STUDY OF A HABOOB IN IRAN

Analysis and numerical simulation of Tehran dust storm on 2nd June 2014

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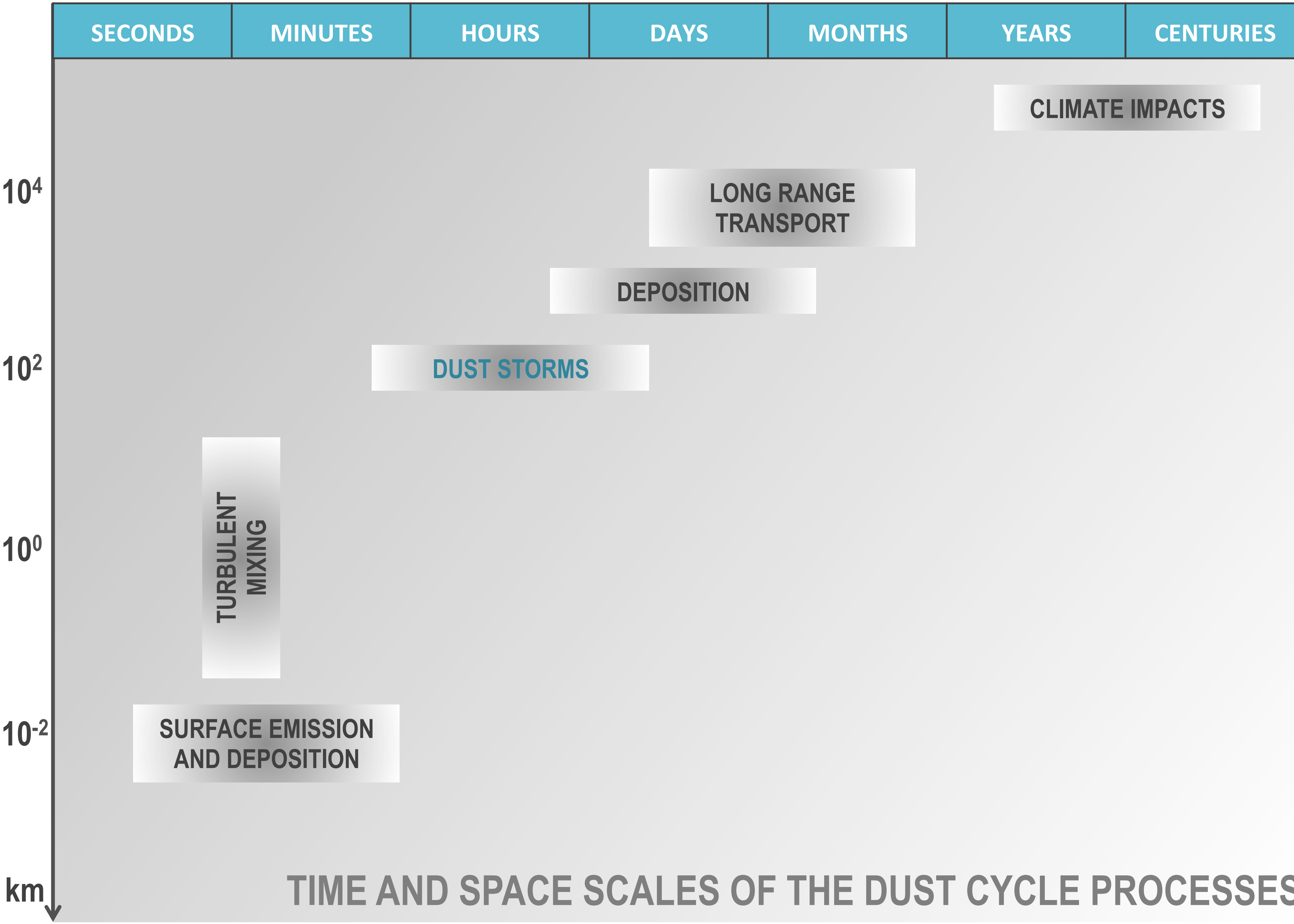

SECONDS
MINUTES
HOURS
DAYS
MONTHS
YEARS
CENTURIES
CLIMATE IMPACTS
LONG RANGE TRANSPORT
DEPOSITION
DUST STORMS
TURBULENT MIXING
SURFACE EMISSION AND DEPOSITION
10^4
10^2
10^0
10^-2
km
TIME AND SPACE SCALES OF THE DUST CYCLE PROCESSES

ATMOSPHERIC DUST MODELLING

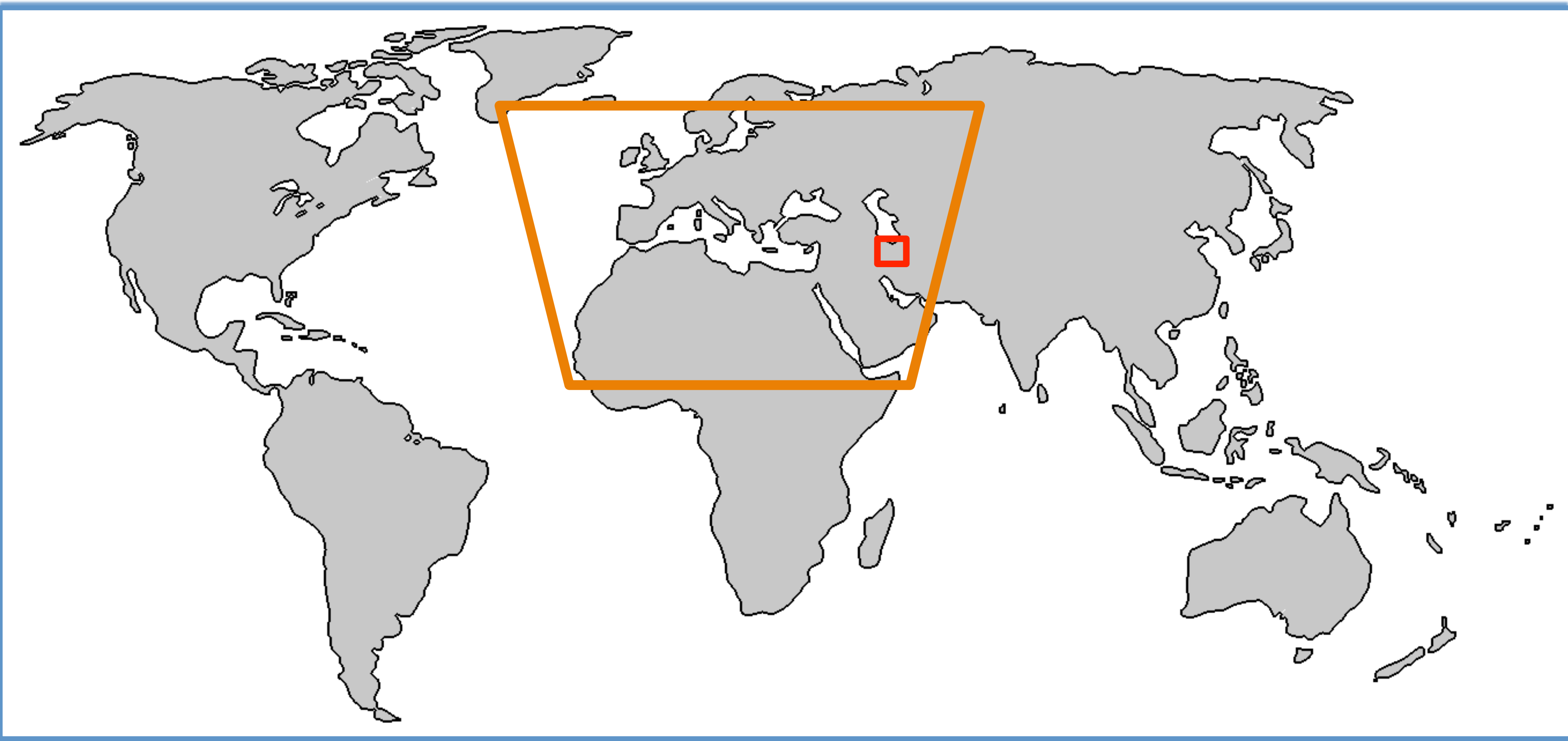
LONG RANGE TRANSPORT:

global and regional models
Coarse resolution (several 10km to ~100km)
Particles mineral composition
Transformation and interaction with the environment

SHORT RANGE TRANSPORT:

Nonhydrostatic regional models
High resolution (several km)
Dust sources weather dependable
Forecast of the dust storms

GLOBAL MODELS **REGIOANAL MODELS** **NONHYDROSTATIC MODELS**



NUMERICAL REPRESENTATION OF ATMOSPHERIC DUST TRANSPORT

Numerically solving the prognostic equation for dust concentration.

Particles are assumed to be spherical.

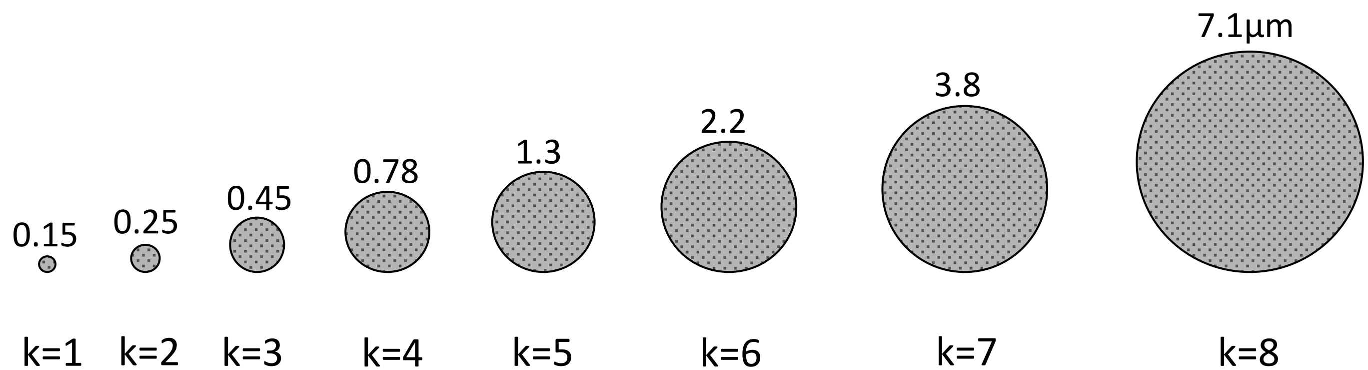
Particles are divided in categories by size.

Number of categories different among modells.

Concentration of particles is calculated for each category in each model grid point.

Example for DREAM

8 particle size categiries:



Prognostic equation for dust particles concentration $\frac{\partial C}{\partial t} = \cdots$

(DREAM Nickovic i dr. 2001, Perez i dr. 2006)

C is calculated for each particle size category, $\boldsymbol{C_k}$, k=1,…8

$-u\frac{\partial C}{\partial x} - v\frac{\partial C}{\partial y}$ horizontal advection

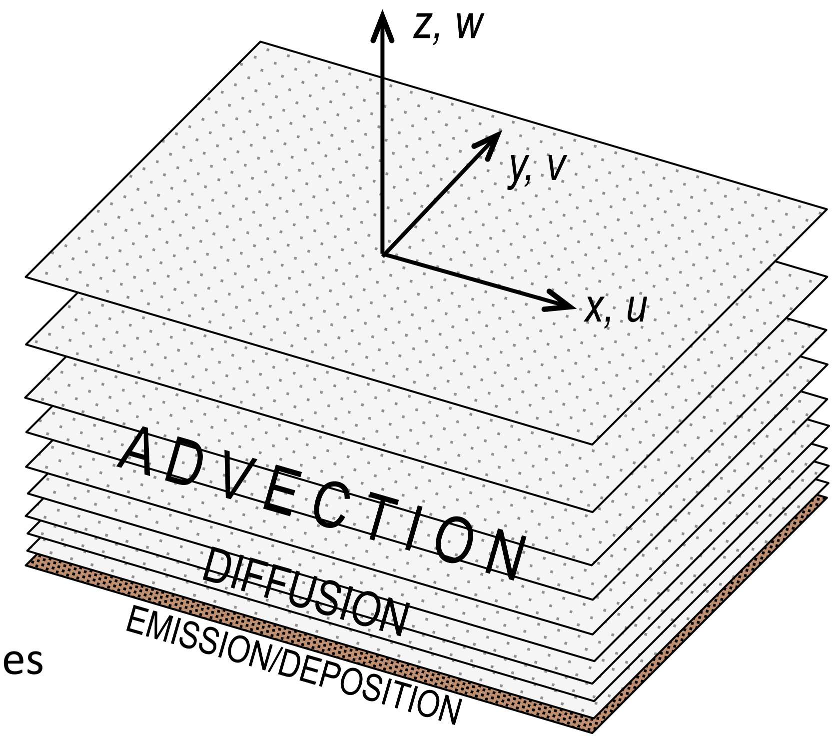
$-(w - \boldsymbol{w_t})\frac{\partial C}{\partial z}$ vertical advection

$-\nabla(K_h \nabla C)$ horizontal diffusion

$-\frac{\partial}{\partial z}\left(K_z \frac{\partial C}{\partial z}\right)$ vertical diffusion

$+\left(\frac{\partial C}{\partial t}\right)_{source}$ source/emission of d-particles

$-\left(\frac{\partial C}{\partial t}\right)_{sink}$ deposition/sink of d-particles

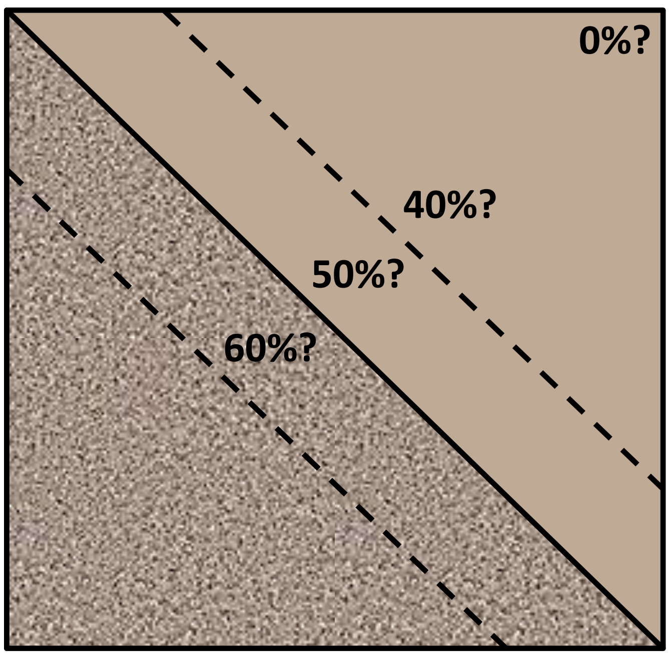


Mapping dust sources

- Mapping areas without vegetation, knowing soil texture and dust particles size distribution (for one grid box**: % bare_land, % silt_clay,** ***% size_category***).
- Purpose of the model use defines methodology in definition and level of complexity of mapping dust sources.

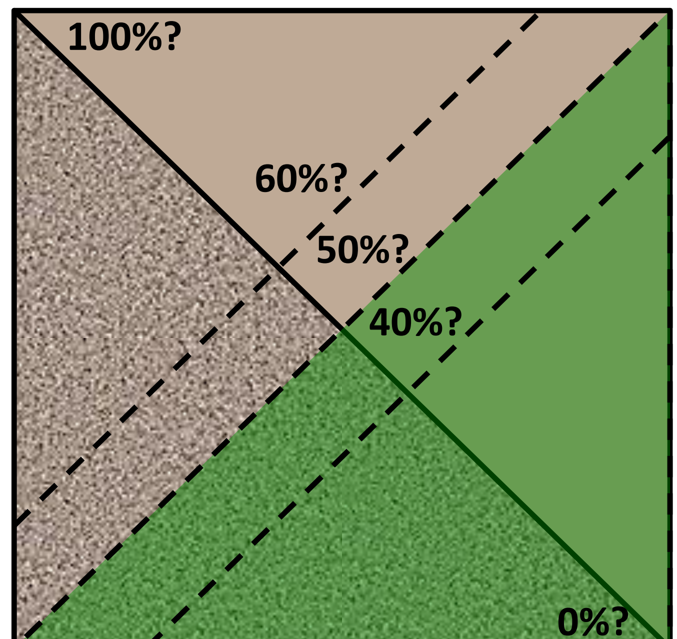
long range transport modelling:
main sources desert areas
%bare_land = 100%
% silt_clay ?!

SOIL TEXTURE POOR QUALITY
Clay and silt content not well known

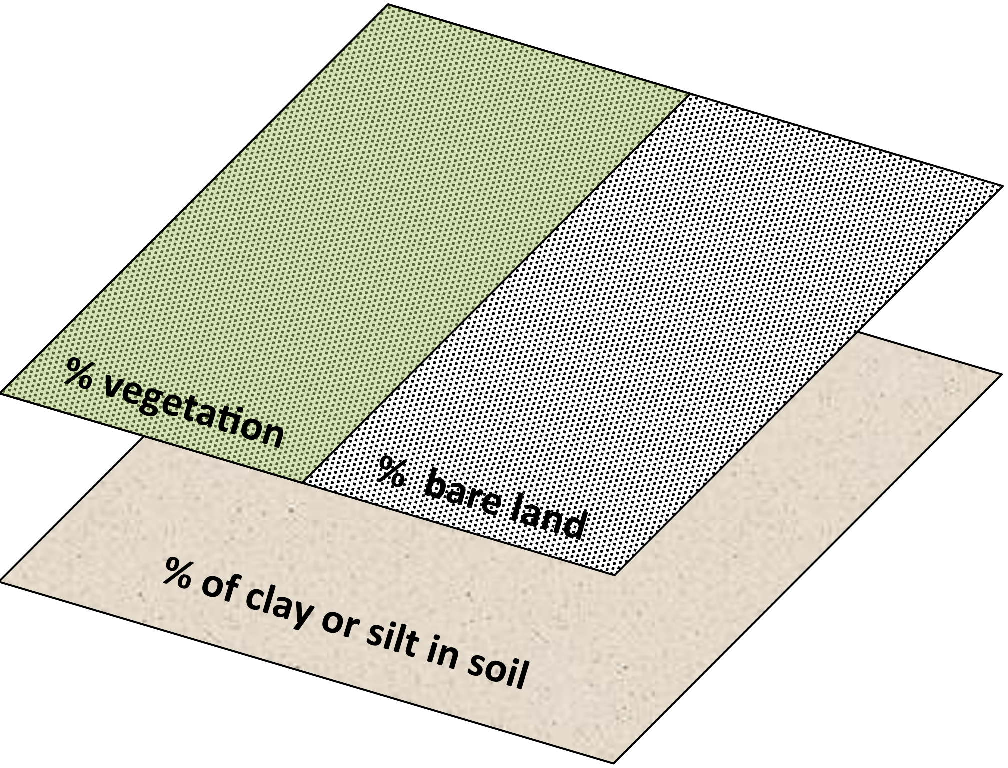


dust storms modelling:
agricultural areas, point like sources
dependant on weather conditions
%silt_clay = higher quality of data
% bare_land ?!

CURRENT VEGETATION COVER UNKNOWN



Similar problem with drying lakes.



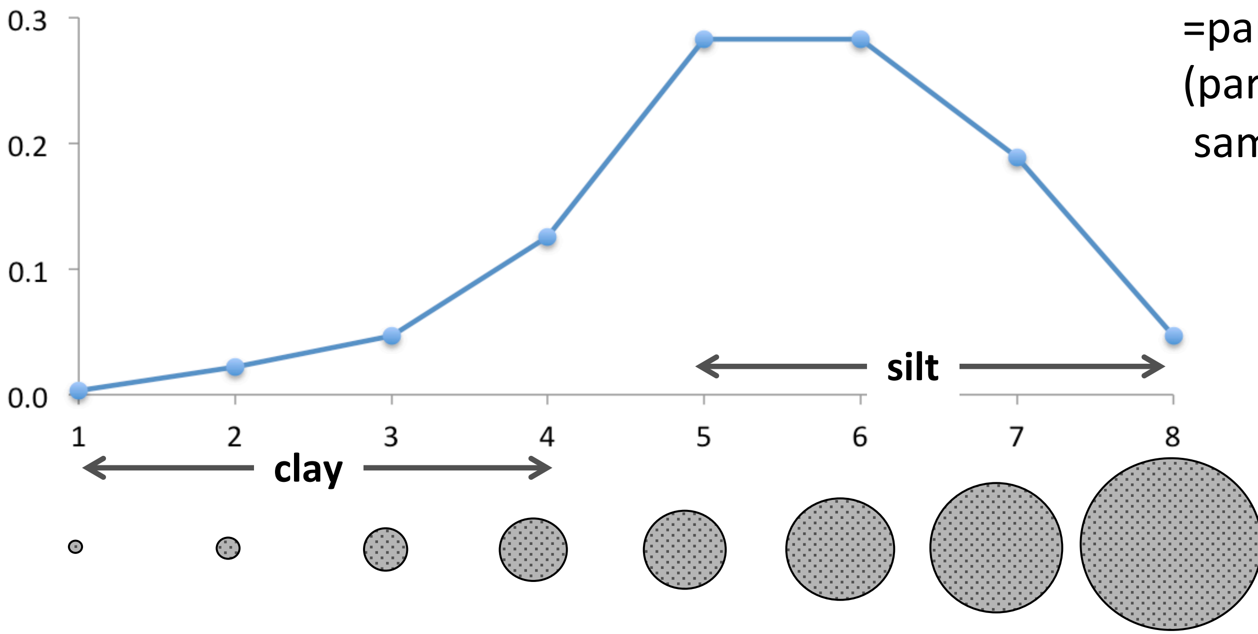
For each model grid box: determine potential for dust emission

APLHA=%of bare land
(can be obtained from satellite data)

BETA=%of clay or % of silt in soil surface
(from soil database, currently STATSGO)

ALPHA*($BETA_{clay}$+$BETA_{silt}$)
=available amount of clay or silt in surface soil in model grid box
=%of dust productive soil surface

GAMMA=%of each category in dust productive soils
=particle size distribution
(parameterized values, same in each grid box)

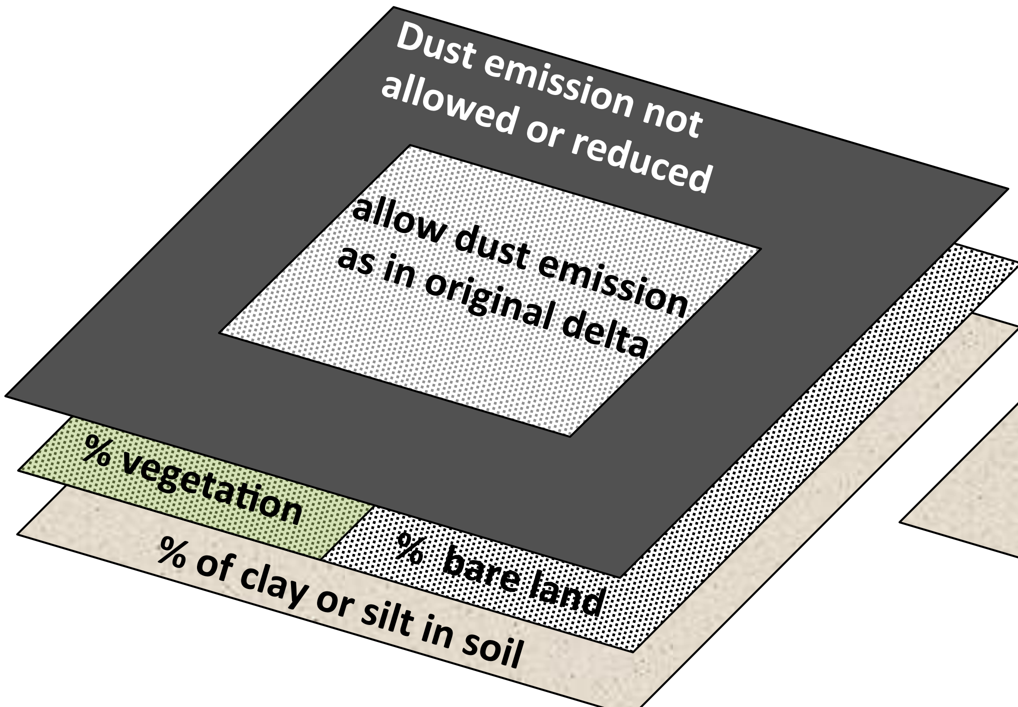


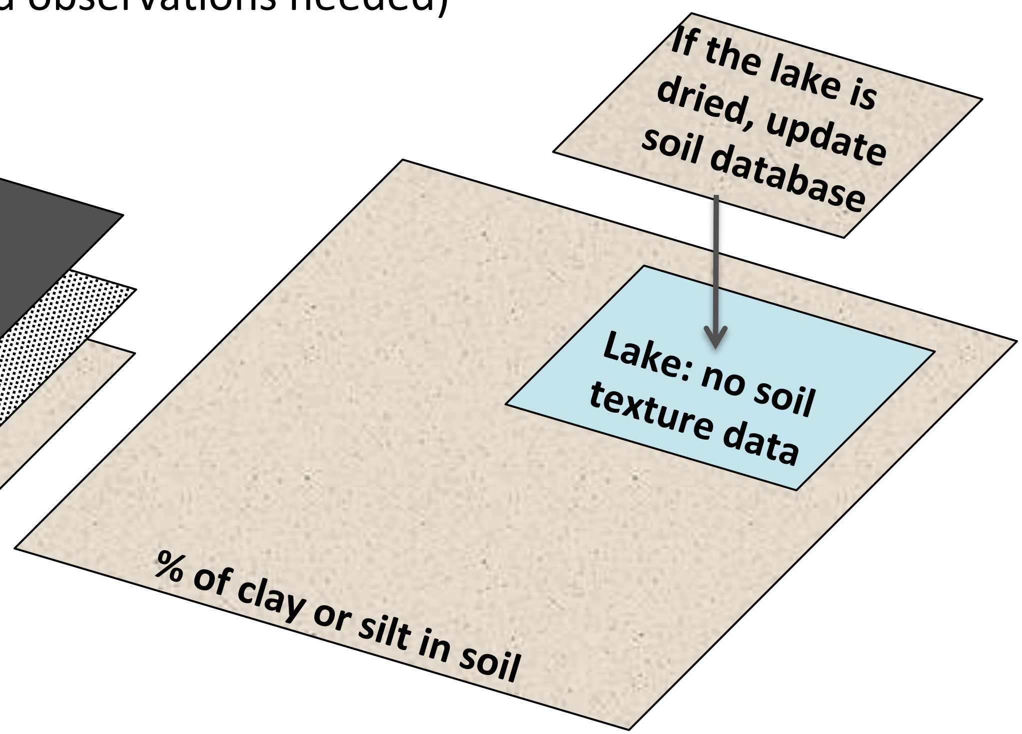
DELTA
=(ALPHA*BETA*GAMMA)
=%of each particle size at surface available for emission

+ needed information for soil wetness and surface wind speed! (from atm. model)

Problems in defining DELTA

- Problems in determining %of bare soil if the sources are seasonable and weather depending (can be solved using regularly updated satellite data)
- Model resolution too coarse to be able to see small point-like sources (adjust model resolution and model domain to the purpose it serves)
- Soil texture data low quality, % of clay and silt is not valid (if there is too much emission from the surface which is known as not dust productive, introduce another layer of "preferential dust source mask" to mask the false sources; if new dry areas appeared, like dried lakes, update soil texture data) – priority for Iran
- Parameterization of particles size distribution same in all dust productive areas (not much can be done on this matter, too much field observations needed)





Emission and turbulent uptake of D-particles

- calculates lower boundary condition for d-concentration (C_{LMk} conc. on lowest model level)
- depends on soil moisture and wind velocity

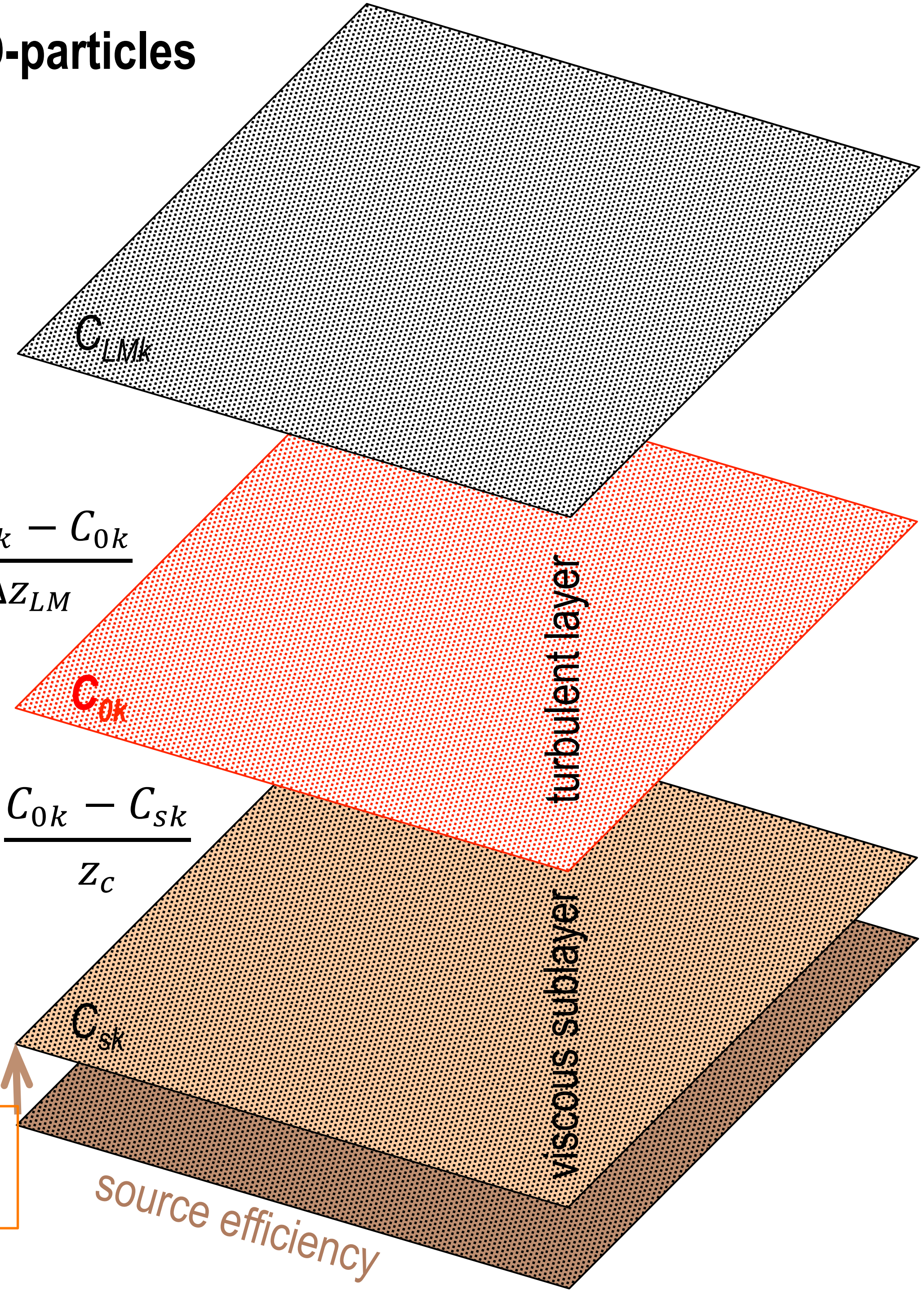
From numerical atmospheric modeling, similar as for water vapor; this approach is different among the models,…

Surface tubulent flux $$F_{Csk} = K_s \frac{C_{LMk} - C_{0k}}{\Delta z_{LM}}$$

Flux at the top of the viscous sublayer (Janjic 1994) $$F_{Csk} = \lambda \frac{C_{0k} - C_{sk}}{z_c}$$

Flux from the surface (calculation of C_{sk}) (Shao i dr. 1993; Marticorena and Birgametti 1995; Shao 2004)

DELTA; soil moisture; surface wind speed => determines flux of each particle



Deposition of D-particles from *LM* level

Dry deposition

(Zhang i dr. 2001, Slinn 1982)

- Include effects:

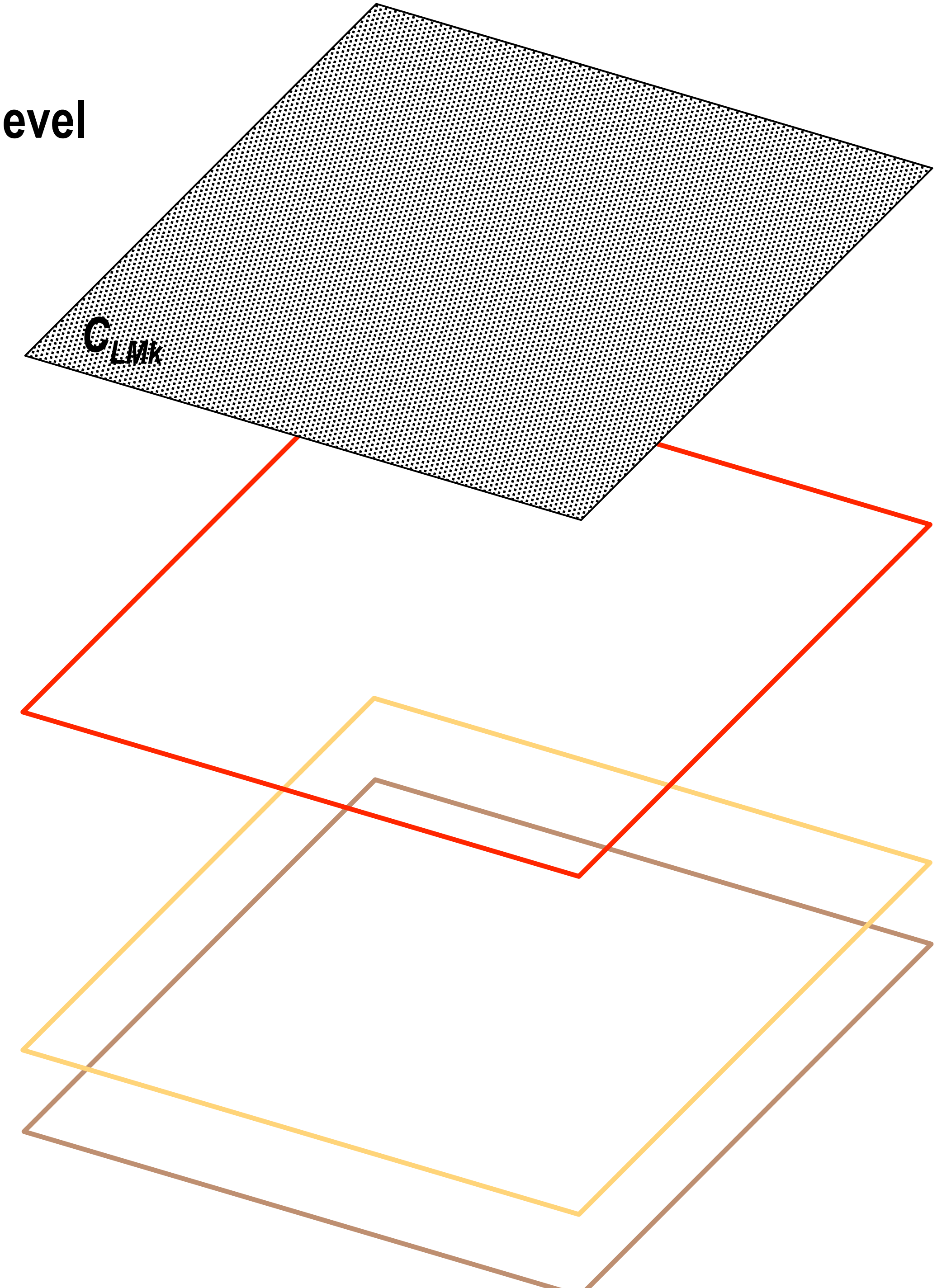
  Brown diffusion,
  impaction, interception
  and gravitational settling

- Accounts for land cover type

$$\left(\frac{\partial C_{LMk}}{\partial t}\right)_{dsink} = -\frac{C_{LMk} v_{dk}}{\Delta z_{LM}}$$

Wet deposition

- washout of atmospheric dust by precipitation

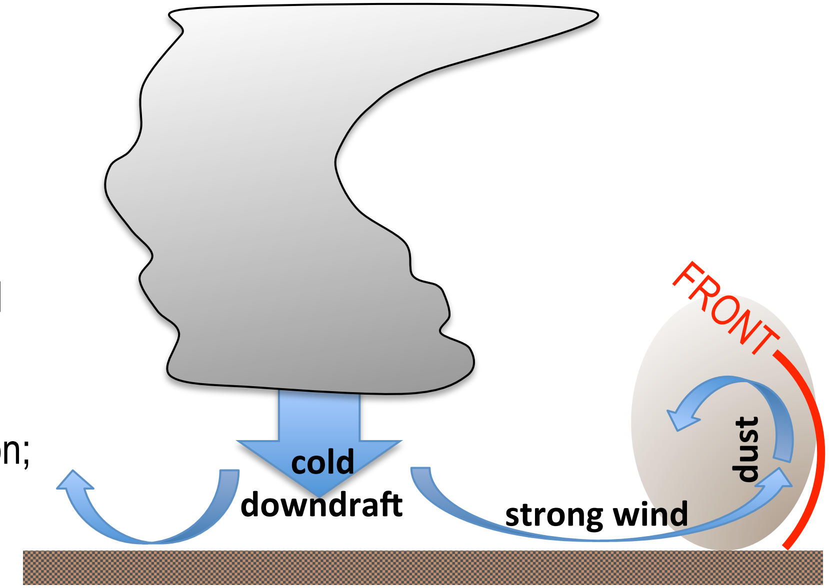


STUDY CASE: TEHRAN DUST STORM 2ND JUNE 2014

Simulation of small scale (local; several 100km), intense (several 1000ug/m3 PM10) & short lived (few hours) dust storms

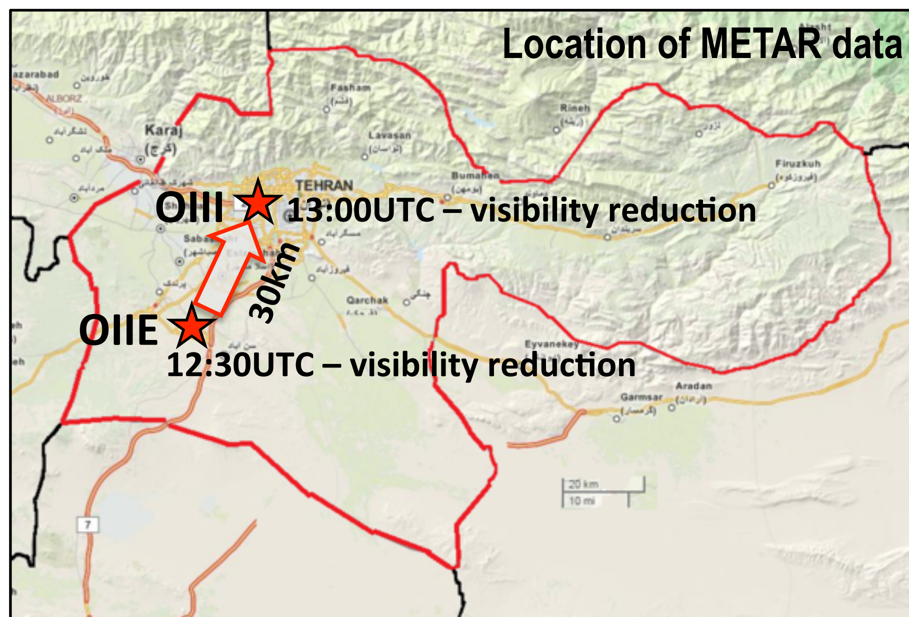
Information from reports

- reached city at 5.30 p.m. local time;
- passing of the sand storm over the fixed site lasted about 15min;
- storm duration less than 2h;
- reduction of visibility to ~10m; wind velocity reached 110 km/h;
- temperature dropped from 33 to 18C in several min;
- at least 5 deaths, 82 injured; multiple vehicle collision;
- 50 000 residential units lost power.

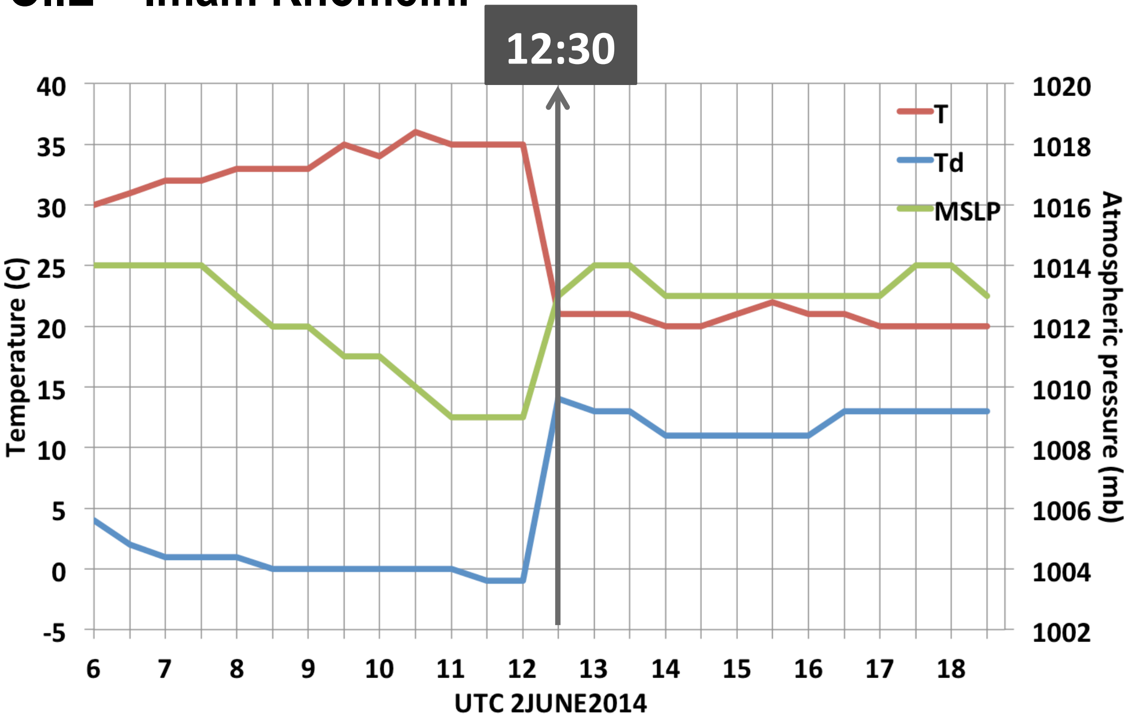


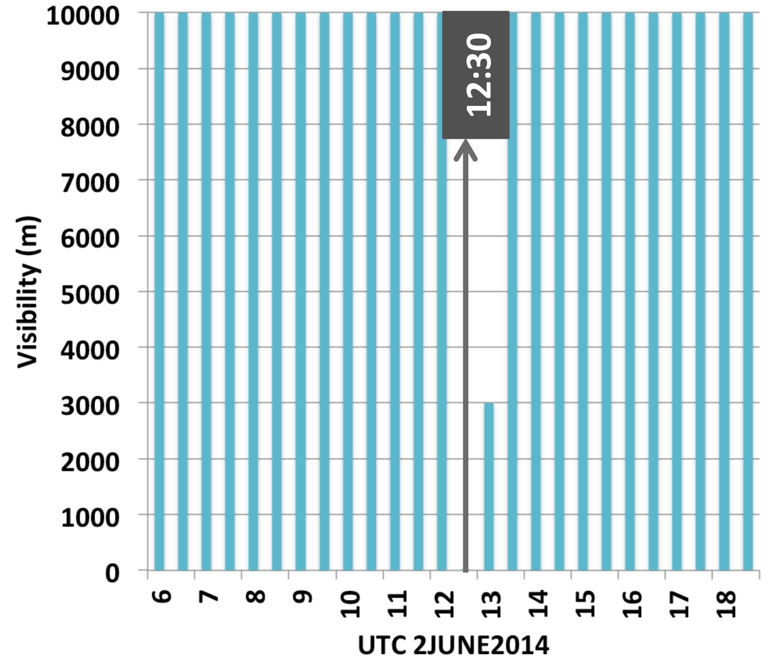
Theory

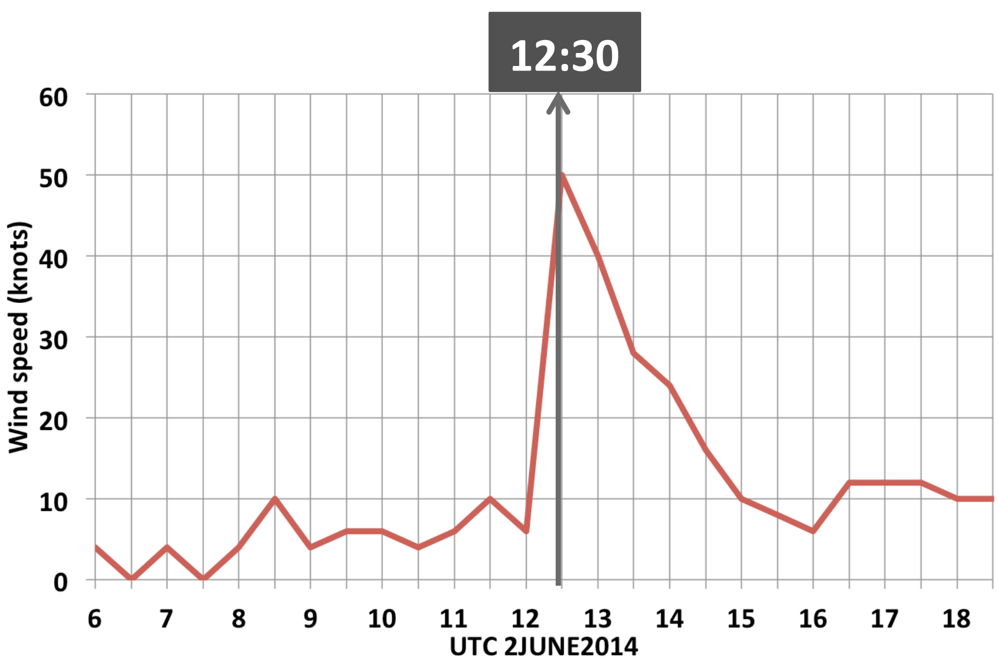
- Intensive cold downbursts from convective cells produced high velocity surface wind, creating cold front which was lifting, mixing and pushing dust towards the city;
- Expected: high wind speed, drop in temperature, rise in humidity, rise in pressure, reduction of visibility.

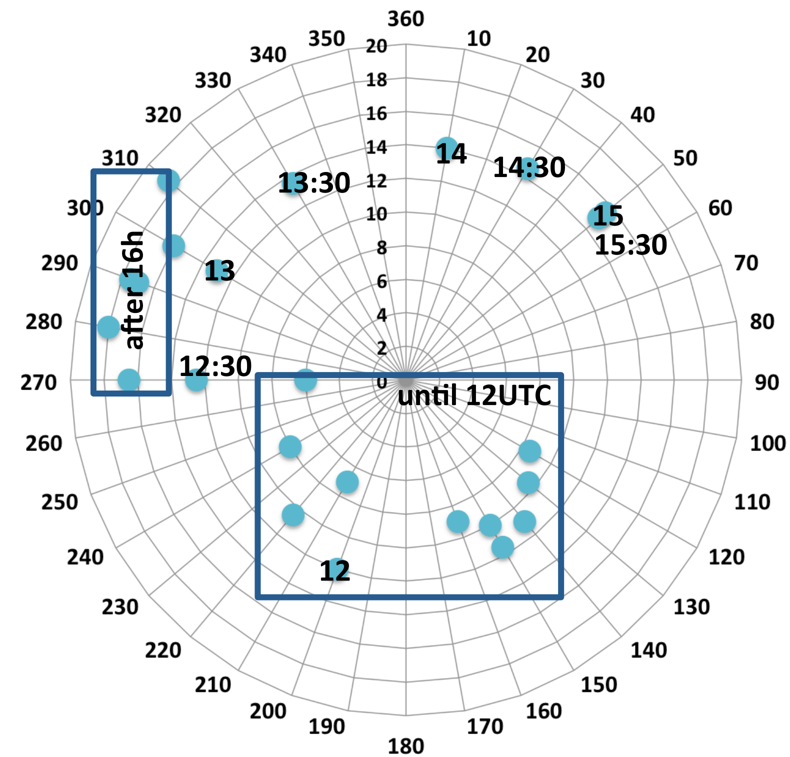


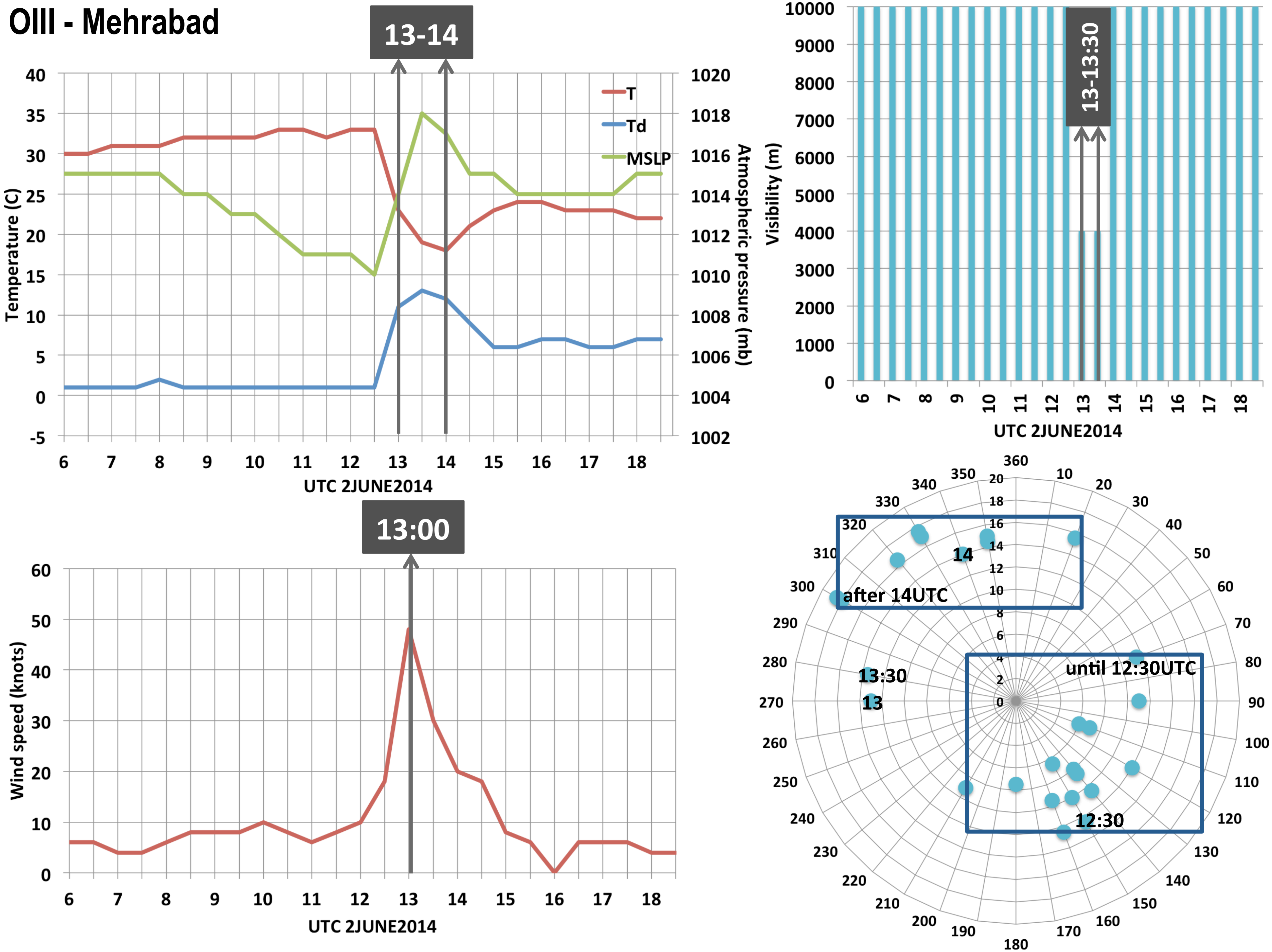
OIIE – Imam Khomeini





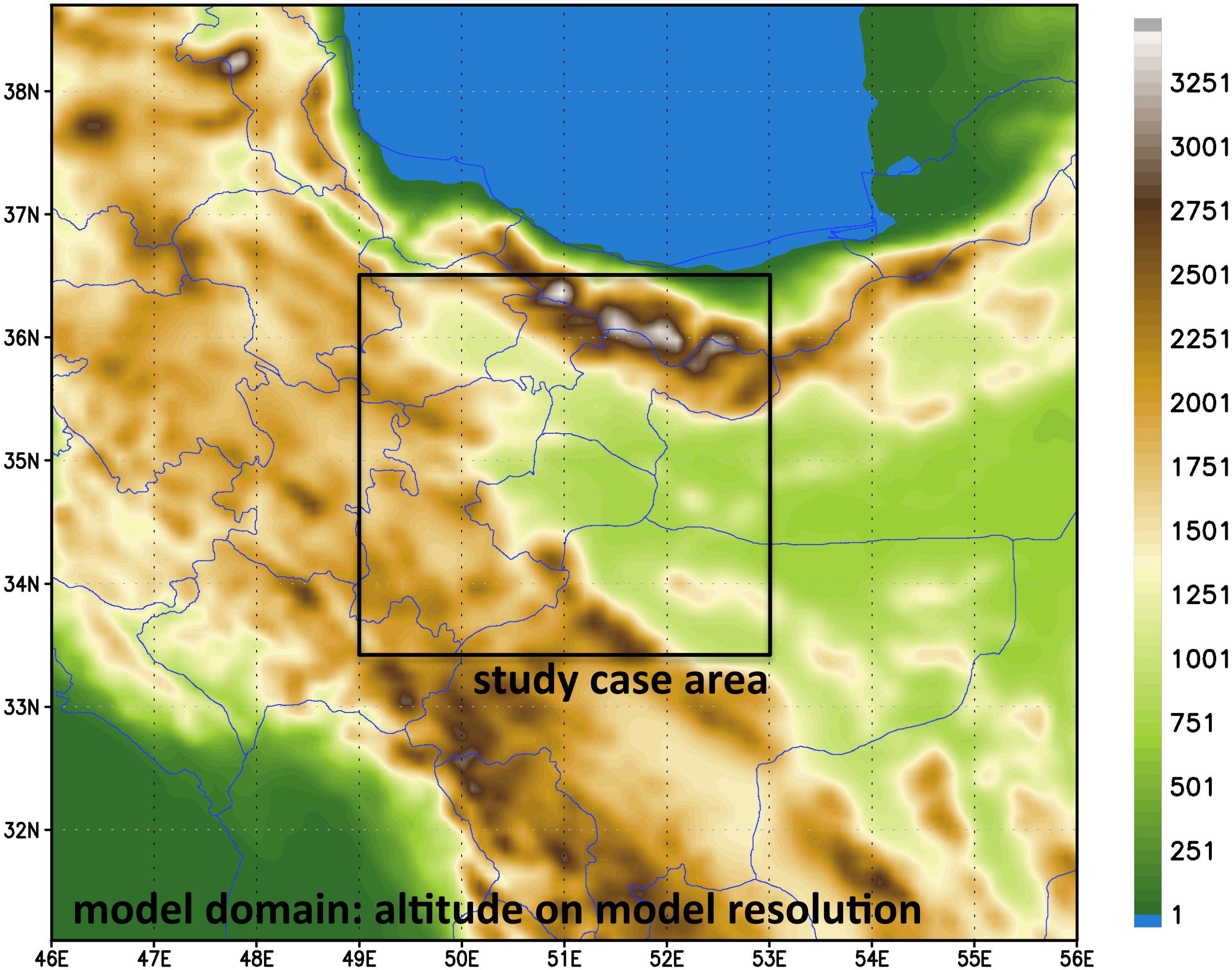





OIII - Mehrabad
13-14
T
Td
MSLP
Temperature (C)
Atmospheric pressure (mb)
UTC 2JUNE2014
13-13:30
Visibility (m)
UTC 2JUNE2014
13:00
Wind speed (knots)
UTC 2JUNE2014
after 14UTC
14
13:30
13
until 12:30UTC
12:30

Numerical simulation of Tehran dust storm 2 June 2014

DREAM – SEEVCCC: NMME atmospheric driver (Vukovic et al. 2014 – HR simulation)
(Perez et al. 2006, Nickovic 2001)
Model domain: lat 31N-39N, lon 46E-56E; Model resolution: 1/40 horizontal (~4km); 60 vertical levels
Forecast time: 12UTC 01 June 2014 – 00UTC 03 June 2014 (36h)
Time of the event: about 12-15 UTC 02 June 2014



Increase 2X horizontal resolution, computing time increases 8X (on the same number of processors). Double the no. of vertical levels is additional 2X. Choose domain, resolution and output frequency wisely!

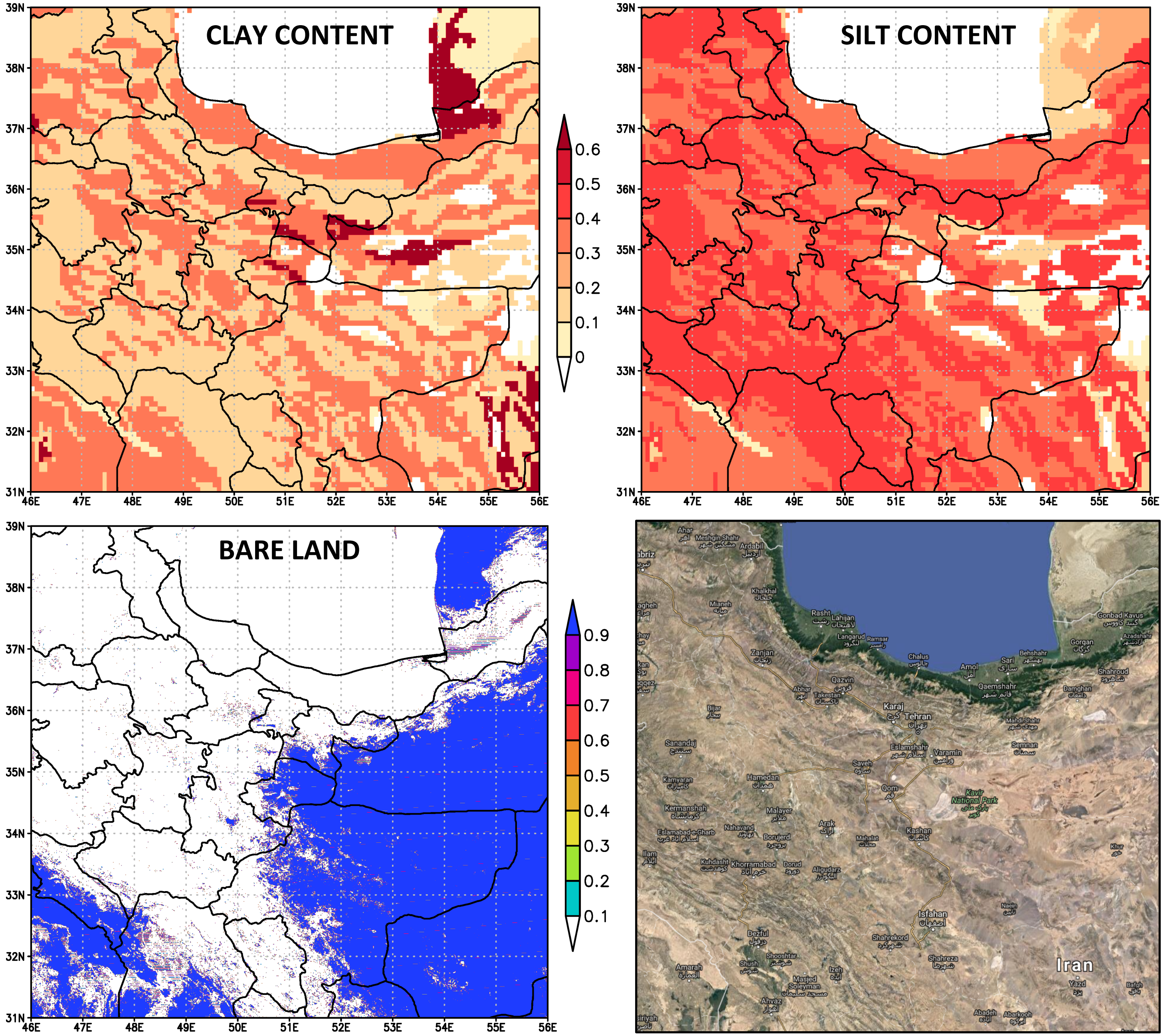
We choose ~4km resolution because operational NWP models nowadays are on ~4km resolution.

The main goal:
To create tool for forecast of intense local short lived dust storms in service of warning system.

clay size particles source potential = (clay content)*(bare land)
silt size particles source potential = (silt content)*(bare land)

From STATSGO-FAO database

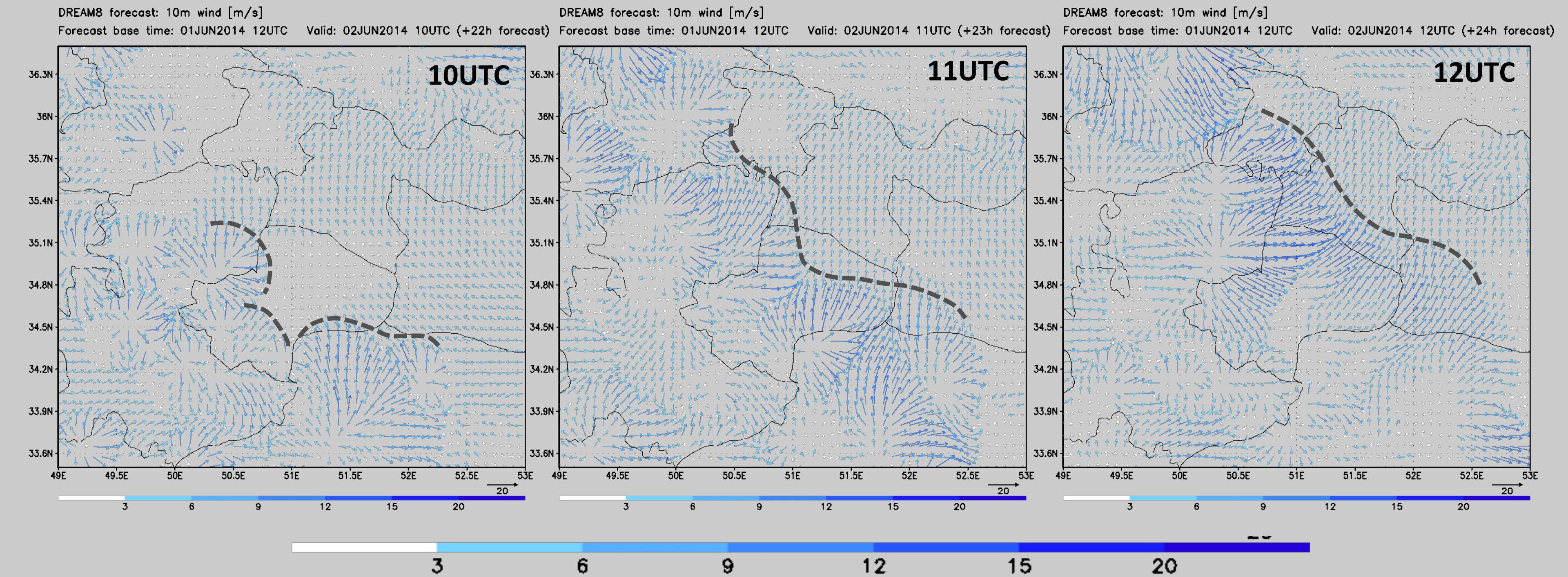
MODIS data for land cover & NDVI (closest to the event)



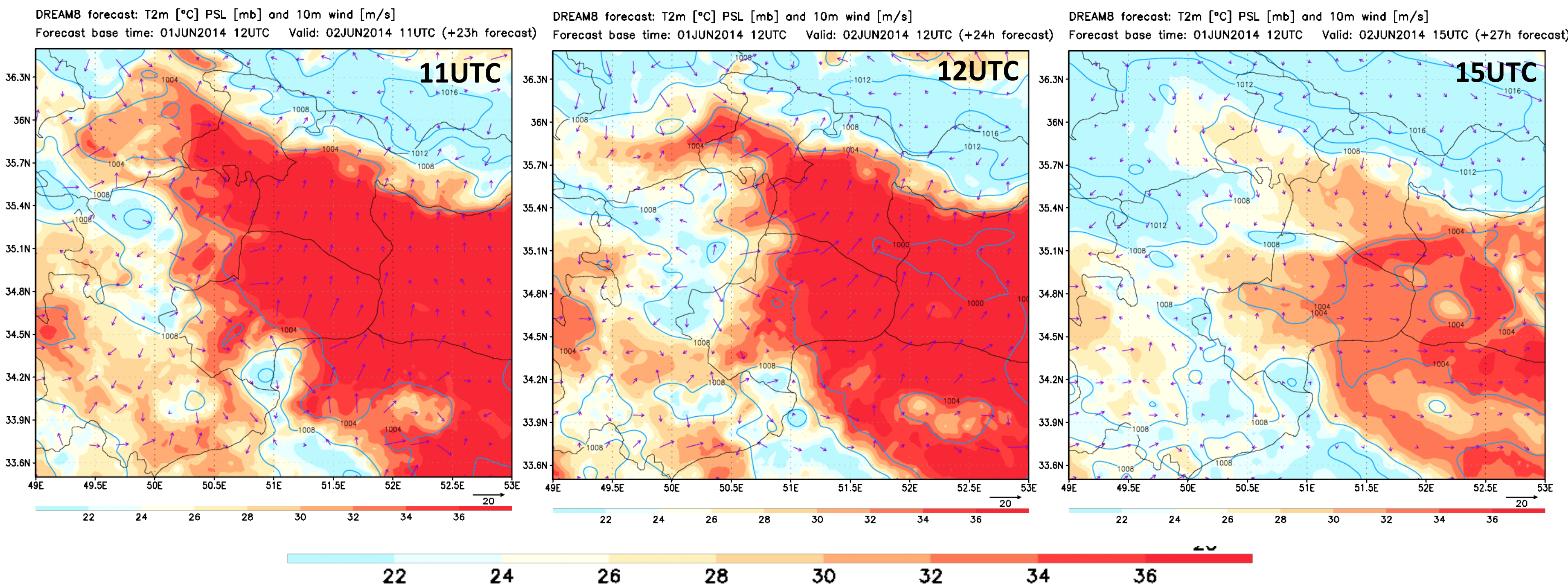
Hypothesis: Multicell storm

Several storm cells with cold downdraft, lifting the dust, formed one after another from south of Tehran province to the west of Tehran province.

Model surface wind velocity and direction



Model 2m temperature, MSLP, wind



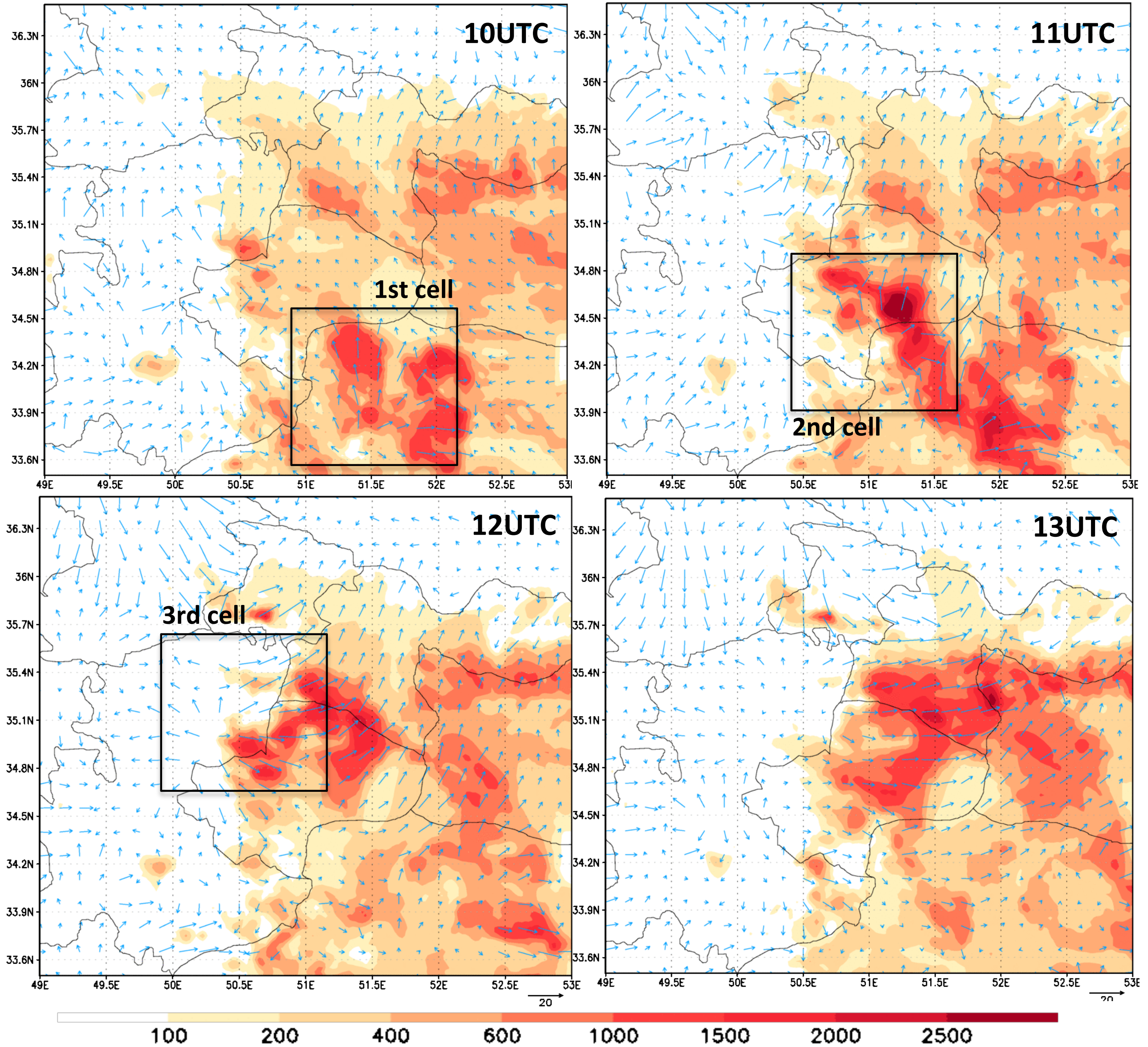
DNC

(surface)

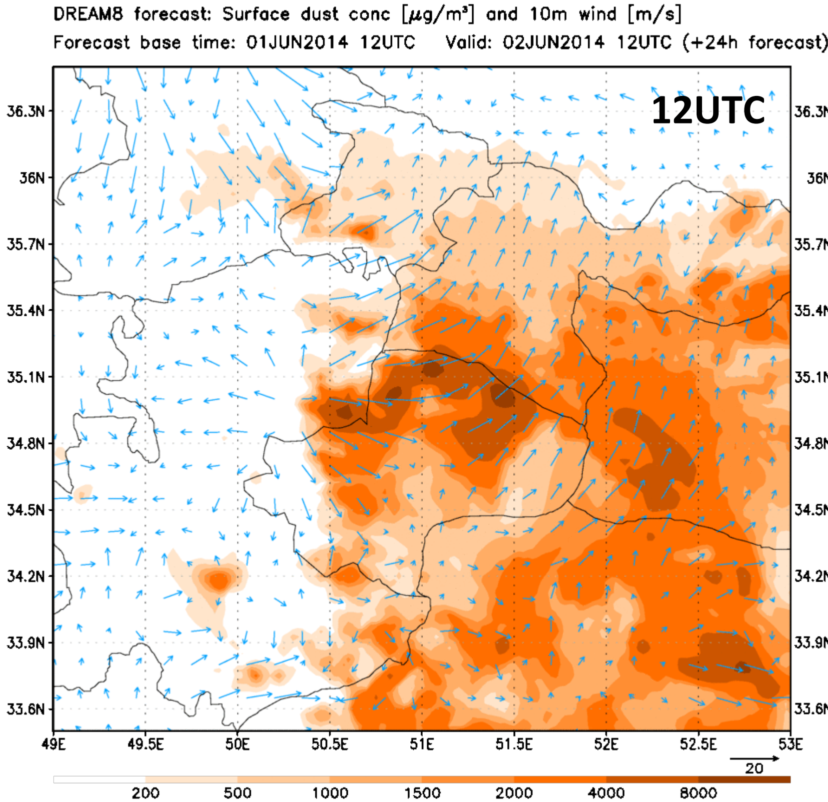
Dust Number Concentration

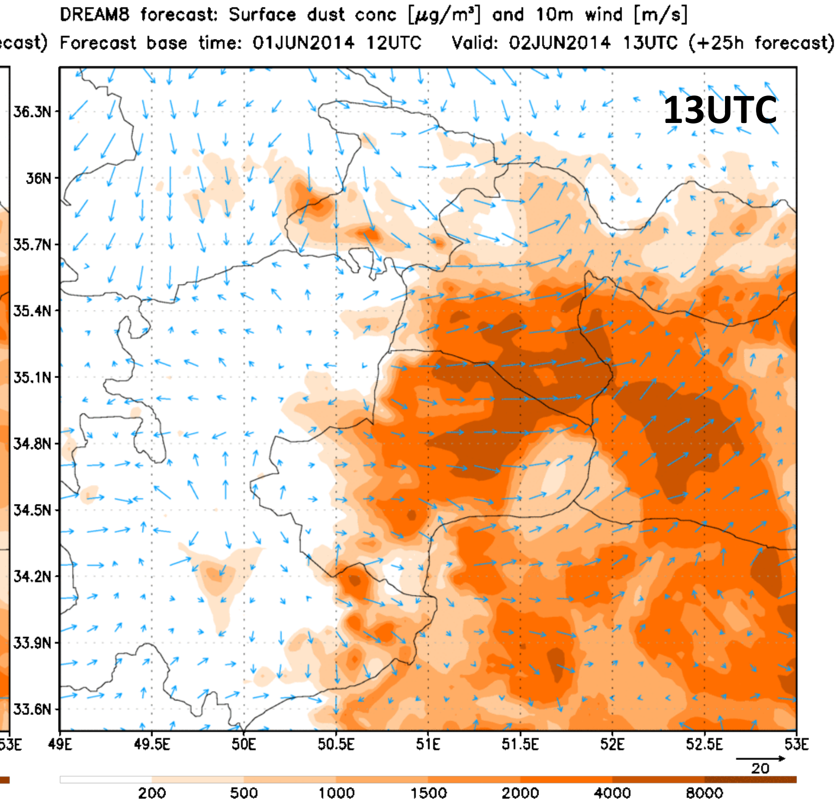
number of dust particles in cm ^{3}

Dust uplift and transport controlled with three main cells.



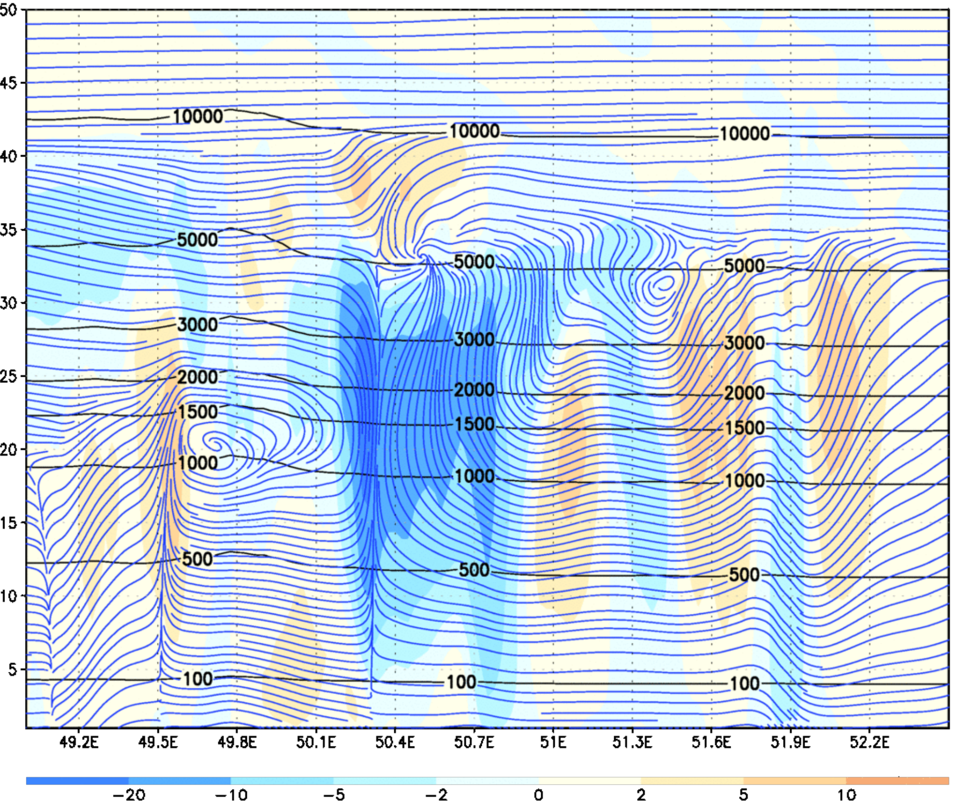
Dust PM10 surface concentration exceeds 4000ug/m3 in southern parts of Tehran province.



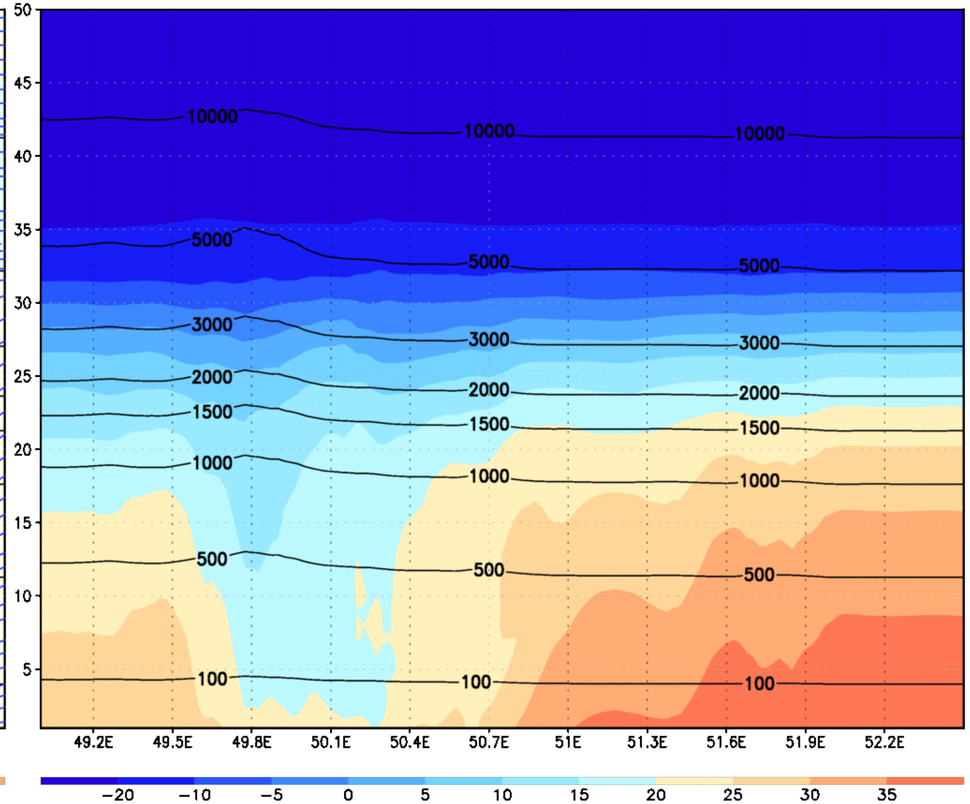


Vertical cross section along 35N

Streamlines (u,w) and vertical wind velocity



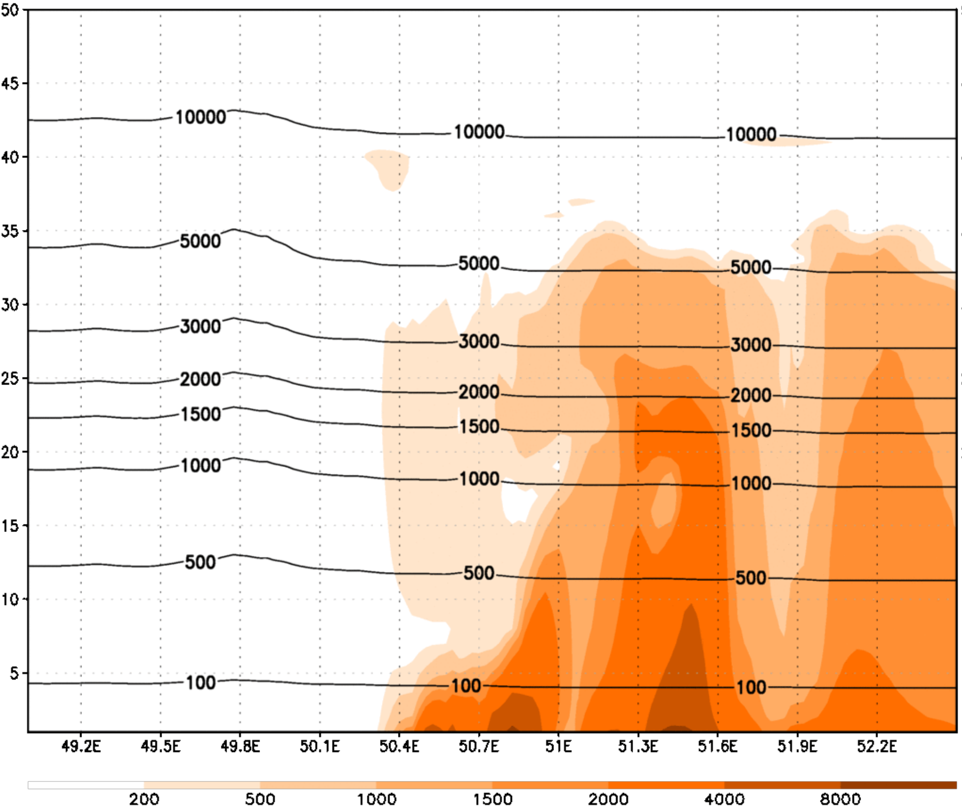
Temperature



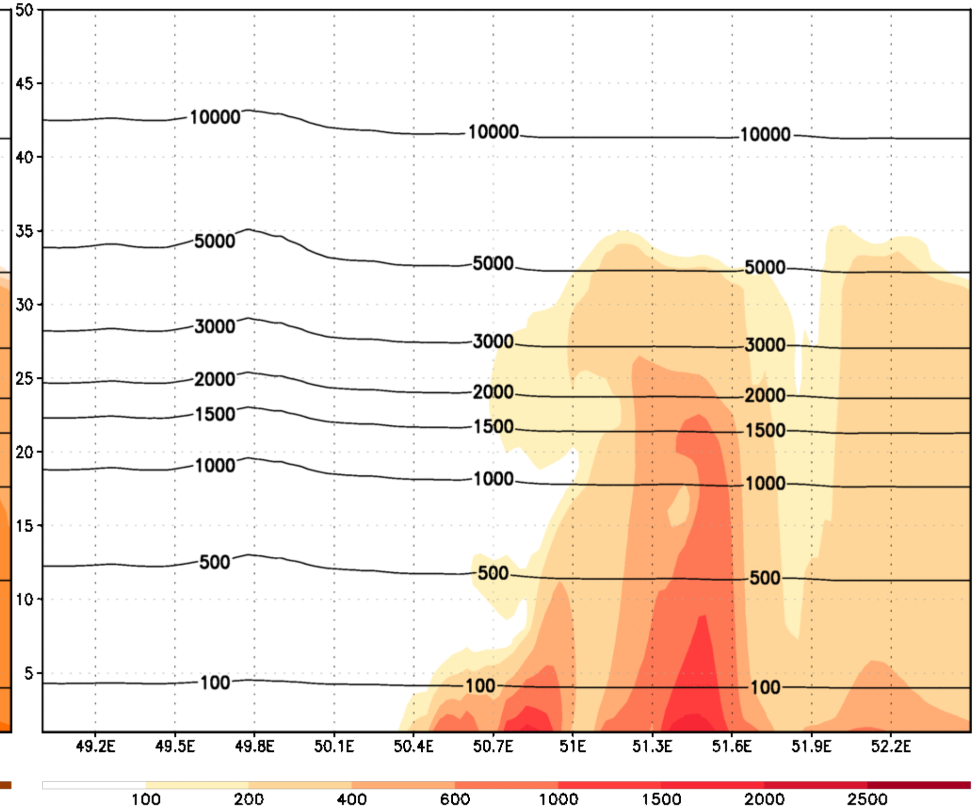
Values are on model levels, altitude of model levels are in black lines.

Vertical cross section along 35N

Dust PM10 concentration



DNC – dust number concentration

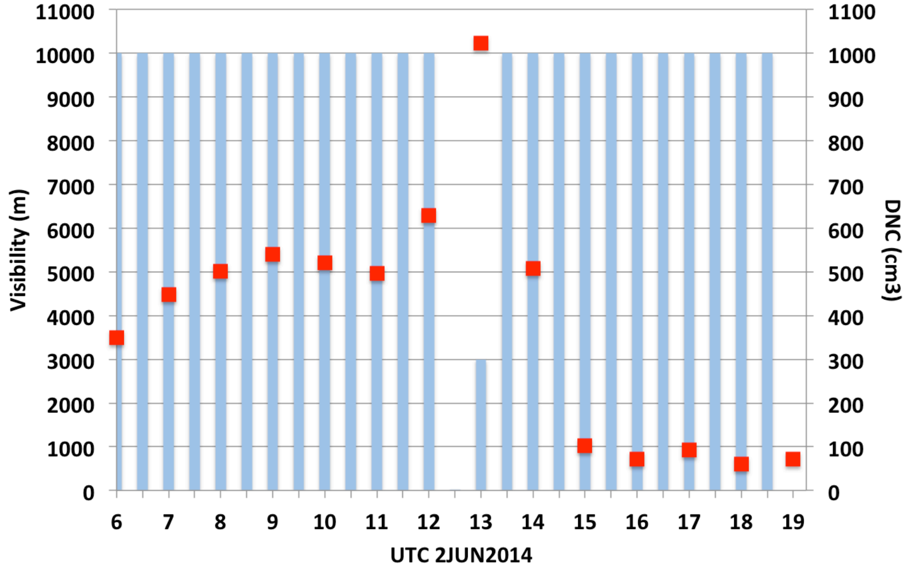


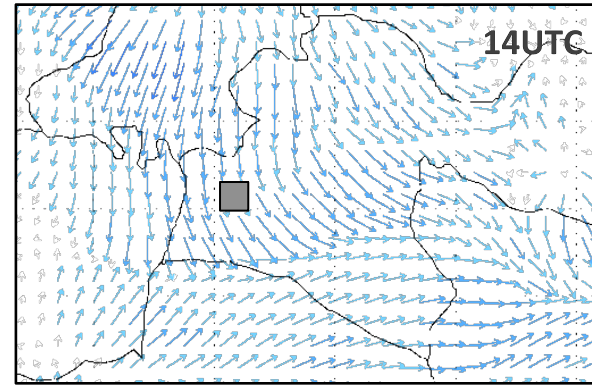
Values are on model levels, altitude of model levels are in black lines.

Imam Khomeini airport OIIE

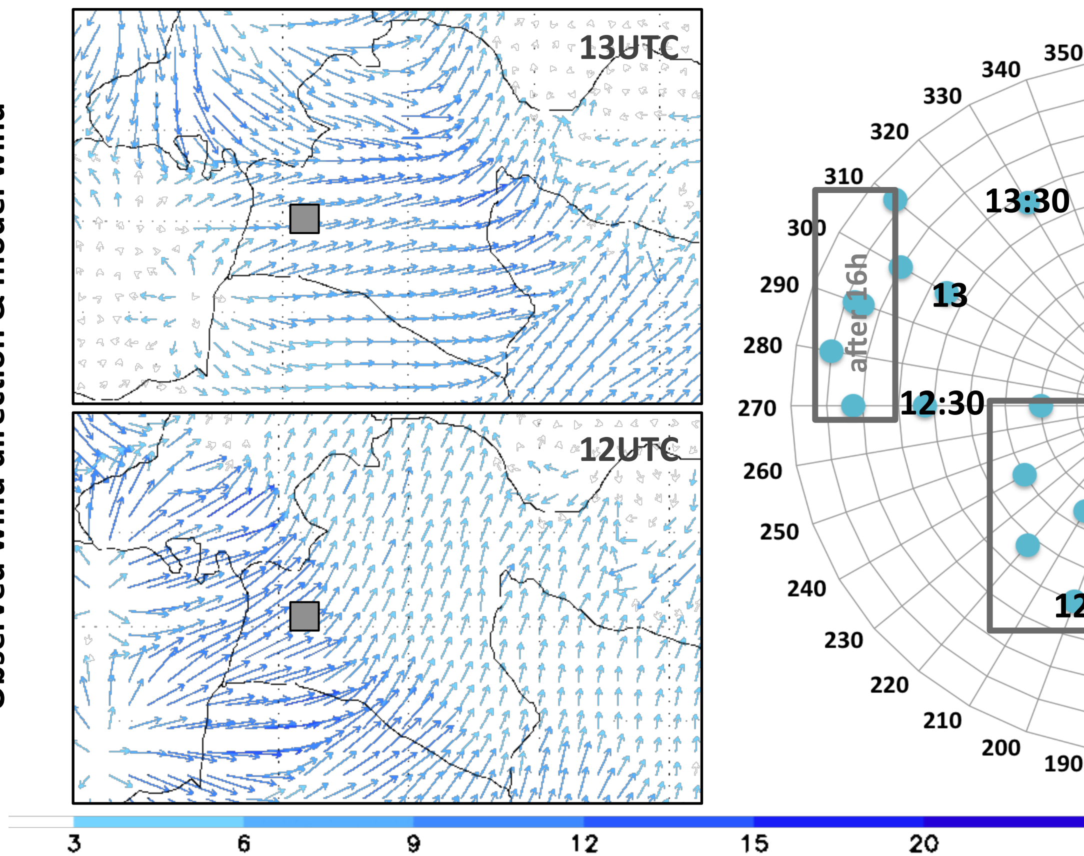
Visibility reduced to 20m at 12:30UTC.
Model output data on available on 1h.

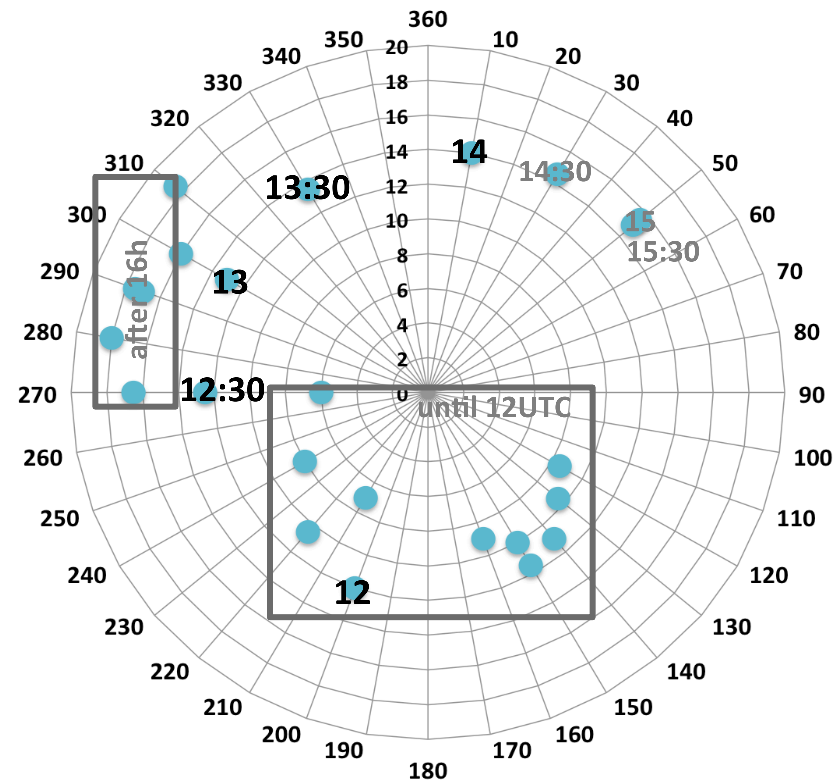
Observed visibility & model DNC



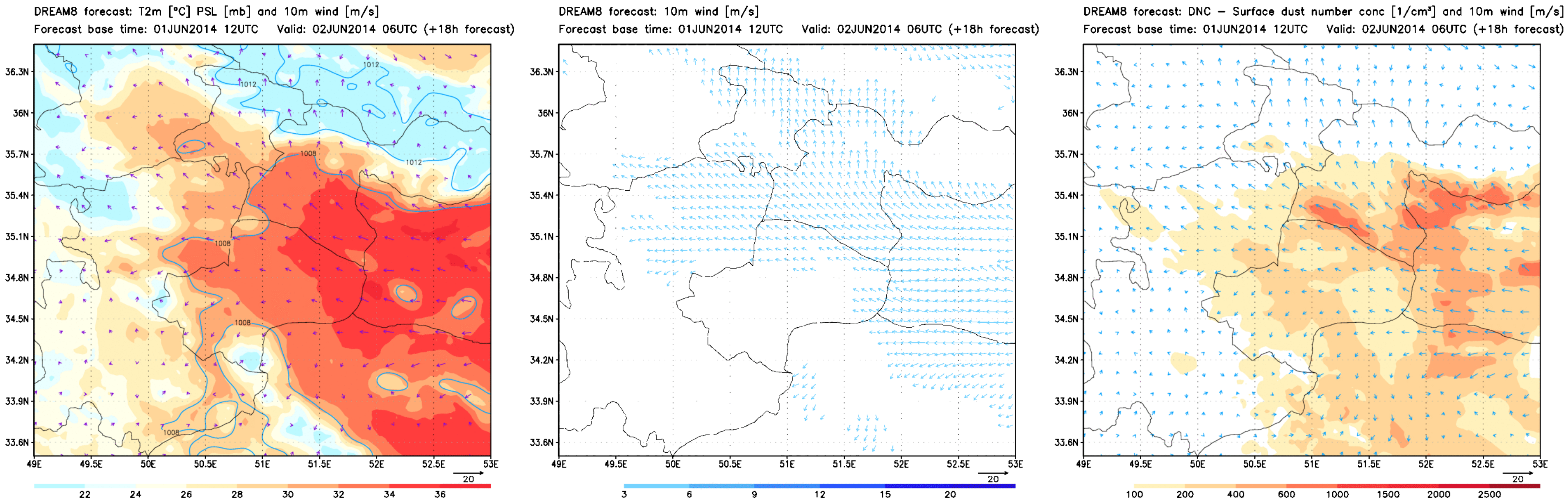


Observed wind direction & model wind





NMME-DREAM (SEEVCCC) simulation results for the period 06-20 UTC 2014



Animation avalaible at:

http://haos.ff.bg.ac.rs/pazisadana/Tehran_training_course_2016/

DUST FORECAST MODEL INTERCOMPARISON: CASE STUDY OF THE DUST STORM OVER TEHRAN ON 2nd JUNE 2014

Joint project in the framework of the WMO SDS-WAS

WORKPLAN

To conduct an in-depth case study of the small-scale, short timed extreme dust storm occurred in Tehran on 2 June 2014:

- qualitative and quantitative description of the storm and environmental conditions which caused such severe event,
- ensemble high resolution coupled atmospheric-dust numerical modelling,
- models' verification,
- identification of dust storm forecast capabilities (benefits and lacks),
- multi-disciplinary and multi-institutional collaboration in developing warning system for such extreme weather event.

MOTIVATION

- Scientific: investigate high resolution dust source identification methods and dust movement dynamics with focus on vertical mixing (high concentration and high speed scenario)
- Social: initialize development of high resolution dust forecast model in service for public safety

INSTITUTIONS

- Department of Environment of the Iranian Meteorological Organization (IRIMO), Tehran, Iran
- Faculty of Geography, University of Tehran, Iran
- Geological Survey of Iran, GSI
- Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS), Spain
- Karlsruhe Institute Technology (KIT), Karlsruhe, Alemania
- Leibniz Institute for Tropospheric Research (TROPOS), Leipzing, Germany
- South East European Virtual Climate Change Center (SEEVCC), Belgrade, Serbia
- National Observatory of Athens (NOA), Athens, Greece
- UK MetOffice, Exeter, United Kingdom
- NOAA/NWS/NCEP Environmental Modeling Center, New York, USA
- Italian Research Council (CNR), Bologna, Italy
- Egyptian Meteorological Authority (EMA), El Cairo, Egypt
- Centro de Investación Atmosférica de Izaña-Spanish Weather Agency (CIAI-AEMET), Santa Cruz de Tenerife, Spain
- and counting…

Nature of experts involvement: modelers, data providers, advisors, observers.

PROGRESS

- identification of participants' role in the project finished;
- gathering observation, input model data and model simulations in progress.

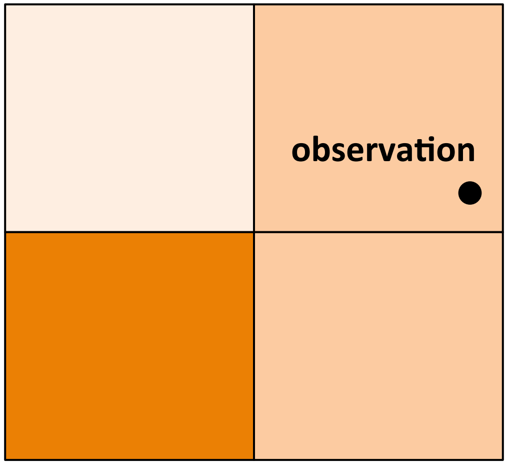
Contact person: Ana Vukovic (pazisadana@gmail.com ; anavuk@agrif.bg.ac.rs)

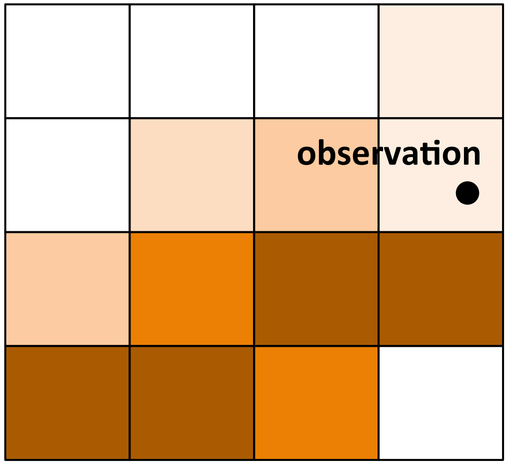
Future work

- Collect more different models' simulations
- Possible correction of the dust masks
- Collect observations and define nature and characteristics of the storm
- Comparison and evaluation of the dust forecast quality

Note:

- Verification method must be adjusted to the available observations
  (usual methods not applicable because of the large temporal and spatial variability of the airborne dust)
- ***Double penalty problem!!!***
  (recognized in precipitation verification; meaning: decrease of scores with increase of resolution)





Dust concentration is higher in the coarse model resolution then in the fine model resolution, but no event is visible. Fine resolution model see the event better but dust plume in model is shifted because of small bias in wind direction and standard verification method (calculating scores comparing point on point values) will give false conclusion that fine resolution model didn't reproduced the storm.