Retrieval of cloud properties using SCIAMACHY on ENVISAT

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AGENDA

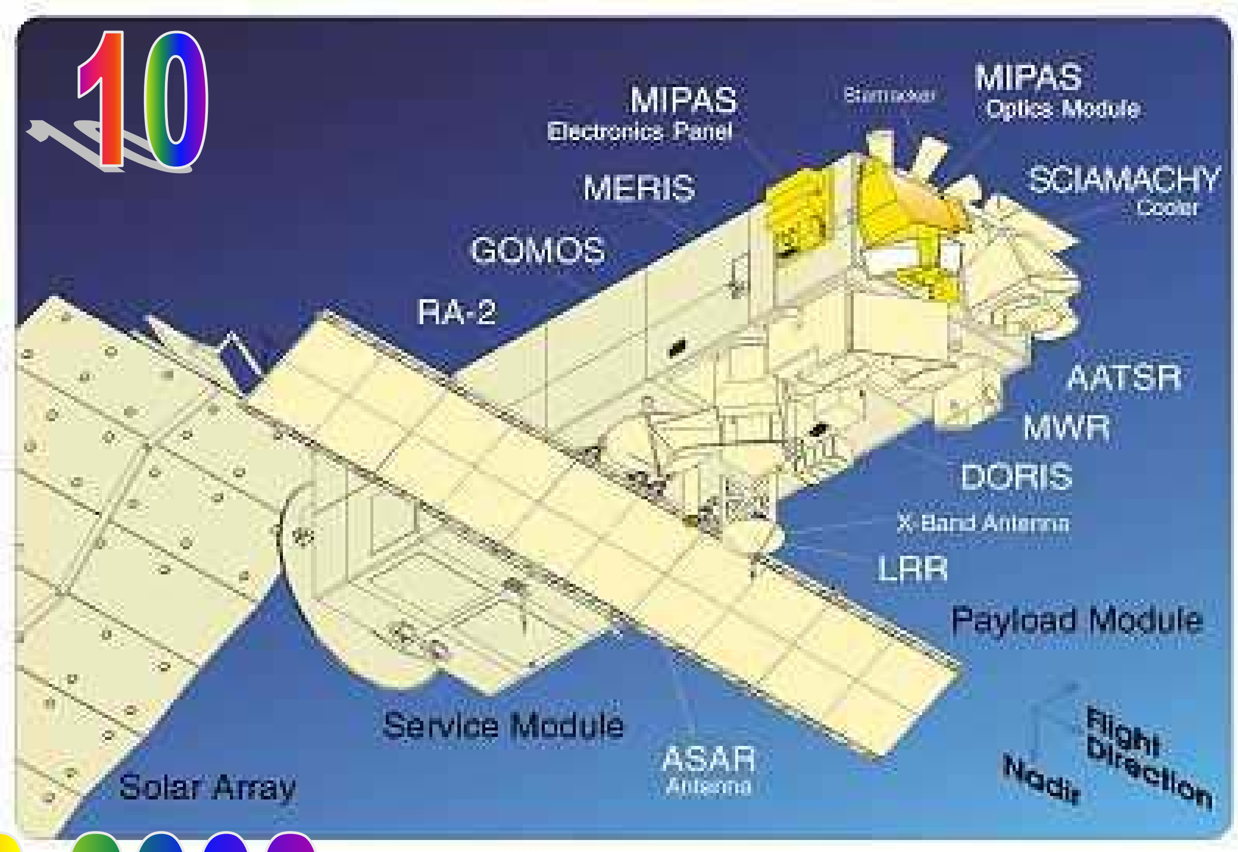
1. Rationale
2. SCIAMACHY and its calibration
3. Algorithms
4. SCIMACHY cloud retrievals
5. Problems to be solved

Rationale: Cloud remote sensing is needed for numerous applications, e.g.

- weather prediction, hydrological cycle studies, climate change studies;
- the improvement of the accuracy of the remote sensing of trace gases from space (e.g., ozone, nitrous dioxide, etc.);
- studies of anthropogenic influences on cloud properties (cloud top height, cloud top temperature, size of particles).

2. 10 INSTRUMENTS

SCIAMACHY/ ENVISAT



01.03.2002

Credit: ESA

ENVISAT Start: 01.03.2002

INSTRUMENTS

1. An Advanced Synthetic Aperture Radar (ASAR), operating at C-band, ASAR ensures continuity with the image mode (SAR) and the wave mode of the ERS-1/2 AMI.

2. MERIS is a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range. Fifteen spectral bands can be selected by ground command, each of which has a programmable width and a programmable location in the 390 nm to 1040 nm spectral range.

INSTRUMENTS

3. The prime scientific objective of the Advanced Along Track Scanning Radiometer (AATSR) is to establish continuity of the ATSR-1 and ATSR-2 data sets of precise sea surface temperature (SST), thereby ensuring the production of a unique 10 year near-continuous data set at the levels of accuracy required (0.3 K or better) for climate research and for the community of operational as well as scientific users who have been developed through the ERS-1 and ERS-2 missions.

4. Radar Altimeter 2 (RA-2) is an instrument for determining the two-way delay of the radar echo from the Earth's surface to a very high precision: less than a nanosecond. It also measures the power and the shape of the reflected radar pulses.

INSTRUMENTS

5. The main objective of the microwave radiometer (MWR) is the measurement of the integrated atmospheric water vapour column and cloud liquid water content, as correction terms for the radar altimeter signal. In addition, MWR measurement data are useful for the determination of surface emissivity and soil moisture over land, for surface energy budget investigations to support atmospheric studies, and for ice characterization.

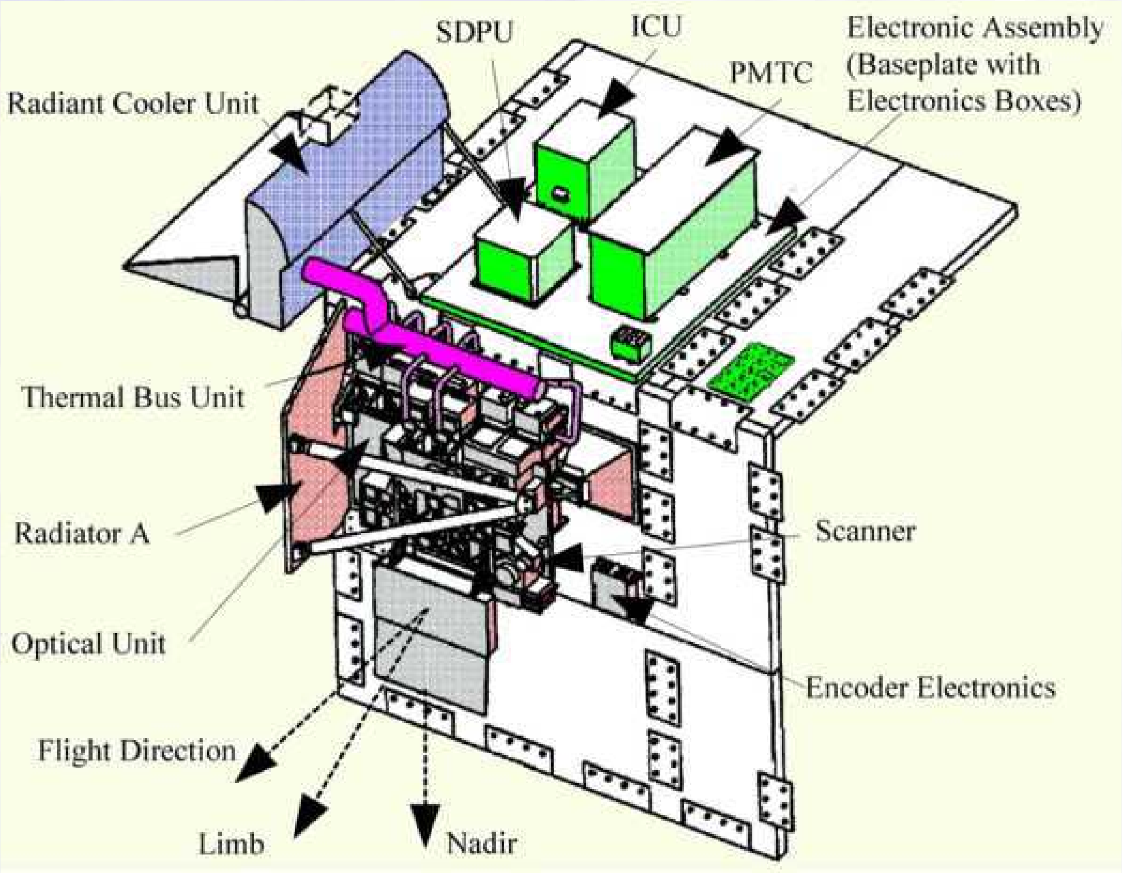
http://earth.esa.int

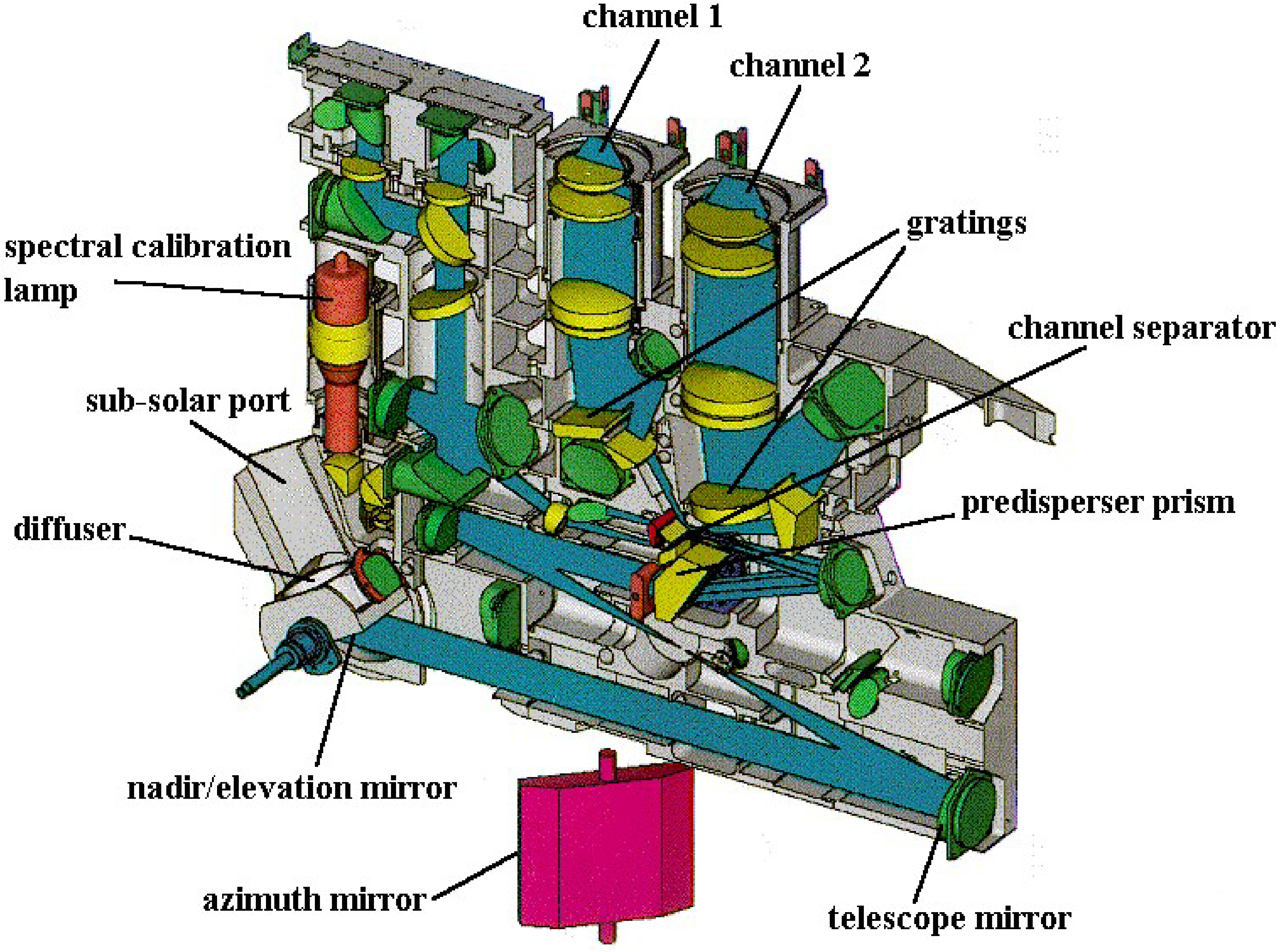
SCIAMACHY Instrument

SCIAMACHY = **SC**anning **I**maging **A**bsorption spectro**M**eter
for **A**tmospheric **CH**artograph**Y**

Characteristics:

- UV/Vis/NIR Spectrometer: 240 - 2380 nm
- Spectral resolution:
  0.2 – 1.5 nm
- 8000 spectral points
- SCIAMACHY measures:
  - **Reflected solar light (nadir)**
  - Scattered solar light (limb)
  - Transmitted solar/moon light (occultation)
  - Solar Irradiance




channel 1
channel 2
spectral calibration
lamp
gratings
channel separator
sub-solar port
predisperser prism
diffuser
nadir/elevation mirror
azimuth mirror
telescope mirror

SCIAMACHY channels(nm)

240-314(0.24)

309-405(0. 26)

COT:443nm 394-620(0.44)*

CTH:760nm 604-805(0.48)*

785-1050(0.54)

ER: 1550nm 1000-1750(1.48)*

1940-2040(0.22)

2265-2380(0.26)

8000

VICARIOUS CALIBRATION USING MERIS

MERIS on ENVISAT spacecraft /1.03.2002-present/

- Instrument bands:
- (1) → 412.5nm /10nm/
- (2) → 442.5nm /10nm/
- (3) → 490nm /10nm/
- (4) → 510nm /10nm/
- (5) → 560nm /10nm/
- (6) →620nm /10nm/
- (7) → 665nm /10nm/
- (8) →681.25nm /7.5nm/
- (9) →708.75nm /10nm/
- (10)→753.75nm /7.5nm/
- (11)→760.625nm /3.75nm/
- (12)→778.75nm /15nm/
- (13)→865nm / 20nm/
- (14)→885nm /10nm/
- (15)→900nm /10nm/

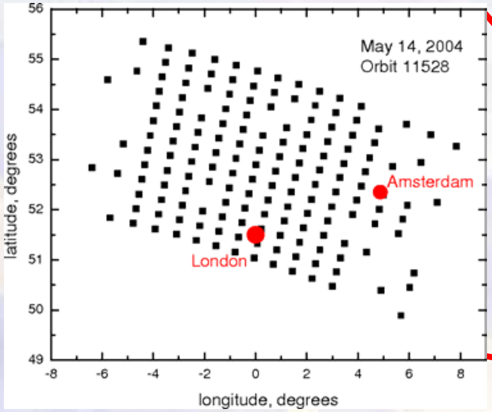
Mission characteristics:

- Orbit: Sun Synhronous at 800km
- Equator Crossing time: 10:00a.m.
- Swath width: 1150 km
- Spatial resolution: 0.3km (1.2km)
- The scene is imaged simultaneously across the entire spectral range, through a dispersing system, onto the CCD array.
- Global coverage: 1-3 days

Comparisons with MERIS (1)

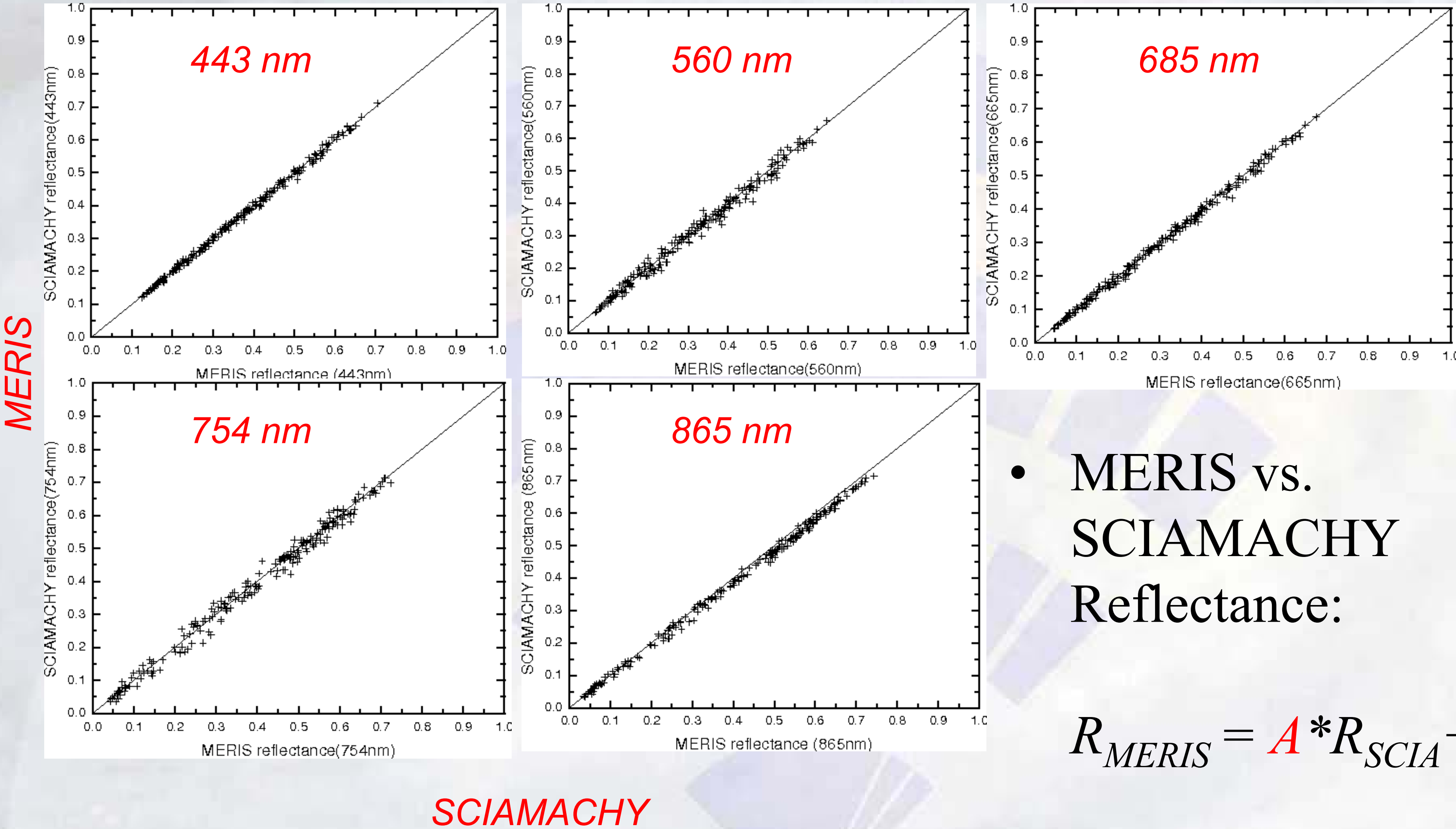
- Analysed data:
  - One state of orbit 11528 (14 May 2004)
    over Western Europe / UK
    - Broken clouds
    - Over ocean and land

    ⇨ Covers almost entire range of reflectance variability
  - MERIS reflectances are averaged over larger SCIAMACHY ground pixels (~1200 MERIS pixels per SCIAMACHY pixel)
  - SCIAMACHY spectral data are averaged over MERIS filter bands



MERIS Browse Image

Comparisons with MERIS (2)



- MERIS vs. SCIAMACHY Reflectance:

  $R_{MERIS} = A * R_{SCIA} + B$

- Results:

  A, *B* and Correlation Coefficient

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SCIAMACHY

Summary: Comparisons with MERIS

Wavelength, nm	*A* slope	*B* bias	Corr. Coeff.
443	1.0017	0.0010	0.9975
560	1.0135	-0.0016	0.9890
665	1.0106	0.0008	0.9966
754	1.0099	0.0002	0.9899
865	1.0375	-0.0007	0.9978

- Good agreement between SCIAMACHY and MERIS
- Bias negligible
- Only 1% difference of reflectances in the visible
- SCIAMACHY reflectance at 865 nm by 4% lower than that of MERIS

⇨ Within specified MERIS reflectance accuracy

3. Algorithms

CLOUD PARAMETERS to be retrieved:

Cloud optical thickness /5-100/

Cloud top height /0.5-10km/

Cloud bottom height/0.5-10km/

Cloud cover /0-1/

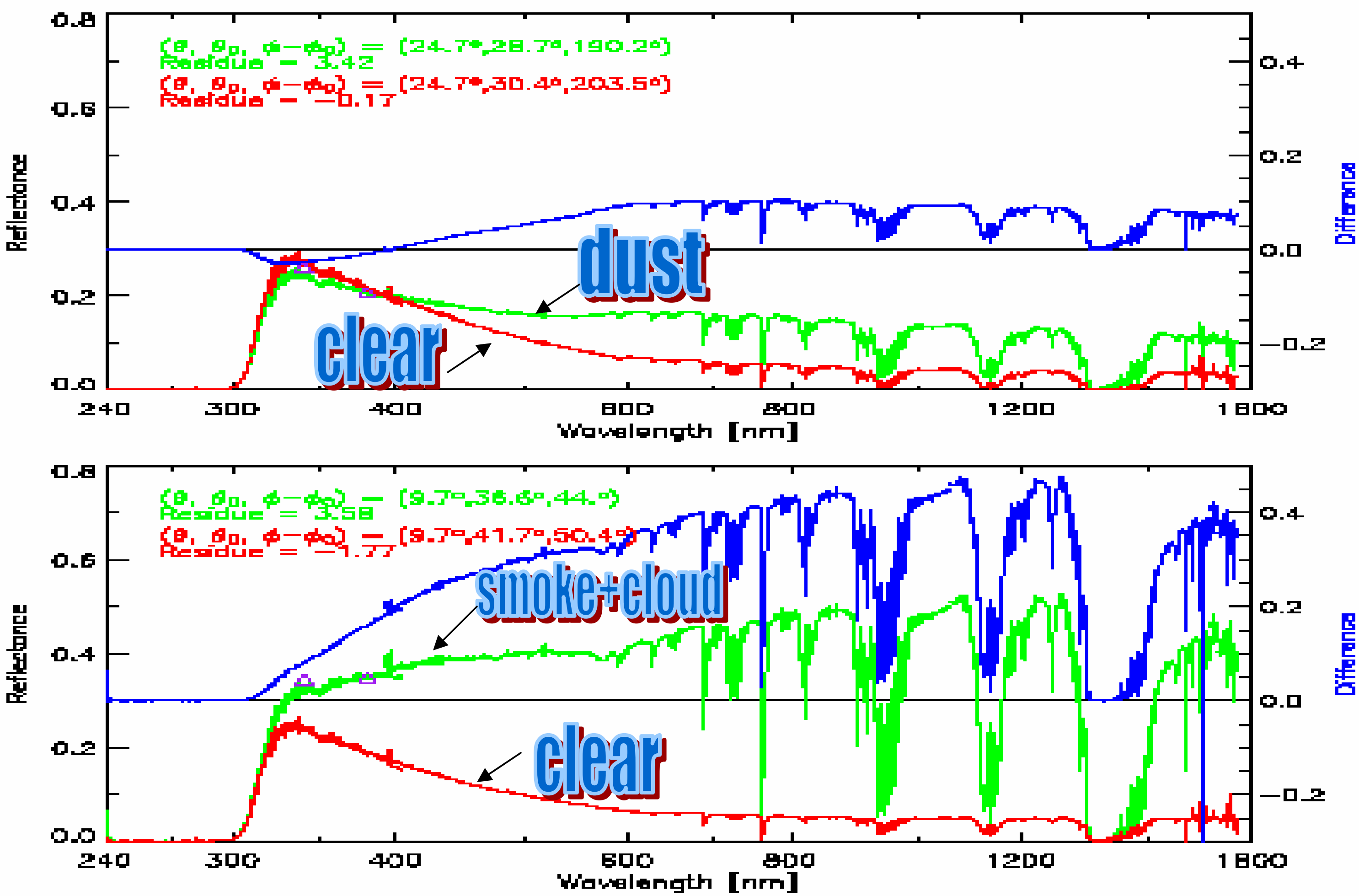
Cloud albedo/0.3-0.8/

Liquid water path /50-200 gm^{-2}/

Thermodynamic phase /ice, water or mixed clouds/

Average size of droplets/crystals

EXPERIMENTAL MEASUREMENTS



credit: de Graaf and Stammes, 2006

OCEAN

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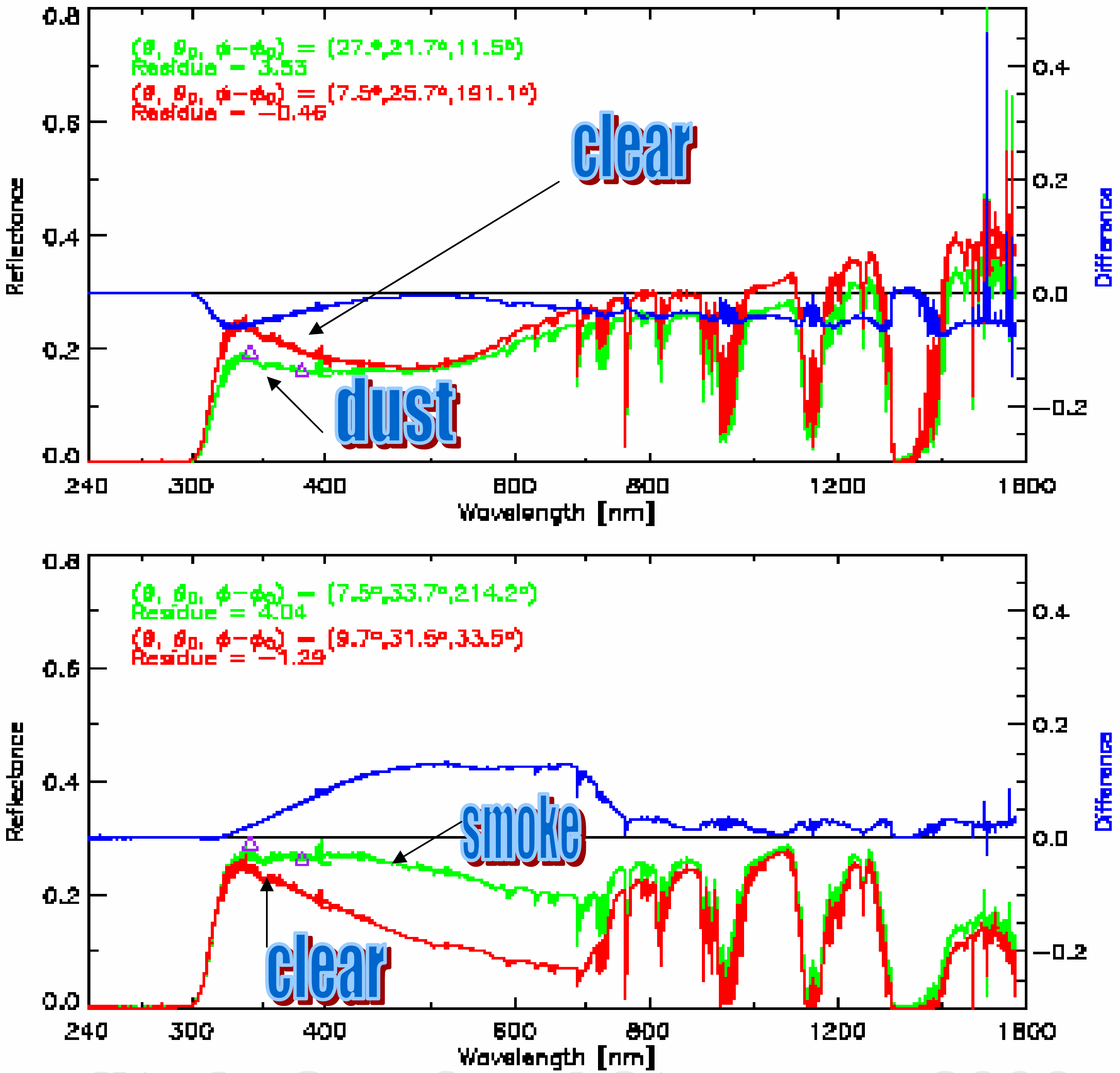

credit: de Graaf and Stammes, 2006

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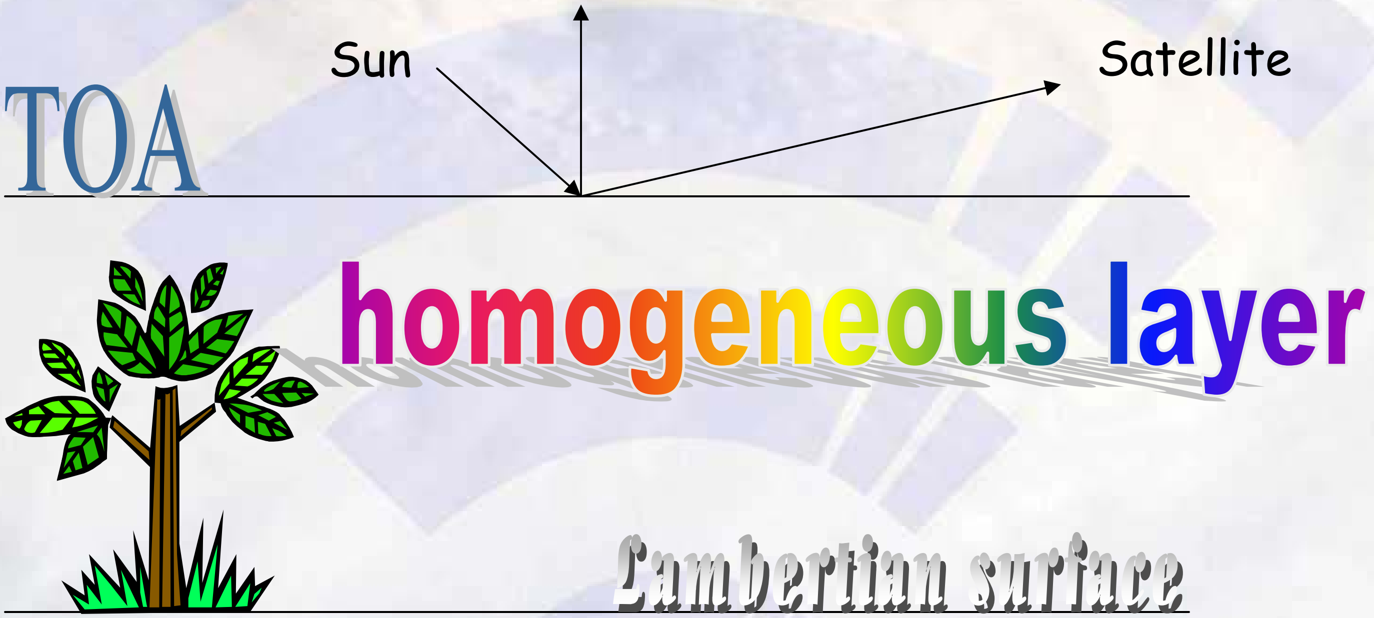
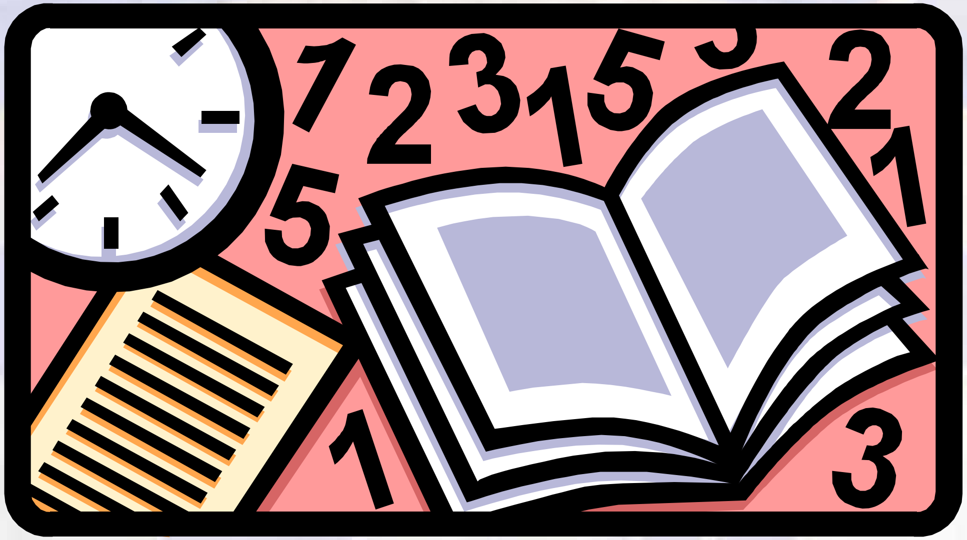
LAND

Assumptions: macro-geometry



Assumptions: mathematical model



$$\cos\vartheta \frac{\mathrm{d}I(\vartheta_0,\vartheta,\phi)}{\mathrm{d}\tau} = -I(\vartheta_0,\vartheta,\phi) + \mathrm{B}(\vartheta_0,\vartheta,\phi)$$

τ – optical thickness

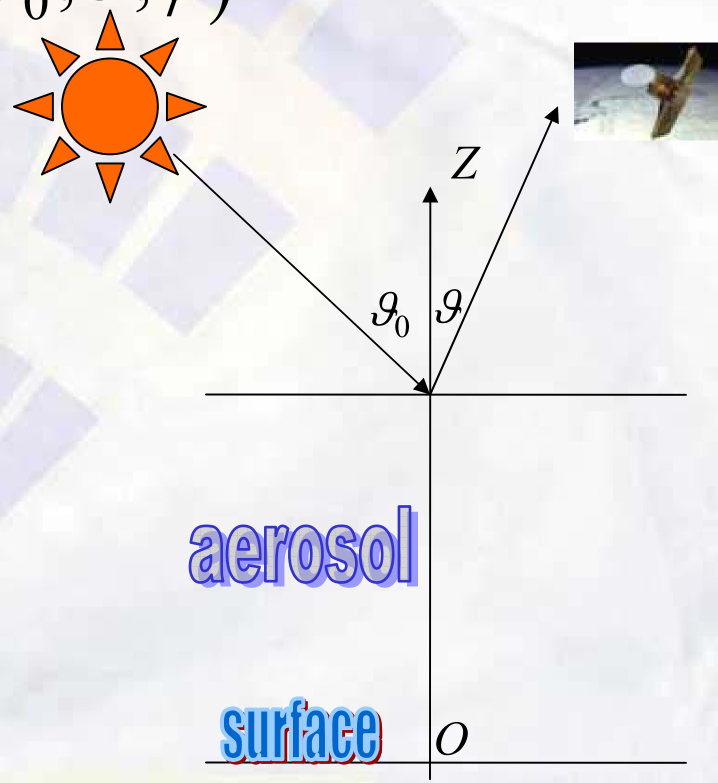
ϑ_0 – zenith solar angle

ϑ – zenith observation angle

ϕ – relative azimuth

I – reflected light intensity

B – source function



Assumptions in cloud retrievals

- No absorbing aerosols present
- Plane-parallel homogeneous layer
- Shape of particles

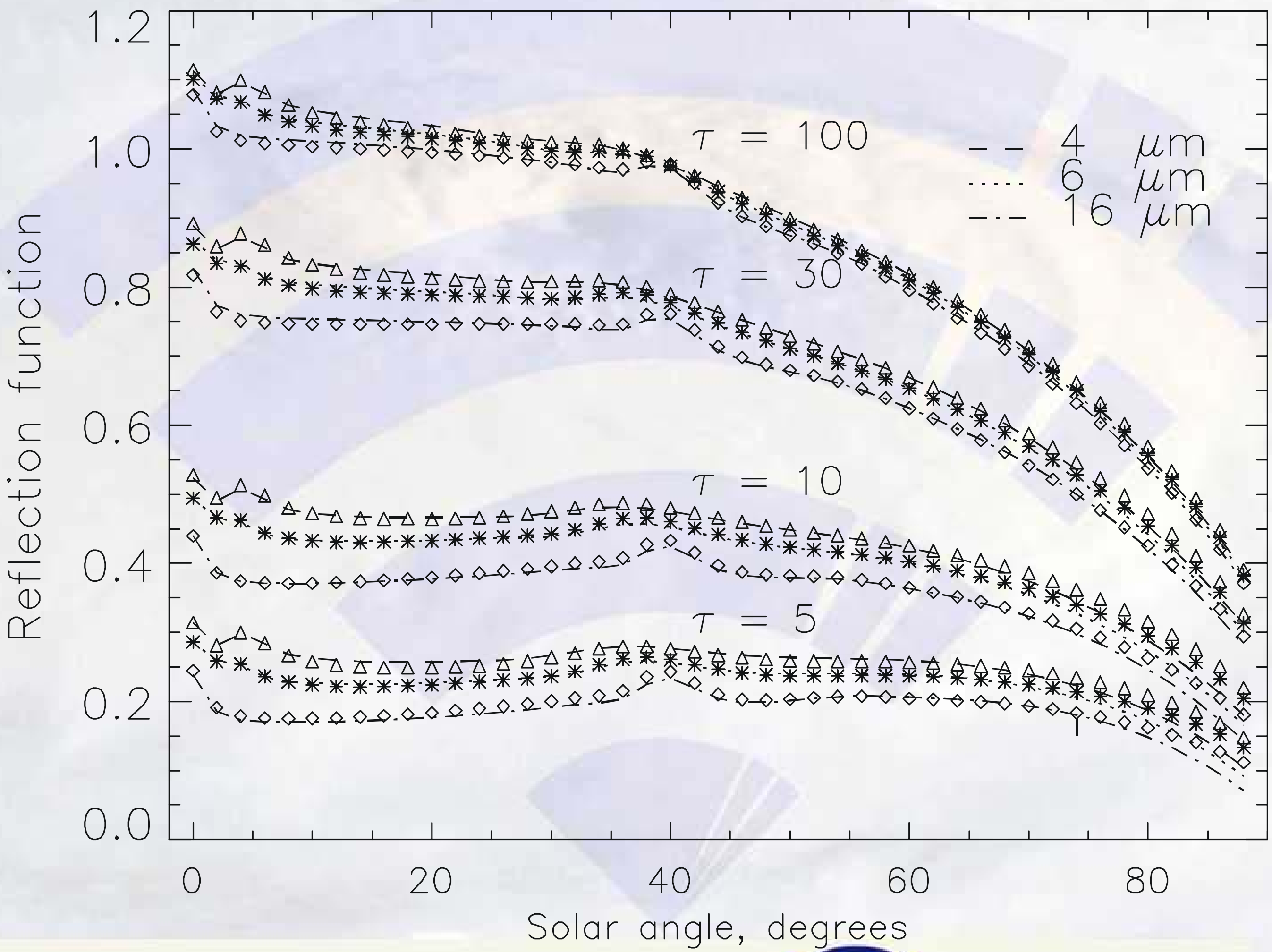
2 channels: VIS, NIR→LWP, ER

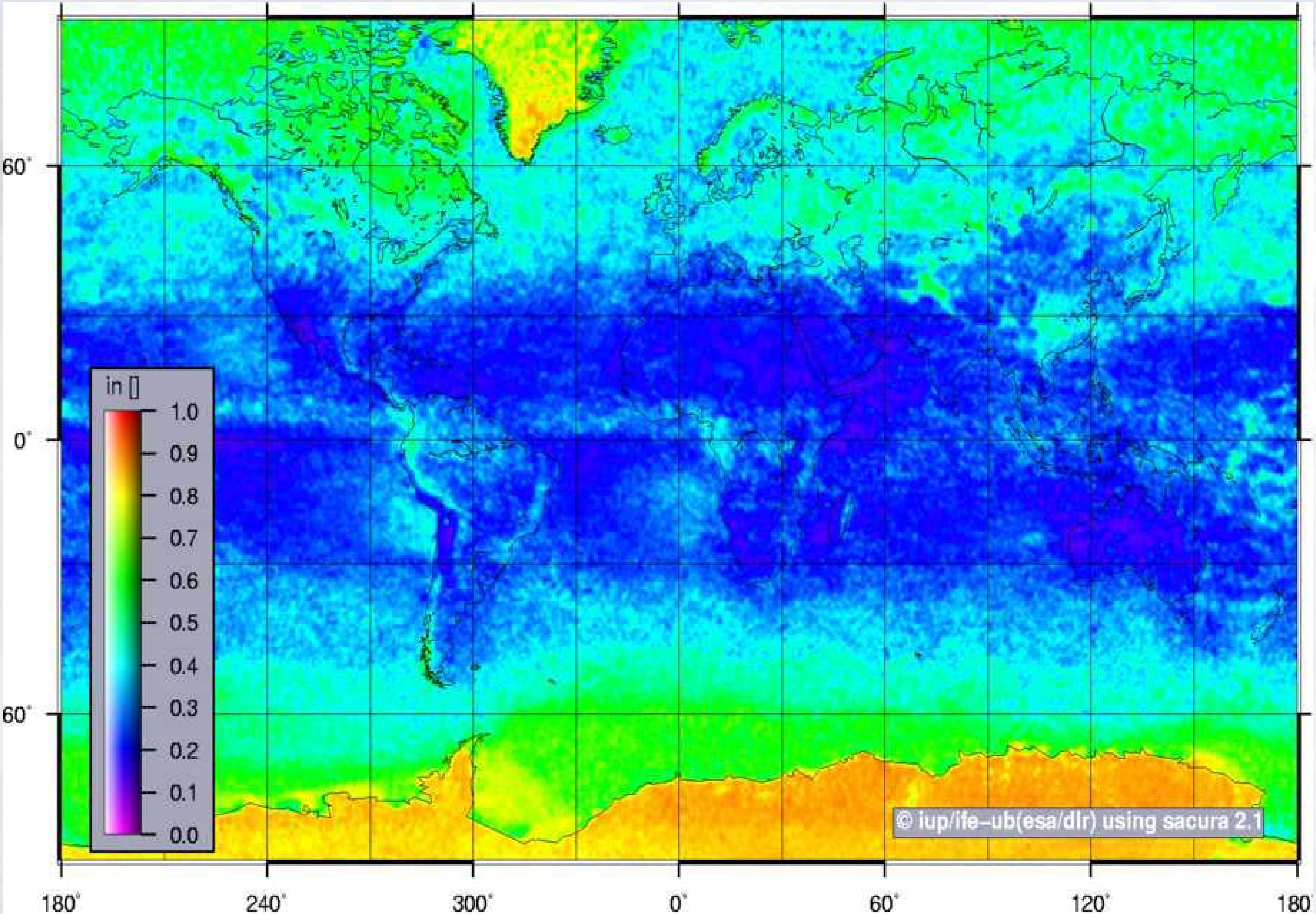
O2 A-band: CTH

PHYSICAL BACKGROUND

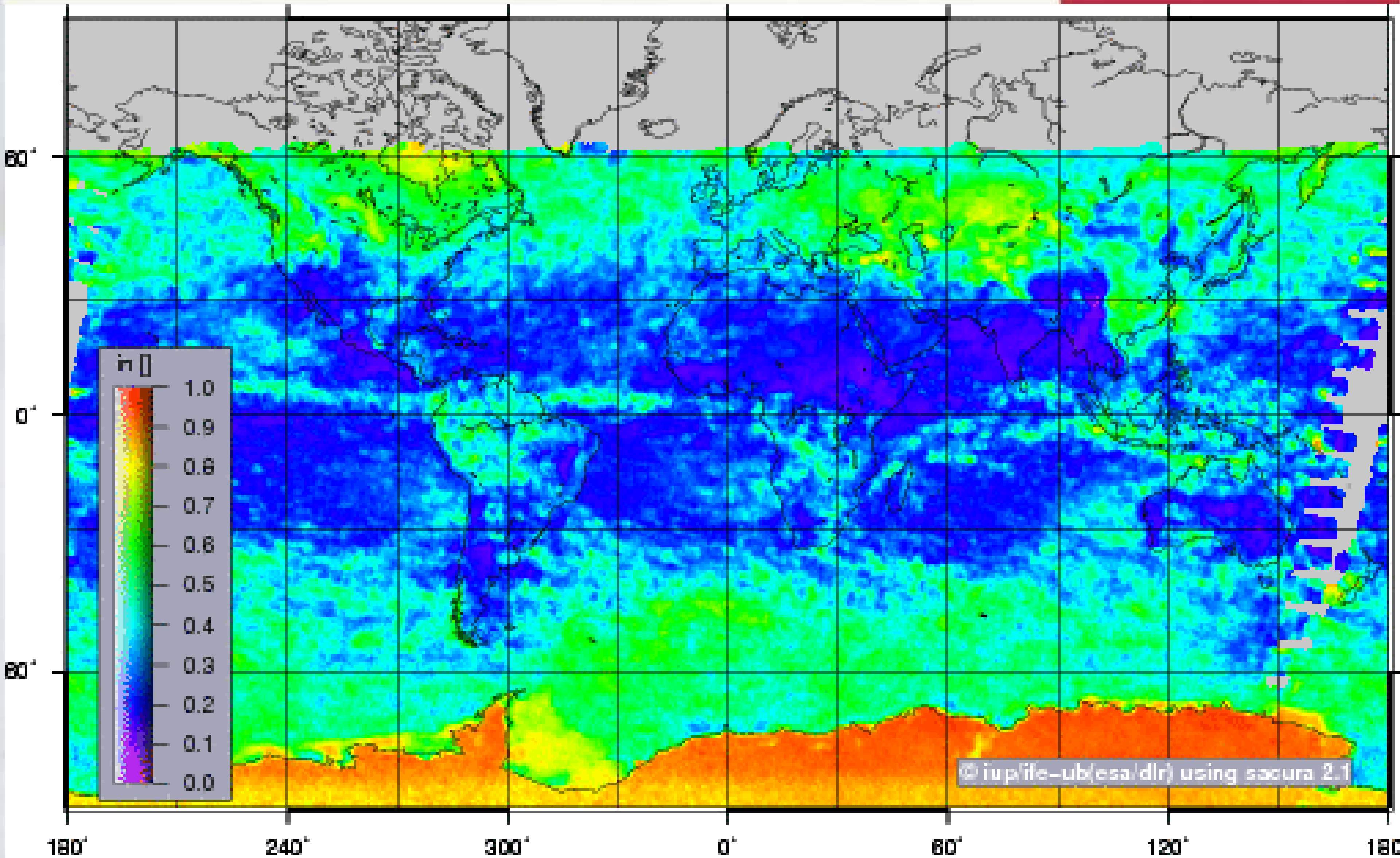
The cloud optical thickness determination: the physical principle

Kokhanovsky and Rozanov,2003 $\lambda = 0.65\,\mu m$

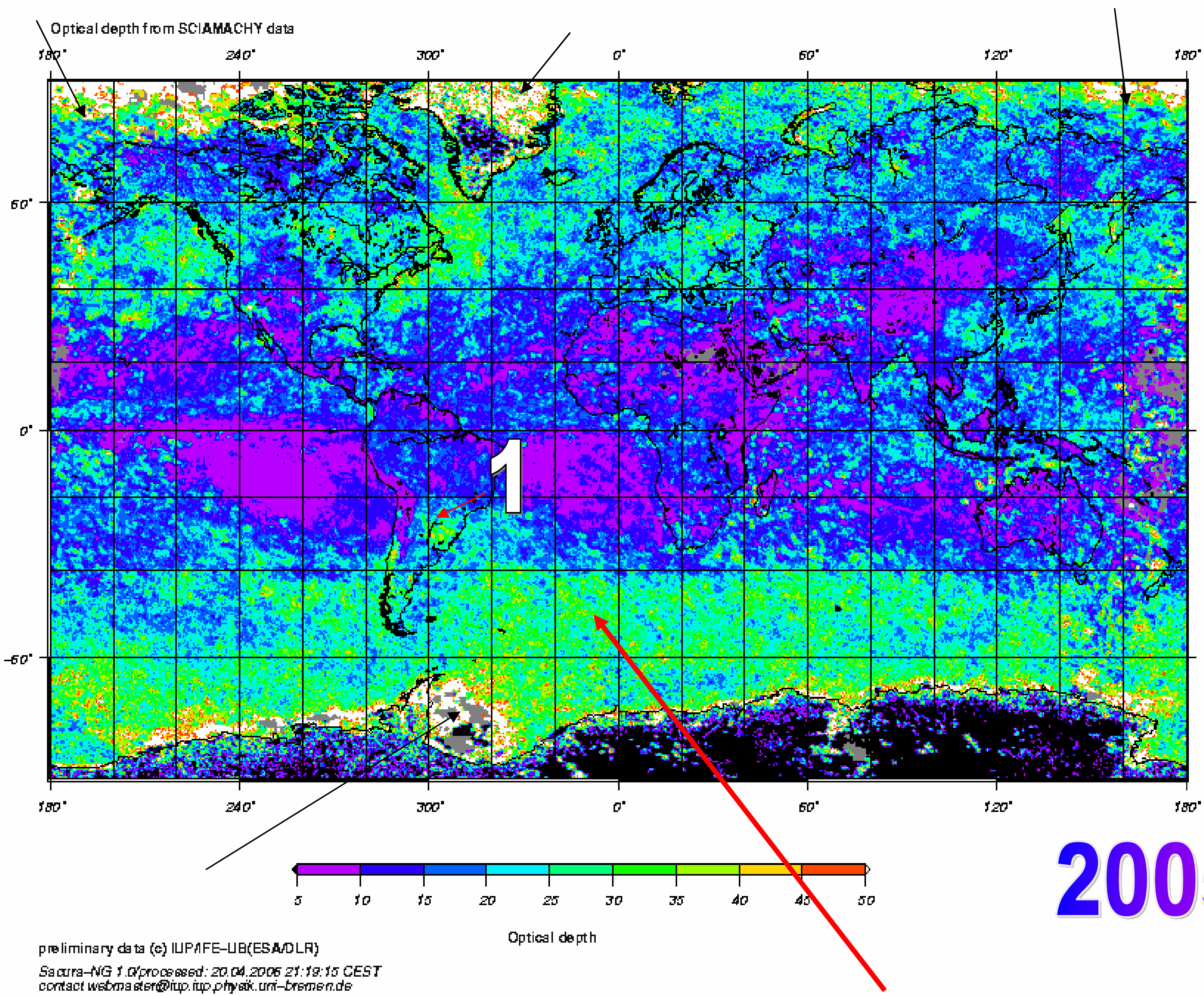




Reflectance at 443 nm from SCIAMACHY data (01. January 2006 – 31. December 2006)



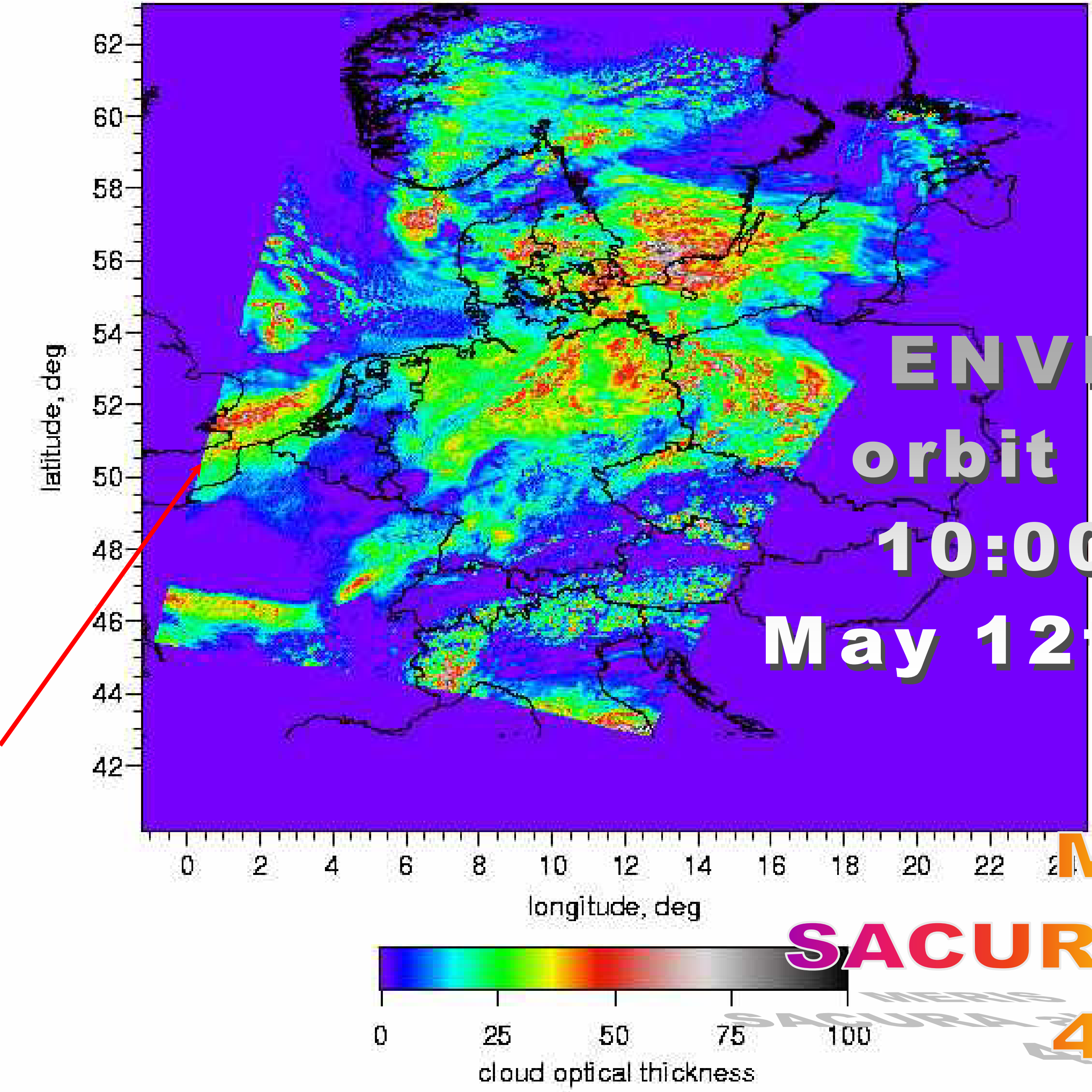
Reflectance at 443 nm from SCIAMACHY data (01. January 2006 – 31. January 2006)


Optical depth from SCIAMACHY data
180°
240°
300°
0°
60°
120°
180°
60°
0°
-60°
1
5
10
15
20
25
30
35
40
45
50
Optical depth
preliminary data (c) IUP/IFE-UB(ESA/DLR)
Sacura-NG 1.0/processed: 20.04.2006 21:19:15 CEST
contact webmaster@iup.iup.physik.uni-bremen.de

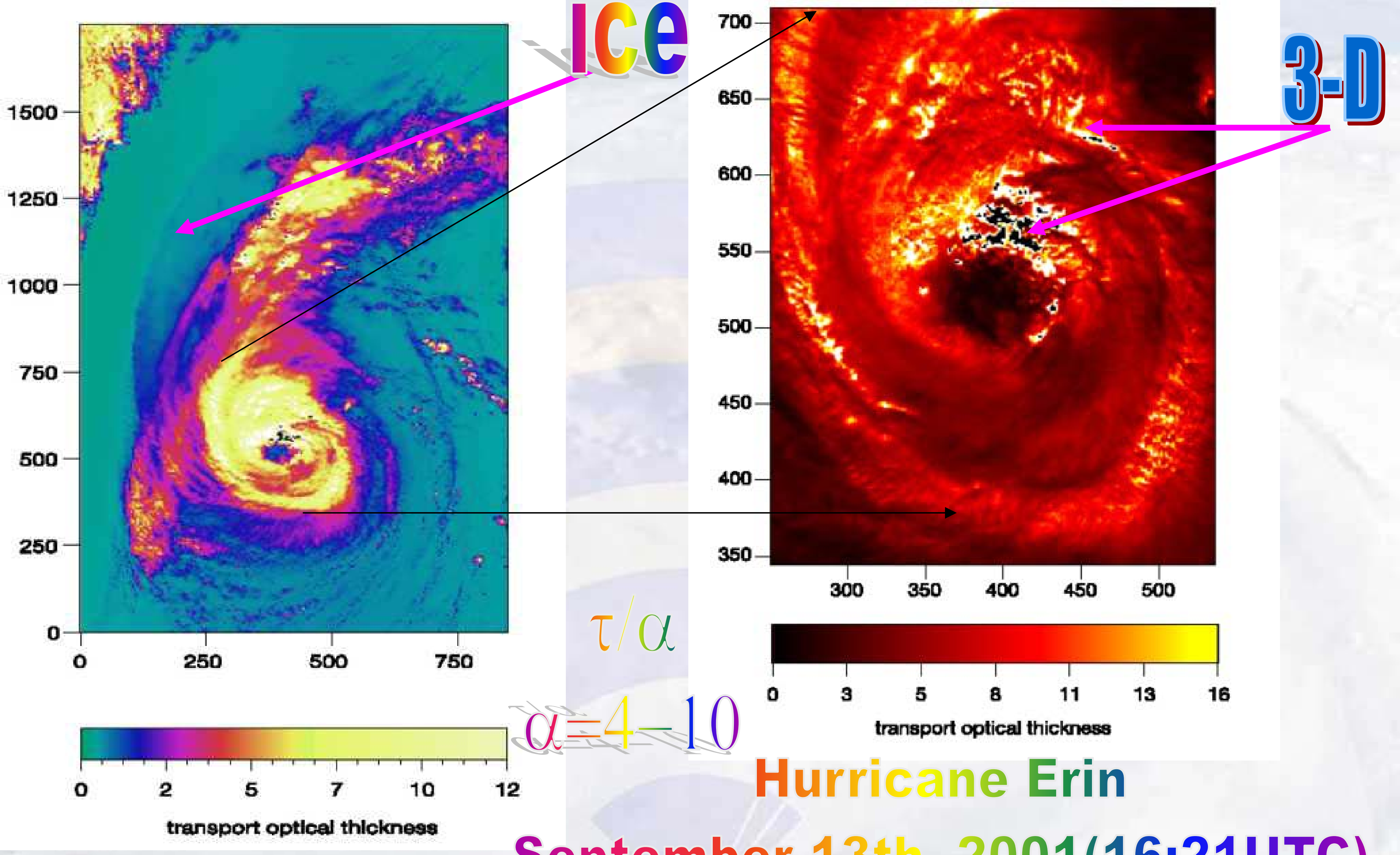
2005

1km*1km

ENVISAT
orbit 11499
10:00 UTC
May 12th, 2004



MERIS
SACURA algorithm
443nm



Hurricane Erin

September 13th, 2001(16:21UTC)

700KM*1400KM

SeaWiFS/SACURA

39N

60W

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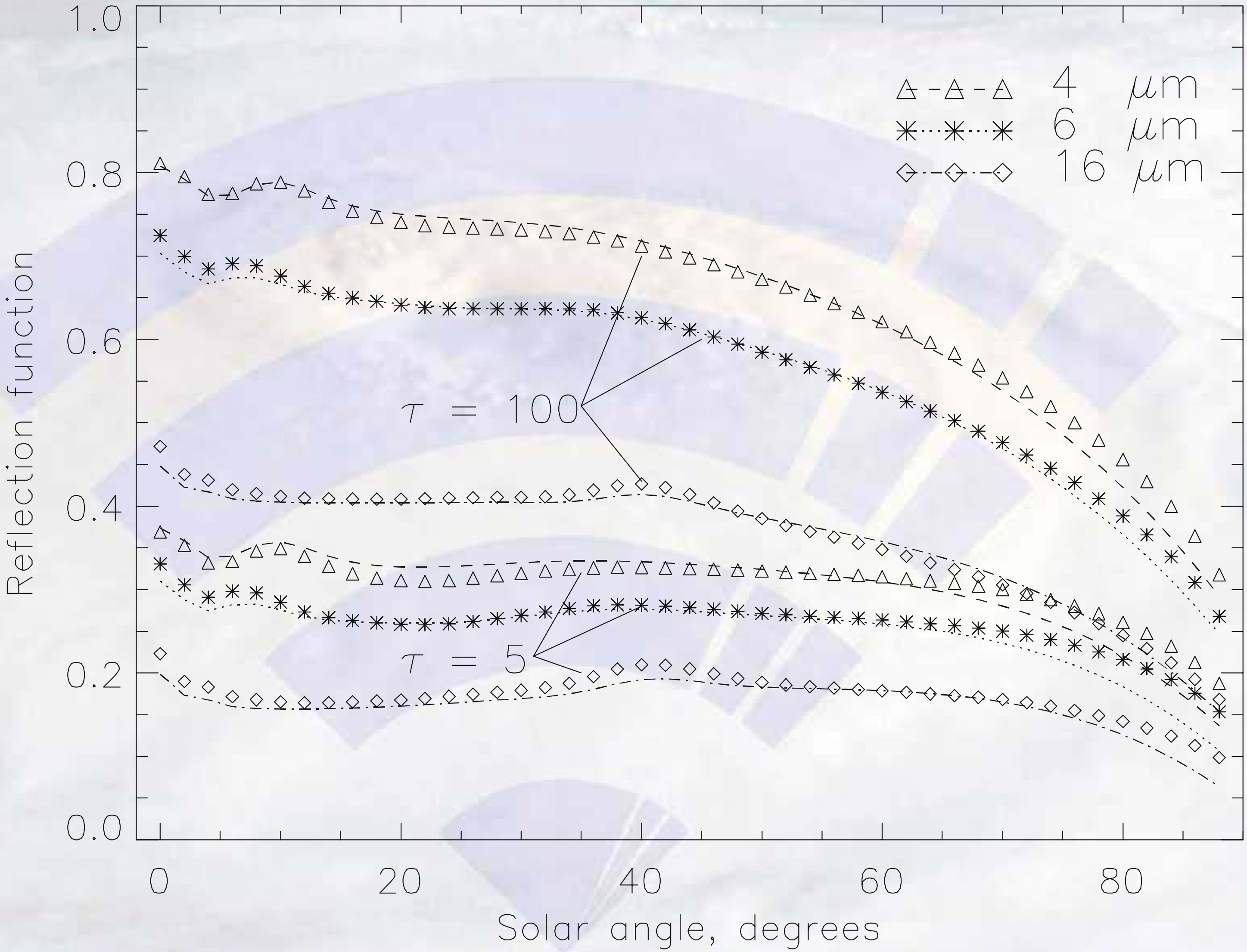
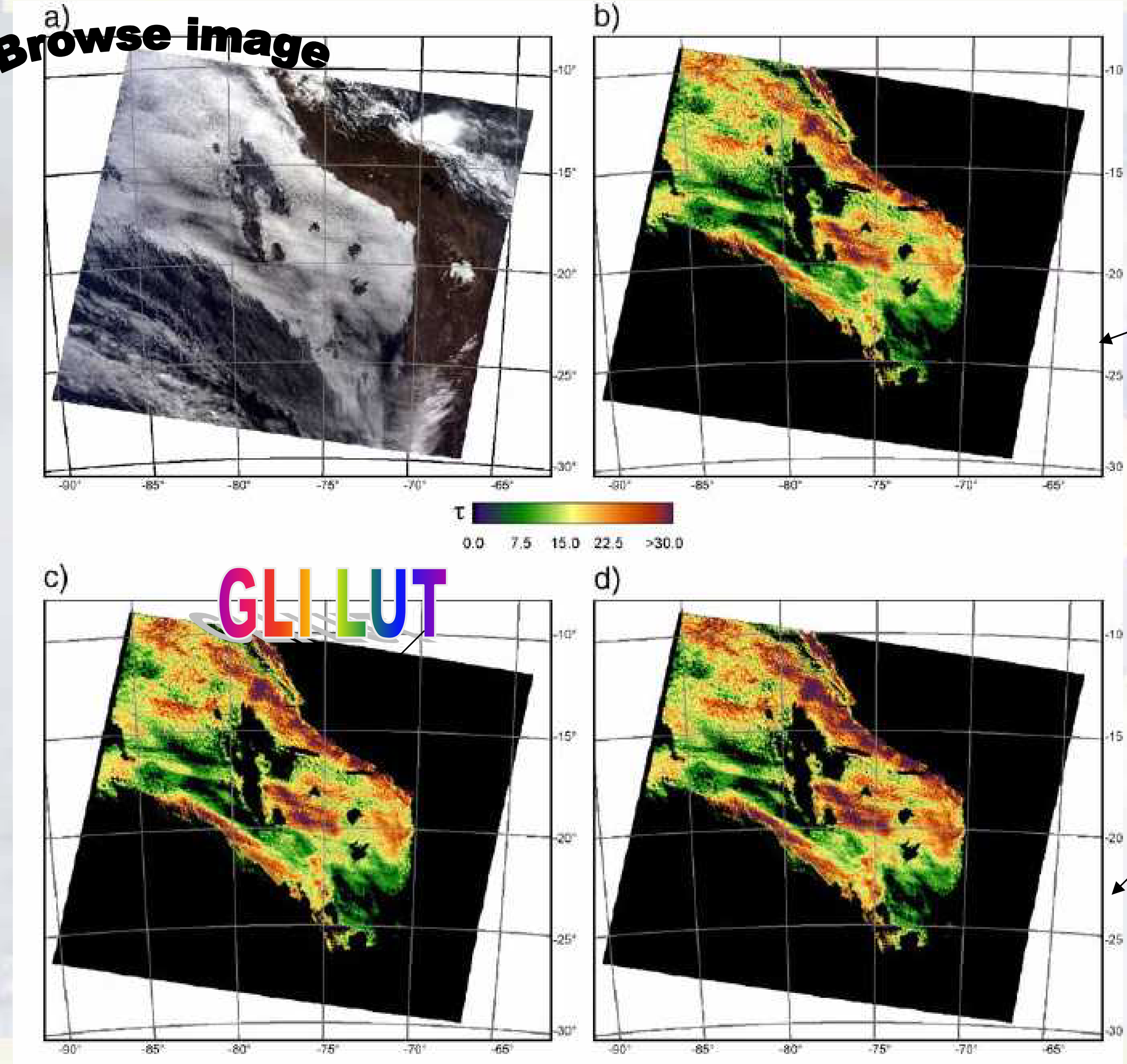
The effective radius determination from a satellite

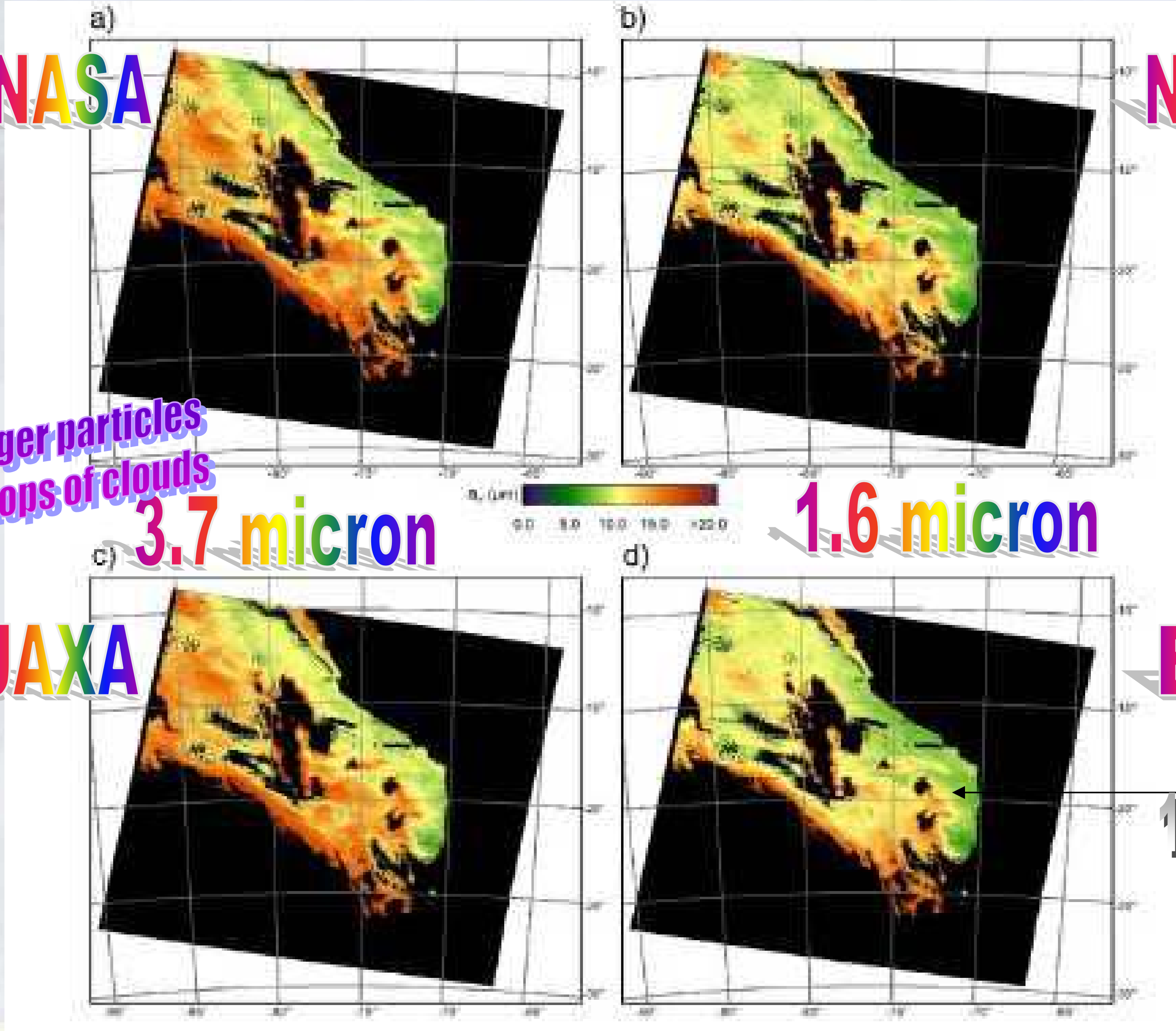
Kokhanovsky and Rozanov, 2003 $\lambda = 1.55 \mu m$





Nauss et al., 2005

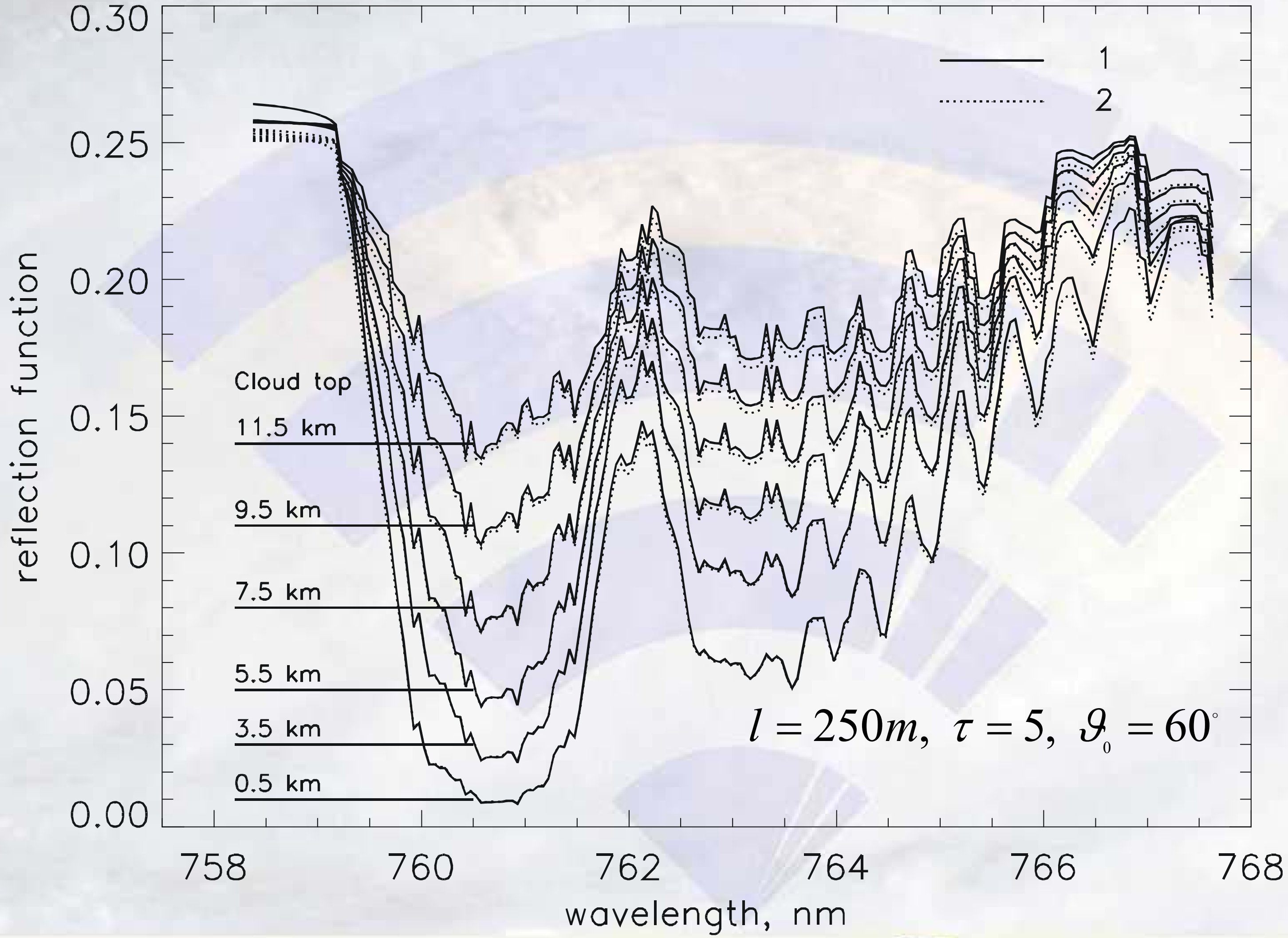
Fig. 2. Composite image (a) and optical thickness retrieved from MOD06 (b), ATSK3 (c) and SACURA (d) f
Terra-MODIS scene from July 18th 2001, 15:30 UTC.



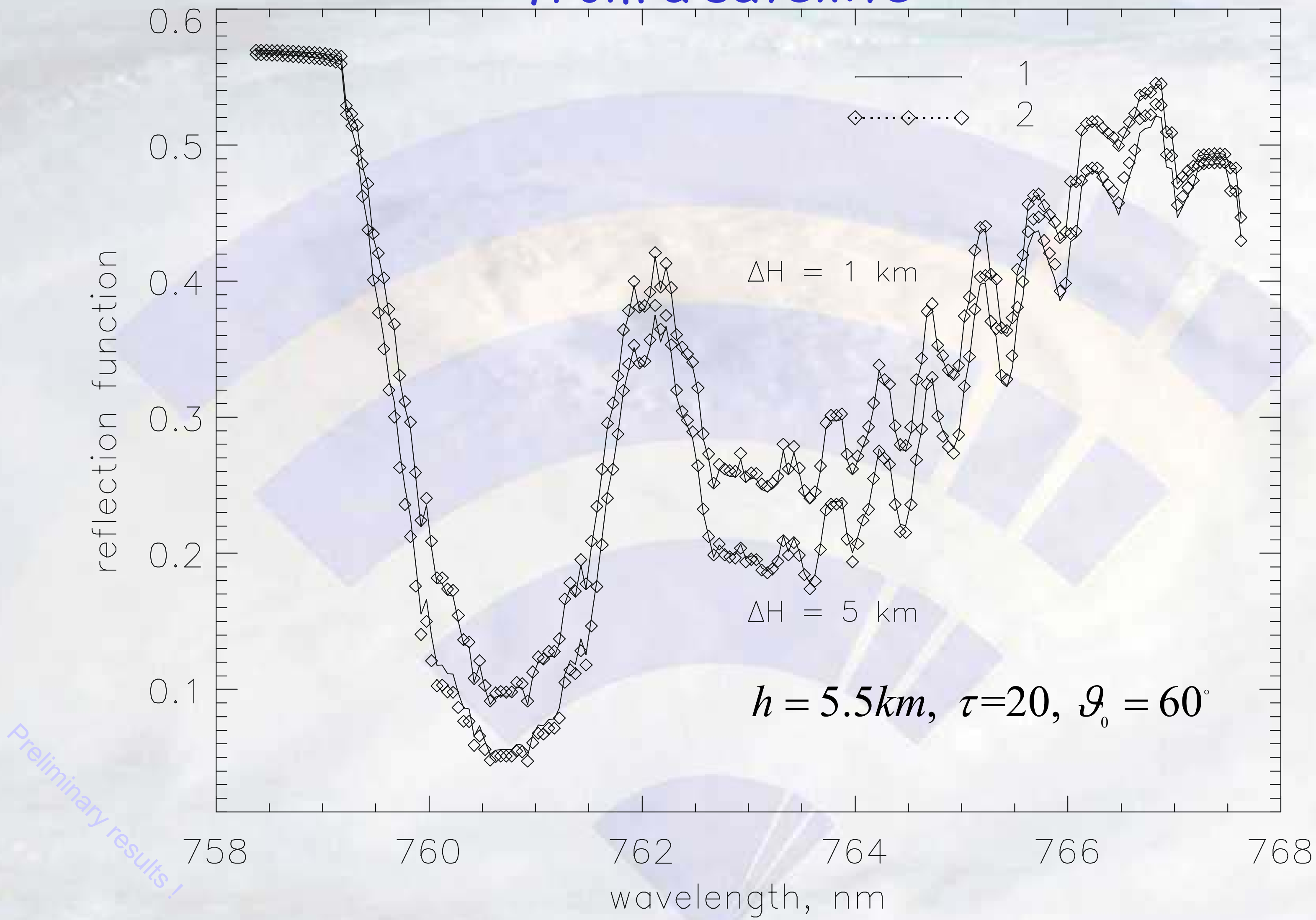
Nauss et al., 2005

Cloud top height determination from a satellite

The physical principle behind the retrieval



Cloud geometrical thickness/bottom height determination from a satellite



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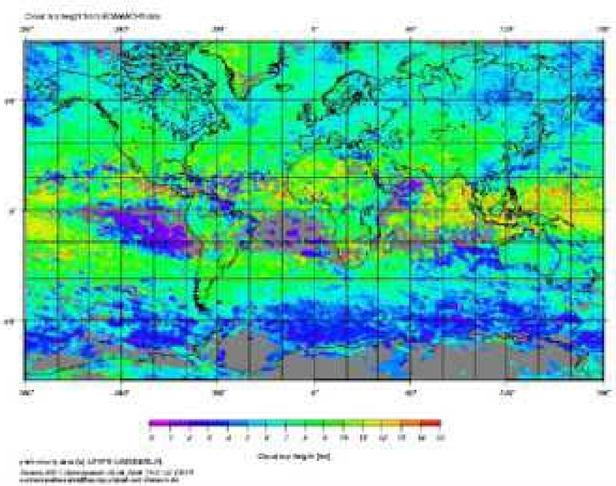
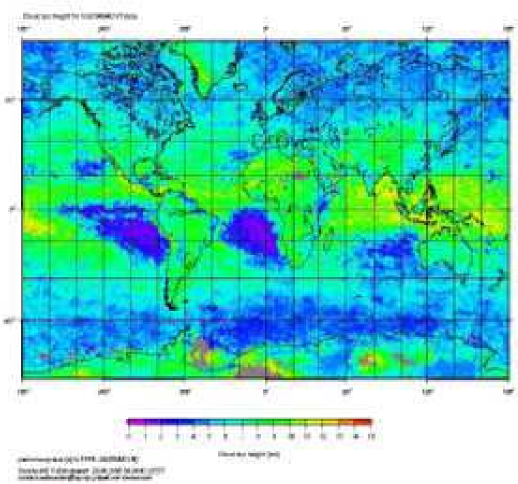
4. SCIAMACHY CLOUD RETRIEVALS

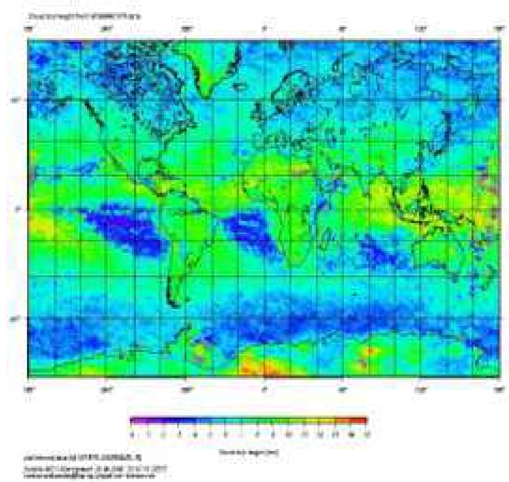
2003



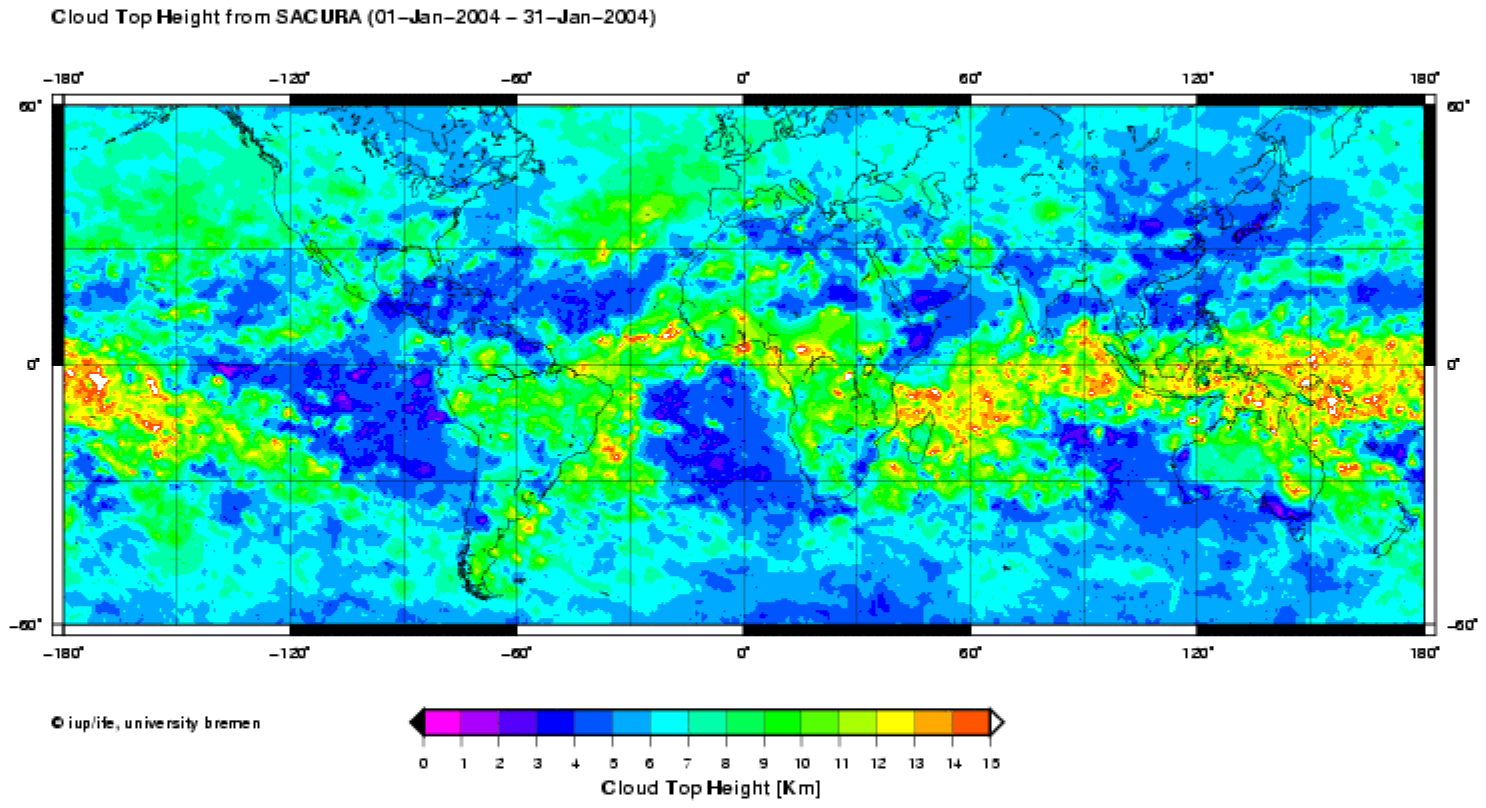
2004



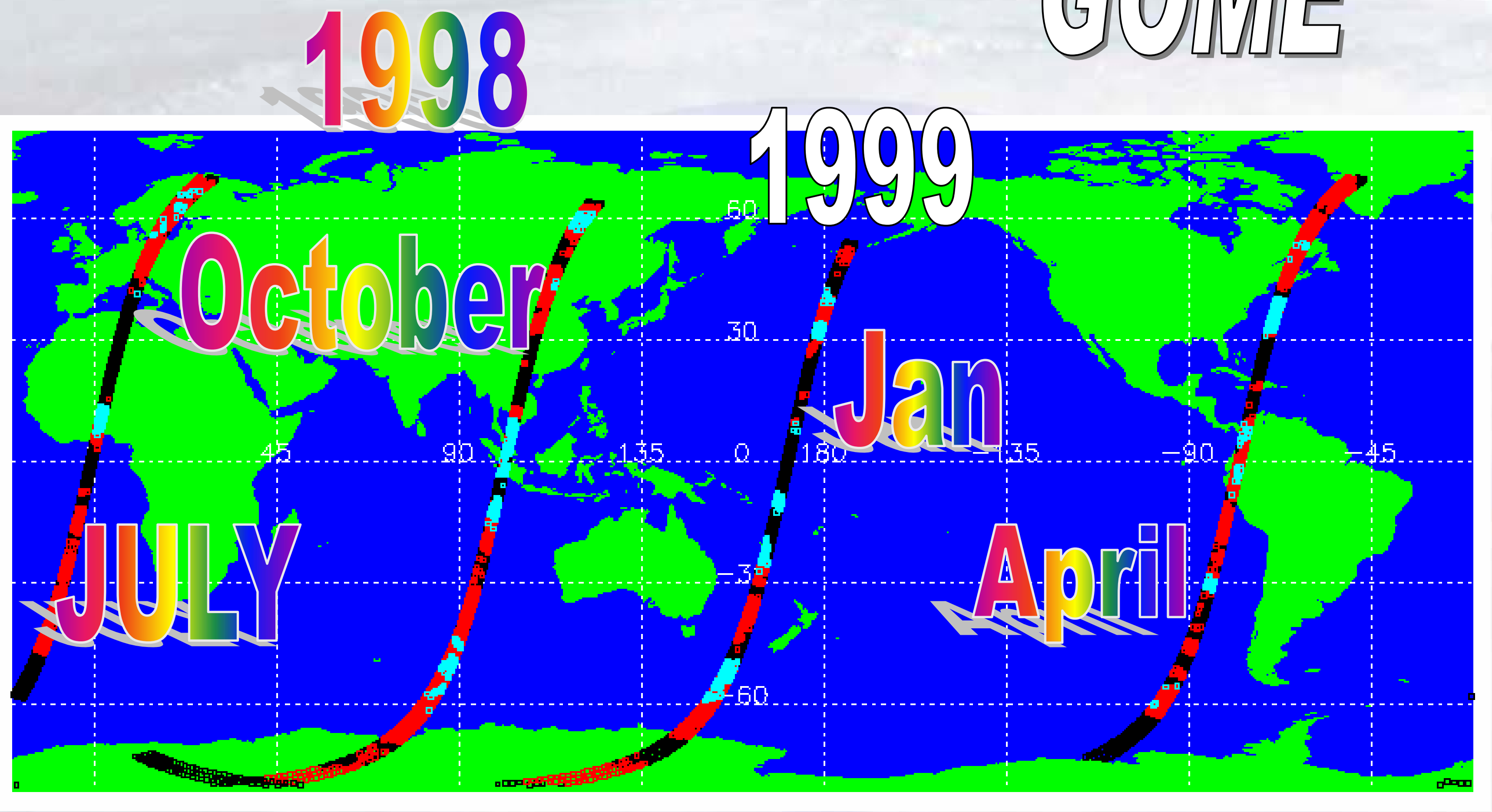
2005



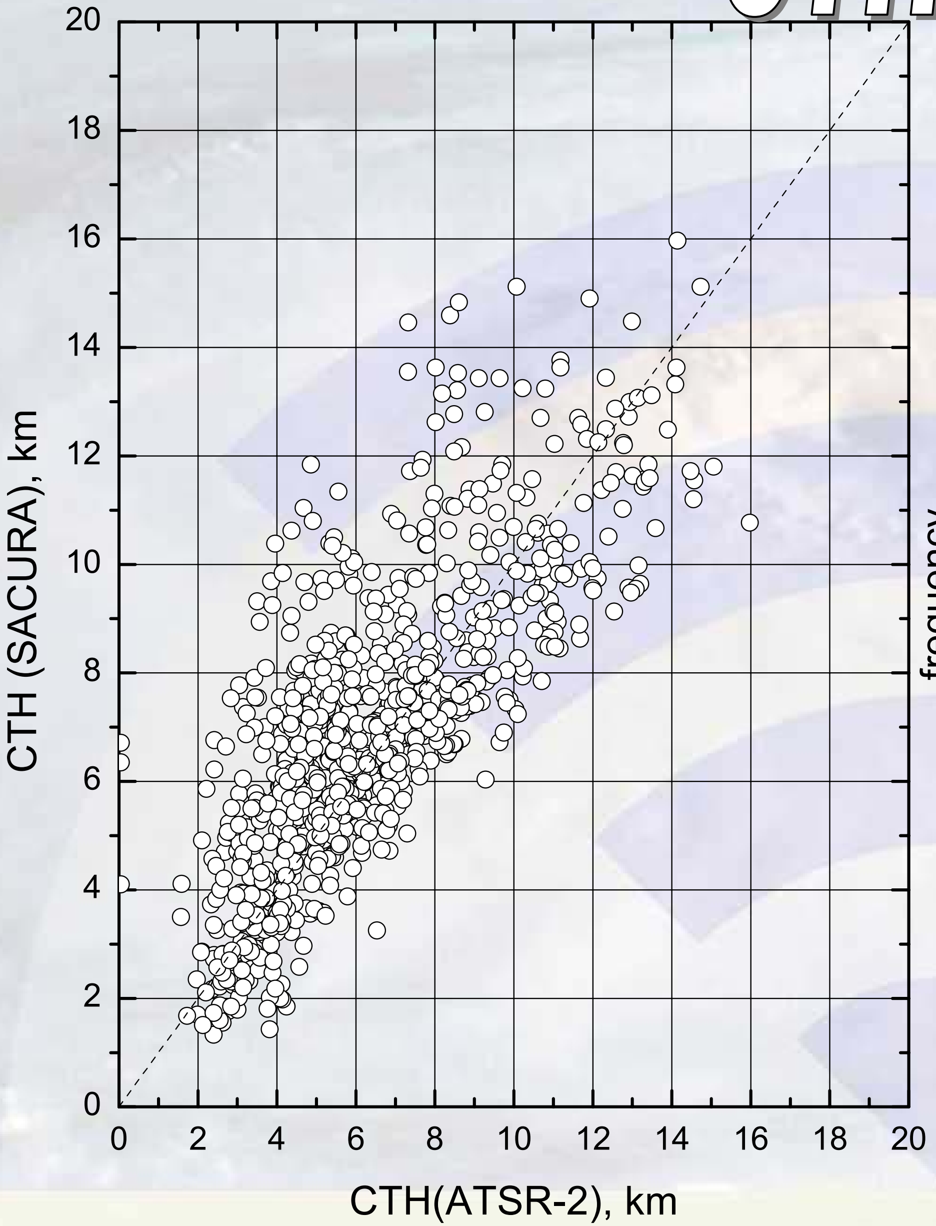
SCIAMACHY on ENVISAT



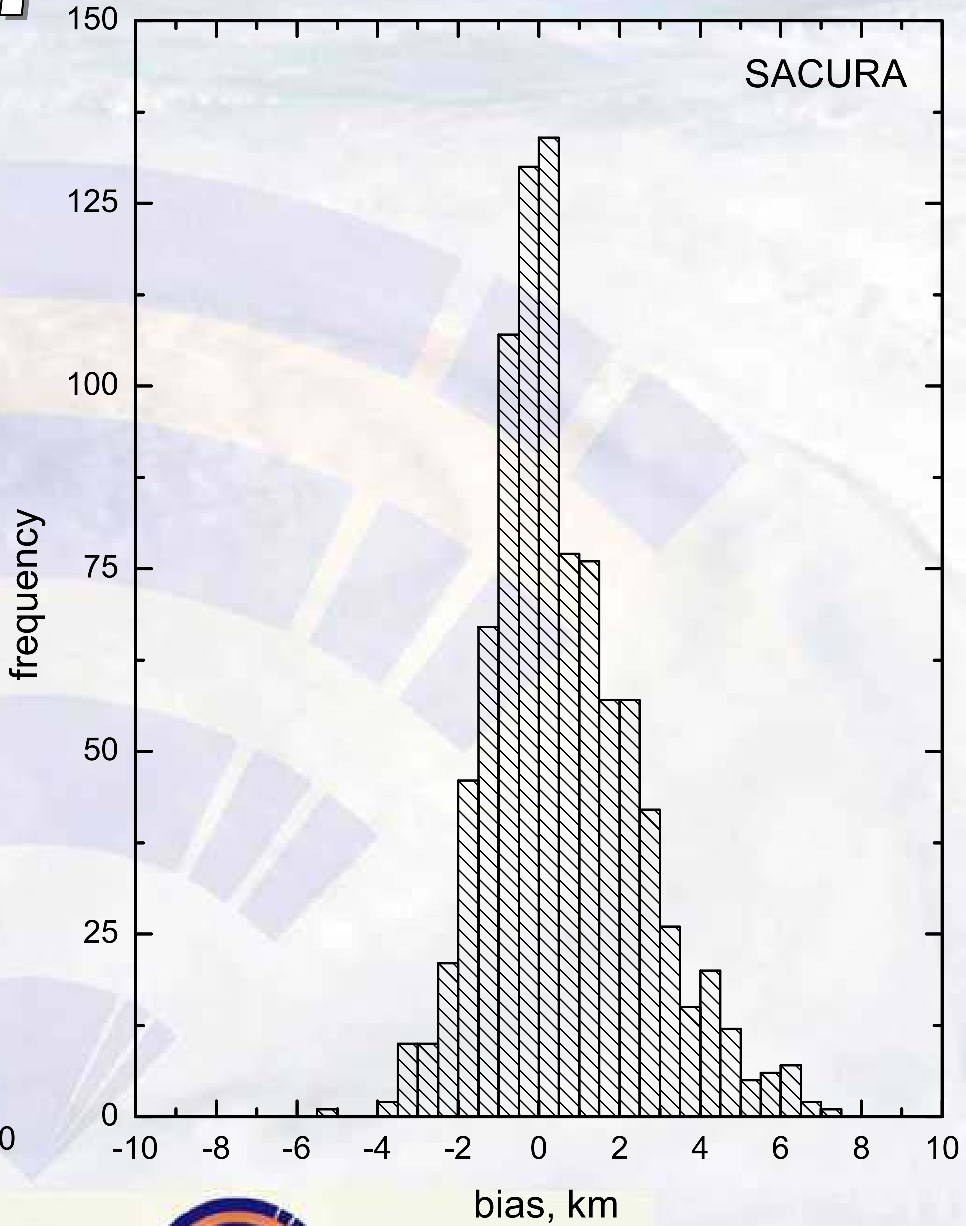
GOME


1998
1999
October
Jan
JULY
April
60
30
45
90
135
0
180
−135
−90
−45
−30
−60

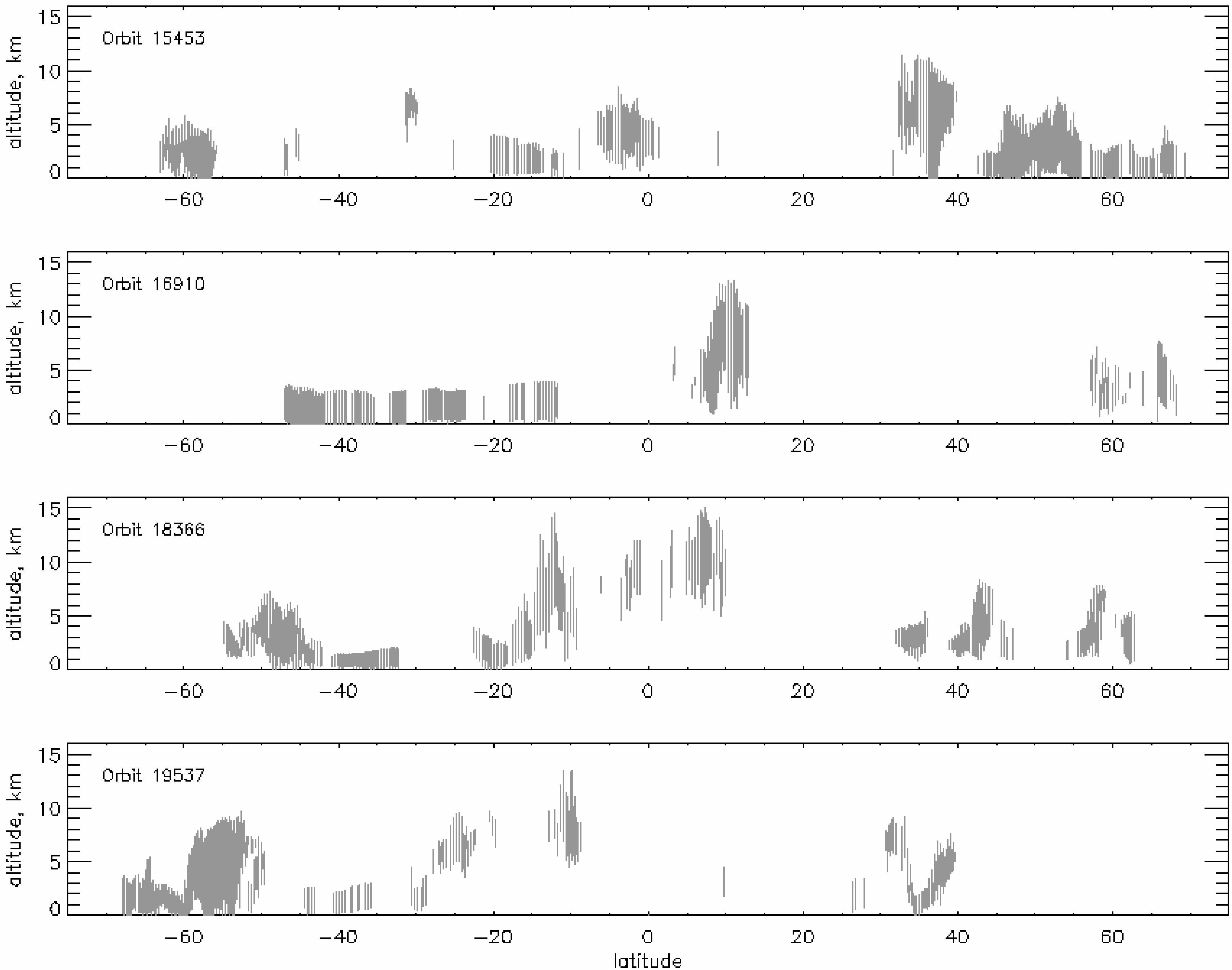
CTH



CTH (SACURA), km
CTH(ATSR-2), km
0
2
4
6
8
10
12
14
16
18
20



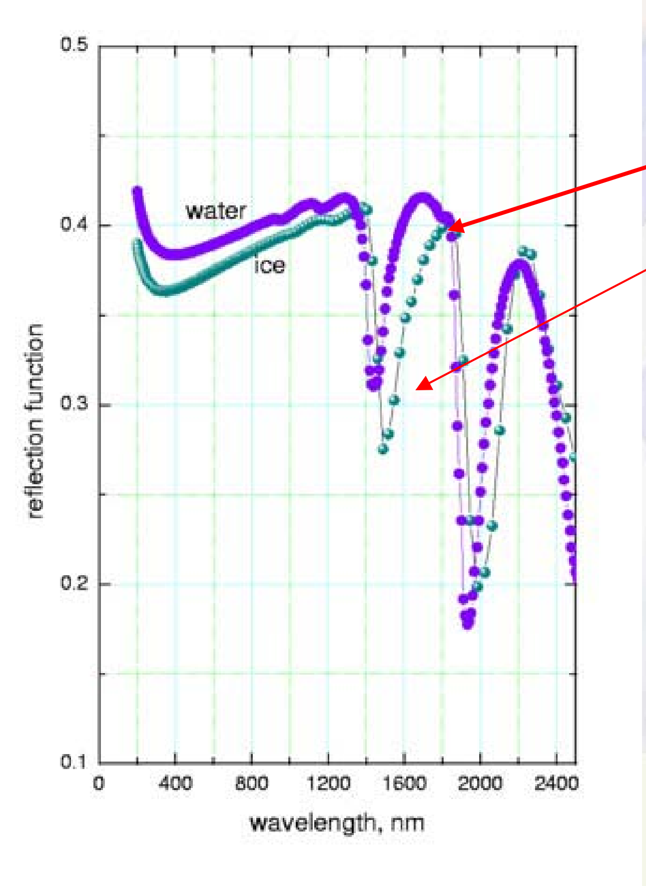
SACURA
frequency
bias, km
0
25
50
75
100
125
150
-10
-8
-6
-4
-2
0
2
4
6
8
10

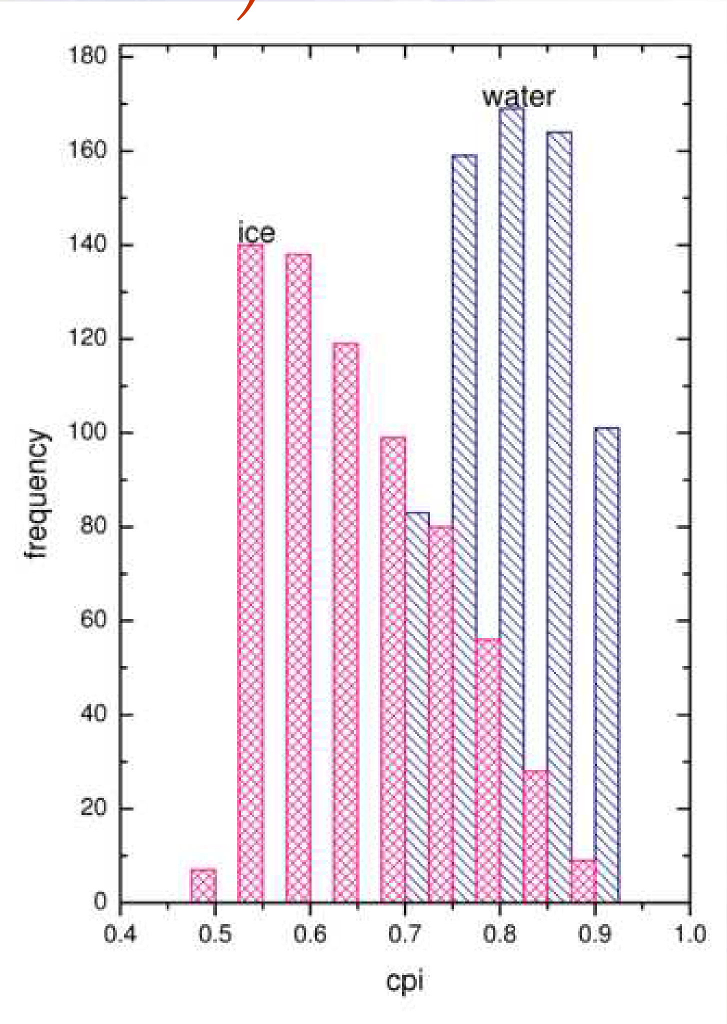


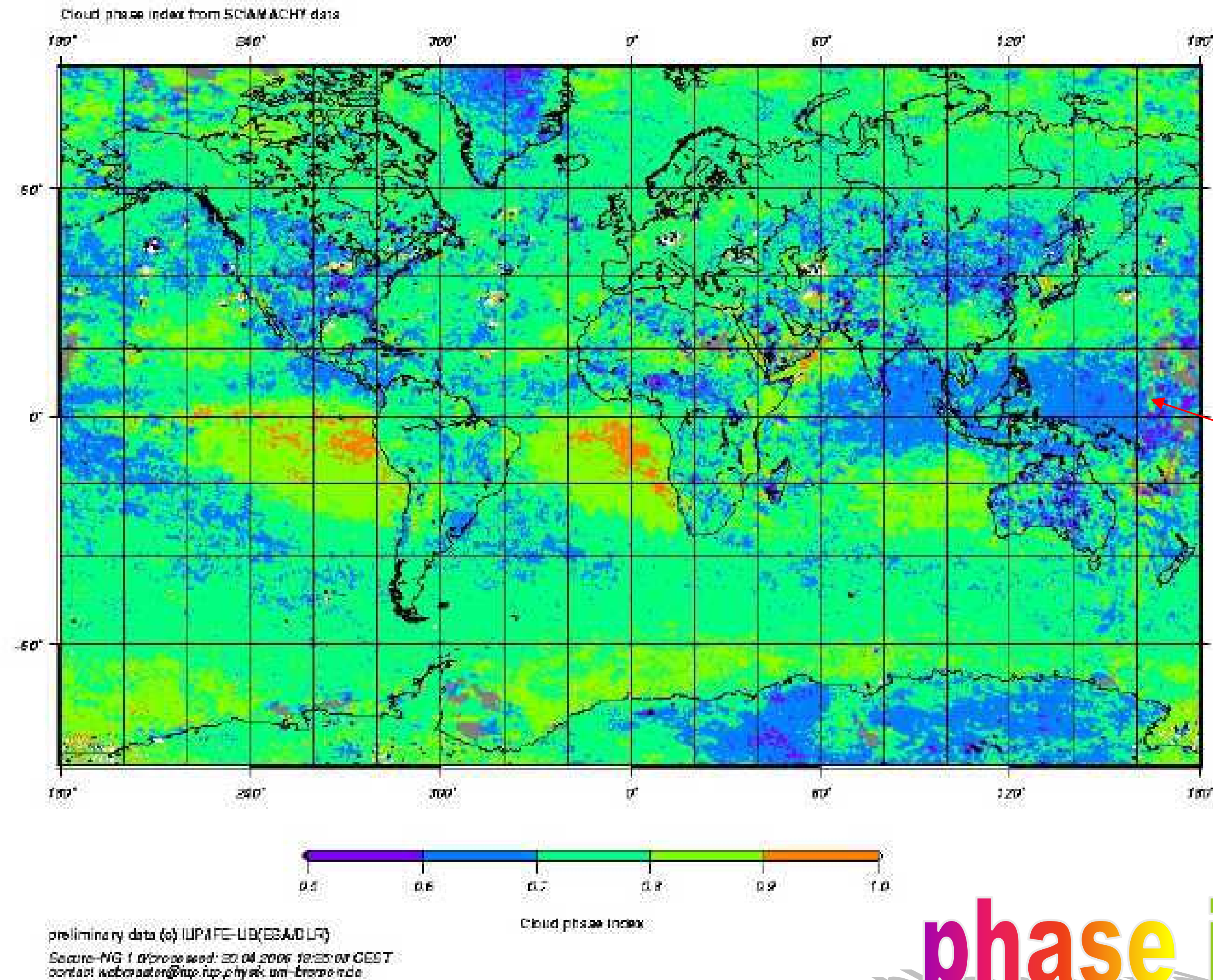
Orbit 15453
Orbit 16910
Orbit 18366
Orbit 19537
altitude, km
latitude
15
10
5
0
−60
−40
−20
0
20
40
60

Cloud Phase

CPI=R(1550nm)/R(1670nm)

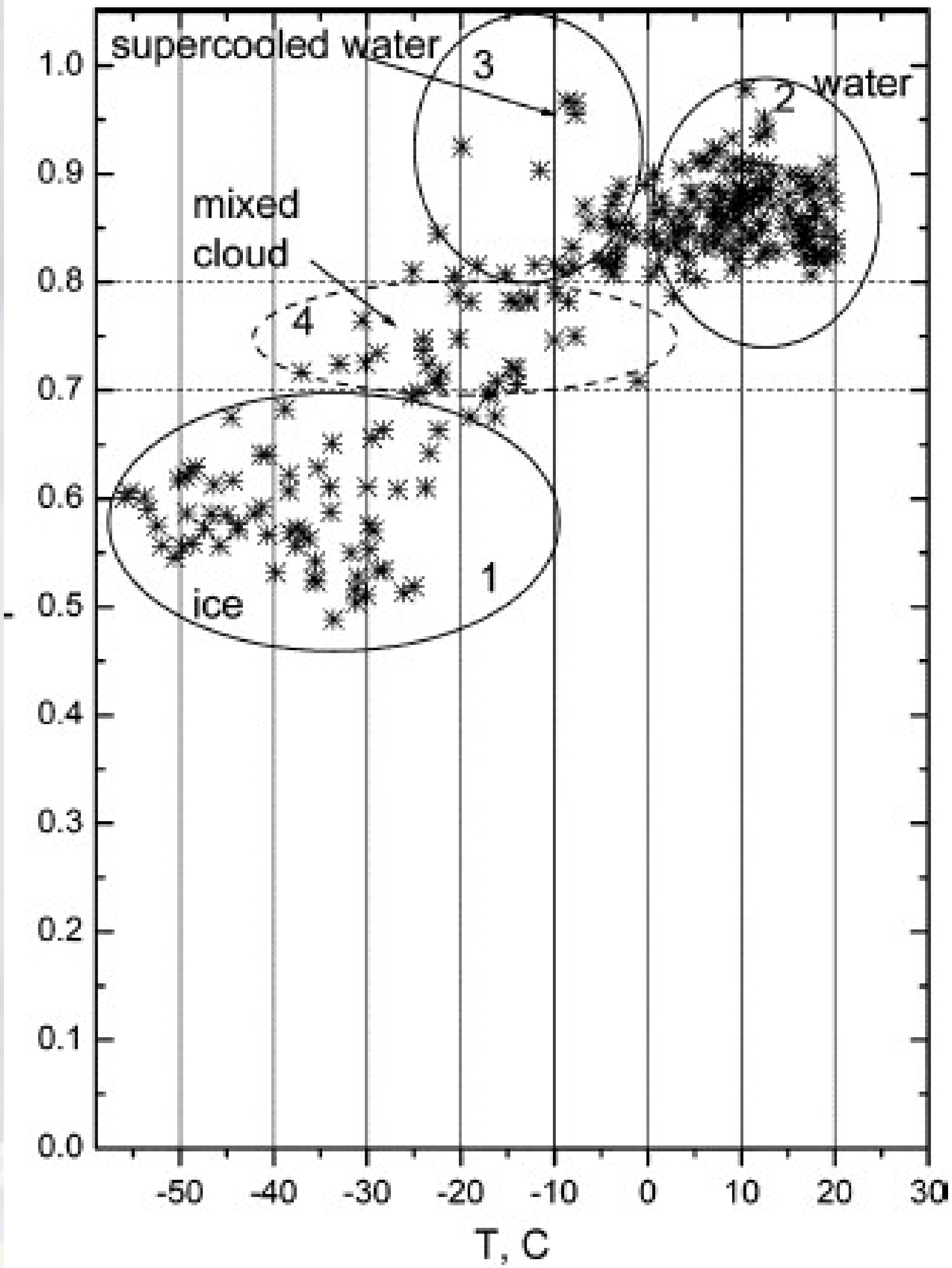






ice

phase index



Hurricane Isabel

17.09.2003

SCIA/AATSR

ENVISAT

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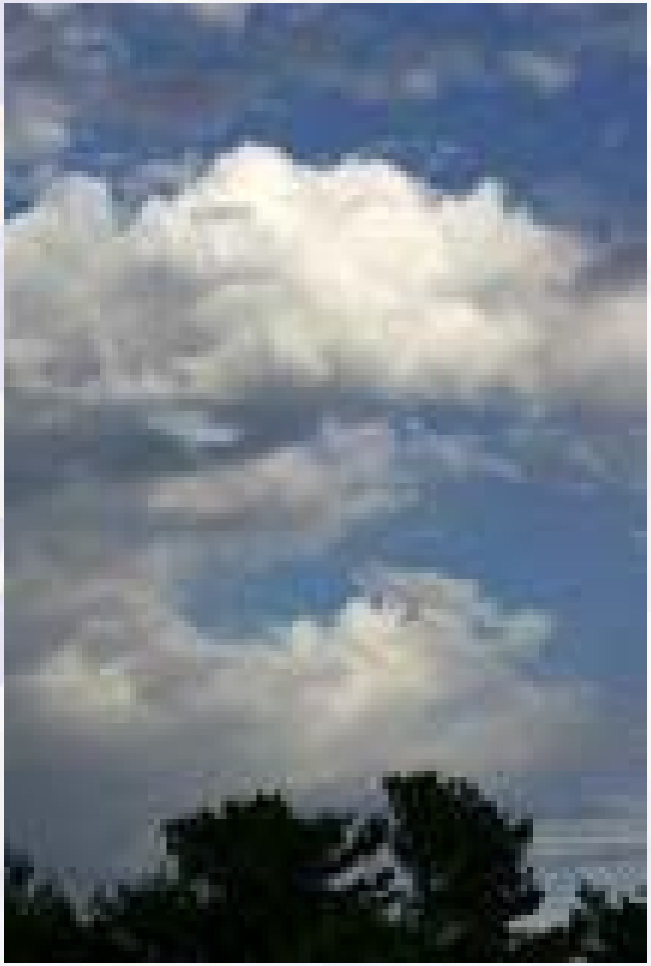
Problems: clouds

- 3-D effects, broken clouds
- Vertical inhomogeneity (e.g., cloud layers)
- The crystal shape-dependent retrievals of cloud properties
- Polluted clouds
- Mixed clouds
- The account of underlying surface BRDF



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