

Sentinel-5 Precursor NO₂ and HCHO validation using NDACC and complementary FTIR and UV-Vis DOAS systems (NIDFORVal)

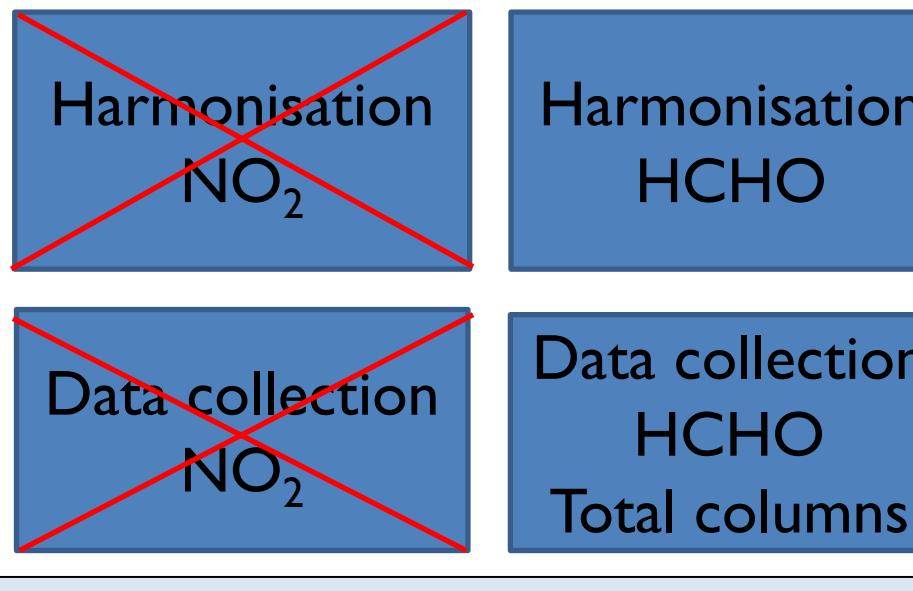
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Belgian Institute for Space Aeronomy, Belgium (BIRA-IASB).



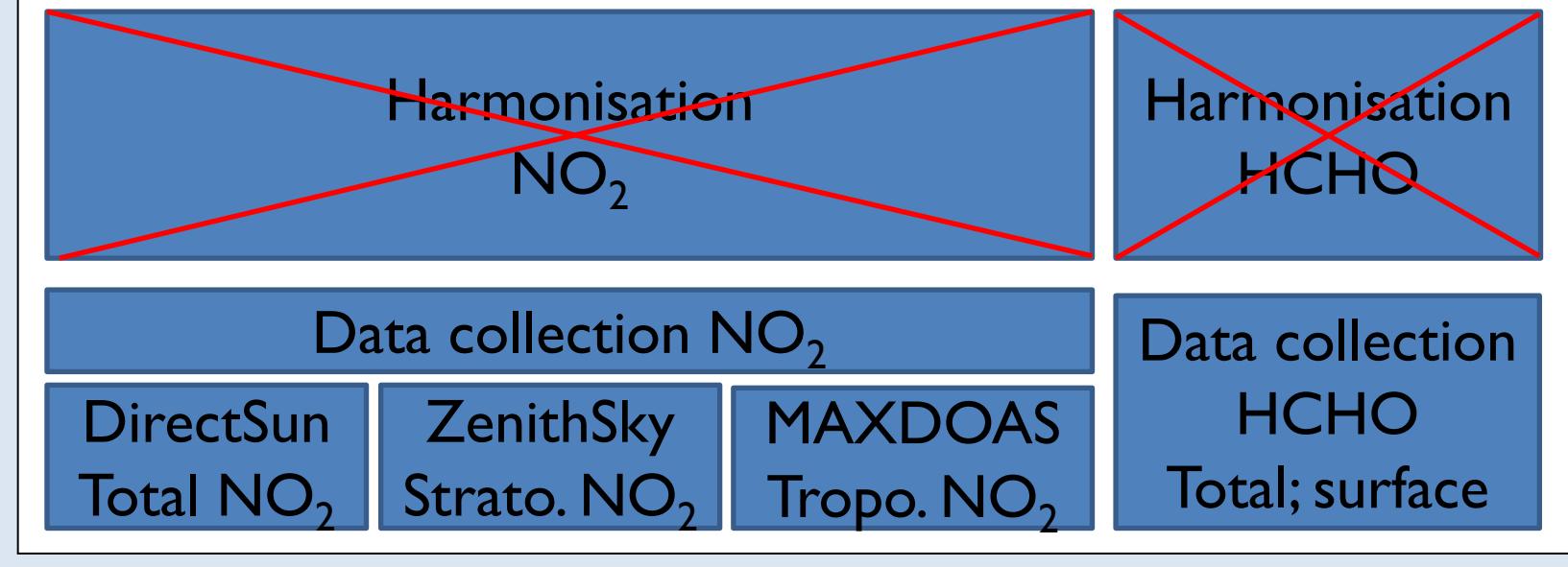
Objectives

- Use two **independent** techniques, Fourier Transform InfraRed (FTIR) and UV-Visible Differential Optical Absorption Spectroscopy (DOAS), to provide data that **fulfill the SSP validation requirements**.

WP1: FTIR time-series



WP2: UV-Vis DOAS time-series



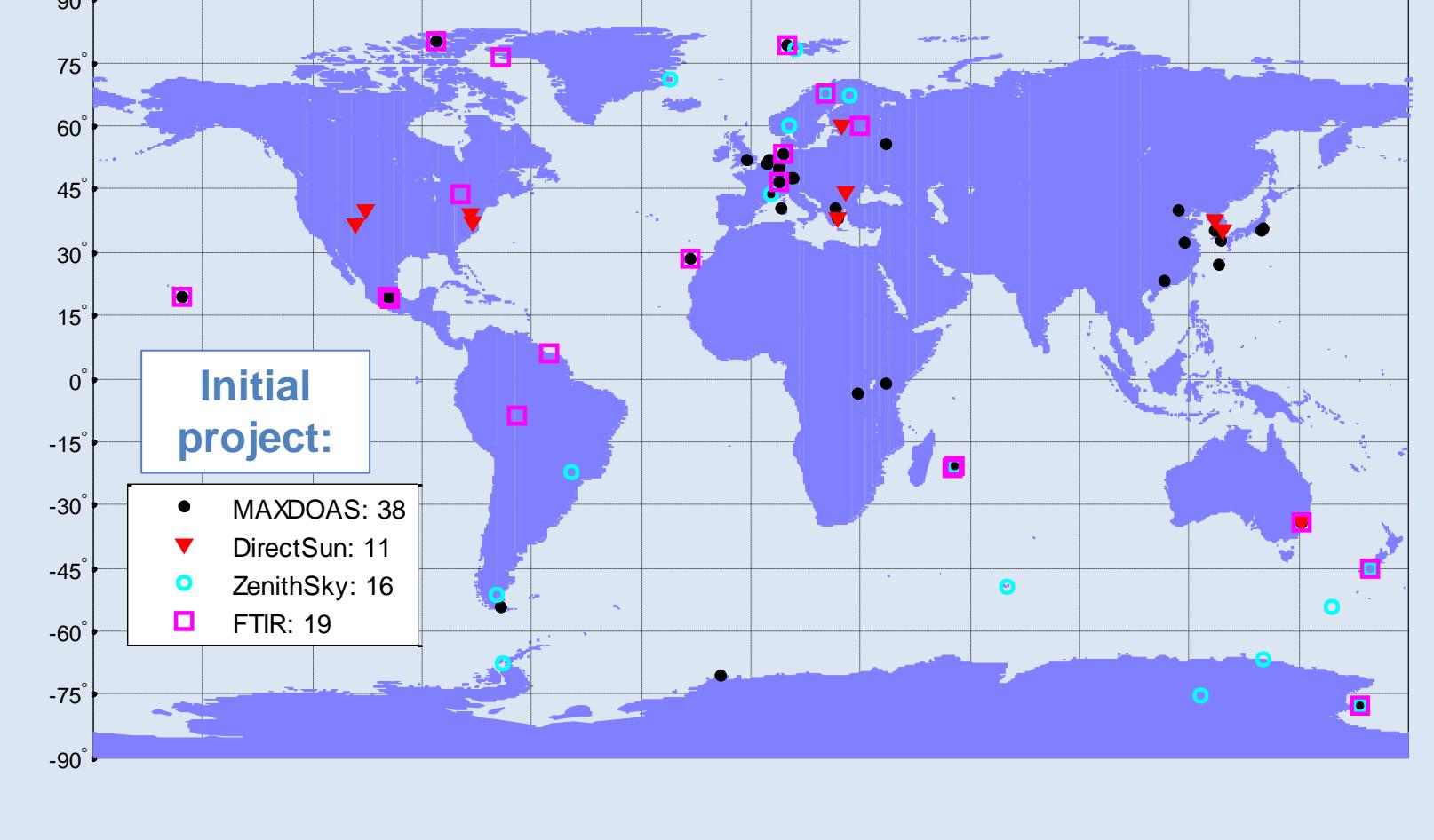
WP3: SSP Validation during Phase E1

First rapid delivery evaluation of SSP data quality

WP4: SSP Validation during Phase E2

SSP data quality; spatial consistency; seasonal cycles; long-term consistency; representativeness.

- WP1 and WP2: Time-series (2016-2023) from **about 80 instruments**, from NDACC (Network for the Detection of Atmospheric Composition Change) and complementary networks or recent infrastructures: **wide range of latitude and pollution conditions**.



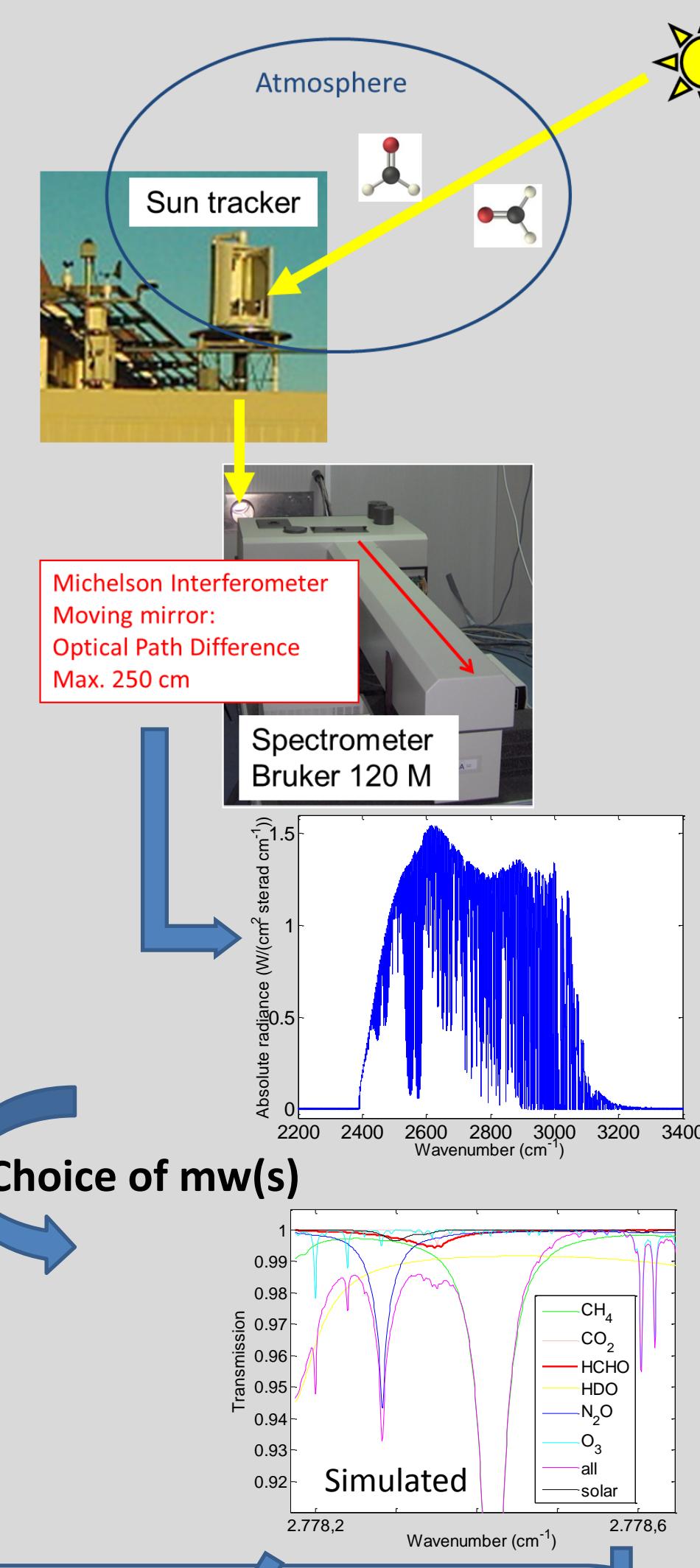
- WP3 and WP4: SSP validation based on the expertise gained at BIRA during precursor projects (Multi-TASTE, O3M-SAF, NORS,...).

WP1: FTIR time-series

- In NDACC: about 15 FTIR sites are archiving data; O₃, HNO₃, HCl, HF, CO, N₂O, CH₄, HCN, C₂H₆ and ClONO₂.
- Currently, **only 4 stations have measured HCHO** (Vigouroux et al., 2009; Jones et al. 2009; Viatte et al., 2014; Franco et al., 2015), using different retrieval strategies and uncertainties estimation.

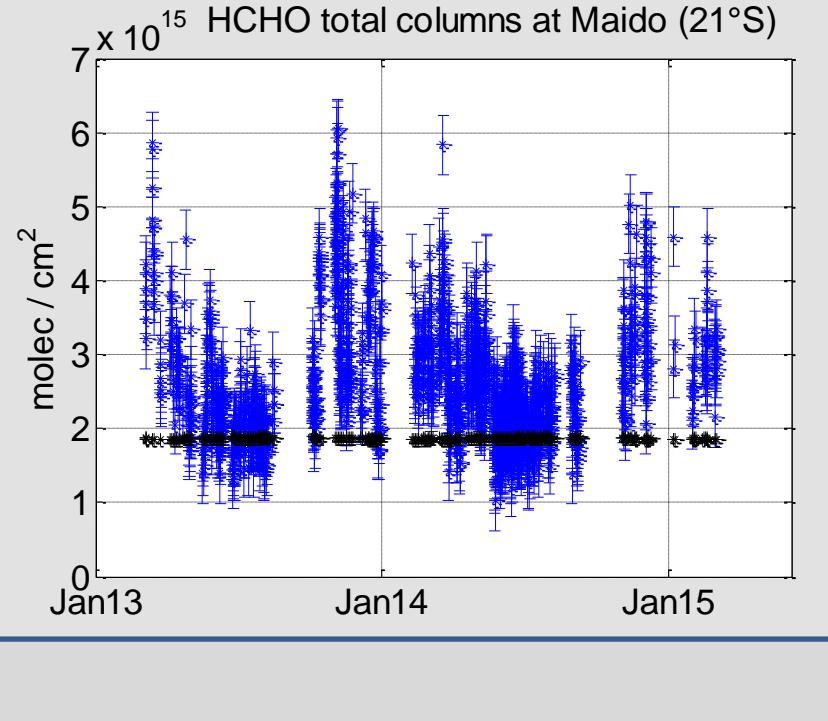
→ In NIDFORVal: define an **harmonized retrieval strategy** for HCHO at NDACC and new FTIR stations.

- Two codes based on **Optimal Estimation** (Rodgers, 2000); SFIT4 (Pougatchev et al., 1995) and PROFITT (Hase, 2000).
- Same spectroscopic database will be used.
- Pressure-temperature profiles from NCEP.
- The choice of spectral micro-windows (mw) will be homogenized.
- The determination of uncertainties will be homogenized.

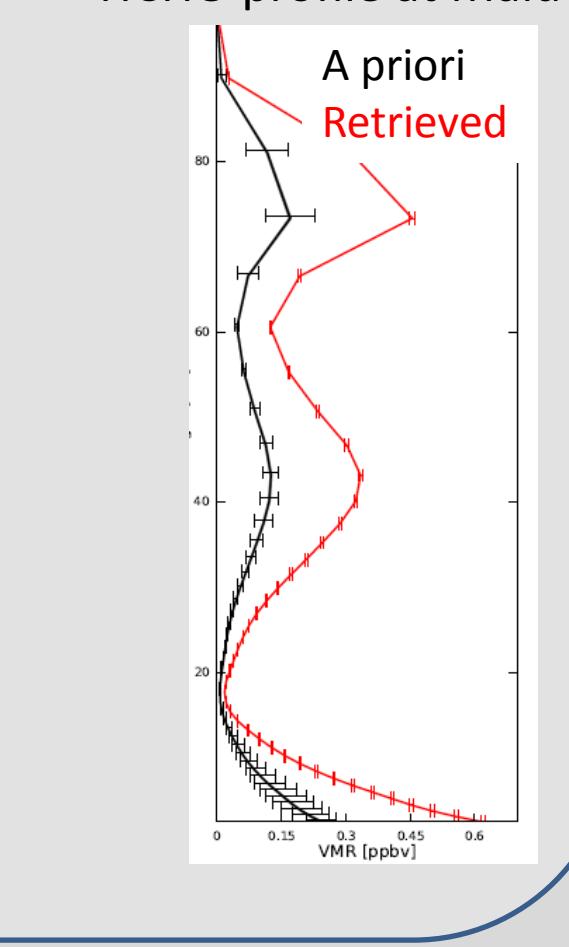


The ground-based FTIR HCHO product

- HCHO FTIR uncertainties:
 - systematic: 10-15%
 - random: 0.4 - 1e15 molec/cm²



- DOFS=1-1.5
- Sensitivity in the troposphere



WP2: UV-Vis DOAS time-series

ZenithSky



Stratospheric NO₂ at twilight

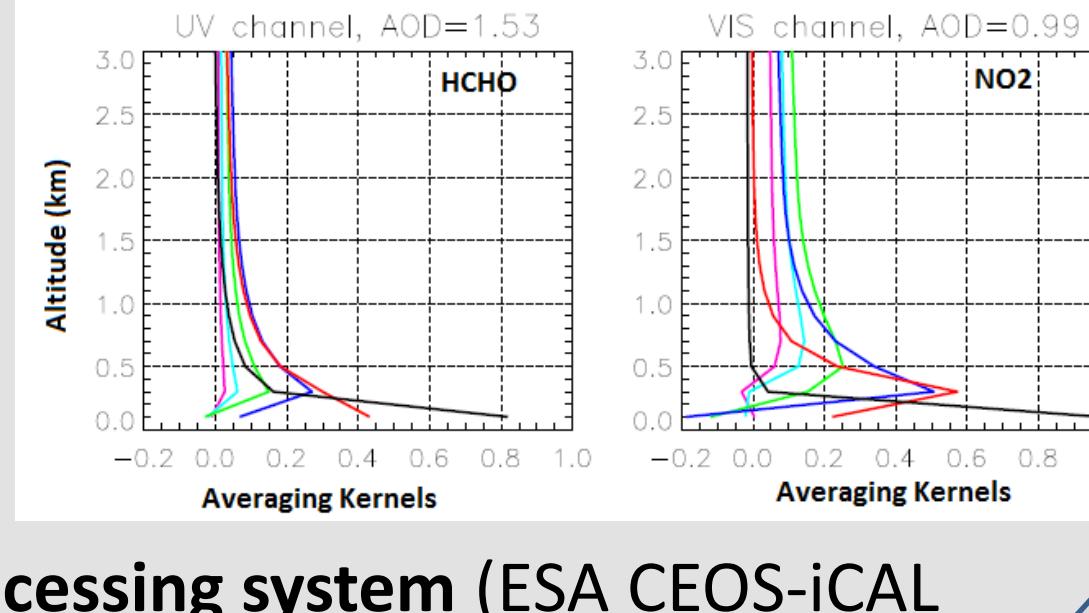
- Effort in NDACC to harmonize VCD retrieval:
 - common SCD retrieval settings
 - provided AMF LUTs
 - discussion on twilight reporting period (and effective SZA)
 - displacement of the effective air-mass location wrt to station coordinates to improve the overall homogeneity of the UV-Vis network (Van Roozendael and Hendrick, 2012; Hendrick et al., 2012).
- NO₂ stratospheric columns uncertainty:
 - Systematic: 11-15%;
 - Random: 0.6e15 molec/cm²

MAXDOAS

National networks in the past decade
e.g., MADRAS (Kanaya et al., 2014), BIRA, BREDEM, Heidelberg, MPIC-Mainz networks, ...

Tropospheric NO₂ and HCHO

- Effort to harmonize retrievals: Roscoe et al. 2010; Pinardi et al., 2013.
- Currently different methods used:
 - Geometrical approach (e.g. Honninger et al., 2004)
 - Optimal estimation (Friess et al., 2006)
 - Parameterization: vertical profile using analytical functions constrained by a few parameters (Irie et al., 2008)
- With inversion methods: **profiles in 0-4 km; DOFS=1.5-3** → tropospheric column + surface concentration + low resolution profile when possible.
- Estimated tropospheric columns uncertainties:**
 - systematic <15% (NO₂); ~20% (HCHO);
 - random : ~30% (NO₂ and HCHO).
- Optional Task: use a demonstration centralized processing system (ESA CEOS-iCAL project, 2014-2016).**



DirectSun



Total NO₂

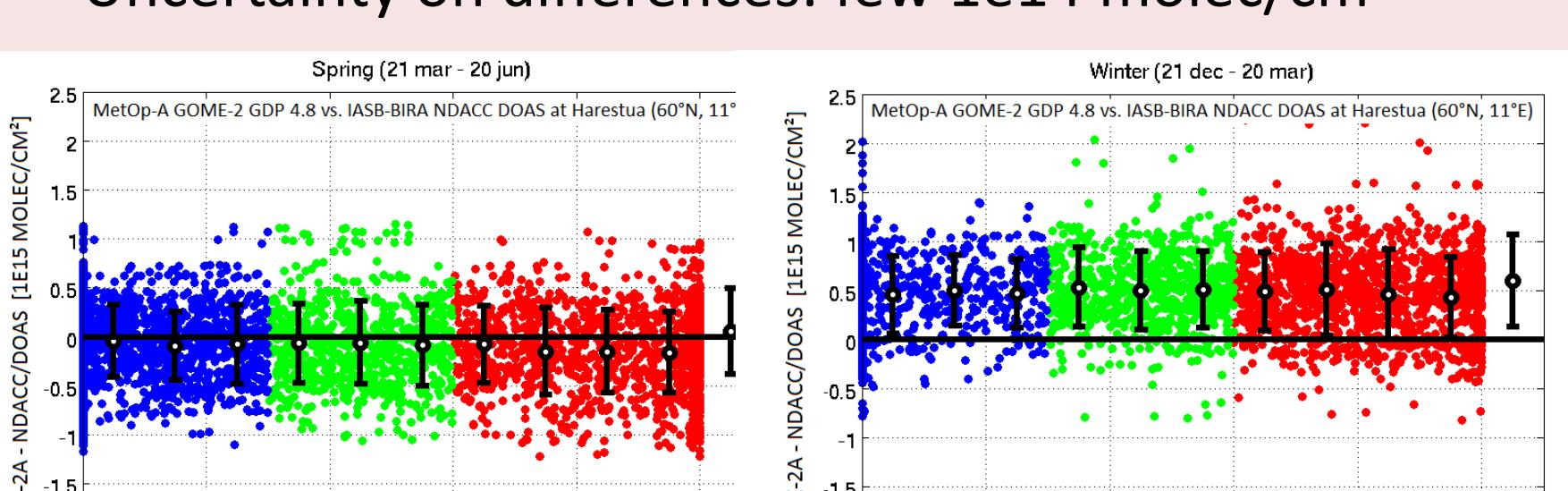
- DirectSun: sensitive to the whole column. Provides accurate total column measurements with a minimum of a-priori assumptions.
- Relies on research instruments and a set of PANDORA instruments (NASA and/or Pandoria network which are harmonized and quality controlled via centralized processing facilities).
- NO₂ total columns uncertainty:
 - Systematic: 10-15%
 - Random: ~2.8e14 molec/cm²

WP3: Validation during Phase E1

- WP3: analysis of the initial SSP data based on a **subset of stations** able to provide data in a **rapid delivery mode**.
- Strong expertise at BIRA in **validation tools**: Multi-TASTE (Hubert et al., 2015; Verhoest et al., 2015), O3M-SAF CDOP (<http://cdop.aeronomie.be/>) and NORS (<http://nors.aeronomie.be/>) projects.

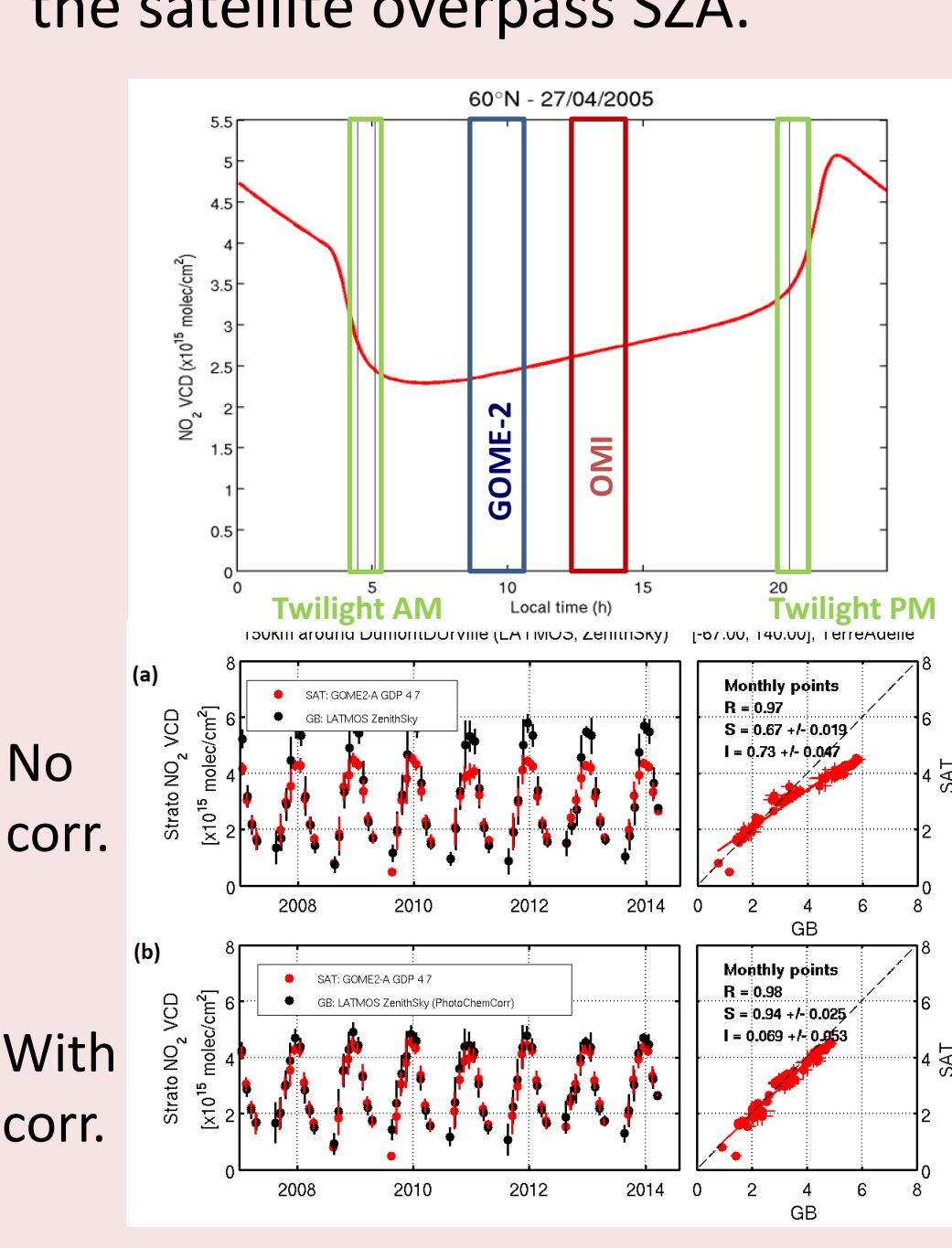
Validation of NO₂ GOME-2 with Zenith-Sky DOAS

- Multi-TASTE versatile validation system: importance of colocation and of photochemistry correction.
- Uncertainty on differences: few 1e14 molec/cm²



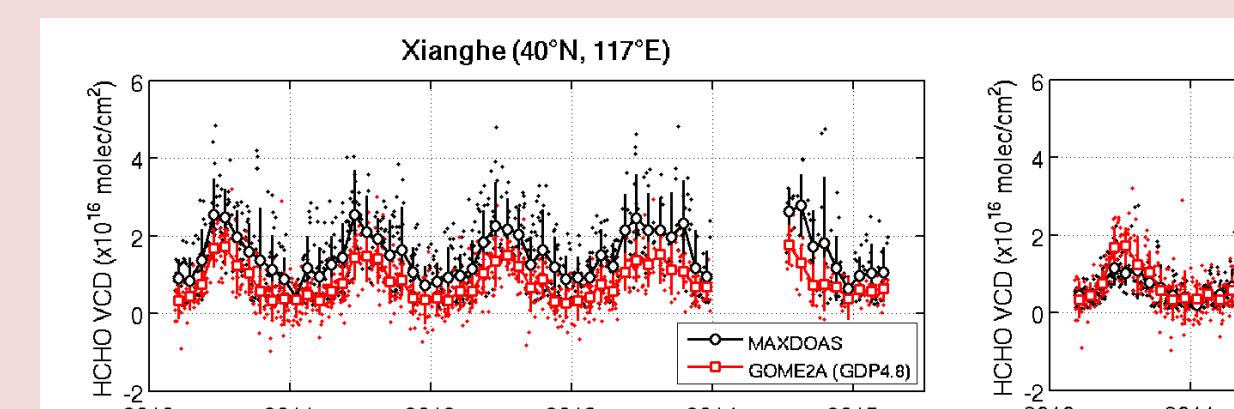
Photochemical correction to take into account NO₂ diurnal cycle

Ex: Zenith-Sky VCDs are photochemically converted to the satellite overpass SZA.

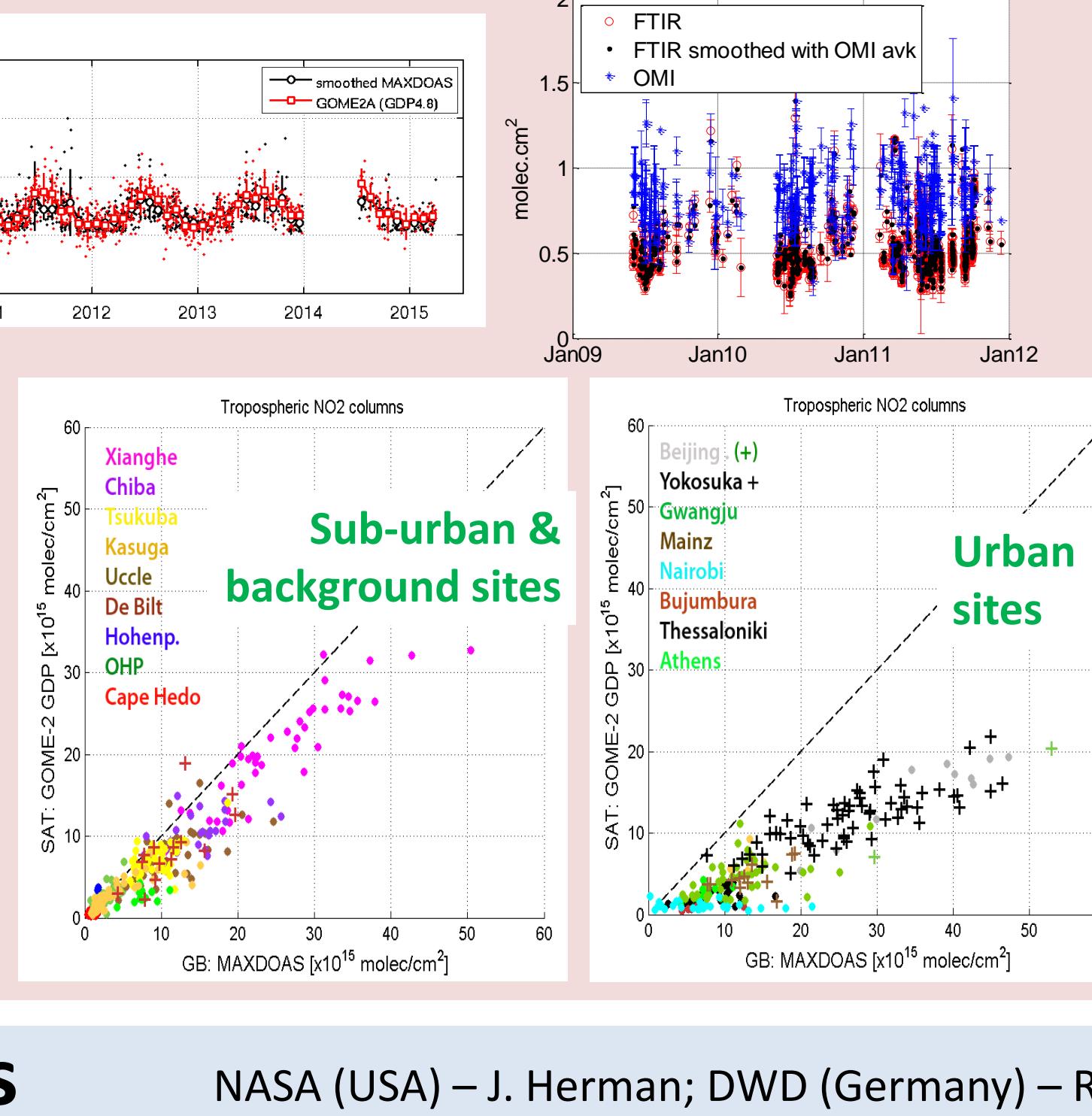


WP4: Validation during Phase E2 (2016-2023)

- Validate the **seasonal cycles** and the **long-term stability** of SSP products by building tools for drift calculation (e.g. Hubert et al., 2015).
- Perform **FTIR / DOAS comparisons** where both techniques are available: quality control & use the different sensitivities of both techniques to explain differences in validation results. E.g. the smoothing of MAXDOAS data with the satellite averaging kernel will have a bigger impact than for the FTIR data, due to the MAXDOAS sensitivity at the surface.



- Study **representativeness of the sampled air masses for SSP 7x7km² resolution**: e.g. GOME-2 (40x80km²) tropospheric NO₂ validation with MAXDOAS urban/background sites.



- The colocation criteria takes into account the line of sight of ground-based data:
- At each station: **statistical bias and standard deviations of the differences** between SSP and correlative data will be compared to the uncertainties budget of the differences. The deliverable will be provided **6 months after the SSP launch**.

FTIR (10)

IMK-ASF, KIT (Karlsruhe) – T. Blumenstock; IARC/AEMET (Spain) – O. García; UNAM (Mexico) – M. Grutter; UCAR (USA) – J. Hannigan; University of Wollongong (Australia) – N. Jones; University of Liège (Belgium) – E. Mahieu; Saint-Petersburg University (Russia) – M. Makarova; IUP-Bremen (Germany) – J. Notbold; NIWA (New Zealand) – J. Robinson, D. Smale; University of Toronto (Canada) – K. Strong

UV-Vis DOAS (25)

AUTH (Greece) – A. Bais; LufBlick (Austria) – A. Cede; GIST (Korea) – J. Chong; BAS (UK) – S. Colwell; IUP-Heidelberg (Germany) – U. Friess; INTA (Spain) – M. Yela Gonzalez, O. Puentedura; DLR (Germany) – N. Hao;

Partners

NASA (USA) – J. Herman; DWD (Germany) – R. Holla; FMI (Finland) – J. Hovila; Chiba University (Japan) – H. Irie; JAMSTEC (Japan) – Y. Kanaya ; IERSD-NOA (Greece) – S. Kazadzis; University of Leicester (UK) – R. Leigh; INOE (Romania) – A. Nemuc; LATMOS (France) – A. Pazmino, J.-P. Pommereau; KNMI (The Netherlands) – A. Piters; IAP/RAS (Russia) – O. Postolyakov; NIWA (New Zealand) – R. Querel; IUP-Bremen (Germany) – A. Richter, F. Wittrock; NILU (Norway) – K. Stebel; University of Toronto (Canada) – K. Strong; University of Colorado (USA), R. Volkamer; University of Wollongong (Australia) – S. Wilson; MPI-Mainz (Germany) – T. Wagner