

# Validation of satellite-derived cloud physical and microphysical properties with aircraft measurements from TC4

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Tropical Composition, Clouds, and Climate Coupling  
Experiment Science Team Meeting

Virginia Beach, VA

26 February, 2008



TC4 Science Team Meeting

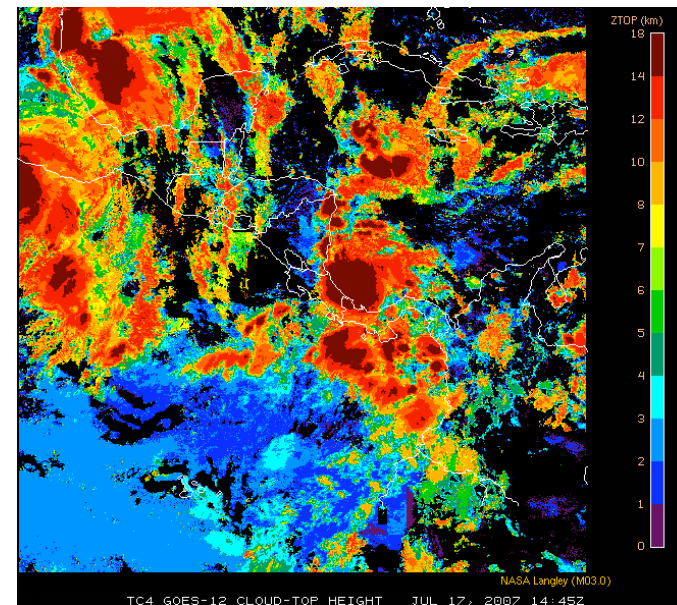
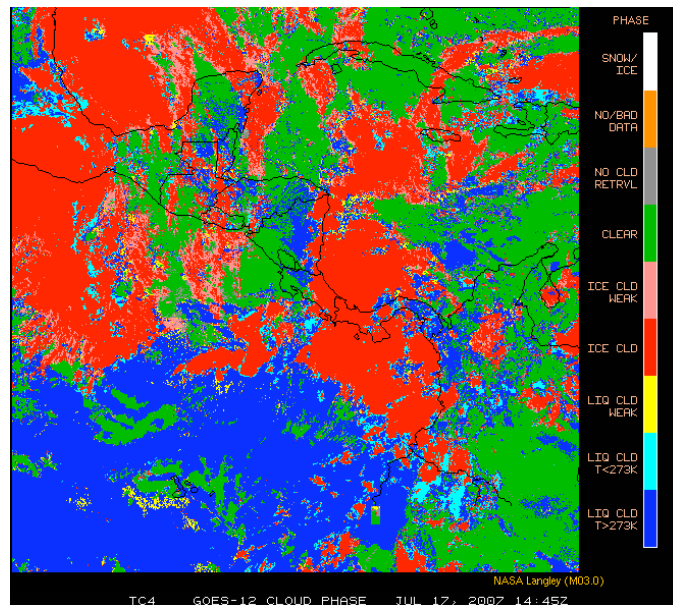


# Outline

- Focus is on ice-phase clouds
- Estimating cloud top height ( $z_{top}$ ) from passive satellite observations
  - Comparisons with the CPL (*McGill et al. 2002*)
  - Theoretical RT calcs
- Estimating ice water path (*IWP*) and ice particle size ( $D_e$ )
  - Case studies from TC4
  - Particle size distributions and ice water content from the Cloud Imaging Probe (CIP; Heymsfield and Bansemer)



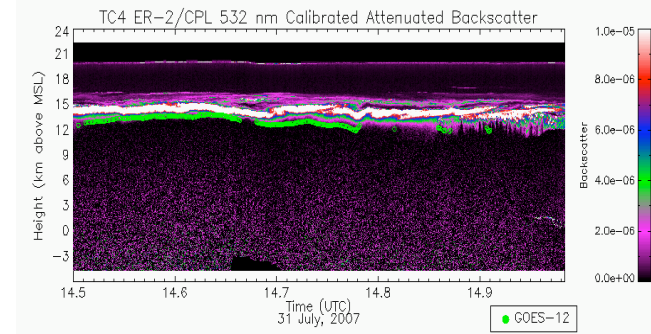
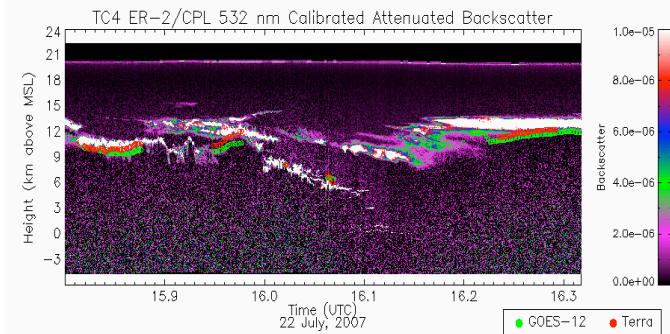
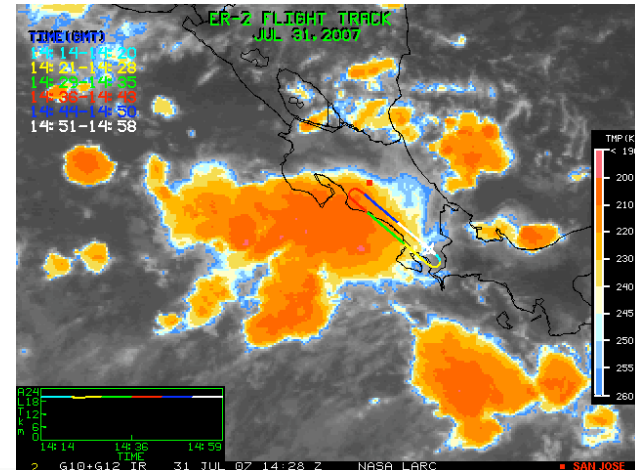
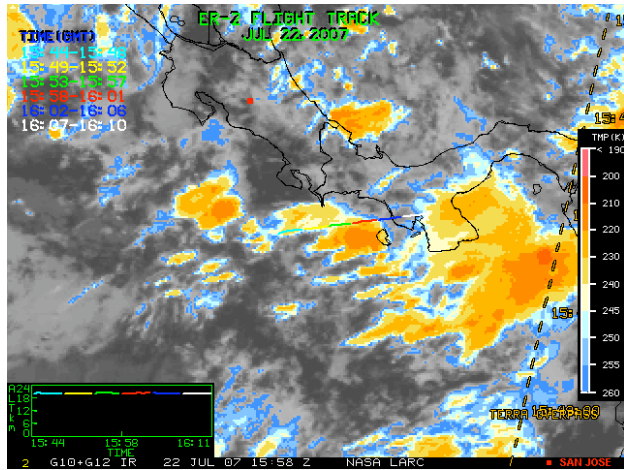
# Satellite Cloud Products



- Visible Infrared Solar-Infrared Split Window Technique (VISST), *Minnis et al.* 1998
  - Used to determine cloud phase, top height, etc. during TC4
  - Run on GOES-12, Terra-MODIS, and Aqua-MODIS data
  - Spatial resolution of cloud products
    - GOES - 4 km
    - MODIS - 2 km

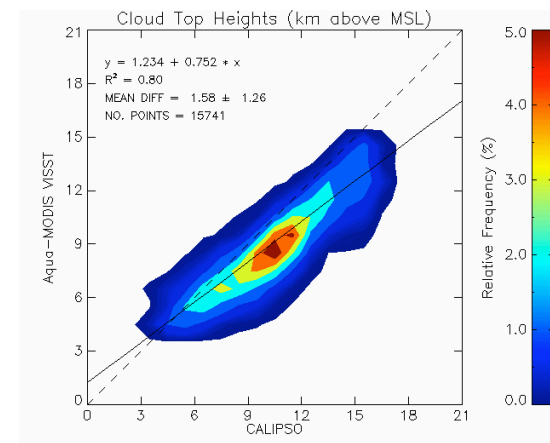
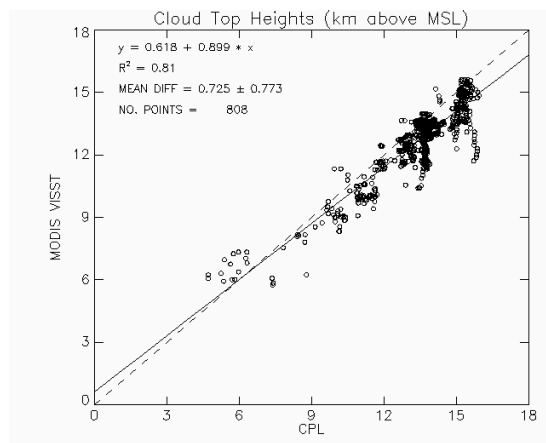
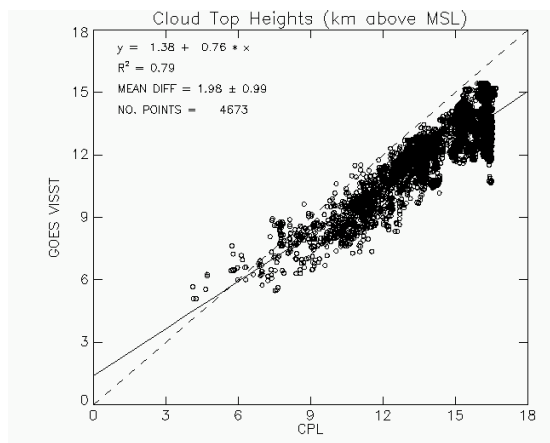


# Cloud Top Heights



- Cloud tops from the Cloud Physics Lidar (CPL) on the ER-2
- VISST underestimates the observed physical top of optically thick ice clouds
- Good correlation with the level at which the lidar totally attenuates
- Optical depth of layer above VISST  $z_{top}$  is  $\approx 3$

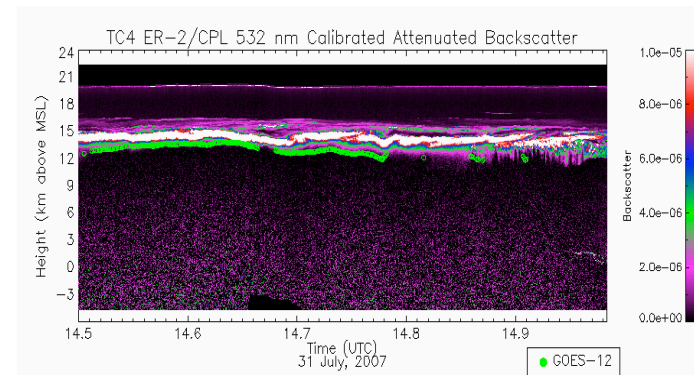
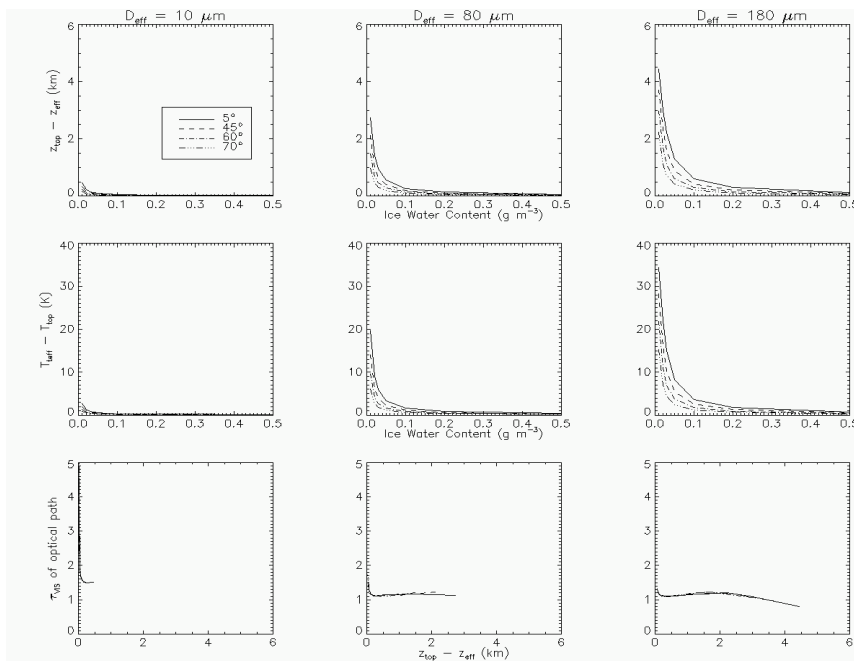
# Cloud Top Heights



- GOES-12 tops underestimated by  $\sim 2$  km on average
- MODIS underestimated by  $< 1$  km
- Similar results with CALIPSO

# Cloud Top Heights

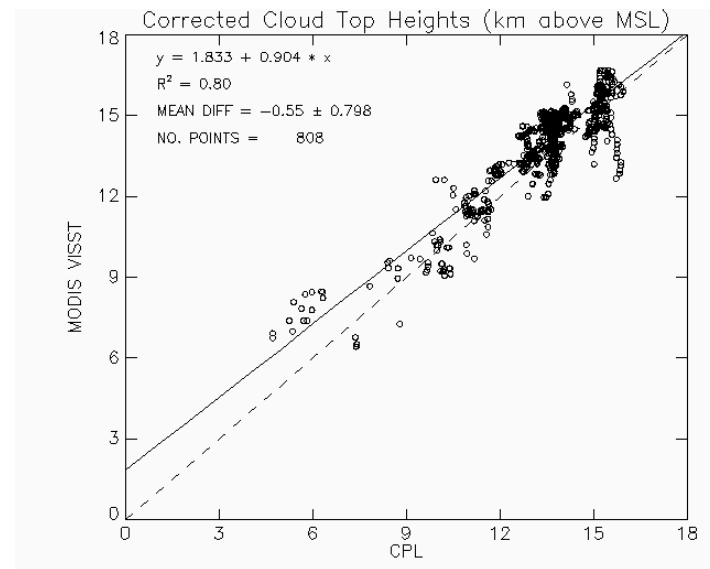
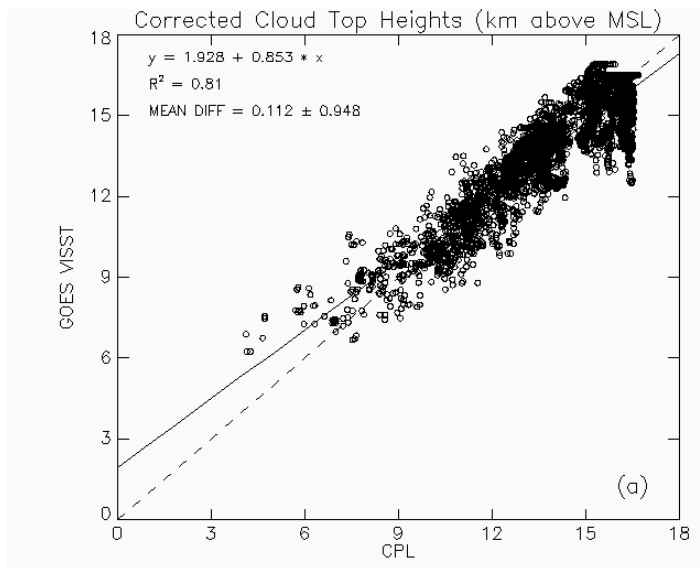
- Difference between VISST  $z_{top}$  and true  $z_{top}$  depends on the  $IWC$  profile near the cloud top
- Sharp boundaries only for the densest clouds



- Forward RT calcs from DISORT (*Stamnes et al., 1988*)
  - IWC,  $0.01 - 0.50 g m^{-3}$
  - 4 viewing angles
  - 3 effective sizes
  - $z_{top} = 13 km, T_{top} = 215 K$
- Calculate  $T_{11}$  at the TOA
- IWC profile can strongly influence the  $T_{11}$  observed from space

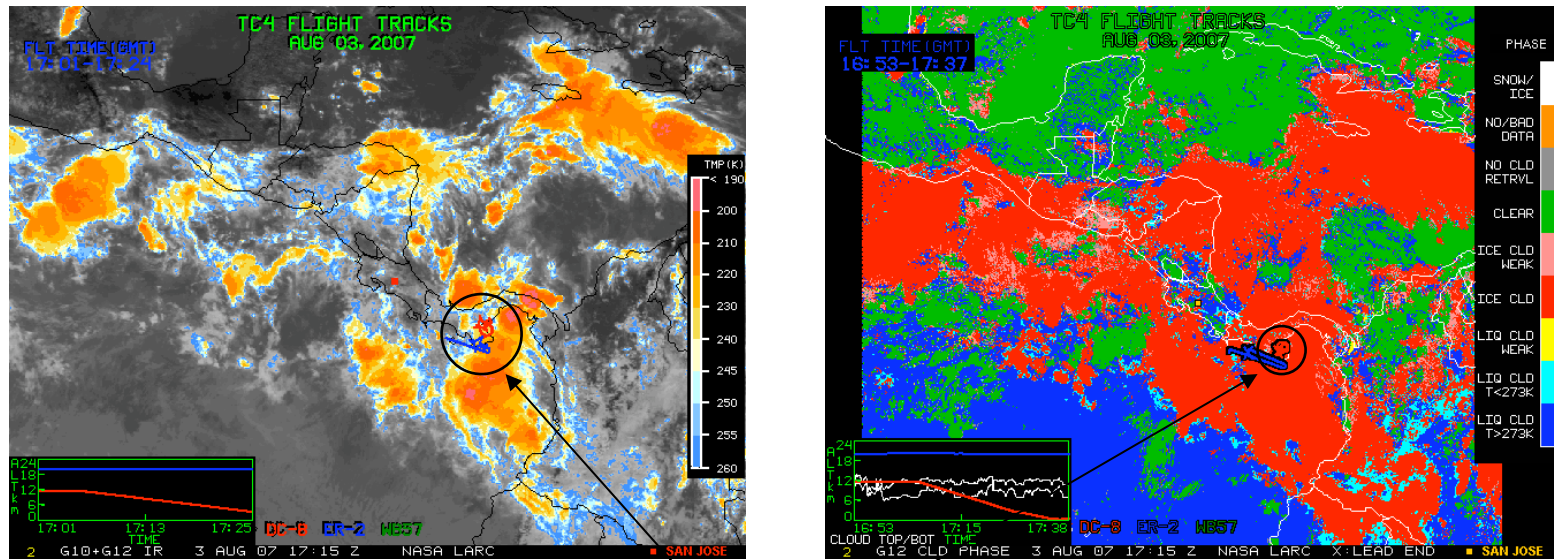


# Cloud Top Heights



- Applied correction based on a month of CALIPSO data
  - Linear least-squares fit
  - Small correction for viewing angle
  - Use tropopause height as an upper limit
  - Use  $D_e$  to constrain solution and reduce scatter?
- Mean difference reduced for both GOES and MODIS

# Ice Water Path

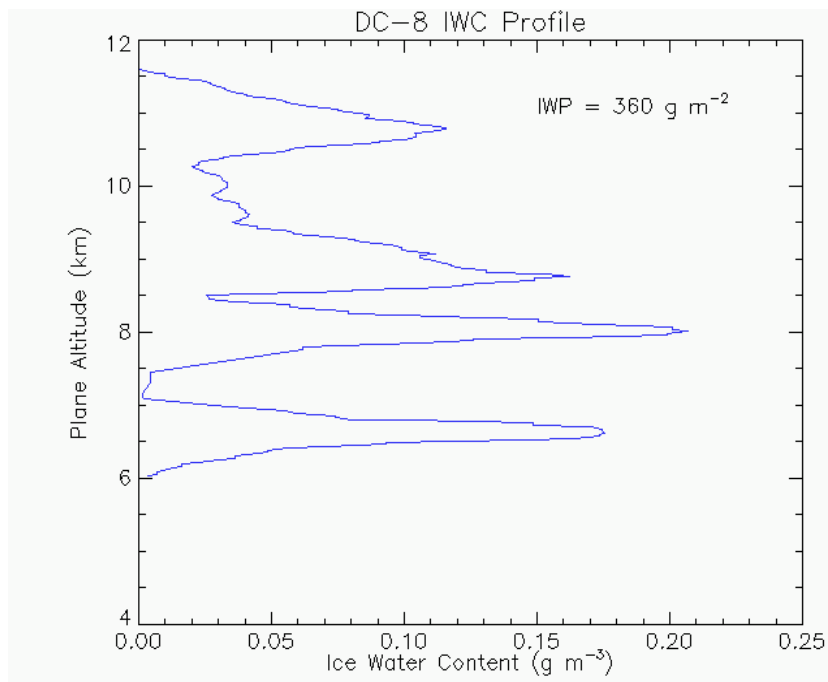


- 3 August, deep convective cloud case
  - DC-8 (red track) made a spiral descent through the cloud
  - CIP sampled ice water content and crystal size
- Useful for validating satellite retrievals of ice water path



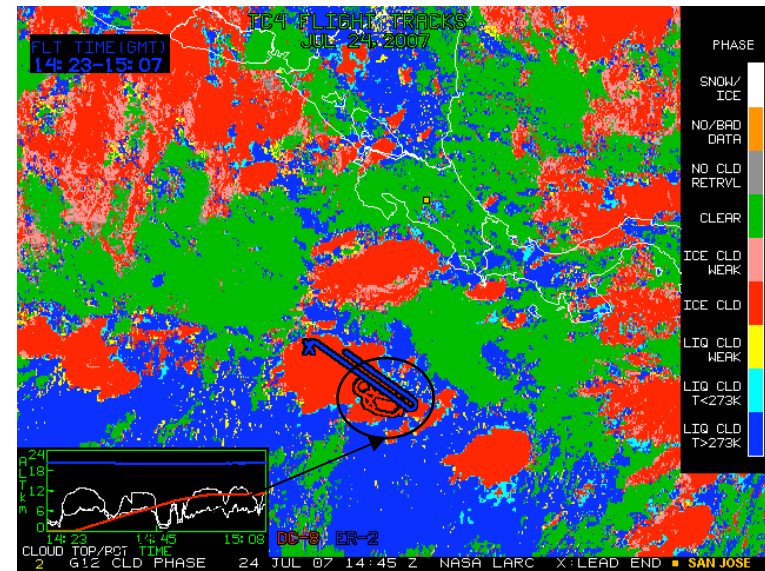
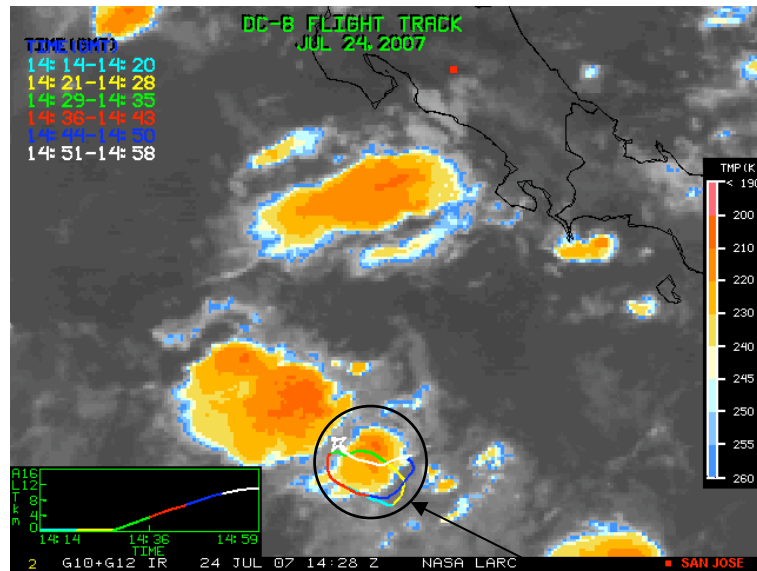
# Ice Water Path

3 August, 2007



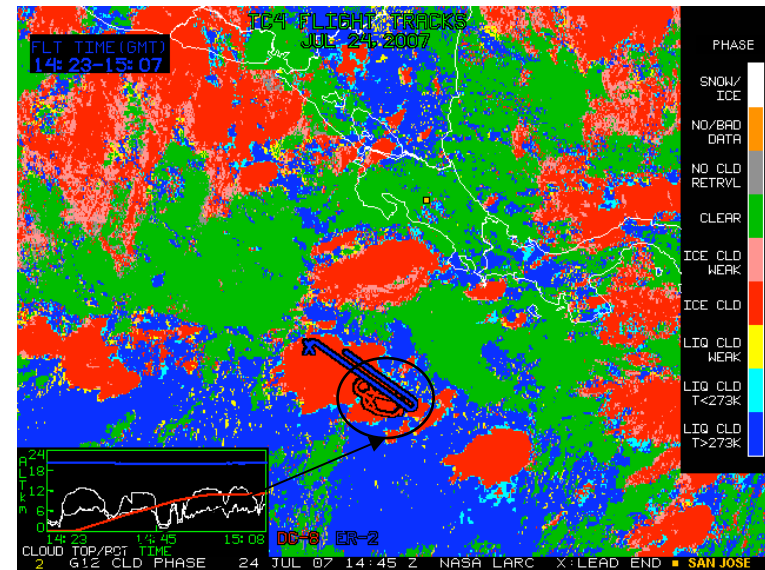
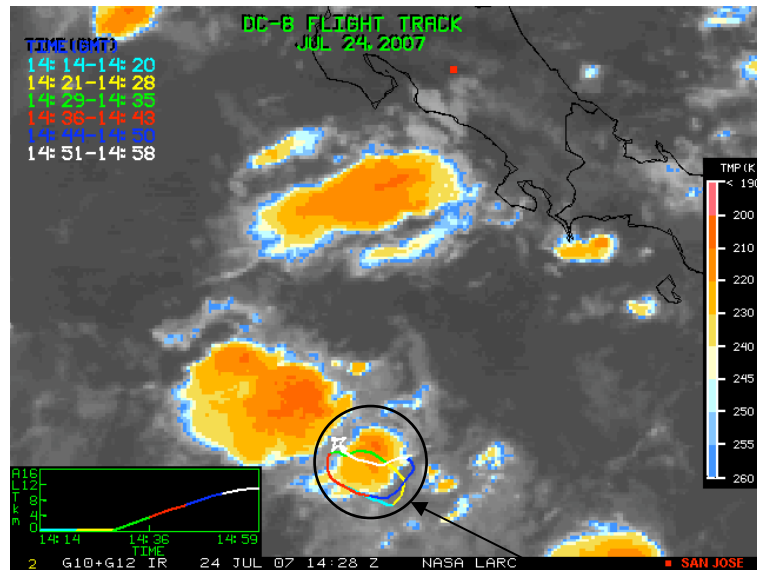
- Integrated the in-situ IWC over the depth of the cloud
- VISST obtained IWP of  $312 \text{ g m}^{-2}$ 
  - Difference of 13%
- Very low IWC near cloud top

# Ice Water Path



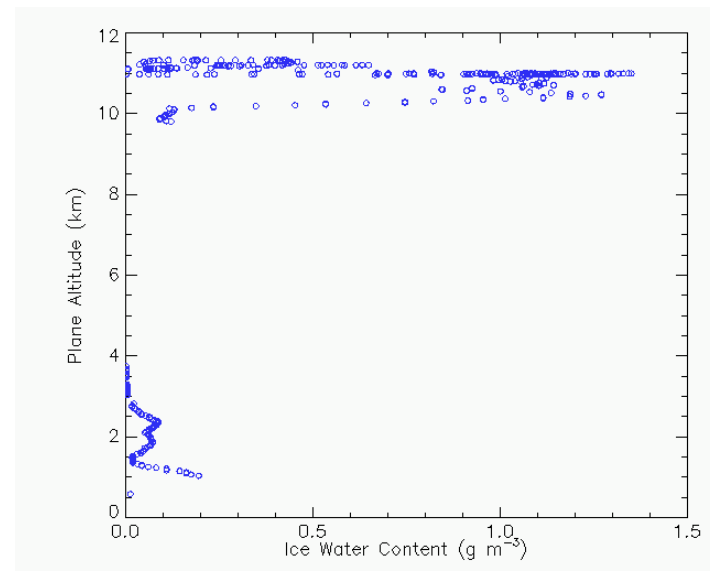
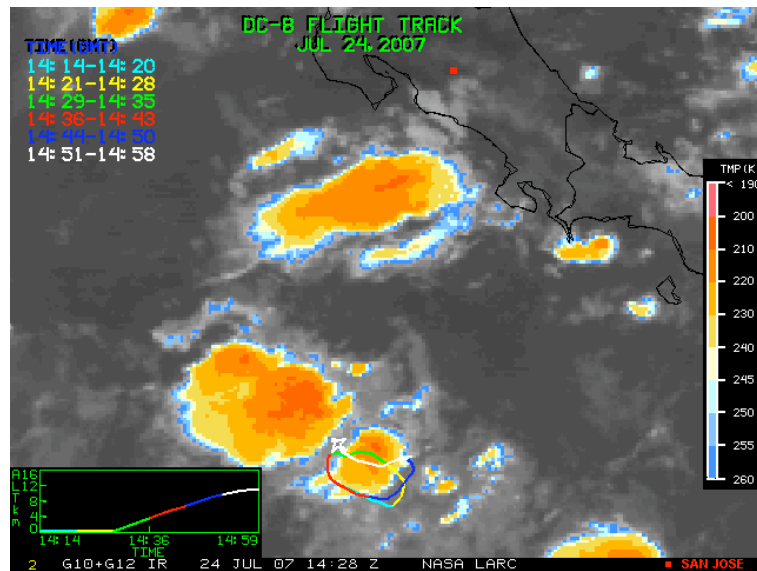
- 24 July, deep convective cloud case

# Ice Water Path



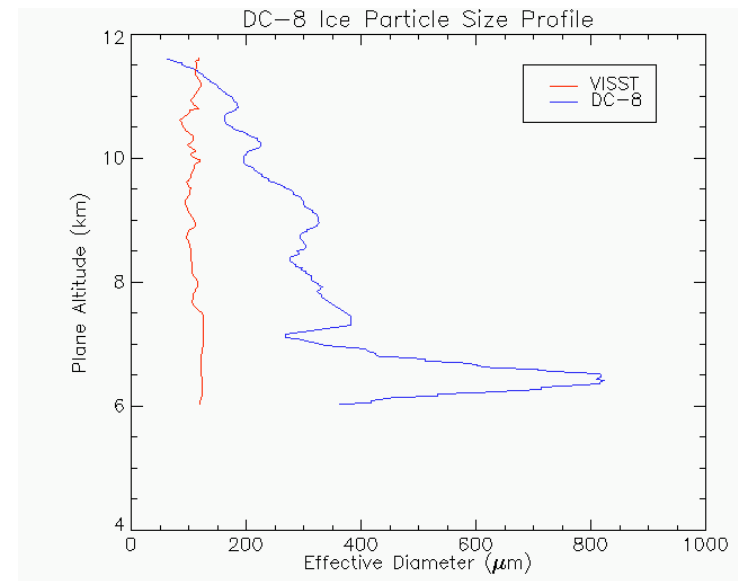
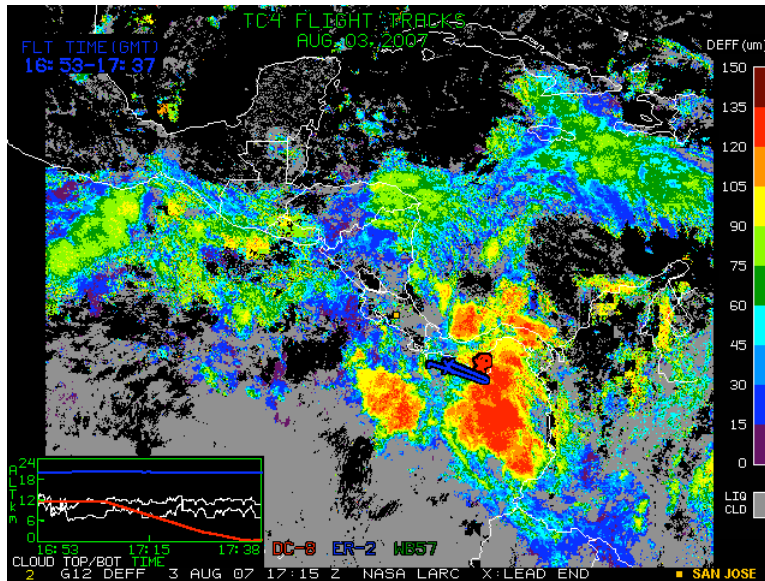
- 24 July, deep convective cloud case
  - Inferred *IWP* from CIP:  $1138 \text{ g m}^{-2}$
  - *IWP* from VISST:  $1397 \text{ g m}^{-2}$
  - 23% difference

# Ice Water Path



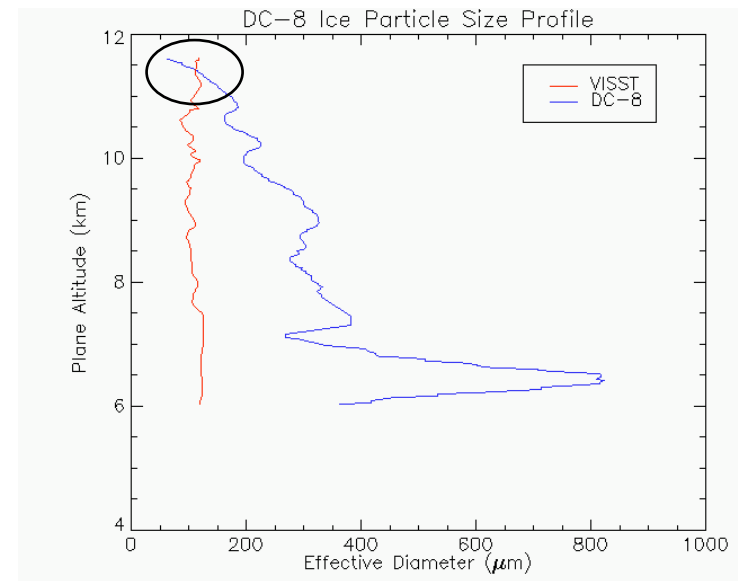
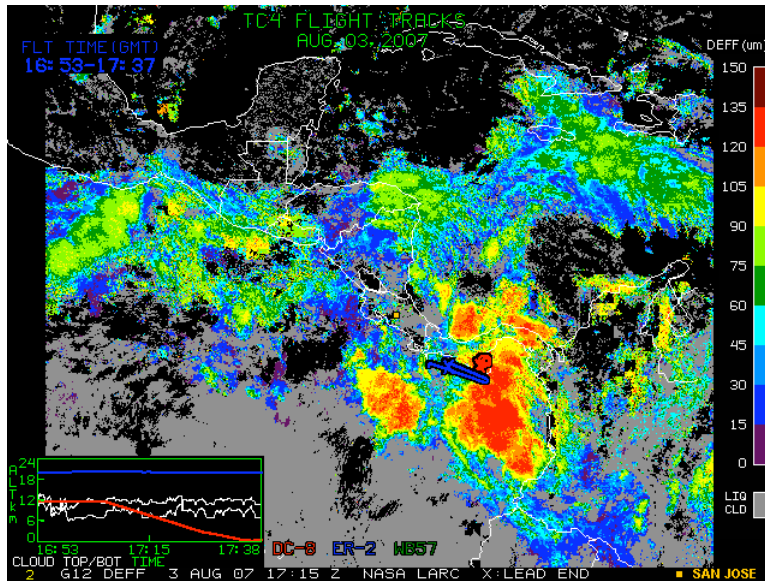
- No *IWC* profile from 14:44 - 14:50 UTC
  - DC-8 flew through clear sky during this leg of the flight
  - Inferred *IWP* from CIP:  $1138 \text{ g m}^{-2}$
  - *IWP* from VISST:  $1397 \text{ g m}^{-2}$
  - *IWC* in mid layers of the cloud might make up the difference

# Particle Size



- Back to 3 August spiral descent case
  - Ice particle size distributions from CIP on the DC-8
  - Integrated over the size distributions assuming hexagonal columns to get  $D_e$
  - Good agreement in the top 500 m
    - Inferred  $D_e$  from CIP: 112 μm
    - $D_e$  from VISST: 116 μm

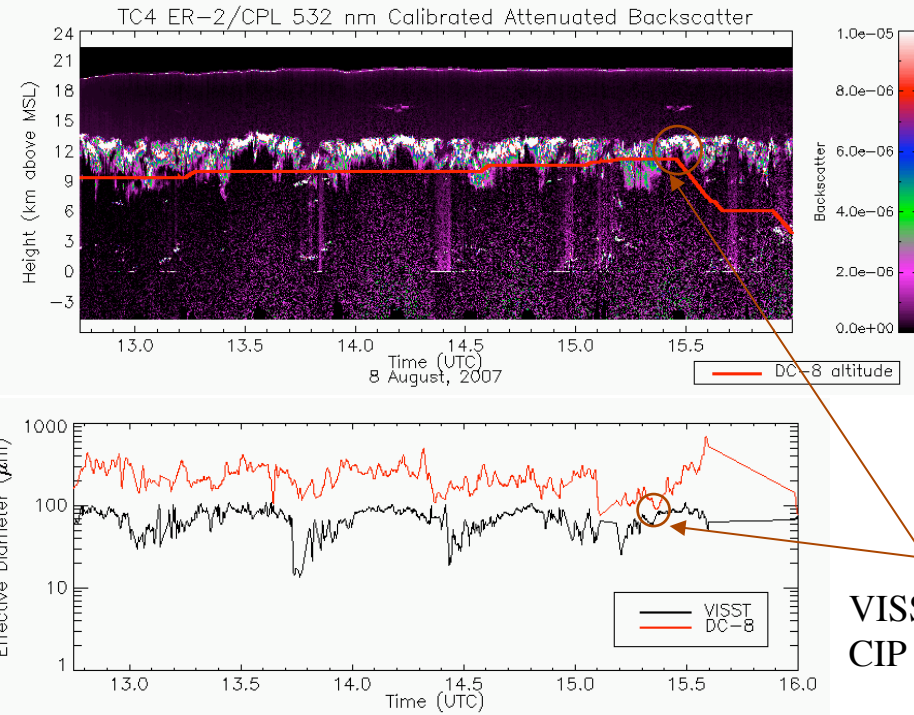
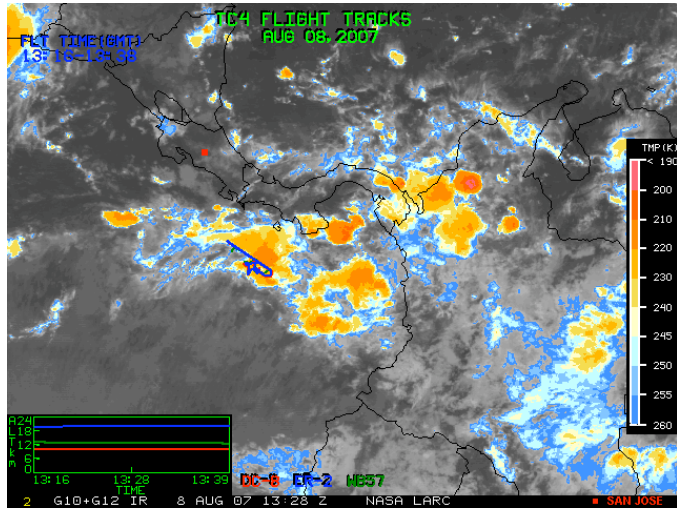
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# Particle Size



VISST: 78  $\mu\text{m}$   
CIP : 107  $\mu\text{m}$

- 8 August, ER-2 and DC-8 made a coordinated flight
  - Trends of  $D_e$  very similar
  - Best agreement when DC-8 flew near the cloud top

# Summary

- Instruments during the TC4 campaign provided measurements of several quantities that we can use to validate satellite cloud products
  - Cloud tops directly from the CPL
  - $IWP$  inferred from  $IWC$  from CIP and cloud physical depth
  - $D_e$  inferred from particle size distributions from CIP
- Correction for thick ice cloud tops based on CALIPSO comparisons
- Initial comparisons of  $IWP$  look promising
  - Need more spiral ascents/descents for further investigation
- Time series of particle sizes follow the same trends and values agree best near cloud top

