Remote sensing of aerosols with IASI
observations and a new retrieval tool

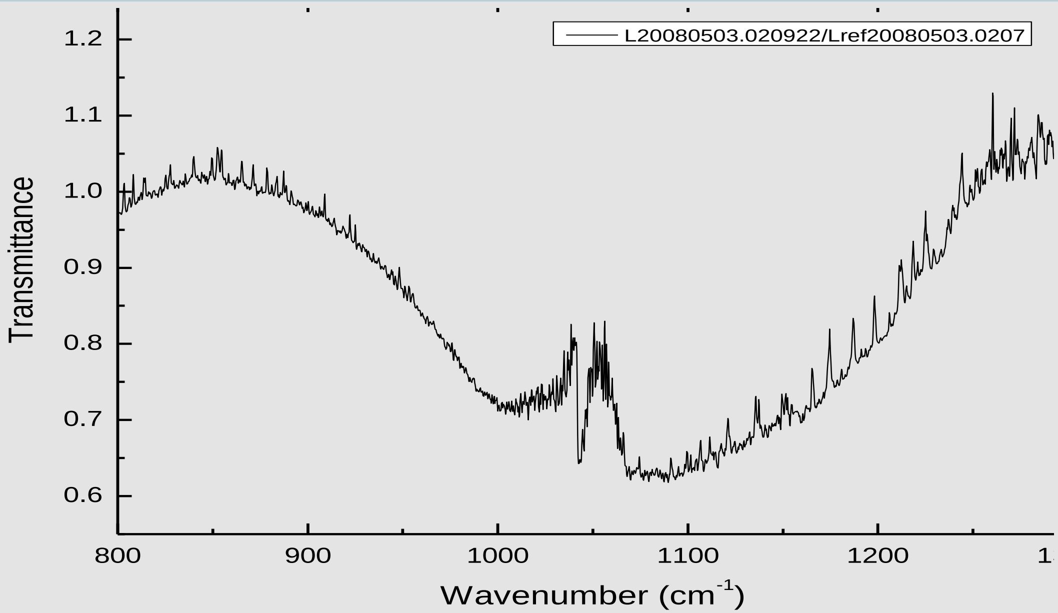
Lieven Clarisse, D Hurtmans,

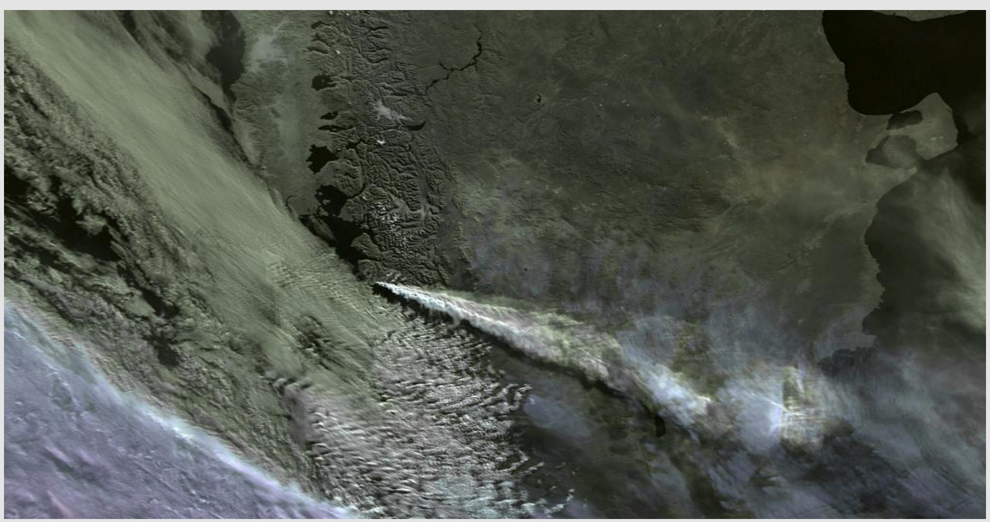
F Prata, C Clerbaux; M De Maziere and PF Coheur

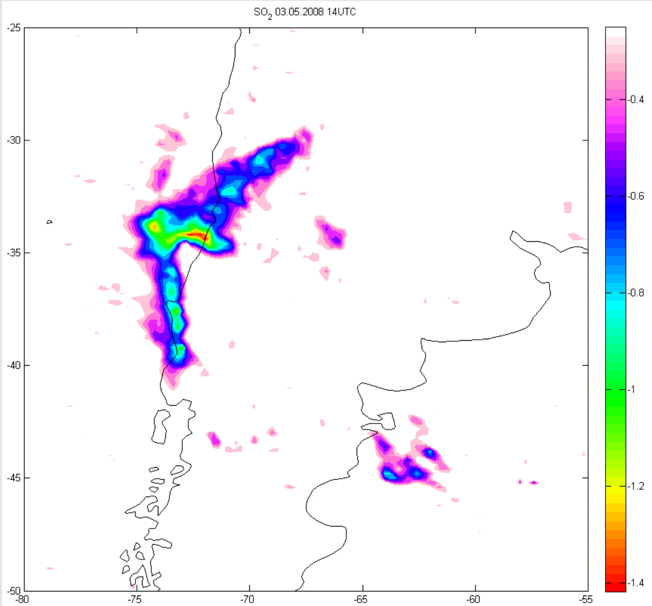
Universite Libre de Bruxelles, Belgium.
NILU, Norway.
UPMC Univ. Paris 06 ; CNRS/INSU, LATMOS-IPSL, France.
Belgian Institute for Space Aeronomy, 3 av. Circulaire, Belgium.

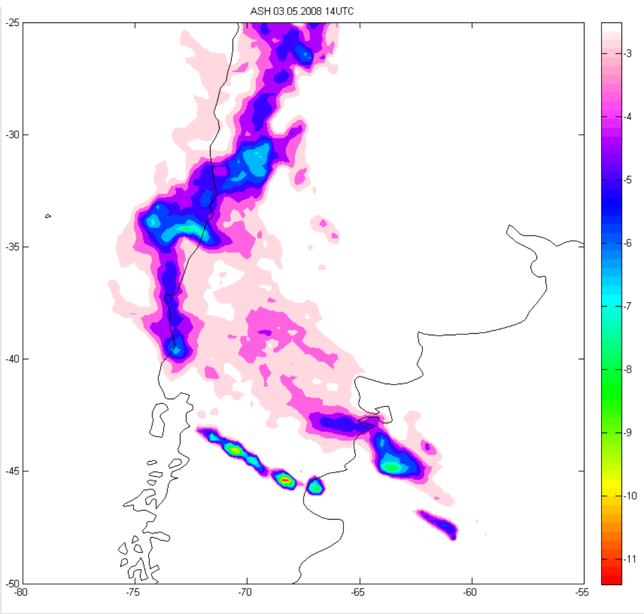
1. Example spectra of aerosols
2. First retrievals
3. Other retrieval approaches
4. The ULB retrieval approach
5. The forward model
6. The inverse model
7. A couple of retrieval examples
8. Conclusion

Example 1: Chaiten Volcanic Eruption (May 2008)



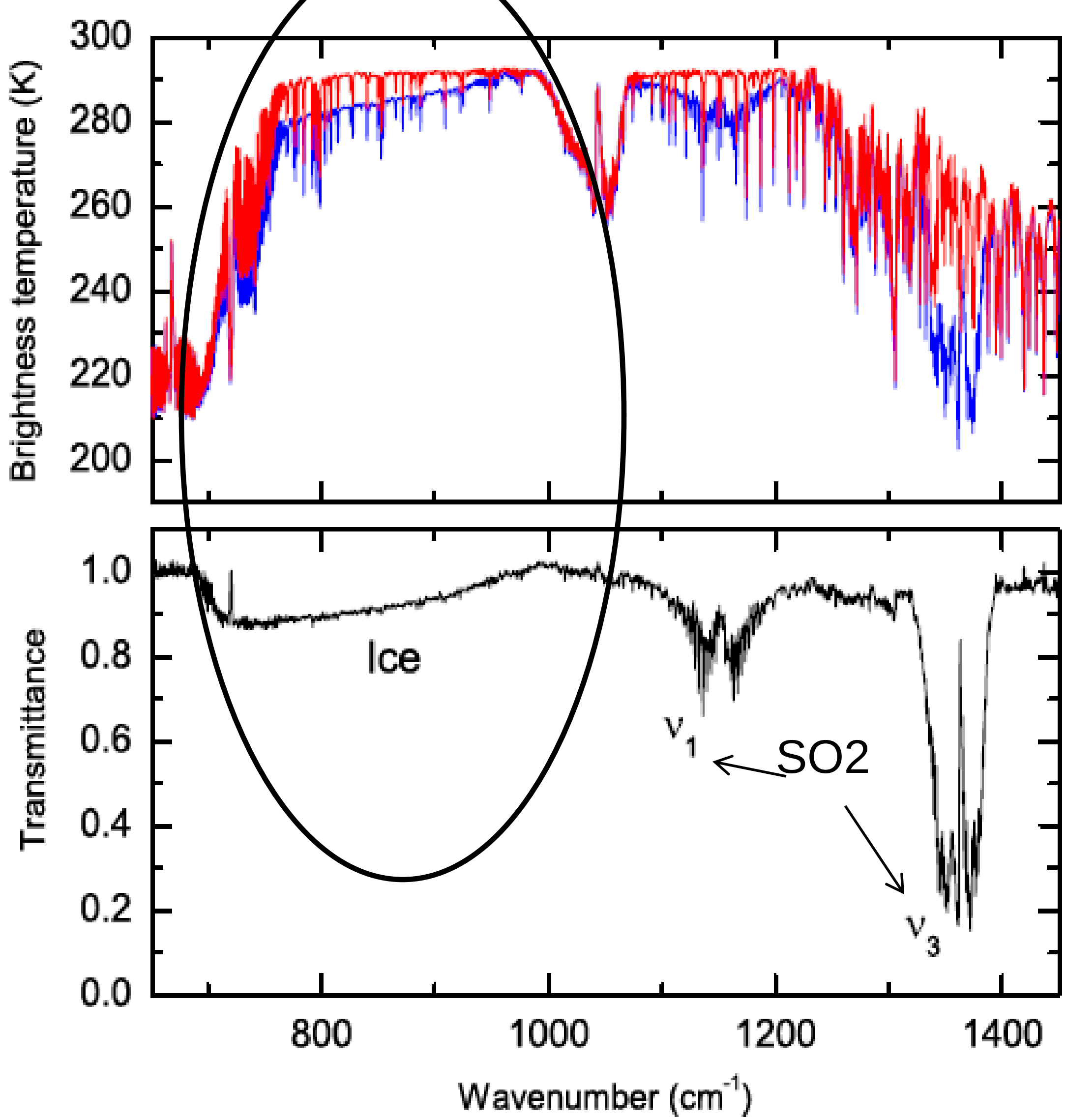


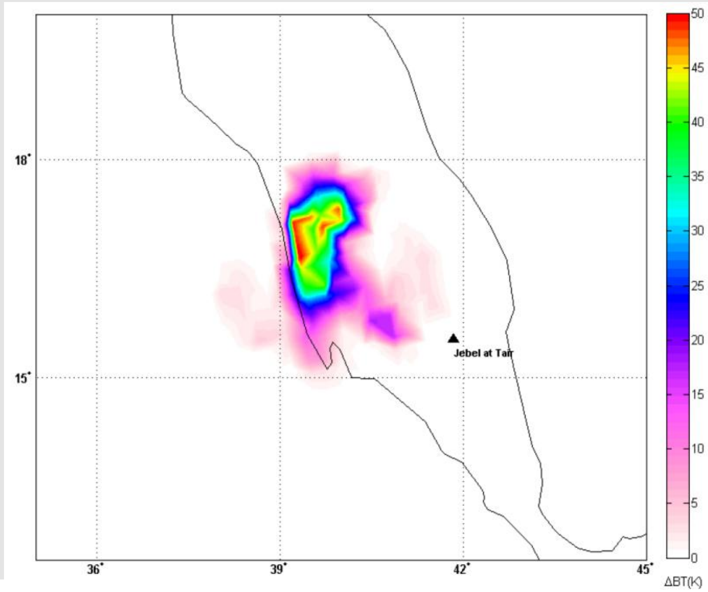


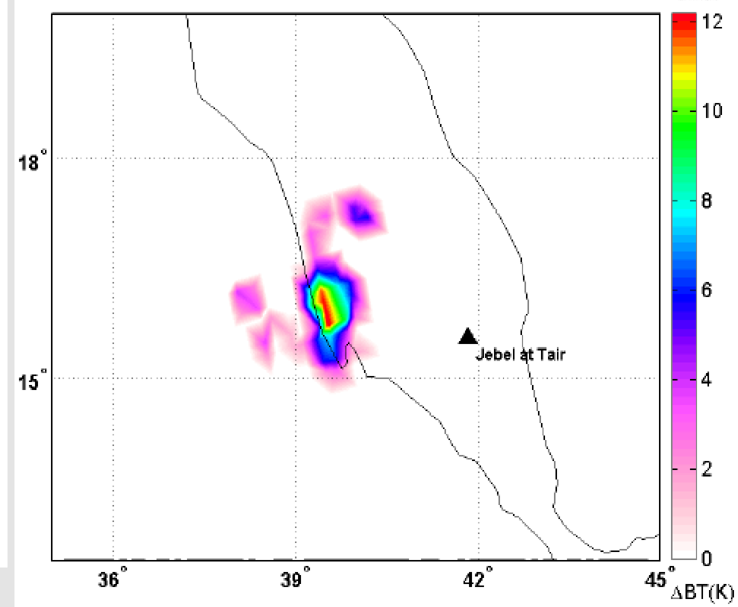


LATMOS ULB

Example 2: Ice in Jebel at Tair Eruption (May 2008)







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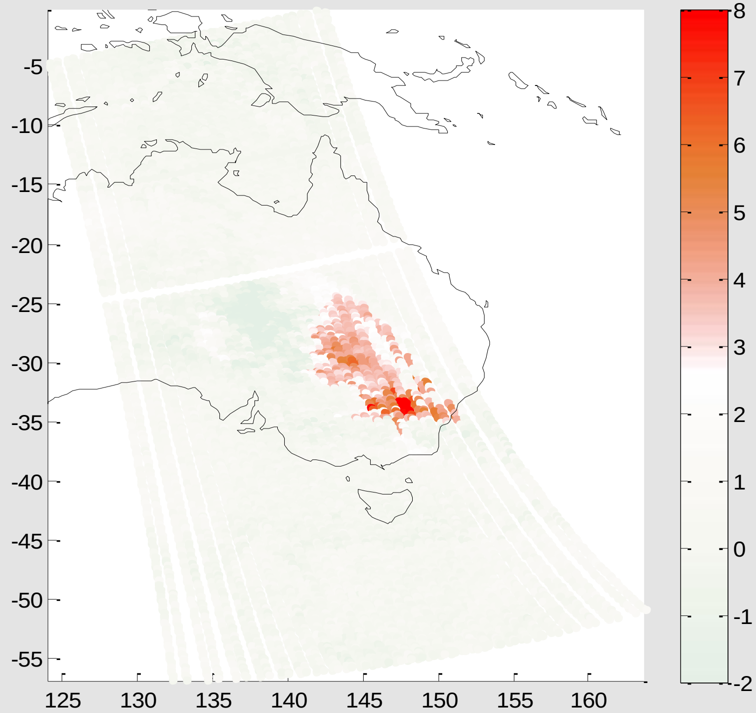
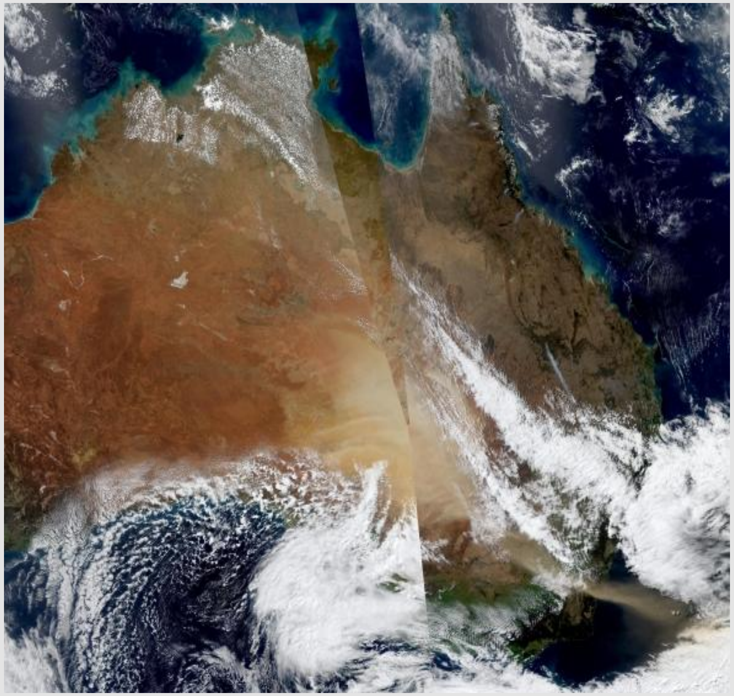
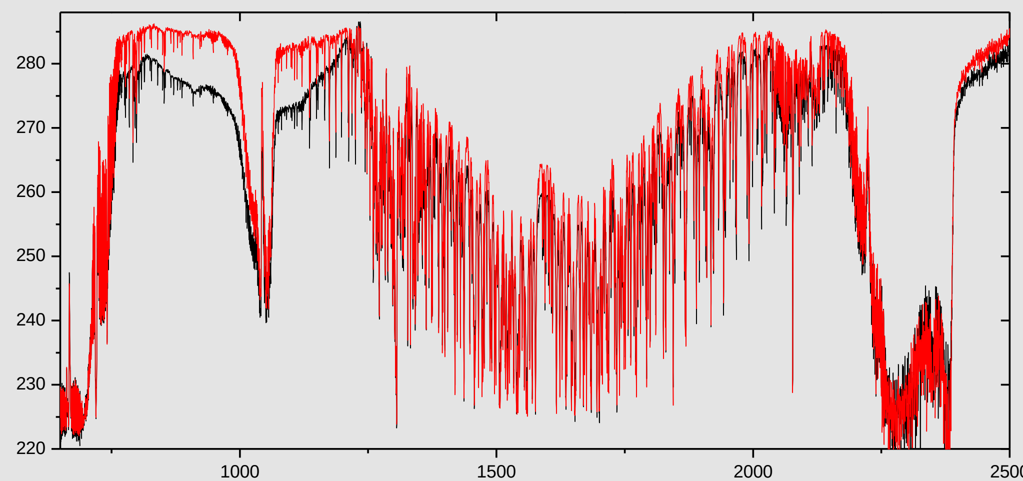
Example 4: Australian dust storm (Sep 2009)







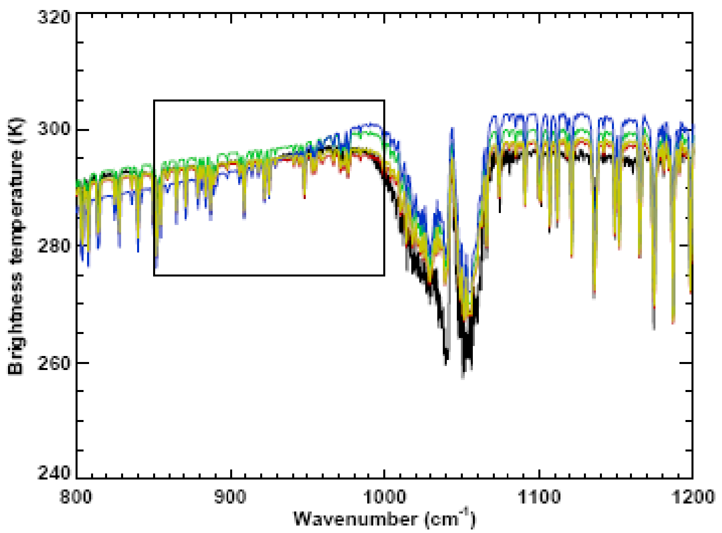
LATMOS ULB

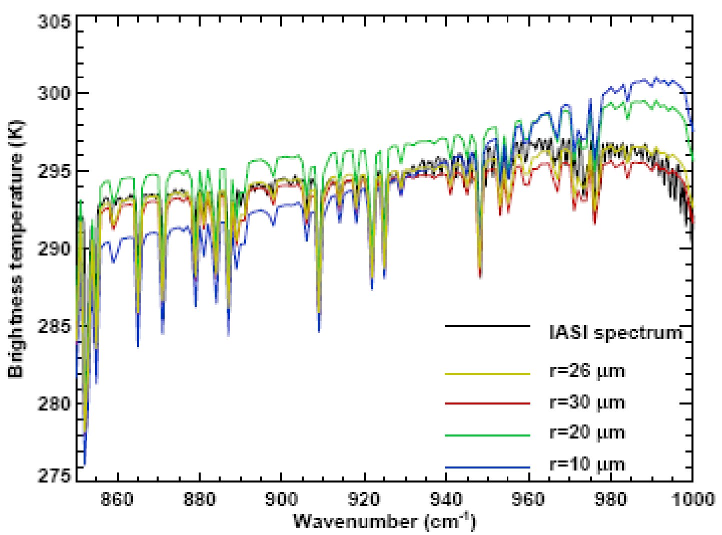
Lieven Clarisse, Annecy, 26 January 2010

Sensitivity parameters, how is the baseline affected

Sensitivity

Baseline SHAPE →	Aerosol Composition →	Dust/Sand Volcanic Ash Water clouds Ice clouds H_2SO_4 Biomass burning (Sea salt) + mixtures!!
Baseline TEMPERATURE →	Tsurf Altitude Size Concentration →	Large, cold part. in high loadings Can be hard to differentiate! Use of broad spectral range
	Particle Shape →	Little or no sensitivity (only for very large particles)

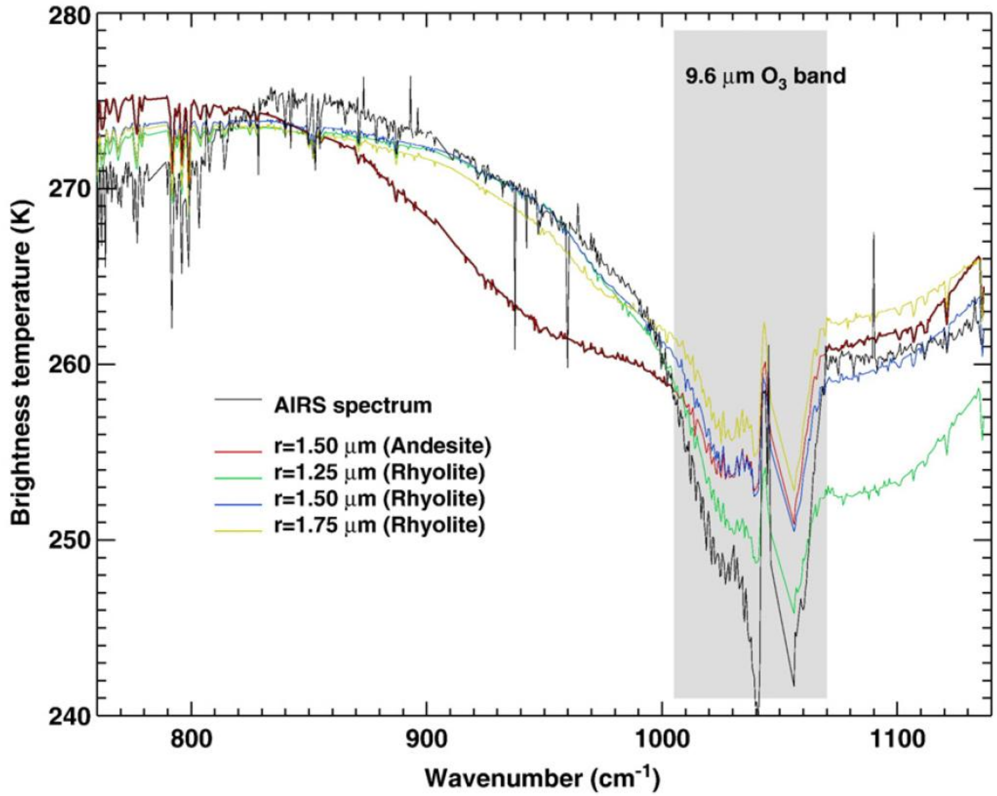




Before: Lookuptable approach!

→Not too nice a fits!

→Radius and optical depths



Carn et al. GRL 2005 → Volcanic ash	- **Microwindows** - ECMWF water profiles - Independent least squares fit of ash
Peyridieu et al. 2009; Pierangelo et al. 2005 → Sa	- **Two step retrieval** (gas/aerosol))
Krugla →Sea	
DeSou →San	- Independent least squares fit of ash
Clarisse ACP 2008 →Ice	- **Pre-calculated spectra** (Lookuptables)

Plan: Make a retrieval program to study extreme pollution events

→ Simultaneously retrieval of aerosols and gases on a broad spectral range

→ Does not rely on ECMWF and other a priori data, precalculated spectra, the use of microwindows or two-step retrievals.

→ By doing so exploiting the full potential of IASI

→ When you are not interested in molecular absorptions

Discrete ordinates method

Adding-doubling technique

Spherical harmonics method

Invariant imbedding method

Monte Carlo method

Successive orders of scattering technique

Q. Liu and F. Weng. Advanced doubling-adding method for radiative transfer in planetary atmospheres. *American Meteorological Society*, December:3459–3465, 2006.

1.7 x faster than VDISORT   61 x faster than AD   differences between 3 <0.01K

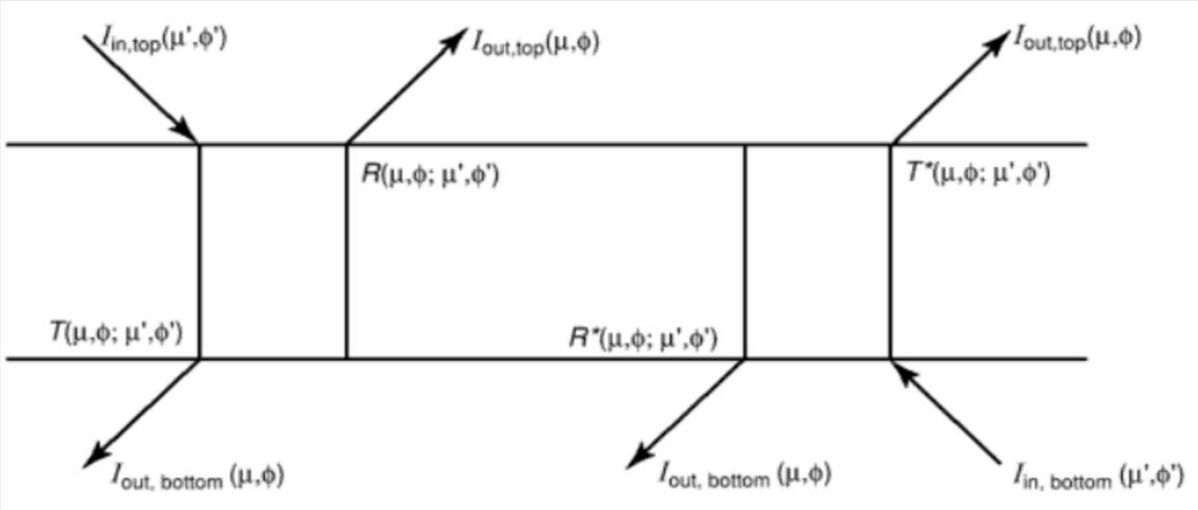
Using discrete angles means going from the integral-differential equation

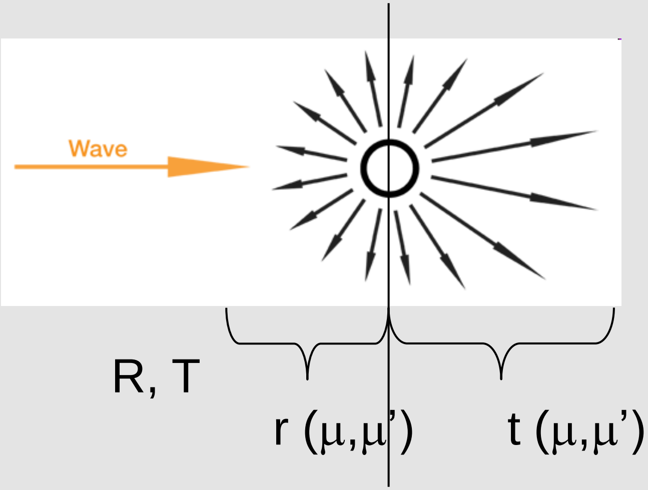
$$\mu \frac{dI(\tau,\Omega)}{d\tau} = I(\tau,\Omega) - \frac{\varpi}{4\pi}\int_{4\pi} I(\tau,\Omega')P(\Omega,\Omega')d\Omega' - (1-\varpi)B(T(\tau))$$

to

2N-streams (N-upward, N-downward)!

$$\mu \frac{dI(\tau,\mu)}{d\tau} = I(\tau,\mu) - \varpi \sum_{j}^{2N} w_j I(\tau,\mu_j)\bar{P}(\mu_i,\mu_j) - (1-\varpi)B(T(\tau))$$





R, T

reflectance and transmittance matrix

Existing Atmosphit RT code:

-line by line

-Voigt and Galatry line shapes

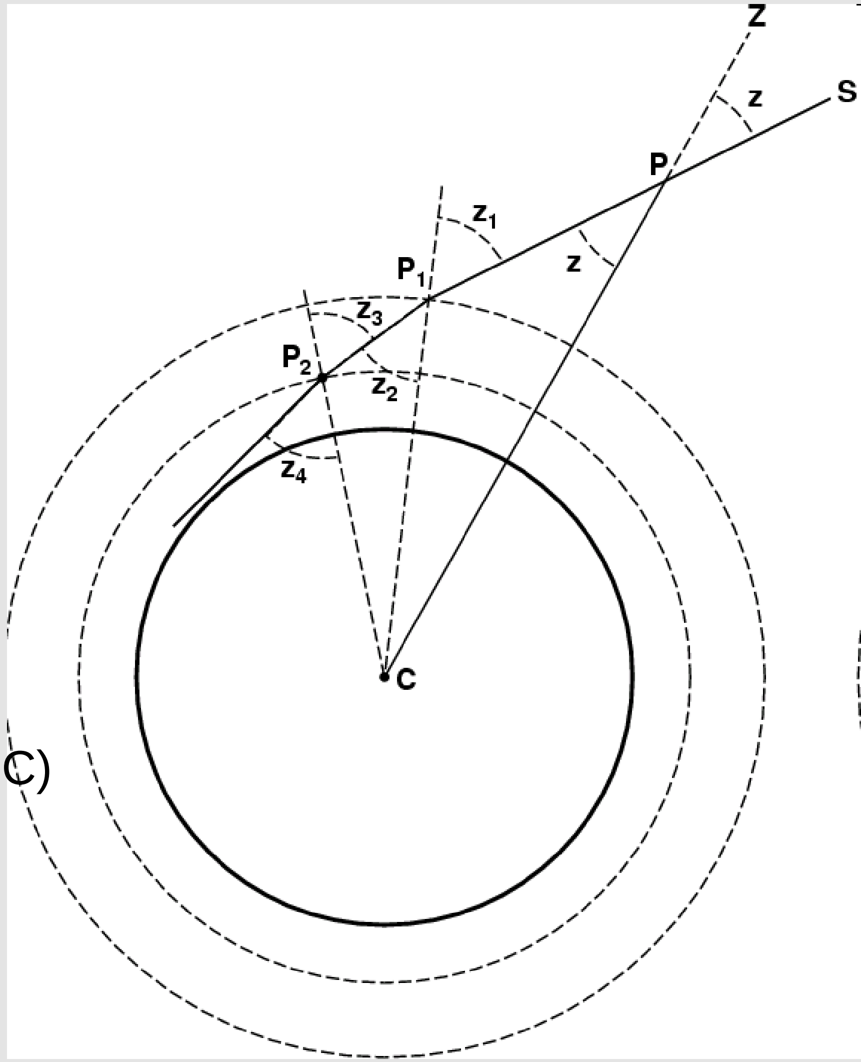
-absorption continua MTCKD

-O2 and N2 collision induced absorptions

-Surface reflectance using representative downward ray (Turner)

- Layer model: averaged layer properties (T, P, PC) → absorption intensities.

- **Full ray tracing on spherical refractive geometry (as opposed to plane parallel)**



We had to restrict ourselves to one aerosol layer

FORWARD

ADA (Radiative transfer)

Doubling Adding
in existing Atmosphit

MALUT (MIE routine)

Stores optical properties
in a lookuptable

INVERSE

AIDA (Advanced Doubling Adding Inversion)

Simultaneous retrieval of both gasses and aerosols

Optimal estimation for radius and concentration

Qe: extinction efficiency

Qa: absorption efficiency

Qs: scattering efficiency

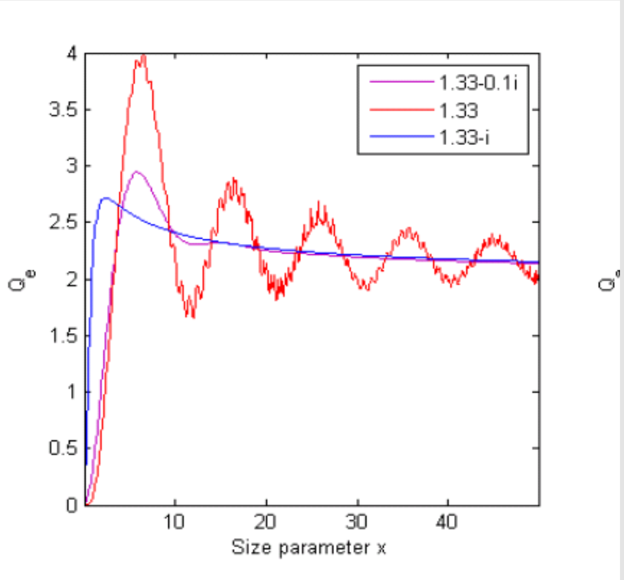
P(θ): phase function → Legendre Moments, Tkunctations factors

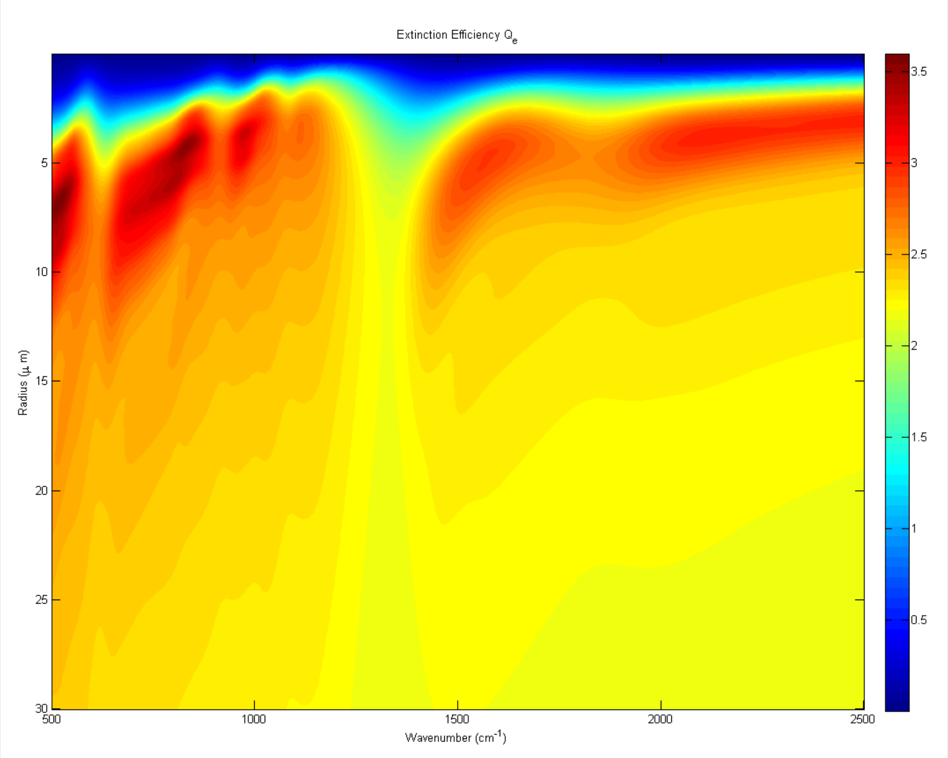
g: assymetry parameter

H. Du. Mie-scattering calculation. *Applied Optics*, 43:1951–1956, 2004.

$$P^*(\cos\Theta) = 2f\delta(1-\cos\Theta) + (1-f)\sum_{n=0}^{2M-1}(2n+1)\chi_n^* P_n(\cos\Theta),$$

Stored in lookuptables!





FORWARD

ADA (Radiative transfer)

Doubling Adding
in existing Atmosphit

MALUT (MIE routine)

Stores optical properties
in a lookuptable

INVERSE

Simultaneous retrieval of both gases and aerosols

Optimal estimation for radius and concentration

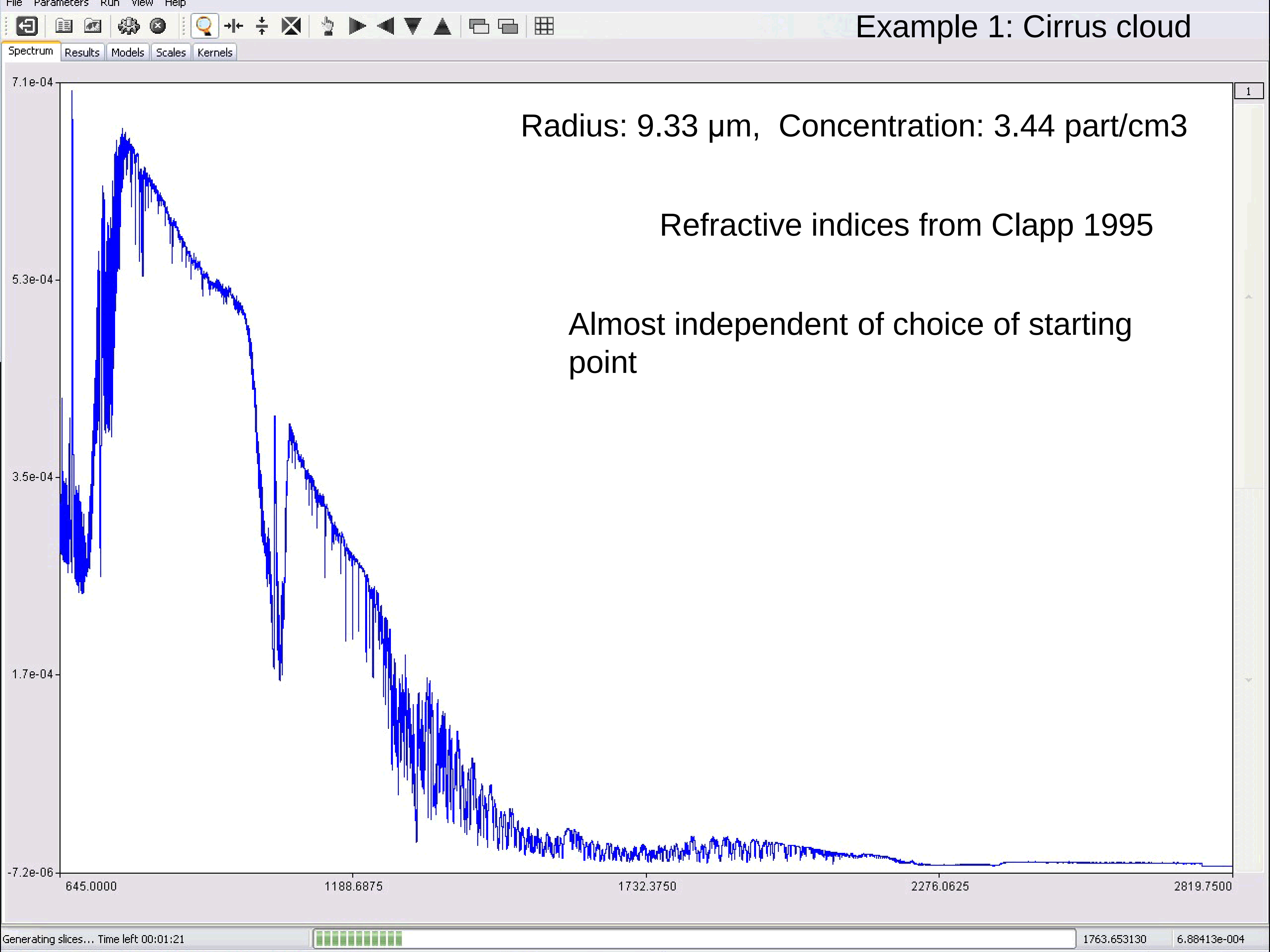
Surface temperature from clear pixel, Altitude from CALIPSO

Example 1: Cirrus cloud

Radius: 9.33 μm, Concentration: 3.44 part/cm3

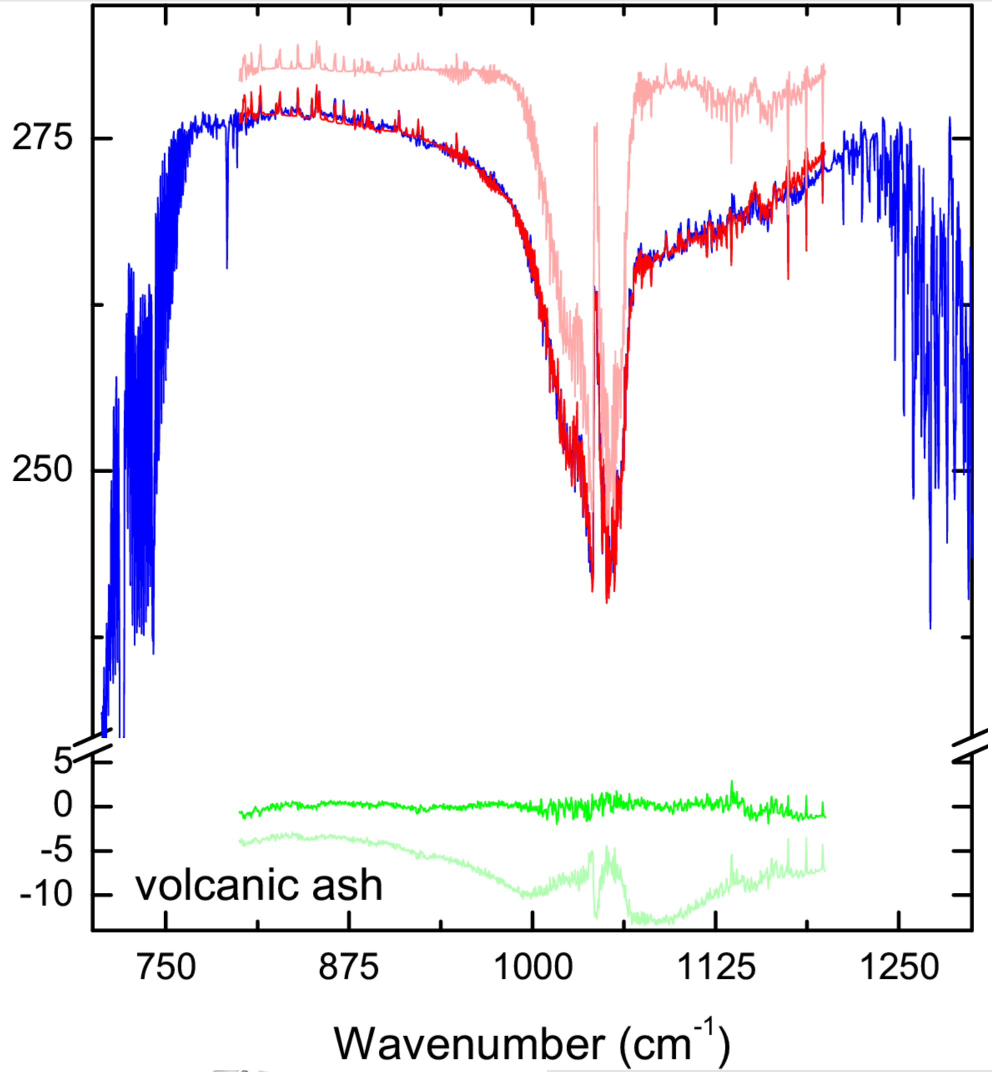
Refractive indices from Clapp 1995

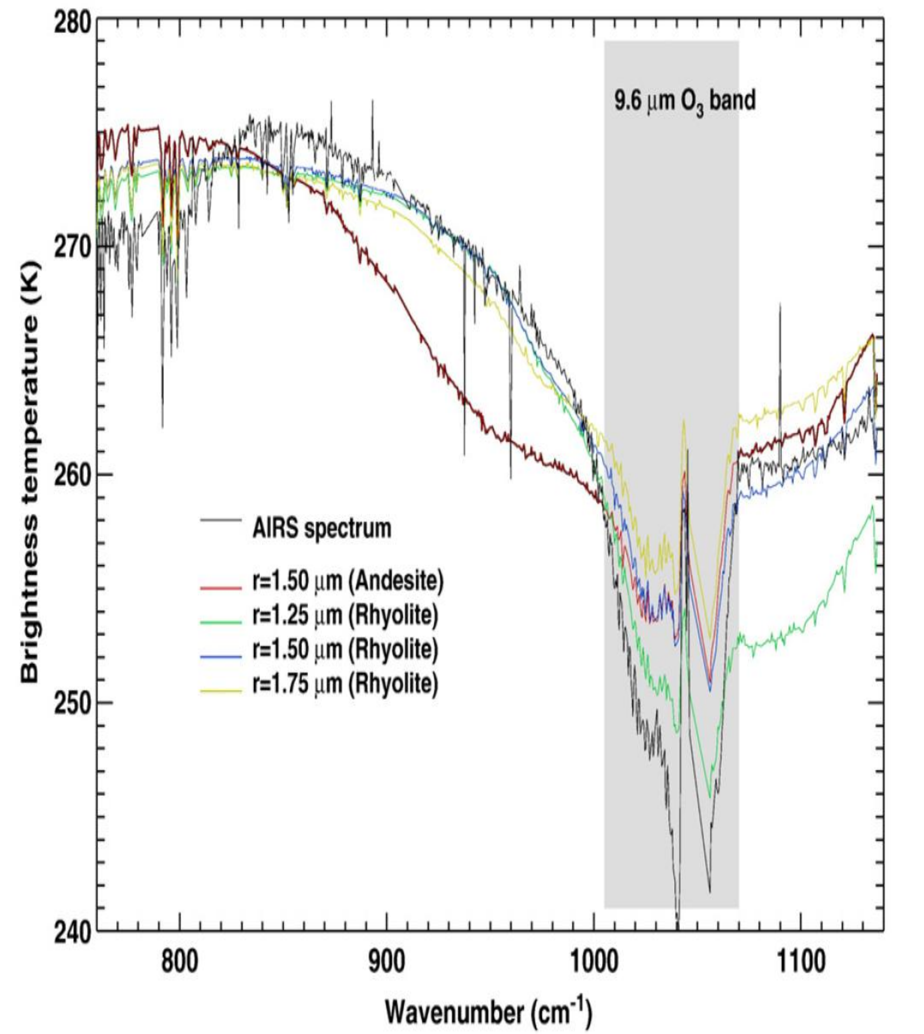
Almost independent of choice of starting point

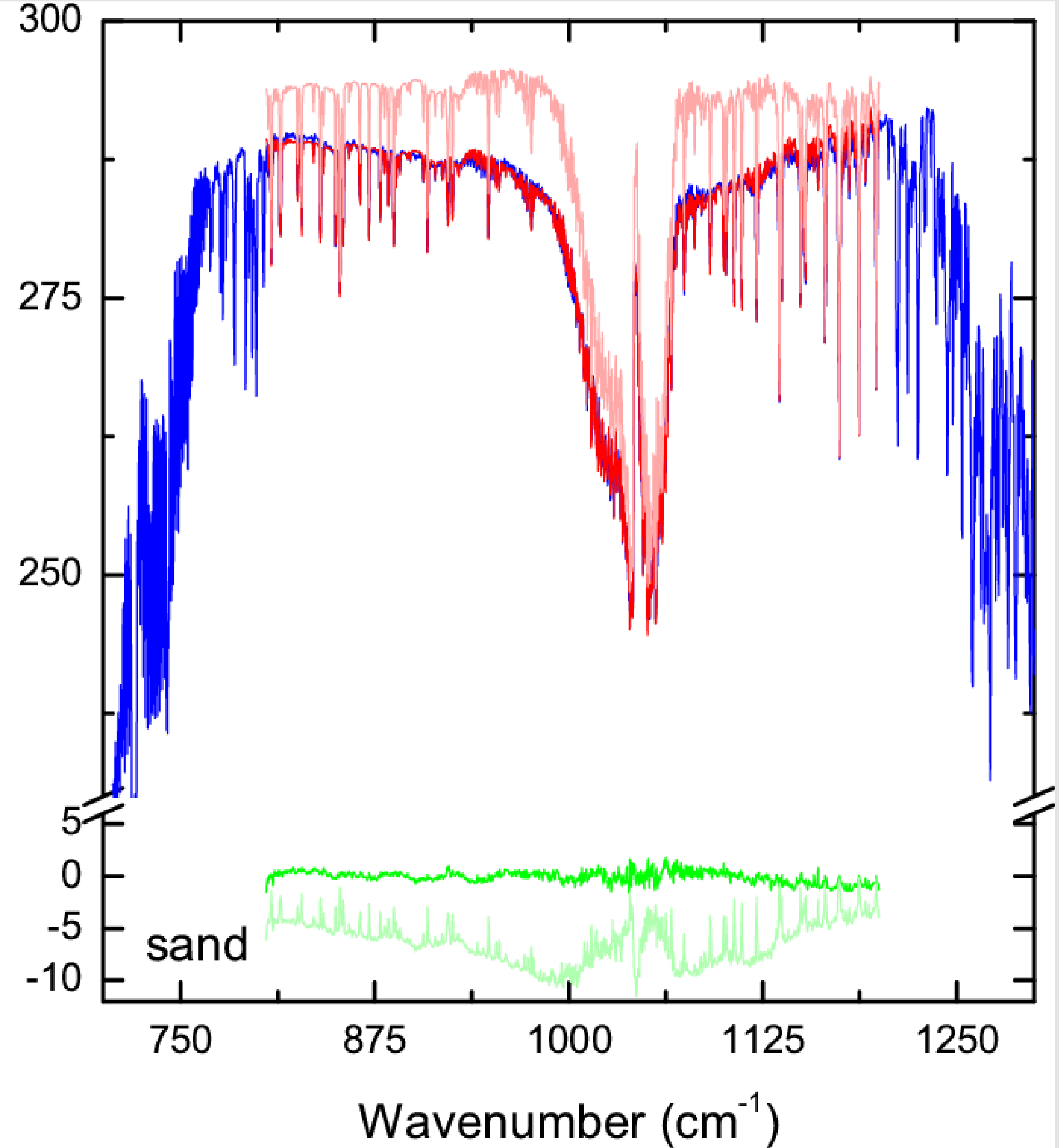


Radius: 1.55 µm, Concentration: 25 part/cm3

Refractive indices from Pollack 1973







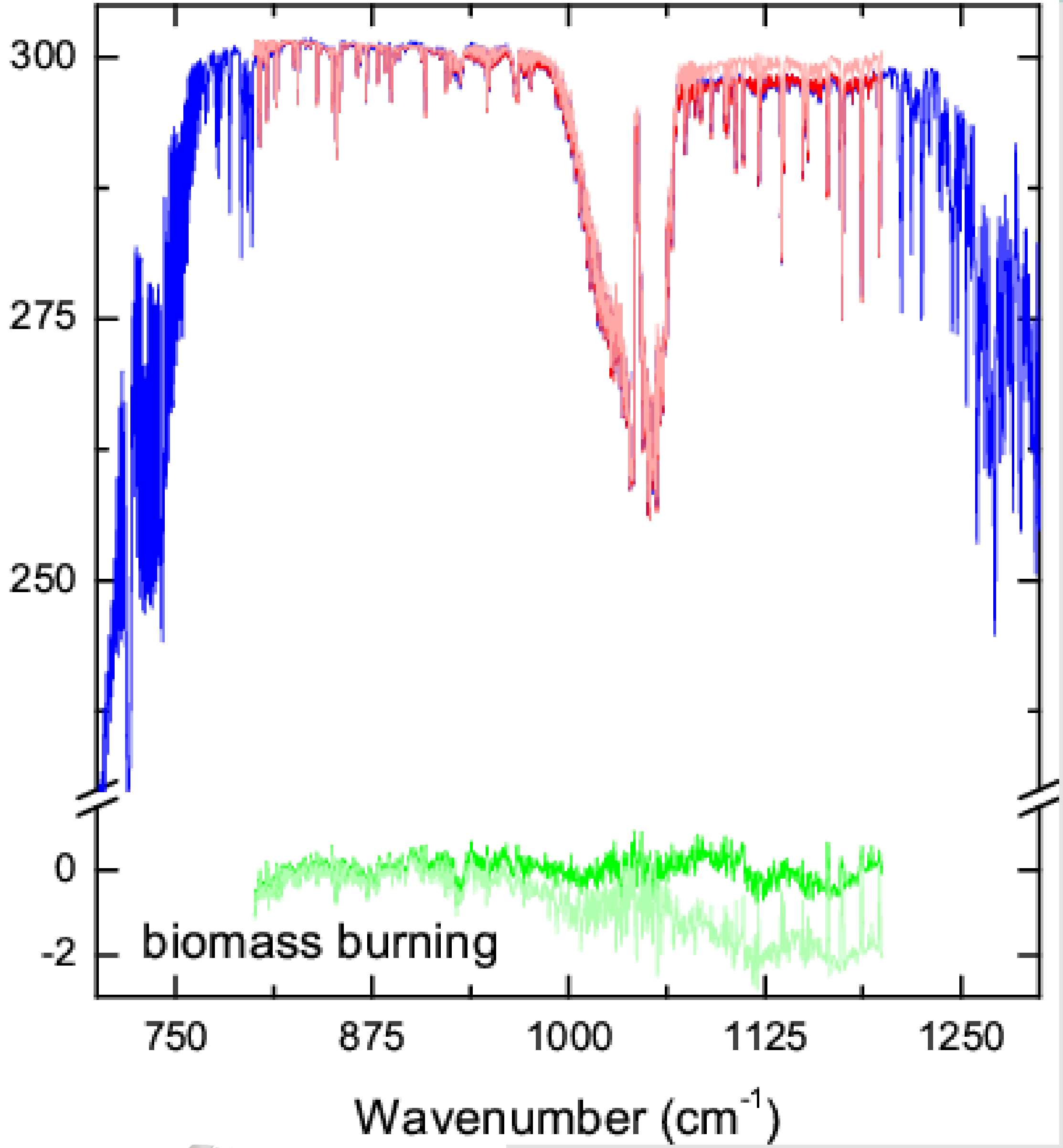
Radius: 2 µm
Concentration: 108 part/cm3

Refractive indices from
Volz 1973

A randomly choicen spectrum
does NOT fitt well.

Problem with refractive indices?

Time to get average refractive
index of a representative sample?

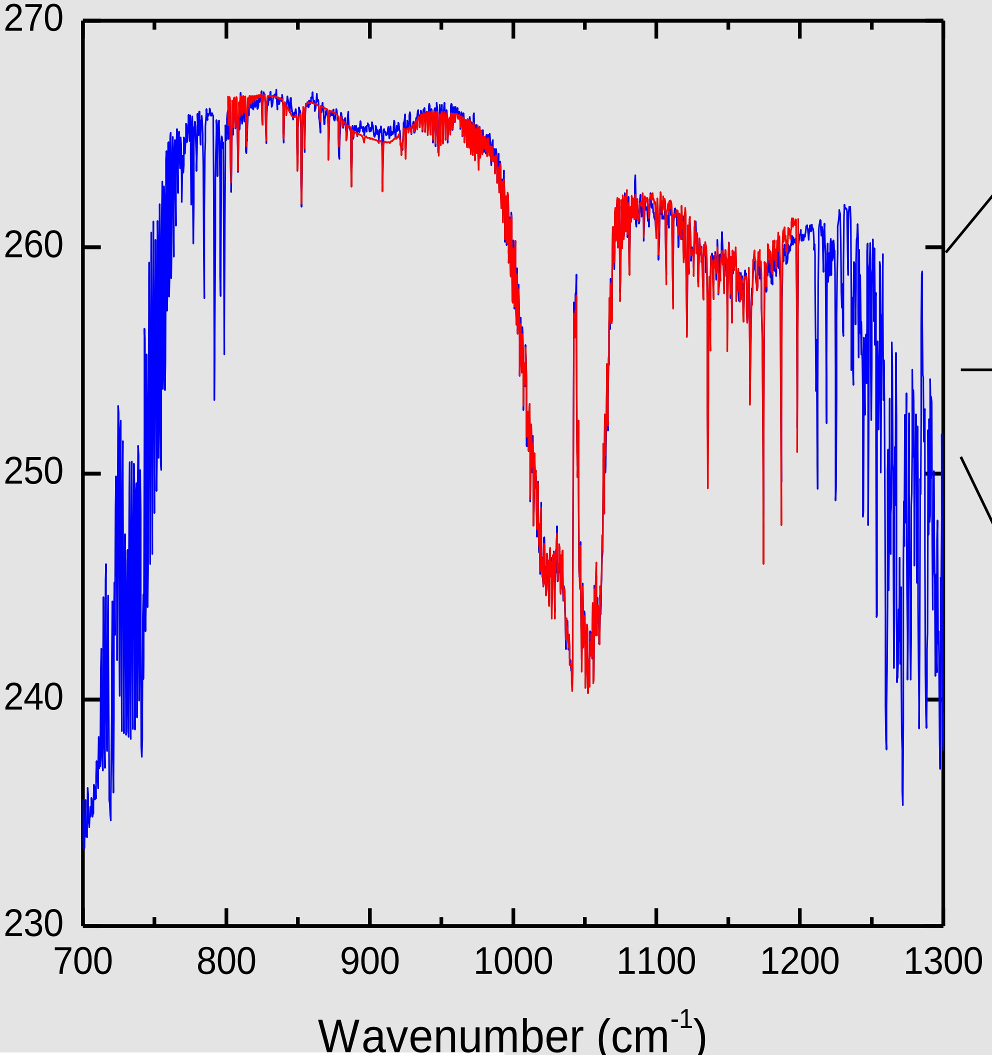


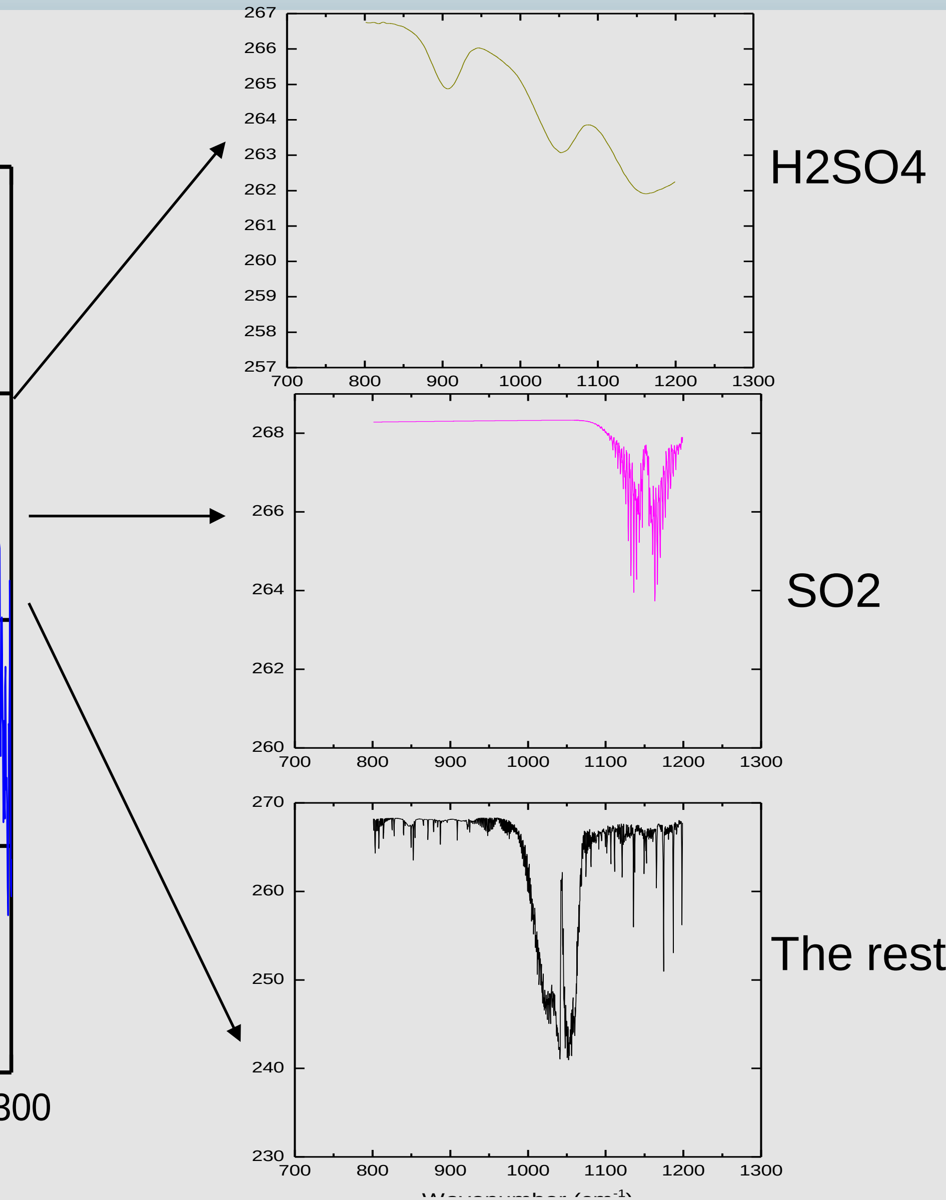
Radius: 0.39 µm
Concentration: 4121 part/cm3

Problem of local minima

Refractive indices from Sutherland 1991

Refractive indices from Tisdale 1998





Good

- Presented a sophisticated tool for the simultaneous retrieval of gases and aerosols
- Capable of retrieving radius and concentration (but indirecty also aerosol altitude)
- Works with any type of aerosol as long as you have the refractive indices
- Ideal to study pollution events.

Bad

- Sand poses the largest problem (refractive index / large number of mixtures)
- Retrievals are time consuming (1/2 hour per spectrum), not suitable for NRT.

Future work

- See what can be done on urban pollution