Agencia Estatal de Meteorología

EUMETSAT NWC SAF
SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING

Preparation of MTG era.

VIS0.9 & VIS0.8 for estimation of integrated precipitable water vapour

Miguel-Angel MARTINEZ

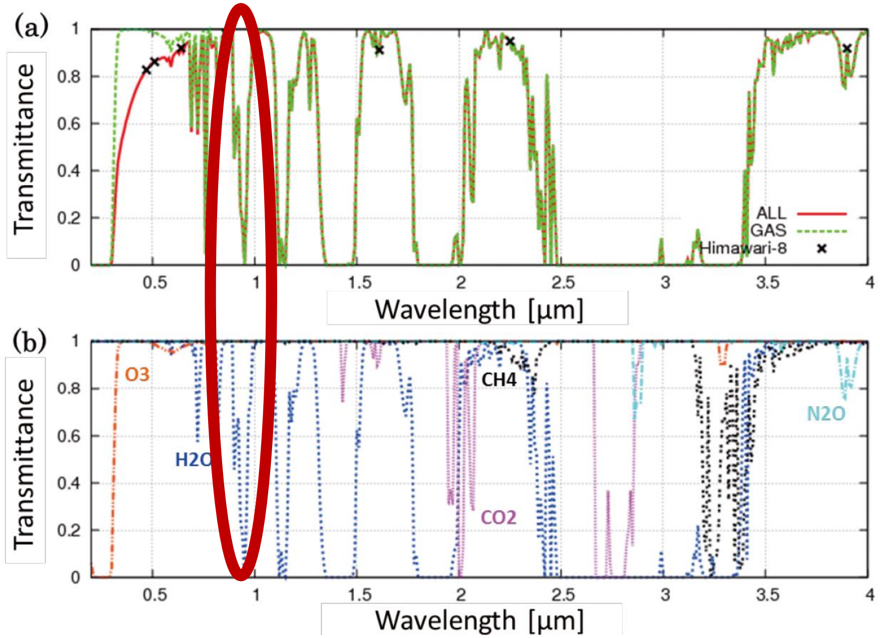
AEMET

mmartinezr@aemet.es

Index

- ✓ Introduction to FCI VIS0.9 channel
- ✓ 1st FCI case of log(VIS0.8)–log(VIS0.9)
  - ✓ 2023-06-27 on Sahara region. Loops real and synthetic.
- ✓ Use of synthetic case to show log(VIS0.8)–log(VIS0.9) to determine physical meaning
  - ✓ Synthetic FCI tests with DestinE model on Ianos medicane case study.
  - ✓ Experiments of FCI with different clouds layers.
  - ✓ physical meaning => TPW on clear pixels and precipitable water content above cloud top on cloudy pixels.
- ✓ Case study 2nd August 2024
  - ✓ log(VIS0.8)–log(VIS0.9) and different with previous hour structures
- ✓ Case study over Ocean.
  - ✓ Hurricanes Kirk and Leslie
- ✓ Transmissivity and weighting functions.
  - 8th January 2024 case study. Very dry profiles.
- ✓ Conclusions
- ✓ outlooks

Fundamentals of VIS0.9 and VIS0.8 channels for total precipitable estimation

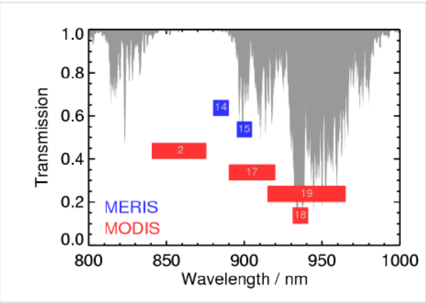


- Atmospheric transmission ≈ exp(IWV)
- Satellites do not measure atmospheric transmission → T is approximated using the radiance ratio of one window and one absorption channel

$$L_{win} = S_0 \cdot A$$

$$L_{abs} = S_0 \cdot A \cdot T^2$$

L: TOA-radiances
S_0: Solar constant
A: Surface albedo (win == abs?)
T: Atmospheric Transmission



- Simulation of L_{win} and L_{abs} for a large number of atmospheric profiles of temperature and aerosol optical properties:

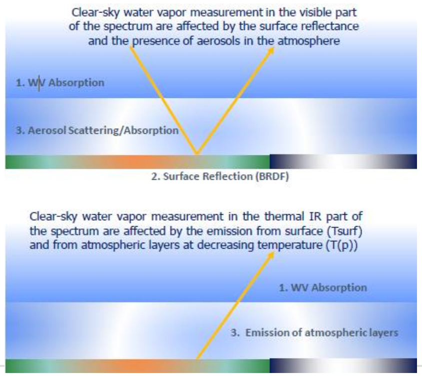
  IWV → L_{abs} / L_{win}

- Inversion using look-up tables or multidimensional non-linear regressions:

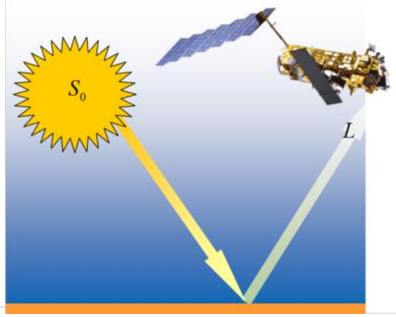
  L_{abs} / L_{win} → IWV

Taken from Rene Preusker (FUB) presentation using ENVISAT/MERIS data in 2007 NWCSAF Workshop link

MTG-I/FCI VIS0.9 is a visible water vapor absorption channel.
It is located in a weak water vapor absorption band.



Measured transmission is an exponential function of the amount of transmitted absorber mass *s*



$$T = L / S_0$$

$$T = e^{-\tau}$$

$$\tau = \beta_{ext} \cdot s$$

$$\Rightarrow$$

$$\ln T \propto s \quad (water\ vapour)$$

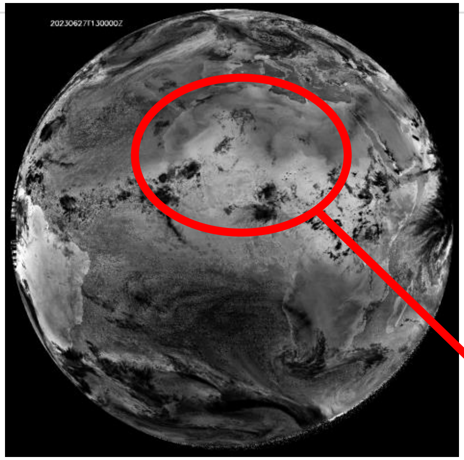
Transmisión ∝ exp(-k*IWV)

log(Transmisión) ∝ IWV

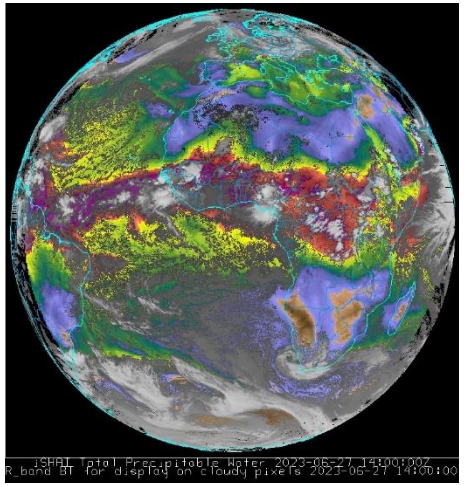
Atmospheric transmission can be estimated using the ratio of an in-band absorption channel (VIS09) to a nearby window channel (VIS08)

Or the difference of the logarithms

Comparison of iSHAI TPW and real MTG-I/FCI estimation of TPW using log(VIS0.8/VIS0.9)



≈ one pixel every 11x11

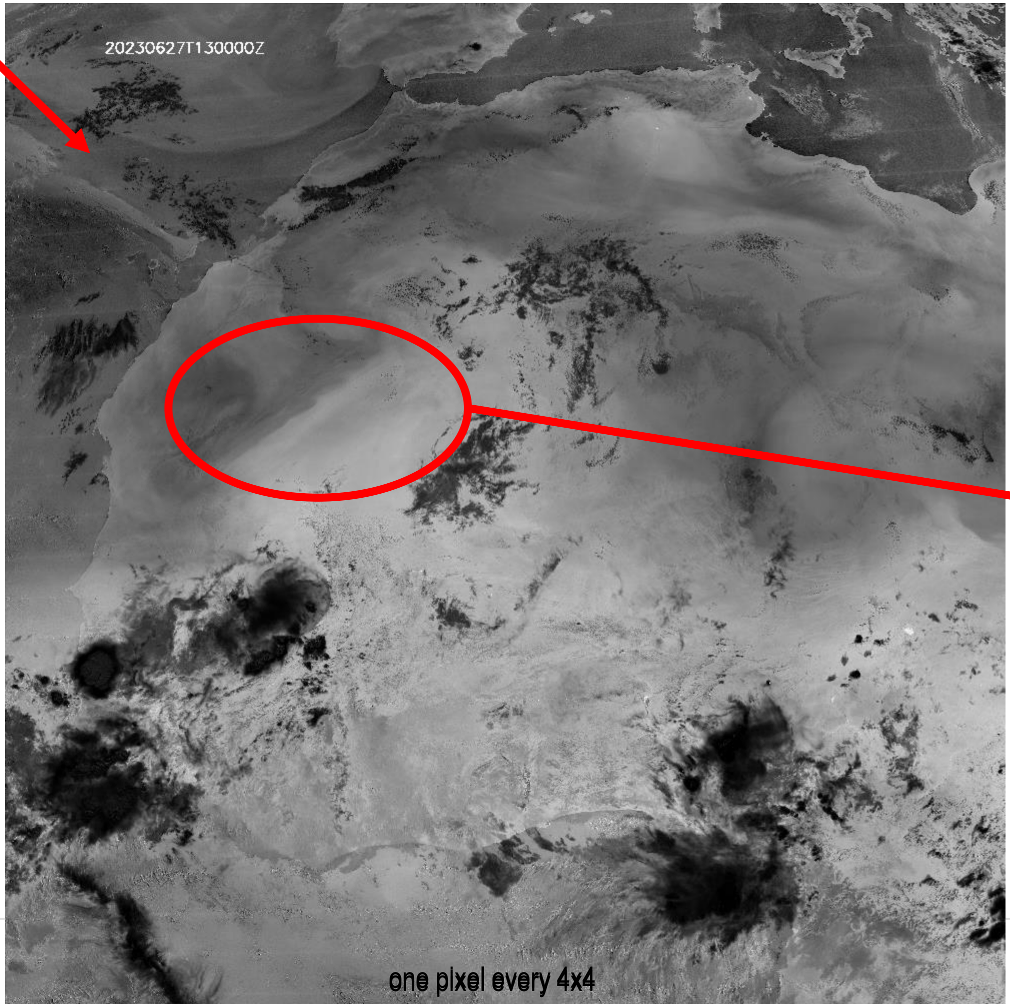


NWCSAF iSHAI TPW

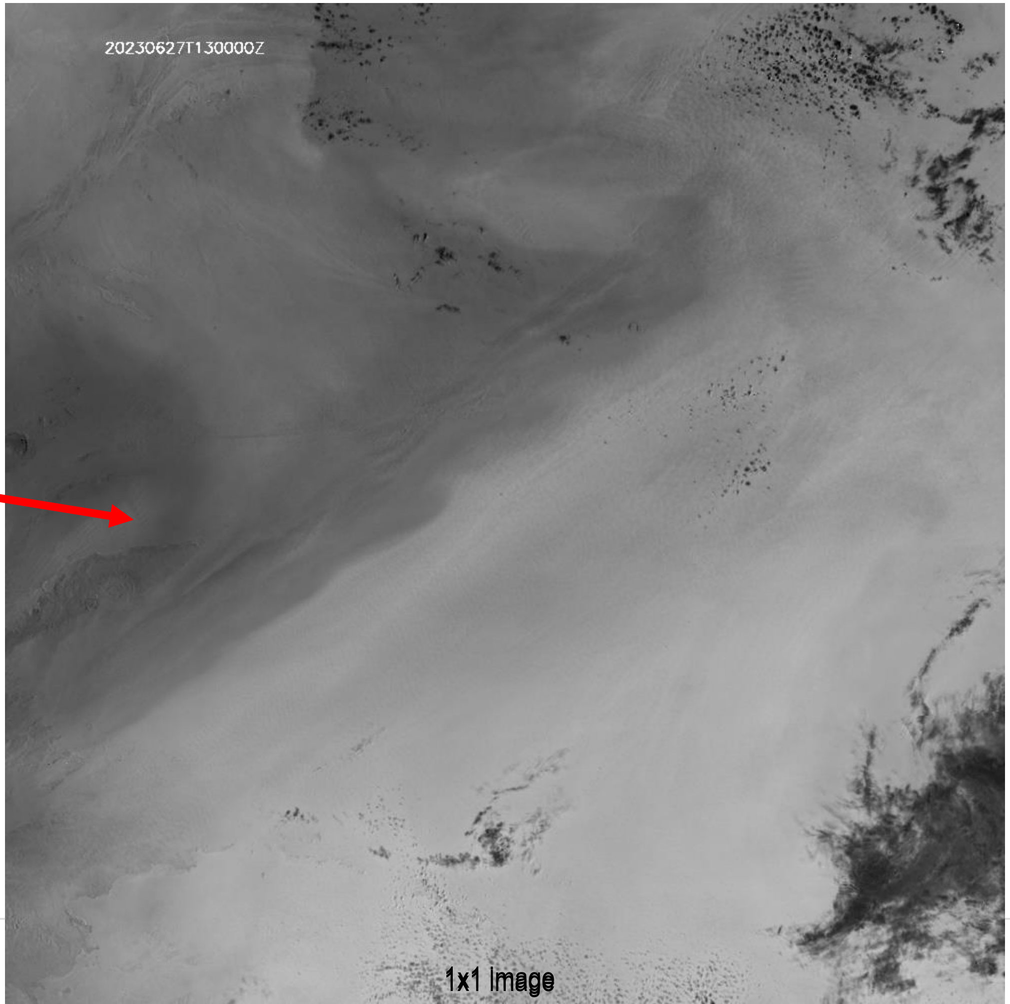
See loops in this link

MTG-I1/FCI 2023-06-27 at 13:00Z

log(VIS0.8)-log(VIS0.9) scaled in range [0, 0.8]

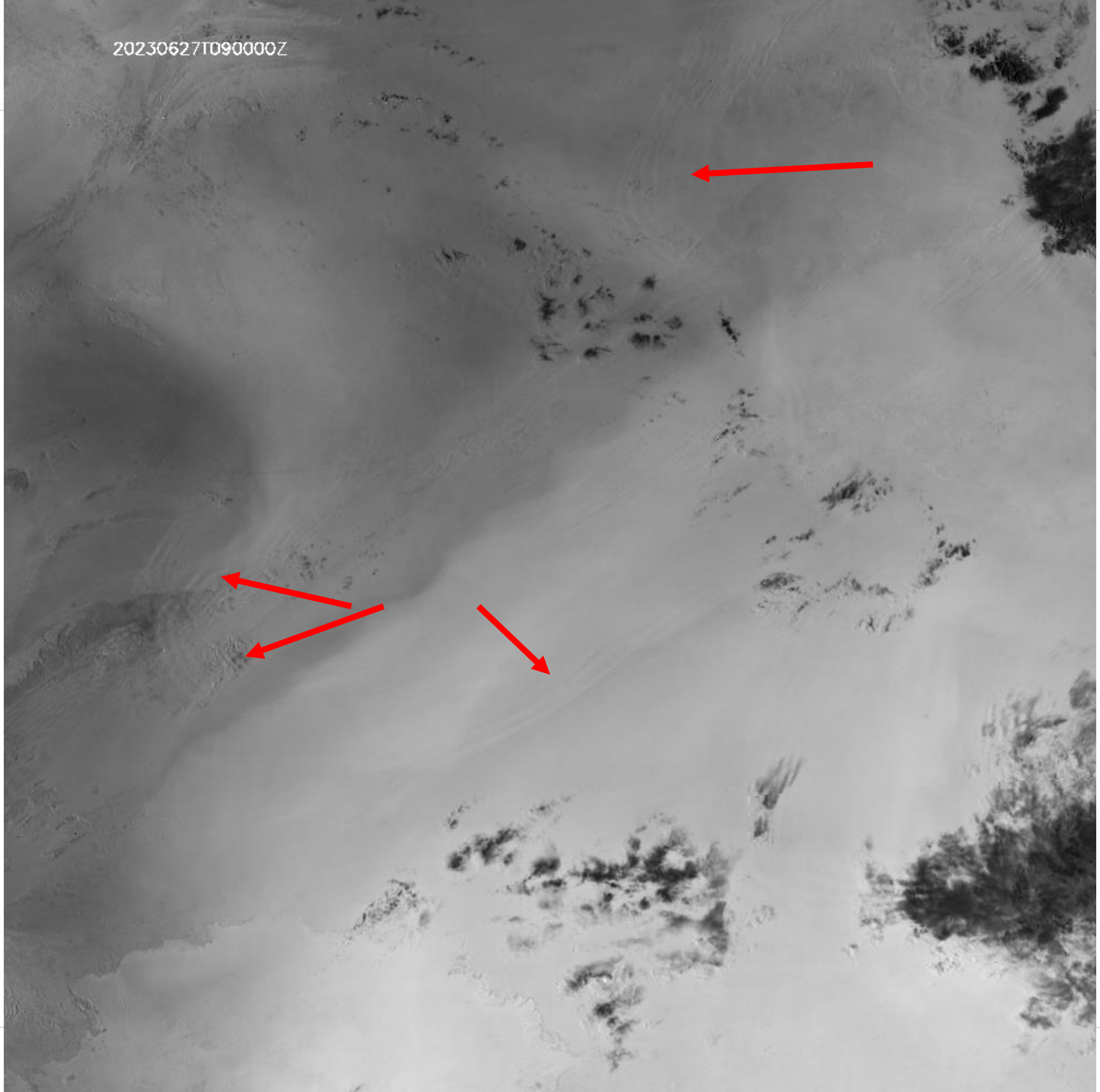


one pixel every 4x4

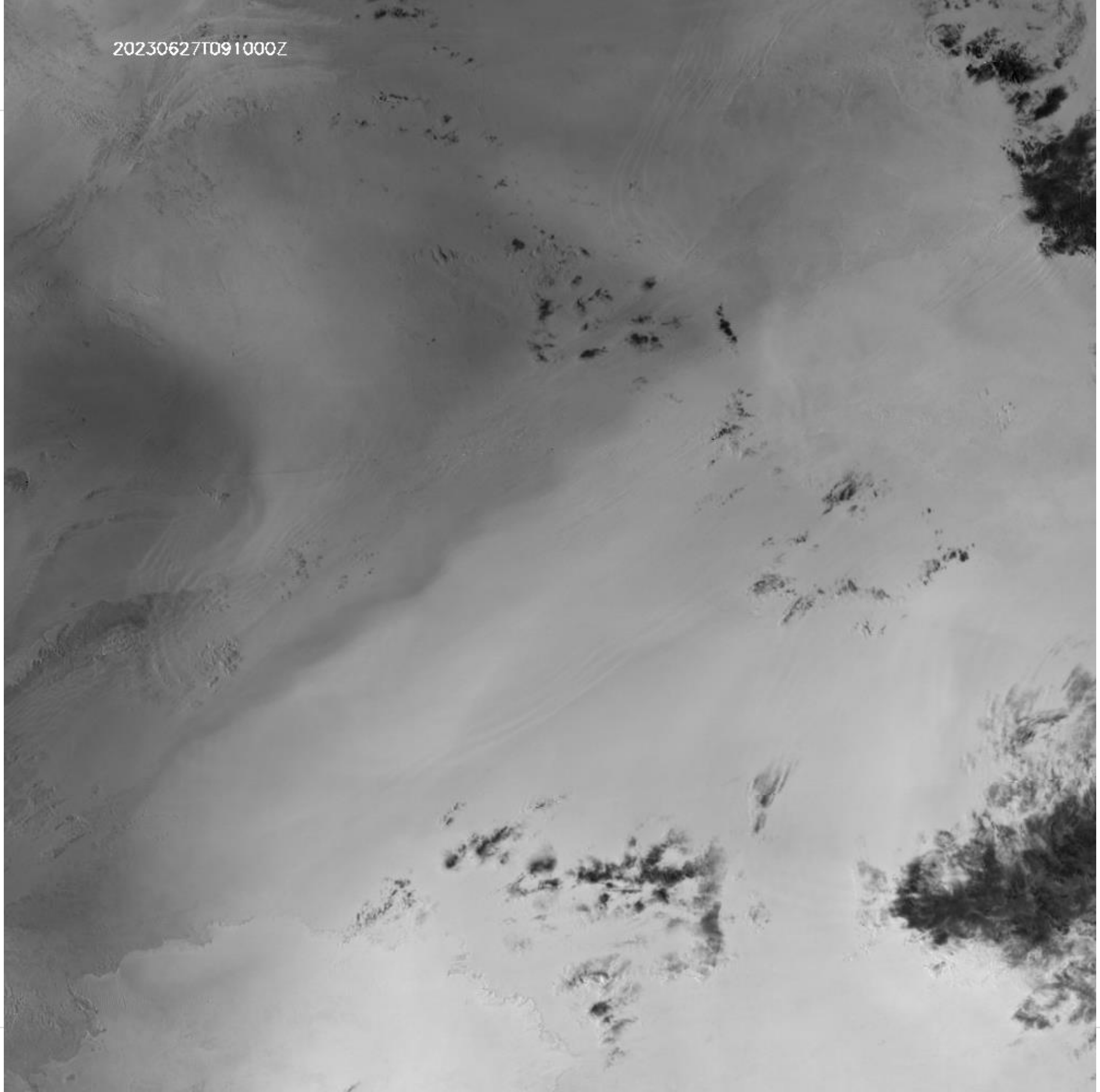


1x1 image

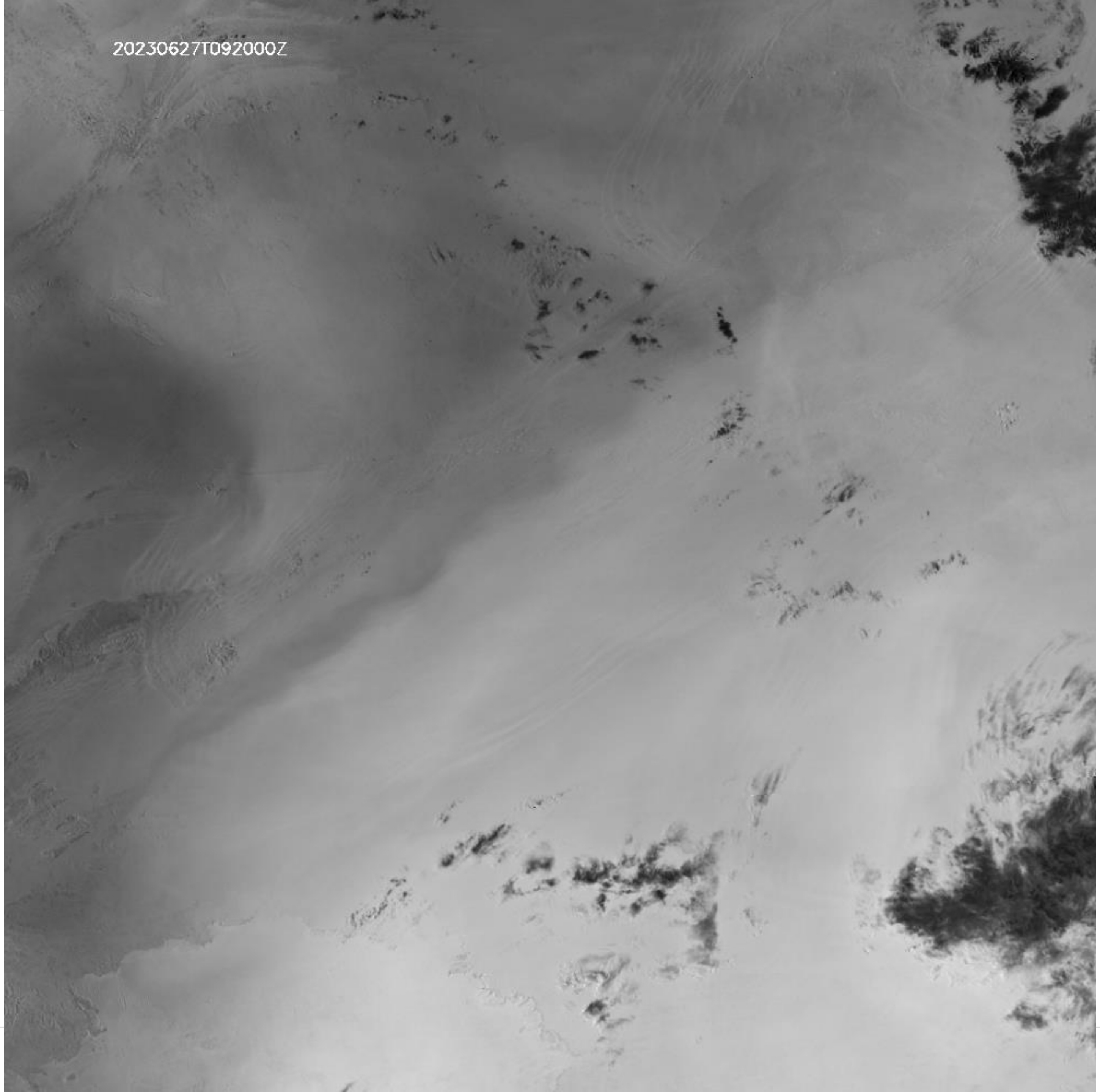
log(VIS0.8)-log(VIS0.9)
scaled in range [0, 0.8]



log(VIS0.8)-log(VIS0.9)
scaled in range [0, 0.8]



log(VIS0.8)-log(VIS0.9)
scaled in range [0, 0.8]



PGE00s programs with RTTOV-13.0 and operational NWP models on NWCSAF vMTG to generate the *first scientifically realistic synthetic MTG-I/FCI and MTG-S/IRS data*

The set of GEO-PGE00-* programs was updated to NWC SAF vMTG (1st version with **MTG-I/FCI grid projection** support) and it has been migrated to **use RTTOV13.0**

GEO-PGE00-VISIR generates **high quality simulation of MTG-I/FCI** (or other imager instruments) **clear and cloudy BTs or reflectance.**

GEO-PGE00-hyper used **now** to make high quality simulation of **MTG-S/IRS** and **IASI** clear and cloudy BTs

First version of PGE00 programs that allows simultaneous generation of synthetic MTG-I/FCI, MTG-S/IRS and IASI radiance on MTG-I/FCI grid.

PGE00 programs and operational ECMWF model for MTG simulations.

Output files are binary files with Nx * Ny records for each position on the FOR (1x1 for FCI and 2x2 for IRS) on IR FCI grid (2x2 km at nadir).

Each record contains:

- ✓ $radiance_{clear}$,
- ✓ $radiance_{cloudy}$,
- ✓ Profiles from NWP at the 54 RTTOV levels: T/q/ozone/cc/clwc/cwic/u/v
- ✓ Surface fields from NWP: P_{sfc}, T_{sfc}, T2m, q2m
- ✓ Ancillary fields: longitude, latitude, topography, sun angles and GEO satellite angles at 0º.

It has been used with Operational ECMWF hybrid GRIB files, ECMWF high spatial resolution experiment, DestineE and Harmonie

In order to have data on 24 hours it is used 75º solar zenith angle during night.

PGE00 programs are highly modular and configurable. They are written in C and Fortran-90 (the core of the process is Fortran-F90).

PGE000 can be used at same time as NWP 4D (presure, time, longitude, latitude) interpolator of NWP GRIB files to satellite positions.

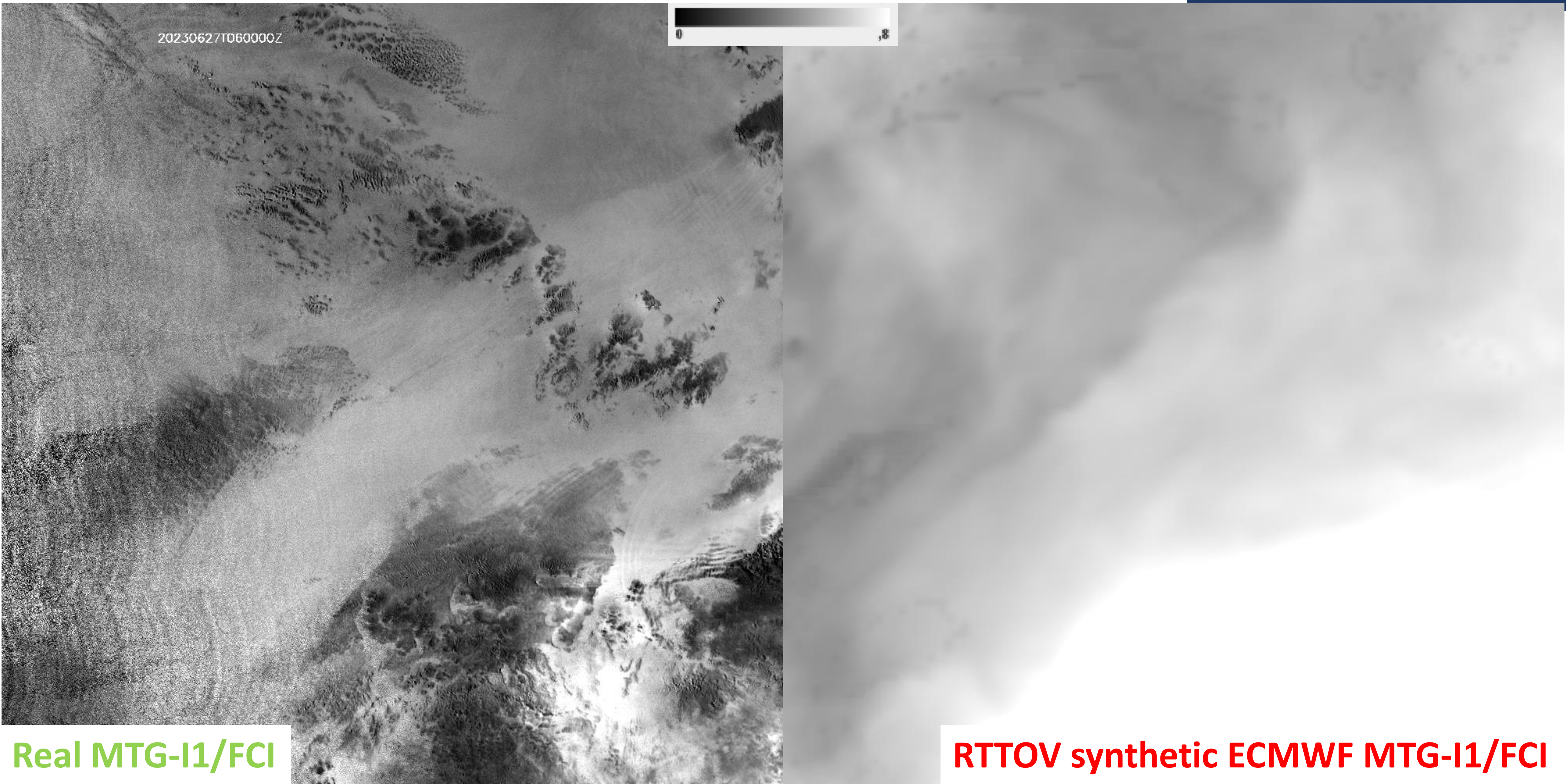
The main options are:

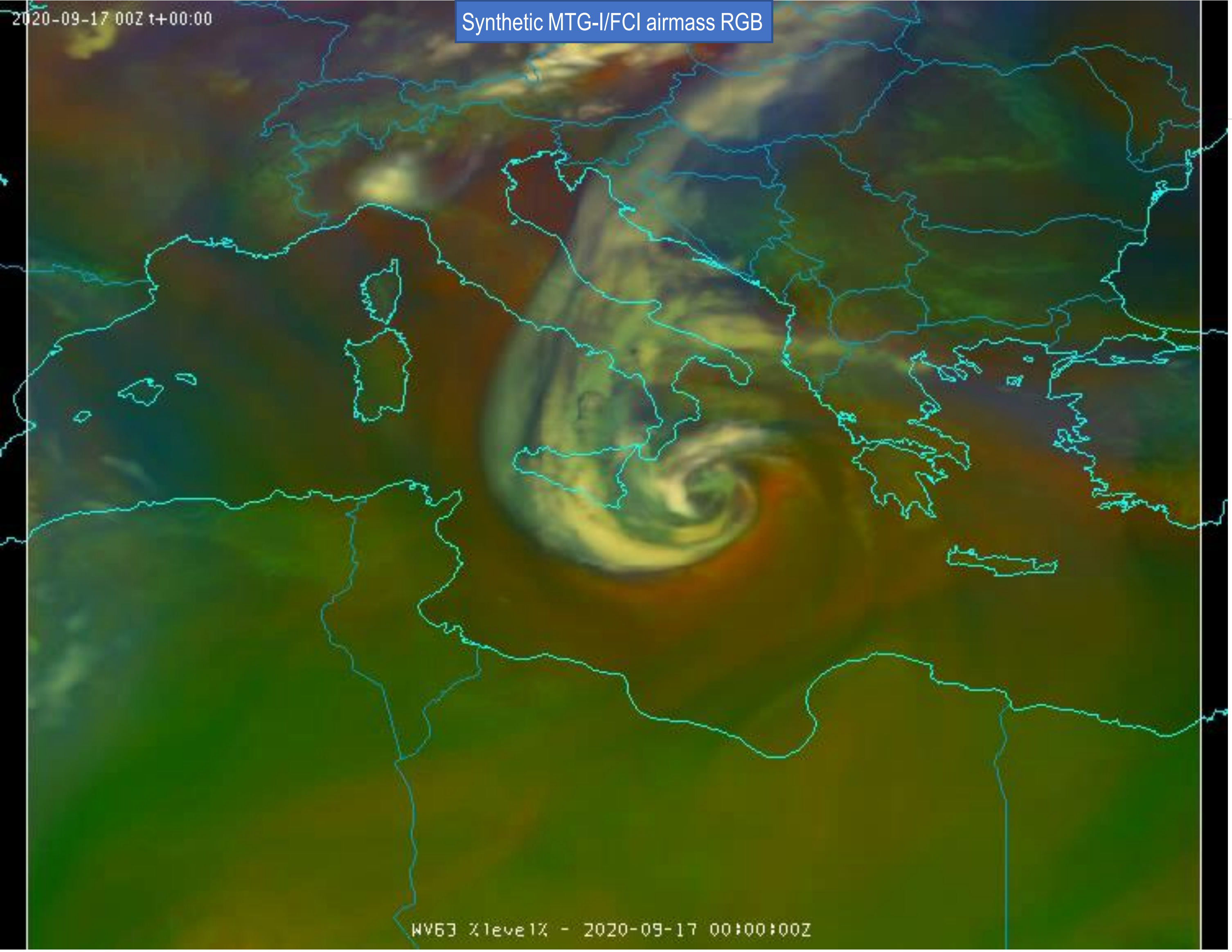
- ✓ The window size for processing in boxes of **M x M** pixels.
- ✓ optional writing: all pixels or just a clear pixels or a set of pixels.
- ✓ To write the profiles at the different steps: a) just read at hybrid level, b) interpolated/extrapolated at RTTOV pressure levels (or user's set of fixed pressure levels in case PGE00 with simple modifications), c) after temporal interpolation, d) using a cloud mask (or a set of predefined pixels), d) calculation of BTs for different satellites.

Loop with the comparison of real and synthetic RTTOV MTG-I/FCI TPW estimation

MTG-I/FCI TPW estimation calculated using **log(VIS0.8)-log(VIS0.9)**

2023-06-27 06:00Z to 18:50Z





DestinE ECMWF

synthetic
MTG-I/FCI
2020-09-17 00Z run
t+00 to t+24 forecast
*every **10** minutes*

DestineE high resolution model has spatial resolution of 1 km and temporal resolution 10 minutes.

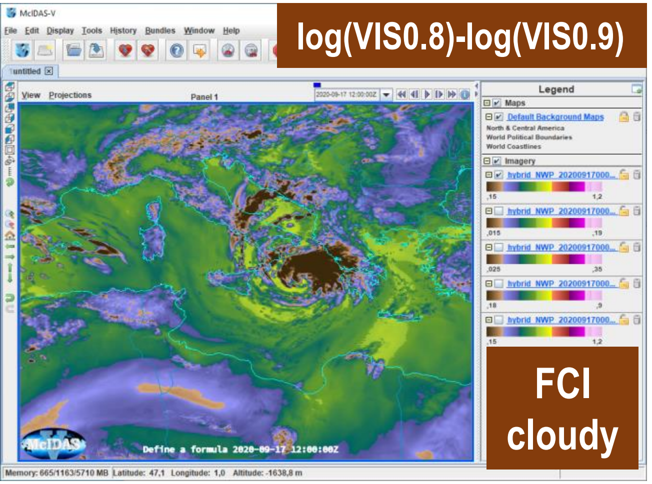
To speed up the generation of the synthetic FCI it has been used same IRS grid 0.04º x 0.04º but every 10 minutes

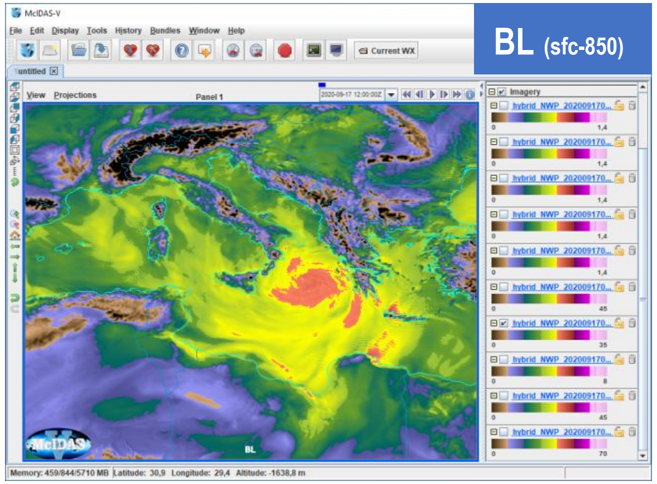
Also could be repeated with MSG/SEVIRI to compare with real MSG/SEVIRI images

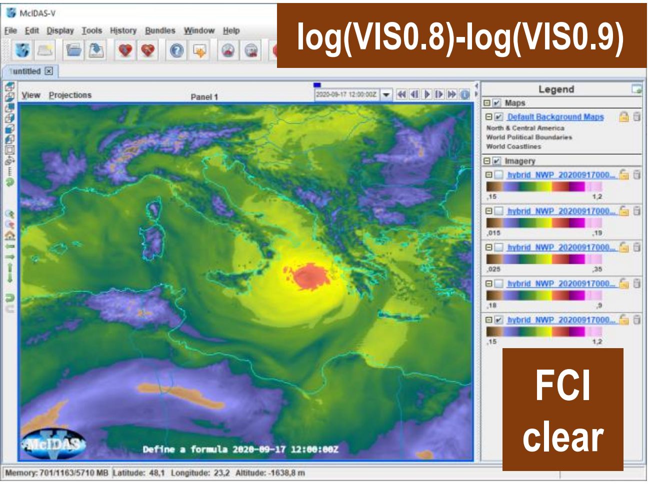
There is complete description of medicanes and IANOS case in EUMETrain
https://resources.eumetrain.org/satmanu/CMs/Medicane/index.htm

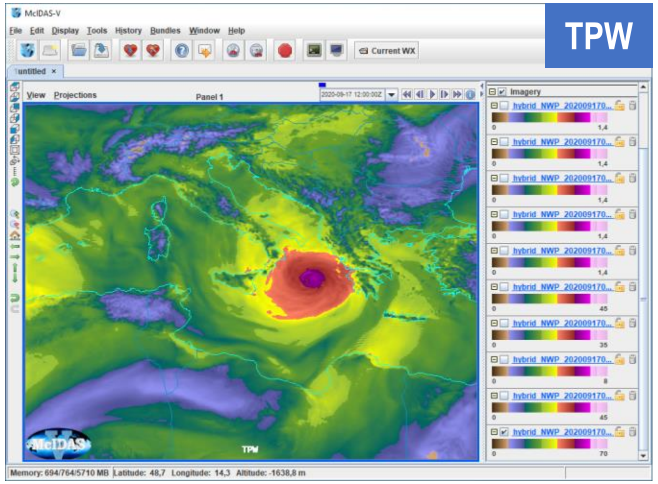
Thanks to DestineE team to provide GRIBs for IANOS case study

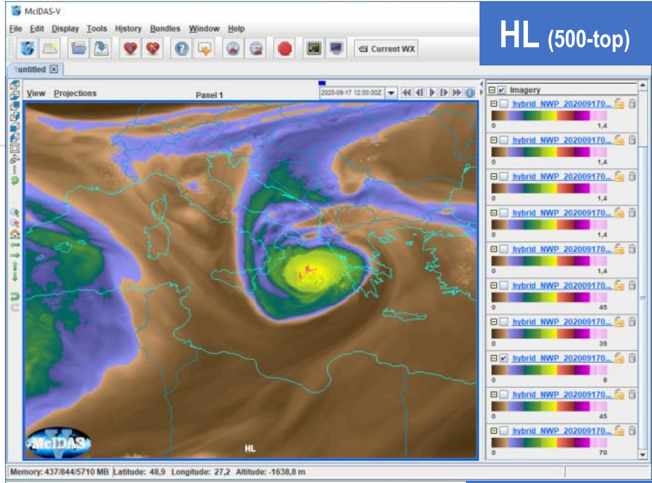
Control FCI simulation

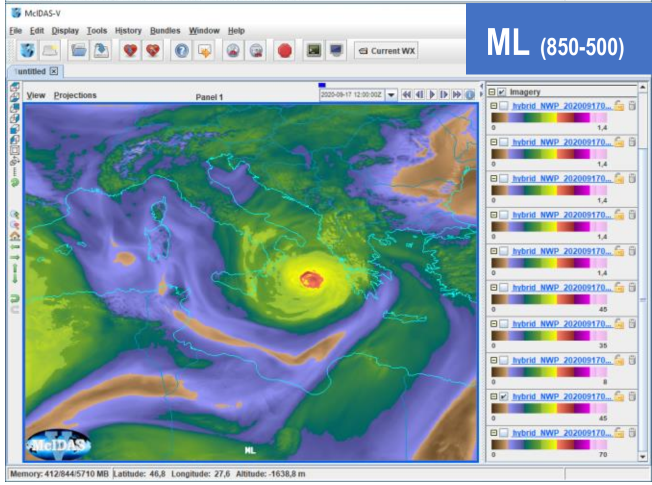


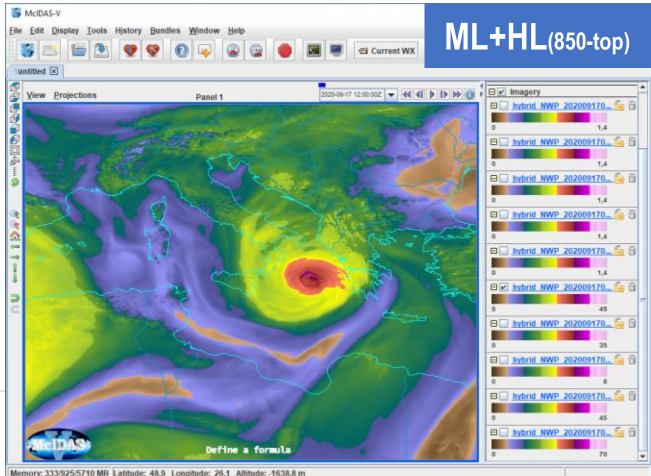






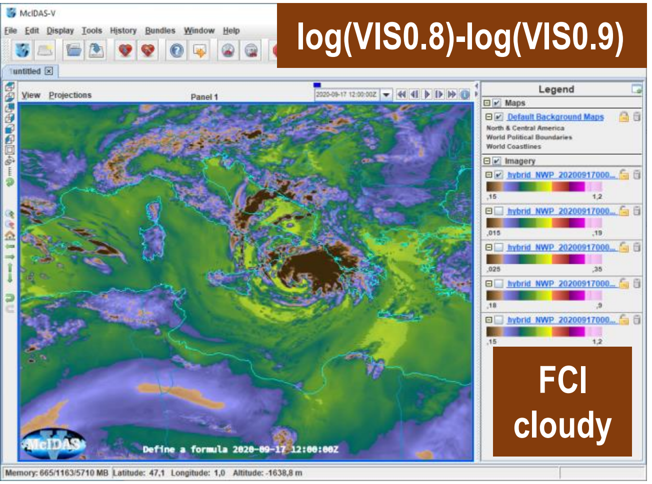






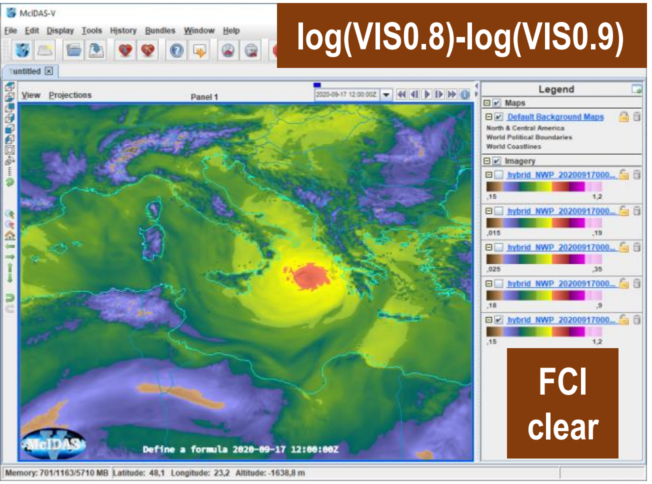
Another confirmation of "log(VIS0.8)-log(VIS0.9)" is more correlated with TPW in clear air pixels

FCI simulations with full cloudy till a fixed level



FCI simulations with full cloudy profiles till a fixed level pressure and the value CLWC profile in all pixels.

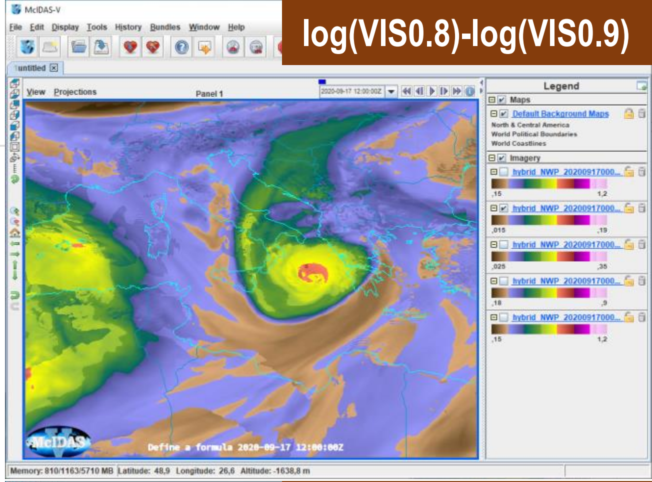
- ✓ CC=1 if pressure level higher than a fixed pressure level
- ✓ maximum CLWC (Cloud Liquid Water Clouds) at this level



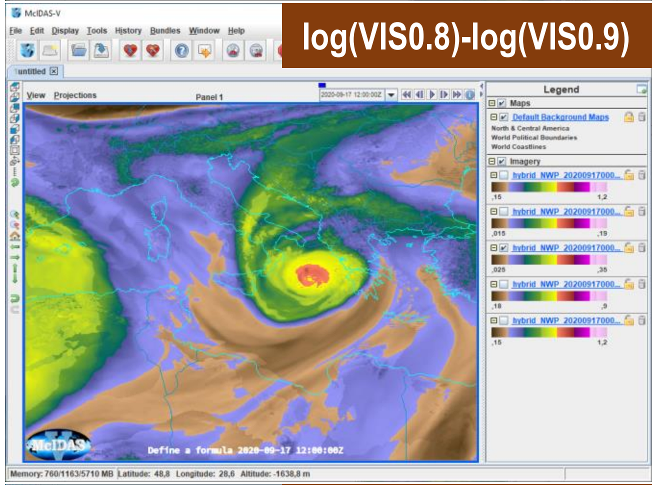
PGE00* can been easily adapted to make experiment on the influence of input profiles on 4D FCI or IRS spectra datacubes.

In this test it has been fixed to maximum value of Cloud Liquid Water Clouds (CLWC) at the hybrid level profile if pressure higher than a fixed pressure (850 or 500 or 300 hPa)

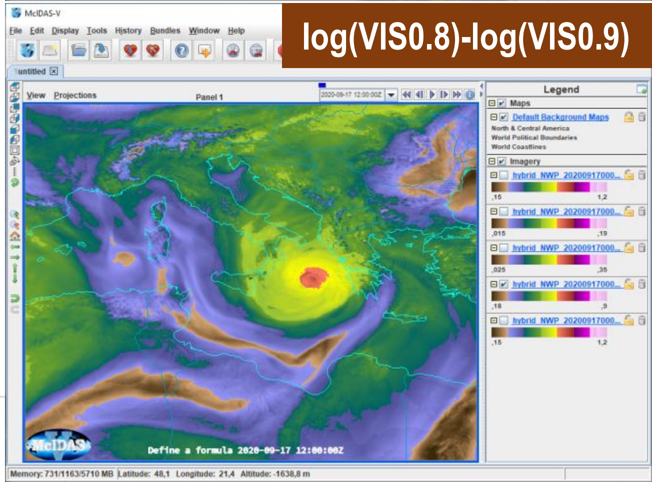
FCI cc300



FCI cc500

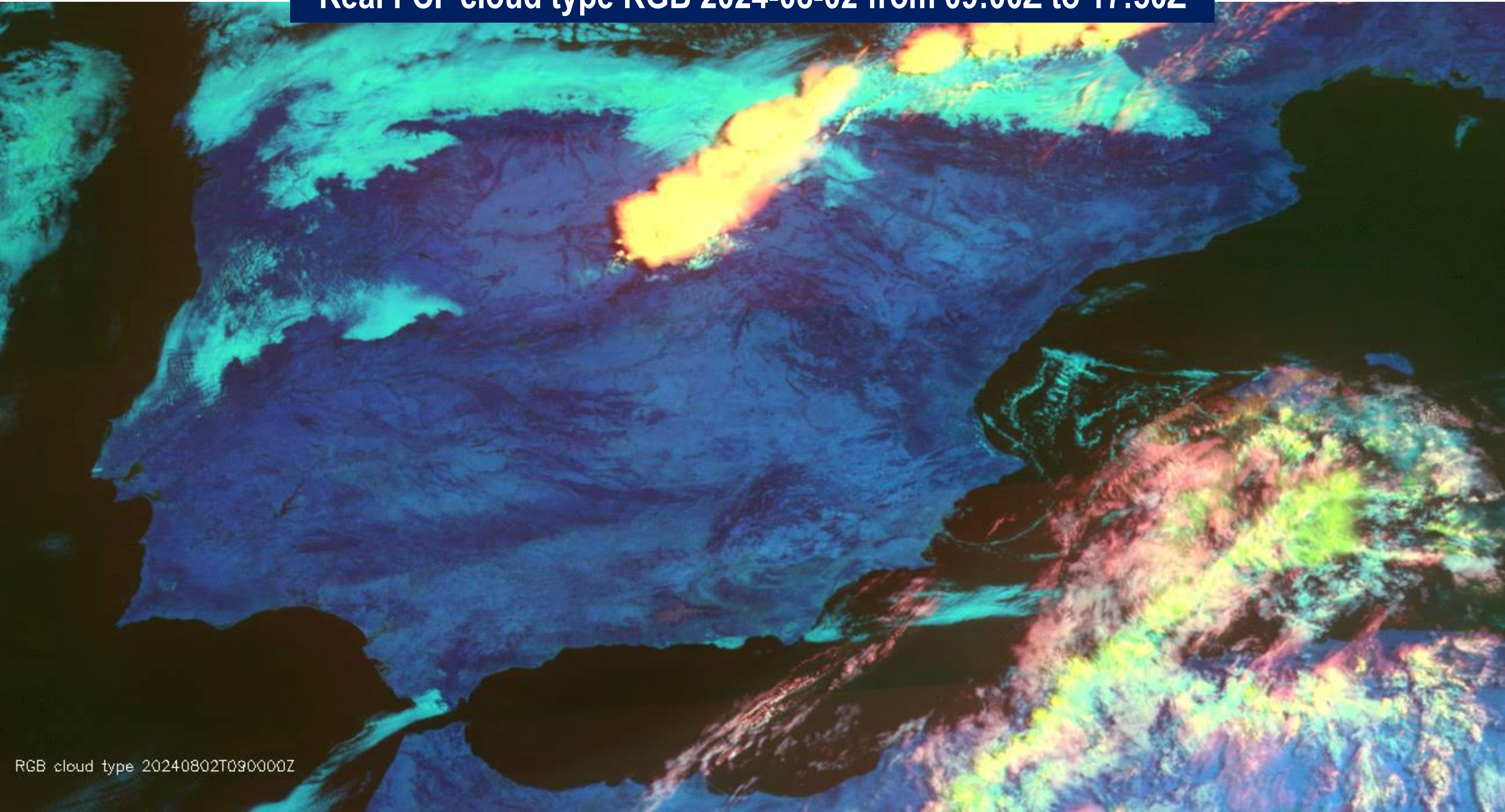


FCI cc850



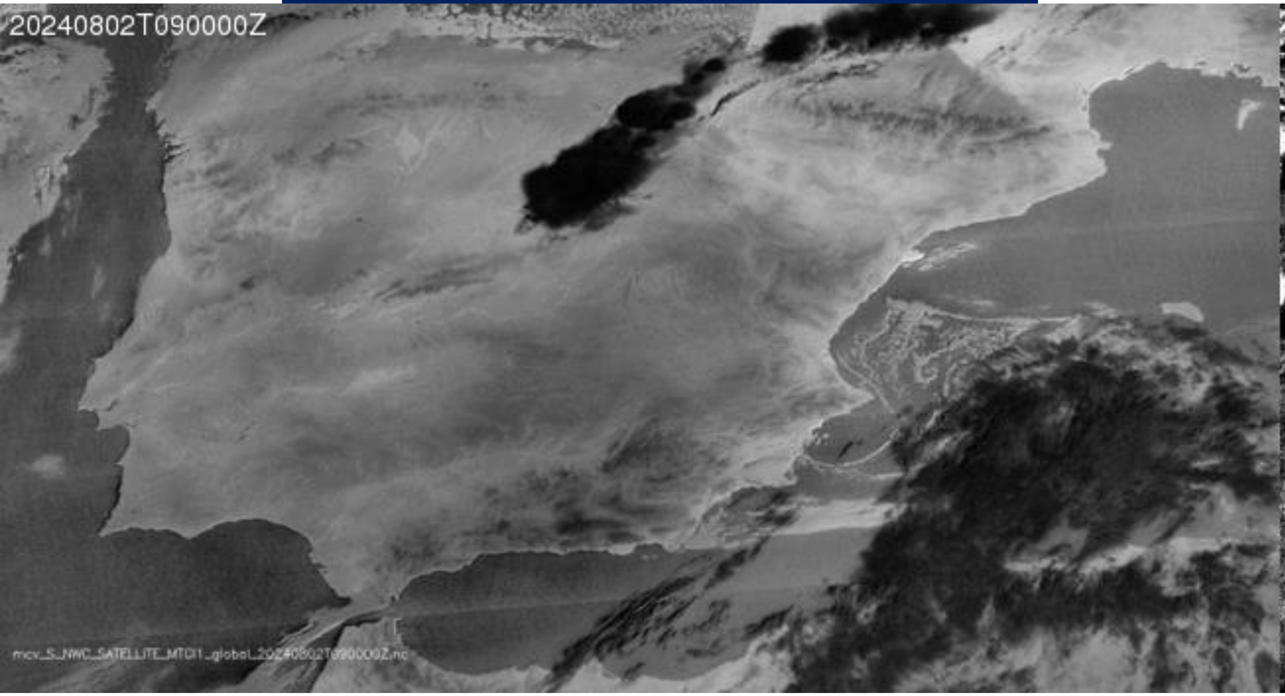
In cloudy pixels "log(VIS0.8)-log(VIS0.9)" is correlated with precipitable in layer above top cloud layer.
In clear pixels it provides an estimation of the TPW (Total Precipitable Water)

Real FCI cloud type RGB 2024-08-02 from 09:00Z to 17:50Z



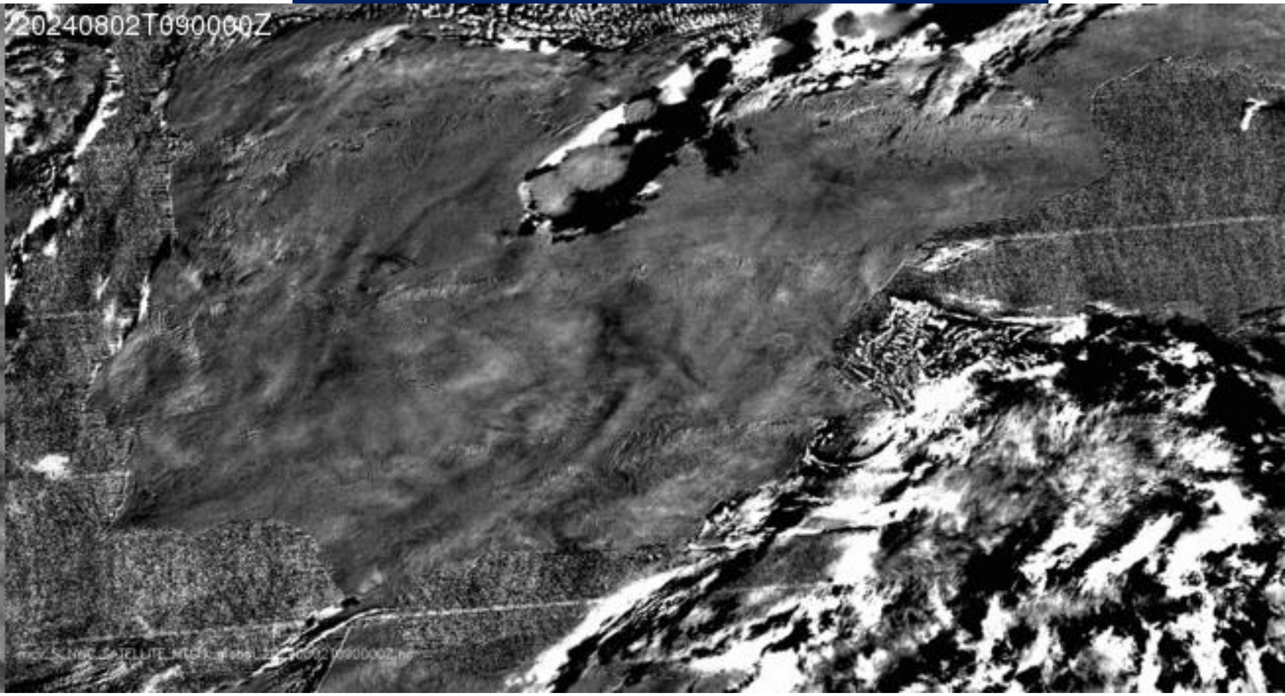
Real FCI 2024-08-02

Real FCI log(VIS0.8)-log(VIS0.9)



Rendering of image loop is smooth and it makes a bit difficult to follow the humidity movements.

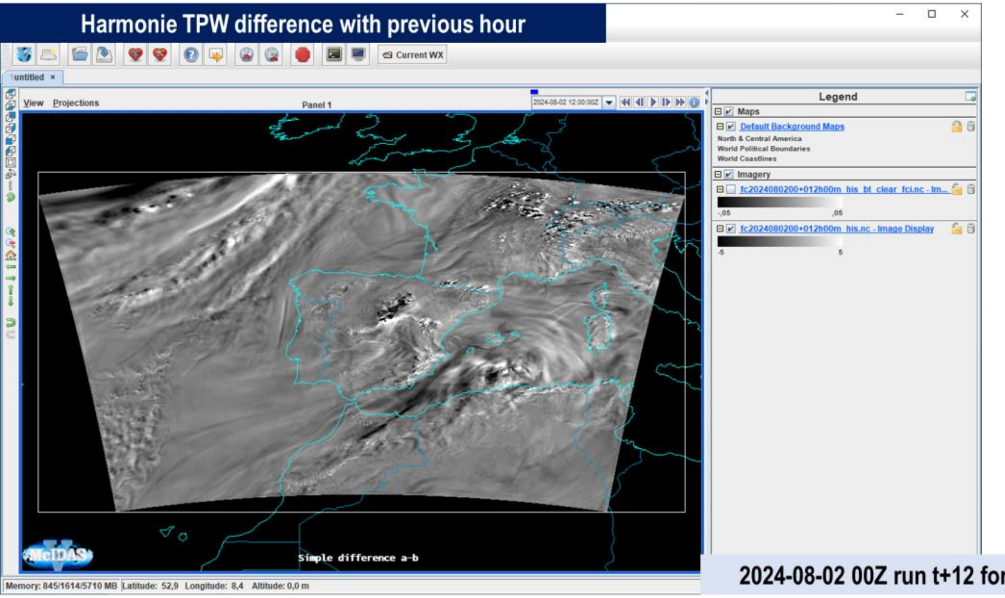
Real FCI log(VIS0.8)-log(VIS0.9) difference with previous hour



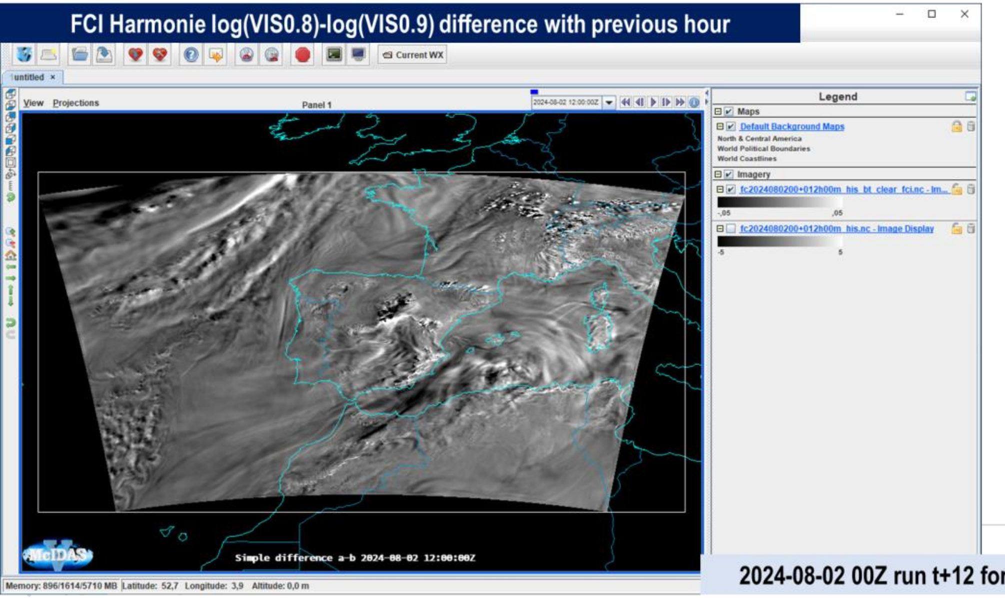
Rendering of image loop with the difference with previous hour allows to detect some hidden structures in the humidity movements.

First comparison of Real FCI log(VIS0.8)-log(VIS0.9) difference with previous hour with:

NWP and synthetic FCI



2024-08-02 00Z run t+12 forecast

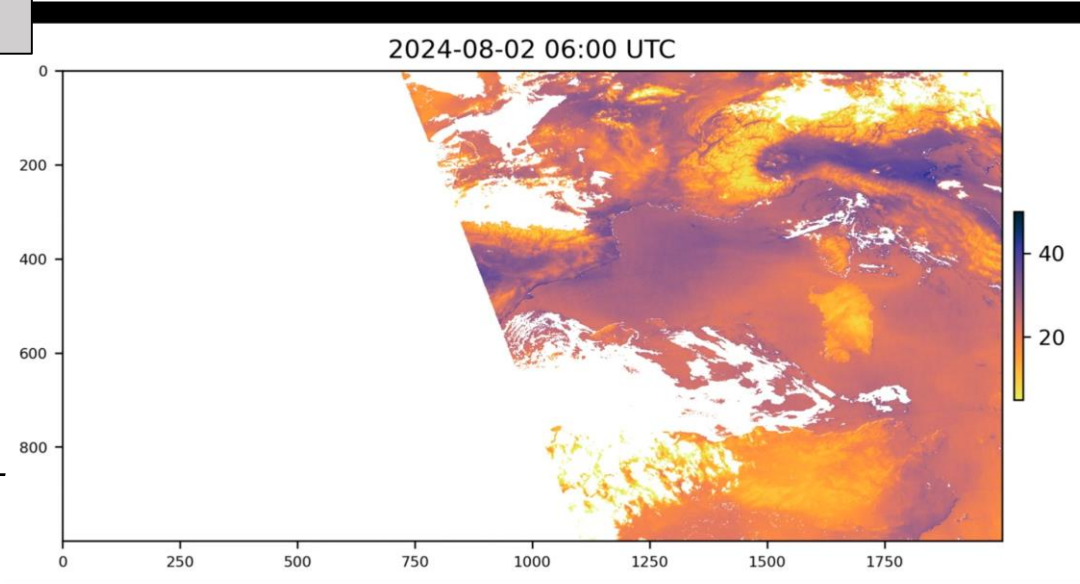


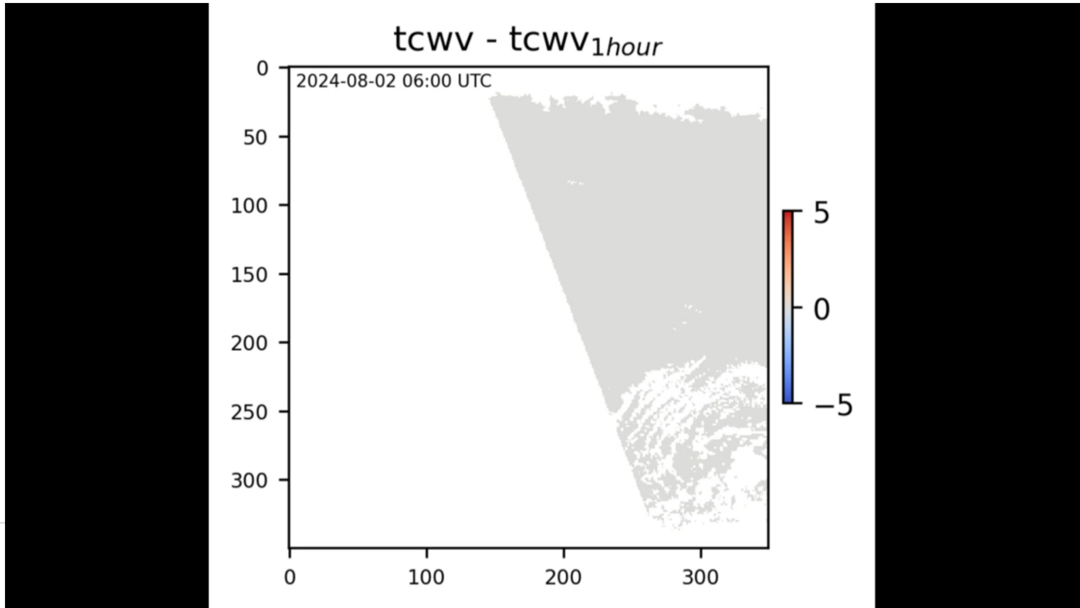
2024-08-02 00Z run t+12 forecast

NWC SAF is also financing a scientific study to develop an algorithm for total water content from VIS0.9 and VIS0.8 channels.

Animations taken from Jan El Kassar, Cintia Carbajal Henken, Rene Preusker, Jürgen Fischer (Freie Universität Berlin Institut Für Meteorologie) and Xavier Calbet AEMET presentation on December 2024 ESSL-EUM Workshop on EUM FCI L2 products

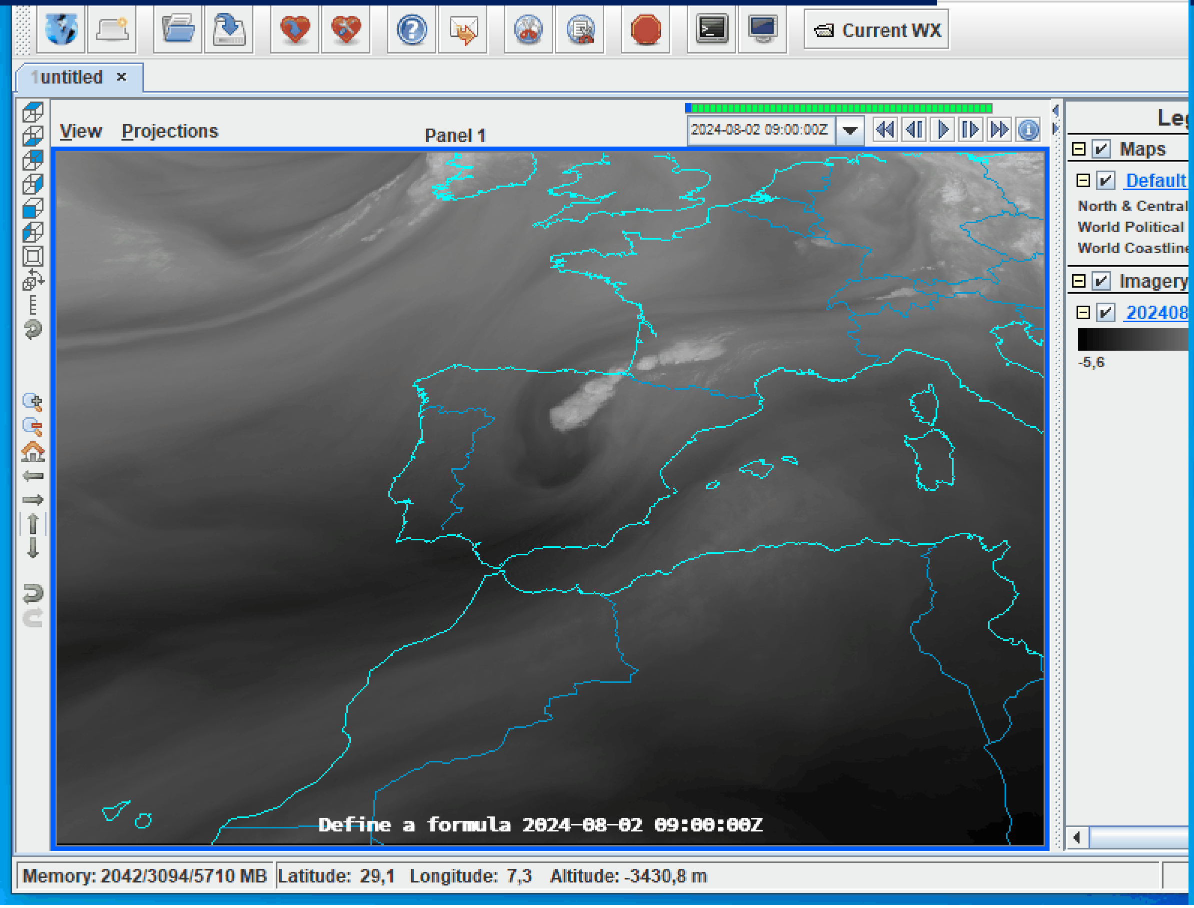
FUB VIS0.9 optimal estimati



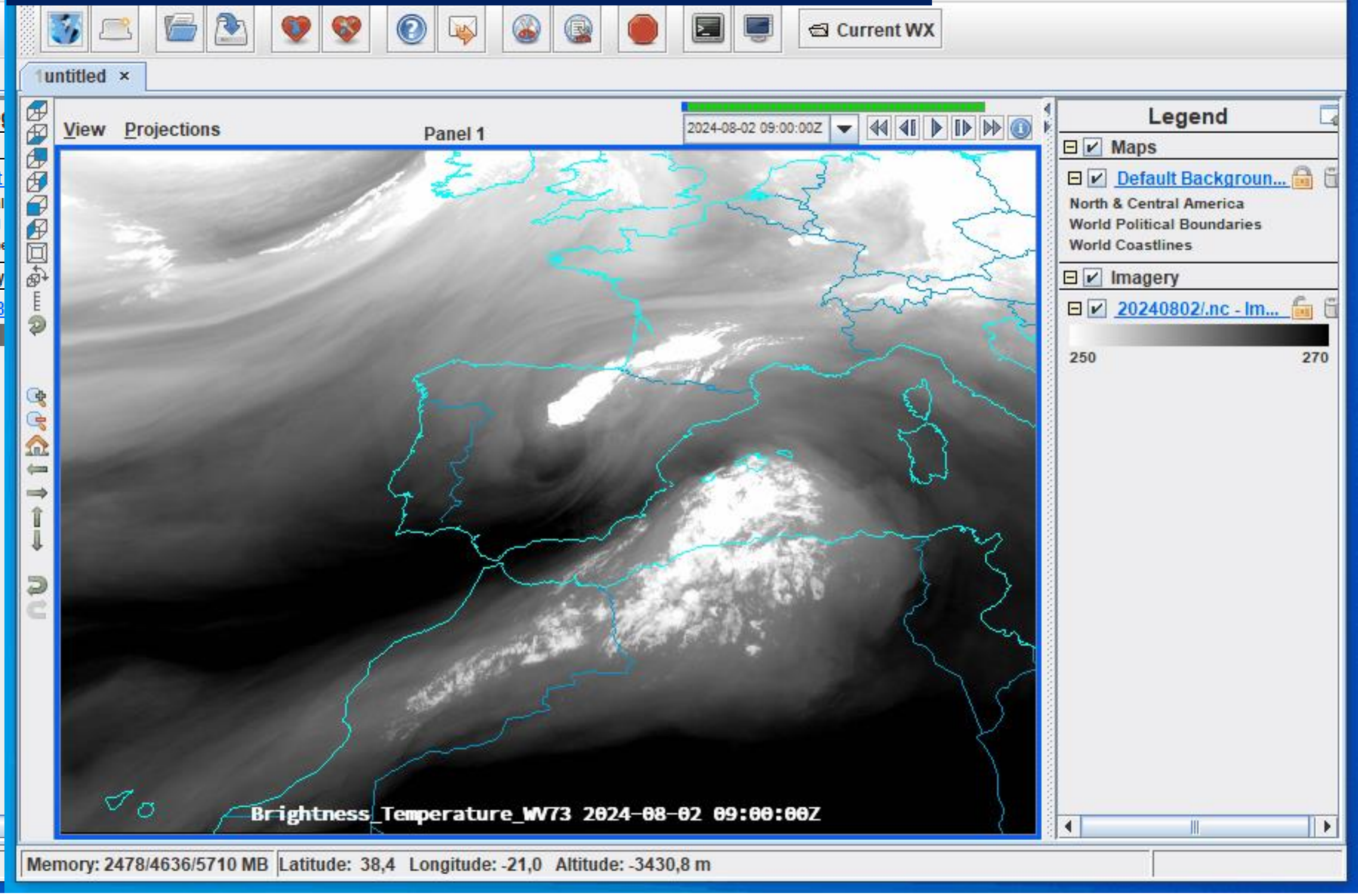


FCI WV channels

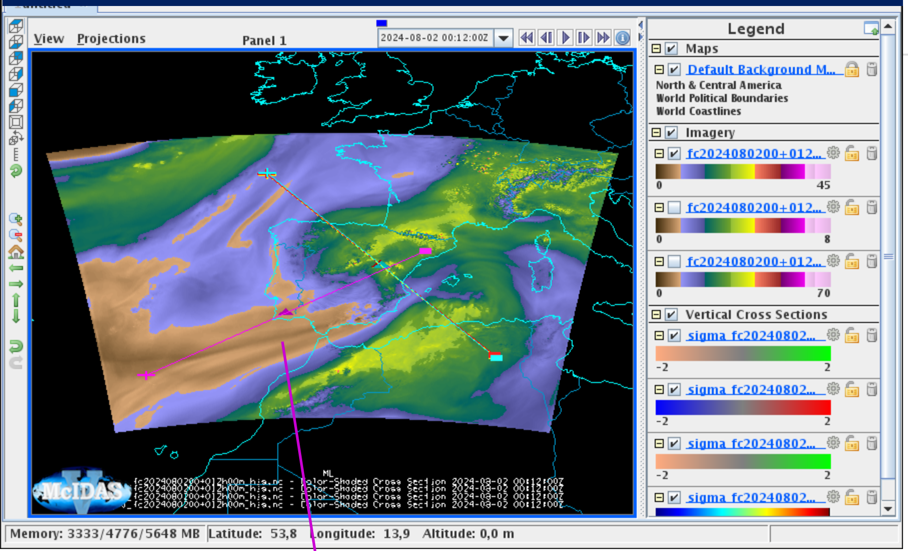
Real FCI log(WV6.3)

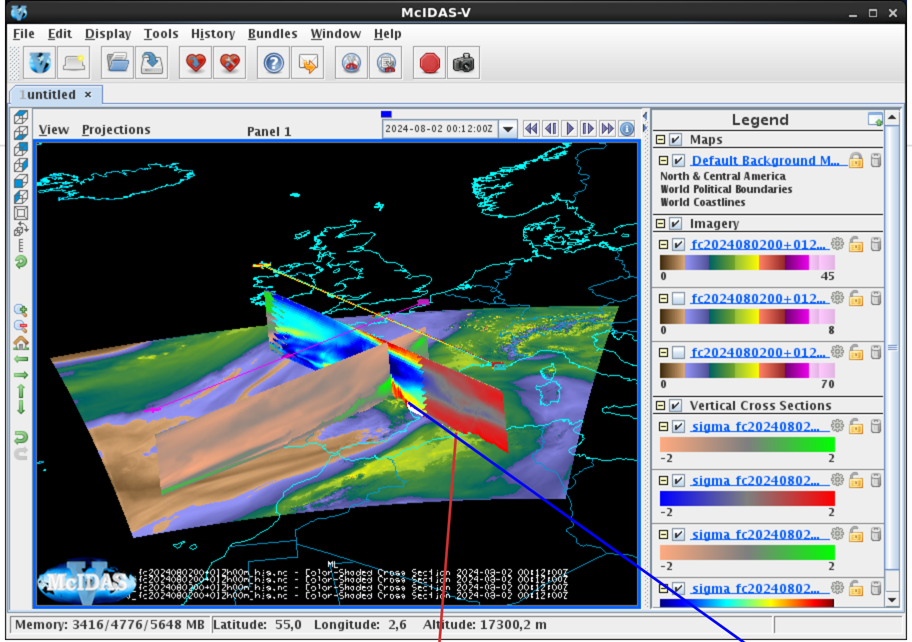


Real FCI WV7.3



iSHAI ML (precipitable water layer 850-500 hPa)





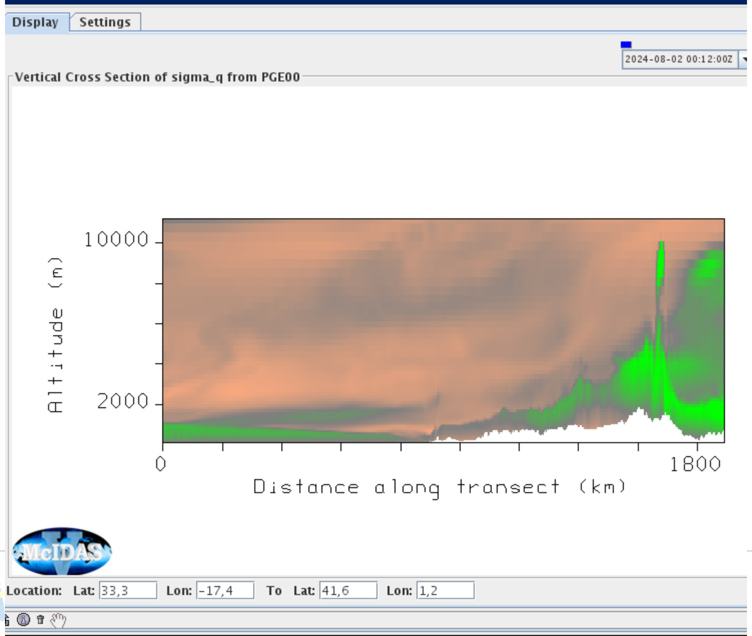
Generated with normalization of every level

Normalization=(field – mean_ref) /stdev_ref

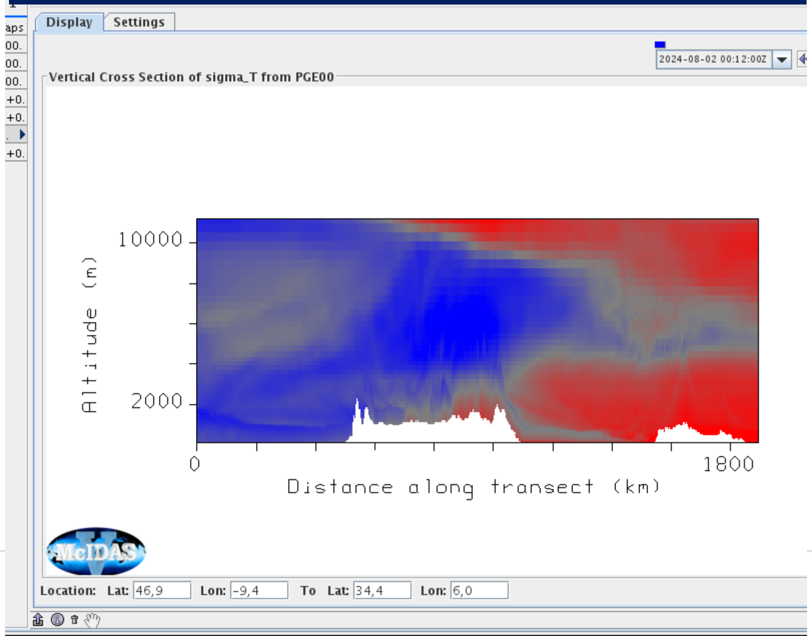
Mean_ref y stdev_ref calculated from t+12

Harmonie NWP model

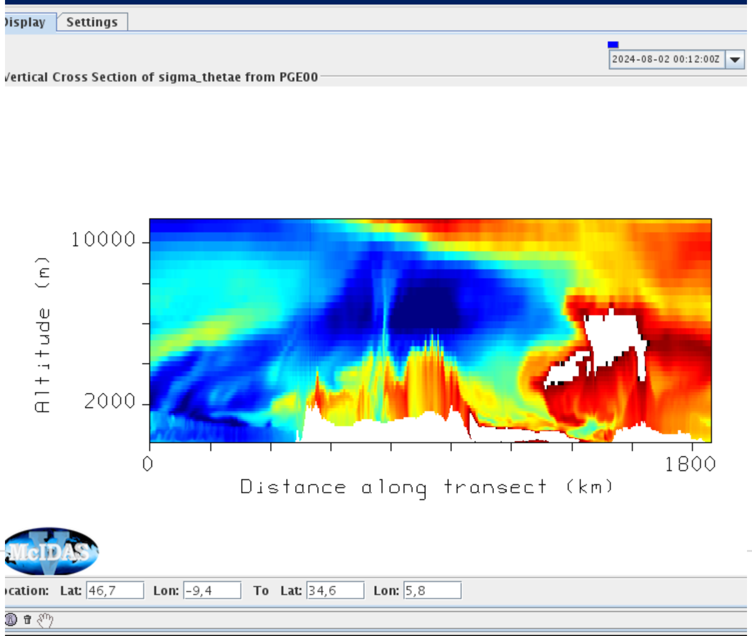
Normalized q on every level



Normalized T on every level



Normalized θ_e on every level

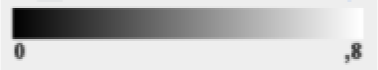


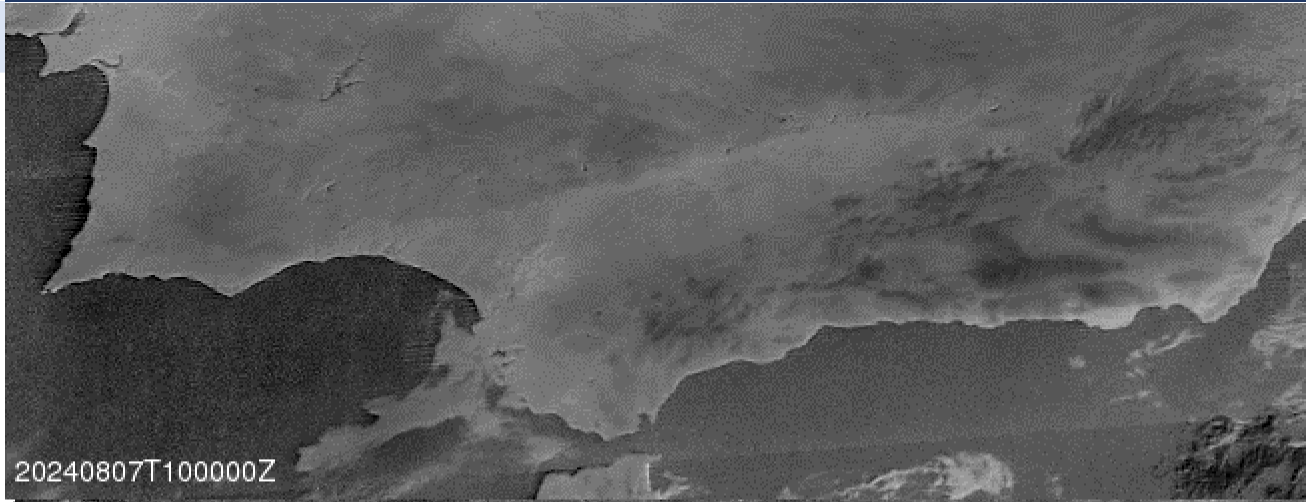
Loop with zoom over South Iberian Peninsula with the comparison of TPW and TPW-mean(6 previous slots) MTG-I/FCI TPW estimation using VIS0.9 & VIS0.8 channels

2024-08-07 from 09:30Z 16:20Z

MTG-I/FCI proxyTPW estimation calculated using **log(VIS0.8)-log(VIS0.9)**

Loop with the log(VIS0.8)-log(VIS0.9) images:
FCI at original resolution 1x1 km at nadir.

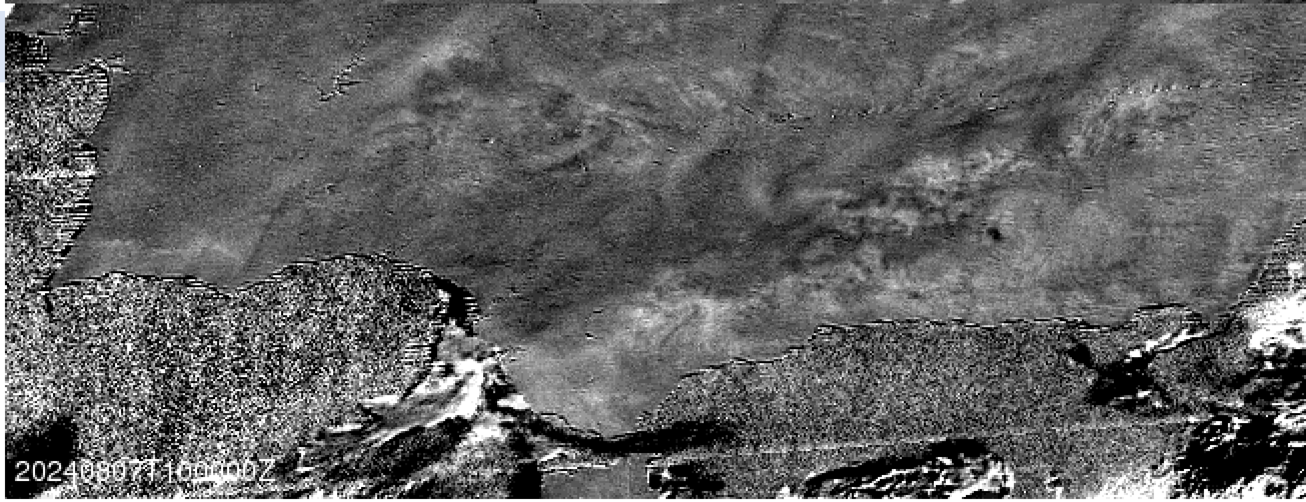


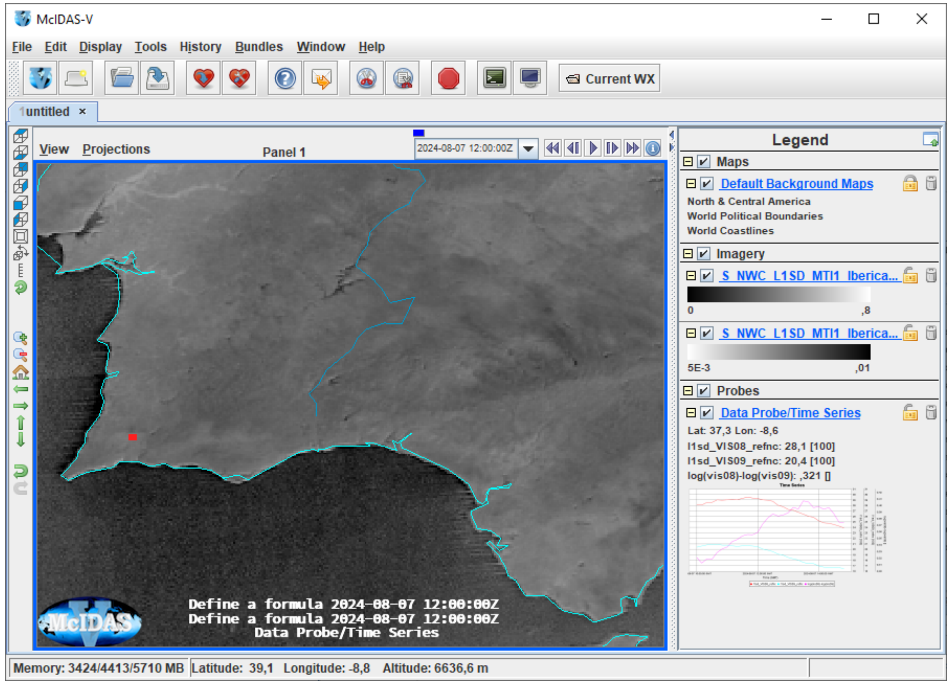


proxyTPW – mean_previous_hour

Loop with difference of image on left loop with the mean on previous hour (6 previous slots).
On South Portugal is possible to see some white lines that are the detection of border where TPW is increasing (sea breezes)

Gray scale [-0.05, 0.05]

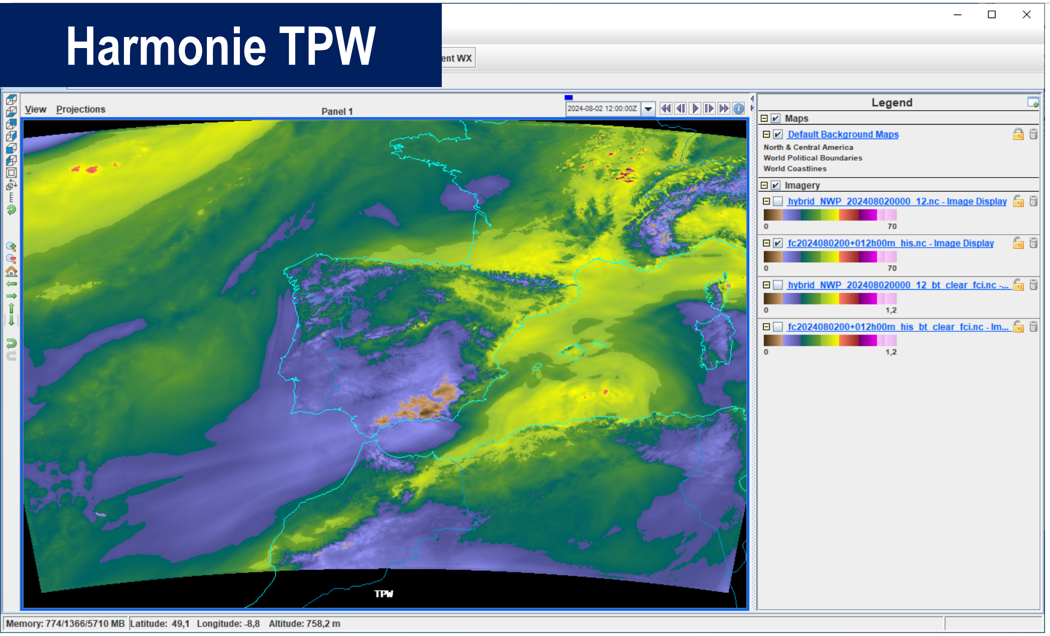


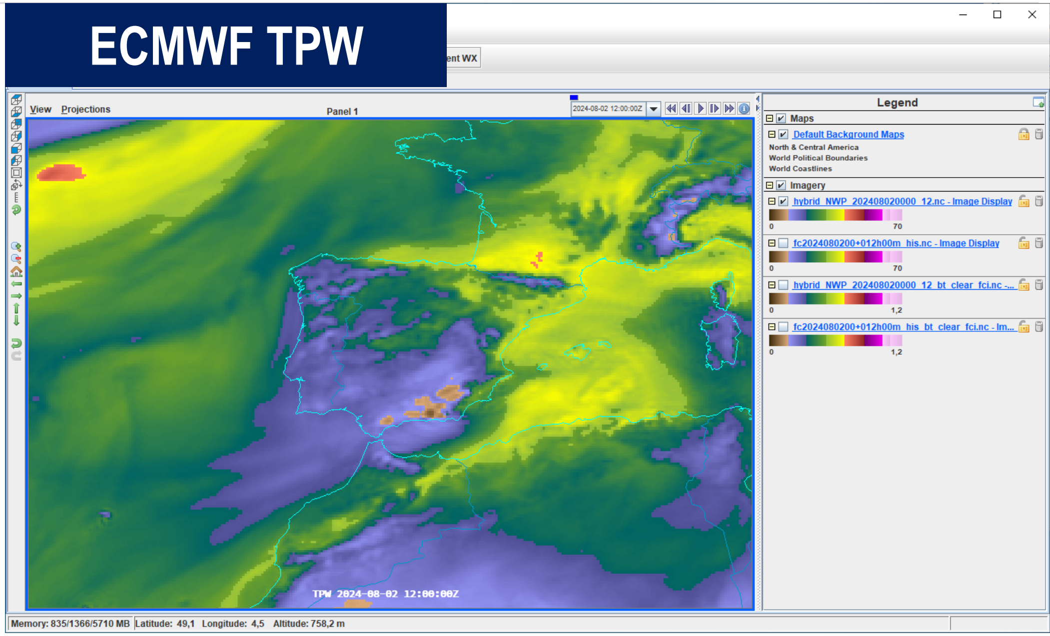


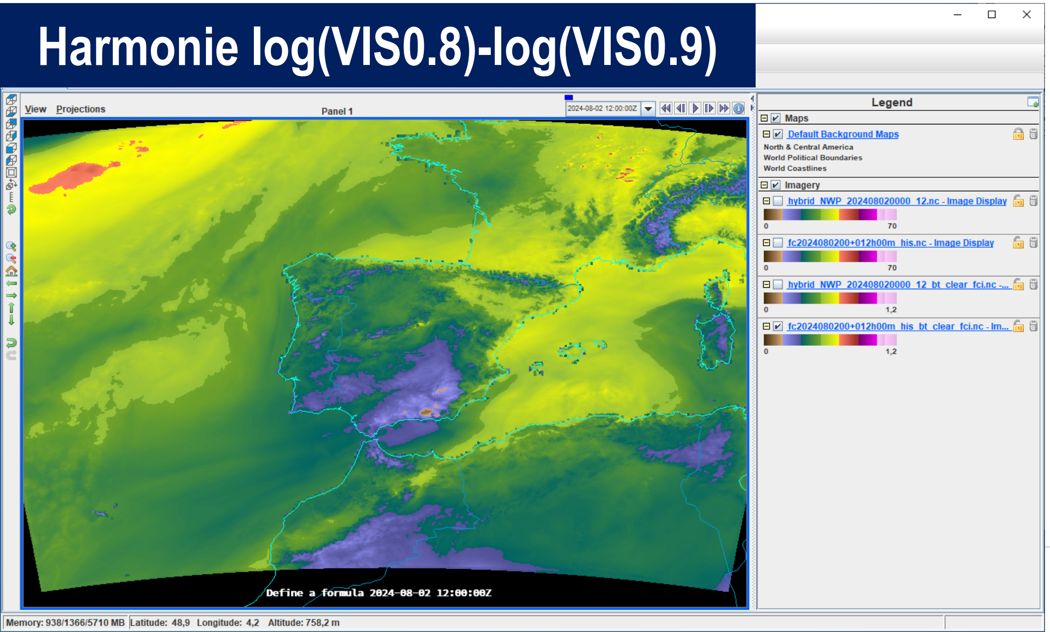
log(VIS0.8)-log(VIS0.9) imagery shows variations at sunset/rise. Although there is a diurnal cycle is possible to use and to follow humidity structures.

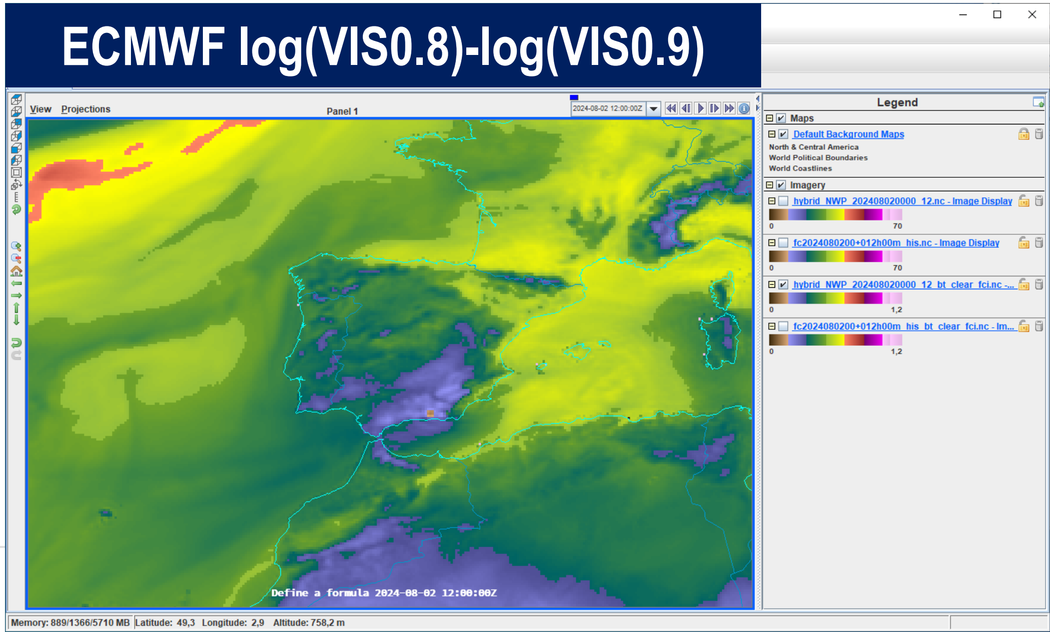
ECMWF and Harmonie TPW and log(VIS0.8)-log(VIS0.9) with same colour palette

2024-08-02 00Z run
t+12 forecast



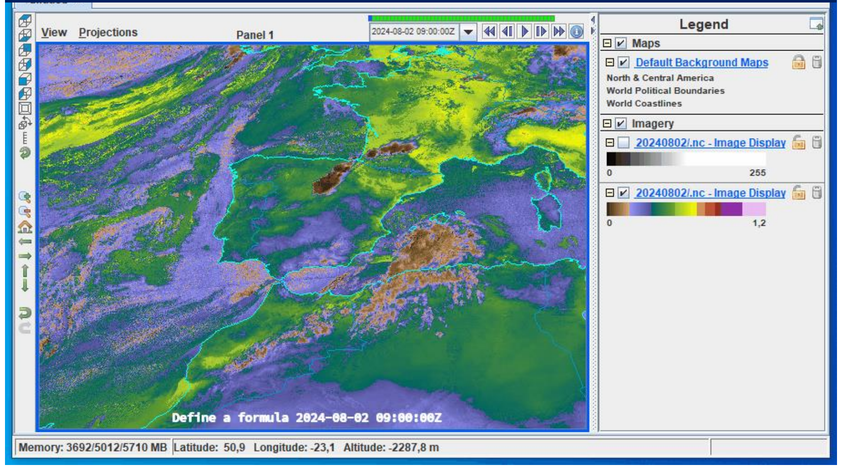




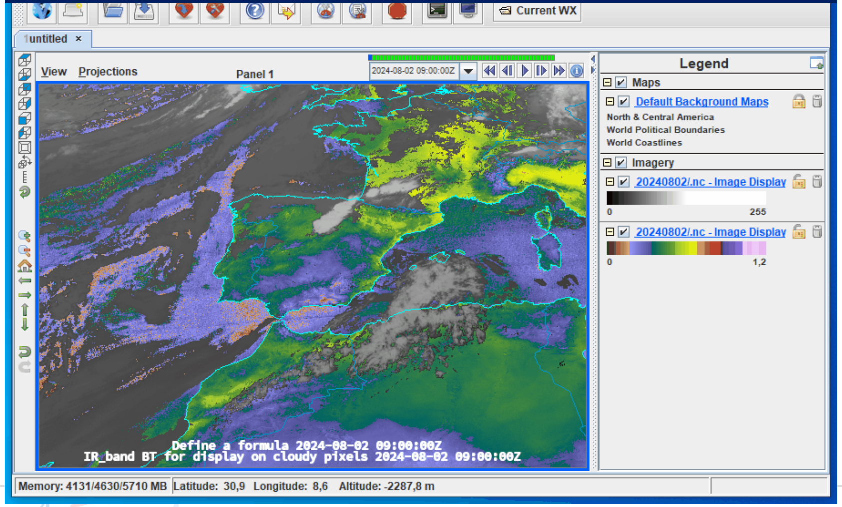


Real FCI log(VIS0.8)-log(VIS0.9) as TPW on clear pixels and precipitable water content above cloud top con cloudy pixels

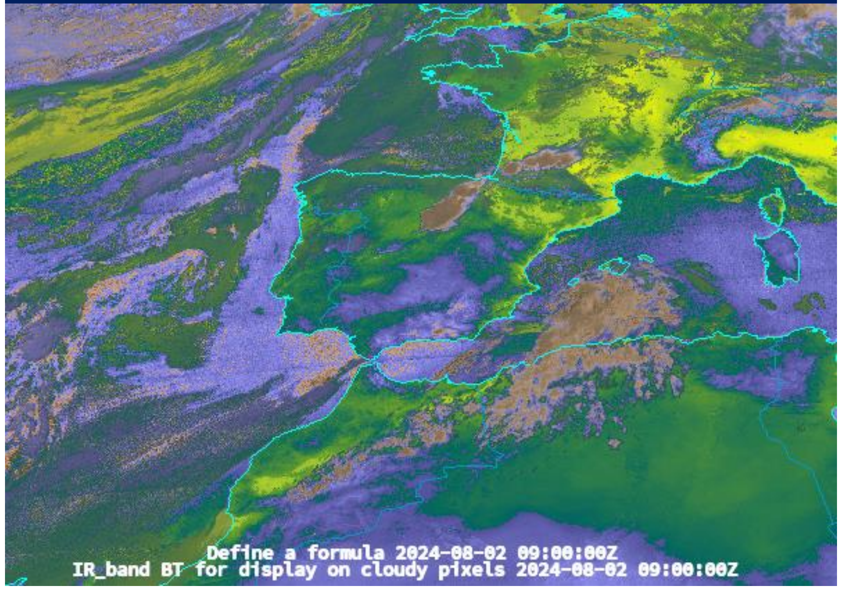
Real FCI log(VIS0.8)-log(VIS0.9)



Real FCI log(VIS08)-log(VIS09) with BT IR10.5 on cloudy pixels



Real FCI log(VIS08)-log(VIS09) with 60% transparency of BT IR10.5 on cloudy pixels

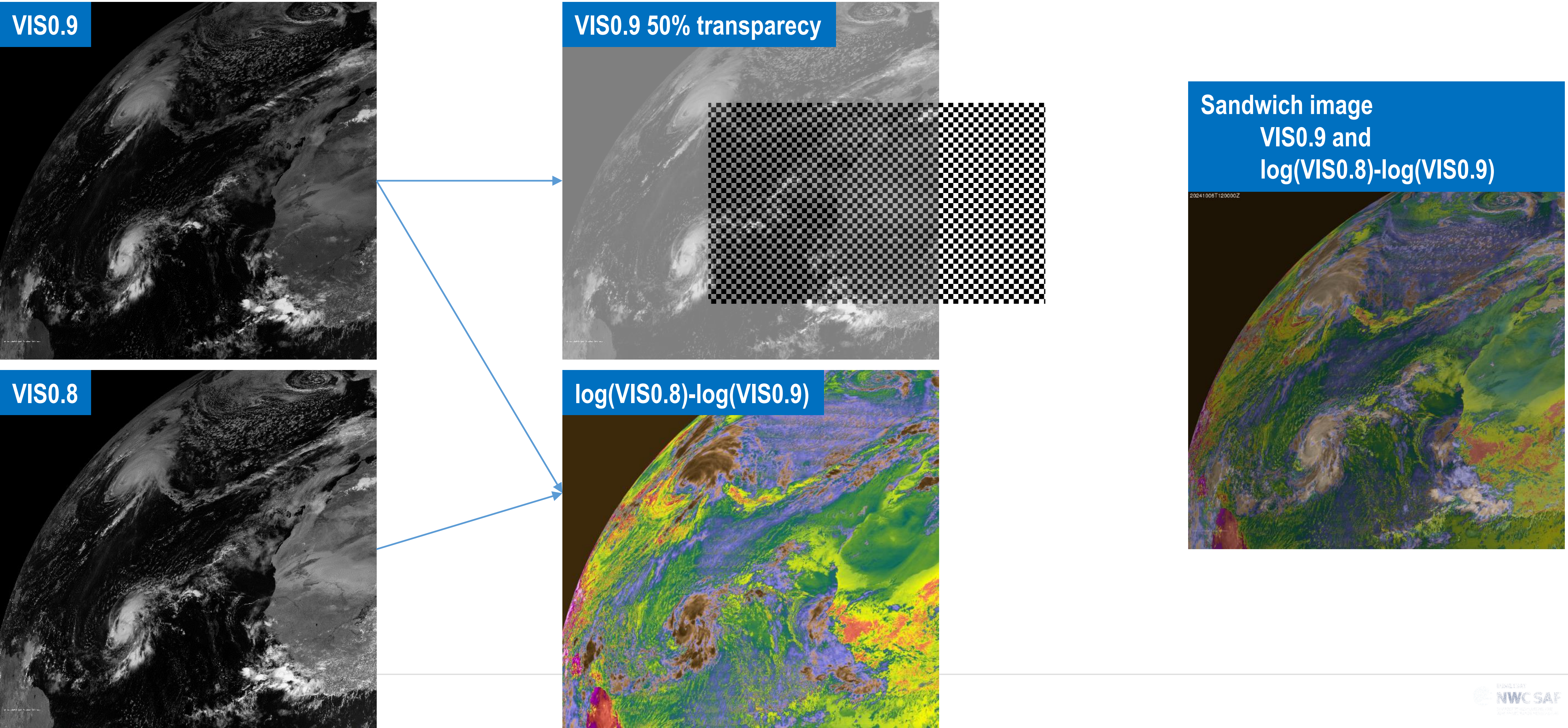


Images generated with real FCI VIS0.8 and VIS0.9 fields from NWCSAF L1SD PGE.

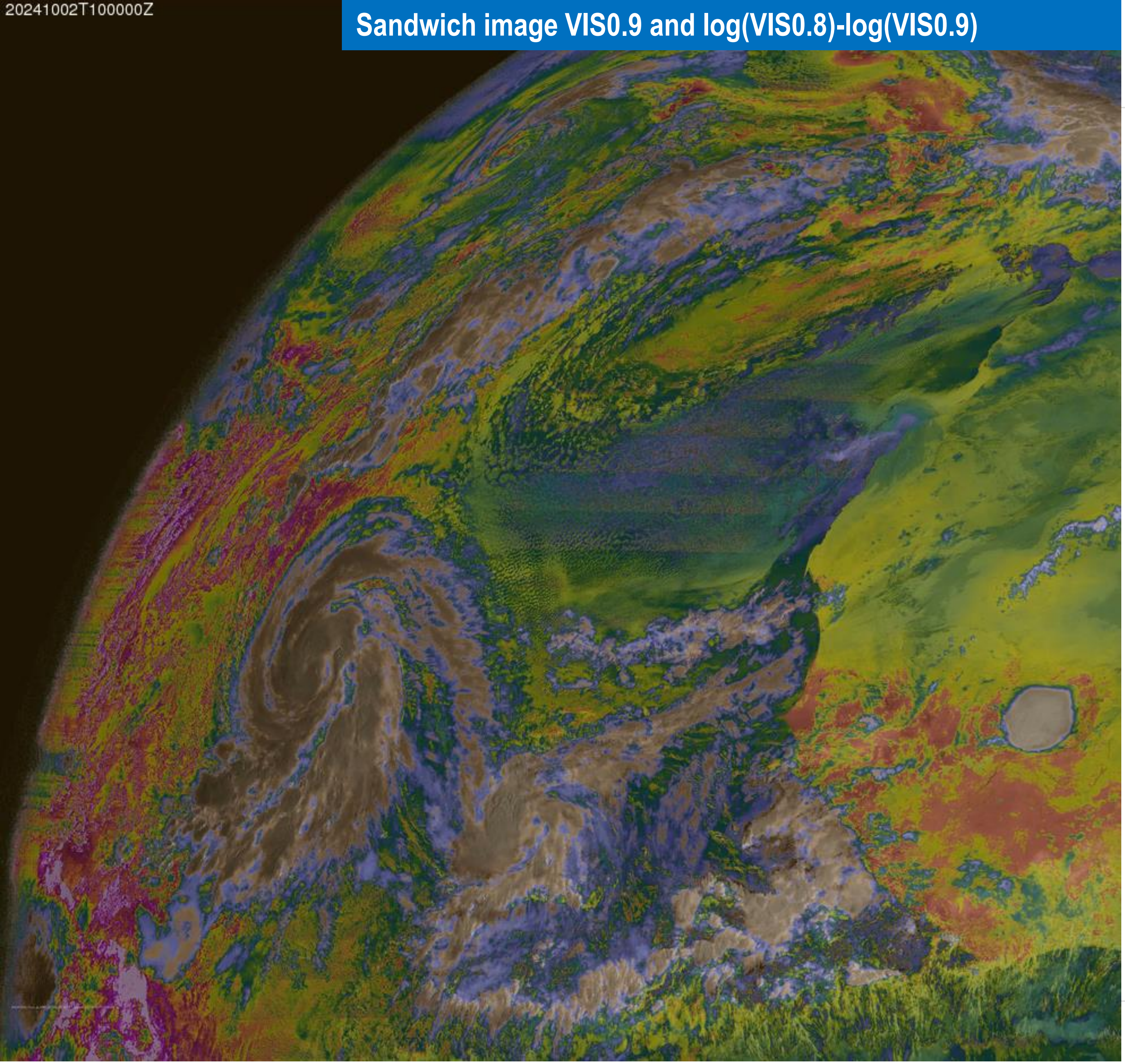
It has been used normalized corrected reflectance of VIS0.8 and VIS0.9 FCI.

L1SD generates netCDF files compatible with many meteorological tools. One of them is McIDAS-V (or IDV).

Sandwich image with VIS channel to provide distinction between dry pixels and cloudy pixels

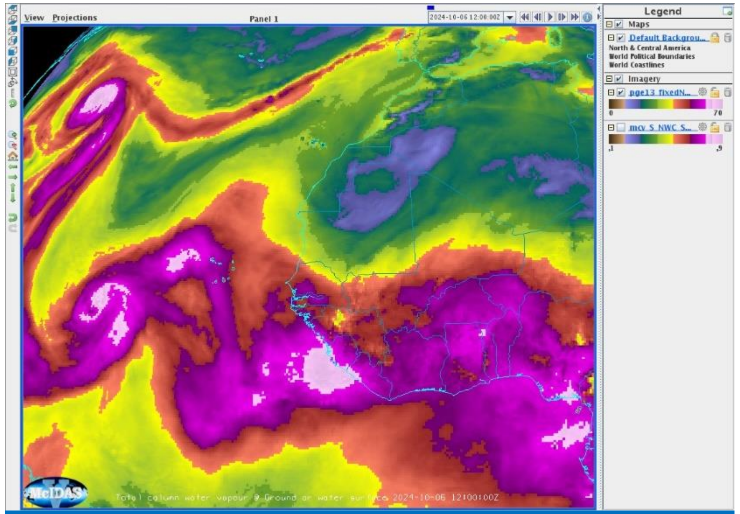


Sandwich image VIS0.9 and log(VIS0.8)-log(VIS0.9)

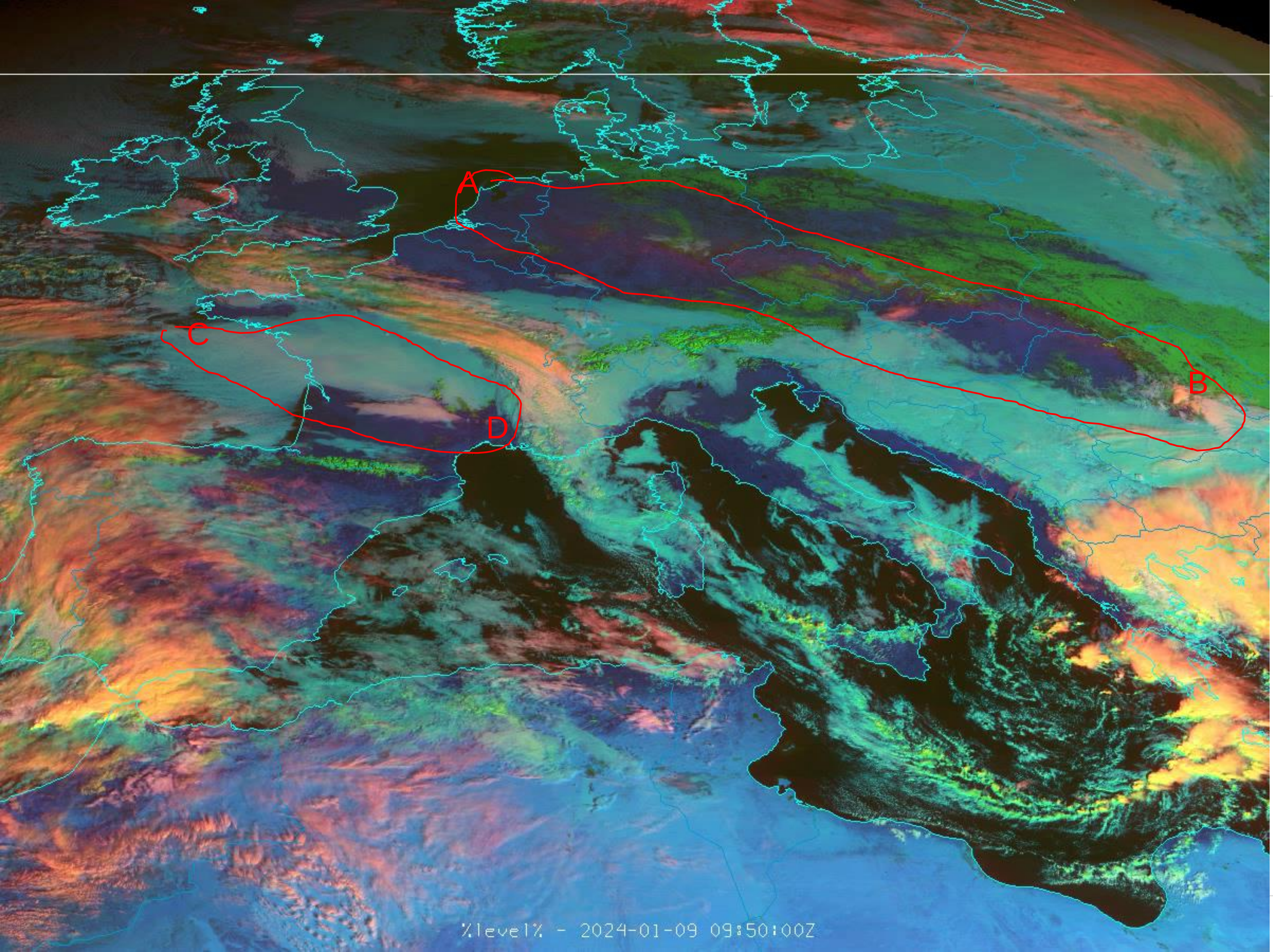


Loop of VIS0.9+logarithm difference sandwich images allows the monitoring water vapour over sea pixels.

It is possible to see the transport of humidity from equatorial regions to mid latitudes regions



2024-10-06 T12Z ECMWF TPW

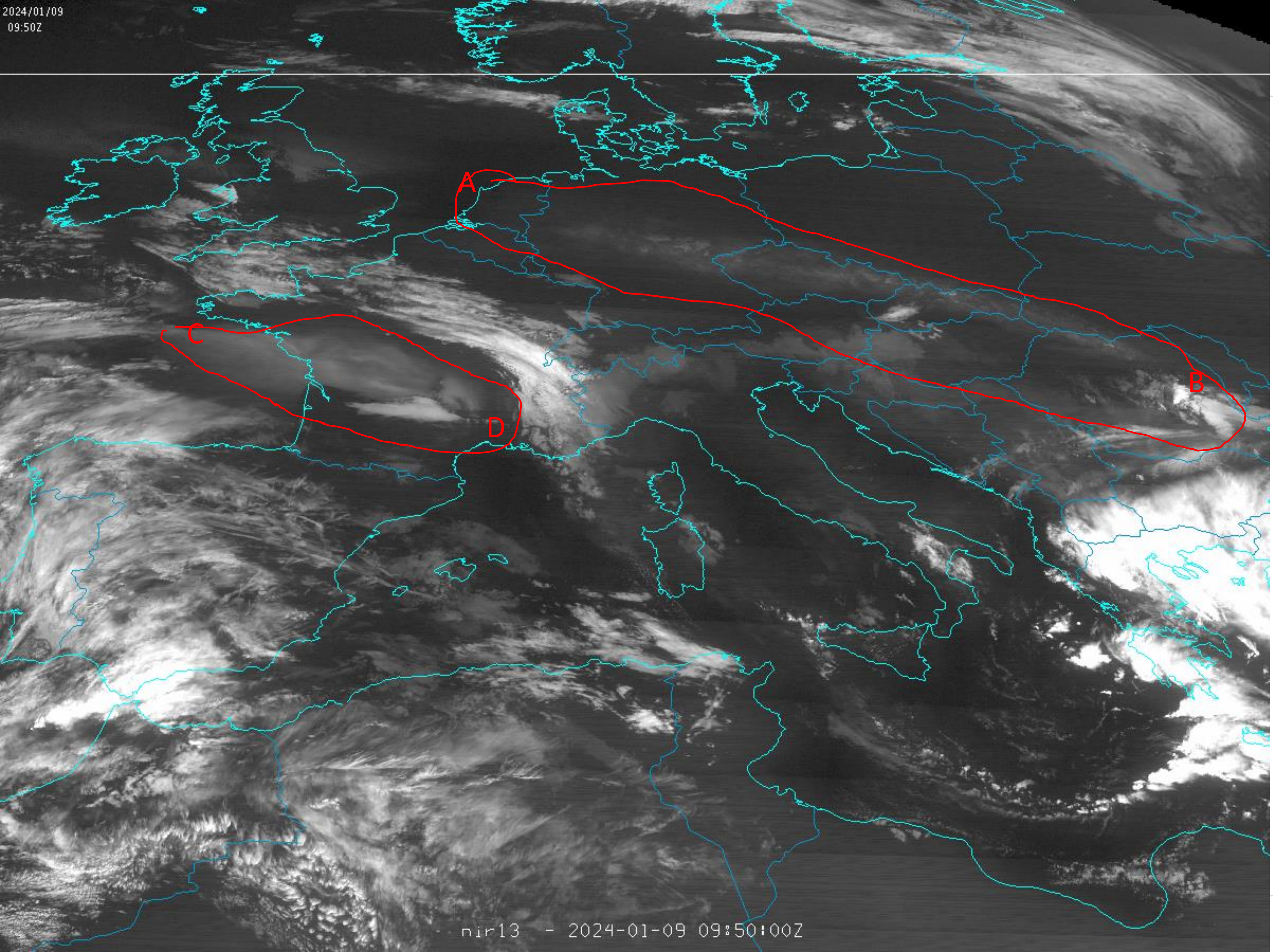


2024-01-09
from 09:50Z to 16:20Z

MTG-I1/FCI
Cloud Type RGB

Real FCI images

Pinky stationary cloud type RGB over Germany



2023-01-09 09:50Z

MTG-I1/FCI

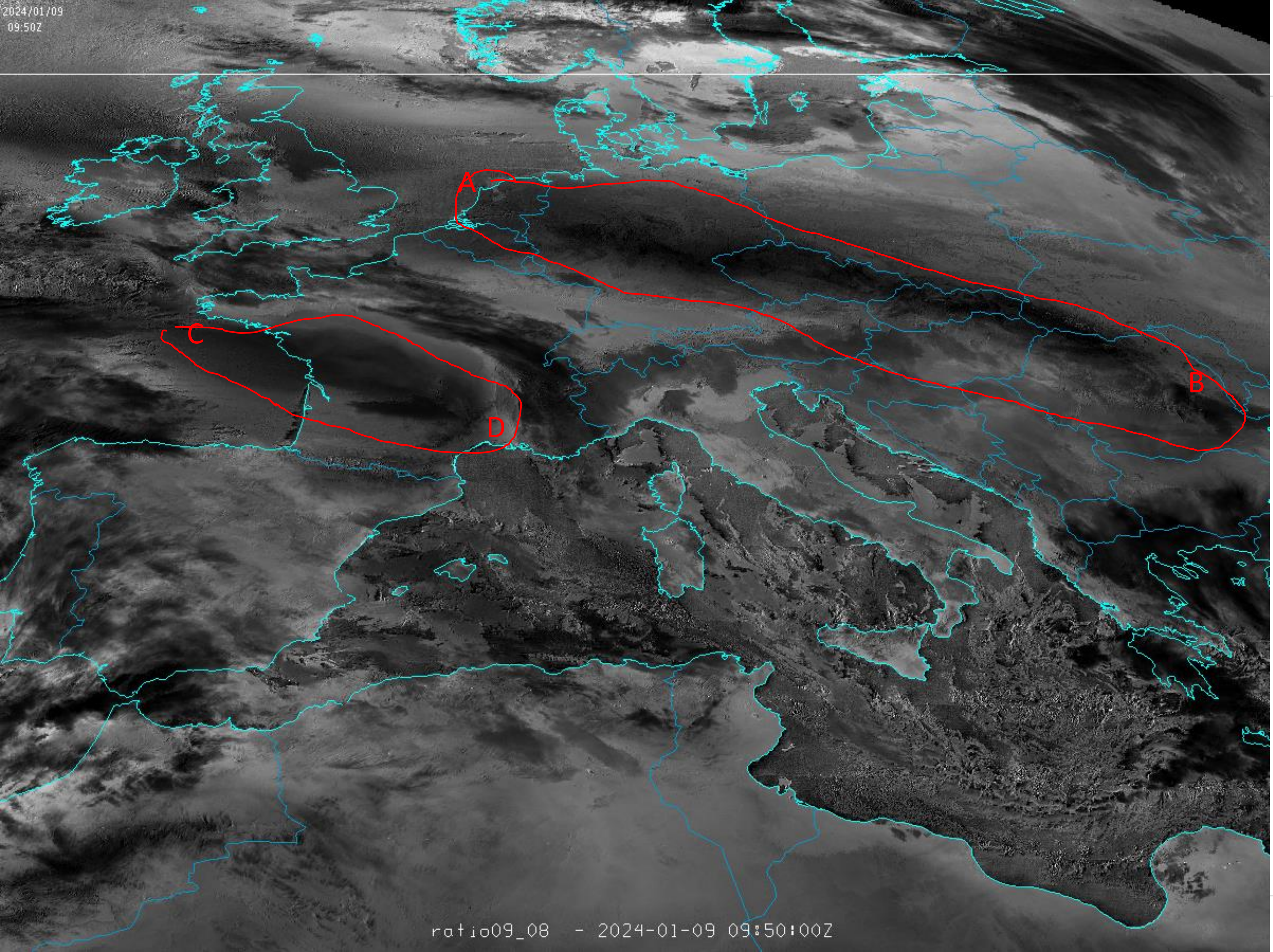
NIR1.3 as used in red beam on Cloud Type RGB

NIR1.3 in range [0,10] scaled in range [0, 255] and with gamma 2.5

Real FCI image

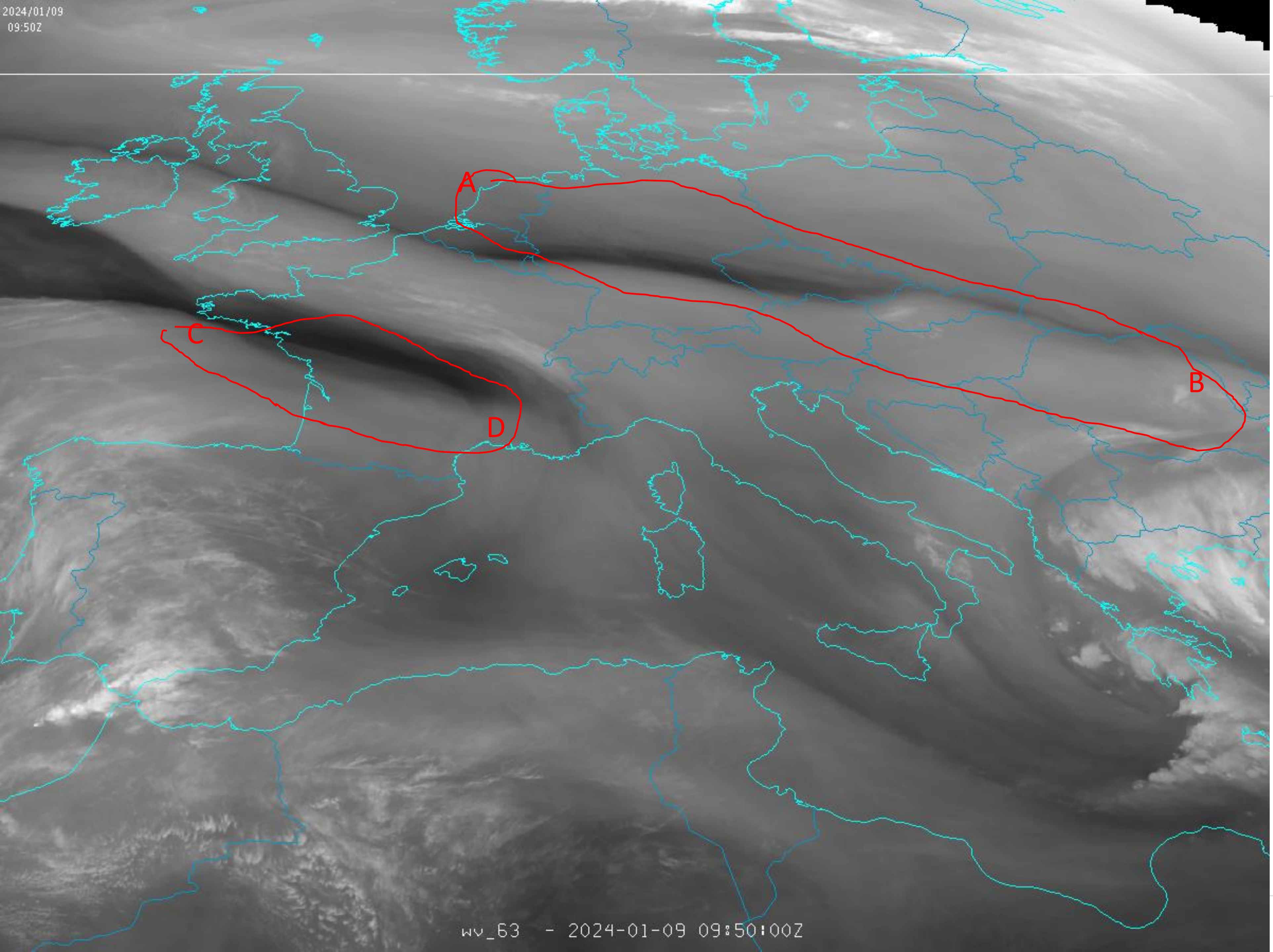
log(VIS0.8/VIS0.9) MTG-I1/FCI for TPW estimation

2023-01-09 09:50Z



MTG-I1/FCI
(log(VIS08)-log(VIS09))
scaled in range [0, 0.7]

Real FCI image

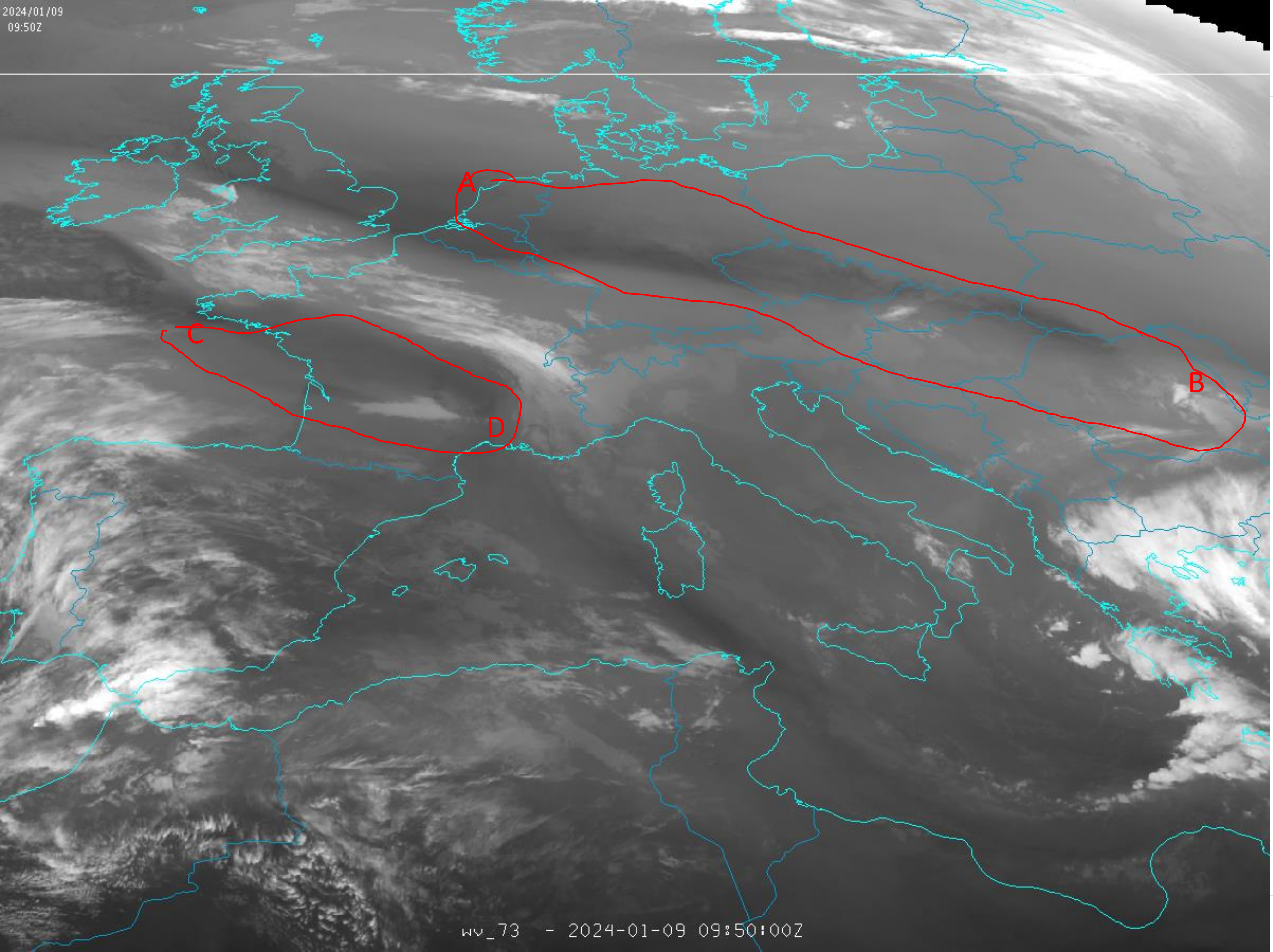


2023-01-09 09:50Z

MTG-I1/FCI
WV6.3
scaled in range [212, 251]
with Inverted Gray Scale

Real FCI image

NWC SAF



2023-01-09 09:50Z

MTG-I1/FCI
WV7.3
scaled in range [220, 270]
with Inverted Gray Scale

Real FCI image

NWC SAF

PGE00 hybrid (Harmonie or ECMWF)+RTTOV versions for MSG, FCI and IRS Synthetic satellite netCDF datasets

RTTOV PGE00s program for MTG-I FCI, MSG, IRS,..

- RTTOV FCI synthetic generation for the whole 16 channels.

1) Normal computer version without parallelization on FCI grid.
2) OpenMP version for HPC ATOS supercomputers (cirrus AEMET or HPC ECMWF Bolonia) with parallelization on NWP grid.

Netcdf files compatibles McIDAS-V => **INTERACTIVE USE**

PGE00* can be used as 4D interpolators (interpolator in the vertical, time and space). Profiles interpolated to configurable set of pressure levels (66 levels in examples) **on netCDF files**

RTTOV simulation of VIS channels is highly CPU consumer; parallelization by lines for same channel.

ECMWF

- Inputs:
  - ECMWF T/q/o3/cc/clwc/ciwc profiles on the 137 hybrid levels on the 137 hybrid levels on lon,lat grids with high resolution 0.1ºx0.1º every 1 hour

2D fields

Synthetic **BT or refl on netCDF files**

Cloudy synthetic data

Clear-air synthetic data

ECMWF TPW, LPWs, instability indices, TOZ, ancillary, etc

Total transmission coefficients

3D fields (66 pressure levels; wf 66-1 layers)

ECMWF 3D profiles
T/q/ozone/CC/CLWC/CIWC

Transmission profiles

Weighting functions

Harmonie

- Inputs:
  - Harmonie T/q/o3/cc/clwc/ciwc profiles on the 65 hybrid levels on Lambert conformal rotated with high resolution 2.5x2.5km^2 every 1 hour
  - Since Harmonie has not ozone; ECMWF o3 profiles on the 137 hybrid levels on lon,lat grids with high resolution 0.1ºx0.1º every 1 hour

2D fields

Synthetic **BT or refl on netCDF files**

Cloudy synthetic data

Clear-air synthetic data

Harmonie TPW, LPWs, instability indices, TOZ, ancillary, etc

3D fields (66 pressure levels; wf 66-1 layers)

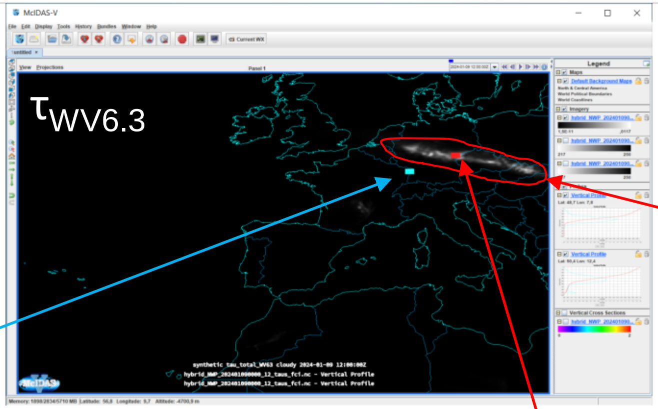
Harmonie 3D profiles
T/q/~~ozone~~/CC/CLWC/CIWC

tausun_levels_path1(nlevel, nchanprof)	Transmittance from each user pressure level to TOA. Only populated for solar-affected channels, zero otherwise.
tausun_total_path2(nchanprof)	Transmittance for combined sun-surface-satellite path. Only populated for solar-affected channels, zero otherwise.

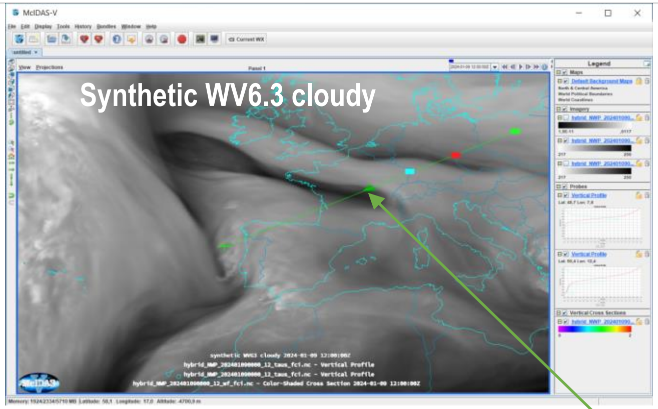
WV6.3 transmissivity profiles and weighting functions

Case study 9th January 2024 narrow very dry band over Germany

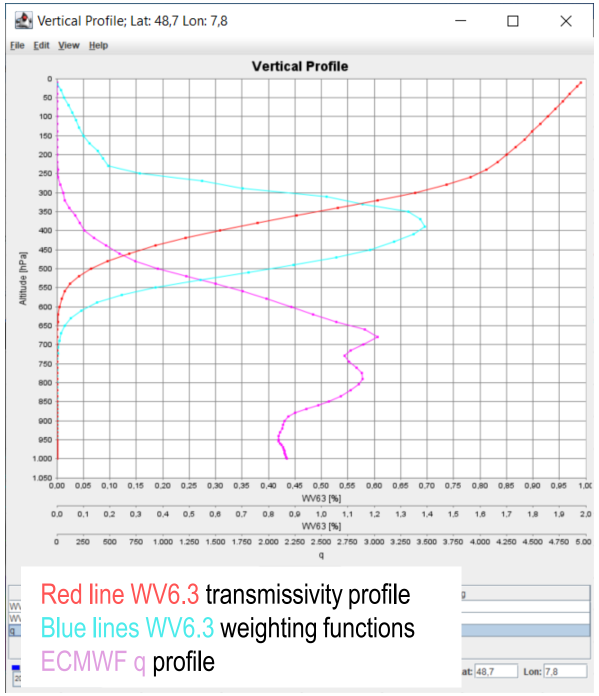
Comparison q profile from ECMWF with transmission and weighing function profiles. **It can be seen the very dry profile at red probe.**



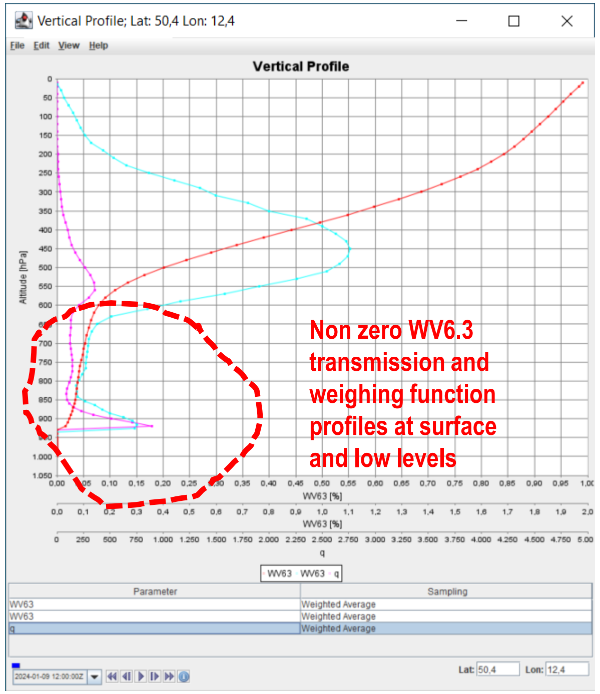
On WV6.3 total transmissivity from ground should be zero but there is a narrow band with non-zero values



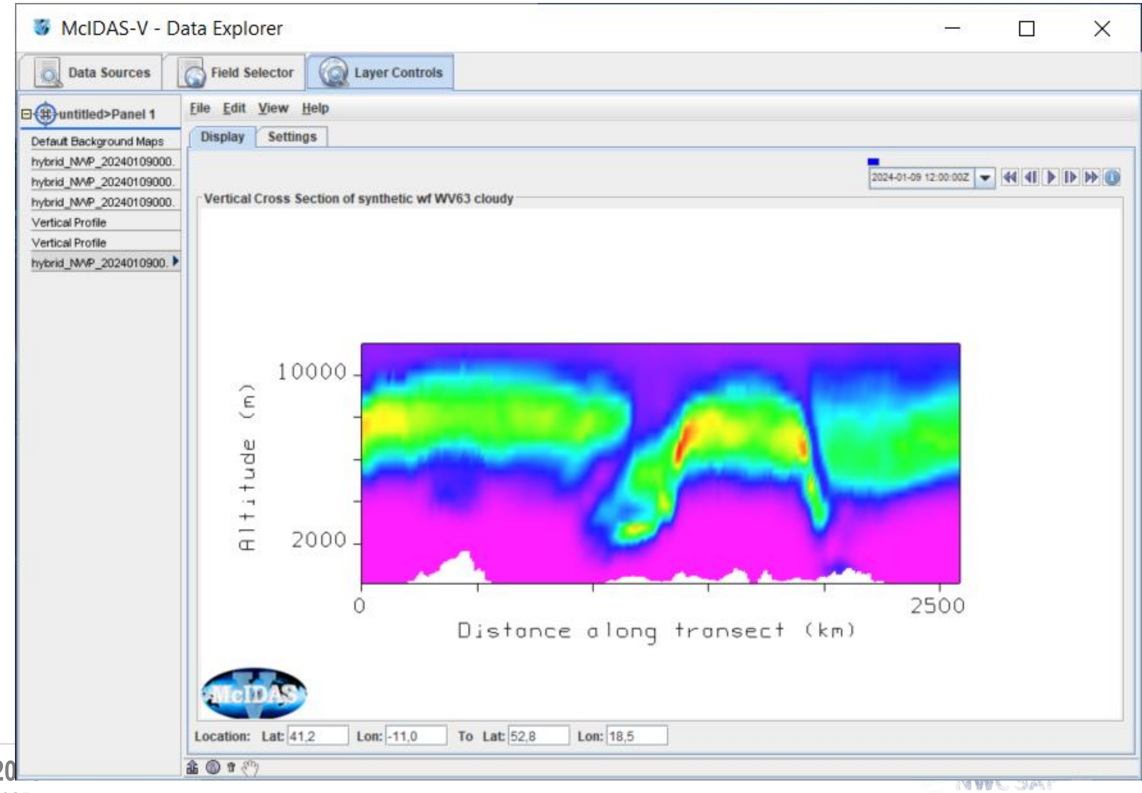
Blue probe located outside dry band



Red probe located in dry band



Vertical cross section of WV6.3 weighting functions at green line

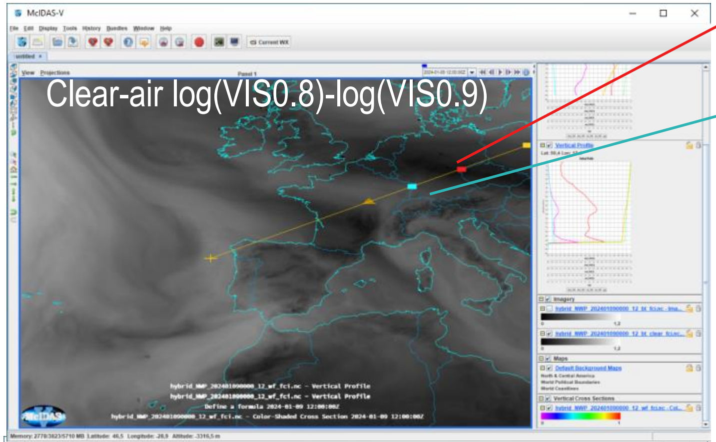


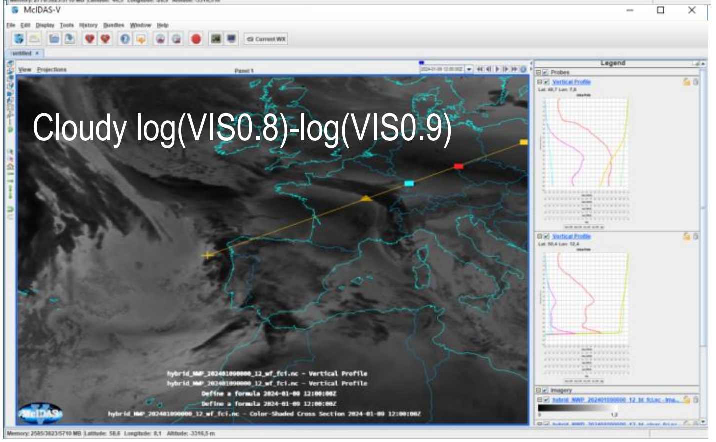
It is possible to make interactive comparison with skew-T sounding or add in probes ECMWF profiles

synthetic data from ECMWF t+12 forecast from 2024-01-09 00Z run

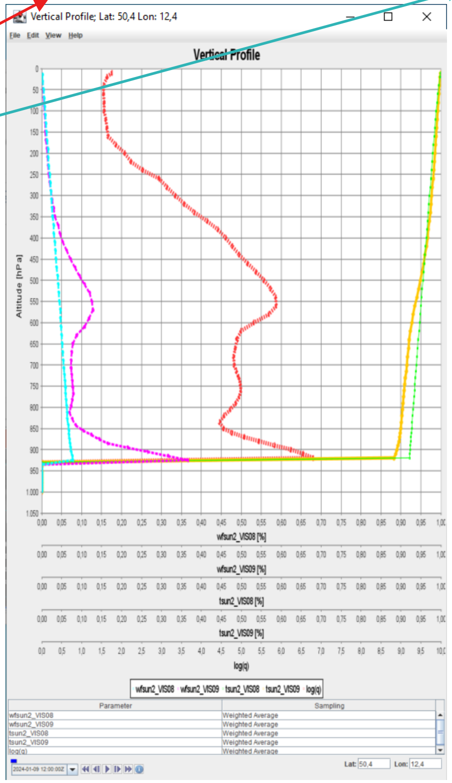
Use of synthetic FCI VIS0.8 and VIS0.9 tausun_levels_path2 profiles and equivalent to “visible weighing functions to assess as proxy of TPW

Use of log(VIS0.8)-log(VIS0.9) as proxy of TPW. See Rene Preusker at link at NWC SAF 2007 Workshop on Physical Retrieval of Clear Air Parameters from SEVIRI

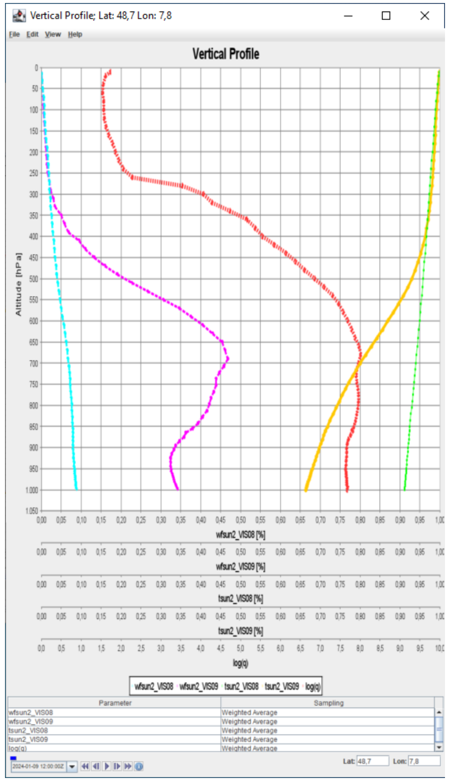




Red probe located in dry band

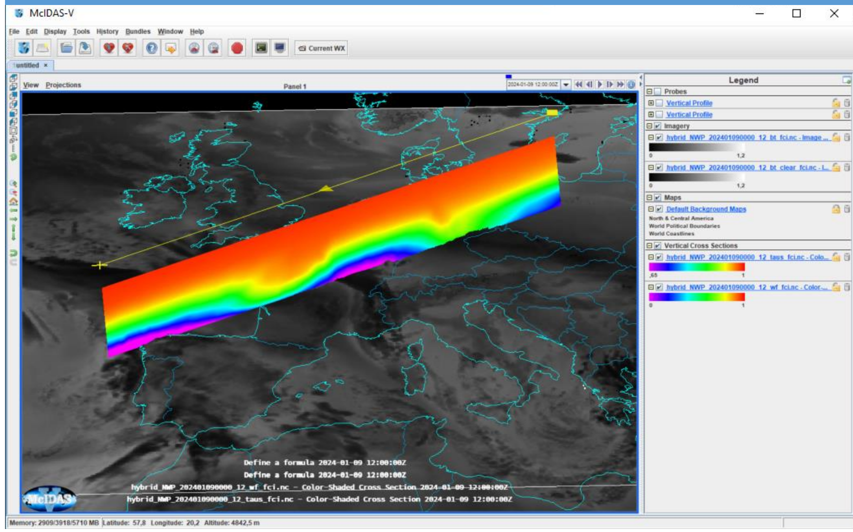


Blue probe located outside dry band

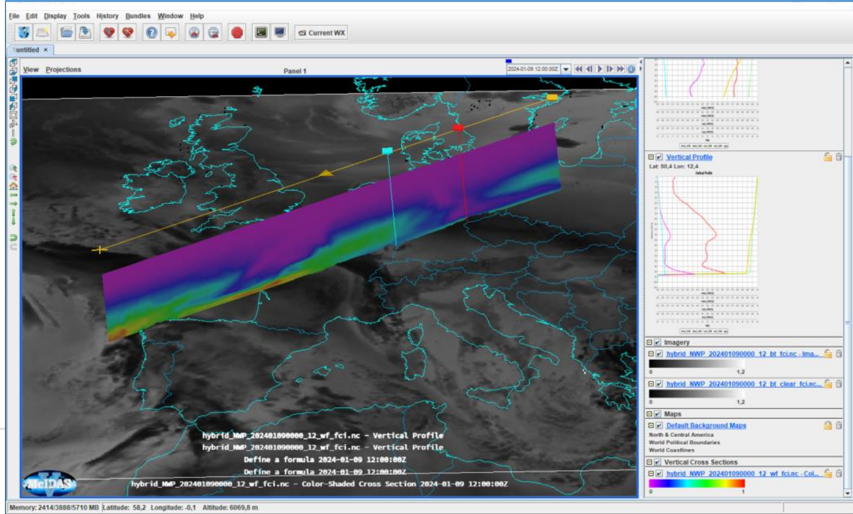


Red line ECMWF log(q) profile
Blue lines VIS0.8 weighting function
Pink line VIS0.9 weighting function
Green line VIS0.8 tausun_levels_path2 profile
Brown line VIS0.9 tausun_levels_path2 profile

VIS0.9 tausun_levels_path2

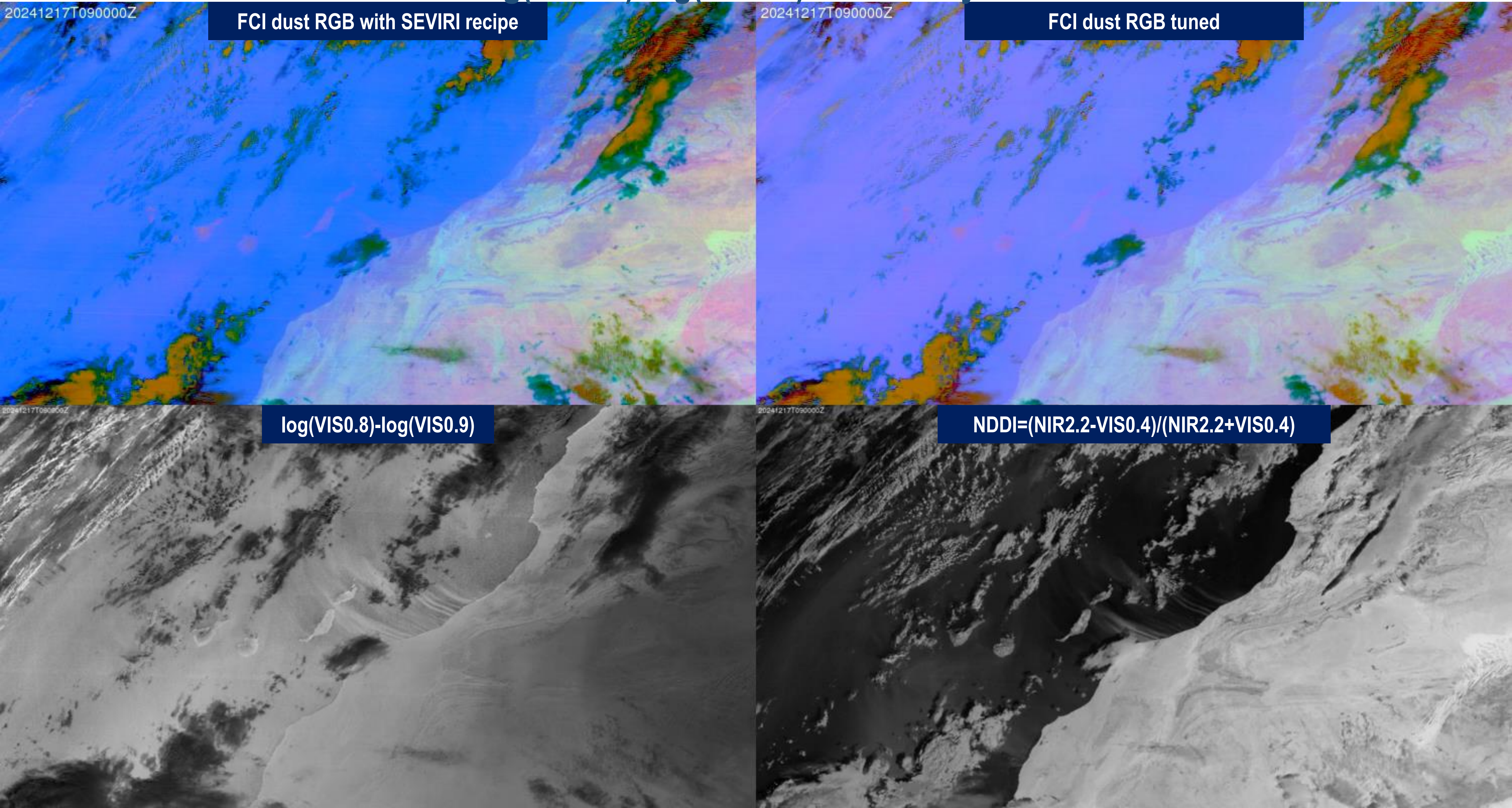


VIS0.9 equivalent to “visible weighing functions” of tausun_path2

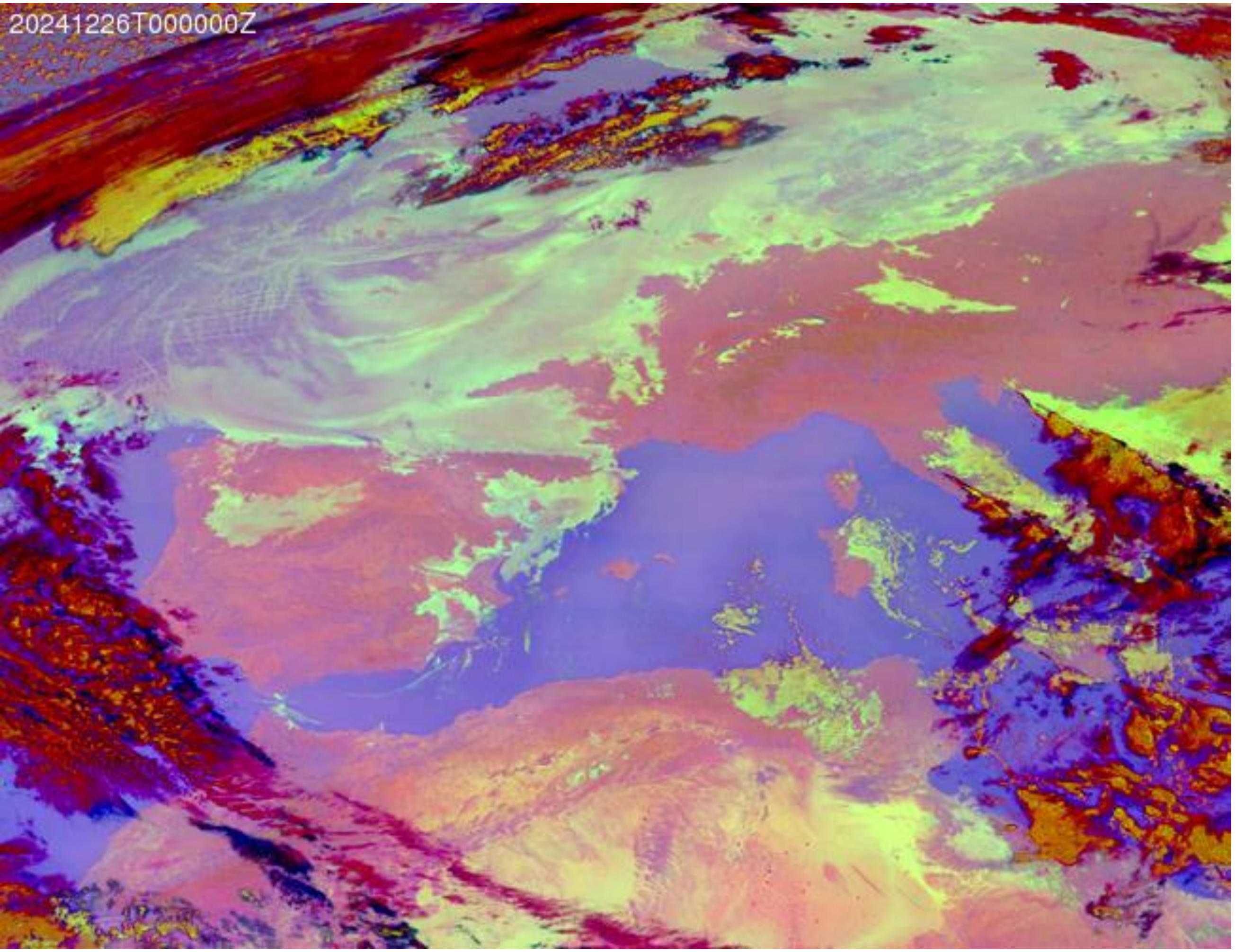


synthetic data from ECMWF t+12 forecast from 2024-01-09 00Z run

log(VIS0.8)-log(VIS0.9) affected by dust.



Loop tuned FCI night-time RGB from 26th December 2024 over Europe



✓ Example of persistent broad fog and low clouds on Duero and Ebro valleys (Iberian Peninsula) and France.

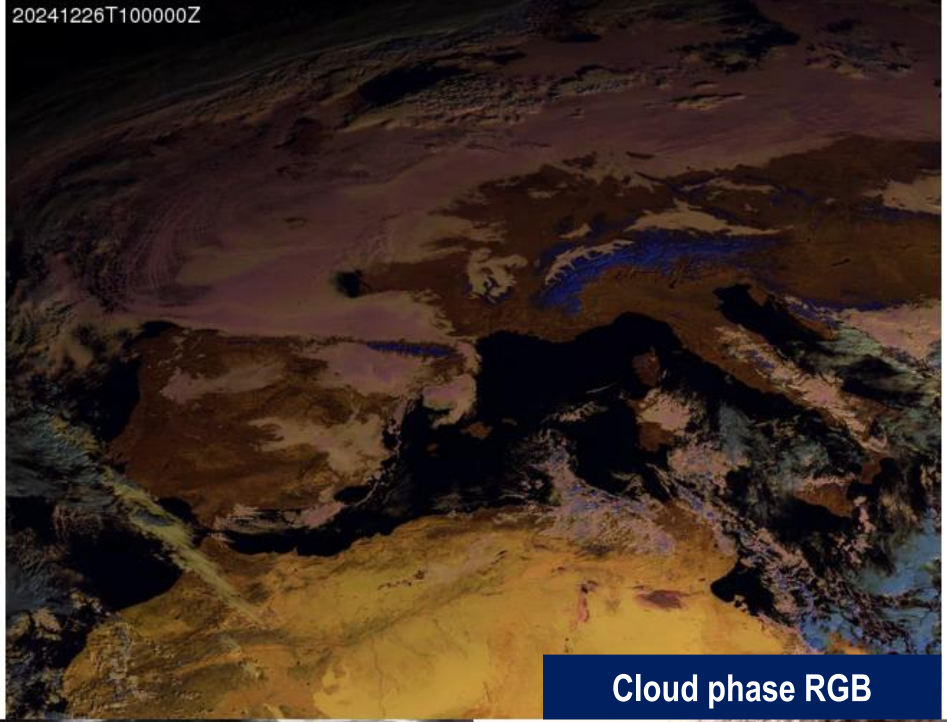
channels	Range	γ
IR12.3-IR10.5	[-7.43, 2.89] K	1
IR10.5-IR3.8	[-3.35, 4.67] K	1
IR10.5	[242.30, 298.02] K	1

Early and provisional new FCI fog RGB

Generated using regressions of MSG to FCI. Then, applying regressions original threshold. It will be used the iSHAI training and validation dataset of collocated MSG-3/SEVIRI and MTI1/FCI for better tuning using both synthetic and real BTs.

More details on tuning of FCI nighttime RGBs on link.

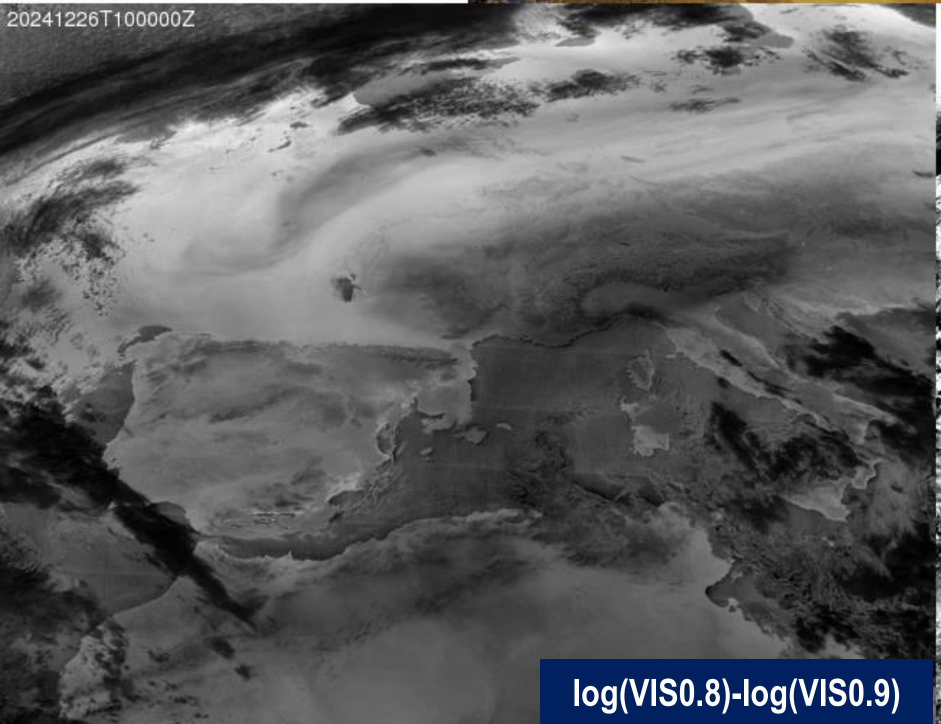
Loops of FCI daytime 26th December 2024



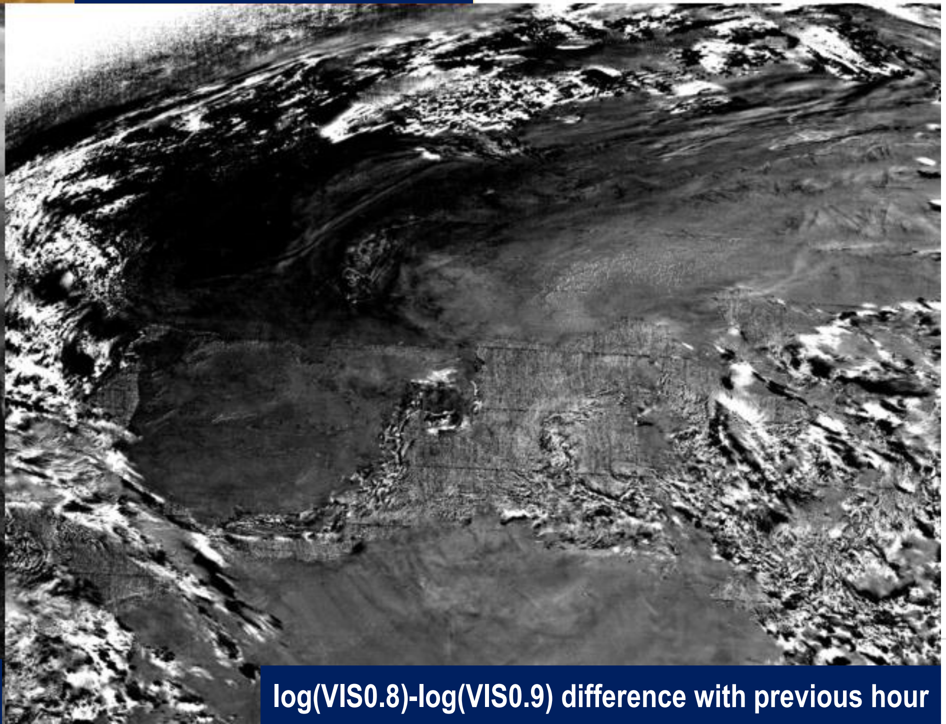
Cloud phase RGB

During daytime, persistent and wide fog clouds fields offer the opportunity log(VIS08)-log(VIS09) for TPW estimation over clouds.

It is a good example of demonstration that over clouds log(VIS08)-log(VIS09) is proportional to the precipitable water above cloud top.

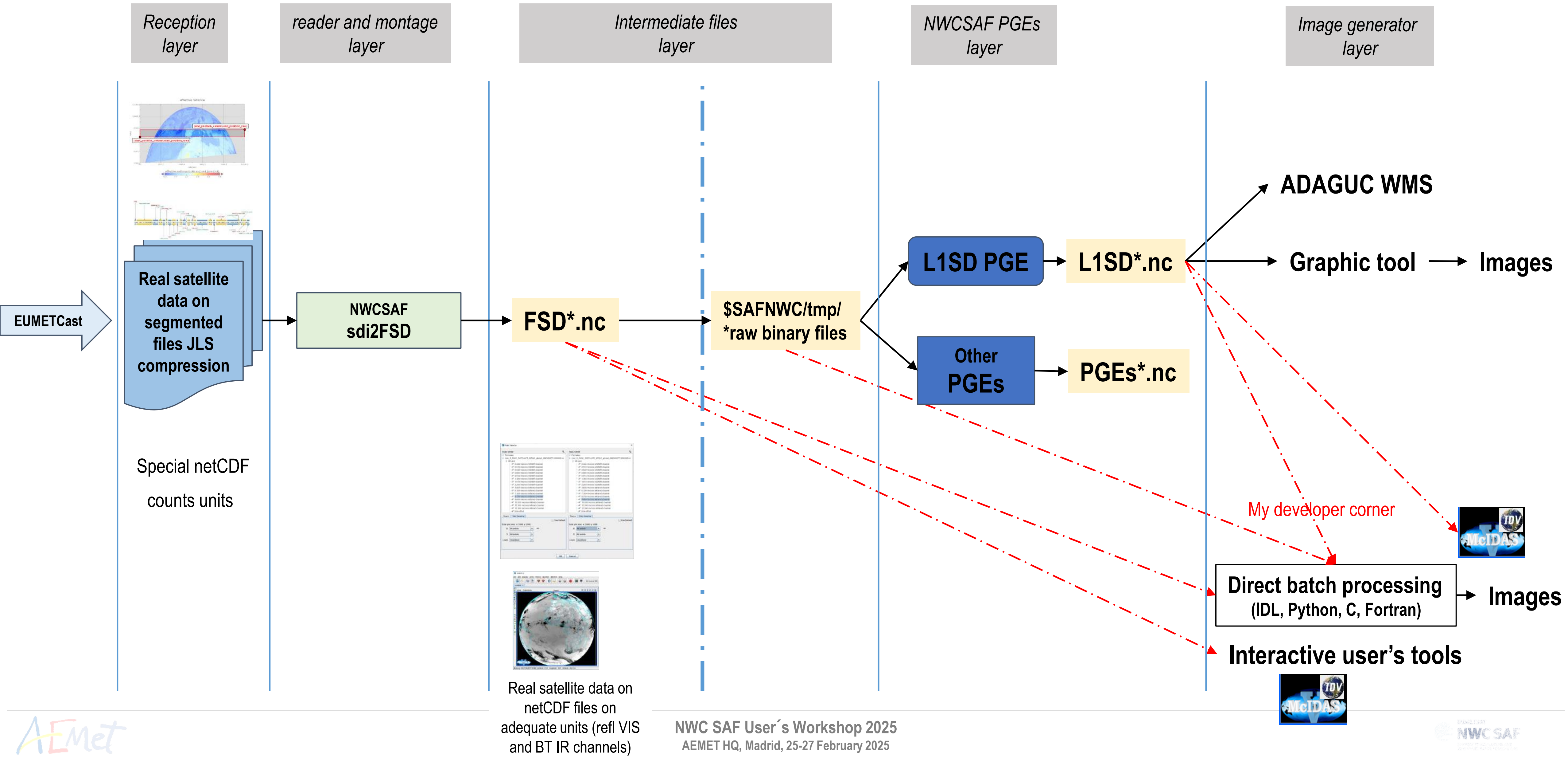


log(VIS0.8)-log(VIS0.9)


log(VIS0.8)-log(VIS0.9) difference with previous hour

More details on FCI log(VIS0.8)-log(VIS0.9) are available in these pptx links [ESSL 1]() and [ESSL2]()

L1 satellite images generation



L1SD inputs and outputs scheme

FCI images

Also other GEO imagers could be used

GEO-L1SD-v*

YYYYMMDDThhmm00Z region config_file

Ancillary and coefficients
Lon, lat, zenith
Bias correction, regression, EOF, etc

netCDF

FCI images on user's NWCSAF region

Also other GEO imagers could be used

Sat_cal: Satellite calibration methods

RAD	Radiances
REFL	Reflectances
REFN	Normalized Reflectances
REFLC	Corrected Reflectances
REFNC	Normalized & Corrected Reflectances
REFM	Normalized Reflectances based on JL&KS algorithm
REFMC	Normalized & Corrected Reflectances JL&KS algorithm
BT	Brightness Temperatures

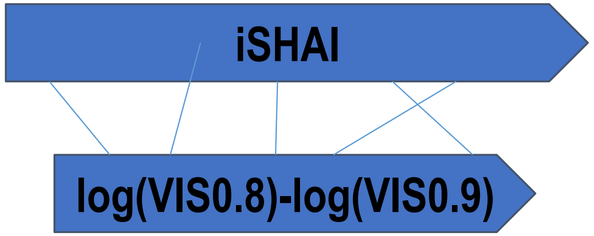
Add log(VIS08/VIS09) as a new configurable field?

SAFNWC/MSG Task Manager synchronizes the execution of the products and the first product that is generated upon the arrival of a new image is the cloud mask.

Conclusions

- NWCSAF early activities related to estimation and monitoring of precipitable water using the new FCI VIS0.9 channel and iSHAI have been presented.
- Comparison of real and synthetic cases (clear and cloudy radiances) with high NWP resolution have been shown. It has been used to better understood the log(VIS0.8)-log(VIS0.9) images. It has been shown that direct log(VIS0.8)-log(VIS0.9) from FCI provides a proxy for Total Precipitable Water (TPW) proxy estimation on clear air pixels and precipitable water content above clouds top on cloudy pixels.
- The idea of 1-hour-differences can be a technique to highlight gradual changes in moisture.
- Estimation of precipitable water over oceans using real FCI log(VIS0.8)-log(VIS0.9) could be of interest for atmospheric rivers monitoring.
- Several complementary tools has been developed (transmissivity and weighting function analysis) and used to compare other FCI channels.
- Search of new RGBs. log(VIS0.8)-log(VIS0.9) could be used to improve dust RGB and to look for future humidity RGBs.
- The TPW estimation from log(VIS08)-log(VIS09) is affected by dust. The use of NDDI or other (as dust flag on NWCSAF) will allow to screen dust contaminated pixels. These could be used for testing better functions for generations of FCI dust RGBs than the simple IR10.5 and IR12.3 difference.
- Together with NIR1.3 synthetic images, the log(VIS0.8)-log(VIS0.9) images could be used to advice for Cloud type RGB with snow view.
- A possible way to implement de FCI log(VIS0.8)-log(VIS0.9) service for TPW estimation is as new field on NWC SAF L1SD PGE.

VIS0.9 and VIS0.8 outlooks



Comparison with synthetic ones. Synthetic cases clear and cloudy radiances with higher NWP resolution will be fundamental in further developments for version MTG Day-2. Several complementary tools has been developed (transmissivity and weighting function analysis).

Difficult to incorporate VIS0.9 and VIS0.8 on iSHAI physical retrieval for local processing but could be tested in other algorithms.
Tests with synthetic refl and BTs as inputs with high resolution NWP.

Use of log(VIS0.8)-log(VIS0.9) as “truth” for iSHAI and exploration of synergies with other FCI channels (new RGBs developments)

Comparison with FUB retrieved ones. → See Xavier Calbet’s presentation.

Exploration of synergies with IRS-L1. See qIRS presentation.

Exploration of synergies with IRS-L2. See sSHAI-ES presentation.

Thanks for your attention