# Thin cirrus in the 1.38 μm band and its visualization by histogram equalization method

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## 1.38 µm spectral band:

- strong attenuation by tropospheric moisture >>> thin cirrus detection, high clouds discrimination

- used either as stand-alone black & white images, or included as red component in the Cloud Type RGB

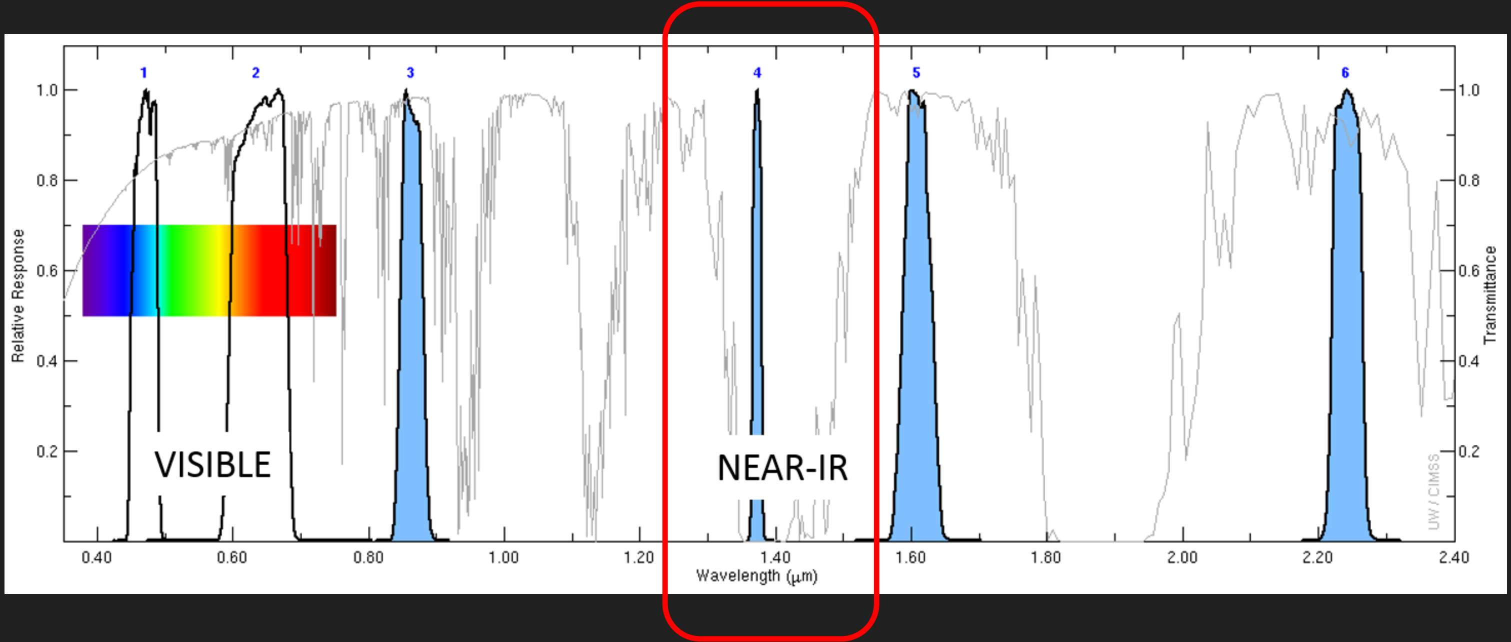
- presently available:

  - MODIS instrument on Terra and Aqua
  - VIIRS instrument of NPP and JPSS satellites (NOAA-20 and on),
  - ABI instrument of GOES-R series satellites (GOES 16 and on),
  - AGRI (FY-4A series), AMI (GEO-Kompsat-2A)
  - **not included** on AHI (Himawari 8/9)

- future availability:

  - MTG-I FCI
  - EPS-SG METimage

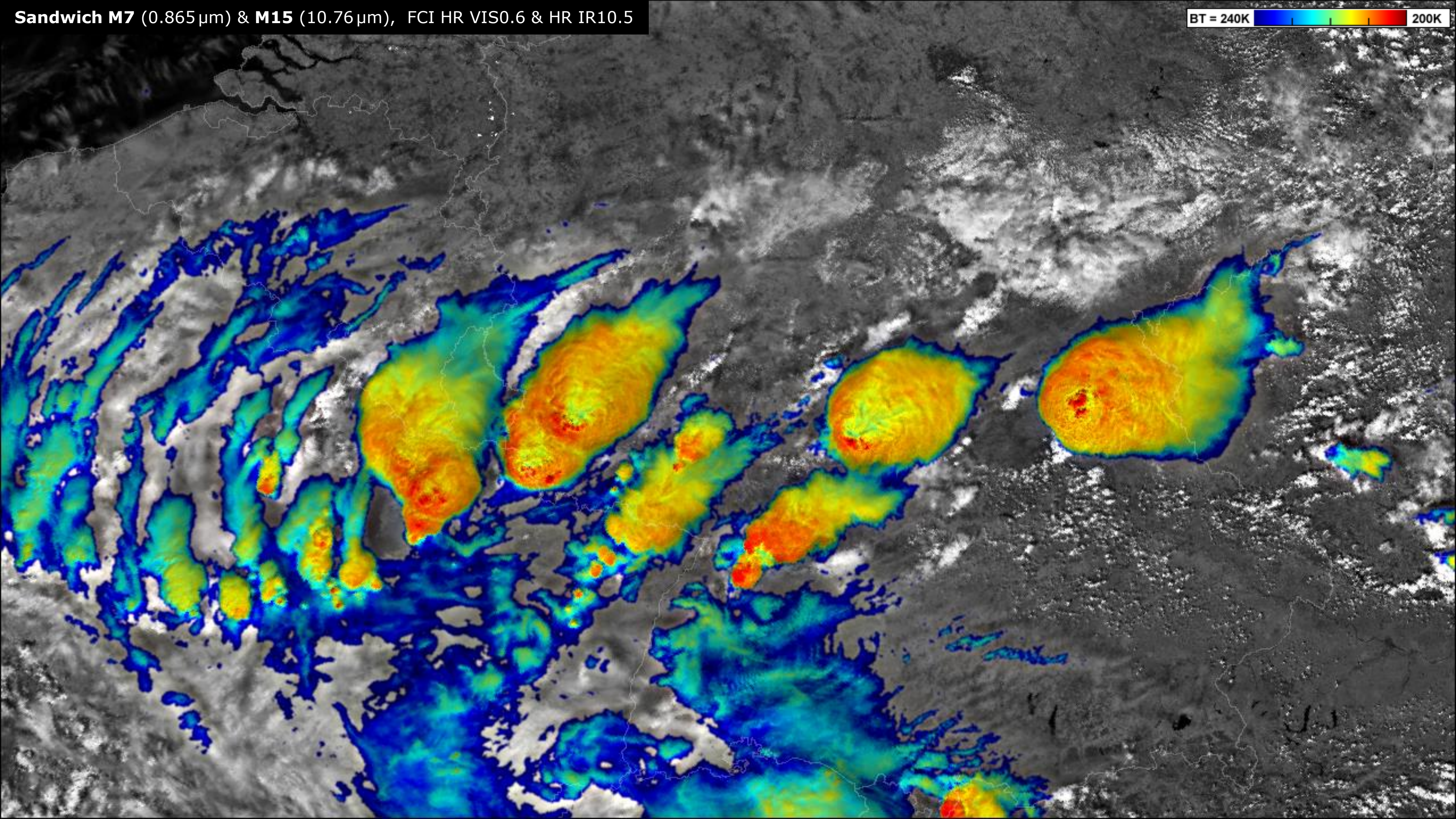
# 1.38 µm spectral band:

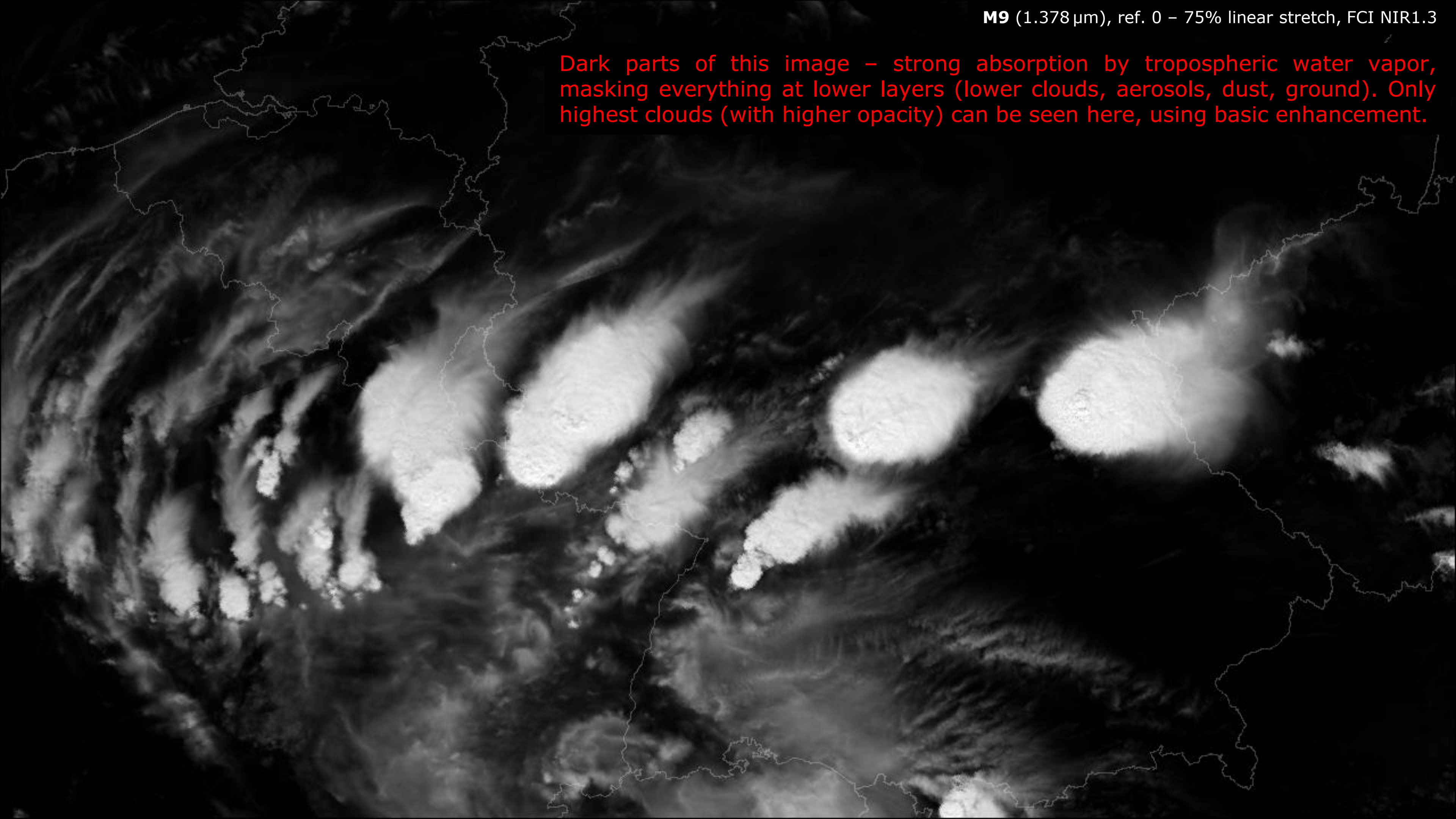


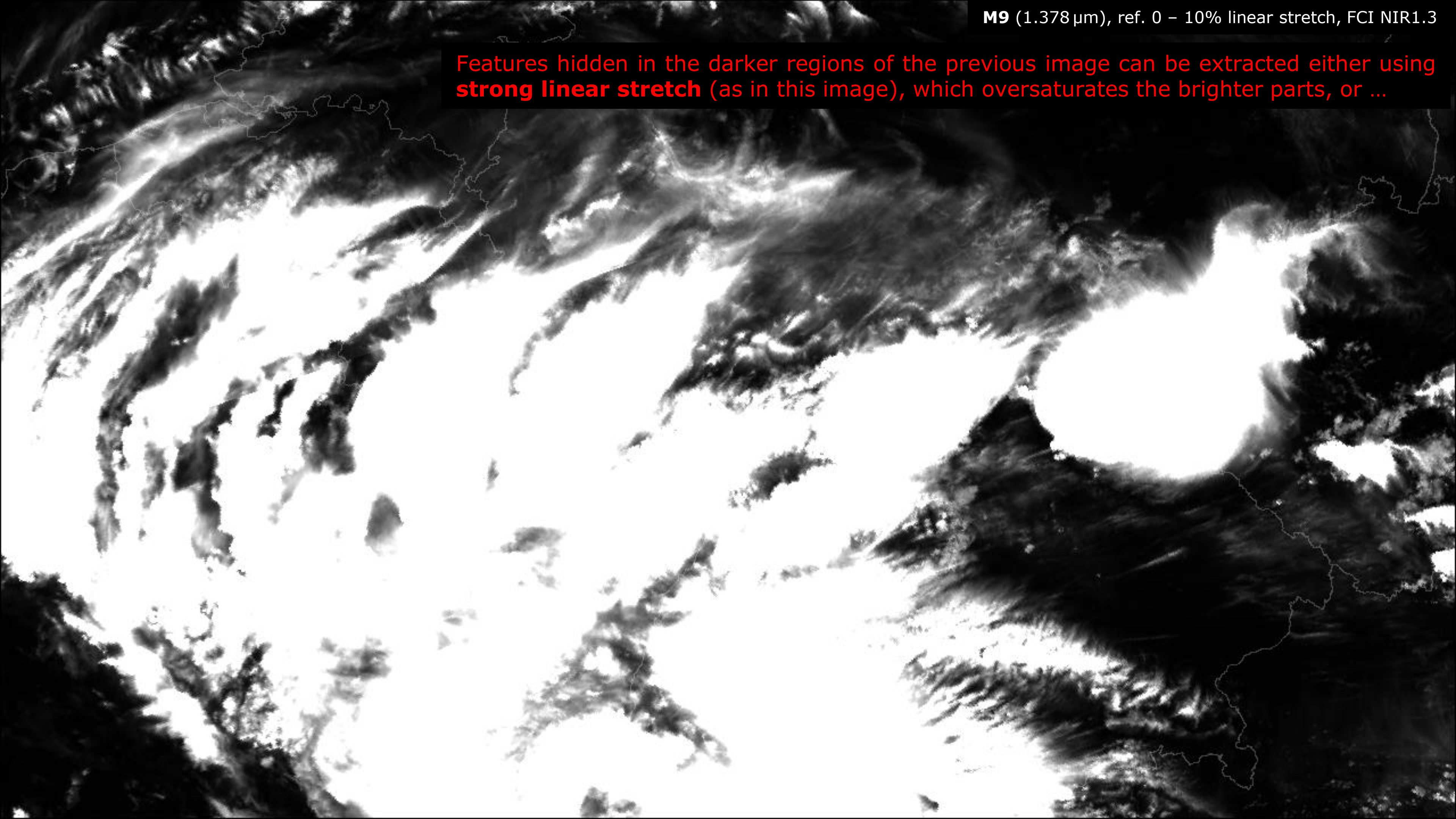

Source: Schmit, T. J., S. S. Lindstrom, J. J. Gerth, M. M. Gunshor, 2018: Applications of the 16 spectral bands on the Advanced Baseline Imager (ABI). J. Operational Meteor., 6 (4), 33-46, doi: https://doi.org/10.15191/nwajom.2018.0604

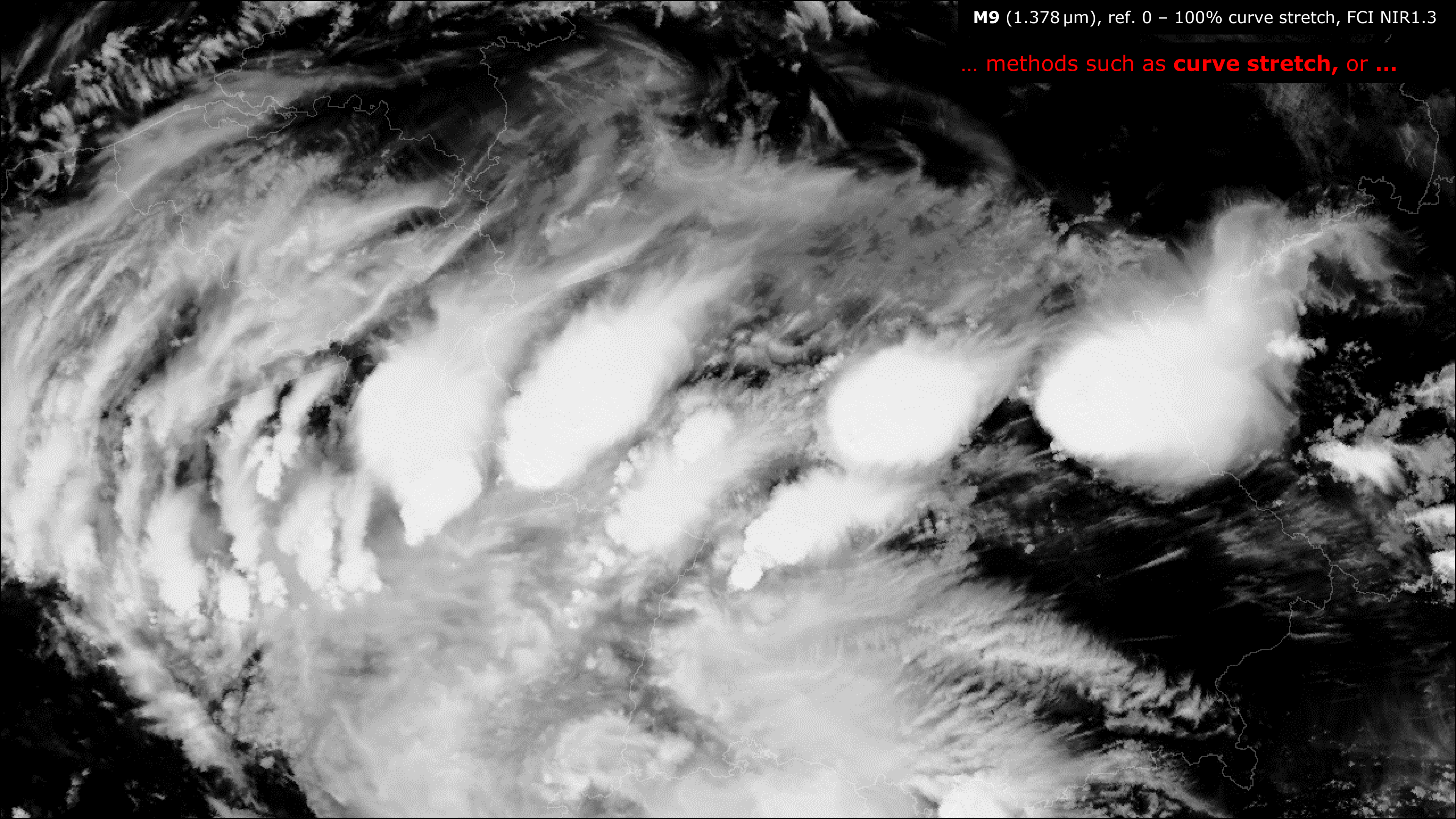
11 June 2018, 11:38 UTC,  NPP VIIRS, M-bands (750 m)

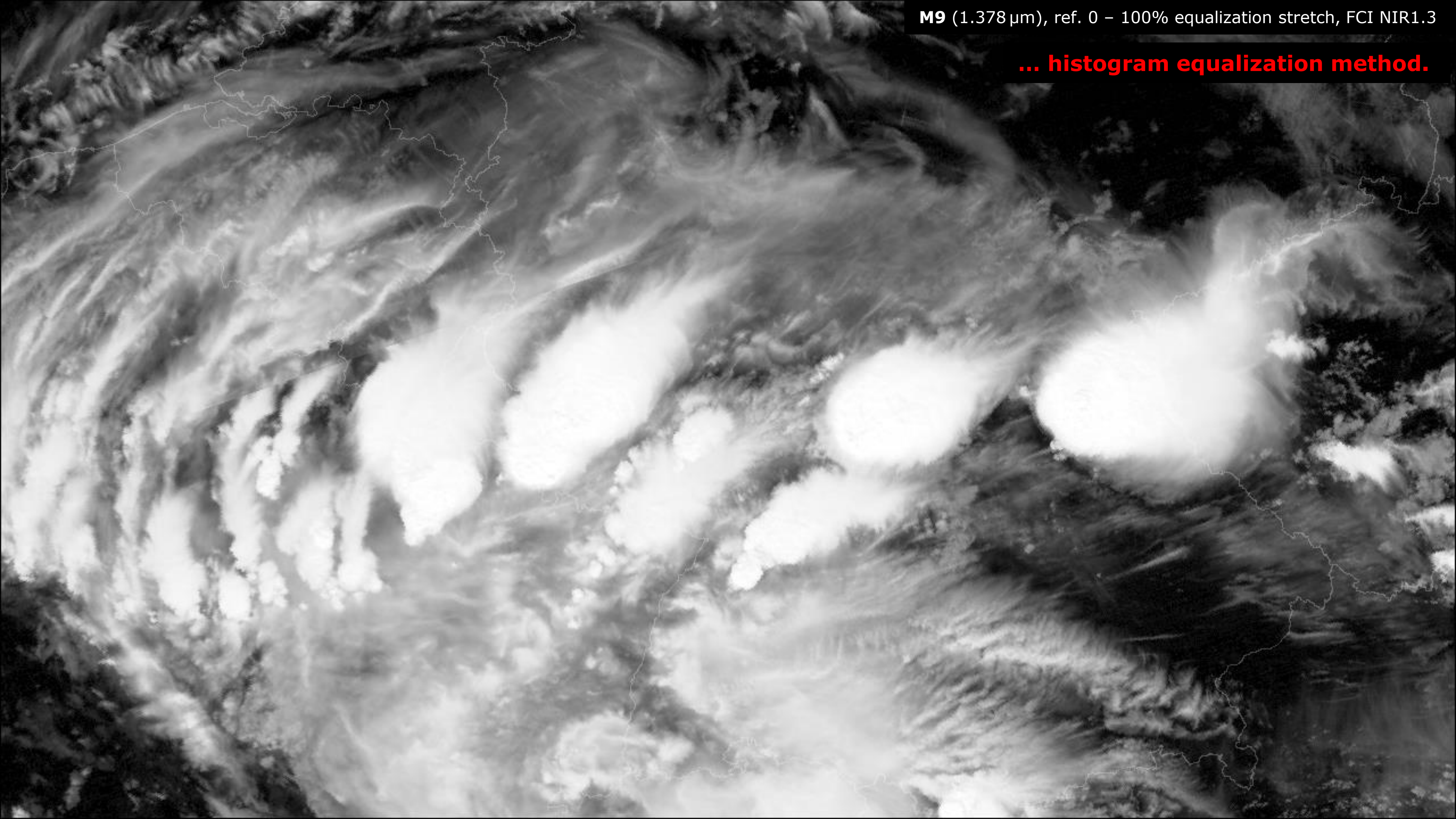
Convective storms, Europe

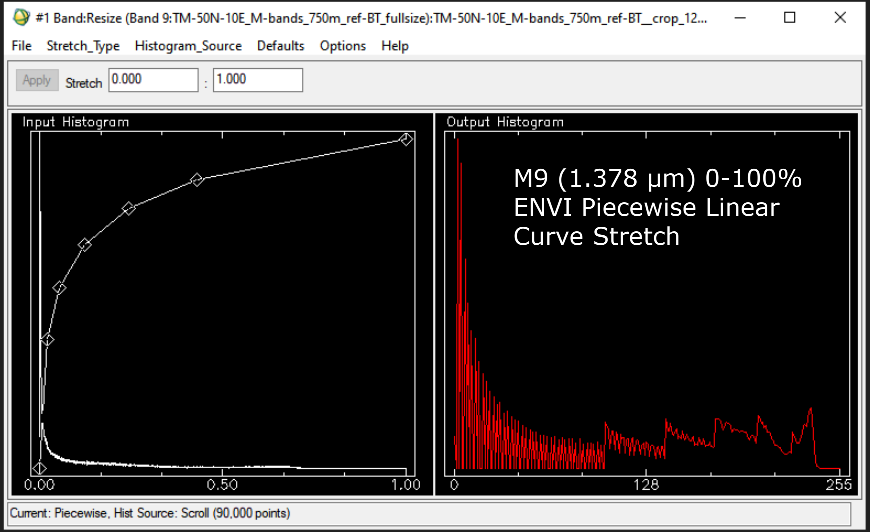

**Sandwich M7** (0.865 µm) & **M15** (10.76 µm), FCI HR VIS0.6 & HR IR10.5
BT = 240K
200K

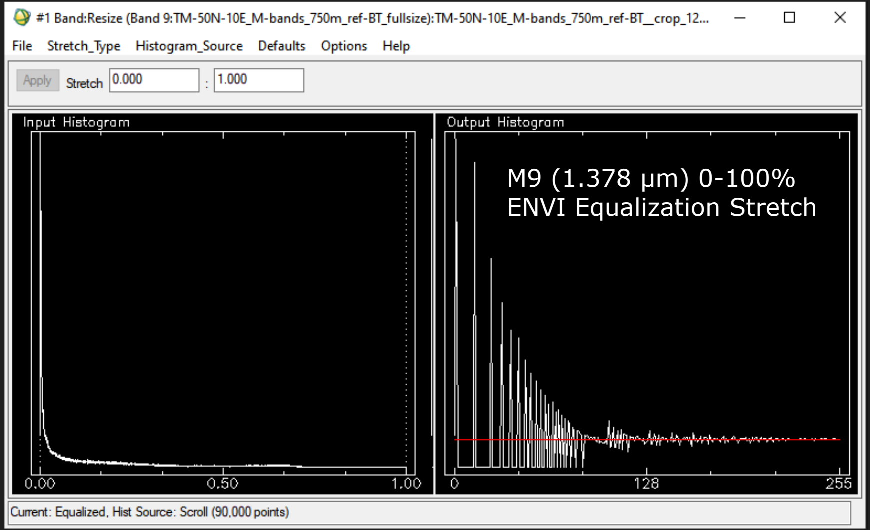

**M9** (1.378 µm), ref. 0 – 75% linear stretch, FCI NIR1.3
Dark parts of this image – strong absorption by tropospheric water vapor, masking everything at lower layers (lower clouds, aerosols, dust, ground). Only highest clouds (with higher opacity) can be seen here, using basic enhancement.

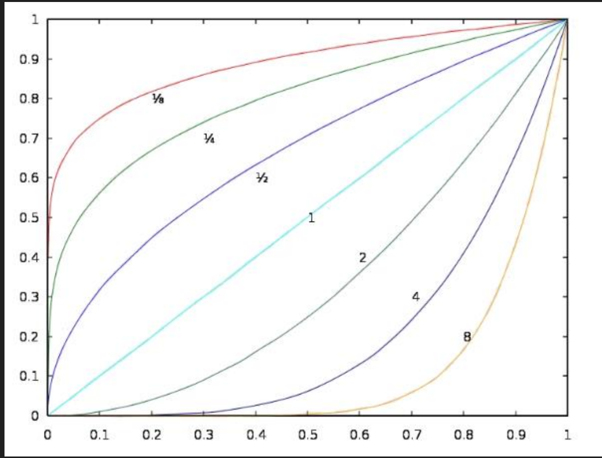

**M9** (1.378 µm), ref. 0 – 10% linear stretch, FCI NIR1.3
Features hidden in the darker regions of the previous image can be extracted either using **strong linear stretch** (as in this image), which oversaturates the brighter parts, or …


**M9** (1.378 µm), ref. 0 – 100% curve stretch, FCI NIR1.3
… methods such as **curve stretch,** or **…**


**M9** (1.378 µm), ref. 0 – 100% equalization stretch, FCI NIR1.3
... histogram equalization method.



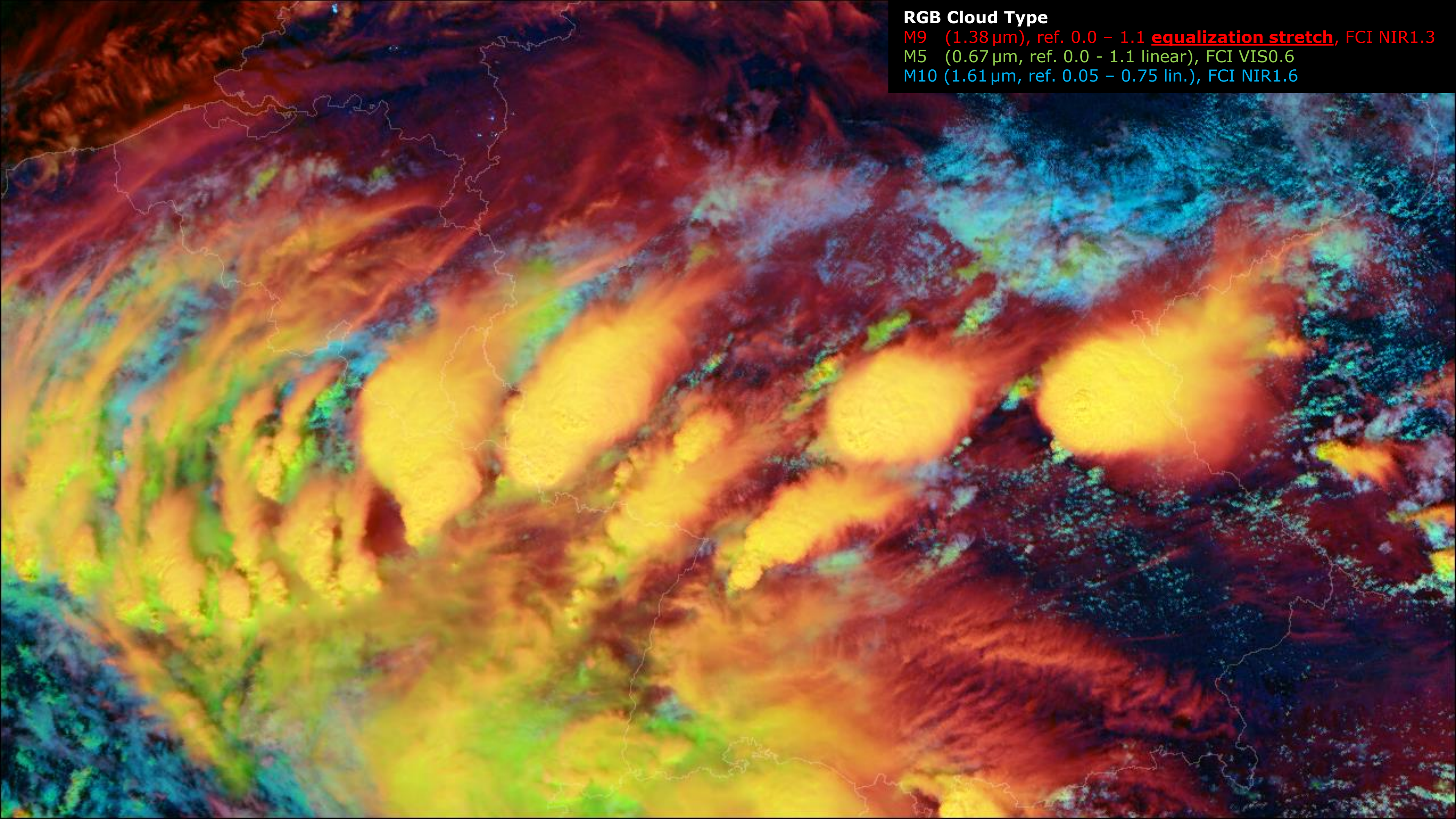




Histogram equalization – a stretch method, by which the input values of an image are divided into a number of output intervals; this is done in such a way that all output intervals contain more or less an equal number of pixels.

ENVI (histogram) equalization stretch – scales the data to have the same number of digital numbers (input data values) in each display (output values) histogram bin.

Corresponding gamma stretch: about 1/4 to 1/8 (in this image)


RGB Cloud Type
M9 (1.38 µm), ref. 0.0 – 0.1 linear stretch, FCI NIR1.3
M5 (0.67 µm, ref. 0.0 – 1.1 linear), FCI VIS0.6
M10 (1.61 µm, ref. 0.05 – 0.75 lin.), FCI NIR1.6


RGB Cloud Type
M9 (1.38 µm), ref. 0.0 – 1.1 equalization stretch, FCI NIR1.3
M5 (0.67 µm, ref. 0.0 - 1.1 linear), FCI VIS0.6
M10 (1.61 µm, ref. 0.05 – 0.75 lin.), FCI NIR1.6

## 1.38 μm spectral band:

- The most interesting information – very thin cirrus, aerosols, dust – is hidden in the darkest parts of the 1.38 μm band, which are typically difficult to brighten, without oversaturating the rest of the image and enhancing image noise.

- The histogram equalization method (its results) strongly depends on selection of the image area and its content, which are used to calculate the enhancement. Applicable namely to interactive image processing, for case studies. This effect will be shown in next slides.

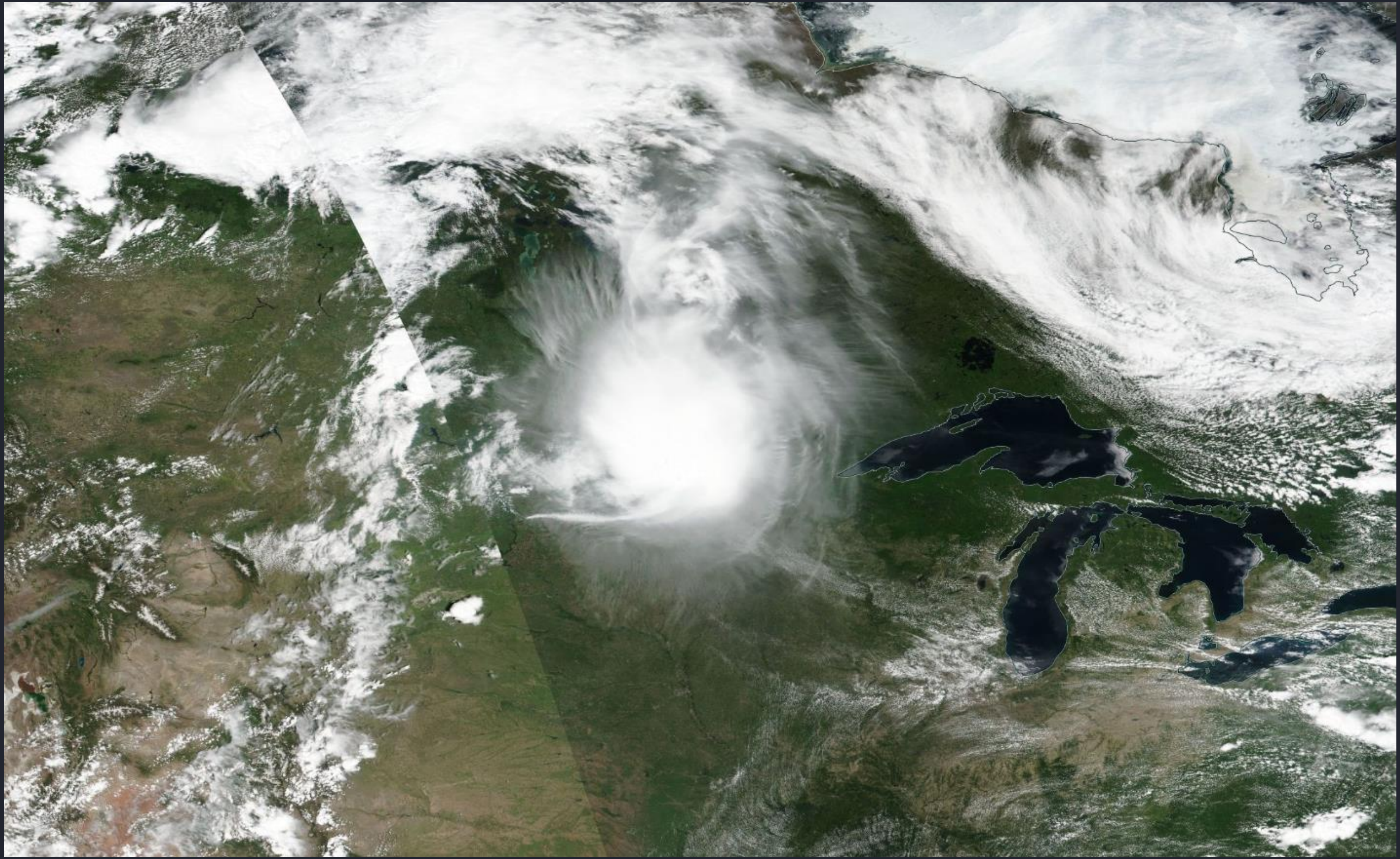
- The piecewise linear stretch (curve stretch) and gamma stretch enhancements independent of the content of the scene – better suited for operational use.

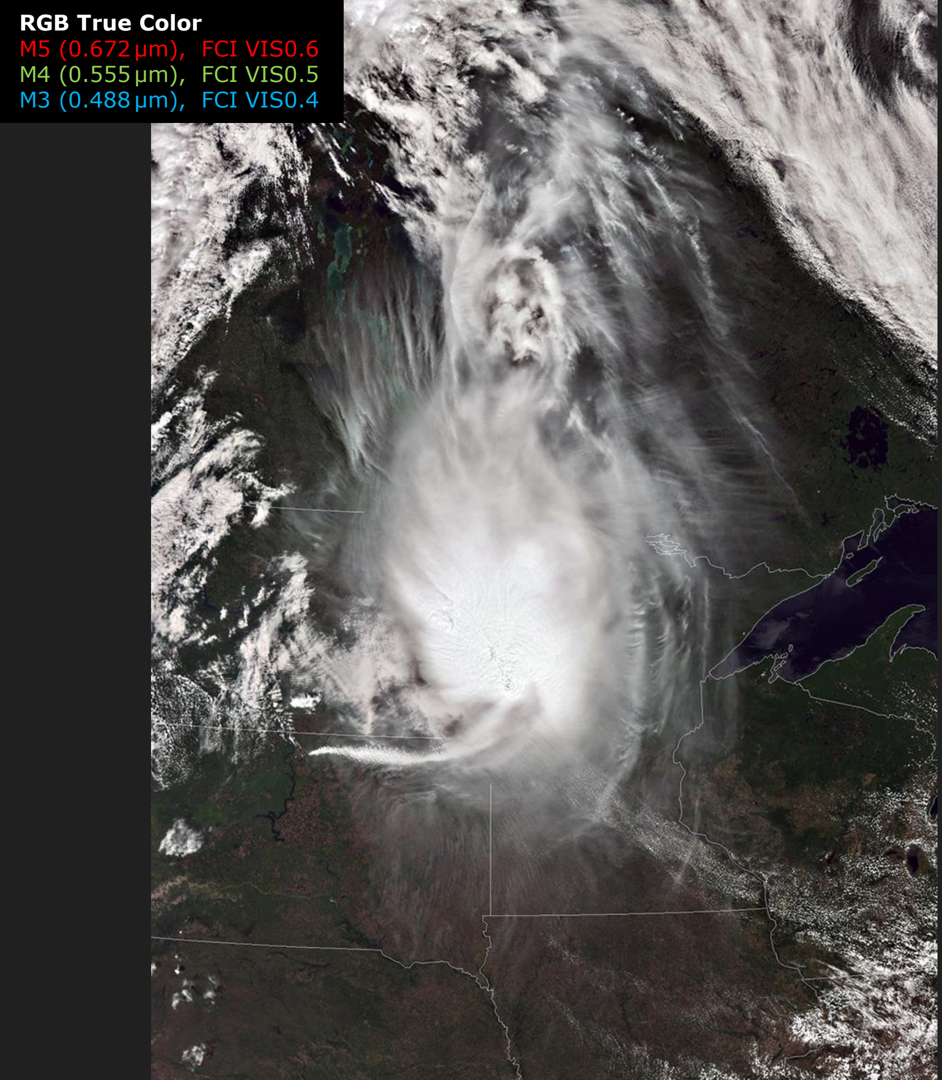
29 June 2019, 18:43 UTC,  NPP VIIRS, M-bands (750 m)

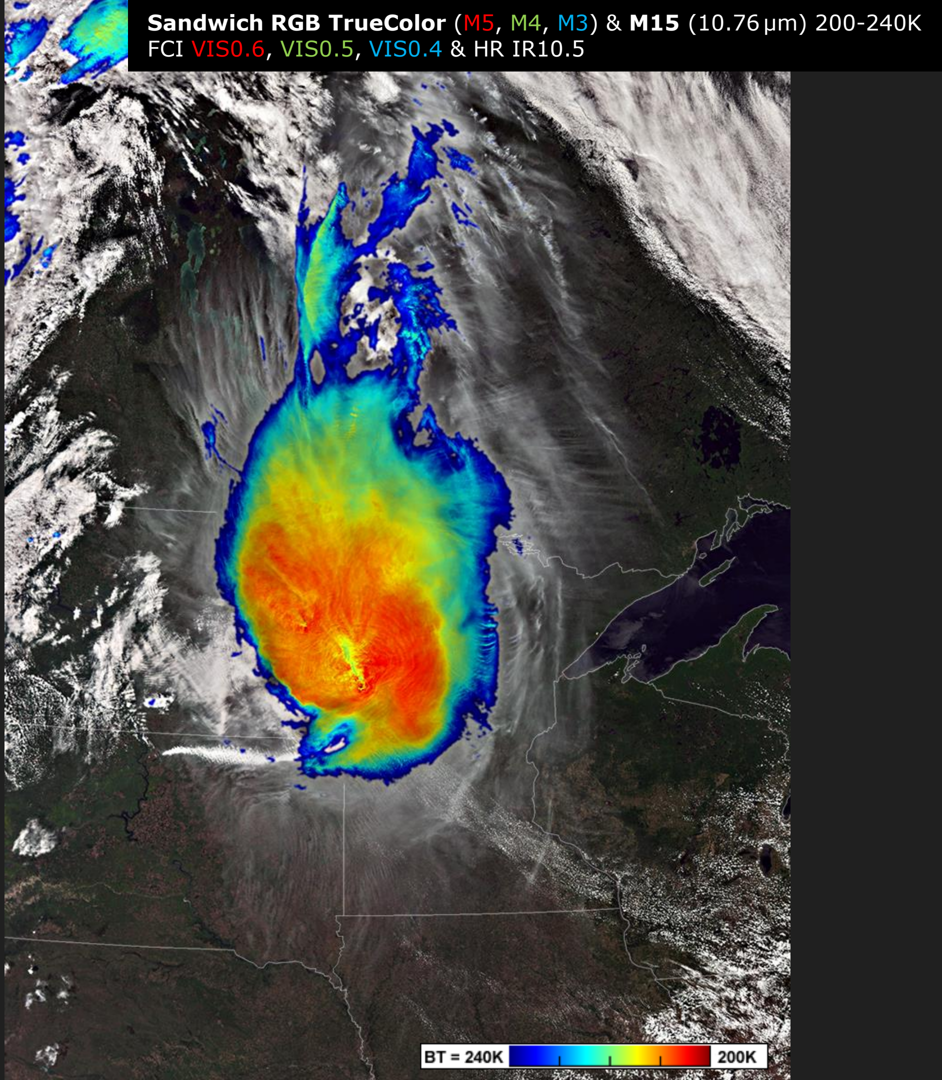
Convective storms, USA (North Dakota, Minnesota)

29 June 2019 18:43 UTC, VIIRS Suomi-NPP, U.S.A. (ND, MN)

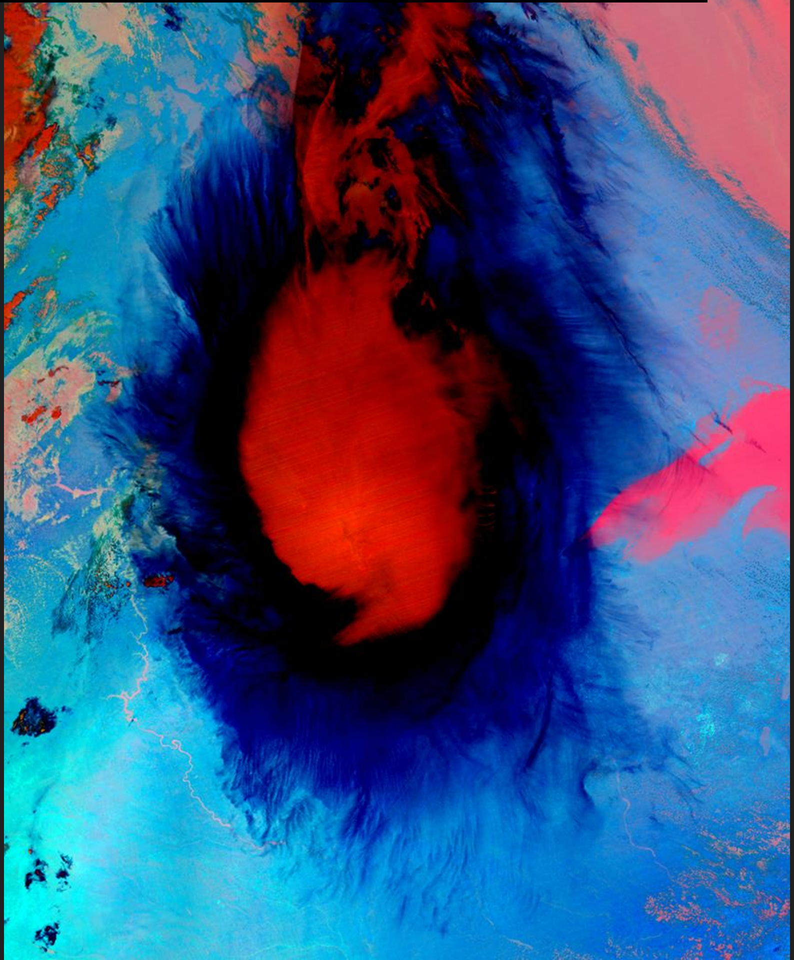
image source: NASA EOSDIS Worldview



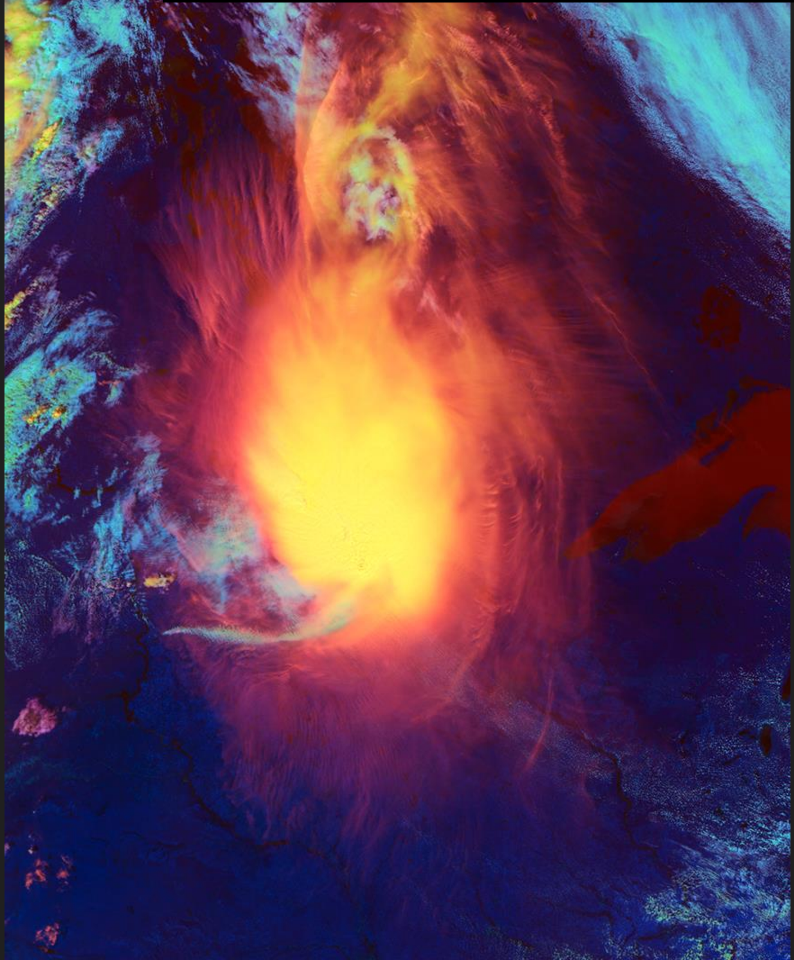

RGB True Color
M5 (0.672 μm), FCI VIS0.6
M4 (0.555 μm), FCI VIS0.5
M3 (0.488 μm), FCI VIS0.4

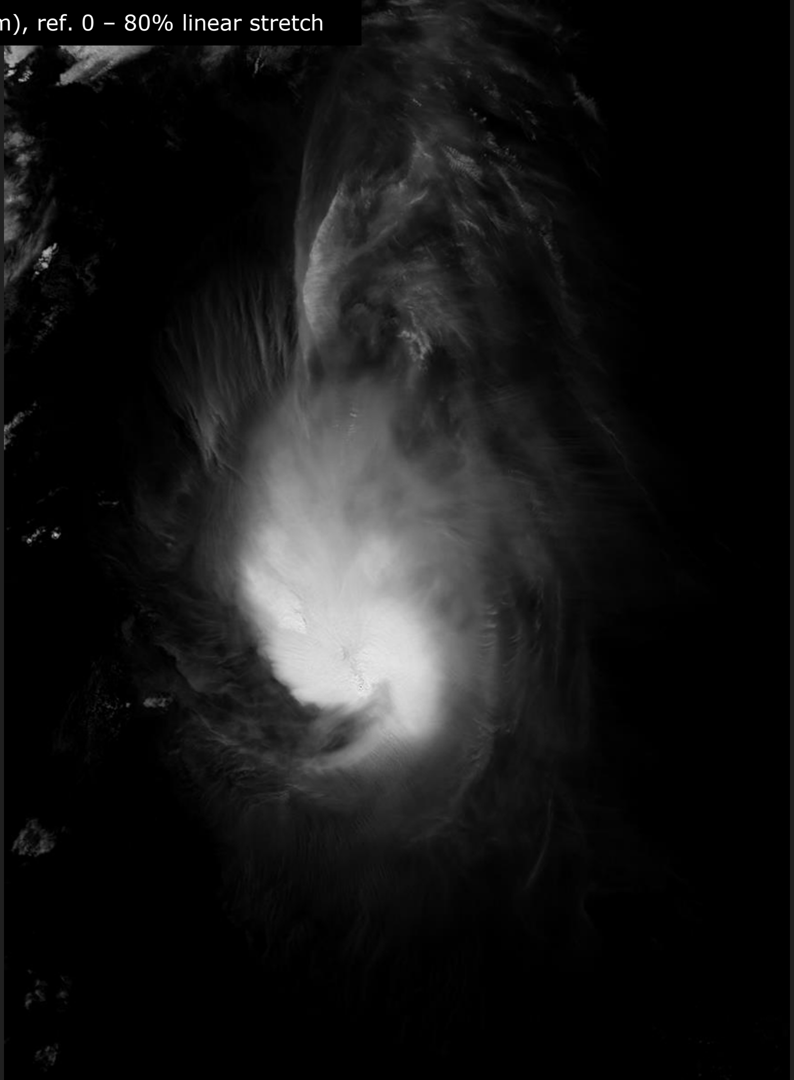

Sandwich RGB TrueColor (M5, M4, M3) & M15 (10.76 μm) 200-240K
FCI VIS0.6, VIS0.5, VIS0.4 & HR IR10.5
BT = 240K
200K

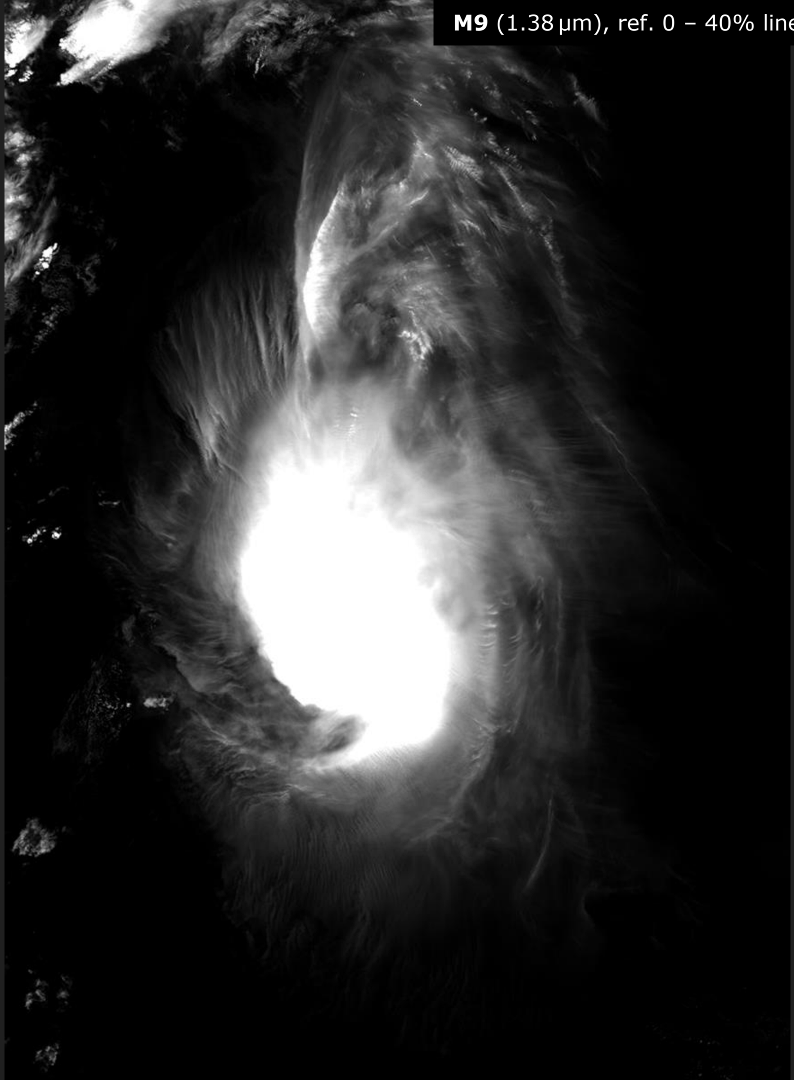
**RGB 24M** (24h Microphysics)
M16 (12.01 µm) – M15 (10.76 µm), -2.5 – +0.5K lin., FCI IR12.3 – IR10.5
M15 (10.76 µm) – M14 (8.55 µm), -0.5 – +5.5K lin., FCI IR10.5 – IR8.7
M15 (10.76 µm), BT 250 – 310K lin., FCI IR10.5

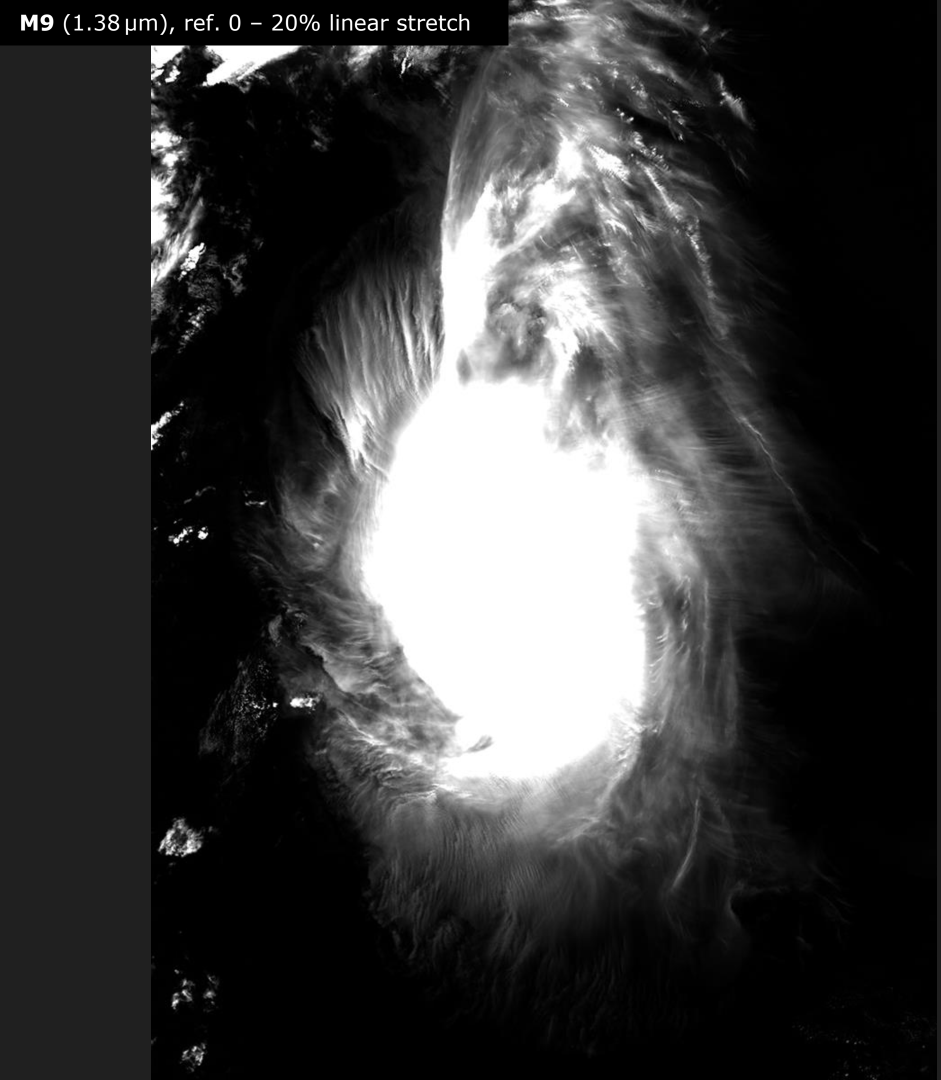


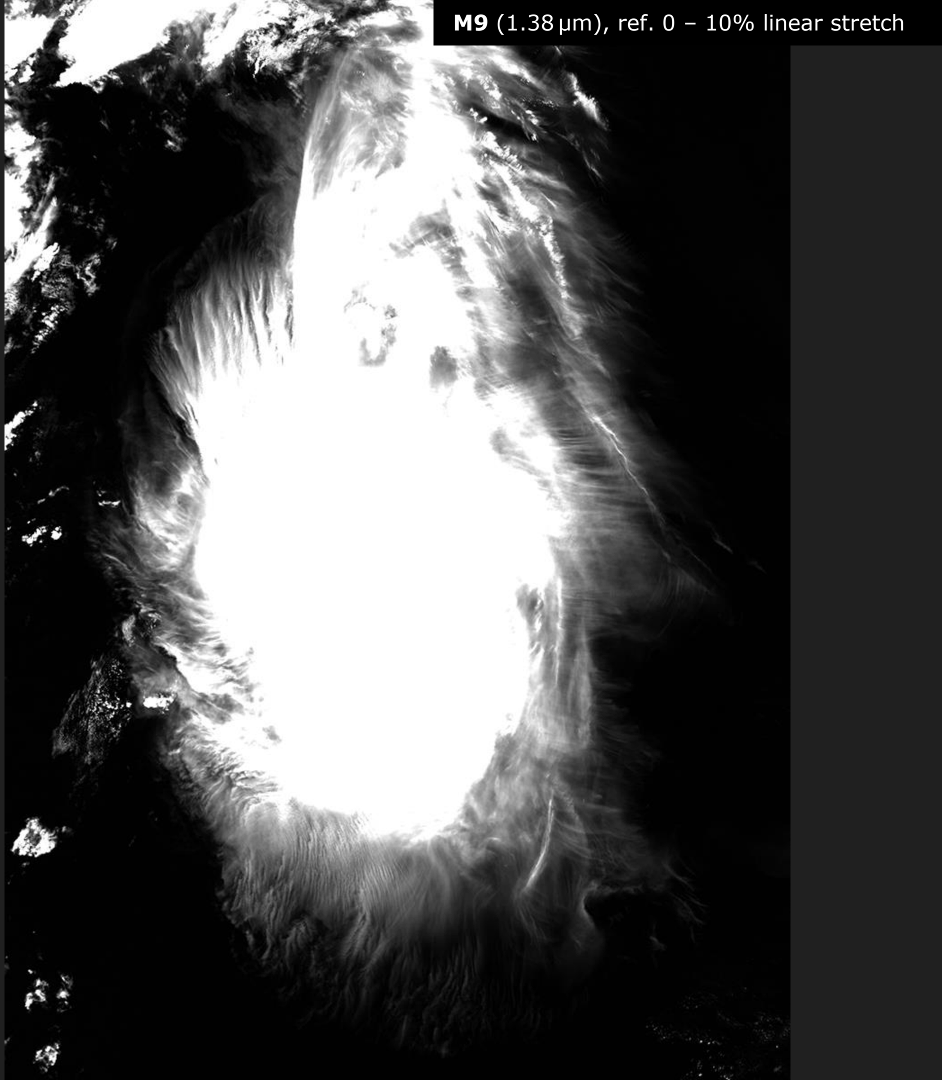
**RGB Cloud Phase Distinction**
M15 (10.76 µm), BT 220 – 310K inverted, linear stretch, FCI IR10.5
M5 (0.67 µm), ref. 0.0 – 1.05 linear, FCI VIS0.6
M10 (1.61 µm), ref. 0.0 – 0.70 linear, FCI NIR1.6

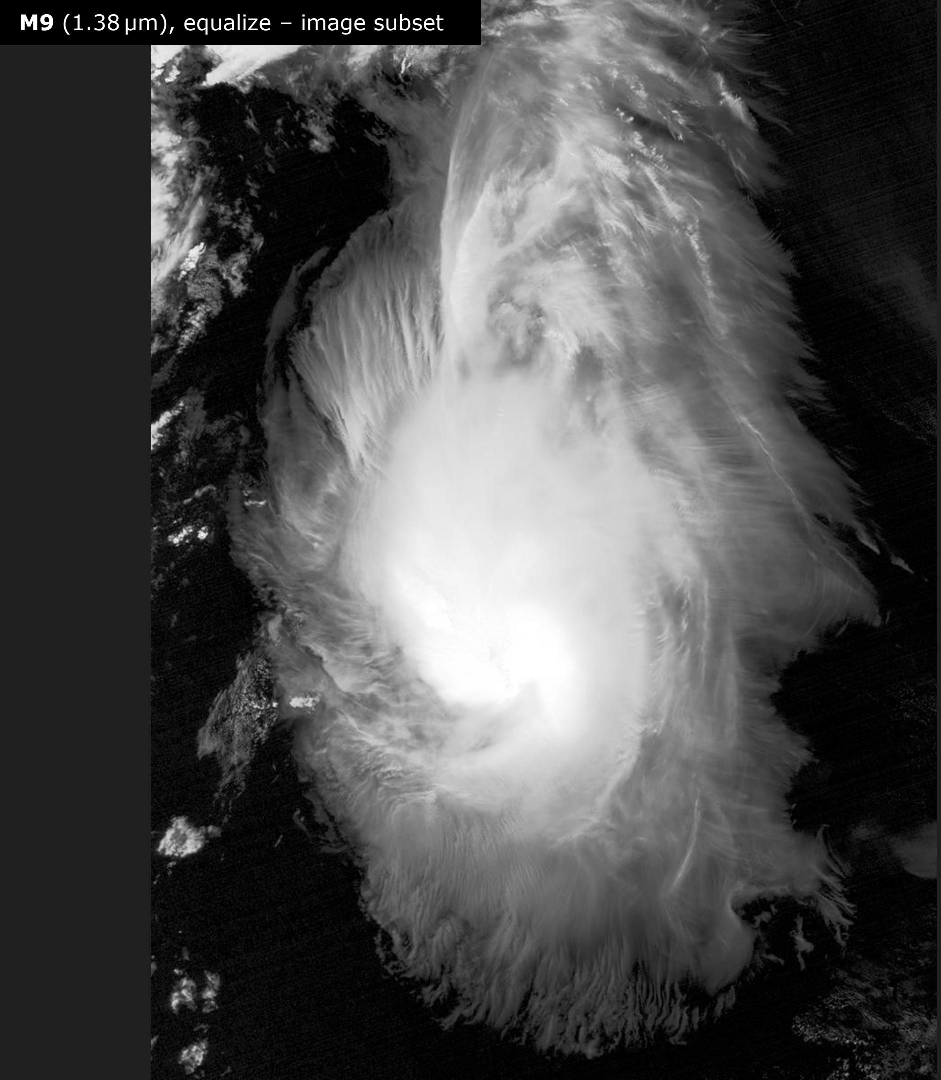


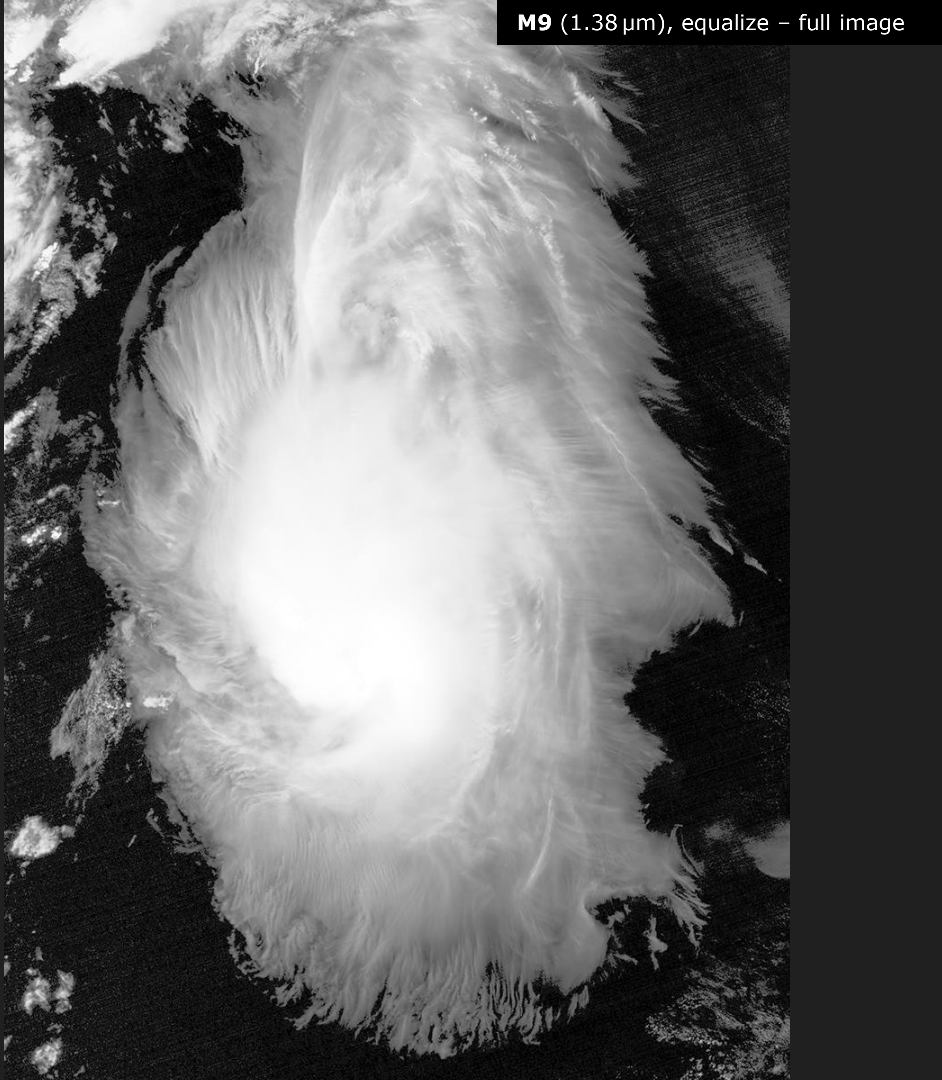

**M9** (1.38 μm), ref. 0 – 80% linear stretch


**M9** (1.38 μm), ref. 0 – 40% linear stretch

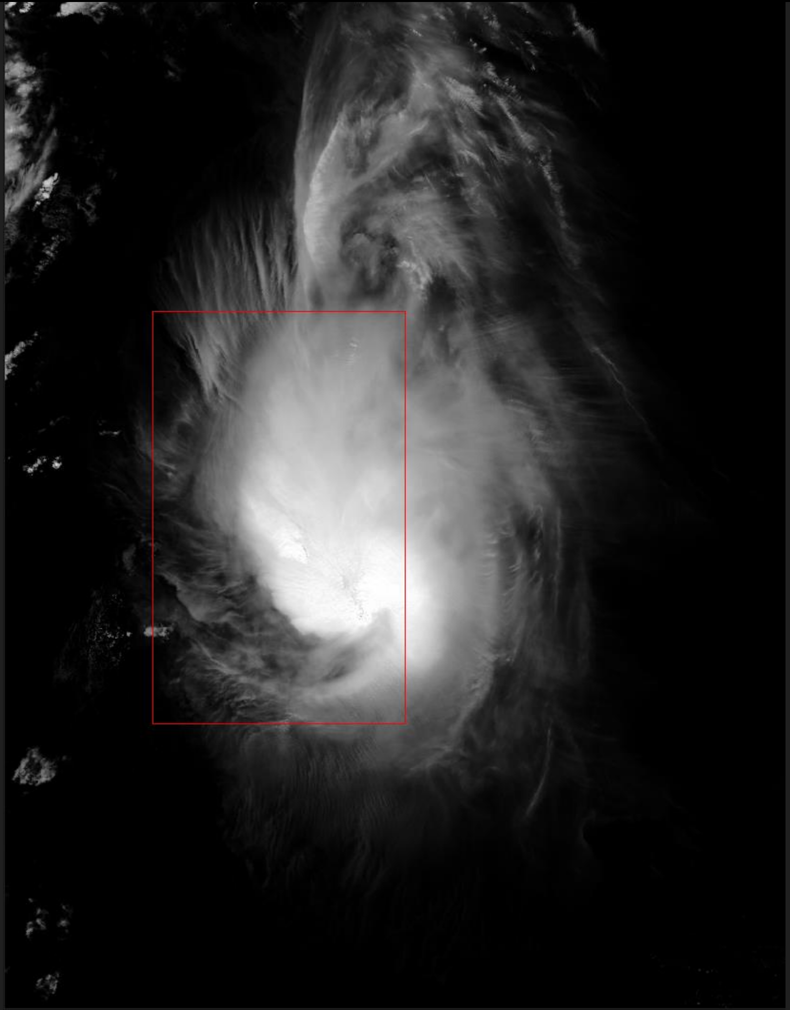

**M9** (1.38 μm), ref. 0 – 20% linear stretch

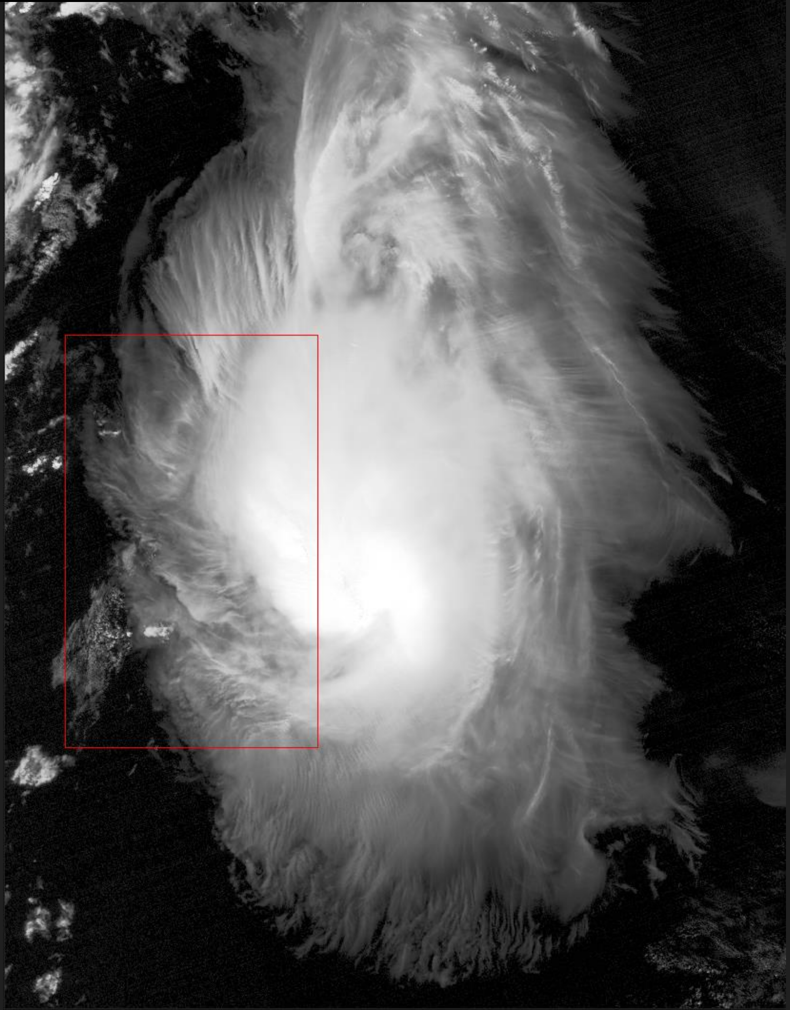

**M9** (1.38 μm), ref. 0 – 10% linear stretch


**M9** (1.38 μm), equalize – image subset

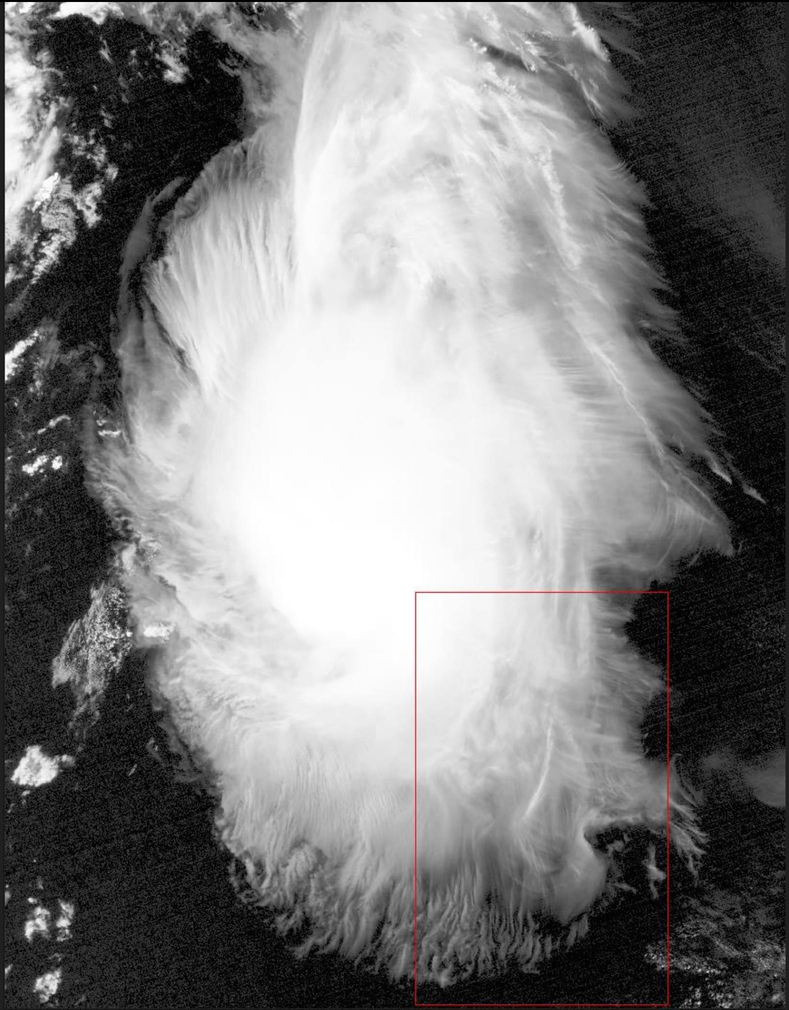

**M9** (1.38 μm), equalize – full image

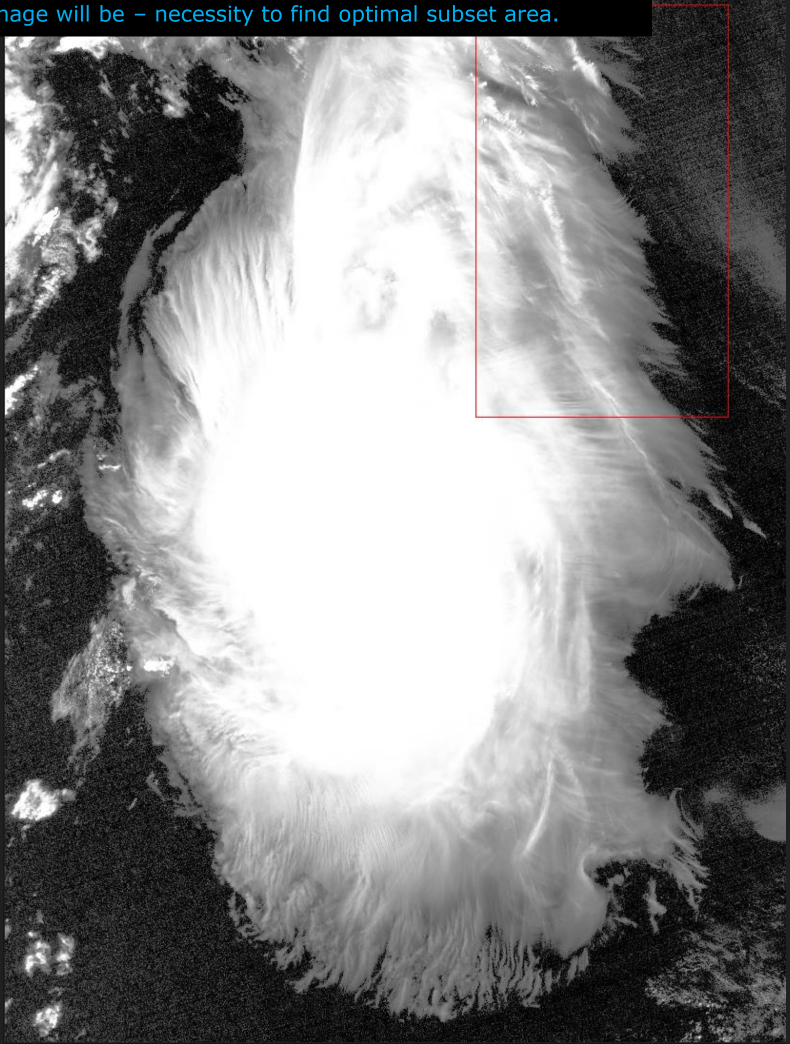
**M9** (1.38 μm), histogram equalization – impact of positioning of the image subset (red rectangle) on the overall appearance of the output image.
The more of the dark pixels are included in the subset window, the brighter the output image will be – necessity to find optimal subset area.





**M9** (1.38 μm), histogram equalization – impact of positioning of the image subset (red rectangle) on the overall appearance of the output image.
The more of the dark pixels are included in the subset window, the brighter the output image will be – necessity to find optimal subset area.



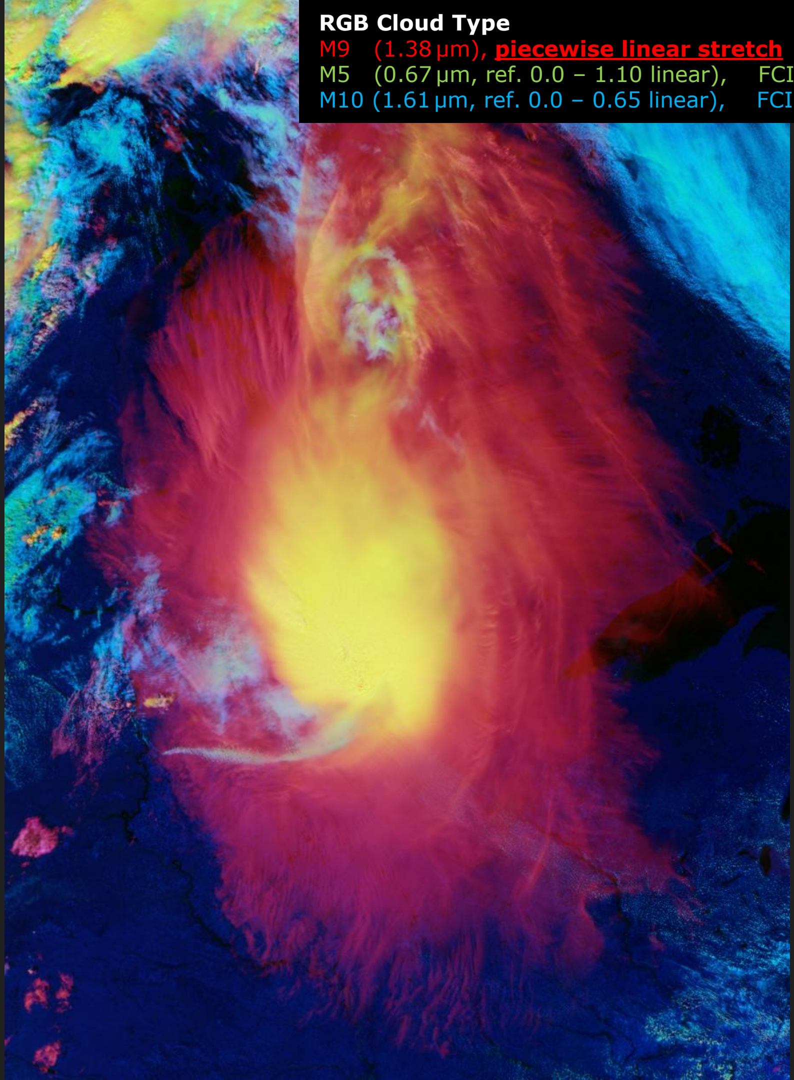


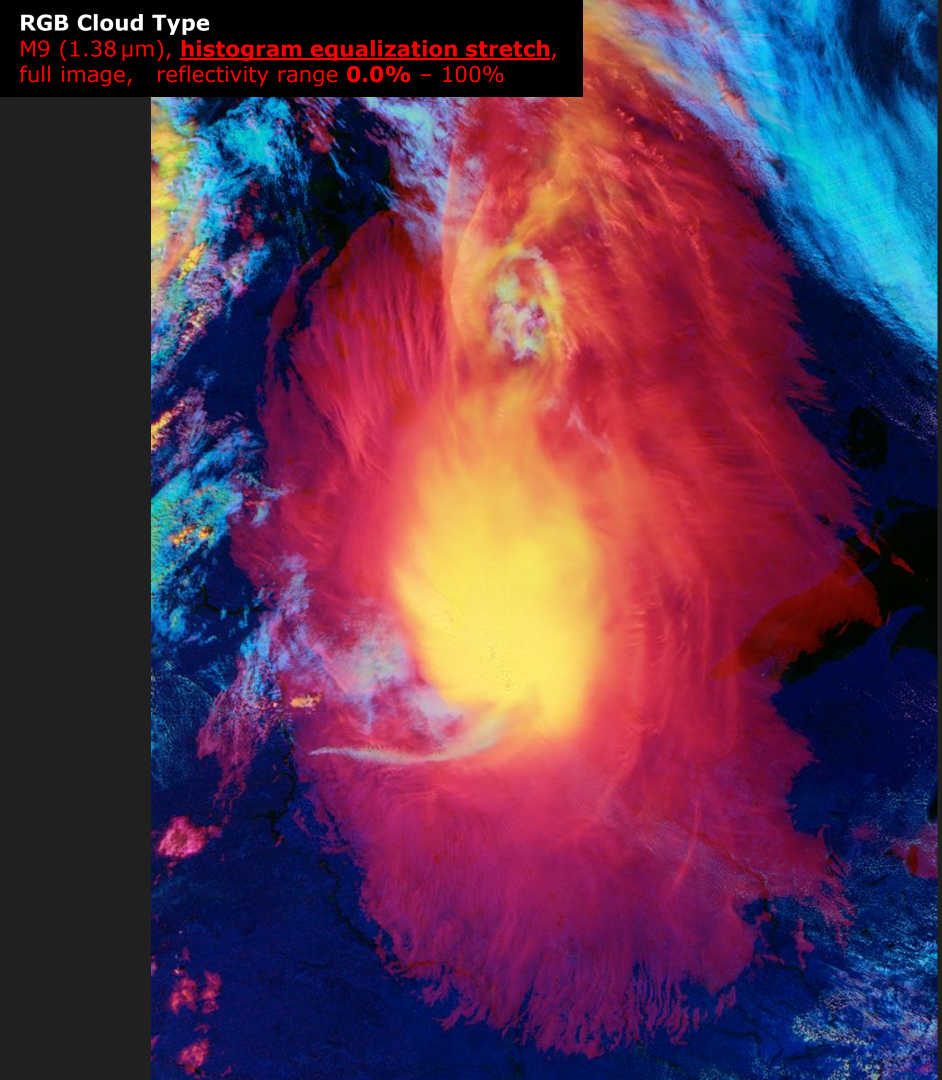
**RGB Cloud Type**

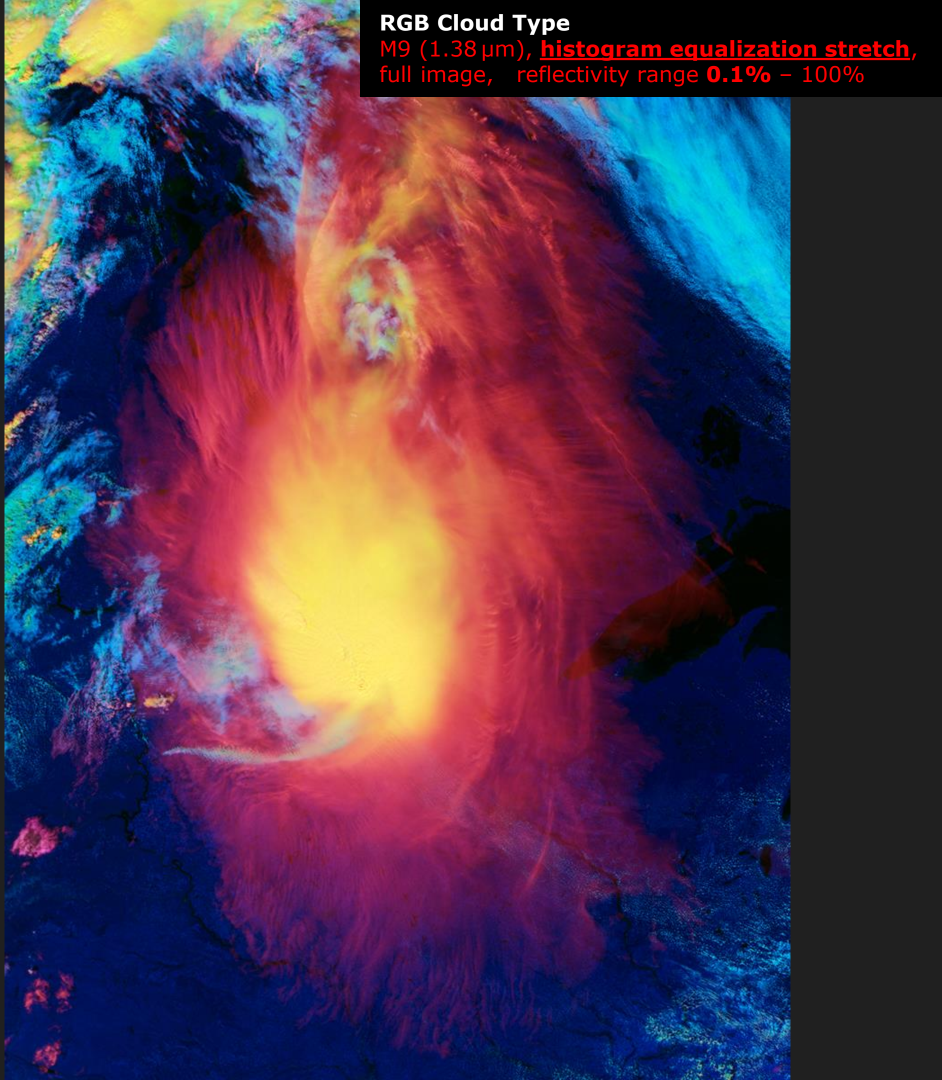
M9 (1.38 µm), **linear stretch** 0–2.5%, FCI NIR1.3
M5 (0.67 µm, ref. 0.0 – 1.10 linear), FCI VIS0.6
M10 (1.61 µm, ref. 0.0 – 0.65 linear), FCI NIR1.6

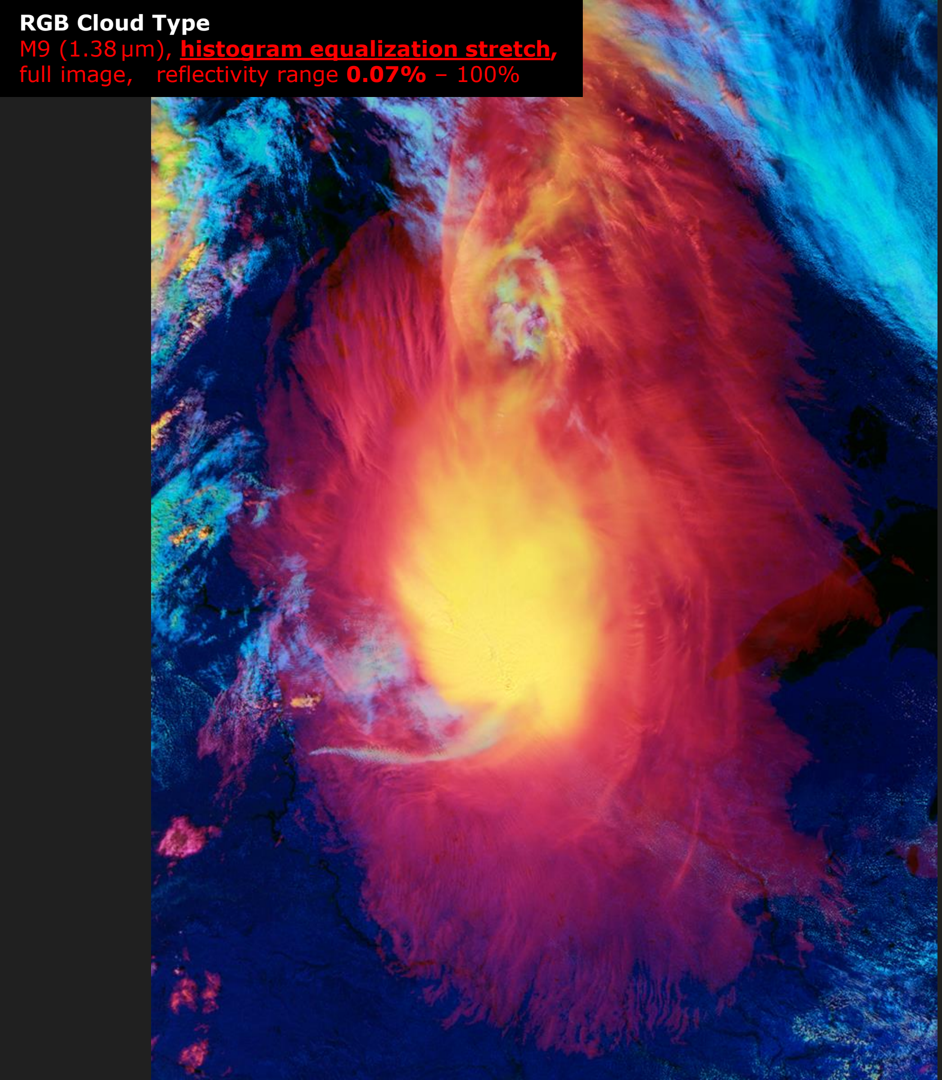
**RGB Cloud Type**

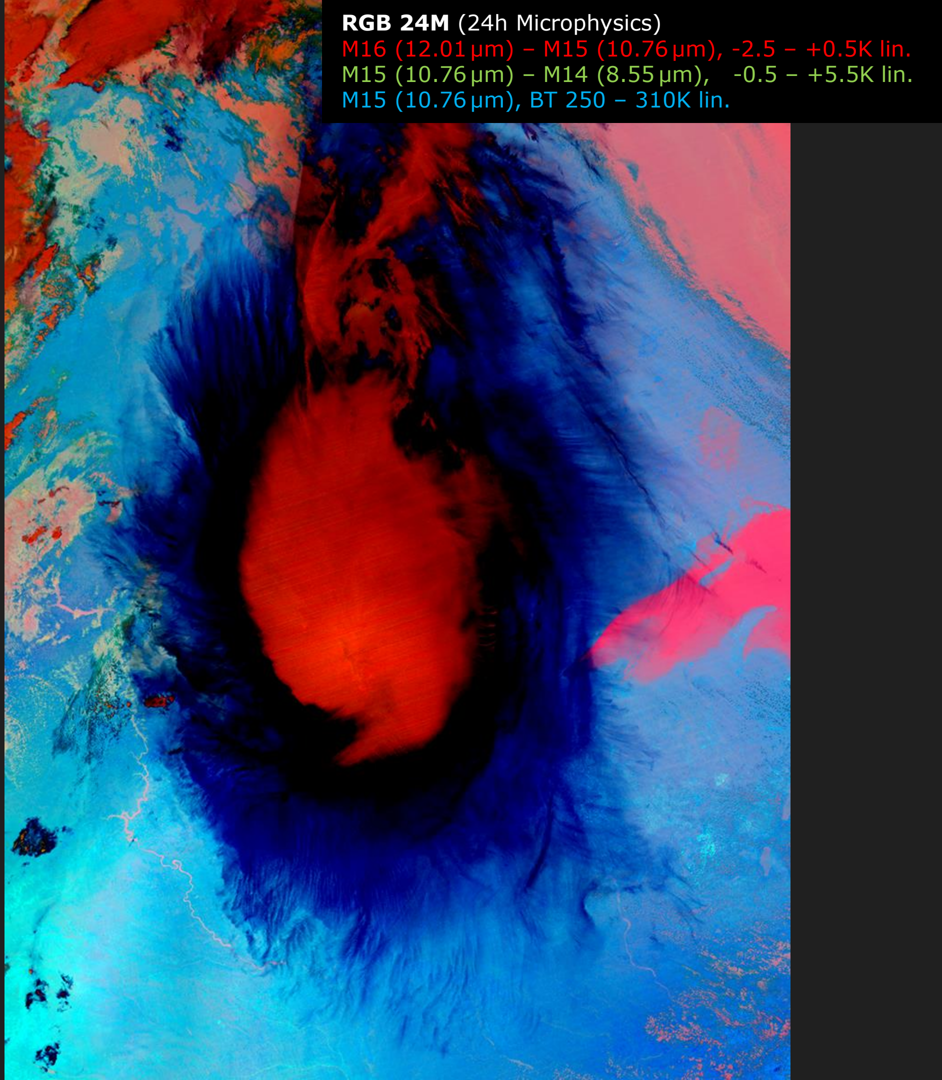
M9 (1.38 µm), **piecewise linear stretch** FCI NIR1.3
M5 (0.67 µm, ref. 0.0 – 1.10 linear), FCI VIS0.6
M10 (1.61 µm, ref. 0.0 – 0.65 linear), FCI NIR1.6

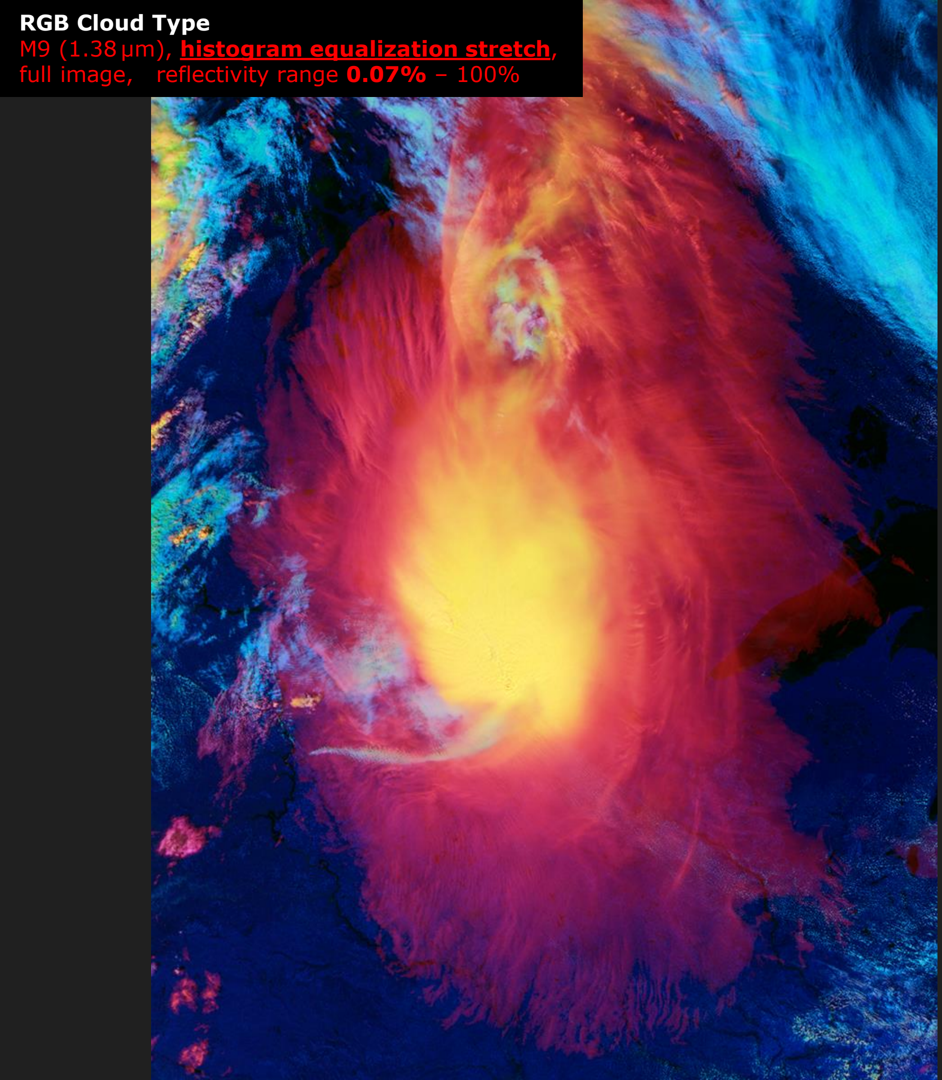


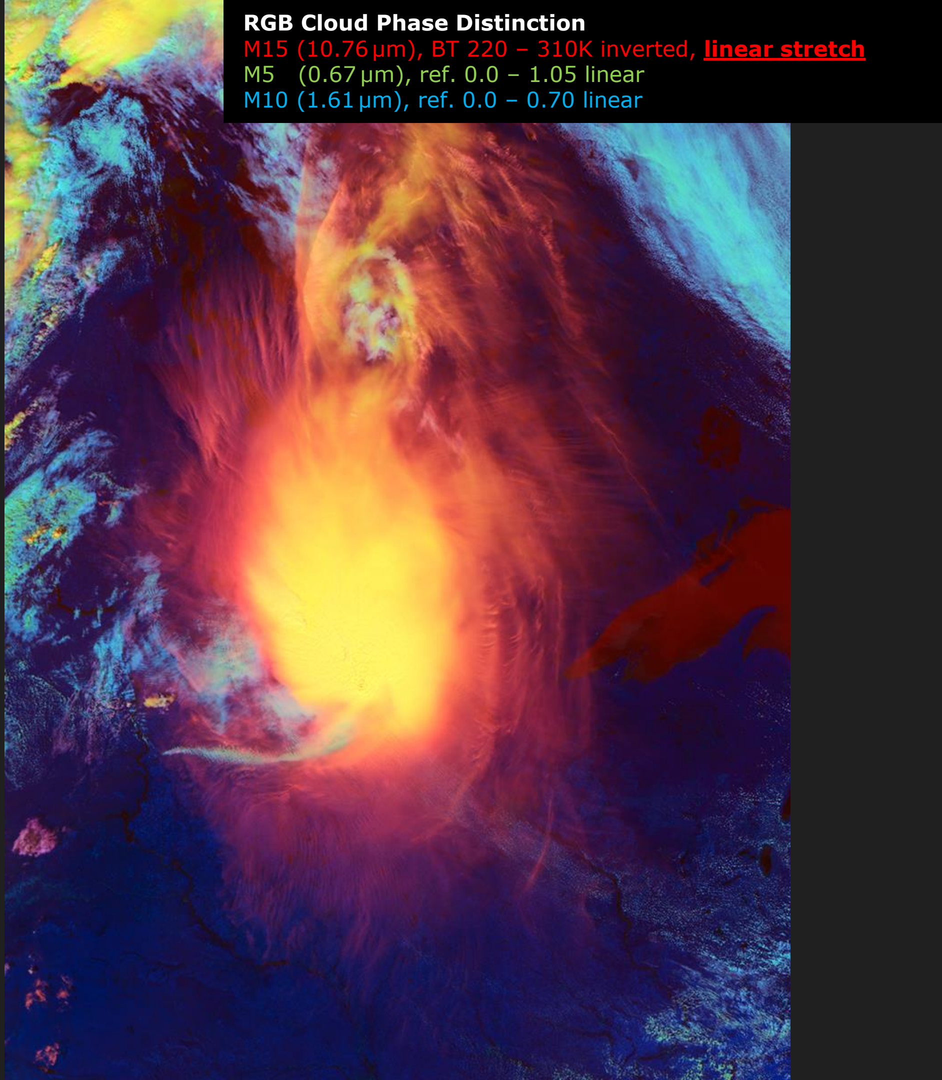

RGB Cloud Type
M9 (1.38 μm), histogram equalization stretch,
full image, reflectivity range 0.0% – 100%

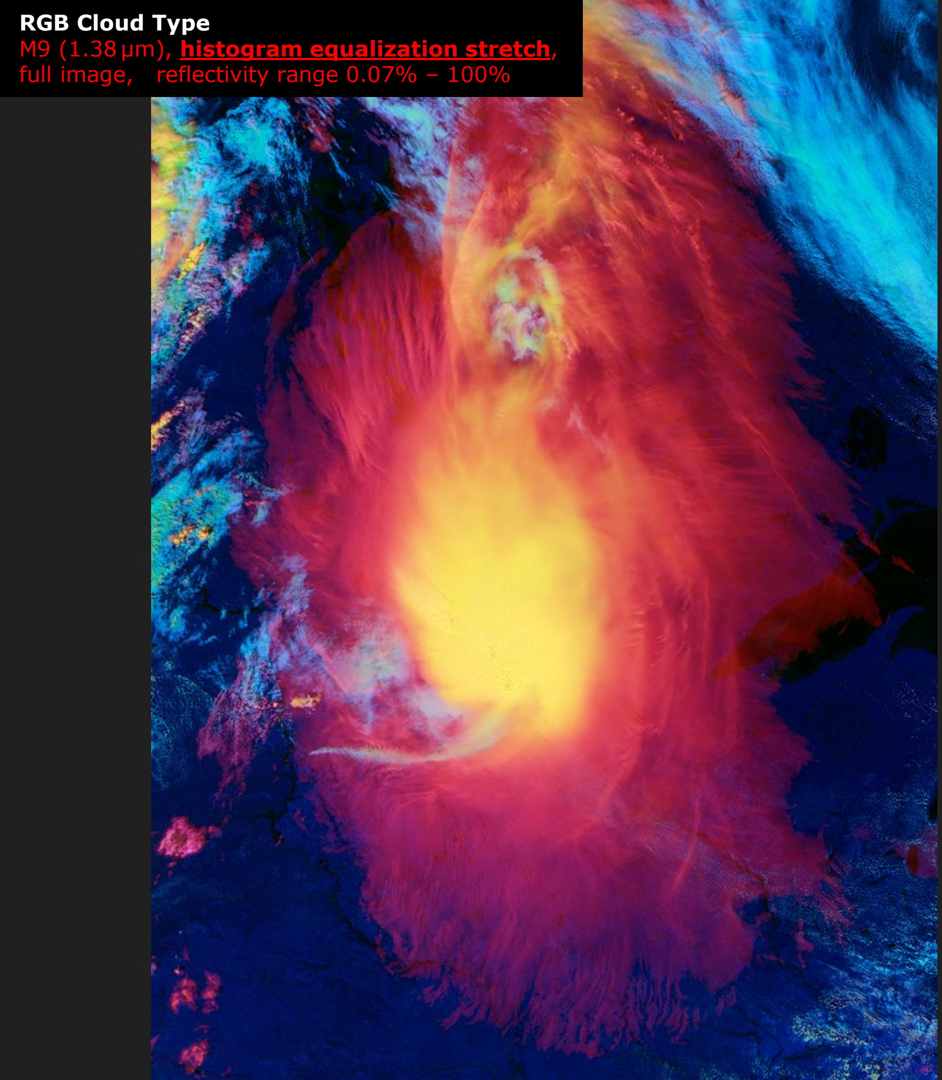

RGB Cloud Type
M9 (1.38 μm), histogram equalization stretch,
full image, reflectivity range 0.1% – 100%

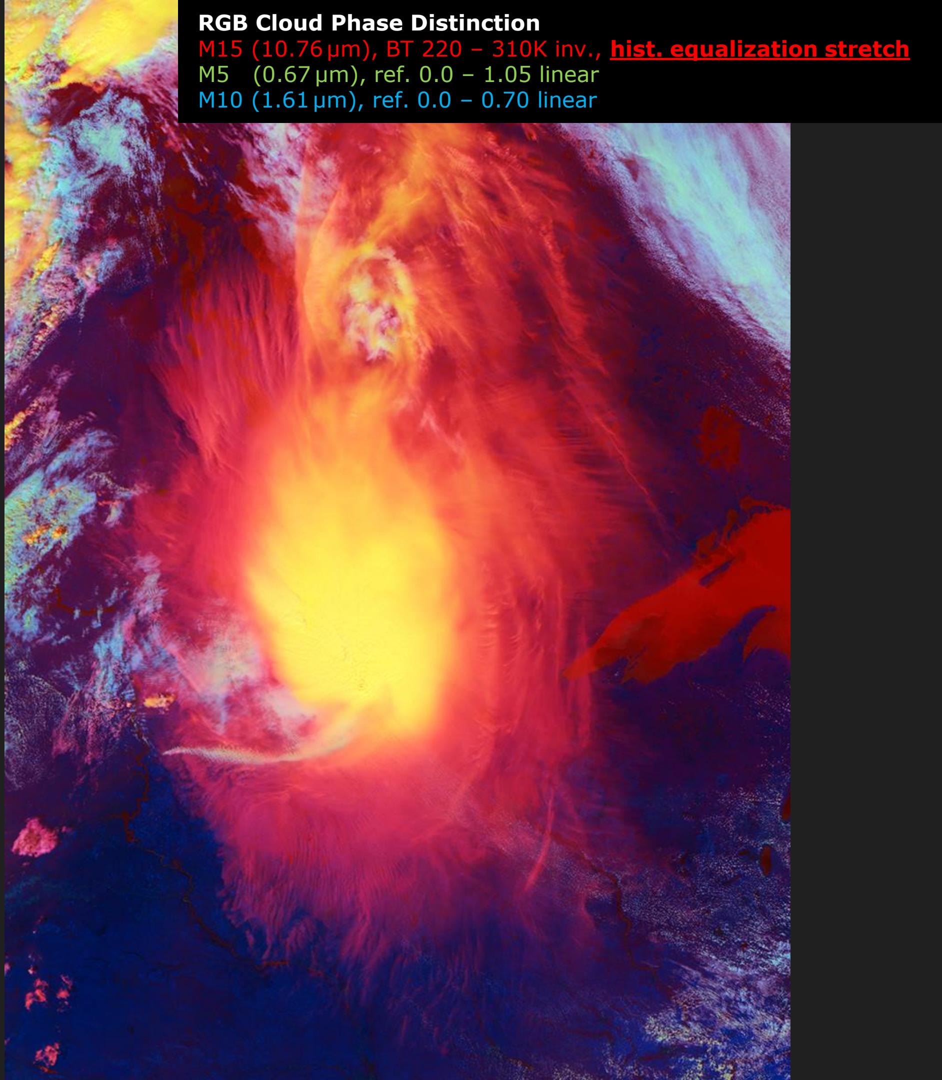

**RGB Cloud Type**
M9 (1.38 µm), **histogram equalization stretch,**
full image, reflectivity range **0.07%** – 100%


**RGB 24M** (24h Microphysics)
M16 (12.01 µm) – M15 (10.76 µm), -2.5 – +0.5K lin.
M15 (10.76 µm) – M14 (8.55 µm), -0.5 – +5.5K lin.
M15 (10.76 µm), BT 250 – 310K lin.


RGB Cloud Type
M9 (1.38 µm), histogram equalization stretch,
full image, reflectivity range 0.07% – 100%

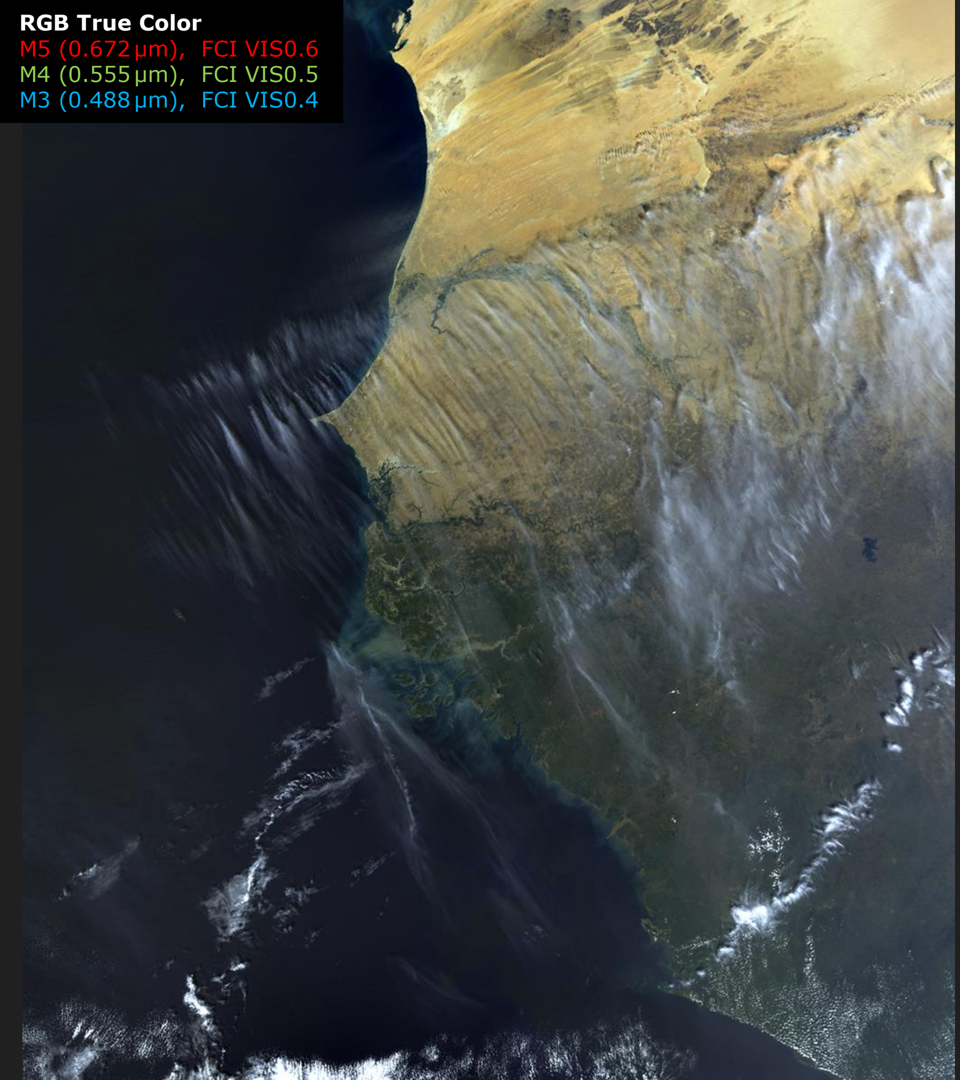

RGB Cloud Phase Distinction
M15 (10.76 µm), BT 220 – 310K inverted, linear stretch
M5 (0.67 µm), ref. 0.0 – 1.05 linear
M10 (1.61 µm), ref. 0.0 – 0.70 linear

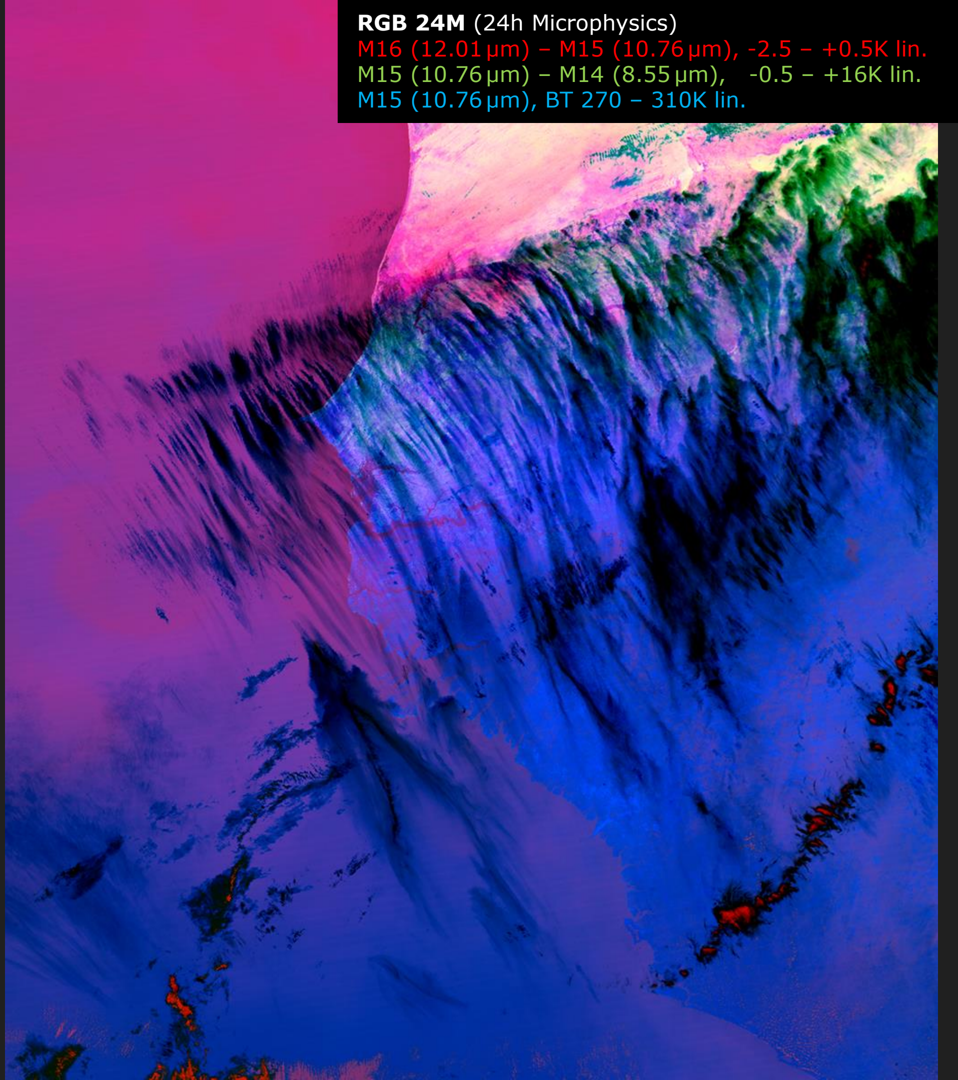

RGB Cloud Type
M9 (1.38 μm), histogram equalization stretch,
full image, reflectivity range 0.07% – 100%

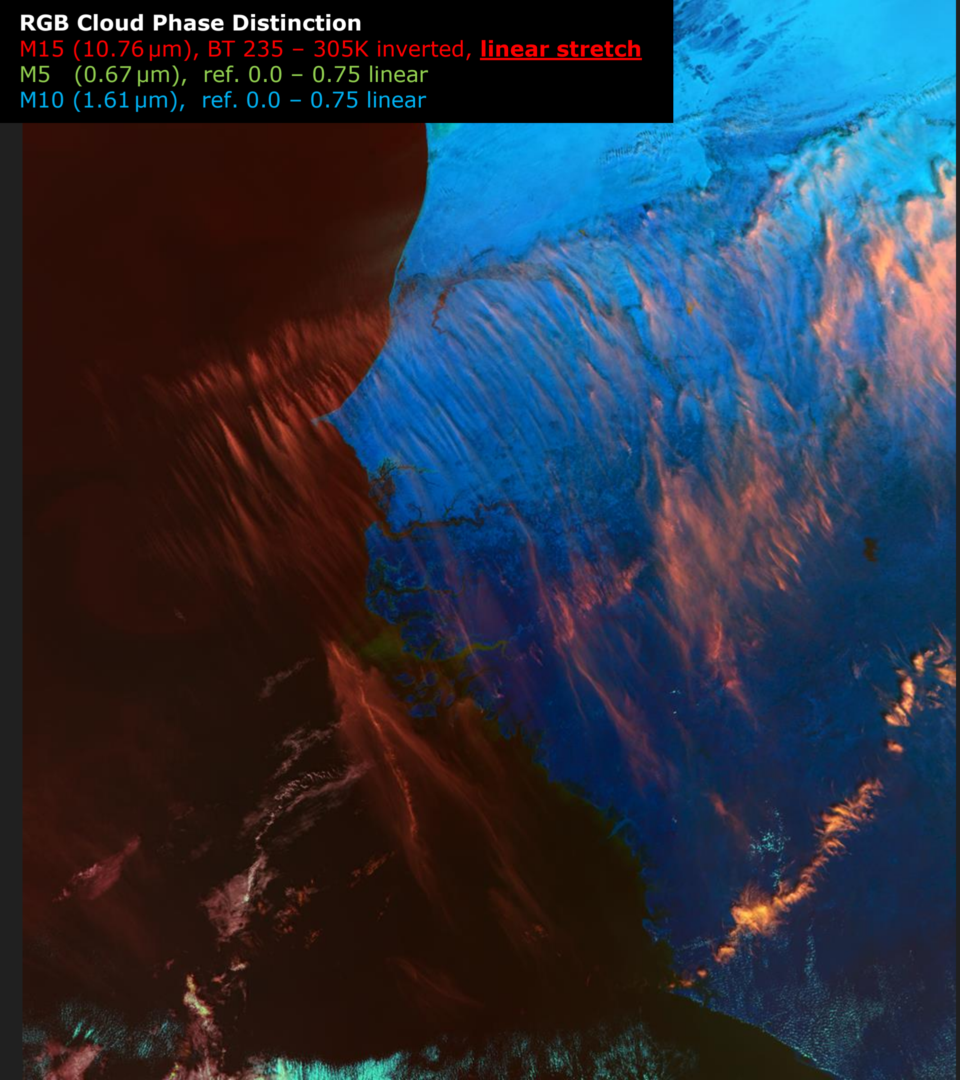

RGB Cloud Phase Distinction
M15 (10.76 μm), BT 220 – 310K inv., hist. equalization stretch
M5 (0.67 μm), ref. 0.0 – 1.05 linear
M10 (1.61 μm), ref. 0.0 – 0.70 linear

09 January 2020, 14:30 UTC,  NPP VIIRS, M-bands (750 m)

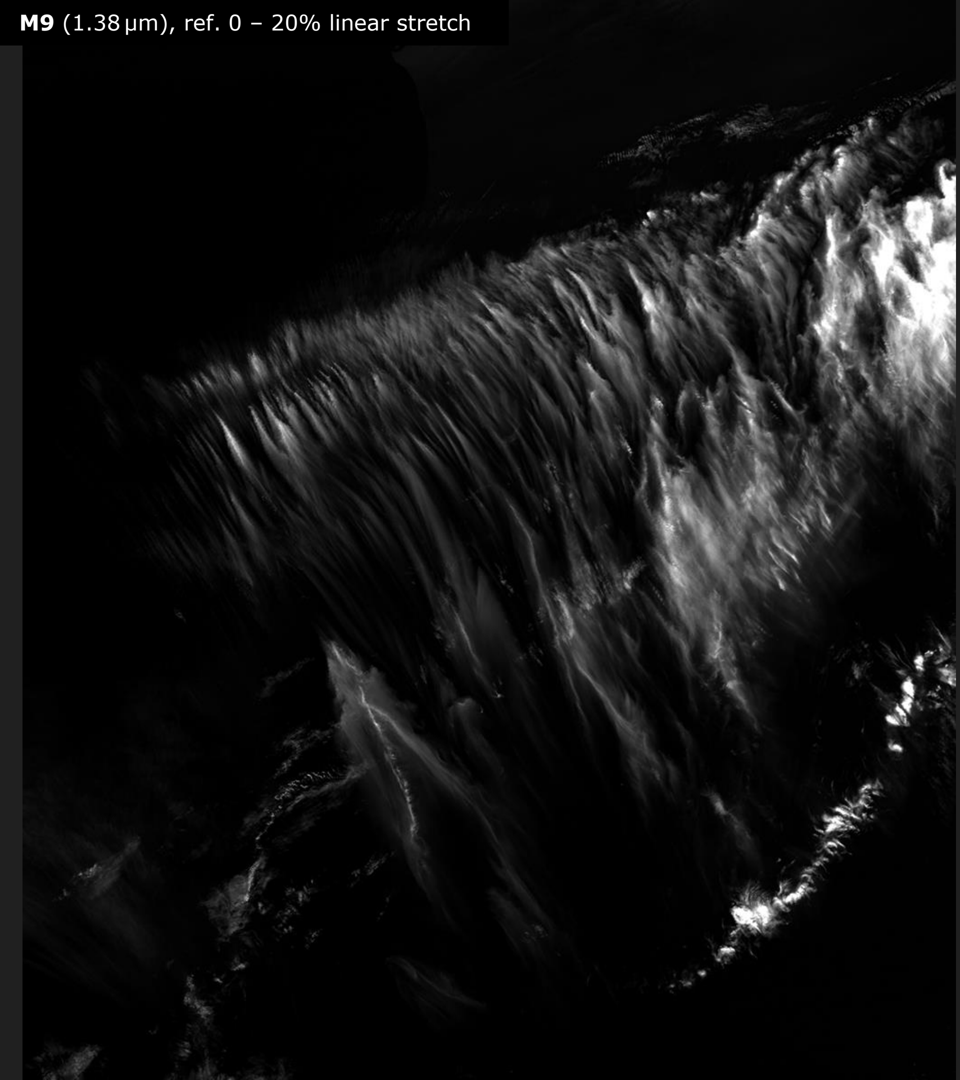
Thin cirrus, West Africa

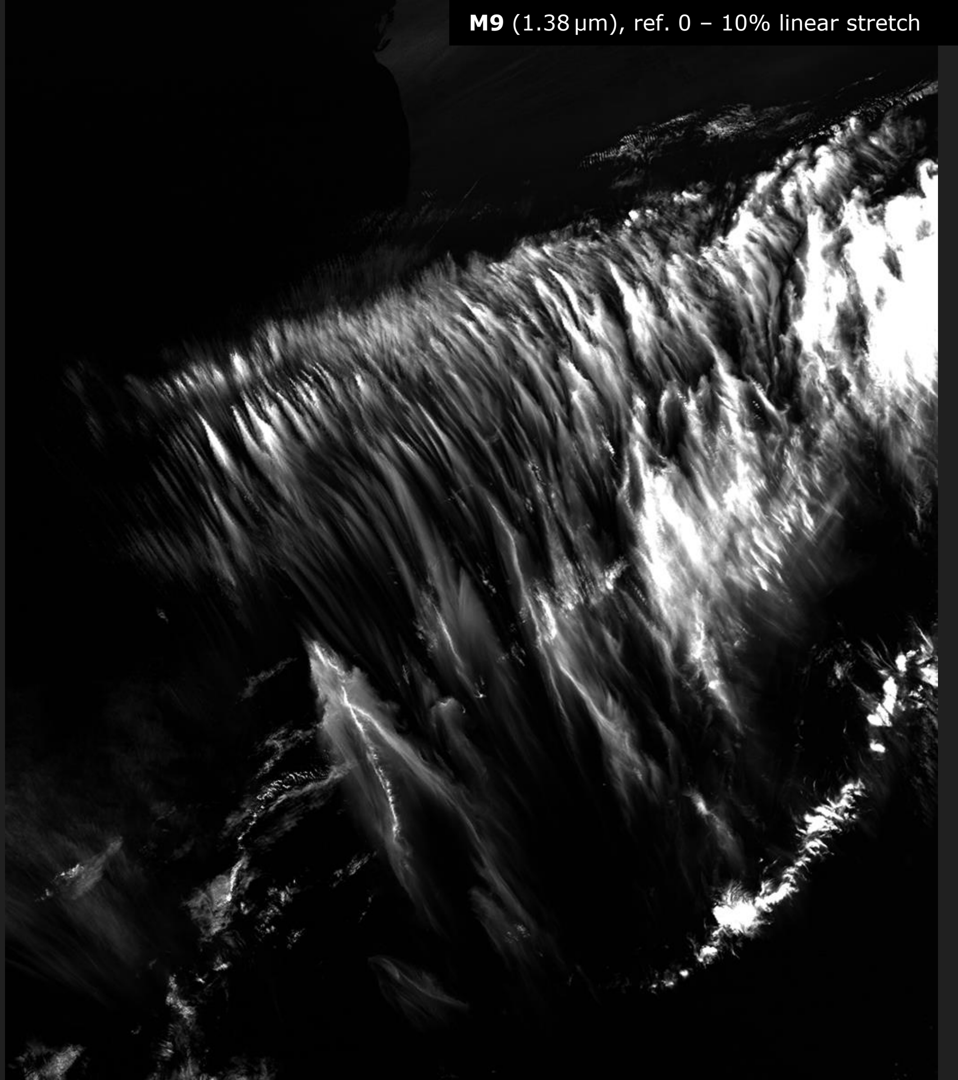

RGB True Color
M5 (0.672 μm), FCI VIS0.6
M4 (0.555 μm), FCI VIS0.5
M3 (0.488 μm), FCI VIS0.4


RGB 24M (24h Microphysics)
M16 (12.01 μm) – M15 (10.76 μm), -2.5 – +0.5K lin.
M15 (10.76 μm) – M14 (8.55 μm), -0.5 – +16K lin.
M15 (10.76 μm), BT 270 – 310K lin.


RGB Cloud Phase Distinction
M15 (10.76 µm), BT 235 – 305K inverted, linear stretch
M5 (0.67 µm), ref. 0.0 – 0.75 linear
M10 (1.61 µm), ref. 0.0 – 0.75 linear

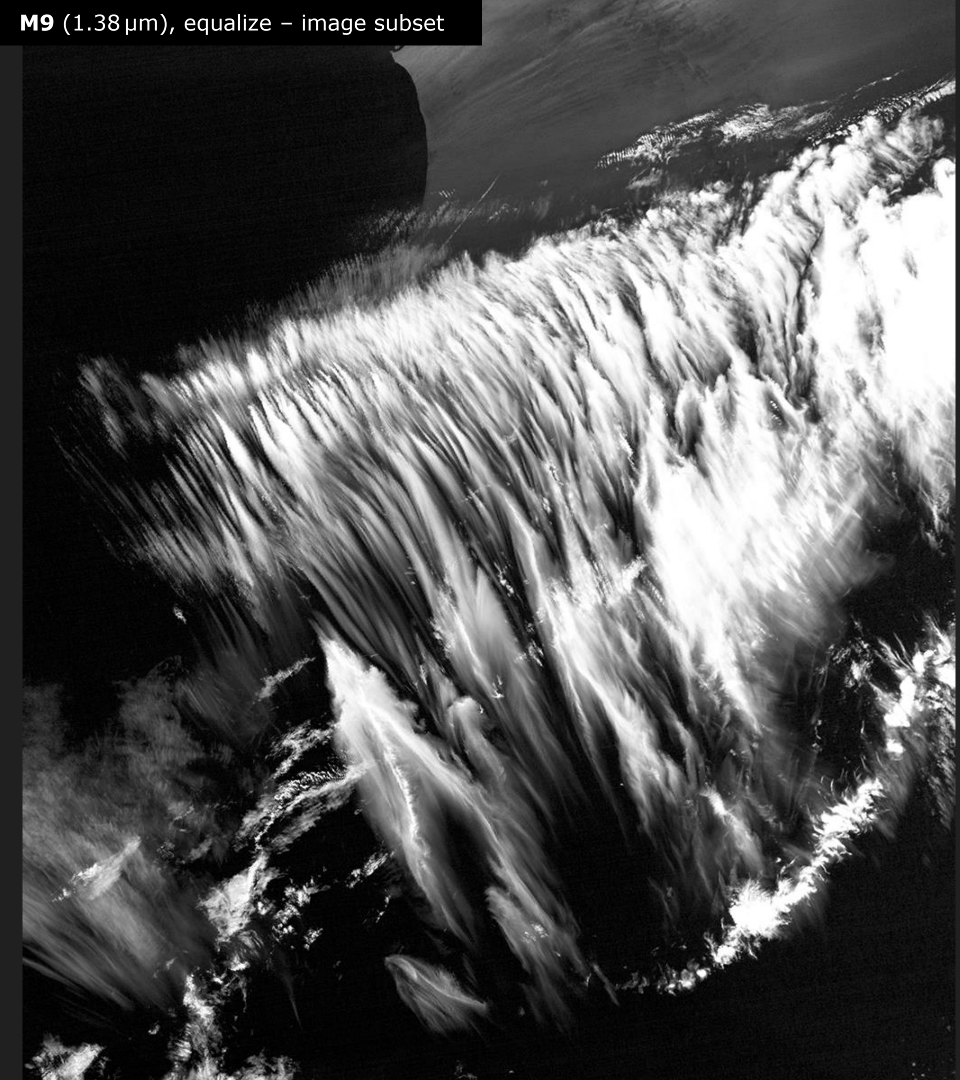

RGB Cloud Phase Distinction
M15 (10.76 µm), BT 250– 305K inv., hist. equalization stretch
M5 (0.67 µm), ref. 0.0 – 0.75 linear
M10 (1.61 µm), ref. 0.0 – 0.75 linear


**M9** (1.38 μm), ref. 0 – 20% linear stretch

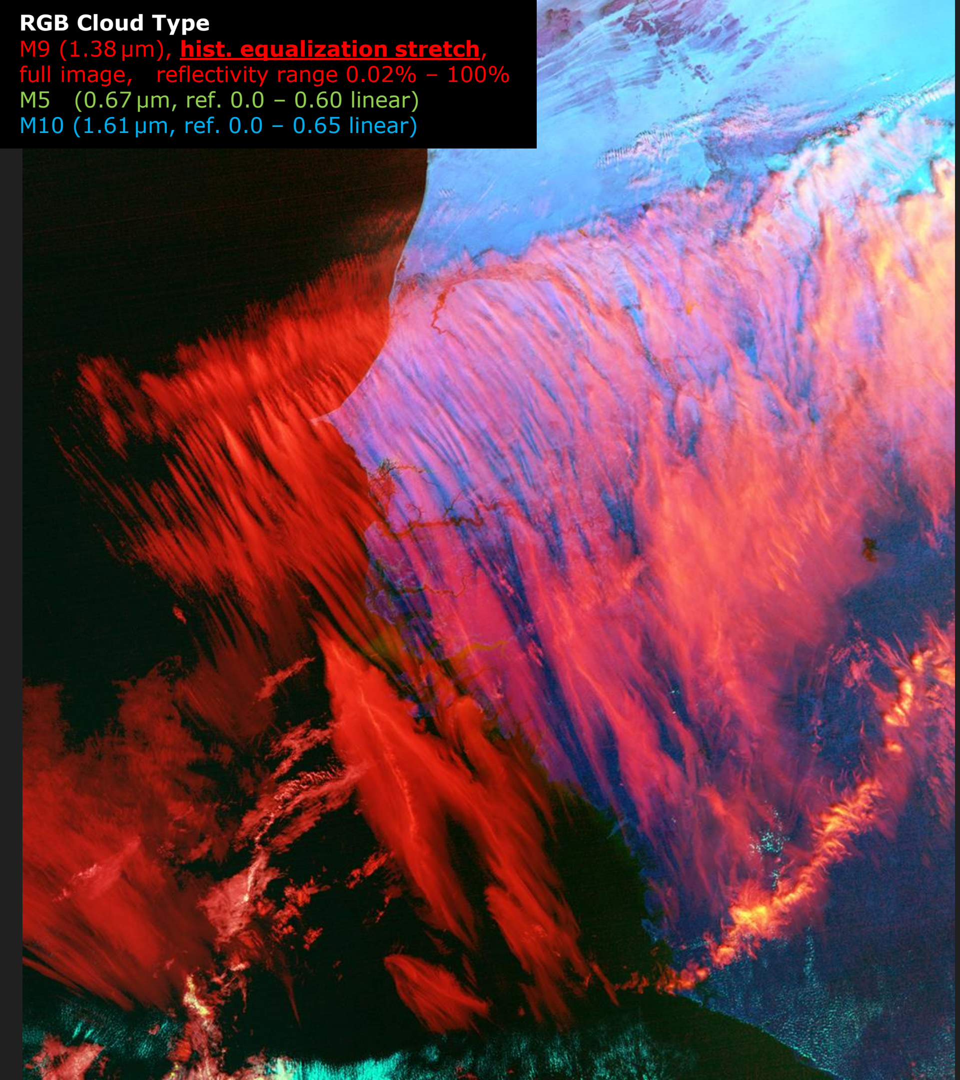

**M9** (1.38 μm), ref. 0 – 10% linear stretch

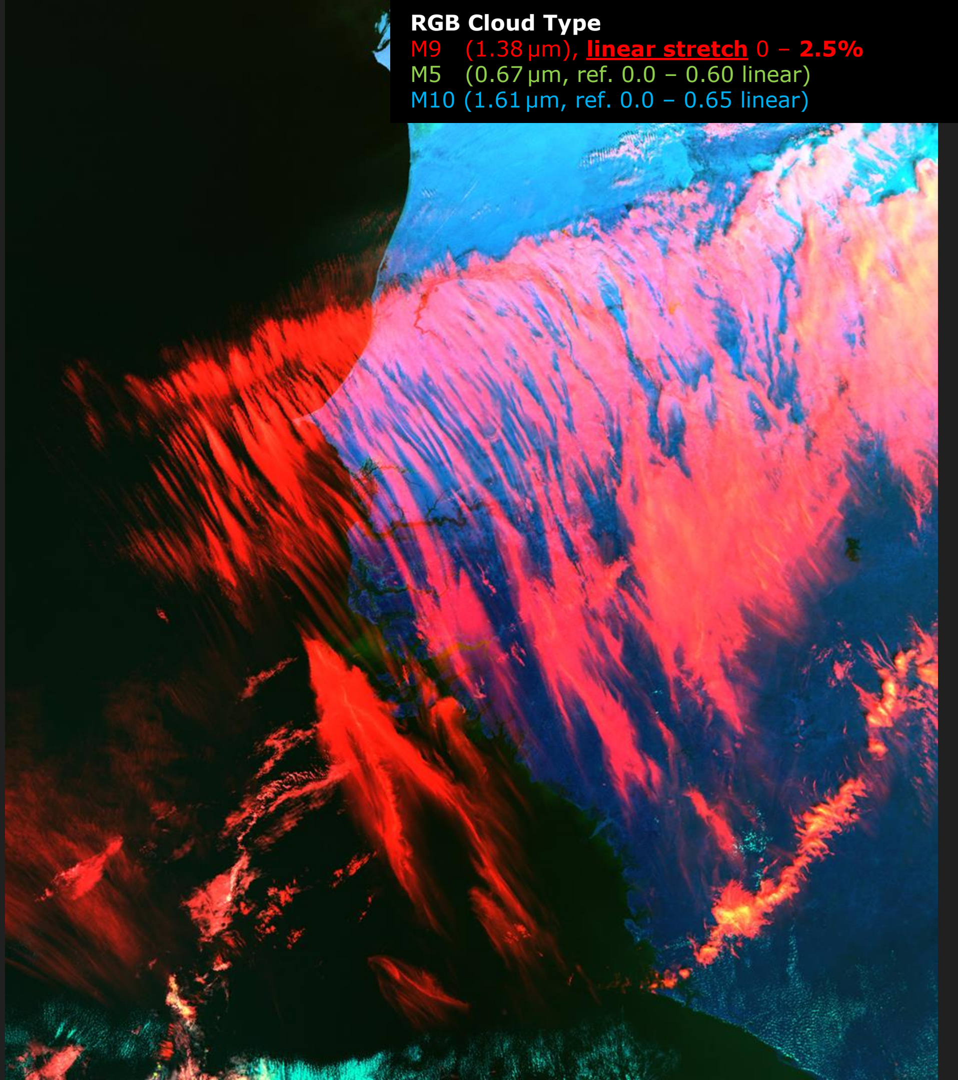

**M9** (1.38 μm), ref. 0 – 5% linear stretch

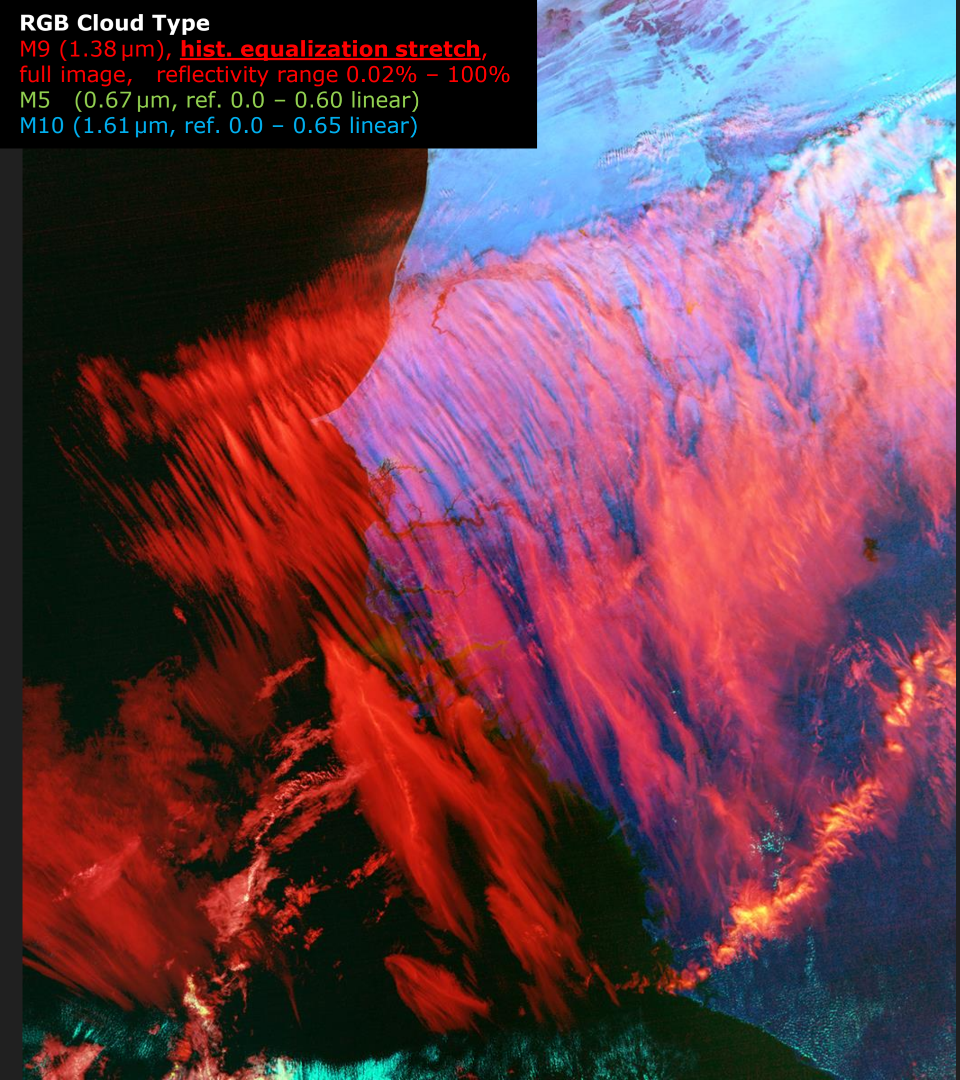

**M9** (1.38 μm), ref. 0 – 2% linear stretch

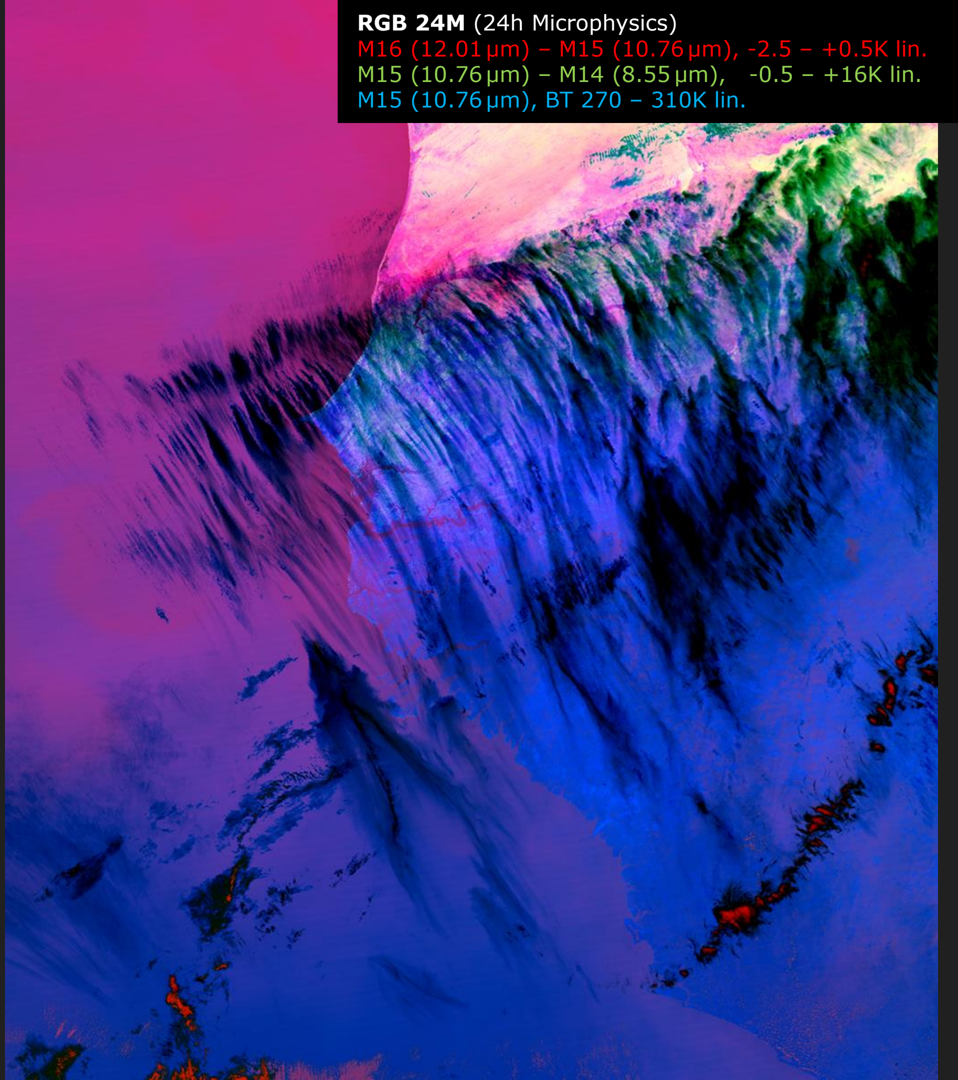

M9 (1.38 μm), equalize – image subset


M9 (1.38 μm), equalize – full image


RGB Cloud Type
M9 (1.38 µm), hist. equalization stretch,
full image, reflectivity range 0.02% – 100%
M5 (0.67 µm, ref. 0.0 – 0.60 linear)
M10 (1.61 µm, ref. 0.0 – 0.65 linear)


RGB Cloud Type
M9 (1.38 µm), linear stretch 0 – 2.5%
M5 (0.67 µm, ref. 0.0 – 0.60 linear)
M10 (1.61 µm, ref. 0.0 – 0.65 linear)


**RGB Cloud Type**
M9 (1.38 µm), **hist. equalization stretch**,
full image, reflectivity range 0.02% – 100%
M5 (0.67 µm, ref. 0.0 – 0.60 linear)
M10 (1.61 µm, ref. 0.0 – 0.65 linear)


**RGB 24M** (24h Microphysics)
M16 (12.01 µm) – M15 (10.76 µm), -2.5 – +0.5K lin.
M15 (10.76 µm) – M14 (8.55 µm), -0.5 – +16K lin.
M15 (10.76 µm), BT 270 – 310K lin.

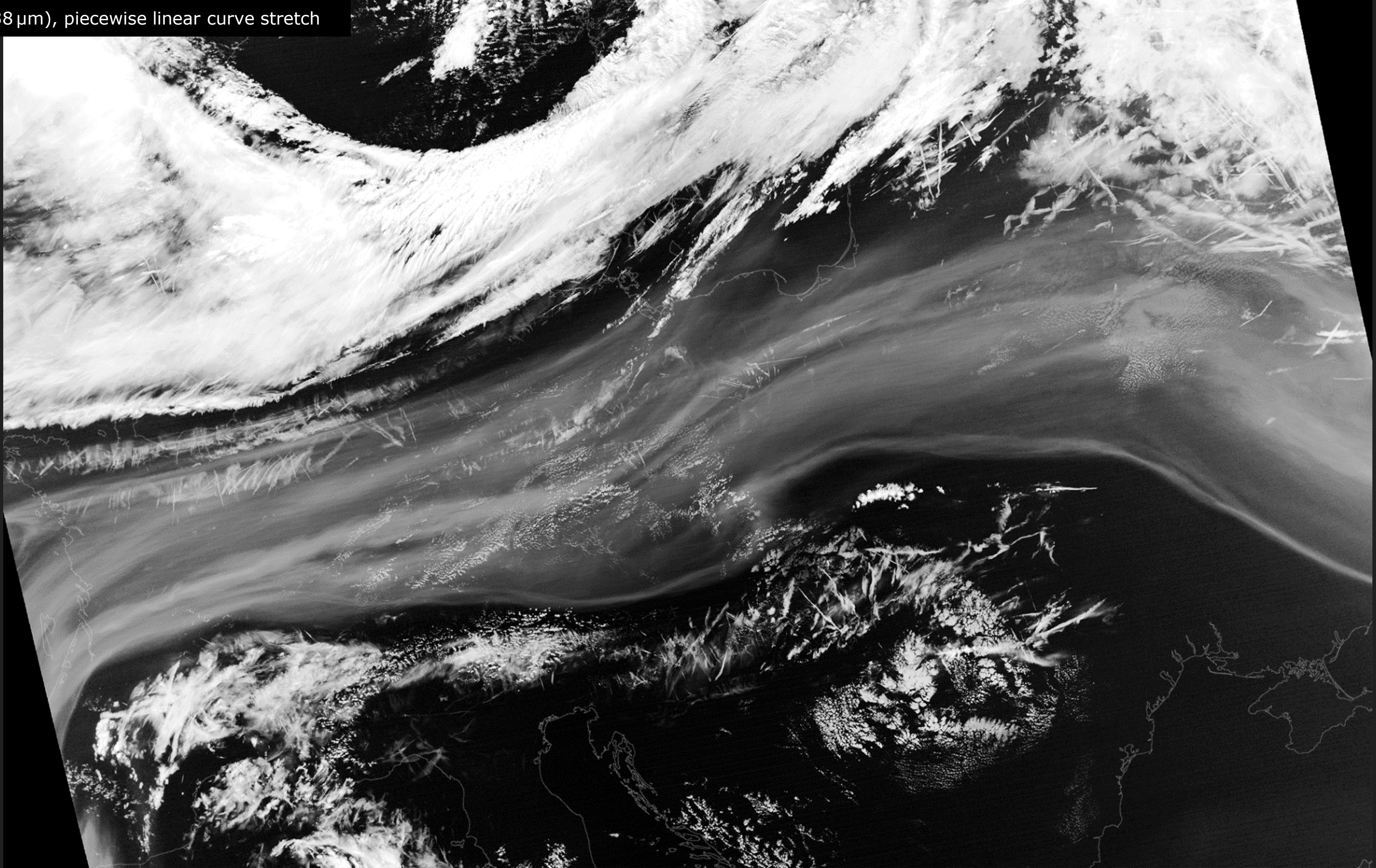
12 September 2020, 11:37 UTC,  NOAA-20 VIIRS, M-bands (750 m)

Dust (from California fires), Europe

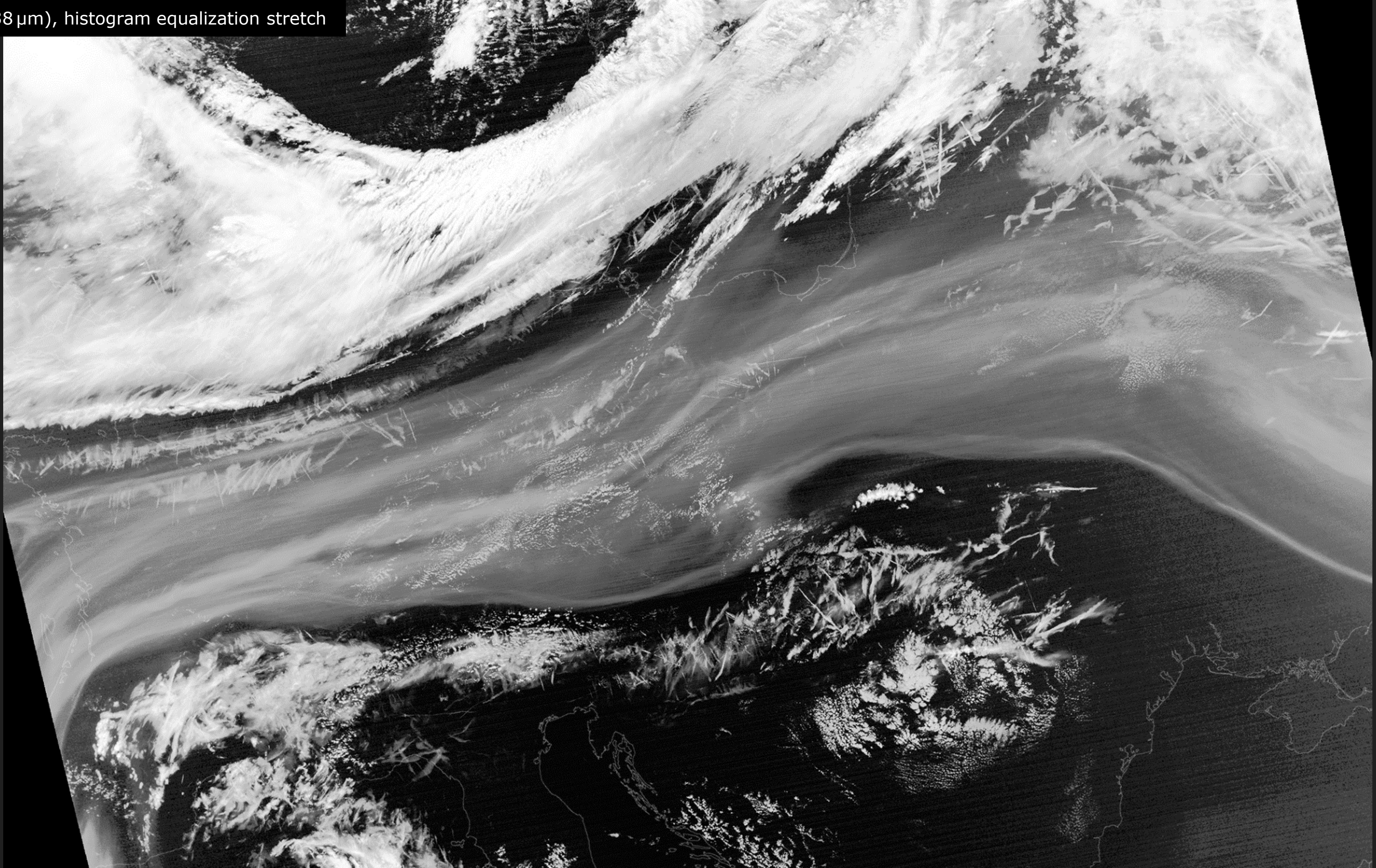
https://www.eumetsat.int/smoke-california-fires-above-europe-seen-noaa-20

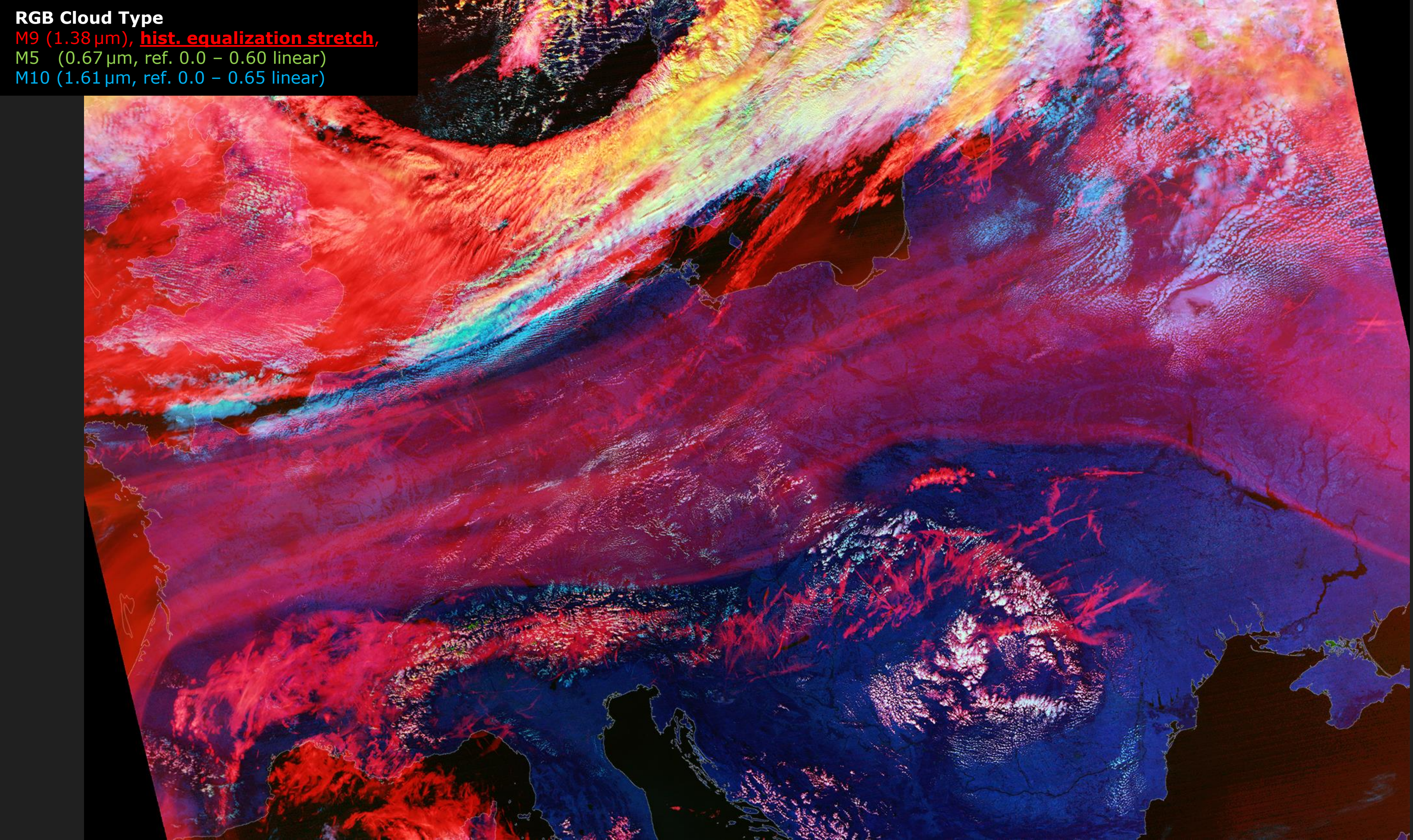

VIIRS RGB 541
M5 (0.672 µm)
M4 (0.555 µm)
M1 (0.412 µm)

**M9** (1.38 μm), piecewise linear curve stretch



**M9** (1.38 µm), histogram equalization stretch




RGB Cloud Type
M9 (1.38 µm), hist. equalization stretch,
M5 (0.67 µm, ref. 0.0 – 0.60 linear)
M10 (1.61 µm, ref. 0.0 – 0.65 linear)

25 February 2021, 11:25 UTC,  NOAA-20, VIIRS, M-bands (750 m)

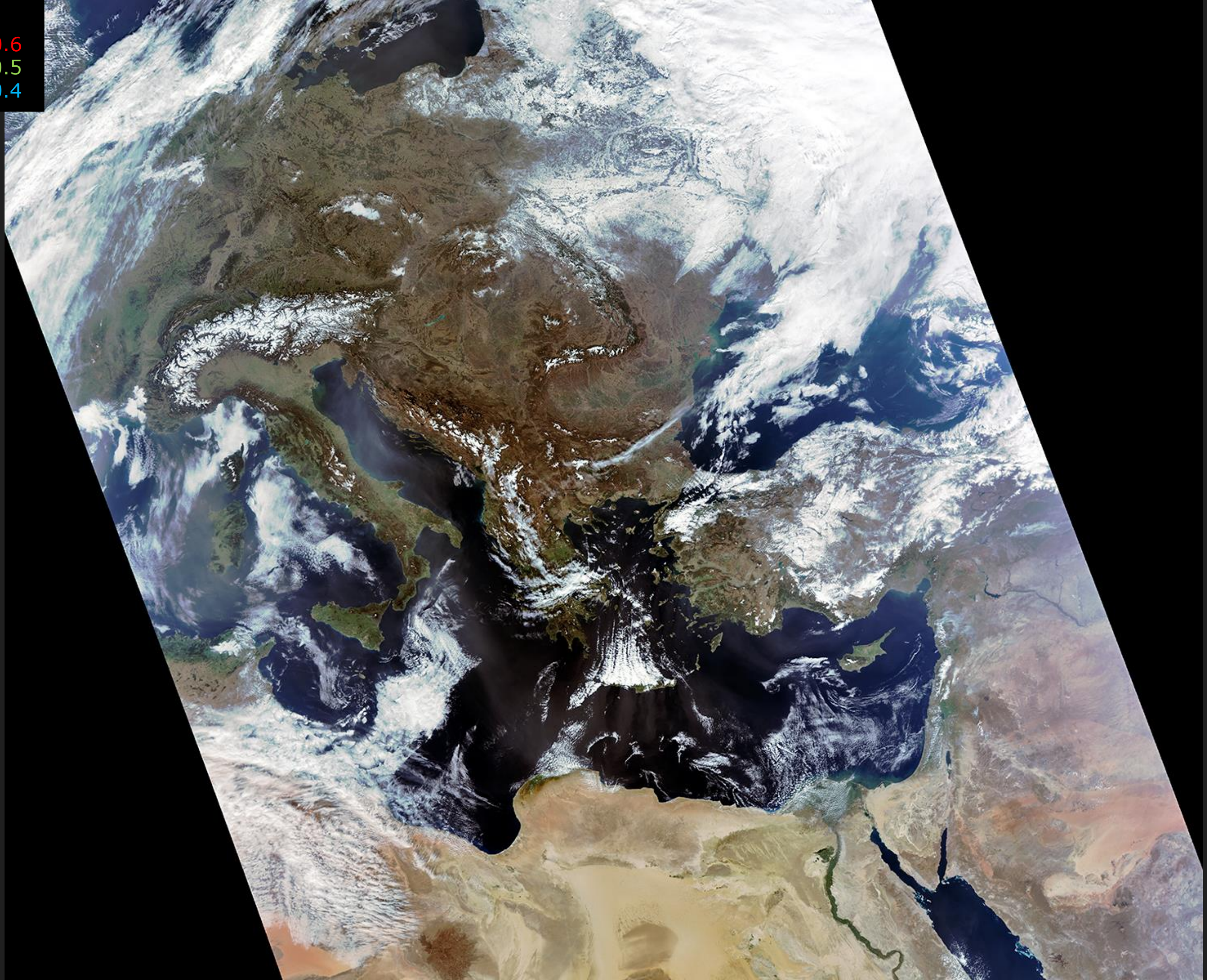
Sahara dust above Europe and north Africa

**RGB True Color**

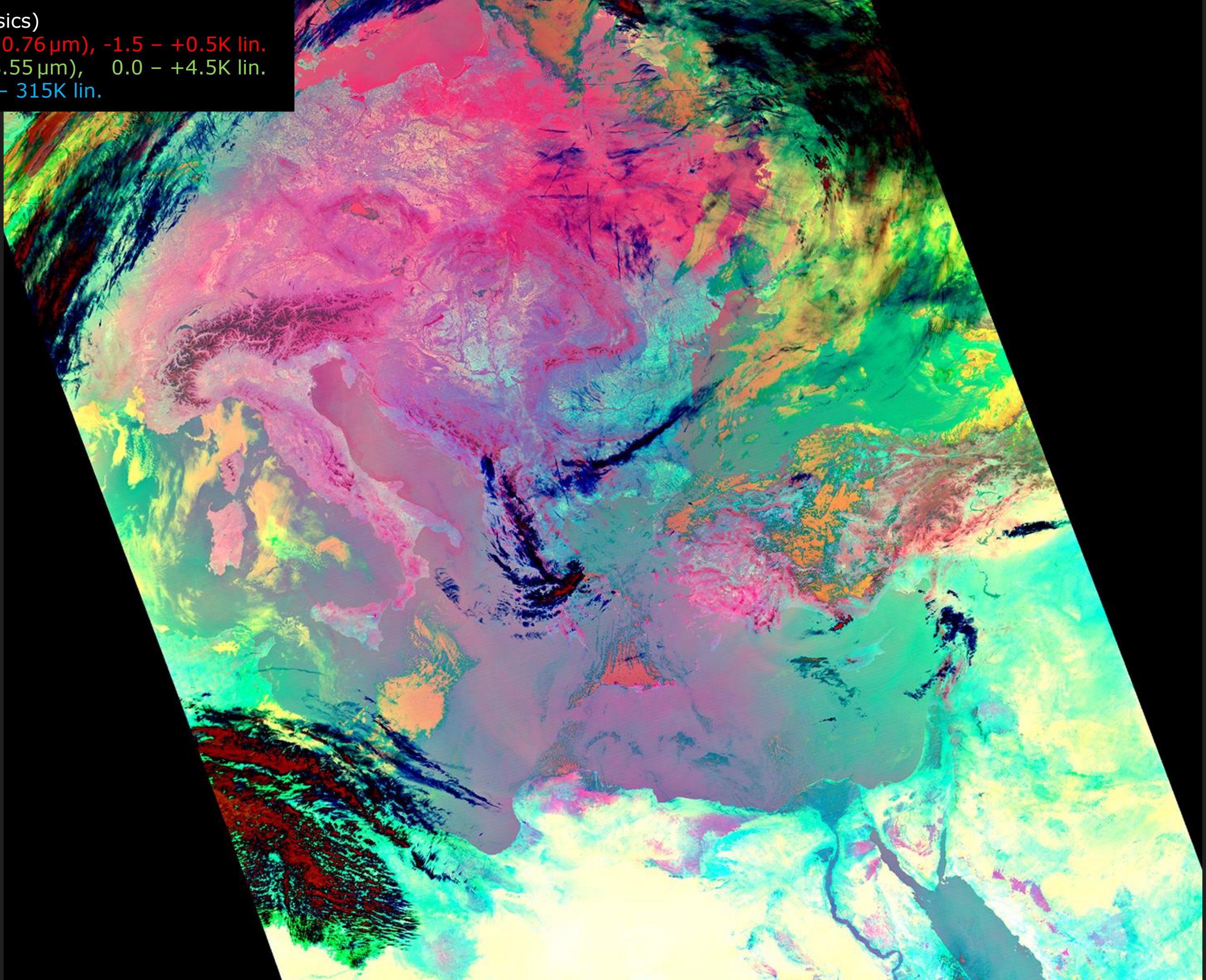
M5 (0.672 µm), FCI VIS0.6

M4 (0.555 µm), FCI VIS0.5

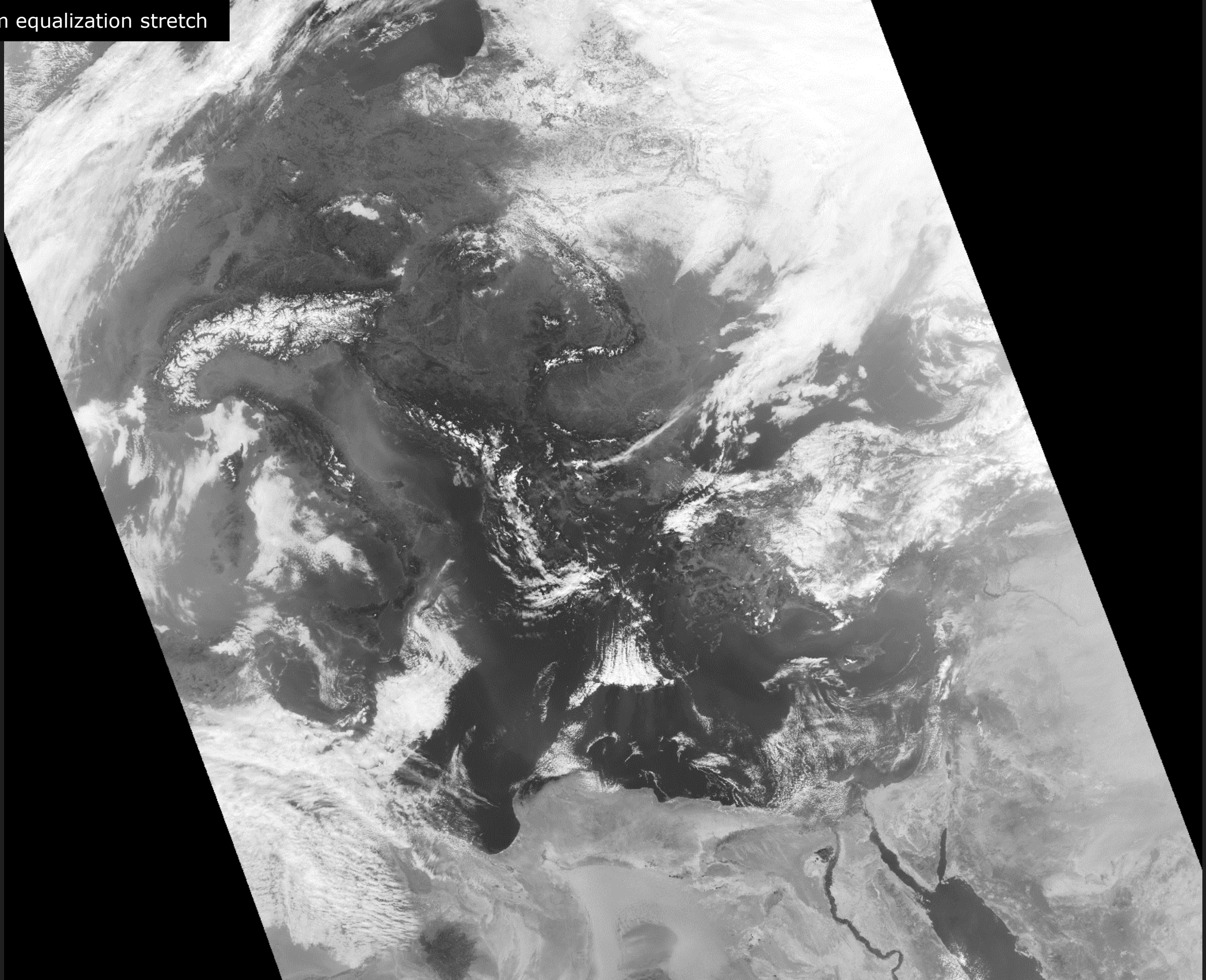
M3 (0.488 µm), FCI VIS0.4



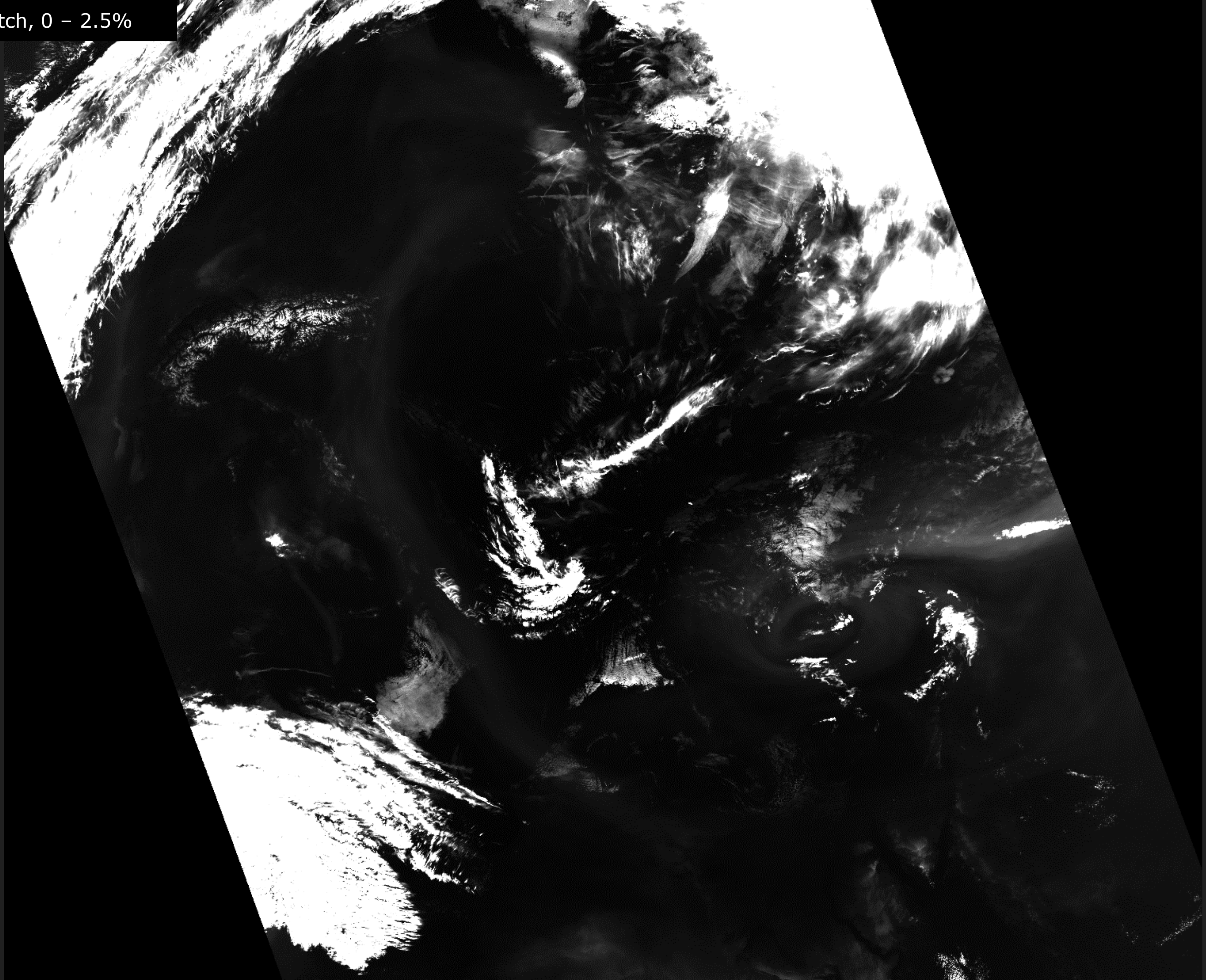
**RGB 24M** (24h Microphysics)
M16 (12.01 µm) – M15 (10.76 µm), -1.5 – +0.5K lin.
M15 (10.76 µm) – M14 (8.55 µm), 0.0 – +4.5K lin.
M15 (10.76 µm), BT 240 – 315K lin.



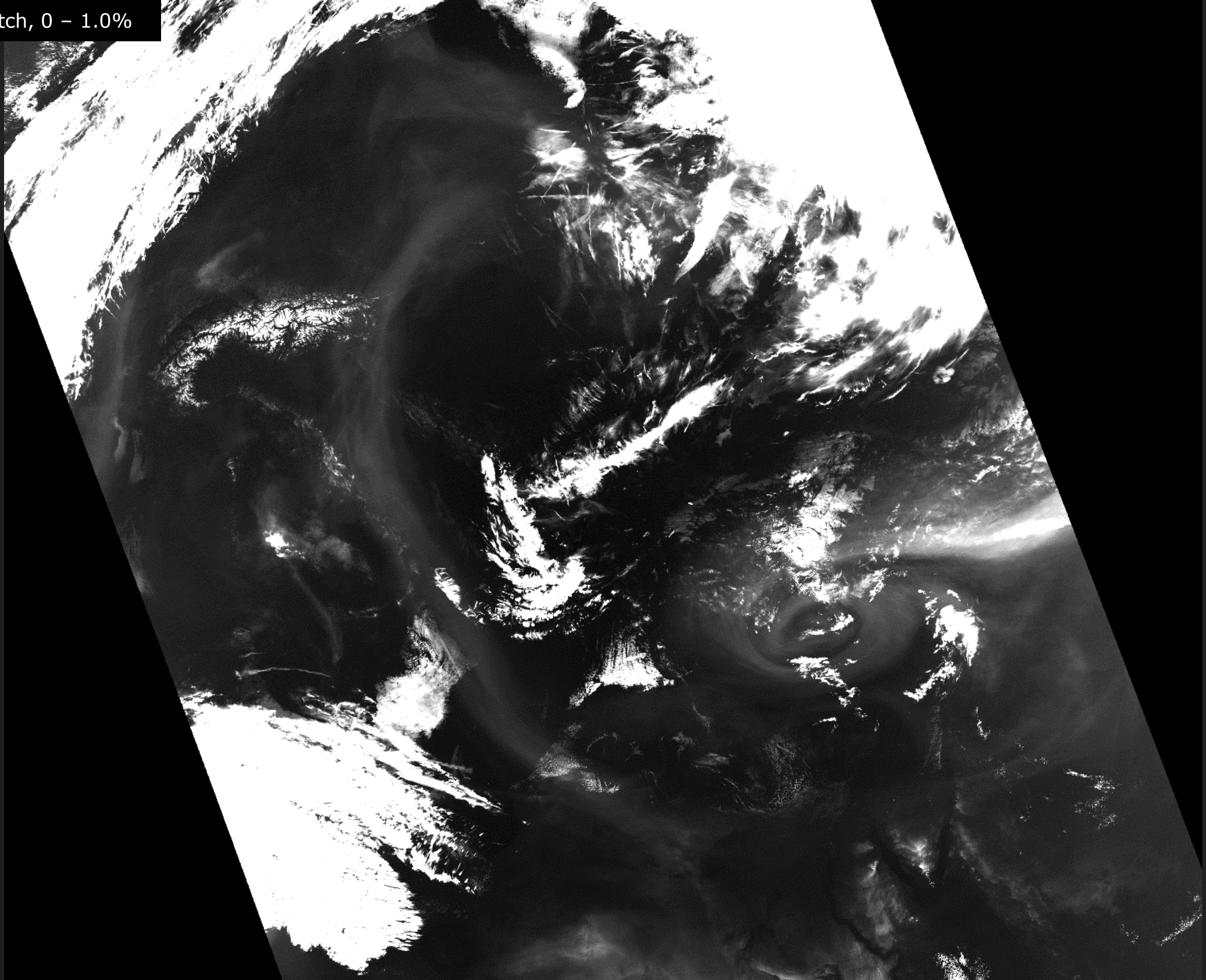
**M3** (0.488 µm), histogram equalization stretch



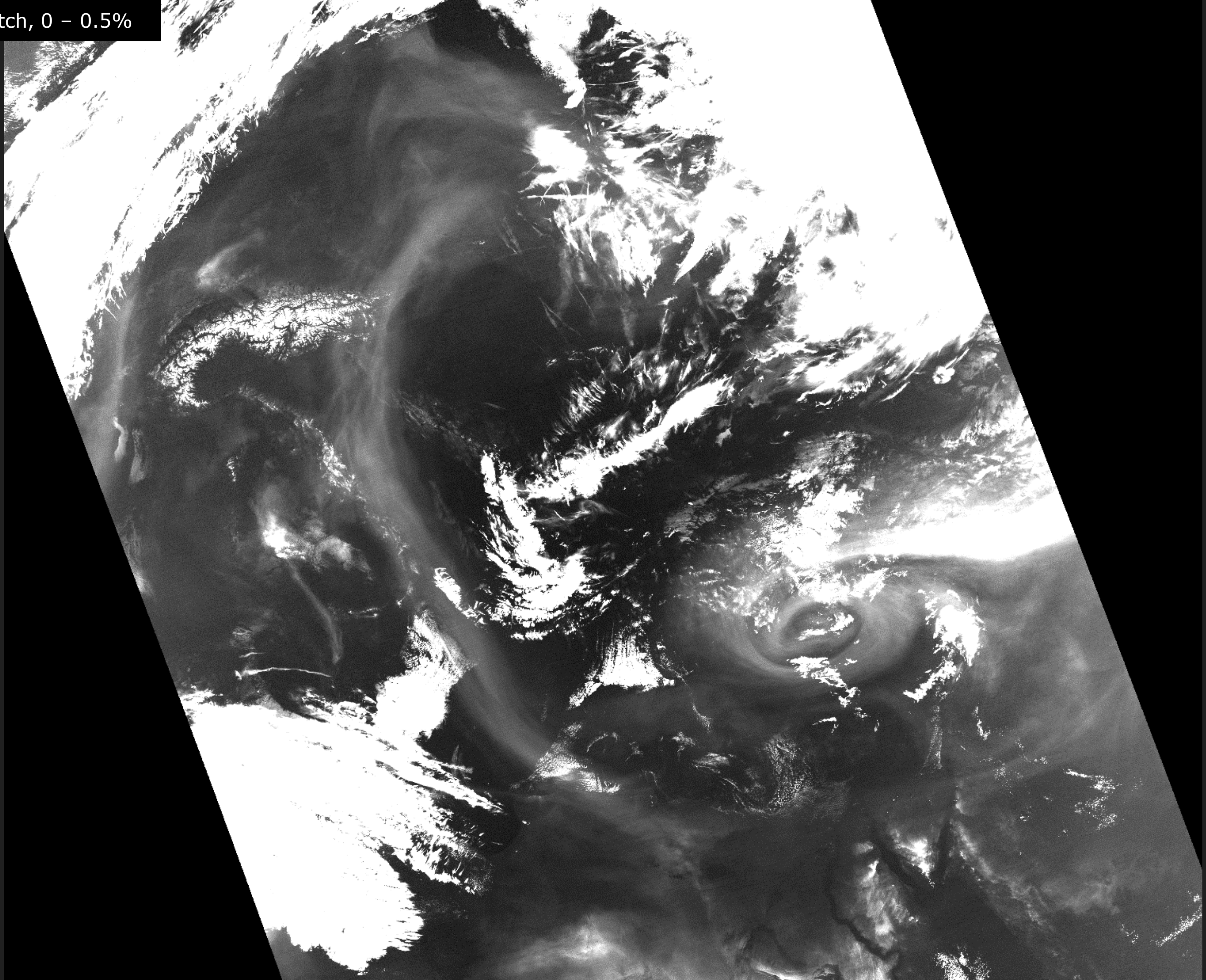
**M9** (1.38 μm), linear stretch, 0 – 2.5%



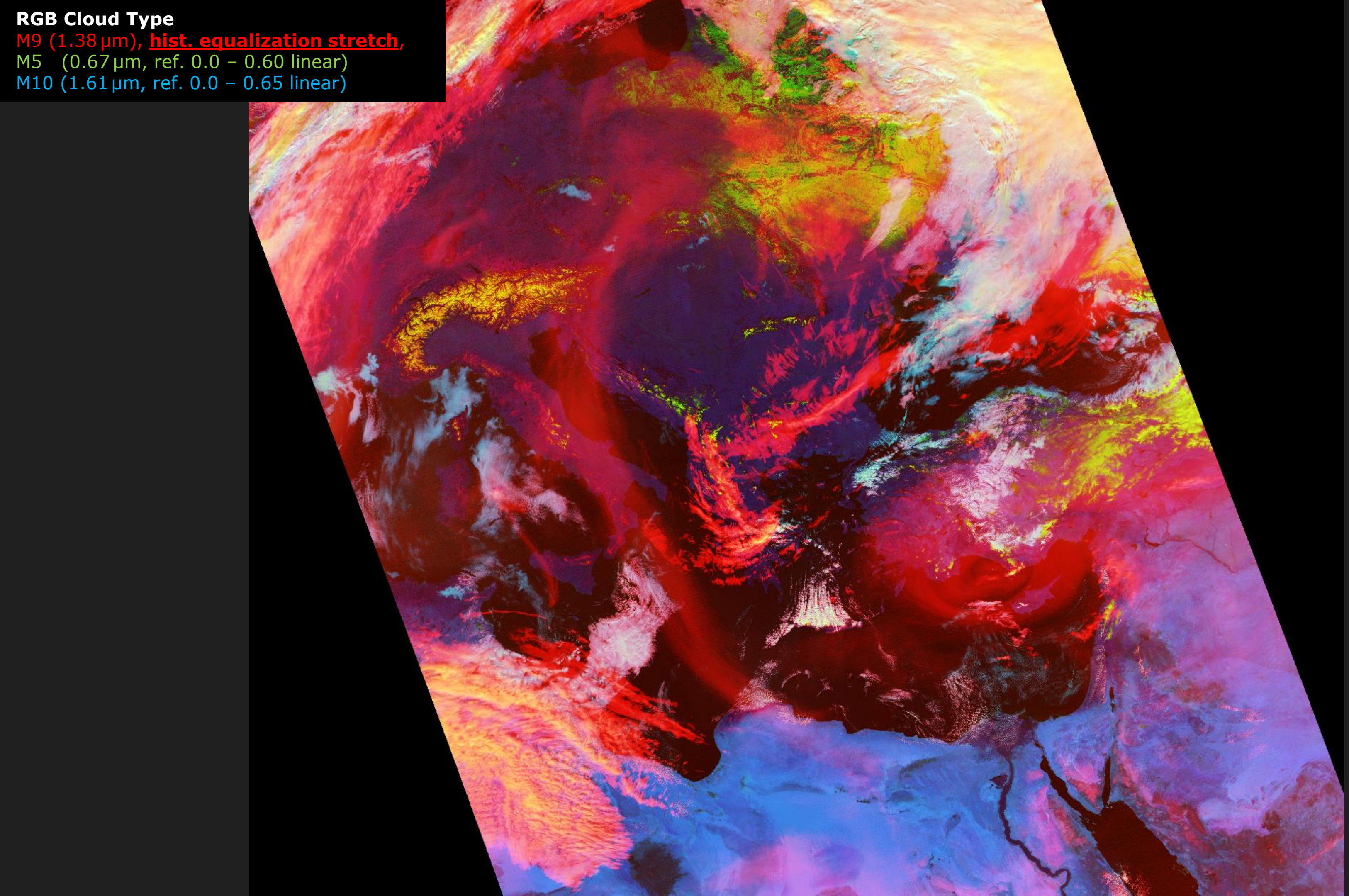
**M9** (1.38 μm), linear stretch, 0 – 1.0%



**M9** (1.38 μm), linear stretch, 0 – 0.5%



**M9** (1.38 μm), histogram equalization stretch


**RGB Cloud Type**
M9 (1.38 µm), hist. equalization stretch,
M5 (0.67 µm, ref. 0.0 – 0.60 linear)
M10 (1.61 µm, ref. 0.0 – 0.65 linear)

# 1.38 µm spectral band – final comments
(based also on several other cases, not shown here)

- The 1.38 µm band and Cloud Type RGB, using the histogram equalization stretch method, or very steep piecewise linear stretch enhancement (or high gamma?) provide slightly better performance for very thin cirrus detection as compared to 24M RGB and Cloud Phase Distinction RGB, namely showing better the details.

- The Cloud Phase Distinction RGB can show more of the thin cirrus when applying the histogram equalization stretch method on the IR band in red channel.

- Besides the thin cirrus, the histogram equalization stretch method can show nicely other very dim features, such as aerosols or dust. However, their detection depends on humidity in the troposphere above these.

- Next work – experiment with gamma enhancement, which might be used instead of the stretch methods described above.

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- Besides the thin cirrus, the histogram equalization stretch method can show nicely other very dim features, such as aerosols or dust. However, their detection depends on humidity in the troposphere above these.
- Next work – experiment with gamma enhancement, which might be used instead of the stretch methods described above.
- All the cases shown above are based on VIIRS. For GEO satellites, applicability of these methods may not be as efficient or straightforward, due to higher noise in their 1.38 µm band in darkest areas, or ESL (Earth Stray Light) issues on MTG FCI.

Source of VIIRS L1B data used in this presentation: NOAA CLASS archive

Processing of the VIIRS L1B data: ENVI and its VCTK plugin.