(Almost) Everything You Always Wanted to Know About Cloud Thermodynamic Phase But Were Afraid to Ask Your Satellite.

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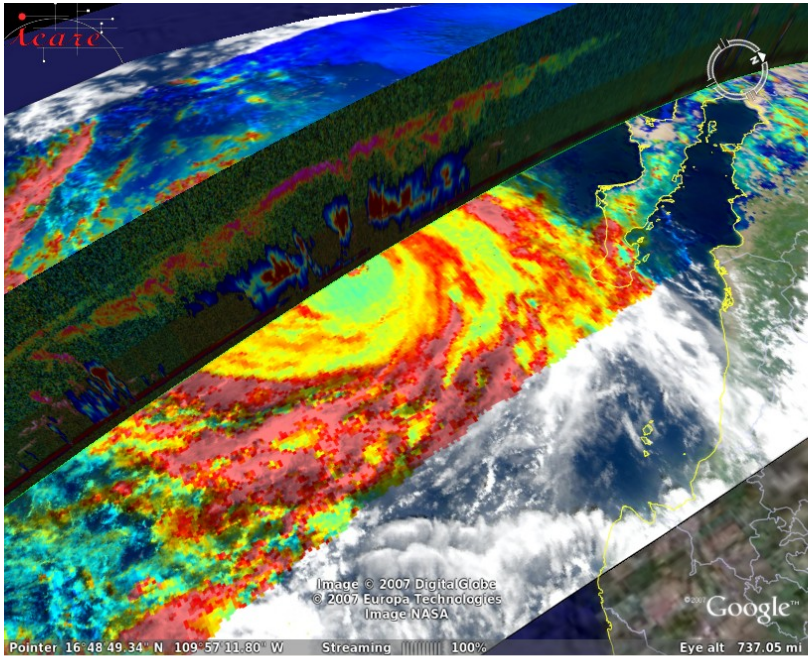

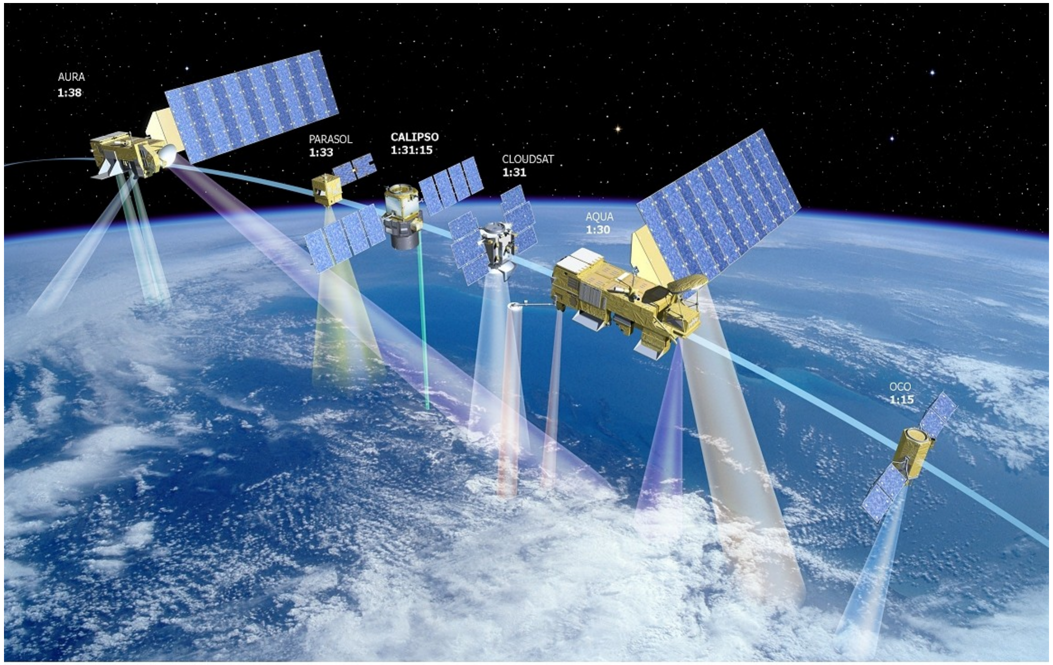

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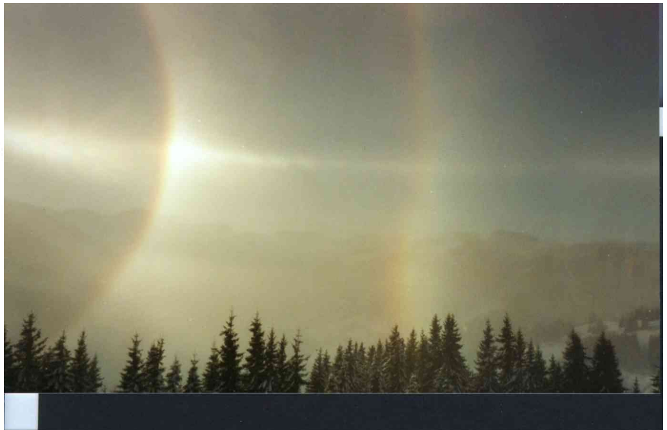
OUTLINE

- What this talk is about :
  - Cloud thermodynamic phase
    - Importance for cloud and climate modelling
    - Importance for cloud remote sensing
  - Remote sensing techniques using solar reflected sunlight and thermal infrared emission
  - A view on Cloud Phase from the A-Train

- What it is not about :
  - microphysical processes in clouds
  - parameterization of cloud phase in models
  - active remote sensing
  - in-situ measurements of cloud phase
  - complex reality of mixed phase clouds

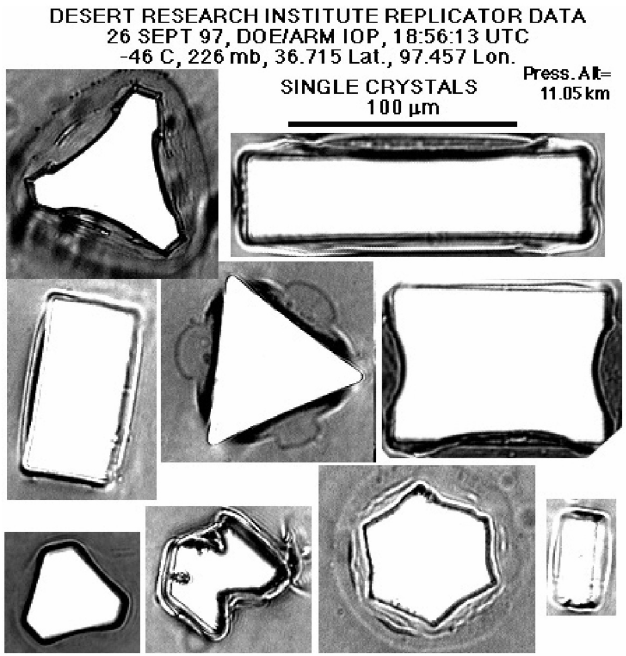
In the beginning there was H_2O ...

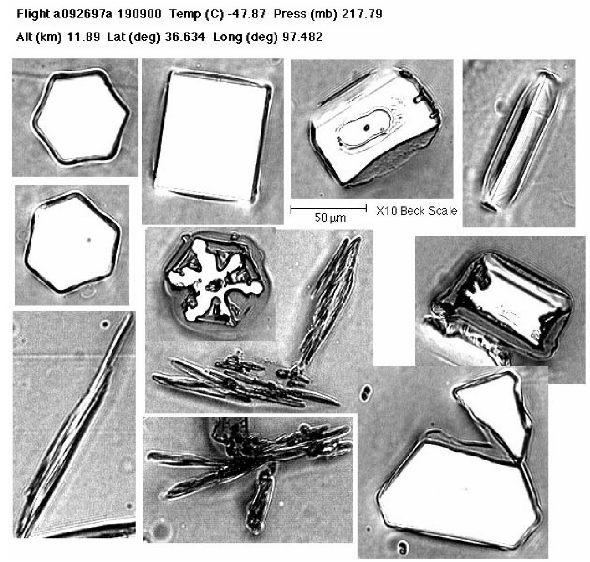









DESERT RESEARCH INSTITUTE REPLICATOR DATA
26 SEPT 97, DOE/ARM IOP, 18:56:13 UTC
-46 C, 226 mb, 36.715 Lat., 97.457 Lon.
Press. Alt= 11.05 km
SINGLE CRYSTALS
100 μm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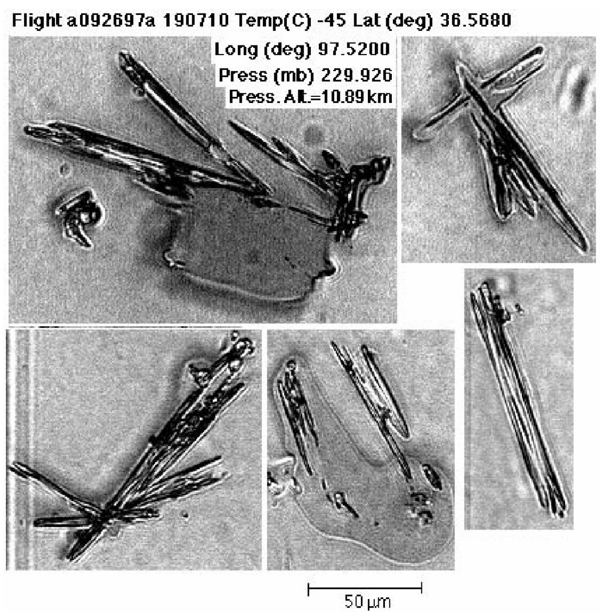
50 μm
X10 Beck Scale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Long (deg) 97.5200
Press (mb) 229.926
Press. Alt.=10.89 km
50 μm


DESERT RESEARCH INSTITUTE REPLICATOR DATA
26 SEPT 97, DOE/ARM IOP, 18:56:13 UTC
-46 C, 226 mb, 36.715 Lat., 97.457 Lon.
Press. Alt.=11.05 km
100 μm
POLYCRYSTALS

and right after came Bob Dylan

Come gather 'round people
Wherever you roam
And admit that the waters
Around you have grown
And accept it that soon
You'll be drenched to the bone.
If your time to you
Is worth savin'
Then you better start swimmin'
Or you'll sink like a stone
For the times they are a-changin'.

The Times they' are changing
Bob Dylan, 1964

Not to mention :

A Hard Rain's A-Gonna Fall

Shelter from the Storm

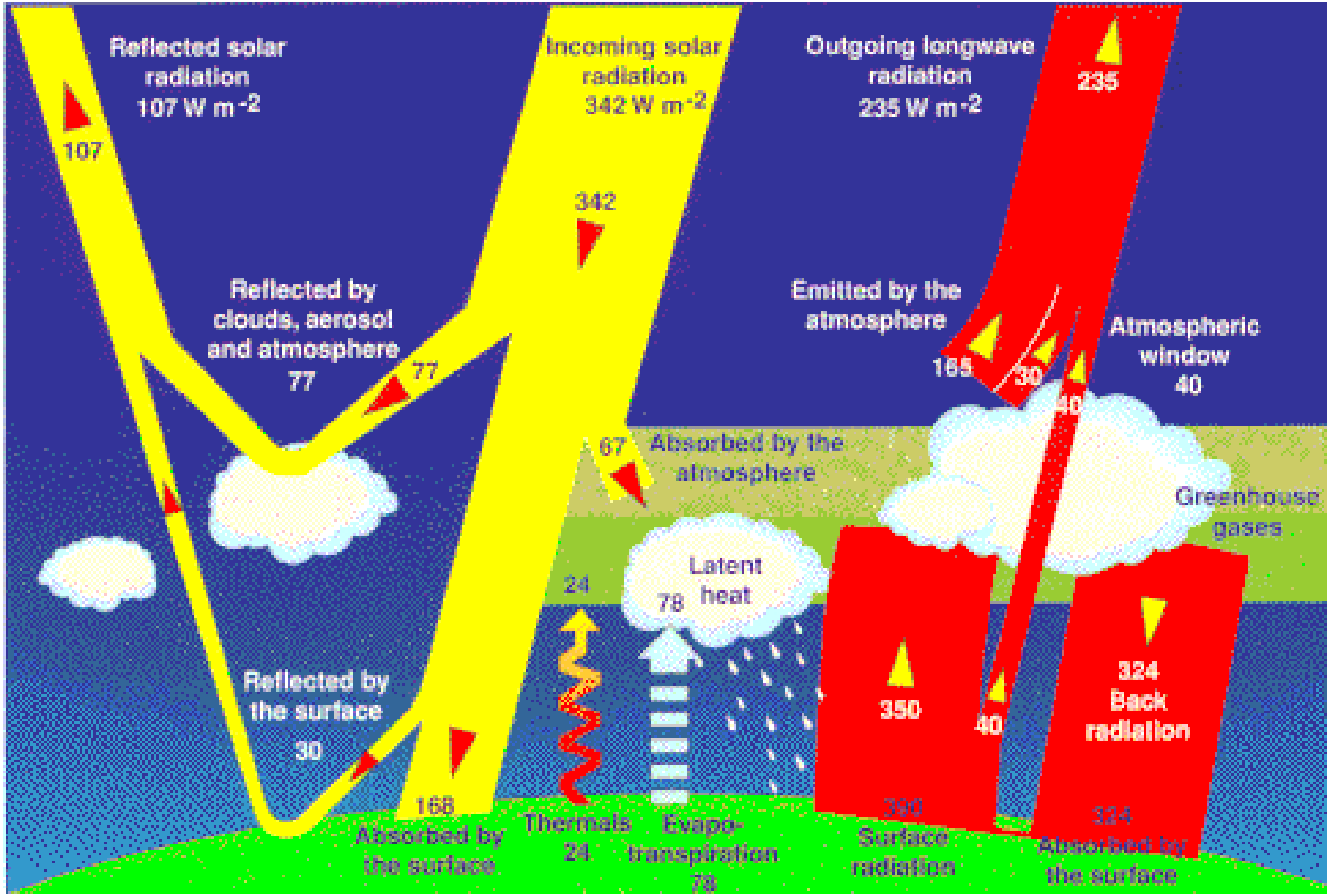
Blowin in the Wind

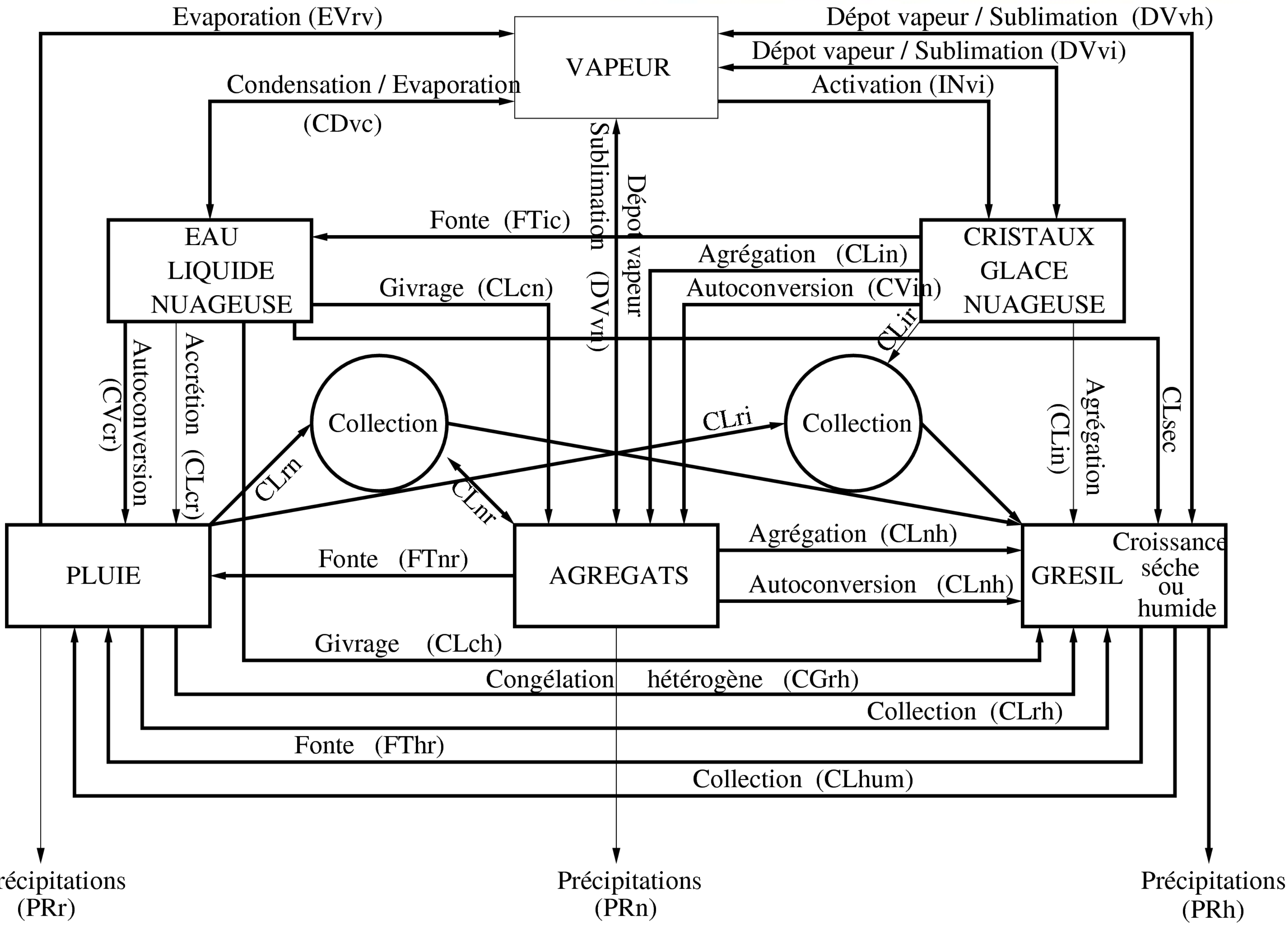
Question :

Who should have received the Nobel prize ? Gore or Dylan ?

Clouds, Radiation and Climate ...

Clouds, Radiation and Climate ...




Evaporation (EVrv)
VAPEUR
Dépot vapeur / Sublimation (DVvh)
Dépot vapeur / Sublimation (DVvi)
Activation (INvi)
Condensation / Evaporation
(CDvc)
Sublimation (DVvn)
Dépot vapeur
EAU
LIQUIDE
NUAGEUSE
Fonte (FTic)
CRISTAUX
GLACE
NUAGEUSE
Agrégation (CLin)
Givrage (CLcn)
Autoconversion (CVin)
CLir
Autoconversion
(CVcr)
Accrétion (CLcr)
Collection
Collection
CLri
CLrn
CLnr
Agrégation
(CLin)
CLsec
PLUIE
Fonte (FTnr)
AGREGATS
Agrégation (CLnh)
Autoconversion (CLnh)
GRESIL
Croissance
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Congélation hétérogène (CGrh)
Collection (CLrh)
Fonte (FThr)
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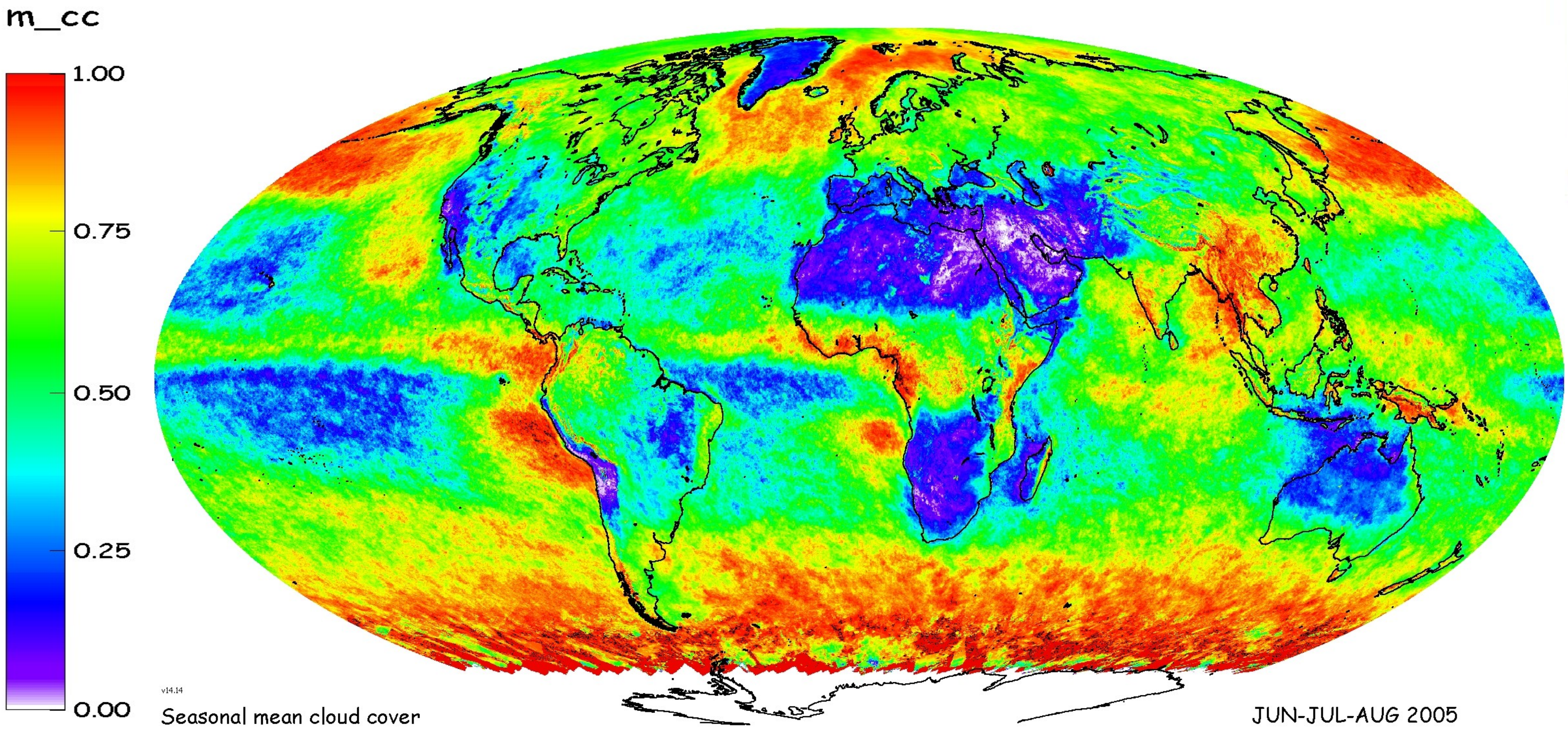
Précipitations
(PRr)
Précipitations
(PRn)
Précipitations
(PRh)

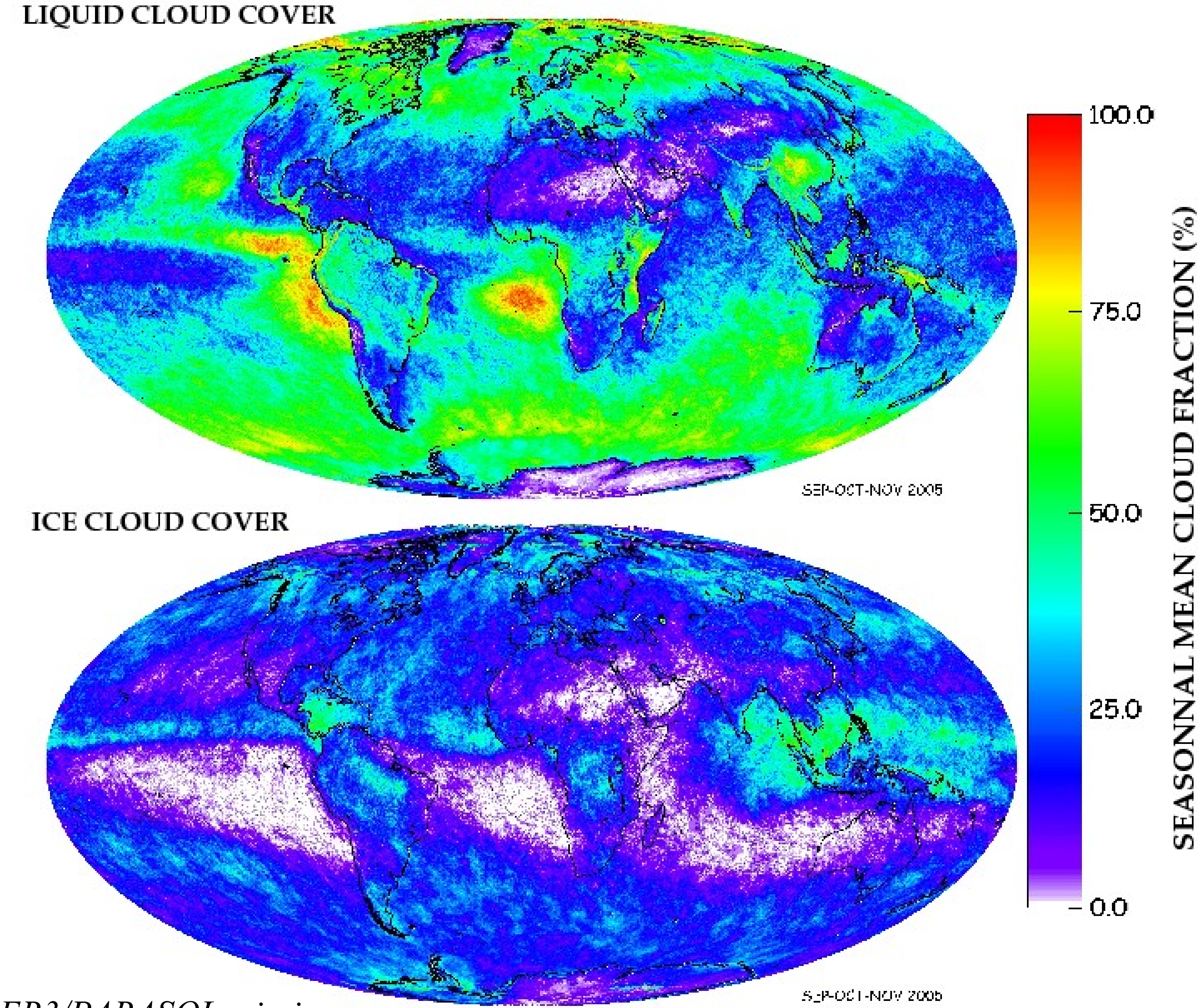
Remote Sensing of Cloud Properties ...

Global Distribution

POLDER



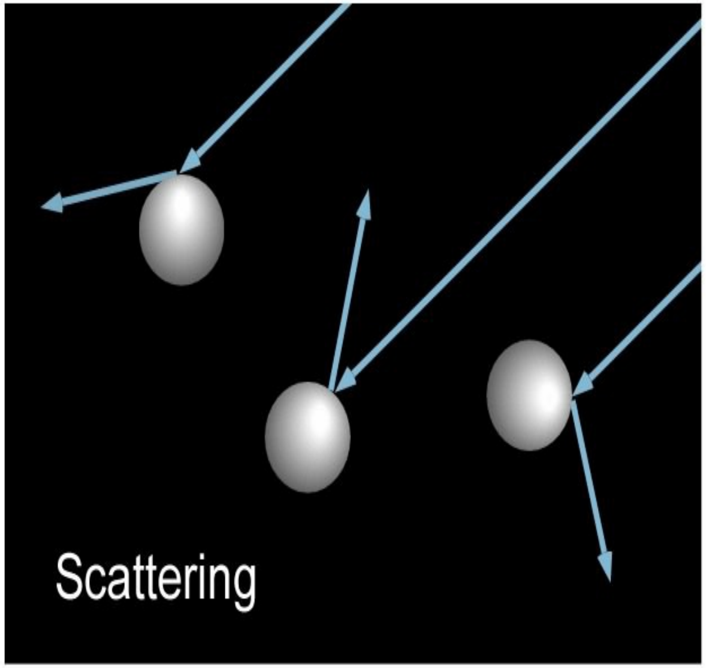
Cloud thermodynamic phase

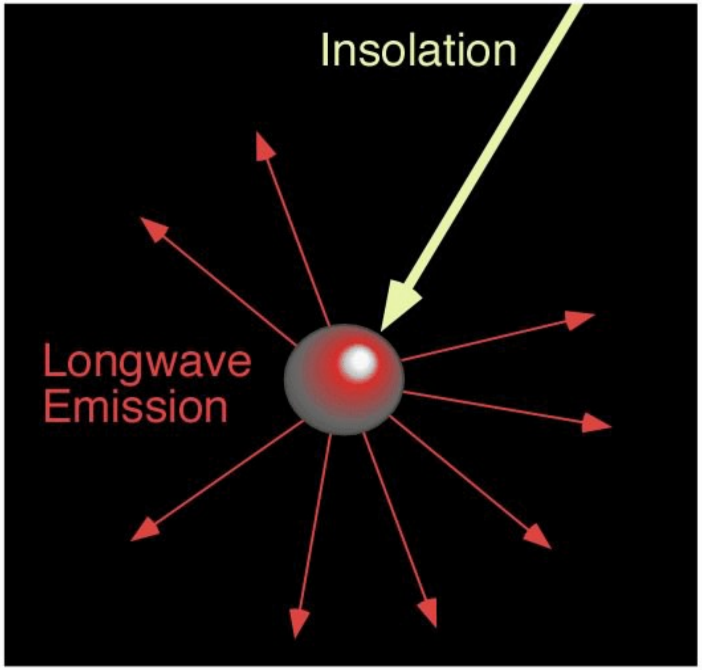


From POLDER3/PARASOL mission

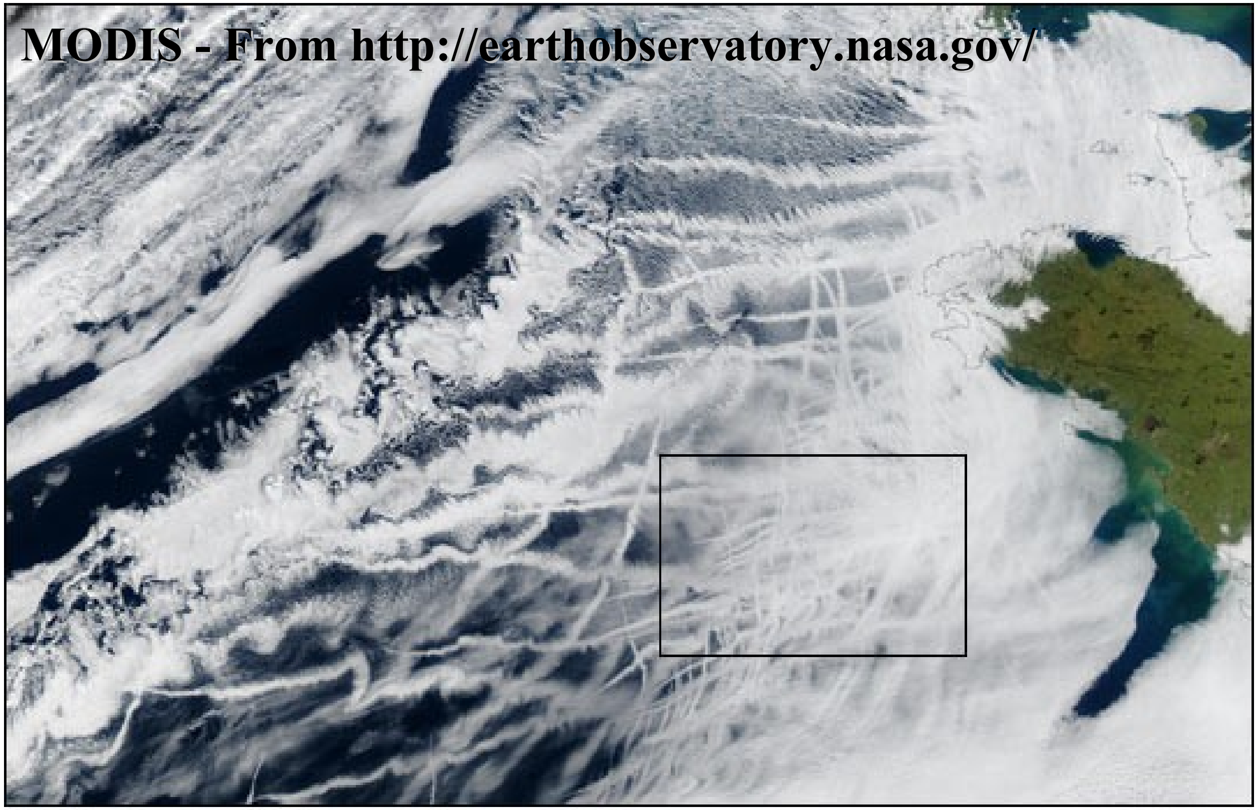
The challenge of cloud properties remote sensing :

How can we get information on particles with size between 1 to 1000 microns when looking from a distance of 800km ?



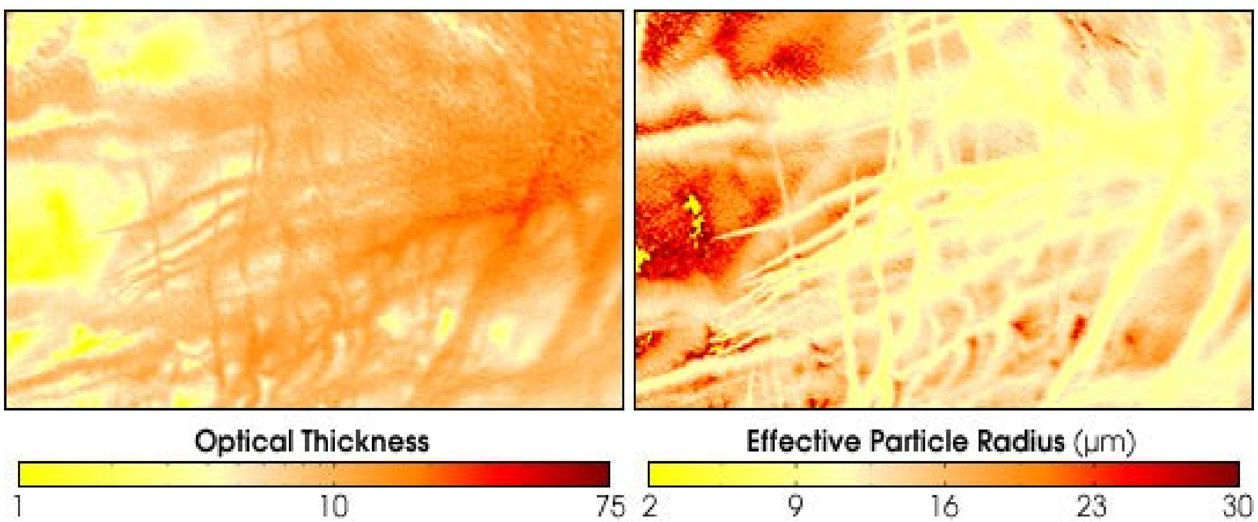


Images from : PhysicalGeography.net



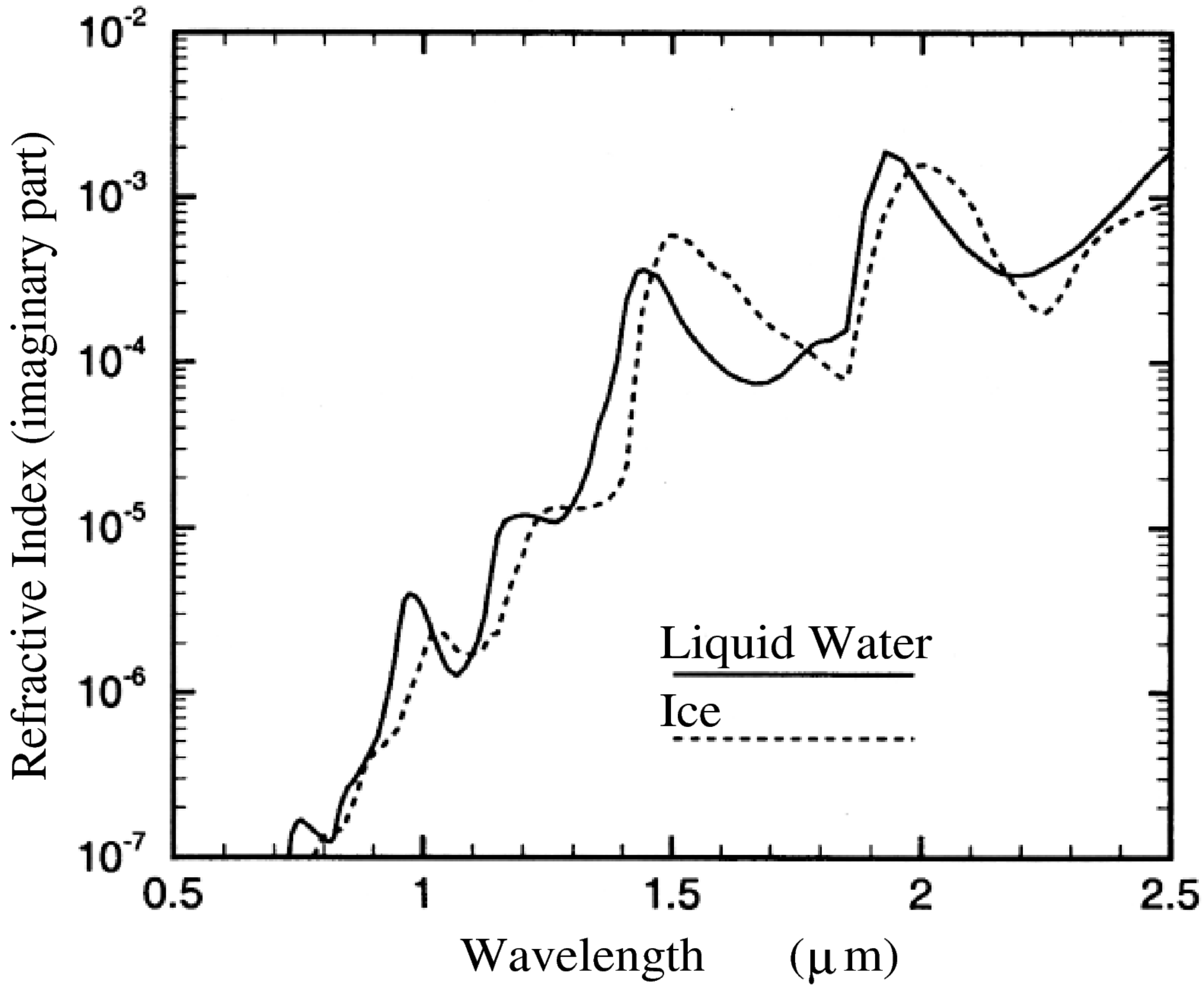
True Color

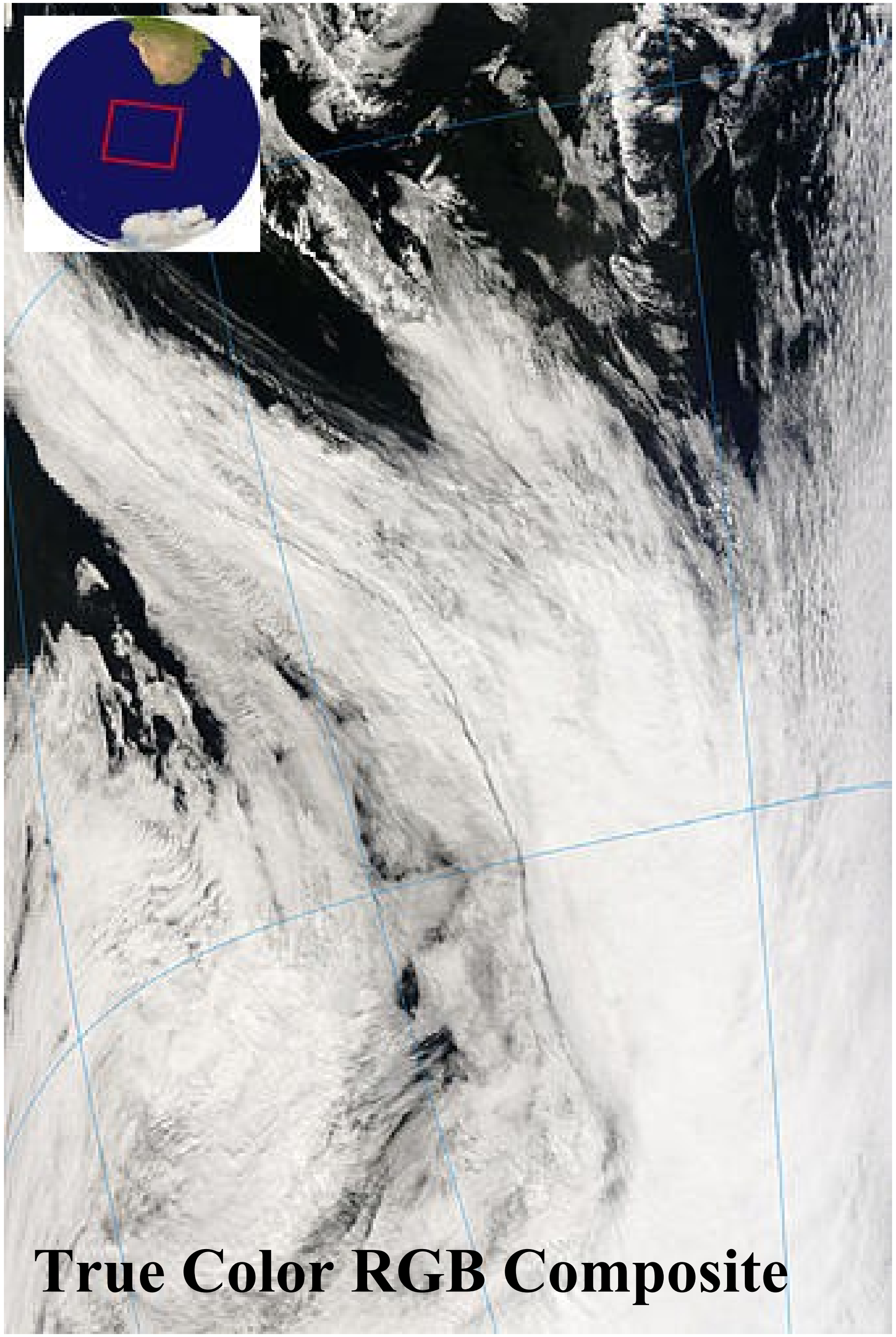
Ship tracks in a stratocumulus cloud field off the coast of France.



MODIS retrievals of cloud optical thickness and effective particle size

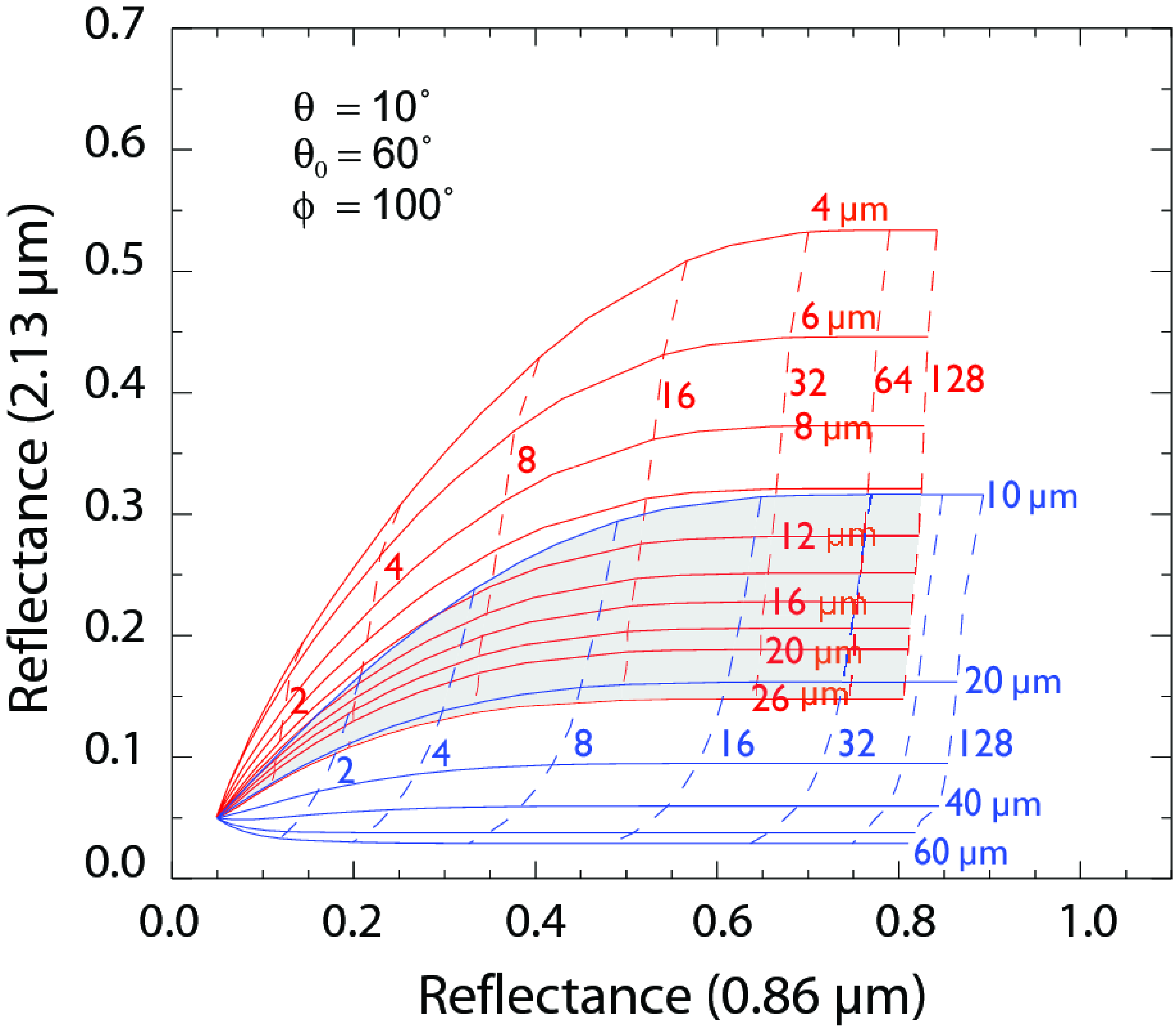
Hansen and Pollack [1970] discussed the interest of shortwave infrared radiation for determination of particle size and phase.




True Color RGB Composite

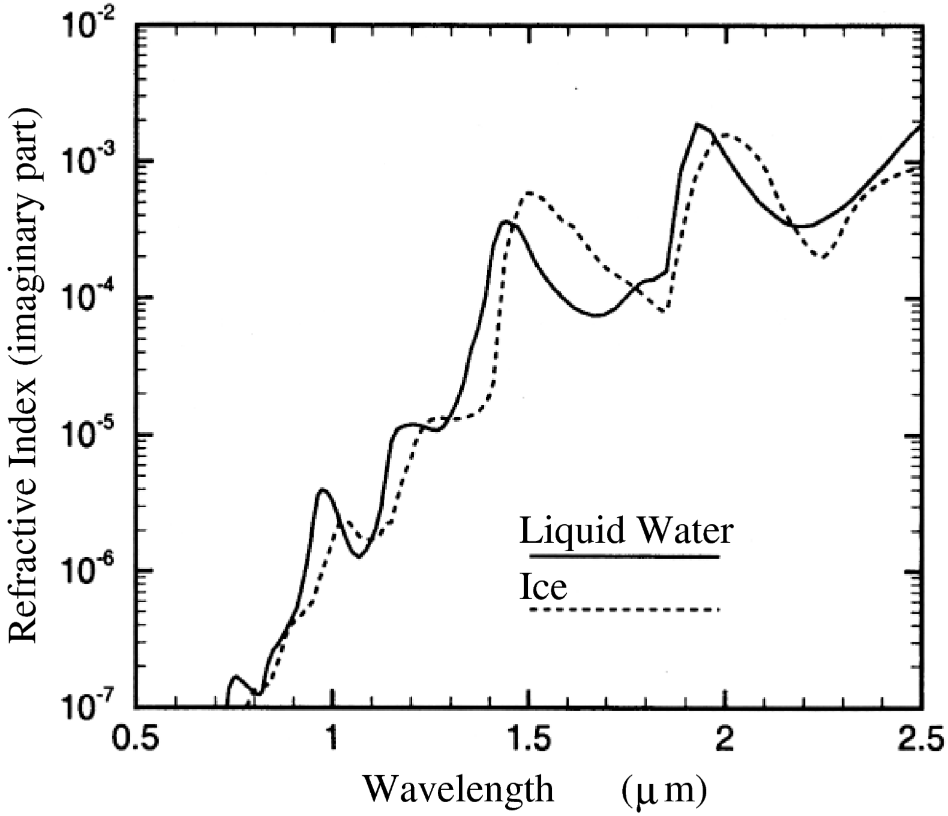

False Color Composite
0.865 – 1.6 – 2.1 microns

Computation of 2.13 against 0.865 microns reflectances for uniform layer of **ice** or **liquid** cloud (various optical thickness and particle size)



Courtesy of Dr. S. Platnick - NASA/GSFC

Pilewskie and Twomey [1986] showed that the maximum absorption occurs at different wavelength for ice and water clouds and that detailled spectrum can be used to infer cloud phase.



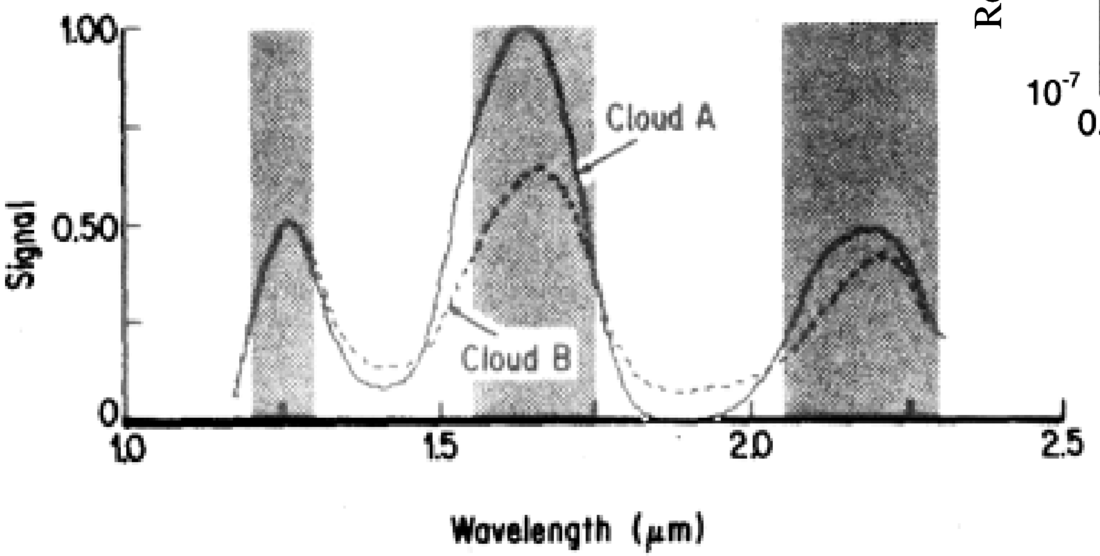
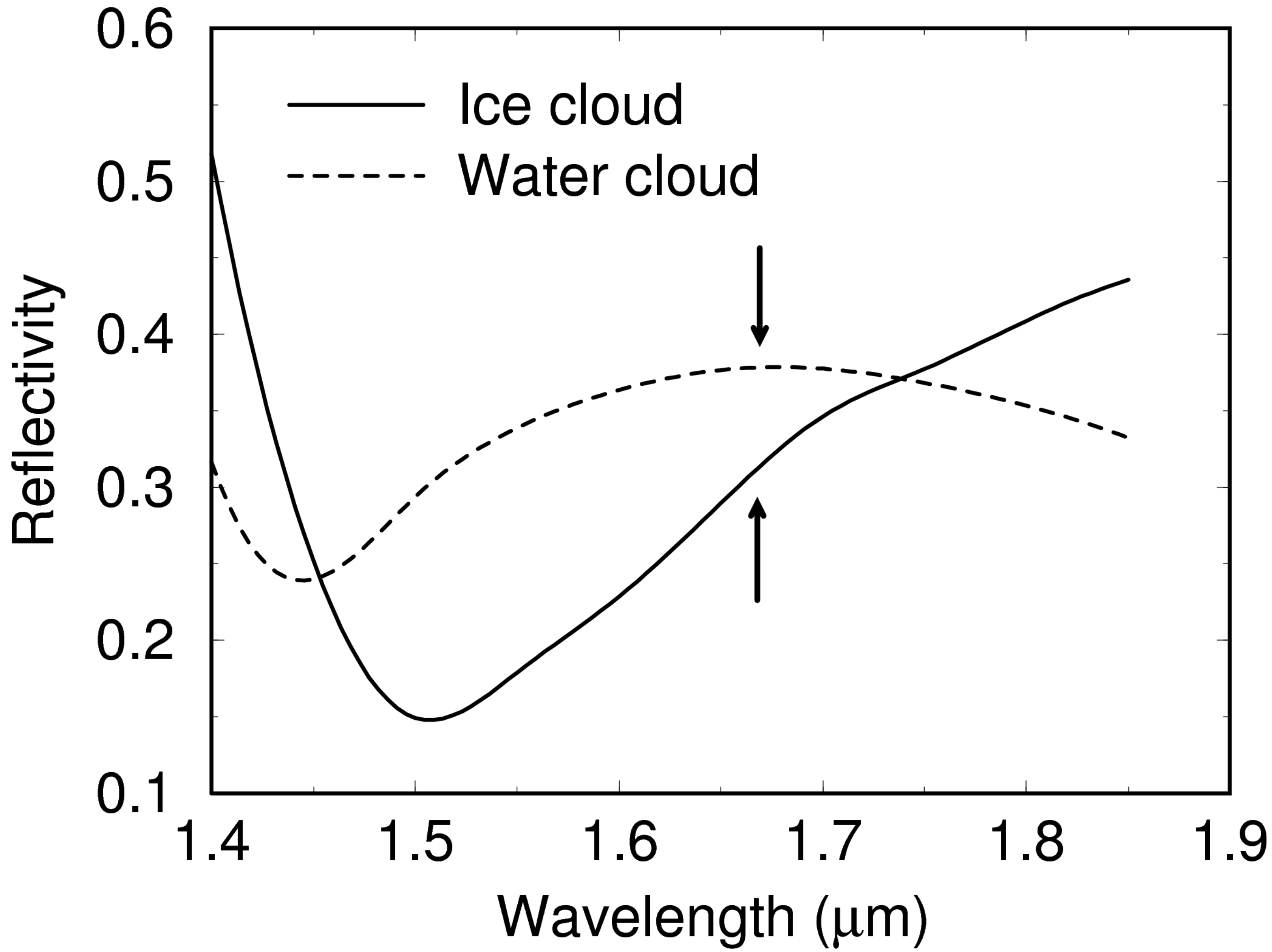
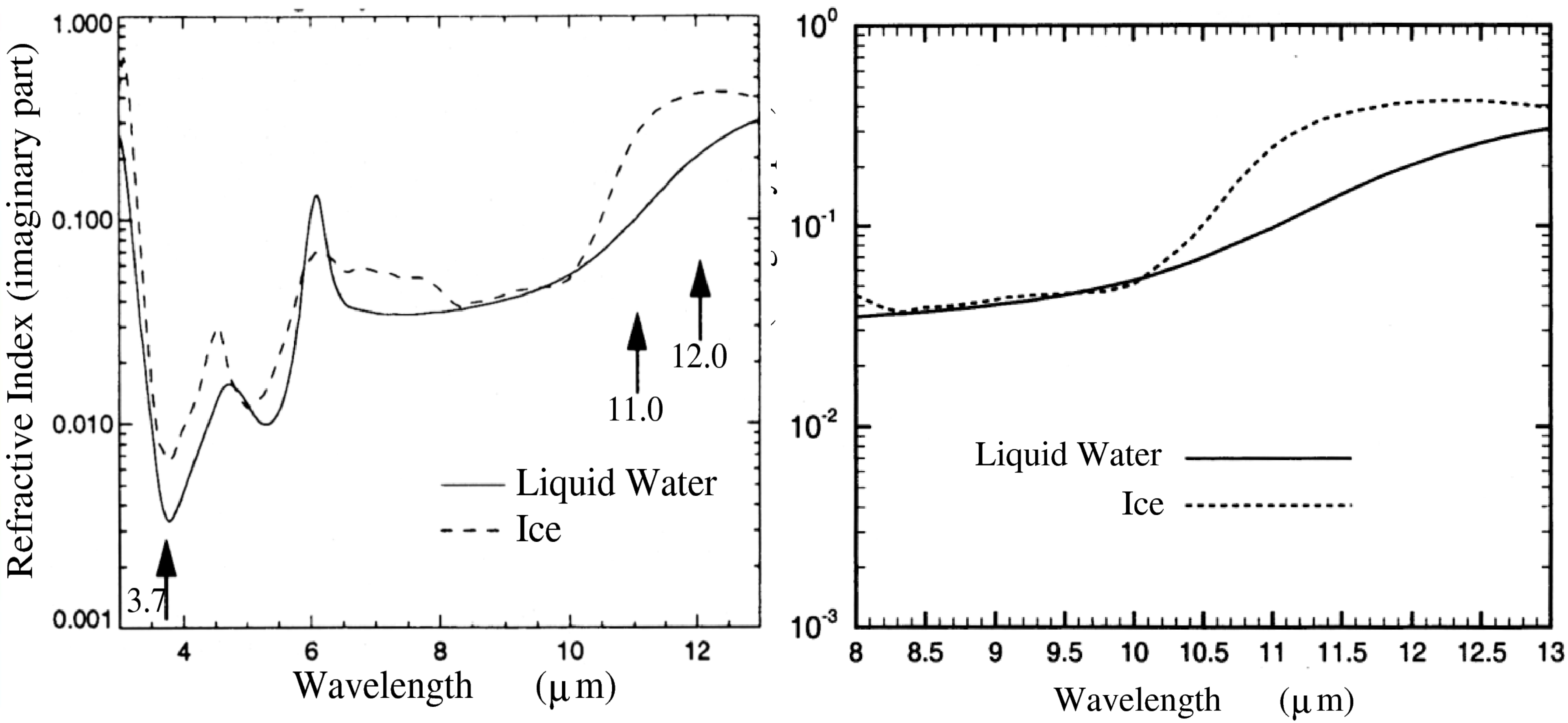


FIG. 3. Two spectra from the same cloud to the northeast of Tucson on 8 August 1986, obtained with the modified spectroradiometer. The cloud B spectrum was recorded 7 min after that of cloud A. Again, shaded regions indicate water-vapor absorption windows.

Knap et al [2001] following Pielewski and Twomey used the **shape of the reflectance spectra** around 1.6 microns to get information on cloud phase.

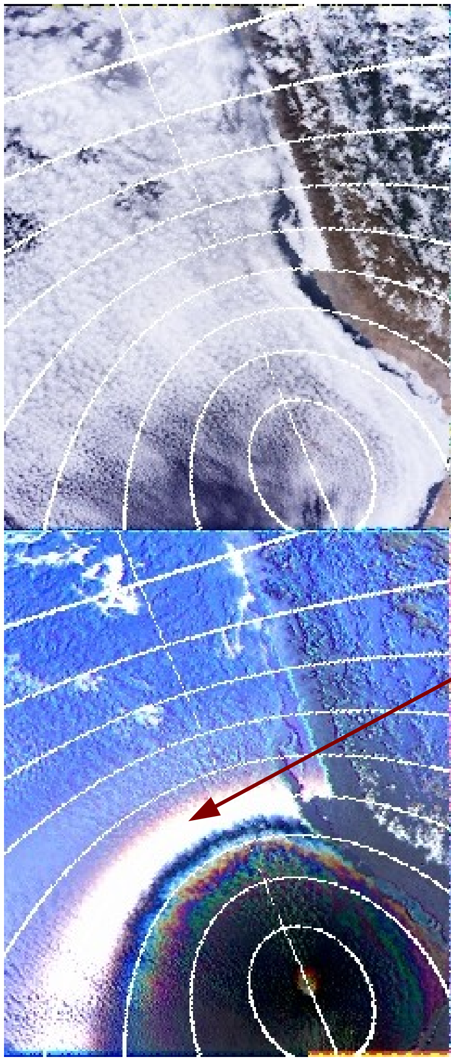


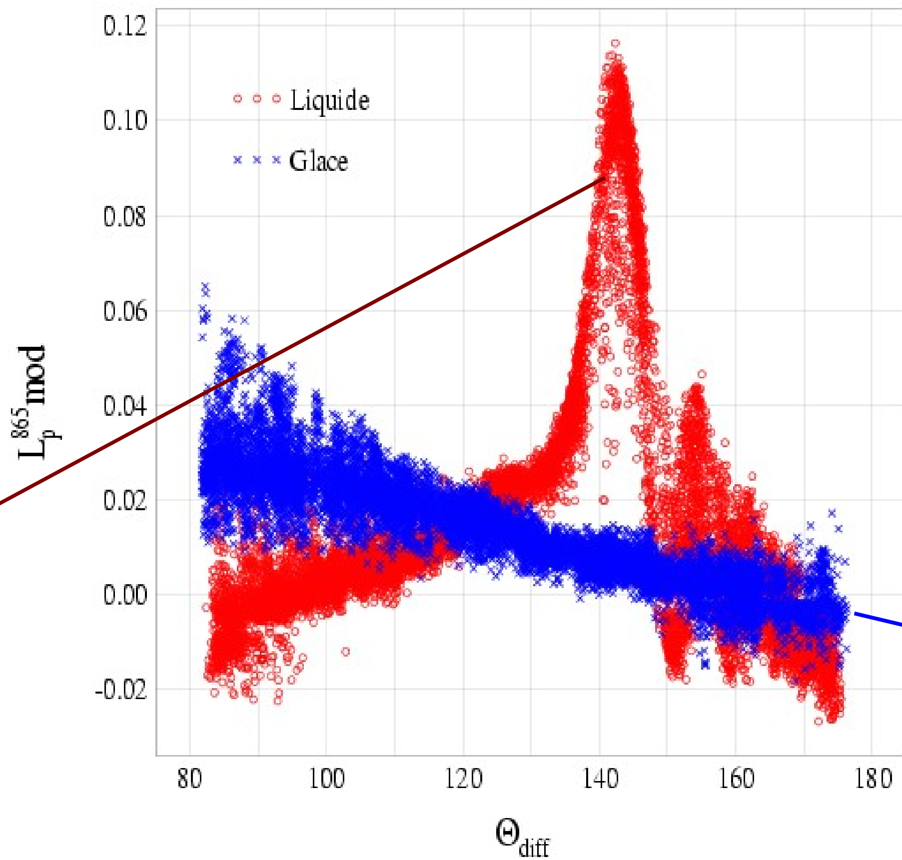
Arking and Childs [1985] used the IR channels of AVHRR to derive phase information, followed by Key and Intrieri [2000] and Baum et al [2000] using MODIS.

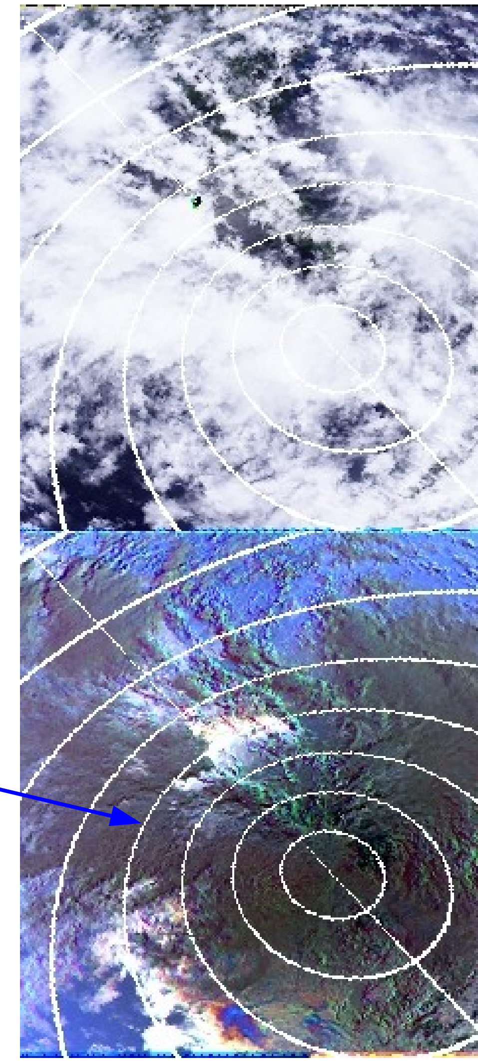


Use of POLDER multiangle polarisation measurements

Goloub et al, 2000 - Riedi et al, 2001

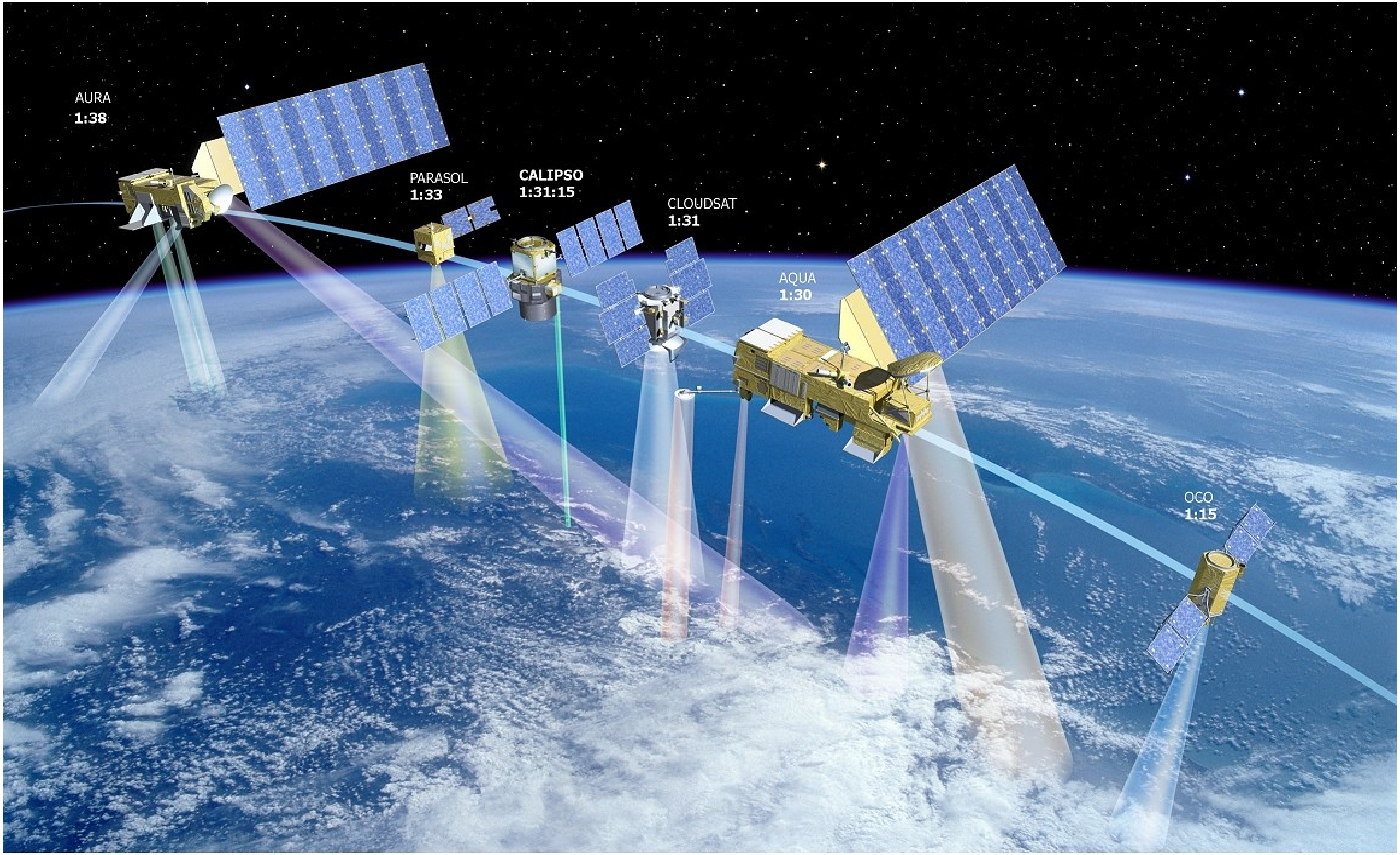




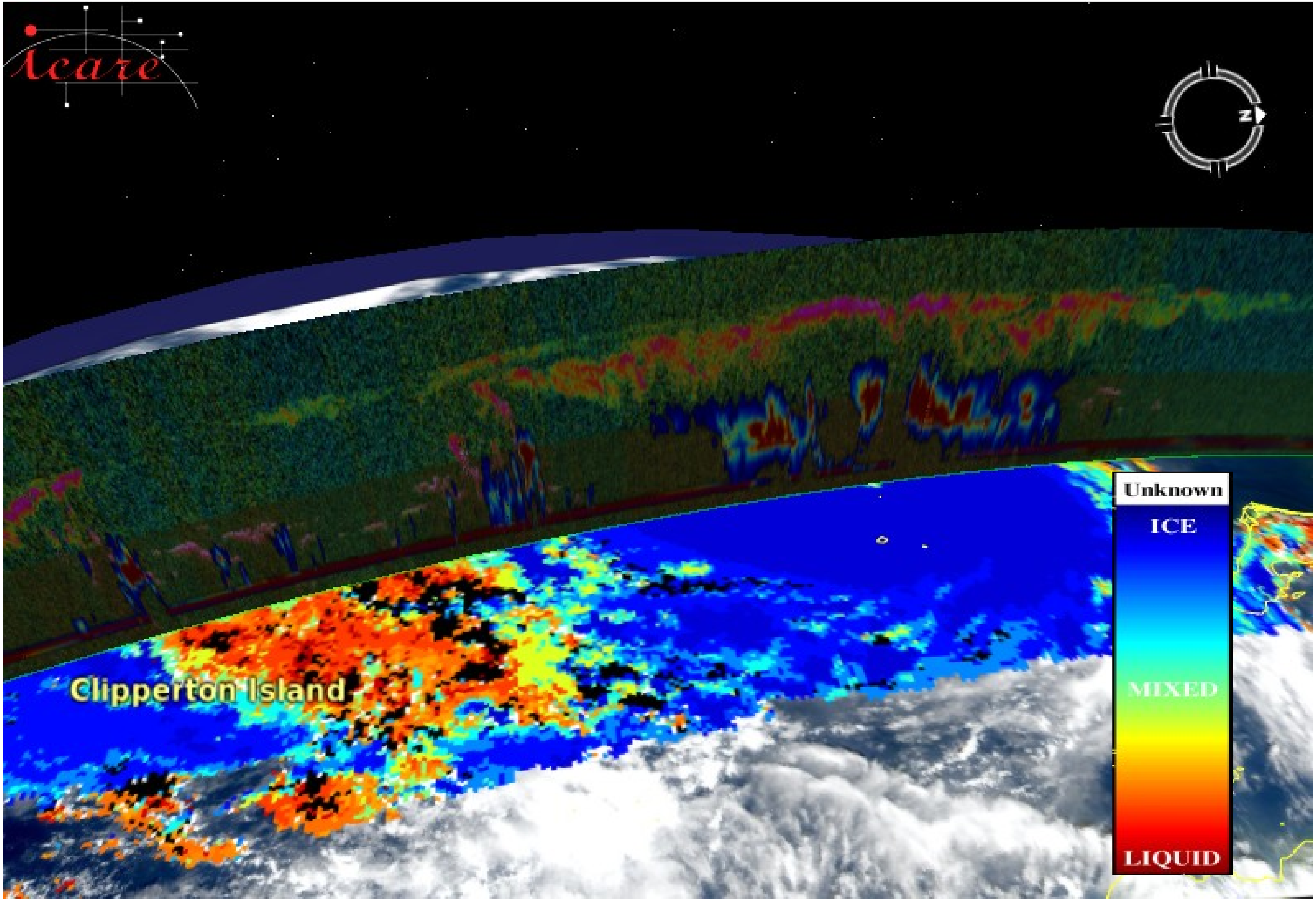


A view from A-Train ...

The A-Train Experiment



Case Study : Typhoon Ileana August 23rd 2006



Cloud thermodynamic phase

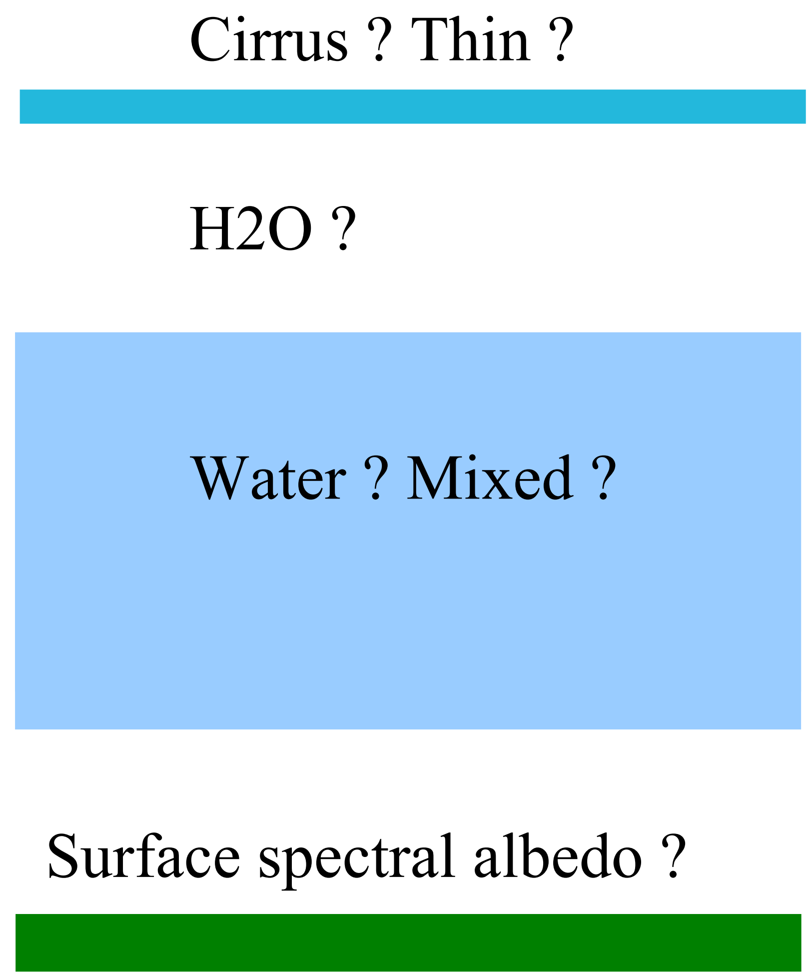
Combination of information on particle shape and absorption properties

Basis

Polarization
mostly single scattering
sensitive to particle shape
Top of cloud but see through it if very thin

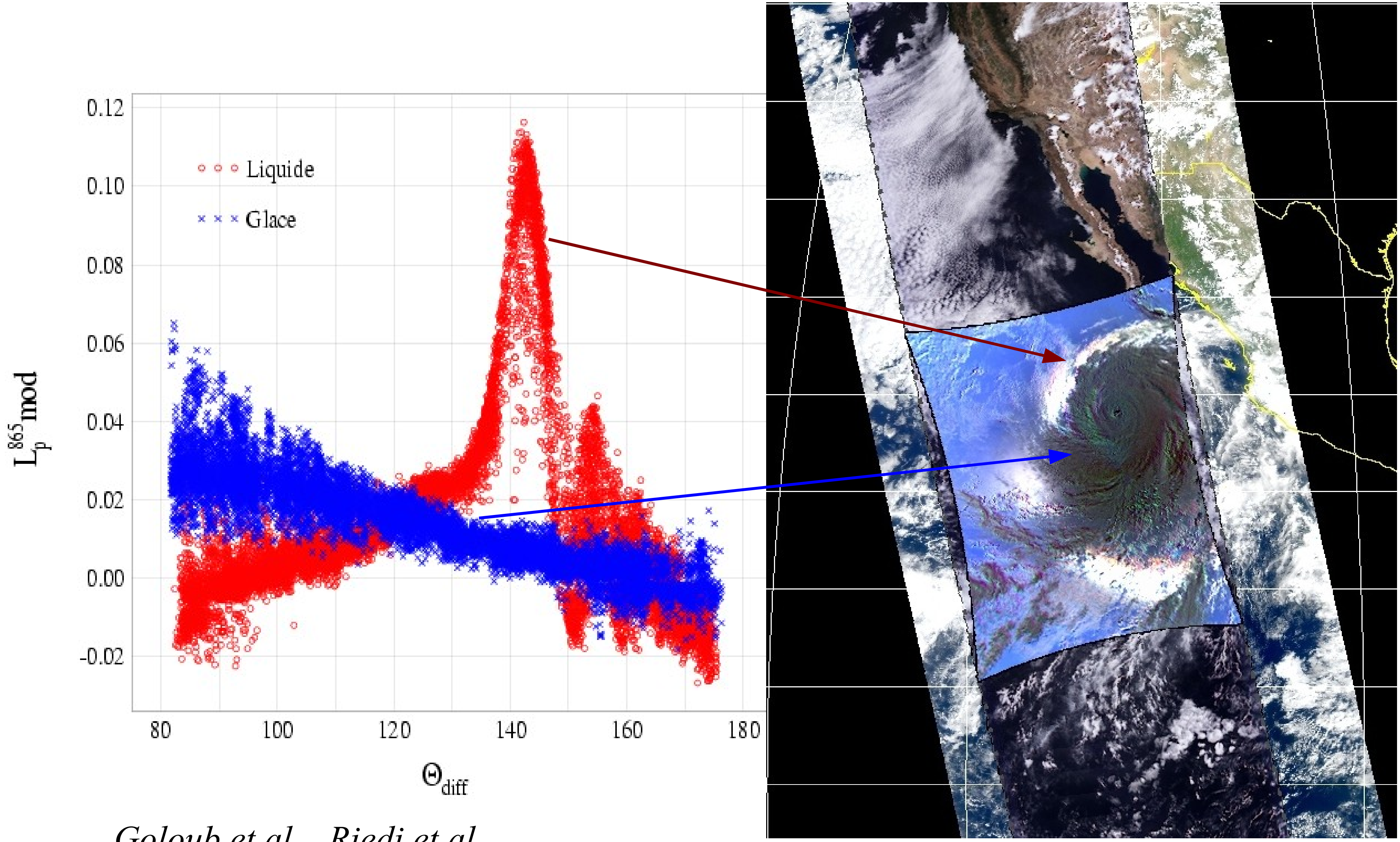
SWIR
Differential Water/Ice Absorption
sensitive to particle size
Some depth in the cloud

Thermal IR
Diff. Water/Ice,
also sensitive to surf. emissivity, H_2O
Some depth in the cloud except thin cirrus



Cloud Top Thermodynamic Phase

Principle : particle shape discrimination spherical vs non sphe.



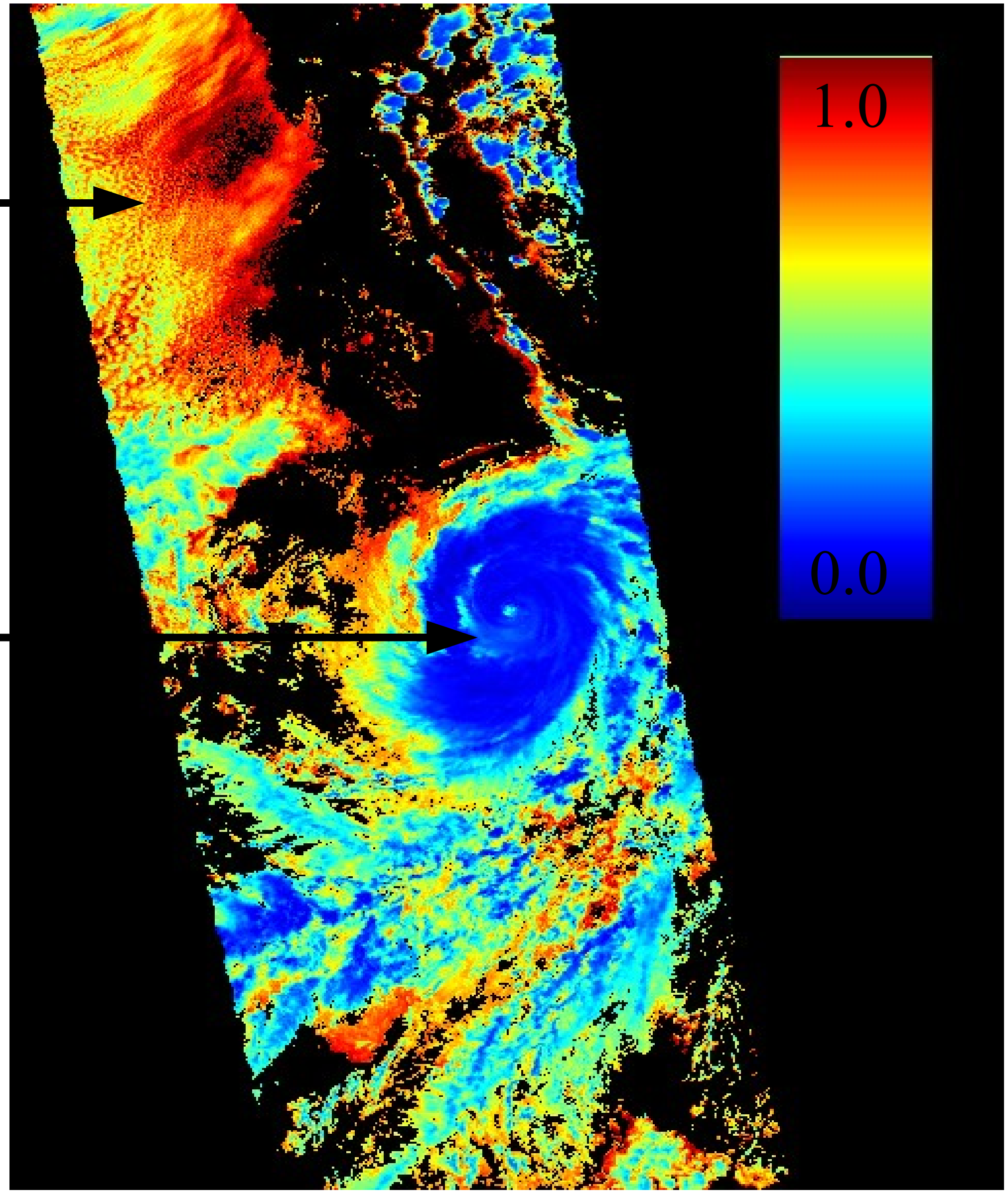
Goloub et al, Riedi et al

Cloud Top Thermodynamic Phase

Principle : Differential Absorption in the Shortwave Infrared

low absorption

high absorption

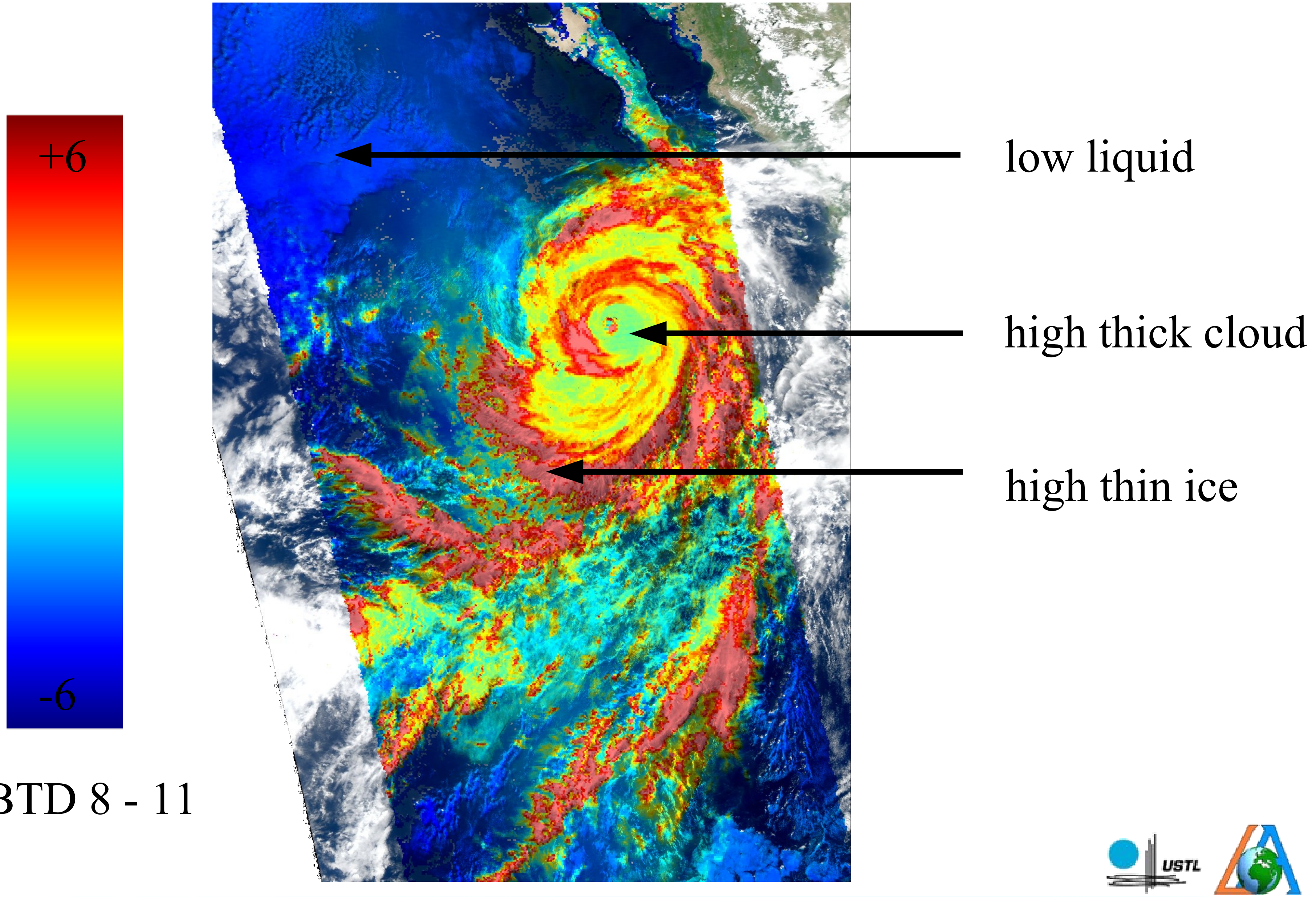


Ratio of MODIS band 7 to band 2

(2.1 over 0.86 microns channels)

Cloud Top Thermodynamic Phase

Principle : Differential Absorption in the Thermal Infrared



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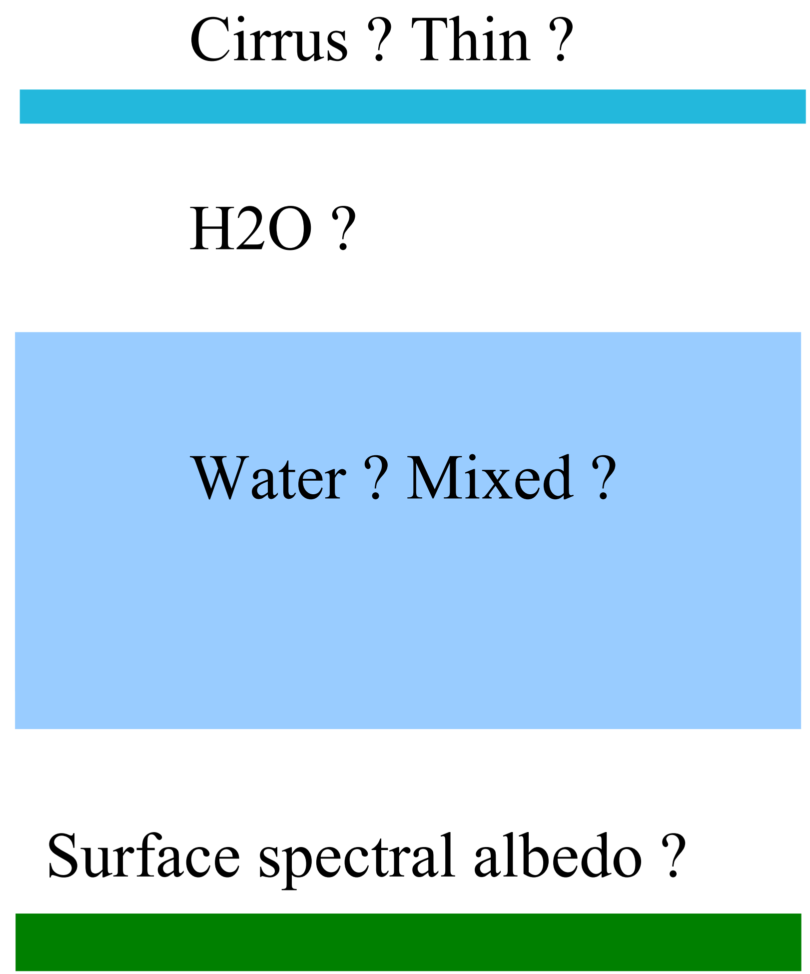
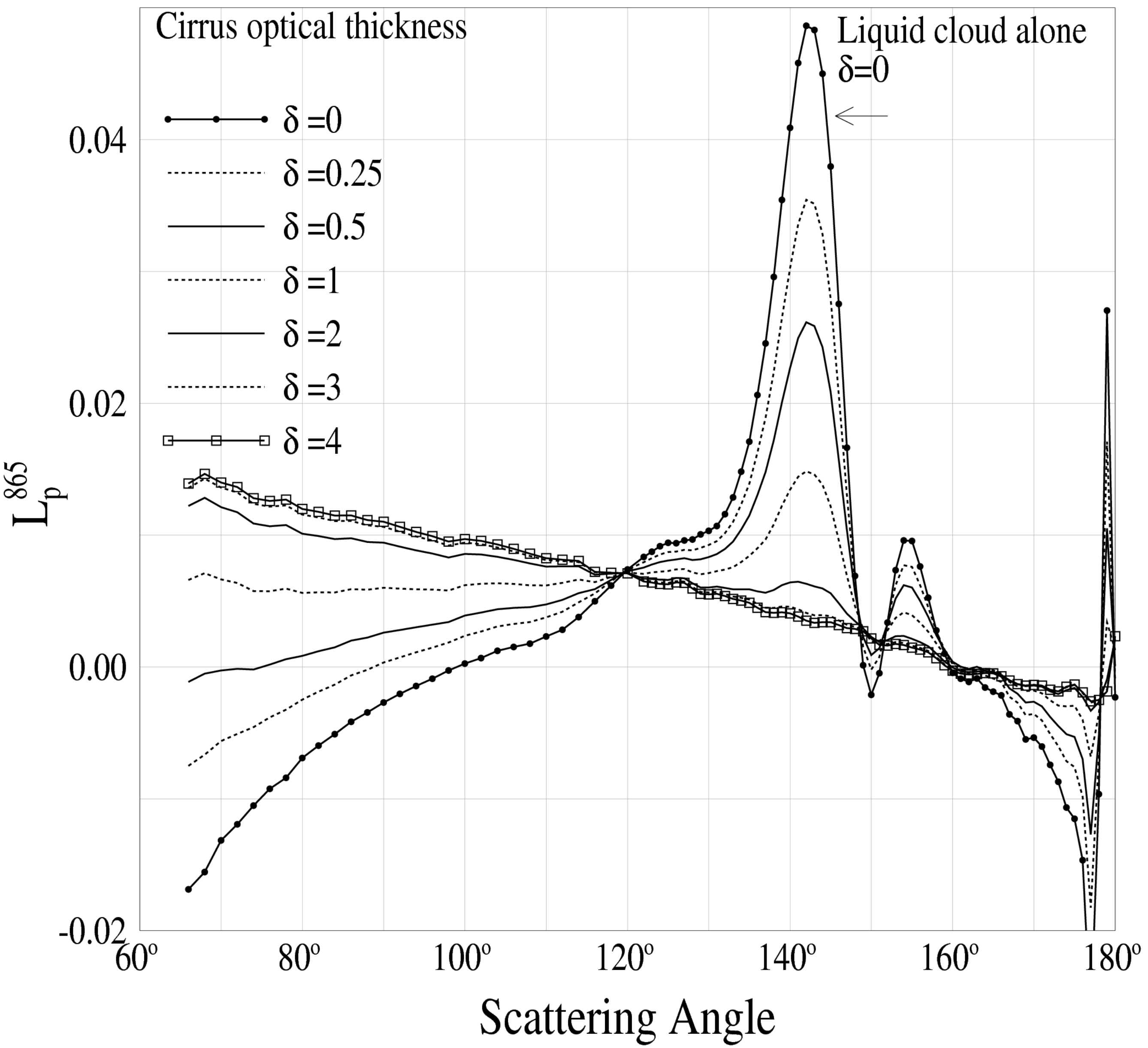
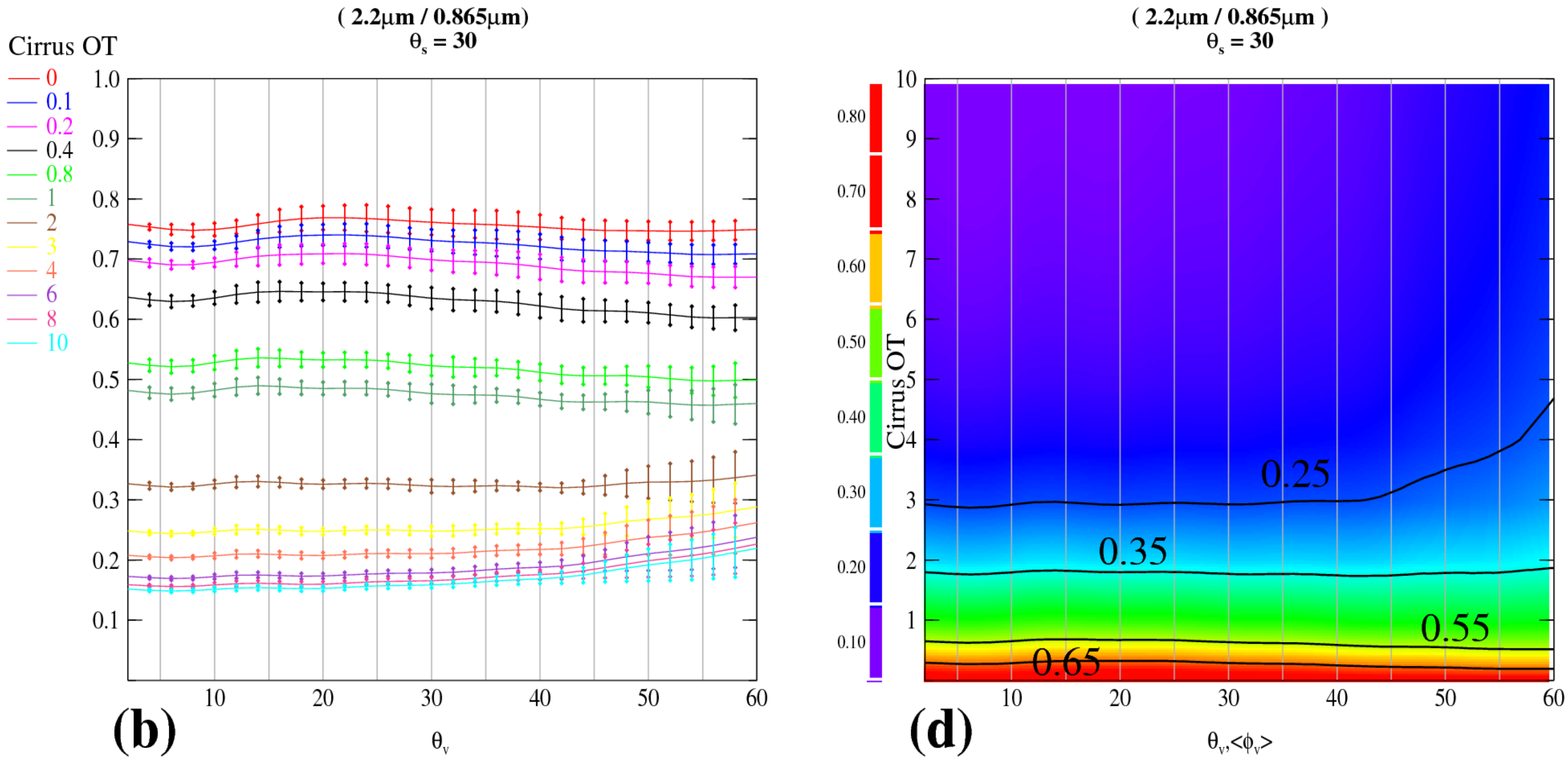


Simulation for cirrus (10km) above low water cloud (2km) - Polarisation



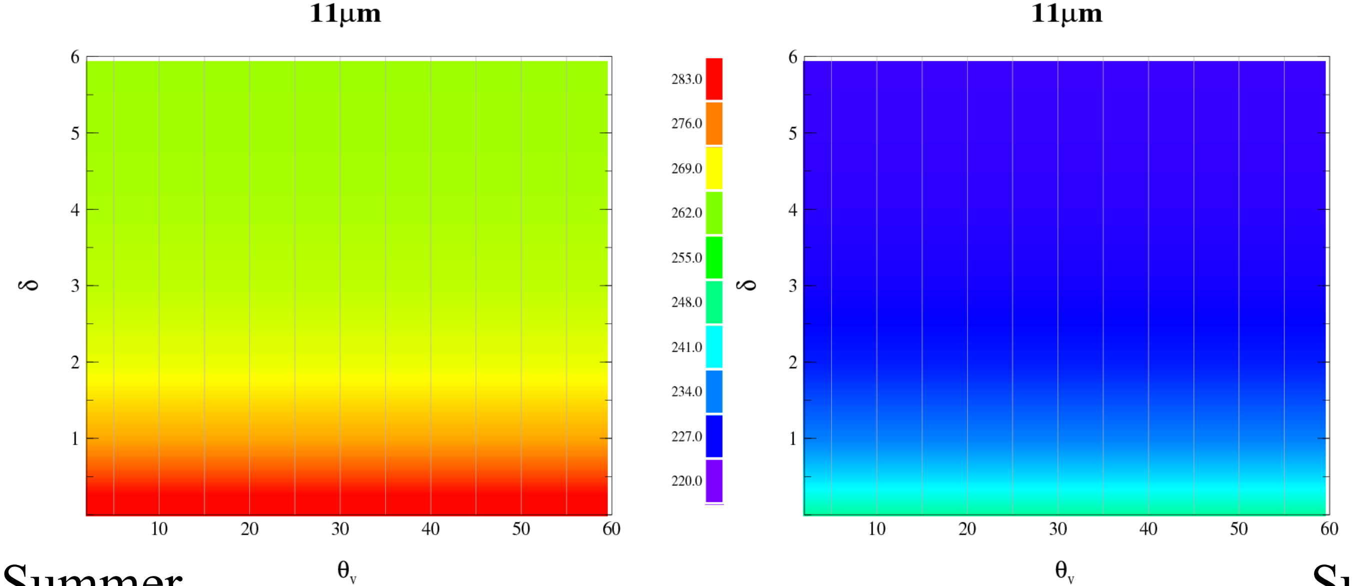
Simulation for cirrus (10km) above low water cloud (2km) - SWIR/VIS



Simulated ratio of the 2.1 to 0.86 microns reflectances for a multilayer situation.

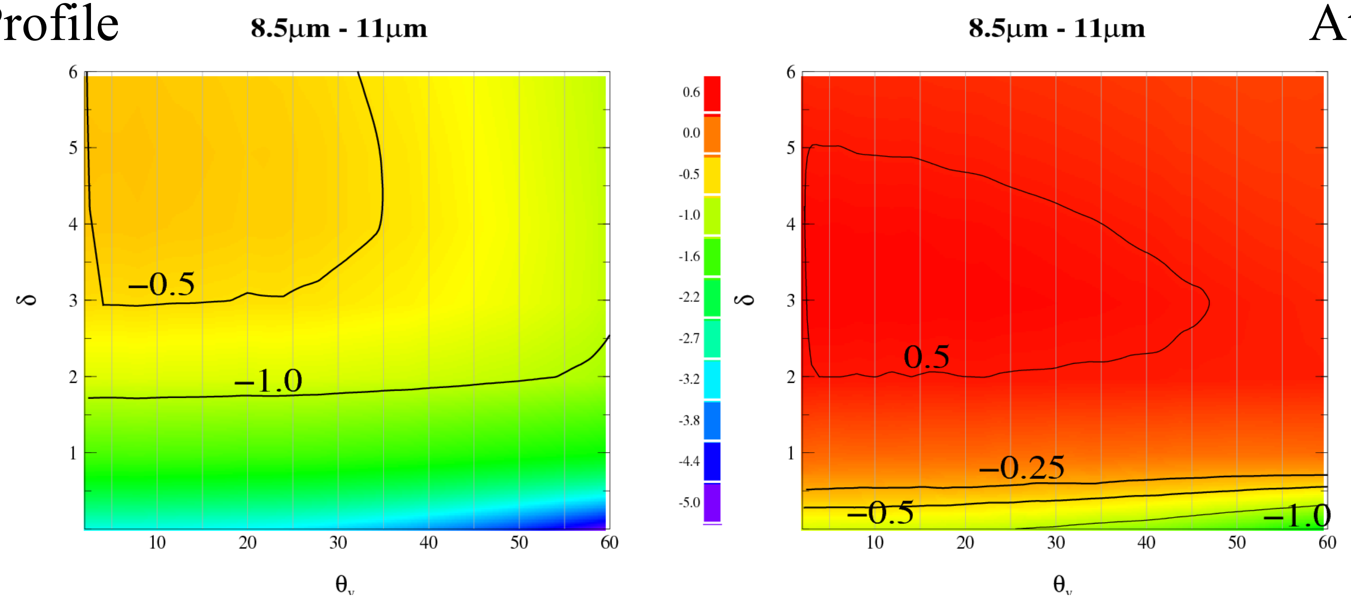
Simulation for cirrus (10km) above low water cloud (2km)

Thermal IR brightness temperature at 11 microns and brightness temperature differences between 8.5 and 11 microns MODIS channels.



Tropical Summer Atmos. Profile

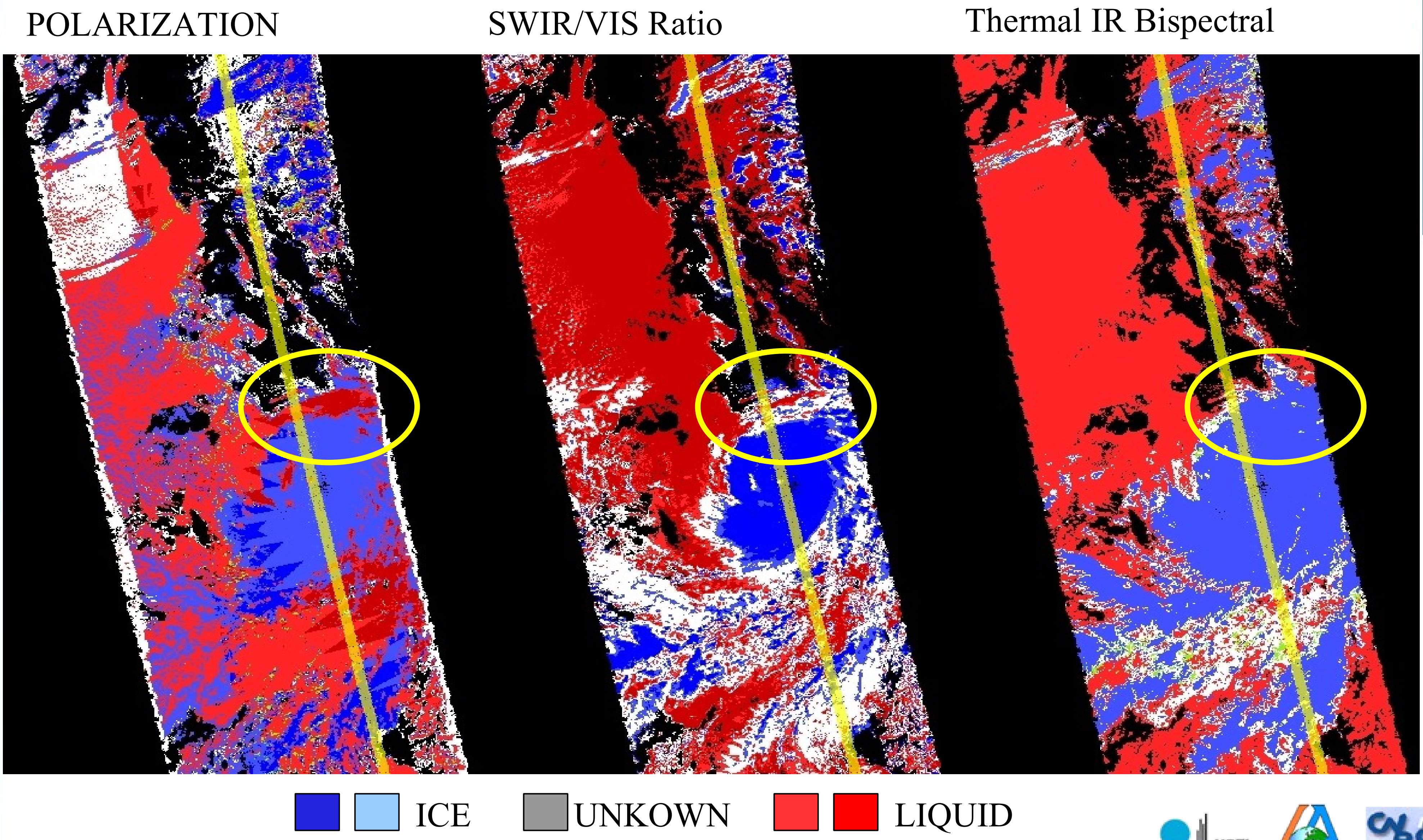
Sub Arctic Winter Atmos. Profile



Cloud thermodynamic phase

Combination of information on particle shape and absorption properties

A-Train analysis : combining POLDER and MODIS to infer cloud phase



Cloud thermodynamic phase

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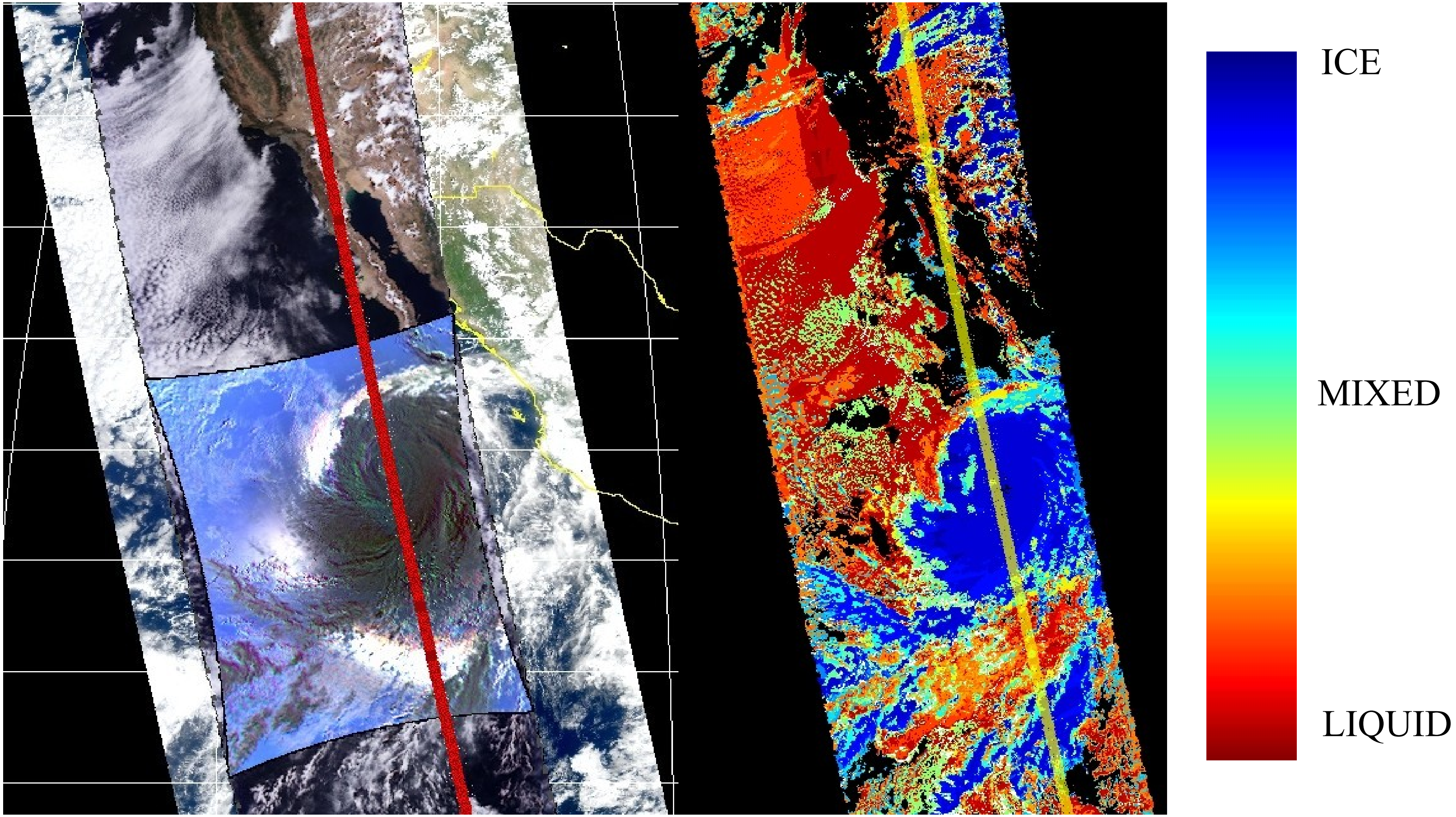

Riedi et al, in ACPD, Oct. 2007

Cloud thermodynamic phase

Atmos. Chem. Phys. Discuss., 7, 14103–14137, 2007
www.atmos-chem-phys-discuss.net/7/14103/2007/

Atmospheric Chemistry and Physics Discussions

Cloud thermodynamic phase inferred from merged POLDER and MODIS data

J. Riedi[1], B. Marchant[1], S. Platnick[2], B. Baum[3], F. Thieuleux[1], C. Oudard[1], F. Parol[1], J-M. Nicolas[4], and P. Dubuisson[1]

[1]Laboratoire d'Optique Atmosphérique, Université des Sciences et Technologies de Lille, France
[2]NASA Goddard Space Flight Center, MD, USA
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ACPD

7, 14103–14137, 2007

Cloud phase from POLDER and MODIS data

J. Riedi et al.

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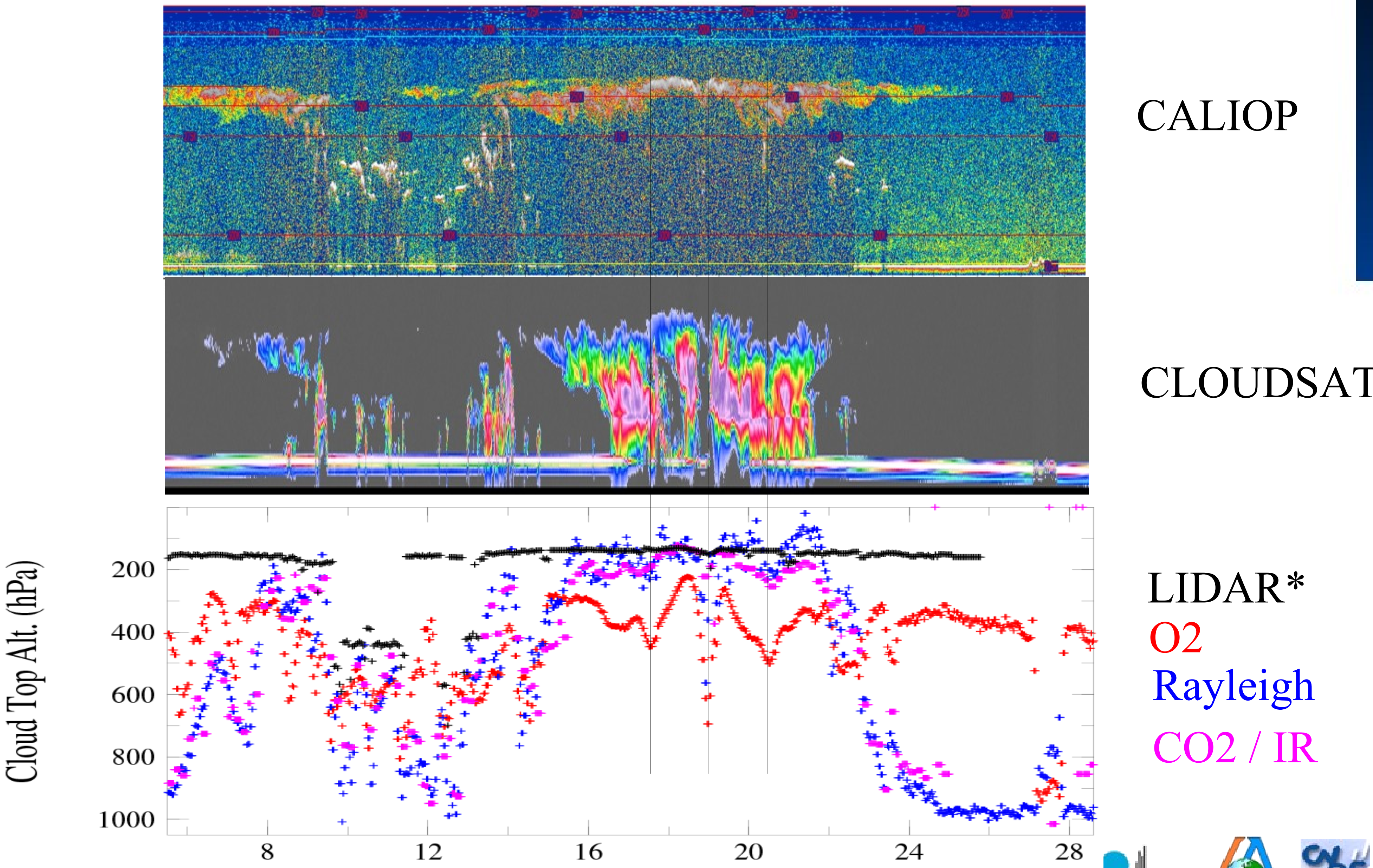
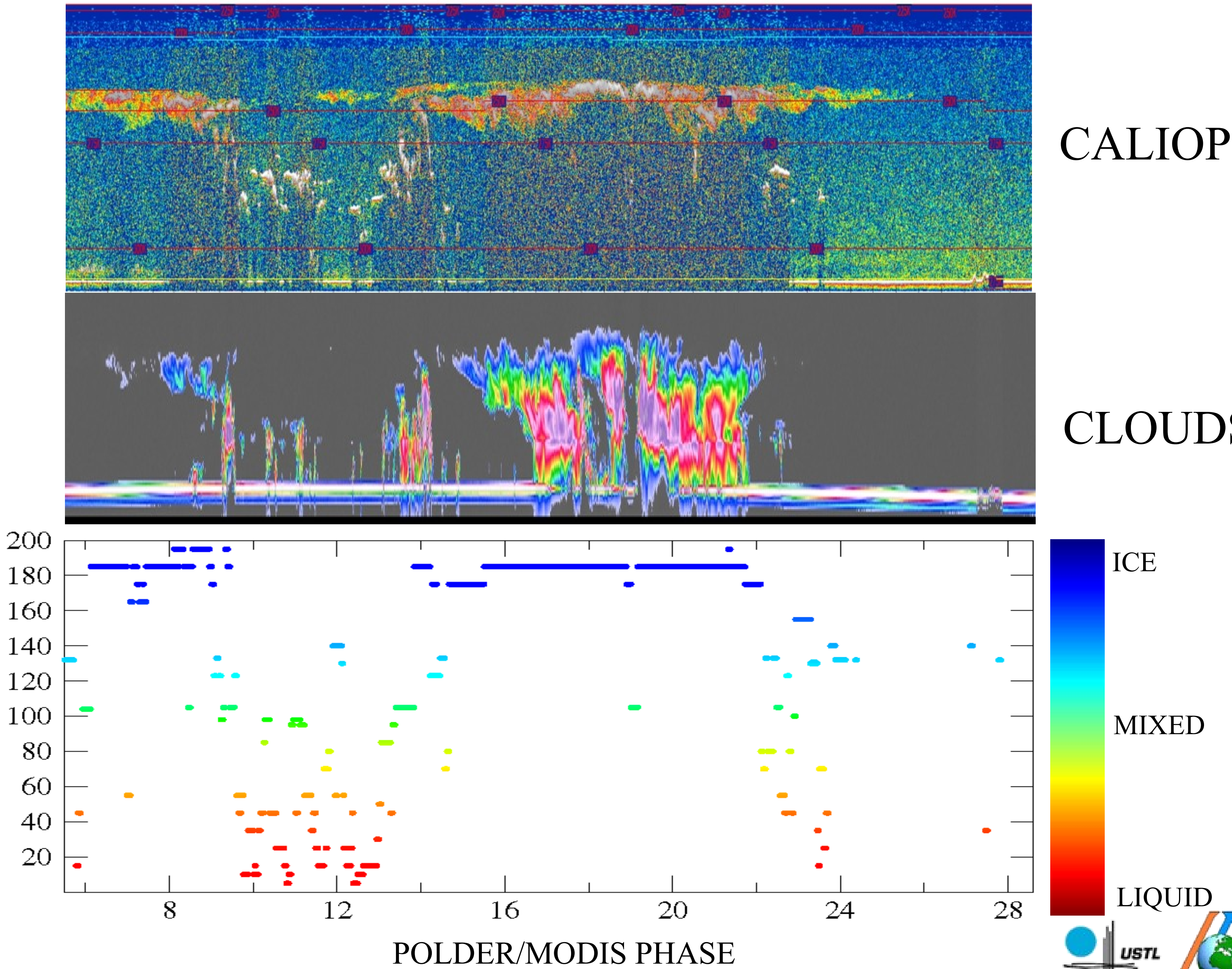
Cloud thermodynamic phase



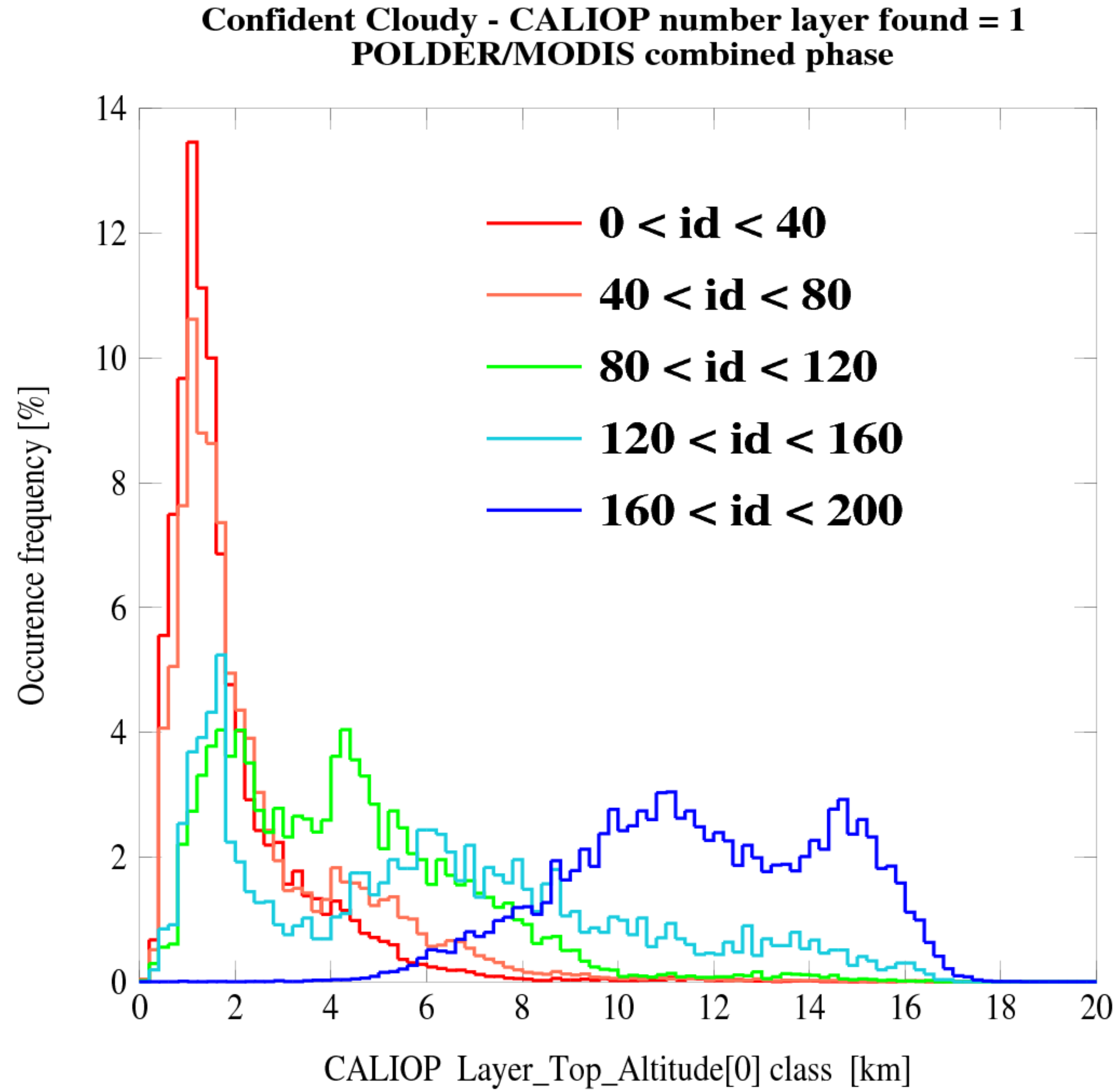
Cloud thermodynamic phase



Cloud thermodynamic phase

PDF of cloud top layer altitude from CALIOP function of cloud phase
Case of single layer

Confident cloudy pixels over land and ocean.
August 2007



Conclusions and Perspectives

Cloud phase is an important parameter for both cloud modelling and cloud properties remote sensing.

Understanding cloud particles optical properties is crucial for cloud phase and microphysical properties retrieval.

No one instrument is expected to provide a right answer to a wrong question : cloud phase information retrieved depends strongly on the type of measurements and cloud vertical structure.

Part of the answer will come from combining observations from different sensors and by trying to link the phase at cloud top to the vertical structure of the atmosphere.

The A-Train observations combined with models will improve our understanding of cloud thermodynamic phase and link with precipitations.