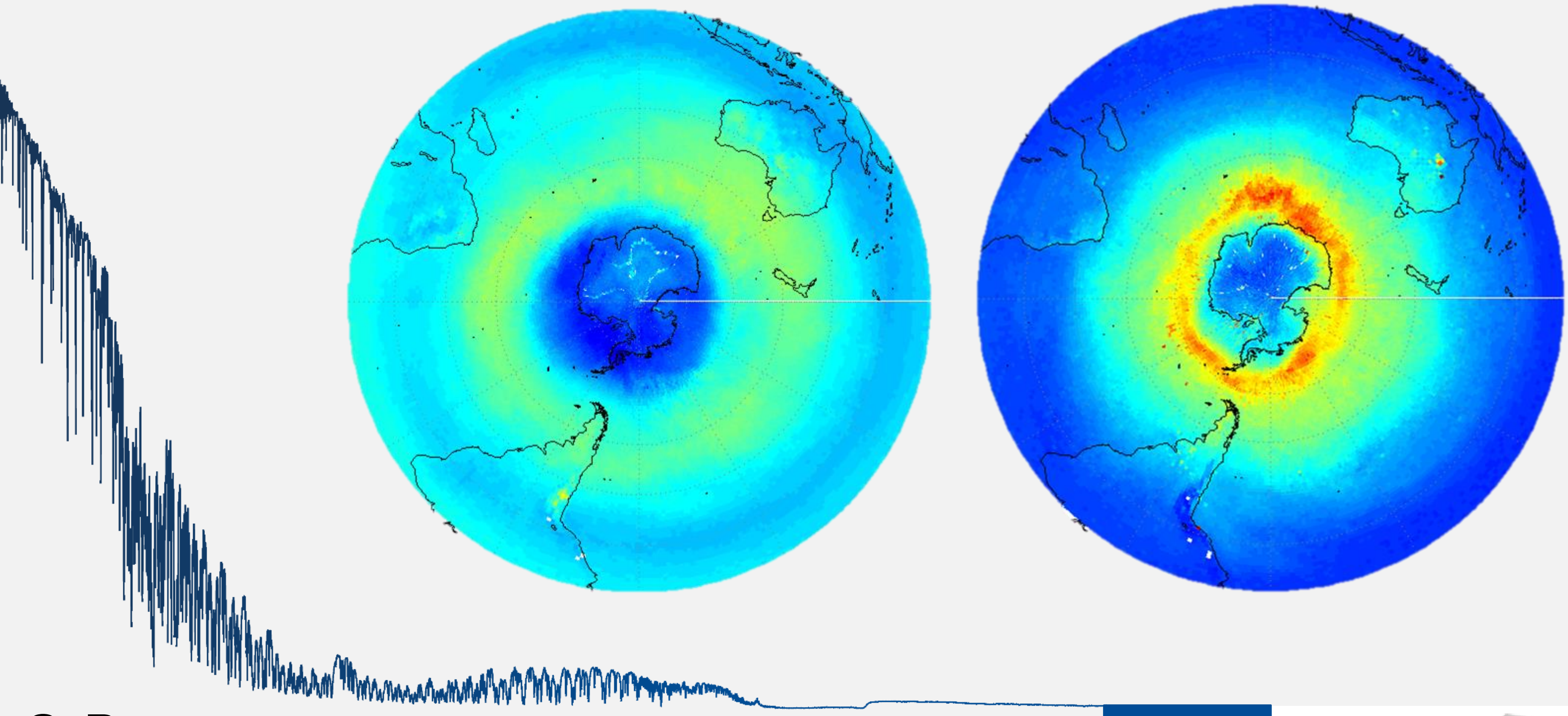
Spatial and temporal variability of stratospheric HNO_3 and O_3 from IASI global measurements



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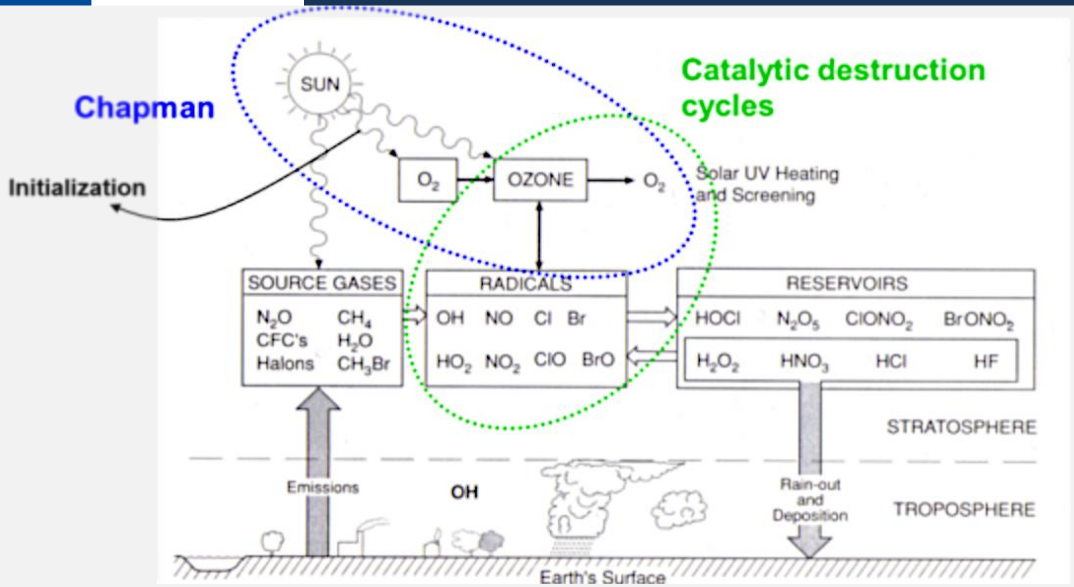
Why study HNO_3?



Atmospheric chemistry & global change G.Brasseur, Oxford University Press

Chapman

Formation of ozone

$O_2 + h\nu \rightarrow O + O$

$O + O_2 + M \rightarrow O_3 + M$

Destruction of ozone

$O_3 + h\nu \rightarrow O_2 + O(^1D)$

$O(^1D) + M \rightarrow O + M$

Net: $O_3 + h\nu \rightarrow O_2 + O$

→ **Overestimation** of the total O_3 column

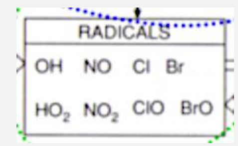
Catalytic destruction cycles

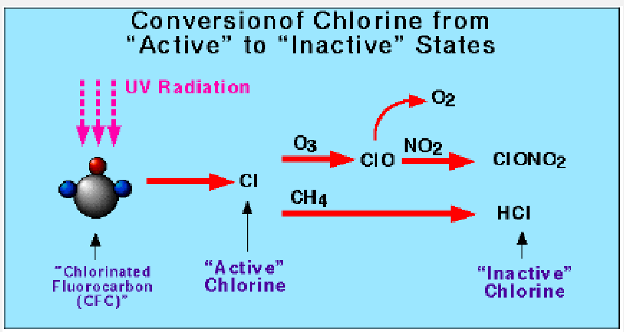
$X + O_3 \rightarrow XO + O_2$

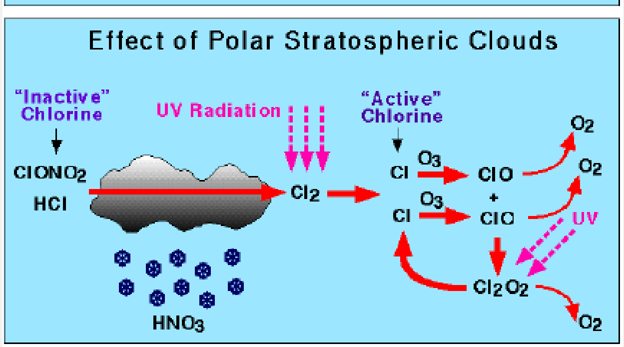
$XO + O \rightarrow X + O_2$

Net: $O_3 + O \rightarrow 2O_2$

X=







http://www.ozonedepletion.info/education/part3/ozonesources.html

- <u>HNO_3</u>

= reservoir for those depleting substances

= source of **polar stratospheric clouds** (PSC: $HNO_3.(H_2O)_3$, $HNO_3.H_2SO_4.H_2O$, …)

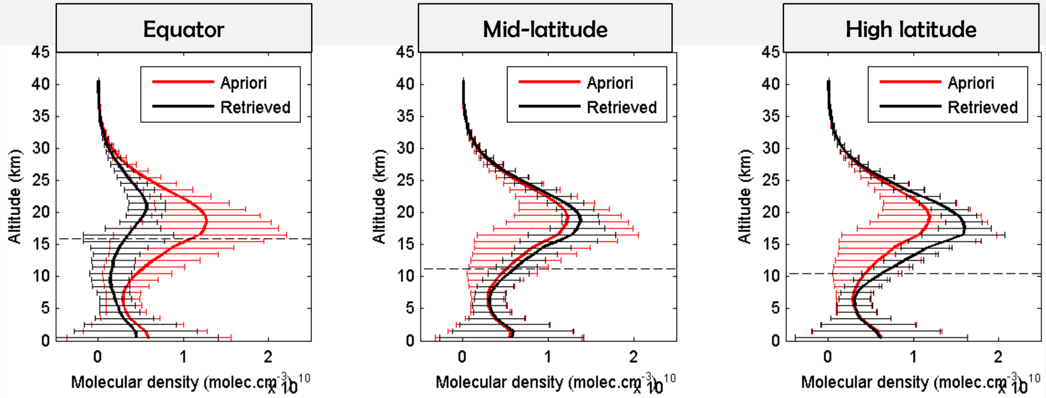
- <u>PSC</u>

= surfaces on which inactive chlorine species can be activated to form radicals destructing O_3

Characterization of FORLI-HNO_3 product (1/2)

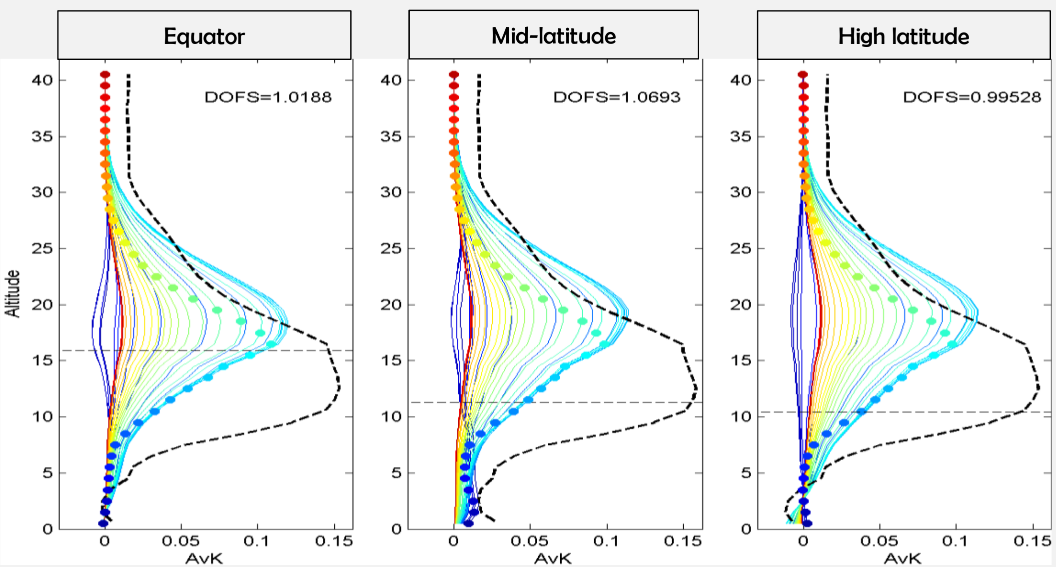
PROFILES

- Max of concentrations between 15 and 25 km altitude
- Latitudinal gradient of concentrations

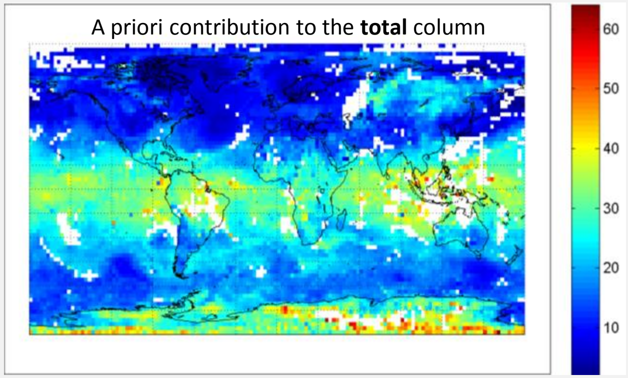


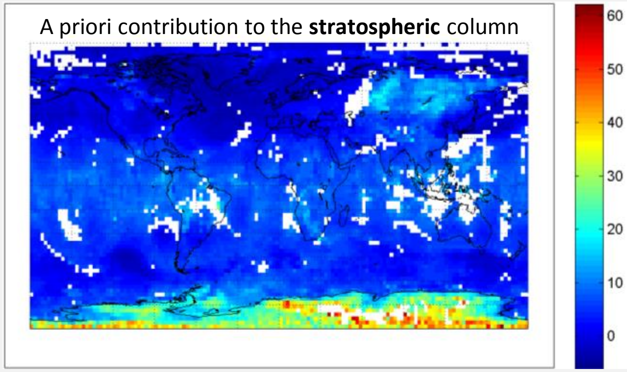
AVERAGING KERNELS

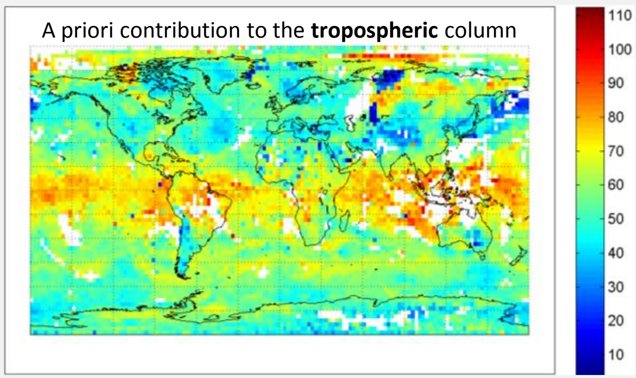
- Max of sensitivity between 15 and 25 km altitude → also where largest independance from apriori



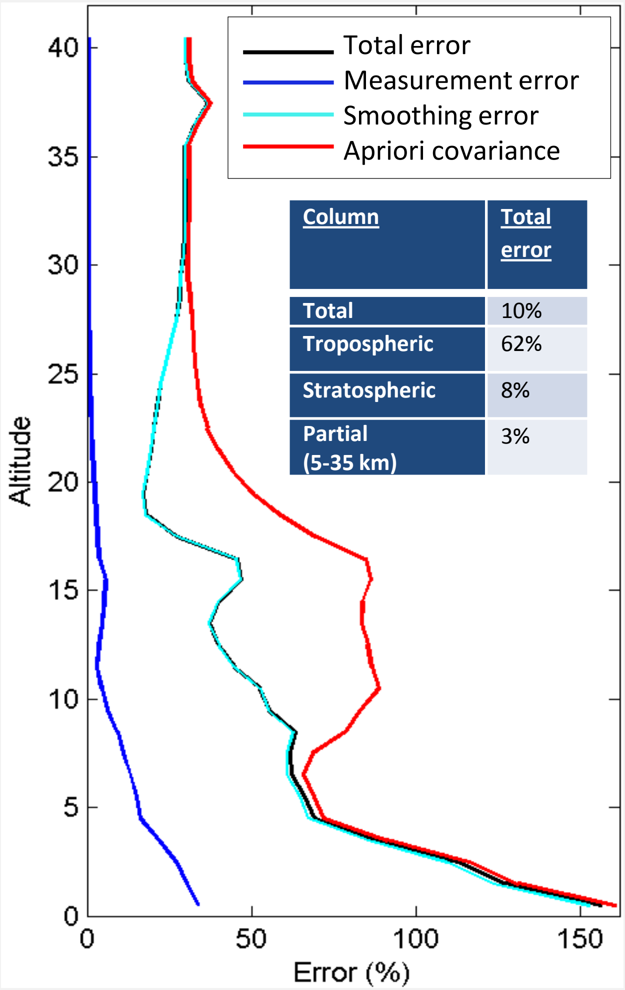
APRIORI CONTRIBUTIONS (%)



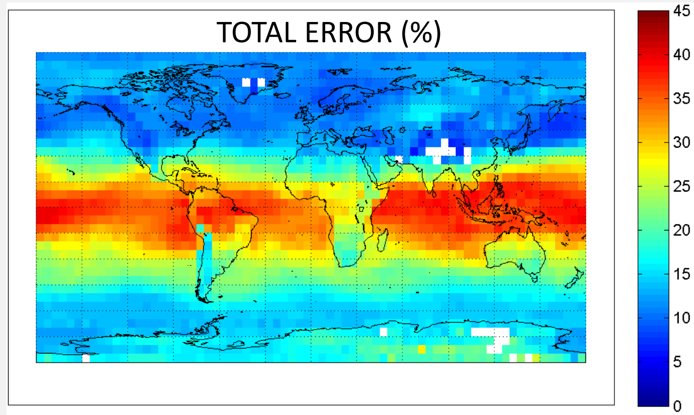




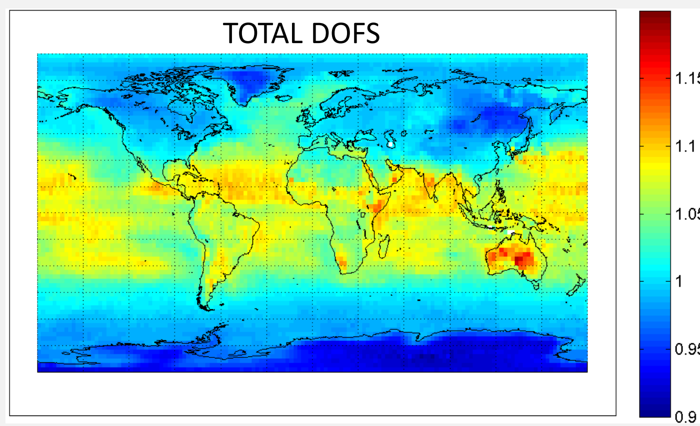
Characterization of FORLI-HNO_3 product (2/2)



Column	Total error
Total	10%
Tropospheric	62%
Stratospheric	8%
Partial (5-35 km)	3%



- Distribution of the **total error** on the total column
  - Max. at the Equator: interference of the signal with absorption lines of water vapor
  - Min. at high latitudes



- Distribution of **DOFS** values (Degree Of Freedom for Signal)
  - Max. at the Equator: high thermal contrast
- Generally: values around 1

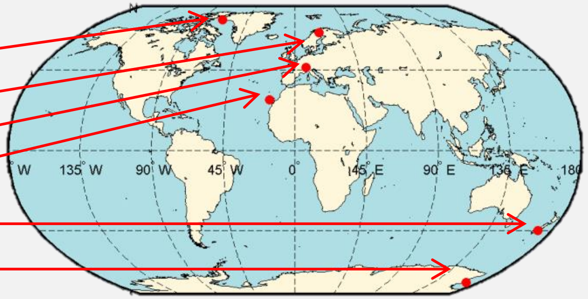
➔ 1 level of information

- Total error (black) dominated by the smoothing error (light blue)
- Measurement error (dark blue): small contribution, especially in the troposphere
- Total error almost equal to apriori variability (red) in the largest part of the troposphere
  - Translates the weak sensitivity of the instrument in that layer
- Gain compared with apriori variability: maximum between 10 and 20 km altitude

Validation of FORLI-HNO_3 (1/3)

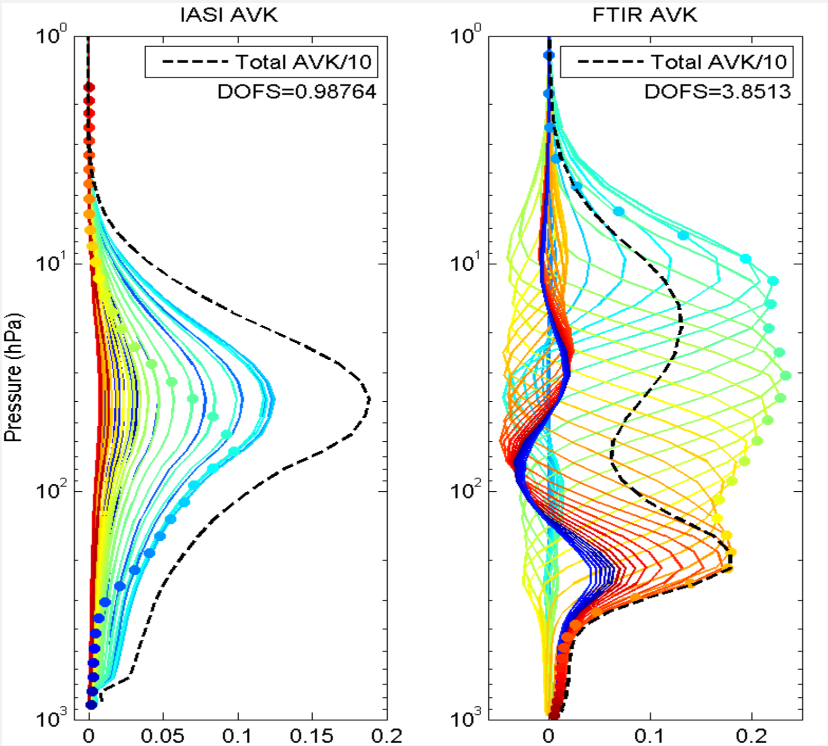
- 6 stations from the NDACC (Network for the Detection of Atmospheric Composition Change), covering a large range of latitudes

Station	Latitude	Longitude
Thule	76.5° N	69° W
Kiruna	67.8° N	20.4° E
Jungfraujoch	46.6° N	8.0° E
Izaña	28.3° N	16.5° W
Lauder	45.0° S	170° E
Arrival Heights	77.8° S	167° E

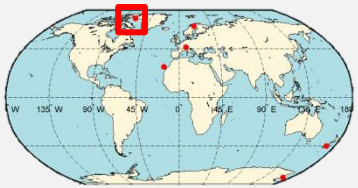


- Ground-based FTIR measurements
  - latitudes between 76.5° N and 77.8° S
  - data all year round for all latitudes
  - except polar regions: need for light prevents measurements during the polar winter

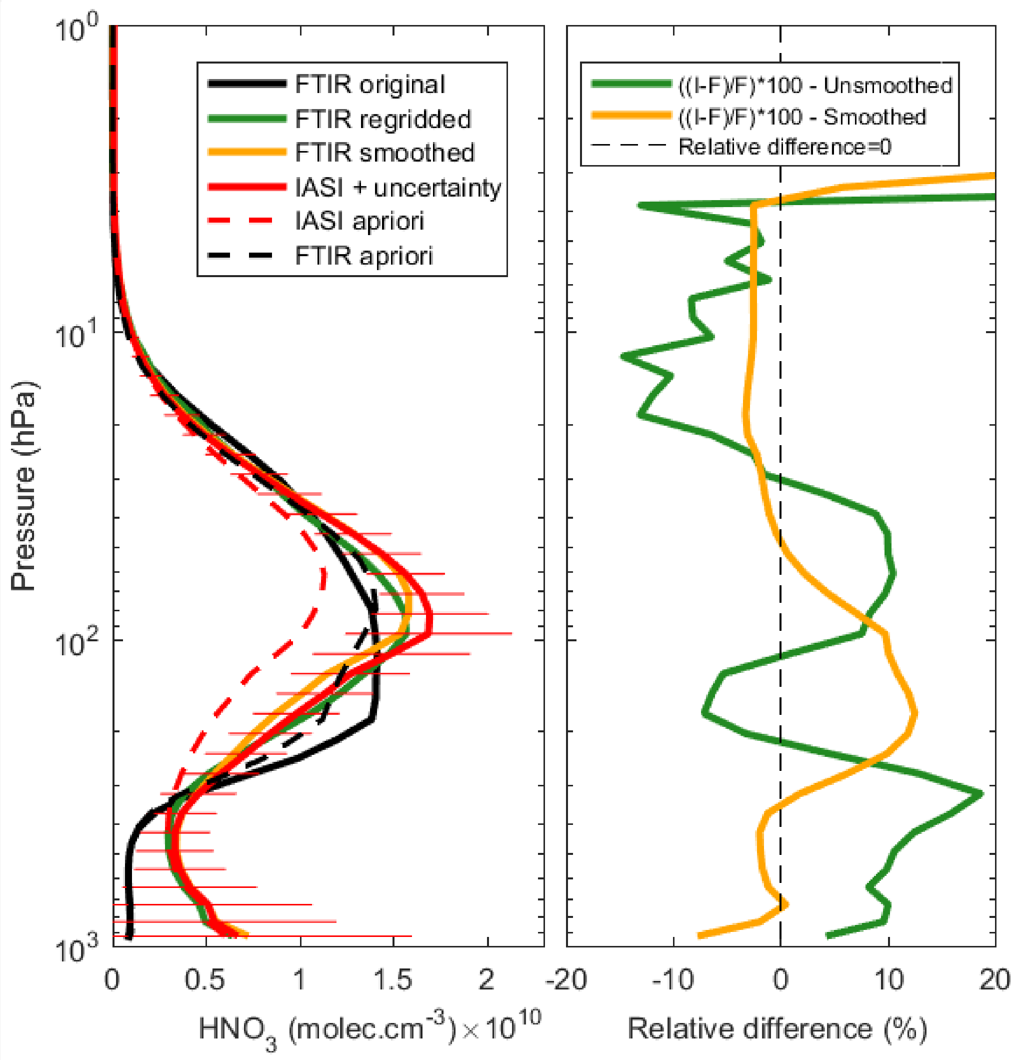
- Validation through the smoothing of FTIR data by the resolution of IASI data (lower resolution)



Validation of FORLI-HNO_3 (2/3)



VERTICAL PROFILES

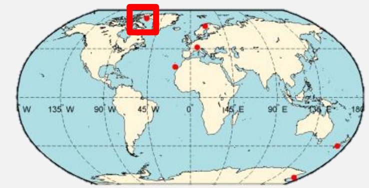


- **Original** FTIR profile largely different from **IASI** profile
- **Regridded** profile still quite different
- **Smoothed** profile much more similar to IASI profile:
  - Differences ranging between 0.1-10%

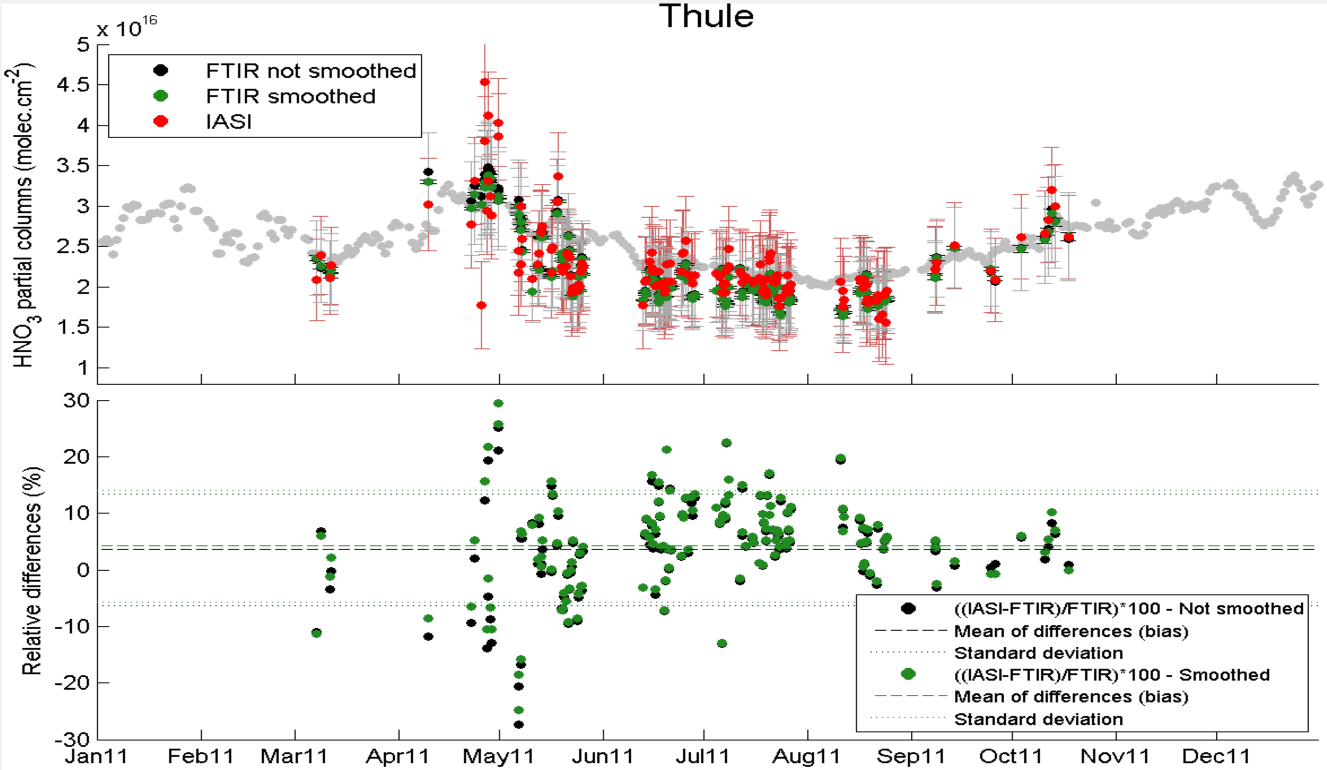
➔ Conclusions valid for all stations

	Differences IASI vs FTIR smoothed profiles		
	Minimum (%) [altitude (km)]	Maximum (%) [altitude (km)]	R
Thule	0.4 [22]	12.5 [13]	0.99
Kiruna	-0.1 [24]	18.0 [13]	0.99
Jungfraujoch	0.1 [37]	25.8[12]	0.99
Izaña	0.21 [2]	45.0 [13]	0.98
Lauder	1.2 [39]	47.2 [12]	0.98
Arrival heights	0.4 [4]	4.7 [13]	0.99

Validation of FORLI-HNO_3 (3/3)



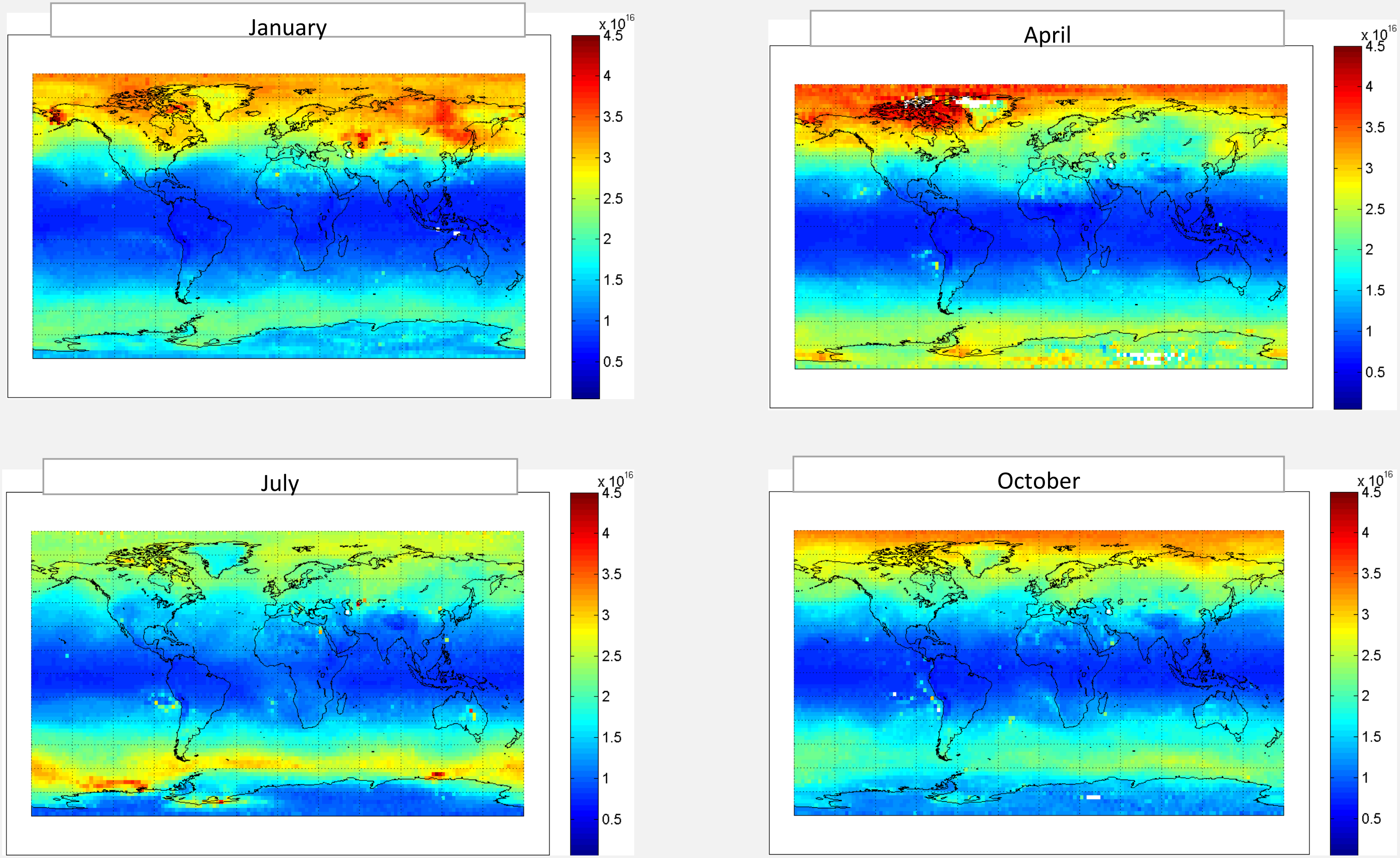
COLUMN VALIDATION



- FTIR (**unsmoothed** or **smoothed**) column values within the uncertainty range of **IASI** measurements
- Smoothing improves comparison
- IASI always positively biased → overestimation of IASI compared with FTIR

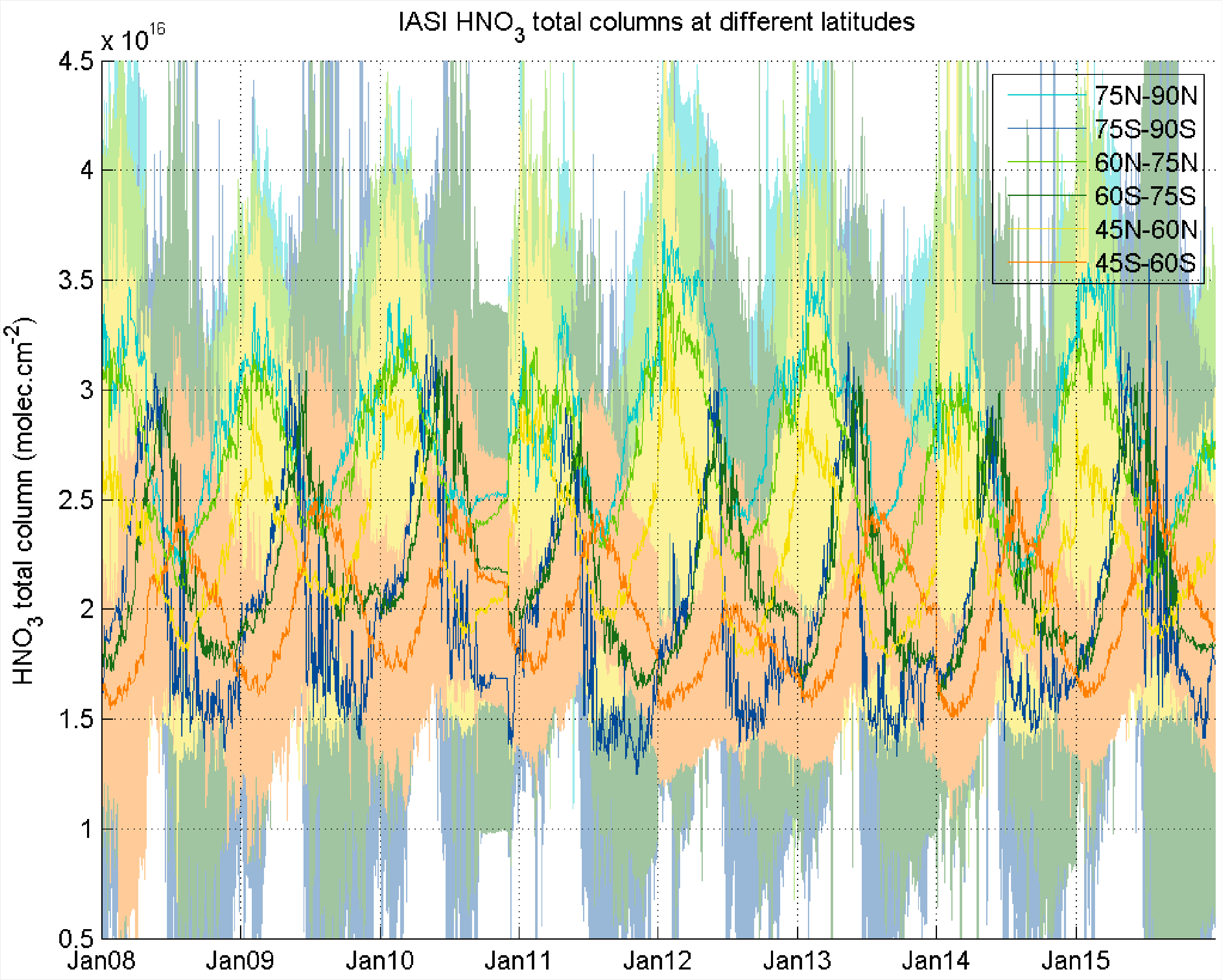
Stations	Bias (%) Unsmoothed FTIR	Bias (%) Smoothed FTIR	Standard deviation (%)	R
Thule	3.4	4.0	9.7	0.84
Kiruna	8.9	8.6	11.9	0.81
Jungfraujoch	13.9	13.9	9.6	0.91
Izana	10.5	9.2	9.8	0.74
Lauder	22.1	21.7	13.0	0.81
Arrival Heights	3.6	1.1	16.3	0.77
Total	11.8	11.5	12.1	0.93

HNO_3 global distributions



- Equatorial belt
  - Low and constant concentrations in the tropical belt
- Higher latitudes
  - Larger concentrations due to low photodissociation ($HNO_3 + h\upsilon \rightarrow NO_2 + OH$) during polar winter
  - Much higher seasonal variability
  - Denitrification process in Antarctica (see July): low concentrations above the pole and remaining high concentrations collar around Antarctica.

HNO_3 time series (2008-2015)



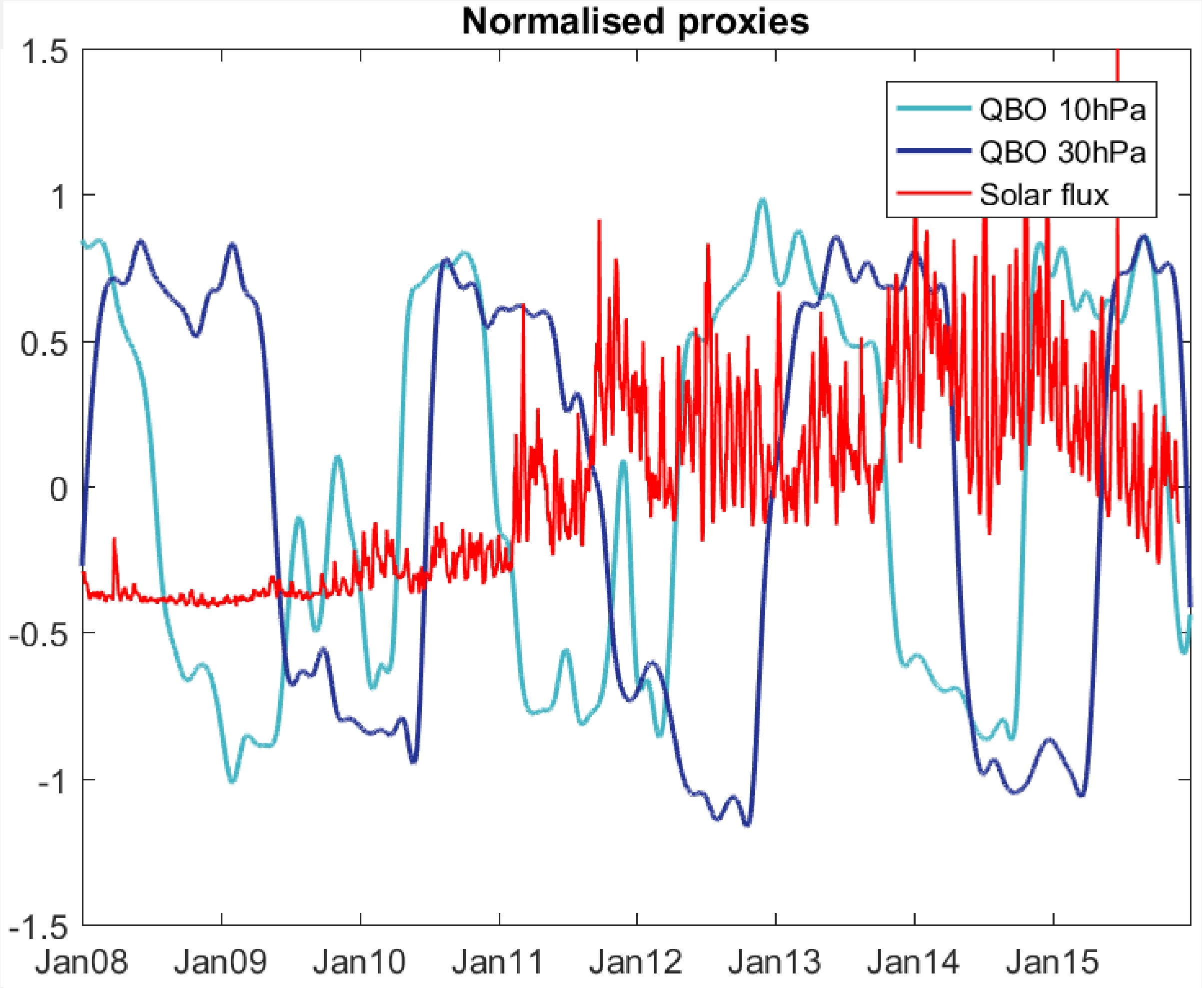
- 15° HNO_3 time series:
  - 45S – 90S
  - 45N – 90N
- Intra-annual variability: seasonality well represented
- Higher concentrations at higher northern latitudes (light blue and green)
- Large depletion at high southern latitudes (dark blue)

Multivariable regression model: first results

$$HNO_3(t) = k + \tau \times t + s \times F_{10.7}(t) + q_1 \times QBO^{10}(t) + q_2 \times QBO^{30}(t) + \sum_{n=1,2}[a_n \times \cos(n\omega t) + b_n \times \sin(n\omega t)] + \varepsilon(t)$$

Solar flux

Atmospheric dynamic terms



- Good results with correlation 0.89 - 0.93
- Median residuals: 0.01 – 0.53 %, depending on the latitude

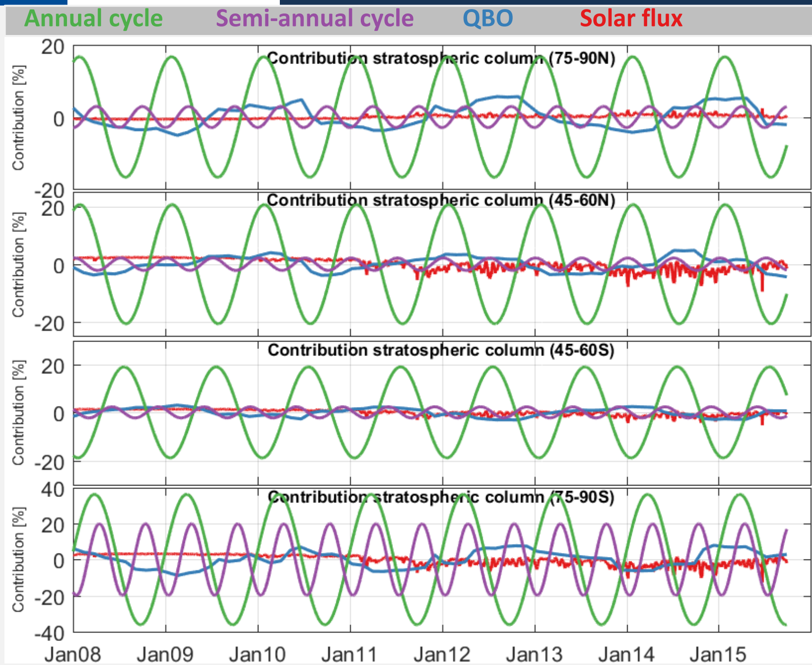
Contributions of each variable

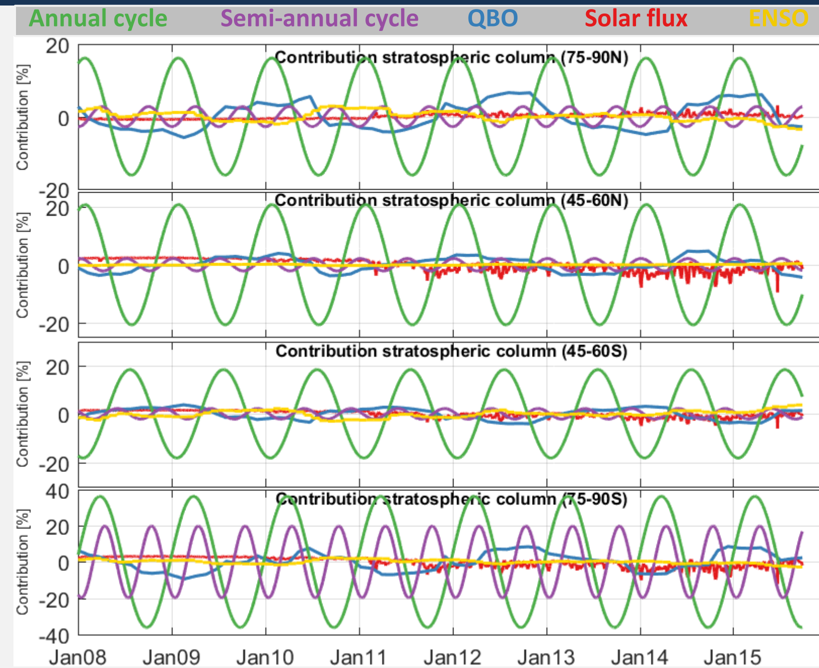
- Main contribution at all latitudes: ANNUAL VARIABILITY
  → due to Brewer-Dobson circulation
- At polar latitudes (esp.South), larger influence of the SEMI-ANNUAL VARIABILITY
  → due to variability in the vortex dynamics

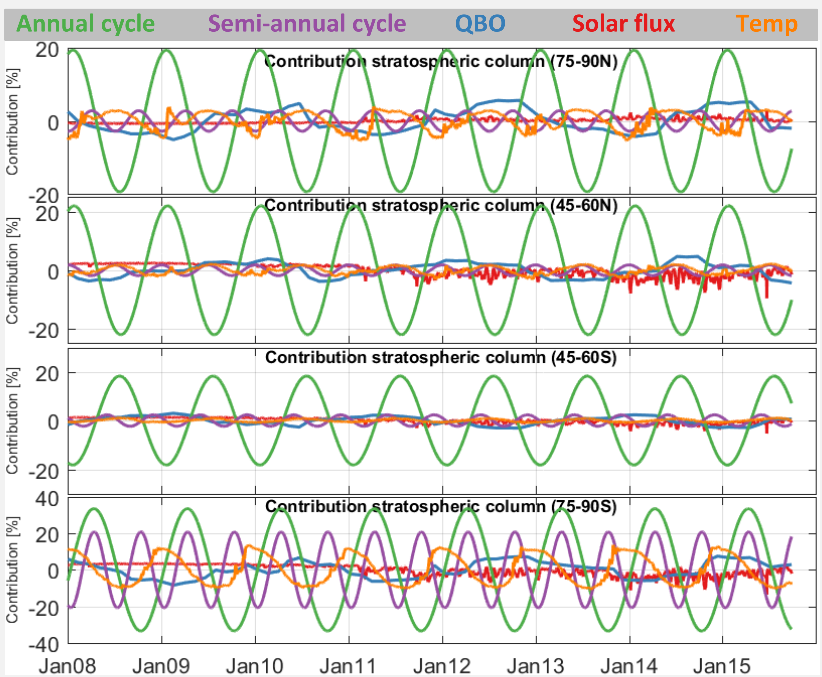
Other variables

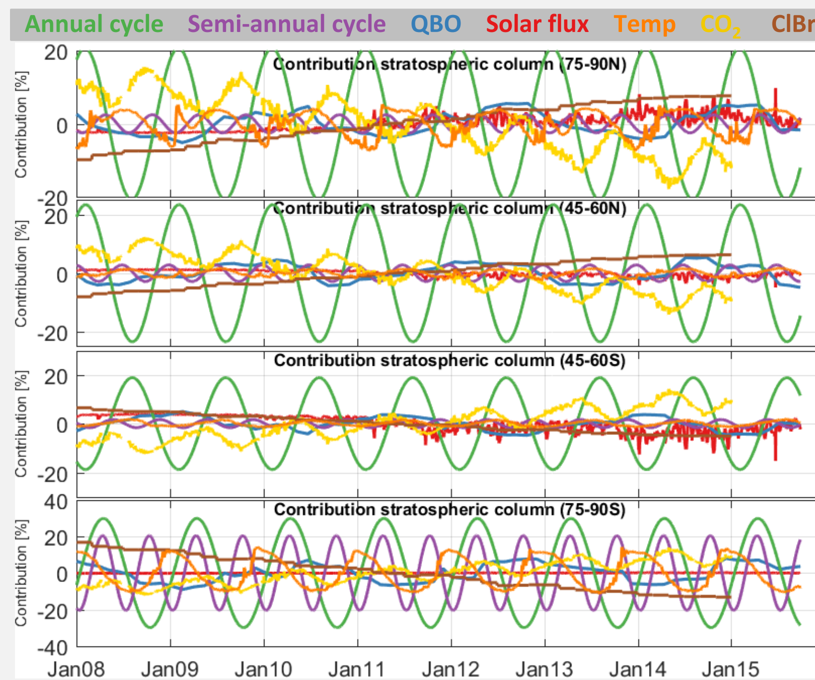
- Chlorine & bromine
- CO_2, N_2O, …
- Temperatures
- AAO, MEI, …

Contributions of different variables

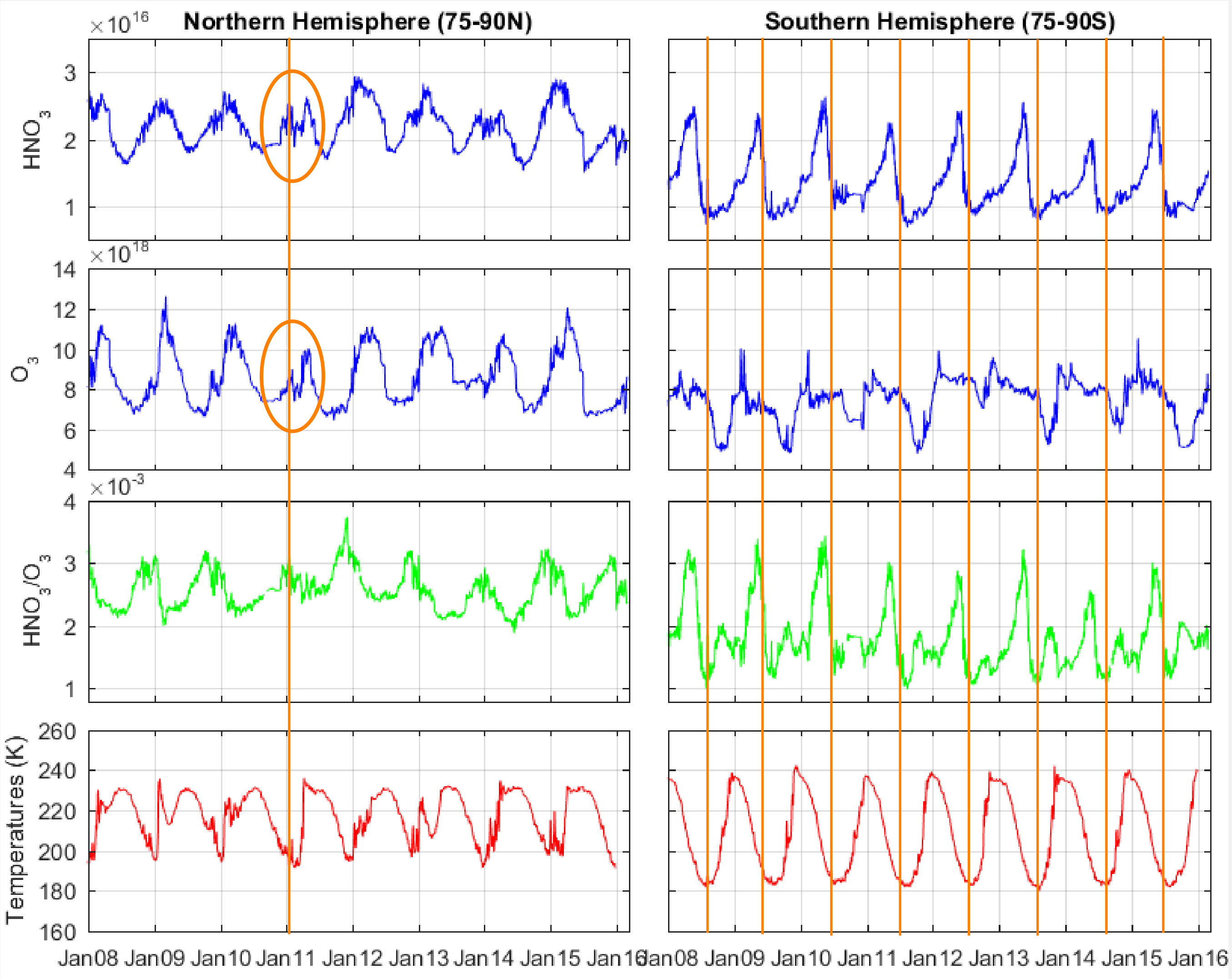








HNO_3 and O_3 time series



Time series (75-90 N/S)

- O_3
- HNO_3
- HNO_3/O_3
- Temperatures

- Clear & systematic pattern in the Southern Hemisphere

- Exceptional O_3 depletion in the Northern Hemisphere winter 2011

Conclusions

- First characterization of FORLI-HNO_3 product:
  - Highest sensitivity in the stratosphere (15-25km altitude)
  - Total error of about 10% in polar regions

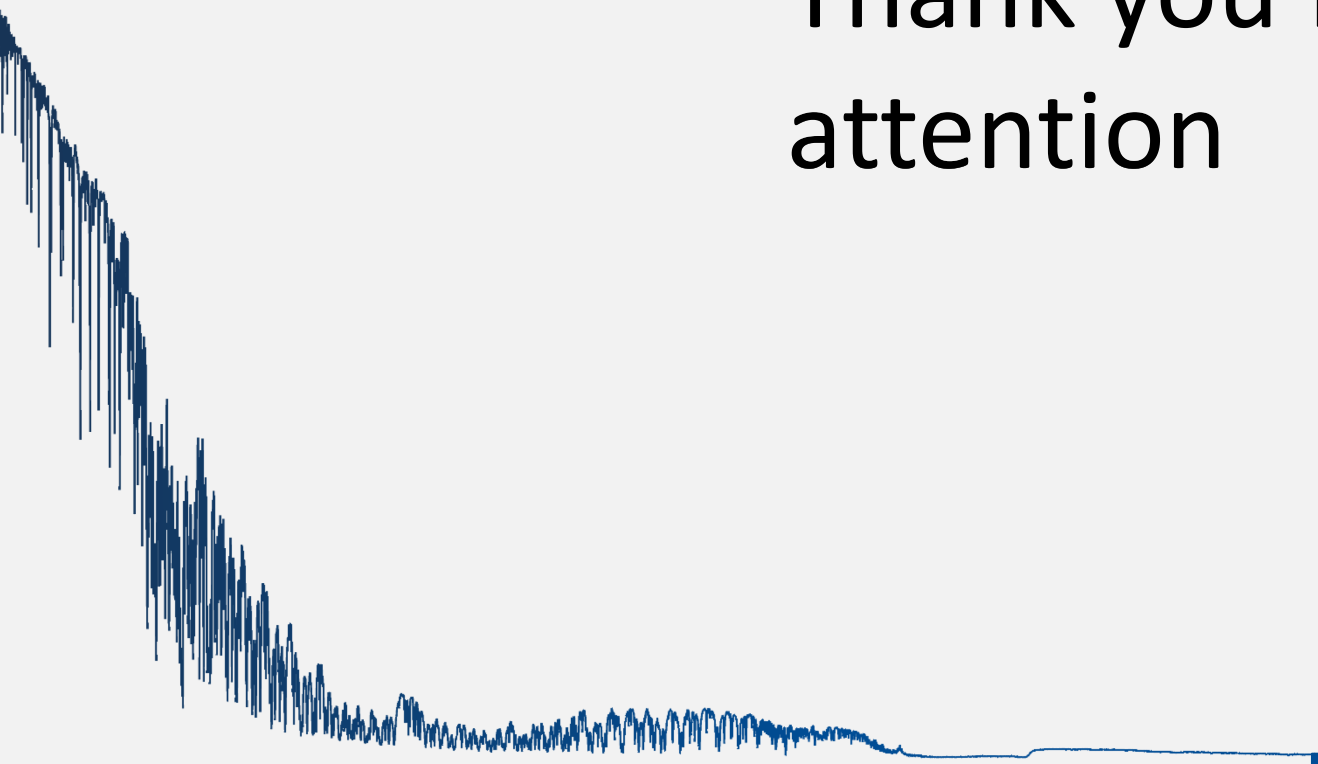
- First validation; good agreement with FTIR ground-based measurement
  - 0.93 overall correlation (all stations)

- IASI global distributions and time series over large time range (2008-2015)
  - First application of a simple multivariable regression model: good results but needs completion through inclusion of other variables

- Co-analysis between O_3 and HNO_3
  - Good visibility of different features in O_3 and HNO_3 time series
  - Needs a more in-depth analysis

➔ Very good instrument for assessing the state of the stratosphere and monitoring the joint behaviours of HNO_3 and O_3

Thank you for your attention



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