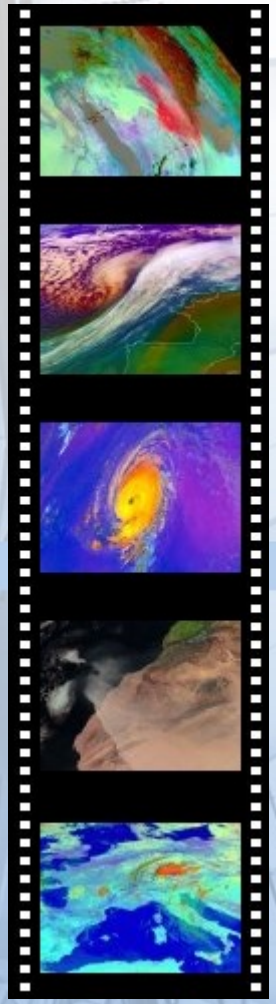

Dust & Smoke Detection with MSG SEVIRI RGB Products

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Satellite Meteorologist, Training Officer
(jochen.kerkmann@eumetsat.int)

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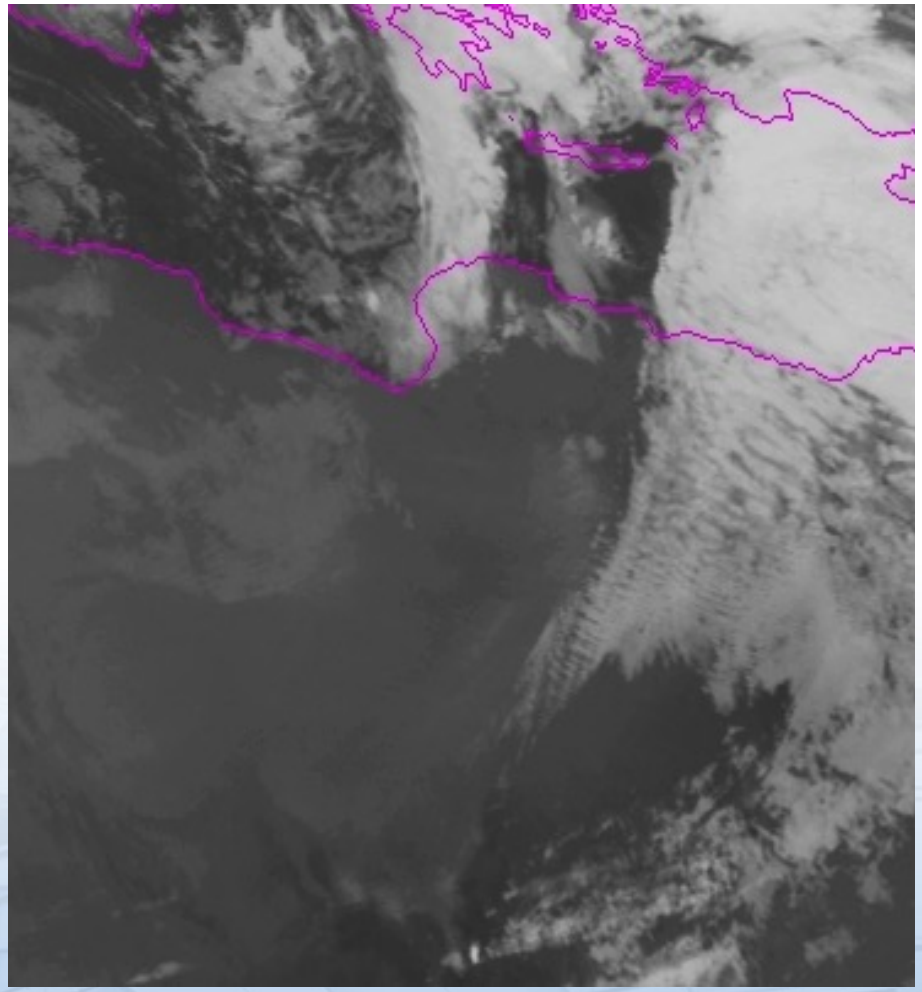
Outline (Dust and Smoke Detection)

- Early MSG Findings
- Introduction to RGB Products
- Smoke versus Dust
- The IR Window Differences
- The Dust RGB Product + Colour Interpretation
- Types of Dust Outbreaks

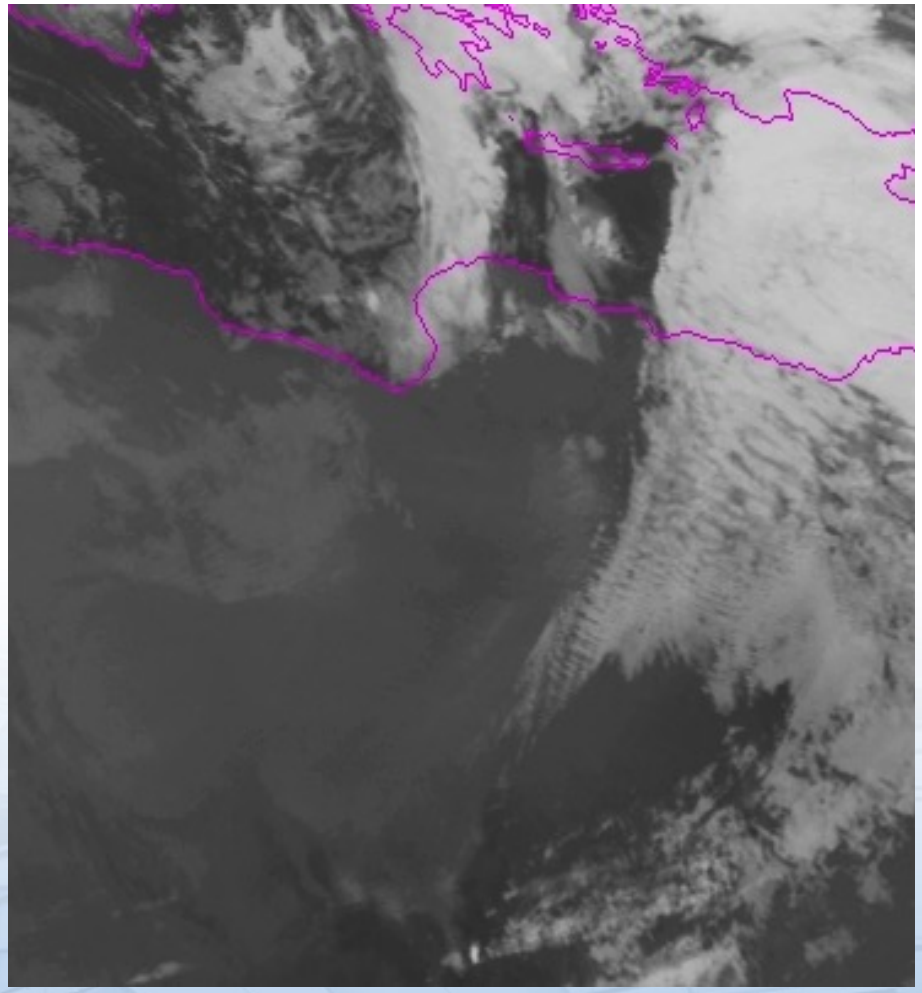
Exercise - where is the dust ?

Met-7 IR image

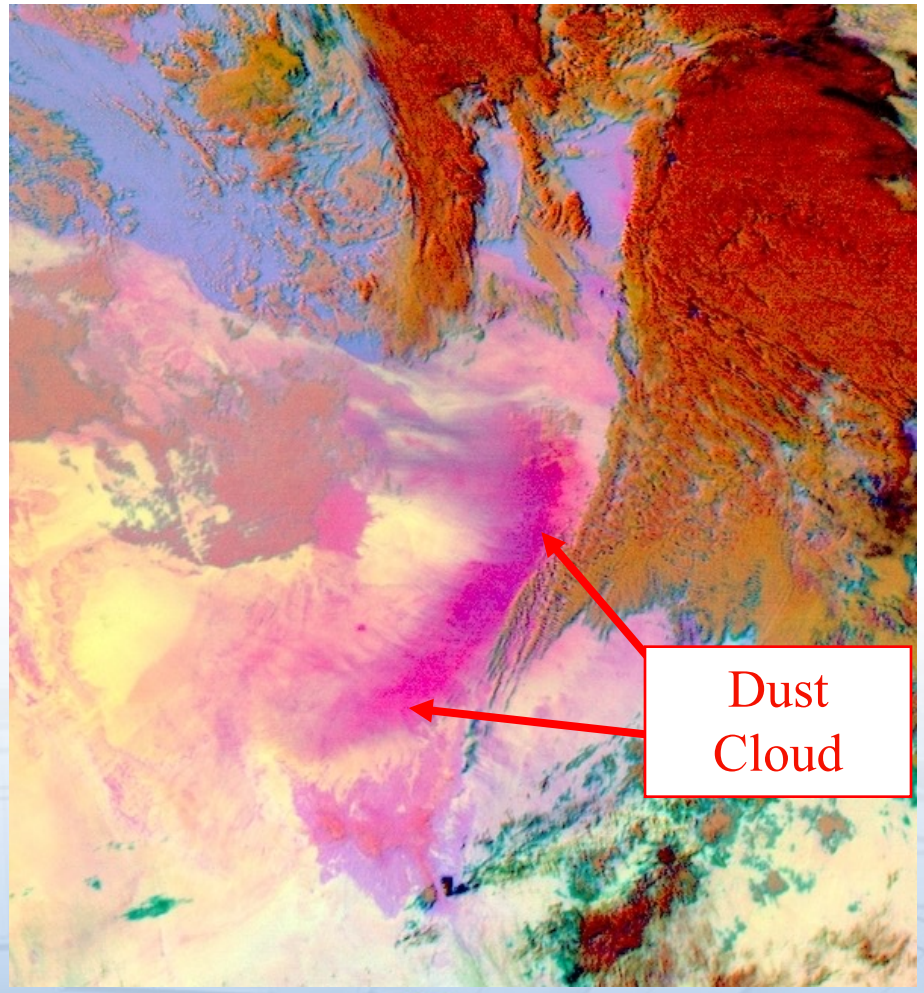


Exercise - where is the dust ?

Met-7 IR image



Met-8 Dust RGB Product



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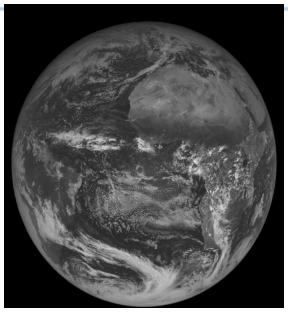
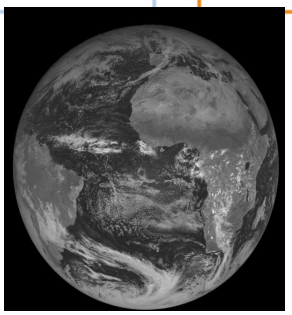
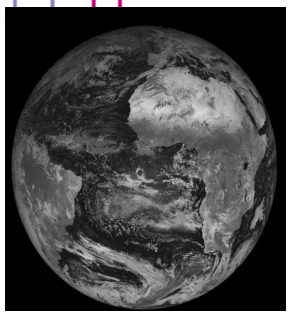
MSG-1 First Image: 28 November 2002



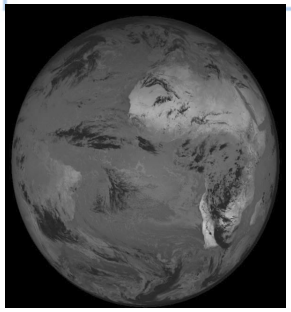
VIS 0.6



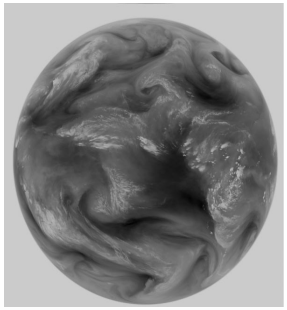
VIS 0.8



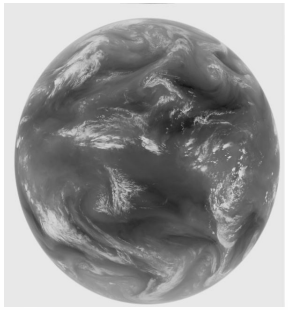
NIR 1.6



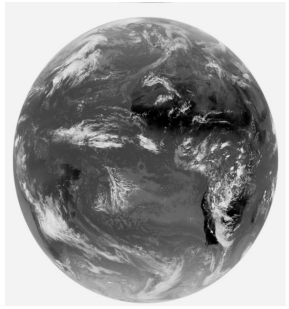
MIR 3.9



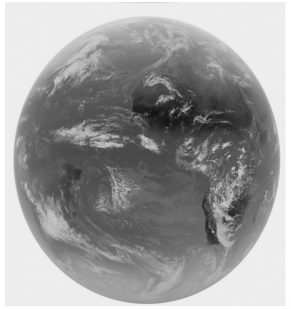
WV 6.2



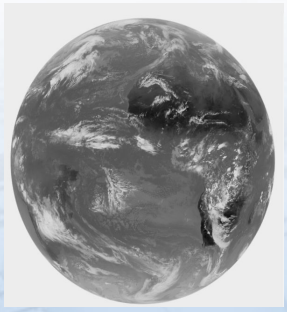
WV 7.3



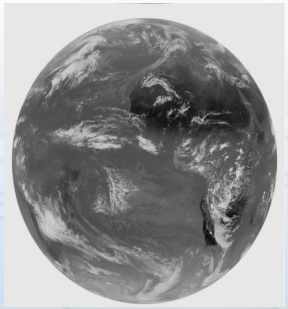
IR 8.7



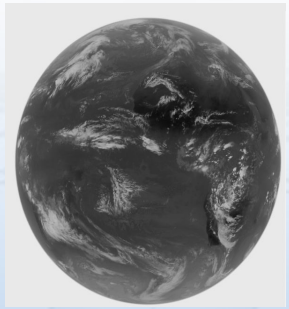
IR 9.7



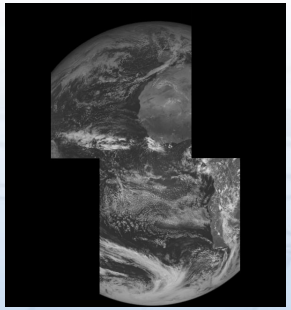
IR 10.8



IR 12.0



IR 13.4



HRV

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7 MSG Window Channels

Window	Band (um)	Airmass	Band (um)
VIS 0.6	0.56 - 0.71	WV 6.2	5.35 - 7.15
VIS 0.8	0.74 - 0.88	WV 7.3	6.85 - 7.85
NIR 1.6	1.50 - 1.78	IR 9.7	9.38 - 9.94
MIR 3.9	3.40 - 4.20	IR 13.4	12.40 - 14.40
IR 8.7	8.30 - 9.10		
IR 10.8	9.80 - 11.80	High Res VIS	
IR 12.0	11.00 - 13.00	HRV	0.4 - 1.1

3 km data sampling intervals, except HRV (1 km)
Images each 15 minutes (5 minutes Met-8 rapid scan)

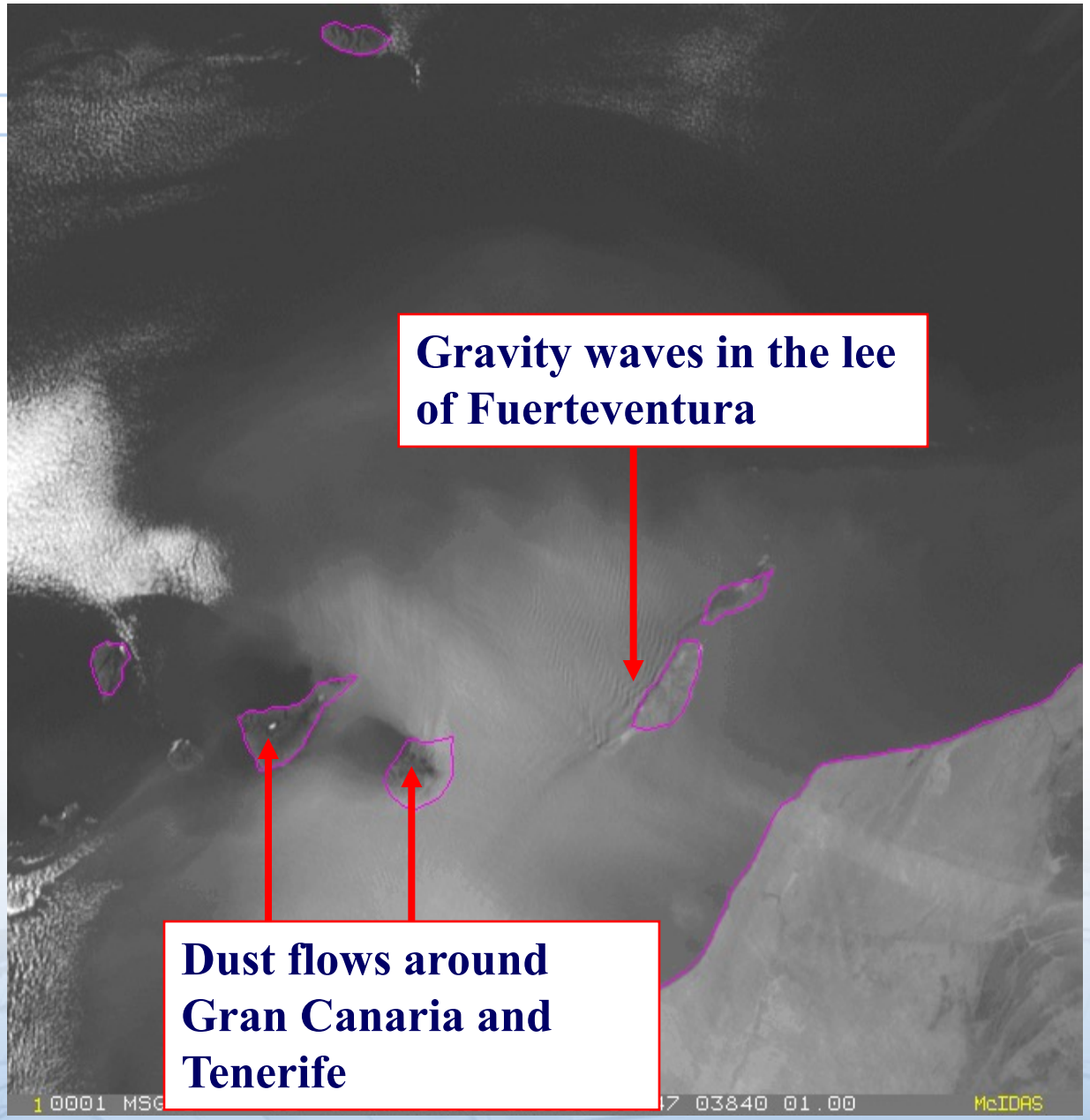
3 MSG Window Channels in IR

Window	Band (um)	Airmass	Band (um)
VIS 0.6	0.56 - 0.71	WV 6.2	5.35 - 7.15
VIS 0.8	0.74 - 0.88	WV 7.3	6.85 - 7.85
NIR 1.6	1.50 - 1.78	IR 9.7	9.38 - 9.94
MIR 3.9	3.40 - 4.20	IR 13.4	12.40 - 14.40
IR 8.7	8.30 - 9.10		
IR 10.8	9.80 - 11.80	High Res VIS	
IR 12.0	11.00 - 13.00	HRV	0.4 - 1.1

Dust Detection
Early MSG Findings

Detection of Dust with MSG SEVIRI

- **VIS0.6 or HRV (VIS0.8, NIR1.6 not good)**
  good over Oceans, only daytime
- **IR3.9r (reflectance part)**
  good over Oceans, only daytime
- **IR10.8 (thermal signal)**
  good over Land, only daytime
- **Difference IR12.0 - IR10.8 (known from AVHRR)**
  good for mid & high dust clouds, day and night, Land and Ocean
- **Difference IR8.7 - IR10.8 (new)**
  good over deserts, day and night
- **Difference IR3.9 – IR10.8 (known from AVHRR)**
  good over Land and Oceans, only daytime



HRV Channel
shows fine details

MSG-1
3 March 2004
17:00 UTC
Channel 12
(HRV)

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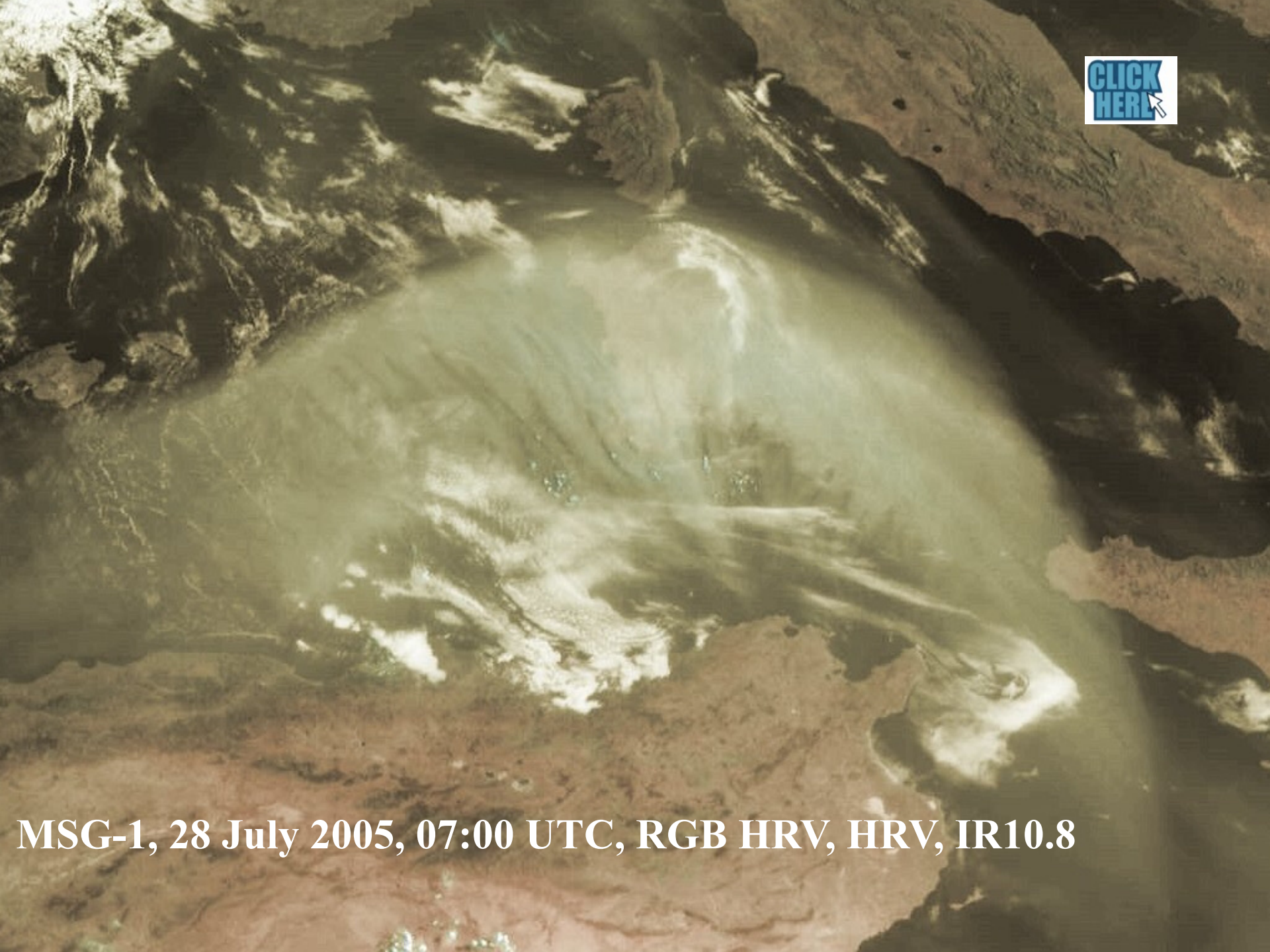
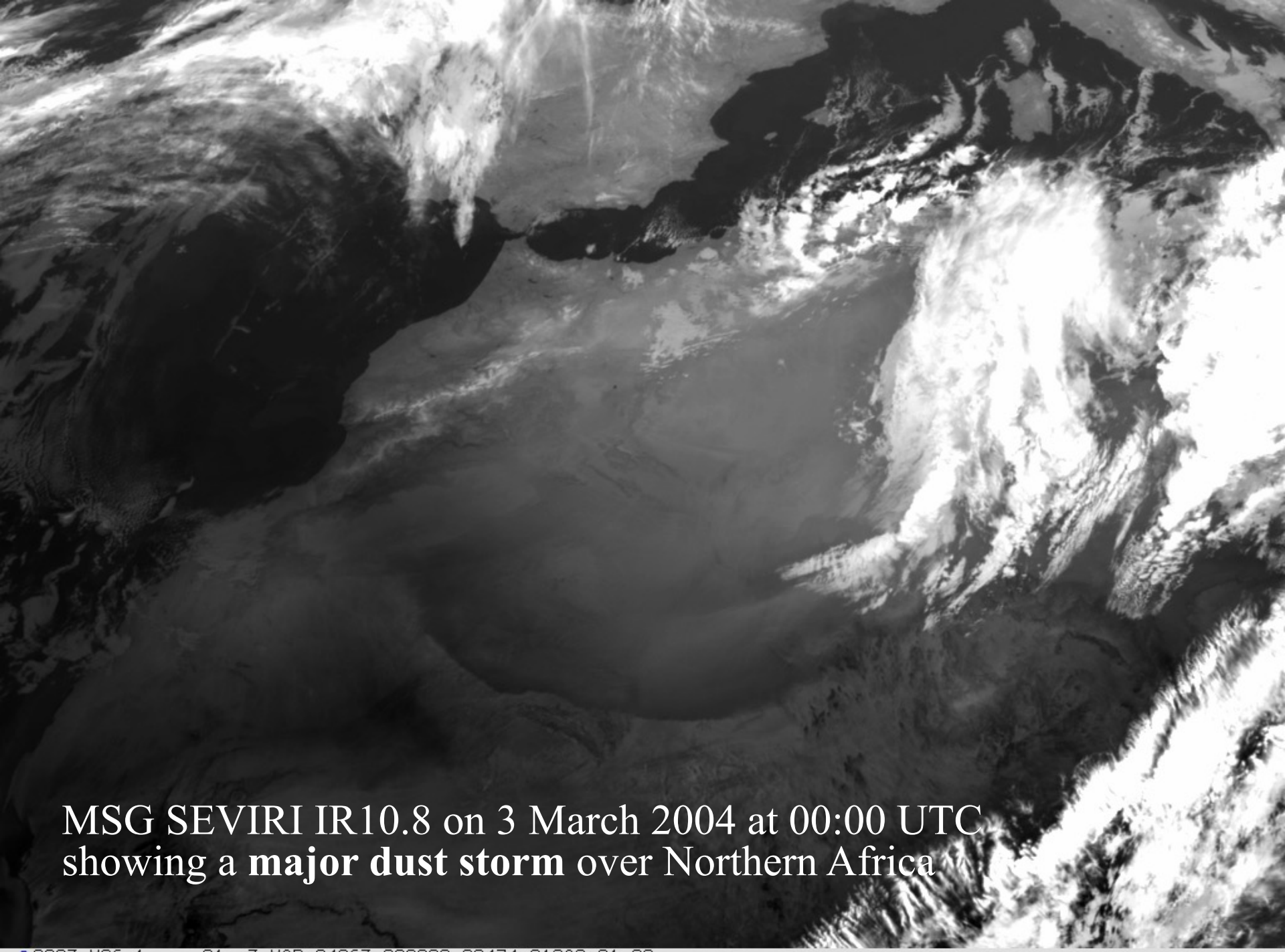
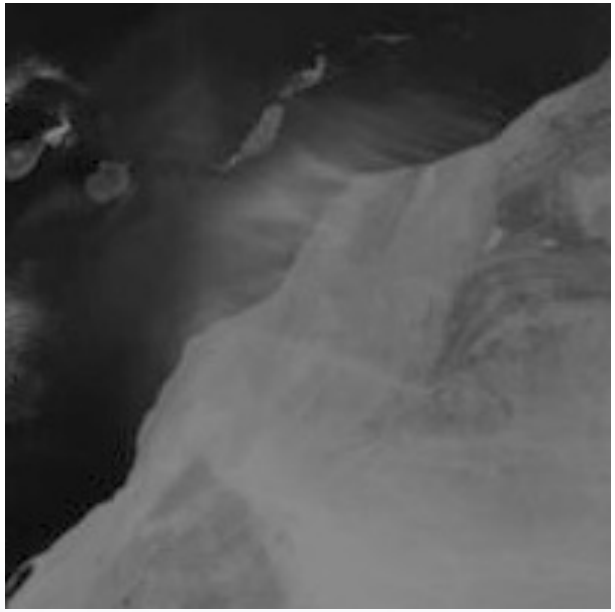


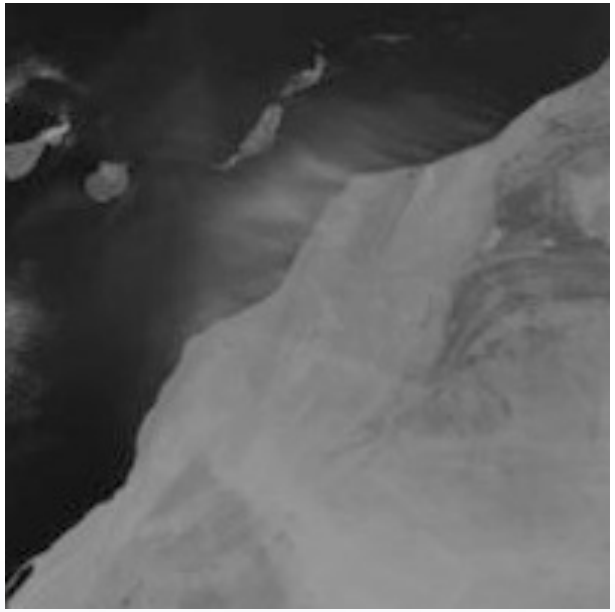
MSG-1, 28 July 2005, 07:00 UTC, RGB HRV, HRV, IR10.8

MSG SEVIRI IR10.8 on 3 March 2004 at 12:00 UTC showing a **major dust storm** over Northern Africa

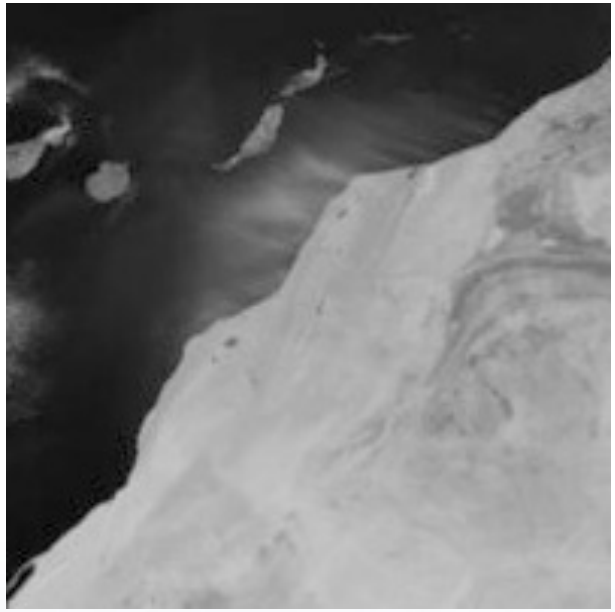

MSG SEVIRI IR10.8 on 3 March 2004 at 00:00 UTC
showing a **major dust storm** over Northern Africa
3 0003 MSG-1 01 3 MAR 04063 000000 00474 01282 01.00



Channel 01 (0.6 μm)



Channel 02 (0.8 μm)



Channel 03 (1.6 μm)

MSG **VIS** imagery on 3 March 2004 at 12:00 UTC
showing a **dust cloud** over the Canary Islands

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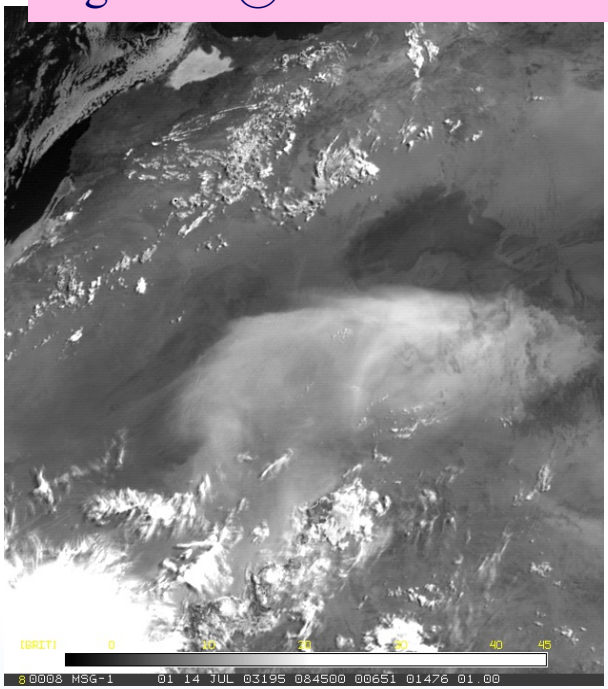
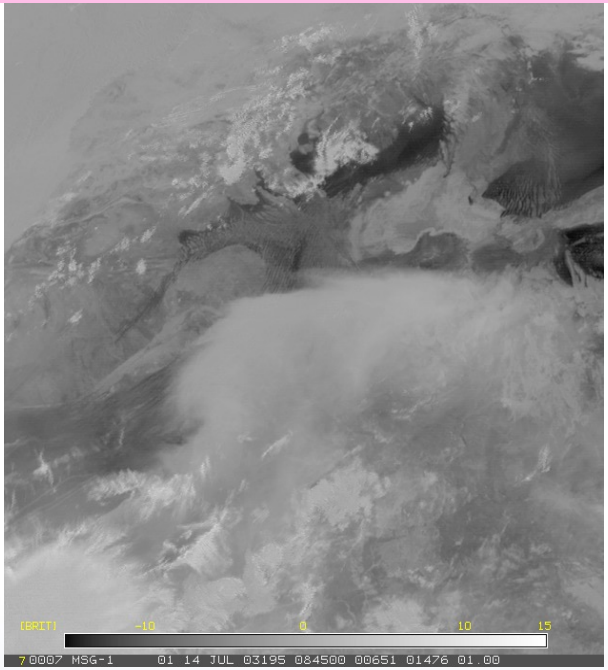
Dust Clouds

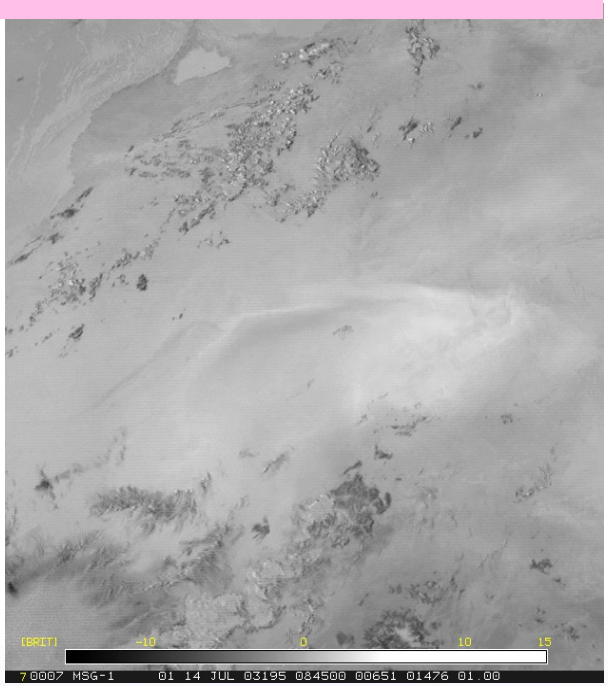
high refl. @ IR3.9 | low emissivity of sand @ IR8.7 | different transmissivities



Diff. 3.9 µm - 10.8 µm



Diff. 8.7 µm - 10.8 µm



Diff. 12.0 µm - 10.8 µm

MSG imagery on 14 July 2003 at 08:45 UTC showing a **dust cloud** over Algeria

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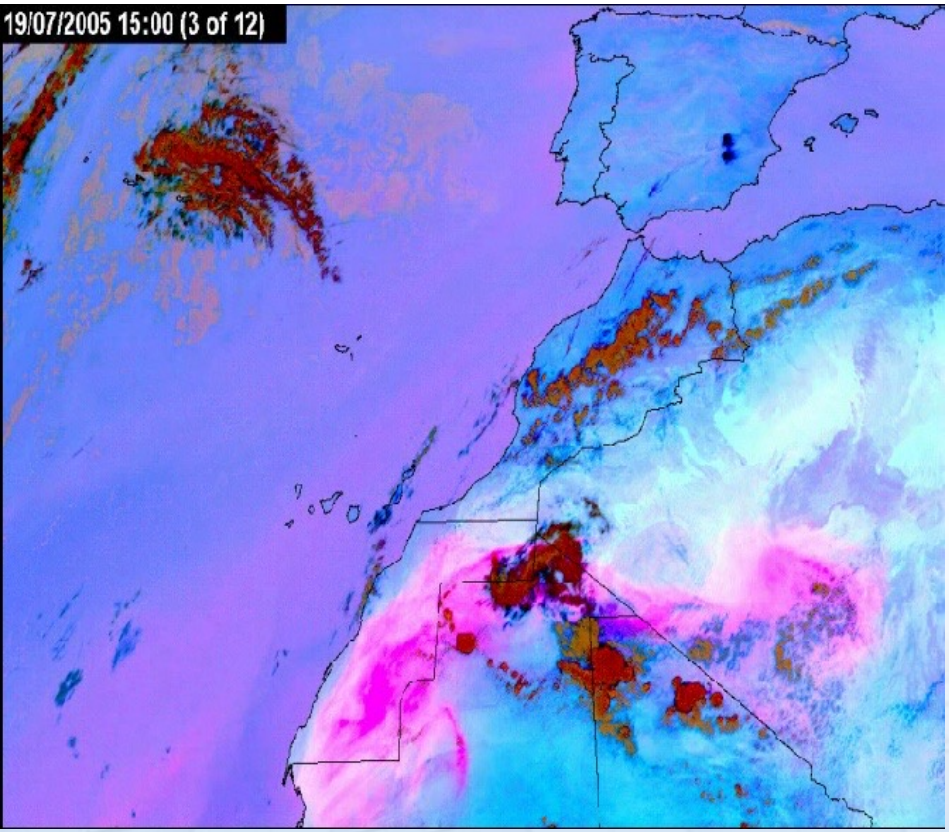
Introduction to RGB Products

RGB Products – How ?



How do we get a picture like this?

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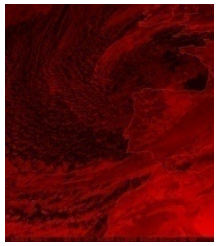
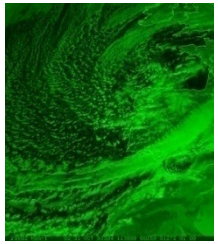
RGB Image Composites: Natural Colours RGB

Ch. NIR1.6



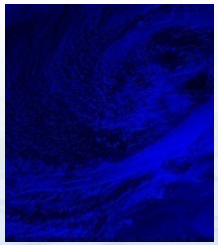
+

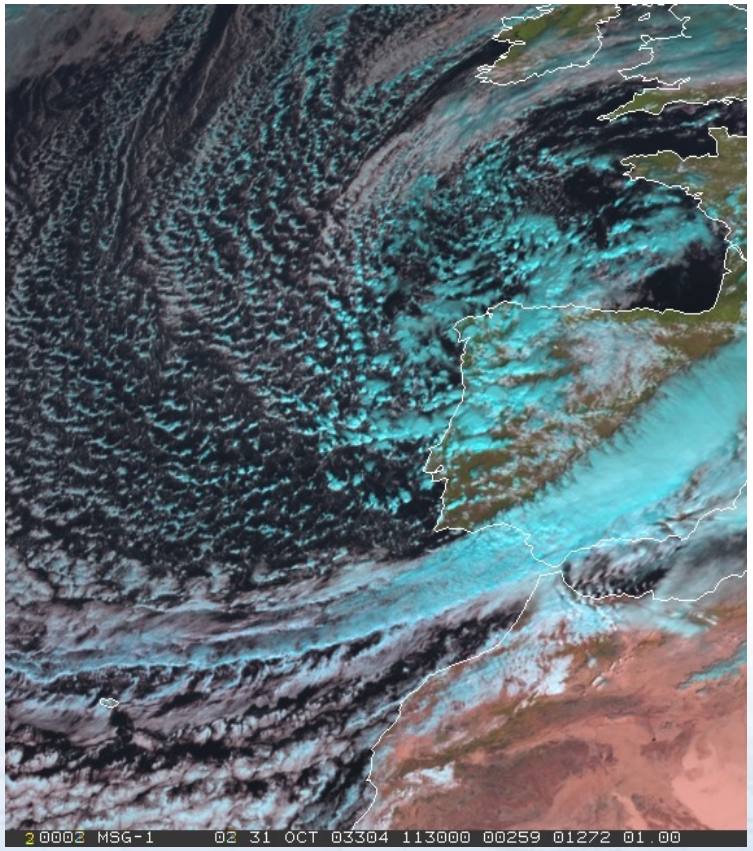
Ch. VIS0.8



+

Ch. VIS0.6





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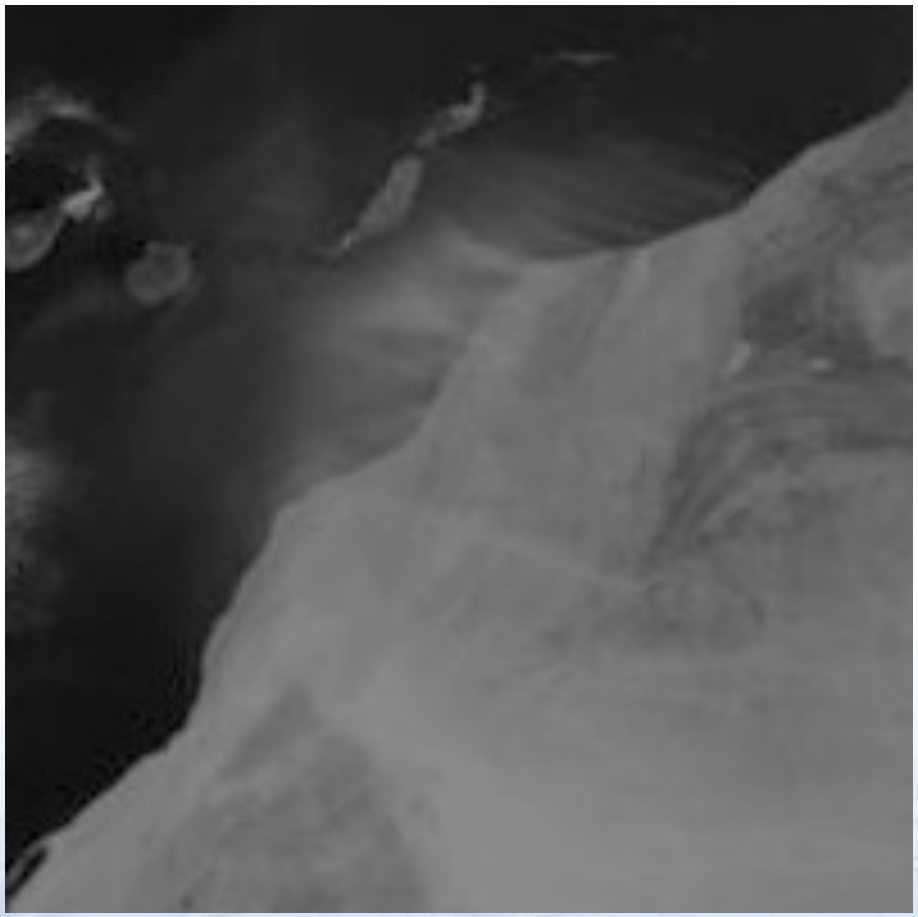
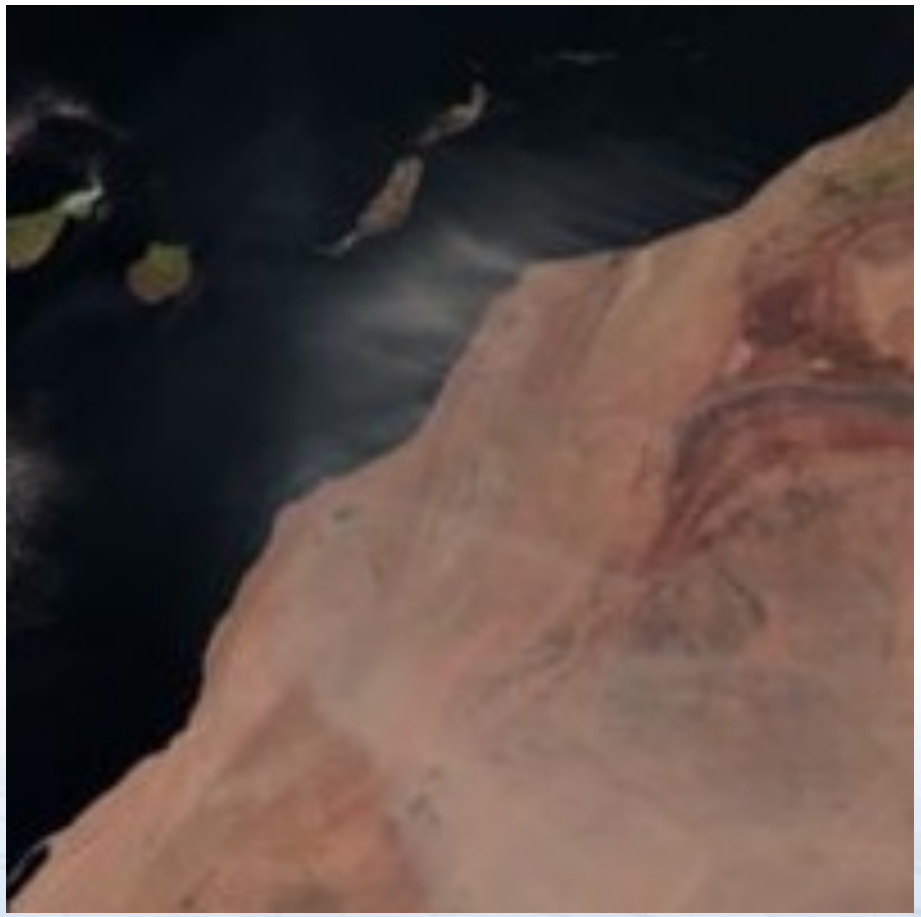
Natural Colours RGB: dust colour



Channel 01 (0.6 μm)



RGB Natural Colours

3 March 2004 at 12:00 UTC

dust cloud over the Canary Islands

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Rules for Creating “Good” RGB Products: Part 1

Select three channels or channel differences that represent three different physical properties !!!

Channel	Main Cloud Physical Properties (clouds, NADIR viewing)
01 (VIS 0.6)	optical thickness, amount of cloud water and ice
02 (VIS 0.8)	optical thickness, amount of cloud water and ice
03 (NIR 1.6)	optical thickness, particle size & shape, phase
04 (MIR 3.9)	Day-time: top temperature, particle size & shape, phase Night-time: top temperature (very noisy below -50°C)
07 (IR 8.7)	top temperature
09 (IR 10.8)	top temperature
10 (IR 12.0)	top temperature

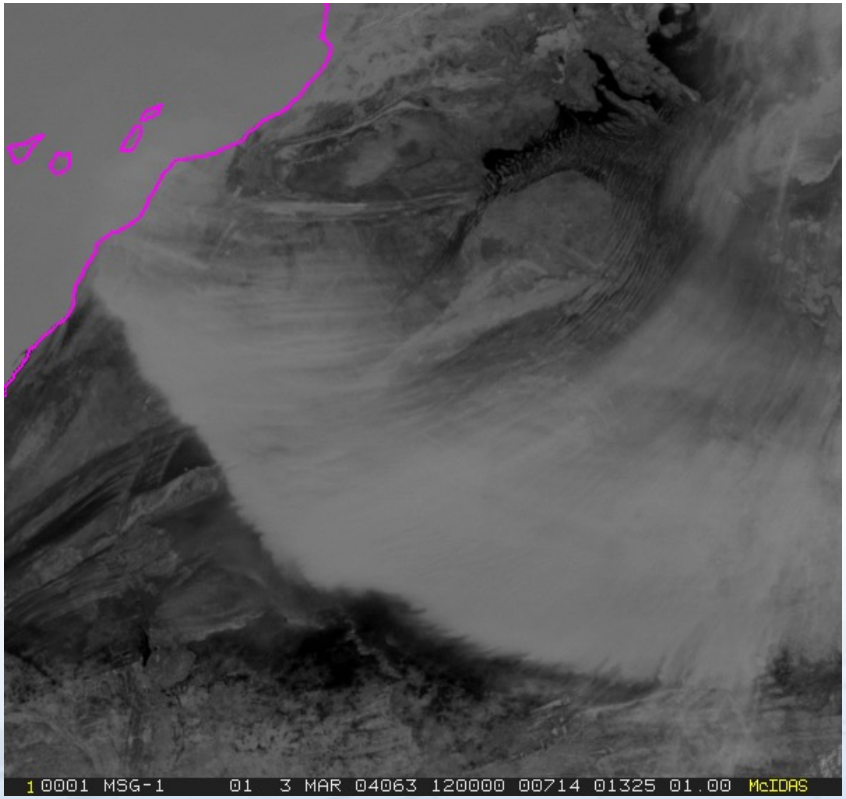
Rules for Creating “Good” RGB Products: Part 2

The best RGBs are achieved using brightness temperatures for IR and (solar zenith angle corrected) reflectances for VIS channels !!!

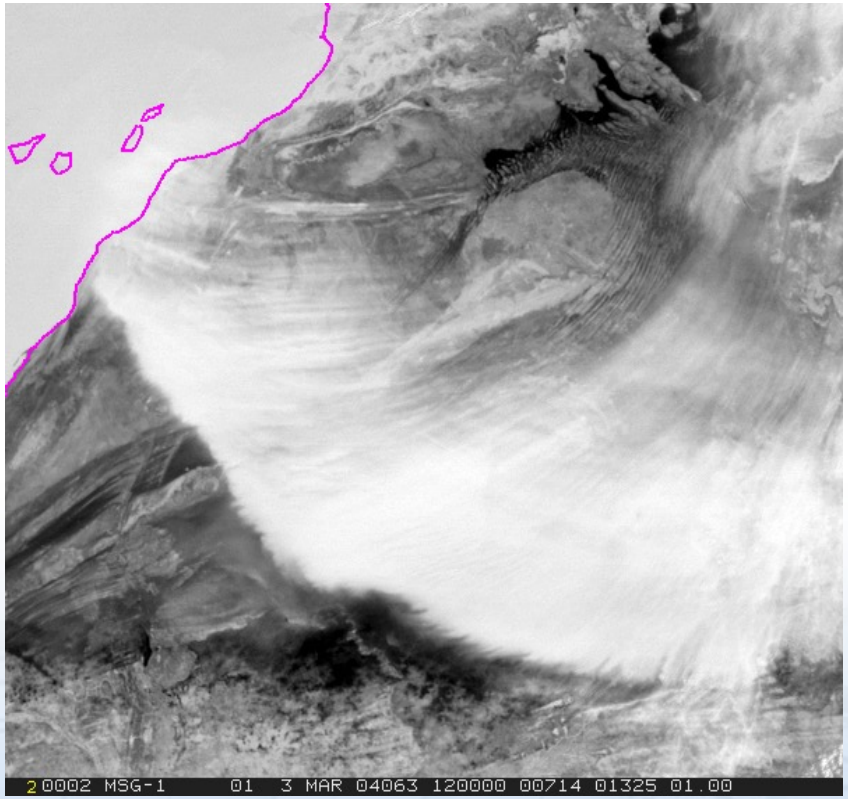
- Counts ∅
- Radiances ∅
- **Brightness temp. (IR channels)** ✓
- **Reflectances (VIS channels)** ✓

Rules for Creating “Good” RGB Products: Part 3

Stretching of Intensity Range



Range = -15 K / +15 K



Range = -15 K / 0 K

MSG-1, 3 March 2004, 12:00 UTC, Diff. IR8.7 - IR10.8

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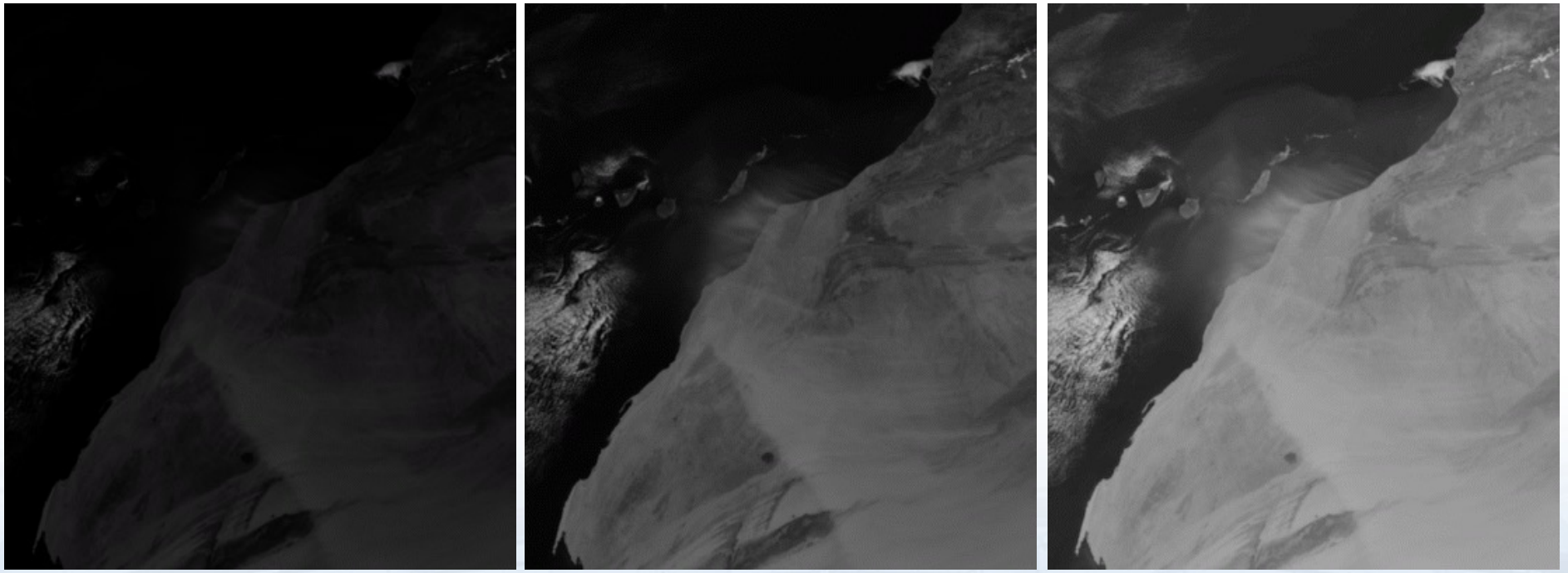
Rules for Creating “Good” RGB Products: Part 4

Perform Gamma correction, if needed



Range = 0 - 100%, Γ=0.5 **Range = 0 - 100%, Γ=1.0** **Range = 0 - 100%, Γ=2.0**

MSG-1, 3 March 2004, 12:00 UTC, Channel 01 (VIS0.6)

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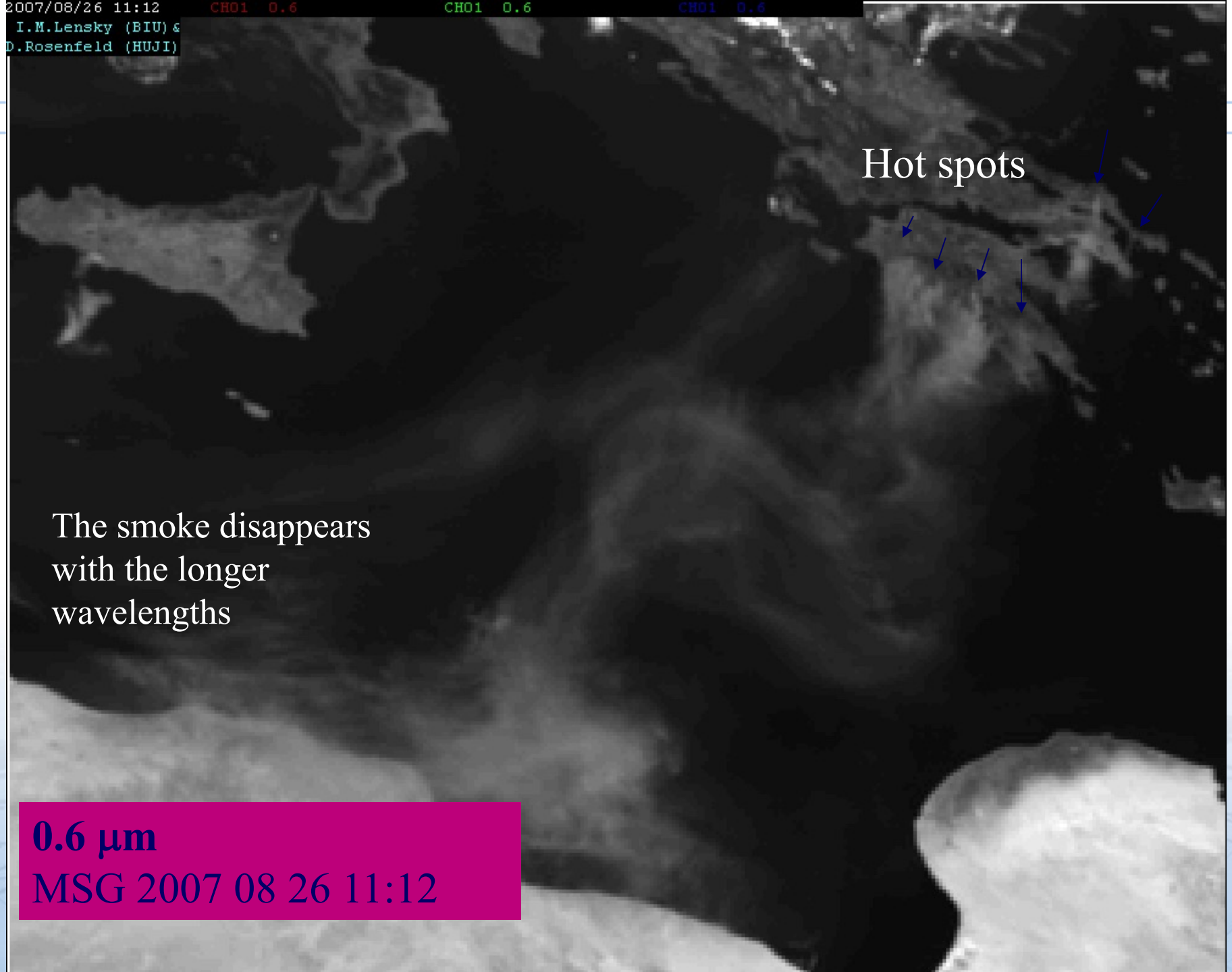
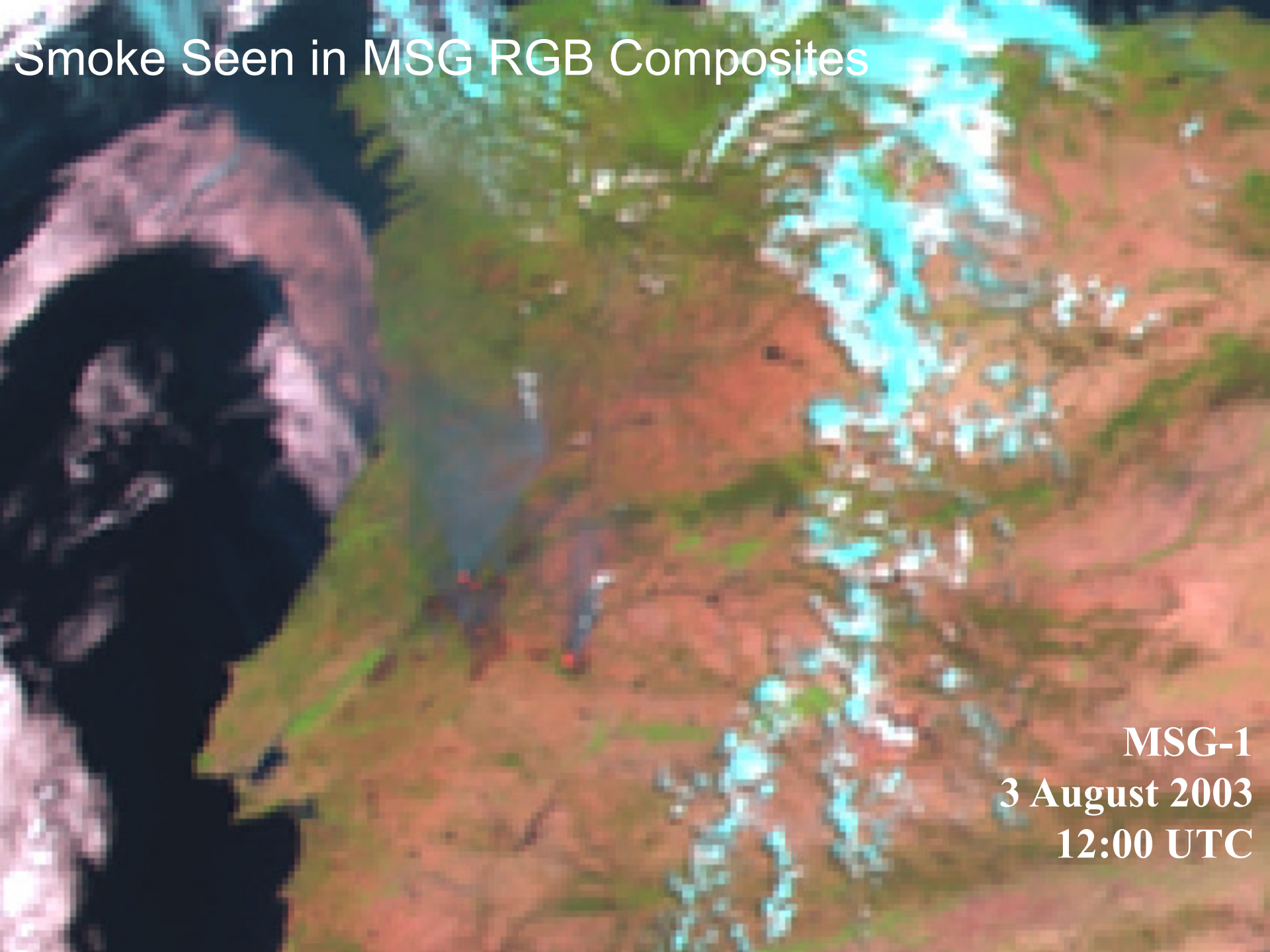
Smoke versus Dust


2007/08/26 11:12
CH01 0.6
CH01 0.6
CH01 0.6
I.M.Lensky (BIU) &
D.Rosenfeld (HUJI)
Hot spots
The smoke disappears with the longer wavelengths
0.6 μm
MSG 2007 08 26 11:12

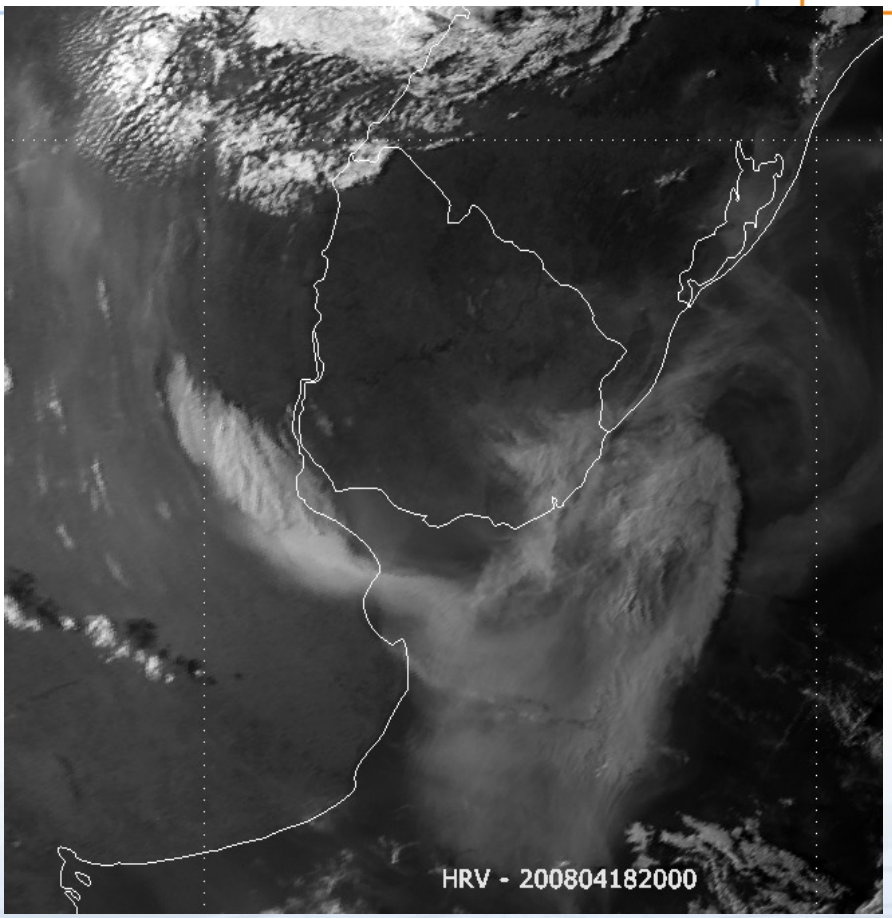

2007/08/26 11:12
CH02 0.8
CH02 0.8
CH02 0.8
I.M.Lensky (BIU) &
D.Rosenfeld (HUJI)
Hot spots
The smoke disappears with the longer wavelengths
0.8 μm
MSG 2007 08 26 11:12

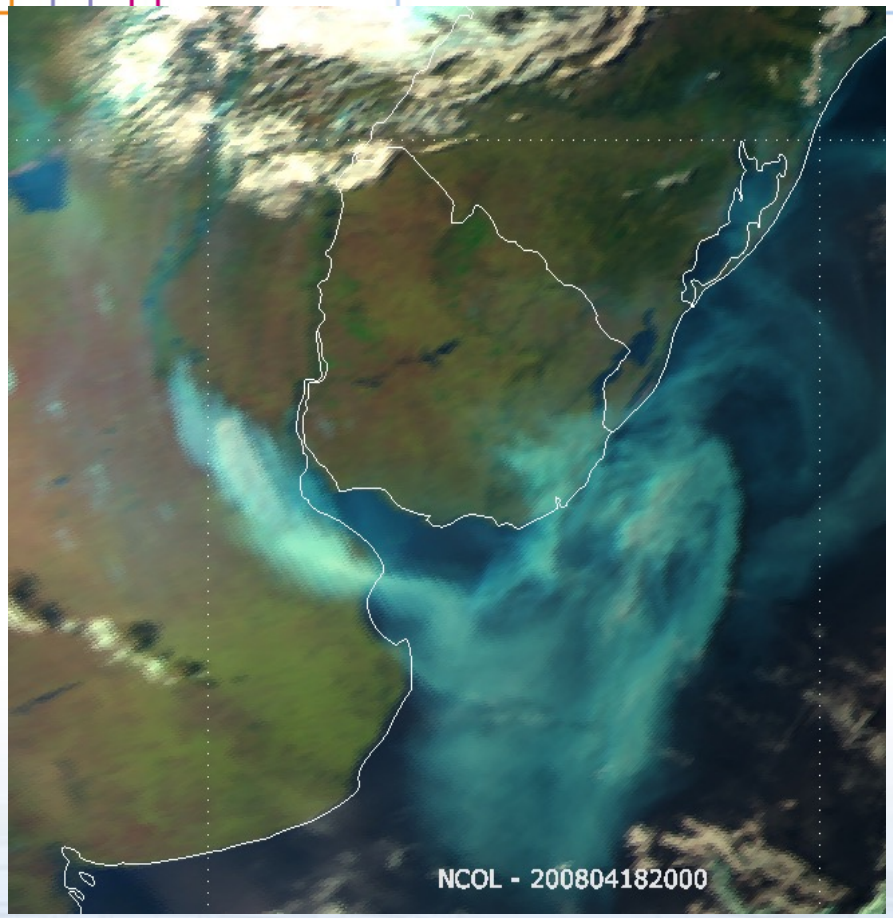

2007/08/26 11:12
CH03 1.6
CH03 1.6
CH03 1.6
I.M.Lensky (BIU) &
D.Rosenfeld (HUJI)
Exercise – what colour does smoke get in the Natural Colours RGB ?
Hot spots
The smoke disappears with the longer wavelengths
1.6 μm
MSG 2007 08 26 11:12

Smoke Seen in MSG RGB Composites



Dense Smoke over Argentina and Uruguay





Met-9, 18 Apr 2008, 20:00 UTC

CLICK HERE

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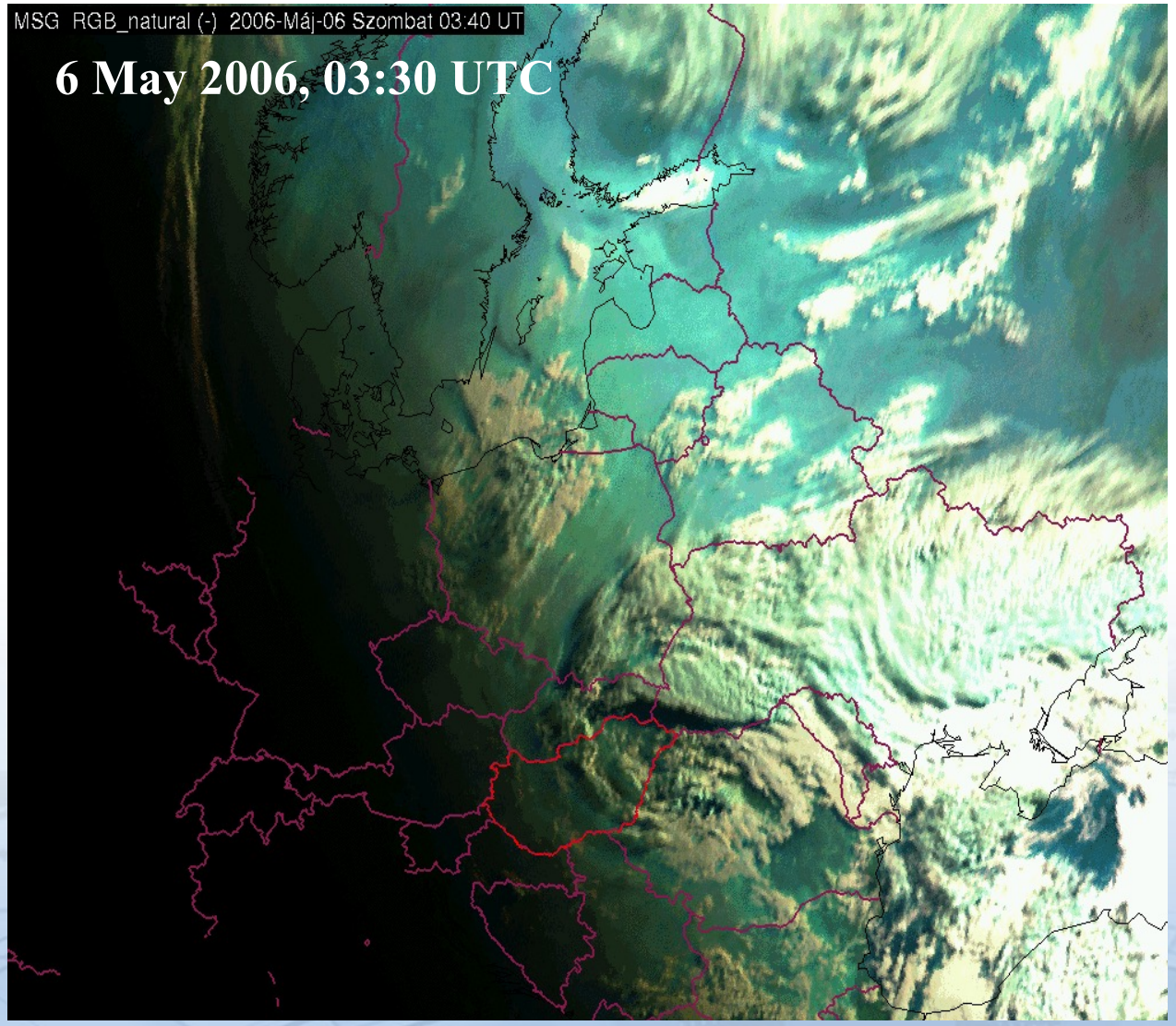
Smoke from Russian / Ukrainian Fires



CLICK HERE

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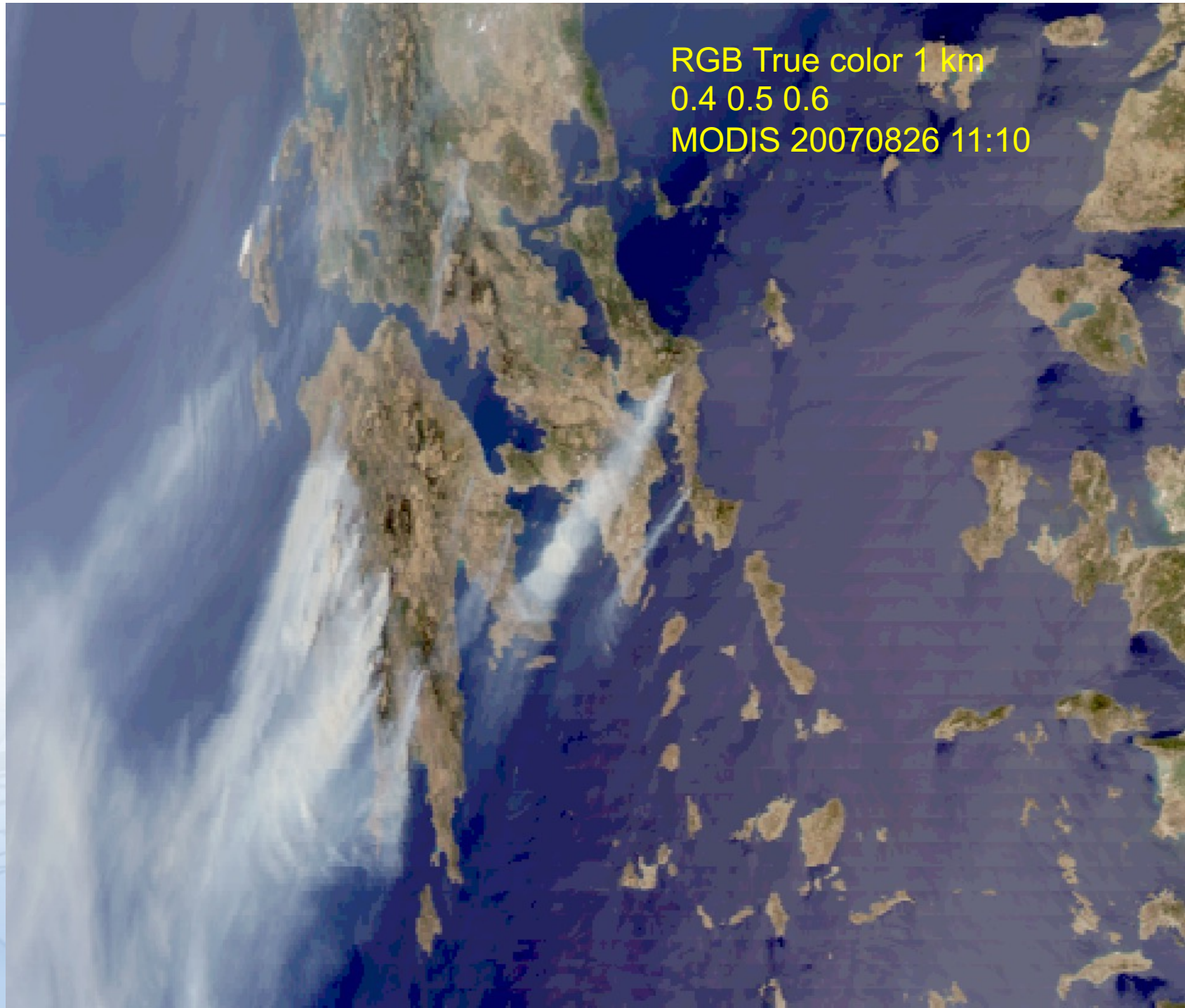
Smoke from Oil Tank Fire (Libya)

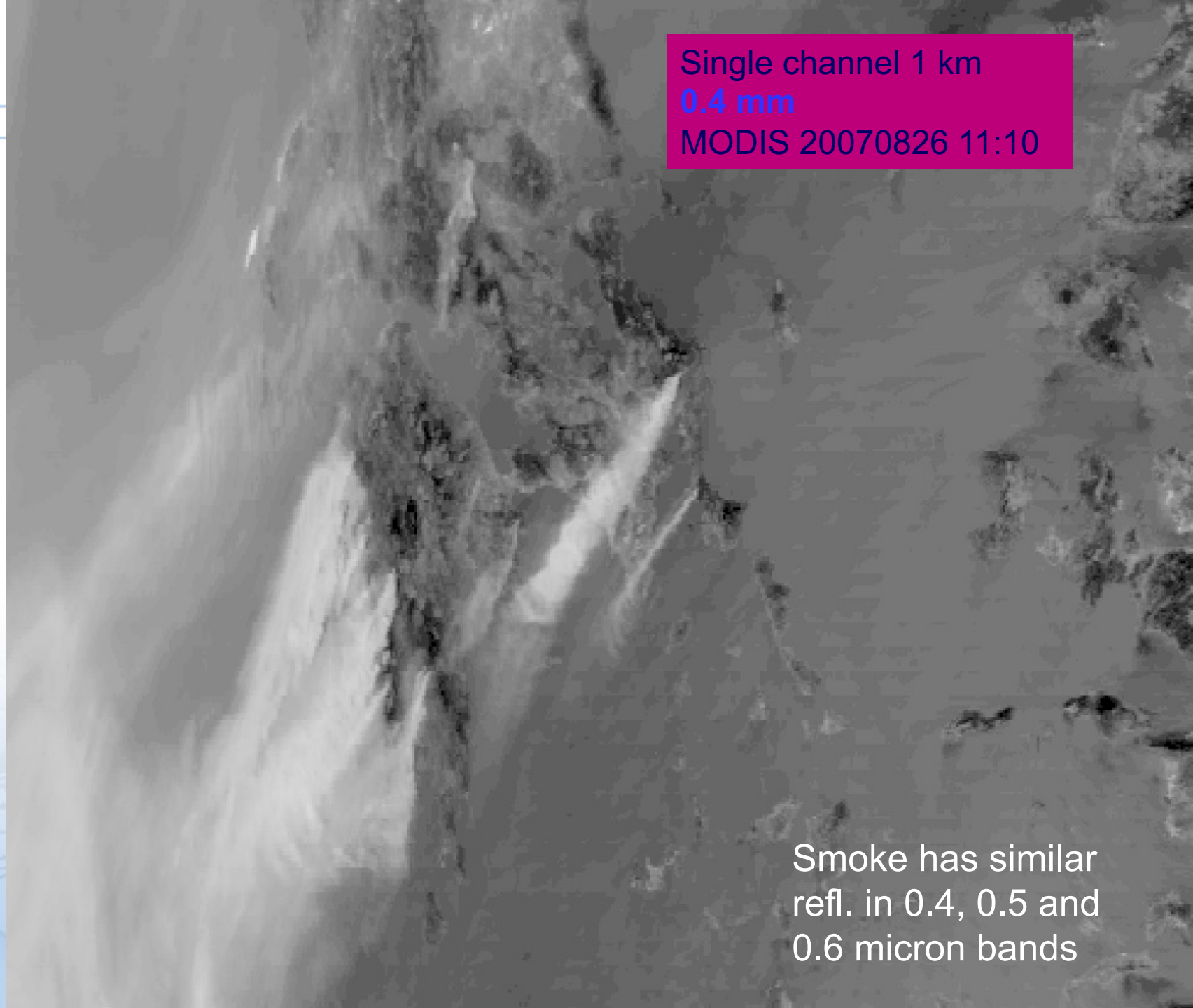
Aqua, MODIS, 20 Aug 2008
True Colour RGB

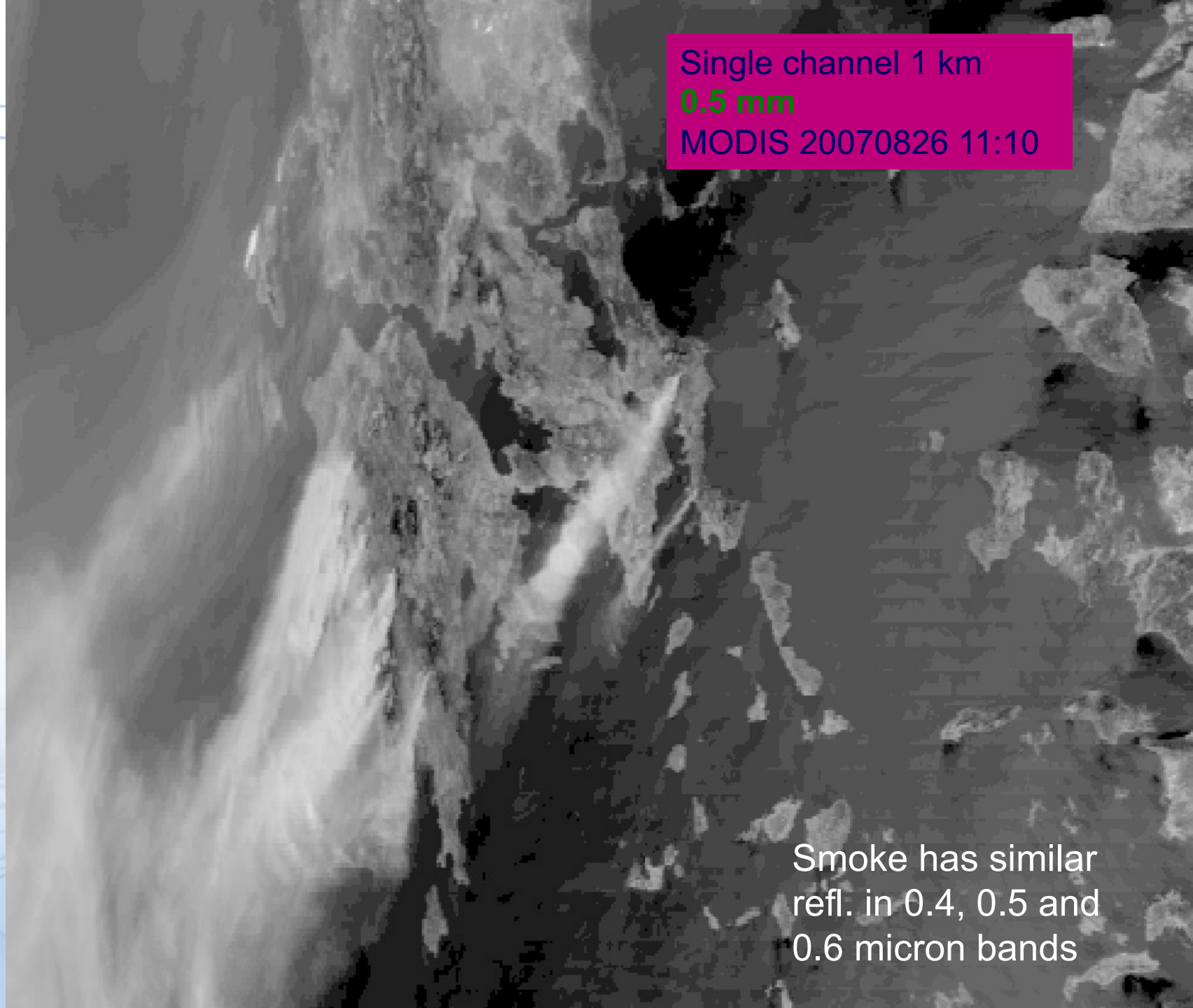
Met-8, 19 Aug 2008
Nat Colour RGB

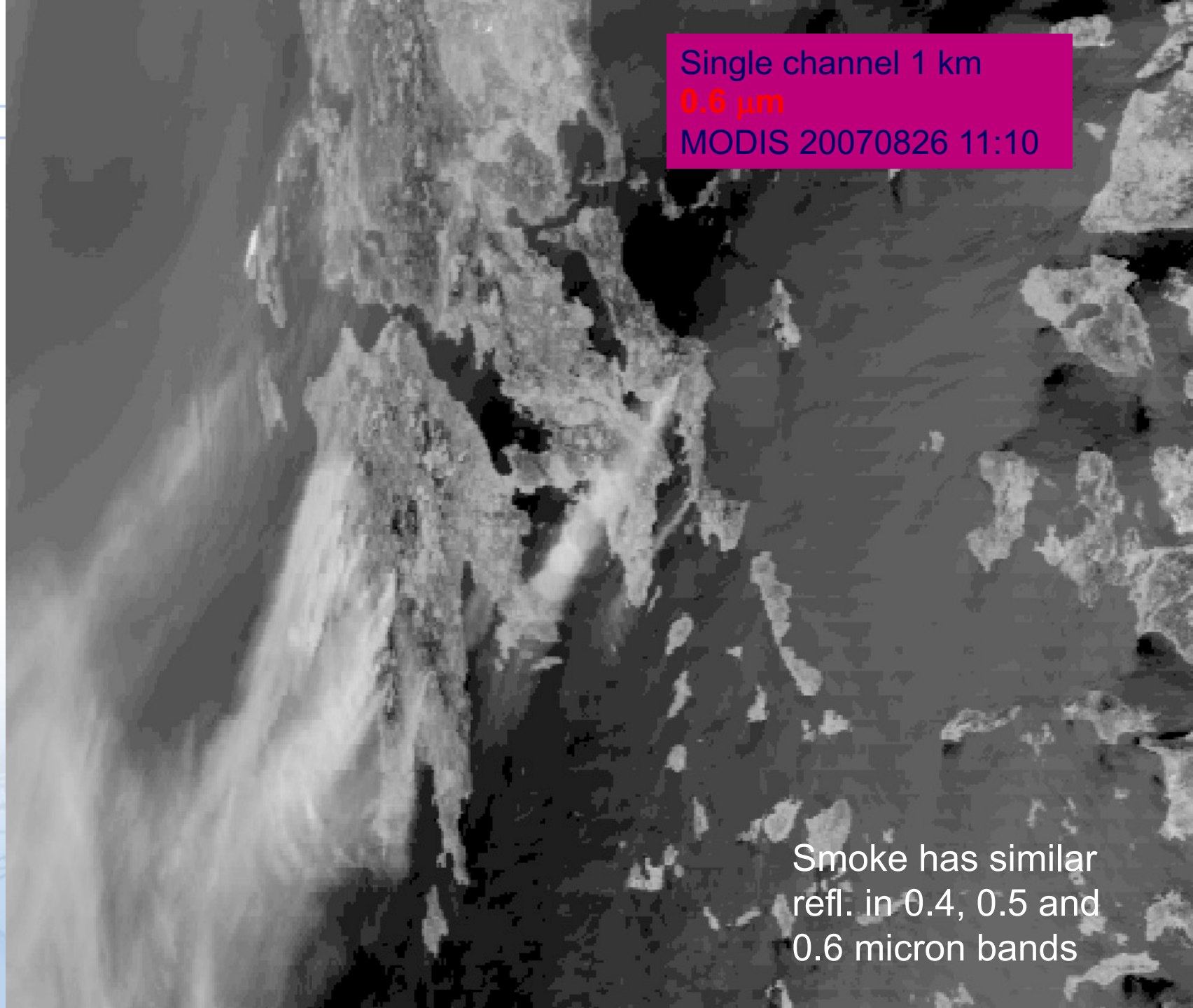
CLICK HERE

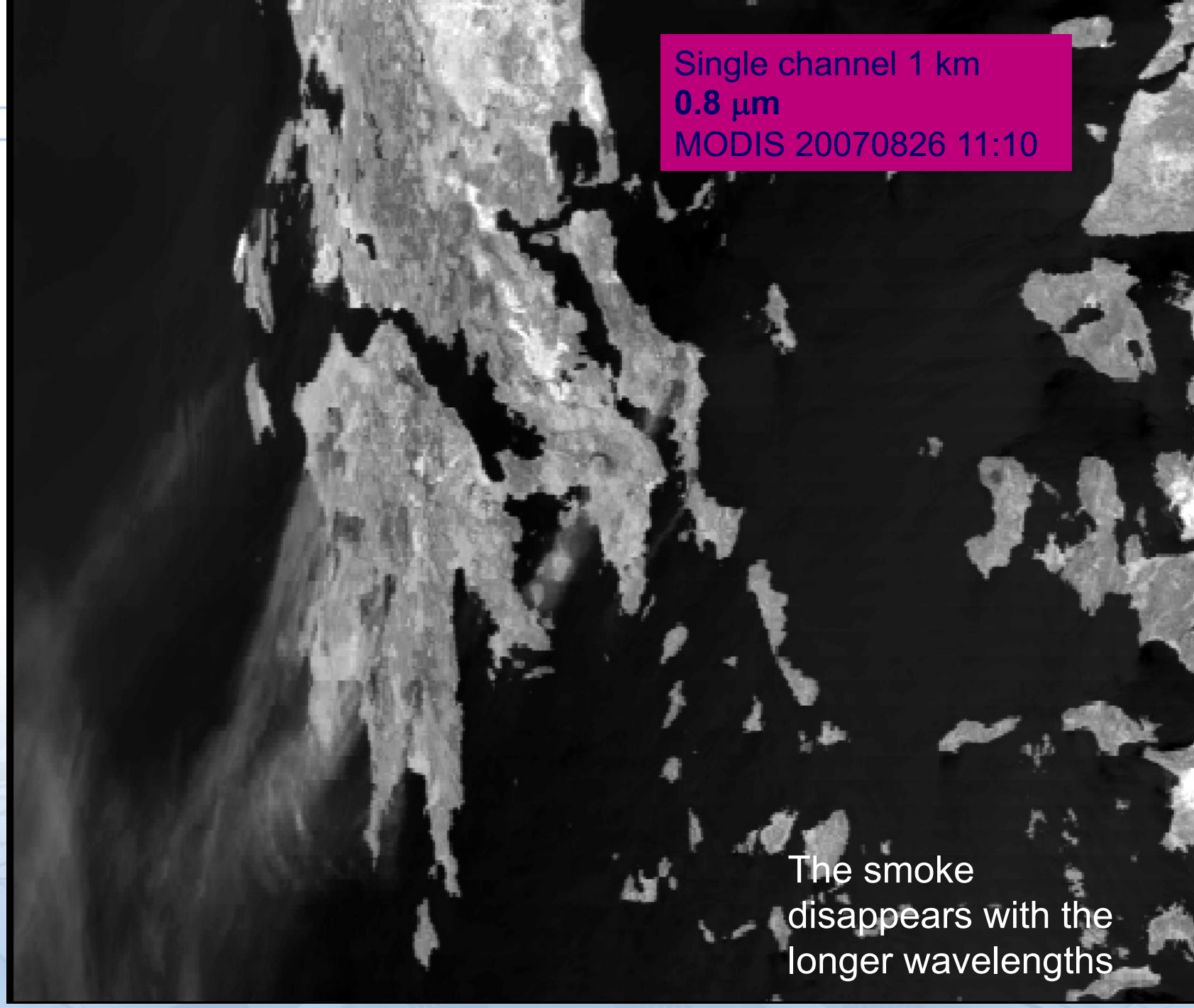
Exercise – what colour does smoke get in the True Colours RGB (MODIS) ?

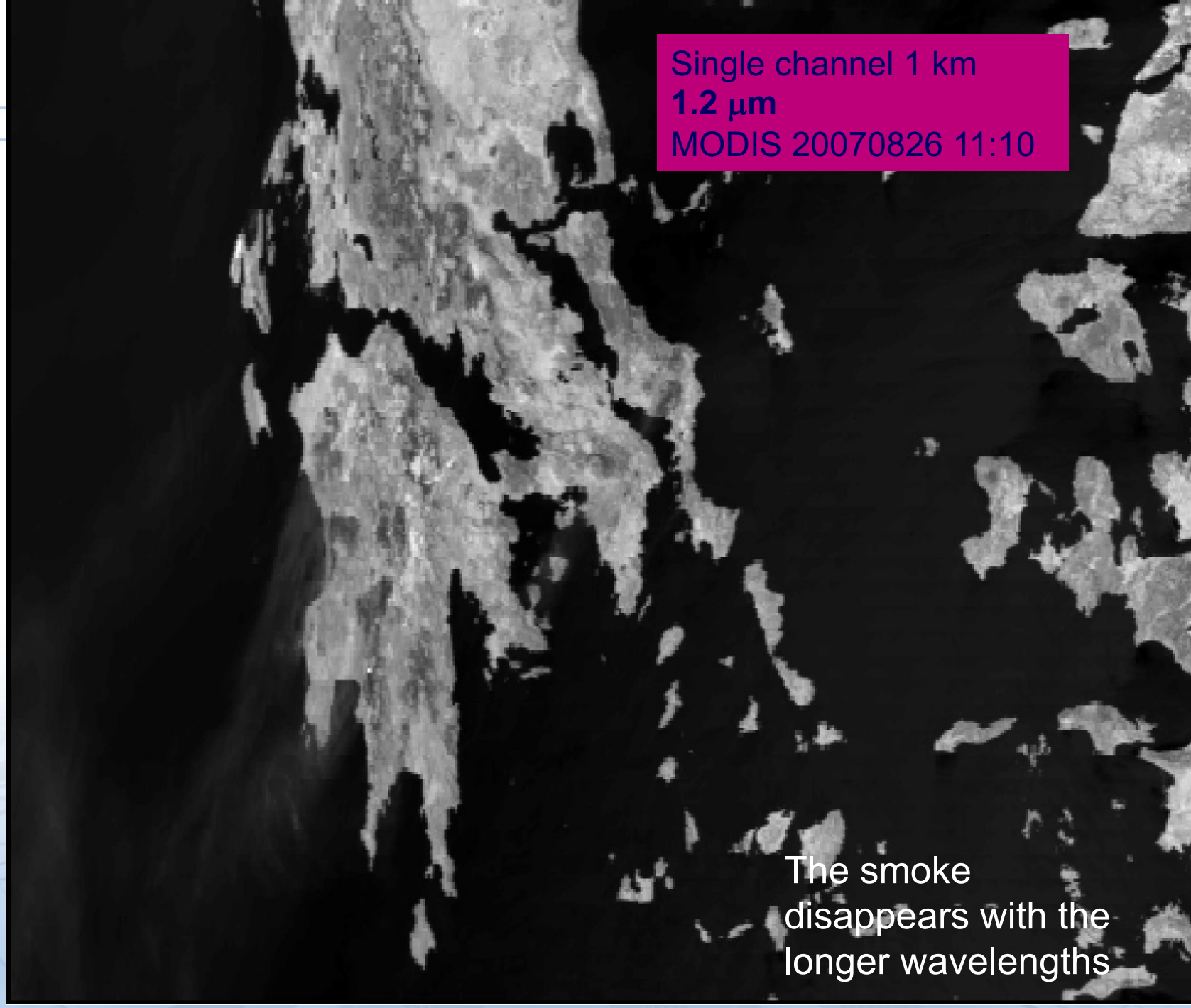

RGB True color 1 km
0.4 0.5 0.6
MODIS 20070826 11:10

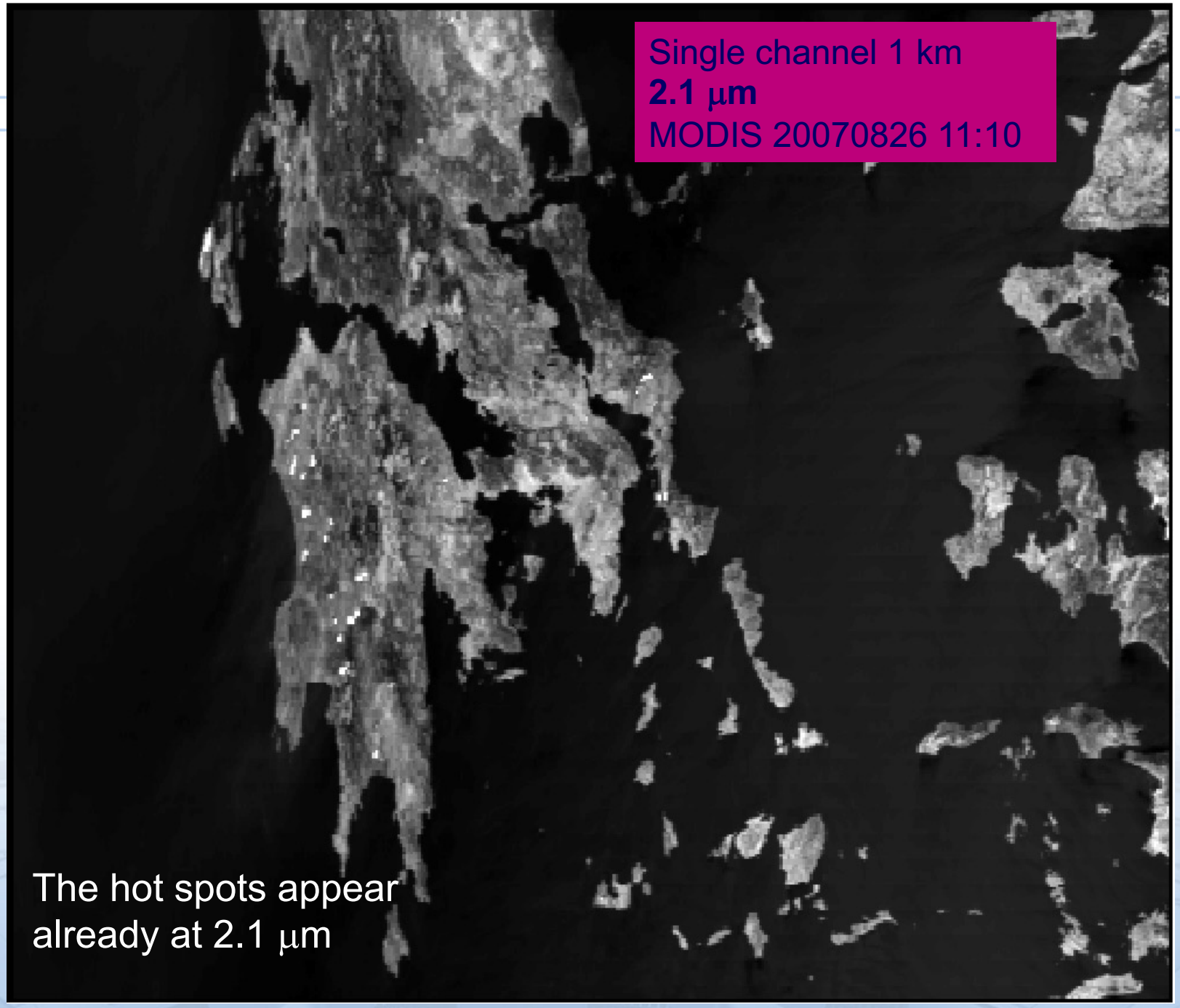

Single channel 1 km
0.4 mm
MODIS 20070826 11:10
Smoke has similar refl. in 0.4, 0.5 and 0.6 micron bands


Single channel 1 km
0.5 mm
MODIS 20070826 11:10
Smoke has similar
refl. in 0.4, 0.5 and
0.6 micron bands

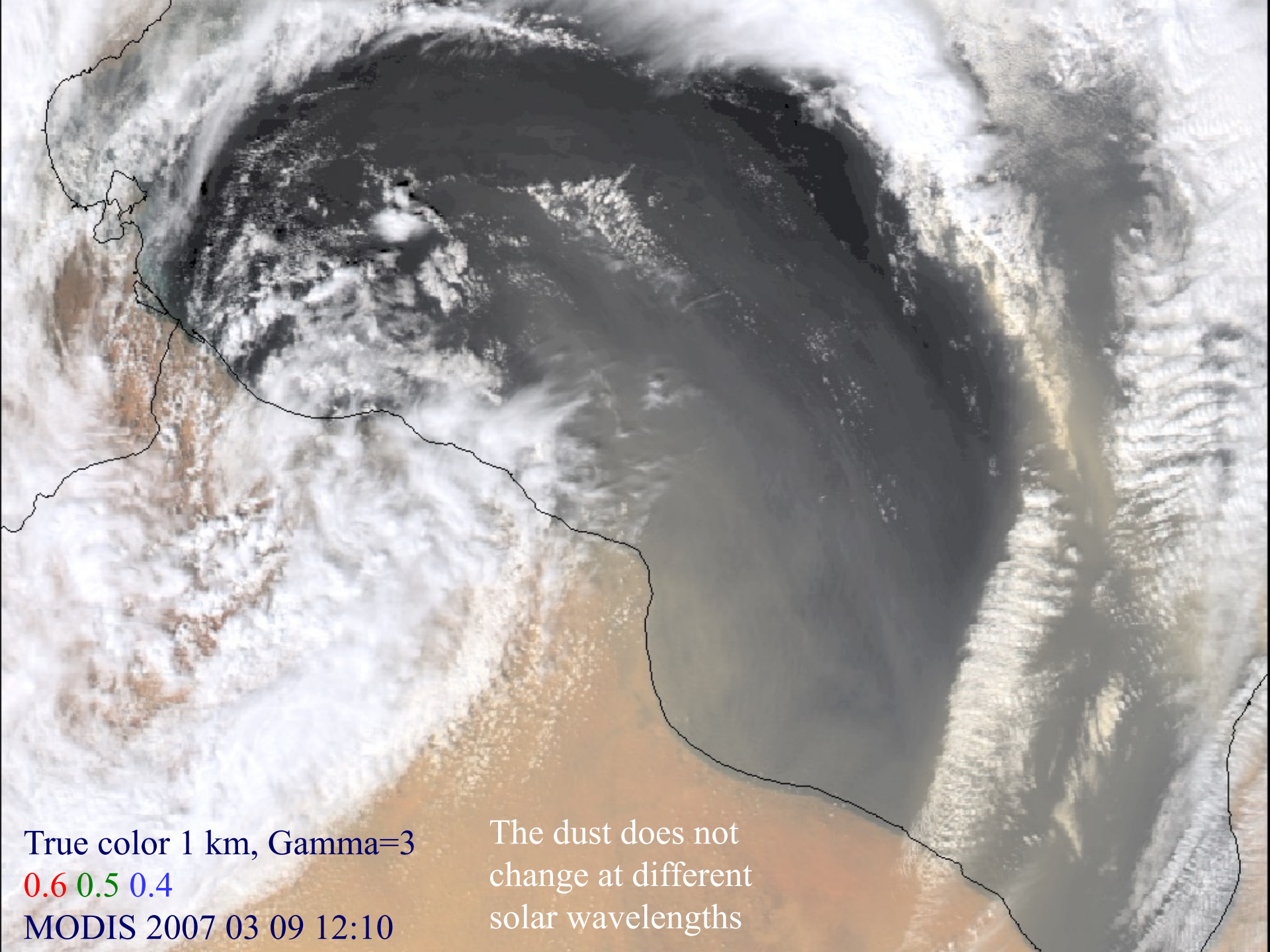

Single channel 1 km
0.6 µm
MODIS 20070826 11:10
Smoke has similar refl. in 0.4, 0.5 and 0.6 micron bands

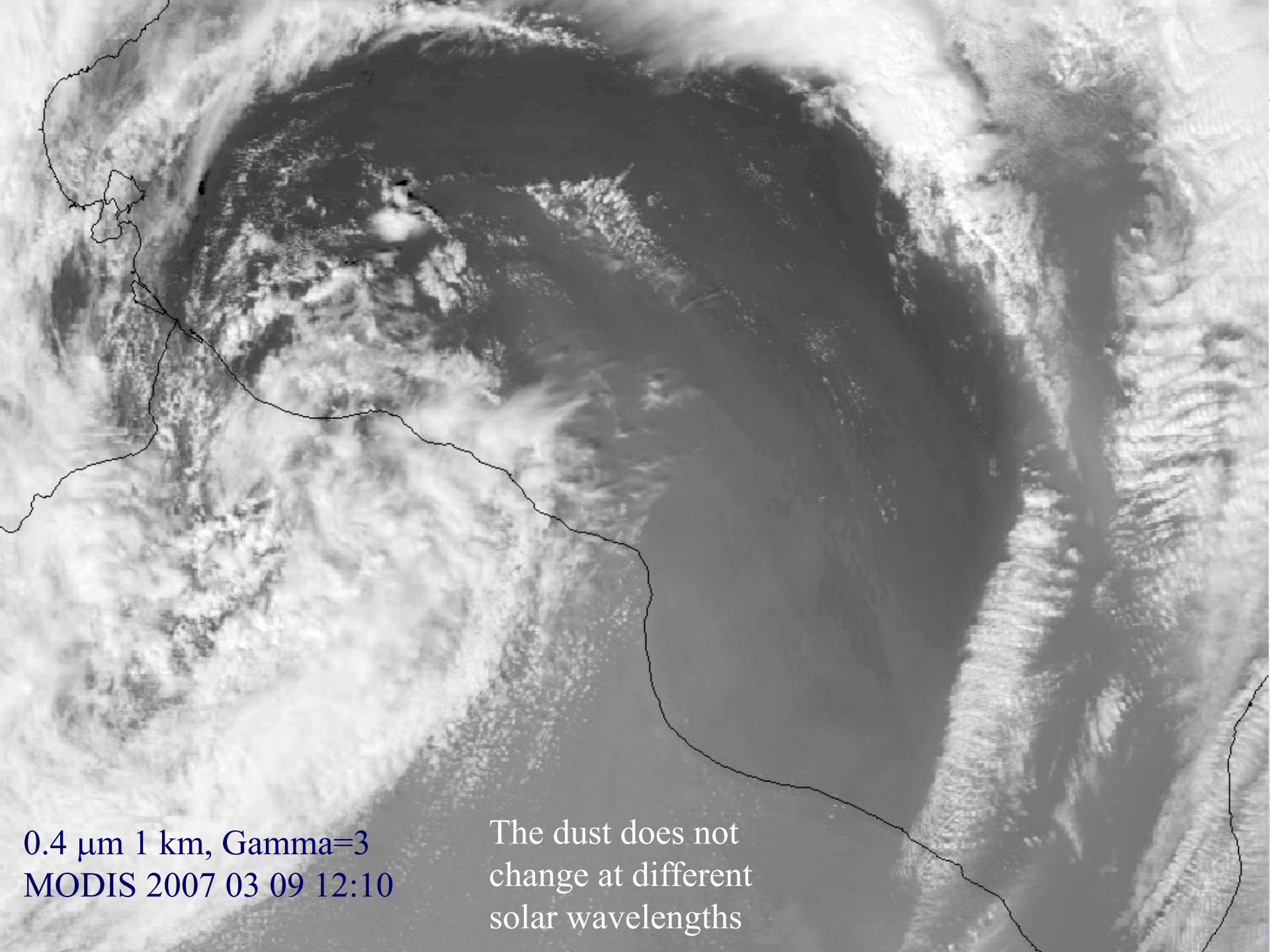

Single channel 1 km
0.8 μm
MODIS 20070826 11:10
The smoke disappears with the longer wavelengths

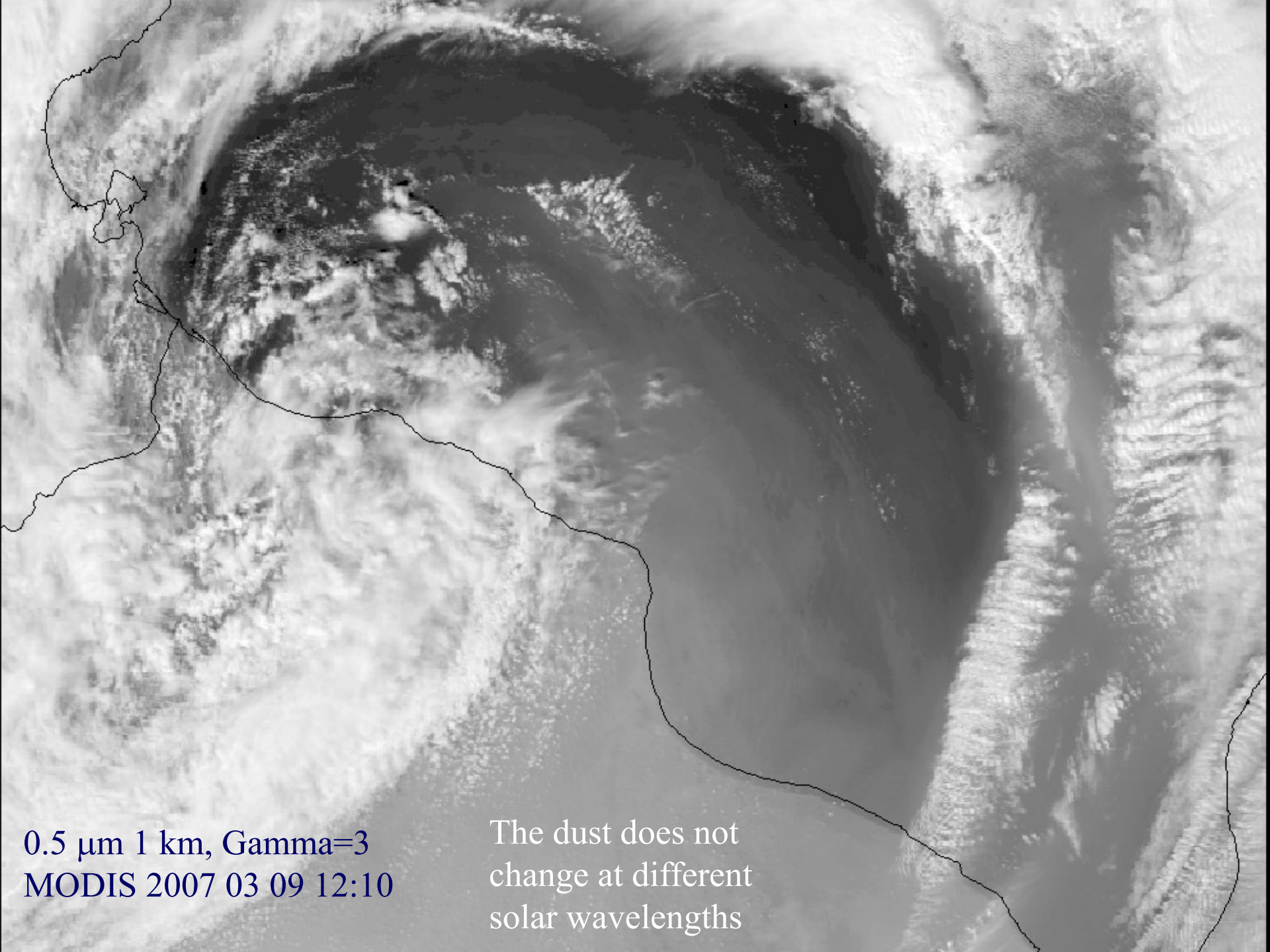

Single channel 1 km
1.2 μm
MODIS 20070826 11:10
The smoke disappears with the longer wavelengths

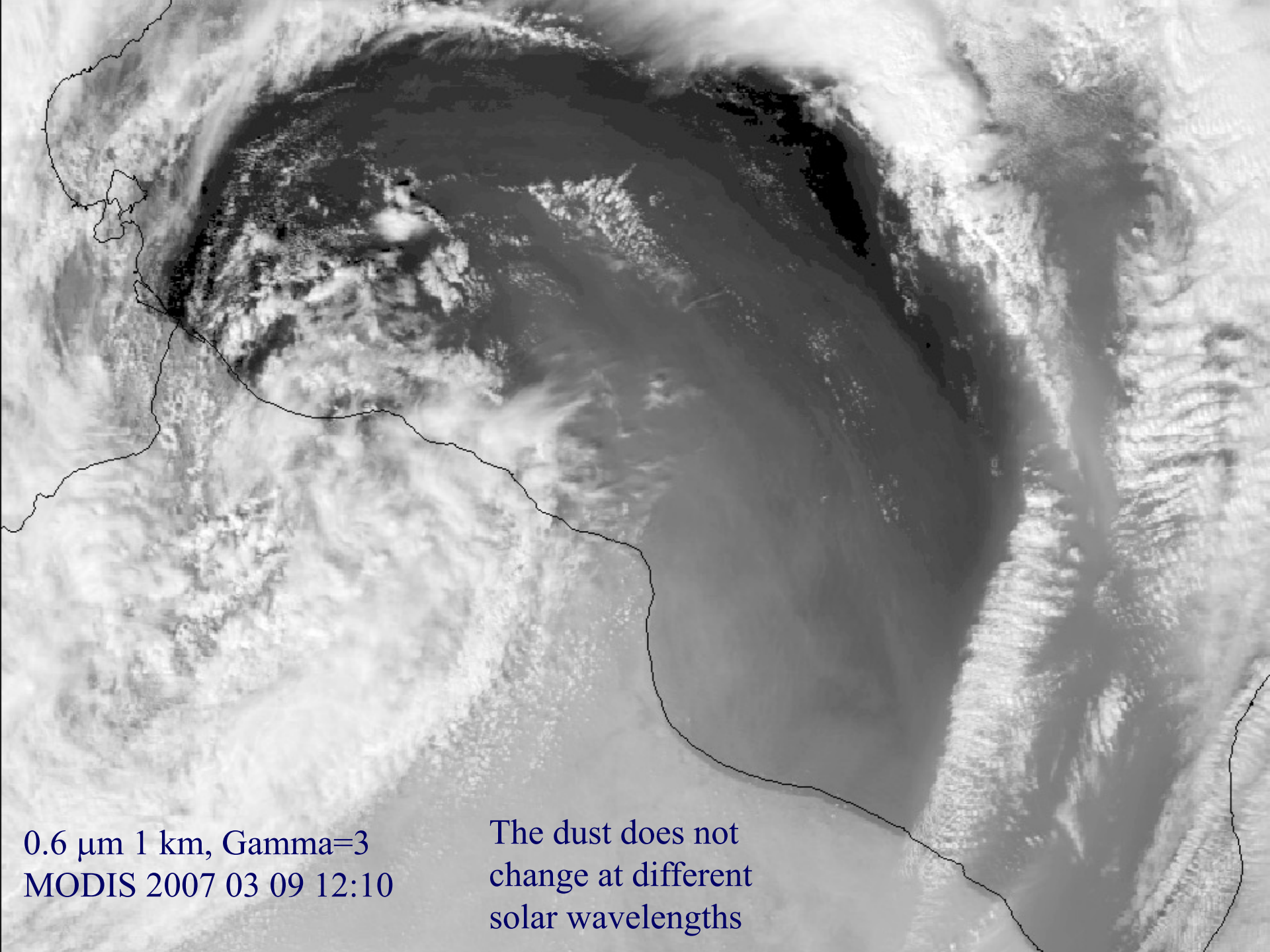

Single channel 1 km
2.1 μm
MODIS 20070826 11:10
The hot spots appear
already at 2.1 μm

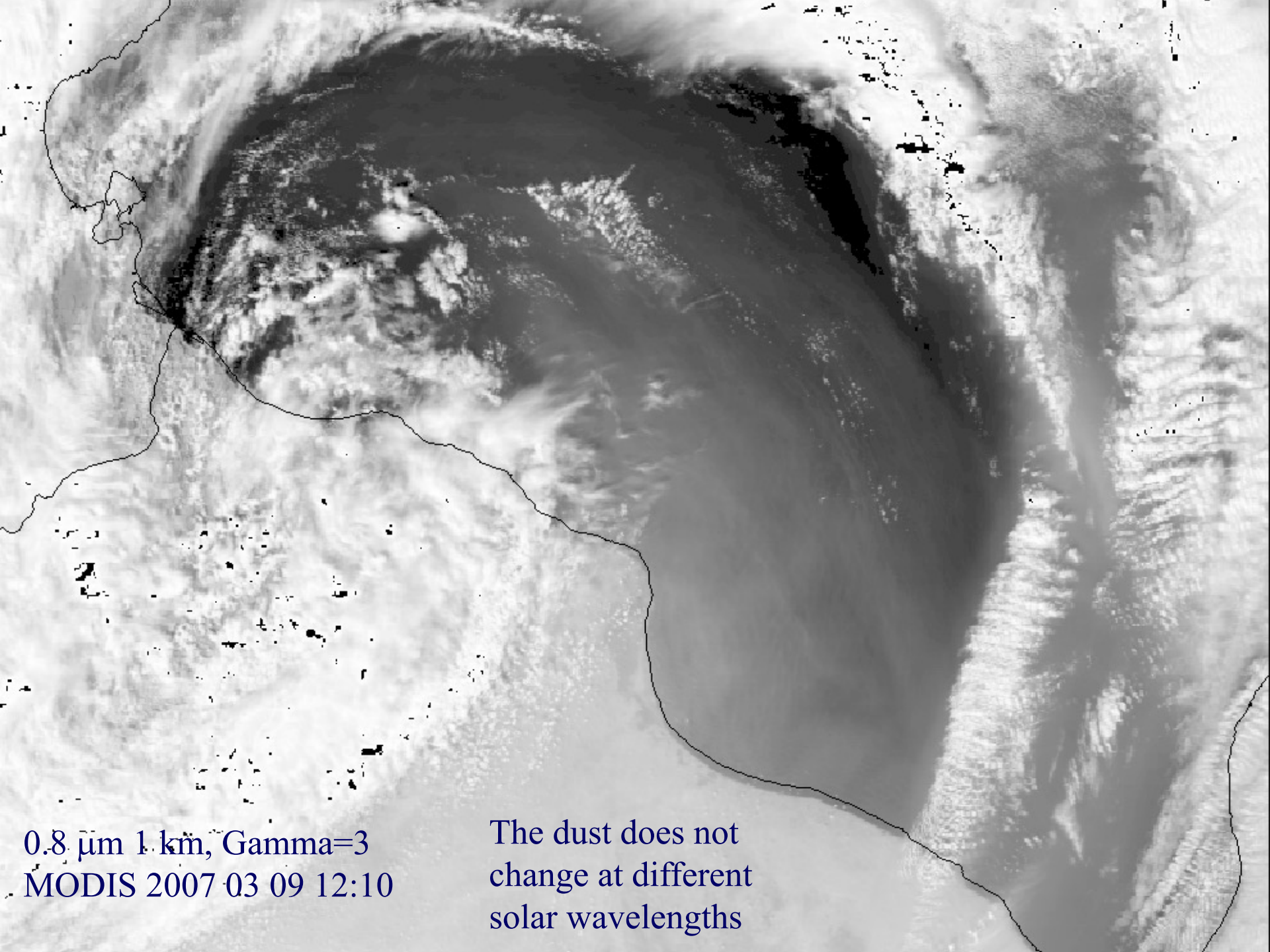

Single channel 1 km
3.7 mm
MODIS 20070826 11:10

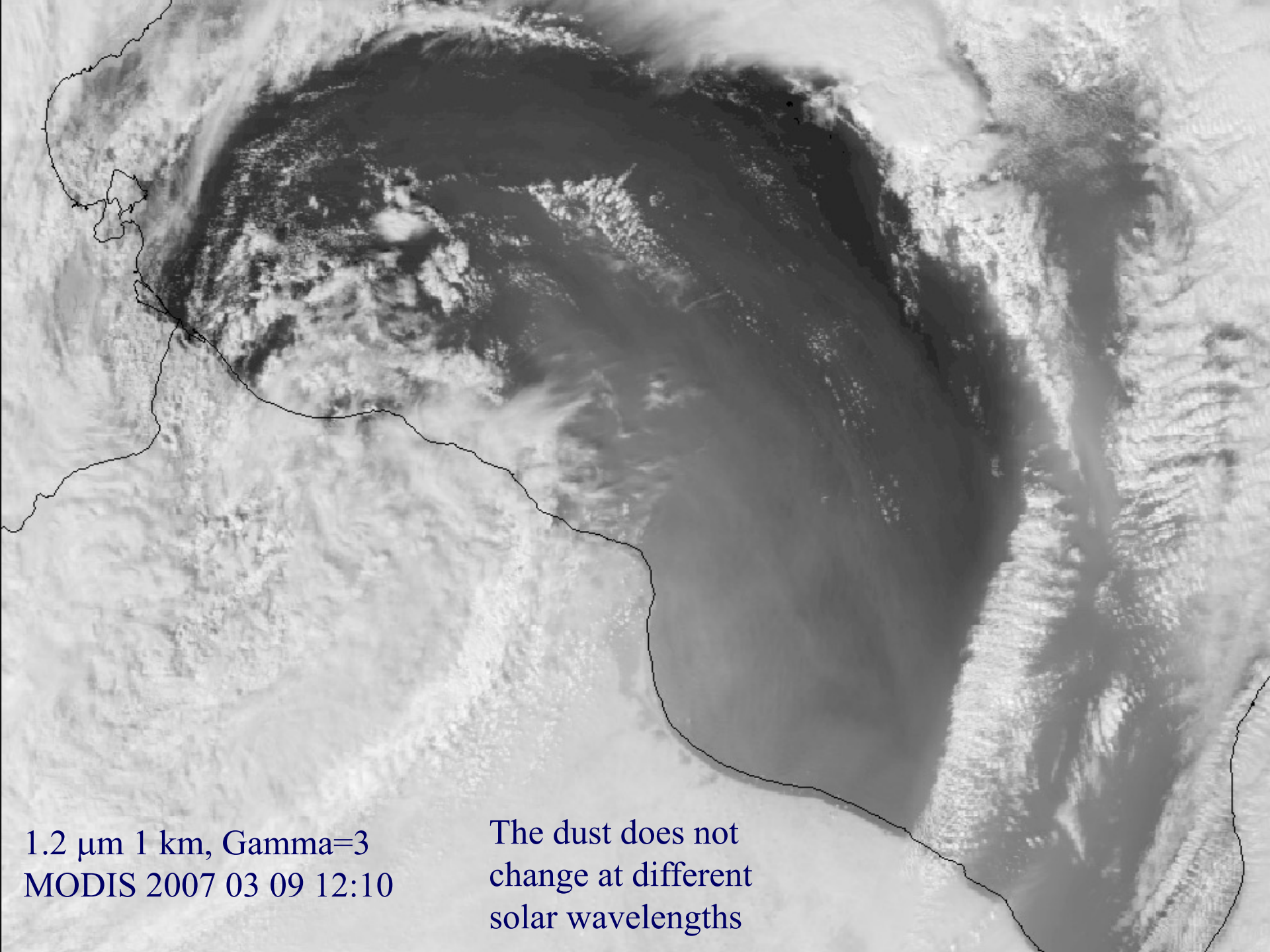

True color 1 km, Gamma=3
0.6 0.5 0.4
MODIS 2007 03 09 12:10
The dust does not
change at different
solar wavelengths

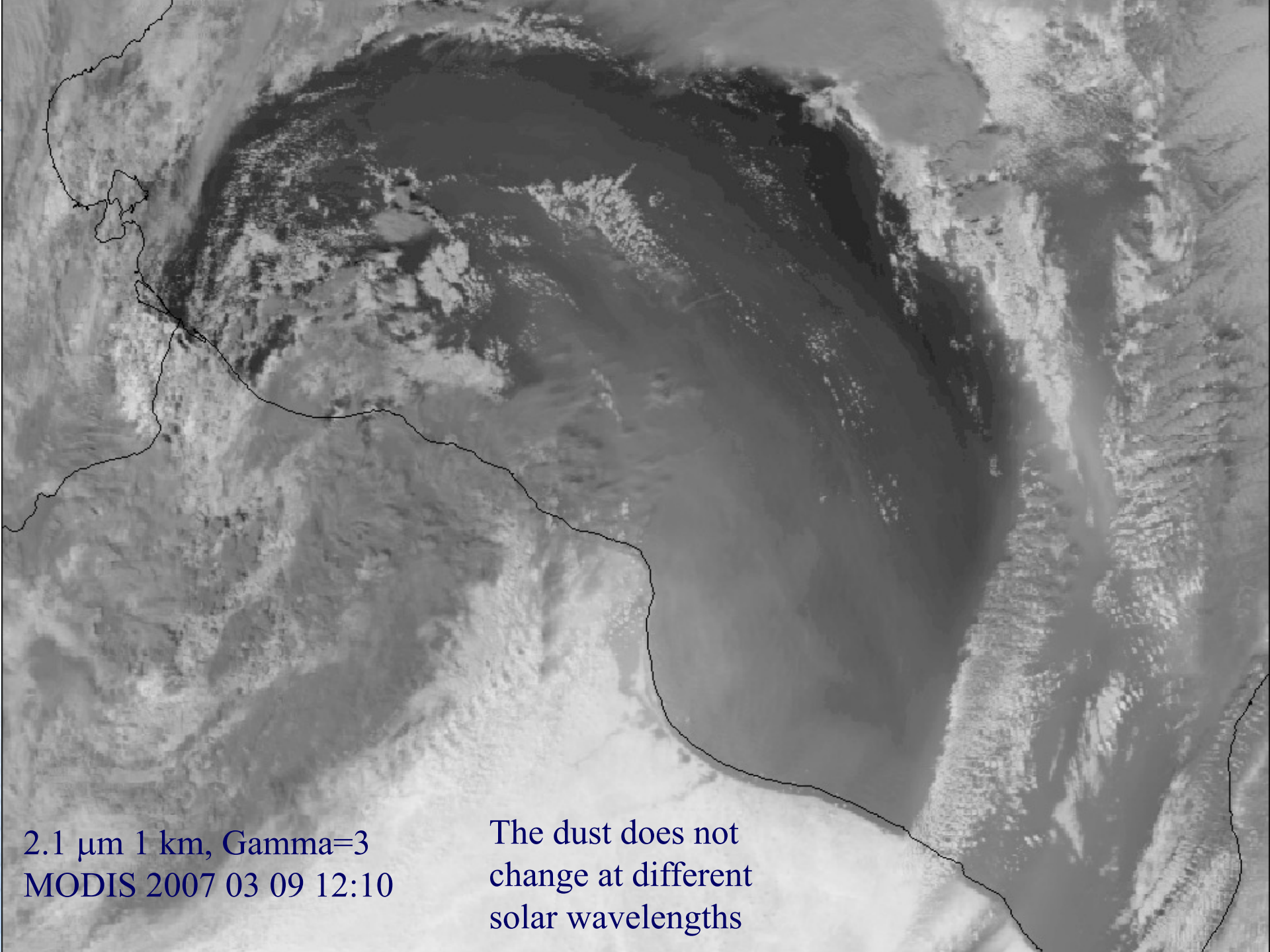

0.4 μm 1 km, Gamma=3
MODIS 2007 03 09 12:10
The dust does not
change at different
solar wavelengths

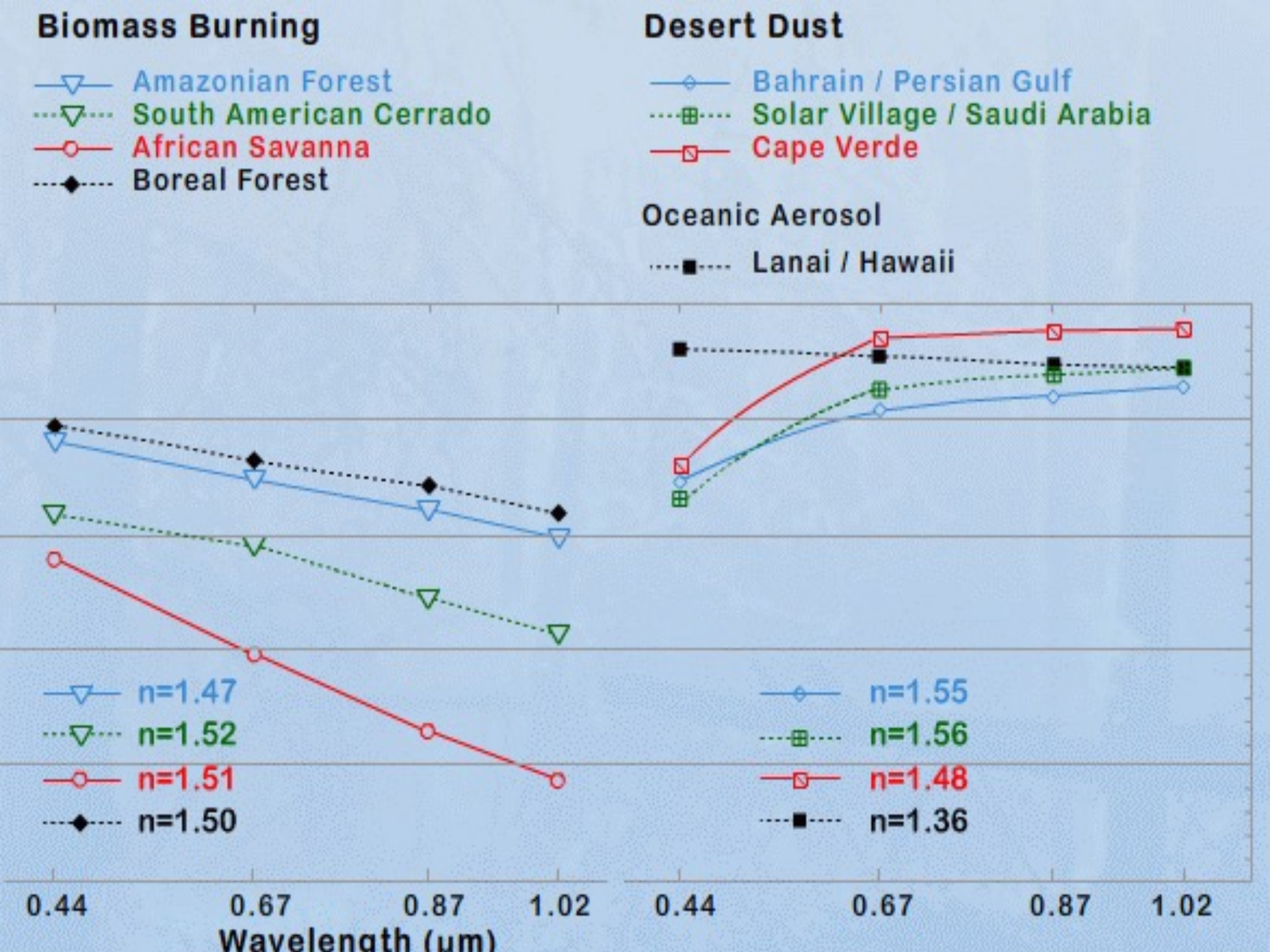

0.5 μm 1 km, Gamma=3
MODIS 2007 03 09 12:10
The dust does not
change at different
solar wavelengths


0.6 μm 1 km, Gamma=3
MODIS 2007 03 09 12:10
The dust does not
change at different
solar wavelengths


0.8 µm 1 km, Gamma=3
MODIS 2007 03 09 12:10
The dust does not
change at different
solar wavelengths

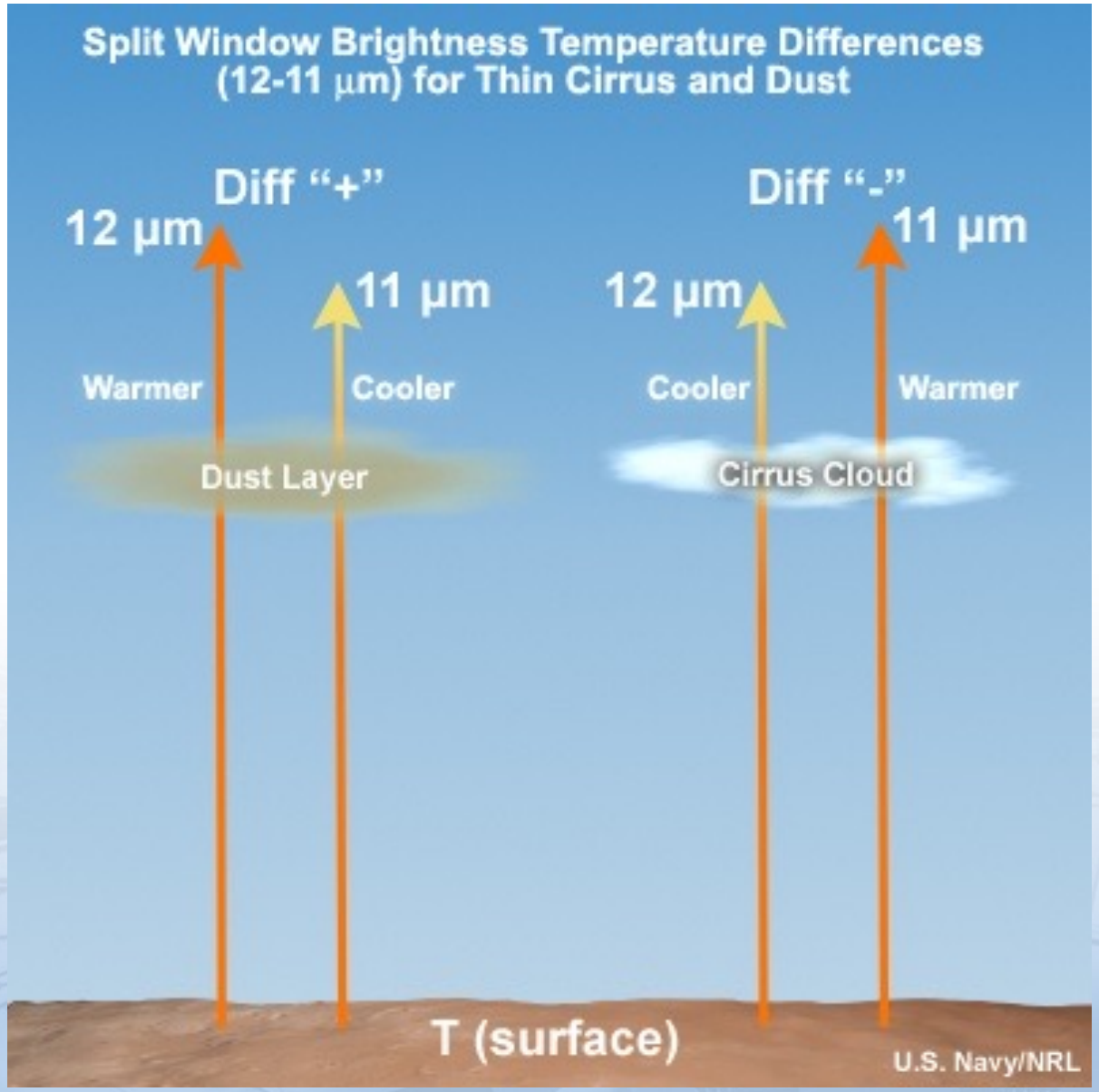

1.2 μm 1 km, Gamma=3
MODIS 2007 03 09 12:10
The dust does not
change at different
solar wavelengths


2.1 μm 1 km, Gamma=3
MODIS 2007 03 09 12:10
The dust does not
change at different
solar wavelengths


Biomass Burning
Amazonian Forest
South American Cerrado
African Savanna
Boreal Forest
Desert Dust
Bahrain / Persian Gulf
Solar Village / Saudi Arabia
Cape Verde
Oceanic Aerosol
Lanai / Hawaii
n=1.47
n=1.52
n=1.51
n=1.50
n=1.55
n=1.56
n=1.48
n=1.36
0.44
0.67
0.87
1.02
0.44
0.67
0.87
1.02
Wavelength (um)

The IR Window Differences
IR12.0 - IR10.8
IR10.8 - IR8.7

Transmission Spectra for Dust & Ice Clouds



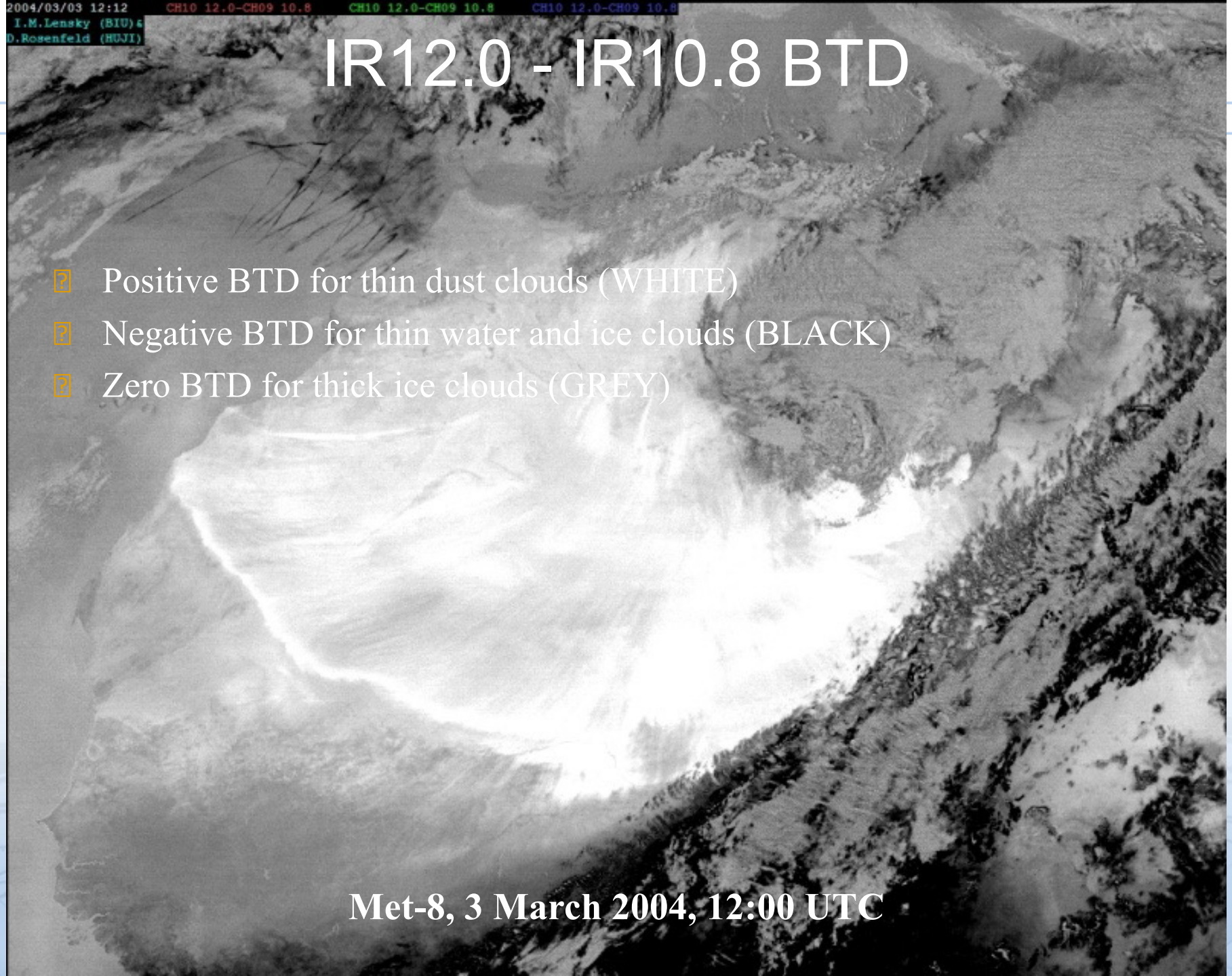
EUMETSAT

Effect on Brightness Temperatures

BTD IR12.0 - IR10.8 > 0 ***for thin dust (ash) clouds***

BTD IR12.0 - IR10.8 < 0 ***for thin ice clouds***

(neglecting other effects)



IR12.0 - IR10.8 BTD

- Positive BTD for thin dust clouds (WHITE)
- Negative BTD for thin water and ice clouds (BLACK)
- Zero BTD for thick ice clouds (GREY)

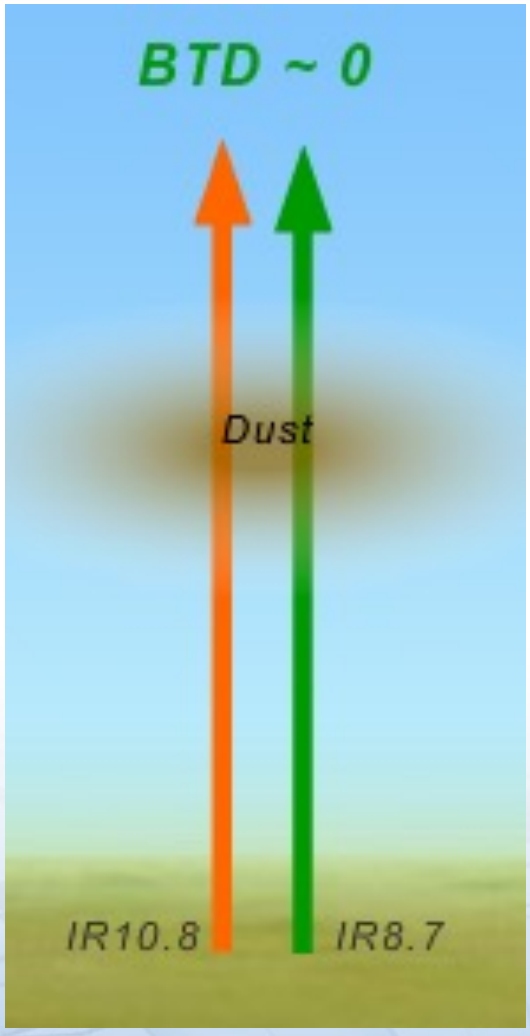
Met-8, 3 March 2004, 12:00 UTC

Challenges to using the 12.0-10.8 um difference product

- Low dust clouds:
  - at night
  - over Ocean
  - obscured by higher clouds
- Mid & High dust clouds:
  - Low dust concentrations

EUMETSAT

Transmission Spectra for Dust Clouds



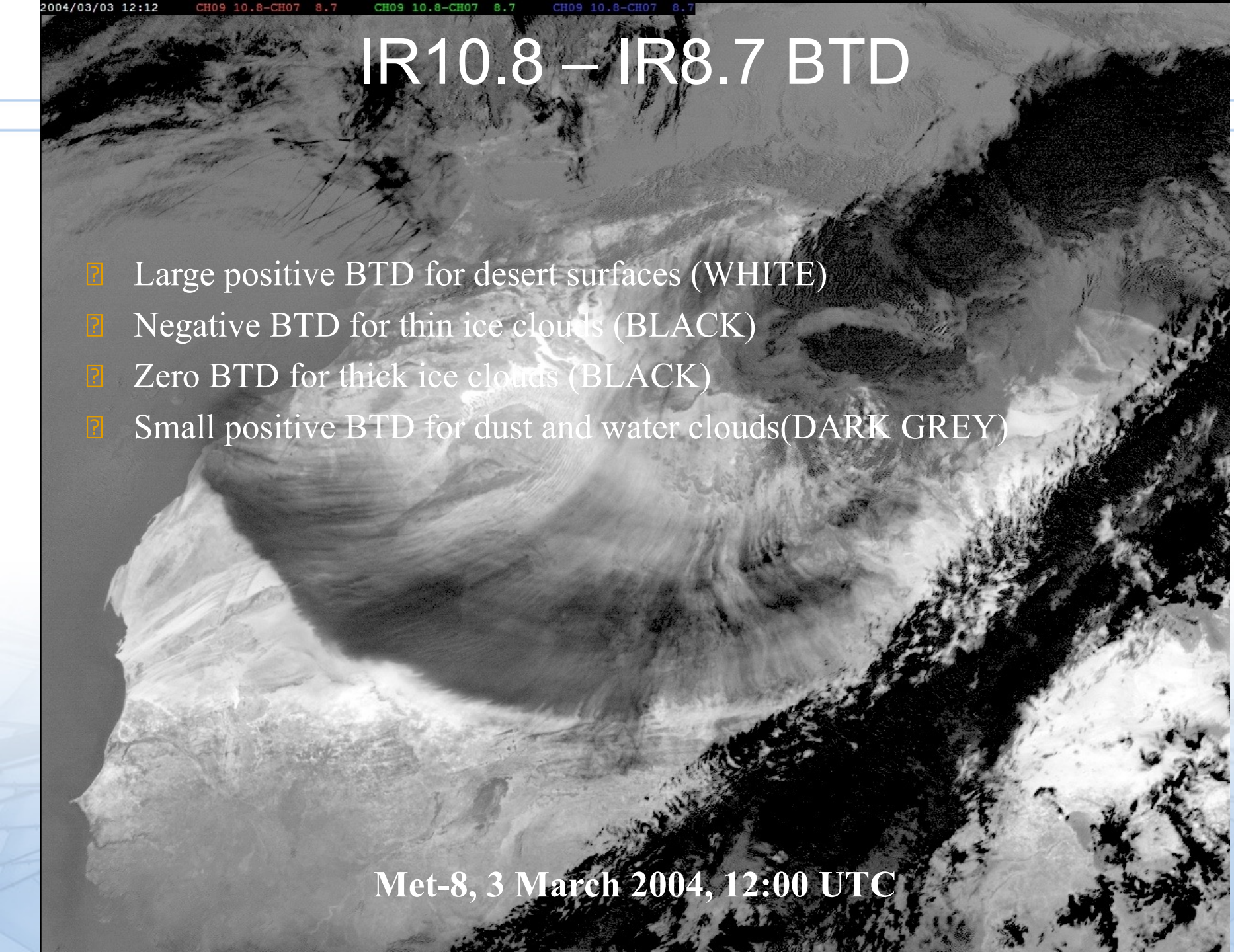
EUMETSAT

Effect on Brightness Temperatures

BTD IR10.8 – IR8.7 >> 0 ***for desert surfaces***

BTD IR10.8 – IR8.7 = 0 ***for clouds***

(neglecting other effects)



IR10.8 – IR8.7 BTD

- Large positive BTD for desert surfaces (WHITE)
- Negative BTD for thin ice clouds (BLACK)
- Zero BTD for thick ice clouds (BLACK)
- Small positive BTD for dust and water clouds(DARK GREY)

Met-8, 3 March 2004, 12:00 UTC

Challenges to using the 10.8 – 8.7 um difference product

- Does not distinguish between Dust Clouds and Water Clouds

The Dust RGB Product

Detection of dust with MSG: which features shall we use for the RGB Product ?

- VIS0.6 or HRV (VIS0.8, NIR1.6 not good)
  good over Oceans, only daytime
- IR3.9r (reflectance part)
  good over Oceans, only daytime
- IR10.8 (thermal signal)
  good over Land, only daytime
- Difference IR12.0 - IR10.8 (known from AVHRR)
  good for mid & high dust clouds, day and night, Land and Ocean
- Difference IR8.7 - IR10.8 (new)
  good over deserts, day and night
- Difference IR3.9 – IR10.8 (known from AVHRR)
  good over Land and Oceans, only daytime

EUMETSAT

RGB 10-09, 09-07, 09 ("24-hour Dust Microphysics")

devised by: D. Rosenfeld

Recommended Range and Enhancement:

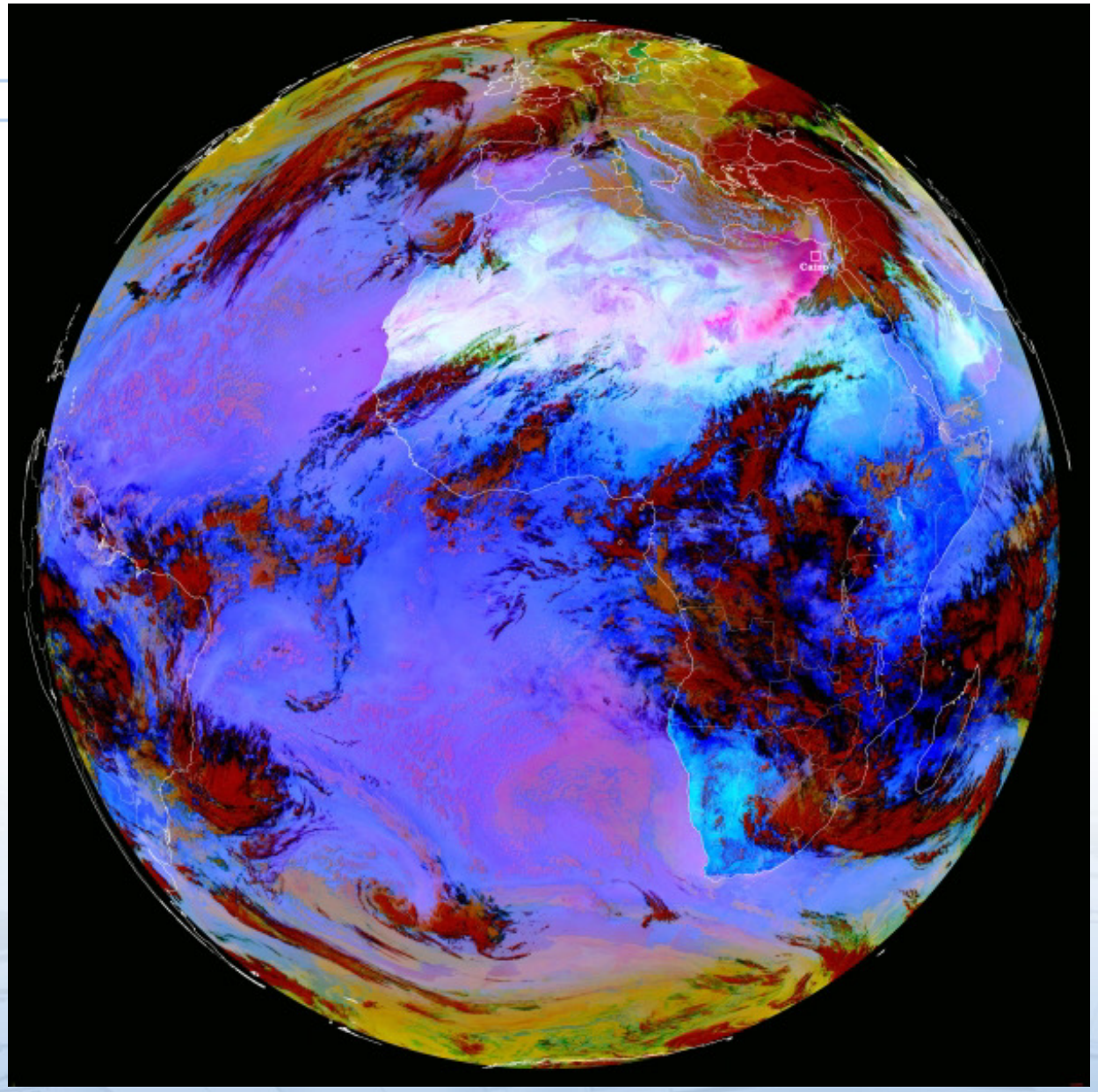
Beam	Channel	Range	Gamma
Red	IR12.0 - IR10.8	-4 … +2 K	1.0
Green	IR10.8 - IR8.7	0 … +15 K	2.5
Blue	IR10.8	+261 … +289 K	1.0

Physical Interpretation (for dust/ash/water/ice clouds)

R = Difference IR12.0 - IR10.8
Optical Thickness, Tsurf-Tcloud

G = Difference IR10.8 - IR8.7
Optical Thickness, Tsurf-Tcloud, Phase

B = Channel IR10.8
Top Temperature

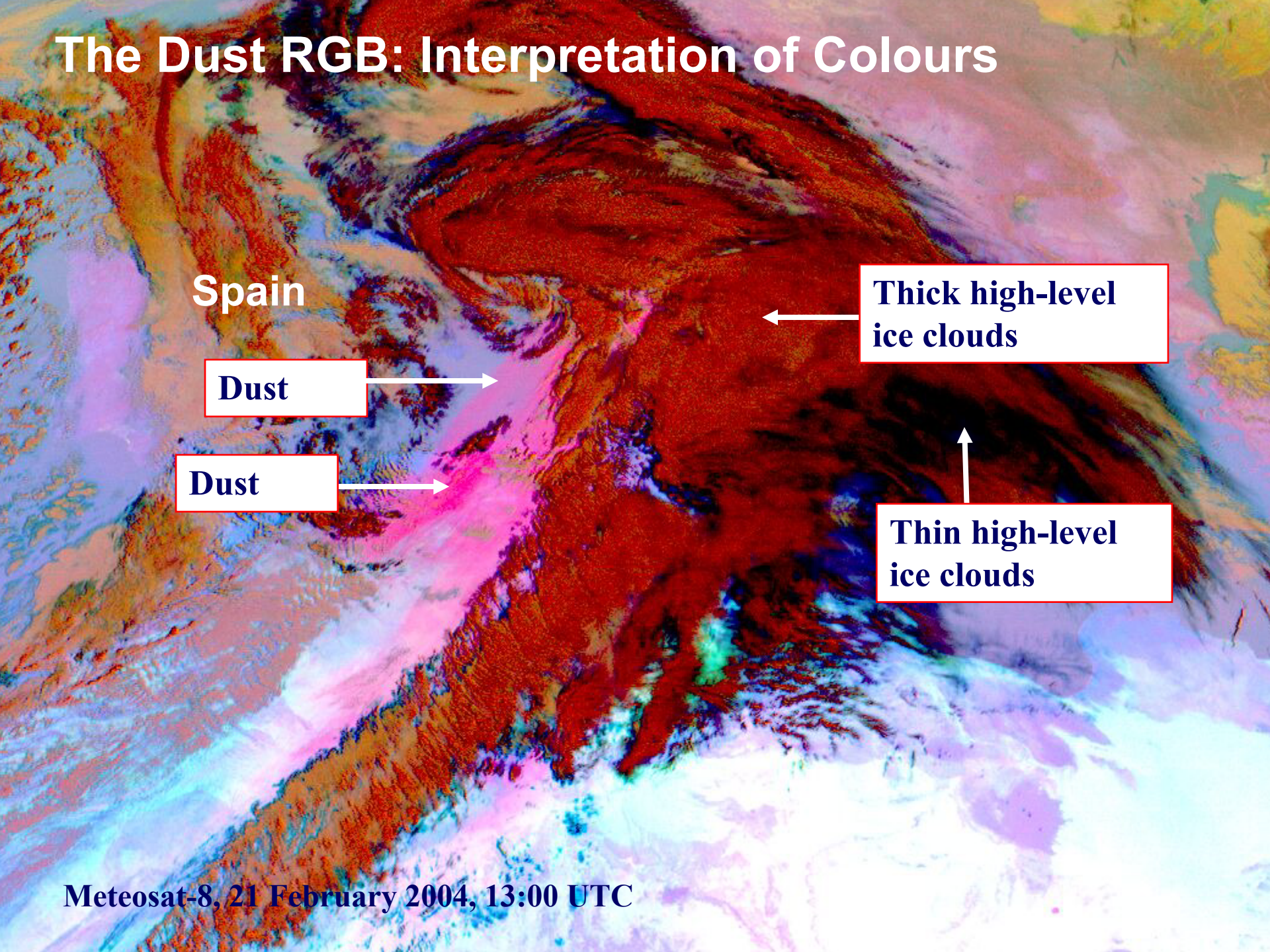


RGB 24-hour Dust Microphysics Global View

MSG-1
22 January 2004
12:00 UTC

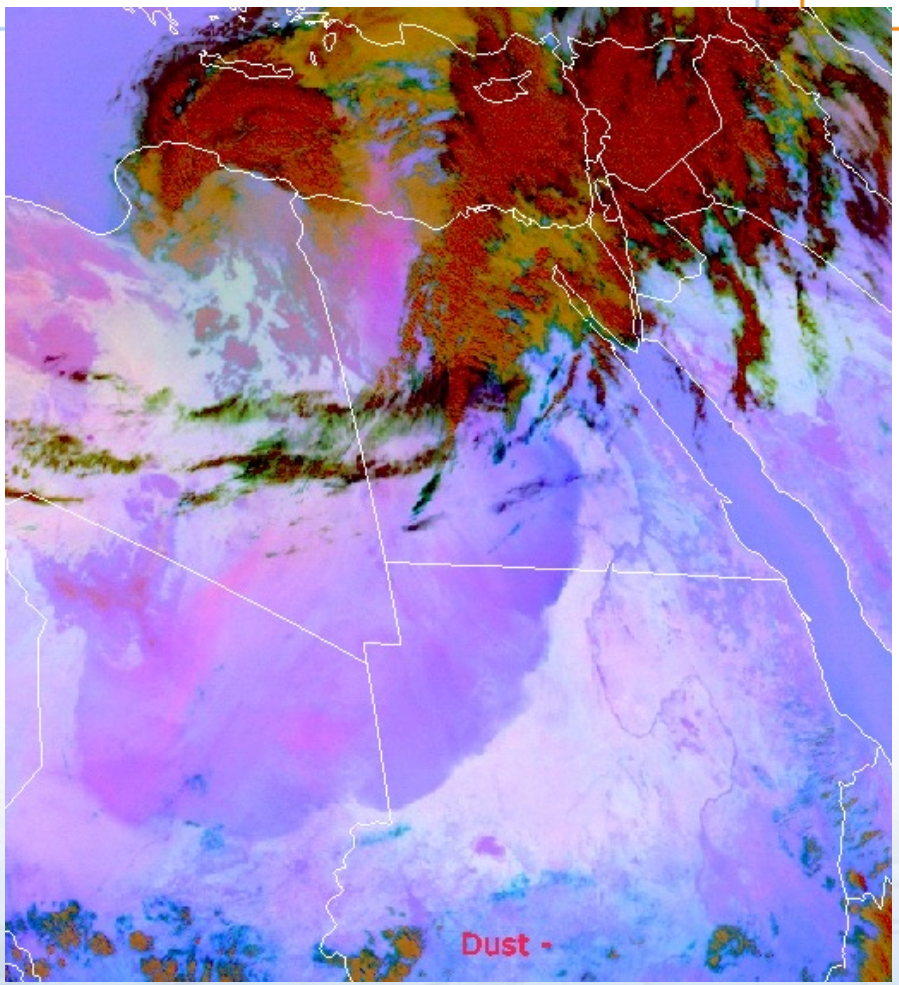
EUMETSAT

The Dust RGB: Interpretation of Colours

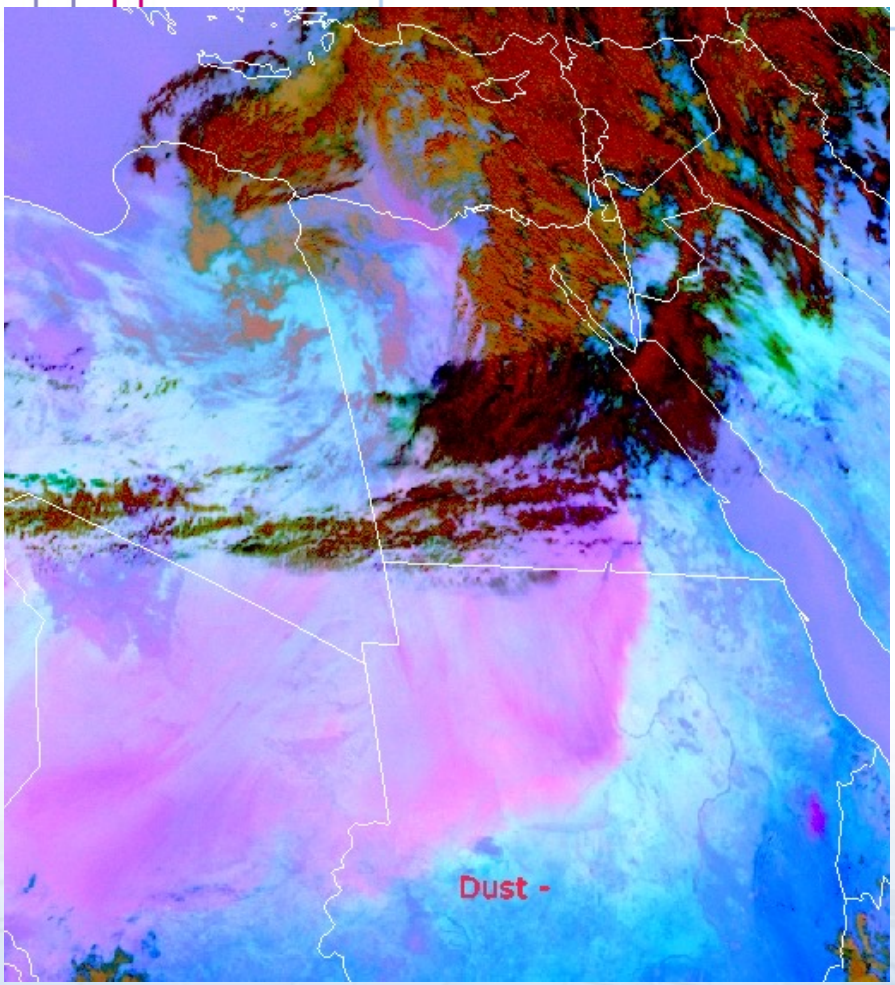


Meteosat-8, 21 February 2004, 13:00 UTC

Comparison: Night vs Day



00:00 UTC

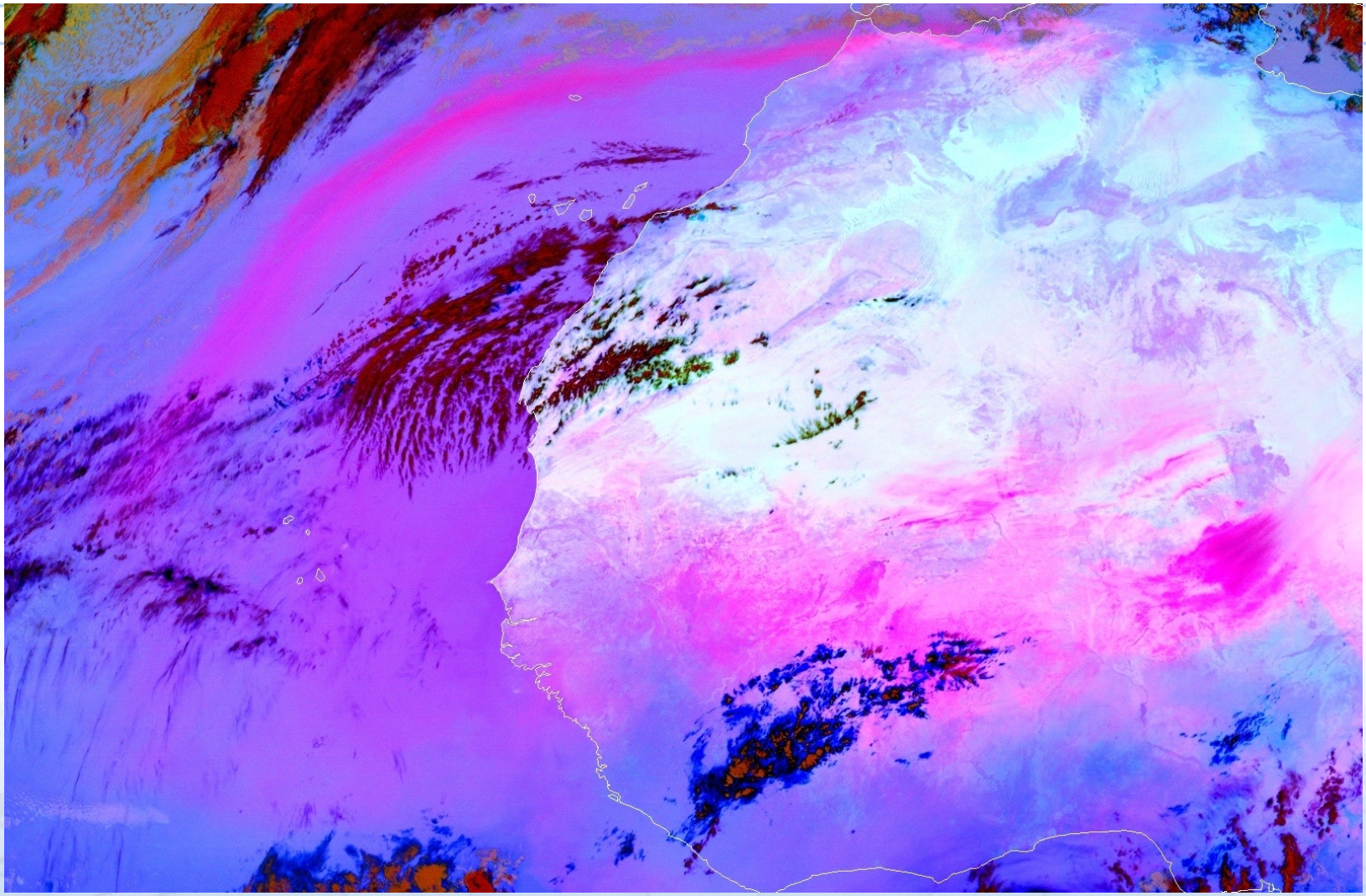


07:15 UTC

MSG-1, 10 May 2007

EUMETSAT

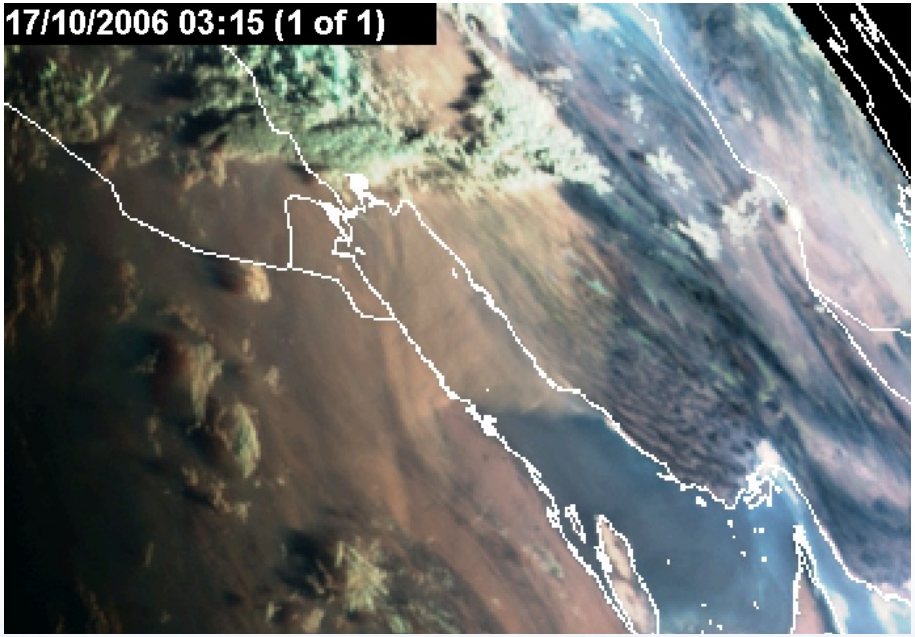
Example: Dust over Ocean

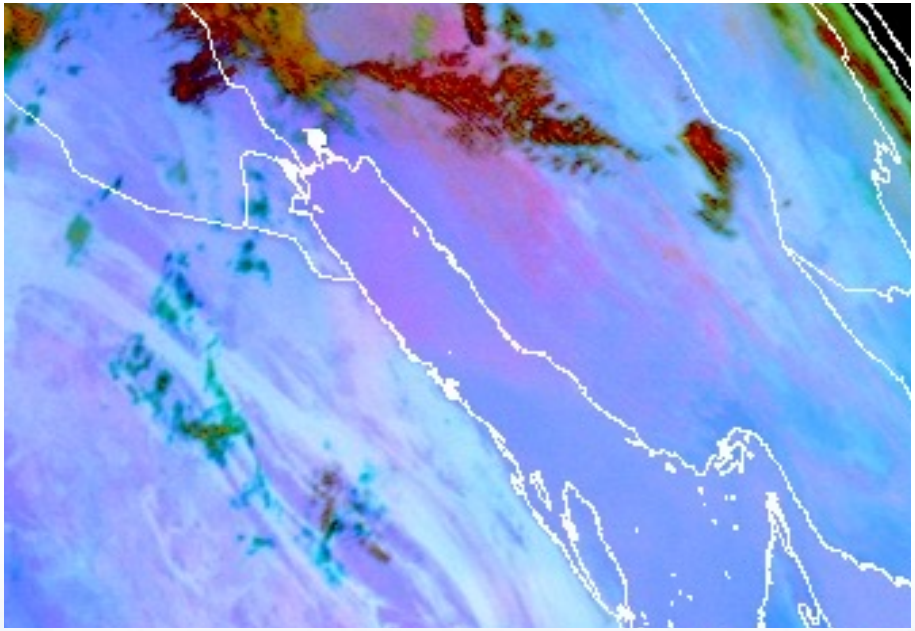


MSG-1, 6 March 2004, 12:00 UTC

EUMETSAT

Example: Dust over Ocean





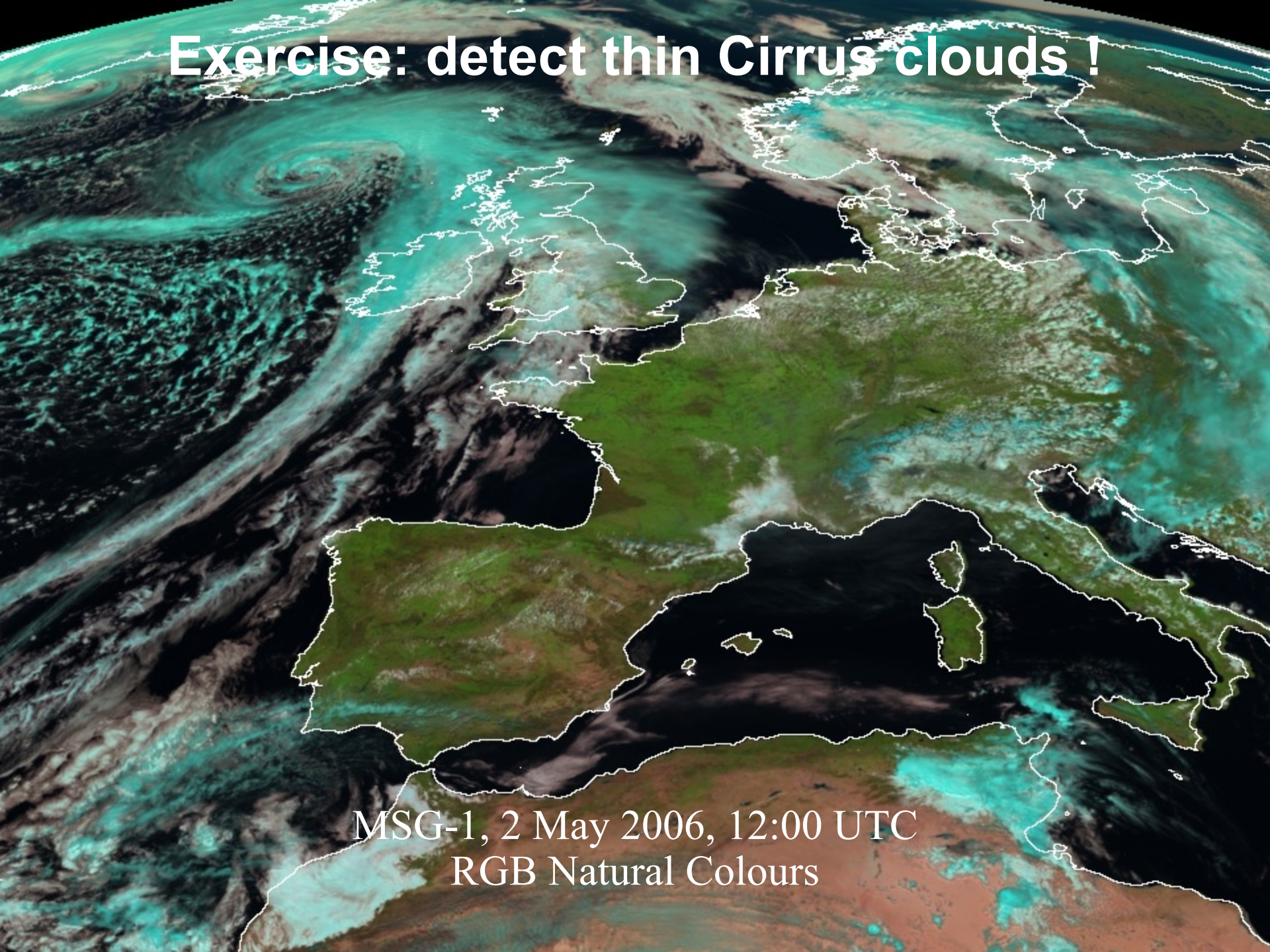
03:15 UTC
Natural Colours RGB

05:00 UTC
Dust RGB

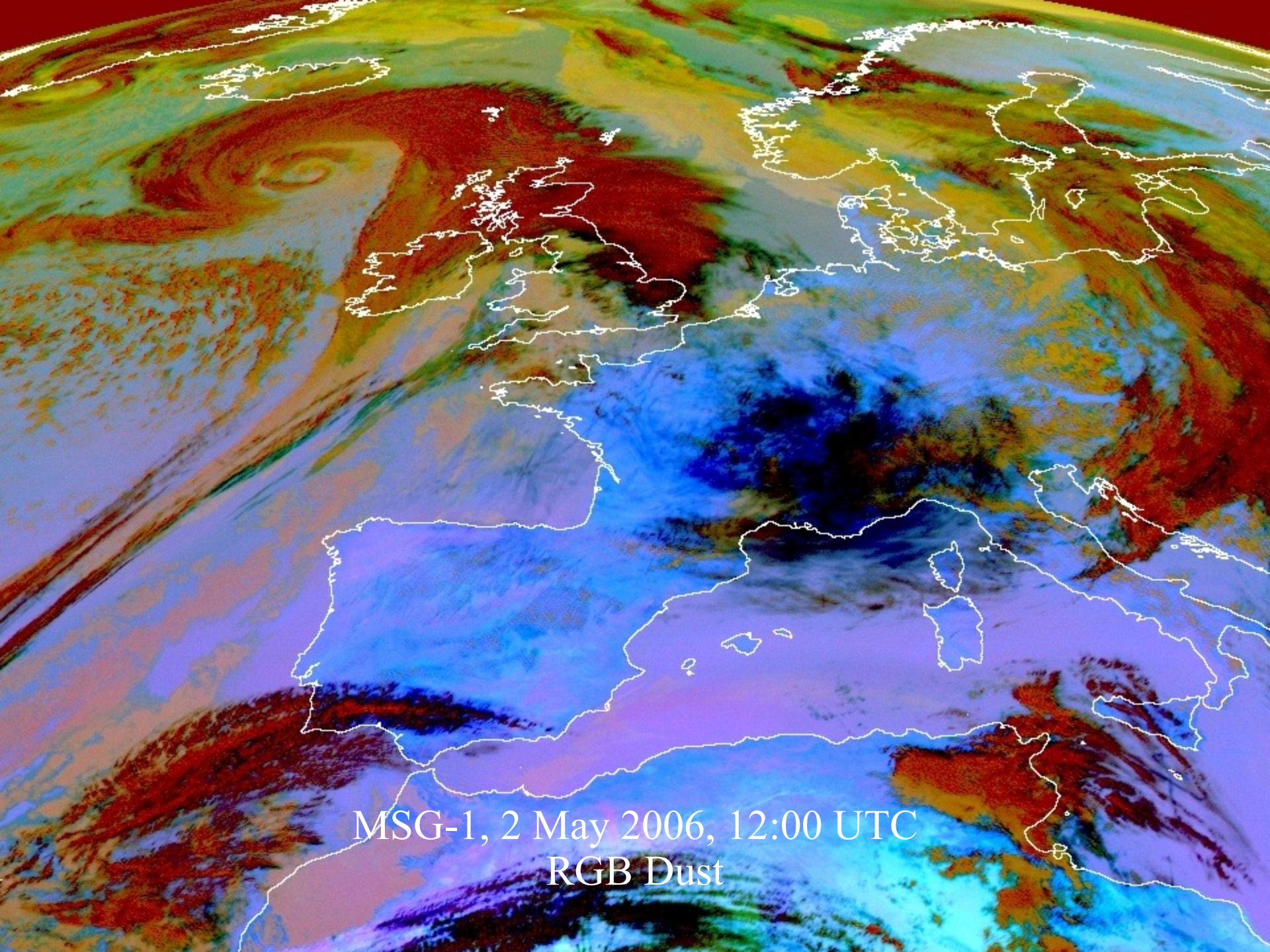
MSG-1, 17 October 2006

EUMETSAT

Exercise: detect thin Cirrus clouds !

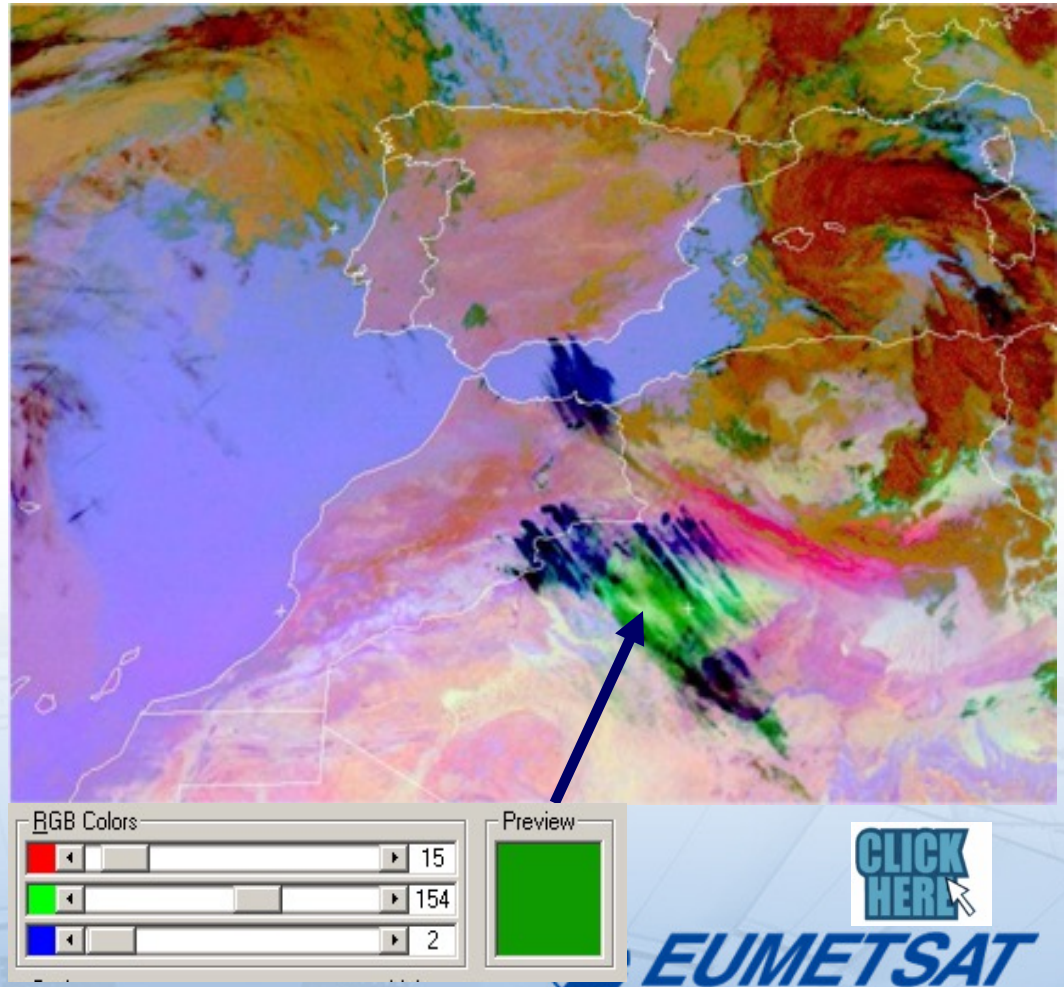


MSG-1, 2 May 2006, 12:00 UTC
RGB Natural Colours


MSG-1, 2 May 2006, 12:00 UTC
RGB Dust

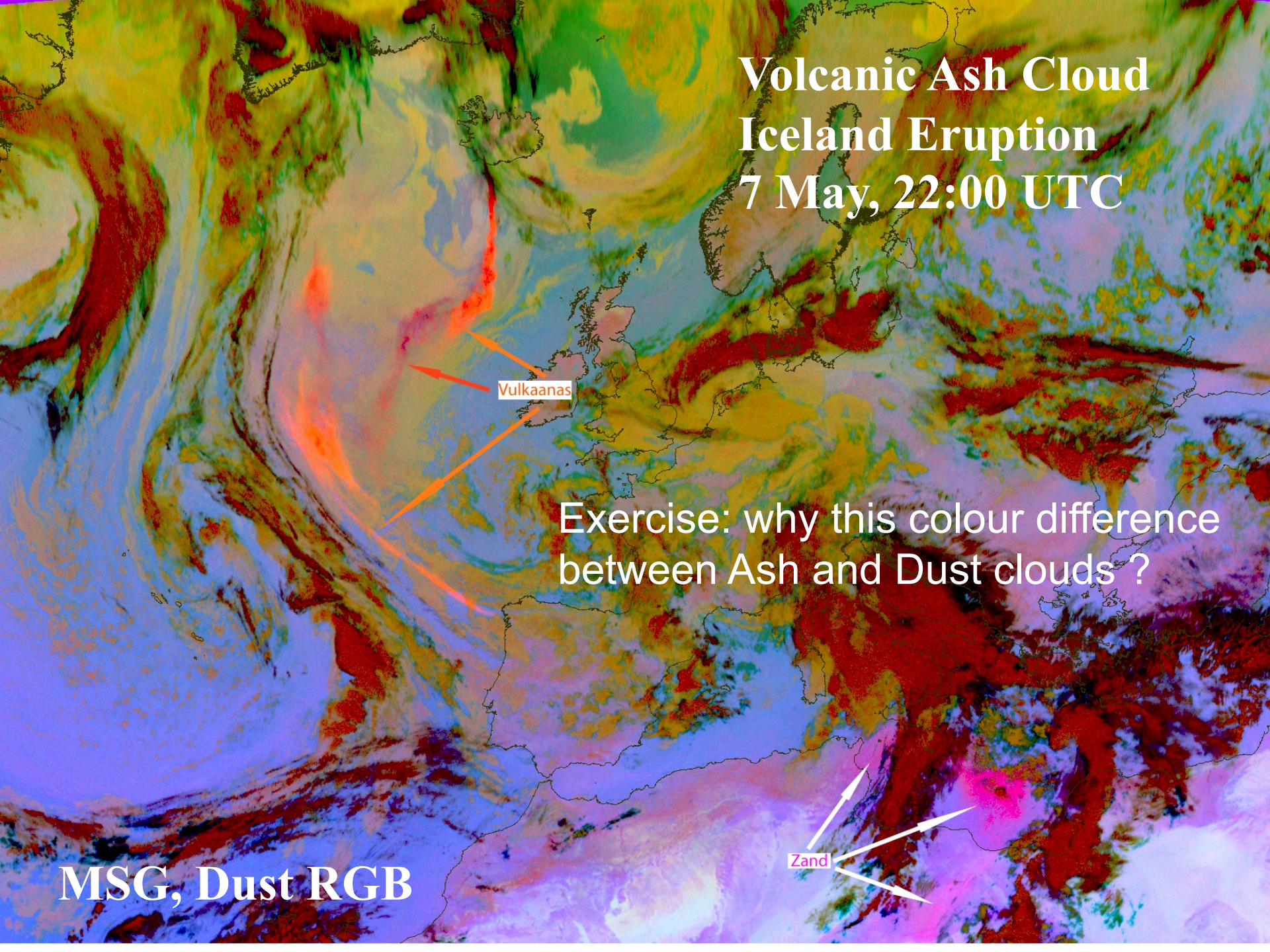
Other colors in “Dust RGB” - Green

Attention - Thin cirrus can also look green over some desert areas due to a different emissivity of the surface at IR 8.7

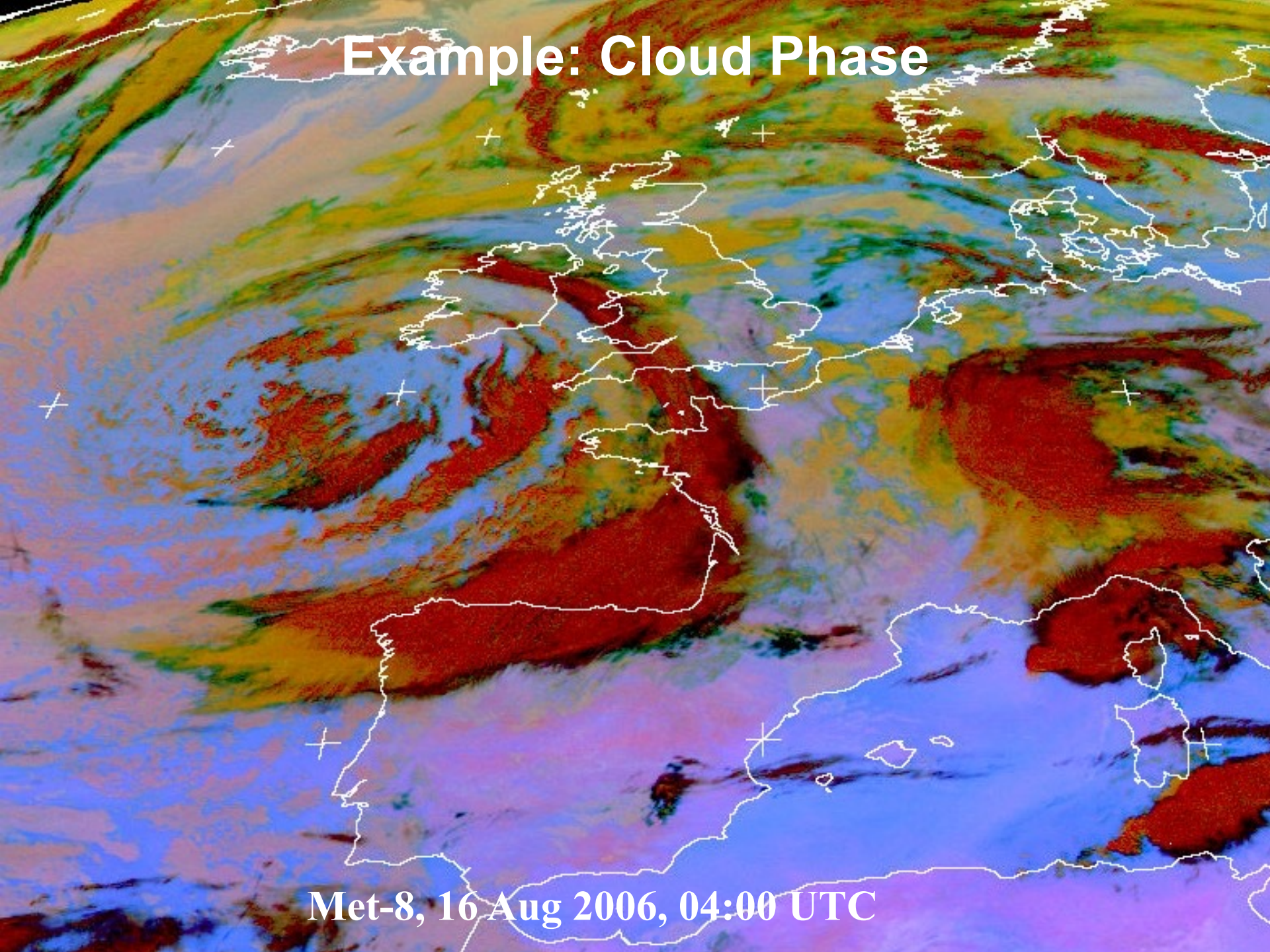


CLICK HERE

EUMETSAT


Volcanic Ash Cloud
Iceland Eruption
7 May, 22:00 UTC
Vulkaanas
Exercise: why this colour difference between Ash and Dust clouds ?
Zand
MSG, Dust RGB

Example: Cloud Phase



Met-8, 16 Aug 2006, 04:00 UTC

RGB 24-hour Dust Microphysics: Interpretation of Colours for High-level Clouds

Cold, thick, high-level clouds

Thin Cirrus clouds / Contrails

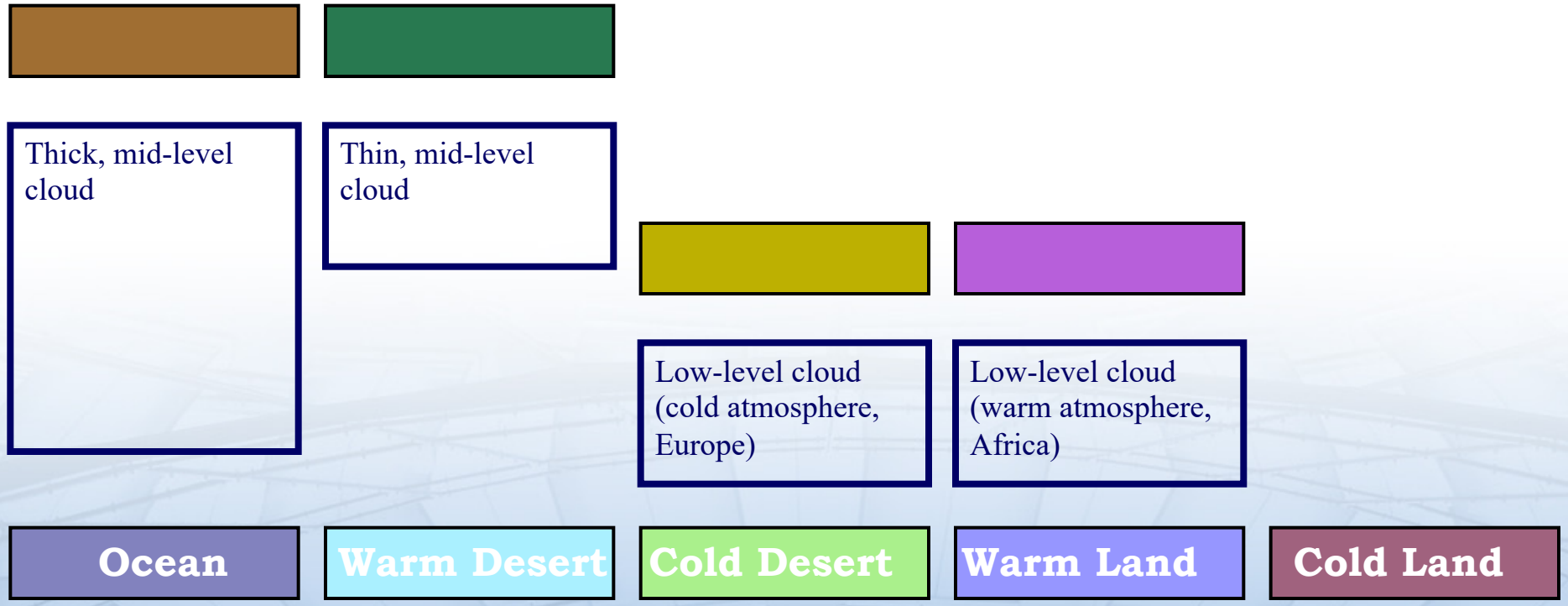
over vegetated land / ocean

over sand desert

Ocean	Warm Desert	Cold Desert	Warm Land	Cold Land

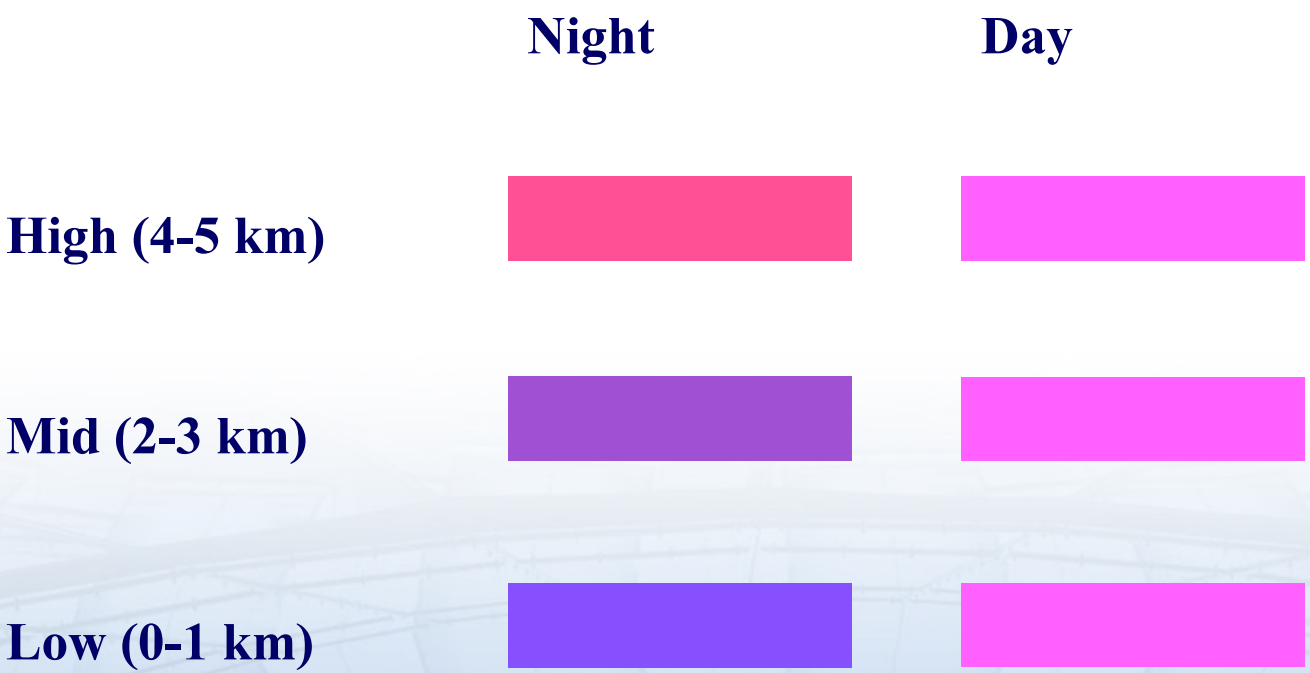
EUMETSAT

RGB 24-hour Dust Microphysics: Interpretation of Colours for Low/Mid-level Clouds

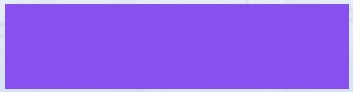
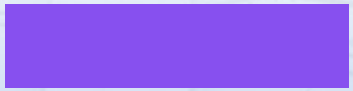


EUMETSAT

The Dust RGB: Interpretation of Colours
1. Thin Dust Clouds

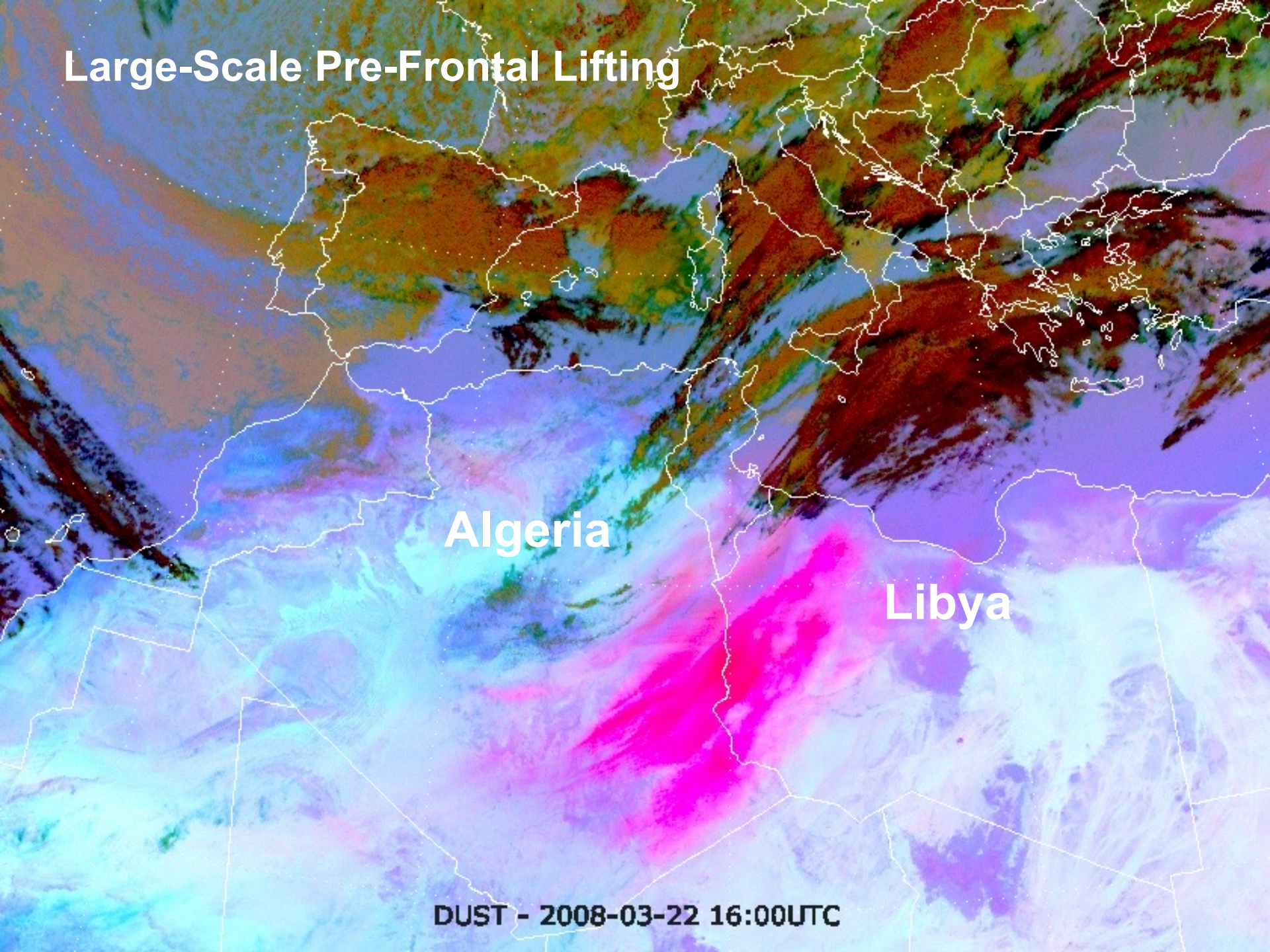


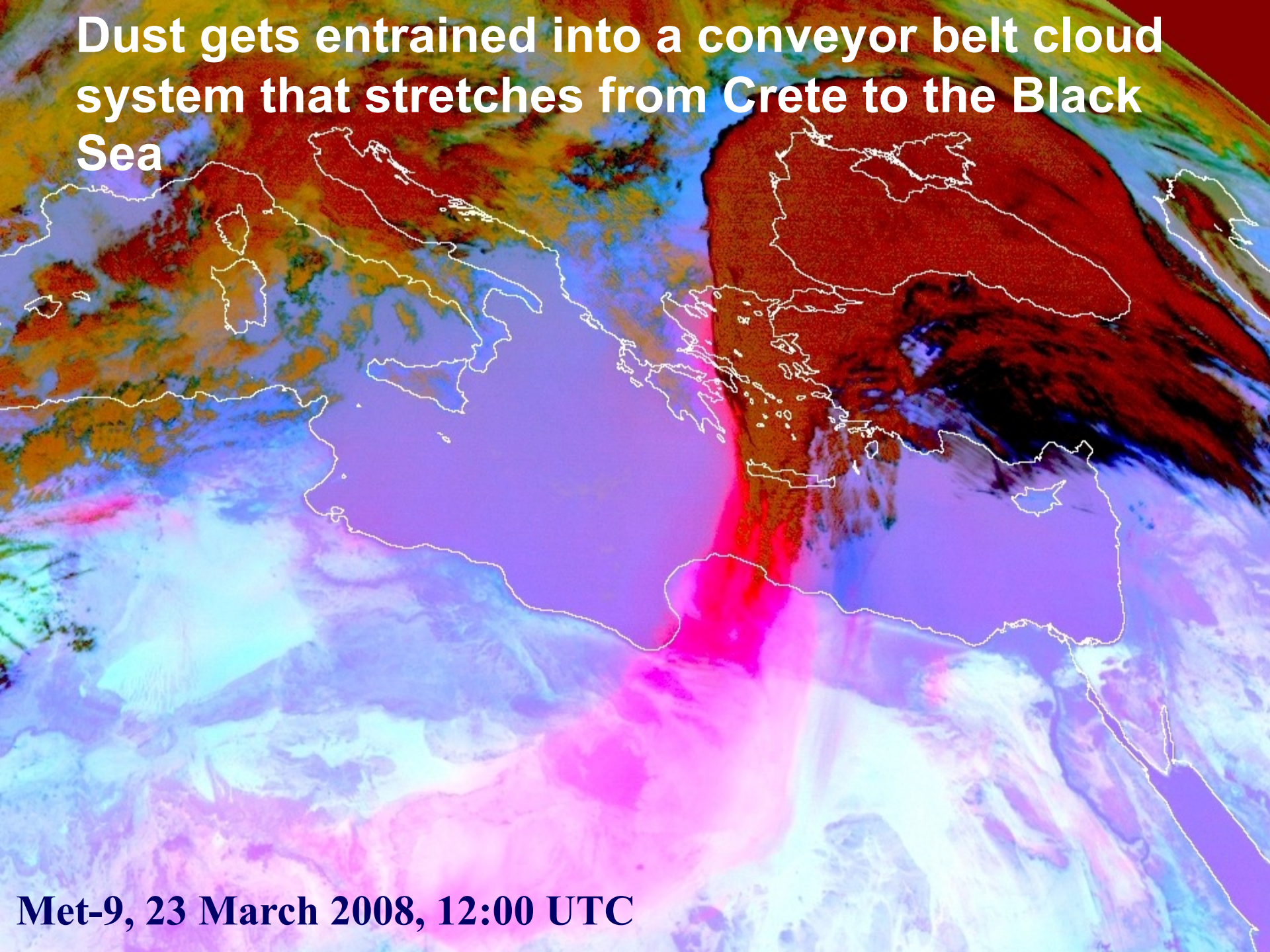
The Dust RGB: Interpretation of Colours
2. Very Thick Dust Clouds

	Night	Day
High (4-5 km)		
Mid (2-3 km)		
Low (0-1 km)		

EUMETSAT

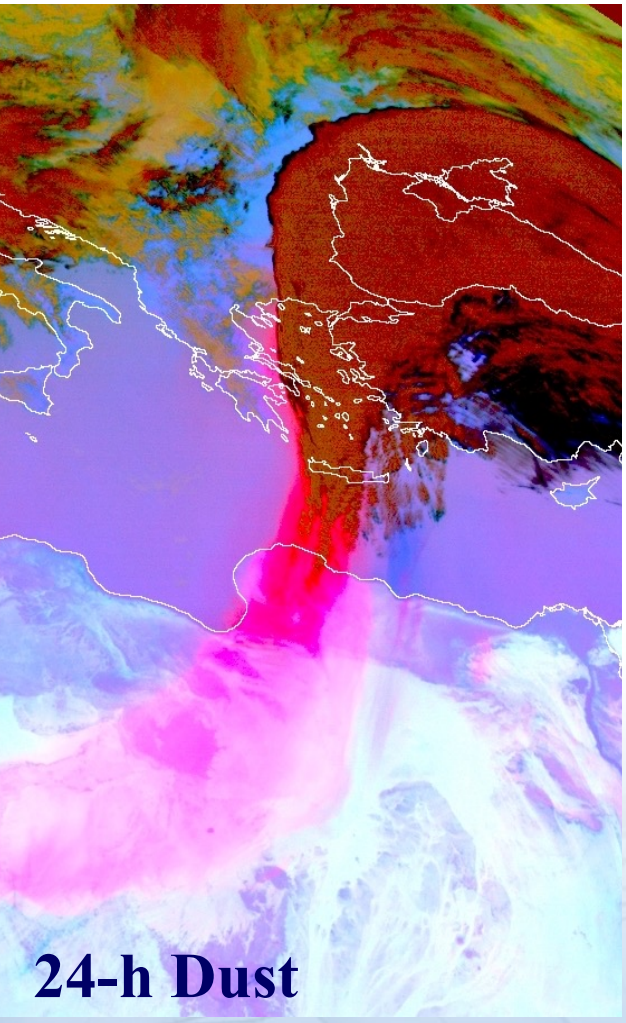
Types of Dust Outbreaks

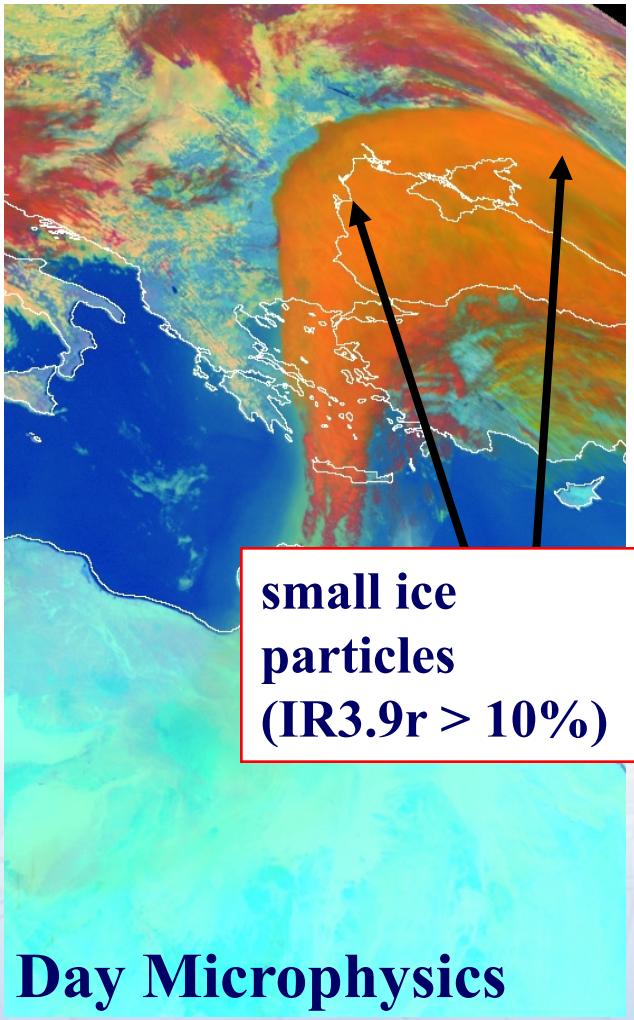

Large-Scale Pre-Frontal Lifting
Algeria
Libya
DUST - 2008-03-22 16:00UTC

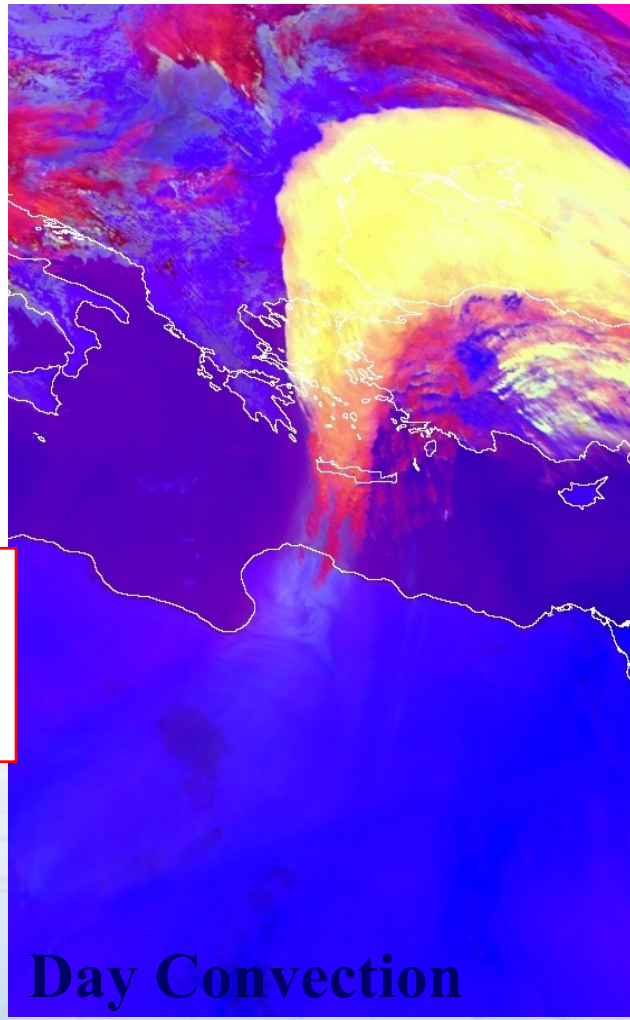

Dust gets entrained into a conveyor belt cloud system that stretches from Crete to the Black Sea
Met-9, 23 March 2008, 12:00 UTC

Dust Changes Cloud Microphysics

cloud glaciates very quickly with lots of needle hydrometeors present
dust acts as very efficient ice nuclei







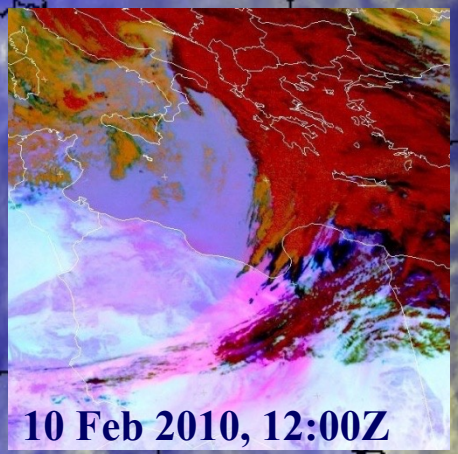
Met-9, 23 March 2008, 12:00 UTC

EUMETSAT

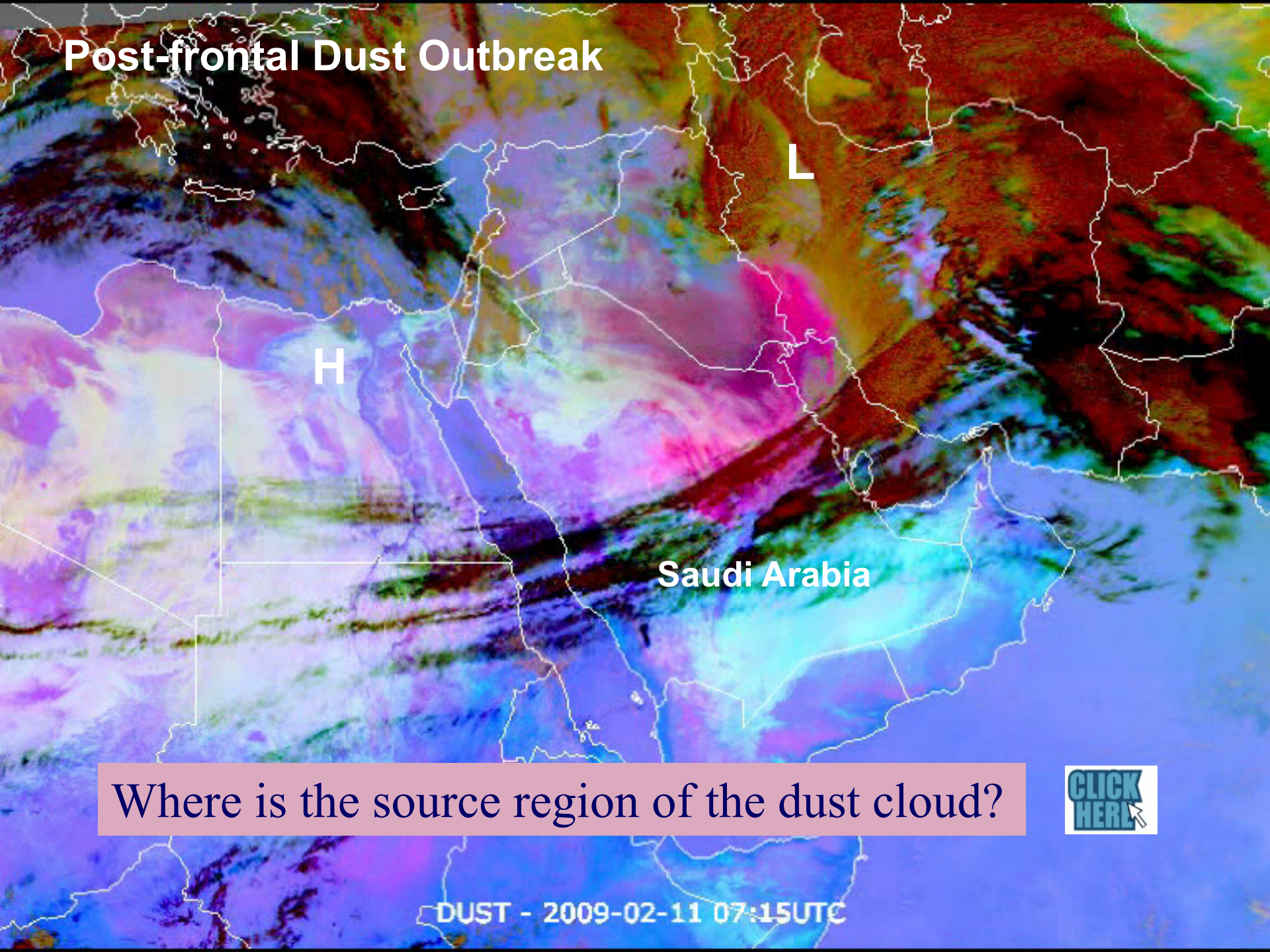
Dust causes Granular Structure of Cirrus Shield

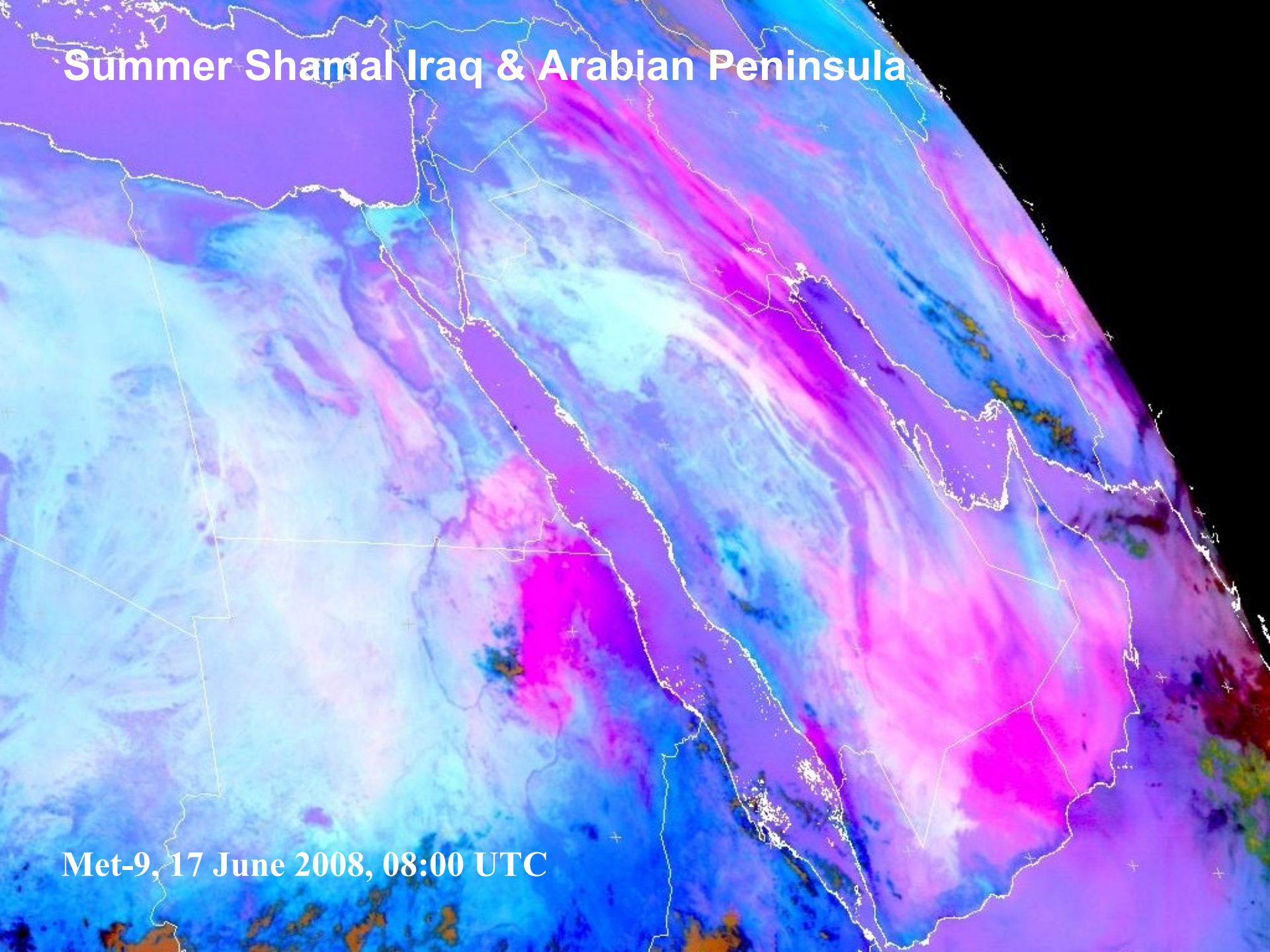
Poland

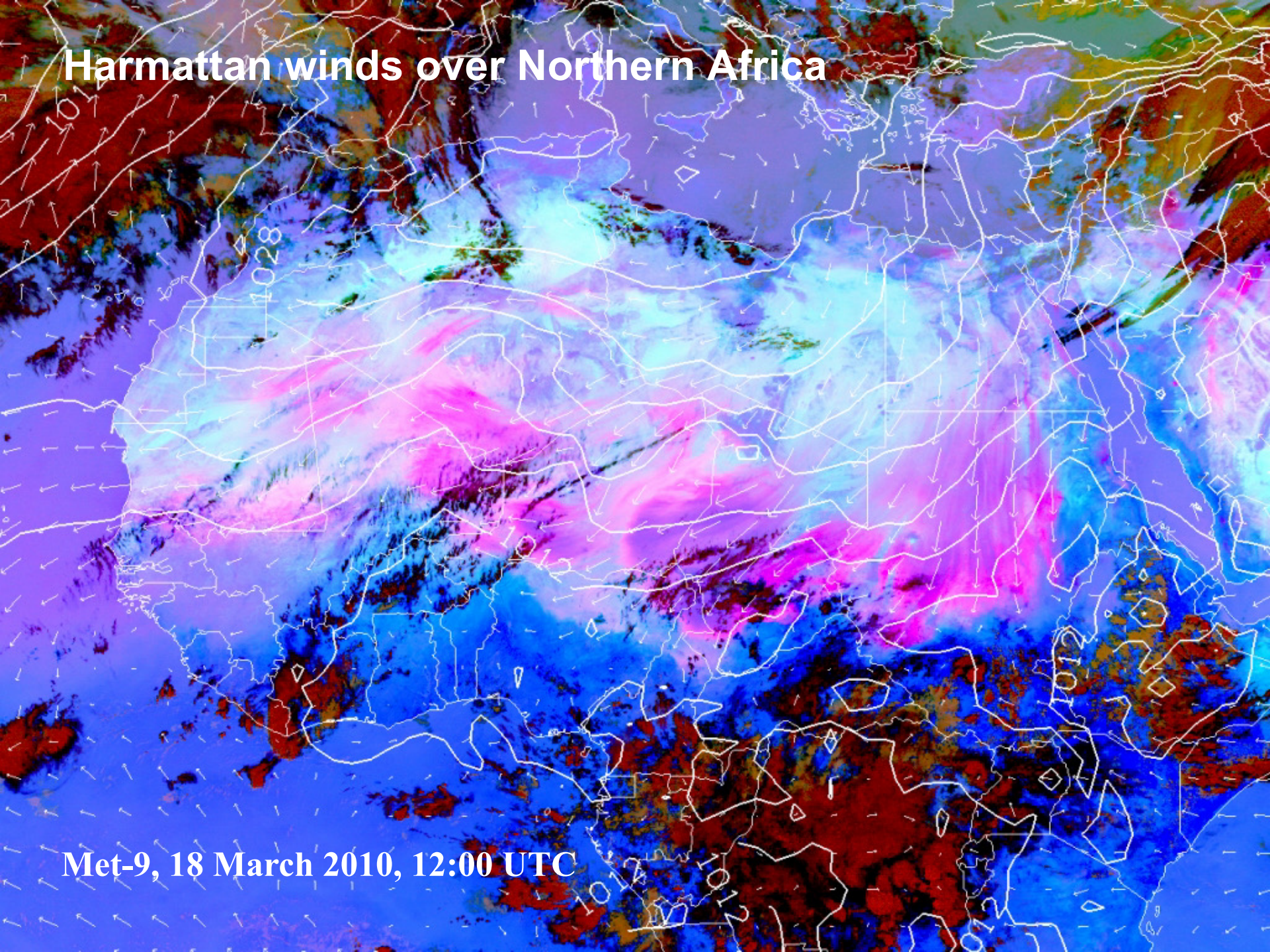
Ukraine



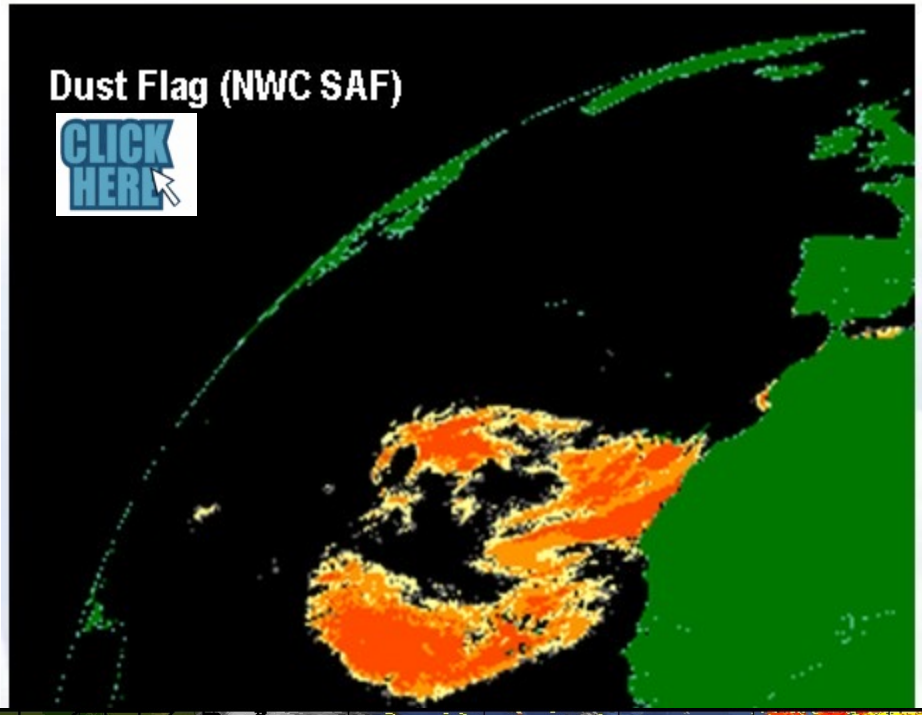
Met-9, 11 February 2010, 06:00 UTC, HRV
Source: K. Kollath, Hungary

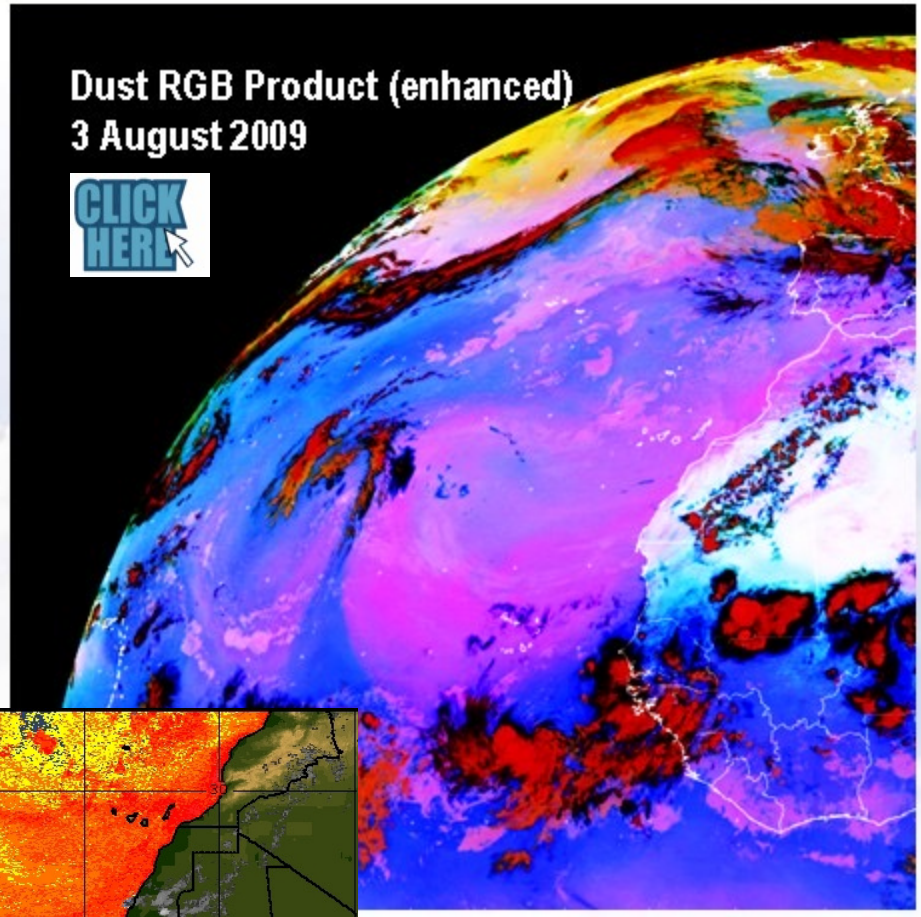

Post-frontal Dust Outbreak
L
H
Saudi Arabia
Where is the source region of the dust cloud?
CLICK HERE
DUST - 2009-02-11 07:15UTC

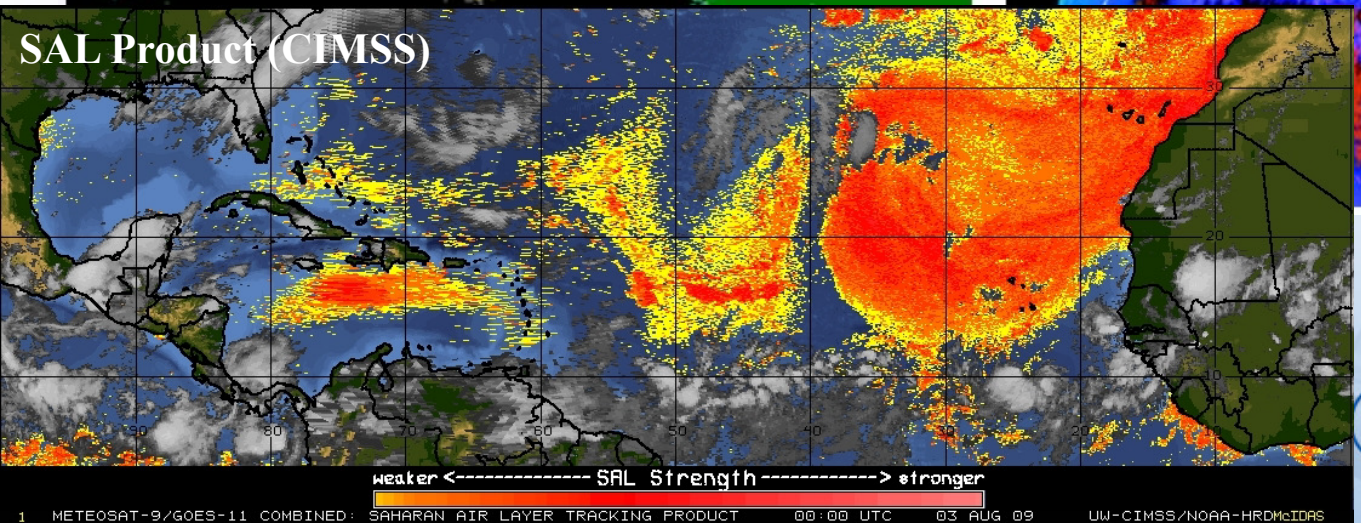

Summer Shamal Iraq & Arabian Peninsula
Met-9, 17 June 2008, 08:00 UTC


Harmattan winds over Northern Africa
Met-9, 18 March 2010, 12:00 UTC

Northeast Trade Winds over the North Atlantic

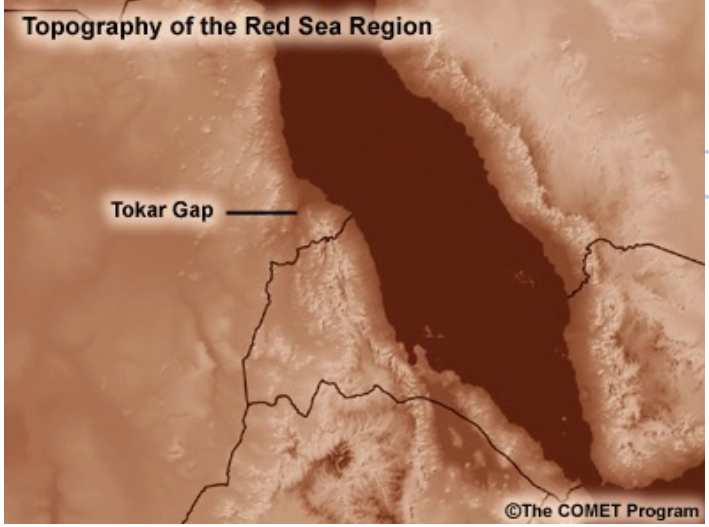




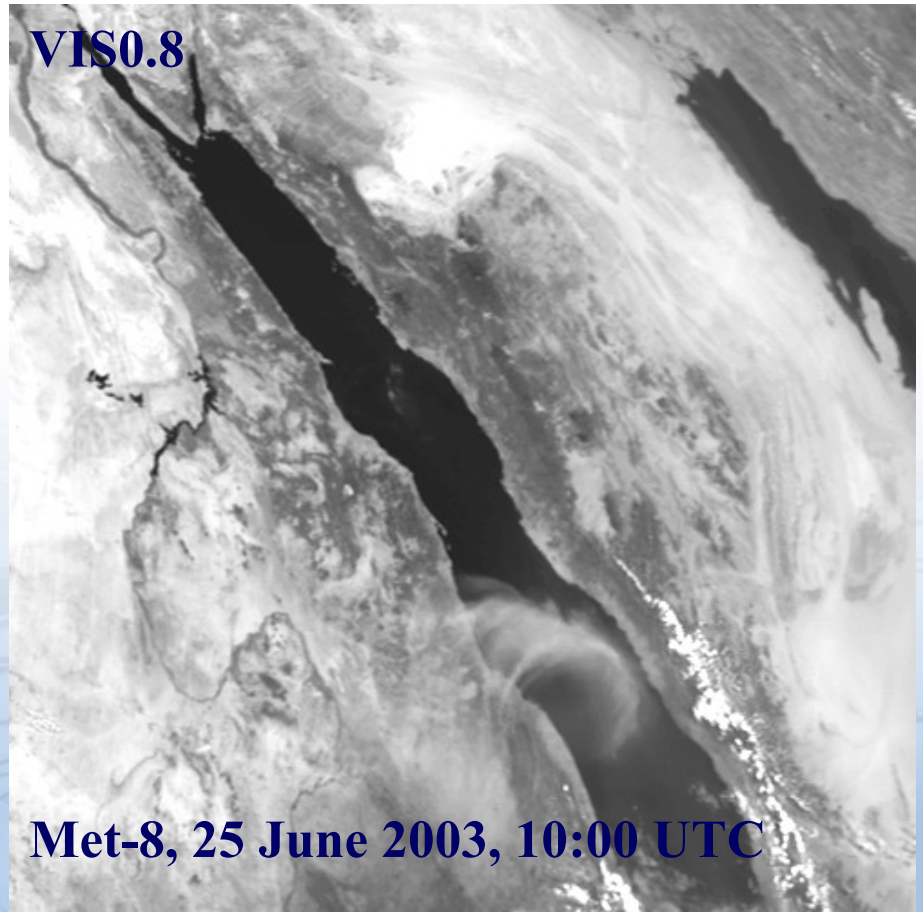


EUMETSAT

Mountain Gap Winds

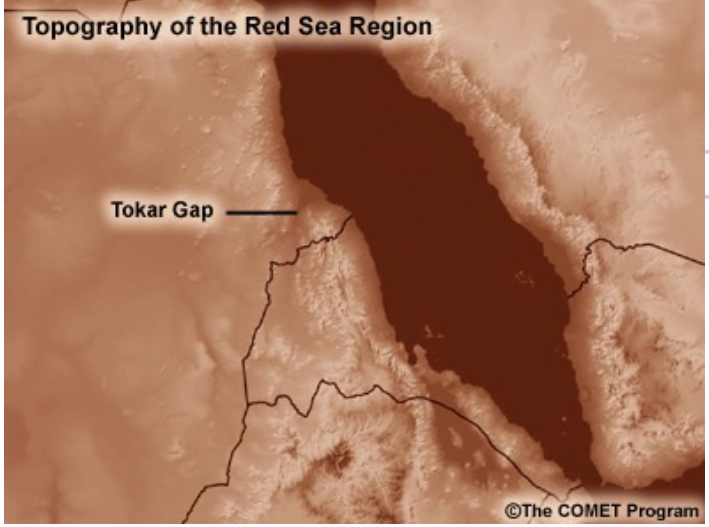


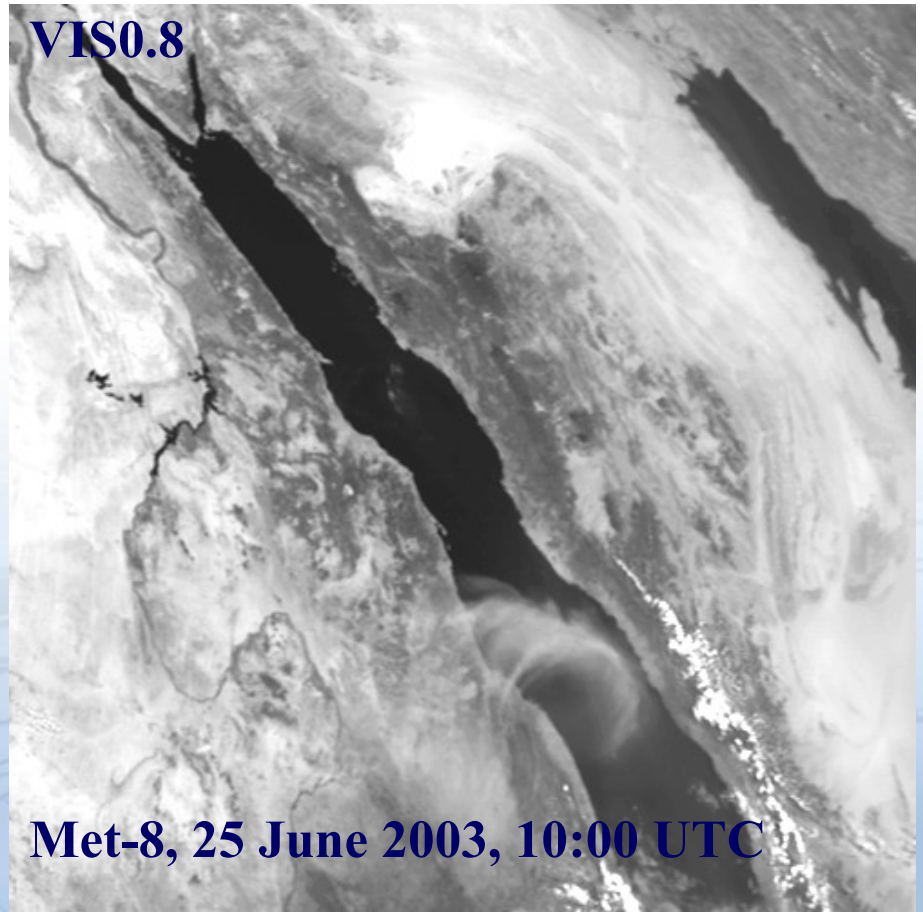
Outline the dust areas!

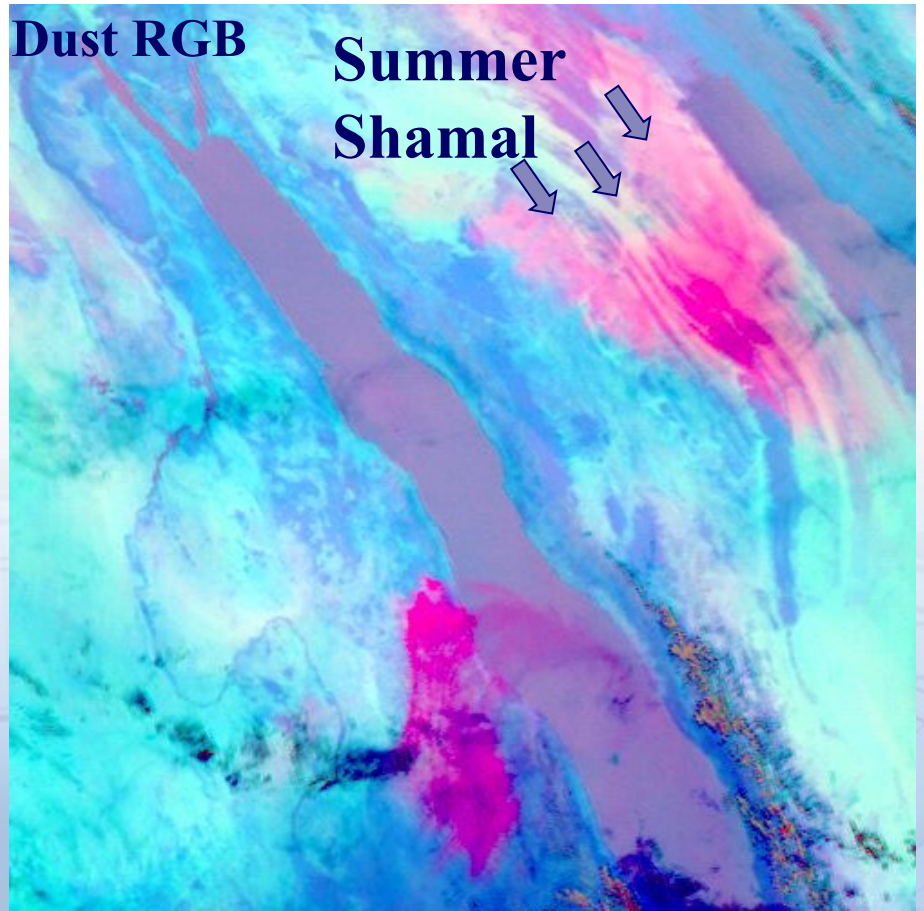


EUMETSAT

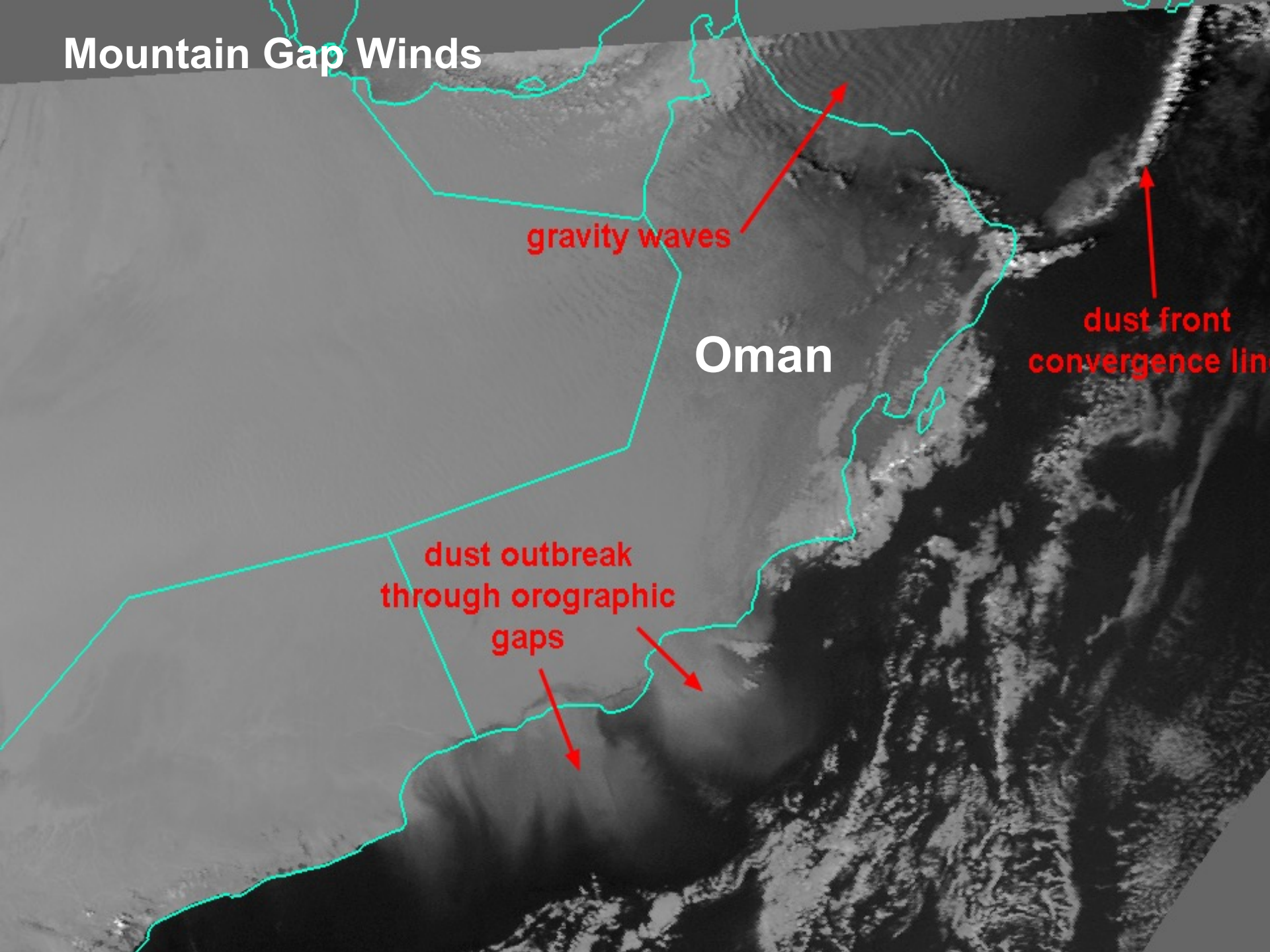
Mountain Gap Winds





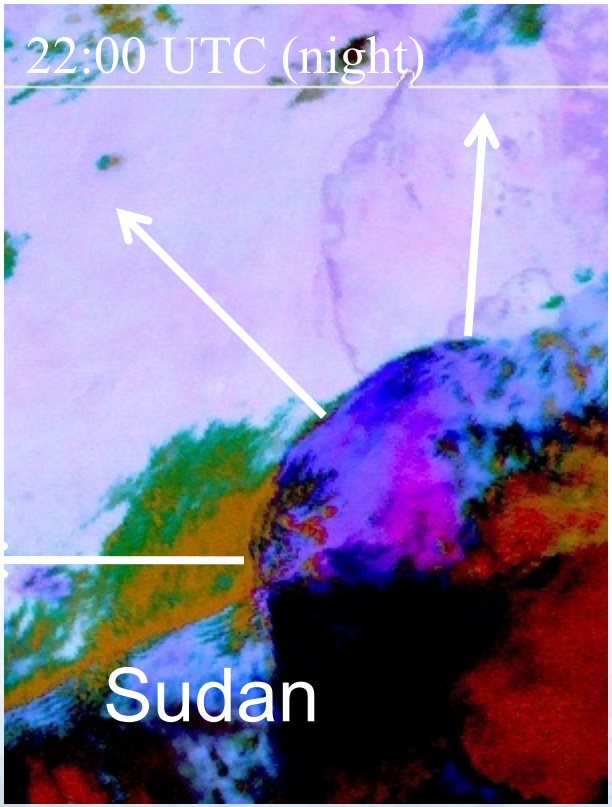


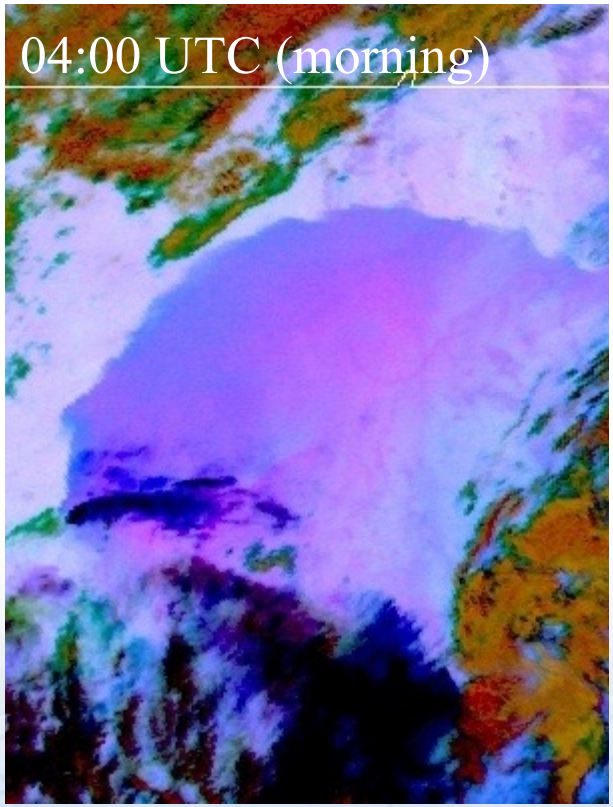
Mountain Gap Winds

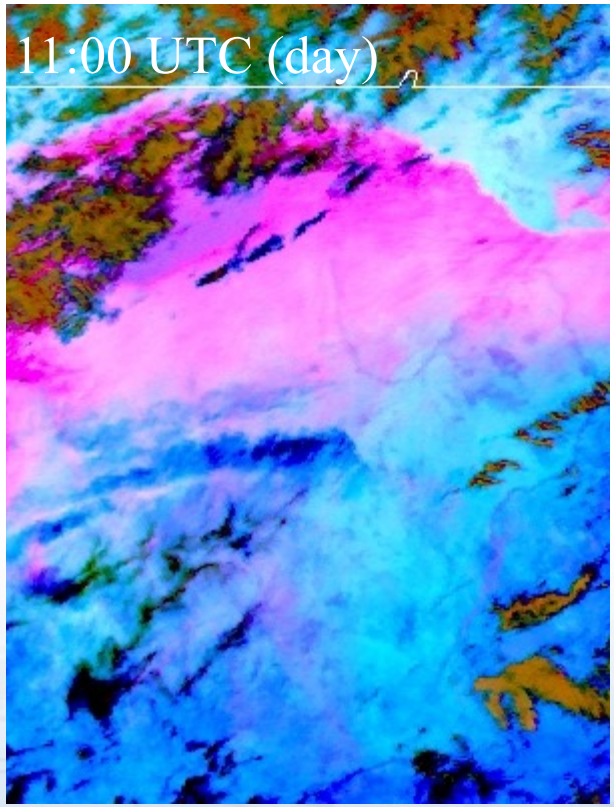



Convective Outflow Winds
(Haboobs, Dust Squalls)
MSG 2005 06 07 12:00

Dust Haboobs can travel fast at night (undular bore?)



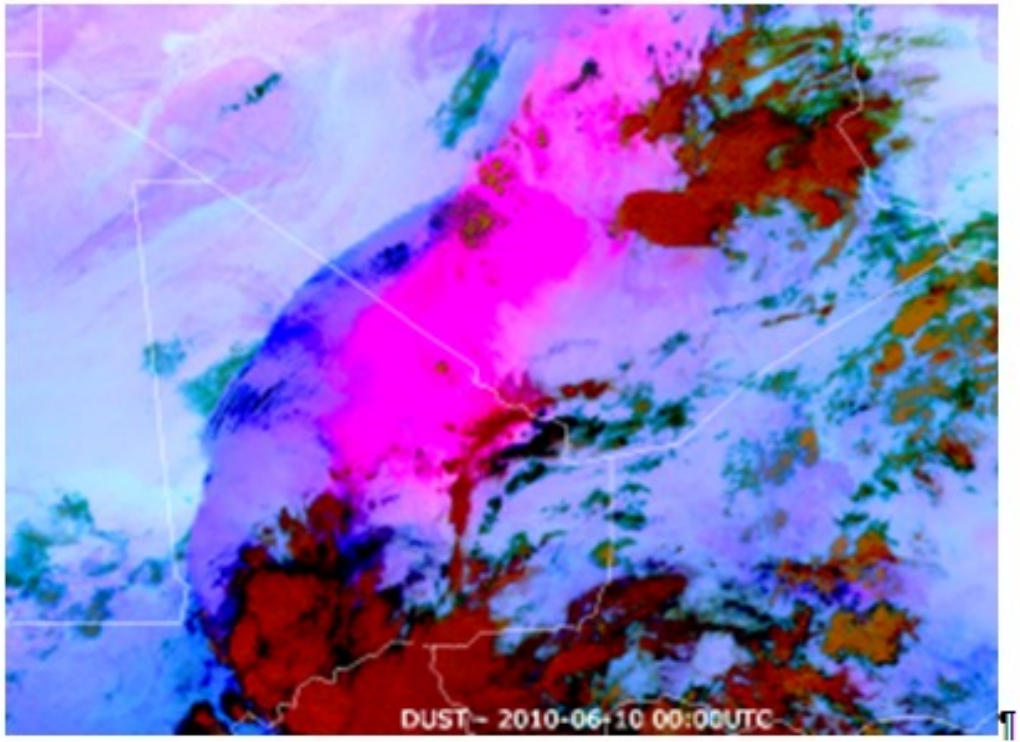




Met-8, 29-30 April 2007

EUMETSAT

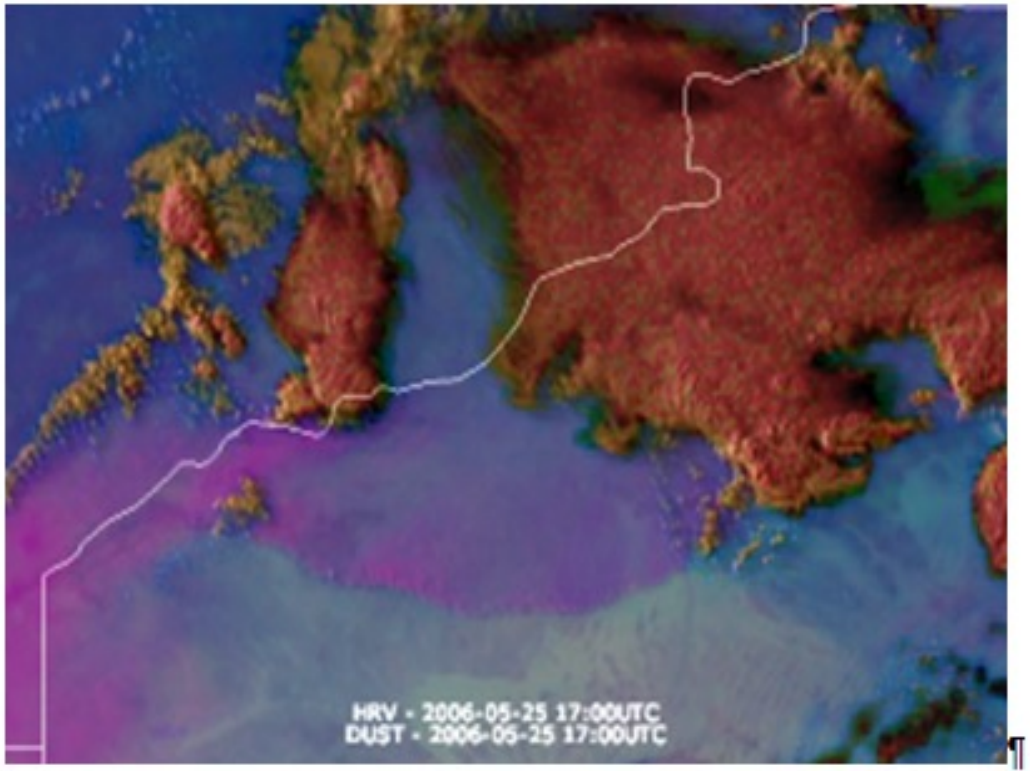
Dust Haboobs can travel long distances



34-hour sequence of MSG (Meteosat-9) Dust RGB products on 9-10 June 2010. Source: EUMETSAT. Images created by HansPeter Roesli.

This MSG Dust RGB sequence shows a large dust squall over Niger, Mali and southern Algeria (highlight), triggered by a thunderstorm system visible in the lower part of the images, that travelled hundreds of kilometers westwards over the Sahara. This shows how long a distance strong haboobs can propagate and how well defined they can be at night. On 9 June, daytime convection lifts part of the low-lying dust higher up -- above the boundary layer -- where westerly winds carry it back in an easterly direction. The higher level dust can be seen very well in the late afternoon and night hours (highlight) by its bright magenta colour (as compared to the dark magenta colour of the low-level dust squall). Note that towards the end of this animation, the westward propagation of the dust squall slows down as it approaches a deformation zone.

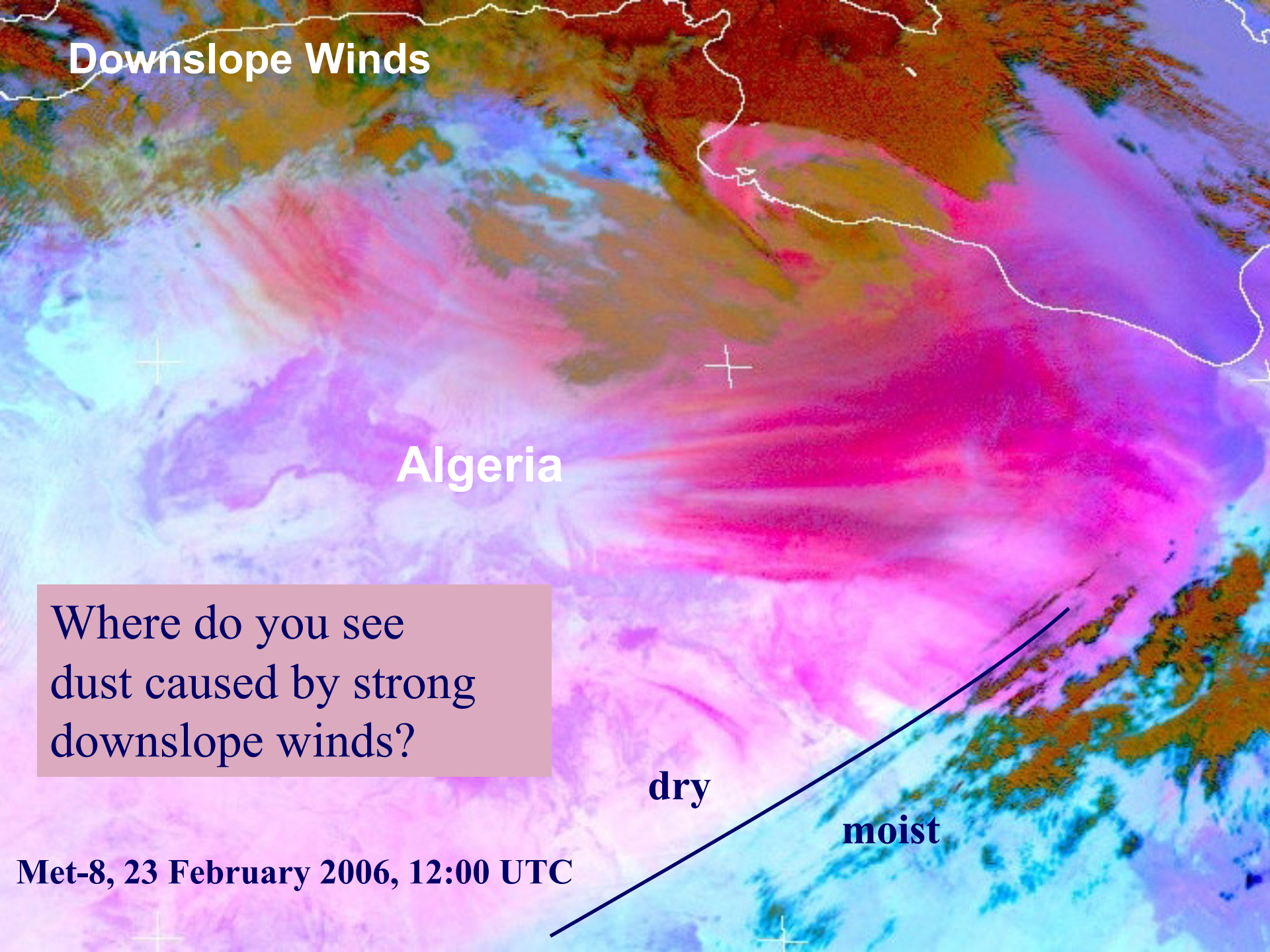
Combination of HRV & Dust RGB



¶

5-hour sequence of MSG (Meteosat-8) blended HRV and Dust RGB products on 25 May 2006 from 12:00 to 17:00 UTC. Source: EUMETSAT. Images created by HansPeter Roesli.¶

Note that this animation shows the HRV / Dust RGB "sandwich product", which is an image combination of the HRV channel and the Dust RGB product, allowing one to spatially co-locate the cloud features like the storm's overshooting top and outflow boundaries (at high resolution) with the dust clouds seen in the Dust RGB (at lower resolution). During daytime, this blended product is probably the best geostationary satellite product to monitor haboobs.¶


Downslope Winds
Algeria
Where do you see dust caused by strong downslope winds?
dry
moist
Met-8, 23 February 2006, 12:00 UTC

SUMMARY

Summary: Key Messages 1

- The Dust RGB can be used during day and night
- Dust Level identification is difficult but not totally impossible
- More contrast to backgroud over land than over ocean
- Over ocean visible imagery is preferable during the day (e.g. Natural Colour RGB)

Summary: Key Messages 2

- Dust changes cloud microphysics
- Mesoscale dust outbreaks cannot be forecasted with dust model (satellite data!)
- HRV / Dust RGB blended product very useful during daytime
- Haboobs can travel very fast at night!

Thank you for your attention !

More info: www.eumetsat.int

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