Metamorphoses

Metadata for the merging of diverse atmospheric data on common subspaces

Objective:

- Develop standards for storage efficient decomposed arrays (important for satellite data reuse!)
- Satellite data fusion (synergetic combination of different satellite sensors)
- Data merging according to Lagrange trajectories (inter-connection of observations on Lagrange subspace)
- Short case study with atmospheric methane (document the scientific impact of the project)

Team:

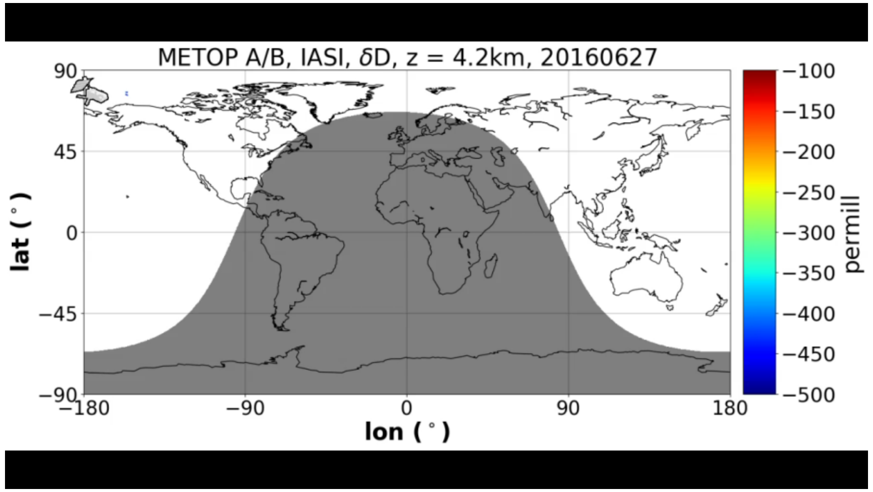
Karlsruhe Institute of Technology,
Institute of Meteorology and Climate Research (IMK-ASF):

- Matthias Schneider
- NN (Postdoc or PHD Student in the field of satellite data fusion)
- Benjamin Ertl
- Peter Braesicke

Forschungszentrum Jülich,
Institut für Energie- und Klimaforschung, Stratosphäre (IEK-7):

- Rolf Müller
- Gebhard Günther
- NN

Standards for storage efficient decomposed arrays (important for satellite data reuse!)



≈ 300000 morning observations per day (local time 9:30)

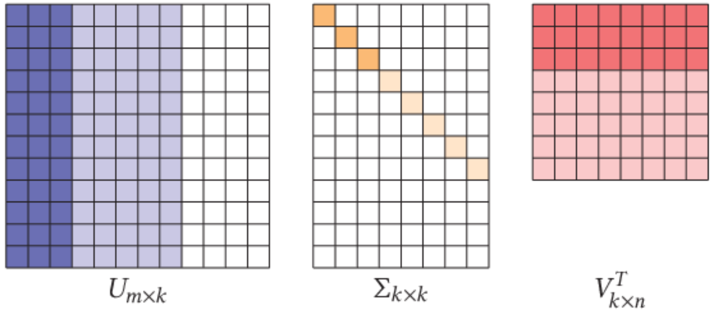
≈ 300000 evening observations per day (local time 21:30)

In the meanwhile three satellites, i.e. about 1 million observations each 24h, even more with new satellite generations…

For each observation:

- Atmospheric states (profile in form of a vector, dimension *n*)
- Characterisation of the atmospheric state (arrays, dimension *n* x *n*):

  Singular vector decomposition: $A = UDV^T$



Decomposed, storage efficient array:

- Rank
- Diagonal values
- Left eigenvectors
- Right eigenvectors

Example of synergetic effects by data fusion (combination of data from different satellite sensors):

Synergetic use of IASI and TROPOMI for generating a tropospheric methane profile product

Matthias Schneider[1], Benjamin Ertl[1,2], Christopher Diekmann[1], Farahnaz Khosrawi[1], Amelie N. Röhling[1], Frank Hase[1] , Darko Dubravica[1], Omaira E. García[3], Eliezer Sepúlveda[3], Alba Lorente[4], Jochen Landgraf[4], Huilin Chen[5], Rigel Kivi[6], Thomas Laemmel[7], Michel Ramonet[7], Cyril Crevoisier[8], Jerome Pernin[8], Martin Steinbacher[9], Frank Meinhardt[10], Voltaire A. Velazco[11], Nicholas M. Deutscher[12], David Griffith[12], Dave Pollard[13], Hartmut Bösch[14], Tim Trent[14], Harald Sodemann[15]

1: Introduction + theoretical background

Measurements from different satellite-based sensors offer different sensitivities. Here, we propose a synergetic exploitation that uses L2 outputs generated by the standard retrievals of the different sensors (optimal a posteriori combination of individual retrieval products). The motivation is to have a computationally very efficient method, applicable to large data volumes.

Data assimilation formalism:

$x^a = x^b + \mathbf{G}[y - \mathbf{H}x^b]$

$\mathbf{G} = \mathbf{S}^b\mathbf{H}^T[\mathbf{H}\mathbf{S}^b\mathbf{H}^T + \mathbf{S}_\varepsilon]^{-1}$

Level 2 output as input

x^b: background state vector
→ **MUSICA IASI profile product**

$\mathbf{S}^b$: background state error covariances
→ **MUSICA IASI a posteriori covariances**

y: measurement state vector
→ **TROPOMI total column product**

$\mathbf{H}$: measurement forward operator
→ **TROPOMI total column kernel**

$\mathbf{S}_\varepsilon$: measurement state error covariances
→ **TROPOMI total column noise**

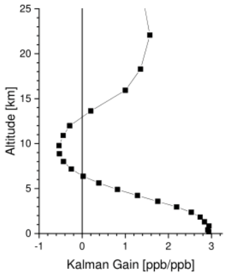
Output:

x^a: analysed state vector

$\mathbf{G}$: Kalman gain matrix

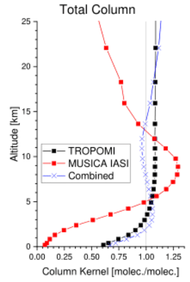
For linear and "moderately non-linear" problems and adjusted IASI and TROPOMI a priori information, this analysed state vector (x^a) is mathematically equivalent to an optimal estimation retrieval that uses a combined {IASI,TROPOMI} measurement state vector.

Kalman gain (**G**):

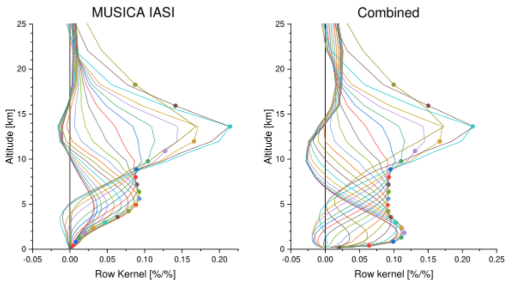


2: Theoretical performance

Column kernel:

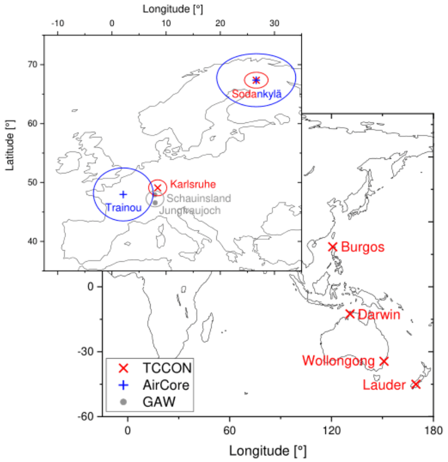


Profile kernels:

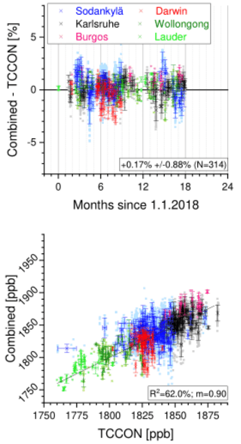


3: Validation

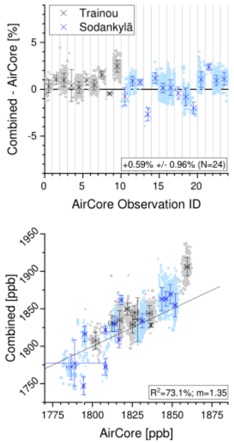
Reference sites:



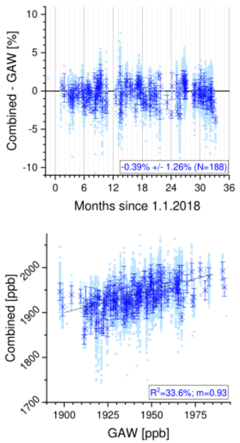
TCCON: total column



AirCore: UTLS



GAW: troposphere

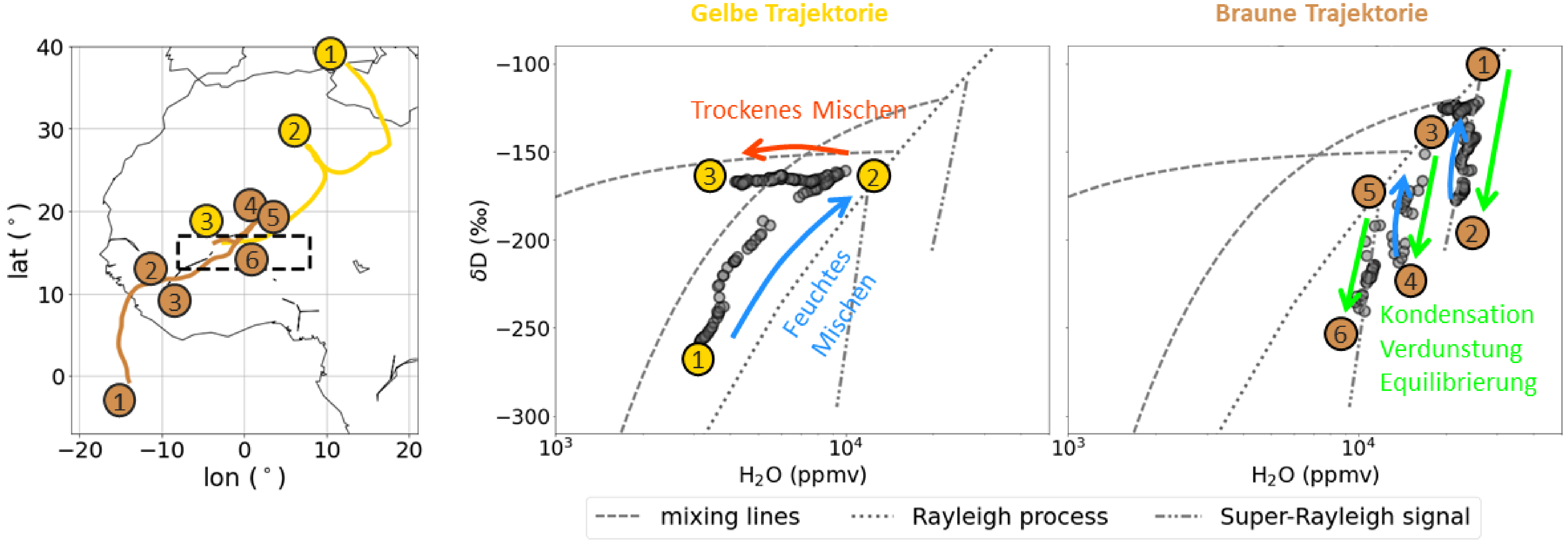


4: Summary + outlook

- TROPOMI: good for XCH_4
- IASI: good for CH_4 in the UTLS
- IASI+TROPOMI: good for XCH_4, CH_4 in the UTLS, and CH_4 in the troposphere!
- Theoretical uncertainty of profile data: ≈1%
- Scatter wrt validation references: 1-1.5%
- IASI and TROPOMI successors will be together on the Metop Second Generation satellites, perfect for spatial collocation, very promising!
- Applicable to other products, e.g. isotopologue ratios (δD)
- More details on the paper at AMTD: https://amt.copernicus.org/preprints/amt-2021-31/

Example of studies on Lagrange trajectories (here atmospheric water vapour isotopologue model data):

H_2O und δD entlang von Luftmassenbewegung



Identifikation von Feuchteprozessen entlang von Trajektorien:
Diekmann et al., 2021c

Link to HMC and expectations:

- The project will improve satellite data reuse, i.e. make the satellite data FAIRer
- The project will improve the possibilities for interpreting satellite data (in a Lagrange subspace)
- Data merging/fusion is important in many research fields, we can share experiences/ideas with others…
- Better understand the importance and potential of metadata for research
- We hope to get support from HMC, for instance for: registering/establishing standards, search for trajectory standards, …
- …

Thanks!