

# EOS MLS Satellite Detection of Cloud Ice over the Tropics and its Effect on the Longwave Radiation Budget - Christopher Nankervis (University of Edinburgh) [NERC Funded PhD Student]

• Two-fold study on both the validity of MLS cloud ice data and its effect on the longwave radiation (LW) budget

## WHAT is the radiation budget?

• The Earth's radiation budget fundamentally comprises of two components. Incoming shortwave radiation from the Sun ( $T=5780K$ ), and outgoing longwave (thermal) radiation to space ( $T=255K$ ). The spectral characteristics are usually represented by a Planck emission function, which is a function of temperature. Clouds, aerosols, water vapour and other greenhouse gases play a key role in regulating the energy budget either by "resisting" the outflow of thermal energy, or by affecting the Earth's reflectivity. The net radiation is **dynamic**, from diurnal scale variability to long term decadal variability.

## WHY study the radiation budget?

• The net longwave emission is a "proxy" for surface temperature, as a net loss of energy from the atmosphere-ocean system, usually indicates a net loss of energy (cooling) from the surface [assuming that solar radiation remains fixed]. At the tropics a net heat gain is counteracted by constant heat and moisture transport from Equator to Pole by the general circulation system. Clouds have the unique ability to reduce incoming solar energy into the system, and even small changes in their reflectivity or abundance have a large effect on the radiation budget and climate of the Earth.

• Changes in the longwave emission are thought to be due to changes in the abundance of various cloud types, changing cloud top altitude, hydrology, and changing ocean - atmosphere dynamics. It is essential that clouds, especially cirrus clouds are represented adequately in Global Climate Models (GCM's) for climate research and policy. Their understanding may clarify future changes in the energy budget and climate.

## HOW is the EOS MLS data best used for estimating Longwave emission?

• Measurements from satellite instruments on the A-train orbit may be inter-compared to allow us to make direct comparisons between the radiation budget and cloud properties which are close in both space and time. This process is known as **collocation**.

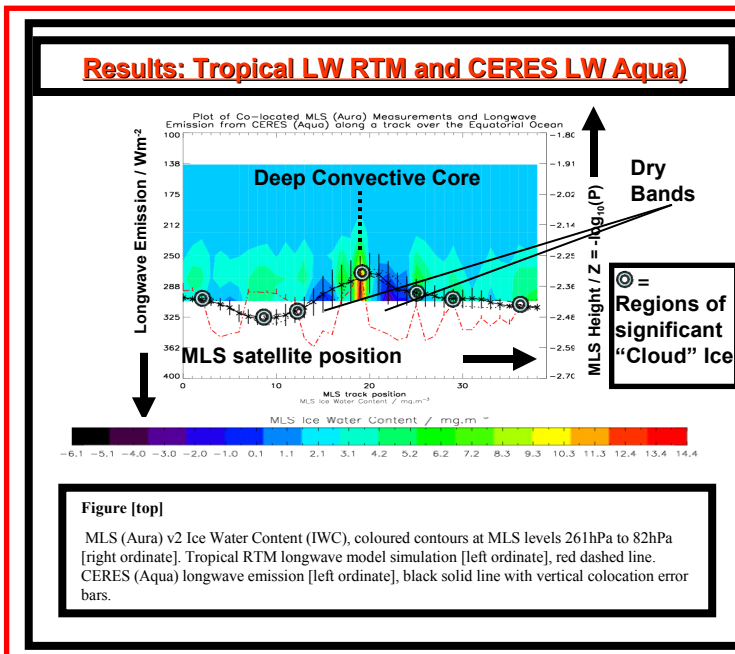
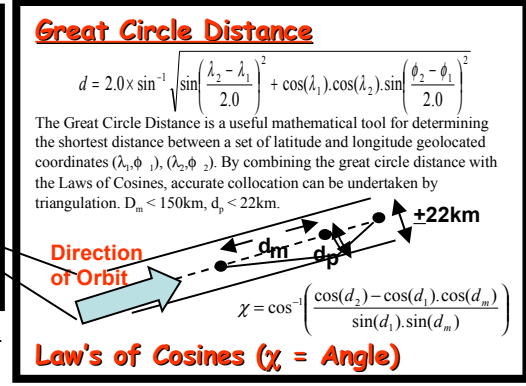
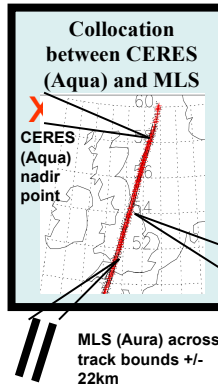
A cloudy sky parameterization of the upper troposphere is used to predict the longwave emission using cloud ice data, water vapour and temperature profiles from the NASA A-Train Microwave Limb Sounder Instrument (MLS) onboard the Aura satellite. Predicted longwave emission is compared to collocated longwave emission measurements from the Clouds and the Earth's Radiant Energy System (CERES) instrument onboard the Aqua A-train platform. The likely radiative effect of upper tropospheric clouds and water vapour at the tropics is then examined in the context of longwave radiation perturbations.

## Methods estimating cloud top LW emission

Component	RTM Parameterization	Cloud - Top Method
Surface Emissivity ( $\epsilon_s$ )	✓ [Inverse SALR computed from 316hPa temperature]	✓ [Inverse SALR computed from 316hPa temperature]
Cloud Top Emissivity ( $\epsilon_c$ )	✓ [Highest level where ice water > 0.3mg.m <sup>-3</sup> ]	✓ [Highest level where ice water > 0.3mg.m <sup>-3</sup> ]
Optical Depth ( $\tau$ )	✓ [Optical depth for cloudy sky profile, where EOS MLS detection is significant! Avoid averaging negative IWC values]	✗ [Assumes ALL clouds possess a cloud-top emissivity of $\epsilon_c=0.6$ , and surface emits with an emissivity of $\epsilon_s=0.4$ ]
-Liquid Water	✓	✗
-Ice Water	✓ [261hPa to 82hPa, 12 levels / decade]	✗
-Water Vapour	✓ [316hPa to 82hPa, 6 levels / decade]	✗
-UT Temperature	✓ [316hPa to 82hPa, 6 levels / decade]	✗
Atmospheric Gases [O <sub>2</sub> , H <sub>2</sub> O, CO <sub>2</sub> ]	✓ [RTTOV is computed to obtain transmissivities of L <sub>up</sub> in the slab from 316hPa to the TOA]	✗

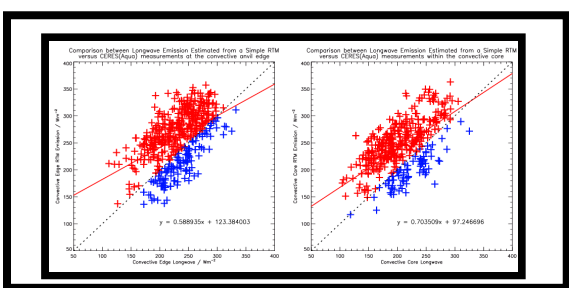
## References

- B. A. Wielicki, et al., Science 295, 841, (2002) .1
- Hatzidimitriou et al., Atmos. Chem. Phys. Discuss., 4, 2727-2745, 2004



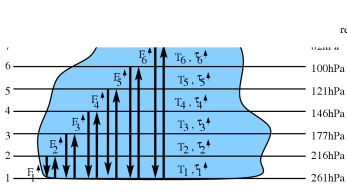
## Convective Anvil & Core Versus Reality [RTM vs CERES], Z < 150km

Figure [right]. Warm bias from model-CERES LW analysis over the tropics / subtropics <35° latitude (red solid crosses). Cold bias from model-CERES LW analysis (blue solid crosses). Edge analysis (bottom left), core analysis (bottom right).



## Radiative transfer in a tropical cloud

(1<sup>st</sup> model step)  $F_2 = (1-\epsilon)\sigma T_1^4 + \epsilon\sigma T_2^4$   
 (n<sup>th</sup> model steps)  $F_n = F_{(n-1)} + \epsilon\sigma T_n^4$



## Conclusions / Further Work

Modelling of tropical clouds is limited by MLS instrumental detection, and collocation biases. Thin cirrus at the edge of convective plumes are in general poorly simulated locally in an RTM due to high variability in the MLS cloud radiances, and complex microphysical properties. A-train collocated measurements make cloudy sky modelling much more rigorous. Cloud scatter information along the limb-view is essential for validating CERES longwave and MLS measurements.