Detection of Single and Multilayer Clouds in an Artificial Neural Network Approach

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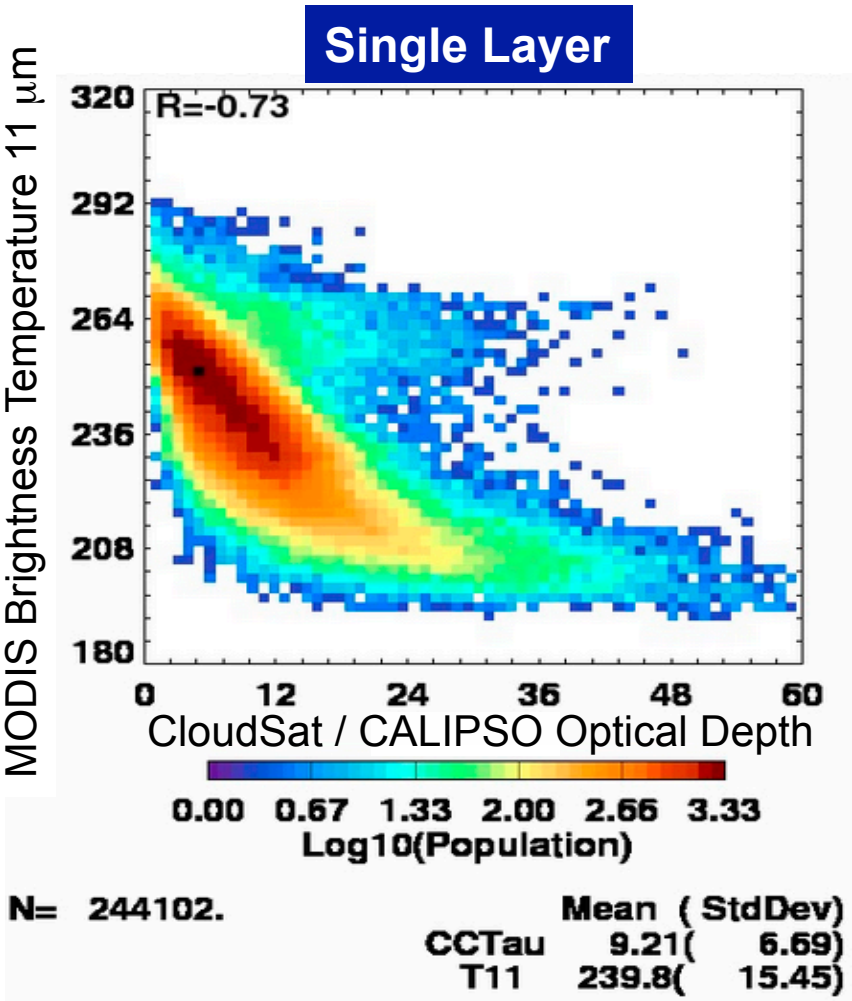
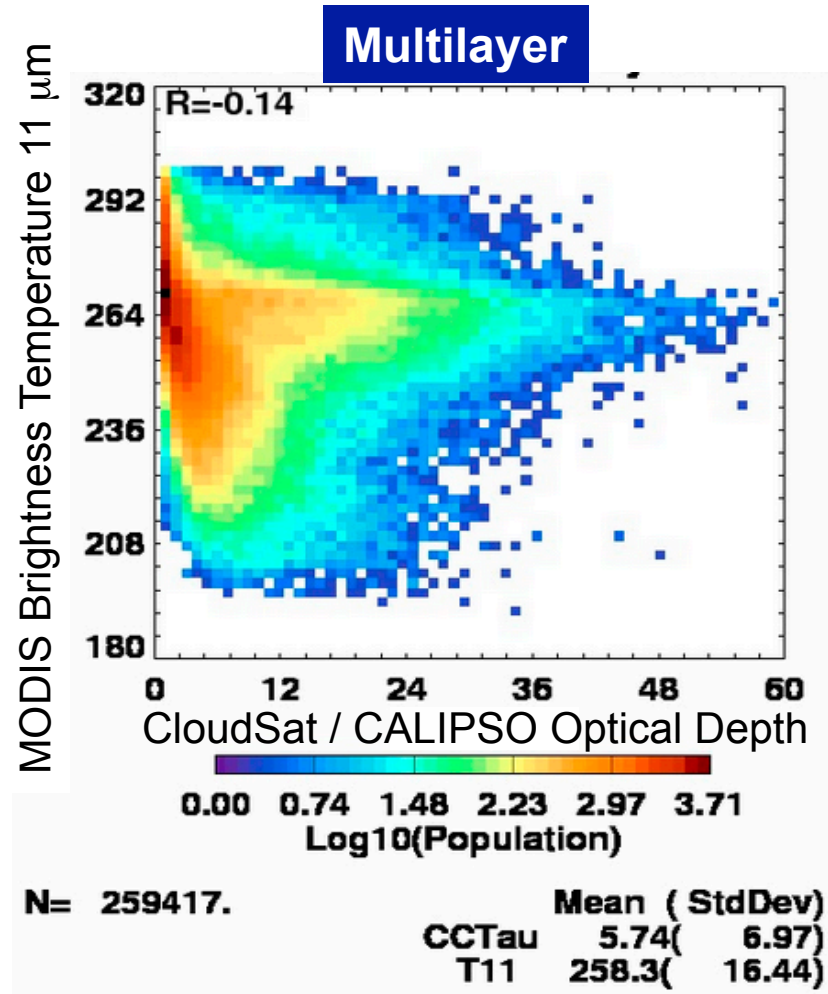
Outline

- Neural Network can be used for multilayer detection
- Methodology
  - Training Data Selection
  - Neural Network
- C3M examples and stats
- Terra and Aqua examples and global maps
- Summary & Future Plans

Correlation of IR data and Cloud Optical Depth
Single Layer .vs. Multilayer Clouds

C3M, October 2009, Night time, Non-Polar





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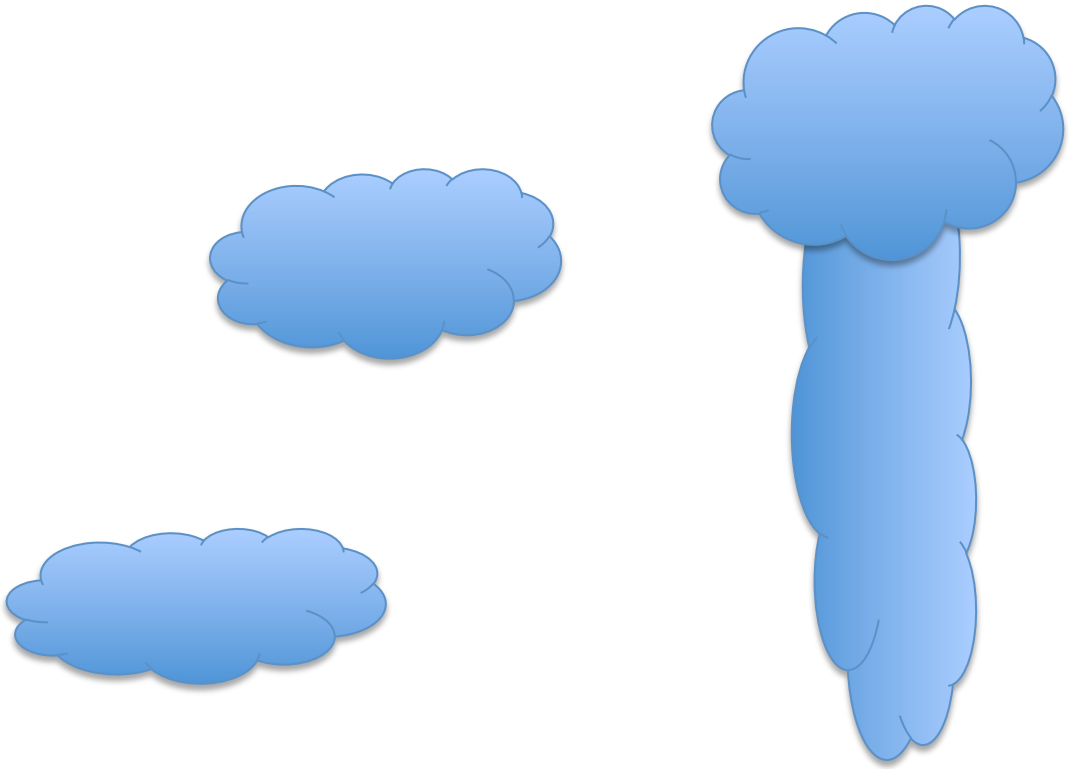
Training Data Selection

C3M, October 2009, non-polar

Build cloud profiles

- CloudSat: Hi Confident Clouds
- CALIPSO: 532 extinction exist



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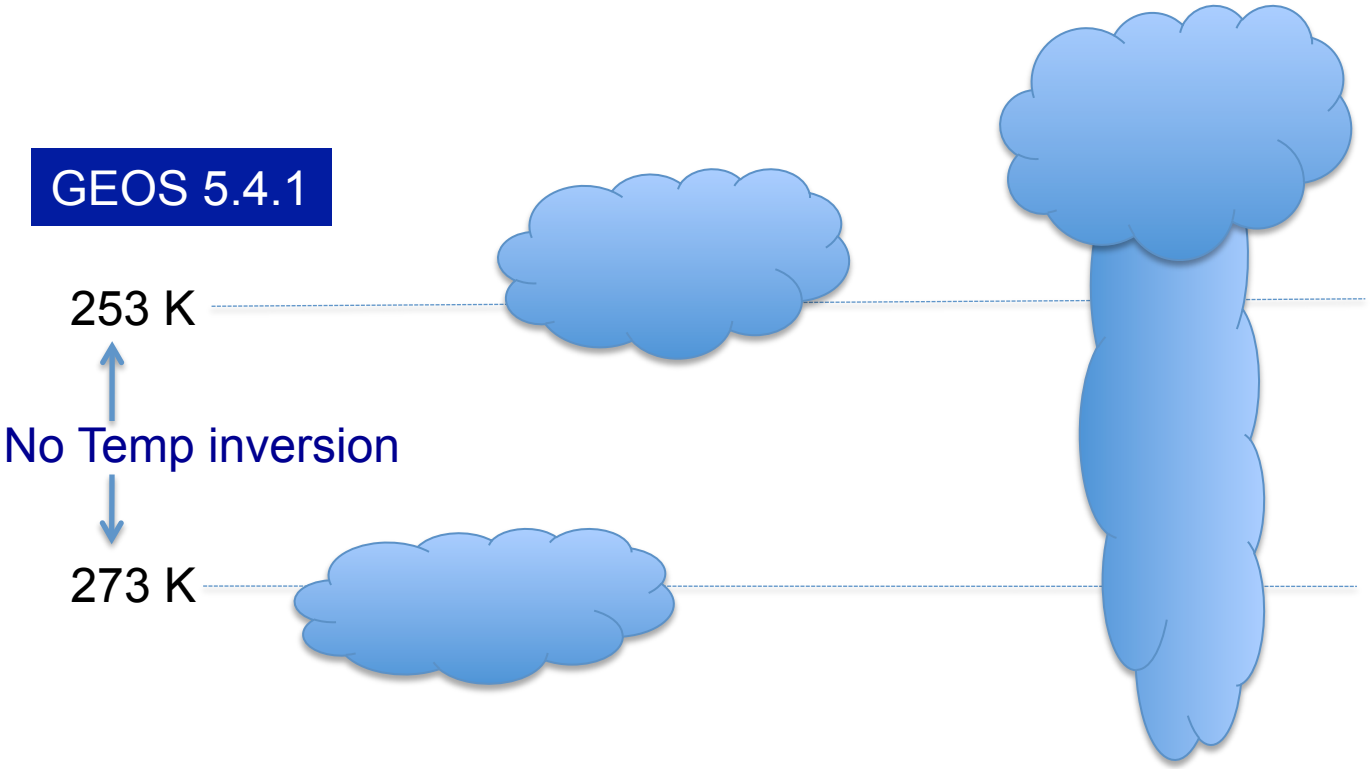
GEOS 5.4.1



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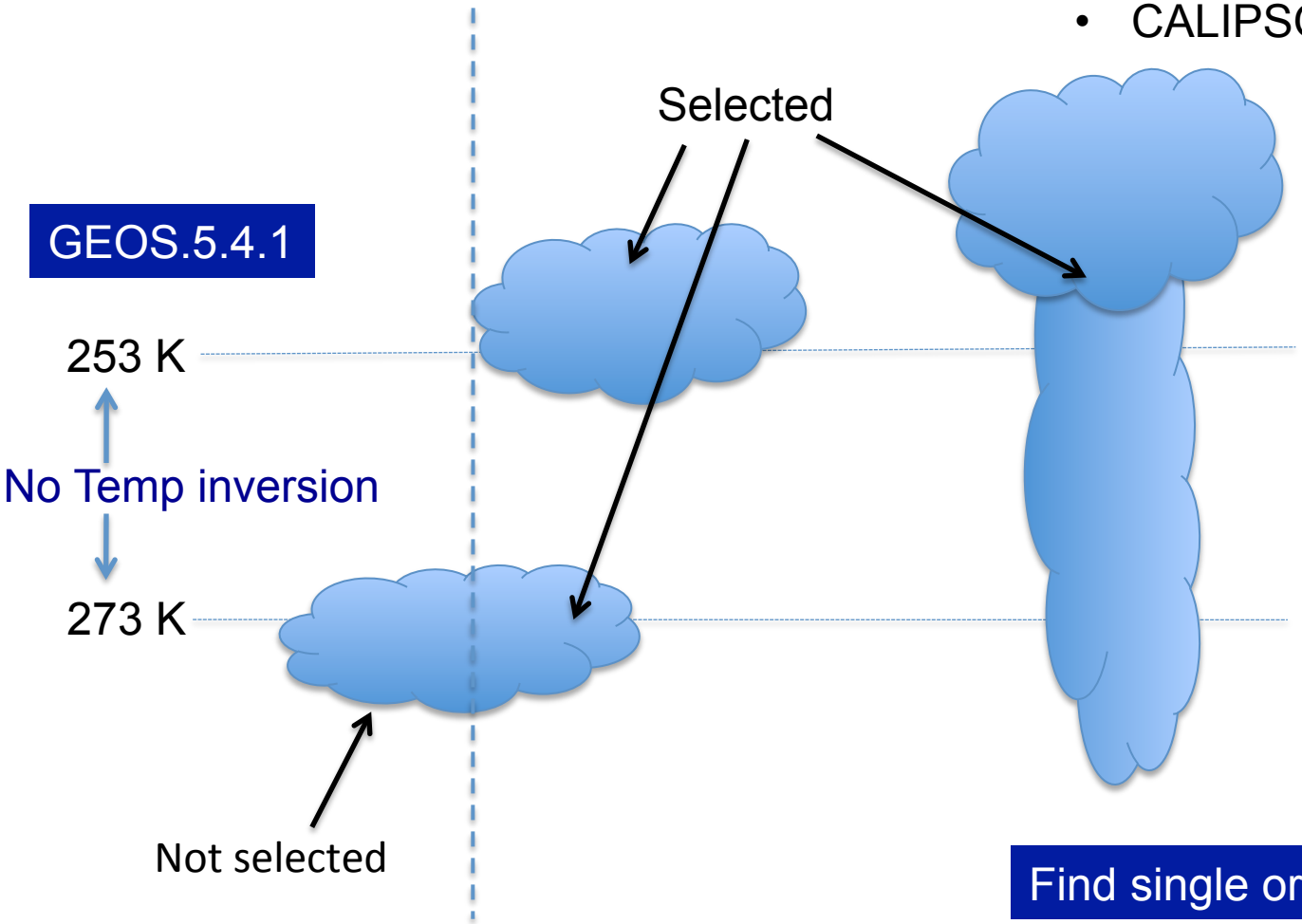
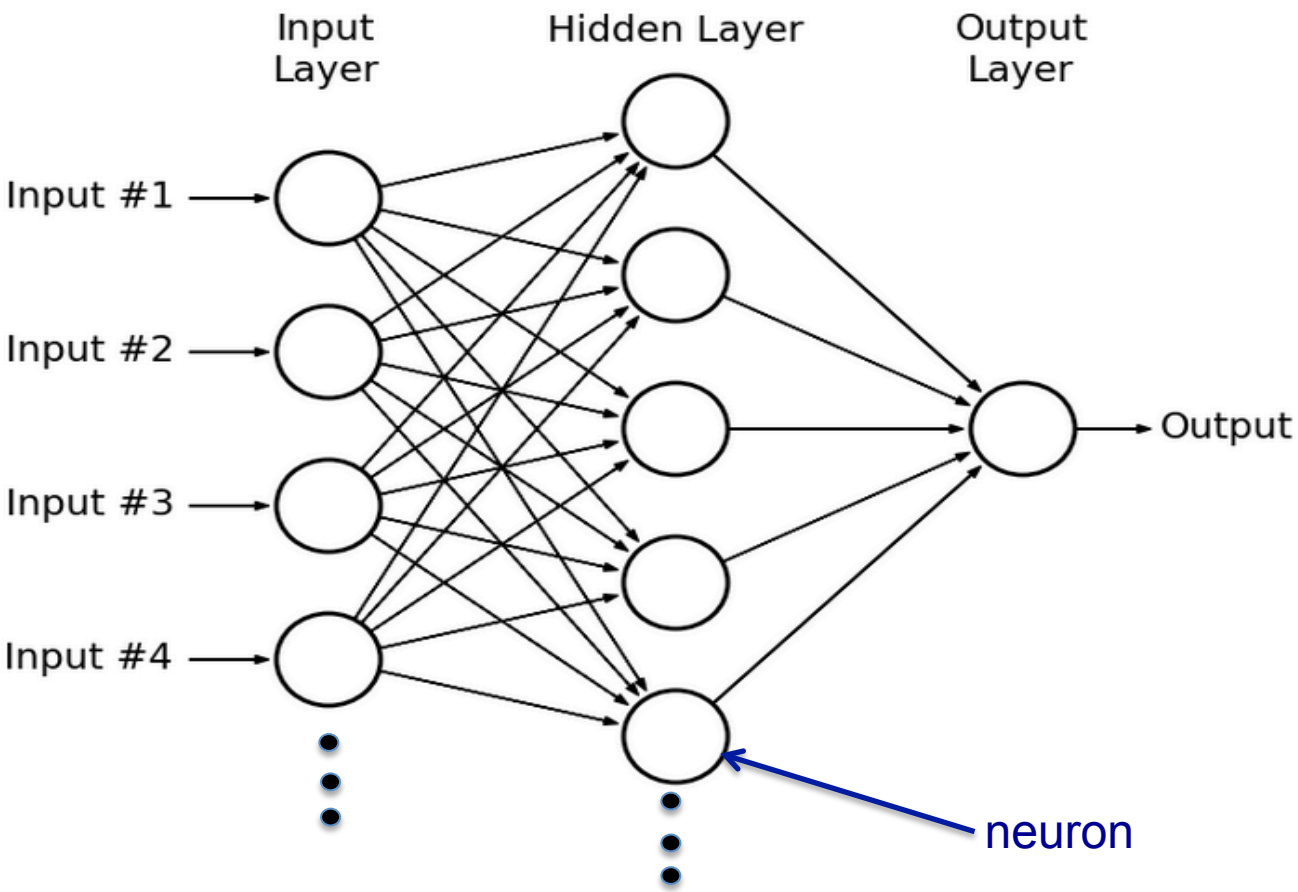


Find single or multi

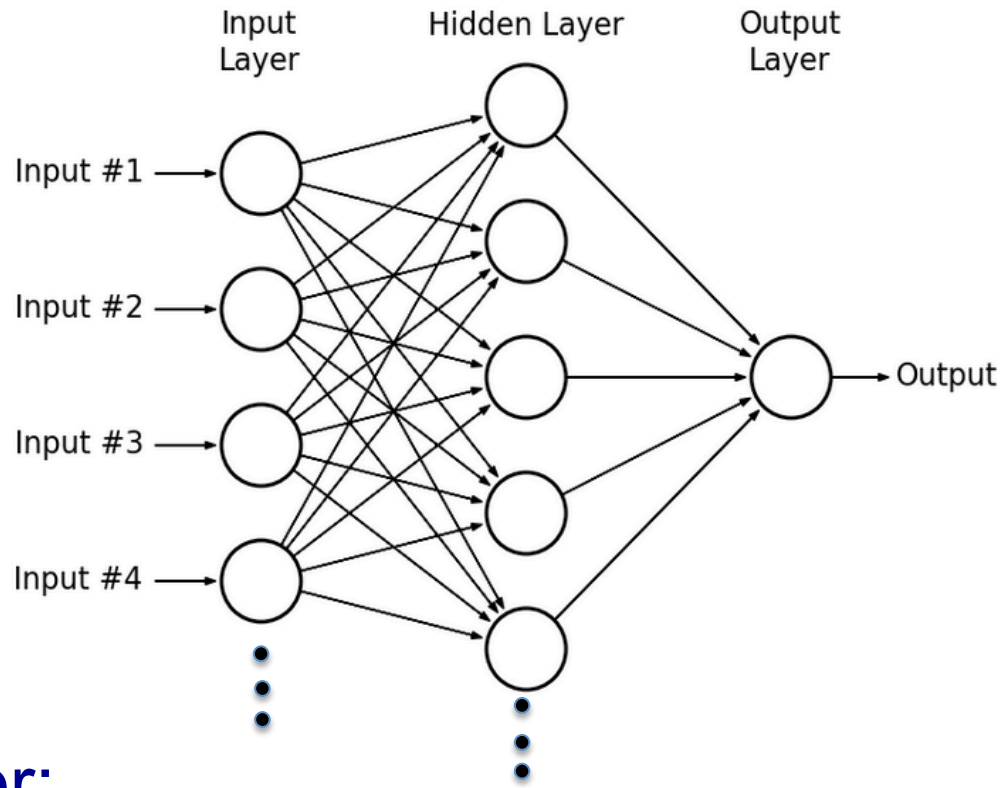
1 km cloud separation.

Neural Network: Pattern Recognition



- The network is trained with scaled conjugate gradient algorithm
- The network updates weight and bias values in both hidden layer and output layer

Neural Network: Pattern Recognition



Output Layer:

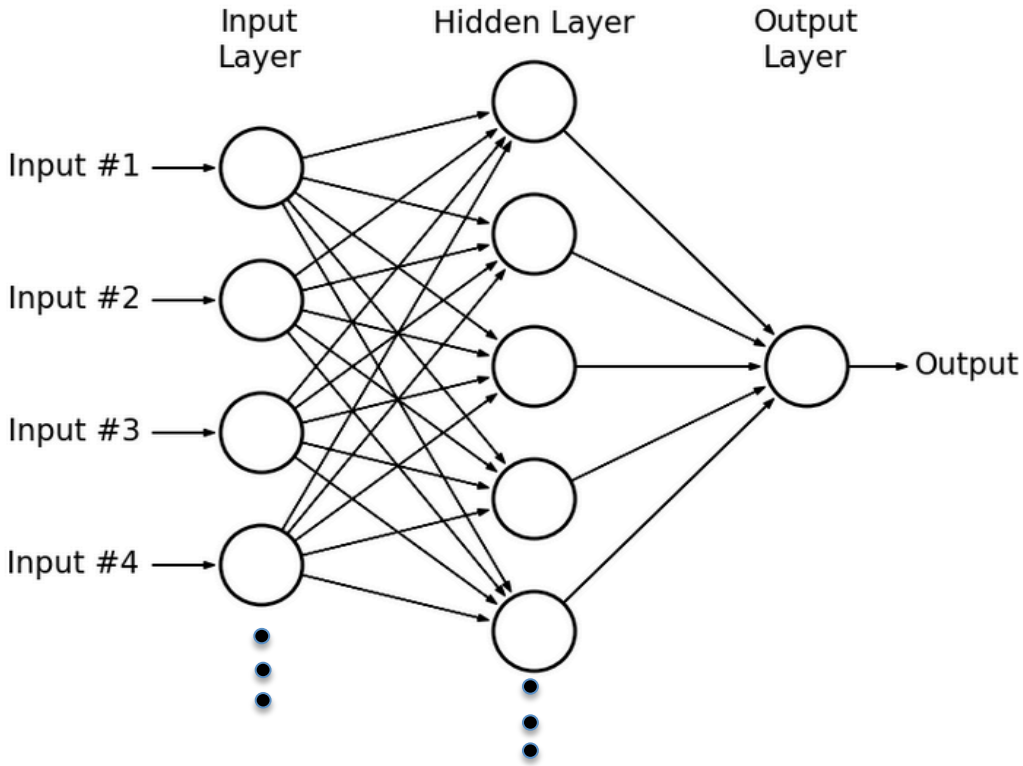
0 or 1
single or multi

Input Layer:

- **Day time, 15 input parameters**
  T(6.7), T(8.5), T(11), and T(12), BTD(6.7-11), BTD(8.5-11), BTD(11-12), lat, lon, skin temperature, ref(0.6), ref(1.24), ref(1.38), ref(2.1), sz

- **Night time, 12 input parameters**
  T(6.7), T(8.5), T(11), and T(12), BTD(6.7-11), BTD(8.5-11), BTD(11-12), lat, lon, skin temperature, T(3.7), BTD (3.7-11)

Neural Network: Pattern Recognition



Hidden Layer:

- n = 50 neurons
- October 2009: 70% for training, 15% for validation, and 15% for testing
- Training percent correct: ~ 79% (day time) and ~ 72% (night time)

Apply a trained neural net to CERES Clouds code

Training Set:

October 2009, C3M

Validation Set:

- July 2008, C3M
- July 2010, Aqua-MODIS & Terra-MODIS
- Conditions to apply Neural Network

  Cloud phase → ice cloud, or

  Cloud phase → water cloud & CO_2 cloud height > 4 km

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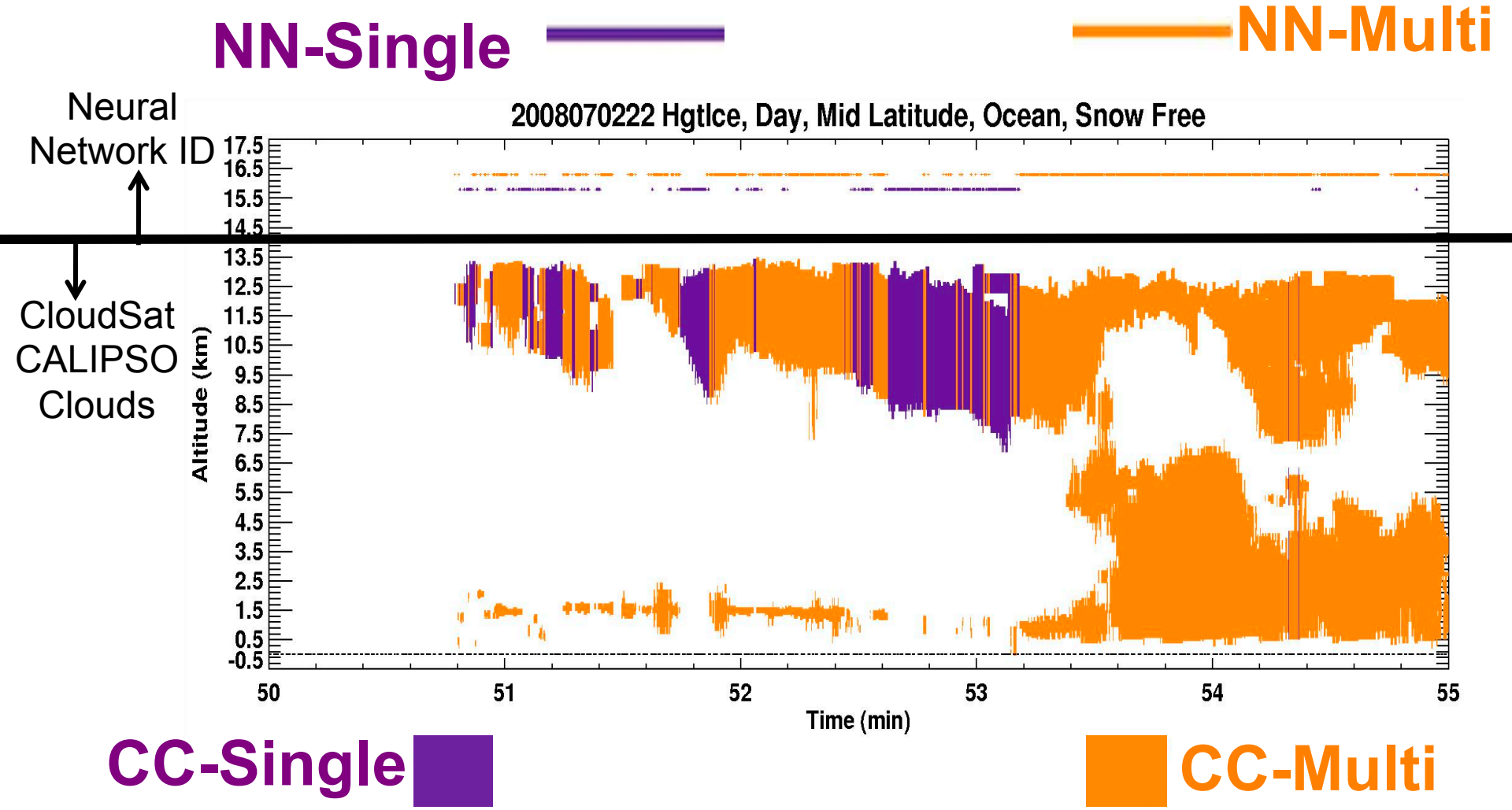
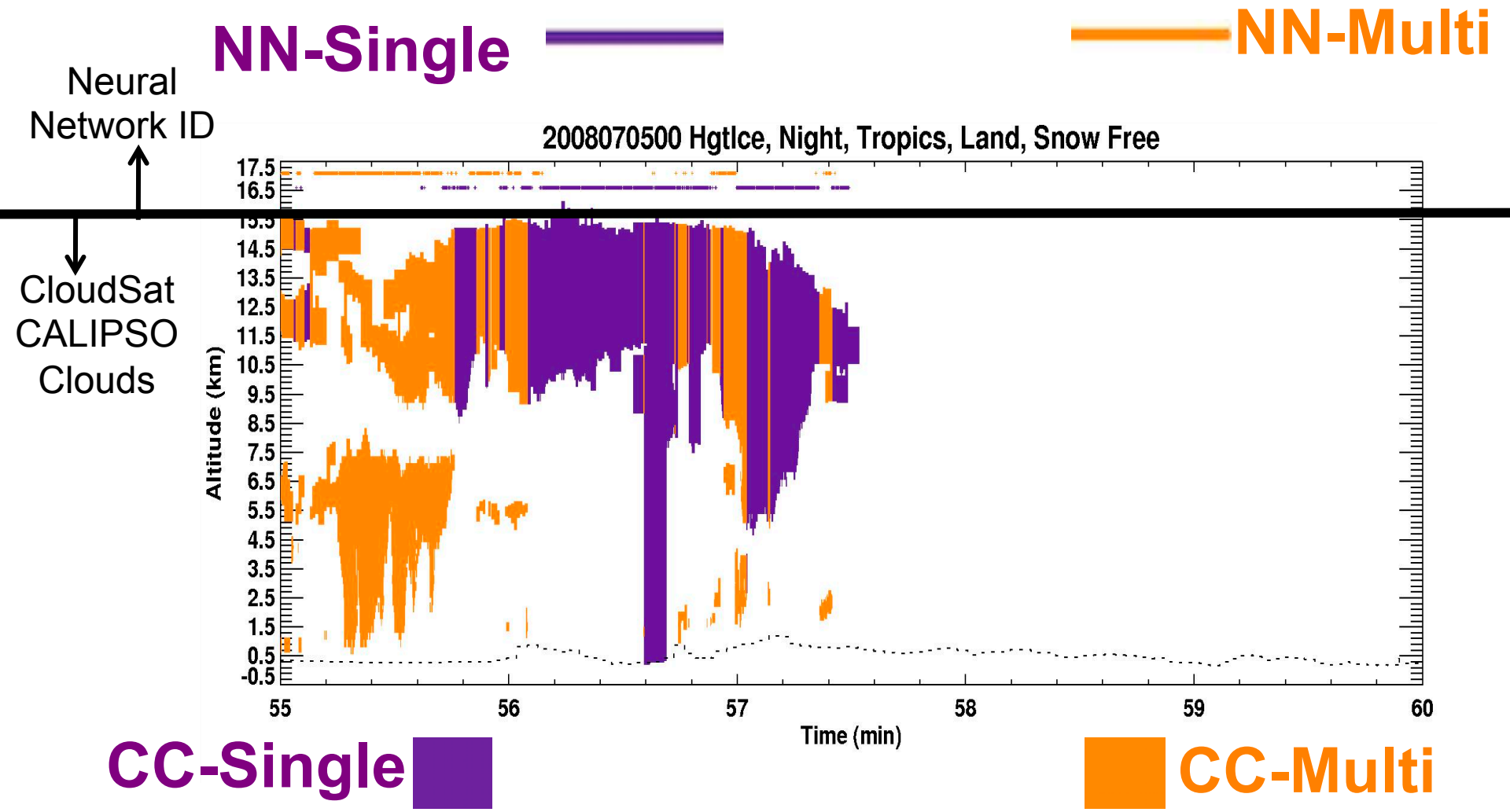
Neural Network Multilayer Identification: C3M, July 2008

Day 2, Hour 22, Day Time, Mid-latitude, Ocean



Neural Network Multilayer Identification: C3M, July 2008

Day 5, Hour 0, Night Time, Tropics, Land



Neural Network Multilayer Identification: C3M, July 2008

N = 3.1 million CloudSat / CALIPSO ice clouds pixels

NN	**CC**	
%	Single	Multi
Single	**45.6**	**16.5**
Multi	**9.3**	**28.6**

Percent Correct: 74.2 (day + night)
Percent Wrong: 25.8 (day + night)

Reminder: Training percent correct: ~ 79% for day time and ~ 72% for night

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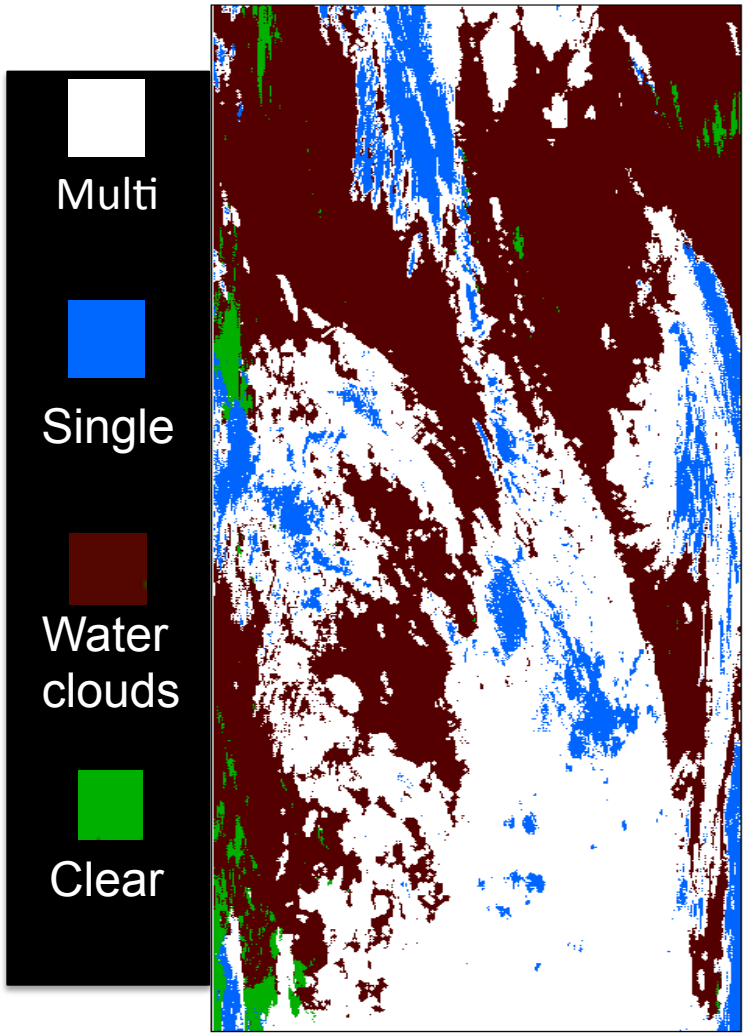
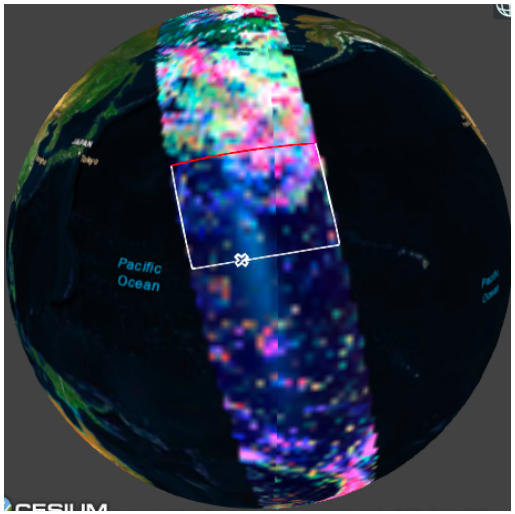
Neural Network Multilayer Identification: **Aqua-MODIS**, July 2010



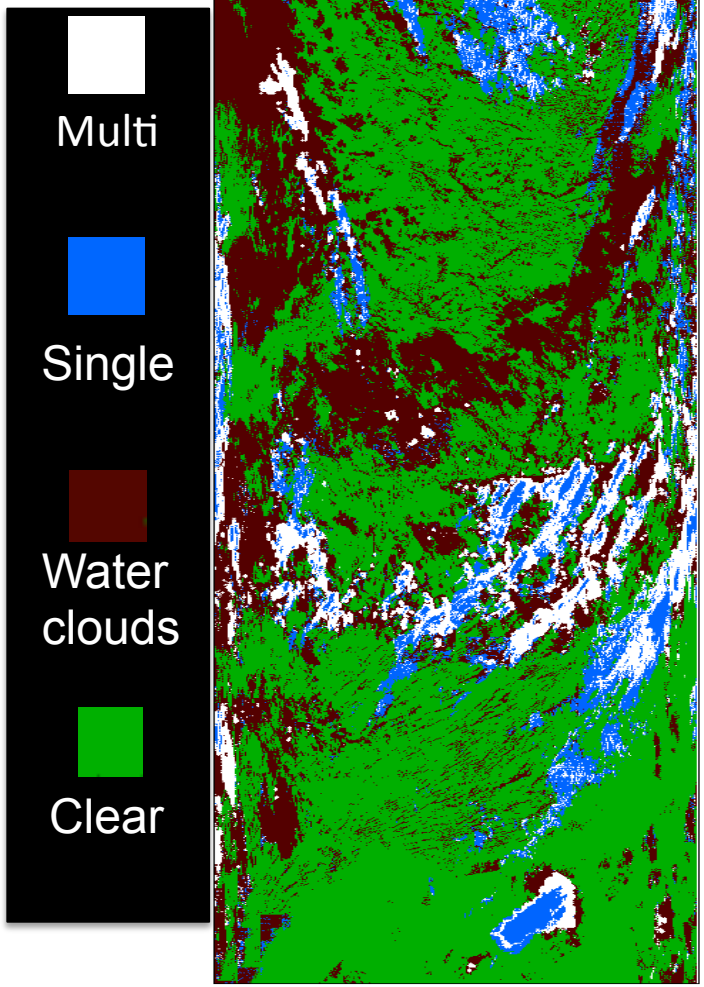


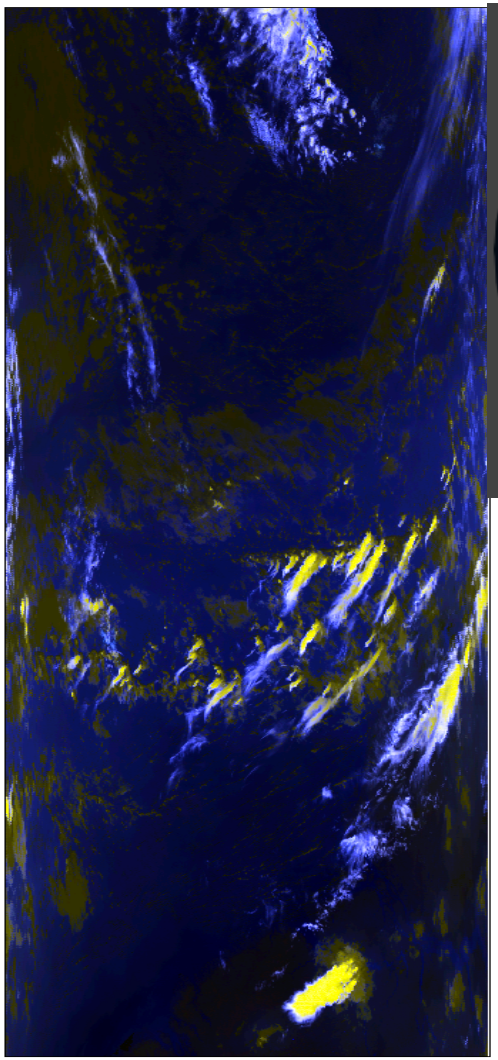
Day Time

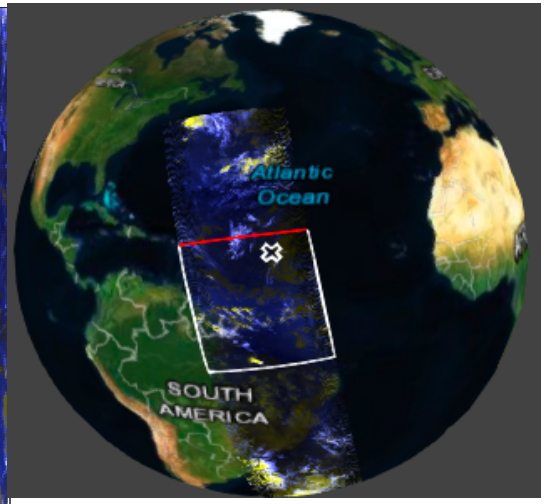
Day 15
Hour 01

RGB
Red: 11, Green: 12, Blue: 3.7-11 μm

Neural Network Multilayer Identification: **Terra-MODIS**, July 2010





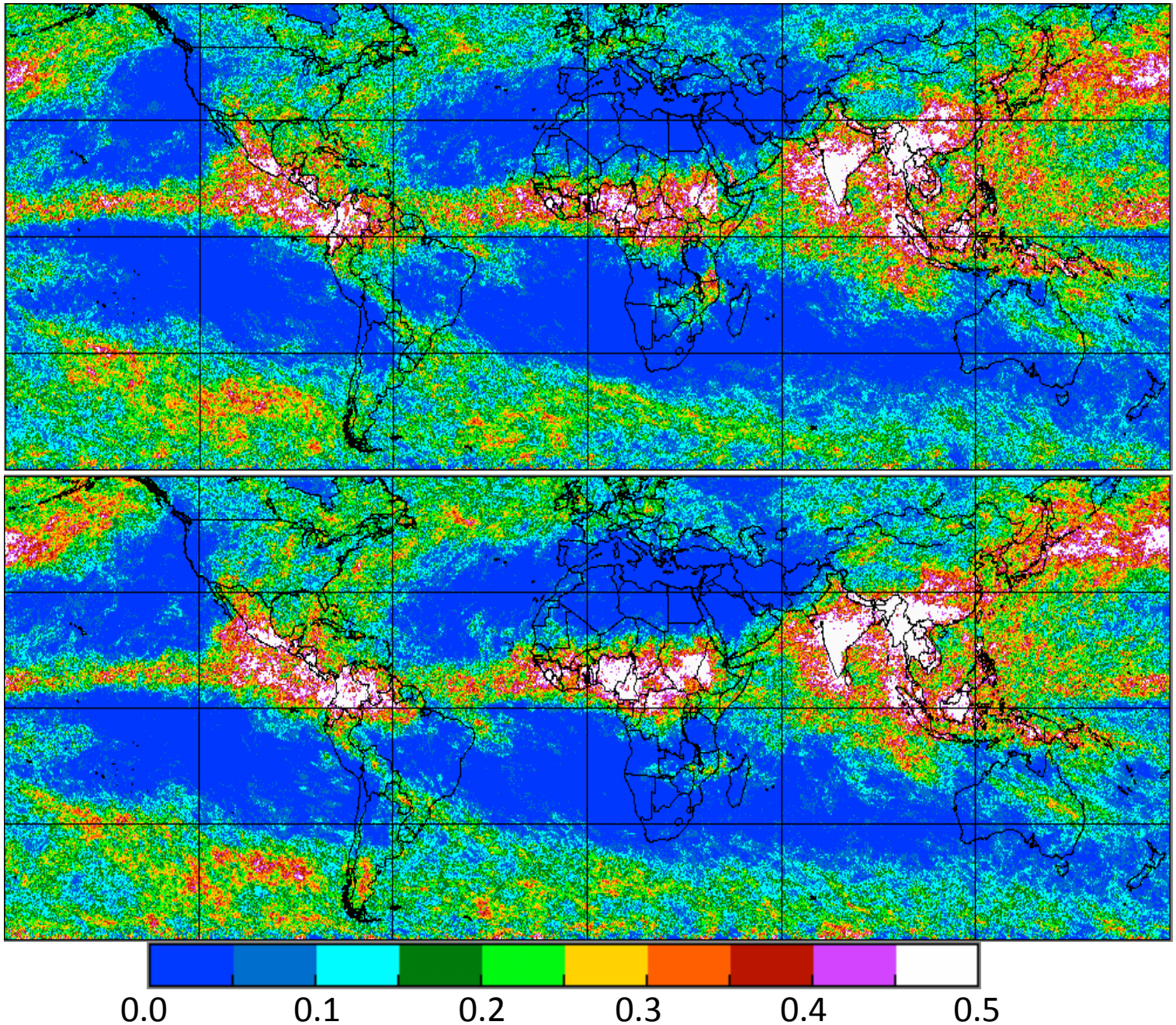


Night Time

Day 14
Hour 01

RGB
Red: 11, Green: 12, Blue: 3.7-11 μm

Multilayer Fraction, July 2010, **Day Time**, Non-Polar

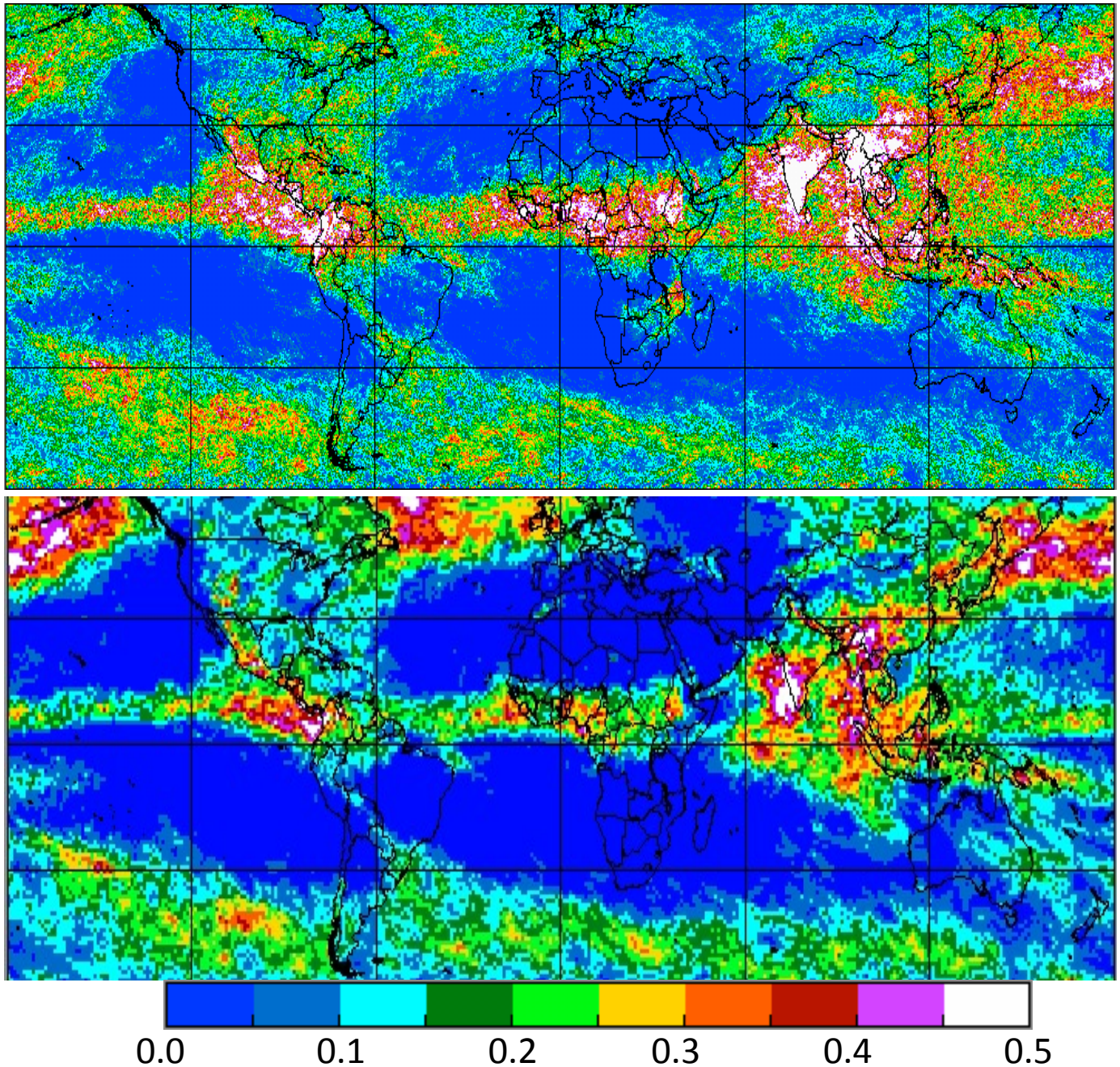


Aqua

Fairly Consistent

Terra

Multilayer Fraction, July 2010, **Day Time**, Non-Polar

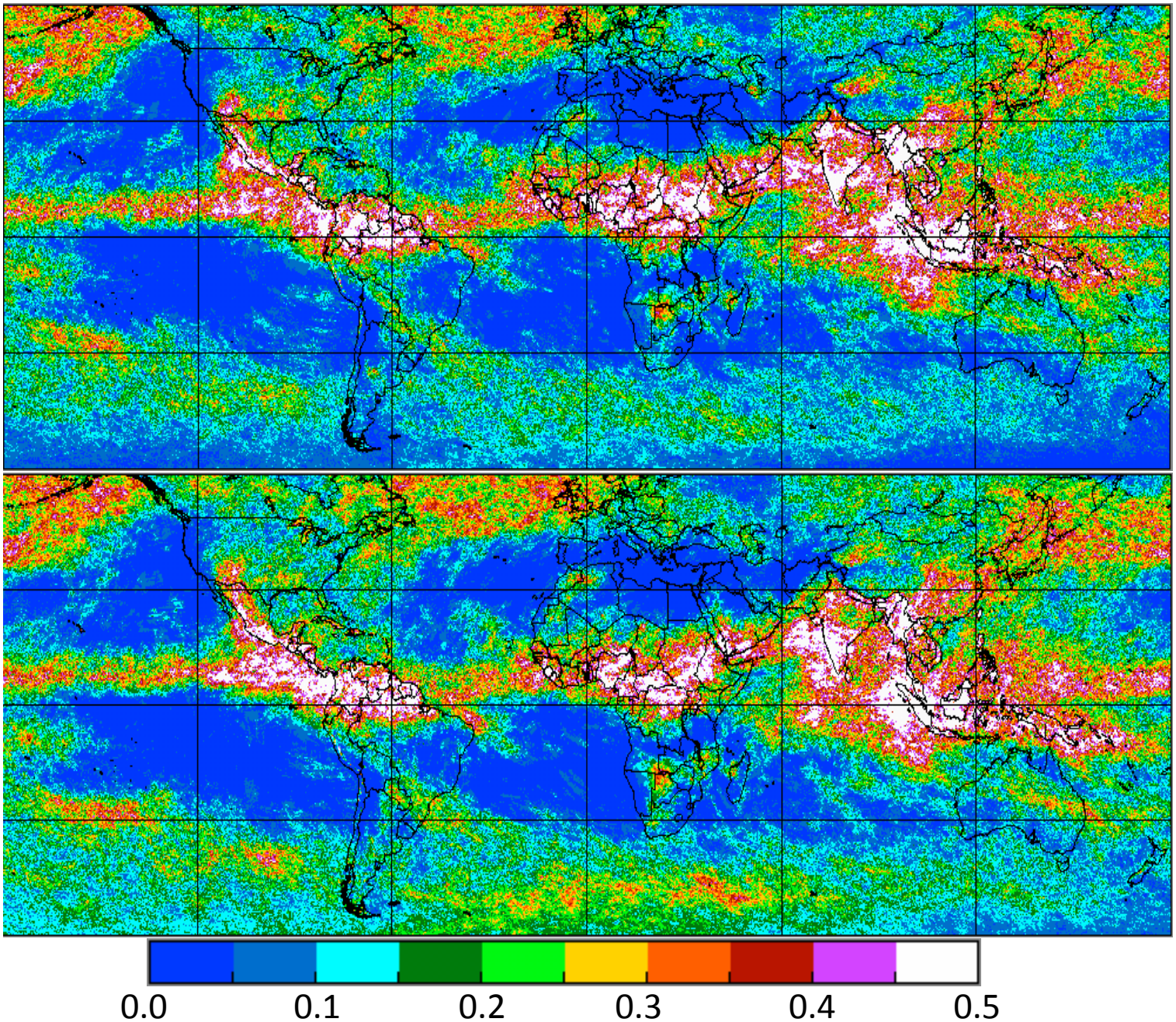


Aqua NN

Significant Differences

Aqua CEM

Multilayer Fraction, July 2010, **Night Time**, Non-Polar



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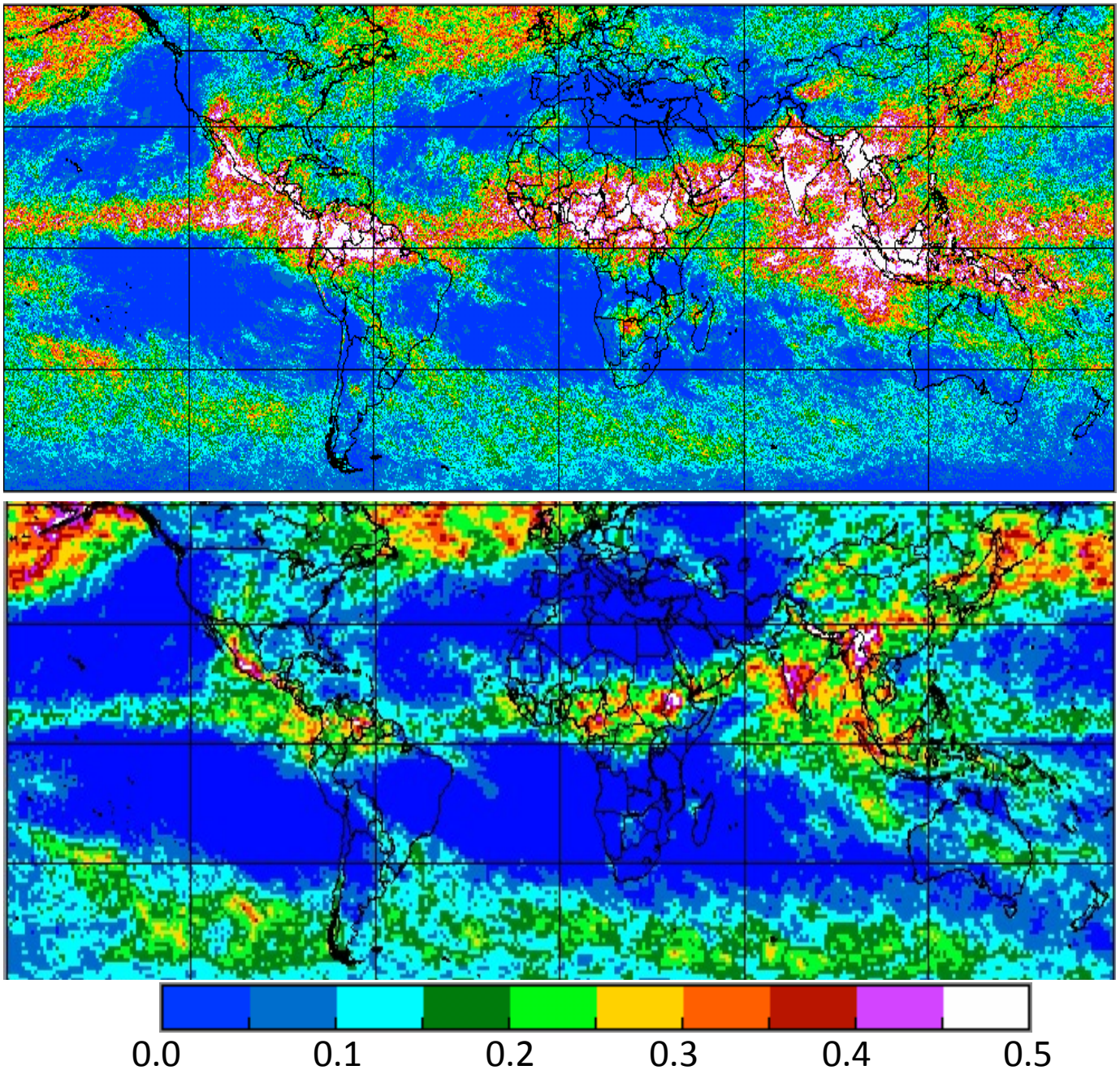
Multilayer Fraction, July 2010, **Night Time**, Non-Polar



Aqua NN

Significant Differences

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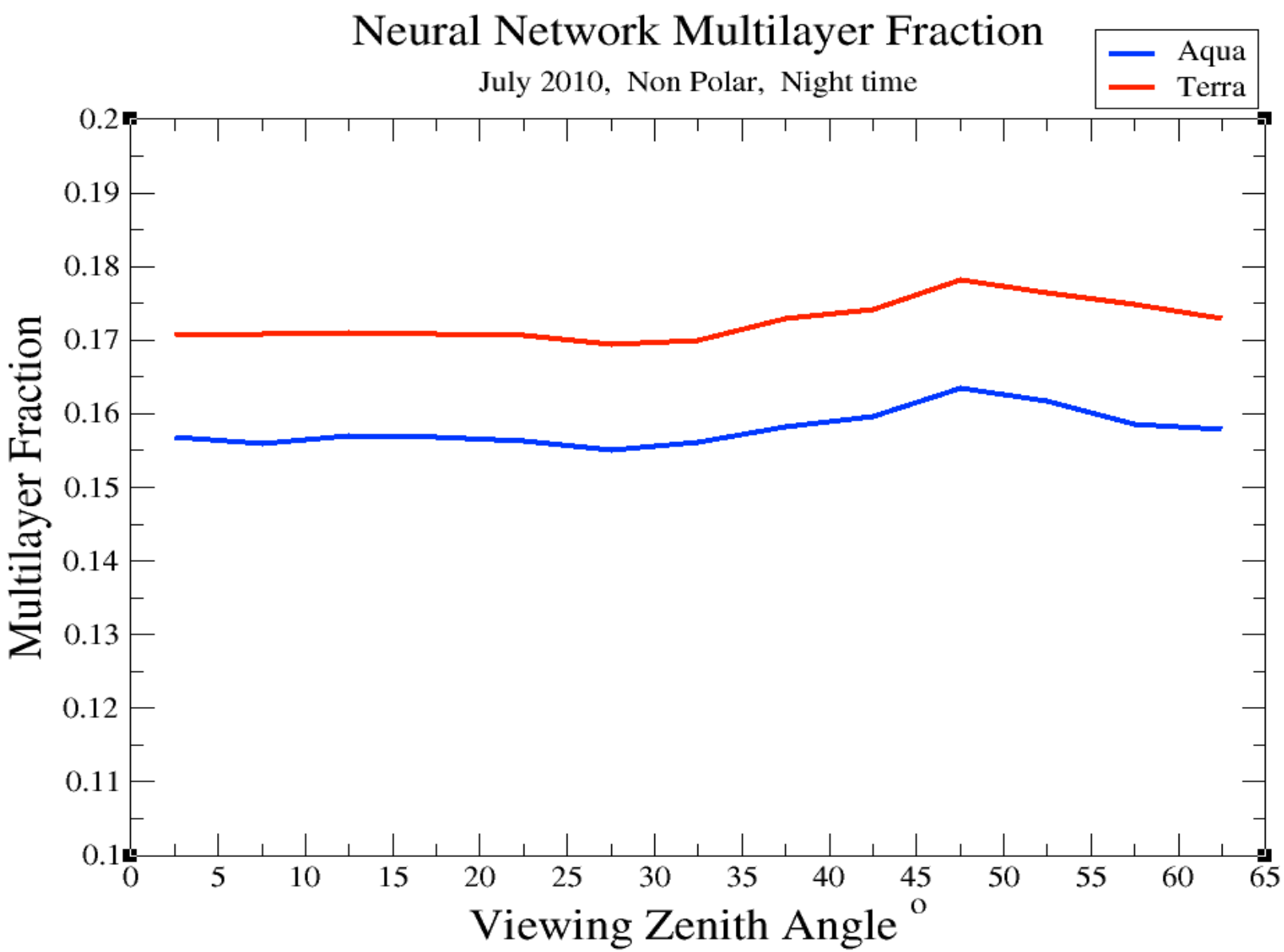
Multilayer fraction as a function of view zenith angle



Summary

- Initial test of neural network multilayer classification is quite promising

- Compared with CloudSat/CALIPSO, the percent correct ~ 74%

- Trained Neural Network with CloudSat/CALIPSO can be applied to other remote sensing data

- Multilayer fractions are very consistent between Terra and Aqua for both day and night, but quite different when compared with CEM_multi.

- Trained neural net was done in the nadir. When applying the same neural net to Terra and Aqua, multilayer fractions are fairly flat independent of view zenith angle.

Future Plan

- Optimize Neural Network (NN) multilayer classification:
  1. Train NN day time without ref(0.6) & ref(1.24), keep 1.38 for non-polar and 2.13 for polar
  2. Train NN over polar regions or snow/ice surfaces
  3. Perform sensitivity studies of vertical clouds separation assumption (1 km, 2 km, maybe 3 km)
  4. Train NN for NPP-VIIRS (no WV) with reduced IR channels. Could apply the NPP NN to all three satellites (Aqua, Terra and NPP) to hopefully get the similar or consistent results.
  5. More validations, e.g. CloudSat/CALIPSO multilayer maps
- Use NN method to obtain cloud properties (Z_{eff}, t, etc) for the top cloud layer. Then use radiative transfer models to retrieve cloud properties for the lower cloud layer.