in each mode
    - http://www.giss.nasa.gov/~fridlind/twp-ice/setup
- no ice nucleus measurements

Number concentration profiles



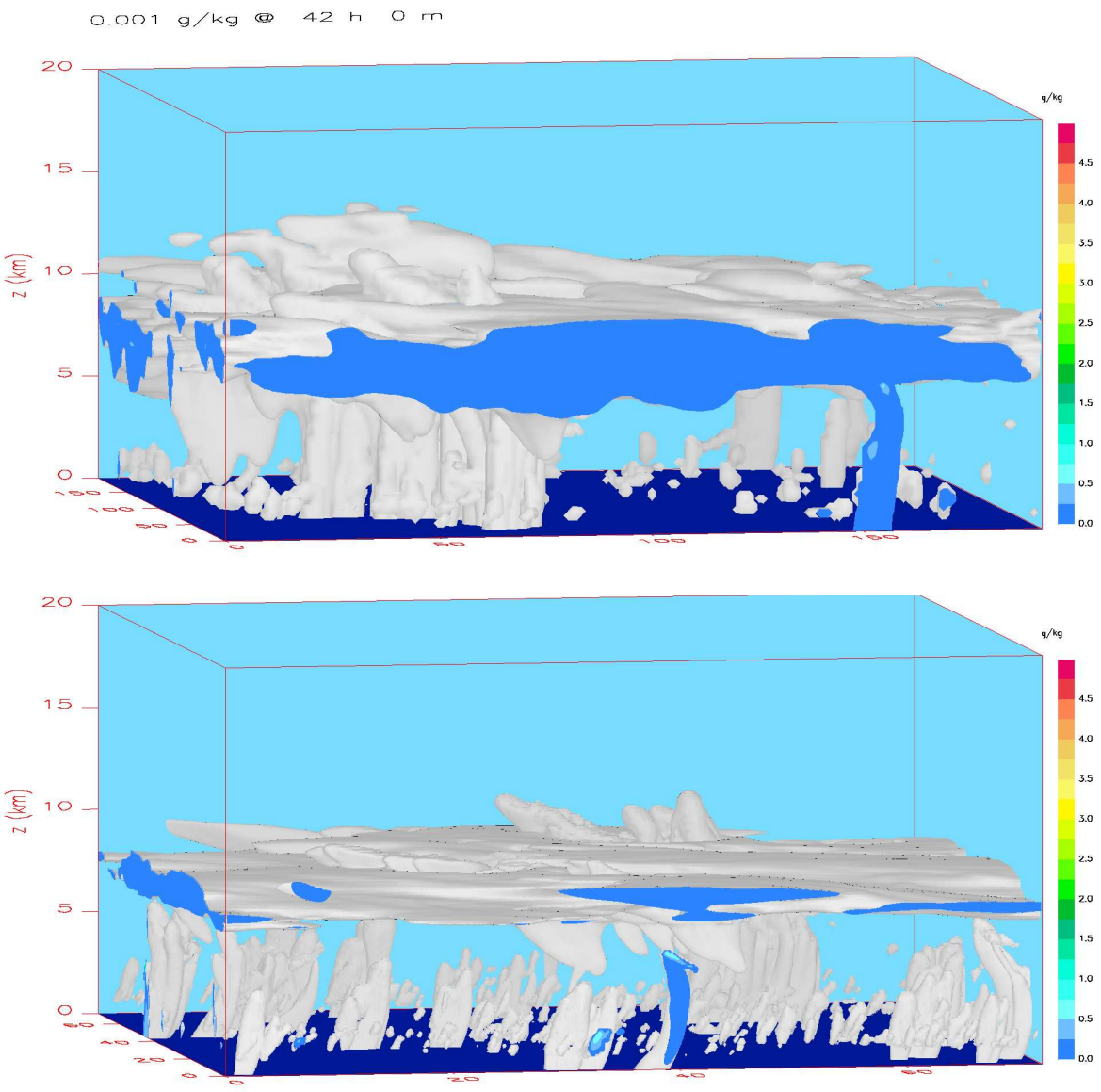
Data: *Martin Gallagher, Paul Williams, Andrew Heymsfield, Aaron Bansemer*

Number size distribution profiles

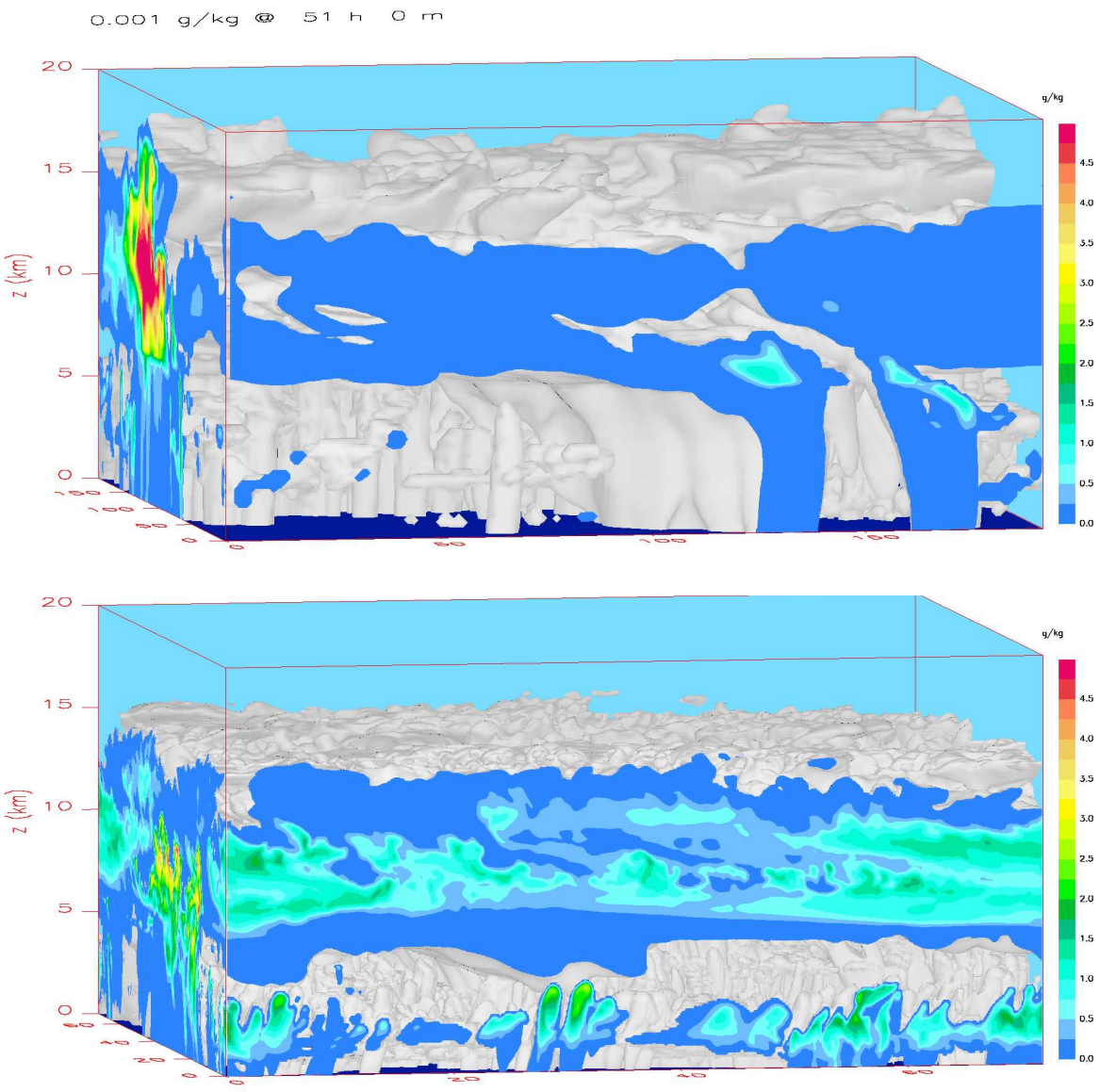


Data: *Martin Gallagher, Paul Williams, Grant Allen*

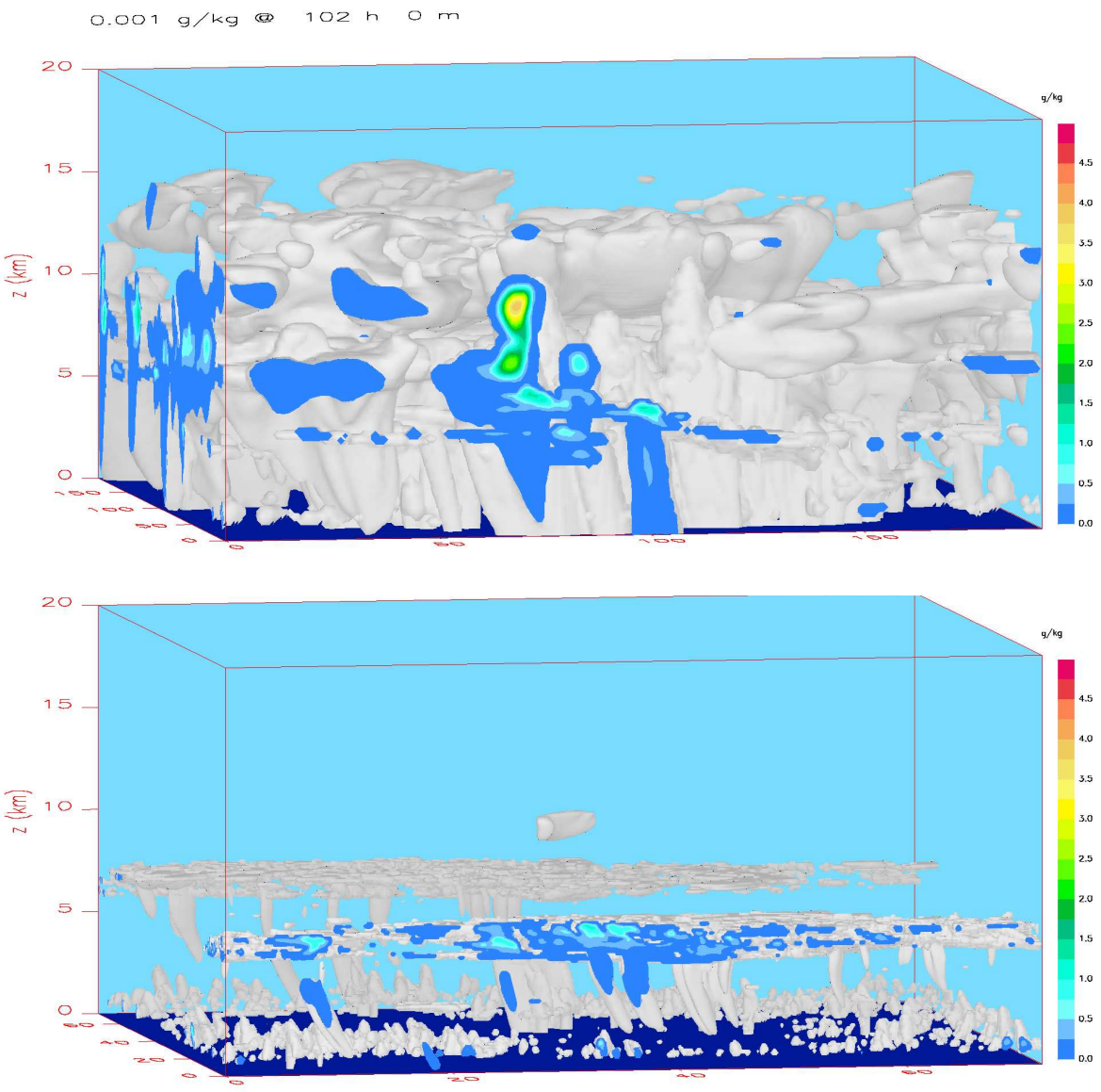
Cloud isosurfaces



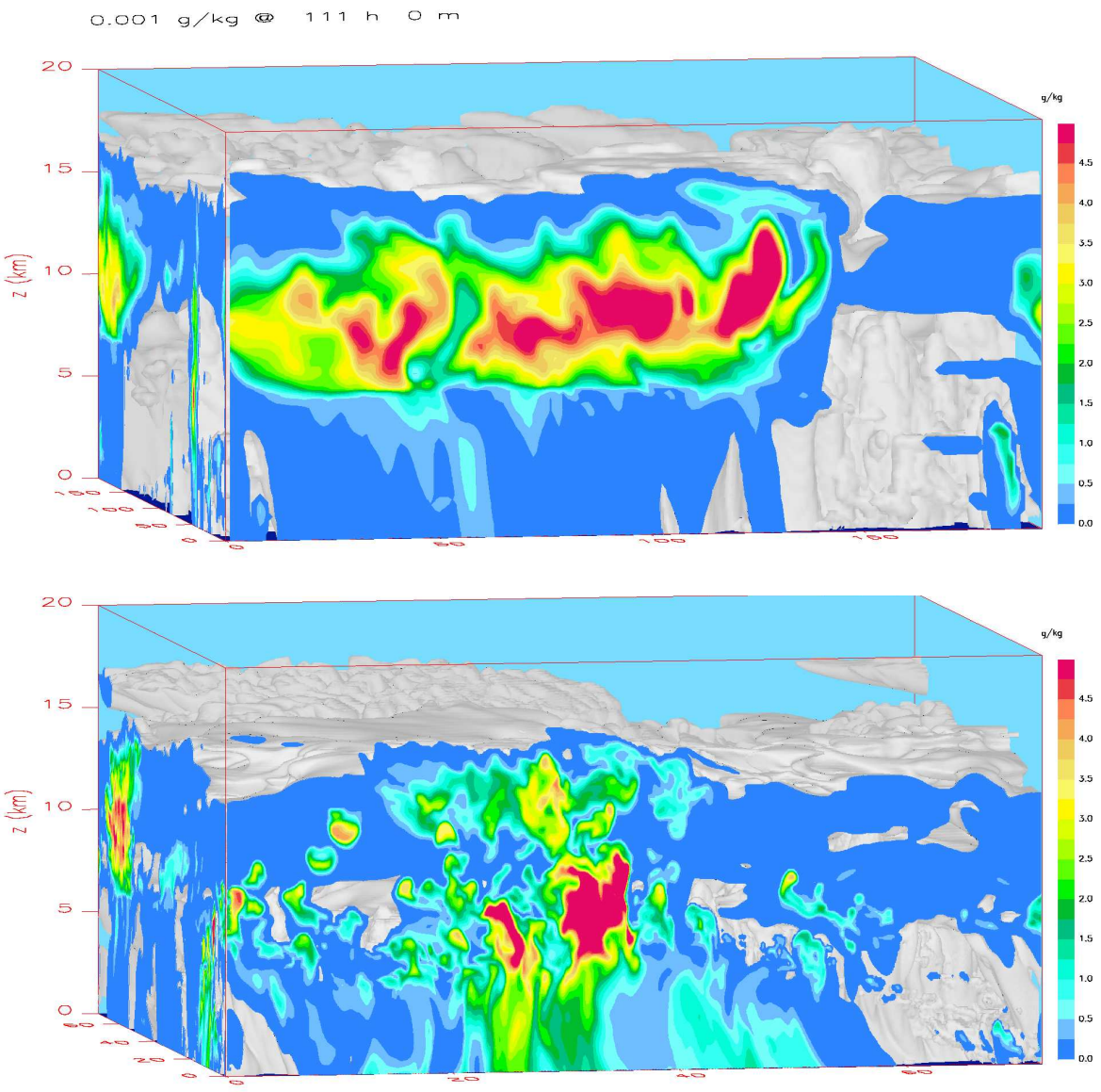
Cloud isosurfaces



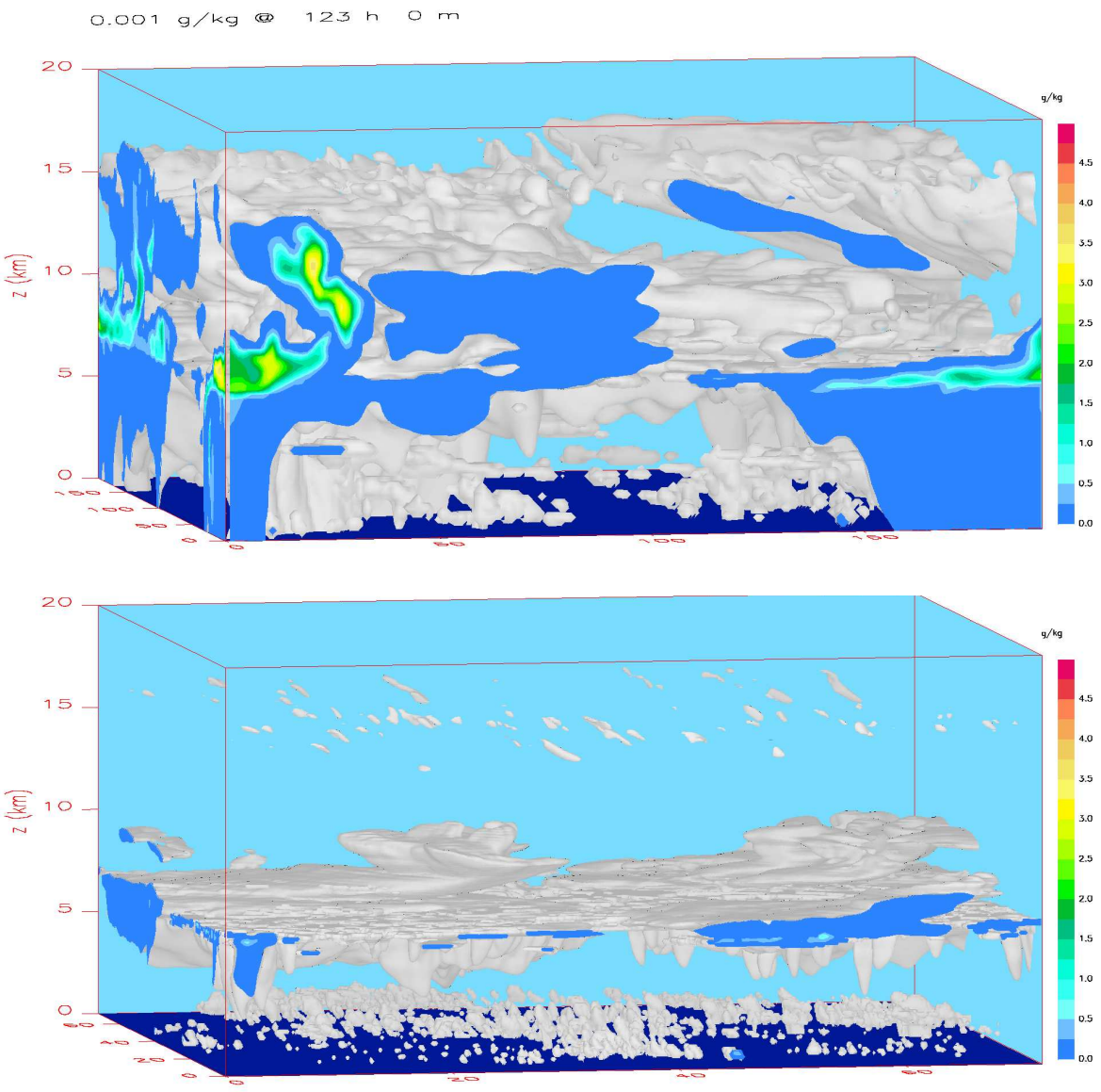
Cloud isosurfaces



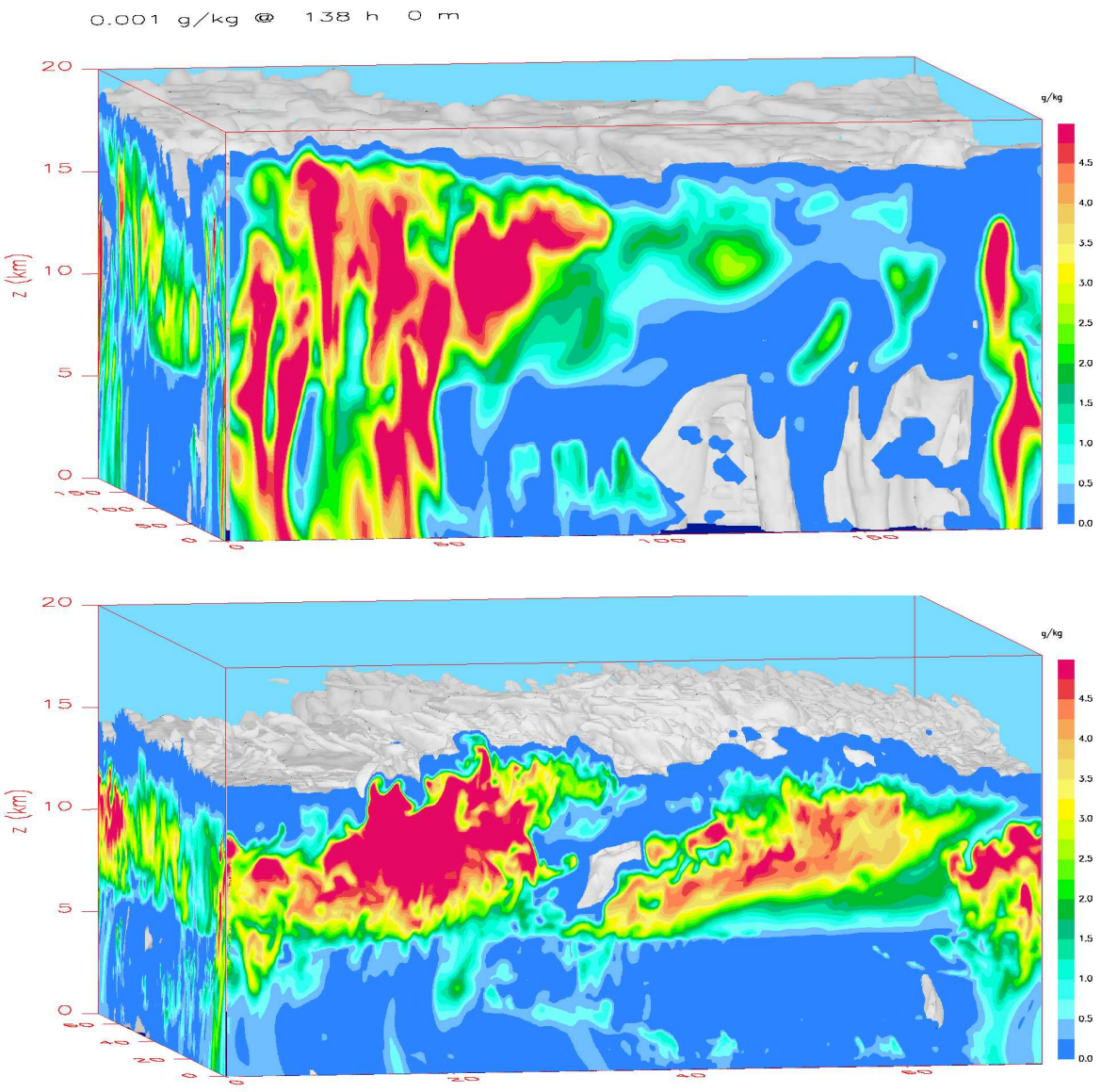
Cloud isosurfaces



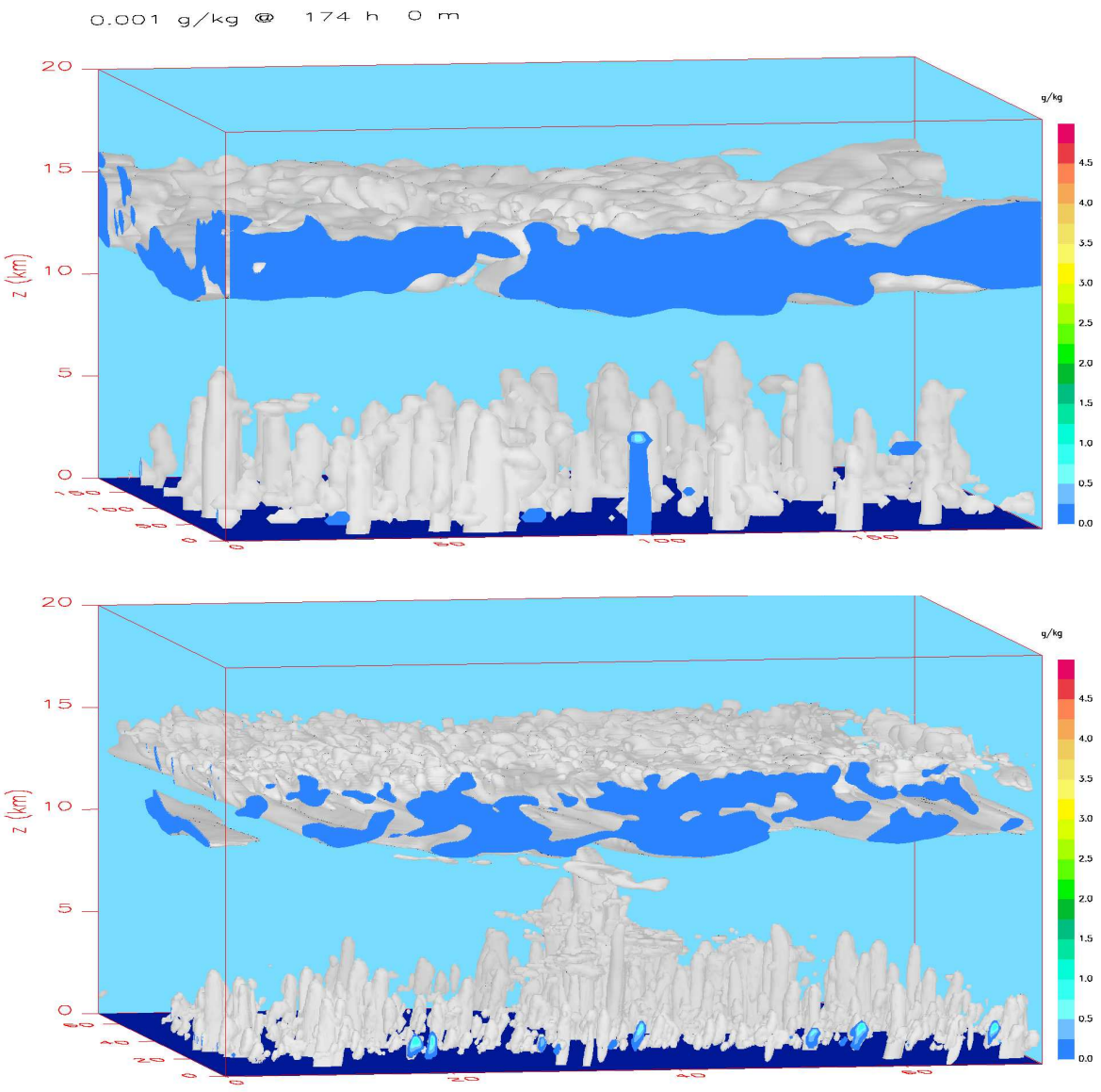
Cloud isosurfaces



Cloud isosurfaces



Cloud isosurfaces



Data constraints on model performance

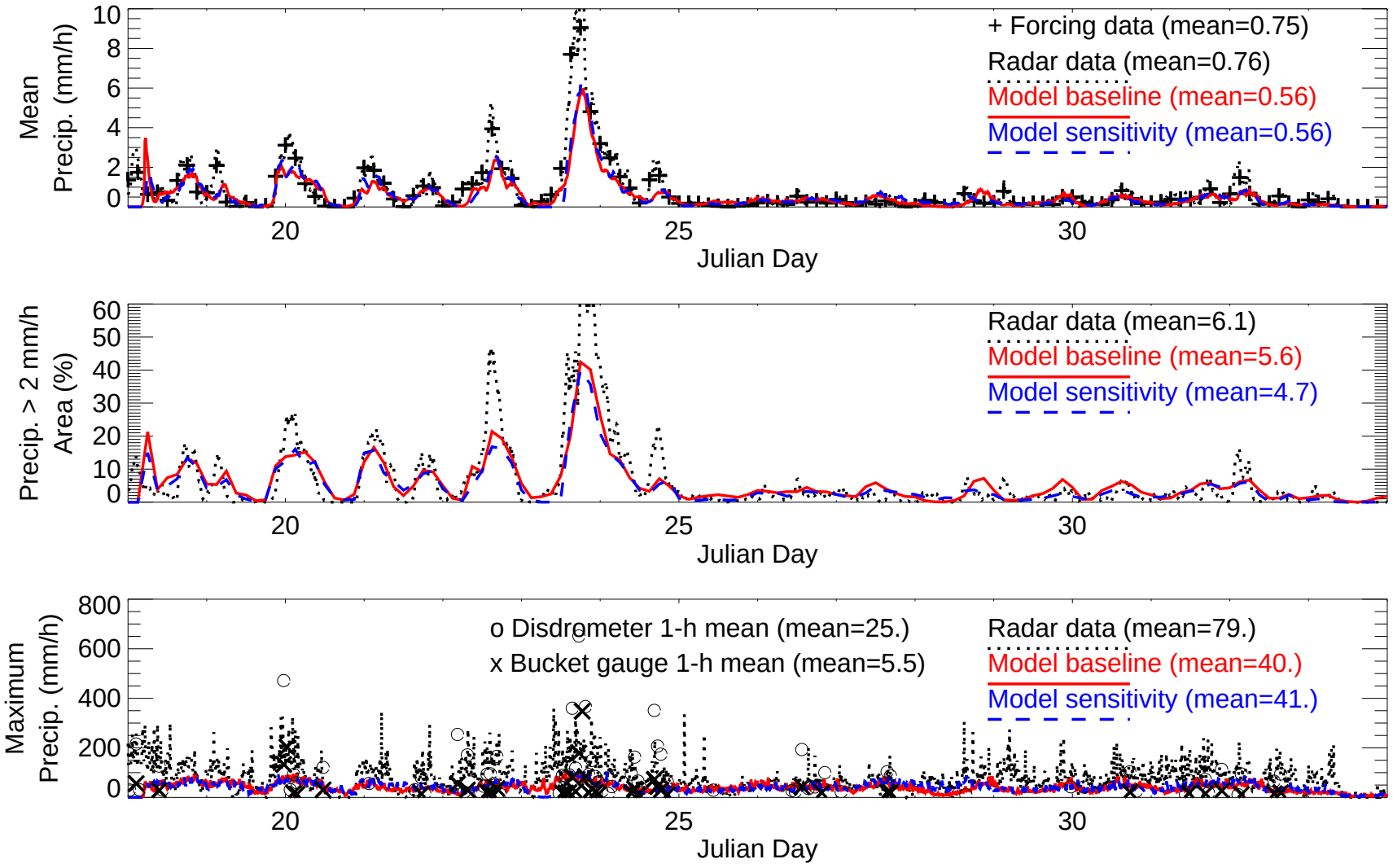
Physical Variable	Data Set (PI)
Precipitation rate	C-pol (May), disdrometer and buckets (Williams)
Liquid water content	disdrometer, TCPRHP (McFarlane/Mather)
Liquid water path	MWR (Turner), TCPRHP
Ice water content	TCPRHP, 3D-Ice (Liu)
Ice water path	VISST (Minnis), TCPRHP, 3D-Ice
Total condensate content	CSI (McFarquhar)
Total condensate path	MODIS
Water vapor	sondes (Jakob/Hume), in situ (Whiteway, Hacker)
Cloud base height	ARSCL, VISST (Minnis)
Cloud top height	ARSCL, VISST
Cloud fraction	TSI (Morris), SFA (Long), MODIS
Radar reflectivity	C-pol, S-band (Williams), disdrometer
Doppler velocity	S-band, disdrometer

Data constraints on model performance

Physical Variable	Data Set (PI)
Particle number	CIP (McFarquhar)
Particle area	CIP (McFarquhar)
Particle size	C-pol, disdrometer, TCPRHP, VISST, MODIS
Cloud optical depth	TCPRHP, VISST, MODIS
SFC broadband flux	TCPRHP, SKYRAD/GNDRAD
TOA broadband flux	TCPRHP, VISST
Column absorption	TCPRHP
Broadband flux profile	aircraft (McCoy), TCPRHP
Broadband heating rate profile	TCPRHP
Latent heating rate profile	C-pol (Schumacher)
Surface SH and LH fluxes	eddy-correlation (Beringer)

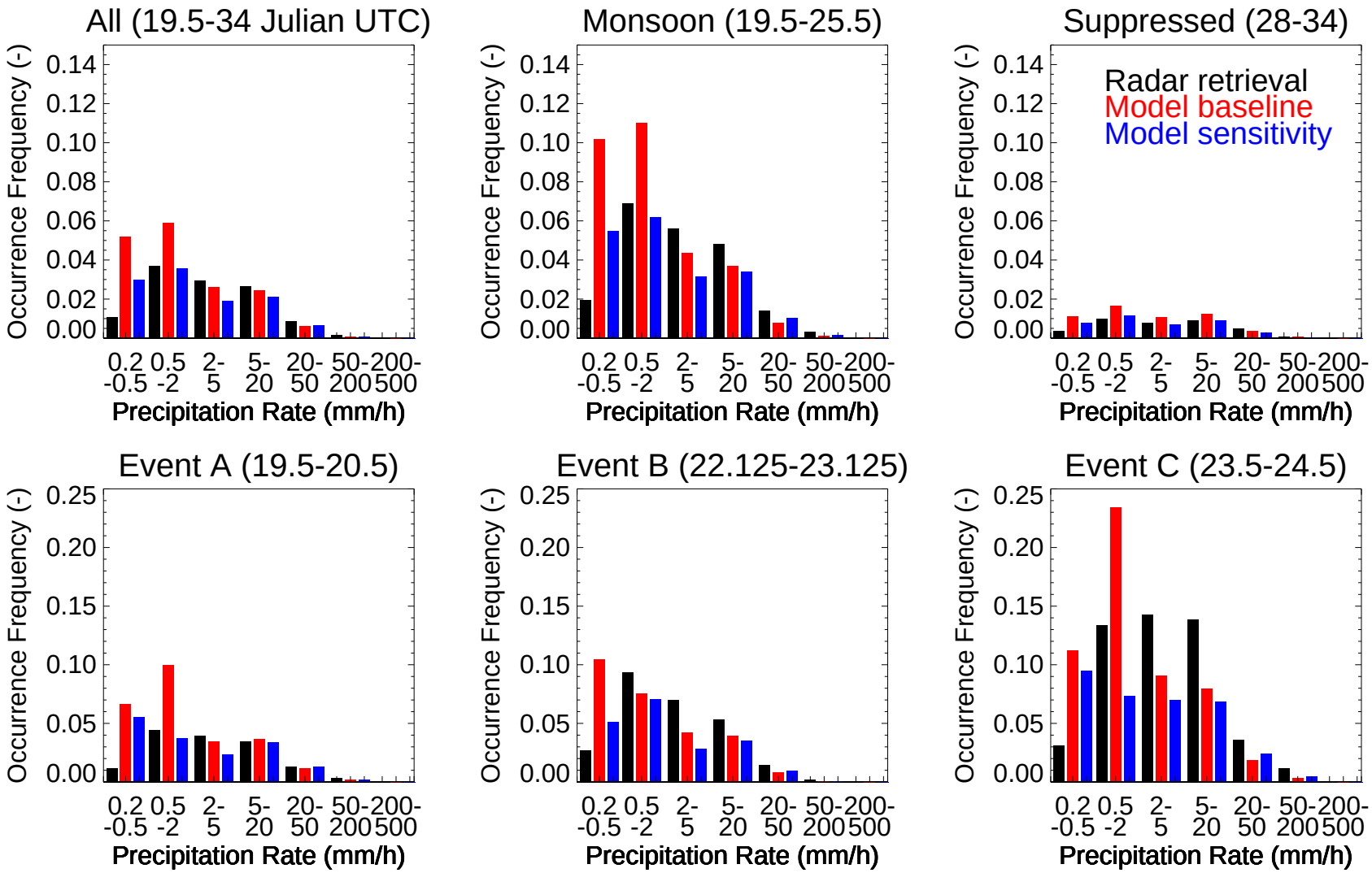
http://www.giss.nasa.gov/~fridlind/twp-ice/data

Precipitation rate



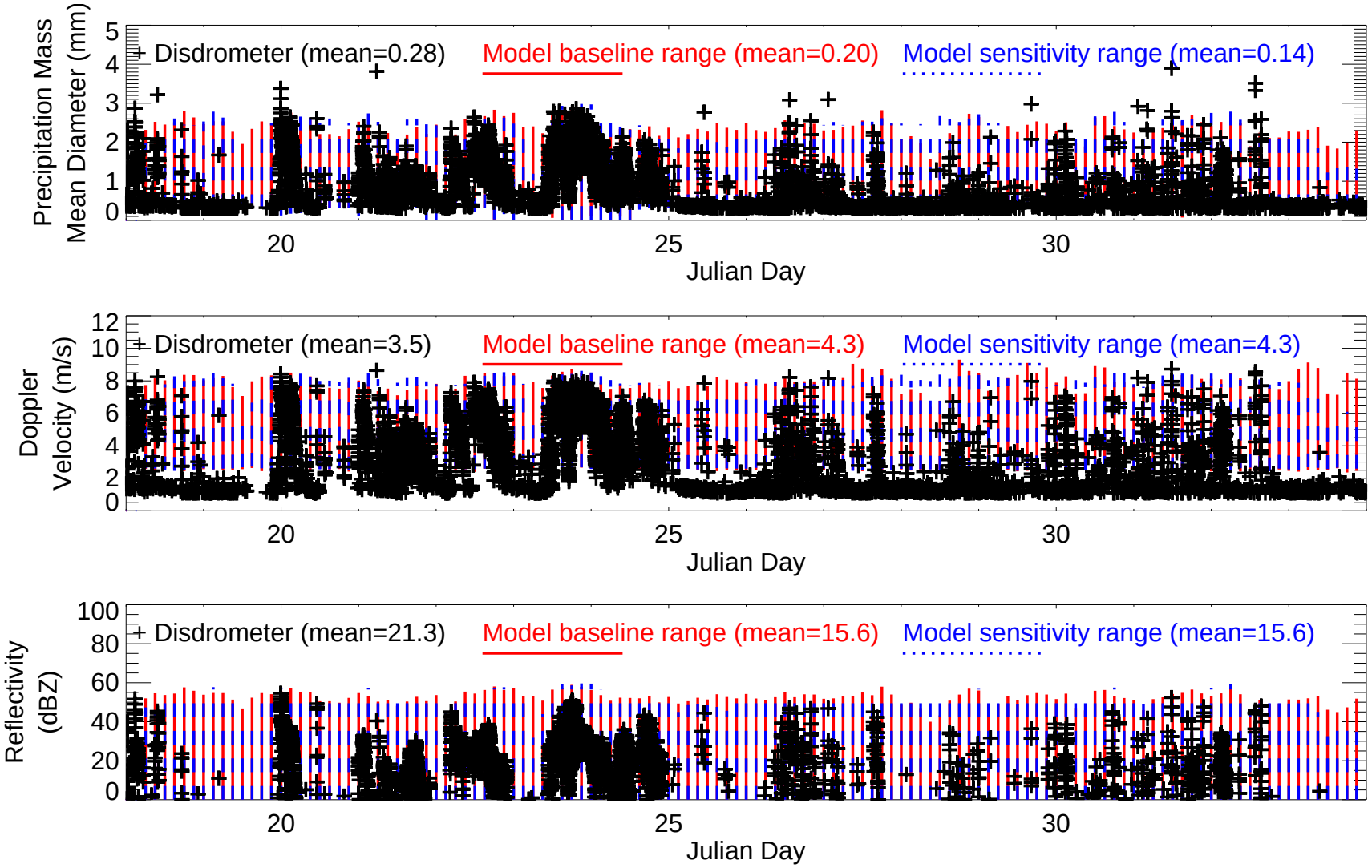
Data: *Shaocheng Xie, Peter May, Christopher Williams*

Precipitation rate



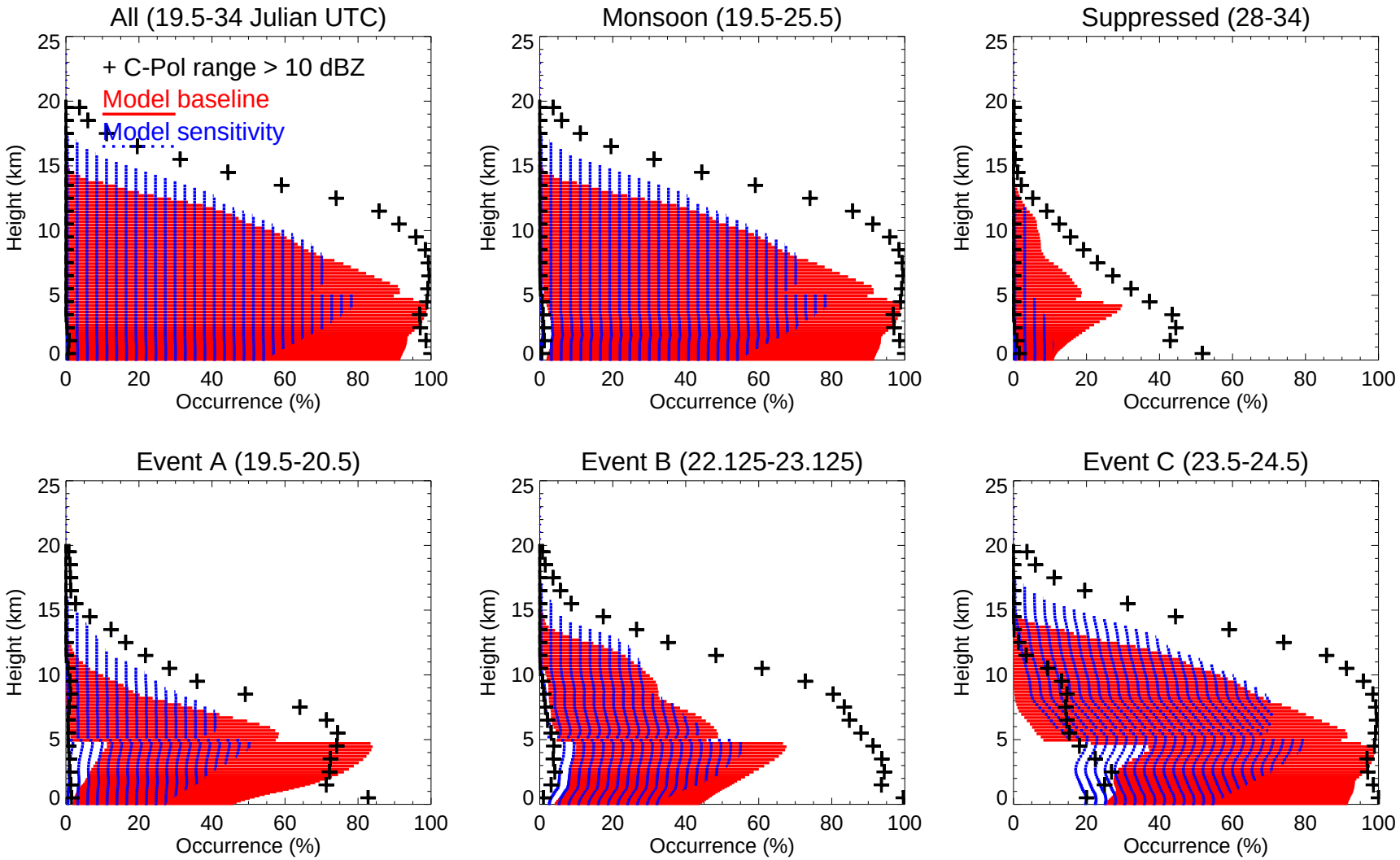
Data: *Peter May*

Precipitation particle size



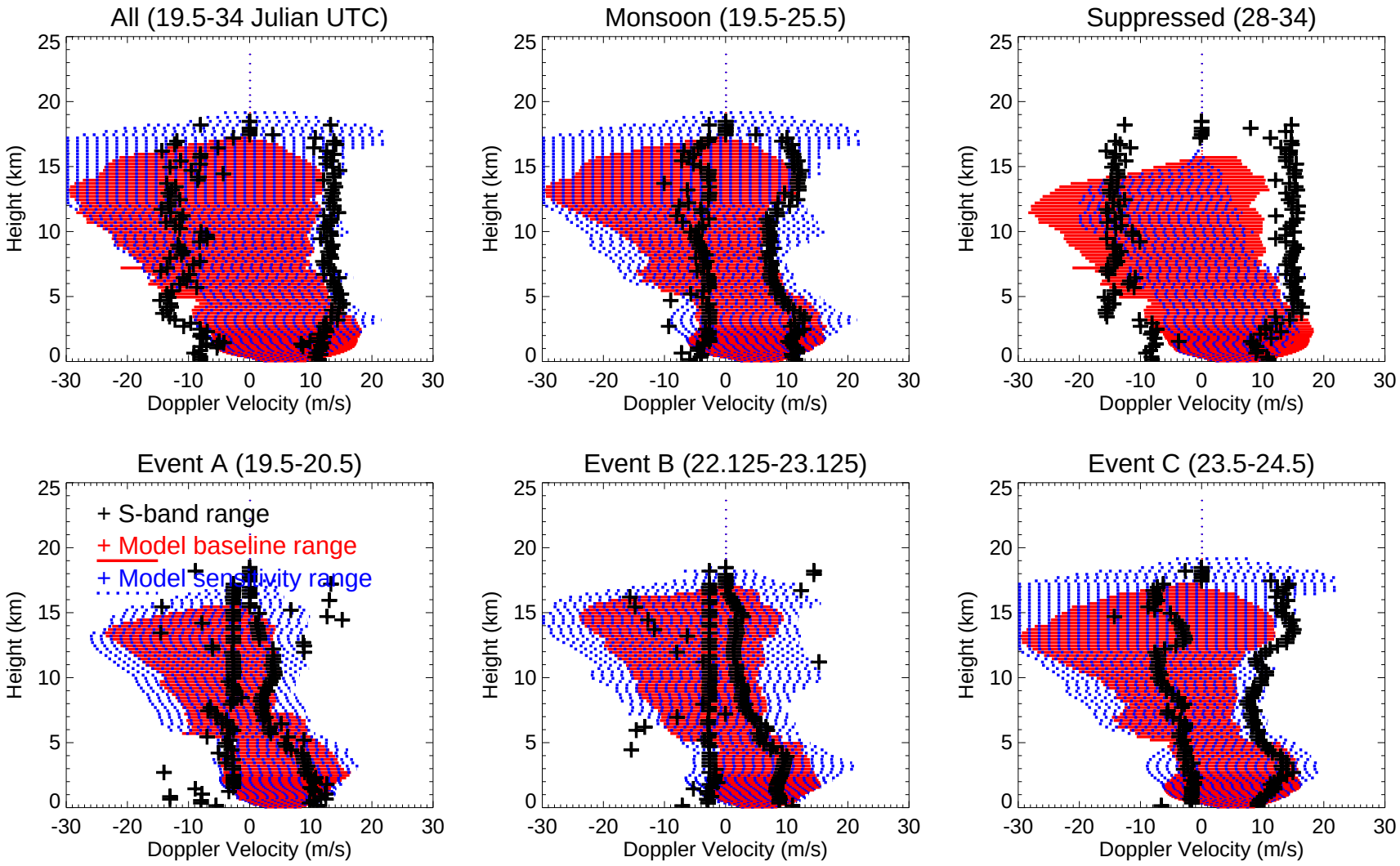
Data: *Christopher Williams*

Radar reflectivity > 10 dBZ



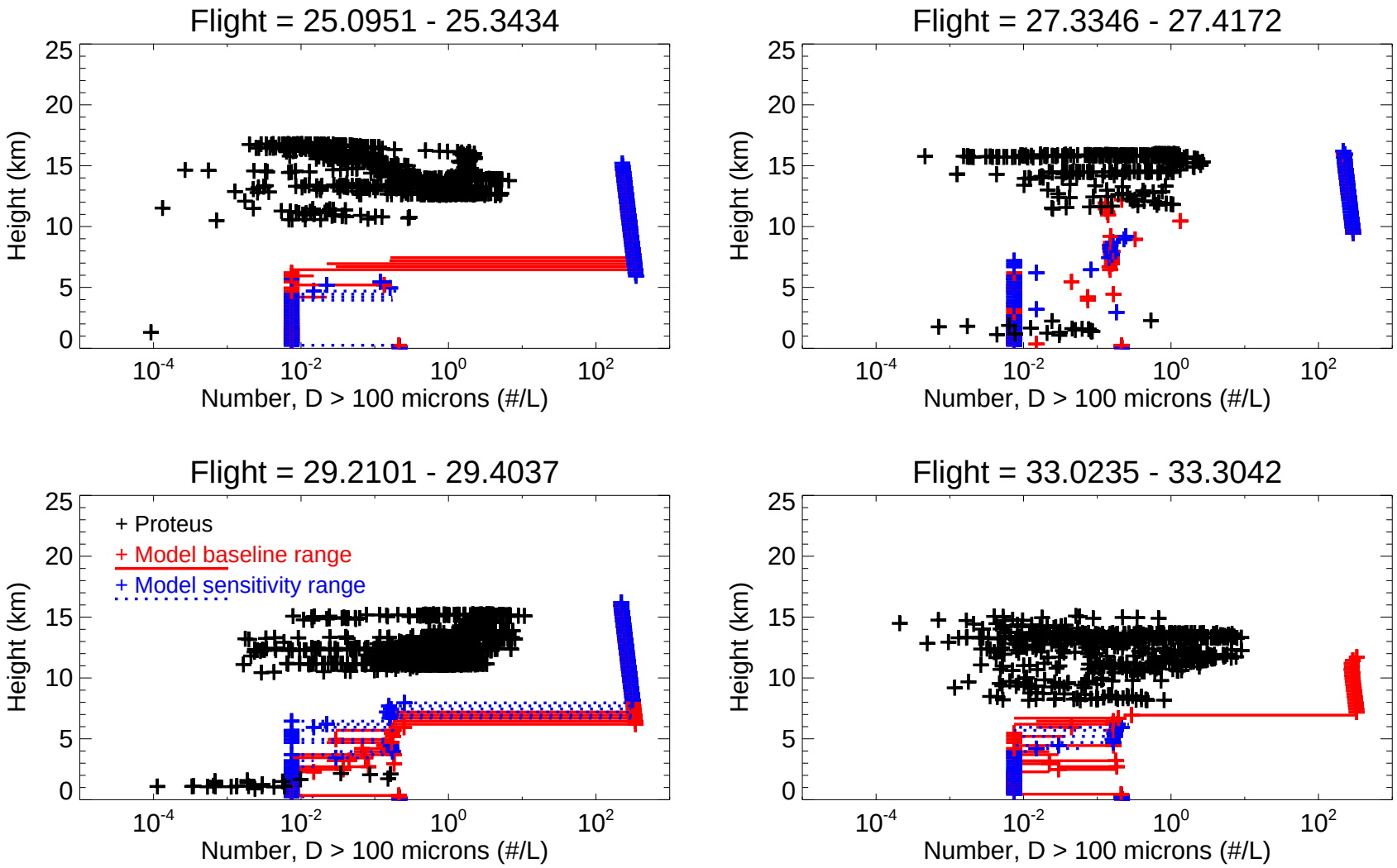
Data: *Peter May*

Doppler velocity



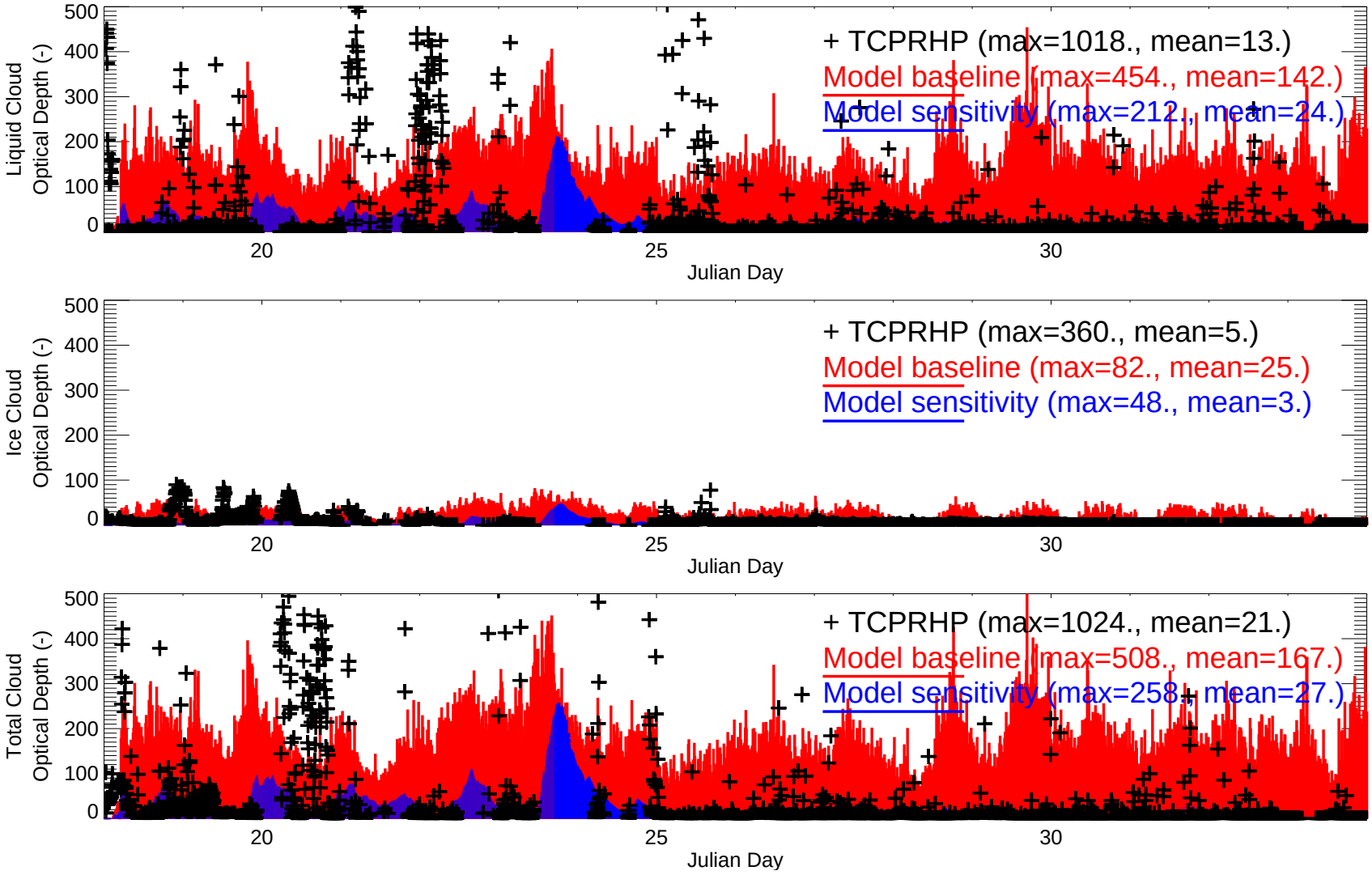
Data: *Christopher Williams*

Number concentration, D > 100 μm



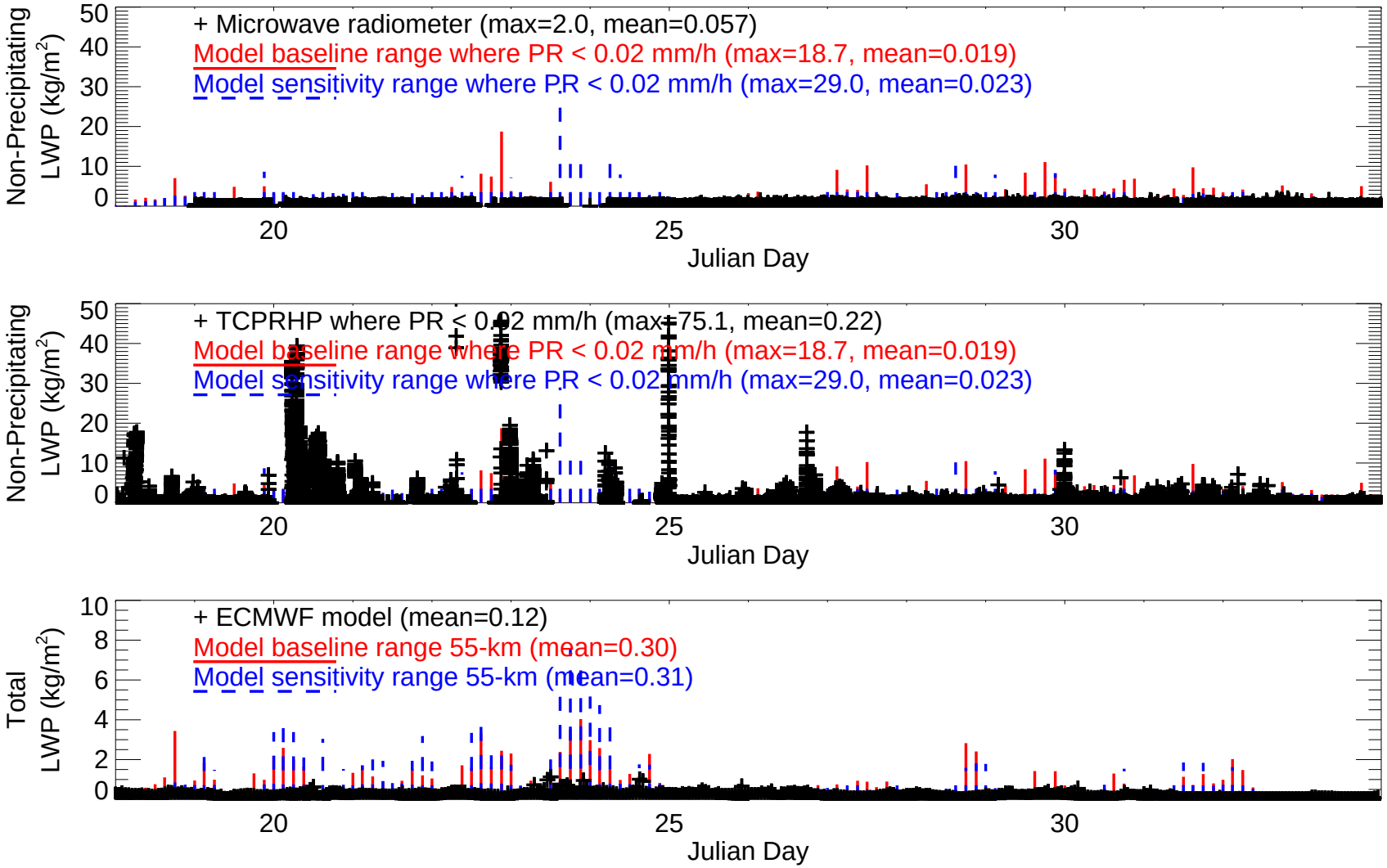
Data: *Greg McFarquhar*

Cloud optical depth



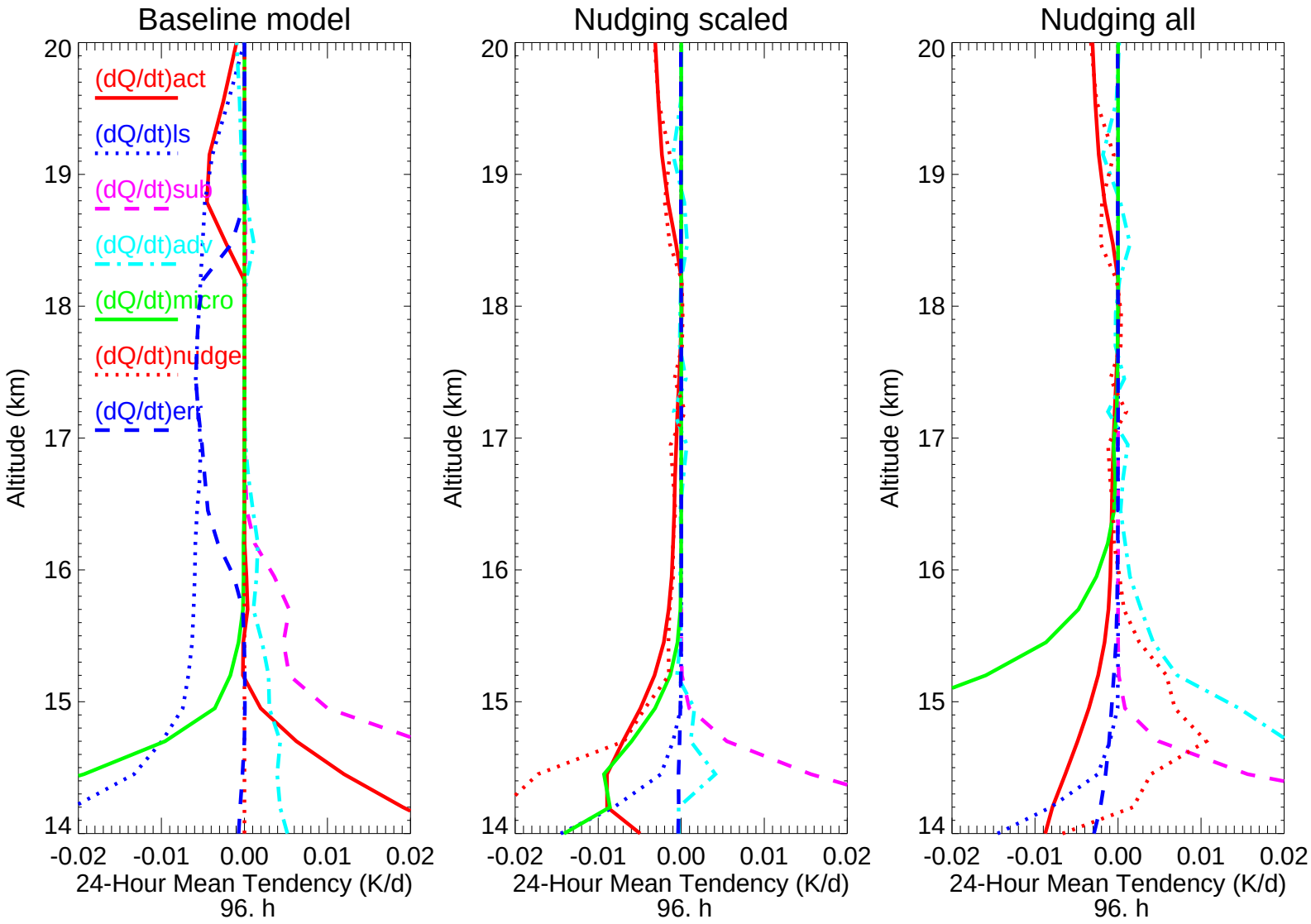
Data: *Sally McFarlane/Jim Mather*

Liquid water path

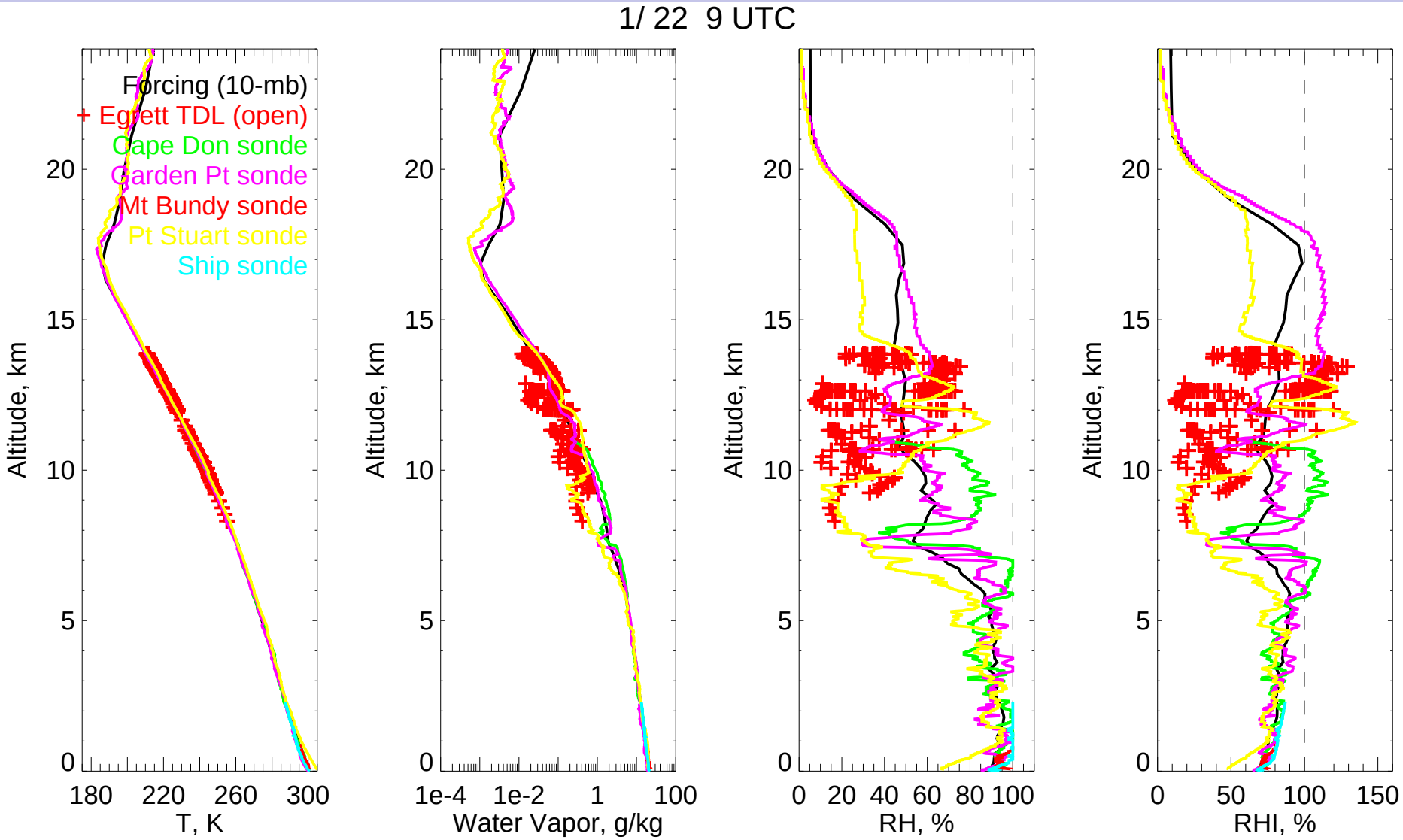


Data: *Dave Turner, Sally McFarlane/Jim Mather, ECMWF*

Moisture budget



Relative humidity data



Source: *Shaocheng Xie, Christian Jakob, Tim Hume, Jim Whiteway, Clive Cook, Grant Allen*

Summary

- CRM case specification
  - idealized marine
  - 16 days
  - participants welcomed
- first goal: closure experiment
  - http://science.arm.gov/wg/cpm/scm/scmic6 (Table 1)
  - http://www.giss.nasa.gov/~fridlind/twp-ice/data (images)
  - do you have any comments?
  - requested diagnostics can still be changed
- second goal: convective transport (water vapor)
  - influence on water vapor near the tropopause?
  - primary uncertainties in simulations and data?
  - tracer analysis