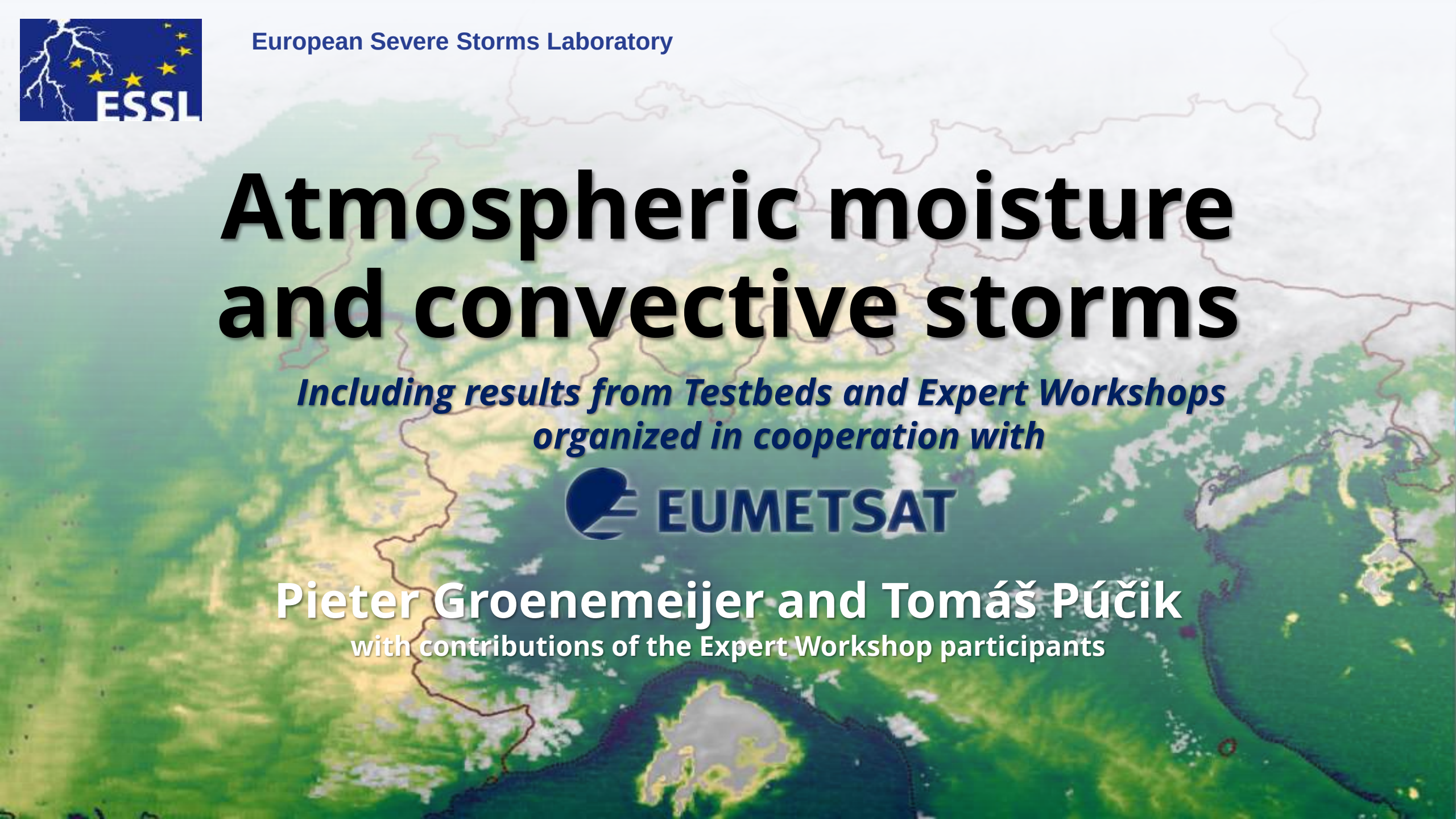


European Severe Storms Laboratory

Atmospheric moisture and convective storms

Including results from Testbeds and Expert Workshops organized in cooperation with

EUMETSAT

Pieter Groenemeijer and Tomáš Púčik

with contributions of the Expert Workshop participants

Topics

Part 1
Moisture and convective storms

Part 2
Detection of moisture by satellite

Moisture and convective storms

Moisture is one of three ingredients for convective storms

1. Moisture
2. Lift
3. Instability

Moisture and convective storms

1. Ensures buoyancy through release of latent heat

What matters:

- boundary layer moisture

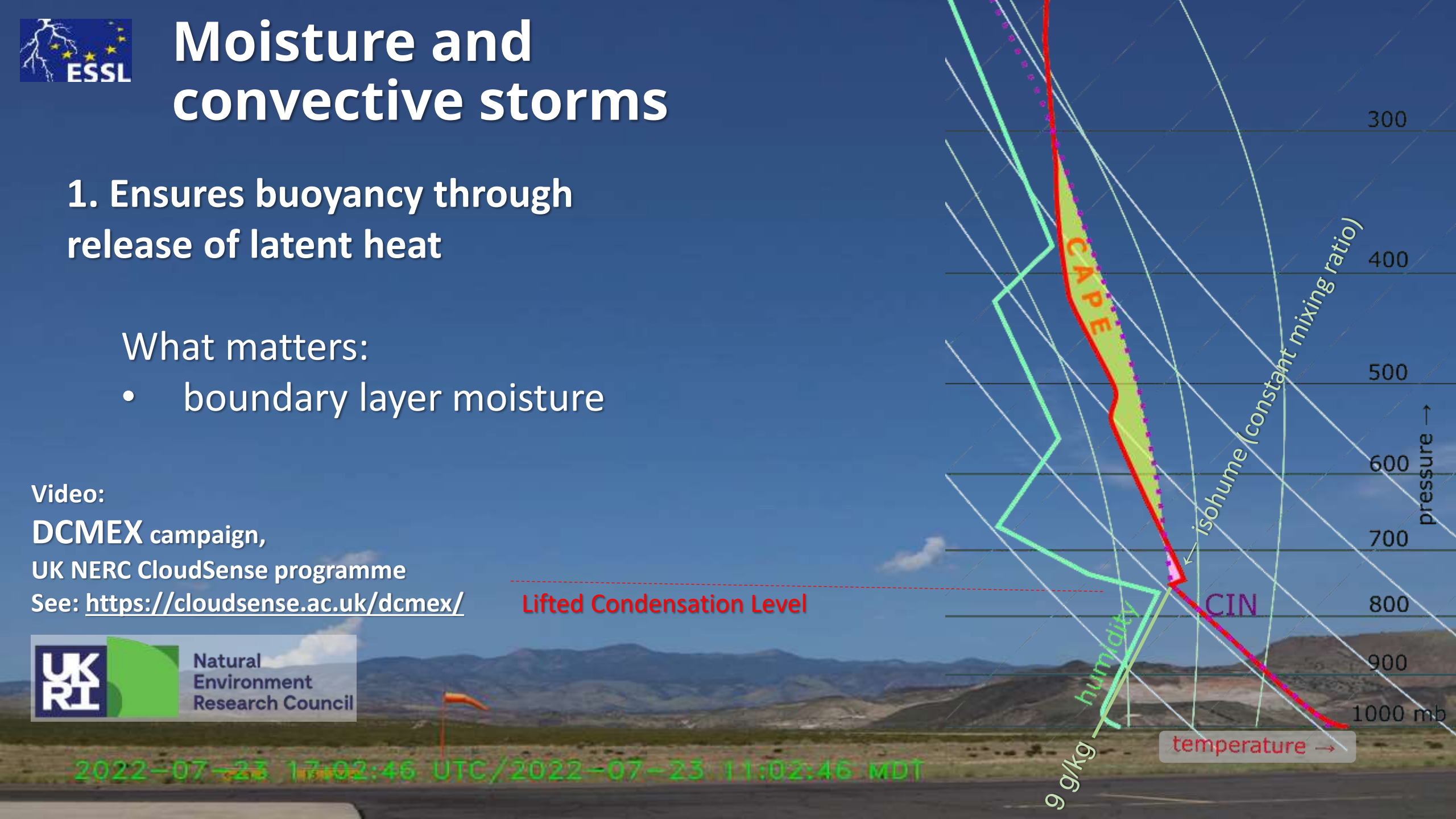
Video:

DCMEX campaign,

UK NERC CloudSense programme

See: https://cloudsense.ac.uk/dcmex/

Natural Environment Research Council

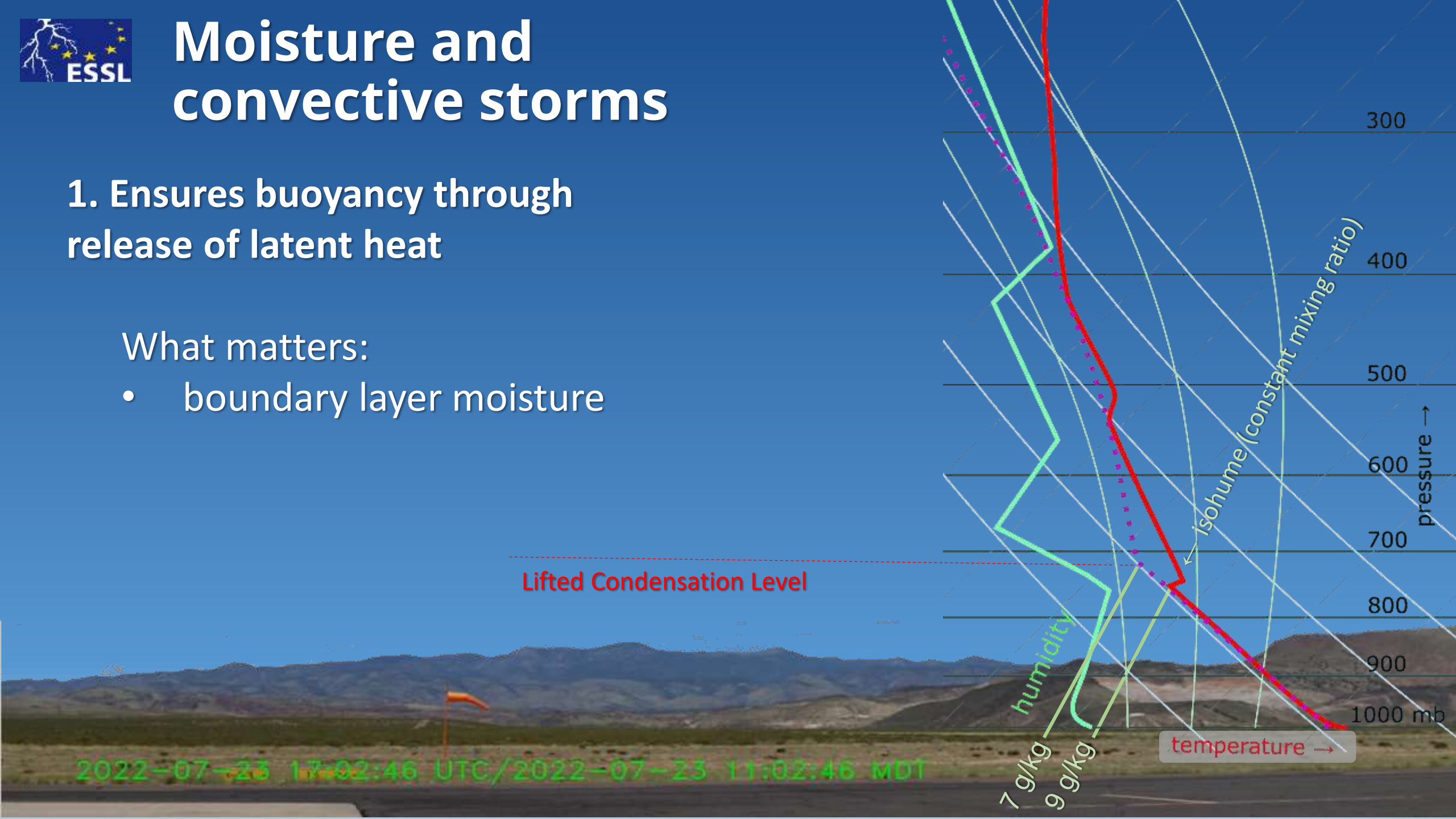


Moisture and convective storms

1. Ensures buoyancy through release of latent heat

What matters:

- boundary layer moisture



Moisture and convective storms

1. Ensures buoyancy through release of latent heat

2. Reduces dilution reduction of buoyancy through mixing above the boundary layer

What matters:

- mid-level moisture

Credits: **Jens Bydal** on YouTube
https://www.youtube.com/watch?v=Z8otb4UdI5U

Moisture and convective storms

1. Ensures buoyancy through release of latent heat

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What matters:

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How does this work?

By mixing with air around the cloud, the temperature of the rising cloud is lowered.

Moisture and convective storms

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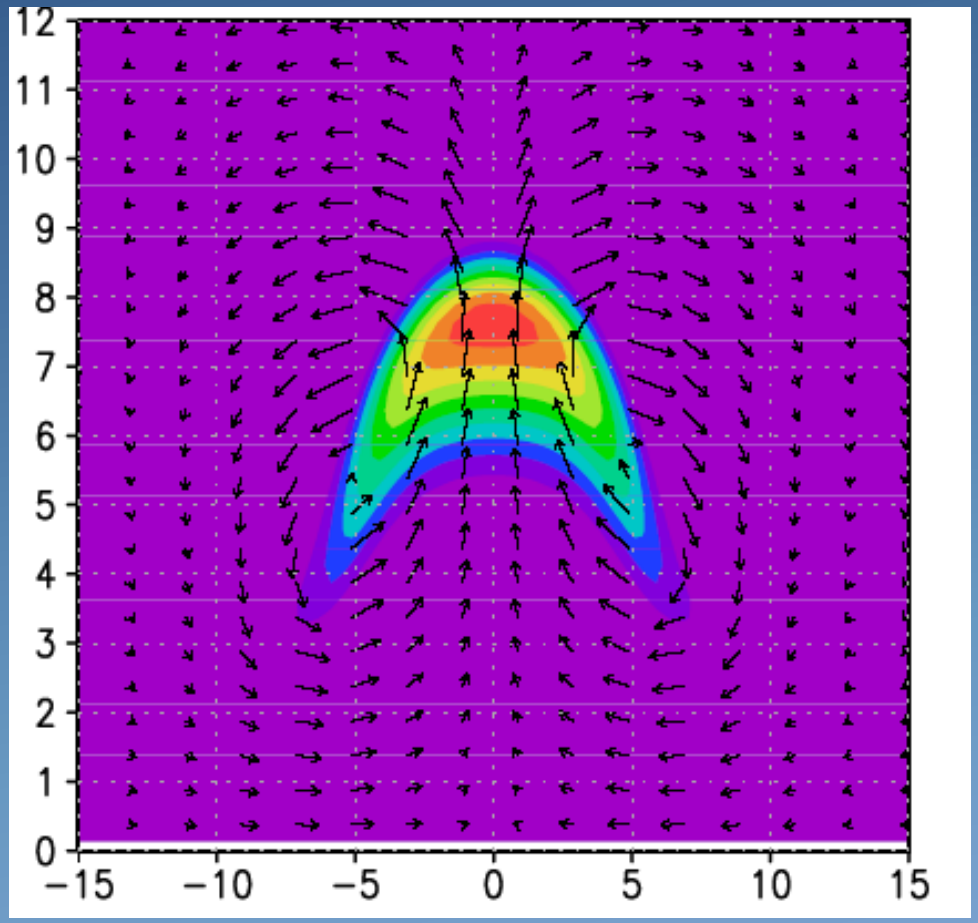
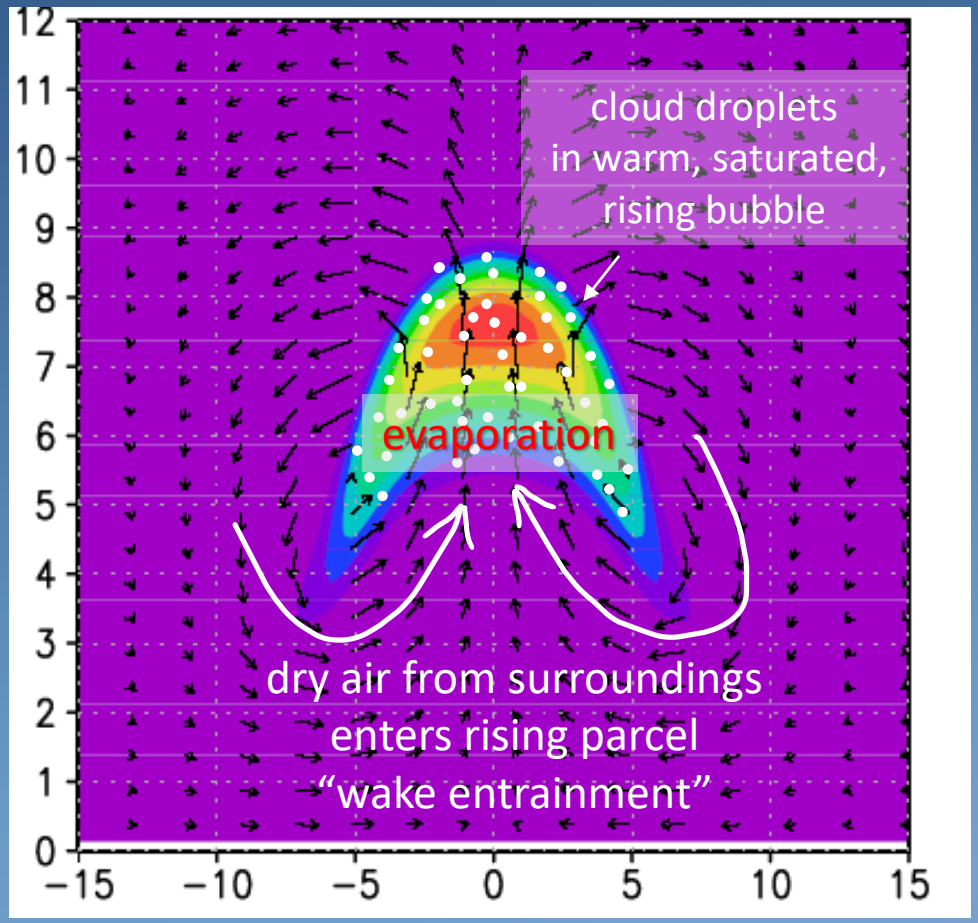
Simulation of rising bubble



Courtesy: Matthew Parker
North Carolina State University

Moisture and convective storms

Simulation of rising bubble



Courtesy: Matthew Parker
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How does this work?

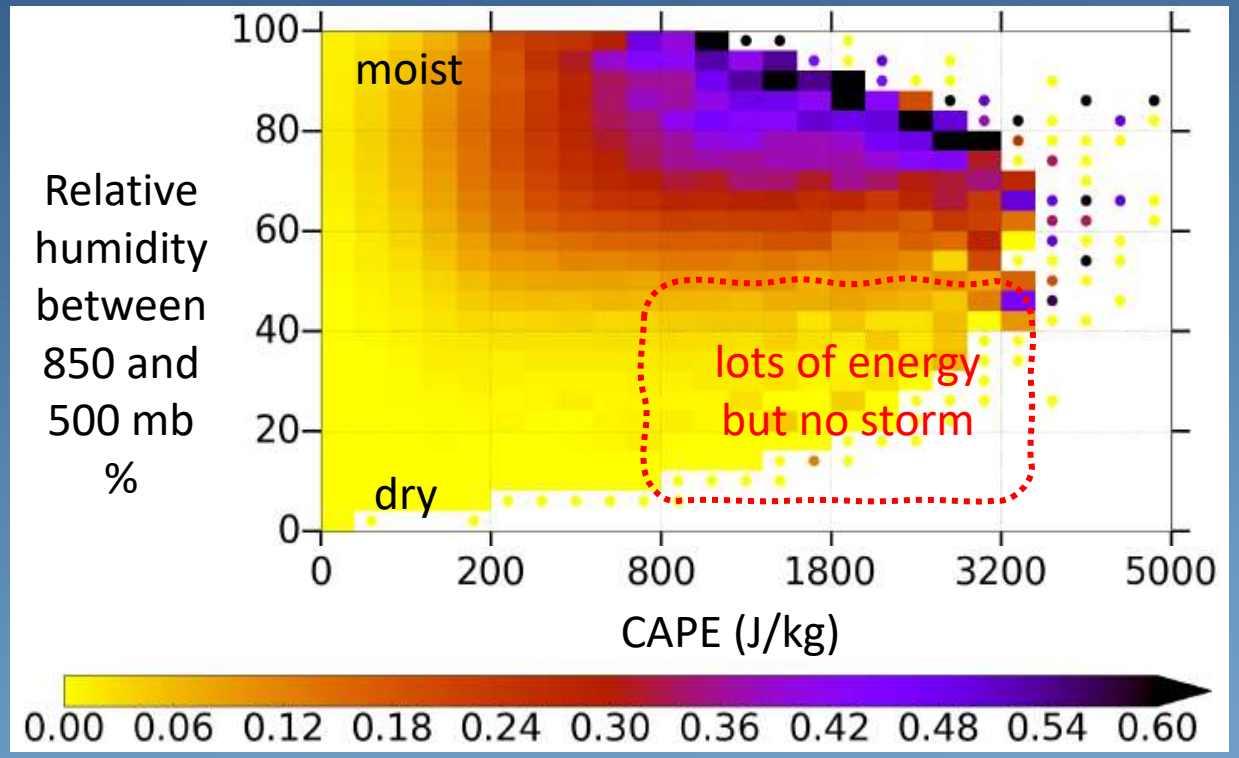
By mixing with air around the cloud, the temperature of the rising cloud is lowered.

If the entraining air is dry as well, much of the water droplets can evaporate, which further lowers temperature

If there is moist air around the cloud, this effect is reduced

Moisture and convective storms

Probability of thunderstorm development



From: Westermayer et al. 2017

How does this work?

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Moisture and convective storms

- **Low-level moisture**
  impacts buoyancy by modulating latent heat release
- **Mid-level moisture**
  impacts dilution of buoyancy by entrainment
- **Upper-level moisture**
  impacts convective storms only indirectly

- **Total column water**
  - is one of many factors that can help predict heavy rainfall potential
  - is often dominated by low-level moisture

Moisture detection by satellite

Three types of moisture detection:

1. With **infrared sounders**

   example: IASI, (future: IRS)

2. With an imager detecting **thermal infrared (TIR) emission**

   examples: SEVIRI, VIIRS, SLSTR, FCI, MetImage

3. With an imager detecting **near infrared (NIR) absorption**

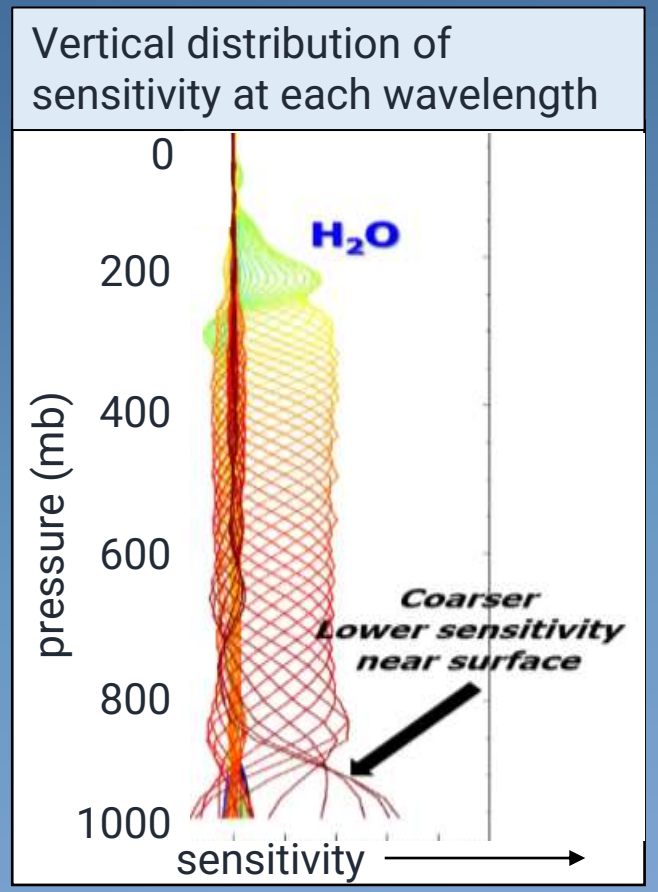
   examples: MODIS, OLCI, (near future: FCI, MetImage)

Infrared Sounder

Example: IASI

Instrument on MetOP-A and MetOP-B

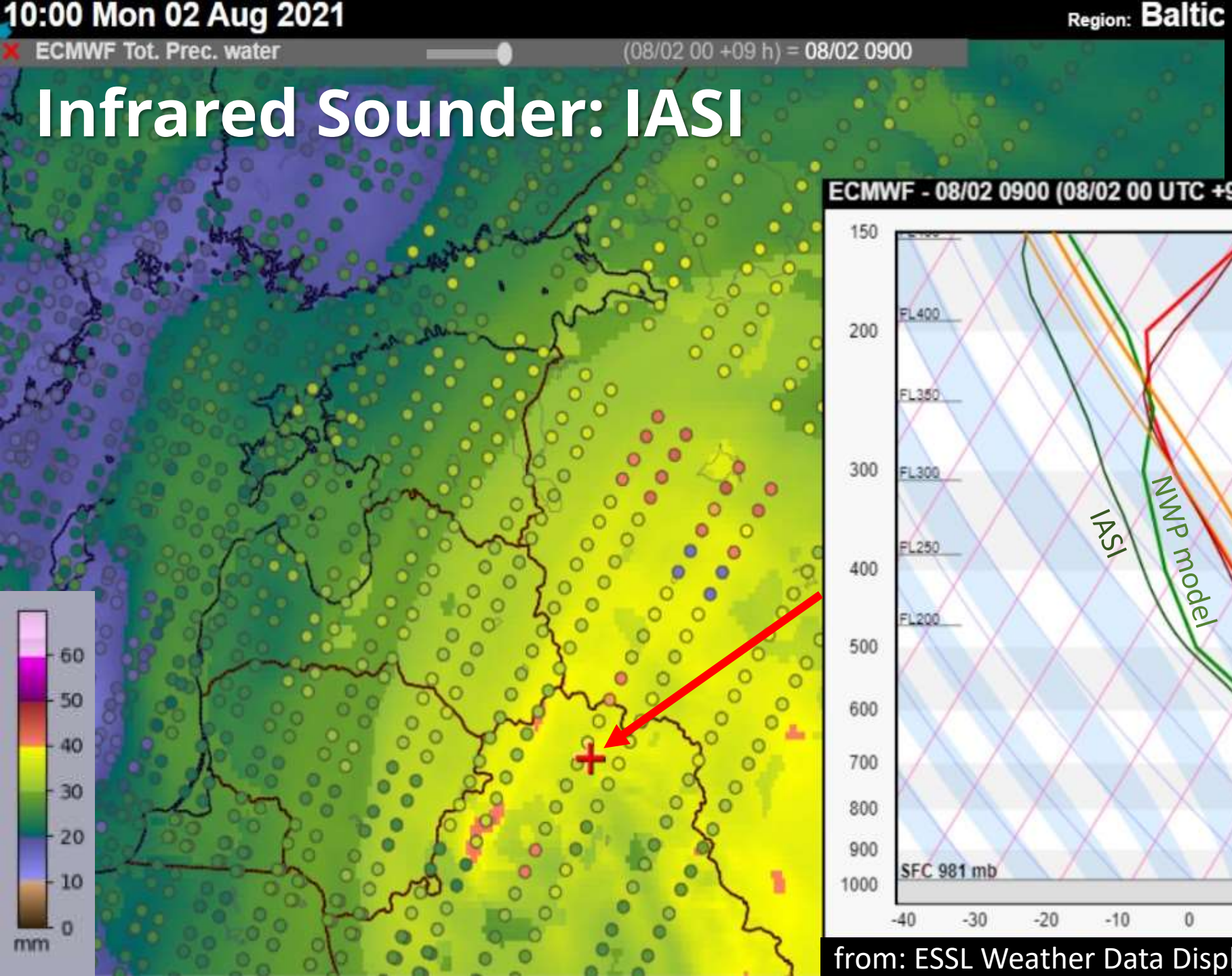
- Using interferometry, measures TIR emission at many different wavelengths
- Different wavelengths have different sensitivities for each altitude/pressure
- Not the best sensitivity for moisture in the boundary layer
  - Surface observations can help mitigate this
- On a polar-orbiting satellite:
  For most European areas, once or twice in morning and evening

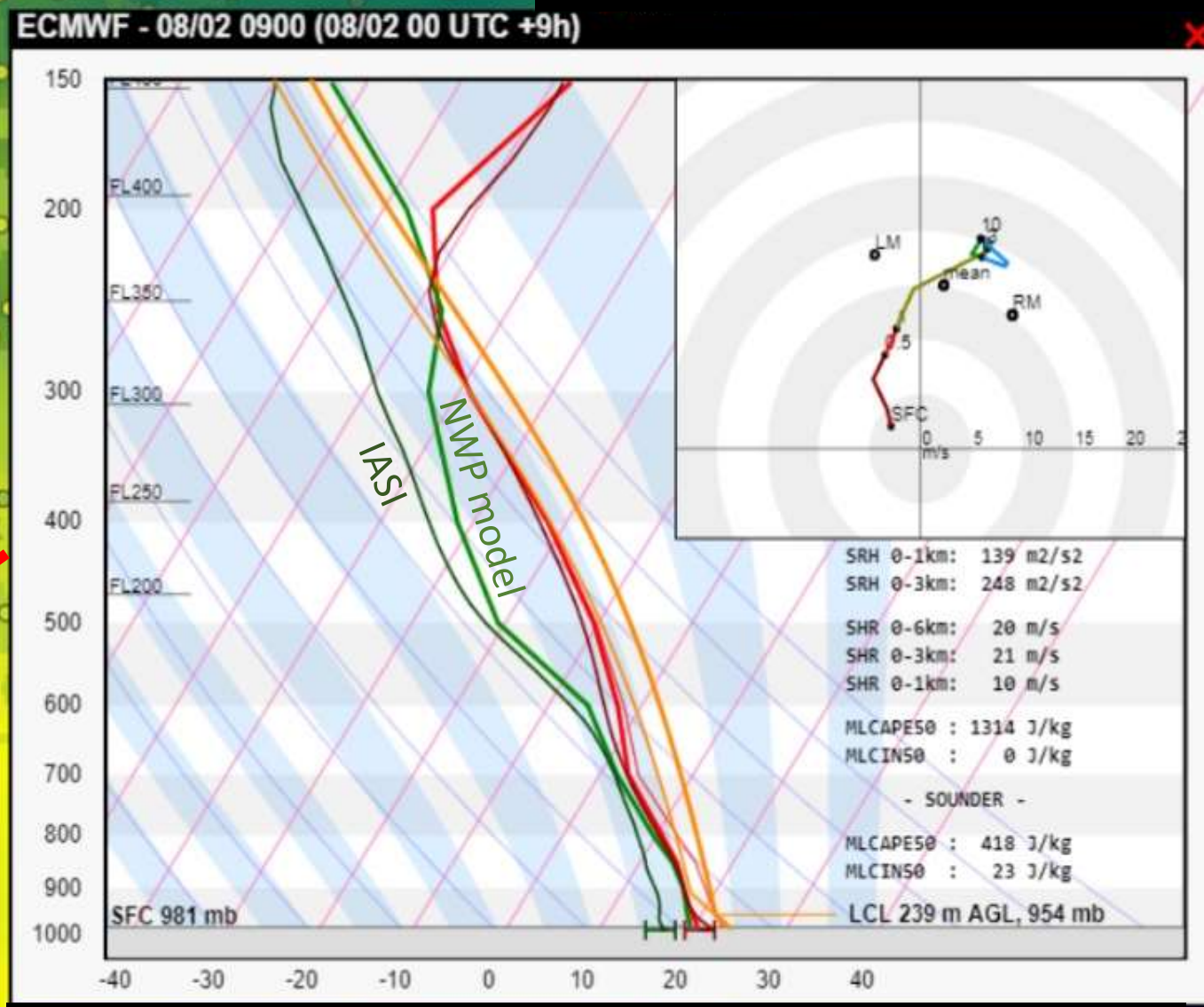


Based on a figure from Thomas August (EUMETSAT)

Infrared Sounder: IASI

Total precipitable water
IASI (dots) and
ECMWF forecast (shaded)

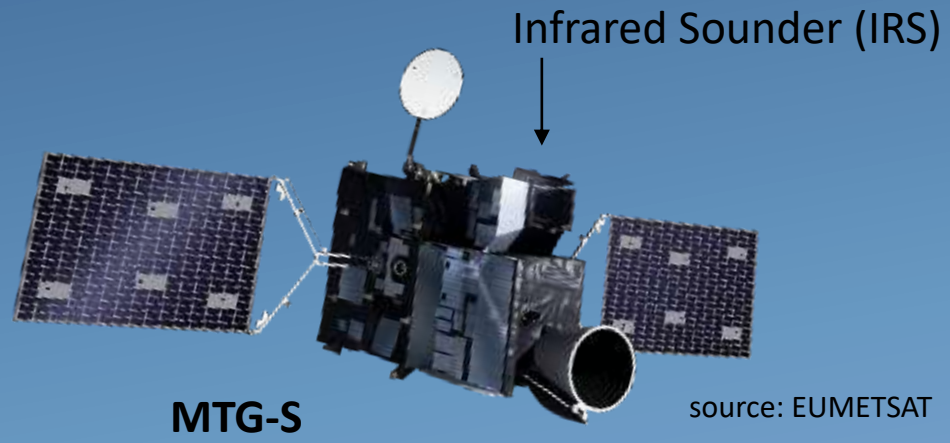




from: ESSL Weather Data Displayer powered by the European Weather Cloud

Infrared Sounder - IRS

- Such sounding data will become available from a **geostationary satellite**: MTG-S1
- Launch: 2024
- Effective resolution: 7 km in cloud-free areas
- Every 30 minutes
- High interest in monitoring trends



Imagers: Thermal Infrared

- Meaures emission of IR radiation by water vapour
- Various infrared channels can be combined to estimate mid- and upper-tropospheric moisture
- NWP model data required for the prediction
- For the lower troposphere sensitivity is rather low

Sensitivity of various IR wavelengths to water vapour at a given height

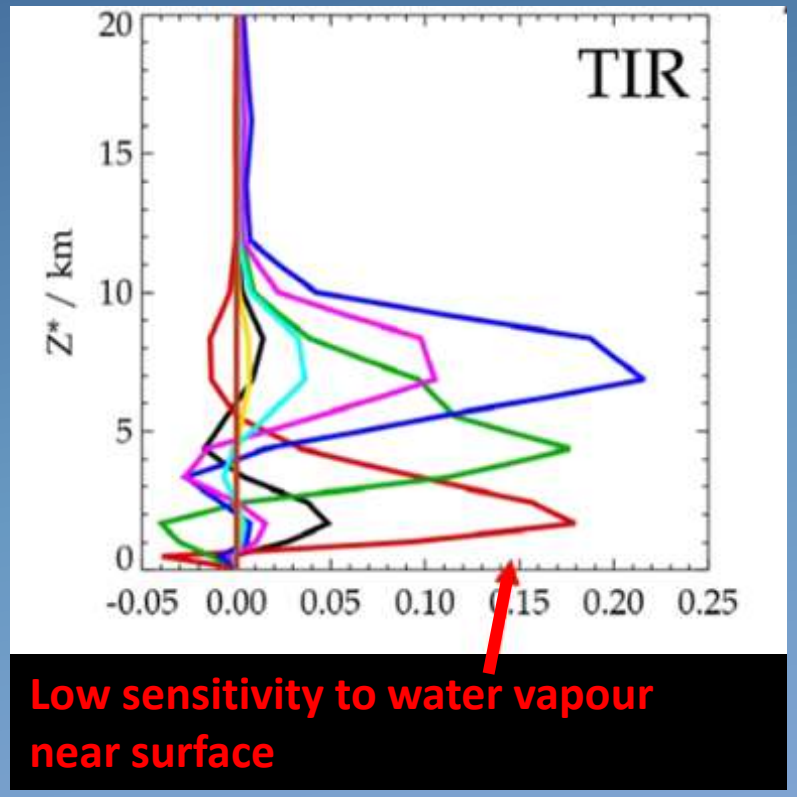


Figure adapted from Phil Watts & Loredana Spezzi (EUMETSAT)

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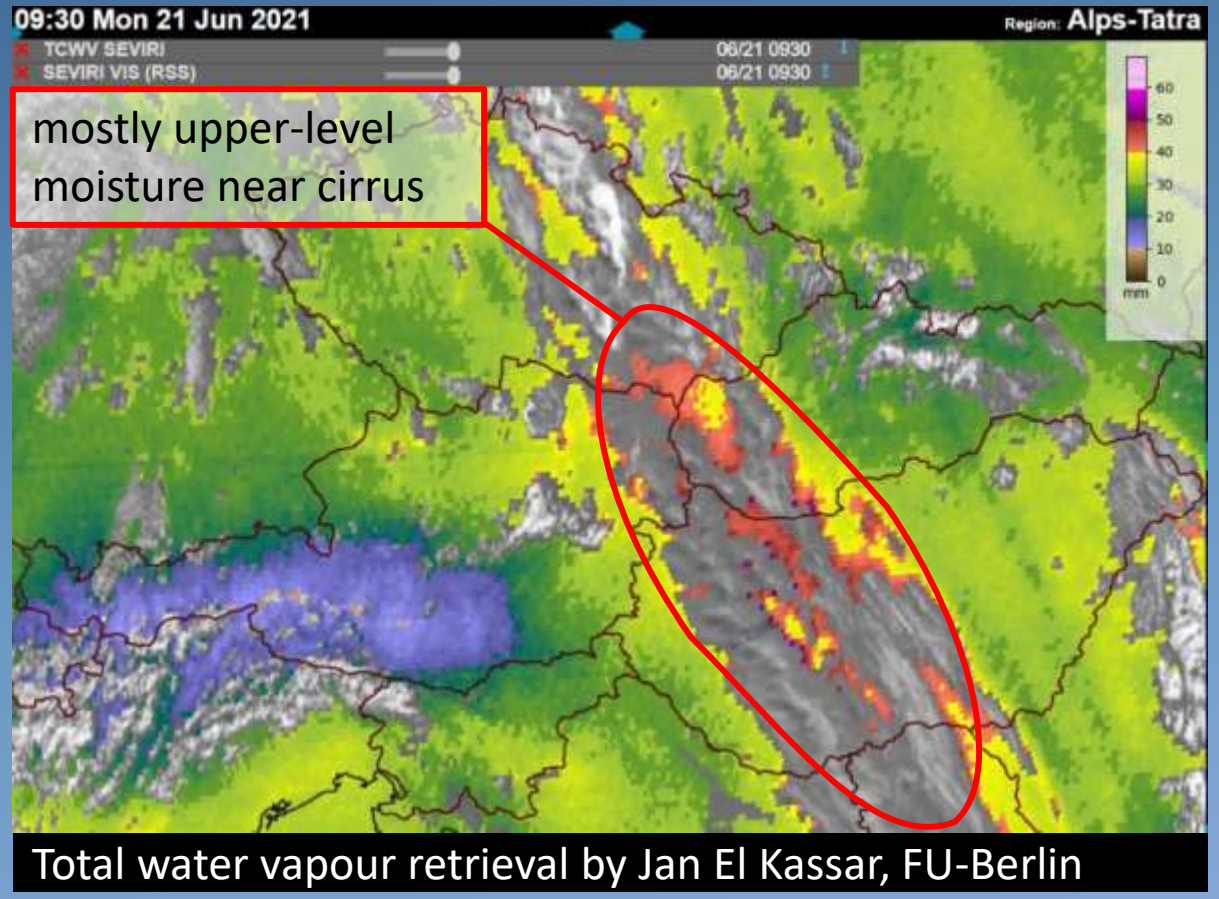
SEVIRI

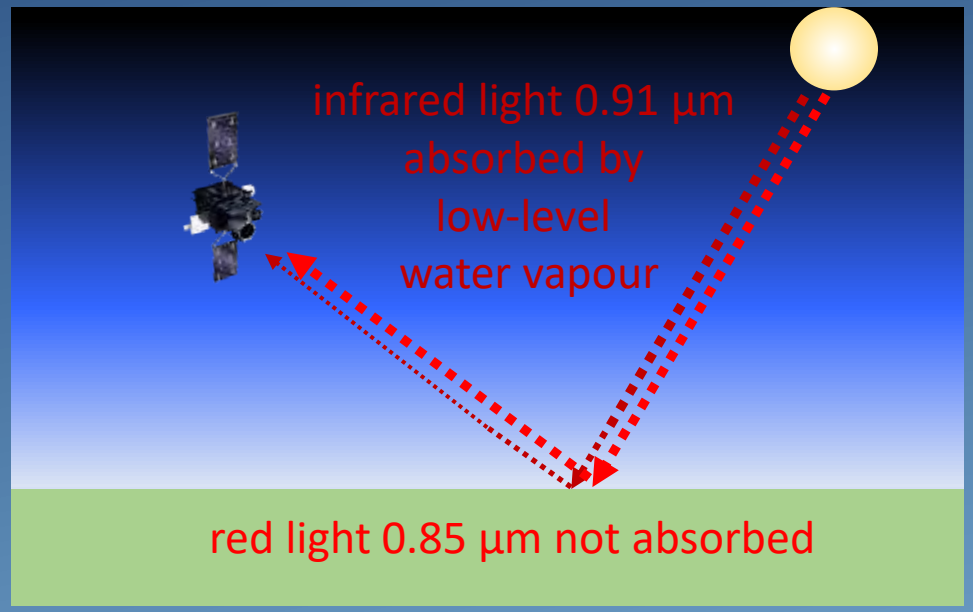
Imager on Meteosat Second Generation satellites



Total water vapour retrieval by Jan El Kassar, FU-Berlin

Imagers: Near Infrared

- Based on different absorption of near infrared and red light by water vapour
- Only some imagers have a suitable near-infrared channel
- Presently, on polar-orbiting satellites only: MODIS, OLCI instruments
- FCI on the stationary MTG-I has it, available in 2023

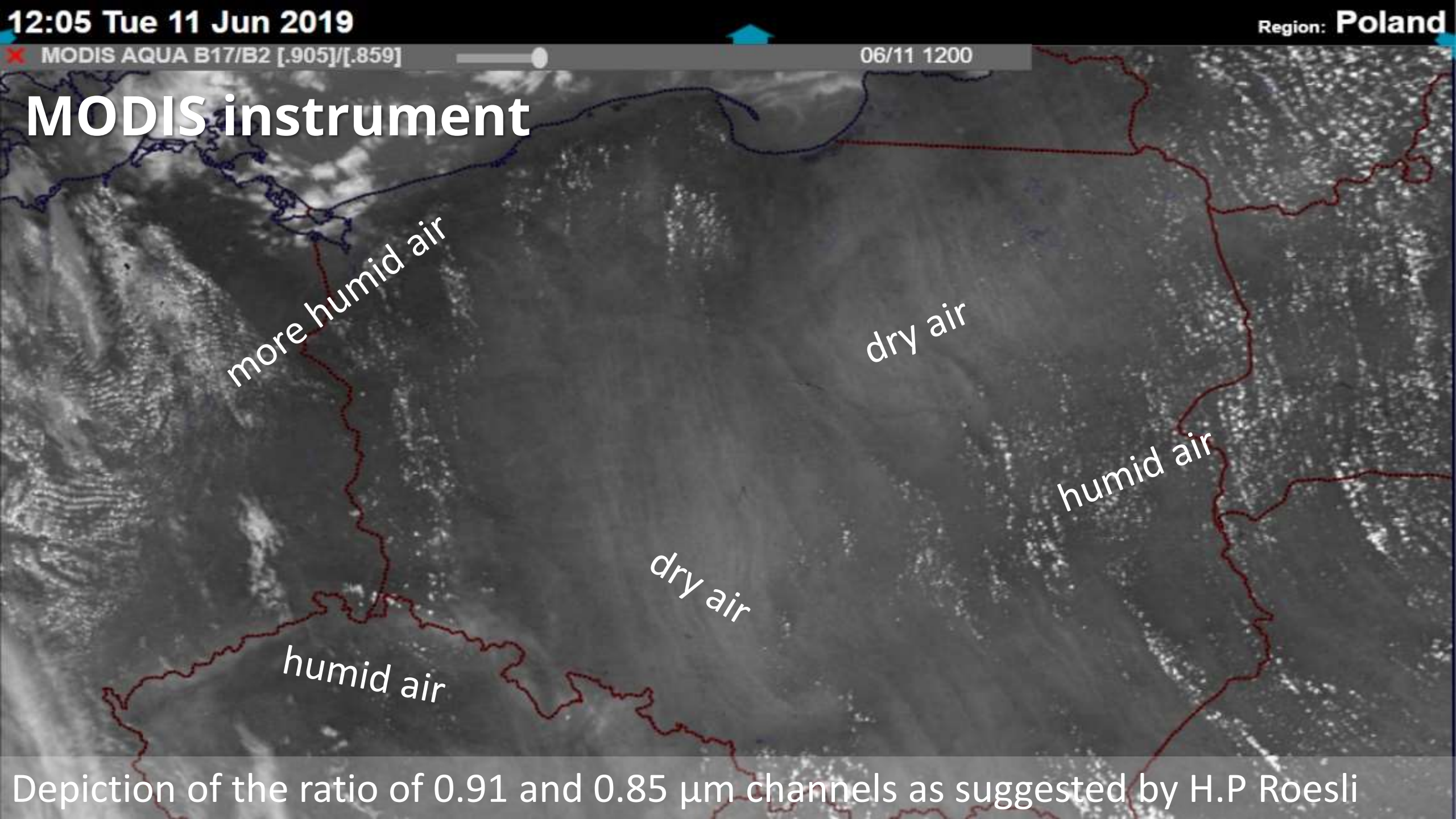


source: EUMETSAT

Absorption can be seen by looking at the ratio: 0.91-band / 0.85-band

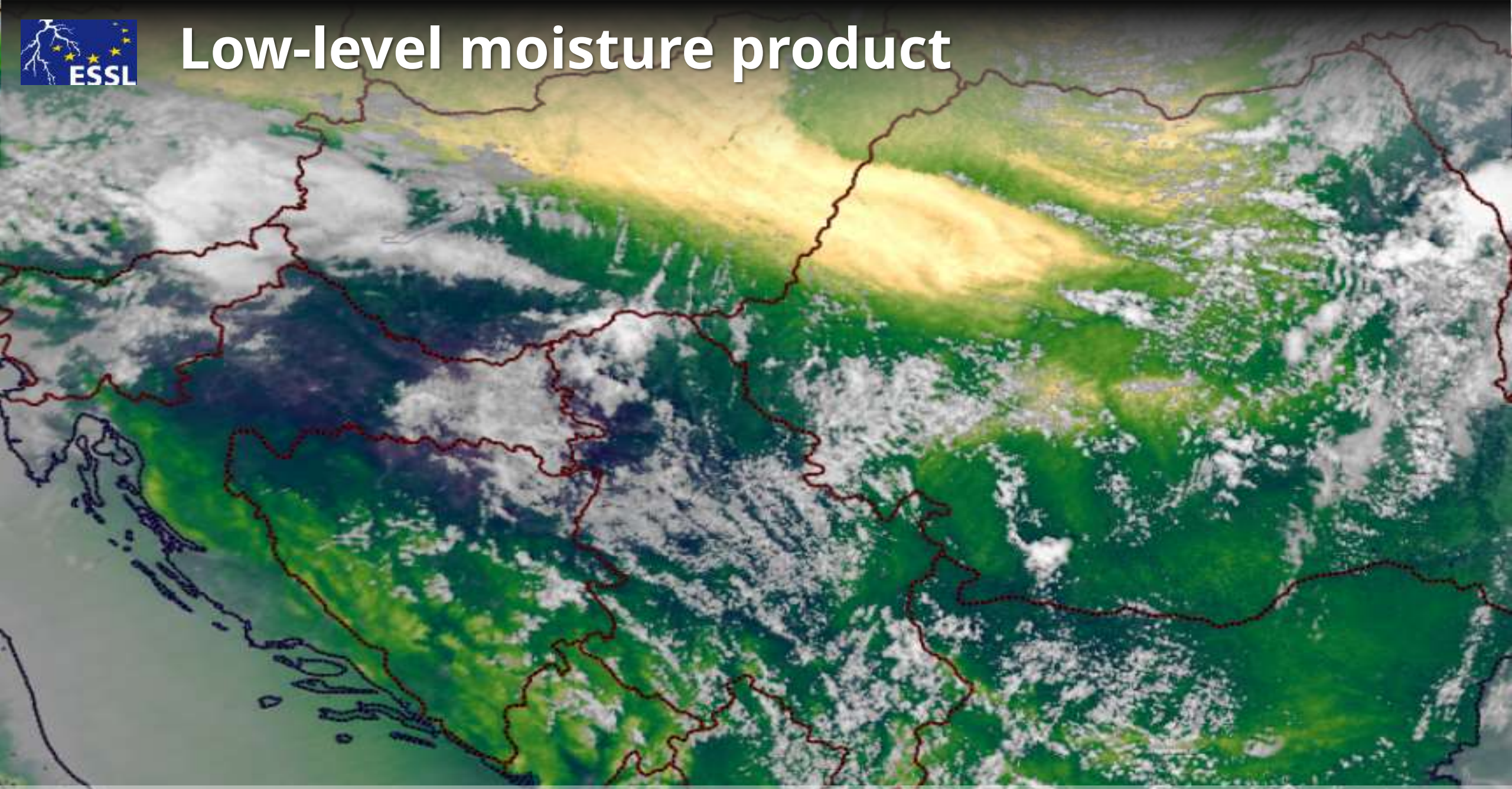
Hans-Peter Roesli introduced this to the workshops

Flexible Combined Imager (FCI)



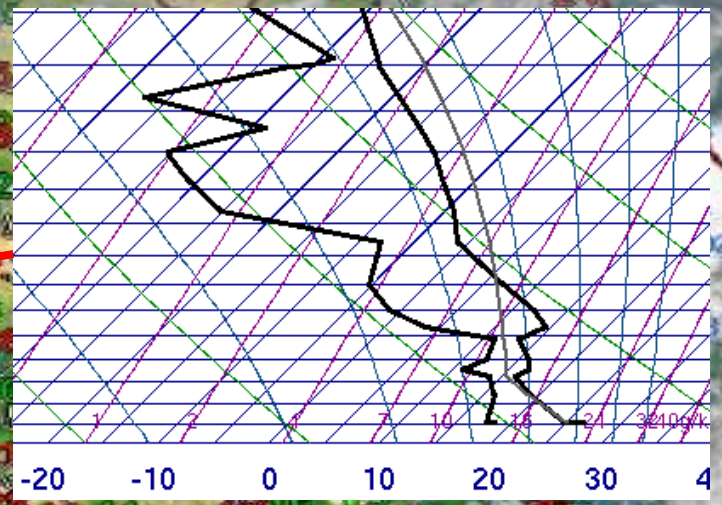
Depiction of the ratio of 0.91 and 0.85 µm channels as suggested by H.P Roesli

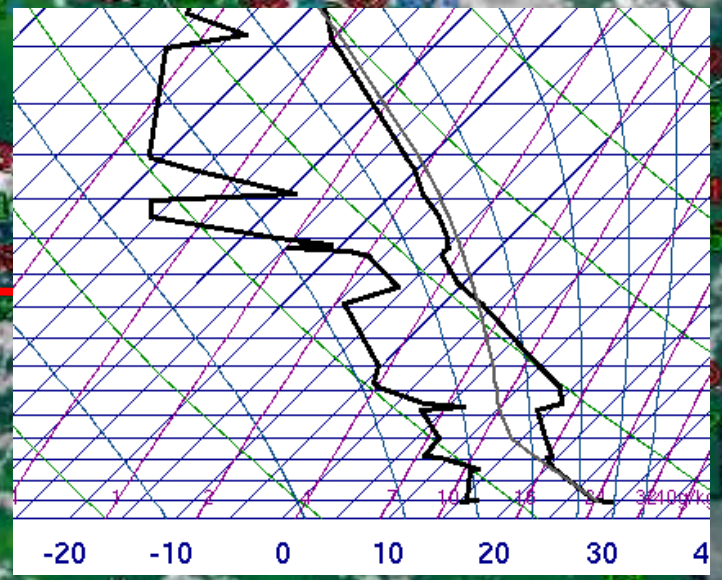
Low-level moisture product



ESSL Low-level moisture product with a colorscale to the ratio of 0.91 and 0.85 µm

Low-level moisture product

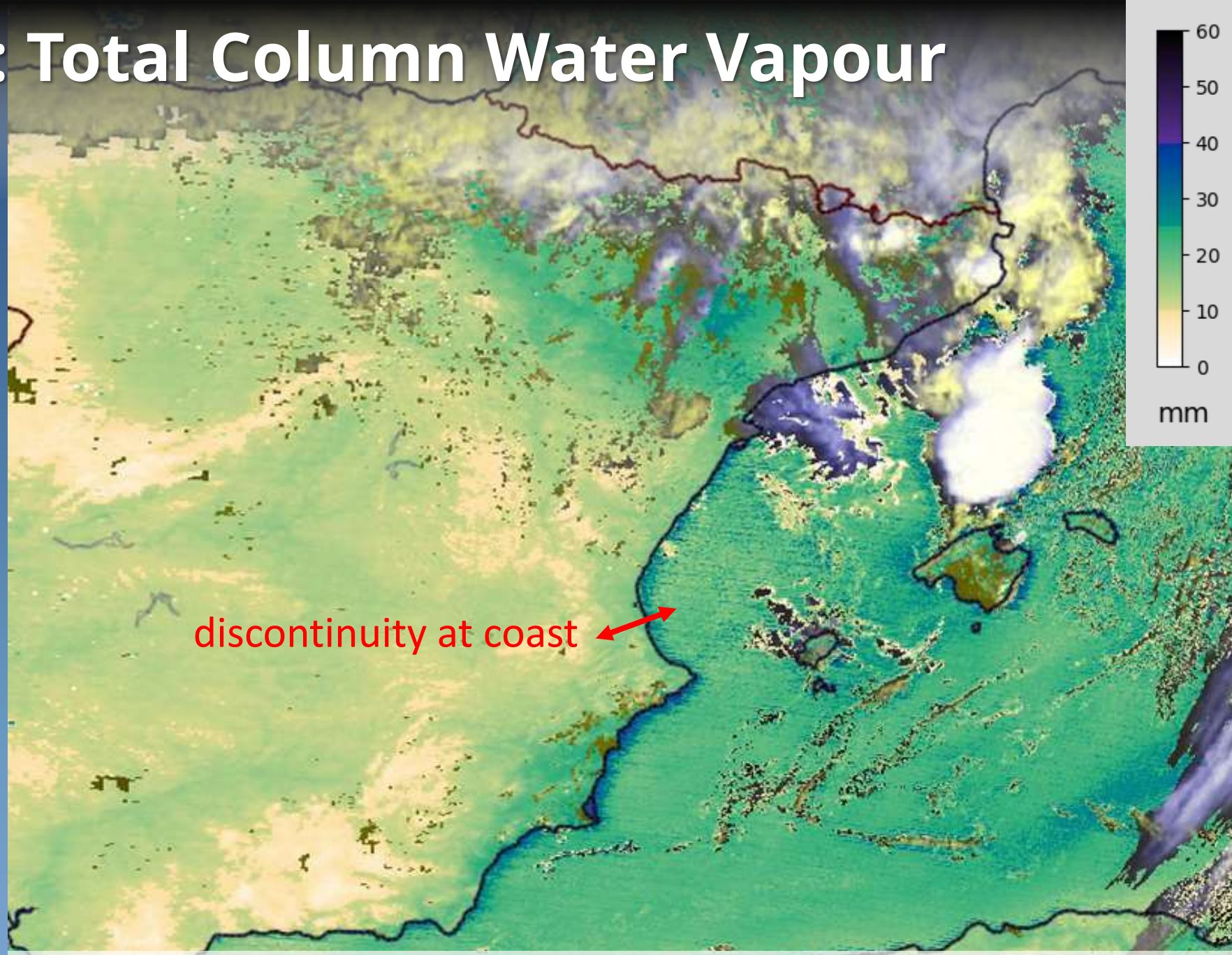




Similar dewpoints!

Retrievals: Total Column Water Vapour

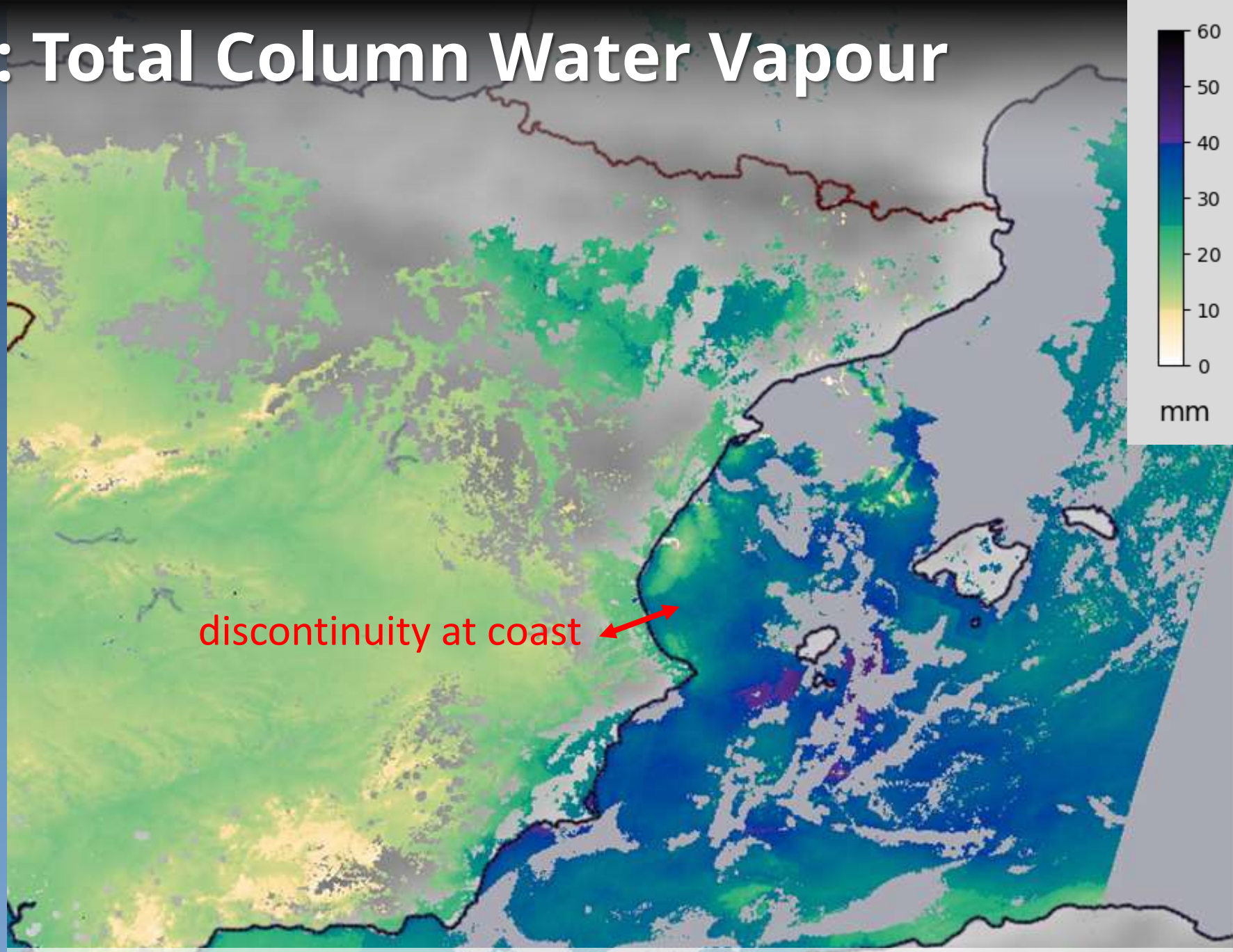
- Calculations to obtain moisture information from various channels



MODIS NIR Retrieval. Data from Loredana Spezzi and Phil Watts, EUMETSAT

Retrievals: Total Column Water Vapour

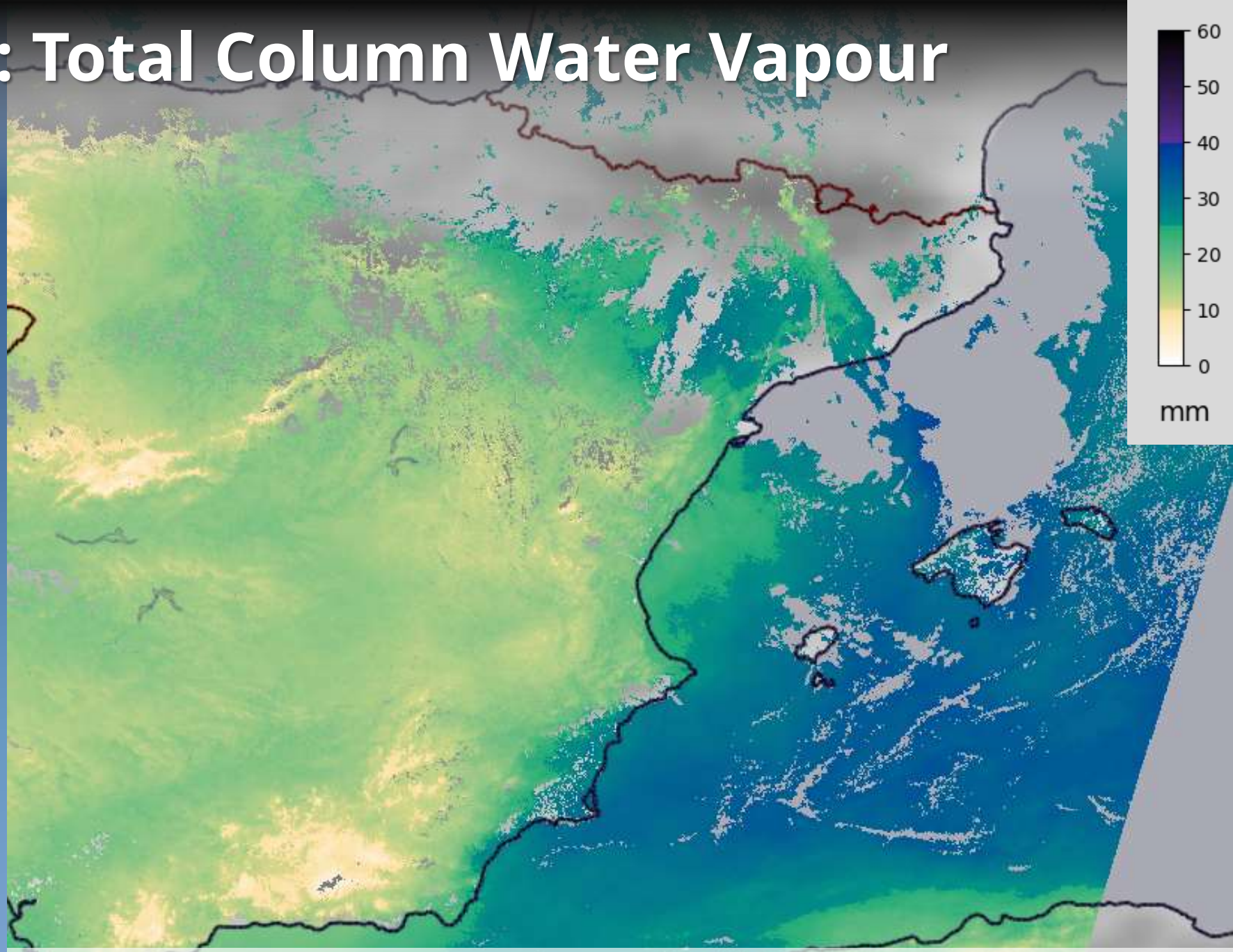
- Calculations to obtain moisture information from various channels



OLCI NIR Retrieval. Data from Jan El Kassar and Cintia Carbajal Henken, FU-Berlin

Retrievals: Total Column Water Vapour

- Calculations to obtain moisture information from various channels
- Those that take both the NIR and TIR into account seem to work best



OLCI/SLSTR NIR+TIR Retrieval. Data: Jan El Kassar and Cintia Carbajal Henken, FU-Berlin

Summary

- Moisture is one of the three ingredients for convective storms
- Low-level and mid-level moisture affect storms most directly
- Besides NWP forecasts, satellite data can help assess moisture
- Sounders, NIR and combinations give most useful information
- Retrievals and direct depiction of channel ratios are both useful
- MTG-I with FCI will provide information on low-level moisture every 10 minutes (later more frequently) in 2023
- MTG-S with will provide soundings every 30 minutes in 2024/25

To learn more about storms, satellites, and more at an ESSL course or Testbed, find out about registration at **essl.org**