Sentinel-5 Precursor NO_2 and HCHO validation using NDACC and complementary FTIR and UV-Vis DOAS systems (NIDFORVal)

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Objectives

- Use two **independent** techniques, Fourier Transform InfraRed (**FTIR**) and UV-Visible Differential Optical Absorption Spectroscopy (**DOAS**), to provide data that **fulfill the S5P validation requirements.**

WP1: FTIR time-series
- Harmonisation HCHO
- Data collection HCHO Total columns

WP2: UV-Vis DOAS time-series
- Data collection NO_2
- **DirectSun** Total NO_2
- **ZenithSky** Strato. NO_2
- **MAXDOAS** Tropo. NO_2 (surface)
- Data collection HCHO
- **MAXDOAS** Total (surface)

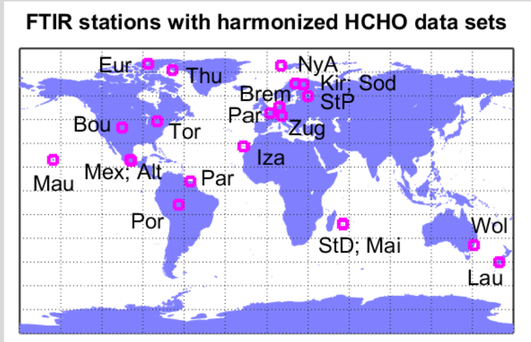
WP3: S5P Validation during Phase E1
- First evaluation of S5P data quality

WP4: S5P Validation during Phase E2
- S5P data quality; spatial consistency; seasonal cycles; long-term consistency; representativeness.

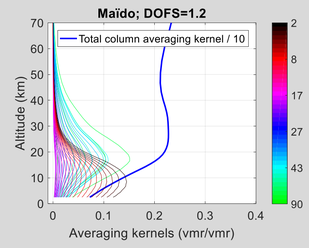
WP1: FTIR HCHO total columns

Retrievals settings have been harmonized at 21 FTIR stations.

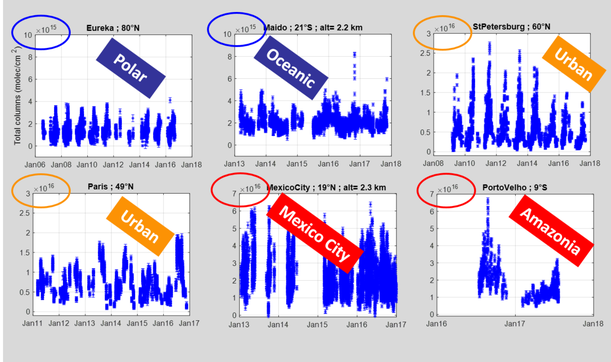
- More details in **Vigouroux et al., submitted AMT, 2018.**
- Systematic uncertainty: 11 to 31% (median 14%)
- Random uncertainty: 1 to 11x10^{14} molec/cm^2 (median 2.6x10^{14})



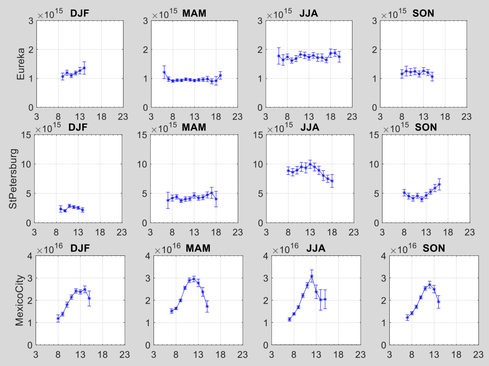
Degrees of freedom for signal ~ 1: total columns, with sentitivity in the whole troposphere.



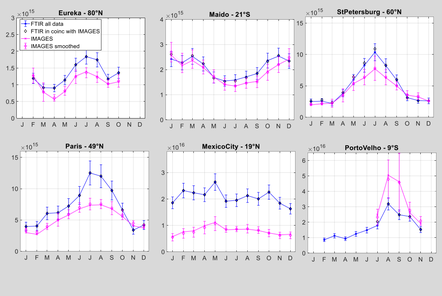
Time-series at clean & polluted sites



Diurnal cycles



Seasonal cycles & model comparisons

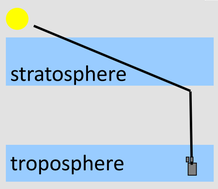


- This new FTIR HCHO harmonized data set can now be used for past and present satellite validation.
- Data providers will update their time-series for TROPOMI validation.
- New sites might join in the future (e.g. Hefei, China; Jungfraujoch, Switzerland)

WP2: UV-Vis DOAS time-series

No founding for harmonization, but best-effort basis on geometry-specific state-of-the-art recommendations for retrieval strategies and reporting (pushing to GEOMS hdf).

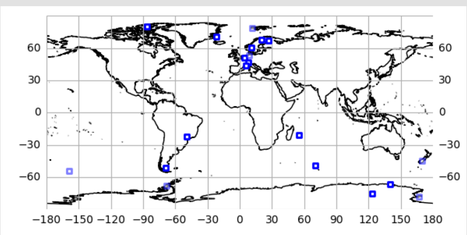
ZenithSky



NDACC network since '90

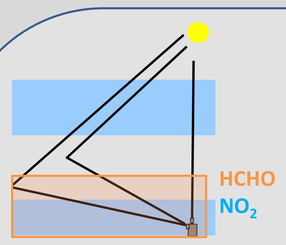
Stratospheric NO_2 at twilight

- **Harmonization**: effort in UV-Vis NDACC network (Van Roozendael and Hendrick, 2012; Hendrick et al., 2012).
- **NO_2 stratospheric columns uncertainty:**
  - Systematic: 11-15%;
  - Random: 0.6e15 molec/cm^2



34 instruments

MAXDOAS



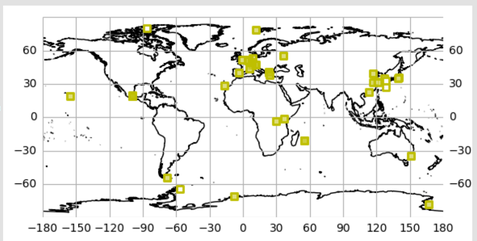
National networks in the past decade e.g., MADRAS (Kanaya et al., 2014), BIRA, BREDOM, Heidelberg, MPIC-Mainz, ChibaU networks, ...

Tropospheric NO_2 and HCHO

- **Harmonization**: efforts in QA_4ECV & CINDI projects for SCD (Peters et al. 2017; Pinardi et al., 2013). Currently different retrieval strategies for tropospheric VCD: **Geometrical/AMF LUT approach** (QA_4ECV outcome), **Optimal estimation based profiling** (Friess et al., 2006; Clémer et al., 2010), **Parameterization**: vertical profile using analytical functions constrained by a few parameters (Kanaya et al., 2014; Irie et al., 2008).
- **Estimated tropospheric columns uncertainties:**
  - systematic <15% (NO_2); ~20% (HCHO);
  - random : ~30% (NO_2 and HCHO).

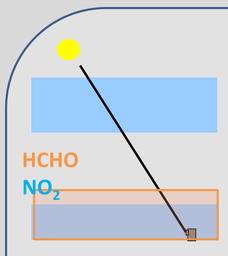
Some stations: low resolution **profiles in 0-4 km**; DOFS=1.5-3 (tropospheric column + surface concentration)

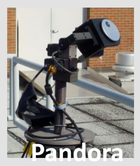
54 instruments (40 for HCHO)



- **Future Task: use outcome of the demonstration centralized processing system** (ESA FRM_4DOAS project) to go one step further on retrieval harmonization.

DirectSun

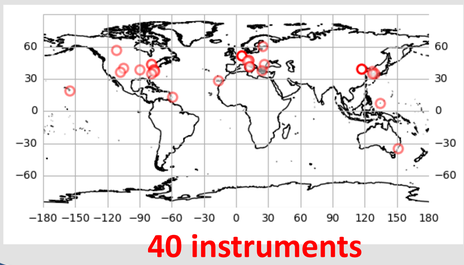




Pandora (NASA & pandonia) network in the past years

Total NO_2

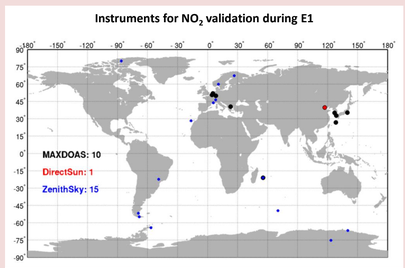
- **Harmonization**: a few research instruments but mostly harmonized PANDORA instruments (NASA and Pandonia networks - centralized processing facilities).
- **NO_2 total columns uncertainty:**
  - Systematic: 10-15%
  - Random: ~2.8e14 molec/cm^2

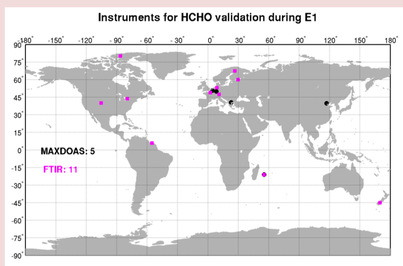


40 instruments

WP3: Validation during Phase E1

- Total of **~40 instruments** interested in the E1 NO_2 and HCHO validation. Already 24 data streams today (covering Nov/Dec 2017):

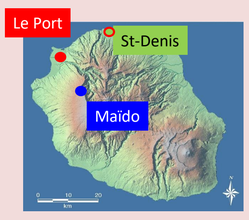


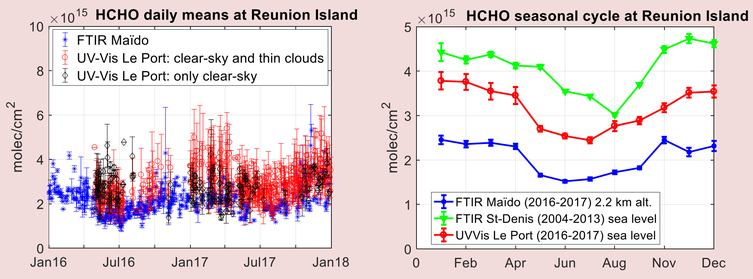


Plan for data collection:
- UV-vis: Jan for Oct/Dec 2017 and Mid March for Jan/Feb
- FTIR: Mid March for Nov → Feb (11 stations)

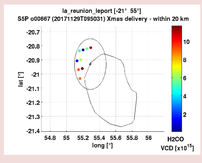
} Results will be presented at EGU

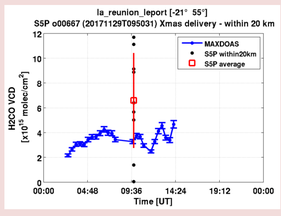
- **HCHO: 3 sites at Reunion Island, 2 for TROPOMI validation:**
  - Maïdo: FTIR total columns at 2.2 km altitude
  - Le Port: MAXDOAS tropospheric columns at sea level
  - St-Denis: 2004-2013 FTIR time-series

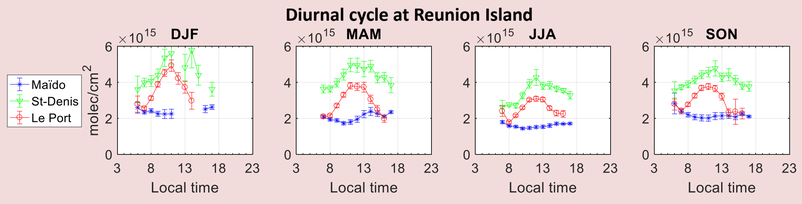




Comparison with TROPOMI Xmas delivery:



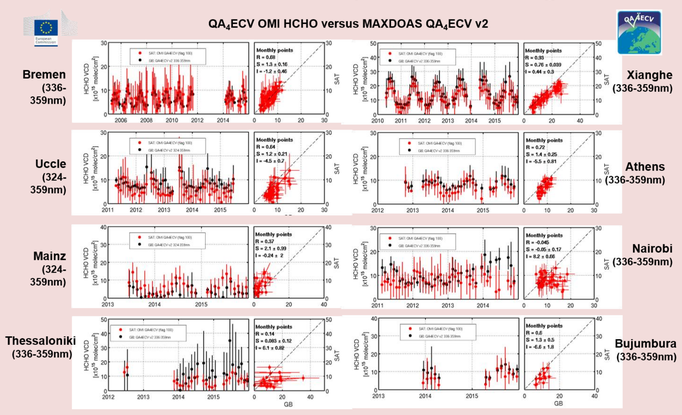




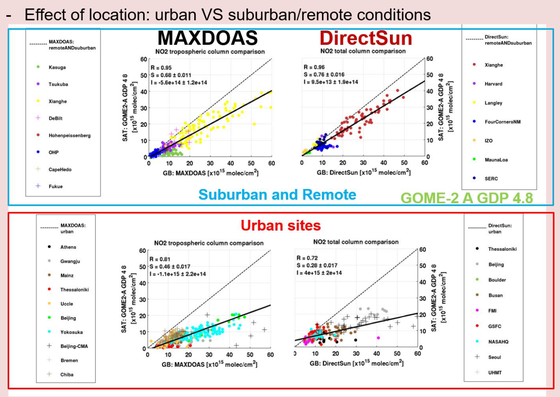
WP4: Validation during Phase E2

Total of **91 stations** (**118 instruments**) involved for the long term NO_2 and HCHO validation.

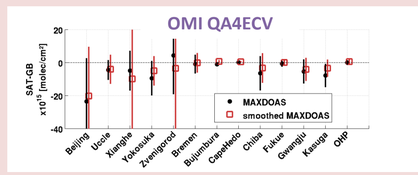
Goals: Assessment of S5P data quality; validation of seas. cycles and long-term stability; study of the sampled air masses at 2,5x7km² resolution (urban VS background sites)



- Effect of location: urban VS suburban/remote conditions



- Effect of the satellite **a-priori profiles**: impact on (SAT-GB) bias



Partners

FTIR (12)
IMK-ASF, KIT (Germany)– T. Blumenstock; IARC/AEMET (Spain) – O. García; UNAM (Mexico) – M. Grutter; UCAR (USA) – J. Hannigan; University of Wollongong (Australia) – N. Jones; FMI (Finland) – R. Kivi; Saint-Petersburg University (Russia) – M. Makarova; IUP-Bremen (Germany) – J. Notholt; NIWA (New-Zealand) – J. Robinson, D. Smale; University of Toronto (Canada) – K. Strong; IMK-IFU (Germany) – R. Sussmann; ERMA-IPSL (France) – Y. Té

UV-Vis DOAS (29)
AUTH (Greece) – A. Bais; AEMET (Spain) – A. Redondas; LufBlick (Austria) – A. Cede; GIST (Korea) – J. Chong; BAS (UK) – S. Colwell; IUP-Heidelberg (Germany) – U. Friess; INTA (Spain) – M. Yela, O. Puentedura; DLR (Germany) – N. Hao; 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. Postylyakov; NIWA (New Zealand) – R. Querel; IUP-Bremen (Germany) – A. Richter, F. Wittrock; NILU (Norway) – K. Stebel; UNAM (Mexico) – M. Grutter; USTC Hefei (China) – C. Liu ; University of Alaska (Canada) – W. Simpson; University of Toronto (Canada) – K. Strong; University of Colorado (USA), R. Volkamer; University of Wollongong (Australia) – S. Wilson; MPI-Mainz (Germany) – T. Wagner