INTEGRAZIONE E FUSIONE DI DATI OTTICI/IR E A MICROONDE PER LA STIMA DI PARAMETRI DI SUOLO, NEVE, VEGETAZIONE E ATMOSFERA

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PRELIMINARY NOTES

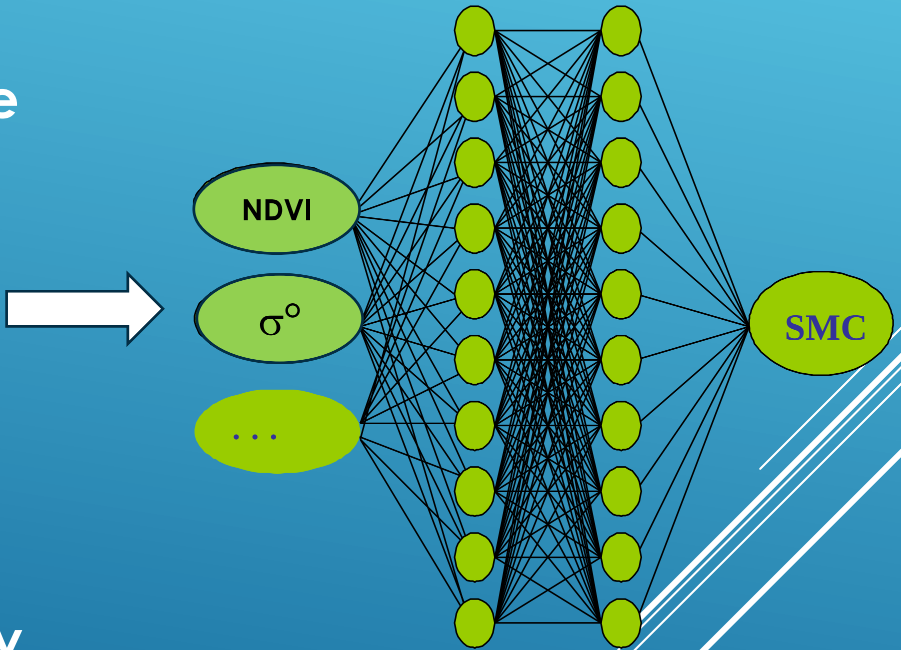
- The integration between optical/infrared and microwave sensors provides significant advantages due to the specific characteristics of these spectral bands:
  - High spatial resolution and sensitivity to surface characteristics of optical sensors
  - Medium-high spatial resolution and high sensitivity of microwave sensors to water content and to the characteristics of the entire observed medium (soil-snow-vegetation-atmosphere)
- Several applications can benefit from this synergy:
  - Agriculture and forestry
  - Hydrology (hydrological cycle)
  - Atmosphere

SYNERGIES PRISMA-COPERNICUS

- The advanced and peculiar characteristics of the hyperspectral instrument of PRISMA make it possible a significant synergy between this mission and those of COPERNICUS program, allowing the project of contributing national missions within the framework of the Sentinels (1-5)
- Fruitful synergies can be implemented between PRISMA and Cosmo-Skymed, PRISMA and S1 or/and S4-S5, PRISMA and MW radiometers.
- The latter mainly for atmosphere sounding purposes, but also in view of implementing algorithms for improving MW radiometers spatial resolution.

SYNERGY METHODS OPTICAL/MW DATA

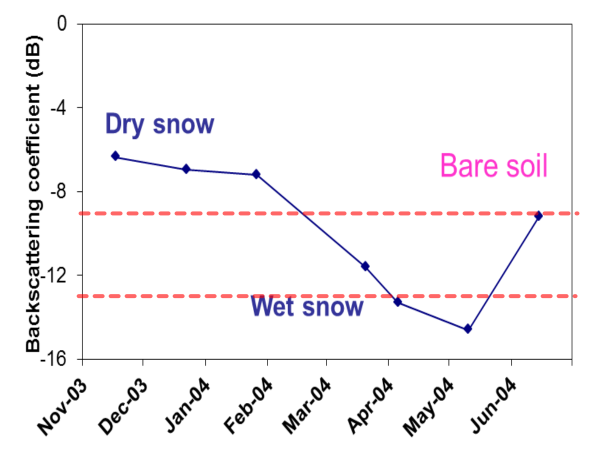
- Use of optical/infrared and microwave data in a separate way for estimating different parameters by applying inversion algorithms and models (e.g. use of NDVI for land classification purposes before the application of MW data/algorithms)
- **Integration of data in single algorithms which take advantage of the different characteristics of the sensors and their synergy. <u>Neural Networks</u> are typical examples.**

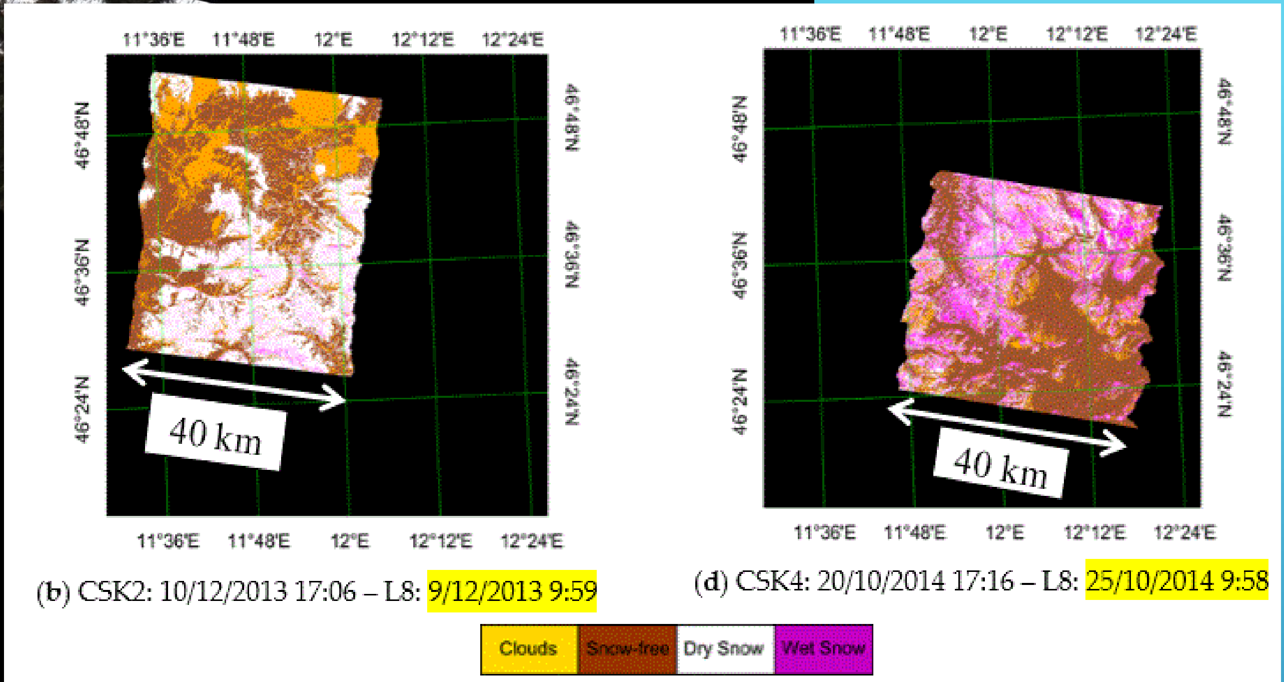


- **Use of 'data fusion' algorithms. These are innovative techniques, which are used for atmospheric investigation purposes at IFAC, by merging optical with infrared data and data from different observation geometries.**

TYPICAL APPLICATIONS: SNOW (CLASSIFICATION & SCA)

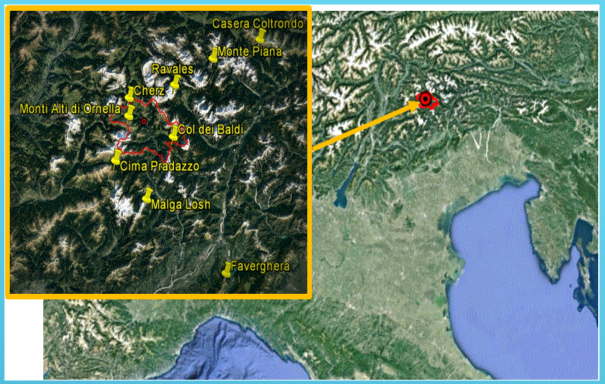
- A conventional system applied so far consists of the use of simultaneous optical (e.g. LANDSAT)and microwave (ENVISAT/S1/Cosmo-SkyMed) images able to classify snow cover by separating **no-snow/dry snow/wet snow** areas.
- **Optical data allow a clear identification of snow cover area (SCA)**
- **The algorithm merges MW with optical images using a threshold (-3dB) in MW images for identifying wet snow (even with clouds)**
- Integration with Cosmo data allows obtaining in many cases even SWE e SD (relevant parameters for hydrological and water resources management)





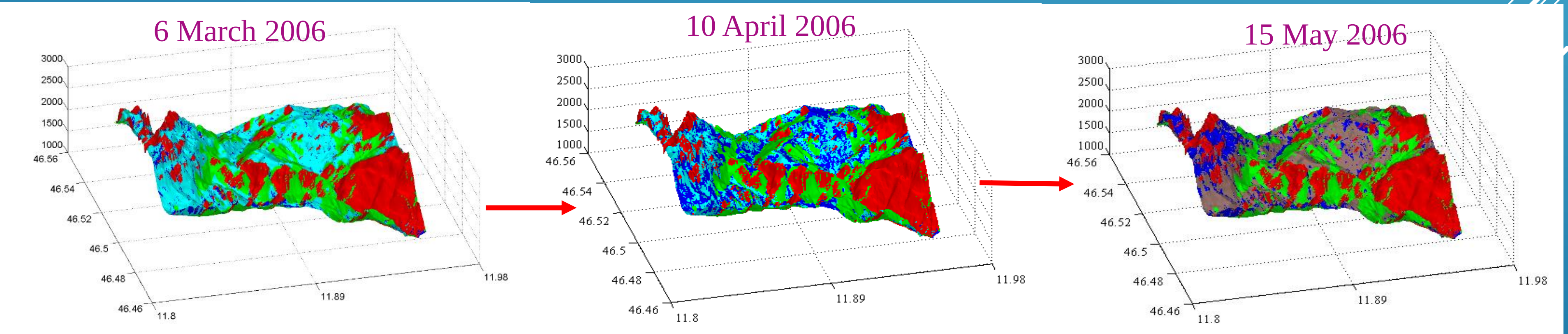
(b) CSK2: 10/12/2013 17:06 – L8: 9/12/2013 9:59

(d) CSK4: 20/10/2014 17:16 – L8: 25/10/2014 9:58



Cordevole basin (Dolomites)

Application of an algorithm using combined information from Landsat and COSMO/ENVISAT/S1 for generating classification maps of snow (no-snow/dry-snow/wet-snow)



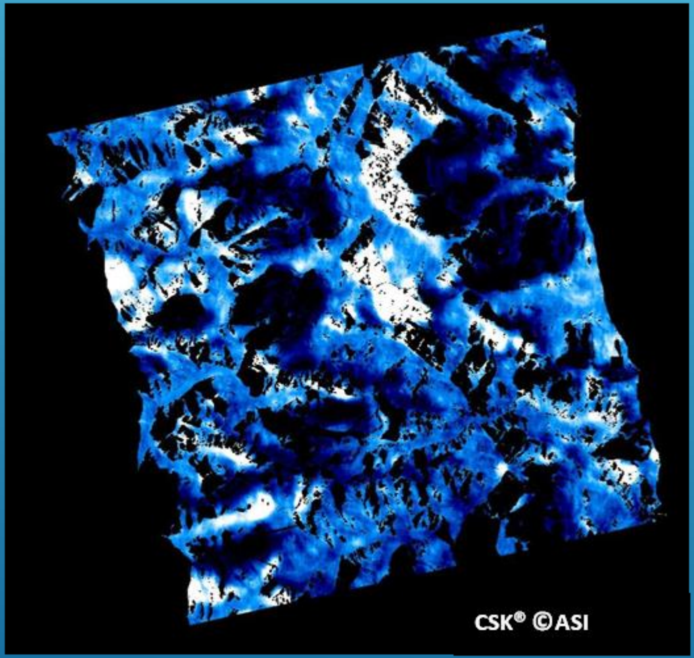
Red: layover and shadow areas; Green: forests; Light blue: dry-snow;
Blue: wet snow; Brown: bare soil

TYPICAL APPLICATIONS: SNOW (SD & SWE)

SCA and SWE (SD) maps estimated from Cosmo-SkyMed data (X band) through a Neural Network algorithm able to integrate MW and optical data (Pettinato et al. 2013)

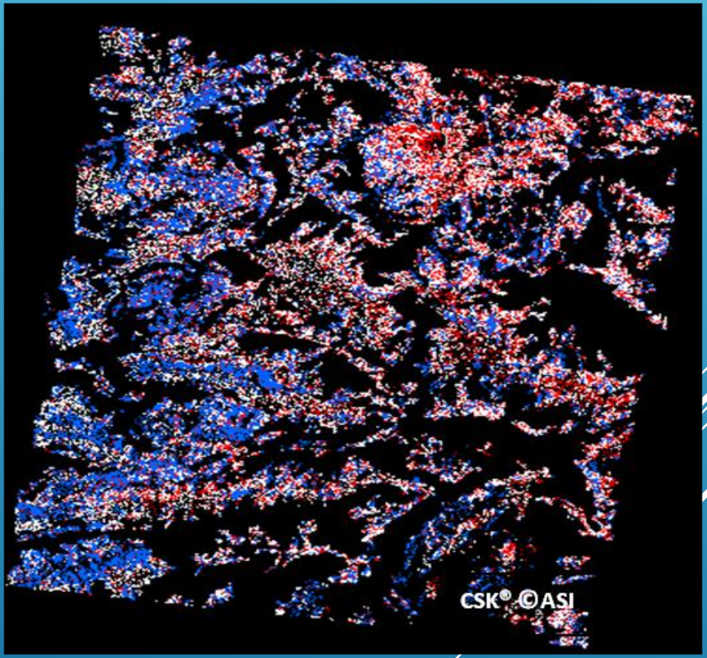
January 22, 2010

40kmx40km

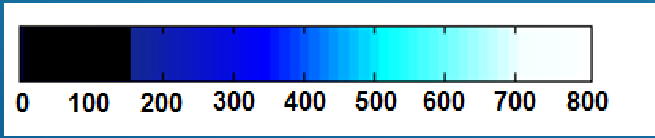


March 29, 2010

30kmx30km



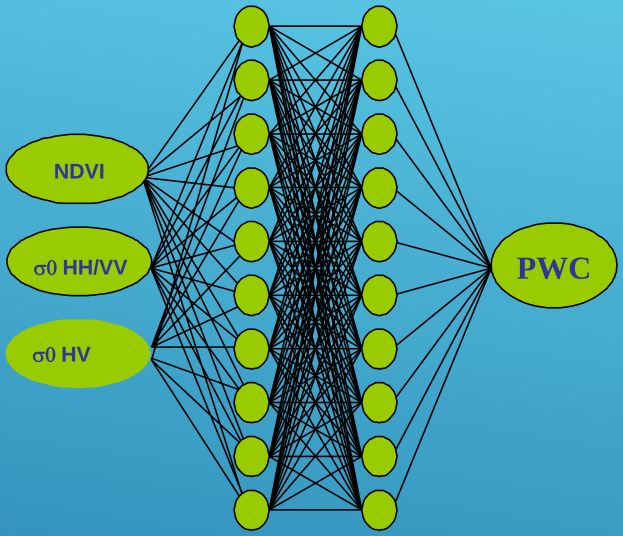
SWE in mm

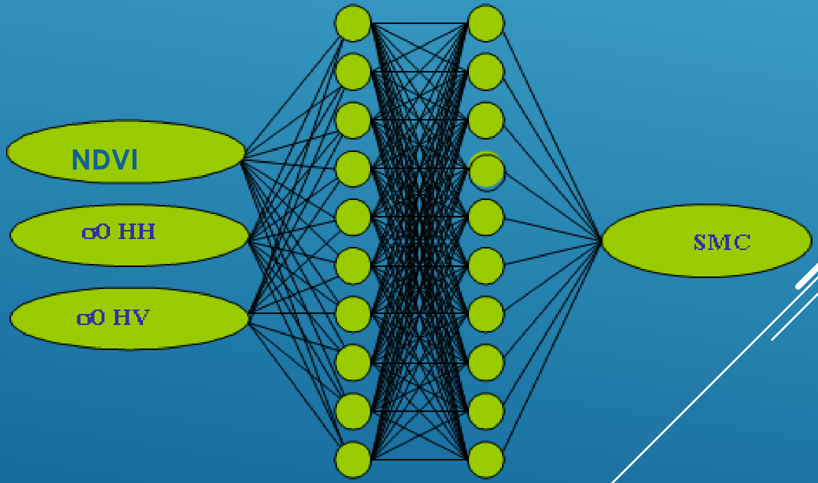


AGRICULTURE: SOIL MOISTURE (SMC) AND BIOMASS (PWC)

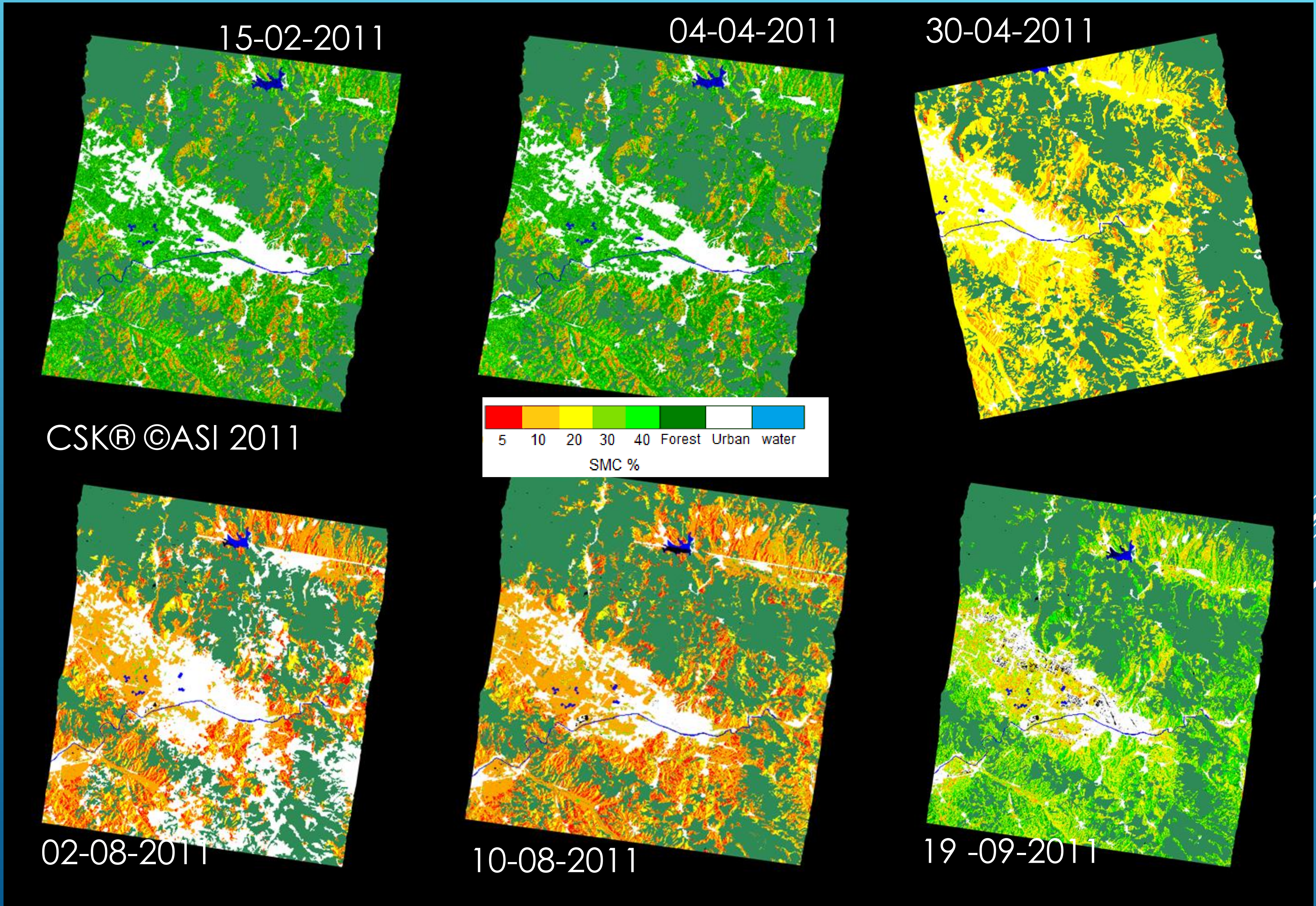
Multispectal NDVI

ENVISAT RGB

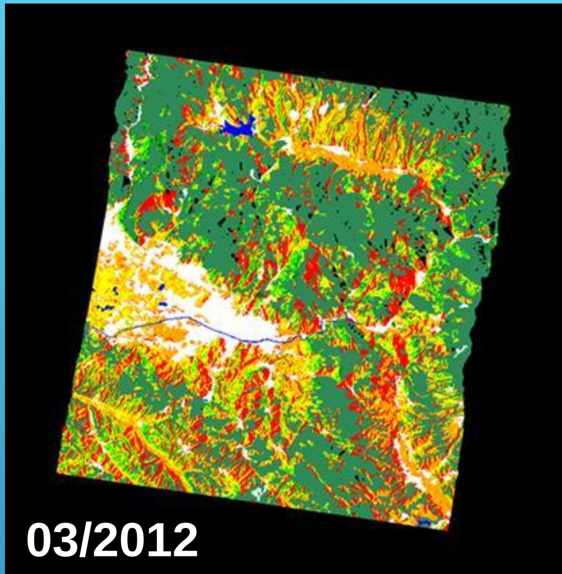


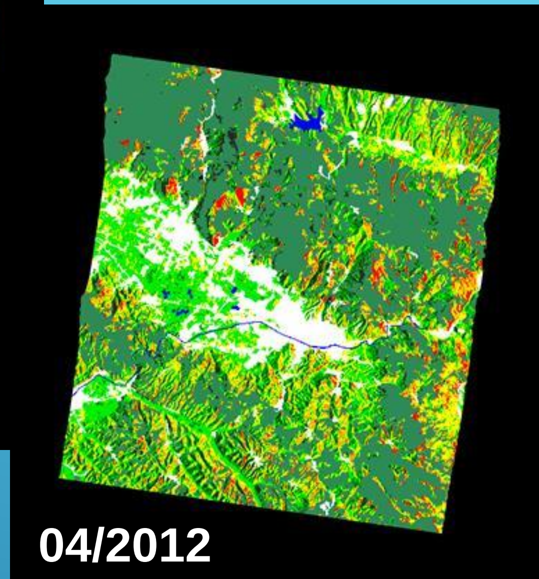


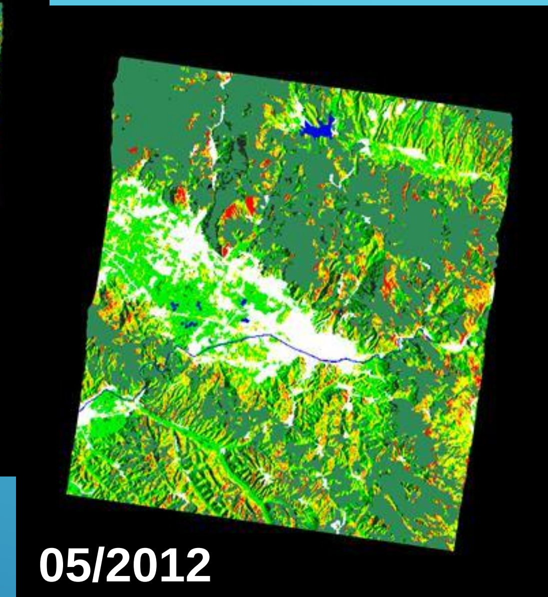
SMC MAPS: SESTO

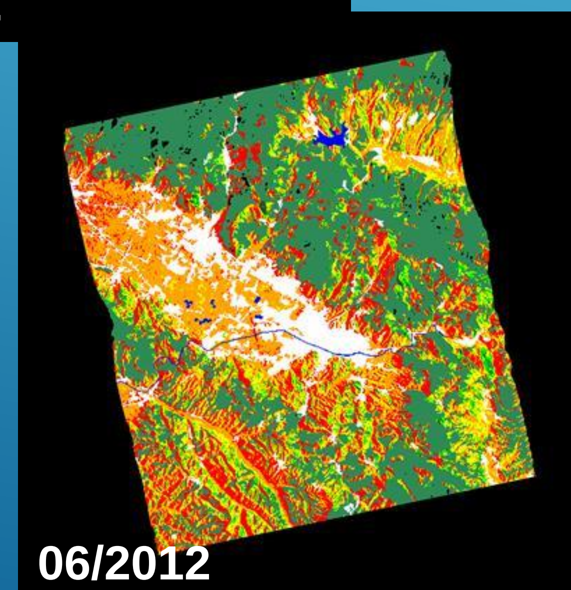


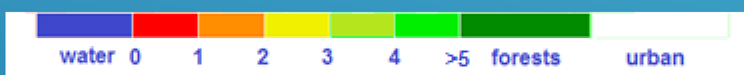
EXAMPLES OF PWC MAPS SESTO FIORENTINO 2012

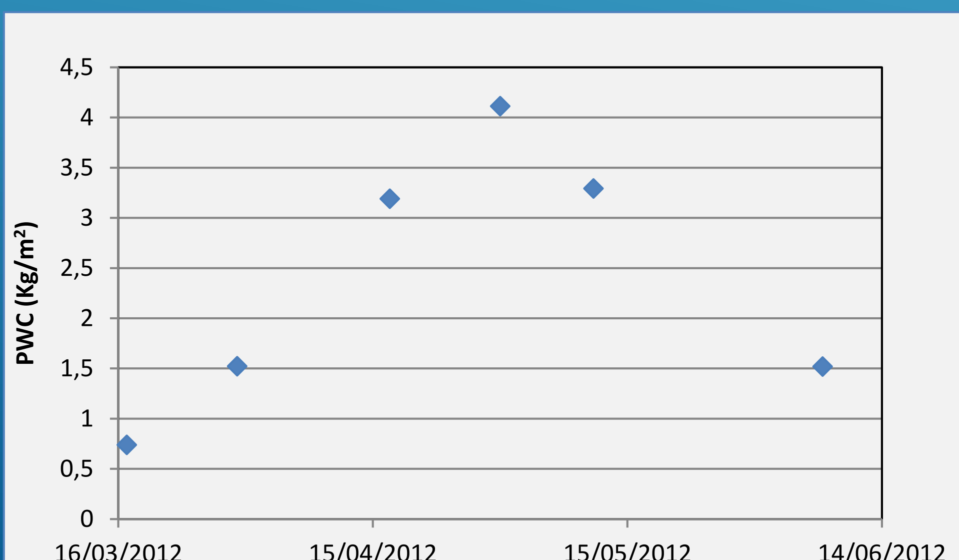






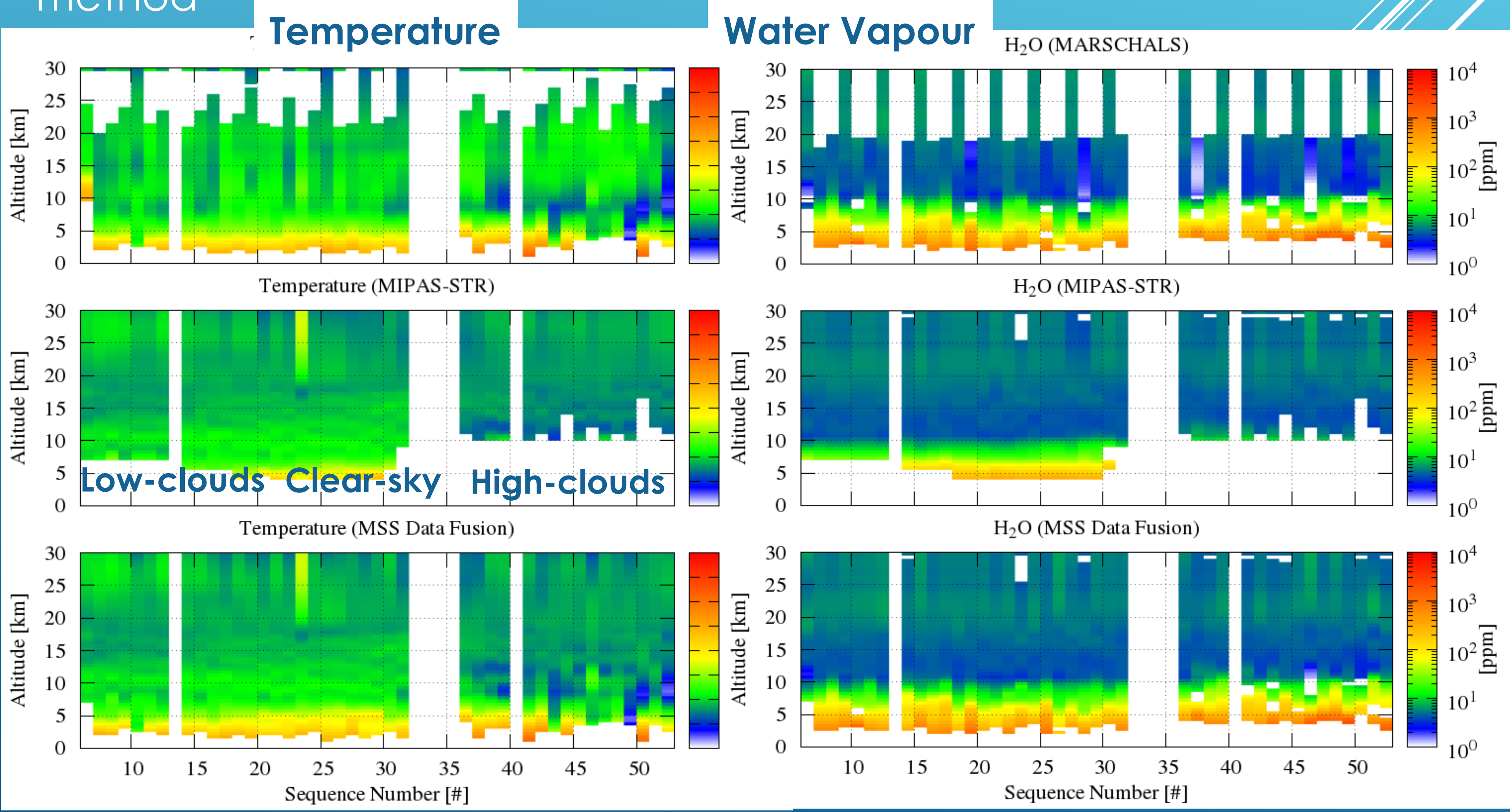






TYPICAL APPLICATIONS: ATMOSPHERE

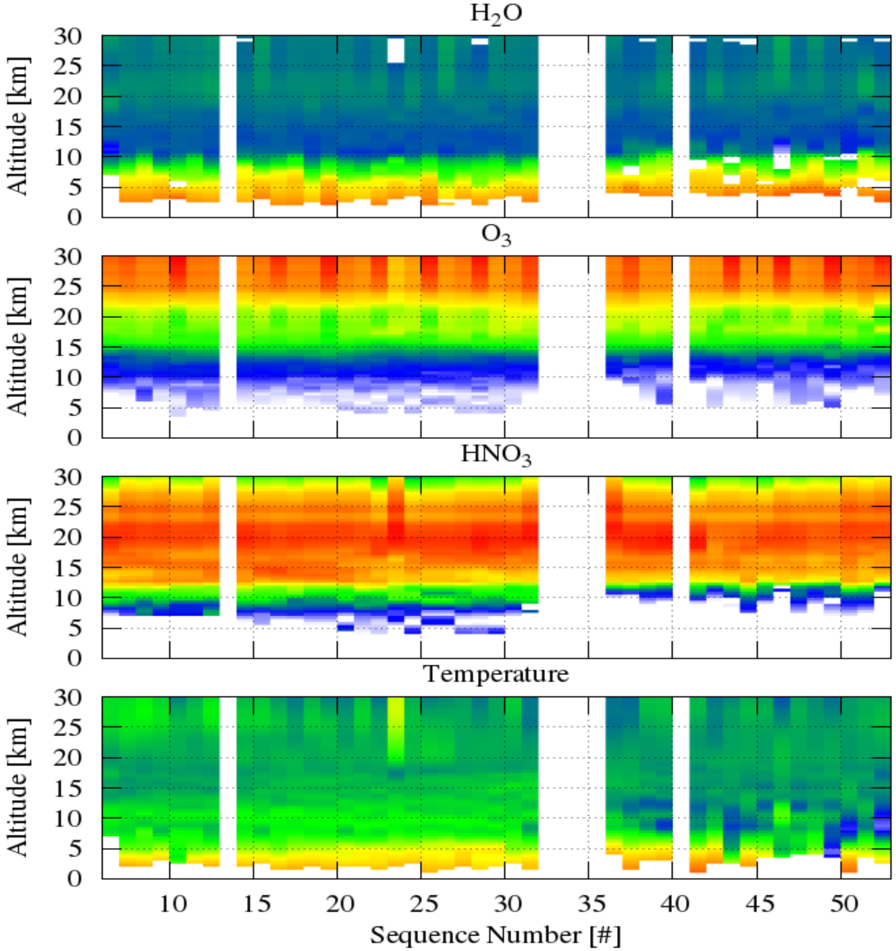
Atmospheric temperature and **water vapour** estimated from airborne limb sounders in the middle infrared (MIPAS-STR), in the mm-wave (MARSCHALS) and using the Measurement Space Solution (MSS) method



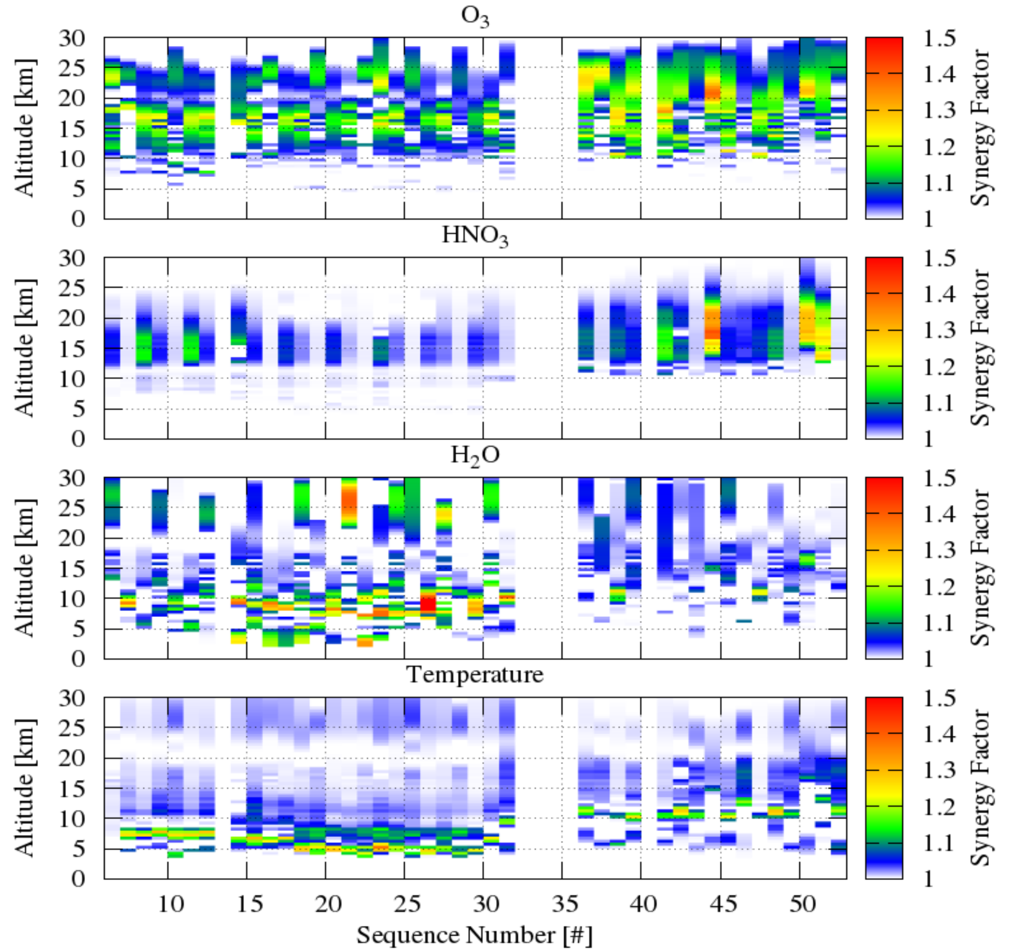
DATA FUSION PRODUCTS

SYNERGY FACTOR = a parameter depending on the uncertainties associated to fused and individual measurements, which is >1 if and only if a synergy between the two individual dataset really exists

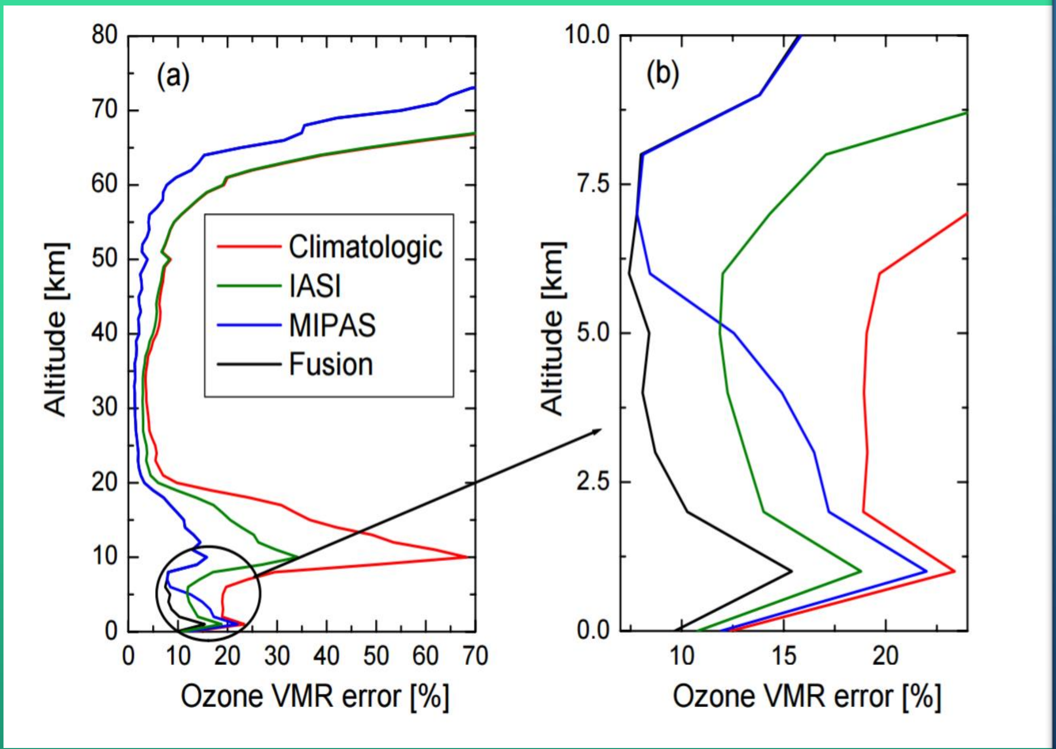
MSS Data Fusion Products (H_2O, O_3, HNO_3, Ta)



Synergy Factor



Application of the MSS method to the combination of measurements acquired using different viewing geometries (nadir and limb sounding)



The uncertainty associated to the fused profile is less than the one of the nadir sounder IASI even if the limb sounder MIPAS is not measuring at low altitude.

Future steps: CDF method (Complete Data Fusion)

- A posteriori combination of the information from two (or more) indipendent datasets based on the standard products of the individual retrievals (vertical profile and associated uncertainty and vertical sensitivity)
- Equivalence of CDF method and simultaneous retrieval from CDF method and MSS method demonstrated by Ceccherini et al. (2015, 2016)
- First attempt to apply CFD to combination of data acquired in various spectral regions AND from different observation geometries and to test the performance of assimilation of fused data currently on-going in the H2020 project AURORA (Cortesi et al., 2015)

SOME CONCLUSIONS

- Theoretical studies, demonstration and application of innovative data fusion methods are part of a dedicated and ongoing research efforts at IFAC-CNR since the last decade.
- The focus is on the exploitation of potential synergies between simultaneous and independent measurements of the same target acquired by two (or more) sensors.
- Interesting results have been obtained by using ANN based algorithms for estimating geophysical parameters through the synergy between optical and MW SAR data (S1/CSK/S2/PRISMA…)
- Substantial results and promising perspectives have been obtained from a posteriori combination of geophysical products retrieved from observations in different spectral regions or with different viewing geometries.
- Potential adaptation and/or further development of these algorithms are in progress for application to data fusion from microwave and optical/infrared data (atmospheric soundings and land surface observation).