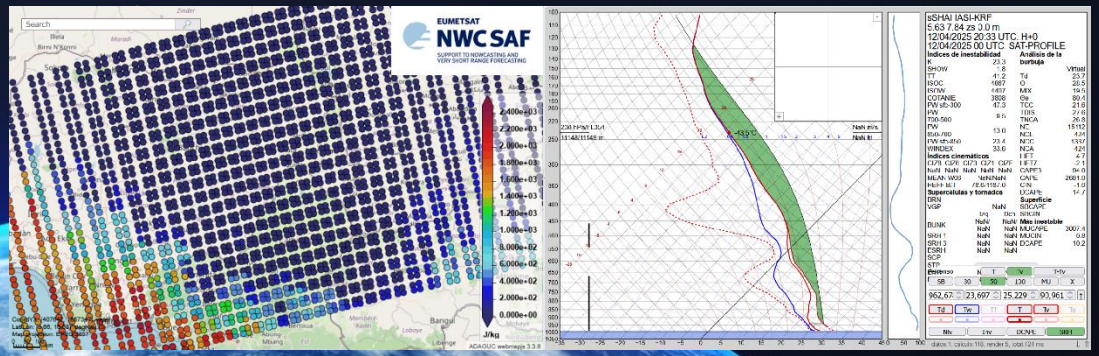
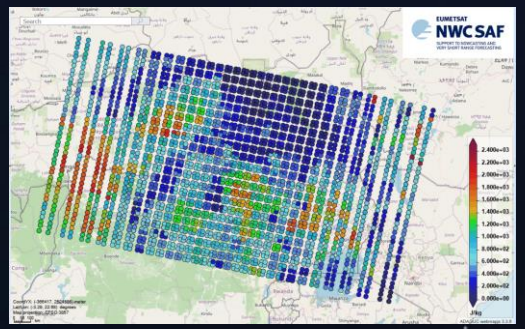


NWC SAF new sSHAI product from MetOp-IASI as a proxy for MTG-IRS



Speakers: Niobe Peinado Galán (npeinadog@aemet.es

Xavier Calbet (xcalbeta@aemet.es)

EUMETrain Workshop: <<Future Nowcasting SAF services and Satellite Humidity And Instability product from MTG-S/IRS data: Examples of use on practical cases with a MetOp-IASI prototype>>
2 June 2025

(Image credit: Thamrongpat Theerathammakorn / EyeEm via Getty Images)

NWC SAF sSHAI: Summary

1. Introduction to **Hyperspectral Infrared Sounders**

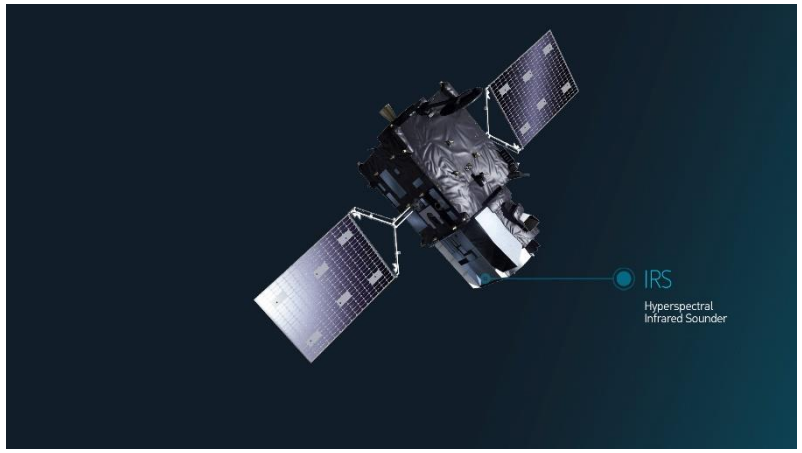
2. The NWC SAF **sSHAI** (**S**atellite **H**umidity and **I**nstability) product: **Methodology and Characteristics**

3. **Severe convection events** analysed with NWC SAF sSHAI prototype product
   I. Spain event 15/07/2015
   II. Centre Europe event 25/06/2021
   III. Nigeria event 11/10/2022
   IV. South Africa event 18/01/2022

4. **Complementing** with Surface station data

5. **Conclusions**

NWC SAF sSHAI: Introduction

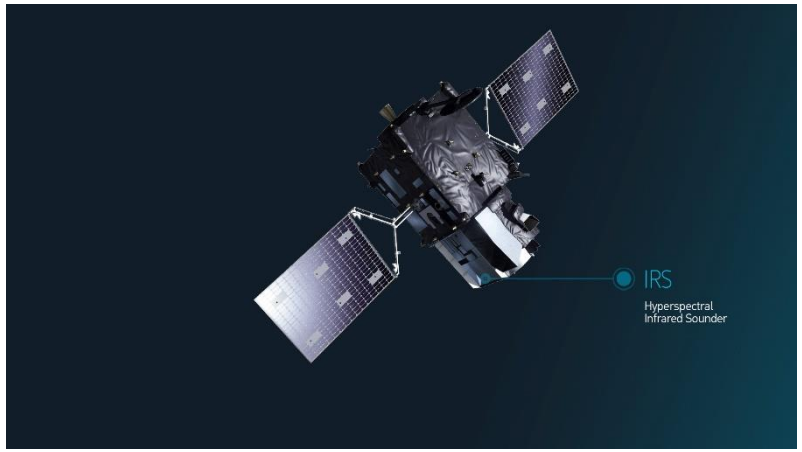


MTG-S satellite. Source: EUMETSAT

- There are currently several **Hyperspectral Infrared Sounders** in **Polar orbit**: AIRS, IASI, CriS. And the FY-4 and MTG-IRS are **geostationary** ones.
- Hyperspectral Infrared Sounders work with **thousands of channels**: 8000 (IASI), 2200 (CrIS), ~2500 (MTG-IRS)

- From the measured radiances of these channels it is possible to obtain, in semi-clear air (up to 80% cloud cover), **temperature and humidity profiles** with **high accuracy** (1 K in 1 km layers for temperature and 15% in 2 km layers for humidity)
- **Until** MTG-IRS data **are available**, in this work we use data from the **IASI** hyperspectral sounder on board the polar-orbiting MetOp satellite **as a proxy** to calculate **temperature, humidity and atmospheric instability profiles**.

NWC SAF sSHAI: Introduction



MTG-S satellite. Source: EUMETSAT

- **IASI** is a nadir looking across scanning **infrared spectrometer** with **mid/high spectral resolution** (0.5 cm^{-1}, 8461 channels) and a **spatial resolution** of **12 km** at sub-satellite point on the **polar orbiting** satellite MetOp.

- MTG-IRS will have a **spatial resolution of 4 km** (7 km over Europe) with a **sampling of 30 min**.

- This new technology will provide valuable information for particular applications → i.e. **CAPE** and **instability indices** for convection.

- **MTG-IRS** is a **new instrument** in **geostationary** orbit holding **great promise** for forecasting**.** Nevertheless, there will be **new challenges:** obtaining **accurate CAPE** indices, **Forecaster familiarization** with the products**, applicability,** etc.

- **The aim** is to design a **real-time operational method** based on **Machine Learning** to help meteorologists monitor and analyse the atmosphere and the possible development of **severe convection**.

NWC SAF sSHAI: Methodology and Characteristics

- **sSHAI** → **s**ounding **S**atellite **H**umidity **A**nd **I**nstability product from **NWC SAF:** Provide **atmospheric vertical profile retrievals** (temperature and humidity) (based on Machine Learning) and **derived stability indices**.

- The **ML model** used in this work is a KRR model based on the selection of Support Vectors (SVs), that allow minimizing the training dataset, which Radial Basis Function kernel is defined as :

$$K = exp(\frac{-|X_{test} - X_{train}|^2}{2\sigma^2})$$

- **Input IASI data** (as a proxy for MTG-IRS) used as independent variable (X) are: **Radiances, Vertical Solar/Satellite Zenith Angle, latitude** and **Surface pressure** from each pixel.

- **Input dependent variables** are built with **ECMWF analysis** are formed by: **Temperature** and **water vapour profiles** at **90 pressure levels**, Surface Air Temperature (**SAT**), Skin Temperature (**SKt**) and Surface Dew point Temperature (**STd**) at surface level.

NWC SAF sSHAI: Methodology and Characteristics

- Finally, the **atmospheric variables** of interest **retrieved** from IASI data are: **T and Td** vertical profiles at 90 pressure levels, **SAT** at 2m from the surface, **SKt and STd** at surface level.

- From atmospheric variables muCAPE, muCIN, level of free convection and lifting condensation level are calculated)

- Retrievals for **clear** and **partly cloudy scenes** (Cloud fraction up to 80%)

- **Classes** of nonlinear retrievals in the prototype:
  - **Retrievals only** with **IASI** data
  - **Retrievals** with **IASI data + ECMWF forecast** as input
  - **Retrievals** with **IASI data + Local Regional NWP forecast** as input (under development)

- Possibility to **complement** IASI **retrievals** with local **surface station** data (under development) -> To **improve** atmospheric profiles and **instability indices**

NWC SAF sSHAI: Stability Indices

- **CAPE** is the **preferred** stability index for **forecasters** (ESSL report 2020)

- **Hyperspectral CAPE**: CAPE indices from retrievals have a **high uncertainty**

- **Other,** simpler, **instability indices are not as useful**, although they are easier to calculate and have a much smaller uncertainty

NWC SAF sSHAI: What does the user get?

- User obtains a **user-configurable software** that is **able** to calculate **several classes** of non-linear **retrievals** from **MTG-IRS** data:
- **Classes** of nonlinear retrievals:
  - **Retrievals only** with **MTG-IRS** data
  - **Retrievals** with **MTG-IRS data + ECMWF forecast** as input
  - **Retrievals** with **MTG-IRS data + Local Regional NWP forecast** as input (under development)
  - All the above **Retrievals** can be **complemented** with **surface station data**.

  It will be possible to **add surface station data to the retrievals** improving the surface measurement, something really valuable for hyperspectral soundings to **improve profiles** and **instability indices**. (Available **when surface station data** is **available**, the user will have to provide it).

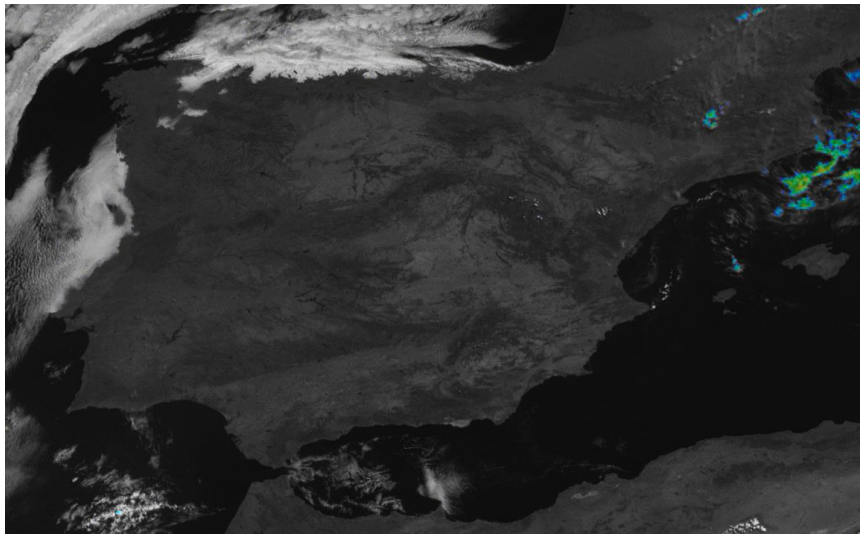
➢ Some examples to take a look to the product: The next **events** have been **analyzed** with **sSHAI prototype**:

NWC SAF sSHAI: Case study I: Spain 15/07/2015

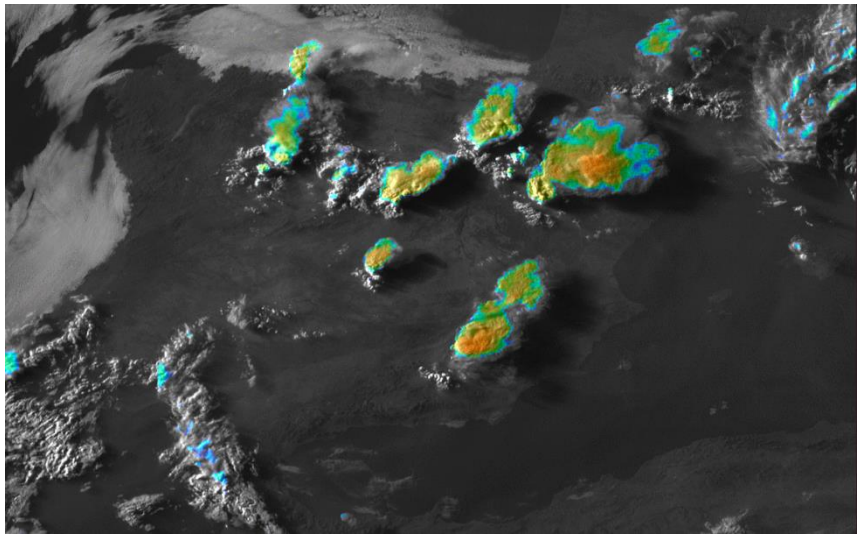
Easy» case: synoptic situation is constant

- **Day suitable** for **hyperspectral sounders** over **Spain** with **clear skies** in the **morning** and **convection** developing in the **afternoon.**

- **Nearly static synoptic situation** → Predictions for the afternoon can be based on morning measurements



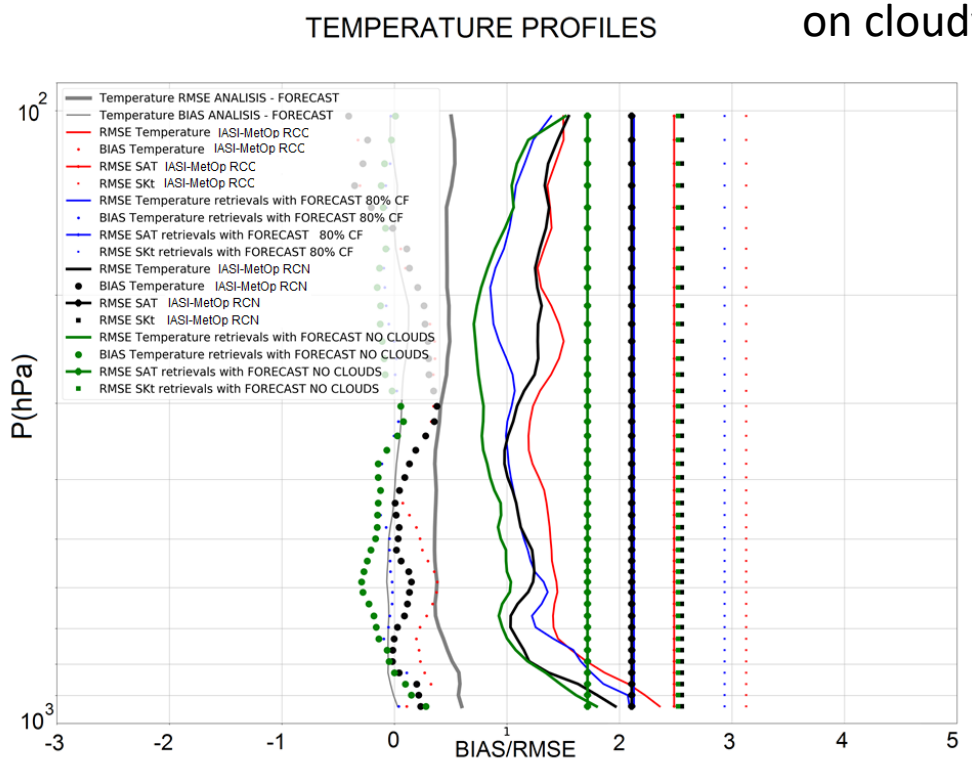
MSG RGB Image at 9:45Z
IASI overpass

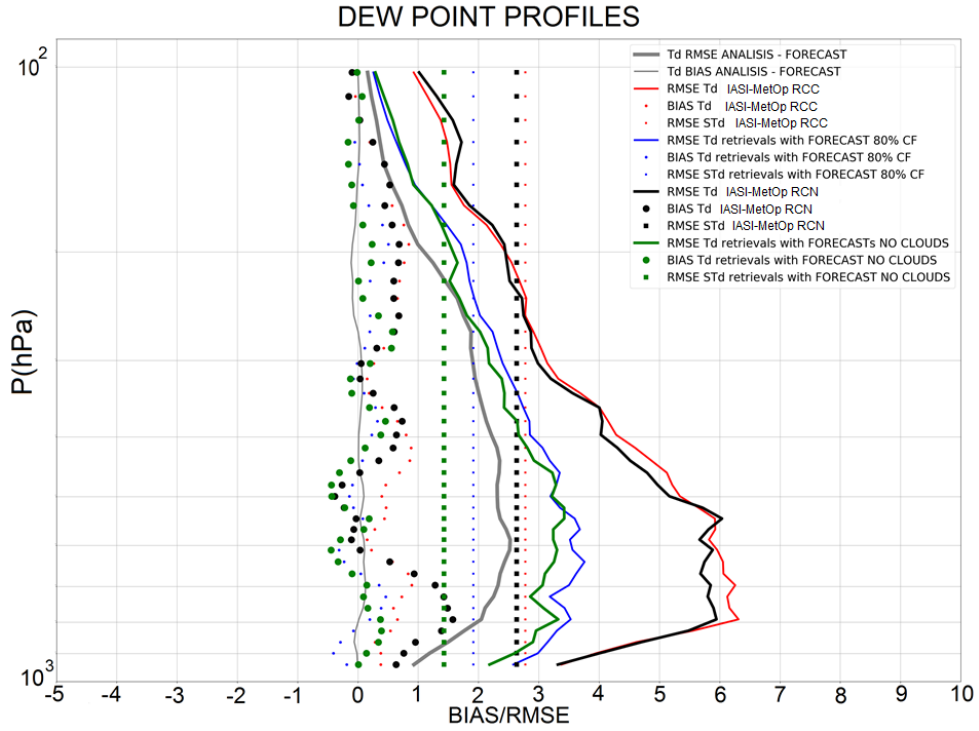


MSG RGB Image at 17:30Z
Convection

NWC SAF sSHAI: Case study I: Spain 15/07/2015

- **Comparison with ECMWF analysis**
- **Best solution** to improve accuracy and spatial and temporal homogeneity are RFCC (**Retrievals using forecast as input** trained on cloudy scenes)





Gray: FCT, Forecast

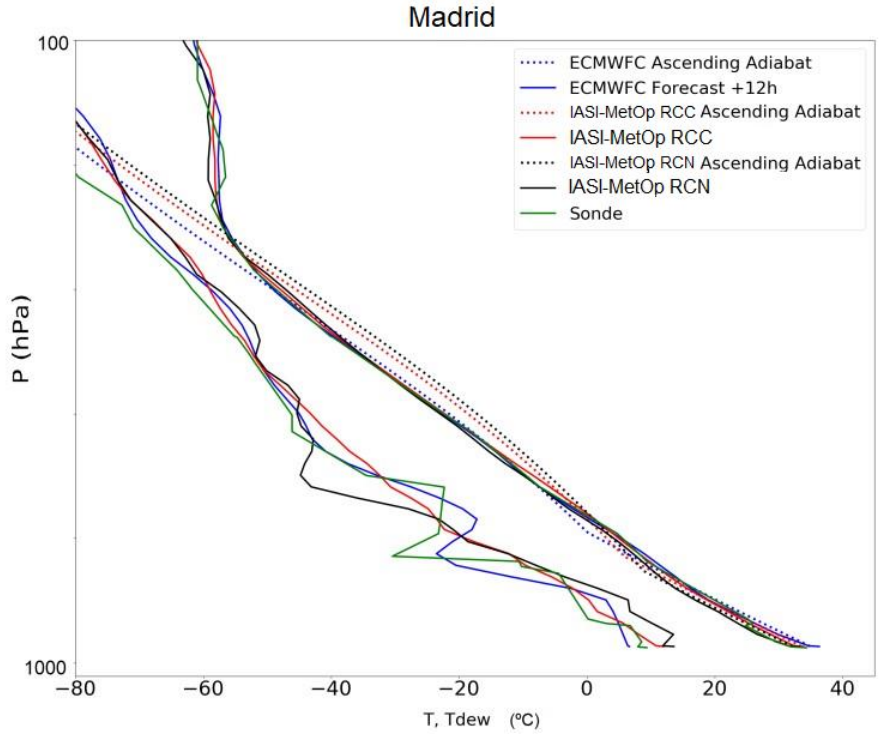
Green: RFCN, Retrievals (+FCT) trained with clouds and tested on clear scenes

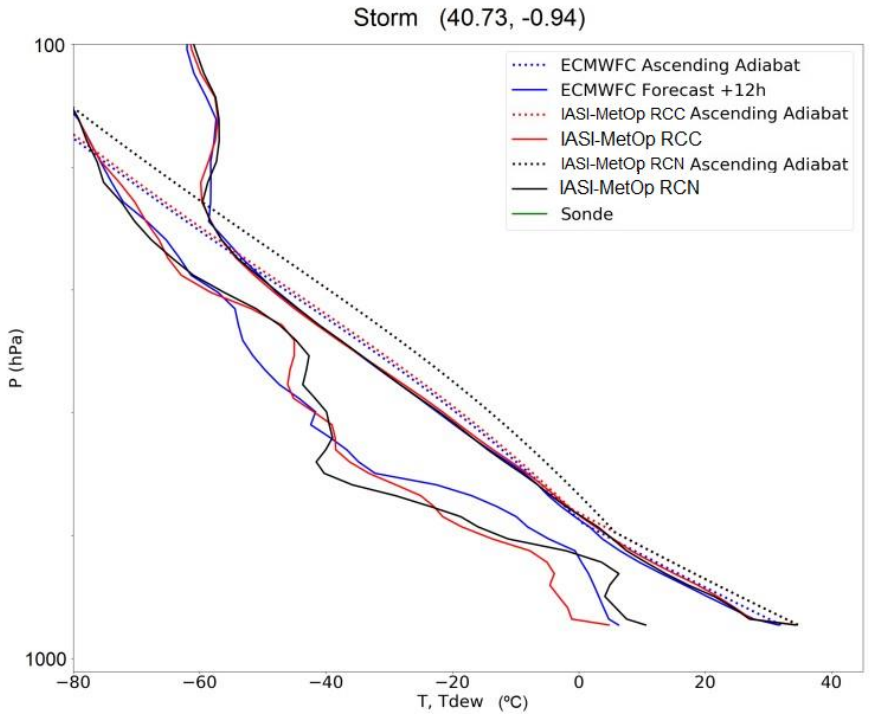
Blue: RFCC, Retrievals (+FCT) trained with clouds and tested on cloudy scenes

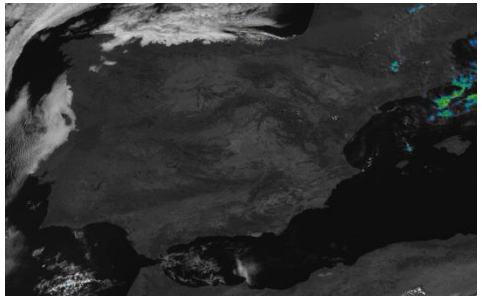
NWC SAF sSHAI: Case study I: Spain 15/07/2015

Radiosonde launched on **15/07/2015 12:00Z** at **Madrid** (40.50ºN, 3.58ºW)

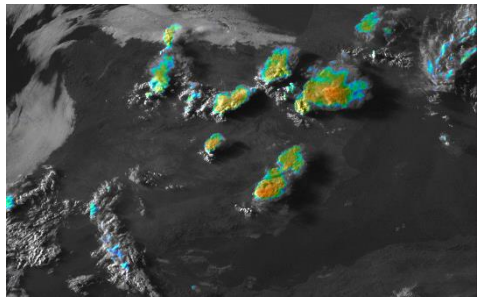
Storm location (40.73ºN, 0.94ºW) in **Aragon**, Spain on **15/07/2015 9:45Z.**
No radiosonde data available





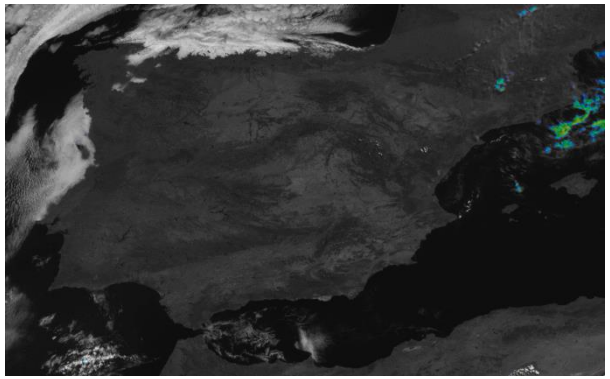


9:45 Z

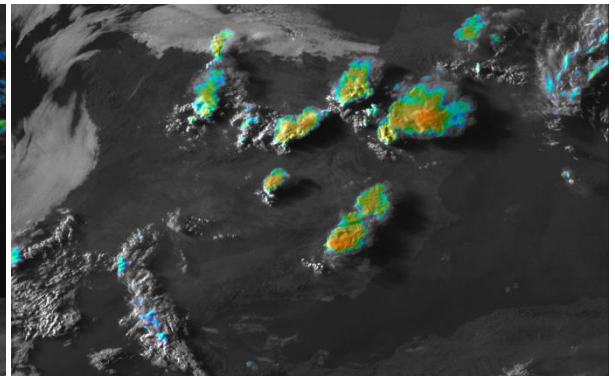


17:30 Z

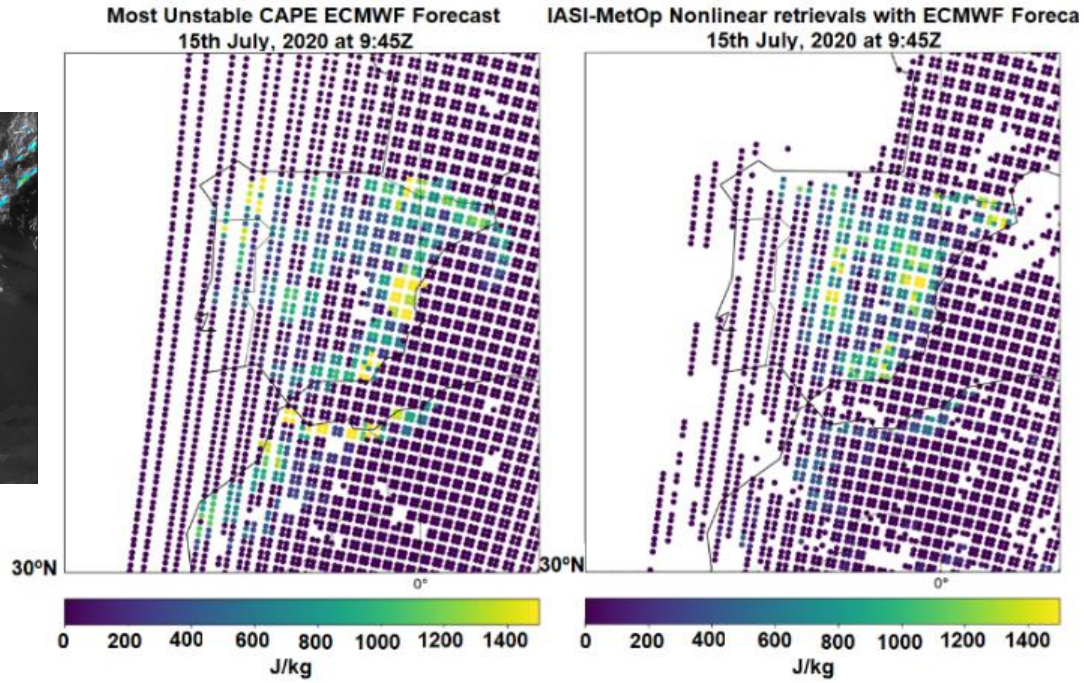
NWC SAF sSHAI: Case study I: Spain 15/07/2015



MSG RGB Image at 9:45Z IASI overpass



MSG RGB Image at 17:30Z Convection



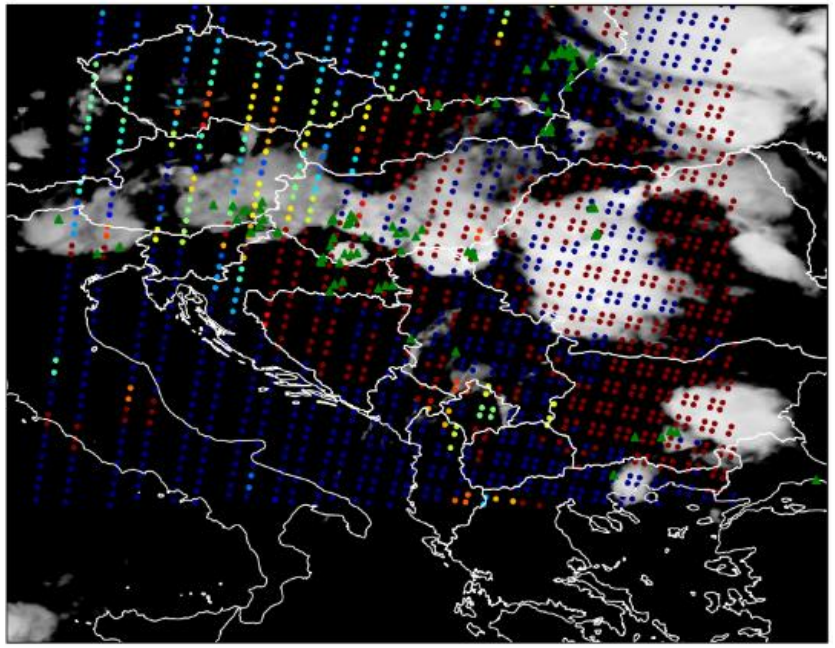
CAPE calculated from atmospheric profiles **from IASI retrievals** show with **high accuracy** the areas **where convection** will **triggered** hours later.

NWC SAF sSHAI: Case study II: Central Europe 25/06/2021

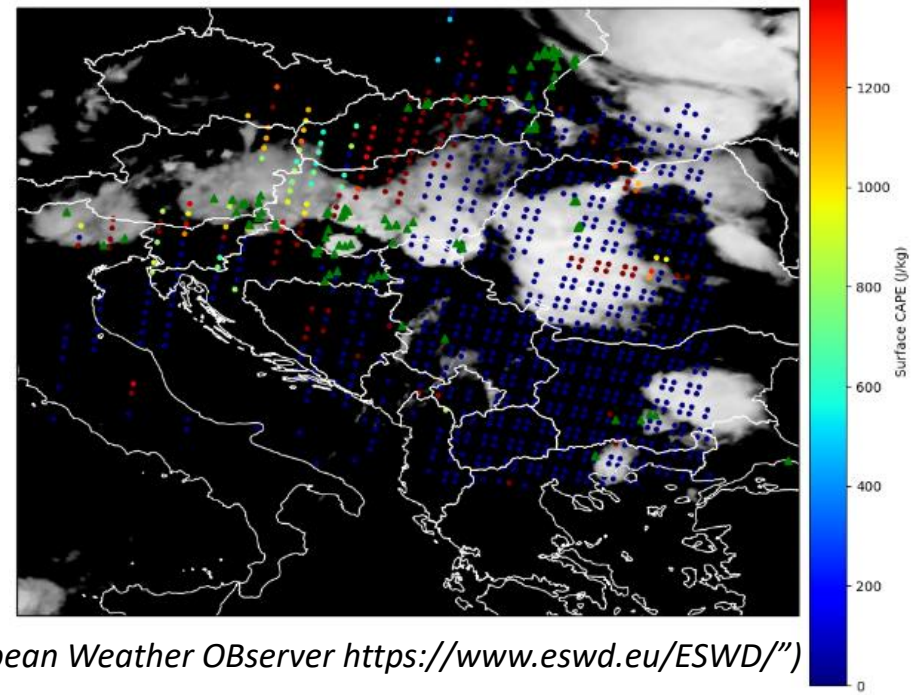
Dynamic situation with **some clouds** located **during morning** over the area to be analyzed during the satellite pass.

sCAPE calculated with IASI retrievals at 8:32Z and compared with the ECMWF forecast at 00+08h.

ECMWF FCST sCAPE 25/06/2021@00Z+8h & MSG@18:30Z



NWCSAF Ret. sCAPE 25/06/2021 IASI@08:27Z & MSG@18:30Z



▲ *Large hail reports (information extracted from ESSL website. Database "ESWD, European Weather OBserver https://www.eswd.eu/ESWD/")*

In **Central Europe**, several **severe convective** events were reported with **large hail** impacts. The surface impact and **large hail reports** have been extracted **from** the ESSL **database** *"ESWD, European Weather OBserver https://www.eswd.eu/ESWD/"*

The **CAPE** calculated **from IASI retrievals** localizes better the instability areas than ECMWF forecast.

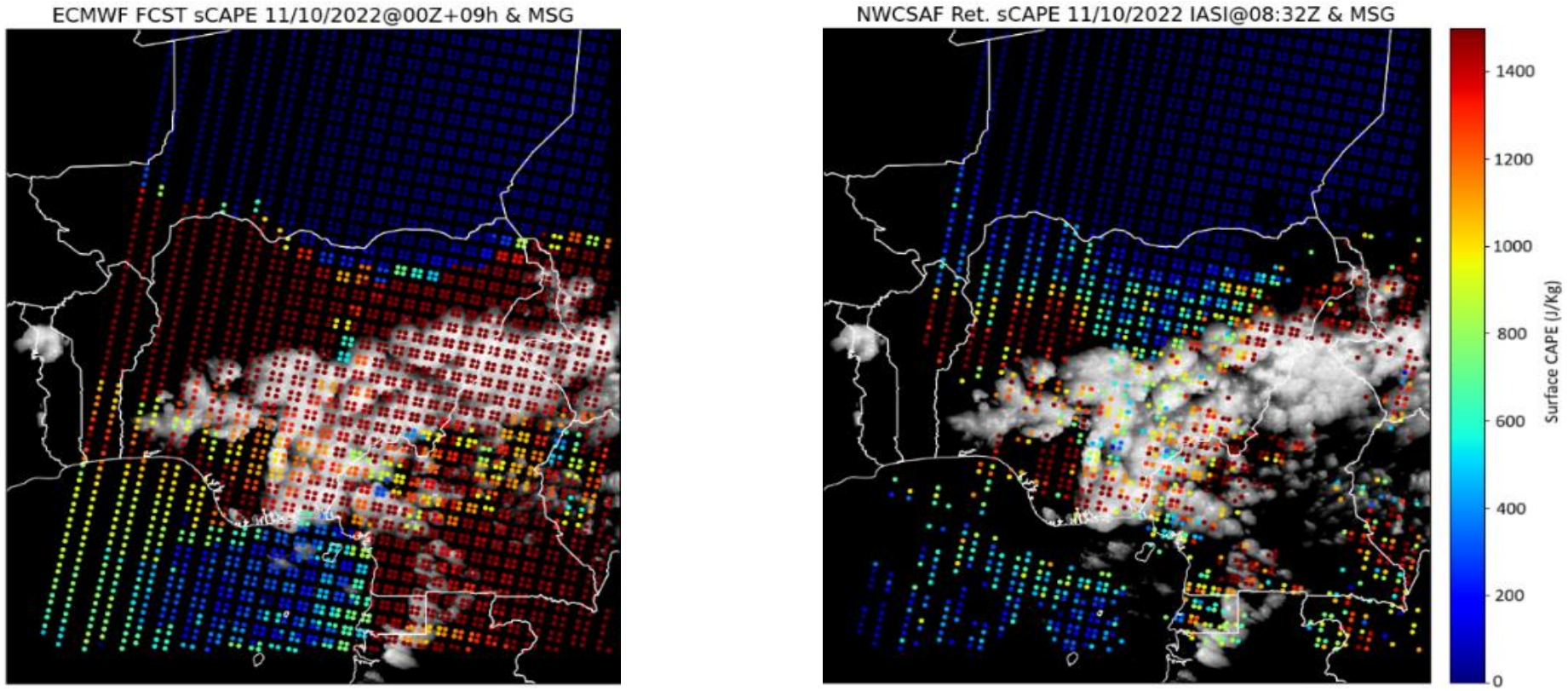
NWC SAF sSHAI: Case study III: Nigeria 11/10/2022

During the day there was **convective cells** triggered around the country starting at the east, moving to the west, **affecting** our **study zone** at **midday**. These storm had a **high impact** on the zone, these false-color images show flooding along the Benue and Niger rivers on October 11 2022 (right) and the same area on October 24 2021 during more typical conditions (left).

First false-color image (left) shows flooding along the Benue and Niger rivers on October 24, 2021. False-colour image (right) shows the same area on October 11, 2022.. (Images from https://earthobservatory.nasa.gov)

NWC SAF sSHAI: Case study III: Nigeria 11/10/2022

sCAPE calculated with IASI at 8:32Z and compared with the ECMWF forecast at 00+09h.



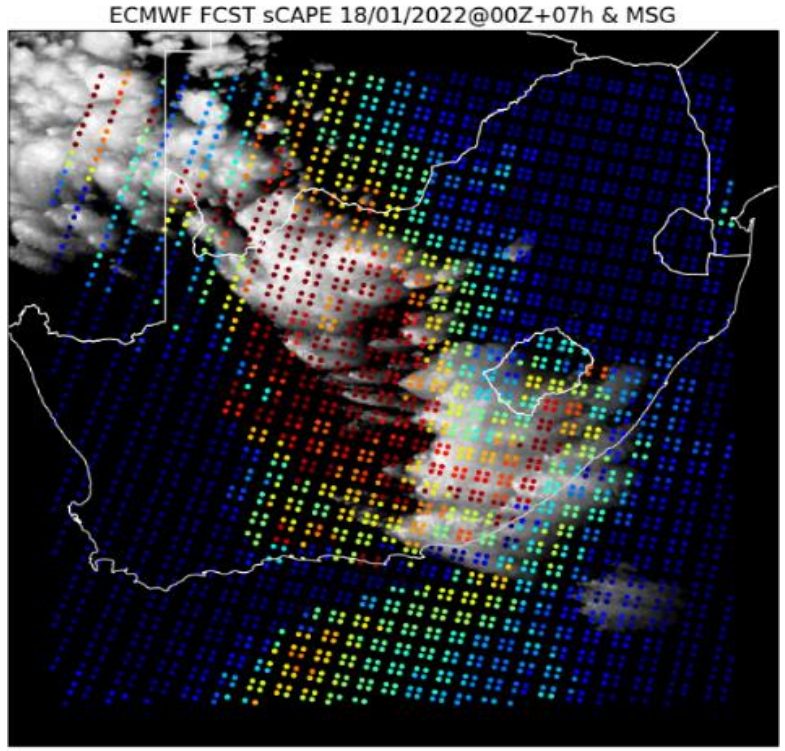
The **CAPE** calculated from the **IASI retrievals better locate** the areas where **convection** will subsequently be triggered.

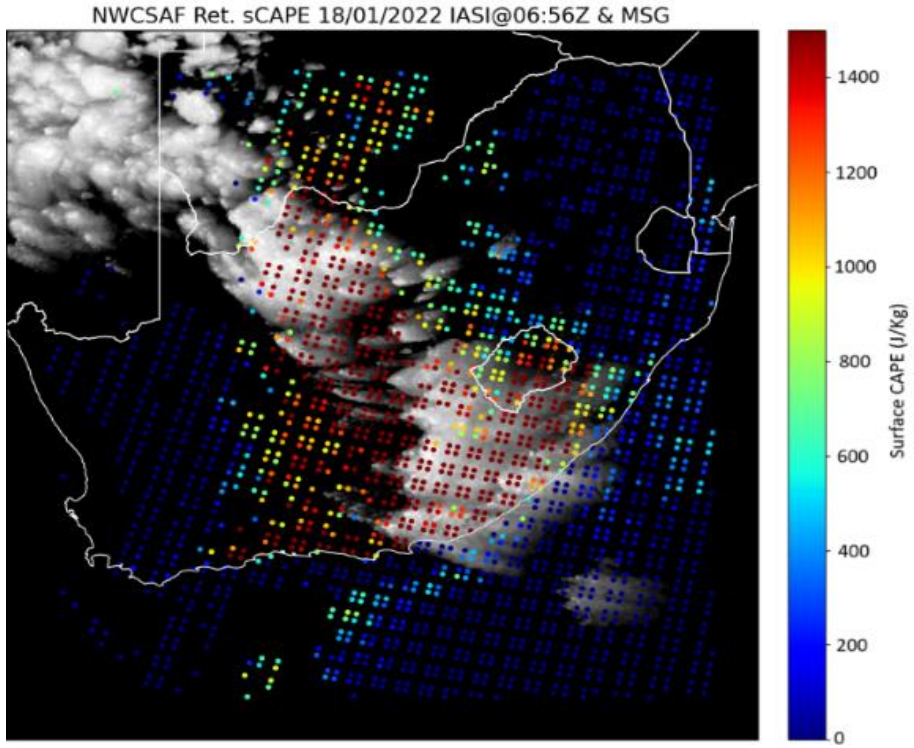
NWC SAF sSHAI: Case study IV

South Africa: 18/01/2022

On 18 January 2022, several **severe convection** events occurred in **south-eastern South Africa**.

sCAPE and instability index calculated with IASI at 07Z and compared with the equivalent ECMWF forecast.



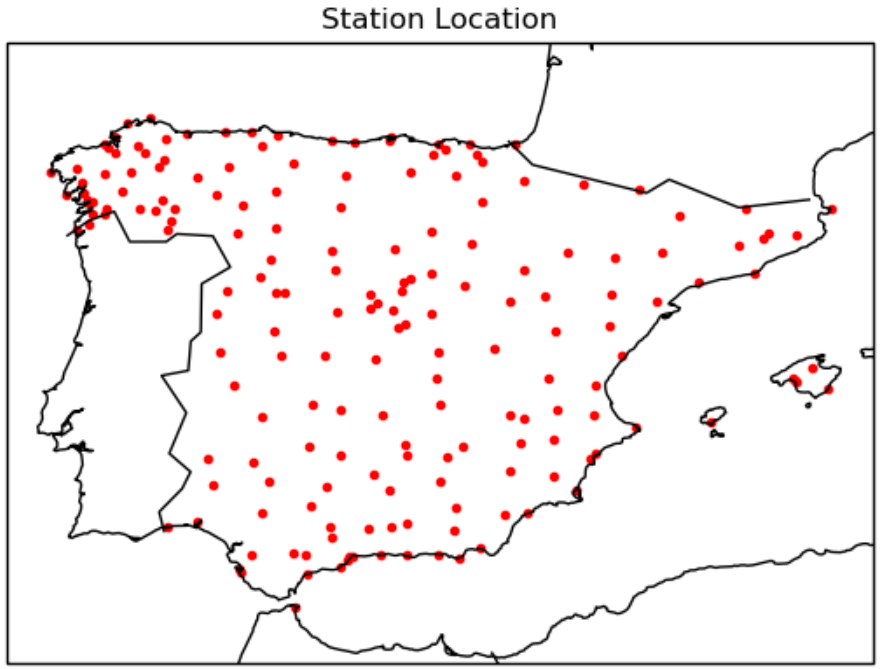


The **areas** where **convection** subsequently develops **are localized** and **defined** by the NWC SAF's **sSHAI** prototype product with **high accuracy**.

NWC SAF sSHAI: Complementing with Surface Station data

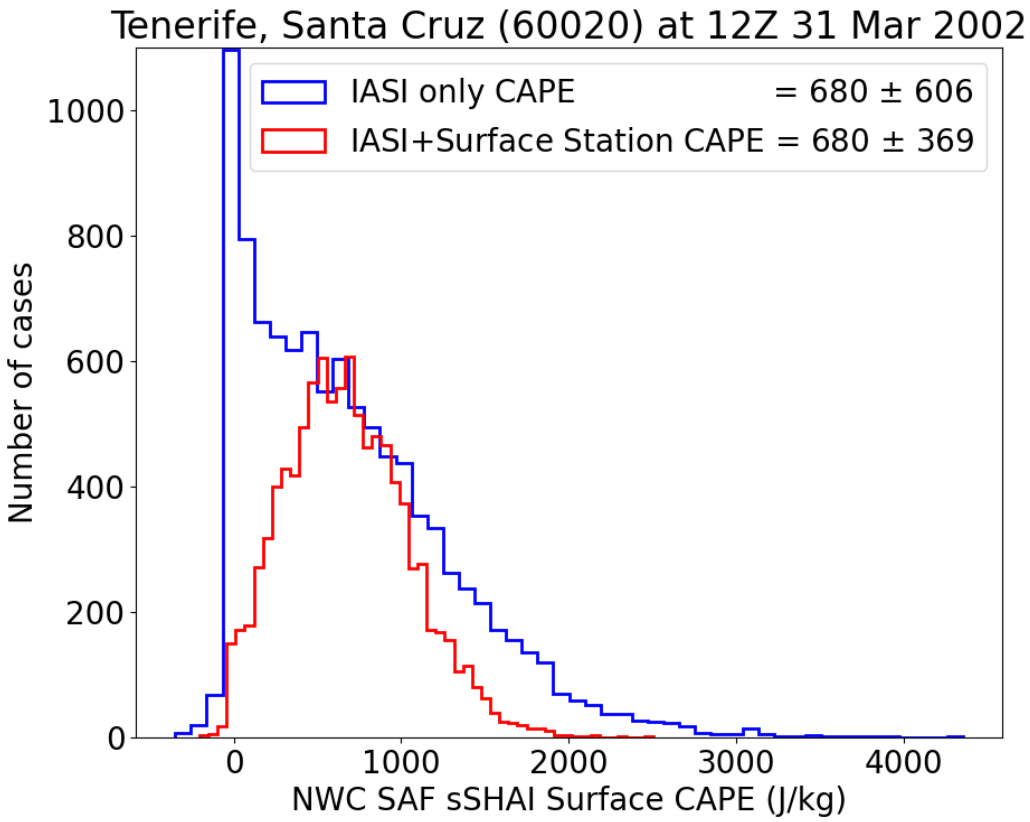
- **Retrievals loose accuracy in lower layers** → where it is most critical for instability indices (e.g. CAPE) → possible solution to **add ground based data** to create **new instability parameters**

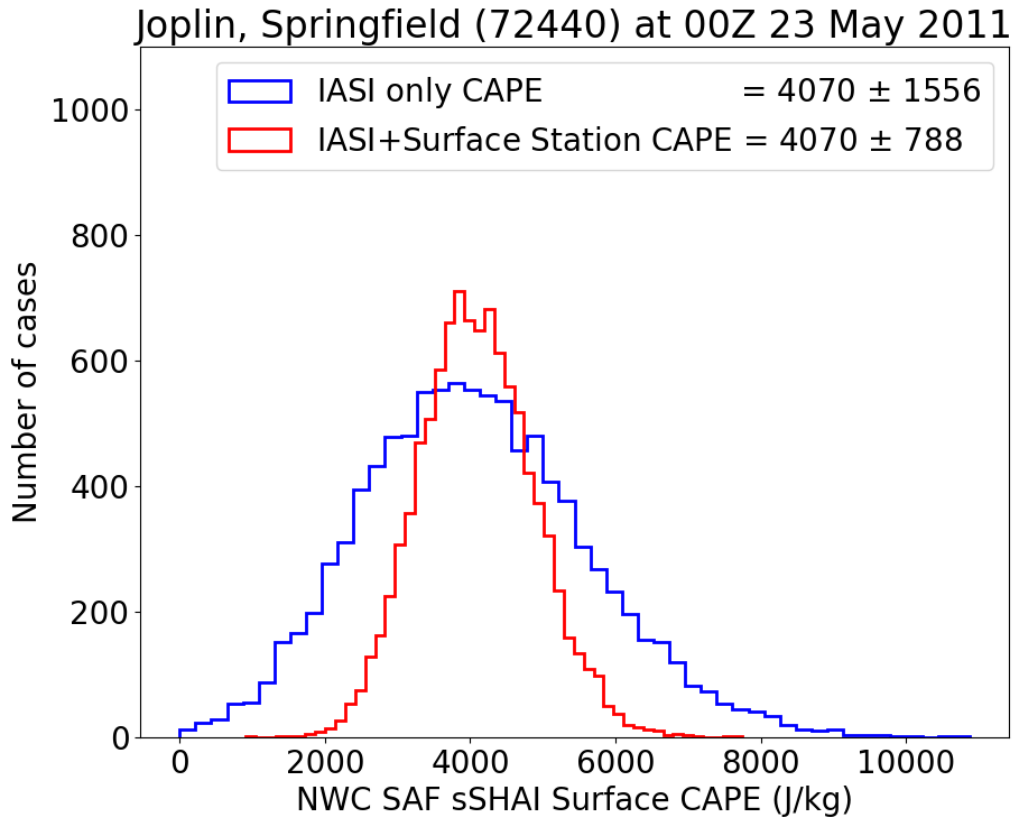
- Surface Automatic Station Locations in Spain



NWC SAF sSHAI: Complementing with Surface station data

- **Propagation** of the **Infrarred Hyperspectral Retrieval uncertainties** onto the **sCAPE uncertainties** using **Montecarlo Simulation** (blue histograms).
- **Complementing** with **surface station** data the **sCAPE uncertainty** is **greatly reduced** (red histrograms)

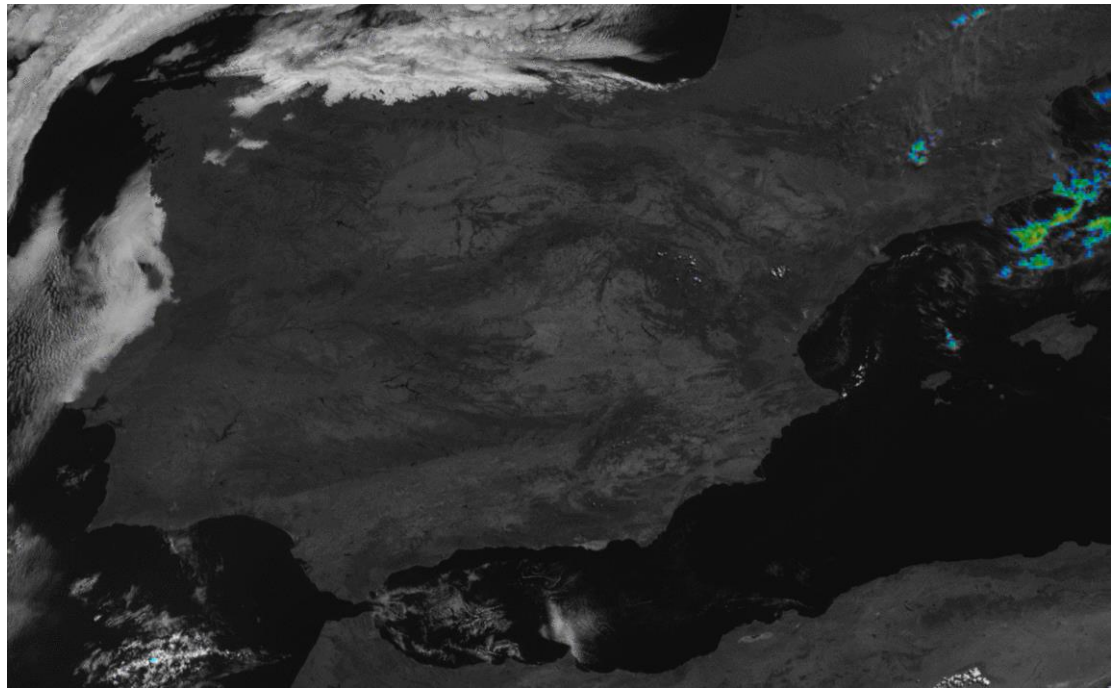




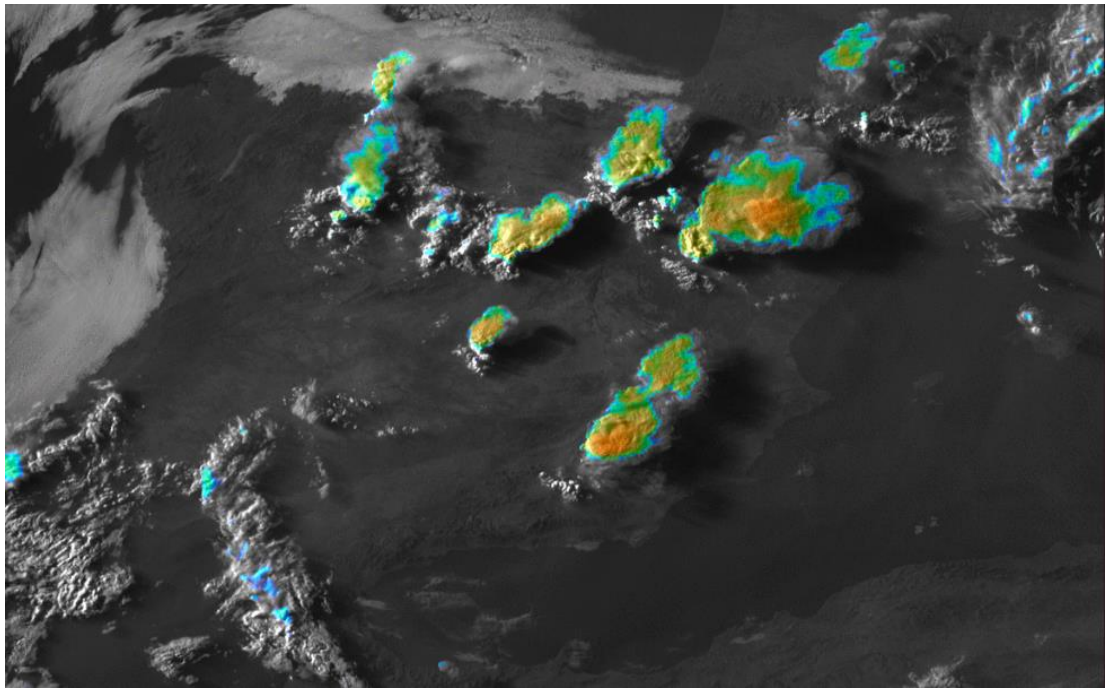
NWC SAF sSHAI: Case study: Spain 15/07/2015

Easy» case: synoptic situation is constant

- Convection triggered by solar heating



MSG RGB Image at 9:45Z
IASI overpass



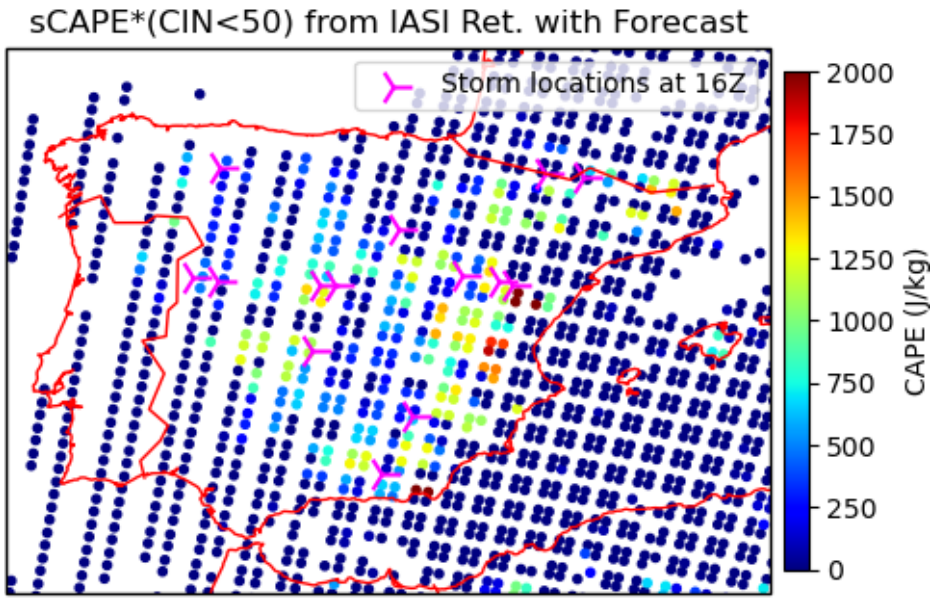
MSG RGB Image at 17:30Z
Convection

NWC SAF sSHAI: Case study - Spain 15/07/2015

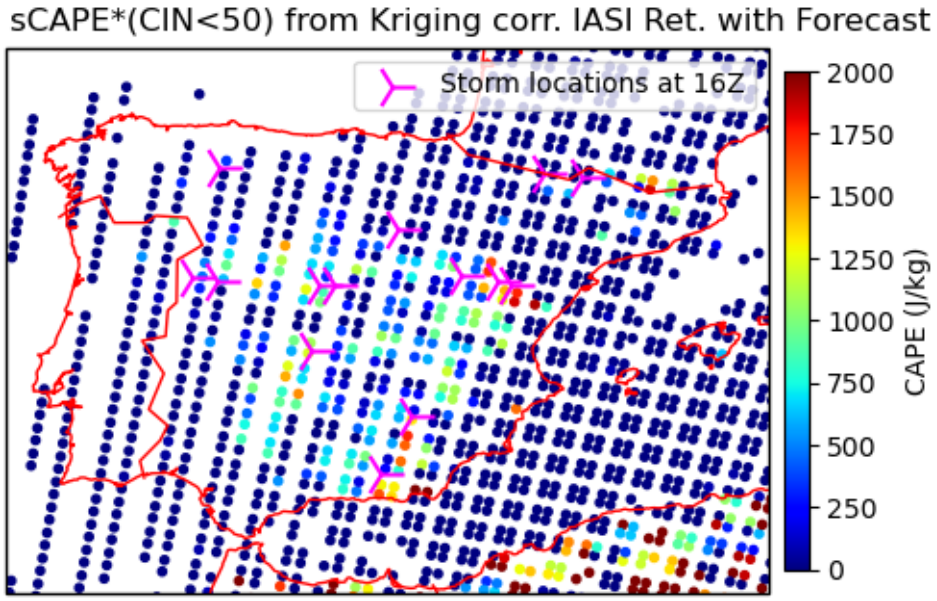
IASI Retrieval with Forecast complemented with Surface Stations

- Slight improvement

Before



After

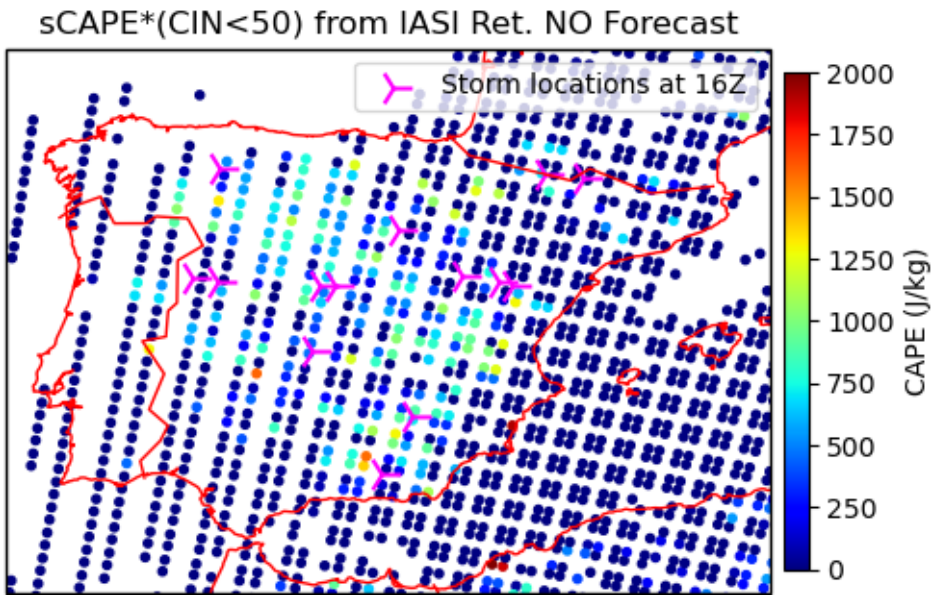


NWC SAF sSHAI: Case study - Spain 15/07/2015

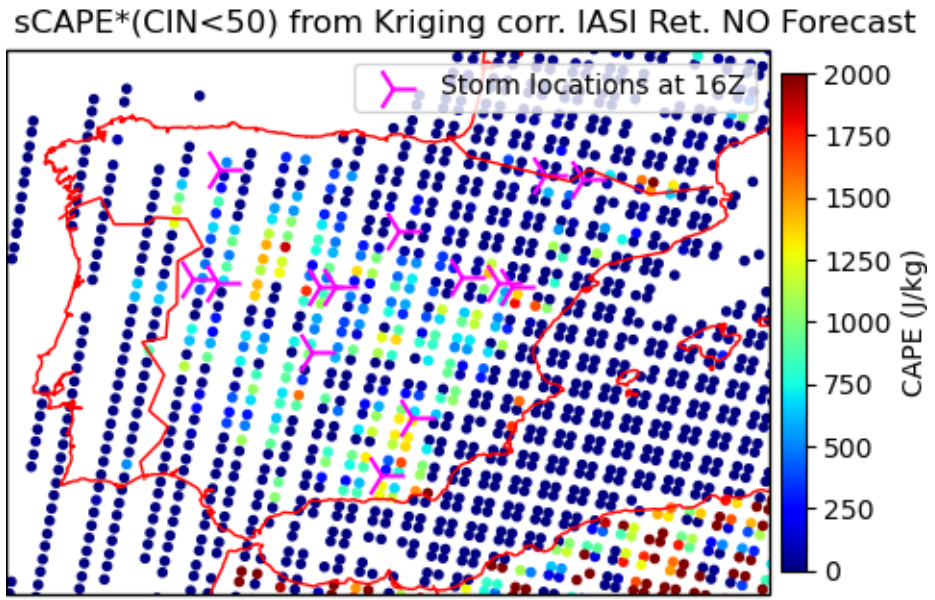
IASI Retrieval NO Forecast complemented with Surface Stations

- Significant improvement

Before



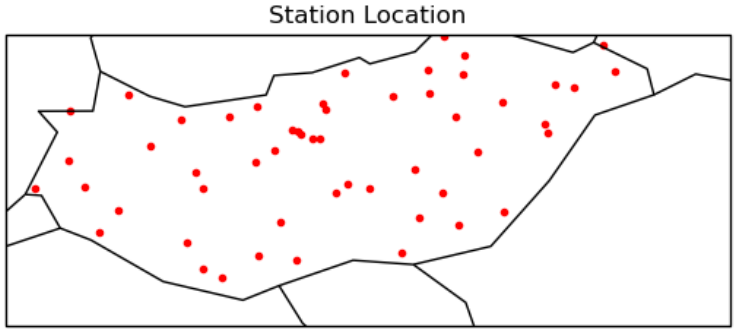
After

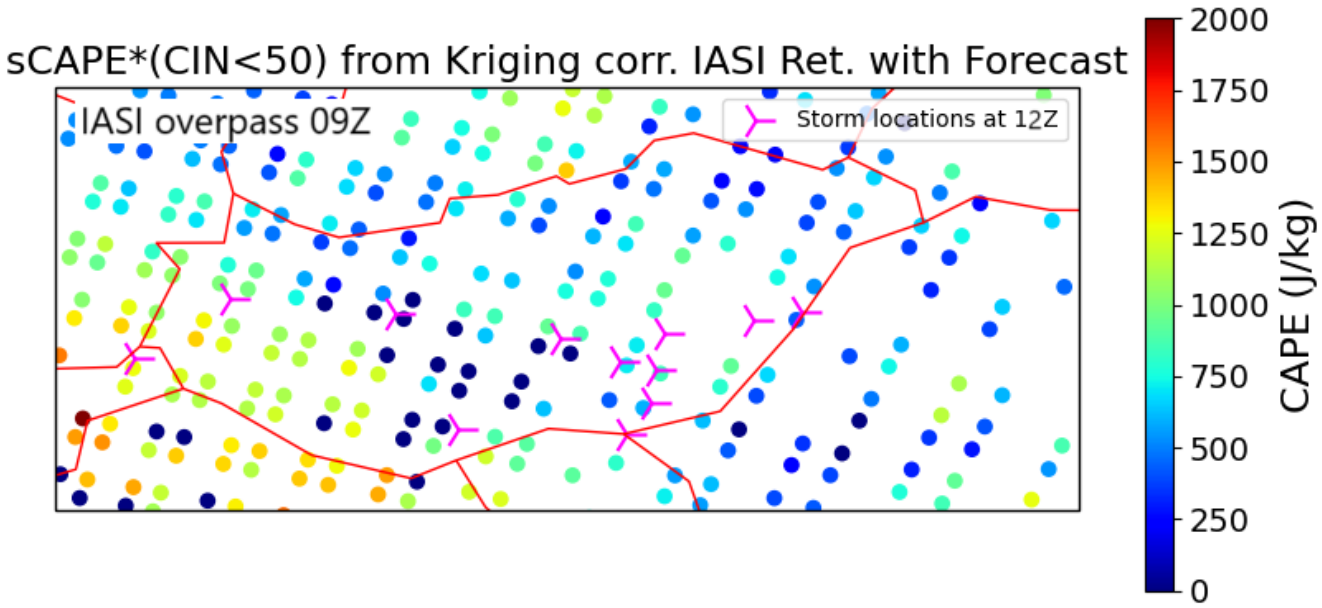


NWC SAF sSHAI: Other Case - Hungary 05/06/2024

- Surface Automatic Station Locations in **Hungary**

Surface stations **data provided** by **Zsofia Kocksis** from **HungaroMet**.





Retrievals instability not so **well** captured most likely due to a **dynamically changing atmosphere**

NWC SAF sSHAI: Complementing with Surface station data

Comparison of IASI retrievals and ECMWF plus Surface Station data

- **IASI retrievals** show a more **accurate location** of atmospheric instability than **ECMWF**
- Complementing with **Surface Station** data shows an even **better localization** of convective situations
- But, **more cases** are needed
- It is intended to **build a database** with results

NWC SAF sSHAI: Conclusions

- **Algorithm** prototype software is **already working** **(experimental)**

•There is **still room for improvement** for MTG-IRS

•**Retrievals lose accuracy in lower layers** → where it is most critical for instability indices (e.g. CAPE) → possible solution to **add ground based data** or creating **new instability parameters**

- **NWP forecast** already have a **high accuracy** and they **also assimilate hyperspectral data** → models will assimilate MTG-IRS data potentially improving
- The **sSHAI** is an **experimental product**. State of the art retrievals methods are needed and knowledge needs to evolve to get more out of the instrument.
- A completely **new product** will be available to users. Comments welcome, on how to represent the product, useful instability indices or anything you would like to share with us to improve the sSHAI product.
- **sSHAI prototype product** is **available** in the NWCSAF-EWC **ADAGUC** server https://adaguc.nwcsaf.eumetsat.ewcloud.host/

NWC SAF sSHAI: HANDS on!!

The **'pseudo-operational'** sSHAI prototype product can be easily **visualised** in the **EWC**! 👇

https://adaguc.nwcsaf.eumetsat.ewcloud.host/

Click at the top left on **"EXP"** → **"Infrared Hyperspectral Retrievals"** → **"NWC SAF sSHAI IASI retrievals with ECMWF"**

Then **click** at the top left on the cogwheel→ **"VertProfiles"** → Click on the map in a **pixel** of the sSHAI product to visualise the **vertical profiles**.