Republic Hydrometeorological Service of Serbia (establishted 1888, WMO member since 1947)

SEEVCCC

Modelling cloud-aerosol (dust) interactions: a potential for further NWP improvements

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with contributions of G. Pejanovic, B. Cvetkovic and S. Petkovic

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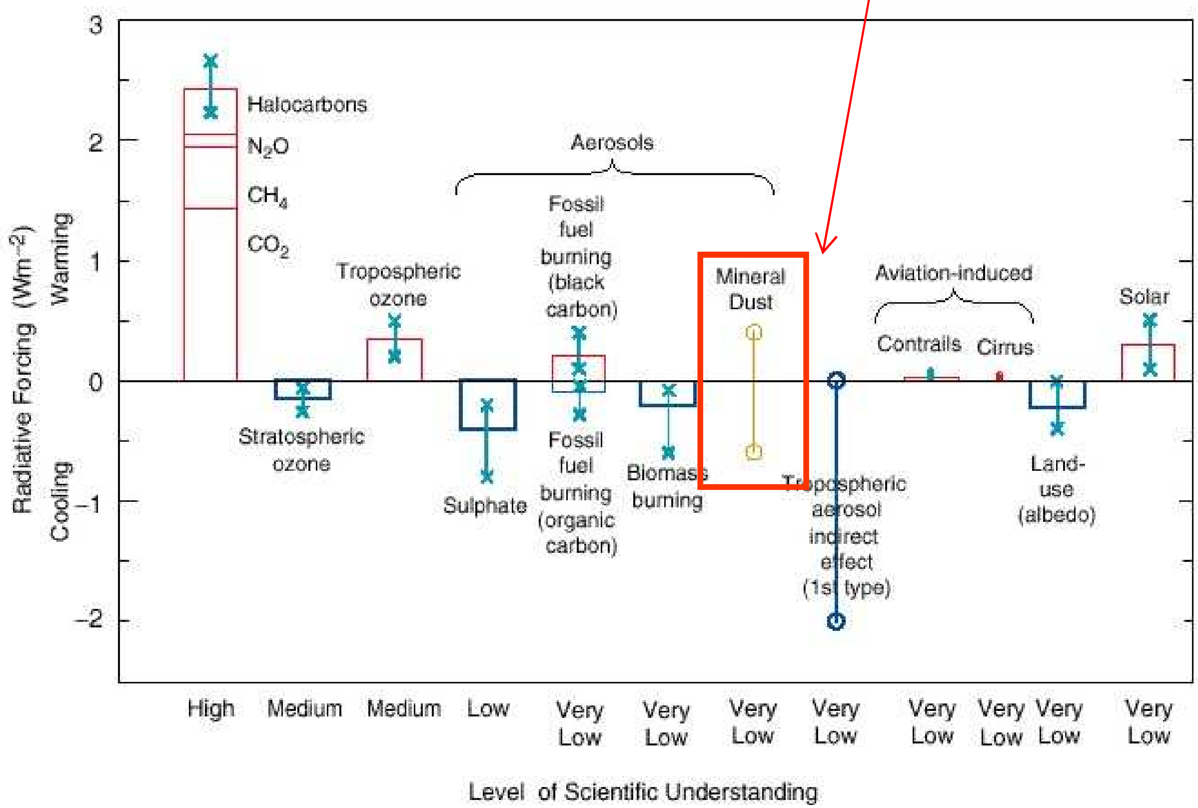
37th EWGLAM and 22th SRNWP Meeting, 5-8 October 2015, Belgrade, Serbia

Why to consider atmospheric desert dust as a factor in NWP models?

IPCC: Both magnitude and the sign of dust radiative forcing yet unresolved (unknown positive or negative)

- **Atmosphere is modified by dust**
  - Through <u>direct effects</u> (affecting radiation)
  - Through <u>indirect effects</u> (affecting clouds)
- **Why dust is a major aerosol?**
  - Most abundant
  - Specific chemical and physical features favorable for direct and indirect effects



How much dust affects the atmospheric radiation?

The outgoing longwave radiation anomaly in the UK operational model over the Sahara due to dust
(Haywood, et al., 2003)

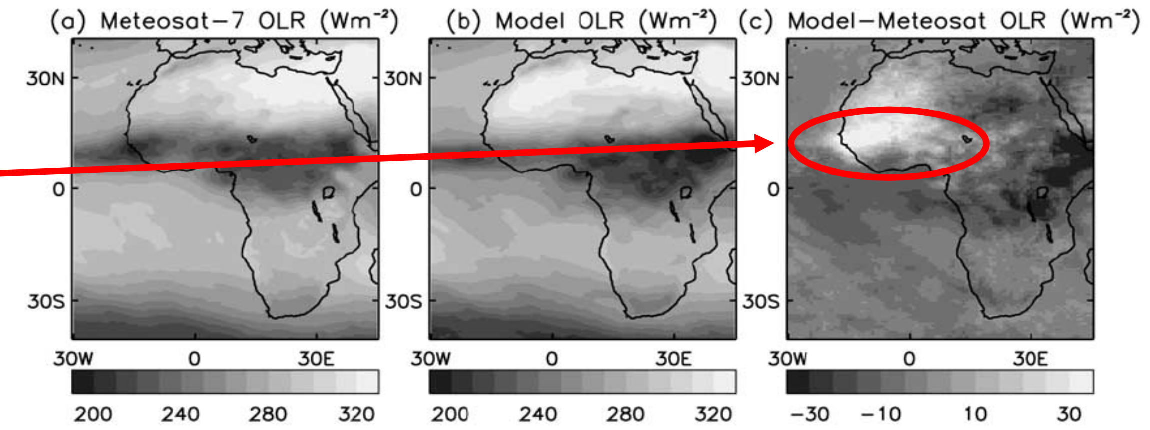
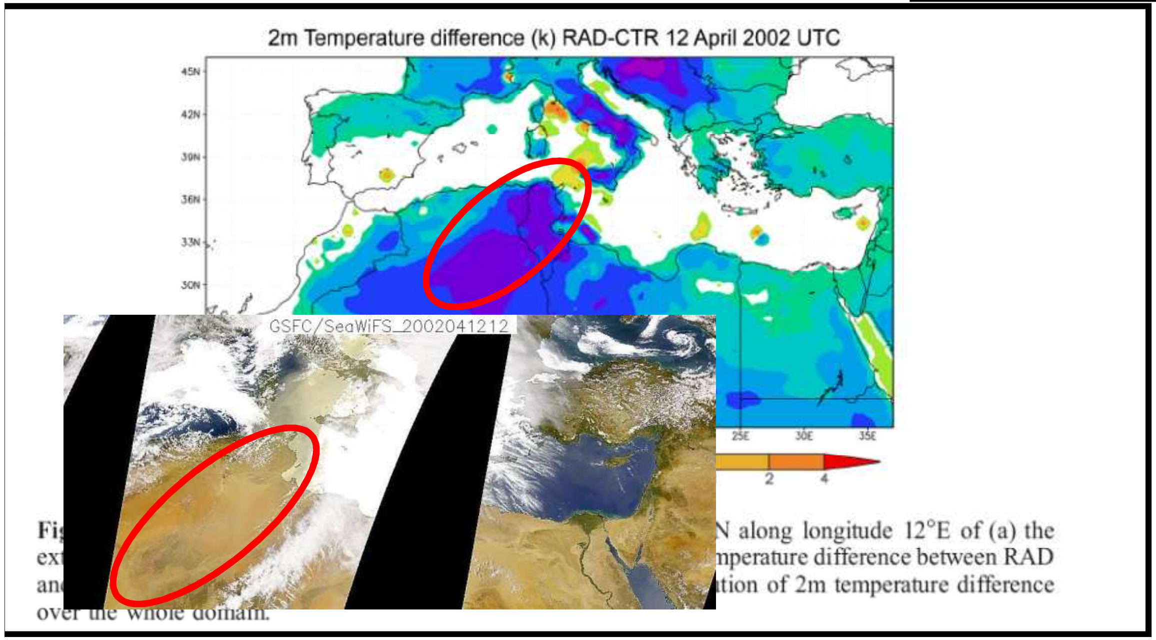


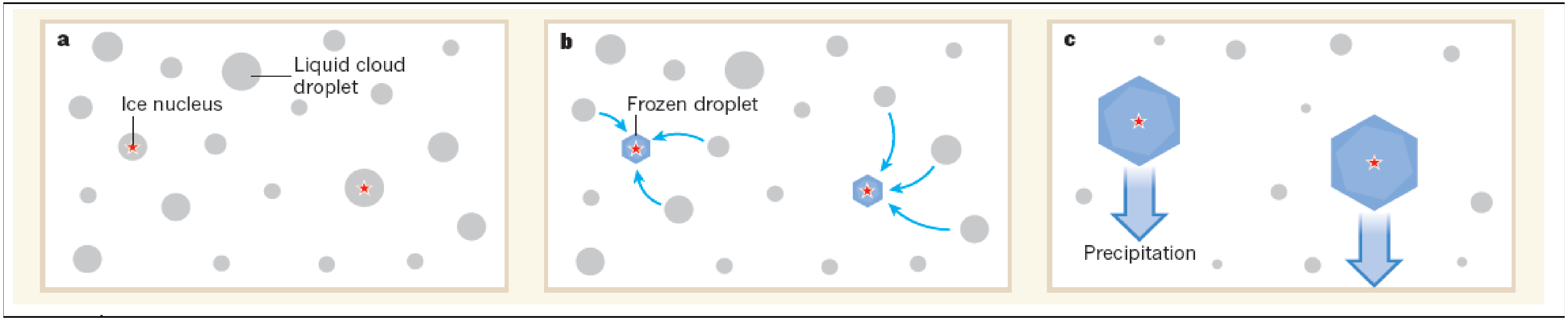
Figure 1. The July 2003 monthly mean for (a) OLR_{Met7}, (b) OLR_{model}, and (c) $OLR_{model} - OLR_{Met7}$. The monthly mean consists of the average of the monthly mean of the OLR diagnosed at 0000 UTC, 6000 UTC, 1200 UTC, and 1800 UTC. Units are Wm^{-2}. See color version of this figure in the HTML.



Cooling surface temperature by ~5°C in DREAM model (not only over Sahara!)
(Nickovic et al, 2004; Perez et al, 2006)

Heterogeneous cold clouds formation

- Several *Science* and *Nature* articles published since 2013 indicate the importance of dust specifically
- Mineral dust particles act as <u>the most efficient</u> heterogeneous ice nuclei in the tropospheric clouds
- Dust particles lifted to the colder tropopause cause earlier glaciation of supercooled cloud water



Ice formation and precipitation

Koop and Mahowald, Nature, 2013

Dust: key **catalyst** for cold-cloud formation <u>even far away from sources</u>

- **2/3 of ice clouds** formed due to pure dust and dust metalics
- Only **small dust concentration** needed
- Dust mineralogy matters!

Sciencexpress

Clarifying the Dominant Sources and Mechanisms of Cirrus Cloud Formation

Daniel J. Cziczo,[1*] Karl D. Froyd,[2,3] Corinna Hoose,[4] Eric J. Jensen,[5] Minghui Diao,[6] Mark A. Zondlo,[6] Jessica B. Smith,[7] Cynthia H. Twohy,[8] Daniel M. Murphy[2]

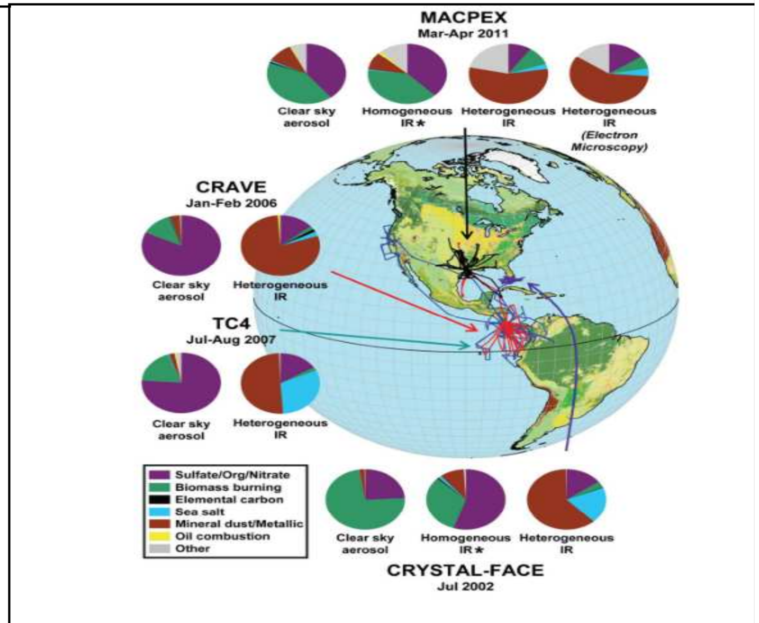
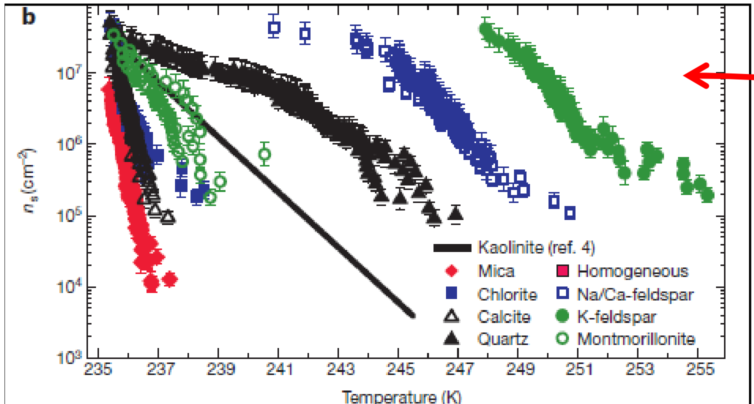


Fig. 1. Flight tracks of ice cloud residual measurements for four aircraft campaigns spanning a range of geographic regions and seasons. The composition of cirrus ice residuals and near-cloud

Cziczo et al, 2013, Science



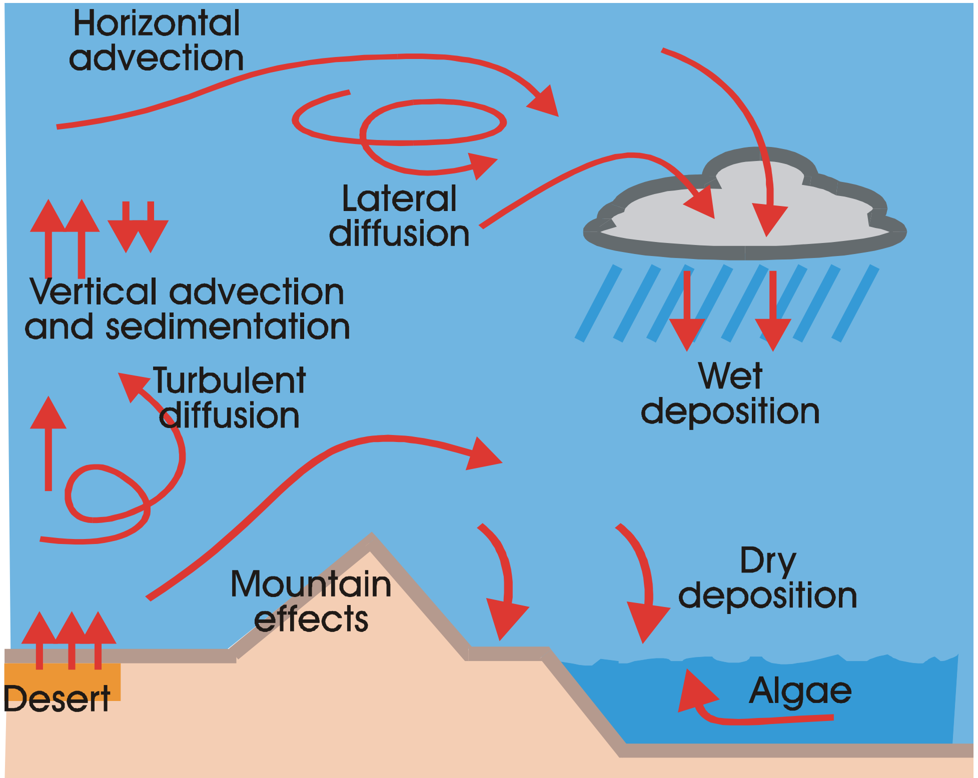
The importance of feldspar for ice nucleation by mineral dust in mixed-phase clouds

James D. Atkinson[1], Benjamin J. Murray[1], Matthew T. Woodhouse[2], Thomas F. Whale[1], Kelly J. Baustian[1], Kenneth S. Carslaw[1], Steven Dobbie[1], Daniel O'Sullivan[1] & Tamsin L. Malkin[1]

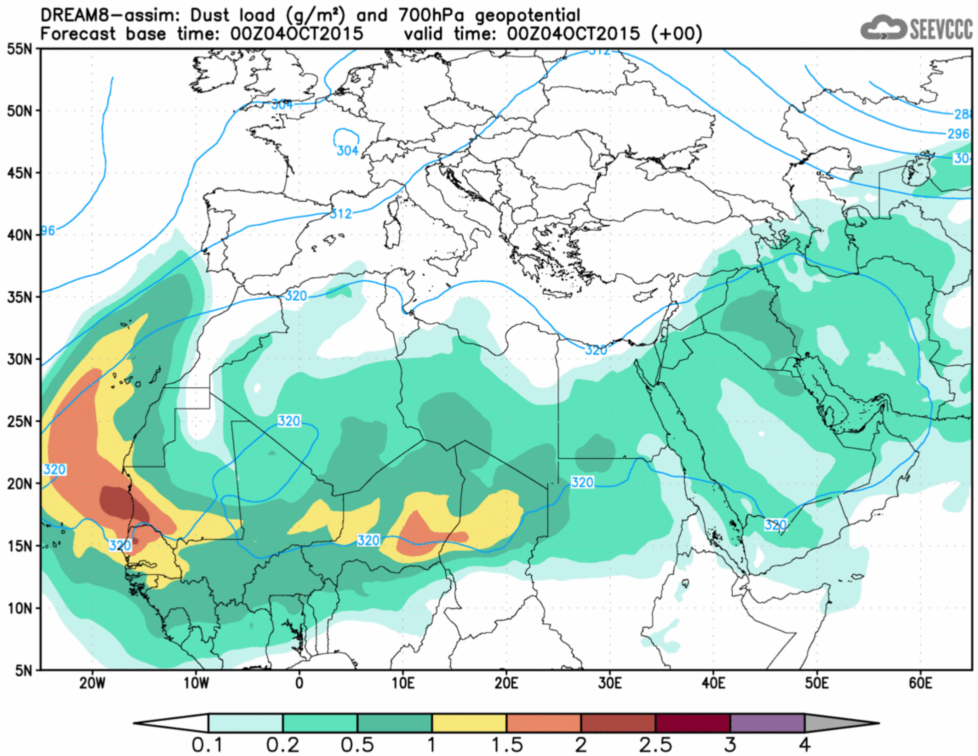
Atkinson et al, 2013, Nature

DREAM - Dust Regional Atmospheric Model

(Nickovic et al, 2001; Pejanovic et al, 2010; Vukovic et al, 2013)



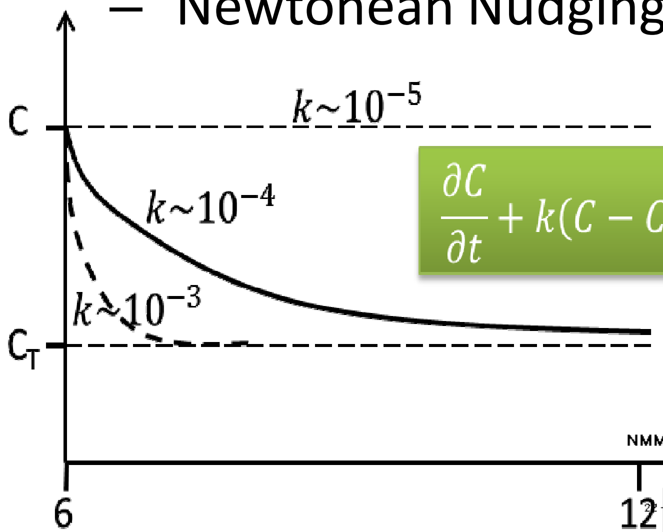
– Widely used dust model in the community
– Operational dust forecasts within the WMO dust SDS-WAS model intercomparison project



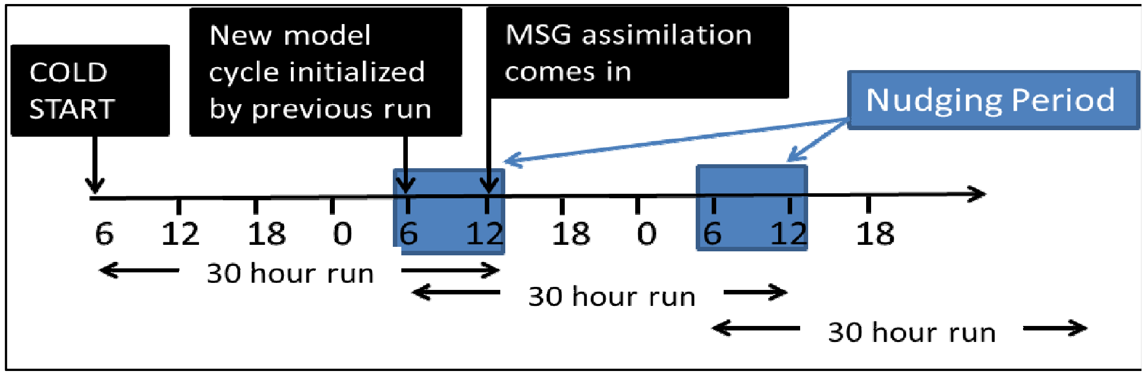
Dust data assimilation in DREAM

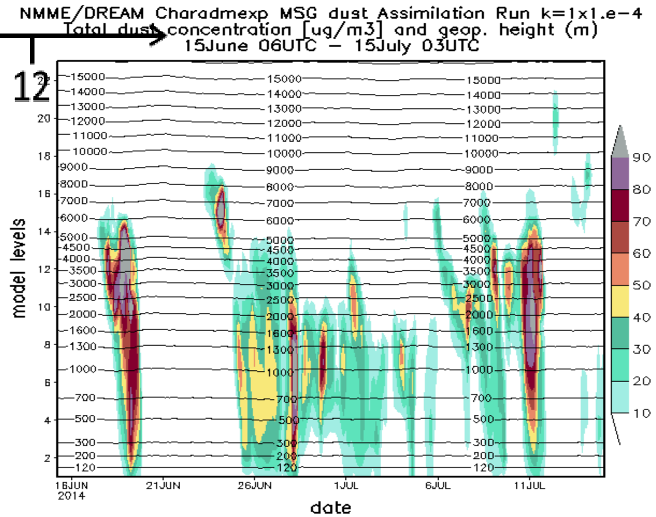
(Nickovic, Pejanovic, Solonos, Cvetkovic, Petkovic, work in progress

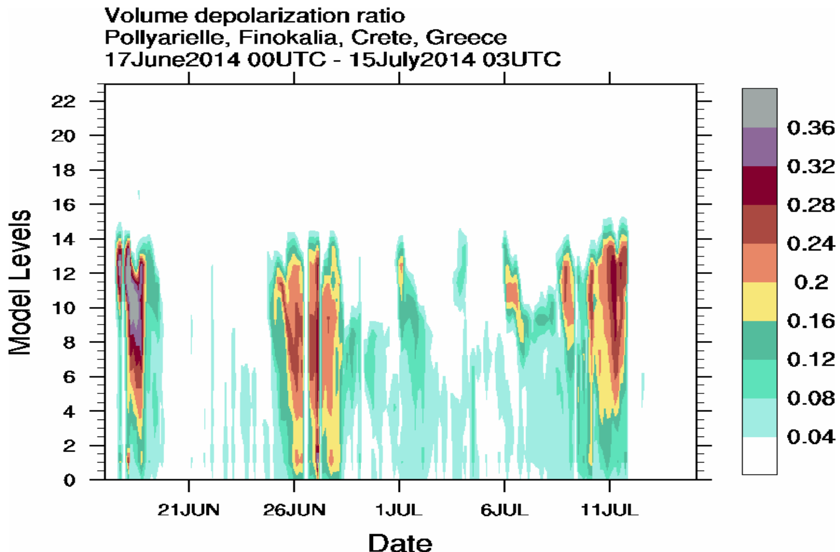
- Collaboration with NOA (Greece) and UK MetOffice
- Observations: MSG/SEVIRI Dust Optical Depth (DOD) over ground only for the moment
- Newtonean Nudging



$$\frac{\partial C}{\partial t} + k(C - C_T) = 0$$







IN parameterization in NMM-DREAM

Example of a typical cloud parameterization in today's models

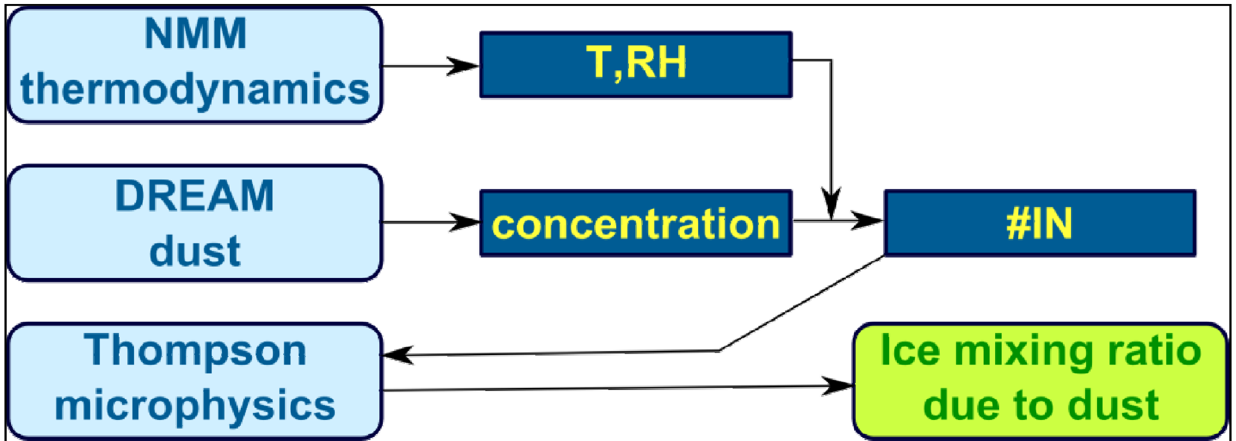
$$\#IN = 100\ m^{-3} = const$$

$$\frac{\partial N_{ice}}{\partial t} = \ldots - \frac{N_c(\#IN)}{q_{ice}} ICEGEN$$

$$\frac{\partial q_{ice}}{\partial t} = \ldots - f(ICEGEN)$$

e.g. Bangert et al, 2011

- Most operational microphysics schemes use predefined #IN
- Instad, we plan to use #IN as predicted variable in the Thompson "dust-friendly" microphysics (MWR,2012)



DREAM #IN parameterization

DREAM dust model

- 25km resolution; Sahara/Mediterranean region
- Particle bin radii: 0.15, 0.25, 0.45, 0.78, 1.3, 2.2 ,3.8 , 7.8 µm

Immersion ice nucleation (two options) [-35°C <T<-5°C]

DeMott et al, (2010)

$$n_{IN} = \left(n_{dust}\right)^{a} 10^{[bT+c]} \quad \left[\frac{\#}{m^3}\right]$$

Niemand et al (2012)

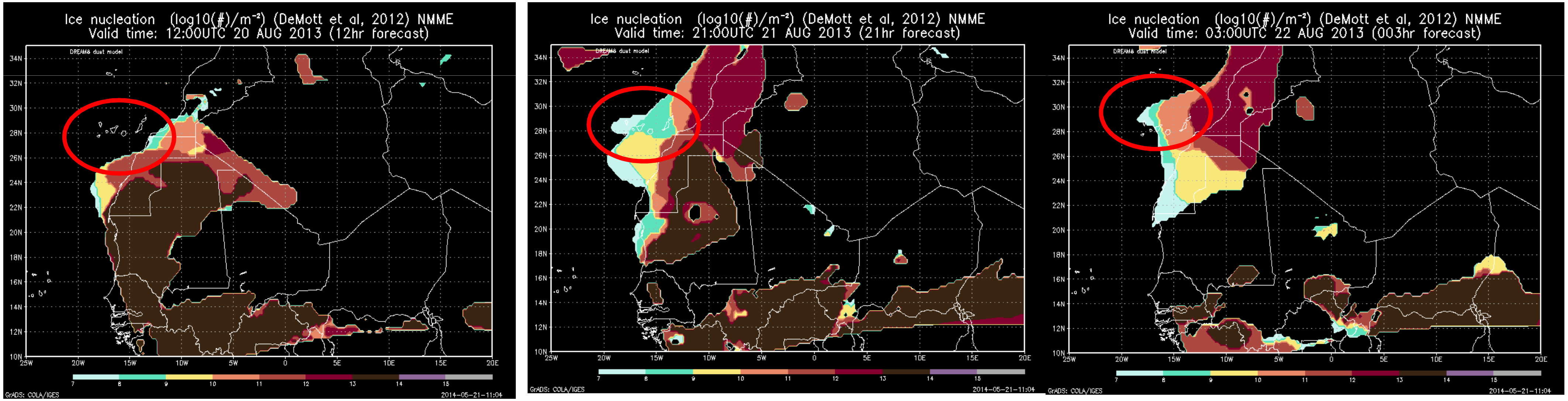
$$n_{IN} = S_{dust} e^{-mT+n} \left[\frac{\#}{m^3}\right]; S_{dust} = \quad surface\ of\ dust\ particles$$

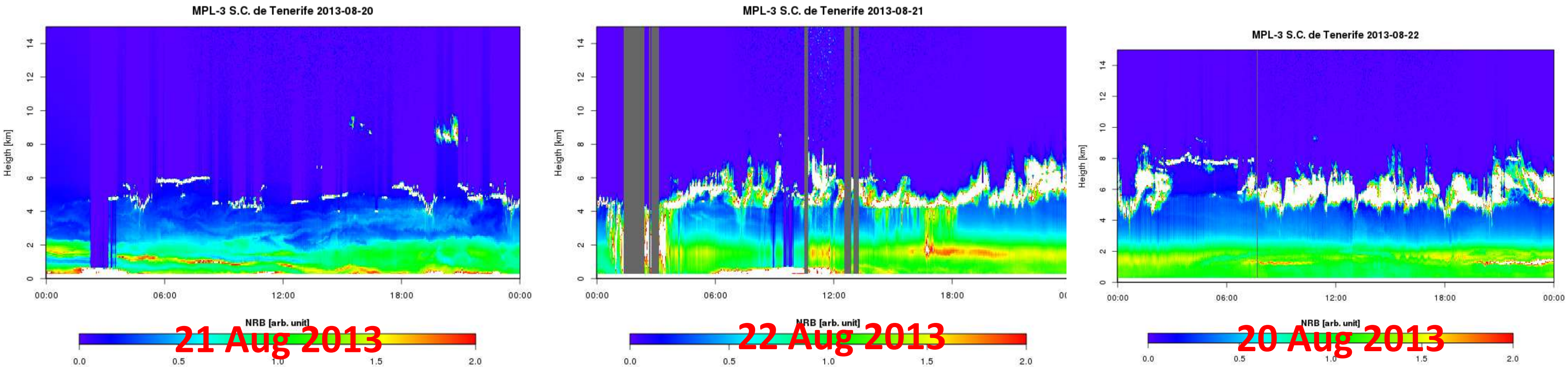
Deposition ice nucleation [-60°C <T<-35°C]

Steinke al (2014)

$$n_{IN} = S_{dust} 1.88 \cdot 10^5 e^{-pT+q\left(RH_{ice}-100\%\right)} \left[\frac{\#}{m^3}\right];$$

Model #IN vs. MPL lidar, Izana



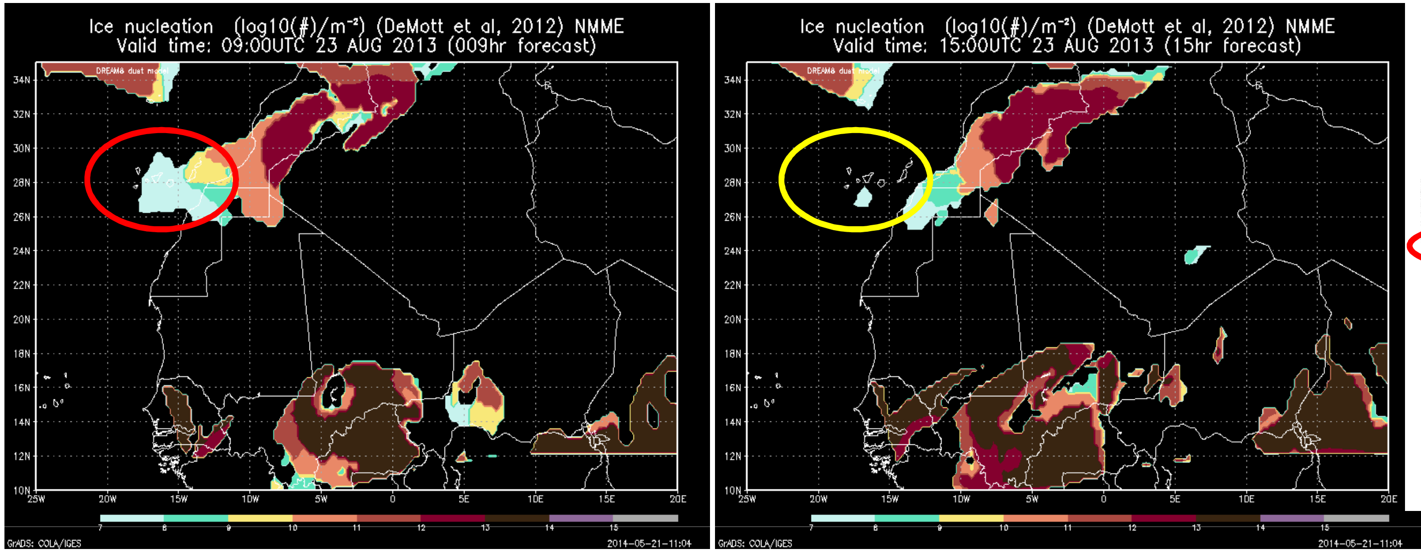


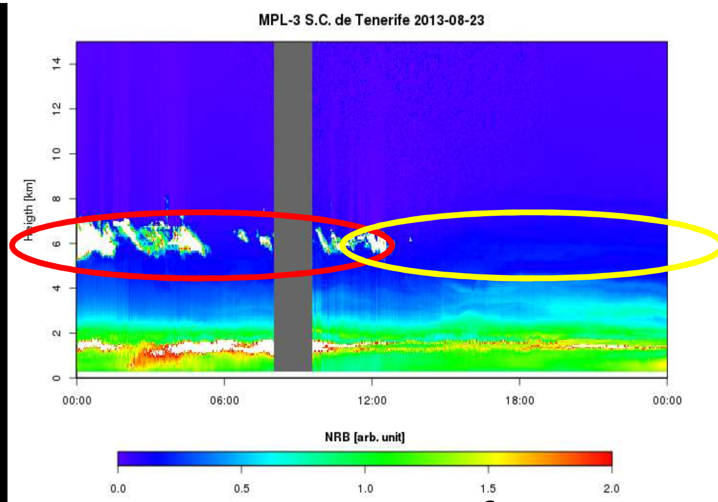
21 Aug 2013

22 Aug 2013

20 Aug 2013

MPL Lidar (Tenerife)





morning *afternoon*

23 Aug 2013

morning *afternoon*

DREAM Model

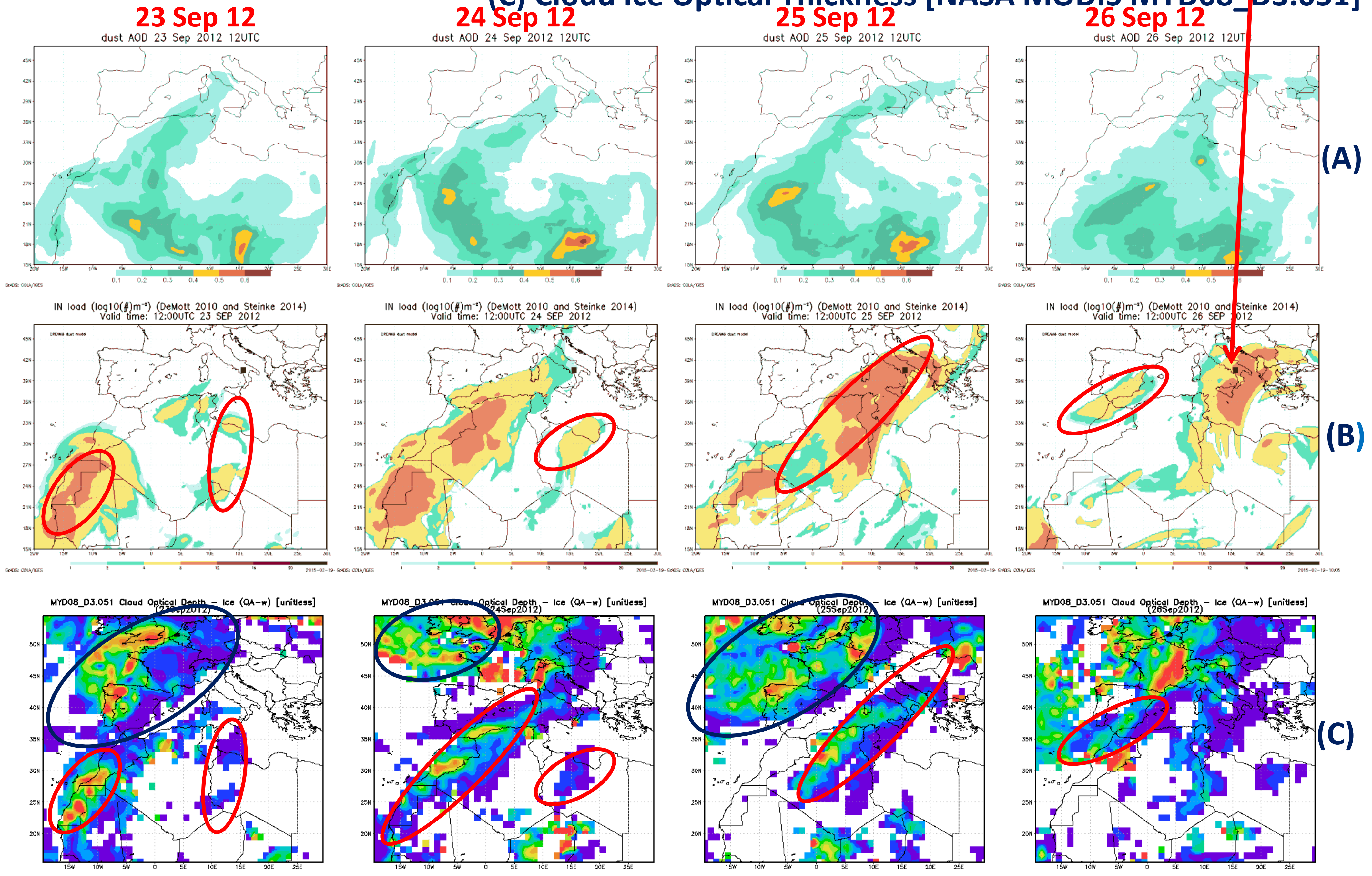
MPL Lidar (Izana) [courtesy of AEMET]

September 2012 event

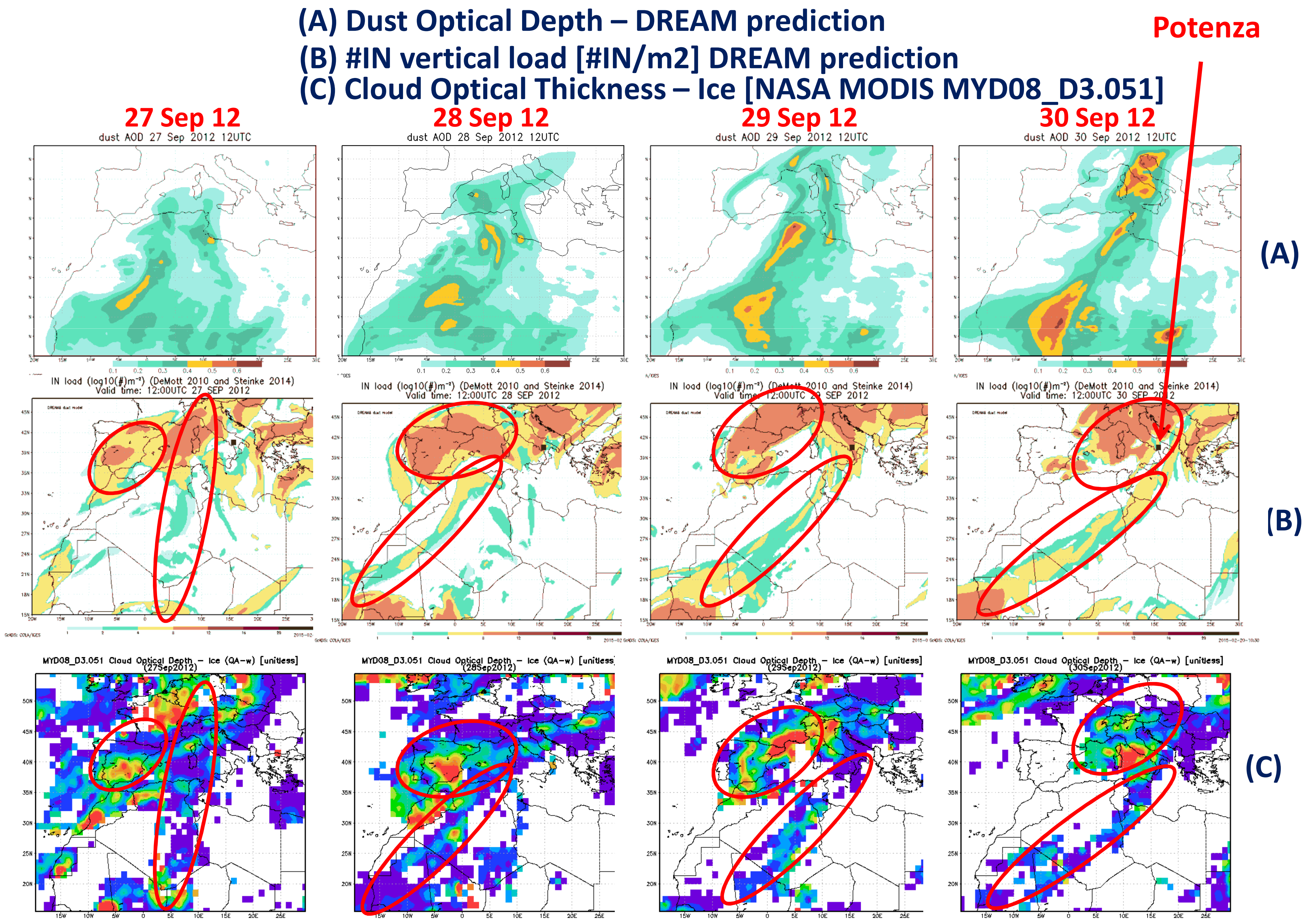
- One week of moderate Saharan dust in the central Mediterranean

#IN vs. cloud ice

(A) Dust Optical Depth – DREAM prediction
(B) #IN vertical load [#IN/m2] DREAM prediction
(C) Cloud Ice Optical Thickness [NASA MODIS MYD08_D3.051]



(A) Dust Optical Depth – DREAM prediction
(B) #IN vertical load [#IN/m2] DREAM prediction
(C) Cloud Optical Thickness – Ice [NASA MODIS MYD08_D3.051]



MODIS maps produced with the Giovanni, developed and maintained by the NASA GES DISC

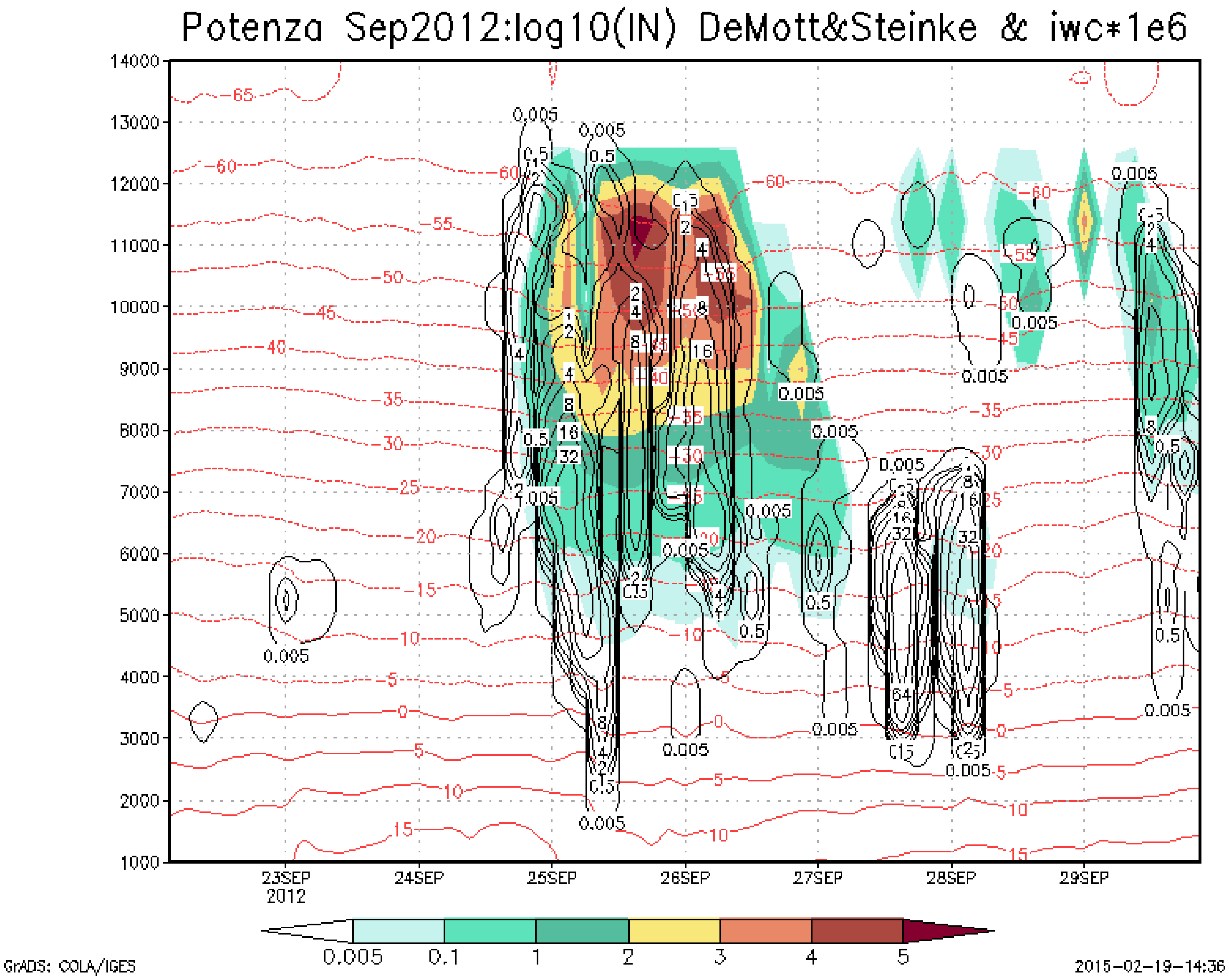
Sep 2012 dust case - Potenza

z-t graph

- Model #IN (color bar)

vs.

- MIRA55 Ice Cloud Water(black line)



Thank you !