The importance of desert dust for weather and climate in the Mediterranean

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Why we care about atmospheric aerosols?

1. **Natural Hazards** (dust storms, aerosol invigorated floods and cyclones, human health implications, visibility issues, aviation safety, biomass smoke, etc.)
2. **Climate change** (Important scientific questions regarding the role of aerosols as weather and climate regulators).

Aerosol Climate impacts

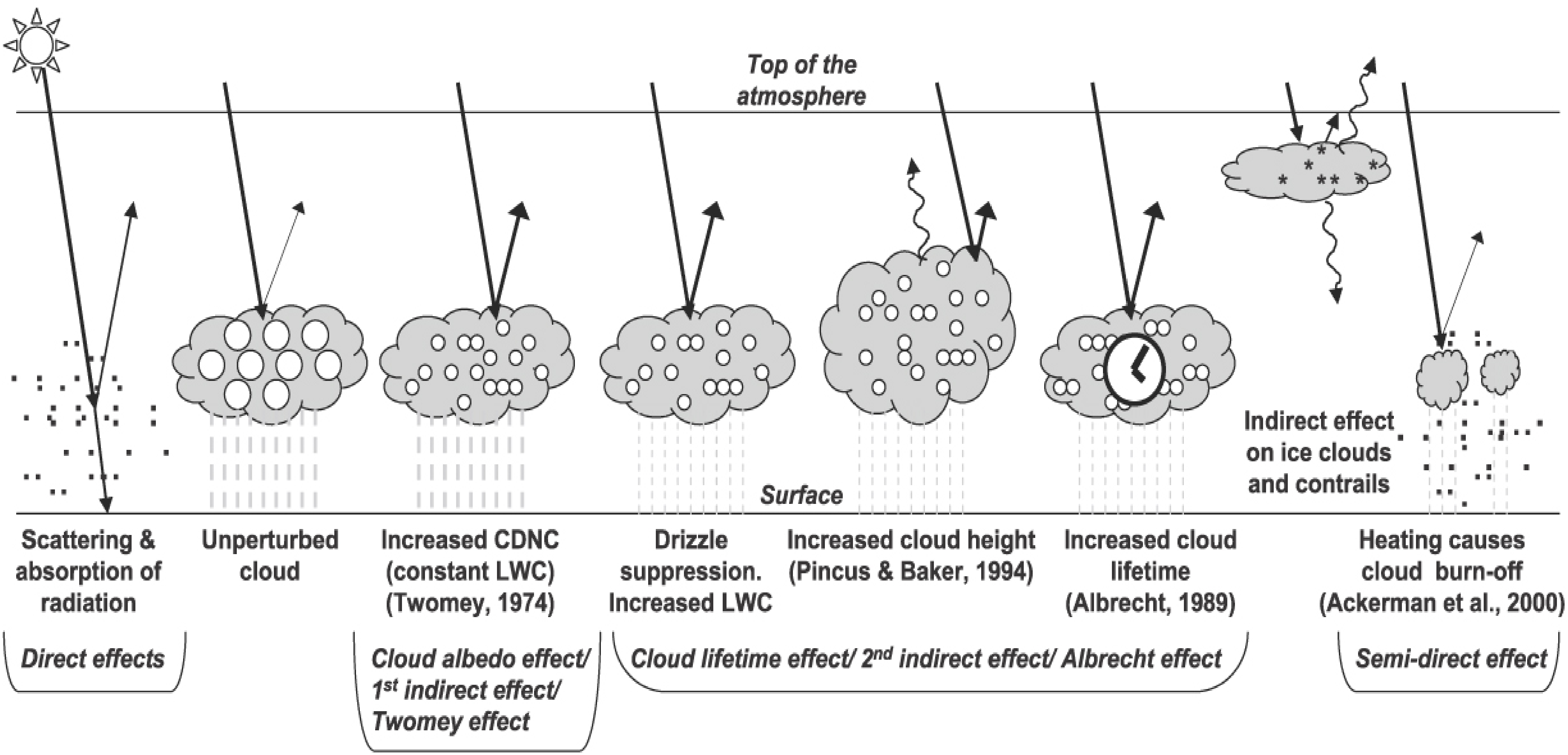
Biomass smoke & mineral dust are the most important natural emissions

Direct Effects :

Scattering and absorption of solar and terrestrial radiation.

Indirect Effects :

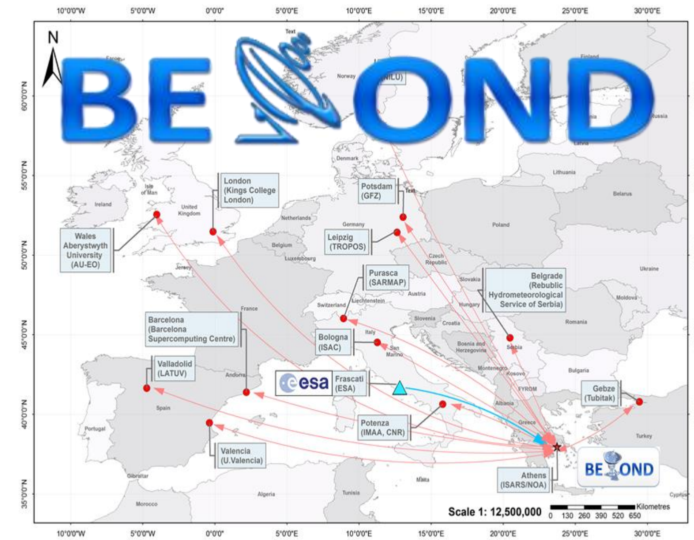
"Polluted" clouds contain more cloud droplets that are smaller in size.



IPCC, 2007

Establishment of an EO Center of Excellence at the National Observatory of Athens - Greece

BEYOND aims to maintain and expand the existing state-of-the-art interdisciplinary research potential, by <u>B</u>uilding a Centre of <u>E</u>xcellence for Earth <u>O</u>bservation based monitoring of <u>N</u>atural <u>D</u>isasters in south-eastern Europe .



http://www.beyond-eocenter.eu/

BUILDING INFRASTRUCTURE CAPACITY

ESA Mirror site

X-/L-band antenna, MSG-Seviri, Sentinel acquisition facilities

LIDAR

Development of a Light Detection And Ranging (LiDAR) system, PollyXT lidar

UHI Patterns extraction

Build and populate a relevant Urban Heat Island database

Floods Monitoring Service

Monitor flood events following the processing of Sentinel-1

Sentinel Interferometry

e.g. earthquakes, volcanoes etc.

BUILDING HUMAN CAPACITY

≈10 Researchers

≈20 Assistant Researchers (PhD and Post-Docs)

FireHub Service

- Satellite fire detection (MSG)
- Smoke dispersion forecast (FLEXPART – WRF)

Dust Service

- Satellite dust retrievals (CALIPSO)
- Dust modeling & assimilation (NMM-DREAM, WRF-CHEM, RAMS)

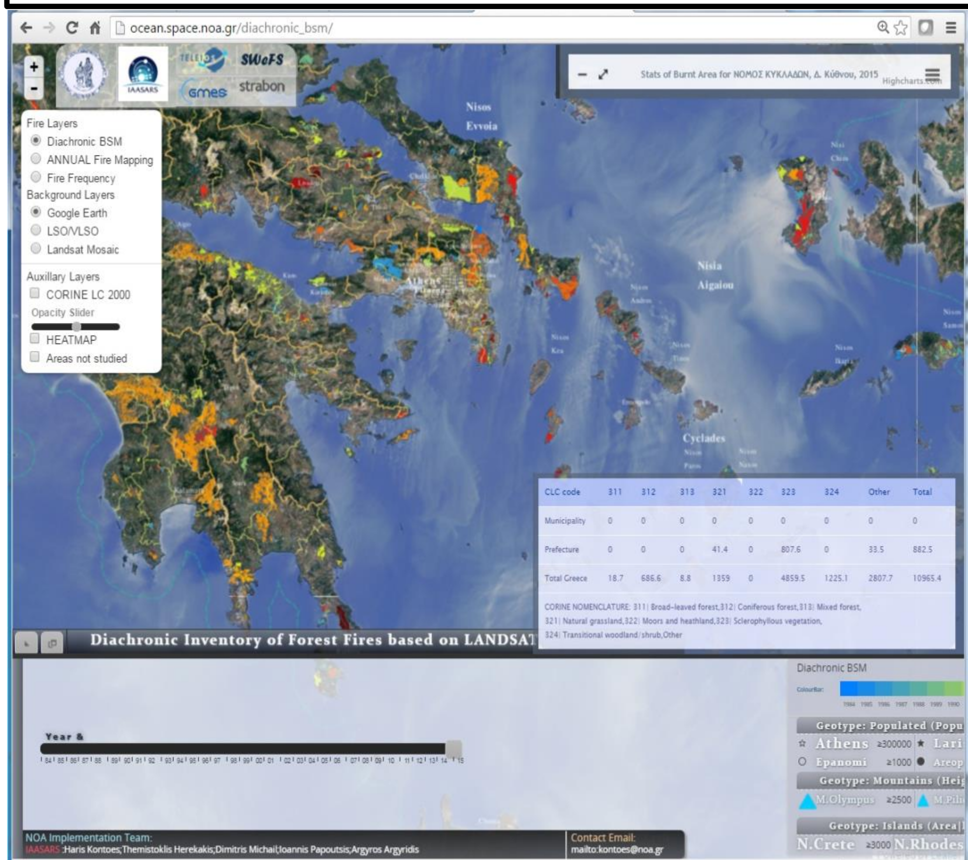
http://geocradle.eu/

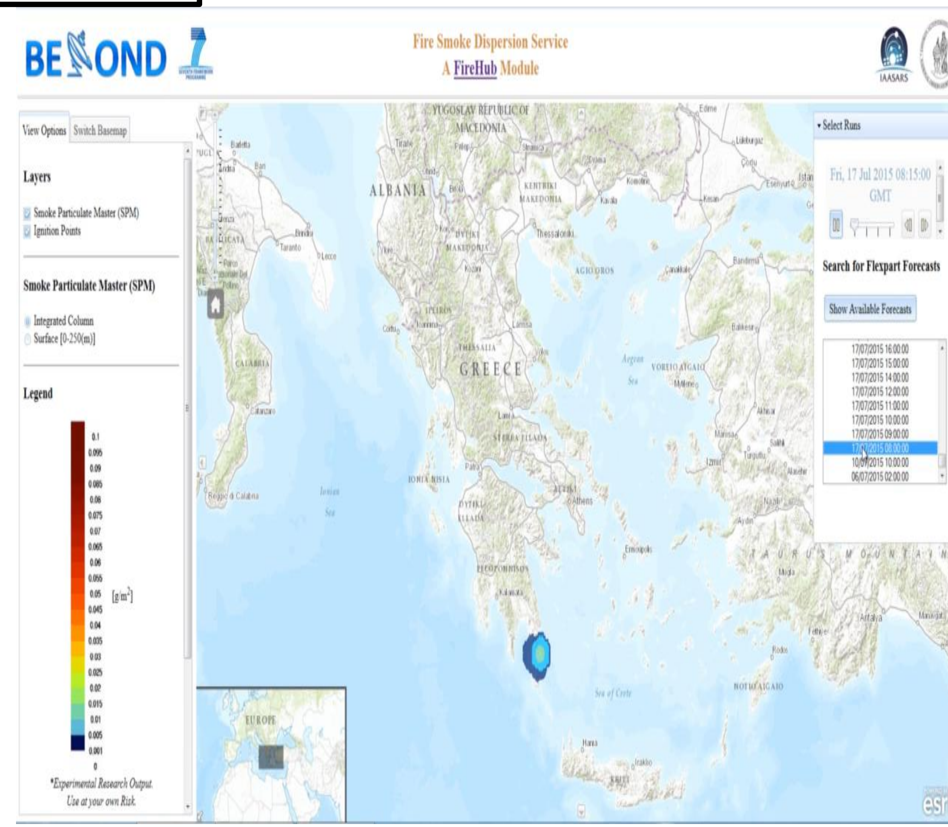
FireHub: A Space Based Fire Management Hub

A synergistic service incorporating

1. **Diachronic Inventory of Forest Fires based on LANDSAT**
2. **Real time Fire Monitoring Service based on MSG SEVIRI**
3. **Smoke dispersion forecast based on FLEXPART-WRF simulations**

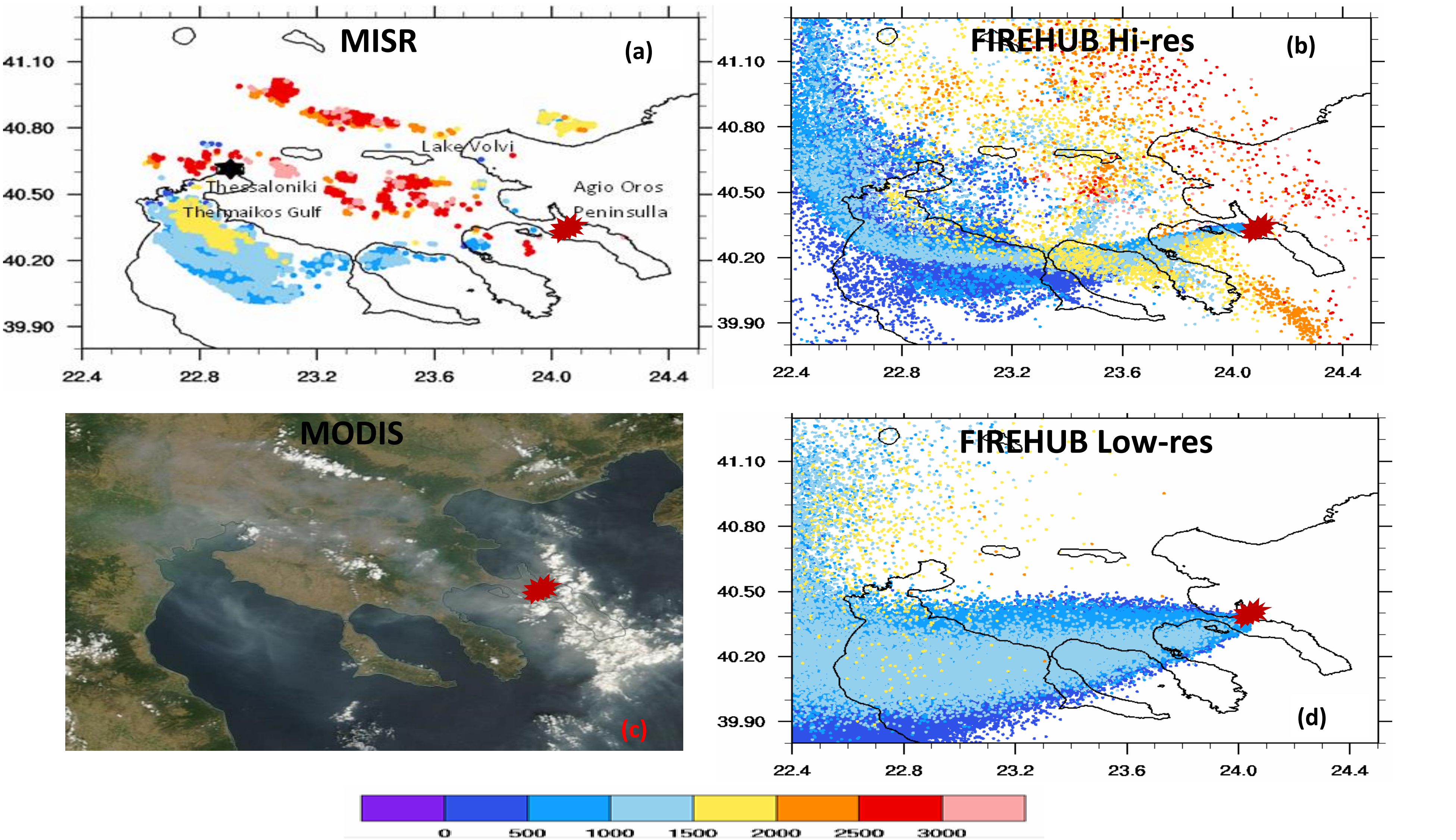
- **FireHub** has been elected as the winner of the Best Service Challenge of the Copernicus Masters 2014
- **FireHub** is integrated into the Global Fire Monitoring Center that belongs to the International Strategy of UN for Disaster Reduction





FireHub – Smoke Dispersion
Comparison with MISR and MODIS satellite retrievals

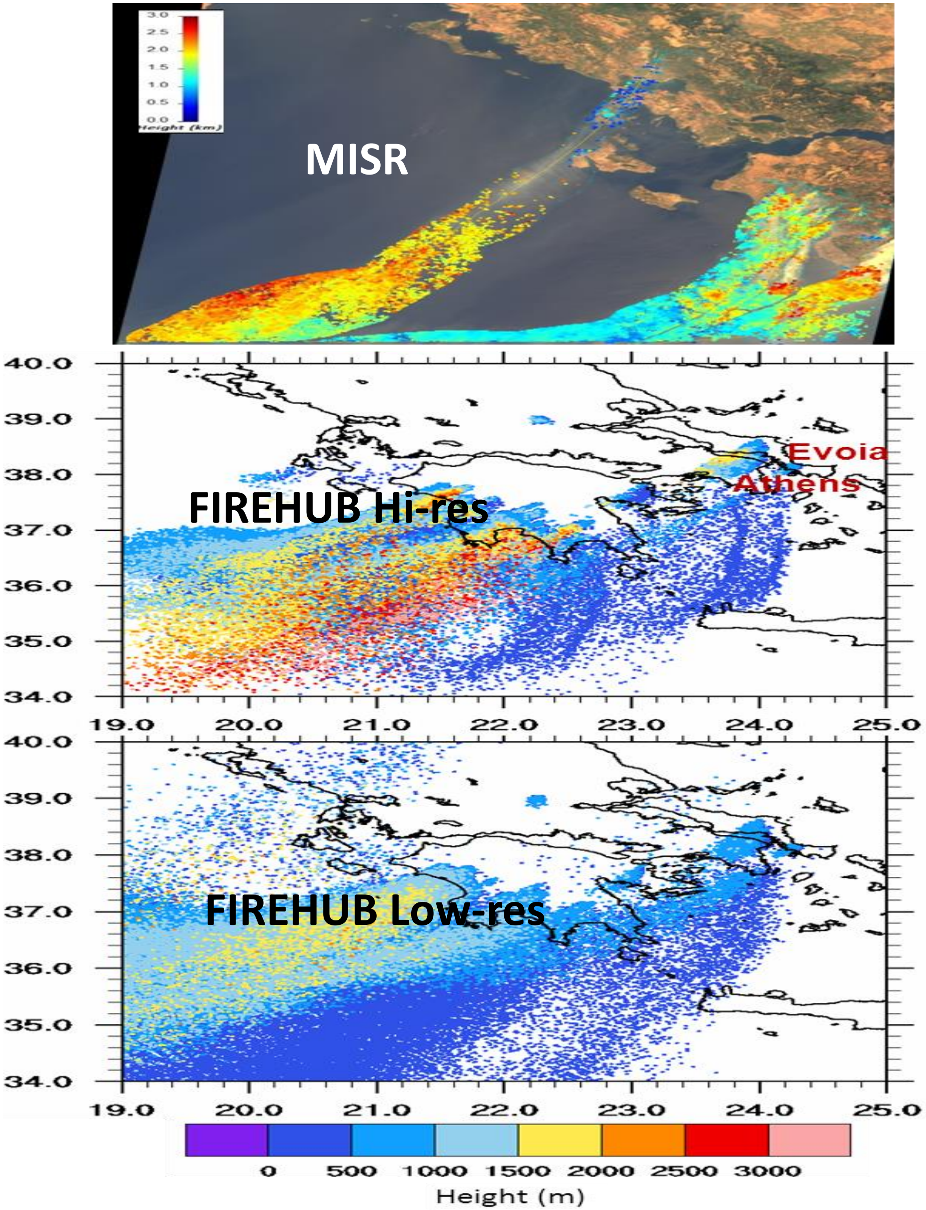
Dispersion of smoke for a case study that combines complex terrain and complex meteorological conditions



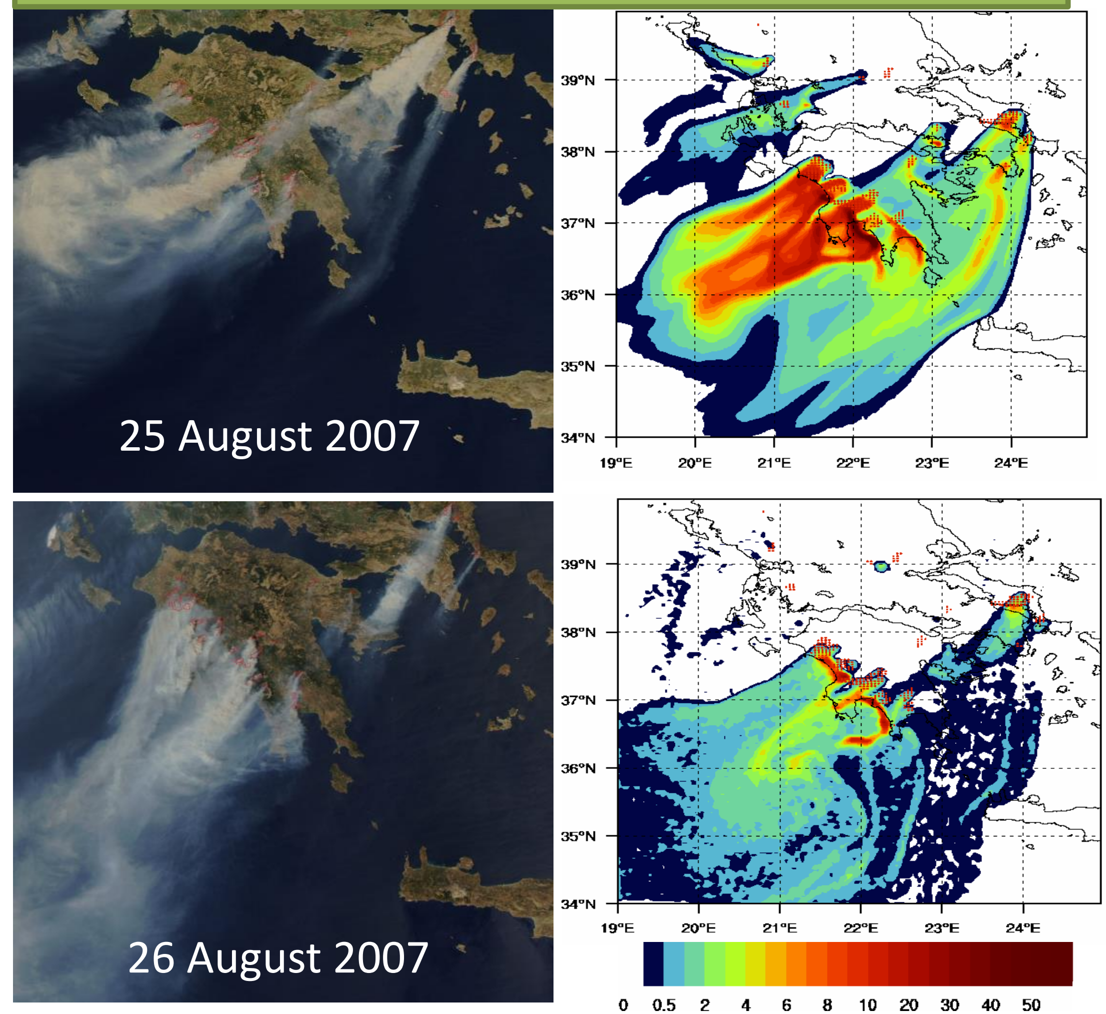
Solomos et al., 2015, Atm. Environment

FireHub – Smoke Dispersion
Comparison with MISR and MODIS satellite retrievals

The interchange between deep land PBL and shallow marine PBL favors long range transport.



Extreme fire event – Peloponnese 2007
Smoke plume height (m)

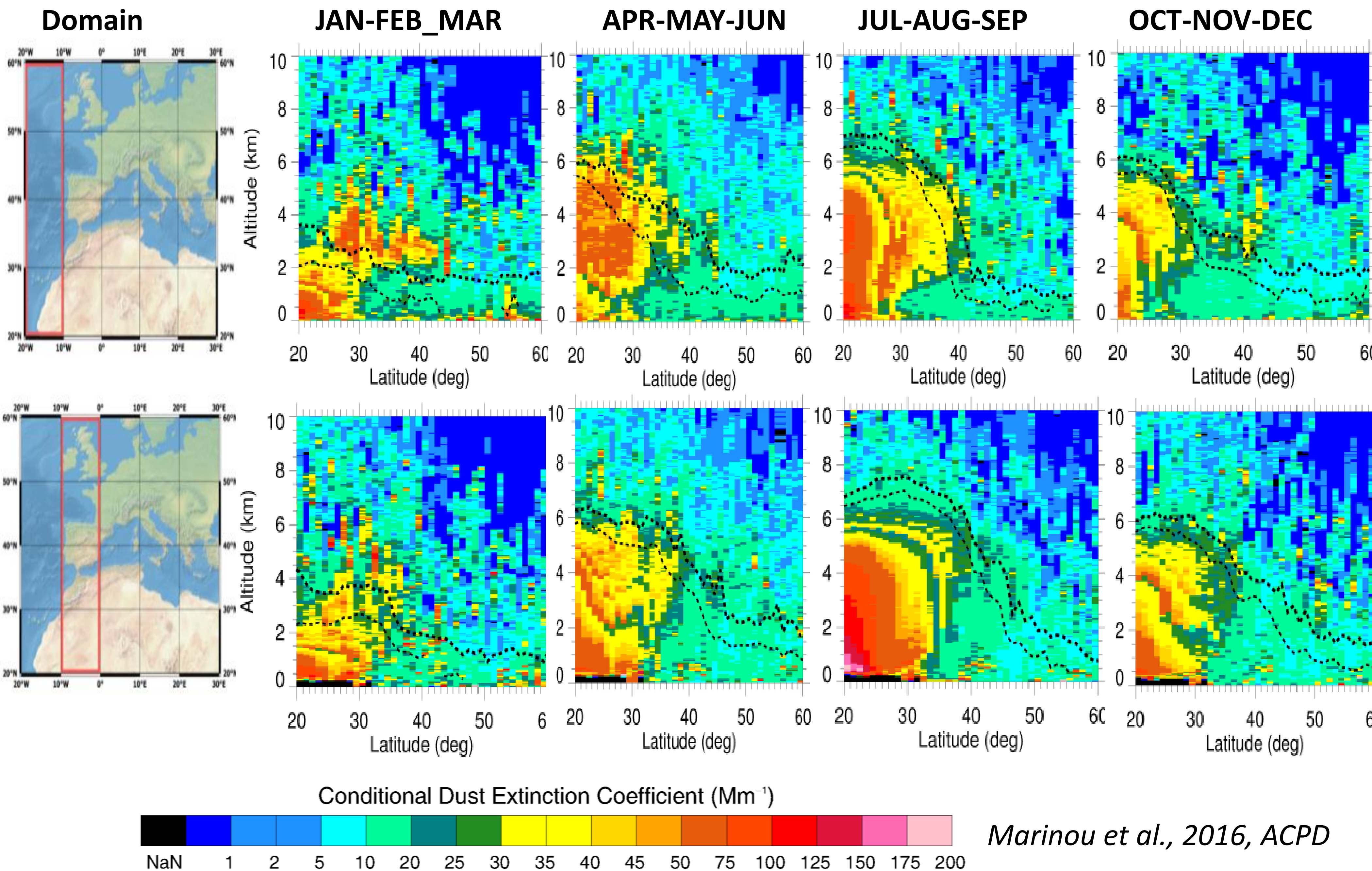


Column concentration of smoke TPM (mg m^{-2})

Solomos et al., 2015, Atm. Environment

Dust is always present in the Mediterranean

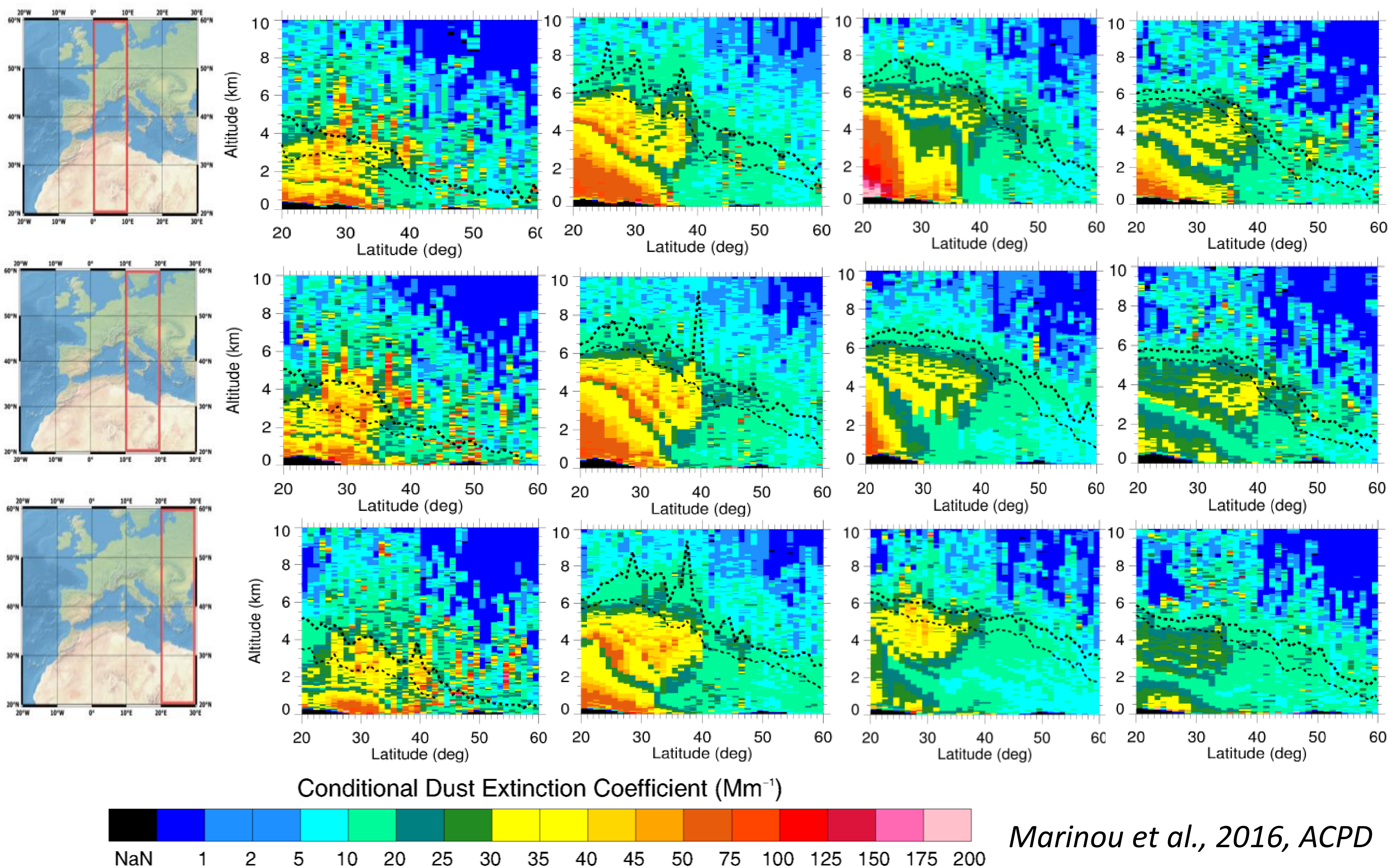
3D evolution of Saharan dust transport towards Europe as captured by the EARLINET-optimized CALIPSO dust product (2007-2015)



Marinou et al., 2016, ACPD

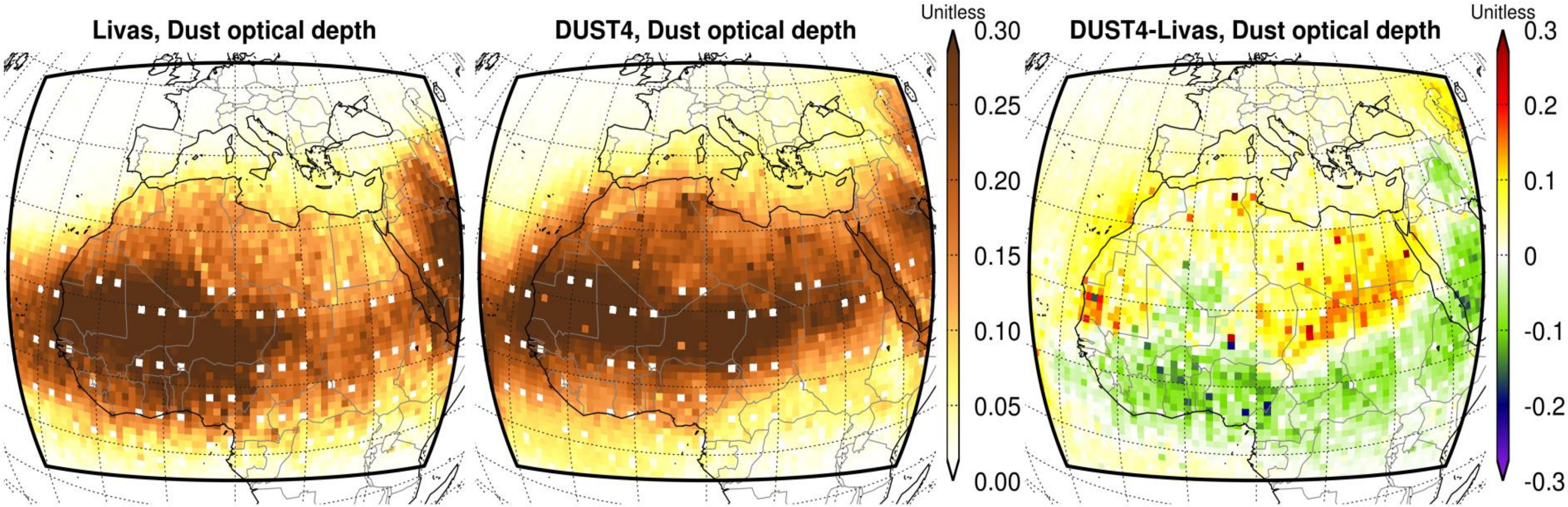
3D evolution of Saharan dust transport towards Europe as captured by the EARLINET-optimized CALIPSO dust product (2007-2015)

Domain | **JAN-FEB_MAR** | **APR-MAY-JUN** | **JUL-AUG-SEP** | **OCT-NOV-DEC**

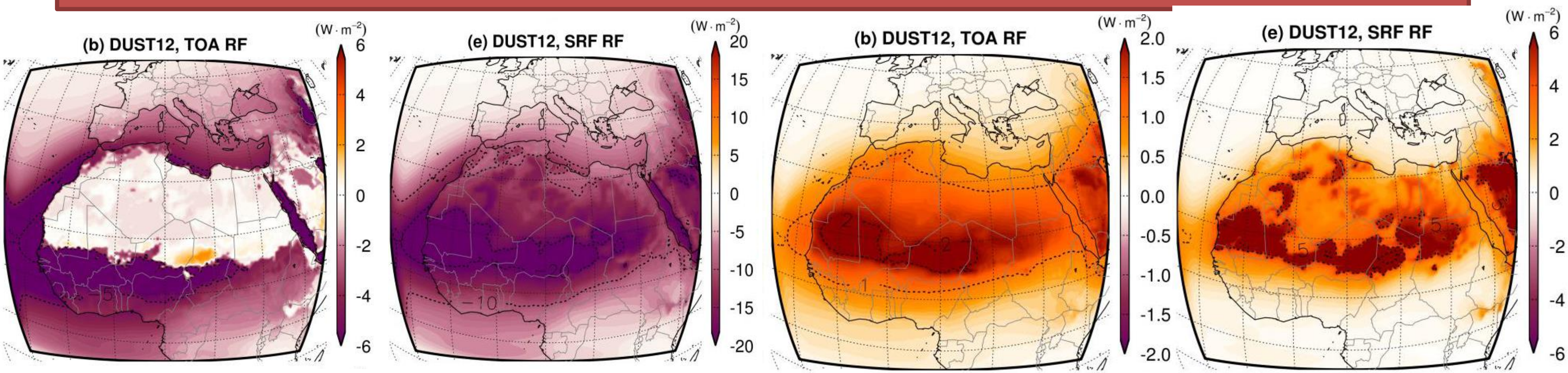


Marinou et al., 2016, ACPD

Dust Radiative Forcing over Mediterranean - RegCM4 / CALIPSO LIVAS



Overall good agreement between RegCM4 2006-2014 optical depth and LIVAS pure dust product
Up to 0.2 overestimation over Sahara sources - Up to 0.1 underestimation over Sahel Arabia



Shortwave radiative forcing (-)
Up to -6 Wm^{-2} at the Top of the Atmosphere (TOA)
Up to -20 Wm^{-2} at the surface (SRF)

Longwave radiative forcing (+)
Up to 2 Wm^{-2} TOA
Up to 6 Wm^{-2} SRF

Tsikerdekis et al., 2016 , ACPD

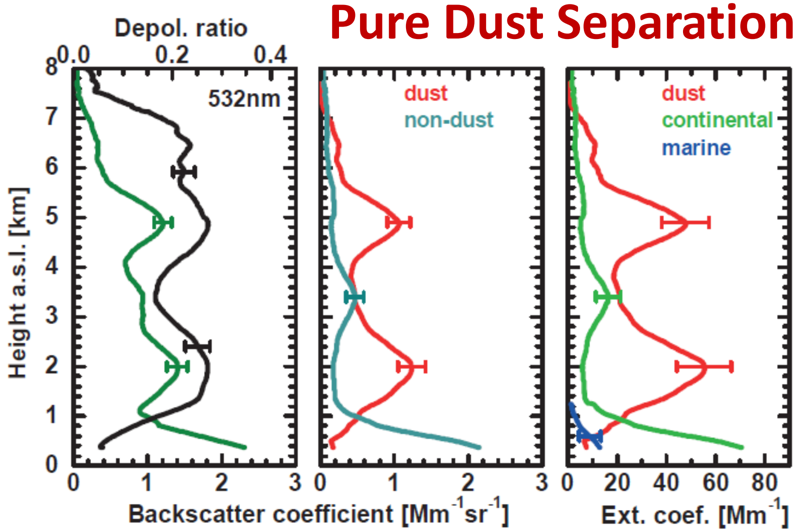
Dust radiative forcing is resolved at an adequate level

Significant uncertainty remains on the cloud – dust interactions (IN, CCN activation)

Dust Ice Nucleating Particles (IN activation)

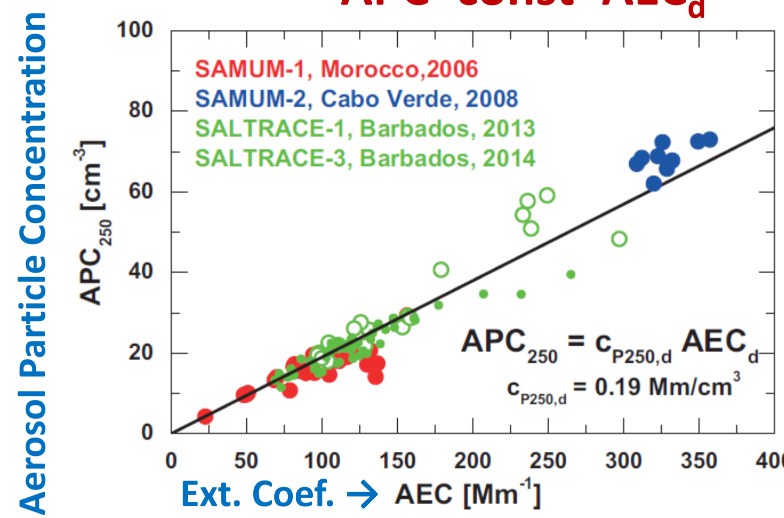
Calculation from ground lidar retrievals

Pure Dust Separation



+

APC=const*AEC$_d$



Steinke et al. (2015) provides a deposition-freezing parameterization:

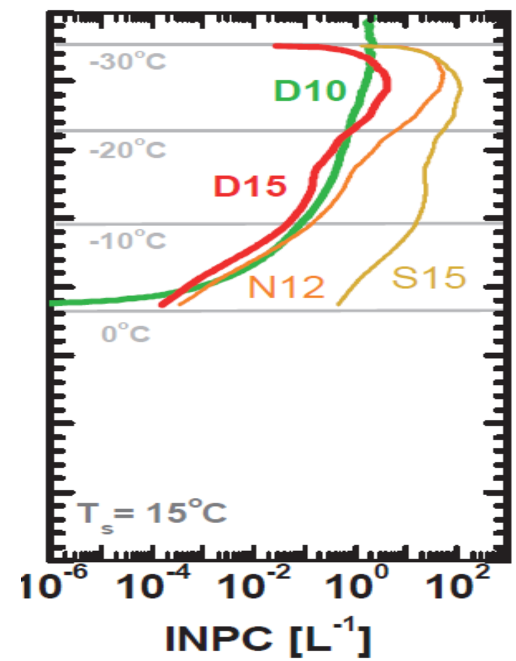
$$n_{\mathrm{INP,d}}(T_z) = 1000 \times s_{\mathrm{d,dry}}(z) \times \eta_{\mathrm{dep}}(T_z)\,, \qquad (17)$$

$$\eta_{\mathrm{dep}}(T_z) = 1.88 \times 10^5 \times \exp(0.2659\,\chi(T_z))\,, \qquad (18)$$

$$\chi(T_z) = -(T_z - 273.16) + (ss_{\mathrm{ICE}} - 1) \times 100 \qquad (19)$$

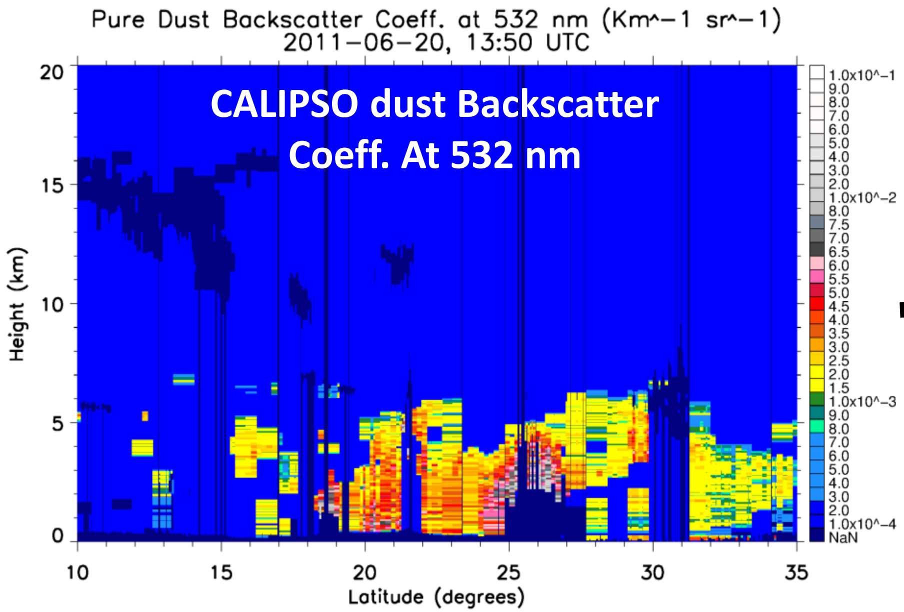
The INPC parameterization scheme for mineral dust is (DeMott et al., 2015):

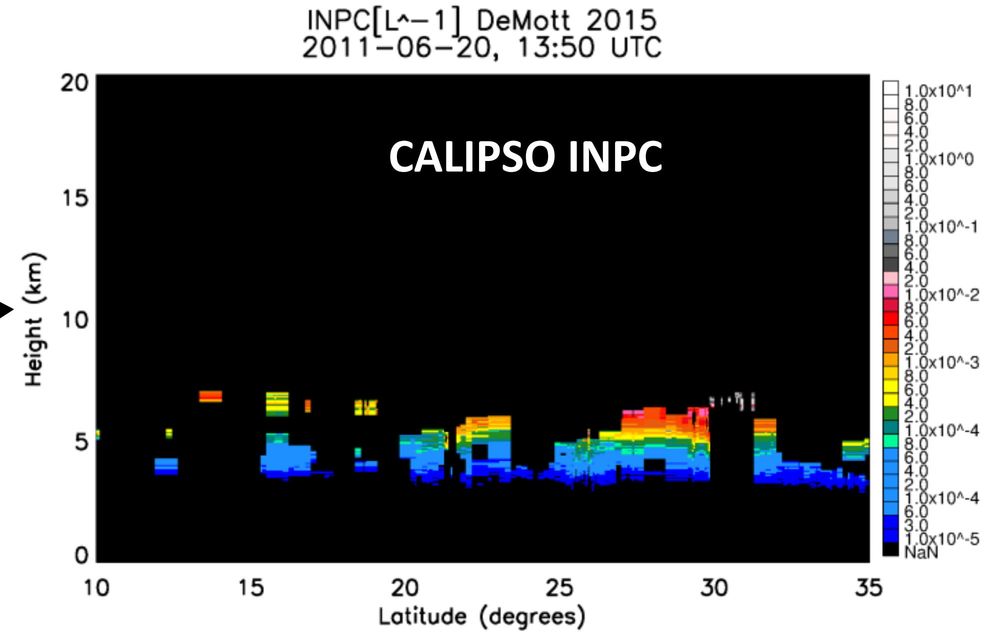
$$n_{\mathrm{INP,d}}(p_0, T_0, T_z) = f_{\mathrm{d}}\, n_{\mathrm{P250,d}}(p_0, T_0)^{[a_2(273.16 - T_z) + b_2]} \times \exp[c_2(273.16 - T_z) + d_2] \qquad (8)$$

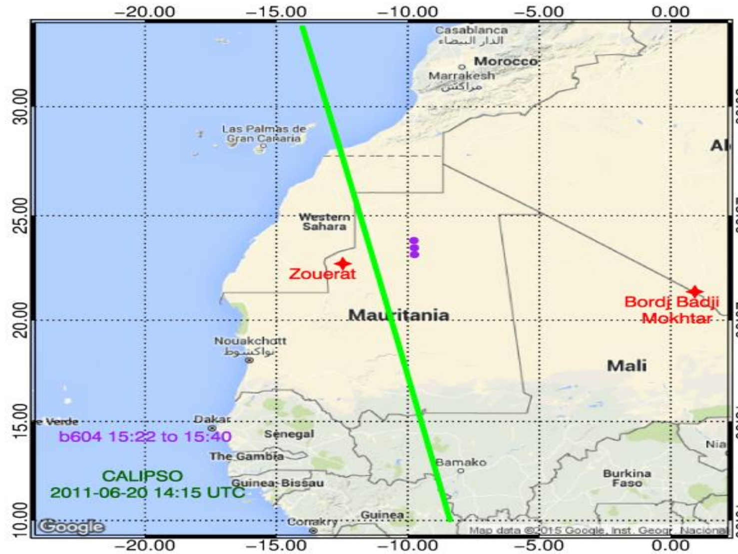


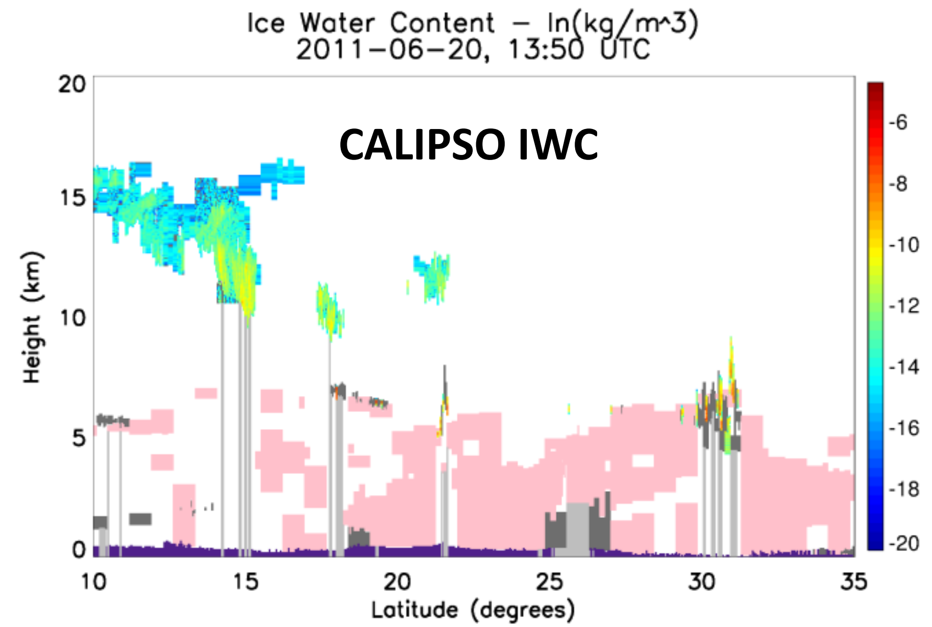
Mamouri & Ansmann 2016, ACP

Ice Nucleating Particles from CALIPSO



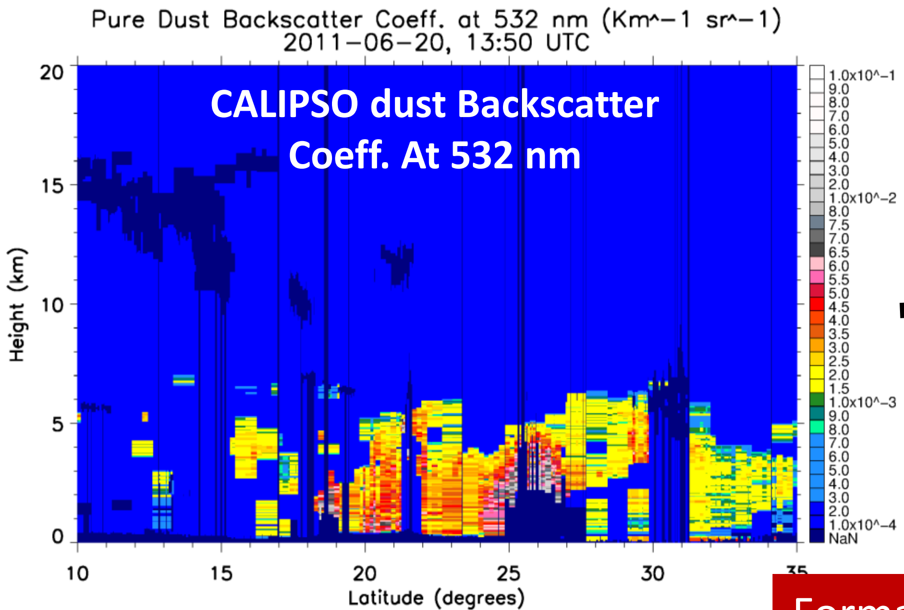


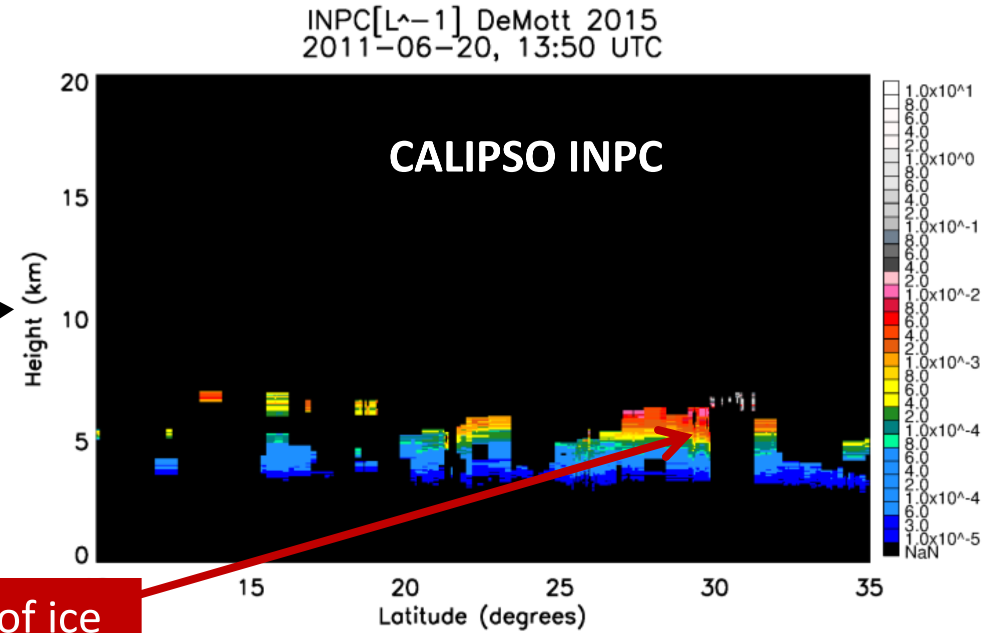




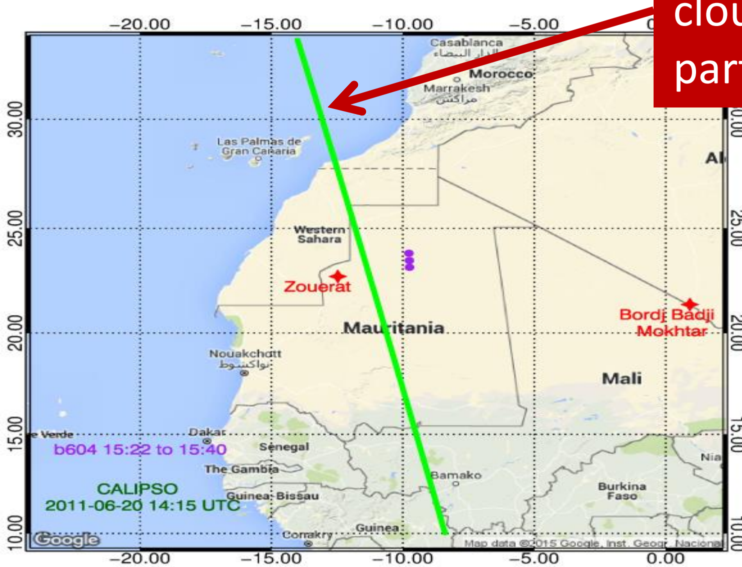
Satellite pass during FENNEC 2011 campaign
Calibration with AERONET and aircraft measurements

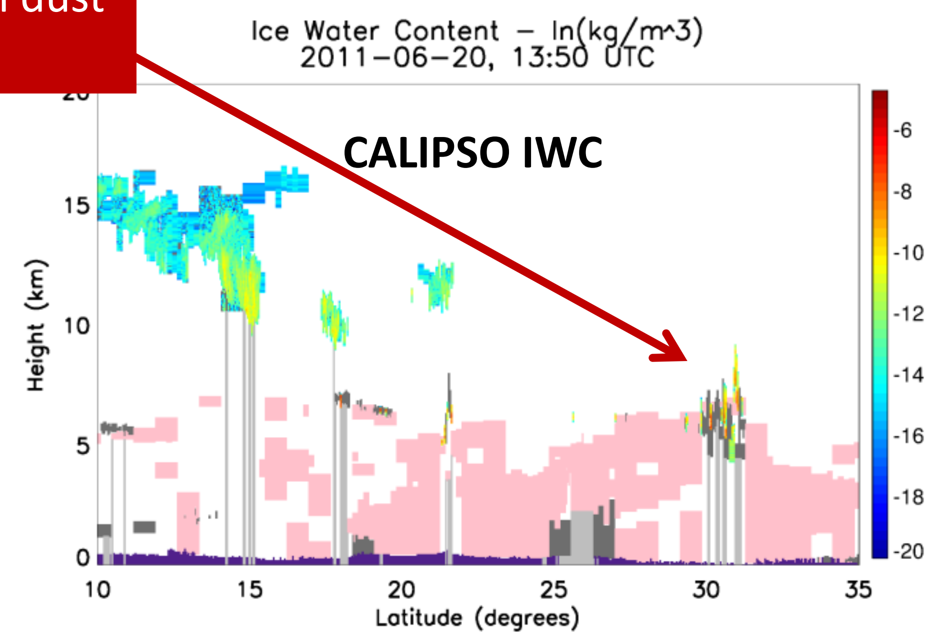
Ice Nucleating Particles from CALIPSO





Formation of ice clouds from dust particles

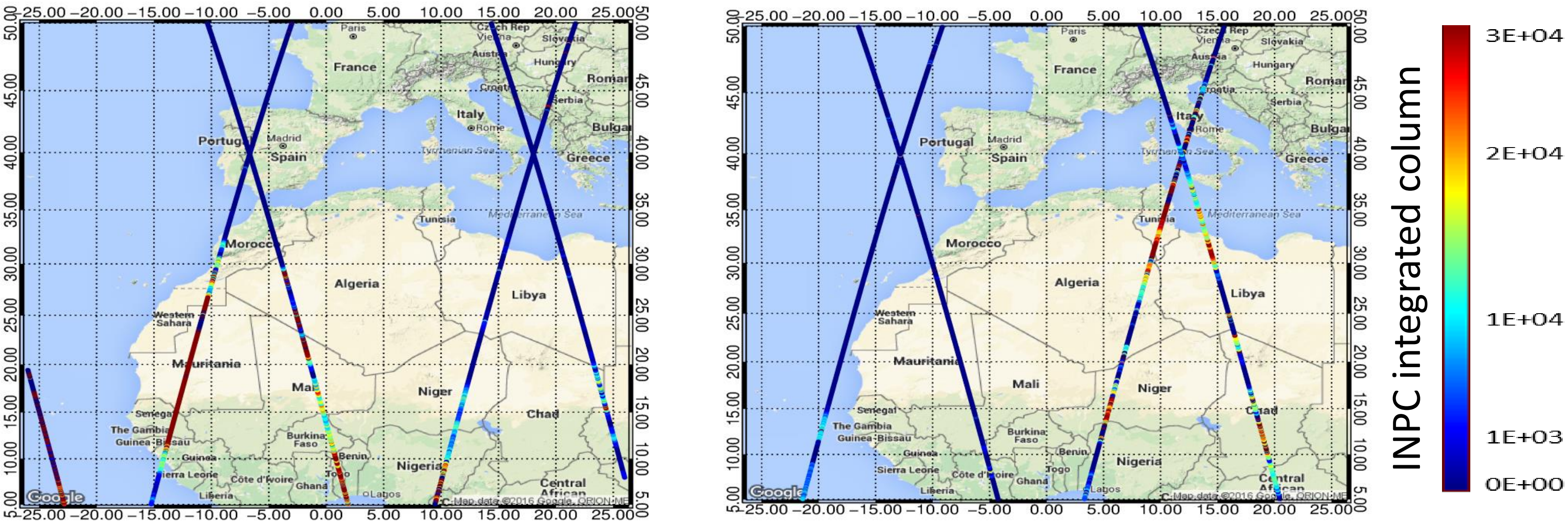


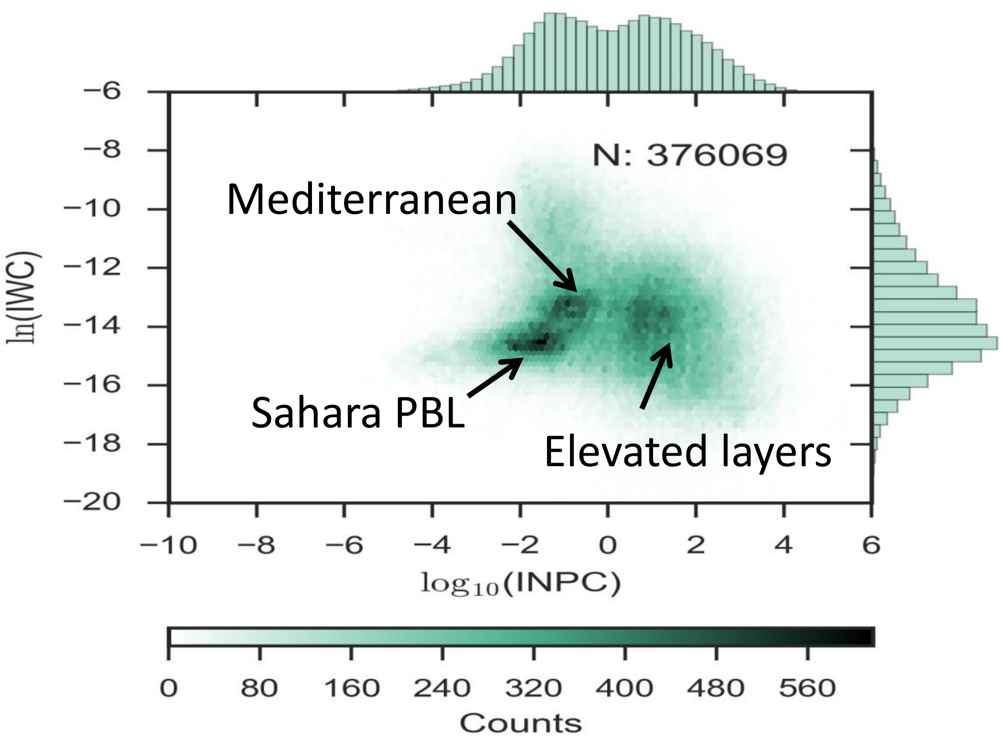


Satellite pass during FENNEC 2011 campaign
Calibration with AERONET and aircraft measurements

Ice Nucleating Particles from CALIPSO

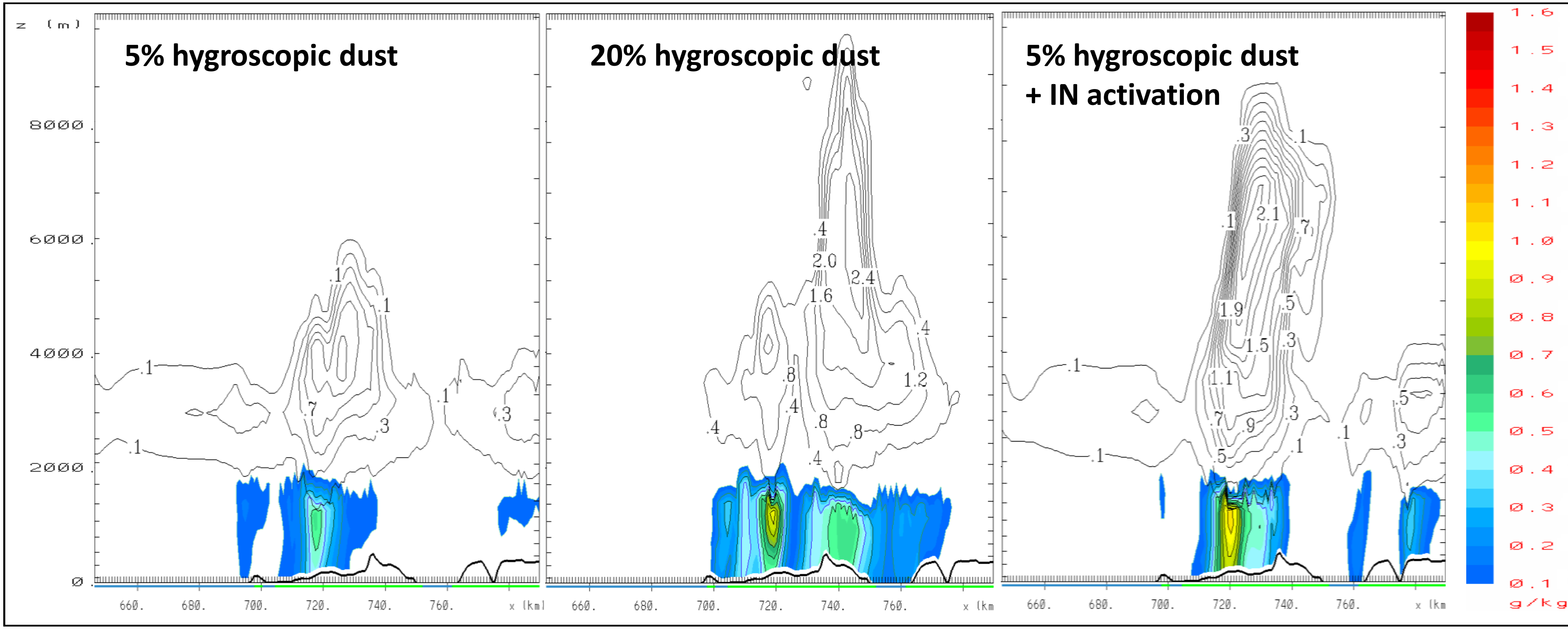
Analysis of IN activation at collocated dust & cloud areas





- Correlation between Liquid Water Content [LWC in ln(kg m^{-3})] and Ice Nuclei Particle Concentation [INPC in $\log_{10}$(#/L)] for the entire 2012
- 3 distinct areas
- IN activation depends on temperature
- Low clouds (Saharan and Mediterranean) contain 0.01-1 IN L^{-1}
- Elevated clouds (higher than 500 mb) contain 10-100 IN L^{-1}.
- Apply this technique to provide a CALIPSO IN product

Effects of dust on Cloud Dynamics



W-E cross-section of rain mixing ratio (colour scale in g/kg) and ice mixing ratio (black line contours in g/kg) over Haifa Israel, *RAMS simulation, 28 January 2003*.

- Dust may act both as CCN and IN.
- Increasing the effectiveness of dust CCN or IN activation results in increased release of latent heat at higher levels and invigoration of convection.
- The dust affected clouds exhibit reach higher tops and produce more rain.

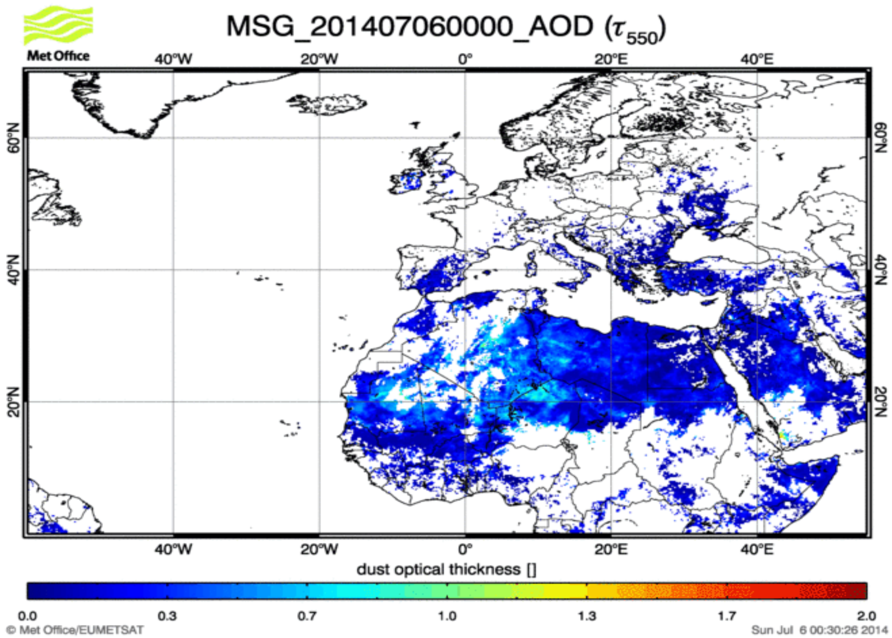
Solomos et al., ACP, 2011 ; Baklanov et al., 2014

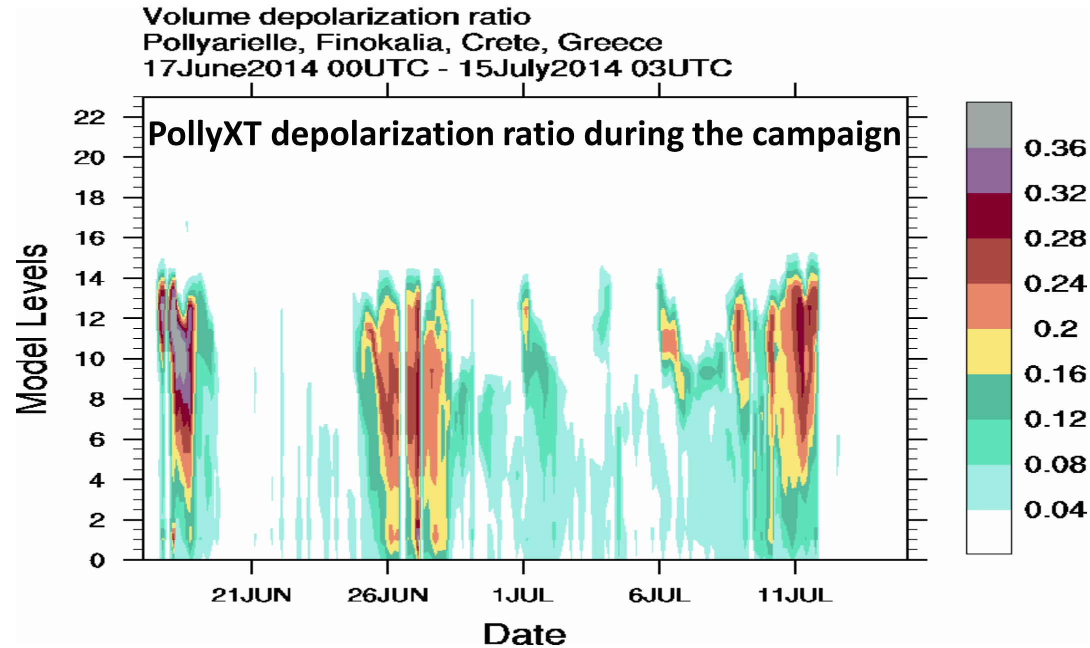
Dust modeling considerations – satellite assimilation

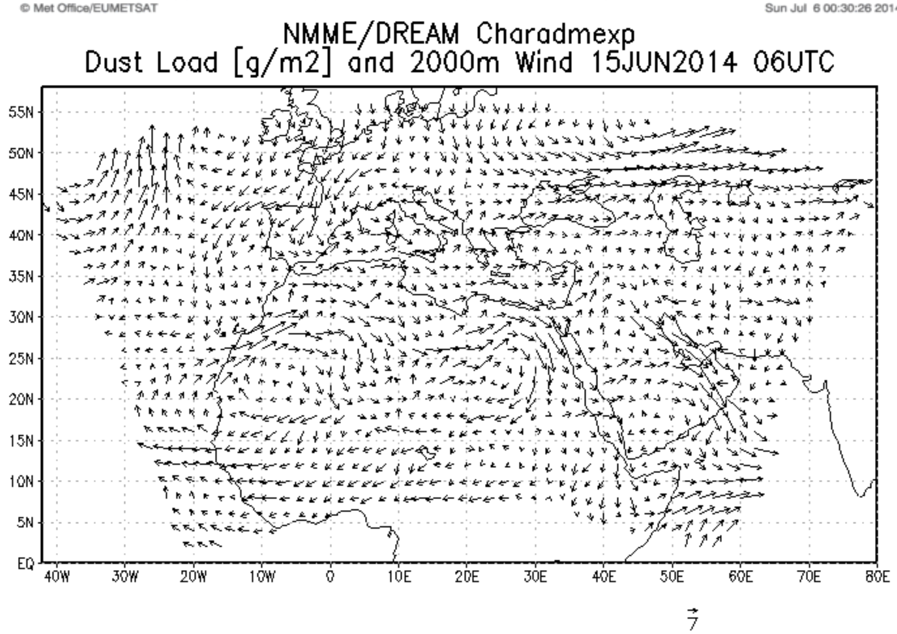
- **Atmospheric dust models rely on their own forecasts for initial and boundary conditions (warm start)**
- **Even at the idealized case of a perfect model run this methodology would imply error propagation from numerical diffusion itself**
- **The use of satellite assimilation to constrain the models is shown to improve forecast skill (e.g. Benedetti et al., 2009, JGR)**
- **Assimilation is promising but it is not a panacea to all our modeling problems**
- **For example in the case of haboobs source identification is not sufficient for describing the dust transfer and one needs to resolve also the density current formation (improve resolution for the explicit schemes or improve convective parameterization schemes)**

CHARADMExp Campaign in Crete (June-July 2014)

Characterization of Aerosol mixtures of Dust And Marine origin



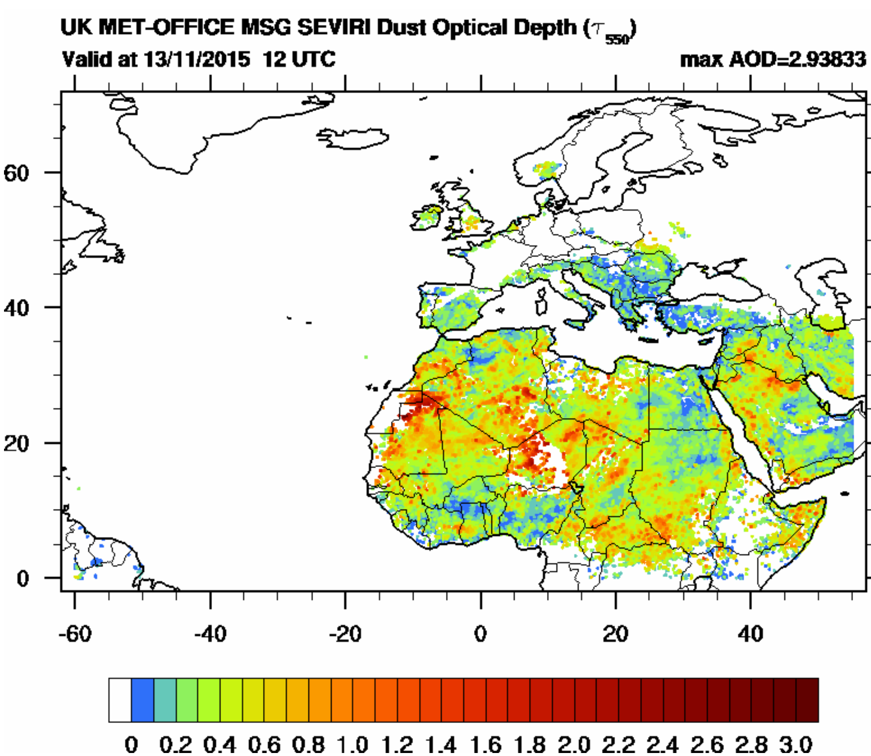




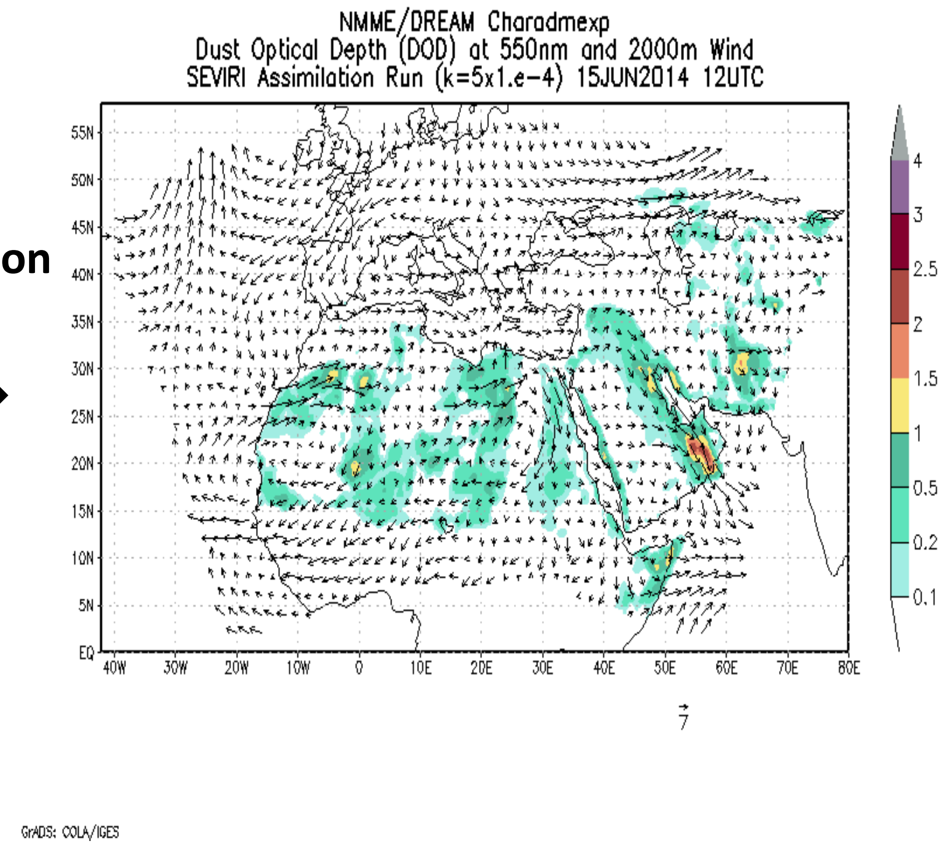
- The U.K. Met Office MSG dust product shows an estimation of the dust optical thickness retrieved from SEVIRI (Brindley, H. E., and J. E. Russell (2009), JGR
- PollyXT lidar system operates 8 channels (3 backscatter, 2 Raman extinction, 2 depolarization and 1 water–vapor sensitive at 407 nm).
- NMME-DREAM dust model with MSG-SEVIRI dust assimilation (Pejanovic et al.,2010 ; AGU, Solomos et al., 2016 ; COMECAP)

GrADS: COLA/IGES 2015-04-23-12:17

Assimilation of MSG/SEVIRI dust in NMME-DREAM



Dust assimilation

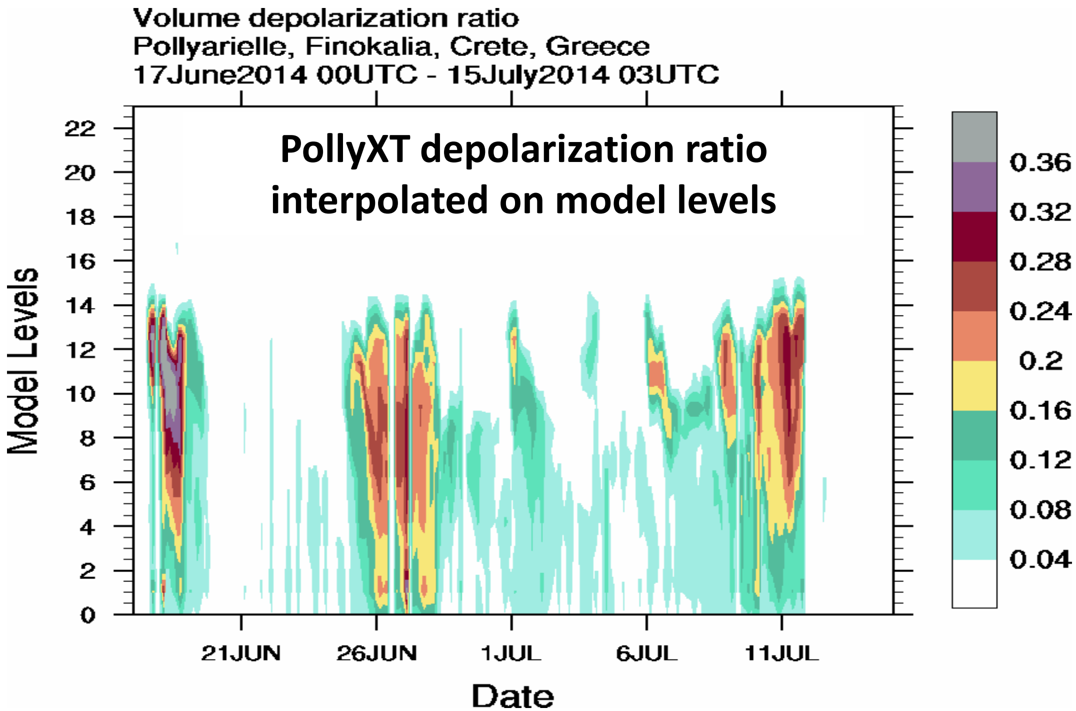


U.K. Met Office MSG dust optical thickness

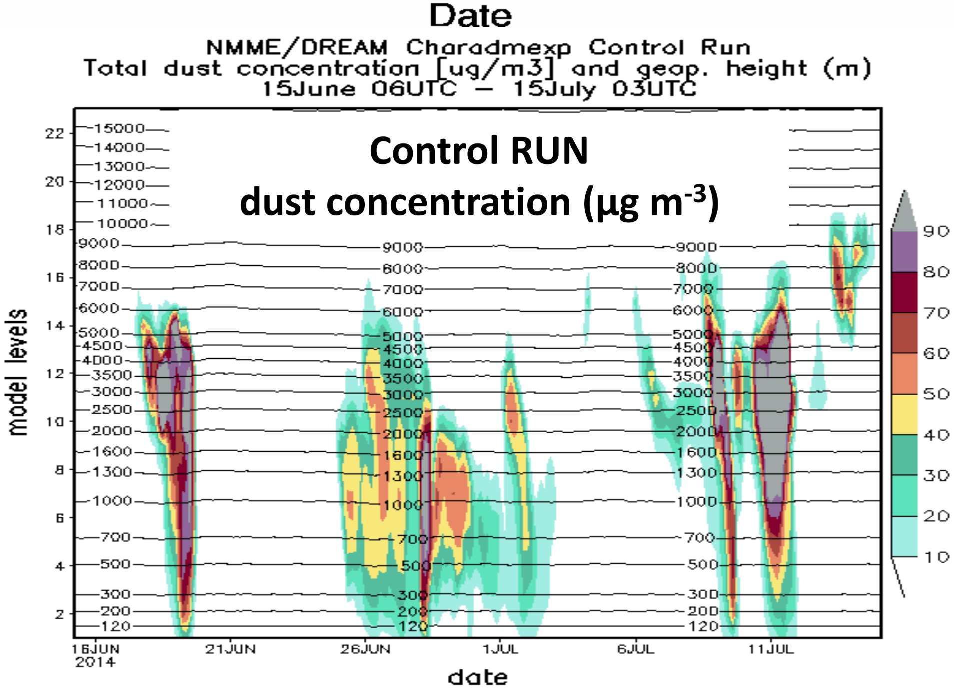
NMME-DREAM model with dust assimilation

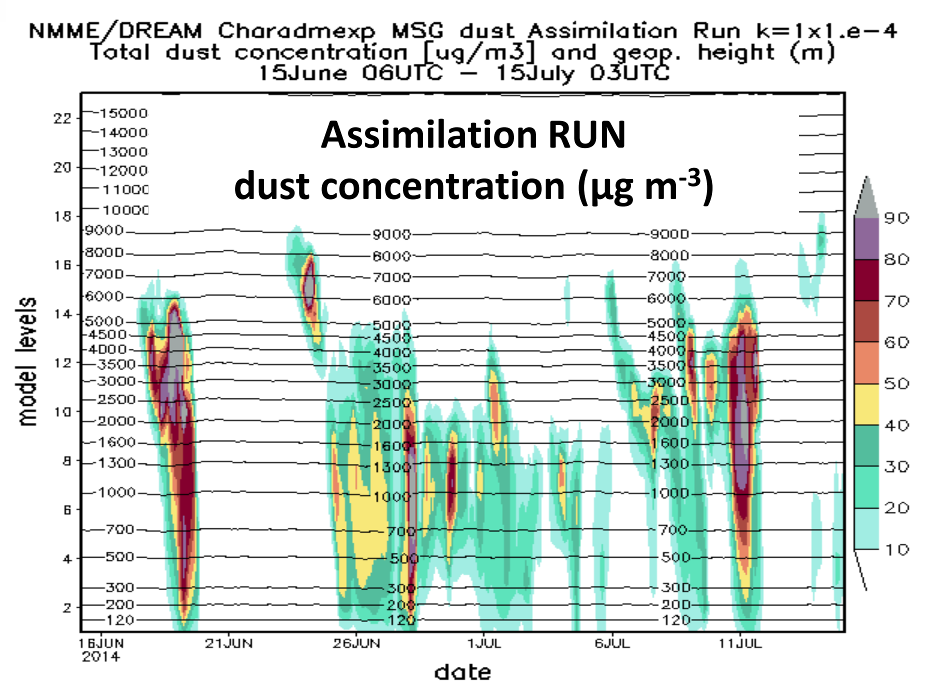
Solomos et al., 2016, COMECAP

NMME-DREAM with MSG-SEVIRI dust assimilation comparison with Finokalia lidar

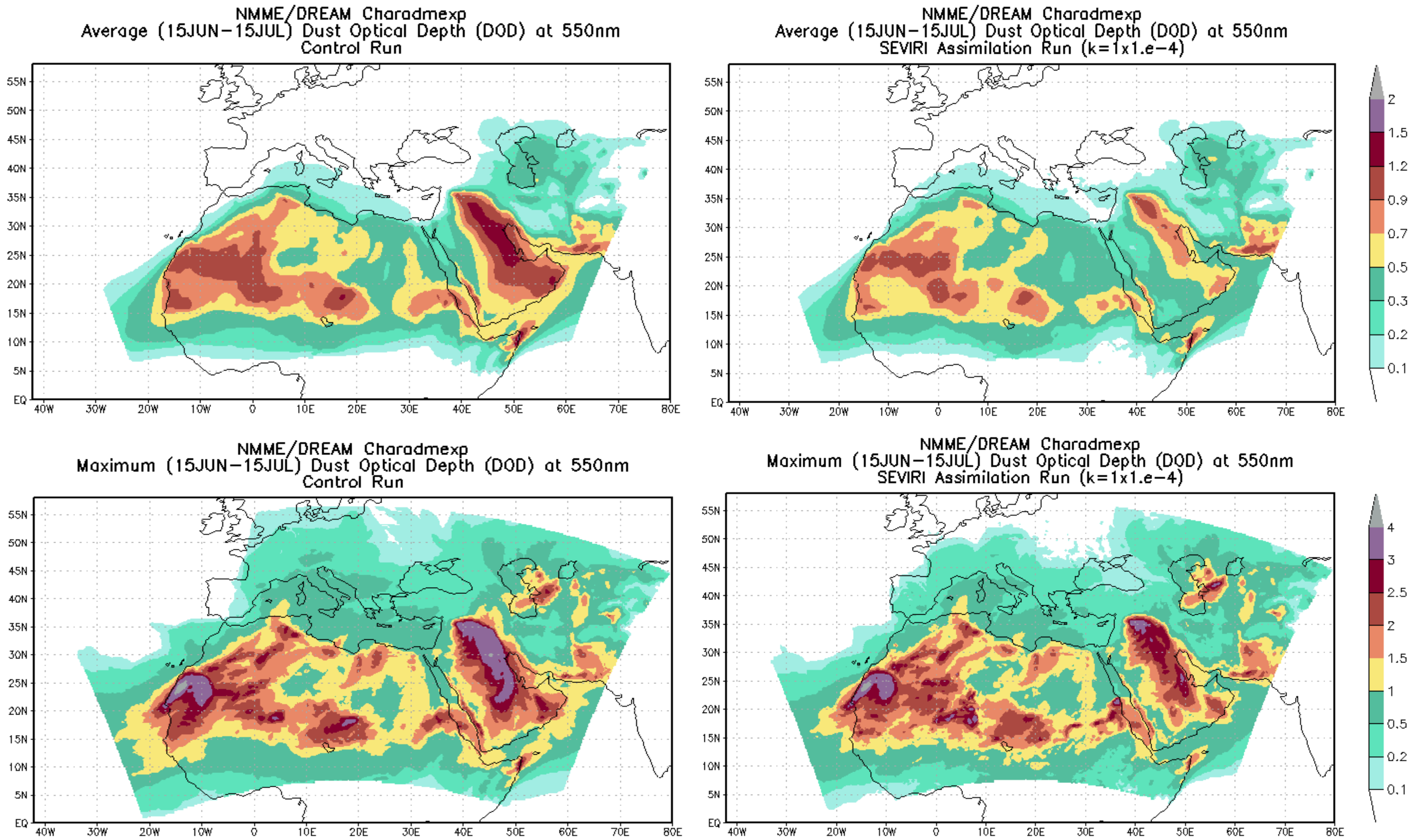


- The model reproduces the spatiotemporal structure of dust layers over Finokalia lidar station
- Quantification of dust remains an issue
- For assimilation purposes error estimation is equally important as the measurement itself





Assimilation of MSG/SEVIRI dust in NMME-DREAM



Assimilation Effects

- Cuts dust production over Arabian Peninsula
- Saharan dust sources are represented in finer detail
- Dust increases over Iberian Peninsula
- Sahel sources may be too strong

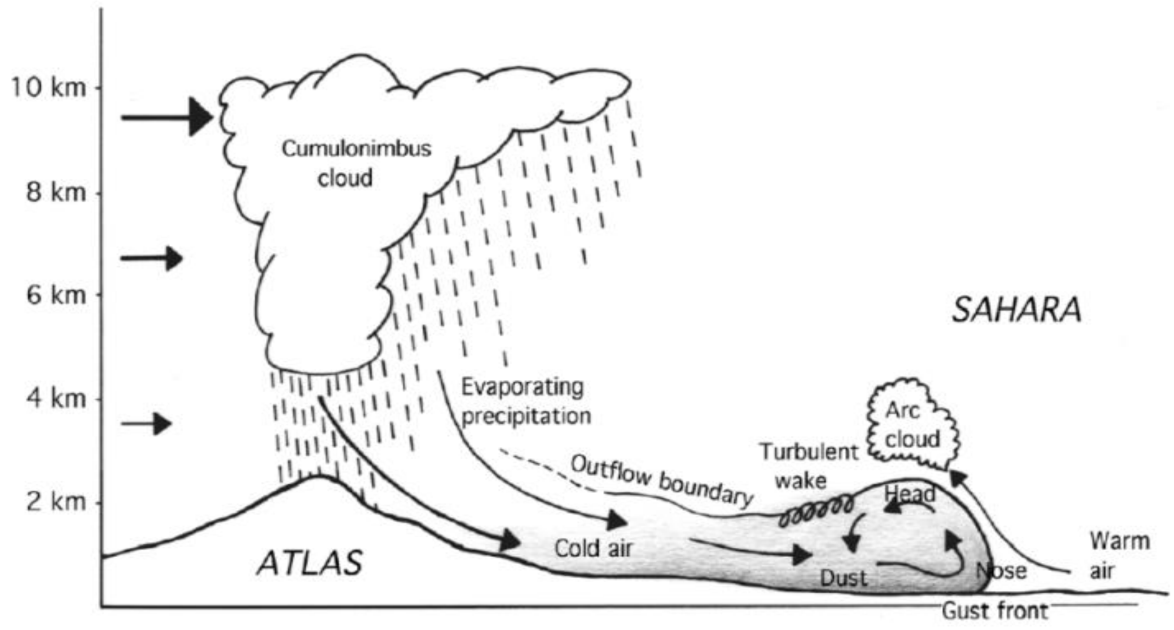
Geostationary assimilation is promising for the accurate description of diurnal dust emissions

But satellite assimilation even when it will reach a mature operational stage will still not solve all our dust modeling problems

Density currents, Cool pools and "Haboobs"

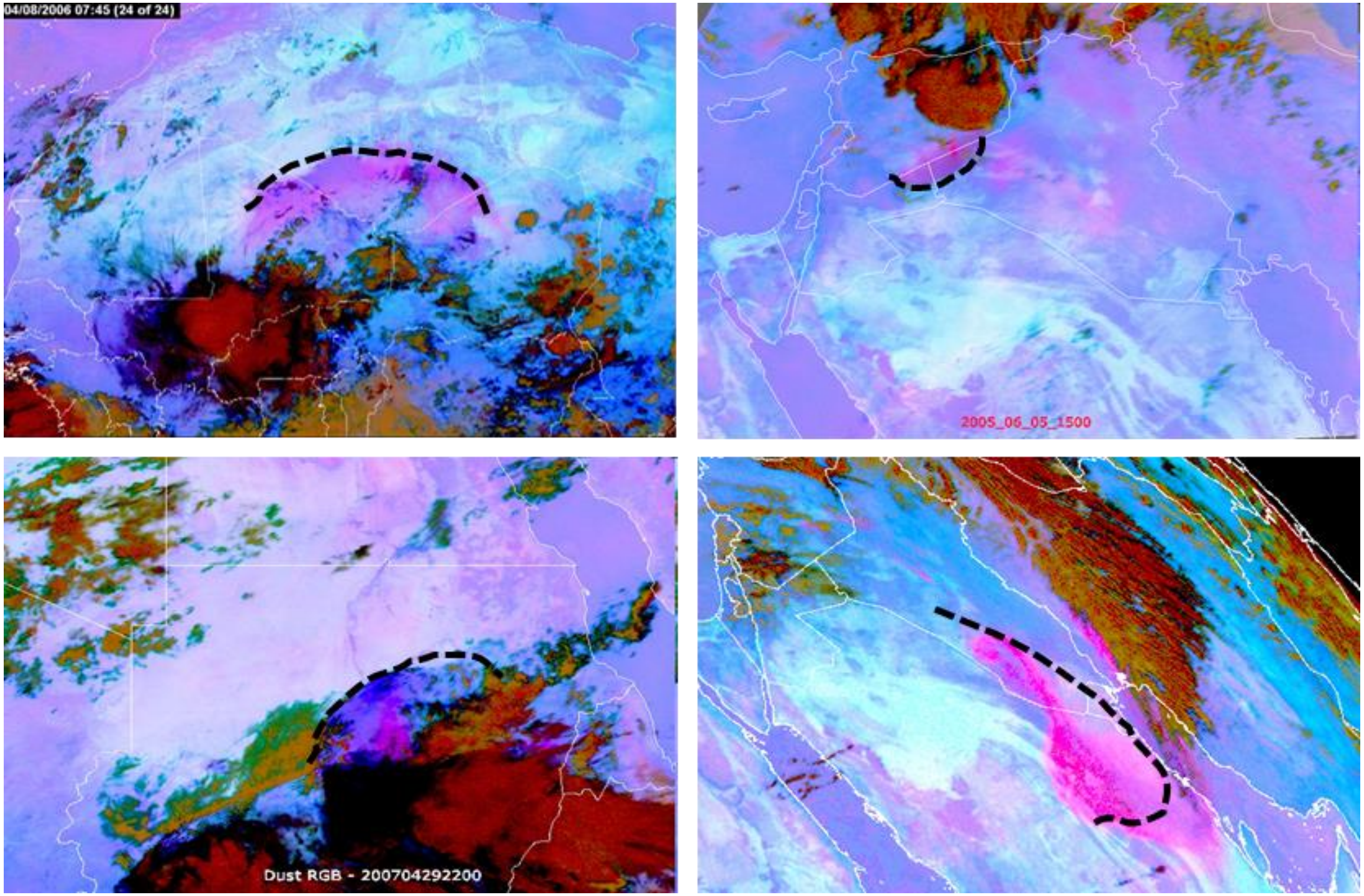
- Atmospheric density currents are usually meso-b/γ mechanisms.
- The formation of a cool pool that is responsible for dust mobilization is the result of deep convective activity over arid and desert areas.
- Simulations of such phenomena require high horizontal and vertical model resolution and advanced convective parameterization schemes.

Schematic representation of density current generation



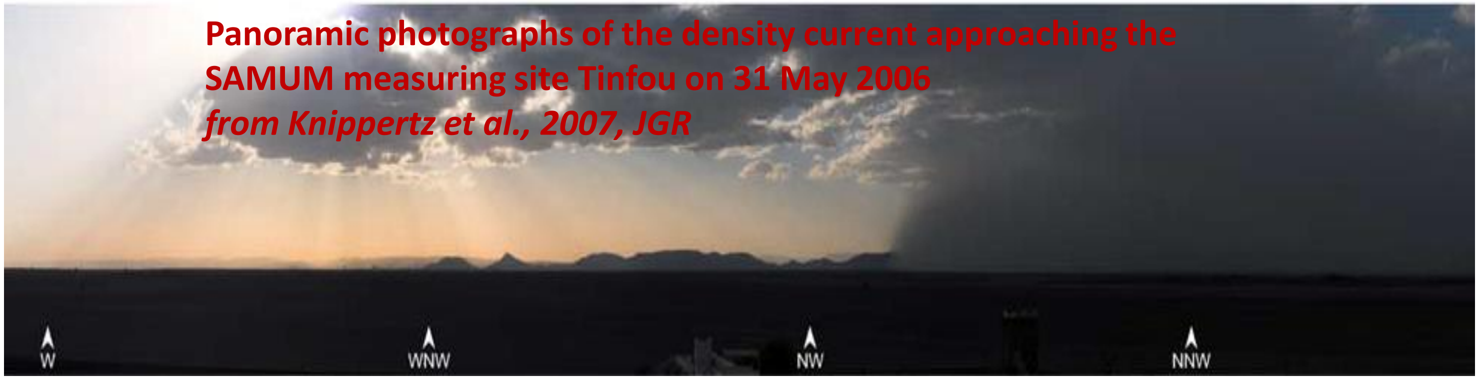
(Knippertz et al., 2007, JGR)

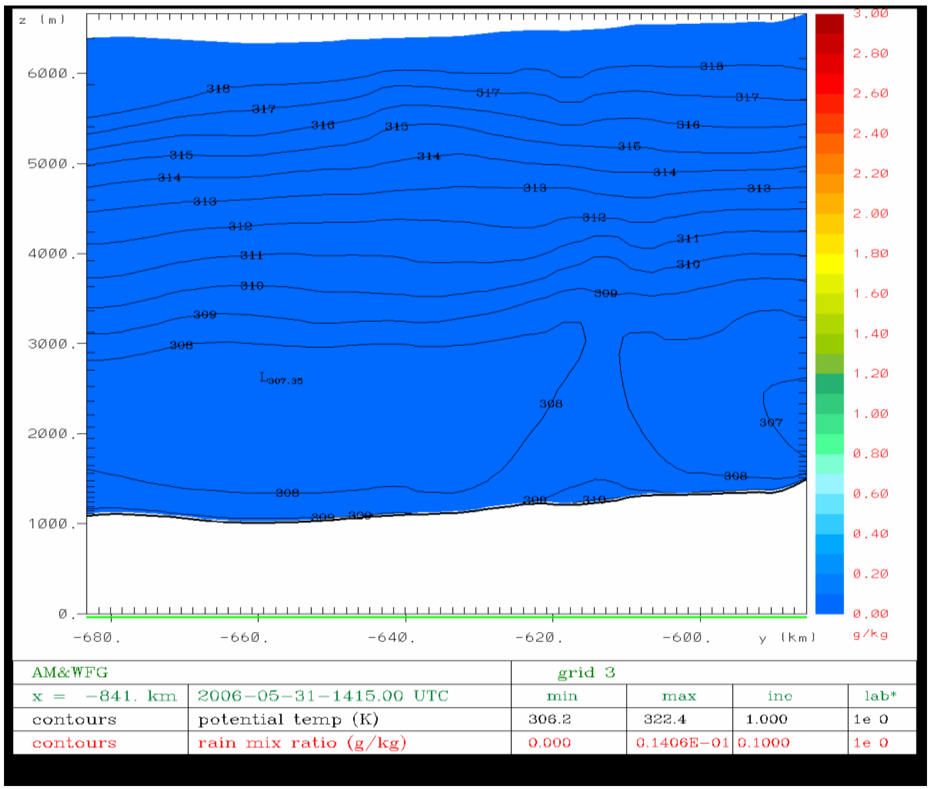
Generation of “haboobs” from Mesoscale Convective Systems



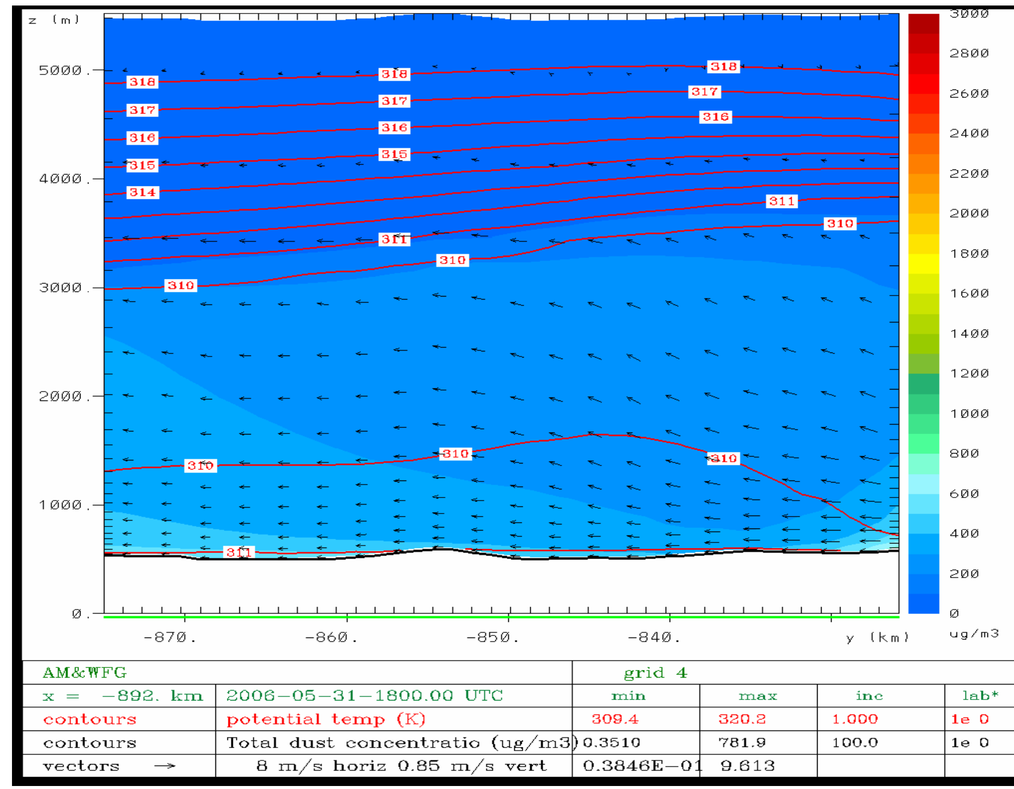
- Density currents and associated mobilization of dust are very common features for desert areas worldwide
- Contribution of haboobs to total dust emissions is estimated up to 30% (Pope et al., 2016, GRL)

Generation of a Saharan haboob south of Atlas Mountains during SAMUM campaign





Potential temperature θ (K) and rain mixing ratio (g/kg), *RAMS simulation 31 May 2006,* ***0.8×0.8 km*** *grid space*

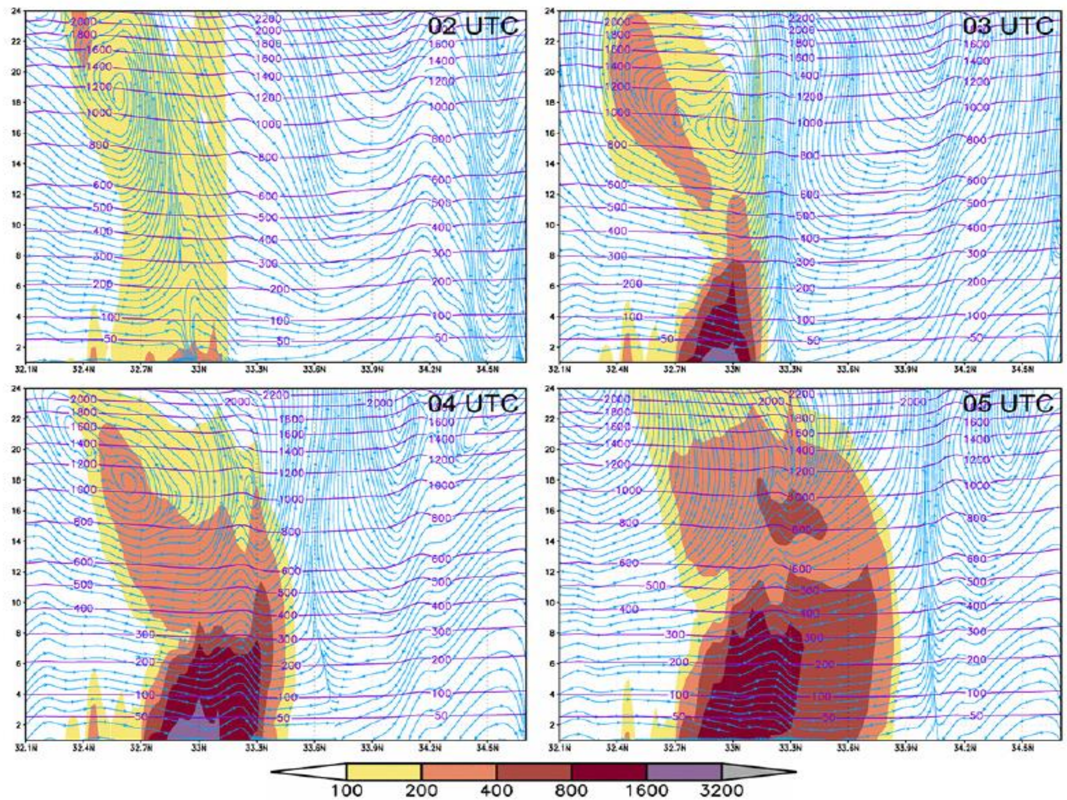


Potential temperature (red contour lines in K) and dust concentration (color scale in μg m^{-3}), *RAMS simulation 31 May 2006,* ***0.8×0.8*** *km grid space*

from Solomos et al., 2012, ACP

An American haboob – simulation with NMME-DREAM

Phoenix arizona, 6 July 2011



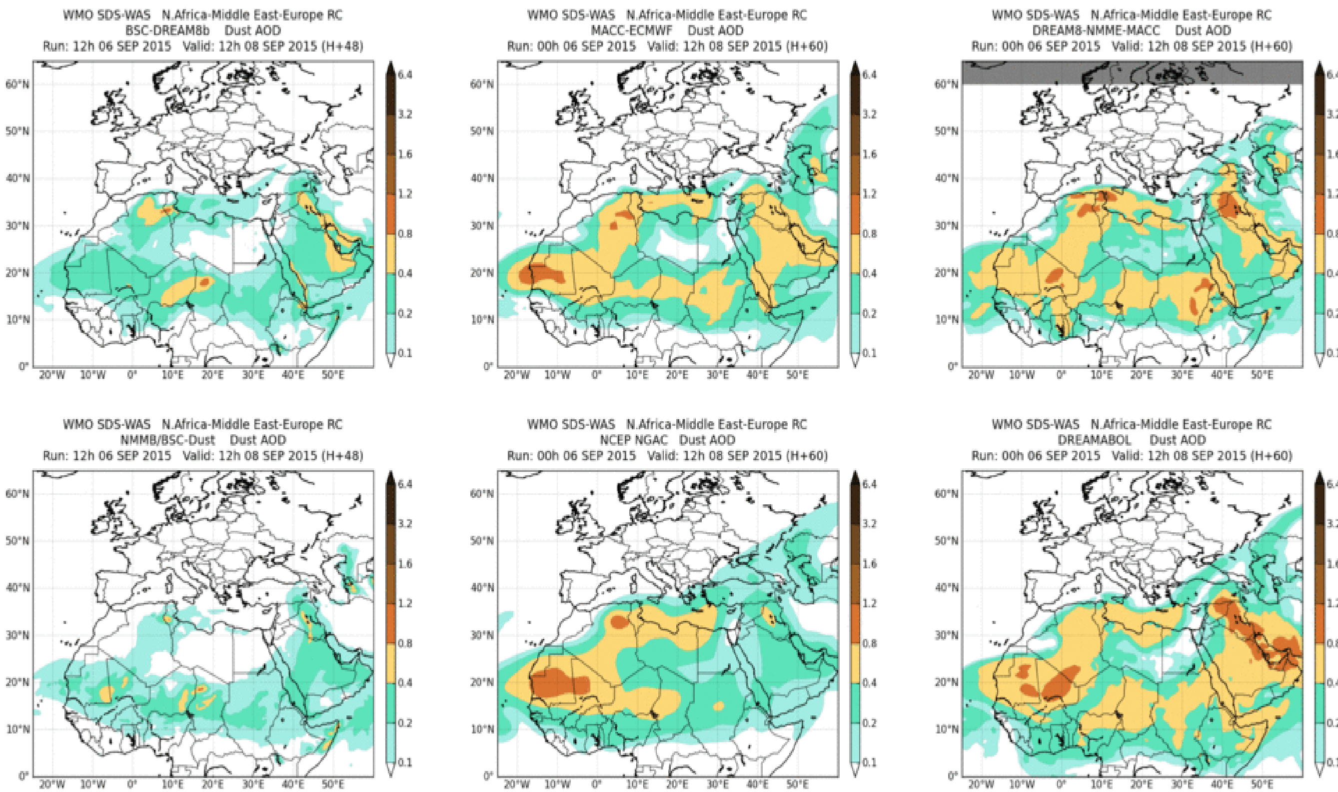
Vertical cross-section of dust concentration (μg/m³) and model streamlines (4×4 km resolution)

The different properties of dust sources in Africa, Asia, America imply the need for a different treatment in numerical models

from Vukovic et al., 2014, ACP

A Middle East haboob 6-13 September 2015

Dust Operational Models (SDS-WAS)



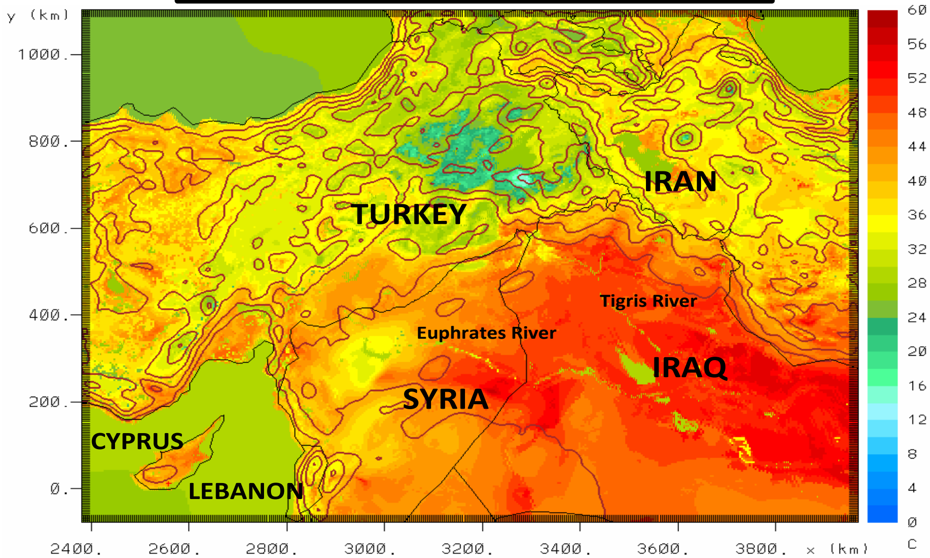
Convective downdrafts over the mountainous areas of East Turkey and North Iran result in mobilization of dust over Middle East and East Mediterranean and extreme record concentrations on Cyprus.

AOD in Cyprus exceeded 5. Mesoscale operational models even with satellite assimilation cannot reproduce the strength of such events.

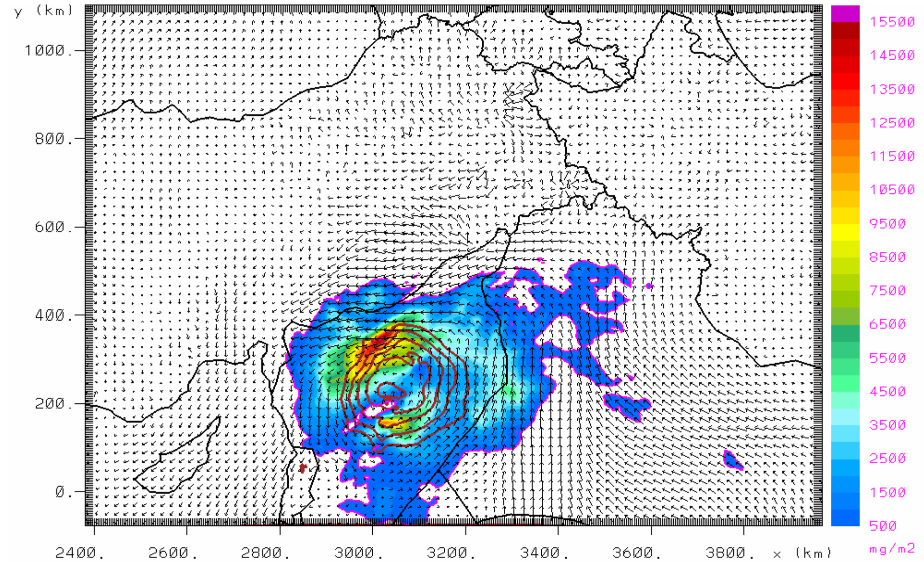
Mamouri et al., 2016, ACPD

A Middle East haboob 6-13 September 2015

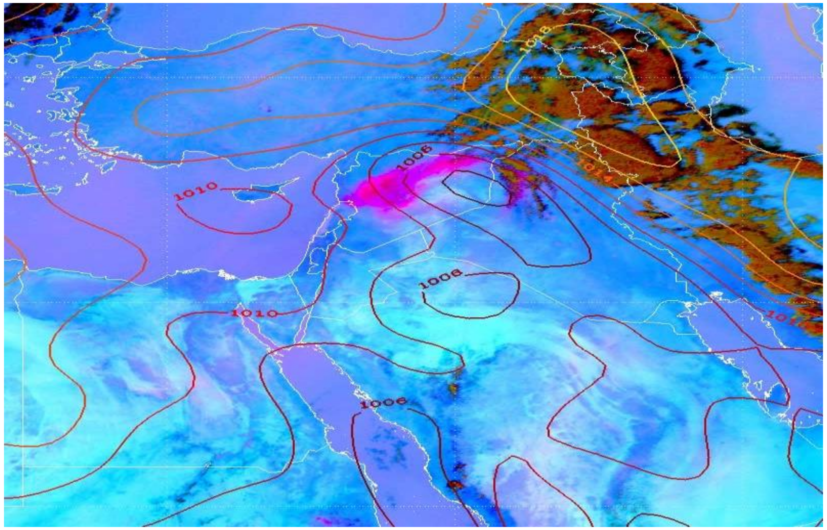
RAMS internal grid 4×4 km



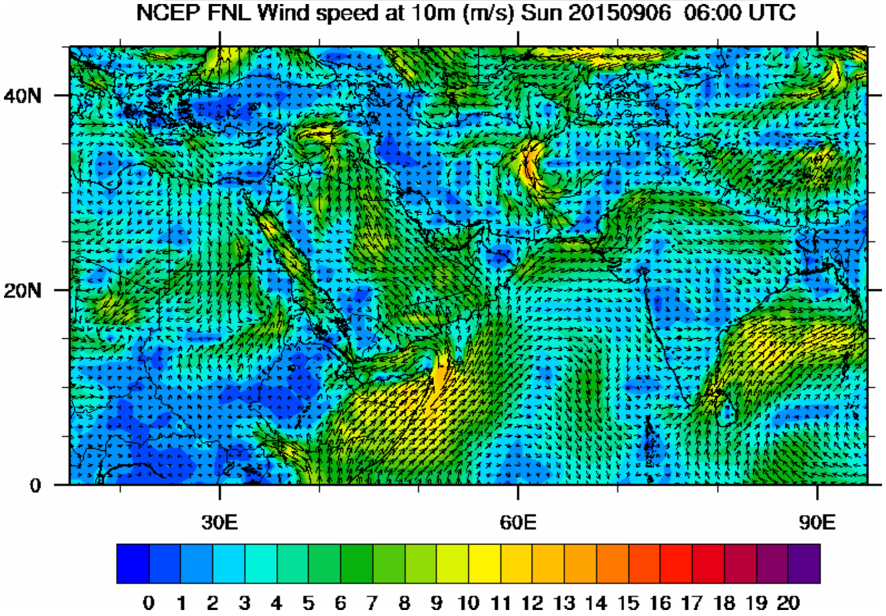
Thermal cyclone formation and dust uplift (model)



Thermal cyclone formation and dust uplift (SEVIRI)

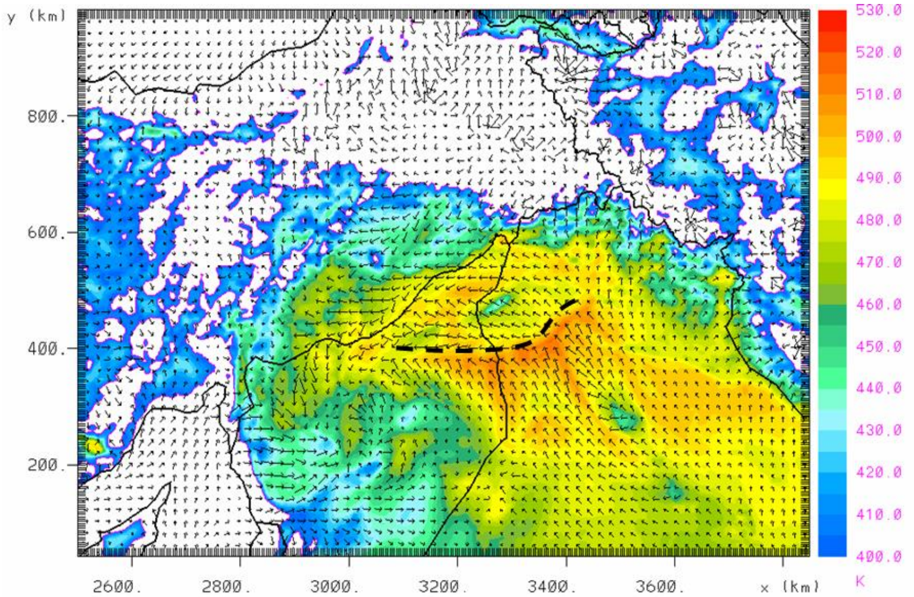


Somalian LLJ (NCEP FNL)

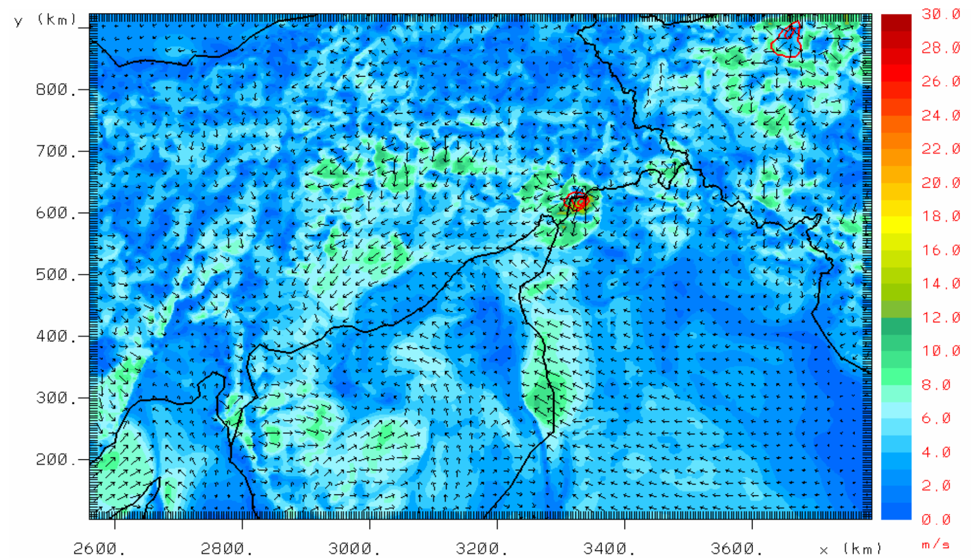


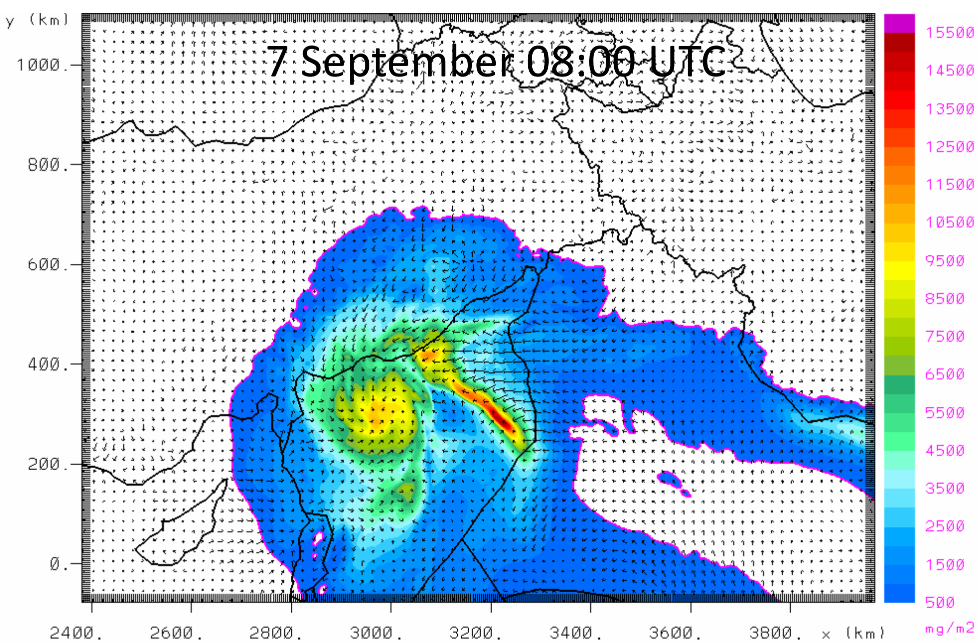
A Middle East haboob 6-13 September 2015

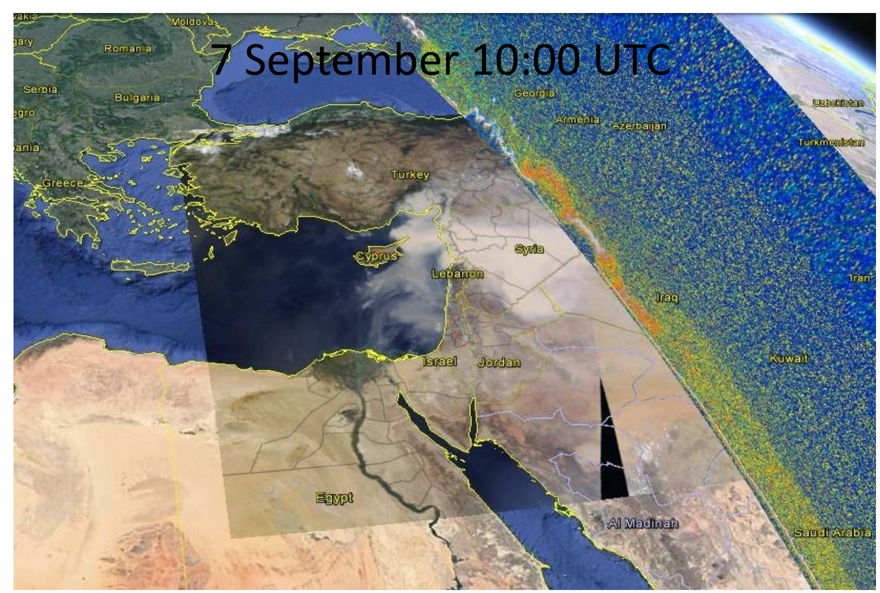
θ_e (K), 6 September 2015, 13:00 UTC



1h accum. precipitation (mm) and 10m wind speed ms^{-1}
6 September 2015, 20:00 UTC

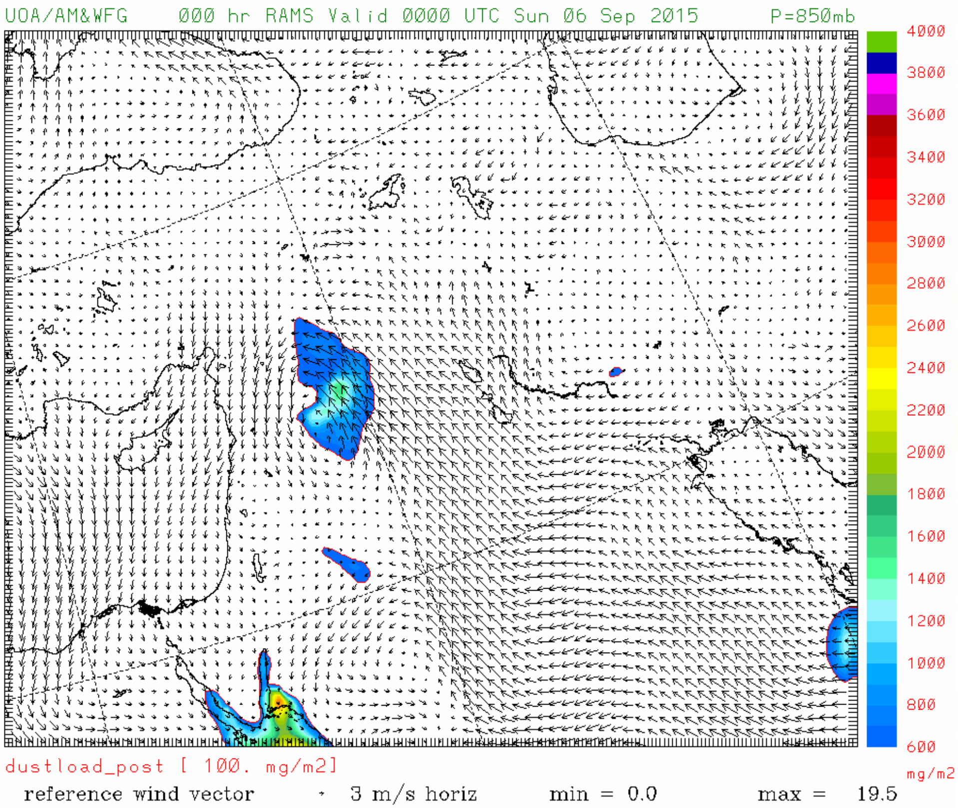


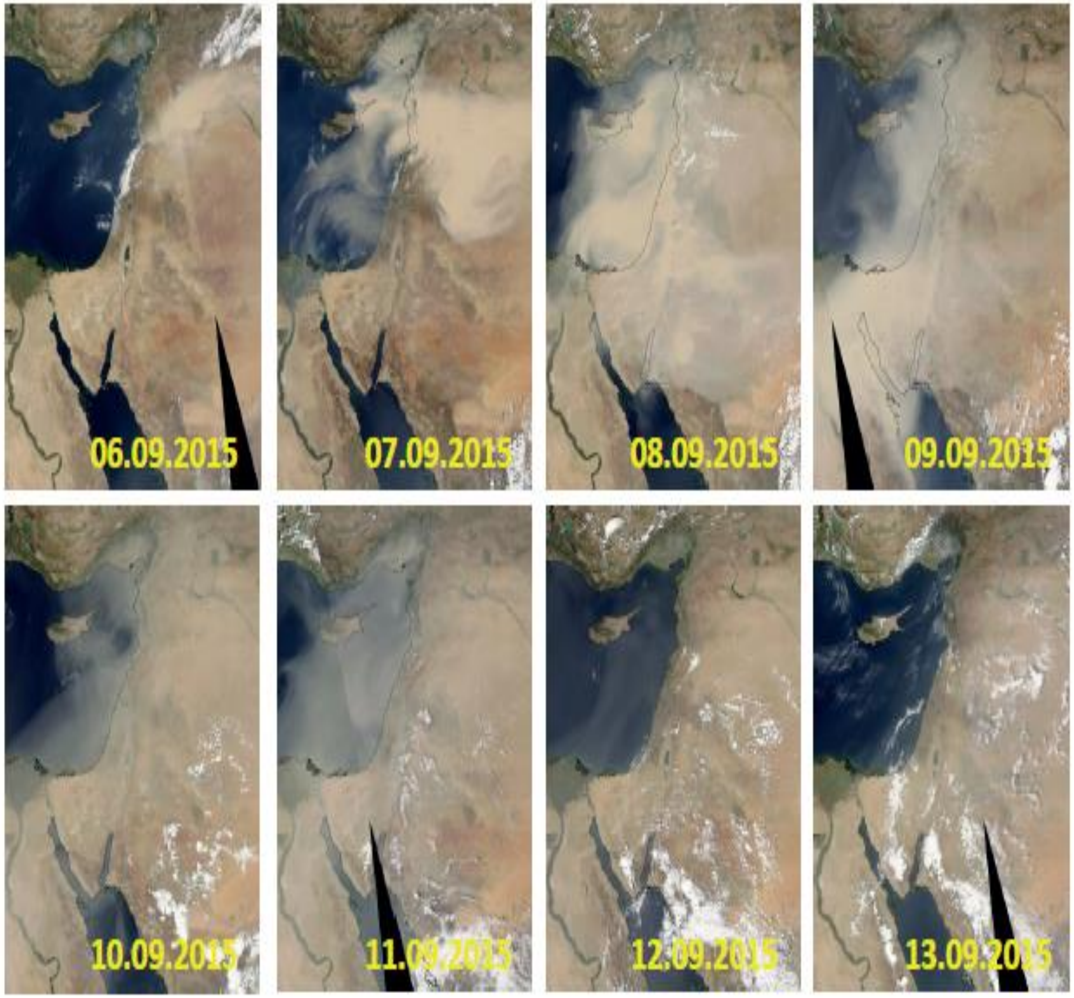




A Middle East haboob 6-13 September 2015

RAMS simulation and MODIS images





The event is reproduced by RAMS-ICLAMS limited area model with the use of advanced explicit microphysics and a high resolution (4×4 km) nested grid

Solomos et al., 2016, ACPD

Summary & Discussion

- **Atmospheric aerosols** induce significant uncertainty in climate studies and weather forecasting
- **BEYOND and GEO-CRADLE** inter-disciplinary research efforts foster scientific synergies and allow a better understanding of atmospheric processes in SE. Europe, N. Africa and the Middle East
- **Improve modeling approach**: resolution, convection, LLJ, sources, assimilation (we need ALL of them)
- **Improve remote sensing approach (CALIPSO/LIVAS)**: Pure dust retrievals & pure observational CALIPSO ice nuclei (IN)
- **Satellite dust assimilation**: The UK Met Office MSG/SEVIRI satellite dust product has been assimilated in NMME-DREAM with promising results
- **Example of an early warning system - FireHub Smoke forecast** : Satellite retrievals and high resolution Eulerian model (WRF) drive the Lagrangian atmospheric model FLEXPART forecasts of biomass smoke dispersion.
- A specific pilot study regarding the **adaptation to climate change (ACC) and focusing on ECV's** has been lunched and will be used as a proxy for future GEO and Copernicus activities at the area

Thank You !

BEYOND

SEVENTH FRAMEWORK PROGRAMME

GEO CRADLE

HORIZON 2020