1.38 µm bands - aerosols, ash and dust

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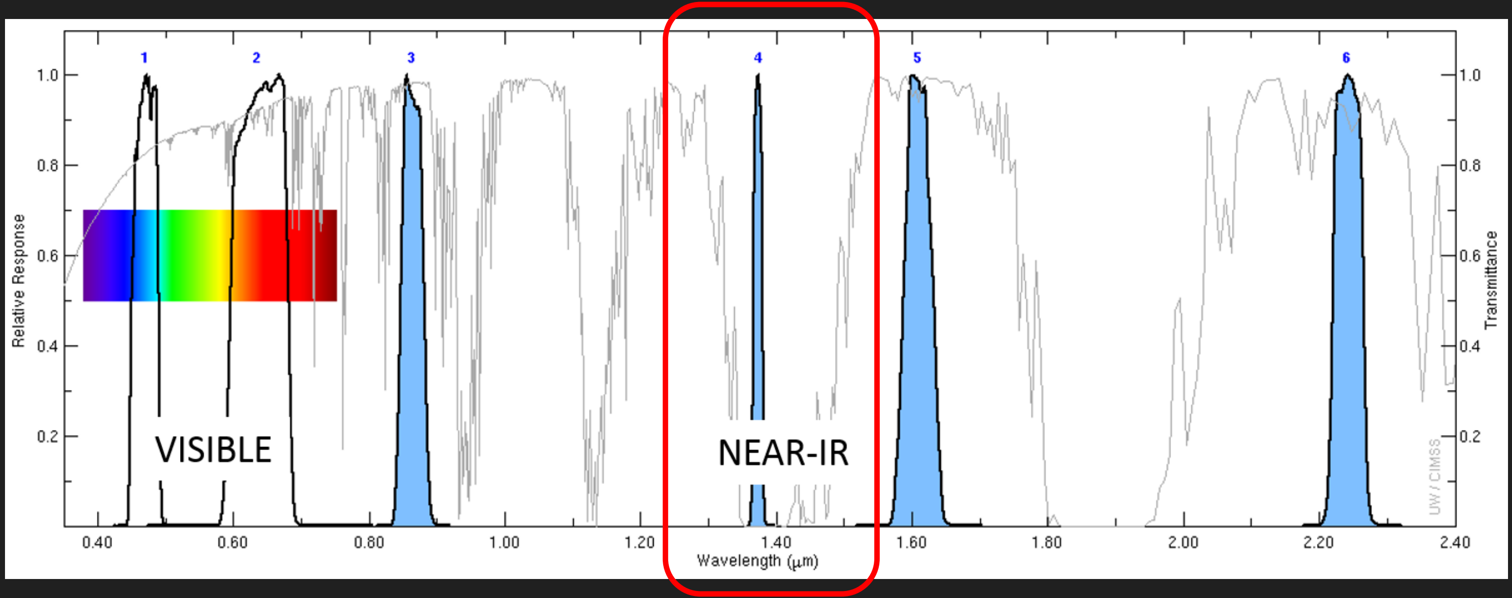
1.38 µm spectral band: general characteristics and availability

- strong attenuation by tropospheric moisture >>> thin cirrus detection, high clouds discrimination
- under favorable conditions also detection of aerosols, ash and dust
- used either as single band 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: GOES-R ABI



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

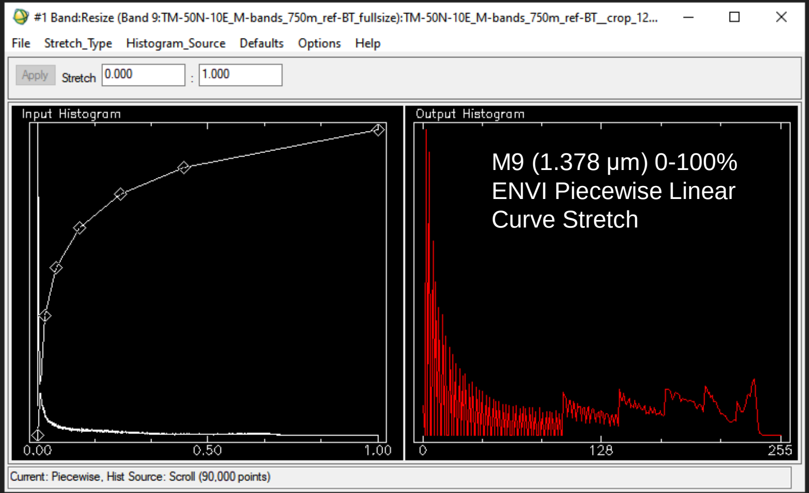
1.38 μm spectral band: enhancement methods

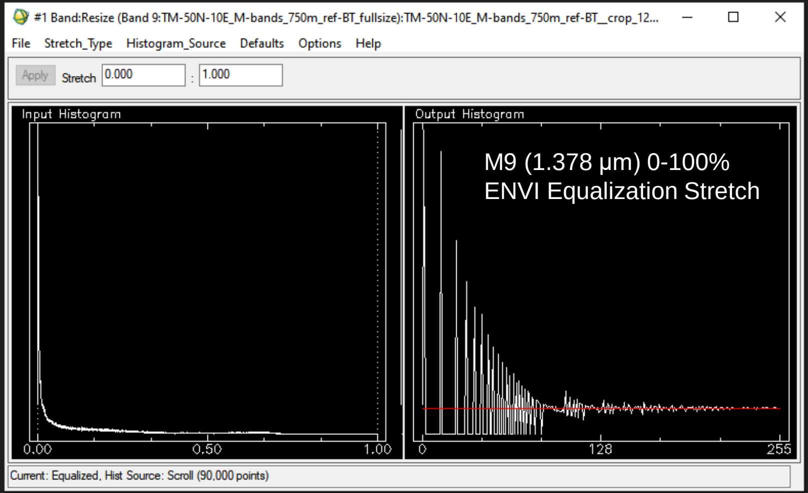
- The most interesting information – very thin cirrus, aerosols, dust – is hidden in the darkest parts of the 1.38 μm band, which are typically difficult to brighten using linear stretch, without oversaturating the rest of the image.

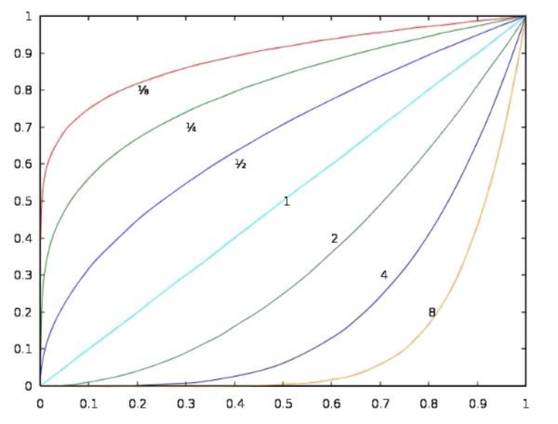
- The piecewise linear stretch (curve stretch) and gamma stretch enhancements independent of the content of the scene – better suited for operational use.

- The histogram equalization method strongly depends on selection of the image area and its content (full image area or its smaller subset), which are used to calculate the enhancement – need to fine-tune it from case to case. Applicable namely in interactive image processing, for case studies, where it provides best results.

1.38 µm spectral band: enhancement methods







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)

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

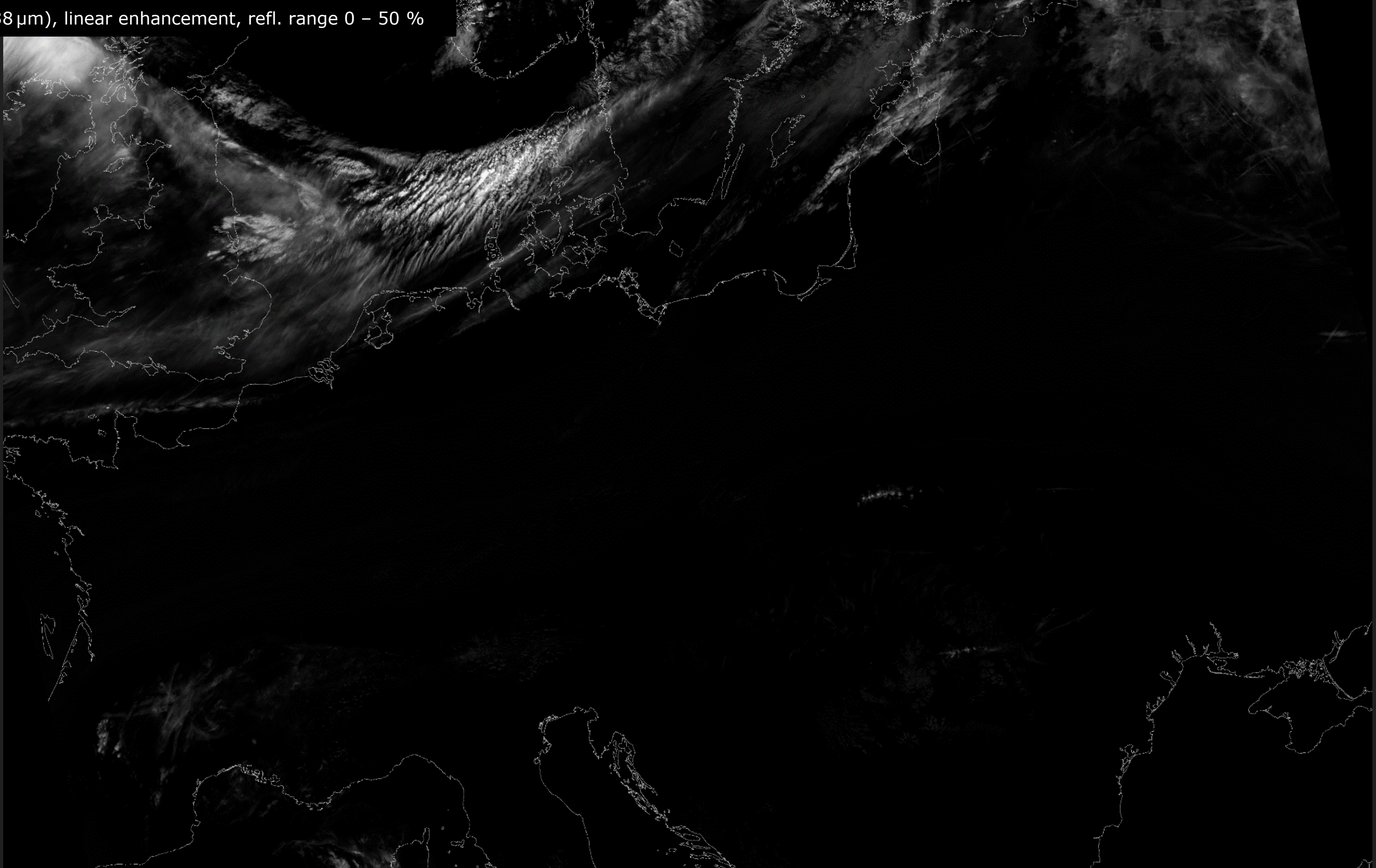
Europe – ash from California fires

Demonstration of various enhancement methods

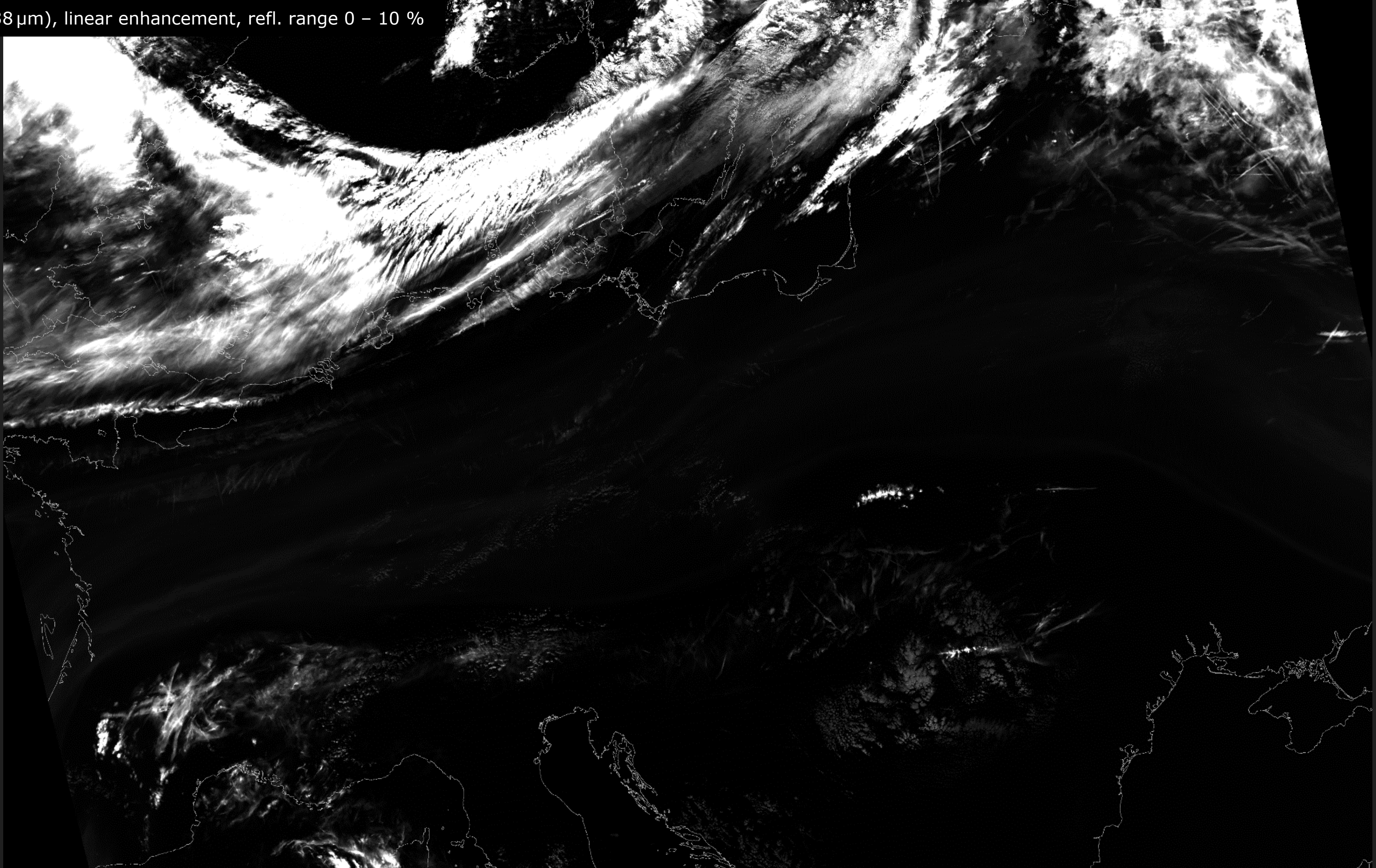
https://www.eumetsat.int/smoke-california-fires-above-europe-seen-noaa-20


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

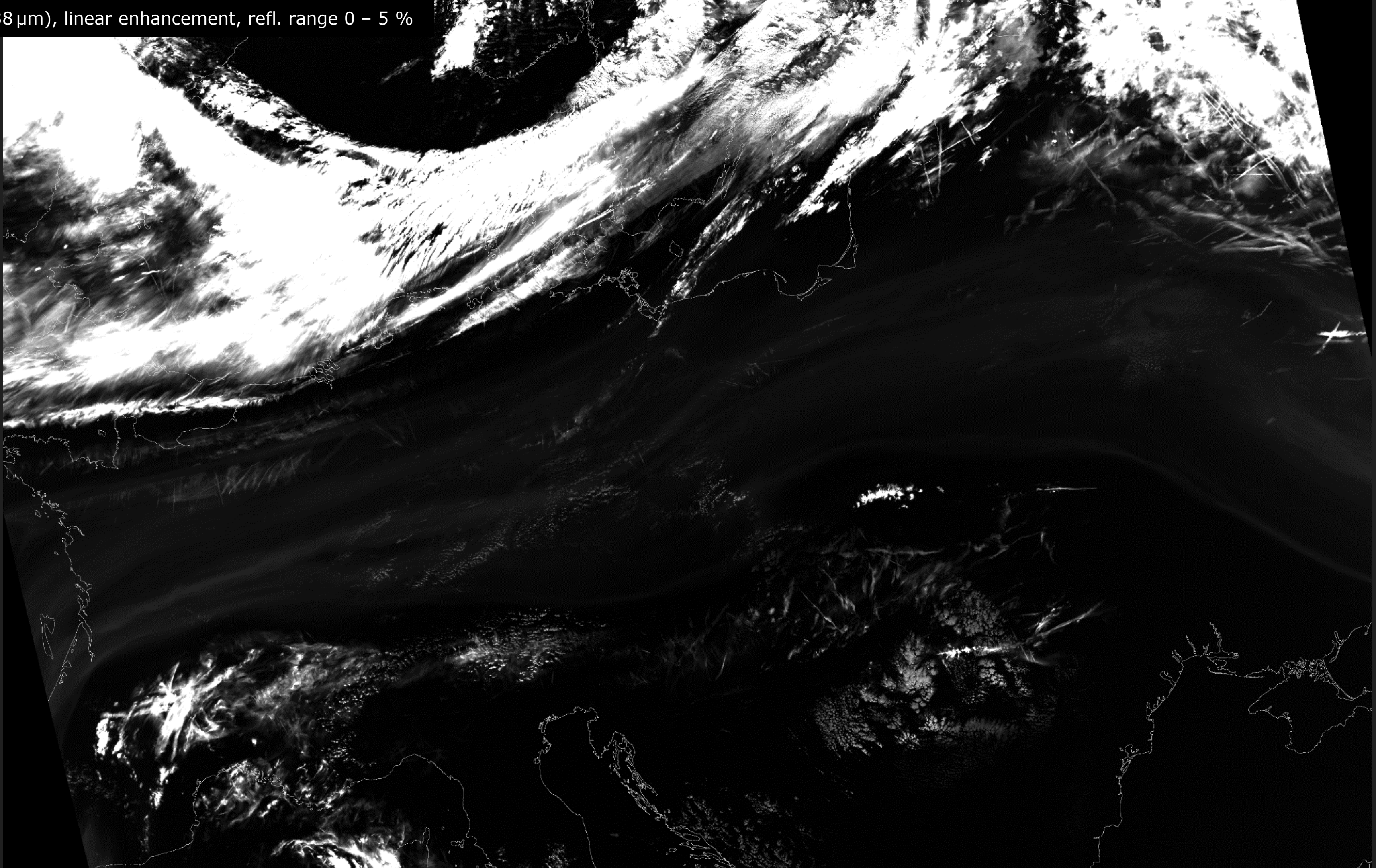
M9 (1.38 μm), linear enhancement, refl. range 0 – 50 %

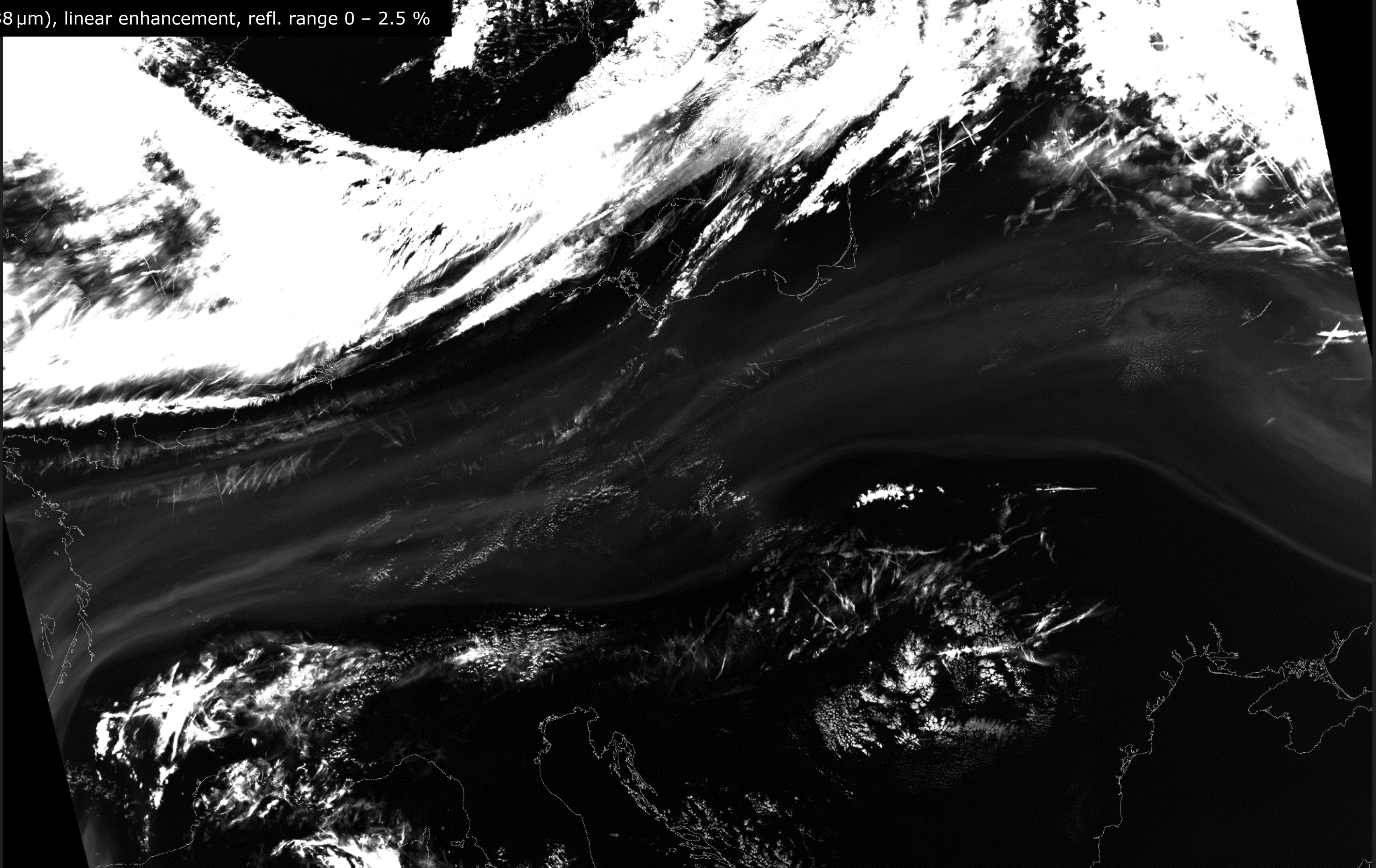


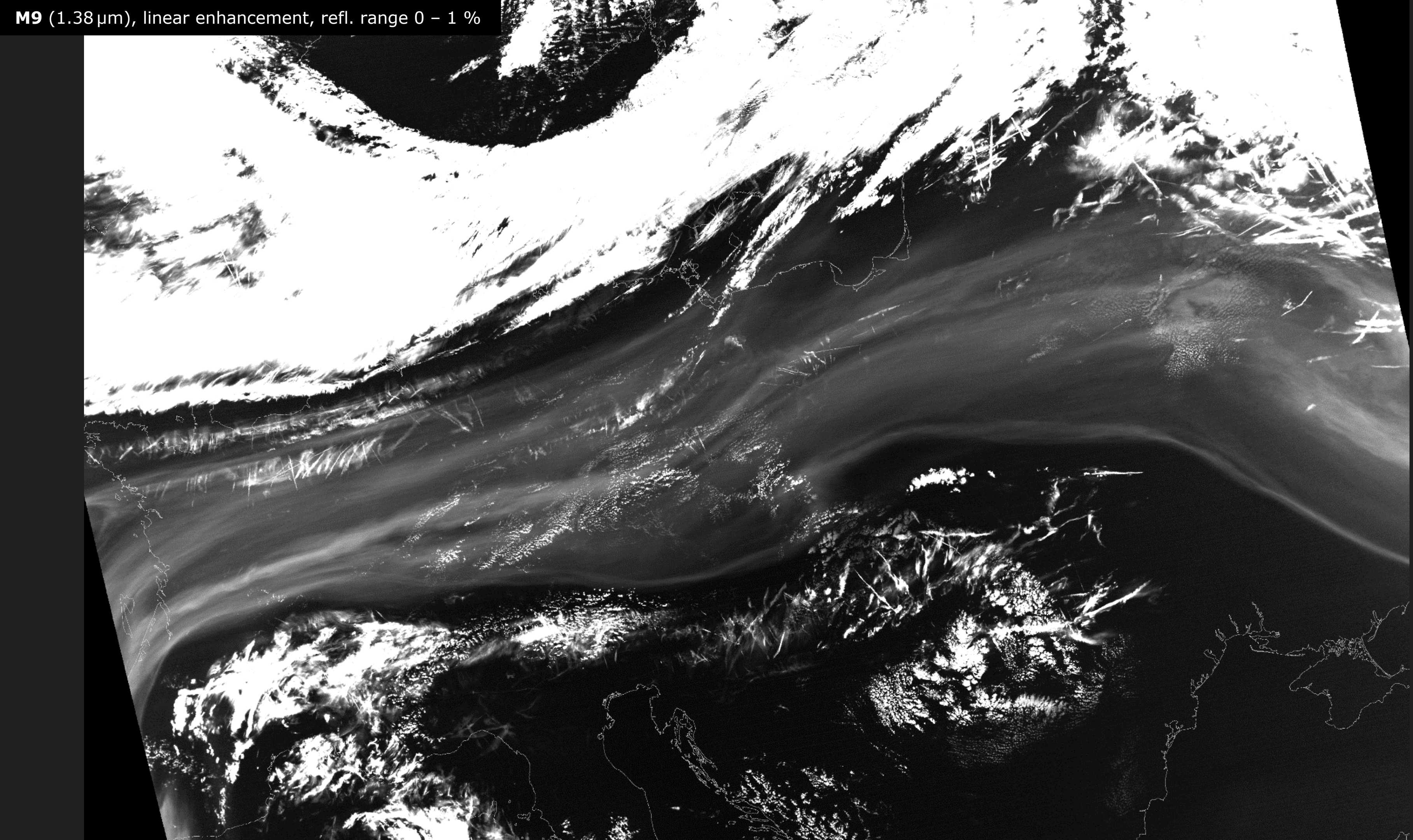
M9 (1.38 μm), linear enhancement, refl. range 0 – 10 %



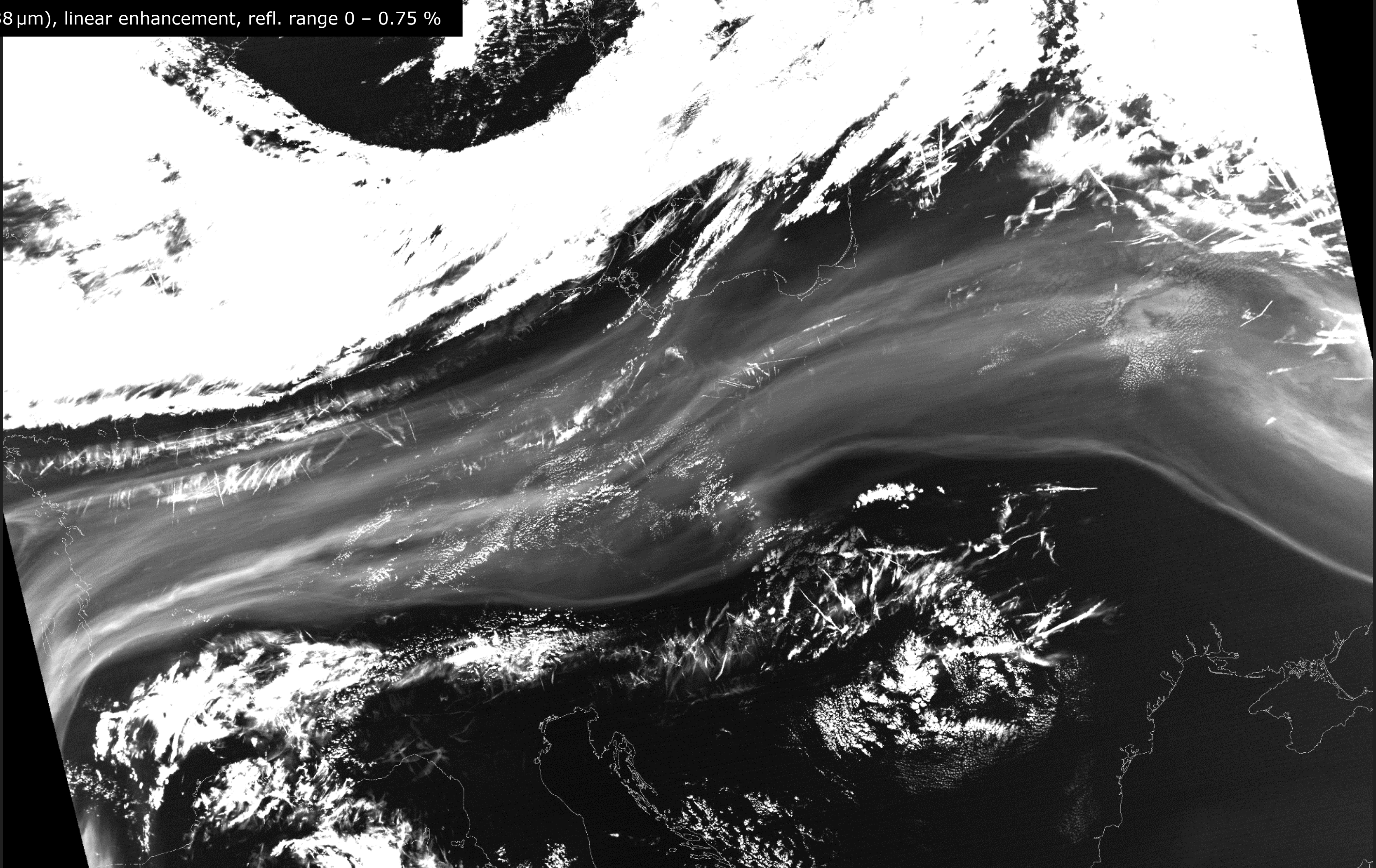
M9 (1.38 µm), linear enhancement, refl. range 0 – 5 %



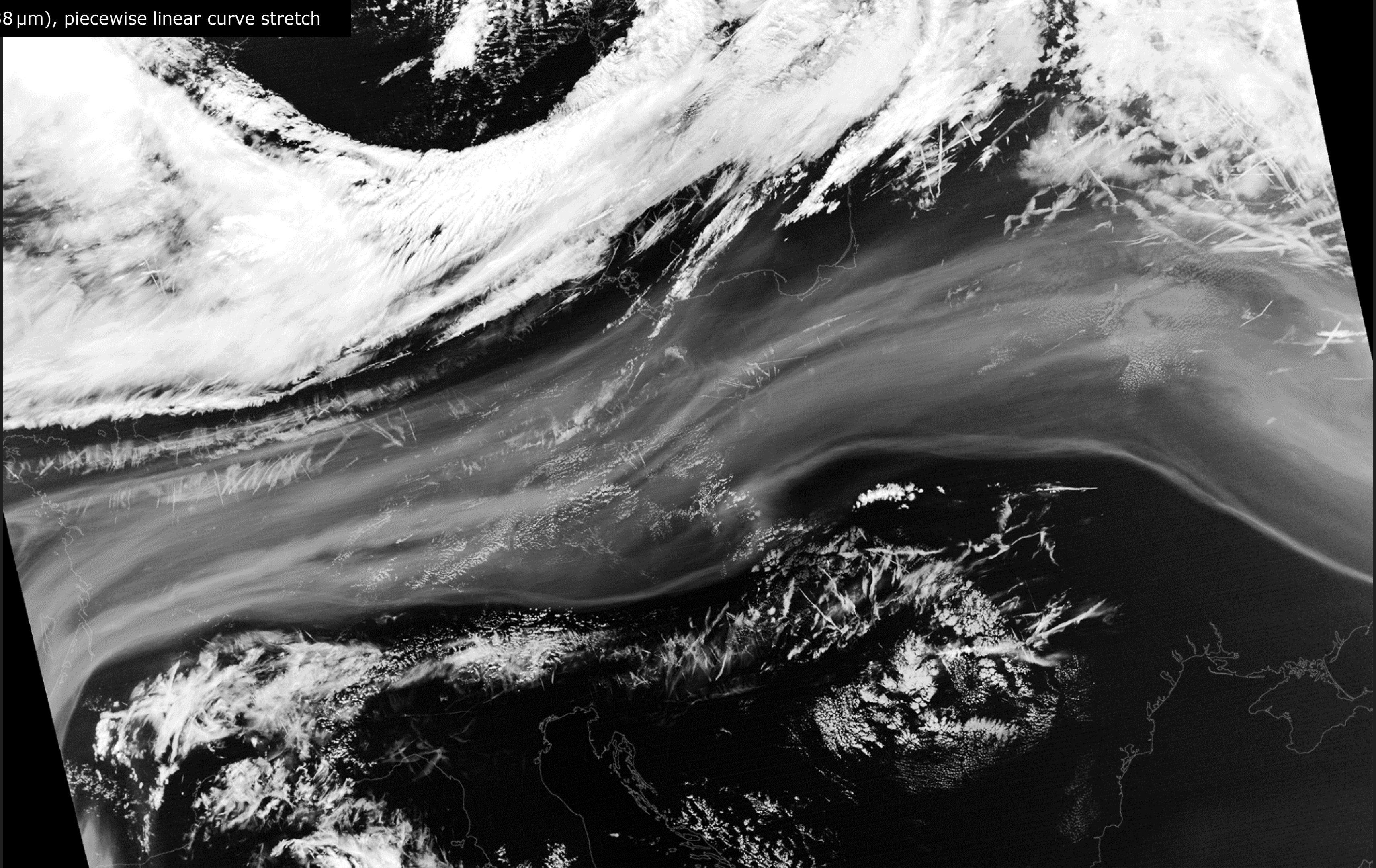

M9 (1.38 μm), linear enhancement, refl. range 0 – 2.5 %


M9 (1.38 μm), linear enhancement, refl. range 0 – 1 %

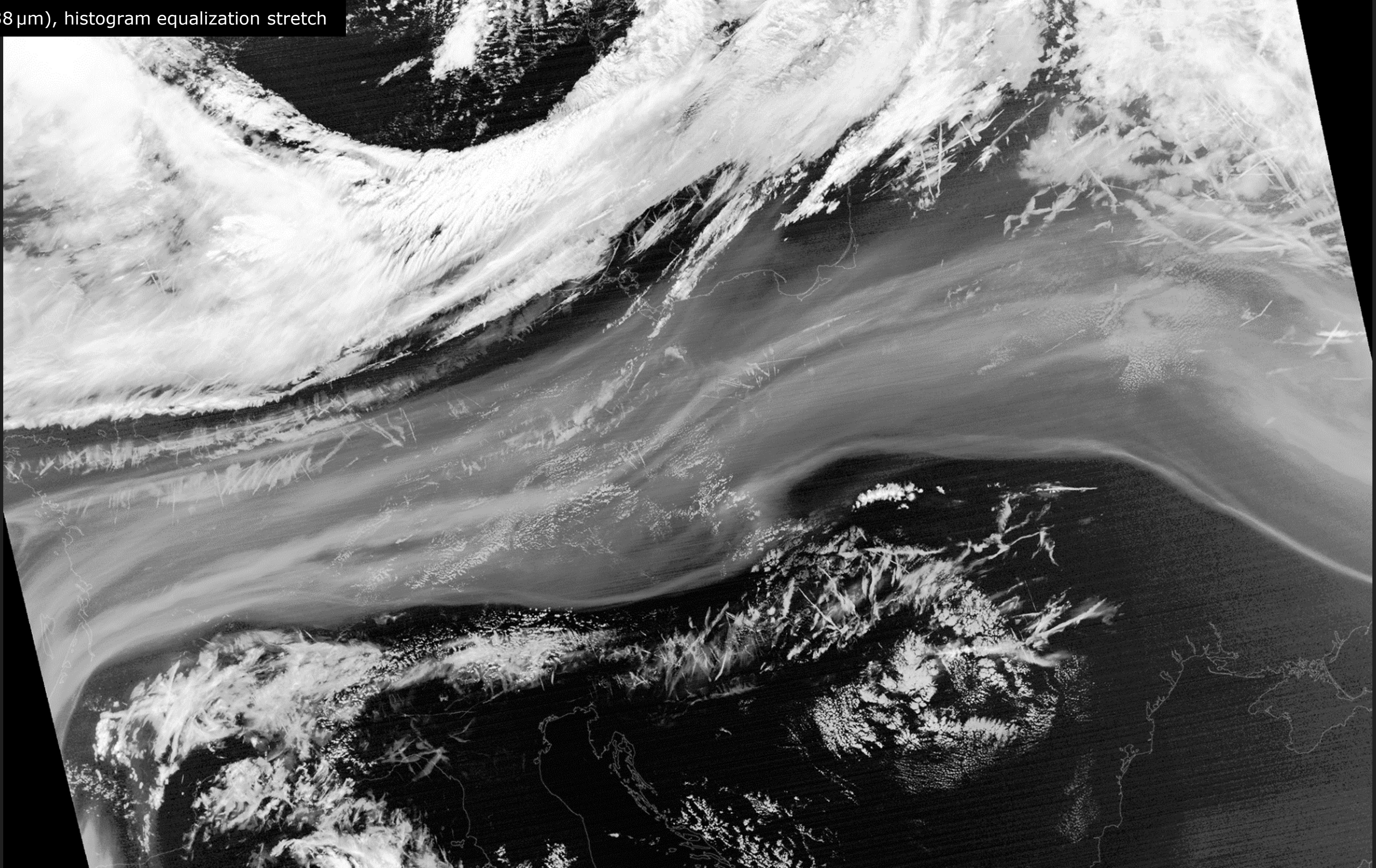
M9 (1.38 μm), linear enhancement, refl. range 0 – 0.75 %

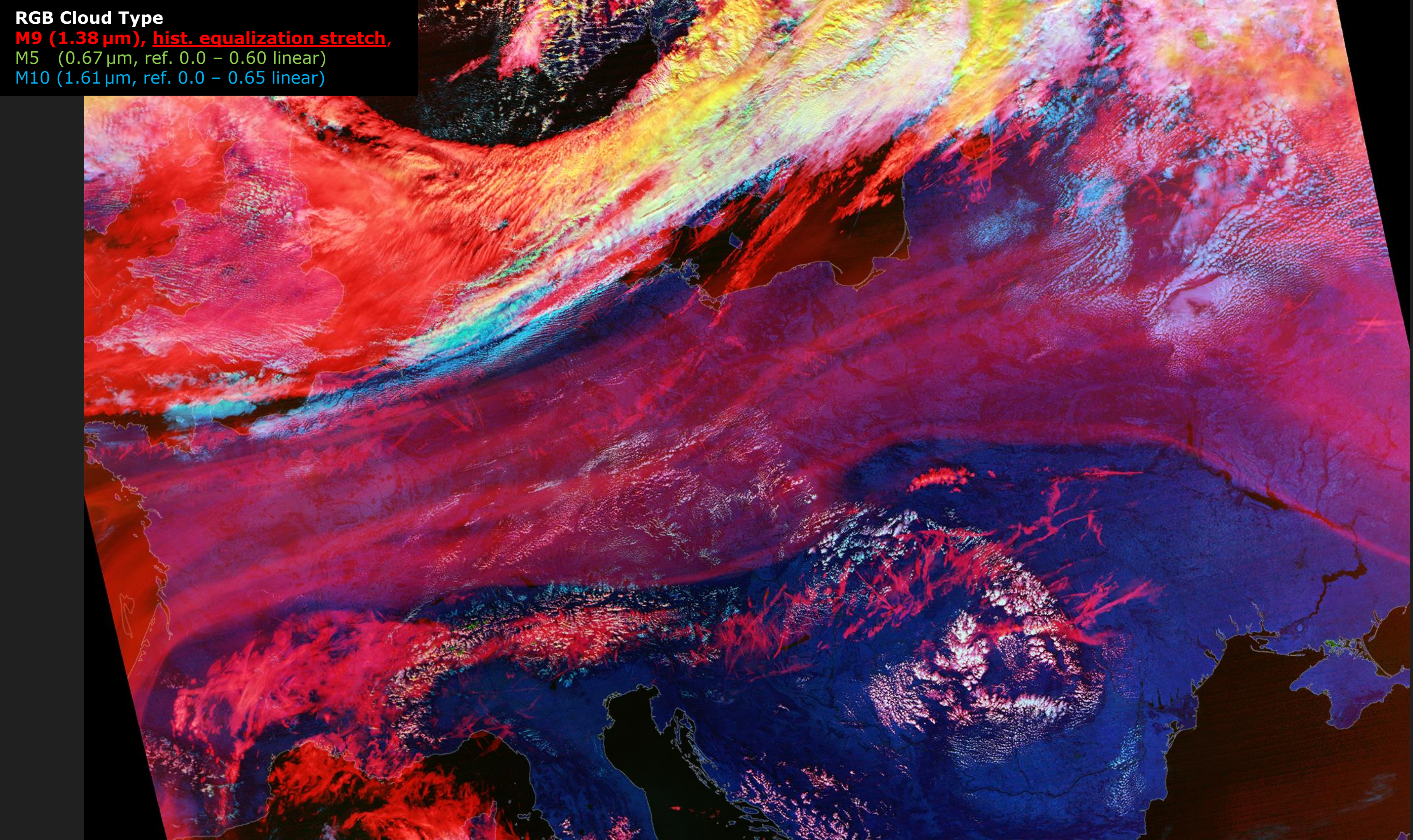


M9 (1.38 μm), piecewise linear curve stretch

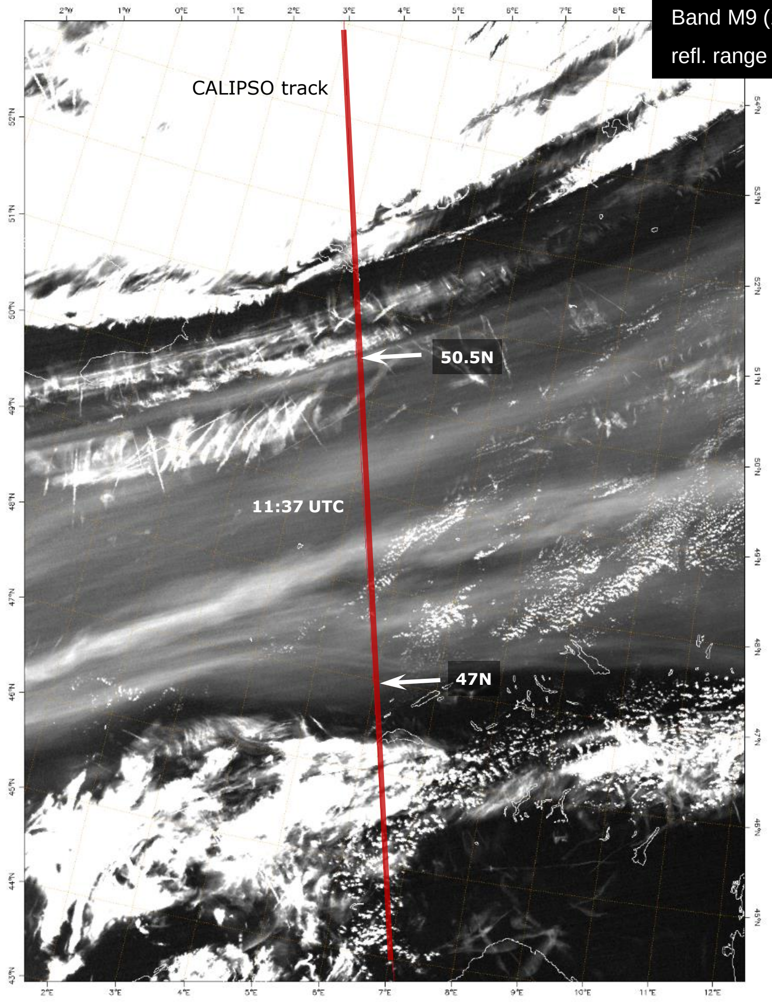


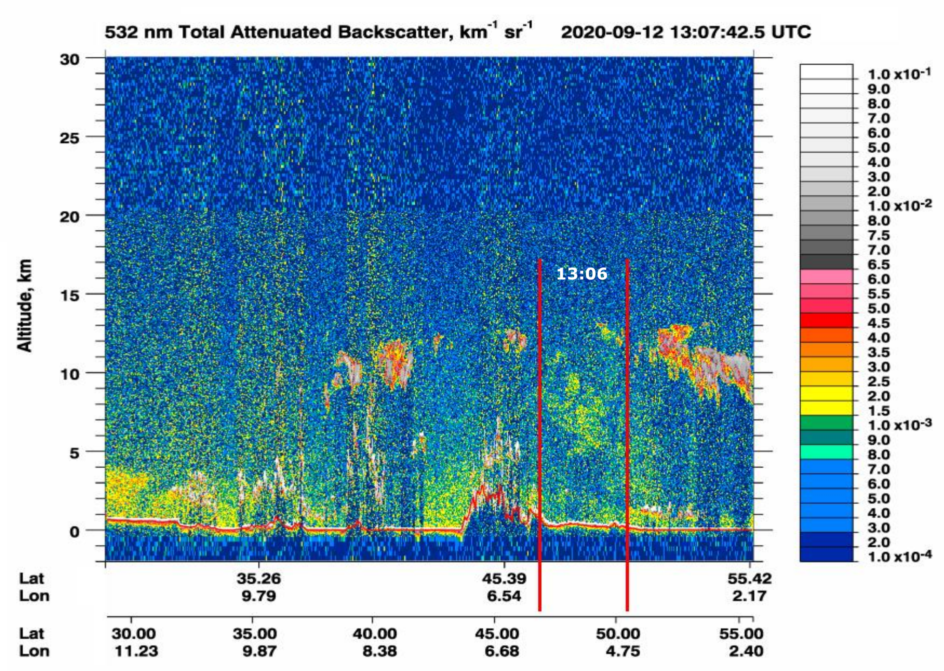
M9 (1.38 μm), histogram equalization stretch




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)

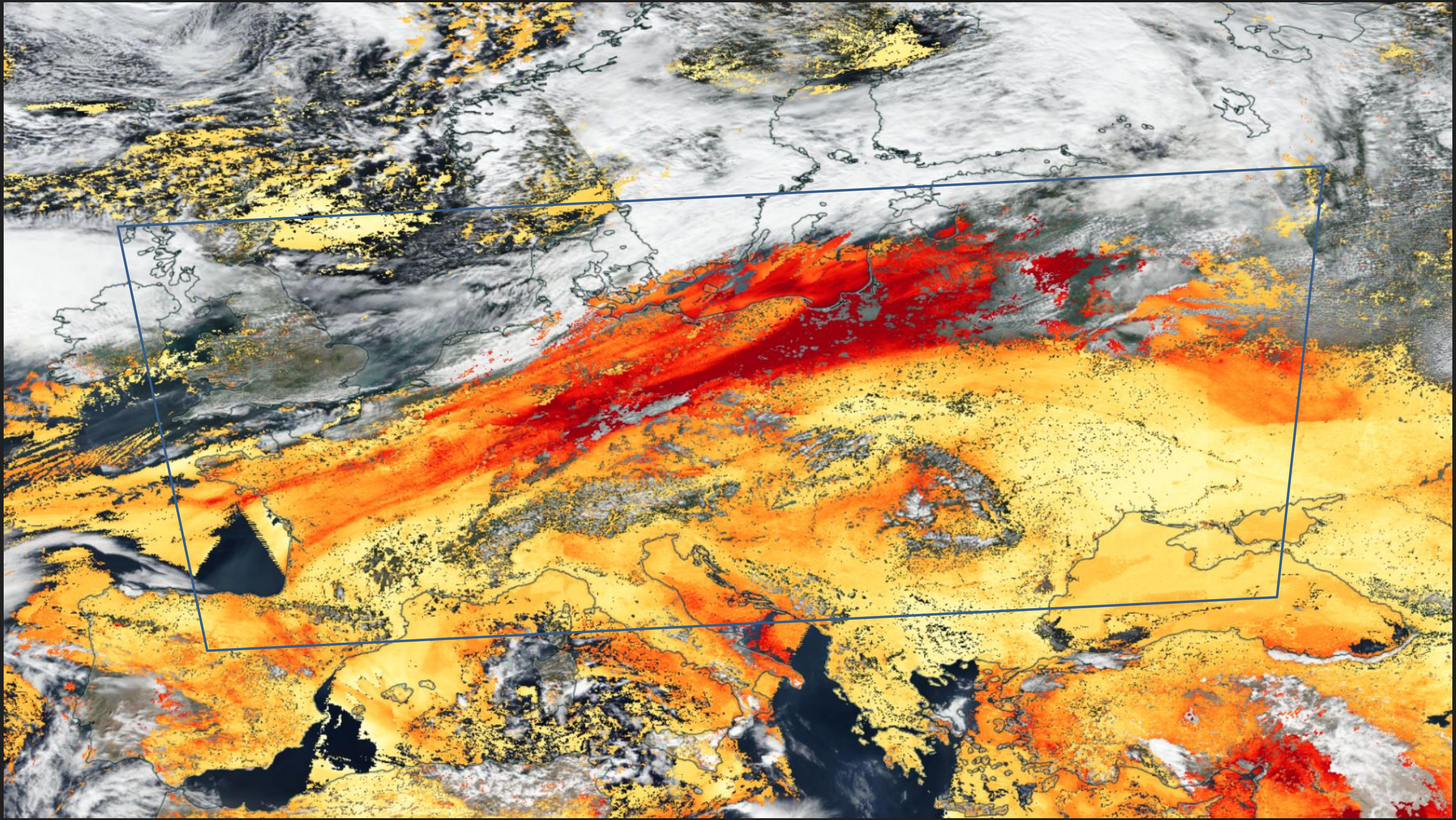
North and south limits of the aerosol belt





CALIPSO CALIOP 532 nm profile (source: NASA LARC, 2020-09-12)

Presence of aerosols can be clearly seen here, between the two vertical bars (at 47N and 50.5N), at ~ 5 – 10 km levels.



MAIAC Aerosol Optical Thickness (MCD19A2N), MODIS Terra/Aqua, source: EOS Worldview (doi: 10.5067/MODIS/MCD19A2N.NRT.006).

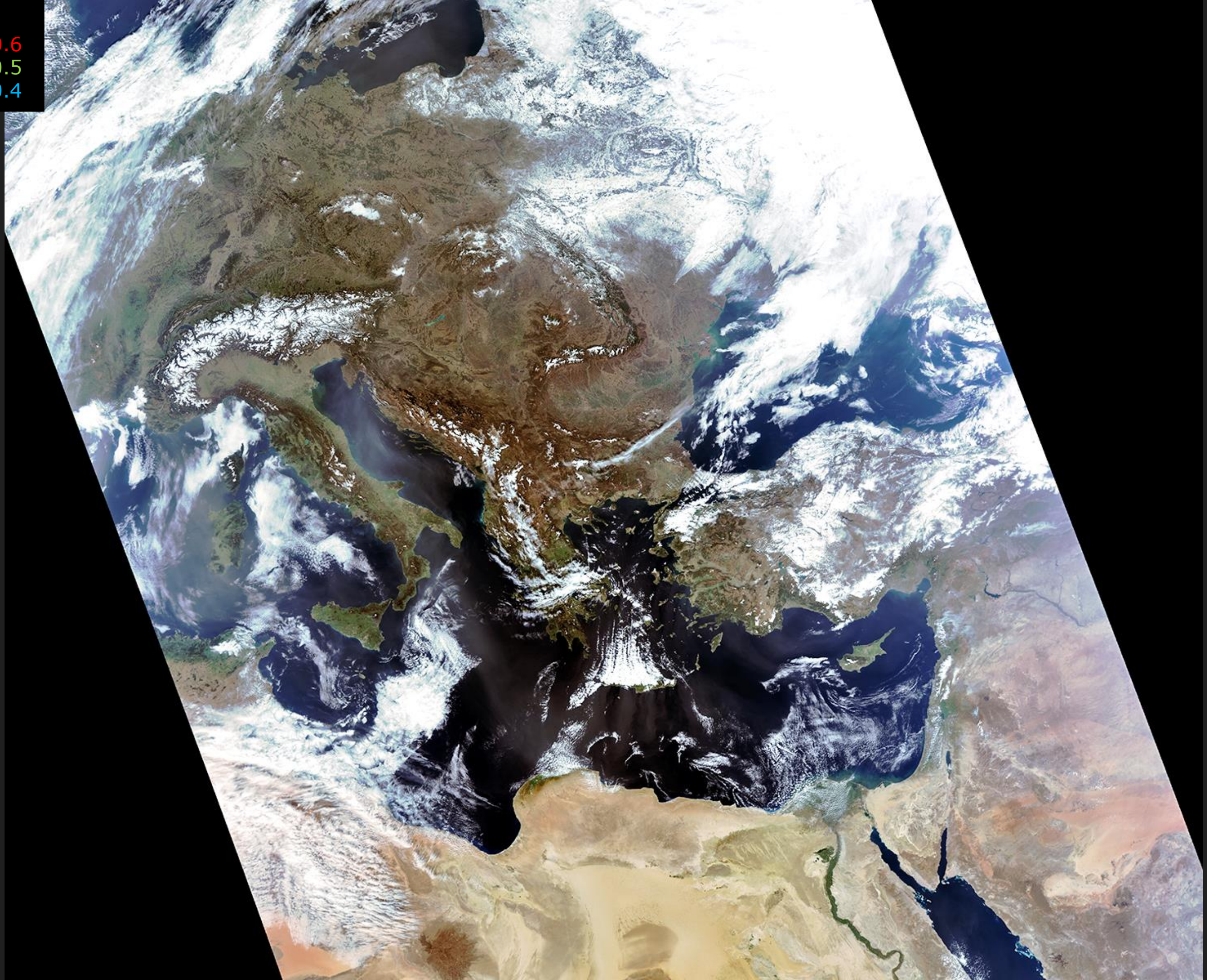
The quadrangle indicates approximate area of the VIIRS images in previous slides.

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

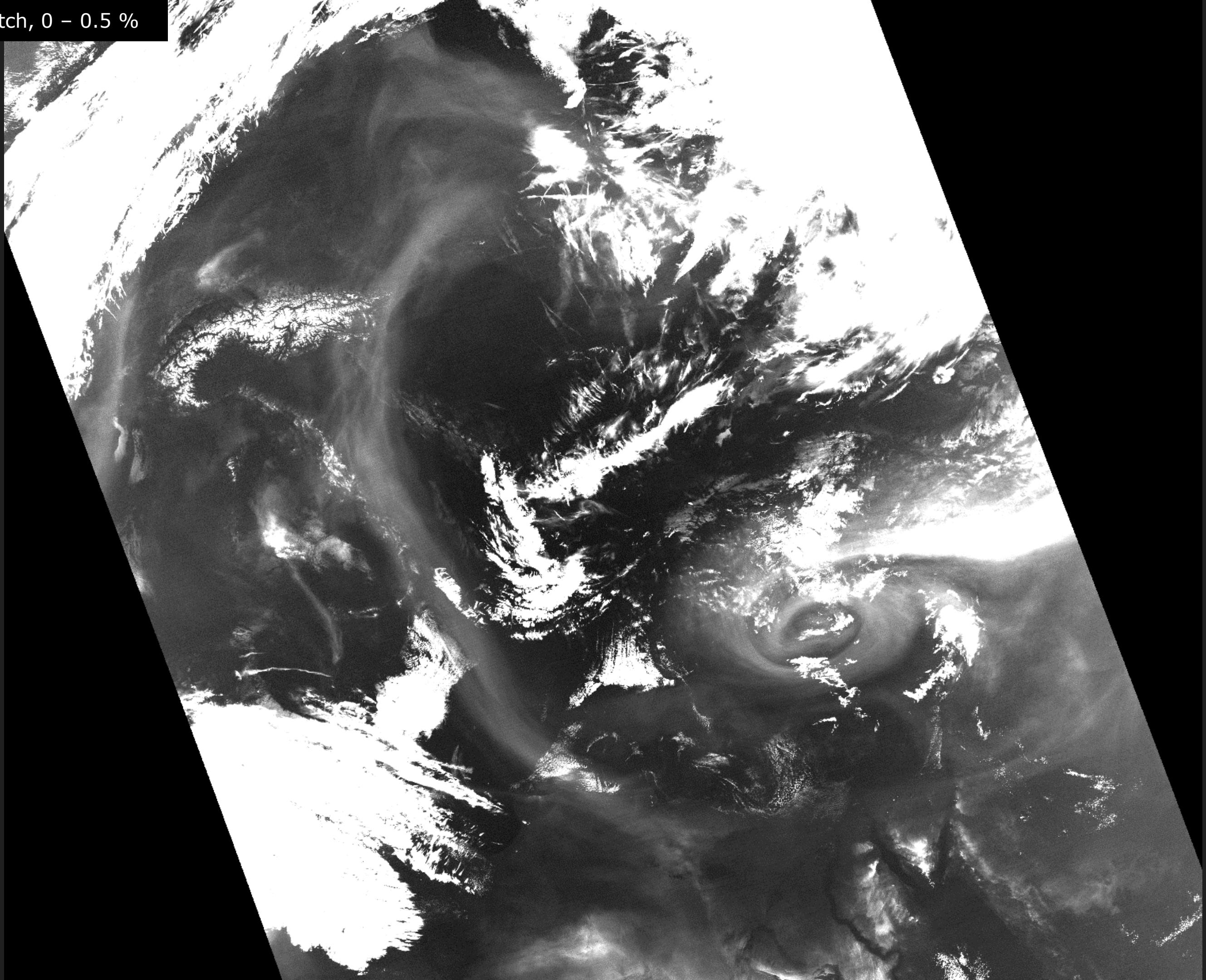
Aerosol band above Europe and northeast Africa

RGB True Color

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



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

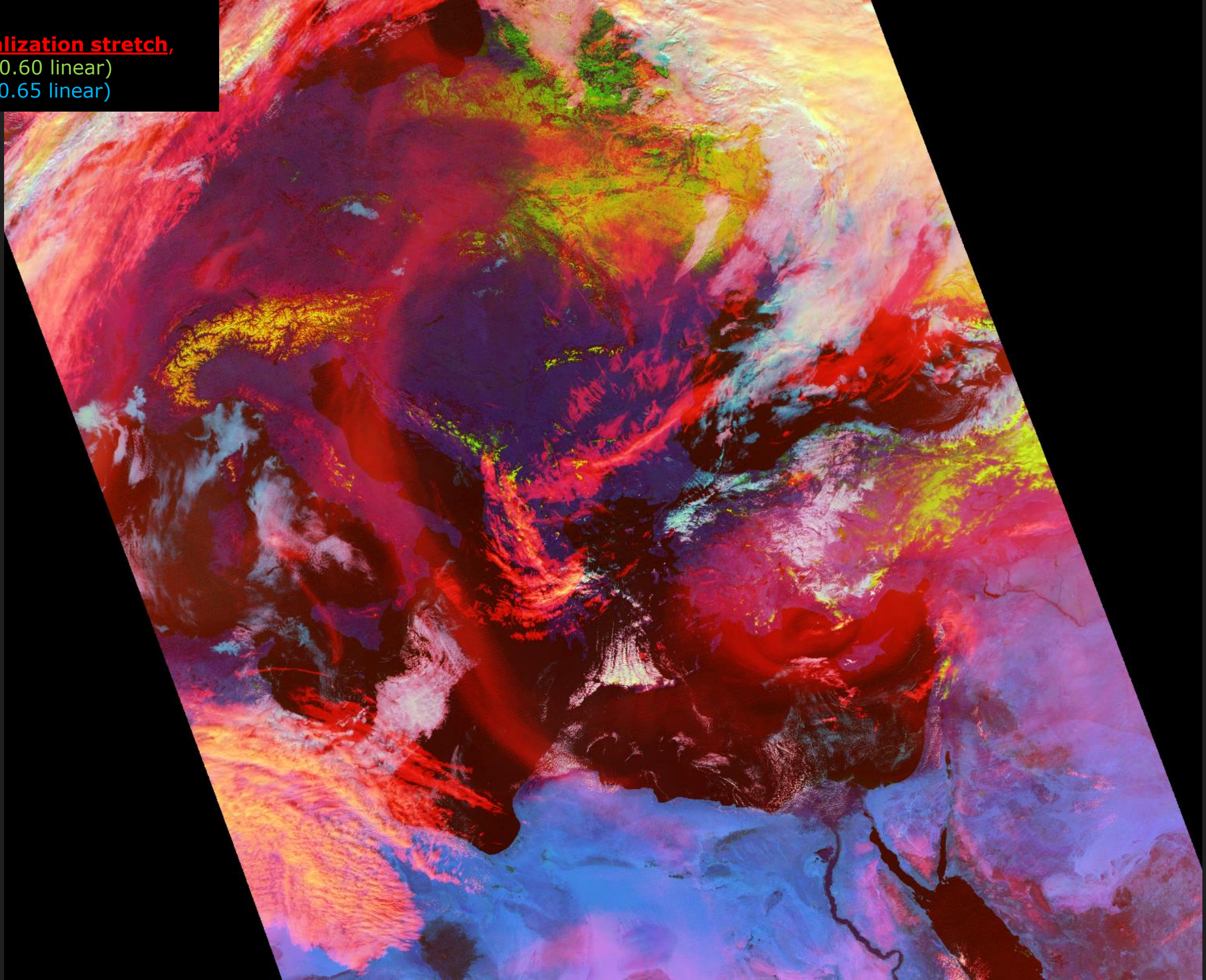


RGB Cloud Type

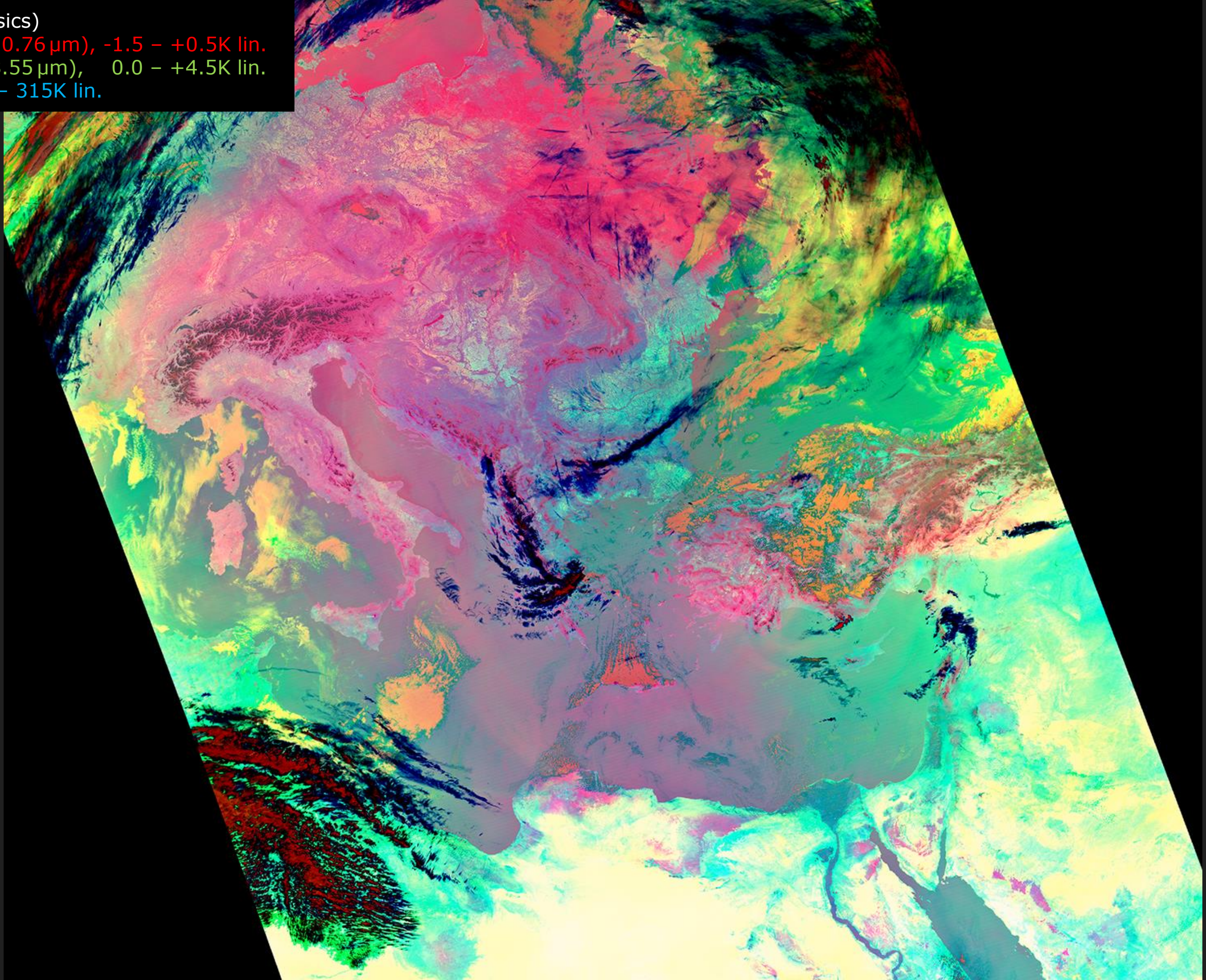
M9 (1.38 µm), **hist. equalization stretch**,

M5 (0.67 µm, ref. 0.0 – 0.60 linear)

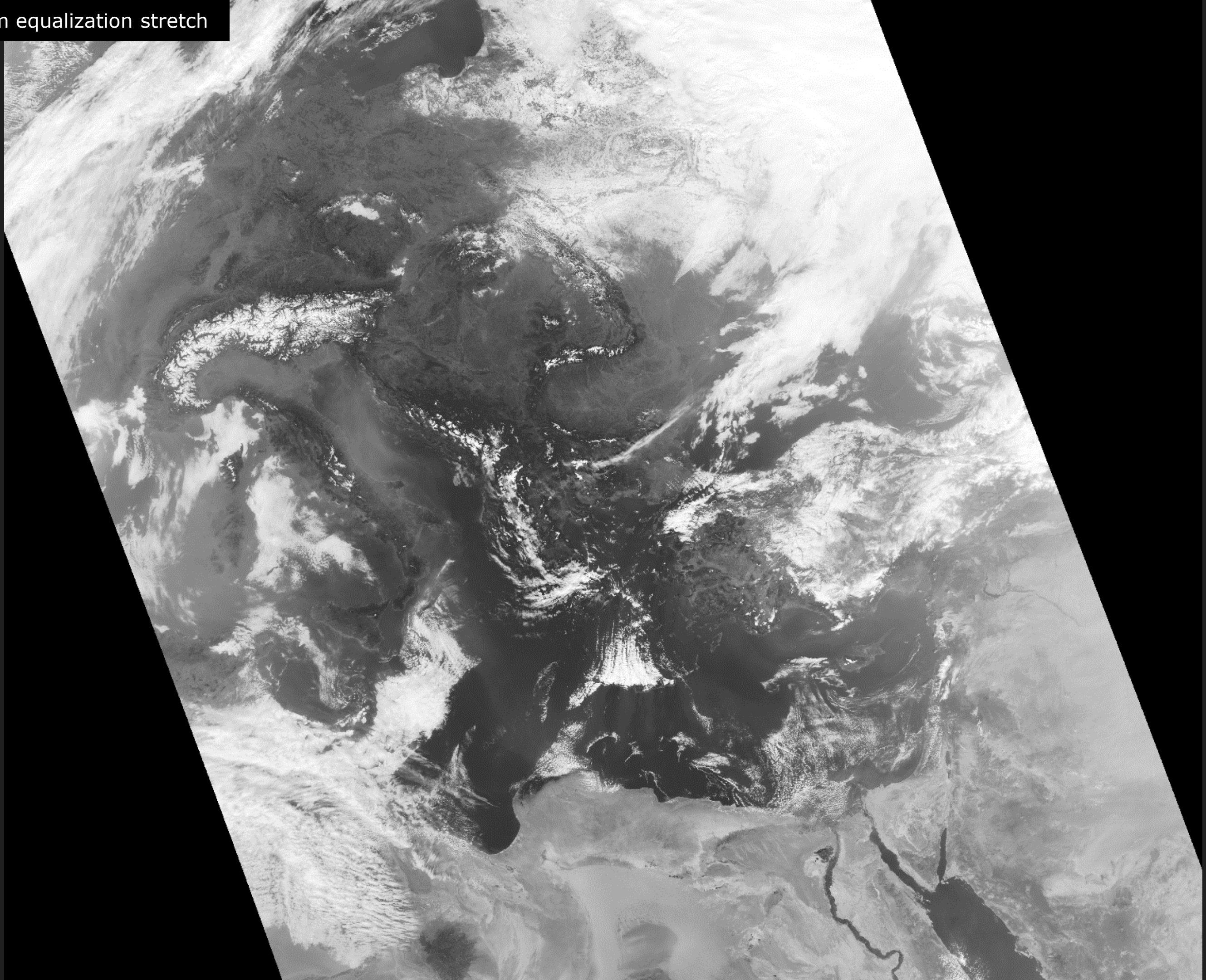
M10 (1.61 µm, ref. 0.0 – 0.65 linear)



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



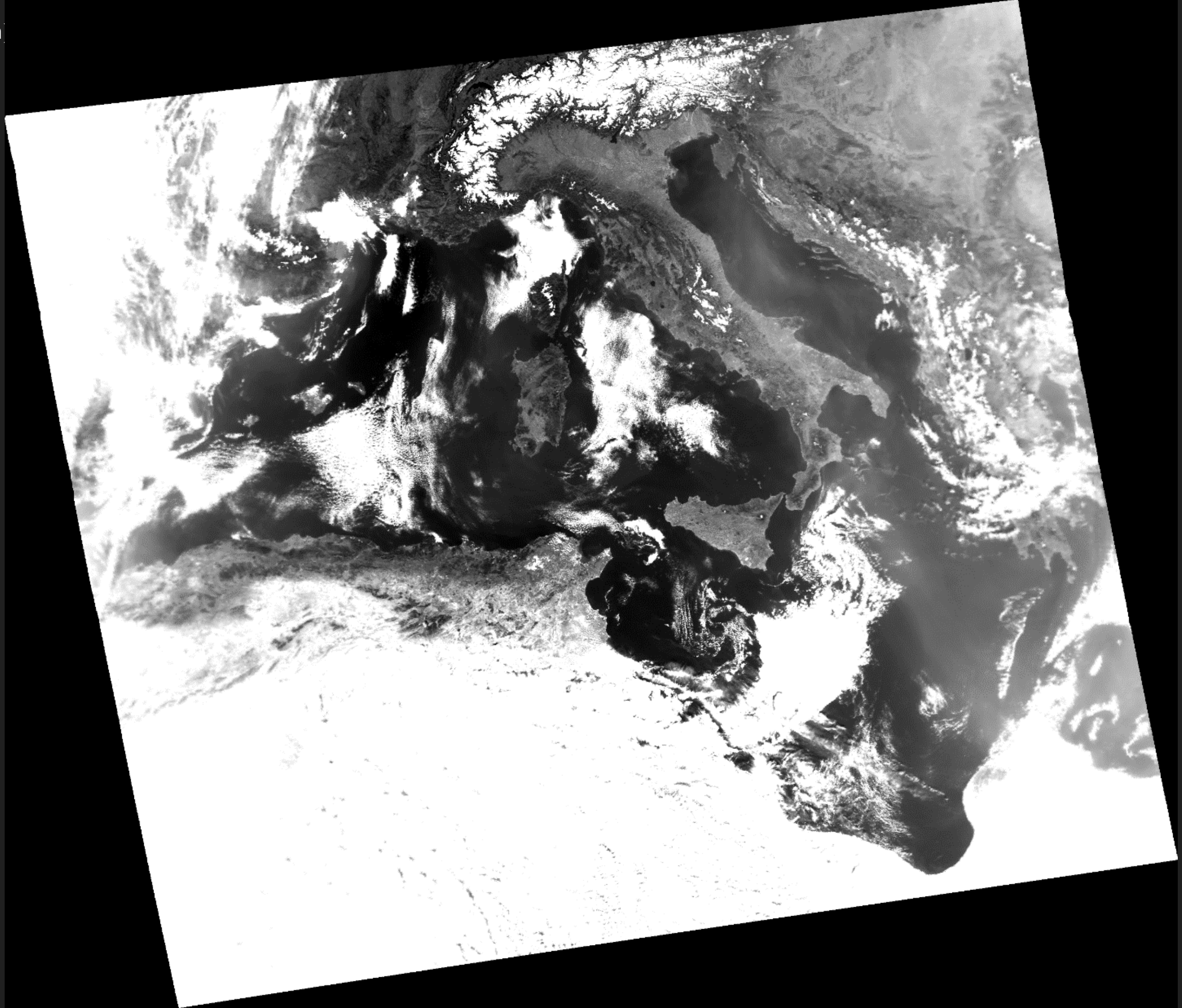
M9 (1.38 μm), histogram equalization stretch

The same case, as seen at 12:25 UTC by Aqua in MODIS 1km bands

and in CALIOP vertical profile

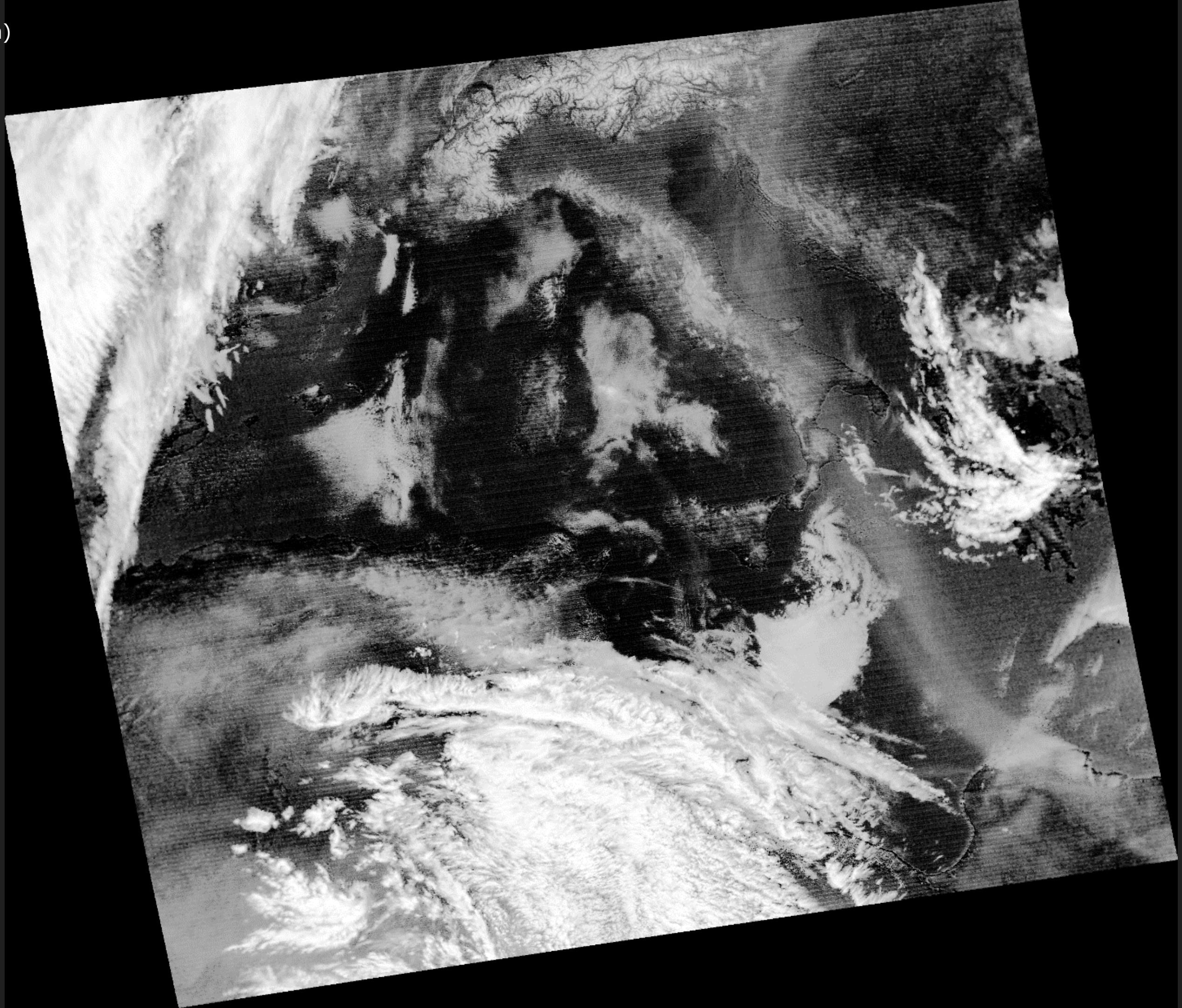
MODIS Band 12 (0.551 µm)

linear enhancement



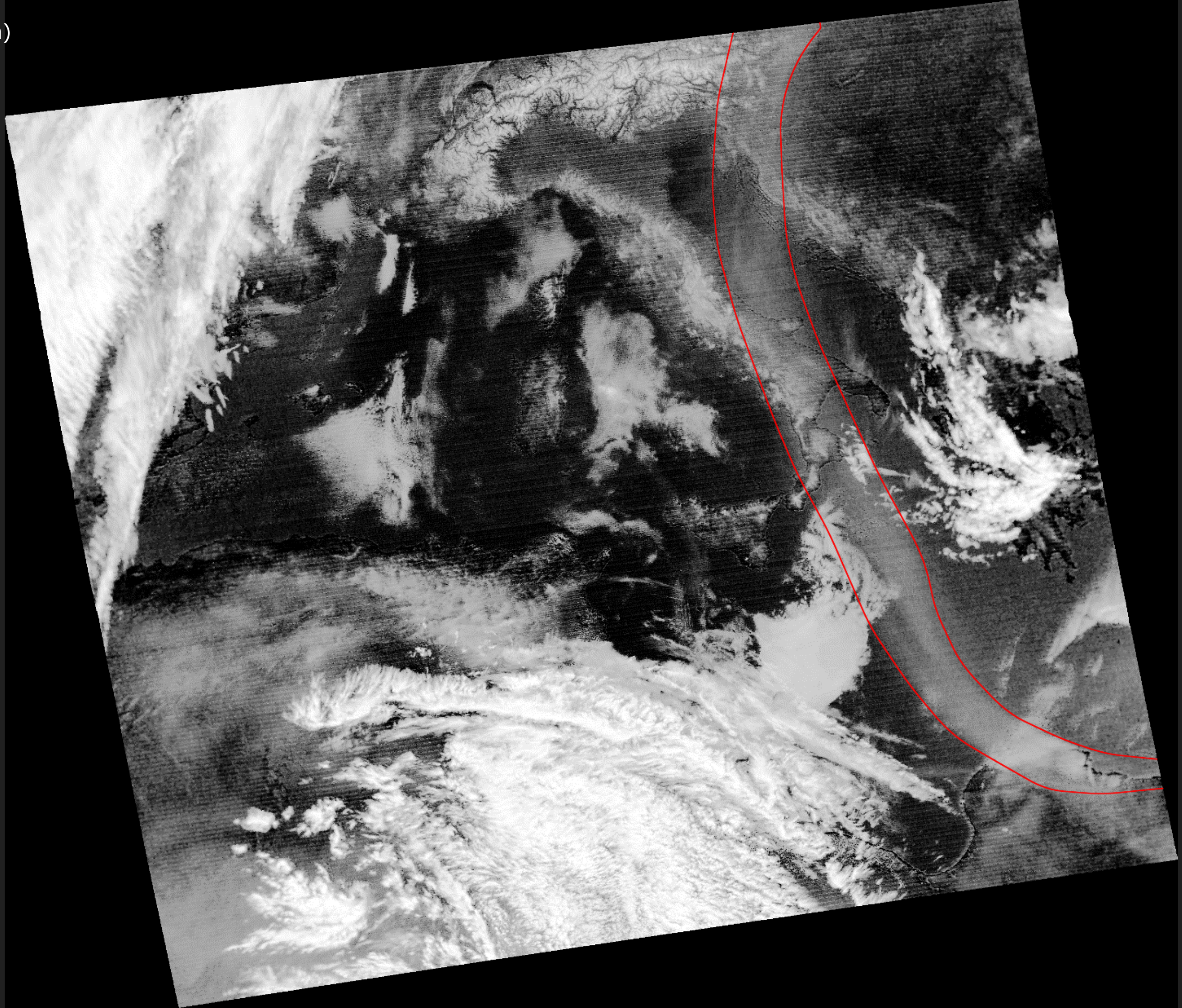
MODIS Band 26 (1.375 μm)

histogram equalization
(based on full image)

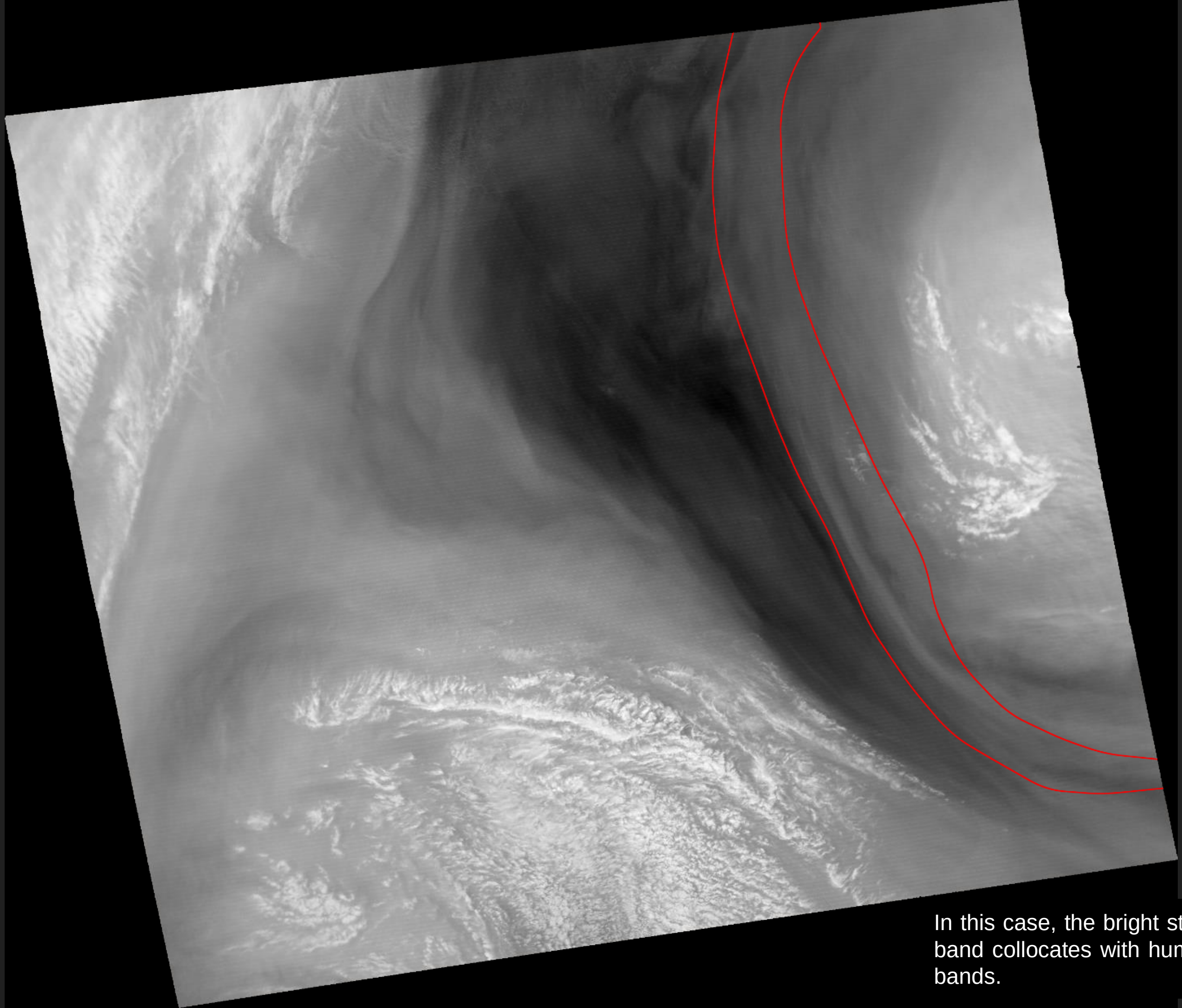


MODIS Band 26 (1.375 μm)

histogram equalization
(based on full image)

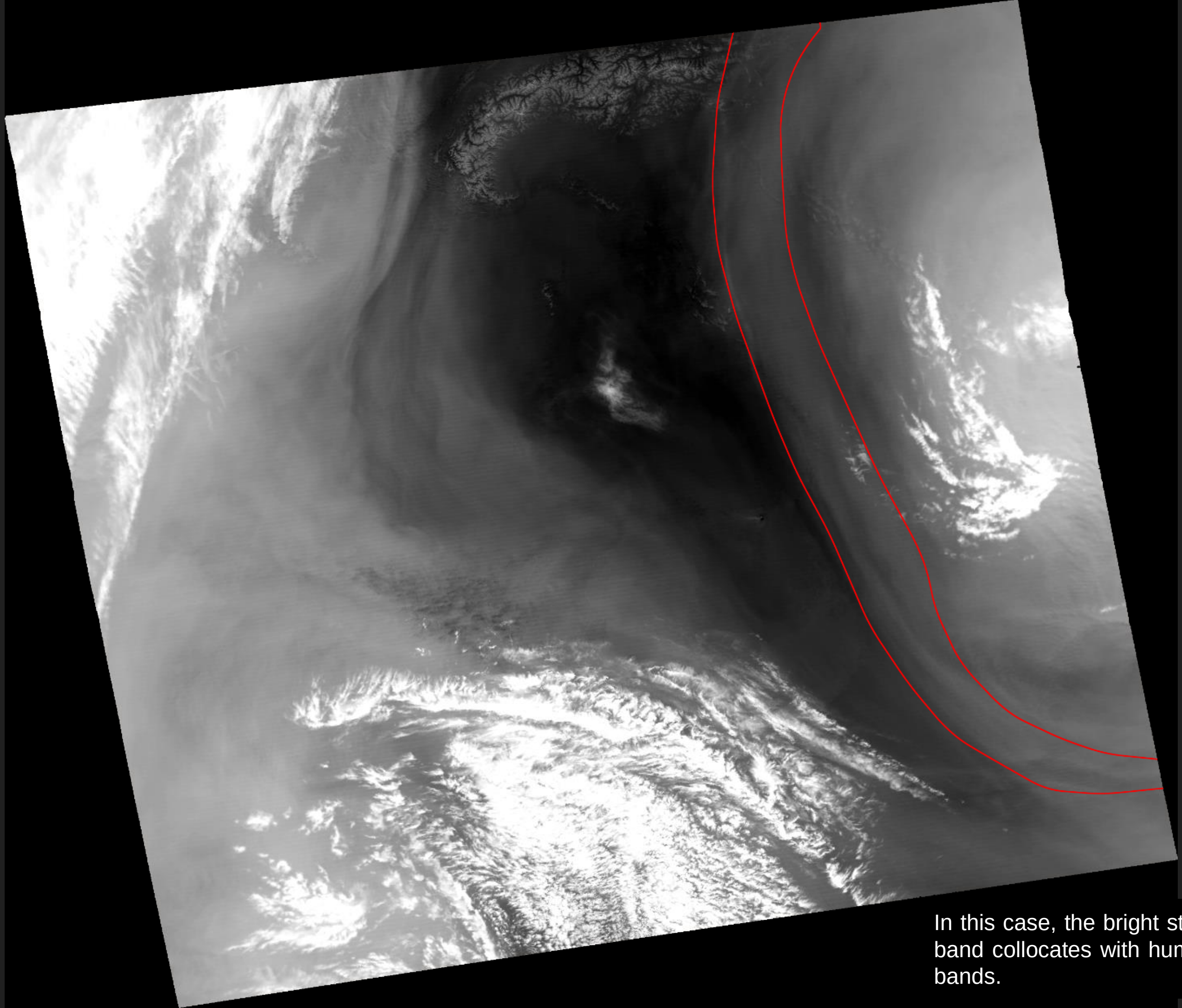


MODIS Band 27 (6.72 μm)



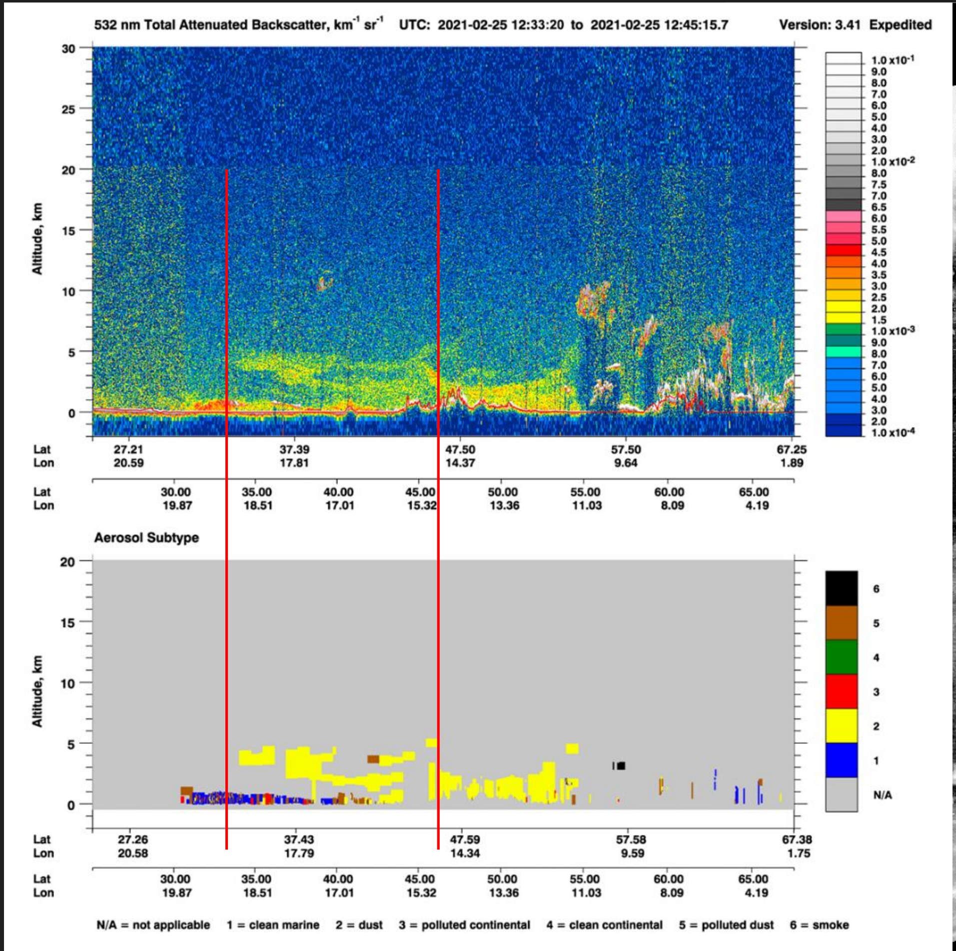
In this case, the bright streak in the VIIRS 1.38 μm band collocates with humid belt in WV 6.2 and 7.3 bands.

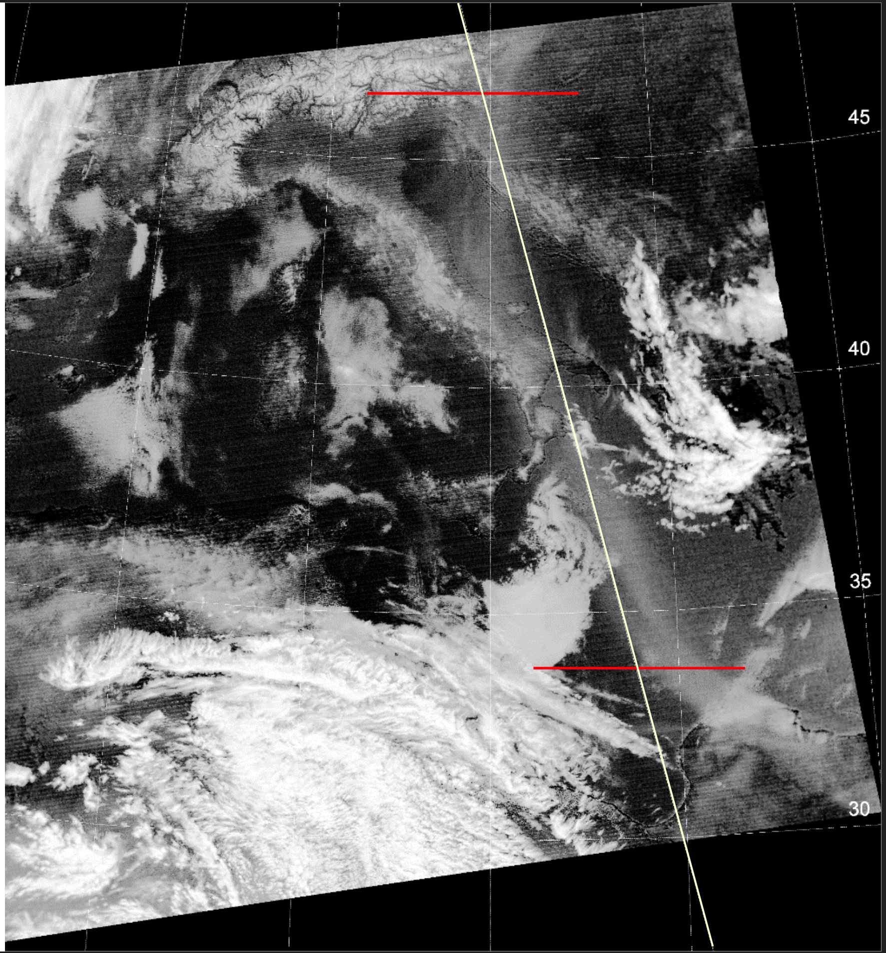
MODIS Band 28 (7.33 μm)



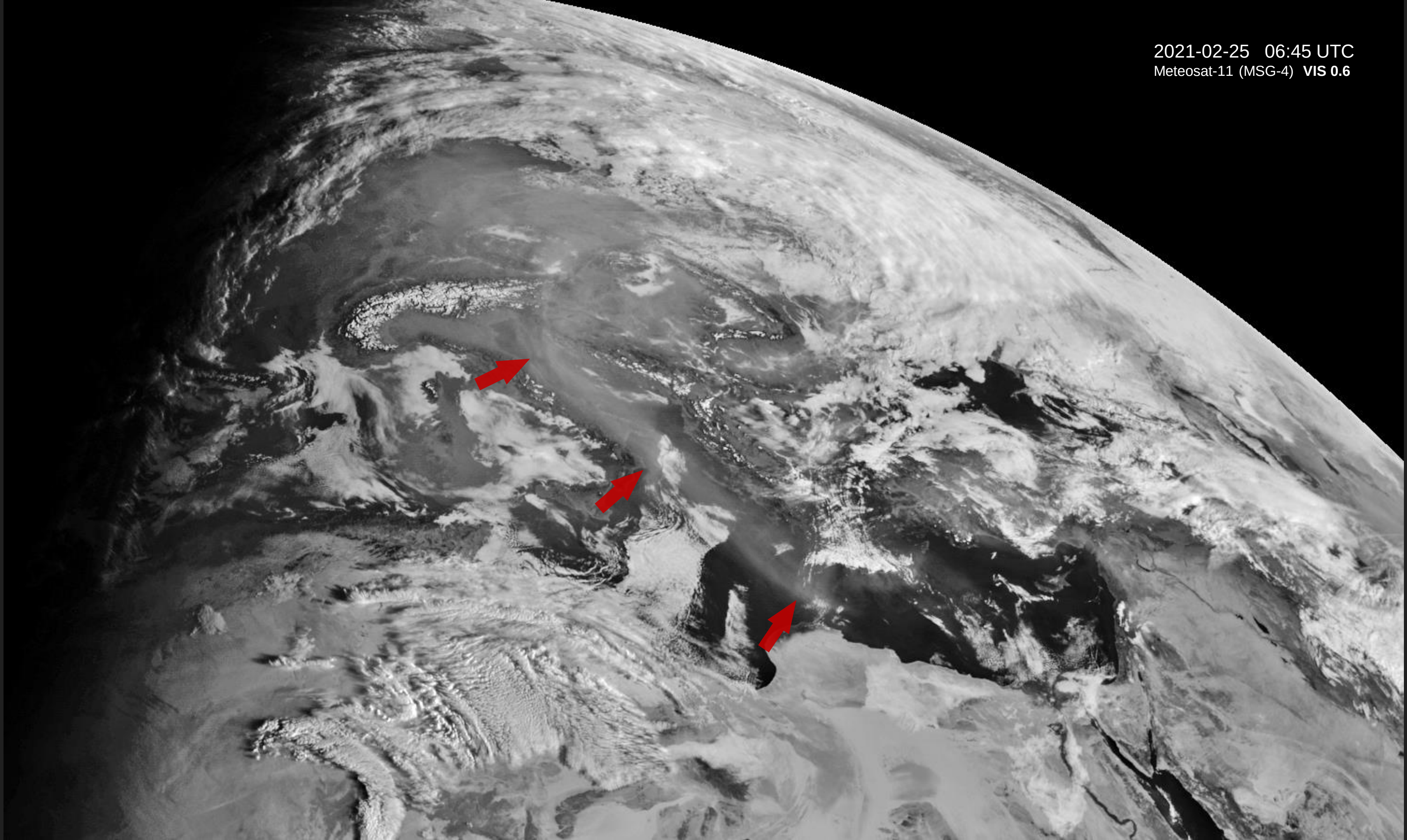
In this case, the bright streak in the VIIRS 1.38 μm band collocates with humid belt in WV 6.2 and 7.3 bands.

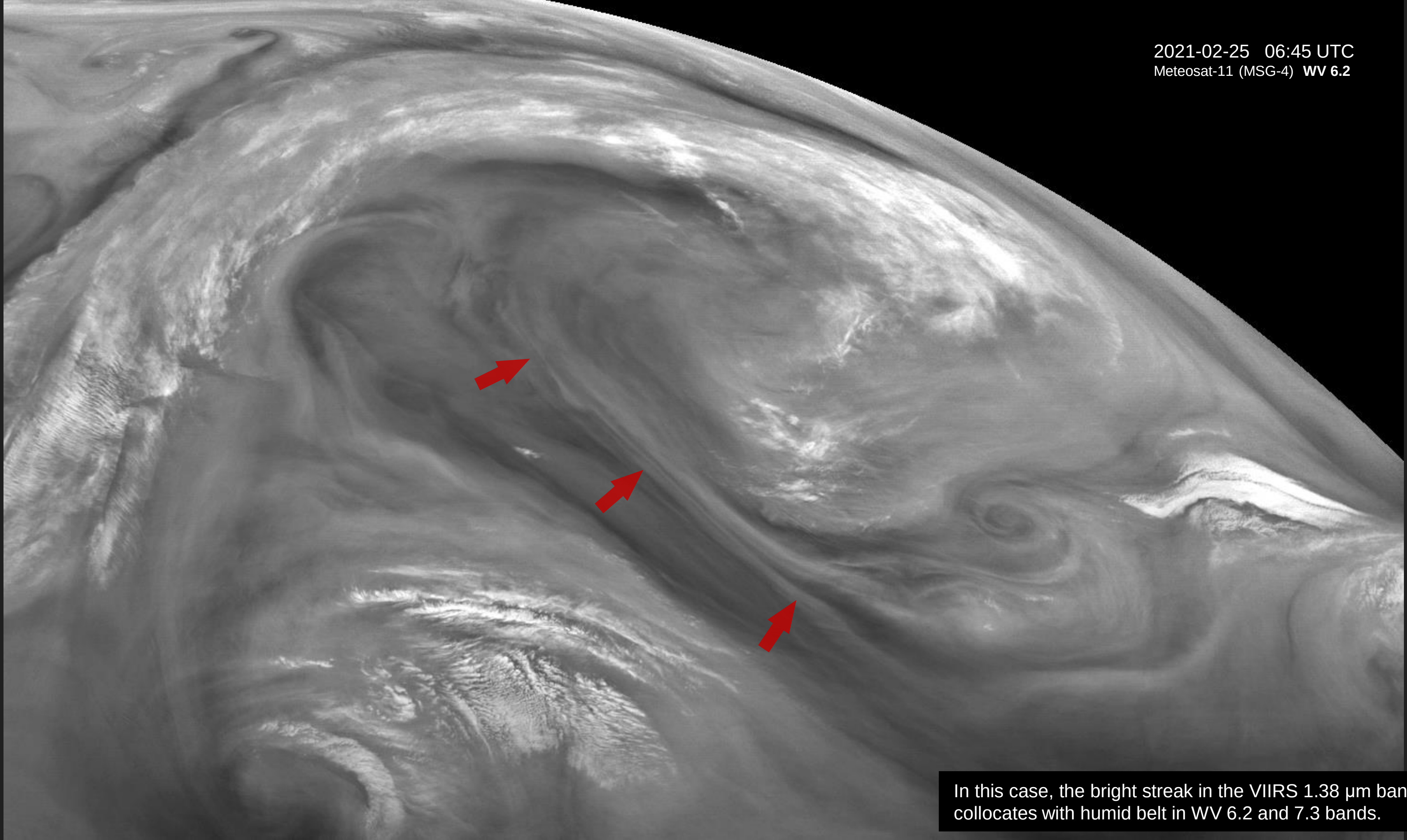
MODIS Band 26 (1.375 μm) and CALIPSO/CALIOP track and profile





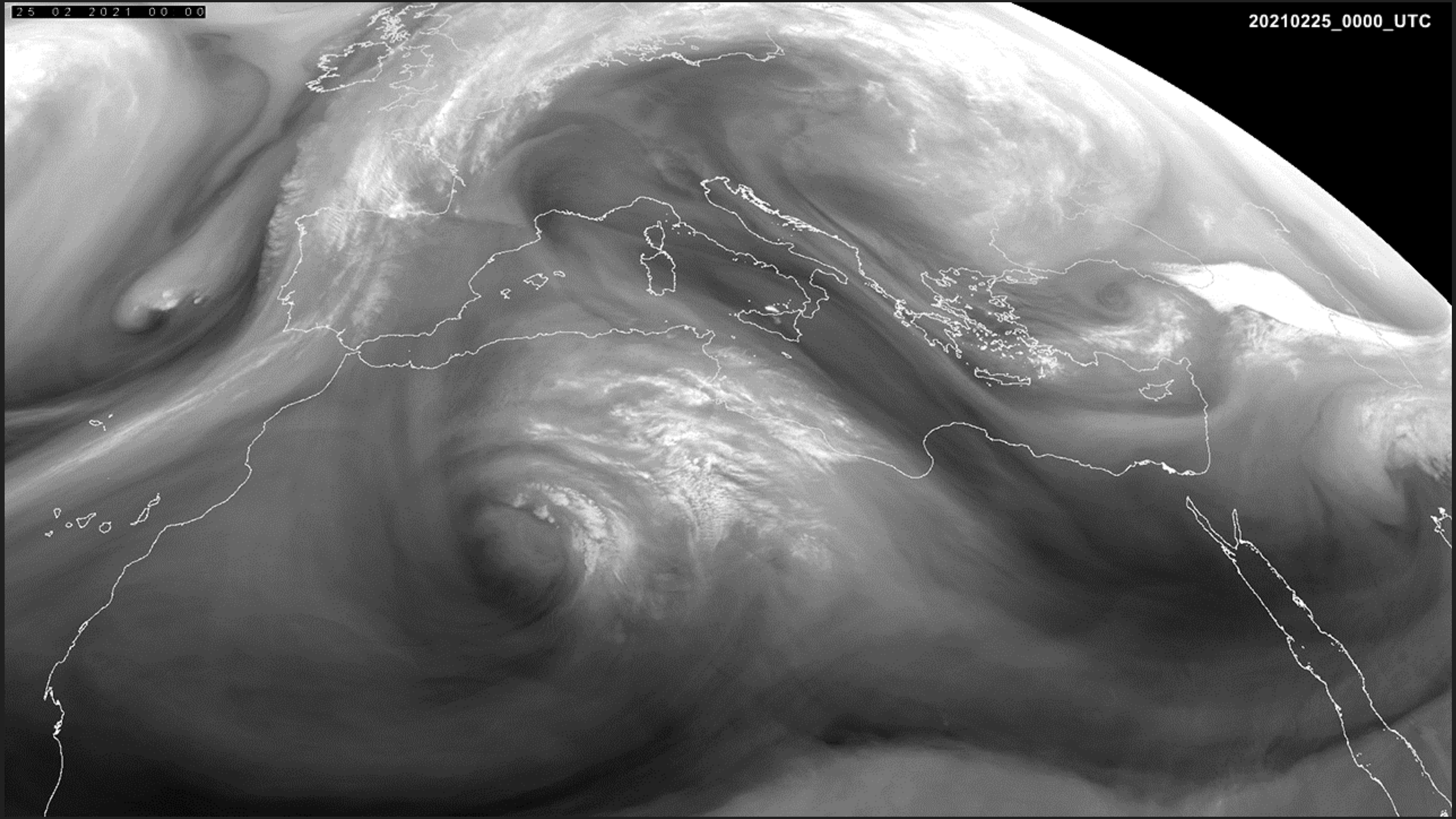
And the same case, as seen by MSG satellites ...

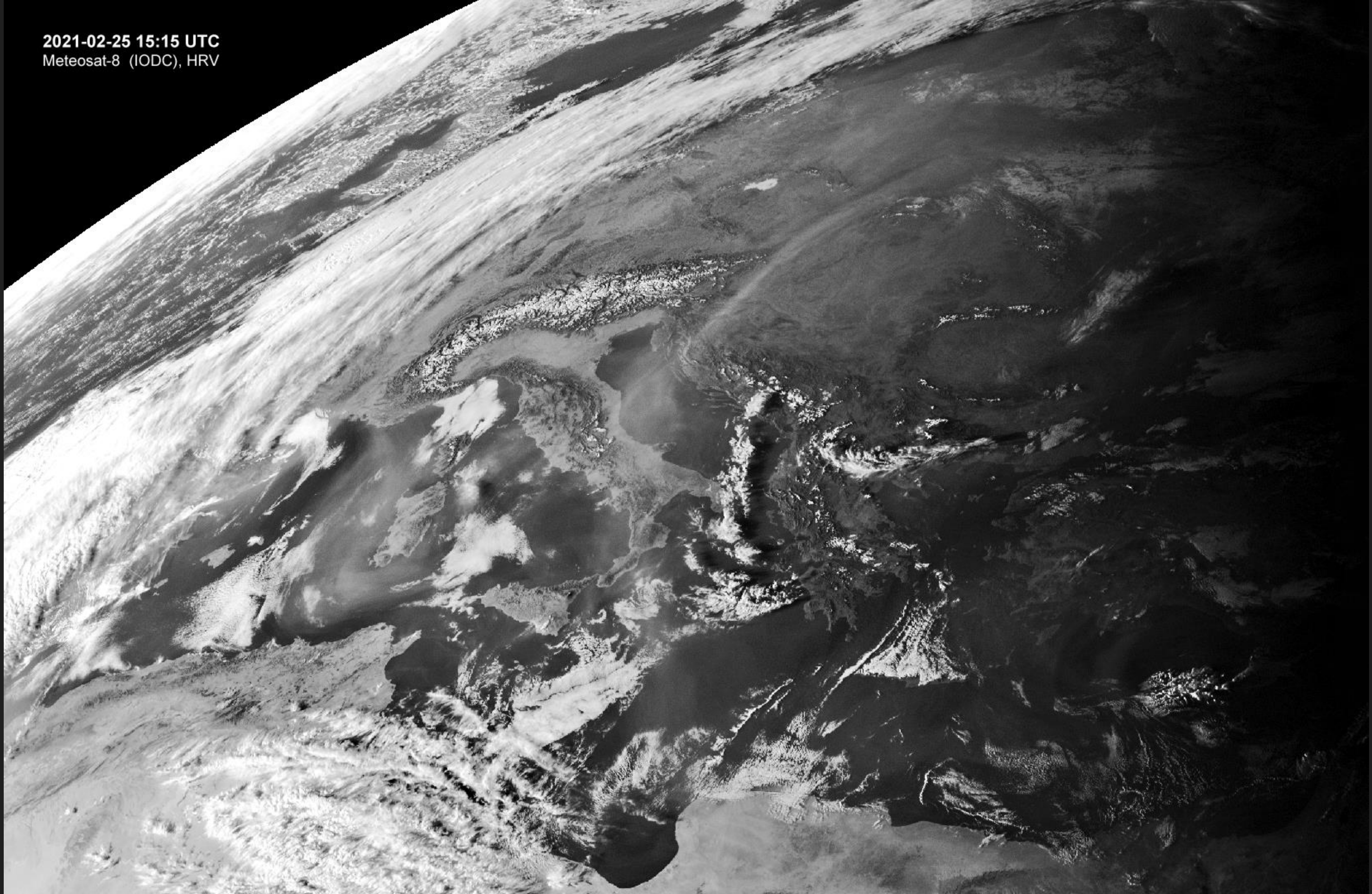

2021-02-25 06:45 UTC
Meteosat-11 (MSG-4) VIS 0.6



In this case, the bright streak in the VIIRS 1.38 µm band collocates with humid belt in WV 6.2 and 7.3 bands.

2021-02-25 Meteosat-11 (MSG-4) **WV 6.2 loop**

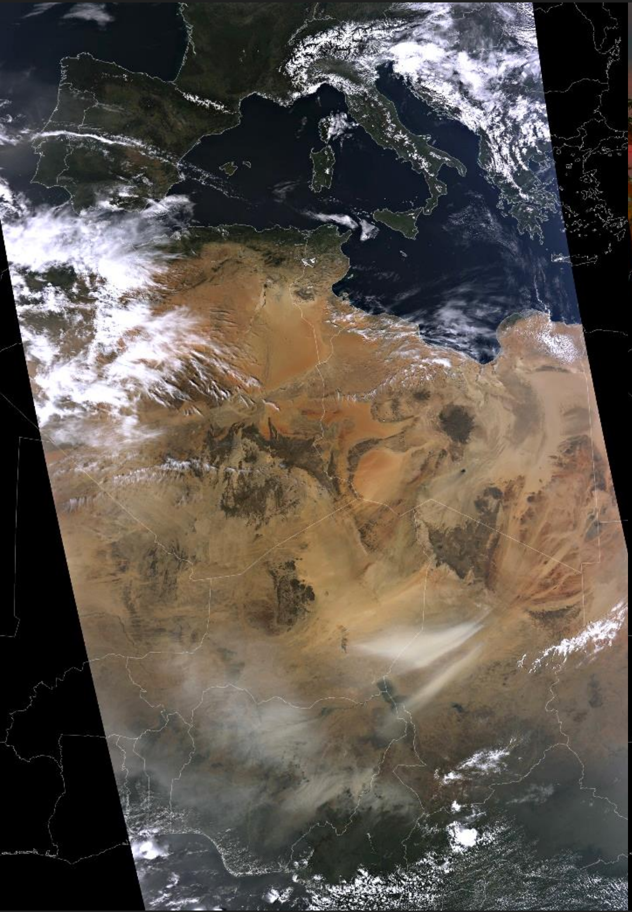



2021-02-25 15:15 UTC
Meteosat-8 (IODC), HRV

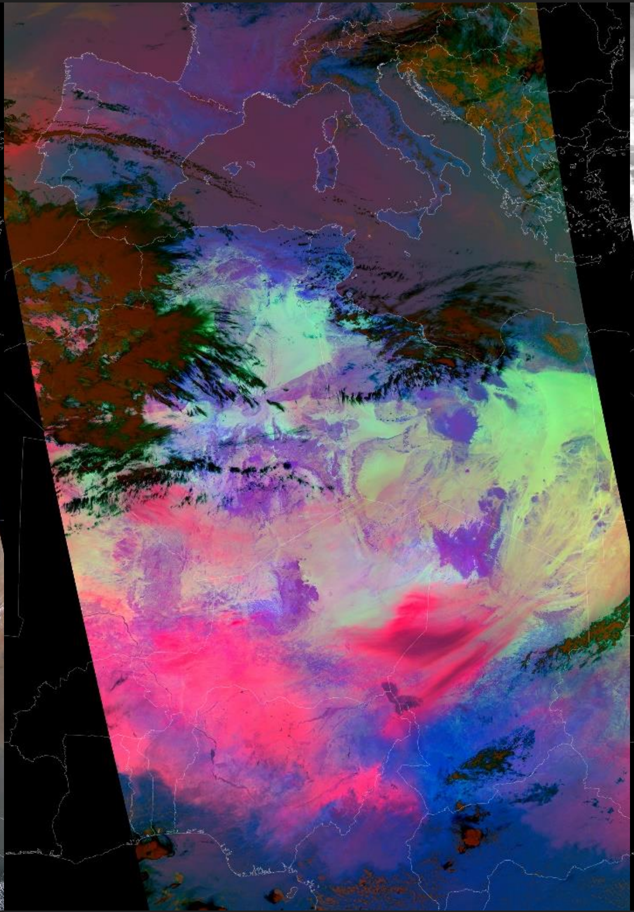
28 March 2021, 12:25 UTC, S-NPP, VIIRS, M-bands (750 m)

Aerosols and dust above northwest Africa

2021-03-28   12:25 UTC   NPP VIIRS

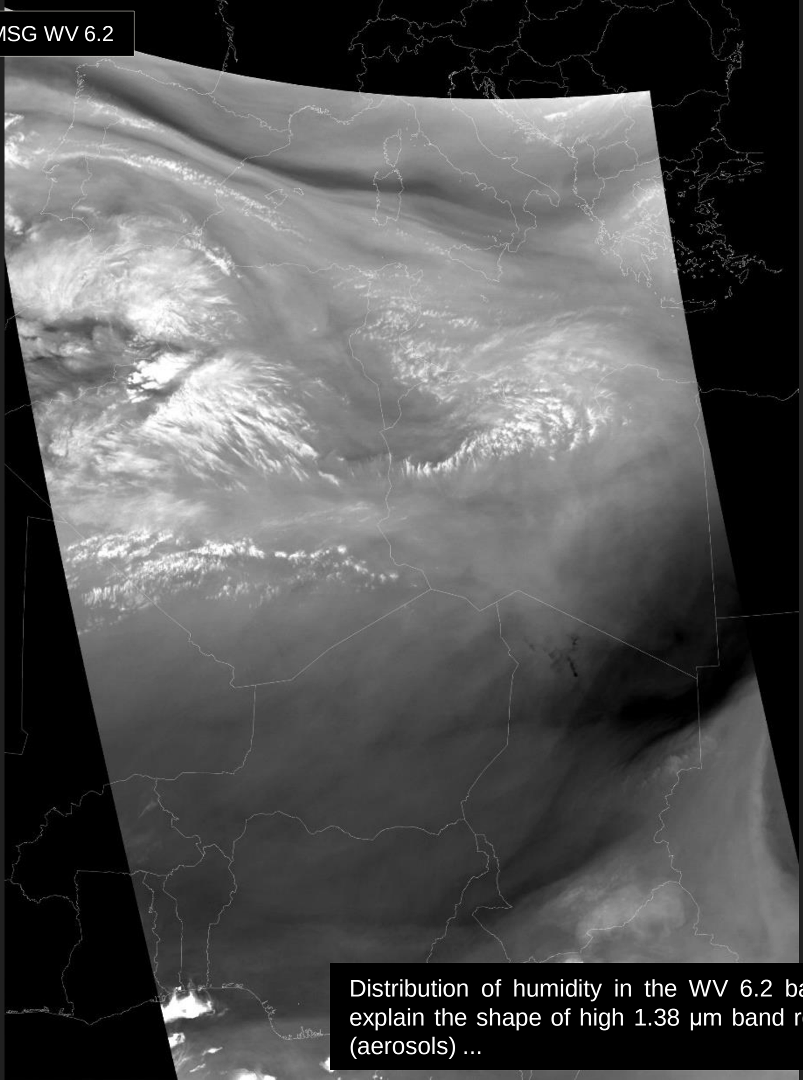


True-color RGB (VIIRS M-bands 5, 4, 3)

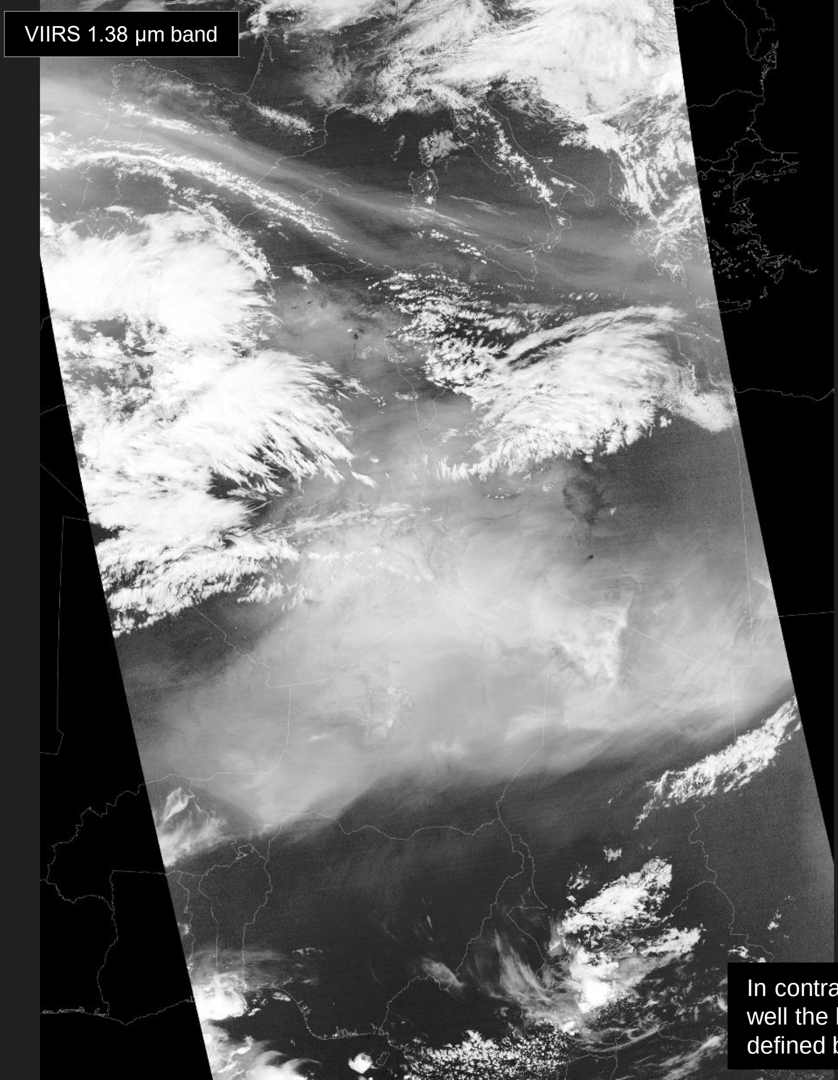


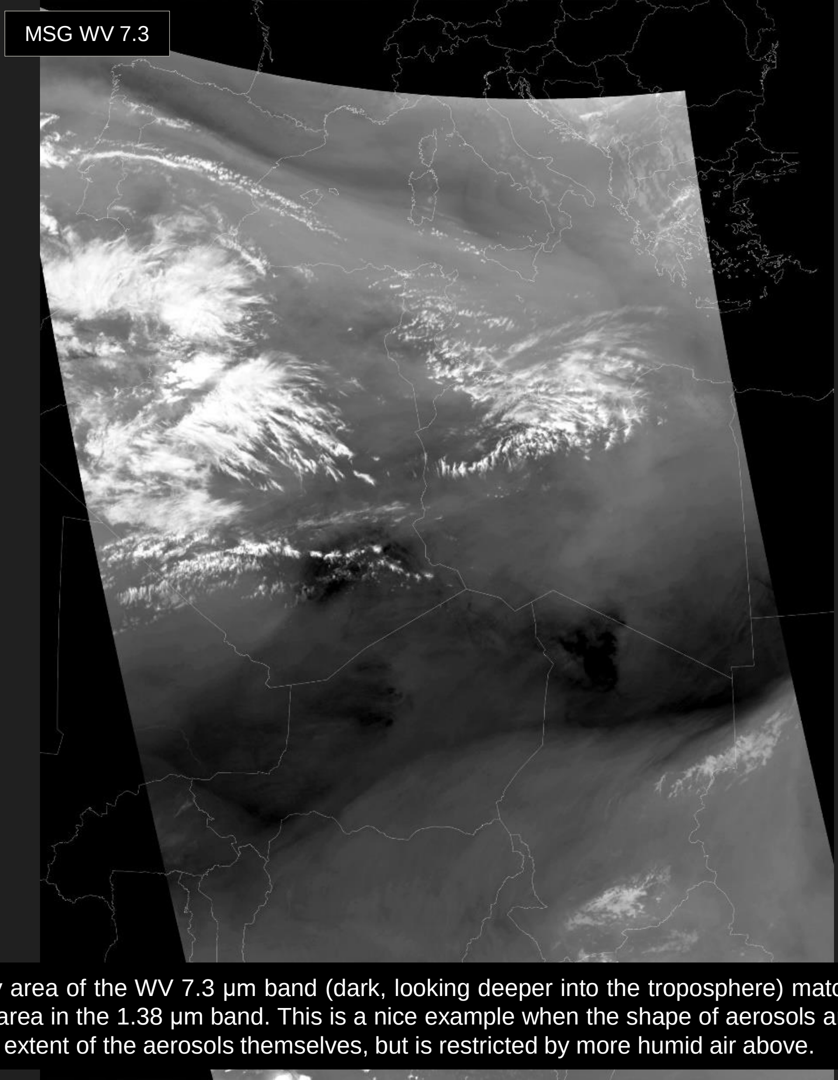
Dust RGB (VIIRS M-bands 16-15, 15-14, 15)

VIIRS 1.38 µm band (M09)

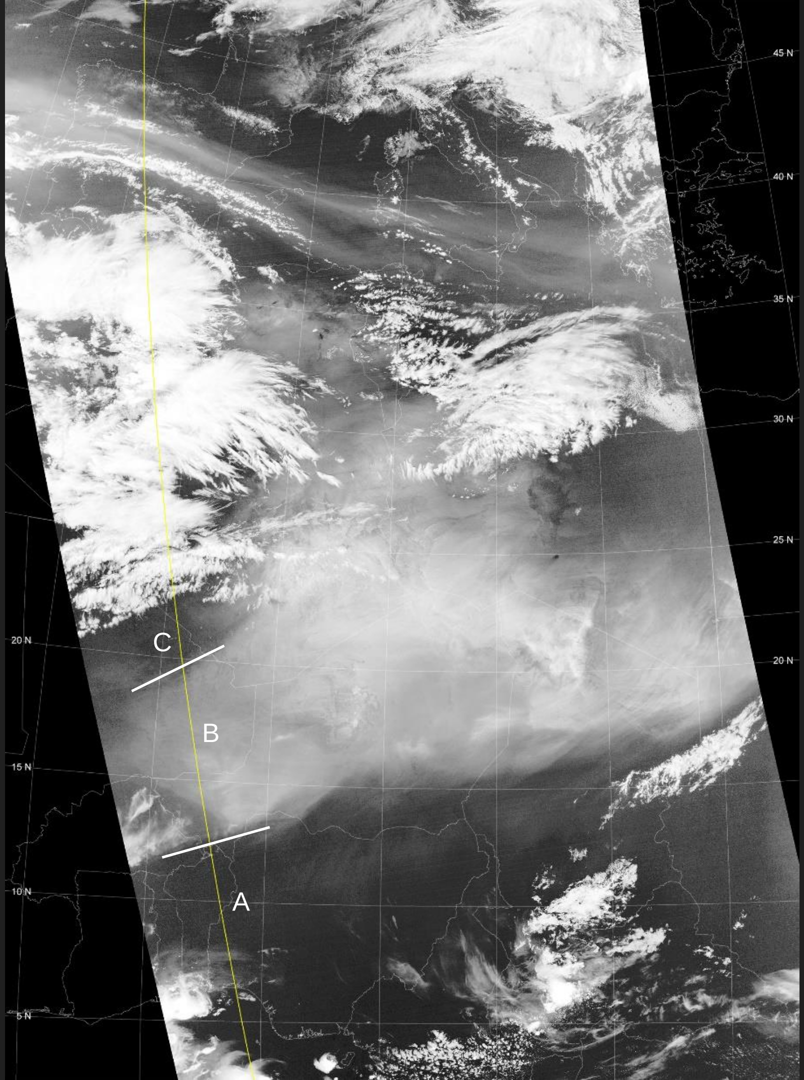


Distribution of humidity in the WV 6.2 band can’t explain the shape of high 1.38 μm band reflectivity (aerosols) ...

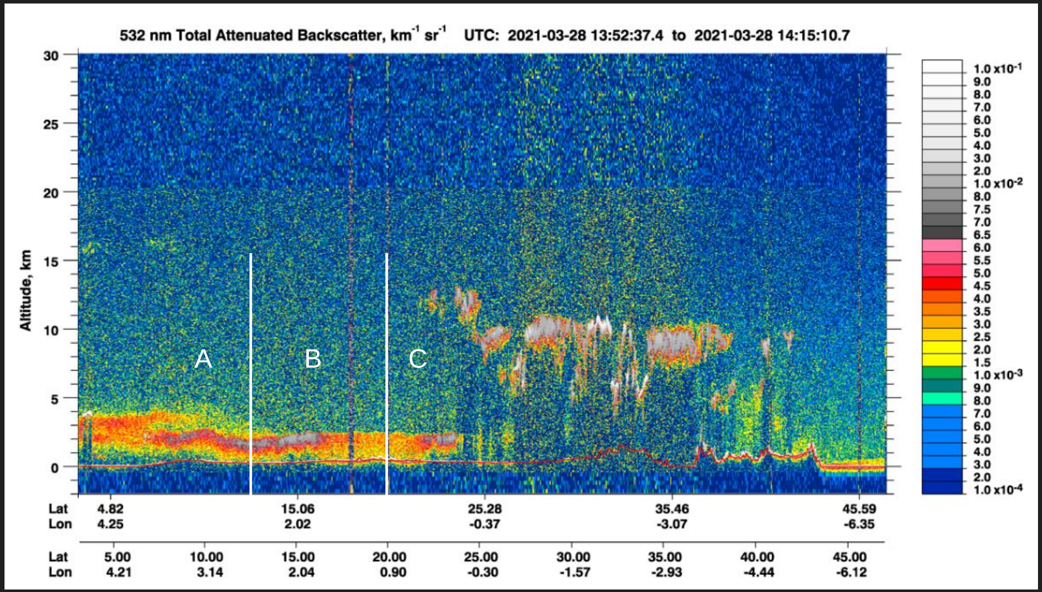




In contrary, dry area of the WV 7.3 μm band (dark, looking deeper into the troposphere) matches very well the bright area in the 1.38 μm band. This is a nice example when the shape of aerosols area is not defined by real extent of the aerosols themselves, but is restricted by more humid air above.

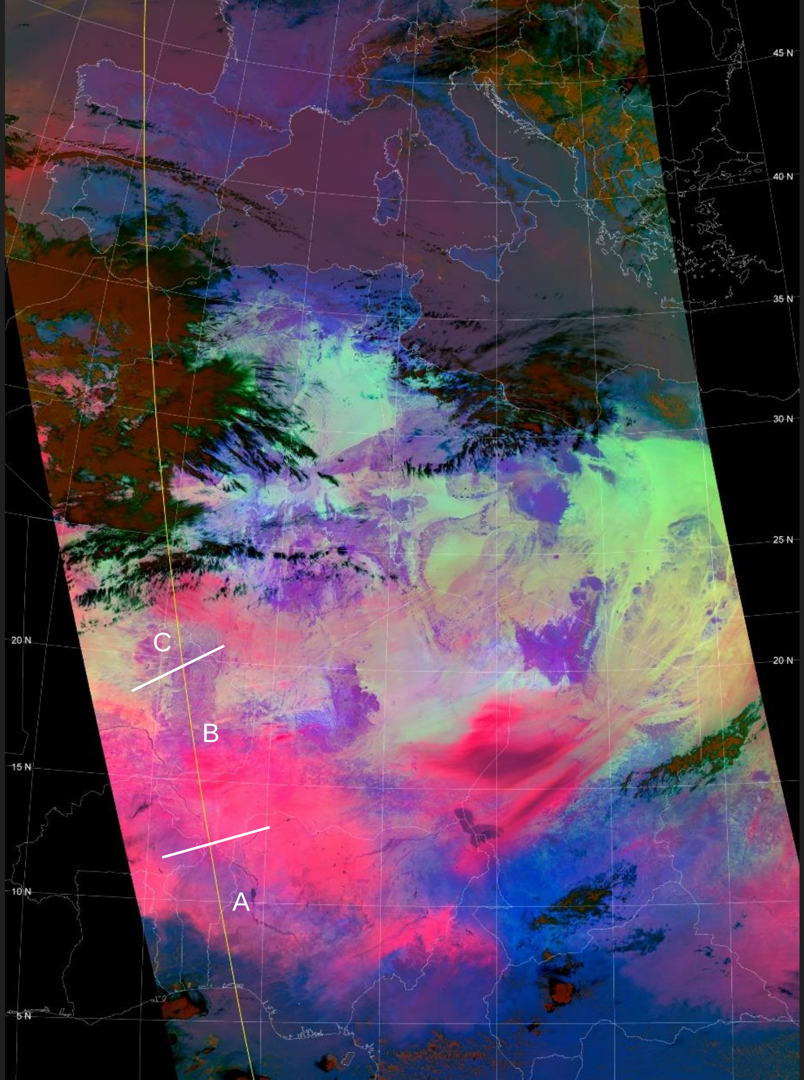


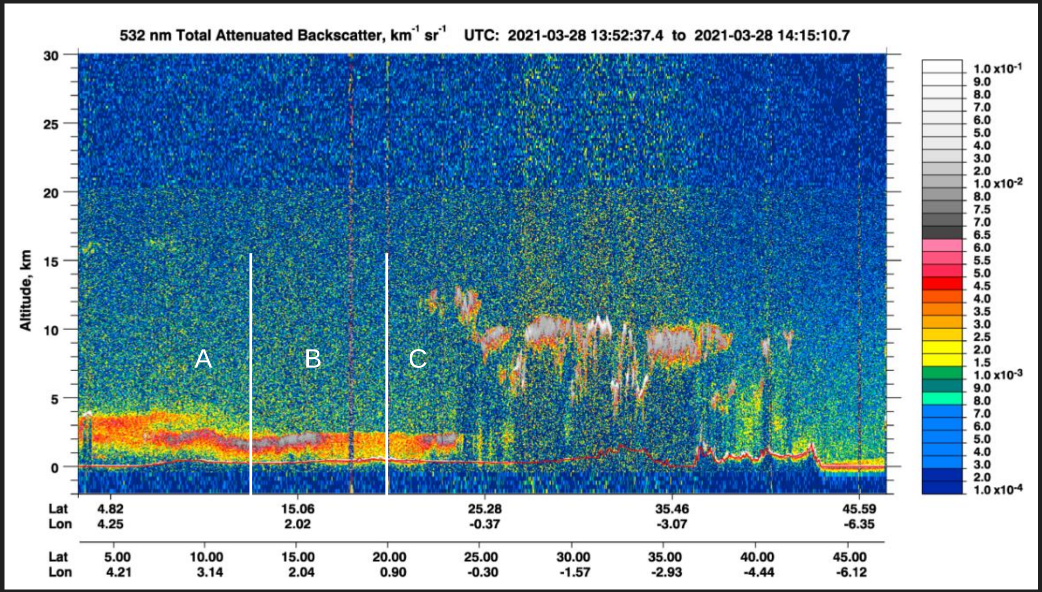
VIIRS 1.38 μm band with CALIPSO track (yellow line), and CALIOP 532 nm profile



In the CALIOP profile, aerosols (dust) are present in all three areas (A, B and C), but in the 1.38 μm VIIRS band we can see aerosols in area B only, which is dry in the MSG WV 7.3 μm band. In areas A and C the total tropospheric moisture masks the aerosols underneath (attenuates the radiance backscattered by these).

VIIRS Dust RGB with CALIPSO track, and CALIOP 532 nm profile





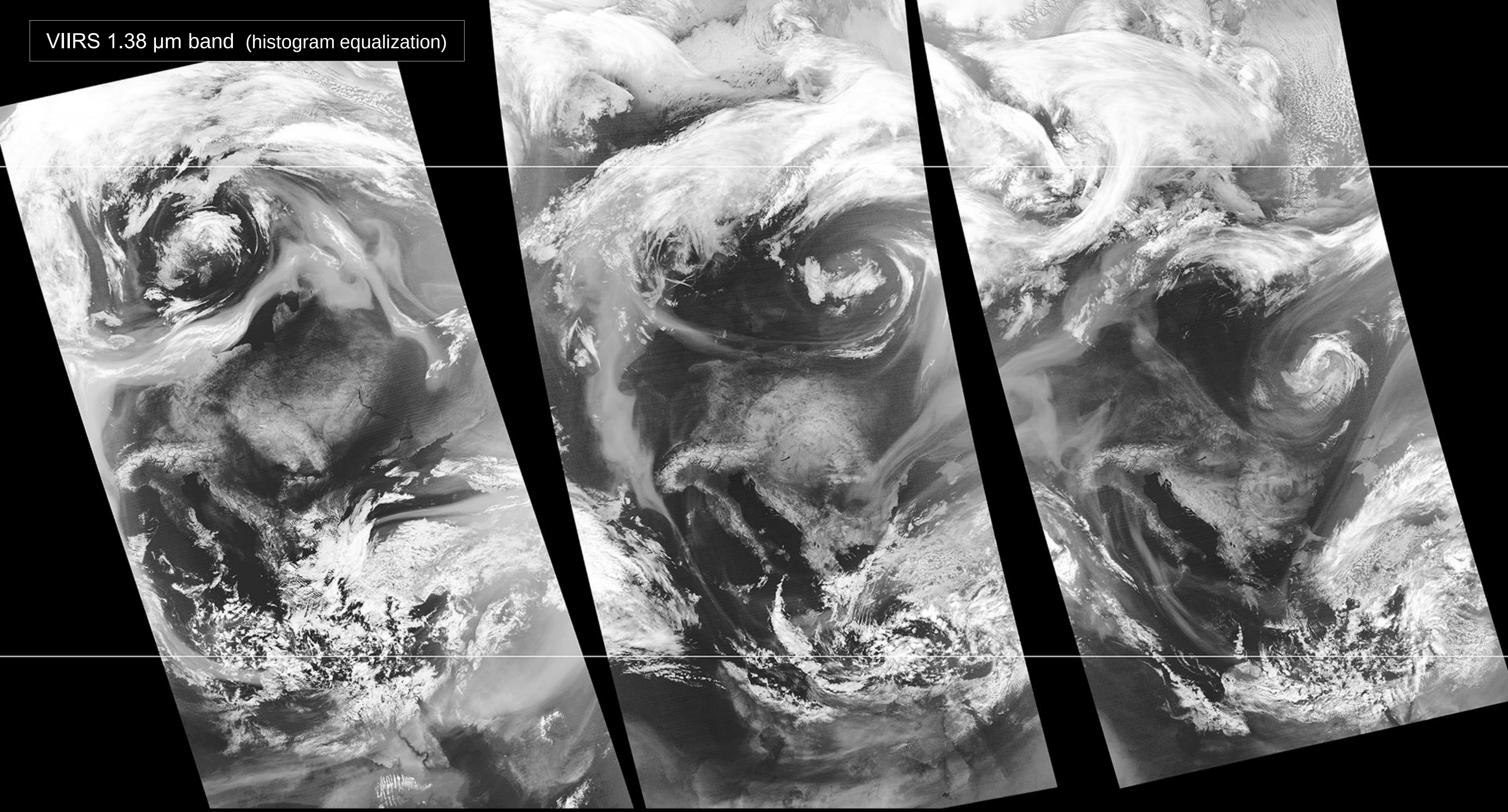
Only part of the aerosols (dust) visible in CALIOP profile can be seen in the Dust RGB, corresponding to the most dense aerosols (highest reflectivity, shown in grey) in the CALIOP profile.

Horizontal distribution of aerosols in the 1.38 µm band is significantly different from extent of dust in the Dust-RGB product, even inside the dry area B.

22 – 24 March 2022, S-NPP and NOAA-20, VIIRS, M-bands (750 m)

Aerosols above Europe

VIIRS 1.38 μm band (histogram equalization)



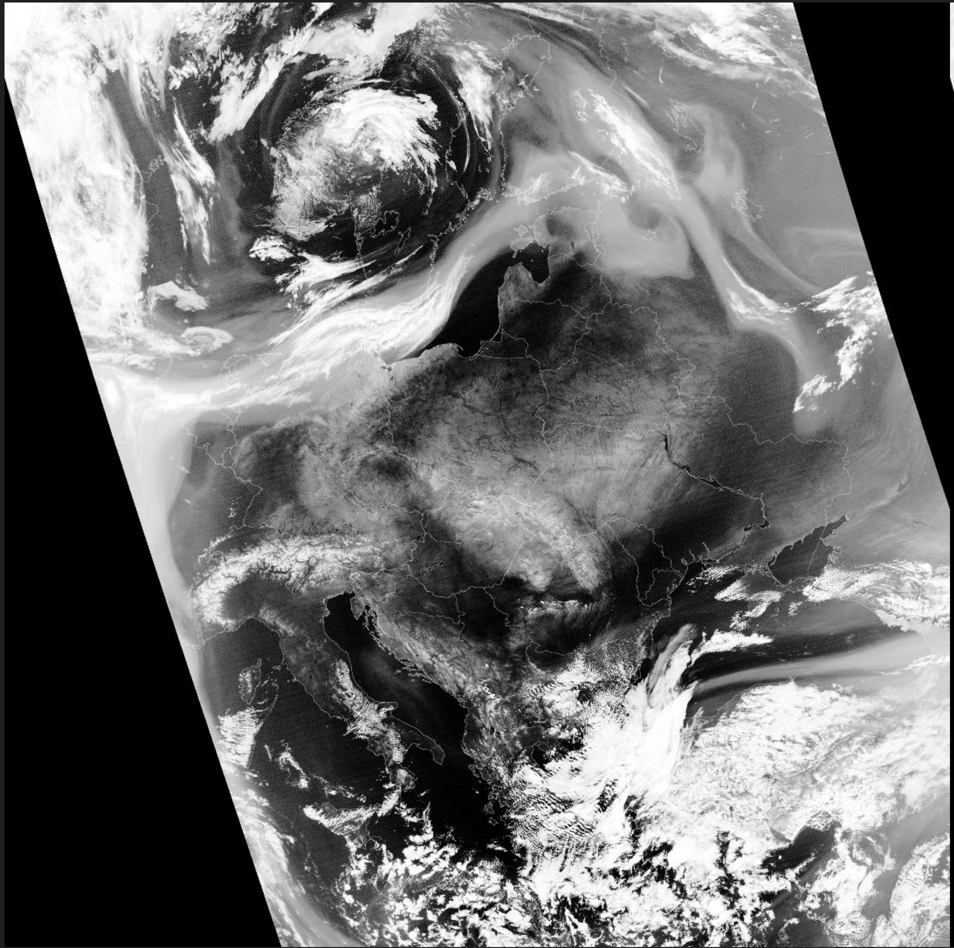
20220322_1115utc_N20_b22489

20220323_1145utc_NPP_b53900

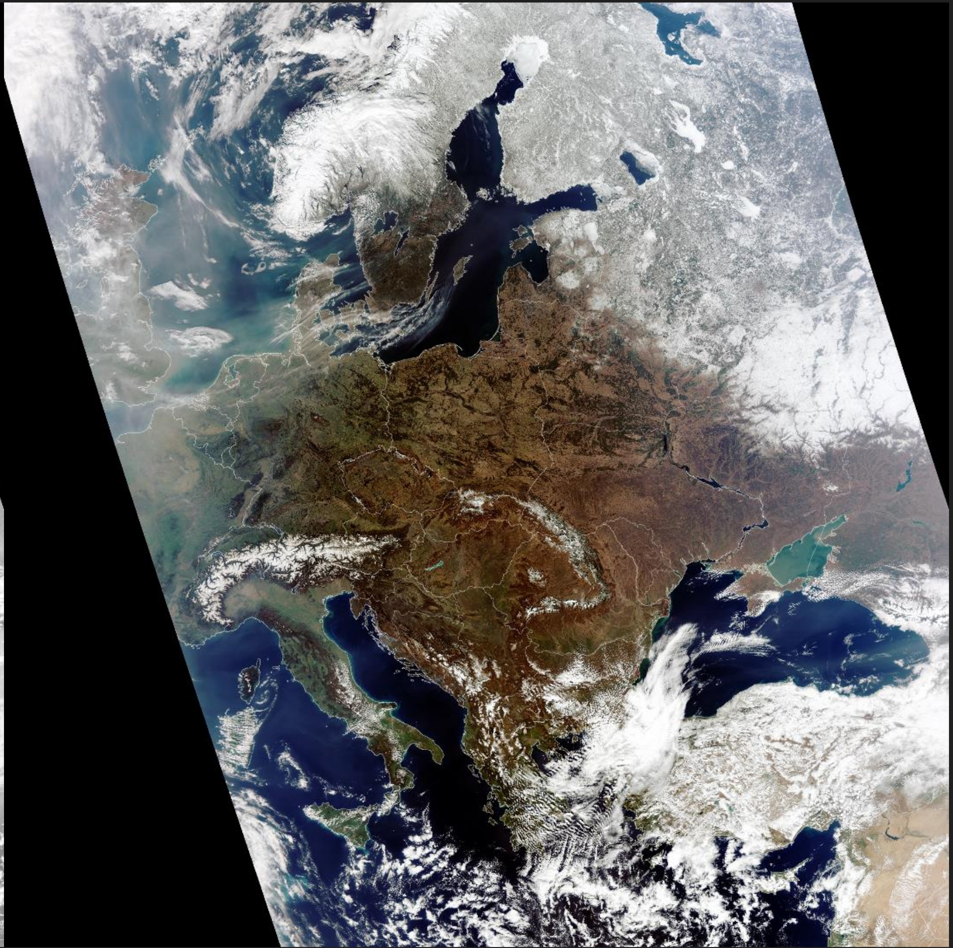
20220324_1125utc_NPP_b53914

22 March 2022 11:15 UTC NOAA-20

2022-03-22 11:15 UTC N20

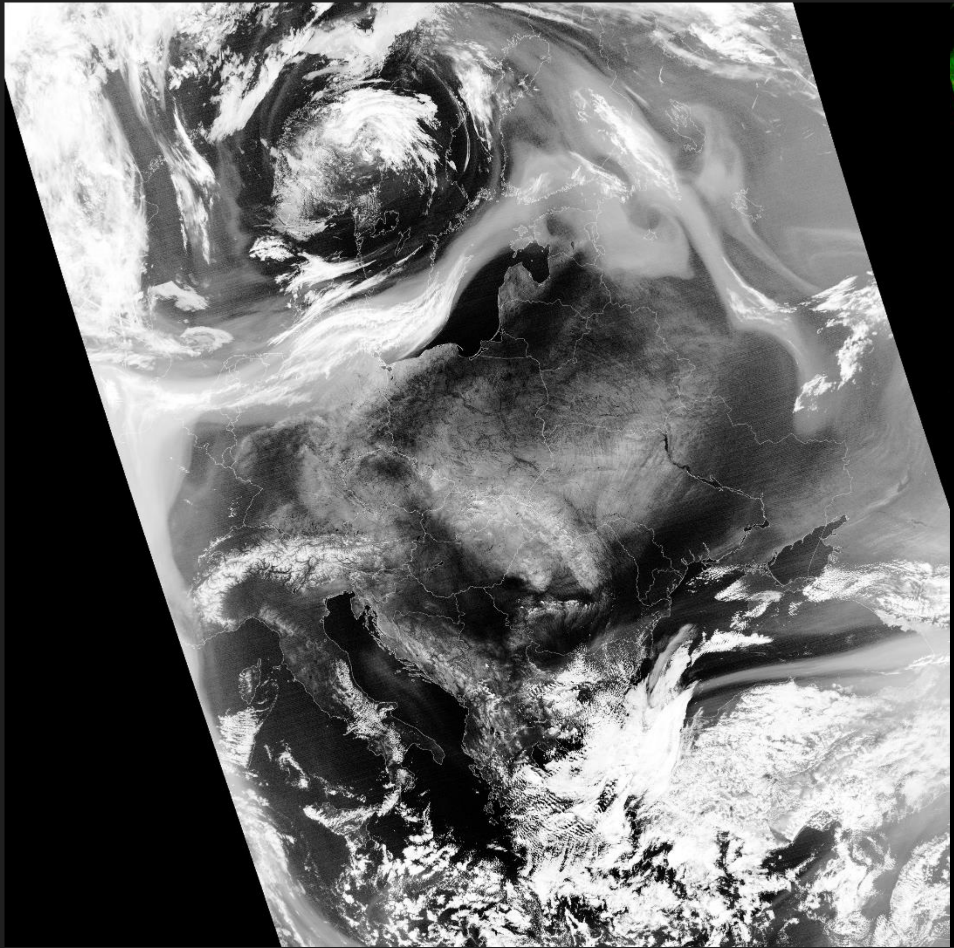


VIIRS 1.38 µm band (M09)

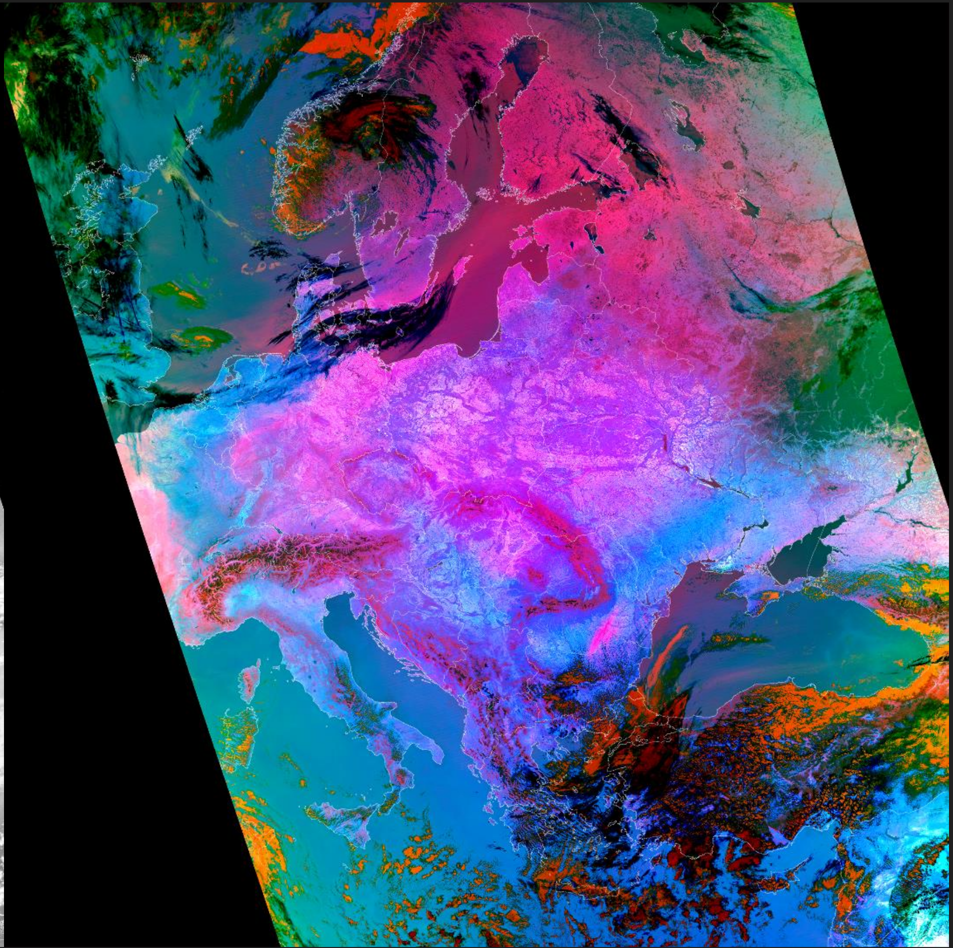


True-color RGB (VIIRS M-bands 5, 4, 3)

2022-03-22 11:15 UTC N20



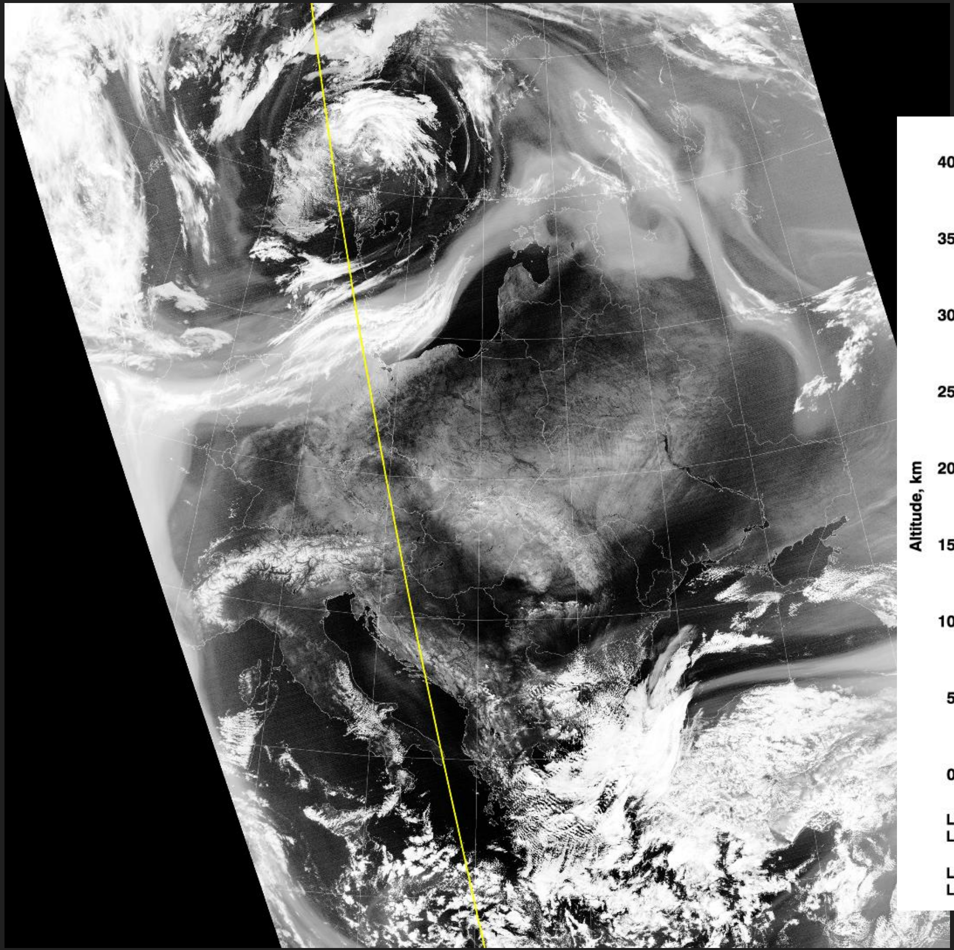
VIIRS 1.38 µm band (M09)

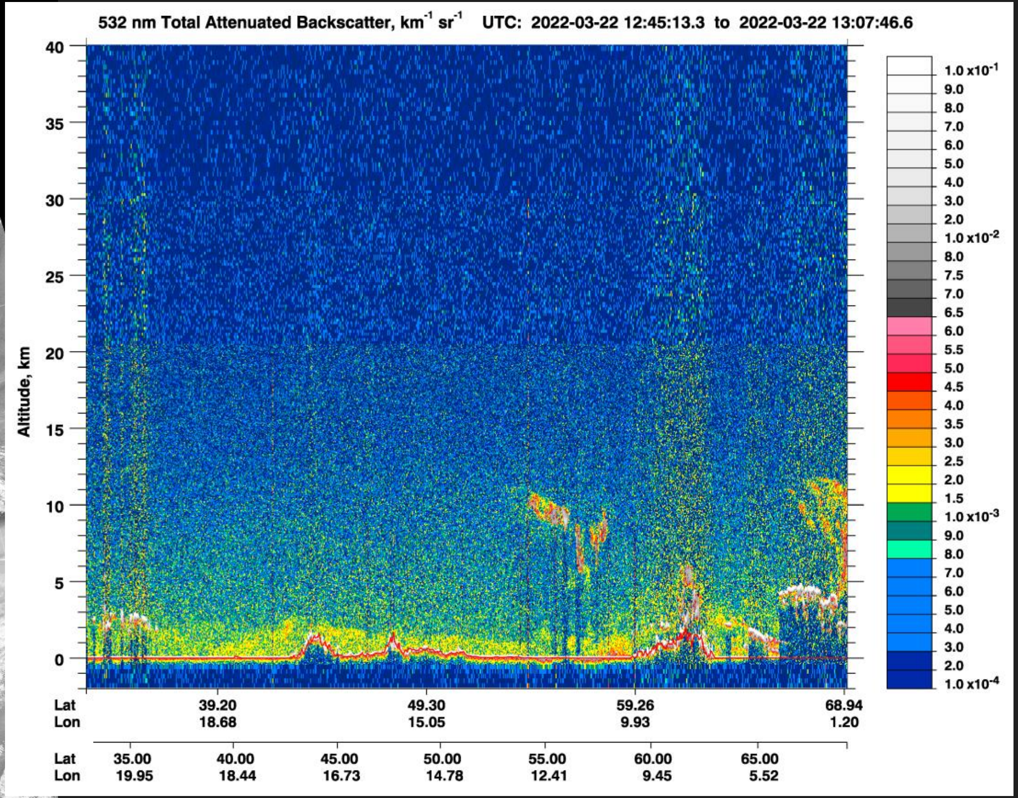


Dust RGB (VIIRS M-bands 16-15, 15-14, 15)

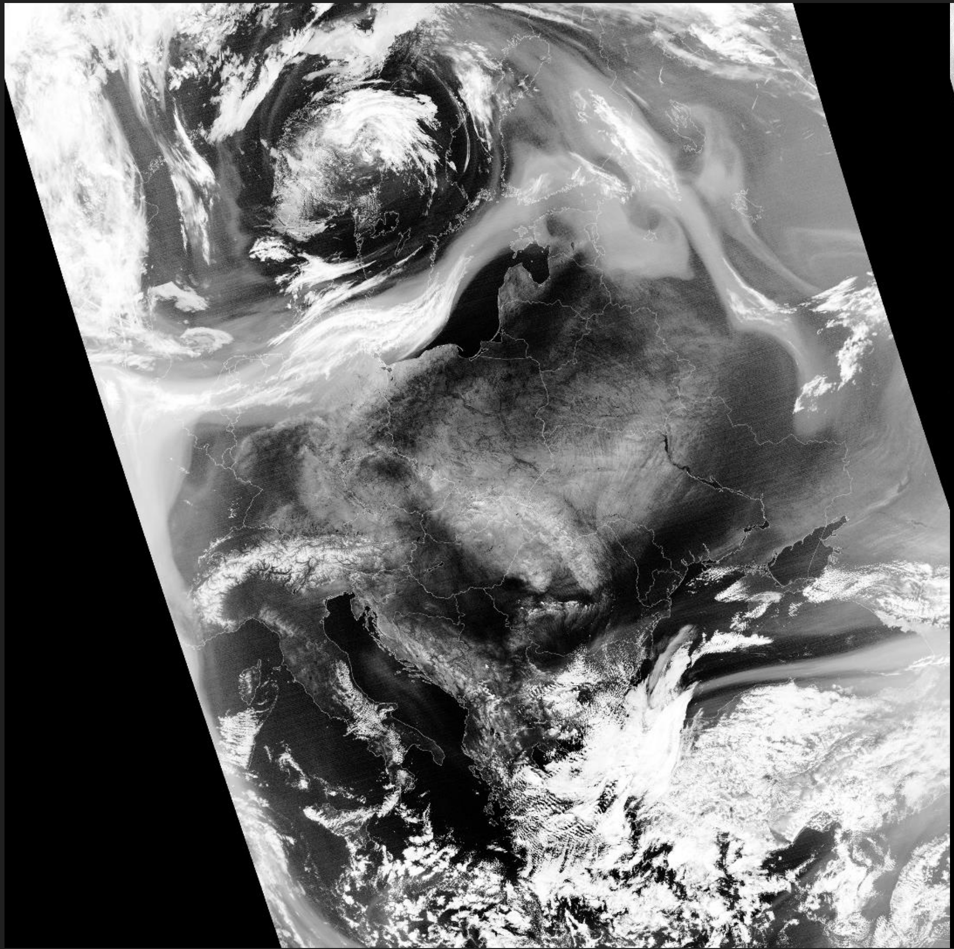
2022-03-22 11:15 UTC N20 VIIRS 1.38 µm band

VIIRS 1.38 µm band with CALIPSO track (yellow line), and CALIOP 532 nm profile

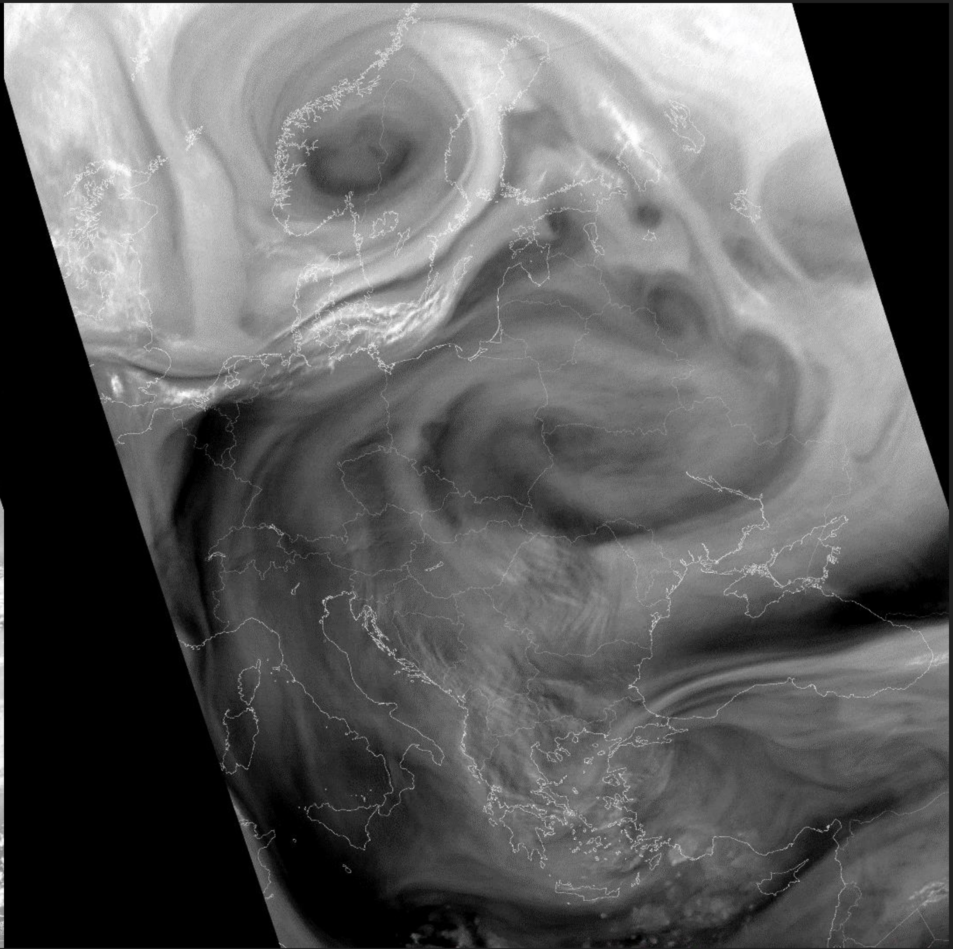




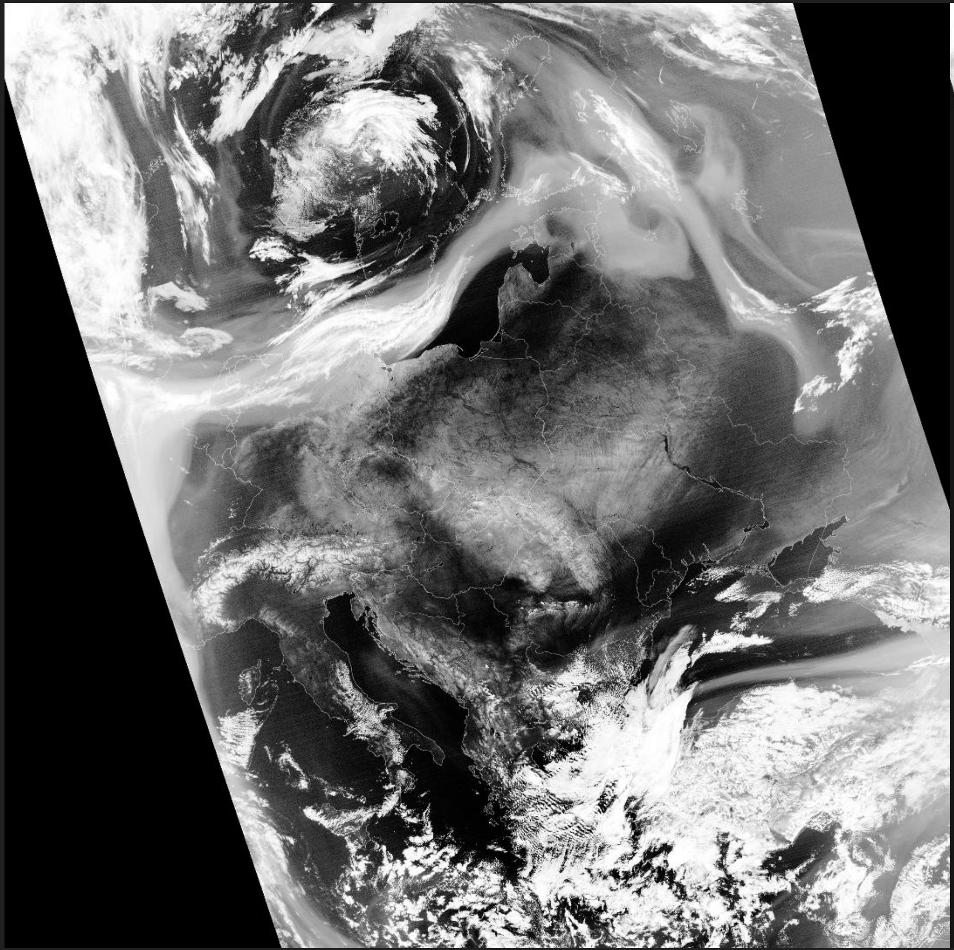
2022-03-22 11:15 UTC N20 VIIRS 1.38 µm band



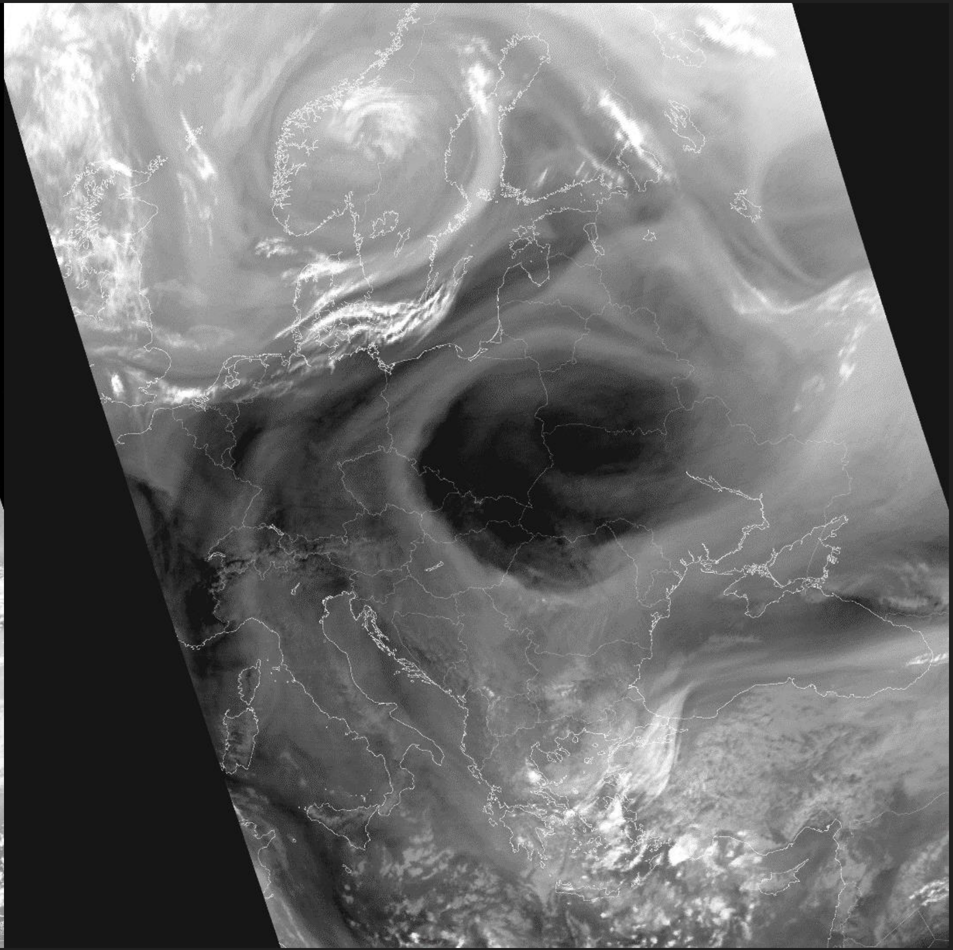
11:15 UTC MSG WV6.2

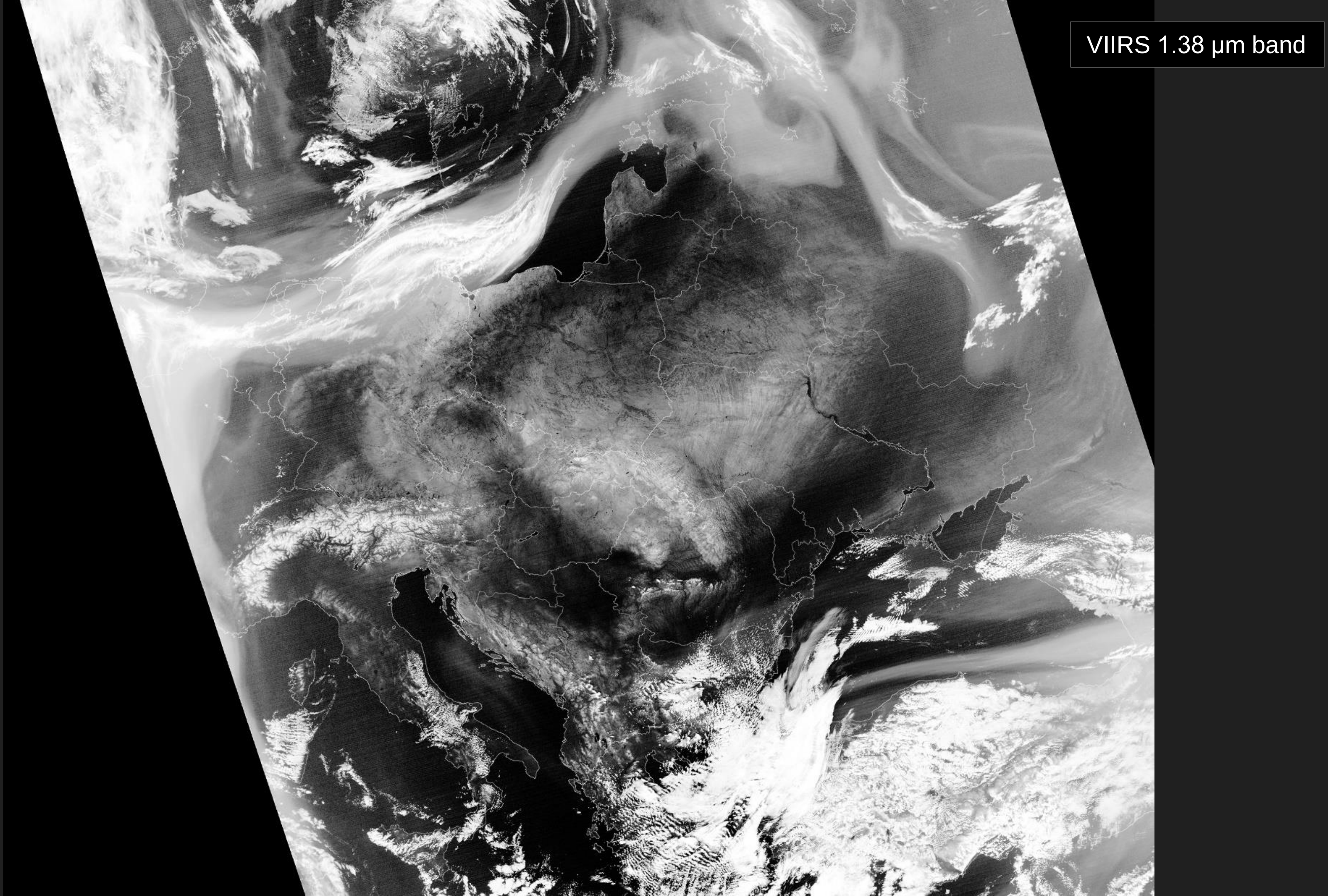


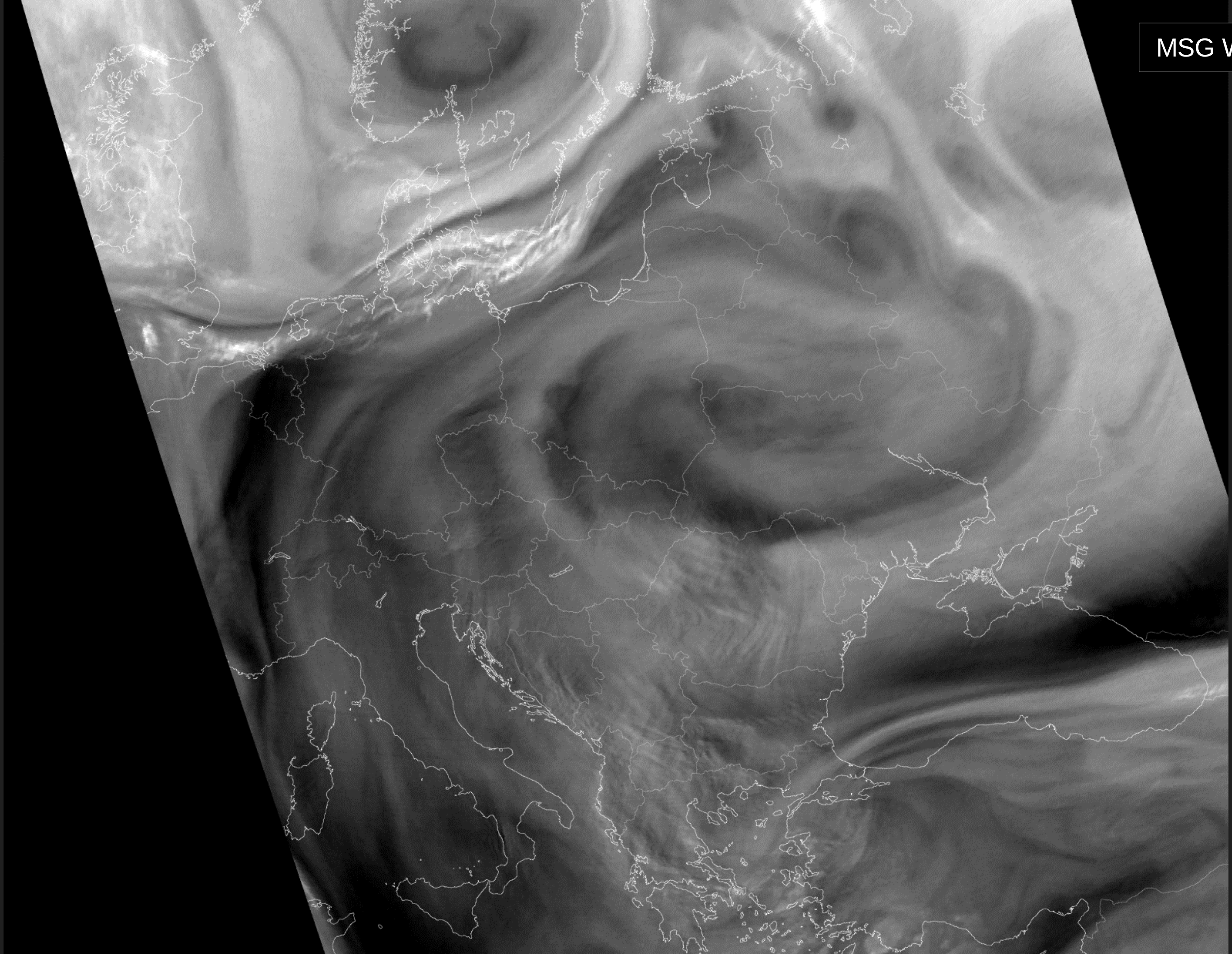
2022-03-22 11:15 UTC N20 VIIRS 1.38 µm band



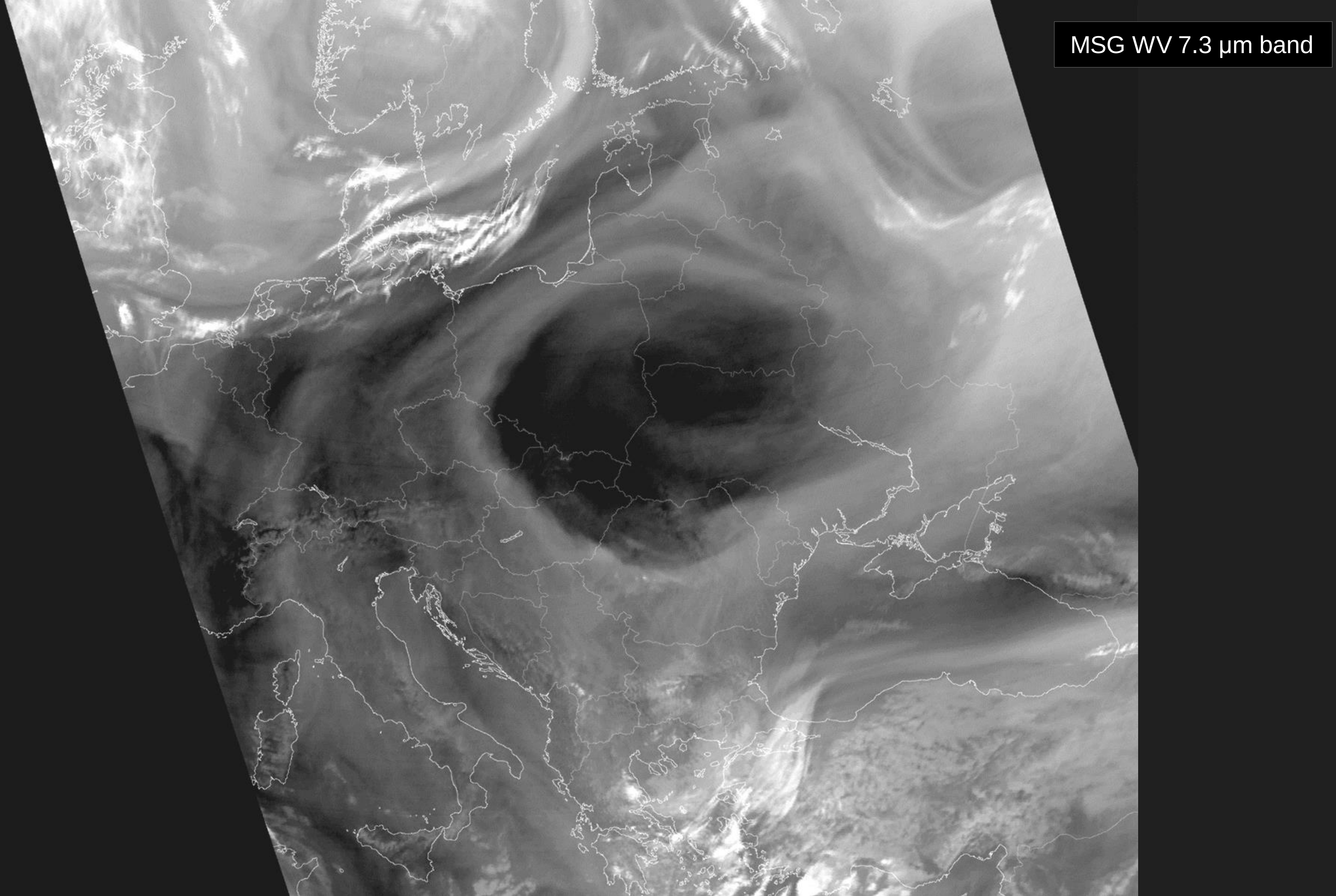
11:15 UTC MSG WV7.3

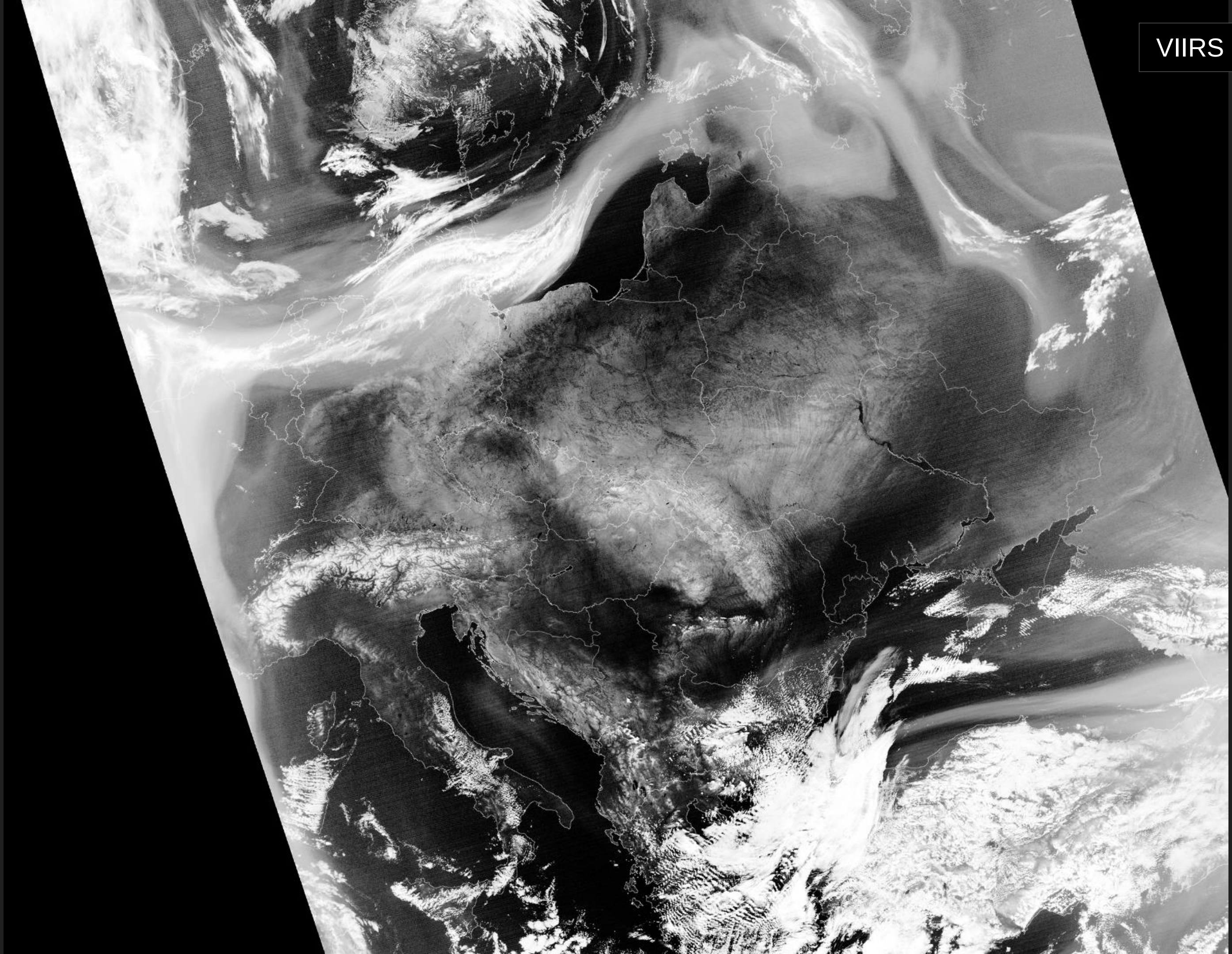



VIIRS 1.38 µm band



MSG WV 6.2 µm band

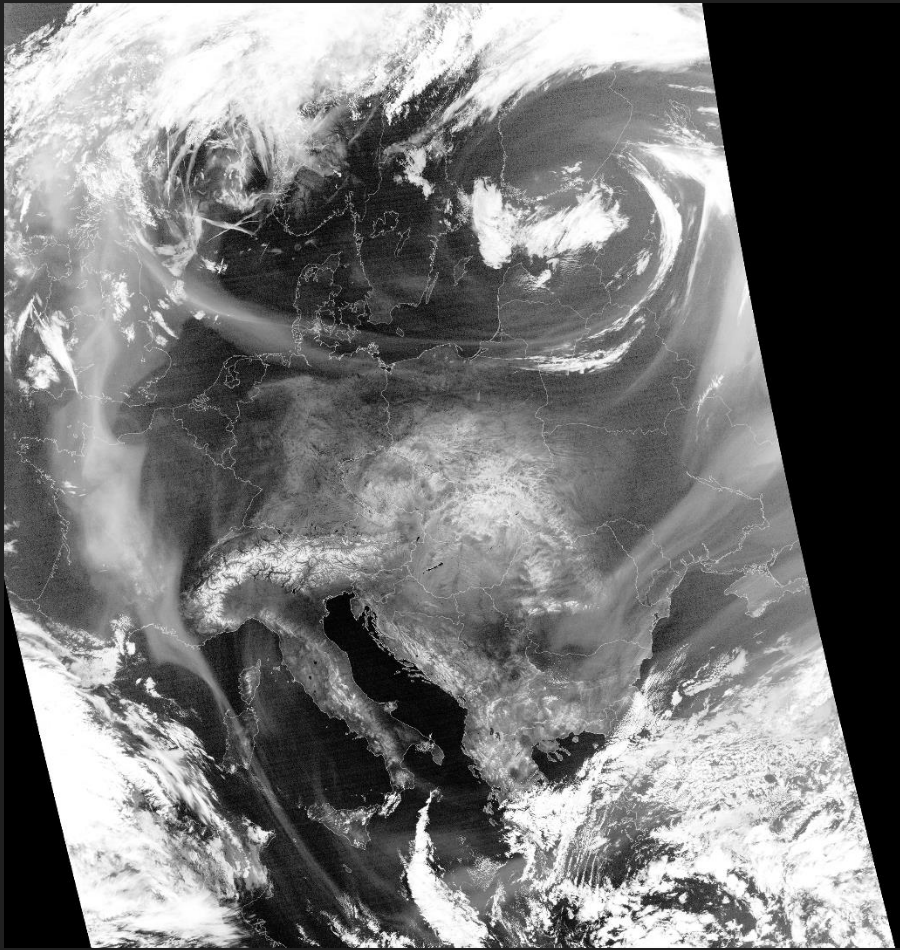

MSG WV 7.3 µm band



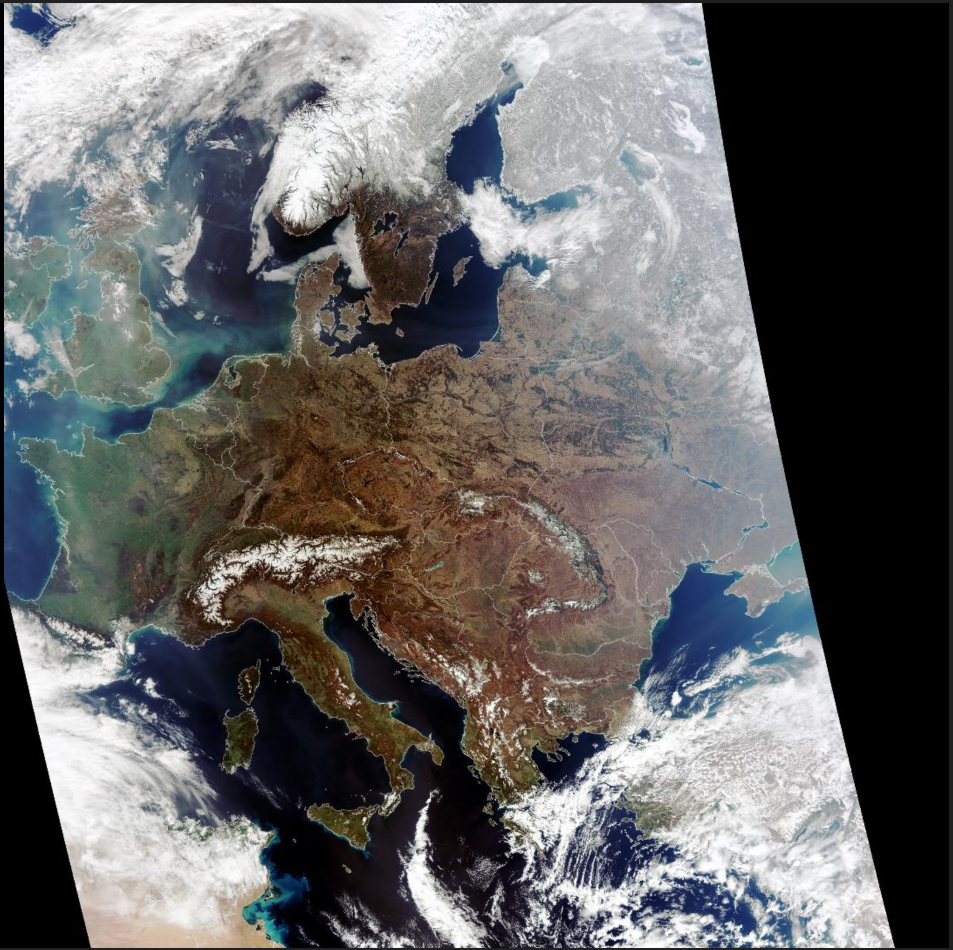
VIIRS 1.38 µm band

23 March 2022 11:45 UTC S-NPP

2022-03-23 11:45 UTC NPP

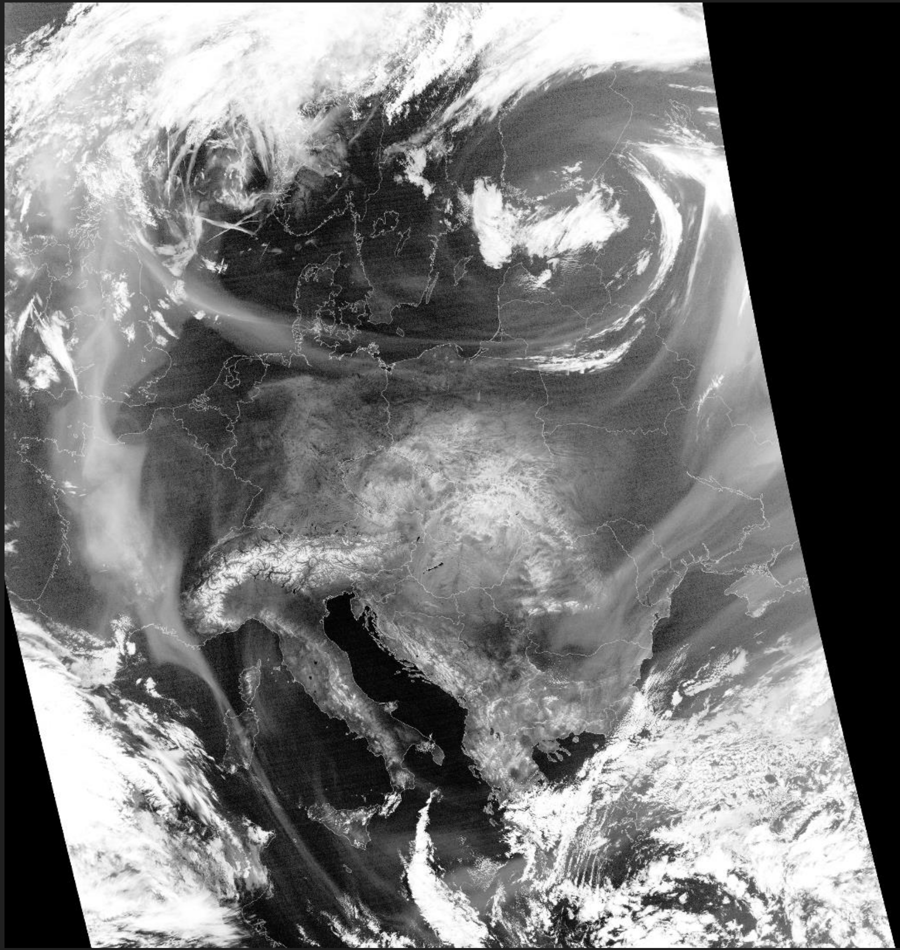


VIIRS 1.38 µm band (M09)

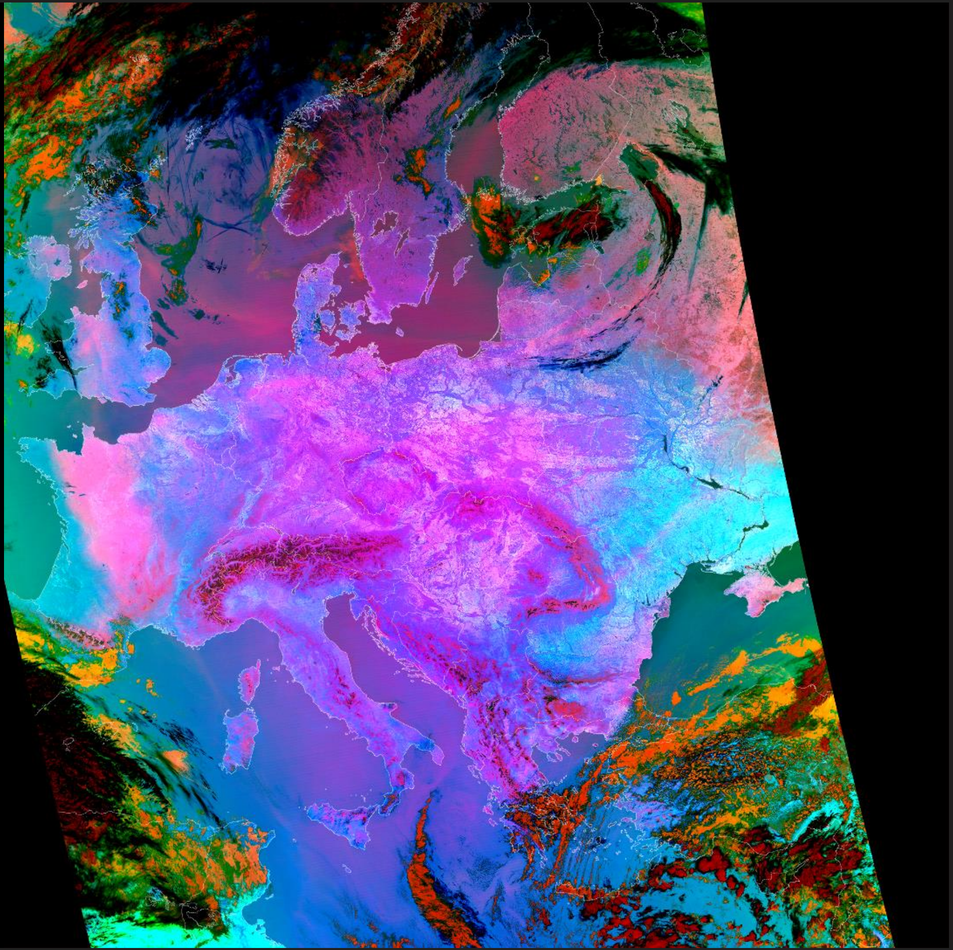


True-color RGB (VIIRS M-bands 5, 4, 3)

2022-03-23 11:45 UTC NPP



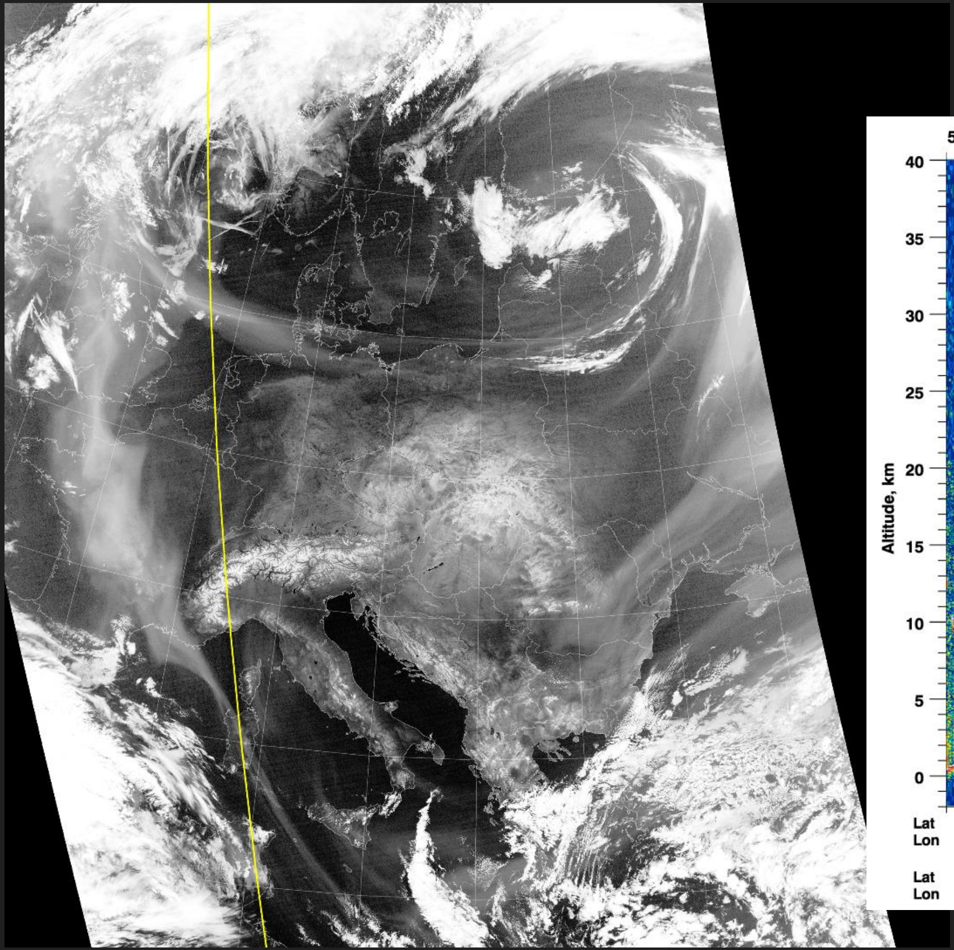
VIIRS 1.38 µm band (M09)

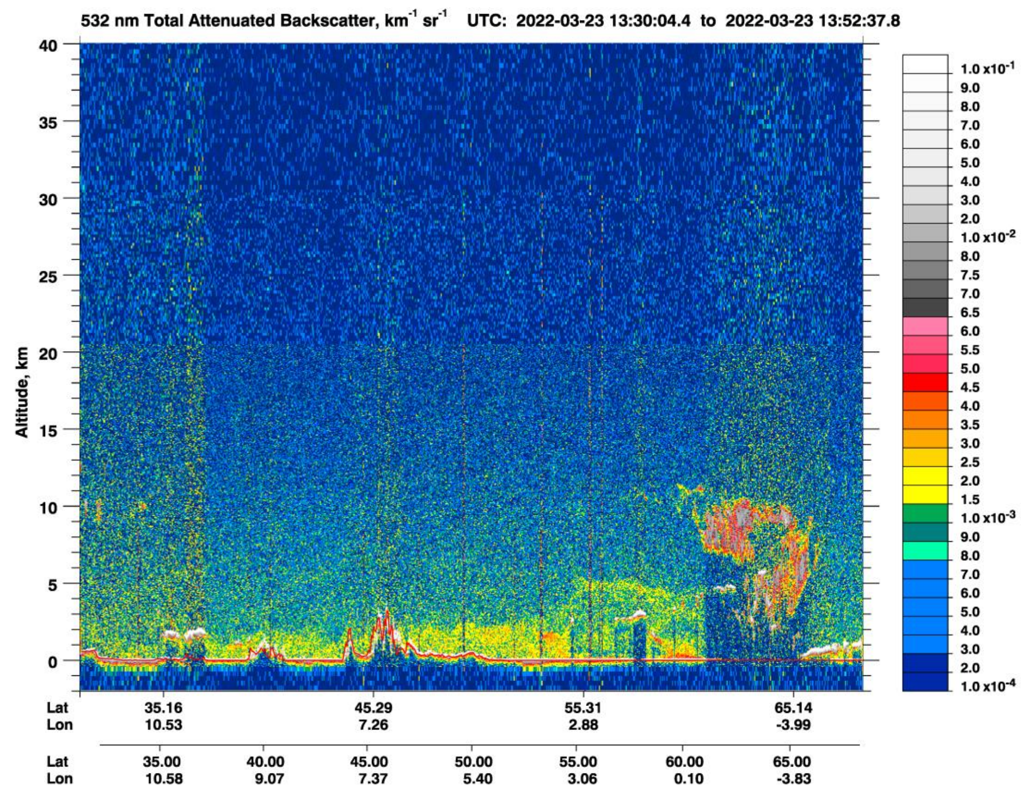


Dust RGB (VIIRS M-bands 16-15, 15-14, 15)

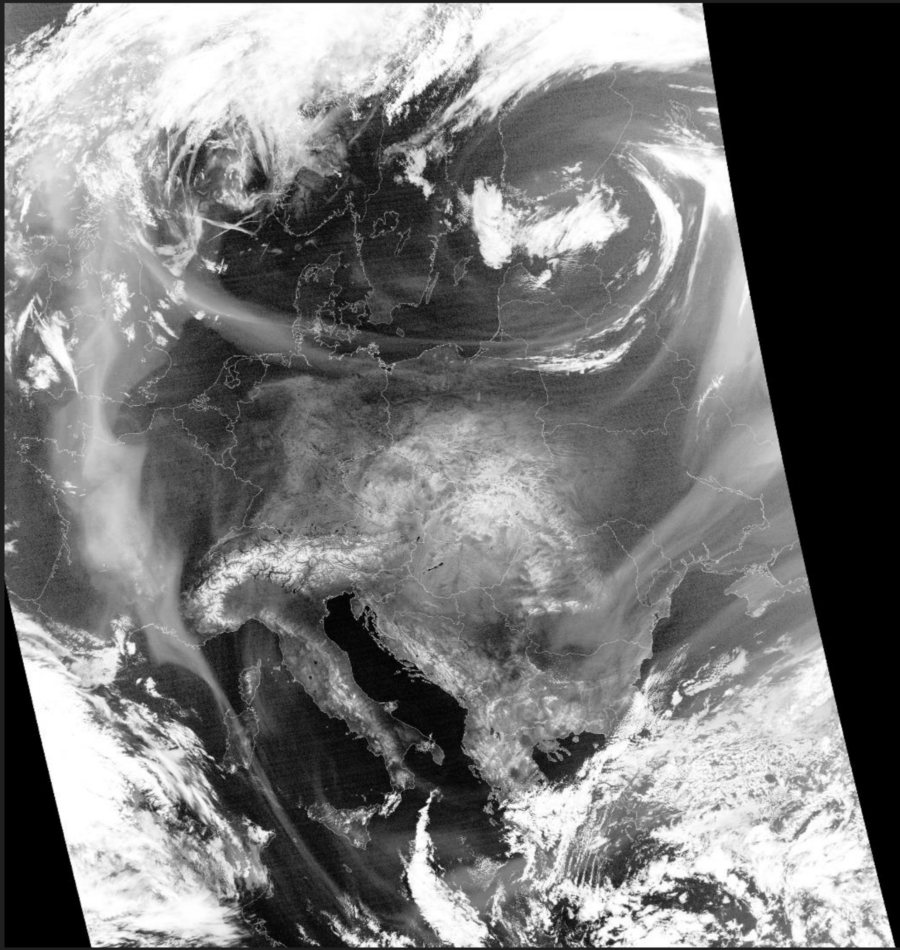
2022-03-23 11:45 UTC NPP VIIRS 1.38 μm band

VIIRS 1.38 μm band with CALIPSO track (yellow line), and CALIOP 532 nm profile

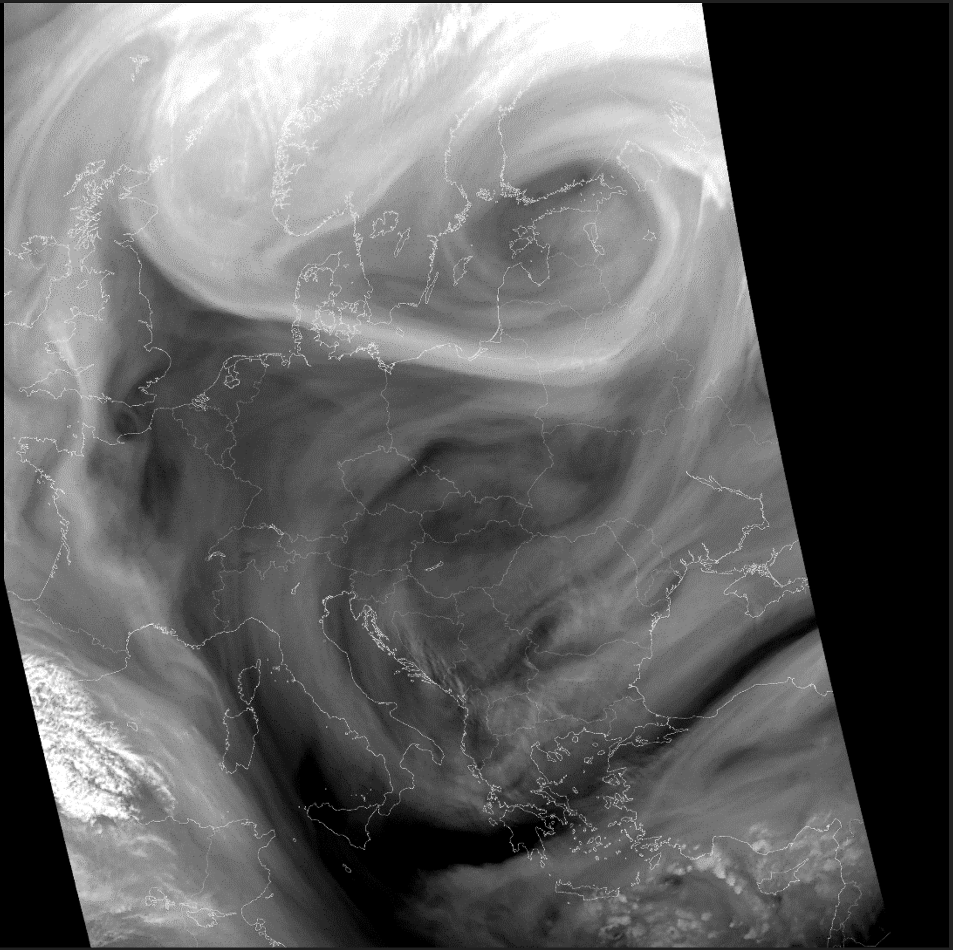




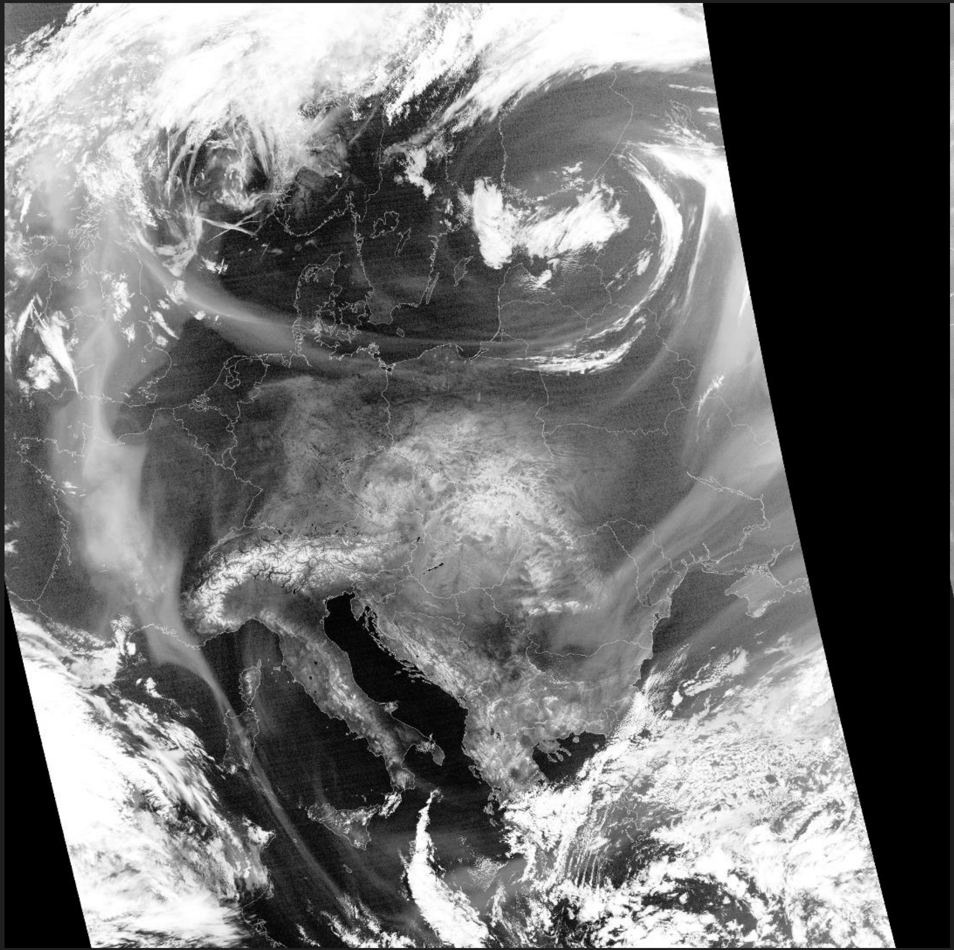
2022-03-23 11:45 UTC NPP VIIRS 1.38 µm band



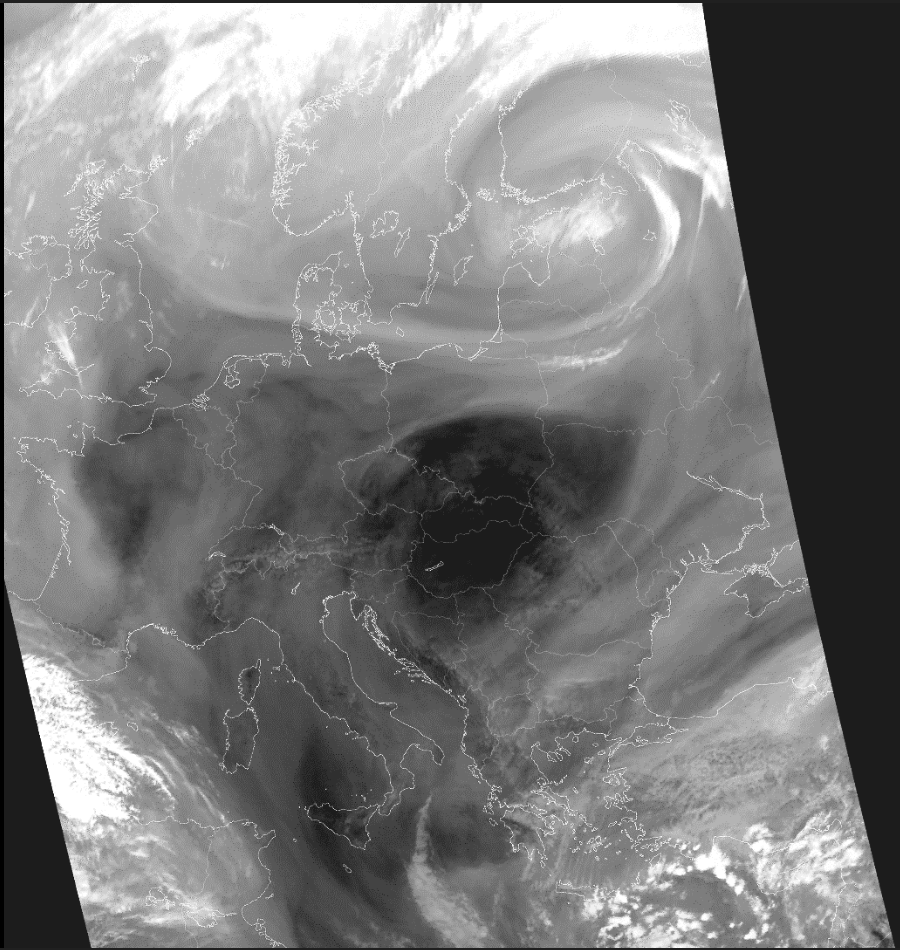
11:45 UTC MSG WV6.2

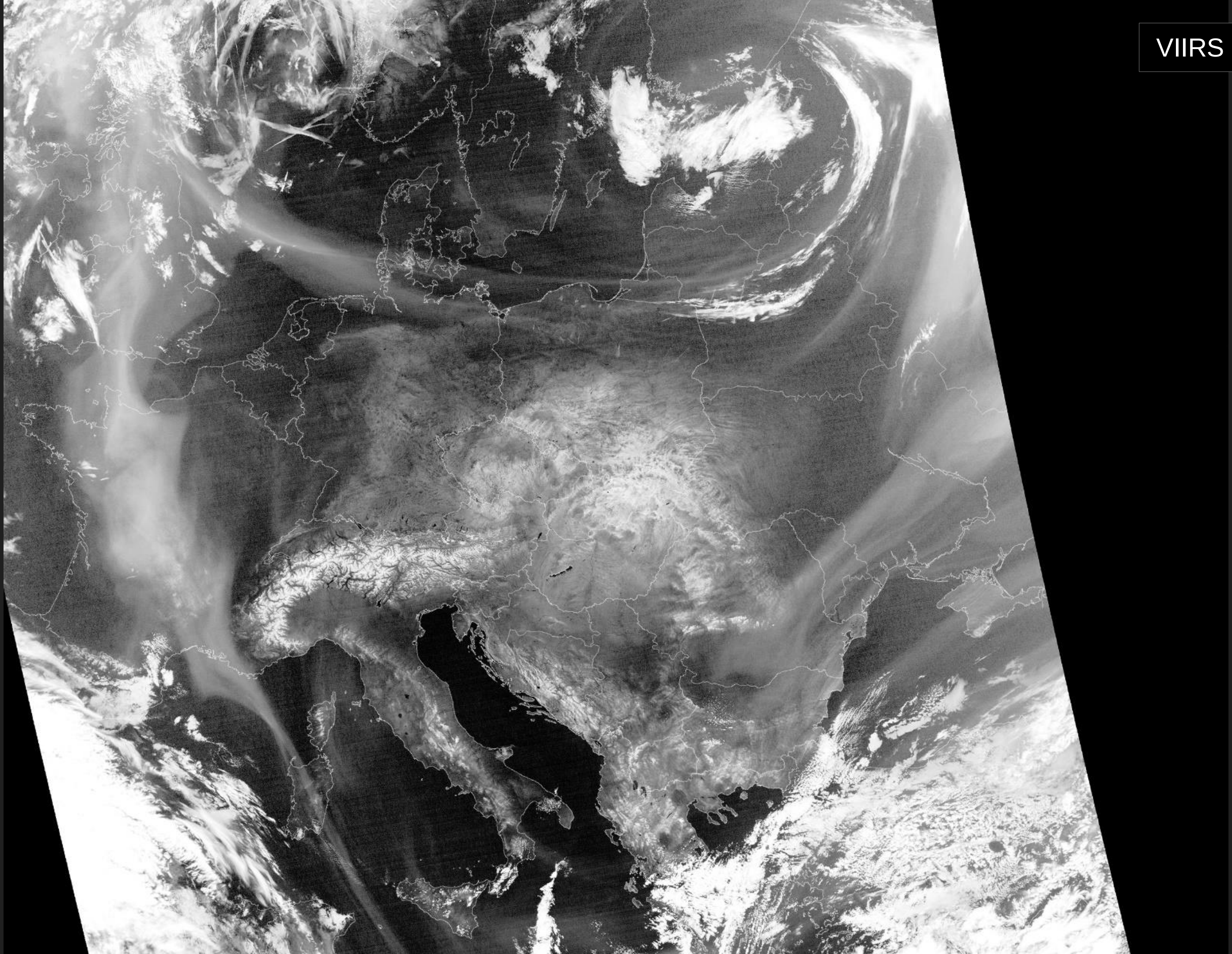


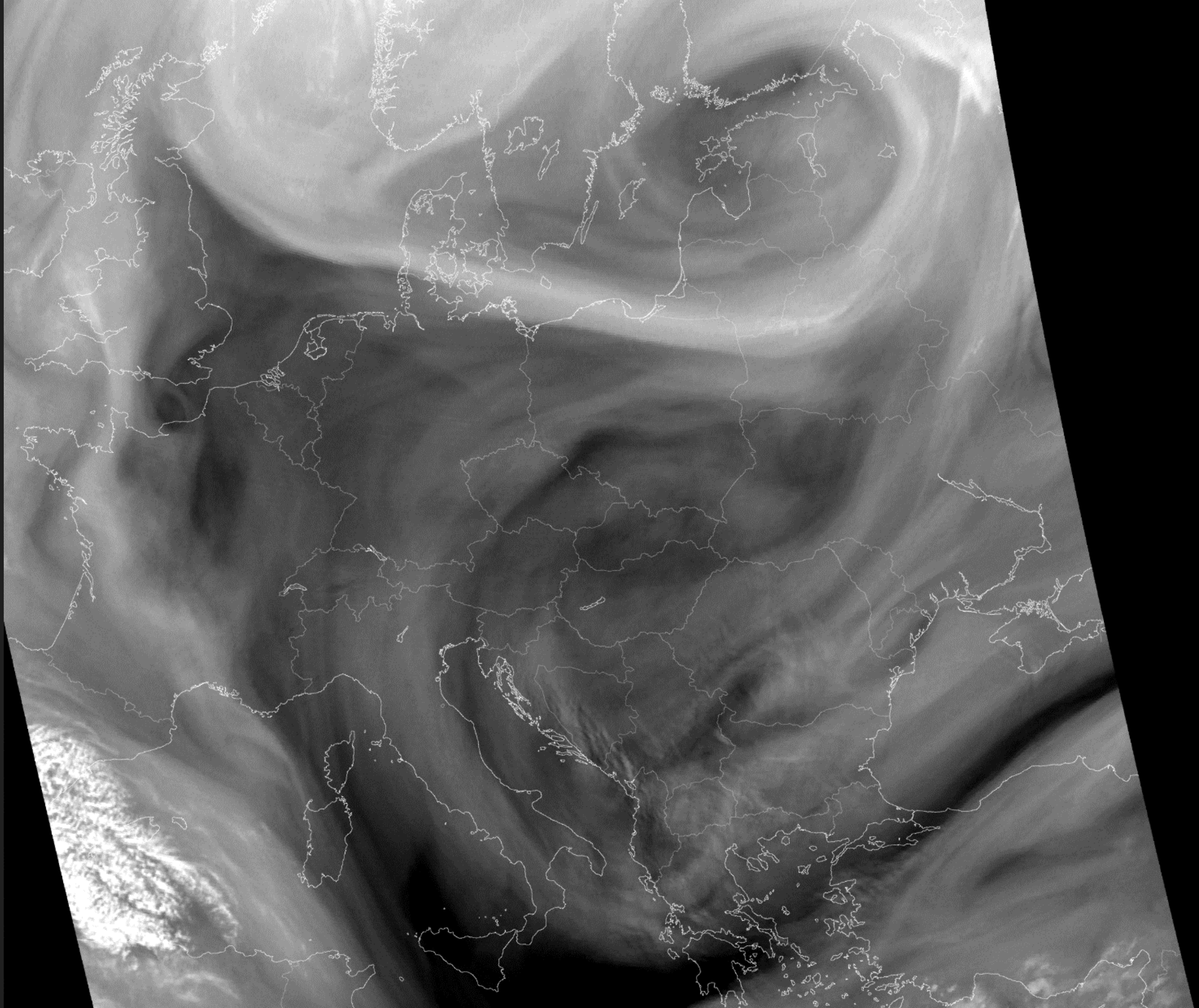
2022-03-23 11:45 UTC NPP VIIRS 1.38 µm band

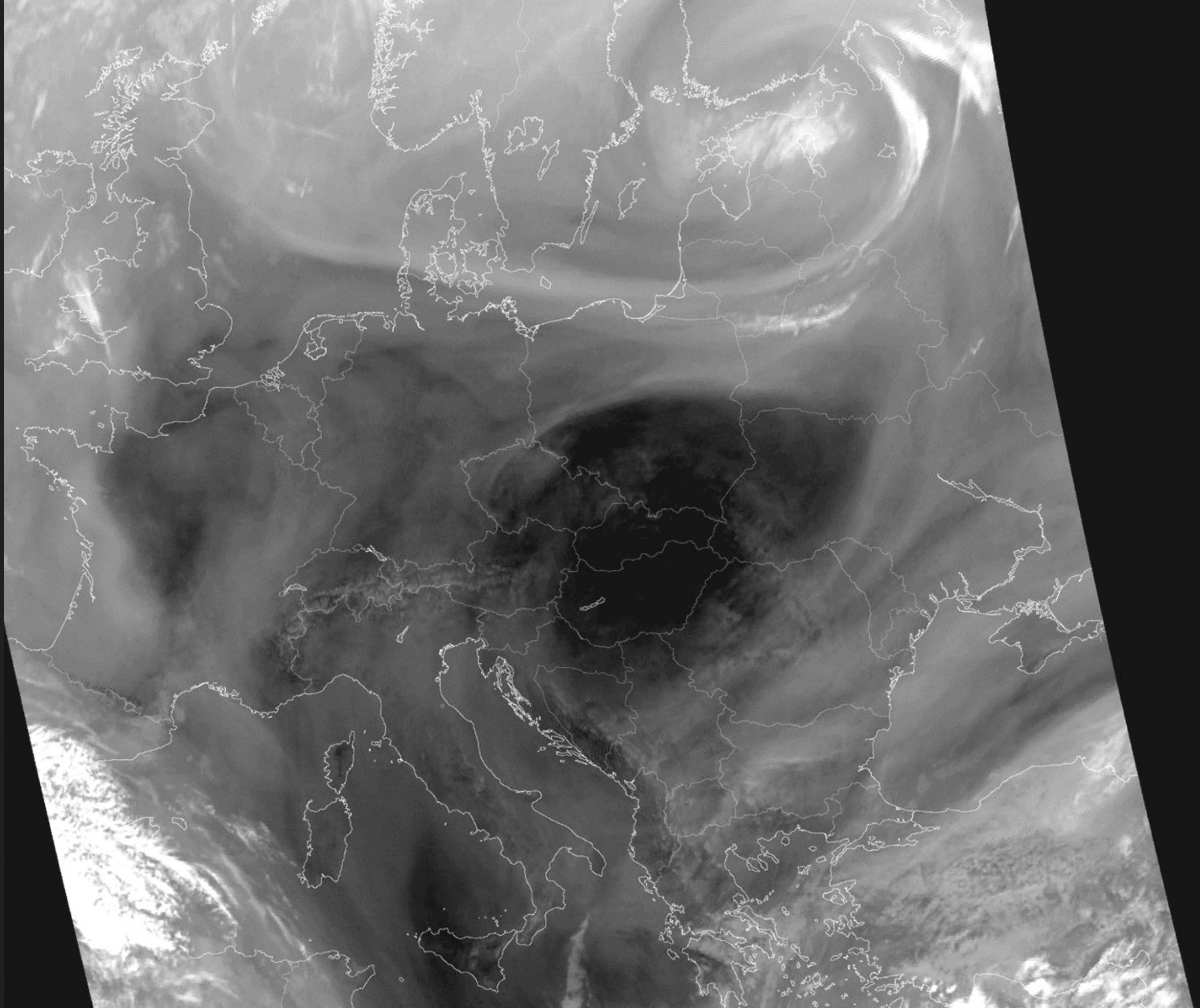


11:45 UTC MSG WV7.3

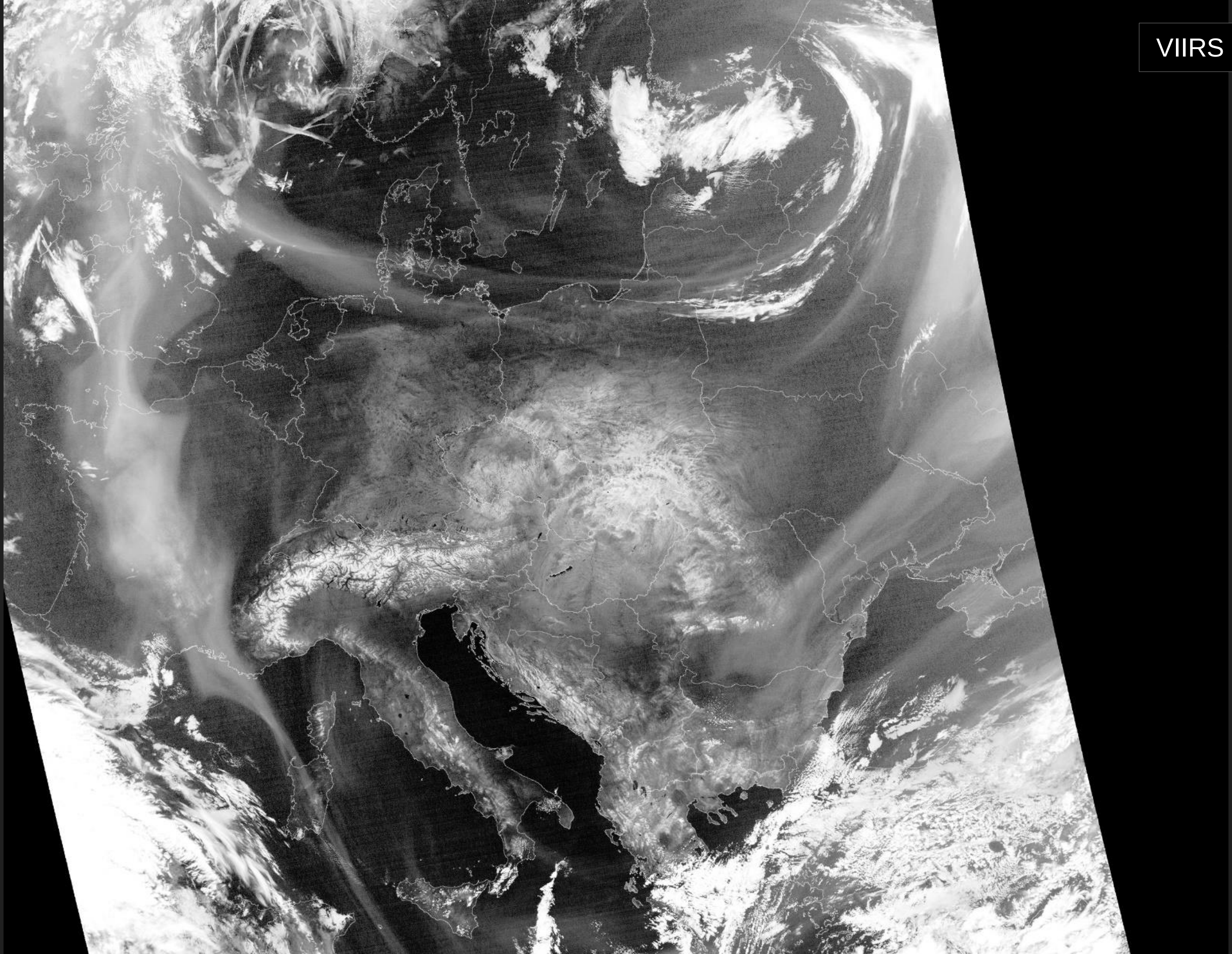



VIIRS 1.38 µm band


MSG WV 6.2 µm band

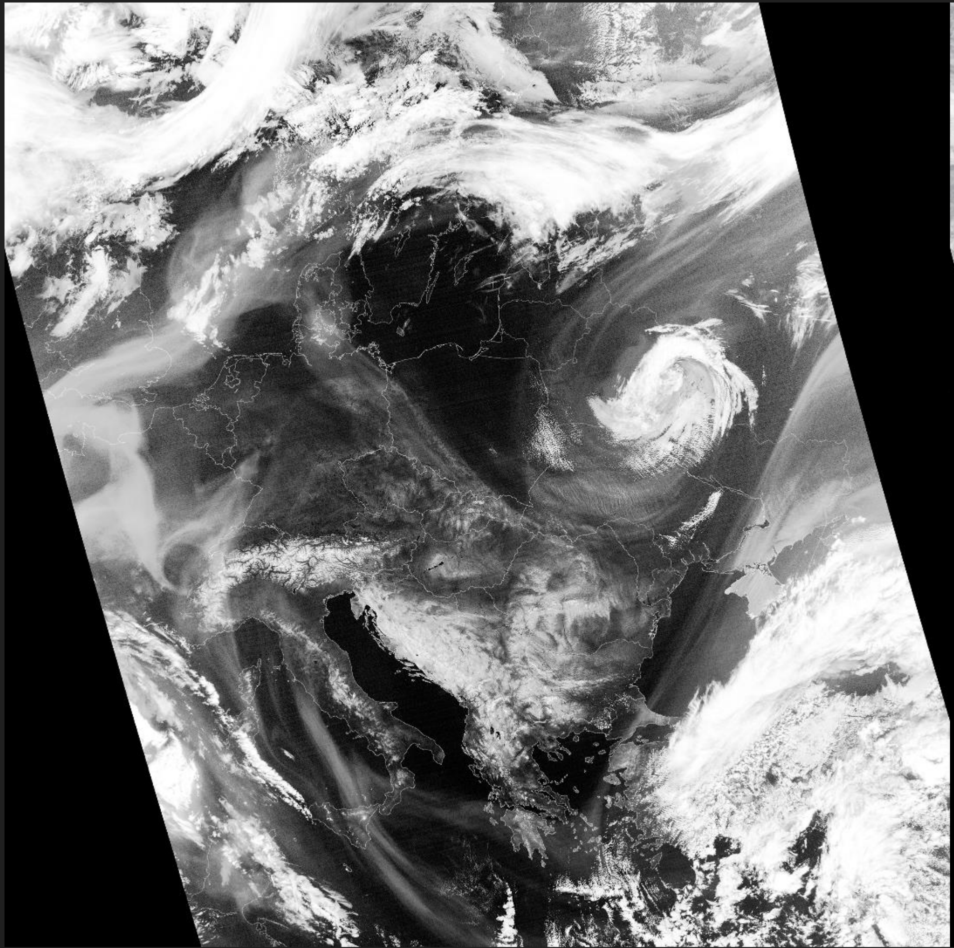


MSG WV 7.3 µm band

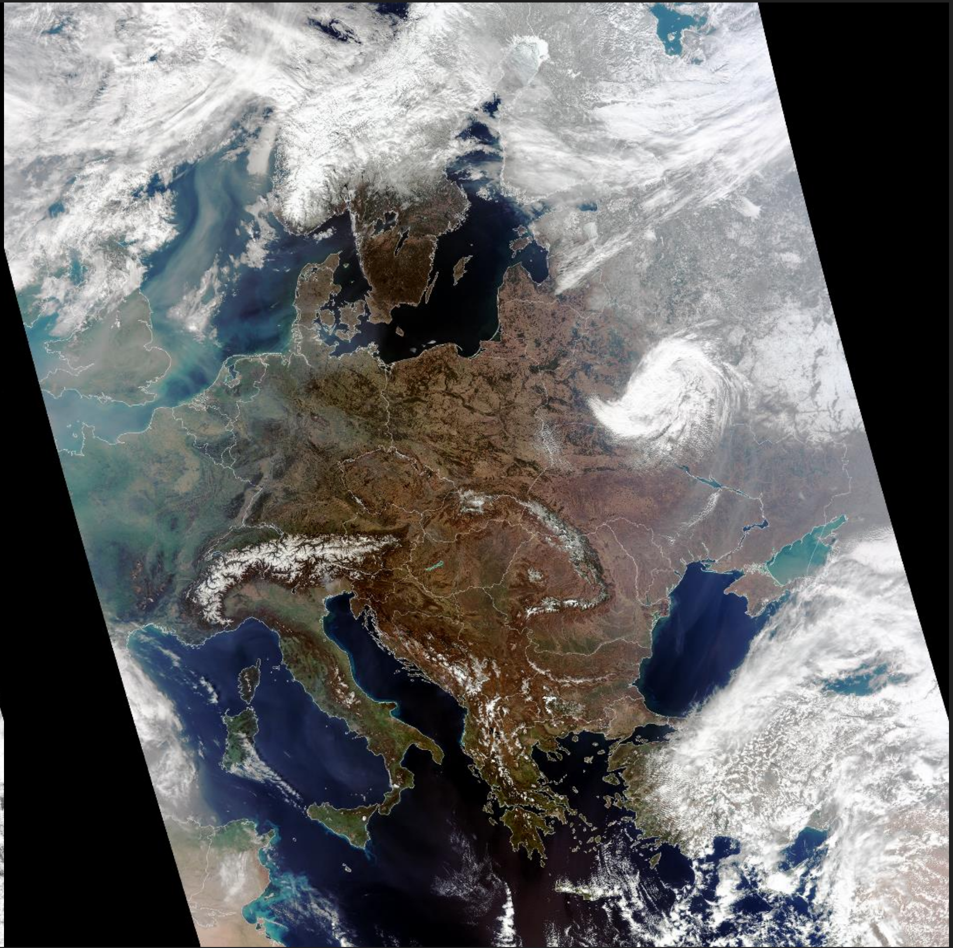

VIIRS 1.38 µm band

24 March 2022 11:25 UTC S-NPP

2022-03-24 11:25 UTC NPP

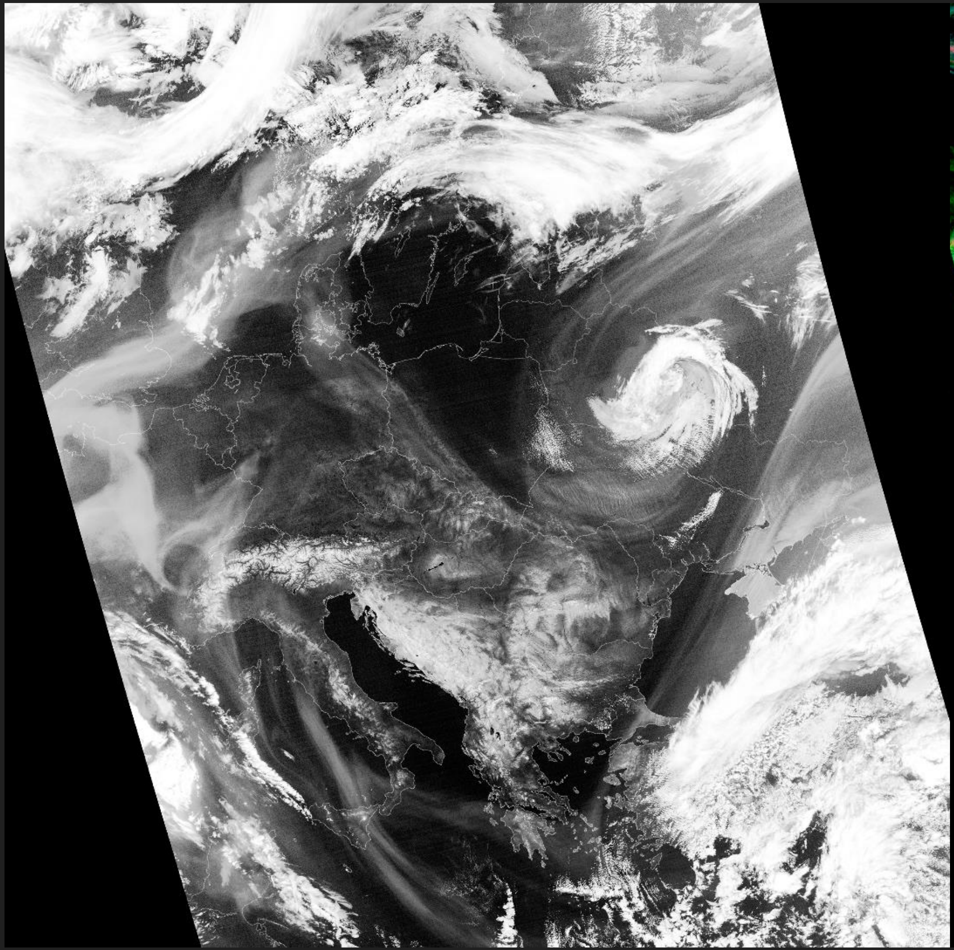


VIIRS 1.38 µm band (M09)

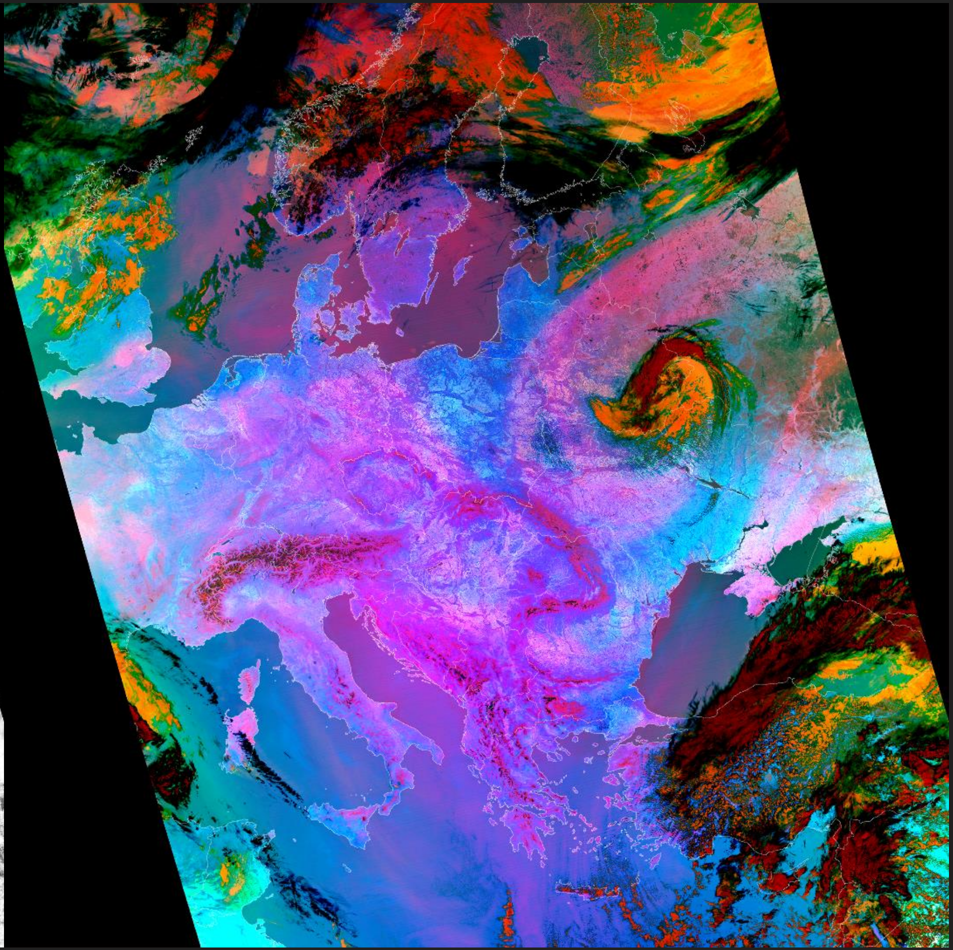


True-color RGB (VIIRS M-bands 5, 4, 3)

2022-03-24 11:25 UTC NPP



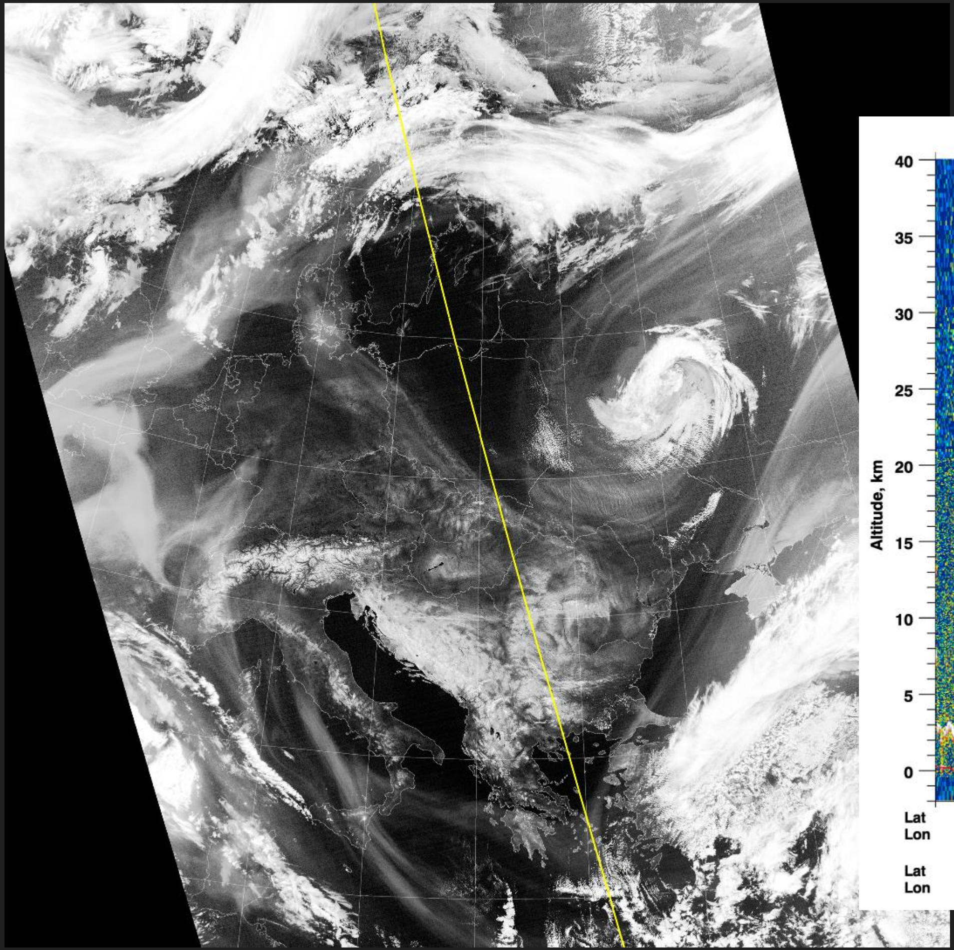
VIIRS 1.38 µm band (M09)

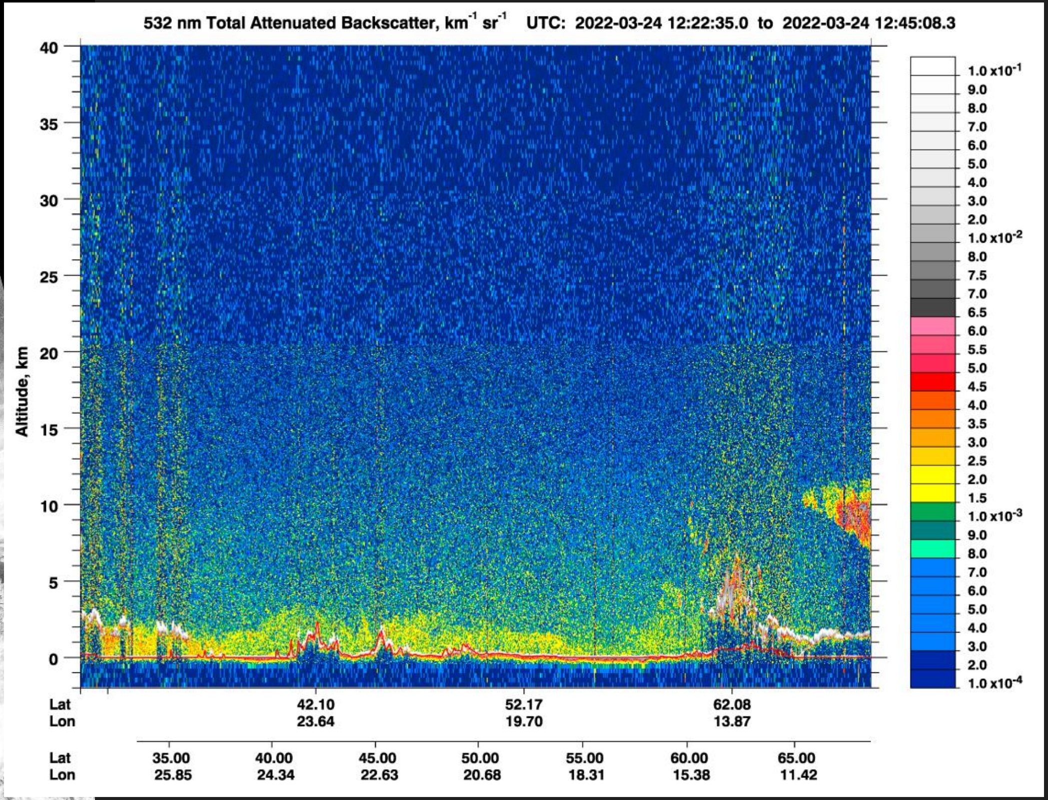


Dust RGB (VIIRS M-bands 16-15, 15-14, 15)

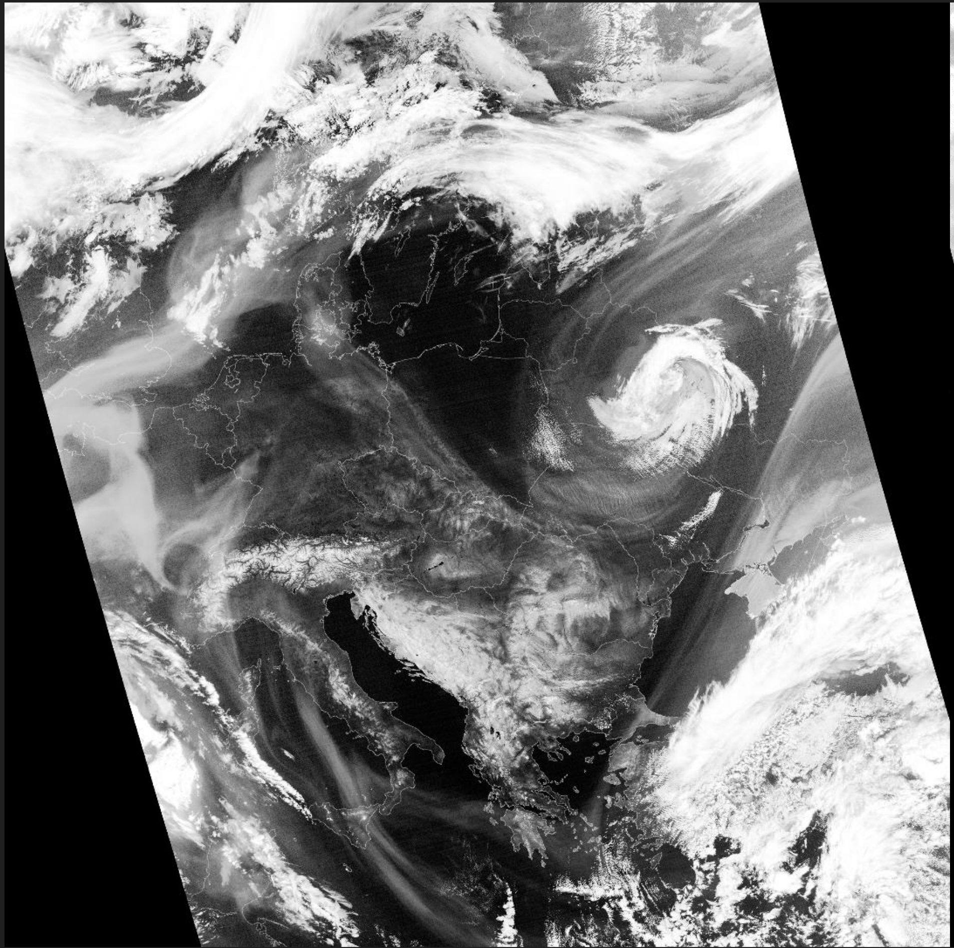
2022-03-24 11:25 UTC NPP VIIRS 1.38 μm band

VIIRS 1.38 μm band with CALIPSO track (yellow line), and CALIOP 532 nm profile

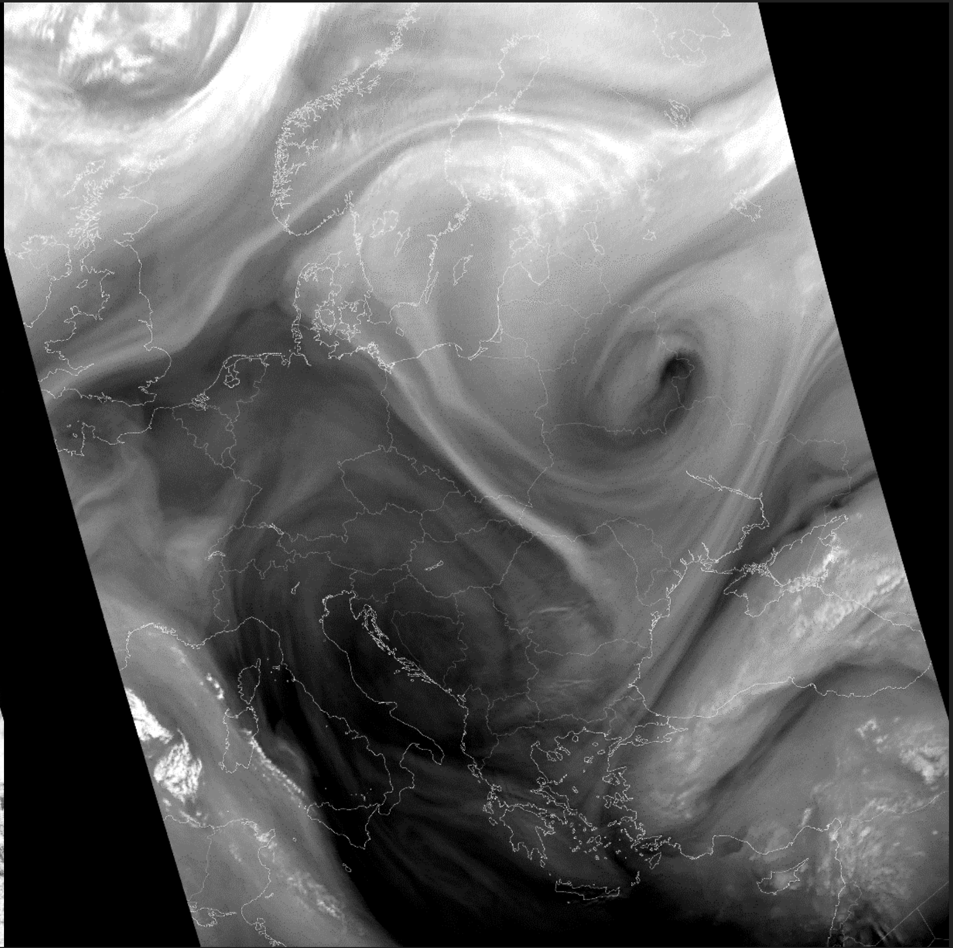




2022-03-24 11:25 UTC NPP VIIRS 1.38 μm band

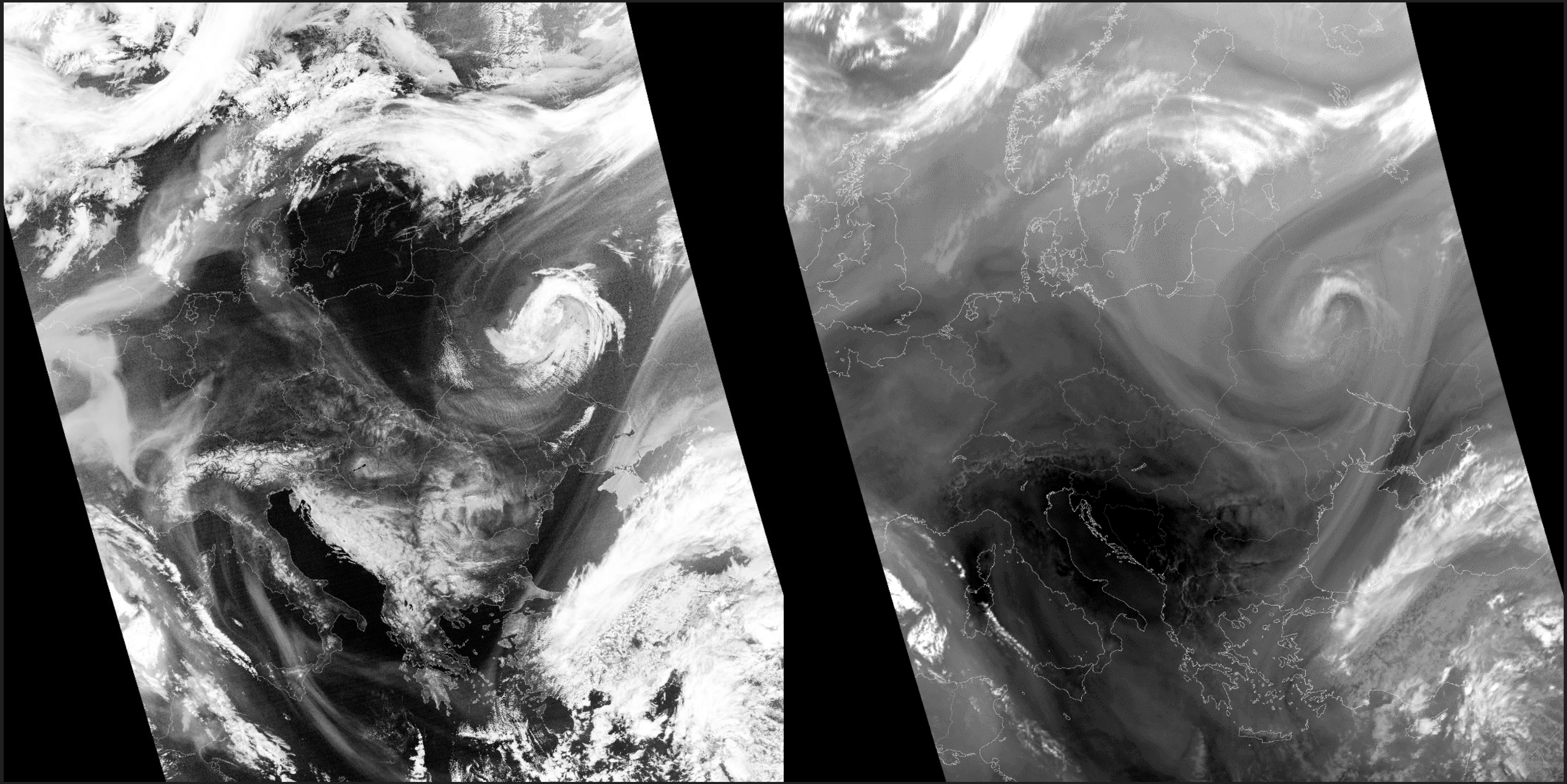


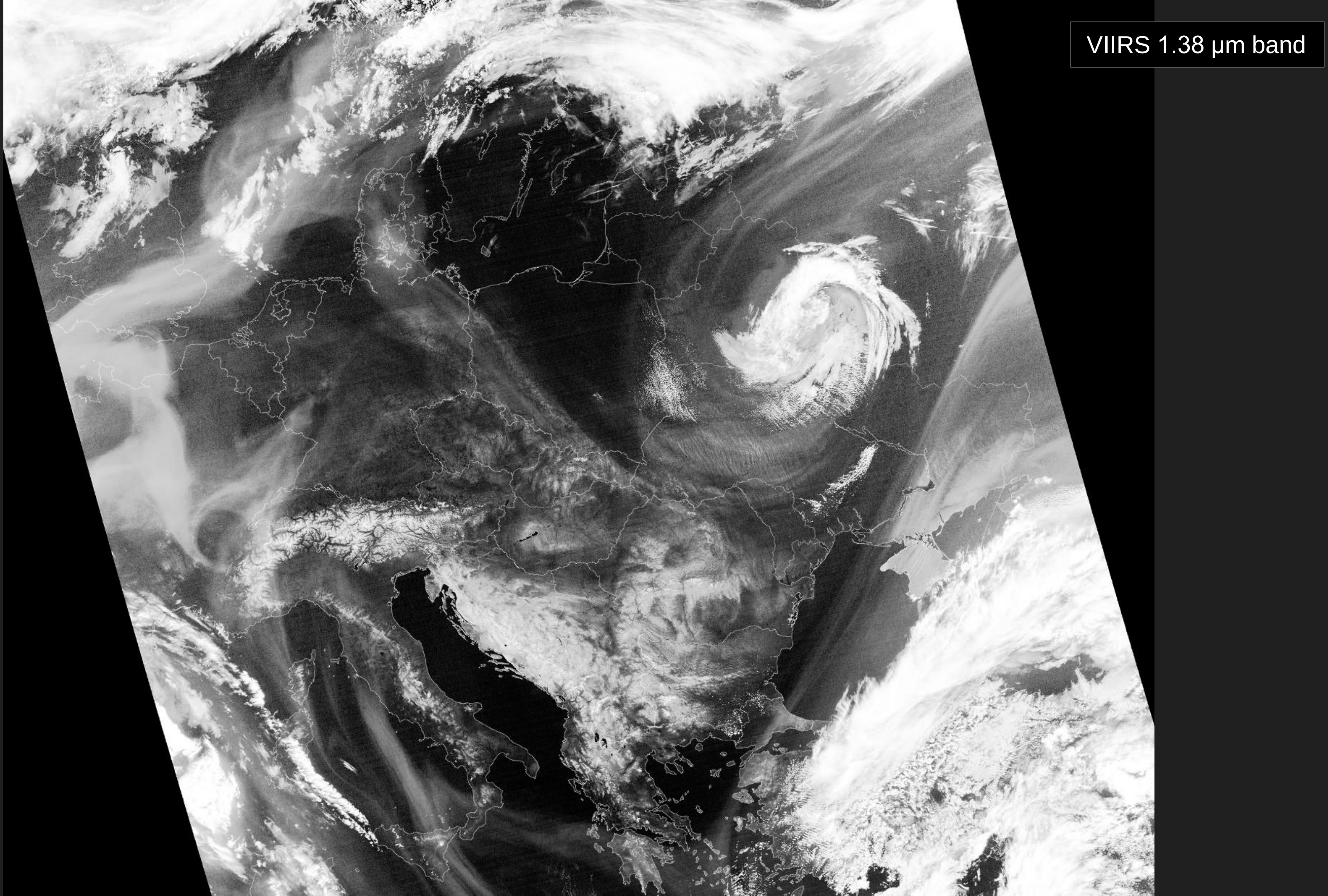
11:25 UTC MSG WV6.2

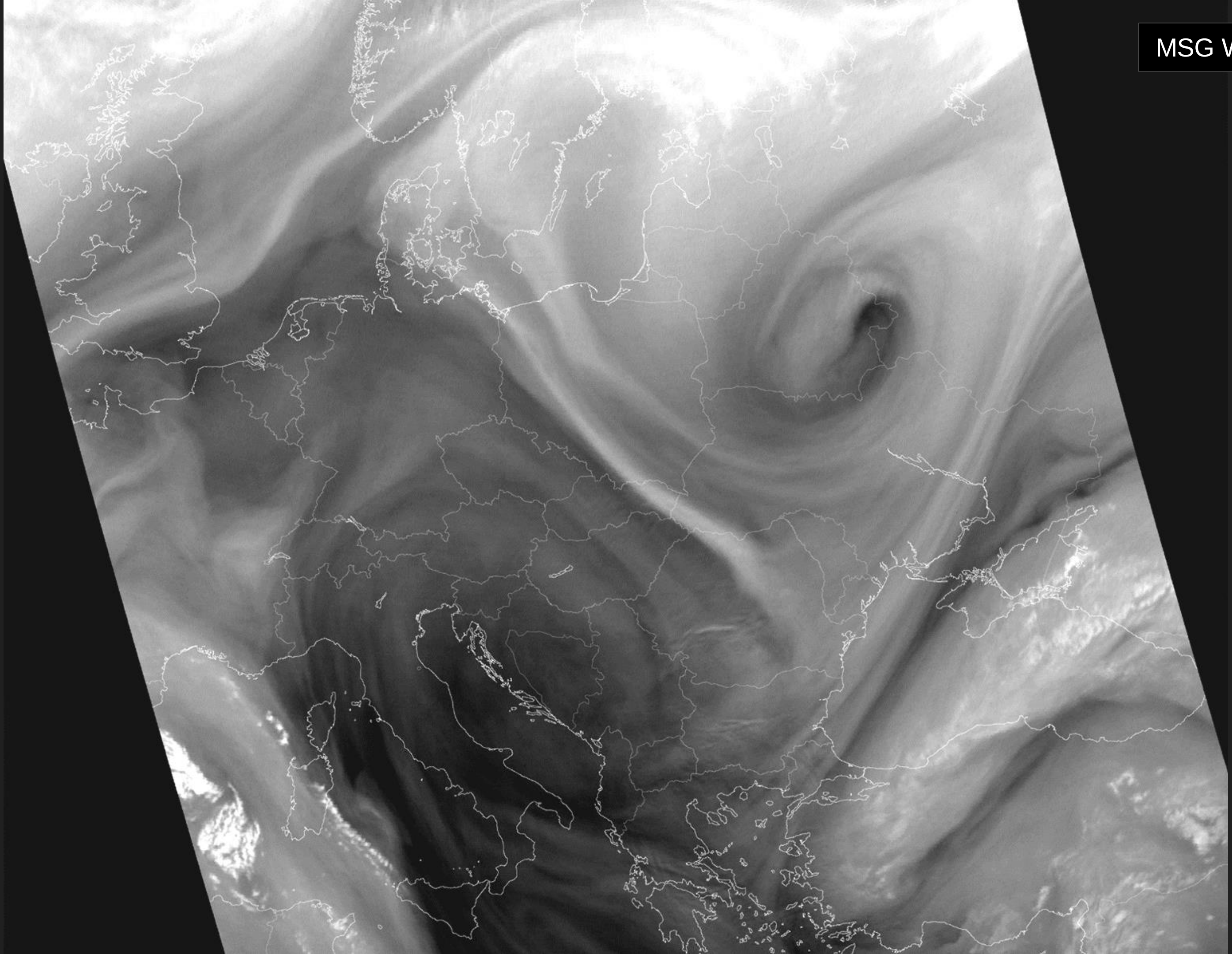


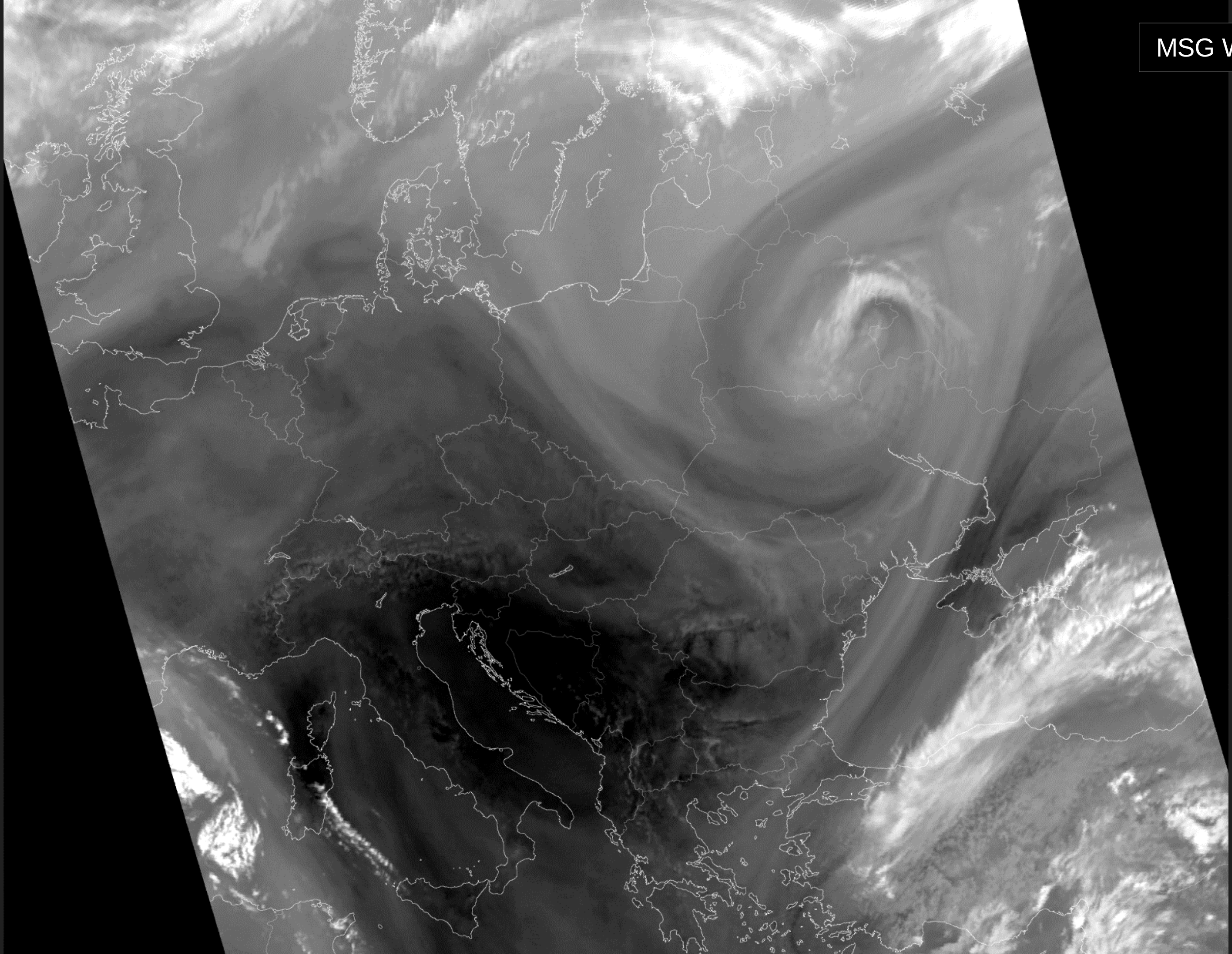
2022-03-24 11:25 UTC NPP VIIRS 1.38 µm band

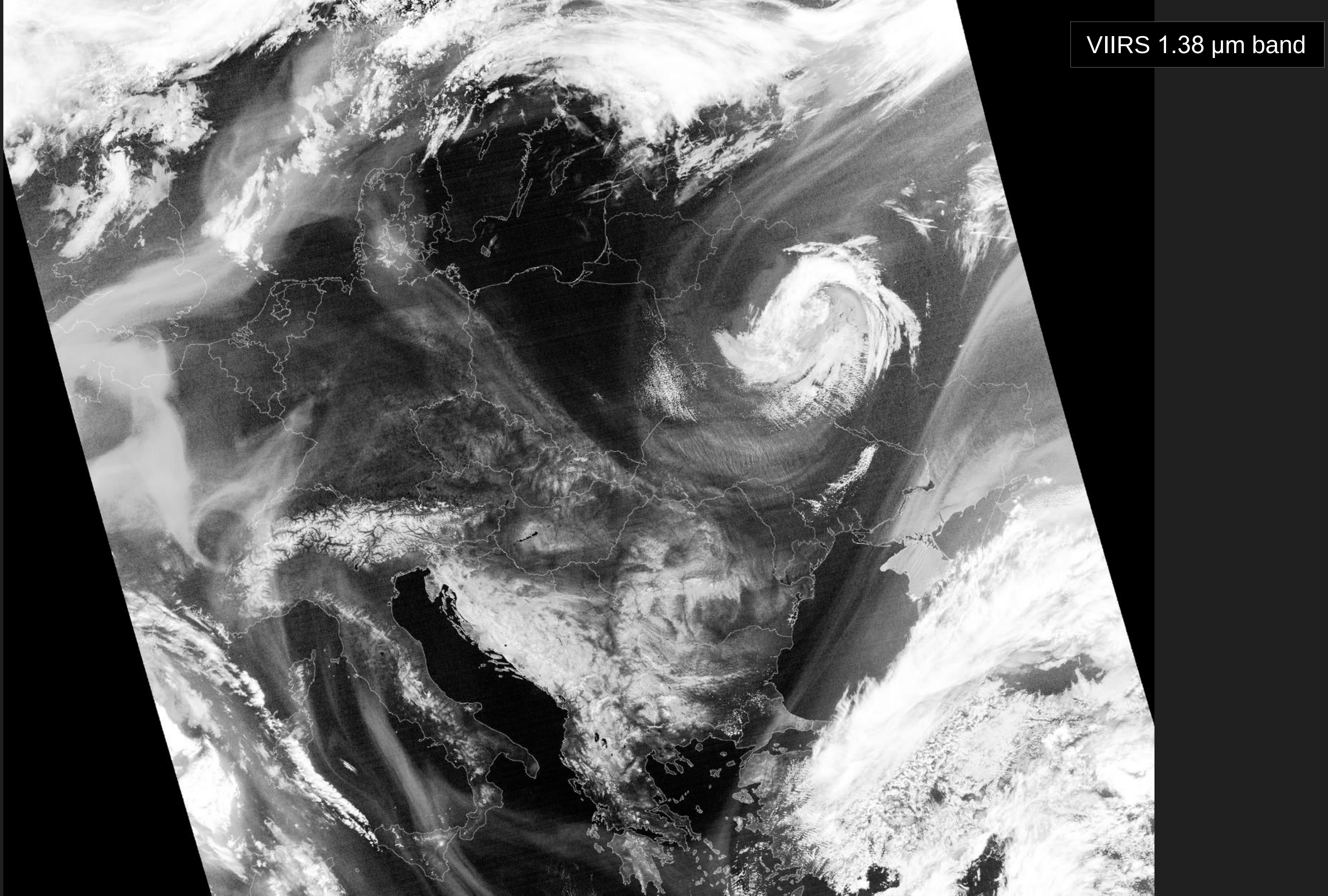
11:25 UTC MSG WV73

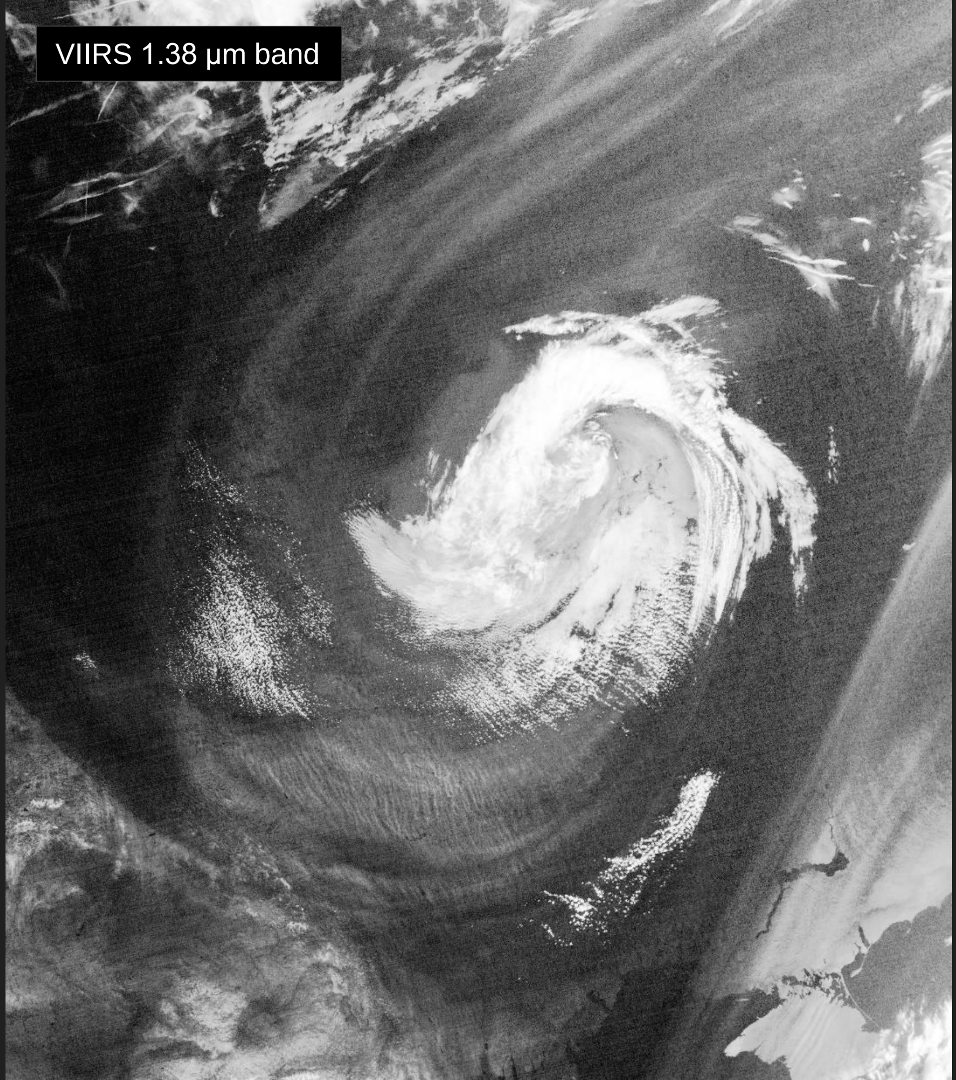


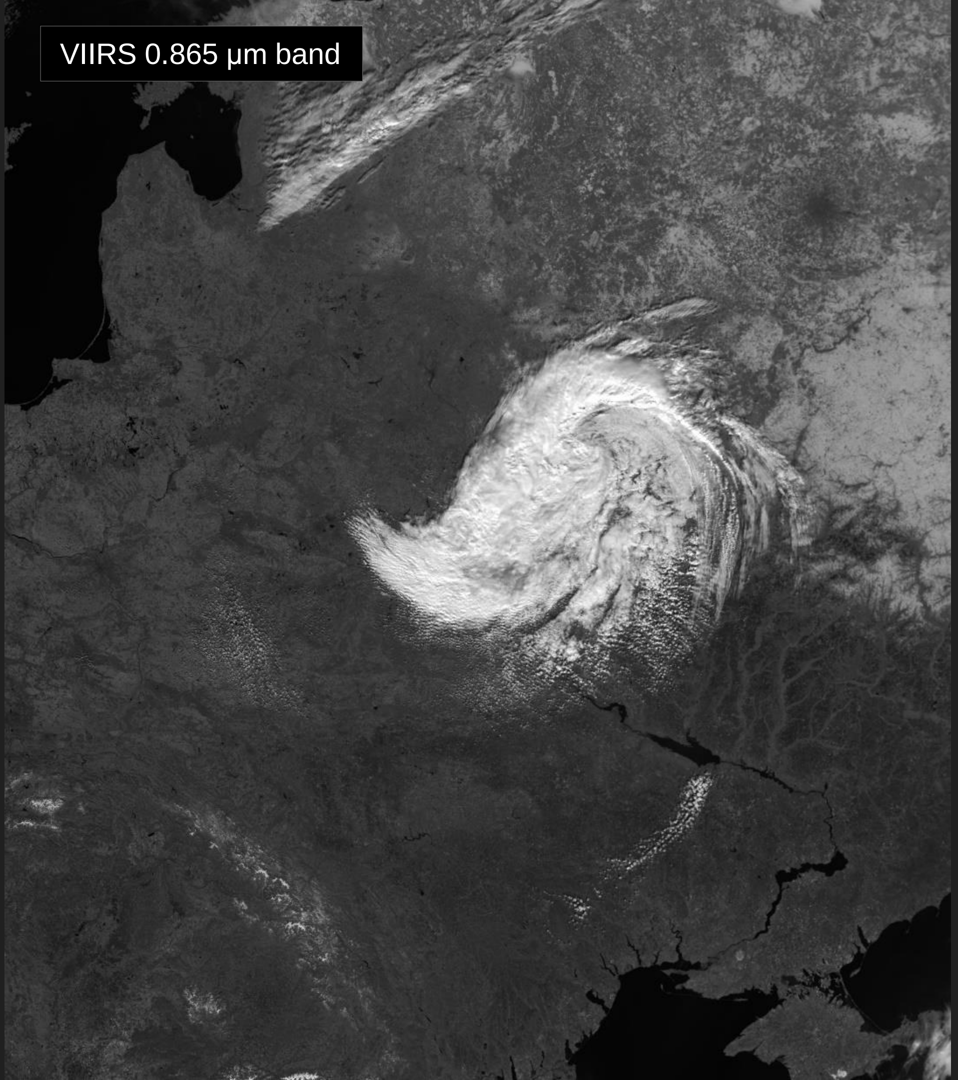

VIIRS 1.38 µm band


MSG WV 6.2 µm band


MSG WV 7.3 µm band


VIIRS 1.38 µm band


VIIRS 1.38 μm band


VIIRS 0.865 μm band

FINAL COMMENTS

1.38 μm spectral band – final comments

- Most of aerosols in the 1.38 μm band are found at very low radiances, typically at reflectance values under about 2.5 %. This necessitates applying very strong enhancement, to show all the details, using either histogram equalization stretch method, or very steep piecewise linear stretch enhancement, or high gamma (not tested by author so far).

- In contrary to very thin cirrus detection, detectability of aerosols usually strongly depends on total humidity in troposphere above these. However, visibility of aerosols is rather complicated – while some aerosols can be seen in dry regions only, in other cases the aerosol bands are co-located with higher humidity structures within the WV spectral bands.

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

- **All the cases shown in this presentation 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 (which will affect namely the MTG-I1 satellite). Should be mitigated for the follow-up MTG-I satellites.**

Data:

- Suomi-NPP and NOAA-20 (JPSS-1) VIIRS M-bands, 750 m pixel resolution
- L1B data source: NOAA CLASS archive

Processing:

- ENVI and its VCTK plugin
- modest fine-tuning of some of the images in Adobe Photoshop

Support and acknowledgements:

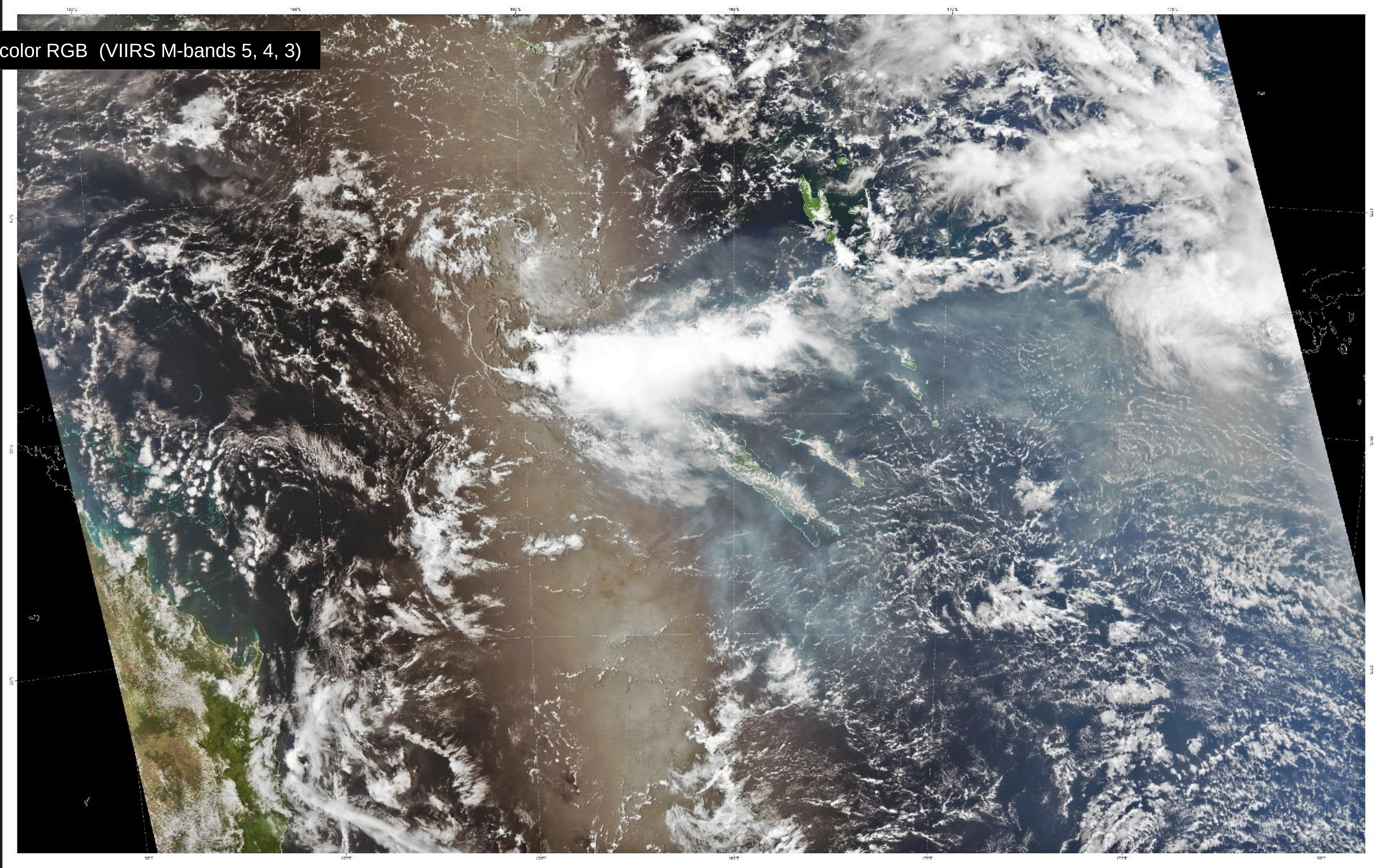
- This work has been partially supported by the CHMI research project „*Dlouhodobá koncepce rozvoje výzkumné organizace (DKRVO) Český hydrometeorologický ústav na období 2018-2022*", financed by the Czech Ministry of Environment.

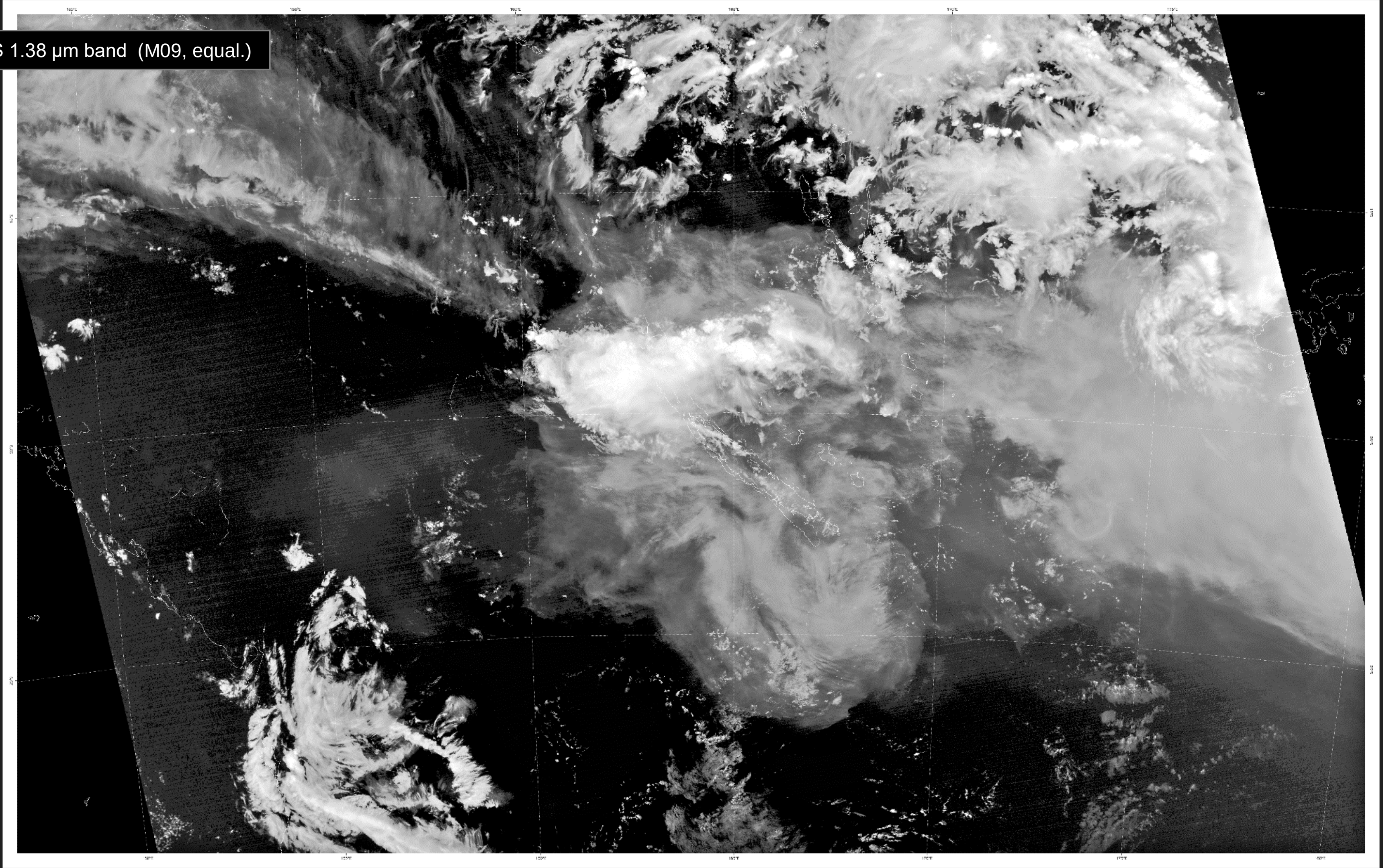
Additional slides

Ash plume from Hunga Tonga eruption

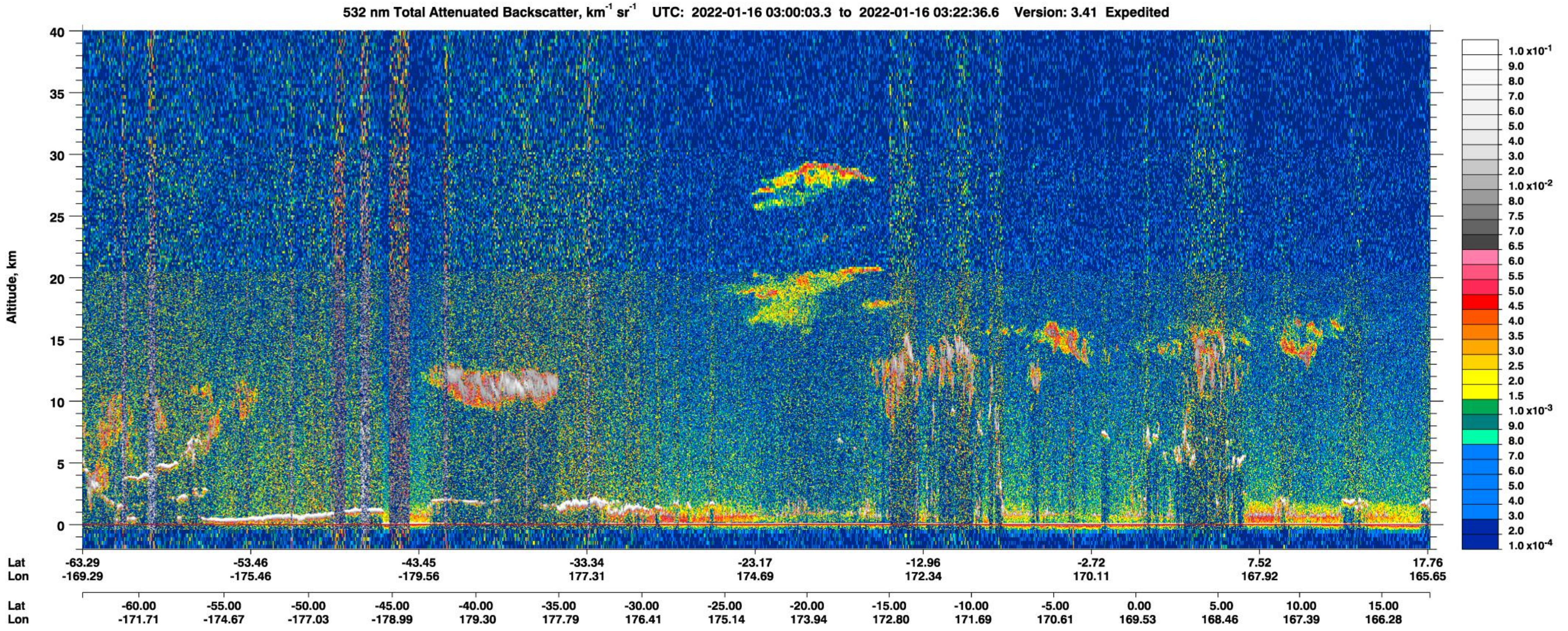
2022-01-16 02:40 UTC NOAA-20

True-color RGB (VIIRS M-bands 5, 4, 3)




VIIRS 1.38 µm band (M09, equal.)

2022-01-16 03:10 UTC CALIPSO / CALIOP 532 nm profile



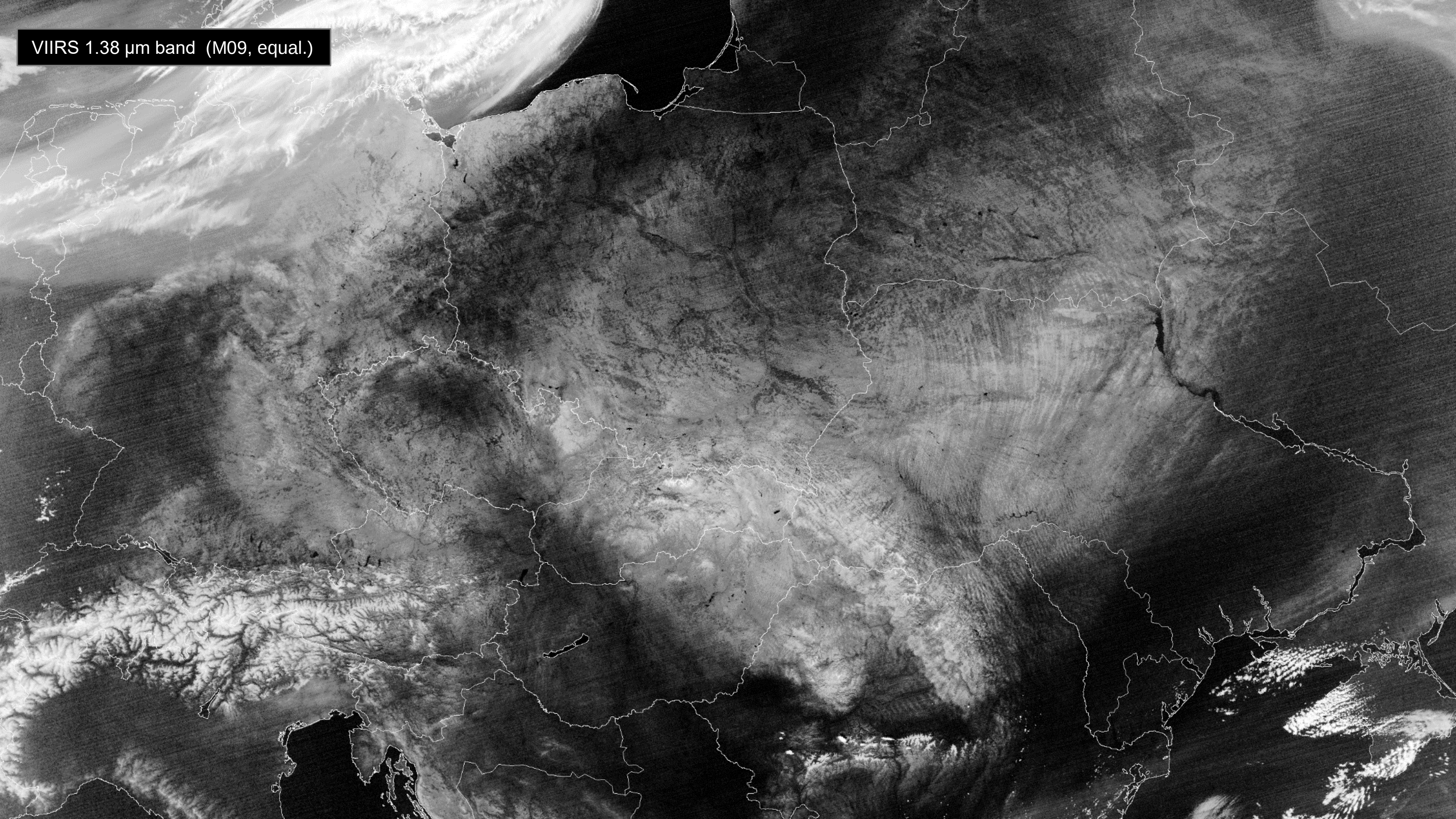
THE END

Additional slides

- – detailed images of near-ground aerosols and moisture

22 March 2022 11:15 UTC NOAA-20

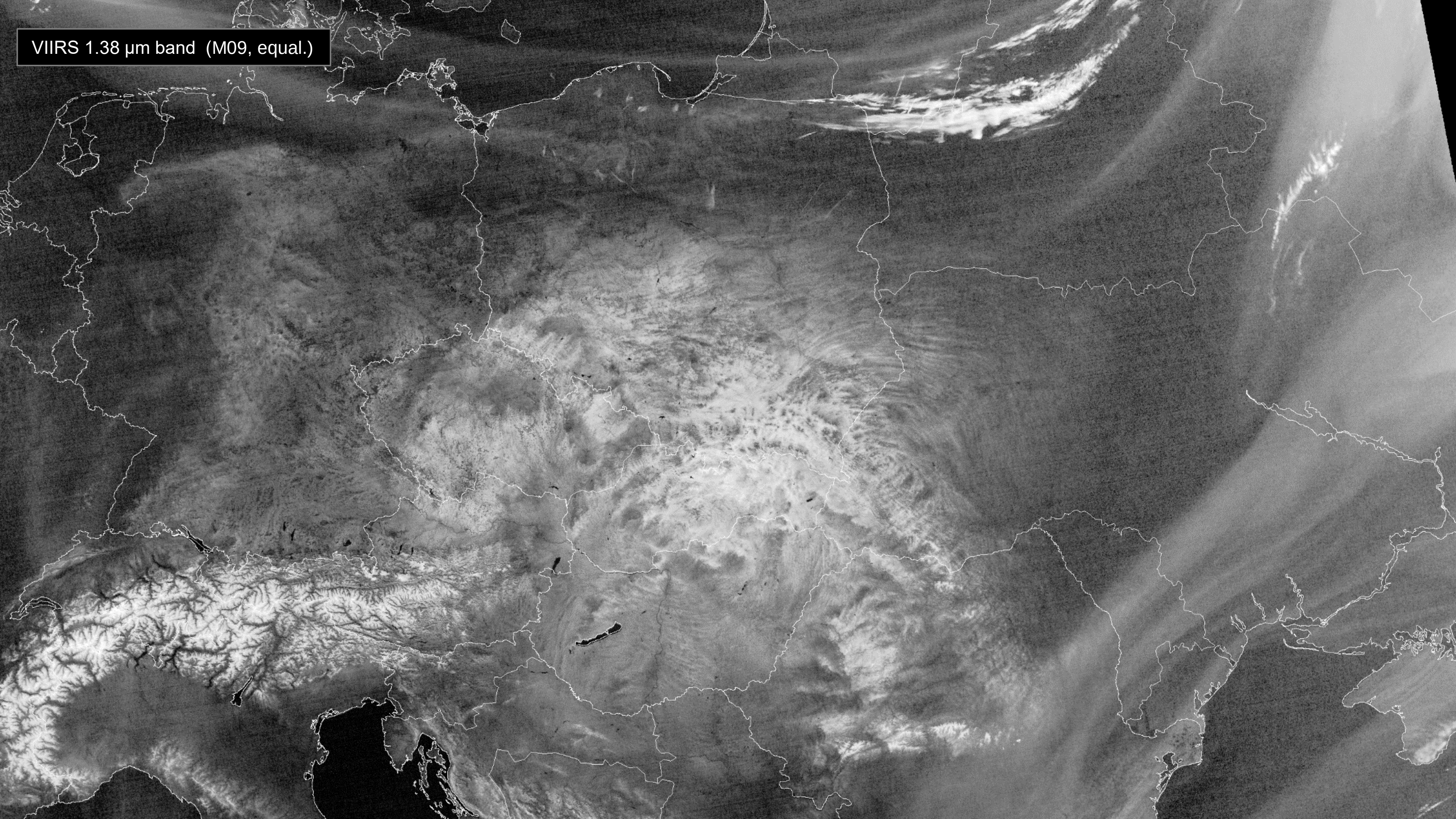

True-color RGB (VIIRS M-bands 5, 4, 3)

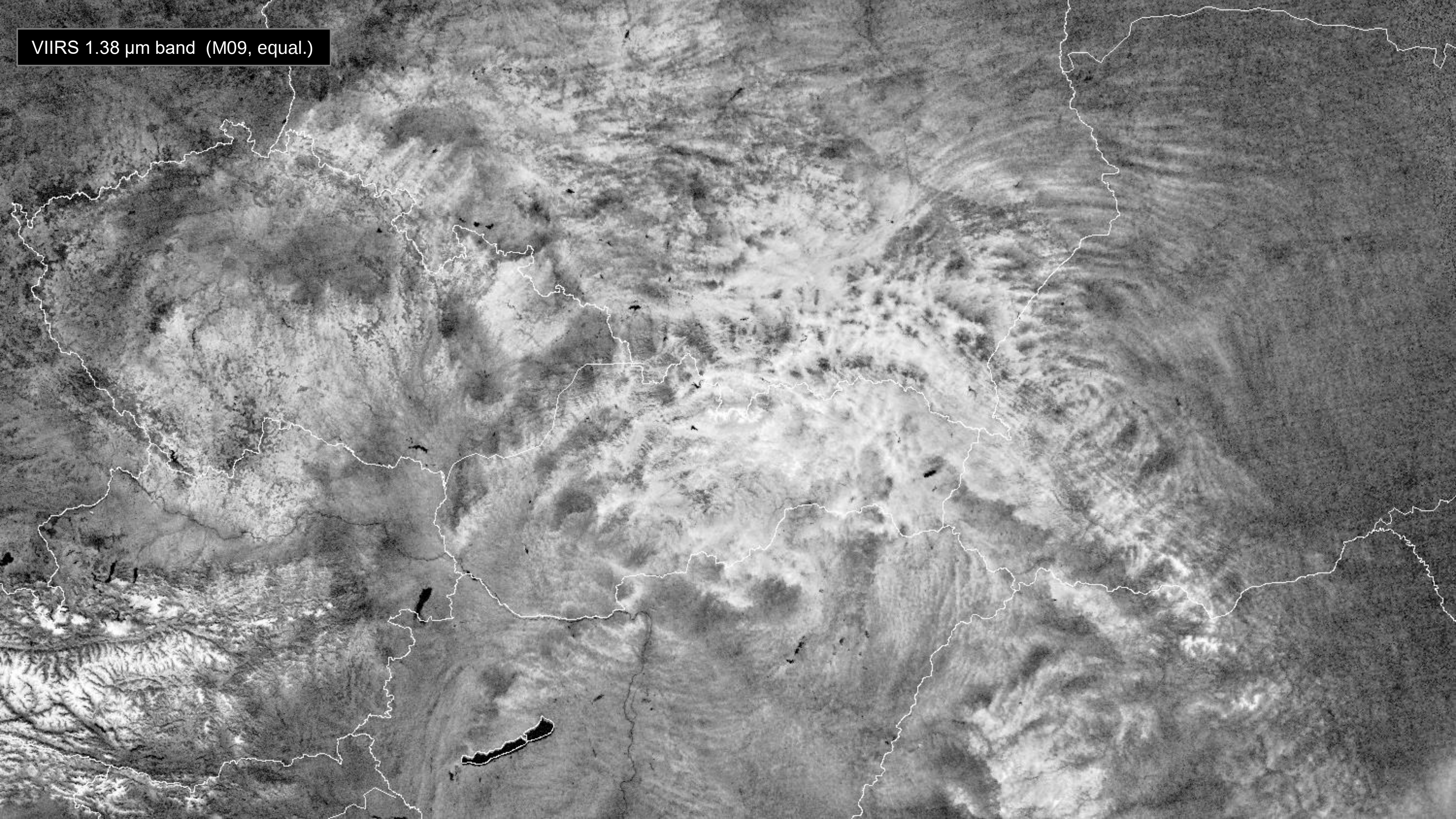

VIIRS 1.38 µm band (M09, equal.)


VIIRS 1.38 µm band (M09, equal.)

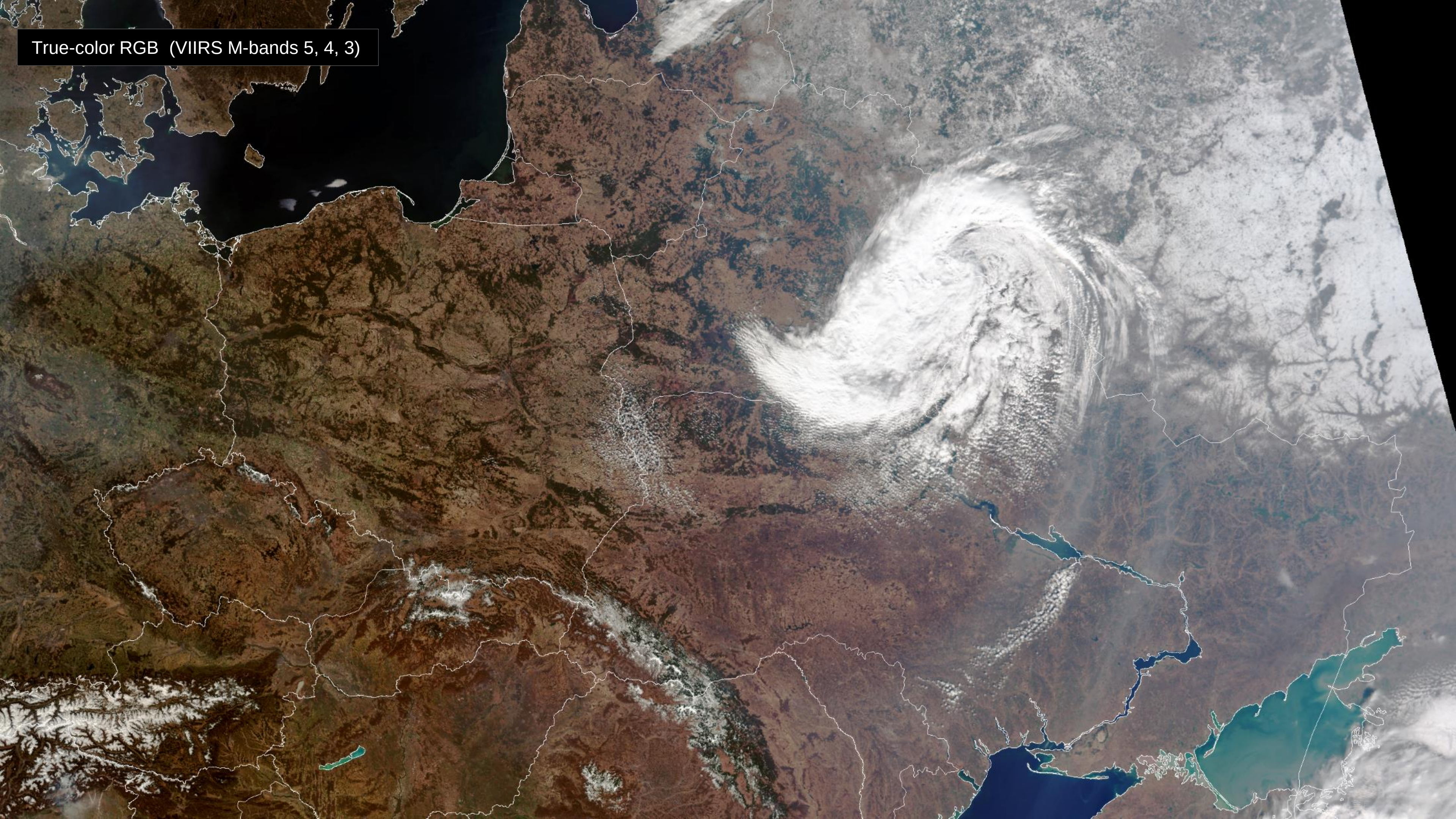
23 March 2022 11:45 UTC S-NPP

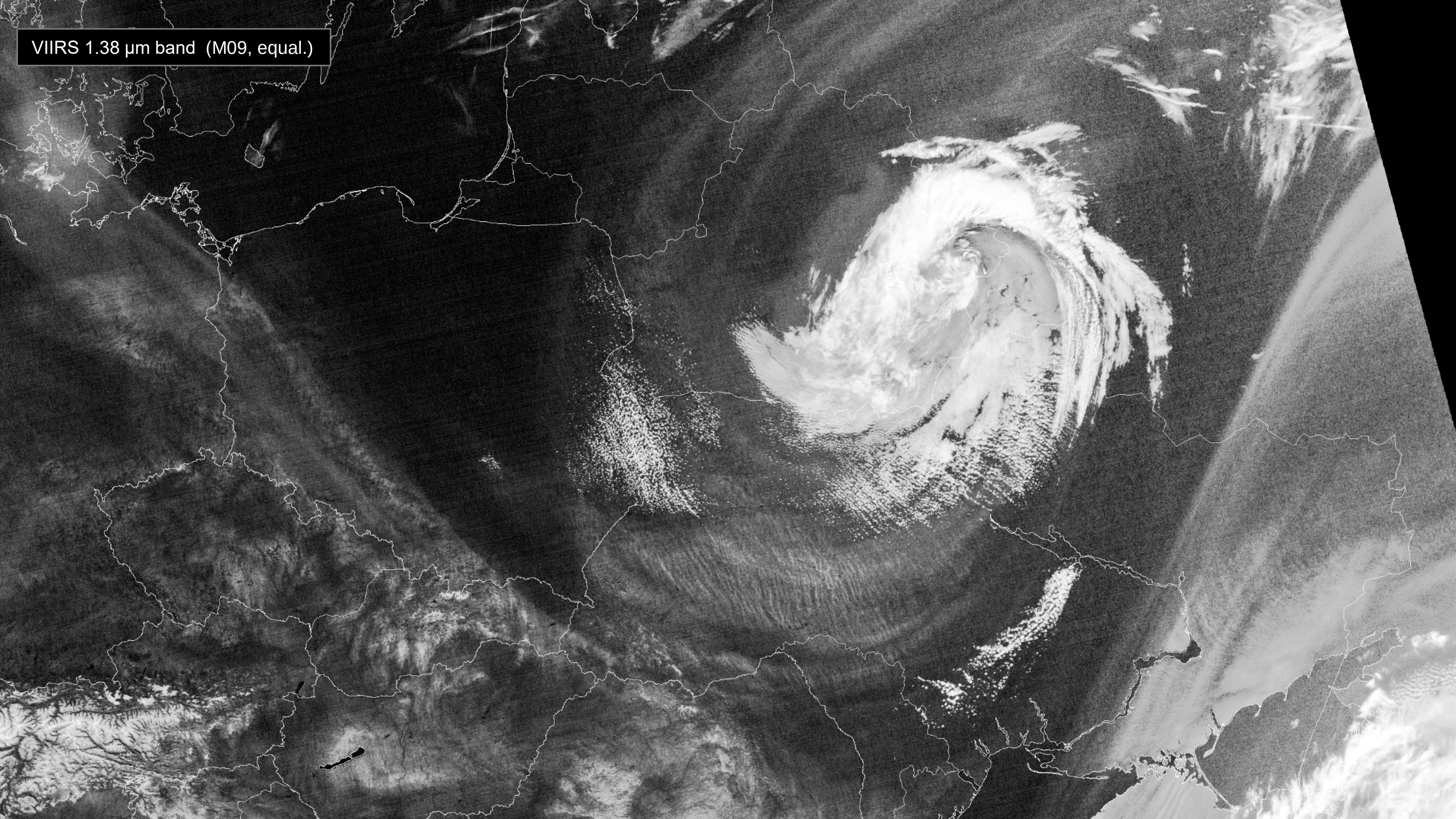

True-color RGB (VIIRS M-bands 5, 4, 3)

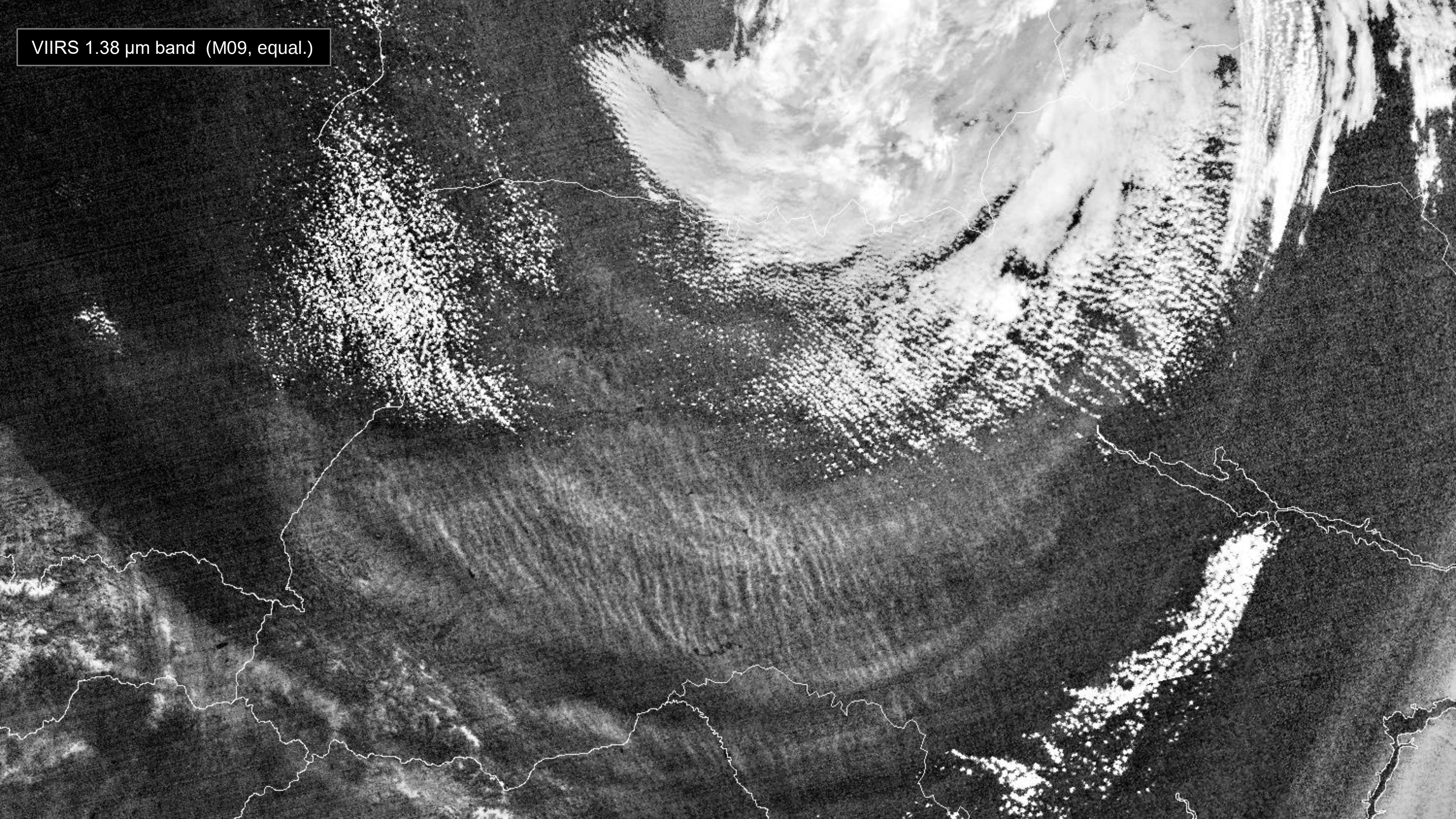

VIIRS 1.38 µm band (M09, equal.)


VIIRS 1.38 µm band (M09, equal.)

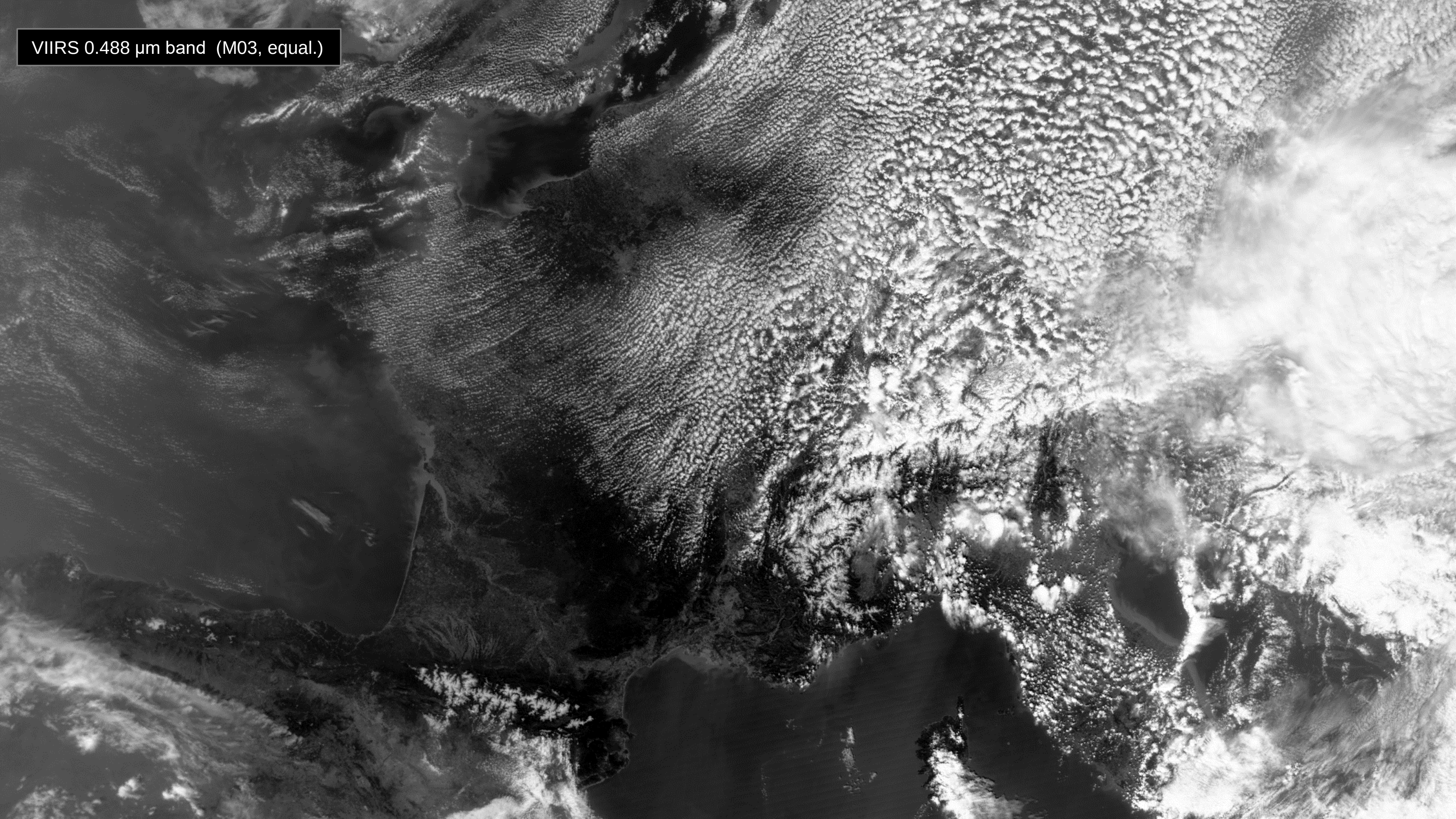
24 March 2022 11:25 UTC S-NPP

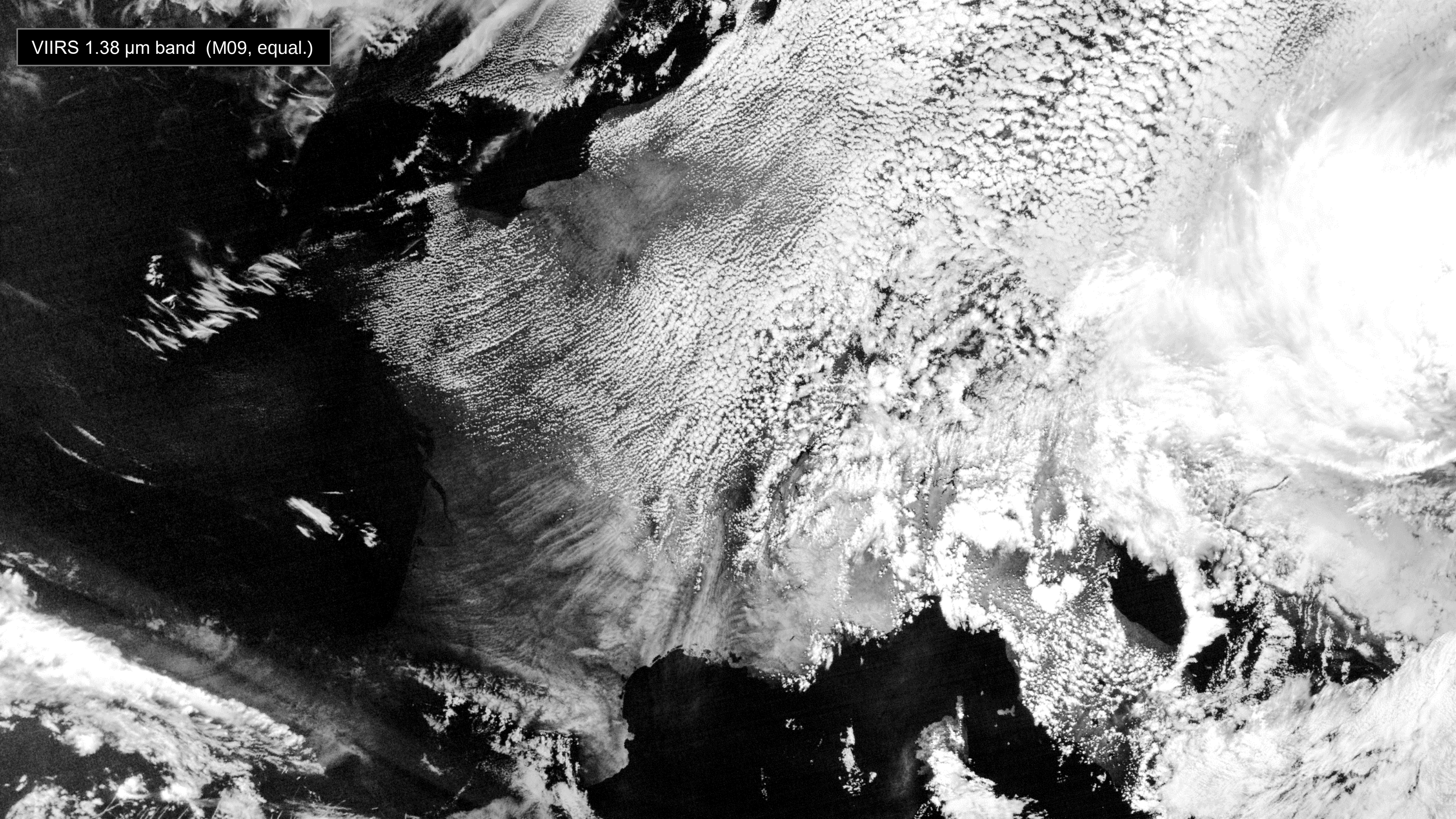

True-color RGB (VIIRS M-bands 5, 4, 3)

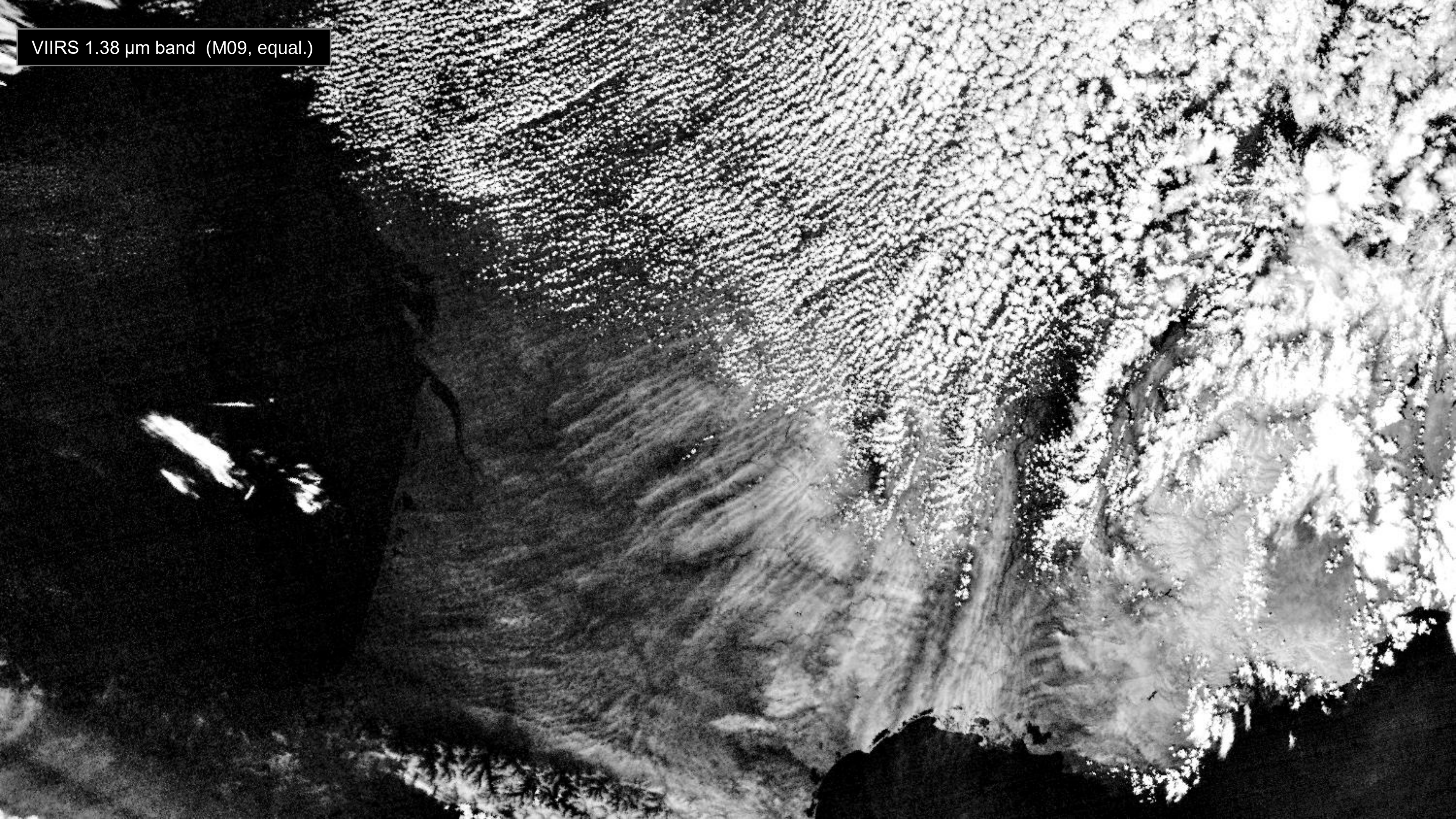

VIIRS 1.38 µm band (M09, equal.)


VIIRS 1.38 µm band (M09, equal.)

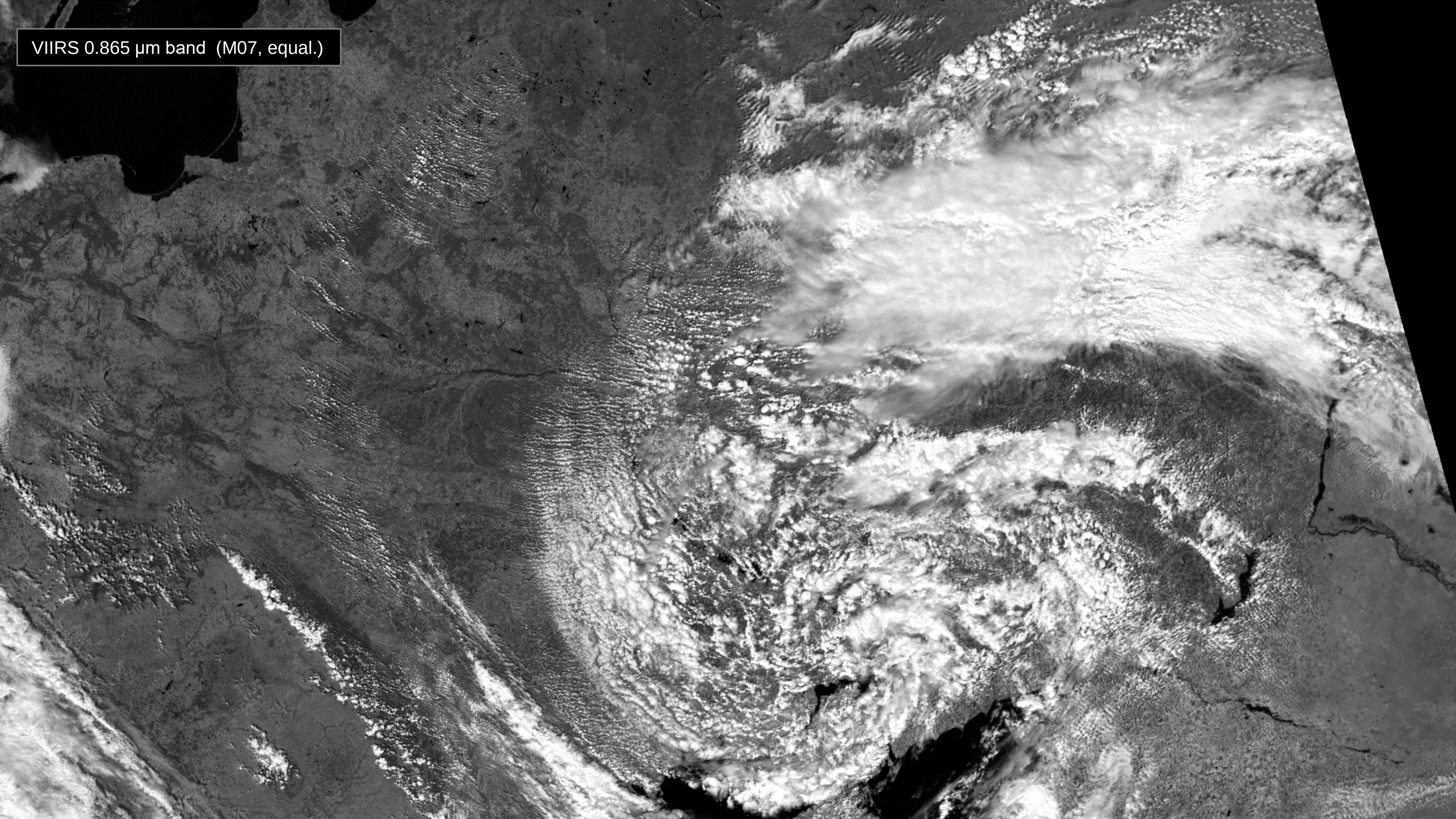
19 April 2017 12:15 UTC S-NPP

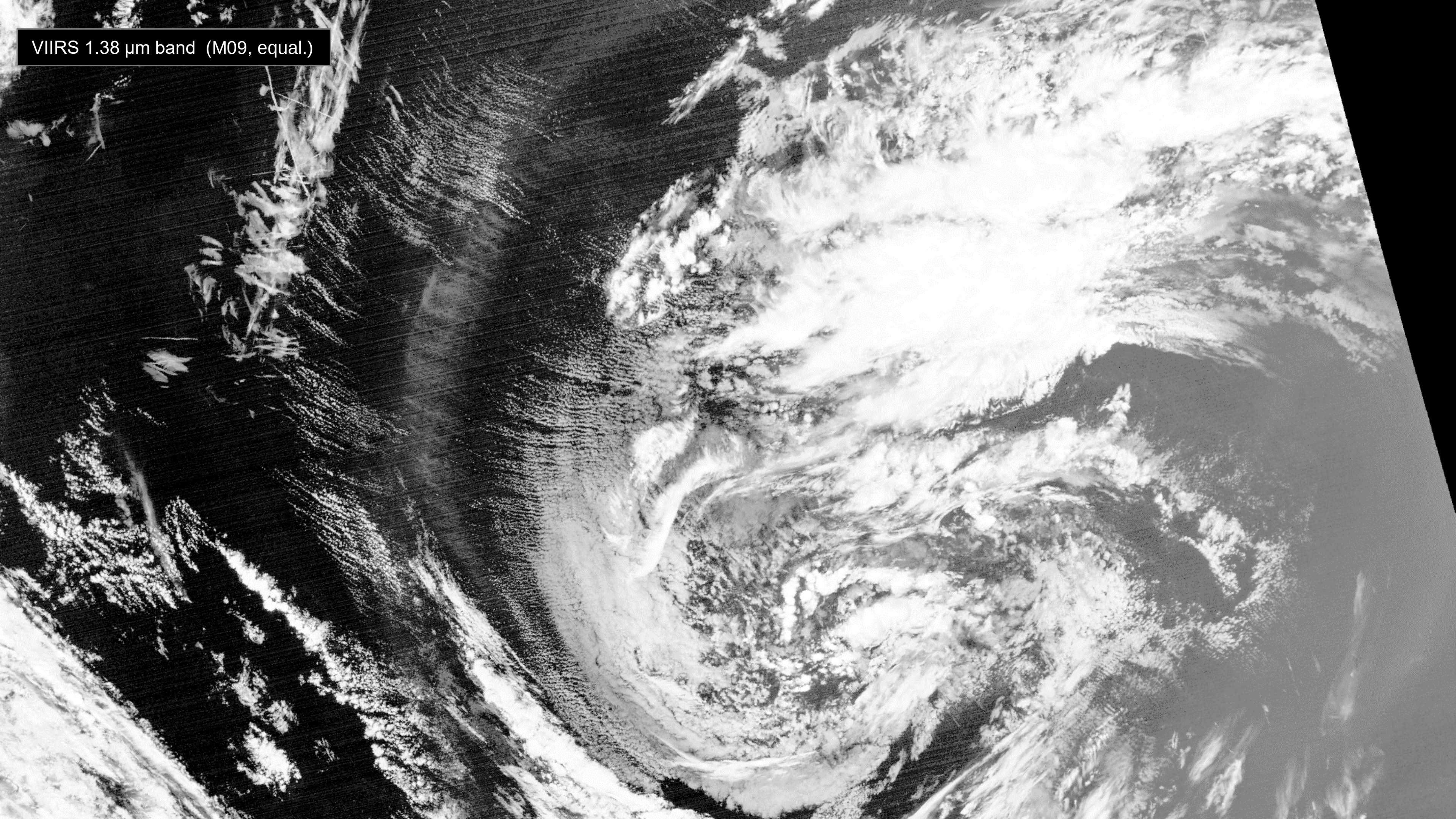

VIIRS 0.488 µm band (M03, equal.)

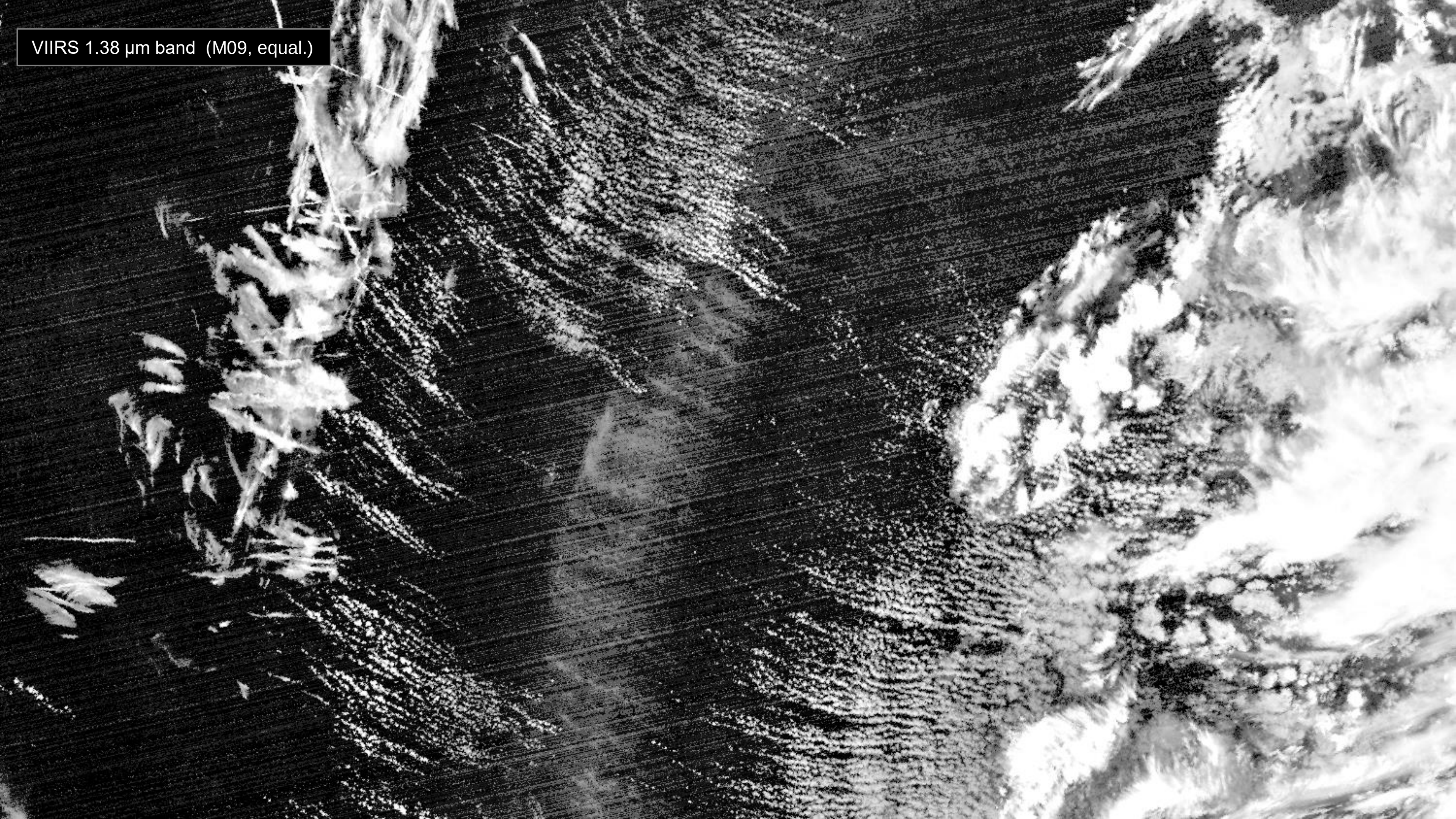

VIIRS 1.38 µm band (M09, equal.)


VIIRS 1.38 µm band (M09, equal.)

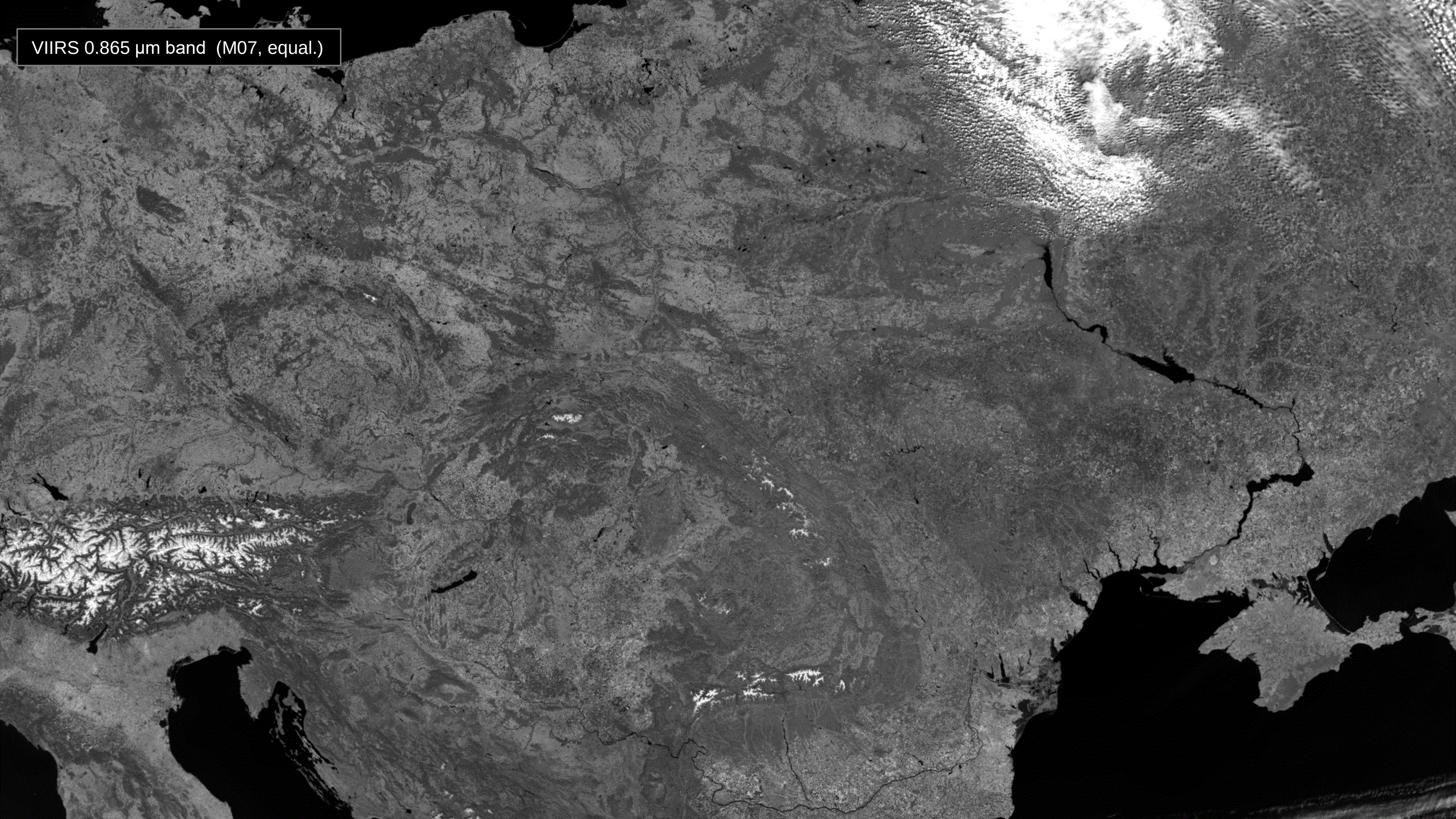
21 May 2021 11:00 UTC NOAA-20

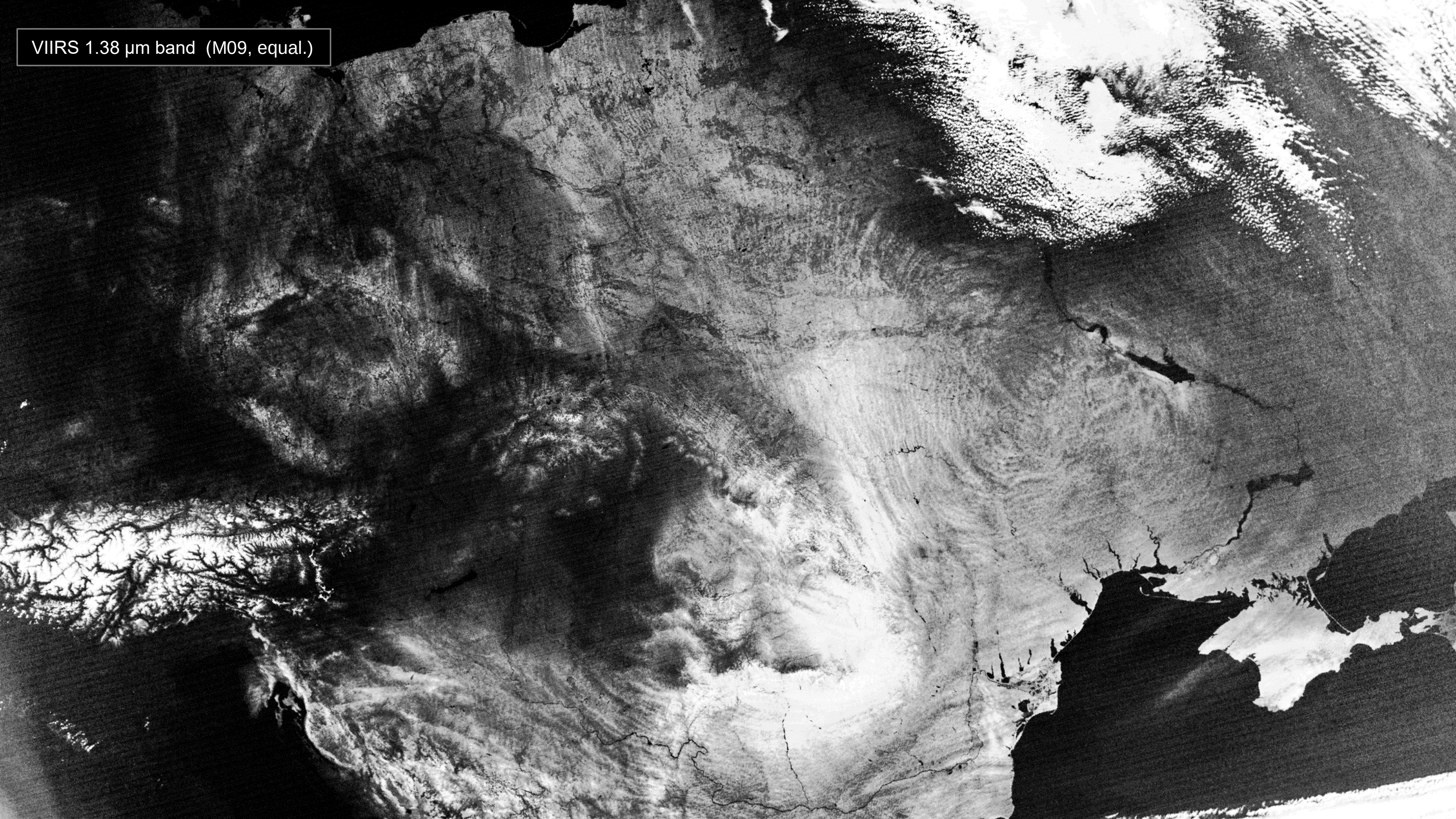

VIIRS 0.865 µm band (M07, equal.)

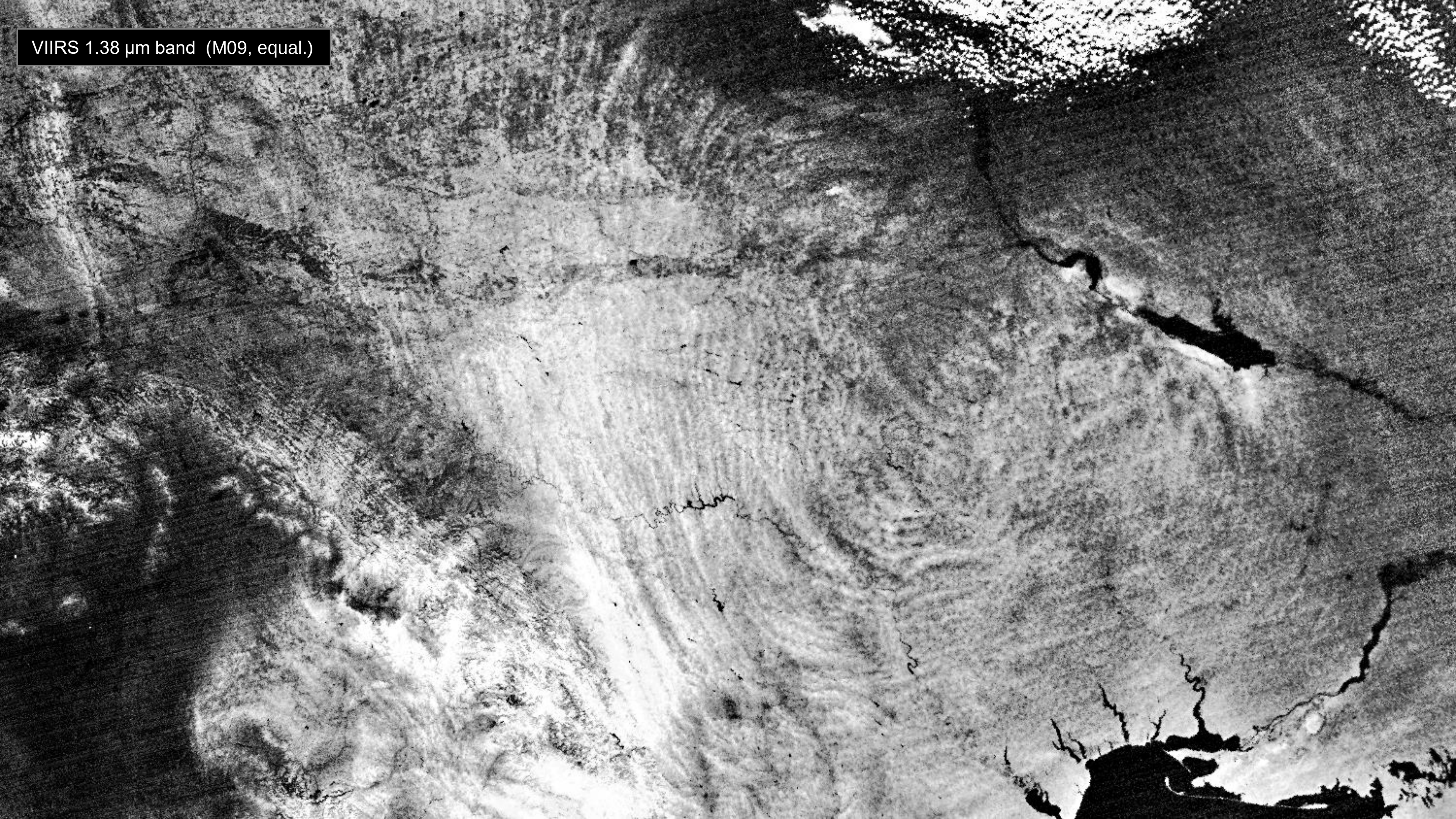

VIIRS 1.38 µm band (M09, equal.)


VIIRS 1.38 μm band (M09, equal.)

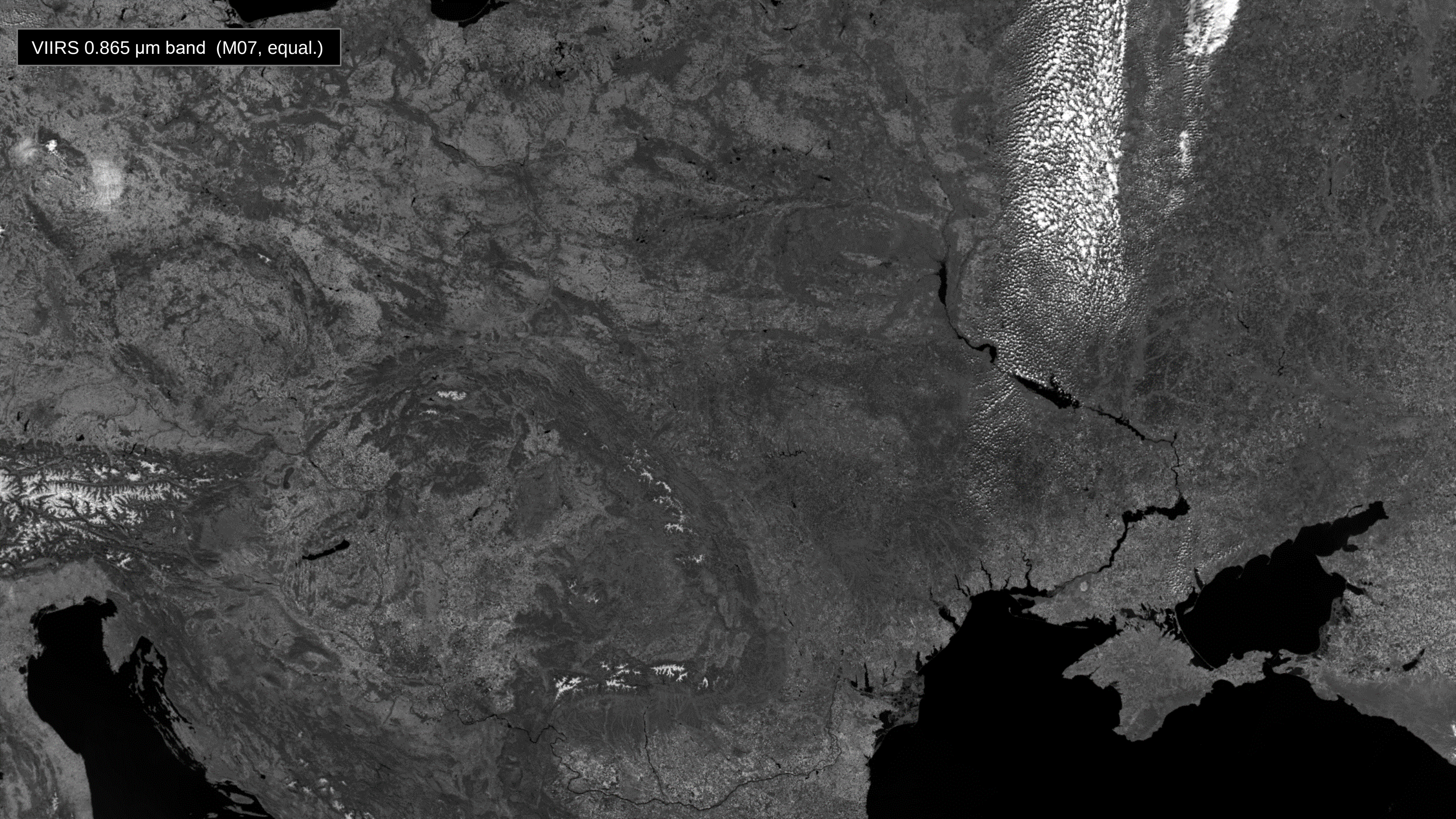
06 April 2020 11:18 UTC NOAA-20


VIIRS 0.865 µm band (M07, equal.)


VIIRS 1.38 µm band (M09, equal.)


VIIRS 1.38 µm band (M09, equal.)

07 April 2020 11:00 UTC NOAA-20


VIIRS 0.865 µm band (M07, equal.)


VIIRS 1.38 µm band (M09, equal.)


VIIRS 1.38 µm band (M09, equal.)