Measuring the amount of precipitable water vapour with VISIR

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ESO Calibration Workshop 23–26 January 2007

Outline

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Water

Water:

- one of the main constituents of the atmosphere:
- mainly found in the lower layers
- can be found
  - in condensed form (*important for optical and NIR*):
    - liquid, as droplets in most clouds
    - solid, as small ice crystals in cirrus clouds
  - as water vapour (*important for NIR and MIR*).

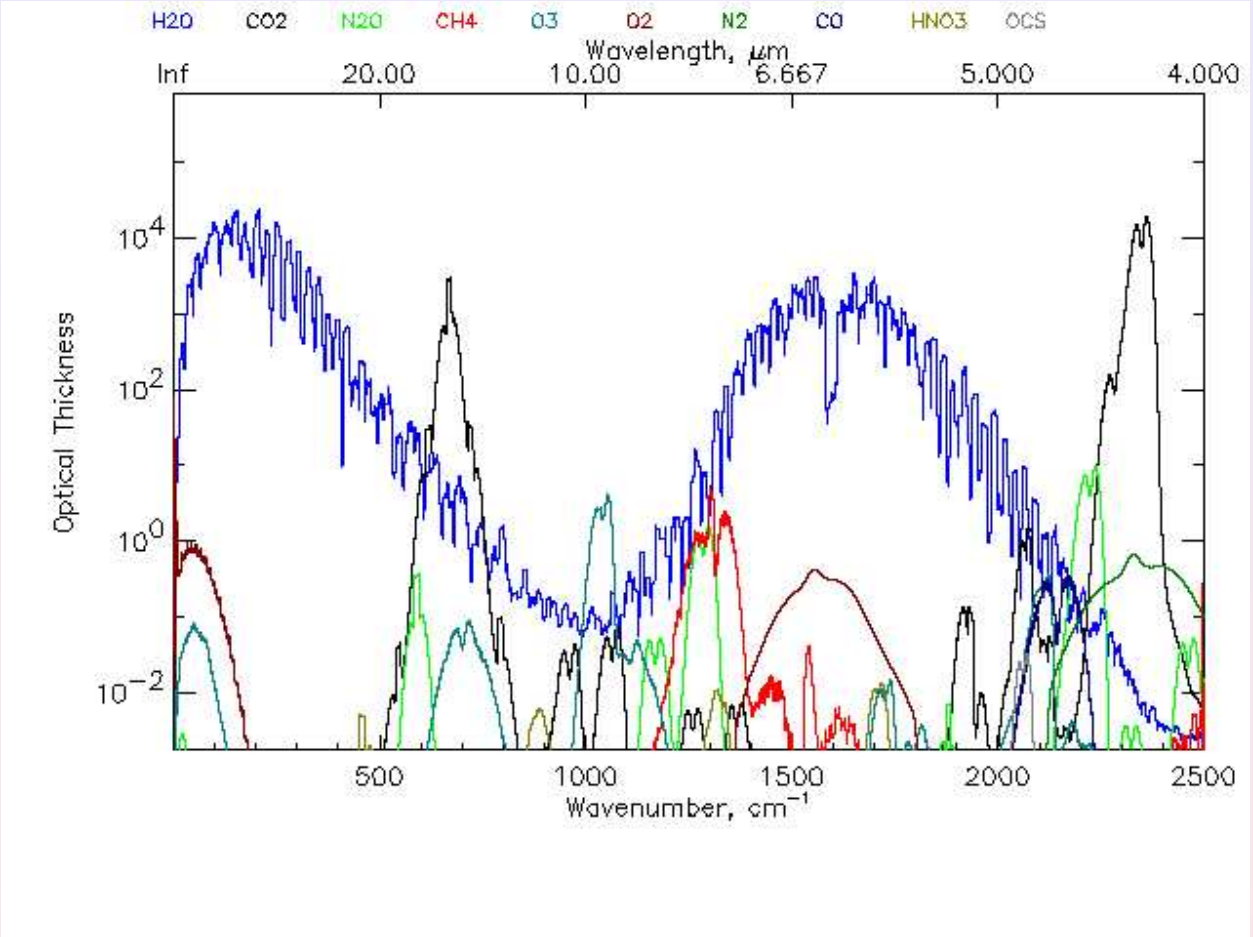


Figure: Atmospheric opacity

http://www-atm.physics.ox.ac.uk/group/mipas/

What?

Usual quantity is the Precipitable Water Vapour (PWV):

- amount of water vapour in the atmospheric column above the observatory
- equivalent to the amount of liquid precipitation that would result if all the water vapour in the column is condensed (in mm)

Why?

- in the NIR (L, M, also in K!): zero-point
- in the MIR:
  - sensitivity, conversion factor
  - passband dependent
  - observations of standard stars is time expensive
- in the sub-mm: *crucial* to correct variations of the path length in the atmosphere

How and when?
1/3: from above

- at ESO (Marc Sarazin, Andre Erasmus): `http://www.eso.org/gen-fac/pubs/astclim/forecast/meteo/ERASMUS/l_p_f0.html`
- based on
  - the Upper Tropospheric Humidity for the middle and upper troposphere (layer between 700 mb and 300 mb (approx. 3000 to 9500 m), determined from 6.7μm images
  - surface relative humidity value derived from the observations of surface relative humidity at the observatory in the 24 hours preceding the forecast
  - satellite images every 3 h + European Centre for Medium-Range Weather Forecasting model

How and when?
2/3: from below

- radiometers (APEX, ALMA):
  - measurement of a water emission line (e.g.: 183 GHz)
  - requires accurate atmospheric model (pressure, temperature)
  - high-accuracy ($\approx 10^{-6}$ mm)
  - real–time
  - *expensive*
- sky dips (e.g.: SCUBA)
  - simple
  - *expensive in execution time*
- absorption lines in stellar spectra (CRIRES SV, P24)
  - some lines are T-insensitive
  - *expensive in execution time*

How and when?
3/3: from below

- VISIR medium-resolution spectroscopy
  - 10 s exposure, 1 min execution
  - near real time
  - sufficient precision
  - requires decent atmospheric model (pressure, temperature)

PWV determination from VISIR spectra

- VISIR sky spectra (MR, 19.5μm (Q3), 0.4” slit) ;
- 10 s exposure time; $\approx$ 1 min execution time
- χ^2 fit using RFM, modifying the H2O concentration by a constant factor in each layer
- IDL interface (*H2Ocalc*) to RFM

RFM: Radiative Forward Model

- RFM: Line–by–line modeling Fortran code, developped by Anu Dudhia (Oxford) to analyse data from MIPAS on-board ENVISAT
- HITRAN database:
  - HITRAN'2004 Database (Version 12.0)
  - 1,734,469 spectral lines for 37 different molecules, including the atom O (singlet) and the ion NO+.
- Atmospheric profile:
  - Lower and upper altitudes of (possibly arbitrarily) layers (typically 50)
  - Mean pressure in each layer
  - Mean temperature in each layer
  - Concentration of H20, CO2, O3, etc... in each layer

Predicted spectra

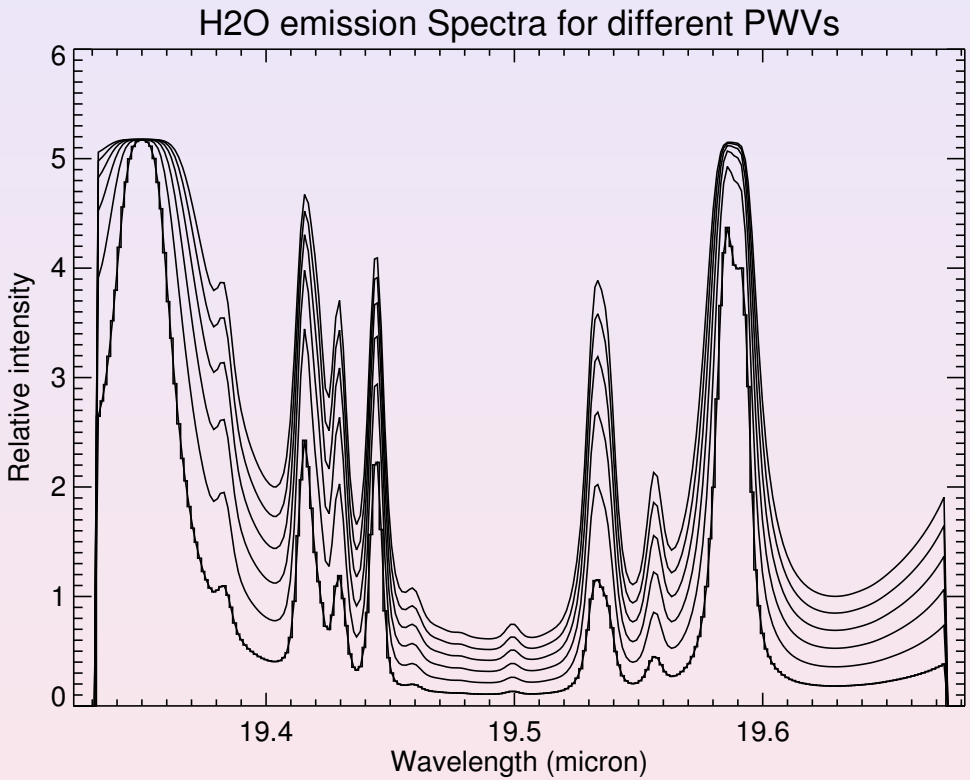


Figure: Predicted MR spectrum

Observed spectra

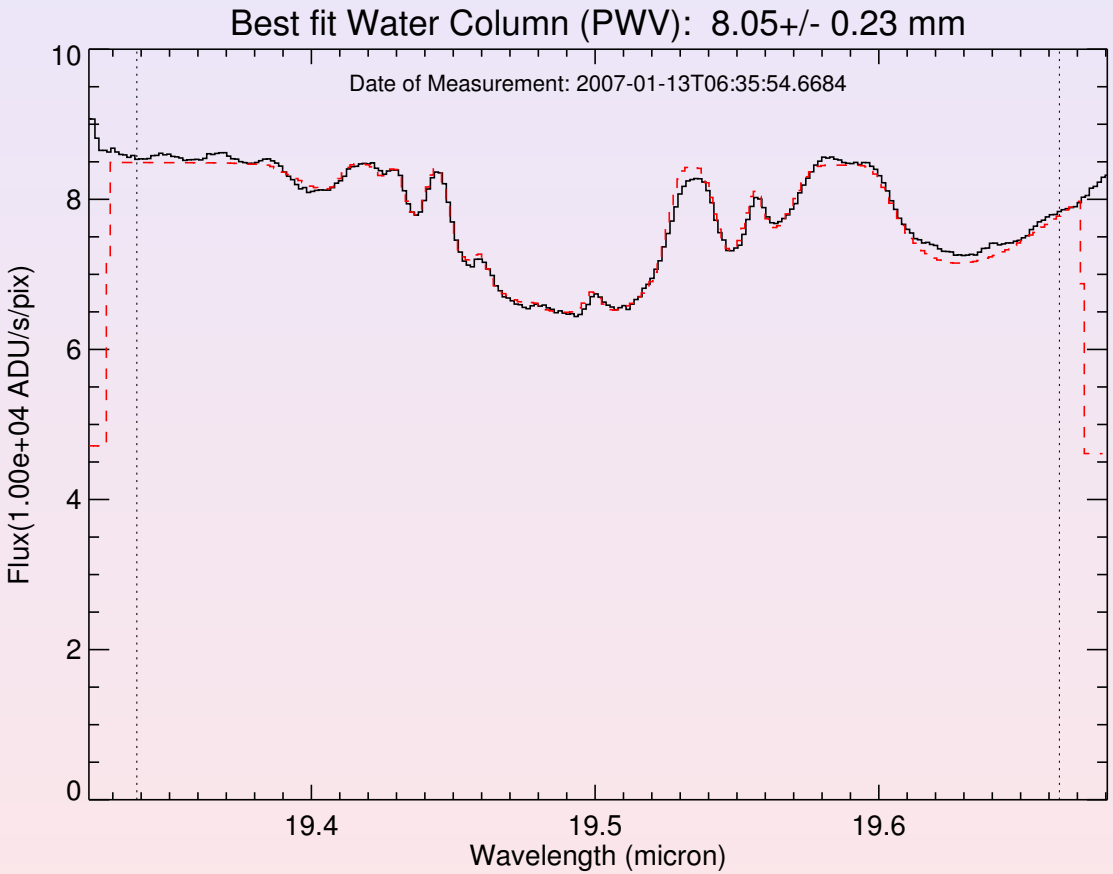


Figure: Examples of measured and fitted spectra

Observed spectra

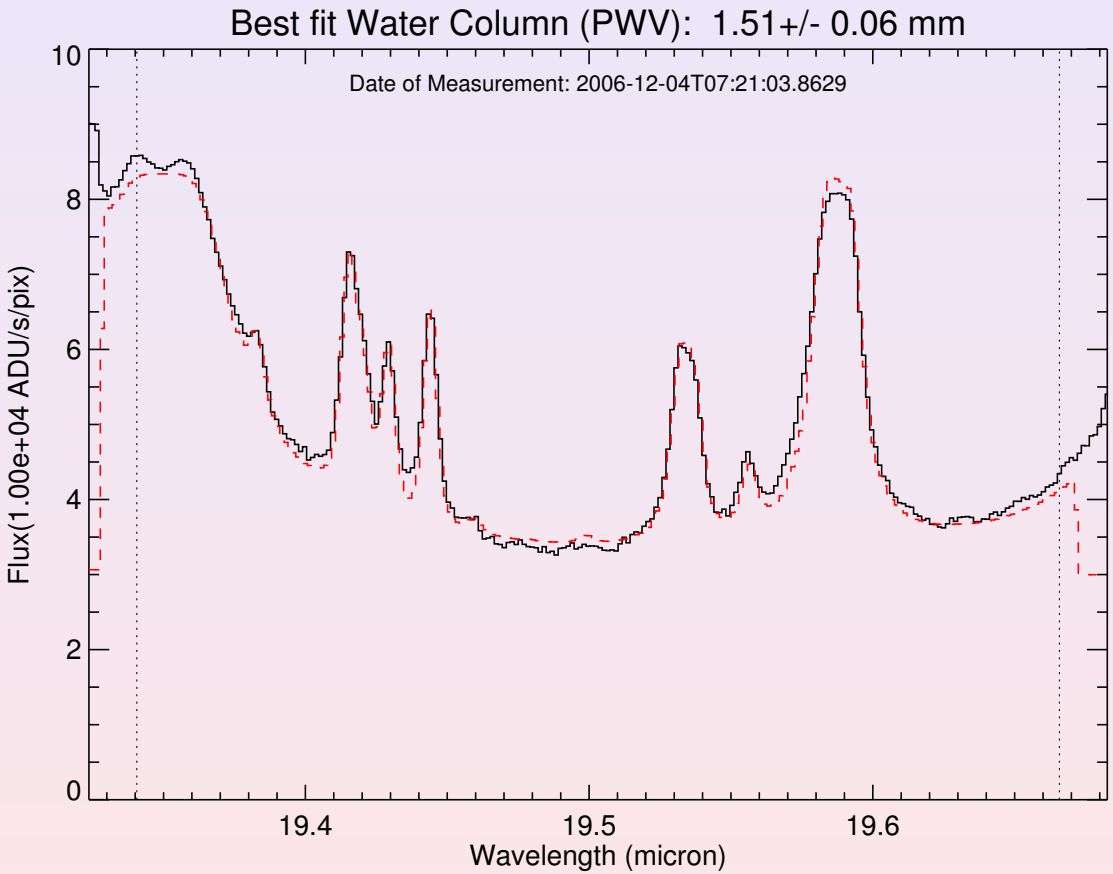


Figure: Examples of measured and fitted spectra

Observed spectra

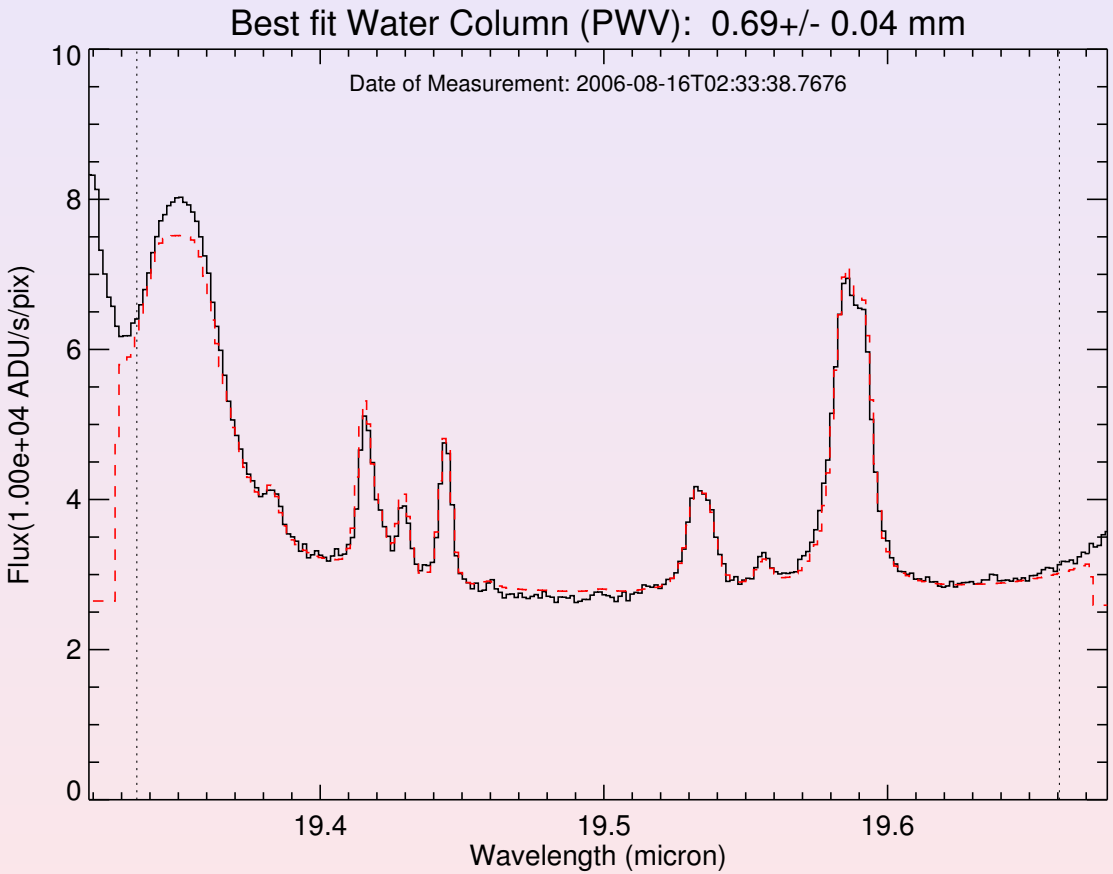


Figure: Examples of measured and fitted spectra

VISIR vs satellite

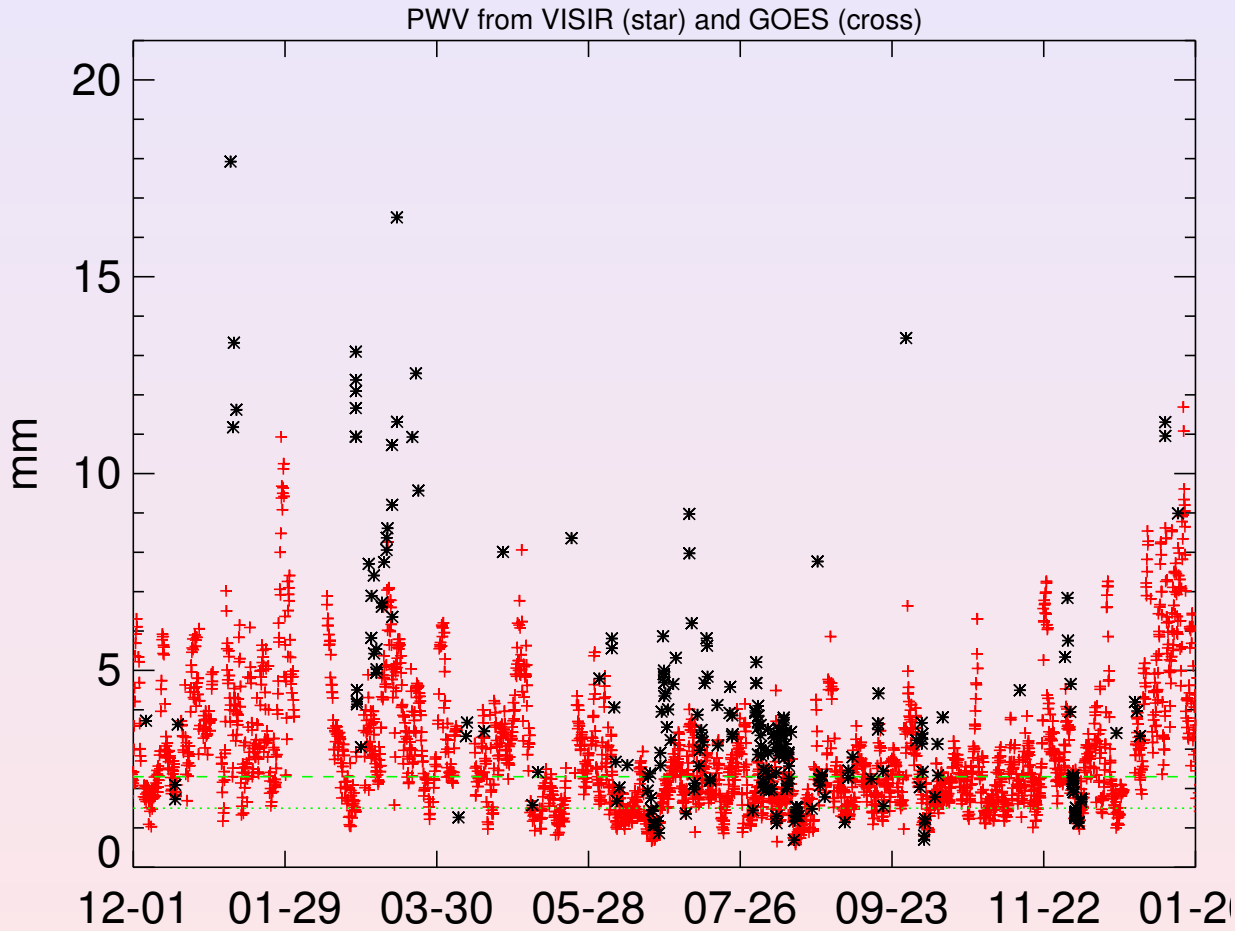


Figure: December 2005 – January 2007

VISIR vs satellite

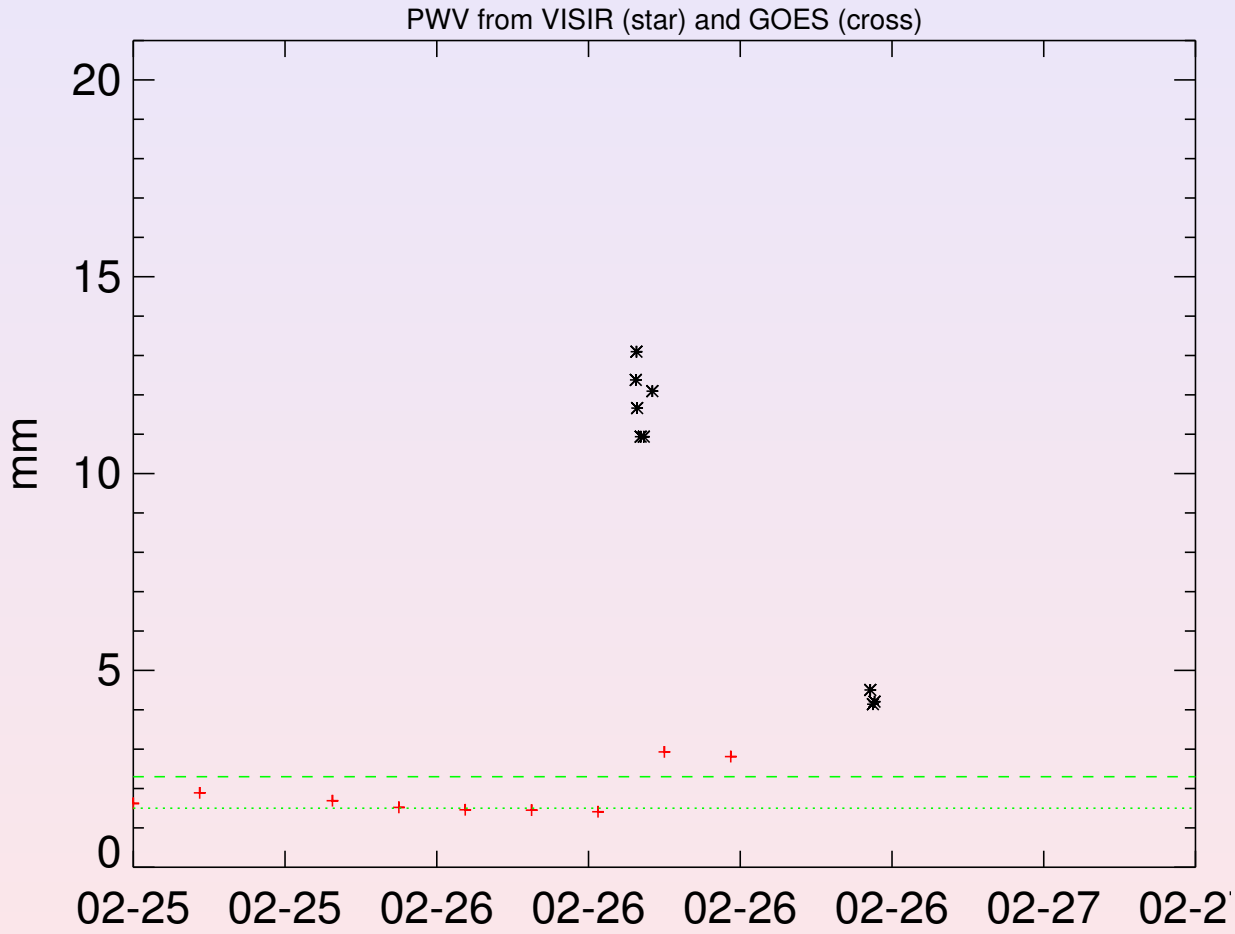


Figure: February 26, 2006

VISIR vs satellite

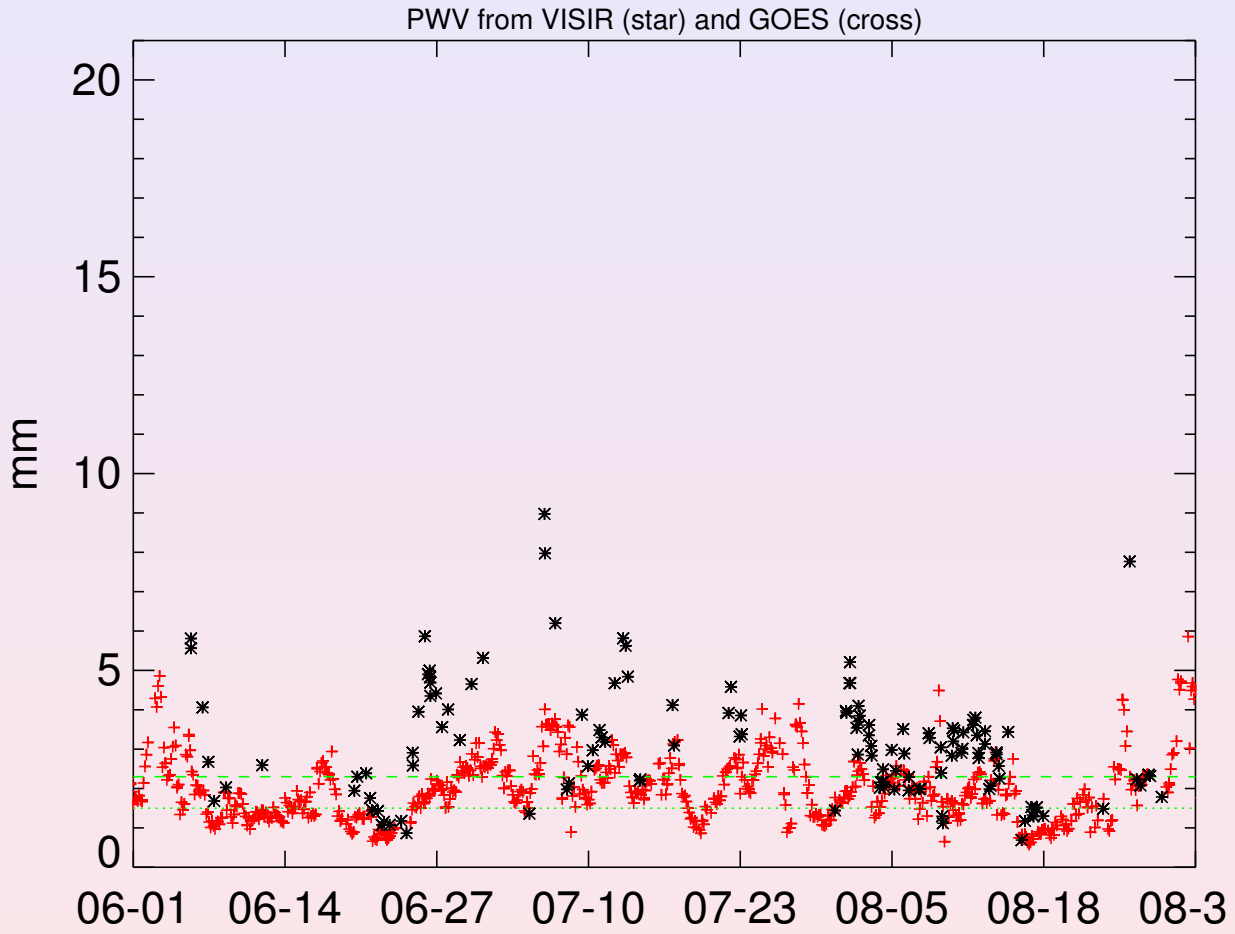


Figure: June 1 – August 31, 2006

Conversion Factor & Sensitivity

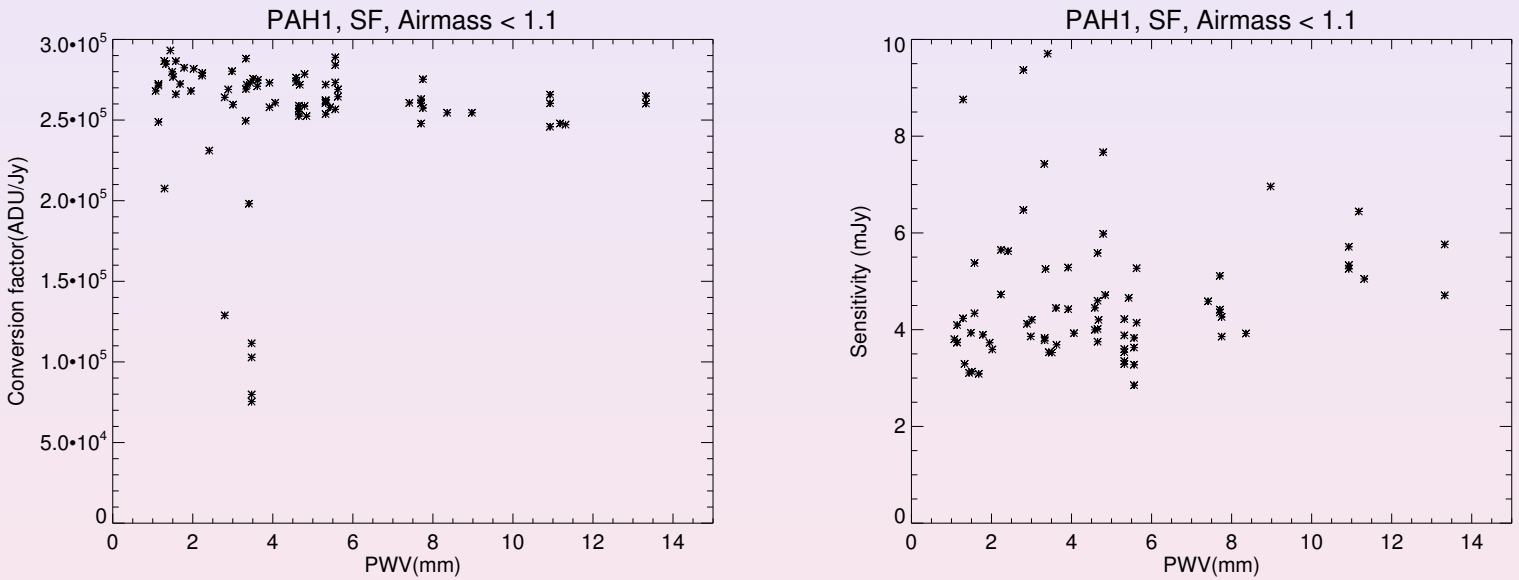
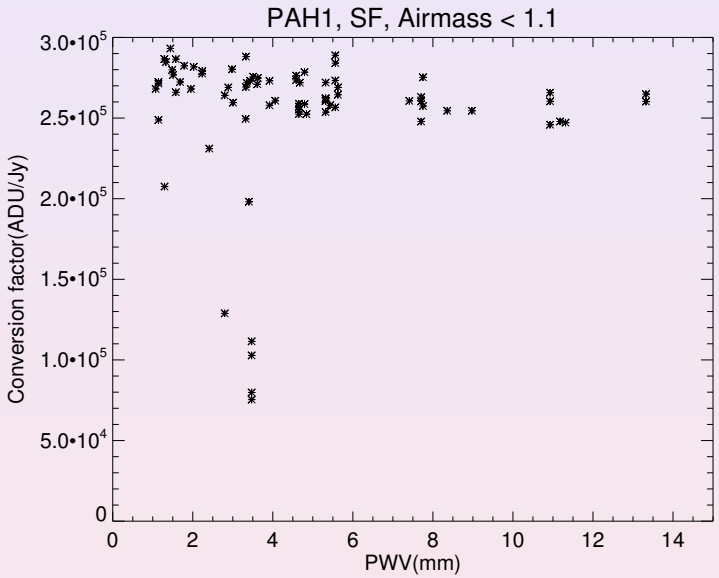


Figure: PAH1

Conversion Factor & Sensitivity



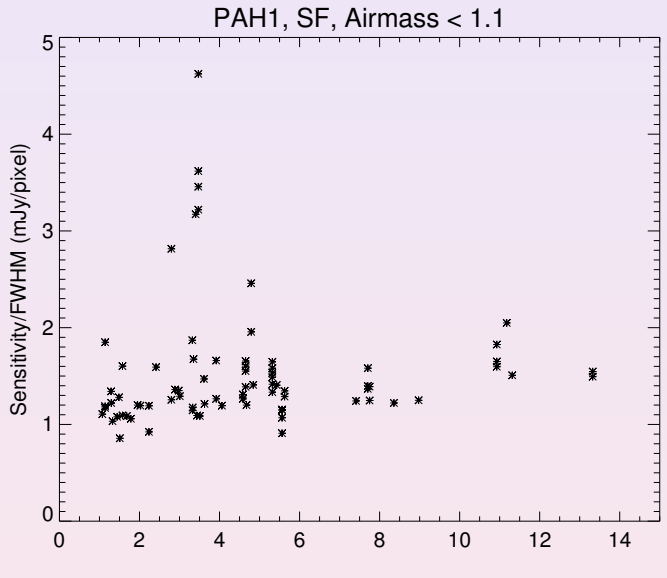
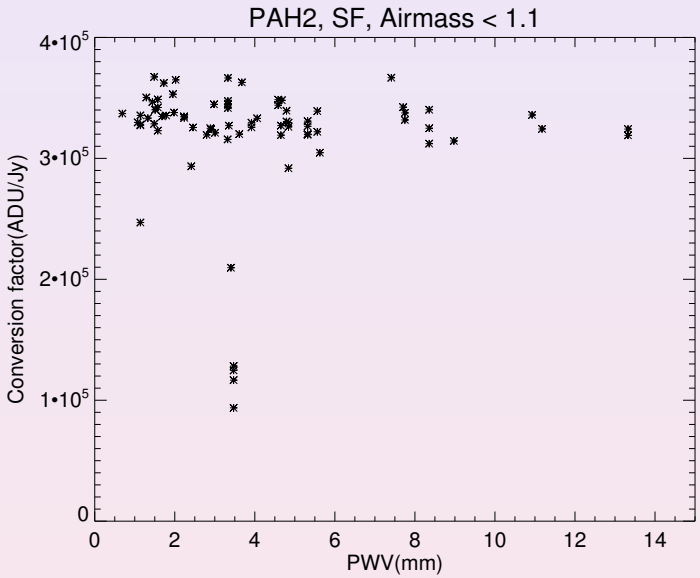


Figure: PAH1

Conversion Factor & Sensitivity



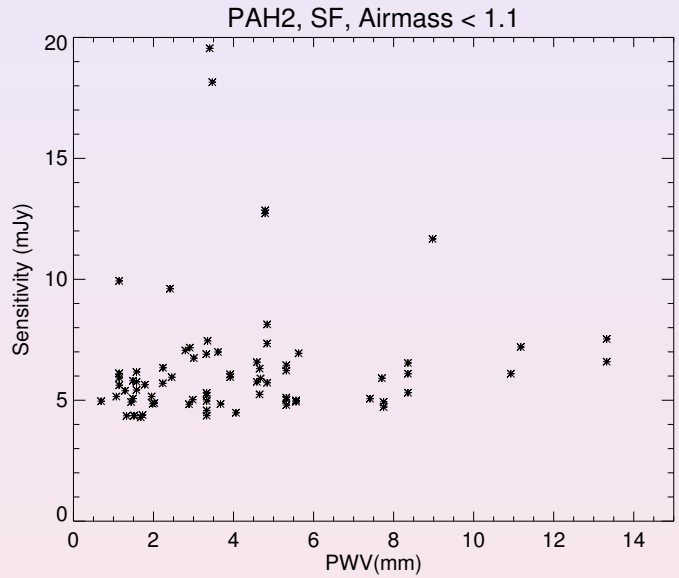
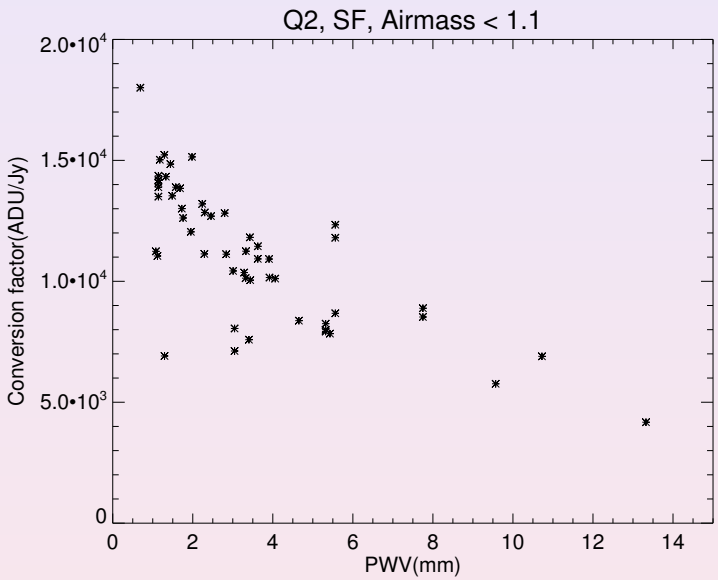


Figure: PAH2

Conversion Factor & Sensitivity



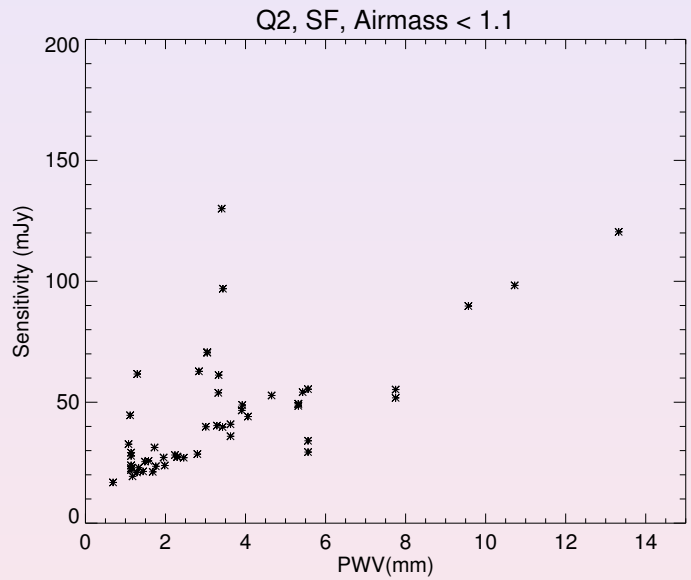


Figure: Q2

Conclusions

- Measuring the amount of PWV with VISIR is now easy
- Preferable than to rely on satellite data
- Allows to easily estimate its effect on the conversion factor and sensitivity with a reasonable accuracy
- Better accuracy could be achieved by using a more appropriate atmospheric profile
- User constraint? (spectroscopy?)
- Values should be available on the web
- Method to be tested with ISAAC, SINFONI, CRIRES spectra