

TIR and SWIR level-1 and level-2 products validation: a deeper insight to updates of the 4A line-by-line radiative transfer model

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The screenshot shows the website interface for Atmospheric Radiation Analysis (ARA) at LMD. It includes a navigation menu on the left with categories like Home, Site map, Research themes, Tools, Databases, and Publications. The main content area features a 'Research themes' section with icons for Clouds, Carbon cycle, Aerosols, and Surface properties. Below that is a 'Tools' section with icons for Forward RT (4Aop), Inverse RT (3T), Cal./Val., and Statistical. The 'Databases' section includes Spectroscopy (GEISA), TIGR, ARSA, and Archives. At the bottom, there are logos for partner institutions: CNRS, LMD, Institut Pierre Simon Laplace, ENS, UPMC Sorbonne Universités, CNES, and CNRS.



INTRODUCTION



- Radiative Transfer « Line by line», « layer by layer» : STRANSAC

➤ *Scott N.A.* 1974

- Radiative Transfer « Line by line», « layer by layer» : 4A

Based on Look-Up Table of optical thicknesses calculated by STRANSAC → 30/100 faster than STRANSAC

➤ *Scott et Chédin* 1981

➤ *Tournier et al., Chéruy et al. (Jacobians)* 1995

- 2001 : first operational version (CNES/NOVELTIS/LMD)

2018

- ✓ important release from the NIR to the TIR
- ✓ New reference paper for 4A/OP in preparation where a new analysis of the performances of the approach is done in the frame of the new space missions like IASI-NG

This presentation outlines

- ✓ Evaluation of the performance of 4A/OP methodology (atlases)
- ✓ Validation of 4A/OP (line shape, continua, emissivity, ...)



✓ Evaluation of the precision of 4A/OP versus nominal LBL Stransac



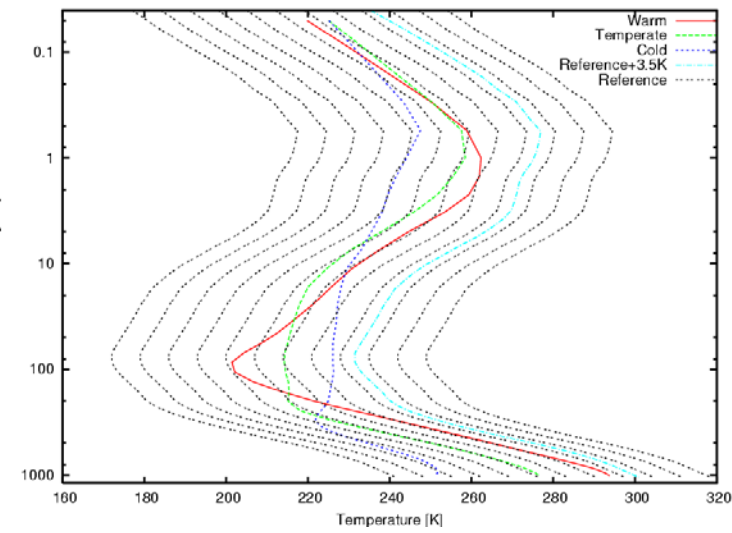
Atlas:

- ▶ Based on latest version of **GEISA-15** database:
 - up to **53** atmospheric molecular species
- ▶ **12** temperature profiles (7K distant);
- ▶ **44** pressure levels between surface and top of the atmosphere
- ▶ **5.10-4 cm-1** nominal spectral step;

4A :

- Interpolation (temperature) in the atlases
- Interpolation in pressure (44 levels to the user-defined levels)

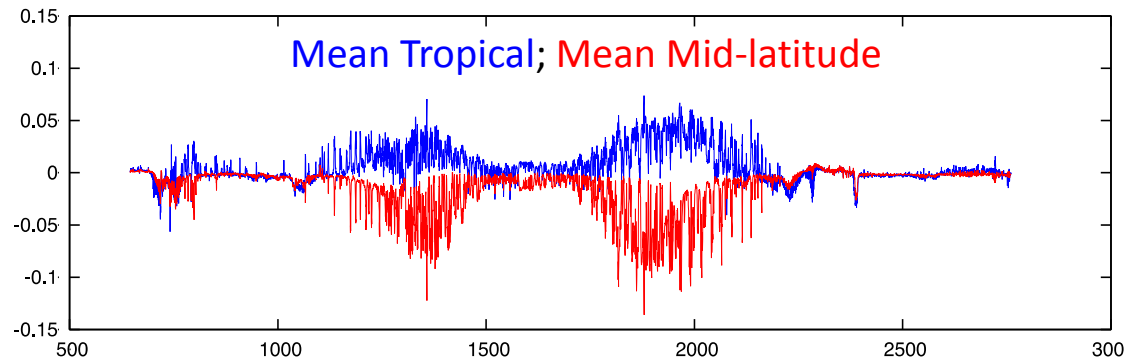
- Correction of the concentration: $\sigma_{\rho} = \sigma_{\rho_{ref}} * \rho / \rho_{ref}$



What is the precision of these interpolations ?

➔ Identification of the source of the differences between 4A/OP in and the LBL STRANSAC (atlases)

Difference 4A/OP vs STRANSAC





✓ Evaluation of the precision of 4A/OP versus nominal LBL Stransac



To quantify precisely the errors, the bias and the standard deviation are calculated using the TIGR database between different sets of atlases

Validation database



● Atlas:

- ▶ Generate different sets of atlases:
 - 12/21 temperature profiles (7K/3.5K distant);
 - 44/87 pressure levels between surface and top of the atmosphere
 - Different concentration profiles
- ▶ Study differences in brightness temperature between two different atlases with 4A/OP

The pressure interpolation not presented today (run in progress)

The Thermodynamic Initial Guess Retrieval (**TIGR**) data set, in its latest version, is a climatological library of **2311** representative atmospheric situations selected by statistical methods from 80,000 radiosonde reports (Chédin et al., 1985; Achard, 1991; Chevallier et al., 1998).

Each situation is described, from the surface to the top of the atmosphere, by the values of the temperature, water vapour and ozone concentrations on a given pressure grid.

Airmass	Atmospheres
Tropical	1 to 872
Mid-lat1	873 to 1260
Mid-lat2	1261 to 1614
Polar1	1615 to 1718
Polar2	1719 to 2311

Evaluation of the precision of atlases: the interpolation in temperature



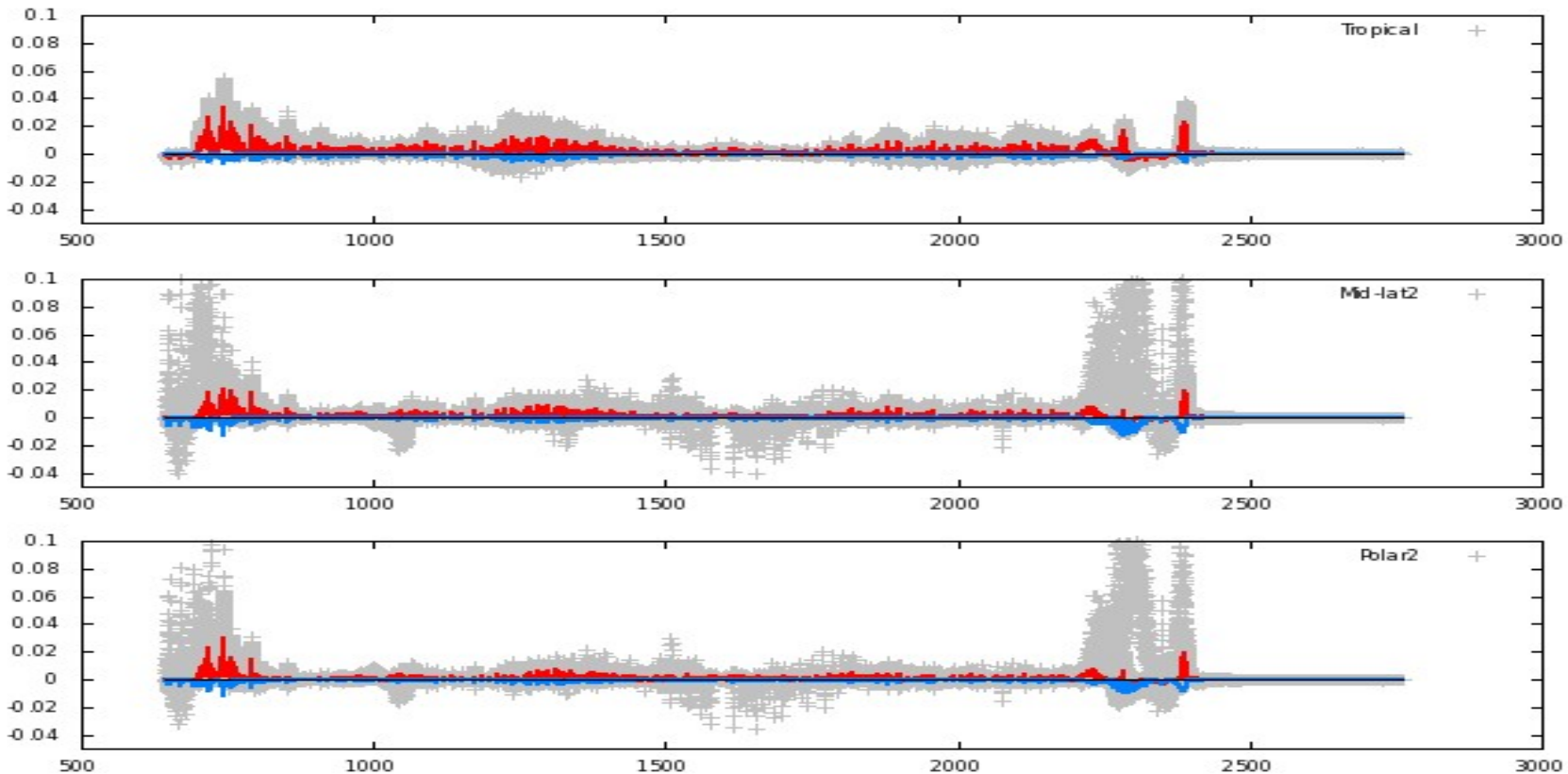
Atlas:

- ▶ Generate different sets of atlases:
 - 12/21 Temperature profiles
 - 3.5K/1.75K corresponding maximum temperature interpolation

Validation database



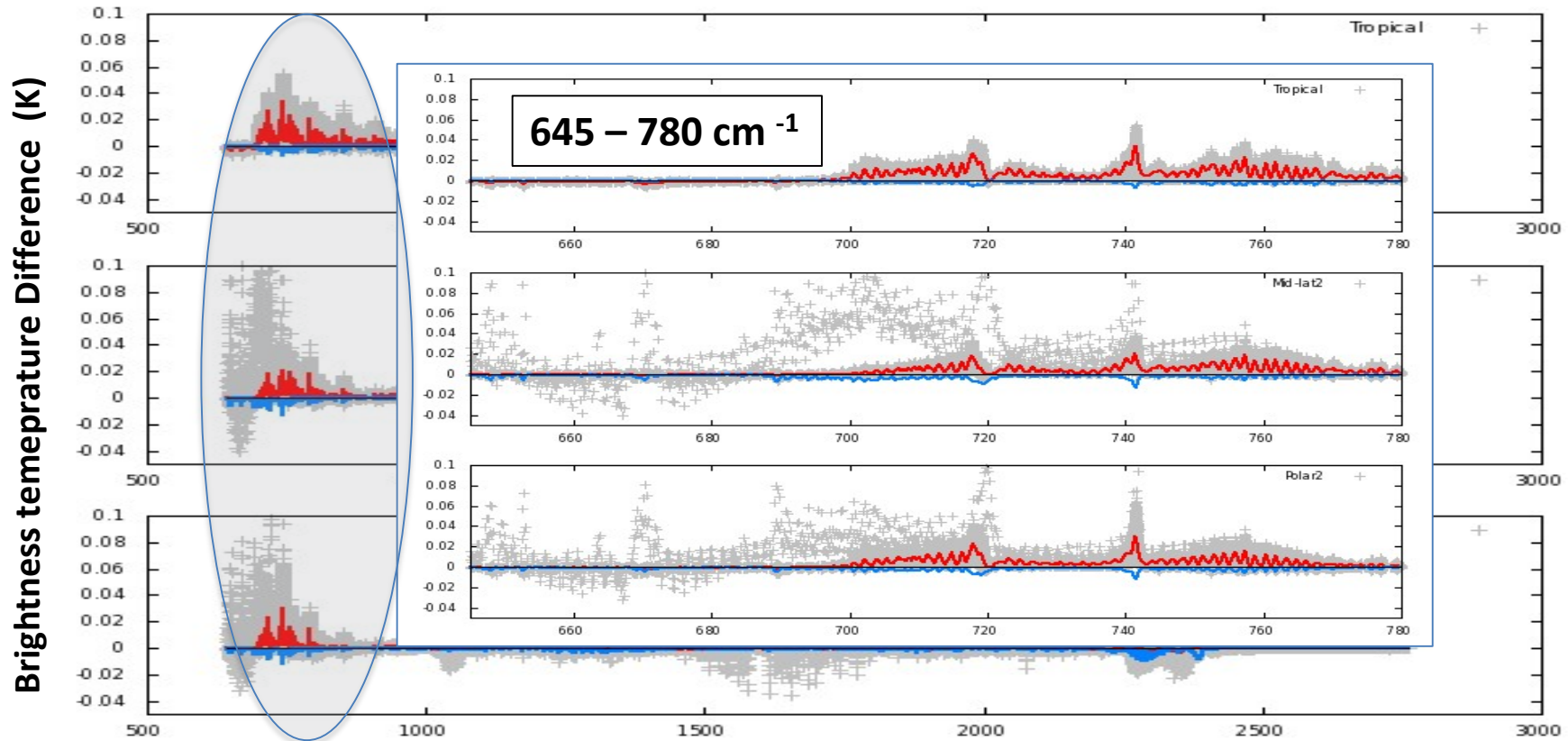
12 vs 21 Temperature profiles : bias Stdv(*-1) 2311 values



Evaluation of the precision of atlases: the interpolation in temperature



- 12 vs 21 Temperature profiles : bias Stdv*(-1) 2311 values



Conclusion

12 temperature profiles kept for 4A/OP-2018

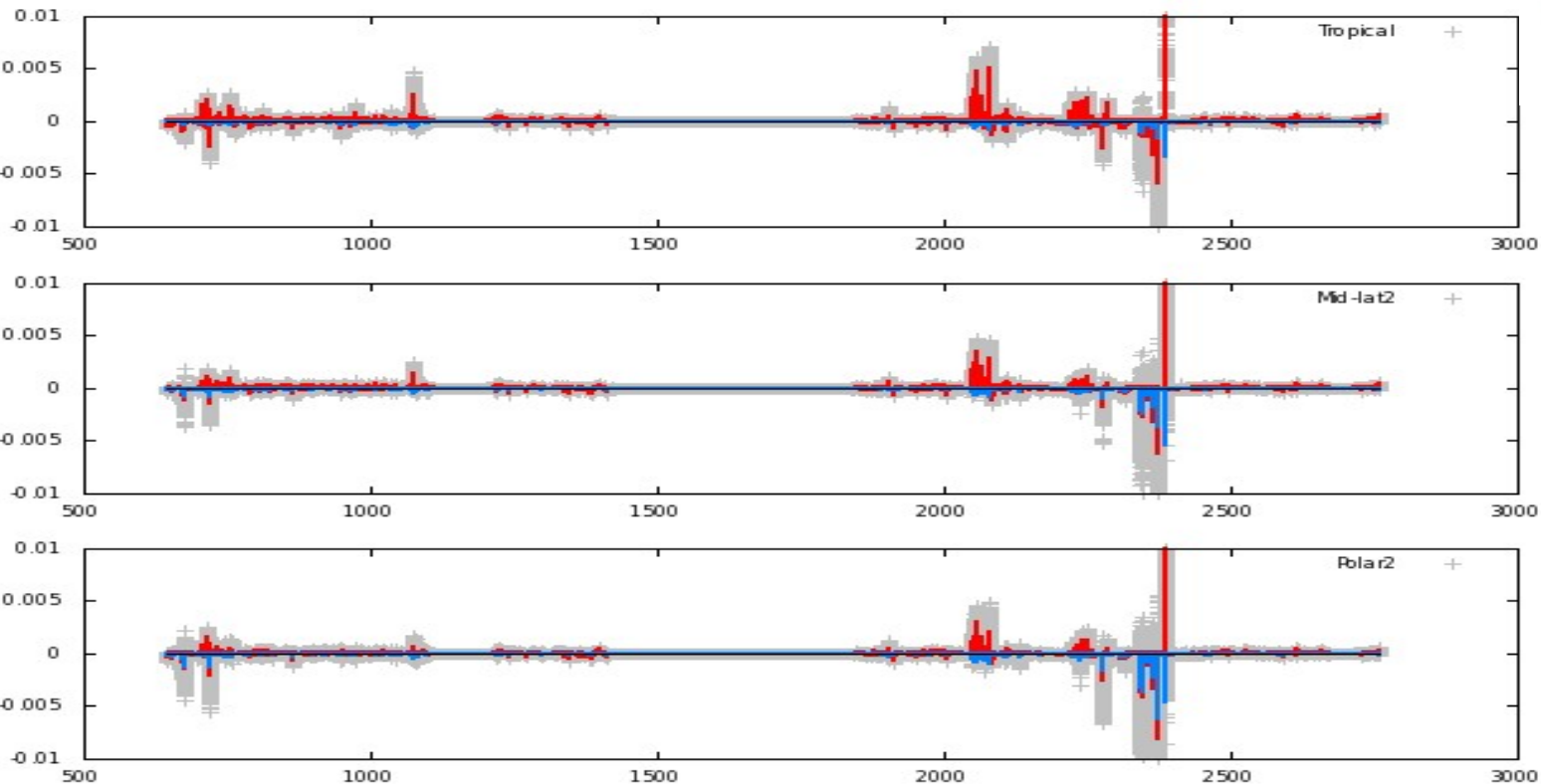
Evaluation of the precision of atlases: handling of the concentration



Atlas:

- ▶ No error in the concentration interpolation of the opt. Thi. : $\sigma_{\rho} = \sigma_{\rho_{\text{ref}}} * \rho / \rho_{\text{ref}}$
- ▶ Lorentz shape (foreign+self broadening) also has a concentration dependence
- ▶ for most of the molecule, the effect is negligible

○ Ex: CO₂ (330 ppmv) vs CO₂ (400ppmv) bias Stdv(*-1) 2311



Brightness temperature Difference (K)

Evaluation of the precision of atlases: handling of the concentration



Atlas:

- ▶ No error in the concentration interpolation of the opt. Thi. : $\sigma_{\rho} = \sigma_{\rho_{ref}} * \rho / \rho_{ref}$
- ▶ Lorentz shape (foreign+self broadening) also has a concentration dependence
- ▶ The most important effect for H₂O

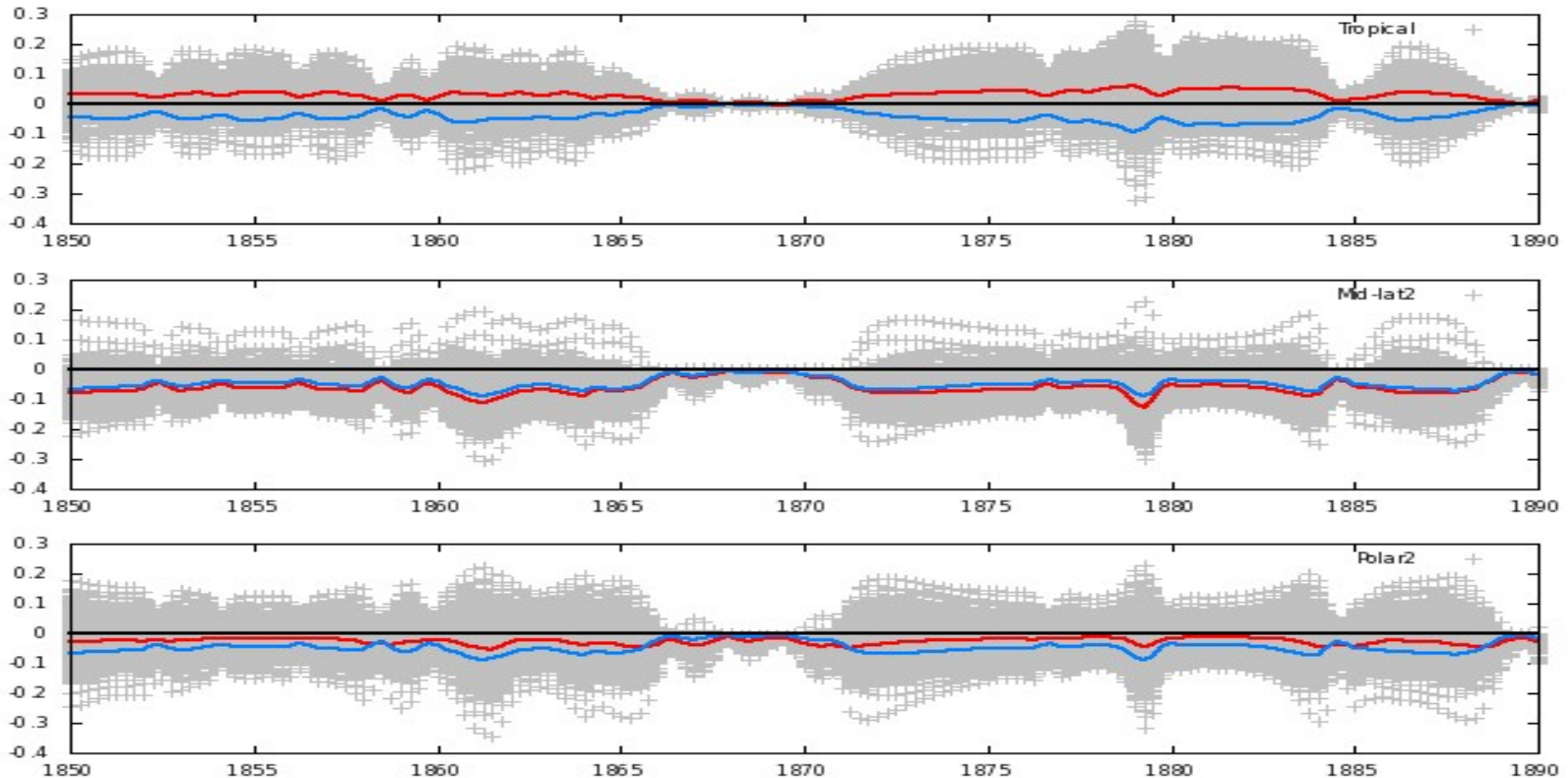
$\rho_{ref} \text{H}_2\text{O}$ vs $\rho_{ref} \text{H}_2\text{O} * 1.5$ (tropical)

$\rho_{ref} \text{H}_2\text{O}$ vs $\rho_{ref} \text{H}_2\text{O} * 0.5$ (polar)

bias Stdv(*-1) 2311 values



Brightness temperature Difference (K)



Zoom around 1870 cm⁻¹

Evaluation of the precision of atlases: handling of the concentration

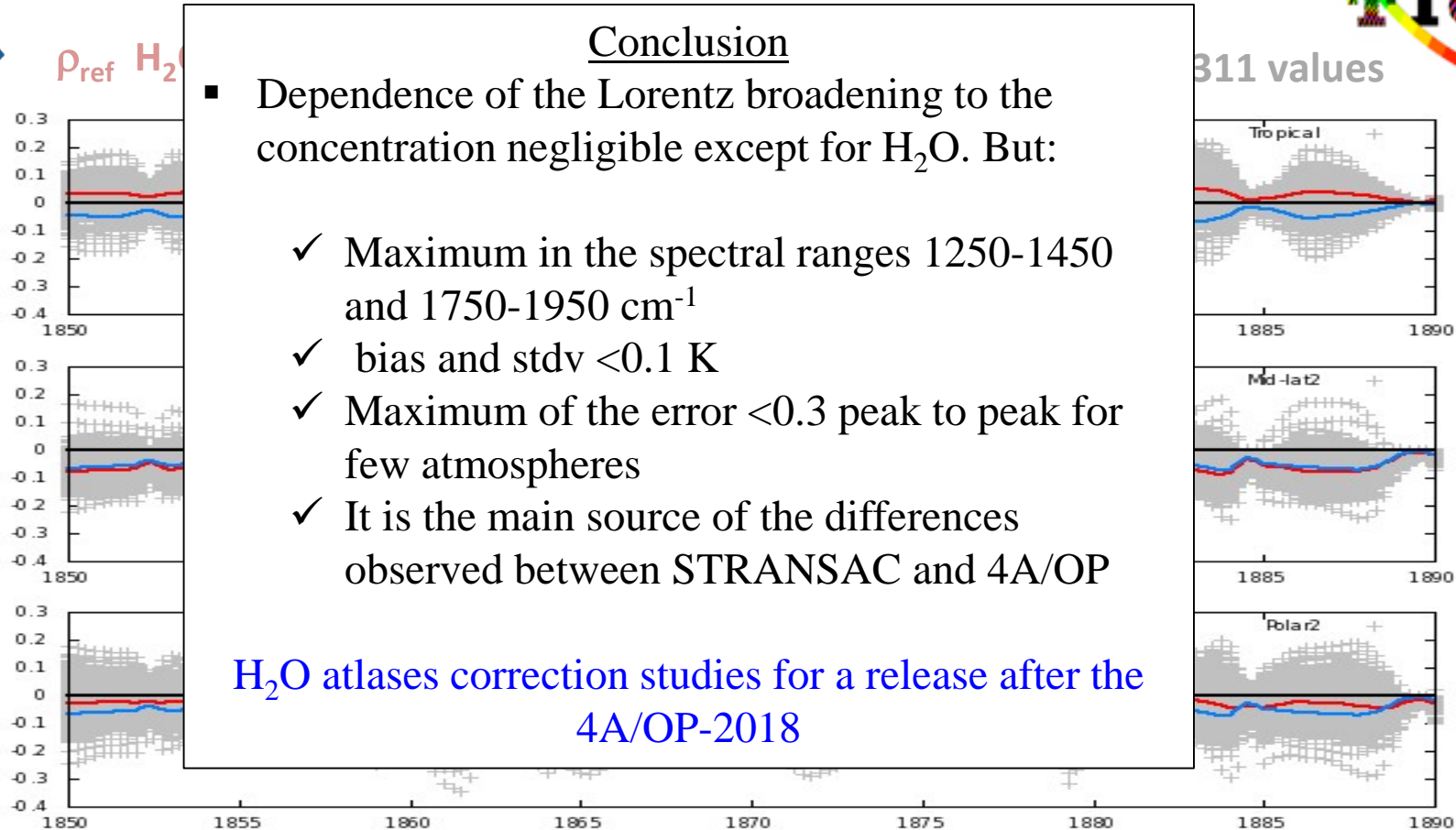


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- ▶ No error in the concentration interpolation of the opt. Thi. : $\sigma_{\rho} = \sigma_{\rho_{ref}} * \rho / \rho_{ref}$
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- ▶ The most important effect for H₂O



Brightness temperature Difference (K)



✓ Spectroscopic Parameters And Radiative Transfer Evaluation (SPARTE)



observations

IASI, TCCON

Clear-sky detection

Clear observed spectra

Spatio-temporal collocations

Description of the atmospheric situation

p6.05 Scott et al

Statistical analysis
(bias and standard deviation)

Differences
« calc-obs »

*Armante et al,
JMS, 2016*

Observed spectra

Simulated spectra

T, gas, surface

4A/OP



2011/2015



Spectroscopic databases

Instrumental parameters

p2.05 armante et al

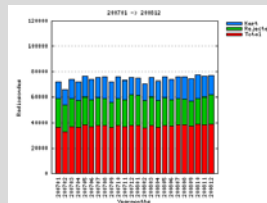
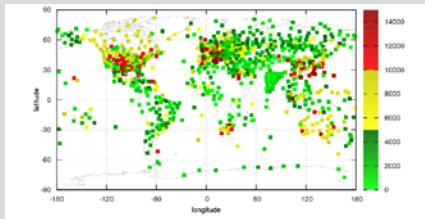
Validation database



A 43-level description of the atmosphere between surface and 0.0026 hPa including P, T, H₂O, Ozone profiles, surface temperature, Geolocation + date/time

ARSA starts in January 1979 and is extended onwards on a monthly basis @ LMD

So far: A total of > 5 million profiles from a total of ~22 millions considered



- ✓ Collocations ARSA/IASI-A Sea/night 2014/01 to 2014/12
- ✓ Revisited (2017) LMD Sea Surface Temperature determination
- ✓ Analysis of the Residuals (4A/OP - IASI obs. (K)) to evaluate the physics in 4A/OP

In parallel, a new intercomparisons between RTTOV-12 and 4AOP have been initiated

- ✓ Same IASI/ARSA collocations (2014)
- ✓ Same emissivity coming from IREMIS/RTTOV-12 (thanks to J. Vidot)
- ✓ Analysis of the residuals and link with the difference in the parametrization between RTTOV-12 and 4A/OP-2018 is in progress

<http://ara.abct.lmd.polytechnique.fr/index.php?page=arsa-database>

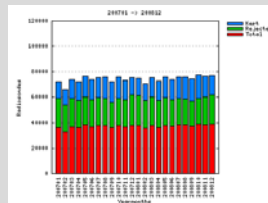
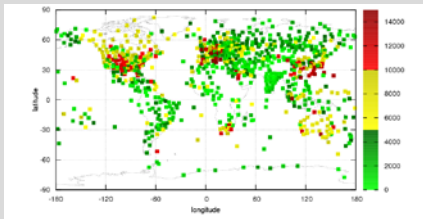
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Validation of the following point are in progress ...

- ✓ Line mixing CO₂,CH₄
- ✓ HNO₃ and CFCs
- ✓ Solar contribution
- ✓ NLTE
- ✓ Concentration profiles of GHG
- ✓ Evaluation of GEISA-2018

- ✓ Emissivity
- ✓ Continuum : N₂, O₂, H₂O
- ✓ ...

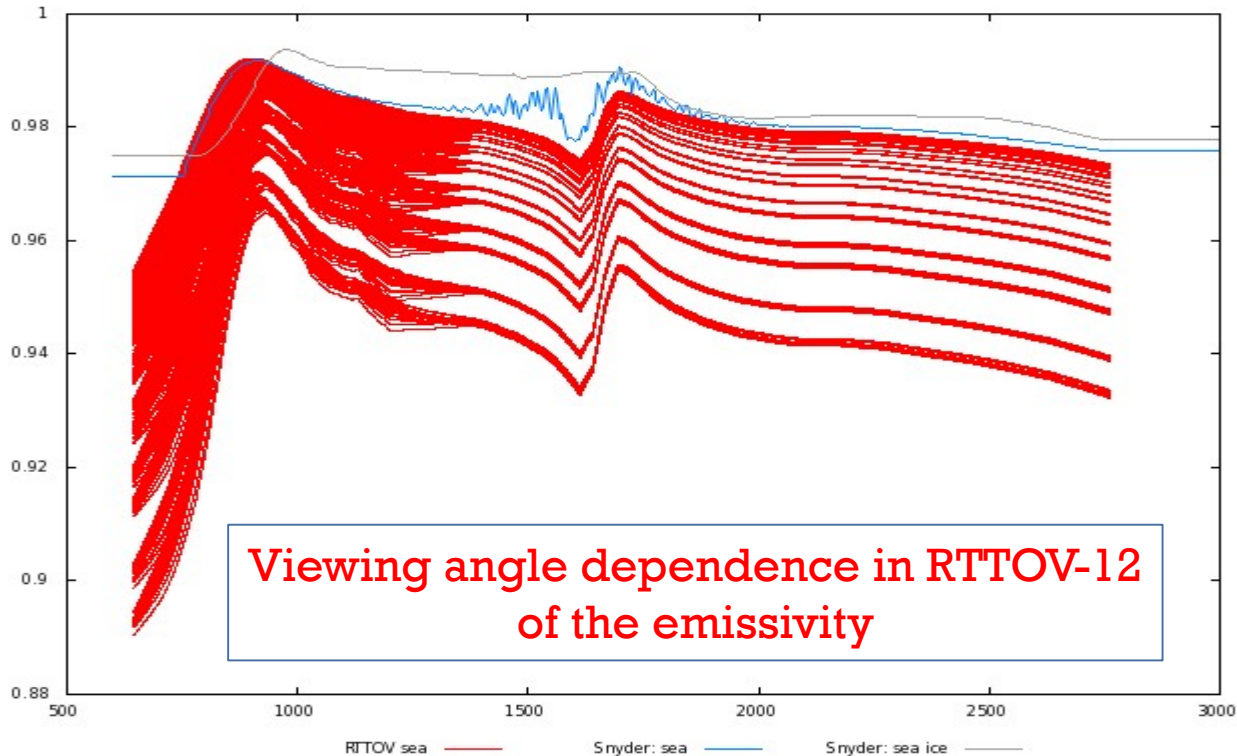


Emissivities in 4A/OP

Sea case



- 4A/OP emissivity
 - Snyder
 - Emissivity extracted from RTTOV-12 for each profile (variability due to the viewing angle)



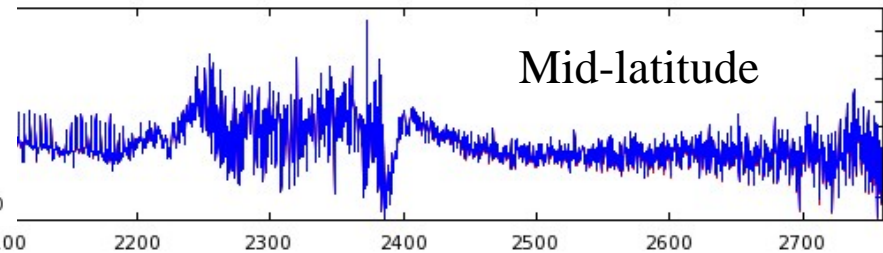
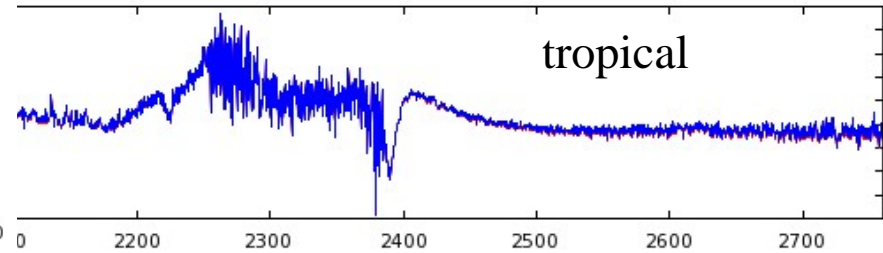
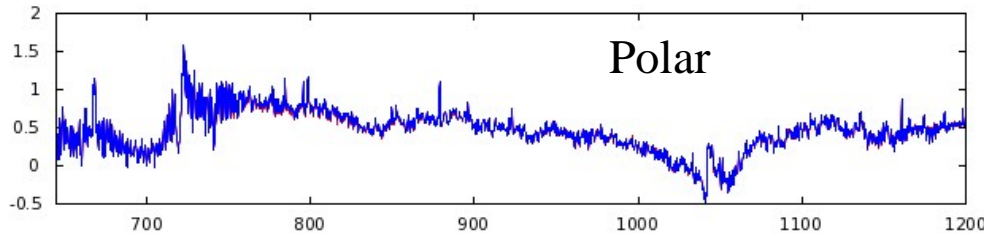
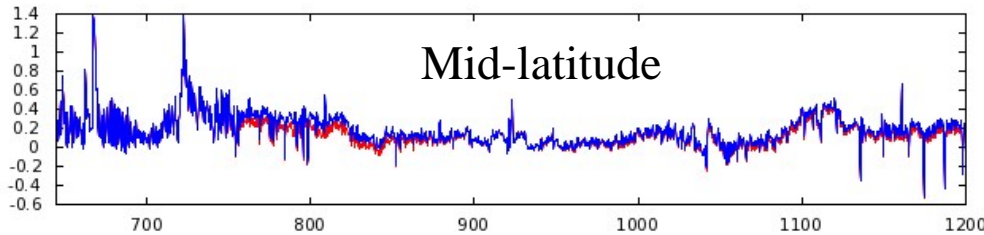
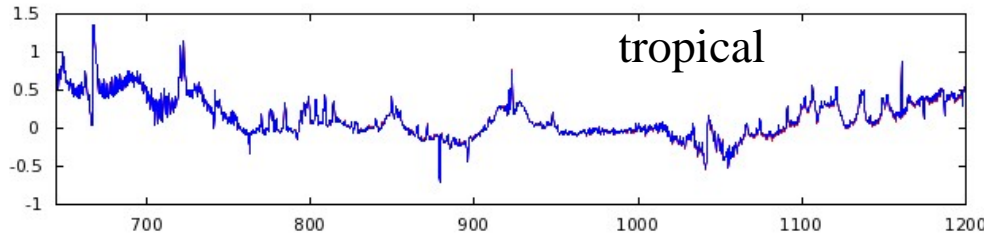
Emissivities in 4A/OP

sea

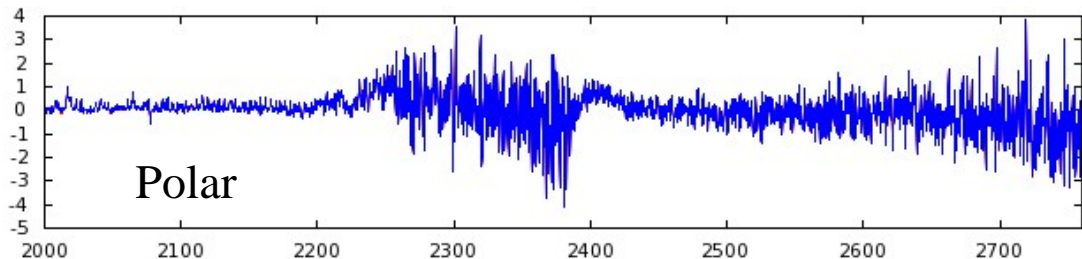


- Comparison (RTTOV-12) and Snyder (4A/OP) for 2014
 - ✓ Over sea ice, use Snyder sea ice emissivity rather than RTTOV ones

Snyder (4A/OP) vs (RTTOV-12)
emissivities
residuals for nadir angles



RTTOV-12 nadir emissivity close to Snyder

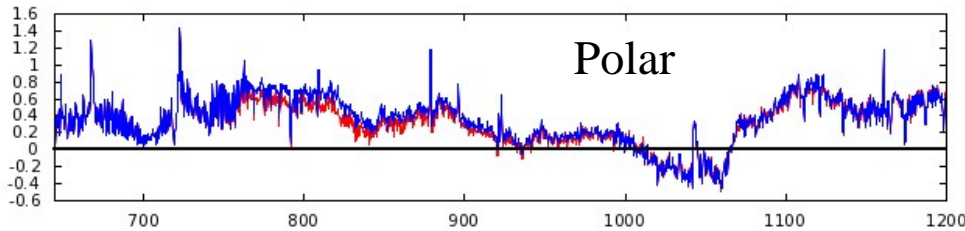
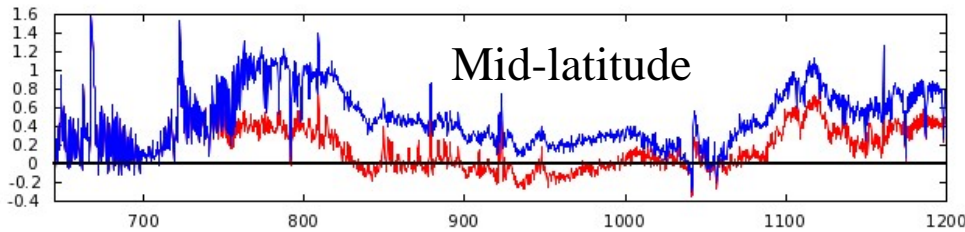
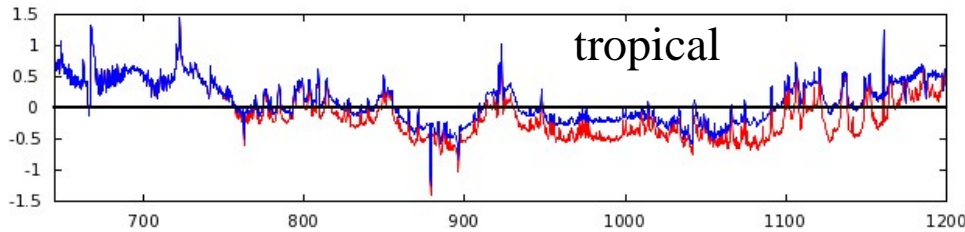


Emissivities in 4A/OP

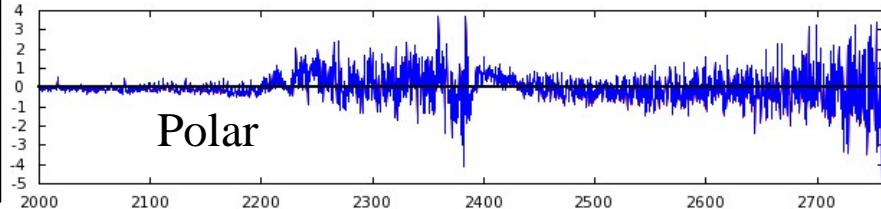
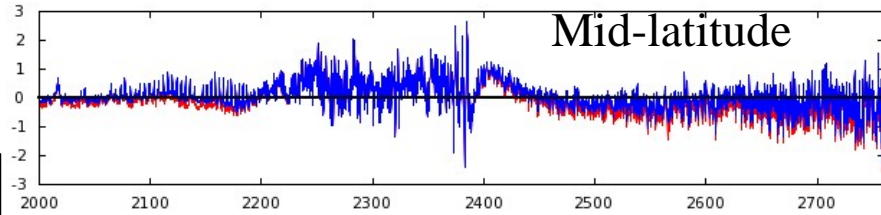
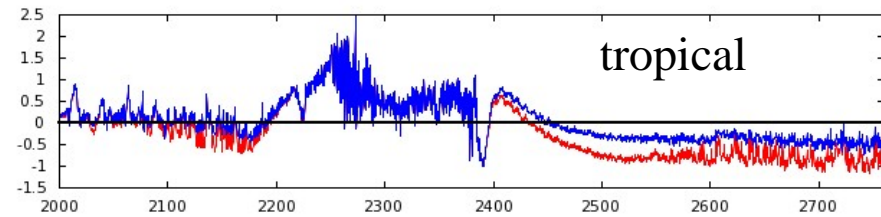
sea



- Comparison (RTTOV-12) and Snyder (4A/OP) for 2014
 - ✓ Over sea ice, use Snyder sea ice emissivity rather than RTTOV ones



Snyder (4A/OP) vs (RTTOV-12)
emissivities
residuals for angles $> 50^\circ$



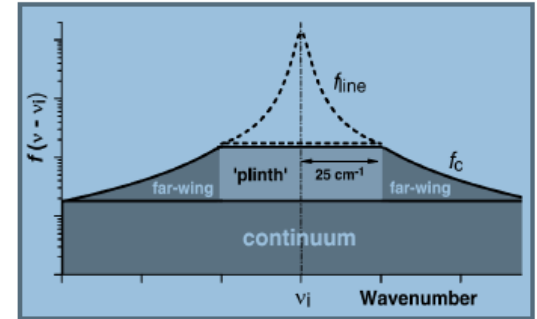
✓ **RTTOV-12** emissivities have a good angular dependency in most of the IASI spectra, except in the B3 where the angular dependency seems to be too important
→ angular dependency introduced in 4A/OP

Validation of 4A/OP H₂O continuum status



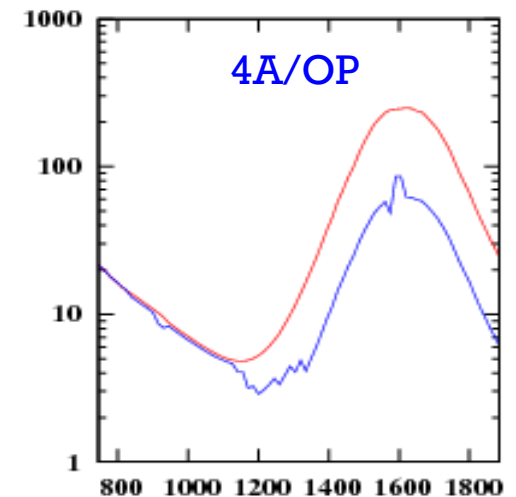
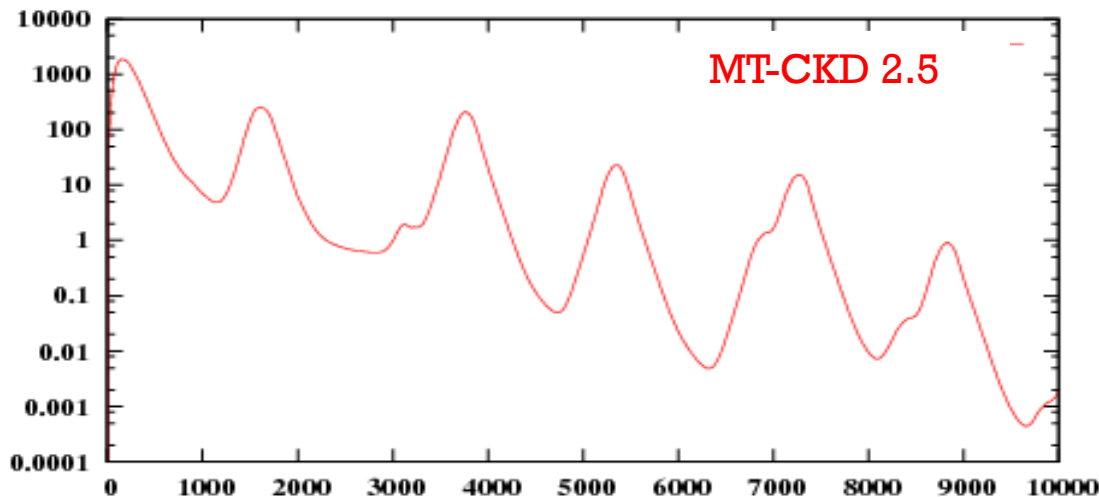
■ H₂O:

- MT CKD2.5, Mlawer, E. J. et al (2012), absorption, Philosophical Transactions of the Royal Society
- Far wing's cut-off in 4A/OP is a function of the Half-Width and Half Maximum (3000 * HWHM of each line in the current version of the atlases)



from, Ptashnik et al 2011

- MT CKD2.5 adjusted to take into account the difference between 25 cm⁻¹(original cut-off) and 3000 HWHM (used in 4A/OP)





Validation of 4A/OP H₂O continuum status

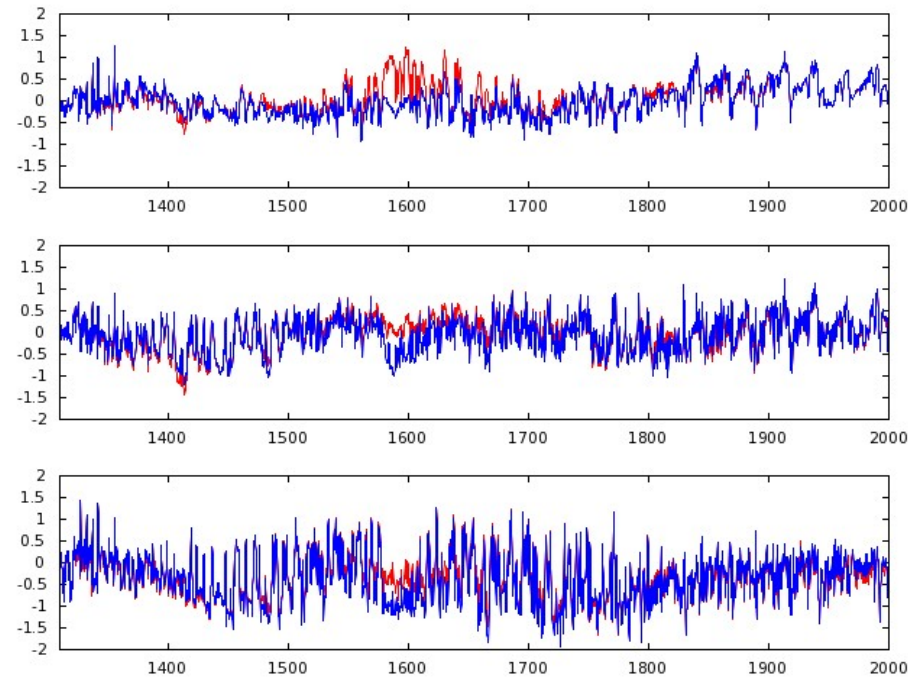
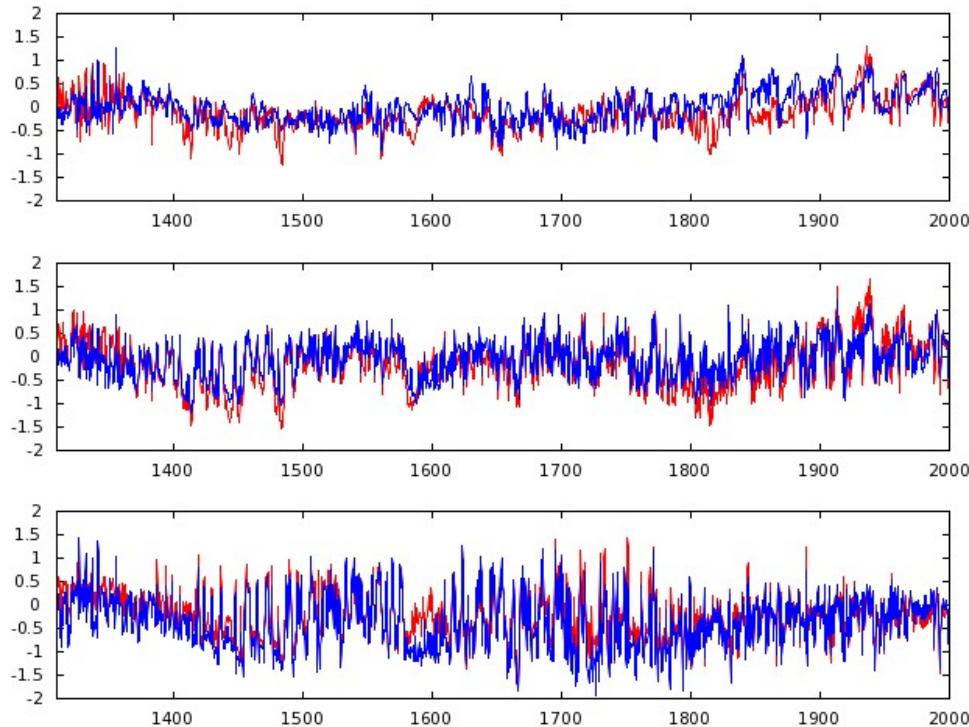


- MT CKD2.5 (RTTOV-12), Mlawer, E. J. et al, *Phil. Trans. Roy. Soc. A*, 370, 1-37, 2012.
- CAVIAR: <http://www.met.reading.ac.uk/caviar/home/>
- 4A/OP : MT CKD2.5 fitted

In 4A/OP same fit done for CAVIAR as it has been done for MT-CKD

RTTOV-12 vs 4A/OP (MT CKD 2.5)

4A/OP (CAVIAR) vs 4A/OP (MT CKD 2.5)



In progress : Studies of the Self, foreign, temperature dependence impacts of the various formulations to explain the residuals

Validation of 4A/OP H₂O continuum status



Important differences between CAVIAR and the other datasets

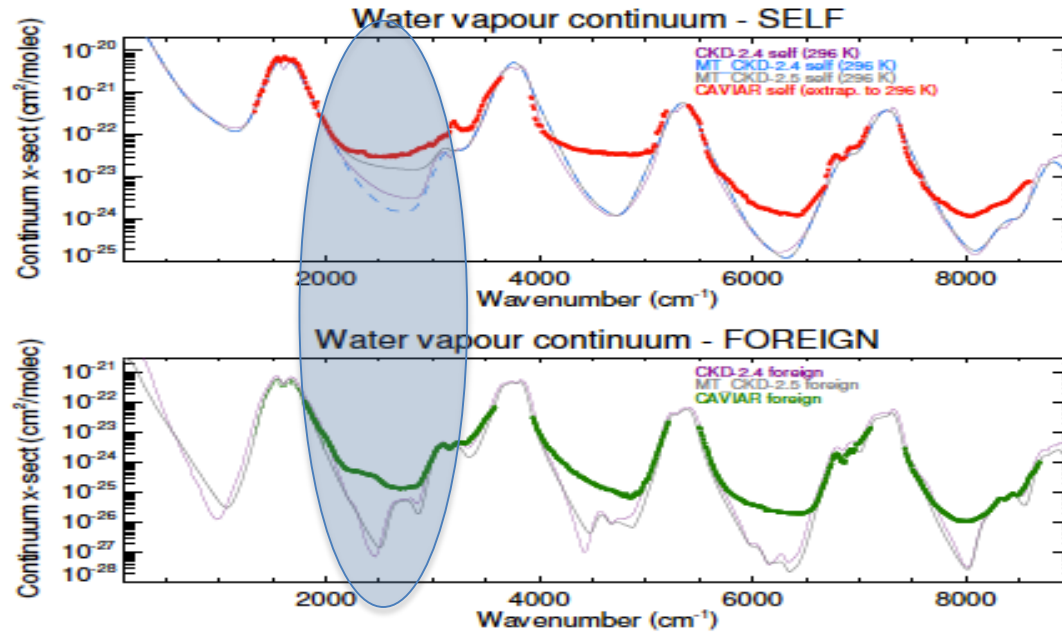
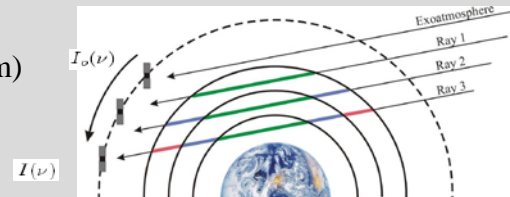


Figure from ITWG
summary report
(S. Newman)



- ACE-FTS instrument : Fourier Transform Interferometer
(Canadian SCISAT satellite)
- Transmission (14 μm - 2.5 μm)
- Spectral resolution: 0.02 cm^{-1}
- vertical resolution ~ 1 km.



Use of ACE/FTS and 4A/OP limb to evaluate different continuum datasets

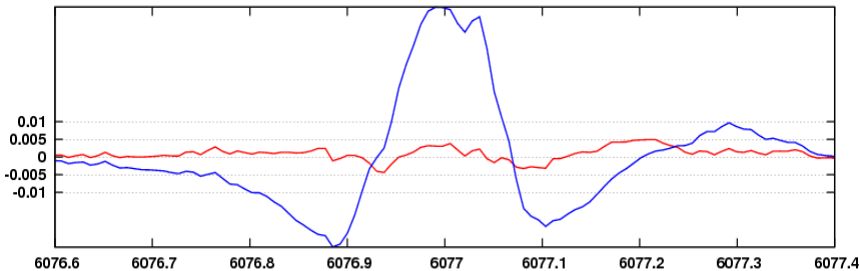
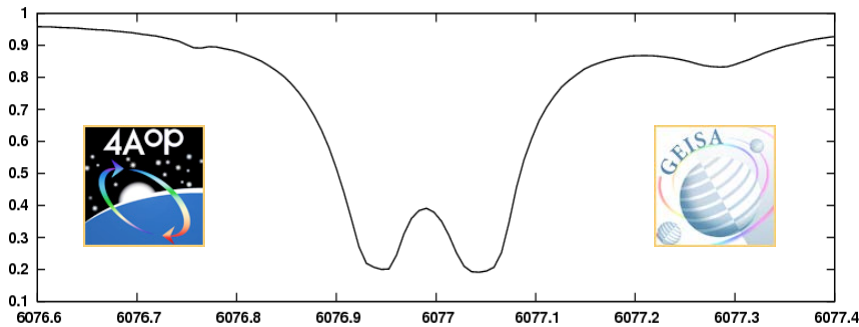
MT CKD 2.5 and 3.2 (new release), CAVIAR, Mondelain (JGR, 2016, new measurement at 3007 cm^{-1} (paper in preparation))



CONCLUSION



- 4A = **A**utomatized **A**tmospheric **A**bsorption **A**tlas
 - New 4A/OP paper in preparation and a New release available in 2018
 - Continue the intercomparisons between RTTOV-12 and 4A/OP-2018
 - 4A/OP involved in new space missions (IASI-NG, Microcarb, MERLIN, ...) including the L2 processing
 - High quality of the modeling except for the dependence of the lorentzian broadening with the concentration that have to be introduced just for H₂O:
 - ➔ but the error is small (bias and stdv < 0.1)



4A/OP vs TCCON : GEISA-2015 + Voigt — red line
 4A/OP vs TCCON : GEISA-2015 + LISA modelina (version Mar 2016) — blue line

To be convinced of the precision of 4A/OP in the simulation...

MERLIN : 4AOP-2018 will be the RTM used for the determination of XCH₄ in the ground segment of MERLIN

Atlas 4A/OP : GEISA-2015 + Voigt
 Atlas 4A/OP : GEISA-2015 + line mixing

- ✓ Current precision 0.35 %
- ✓ Mission requirements: 0.20 % (challenging)