European Severe Storms Laboratory
Science & Training

EUMETSAT

# Hyperspectral sounding for severe storm Forecasting

## Testbeds to assess potential and practical requirements in Europe

contract EUM/CO/184600002214/TA

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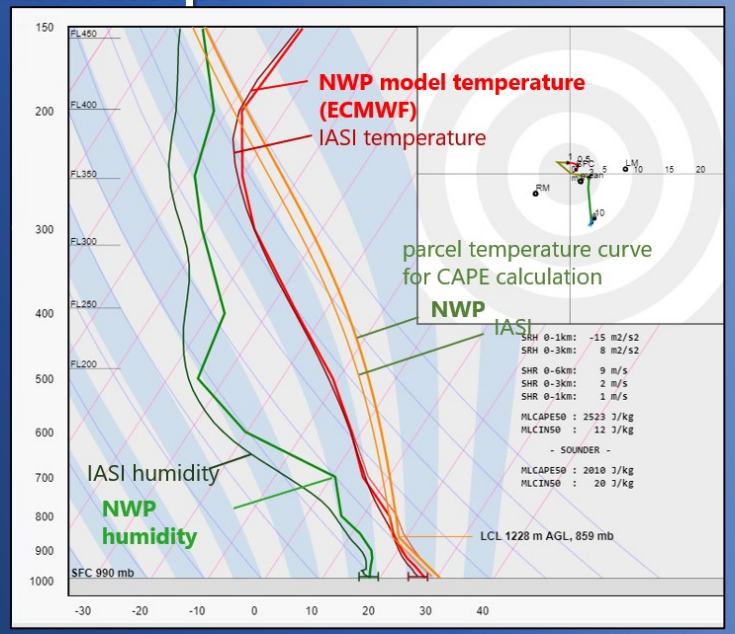
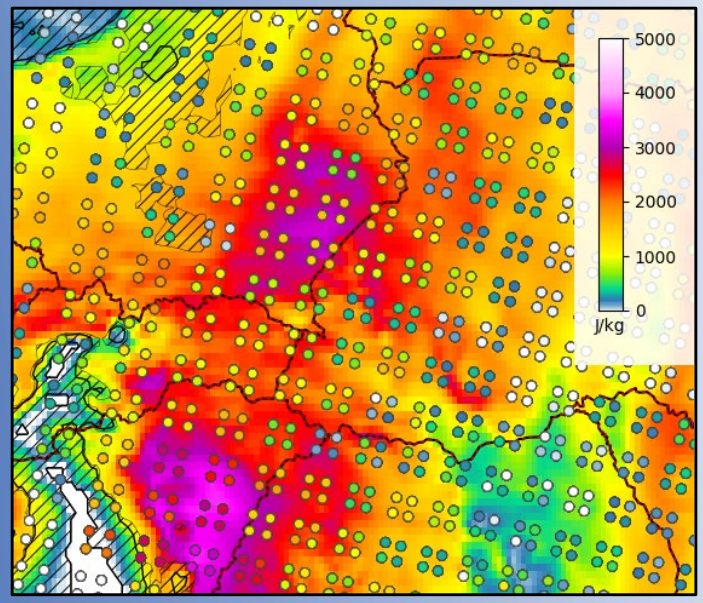
*EUMETSAT, Darmstadt, 17 January 2020*

Infrared Atmospheric Sounding Interferometer (IASI)

**Metop**



# Project goals

1. **Evaluate direct use** of hyperspectral sounding products in severe storm forecasting
   - Assess potential for use of such products, **also in the light of MTG-IRS**

2. Gain practical experience with users
   - **collect feedback to products**
   - **and to specific product visualizations/implementations**
   - **Identify possibilities for further visualizations/implementations**

3. **Raise awareness and preparedness** of potential users

4. Support the **consolidation of L2 product requirements**

# Project components

1. **Integration of IASI-EARS L2 data into Testbed platform**
   - develop visualizations of the data

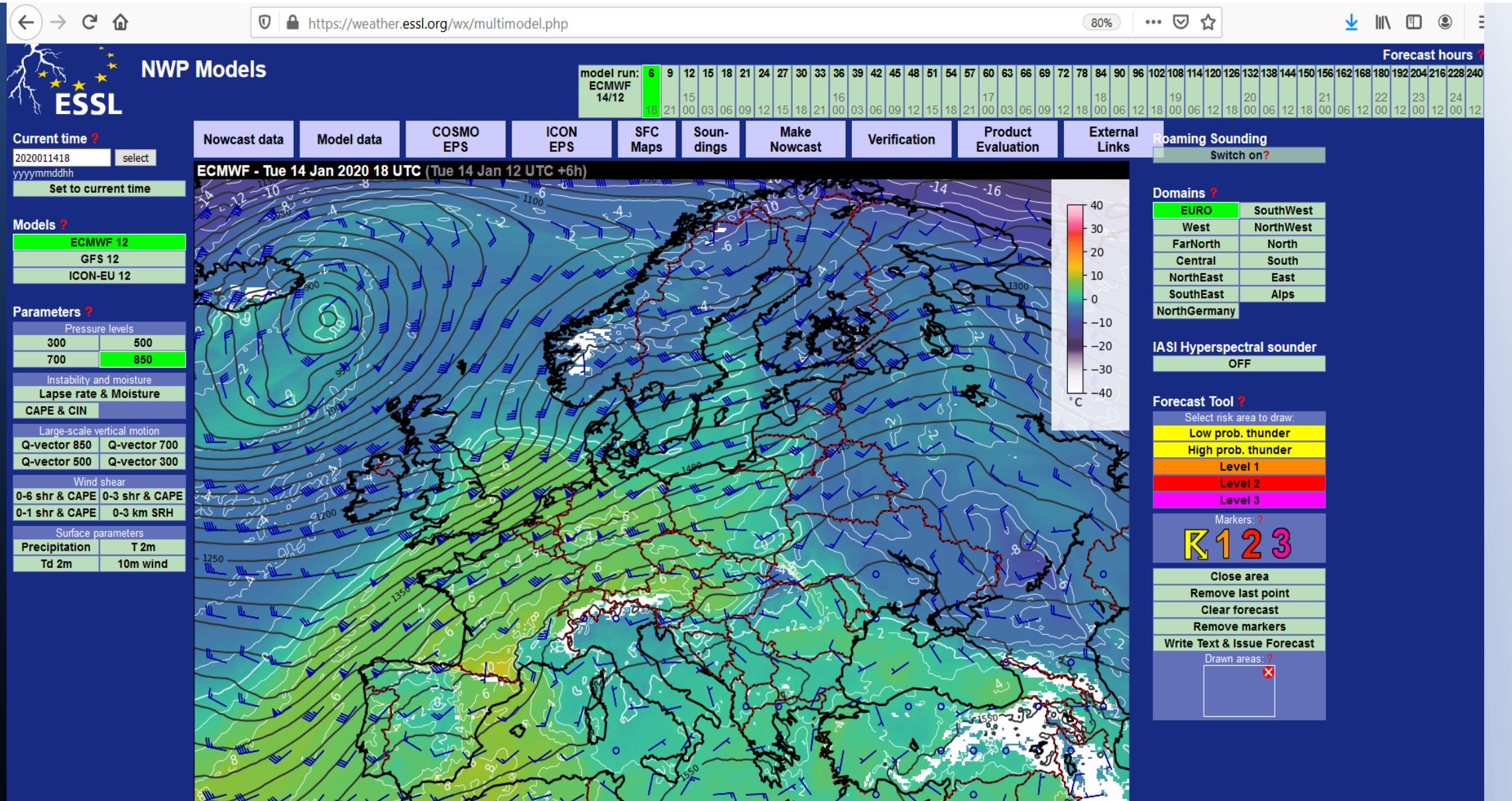
2. **Evaluation at the ESSL Testbed**
   - collect feedback from users

3a. **Perform 10 case studies**
3b. **Develop extended case catalogue** (40 cases)

4. **Provide training at EUMETSAT** (April 2019)

5. **Reporting:** 102-page (draft) report.

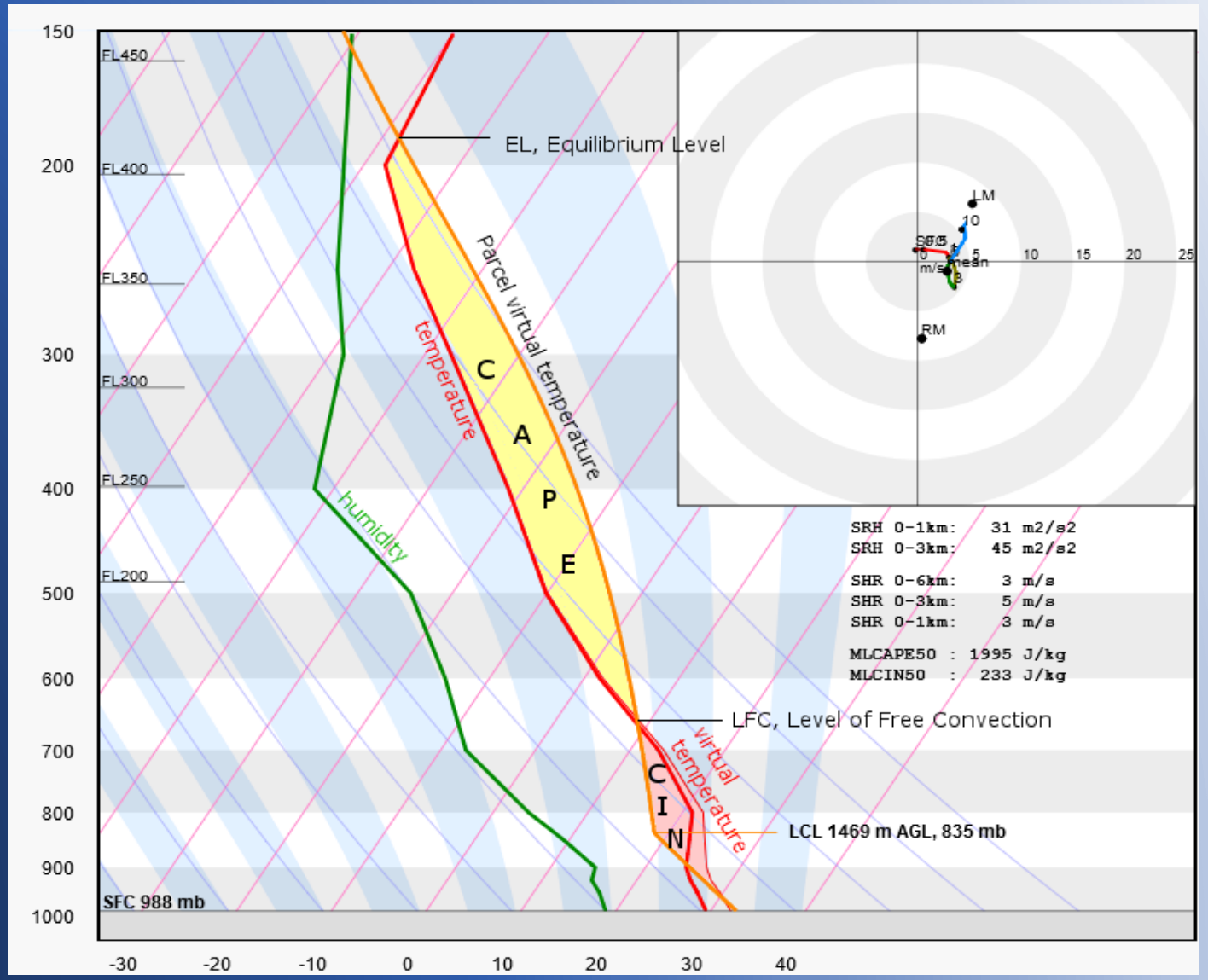
# Integration into Testbed platform



# Integration into Testbed platform

## Selected parameters

- Based on the ingredients-based methodology



# Convective parameters

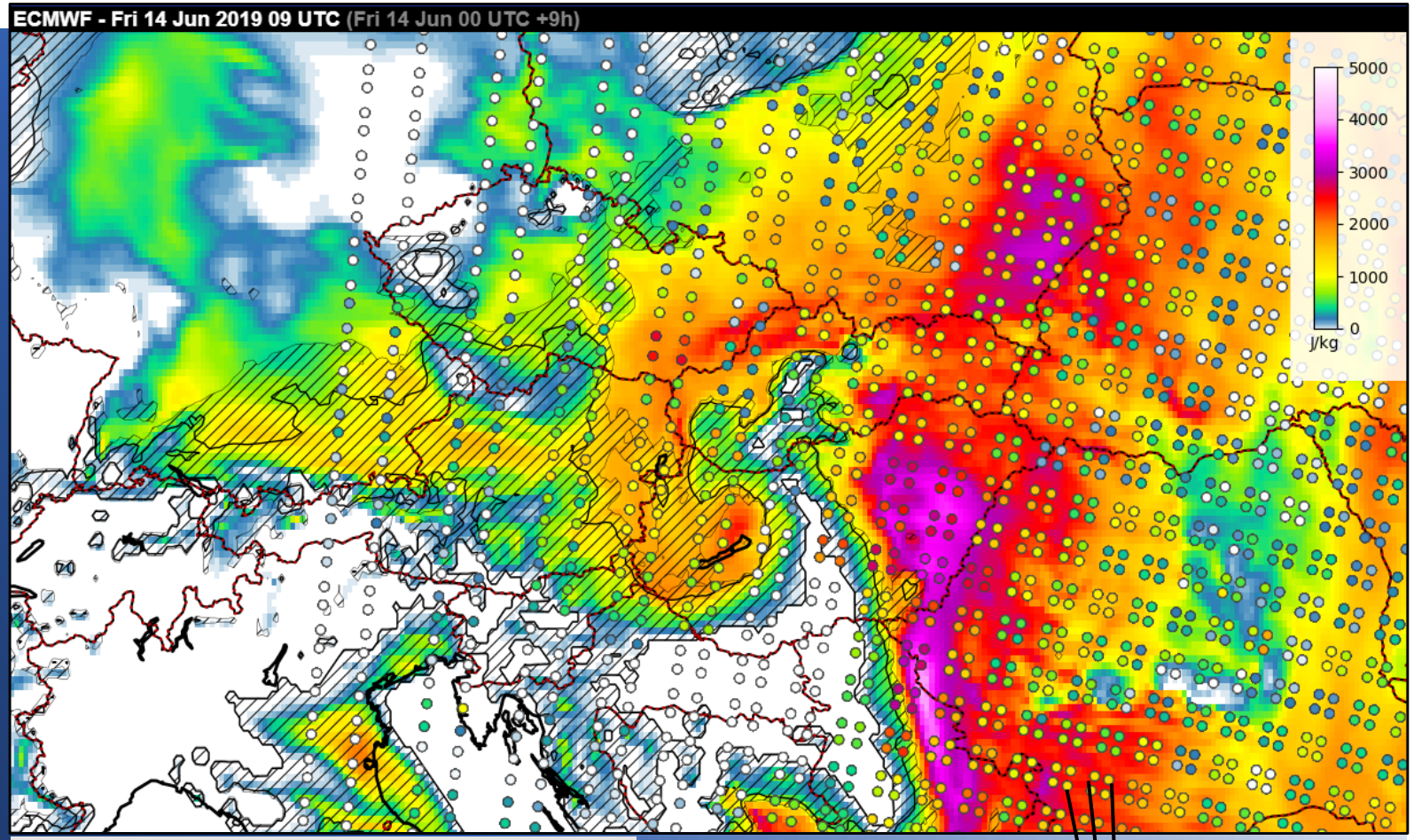
## Selected parameters

- Based on the ingredients-based methodology
- Computation was programmed in Python, using the IASI L2 data in HDF5 format.
- Code has been delivered to EUMETSAT in July 2019

| Parameter | Description | Unit |
|---|---|---|
| MLCAPE50 | Mixed-layer Convective Available Potential Energy mixing layer: 50 hPa | J/kg or $m^2/s^2$ |
| MLCAPE100 | mixing layer: 100 hPa | J/kg or $m^2/s^2$ |
| SBCAPE | Surface-based parcel, i.e. using lowest temperature/dew point | J/kg or $m^2/s^2$ |
| MUCAPE | Most unstable parcel, i.e. parcel with the most CAPE | J/kg or $m^2/s^2$ |
| MLCIN50 | Convective inhibition for 50 hPa parcel | J/kg or $m^2/s^2$ |
| SFC mixr | Mixing ratio at lowest level in the profile | J/kg or $m^2/s^2$ |
| ML50 mixr | Mixing ratio for 50hPa mixed-layer parcel | g/kg or $10^{-3}$ |
| ML100 mixr | Mixing ratio for 100hPa mixed-layer parcel | g/kg or $10^{-3}$ |
| Total Precip. Water | Total precipitable water in the column | mm |
| SFC-500 mb lapse rate | Vertical temperature gradient (surface to 500 mb) | K/km or $10^{-3}$ K/m |
| 850-500 mb lapse rate | Vertical temperature gradient (850 to 500 mb) | K/km or $10^{-3}$ K/m |
| MLLI50 | Lifted index, or temperature difference between parcel and environment at 500 mb | K or °C |

# Comparison of convective parameters

**Example visualization:**



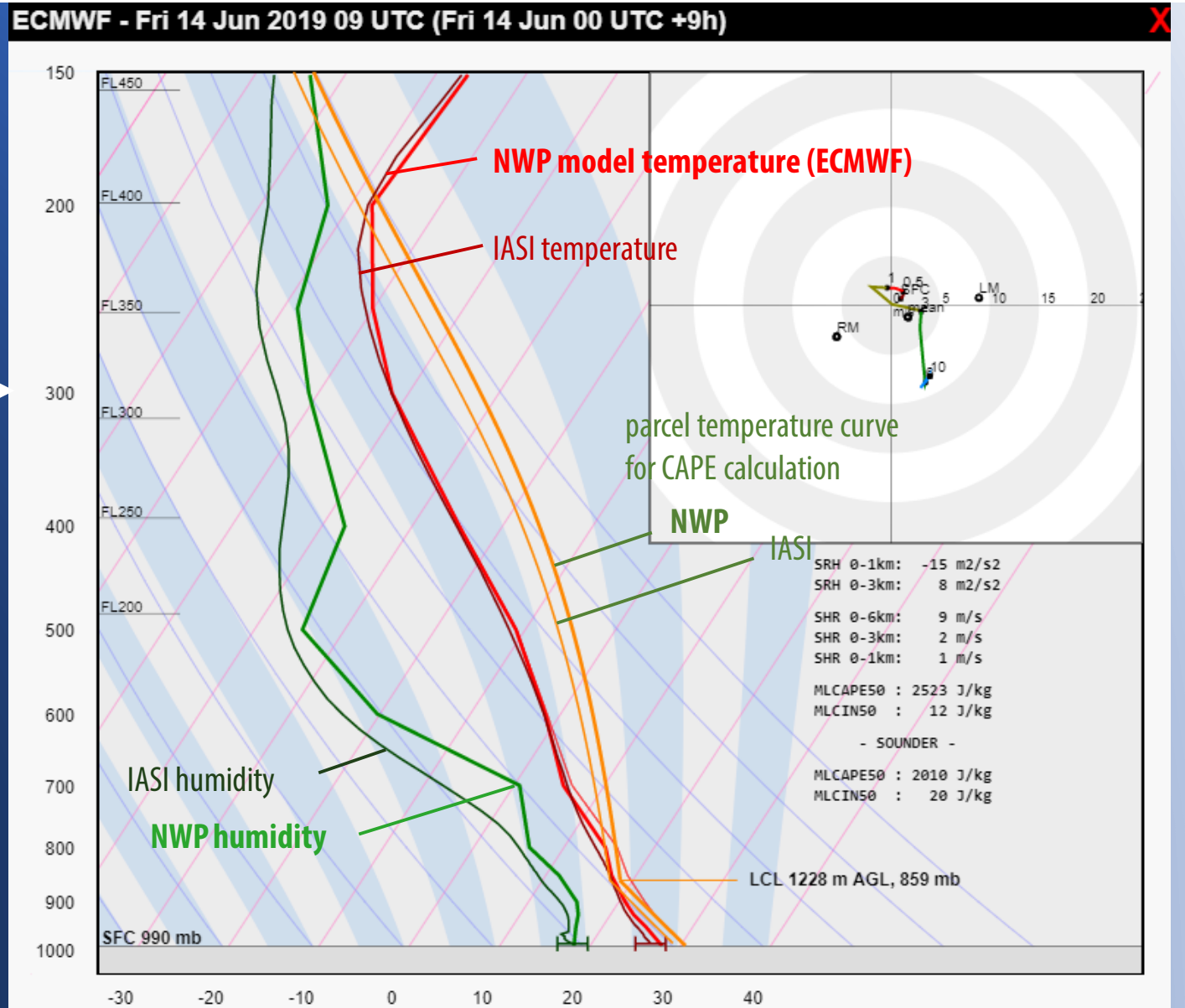

**50 mb mixed-layer CAPE**

background: values derived from +9 h model forecast (ECMWF IFS)

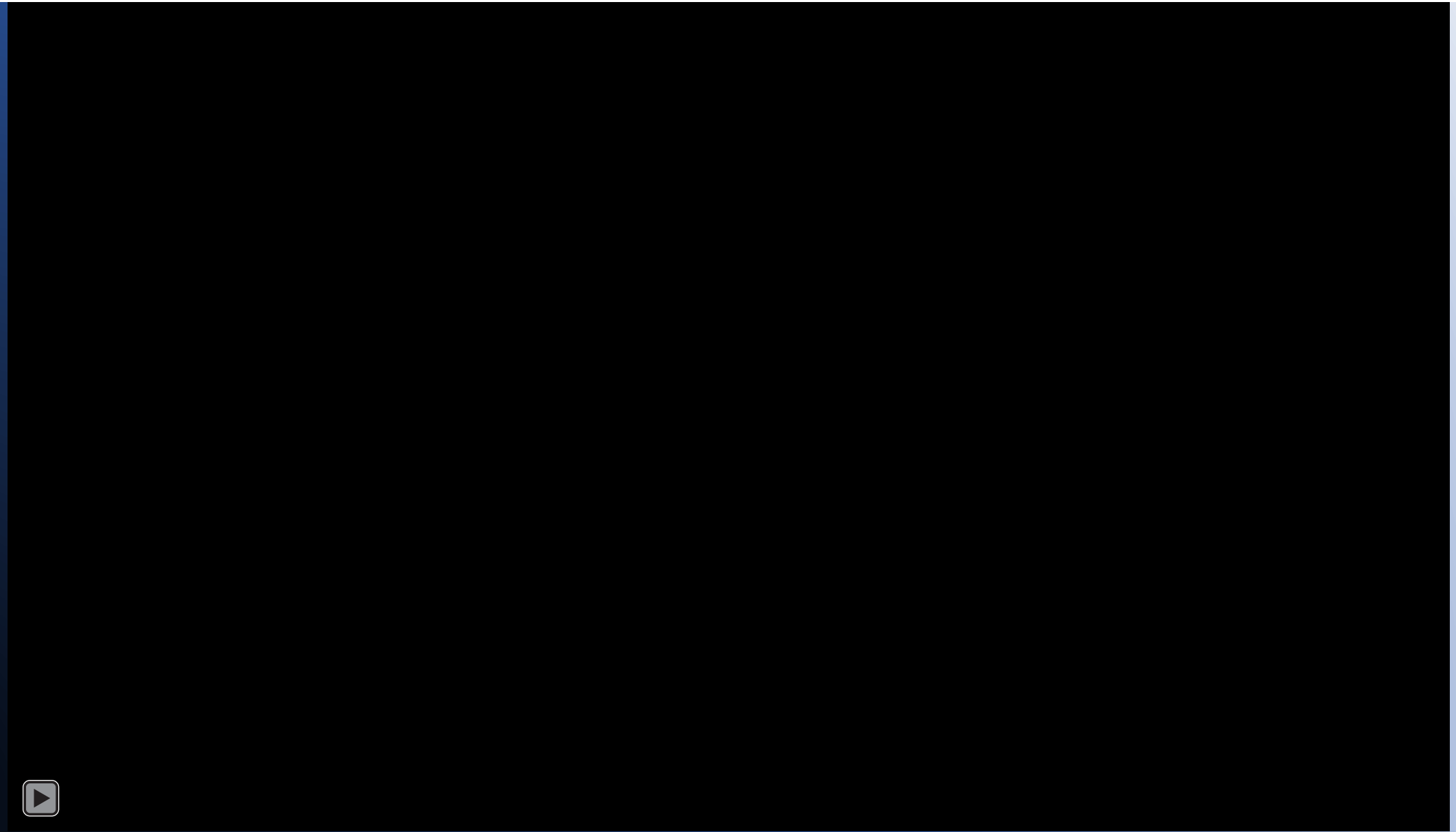
dots indicate IASI-derived values

# Comparison of IASI with NWP

"Roaming sounding" diagram from the Testbed data interface



# Comparison of convective parameters



# Testbed evaluation

ESSL Testbed

41 Testbed participants from 14 countries

2019 Edition:

During four weeks in June and July

In Wiener Neustadt, Austria

ESSL Research and Training Centre

make experimental forecasts for (severe) convective storms

# Testbed evaluation

## IASI questions

***Question 1***

*Could atmospheric soundings such as those provided from Metop/IASI (available within 30 minutes from sensing) be useful for your forecasting work? In what way?*

**Of 15 groups of respondents,**

**12 thought it was useful in principle**

*One other group found it a potential source of confusion and another commented on the need for knowing the quality of the data*

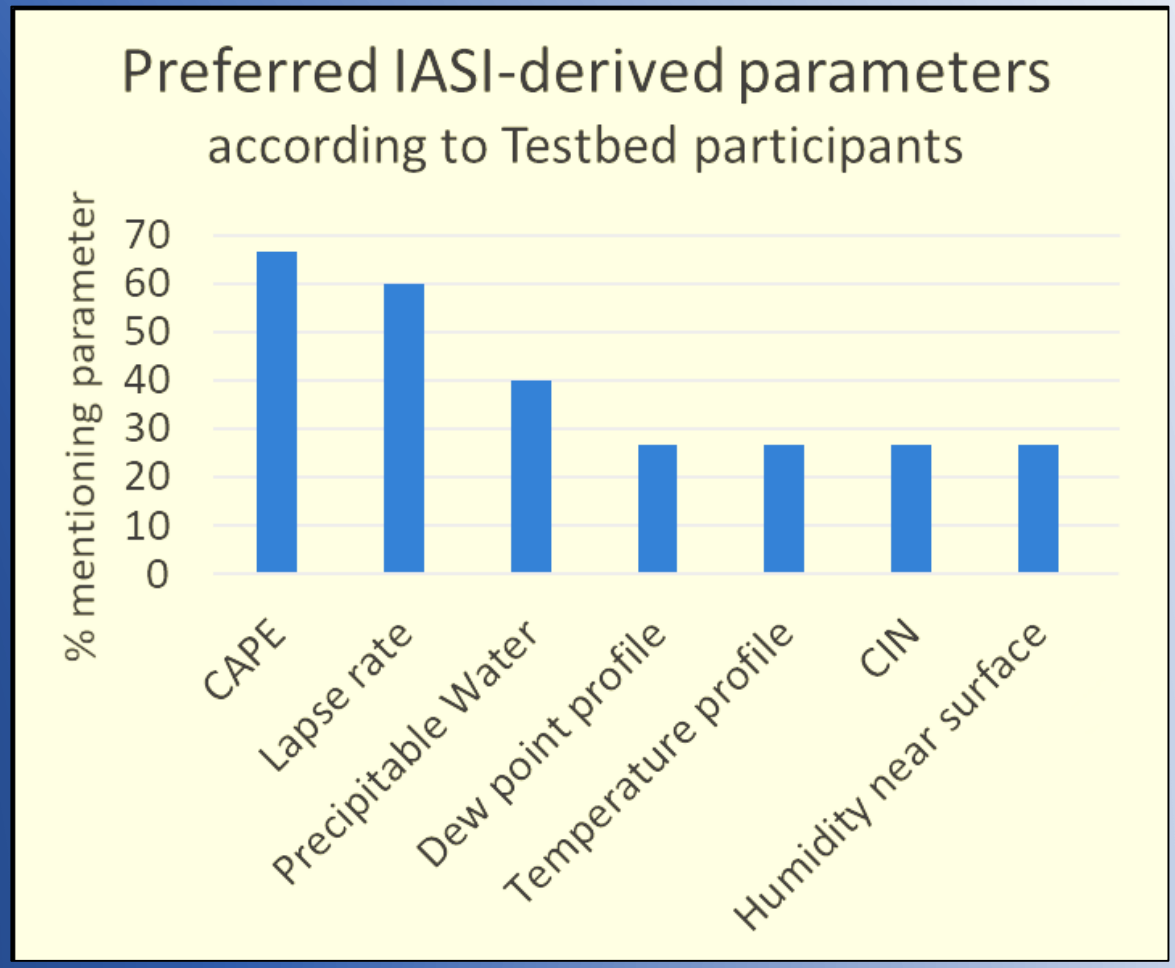
*One responded that it was not useful in an experiment of assimilating the data at the Italian Weather Service —but that was not the question that was asked.*

# Testbed evaluation

## IASI questions

### *Question 2*

*Which of the provided parameters based on the sounder data do you find most useful? Please mention the 3 to 5 most useful ones.*



# Testbed evaluation

## IASI questions

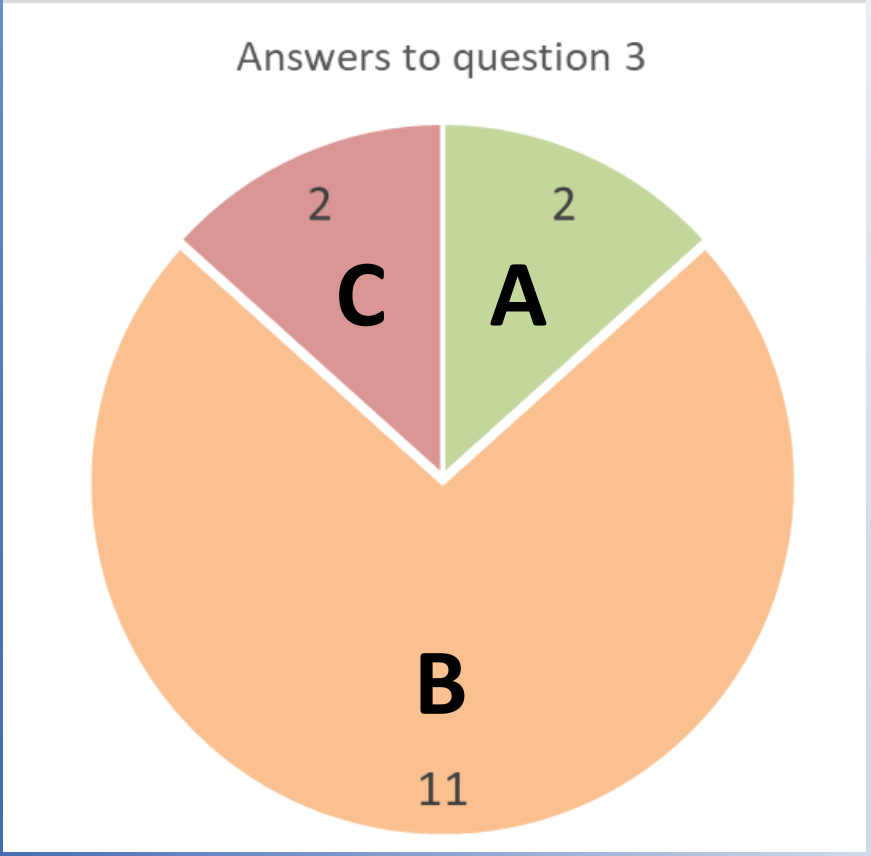
### *Question 3*

***Choose the statement that applies best***

A. *I think the IASI products with their limited temporal availability (twice a day) already provide important additional information that makes the data interesting to use.*

B. *I think the IASI products could be useful for forecasting, but first it is necessary that more observations become available throughout the day.*

C. *I think the IASI products have limited value for forecasting, but are interesting to prepare for the MTG-IRS data, that will have better resolution.*



# Testbed evaluation

## IASI questions

### *Question 4*

*In principle, NWP (forecast model) data could be used to improve the limited vertical resolution of hyperspectral sounder products, but this would introduce a dependence on them. In their present form the data are available in the form of smoother/less resolved profiles (than e.g. sondes) and as integrated-/lapse-/instability quantities, but they are fully independent of any NWP model.*

*How important is it to your work that the products are independent of any NWP model?*

**Almost all participant groups (14 out of 15) stated that it was important or very important to have an IASI dataset that is independent from numerical model output.**

*”We think that it should be independent, so that observations are closer to reality and then we could compare them with model data. But of course, it is a good thing that the IASI data are assimilated into the model to improve the performance of the model.”*

# Testbed evaluation

## IASI questions

***Question 5***

*The vertical profiles are currently provided with a single error estimate, displayed with an error bar at the bottom of the profile. In principle, it is possible to display errors for any given level.*

*How useful do you think this would be for your work?*

*In practice, how would you use this quality-control information?*

**12 out of 15 participant groups responded that they would find such information useful.**

3 out of 15 thought it would not be useful, the main objection being the risk of overloading the user with information.

# Testbed evaluation

## IASI questions

***Question 6***

*Do you have any additional comments or suggestions regarding the data?*

*Did something in particular catch your attention?*

**General comments:**

- Half of the groups noted differences in near-surface humidity between the IASI data and NWP model, or between IASI and surface observations
- an **underestimation** of the humidity was most common.
- Two groups mentioned that the temperature profile seems to be (much) better.

**Visualization suggestions:**

1. enable a 3D (i.e. cross-section) view of sounder data
2. display low-level dew point temperature from IASI as a parameter
3. indicate the time difference between time of the sounder and the NWP model
4. highlight CAPE area in sounding profile by shading it

# Testbed evaluation

## Main outcomes:

1. most (80%) of participants found the data useful in principle
2. forecasters would welcome a higher (spatio-) temporal availability
3. IASI profiles should stay completely independent of the model data
4. There was concern about the accuracy of the near-surface humidity data

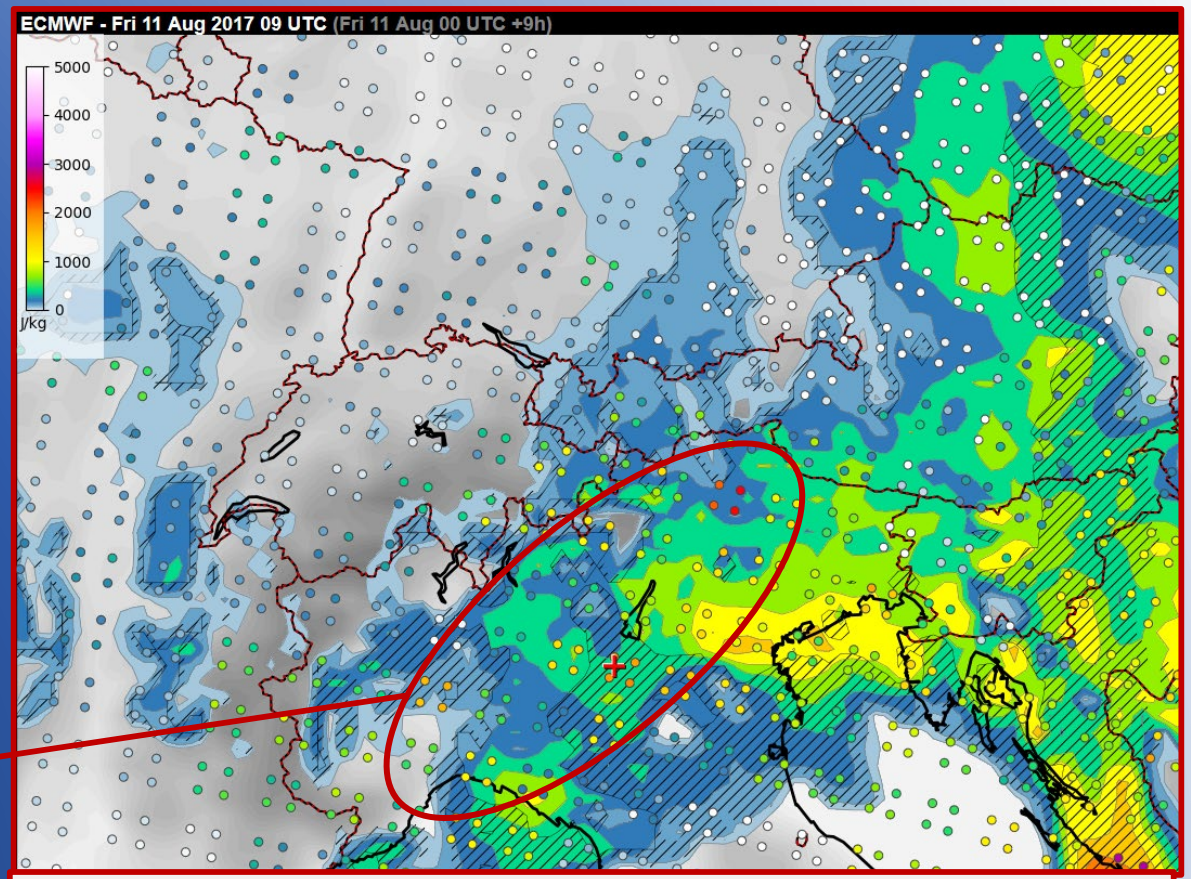
ESSL Testbed

# Studies of past cases

**ESSL studies past cases of severe convection that were impactful or not well anticipated by numerical weather prediction.**

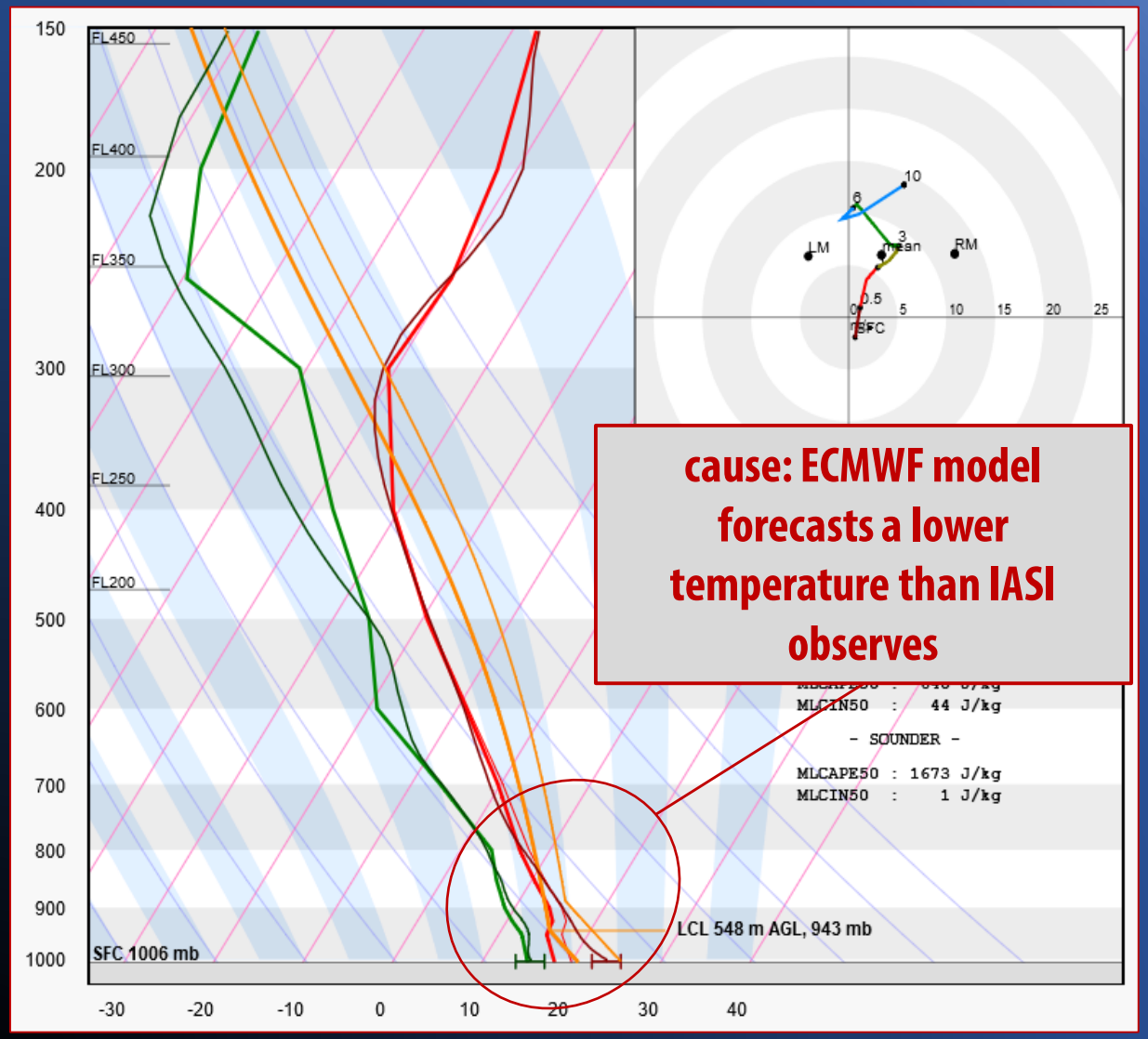
An example...

**area with higher CAPE according to IASI than in the ECMWF model**

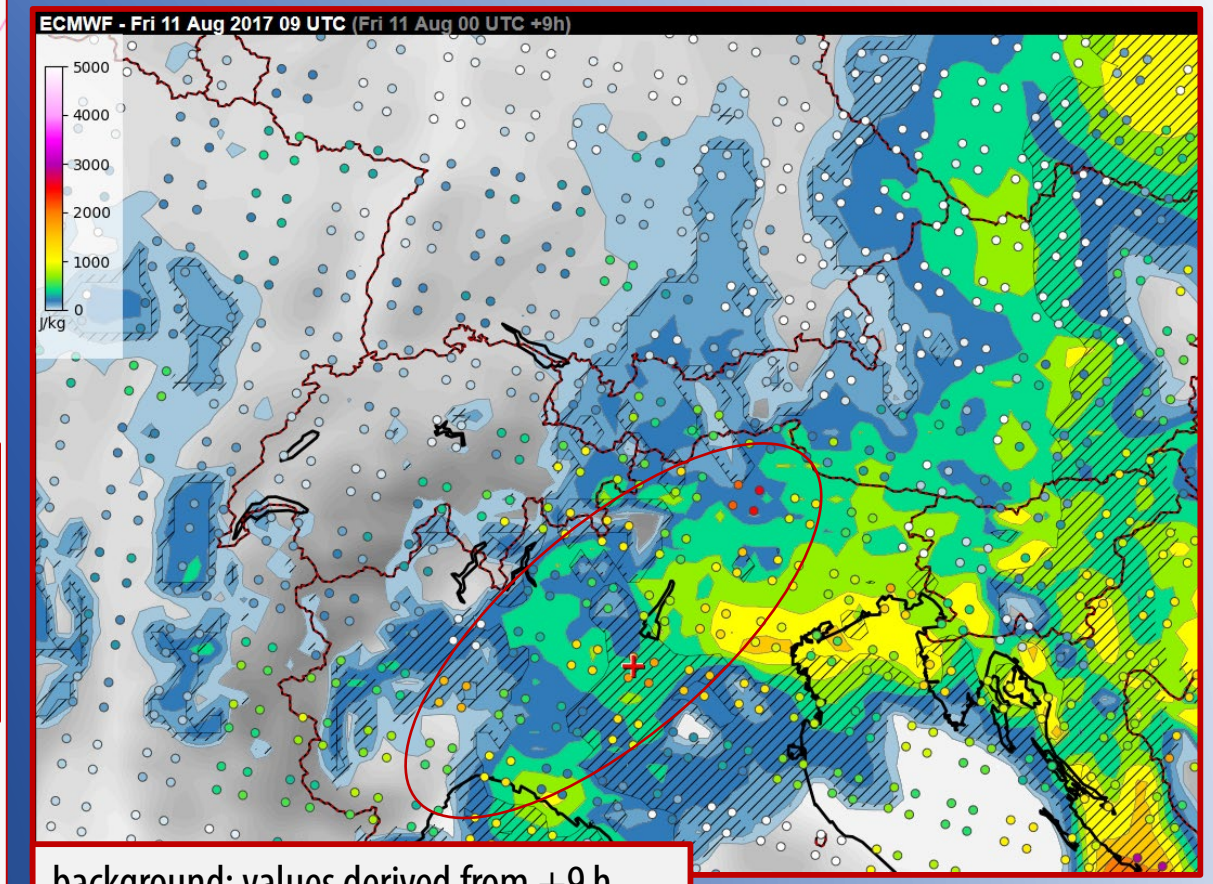



background: values derived from +9 h model forecast (ECMWF IFS). Dots indicate IASI-derived values

# Studies of past cases



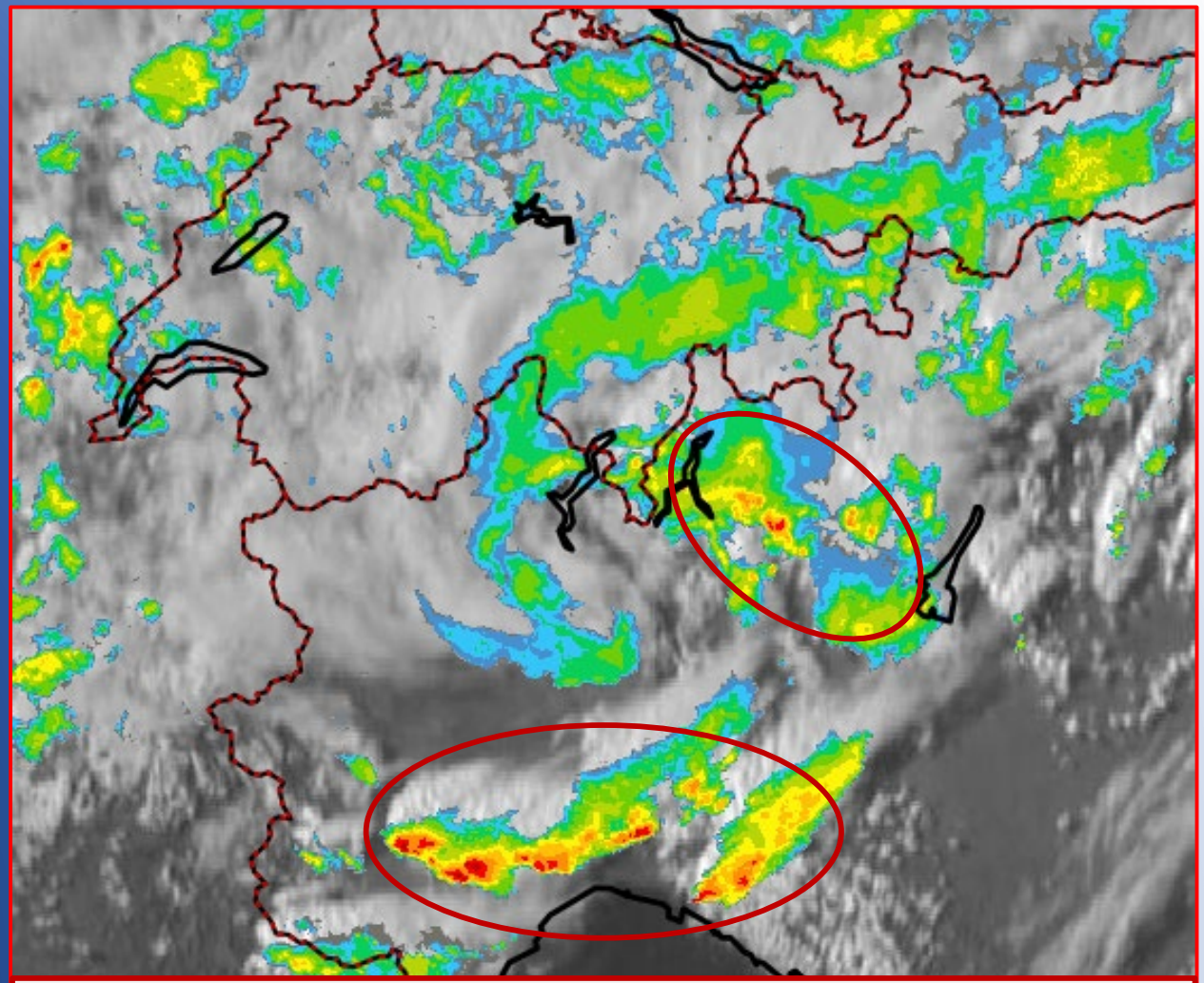

**cause: ECMWF model forecasts a lower temperature than IASI observes**




background: values derived from +9 h model forecast (ECMWF IFS). Dots indicate IASI-derived values

# Studies of past cases

widespread convective storm development by 1500 UTC

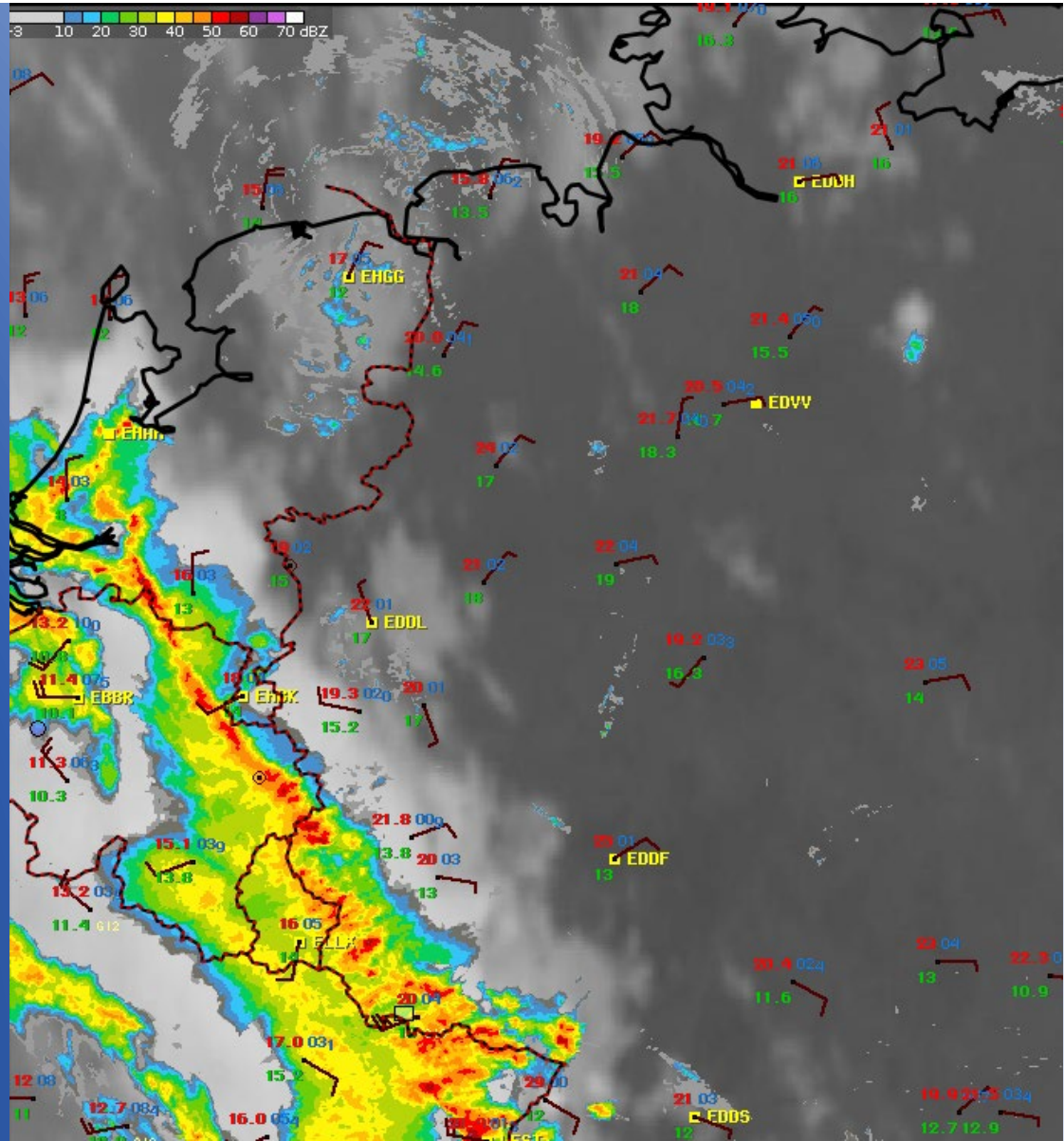


radar and VIS satellite at 1500 UTC

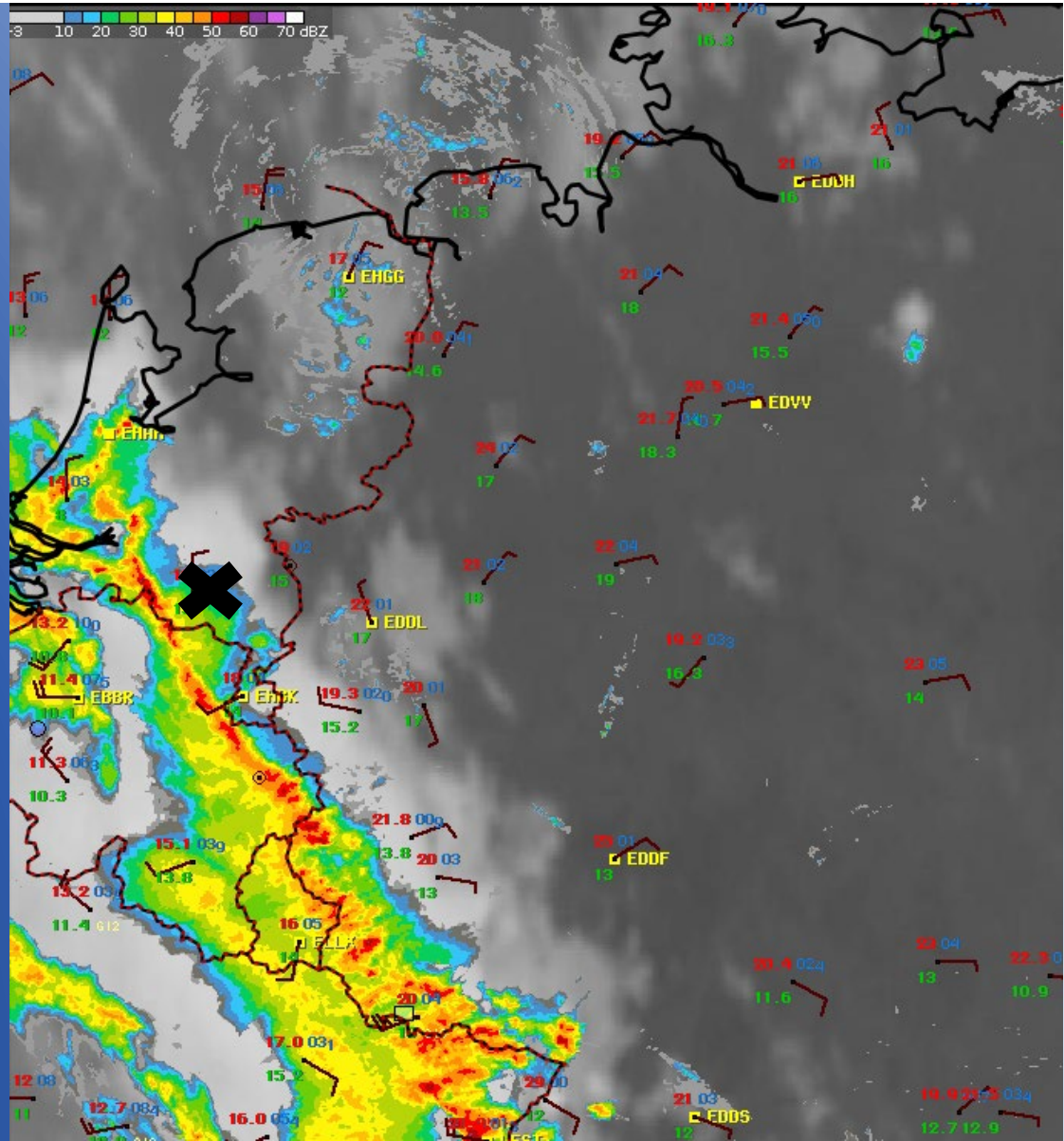
# 5 June 2019

Fast moving convective system

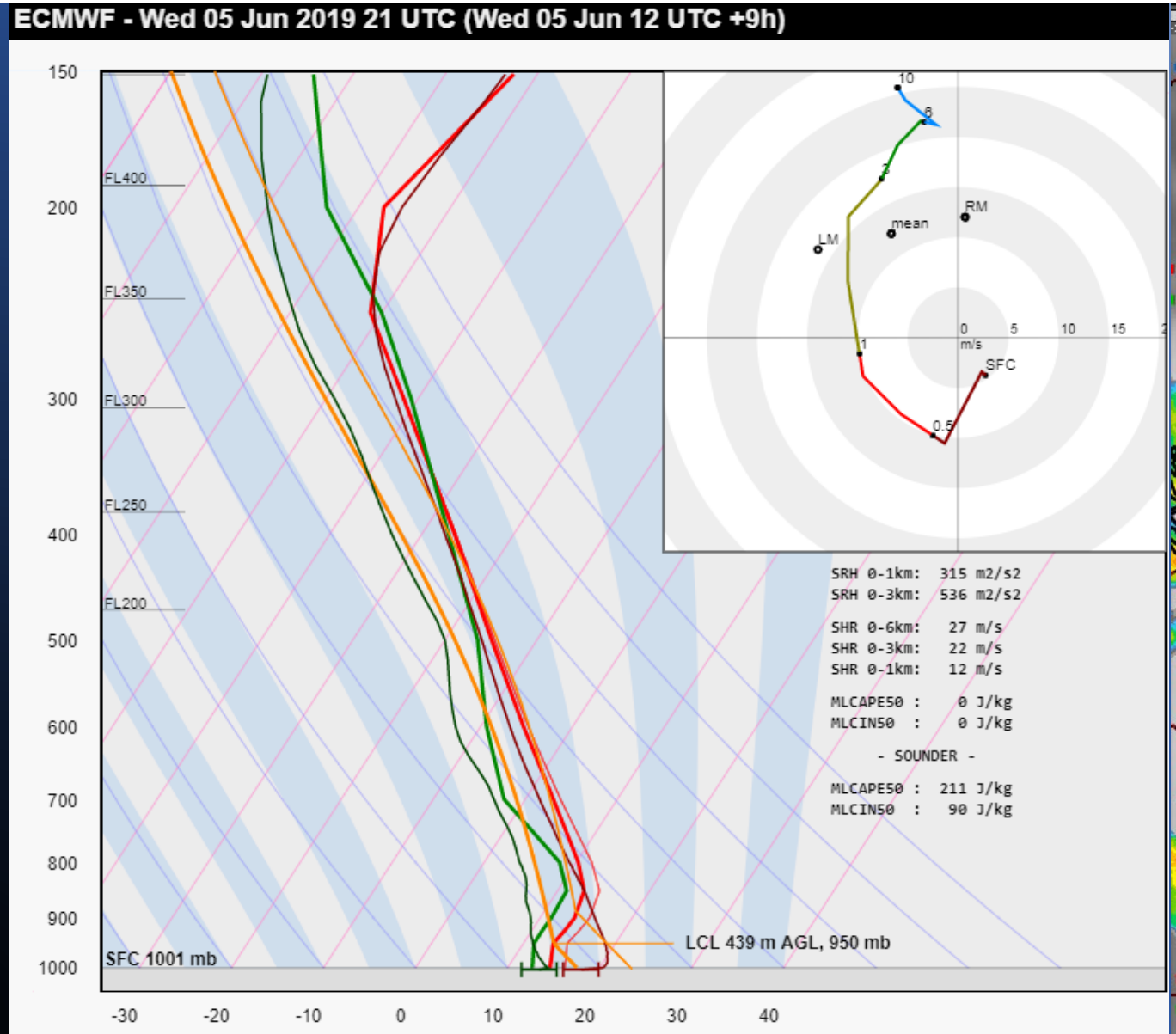
Is it capable of severe wind gusts?

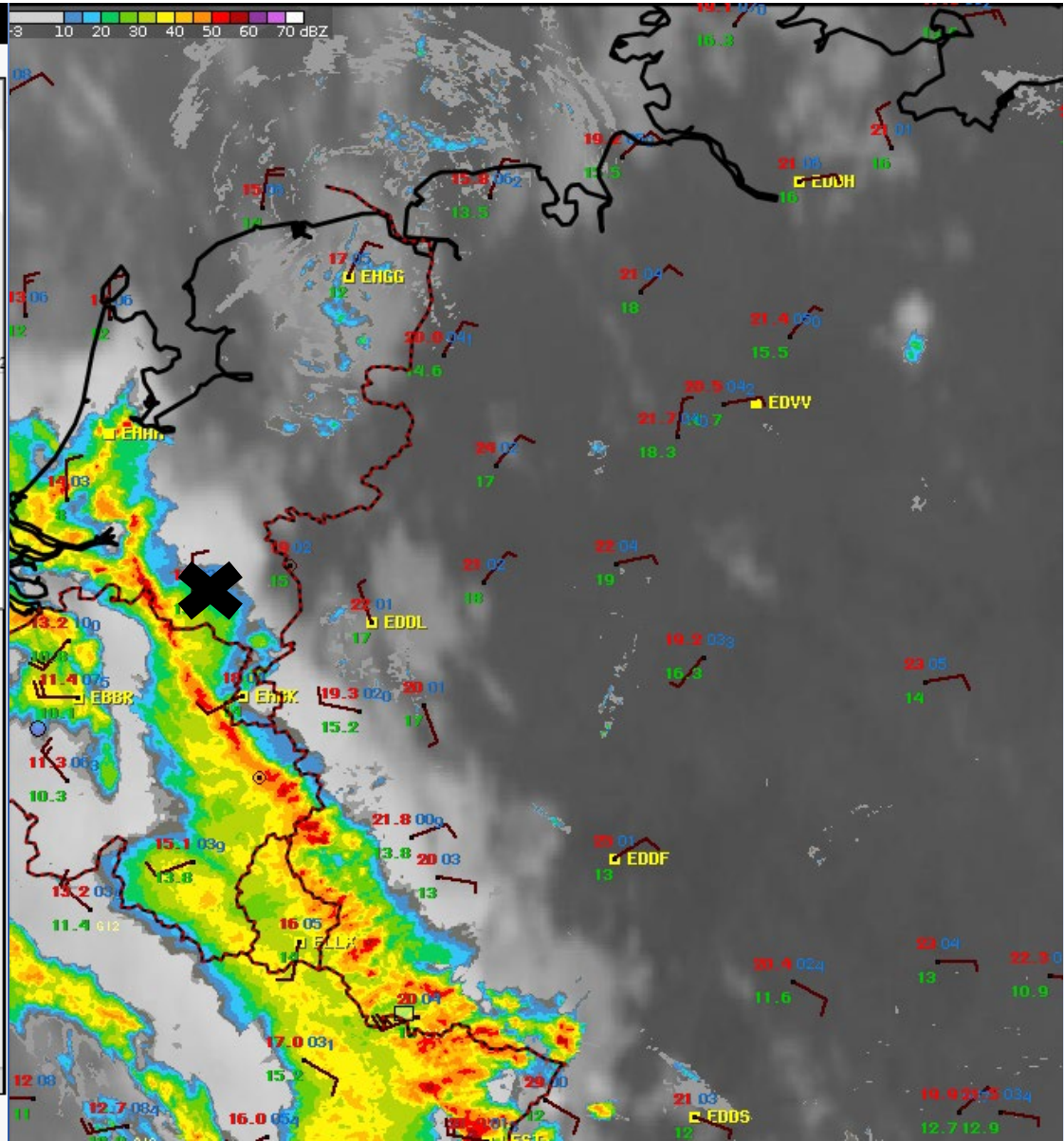


# 5 June 2019 – ahead of system



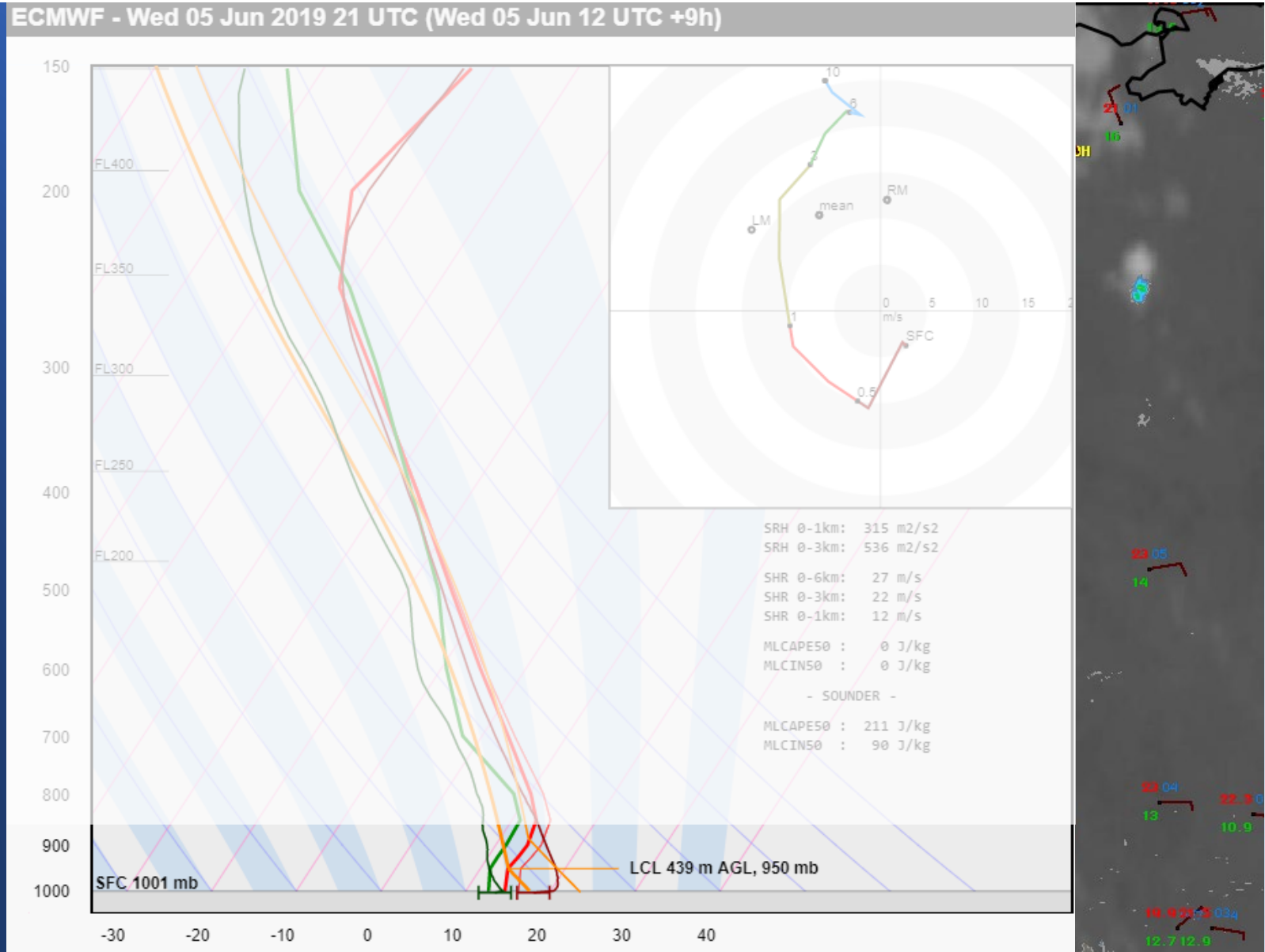
# 5 June 2019 – ahead of system



# 5 June 2019 – ahead of system

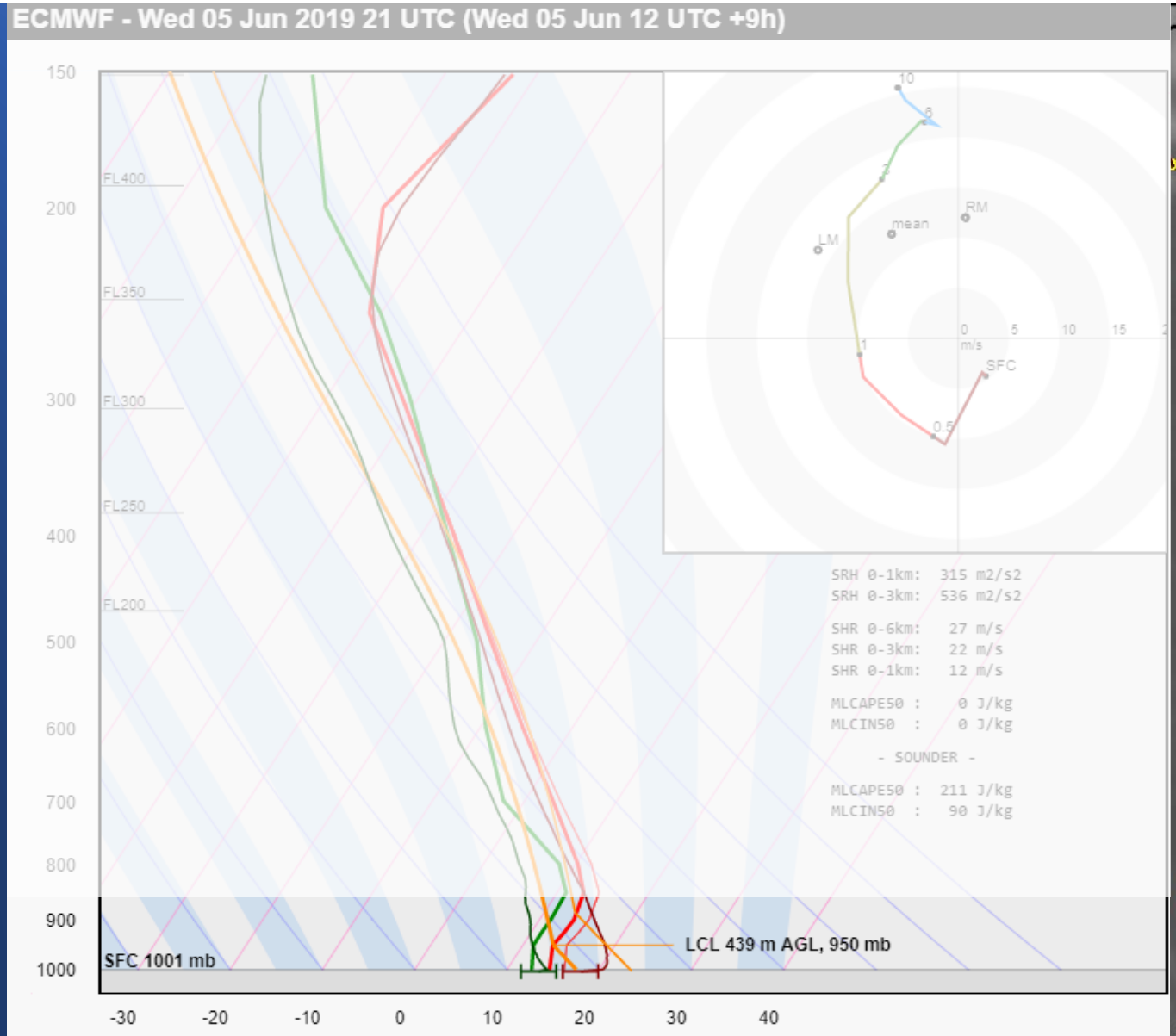
**Surface temperature higher than forecast**

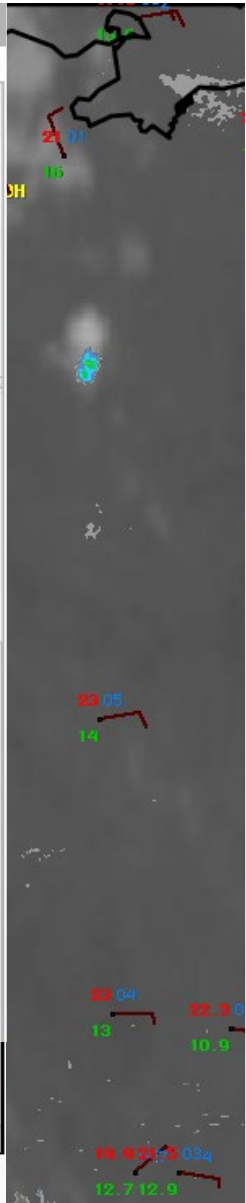


# 5 June 2019 – ahead of system

**Surface temperature higher than forecast**

**Observations confirm this**



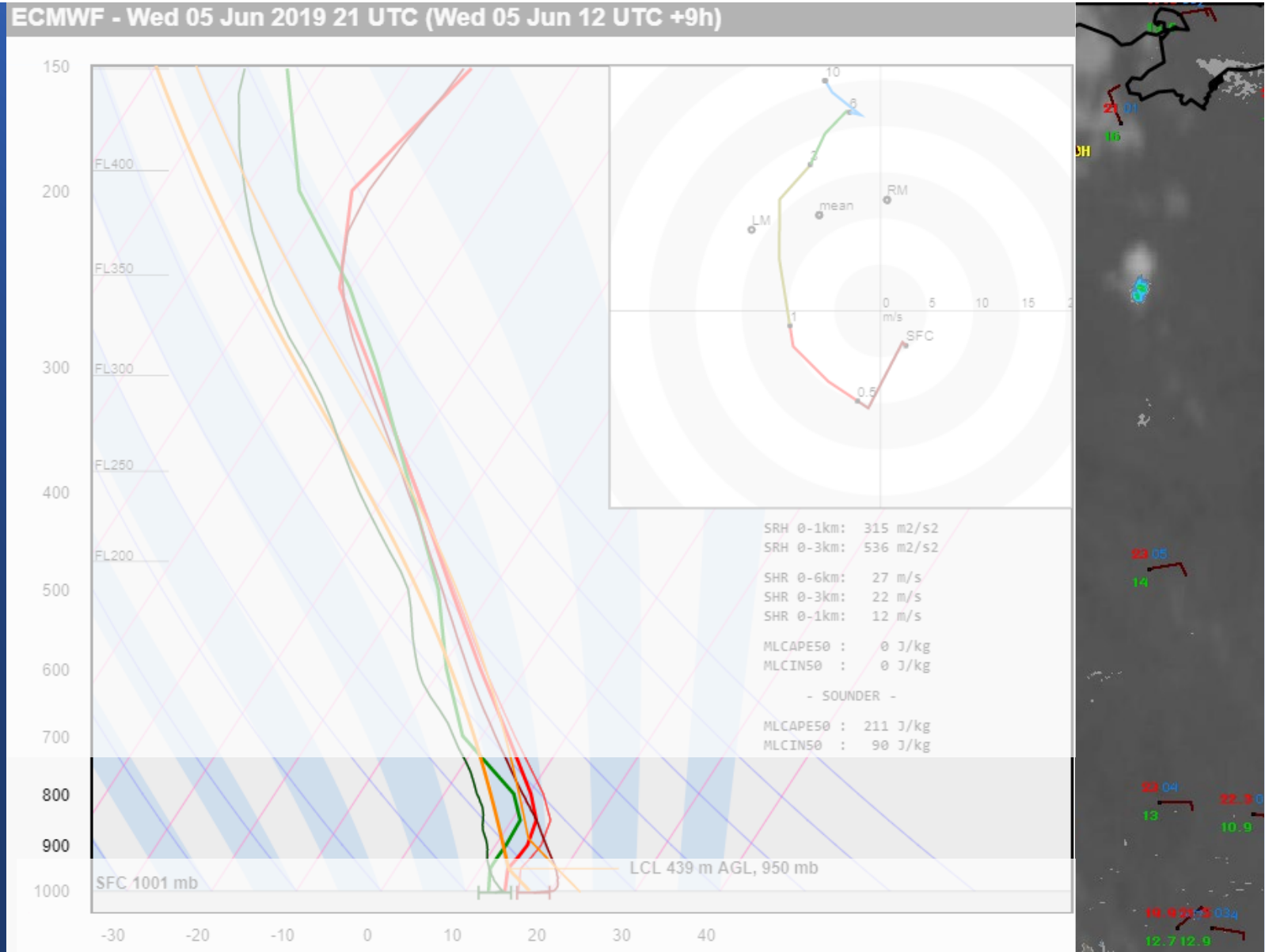



# 5 June 2019 – ahead of system

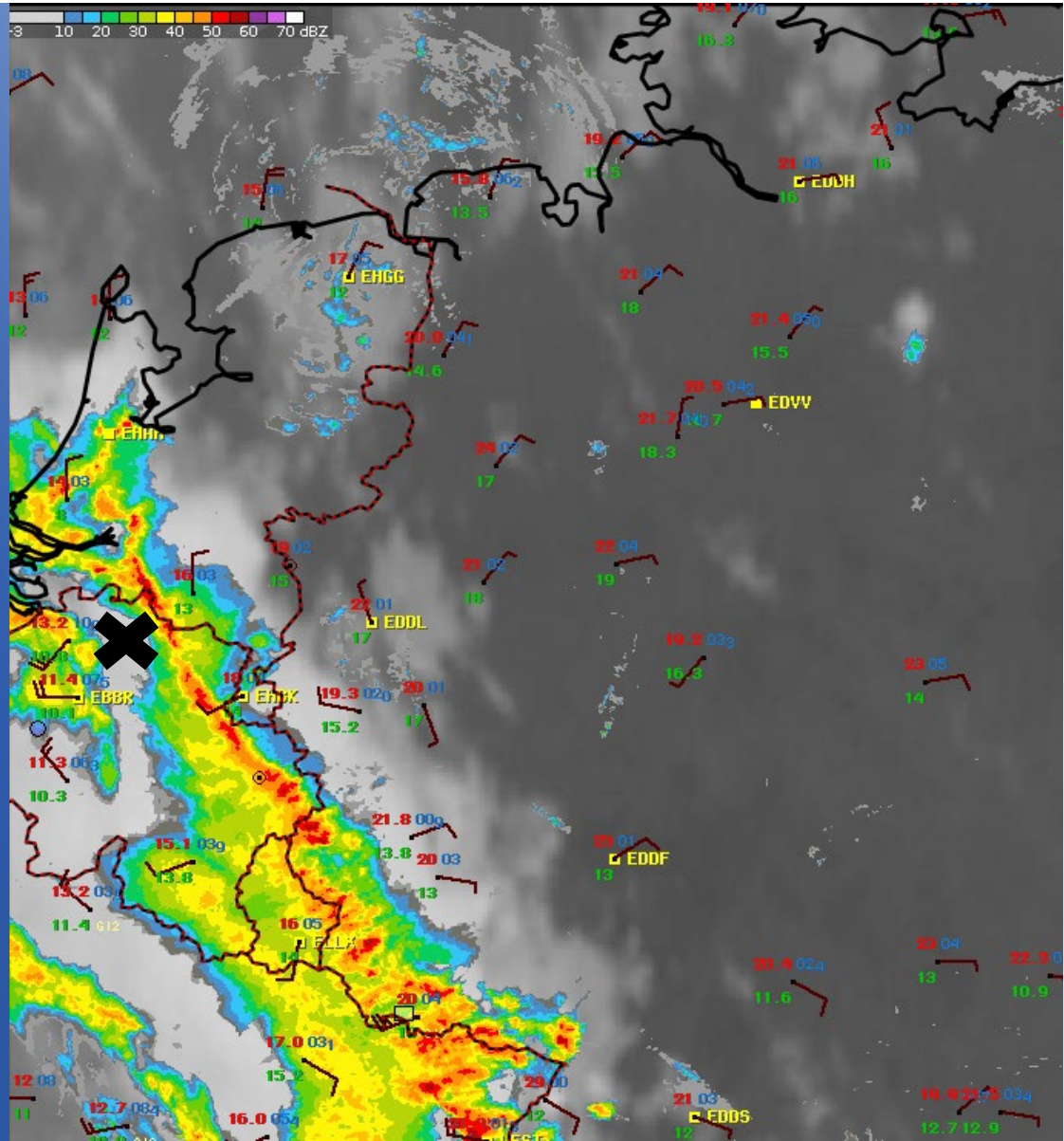
Surface temperature higher than forecast

Observations confirm this

Layer with substantial CAPE not detected



# 5 June 2019 – behind system



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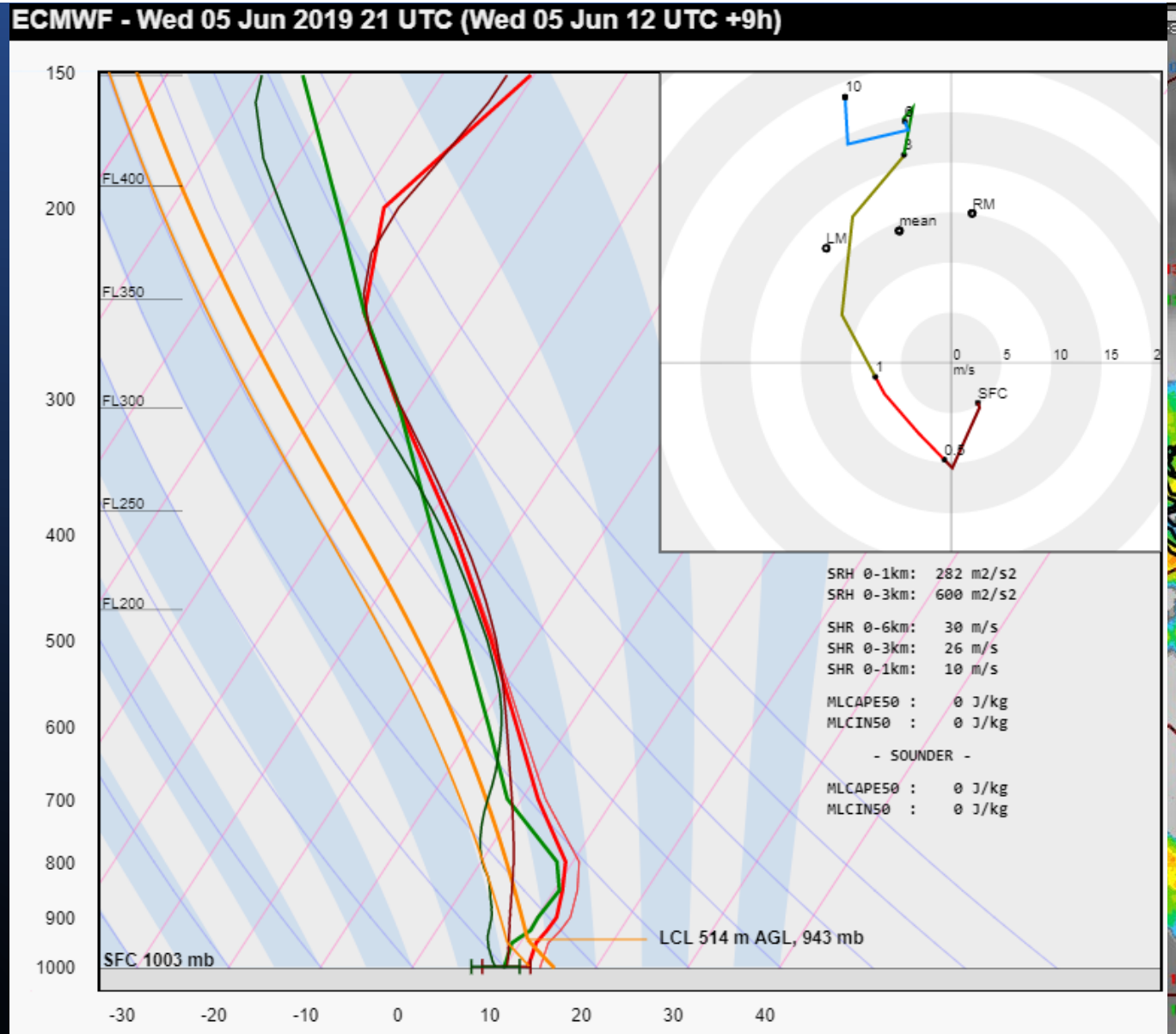
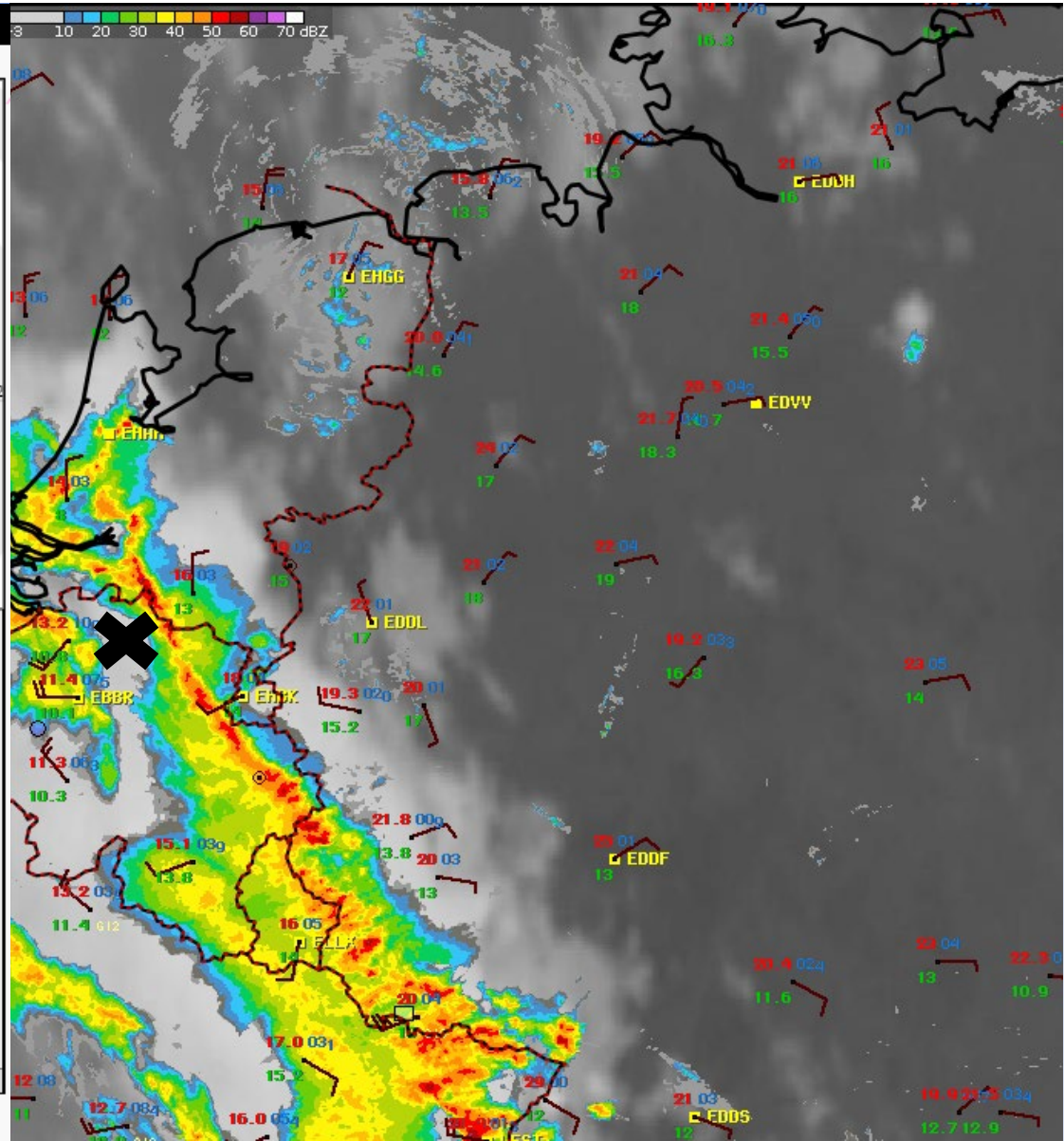
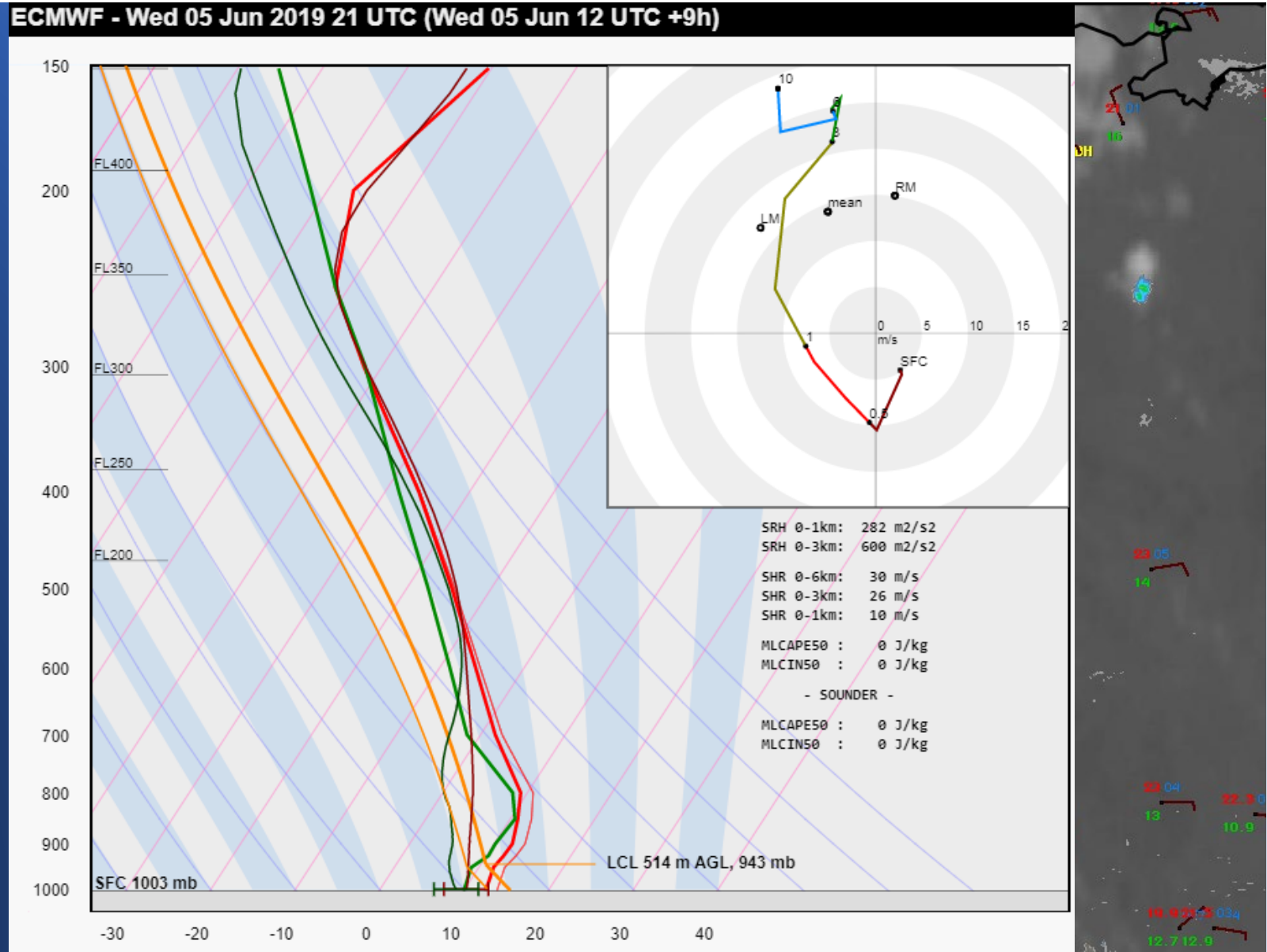


# 5 June 2019 – behind system

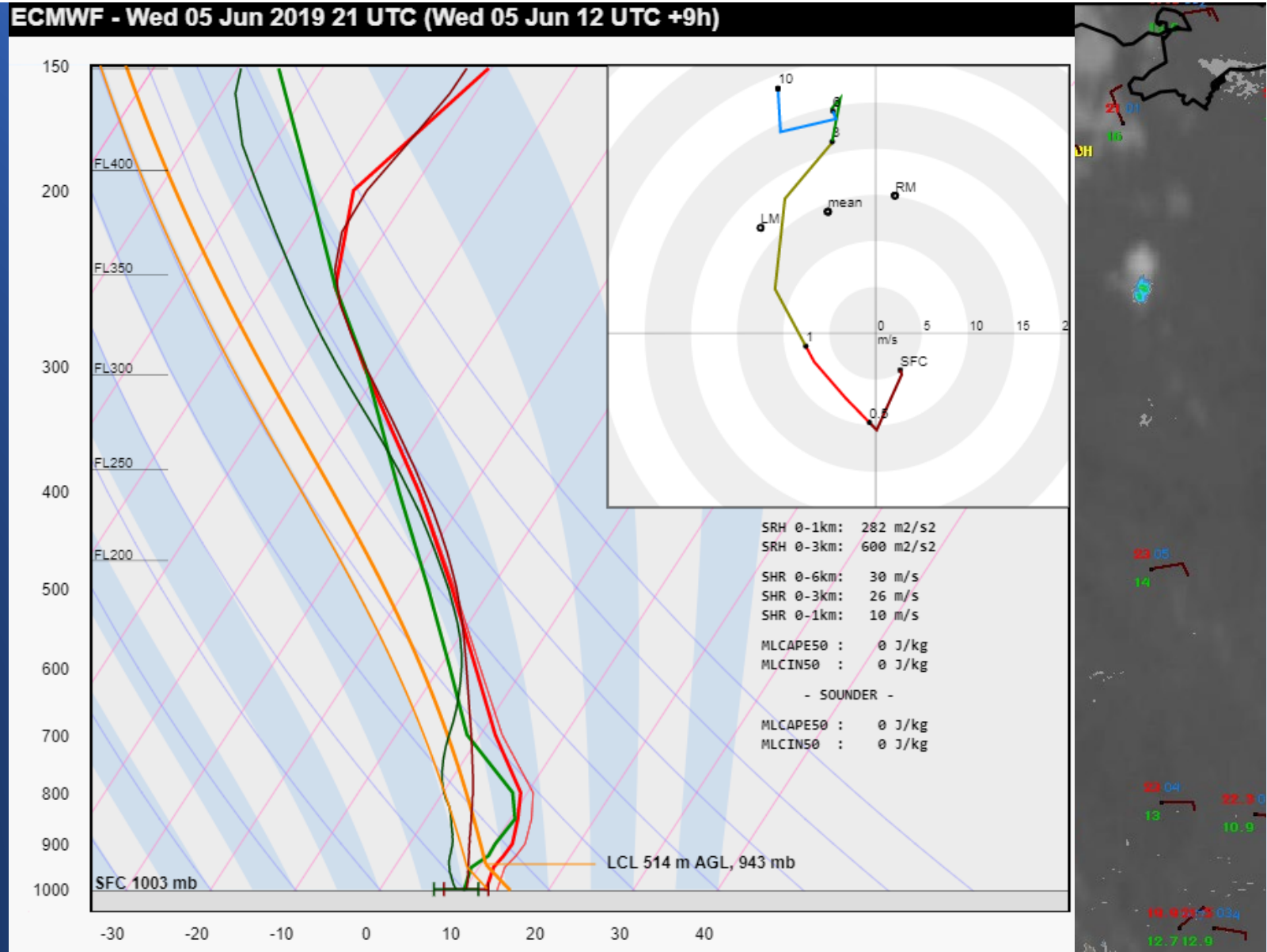
**Decrease in temperature and dewpoint**



# 5 June 2019 – behind system

**Decrease in temperature and dewpoint**

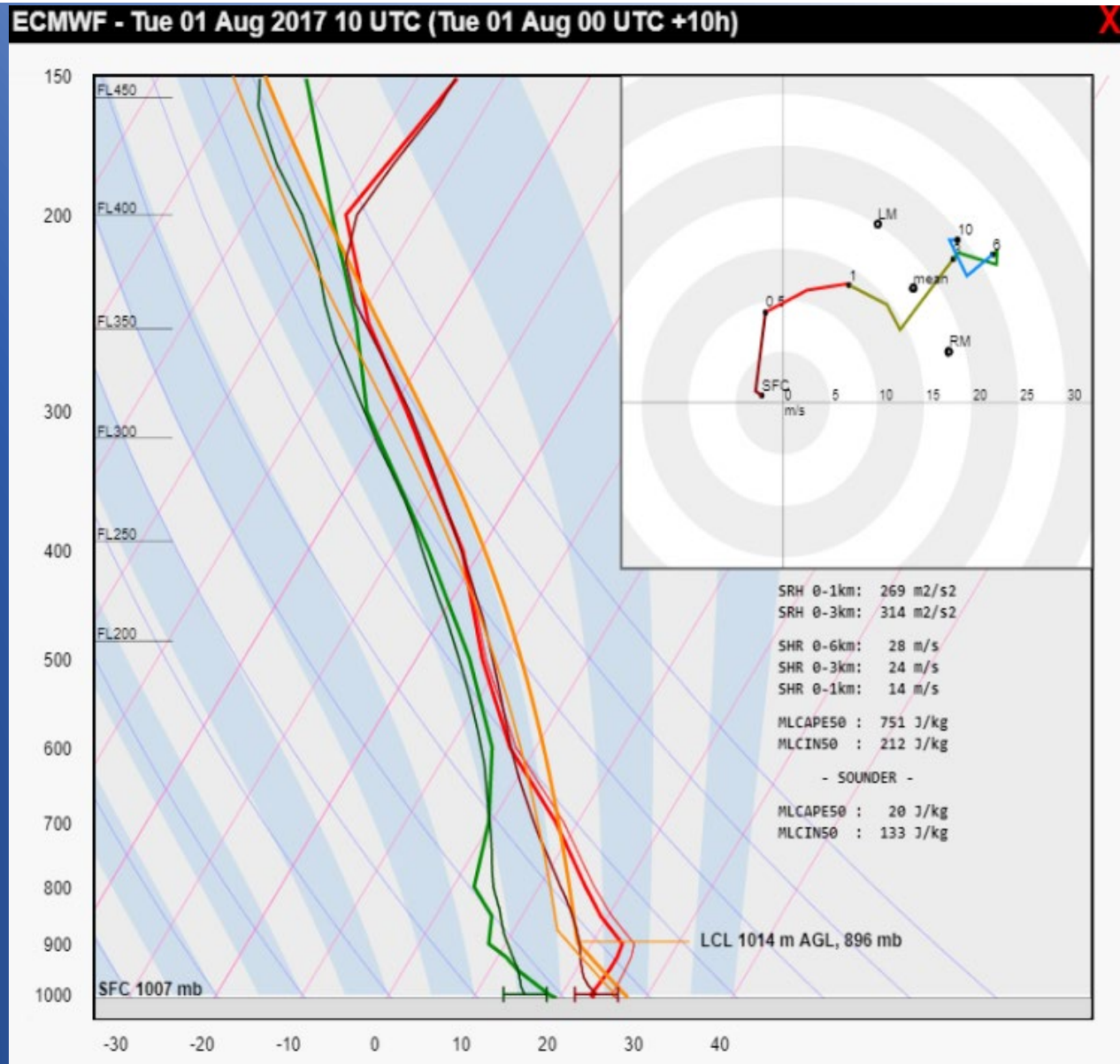
**Reduction in CAPE**



# 1 August 2017

**Failure in convective initiation**

**Can we measure the convective inhibition?**

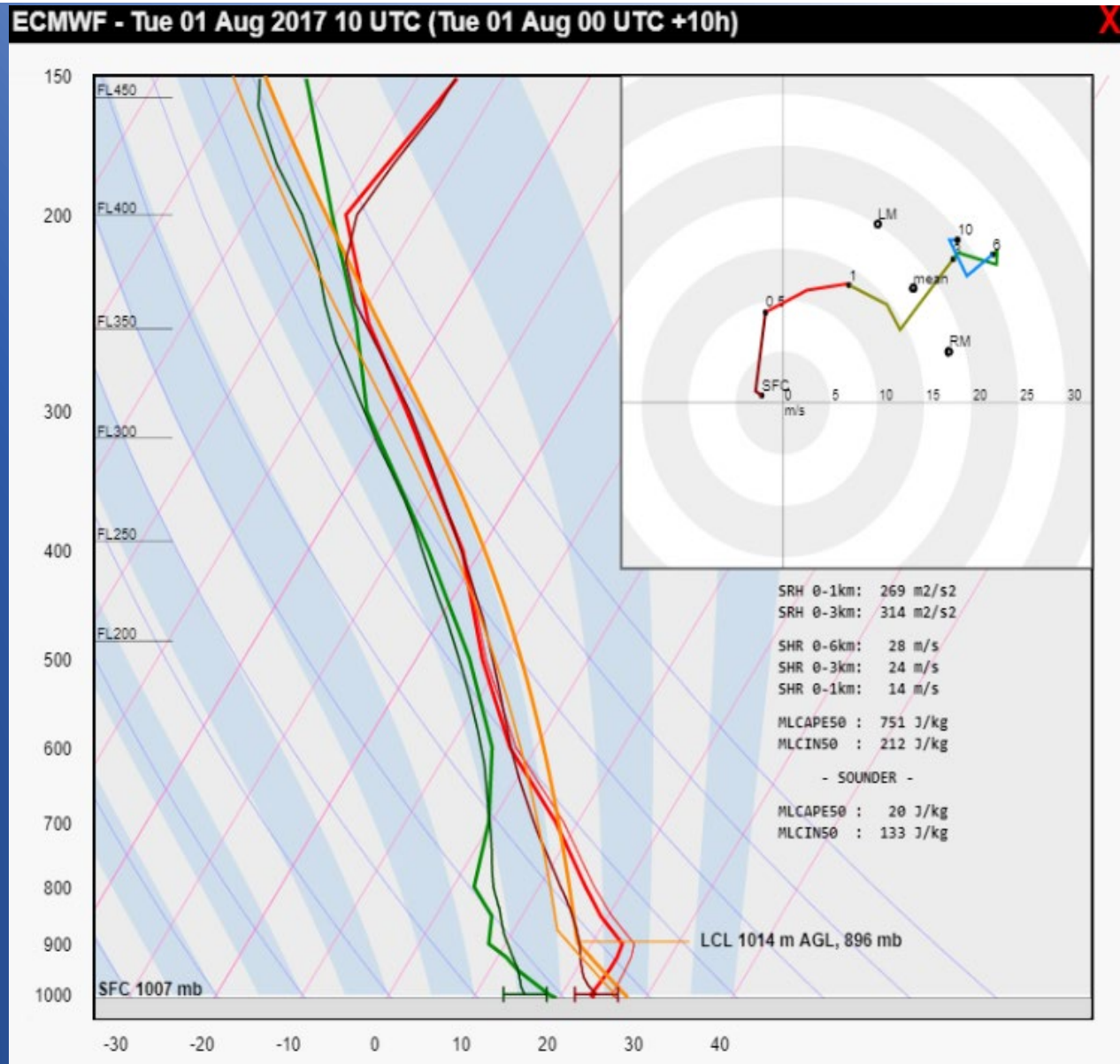


# 1 August 2017

No stable layer in IASI data

Less moisture than in model

Model closer to reality than IASI



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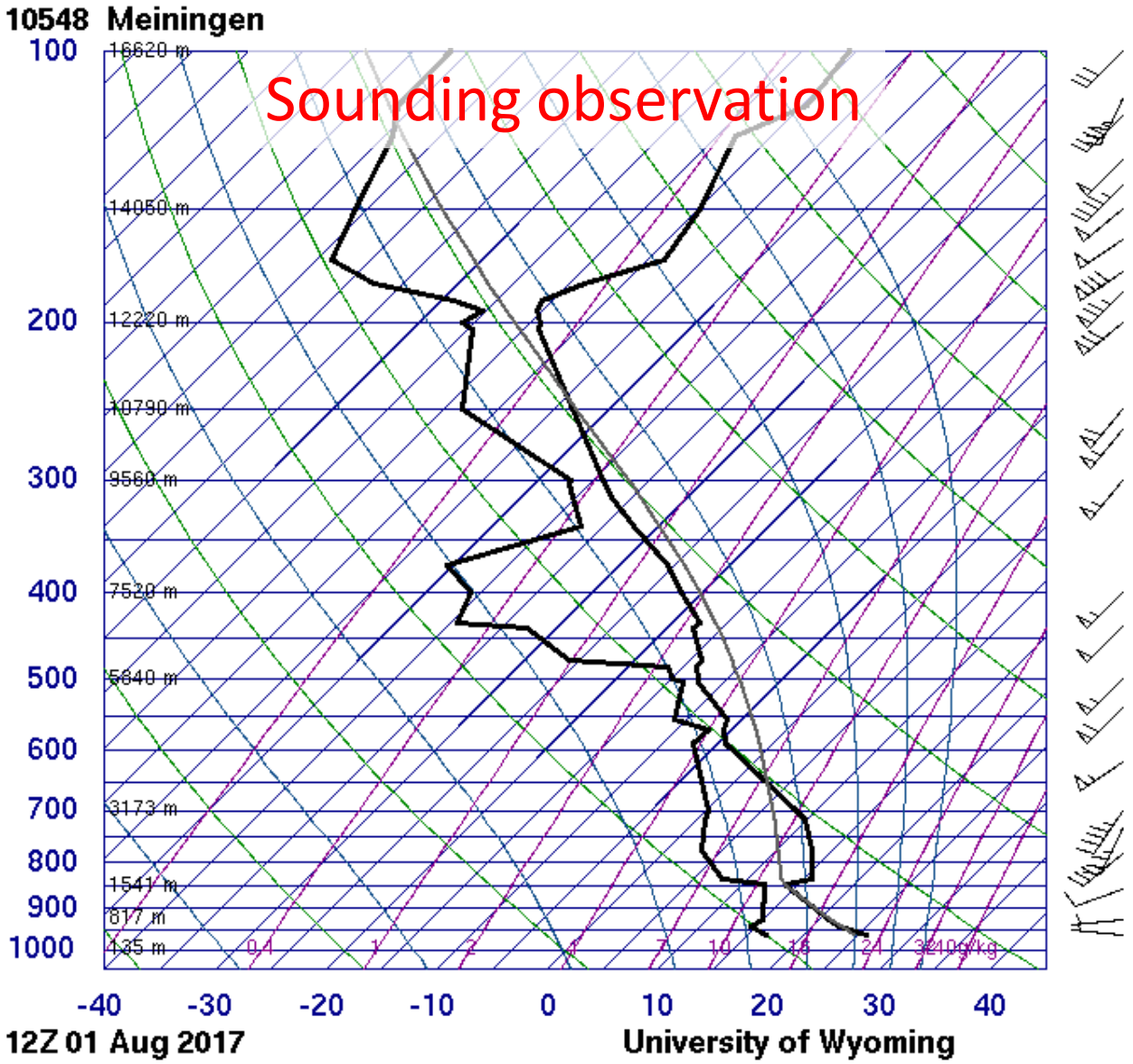
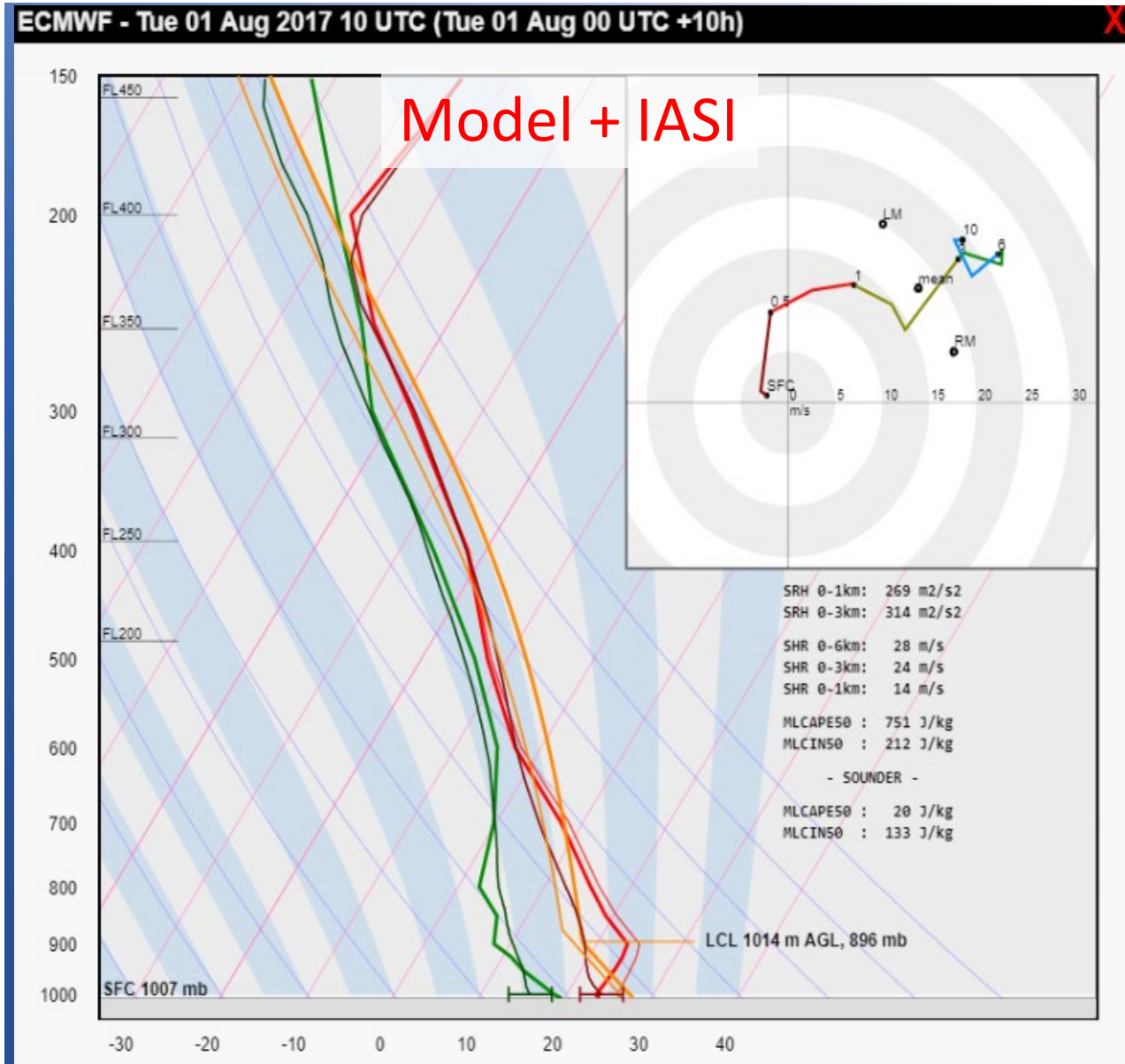
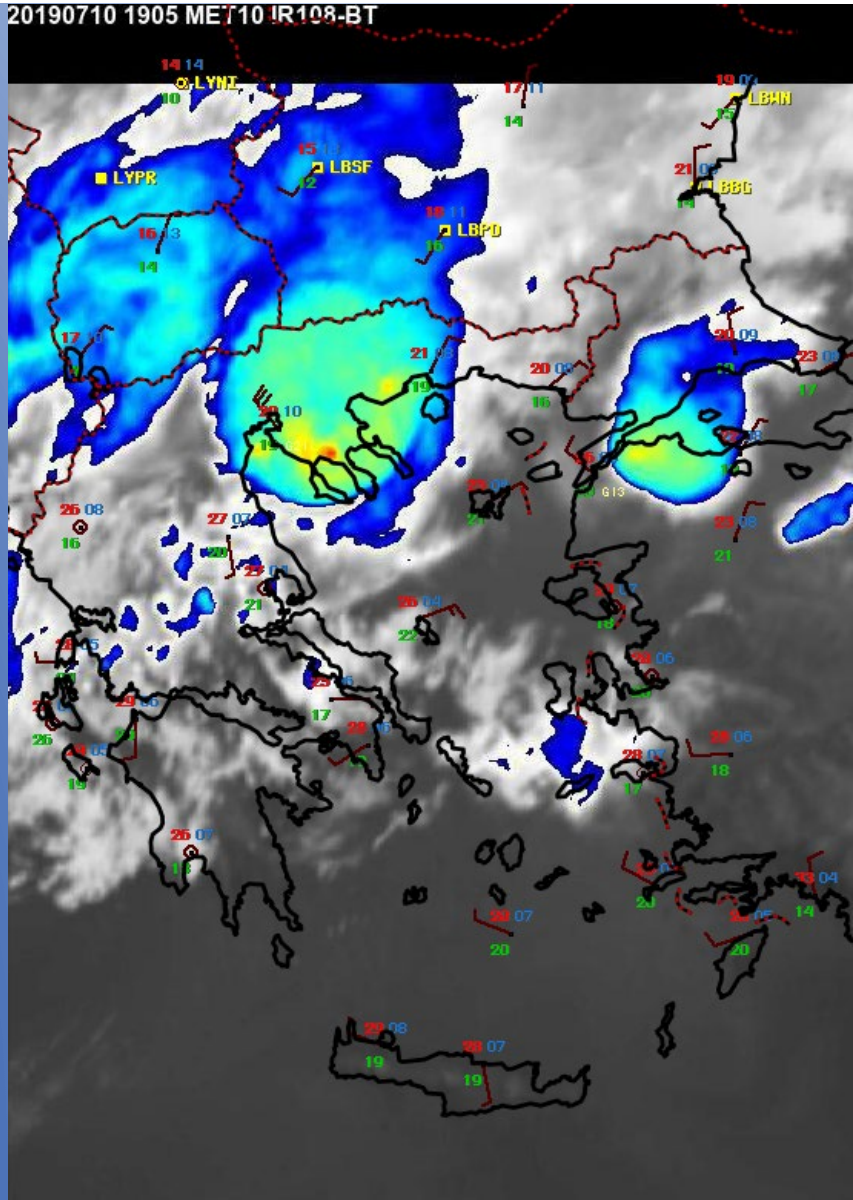


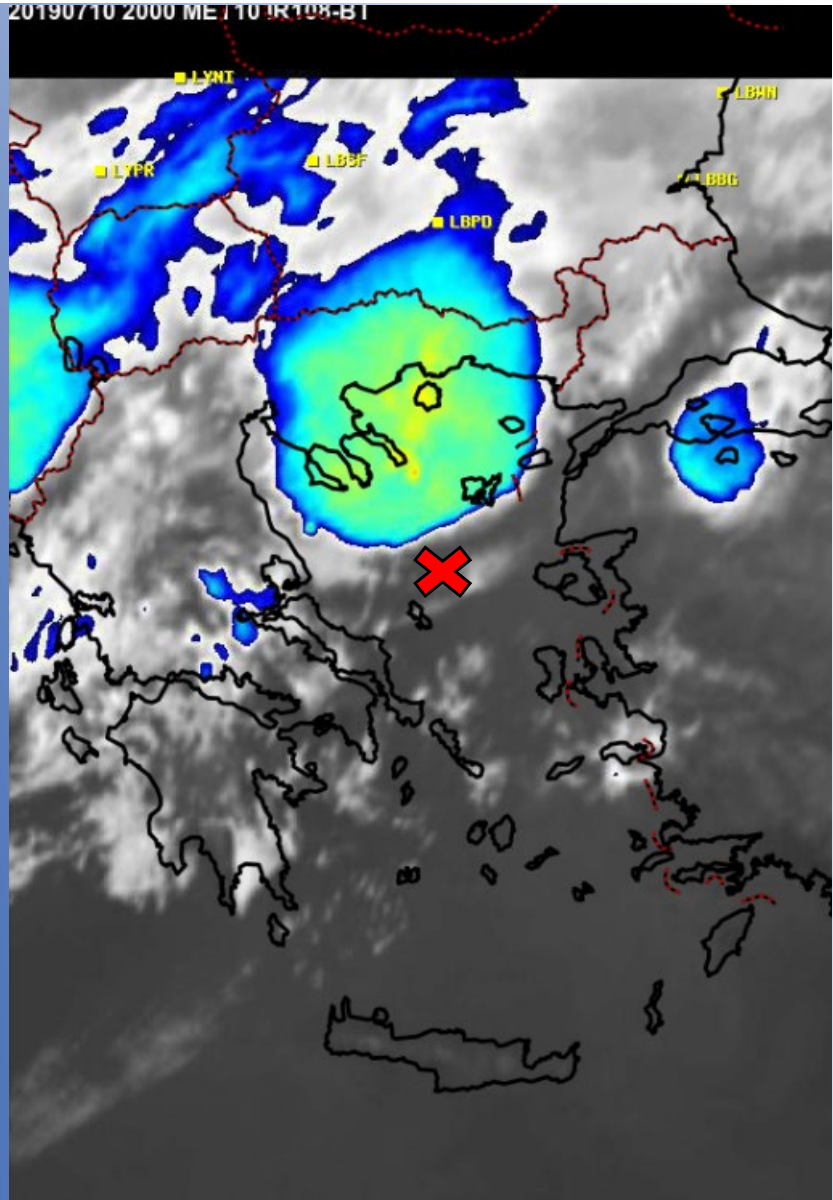
# 10 July 2019

**Damaging windstorm over Halkidiki, Greece**



# 10 July 2019

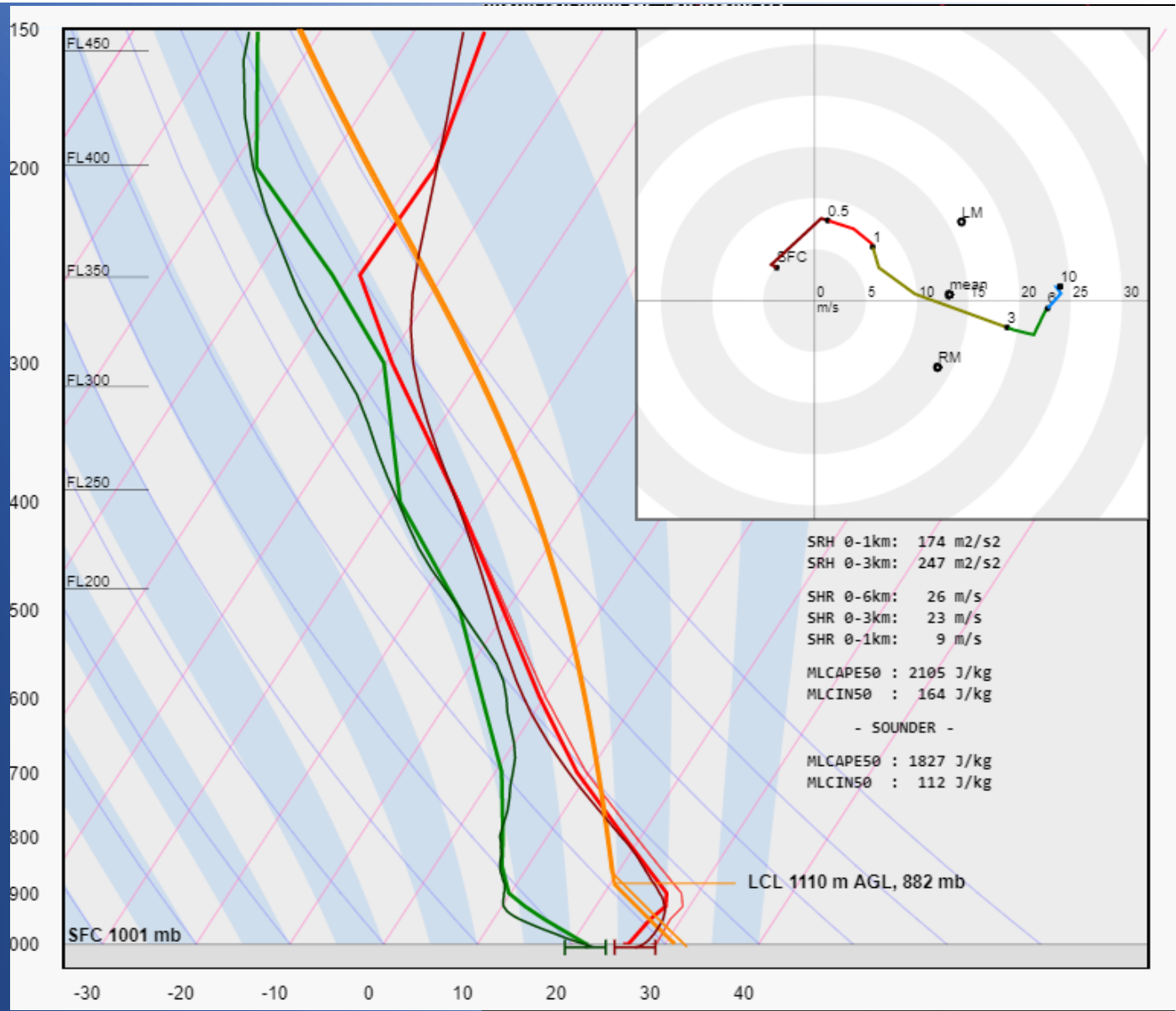
Storm weakening as it moves southeastward



# 10 July 2019

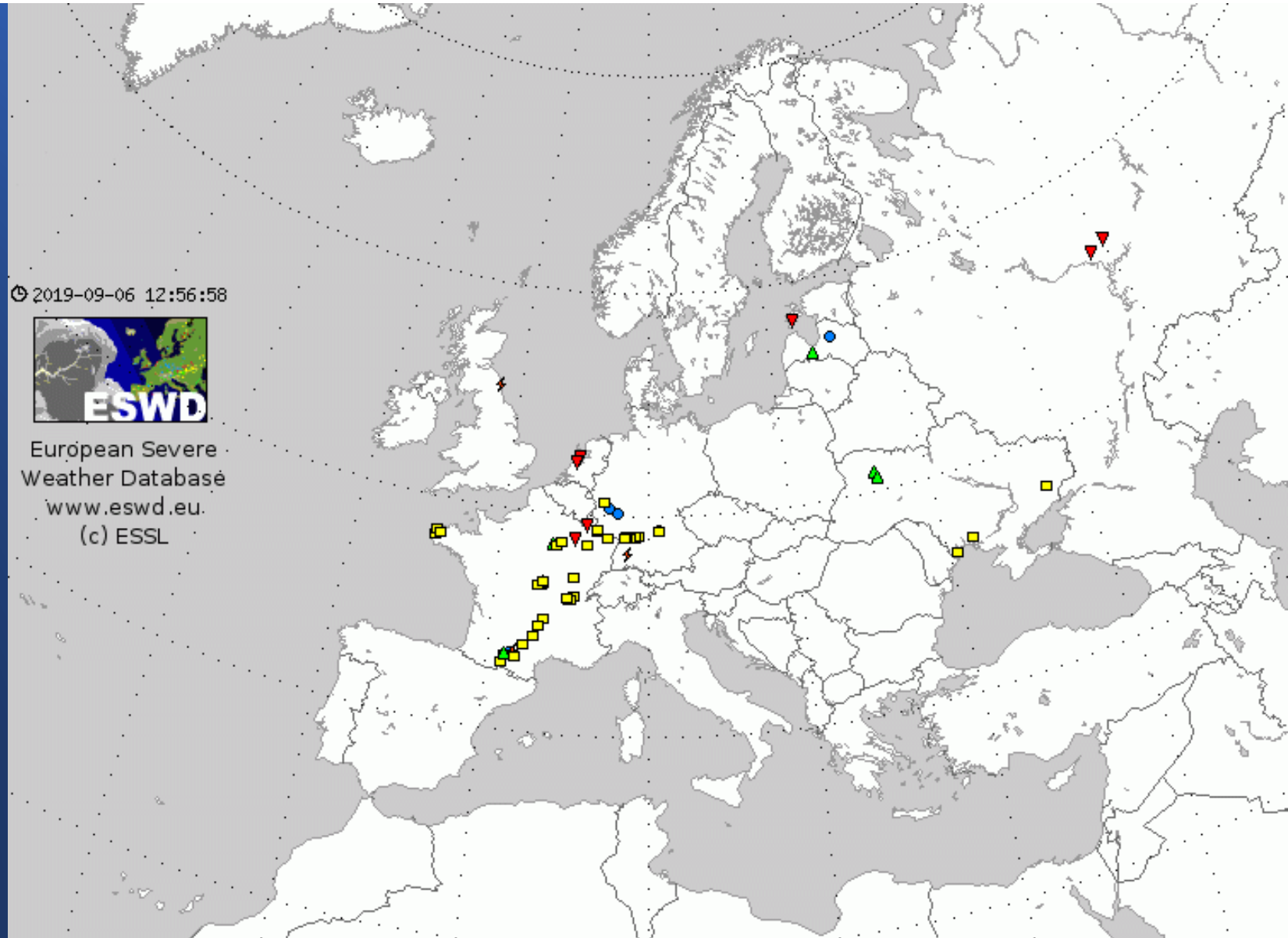
**Reason: high CIN over the Aegean Sea**

**Stable layer well represented by the IASI**



# 9 August 2019

**Tornadoes and damaging wind gusts**



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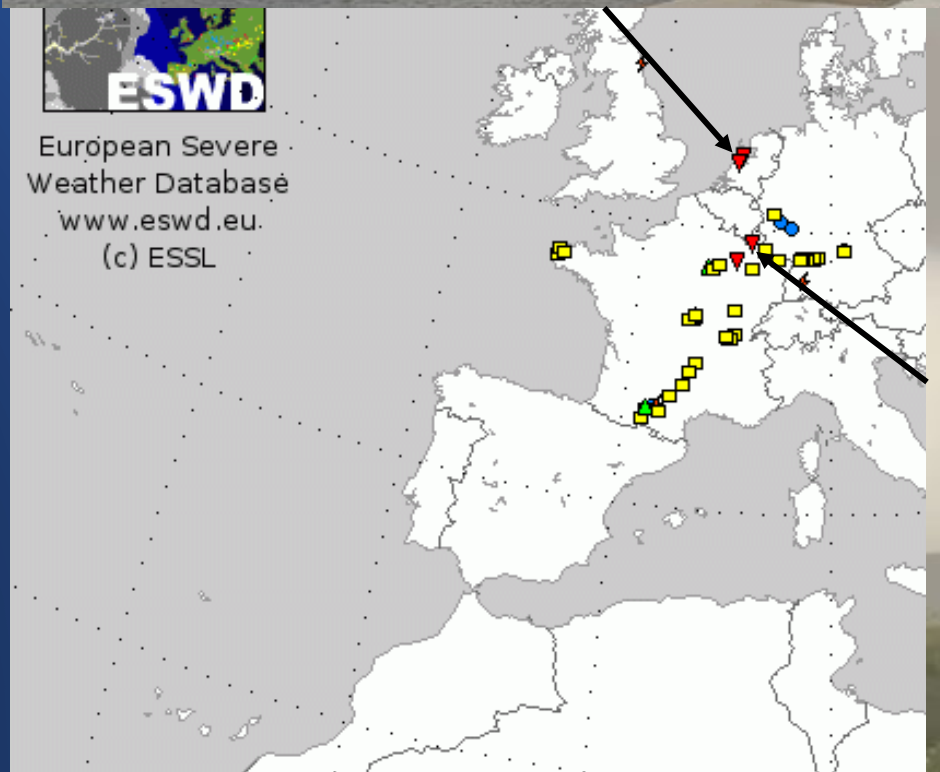
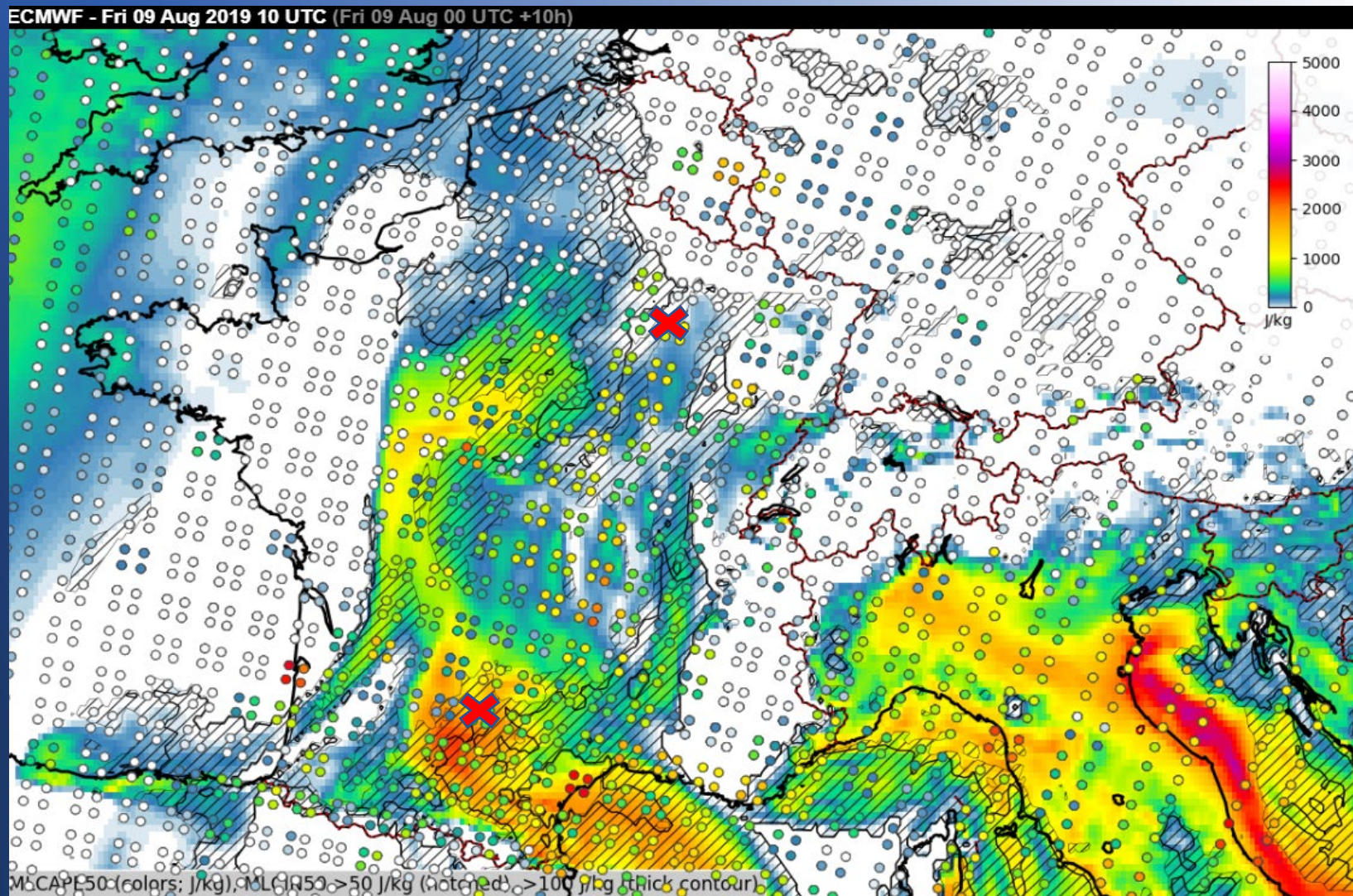



# 9 August 2019

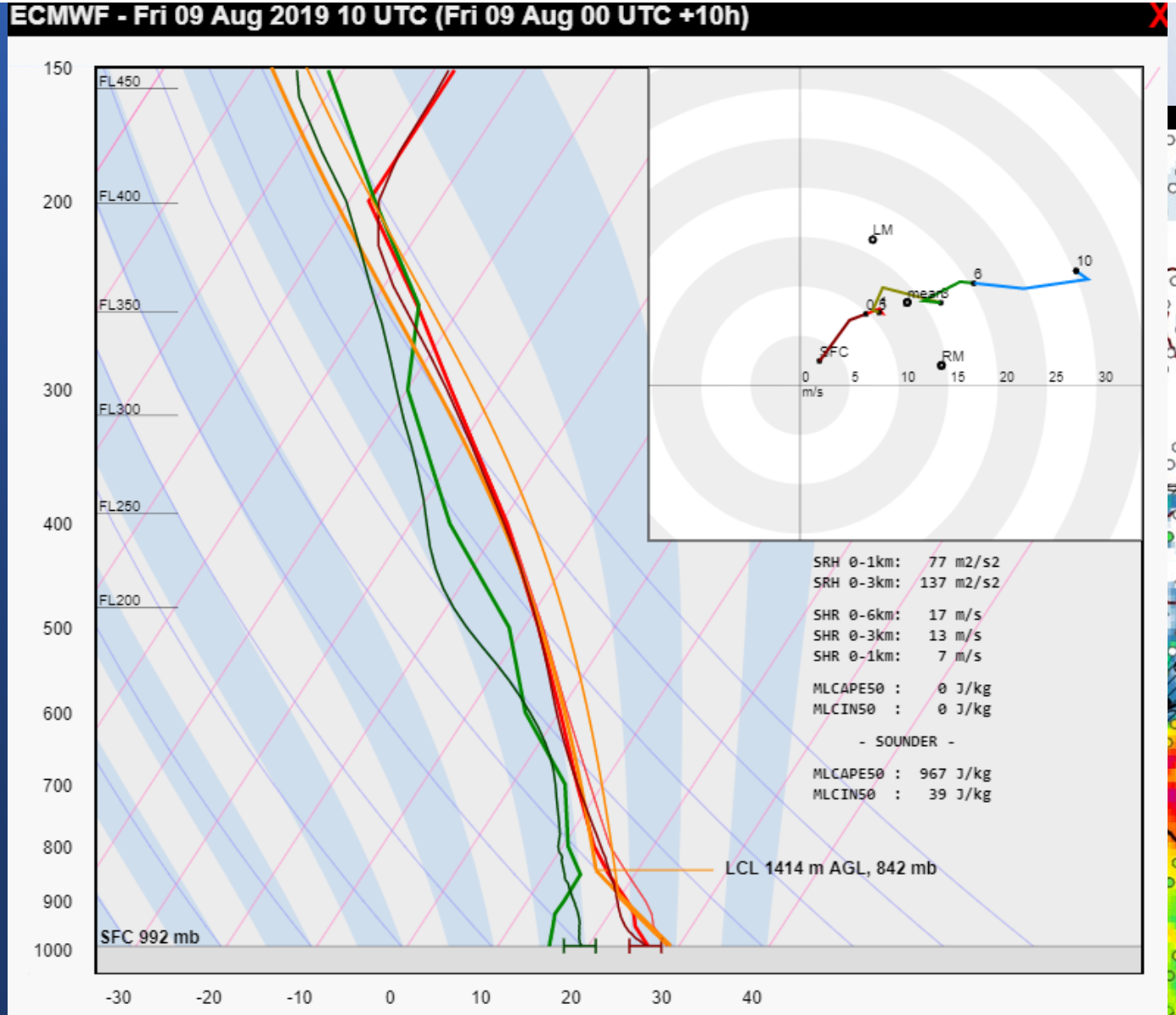
## Morning overpass

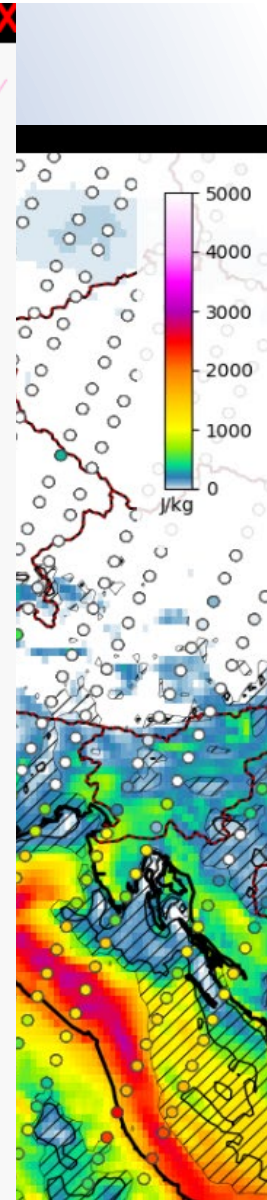


# 9 August 2019

**N France:**

**Higher dewpoint than forecast**



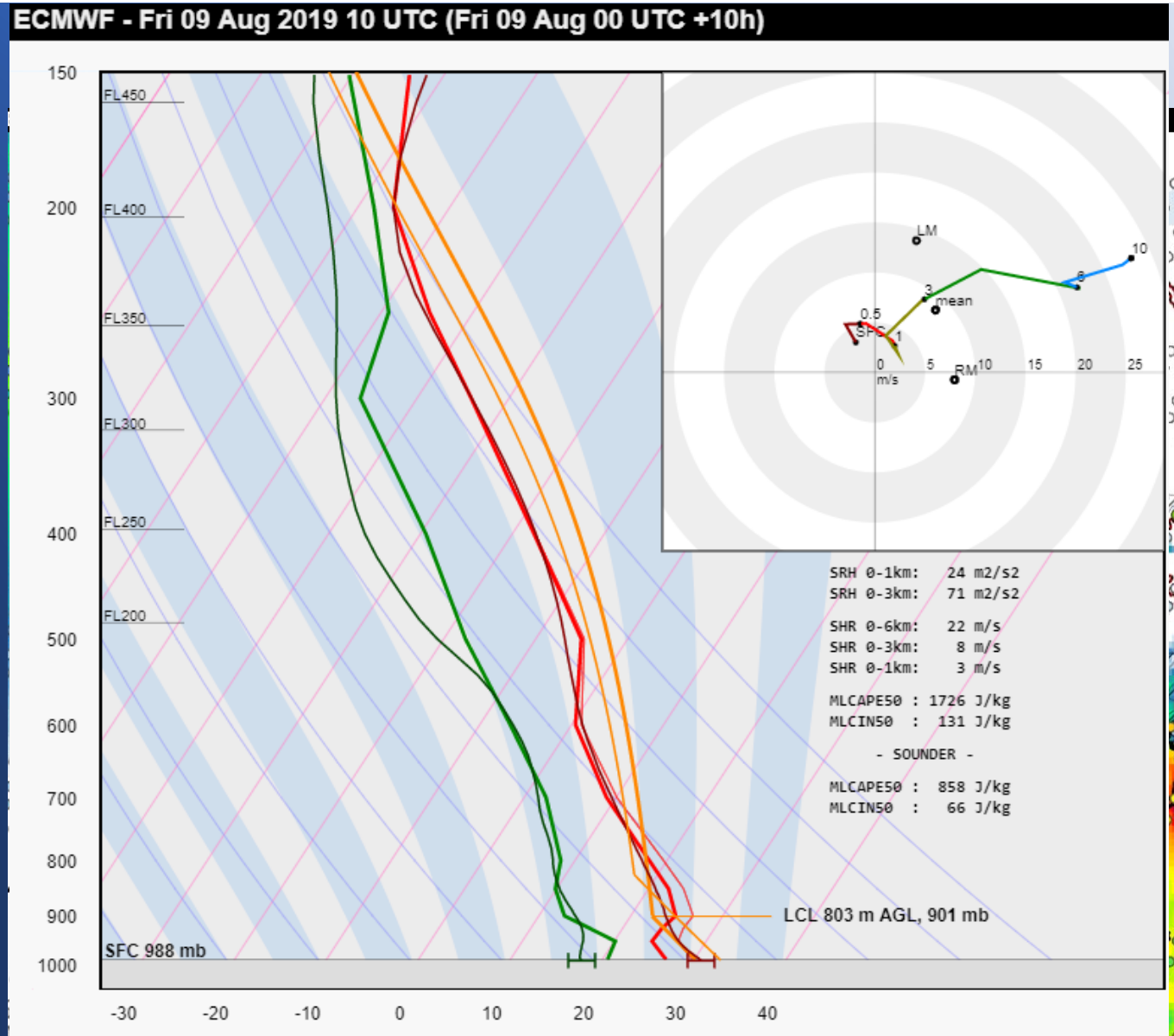
# 9 August 2019

**S France:**

**Higher temperature**

**BUT**

**Lower dewpoint**

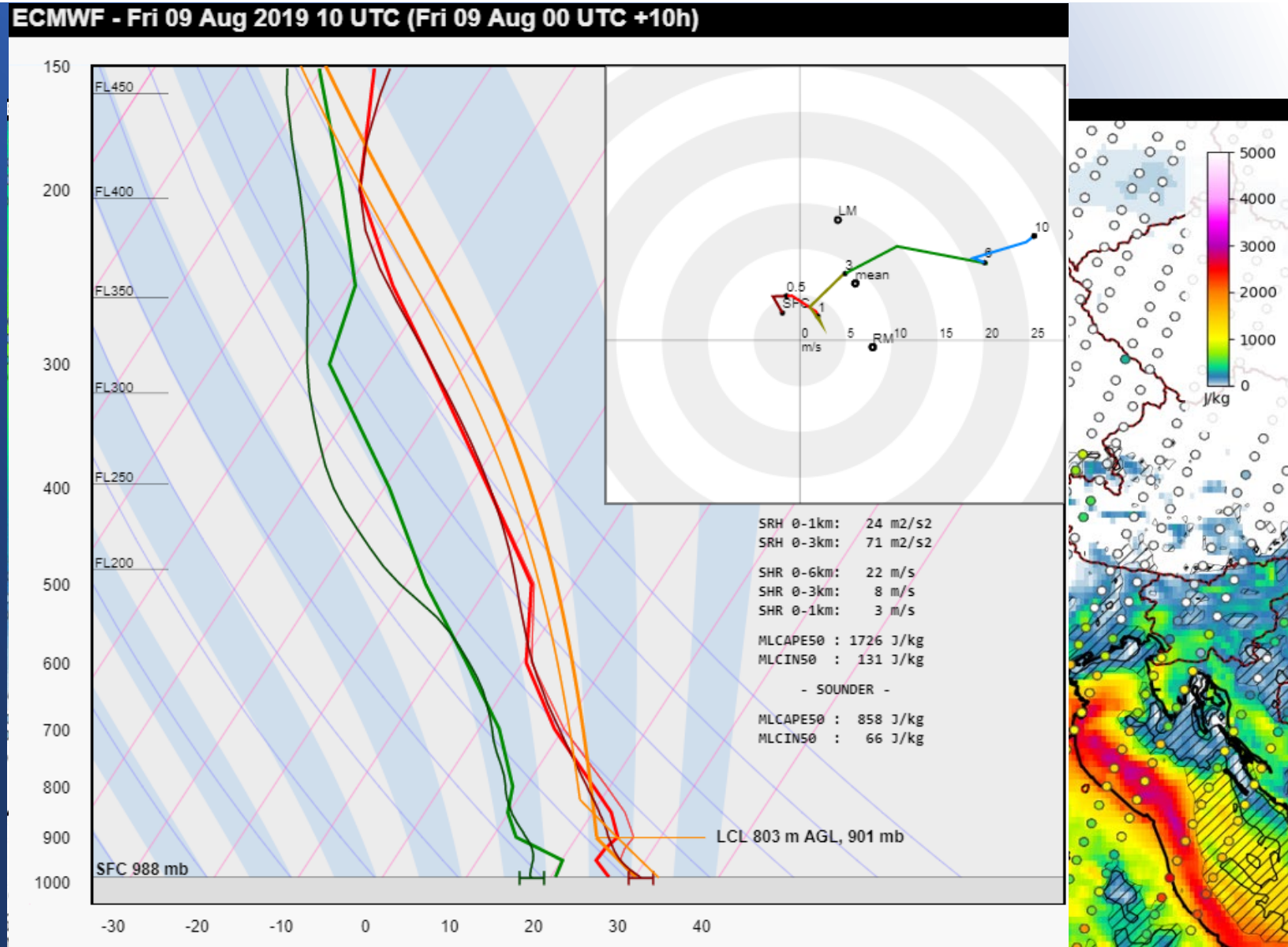


# 9 August 2019

**Regarding moisture:**

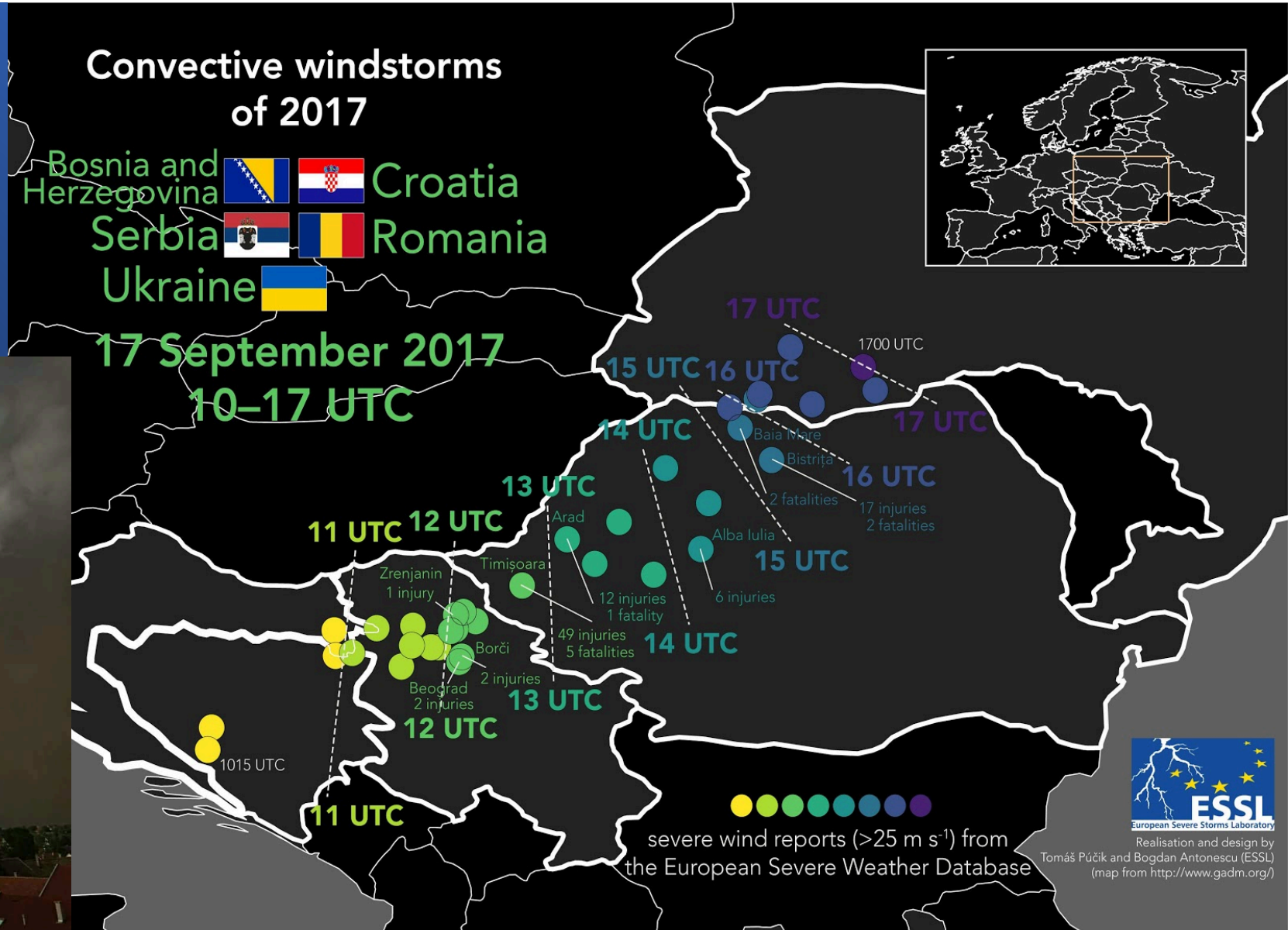
**IASI closer to reality than model over N France but worse over S France**

**Depth of moisture?**



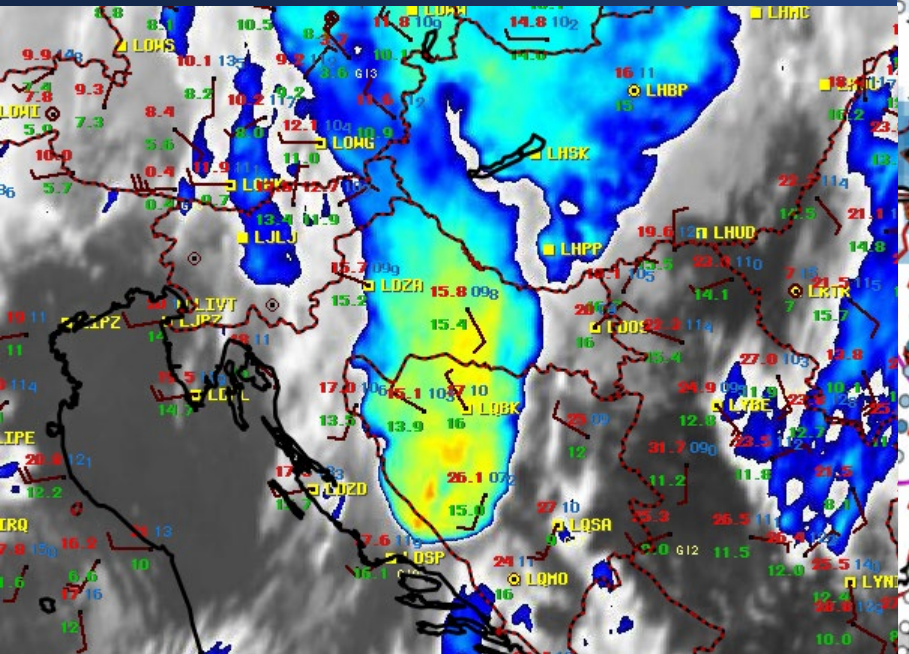
# 17 September 2017

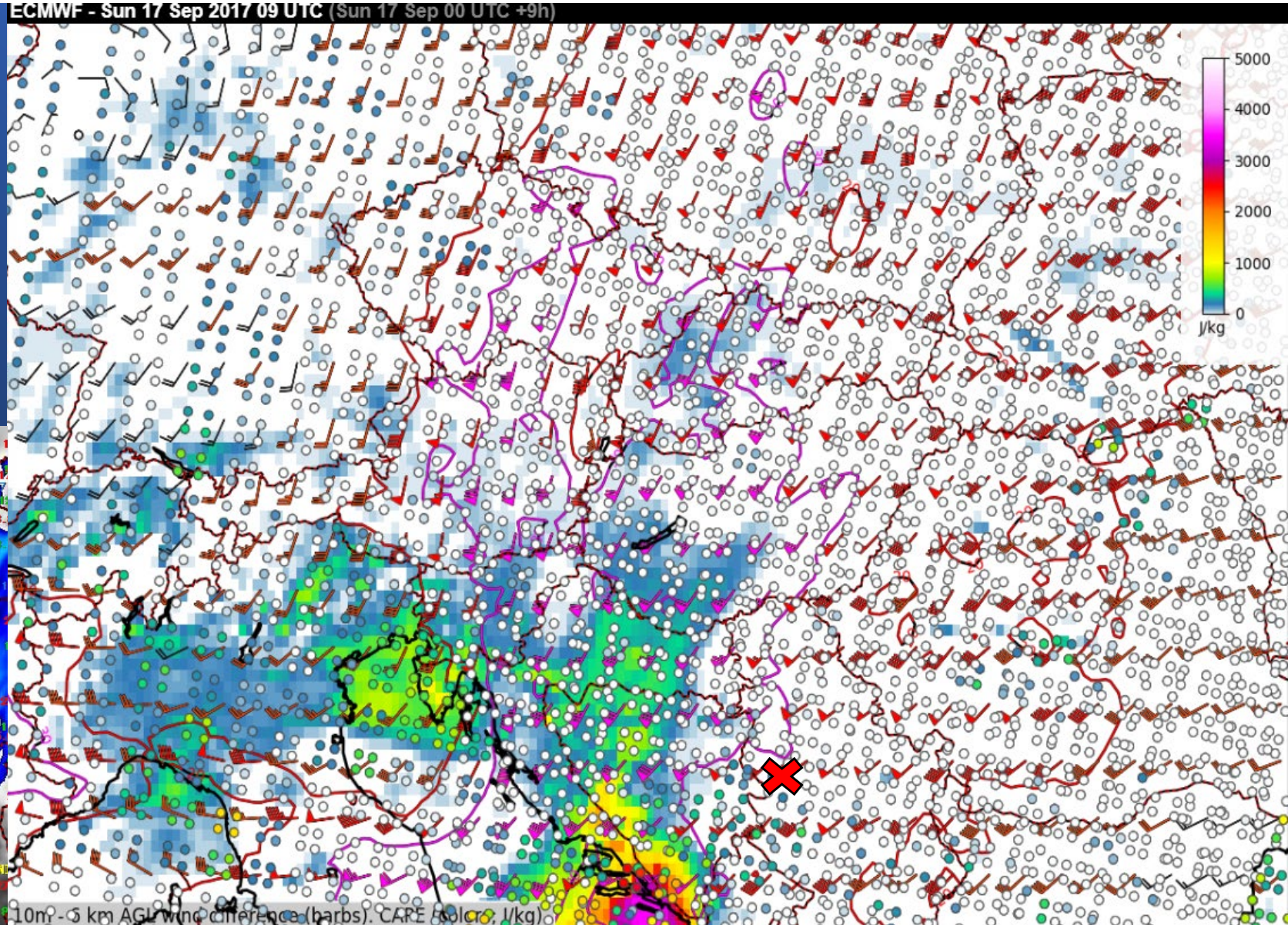
**Extremely severe gusts in low CAPE regime**



# 17 September 2017

**IASI detects higher CAPE in path of the storm**

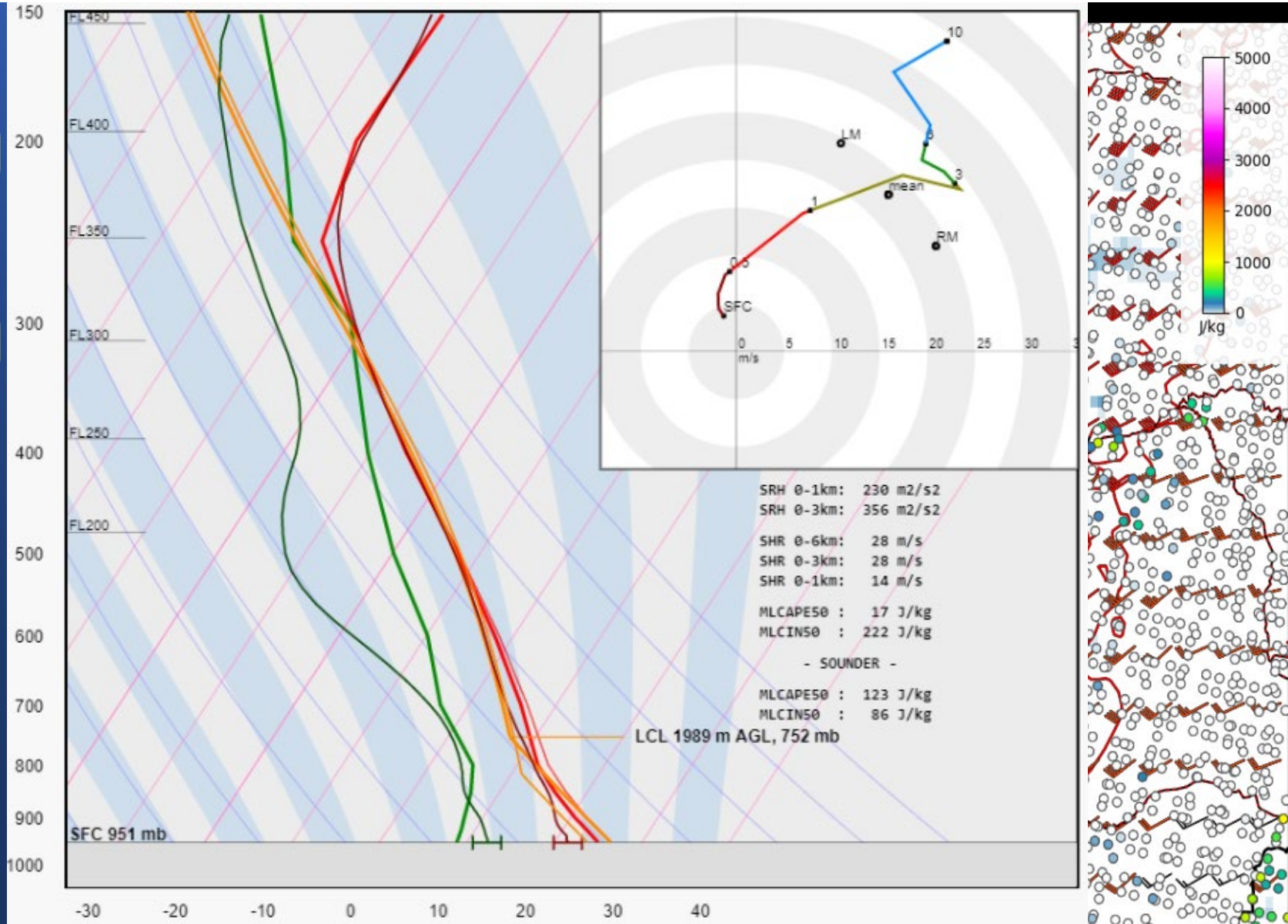




# 17 September 2017

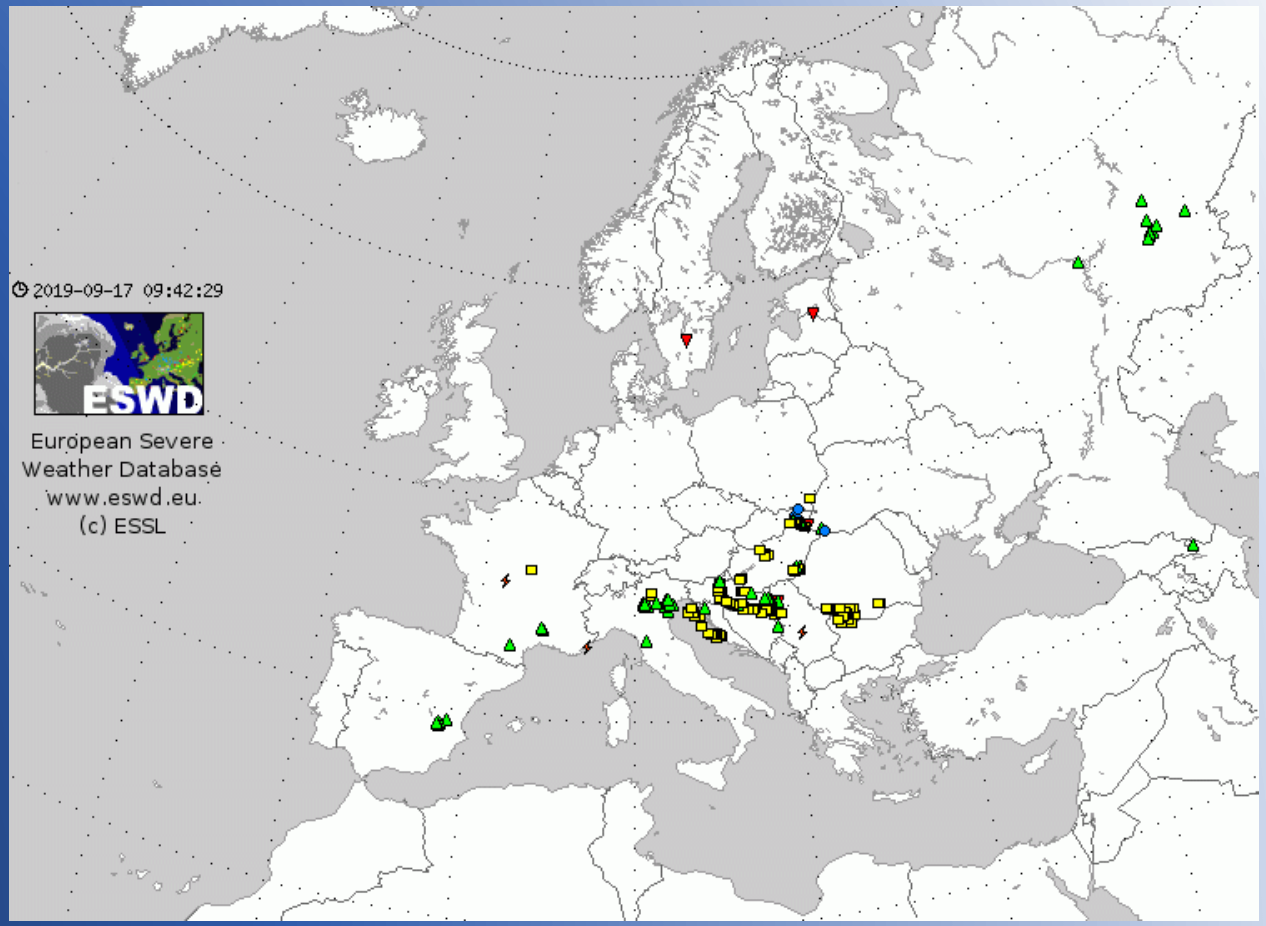
**Higher CAPE due to higher moisture**

**Confirmed by surface observations**



# Catalogue of short cases

- 40 cases containing:
- Short overview
- Model to reality check
- ESWD reports map



# Conclusions

1. **The independence of the soundings from NWP is (very) important,** since it can only then serve as a check on those models

2. **The soundings sometimes give an important clue about model bias**
   - especially in case of low-level temperature biases

3. **IASI soundings were appreciated by forecasters**
   - Forecasters can live with limited vertical resolution
   - Temporal resolution is a more important limiting factor

4. **Limited accuracy of low-level humidity is an important issue, since storm potential strongly depends on it**

# Potential follow-up work

1. Include surface (and possibly AMDAR & LIDAR) observations to create an improved observation-based 3D grid of temperature and humidity

2. Investigate further retrievals for low-level humidity

3. Visualize gridded NWP-IASI difference fields for selected parameters

4. Implement error estimates of the measurements throughout the retrieved vertical profiles and the (minor) visualization improvements suggested by forecasters

5. Facilitate further forecasters' feedback on the products and their evolutions