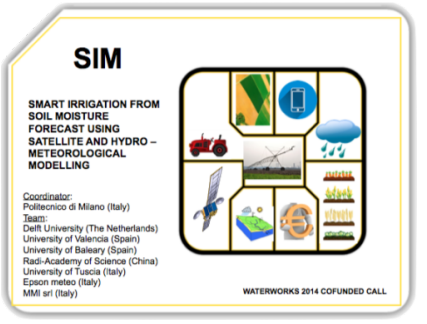


SMART IRRIGATION THE SIM PROJECT

SMART IRRIGATION MONITORING AND FORECASTING USING SATELLITE AND HYDRO METEOROLOGICAL MODELLING

José A. Sobrino, Drazen Skokovic

GLOBAL CHANGE UNIT IMAGE PROCESSING LABORATORY
UNIVERSITY OF VALENCIA
June 12, 2019 Roma

SIM FINAL MEETING

-AREA DESCRIPTION

-IN-SITU DATA

-SATELLITE DATA

-PROCESSING CHAIN AND ALGORITMS

-PRODUCTS VALIDATION (Albedo and LST)

-SATELLITE NEAR-REAL TIME EXAMPLES

Barrax: Area description

-Experimental farm in Albacete (Castilla La Mancha Region) (39°3’ N, 2°6’ W, 700 m a.s.l) characterized by an alternation of irrigated and dry cultivated area with corn, barley, sunflower, alfalfa, vineyards, sugar beet, onions etc. Soils are classified as Petrocalcic Calcixerepts. Texture is silty–clay–loam.

-Managed by a public company: the Technical Agronomic Institute of the Province (ITAP) (http://www.itap.es/).

-Climate is semiarid with temperate Mediterranea that include warm but with extreme temperatures in summer and winter. The average annual precipitation is 325 mm, and the average annual reference ET (ETo) (Penman–Monteith equation) is 1,280 mm.

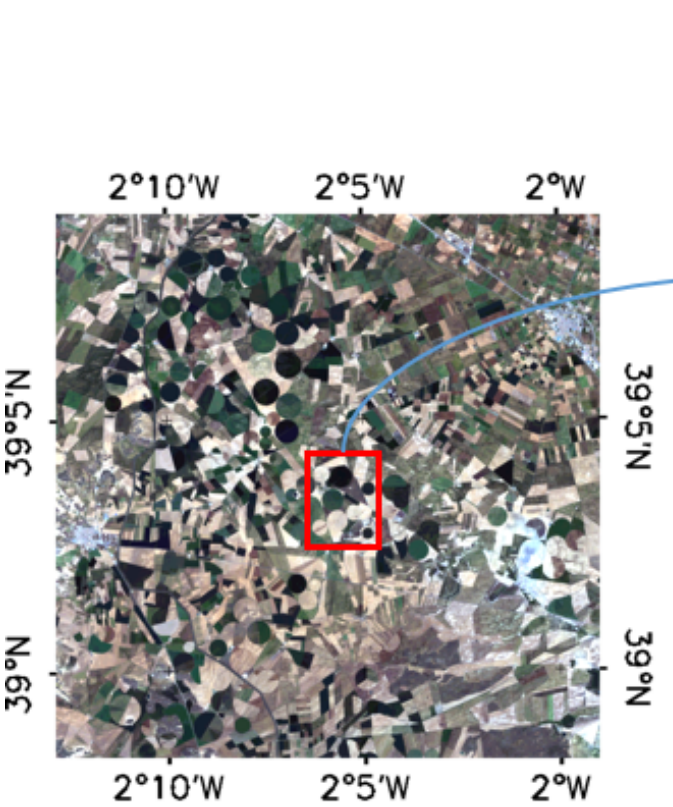
Problem: Scarcity of water

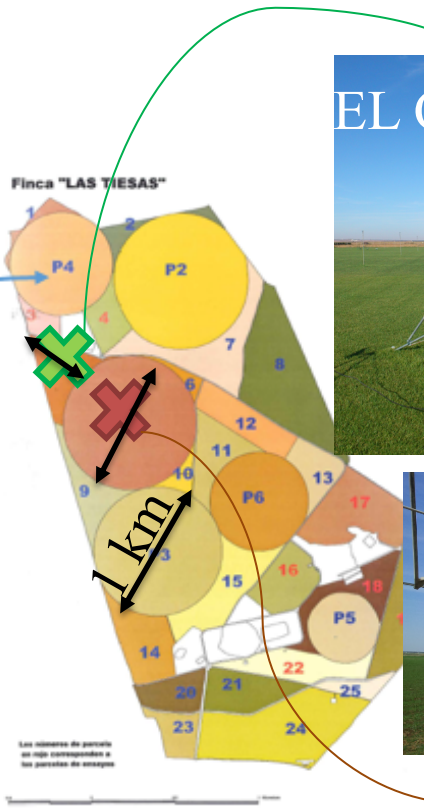
92% of the water destined to meet the needs of the crops comes from the subterranean water of the aquifer, and only 6% from surface run-offs of rivers and streams. Water price: 0.1067 €/m^3 (including pumping, distribution, etc.)

SMART IRRIGATION
THE SIM PROJECT

Barrax: Stations

Barrax is a traditional ESA test site for international campaigns (SEN2FLEX, SPARC, DAISEX, REFLEX) and a Cal/Val site of the Global Change Unit





Grass field
100×100 m

Pivot field
1×1 km

Station	Radio meters	Flux data	Temp & humidity	Others
El Cruce	Yes	Yes	Yes	Wind velocity, Soil flux, moisture and temperature
Las Tiesas	Yes	No	Yes	GPS
Lysimeter	No	No	No	Evapotranspiration

SMART IRRIGATION
THE SIM PROJECT

Barrax: Stations

There are not eddy covariance data, but air temperature and humidity sensors at two heights have been installed recently in order to estimate evapotranspiration and heat fluxes by the application of Bowen ratio method. Complementing the balance energy, net radiation (Rn) and soil flux (G) are also measured at grass field station. These data are available every hour from year 2011 until current date

Temperature & Humidity

Soil moisture

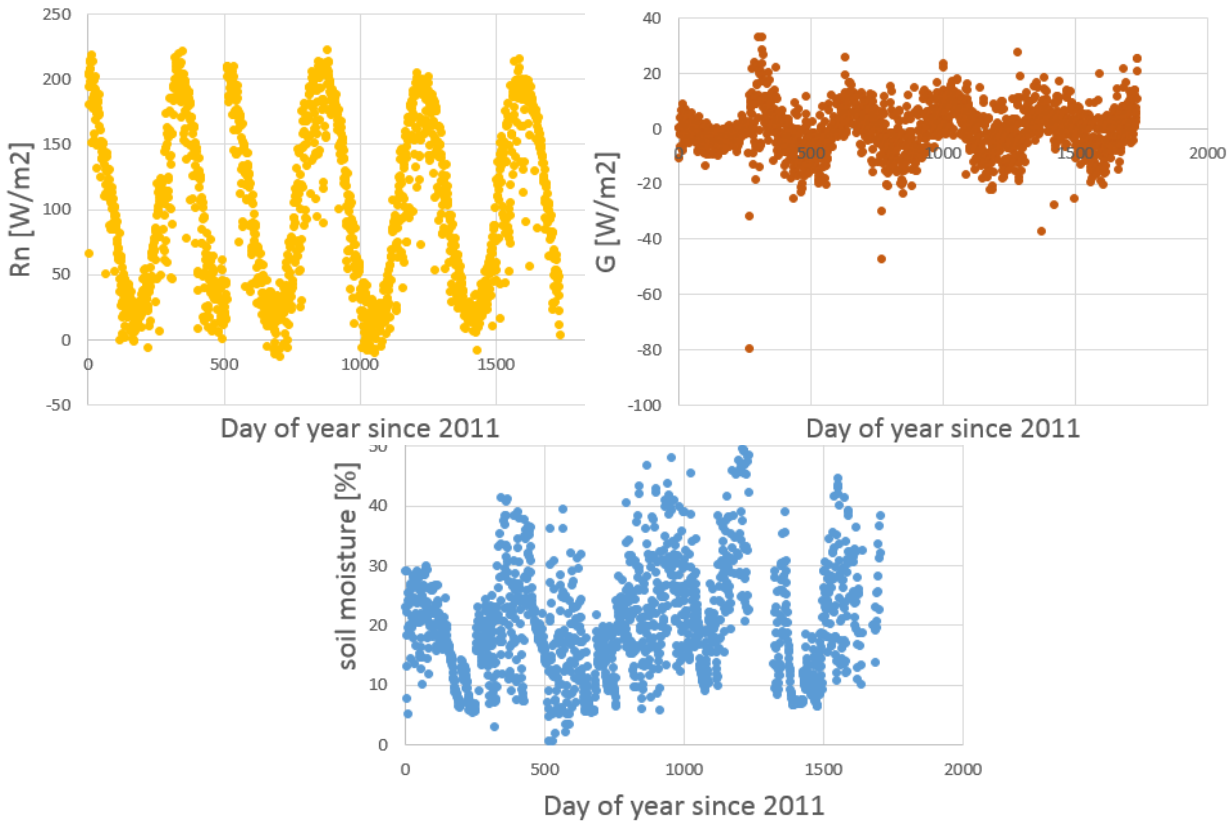
Energy Flux

Broadband radiometer (8-14) µm

IN-SITU DATA

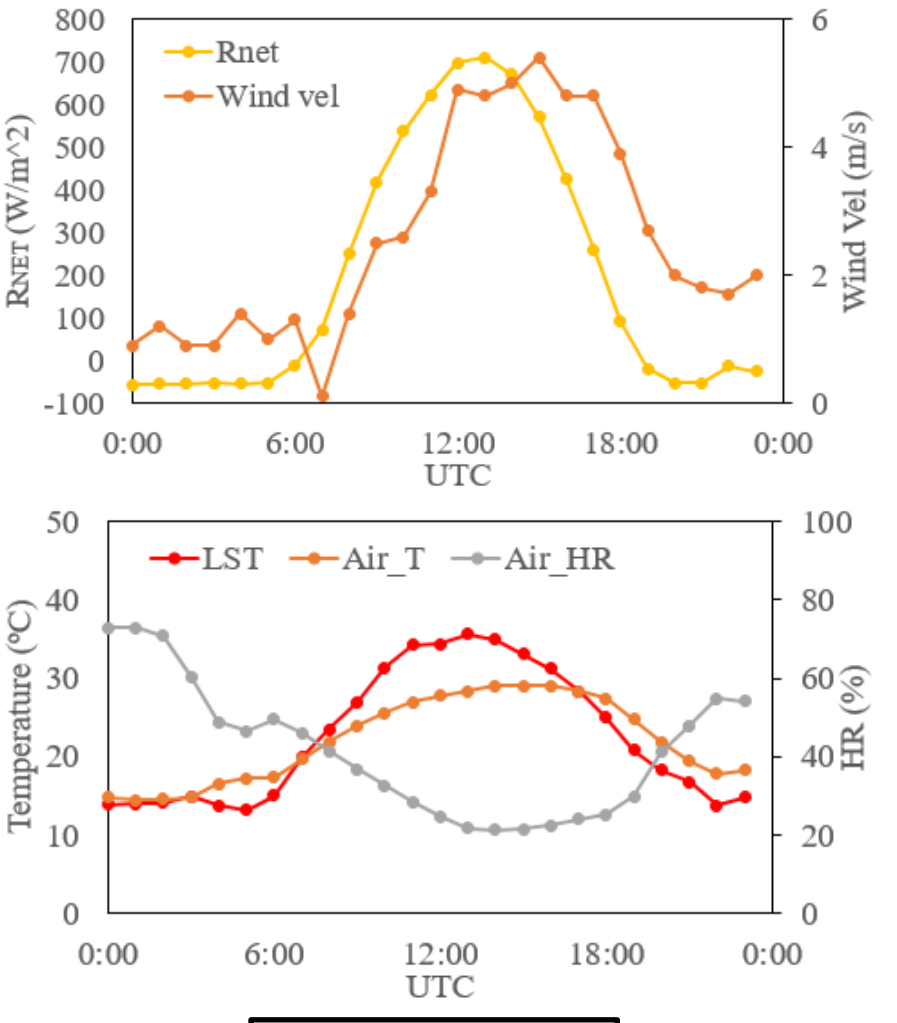
In-situ data

FROM 2011



- Nine years of continuous data (2011-2019)
- Real time reception of incoming solar radiation, LST, air temperature and humidity, wind velocity.

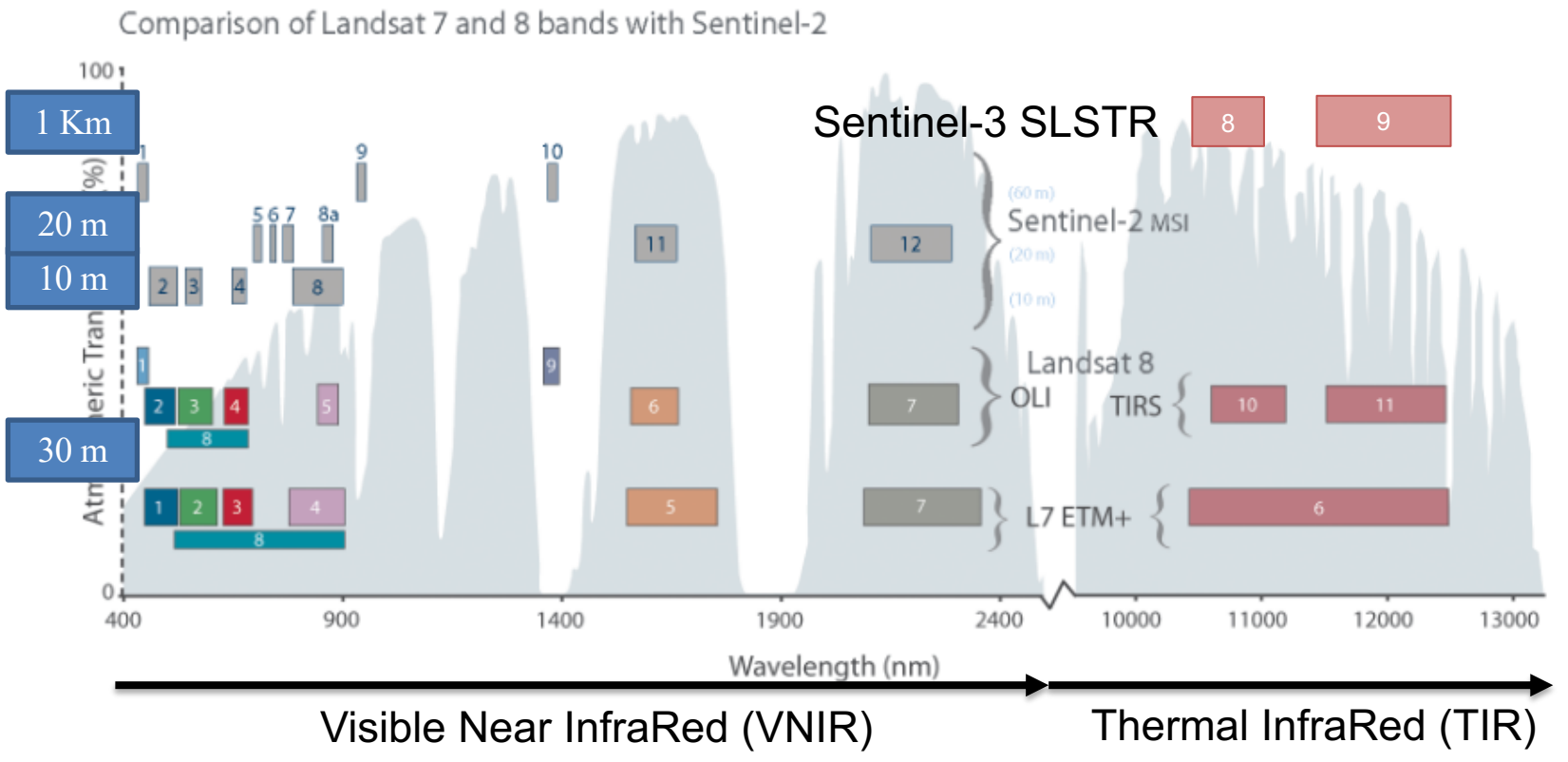
NEAR-REAL TIME DATA



June 03, 2019

SATELLITE DATA

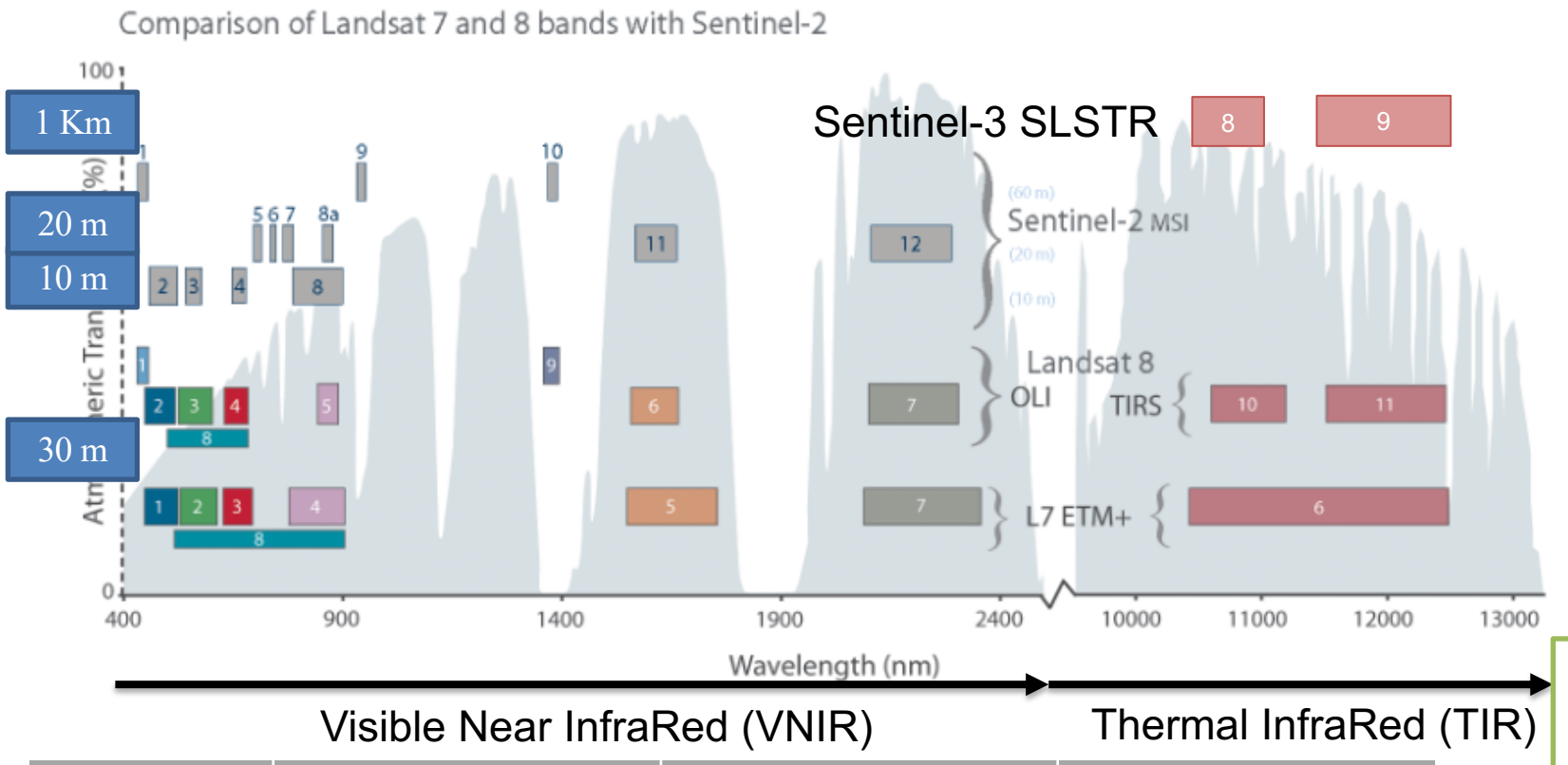
Sensors used for satellite monitoring



Platform	Sensor	Spatial Resolution	Revisit time	VNIR Bands	TIR Bands
Sentinel-2A/2B	MSI	10-20-60 m	5 days	12	0
Landsat-7	ETM+	30 m	16 days	7	1
Landsat-8	OLI-TIRS	30 m	16 days	9	2
Sentinel-3A/3B	SLSTR	1000 m	6-12 hours	6	2

SATELLITE DATA

Sensors used for satellite monitoring



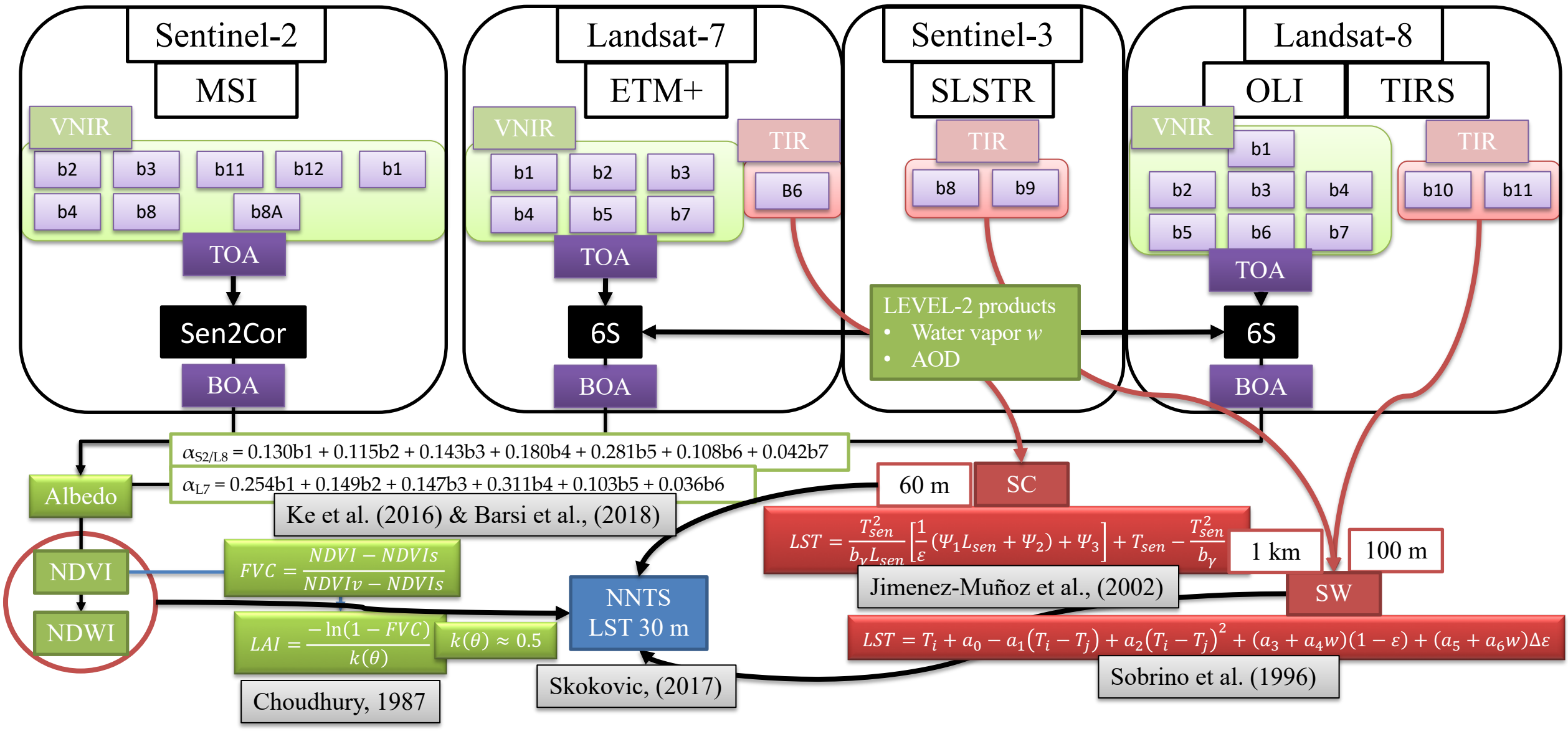
Data type	Sensors	Products	Product spatial resolution
VNIR	S2-MSI L8-OLI	NDVI, fCover, LAI, Albedo	30 m
TIR	L8-TIRS L7-ETM+ S3-SLSTR	Land Surface Temperature (LST)	30 m (resampled data)

16-days composite image are performed for Albedo, NDVI, fCover and LAI.

- Number of images averaged per composite image creation:
  - Puglia: 5-6 images
  - Barrax: 8-10 images

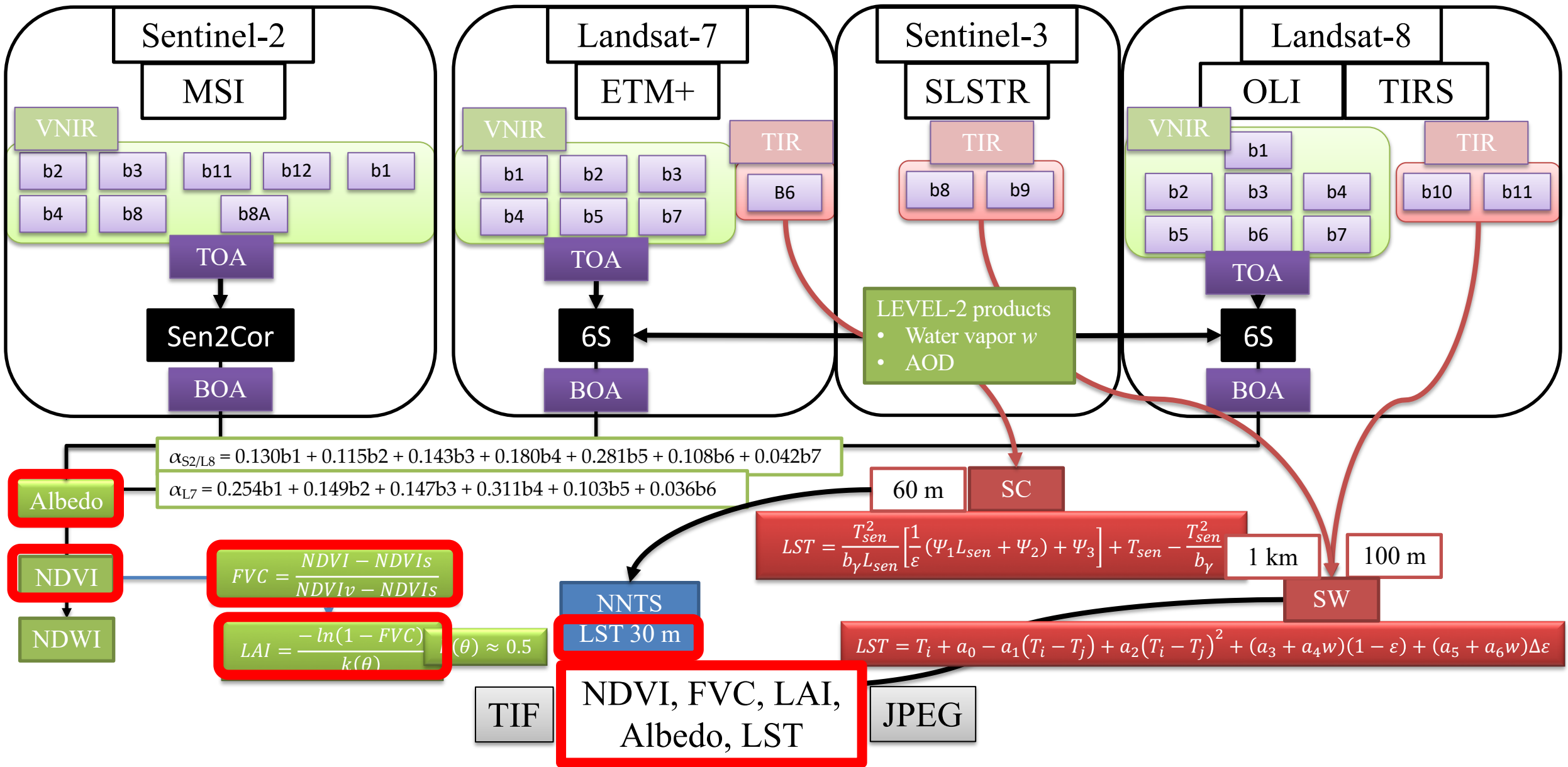
SATELLITE DATA

Processing chain and algorithms for near-real time satellite data



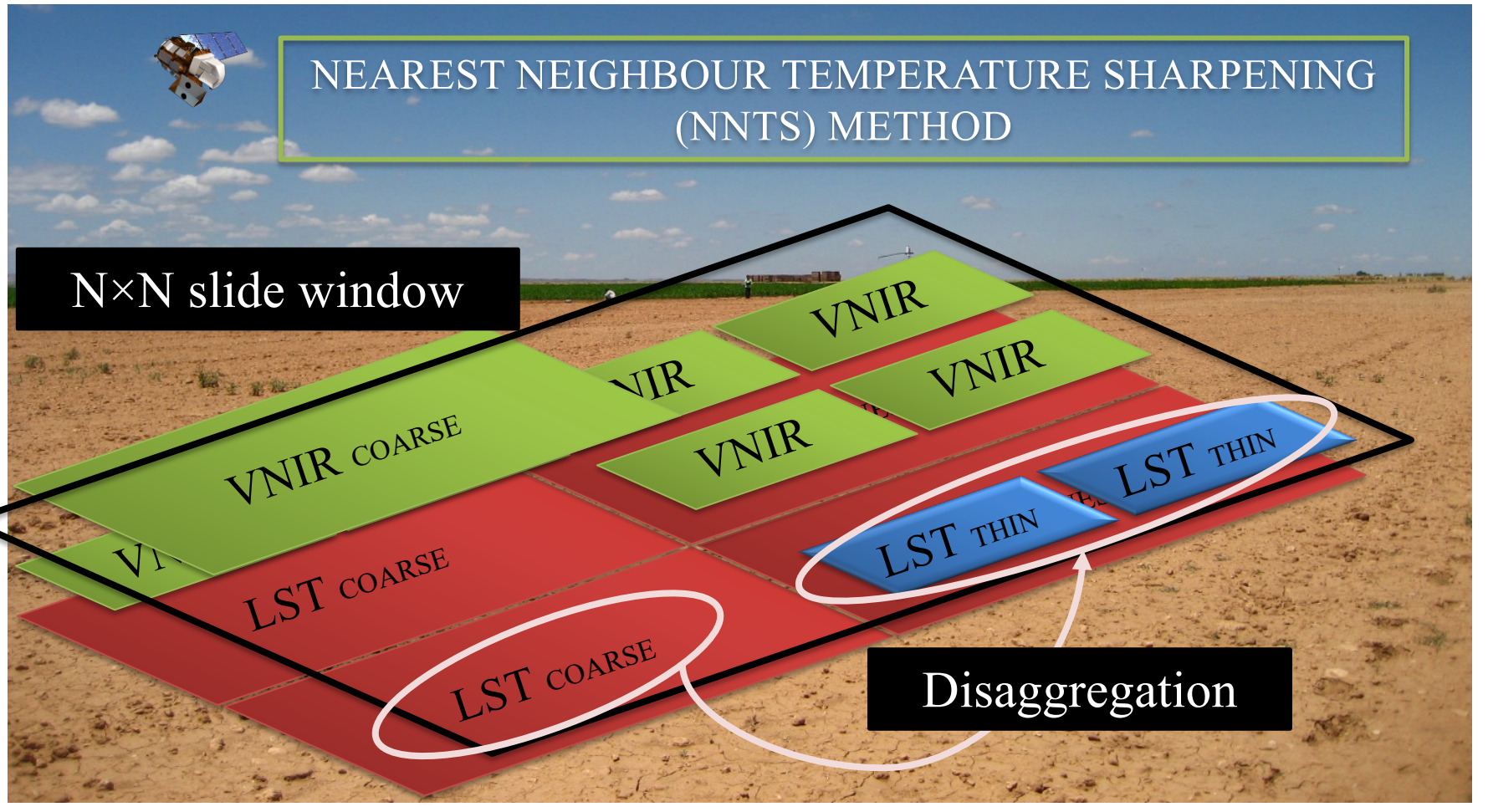
SATELLITE DATA

Processing chain and algorithms for near-real time satellite data



SATELLITE DATA

Processing chain and algorithms for near-real time satellite data

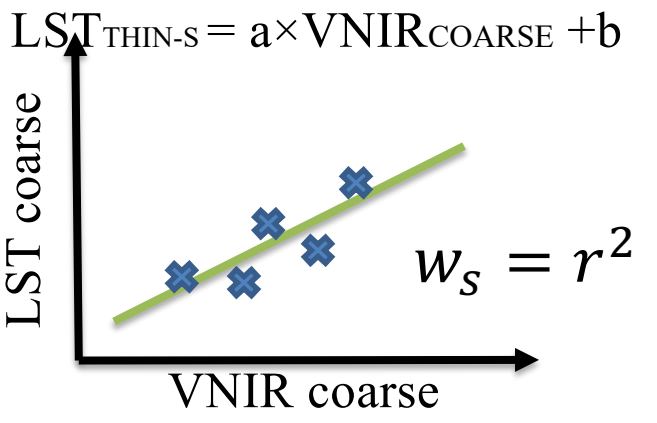


Statistical relation

Best relation (higher r^2)

- NDVI vs LST
- NDWI vs LST

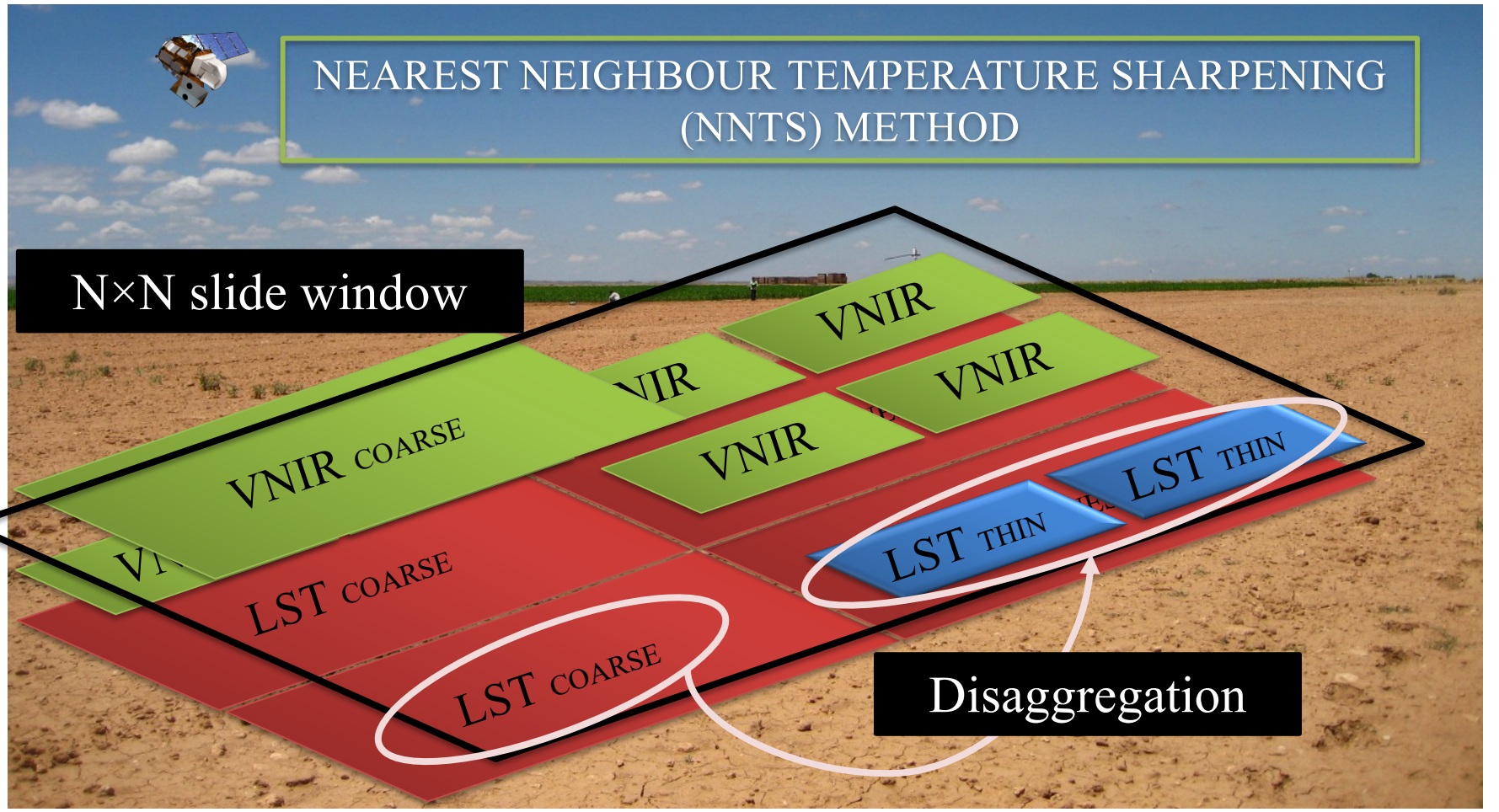
$LST_{THIN\text{-}S} = a \times VNIR_{COARSE} + b$



Higher weight (w_s) when stronger relation

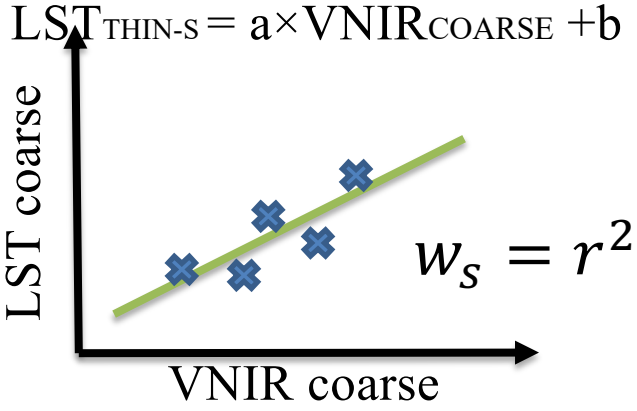
SATELLITE DATA

Processing chain and algorithms for near-real time satellite data



Statistical relation

$$LST_{THIN\text{-}S} = a \times VNIR_{COARSE} + b$$



Nearest neighbour VNIR pixel

$$LST_{THIN-N} = \frac{\sum_{i=0}^{pixels} LST_{coarse_i} \times 1/d_i}{\sum_{i=0}^{pixels} 1/d_i}$$

$$w_n = 1 - r^2$$

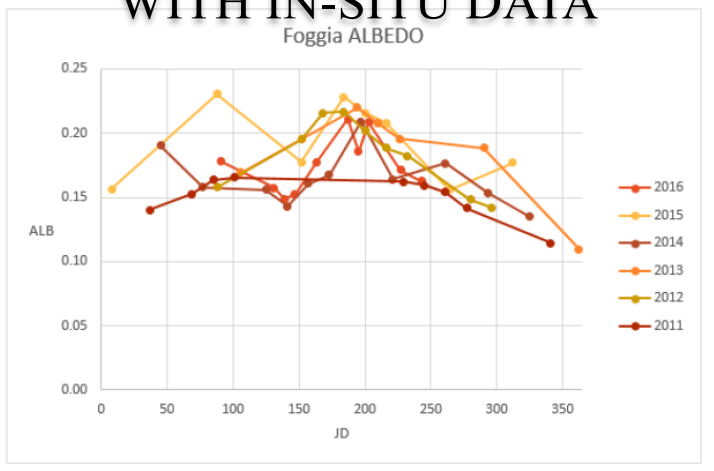
Final LST_{THIN} value is a combination of both LST but taking into account the statistical and nearest neighbour weight

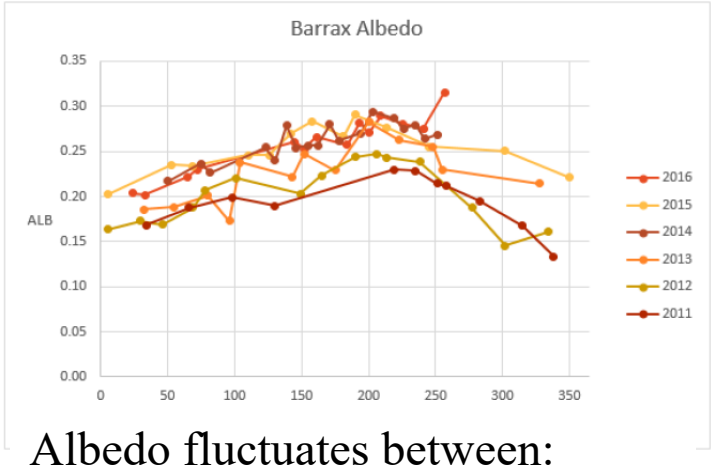
$$LST_{THIN} = w_s \times LST_{THIN-S} + w_n \times LST_{THIN-N}$$

PRODUCTS VALIDATION

OLI-MSI Albedo validation with in-situ data

ALBEDO YEARLY EVOLUTION
WITH IN-SITU DATA

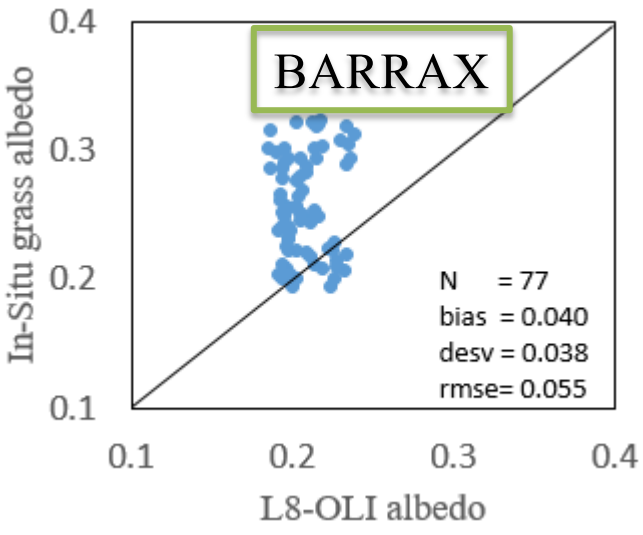


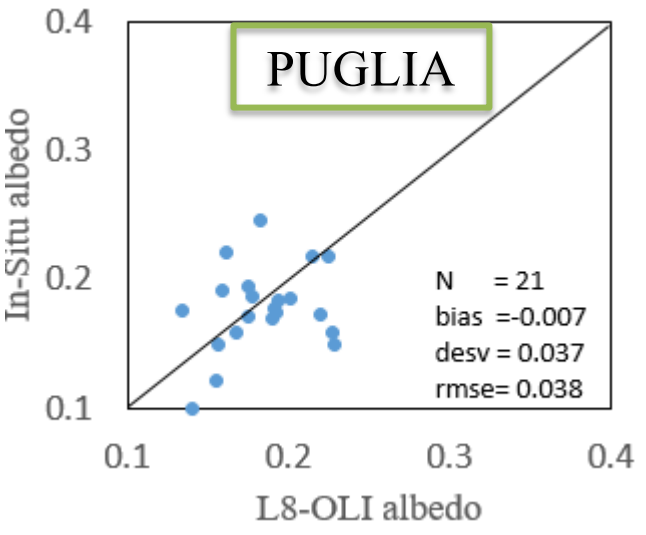


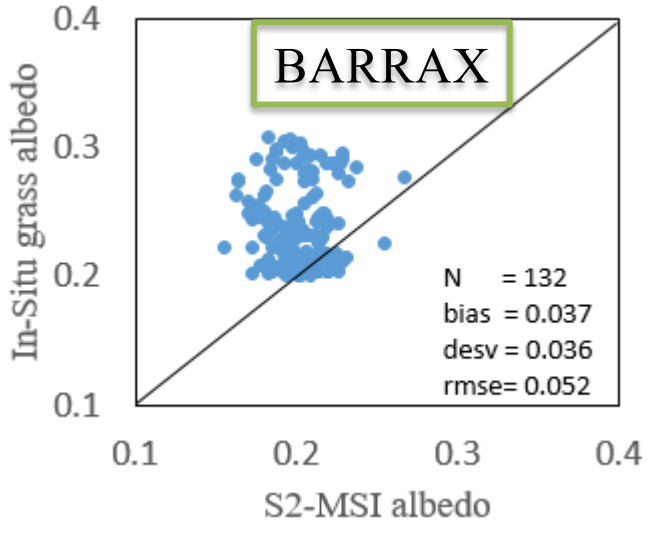
Albedo fluctuates between:

- Puglia: 0.10-0.25
- Barrax: 0.15-0.30

ALBEDO VALIDATION
SATELLITE VS IN-SITU DATA







RMSE validation values between 0.04-0.06

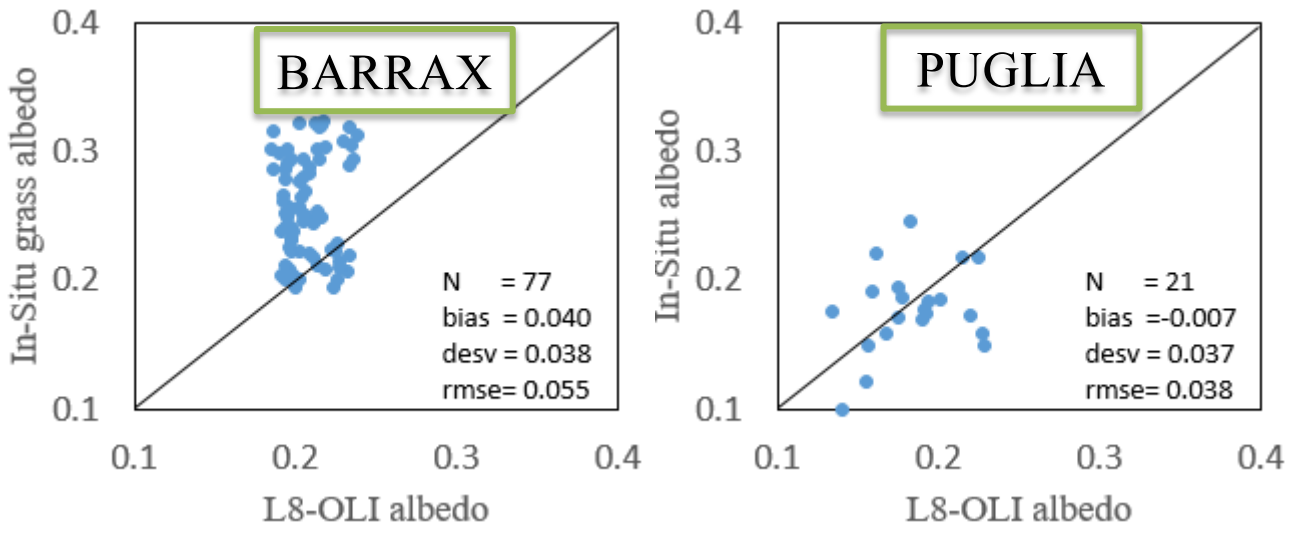
- Accuracy directly related to NDVI:
  - For higher NDVI's lower albedo differences between in-situ and sensor data.

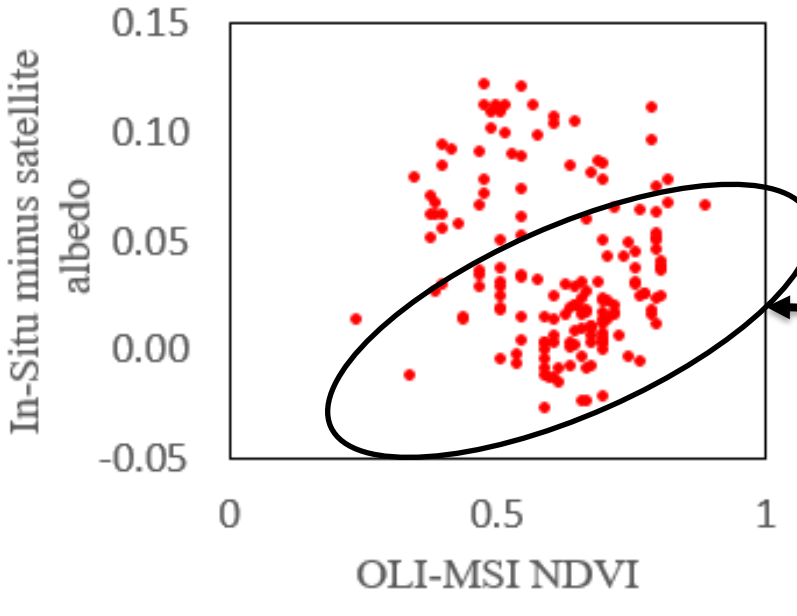
PRODUCTS VALIDATION

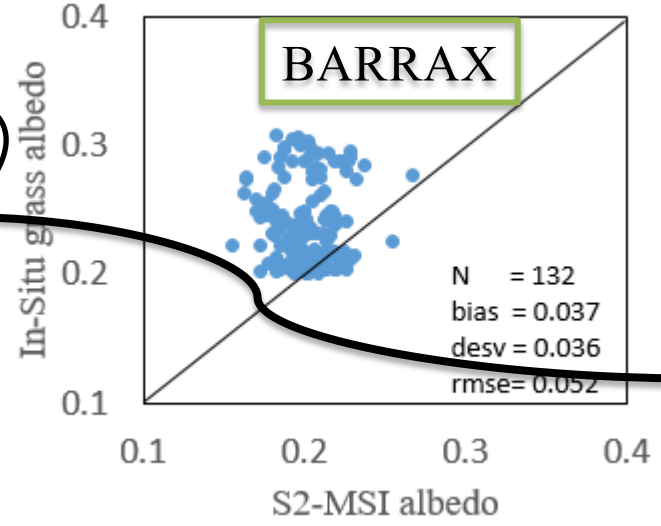
OLI-MSI Albedo validation with in-situ data

ALBEDO YEARLY EVOLUTION
WITH IN-SITU DATA

ALBEDO VALIDATION
SATELLITE VS IN-SITU DATA





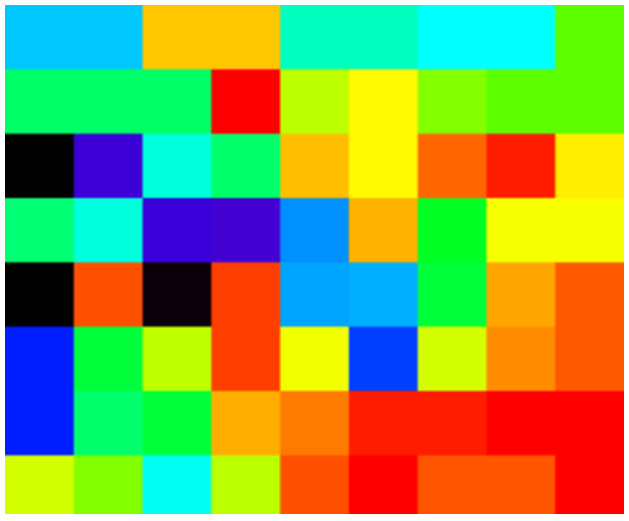


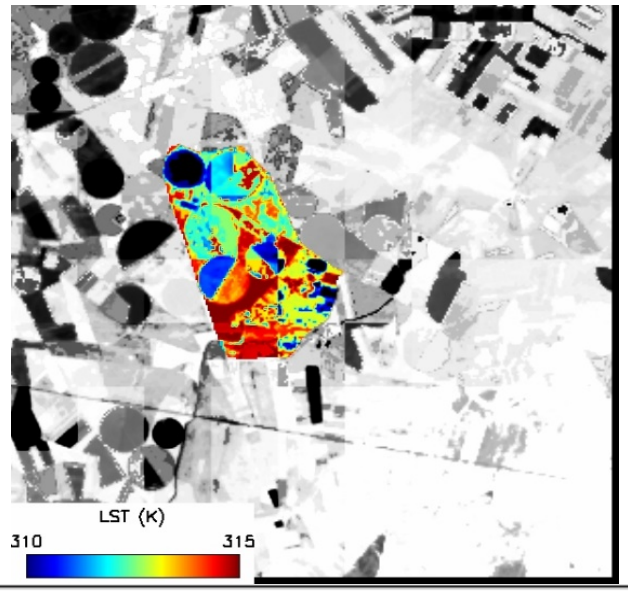
RMSE validation values between 0.04-0.06

- Accuracy directly related to NDVI:
  - For higher NDVI's lower albedo differences between in-situ and sensor data.

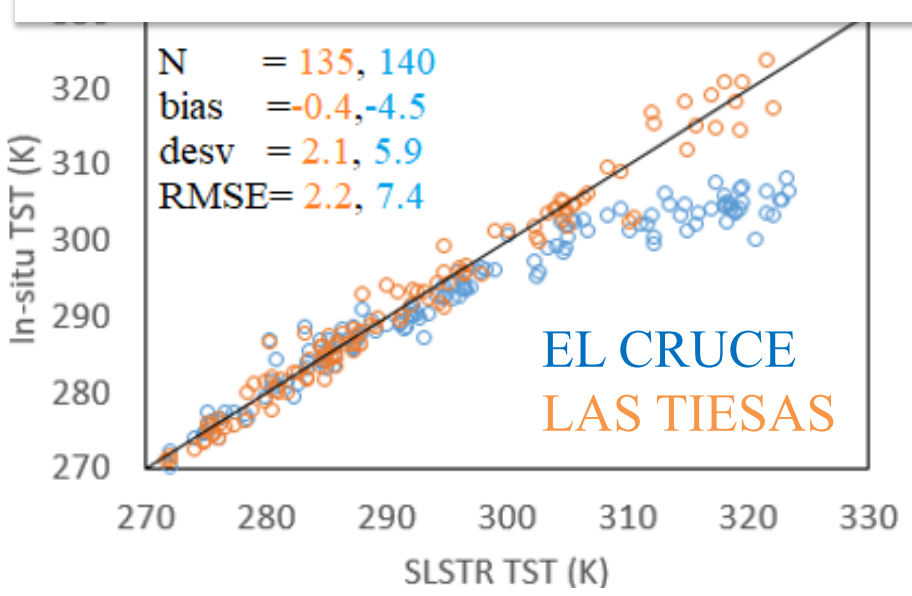
PRODUCTS VALIDATION

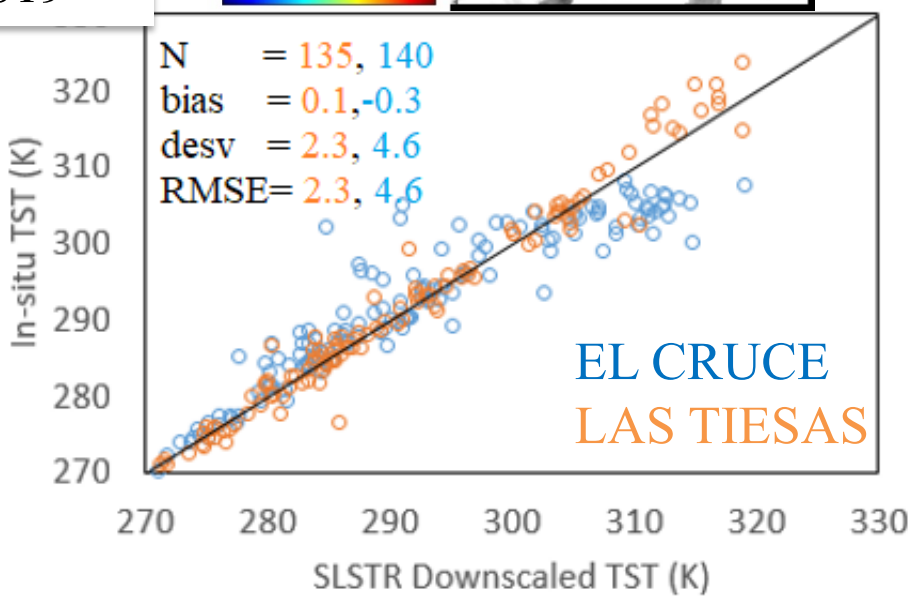
LST validation of Sentinel-3 SLSTR product at original (1 km) and resampled (30 m) spatial resolution





IMAGES FROM JUNE 2018 TO MAY 2019



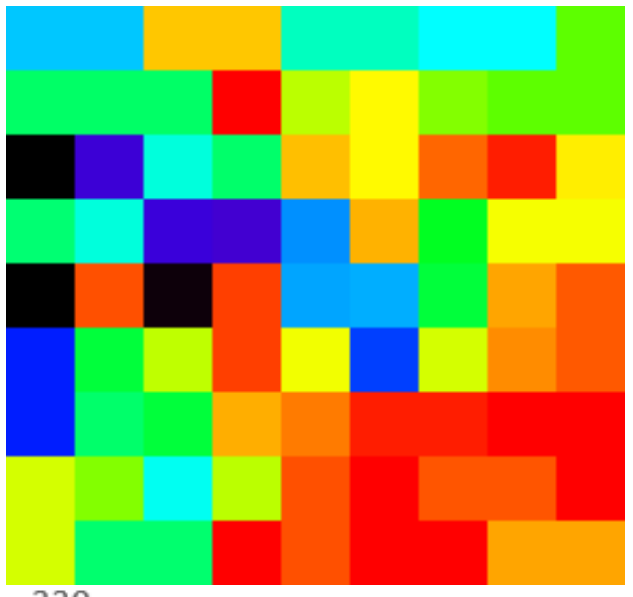


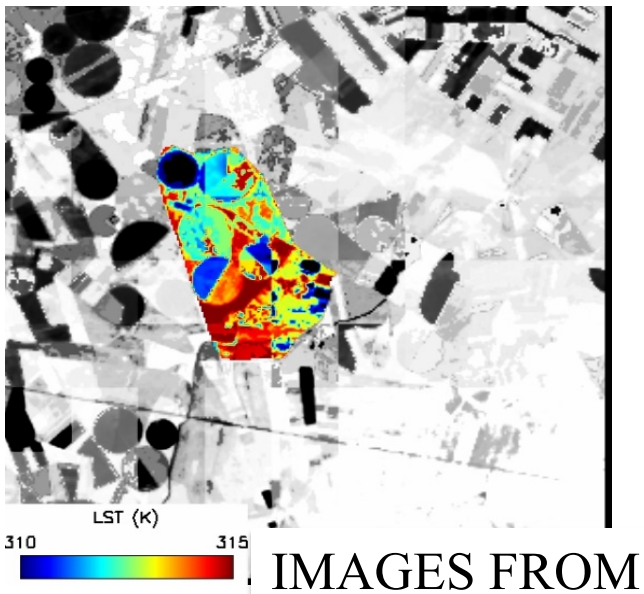
Pivot field
1×1 km

Grass field
100×100 m

PRODUCTS VALIDATION

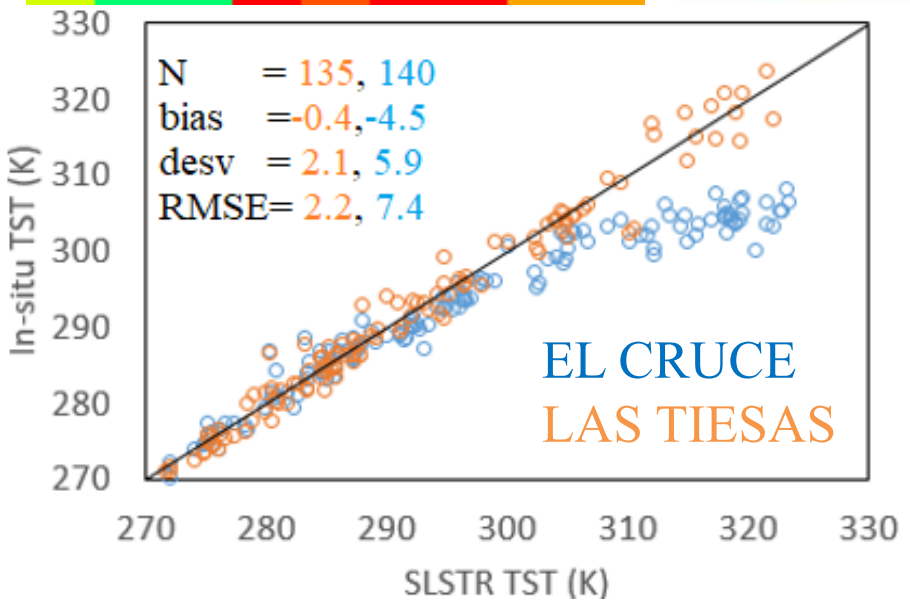
LST validation of Sentinel-3 SLSTR product at original (1 km) and resampled (30 m) spatial resolution

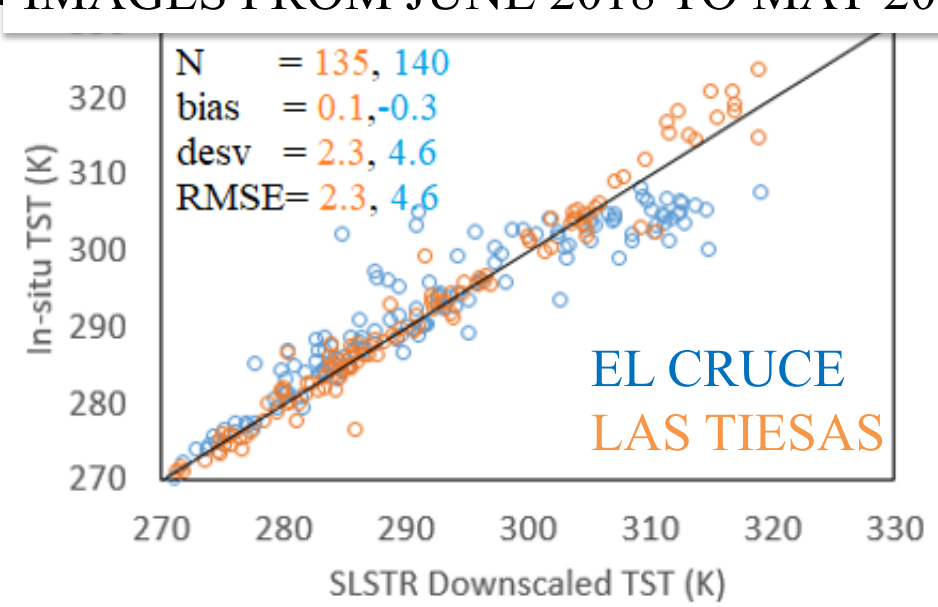




- Results show that the downscaling process improves the accuracy of LST on small fields
- Concretely, diminution of 4 K and 1 K was observed on bias and standard deviation, respectively.
- Large fields the results show no difference.

IMAGES FROM JUNE 2018 TO MAY 2019





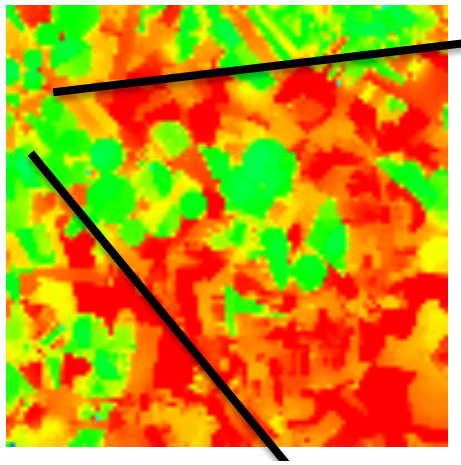
Pivot field
1×1 km

Grass field
100×100 m

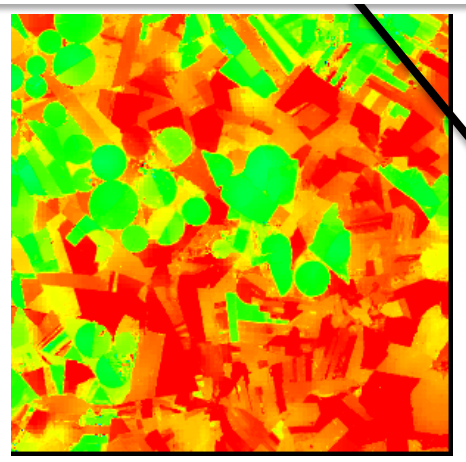
PRODUCTS VALIDATION

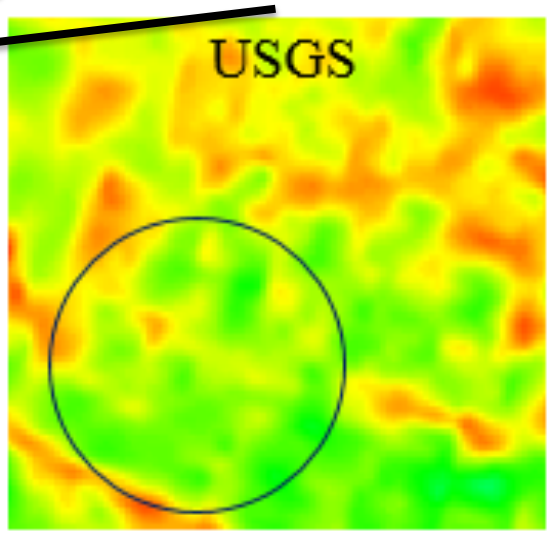
LST validation of resampled TIRS/ETM+ data

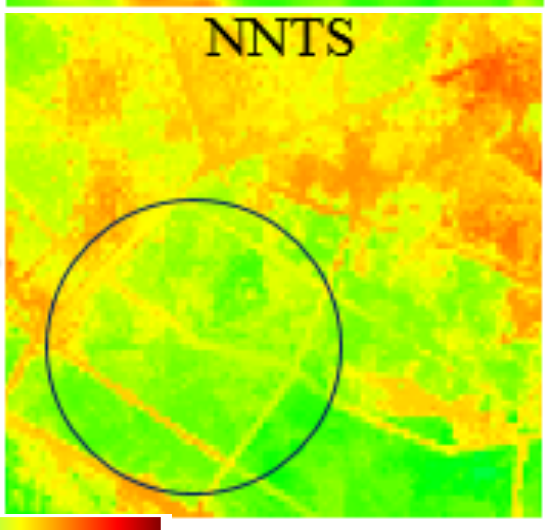
Landsat-8 original image

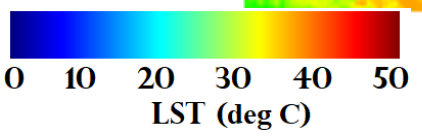


Landsat-8 downscaled



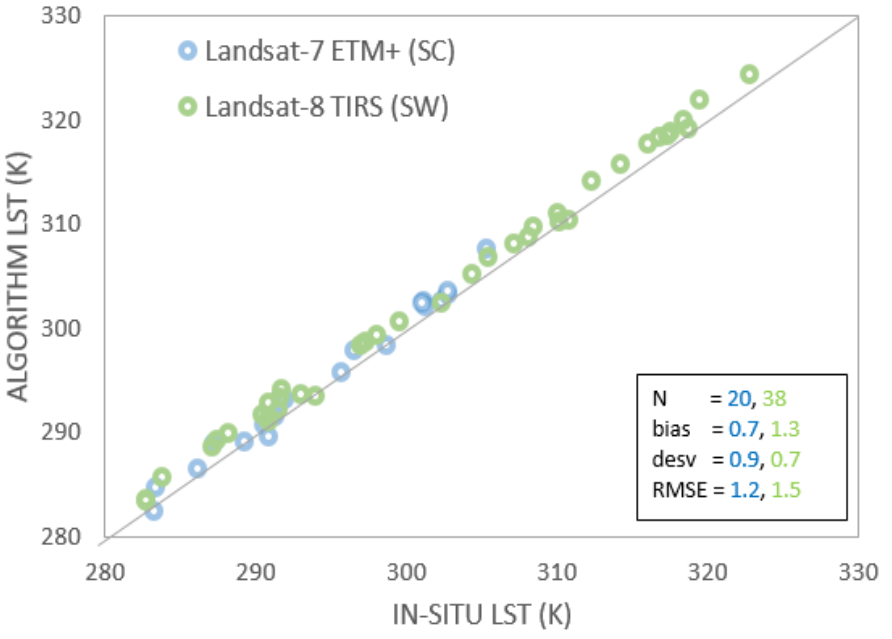






- The total RMSE is 1.4 K with a little biased values in favor to algorithm data of 1.1 K (Algorithm minus in-situ data)

IMAGES FROM APRIL 2013 TO MAY 2016



- Downscaled image is more detailed than the original image provided by USGS (NASA)

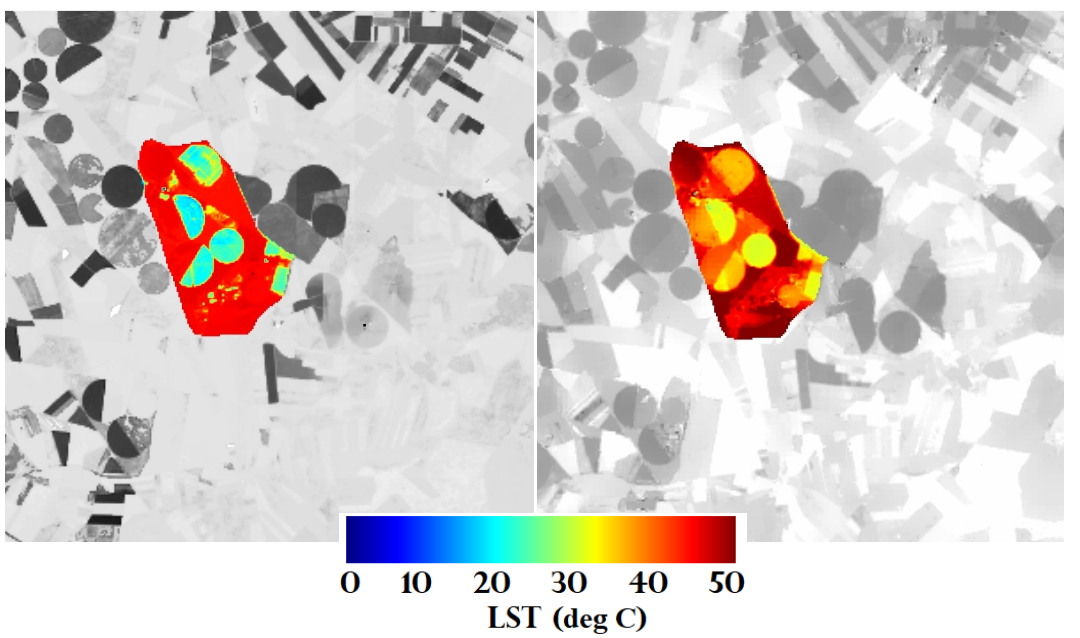
SATELLITE NEAR-REAL TIME EXAMPLES

Near-Real Time images

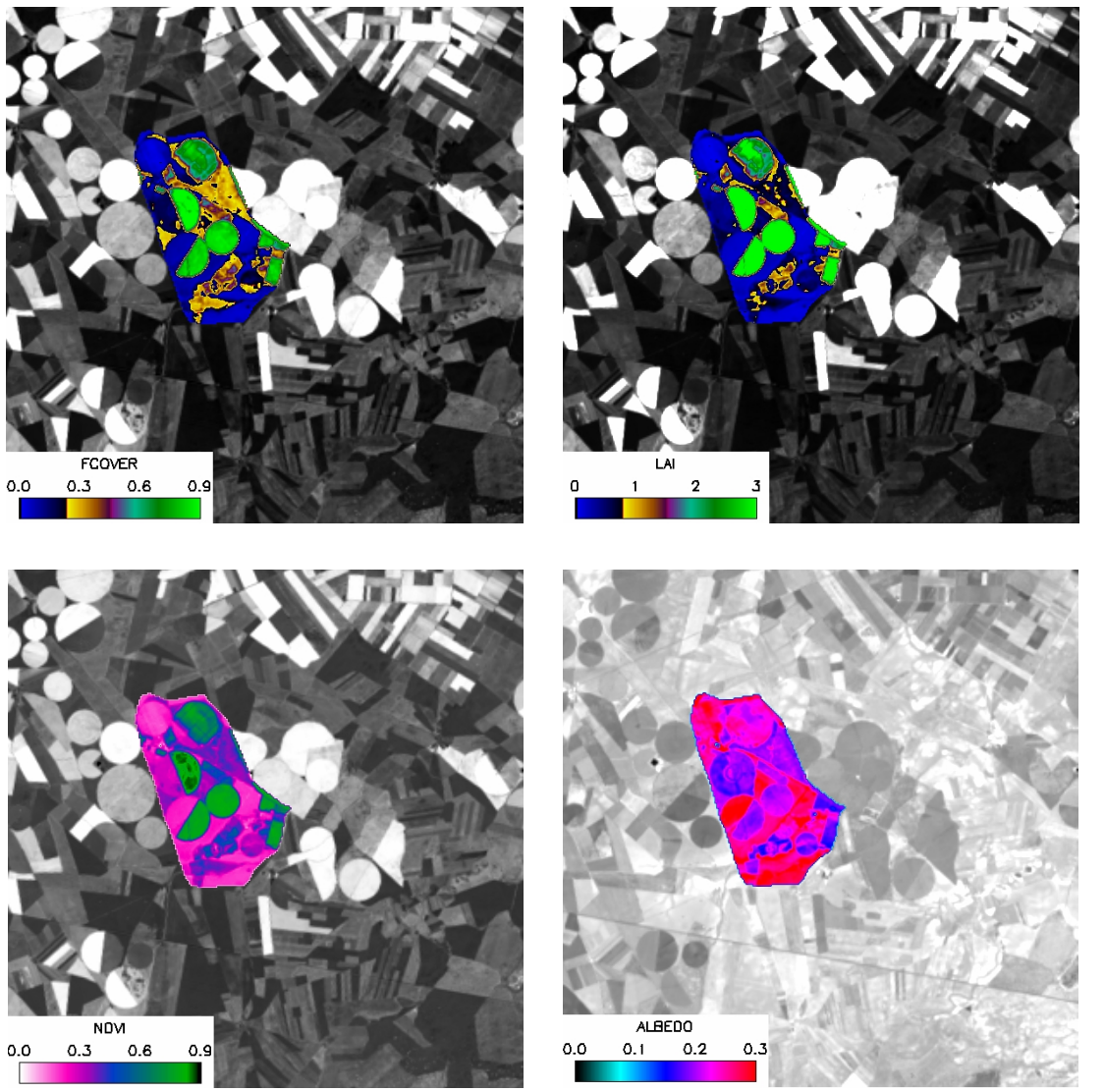
BARRAX
JUNE 02, 2019

LANDSAT-8 TIRS
10:55 UTC

SENTINEL-3 SLSTR
09:46 UTC



LANDSAT-8 OLI
COMPOSITE 16-D



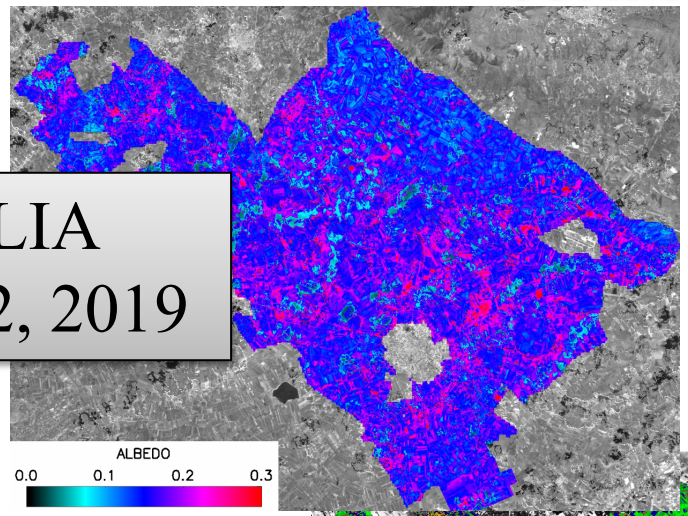
SATELLITE NEAR-REAL TIME EXAMPLES

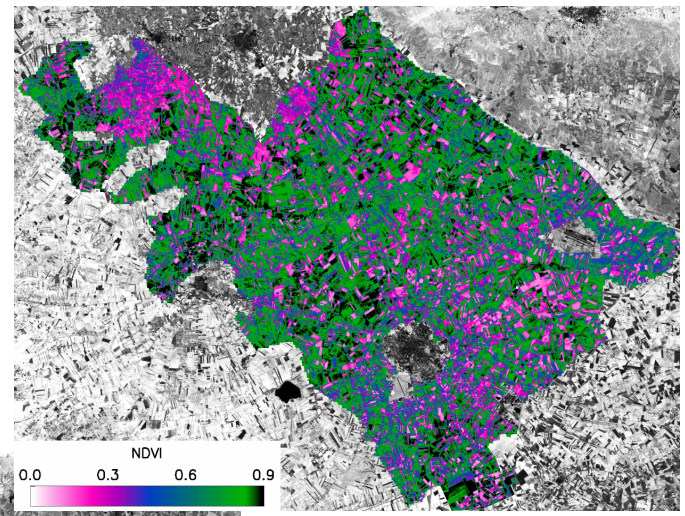
Near-Real Time images

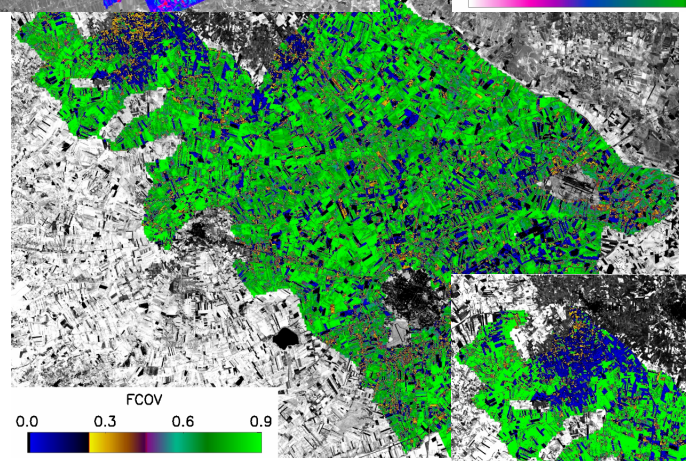
SENTINEL-2 MSI
COMPOSITE 16-D

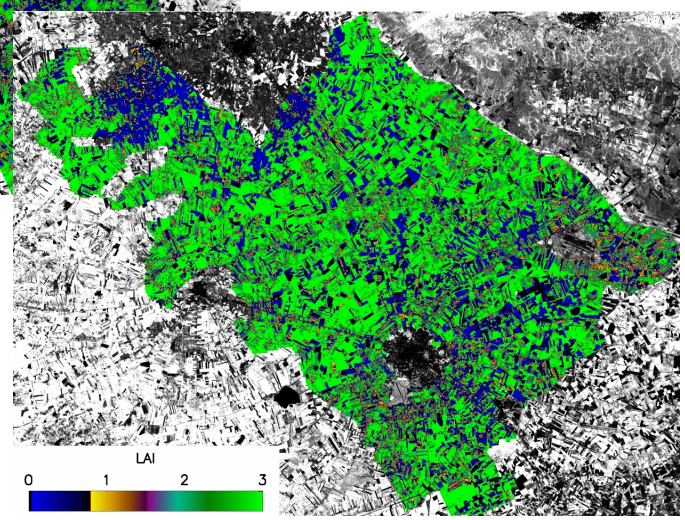
PUGLIA
JUNE 02, 2019

PUGLIA
MAY 19, 2019



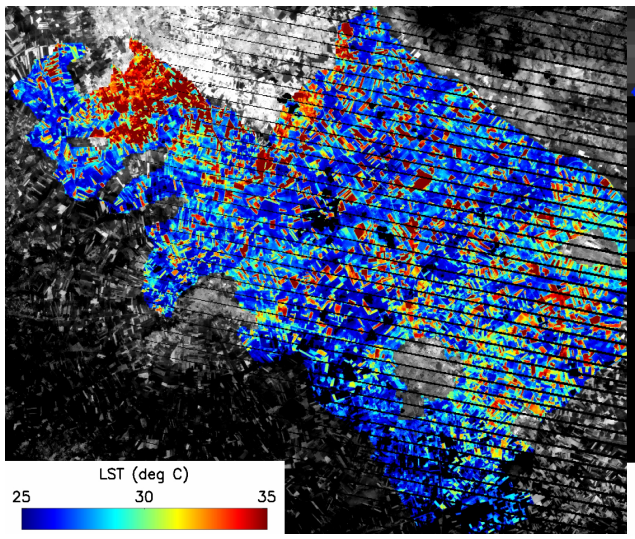


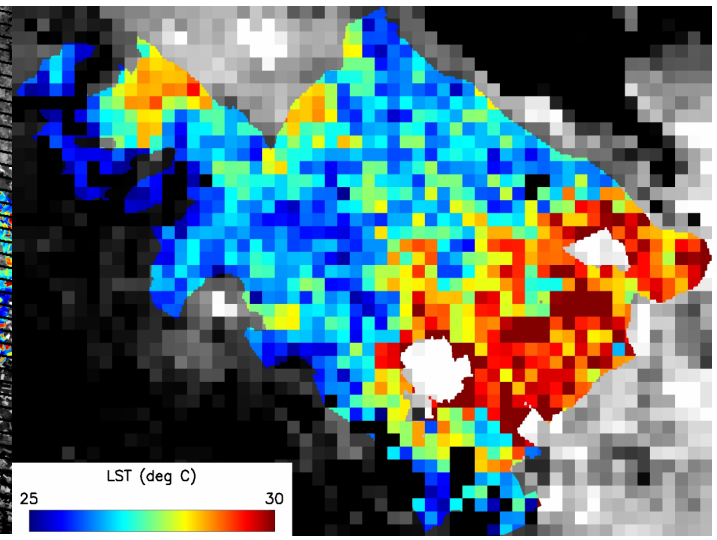




LANDSAT-7 ETM+
09:45 UTC

SENTINEL-3 SLSTR
09:16 UTC





CONCLUSIONS

- Currently**, Barrax station El Cruce** is providing **in-situ real-time data every day.**

- **Processing chain** has been developed for automatic retrieval of **Vegetation Index** (NDVI, FVC, LAI), **albedo** and **LST** (resampled to 30 m)
  - **Landsat-7/8 and Sentinel-2/3** have been selected as source of VNIR and TIR data.
  - **Near-real time data** is available **24-36 hours** after image acquisition.

- Used **algorithms** have been **tested with in-situ data** (LST and albedo) with Barrax in-situ data.
  - **Albedo** has shown an **accuracy near to 0.04** and **standard deviation of 0.04.**
  - **Resampled LST data** show **RMSE below to 2.0 K (**Landsat **ETM+/TIRS case)** and **improves** LST estimation on small fields (Sentinel-3 **SLSTR** case)
    - More validation is required on the Puglia test site

- **Future improvements** will include:
  - **Sharpened Sentinel-3 LST** images for Puglia test site and addition of Chiesa test site to our processing chain.
  - Additional vegetation index as well as water stress index (**SAVI, MSI and CWSI**).