Feature level Data Fusion for enhancing the spatiotemporal resolution of Copernicus Sentinel products

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Outline

- Motivation
- Characteristics of Copernicus WV products
- Approach
- First results
- Outlook

Motivation

Source: ESA

Motivation

- Different Copernicus Sentinel missions launched
- Optical / radar sensors, covering multiple thematic domains
- Earth as complex system with interconnected geo-informational characteristics
- Overlapping information space, similar data products
- Significant differences
  - Spatial resolution
  - Temporal resolution
  - Spectral coverage
  - Different retrieval algorithms

- **→ Synergies when combining complementary products into a new, enhanced information product**

Characteristics of Copernicus WV products

- **Water Vapour (WV)**
  - Important Greenhous Gas
  - Absorbing thermal infrared radiation
- **WV products from S3 / S5P**
  - Same feature (total water vapour column)
  - Different spatio-temporal and spectral/radiometric resolution
  - Different bands and algorithms used for retrieval

	Sentinel-3	**Sentinel-5P**
Instrument	OLCI	TROPOMI
Revisit time	< 2 days for S3A and S3B	daily
Spatial resolution	RR: 1.2 x 1.2 km (FR: 300m x 300m)	5.5 x 3.5 km
Water Vapour Variable	IWV	total_column_water_vapor
Description	Integrated water vapour column above the current pixel	Total vertical column of water vapor
Unit	kg/m^2	kg/m^2
Band for Water vapour retrieval	NIR: Oa18 (885 nm), Oa19 (900 nm)	Blue band (435 – 455 nm)
Local equatorial overpass time	10:00h	13:30h

Approach (Preprocessing)

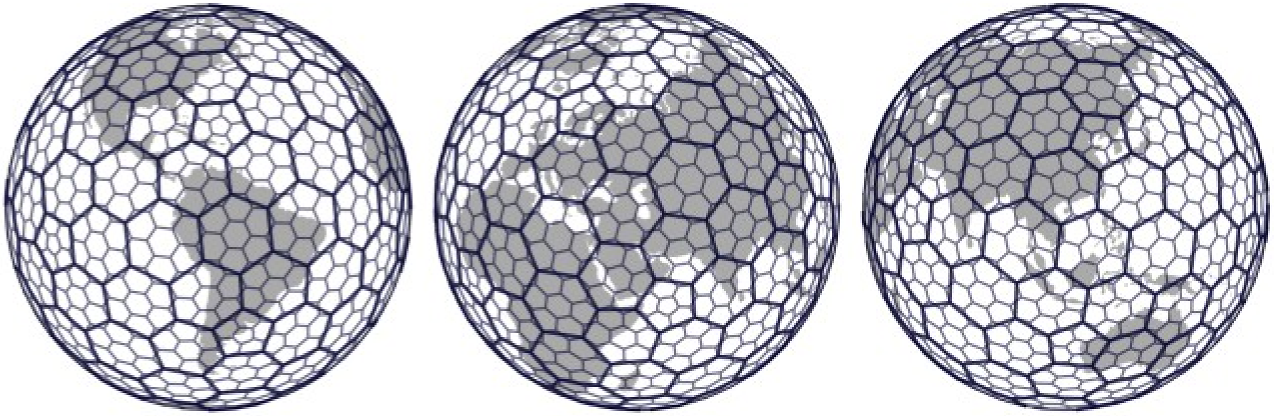
- **Data matching**
  - Detection of cloudfree pairs of S3 / S5P images with overlapping geographical coverage and close acquisition times

- **Data download and consolidation**
  - Download from Scihub (S3) and DLR internal S5P data hub
  - Consolidation of separated S3 files (geographic coordinates and water vapour retrievals) into a single netCDF file

- **Discrete Global Grid System (DGGS)**
  - Transform all S3/S5P data into to a uniform, standardised 2D grid with fixed locations

Approach (Preprocessing)

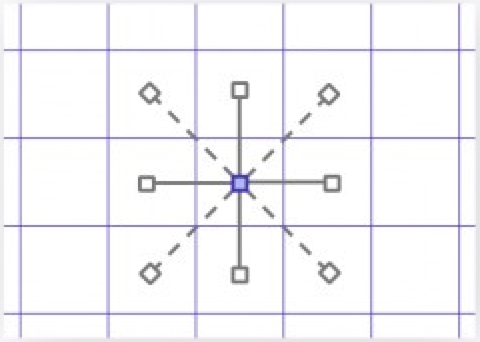
- **H3: Hexagonal Hierarchical Spatial Index**
  - Developed by Uber, open sourced on GitHub
  - Combination of **hexagonal global grid system** with **hierarchical indexing system**
  - H3 is used to transform all S3/S5P data into a hierarchical spatial index
  - Fixed grid with pre-defined locations allows for easy combination of all types of spatial data (remote sensing, in-situ measurements, social media)
  - Hierarchical index enables integration of spatial data with different resolutions
  - Hierarchical index allows for up- and downscaling (interpolated)
  - 16 resolutions, down to square meter

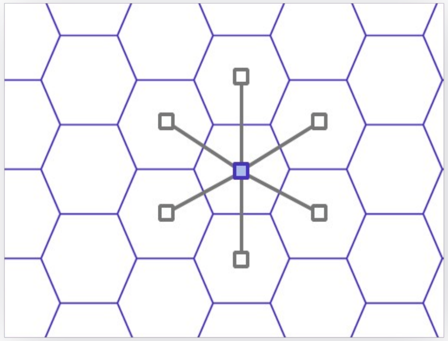


H3 Hierarchical hexagonal global grid system (source: Uber)

Approach (Preprocessing)

- **H3: Hexagonal Hierarchical Spatial Index**
  - Hexagonal areas have a certain characteristic: all distances between a cell and its six neighbours have the same length
  - This equidistance allows for easier application of algorithms like convolutions and data smoothing
  - Advantage to rectangular grids, where the geographical distance needs to be considered
  - Also enables enhanced movement analysis and model flow

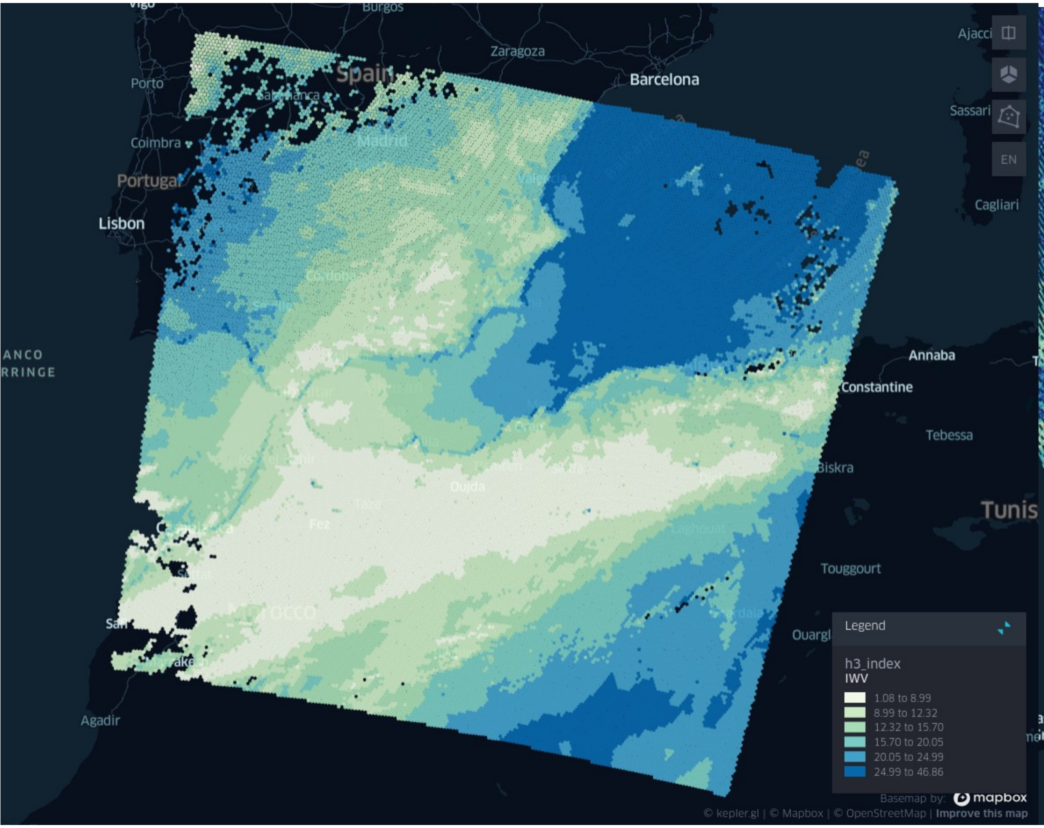


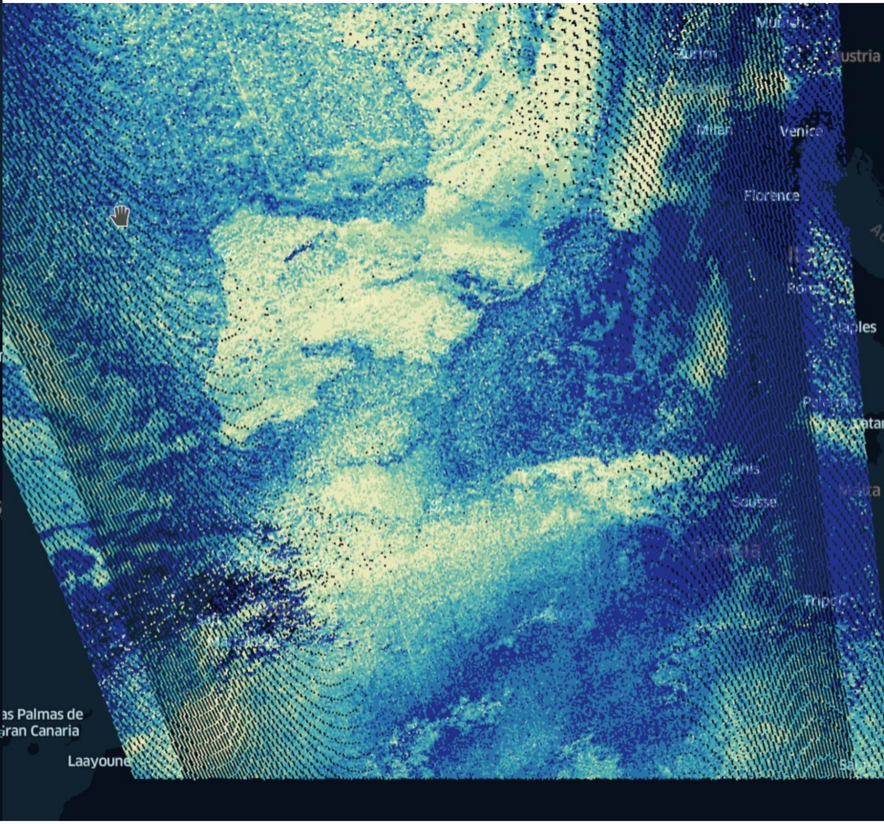


Distances between neighbor cells in square grid (left) and in hexagonal grid (right) (source: Uber)

Approach

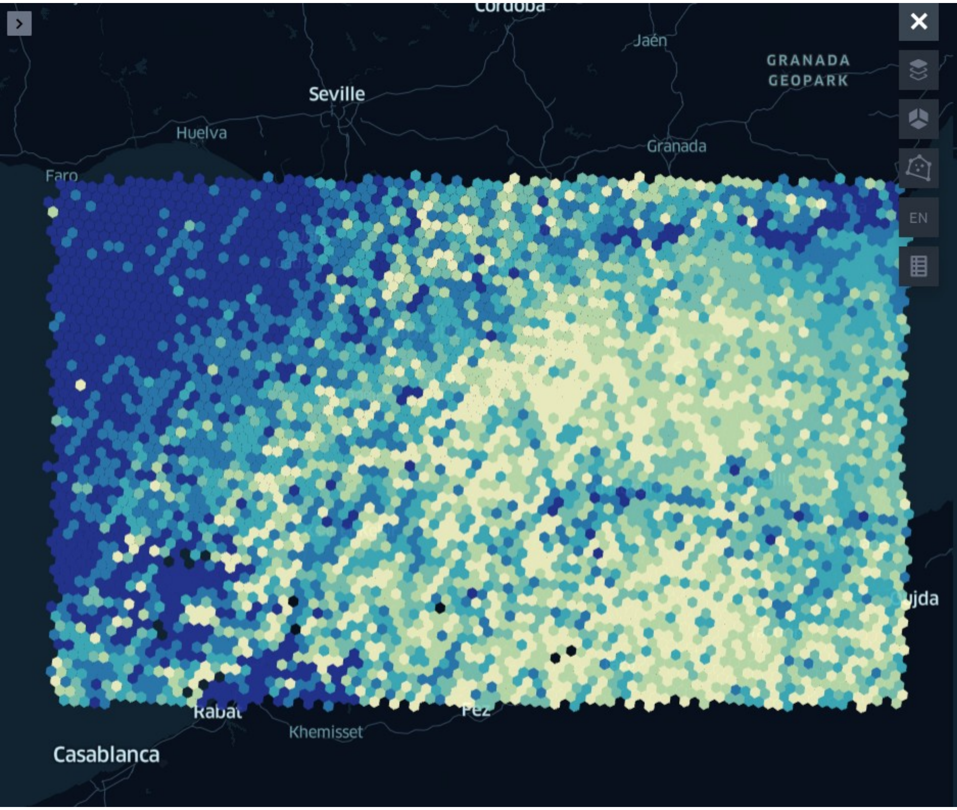
- A pair of S3/S5P water vapour products with high resolution (interpolated for S5P) and similar / close timestamps (2021-05-24 10:16 – 10:19 for S3, 2021-05-24 for S5P)
- All data on the same H3 grid

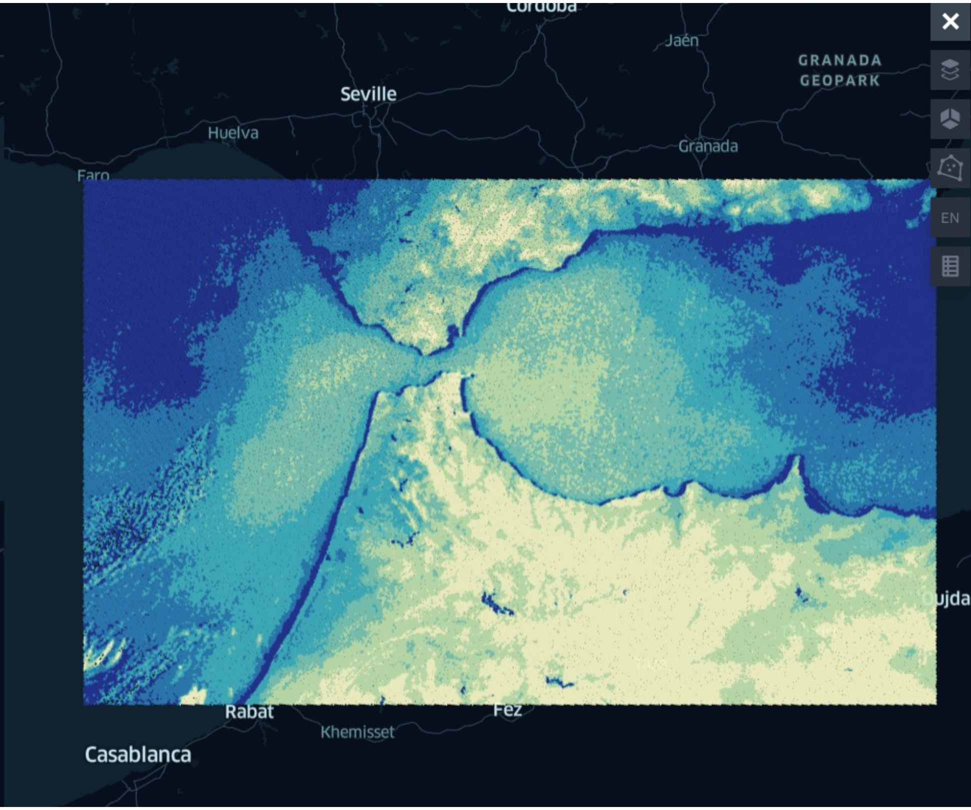




Approach

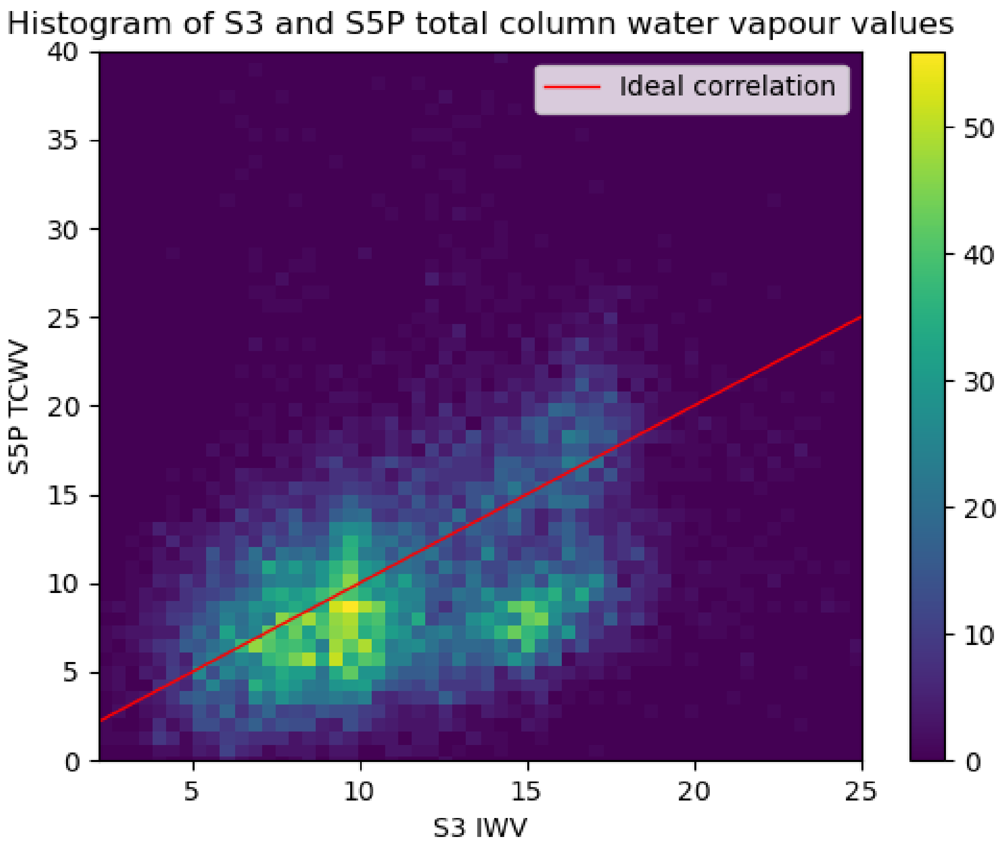
- **Street of Gibraltar**
  - **S5P TCWV** (left): H3 resolution **6** (avg. hex. area 36.13 km^2)
  - **S3 IWV** (right): H3 resolution **8** (avg hex. area 0.74 km^2)





Approach

Correlation of cropped S3/S5P data after preprocessing



Approach

Main approach:

Regression with a deep neural network (DNN)

Dataset

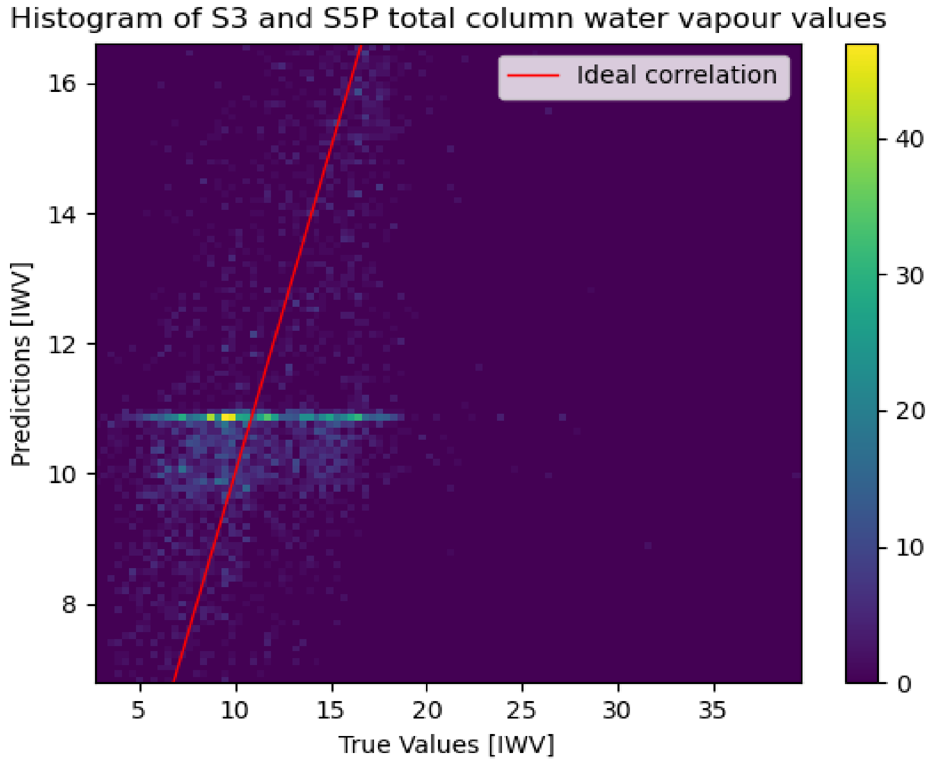
- Create **overlapping subset samples** from S3/S5P data
- Directly comparable as corresponding subsets are located in the same H3 cells
- Use S3 data as fine-scaled reference / label

Deep Neural Network for regression

- Use a share of the subsets for training the DNN
- Use the remaining subsets for validation

First results

- Initial results show improvement of correlation between DNN model predictions and S3 values
- Further enhancement of model architecture for optimisation of results



Outlook

- **Create prototype from demonstration**
  - Include additional datasets for training & validation to enhance results
  - Improve robustness and scalability of algorithms

- **Sentinel-4**
  - Upcoming Copernicus mission for atmospheric monitoring:
  - Hourly monitoring over Europe
  - Very high temporal resolution
  - Can be combined with similar products from LEO missions (S5P, S3) and GEO missions (MTG IRS)

- **Application for other (atmospheric) products**
  - O3, NO2, PM, etc.
  - Land monitoring
  - Combination of Copernicus data with commercial products