Cases of low-level humidity displayed in images using MODIS band ratio 0.9µ/0.8µ

MODIS bands 17 (0.905µ) and 2 (0.8585µ) resampled to ~local spatial resolution of FCI proxies for FCI bands 5 (0.914µ) and 4 (0.865µ)

HansPeter Roesli
Locarno, Switzerland
satmet.hp@ticino.com

Objectives

- Propose for FCI bands images from a simple moisture index (Solar Moisture Transmittance – smt)
- Use MODIS bands 17 and 2 as proxy data
- Discuss new RGB schemes for FCI that include smt
- Showcase meteorological situations where

Background – 1

- Operational monitoring of water vapour in the middle-upper troposphere was introduced by the water vapour bands of the SEVIRI series

- Nowcasting requirements for MTG included a similar capability for the ~boundary layer

- FCI will fly NIR0.9 as band 5: centre wavelength 0.914μ, spectral width 0.020 μ, spatial sampling distance (SSD) 1.0km

- Currently there are two operational instruments in orbit with NIR0.9 bands similar to FCI: MODIS (bands 17 or 19) on Terra/Aqua and OLCI (band Oa19) on Sentinel-3A/B

Background – 2

- MODIS offers the “Total Precipitable Water Vapor” product (MOD/MYD05_L2) that is archived in hdf files of 5-minute chunks

- Not useful for FCI nowcasting proxy

- Devise nowcasting imagery that monitors lower-level moisture fields in relation to other weather phenomena like convection or frontal systems, i.e. produce “natural-looking” image sequences similar to those already at disposal

- Display the ratio of the reflectance of a water vapour-absorbing band with the that of an adjacent atmospheric-window band, i.e. the solar water vapour transmittance – called smt for ‘Solar Moisture Transmittance’ in the following

Background – 3

- MODIS has three NIR bands with decreasing water vapour absorption: 0.940μ (band 19), 0.936μ (band 18) and 0.905μ (band 17). The weak absorption band 17, which is a good proxy for the FCI NIR0.914 band, is most useful in humid conditions and/or at low solar elevation (Eurasia!)

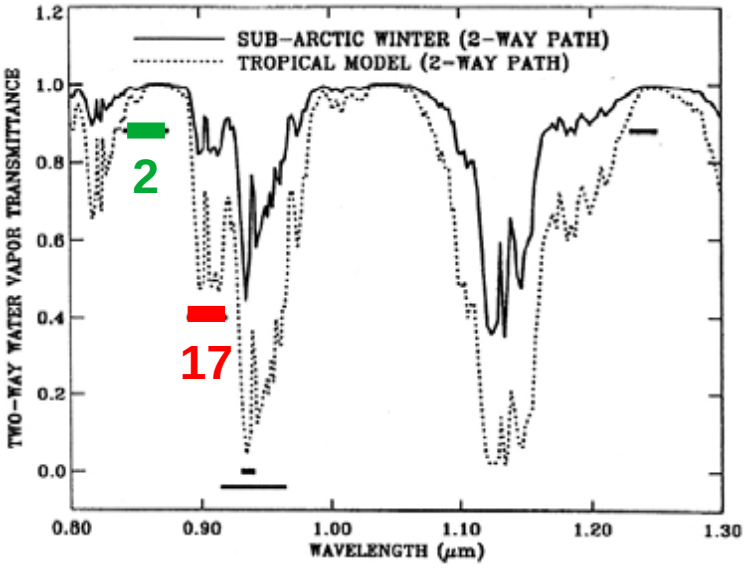
→ **numerator of smt**

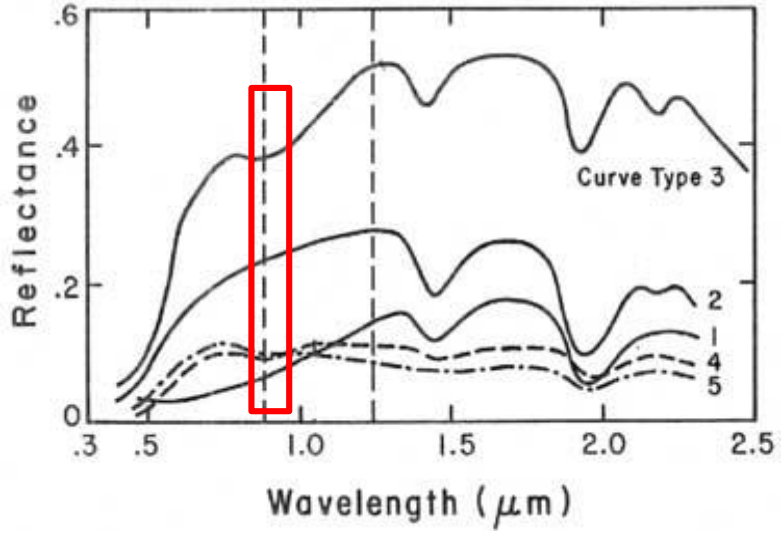
- An atmospheric window is situated half-way between 0.8μ and 0.9μ where surface reflectance is similar

→ **denominator of smt**

Two-way atmospheric water vapour transmittance spectra with possible bandwidths of relevant MODIS bands 17 and 2

Soil reflectance curves for major soil types, bands 17 and 2 fairly linear or cor





Algorithms for smt_{proxy} and smt_{FCI}

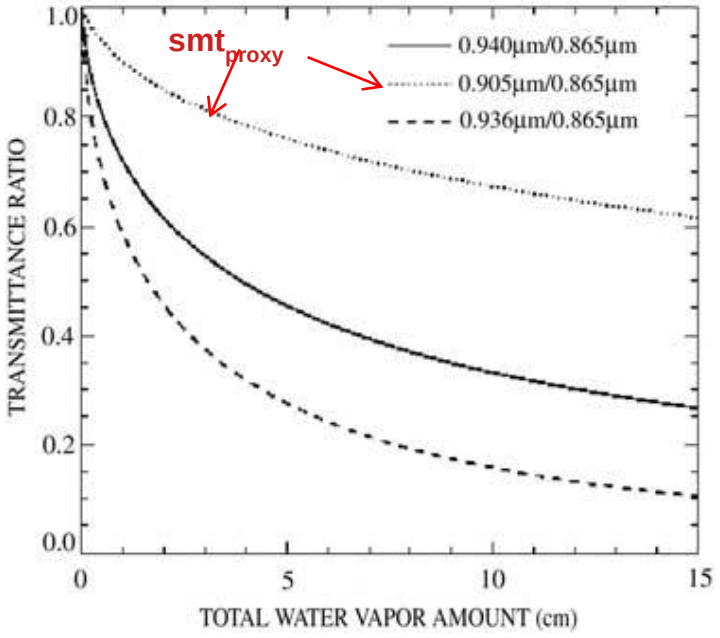
- FCI has band NIR 0.865μ (band 4) in the window, the MODIS proxy band NIR 0.8585μ (band 2) is very close-by – thus we have the following ratios:

- **smt_{proxy} = 0.905μ (band 17) / 0.8585μ (band 2)**
  smt_{FCI} = 0.914μ (band 5) / 0.865μ (band 4)

- MODIS bands varies from 250m for band 2 to 1km for band 17 and is resampled to the FCI SSD over the areas of interest
- For FCI it will be advisable to correct the reflectance for the sun position, though this is partially compensated by the ratio operator

Range of smt_{proxy} values

- Examples of simulated transmittance ratios of two channels (absorption band / window band) as a function of total water vapour amount in the Sun-surface sensor path, from Gao&Kaufman:

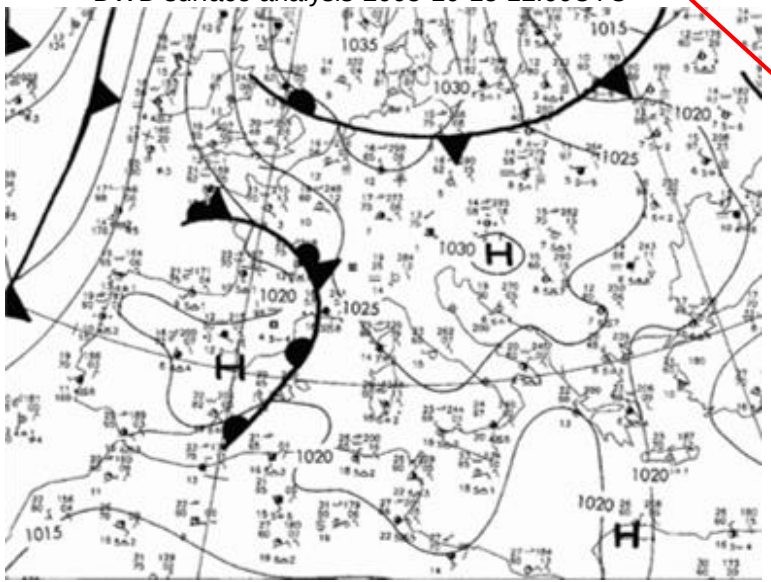


- Thus, theory suggests a range of 0.6 to 1.0 for smt_{proxy}
- Range is confirmed in studied situations, this range clipping is applied to proxy smt/RGB products shown

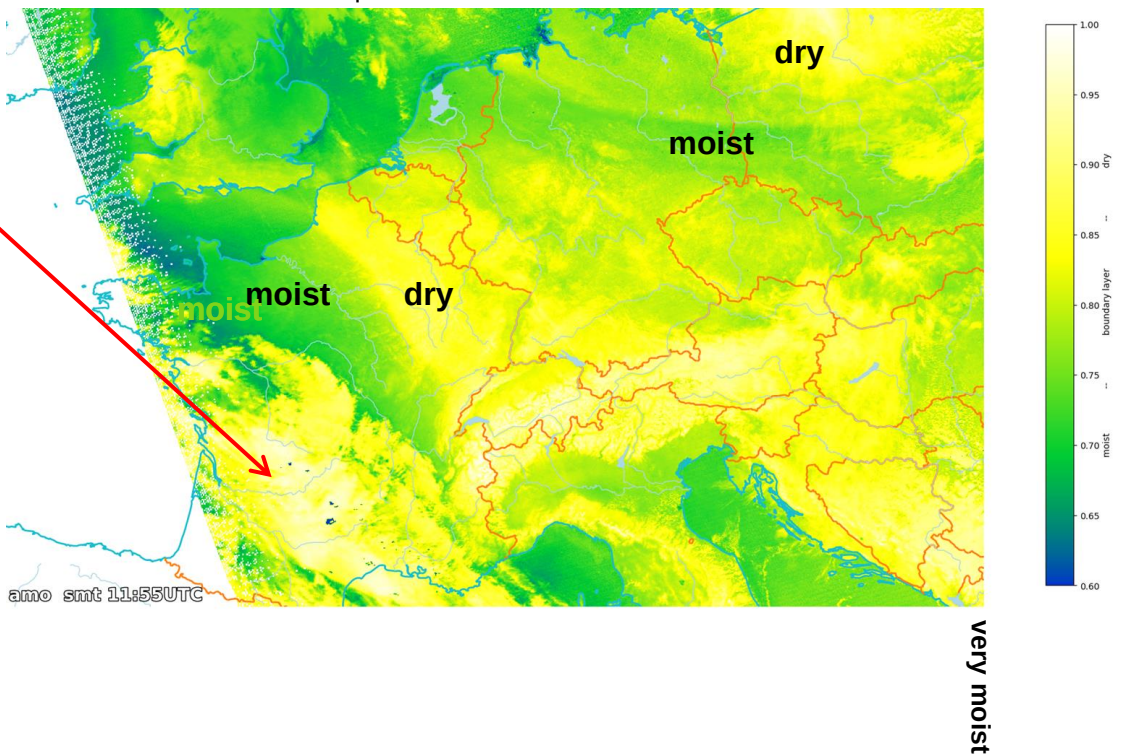
First example of a colourised smt_{proxy} image

- White-yellow-green-blue colour map with gamma=0.75 (stretch yellow-white range)
- smt's dry-moist patterns render well the two frontal zones over France and Germany
- Moist intrusion over the Po Valley, not an obvious feature
- In the occlusion smt differentiates between lower (yellowish) and higher (whitish) clouds

DWD surface analysis 2005-10-15 12:00UTC



Aqua smt 2005-10-15 11:55UTC



Possible RGB schemes using smt_{proxy}

roughly tuned only

0.905/0.8585 – smt

band [µ]	range	gamma [$x^{1/\Gamma}$]
smt / 17:2	0.6..1	0.75

Natural Colour RGB heritage – smtNatcol

band [µ]	range	gamma [$x^{1/\Gamma}$]
NIR1.64 / 6	0%..100%	0.667
smt	0.6..1	0.667
VIS0.645 / 1	0%..100%	0.667

Dust RGB heritage – smt&tmt

band [µ]	range	gamma [$x^{1/\Gamma}$]
IR12-IR11 / 32-31	0K..15K	0.4
smt	0.6..1	0.833
IR11 / 31	290K..240K	1

new RGB – smt&nir13

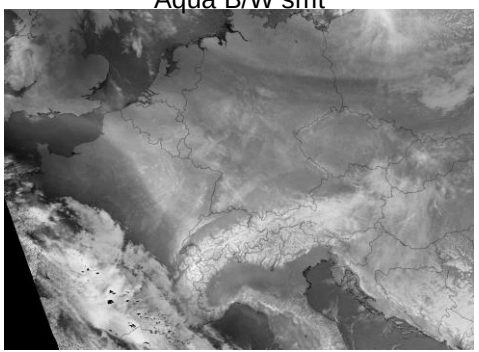
band [µ]	range	gamma [$x^{1/\Gamma}$]
smt	0.6..1	0.833
NIR1.3 / 26	0%..40%	0.25
IR11 / 31	290K..240K	1

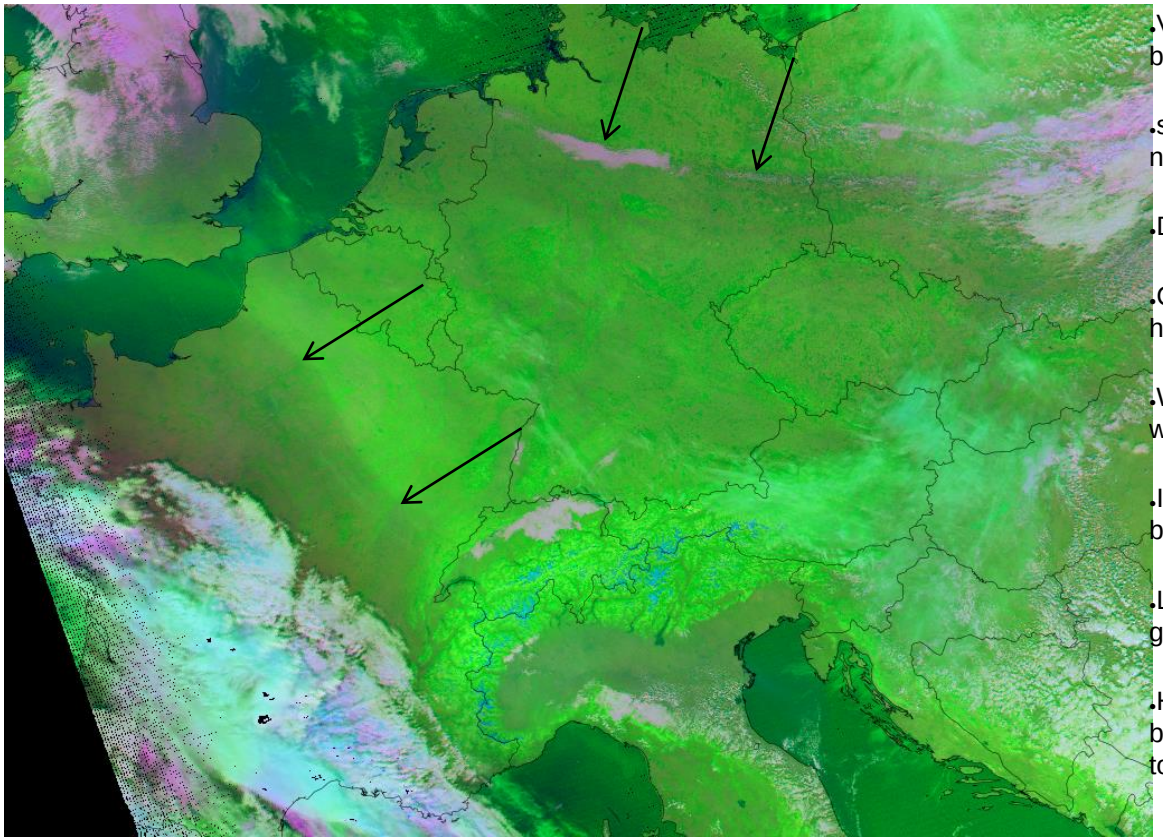
Possible RGBs using smt – 1
Natural Colour RGB heritage

Natural Colour RGB

2005-10-15 11:55UTC

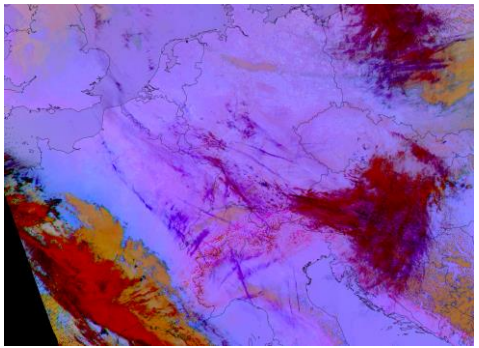
Aqua B/W smt





- VIS 0.865 vegetation band (green beam) substituted with smt
- smt patterns well rendered (arrows), not visible in Natural Colour RGB
- Differentiates land-water-moisture
- Cloud colours complex – some heritage from Natural Colour RGB
- Water cloud: white to magenta
- Ice cloud: blue to cyan
- Lower (water) cloud: greyed due to small smt values
- Higher (water/ice) cloud: brightened due to smt values close to 1

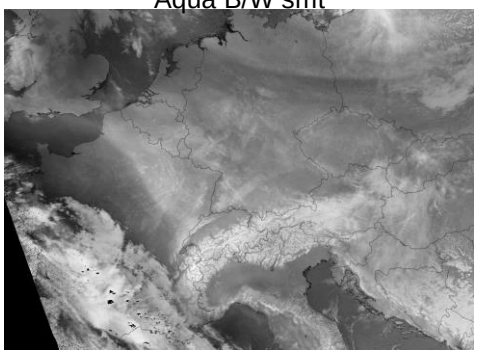
Possible RGBs using smt – 2
Dust RGB heritage

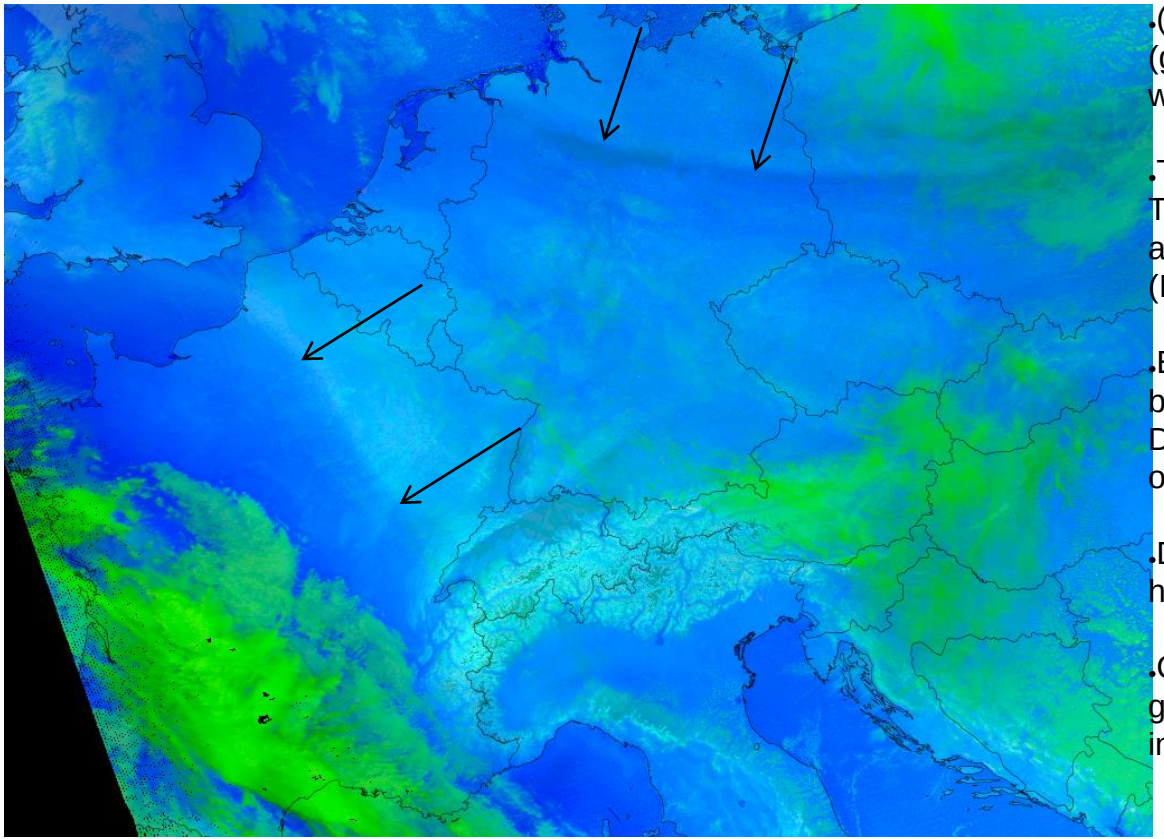


Dust RGB

2005-10-15 11:55UTC

Aqua B/W smt





- (IR10.8-IR8.7) dust band (green beam) substituted with smt
- Thermal Moisture Transmittance (IR12-IR11) and temperature profile (IR0.8) are retained
- Enhances moisture boundaries (arrows) – in Dust RGB only faintly visible or by hindsight
- Dust signal absent (no dust here, of course)
- Cloud given by smt only, getting lighter green with increasing top height

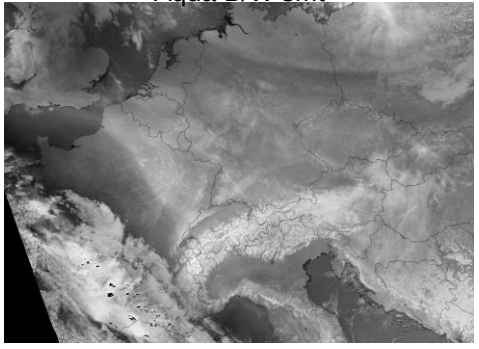
Possible RGBs using smt – 3

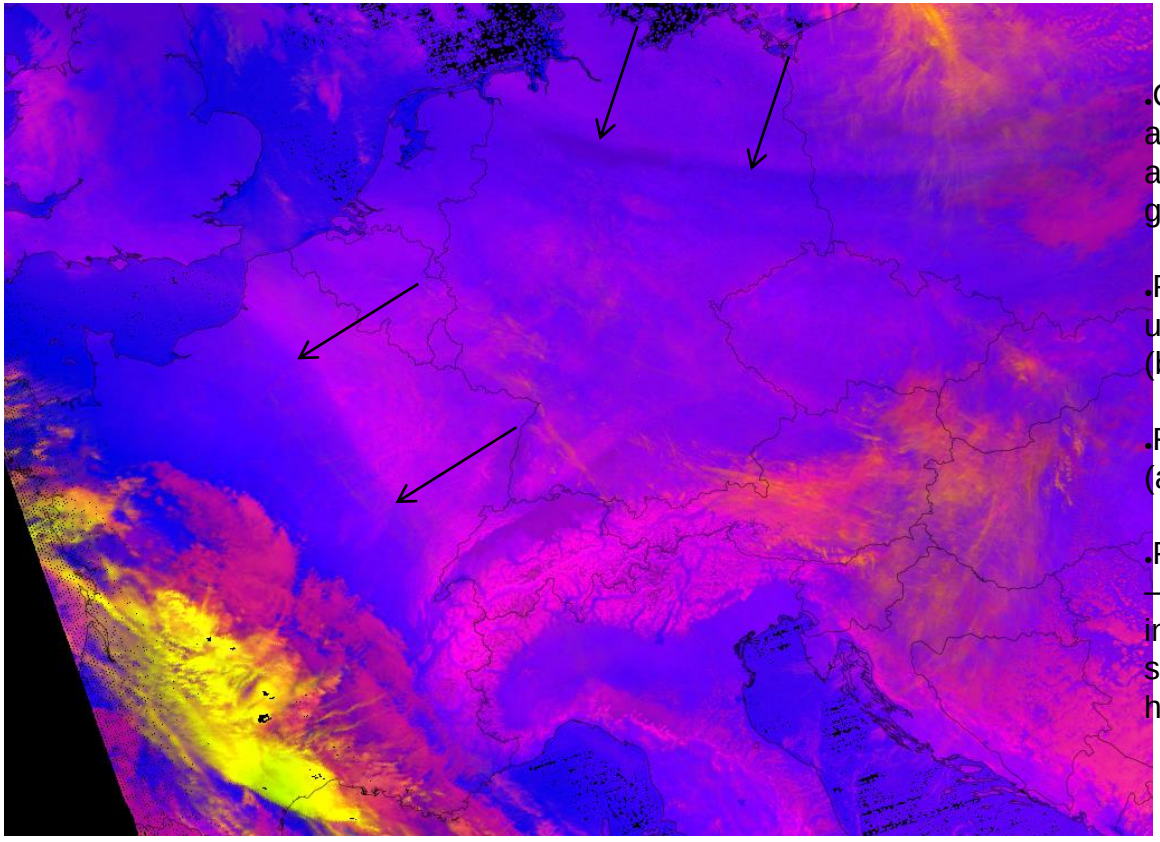
smt&nir13 RGB very limited SEVIRI RGB heritage

Natural Colour RGB

2005-10-15 11:55UTC

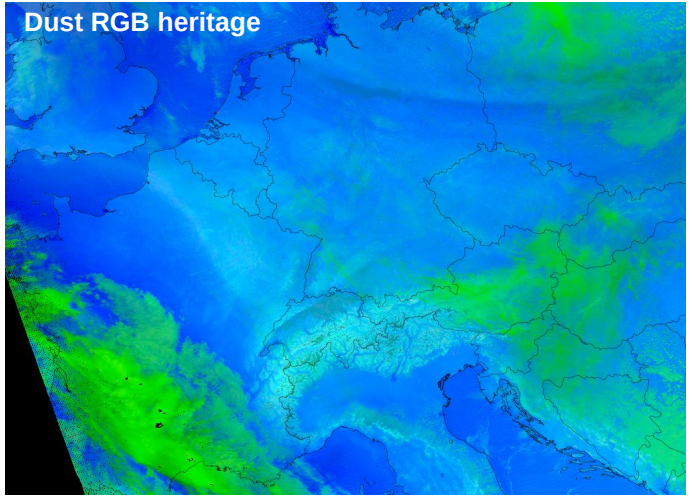
Aqua B/W smt

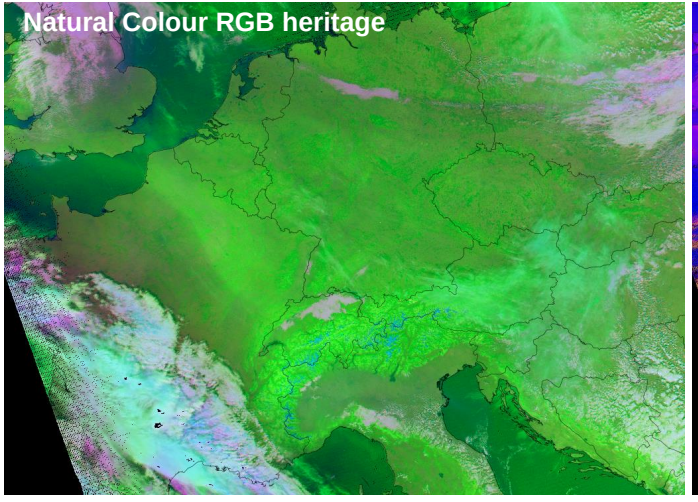


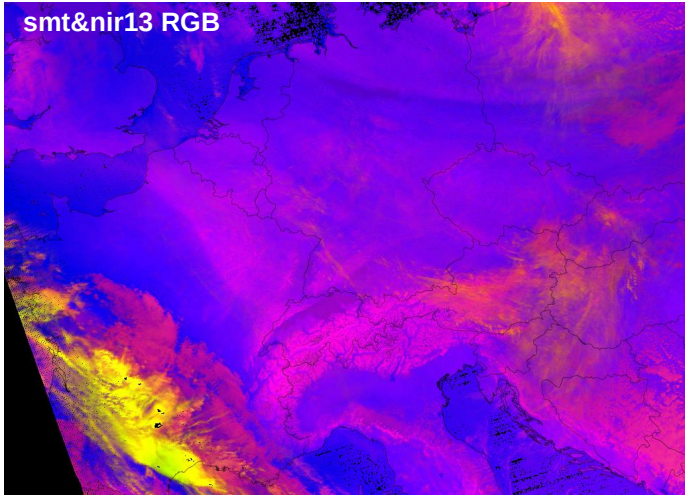


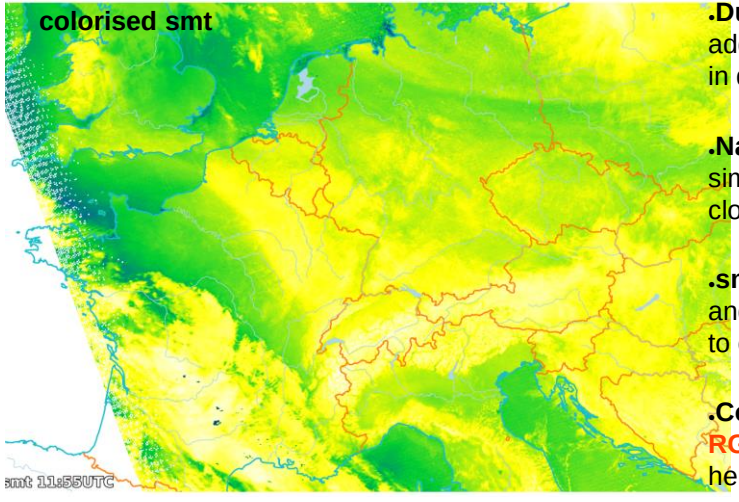
- Couples smt (red beam) with another solar-moisture absorption band (NIR1.3 – green beam)
- Preserves temperature profile used in some SEVIRI RGBs (blue beam)
- Renders moisture boundaries (arrows)
- Presence of clouds (from smt – red hues) enhanced by inclusion of cirrus/contrail streaks (from NIR1.3 – green hues)

smt RGBs - comparison/selection







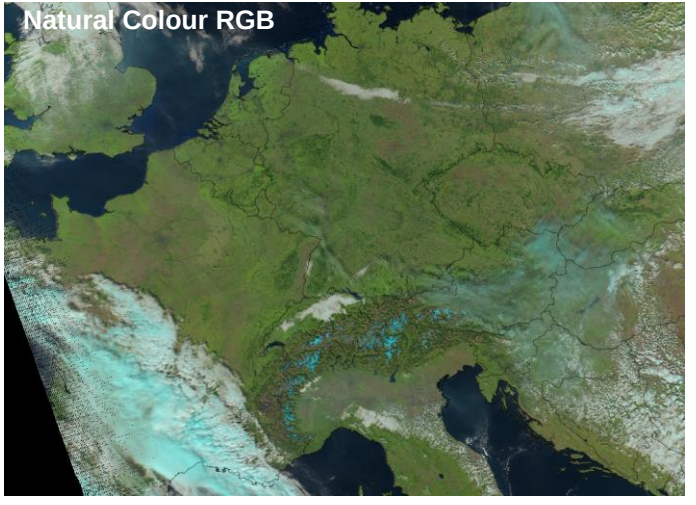


.**Dust RGB heritage:** blue-green only, not much additional information over smt B/W, might be considered in dust situations

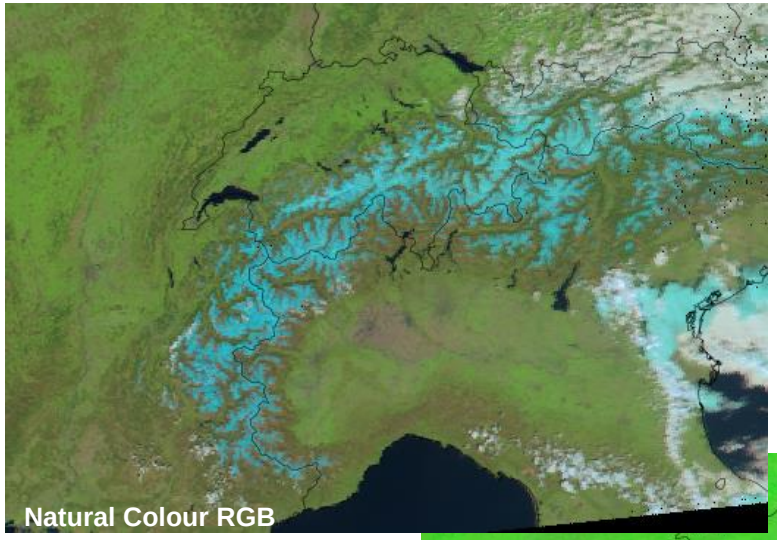
.**Natural Colour RGB heritage:** moisture information similar to Dust heritage but adds more (multi-coloured) cloud information

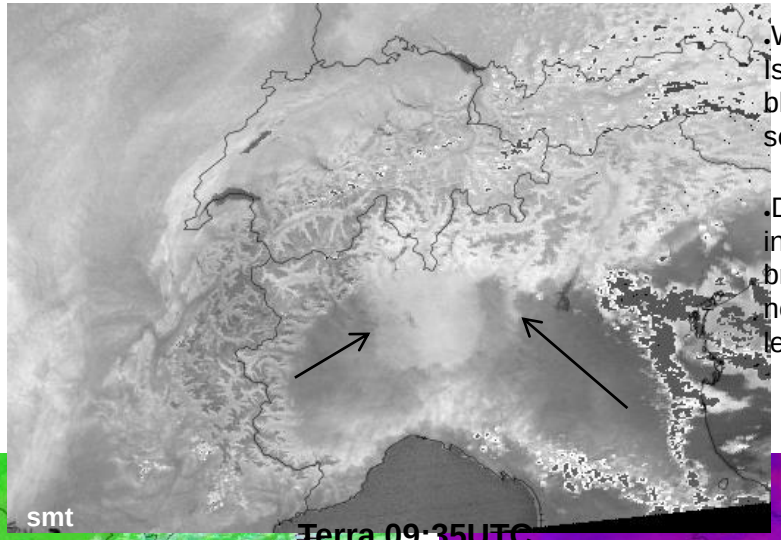
.**smt&nir13 RGB:** moisture information similar to Dust and Natural Colour heritages, expands cloud information to cirrus and contrails

.**Conclusion**: **Natural Colour RGB heritage**, **smt&nir13 RGB** and **(colourised) smt** look promising, Dust RGB heritage needs further evaluation under dust events



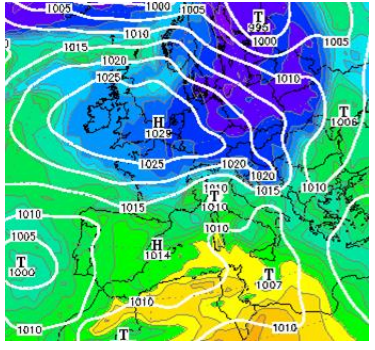
North-foehn over Lombardy, 2020-04-14



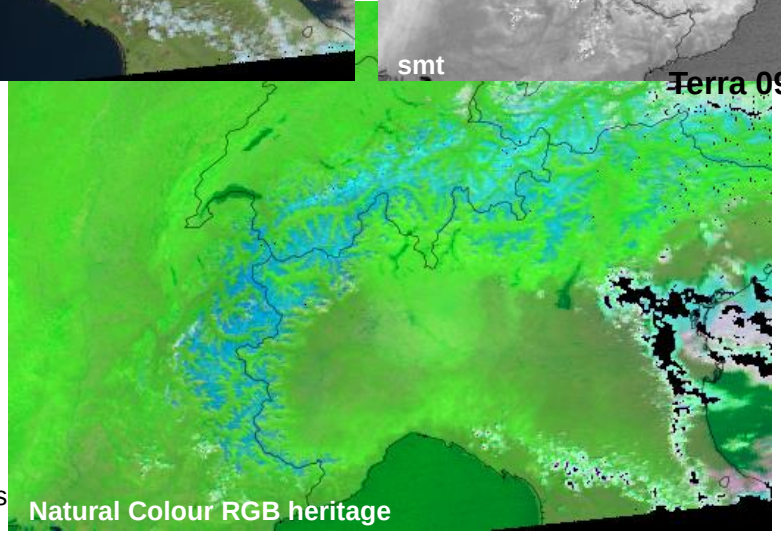


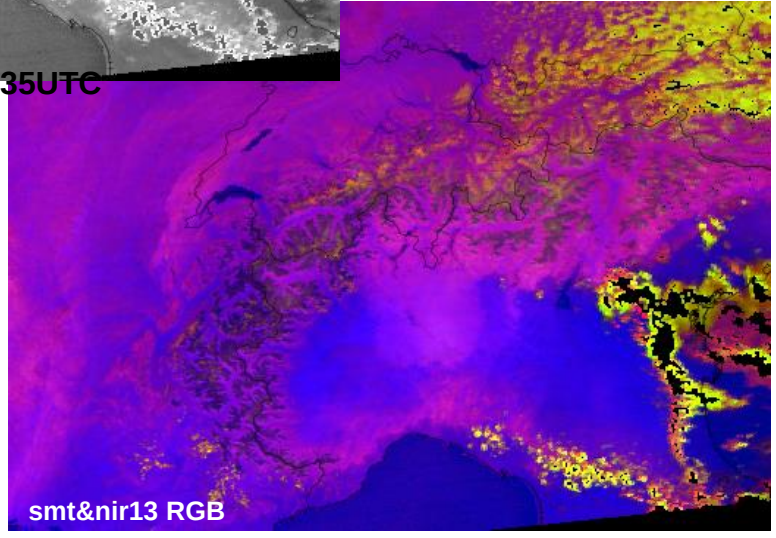
- Weather analysis shows high over British Isles and polar air at 850hPa (blue) being blocked north of the Alps while flowing southward further east

- Dry north-foehn flow from the Central Alps into Lombardy rendered in smt by two bright (dry) swaths (arrows) – both swaths not present in Natural Colour RGB to the left, but in other two RGBs at the bottom

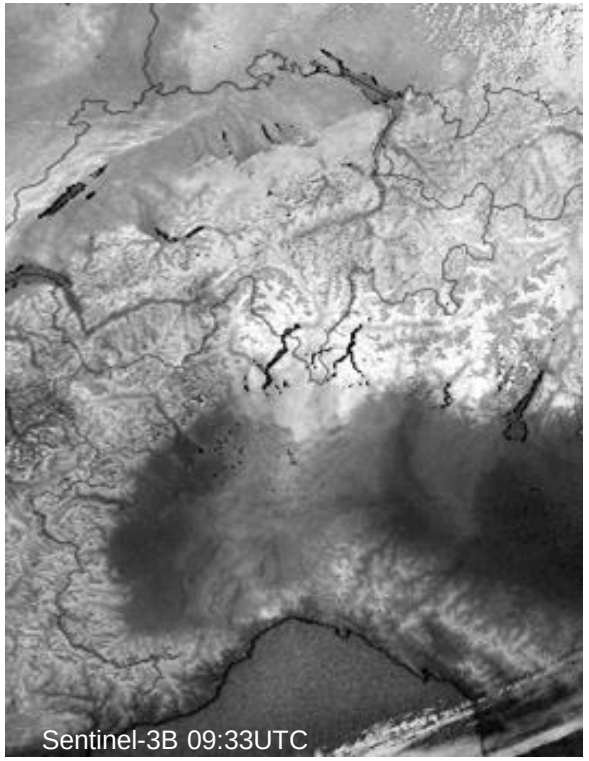


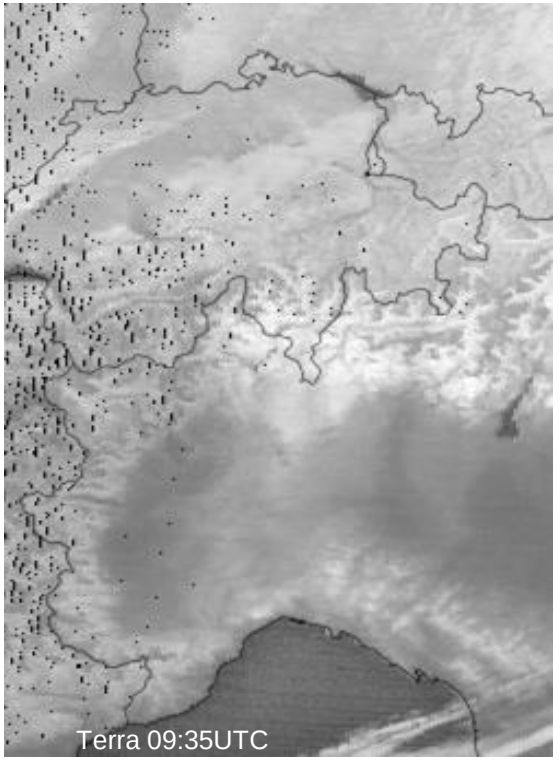
DWD MSLP & 850hPa analys
12:00UTC

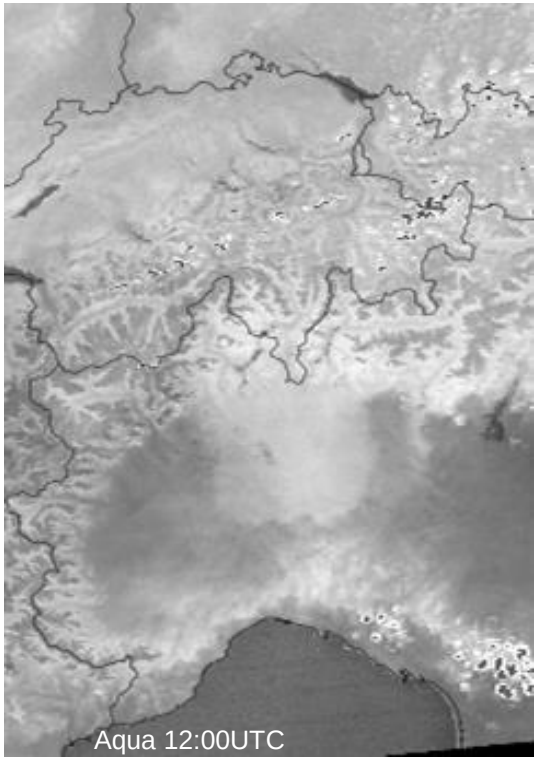




North-foehn over Lombardy, 2020-04-14
compare smt from MODIS/OLCI, temporal evolution



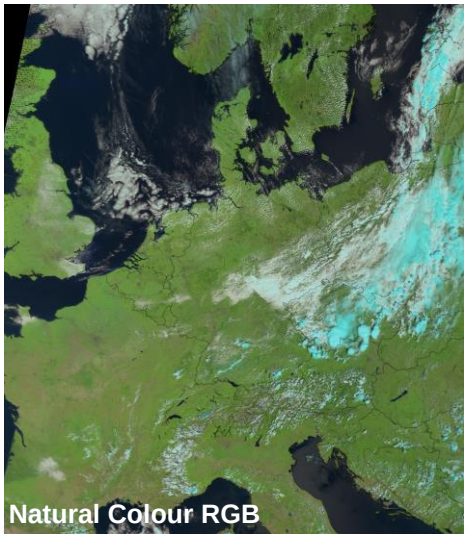


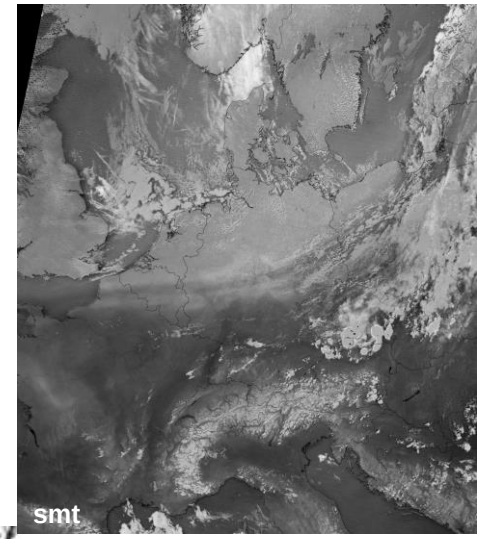


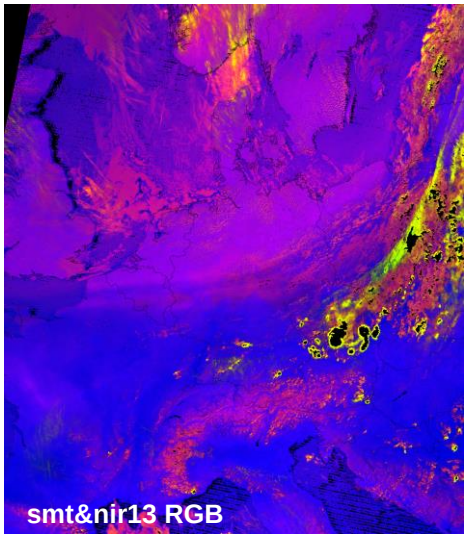
- OLCI on Sentinel-3A/B has NIR 0.865 and NIR 0.90 (bands 17 and 19) that may used for smt, quite similar to MODIS – compare images on the left and in the middle, taken almost at the same time – beyond different contrast patterns are very similar

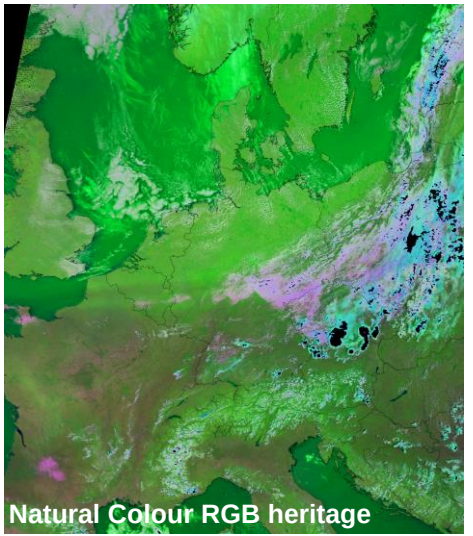
- Being able to follow the foehn flow improves nowcast of its extent/strength and, in particular, its breakdown when Bora winds penetrate the Po Valley from the Adriatic Sea – was among the drivers for the recommendation to add NIR0.9 to FCI

Frontal tails over France-Germany, 2018-05-13

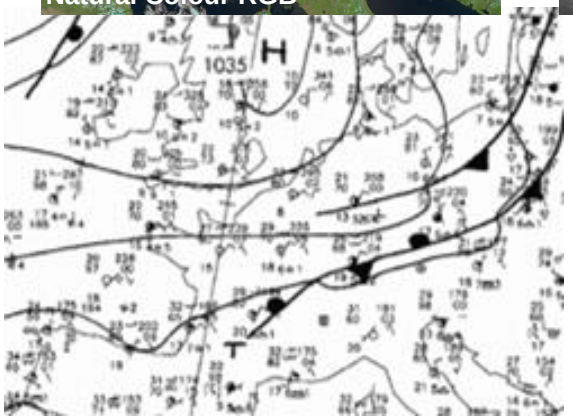








Terra 10:15UTC

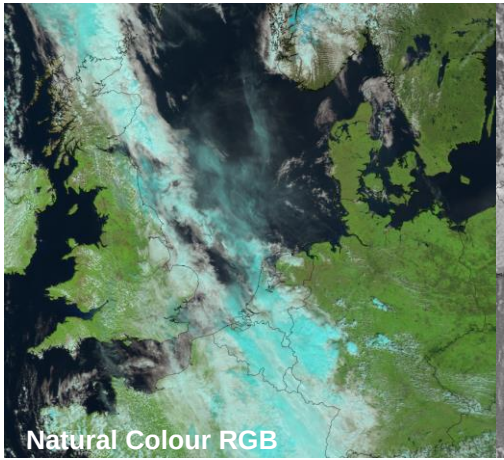


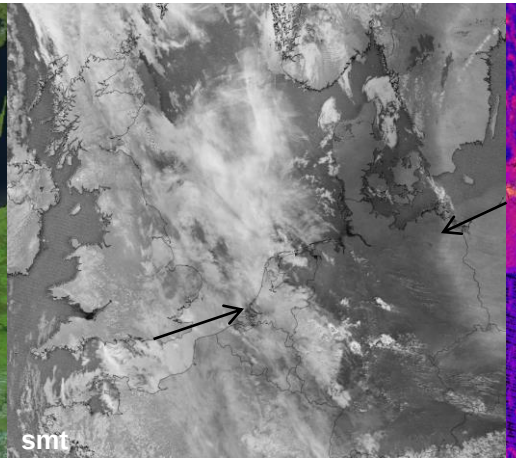
DWD MSLP analysis 12:00UTC

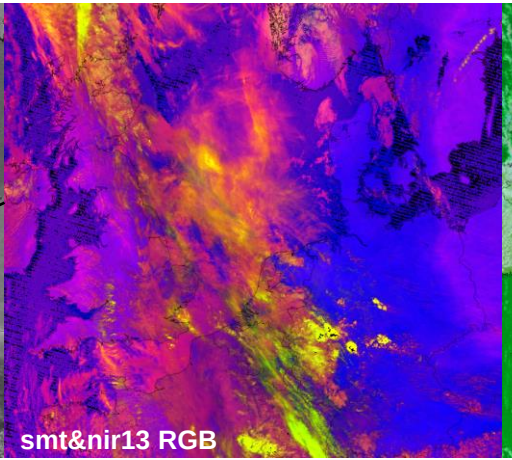
- Weather chart shows frontal tails under anticyclonic influence
- Natural Colour RGB just shows some remnant cloud
- New imagery shows a clear boundary between dry air north and moist air south of the frontal tails, and more important clouds in the active part of the frontal zone in the east (colour identification marred by invalid MODIS pixels)
- Lingering old airmass boundaries might still have impact on local weather in warm season

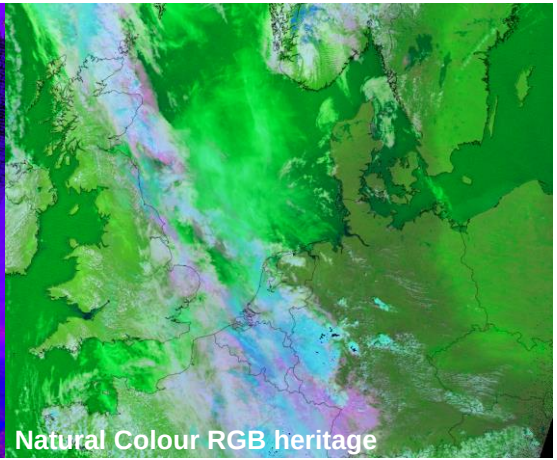
Terra 09:35UTC

Convergence line over UK-NL, 2018-05-13

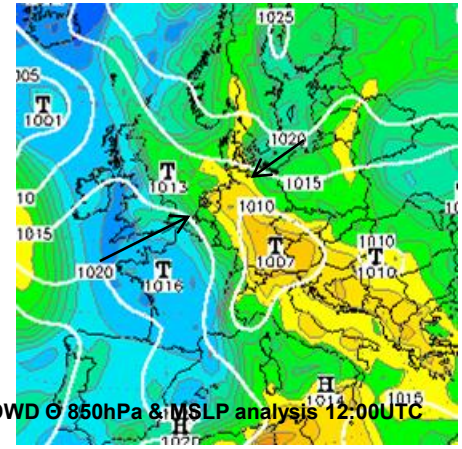








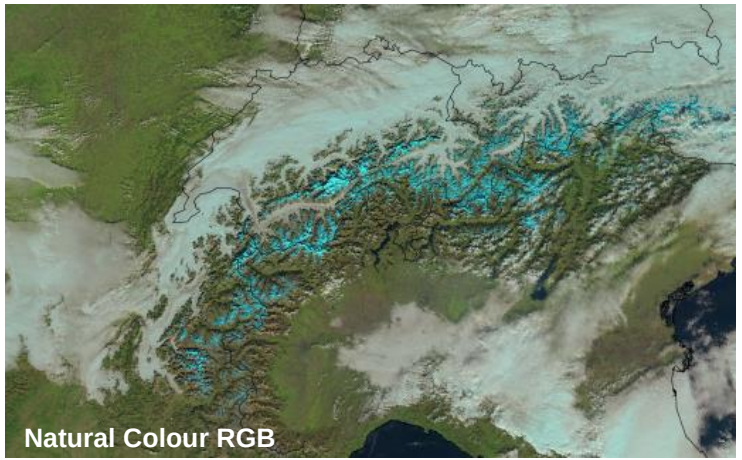
Terra 11:00UTC

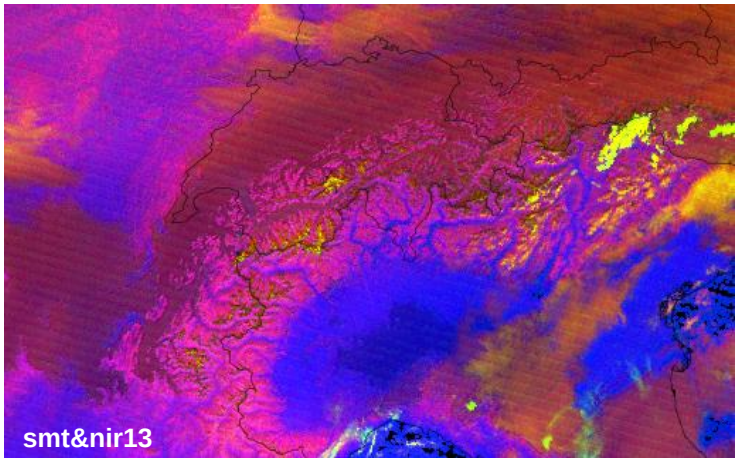


- Weather chart shows convergence zone from England to the Netherlands (arrows)
- Natural Colour RGB shows convective cells along the convergence zone
- smt RGBs add a corresponding dry-moist-dry airmass sandwich (arrows)
- Lingering airmass boundaries tend to get lost/forgotten, but might still have impact on local weather

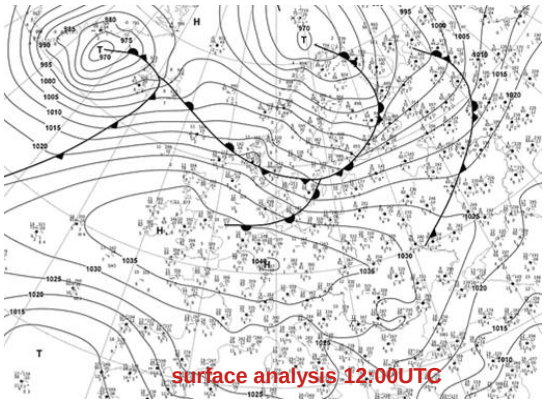
Terra 09:35UTC

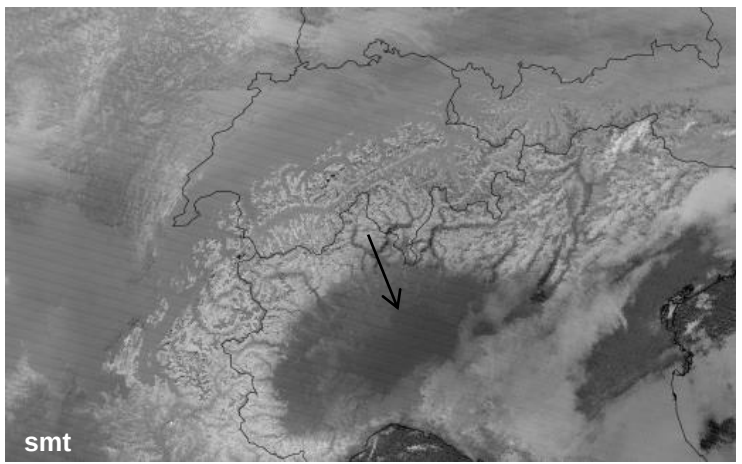
Low clouds around the Alps, 2020-11-05

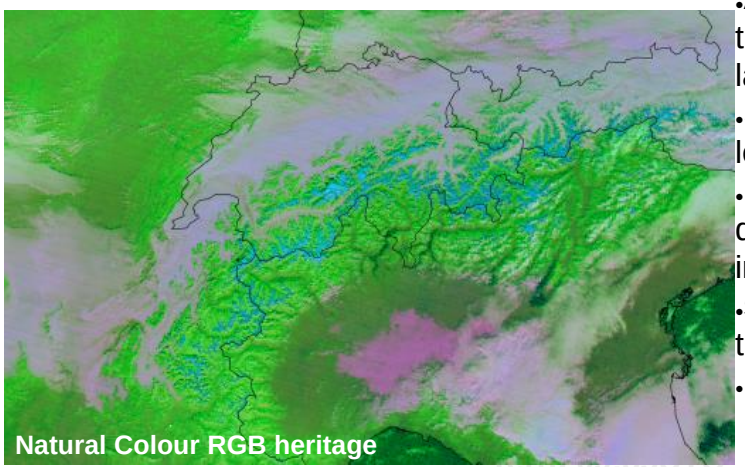




Terra 10:45UTC

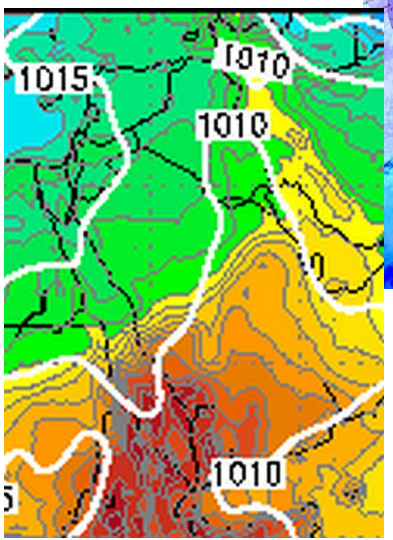




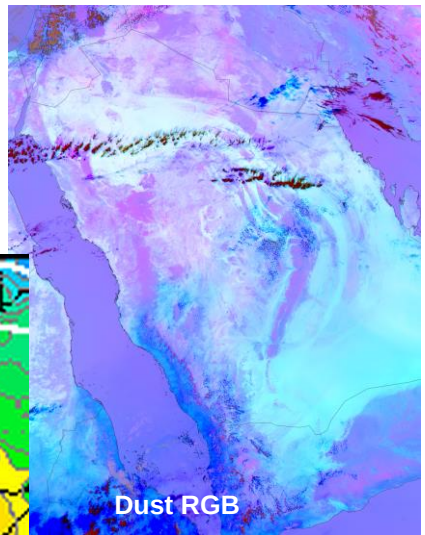


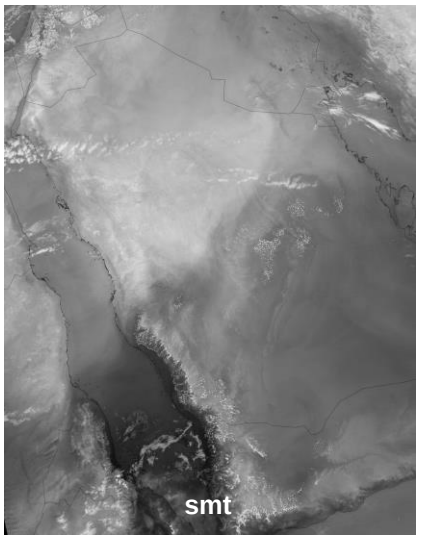
- Anticyclonic late-autumn conditions over the Alps – potential for moist boundary layers
- Snow badly detectable in smt RGBs (a bit less so in Natural Colour RGB heritage)
- Natural Colour RGB heritage differentiates well between cloud top levels in Po Valley (smt shows very dark fog)
- smt&nir13 RGB enhances high cloud in the east
- Moisture adds valuable information

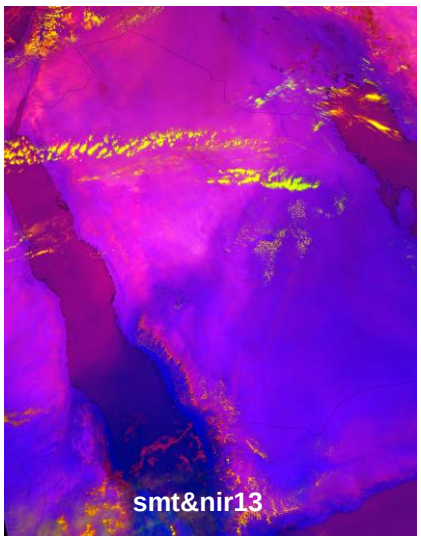
Dry intrusion over Arabian Peninsula, 2006-03-15

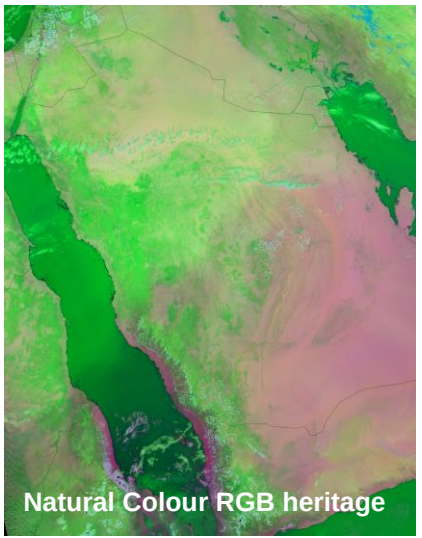


DWD Θ-analysis 850hPa 12:00UTC





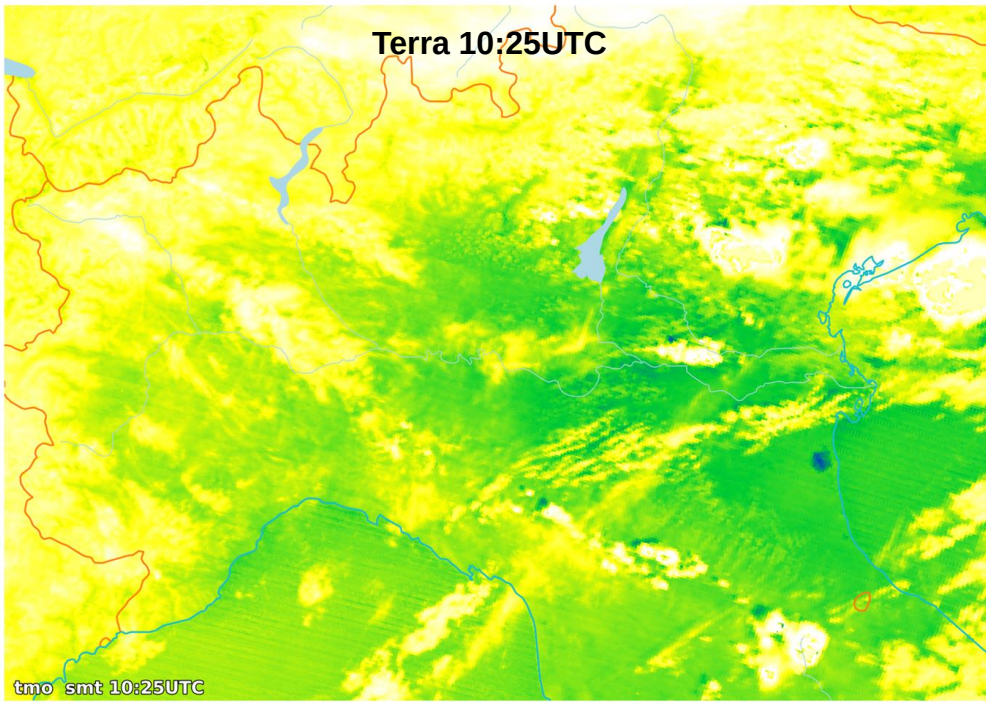


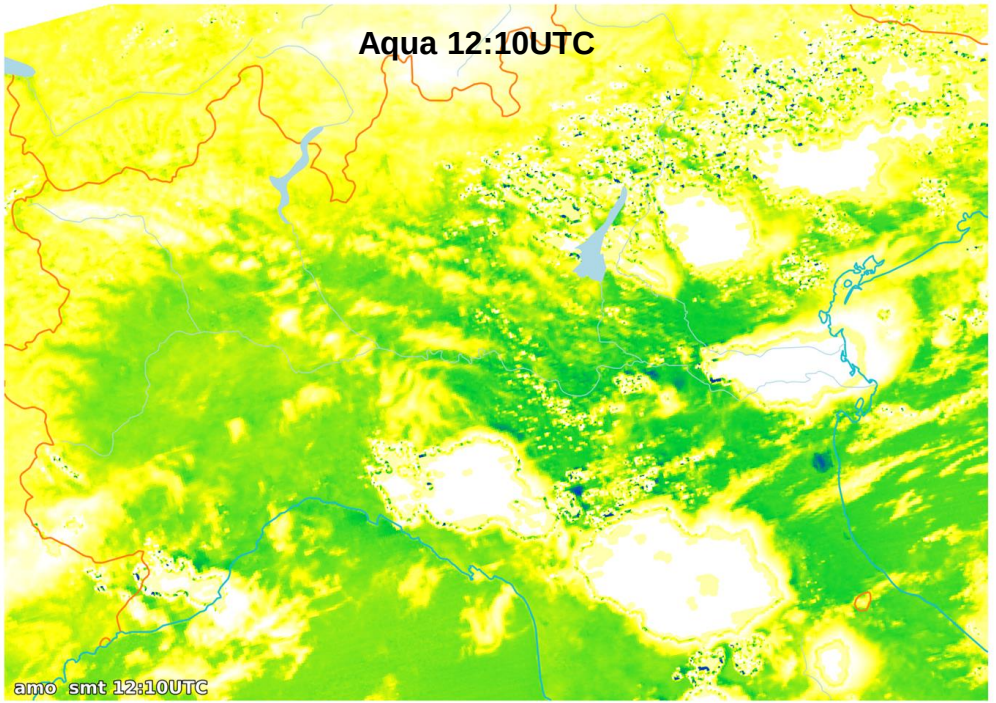


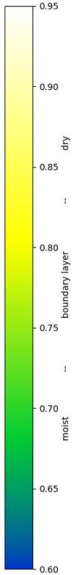
Aqua 10:20UTC

- Intrusion of dry air from north is well marked by the green-ochre coloured boundary Θ-analysis at 850hPa
- Some sign of the airmass boundary on the Dust RGB
- Much better rendered on the other 3 images to the right
- On top, smt&nir13 RGB enhances the cirrus streaks (yellow) over the northern part of the peninsula
- Shamal situation, usually leading to blowing sand and haboobs – will assist storm watch (in daylight)

Clouded case: eastern backflow into Po Valley
2022-05-28







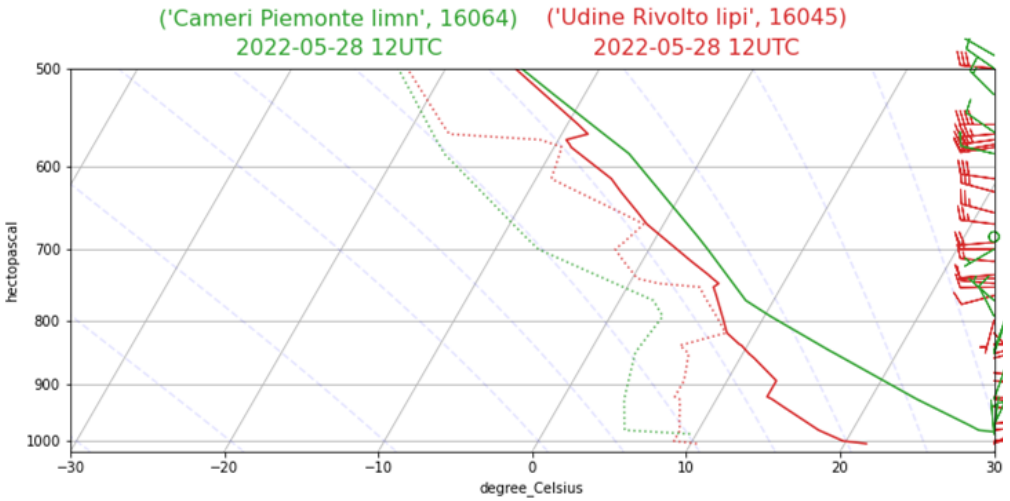
- Slow intrusion of Bora-type air up the Po Valley

- Convection above boundary layer partially hides moisture line
→ a case for time series!

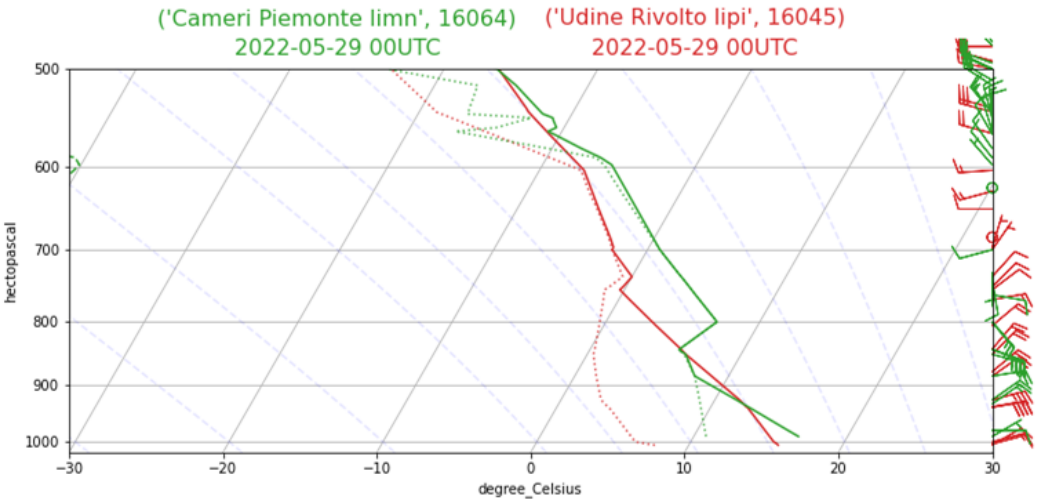
- Severe night-time convection over most western part of Po Valley

Clouded case: eastern backflow into Po Valley 2022-05-28

28 May 12UTC

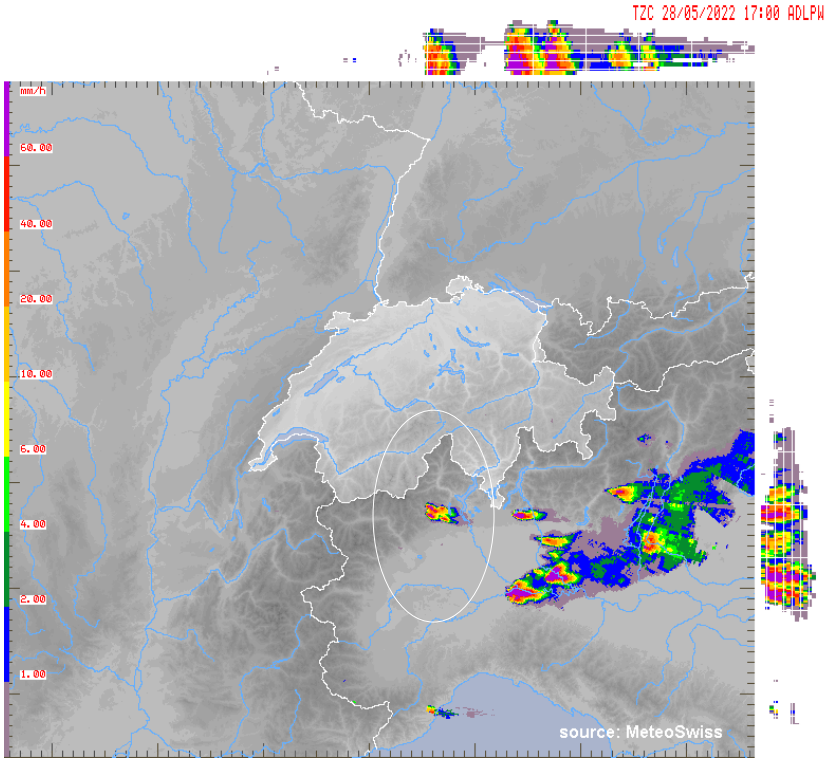


29 May 00UTC



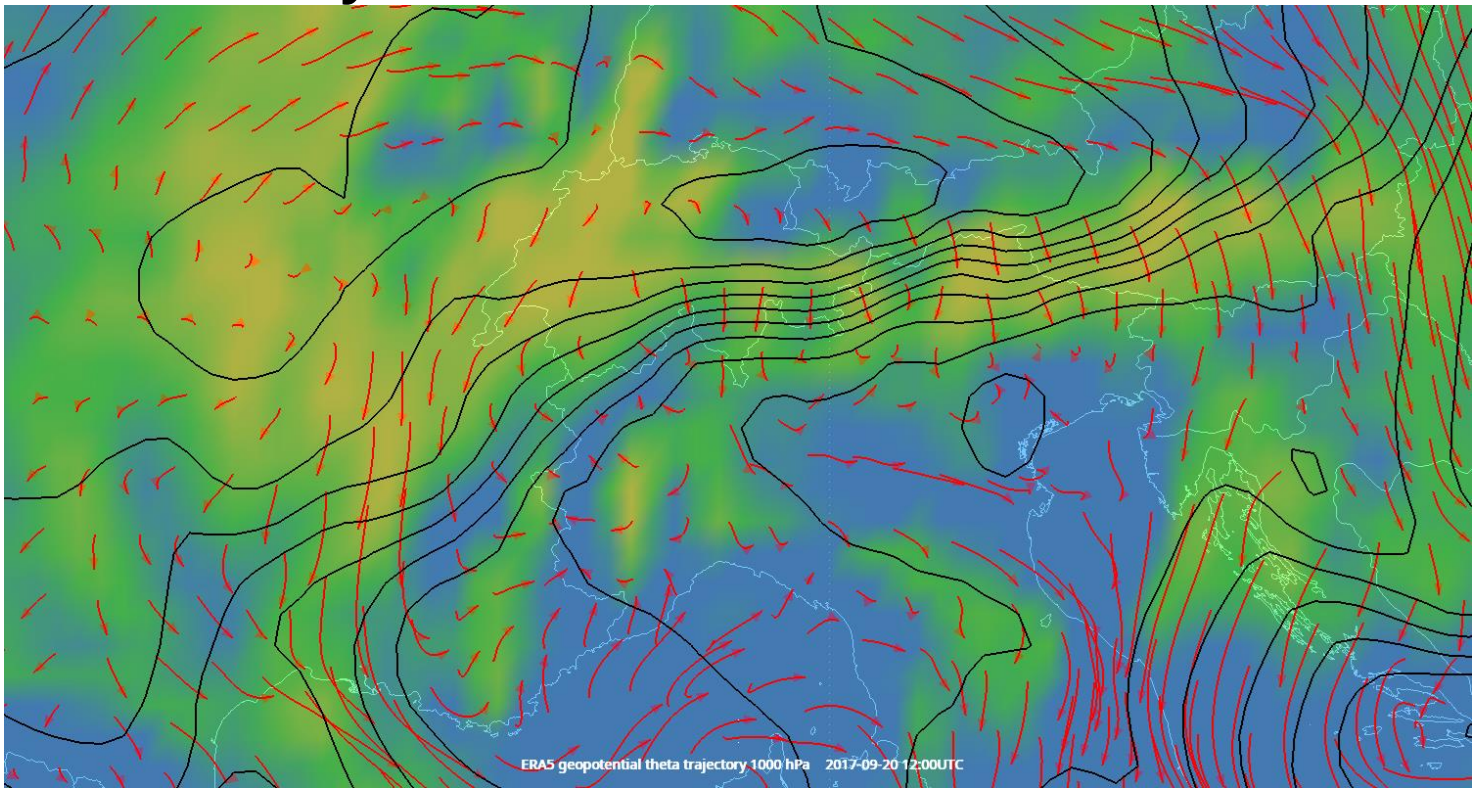
- Radiosoundings at Udine (east) and Cameri (west)
- Moistening and cooling below ~800hPa by midnight at Cameri

Clouded case: eastern backflow into Po Valley 2022-05-28



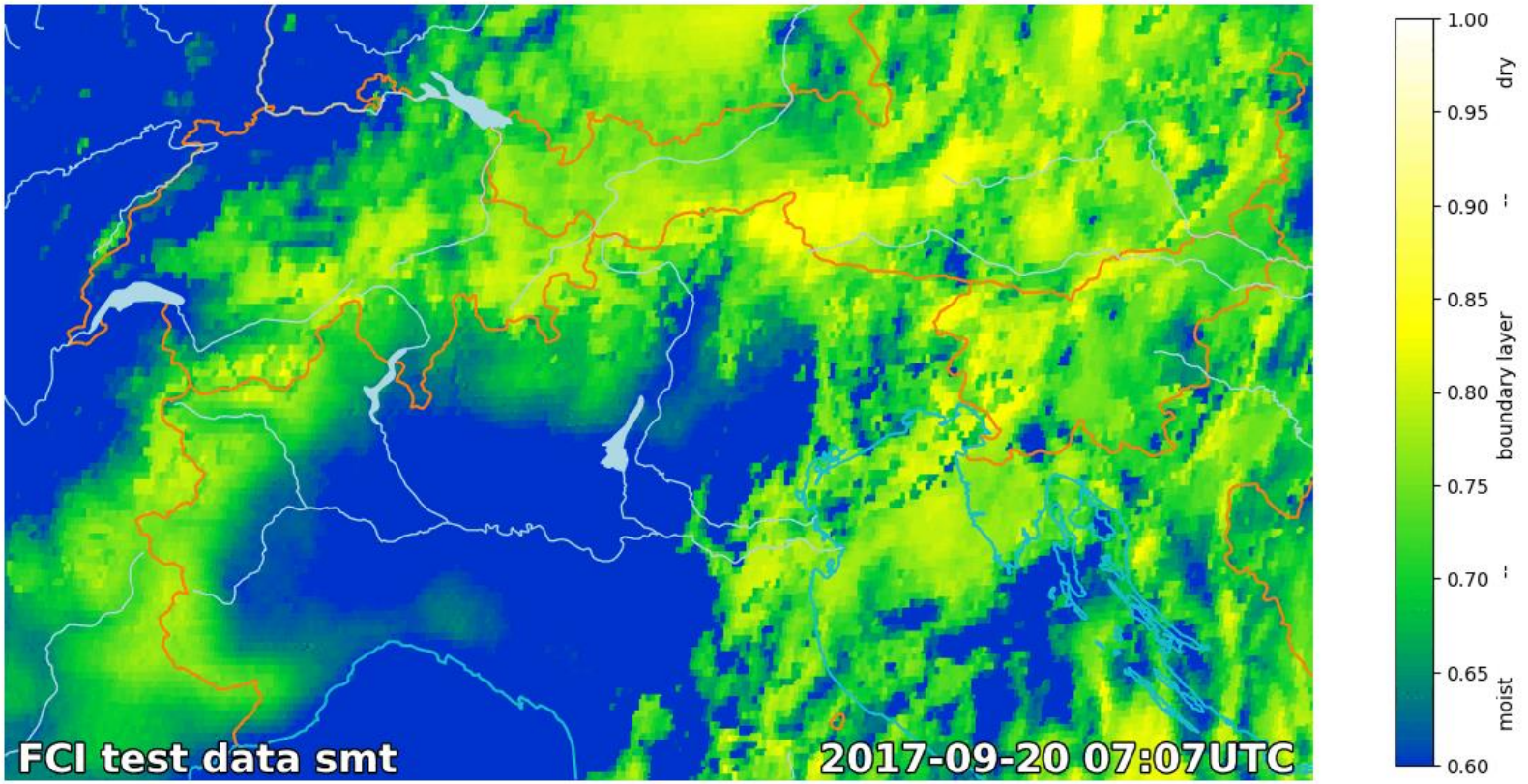
- 10min-frames from MeteoSwiss radar network, 17UTC – 22UTC
- Severe back-building convective cells over Piedmont Alps (white ellipse)

Colourised smt time series from FCI test data set
ERA5 analysis 1000hPa 2017-09-20 12UTC



- Geopotential (black isolines), θ (yellow-green-blue shades), trajectories (red arrows)
- North-wind regime – similar to first case shown here
- Dry north foehn along Alpine south-side
- Moist airmass over eastern Po Valley emptied into Adriatic Sea

Colourised smt time series from FCI test data set 2017-09-20 07:07UTC – 15:07UTC



based on partially synthetic band 5 (0.914µ) and SEVIRI-based band 4 (0.865µ)
for illustrative purpose only!

Conclusions

MODIS data resampled to FCI spatial sampling distance of 1km shows:

- smt (B/W or colourised) images allow for monitoring of frontal zones, convergence and dry lines as well as other phenomena linked to lower-level moisture fields under moderately clouded to clear sky
- New RGB schemes with smt on one colour beam