

**Improving CERES Upper Thin and Multi-layered  
Cloud Retrievals:  
Uncertainty and Error Reduction**

**Fu-Lung Chang**

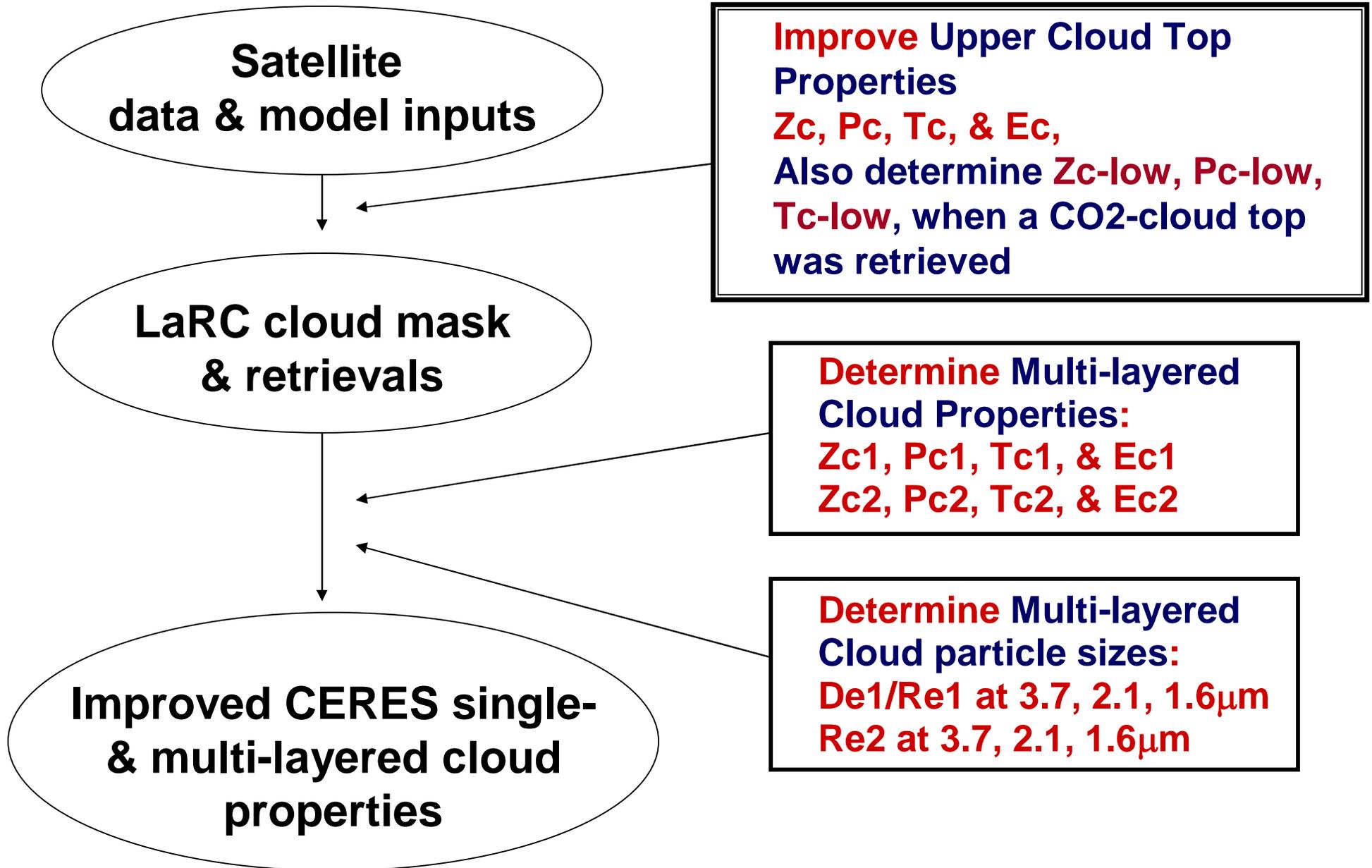
**About this Talk**

- **Improved Forward & Inversion Models, and so improved Cirrus, Tenuous, and Multi-layered Cloud Property Retrievals**

## Why and What to Improve?

- **CERES Ed3 First “GET\_MULTI” Code was delivered in Summer 2006, but later validation with CALIPSO & CloudSAT data found that:**
  1. **CERES upper clouds were too low and too few,**
  2. **CERES multi-layered clouds were too few and some occurred were convective clouds.**
  3. **CERES multi-layered lower-cloud heights were mainly default values in pixel-scale processing.**
- **Main uncertainty and errors in multi-layered clouds:**
  1. **Original CO<sub>2</sub>-retrieved upper cloud tops were too low,**
  2. **Good neighbor low clouds were hard to call in in real-time processing.**

# Improve CERES Thin and Multi-layered Cloud Retrievals

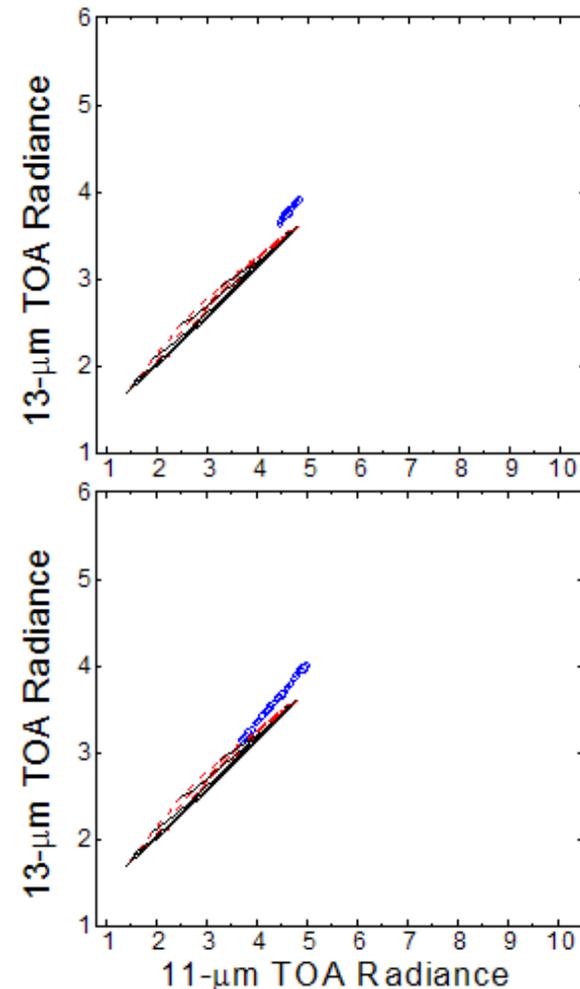
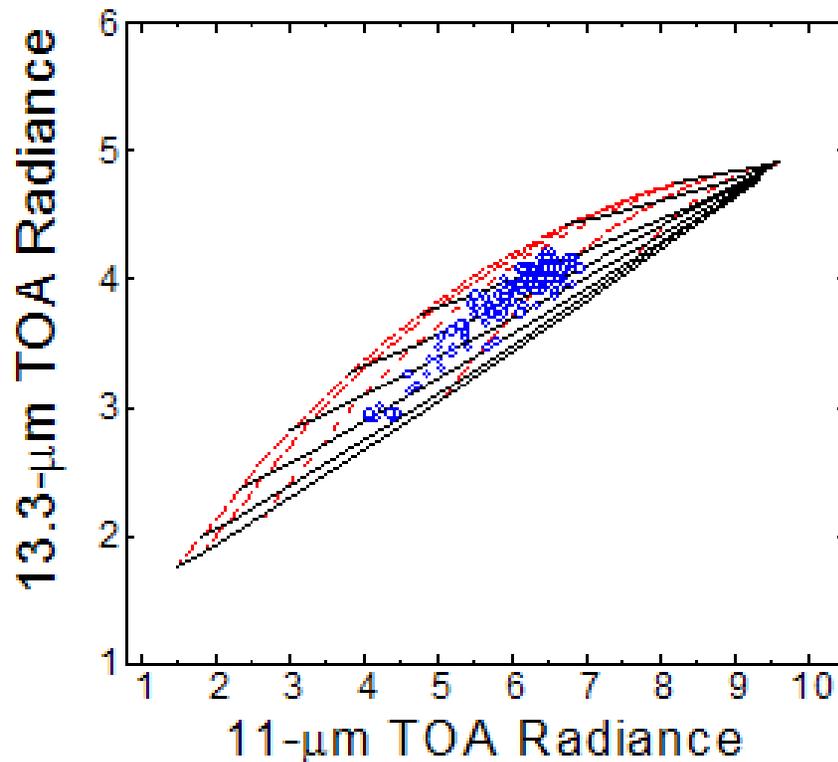


## Forward Model Improvement

- For CO2-cloud top retrieval, the vertical resolutions below 100 mb increased from every 50 mb to various pressure levels at:  
100, 125, 150, 175, 200, 225, 250, 275, 300, 330, 360, 400, 440, 500, 600, 700, 800, and 900 mb, plus the surface level.
- For multi-layered retrieval, a benchmark lookup-table radiance library is created using the standard LaRC Minnis cloud properties. The radiance library consists of various upper-layer ice-cloud properties (optical depths, particle sizes, heights) and lower-layer water-cloud properties (optical depths, particle sizes, heights) at various solar zenith, satellite zenith, and associated relative azimuth angles for two standard mid-latitude atmospheric profiles in winter and summer.
- **\*Running FAST and ACCURATE is all the matters.**

## Uncertainty and Error Reduction

- Uncertainty can come from both satellite data and model simulations.
- Errors can come from the single cloud layer assumption.



## Improvement for CERES Upper and Lower Clouds

- The upper cloud top properties were retrieved iteratively together with their associated underlying lower cloud properties.
- The lower cloud properties were in fact only an underlying radiative background information, but will be a candidate for potential multilayered lower cloud layer.

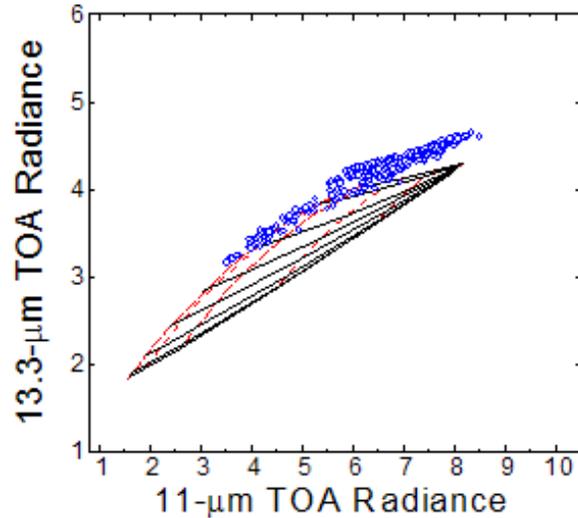
**Upper clouds:**  
 *$T_{CO_2}$ ,  $P_{CO_2}$ ,  $Z_{CO_2}$*

**Background lower clouds:**  
 *$T_{c-low}$ ,  $P_{c-low}$ ,  $Z_{c-low}$*

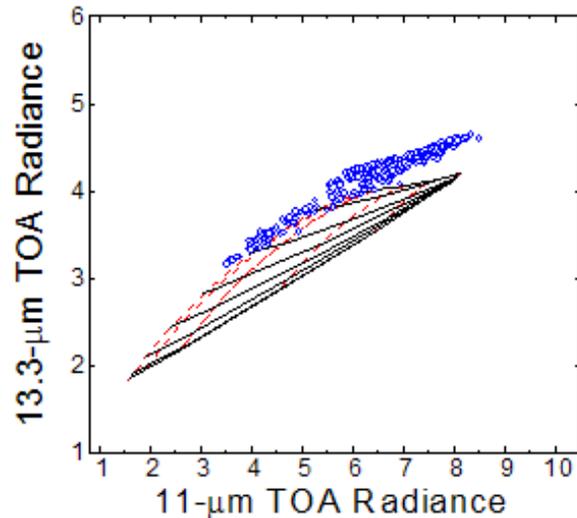
**Background surface:  $T_s$ ,  $P_s$ ,  $Z_s$**

# Uncertainty and Automated Adjustment

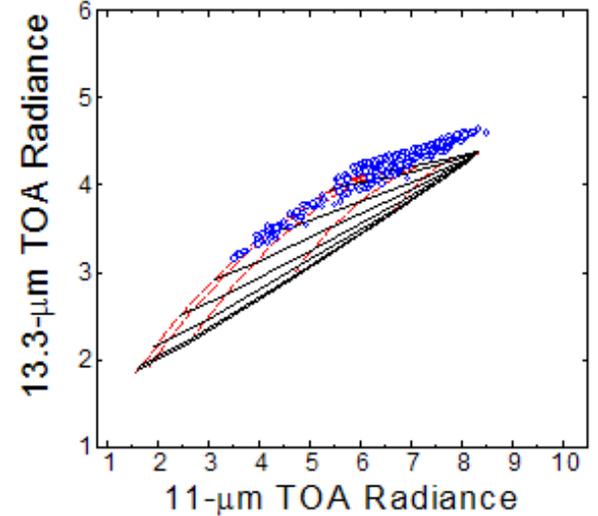
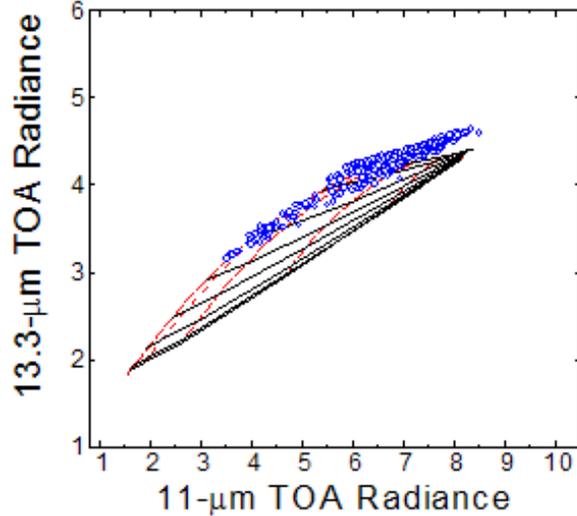
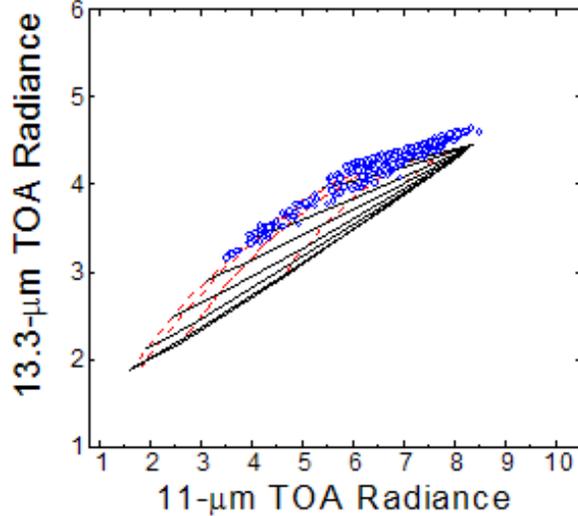
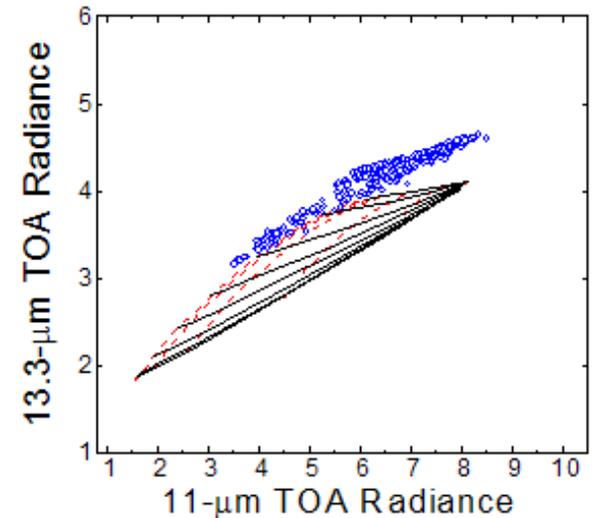
330PPM



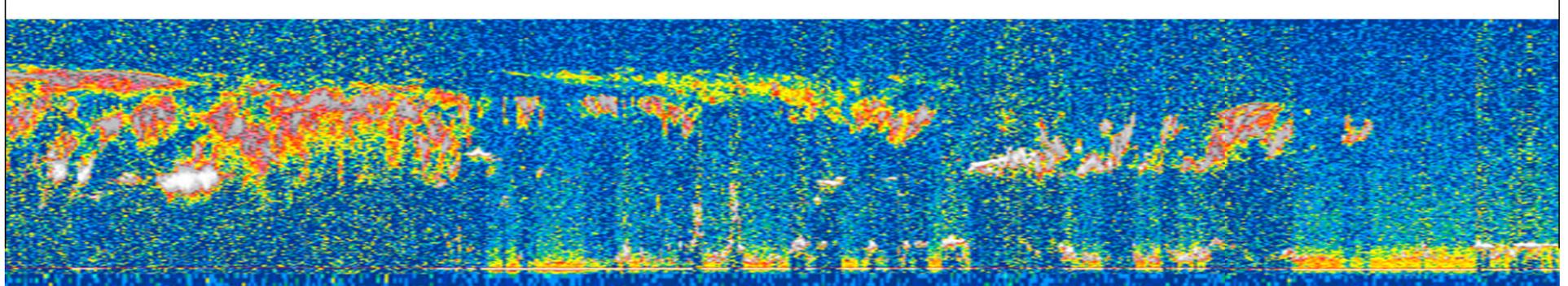
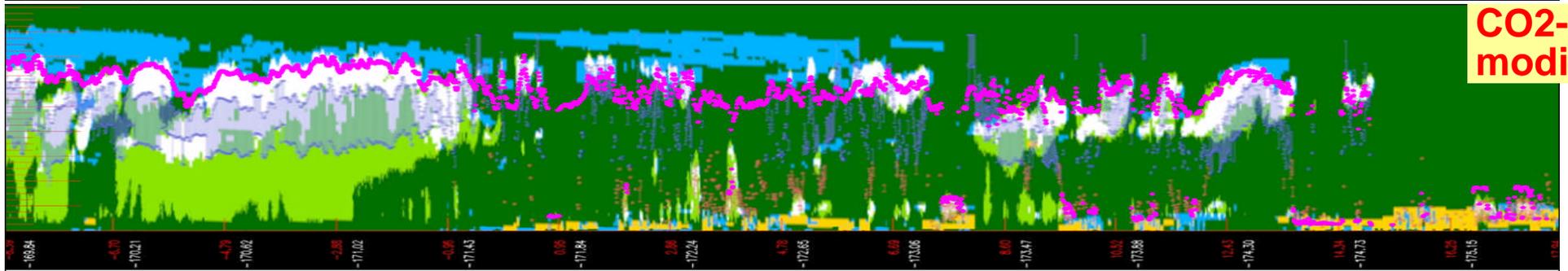
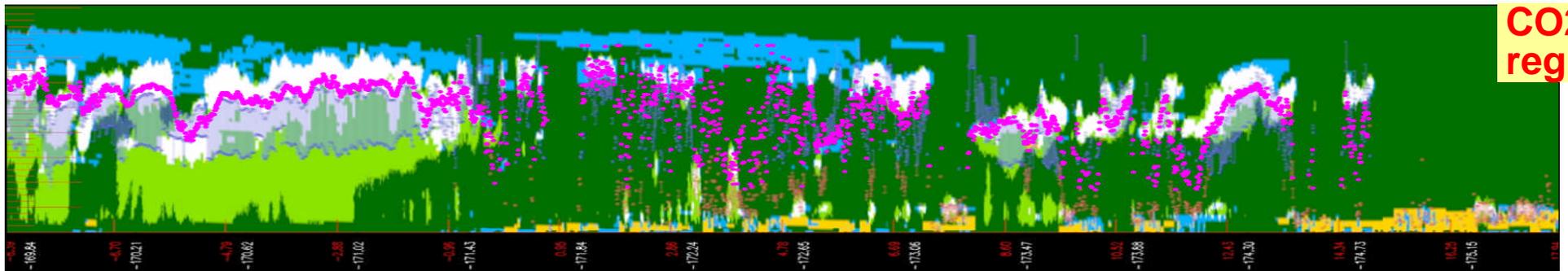
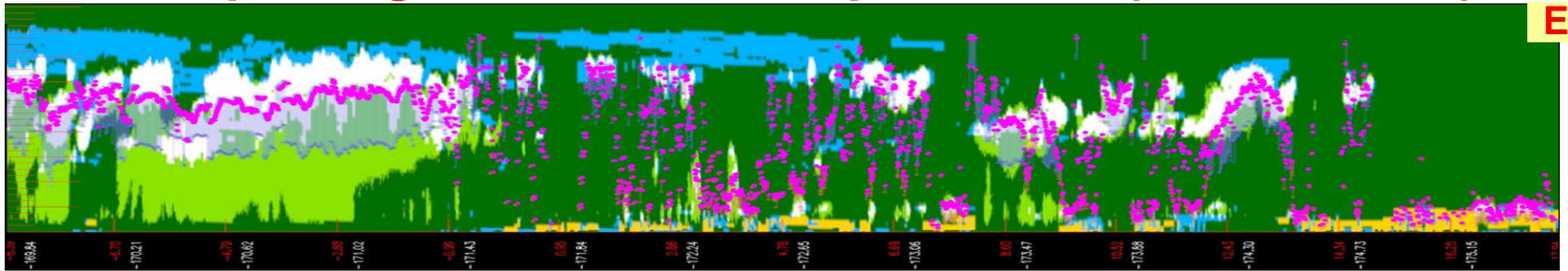
360PPM



390PPM



# Improving CERES Cloud Top Location (Vertical View)



# Improving CERES Cloud Top Location

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LON=168°E

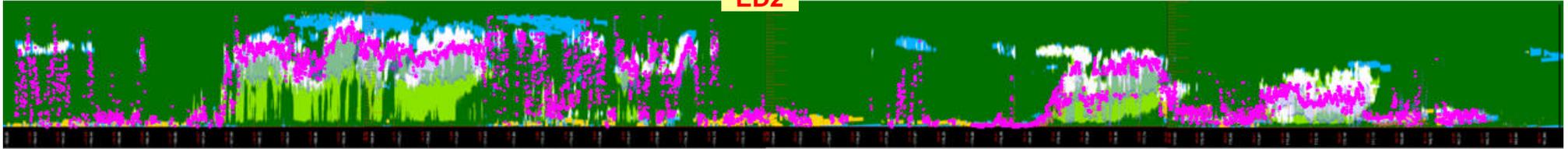
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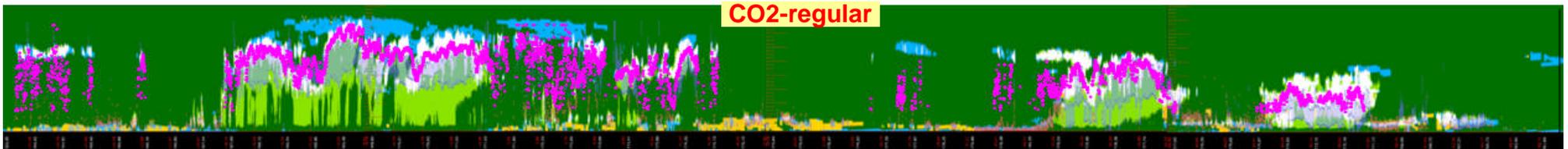
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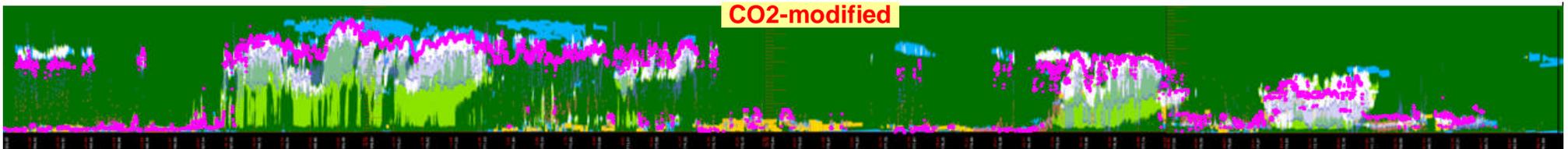
ED2



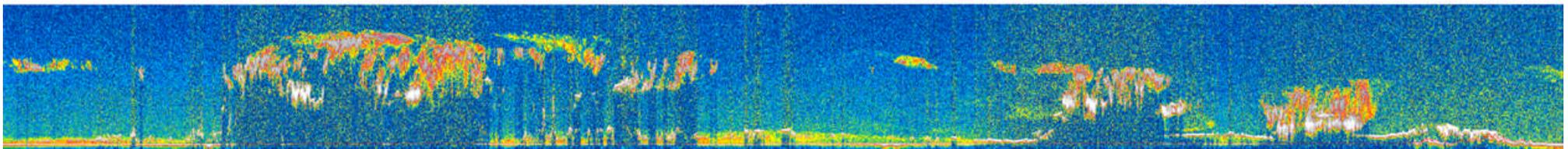
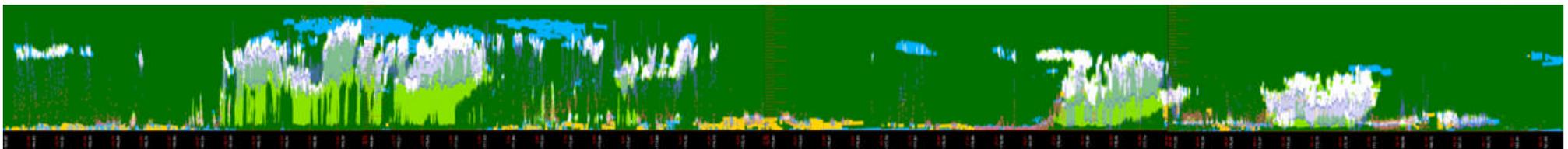
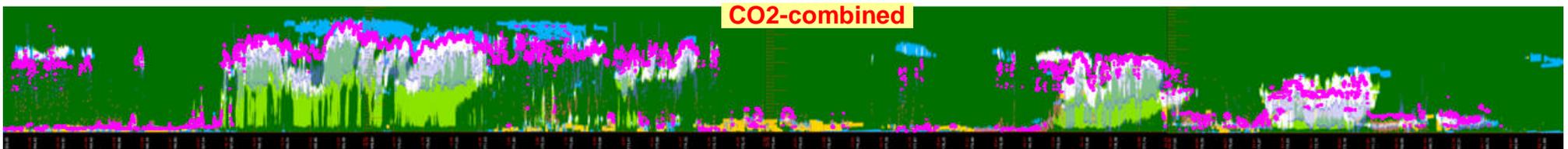
CO2-regular



CO2-modified



CO2-combined



# Improving CERES Cloud Top Location

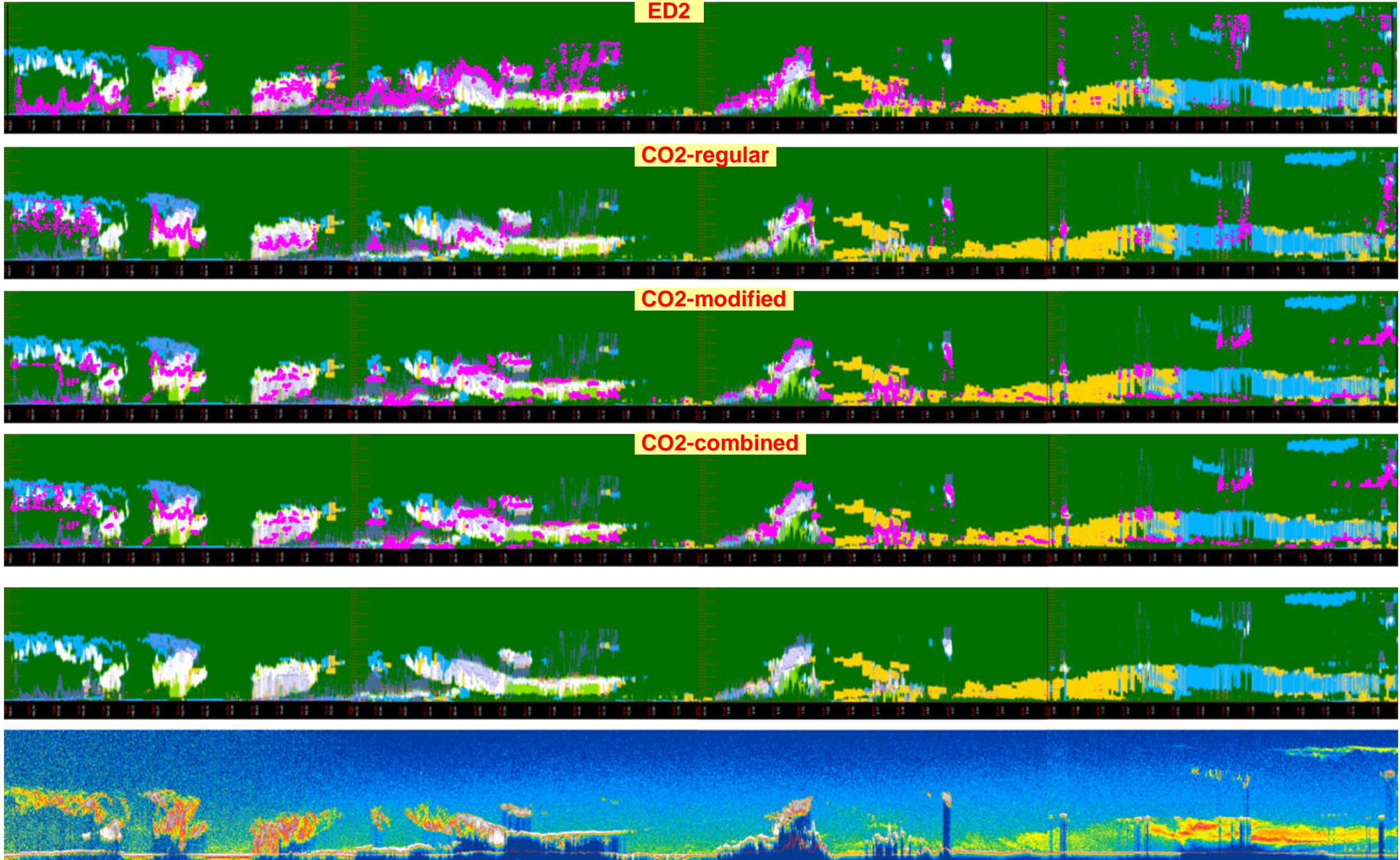
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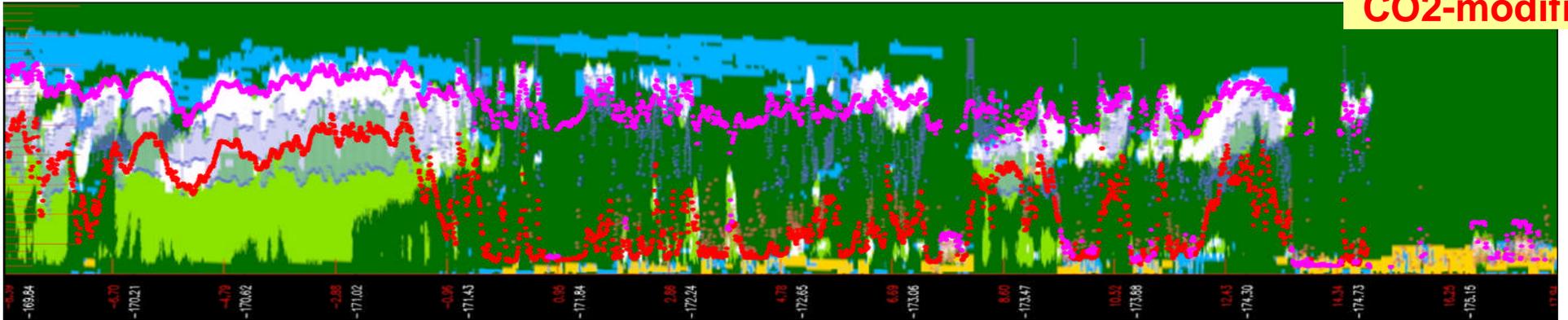
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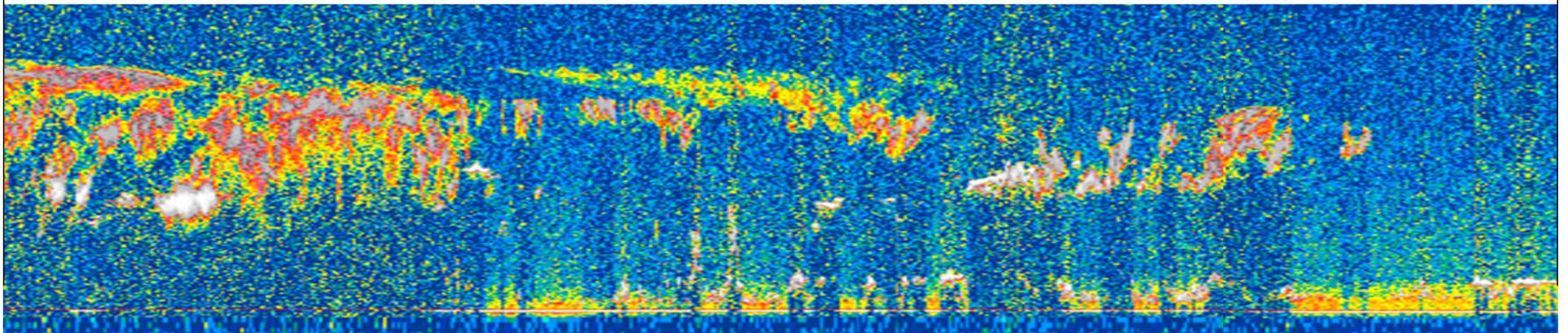
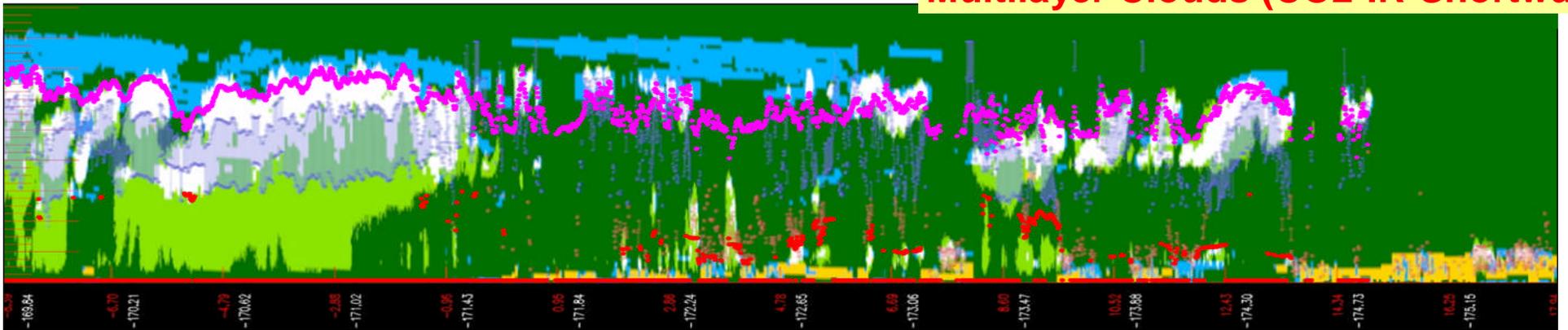


# Improving Multi-layered Cloud Properties (Vertical View)

CO2-modified



Multilayer Clouds (CO2-IR-Shortwave)



# Improving Multi-layered Cloud Properties

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LON=168°E

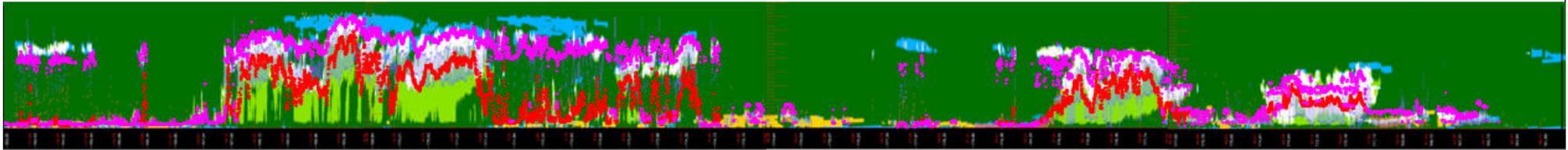
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SZA=25°

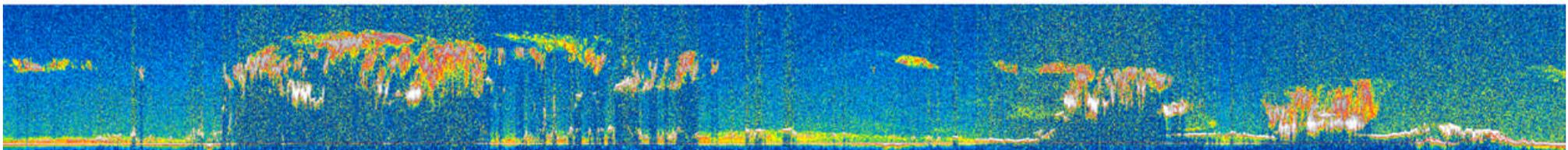
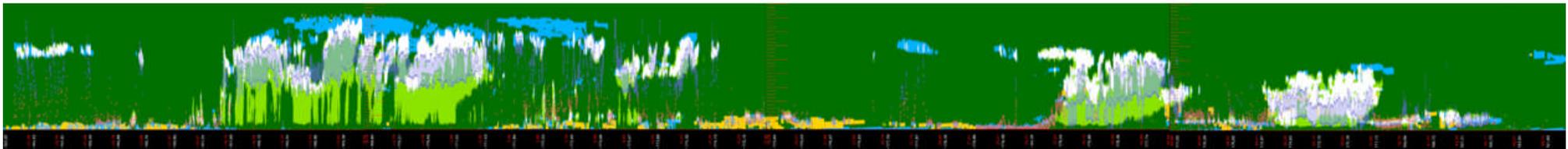
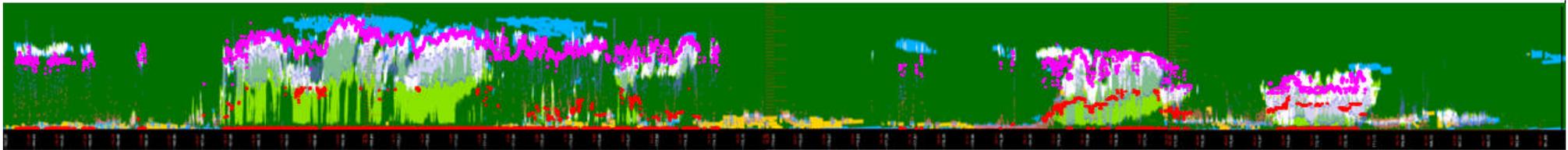
LAT=45°N  
LON=177°W

SZA=65°  
LAT=70°N  
LON=160°W

**CO2-modified**



**Multilayer Clouds (CO2-IR-Shortwave)**



# Improving Multi-layered Cloud Properties

SZA=65°  
LAT=70°N  
LON=160°W

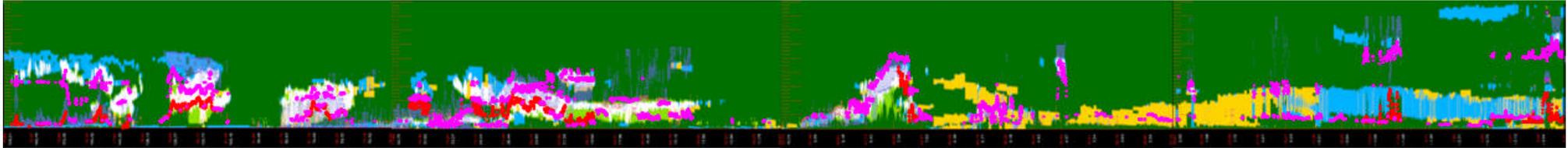
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SZA=114°

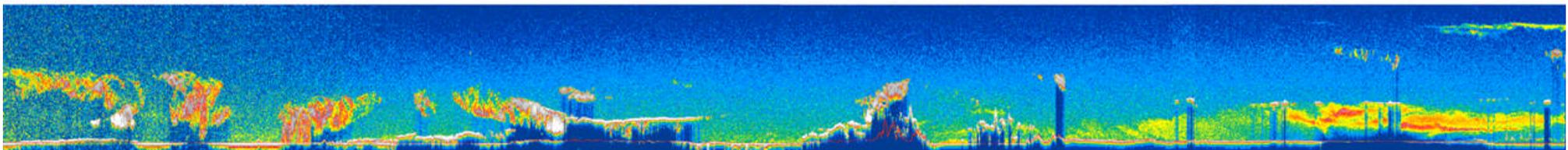
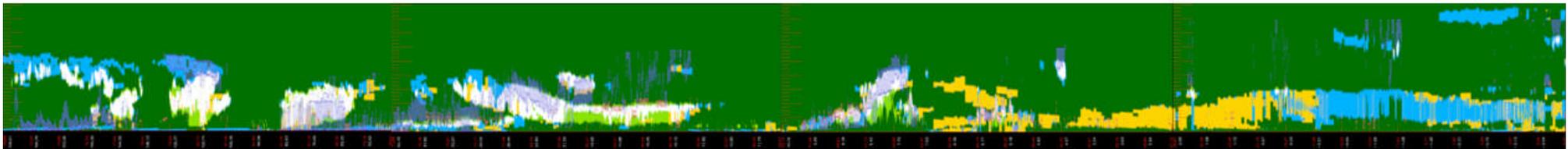
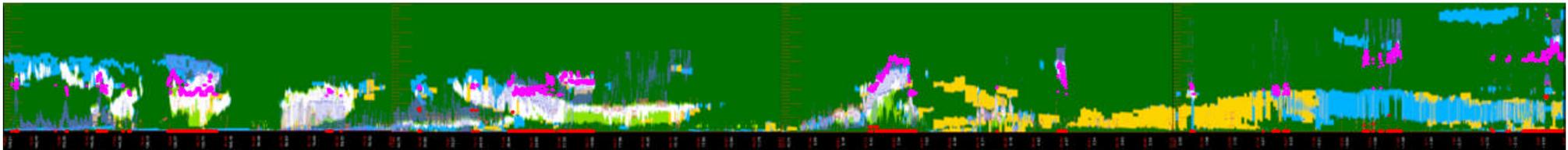
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SZA=154°  
LAT= 0°S  
LON= 4°E

## CO2-modified

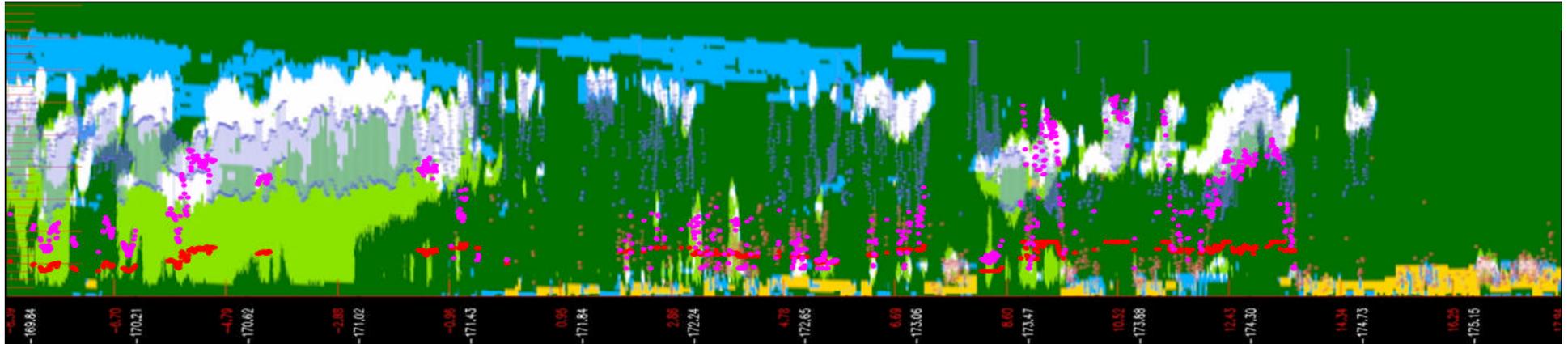


## Multilayer Clouds (CO2-IR-Shortwave)

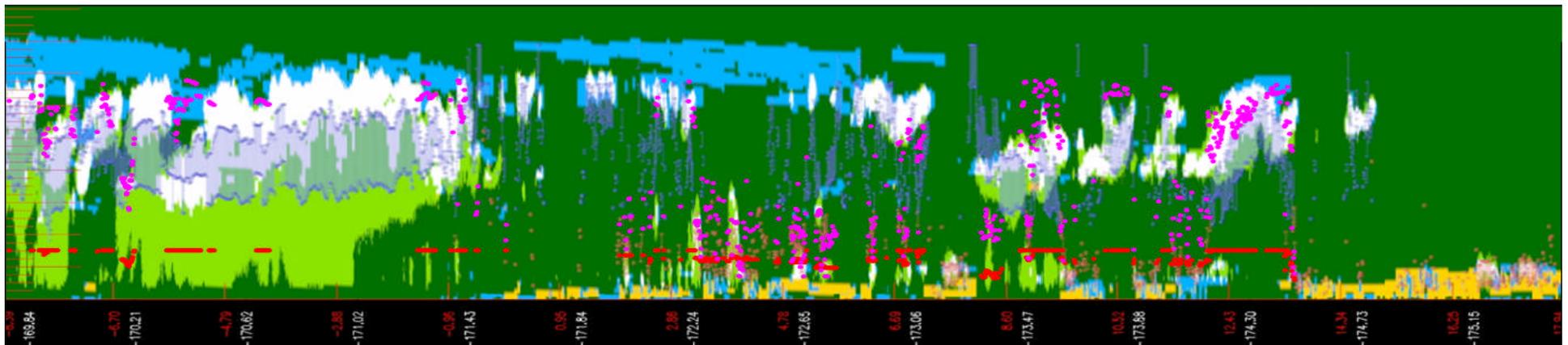


# Improving Multi-layered Cloud De/Re (Vertical View)

De/Re-3.7-um channel



De/Re-2.1-um channel



# Improving Multi-layered Cloud De/Re

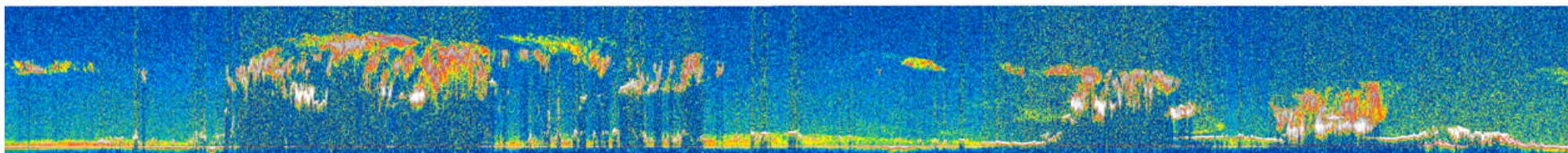
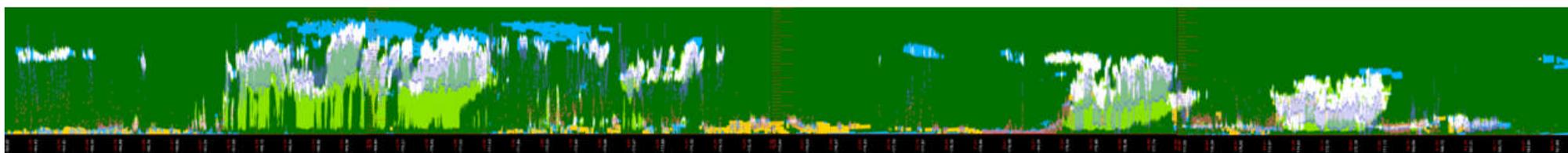
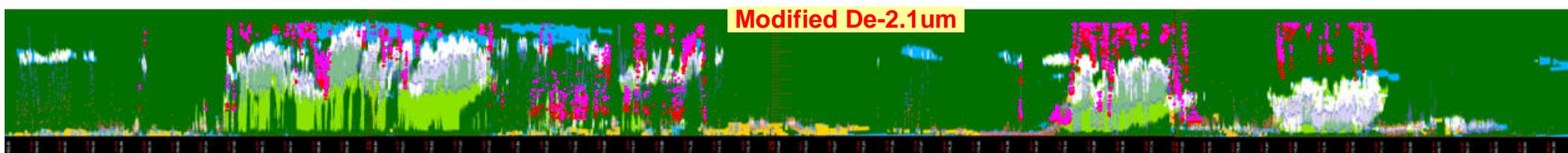
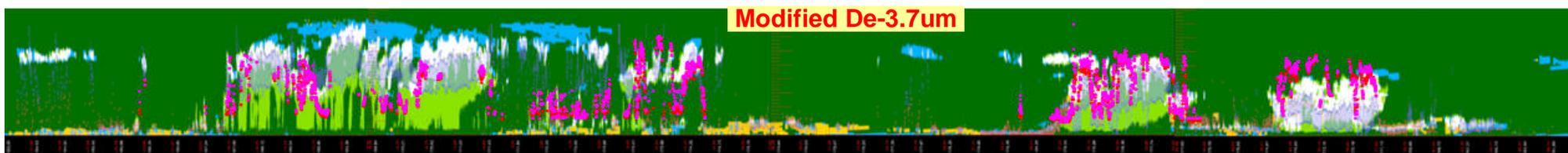
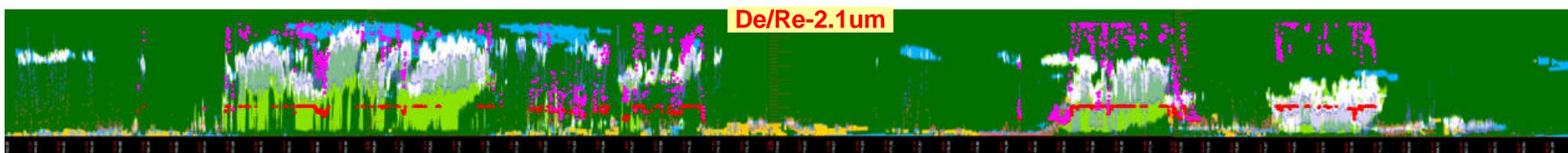
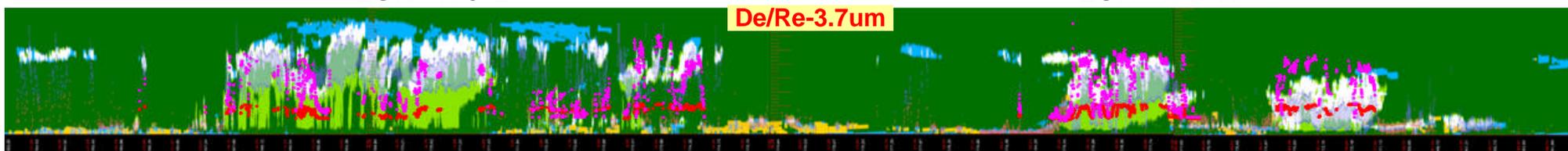
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SZA=25°

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# Improving Multi-layered Cloud De/Re

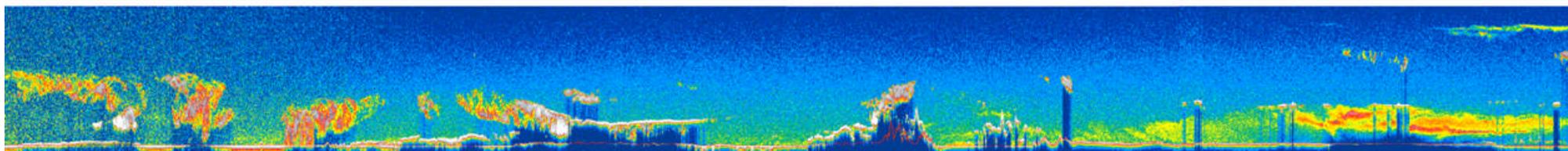
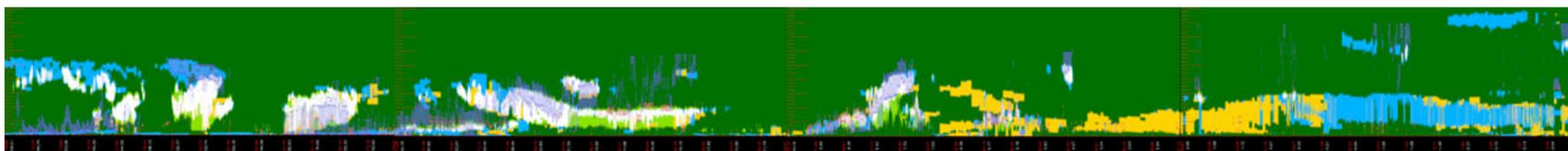
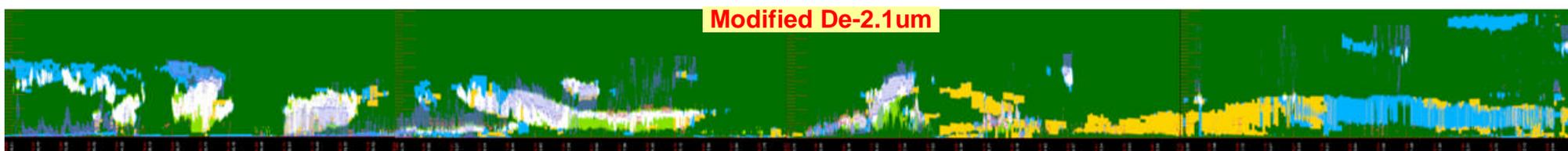
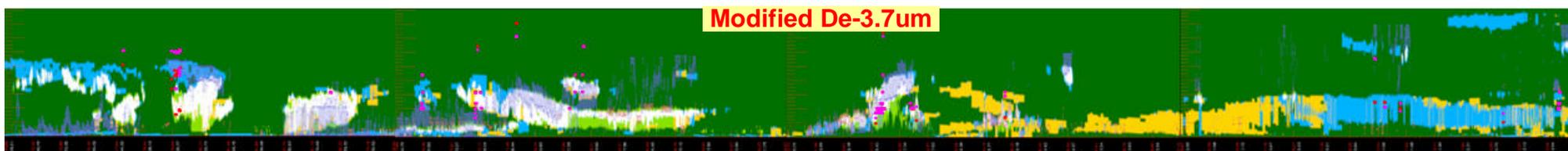
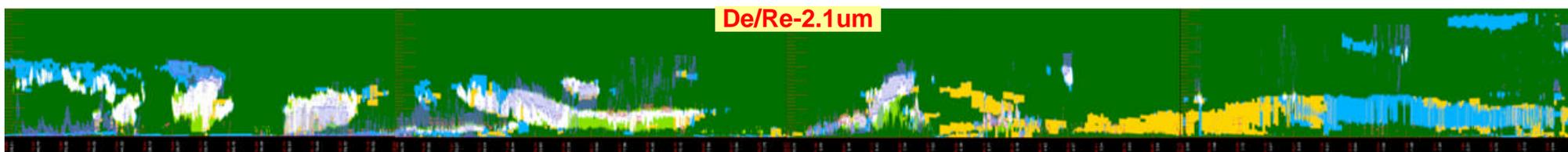
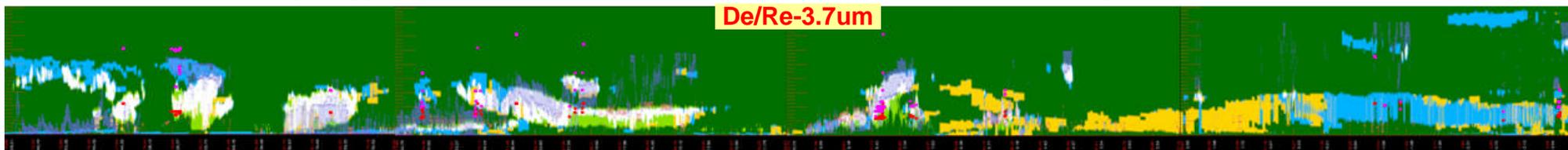
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LAT=70°N  
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LAT=82°N  
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SZA=114°

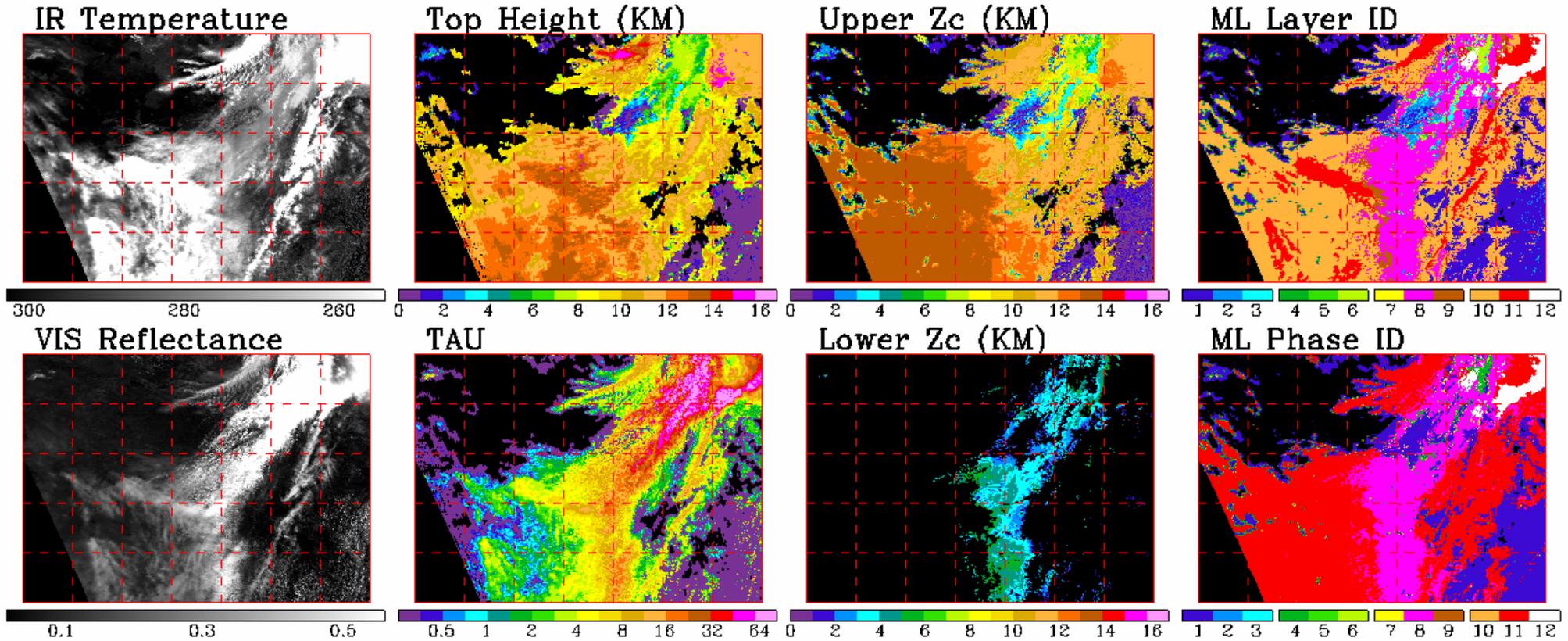
LAT=27°N  
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SZA=154°  
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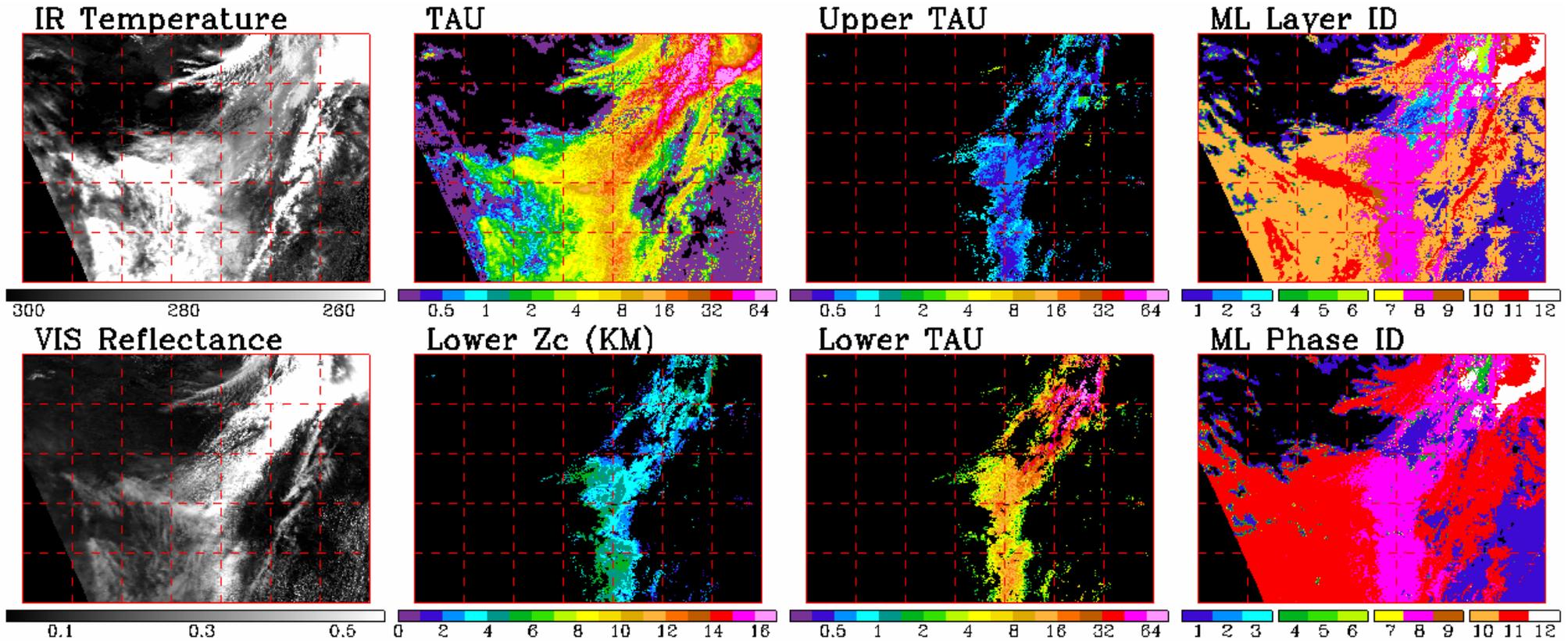


```
c
c Description for the 12-code multi-layer ID and retrieved cloud properties:
c   mlayer= 0: Clear (no cloud retrieval)
c   mlayer= 1: Low thin cloud (Tau < 3.6)
c   mlayer= 2: Low median cloud (Tau = 3.6-23)
c   mlayer= 3: Low thick cloud (Tau > 23)
c   mlayer= 4: Mid thin cloud (Tau < 3.6)
c   mlayer= 5: Mid median cloud (Tau = 3.6-23)
c   mlayer= 6: Mid thick cloud (Tau > 23)
c   mlayer= 7: *Multi-layer mid-top cloud (tau1/tau2 retrieved)
c   mlayer= 8: *Multi-layer high-top cloud (tau1/tau2 retrieved)
c   mlayer= 9: *Multi-layer cloud (Weak)
c   mlayer=10: High-top cirrus cloud (Tau < 3.6)
c   mlayer=11: High-top cirrocumulus/cirrostratus (Tau = 3.6-23)
c   mlayer=12: High-top deep convective cloud (Tau > 23)
c *For all mlayer=1-12, [pc1,tc1,tau1,ph1,re1,em1] are retrieved for
c                       the single or upper-layer cloud properties;
c *For only mlayer=7-8, [pc2,tc2,tau2,ph2,re2,em2] are retrieved for
c                       the lower-layer cloud properties;
c
c Description for the 12-code multi-phase ID (For reference only):
c   mphase= 0: Clear (no cloud retrieval)
c   mphase= 1: SL Low Water
c   mphase= 2: SL Low Ice (Weak)
c   mphase= 3: SL Low Ice
c   mphase= 4: SL Mid Water
c   mphase= 5: SL Mid Ice (Weak)
c   mphase= 6: SL Mid Ice
c   mphase= 7: *ML Water
c   mphase= 8: *ML Ice-over-Water
c   mphase= 9: *ML Ice (Weak)
c   mphase=10: SL Hi Ice (Weak)
c   mphase=11: SL Hi Ice
c   mphase=12: SL Deep Ice
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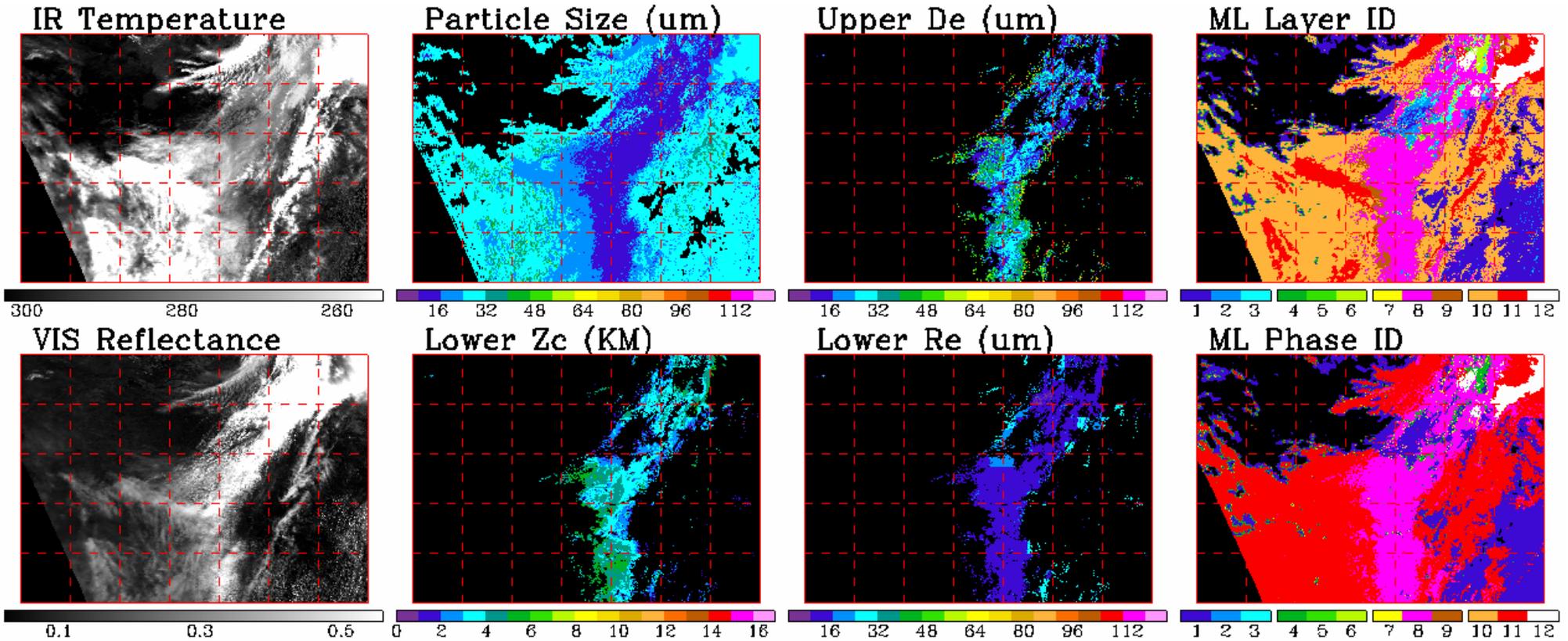
# Improving Multi-layered Cloud Properties (AQUA View)



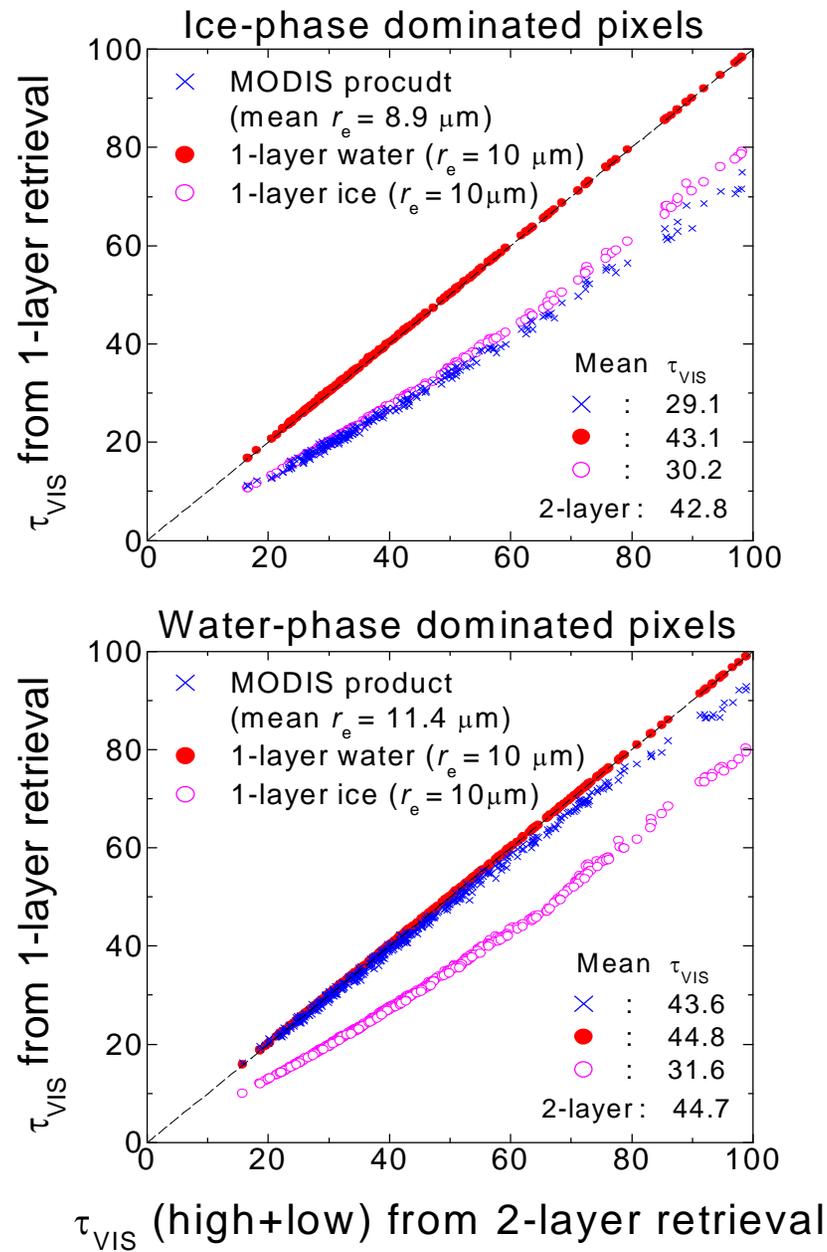
# Improving Multi-layered Cloud Properties (AQUA View)



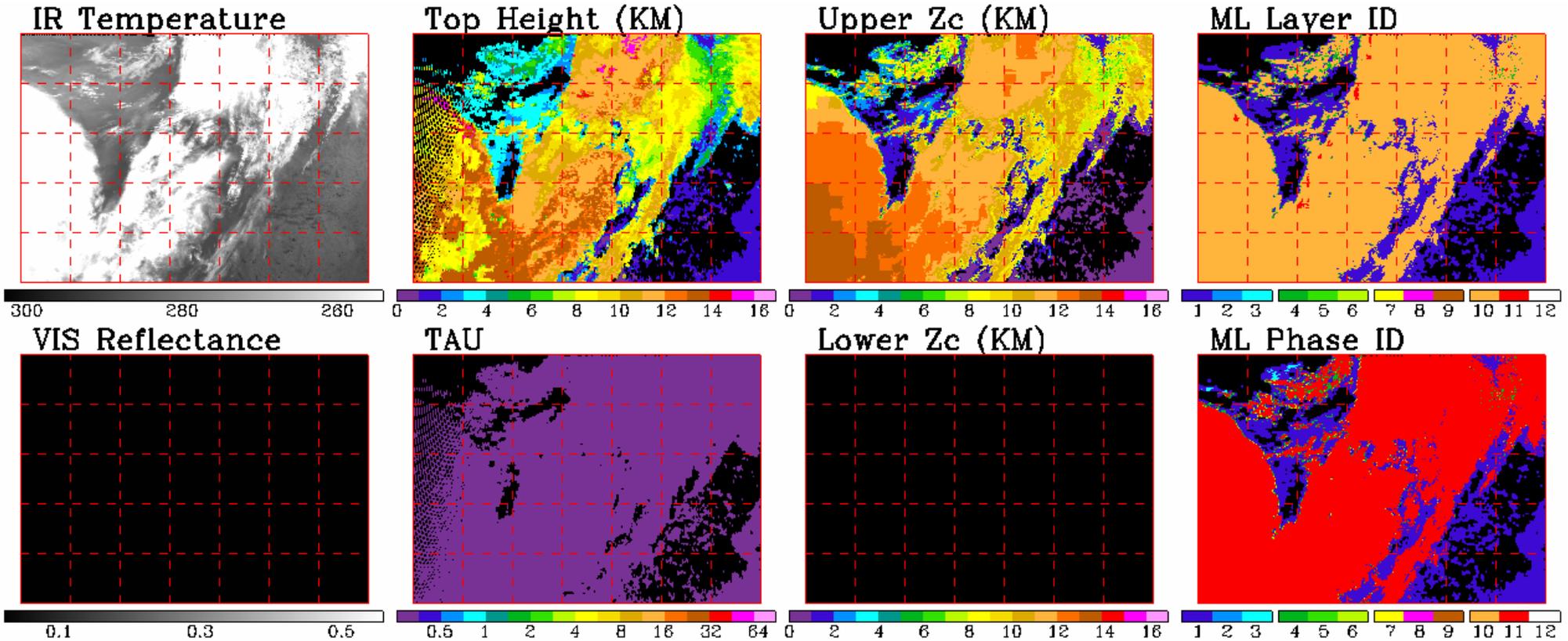
# Improving Multi-layered Cloud Properties (AQUA View)



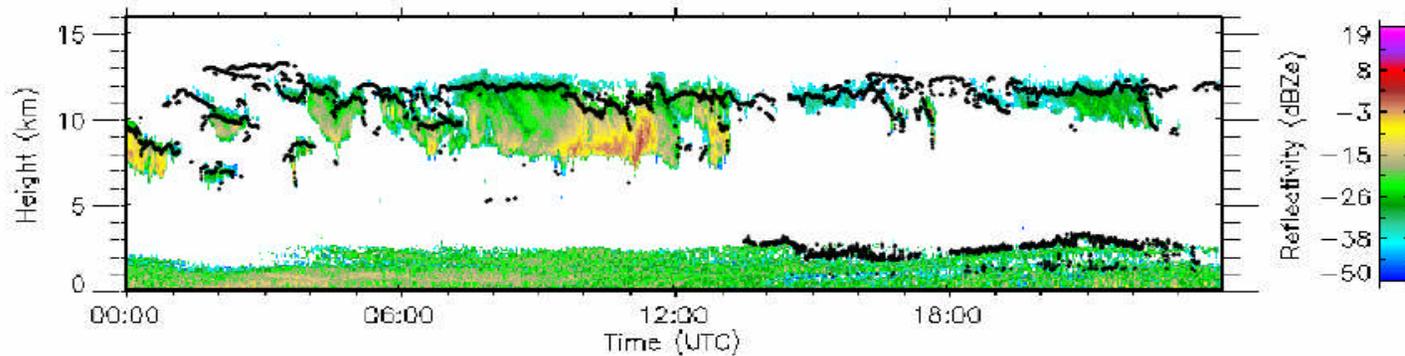
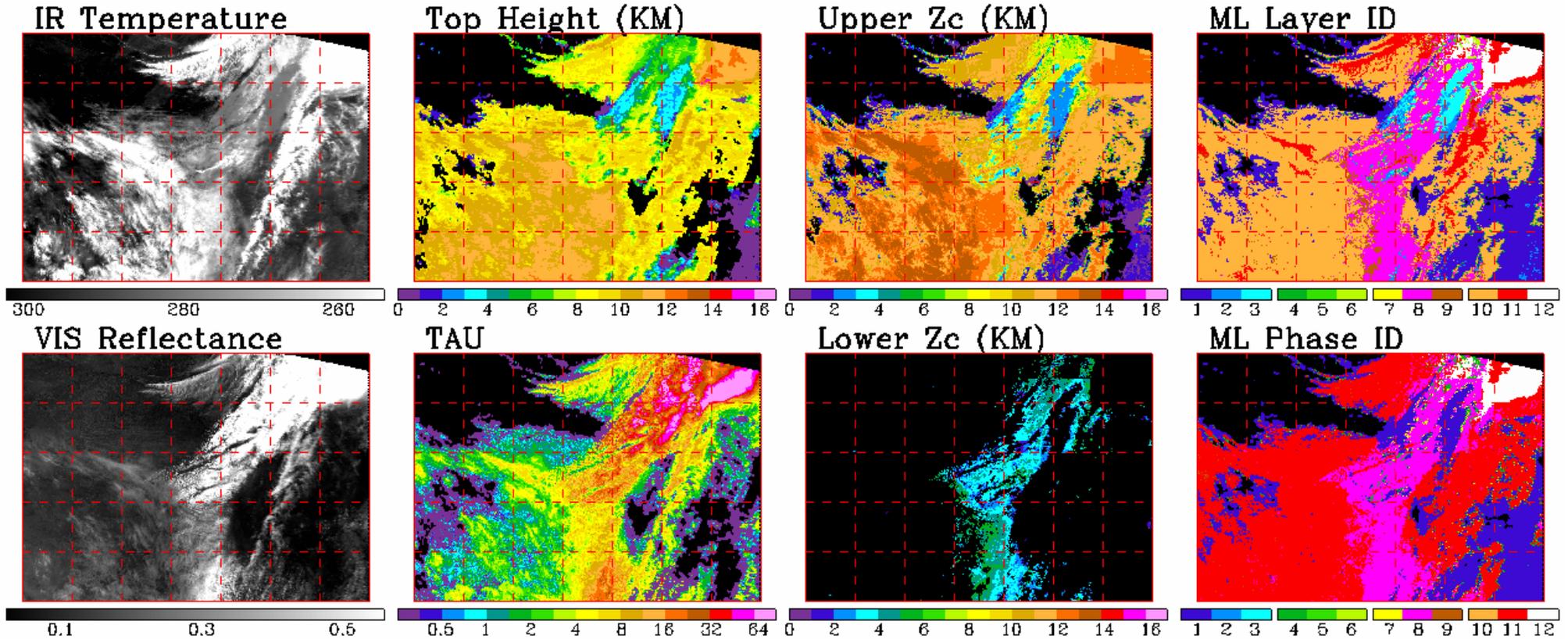
# Single-layer vs Two-layer Cloud Simulations



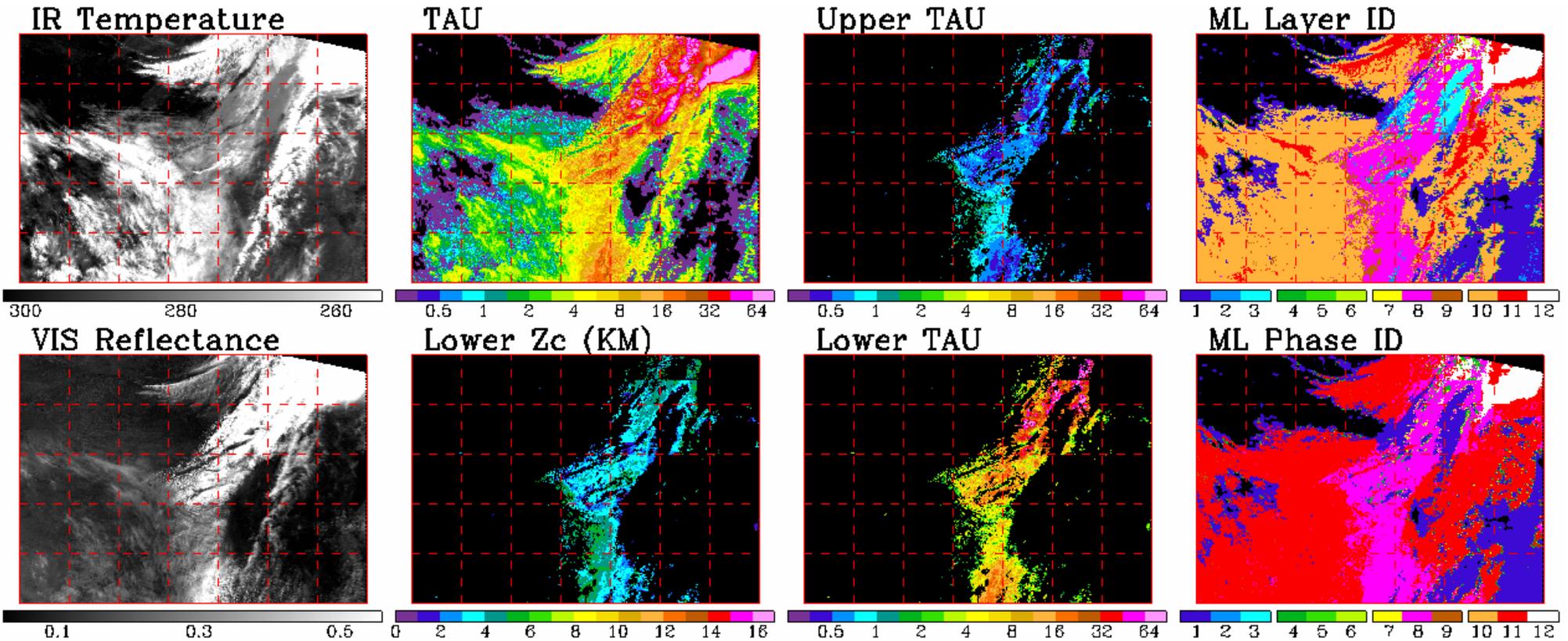
# Improving Multi-layered Cloud Properties (AQUA View)



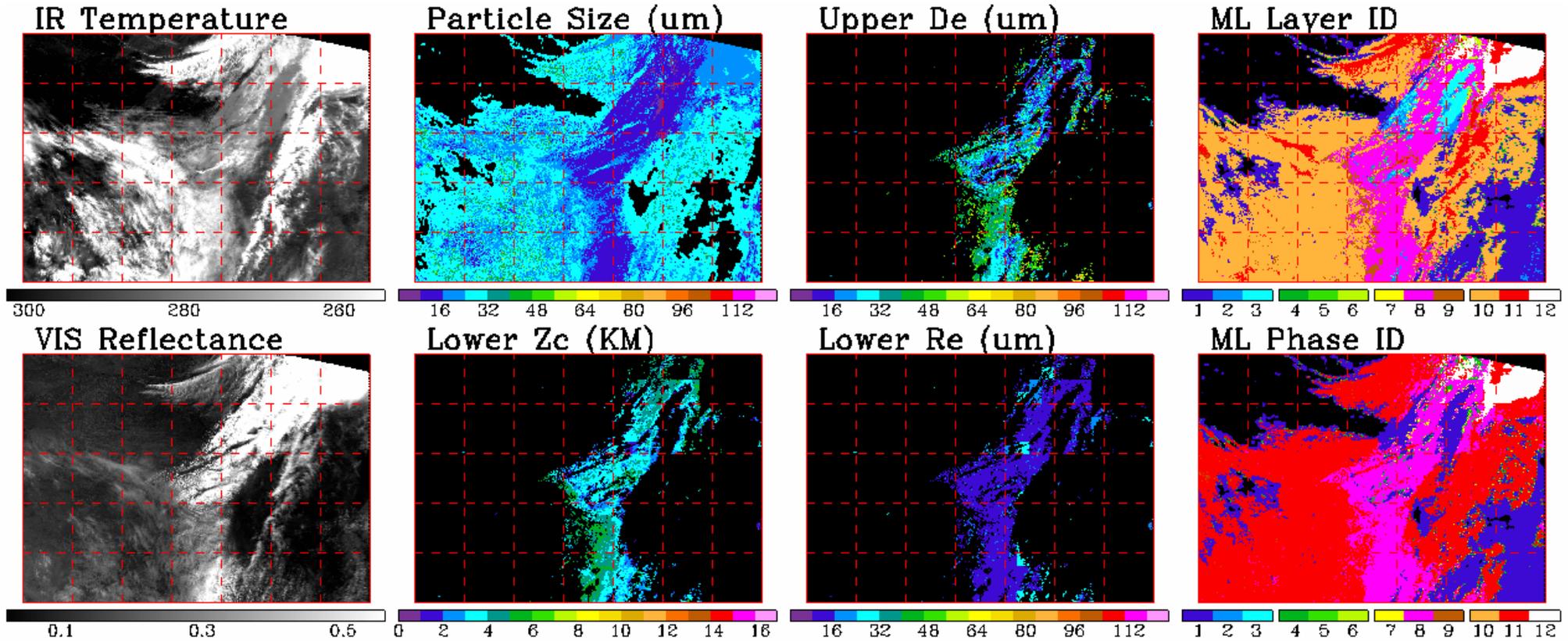
# Improving Multi-layered Cloud Properties (TERRA View)



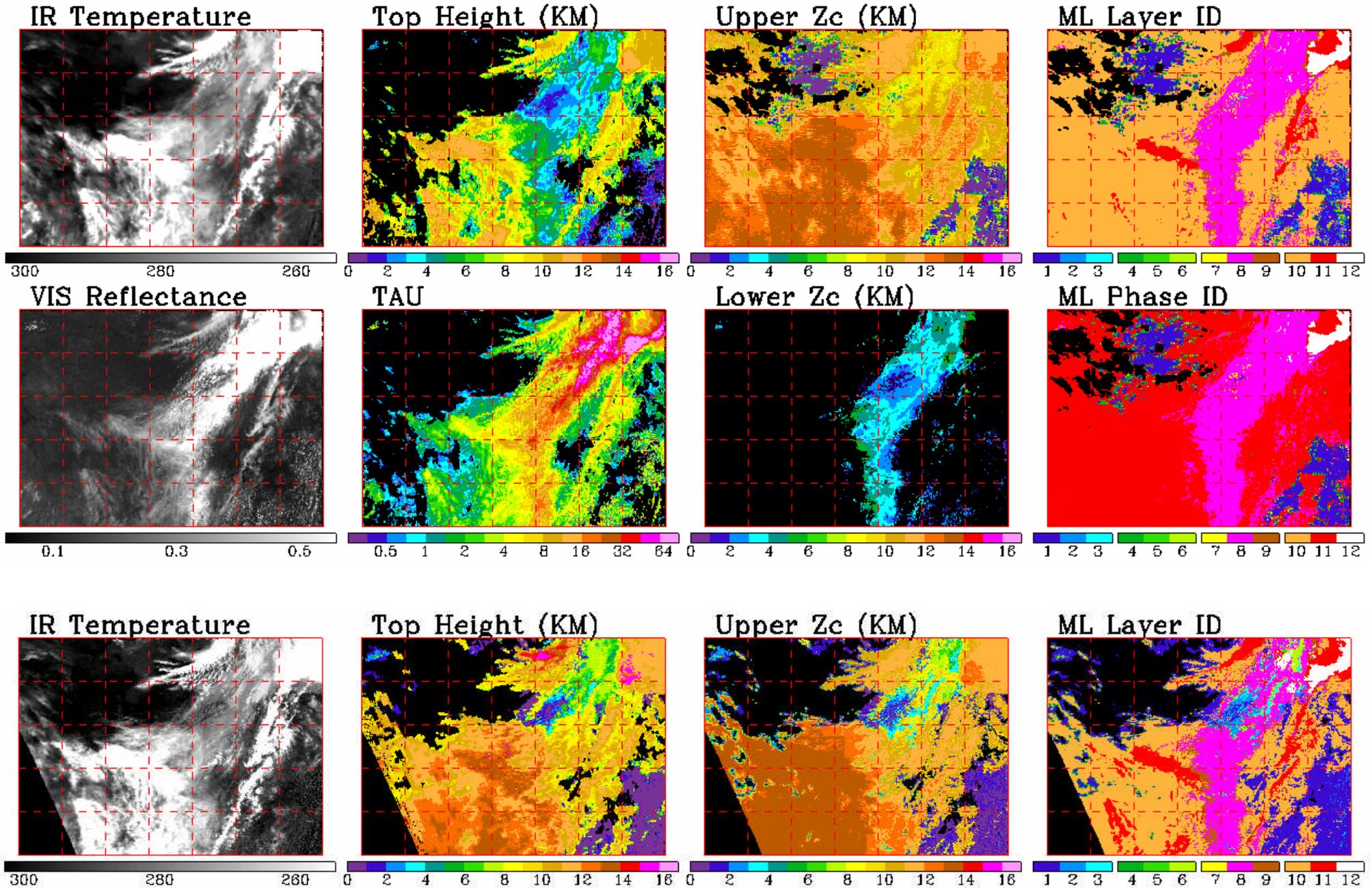
# Improving Multi-layered Cloud Properties (TERRA View)



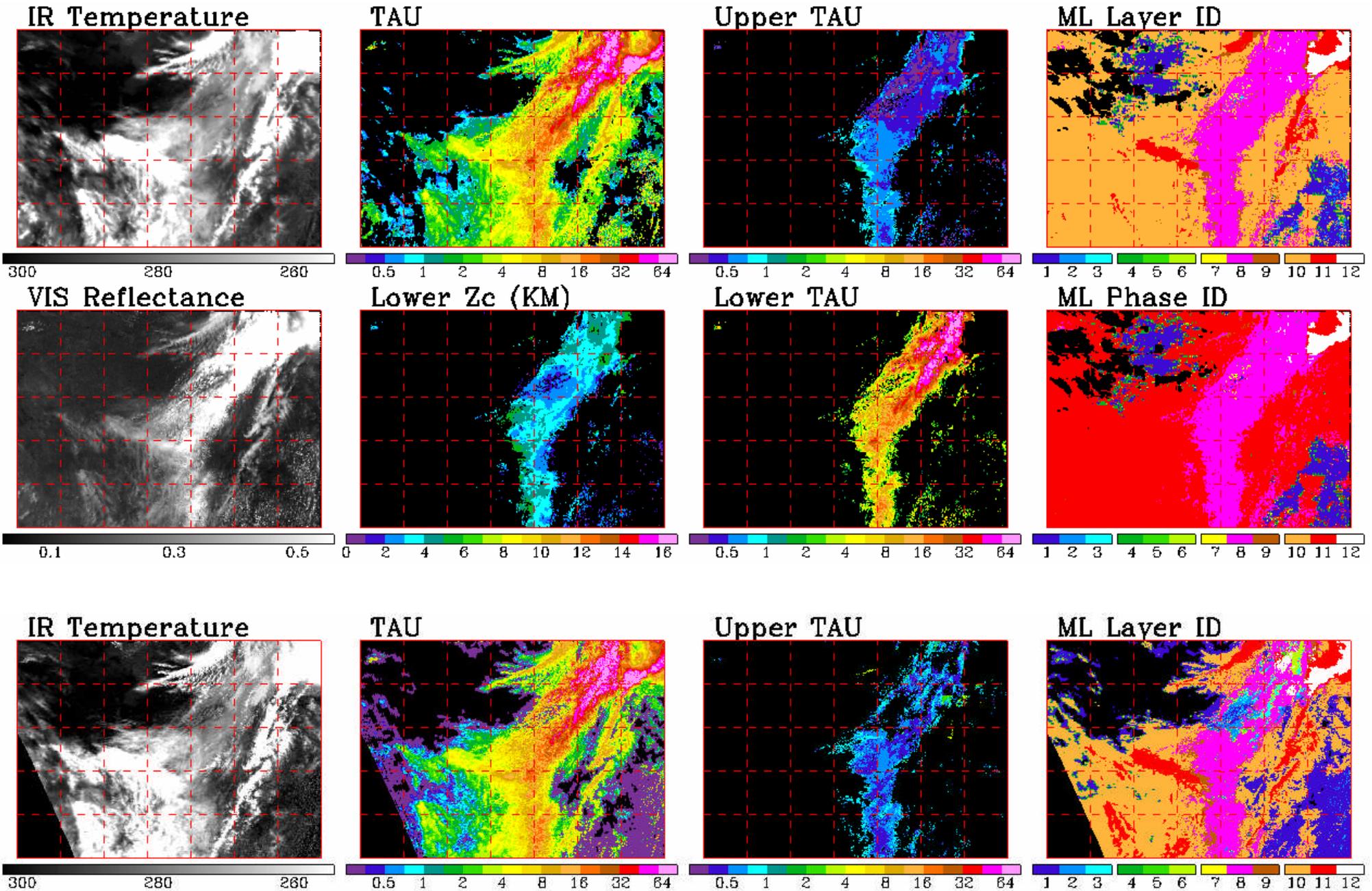
# Improving Multi-layered Cloud Properties (TERRA View)



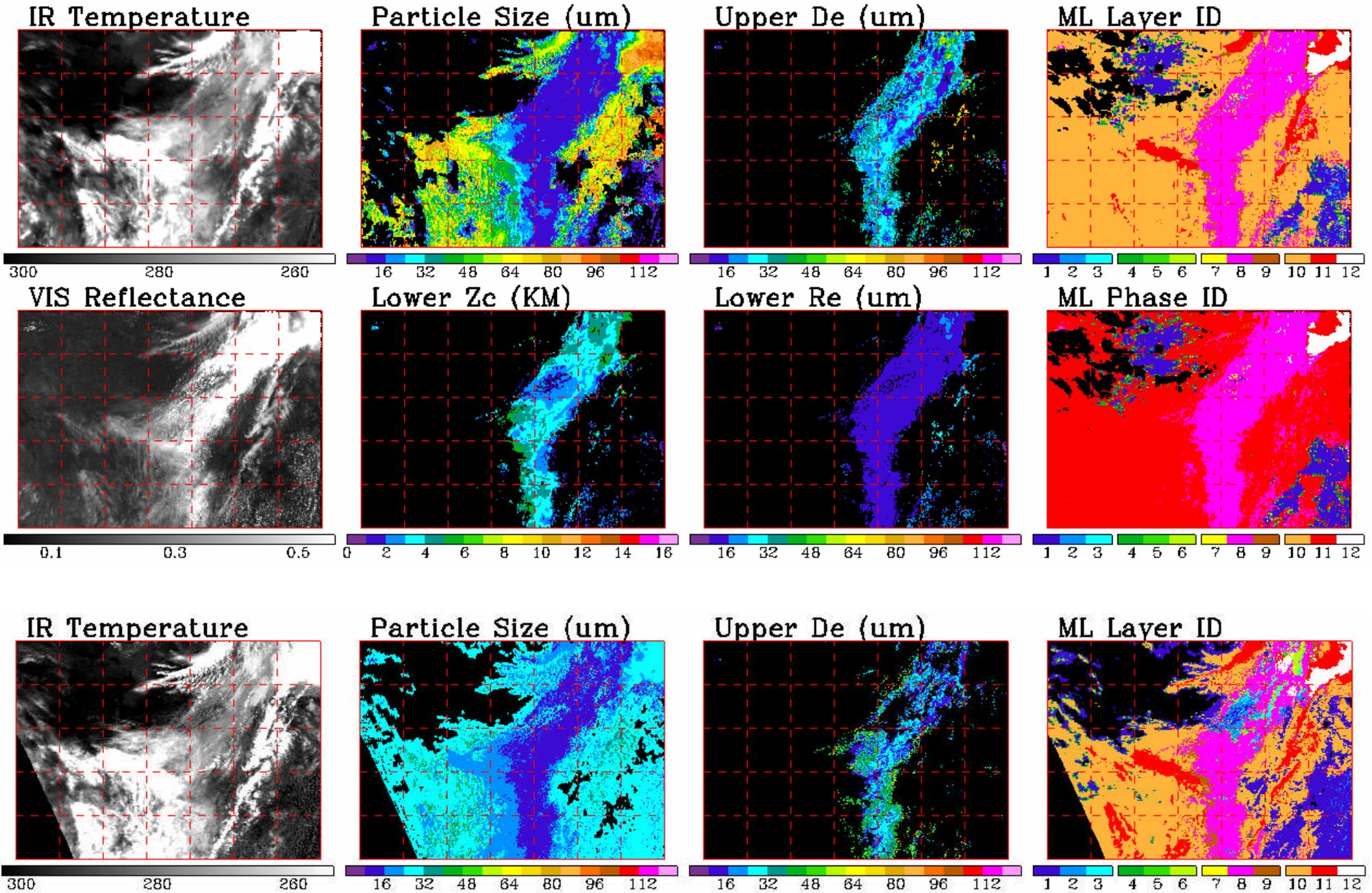
# Improving Multi-layered Cloud Properties (GOES12 View)



# Improving Multi-layered Cloud Properties (GOES12 View)



# Improving Multi-layered Cloud Properties (GOES12 View)



## Conclusion

- The improved results from modified GET\_CO2, GET\_MULTI, and GET\_MULTI\_Re, looked encouraging.
- But the tests were off-CERES frame work processing.
- GET\_MULTI and GET\_MULTI\_Re are working.
- Future work will be mainly testing the robustness of the modified CO2 retrievals.