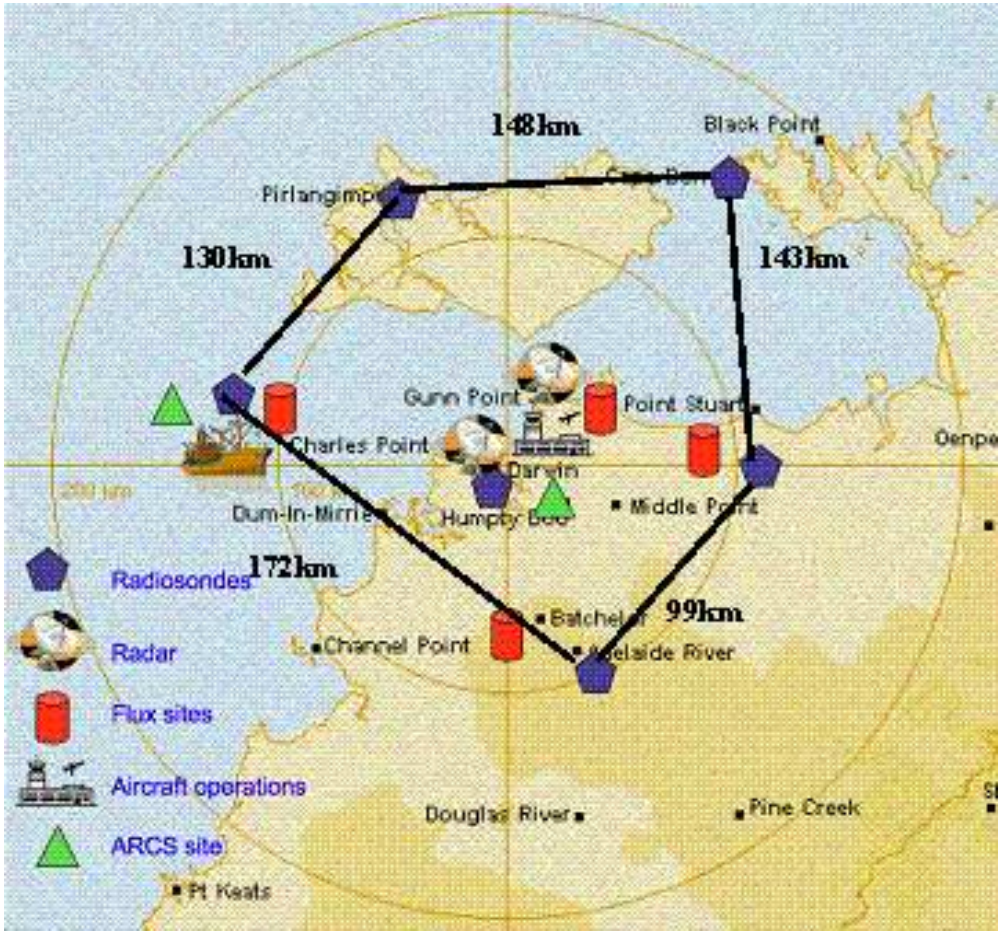
ARM/GCSS/SPARC TWP-ICE CRM Study

Ann Fridlind and Andrew Ackerman • NASA GISS
with contributions from
Jean-Pierre Chaboreau • University of Toulouse/CNRS
Jiwen Fan • PNNL Laboratory
Adrian Hill, Jon Petch, and Paul Field • UK MetOffice
Todd Jones • Colorado State University
Hugh Morrison • NCAR
Sunwook Park and Xiaoqing Wu • Iowa State University
Jun-Ichi Yano • CNRM, Meteo France

Cloud Modeling Working Group Meeting • 29 September 2009

Experiment domain

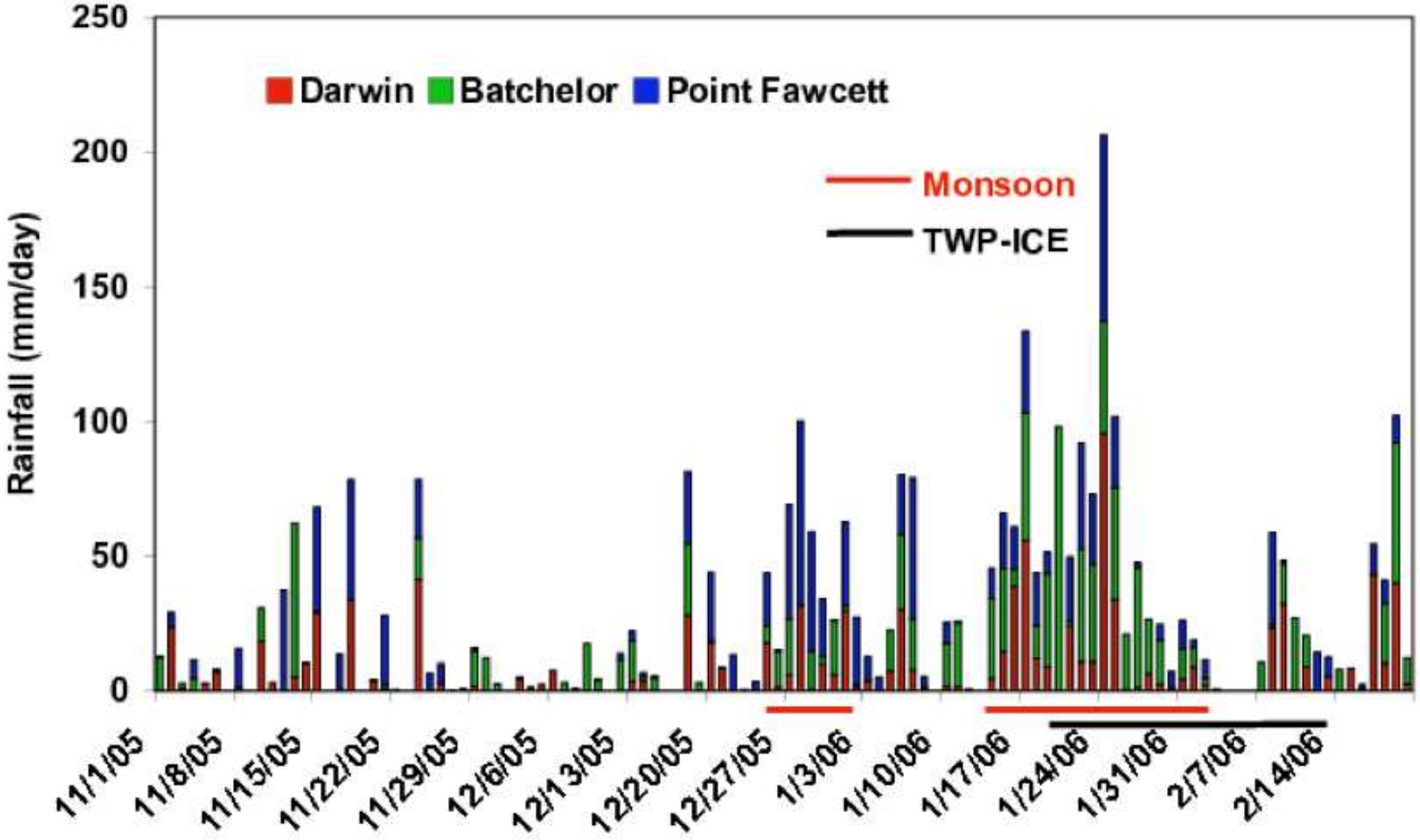


Source: *Shaocheng Xie, LLNL*

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-day simulation and sensitivity test
- single-column models (SCMs) - Christian Jakob/Laura Davies
  - 26-day ensemble
- limited-area models (LAMs) - Ping Zhu
  - 3-day monsoon trough
  - 3-day suppressed monsoon
  - 16-day CRM time period
- general circulation models (GCMs) - Yanluan Lin
  - 27-day composite
  - daily forecasts in NWP-mode

Participants

- CSUVVM 3D
- DHARMA 3D
- EULAG 2D
- ISUCRM 2D
- MESONH 3D
- NAMSCA 3D
- SAM 3D
- UKMO-LEM 2D

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
- study anvil cirrus evolution

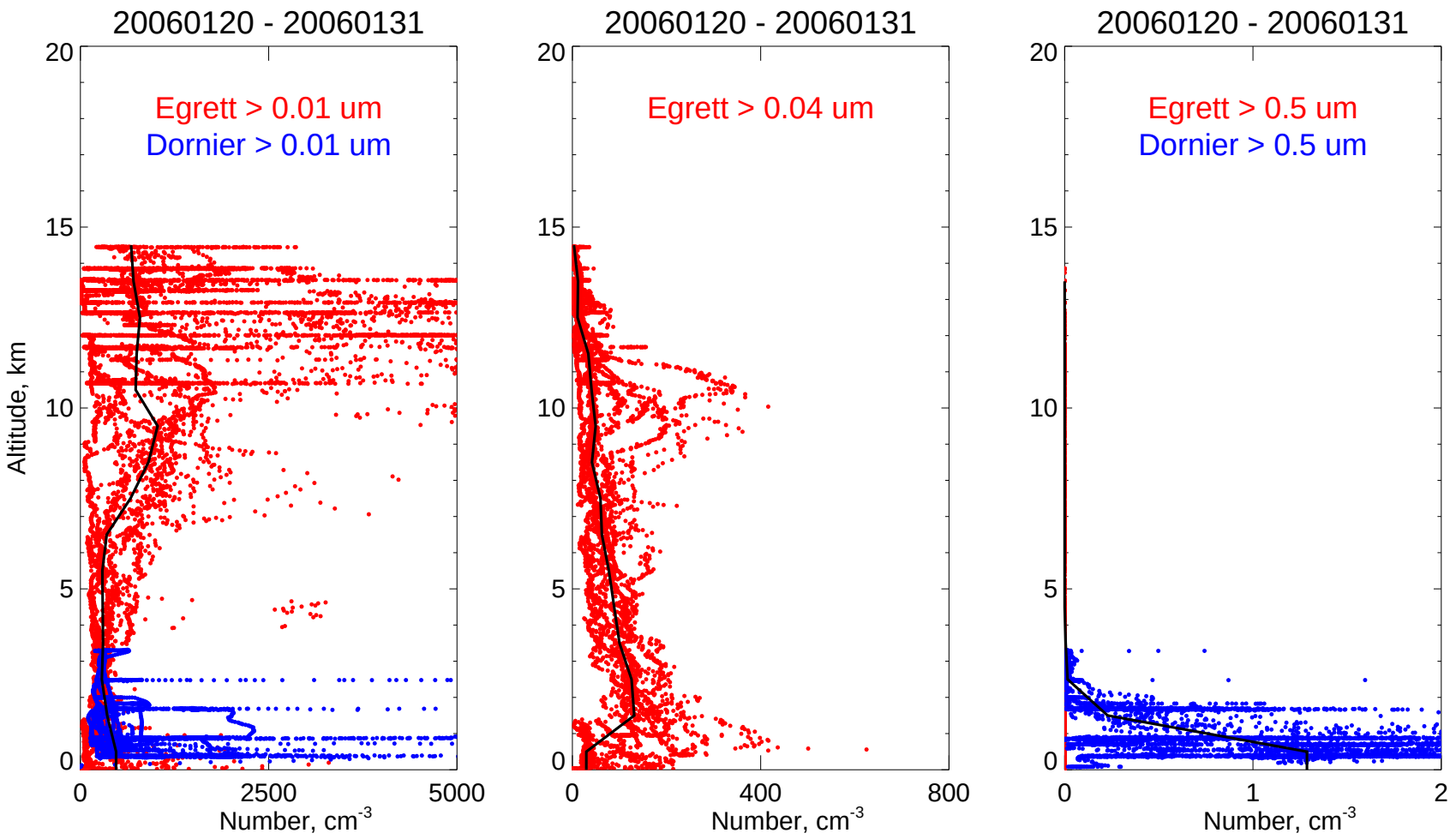
Model set-up

- general specification
  - horizontal domain size = 176 x 176 km
  - periodic boundary conditions (idealized marine)
  - fixed SST = 29°C
  - interactive surface fluxes
  - large-scale forcings from variational analysis (S. Xie)
  - 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
- GISS submission
  - vertical domain size = 24 km
  - horizontal grid = 900 m
  - vertical grid = 100–250 m
  - bulk microphysics (Grabowski, 1999)
    = cloud liquid, rain, fluffy ice, dense ice
  - 2-stream radiative transfer, 44 bands, size-resolved Mie

Aerosol specification

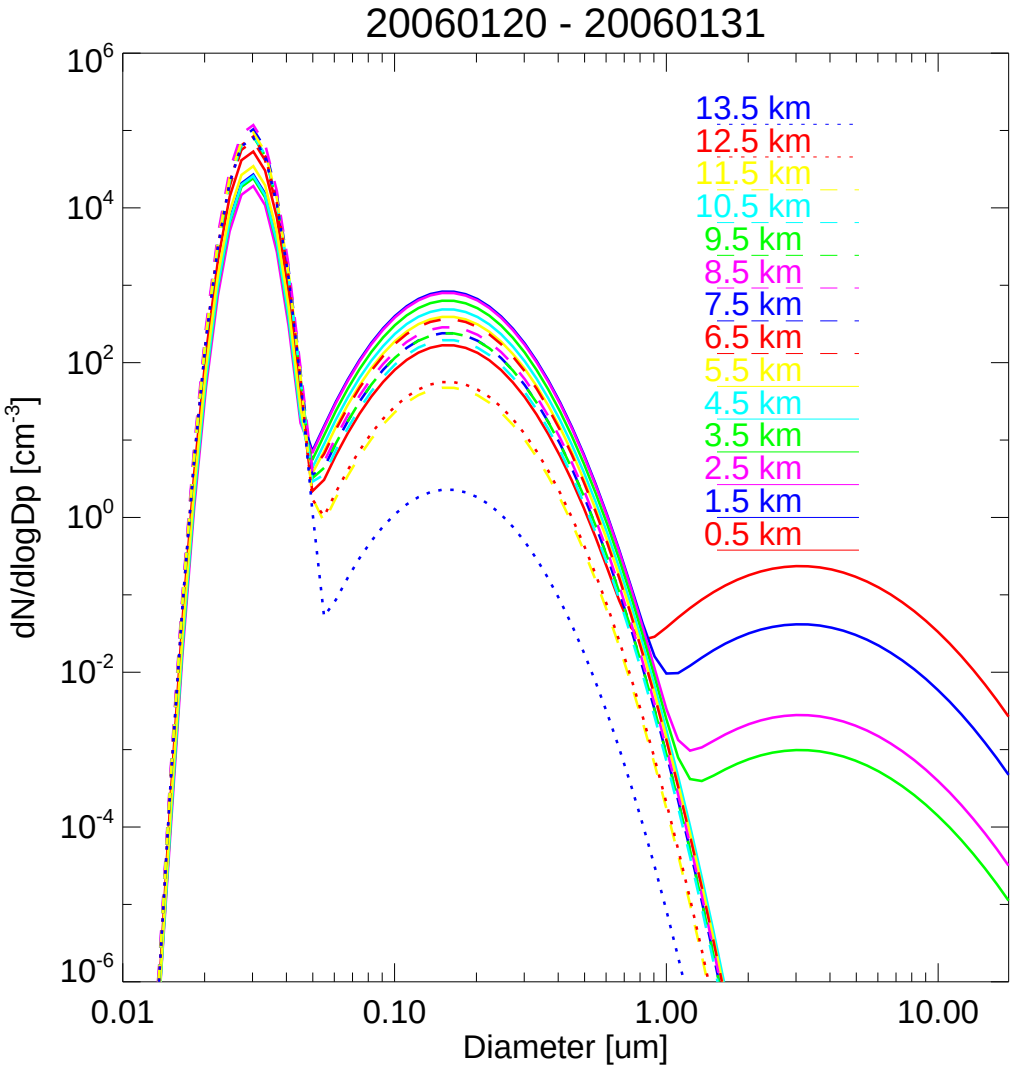
- Aerosol and Chemical Transport in tropIcal conVEction (ACTIVE)
  - funded by the UK Natural Environment Research Council
  - http://cloudbase.phy.umist.ac.uk/field/active
- bulk mass composition [*Allen et al., 2008*]
  - 80% ammonium sulfate
  - 20% organics
- number size distribution profiles
  - 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



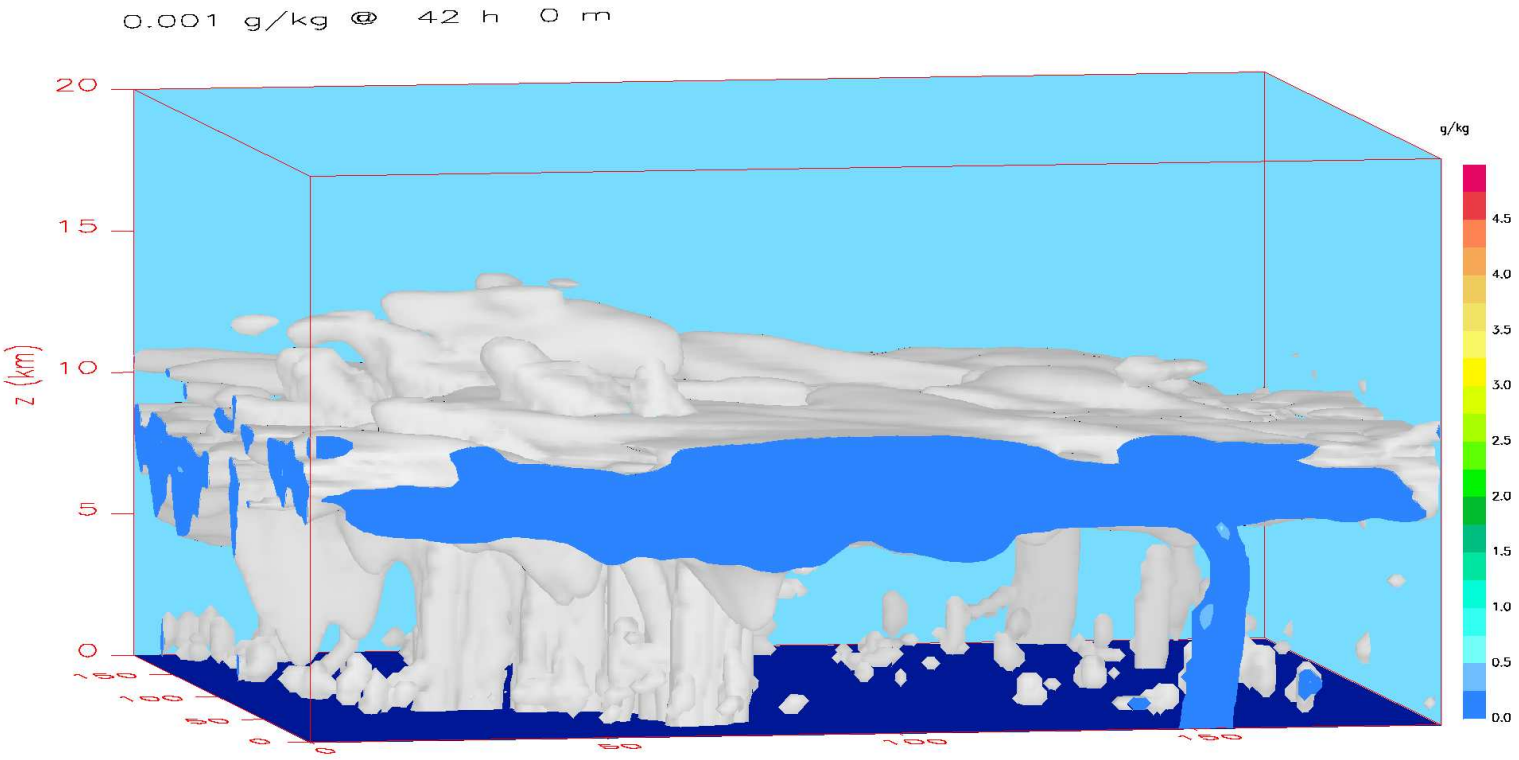
Data: *Martin Gallagher, Paul Williams, Andrew Heymsfield, Aaron Bansemer*

Number size distribution profiles

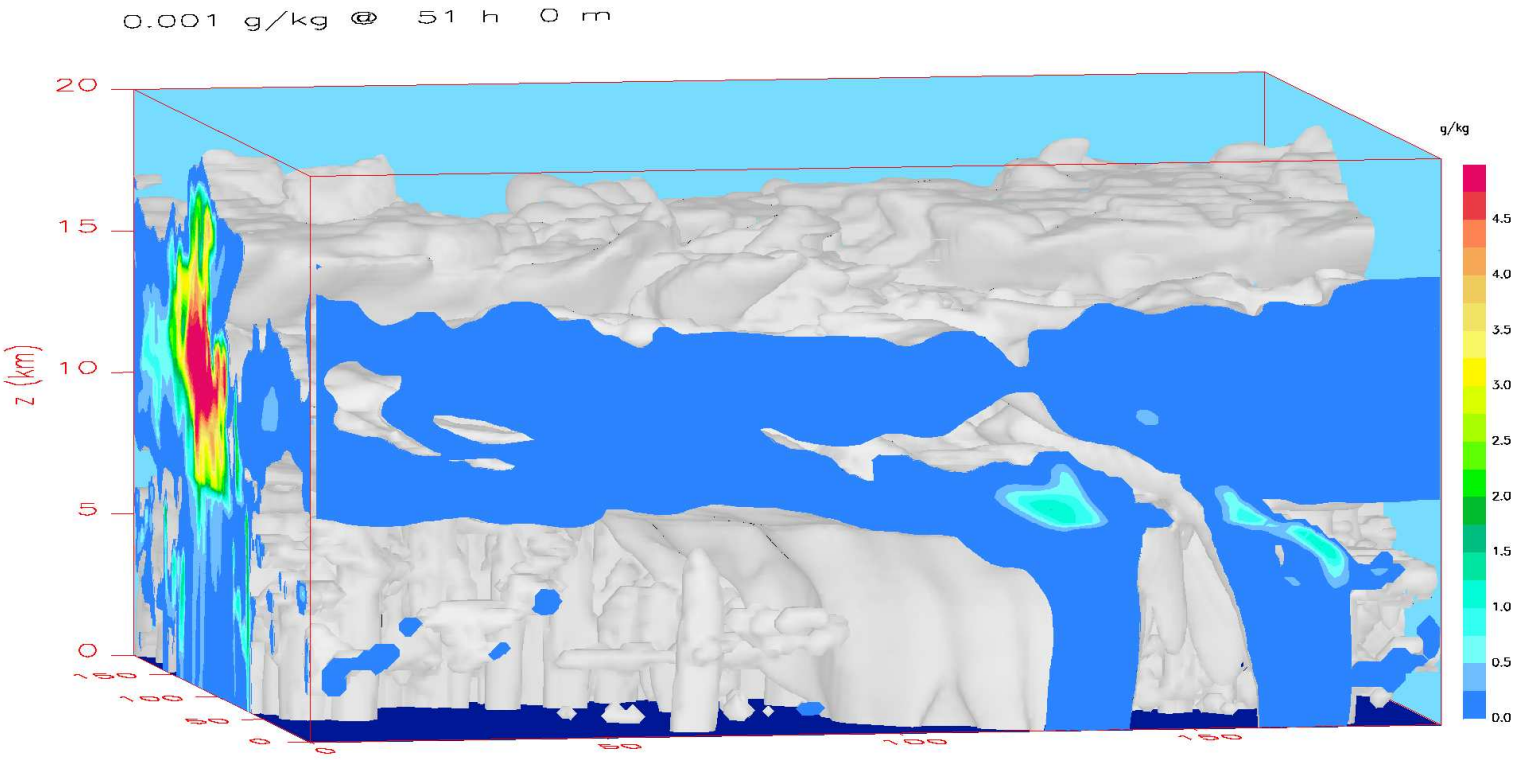


Data: *Martin Gallagher, Paul Williams, Grant Allen*

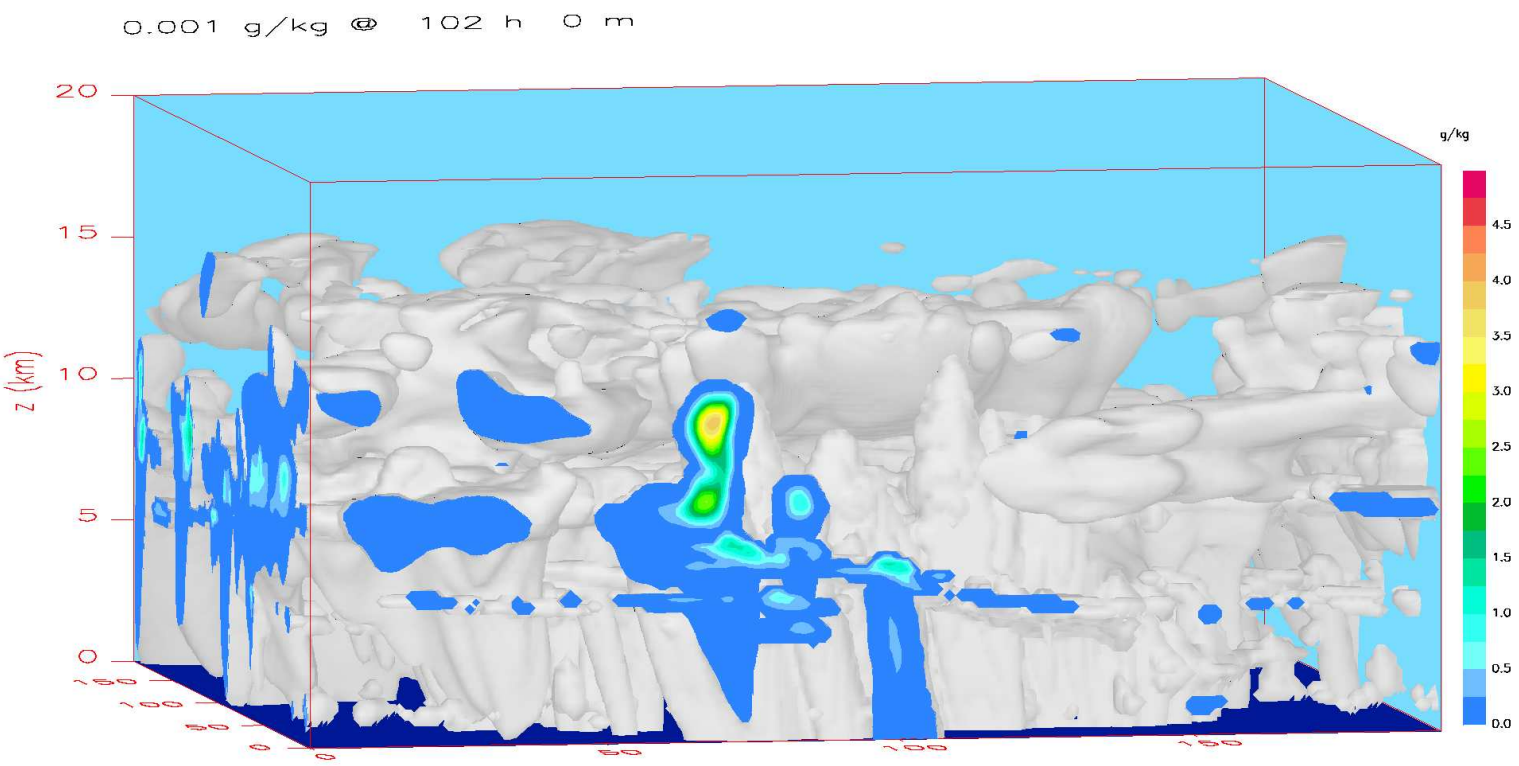
Cloud isosurfaces



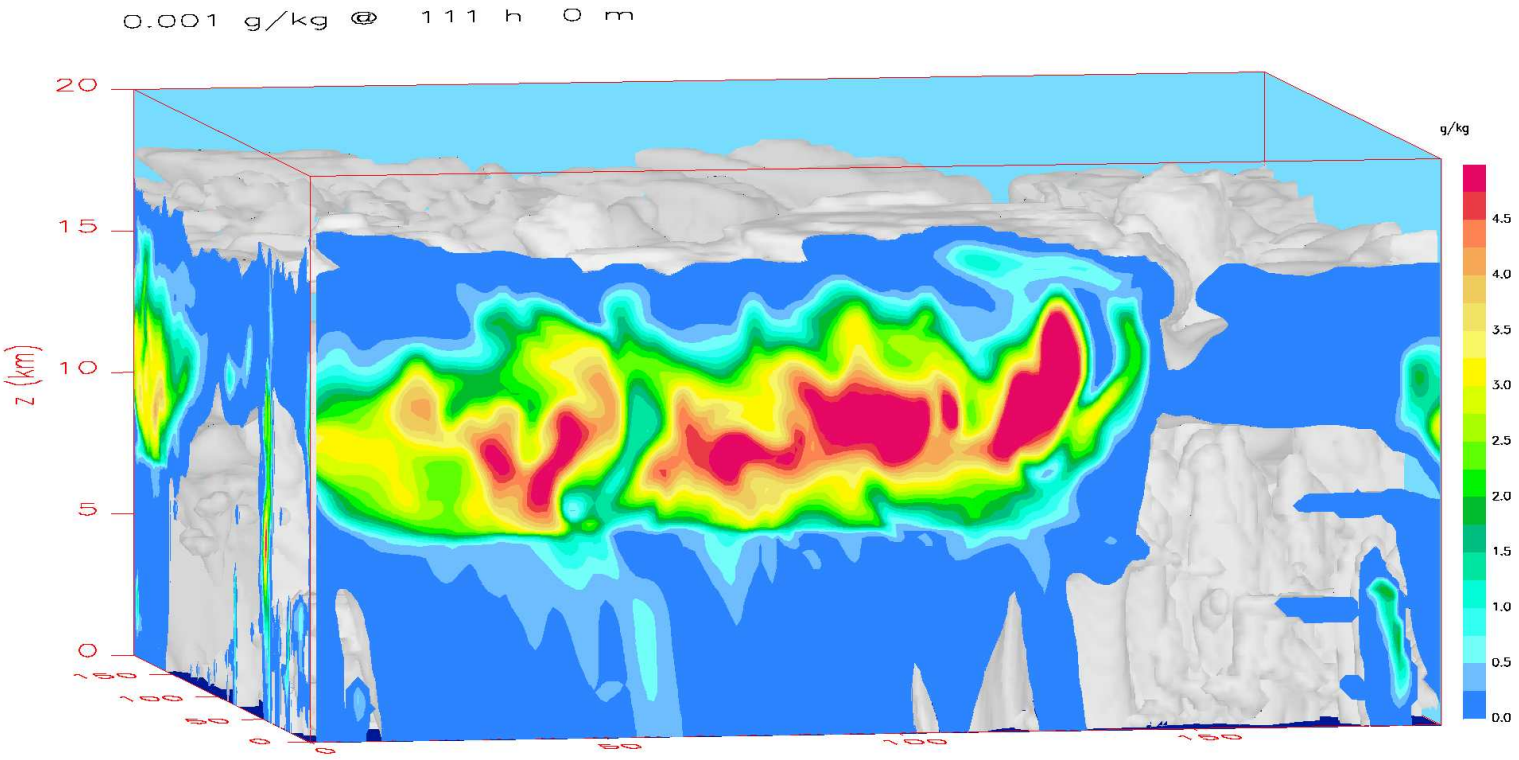
Cloud isosurfaces



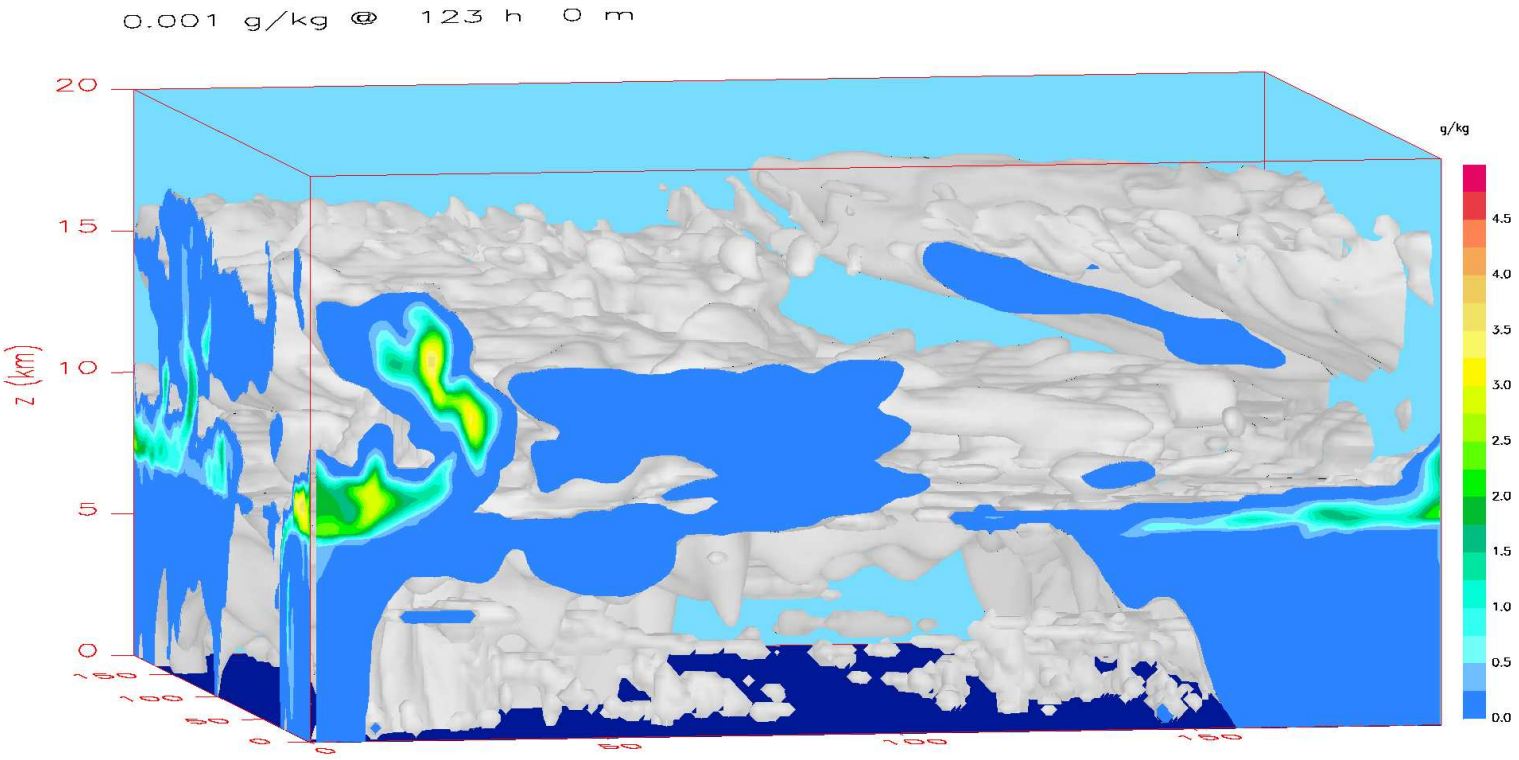
Cloud isosurfaces



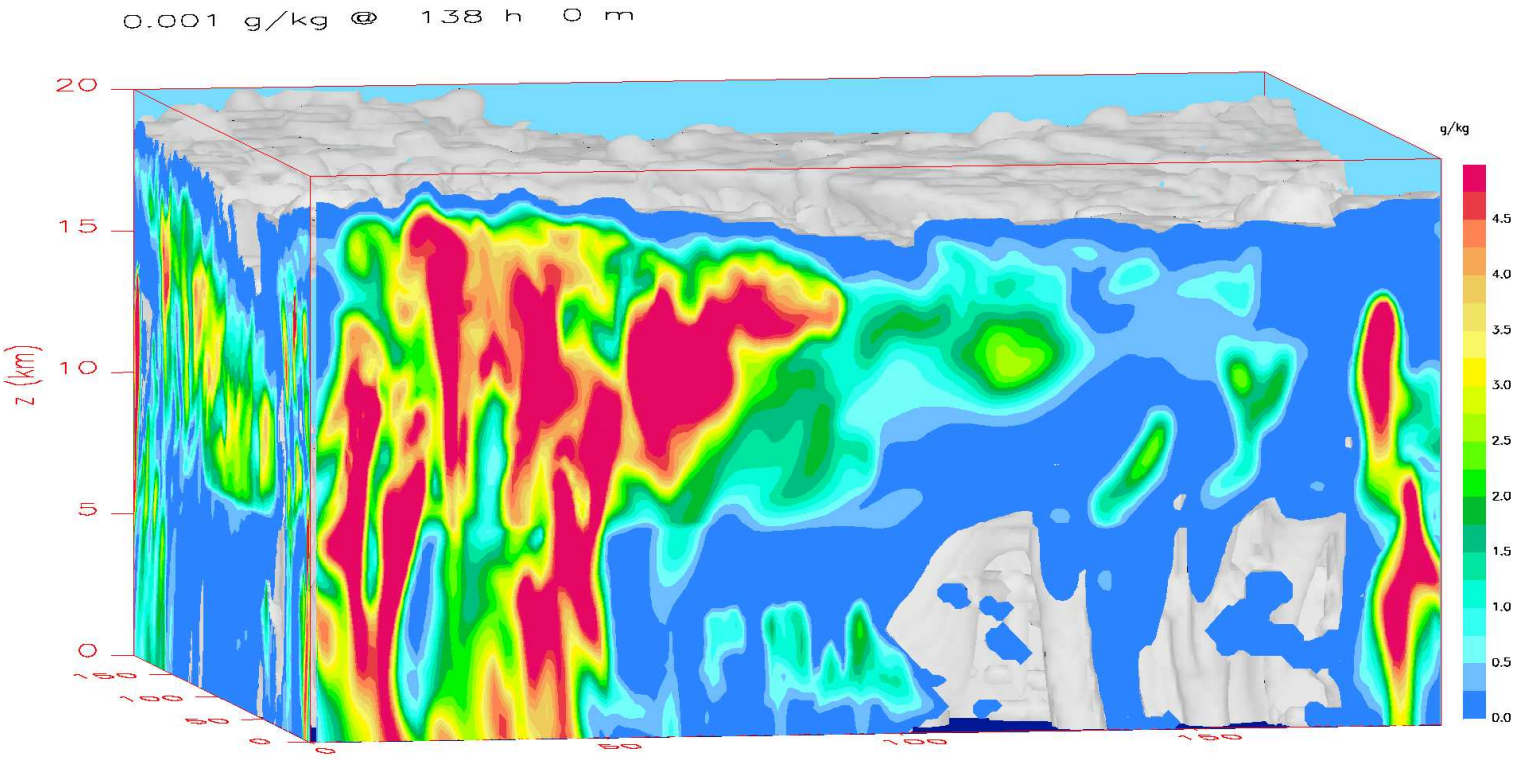
Cloud isosurfaces



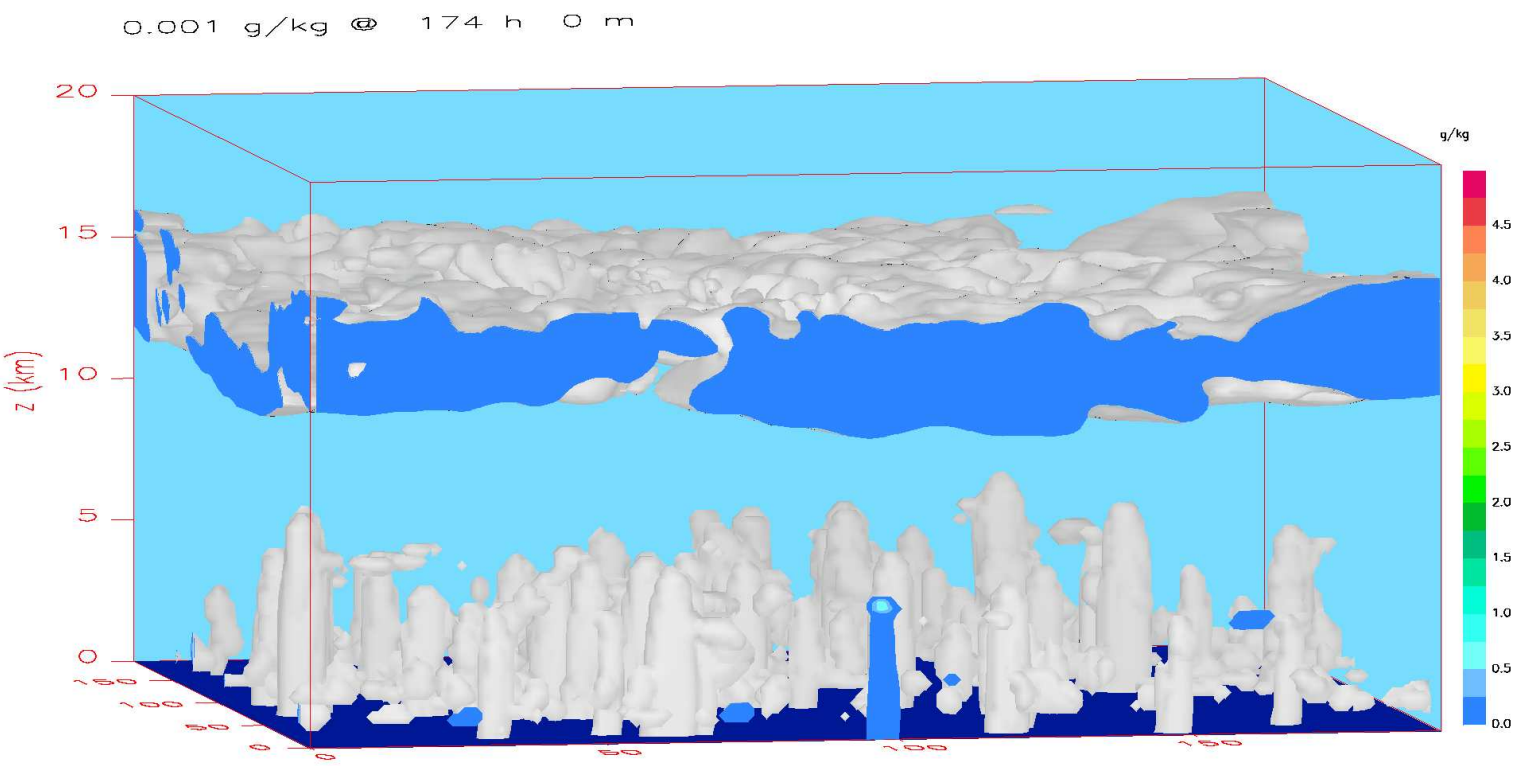
Cloud isosurfaces



Cloud isosurfaces



Cloud isosurfaces



Data constraints on model performance

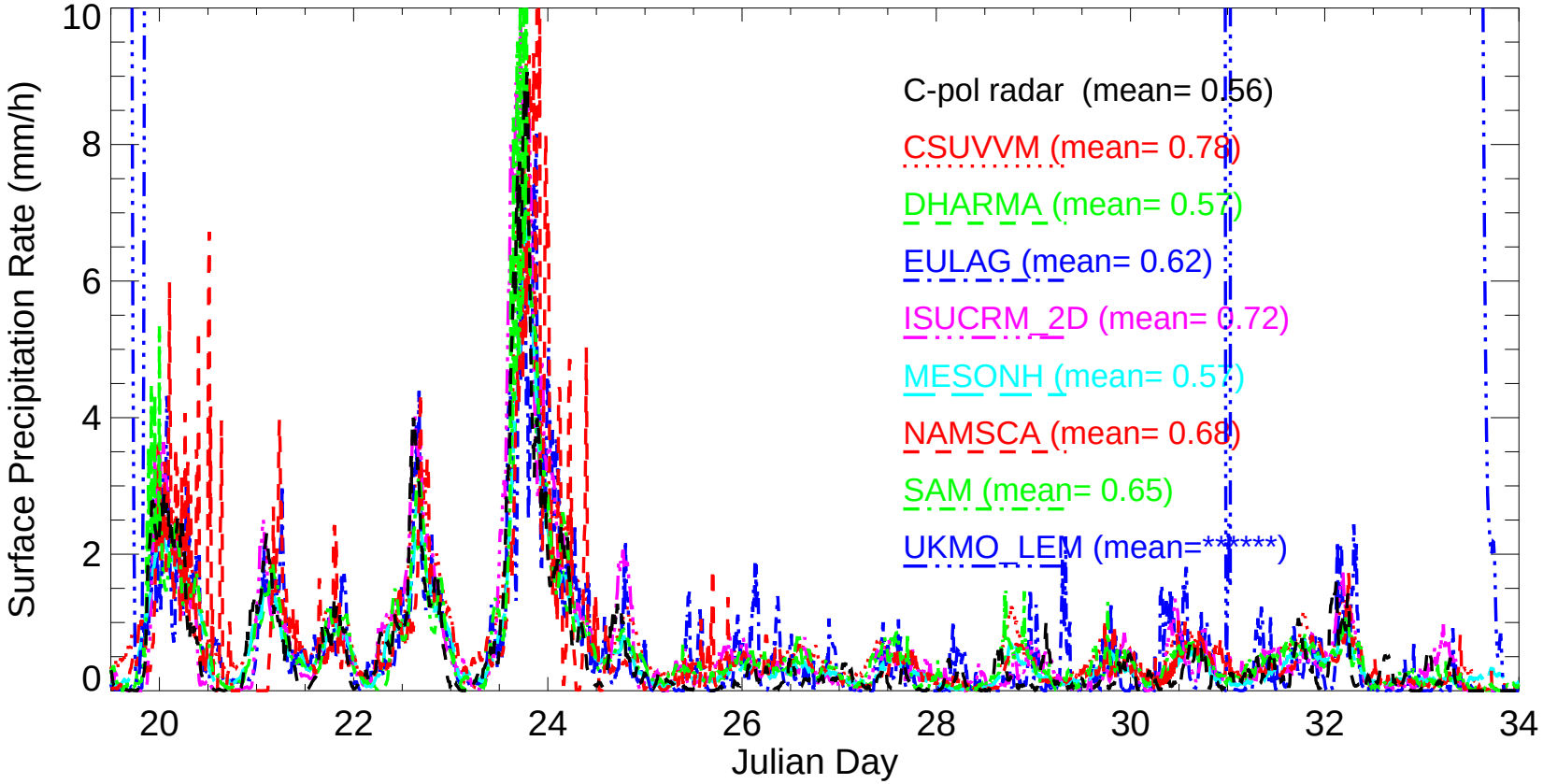
Physical Variable	Data Set (PI)
Precipitation rate	C-pol (May), disdrometer and buckets (Williams)
Liquid water content	disdrometer, TCPRHP (McFarlane/Mather)
Liquid water path	MWR (Turner), TCPRHP, TMI
Ice water content	TCPRHP, 3D-Ice (Liu)
Ice water path	VISST (Minnis), TCPRHP, 3D-Ice
Total condensate 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	PNNL-CR, RFA, VISST, MODIS
SFC broadband flux	QCRAD, TCPRHP
TOA broadband flux	VISST, TCPRHP
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)

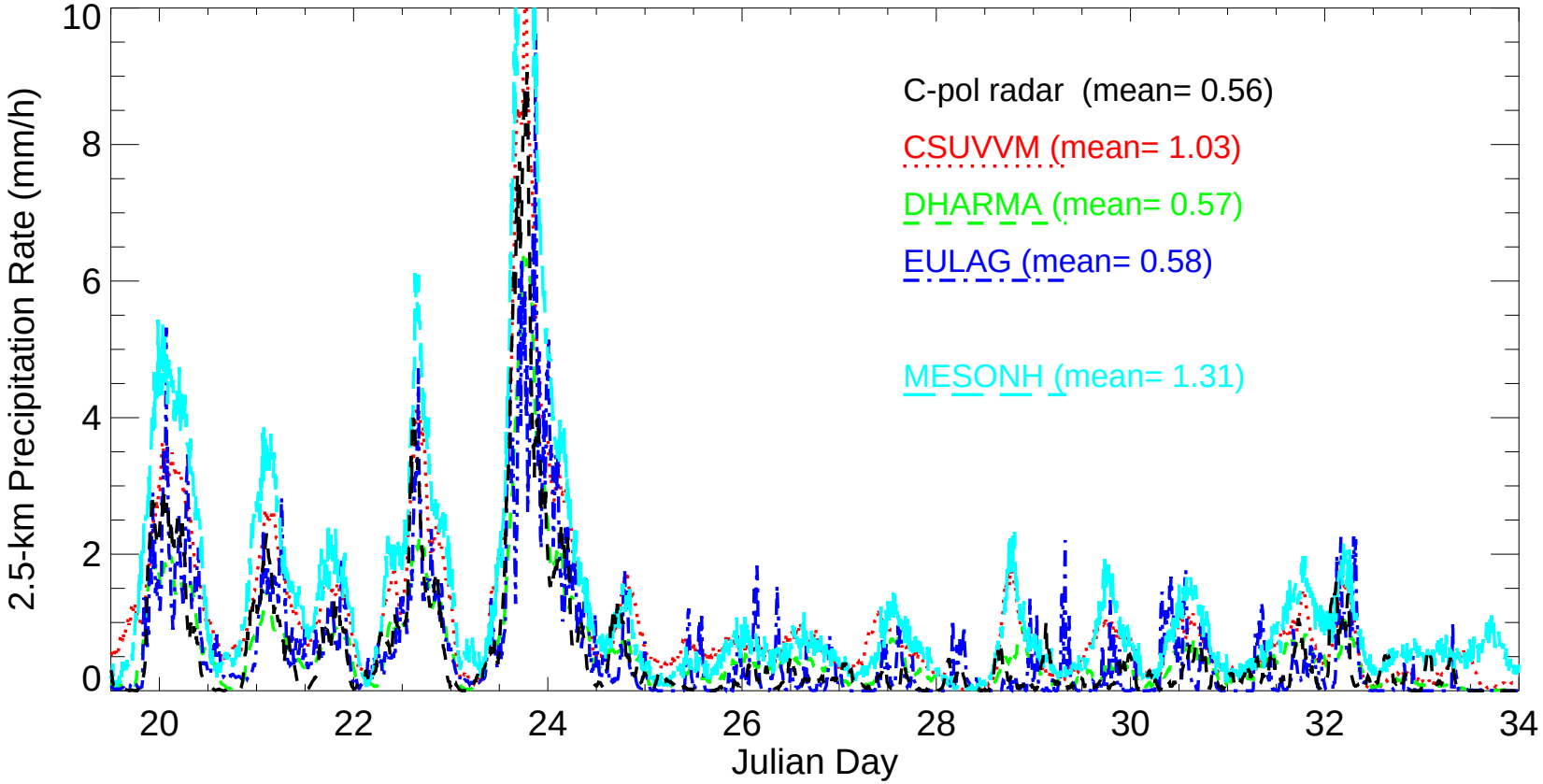
http://science.arm.gov/wg/cpm/scm/scmic6/data

Precipitation rate



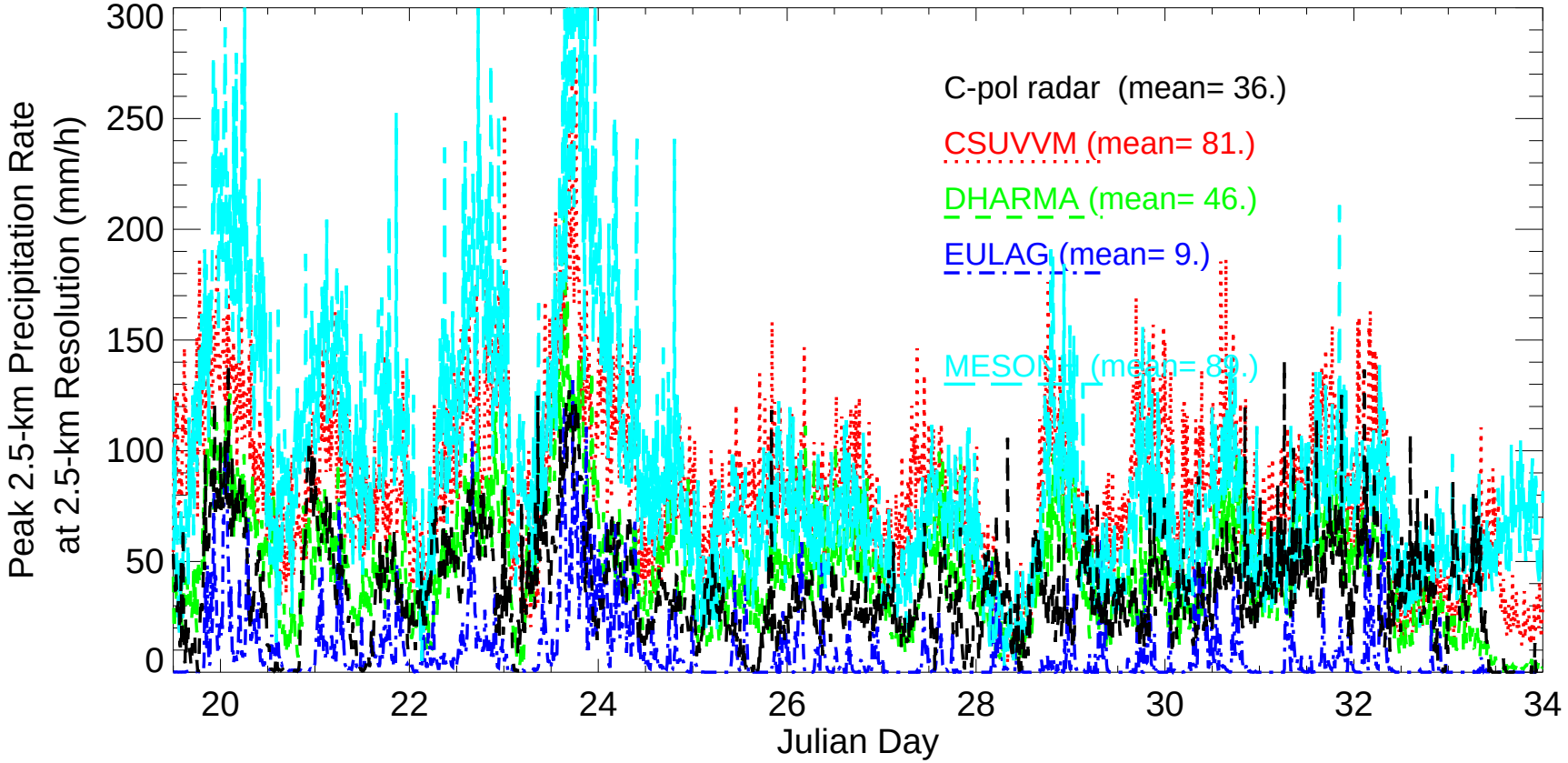
Data: *Peter May et al.*

Precipitation rate



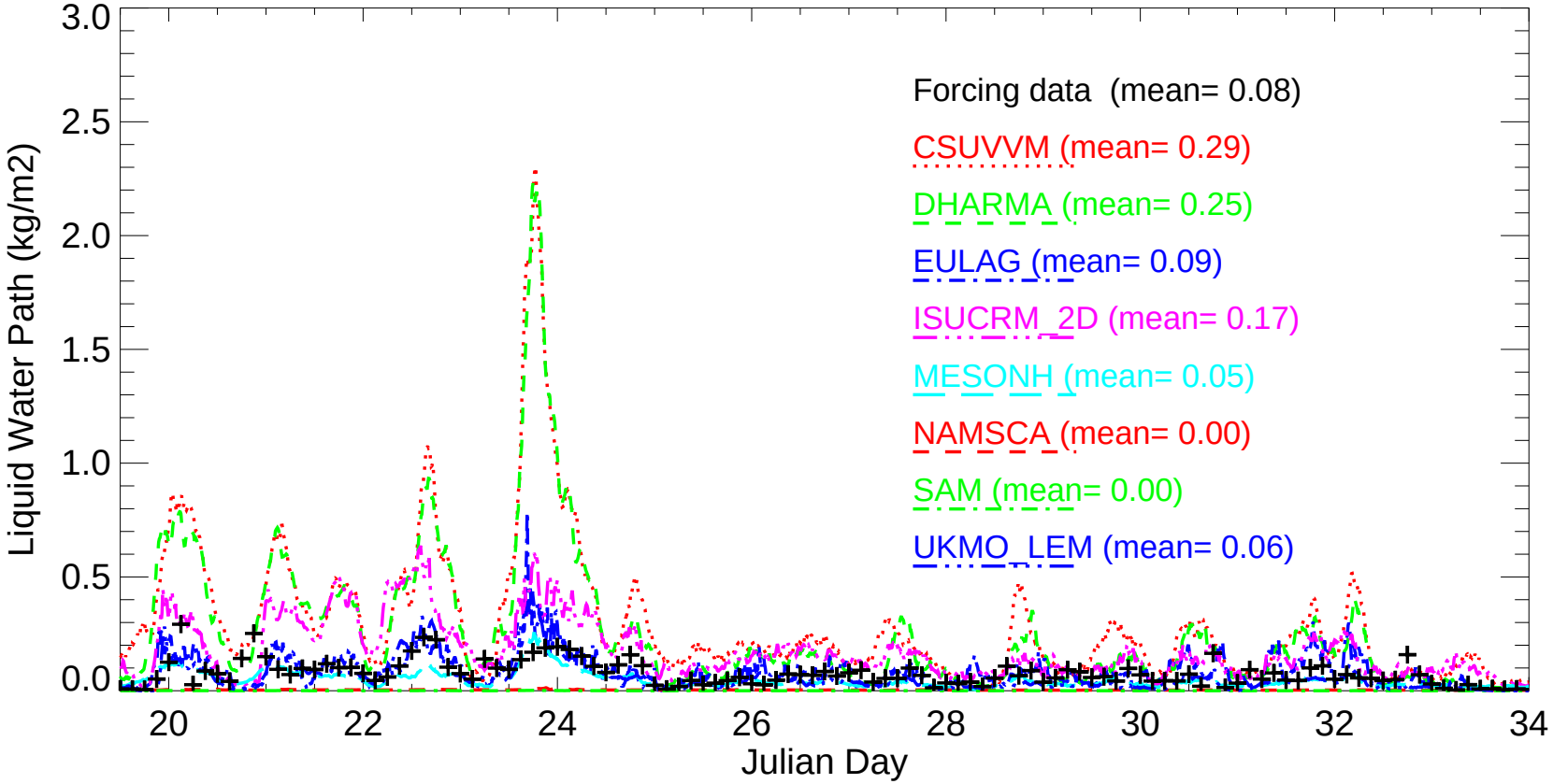
Data: *Peter May et al.*

Precipitation rate



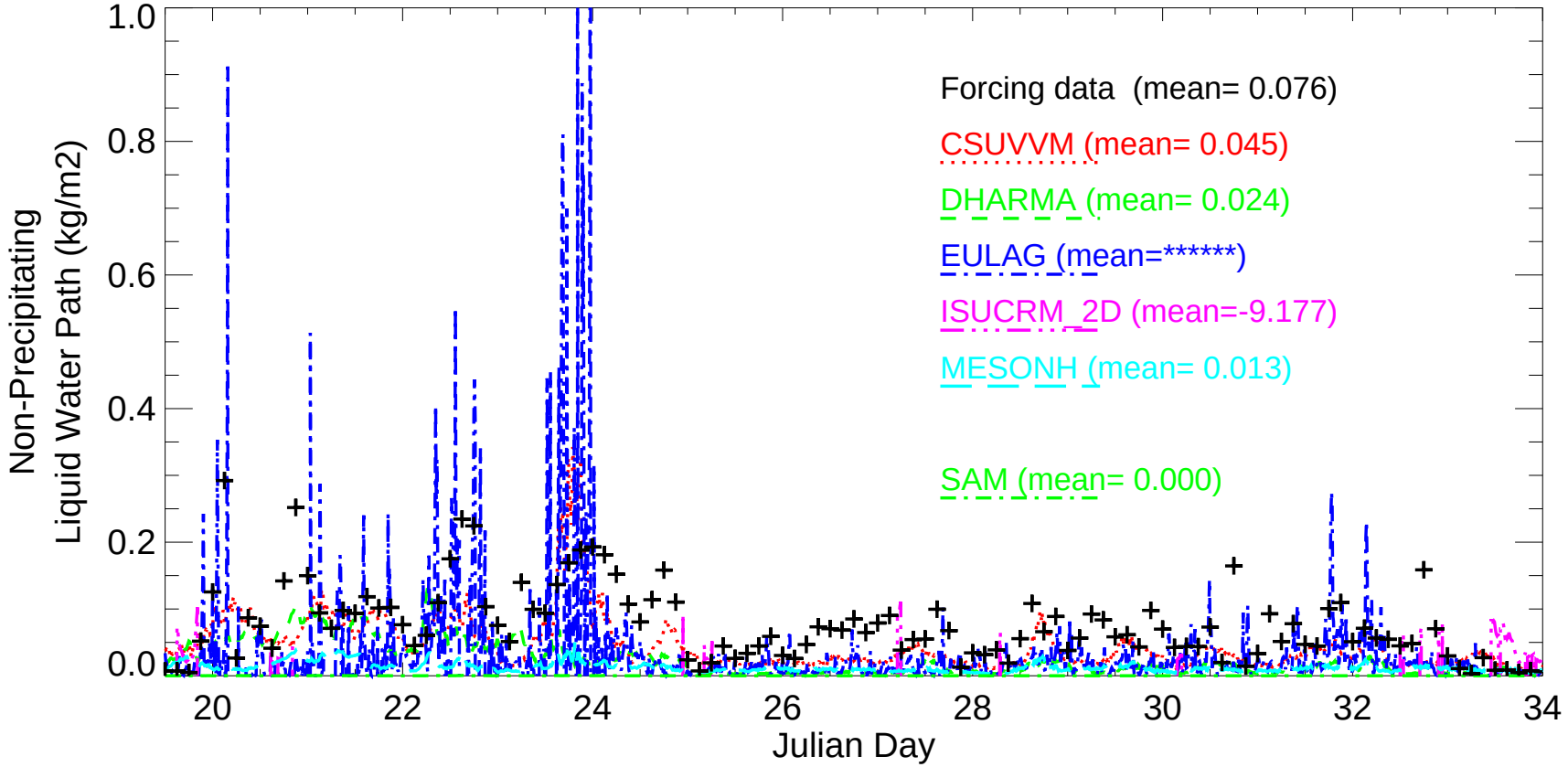
Data: *Peter May et al.*

Liquid water path (cloud + rain)



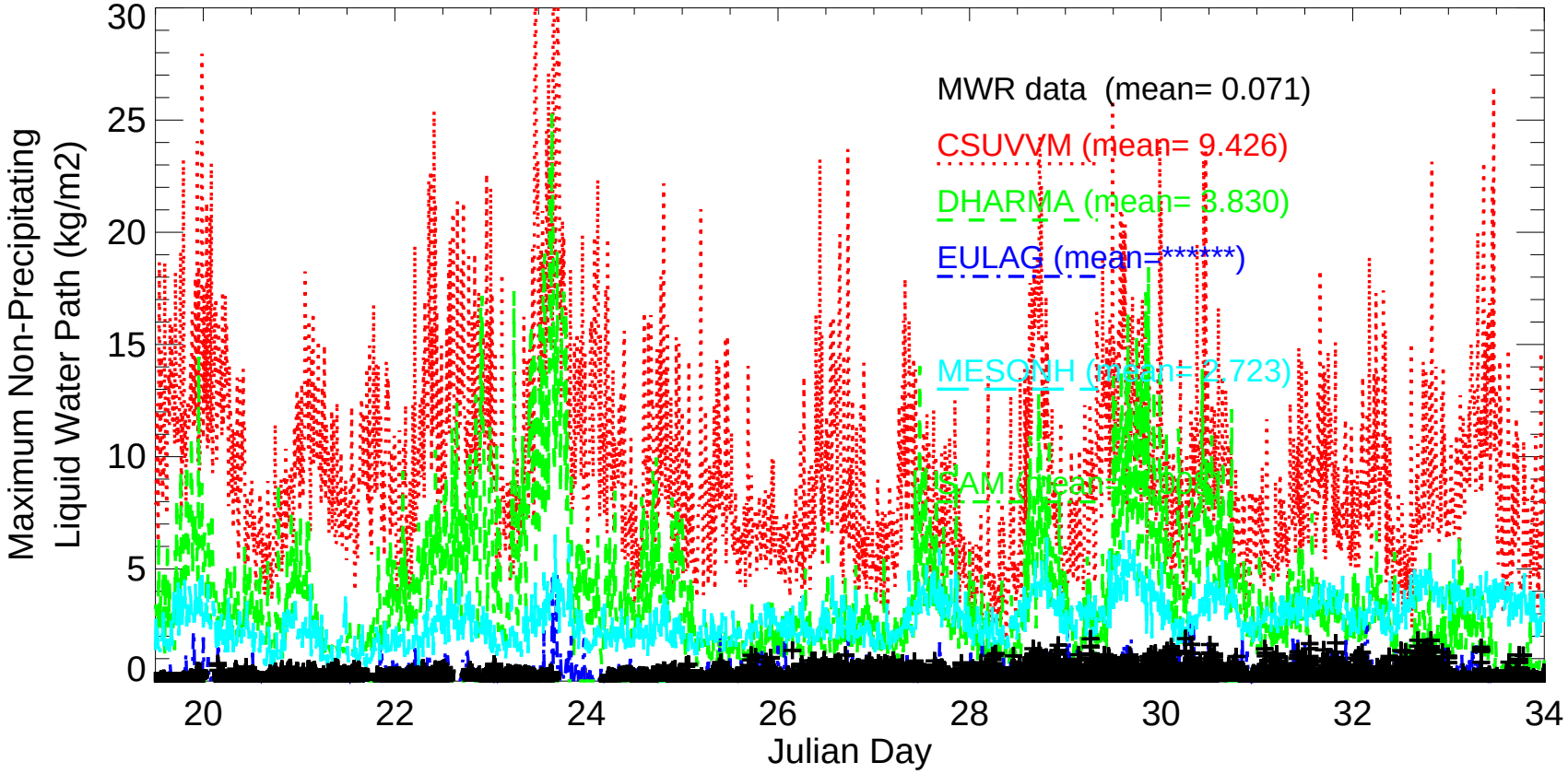
Data: *Shaocheng Xie et al.*

Liquid water path (cloud + rain)



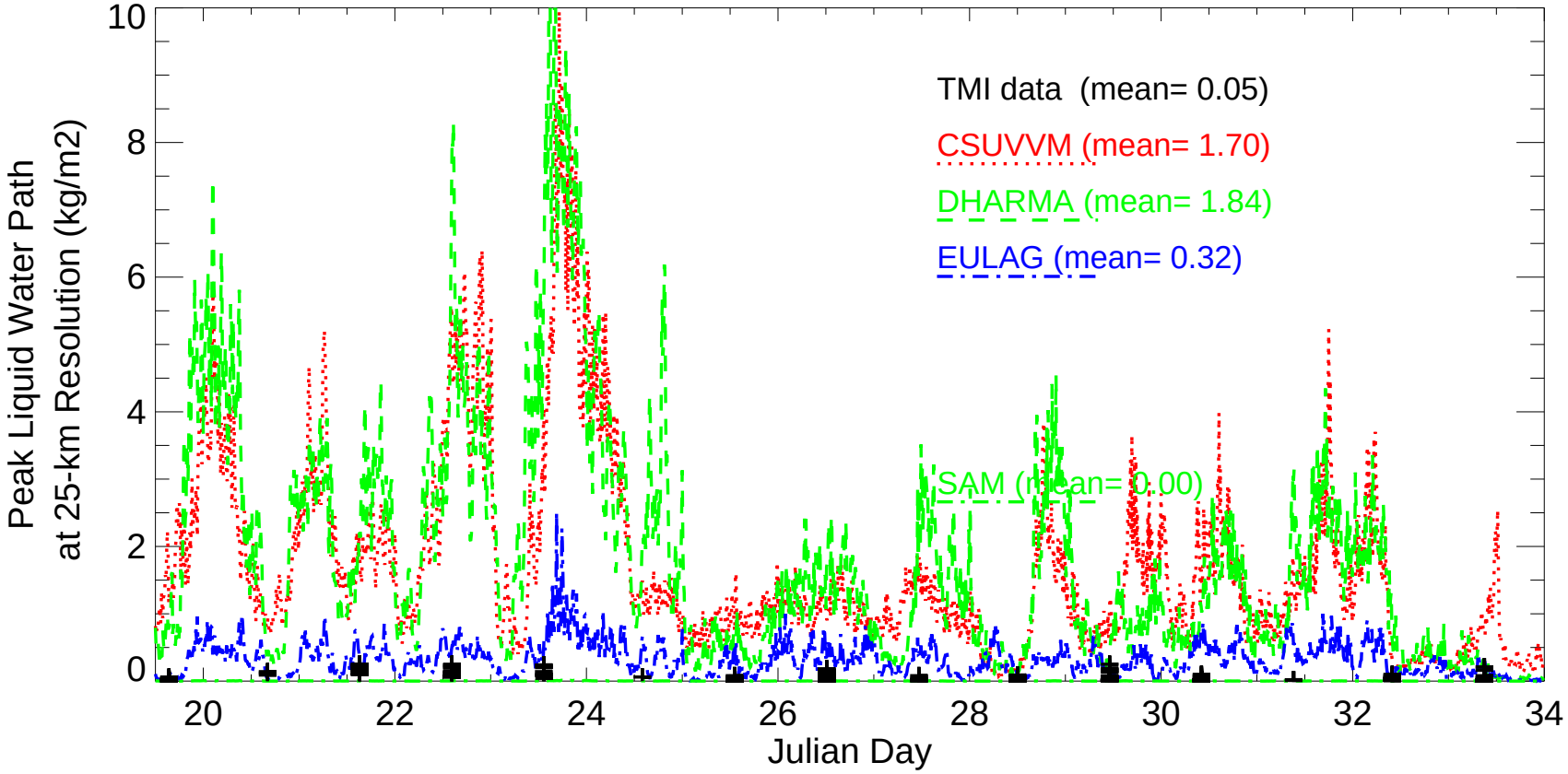
Data: *Shaocheng Xie et al.*

Liquid water path (cloud + rain)



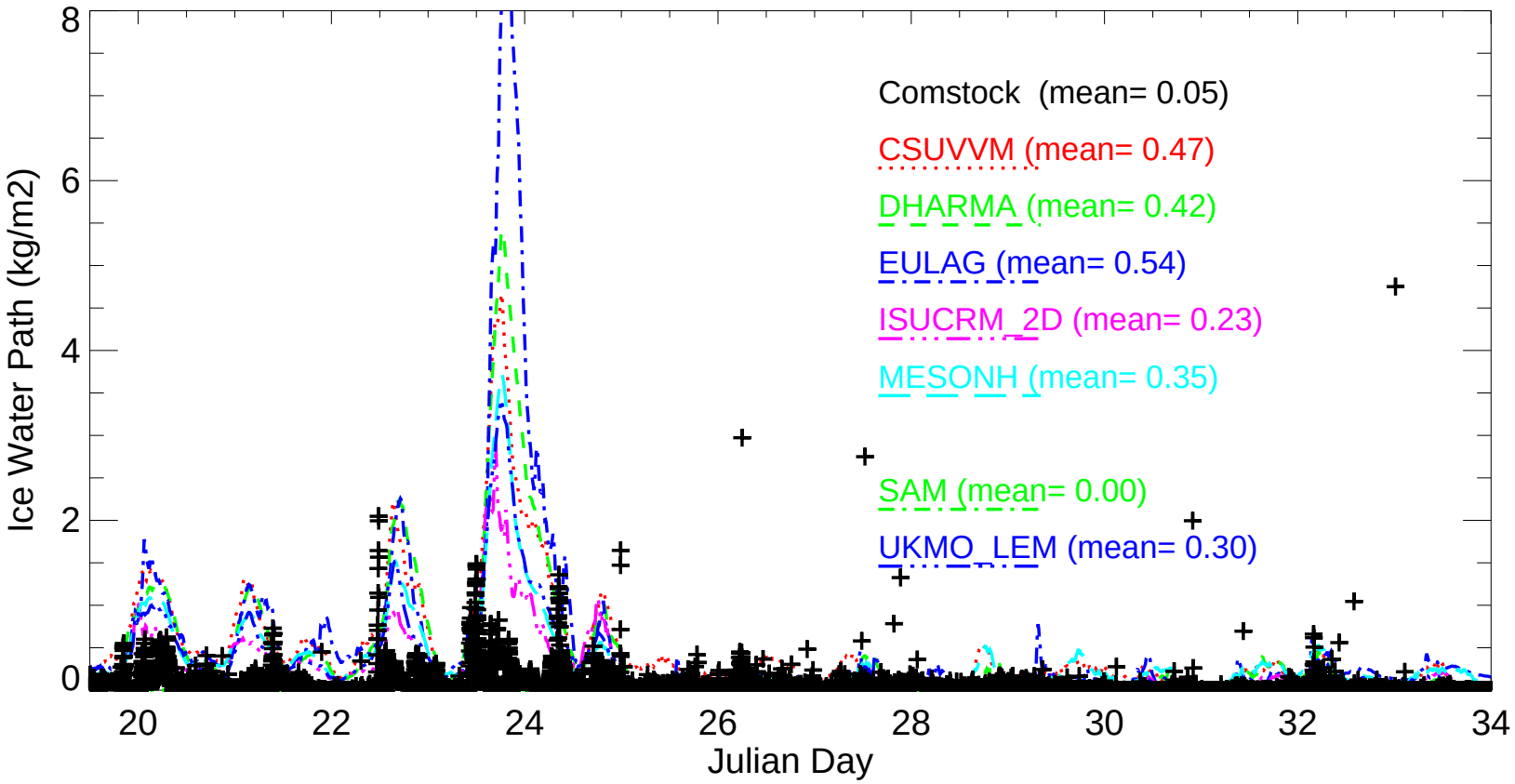
Data: *Jennifer Comstock et al.*

Liquid water path (cloud + rain)



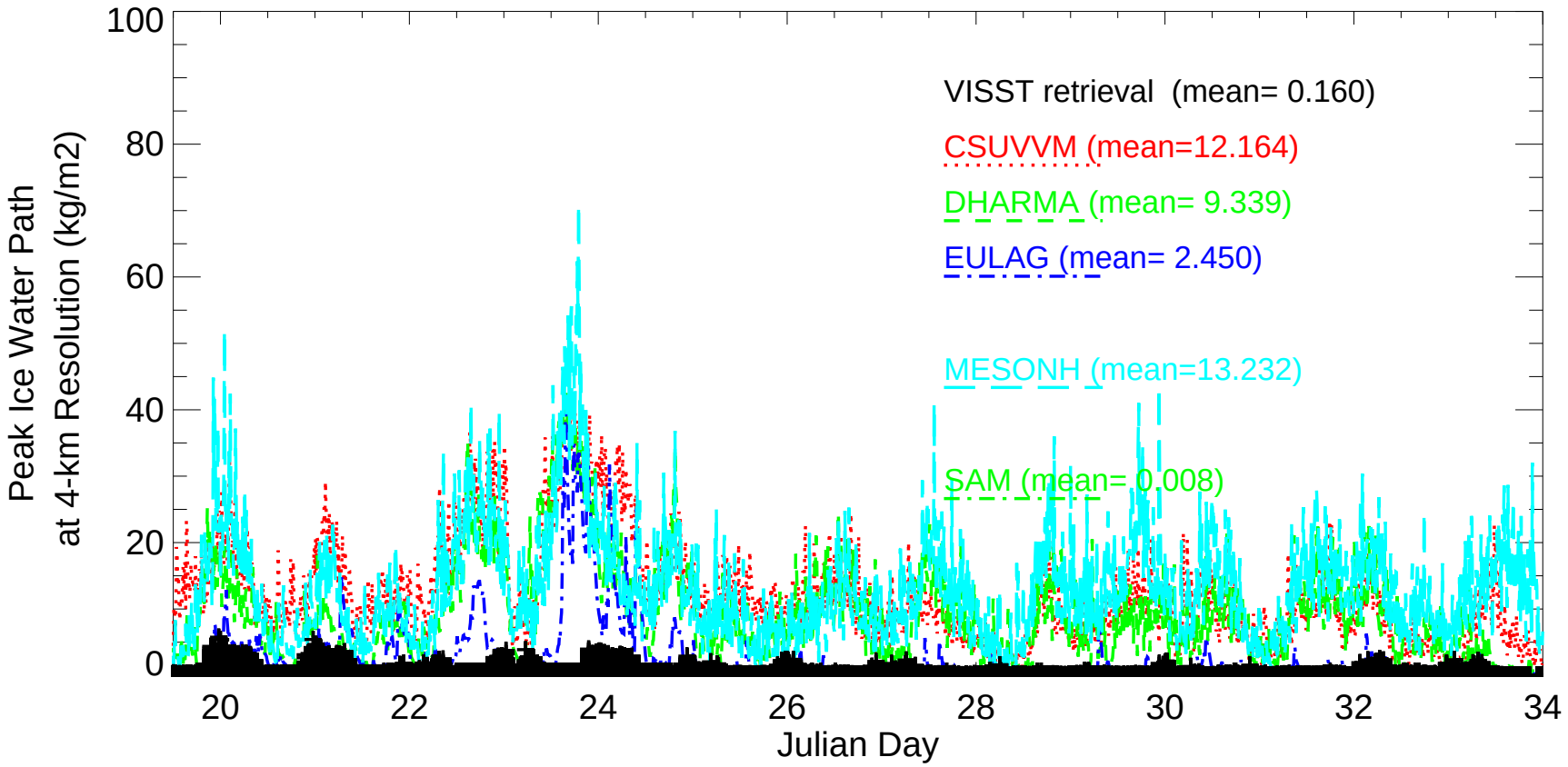
Data: *Dave Turner et al.*

Ice water path



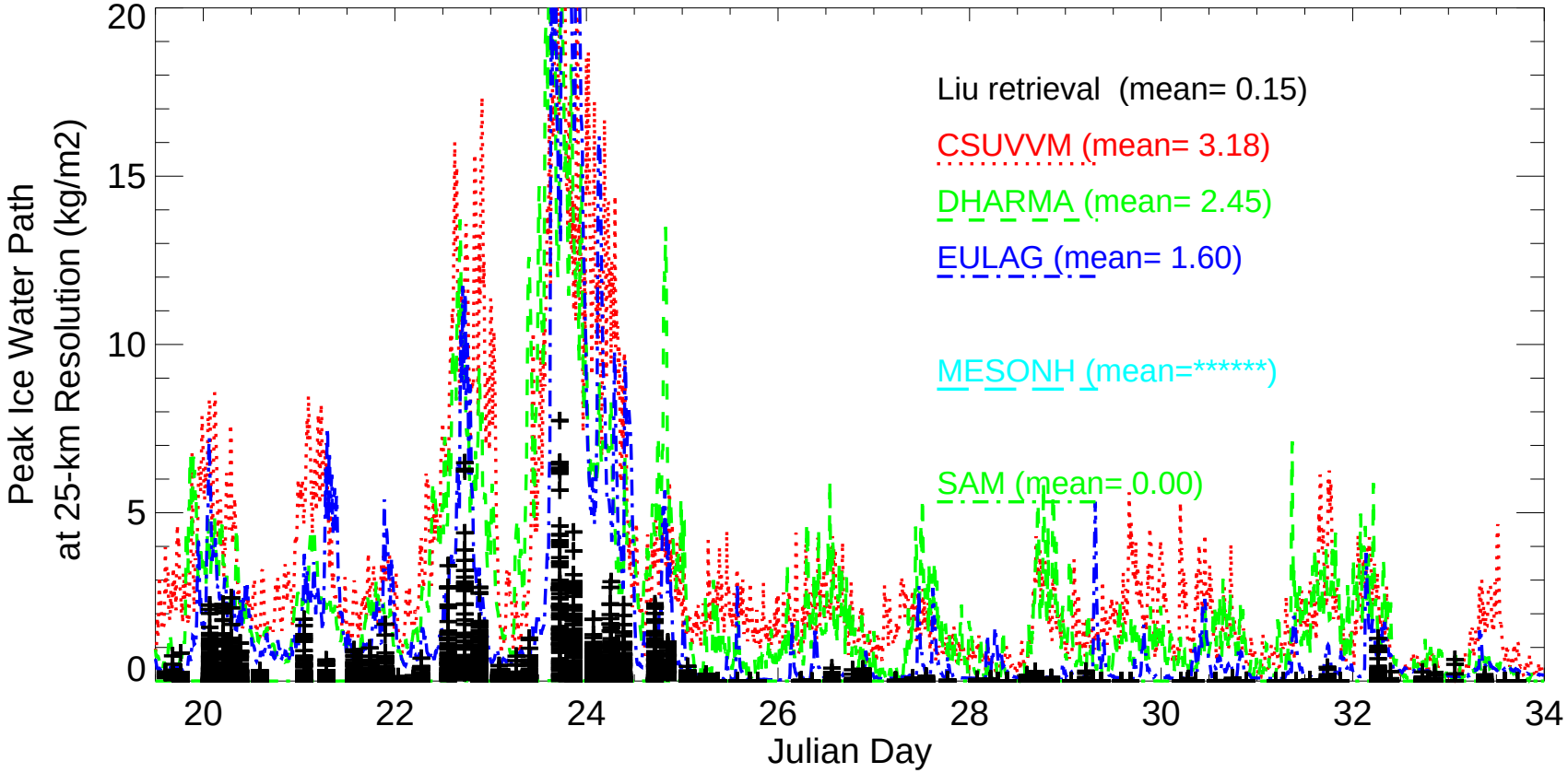
Data: *Jennifer Comstock et al.*

Ice water path



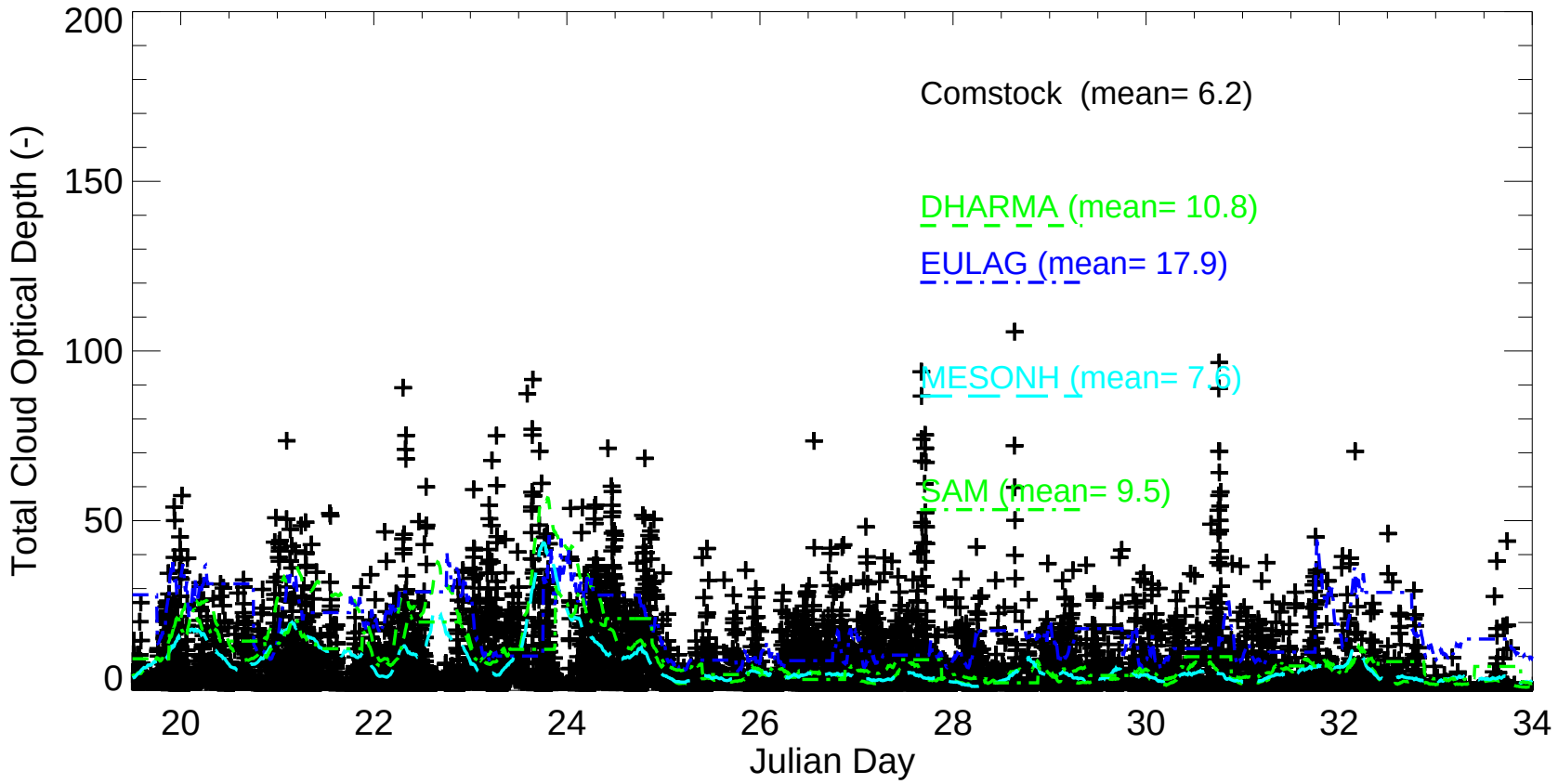
Data: *Pat Minnis et al.*

Ice water path



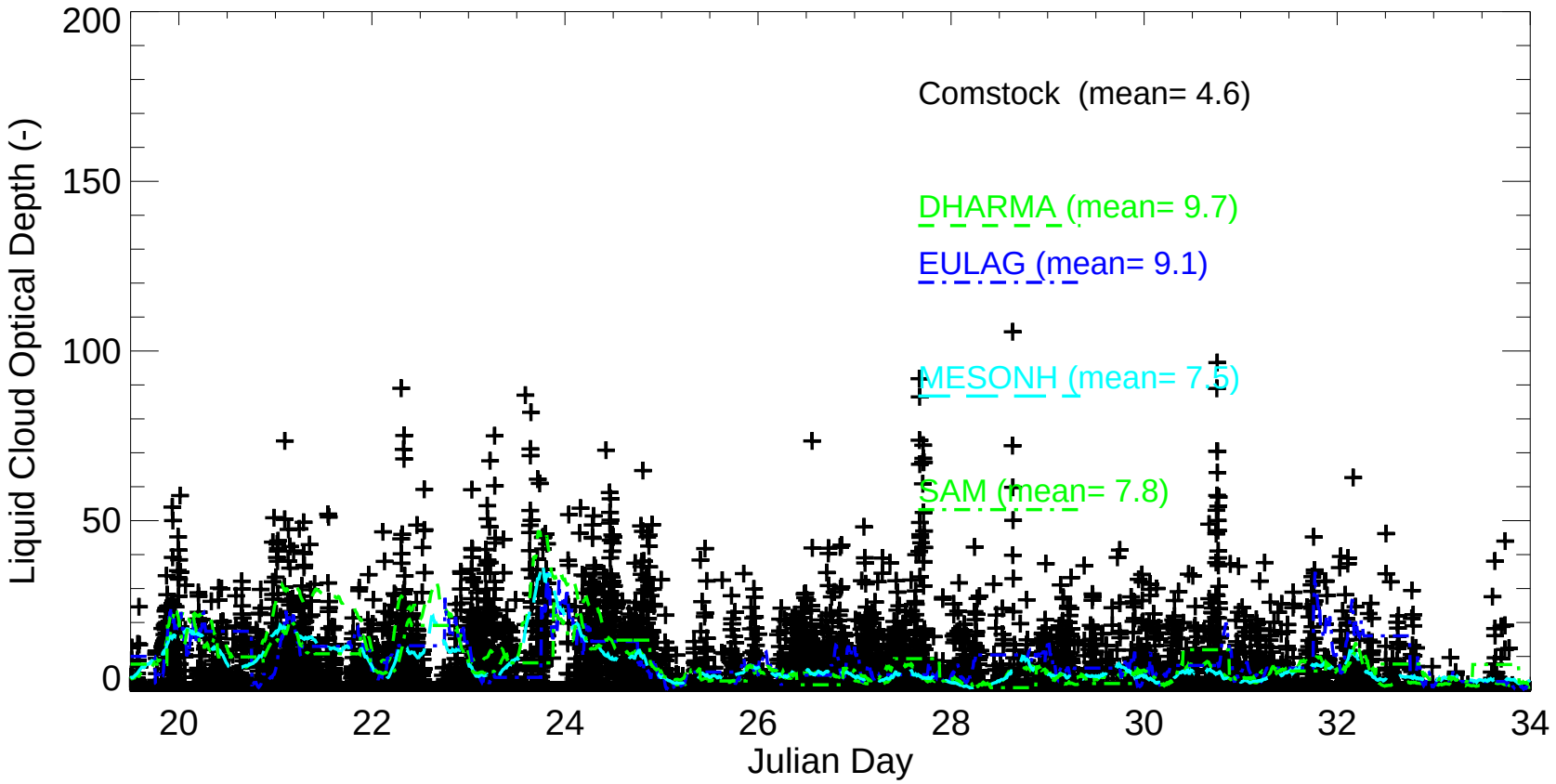
Data: *Guosheng Liu et al.*

Cloud optical depth



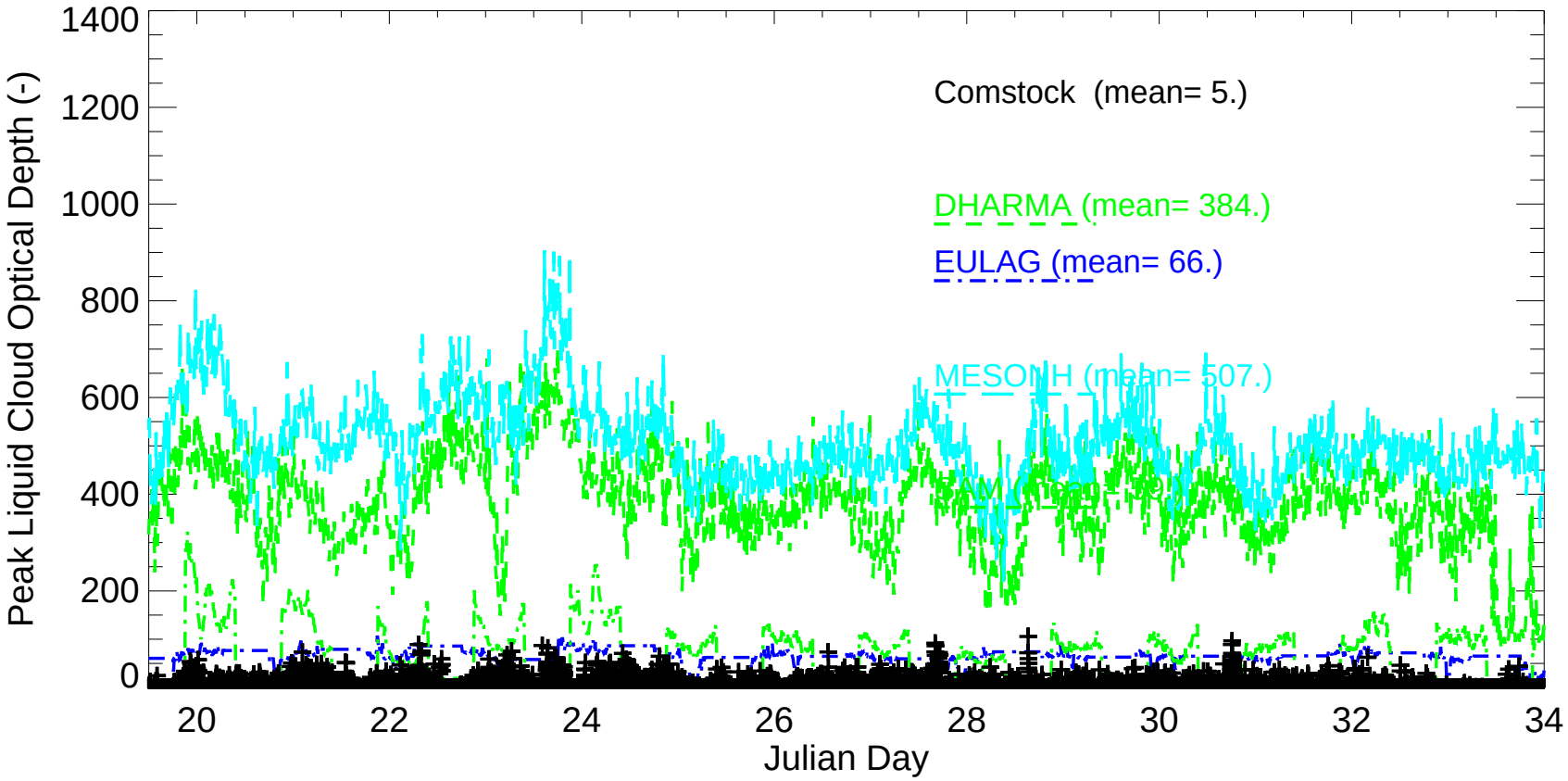
Data: *Jennifer Comstock et al.*

Cloud optical depth



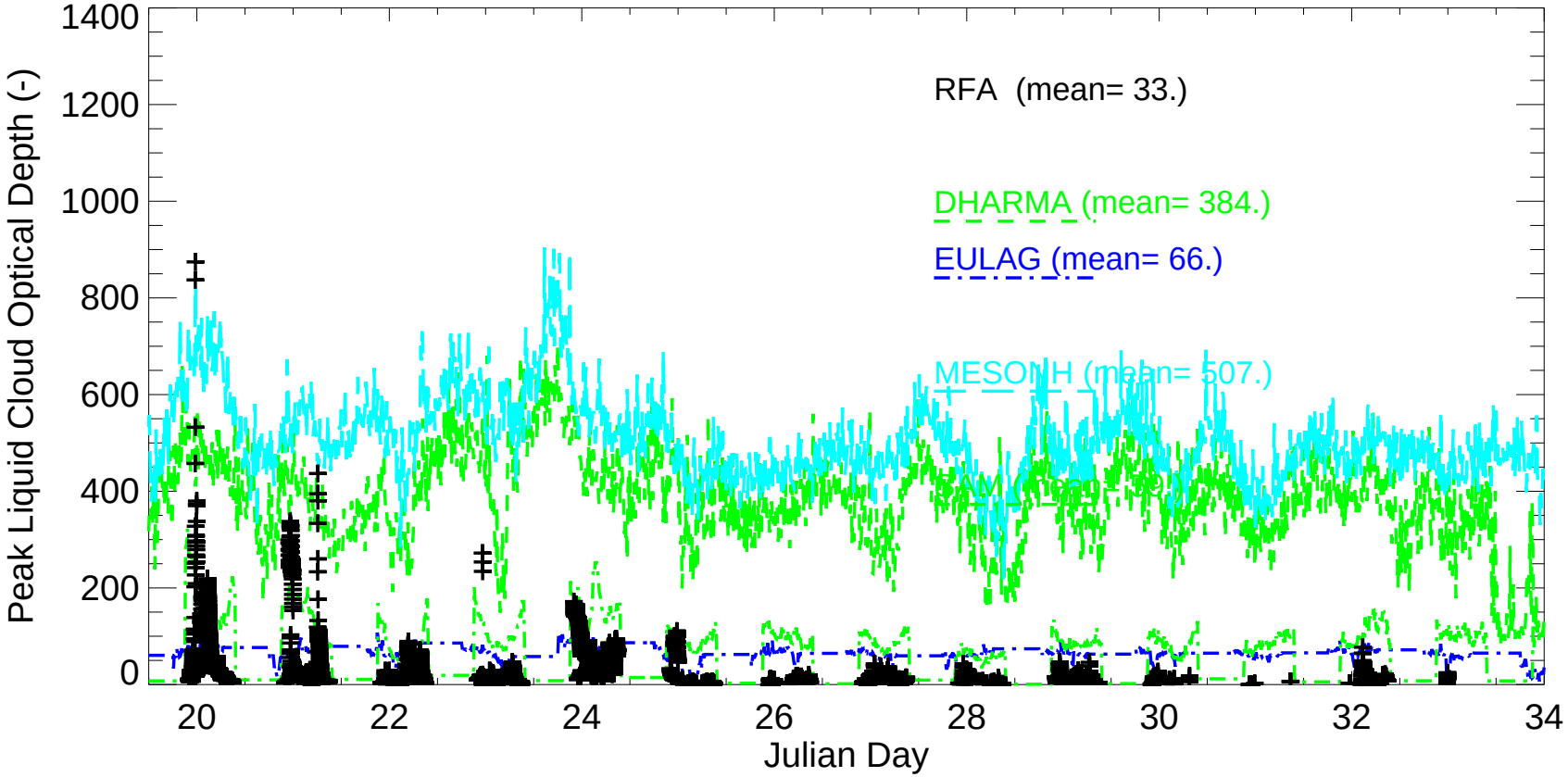
Data: *Jennifer Comstock et al.*

Cloud optical depth



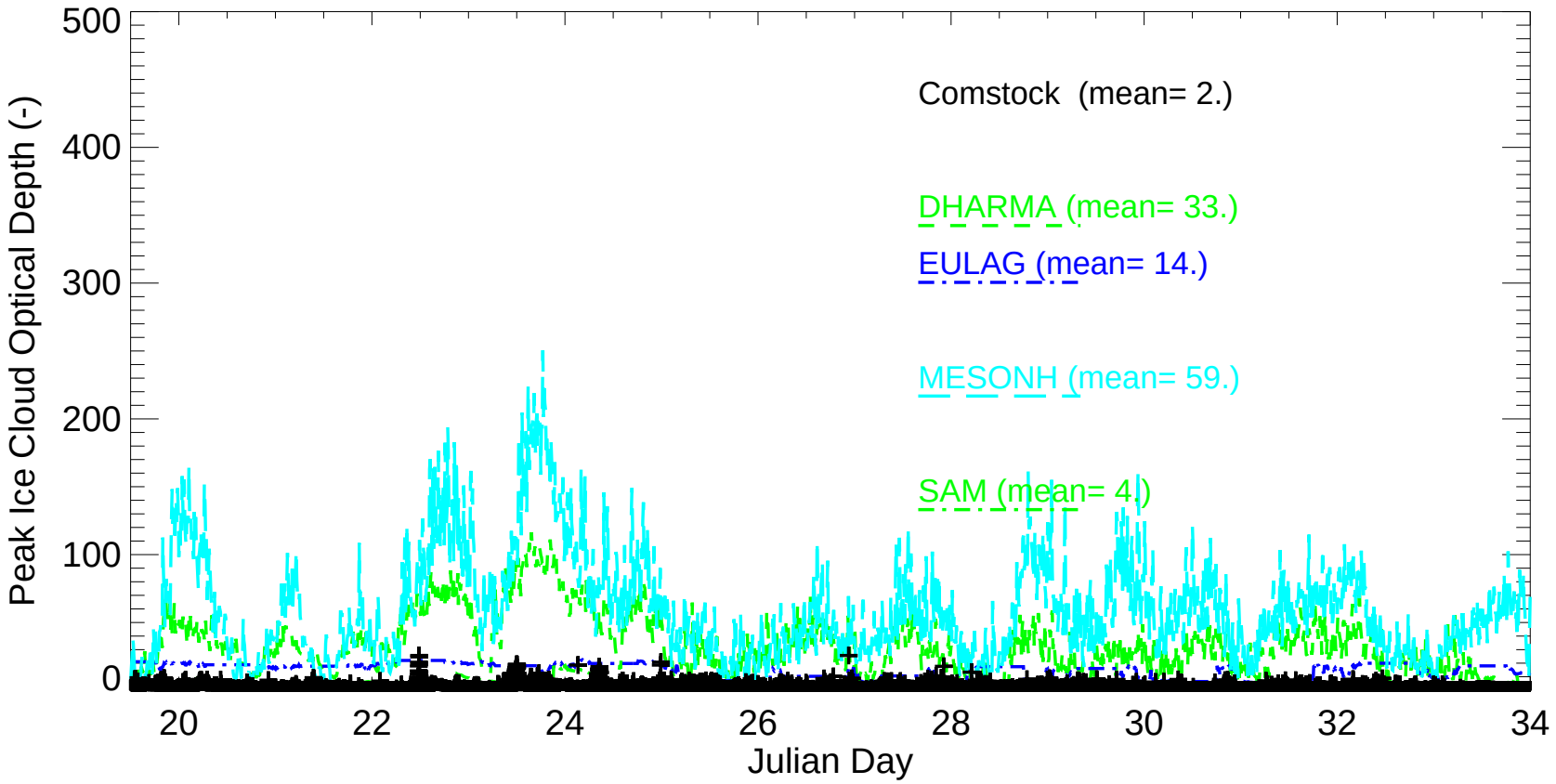
Data: *Jennifer Comstock et al.*

Cloud optical depth



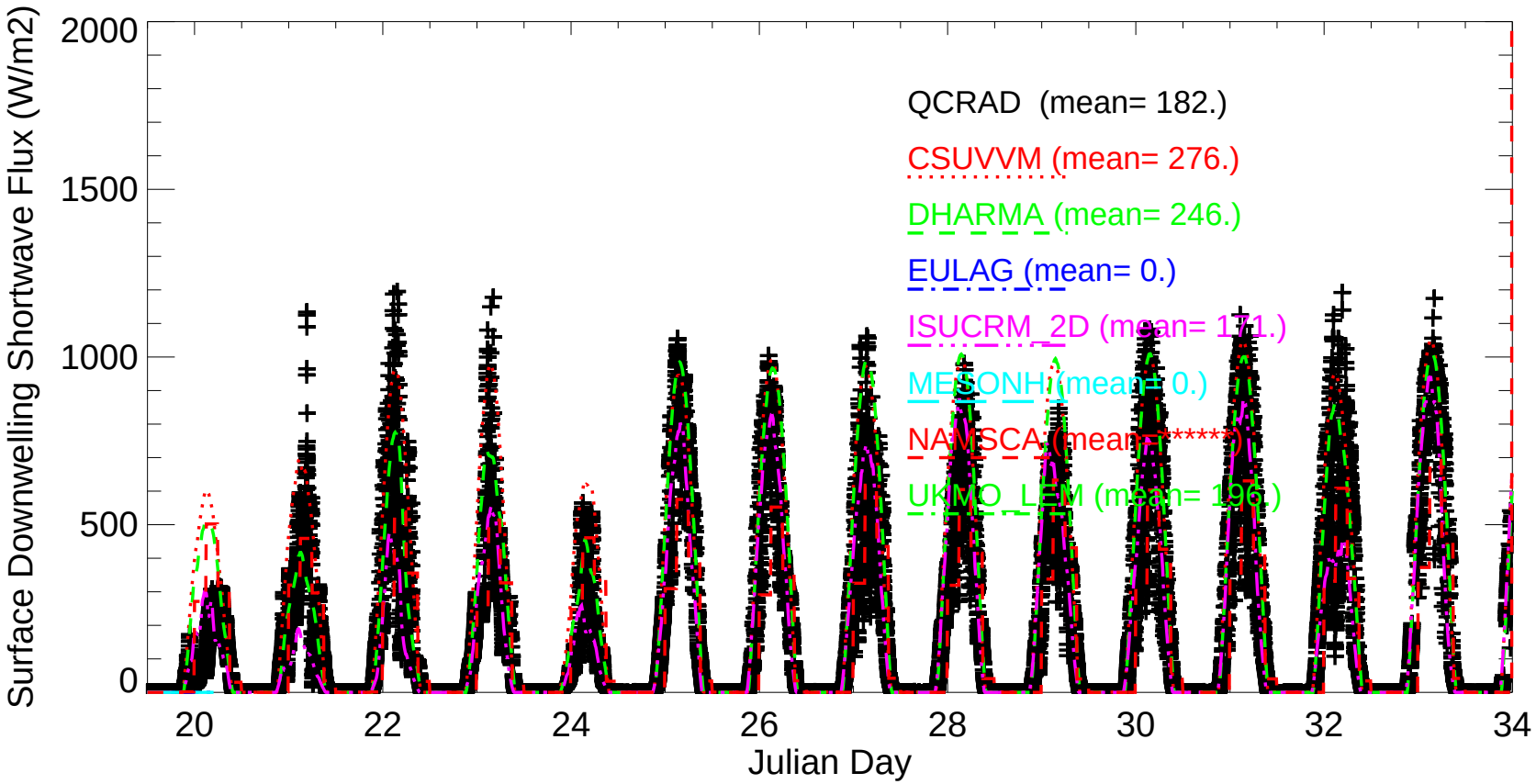
Data: *Chuck Long et al.*

Cloud optical depth



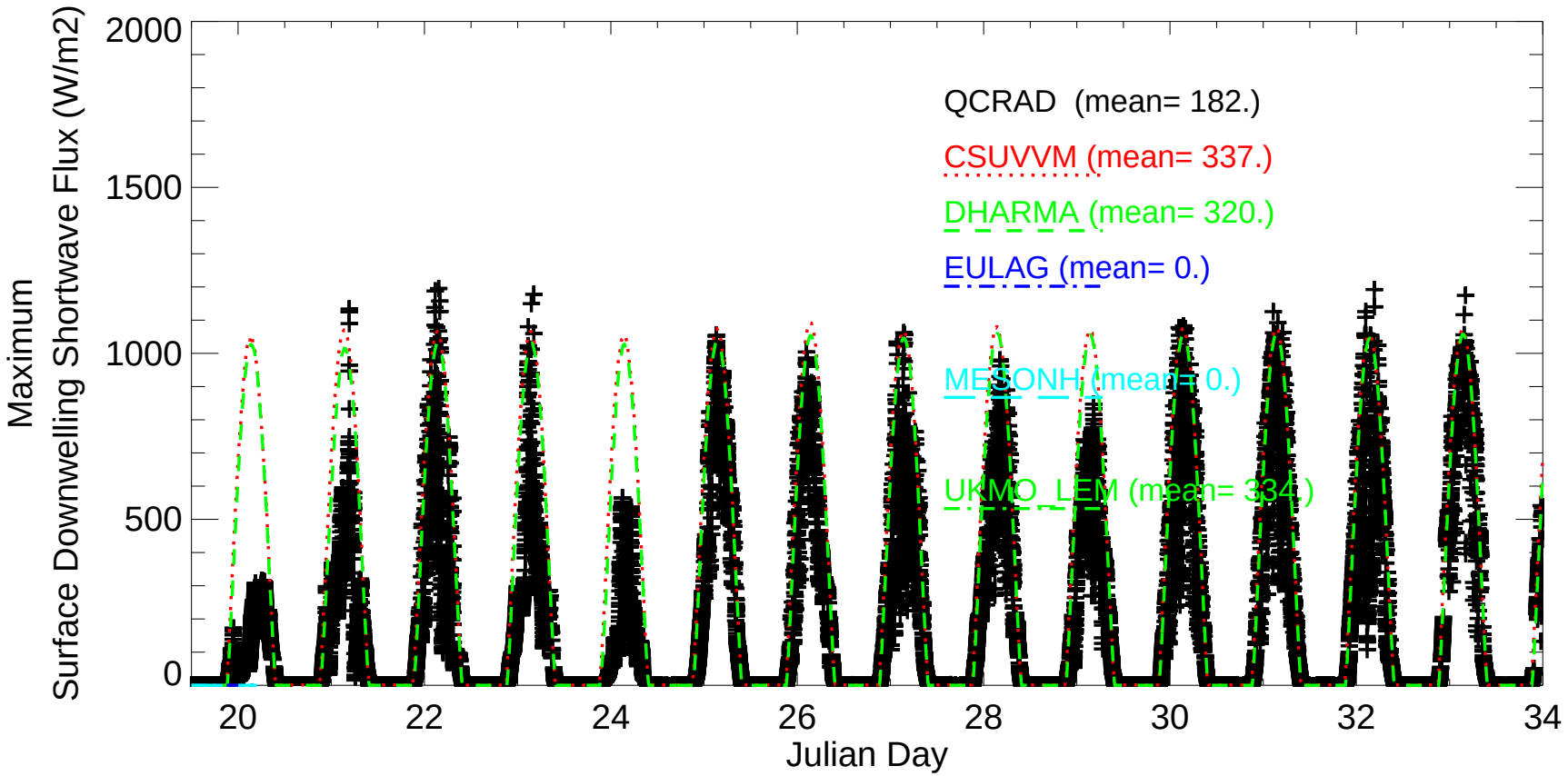
Data: *Pat Minnis et al.*

Surface Downwelling Shortwave Radiative Flux



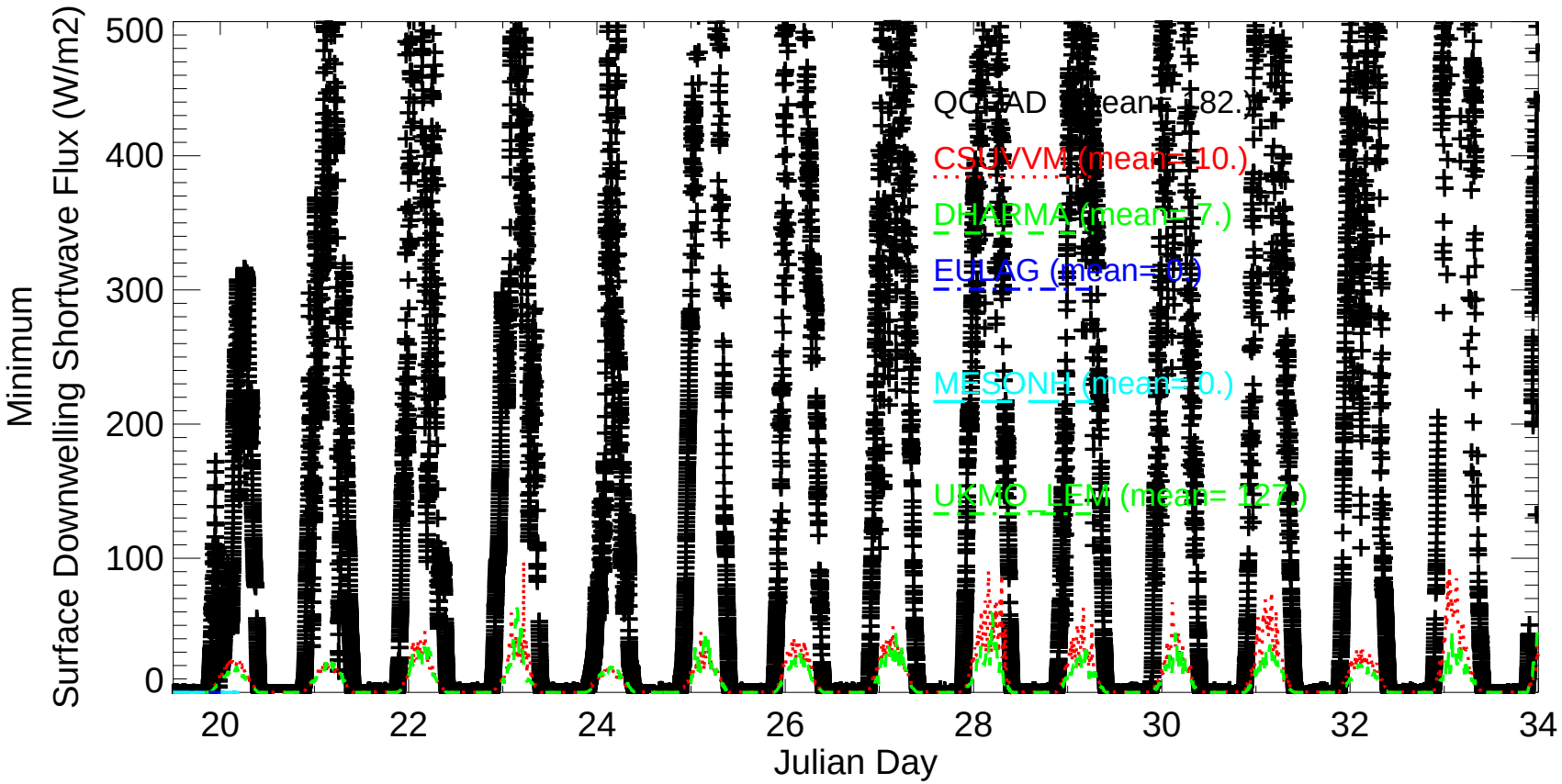
Data: *Chuck Long et al.*

Surface Downwelling Shortwave Radiative Flux



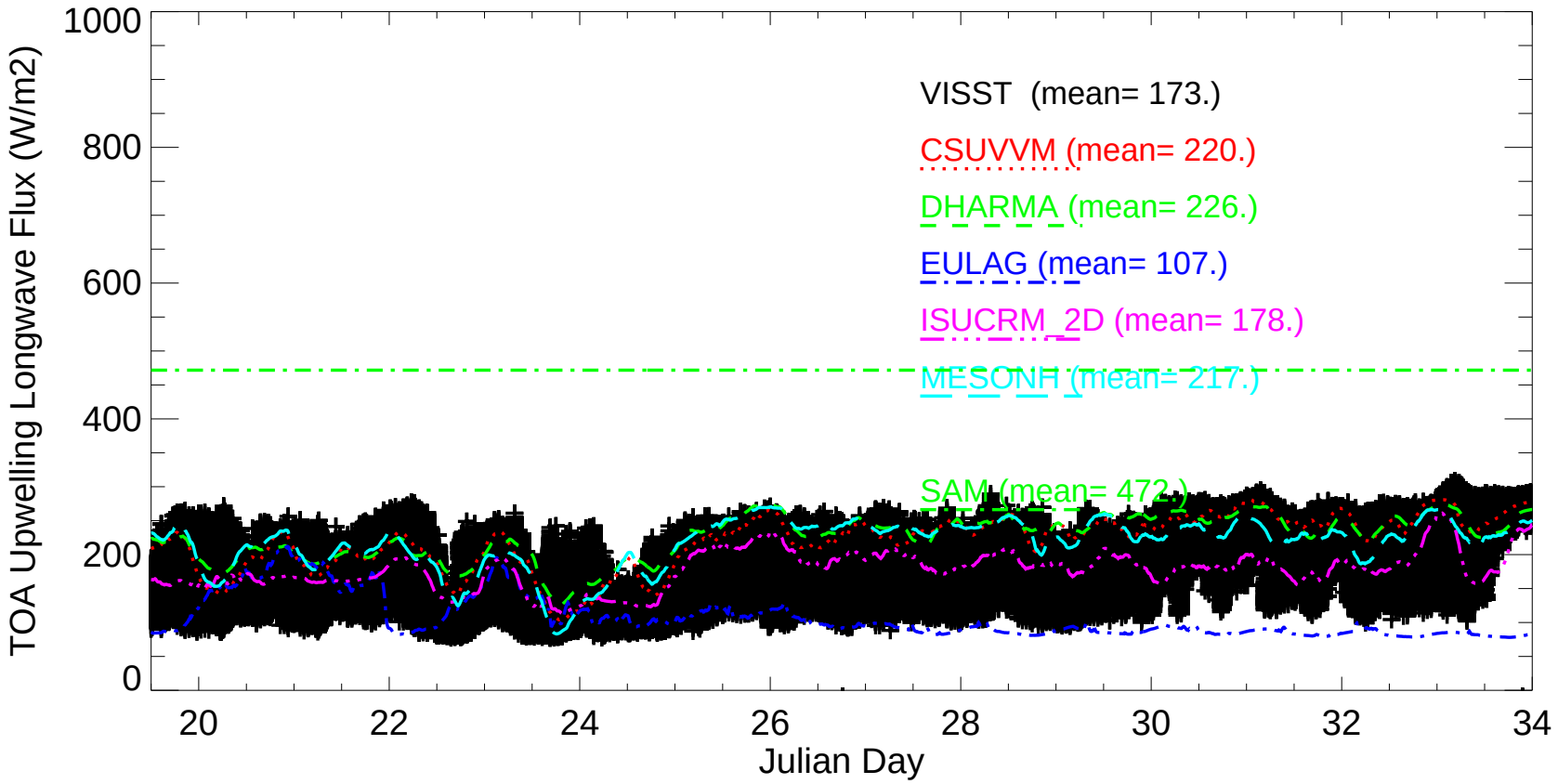
Data: *Chuck Long et al.*

Surface Downwelling Shortwave Radiative Flux



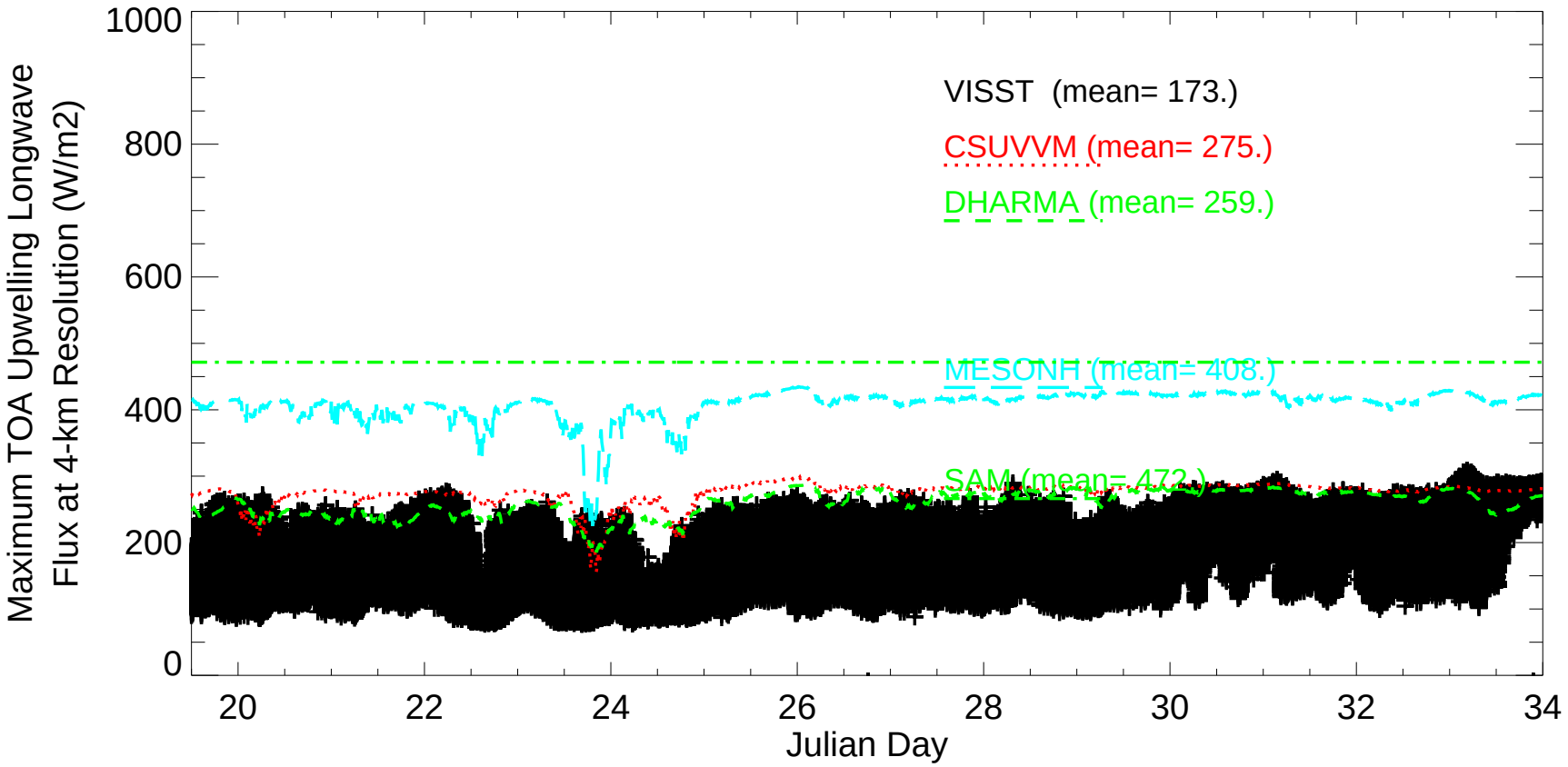
Data: *Chuck Long et al.*

TOA Upwelling Longwave Radiative Flux



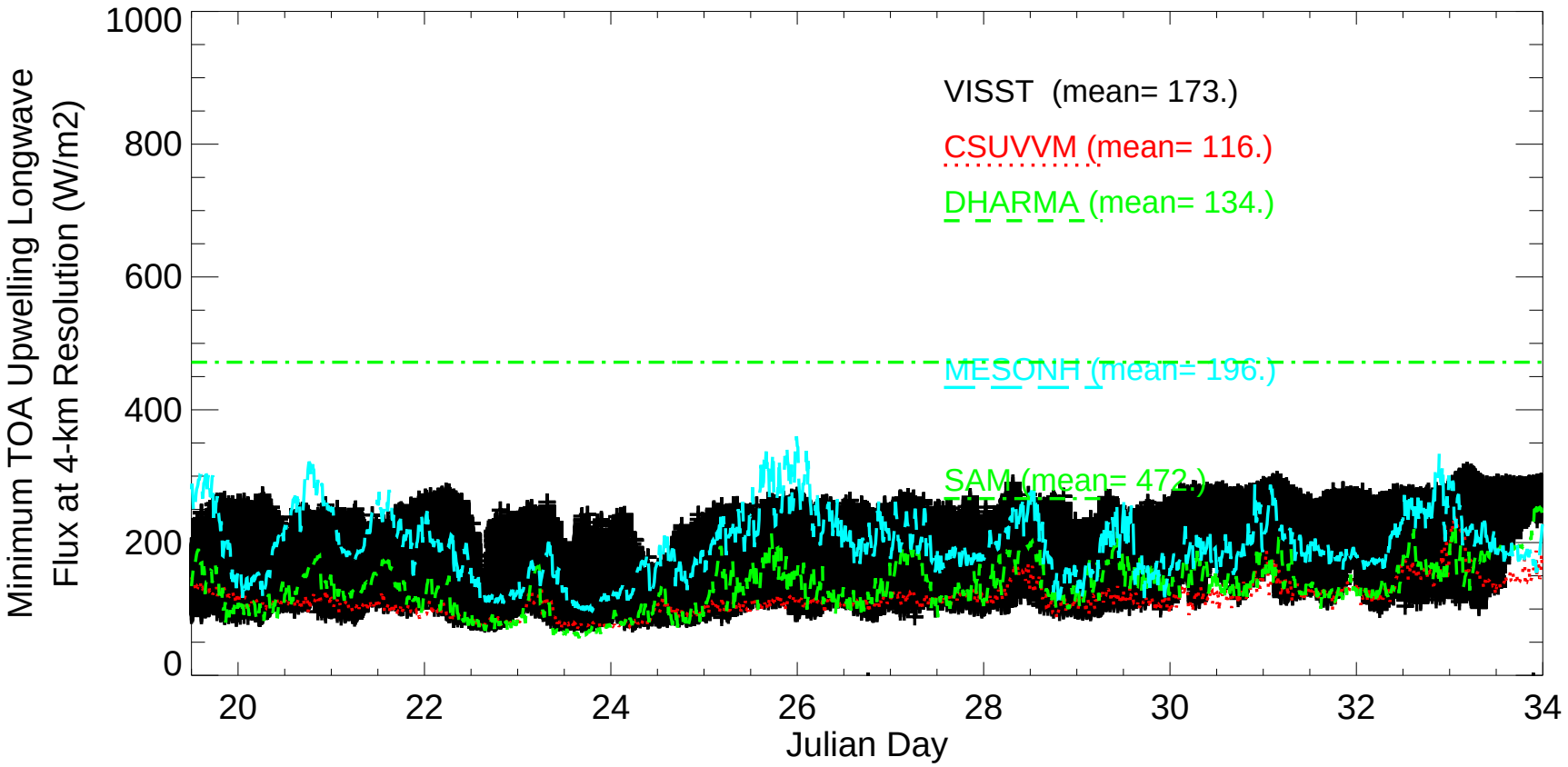
Data: *Pat Minnis et al.*

TOA Upwelling Longwave Radiative Flux



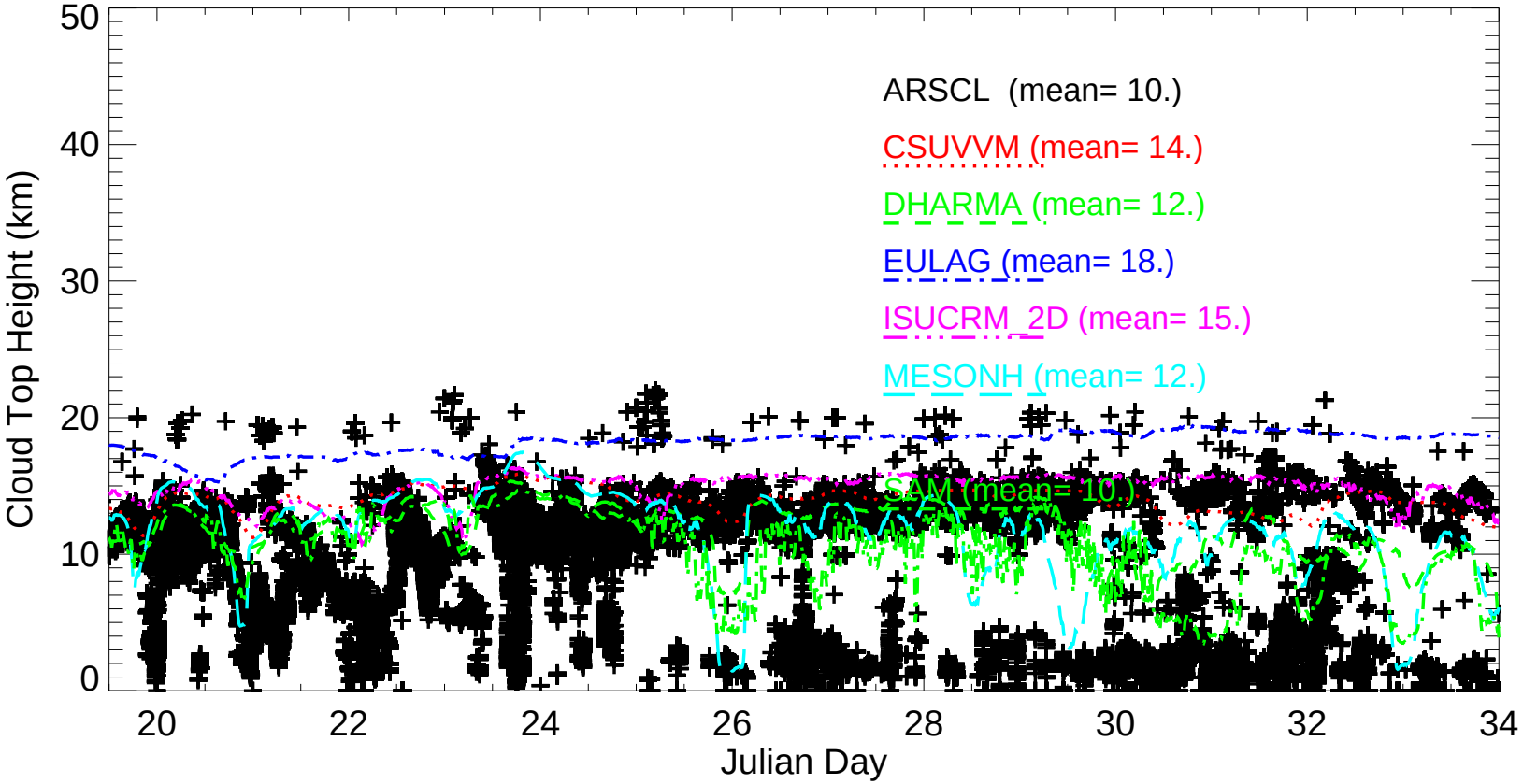
Data: *Pat Minnis et al.*

TOA Upwelling Longwave Radiative Flux



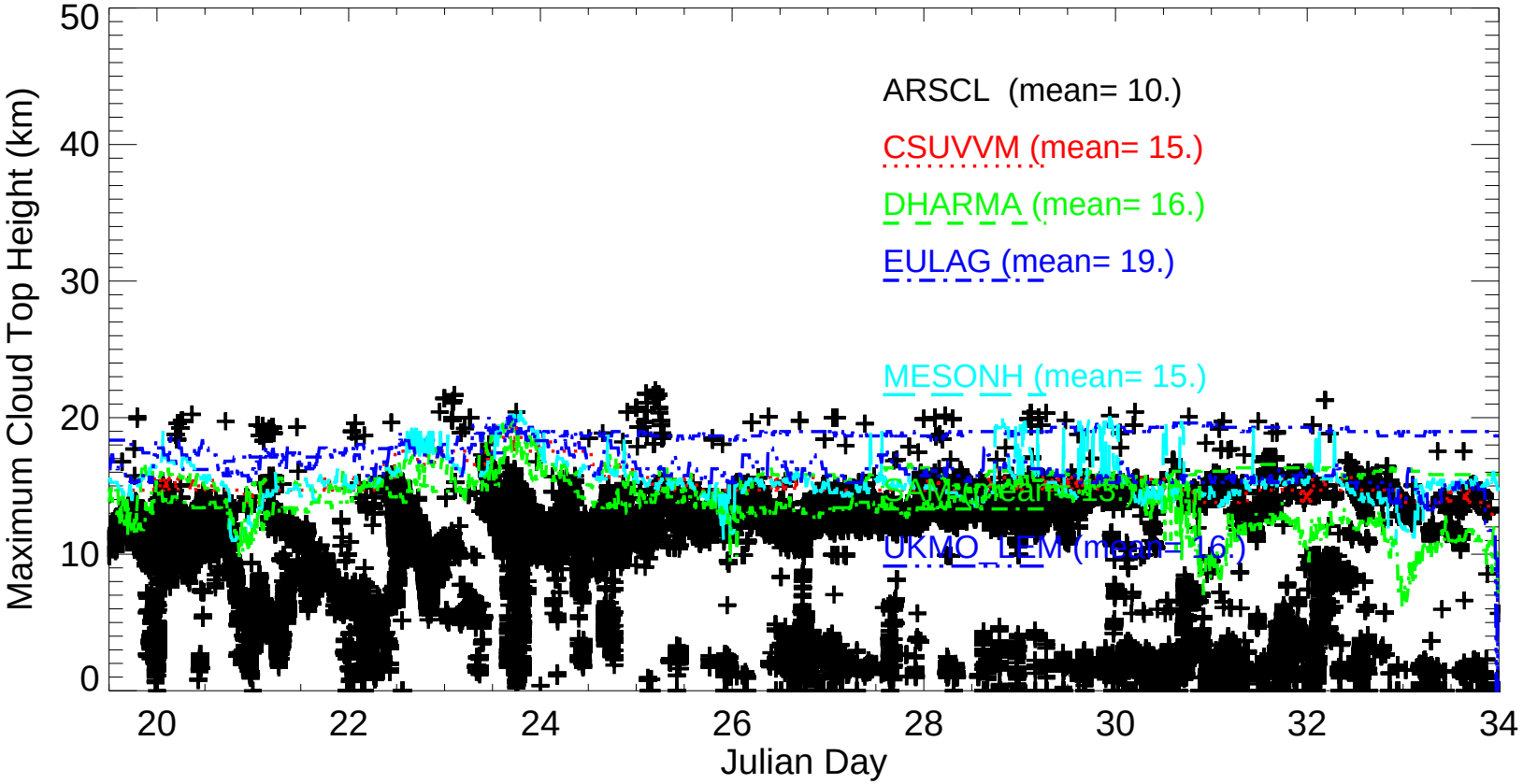
Data: *Pat Minnis et al.*

Cloud Top Height



Data: *Eugene Clothiaux et al.*

Cloud Top Height



Data: *Eugene Clothiaux et al.*

Summary

- CRM case specification
  - idealized marine
  - 16 days
  - eight models participating
- first goal: closure experiment
  - mean surface PR better than peak rates at 2.5 km
  - mean LWP totally unconstrained by measurements
  - measurements of peak LWP where PR=0 confounding
  - model and observed mean and peak IWP severely disparate
  - model cloud optical thickness too high, but also SFC-SWdn
  - model TOA LWup and CTH paint consistent picture