Water vapour in UT/LS

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  - what are their characteristics?
- UT/LS water vapour from SCIAMACHY
  - what is the added value?
  - how is it retrieved?
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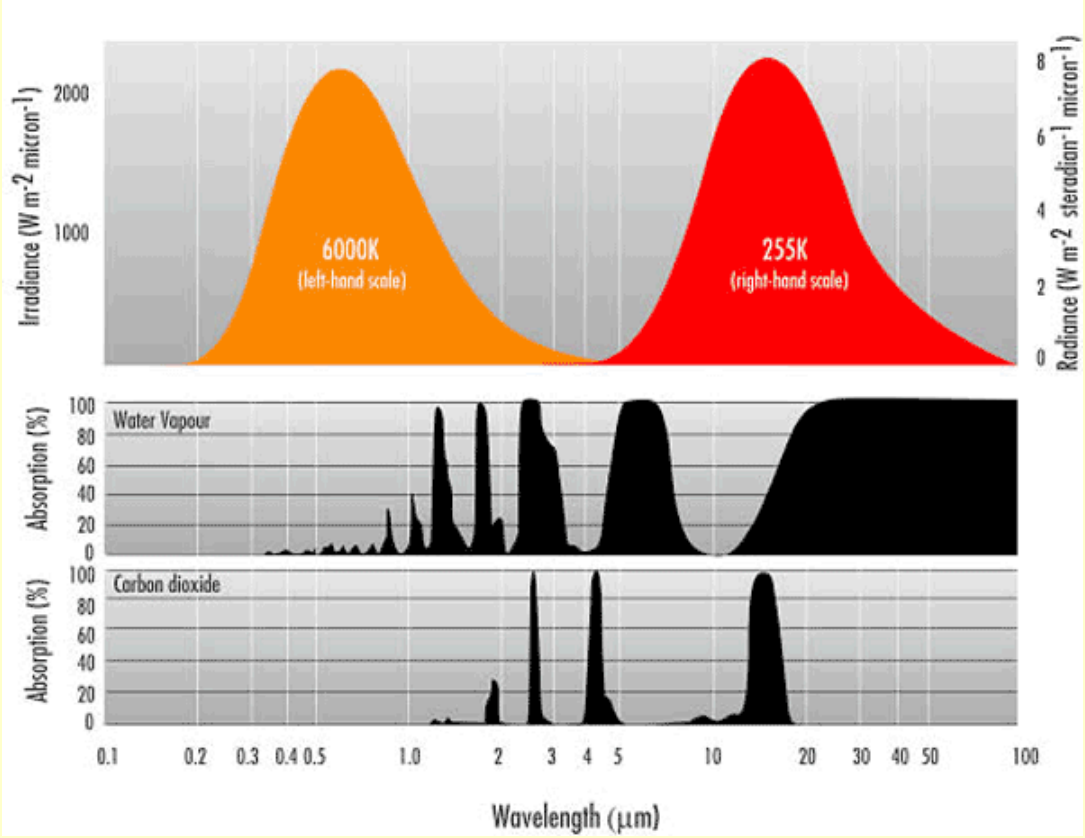
Water vapour and climate
Troposphere

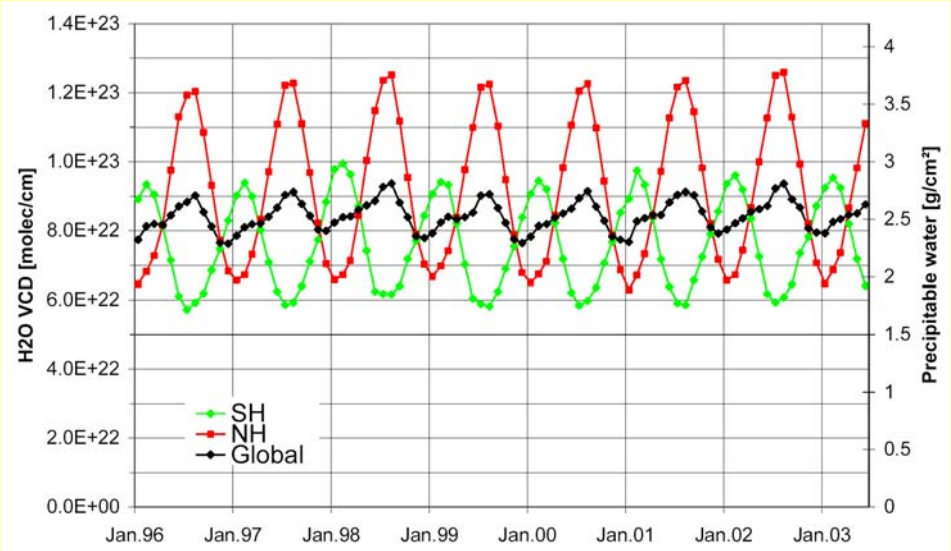
- most important GHG
- negligible anthropogenic emission
- strongest positive feedback mechanism

  → doubles GH effect from CO_2

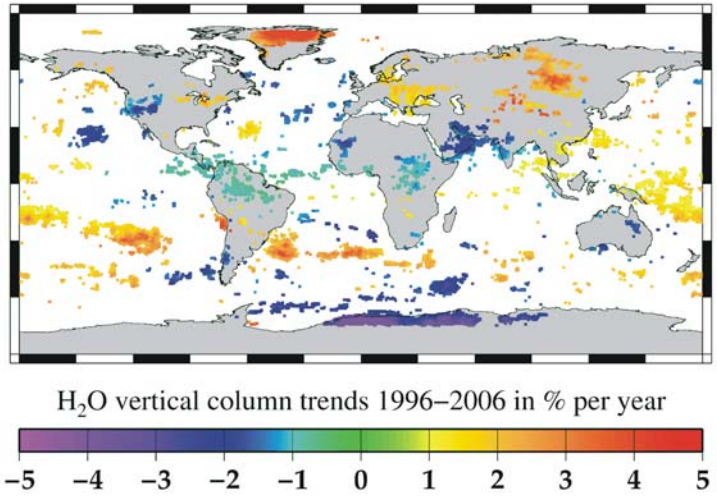


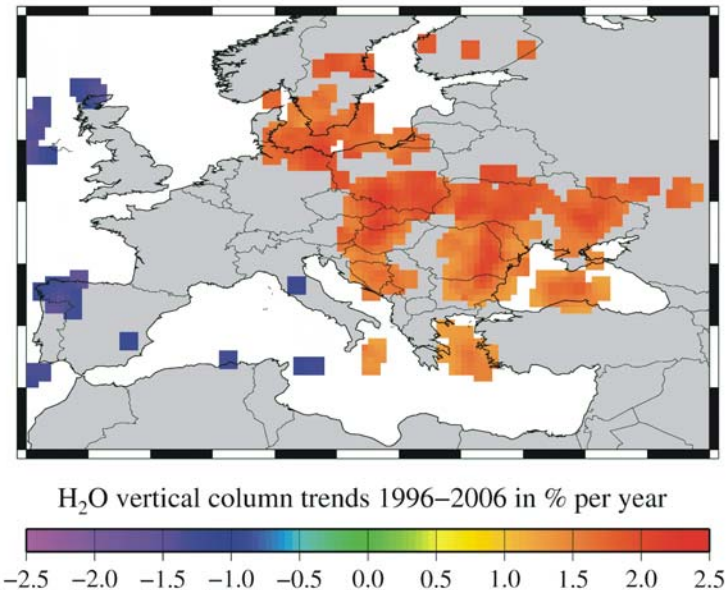
Water vapour and climate
Troposphere

- average positive trend due to global warming: 1.2 ± 0.3% per decade from 1988 to 2004 over oceans (IPCC)
- regional differences due to transport



‘trends’ derived from GOME (1996-2003, Wagner et al, JGR, 2006) and GOME/SCIAMACHY: (1996-2006, Mieruch et al, ACP, 2007)

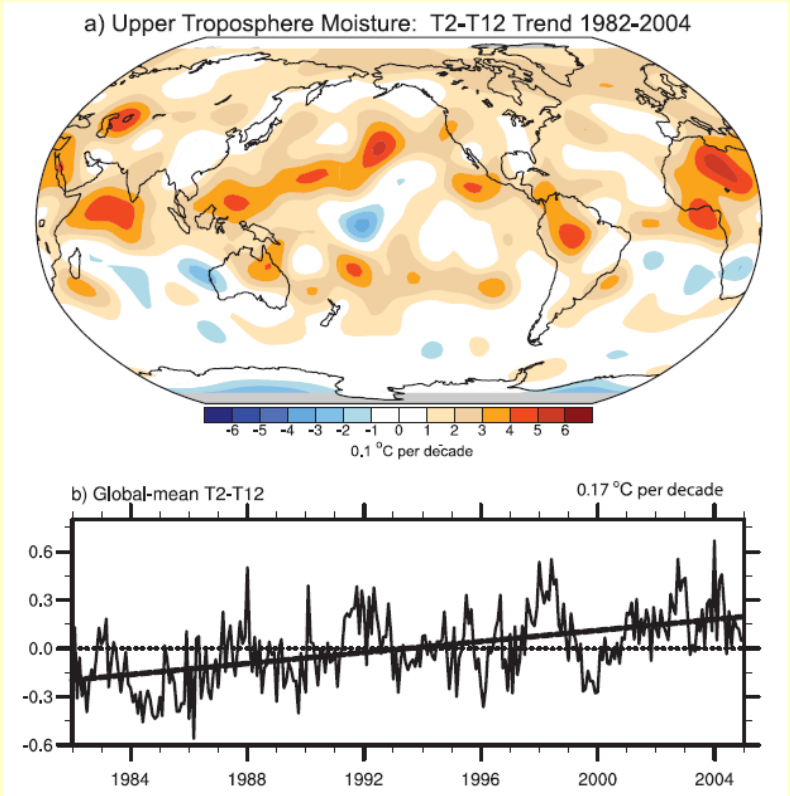




Water vapour and climate
Upper Troposphere

- Greenhouse effect is stronger in upper troposphere
  - larger temperature contrast
  - less water vapour
- Long-term changes difficult to assess (instrumental limitations)
- From brightness temperature differences HIRS (T12) – MSU (T2):

  → Increase in upper tropospheric moisture between 1982 and 2004 (Soden et al, Science, 2005)
- No trend observed in relative humidity → consistent



Water vapour and climate
Stratosphere

Anomalies typically enter stratosphere via tropical tropopause

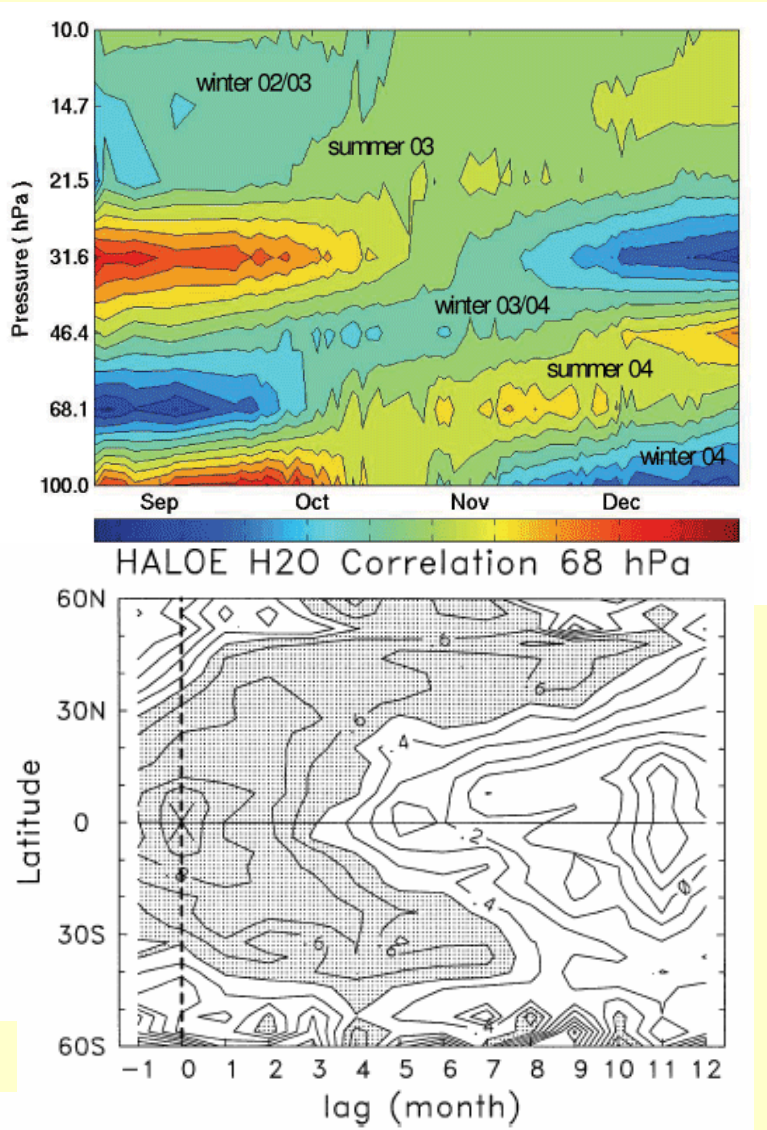
time lag in altitude - 'tape-recorder'

AURA-MLS water vapour anomalies 12S-12N

© *C. Jimenez*

time-lag in latitude

UARS-HALOE deseasonalised water vapour anomalies at 68 hPa correlated with equator time series



Randel et al, J.Atm.Sc., 2004

Potential sources of stratospheric water vapour changes

- increasing CH_4:
  - only partly explains rise in strat wv,
  - estimated RF: +0.07 [± 0.05] W/m^2

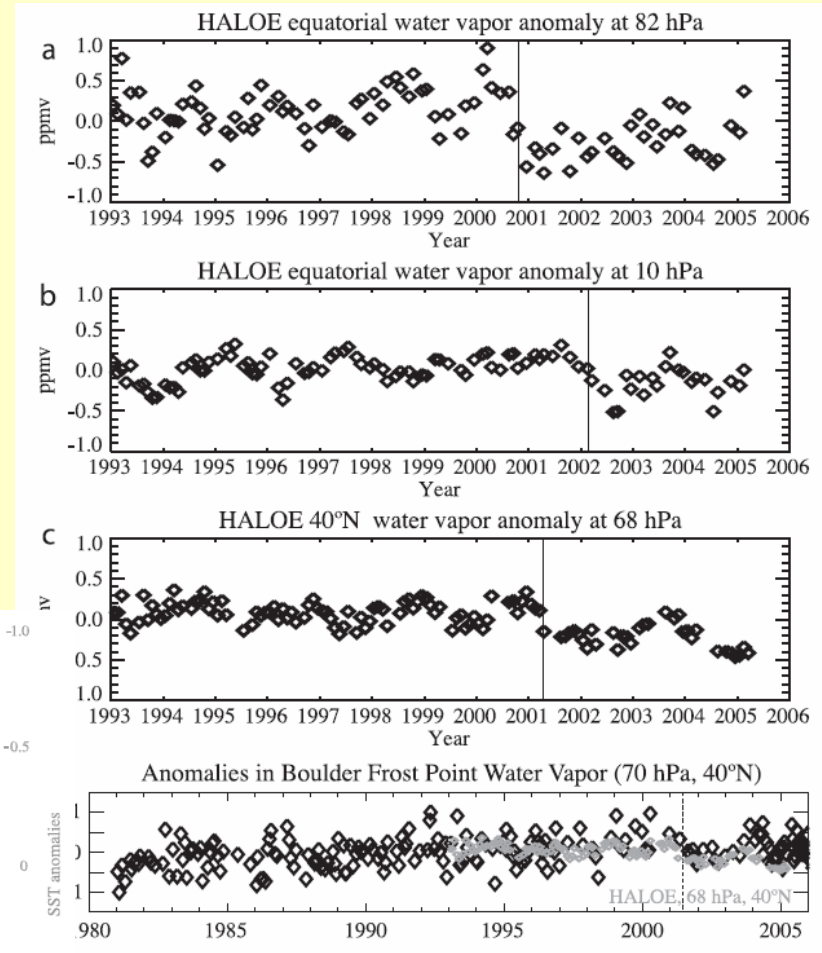
    uncertain: only partial understanding of vertical profile
- change in aircraft emissions
- volcanic eruptions → potential change in cross-tropopause wv flux
- changes in biomass burning aerosol
- changes in tropospheric SO_2
- changes in CH_4 oxidation rates from changes in stratospheric chlorine, ozone and OH
- changes in tropopause temperatures or circulation

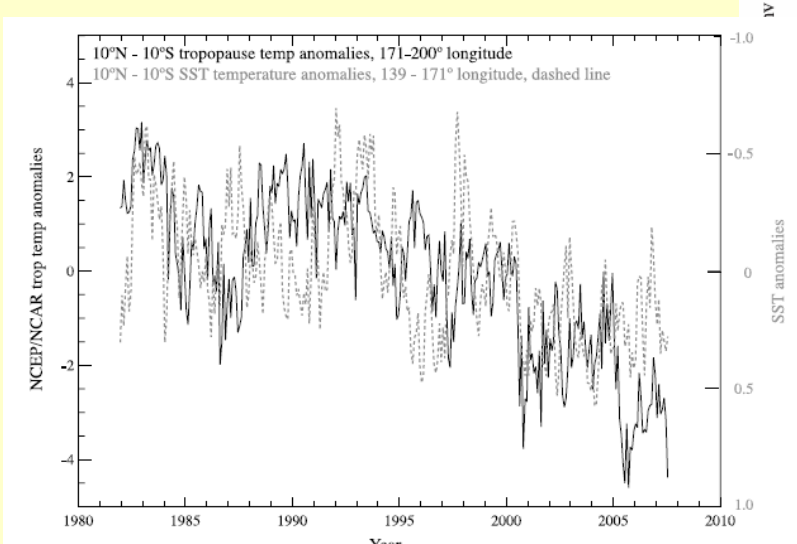
Note: *different mechanisms can affect trends at different altitudes*

Water vapour and climate
Stratosphere

Rosenlof and Reid, JGR, 2008:

- HALOE shows positive trend above 82 hPa
- sudden decrease in 2000 (82 hPa, eq), 2001 (68 hPa, 40N), 2002 (10 hPa, eq)
- consistent with Frost Point Hygrometer measurements in Boulder
- correlations with tropopause temperatures and SST suggest that increased cooling may be indication of strengthening tropical convection

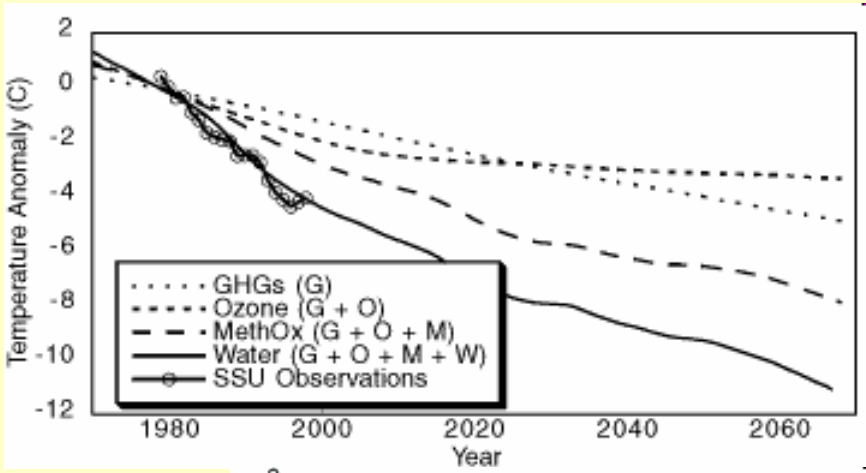


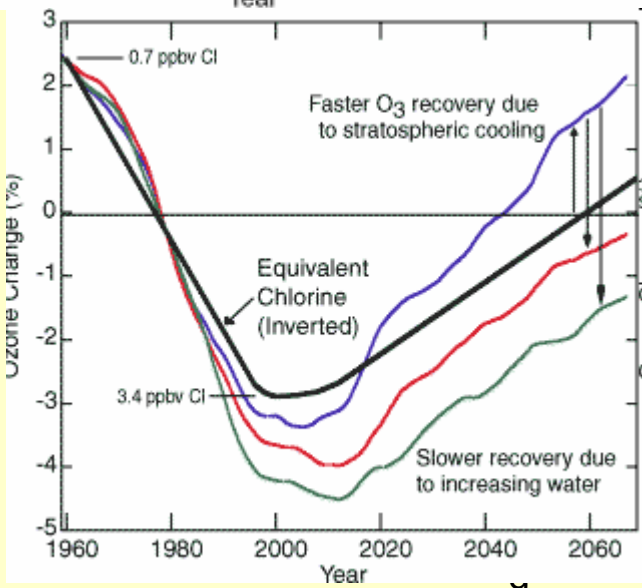


Water vapour and climate
Stratosphere

Shindell, 2001:

- 30-50 km: water vapour increase together with strong cooling
- climate model reproduces the trend only when stratospheric water is increased
- increasing water vapour slows down the ozone recovery





Water vapour and climate
Summary

- Most important GHG
  - GH effect strongest in UT/LS
  - Strongest Positive Feedback
- Tropospheric WV increases due to global warming
- Upper Tropospheric WV increases
  - instrumental limitations
- Stratospheric WV increases
  - sources and RF are not quantified
- Different mechanisms affect different altitudes

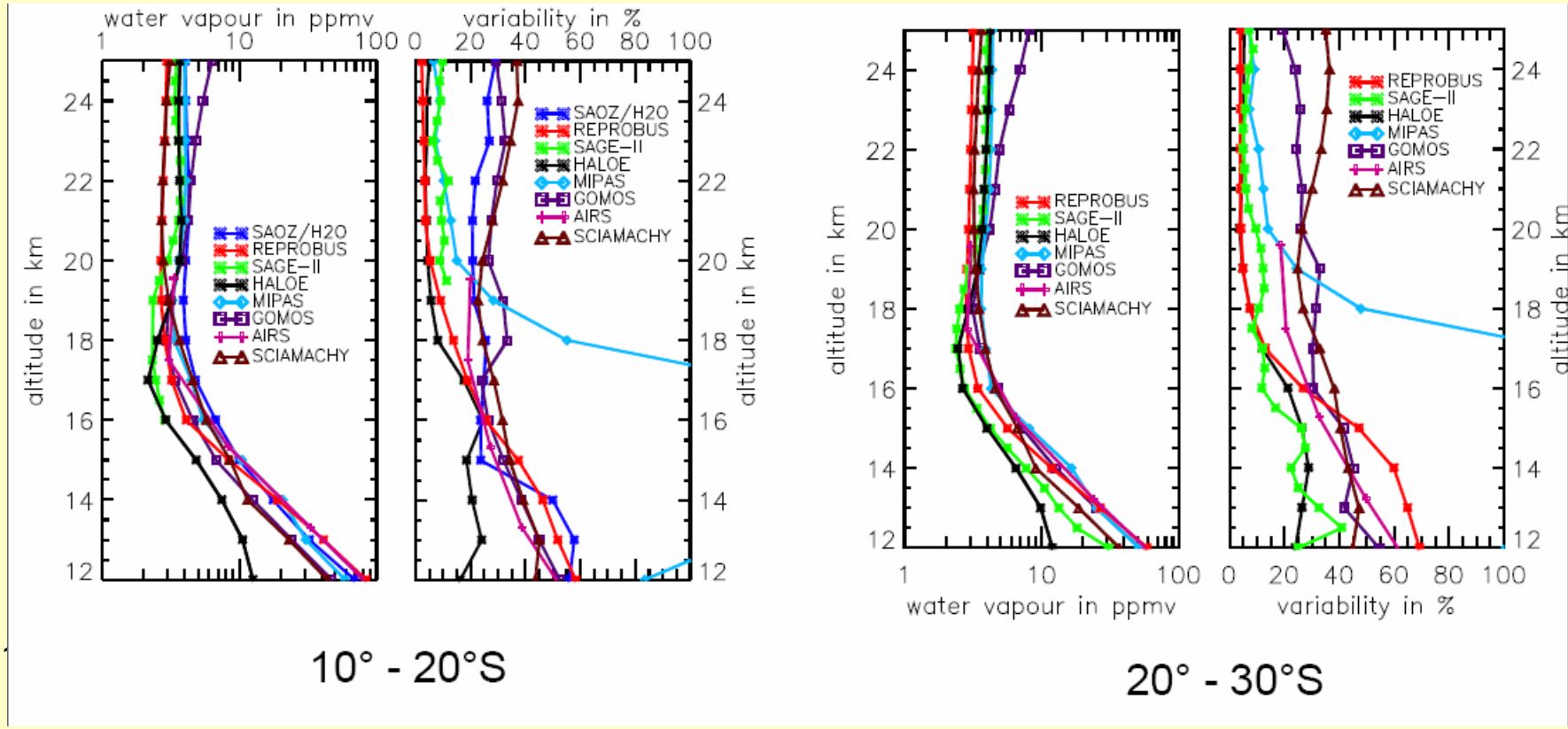
Satellite observations of UT/LS water vapour

- In general: satellites give a global picture:
  - different trends in different regions?
  - correlations with other global parameters?
- UARS-HALOE: 1992-2005 longest stratospheric WV record
- Techniques:
  - solar occultation (HALOE, SAGE)
  - μ-wave limb (MLS)
  - VIS-SWIR nadir/limb scanning (SCIAMACHY)
  - IR limb (MIPAS)

Intercomparison of wv profiles 12-25 km

- Large differences in zonal mean profiles:
  - HALOE and SAGE deviate below 18 km
  - GOMOS deviates above 23 km
  - MIPAS variability very large below 18 km

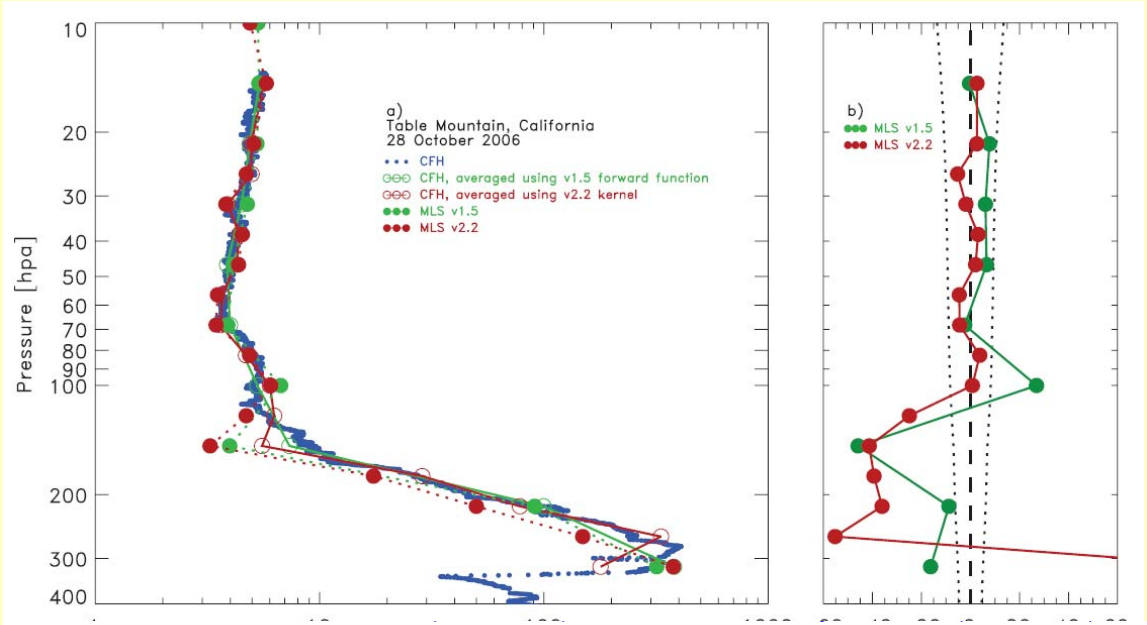
Montoux et al, 2008



Intercomparison with Frost Point Hygrometer

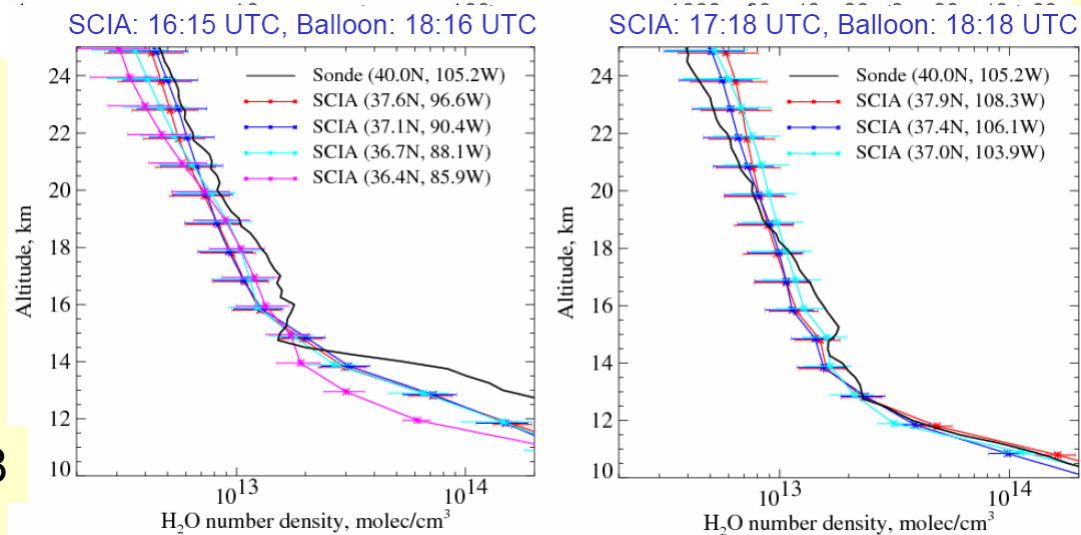
- AURA-MLS

Vömel et al, 2007



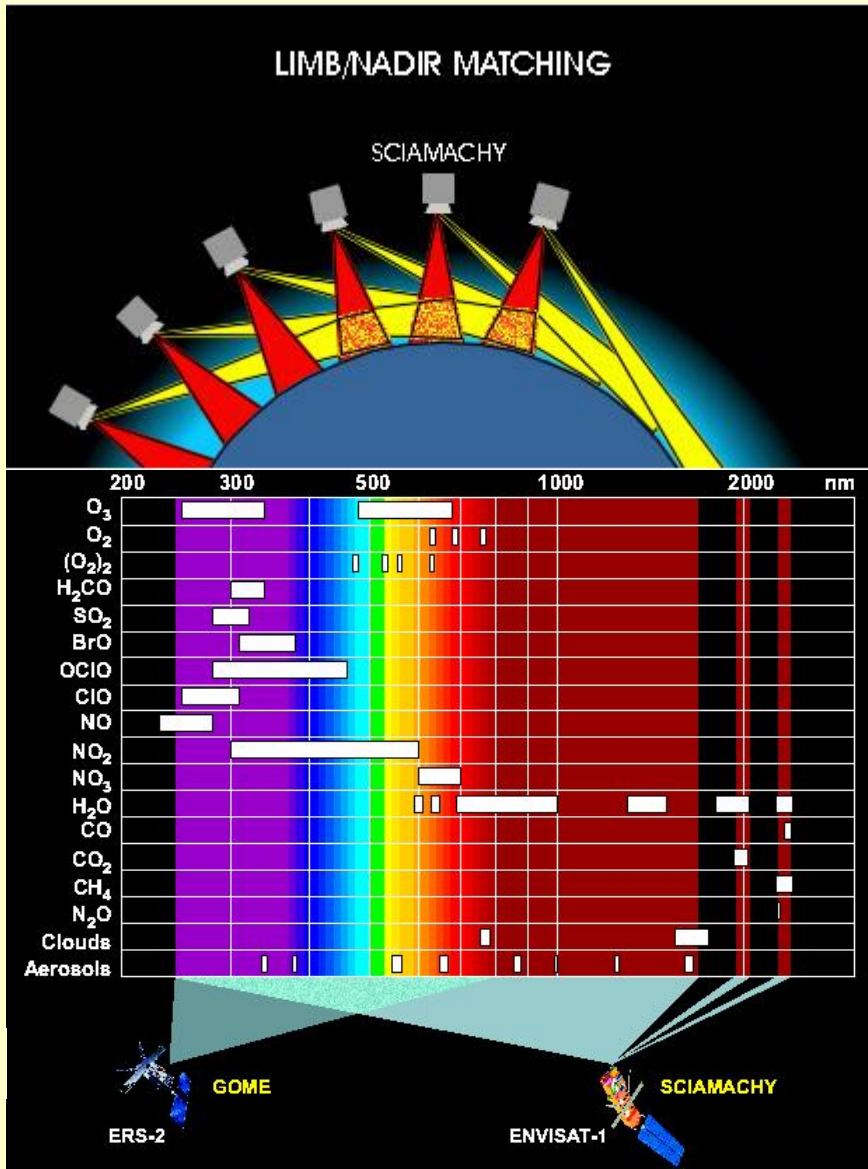
- ENVISAT-SCIAMACHY

Rozanov, 2008



UT/LS water vapour from SCIAMACHY
Added value

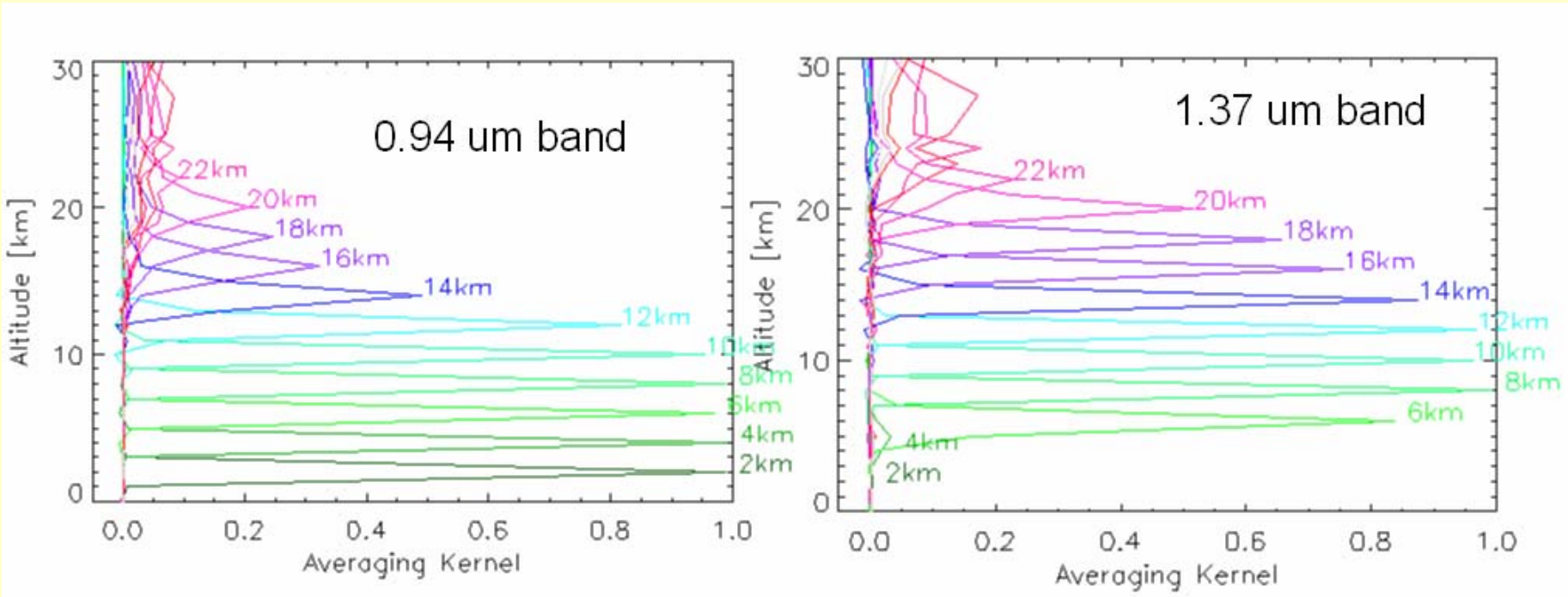
- measurement frequency: Daily measurements within 800 km radius since 2002
- Combination of nadir and limb: accurate information on tropospheric water vapour and clouds → higher accuracy in UT
- Large wavelength region → large vertical range



Different wavelengths

- Weaker lines provide information for lower altitudes

courtesy: Dave Flittner

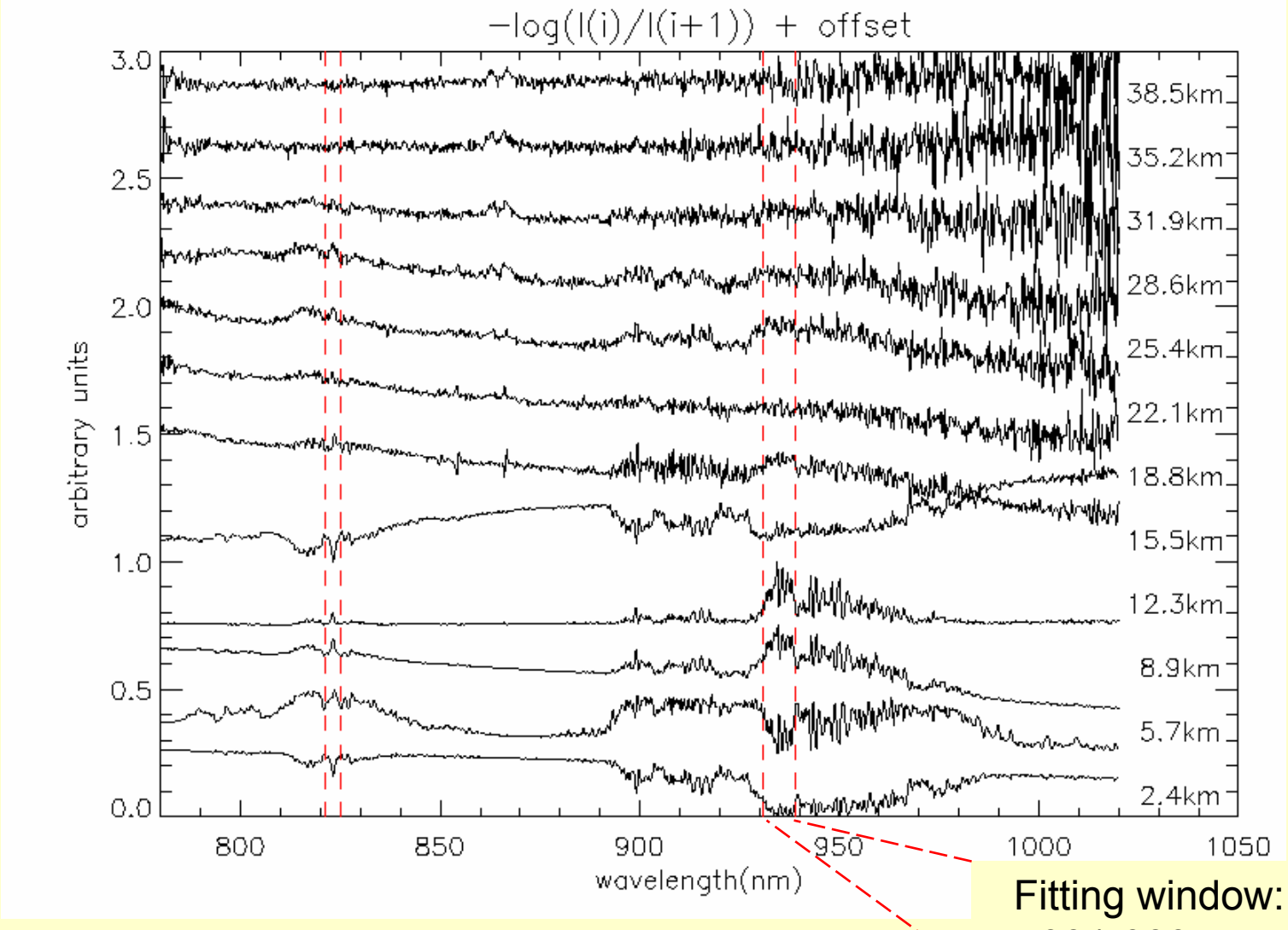


UT/LS water vapour from SCIAMACHY

Retrieval Method

Ratio of radiances

Ratio of radiances between two consecutive lines of sight



Fit differential structures

Fit differential H_2O structures in ratio of radiances, using a linear relaxation technique:

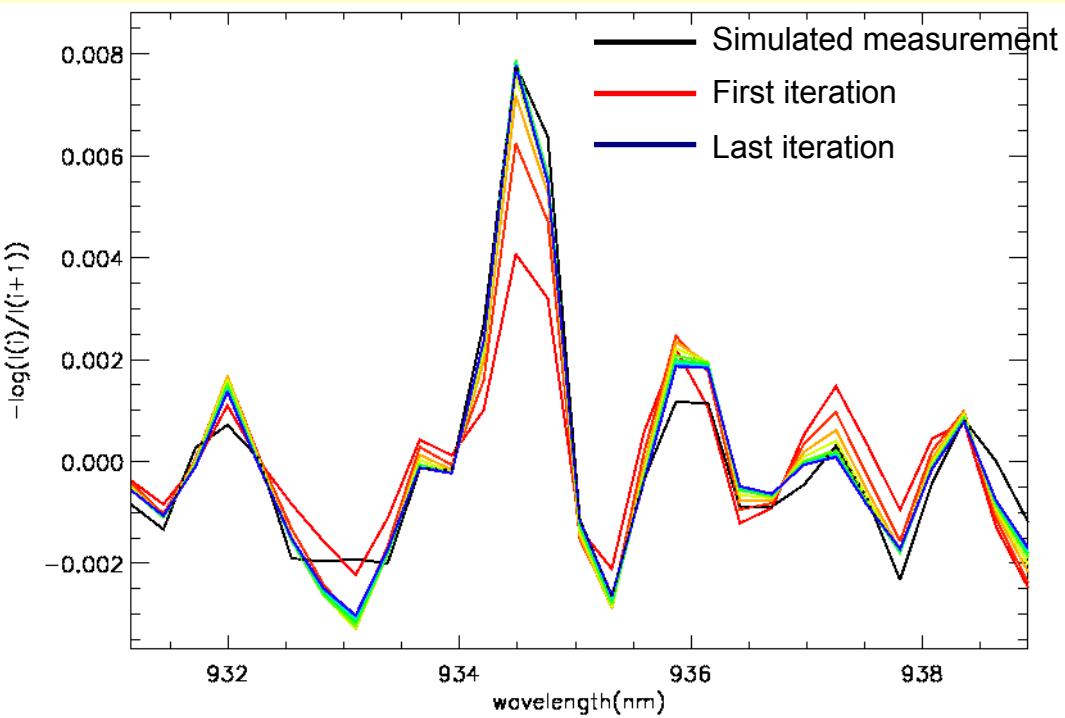
$$x_{i+1} = x_i + G[y - F(x_i)]$$

x: solution vector

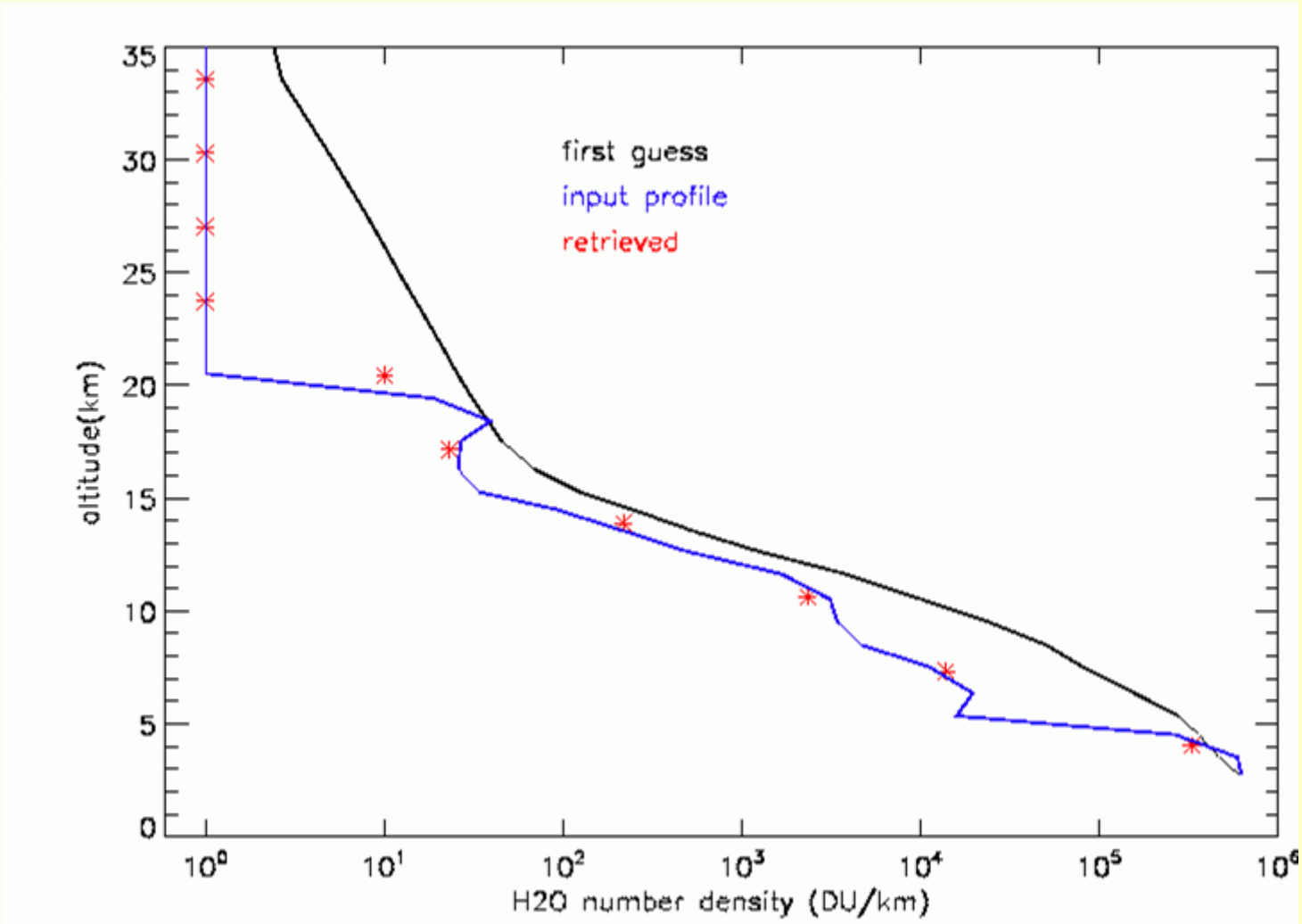
y: observation vector

F: Forward model

G: correction matrix



Retrieval (simulation)

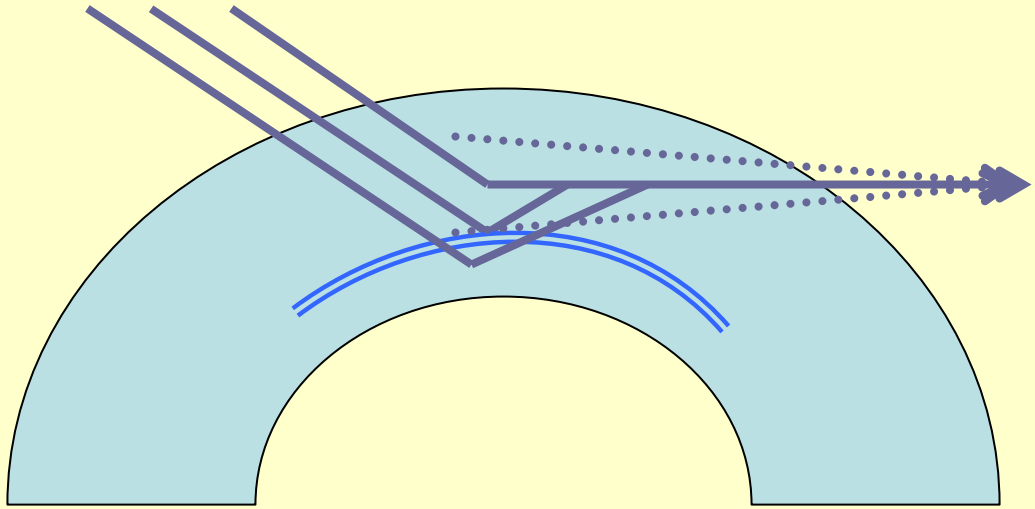


UT/LS water vapour from SCIAMACHY

Error sources

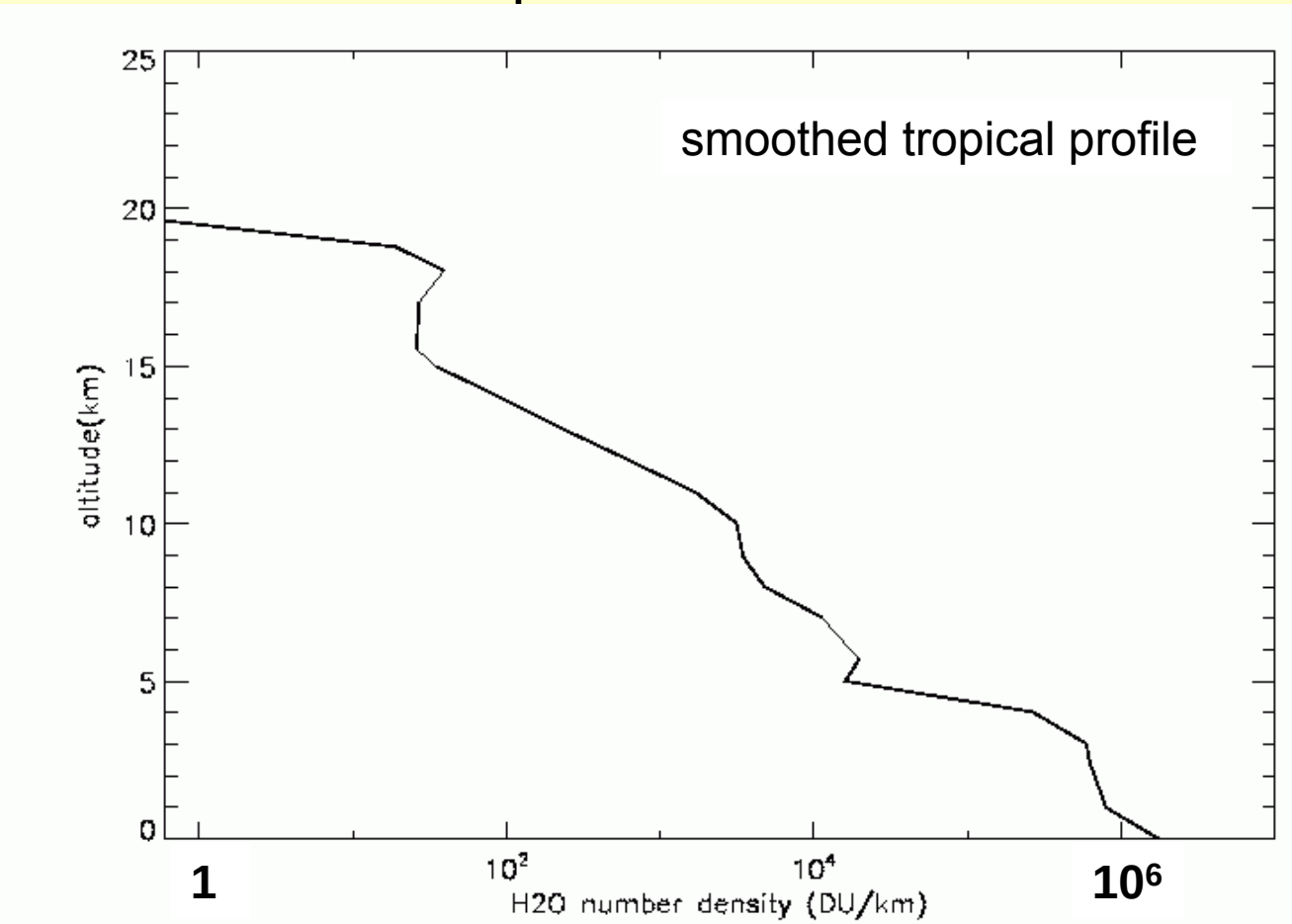
Limb viewing

- Multiple scattering → information from lower levels
- Scattering by clouds and aerosol
- Limb straylight: light from other directions

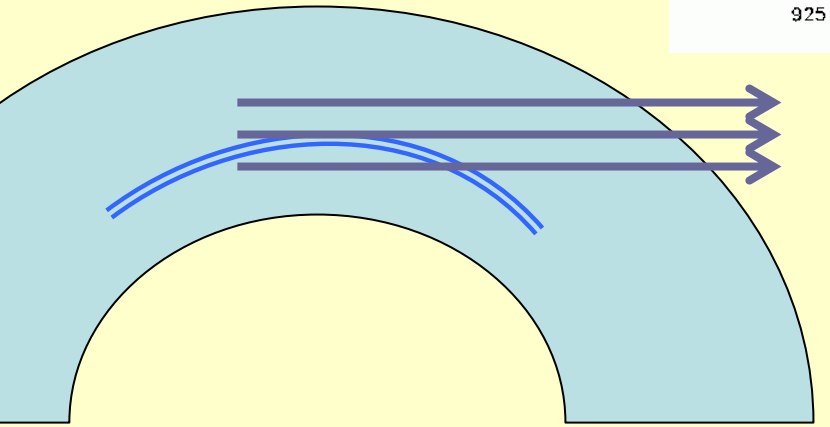


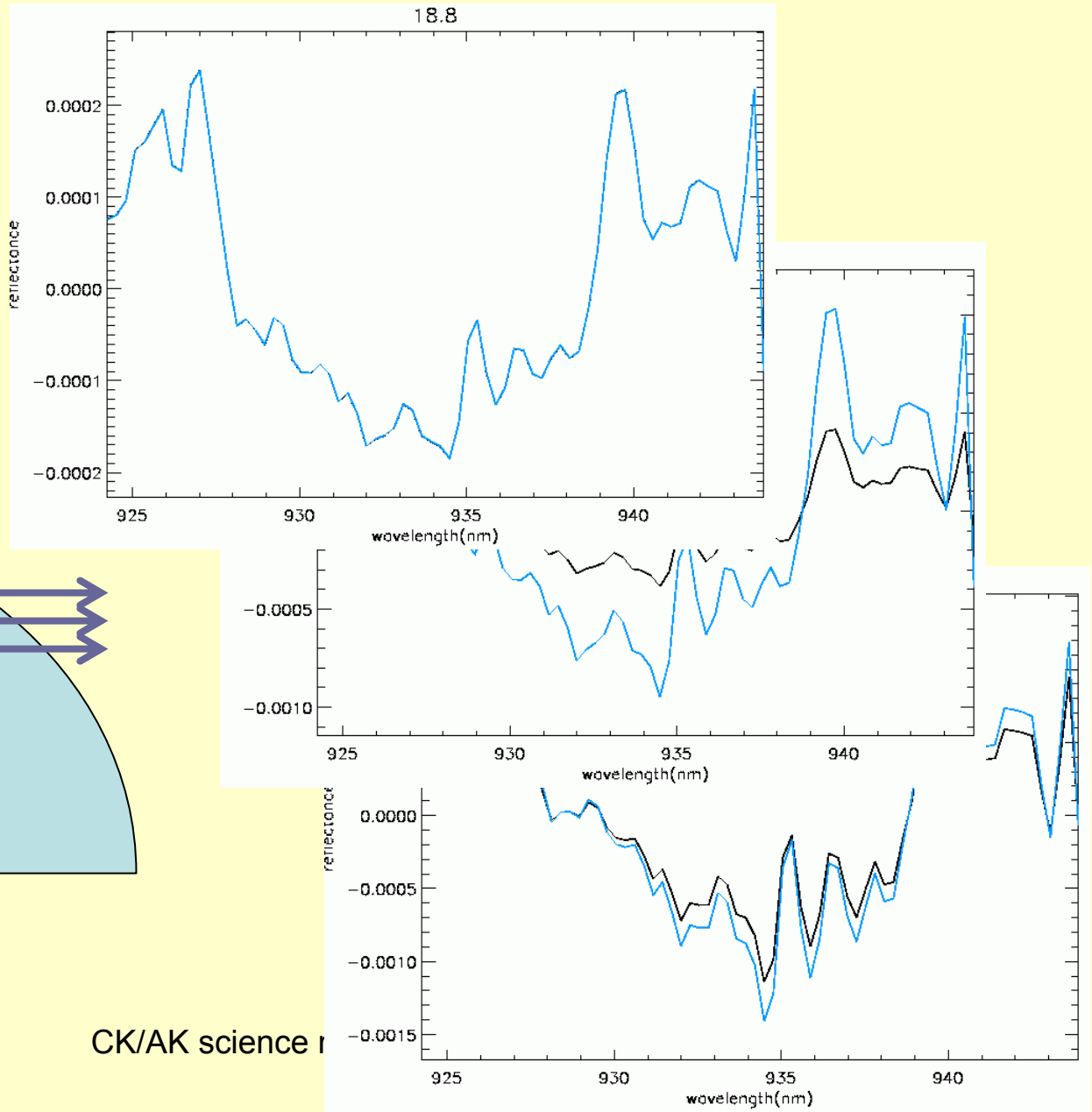
H_2O profile

- Number density decreases many orders of magnitude from surface to stratosphere



Thin scattering layer

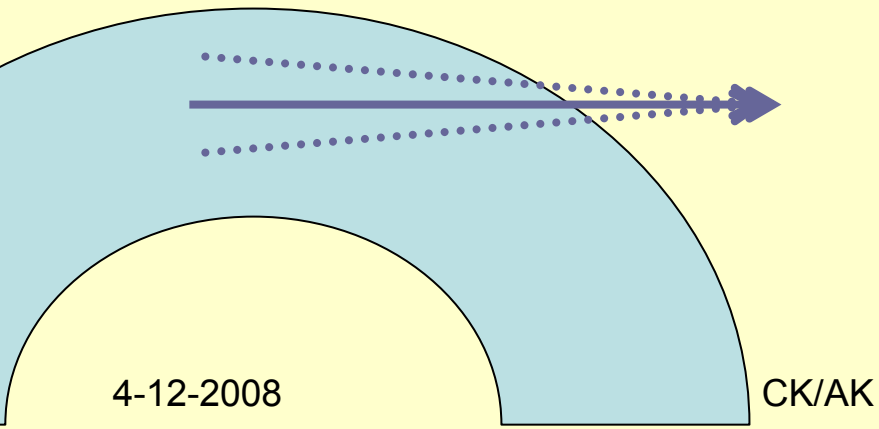


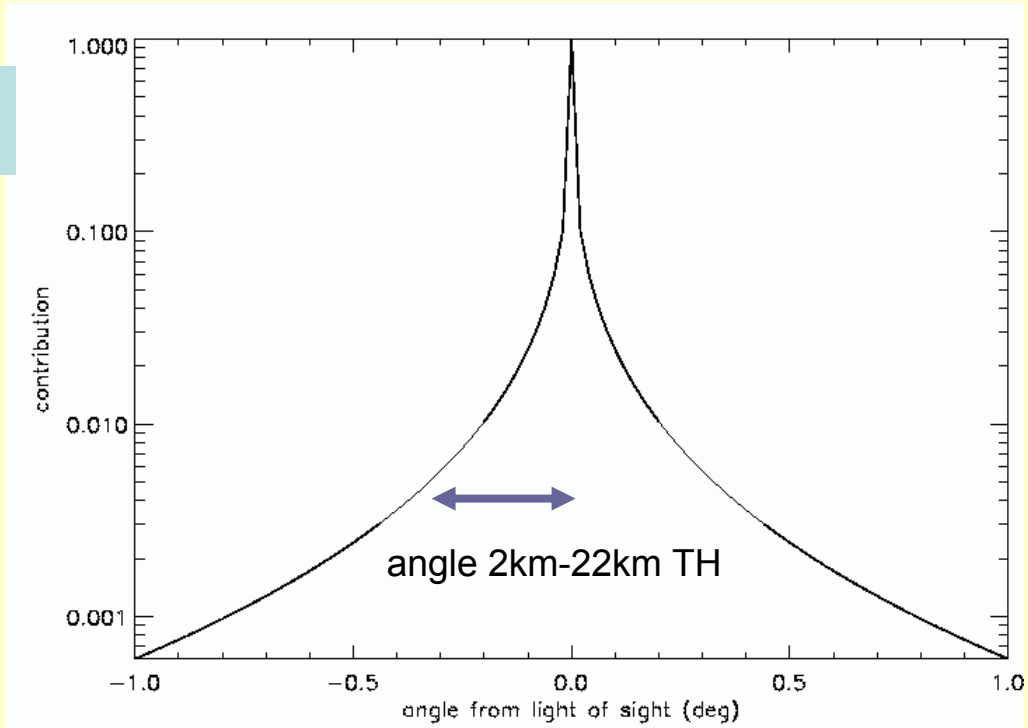


Limb straylight

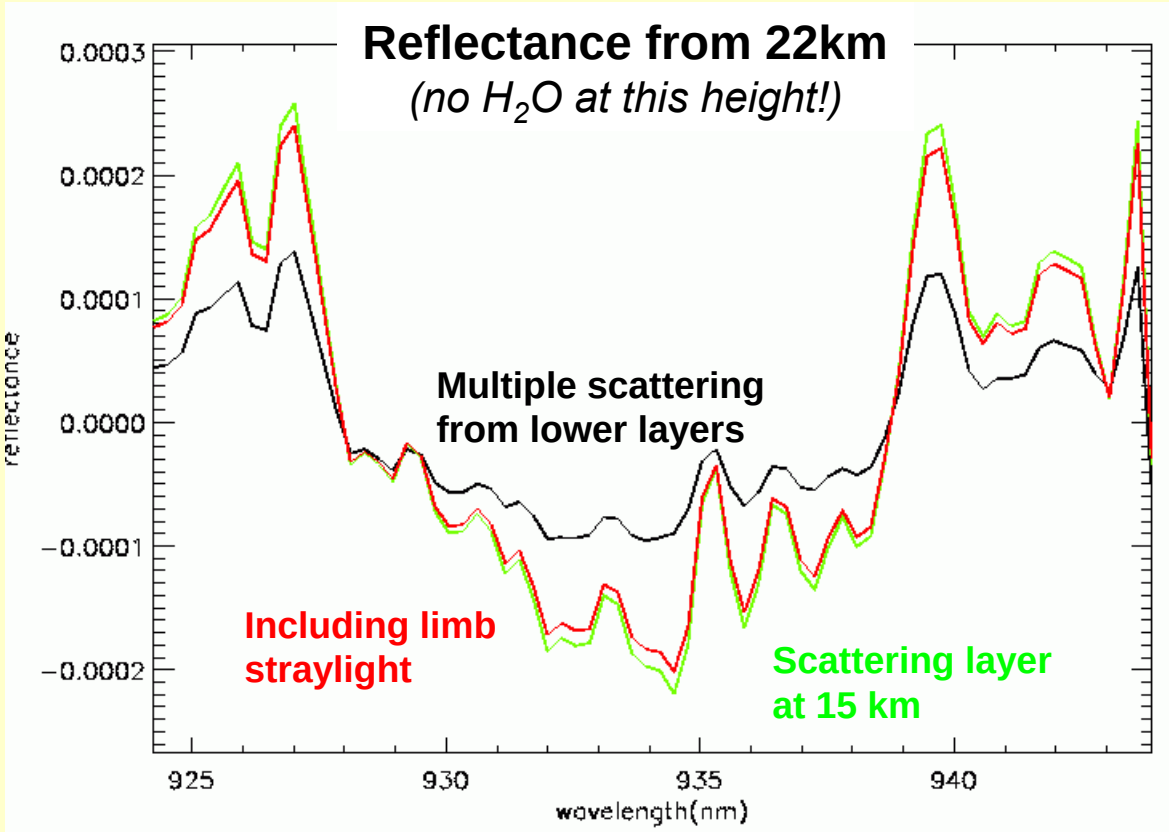
- Light reflecting from the baffles and other parts of the limb port into line of sight
- Small effect in channel 5 for the absolute radiance
- Currently being characterized, here a model is used
- Radiation field is convoluted with this model

Example: 0.4% of light from 2km TH contributes to 22km TH spectrum





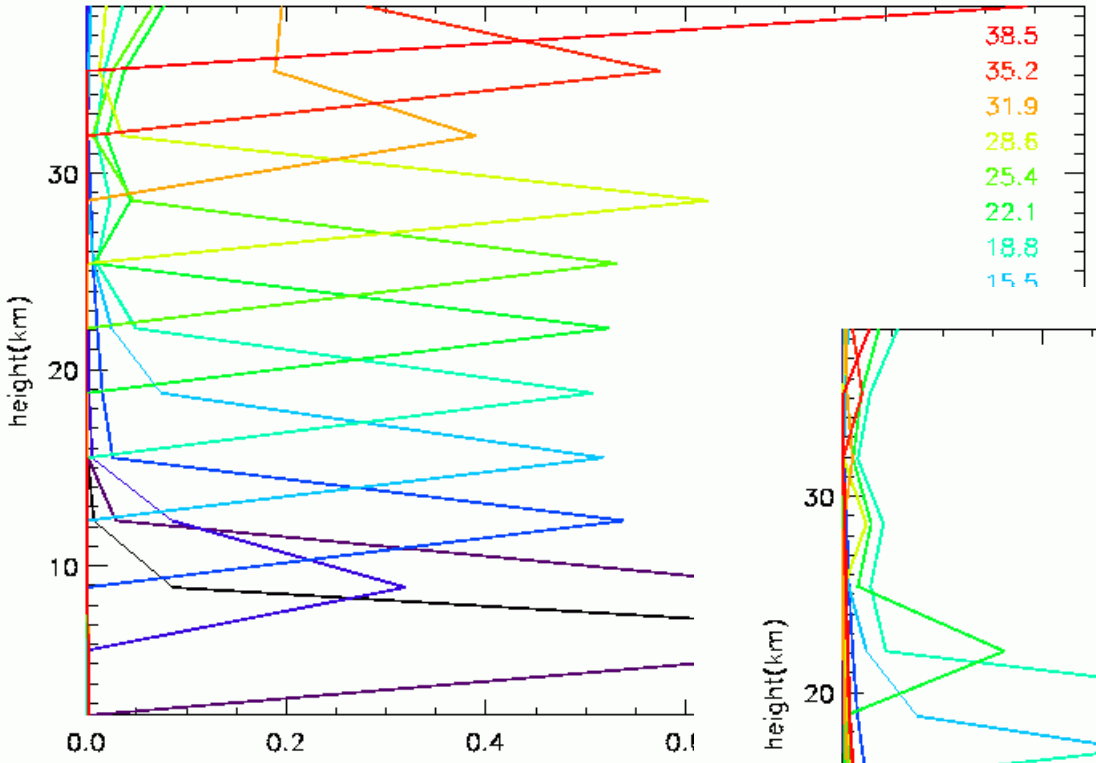
Influence of limb stray light on spectrum



Note: straylight from the horizontal is not accounted for here!

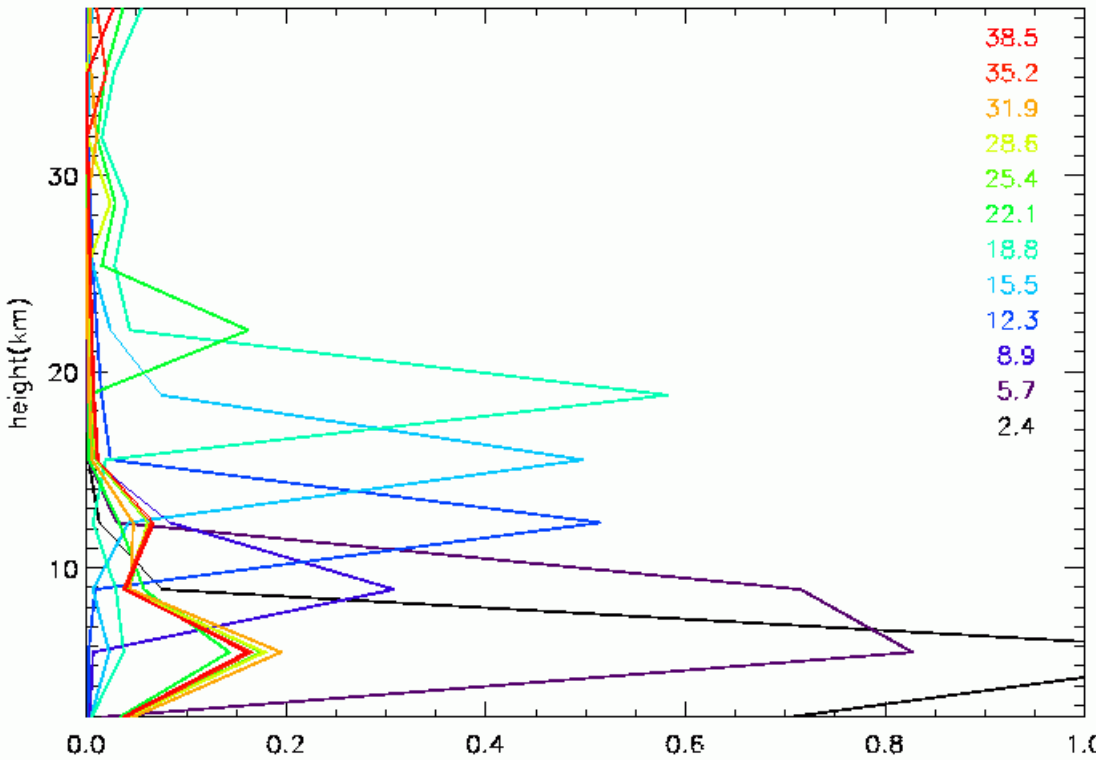
Sensitivity functions

- Response to a change in profile



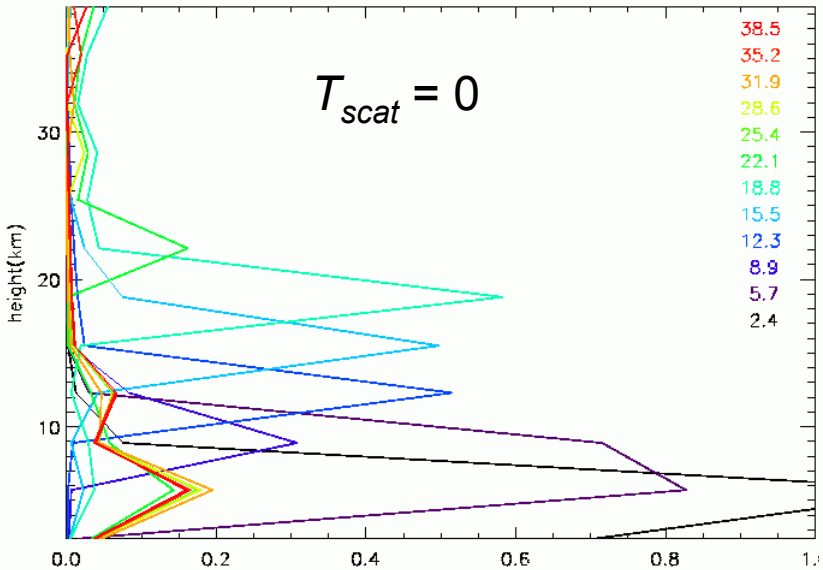
- no limb straylight
- no scattering layer

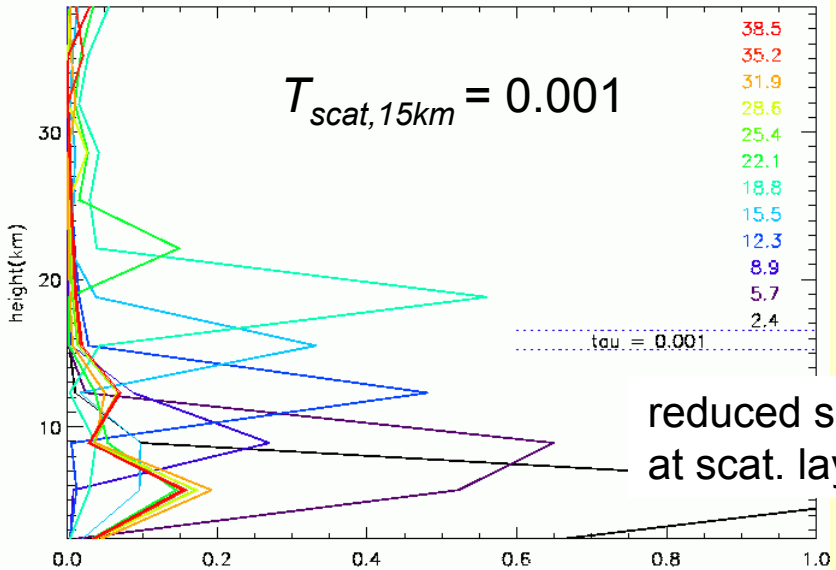
- including limb straylight



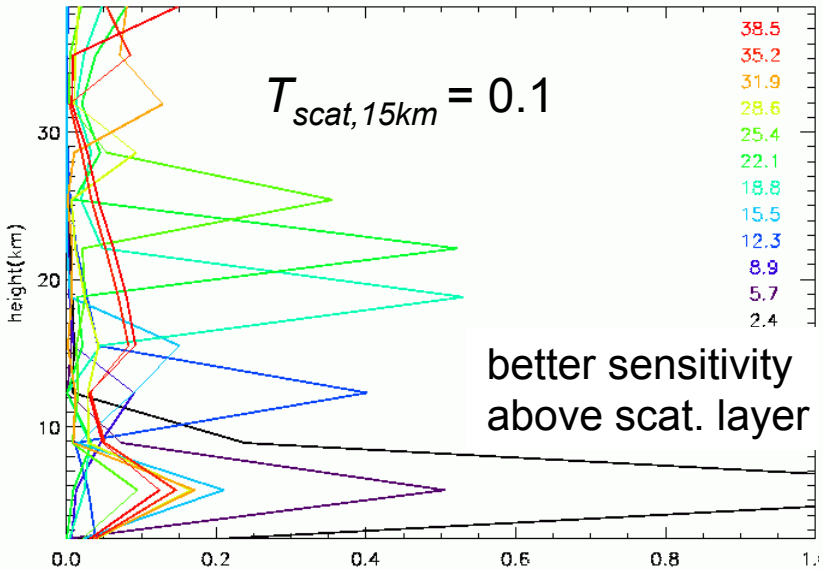
4-12-2008

Influence of scattering layer on sensitivity

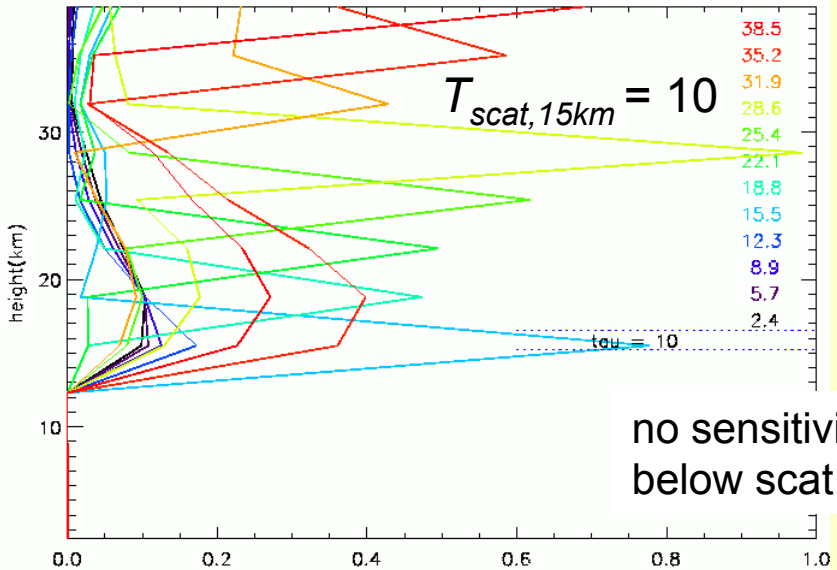




reduced sensitivity at scat. layer

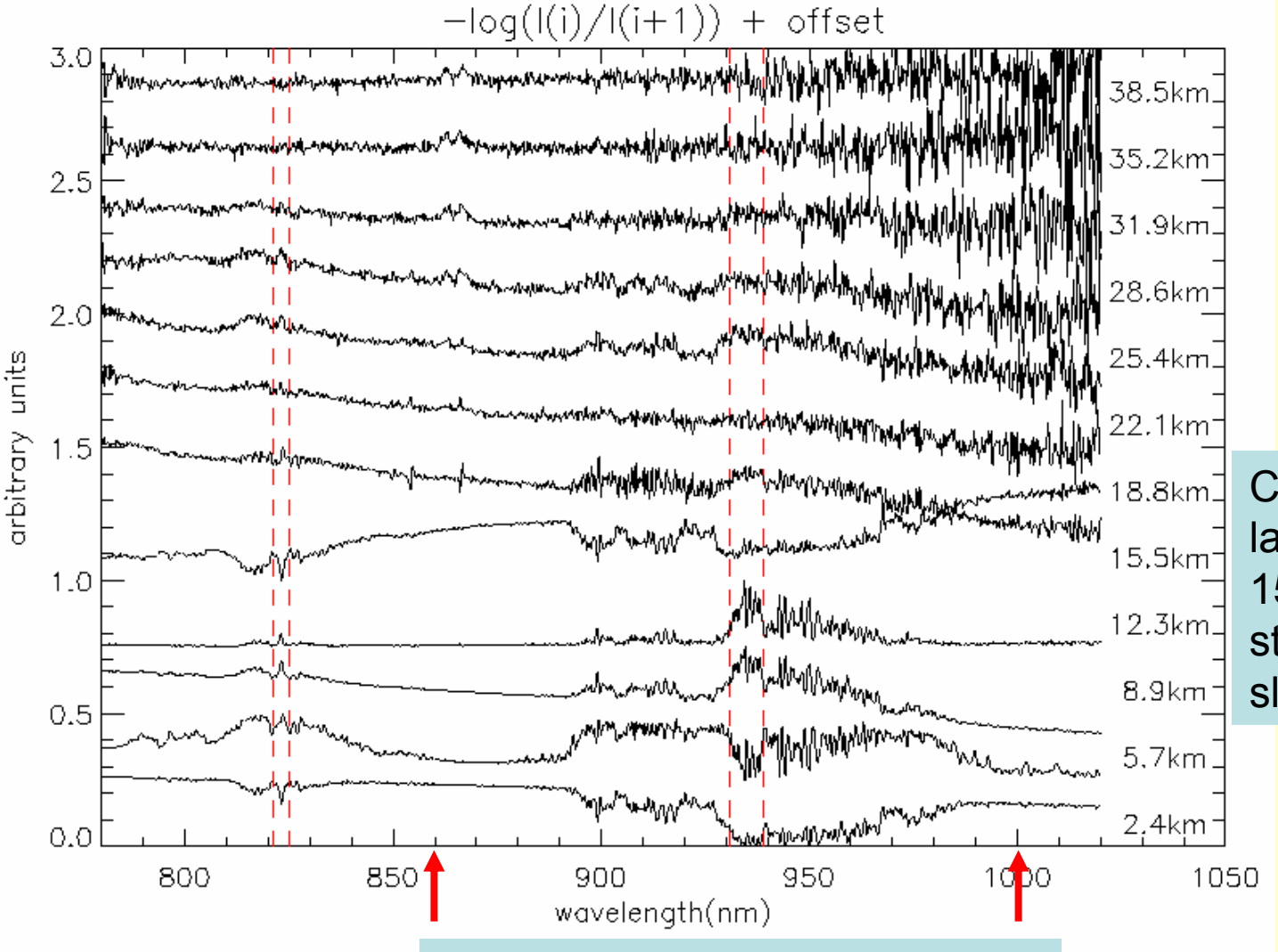


better sensitivity above scat. layer



no sensitivity below scat. layer

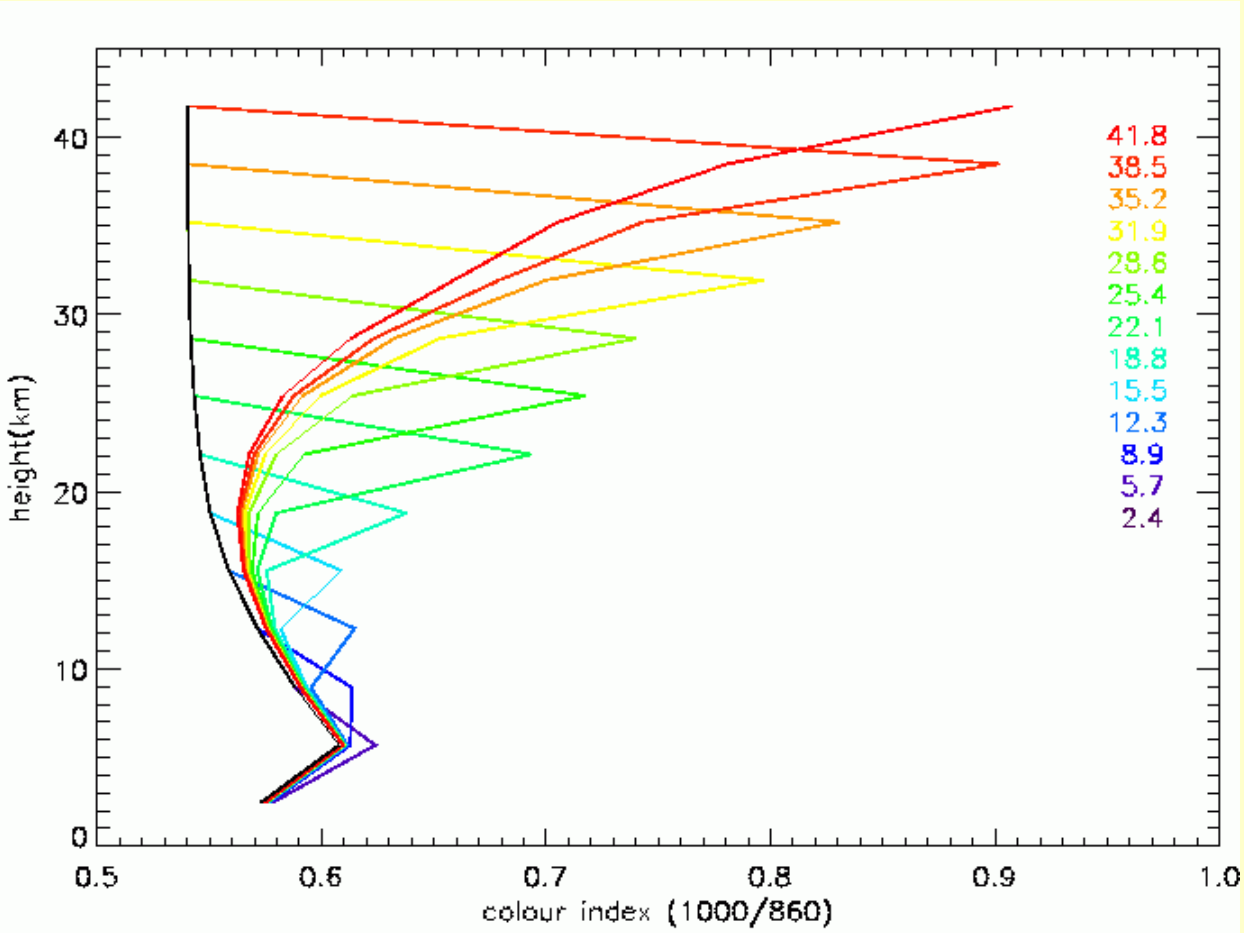
Effect of scattering on spectral slope



Cirrus or aerosol layer between 15 and 18 km: strong change in slope

Colour index: R(1000)/R(860)

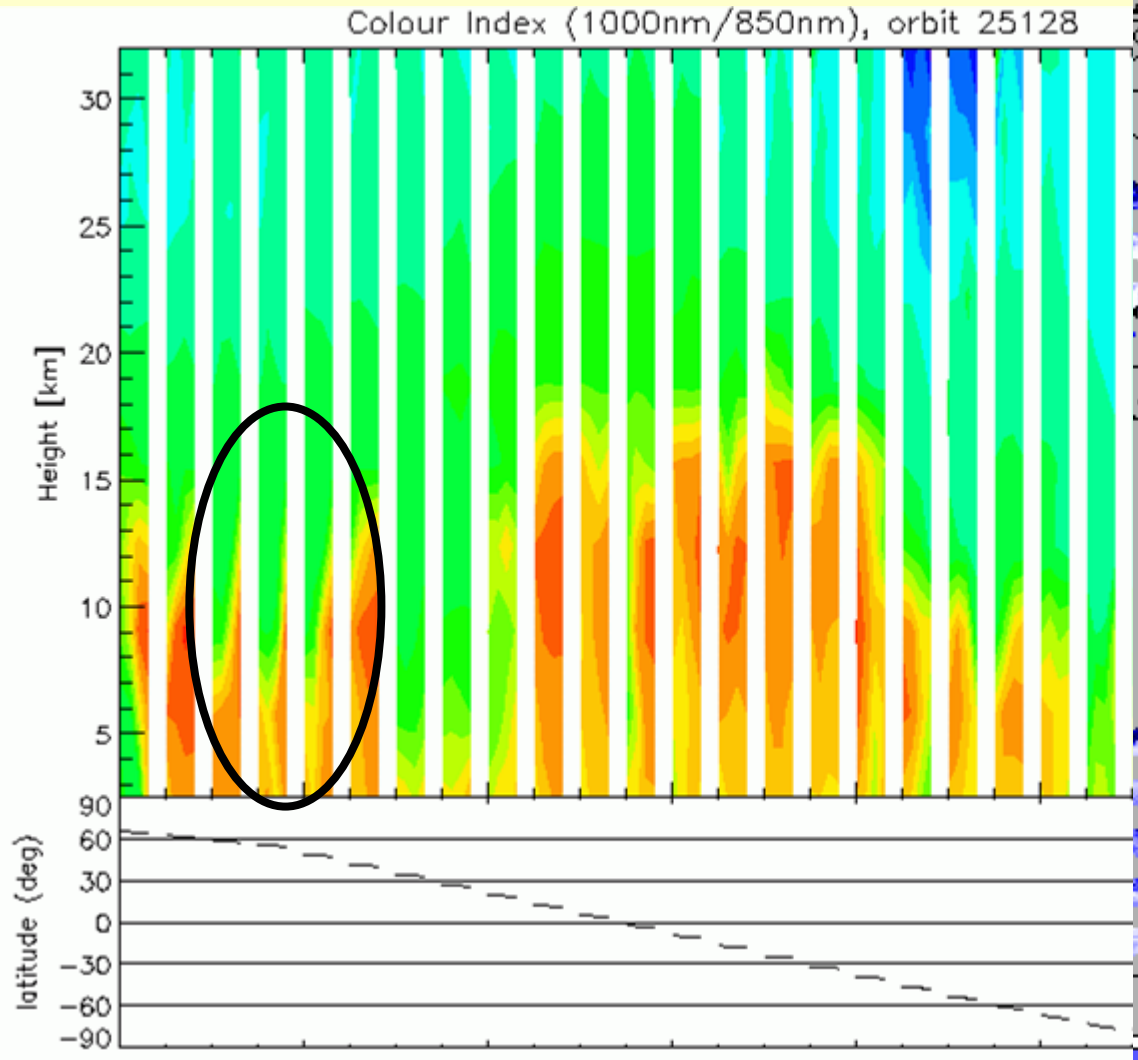
Colour index R_{1000}/R_{860}

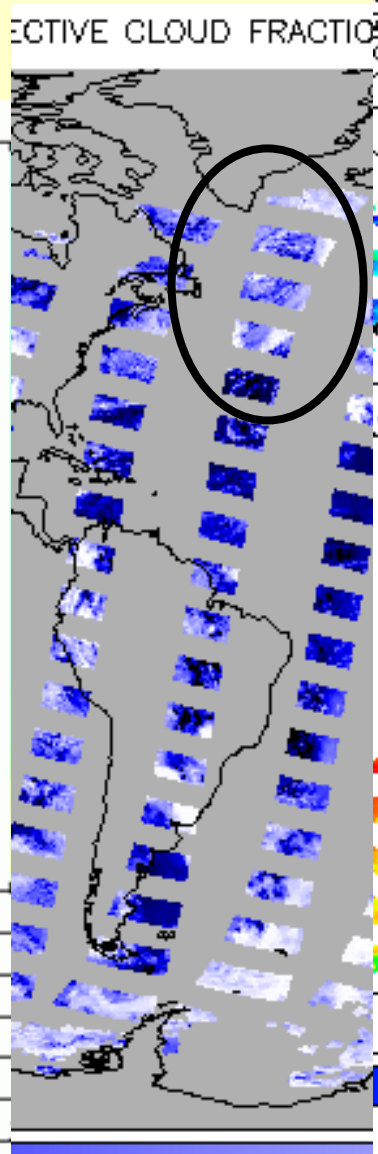


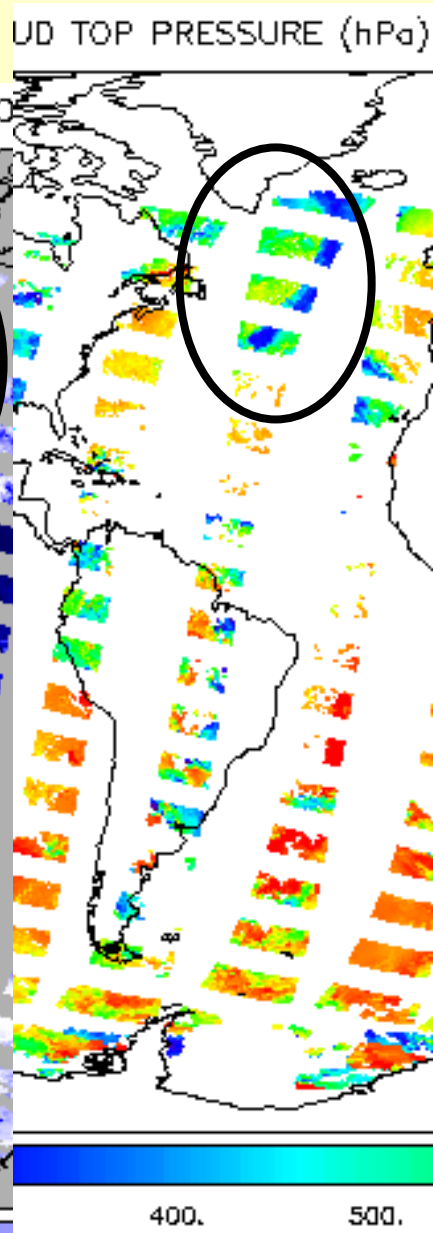
Different colours denote different heights of scattering layer. (tau=10^{-4})

From colour index profile, scattering optical depth can be retrieved

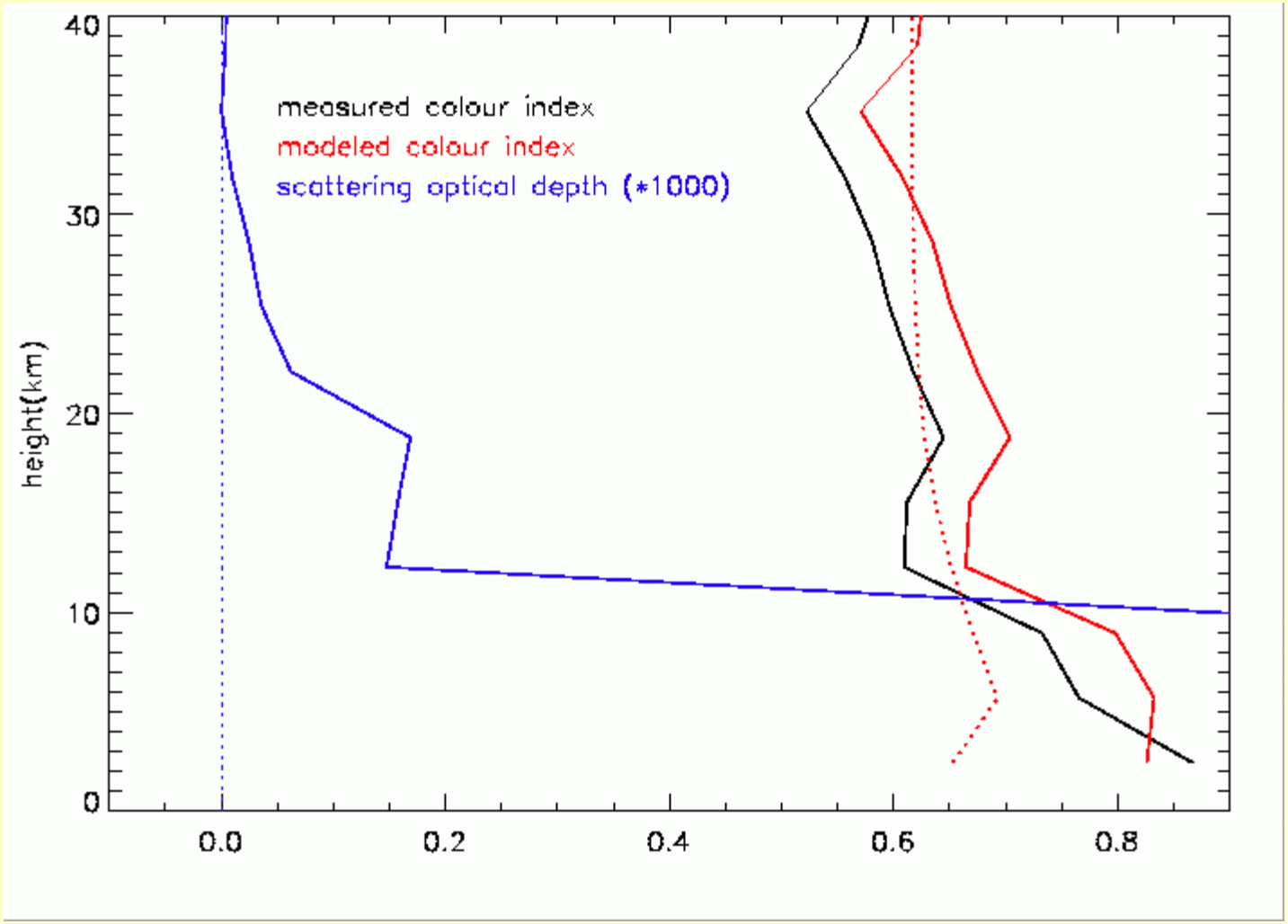
Colour index over one orbit







Deriving scattering profiles



Summary

- Water vapour is most important GHG, key issues are:
  - stratosphere: identification of sources and quantification of RF
  - upper troposphere: quantification of trends
- Time series of UARS-HALOE will be continued by AURA -MLS and Envisat-SCIAMACHY and -MIPAS
- SCIAMACHY and MLS have potential to go to accurate water vapour down to UT
- First retrievals of SCIAMACHY LS water vapour (from IFE) are demonstrated against correlative measurements
- SCIAMACHY limb straylight strongly reduces the sensitivity above ~20km (at 940 nm)
- Scattering by aerosols and clouds enhance the sensitivity above the scattering layer, but introduce large errors when not accounted for
- The scattering optical depth profile can be retrieved simultaneously with the water vapour profile