Boundary Layer Lapse Rate in Cloudy Areas Derived using CALIPSO Data

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Objective

- **Use CALIPSO and CloudSat data products to**

  - develop improved algorithms for CERES clouds

CERES-MODIS Cloud Retrieval Methodology.

(Apply CERES algorithms to MODIS imager data)

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)*

SNOW (DAY): Solar-Infrared Infrared Near-Infrared Technique (SINT)

2.1, 3.8, 10.8, & 12.0 μm *see Platnick (JGR, 2001), Minnis et al. (2007b)*

CERES 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 GEOS 4.03

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 $T_{500} = T_{500}$(GEOS 4)

(Minnis et al., JAM, 1992; TGARS, 2007)

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)

CERES Cloud-base Height Estimation

Cloud thickness: $\Delta Z = f(\text{phase}, T_{eff}, \tau)$

based on surface & aircraft radar/lidar data

Cloud base Height: $Z_{base} = Z_{top} - \Delta Z$

Constraint: $Z_{base} > Z_o$

(Minnis et al., JAM 1992, TGARS, 2007; Chakrapani, ARM 2002)

DATA

Aqua - MODIS:

L1B: MAC02 (radiance)

Full resolution (1 km) with 22 bands subset: 201 km MODIS swath centered at the CloudSat nadir track.

L1B: MAC03 (geolocation)
L2: MAC04 (aerosol).

CALIPSO:

L2: Vertical Feature Mask (VFM).

L2: 5 km Cloud Profile (05kmCPro)

L2: 5 km Layer Aerosol (05kmALay)

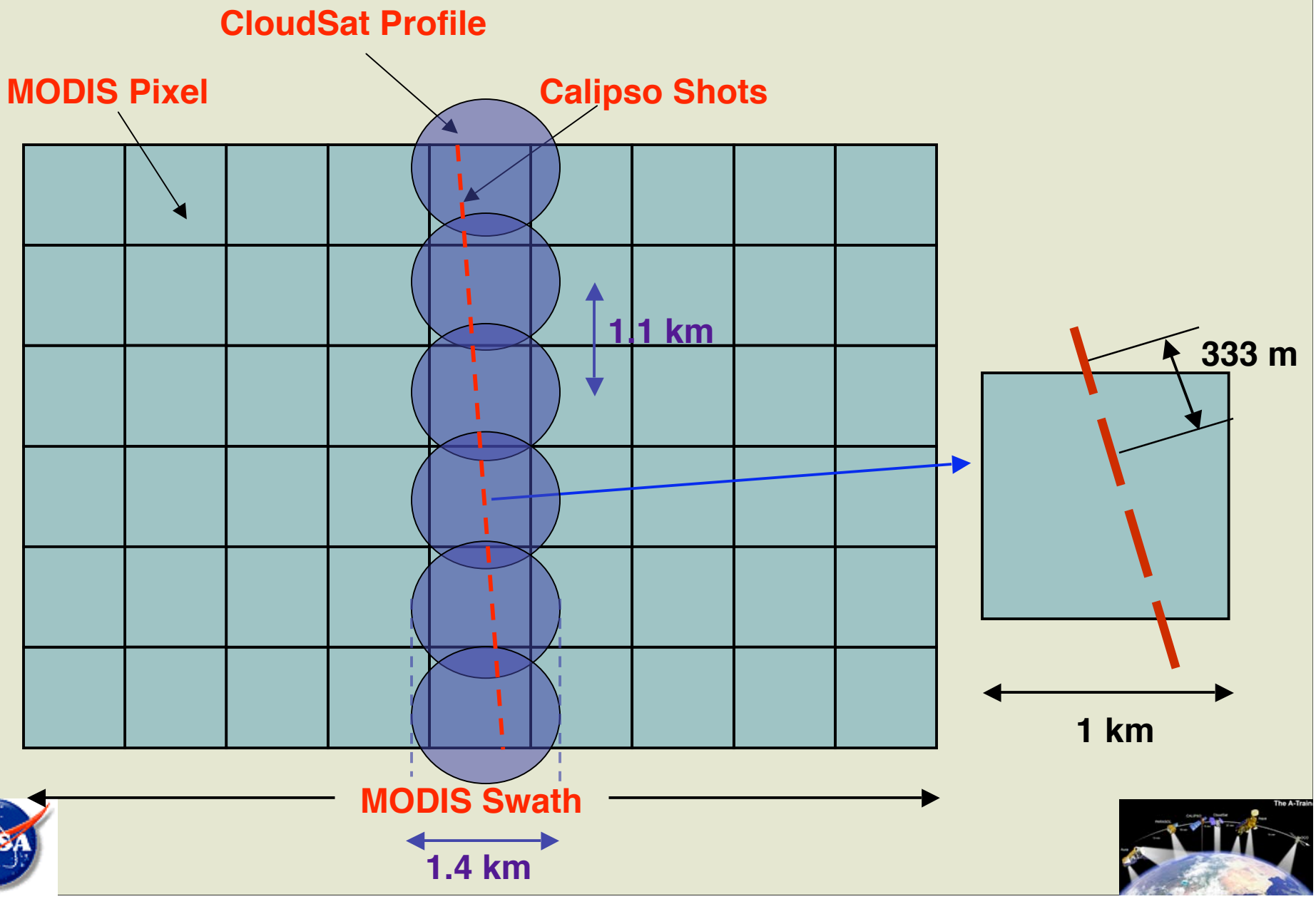
CloudSat:

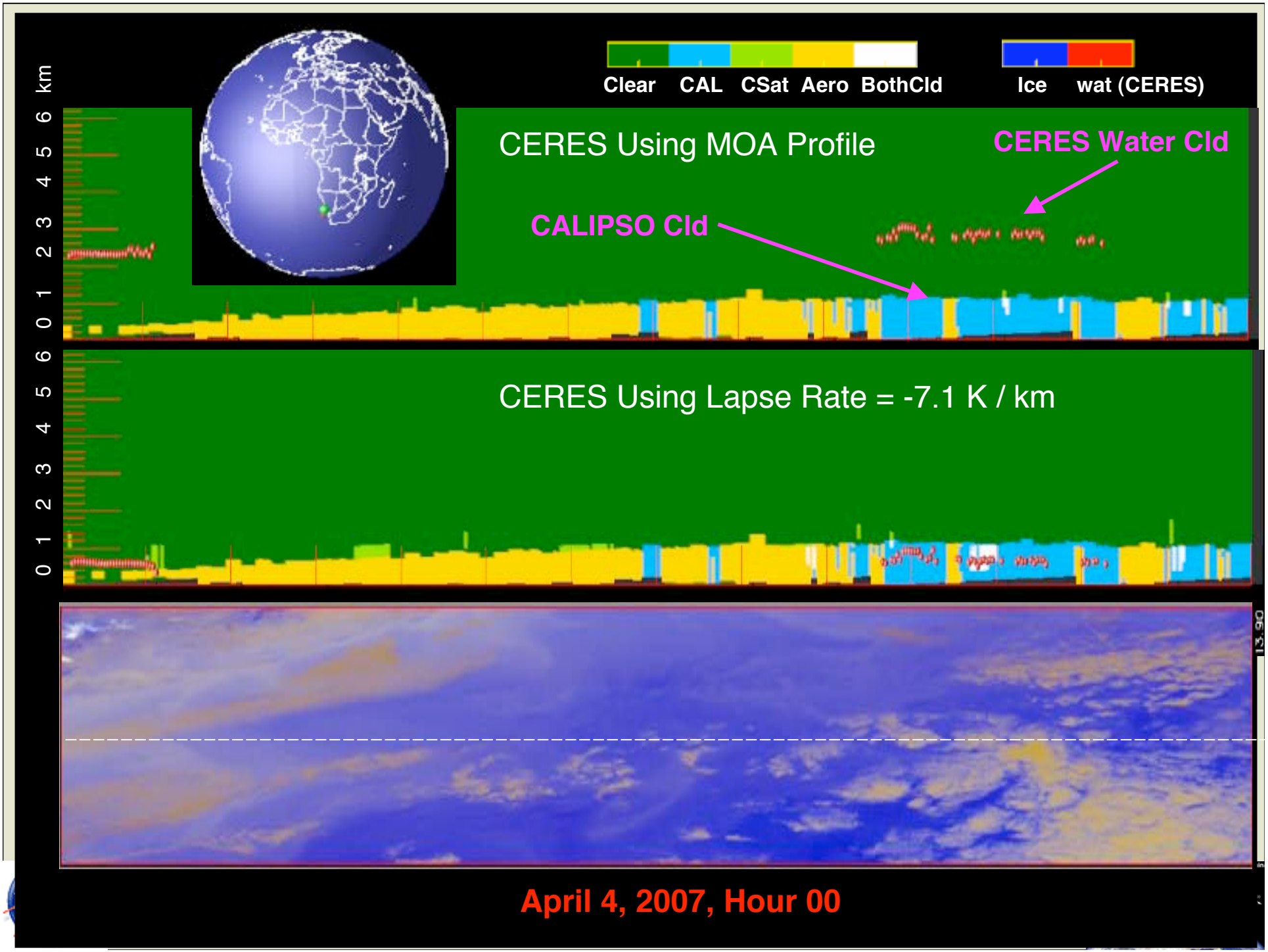
L2: Cloud Scenario Classification (CLDCLASS):

L2: 2B-CWC-RO

L2: 2B-Tau (future)

MODIS, Calipso and CloudSat Collocation Match Up.




km
6
5
4
3
2
1
0
Clear
CAL
CSat
Aero
BothCld
Ice
wat (CERES)
CERES Using MOA Profile
CERES Water Cld
CALIPSO Cld
CERES Using Lapse Rate = -7.1 K / km
April 4, 2007, Hour 00

Lapse Rate Calculation

For Merged CALIPSO and CERES Clouds

CALIPSO Clouds:

(1) Single Layer

(2) Transparent Clouds

(3) Cloud Top Height: Z_{top}

Surface Height: Z_{sfc}

$Z_{top} - Z_{sfc} < 4$ km

CERES Clouds:

(1) Water Clouds

(2) Cloud Top Temp: T_{top}

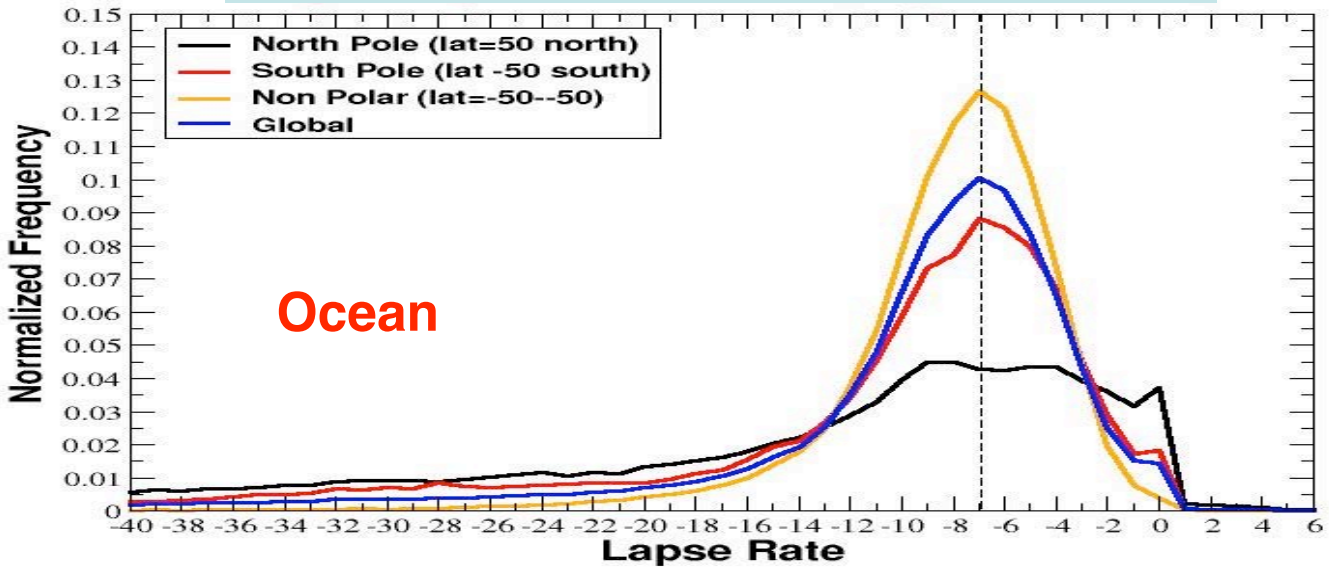
(3) For Ocean: T_{skin}

(4) For Land: $T_{sfc\text{-}24h\text{-}mean}$

Lapse Rate $= (T_{top} - T_{skin}) / (Z_{top} - Z_{sfc})$ <------ For Ocean

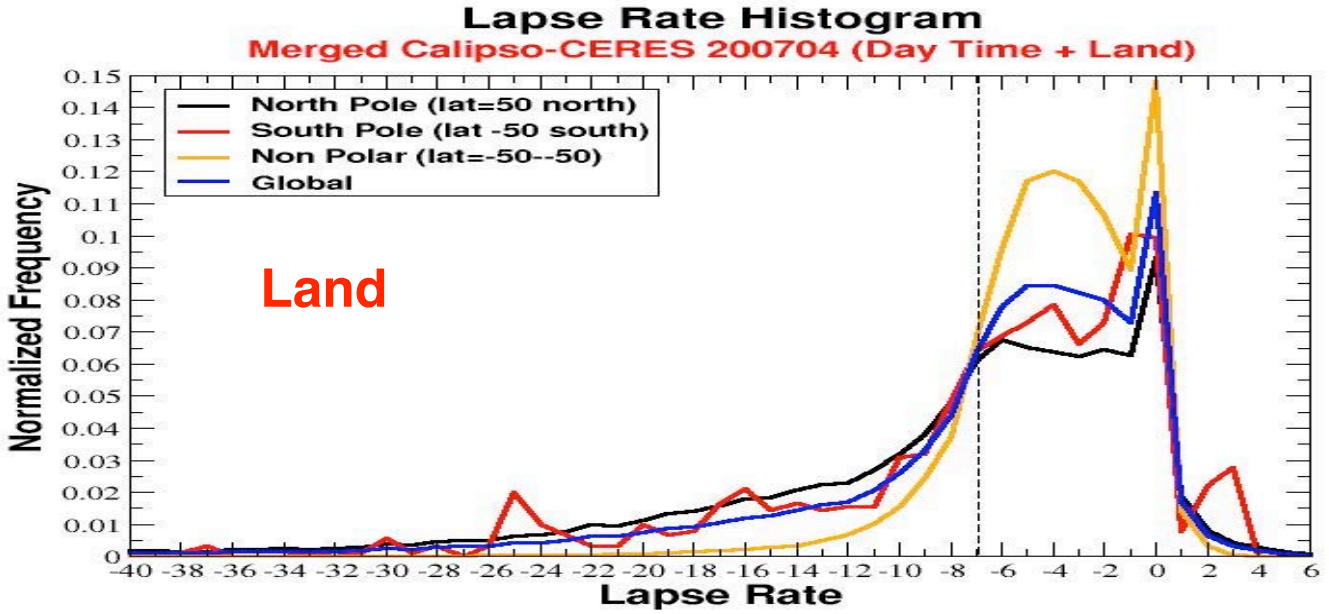
Lapse Rate $= (T_{top} - T_{sfc\text{-}24h\text{-}mean}) / (Z_{top} - Z_{sfc})$ <------ For Land

Lapse Rate Histogram (April 2007)



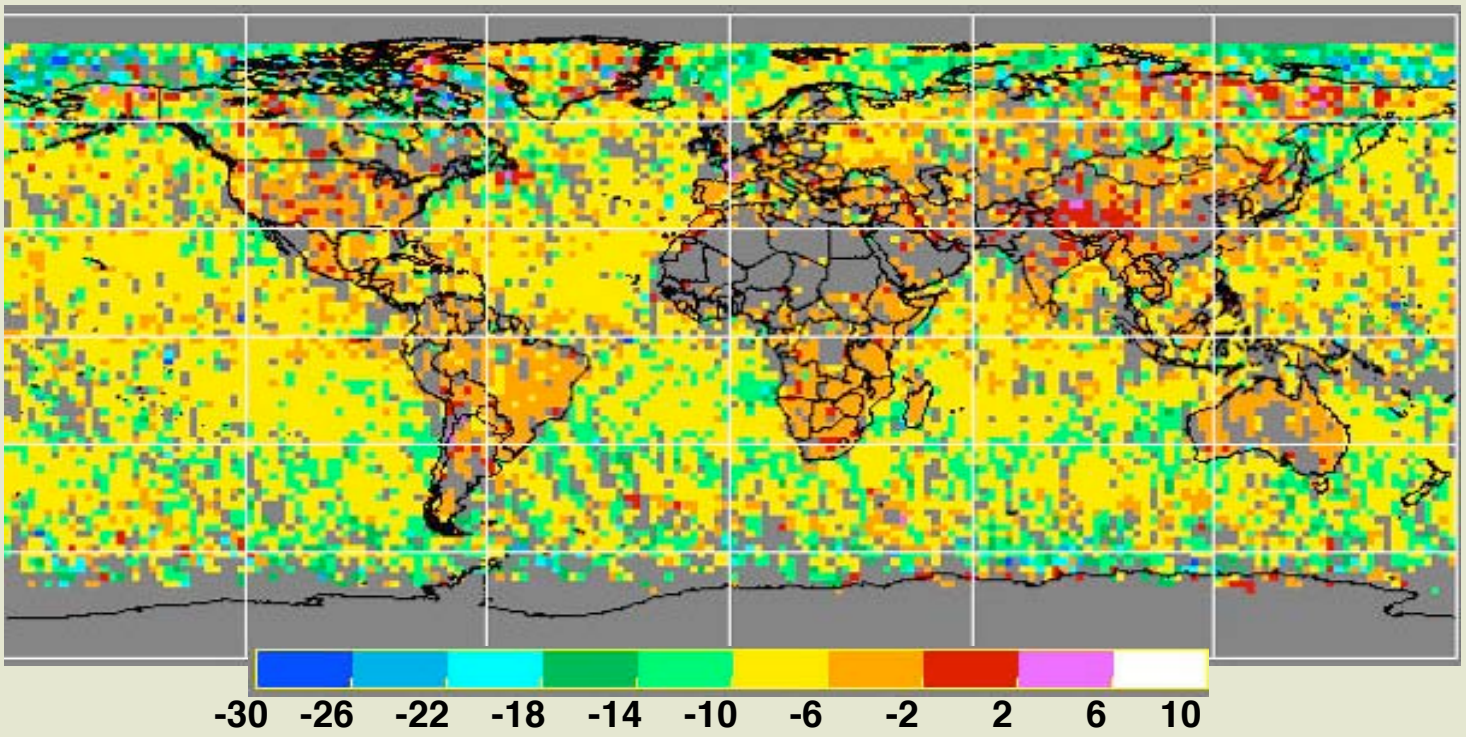
Ocean

Day Time

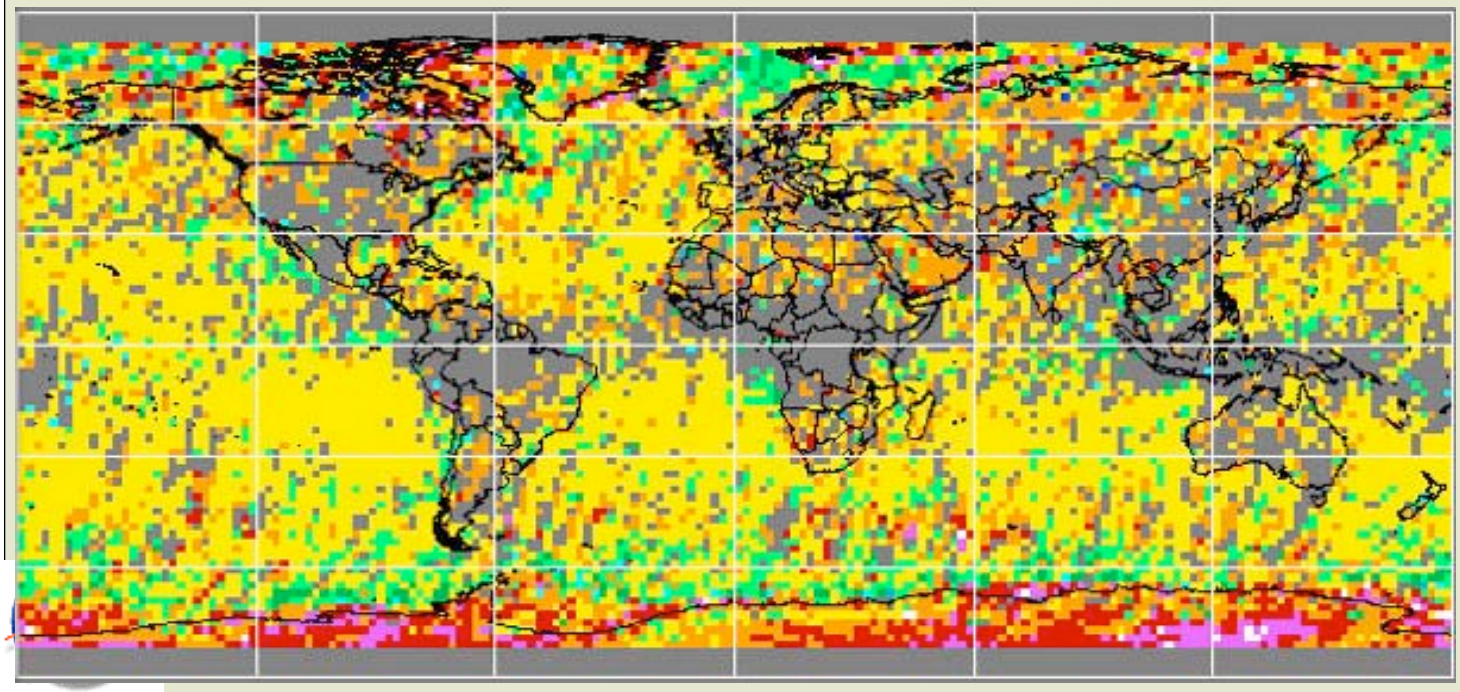


Land

Global Maps of Lapse Rate (April 2007)

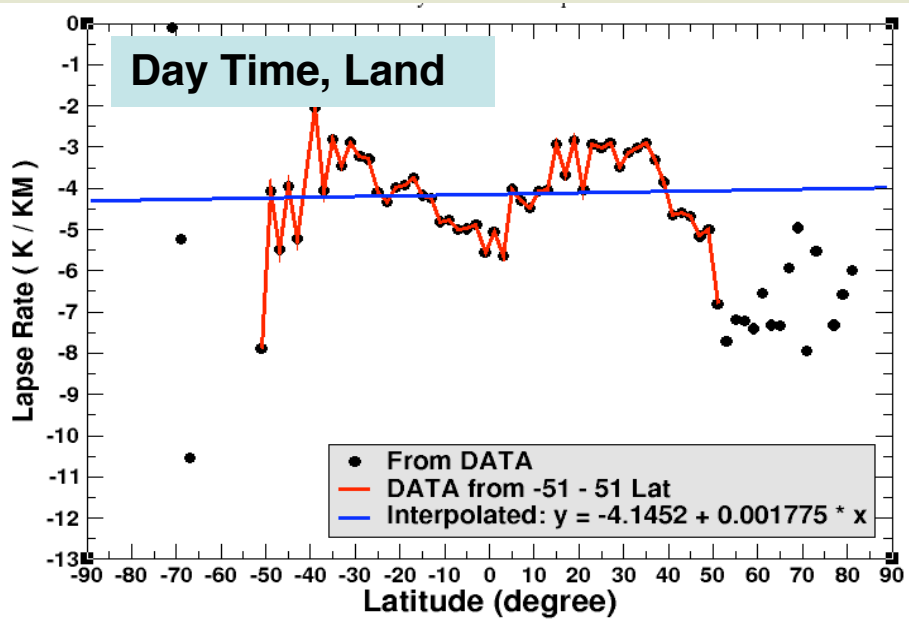


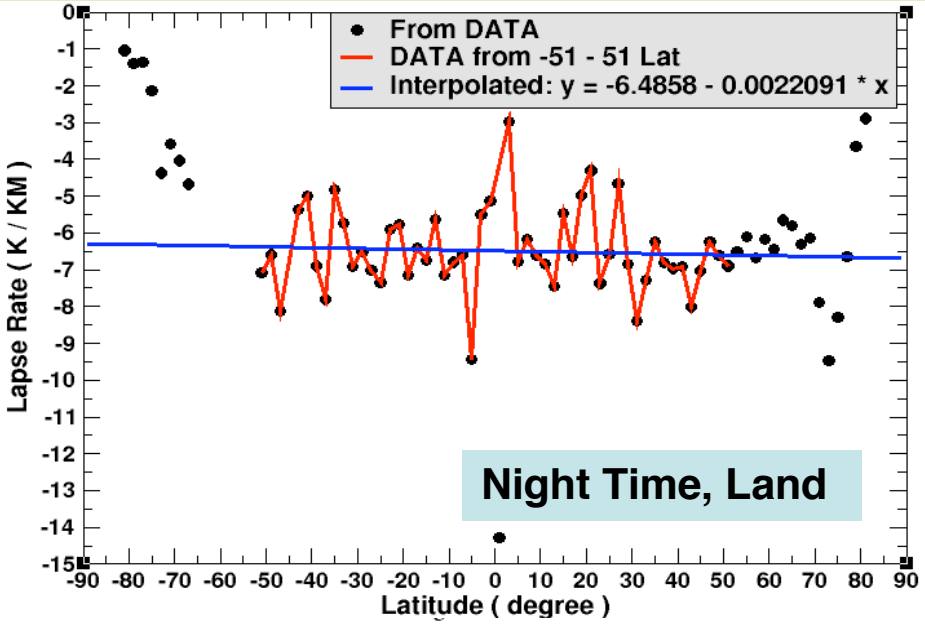
Day Time

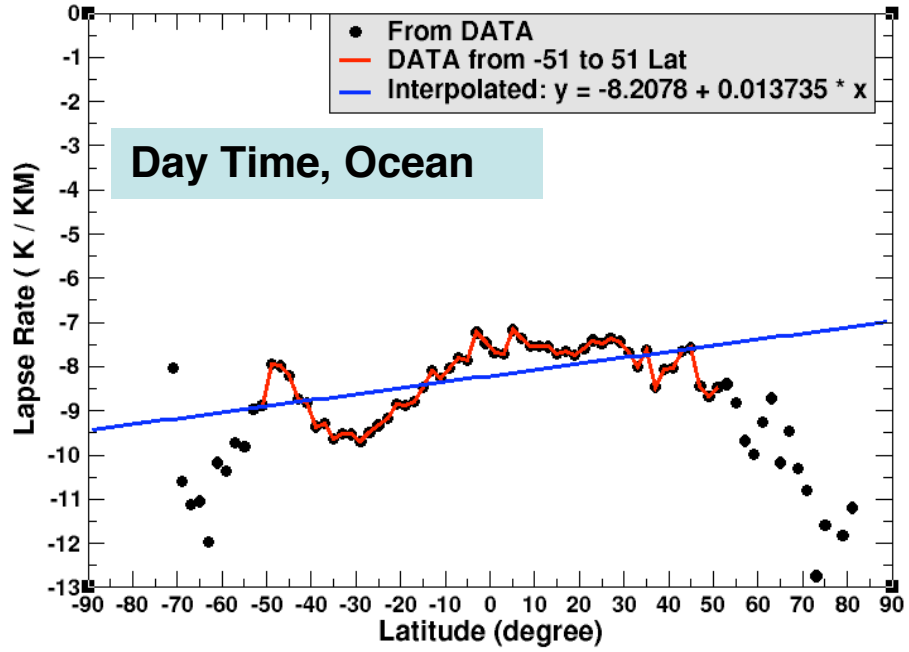


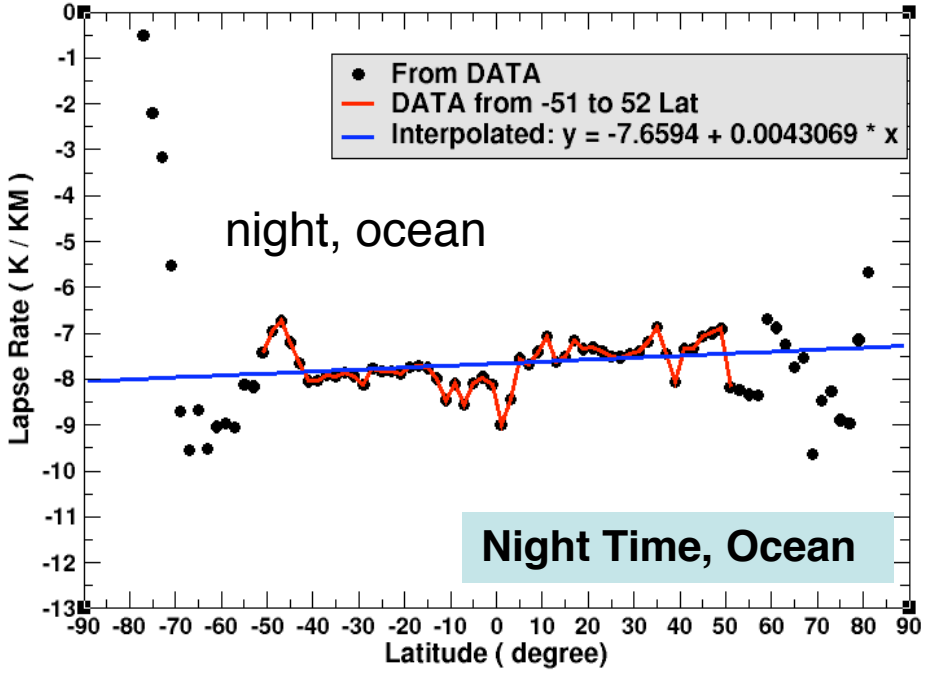
Night Time

Zonal Lapse Rate (April 2007)

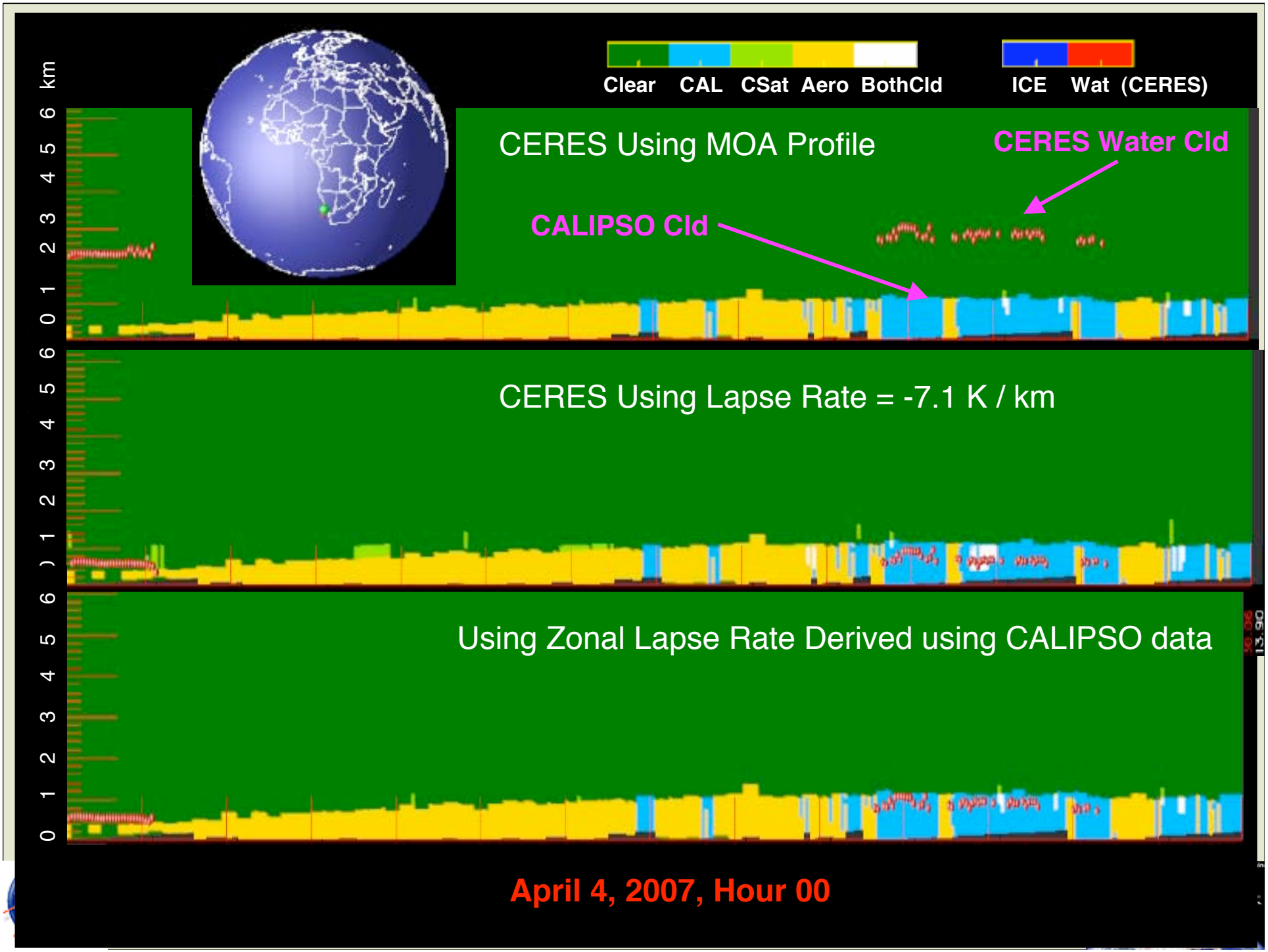


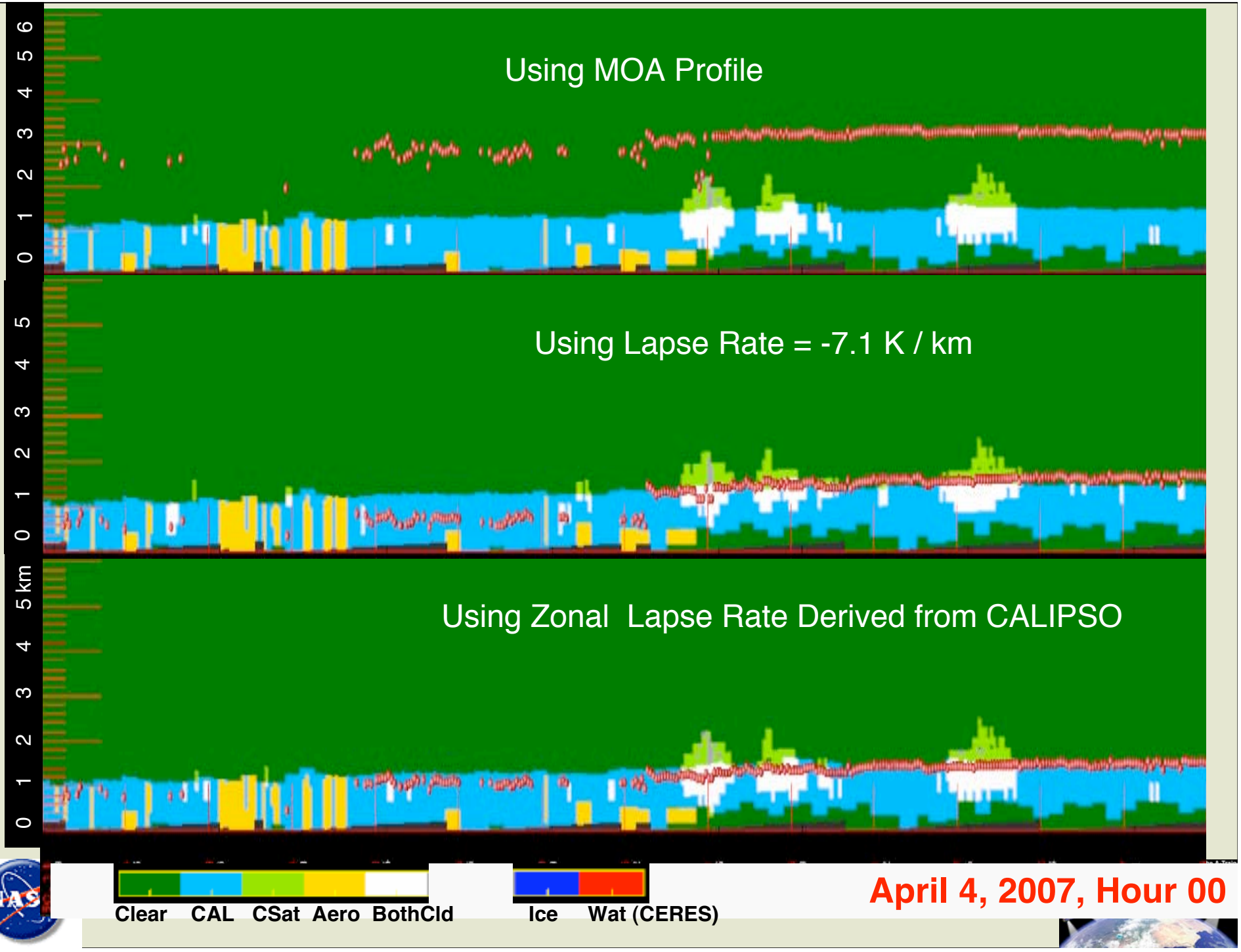




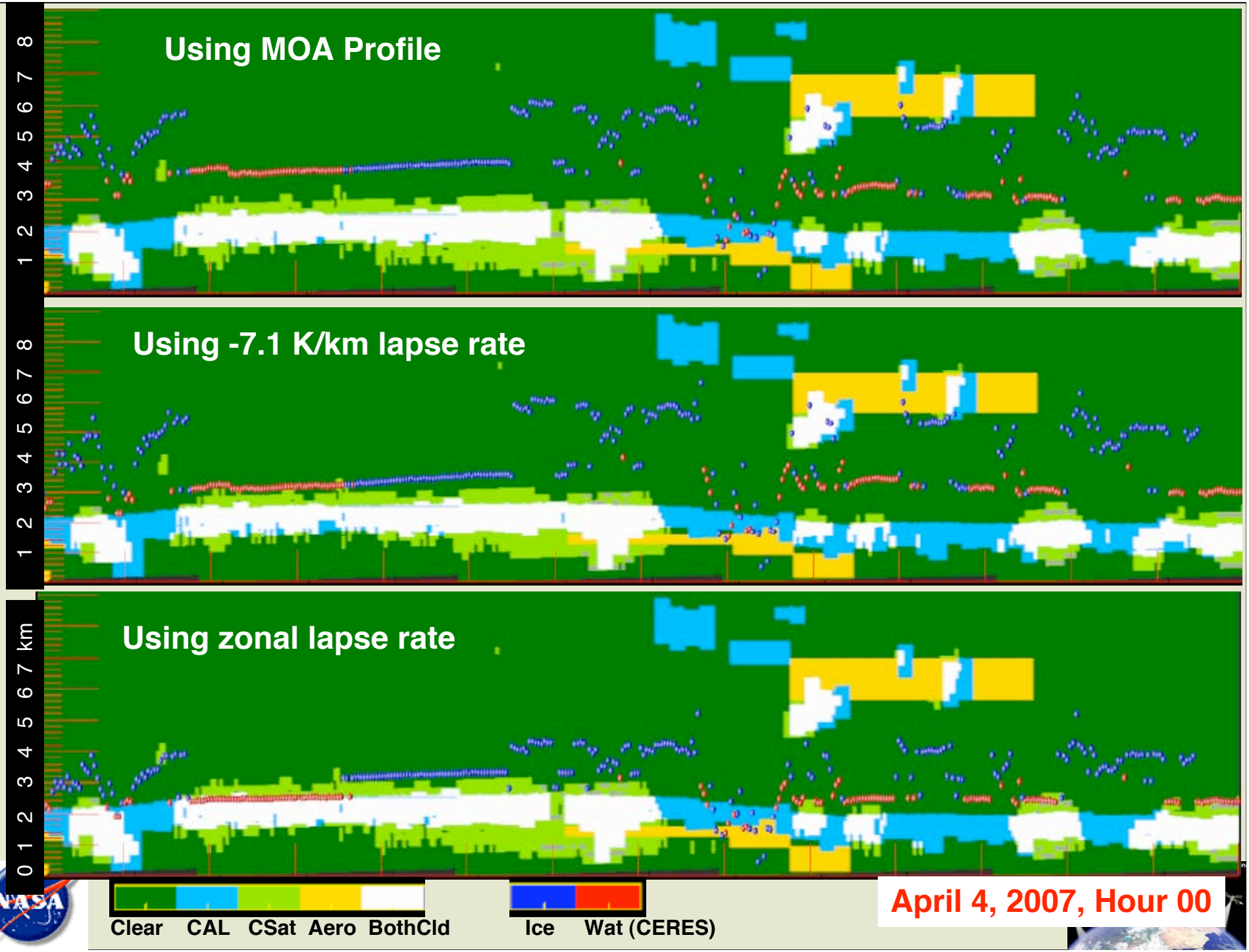


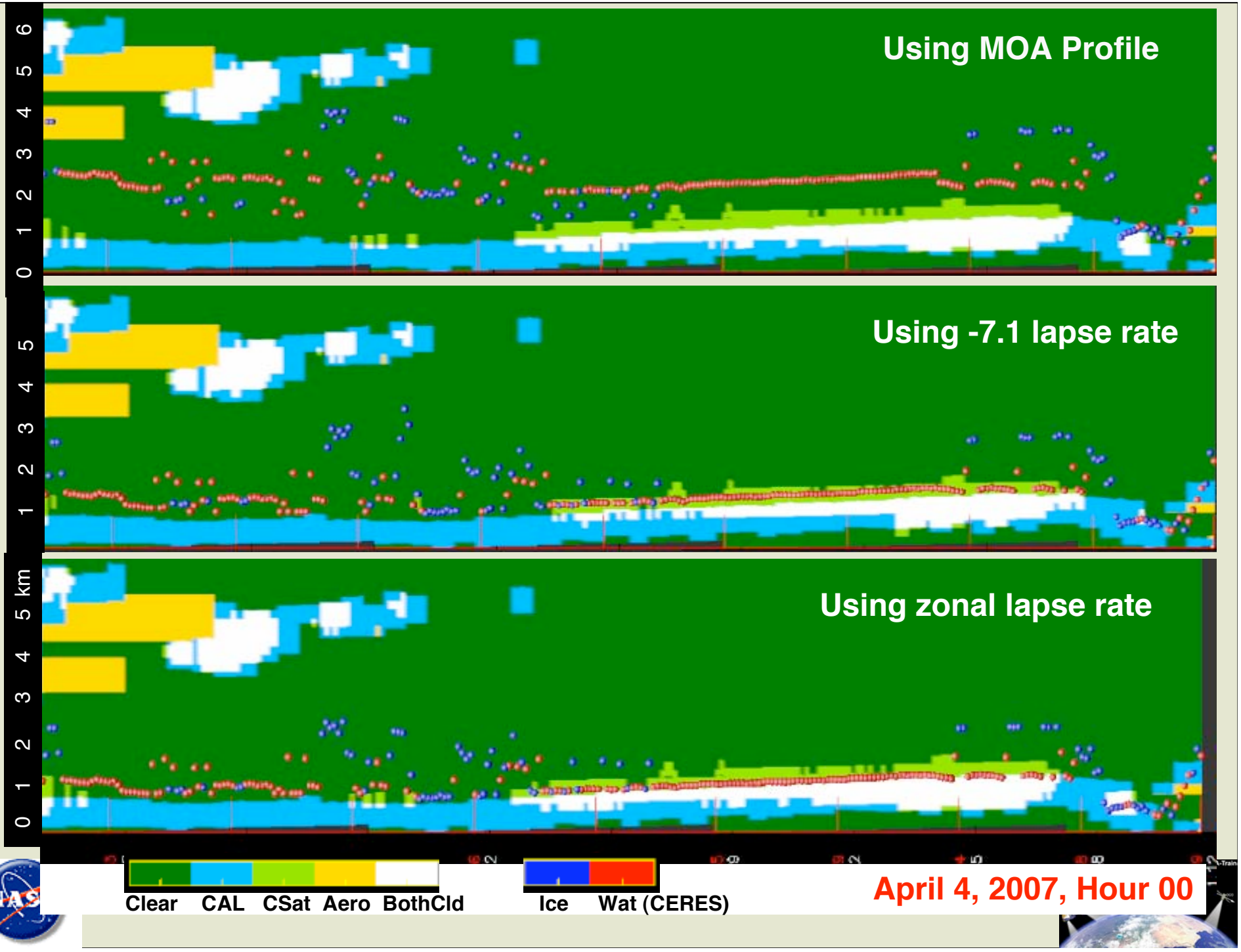
Before and After Cases


km
Clear CAL CSat Aero BothCld
ICE Wat (CERES)
CERES Using MOA Profile
CERES Water Cld
CALIPSO Cld
CERES Using Lapse Rate = -7.1 K / km
Using Zonal Lapse Rate Derived using CALIPSO data
April 4, 2007, Hour 00



April 4, 2007, Hour 00


Using MOA Profile
Using -7.1 K/km lapse rate
Using zonal lapse rate
0 1 2 3 4 5 6 7 km
1 2 3 4 5 6 7 8
Clear
CAL
CSat
Aero
BothCld
Ice
Wat (CERES)
April 4, 2007, Hour 00


Using MOA Profile
Using -7.1 lapse rate
Using zonal lapse rate
0 1 2 3 4 5 6
1 2 3 4 5
0 1 2 3 4 5 km
Clear CAL CSat Aero BothCld
Ice Wat (CERES)
April 4, 2007, Hour 00

Conclusion

- CALIPSO, CloudSat & CERES-MODIS are merged at NASA Langley
- CALIPSO is improving CERES retrievals
- Need close examination of cloud temperatures and lape rates voer polar regions.
- Need to process more months to get seasonal lapse rates.