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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NOVELTIS

cnes
De l'Espace pour la Terre

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)

<u>2018</u>

✓ 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

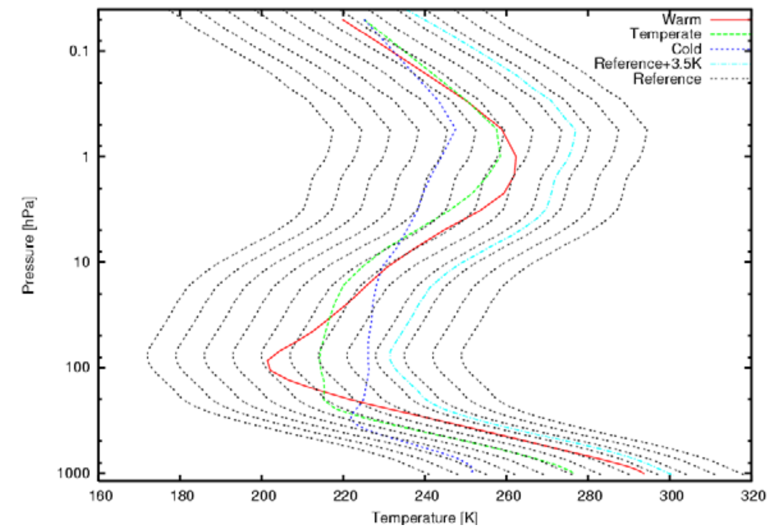
This presentation outlines

✓ Evaluation of the performance of 4A/OP methodology (atlases)

✓ Validation of 4A/OP (line shape, <u>continua</u>, <u>emissivity</u>, …)

✓ 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;



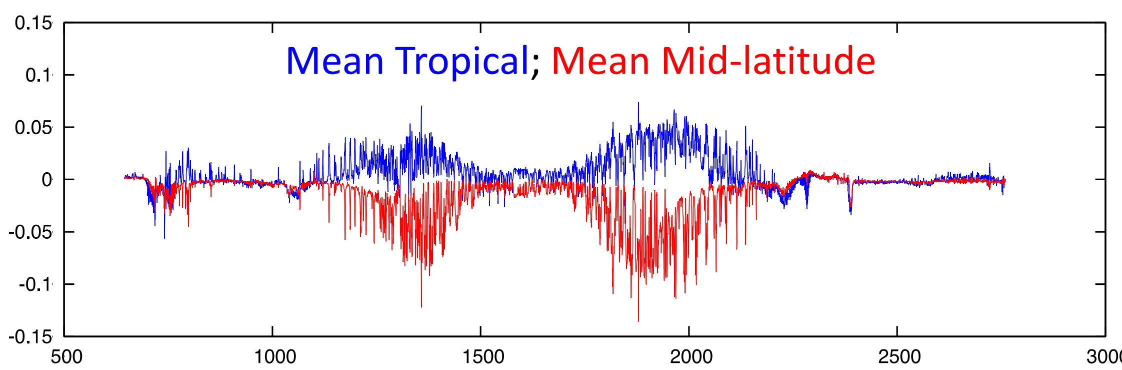
- 4A :

- 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

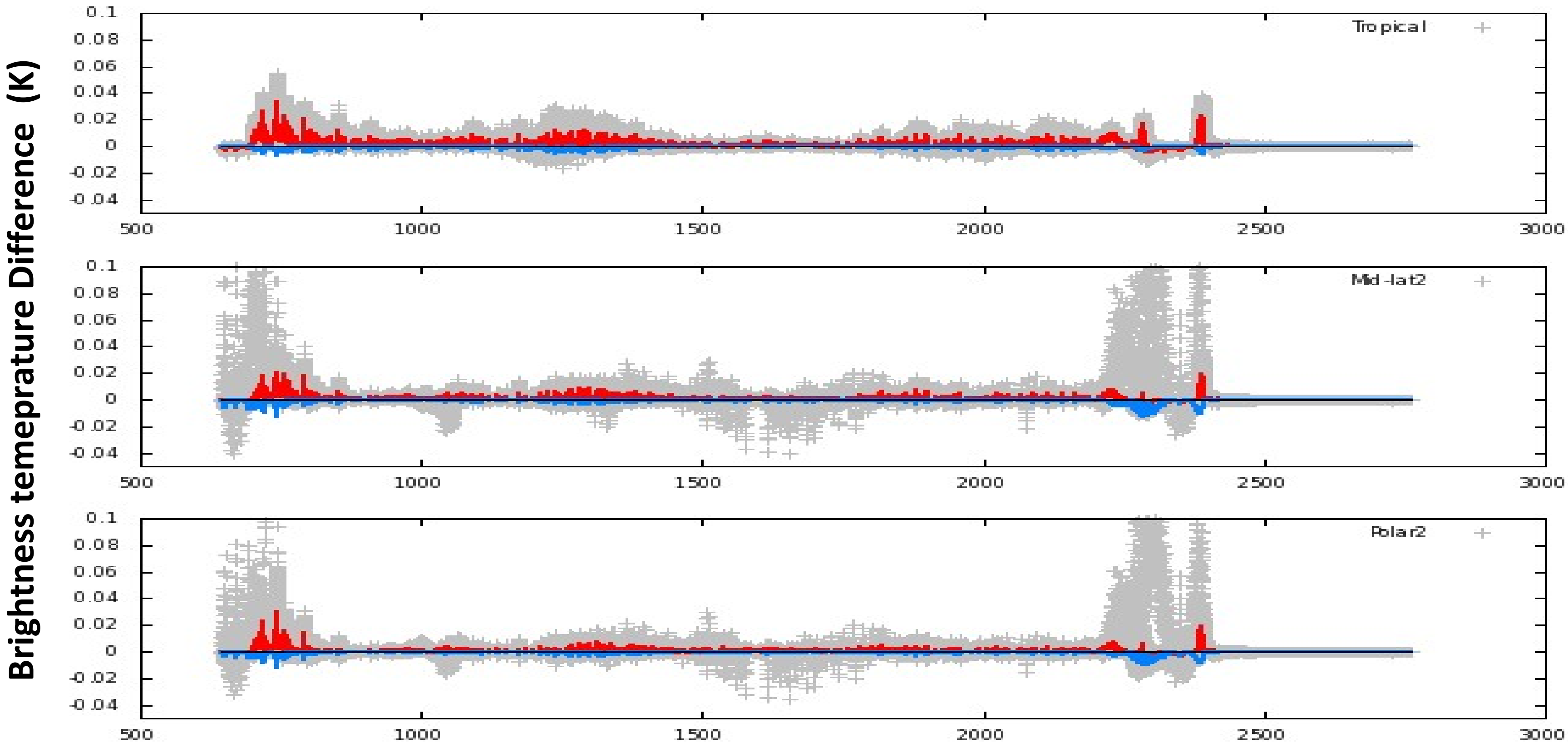
http://ara.abct.lmd.polytechnique.fr/index.php?page=tigr

Evaluation of the precision of atlases: the interpolation in temperature

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

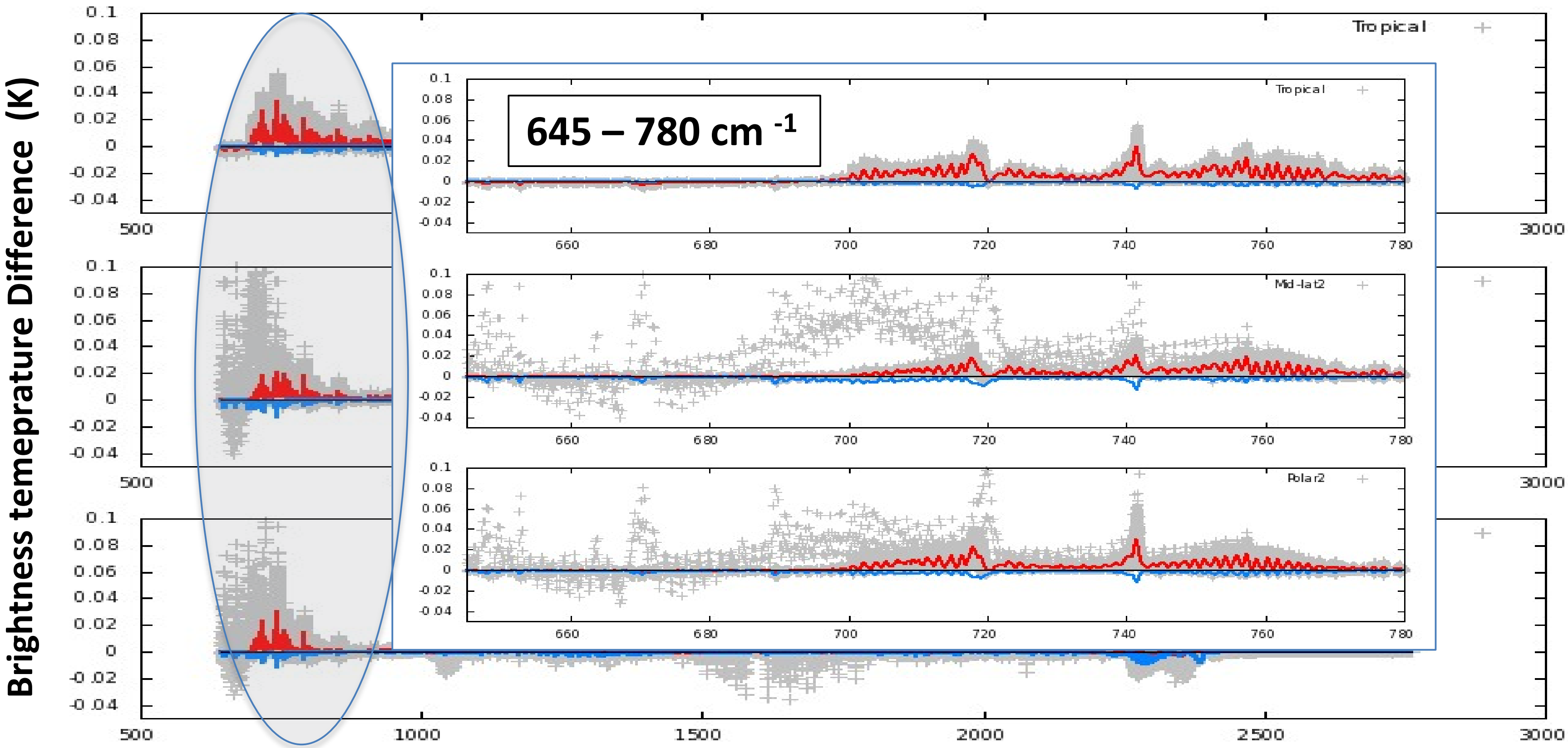
Validation database

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

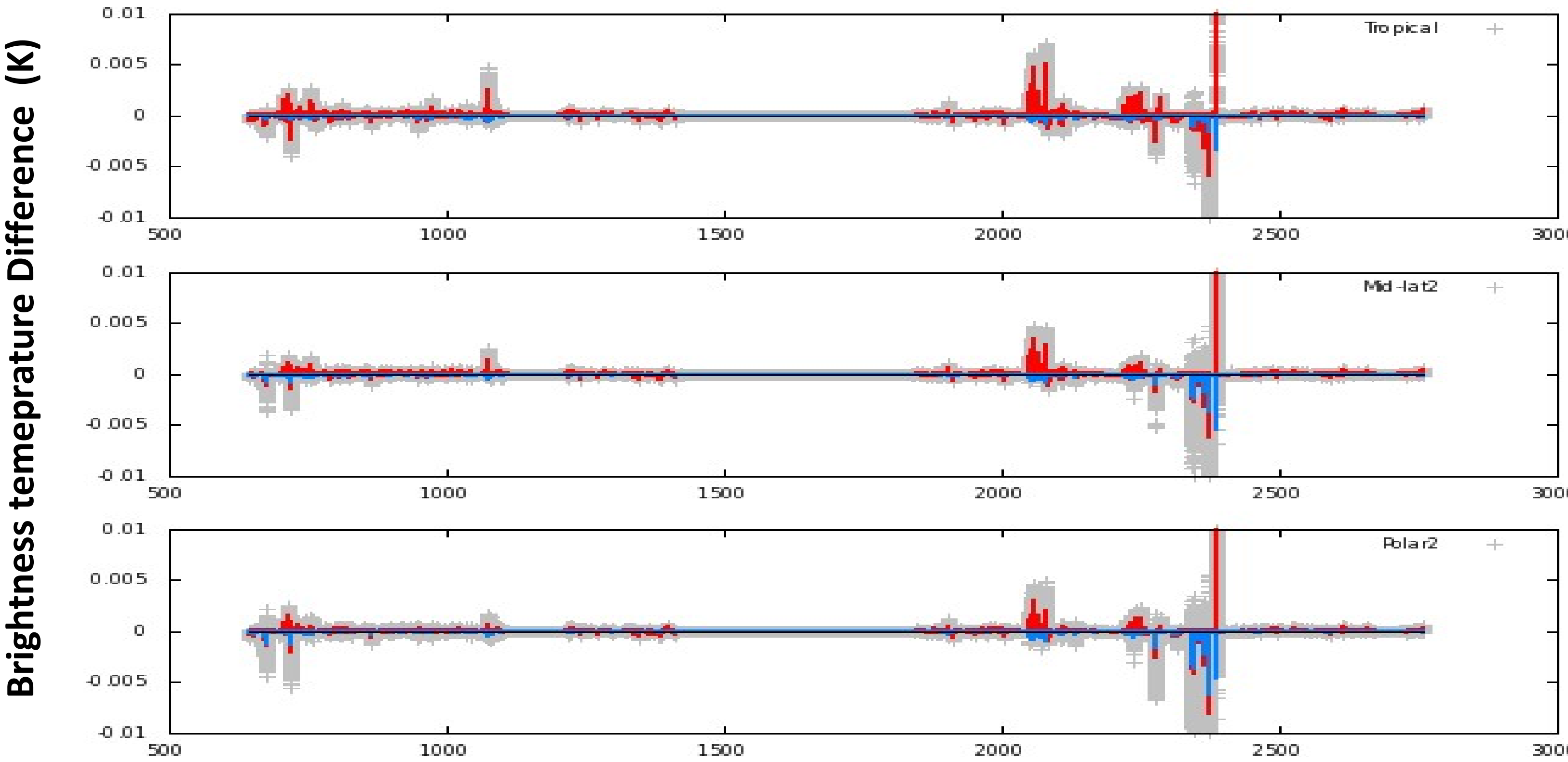
12 temperature profiles kept for 4A/OP-2018

Evaluation of the precision of atlases: handling of the concentration

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

  o Ex: CO_2 (330 ppmv) vs CO_2 (400ppmv)

bias Stdv(*-1) 2311 values



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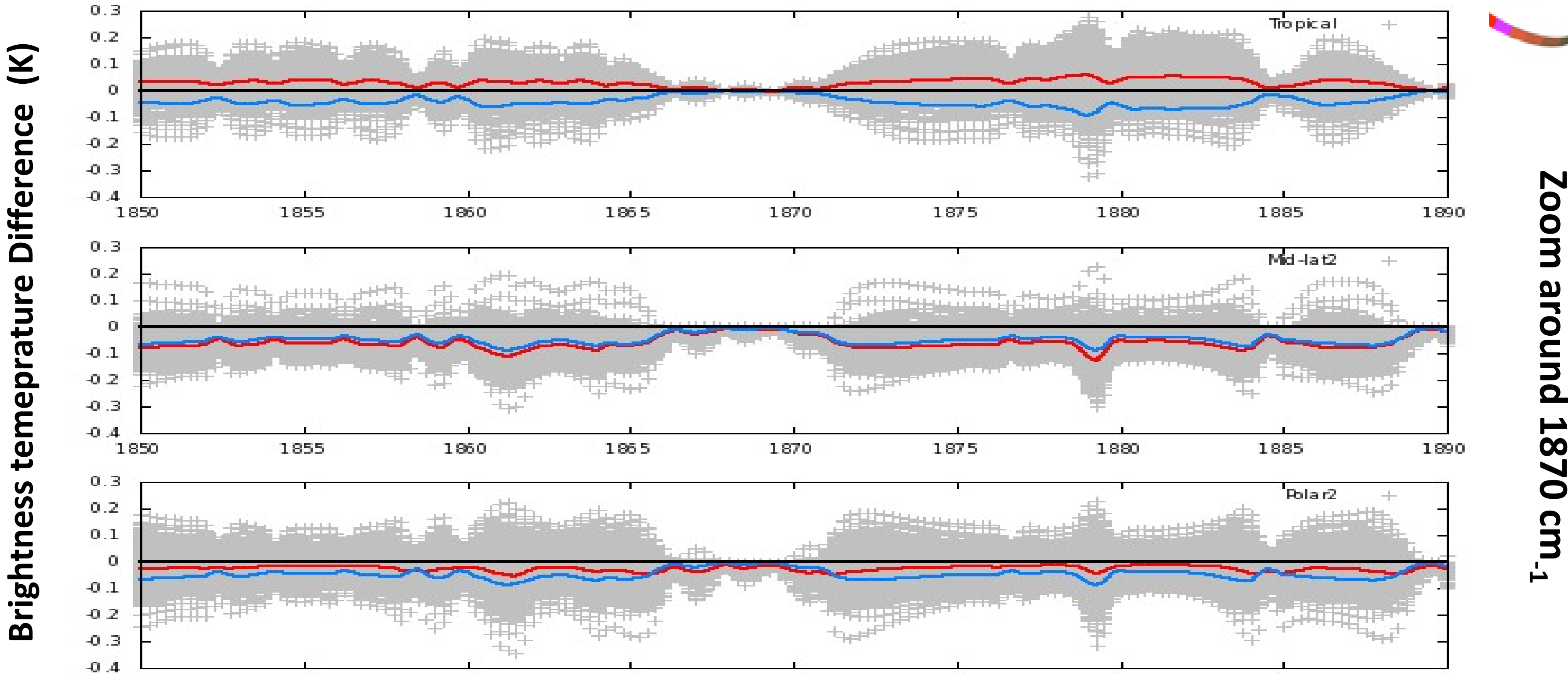
  - The most important effect for H_2O

ρ_{ref} H_2O vs ρ_{ref} H_2O * 1.5 (tropical)

ρ_{ref} H_2O vs ρ_{ref} H_2O * 0.5 (polar)

bias Stdv(*-1) 2311 values



Evaluation of the precision of atlases: handling of the concentration

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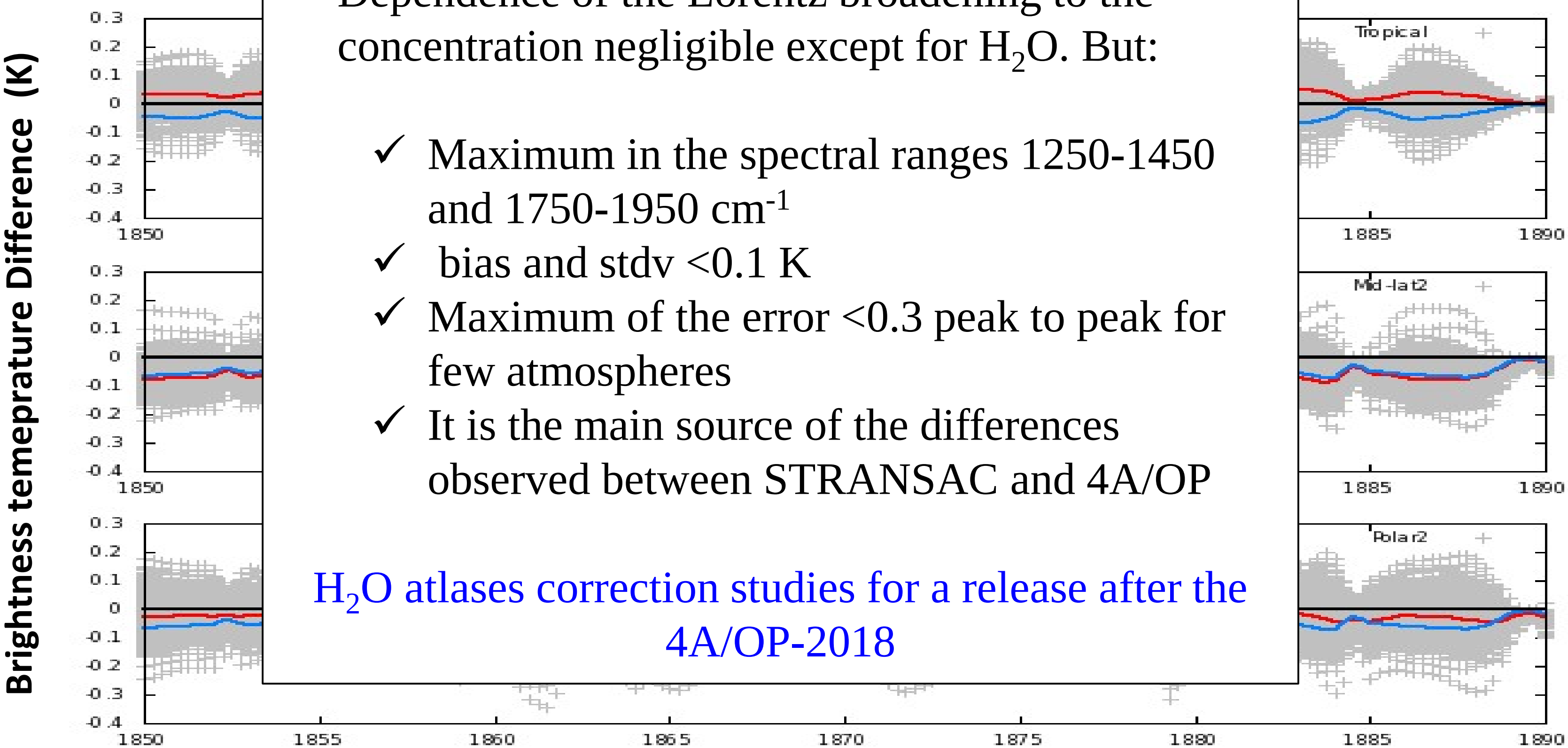
  - The most important effect for H_2O
  - ρ_{ref} H_2… …311 values

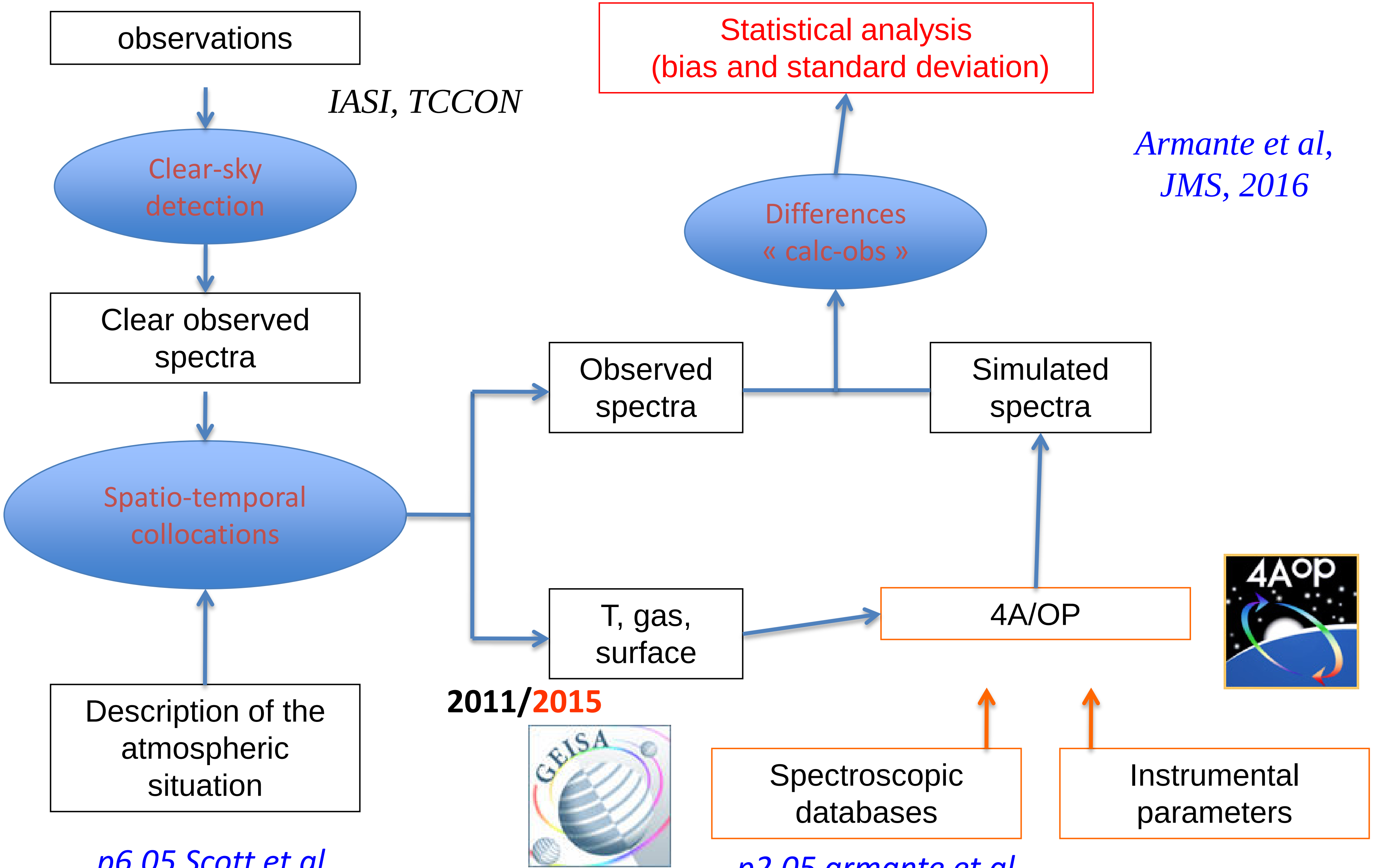


Conclusion

- Dependence of the Lorentz broadening to the concentration negligible except for H_2O. But:
  - ✓ Maximum in the spectral ranges 1250-1450 and 1750-1950 cm^{-1}
  - ✓ bias and stdv <0.1 K
  - ✓ Maximum of the error <0.3 peak to peak for few atmospheres
  - ✓ It is the main source of the differences observed between STRANSAC and 4A/OP

H_2O atlases correction studies for a release after the 4A/OP-2018

✓ Spectroscopic Parameters And Radiative Transfer Evaluation (SPARTE)



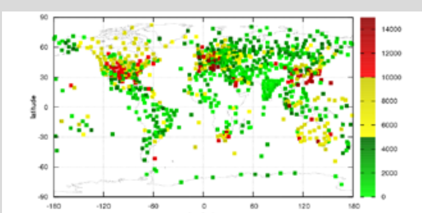
Validation of 4A/OP

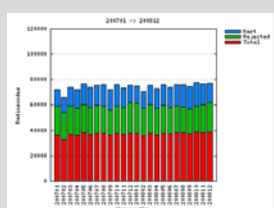
Validation database

A 43-level description of the atmosphere between surface and 0.0026 hPa including P, T, H_2O, 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





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Cf p6.05 Scott et al

- ✓ 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

Validation of 4A/OP

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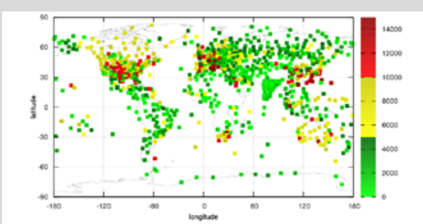
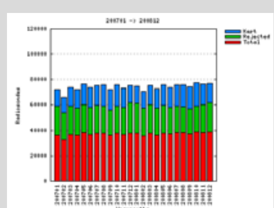


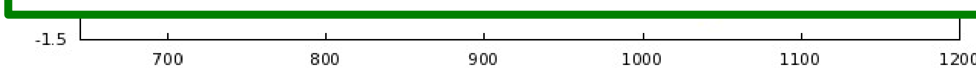


http://ara.abct.lmd.polytechnique.fr/index.php?page=arsa-databas

Validation of the following point are in progress …

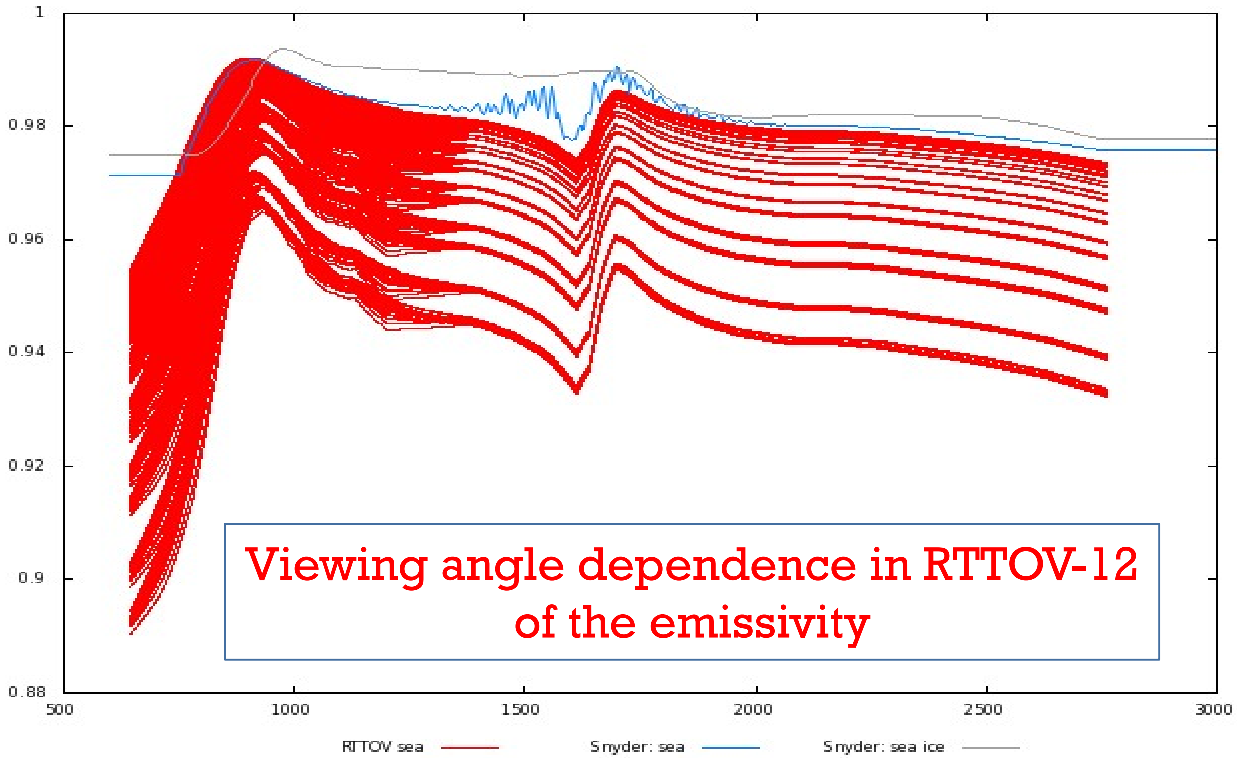
- ✓ Line mixing CO2,CH4
- ✓ HNO3 and CFCs
- ✓ Solar contribution
- ✓ NLTE
- ✓ Concentration profiles of GHG
- ✓ Evaluation of GEISA-2018

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



Emissivities in 4A/OP
Sea case

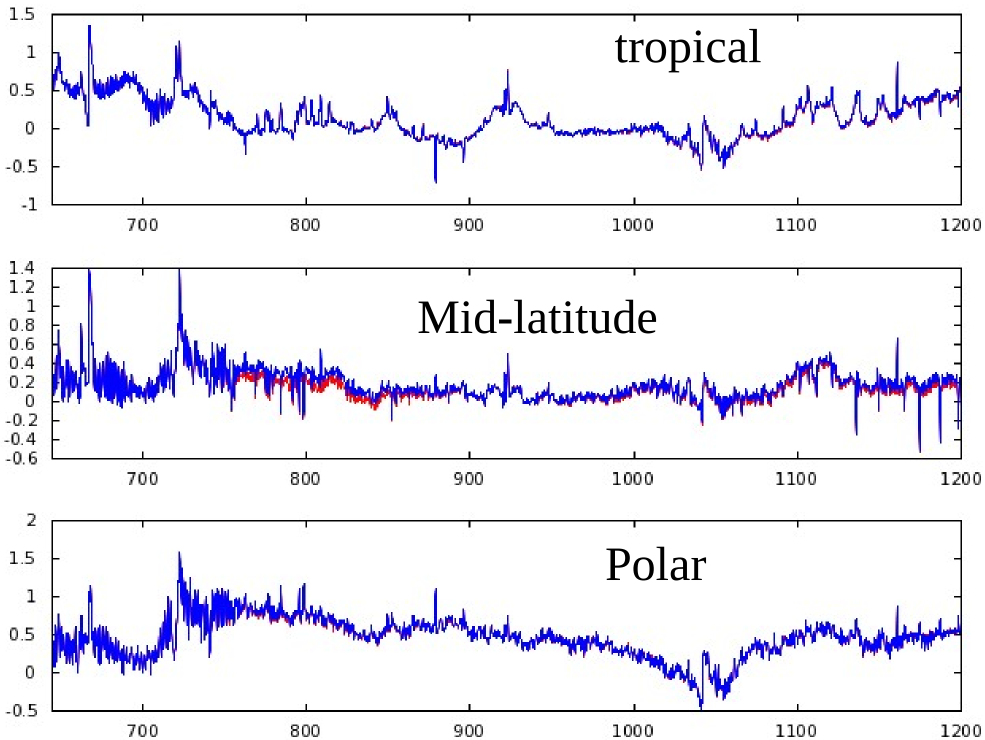
- 4A/OP emissivity
  - Snyder
  - Emissivity extracted from RTTOV-12 for each profile (variability due to the viewing angle)

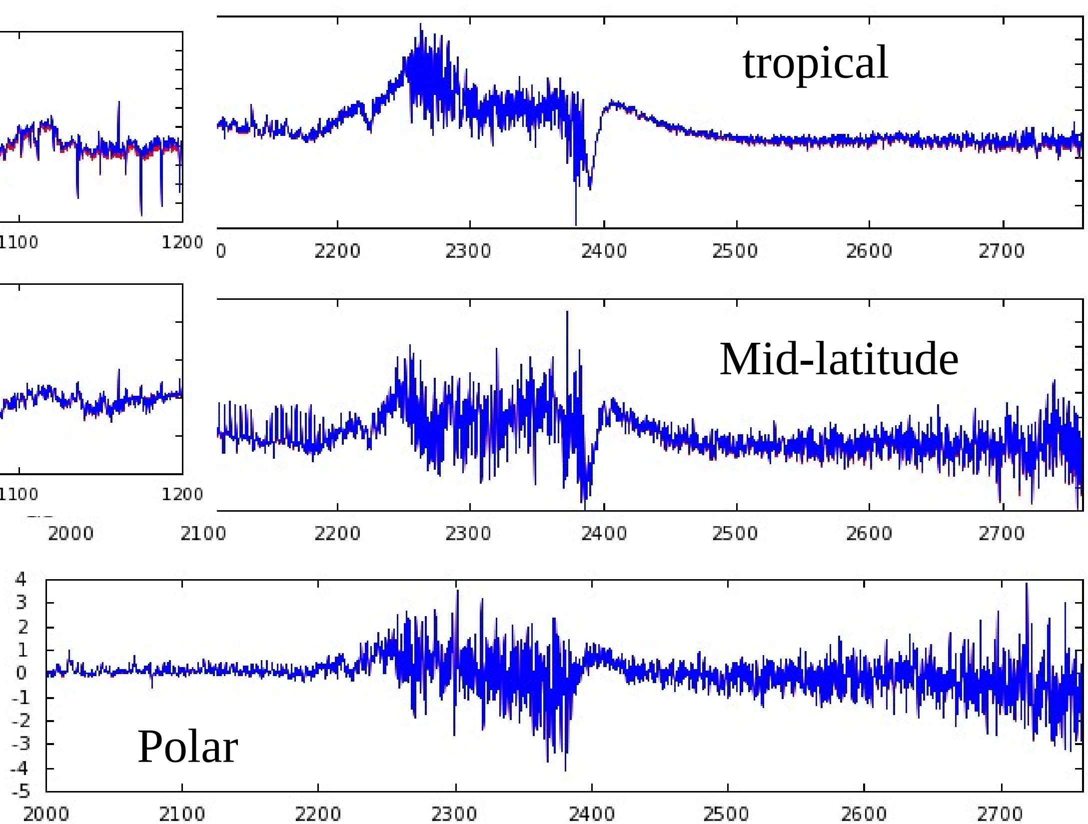


Emissivities in 4A/OP *sea*

- 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

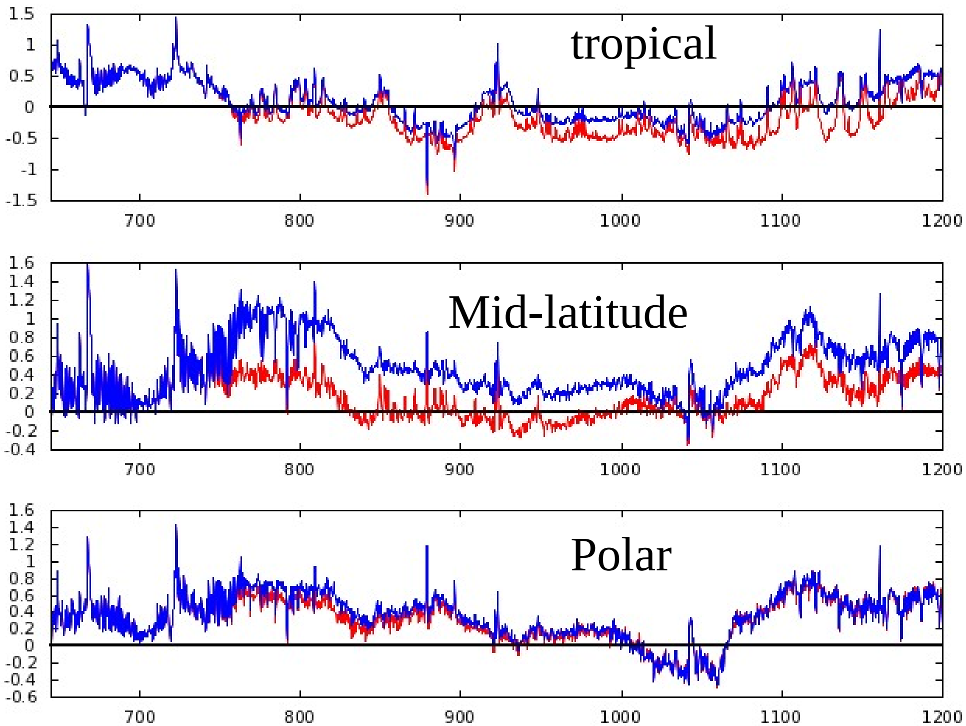




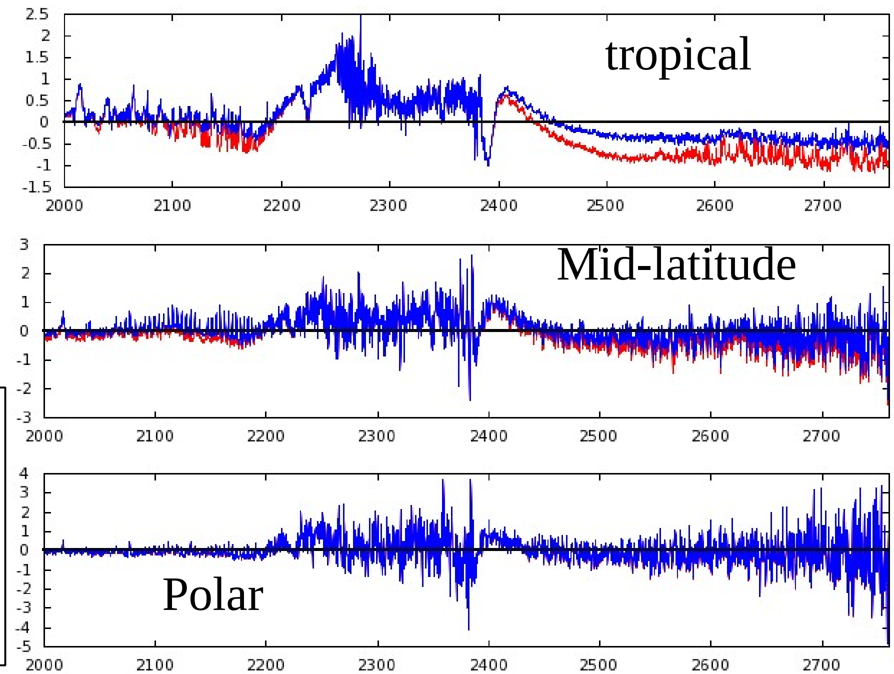
RTTOV-12 nadir emissivity close to Snyder

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°

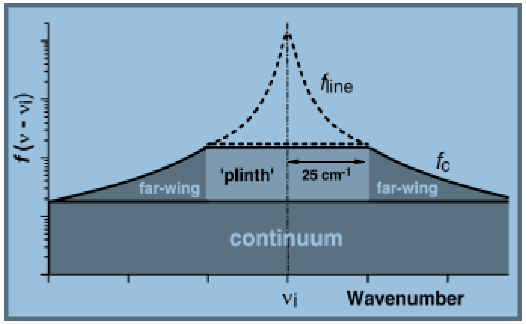


✓ **RTTOV-12 emissivities have a good angular dependency in most of the IASI spectra, except in the B3 where the angular dependency seems to be too important**

➔ angular dependency introduced in 4A/OP

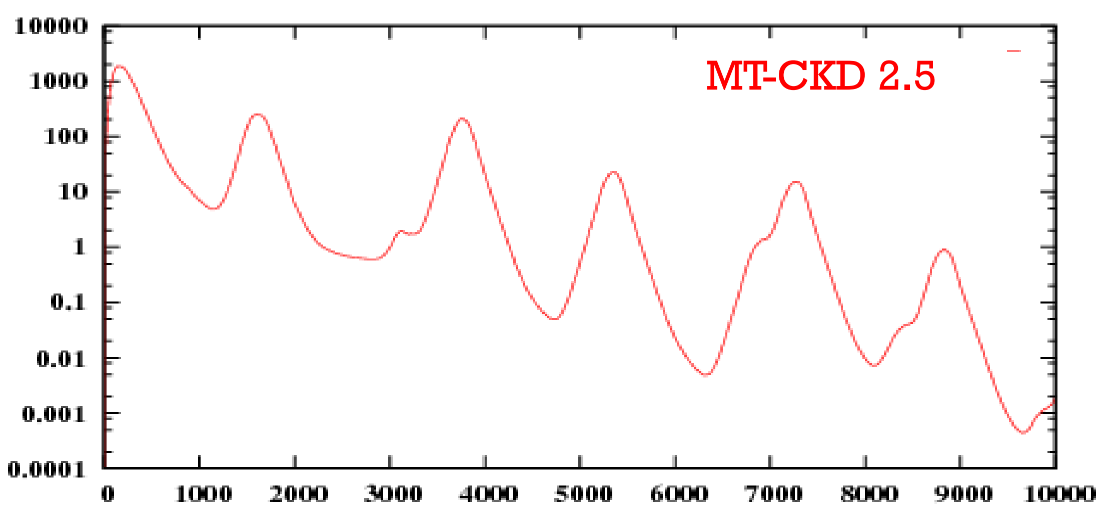
Validation of 4A/OP H_2O continuum status

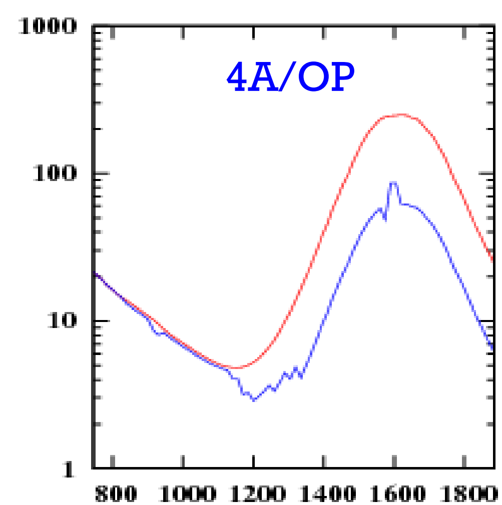
- H_2O:
  - MT CKD2.5, Mlawer, E. J. et al (2012), absorption, Philosophical Transactions of the Royal Society
  - Far wing's cut-off in 4A/OP is a function of the Half-Width and Half Maximum (3000 * HWHM of each line in the current version of the atlases)



from, Ptashnik et al 2011

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



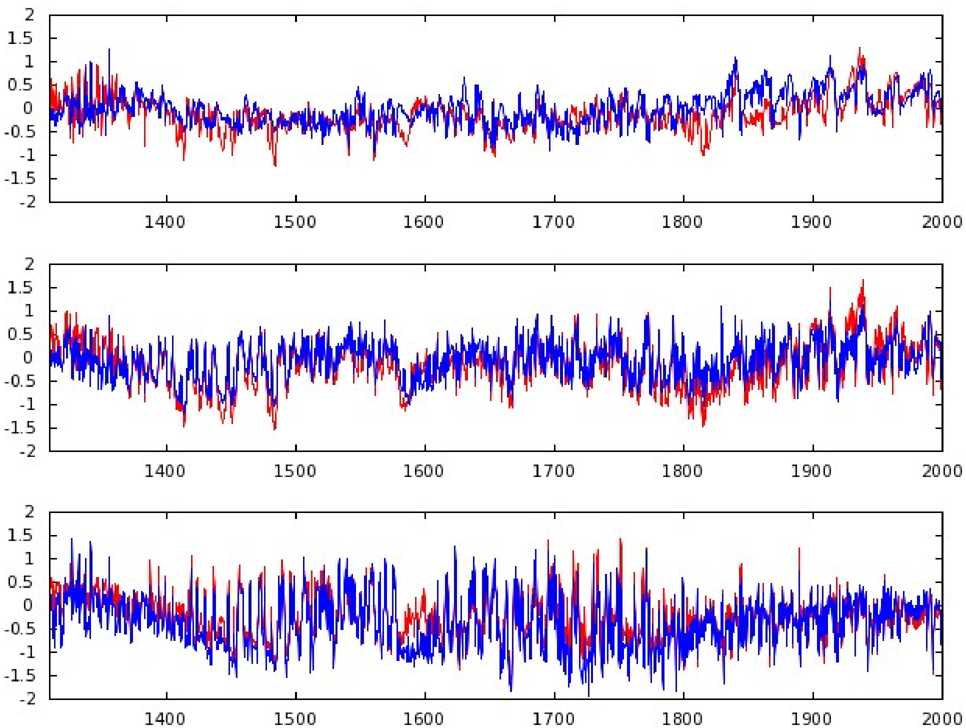


Validation of 4A/OP H_2O continuum status

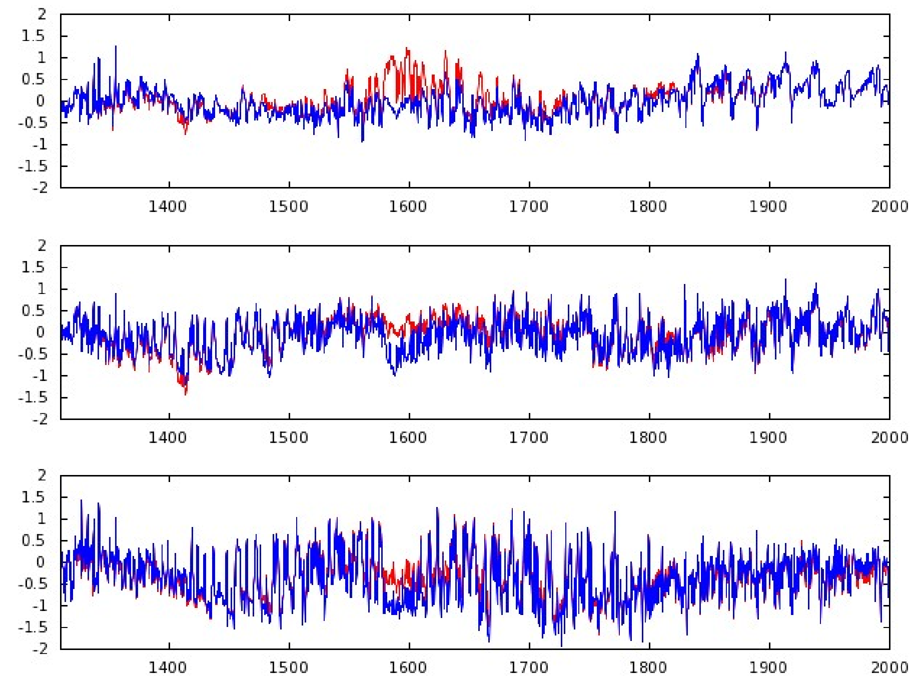
- MT CKD2.5 (RTTOV-12), Mlawer, E. J. et al, *Phil. Trans. Roy. Soc. A*, *370*, 1-37, 2012.
- CAVIAR: http://www.met.reading.ac.uk/caviar/home/
- 4A/OP : MT CKD2.5 fitted

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
H_2O continuum status

Important differences between CAVIAR and the other datasets

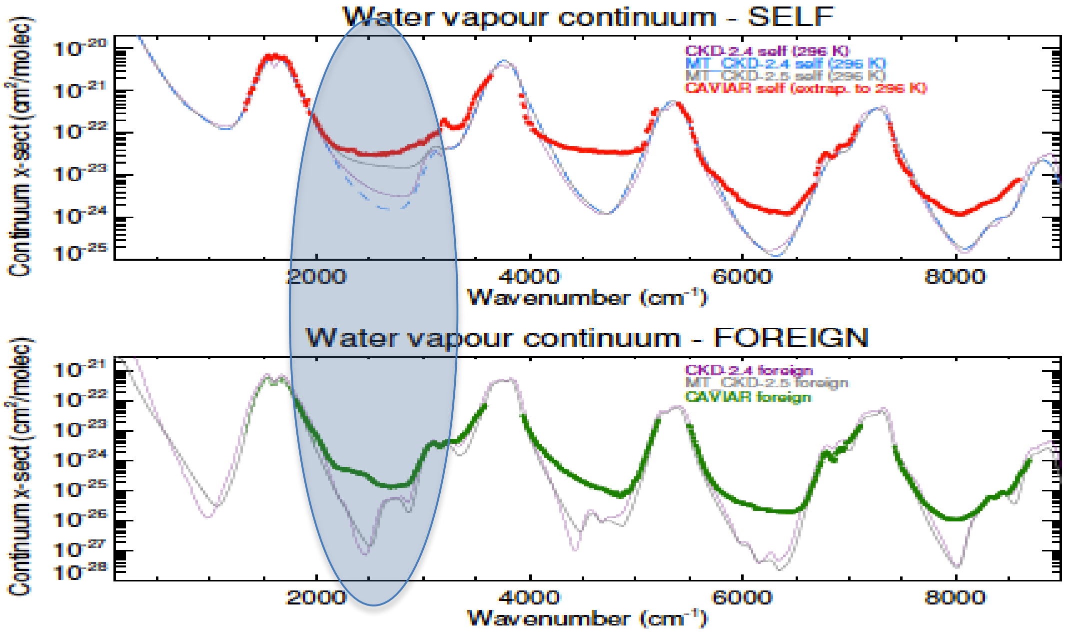
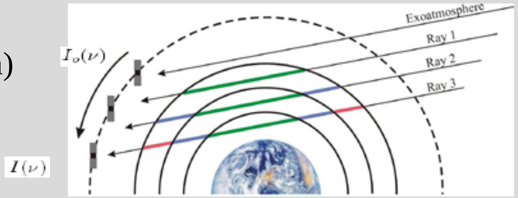


Figure from ITWG summary report (S. Newman)

- **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.



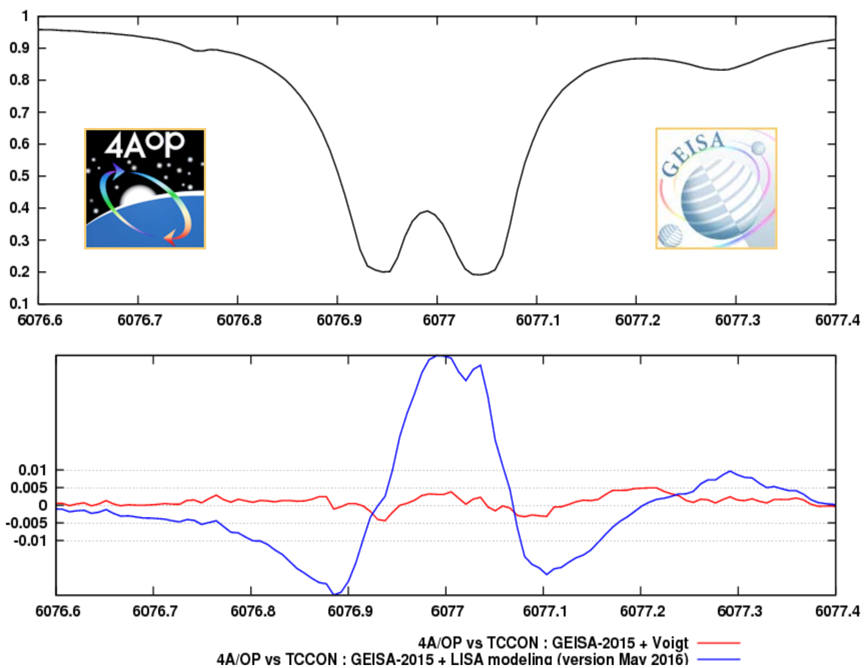
Use of ACE/FTS and 4A/OP limb to evaluate different continuum datasets

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 H_2O:

  ➔ but the error is small (bias and stdv < 0.1)



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

<u>MERLIN</u> : 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)