Validation of Satellite-Derived Cloud Properties Using TC4 Data

P. Minnis, L. Nguyen, W. L. Smith

LaRC, Hampton, VA

K. Ayers, C. R. Yost, M. Nordeen,
R. Palikonda, D. Spangenberg

SSAI, Hampton, VA

M. McGill

NASA GSFC, Greenbelt, MD

A. Heymsfield

NCAR, Boulder, CO

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Objectives

- Validate & improve passive satellite retrievals of cloud properties

- Provide context for in situ measurements

- Determine large-scale optical and physical properties (time and space) of tropical convective cells

Data

- Satellite
  - GOES-12, (4-km, 15 min)
  - Terra & Aqua MODIS (1-km, 2/day)

- Aircraft
  - ER-2 (CPL)
  - DC-8 ()

CERES-MODIS Cloud Retrieval Methodology.

(Apply CERES algorithms to MODIS & GOES imager data)

1) Apply cloud mask ***see Minnis et al. (2007a), Trepte et al. (2007)***

2) Compute ice & water phase solution, select most likely phase based on temperature, model fits, LBTM classification, 2.1-μm reflectance

DAY: Visible Infrared Solar-Infrared Split-Window Technique (VISST)

0.65, 3.8, 10.8, & 12.0 μm ***see Minnis et al. (1995, 1998, 2007b)***

NIGHT: Solar-infrared Infrared Split-Window Technique (SIST)

3.8, 10.8, & 12.0 μm ***see Minnis et al. (1995, 1998, 2007b)***

Imager Cloud-Top Height Estimation

Observed 11-μm radiance: $L = (1- \varepsilon)\, L_s + \varepsilon\, L_{eff}$

Corresponding effective cloud temperature: $T_{eff} = B^{-1}(L_{eff})$

For high clouds: $Z_{eff} = Z(T_{eff})$

Z(T) - sounding from GFS

For low clouds: $Z_{eff} = (T_{eff} - T_o) / \Gamma + Z_o$

Z_o = surface height above sea level, T_o = skin temp , Γ = -7.1K/km

is adjusted between 700 & 500 hPa so that $T_{500} = T_{500}$(GFS)

(Minnis et al., JAM, 1992; TGARS, 2008)

For optically thick & water clouds, $Z_{top} = Z_{eff}$

For optically thin ice clouds, $Z_{top} = Z(T_{eff}, \tau)$

(Minnis et al., JAS, 1991)

GOES/MODIS imagery & products available on web via central web site

http://angler.larc.nasa.gov/tc4/

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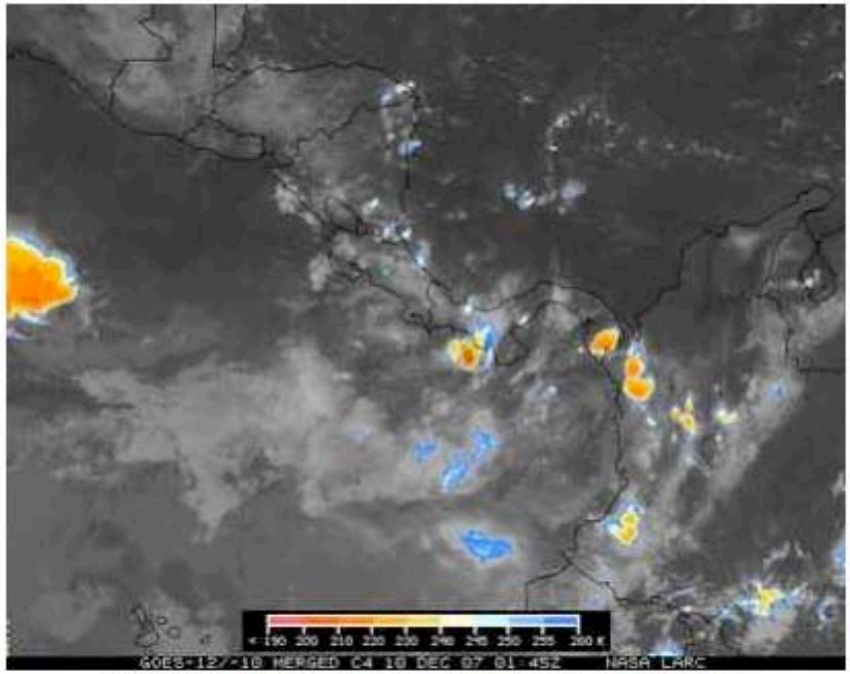
+ GOES SATELLITE IMAGERY
+ GOES CLOUD PRODUCTS
+ MODIS CLOUD PRODUCTS
+ SATELLITE PREDICTION TOOLS
+ GOOGLE EARTH KML FILES
+ ER-2 FLIGHT TRACK
+ DC-8 FLIGHT TRACK
+ WB-57 FLIGHT TRACK
+ ALL FLIGHT TRACK
+ CLD PRODUCTS ALONG TRACK

SEARCH LANGLEY + GO

REAL-TIME GOES IMAGERY



This GOES IR image was taken on 2007344 (12/10) 0145 UTC .

QUICK LINKS

Animated GIF
+ WV 3-hourly loop
+ IR 3-hourly loop

GOES Single Image
+ IR 11um color
+ IR 11um gray
+ VIS (4km)
+ VIS (1km)
+ RGB false color
+ RGB2 false color
+ IR 3.9um
+ Water Vapor
+ BTD 3.9-11um

GOES JAVA Loops
(pop-up window)
+ Costa Rica
+ TC4 (680x540)
+ TC4 (1080x1360)
+ TC4 1km VIS

GOES FTP Archive
+ JPEG Imagery
+ GIF Imagery

DISPLAY GOES LOOPS

Non-JAVA Animation

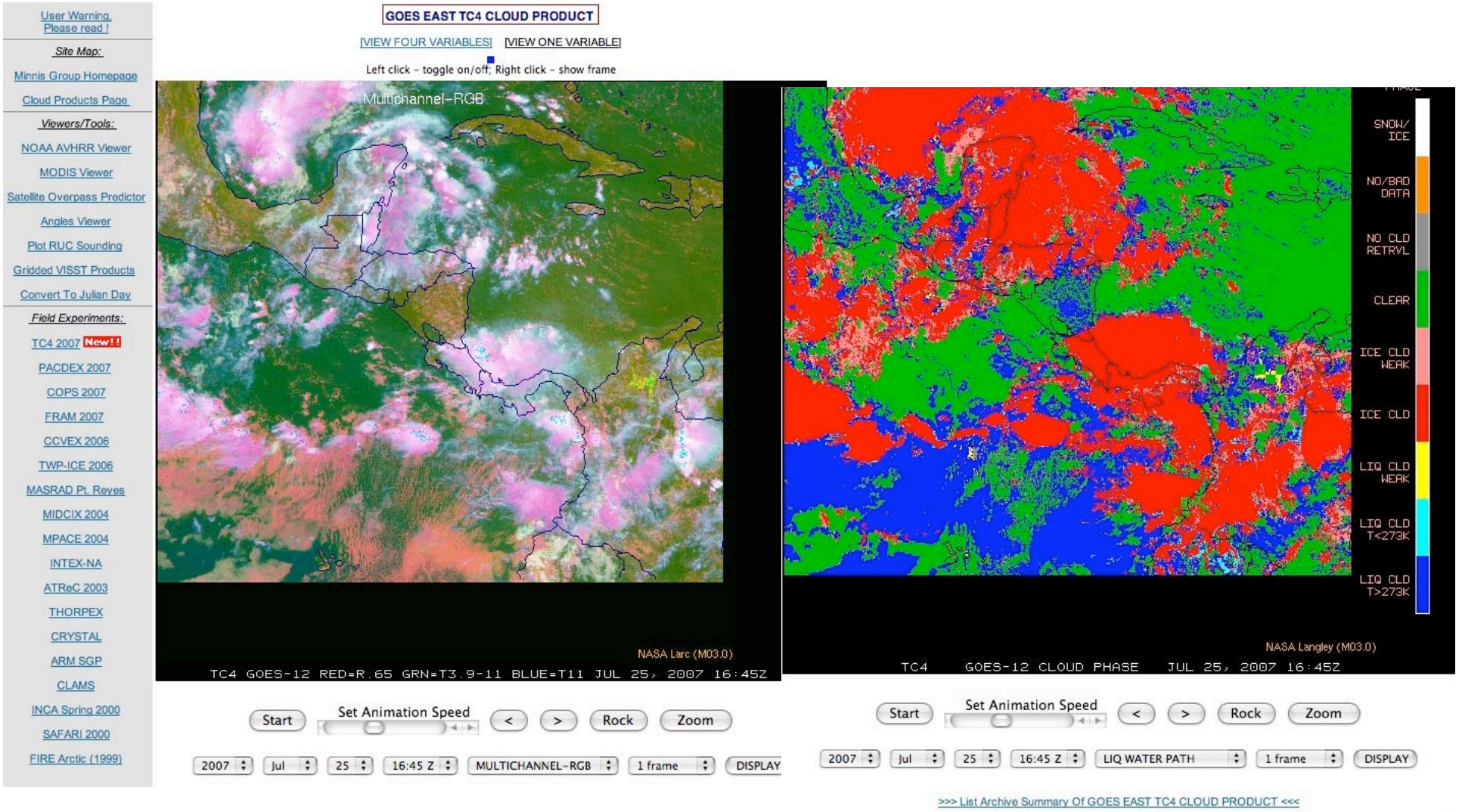
1-Panel: Real-time Archive Jul 24 2007 14 Z

IR 8km color (sm) JavaScript Loop 1 frms Display

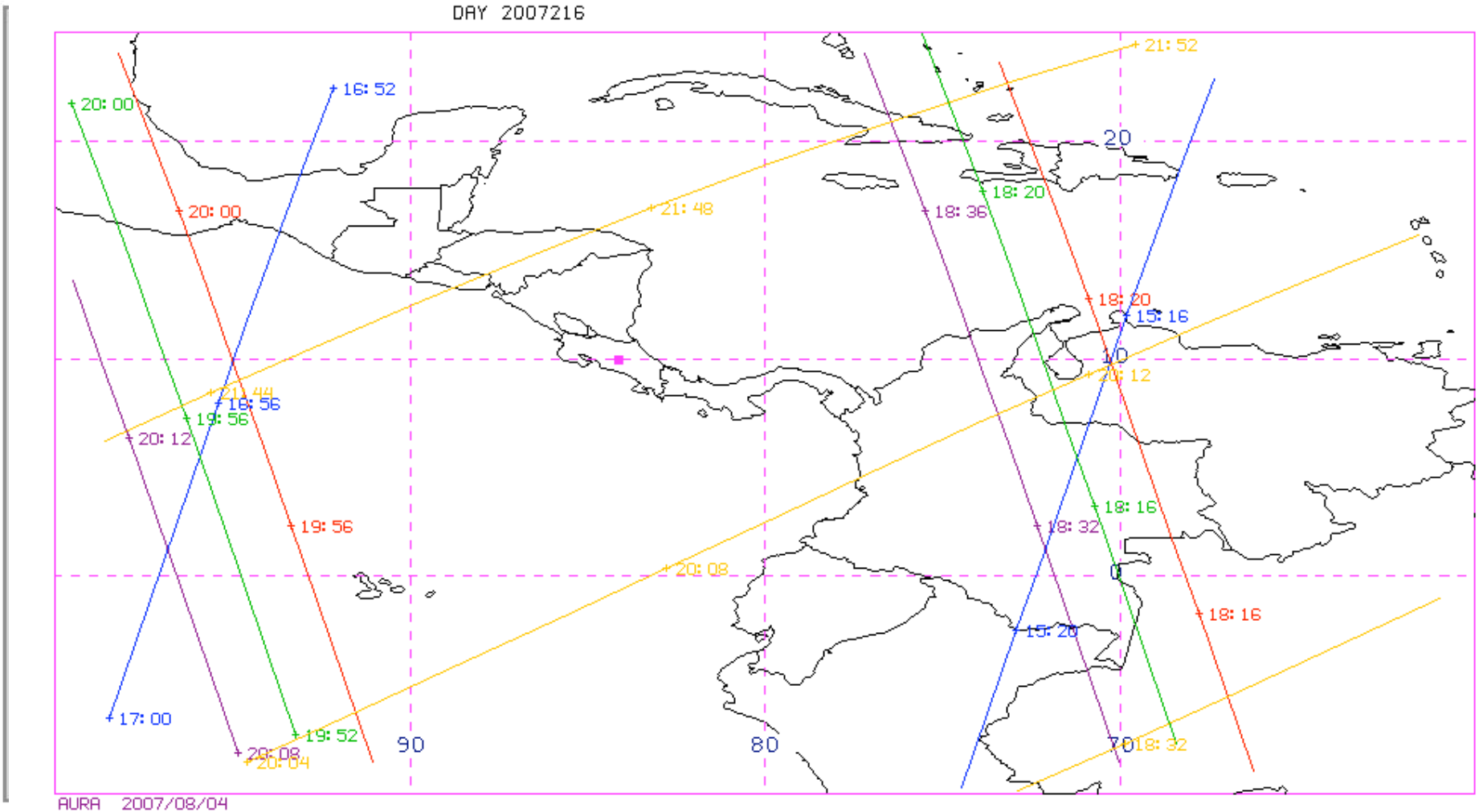
(+ click here to list archive summary of available dates)

Select Analyzed Products

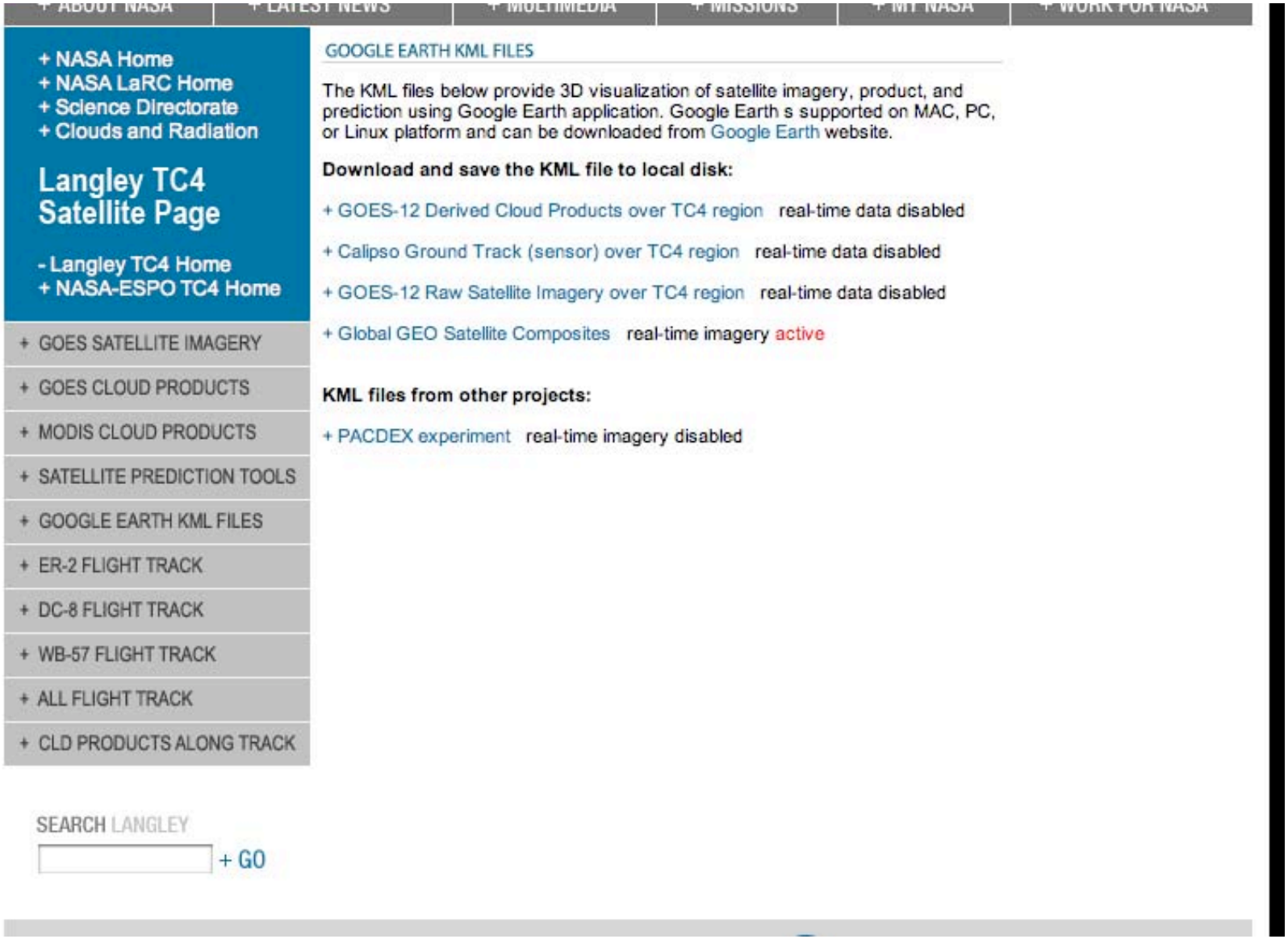
Example 24 July 2007



NASA LaRC Satellite Overpass Predictor



If a Google-Earth display is desired…



All Aircraft Flight Track Overlay on GOES Imagery

Select a flight day.

Jul-Aug 2007						
Su	Mo	Tu	We	Th	Fr	Sa
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	01	02	03	04
05	06	07	08	09	10	11

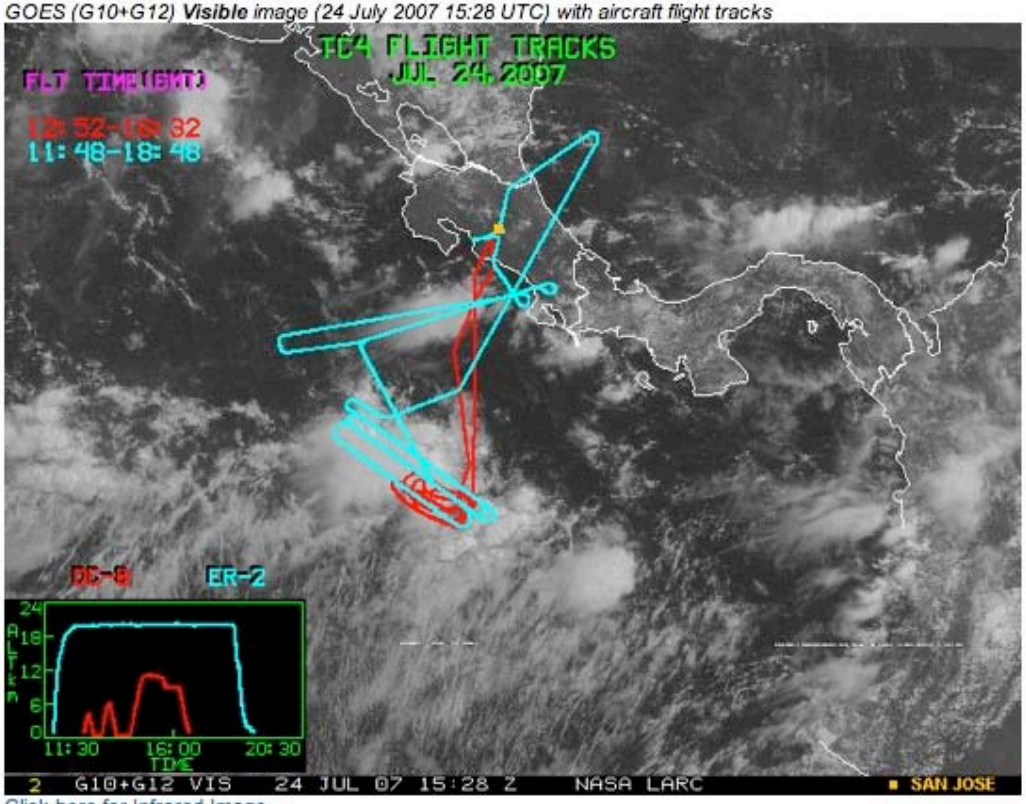
Select a flight day

- plane(s)
- image type
- loop or still

Or link to product overlay page

Flight Tracks for July 24, 2007

*GOES (G10+G12) **Visible** image (24 July 2007 15:28 UTC) with aircraft flight tracks*

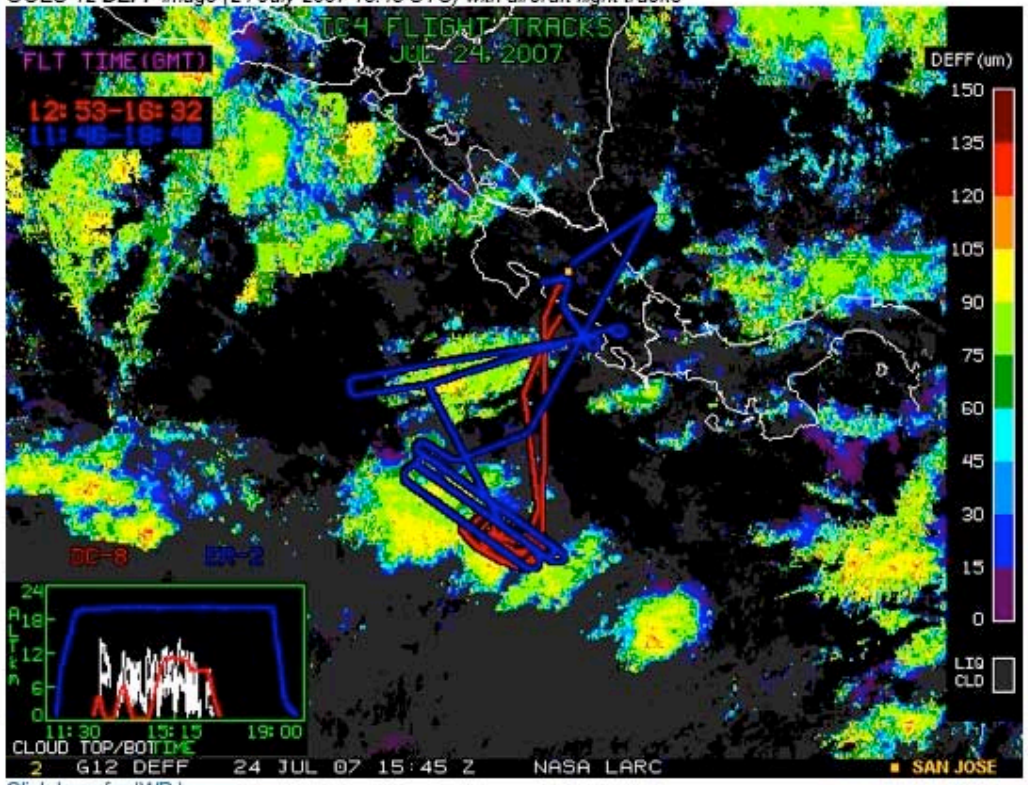


Click here for Infrared Image

- **Flight Tracks overlayed on G10+G12 Imagery**
  - JavaScript Loop: Visible, Infrared
  - Animated GIF Loop: Visible, Infrared
  - VIS Images: 12:15, 12:28, 12:45, 12:58, 13:15, 13:28, 13:45, 13:58, 14:15, 14:28, 14:45, 15:15, 15:28, 15:45, 15:58, 16:15, 16:28, 16:45, 16:58, 17:15, 17:28, 17:45, 18:15, 18:45
  - IR Images: 12:15, 12:28, 12:45, 12:58, 13:15, 13:28, 13:45, 13:58, 14:15, 14:28, 15:15, 15:28, 15:45, 15:58, 16:15, 16:28, 16:45, 16:58, 17:15, 17:28, 18:15, 18:45
- Flight Track Overlay on Cloud Product Images
- **Aircraft Navigation Data:**
  - DC8 navigation file
  - ER2 navigation file

Flight Tracks for July 24, 2007

*GOES-12 **DEFF** image (24 July 2007 15:45 UTC) with aircraft flight tracks*



Click here for IWP Image
Click here for PHASE Image
Click here for TAU Image
Click here for TEFF Image
Click here for ZTOP Image

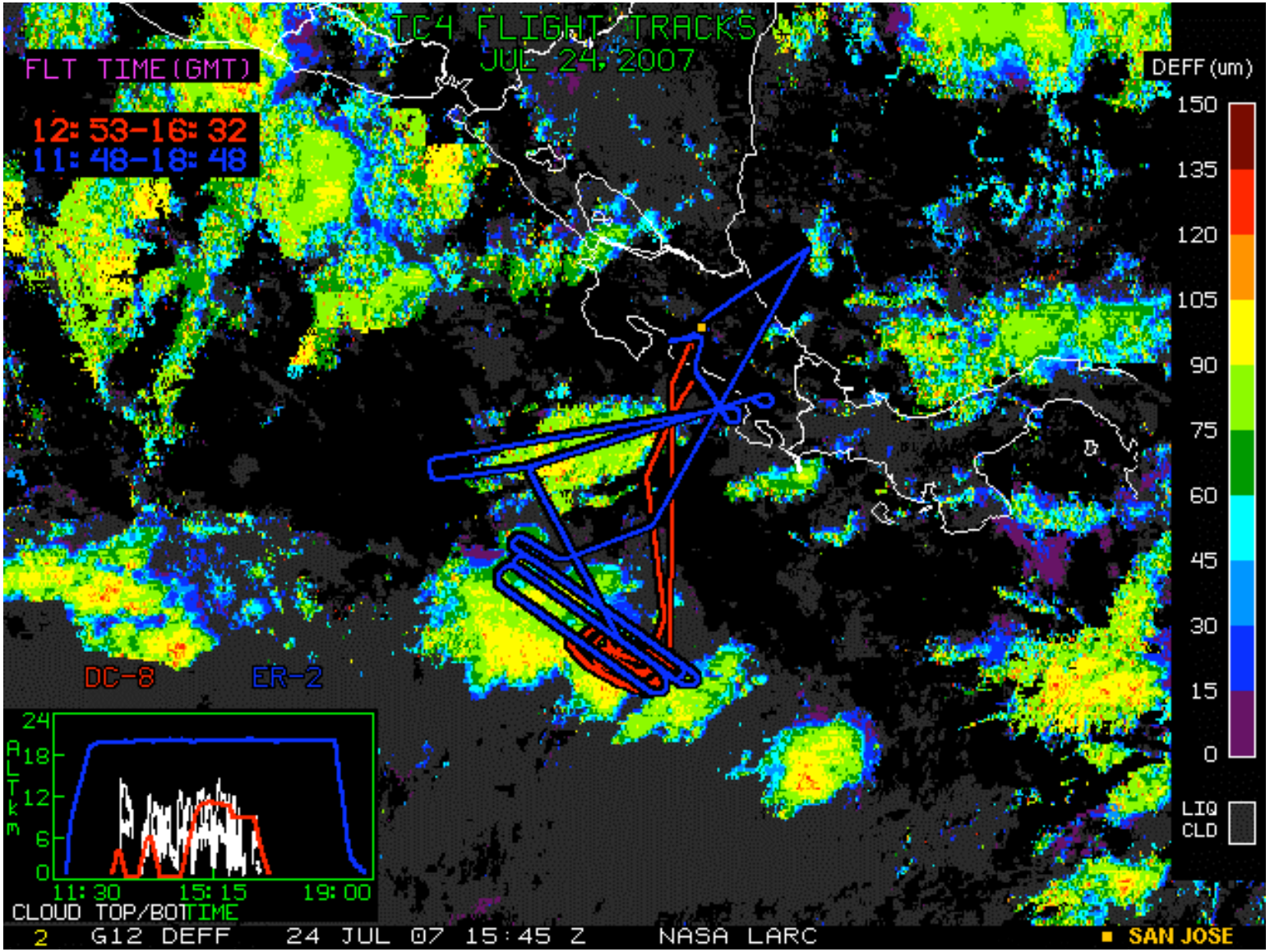
- JavaScript Loop: DEFF, IWP, PHASE, TAU, TEFF, ZTOP
- Animated GIF Loop: DEFF, IWP, PHASE, TAU, TEFF, ZTOP

- DEFF Images: 12:45, 13:15, 13:45, 14:15, 14:45, 15:15, 15:45, 16:15, 16:45, 17:15, 17:45, 18:15, 18:45
- IWP Images: 12:45, 13:15, 13:45, 14:15, 14:45, 15:15, 15:45, 16:15, 16:45, 17:15, 17:45, 18:15, 18:45
- PHASE Images: 12:45, 13:15, 13:45, 14:15, 14:45, 15:15, 15:45, 16:15, 16:45, 17:15, 17:45, 18:15, 18:45
- TAU Images: 12:45, 13:15, 13:45, 14:15, 14:45, 15:15, 15:45, 16:15, 16:45, 17:15, 17:45, 18:15, 18:45
- TEFF Images: 12:45, 13:15, 13:45, 14:15, 14:45, 15:15, 15:45, 16:15, 16:45, 17:15, 17:45, 18:15, 18:45
- ZTOP Images: 12:45, 13:15, 13:45, 14:15, 14:45, 15:15, 15:45, 16:15, 16:45, 17:15, 17:45, 18:15, 18:45

- **Aircraft Navigation Data:**
  - DC8 navigation file
  - ER2 navigation file

Flight Tracks over GOES-12 Deff Imagery

DC-8 & ER-2, 24 July 2007



Comparison Approach

- Compare in situ and active sensor data with comparable GOES or MODIS retrievals

- Average 4 4-km or 1-km pixels along flight track
    - interpolate in time between images for GOES
    - use 0.5-h for MODIS

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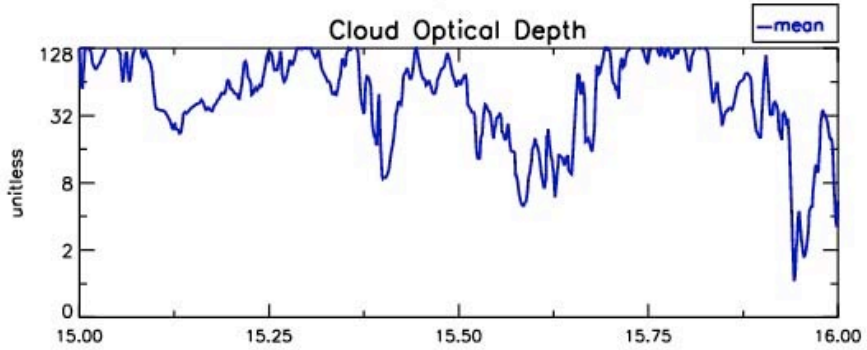
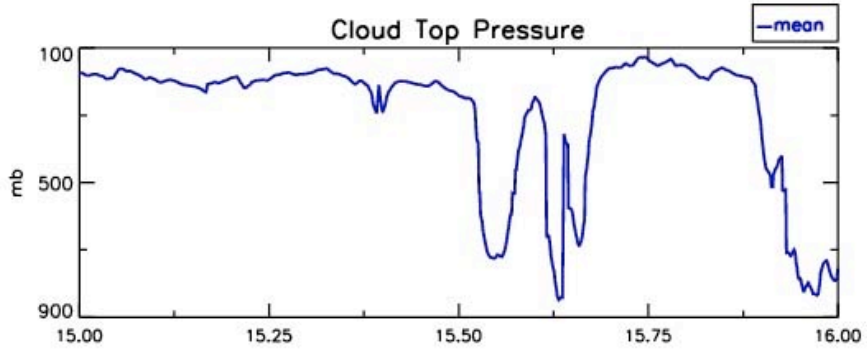
GOES or MODIS VISST Derived Cloud Products Along the Aircraft/Calipso Track

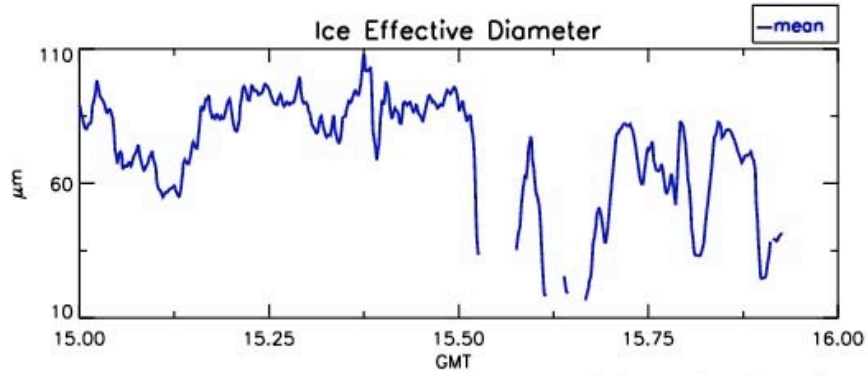
GOES/MODIS VISST Derived Cloud Products are computed from the individual aircraft or Calipso navigation files, where the cloud retrieval parameter is based on the weighted average of 4 imager pixels centered on the aircraft location. The (spatial) standard deviation is based on a weighted distribution of the closest pixel and the 8

End Hour 16.0

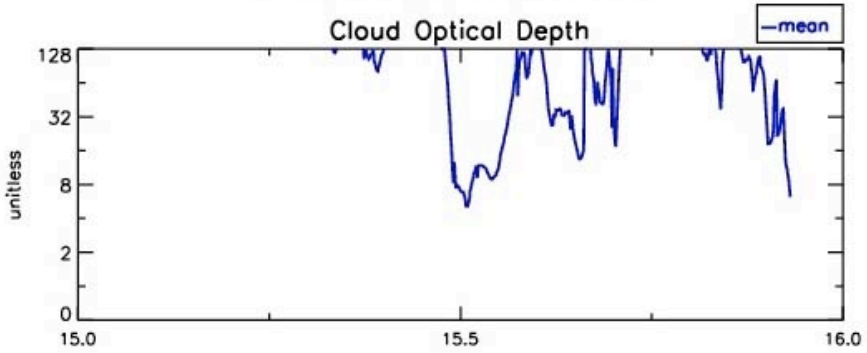
NASA–Langley GOES–12 VISST Derived Cloud Products
ER–2 Matched, 24 JULY 2007

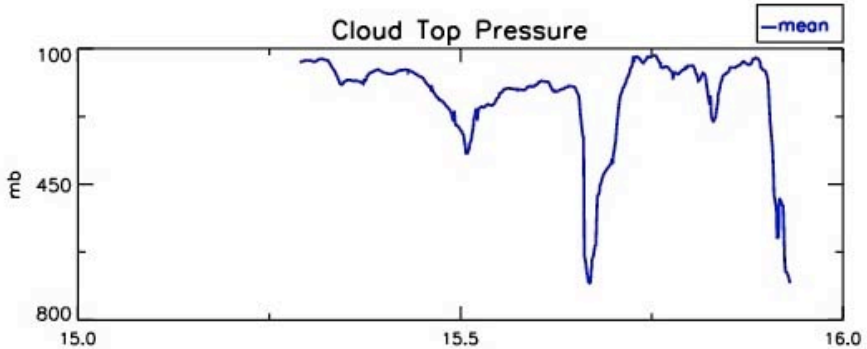


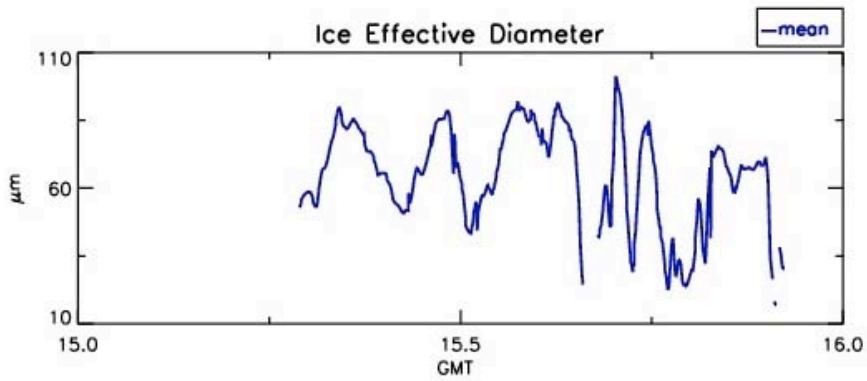




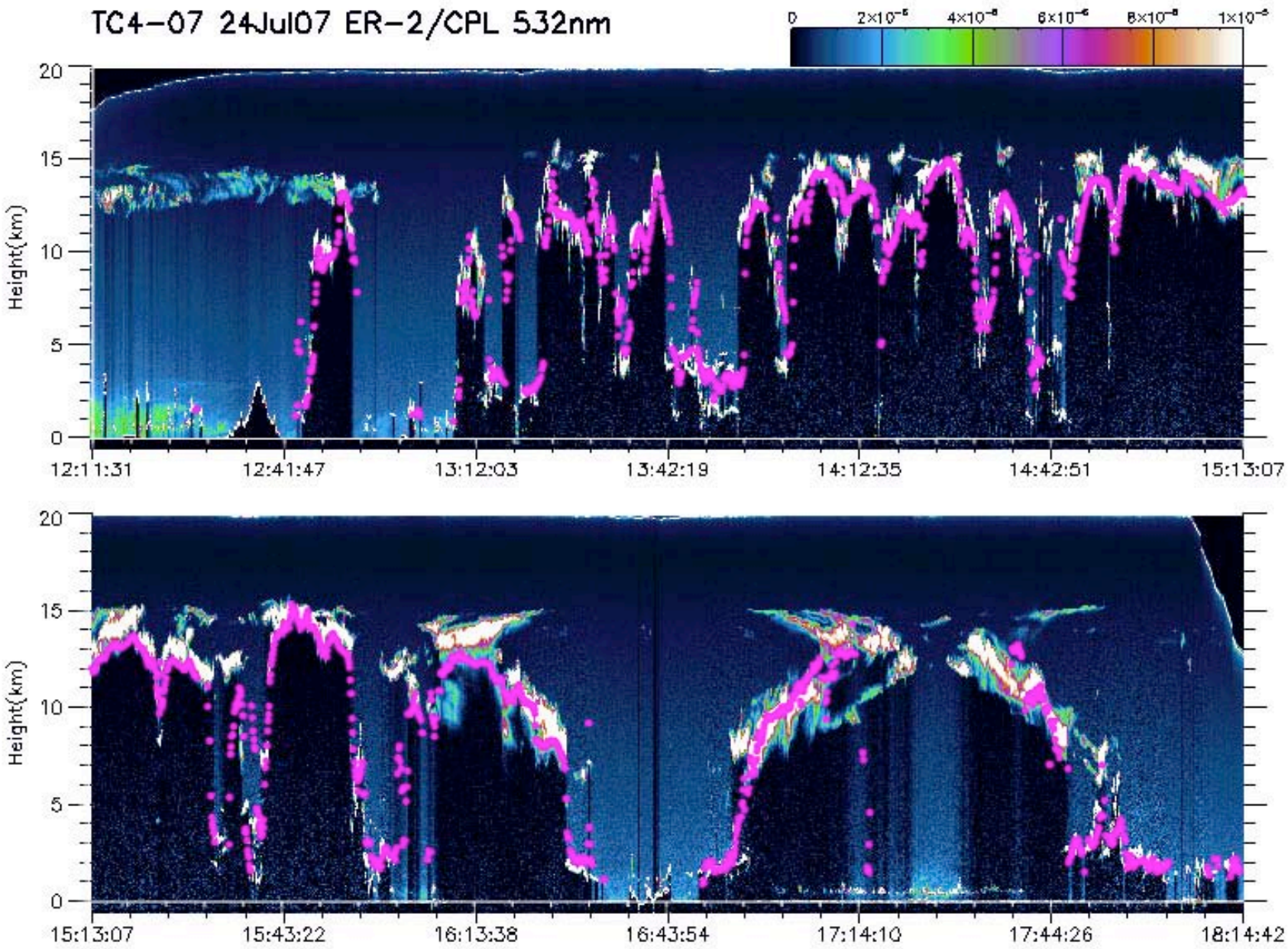
NASA–Langley TERRA VISST Derived Cloud Products
ER–2 Matched, 24 JULY 2007





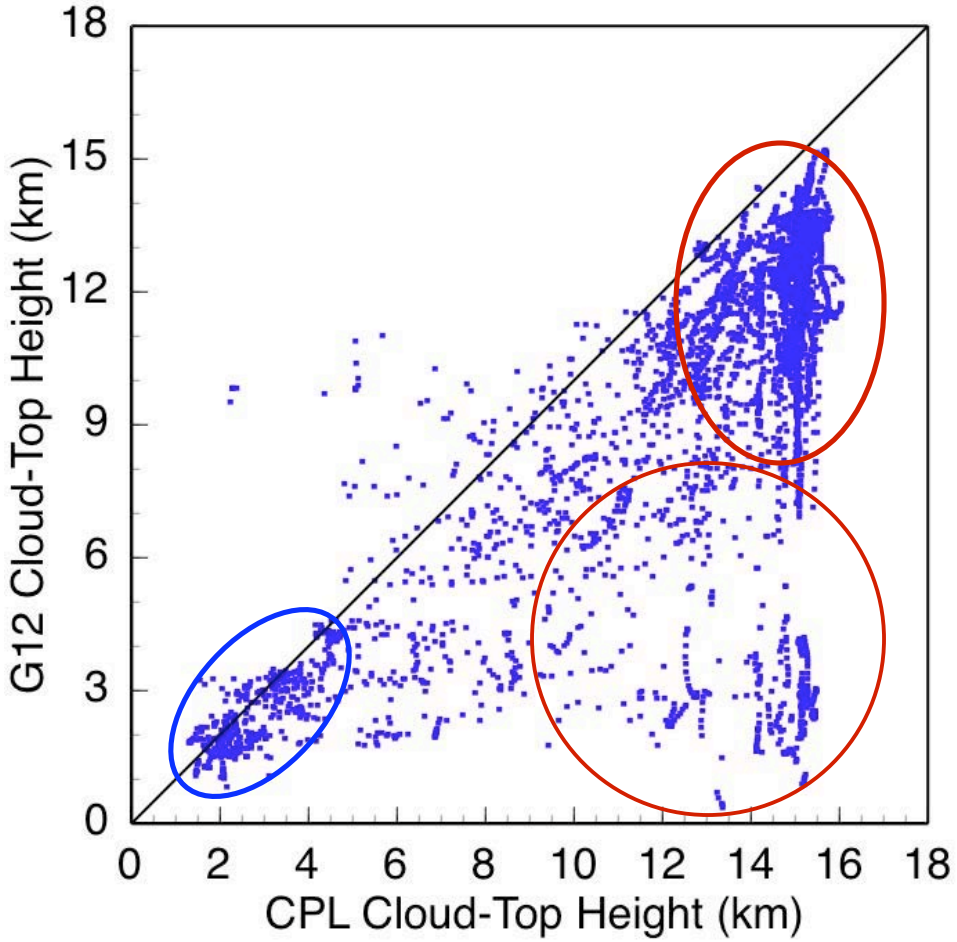


GOES Cloud Top Heights vs ER-2 CPL Backscatter



GOES Cloud Top Heights vs ER-2 CPL Highest Heights

- Some multi-layered clouds induce large discrepancies
- Low cloud heights in good agreement
- High clouds differ by large amounts

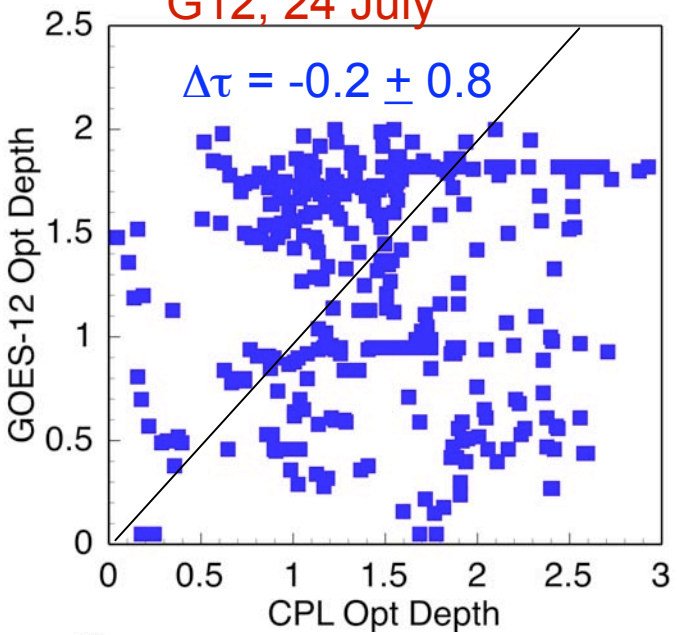


Thin Ice Cloud Comparisons

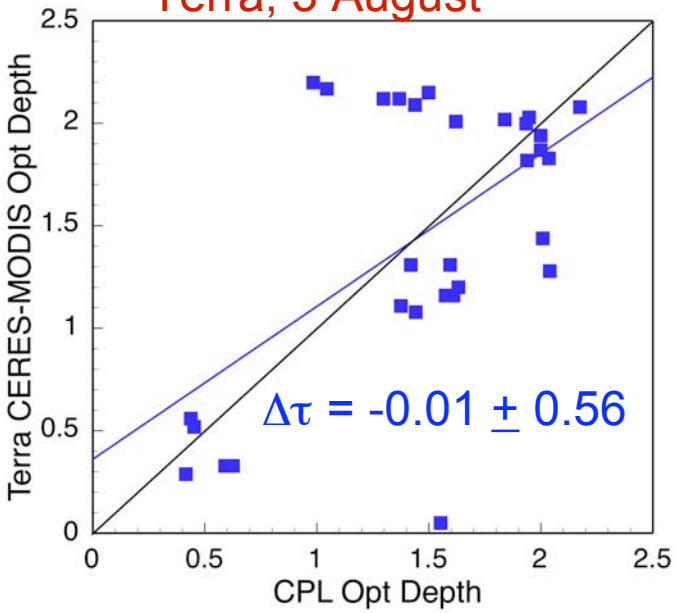
Optical depth

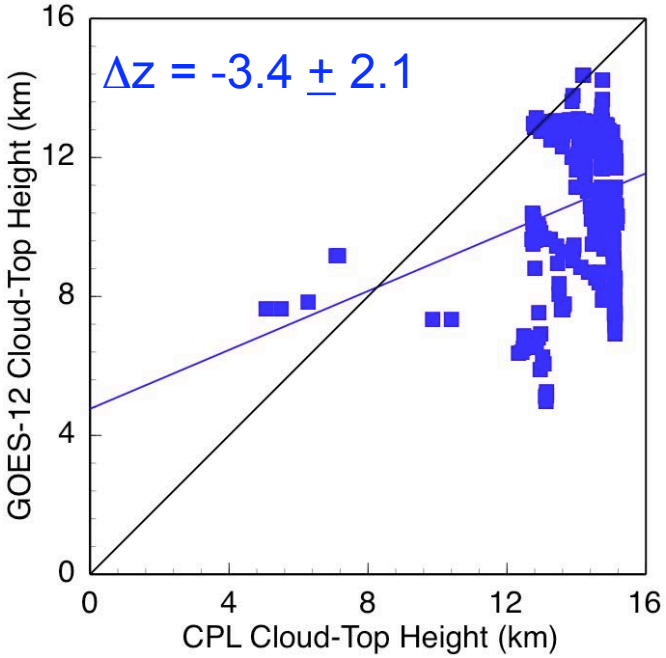
Cloud top height

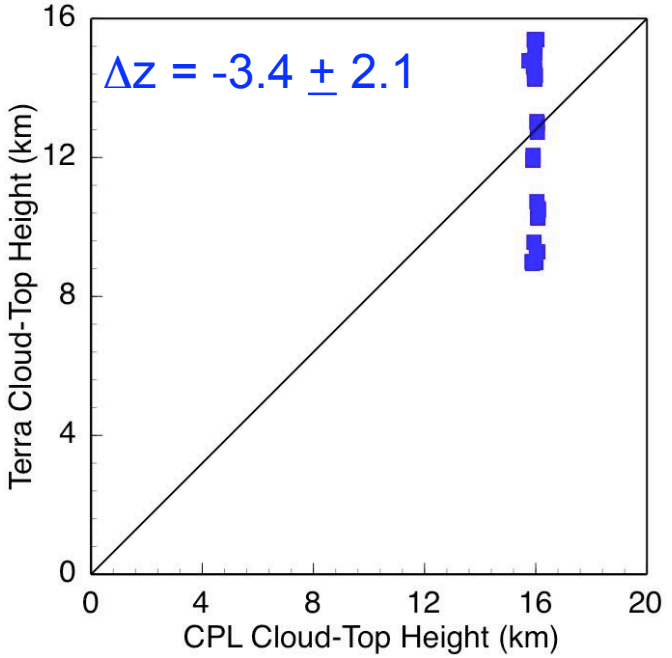
G12, 24 July



Terra, 3 August

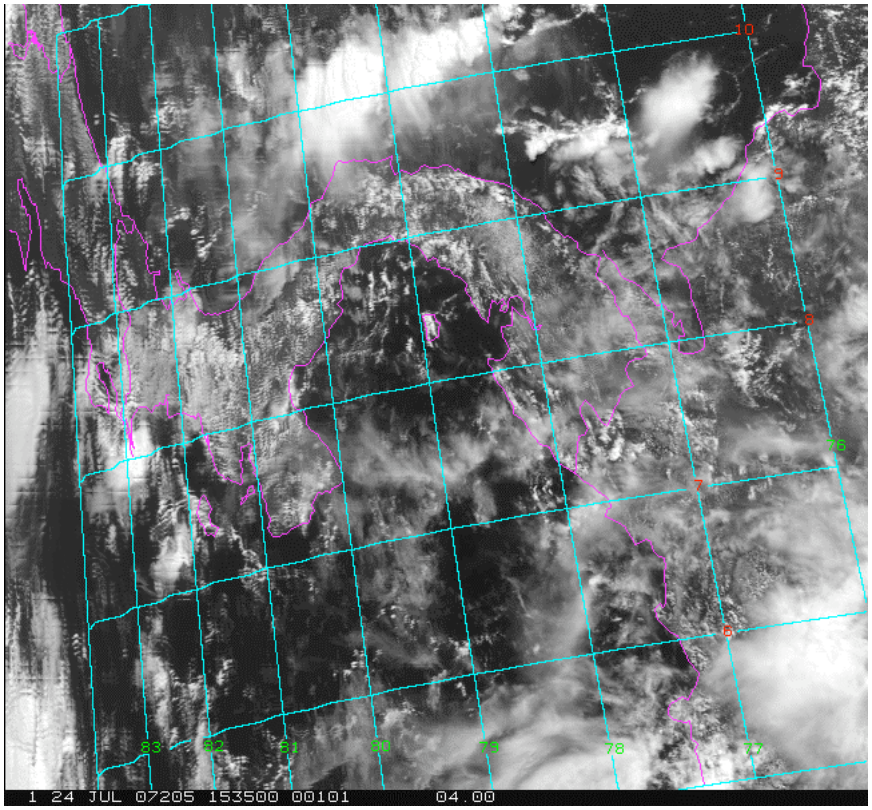




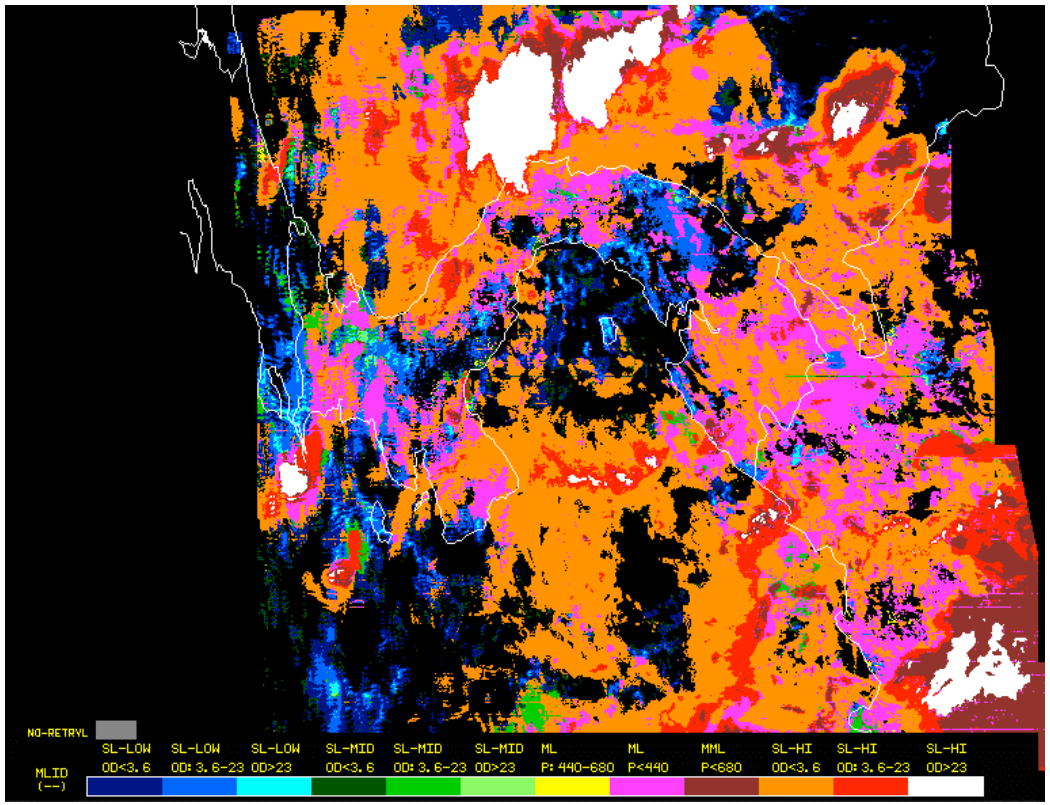


Multilayer Cloud Detection

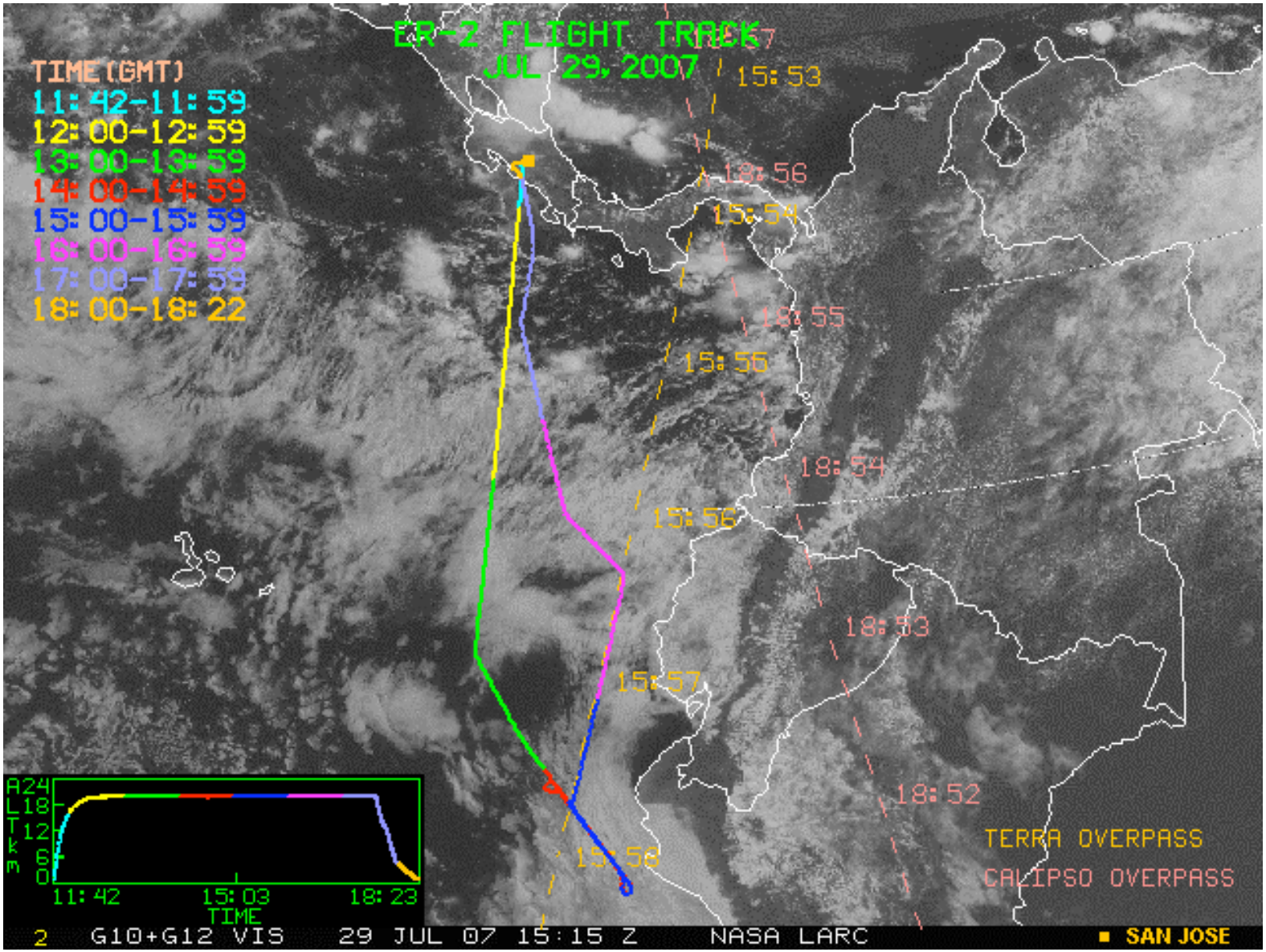
Terra VIS, 24 July 07



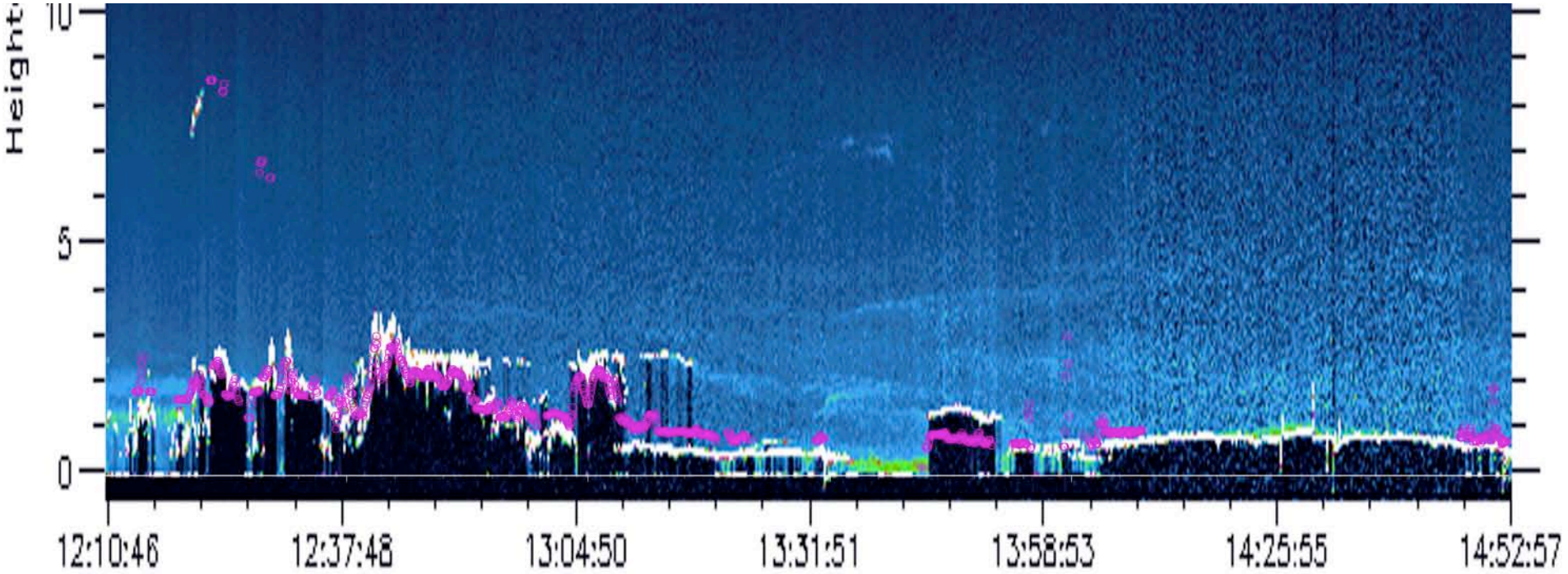
Terra ML Cloud Category, 24 July 07



TC4 data will be used to verify multilayer cloud retrievals using CO2 channel and VISST

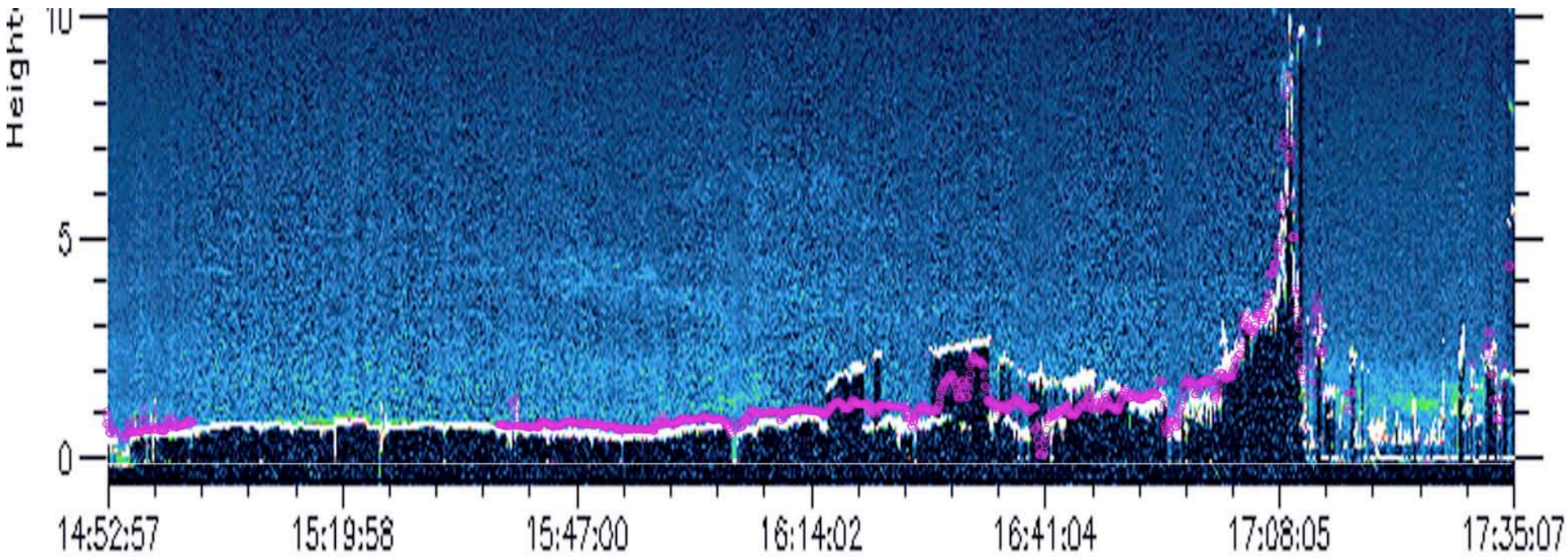

ER-2 FLIGHT TRACK
JUL 29, 2007
TIME(GMT)
11:42-11:59
12:00-12:59
13:00-13:59
14:00-14:59
15:00-15:59
16:00-16:59
17:00-17:59
18:00-18:22
15:53
18:56
15:54
18:55
15:56
18:54
15:56
18:53
15:57
18:52
15:58
TERRA OVERPASS
CALIPSO OVERPASS
ALT km
24
18
12
6
0
11:42
15:03
18:23
TIME
2 G10+G12 VIS 29 JUL 07 15:15 Z NASA LARC
SAN JOSE

ER-2 Flight: July 29, 2007

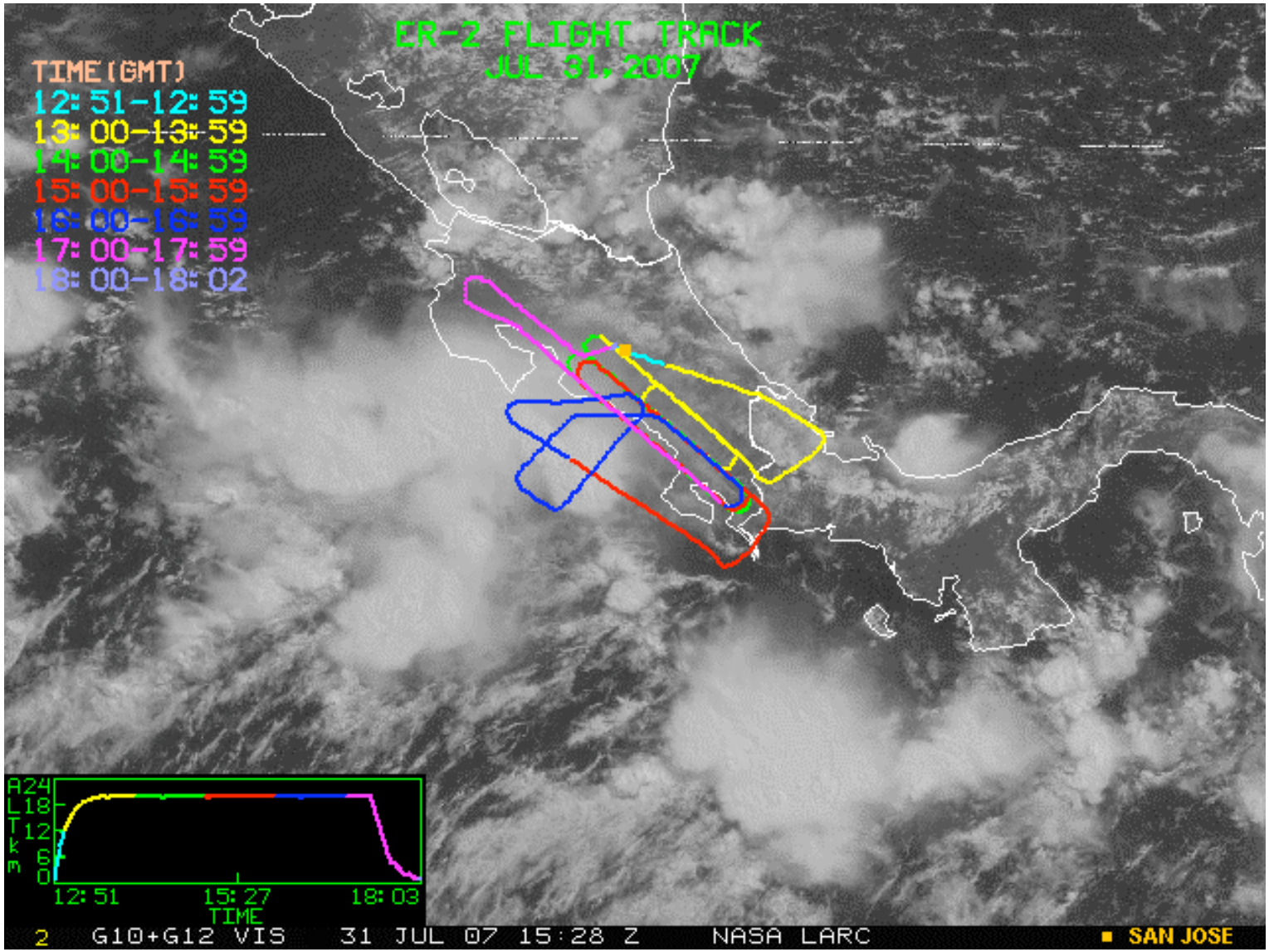


- GOES-derived effective cloud top within a few hundred meters of marine stratus tops

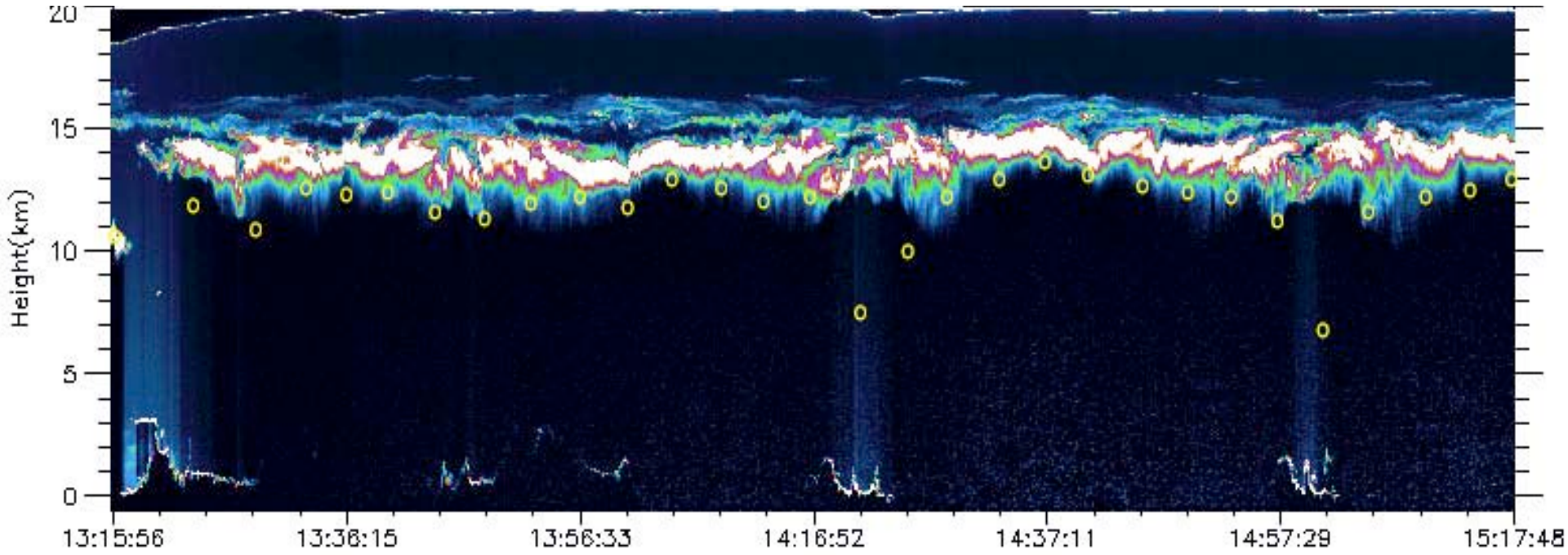
ER-2 Flight: July 29, 2007



- GOES-derived effective cloud top within a few hundred meters of marine stratus tops in second section also


ER-2 FLIGHT TRACK
JUL 31, 2007
TIME(GMT)
12:51-12:59
13:00-13:59
14:00-14:59
15:00-15:59
16:00-16:59
17:00-17:59
18:00-18:02
ALT Km
24
18
12
6
0
12:51
15:27
18:03
TIME
2 G10+G12 VIS 31 JUL 07 15:28 Z NASA LARC
SAN JOSE

ER-2 Flight: July 31, 2007

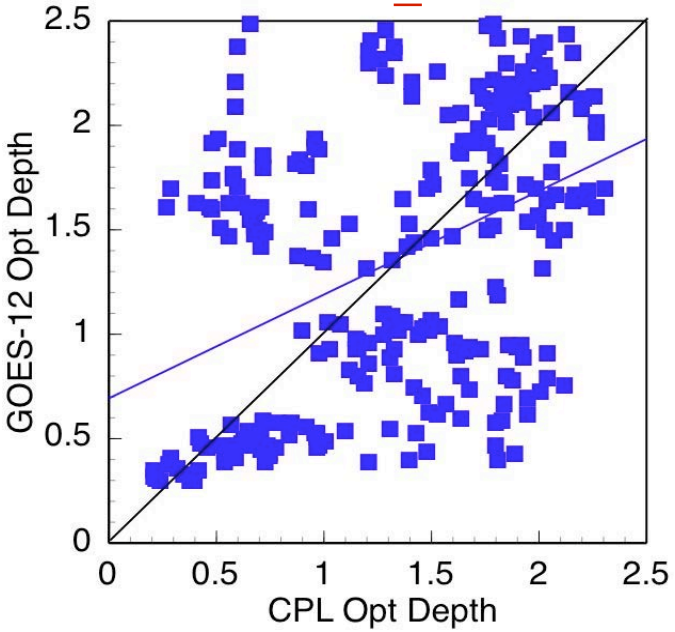


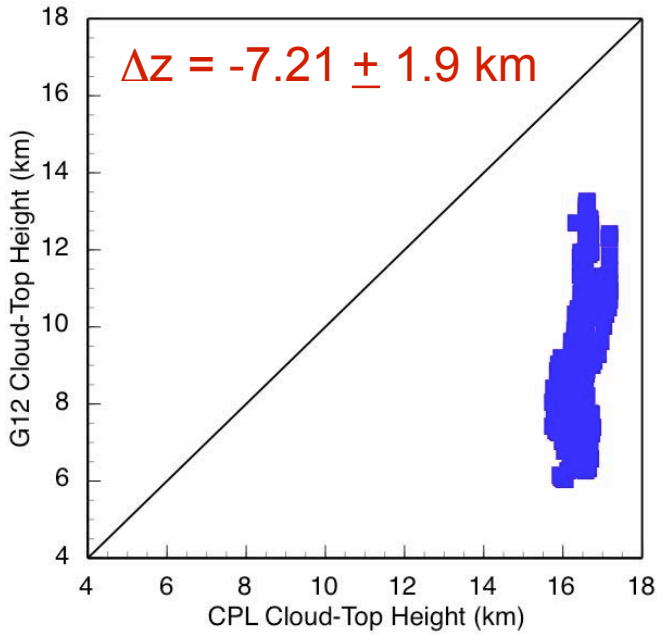
- GOES-derived effective cloud top corresponds to base of lidar penetration in optically thick anvils
- For semitransparent cirrus over low cloud, top is between lower & upper cloud
- ***Need to add 2-3 km to GOES height to find true top***

Cloud Comparisons, 31 July 2007

$\tau < 2.5$

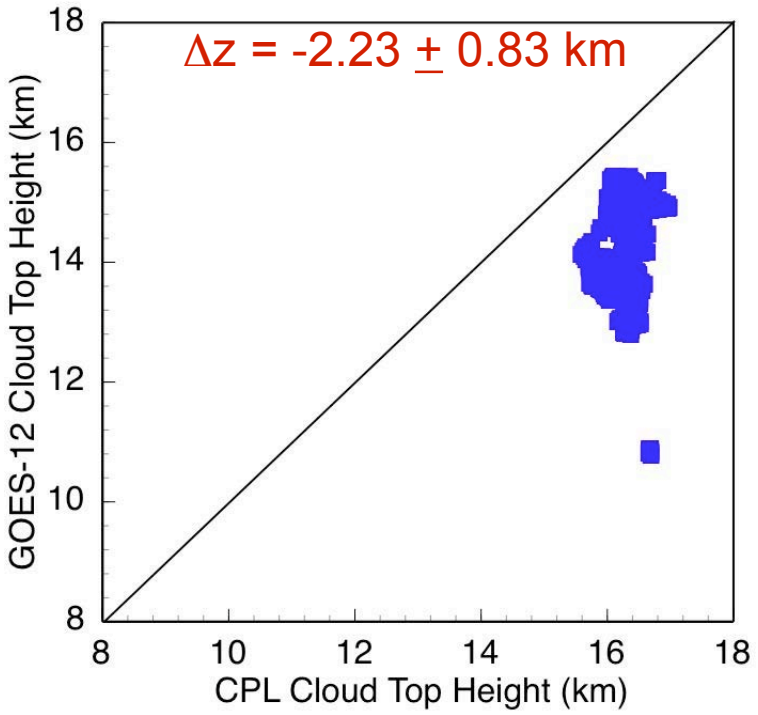
$\Delta\tau = 0.02 \pm 0.67$





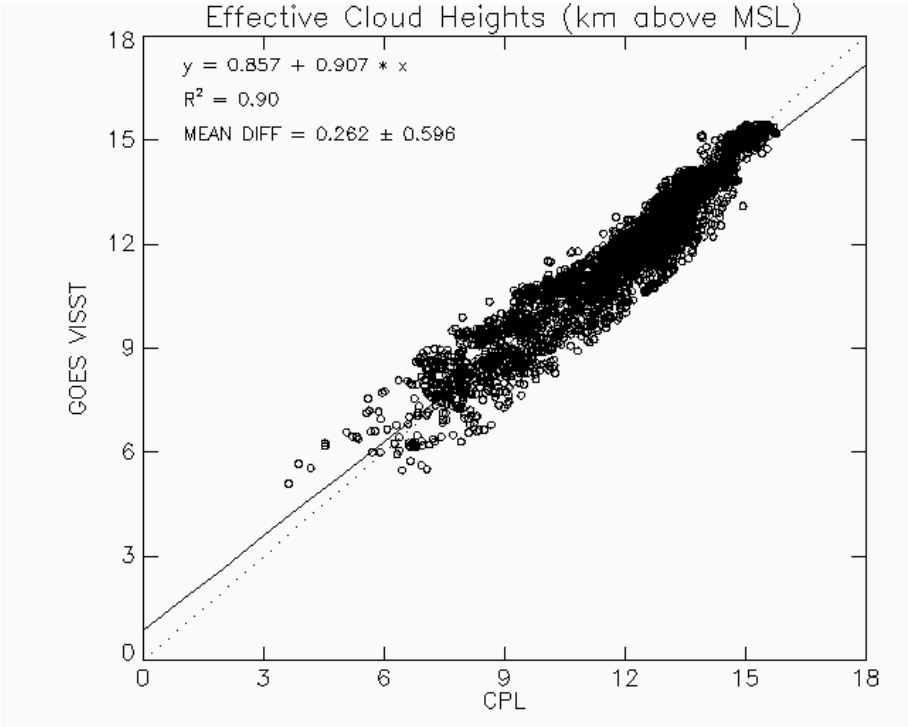
- Optical depth correlation better for GOES
- Underestimate of thin cirrus height worse
- Thick cloud top penetration slightly greater than during CRYSTAL-FACE

$\tau > 20$

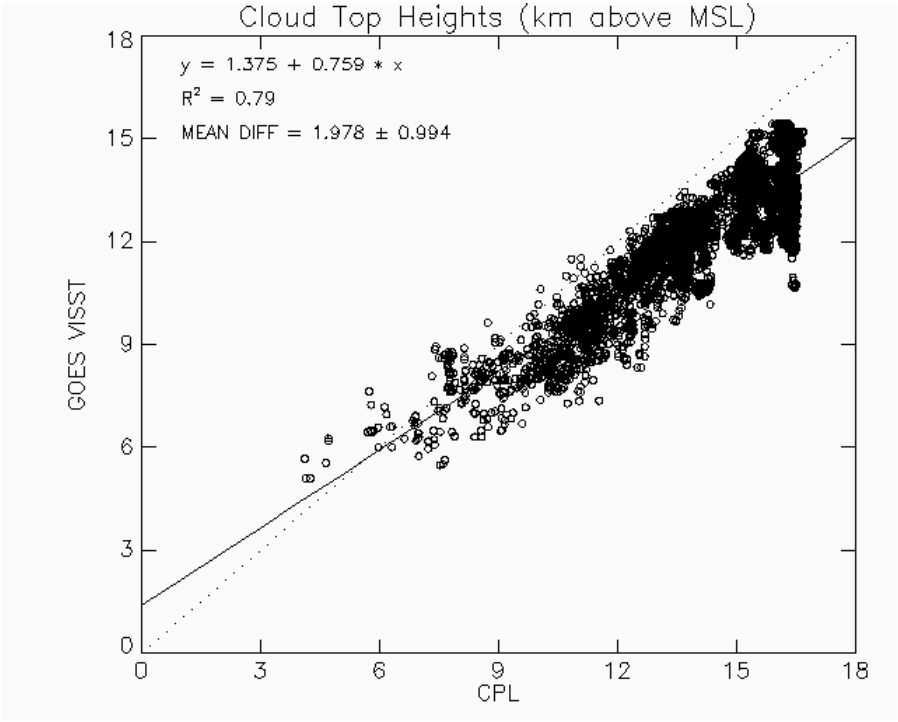


Comparison of Thick Ice-Cloud Heights, GOES vs ER2, TC4

GOES Z(T11) vs height of full attenuation of CPL signal



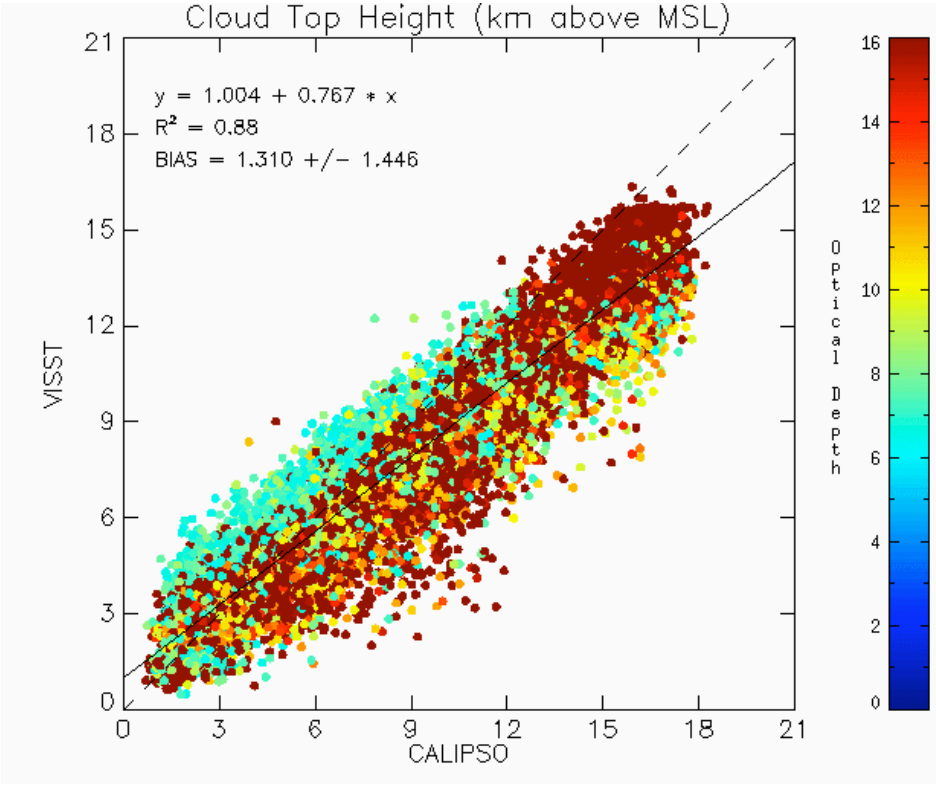
GOES Z(T11) vs height of first attenuation of CPL signal



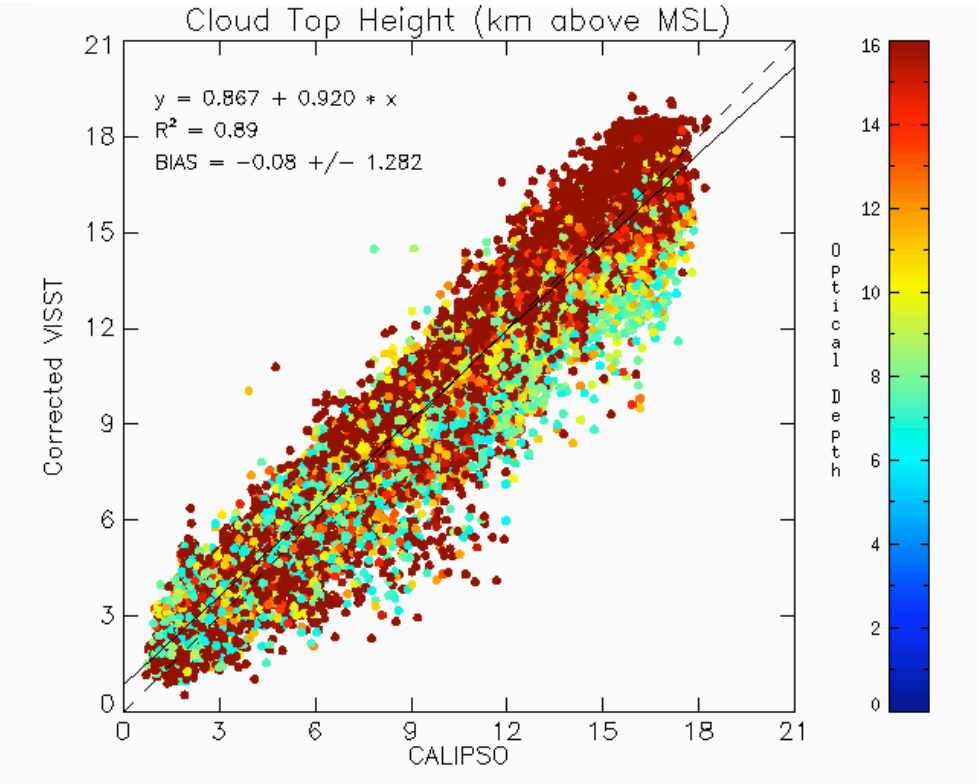
- GOES Teff very close to height of attenuated signal
- Correction need to obtain physical cloud top

Cloud-Top Height Correction Developed from CALIPSO & Aqua MODIS Data

Comparison of Zeff & CALIPSO Ztop, 27 April 2006



Comparison of Ztop & CALIPSO Ztop, Using 27th Correction, April 2006



- Correction works well with Aqua & CALIPSO

Before & After Using CALIPSO-based Height Correction

GOES-12

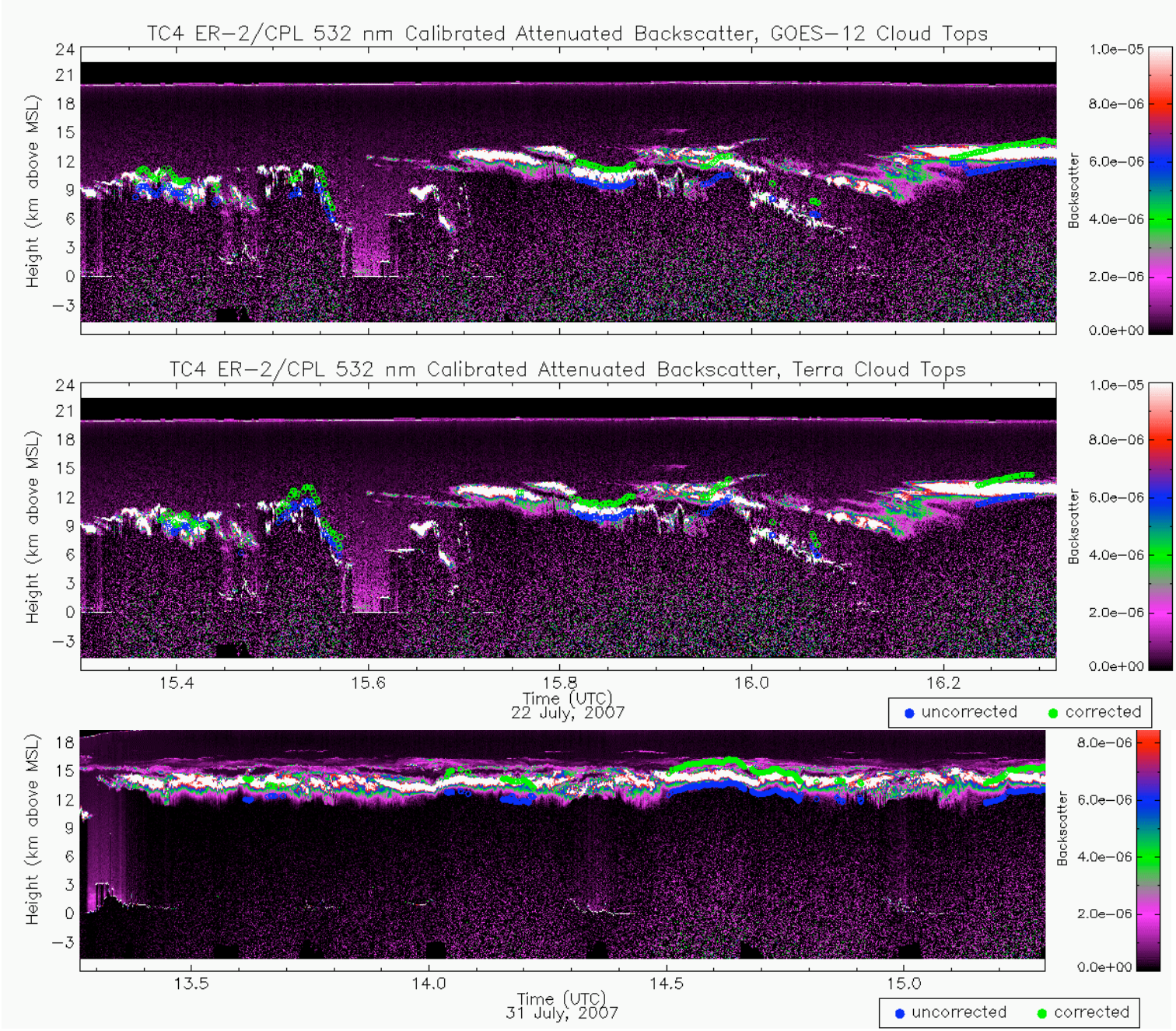
7/22

Terra

7/22

GOES-12

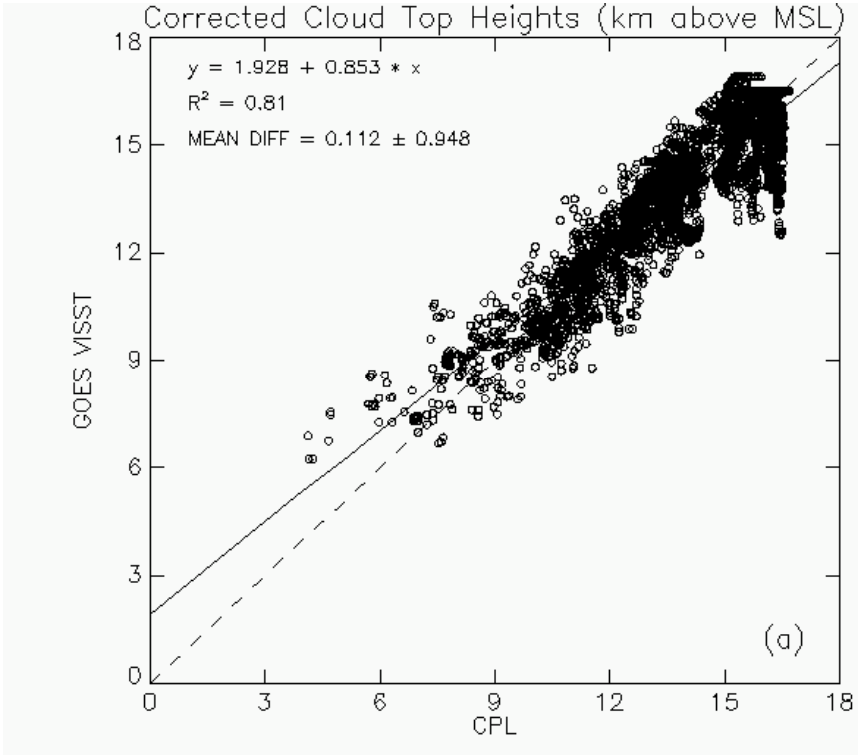
7/31



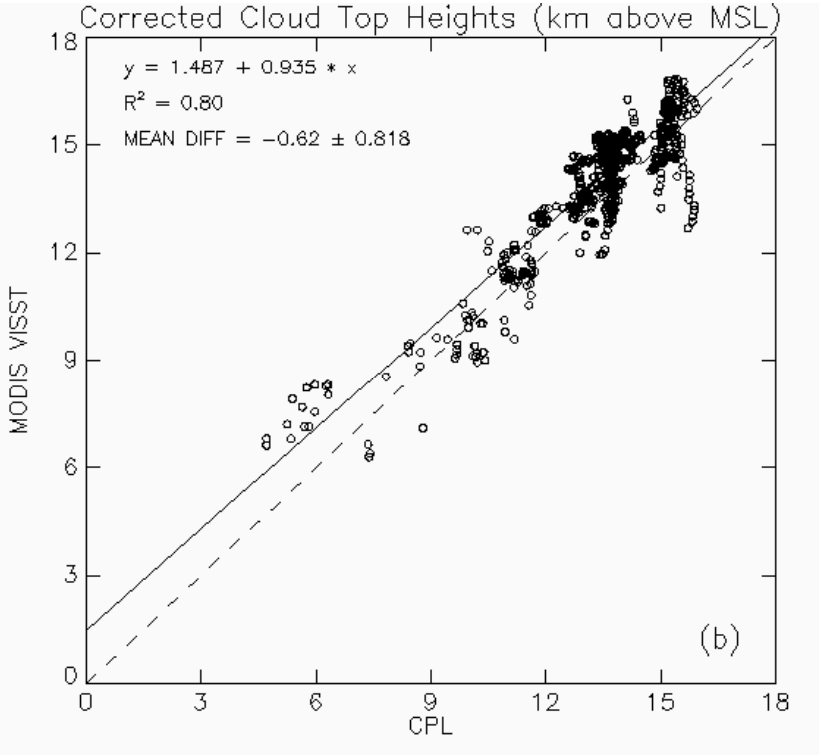
Comparison of Corrected Cloud Tops With ER2 CPL

TC4 Period

GOES-12



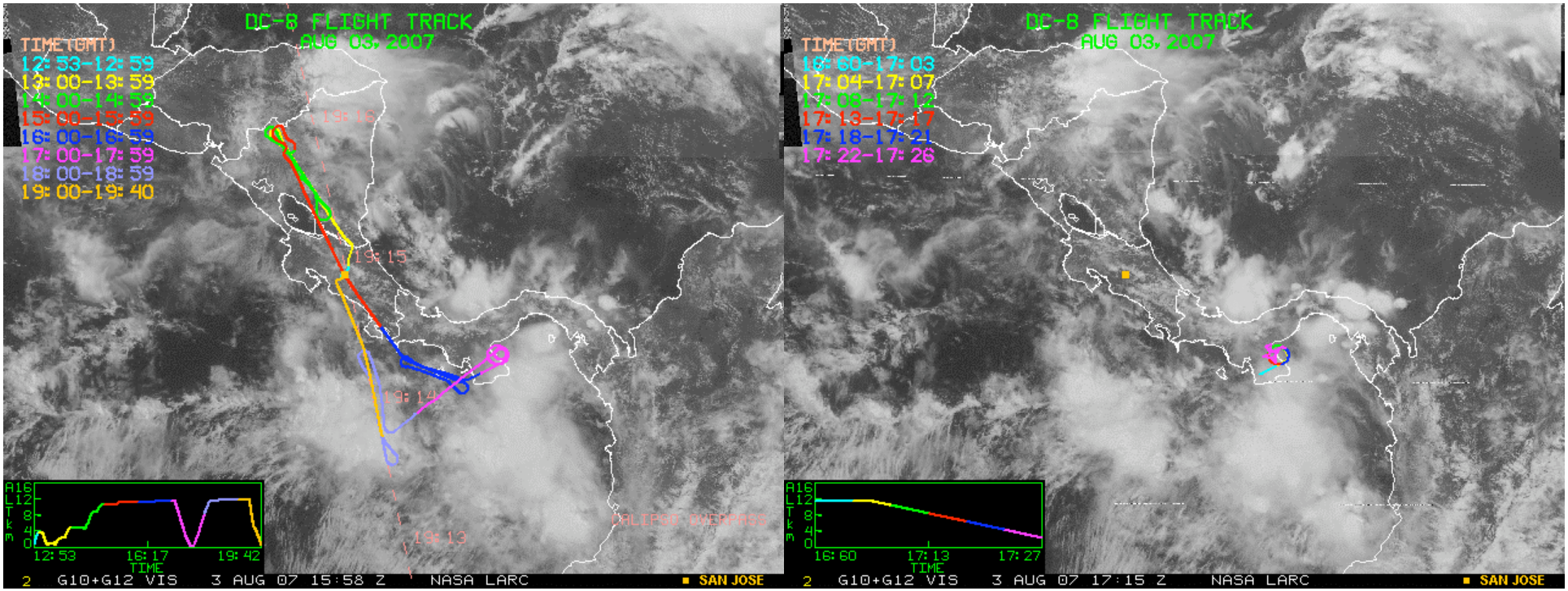
MODIS



- GOES correction very effective (near-nadir)
- MODIS correction too much (off nadir), need VZA factor

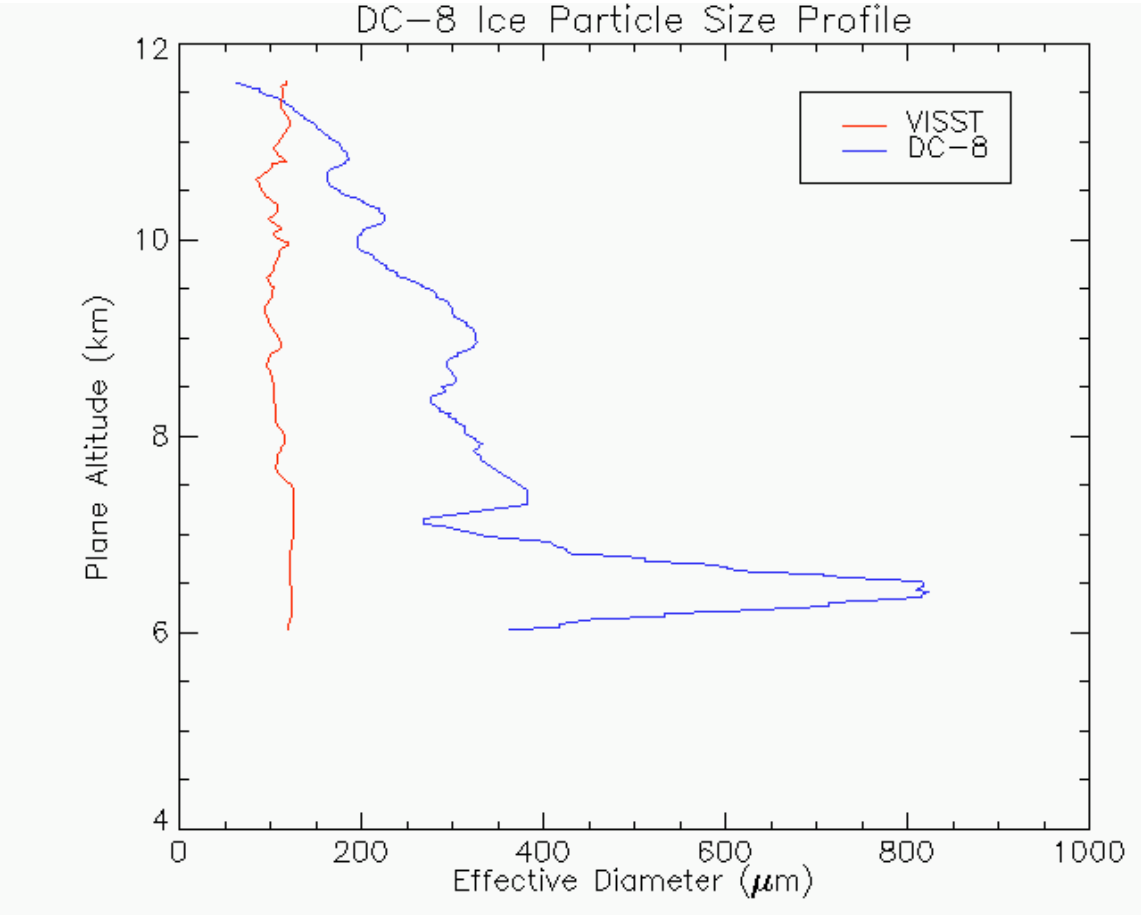
Comparison of Cloud Properties from DC-8

3 Aug 2007



Use Integrated Values from Spiral to Compare with GOES Retrievals

Comparison of Deff and IWP from Aug 3 Spiral



- Godd agreement in top of cloud (first 1-2 km)
- In situ IWP = 391 gm^{-2}; GOES IWP = 312 gm^{-2}

Summary & Future Research

- TC4 cloud & TOA radiation products available from GOES & MODIS
  - matched with aircraft data
  - high temporal and spatial resolution
- Single-layer low cloud heights within few hundred meters of lidar
- High cloud tops are underestimated
  - thin clouds 3 - 7 km too low (mean tau is good)
    - rougher crystals (?), low-level clouds, VIS-to-IR conversion
  - thick clouds 2.2 km too low
    - new empirical correction looks good
- Data will be reprocessed with new algorithms ($?)
  - correct for multi-layer clouds
  - correct cloud top heights
  - examine effect of roughened crystals
- More comparisons with ER2, WB-57, DC-8 ($?)