Satellite Products

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Meteorological Products – Definition

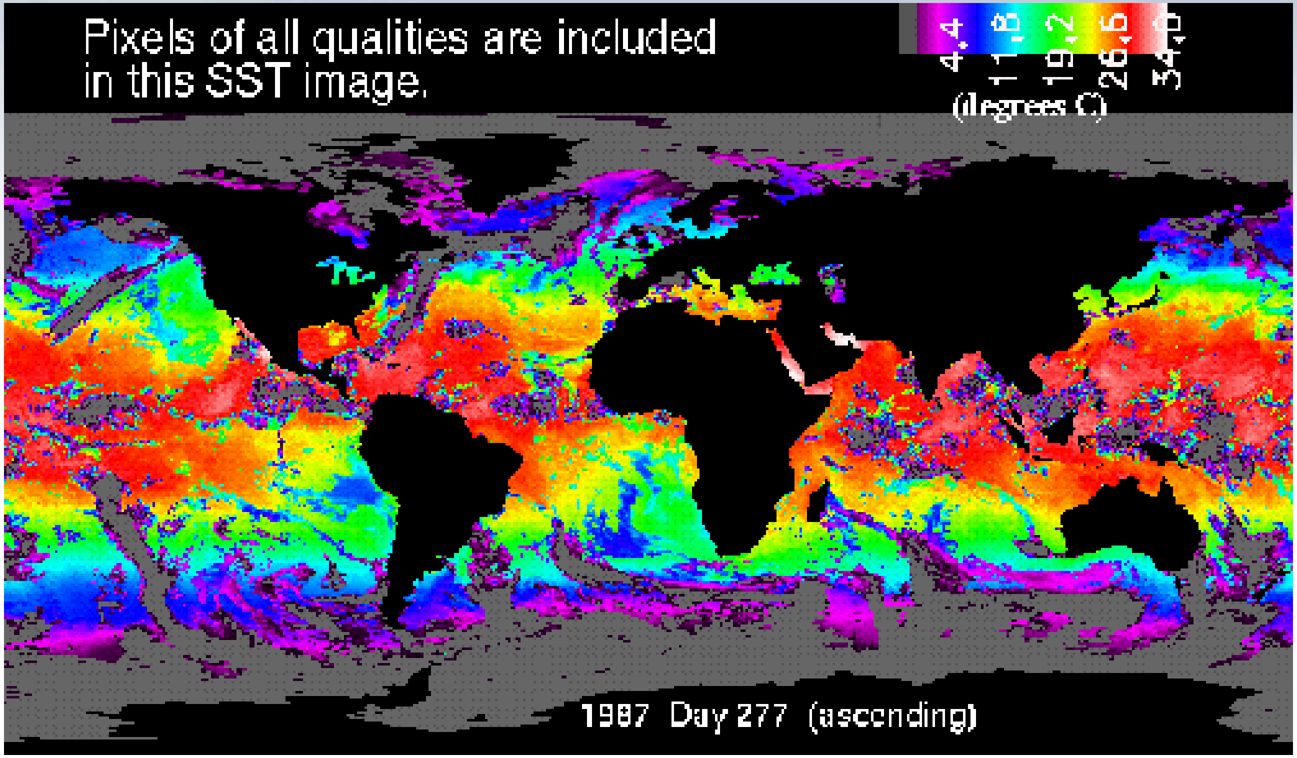
Meteorological products:

- Meteorological parameters extracted from the satellite measurements – supplement to other observations (ground, upper air, …)
- Correct metadata included (e.g. units, location, time, …)

Product Examples

- Surface temperature, e.g. SST
- Wind speed and direction at a certain height
- Cloud top height
- Other cloud products, e.g. cloud phase, cloud liquid water content
- Clear air products: temperature and humidity profile
- Atmospheric chemistry: trace gases (profile, total column)
- Scene identification (e.g. pixel contains a wild fire)
- Volcanic ash products (ash identification, concentration, height)

Typical Displays



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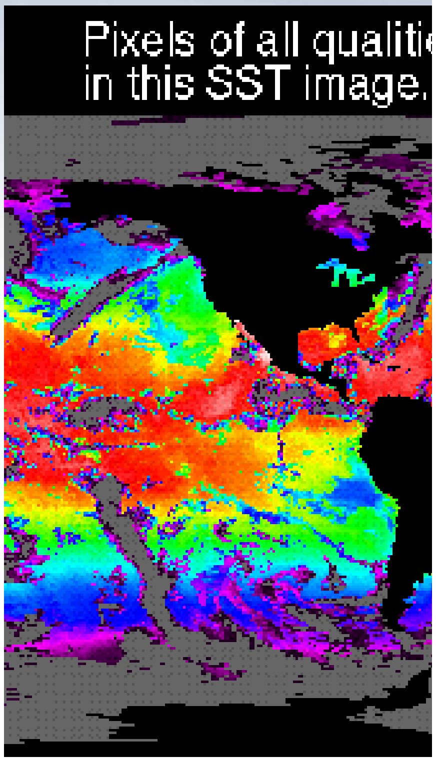
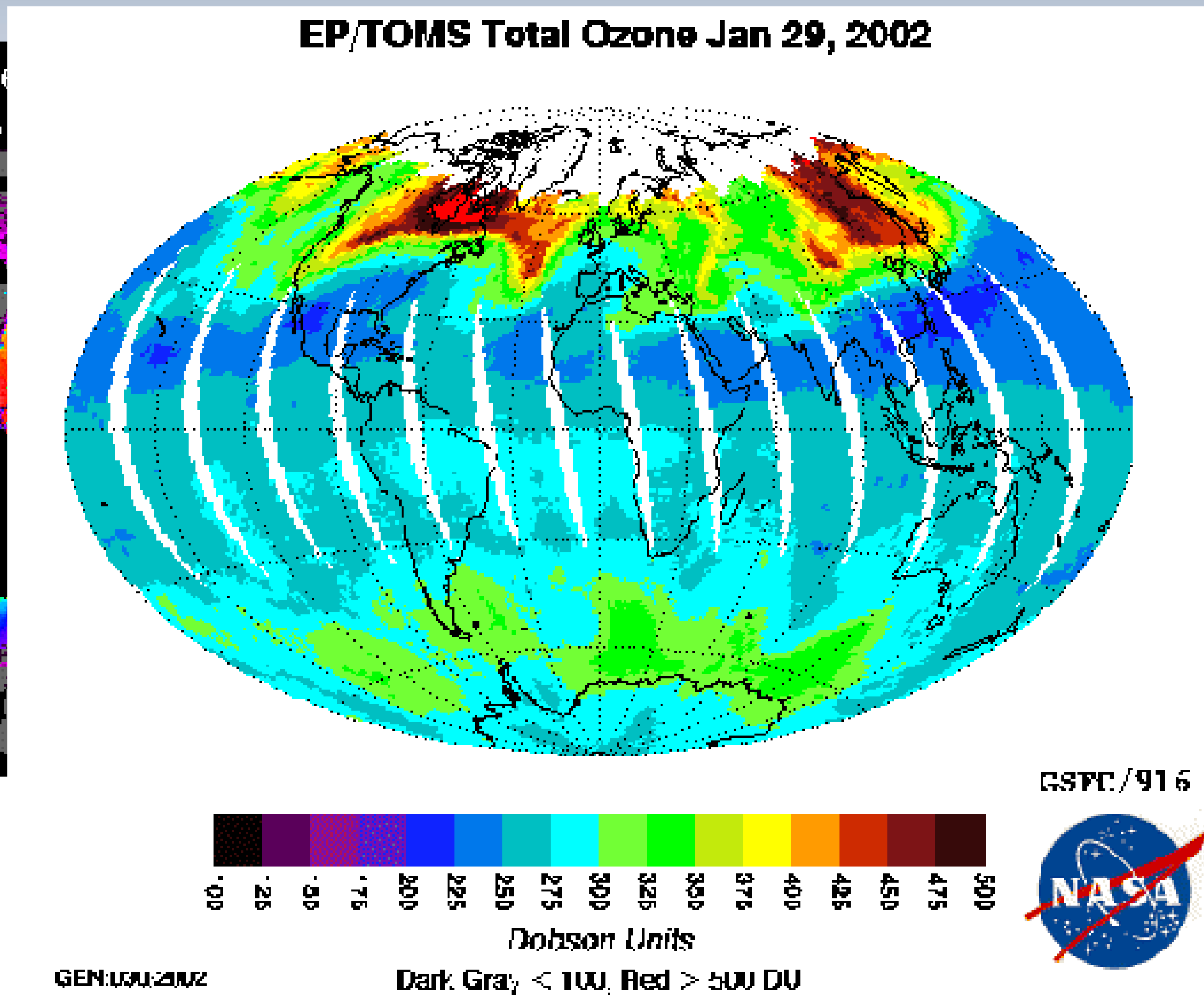
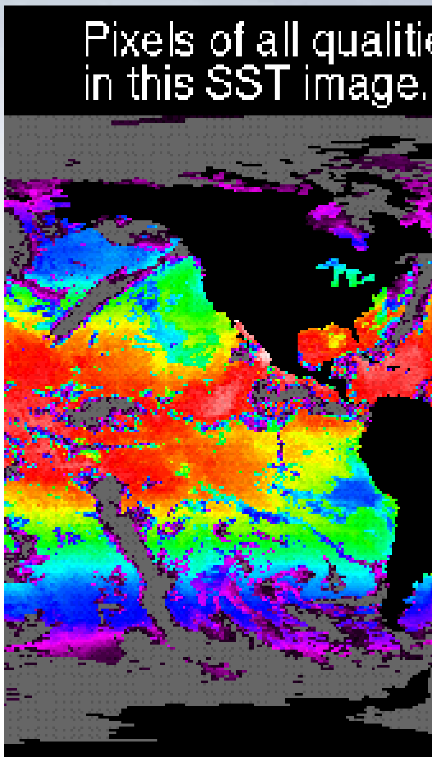
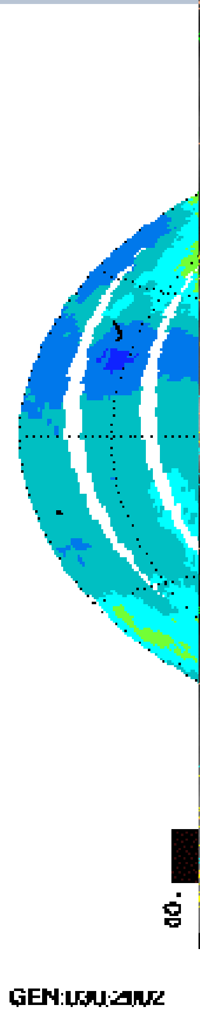
Typical Displays

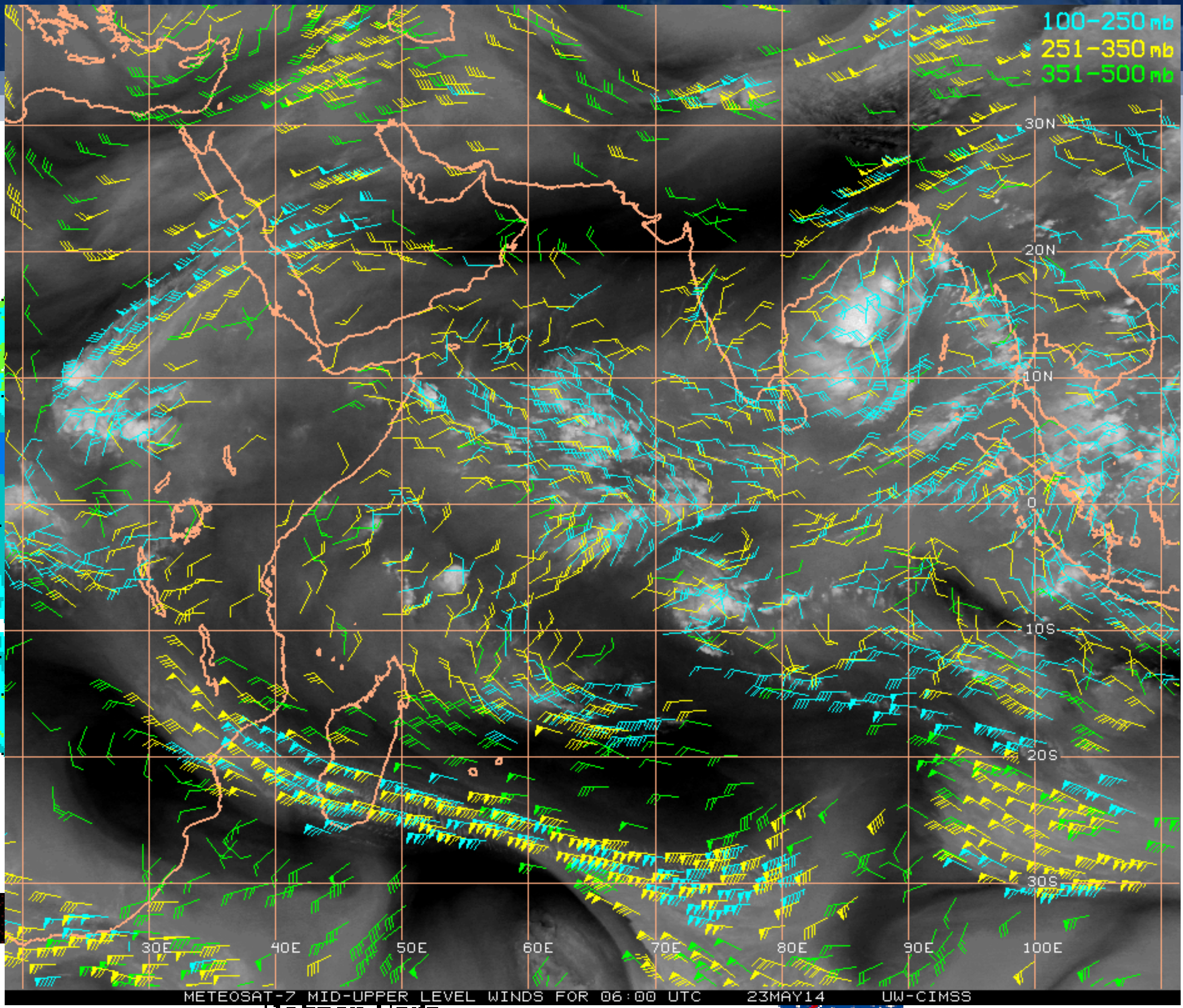




Typical Displays







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Why Products?

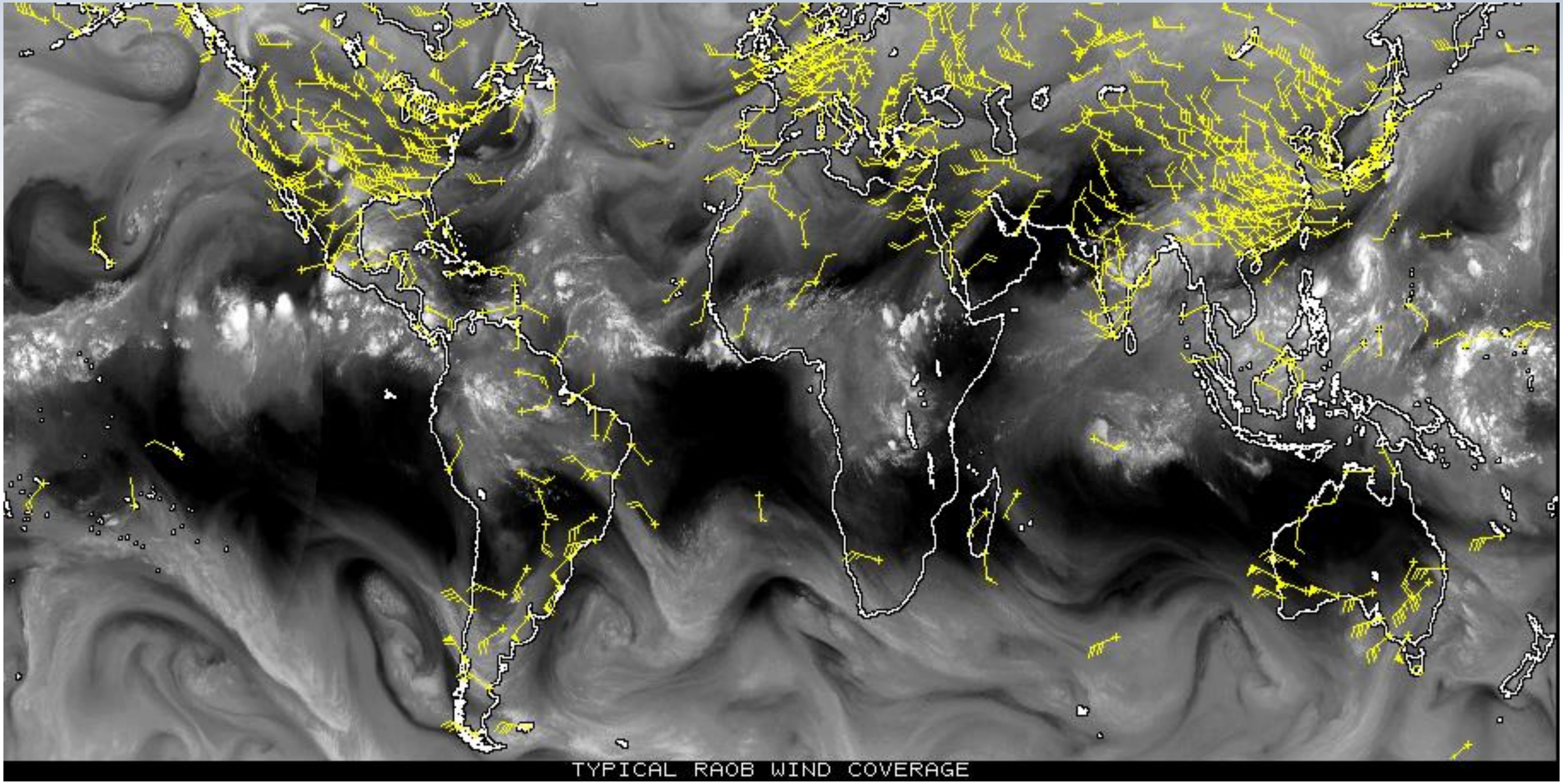
Other than the “raw” measurements, the products can be easily understood, assimilated in models, amended with other observations.

Advantages of the satellite products:

- High spatial / temporal coverage
- “Objective” interpretation of the measurements

There are disadvantages as well – we’ll come to that later

Coverage Example: Radiosonde Winds



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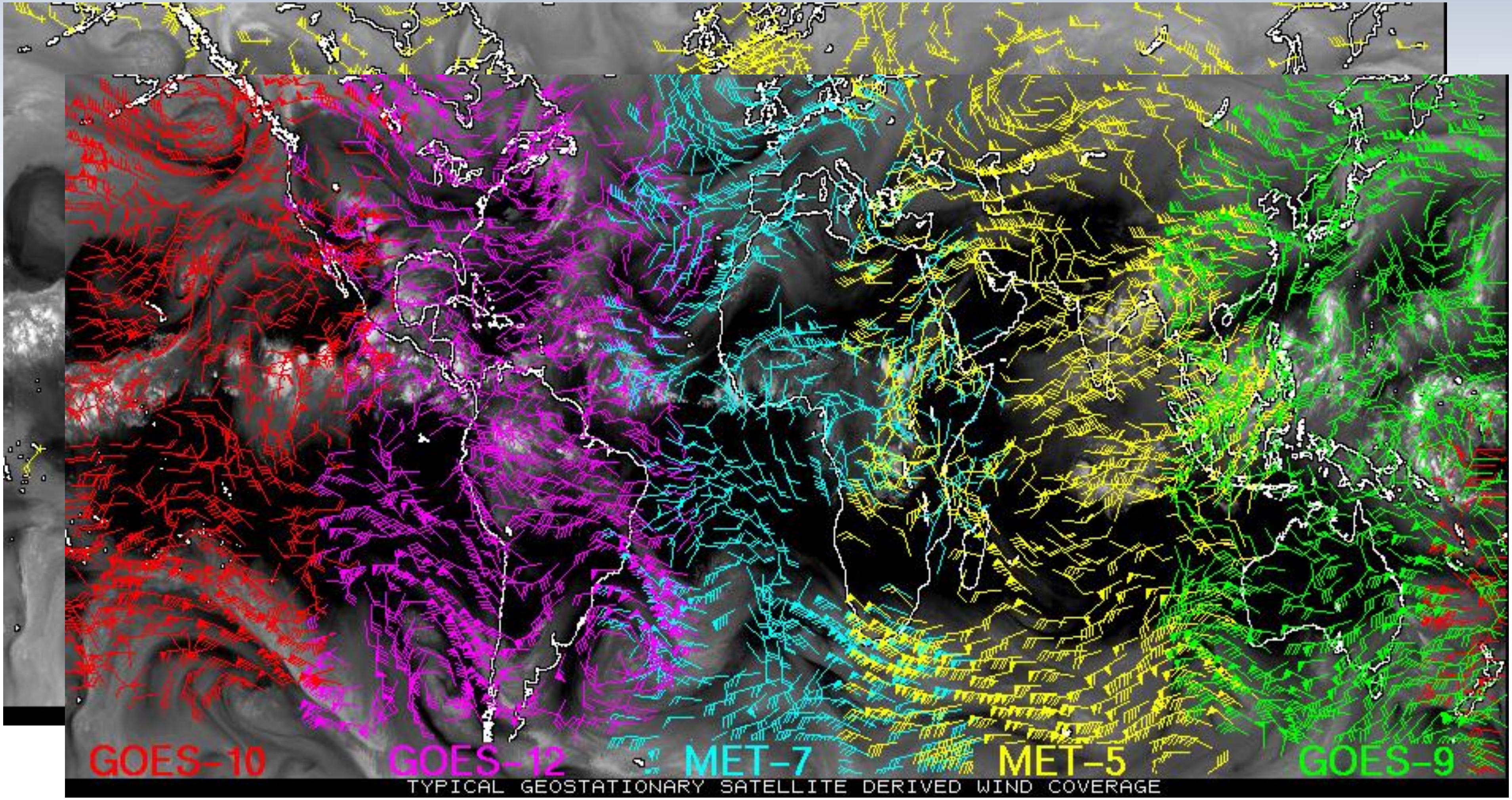
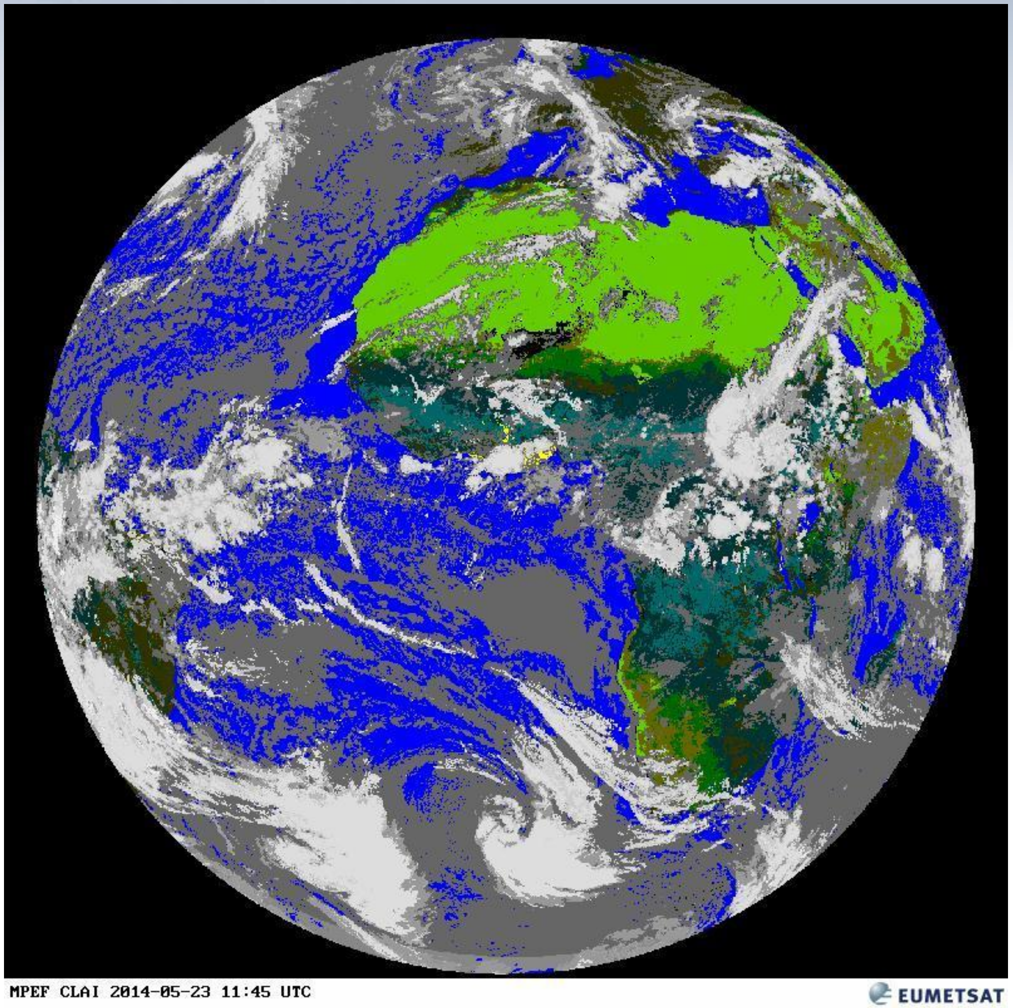
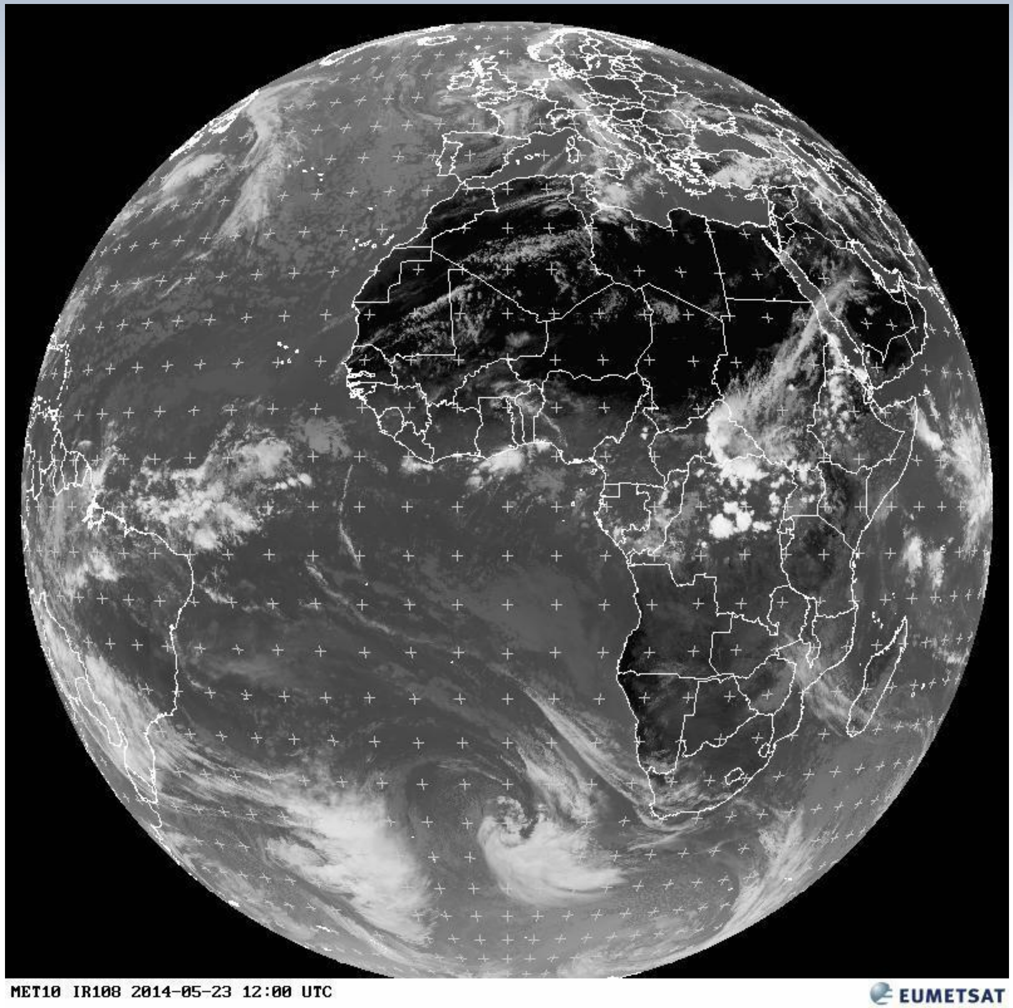
Coverage Example: Satellite Winds (geo)



“Objective” Interpretation Example





Important Pre-Condition

The information on the product MUST be already contained in the original measurement:

Example 1:

“Product” of this x-ray image should be some information about the outside colour of the fish

That would surely not work, as the x-ray image does not carry the information
(a red fish would produce the same x-ray picture as a blue fish)

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Important Pre-Condition

The information on the product MUST be already contained in the original measurement:

Example 2:

"Product" of this photograph should be some information on the bone structure

That would surely not work, as the photo does not carry this information - a fish with a broken rib may look exactly the same as a fish with non-broken ribs

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Pre-Condition – Meteorological Examples

- No SST information when (thick) clouds are obscuring the surface view
- No wind information if we don't have multiple views taken at different times
- No information on a particular trace gas if the spectral signature of this gas is not in the measurement (e.g. measurement outside the absorption band for the gas)
- No cloud top height information from VIS images (clouds here are always "white")
- No information on the moon when the instrument looks at Mars

Product Retrieval Strategies

… very many!

Typically used:

- Statistical approaches (neural nets)
- Comparison to other data (threshold techniques)
- Optimal estimation approach – often combination with other data

Retrieval Techniques

1. Statistical Approach:

From many observations, a (simple) statistical relationship is found between the measurement(s) and the product.

Retrieval Techniques

Example:

SST, to be retrieved from 2 IR window channels (where one is more affected by humidity than the other) – split window technique from measurements T_1 and T_2

$$SST = T_1 + \alpha_1 (T_1 - T_2) + \alpha_2 (T_1 - T_2)^2 + \ldots$$

(α_1 and α_2 could e.g. depend on the viewing angle, the near surface wind speed …)

Result:

A very fast algorithm which is valid for one particular instrument!

Quality/confidence information often missing

Retrieval Techniques

2. Threshold Techniques

Very commonly used in products derived from imagers, e.g. for scene identification:

The measurements (IR, VIS) are compared to an “expected” value for cloud free conditions

The “expected cloud free” measurement could e.g. be simulated from forecast data together with a radiative transfer mode

Retrieval Techniques

Example 1

Measurement (IR window channel): 267 K

Expected from the forecast: 291 K -> Pixel would be flagged as cloudy

Retrieval Techniques

Example 1

Measurement (IR window channel): 267 K

Expected from the forecast: 291 K -> Pixel would be flagged as cloudy

Example 2

Measurement (IR window channel): 290.8 K

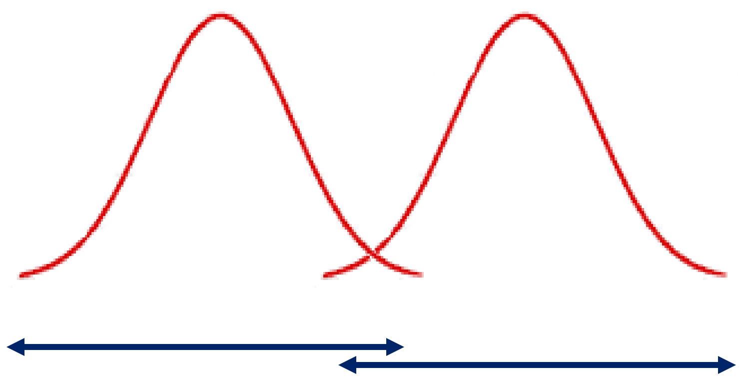
Expected from the forecast: 291 K -> hmmmmm … we should allow for such small differences and still declare the pixel as cloud free ("tuning" of such algorithms)

Quality information e.g. by combining different threshold tests

Retrieval Techniques

3. Optimal Estimation

Combines measurement with background
(e.g. model, climatology, ..) information, retaining all uncertainties!



Probability of product, given a measurement and its uncertainty

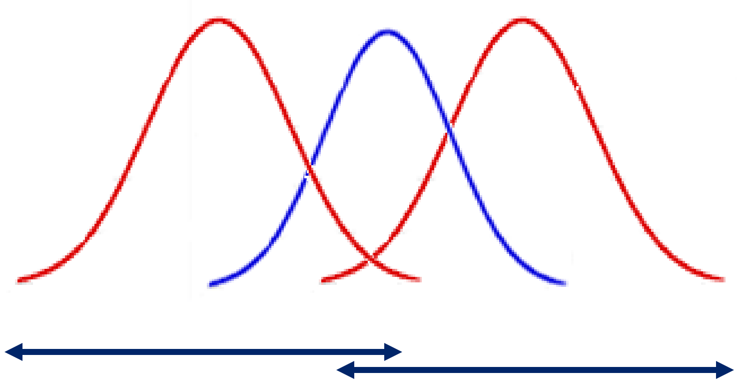
Probability of product from the background information and its uncertainty

Retrieval Techniques

3. Optimal Estimation (OE)

Combines measurement with background (e.g. model, climatology, ..) information, retaining all uncertainties!

Final answer from OE scheme:
Product plus Uncertainty!



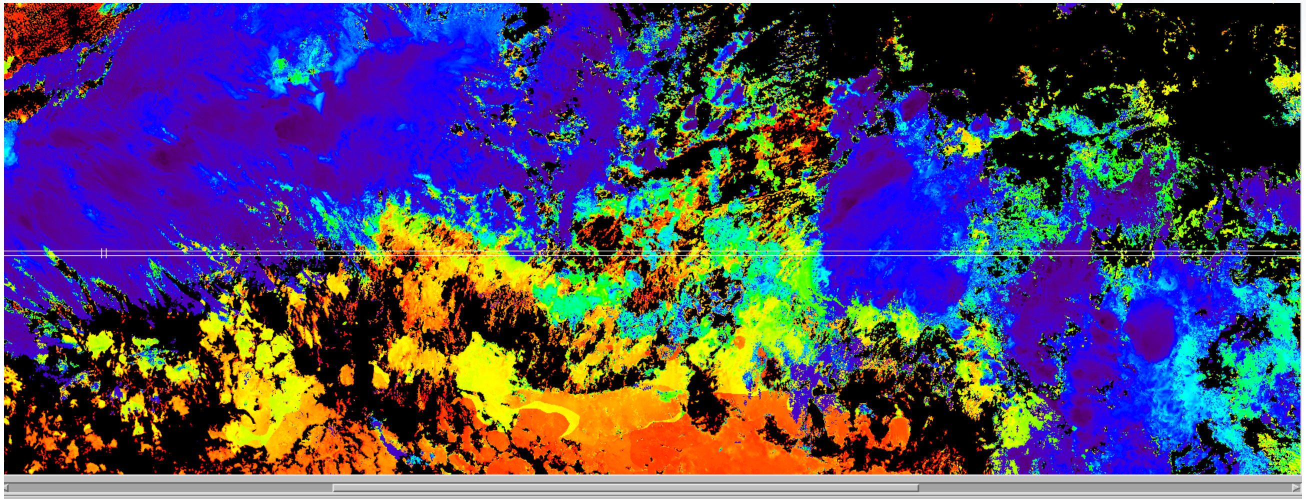
Probability of product, given a measurement and its uncertainty

Probability of product from the background information and its uncertainty

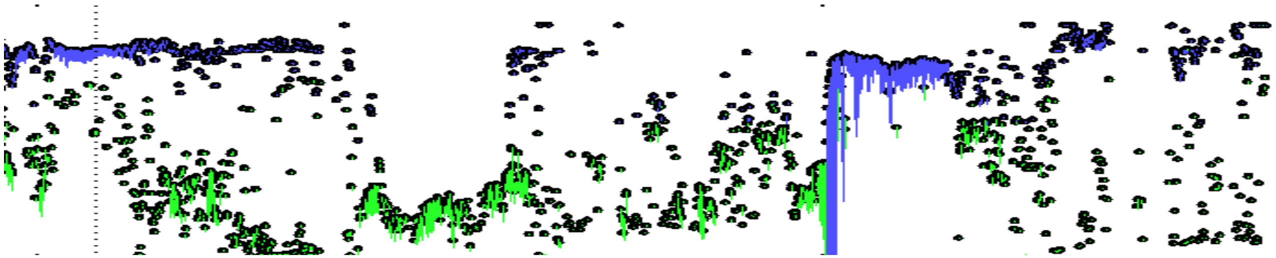
OE approaches can accommodate MANY measurements in a single framework

Important: Validation

All product development should come with some validation (comparison to model analysis/forecast, comparison to in-situ observations, comparison to other satellite products)



MSG Cloud Top Pressure product
(purple to red form high to low clouds)



Validation with CloudSat along the indicated track

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Disadvantages – Examples to Follow Later

- Any product can only be as good as the input data

  calibration issues, navigation issues, problems with auxiliary data as e.g. the forecasts, limitations of the radiative transfer model, problems with other assumptions in the product processing

- Product Processing may need considerable CPU power and time

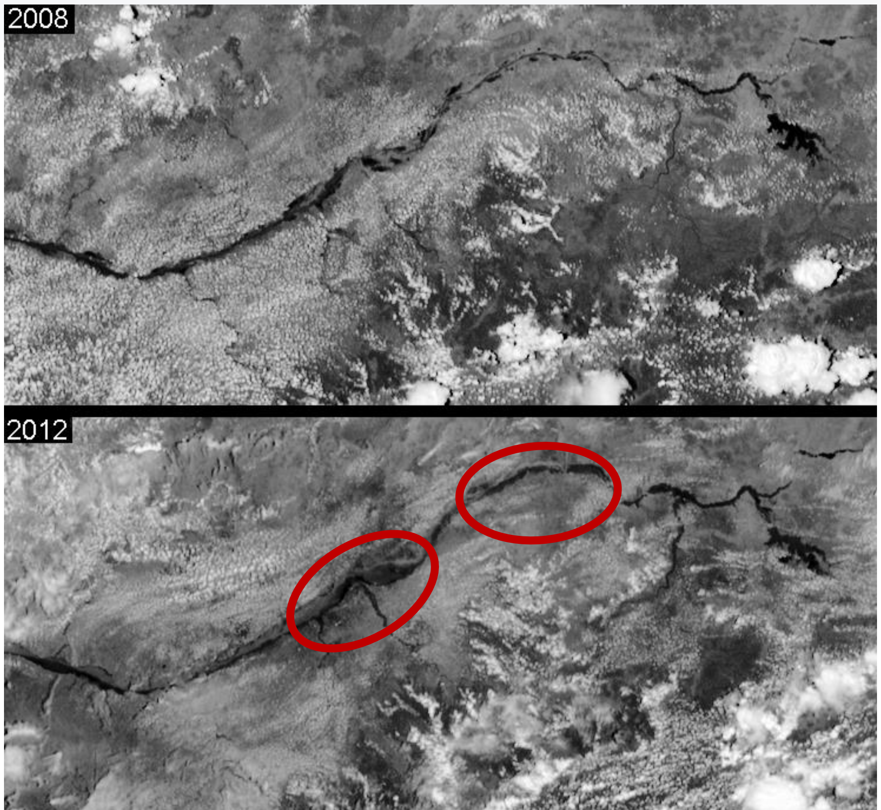
  Especially true for optimal estimation approach

- Human eye + brain may in some cases be the superior tool
- Any product processing has a "model" of the truth – if we have measurements that don't follow this model at all we are los

Example of this Last Disadvantage

Product: Identification of a flooded area

Assumption: Any surface which is usually bright - if it is suddenly darker then this must be due to some flooding



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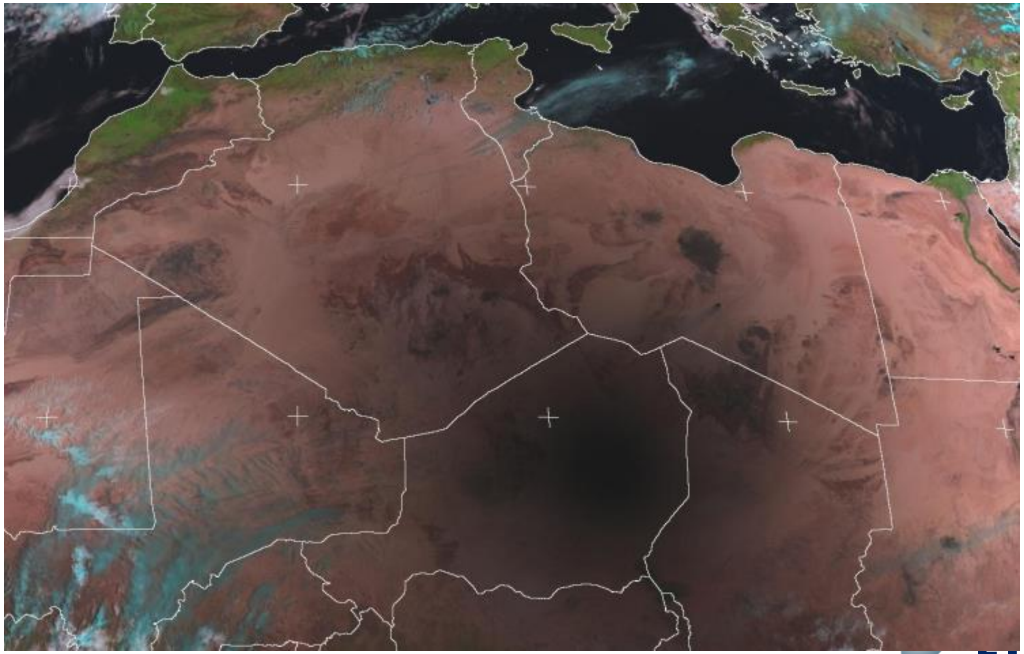
Example of this Last Disadvantage

Product: Identification of a flooded area

Assumption: Any surface which is usually bright - if it is suddenly darker then this must be due to some flooding

This is usually fine – but there can be other reasons for sudden darkening:

The example shows the moon's shadow on the Sahara during a solar eclipse – the "flood" product would go horribly wrong here!



Typical Underlying Assumptions

- Pixel is either completely clear or completely cloudy
- Clouds (in radiative transfer models) are often treated as plane-parallel features (e.g. cloud shadows often disregarded)
- Details of atmospheric state (trace gases, aerosols) often disregarded or just taken from climatology
- Fine structure of underlying surface (e.g. IR emissivity) disregarded or not known
- Scattering of ice clouds: some ice crystal shape has to be assumed

We have instruments in space that can in principle measure many of these unknowns – but we are far from a combined use of all instruments everywhere and at all times

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Meteorological Products

EUMETSAT Satellite Data Processed:

- At EUMETSAT Headquarter (CF)
- At Various SAFs (OSI SAF, CM SAF, Hydro SAF, Land SAF)
- Product services provided by NWP SAF and NWC SAF

Focus of this presentation:

CF product processing for MSG

MSG Products –Derived Centrally at EUMETSAT

Cloud Products (cloud mask, cloud top pressure, …)

Radiance / reflectance products

Atmospheric Motion Vectors

Fire Detection

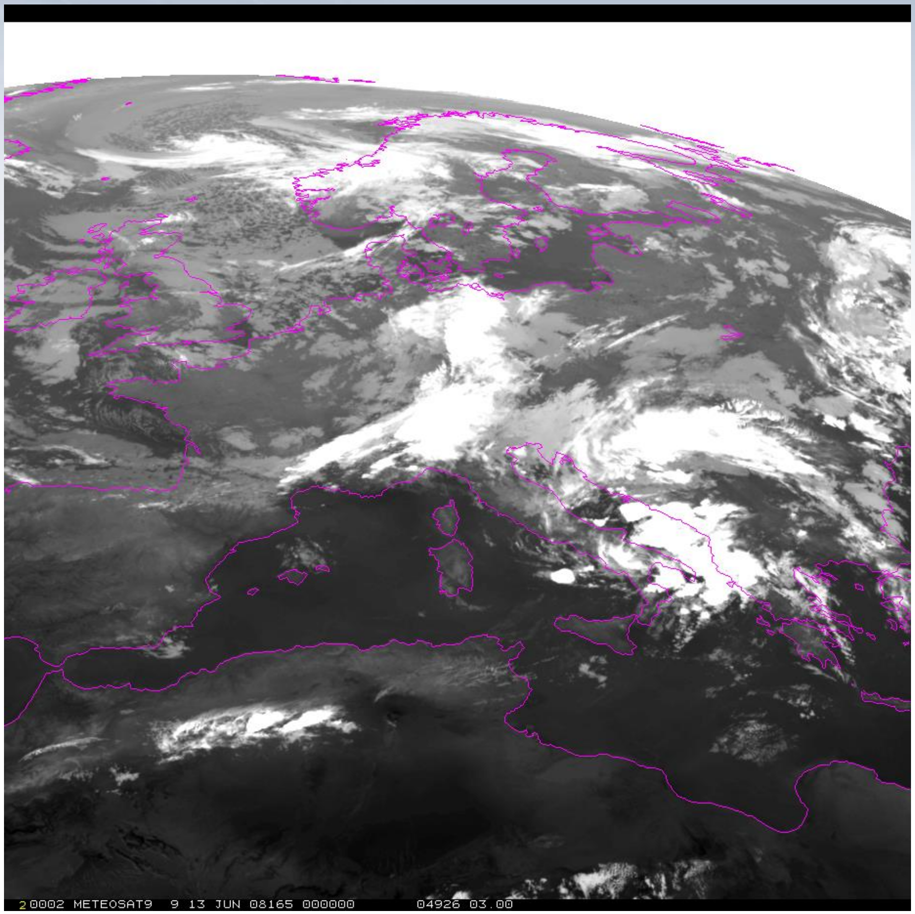
Volcanic Ash

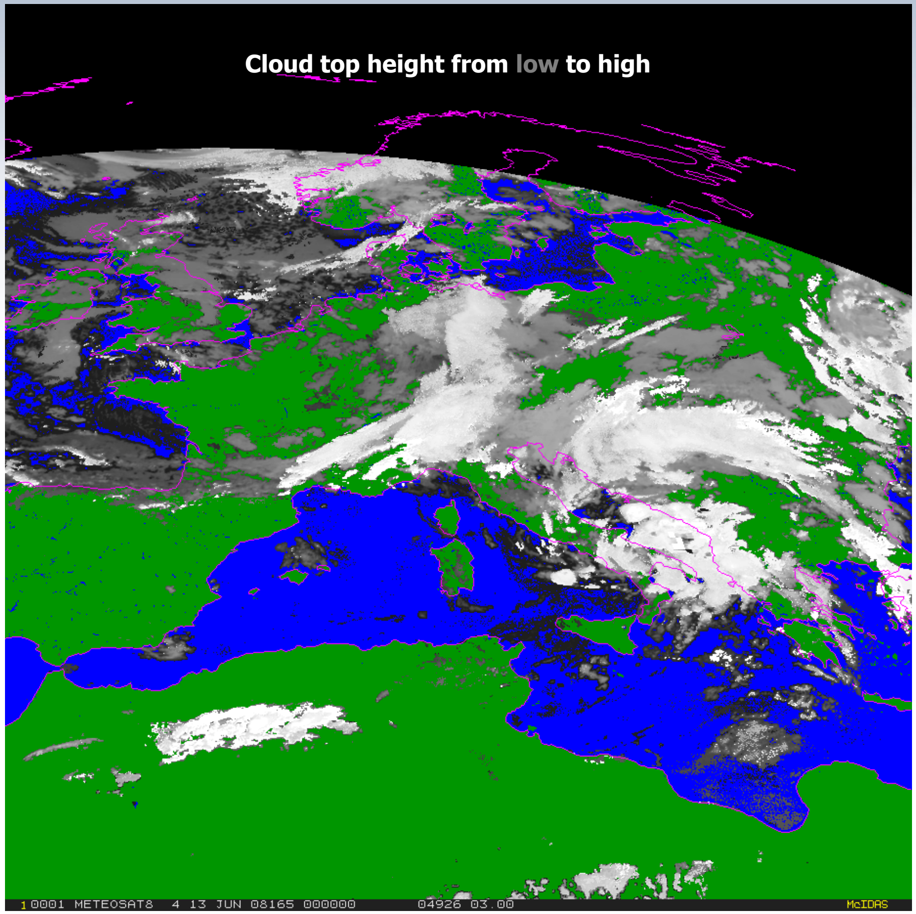
Global Instability Indices

Total Ozone

Aerosol over Sea Product

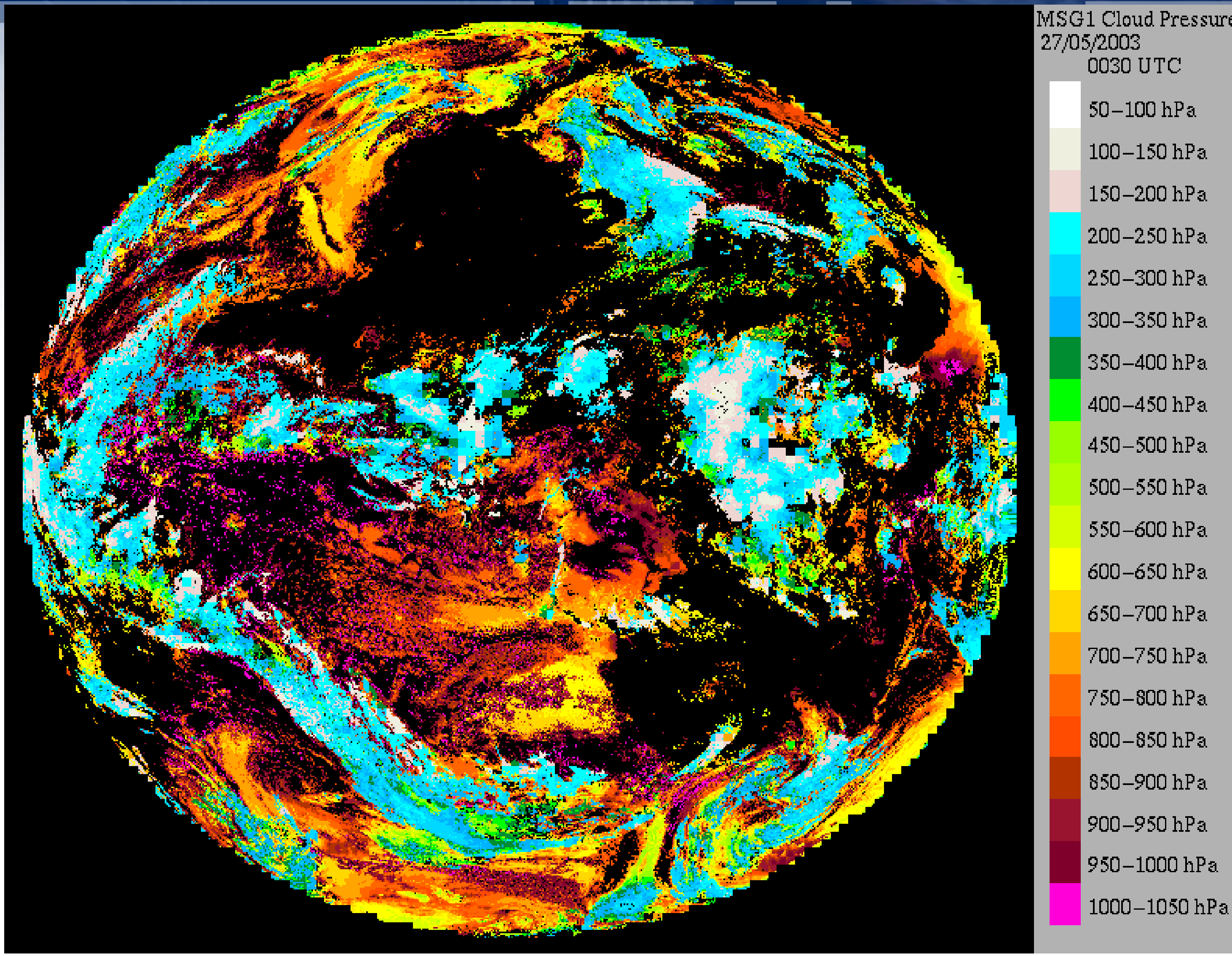
Cloud Product Example





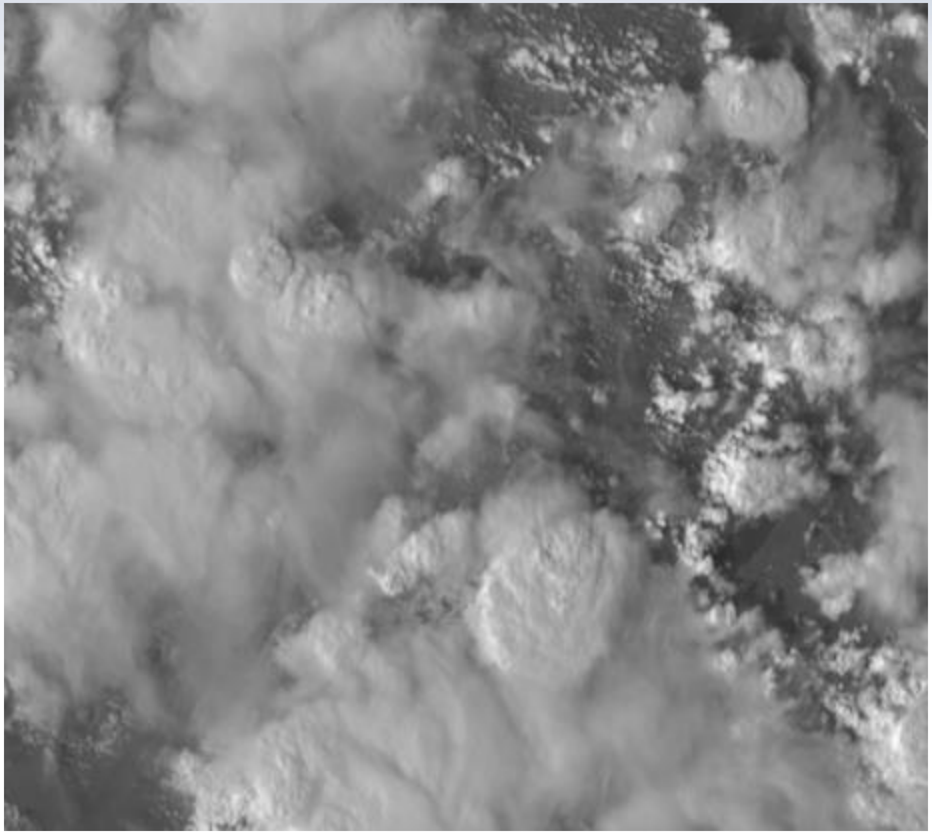
Application: Nowcasting, use in other products

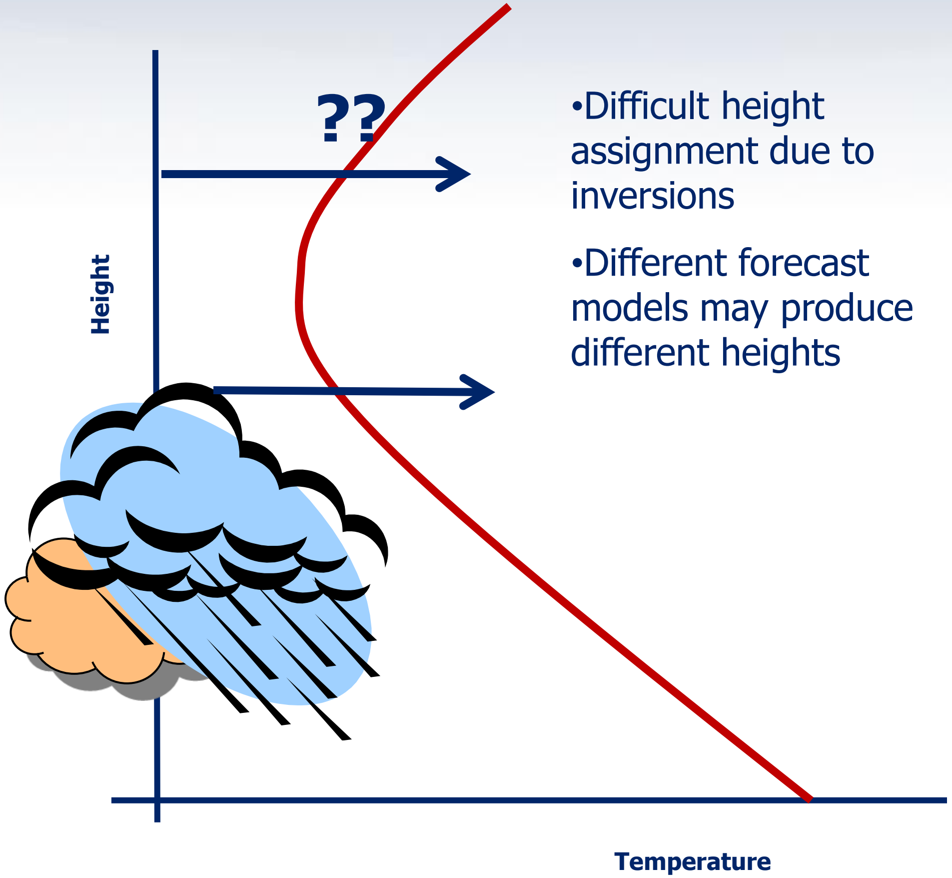
Cloud Top Height – Typical "Problem"



“Blocky” Structure Due to Use of Forecast Fields

Cloud Top Height in case of inversions:





- Difficult height assignment due to inversions
- Different forecast models may produce different heights

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Radiance / Reflectance Product

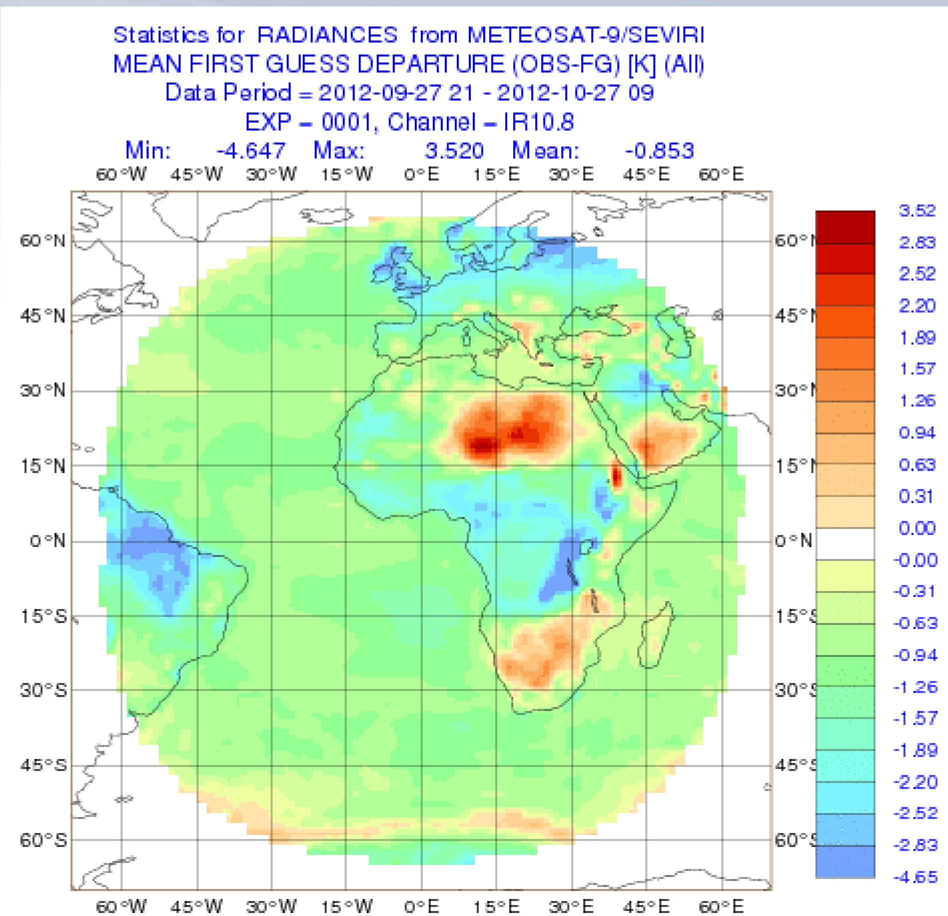
All Sky Radiance Product:

Provides for all infrared channels the average radiances for clear sky, low, medium and high clouds, aver n x n pixels. Use: Assimilation in NWP

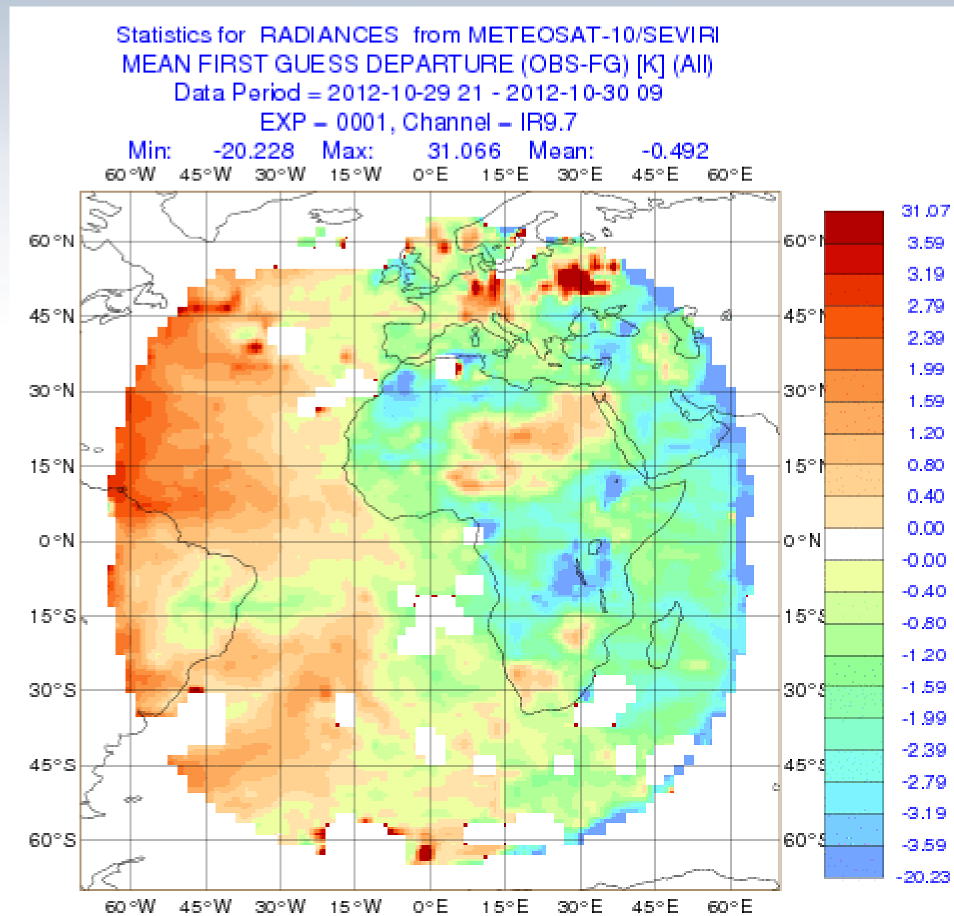
Clear Sky Reflectance Map Product:

Provides the reflectance for a given time of the day, for each pixel, for cloud free conditions (cloud free pixels are accumulated over 10 days). Internal use within the cloud processing.

Clear Sky Radiance Monitoring at ECMWF



Meteosat-9



Meteosat-10

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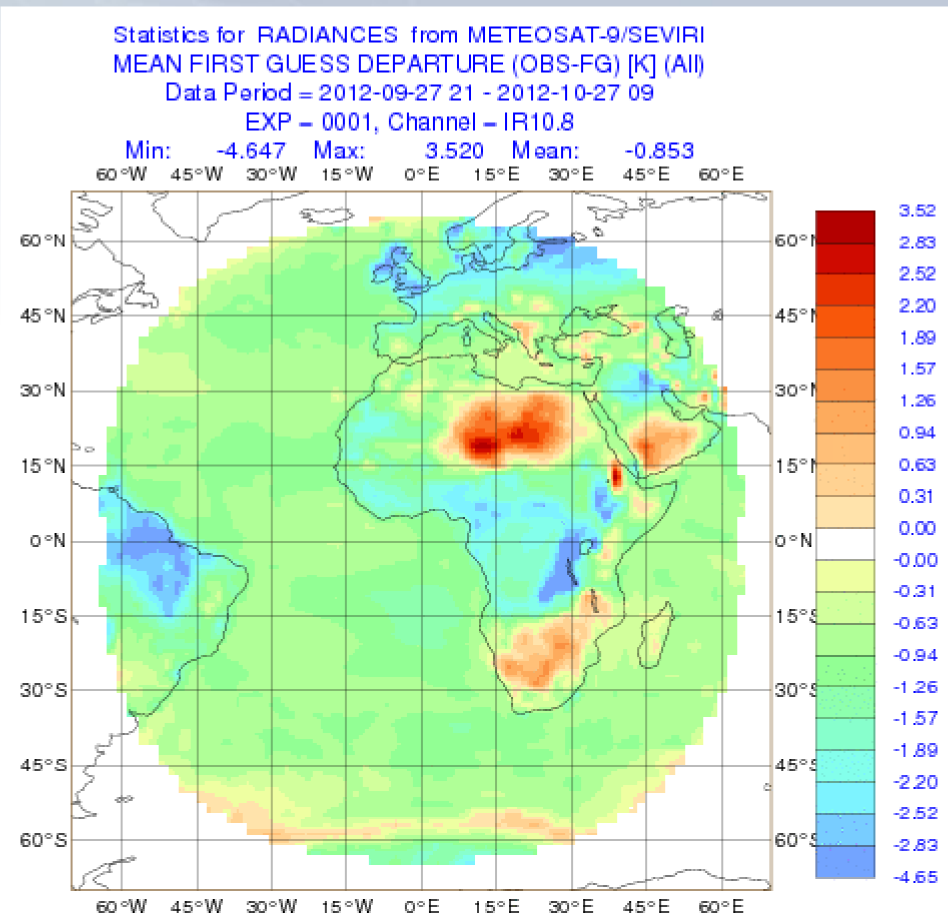
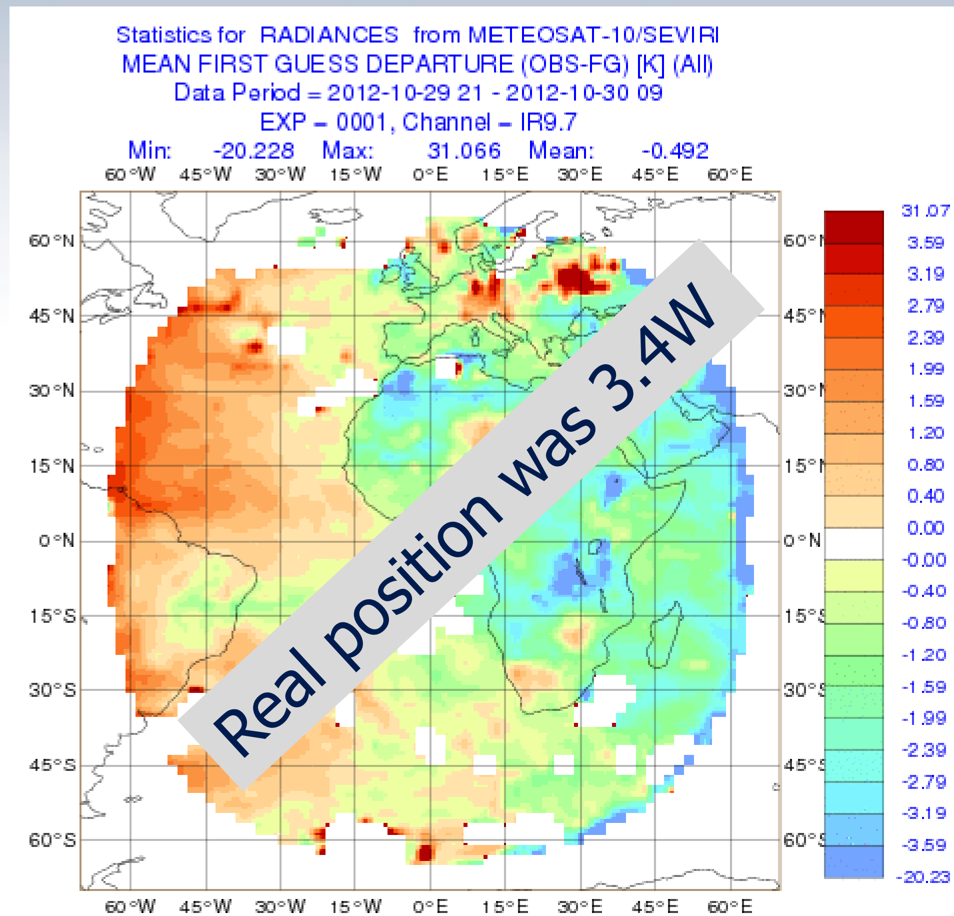
Clear Sky Radiance Monitoring at ECMWF



Meteosat-9



Meteosat-10

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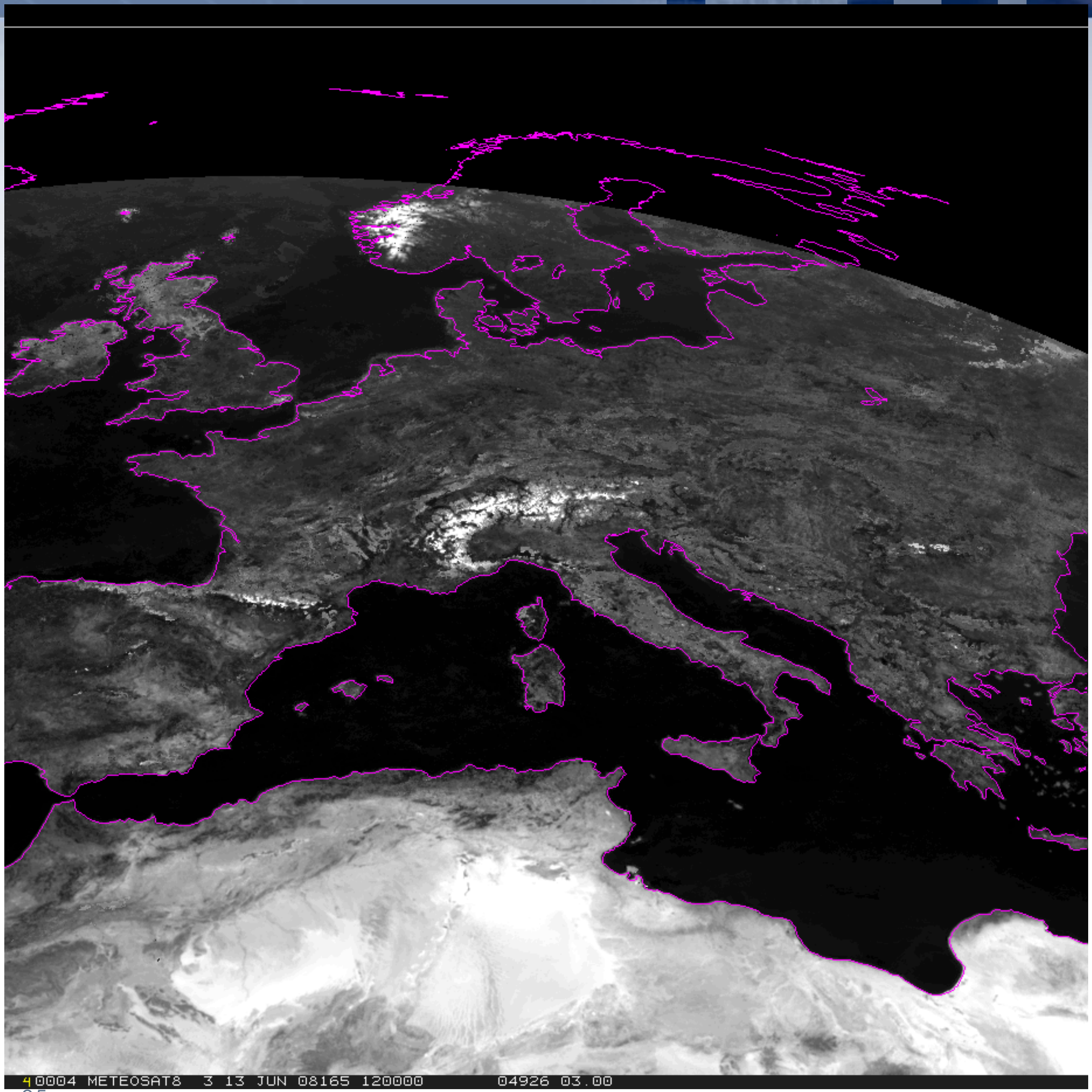
Clear Sky Reflectance Map



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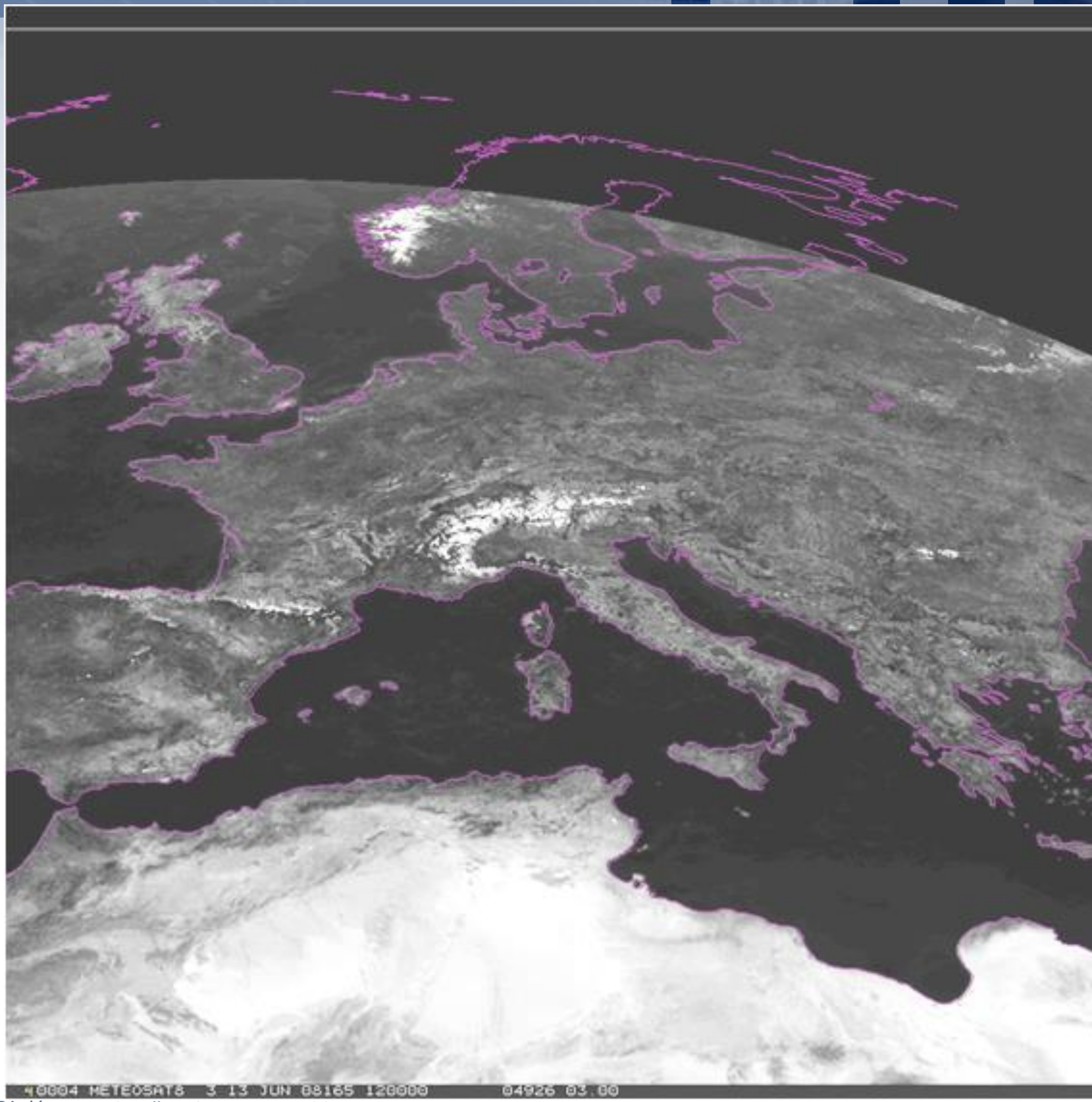
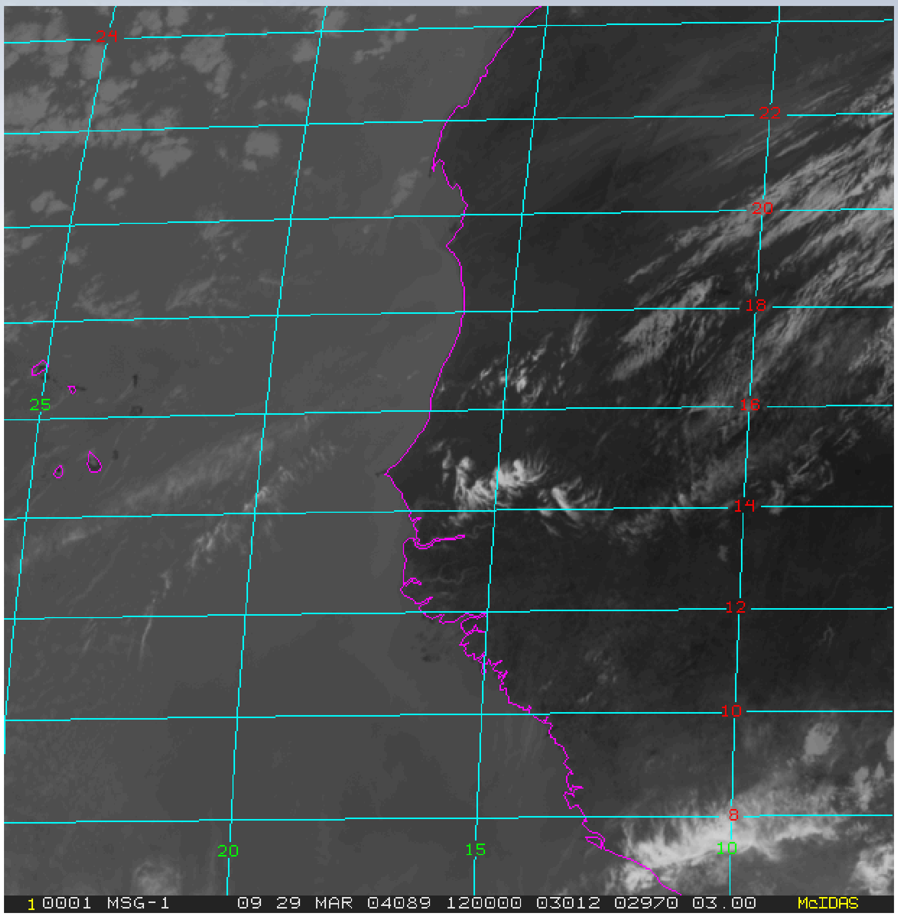
Clear Sky Reflectance Map

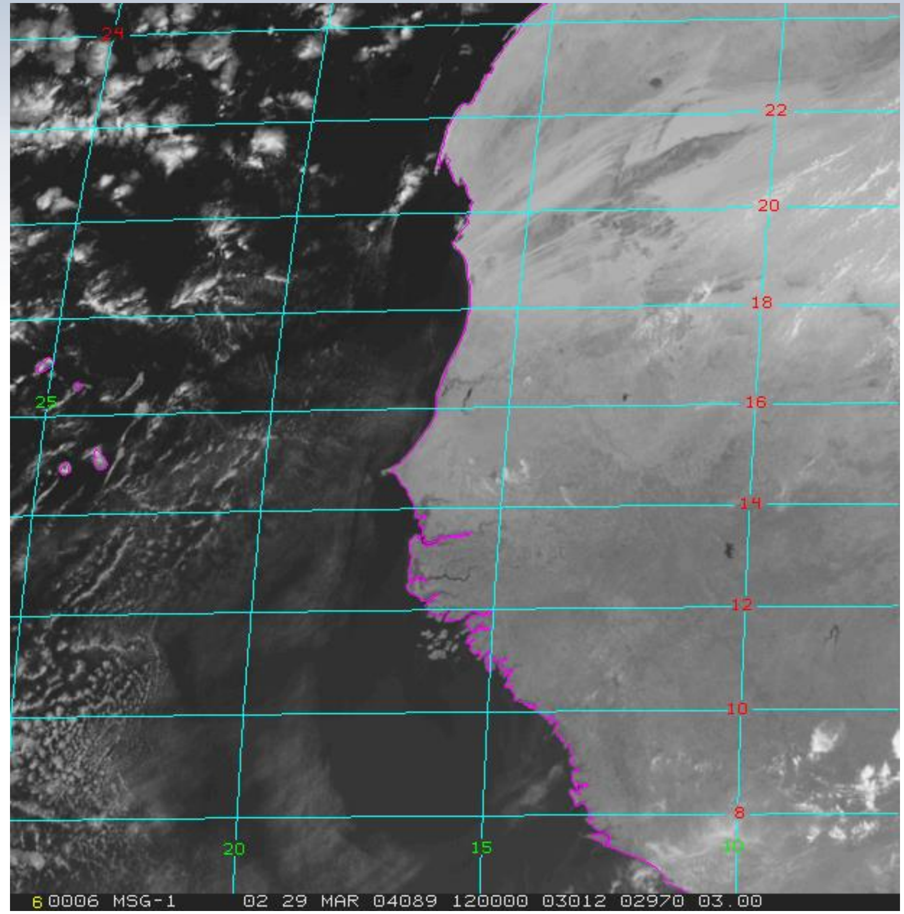


Problems are undetected clouds showing up in the map – constant use of this map may produce some "runaway" effects:

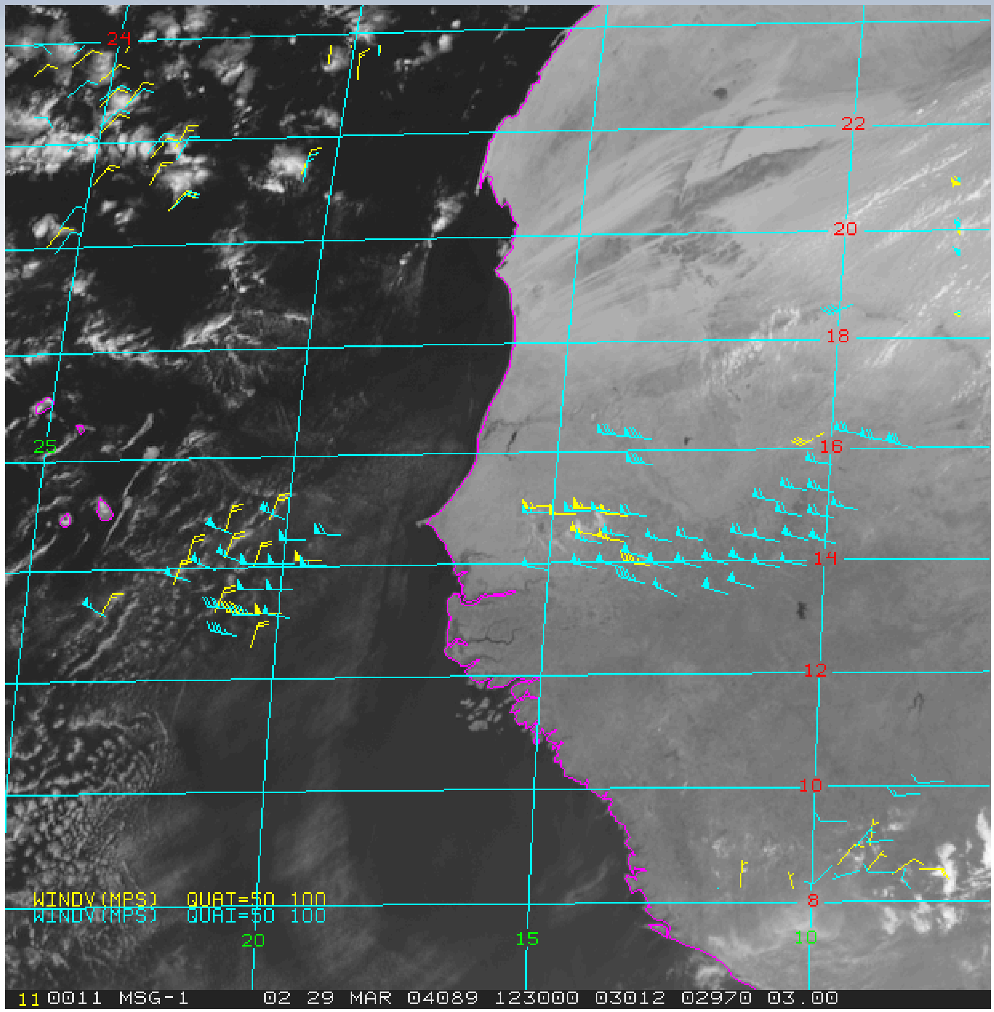
More clouds are undetected, i.e. background becomes brighter – effect can be reduced by also using "climatology" as background

Atmospheric Motion Vector Product





Atmospheric Motion Vector Product



Main problem area here:

Correct height assignment (related to the cloud top height problem!)

Application: Assimilation in NWP

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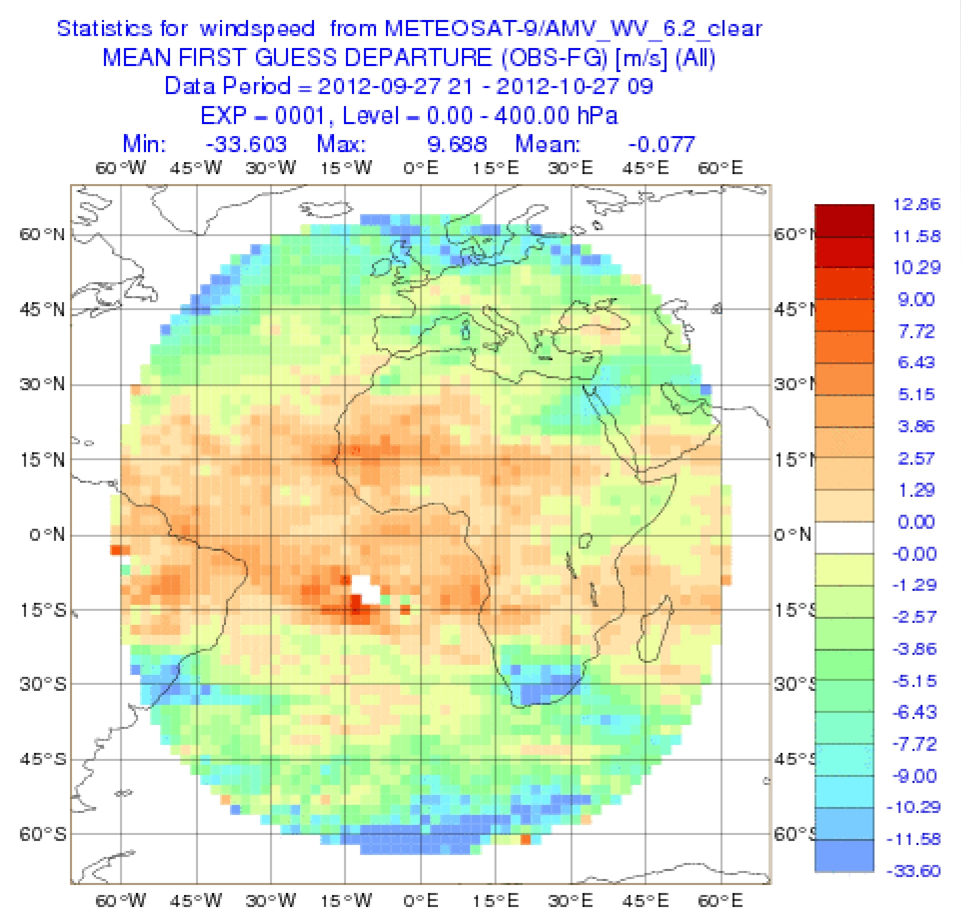
AMV Monitoring at ECMWF



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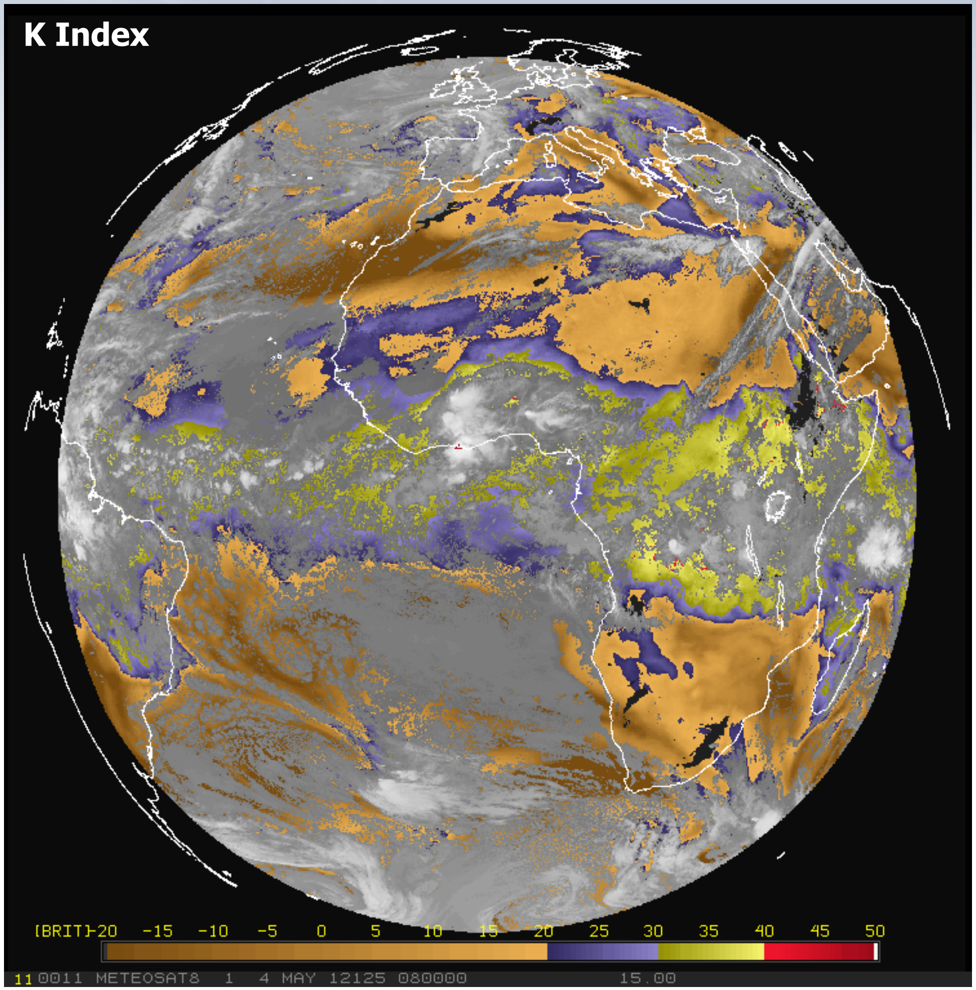
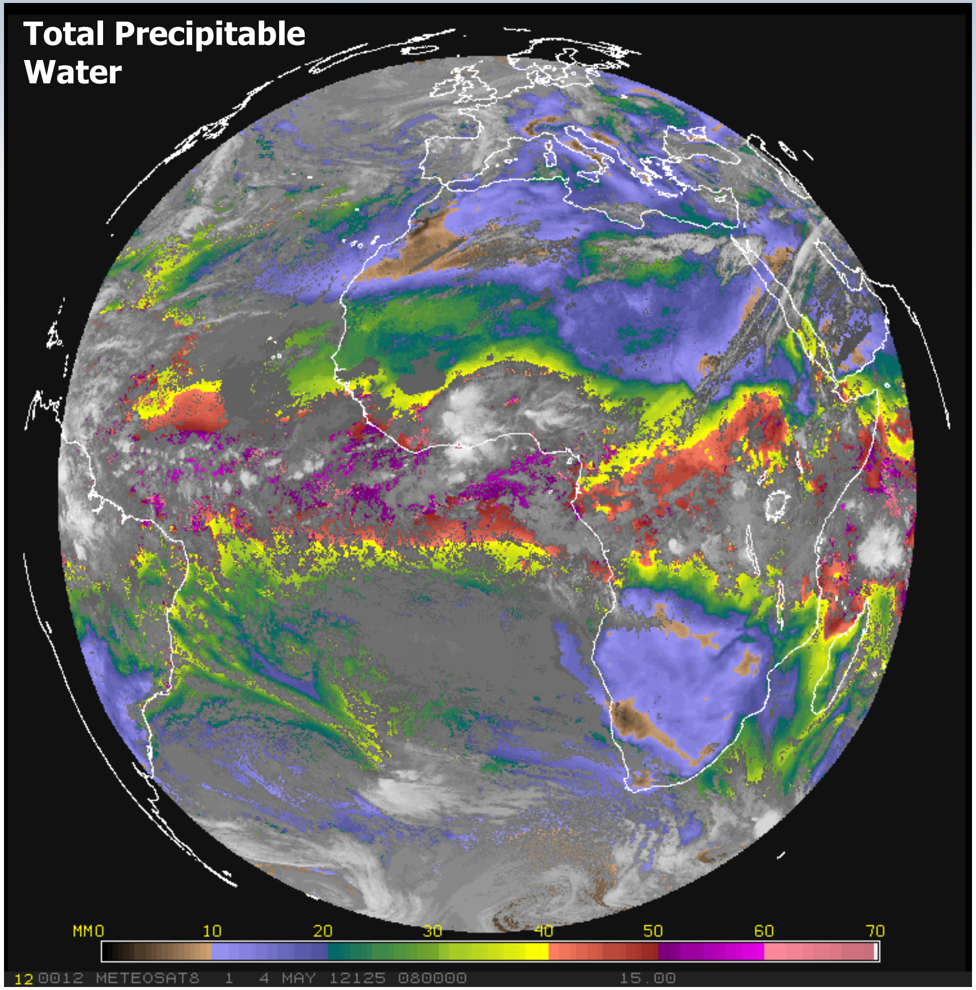
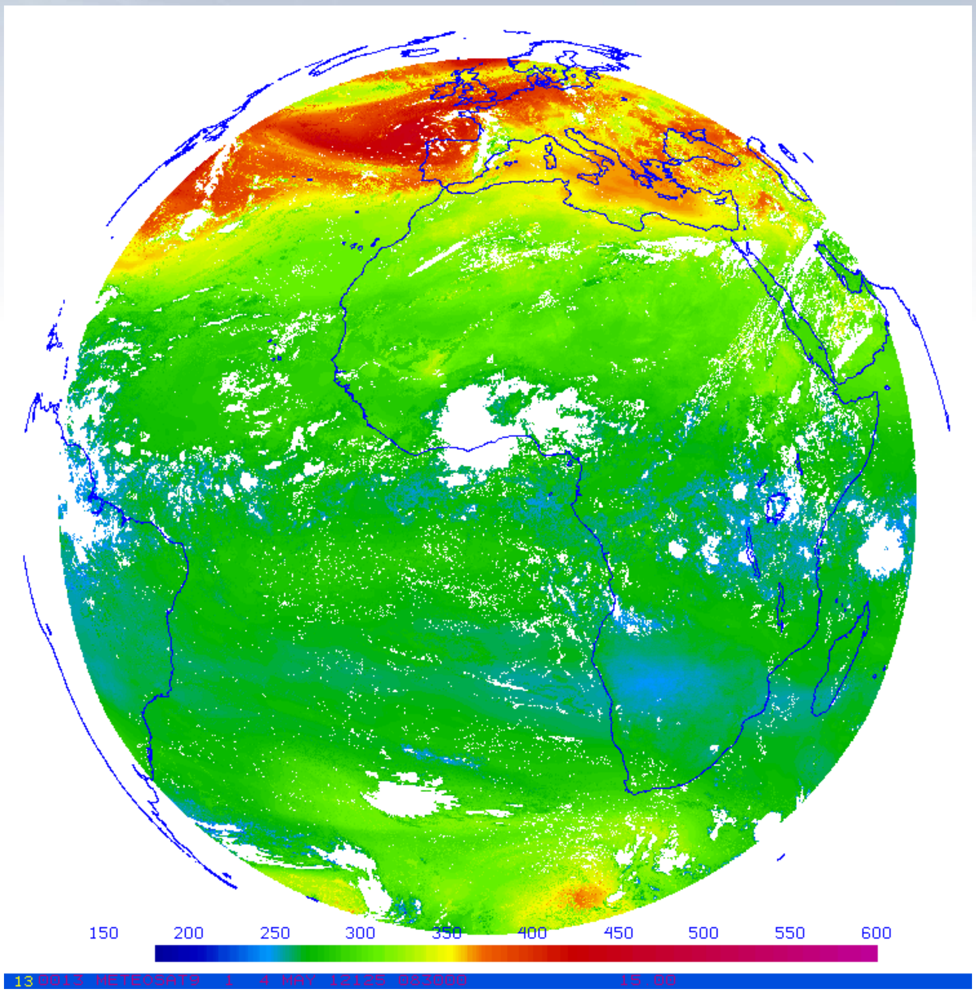
Global Instability Index Product (GII)





Application: Nowcasting

Total Ozone Product (TOZ)



Application: Nowcasting – comparison of frontal positions to NWP

GII and TOZ are retrieved using a optimal estimation scheme on 7 IR channels

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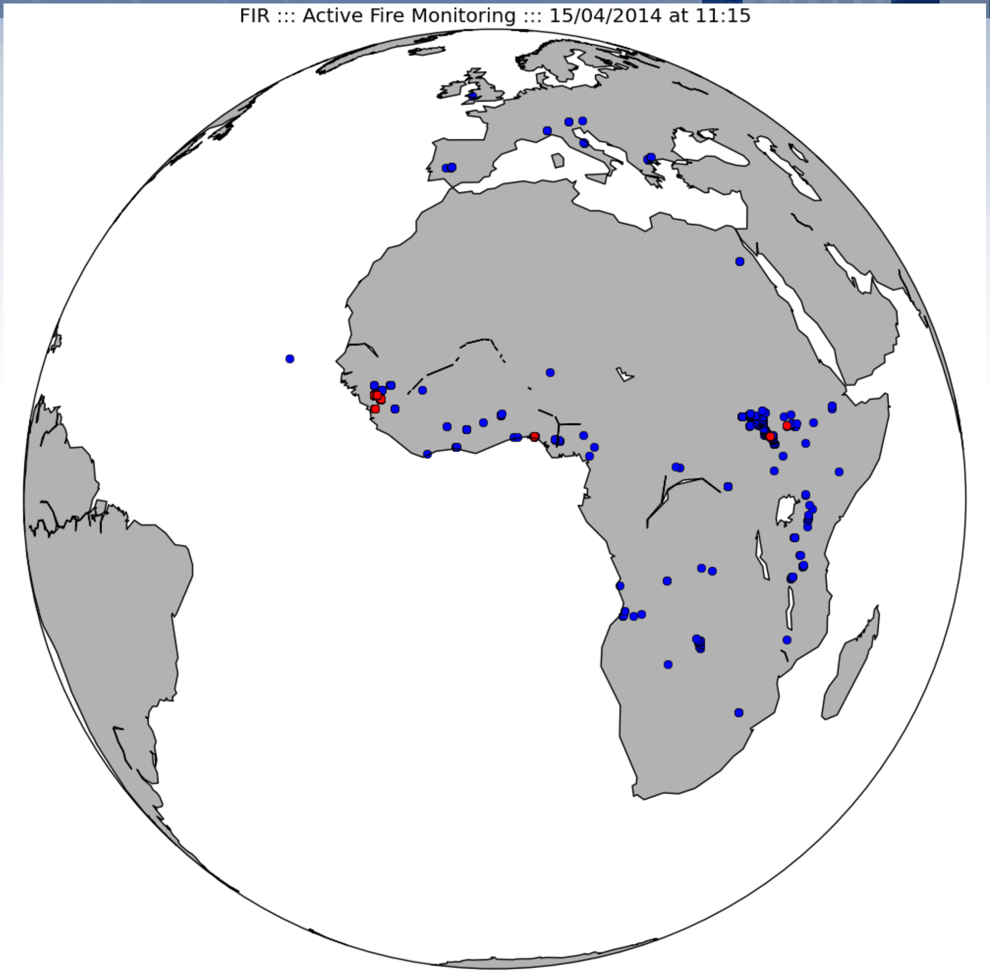
Fire Detection (Active and Potential Fires)



Active fires in red, probable fires in blue

Thresholding Technique:

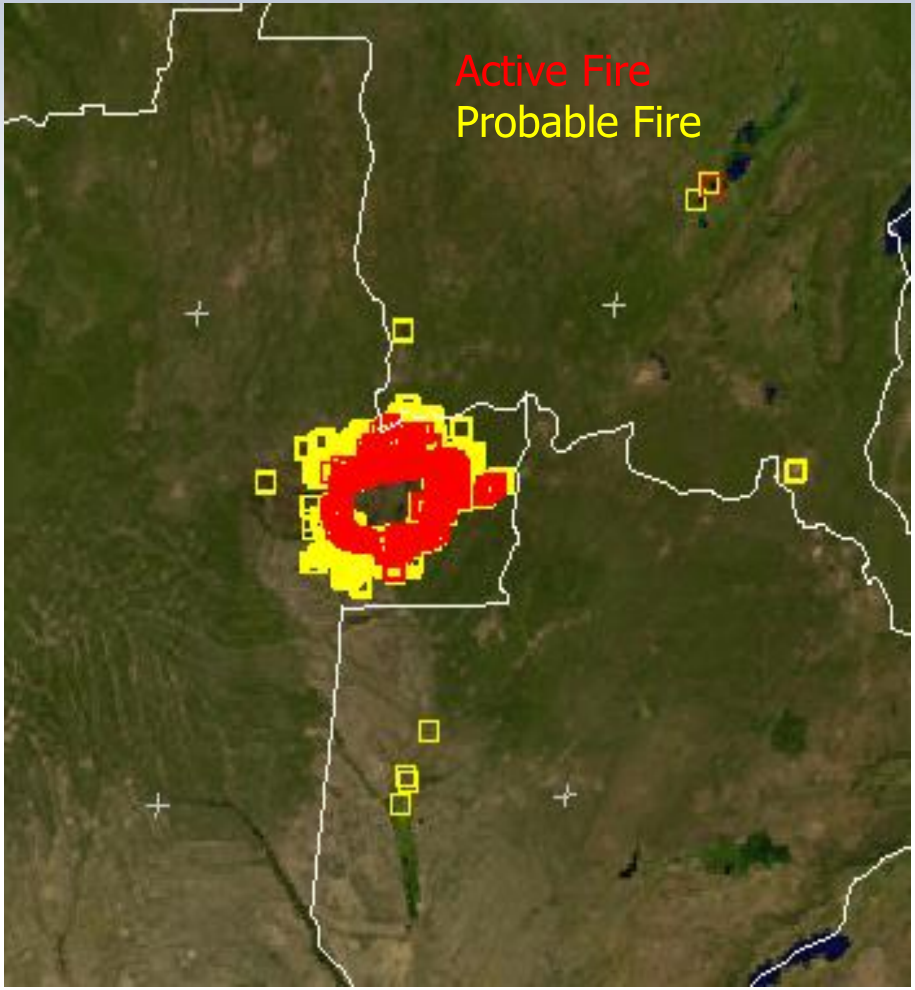
Threshold well exceeded => active fire

Close to thresholds => probable fire

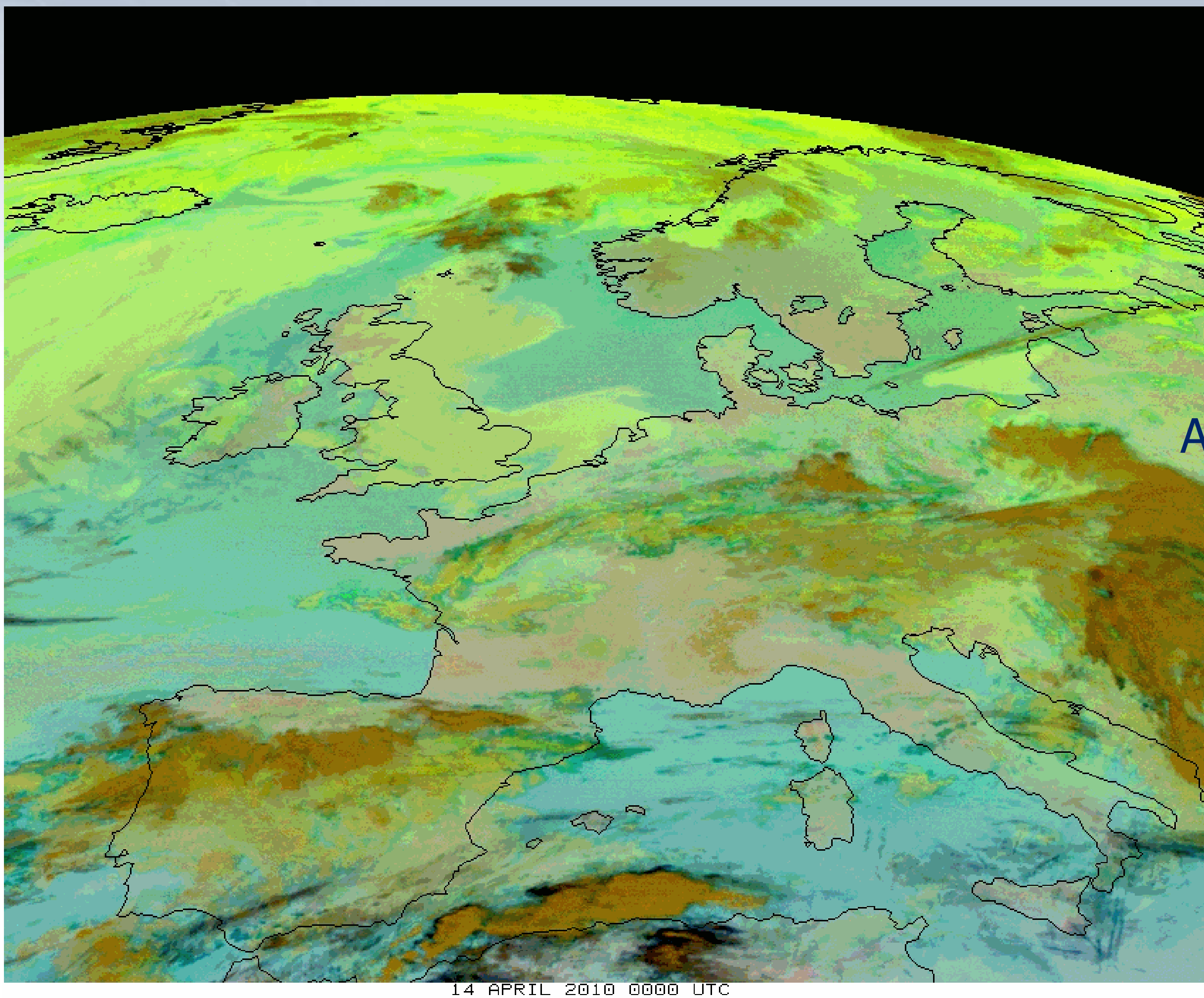
Application: Nowcasting (limited), climate

Product Limitation

Product Limitation: Extreme Sunglint



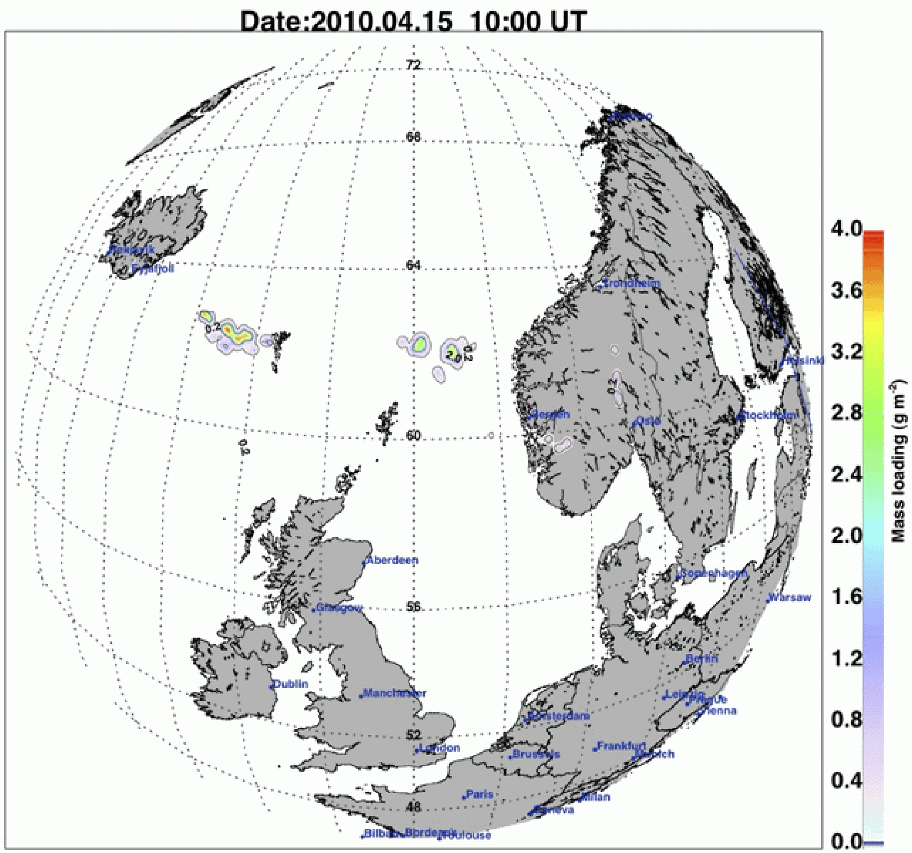
Volcanic Ash Product: RGB



Application: Air Traffic Control, VAACs

This is an example where a skilled human forecaster would better detect ash than any current algorithm

Volcanic Ash Product: Mass Loading



Source: Fred Prata, NILU

Application:

To be used with other information!

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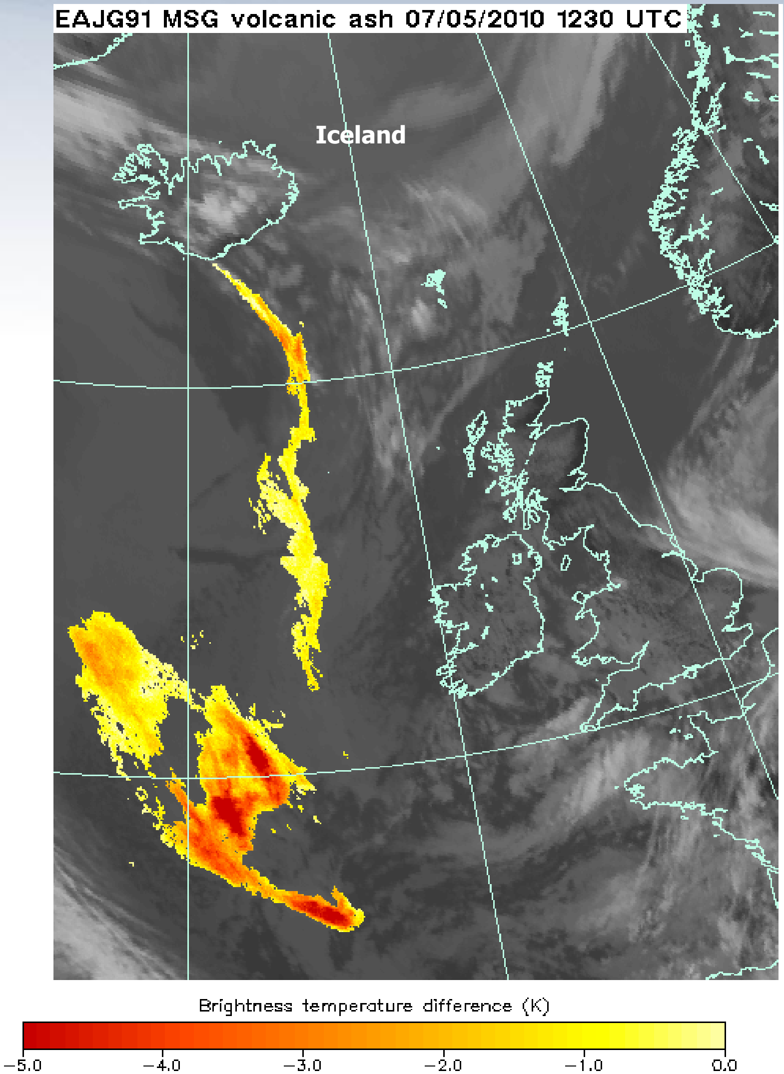
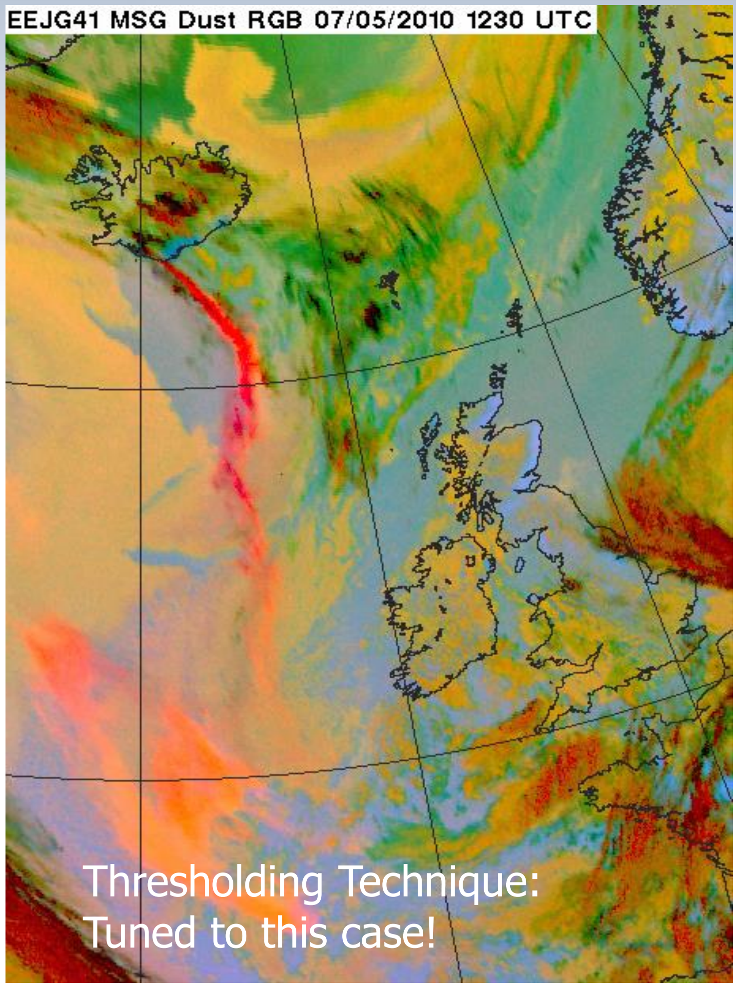
Problem: Reliable Ash Detection





Other Products

In support to international datasets:

- ISCCP (International satellite cloud climatology project)
- GPCP (Global precipitation climatology project)

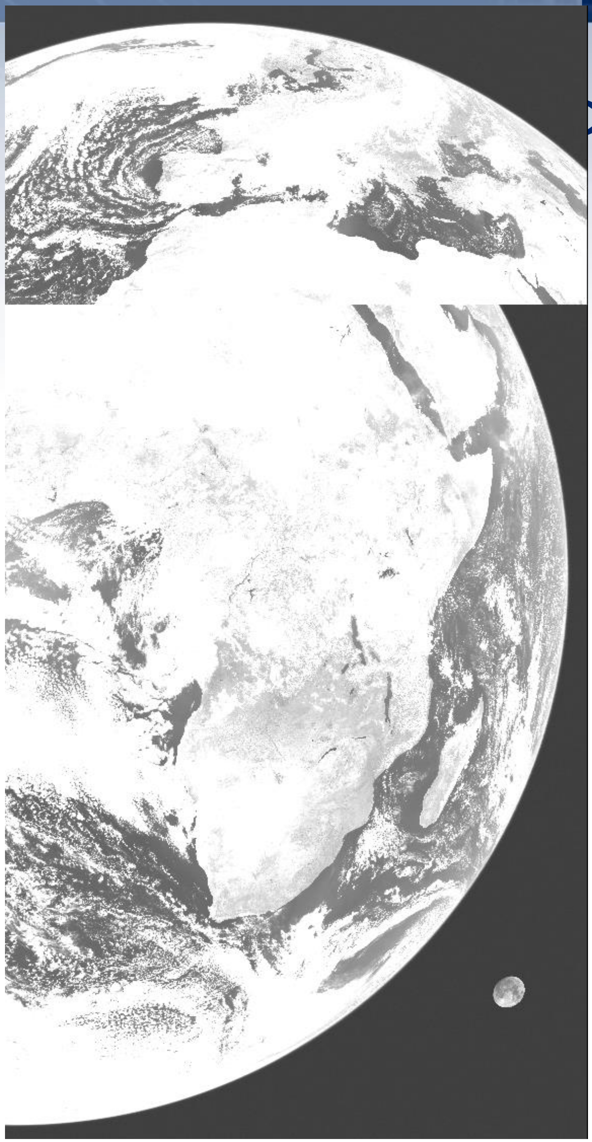
In support to calibration:

- Calibration scheme for the solar channels (no onboard functionality)
- Calibration monitoring of infrared channels (comparison with SSTs)
- Daily inter-calibration with IASI

Calibration of Solar Channels

Various techniques in place, moon is one example:

Calibration of Solar Channels

Varioce, moon is one example:

Raw HRVIS image with moon in SE corner

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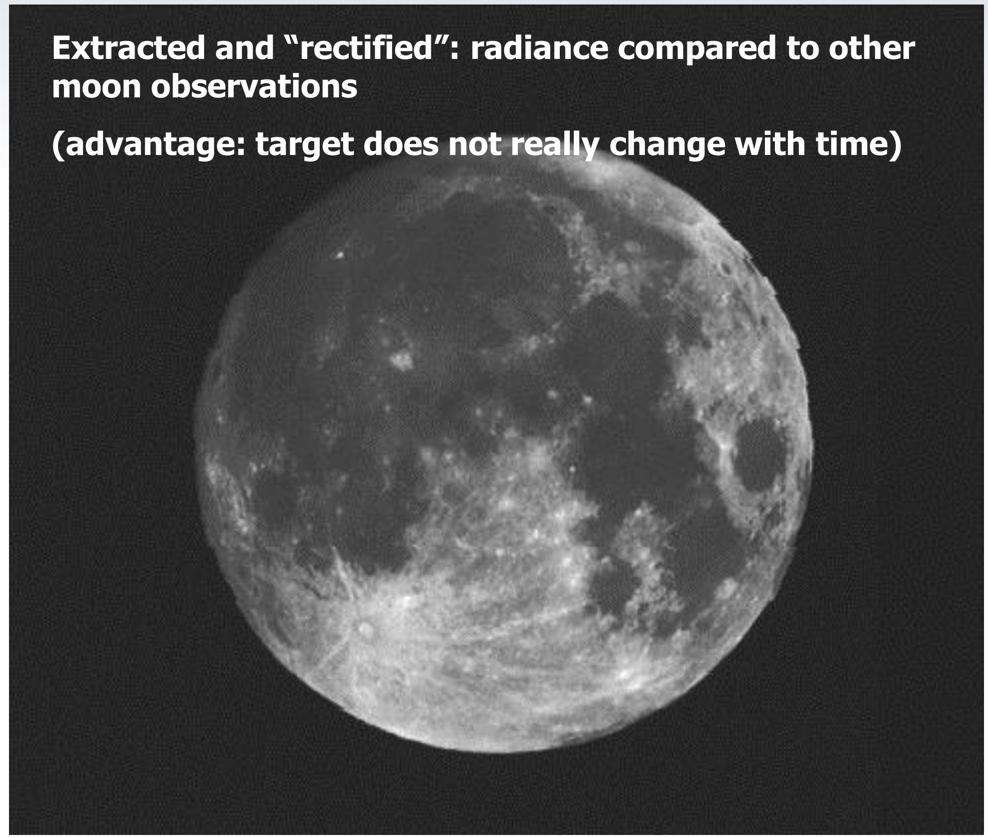
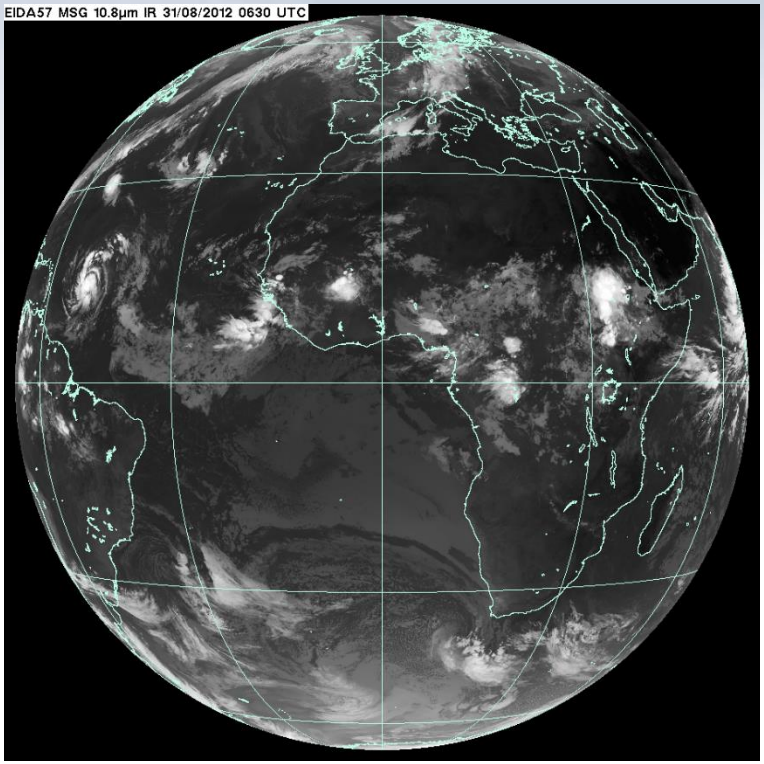
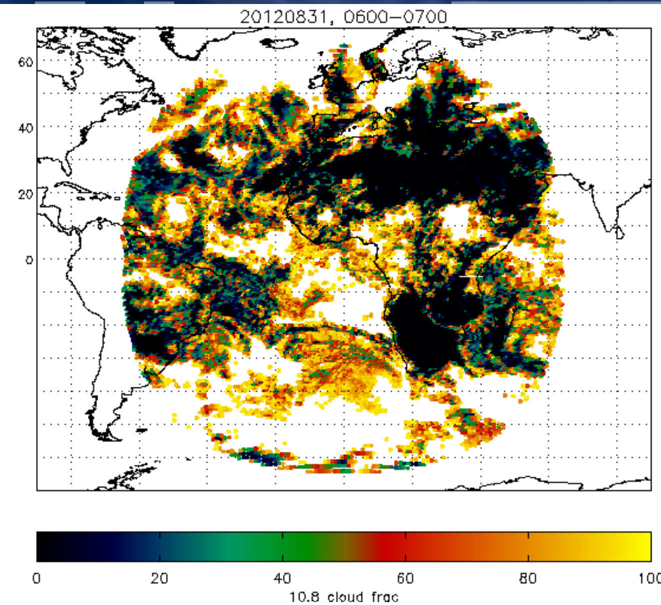
Calibration of Solar Channels

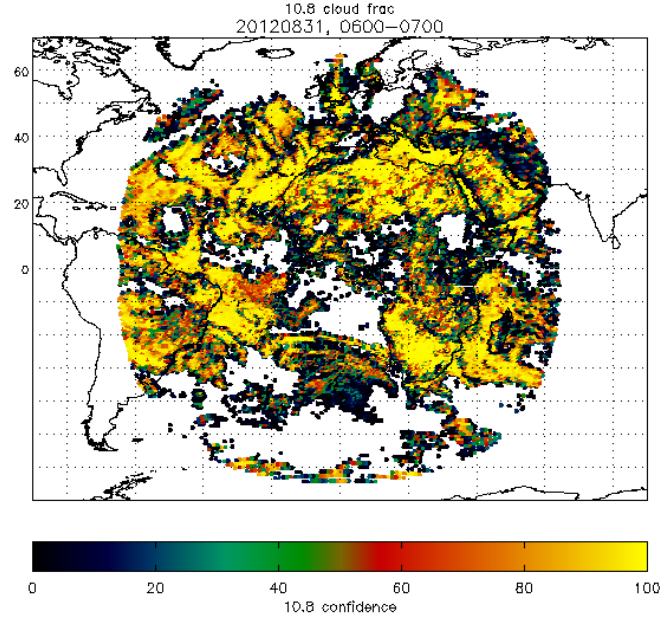
Vario e, moon is one example:



Product Limitation: Quality of Input Data







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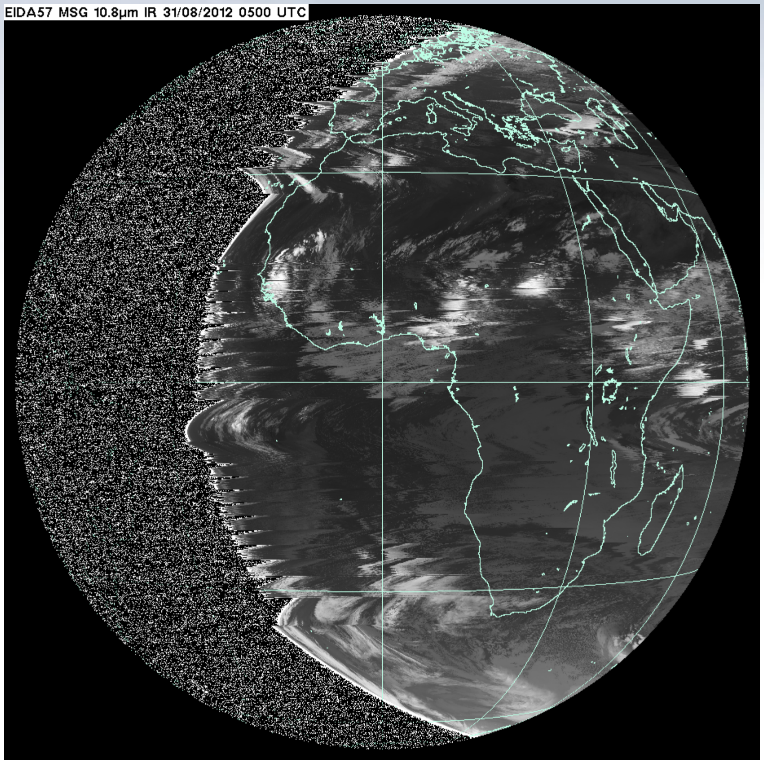
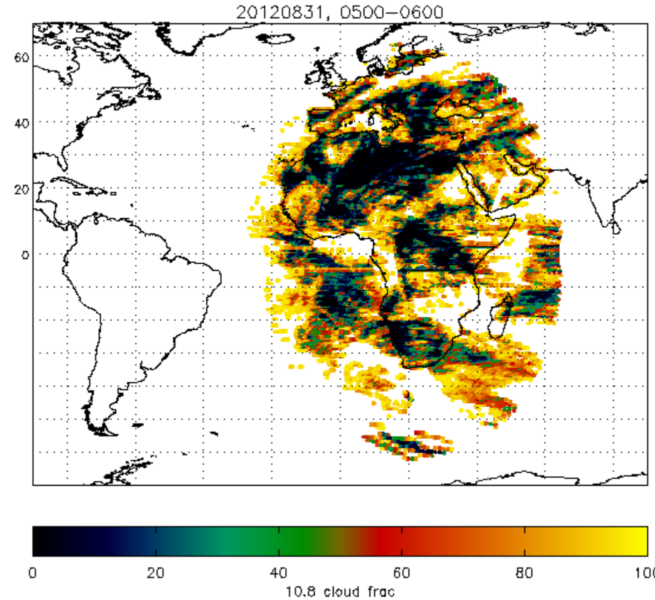
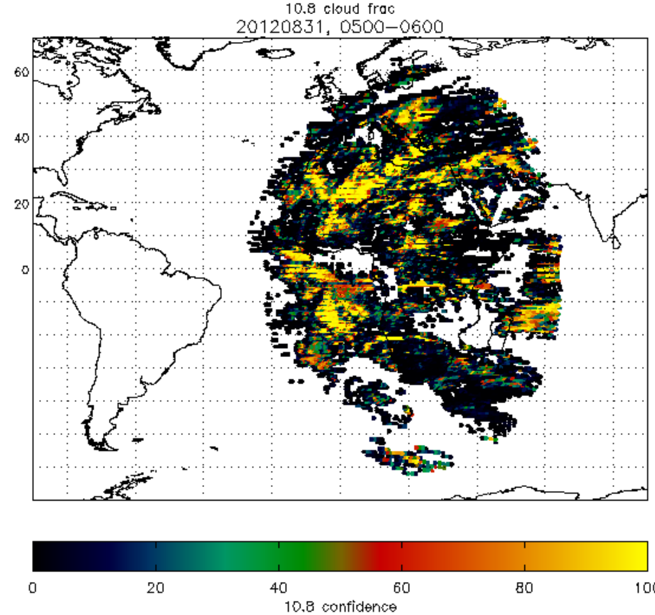
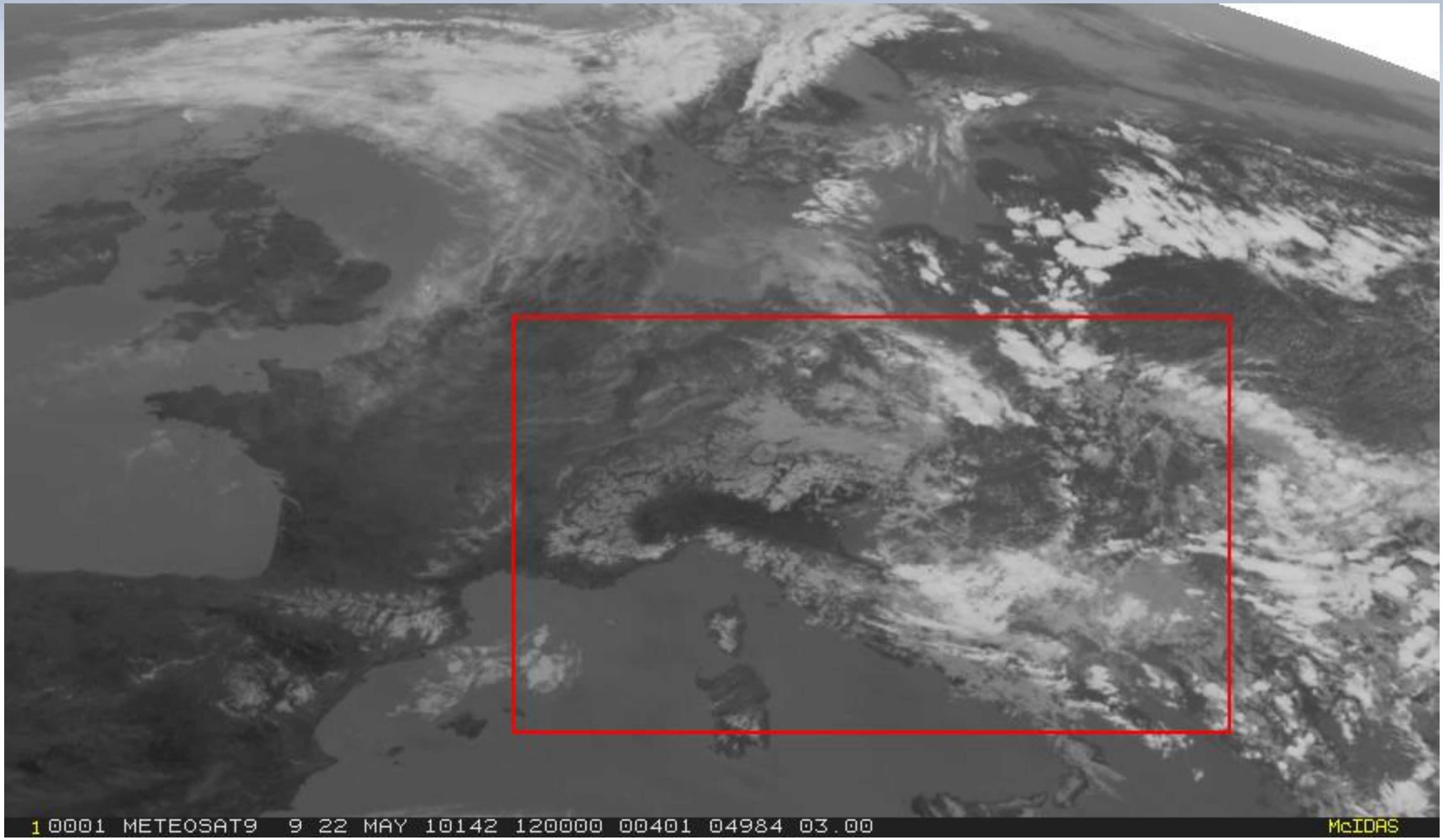






Product Limitation: Resolution



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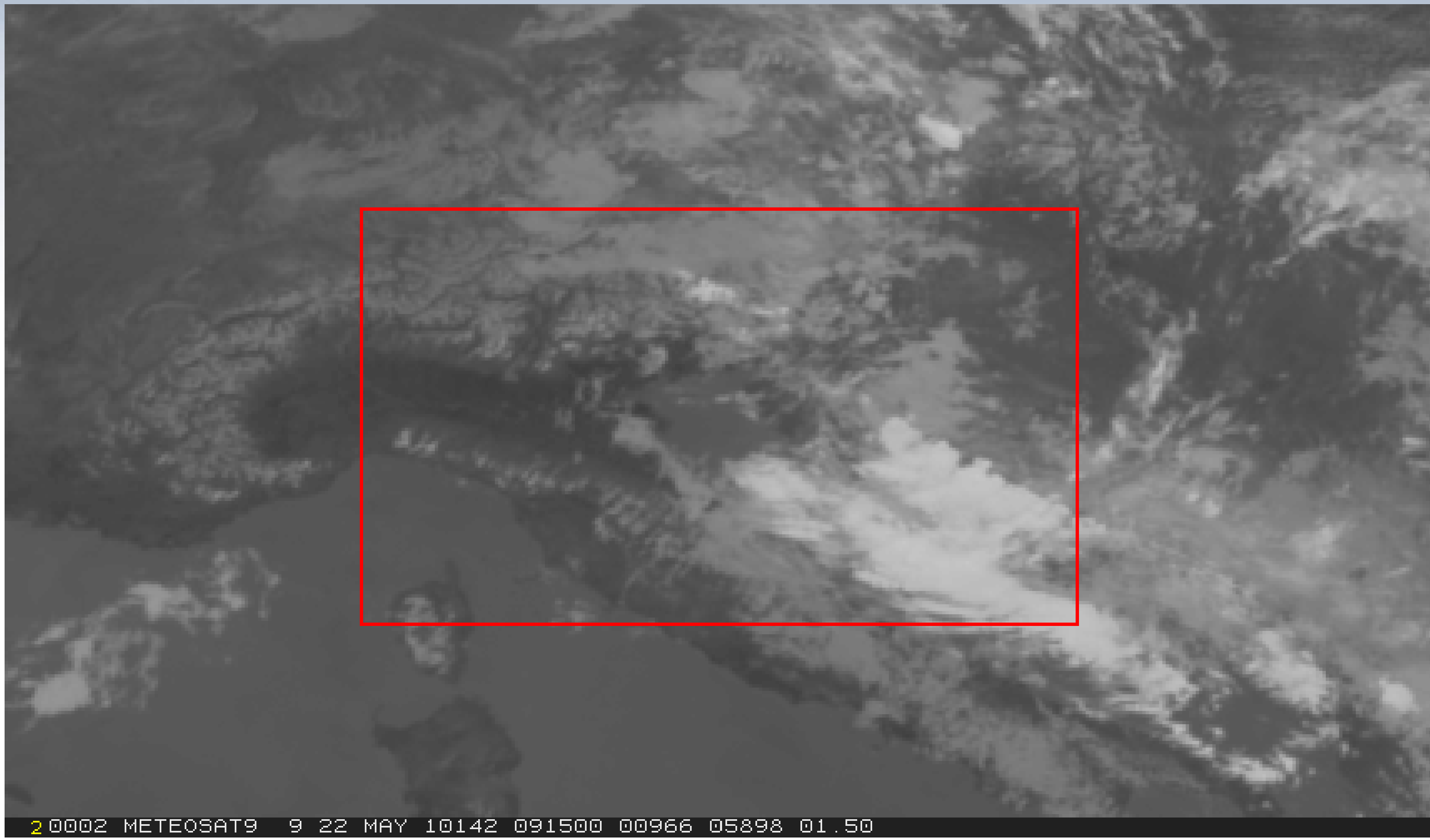
Product Limitation: Resolution



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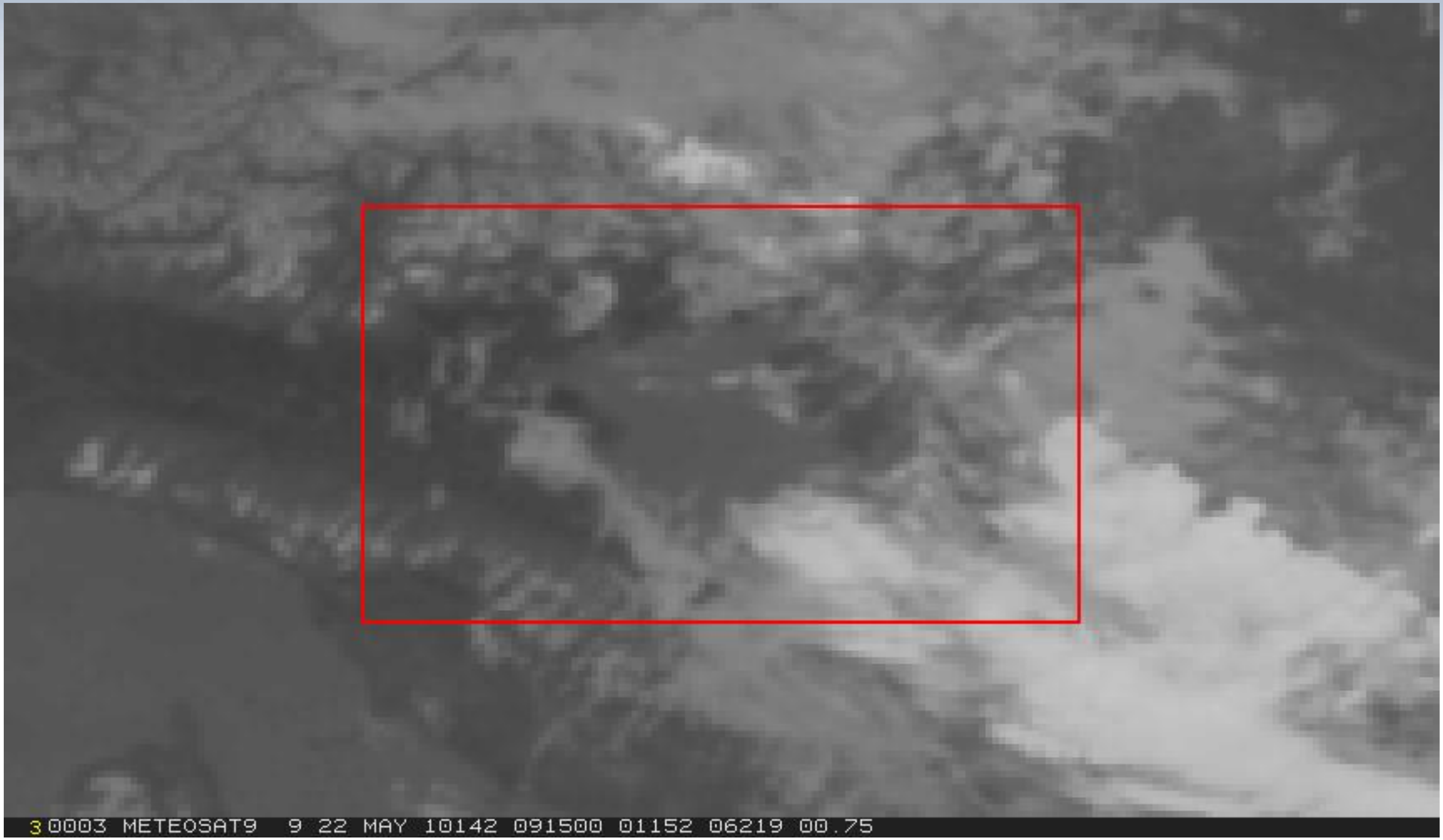

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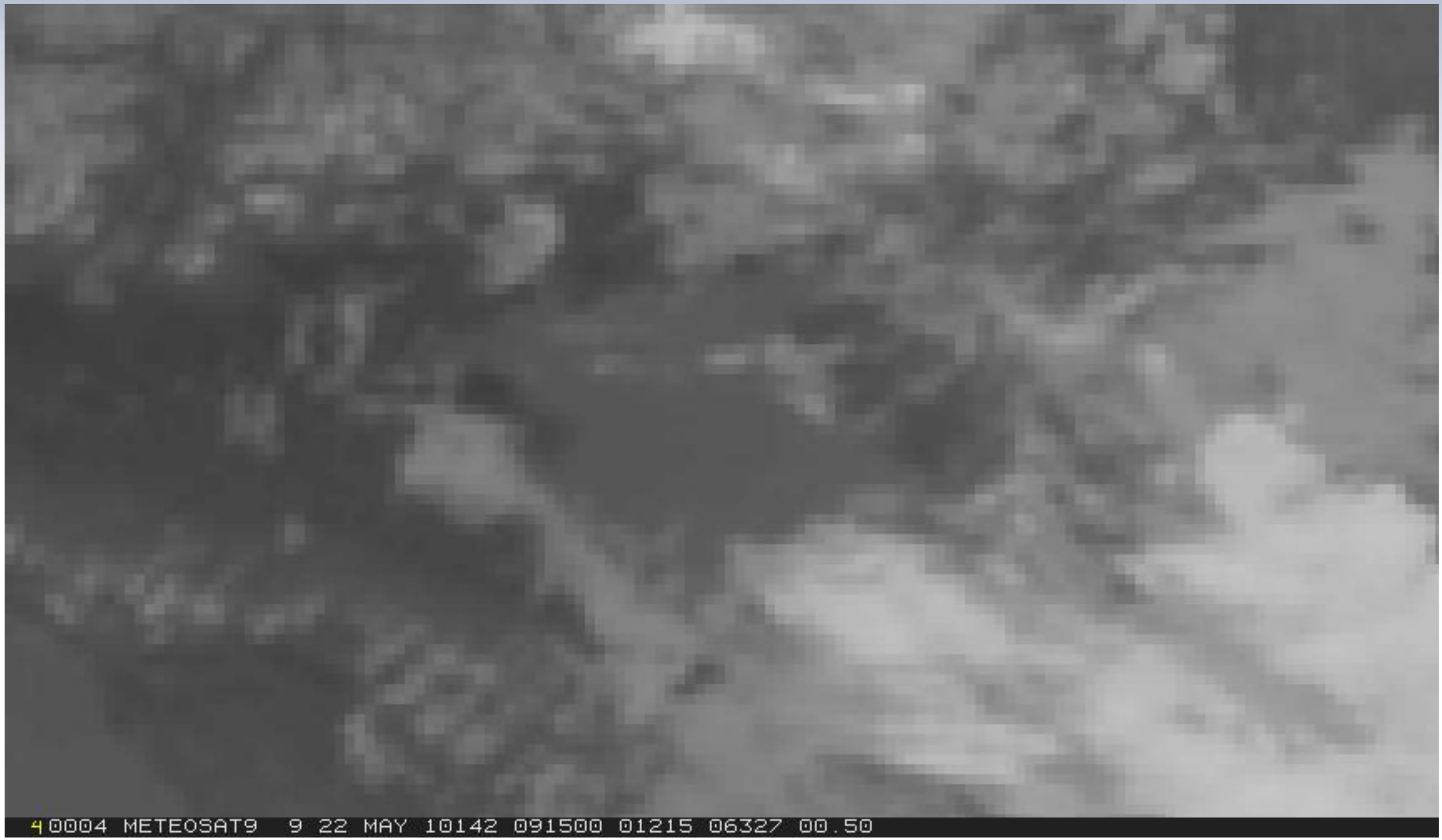
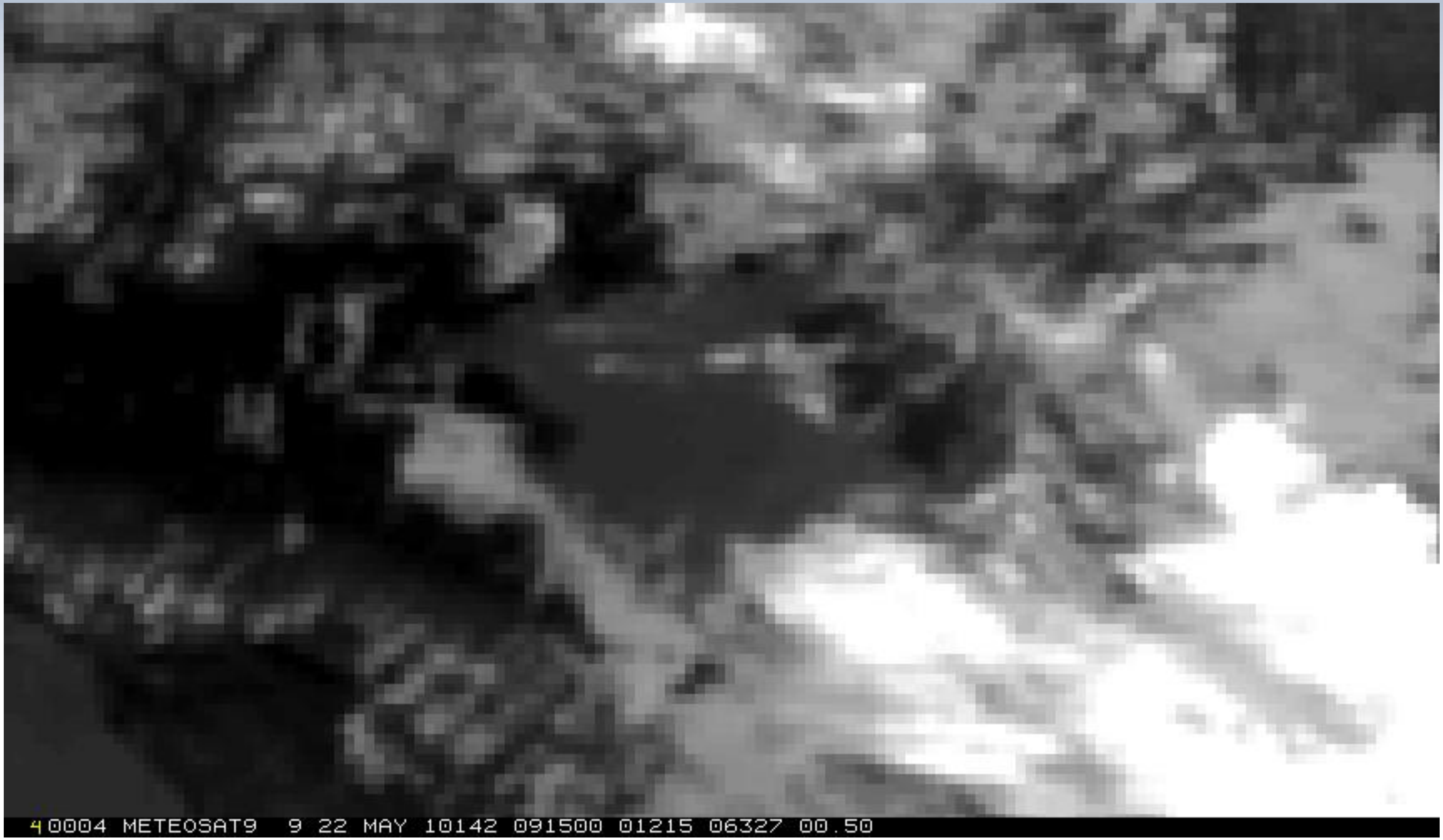
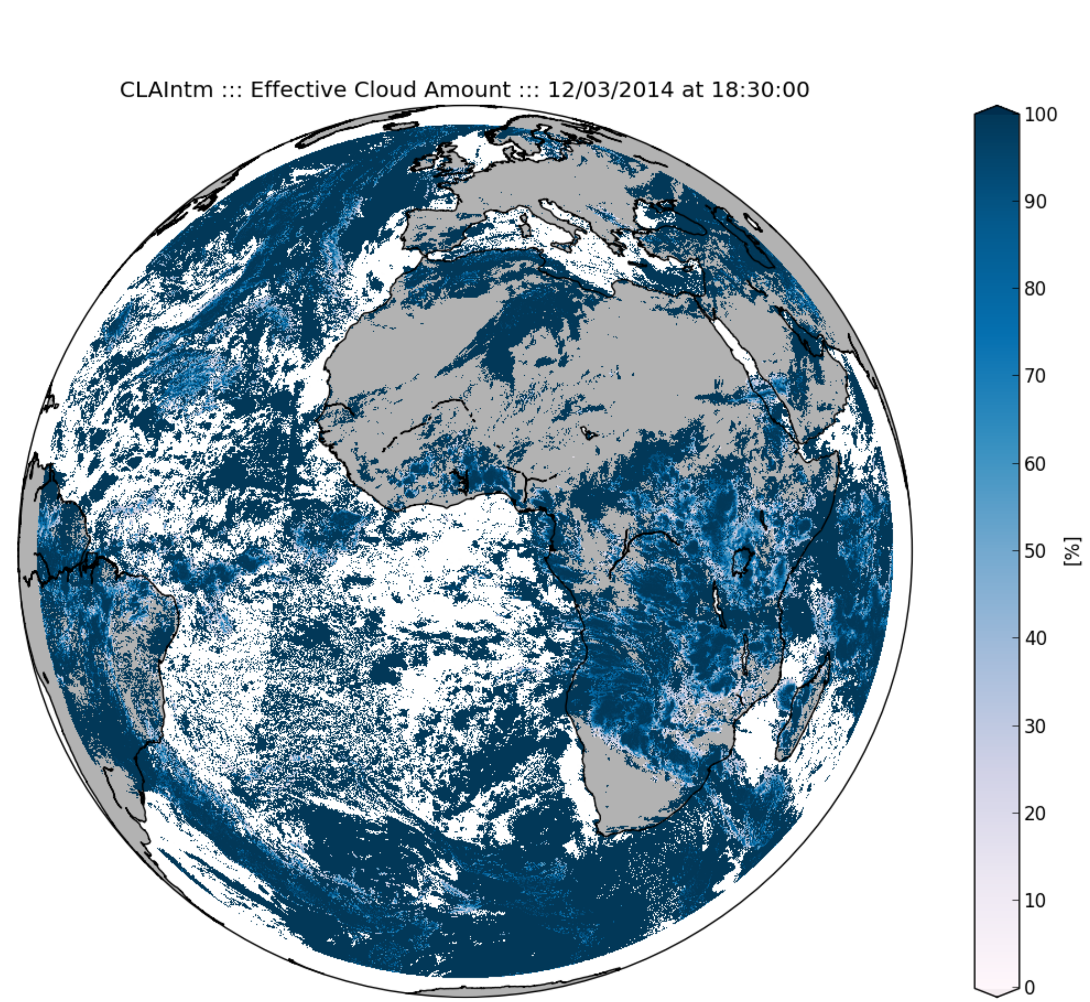
Product Limitation: Resolution



Product Limitation: Resolution



Product Limitation: Day – Night Problem



Example:

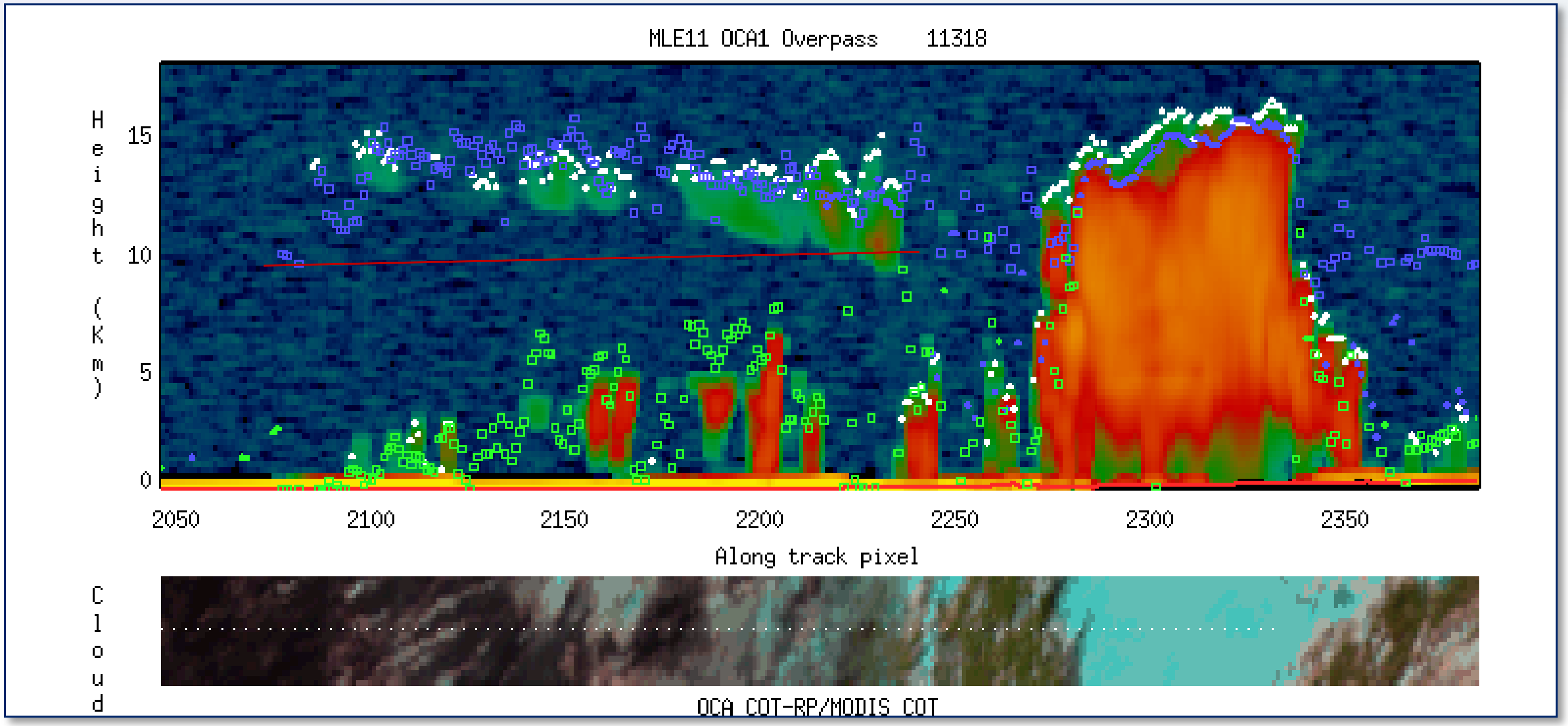
Cloud detection using VIS and IR channels at daytime, only IR channels at night:

"Terminator" shows up in the product

(more clouds are detected with IR+VIS than with only IR)

Product Limitation: Multi-Layer Cloud Situations

There is hope – using suitable optimal estimation schemes:



Cloudsat
and MSG cloud products

MSG RGB

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Thank you

for your attention!

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