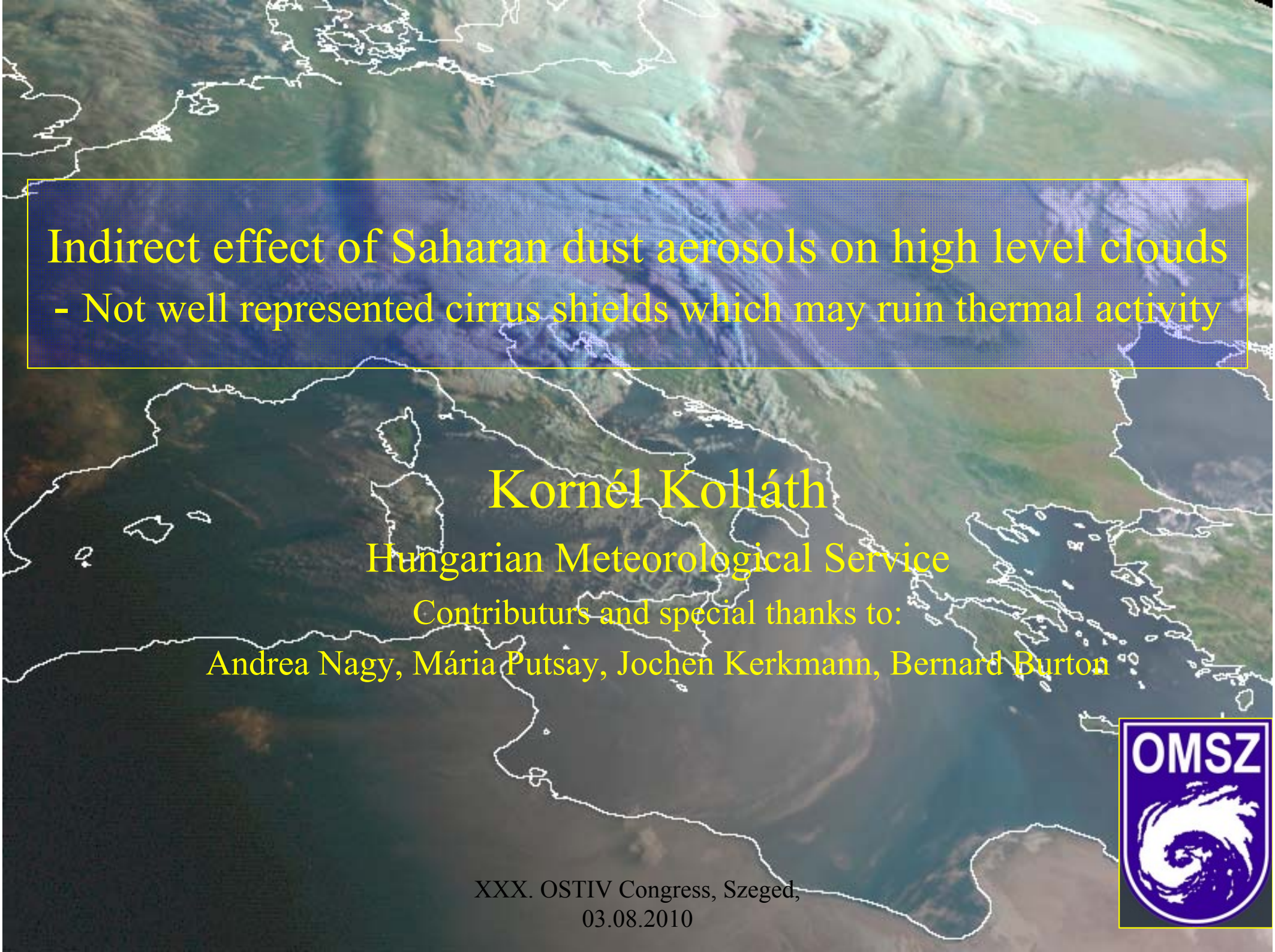


Indirect effect of Saharan dust aerosols on high level clouds

- Not well represented cirrus shields which may ruin thermal activity

Kornél Kolláth

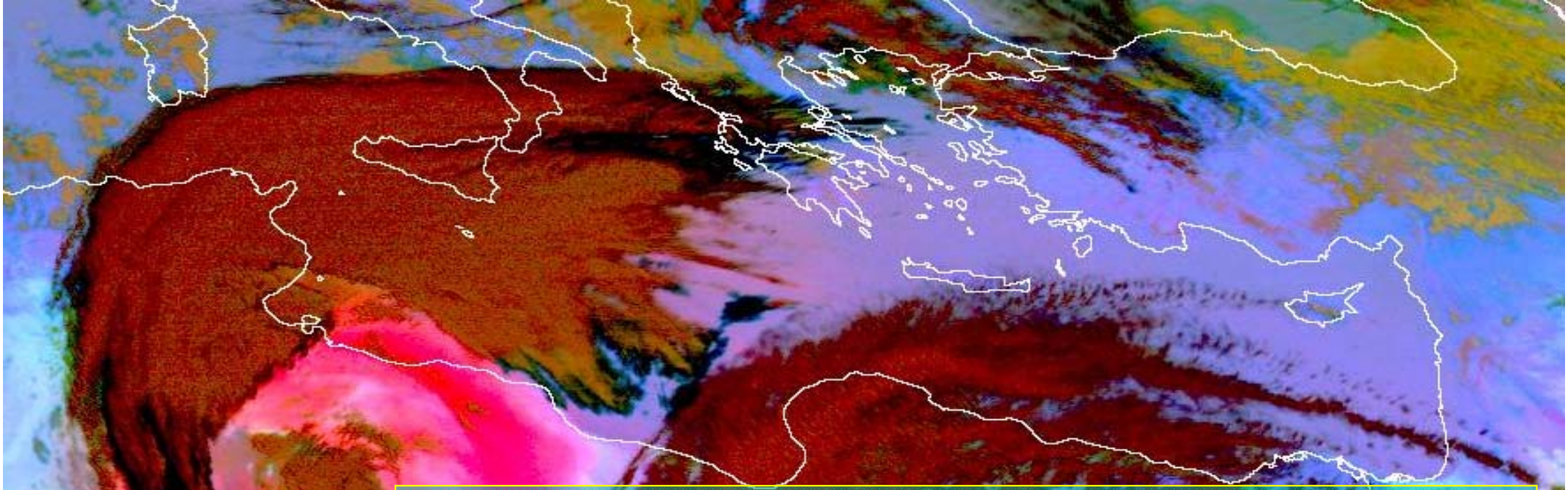
Hungarian Meteorological Service

Contributurs and special thanks to:

Andrea Nagy, Mária Putsay, Jochen Kerkmann, Bernard Burton

XXX. OSTIV Congress, Szeged,

03.08.2010



Contents

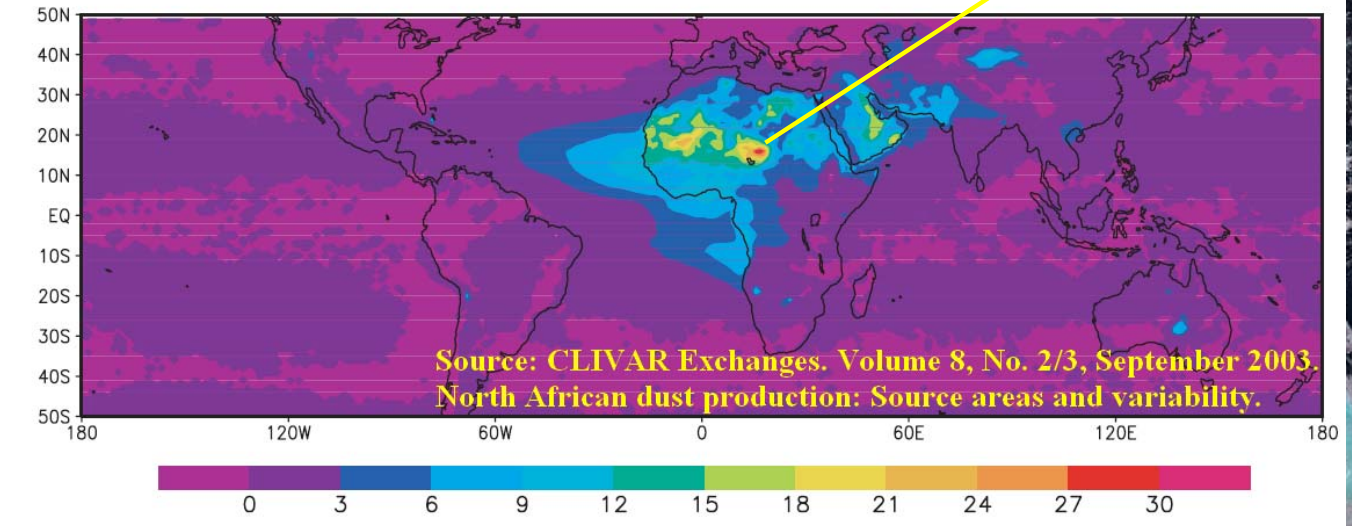
- *Mineral dust emmission in the globe*
- *potential effects of dust*
- *wet deposition, optical appearence of the sky*
- *satellite imagery*
- *behaviour of cirrus shields in high dust concentration environment, cellular convection at the top of high level clouds*
- *guideline, tips for weather forecasters*
- *further research*

Mineral dust emmission

Mineral dust is a term used to indicate atmospheric aerosols originated from the suspension of minerals constituting the soil, being composed of various oxides and carbonates. It is mainly constituted of the oxides (SiO_2, Al_2O_3, FeO, Fe_2O_3, CaO, and others) and carbonates ($CaCO_3$, $MgCO_3$) that constitute the Earth's crust. Global mineral dust emissions are estimated 100-500 millions of tons per year.

Sahara is the No. 1. source in the world

The most significant source in Sahara is the ***Bodélé-depression***



World map of annual mean Aerosol Index (AI) values (x 10) determined by TOMS.

mediterranean cyclones

passat

[animation (globe)]

[animation (Mediterranean)]

[animation (Bodélé)]

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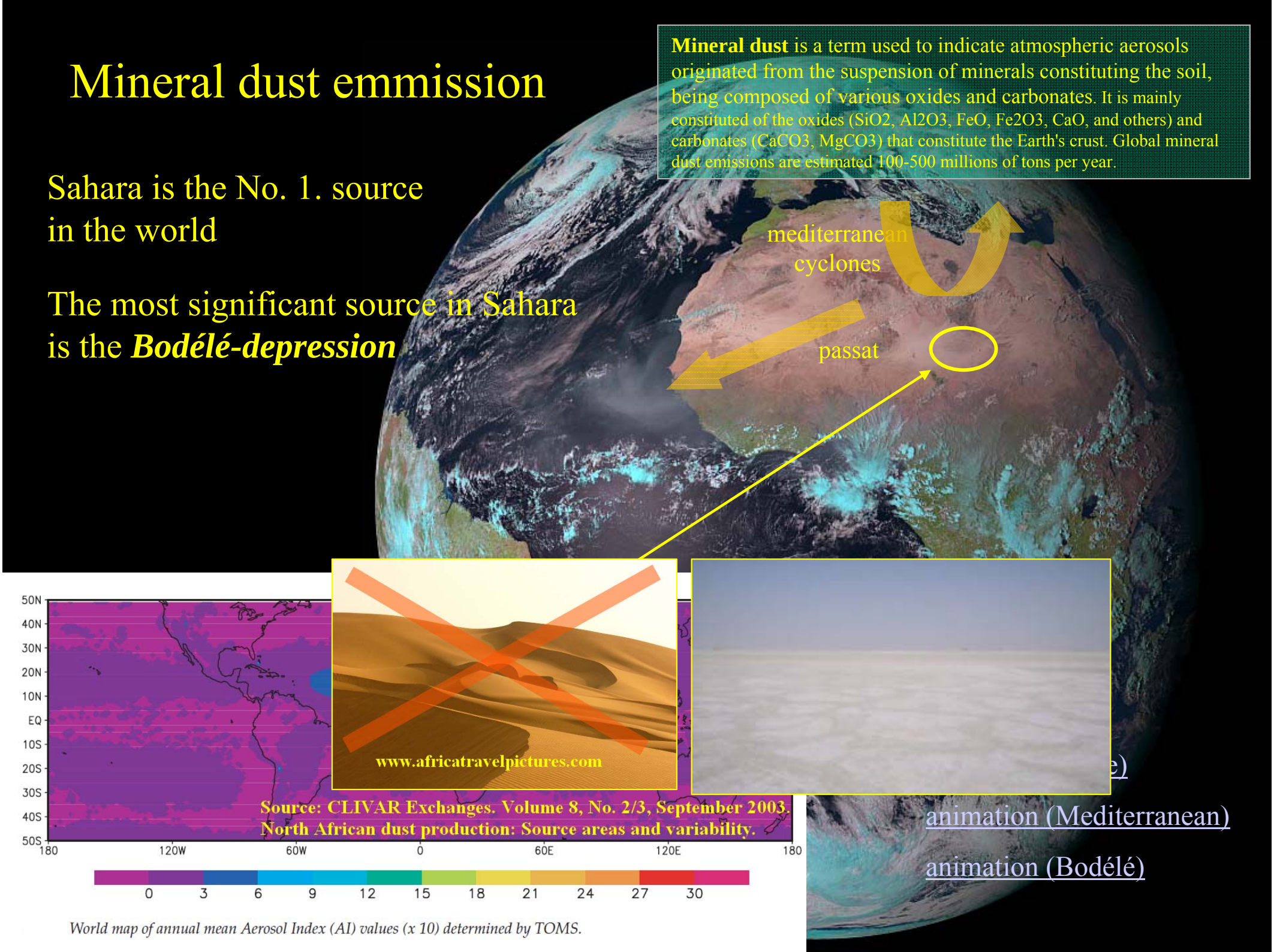

Source: CLIVAR Exchanges. Volume 8, No. 2/3, September 2003.
North African dust production: Source areas and variability.

World map of annual mean Aerosol Index (AI) values (x 10) determined by TOMS.

e)

animation (Mediterranean)

animation (Bodélé)

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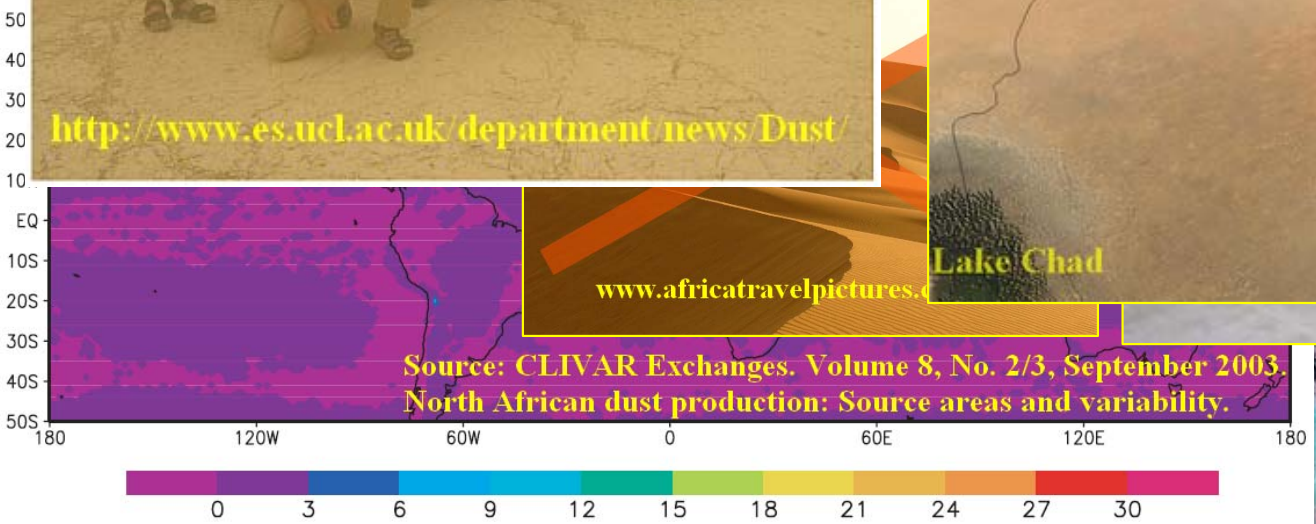


Source: CLIVAR Exchanges. Volume 8, No. 2/3, September 2003.
North African dust production: Source areas and variability.

World map of annual mean Aerosol Index (AI) values (x 10) determined by TOMS.

mediterranean

animation (Mediterranean)

animation (Bodélé)

Effects

• Direct effects: Absorb and scatter the solar and infrared radiation

Examples: decrease the solar radiation reaching the surface and heat the dusty layer, so it changes the stability: HRV animation; Decrease the hurricane activity in the Atlantic; etc. /The estimated global net effect is -0,3 and +0,1 W/m2, so it is quite uncertain!/

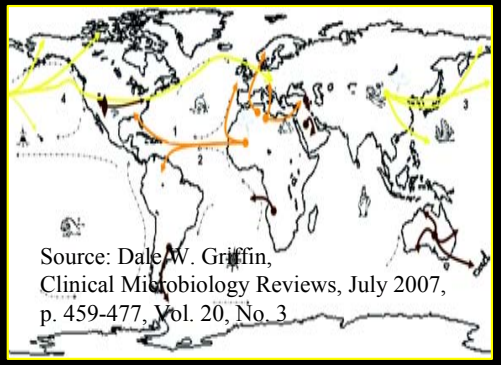
• Indirect effects: Some components of the mineral dust are cloud condensation nuclei and few are ice nuclei. Particle (cloud ice, cloud water) *size spectrum can shift to smaller particles*.

→ ***incresing albedo,***

→ ***usually decreasing precipitation efficiency and longer lifespan***

(not always true for clean, aerosol free environment),

Numerous uncertainty! Widespread research is going on …

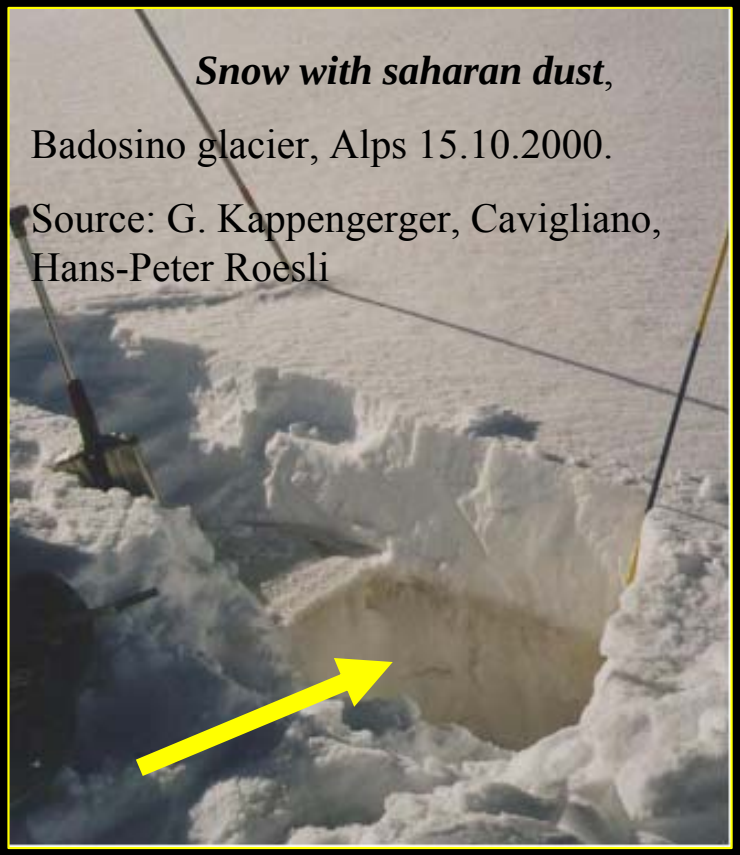


• Ecosystem: nutrient supply (fertilization) for plants /example: Saharan dust is the main mineral source that fertilizes the Amazon basin./

• Human life: air quality, dust can carry microorganisms, in case of high concentration it can affect transportation (reduced visibility)

Wet deposition

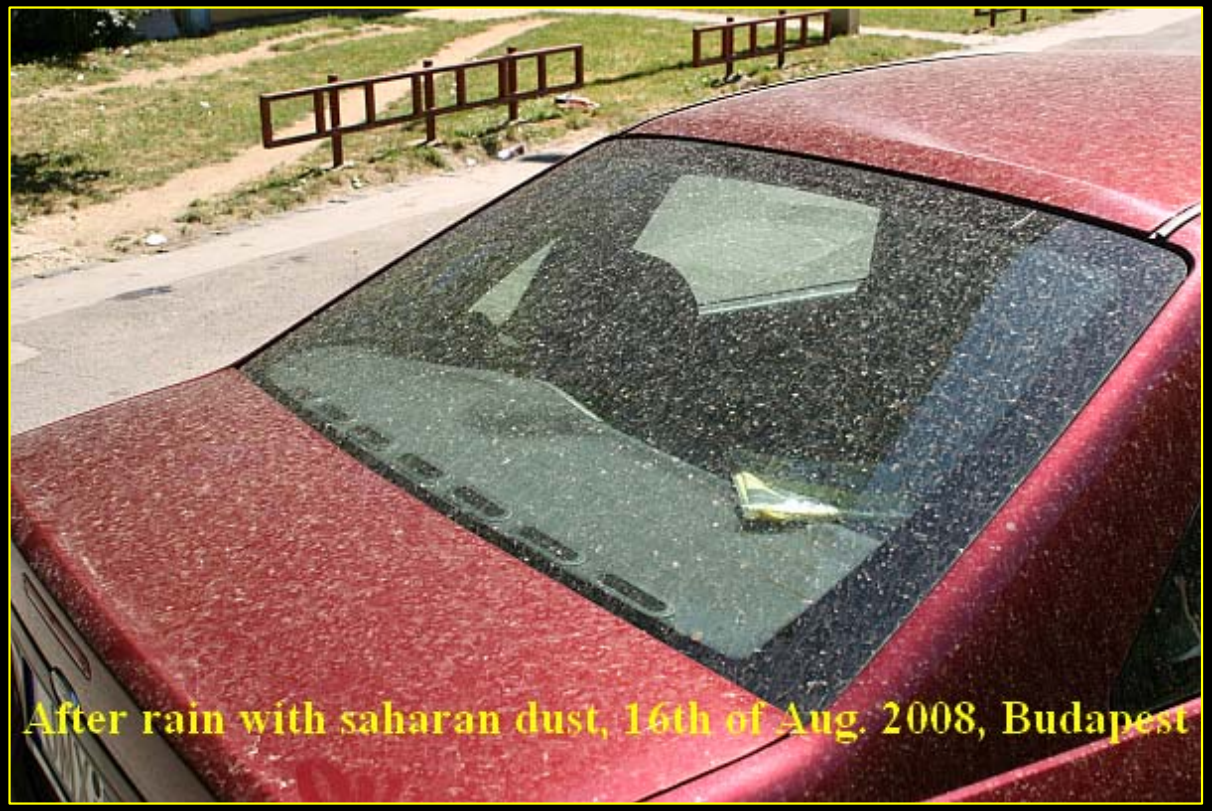
(„coloured” rain or snow)



Snow with saharan dust,

Badosino glacier, Alps 15.10.2000.

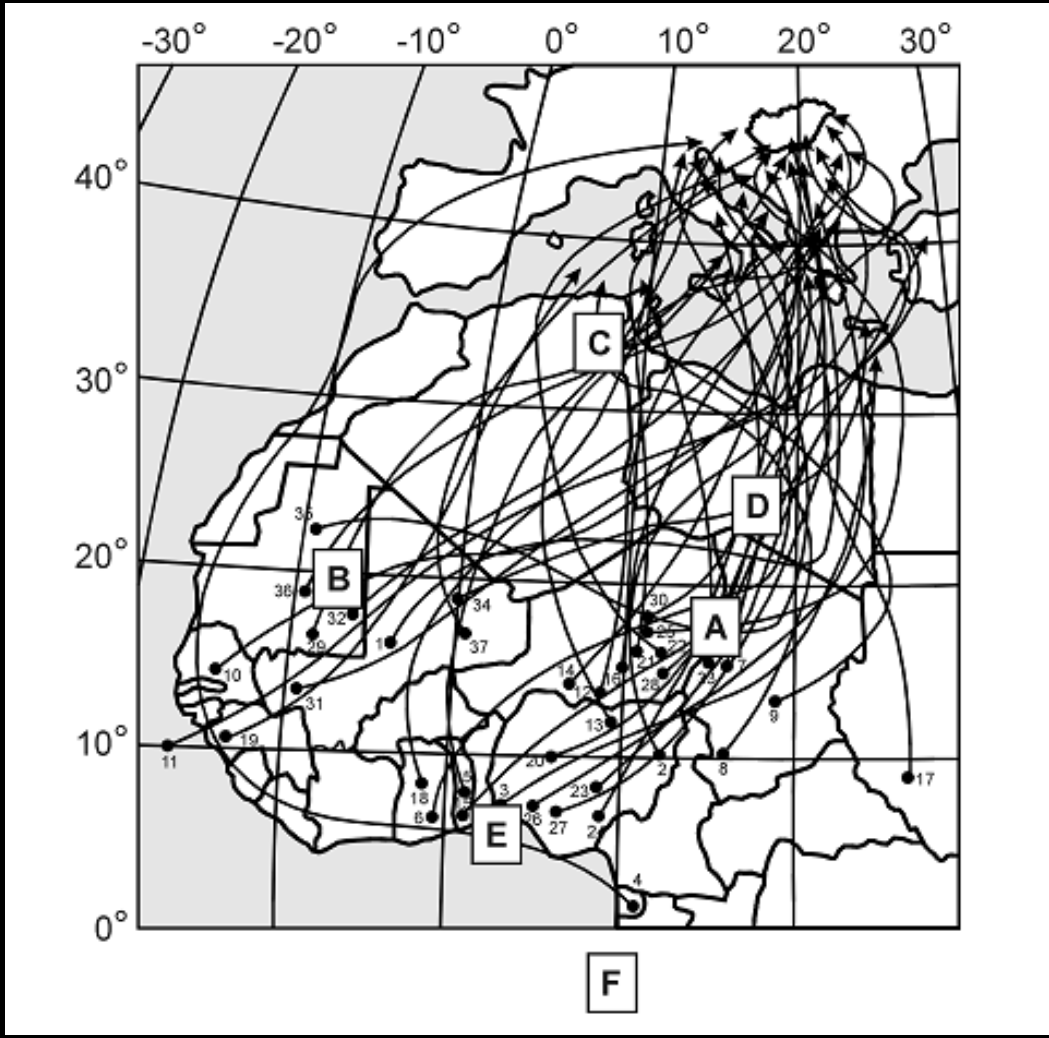
Source: G. Kappengerger, Cavigliano, Hans-Peter Roesli

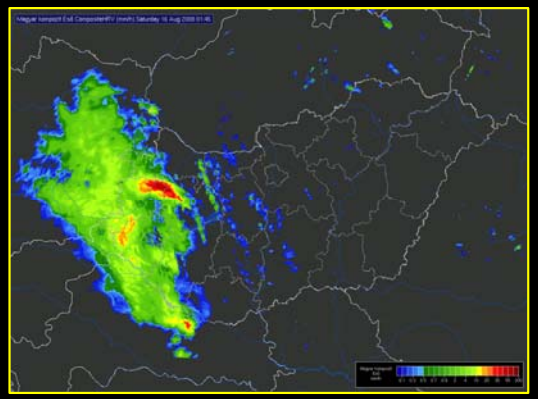


Erdődiné Molnár, Zs., Kovács, A., 2005: *Szaharai homok Borsodban*, Légkör – 50. évf., 2005. 4. szám.

Borbély-Kiss, I., Kiss, A.Z., Koltay, E., Szabó, G., Bozó, L., 2004: *Saharan dust episodes in Hungarian aerosol*: elemental signatures and transport trajectories, Journal of Aerosol Science 35 (10), 1205–1224.

Determination of the source territory is possible with precipitation chemistry



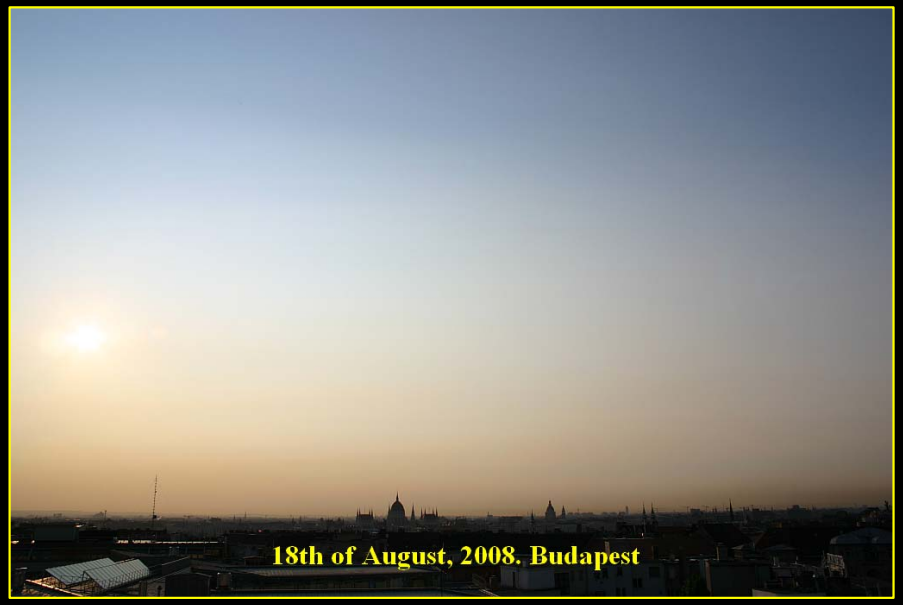


E. Koltay, I. Borbély-Kiss,* Zs. Kertész, Á. Z. Kiss, Gy. Szabó: *Assignment of Saharan dust sources to episodes in Hungarian atmosphere* by PIXE and TOMS observations. Journal of Radioanalytical and Nuclear Chemistry, Vol. 267, No.2 (2006) 449–459

Visual optical signs of the presence of dust
Appearance in visible range satellite images

- Ratio of scattered radiation is high even if higher elevation angle of the Sun

- yellowish, brownish colours

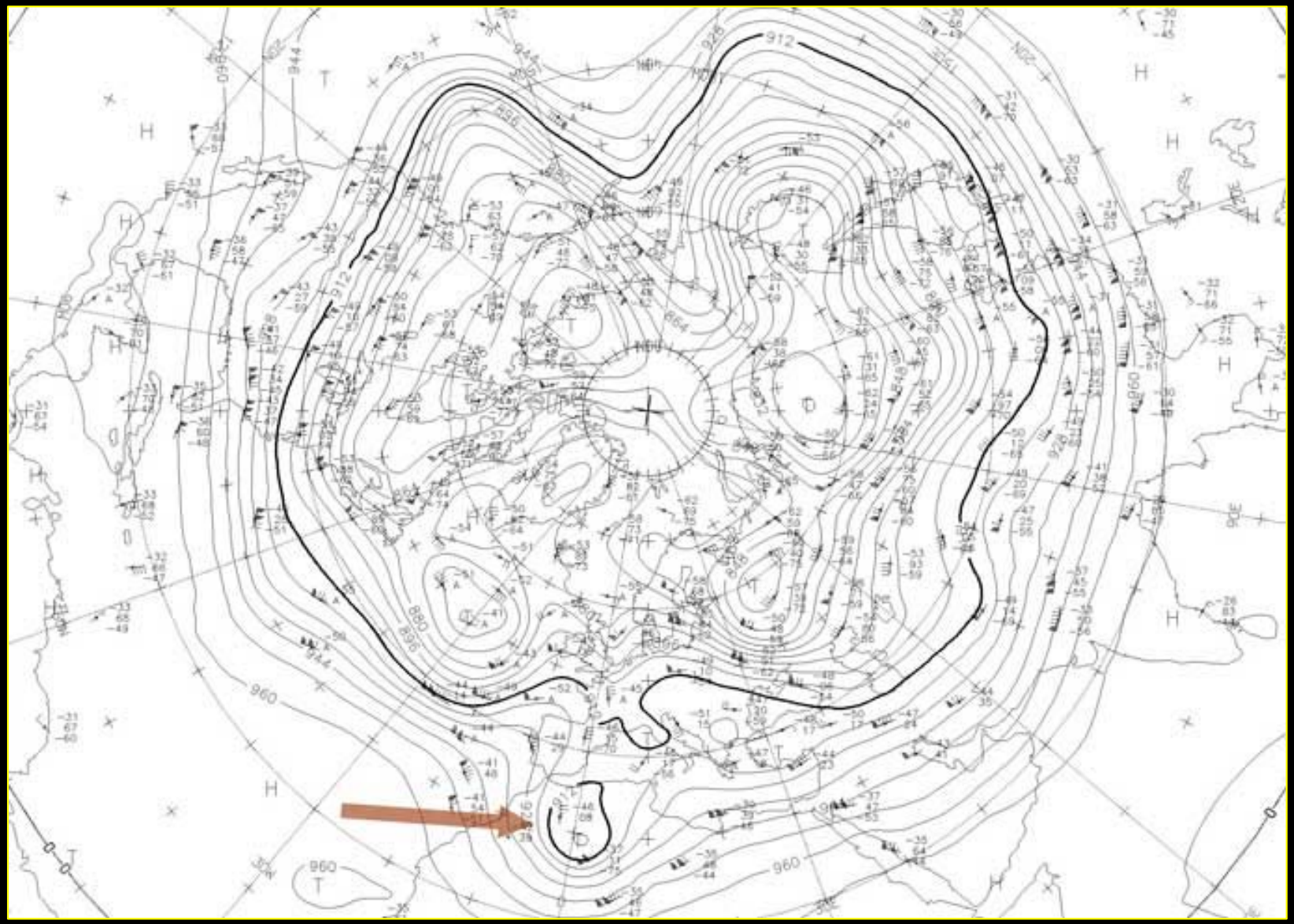


MSG-HRV animation, (18th of August, 2008.)

- Bishop's ring

* A ***Bishop's Ring*** is a diffuse brown or bluish halo observed around the sun caused by diffraction on aerosol particles with narrow size range.

An example of a cyclone development in North-Africa which produced dust storm (20-24 of February, 2007.)



animation

Source (Kolláth, Putsay, Kerkmann): www.eumetsat.int, http://oiswww.eumetsat.org/WEBOPS/iotm/iotm/20070222_dust/20070222_dust.html

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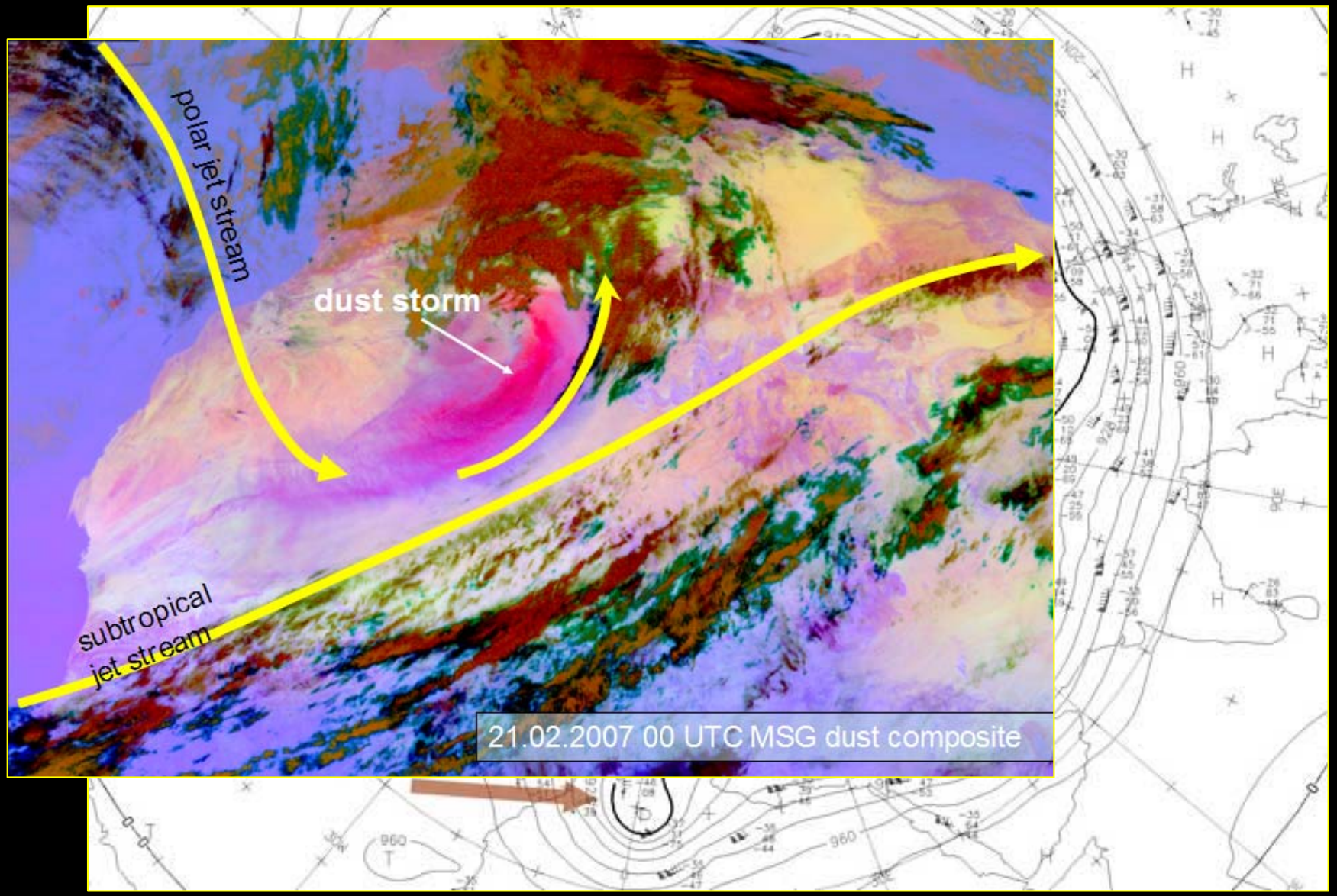

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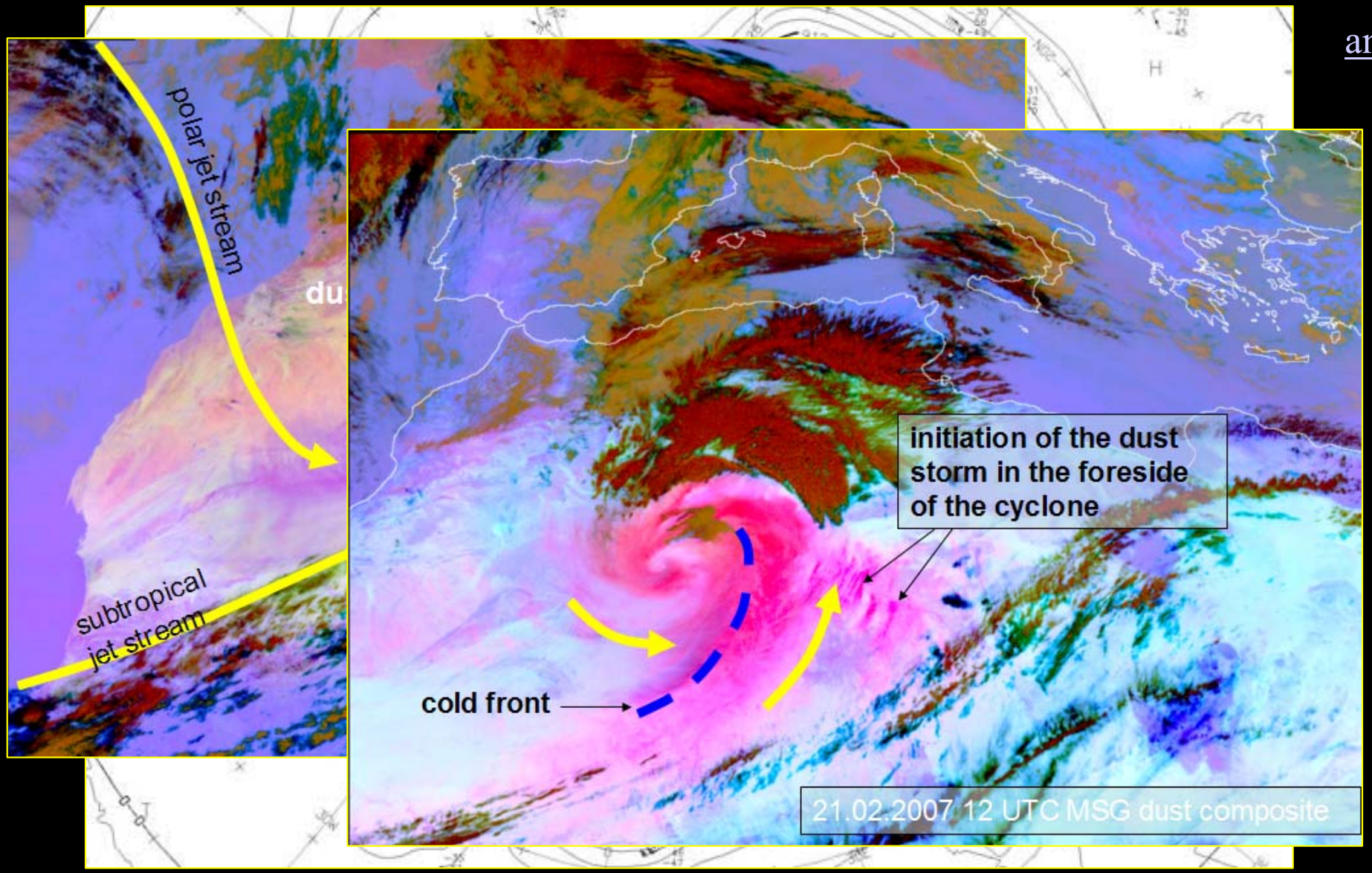
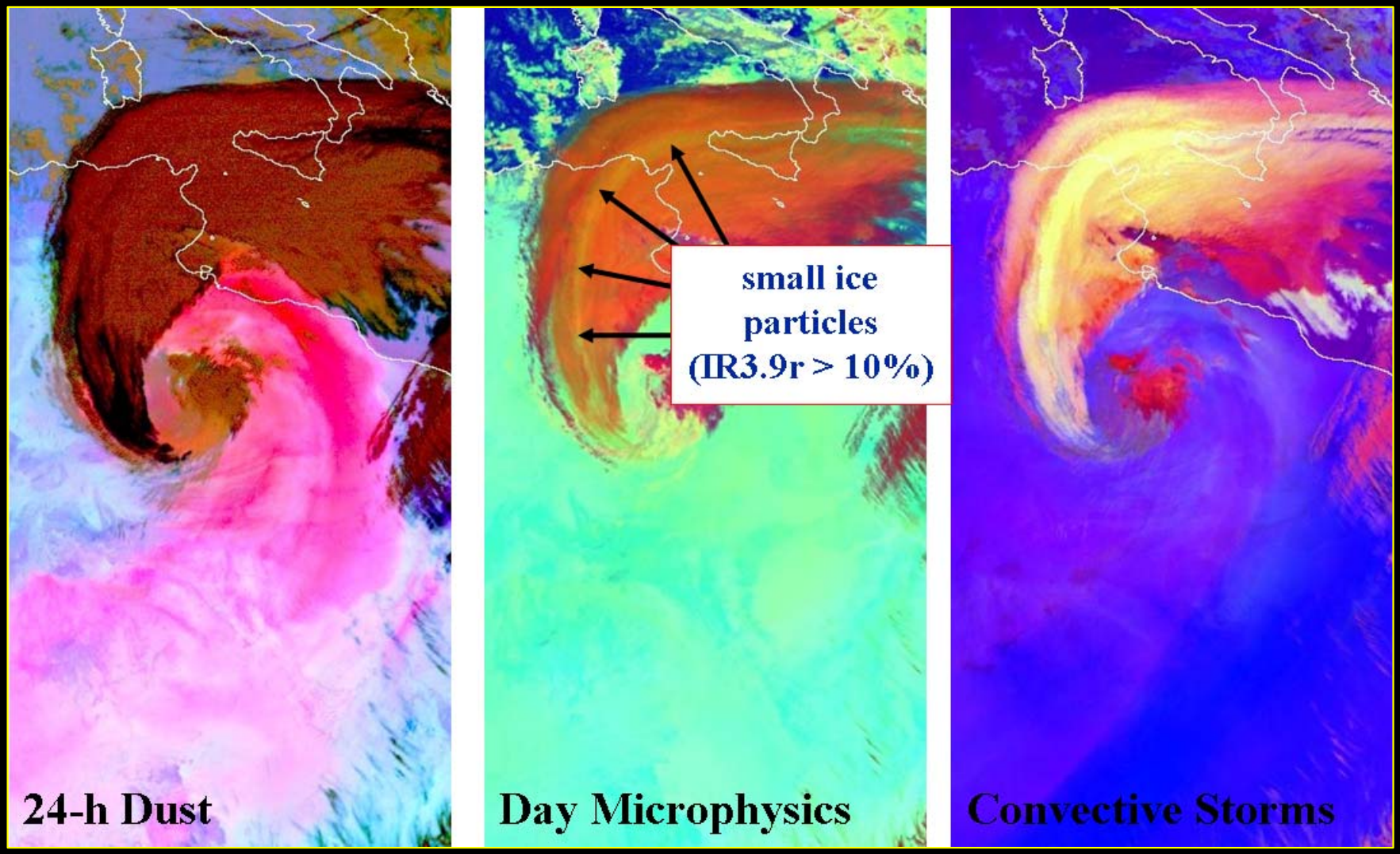


animation

Source (Kolláth, Putsay, Kerkmann): www.eumetsat.int, http://oiswww.eumetsat.org/WEBOPS/iotm/iotm/20070222_dust/20070222_dust.html

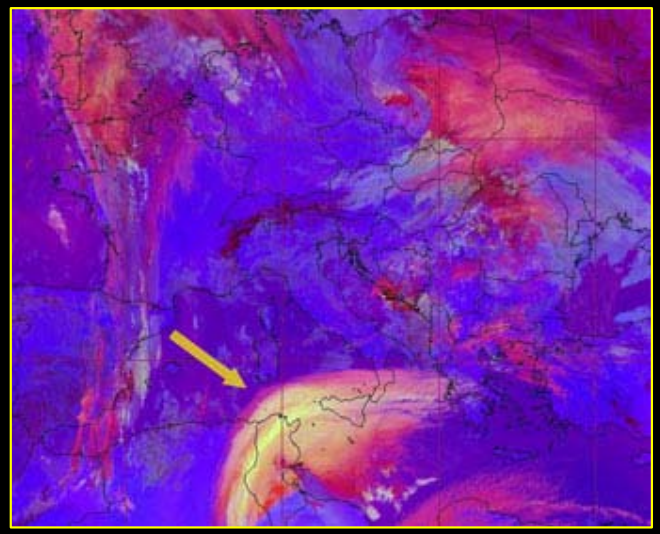
Signs in satellite images of high aerosol content in the clouds (higher reflectence in IR 3.9μm)

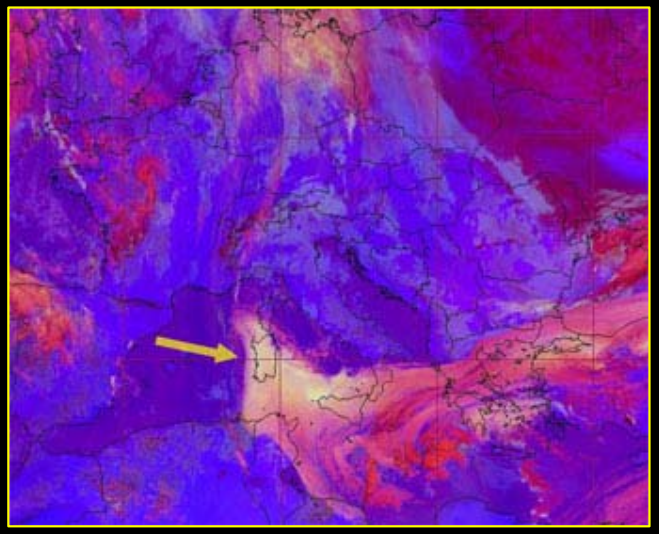


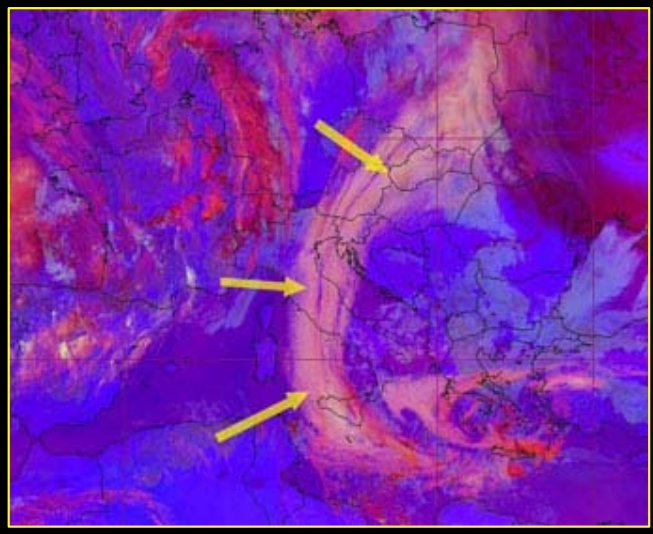
Source: Jochen Kerkmann (EUMETSAT) and Kornél Kolláth (OMSZ): Large dust swirl over Algeria

http://oiswww.**eumetsat**.org/WEBOPS/iotm/iotm/20070222_dust/20070222_dust.html

„Strange” cirrus/cirrosstratus shields
longer lifespan, „grainy” cloud top structure





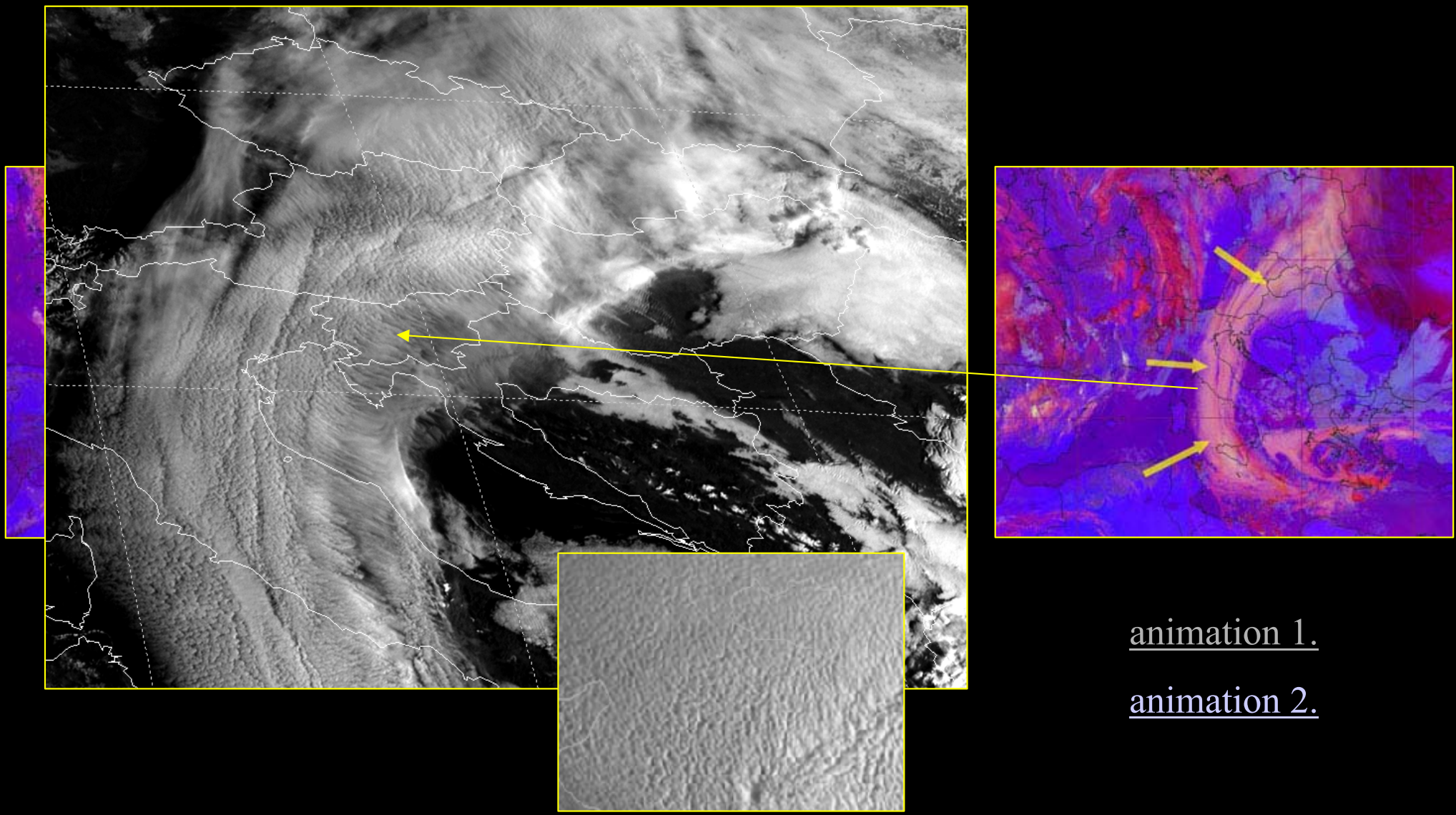


animation 1.

animation 2.

Source: Kolláth Kornél, Putsay Mária és Kerényi Judit: Homokvihar Észak-Afrikában és annak felhőzetre gyakorolt hatása, www.met.hu/pages/witem20070220-24.html

„Strange” cirrus/cirrosstratus shields longer lifespan, „grainy” cloud top structure



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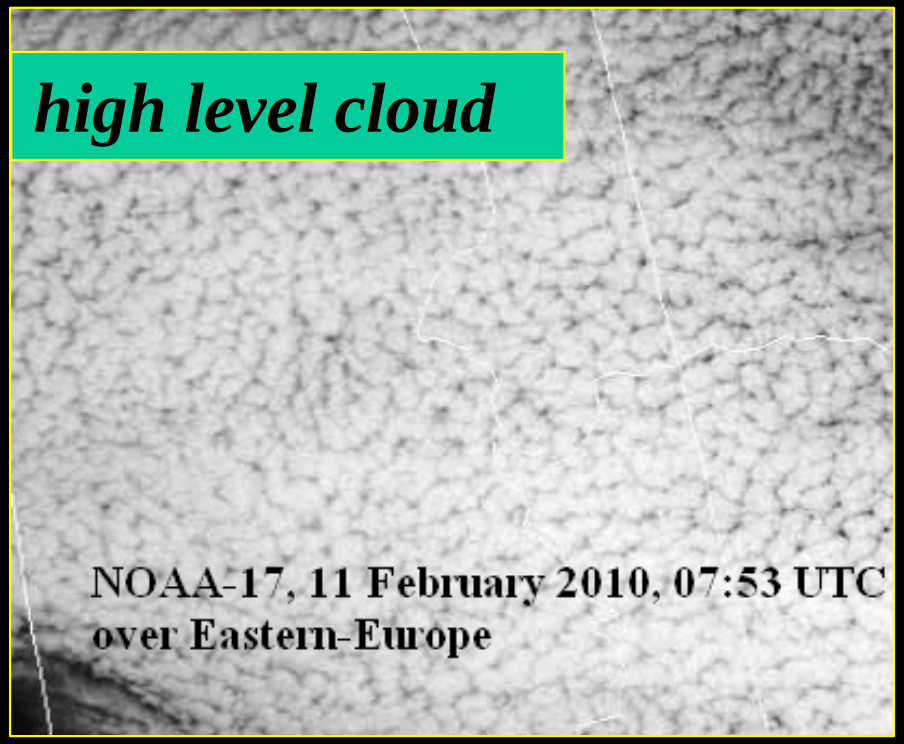
Unusual cumuliform high level clouds (cirrus/cirrosstratus shields)



→ closed-cell convection

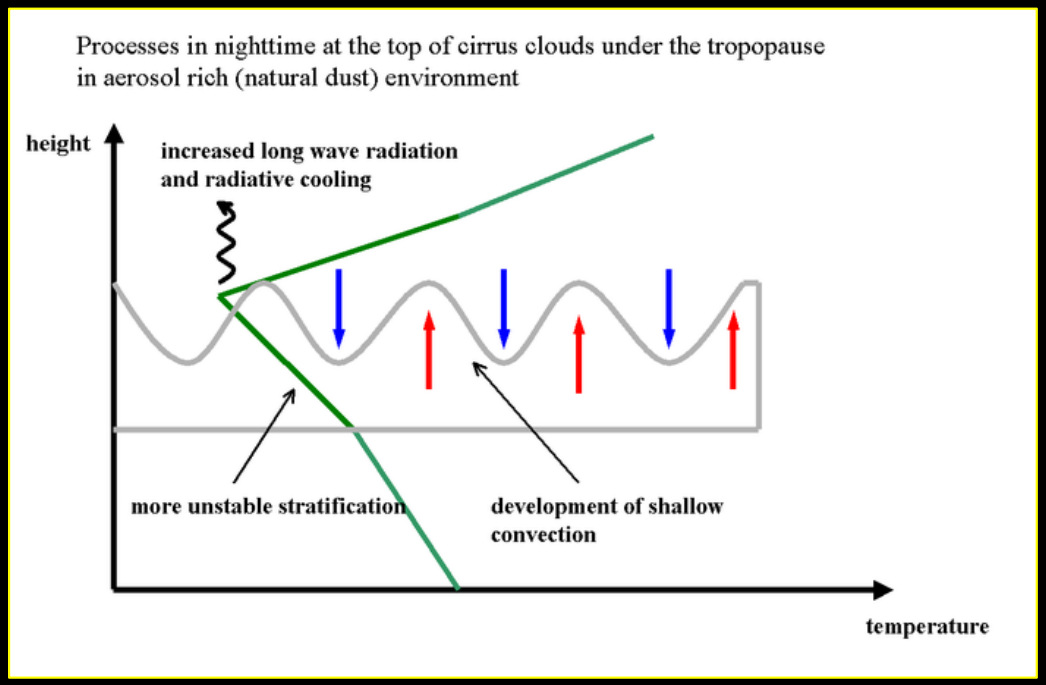
See also:

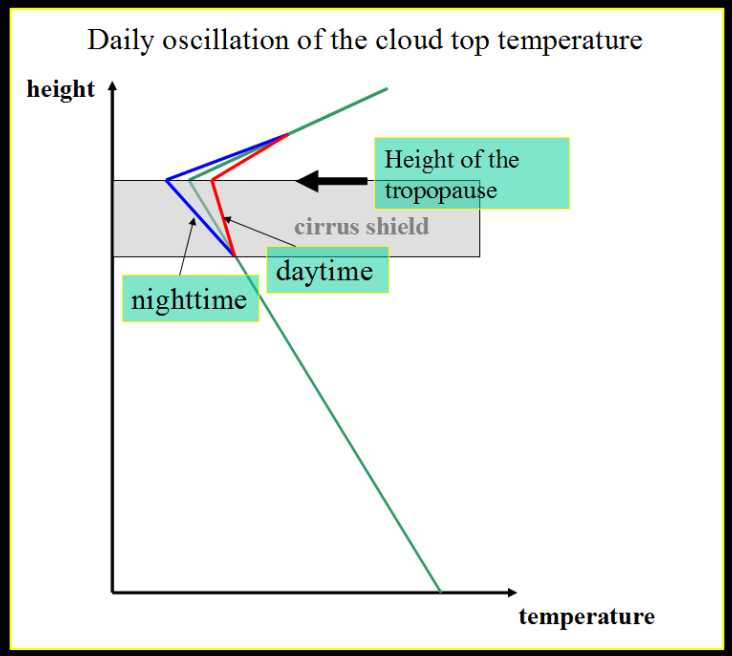
HansPeter Roesli, Jochen Kerkmann (EUMETSAT) and Daniel Rosenfeld (HUJI): http://oiswww.eumetsat.org/WEBOPS/iotm/iotm/20060508_benard/20060508_benard.html

Persistent cloud patch moving along the Norwegian coast (7-10 May 2006)

Possible explanation of the cumuliform structure

Hypothesis: High concentration of dust can lift up to the tropopause, and can change of the radiation properties. Absorbance of the short waves can increase (daytime), cooling effect due to long wave radiation can increase (can be dominant in nighttime). Cloud top temperature and stratification closo to the top can change.





HRV anim. 1.

infra anim. 2.

Asia infra

Sources:

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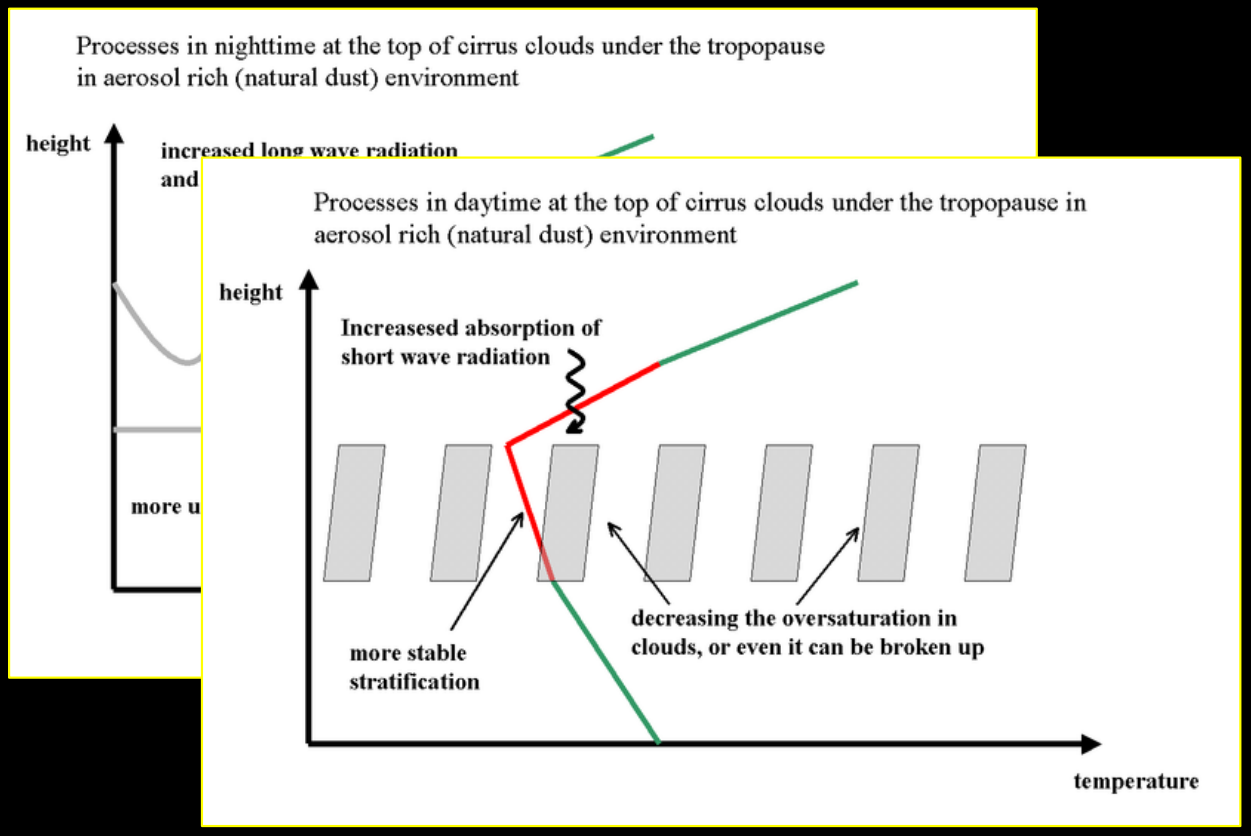

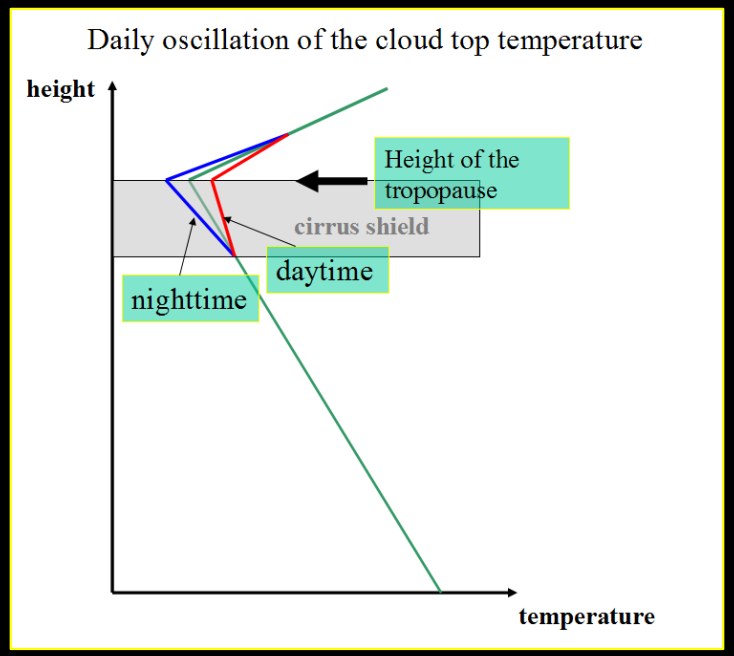

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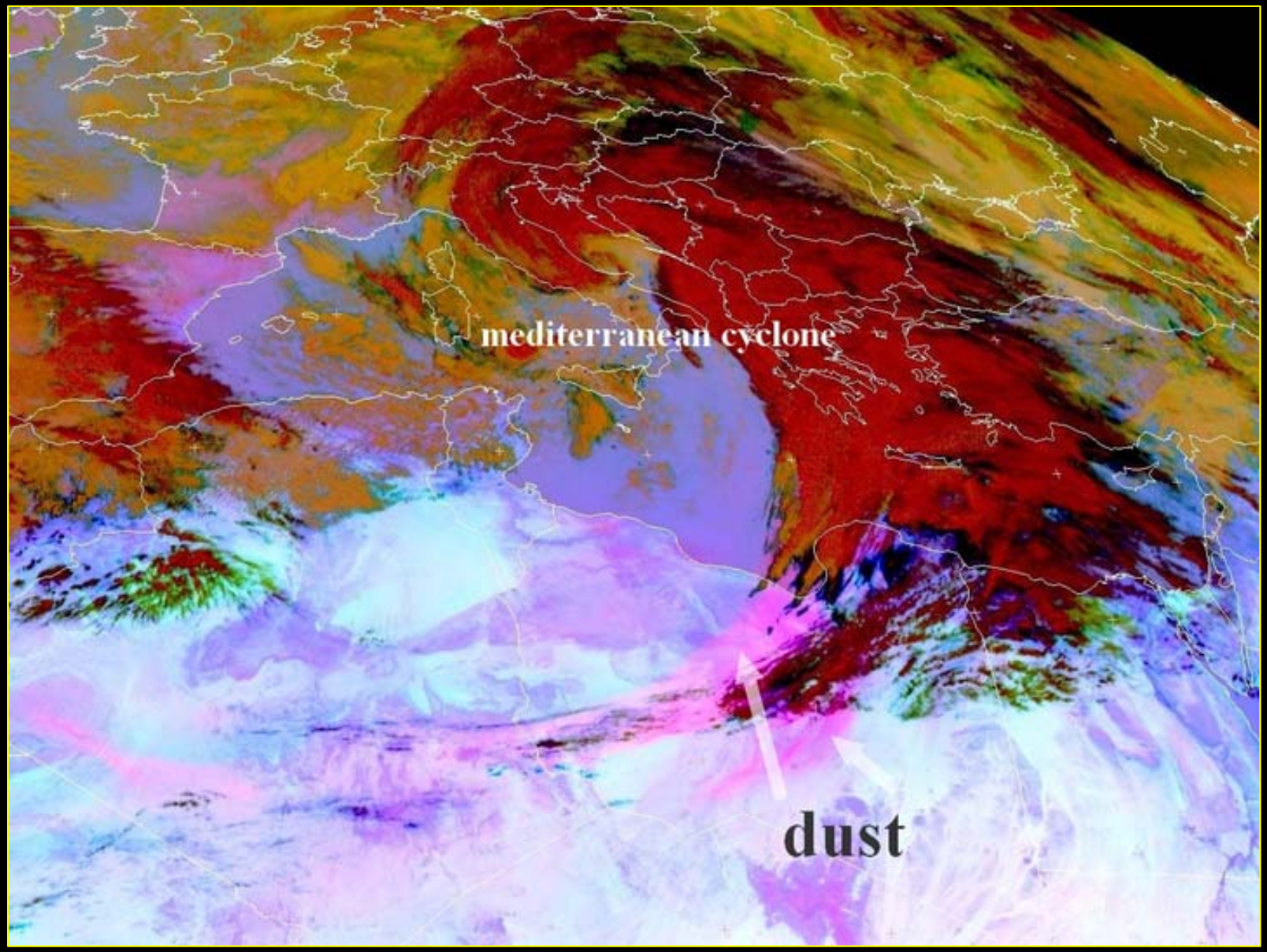
11 February 2010, Case study
Demonstration of the concept with radiosonde meauserements



WV-IR

300hPa_PV

WV-IR 2.

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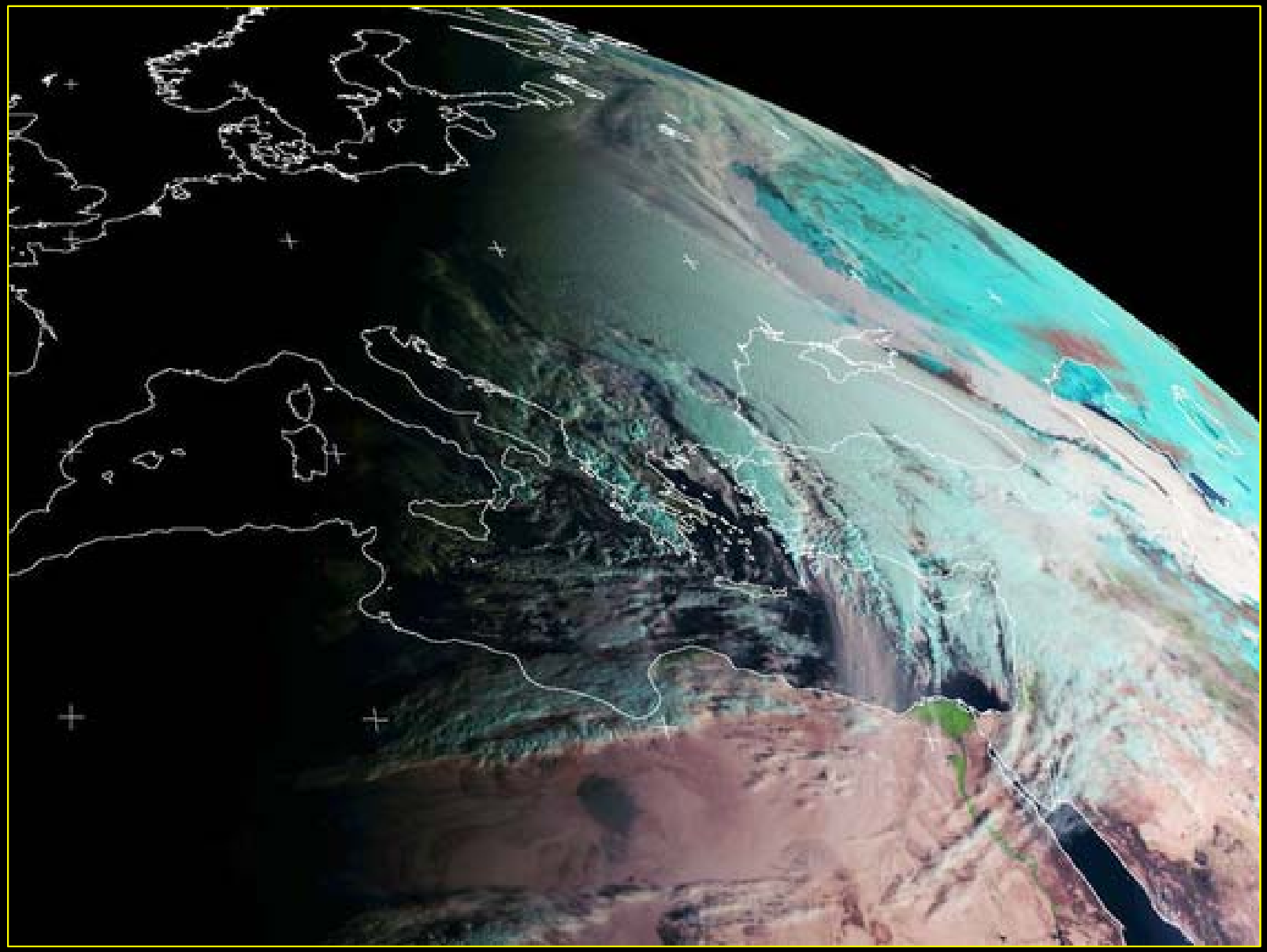

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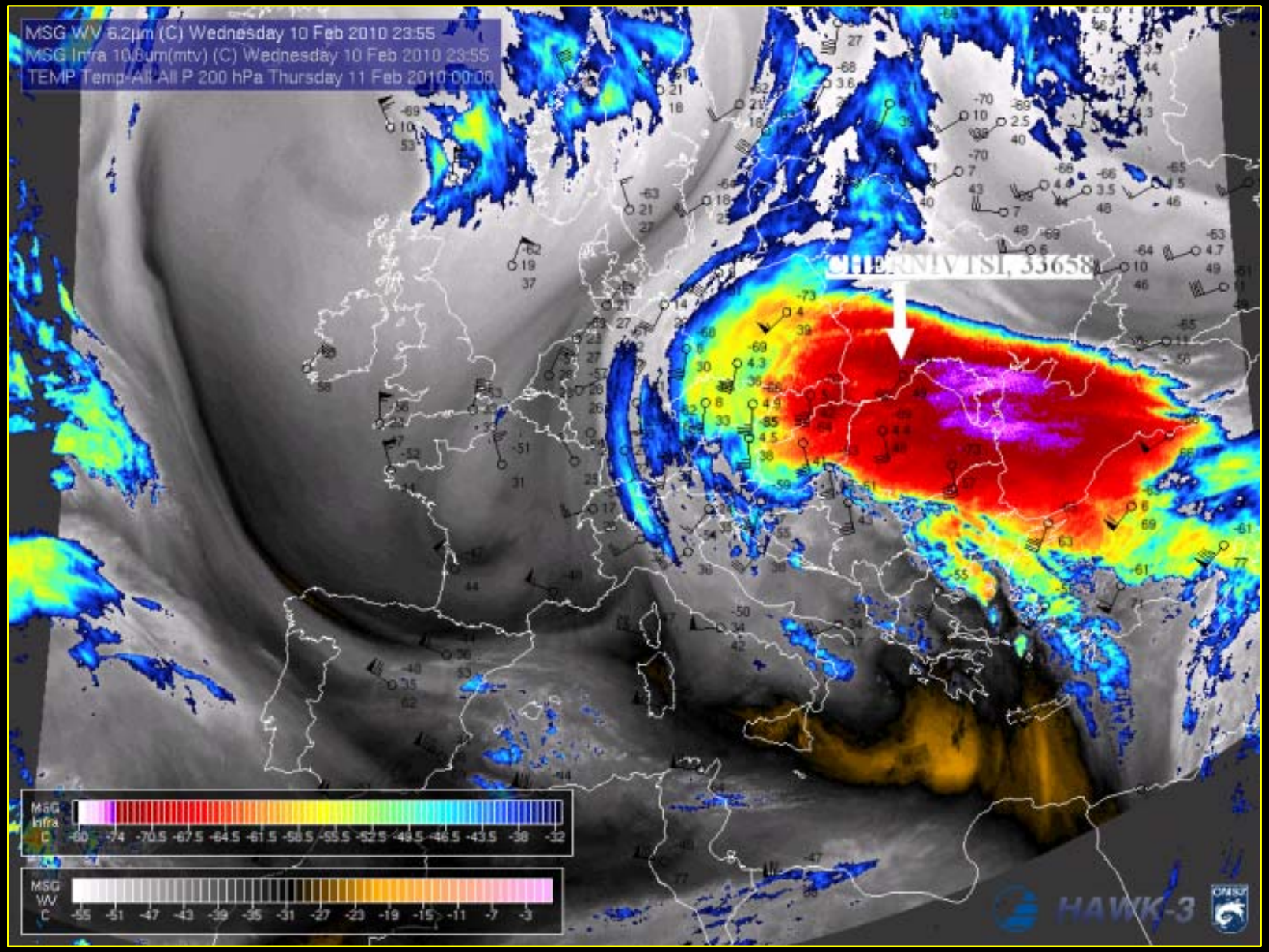

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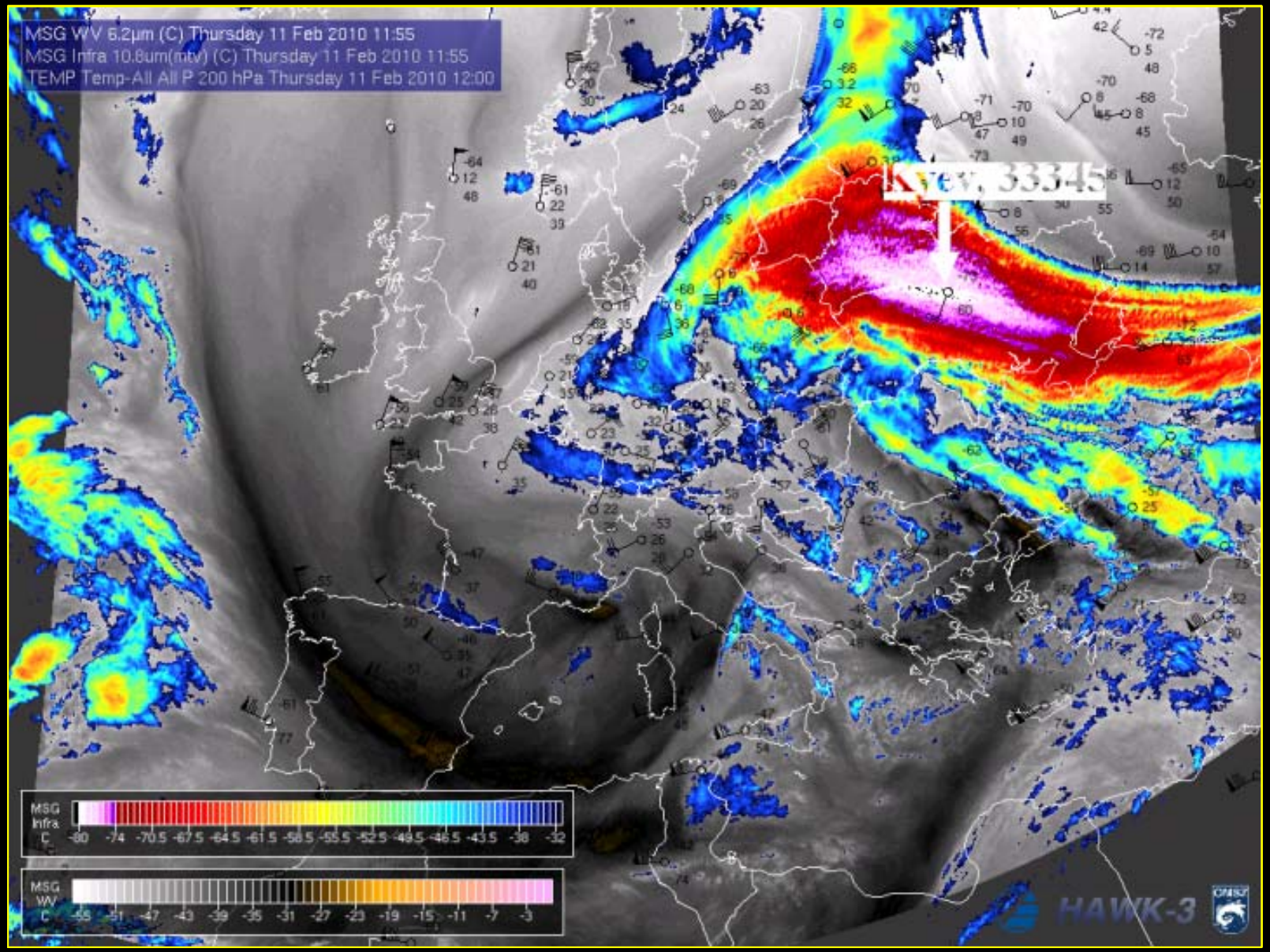

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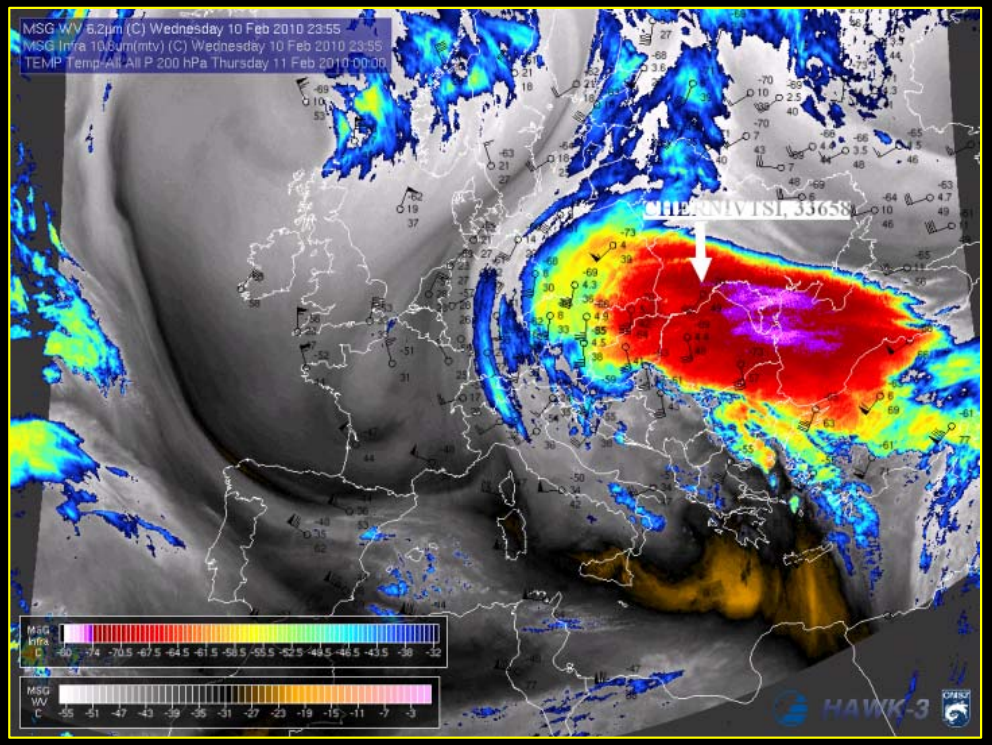
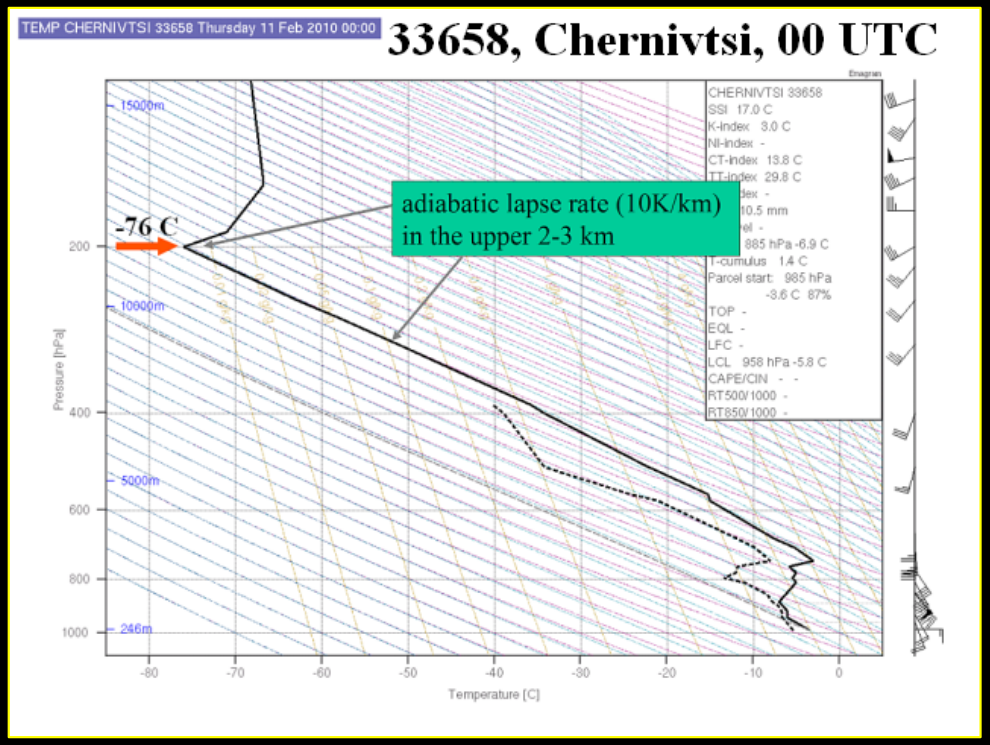
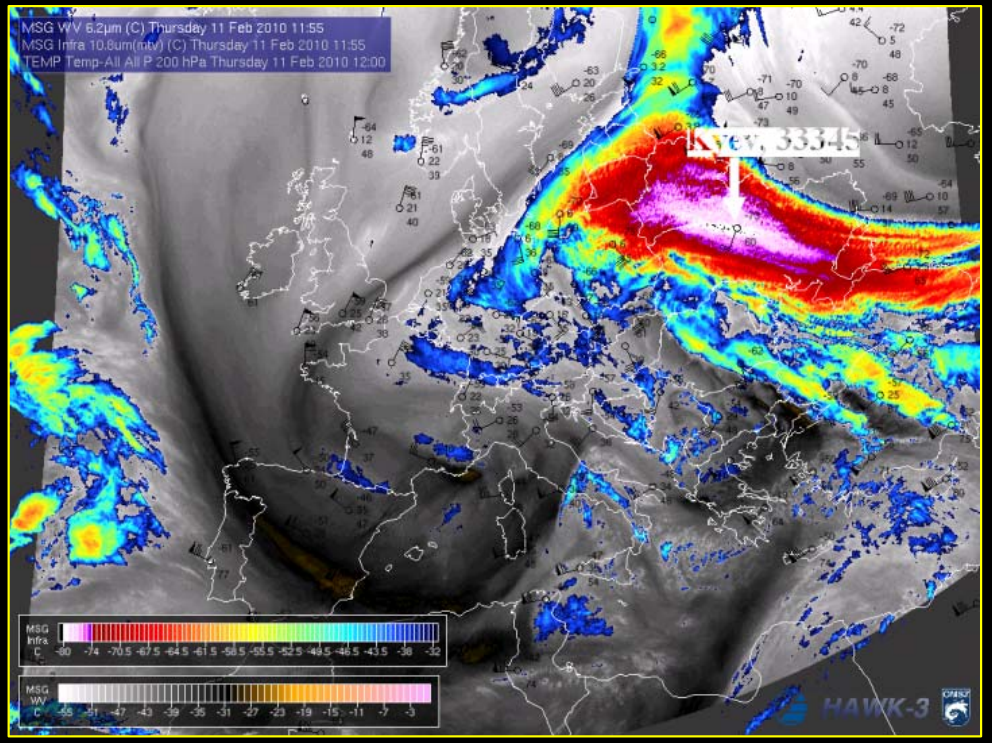
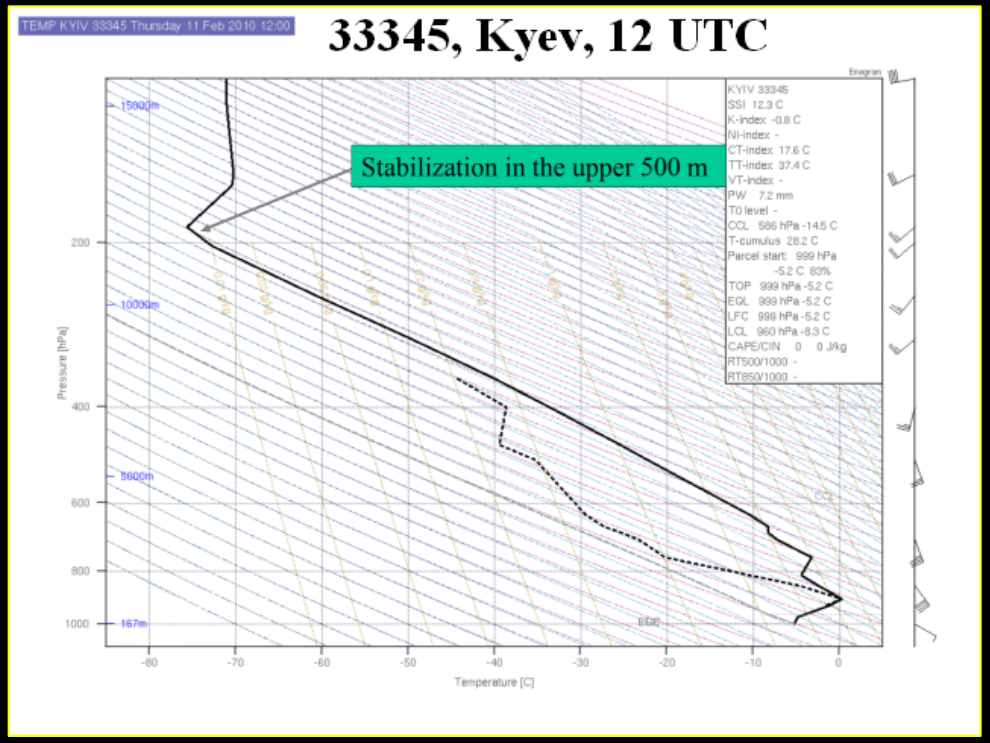
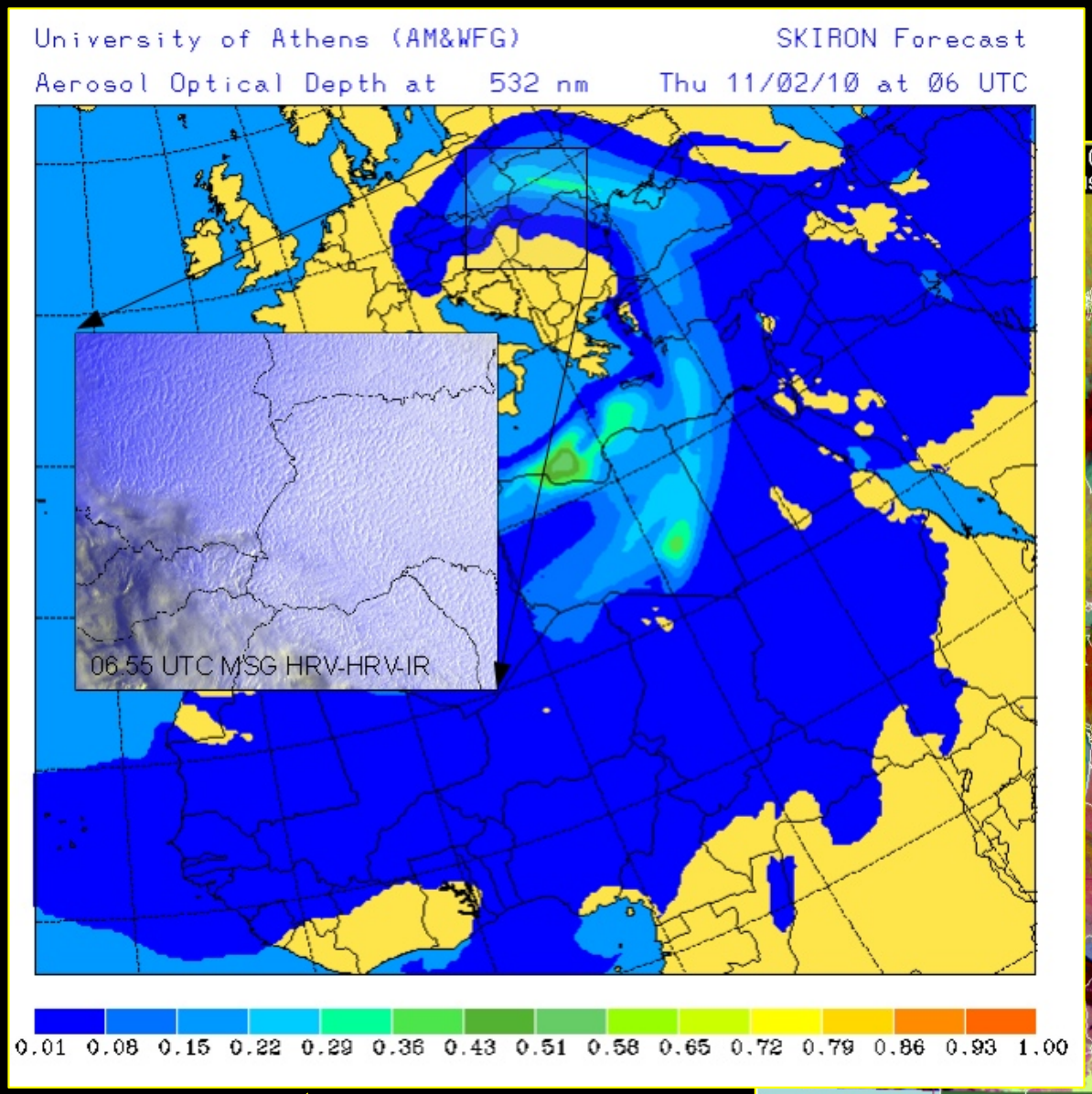

MSG WV 6.2µm (C) Wednesday 10 Feb 2010 23:55
MSG Infra 10.8um(mtv) (C) Wednesday 10 Feb 2010 23:55
TEMP Temp-All All P 200 hPa Thursday 11 Feb 2010 00:00
CHERNIVTSI, 33658
HAWK-3

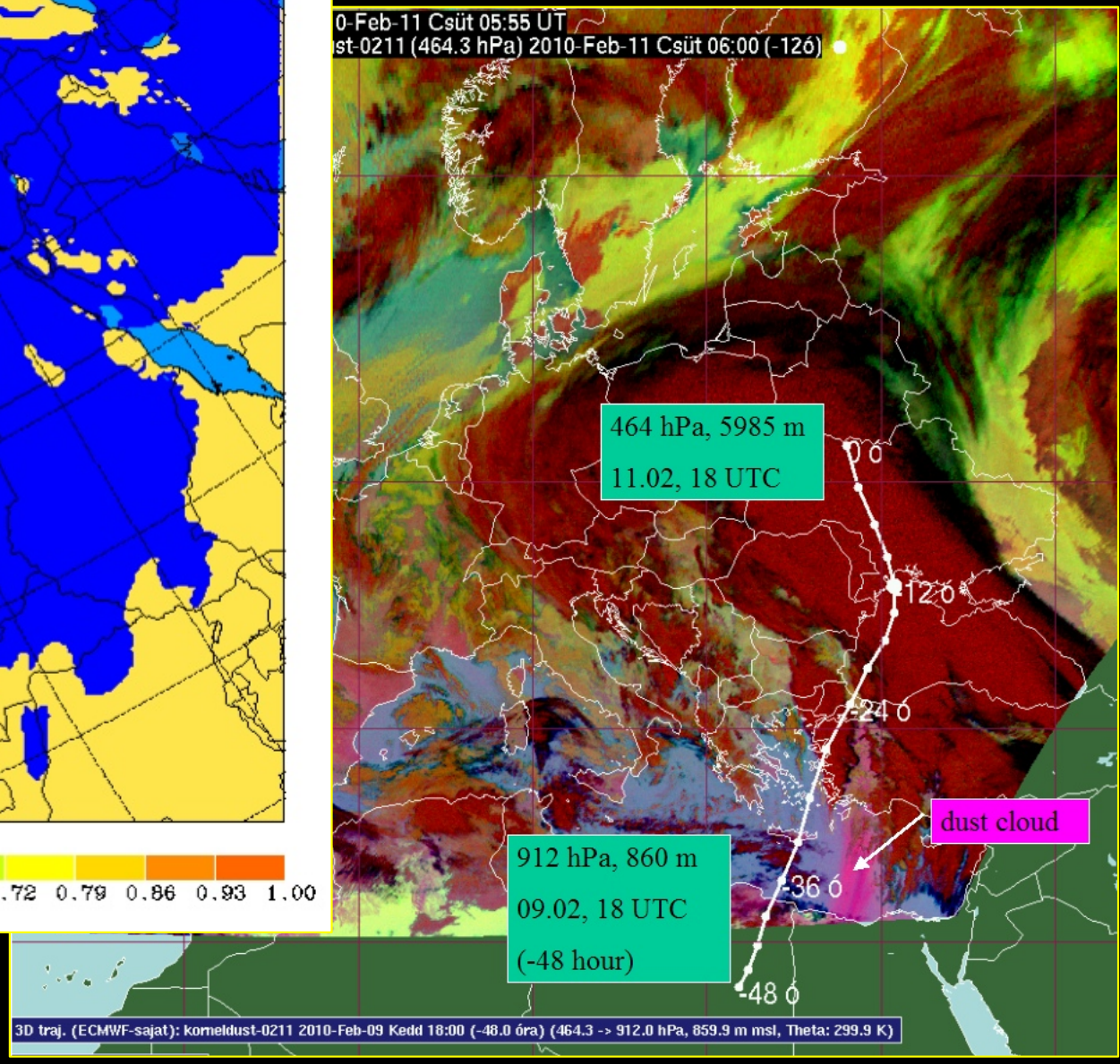

TEMP CHERNIVTSI 33658 Thursday 11 Feb 2010 00:00
33658, Chernivtsi, 00 UTC
-76 C
adiabatic lapse rate (10K/km)
in the upper 2-3 km
CHERNIVTSI 33658
SSI 17.0 C
K-Index 3.0 C
NI-Index -
CT-Index 13.8 C
TT-Index 29.8 C
PW 10.5 mm
885 hPa -6.9 C
T-cumulus 1.4 C
Parcel start: 985 hPa
-3.6 C 87%
TOP -
EQL -
LFC -
LCL 958 hPa -5.8 C
CAPE/CIN - -
RT500/1000 -
RT850/1000 -
Pressure [hPa]
Temperature [C]


MSG WV 6.2µm (C) Thursday 11 Feb 2010 11:55
MSG Infra 10.8um(mtv) (C) Thursday 11 Feb 2010 11:55
TEMP Temp-All All P 200 hPa Thursday 11 Feb 2010 12:00
Kyev, 33345
HAWK-3


TEMP KYIV 33345 Thursday 11 Feb 2010 12:00
33345, Kyev, 12 UTC
Stabilization in the upper 500 m
KYIV 33345
SSI 12.3 C
K-Index -0.8 C
NI-Index -
CT-Index 17.6 C
TT-Index 37.4 C
VT-Index -
PW 7.2 mm
T0 level -
CCL 586 hPa -14.5 C
T-cumulus 28.2 C
Parcel start: 999 hPa
-5.2 C 83%
TOP 999 hPa -5.2 C
EQL 999 hPa -5.2 C
LFC 999 hPa -5.2 C
LCL 960 hPa -8.3 C
CAPE/CIN 0 0 J/kg
RT500/1000 -
RT850/1000 -
Pressure [hPa]
Temperature [C]

Aerosol concentration forecast, trajectories

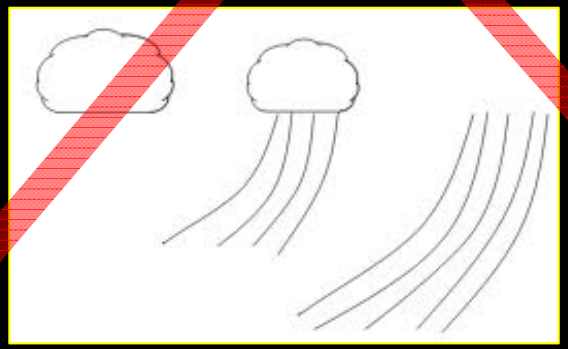




Source: Aerosol forecast (SKIRON, University of Athens): http://forecast.uoa.gr/dustindx.php

Loger lifespan of high level clouds

We can suspect that in specific situations underestimation of the high-level clouds in NWP can occasionally be the consequences of the higher concentration of dust aerosols. Dust particles as ice nuclei can decrease the average size of the ice crystals → ***they cannot fall out***.

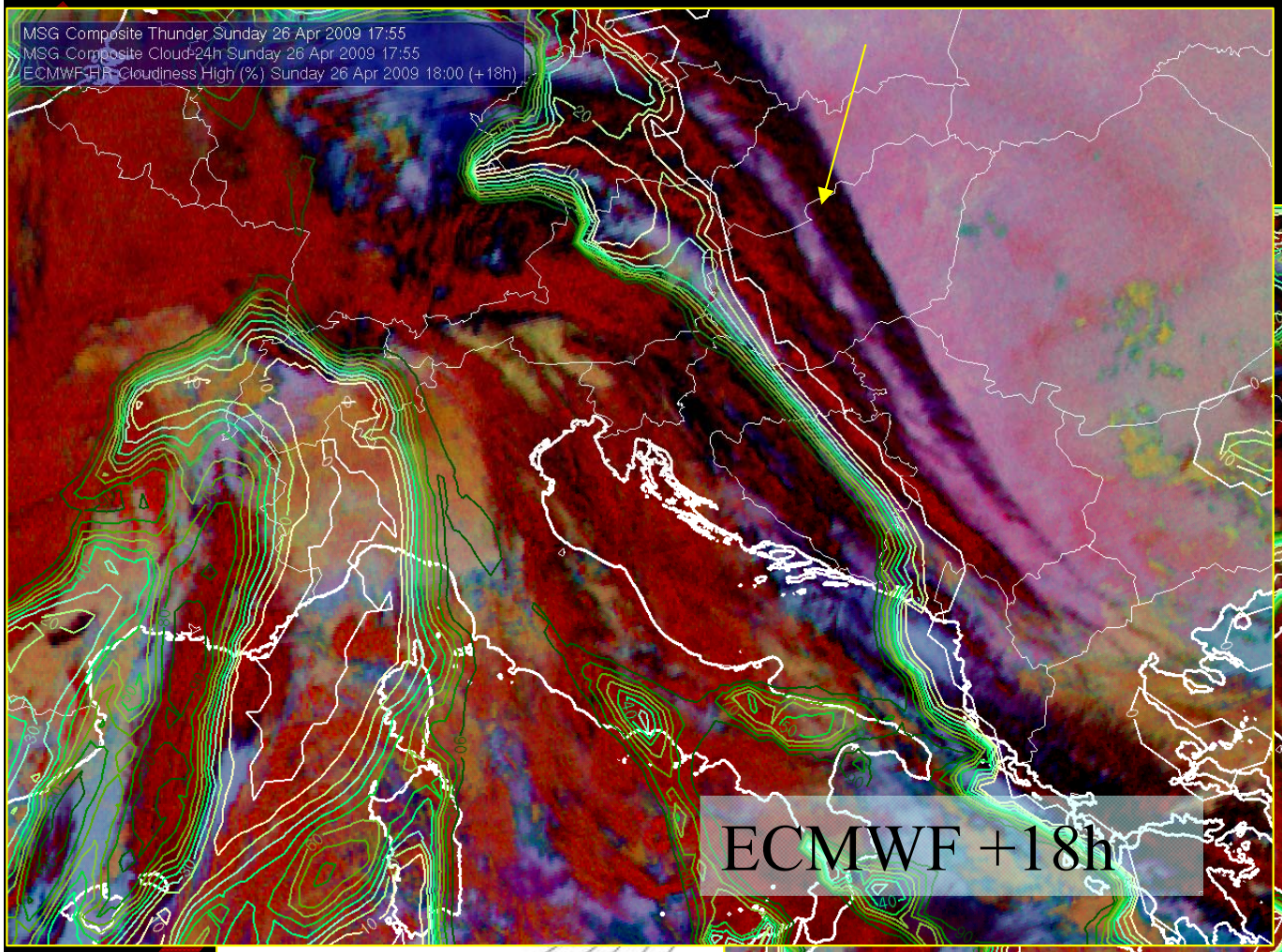


HRV animation

infra animation

Loger lifespan of high level clouds

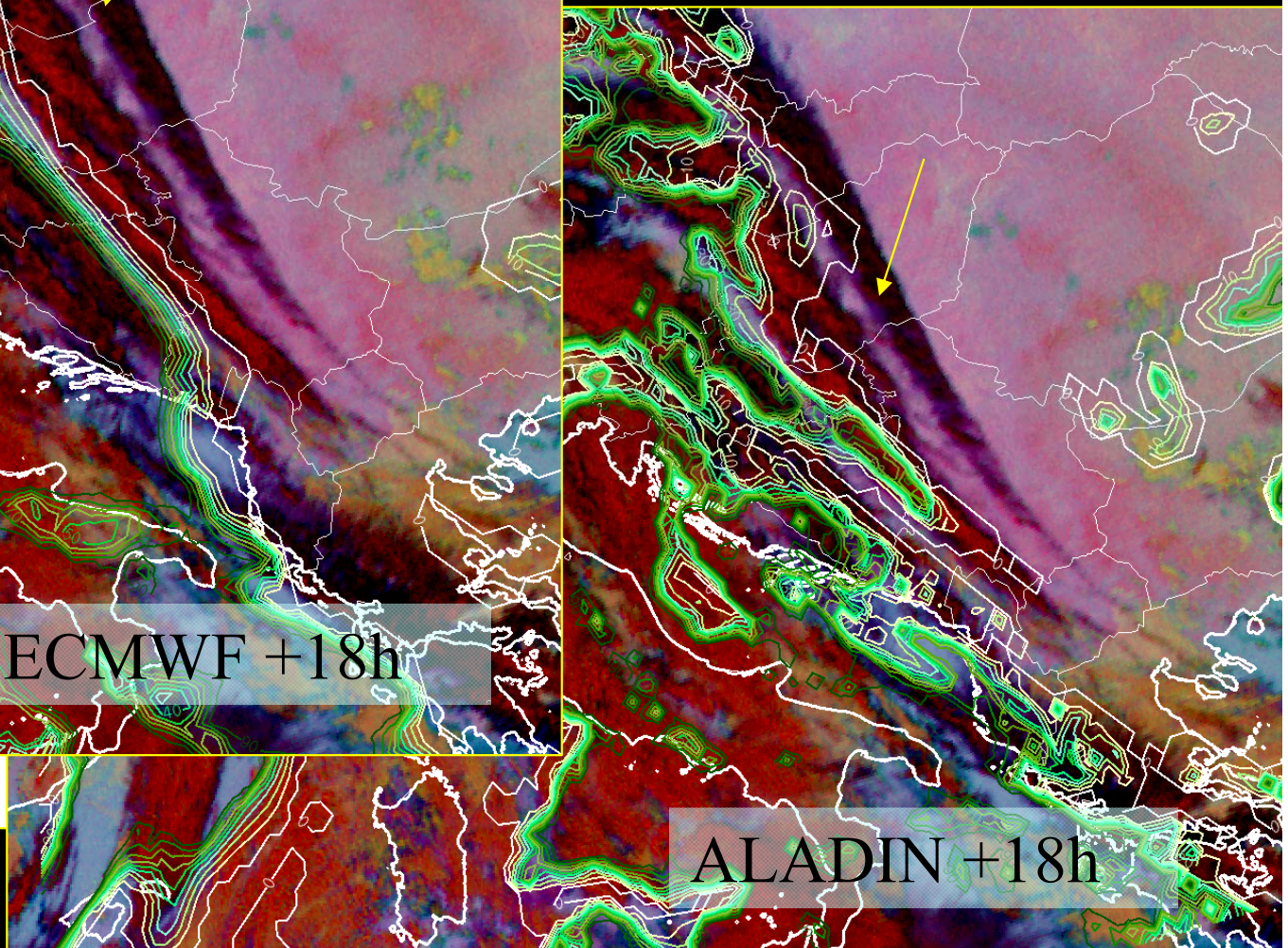
We can suspect that in specific situations underestimation of the high-level clouds in NWP can occasionally be the consequences of the higher concentration of dust aerosols. Dust particles as ice nuclei can decrease the average size of the ice crystals → ***they cannot fall out****.*



ECMWF +18h

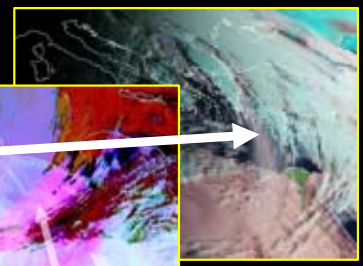
HRV animation

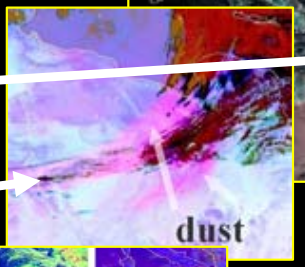
infra animation



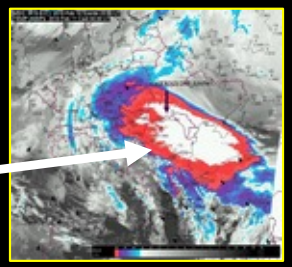
ALADIN +18h

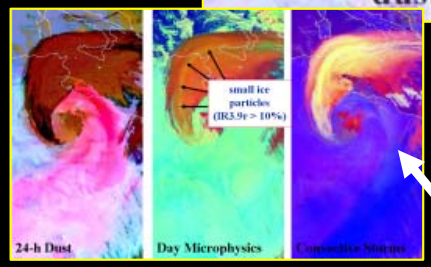
Recommendations, tips for forecasters



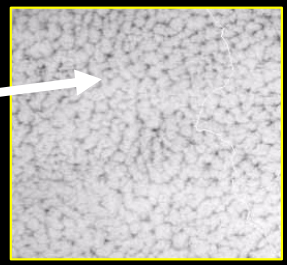


- Check the direct presence of dust in the Mediterranean in sat. images:
  - ***Visible channel*** especally in low Sun angle (morning and early evening hours)
  - RGB infrared composite images: ***MSG dust or 24 hours composite***





- ***Forward trajectories*** (*) from the position of the dust
- Suspicious cloud shields:
  - ***Extended and very cold high level cloud shields***
  - ***MSG microphysical composite images*** (enhanced reflectance in 3.9 mm) indicates the presence of ice particles with small effective radius
  - ***Cumuliform structure*** at the top (especially in the morning hous in ***HRV images***)



- ***Backward trajetories*** (*) from the position of the cloud shield
- ***Aerosol forecast***; parameters: aerosol optical depth, dust load
  (e.g.: SKIRON/University of Athens http://forecast.uoa.gr/dustindx.php or GEMS/Ecmwf: http://gems.ecmwf.int/)
- Be aware of the fact: saharan dust may modify the atmospheric conditions (usually not represented processes well in NWP)
  - ***Direct effect***: in sunny weather dust increases the stability in the boundary layer
  - ***Indirect effect***: dust may enhance the high level cloud shields
    - ➢ ***Both can weaken the thermal/convective activity***

(*) Online tracetory calculation (NOAA HYSPLIT):
http://www.ready.noaa.gov/ready/open/hysplit4.html

What we have done?

• Systematic subjective analysis of MSG Satellite images in the Mediterranean and Central-Europe (2004-2010)

• We formed a possible hypothesis for the cumuliform structure of „dusty" cirrus shields and daily variation of the cloud top temperature

Ideas for Further research

• Objective validation of the cloud top temperature variation

• Objective examination of the increased lifespan of the cirrus shields

• Objective verification of NWP high level cloud forecast (with the amount of the saharan dust)

• Applying NWP with adequate microphysical and radiational scheme (it can be a simplified one-dimensional model) for checking our hypothesis

• Case studies of the „dusty" cloud shields with LIDAR measurements

• In situ measurements of the cloud shields (profiles: microphysical properties of the cloud elemets; aerosol; temperature; etc.)

Thank You for your Attention!