Remote sensing of liquid cloud properties: Where is the physics?

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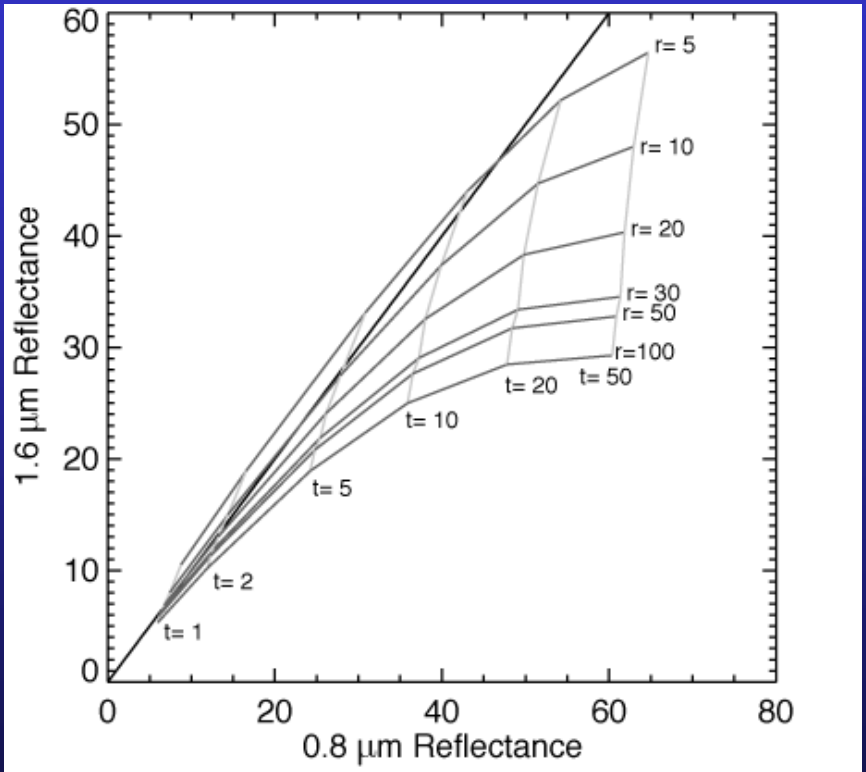
University of Wisconsin

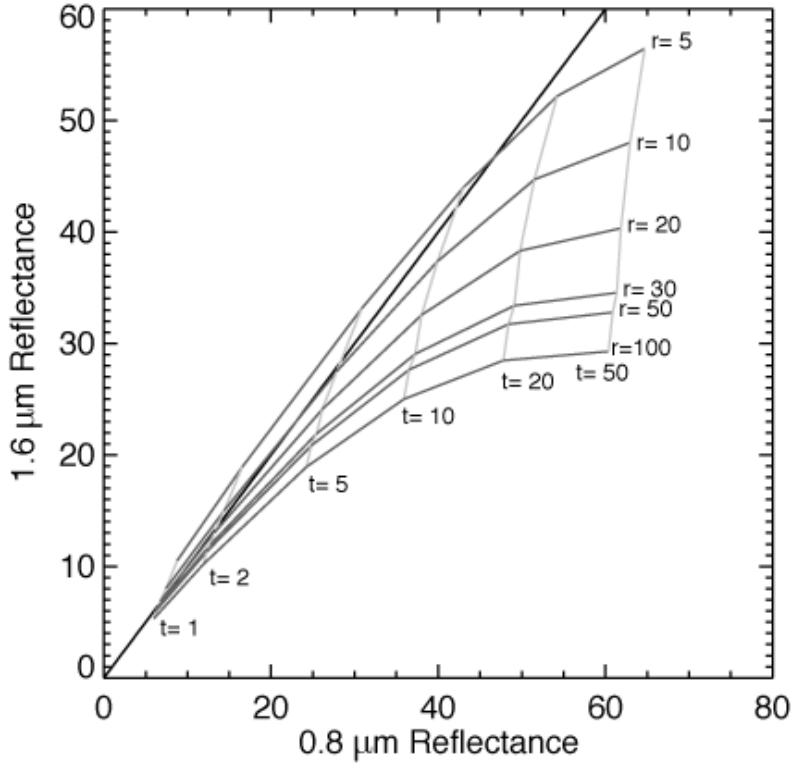
Outline

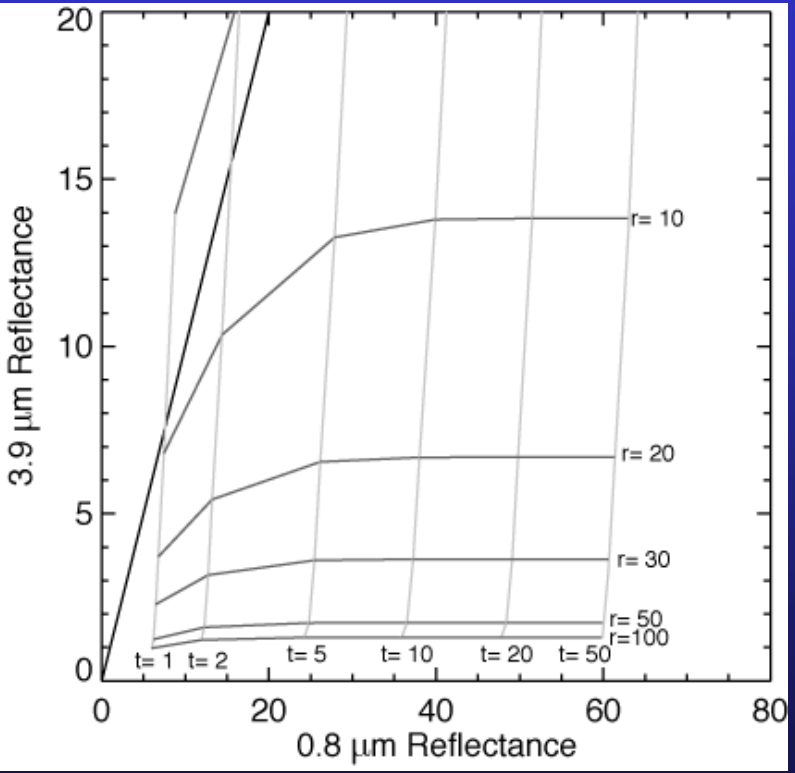
- Some basics
- Effective radius: Something is missing….
- Liquid water path
- Conclusions

Nakajima-King retrieval

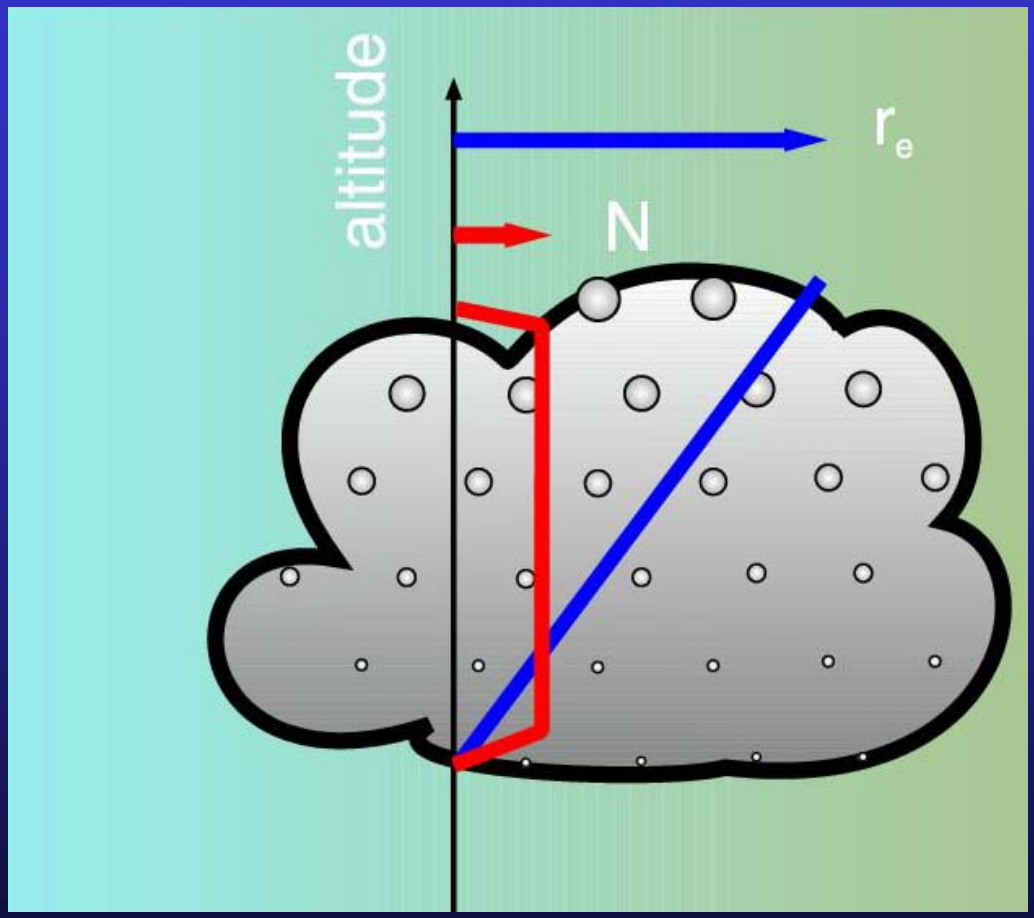


Nakajima-King retrieval

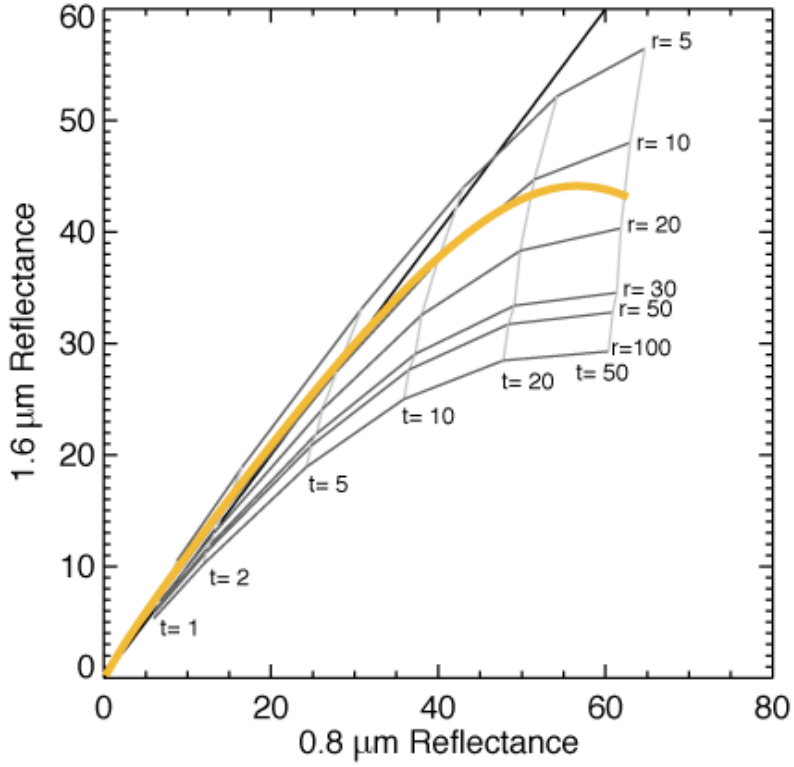


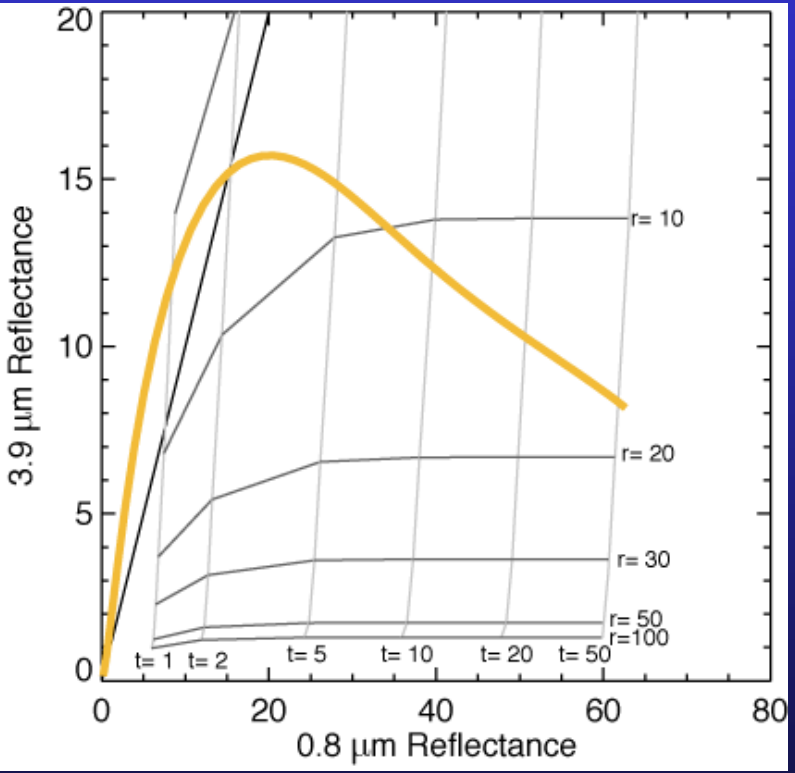


(Sub) adiabatic stratiform clouds

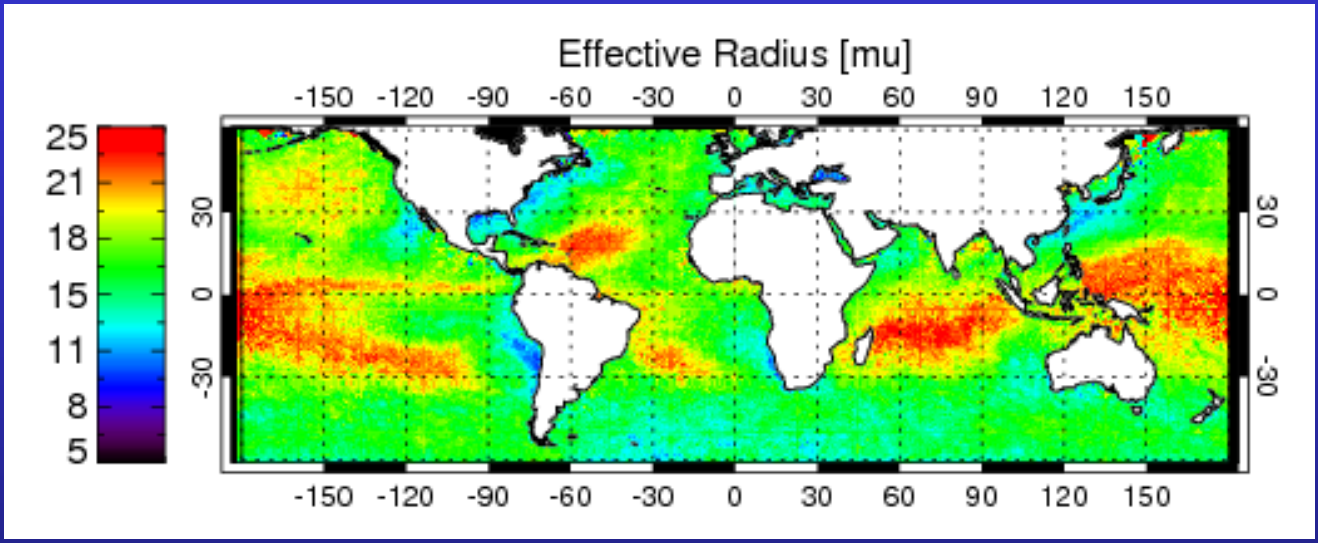


Adiabatic cloud





Effective Radius



We are done!

- Retrieval of two key cloud parameters based on two independent measurements
- Easy to implement based on LUTs, OE, or any other inverse technique
- Physical interpretation straight forward: *“We retrieve the effective radius and optical thickness of a plane-parallel, vertically homogeneous cloud matching the observed radiances”*

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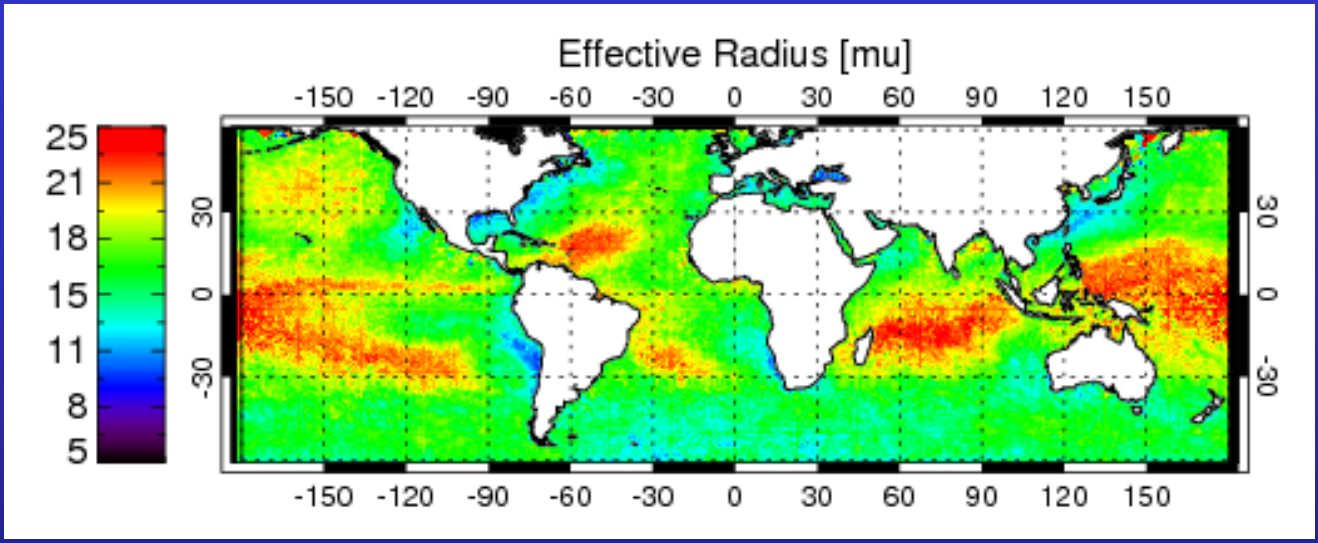
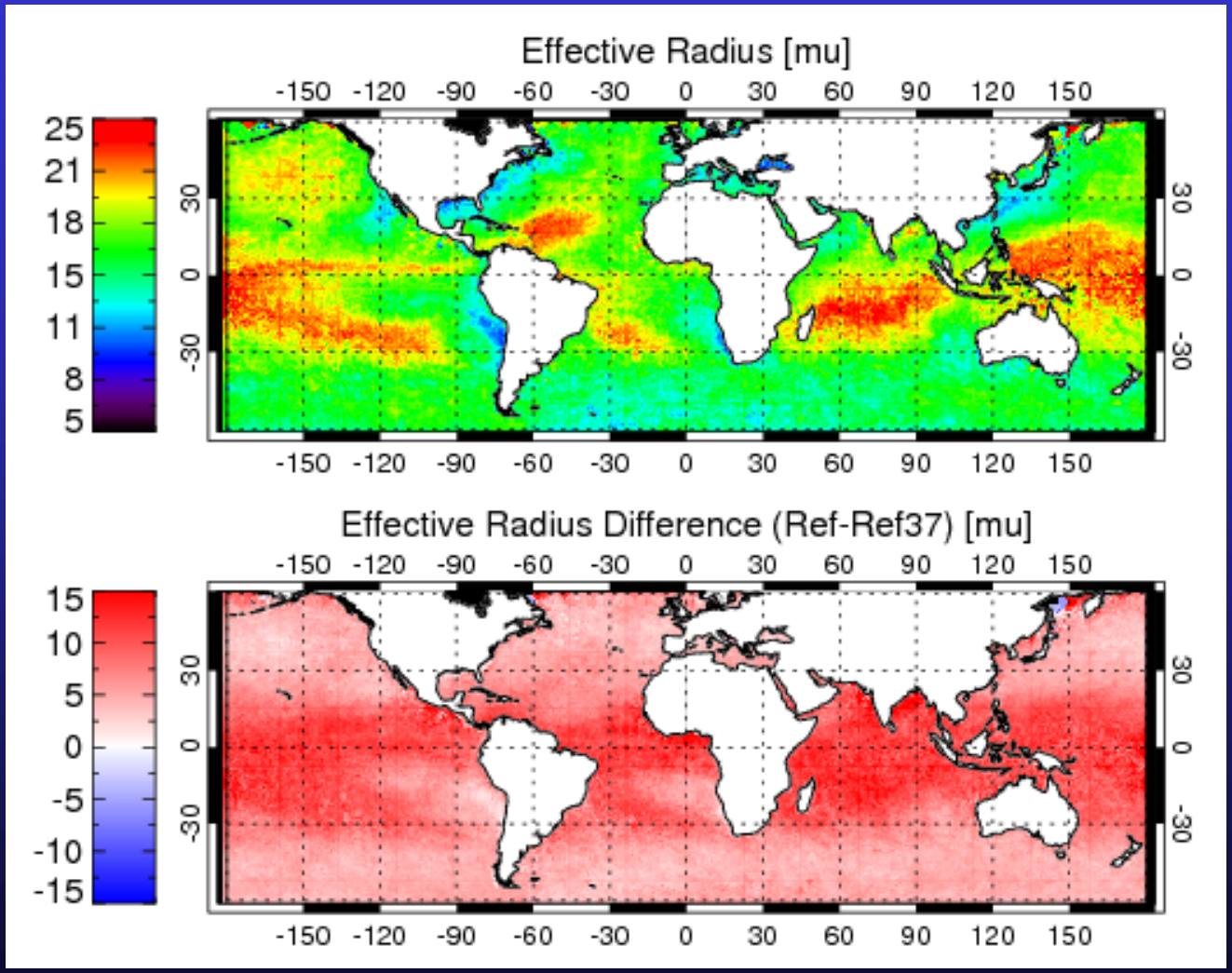
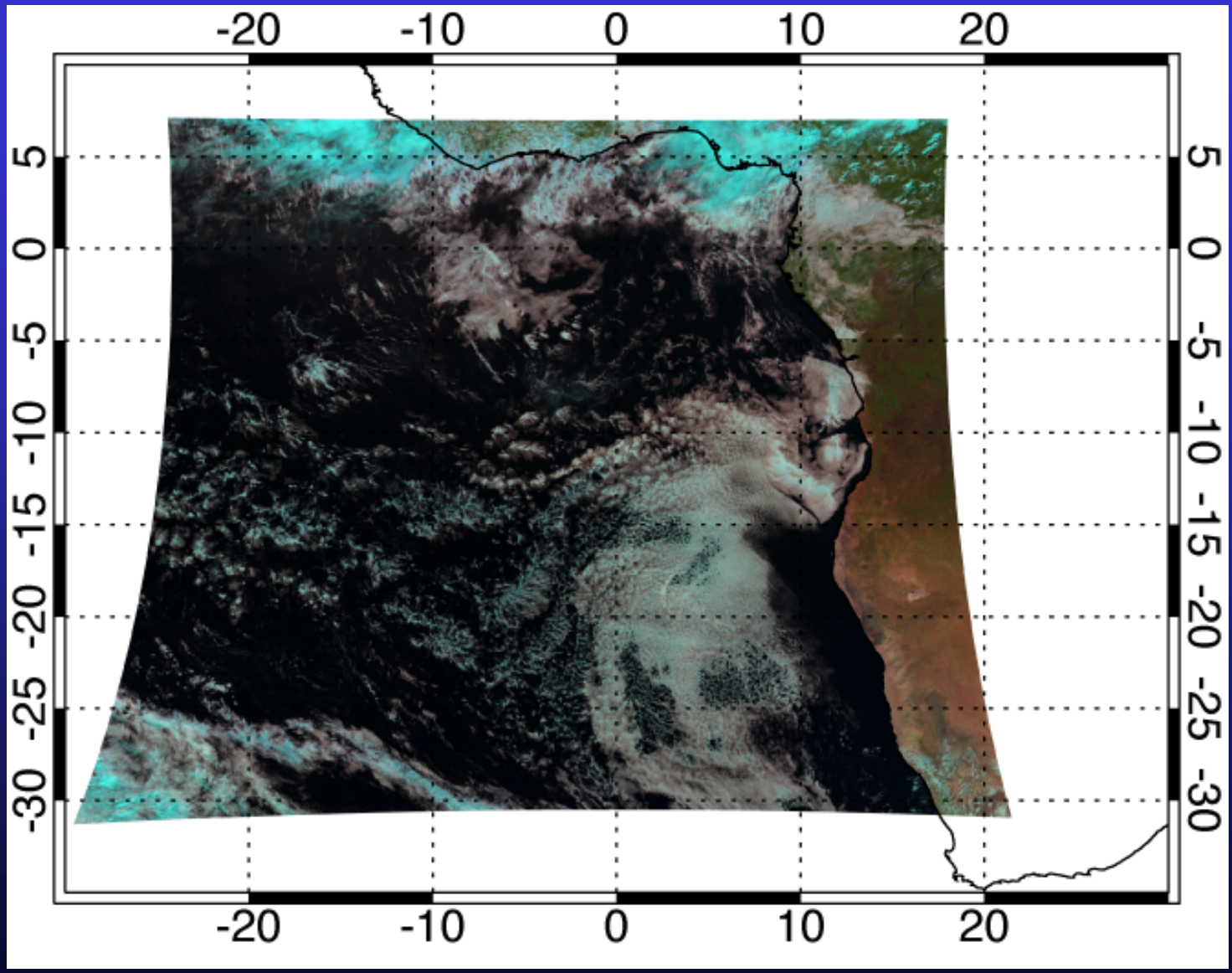
Or, are we?

Effective Radius



Effective Radius

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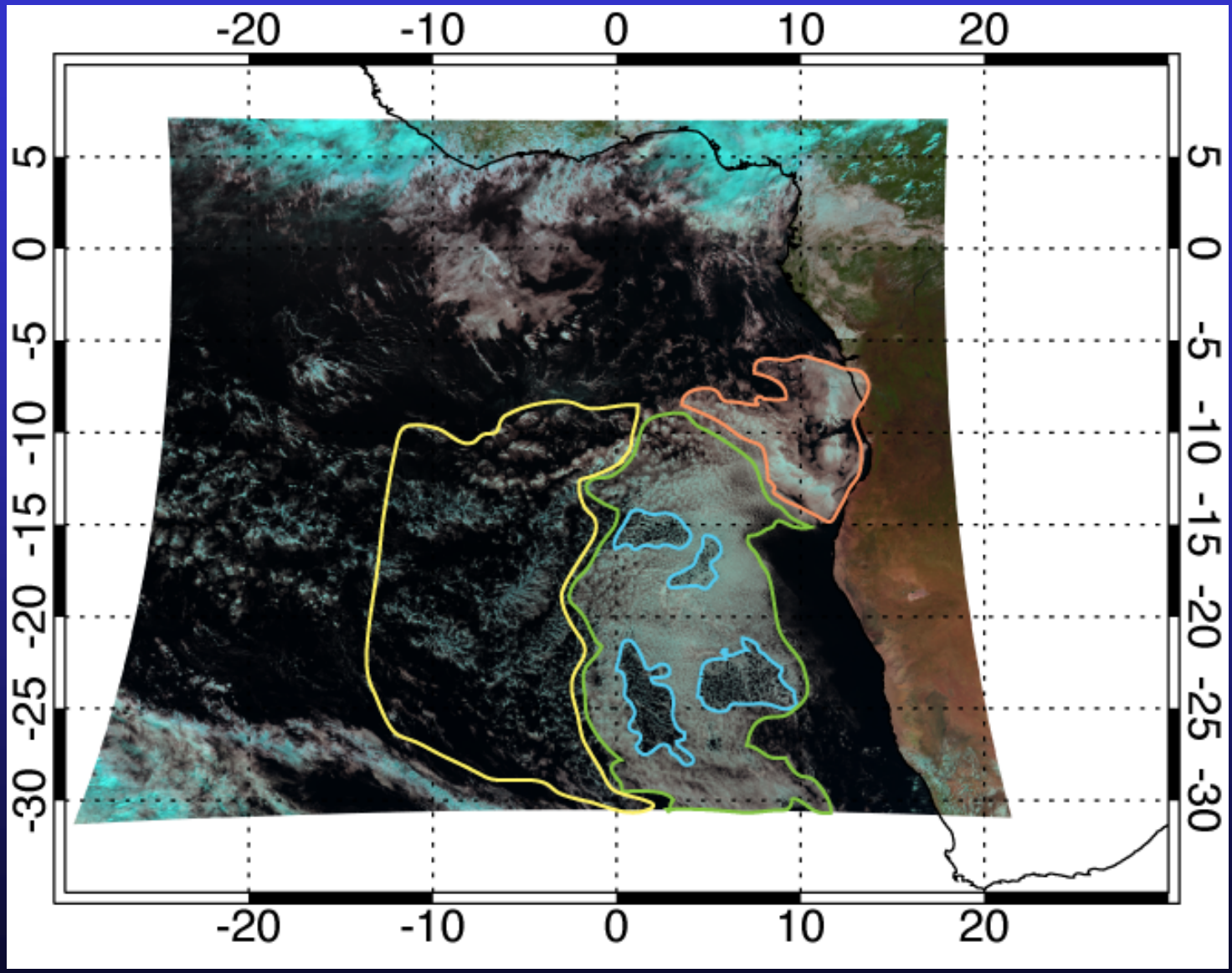
-30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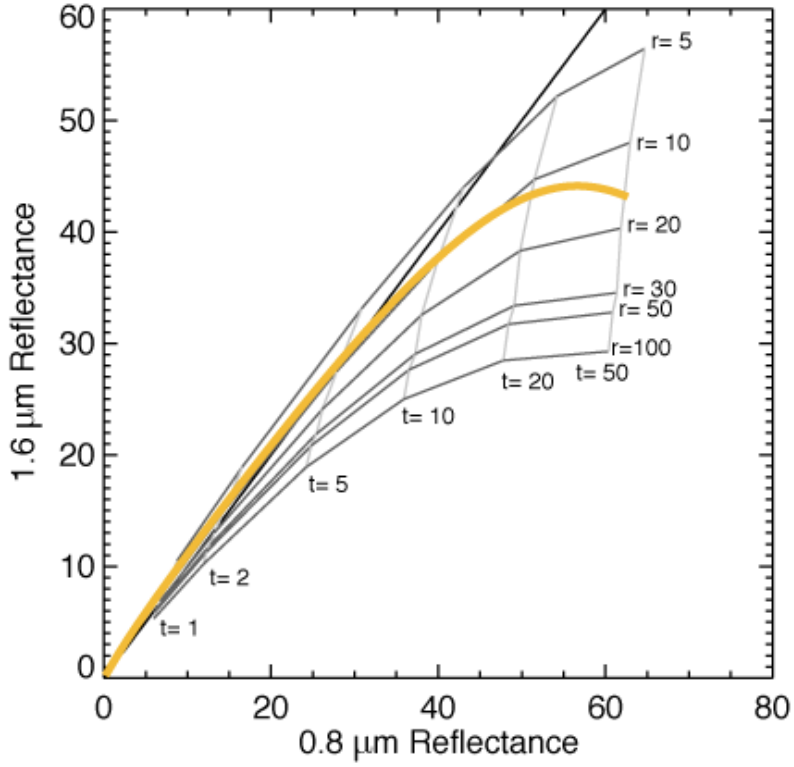
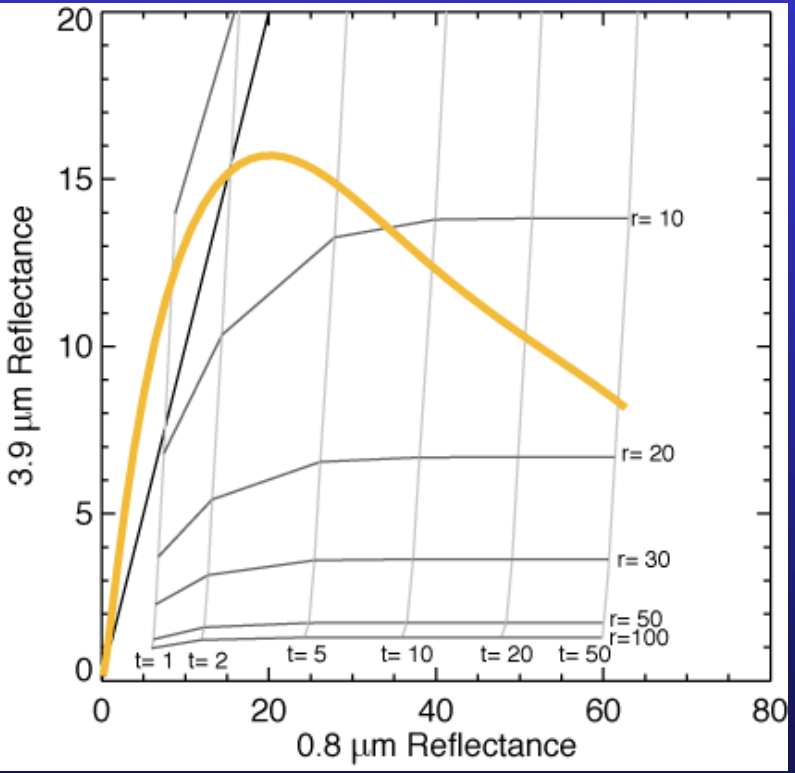
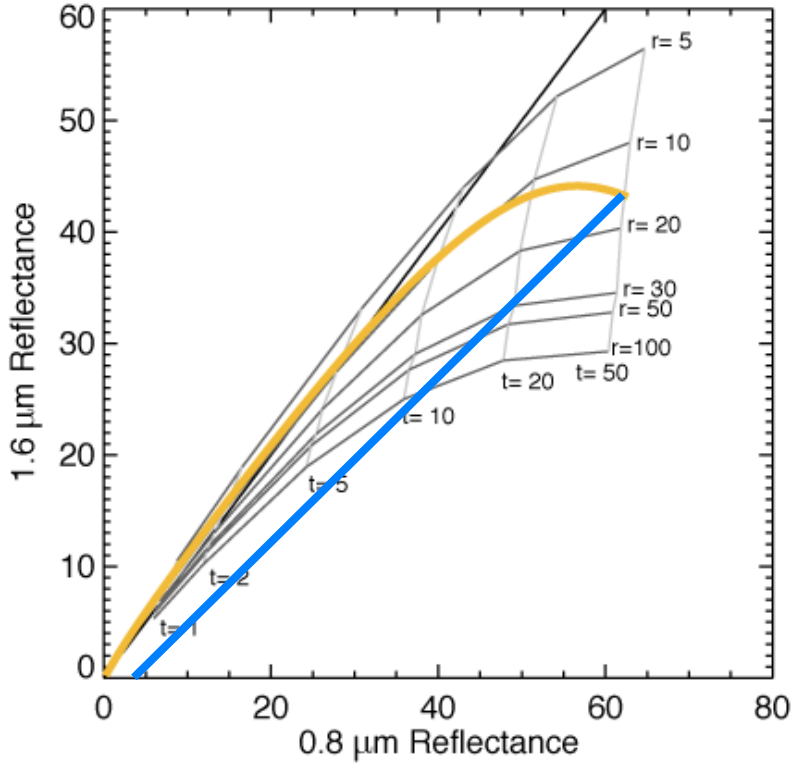
Adiabatic cloud

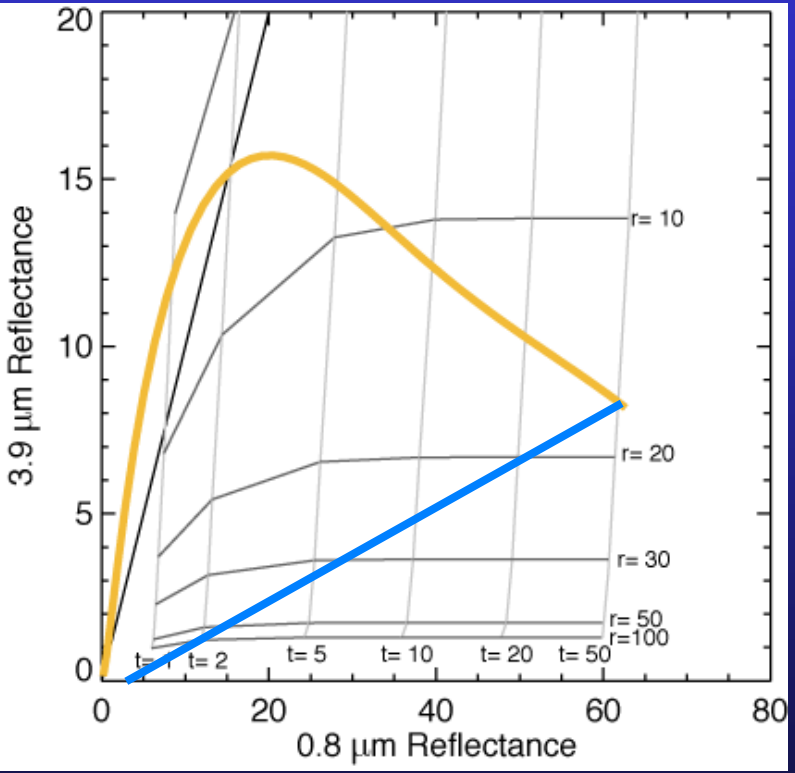




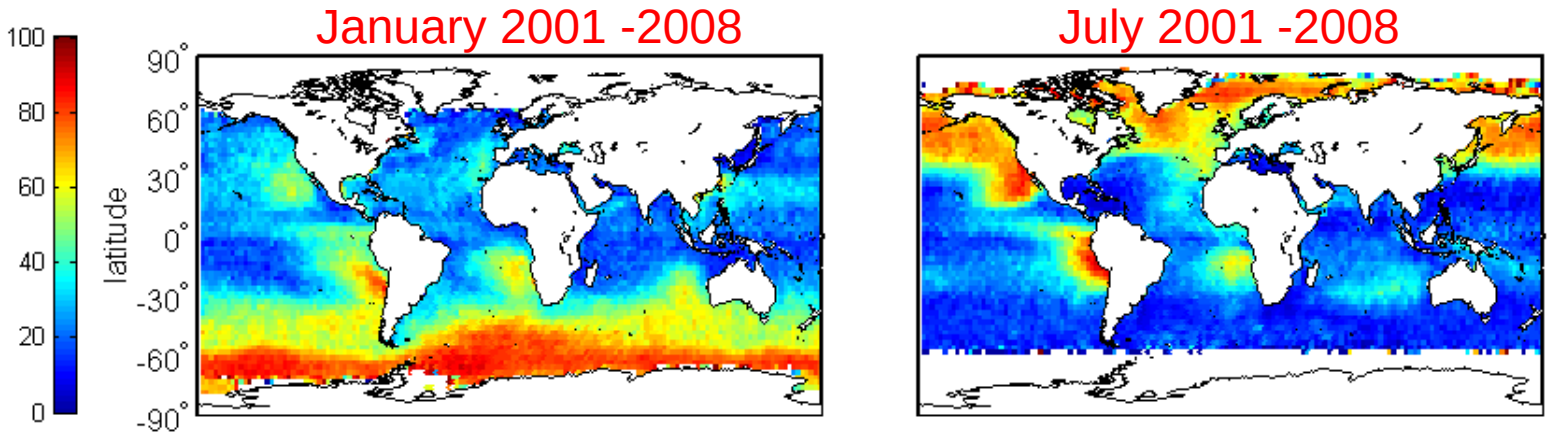
Adiabatic cloud

Fractional coverage with open water within FOV



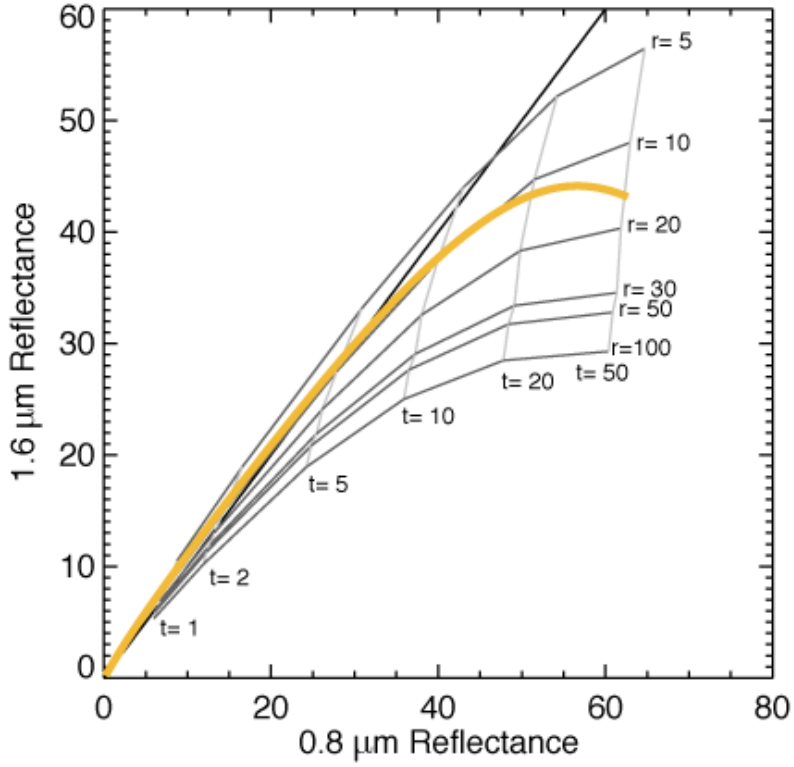


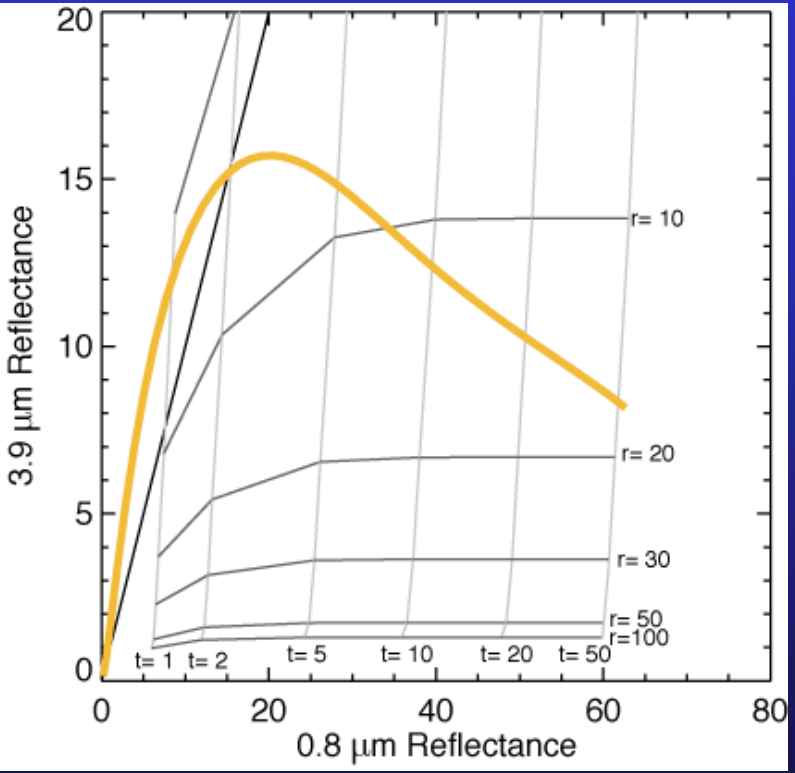
Frequency in which the BRF is angularly consistent in BRF to within 5% of its plane-parallel value (from *Di Girolamo et al. 2010*)



Di Girolamo

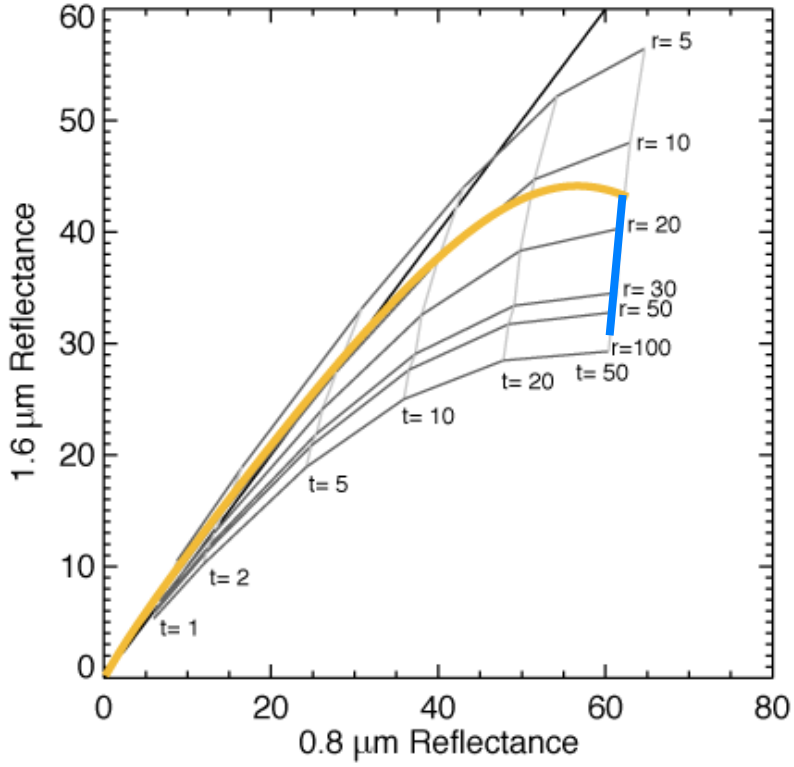
Adiabatic cloud

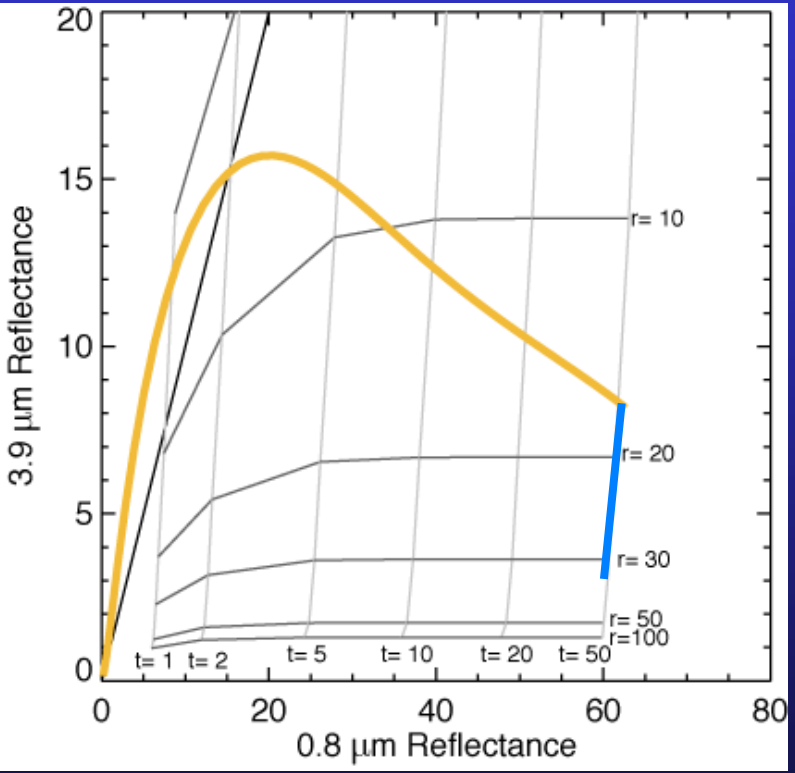




Adiabatic cloud

Partially glaciated (and not detected)

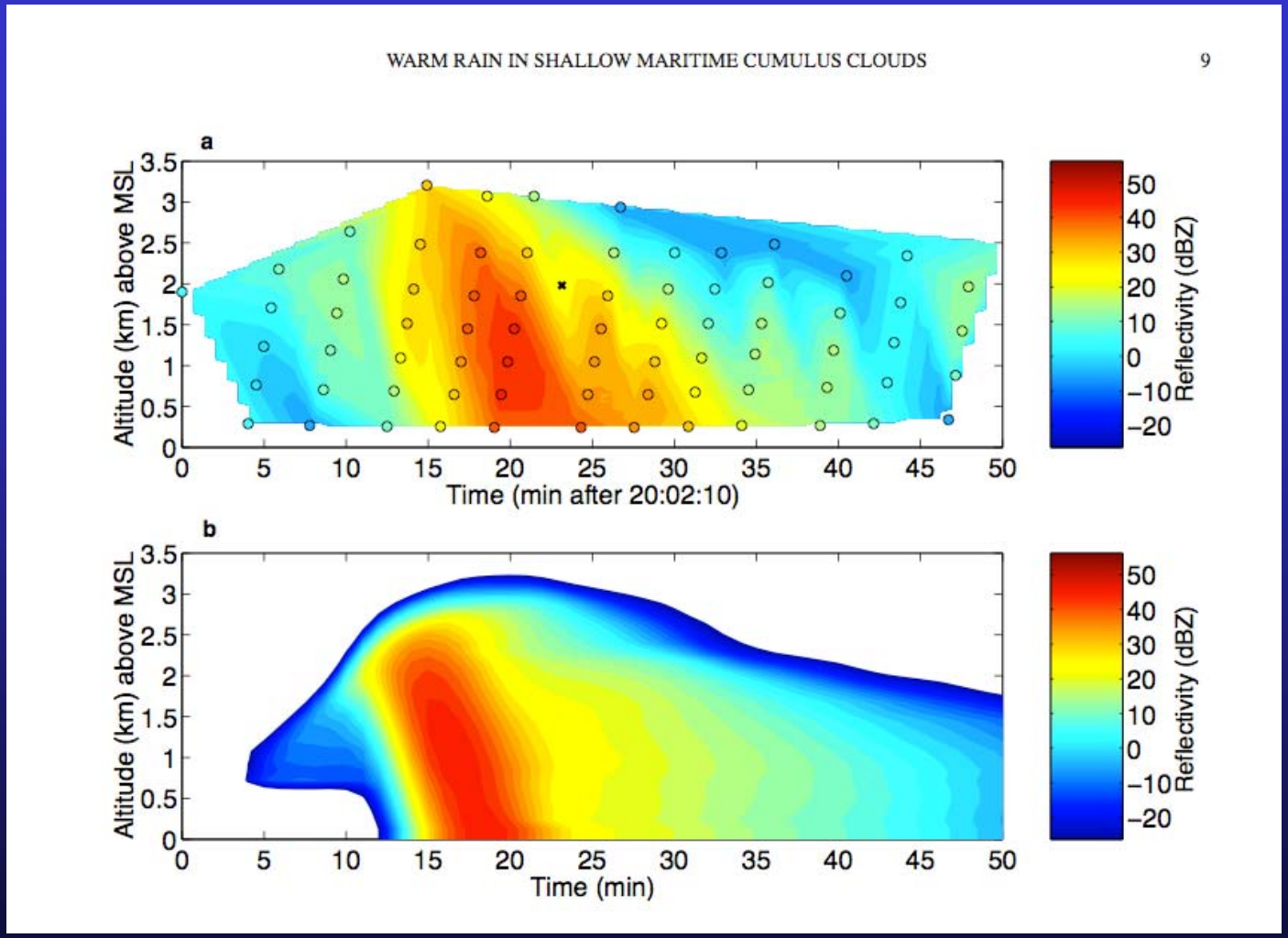




Warm rain

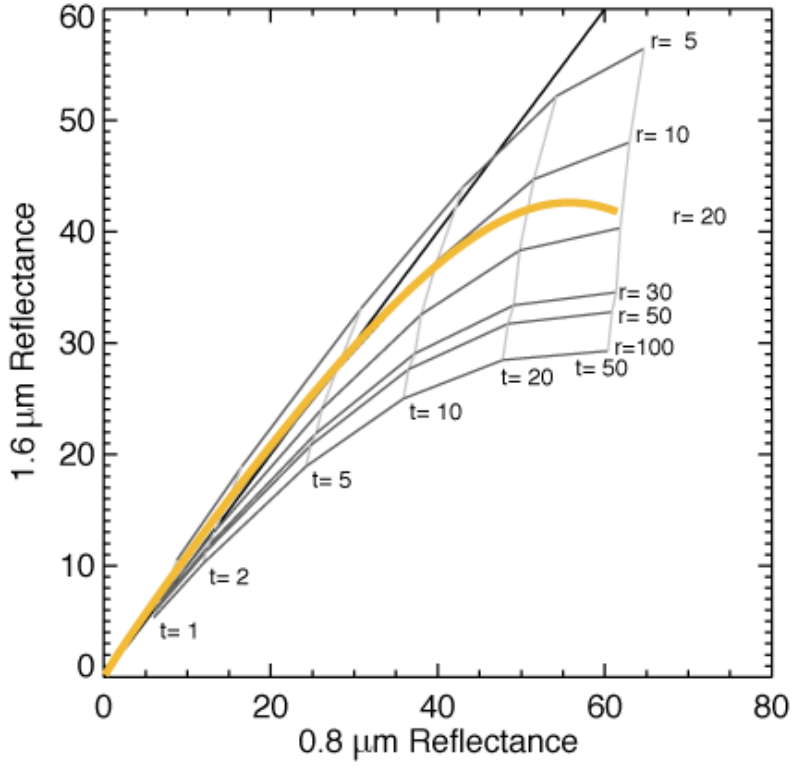
QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

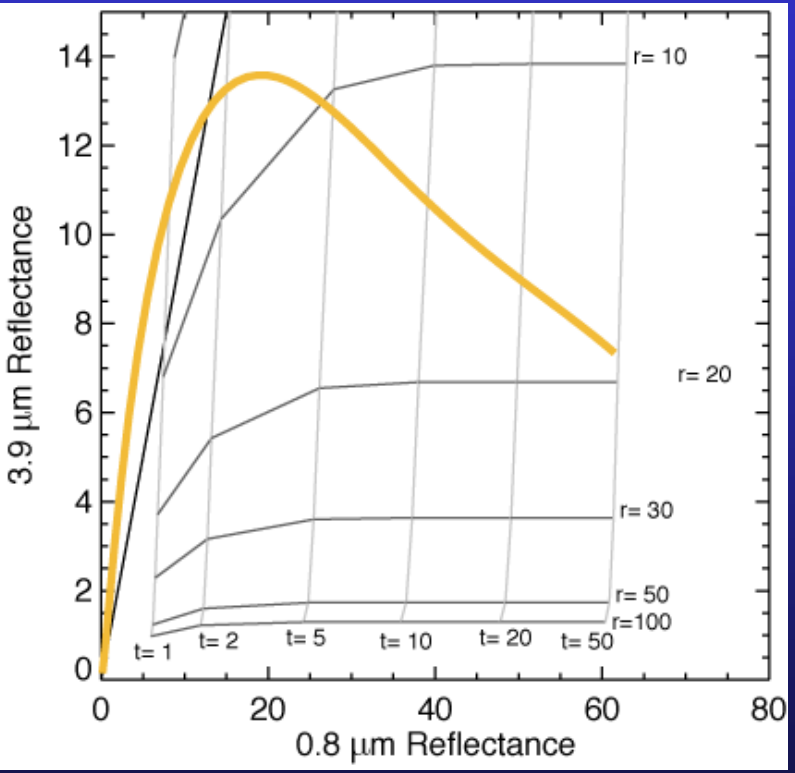
Warm rain



From Lowenstein et al., 2009, QJRMS

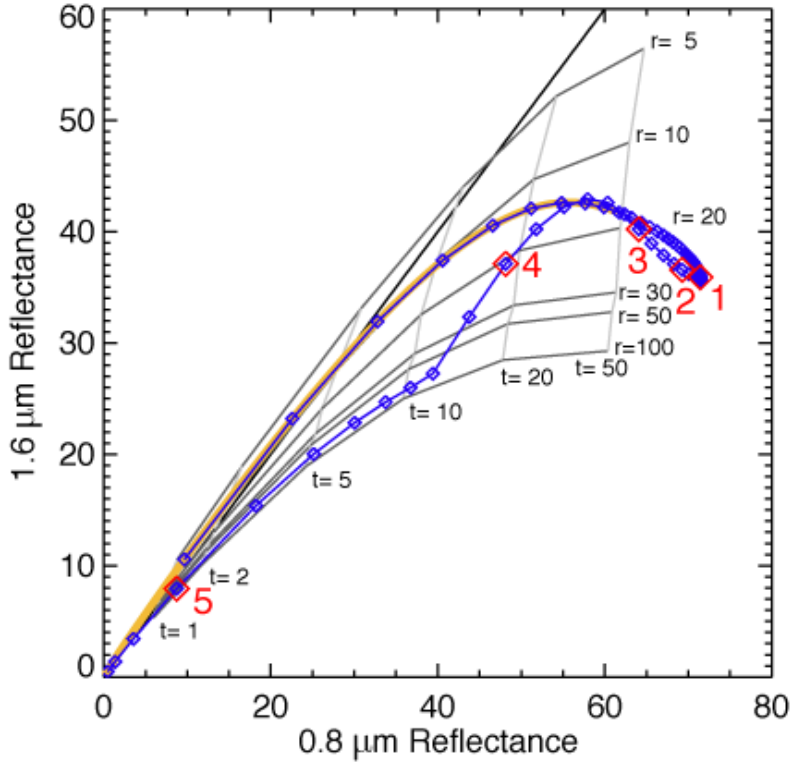
Simulated Cu cloud

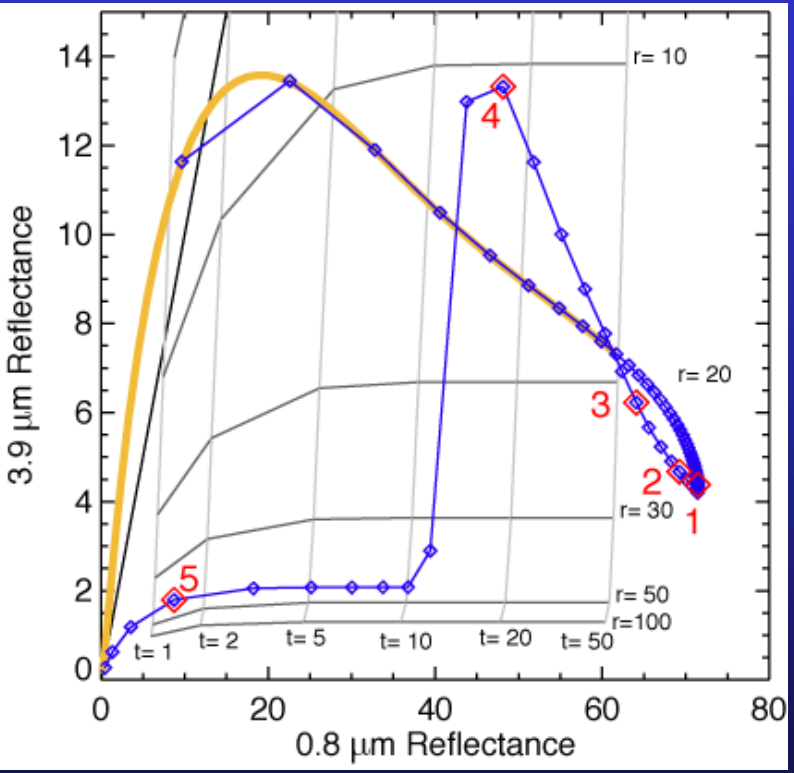




Simulated Cu cloud

Rain in field of view (not or only partly obstructed by cloud)





What causes the observed differences?

- Cloud-free
- Ice
- Rain
- Something else? (3D, maybe?)
- We do not know yet

Liquid water path

$$\tau_{MW} = \sigma \cdot LWP$$

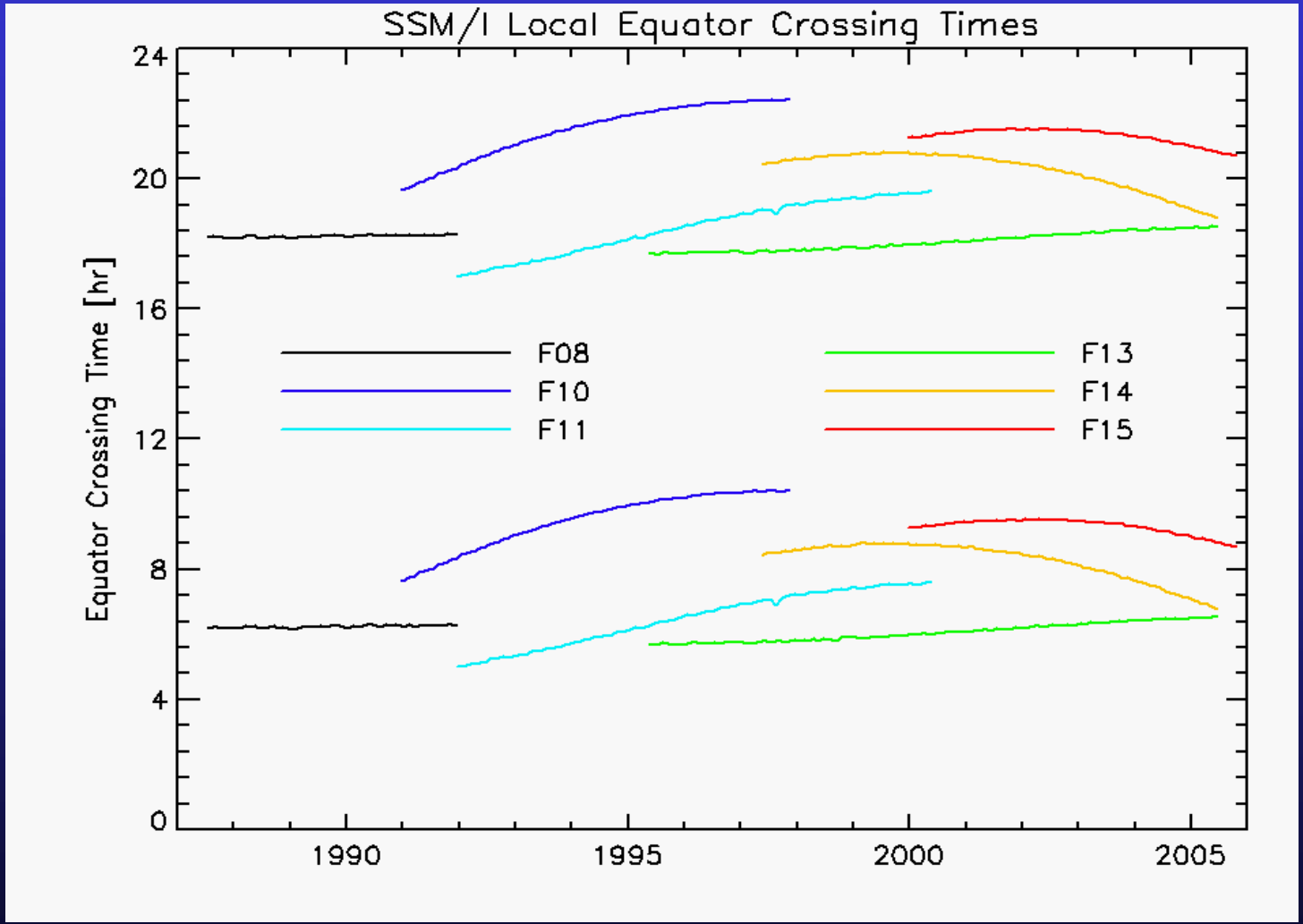
$$\tau_{VIS/NIR} = f \frac{LWP}{\rho_L r_{EFF}}$$

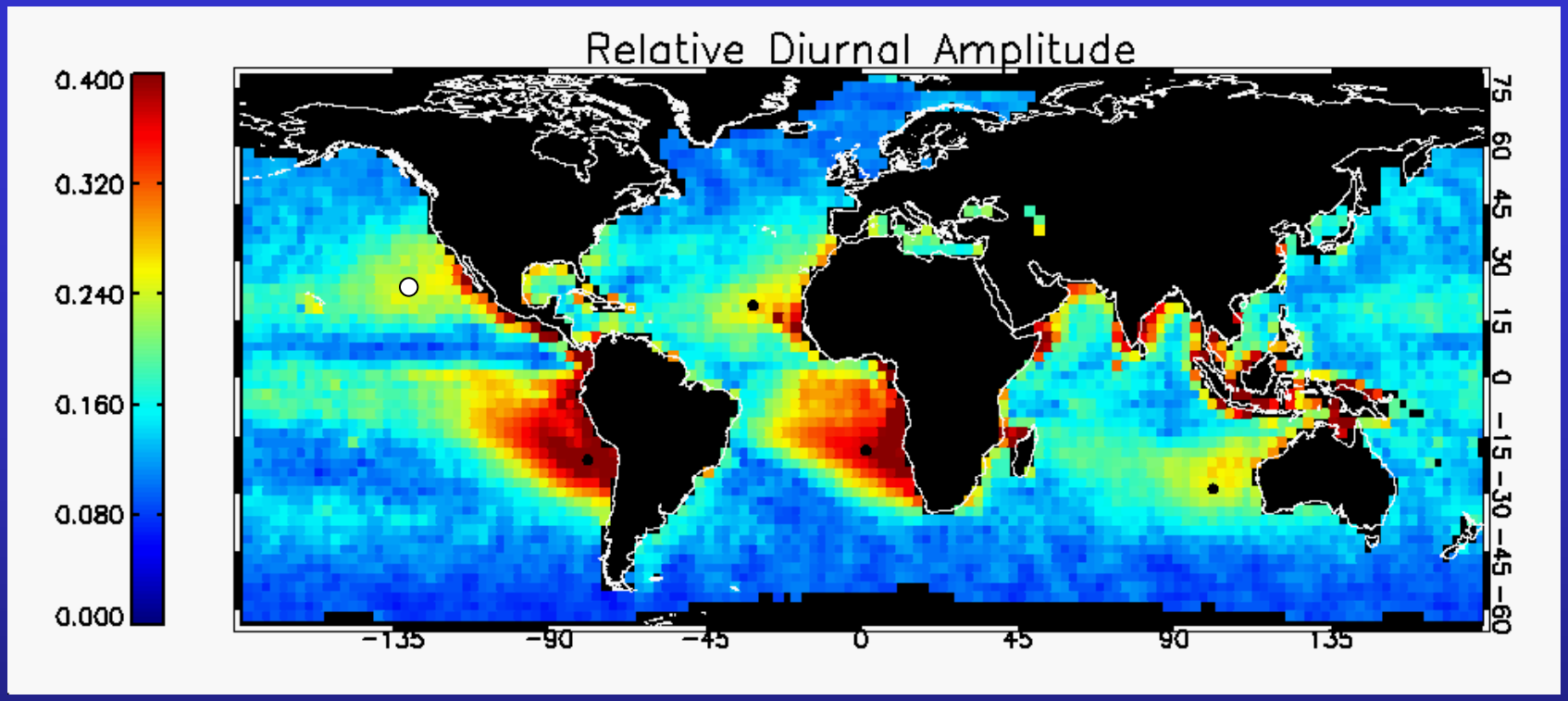
- MW: Very direct measurement. Mass absorption coefficient depends slightly on temperature, depends on rain water too
- VIS/NIR: Factor f depends on stratification of cloud (9/5 for adiabatic, 3/2 for vertically uniform)

Cloud liquid water path climatology

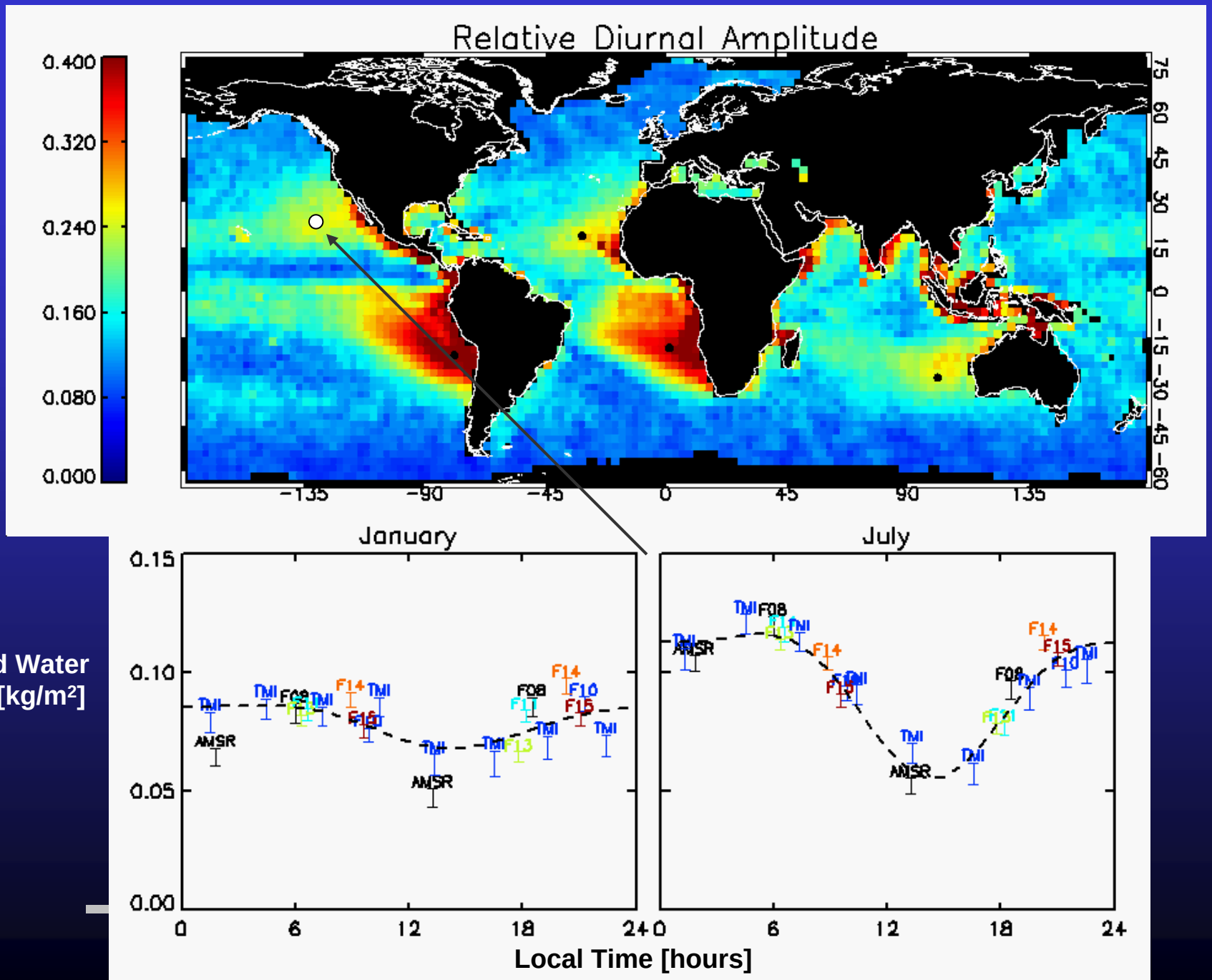
- Based on Wentz SSM/I since 1987, AMSR-E, and TMI
- Monthly diurnal mean liquid water path
- Climatological diurnal cycle
- O’Dell, Wentz, and Bennartz, J Climate, 2008
- Various limitations for high LWP (due to presence of rain), slight biases for low LWP

Special Sensor Microwave/Imager

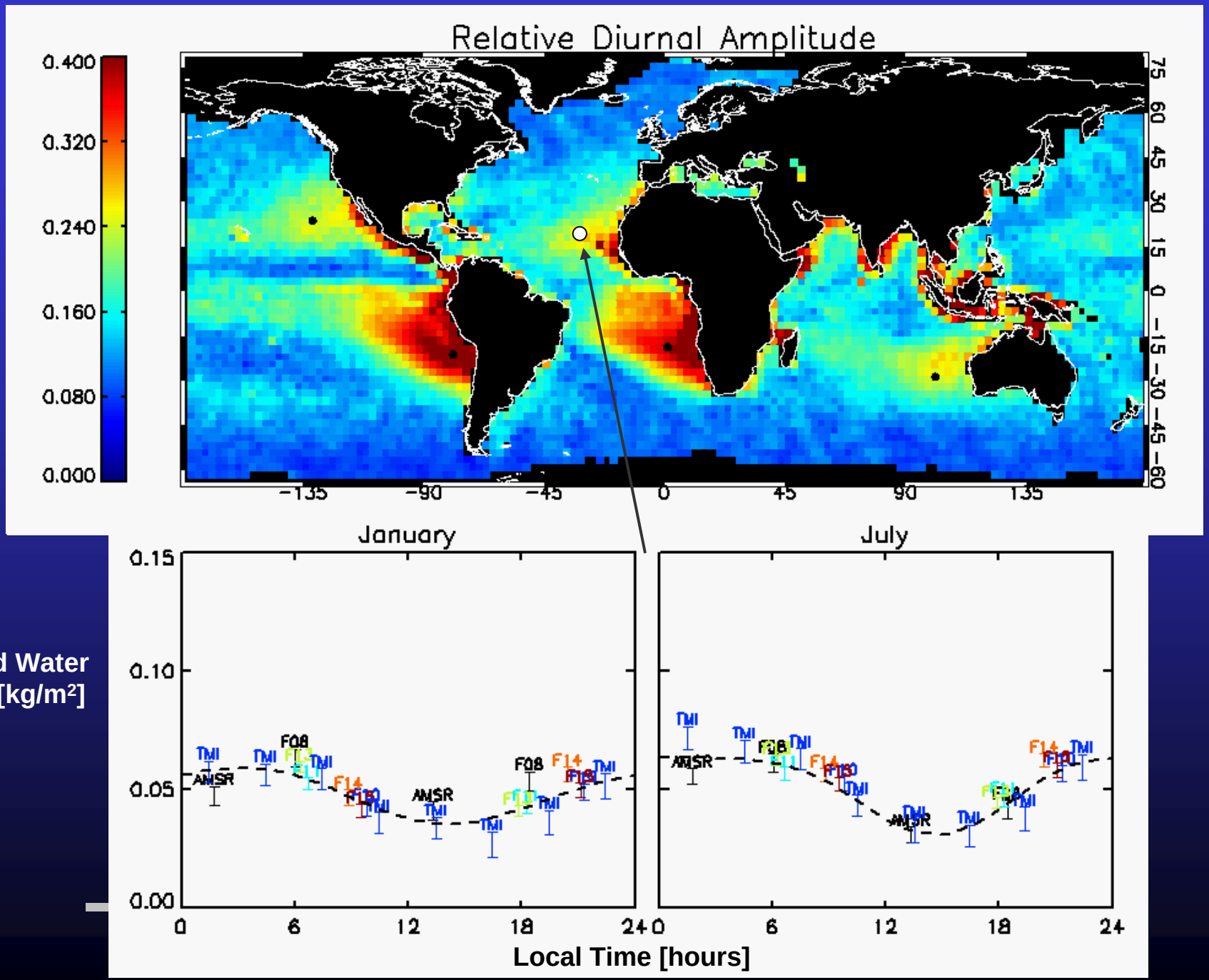




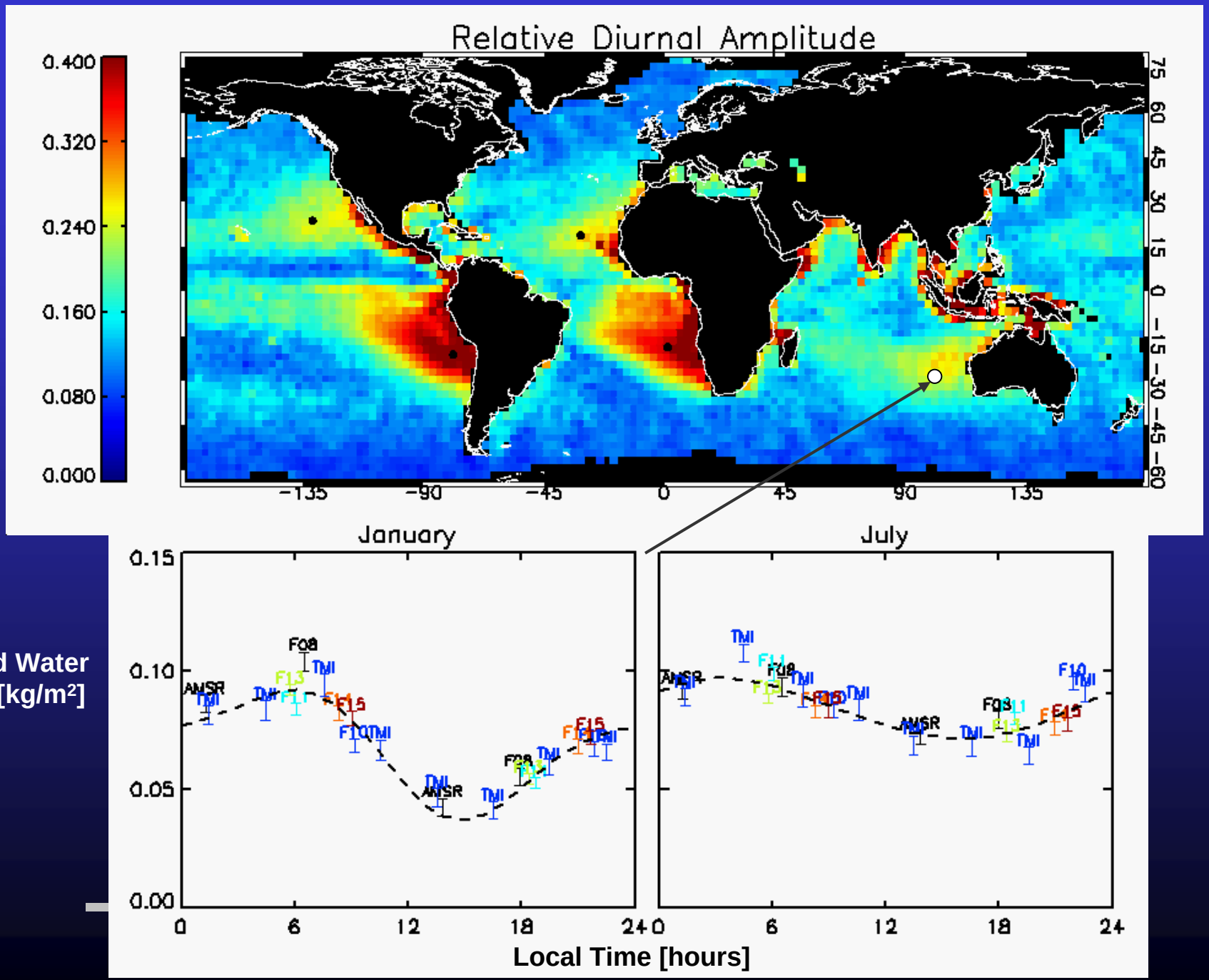
Local Time [hours]

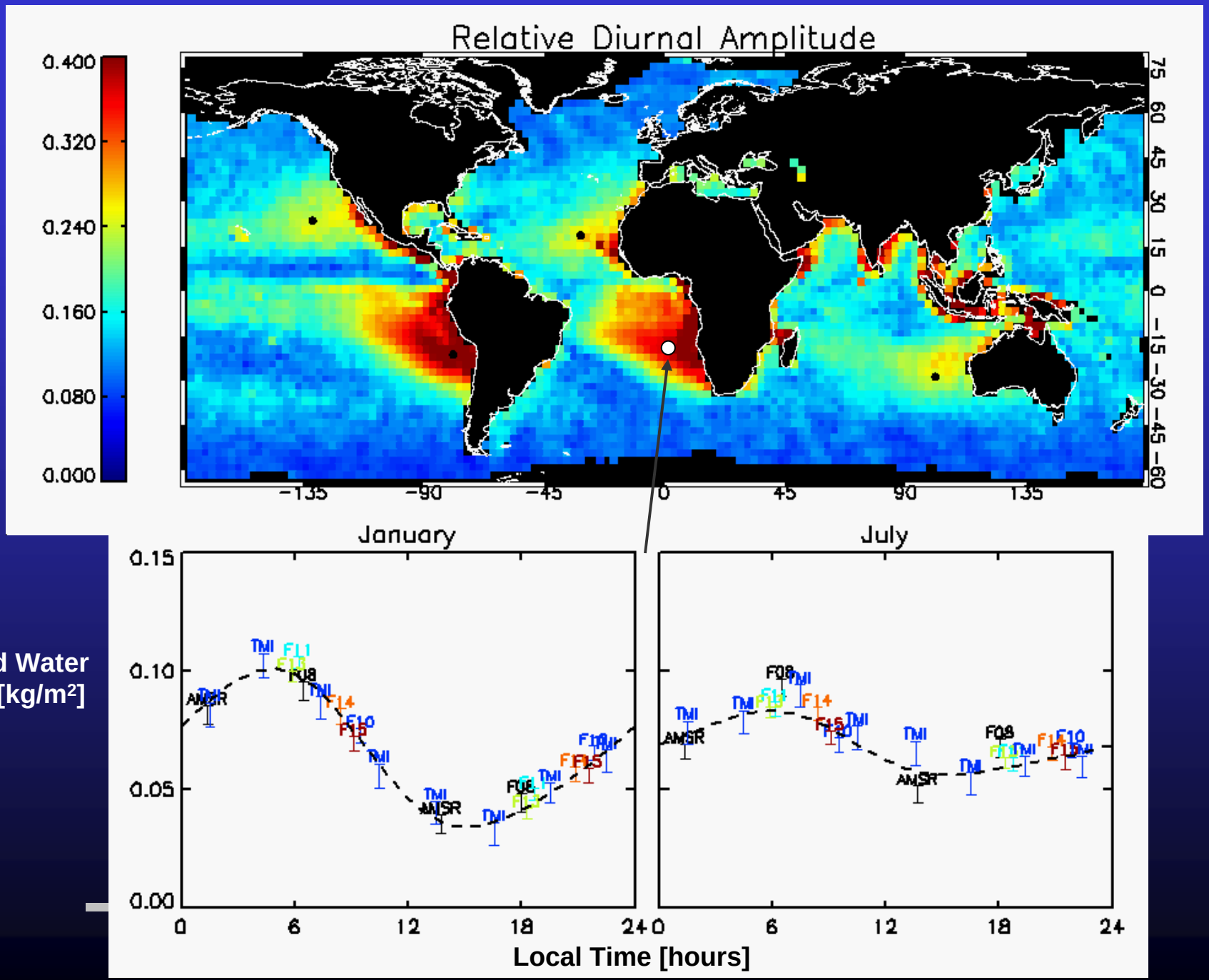


Liquid Water Path [kg/m²]

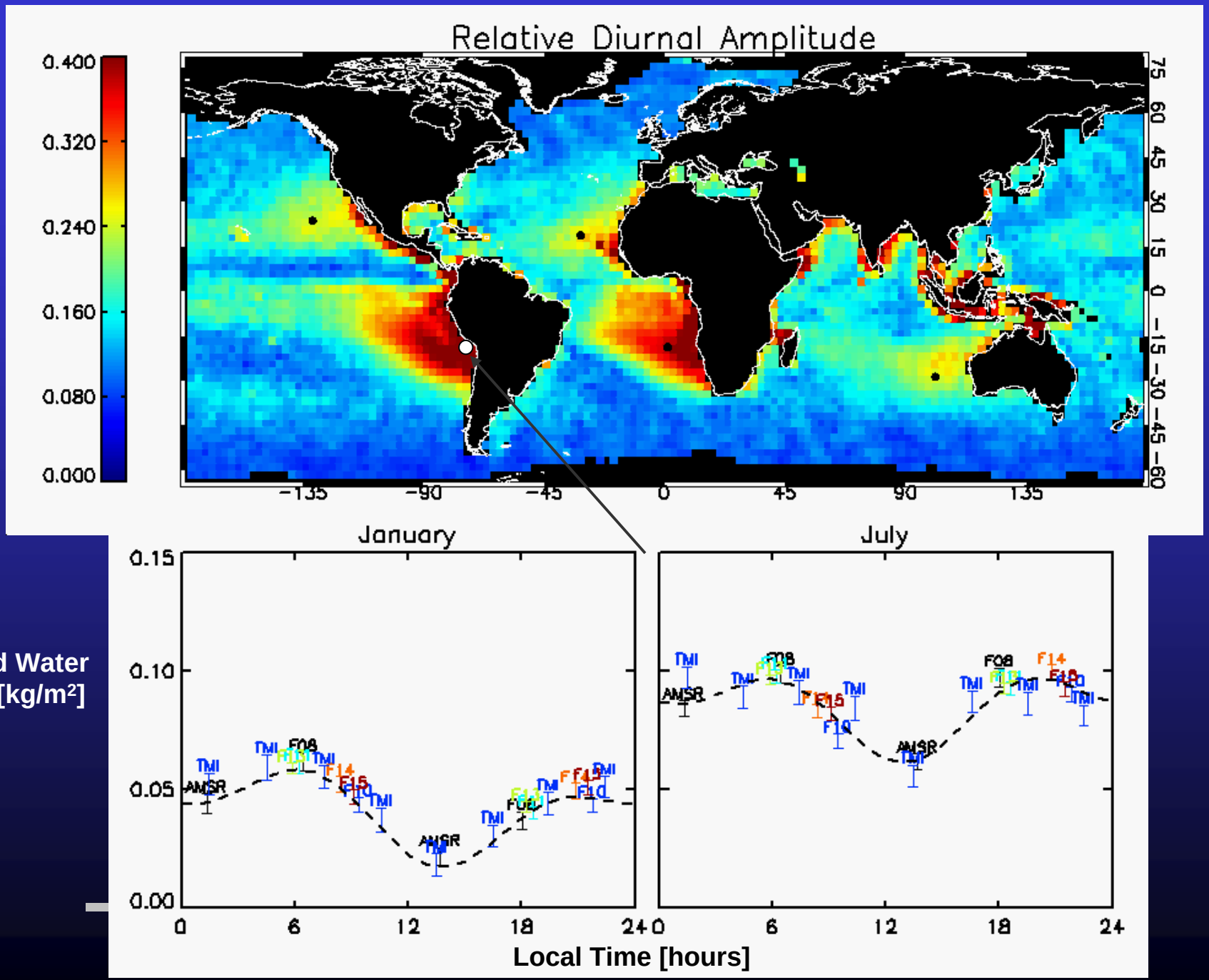


Liquid Water Path [kg/m²]

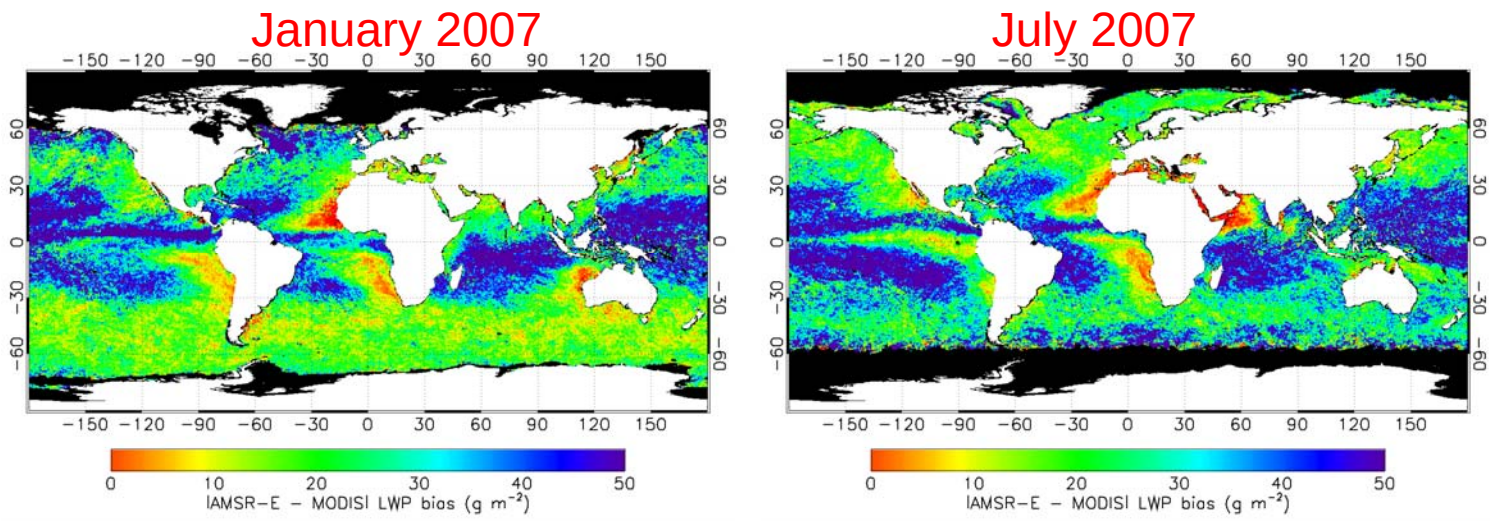

Relative Diurnal Amplitude
0.400
0.320
0.240
0.160
0.080
0.000
75 60 45 30 15 0 −15 −30 −45 −60
−135 −90 −45 0 45 90 135
January
July
0.15
0.10
0.05
0.00
0 6 12 18 24
Local Time [hours]
Liquid Water Path [kg/m²]



Liquid Water Path [kg/m²]



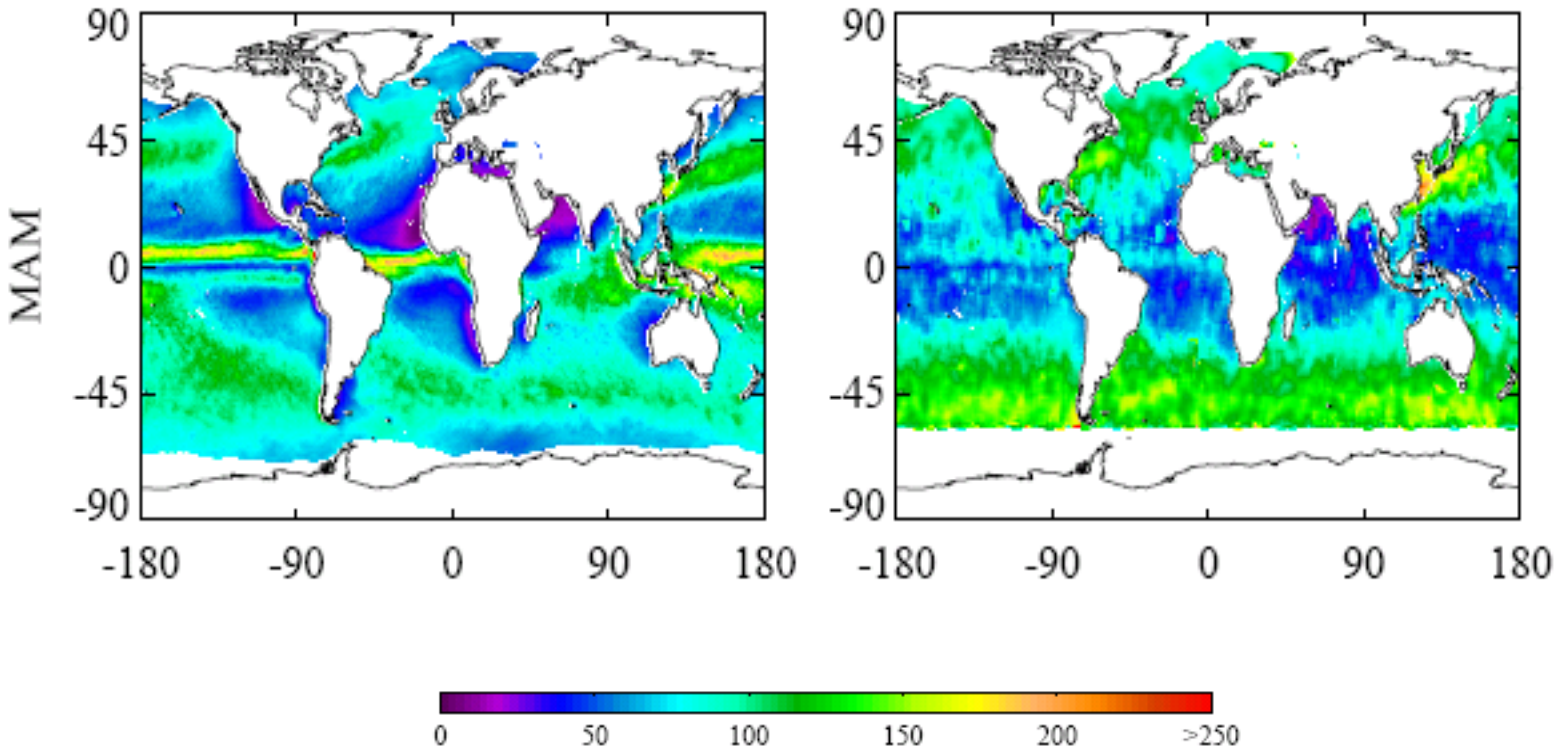
Liquid Water Path [kg/m²]



Mean absolute value difference in LWP between MW and VIS/NIR (based on *Seethala and Horvath 2010*)

Results from Seethala

LWP Comparison with UWISC data set.



UWISC: Multi year composite interpolated to 10:30
From O'Dell et al 2008 (J Climate)

Difference correspond to areas of multi- layer cloud
-ATSR retrieves this as ice in tropics→ underestimates
-ATSR retrieves as water in extra tropics → over estimates

Results from Poulsen

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Rutherford Appleton Laboratory
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Conclusions I/II

- Current datasets are advanced enough to draw valuable and relevant conclusions in climate research
- However, uncertainties and the limits of our current understanding need to be conveyed
- Good news: There is more information in the observed radiances
- Bad news: Our simple models do not fully cover it yet. Candidate explanations need to be tested with more complex models

Conclusions II/II

- Comparisons between different sensors/methods are important to identify strengths, weaknesses, issues, shortcomings of individual algorithms.
- Most important use to support hypothesis testing.
- We have to make sure we are not loosing sight of the wood for the trees.
- Need to rethink the User -- Developer dichotomy