# Retrievals of Multi-layered Cloud Properties

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# *OUTLINE*

## ❑ *Objectives*

- *Improve the retrievals of upper-layer cloud top Tc/Pc/Zc*
- *Improve the retrievals of lower-layer cloud top Tc/Pc/Zc*
- *Improve CERES cloud phase, optical depth, particle size, liquid/ice water paths, etc.*

## ❑ *Challenges*

- *Ill-posed problem*
- *Individual pixel cloud retrieval approach*
- *Retrieval (not a guess) of the lower-layer Tc/Pc/Zc*
- *Processing time and data volume*

## ❑ *Proposed Methodology*

- *Use a pair of 11-µm and 13.3-µm channels to retrieve upper-layer and lower-layer cloud top heights*
- *Implement the new 11-/13.3-µm-retrieved cloud top heights into the updated CERES cloud algorithm*

## ❑ *Results and Validation*

## *The Proposed "New" 11-/13.3-µm-CO2 retrieval Method*

- *Use a pair of 11-µm and 13.3-µm channels to retrieve upper-layer and lower-layer cloud top heights*
- *Implement the new 11-/13.3-µm-retrieved cloud top heights into the updated CERES cloud algorithm*

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### Cloud Retrieval Using Infrared Sounder Data: Error Analysis

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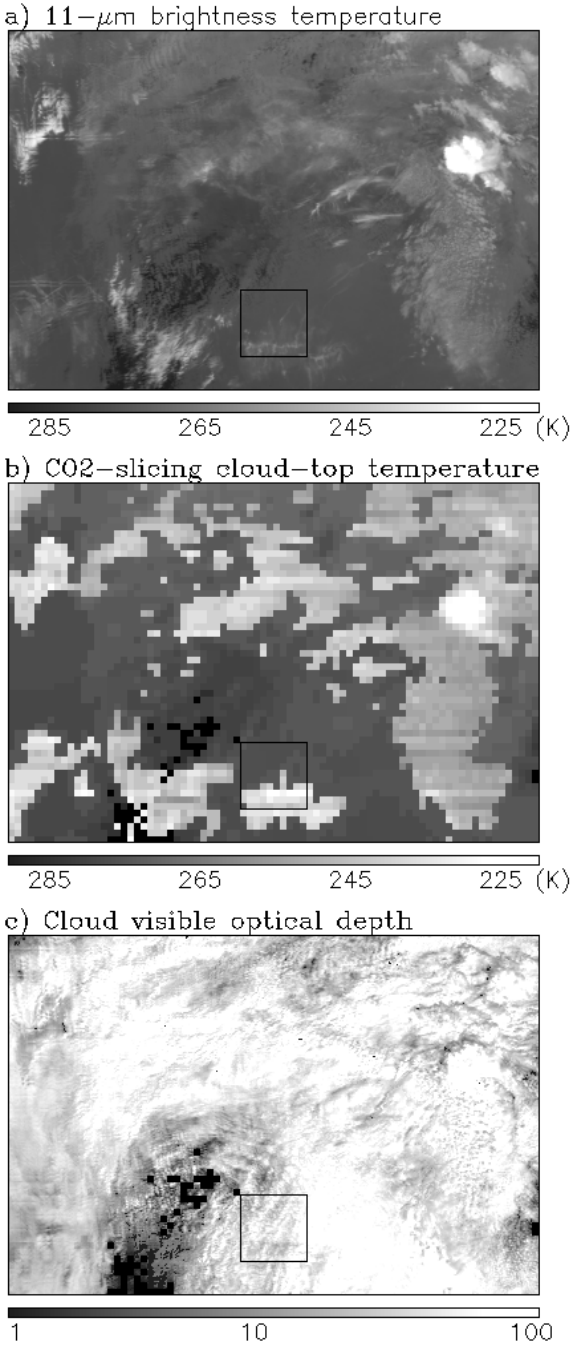
*National Center for Atmospheric Research,[2] Boulder, CO 80307*

(Manuscript received 22 July, 1980, in final form 21 November 1980)

ABSTRACT

An error analysis is presented for cloud-top pressure and cloud-amount retrieval using infrared sounder data. Rms and bias errors are determined for instrument noise (typical of the HIRS-2 instrument on TIROS-N) and for uncertainties in the temperature profiles and water vapor profiles used to estimate clear-sky radiances. Errors are determined for a range of test cloud amounts (0.1–1.0) and cloud-top pressures (920–100 mb). Rms errors vary by an order of magnitude depending on the cloud height and cloud amount within the satellite's field of view. Large bias errors are found for low-altitude clouds. These bias errors are shown to result from physical constraints placed on retrieved cloud properties, i.e., cloud amounts between 0.0 and 1.0 and cloud-top pressures between the ground and tropopause levels. Middle-level and high-level clouds (above 3–4 km) are retrieved with low bias and rms errors. For instrument noise the 4.3 $\mu$m channels provide the smallest errors. For temperature profile and water vapor

# *A Little Background on the CO2-Multi Retrieval Method*



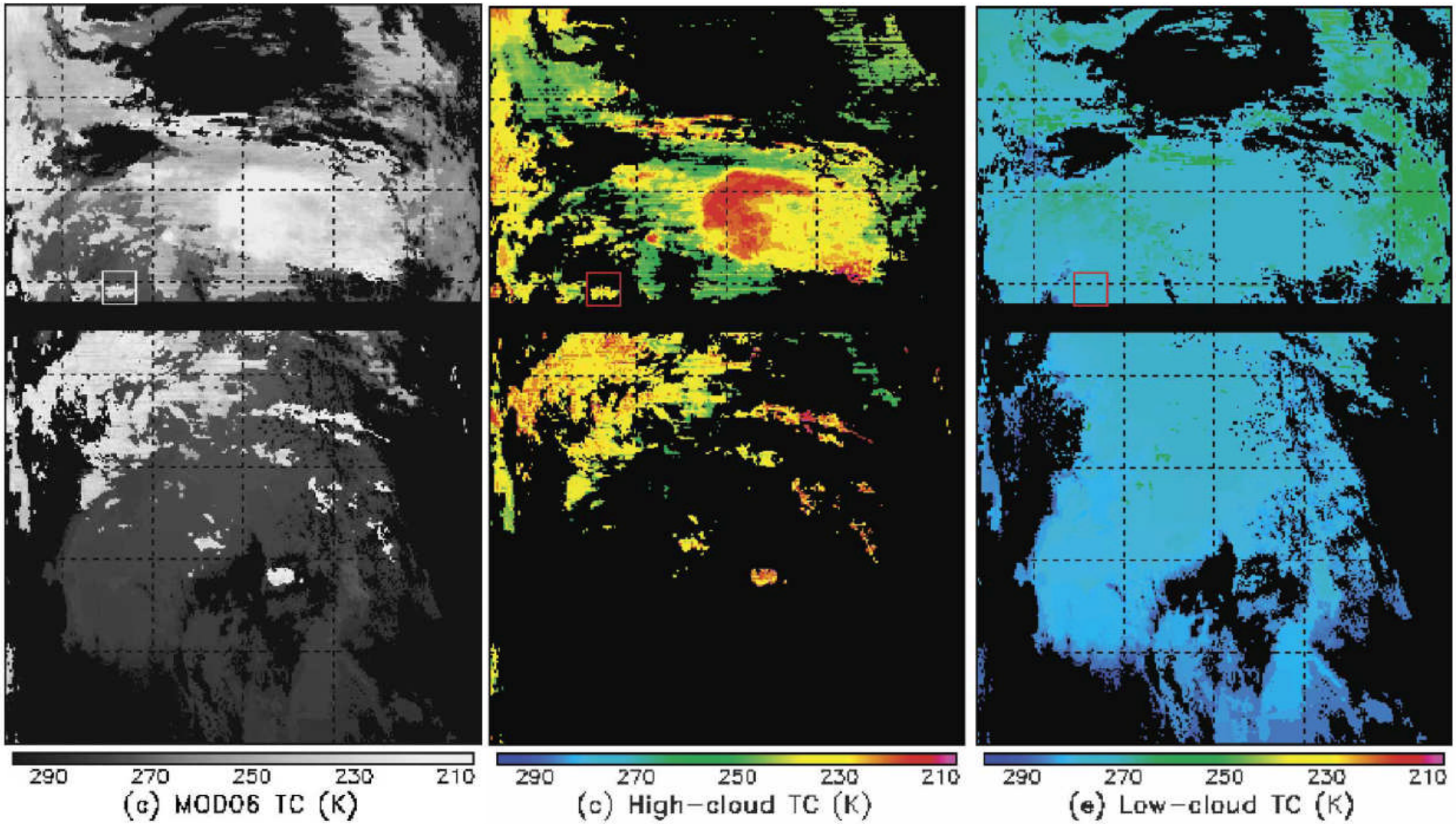

## In the paper of Chang and Li (2005):

MOD06 5-km CO2 cloud top properties → Retrieve two-layered cloud properties ← MOD06 1-km cloud visible optical depth

## Need to do in CERES ed3:

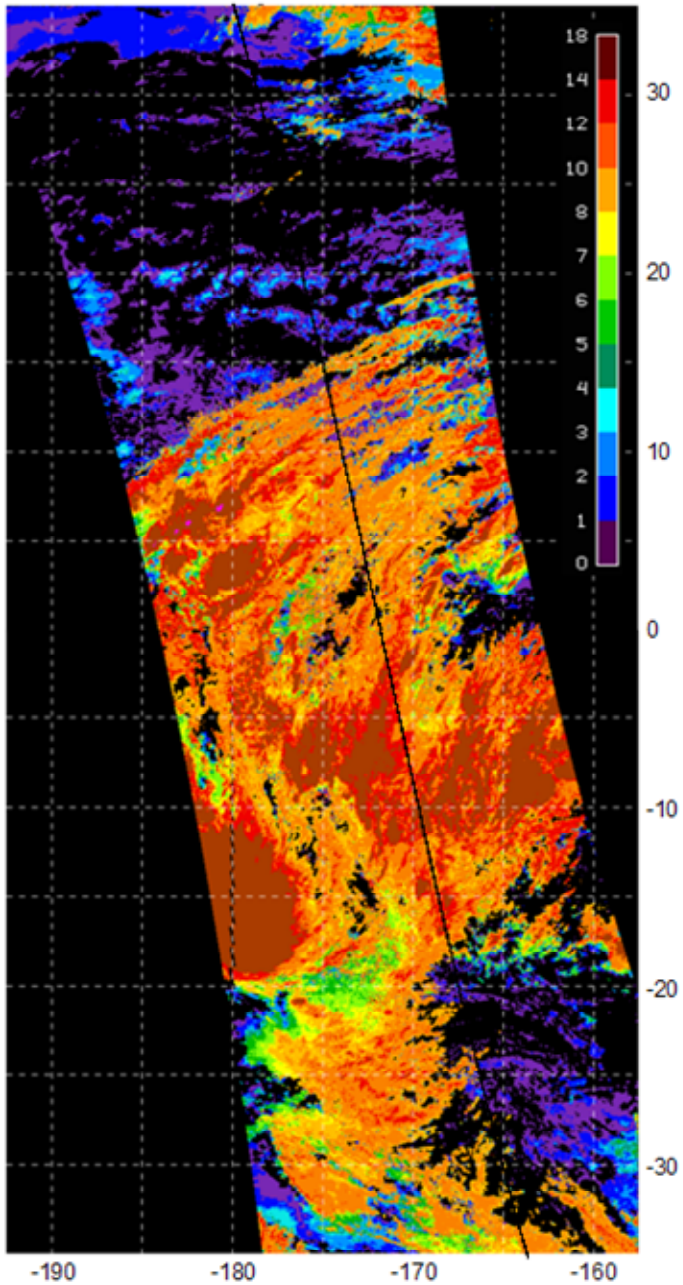
CERES 1-km CO2 cloud top properties → Retrieve two-layered cloud properties ← CERES 1-km cloud visible optical depth

# *When the Love Connection Made at First …*
# *Why Is It So Tough Now?*

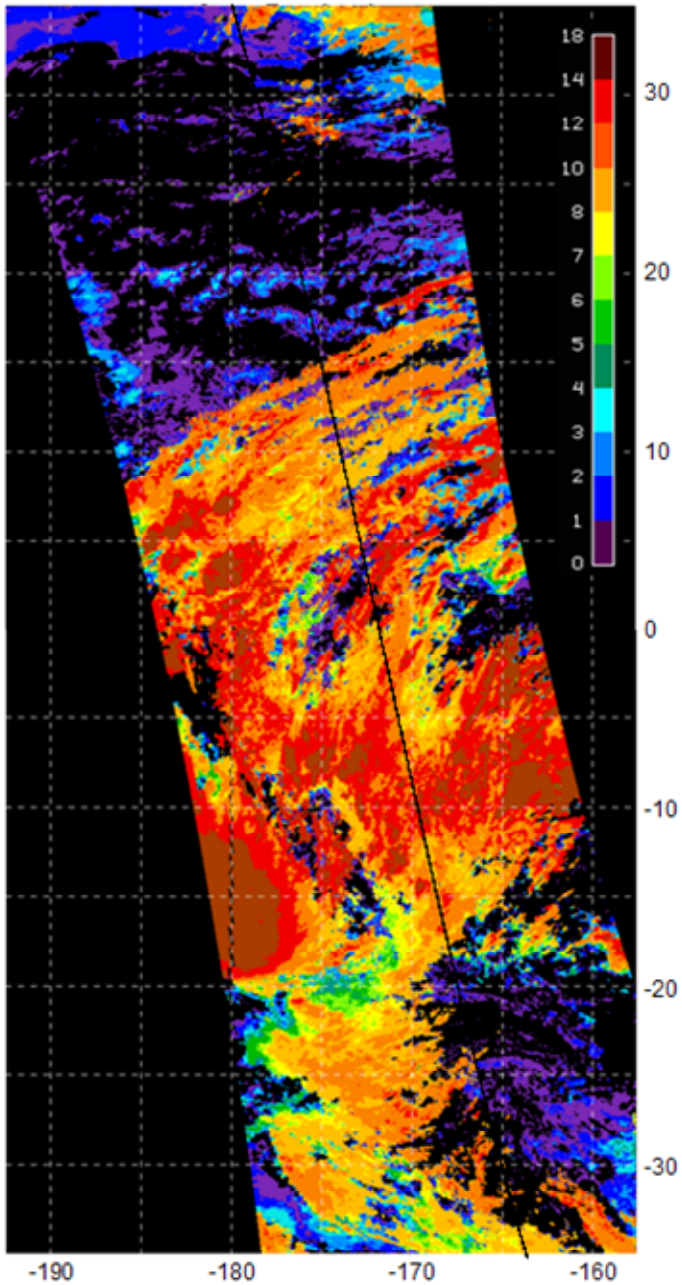


# *Small Challenge: Computing Time to Process the MODIS 1-km Data?*

**CERES 1-km Zc, 11.0/13.3µm**

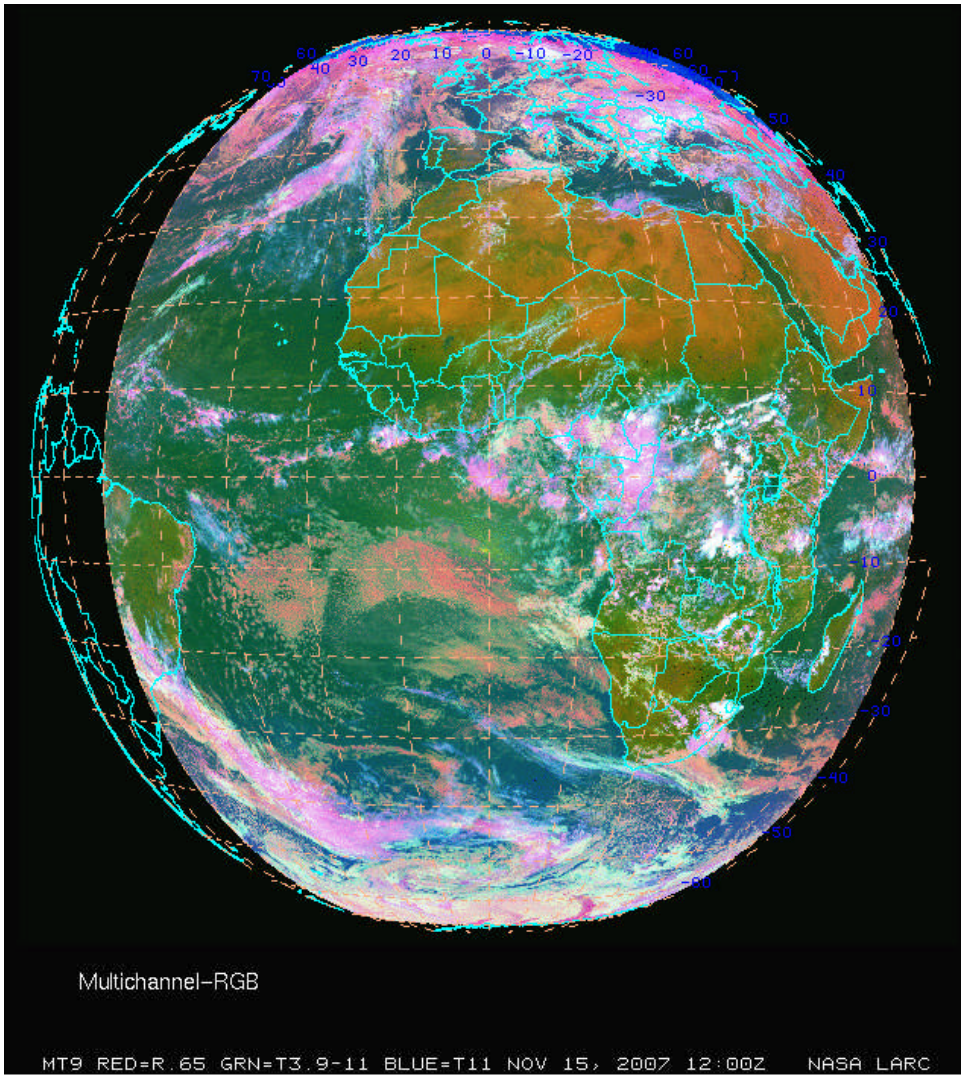


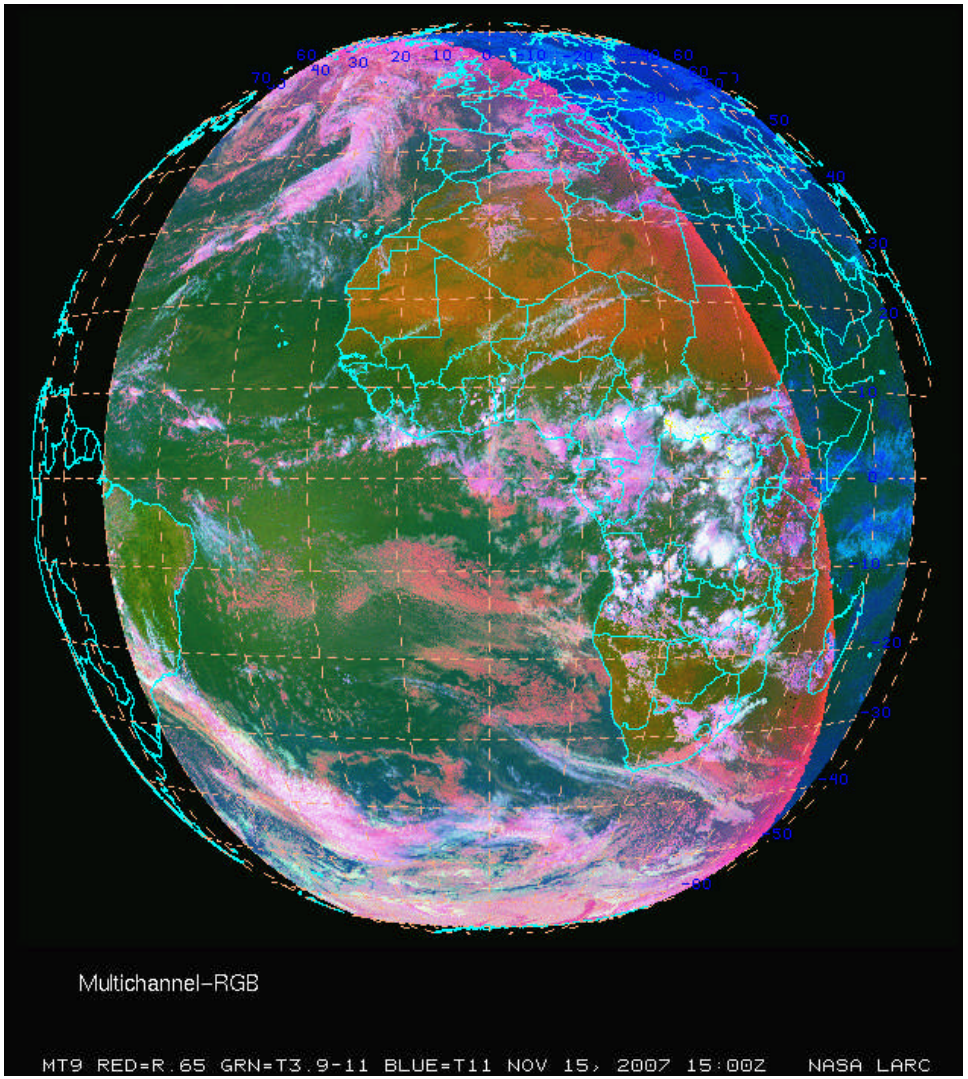

**MYD06 5-km Zc, 11.0/13.3/13.6/13.9/14.2µm**



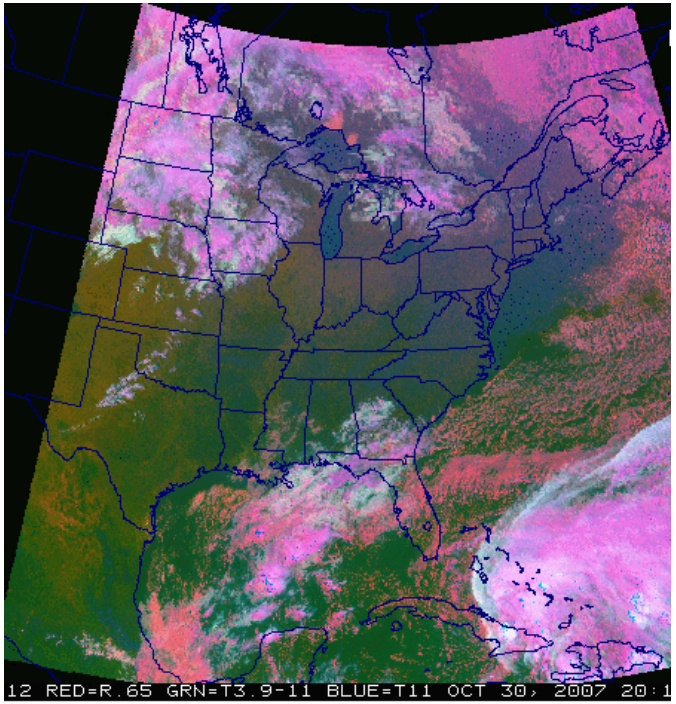
# *Bigger Challenges?*

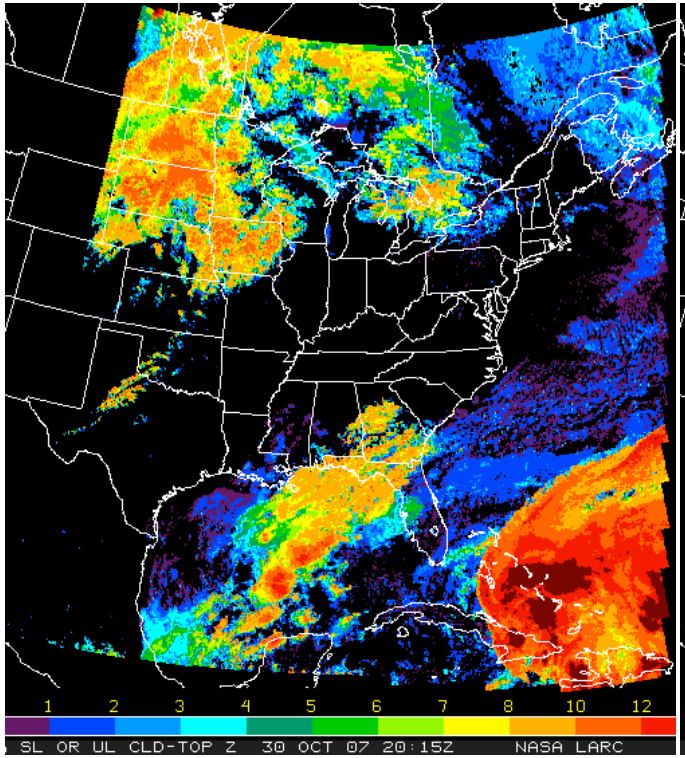
- *CERES-MODIS real-time processing*
- *GOES-12 real-time processing*
- *SEVIRI real-time processing (on MSG & MTG)*

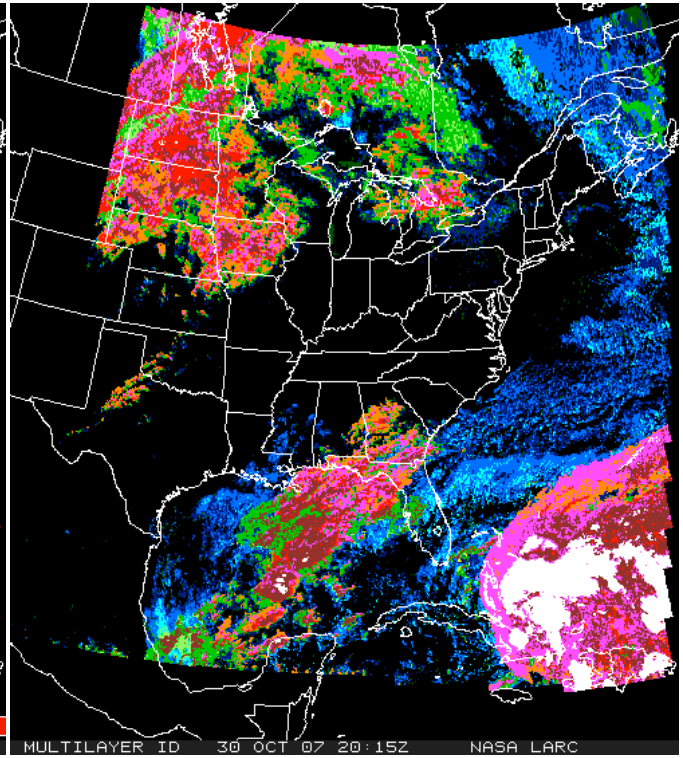


# *A Pixel-by-pixel Multi-layered Cloud Retrieval Approach*
# *No Coming Back!?*




↑ GOES-12 false-color RGB
Oct. 30, 2007 **UTC 20:15**

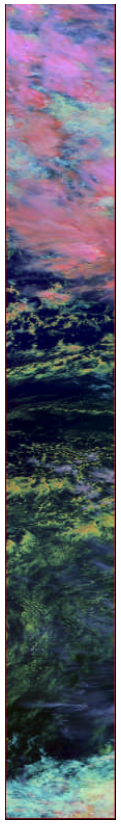
↑ Cloud-top Zc

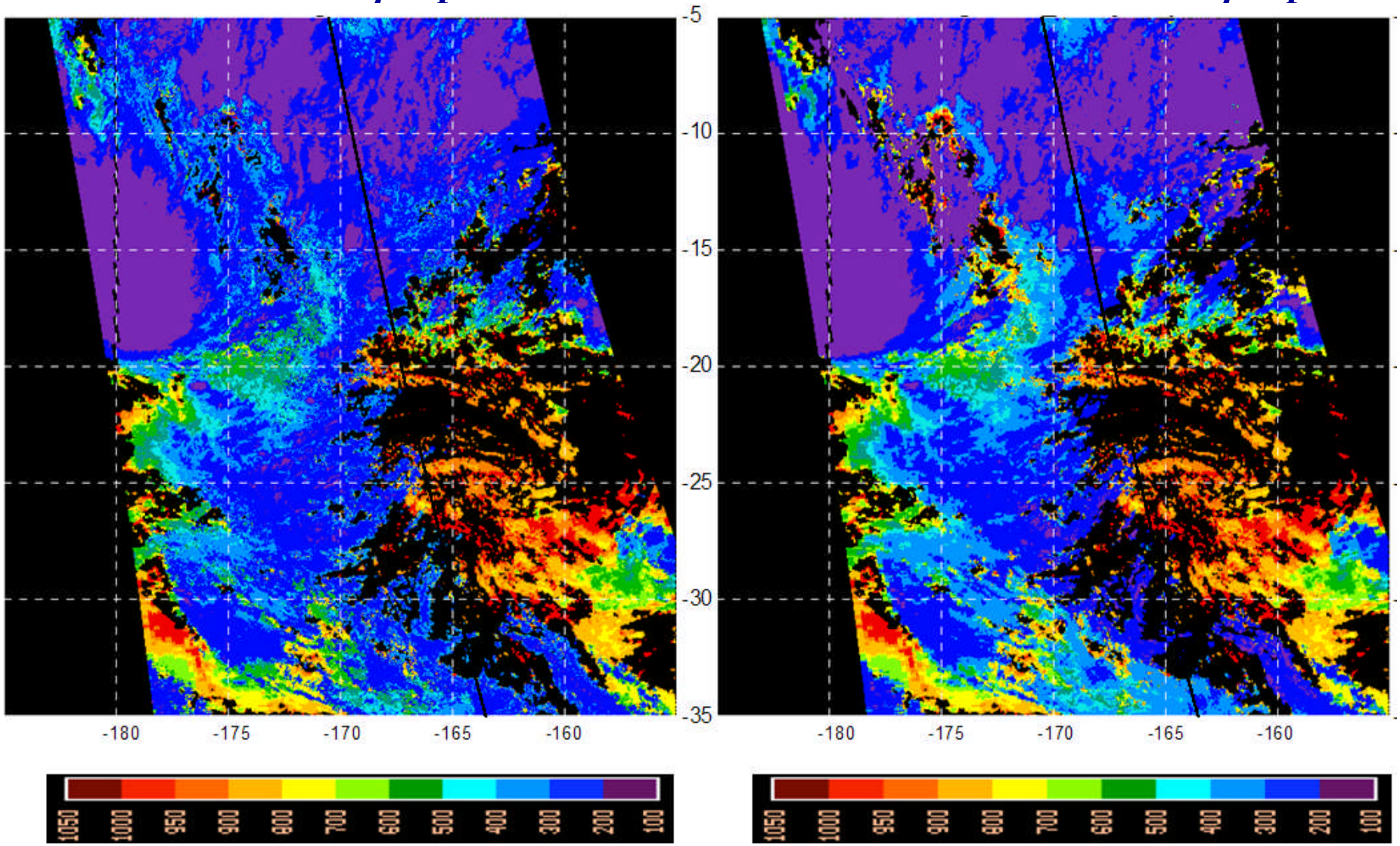
↑ Multi-layer ID

# *Comparison of the CERES and MYD06 CO2-Cloud-Top Pressures*

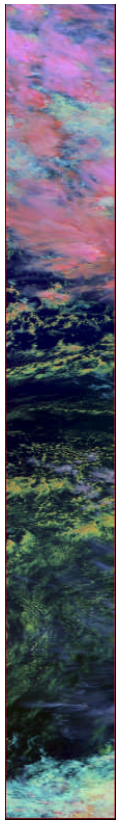
***CERES 1-km Pc***
***Used 11.0/13.3-µm pairs***

***MYD06 5-km Pc***
***Used 11.0/13.3/13.6/13.9/14.2-µm pairs***

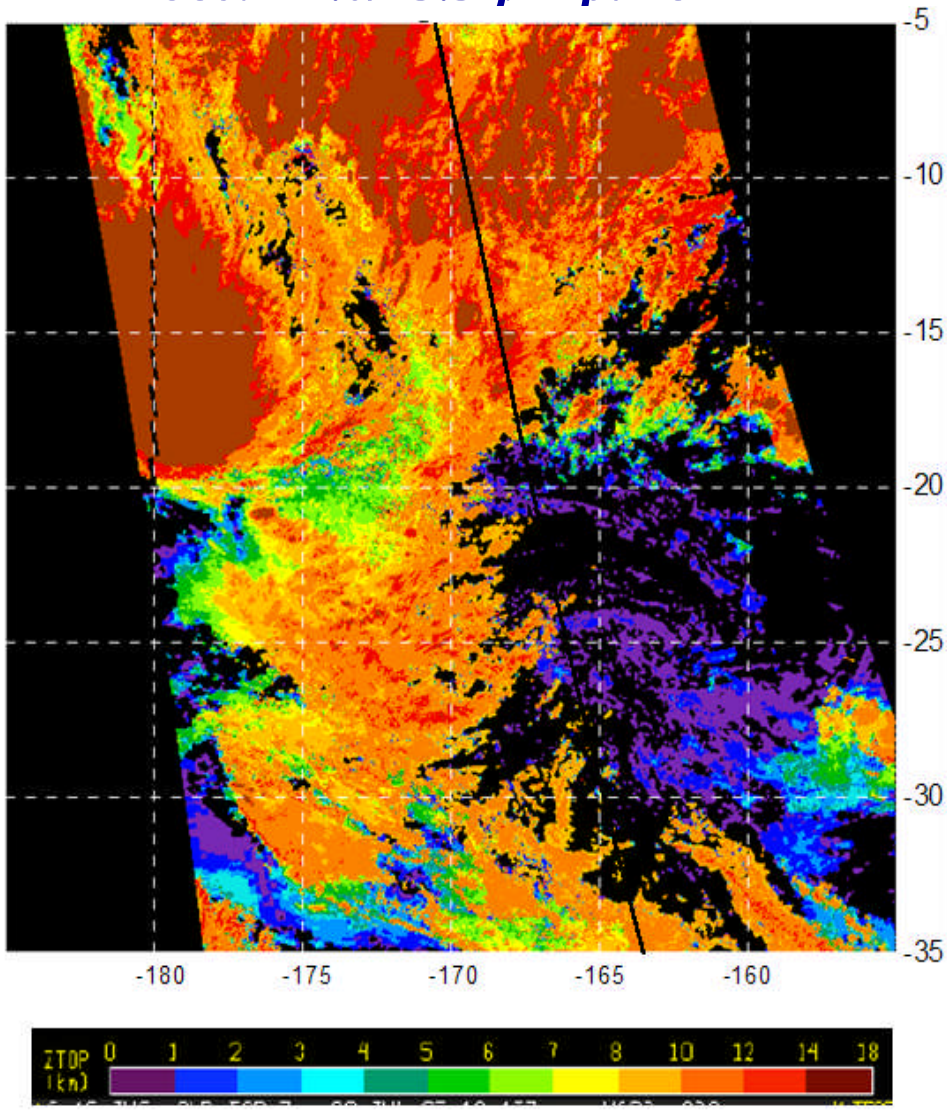




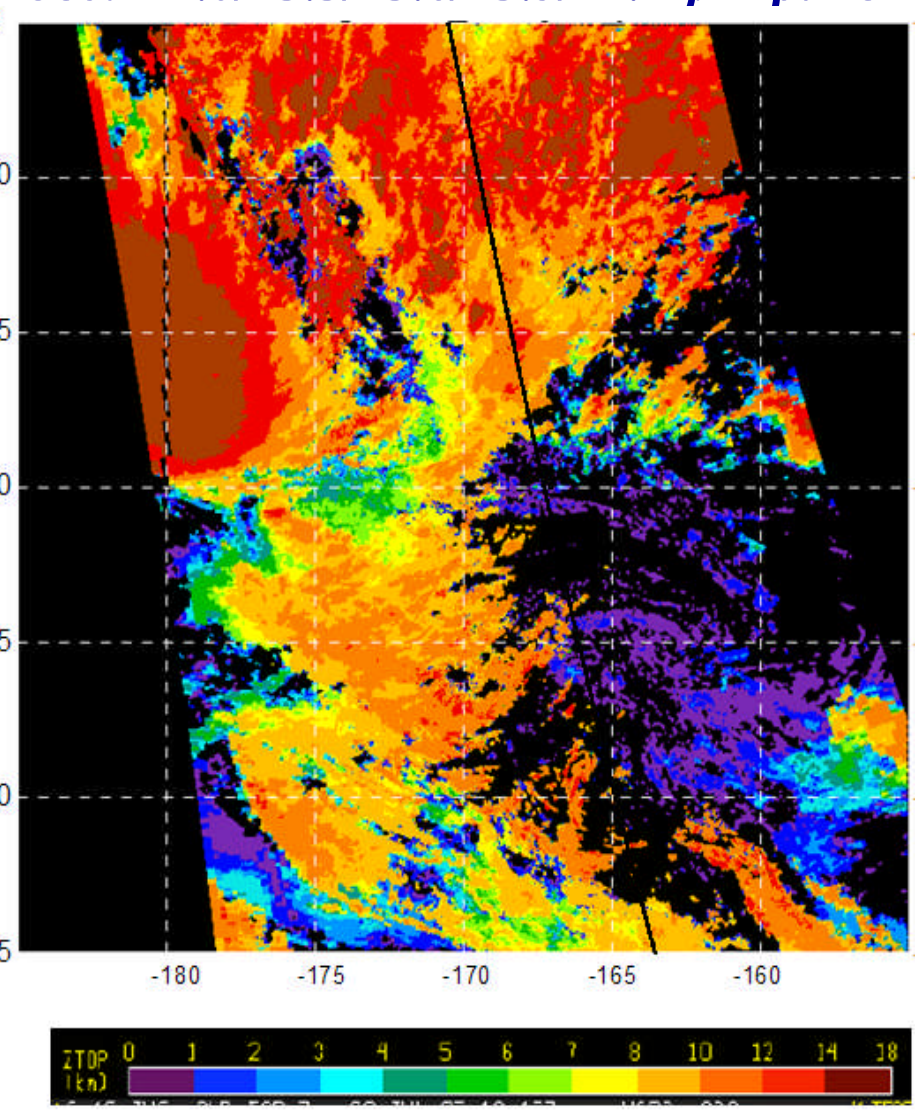
# *Comparison of the CERES and MYD06 CO2-Cloud-Top Heights*



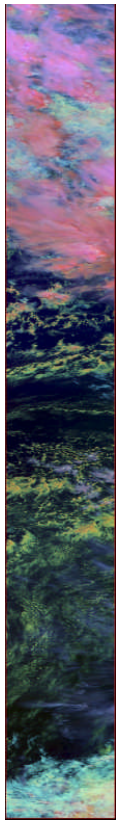
***CERES 1-km Zc***
***Used 11.0/13.3-µm pairs***



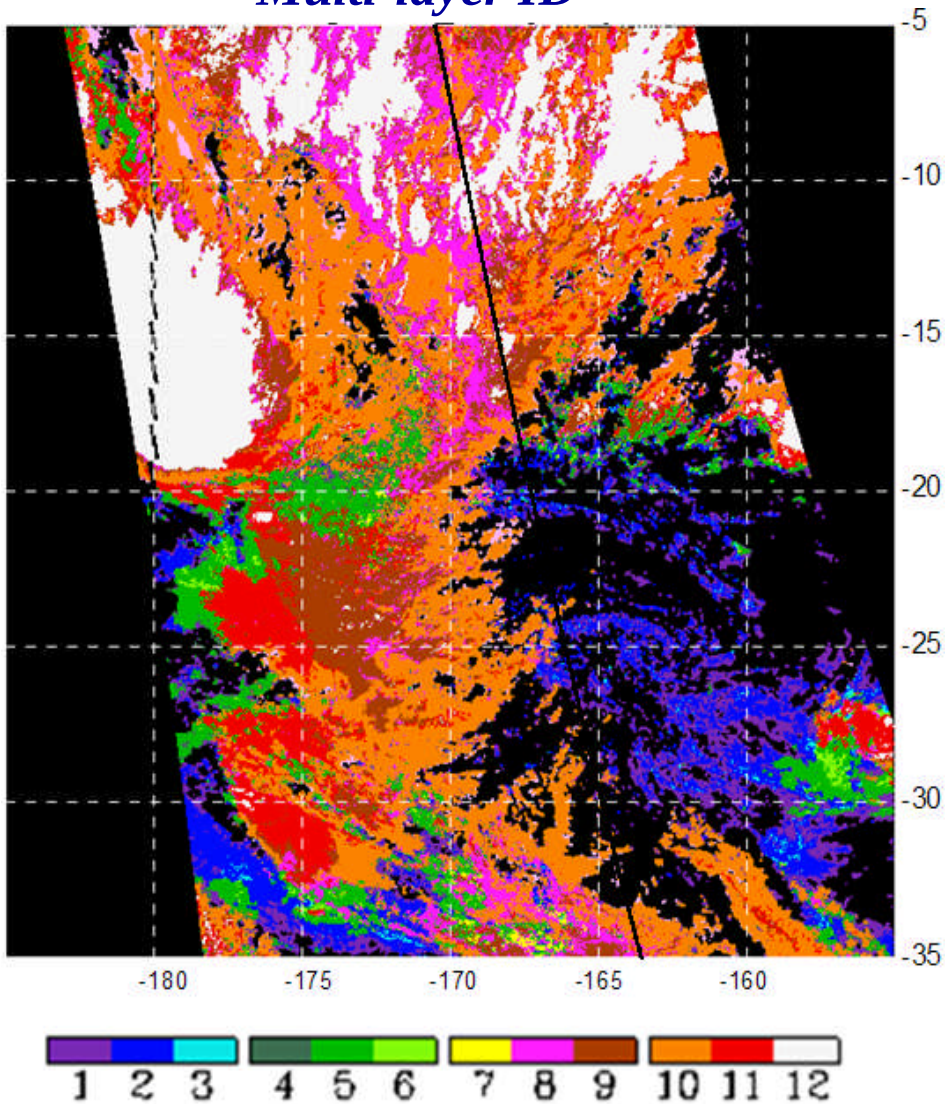

***MYD06 5-km Zc***
***Used 11.0/13.3/13.6/13.9/14.2-µm pairs***



# *Current Classifications of the CERES Multi-layered ID*



## *CERES 1-km Multi-layer ID*




## *Definitions of the 12-code Multi-layer ID*

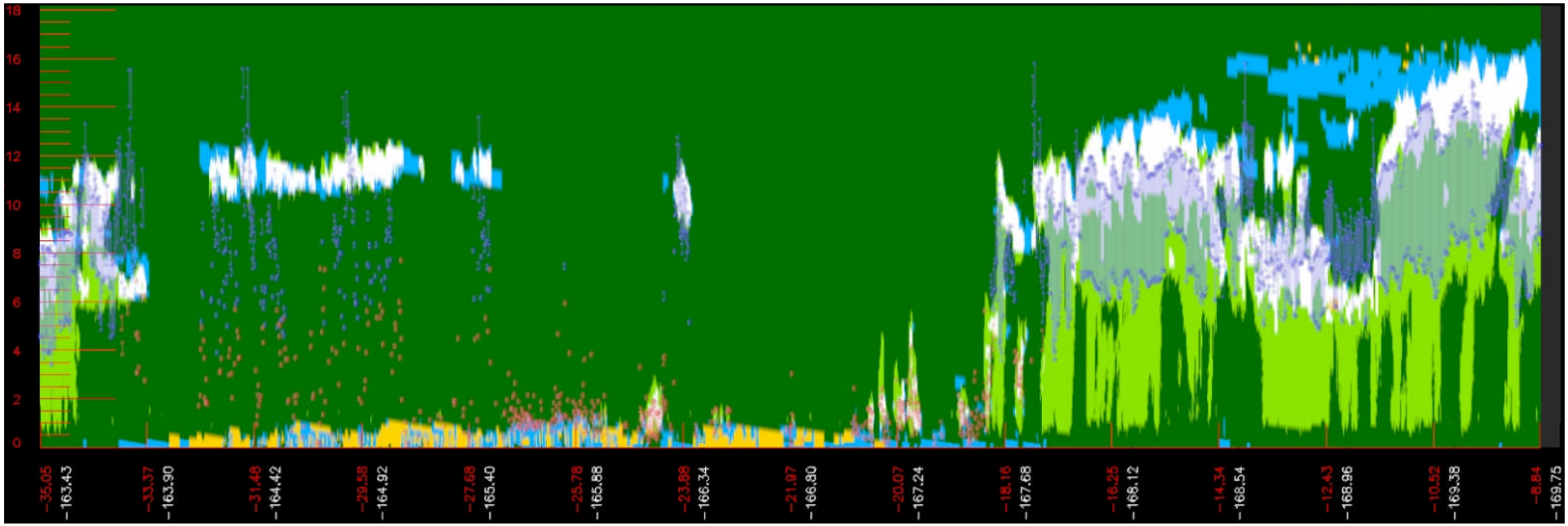
1: Low thin cloud (Tau < 3.6)
2: Low median cloud (Tau = 3.6-23)
3: Low thick cloud (Tau > 23)

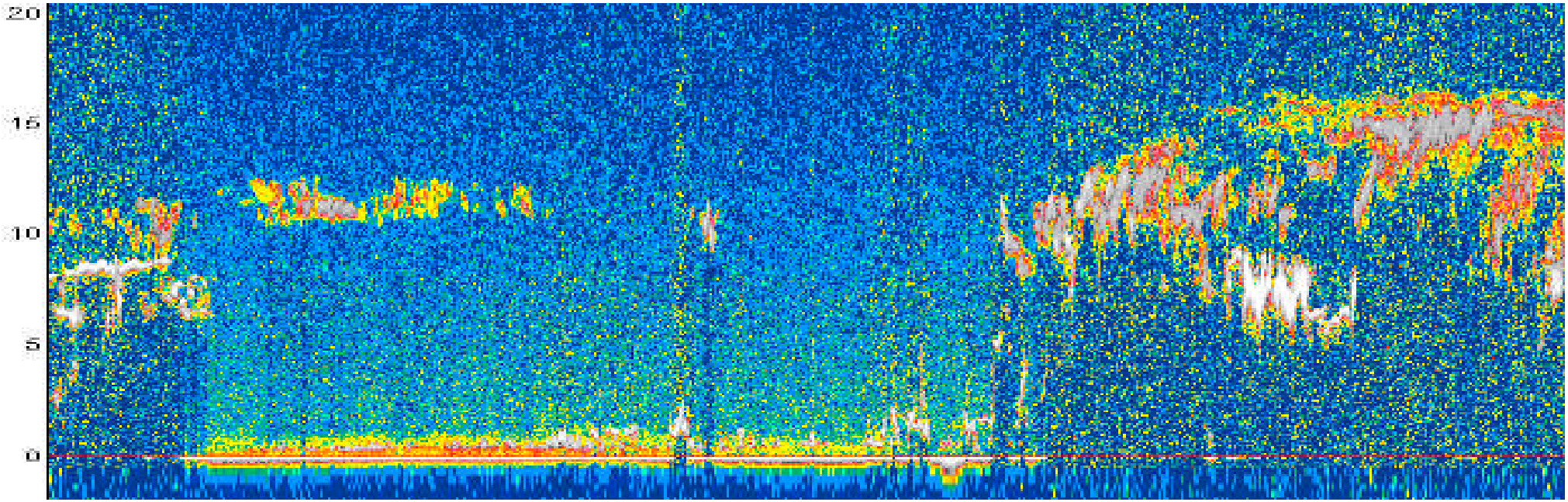
4: Mid thin cloud (Tau < 3.6)
5: Mid median cloud (Tau = 3.6-23)
6: Mid thick cloud (Tau > 23)

7: Multi-layered mid-top cloud (2-layer retrieval)
8: Multi-layered high-top cloud (2-layer retrieval)
9: Multi-layered cloud (Weak)

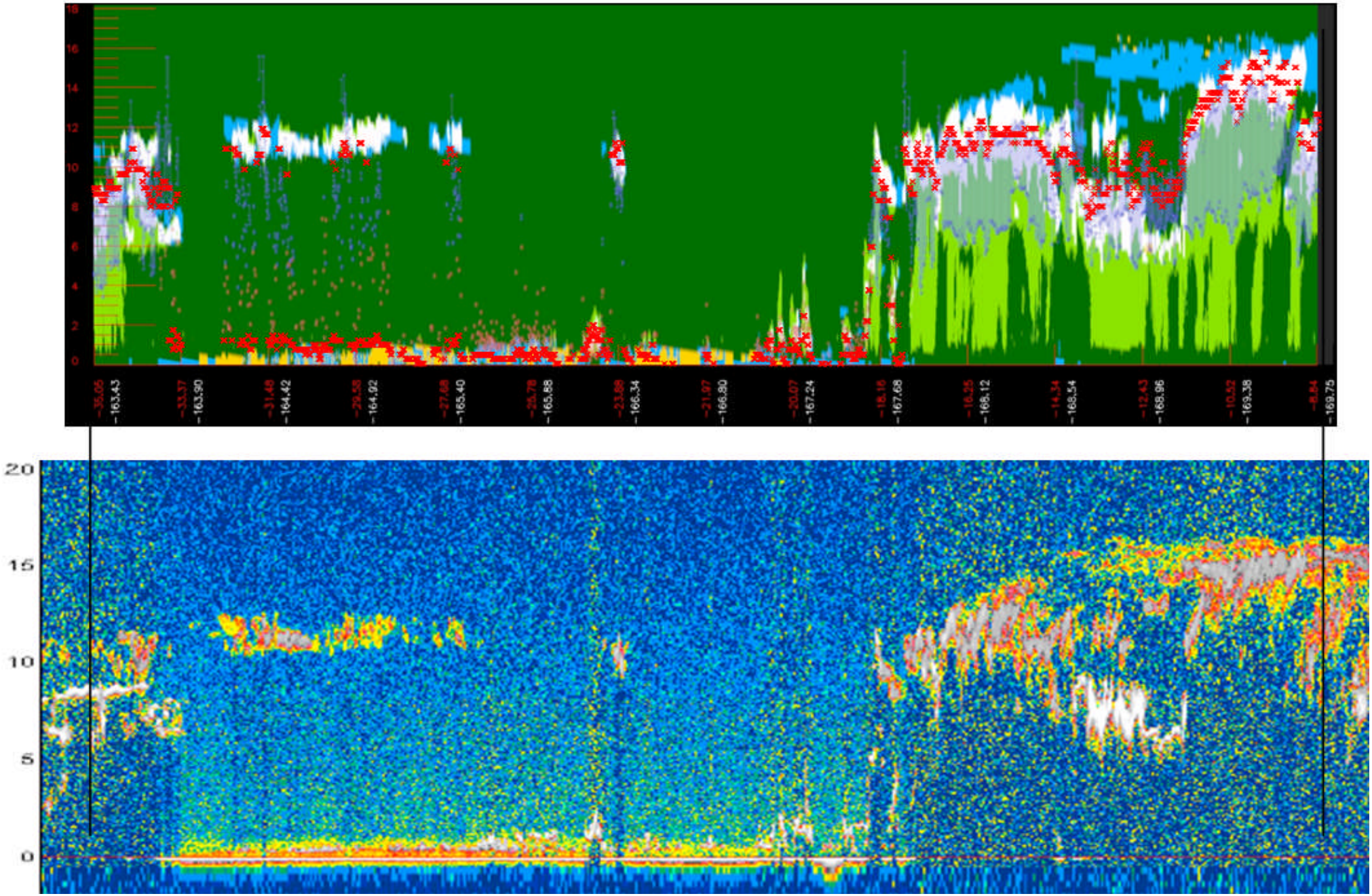
10: High-top cirrus cloud (Tau < 3.6)
11: High-top cirrocumulus/cirrostratus (Tau= 3.6-23)
12: High-top deep convective cloud (Tau > 23)

# *CALIPSO-CloudSat Merged Cloud Vertical Profiles*

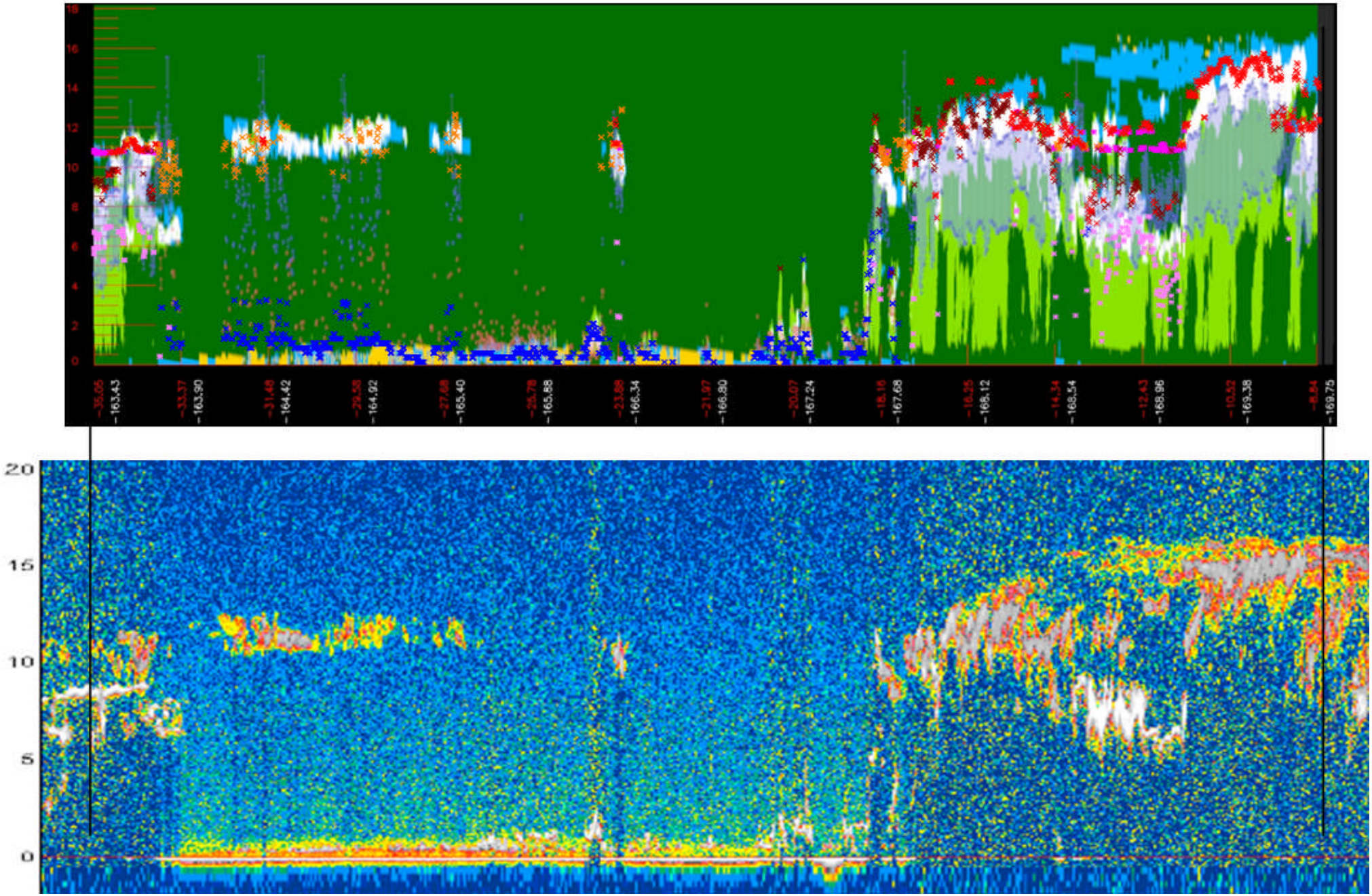


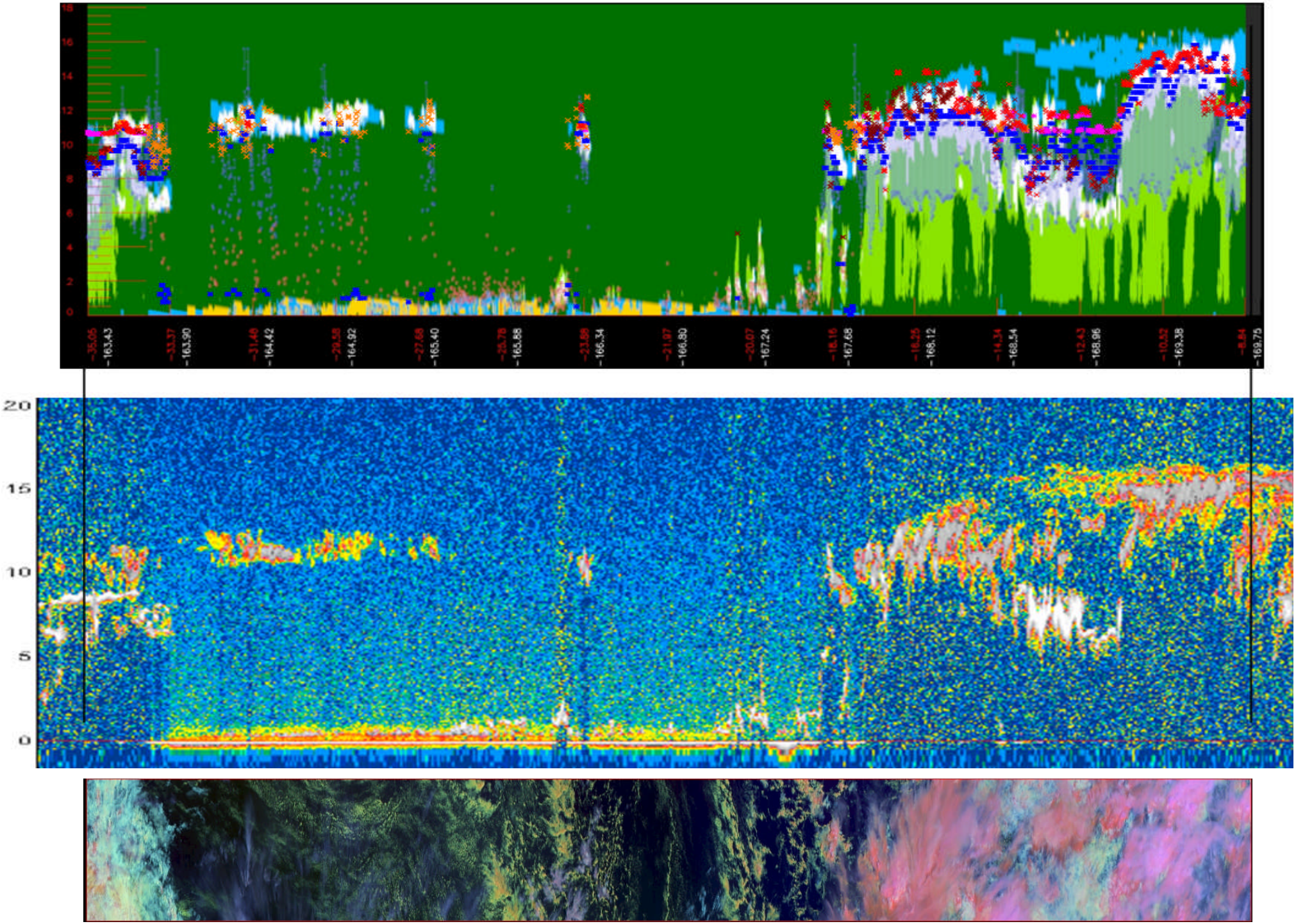



# *Cloud-Top Heights from the MYD06 CO2 Method*



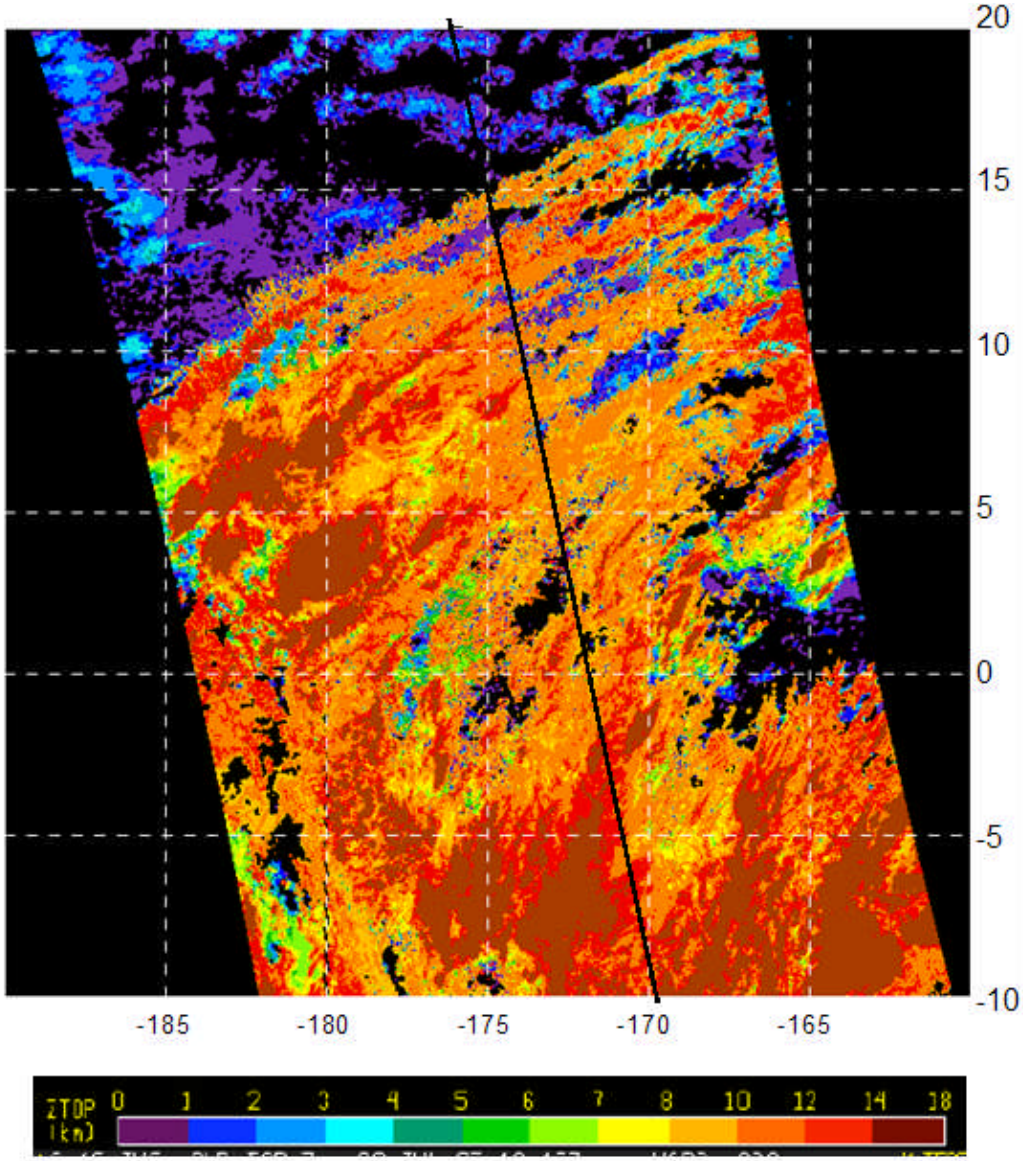
# *Cloud-Top Heights from the CERES CO2 Method*



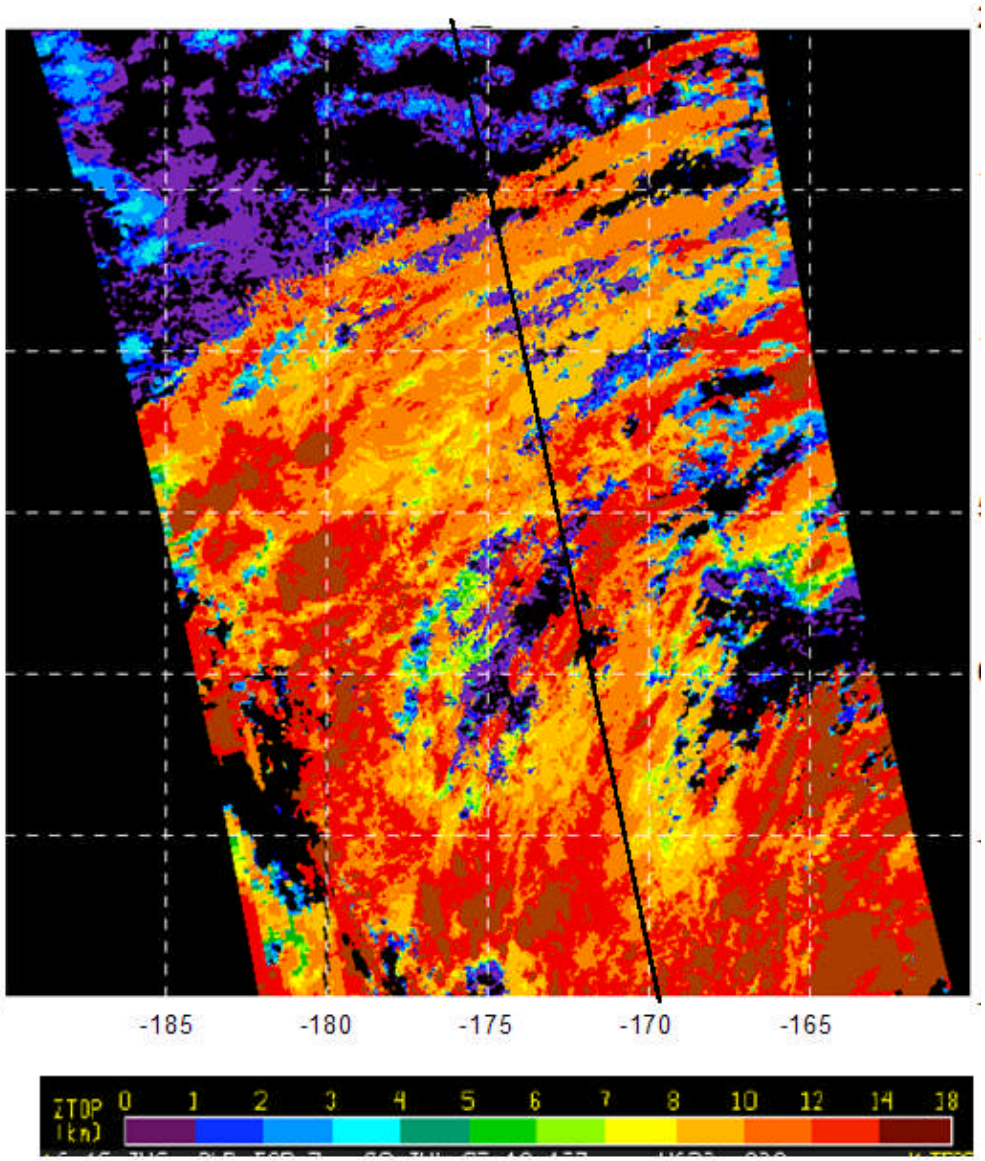

18
16
14
12
10
8
6
4
2
0
-35.05
-163.43
-33.37
-163.90
-31.46
-164.42
-29.58
-164.92
-27.68
-165.40
-25.78
-165.88
-23.88
-166.34
-21.97
-166.80
-20.07
-167.24
-18.16
-167.68
-16.25
-168.12
-14.34
-168.54
-12.43
-168.96
-10.52
-169.38
-8.64
-169.75
20
15
10
5
0

# *Comparison of the CERES and MYD06 CO2-Cloud-Top Heights*

***CERES 1-km, 11.0/13.3µm***

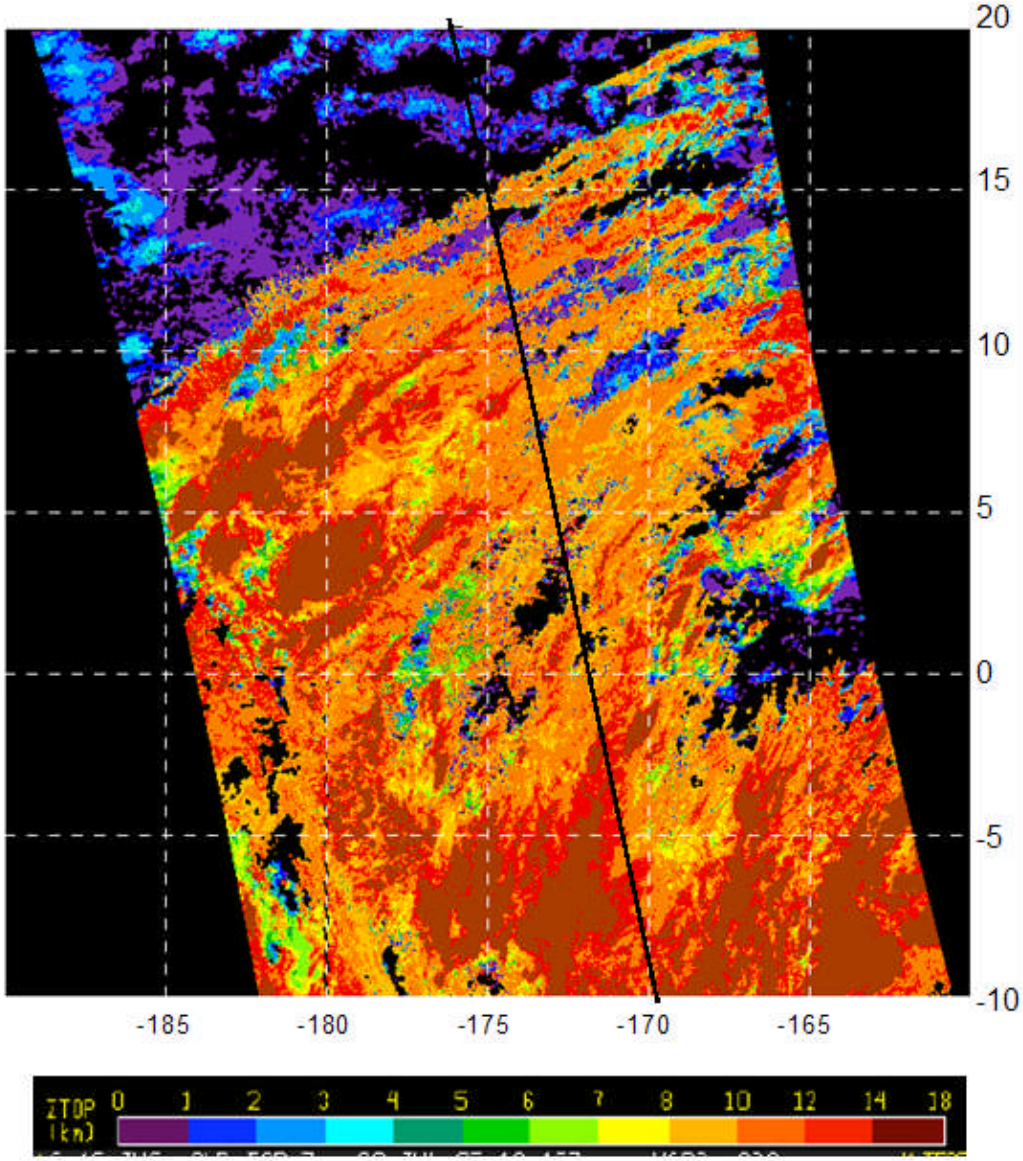



***MYD06 5-km, 11.0/13.3/13.6/13.9/14.2µm***

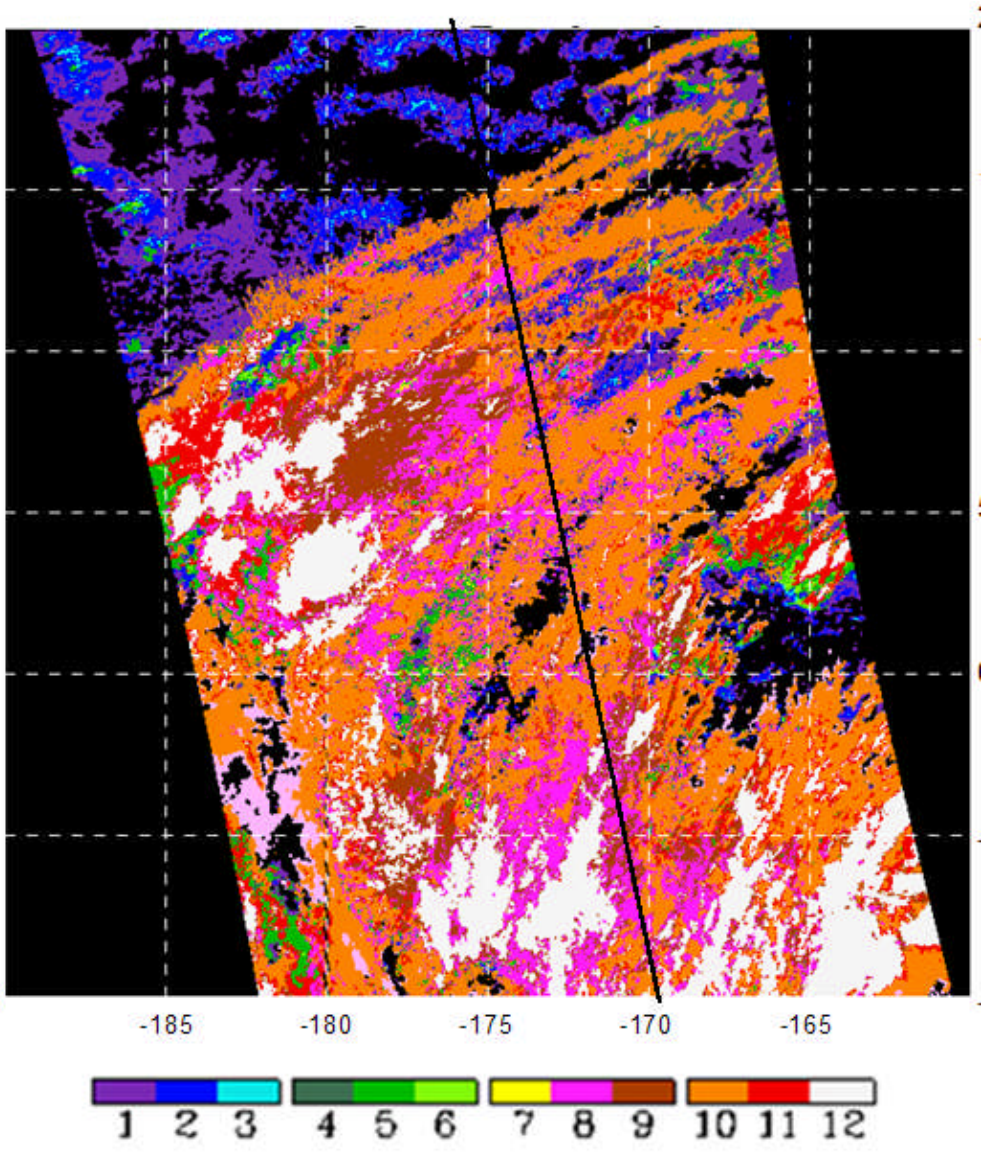


# *The CERES Cloud Top Height and Multilayer ID*

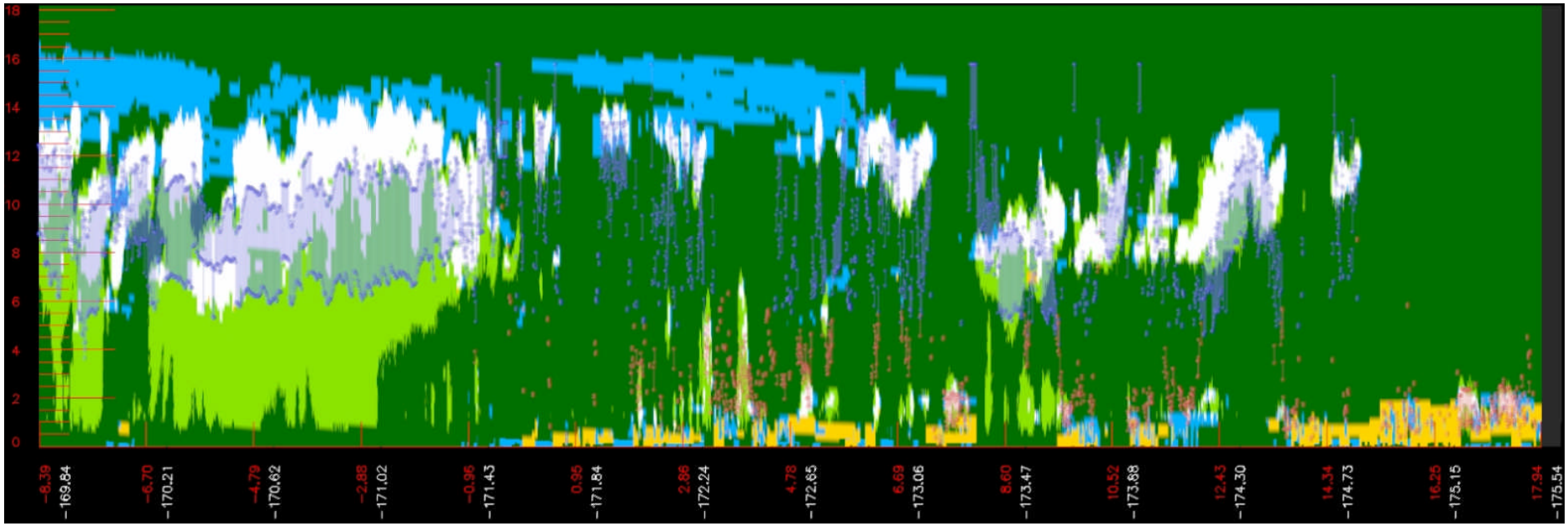
## *CERES 1-km Zc, 11.0/13.3µm*

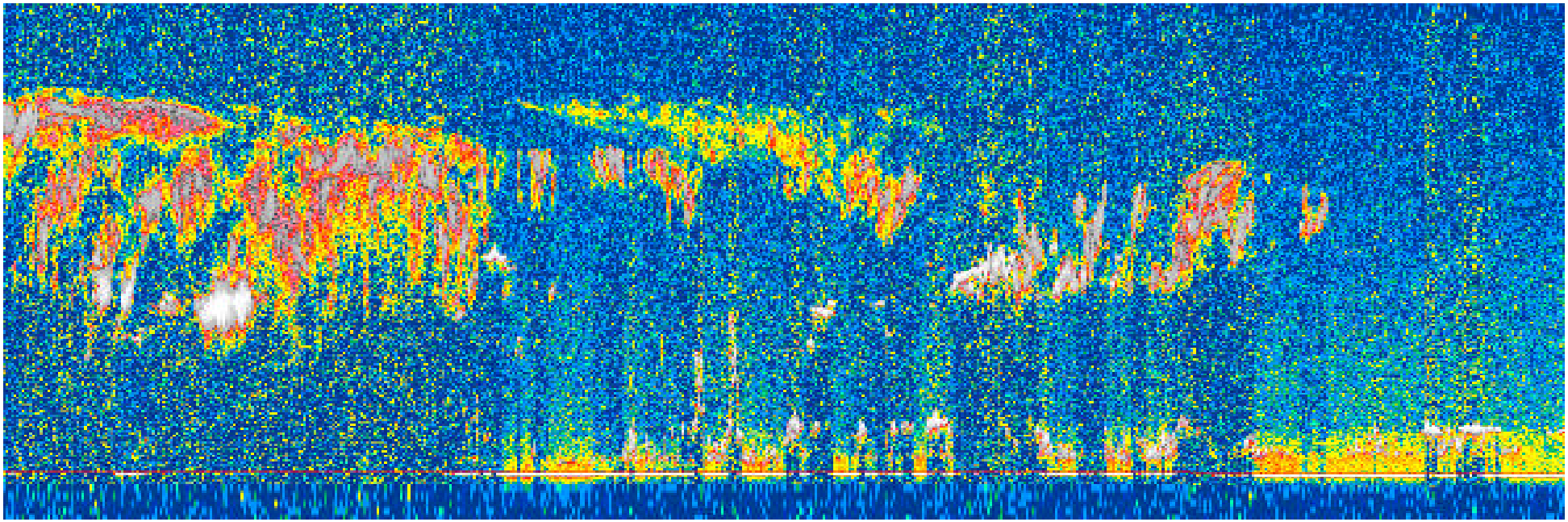



## *CERES 1-km Multilayer ID*

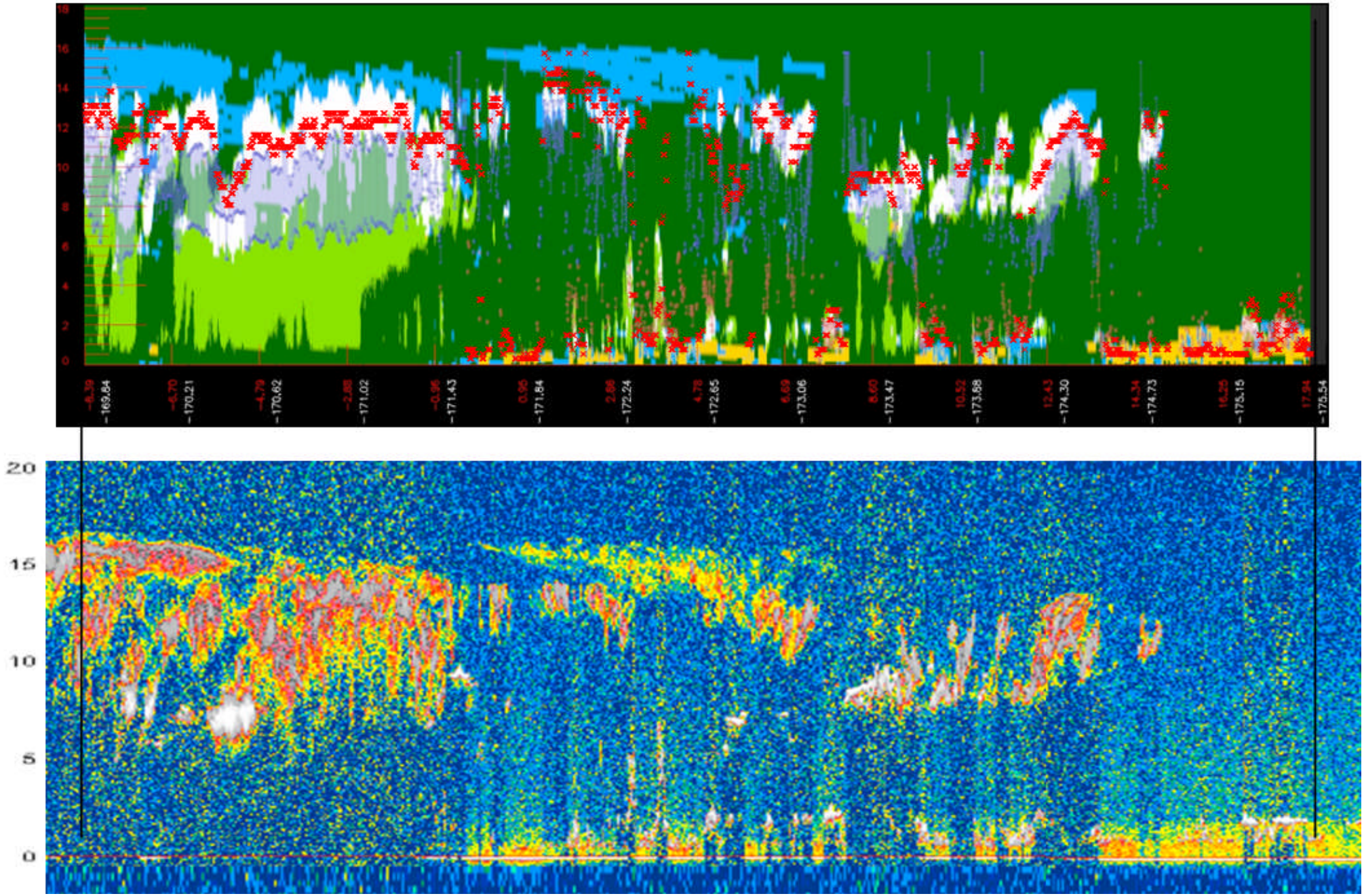


# *CALIPSO-CloudSat Merged Cloud Vertical Profiles*

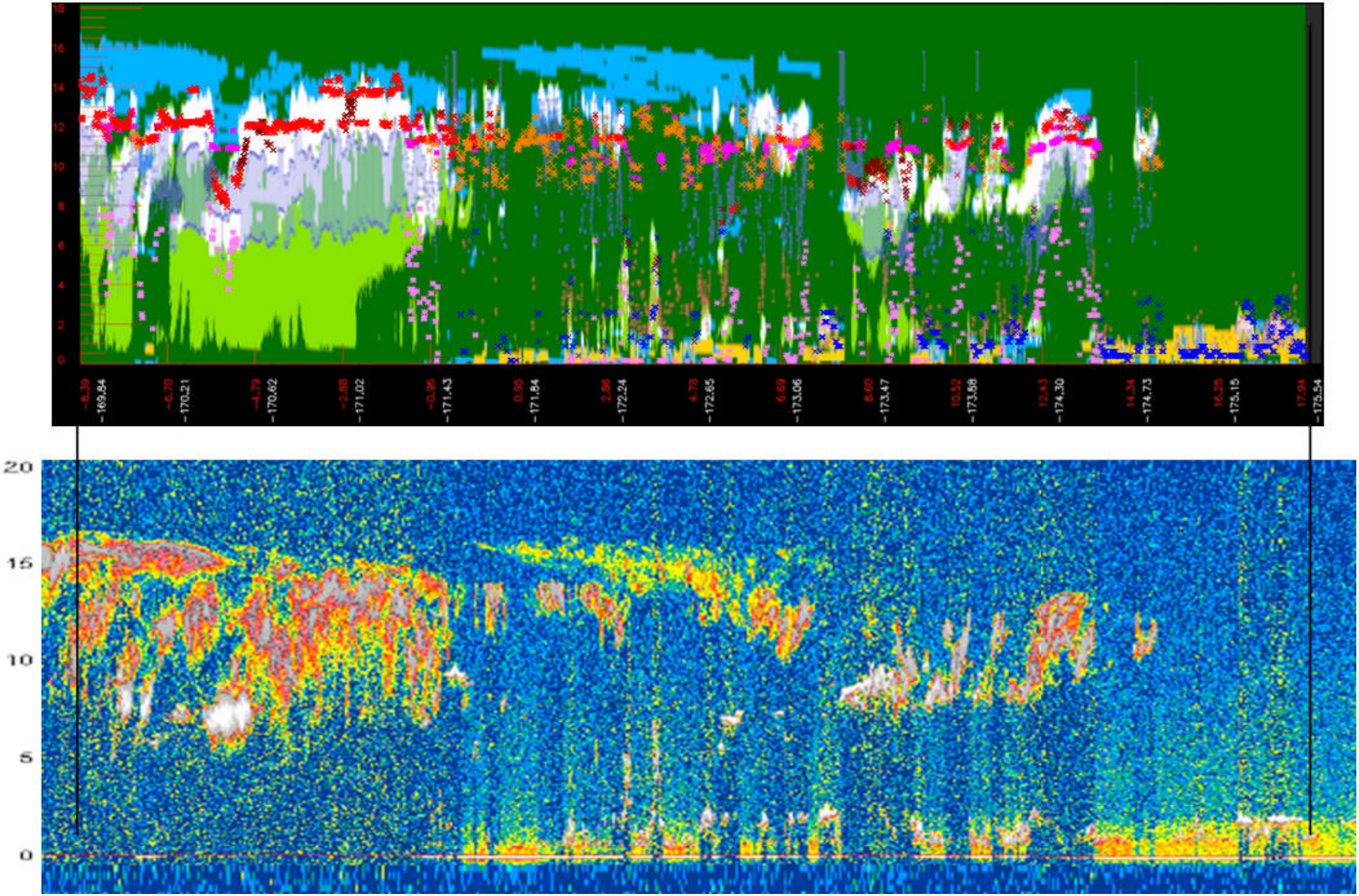


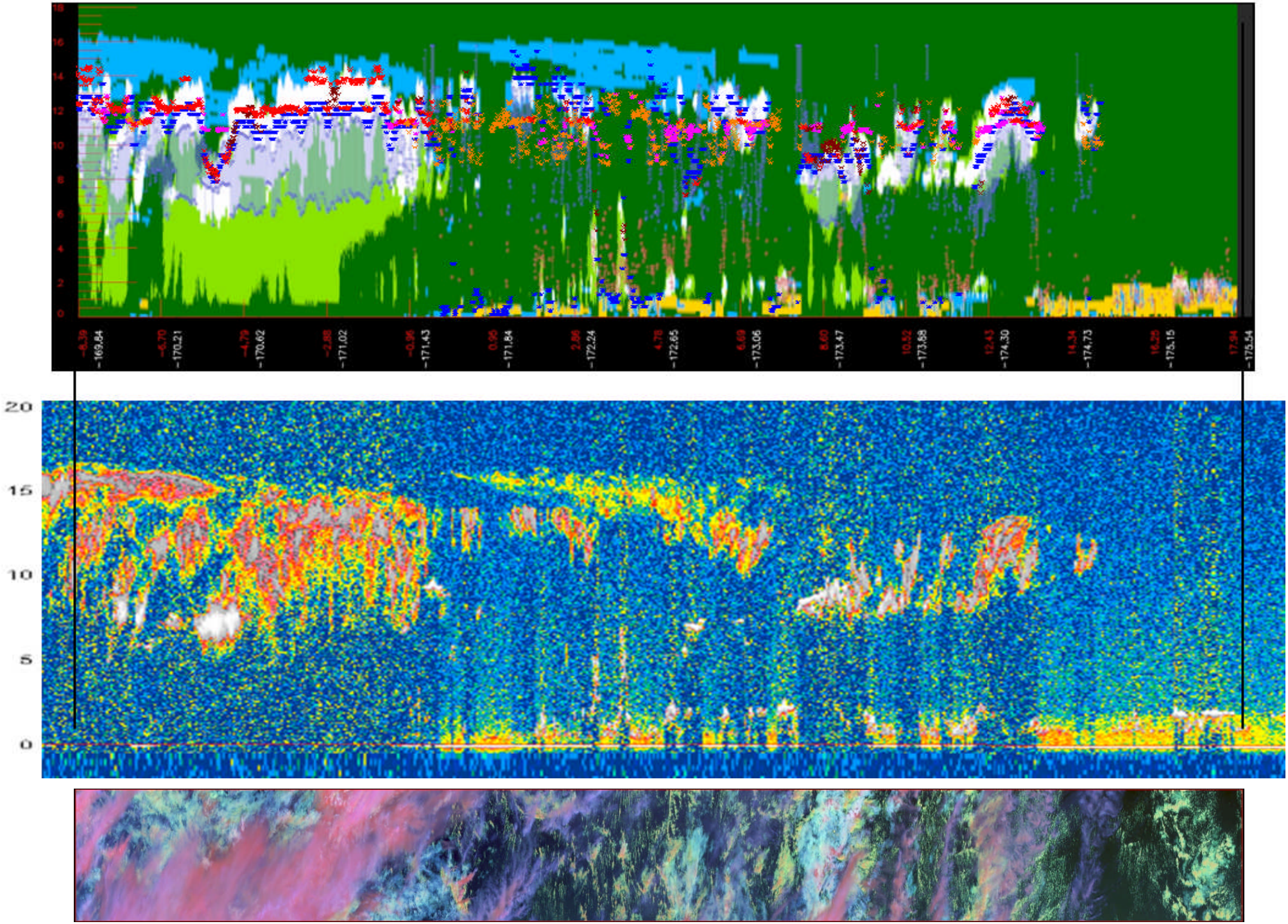



# *Cloud-Top Heights from the MYD06 CO2 Method*



# *Cloud-Top Heights from the CERES CO2 Method*




18
16
14
12
10
8
6
4
2
0
-8.39
-169.84
-6.70
-170.21
-4.79
-170.62
-2.88
-171.02
-0.96
-171.43
0.96
-171.84
2.86
-172.24
4.78
-172.65
6.69
-173.06
8.60
-173.47
10.52
-173.88
12.43
-174.30
14.34
-174.73
16.25
-175.15
17.94
-175.54
20
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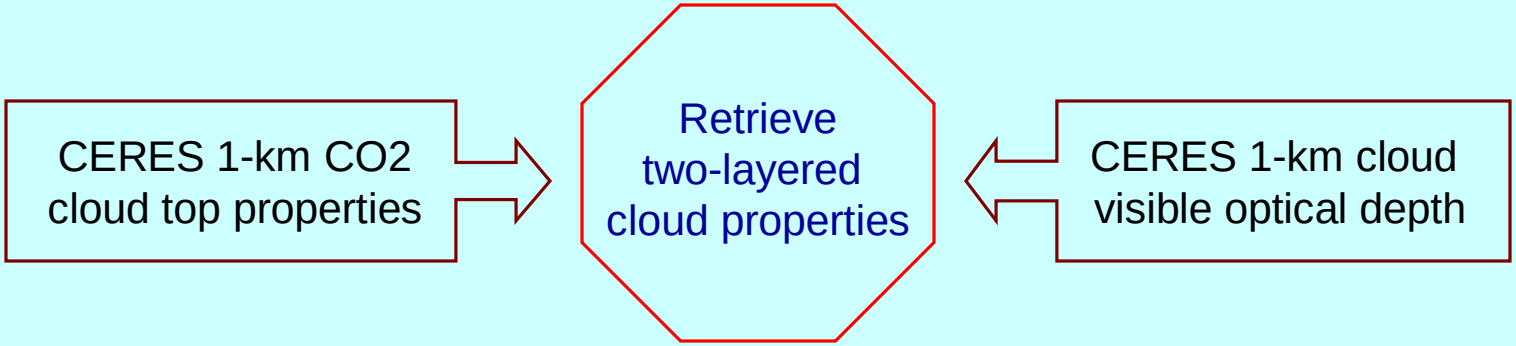
10
5
0

# *Now the Proposed CO2-Multilayer Retrieval Algorithm*

## In CERES ed3?




## Now in CERES ed3: