Università degli studi di Torino

Facoltà di Scienze Matematiche, Fisiche e Naturali

Corso di Laurea in Fisica

Cloud detection by weather radar and satellites for JEM-EUSO mission

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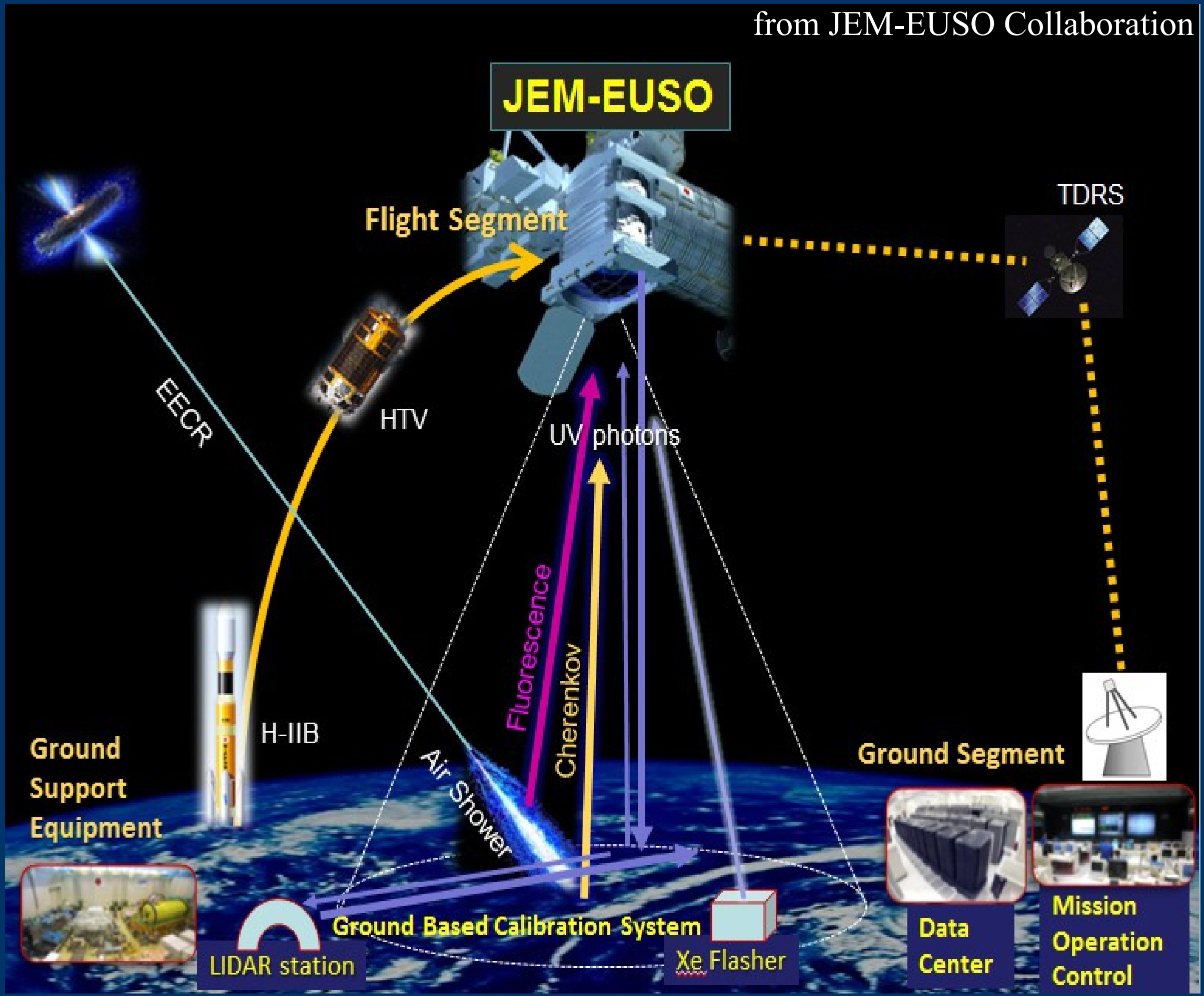
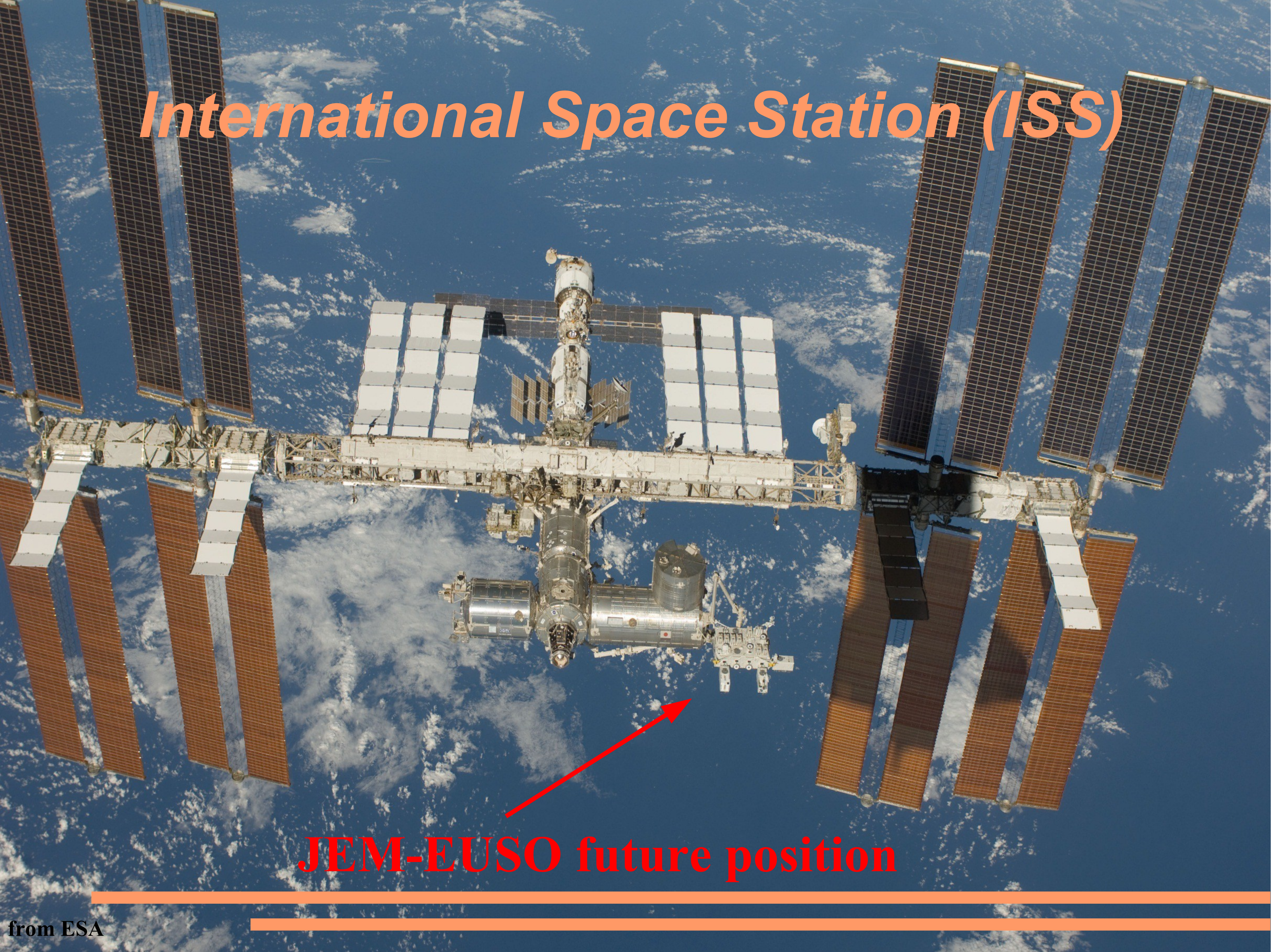
JEM-EUSO

- It is an observatory, in orbit on the ISS at about 400 km, that will utilize very large volumes of the Earth's atmosphere as a detector of Extreme Energy Cosmic Rays (> $5*10^{19}$ eV)



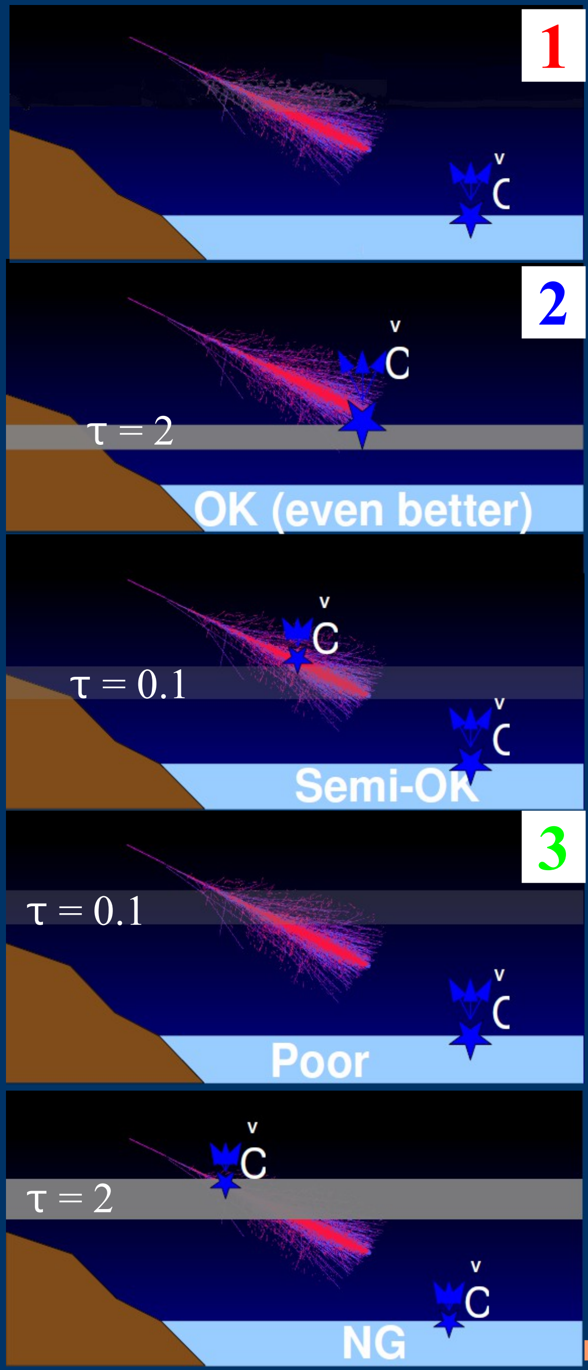
- JEM-EUSO will capture the fluorescent UV and Čerenkov photons, produced by the cosmic ray particle approaching the Earth's atmosphere

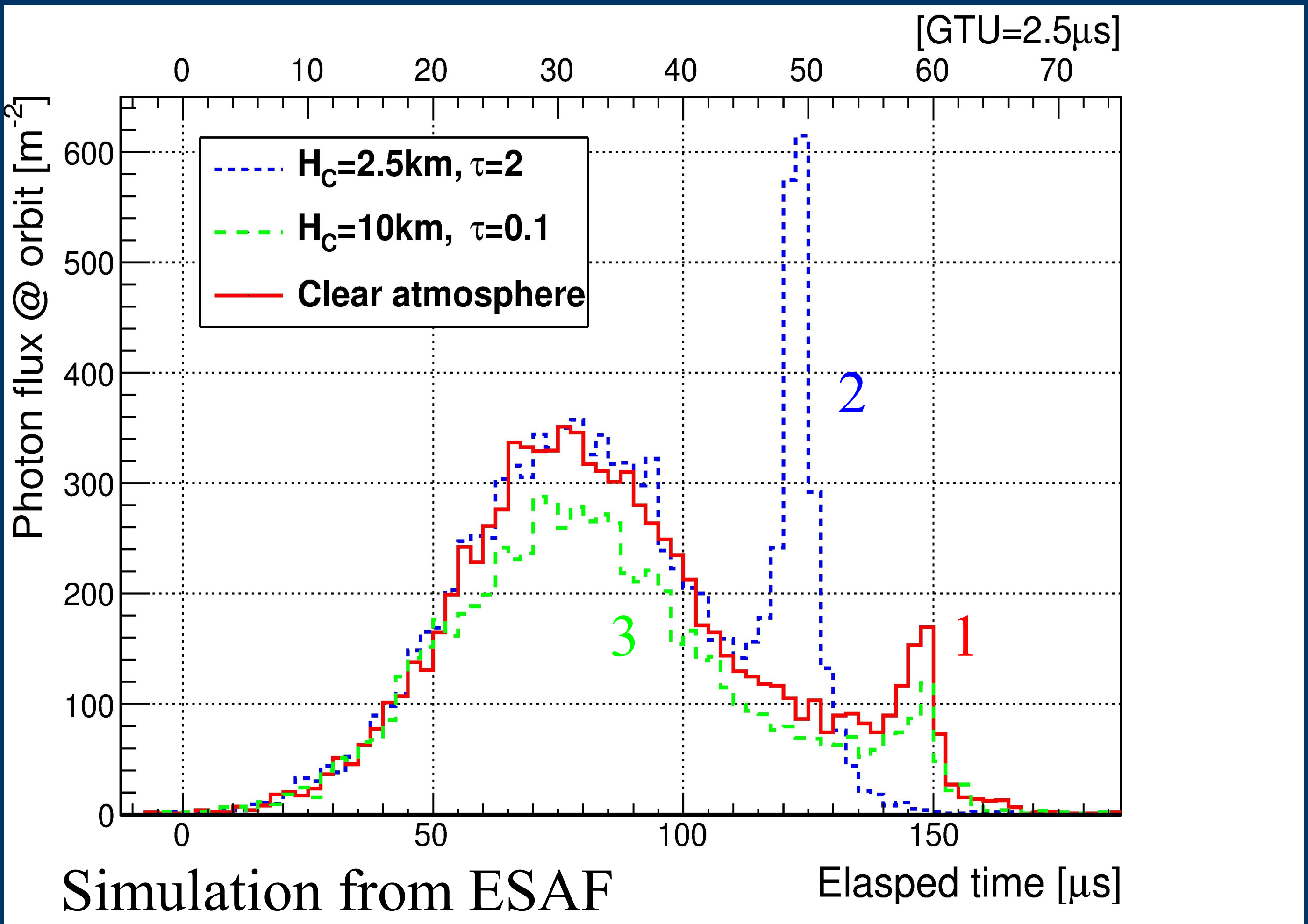
International Space Station (ISS)



from ESA

Interaction between EAS and clouds





- Observed EAS parameters and JEM-EUSO acceptance strongly depend on cloud amount and <u>cloud-top altitude</u>

NOTE: Č = Čerenkov Light reflection

The target of my study

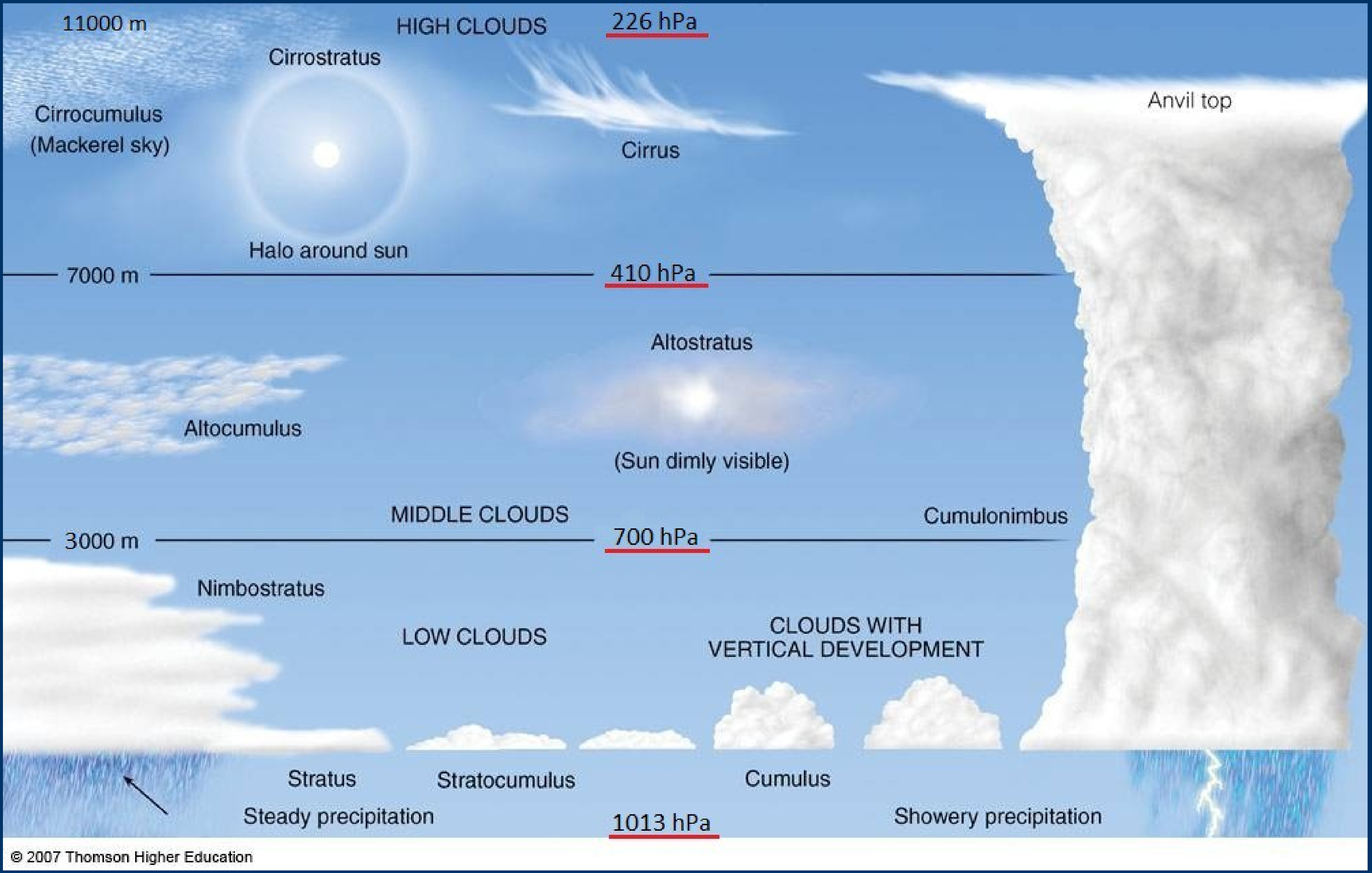
- Define the accuracy of Cloud Top Height estimates and identify possible sources of uncertainty, by comparing satellites data from radiative models and data from weather radars

- Different sensors and different algorithms:

MSG: $$T(\nu)=\left[\frac{k}{h\nu}\ln\left(R(\nu)+\frac{2h\nu^3}{c^2}\right)\right]^{-1}+offset$$

MODIS: $$R(\nu)=(1-NE)R_{clr}(\nu)+NE*R_{bcd}(\nu,P_c)$$

Atmosphere profile and cloud types



Cloud Coverage Climatology

Clear sky ~ 29%
Green band ~ 60%

Cloud top

F.Garino et al., ID398

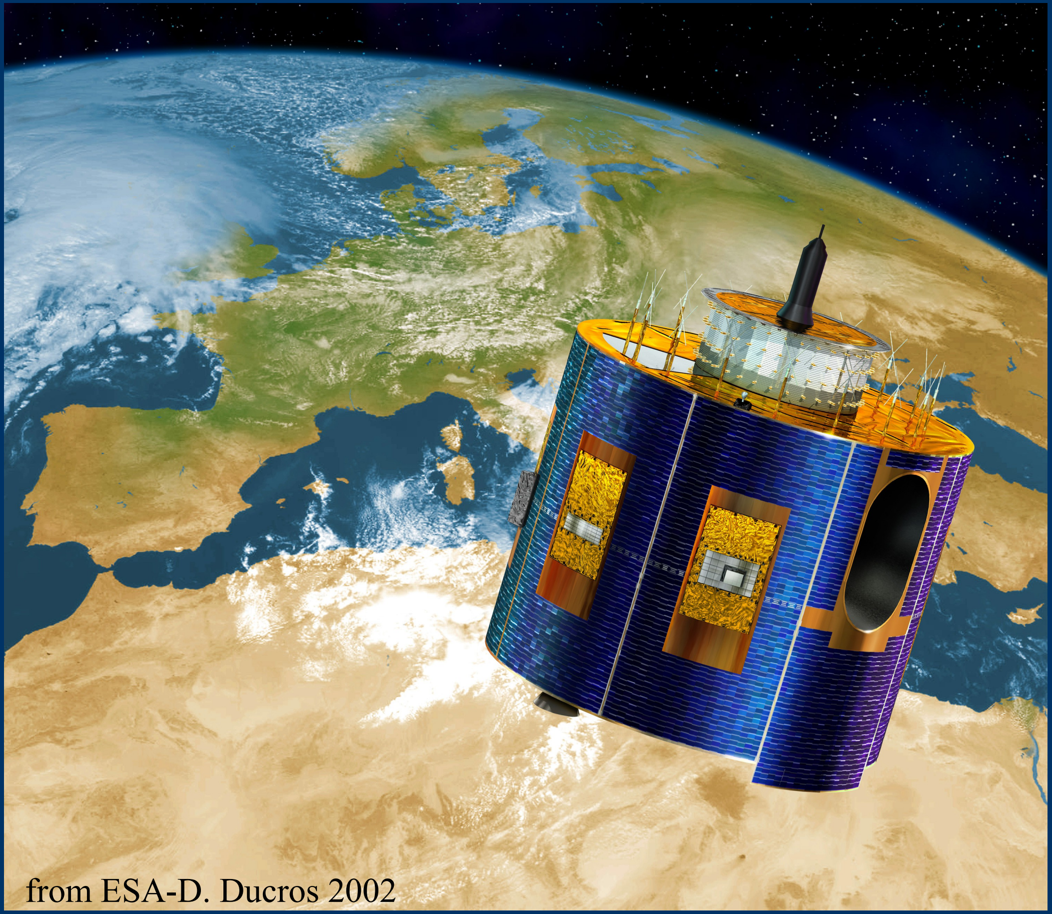
Optical Depth

	<3 km	3-7 km	7-10 km	>10 km
OD>2	17.2	5.2	6.4	6.1
OD:1-2	5.9	2.9	3.5	3.1
OD:0.1-1	6.4	2.4	3.7	6.8
OD<0.1 INCLUDING CLEAR SKY	29.2	<0.1	<0.1	1.2

Occurence of clouds (in %) between 50° N and 50° S

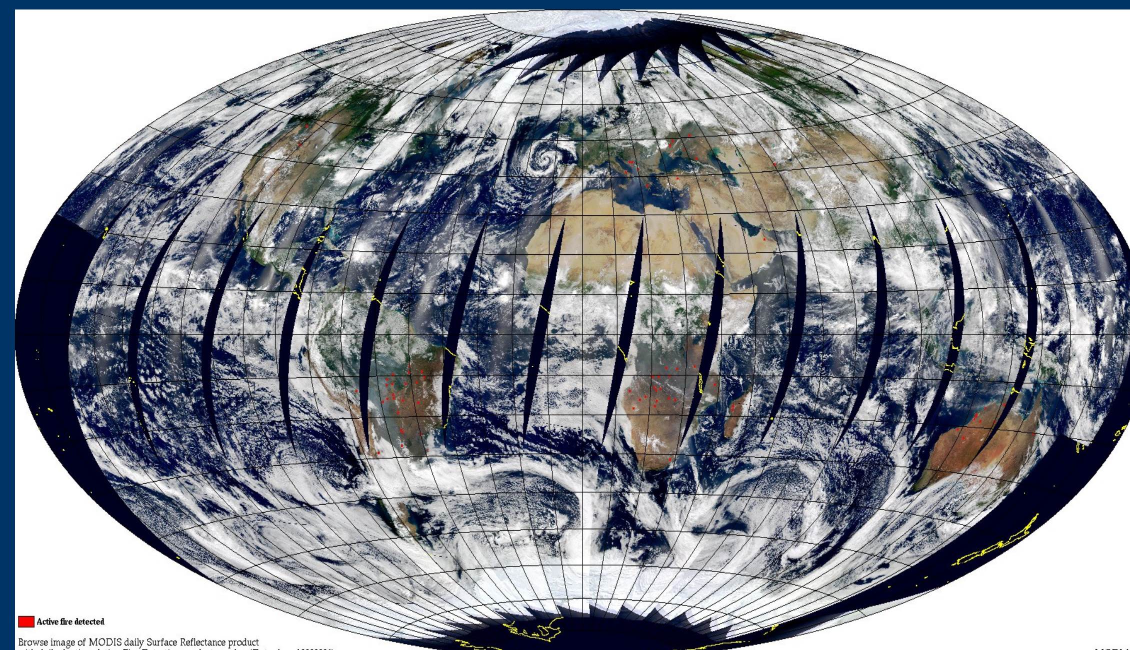
Data sources: SEVIRI MSG

- Sensor which operates in 12 spectral bands between visible and infrared, situated on board the Meteosat Second Generation geostationary satellites. It has a 3 km spatial resolution and a 15 minutes temporal resolution.



Data sources: MODIS Terra Aqua

- Sensor which operates in 36 spectral bands, situated on board the <u>polar</u> satellites Terra and Aqua, which have a "Sun-syncronous" orbit at about 705 km altitude. Both the satellites scan the entire Earth surface in 1-2 days. <u>Spatial resolution variable</u> depending on the product.



from LPDAAC USGS

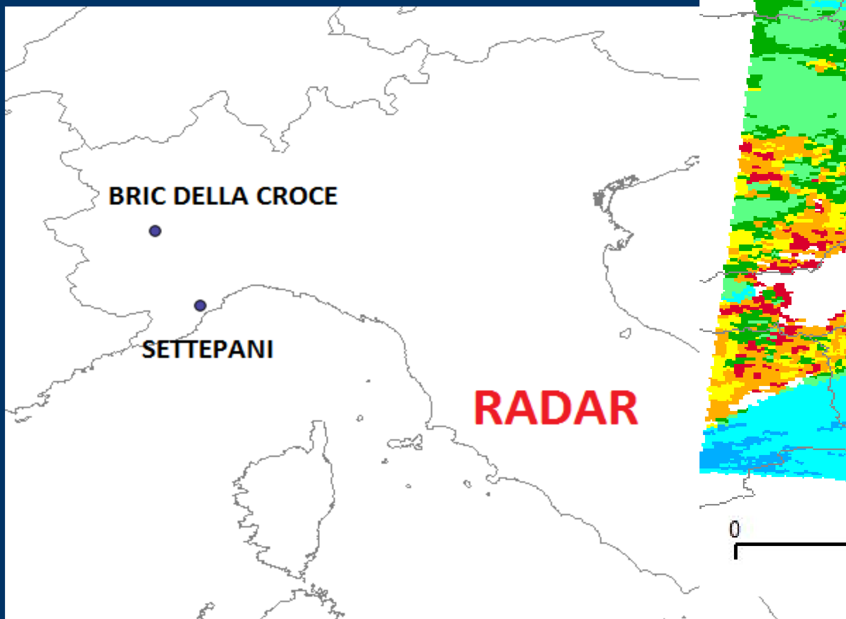
Data sources: Weather Radar

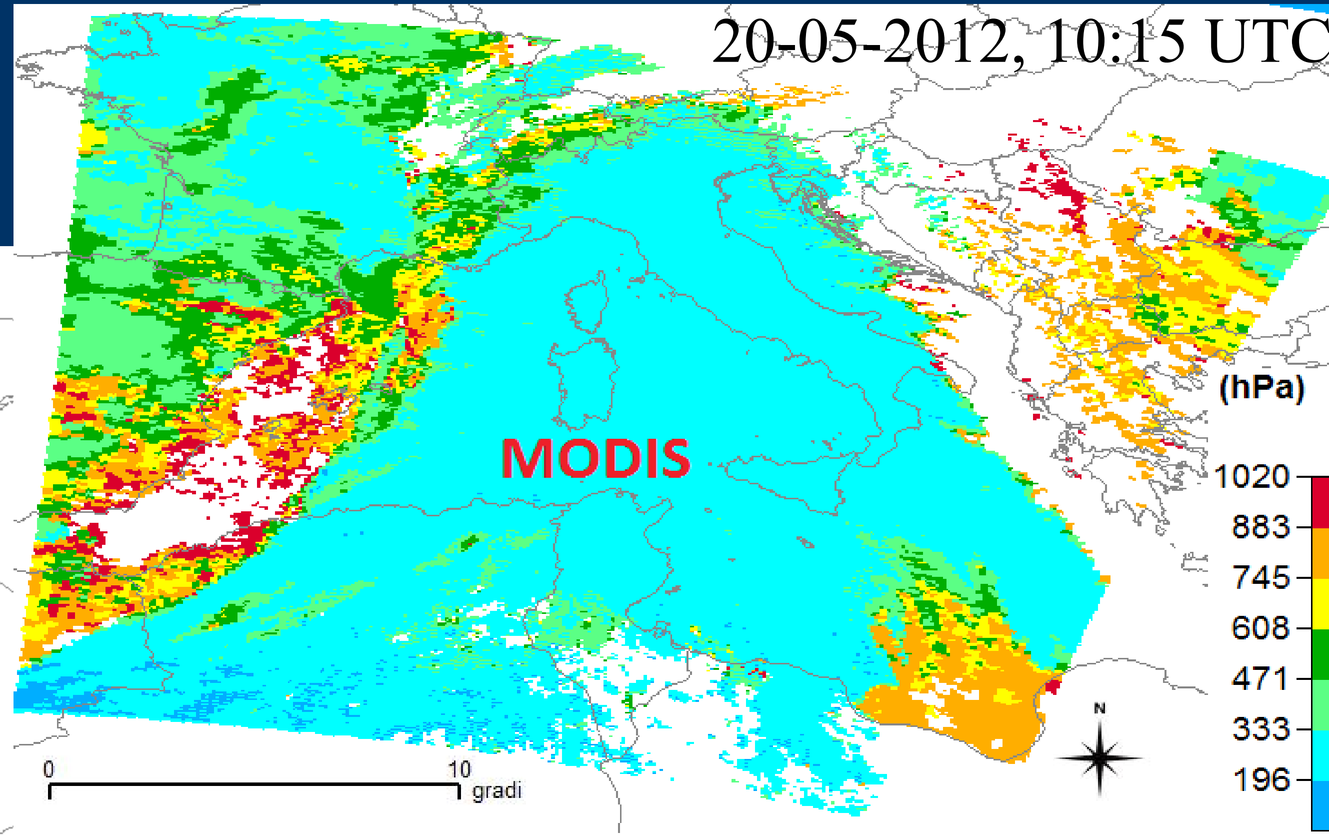
- Both the instruments (Bric della Croce (TO) and Settepani (SV)) are polarimetric doppler radar. In my work I used the products of the VAD tecnique, with which I could determine the Cloud Top Height at radar's zenit. Temporal resolution: 10 minutes.

from NSSL NOAA


from Arpa Piemonte

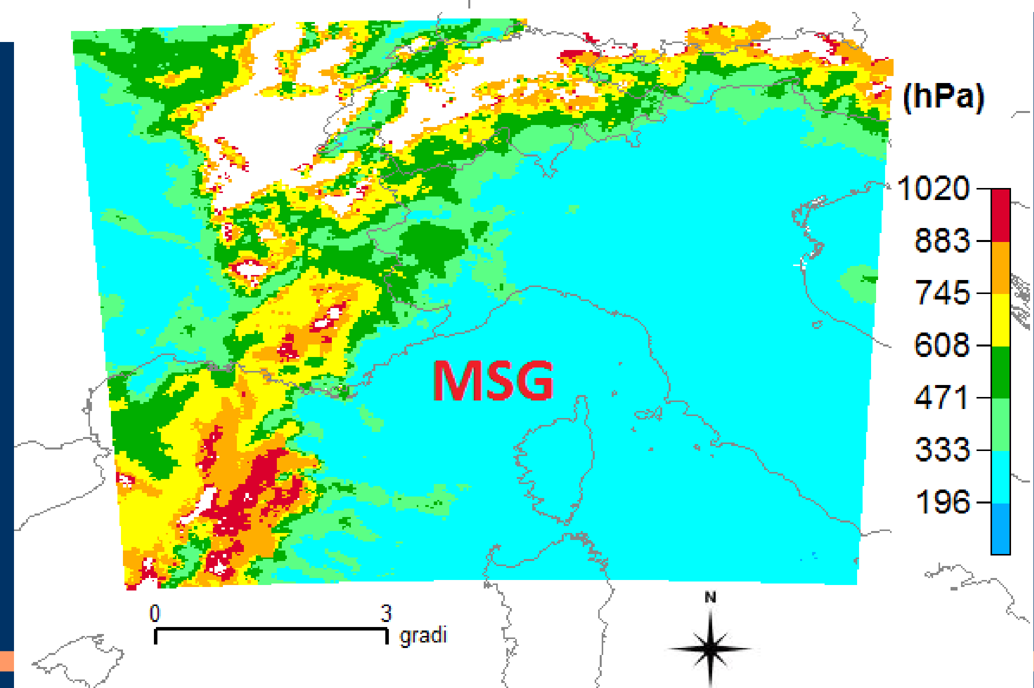
Starting conditions:





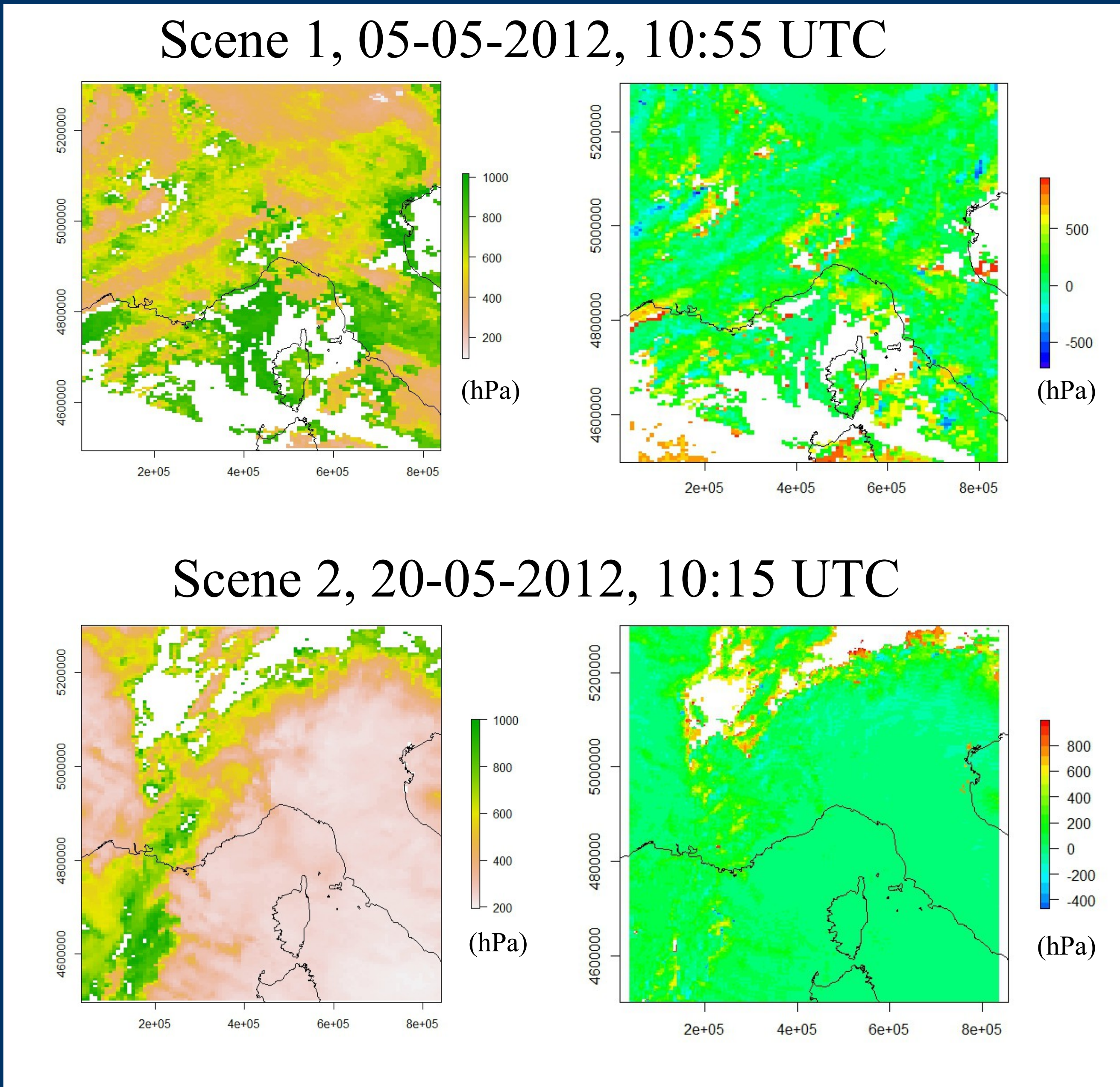
TO DO LIST:

- Reprojection
- Cutting
- Resampling
- Creation of the raster MSG – MODIS



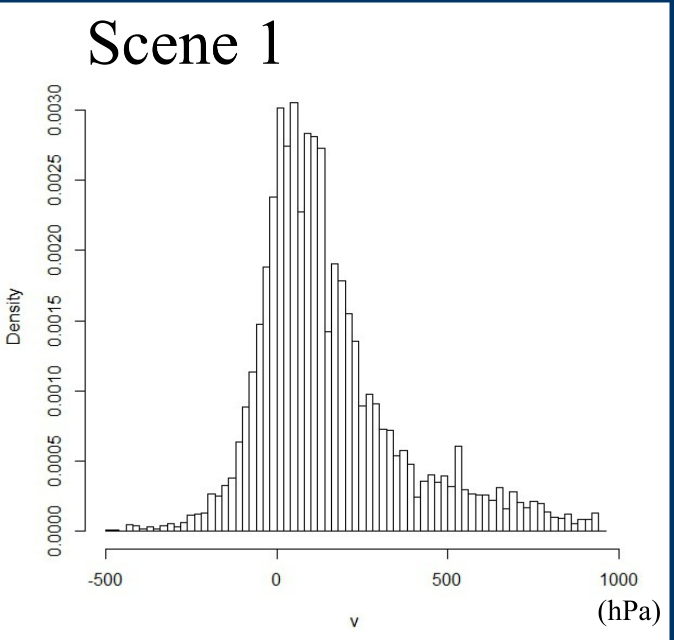
Visual analisys:

NOTE: Δt1 = 2 min
Δt2 = 4 min



- Fractional cloud covering, high differences in the whole scene
- Almost uniform cloud covering, high differences in CLOUD – NO CLOUD transition regions

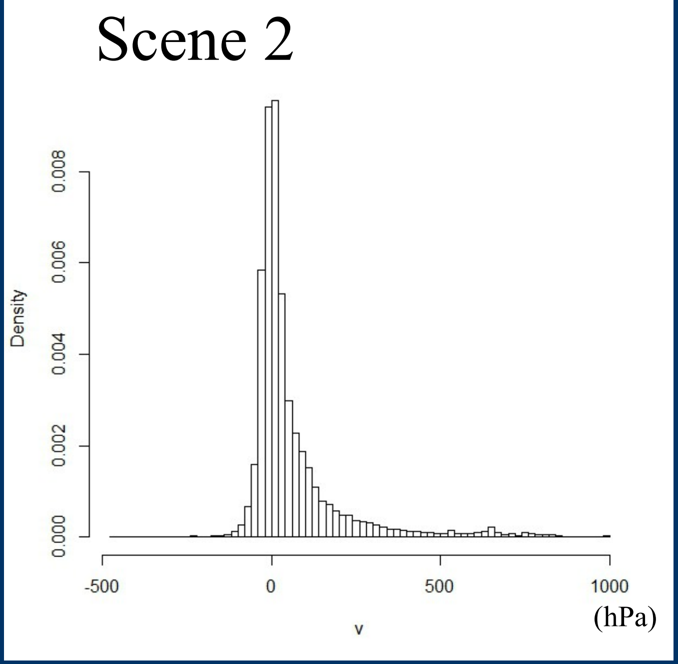
Statistical analisys:



Mean = 154.8 hPa

SD = 218.3 hPa

Median = 108.0 hPa



Mean = 61.9 hPa

SD = 145.9 hPa

Median = 15.0 hPa

From a not uniform scene to a uniform one:

Reduction of Mean and SD

↓

Agreement between the two satellite systems is better for uniform scenes

Reduction of Median

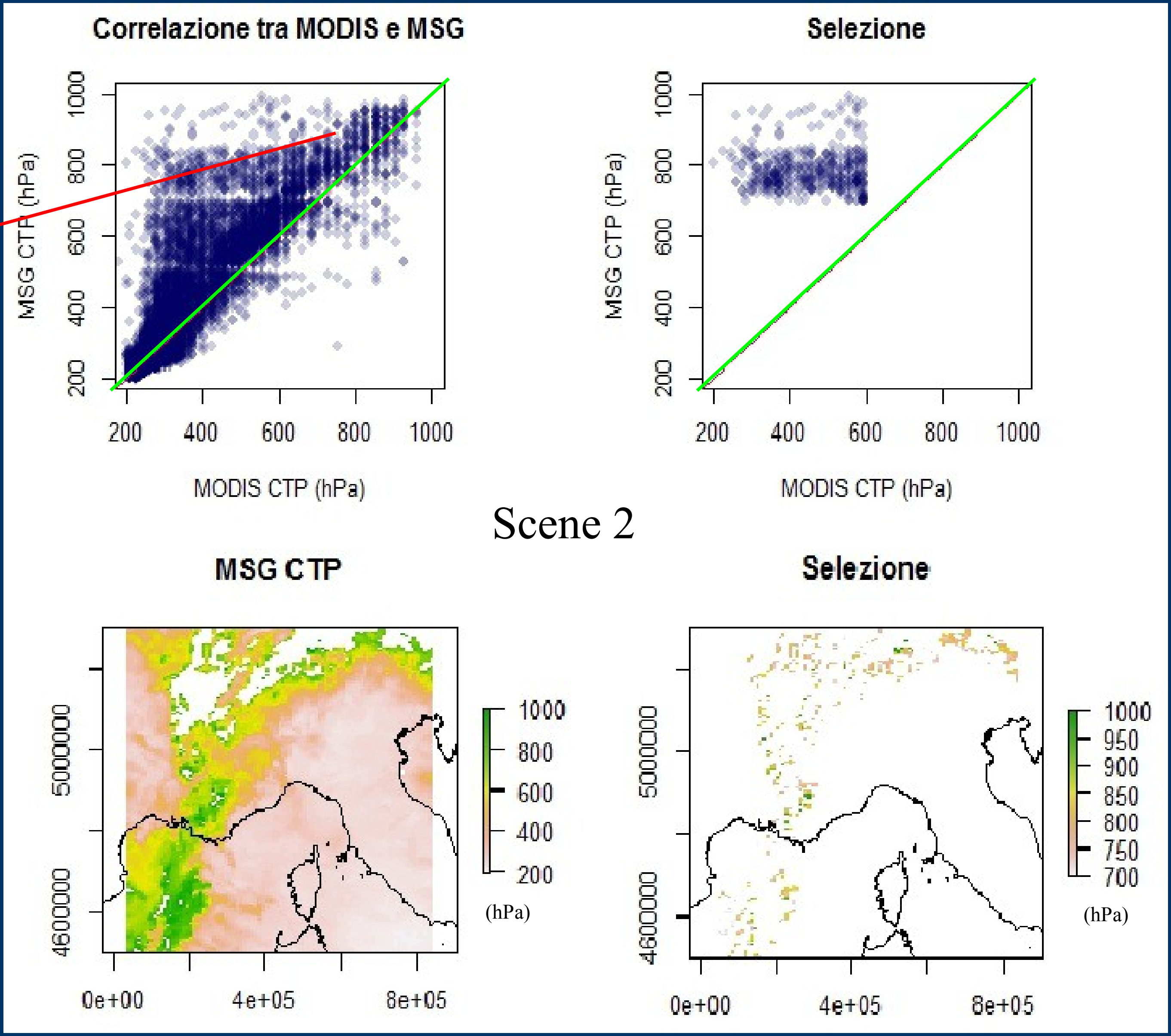
↓

There could not be a uniform BIAS, it depends on the type of the scene

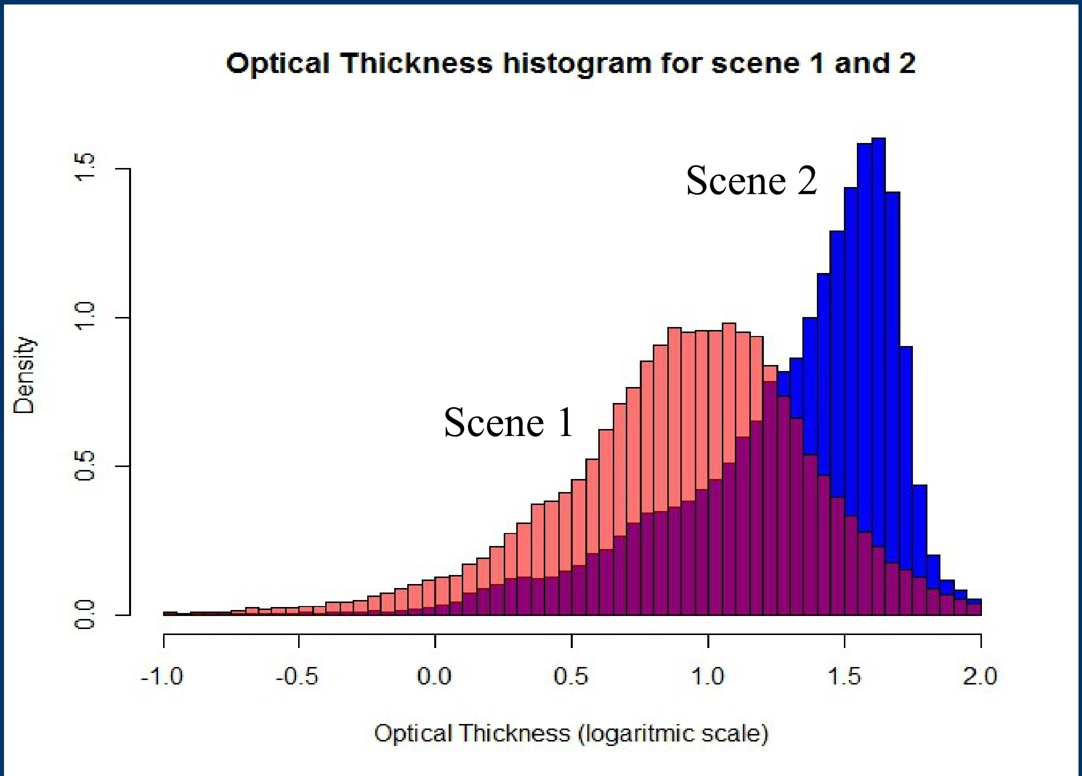
Correlation: scatter plot

- BIAS stronger for high pressures and smaller for low pressures

- CLOUD – NO CLOUD transiton regions

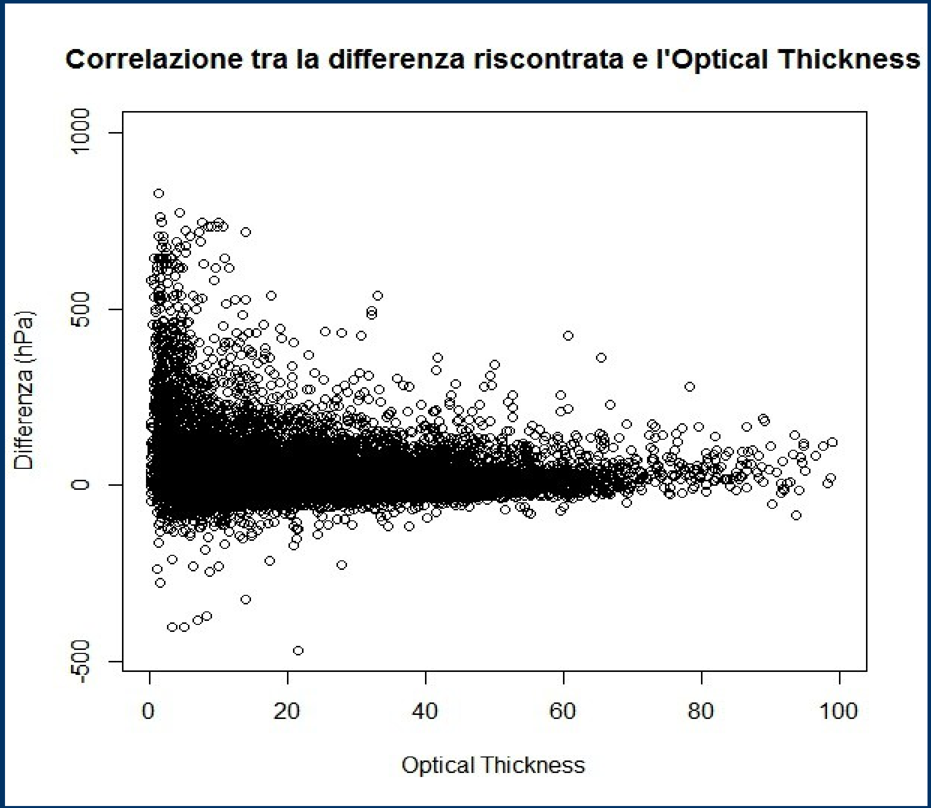


Correlation: Optical Thickness



Physical quantity that help to characterize the cloud

- Mean difference decreases when the cloud gets optically thicker



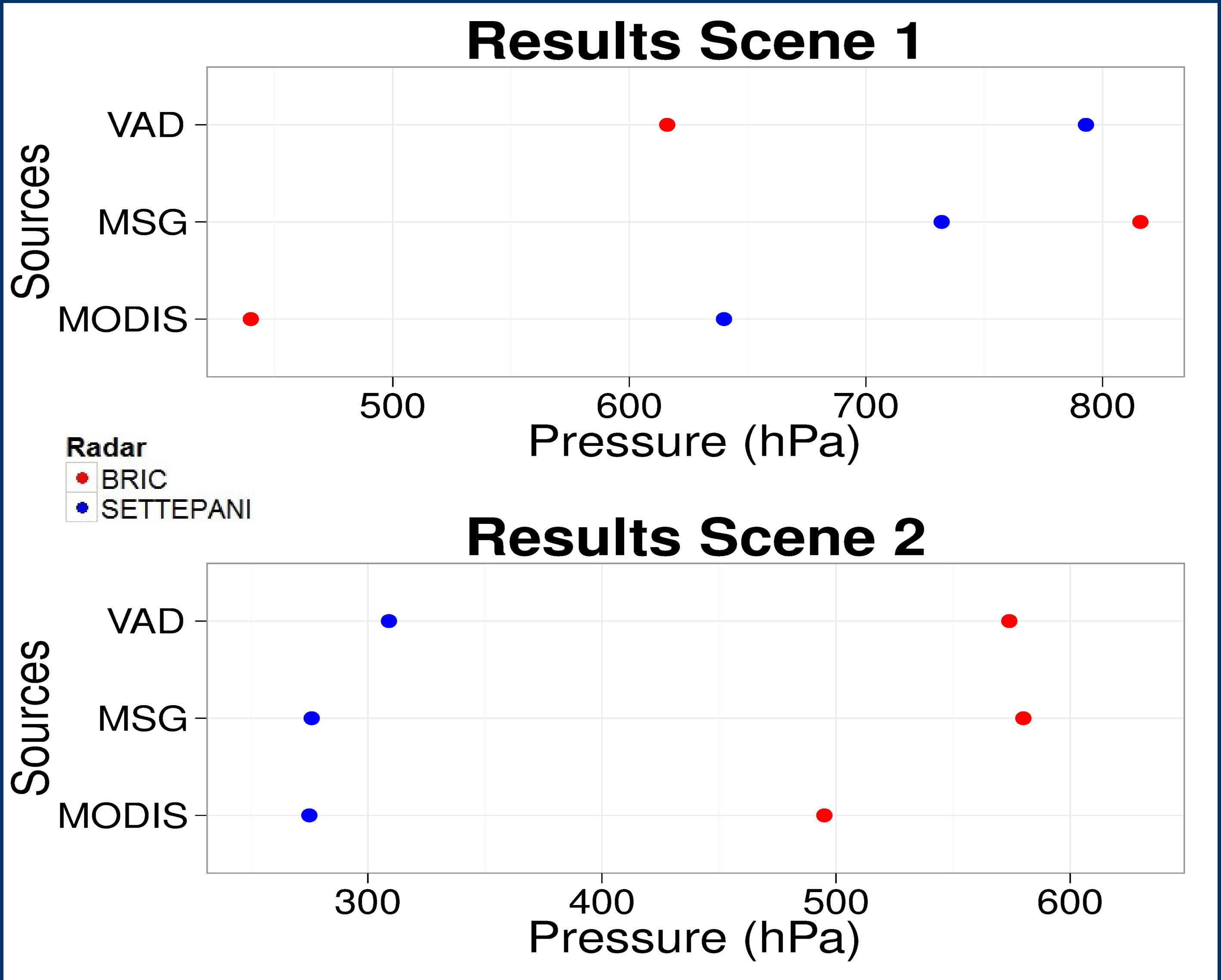
Radar and satellite data comparison:

- This results support the hypotesis of BIAS stronger for high pressures and weaker for low pressures

- Little VAD overestimate

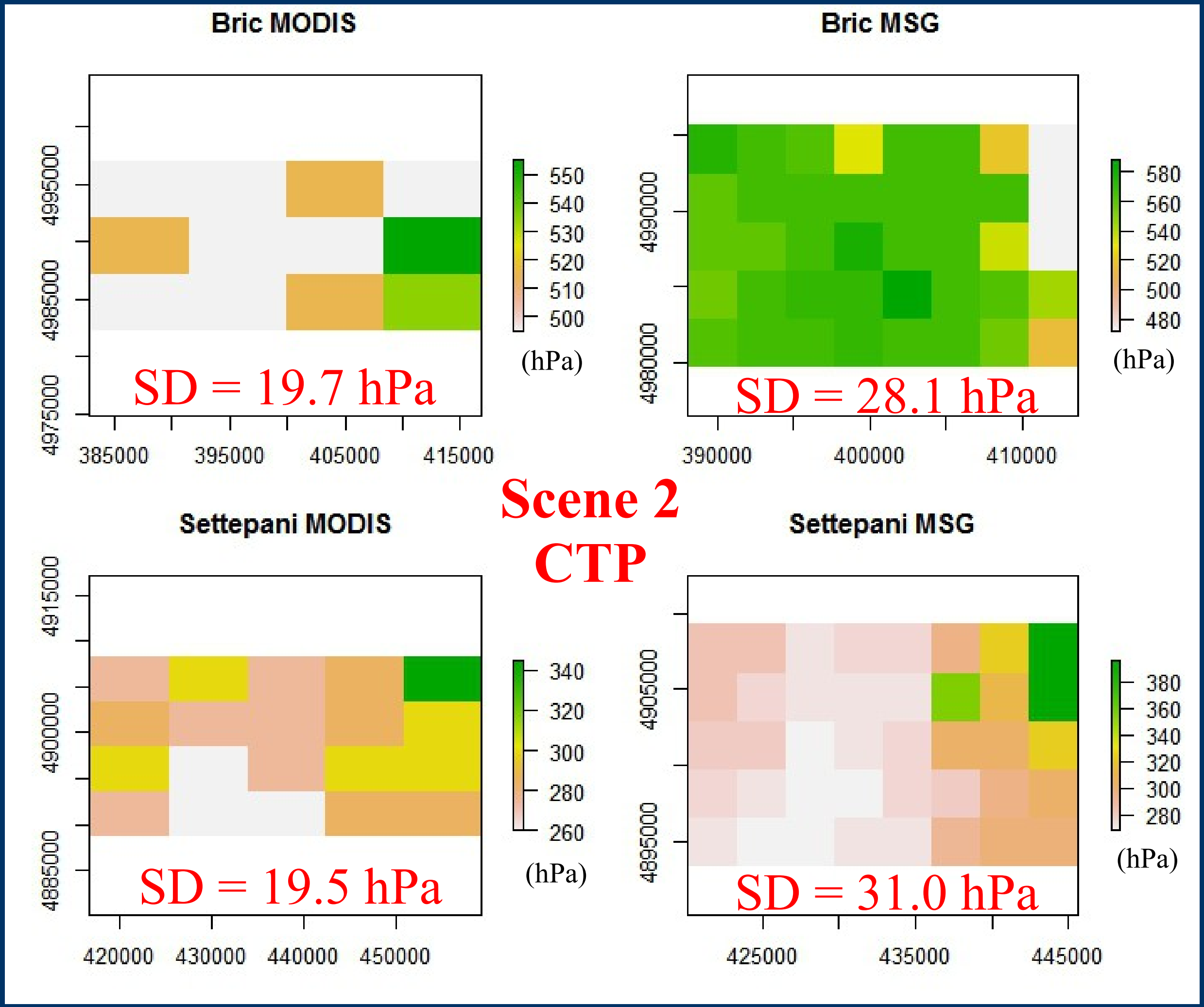
↓

it was expected



- **Differences depend on spatial variability**

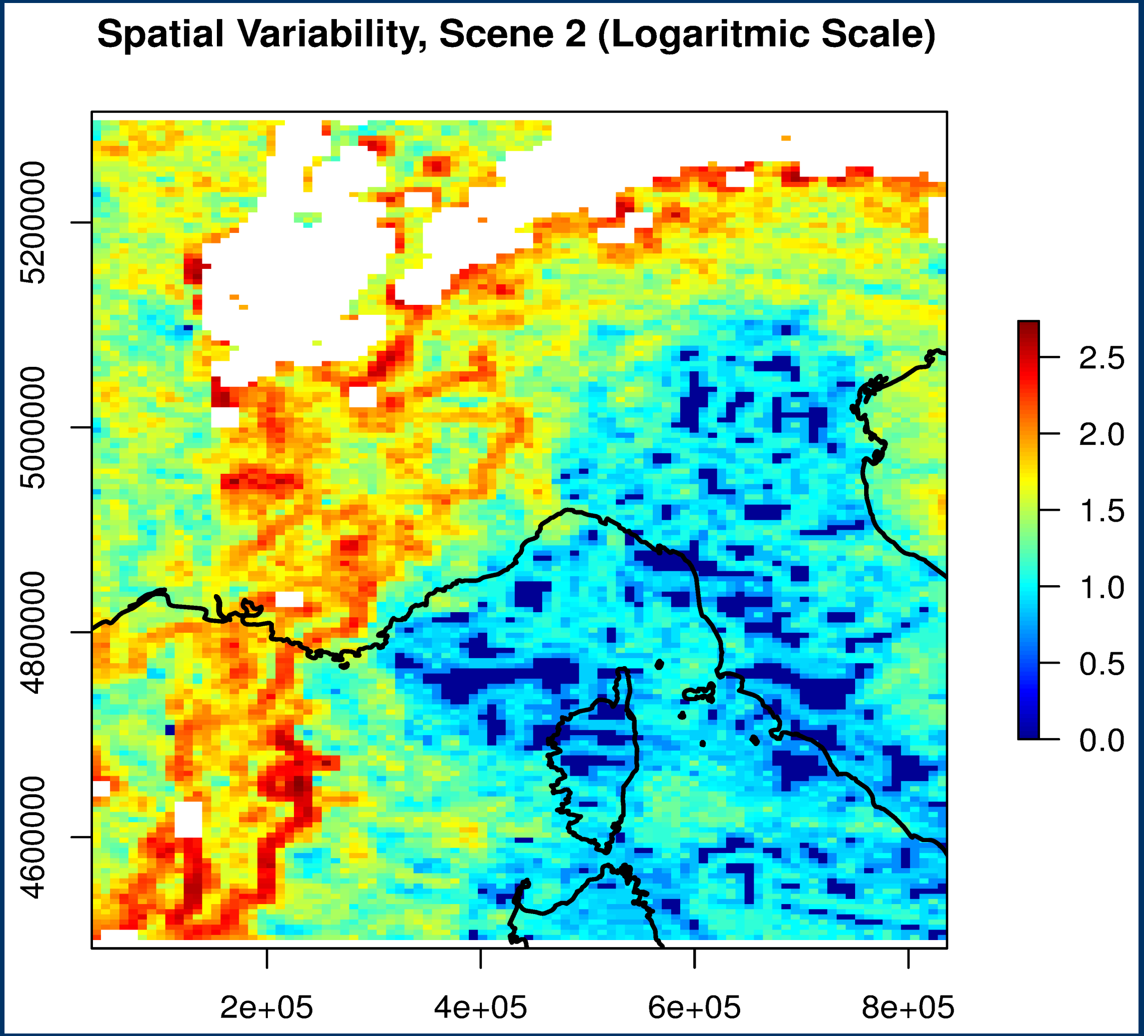
Spatial variability around the Radar



- More spatial variability means more difficulties in Cloud Top Pressure identification

The Spatial Variability criterion

- Extendig the last consideration I developed an **R** algorithm which calculates the spatial variability for each pixel of the raster



- The parameter used for spatial variability is:

$$SD = \sqrt{\frac{\sum_{i=1}^{8}(a-i)^2}{8}}$$

where **a** is the pressure value in the central pixel and **i** is the pressure value of each adjacent pixel

Conclusions and Results

- The agreement between the different sensors and algorithms is better for low pressure values (high clouds)

↓

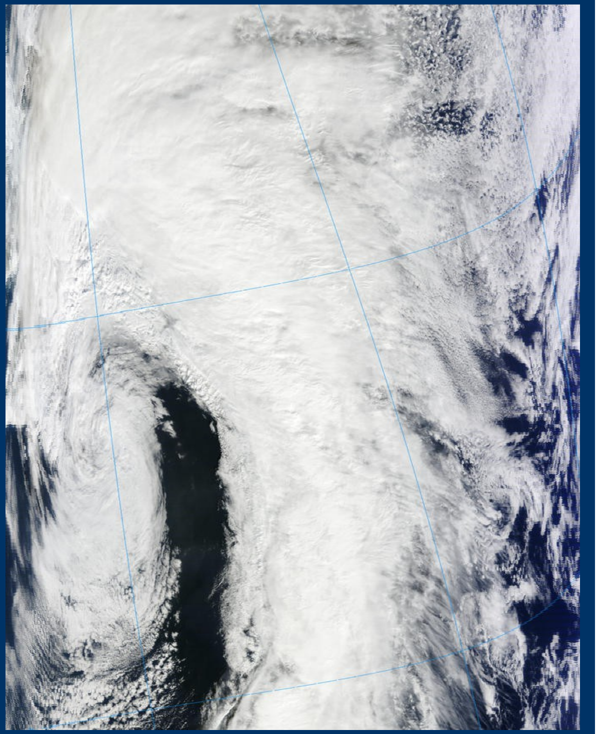
- BIAS which depends on the scene

- Better agreement for optically thick clouds

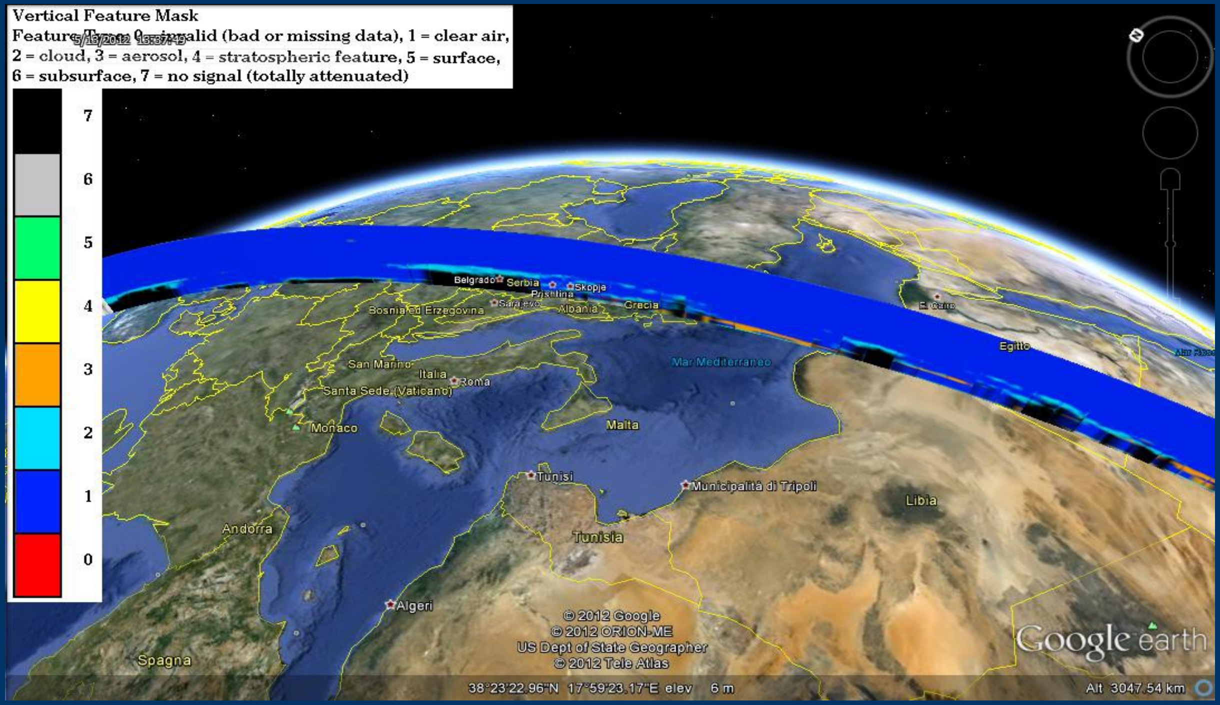
- Worse agreement with high spatial variability of clouds

Next steps:

- Validation of the obtained results using other scenes →
- Ocean scene: useful for JEM-EUSO



- Comparison with NWP Models



- Comparison with data from CALIPSO (LIDAR)

Thank you