The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

**2148-26**

**Fifth ICTP Workshop on the Theory and Use of Regional Climate Models**

***31 May - 11 June, 2010***

# The effects of mineral aerosols on the summertime climate of Southwest Asia

MARCELLA PACE Marc

*Dept.of Earth, Atmosphere & Planetary Sciences*
*Massachusetts Institute of Technology, 77 Massachusetts Ave.*
*Bldg. 48, MA 02139-4307*
*Cambridge*
*U.S.A.*

# Improving the modeling of mineral aerosols over semi-arid regions

## Enhancements made to the dust emission scheme of RegCM3

Marc P. Marcella

Elfatih A.B. Eltahir

Massachusetts Institute of Technology

Department of Civil & Environmental Engineering
Massachusetts Institute of Technology

# Outline

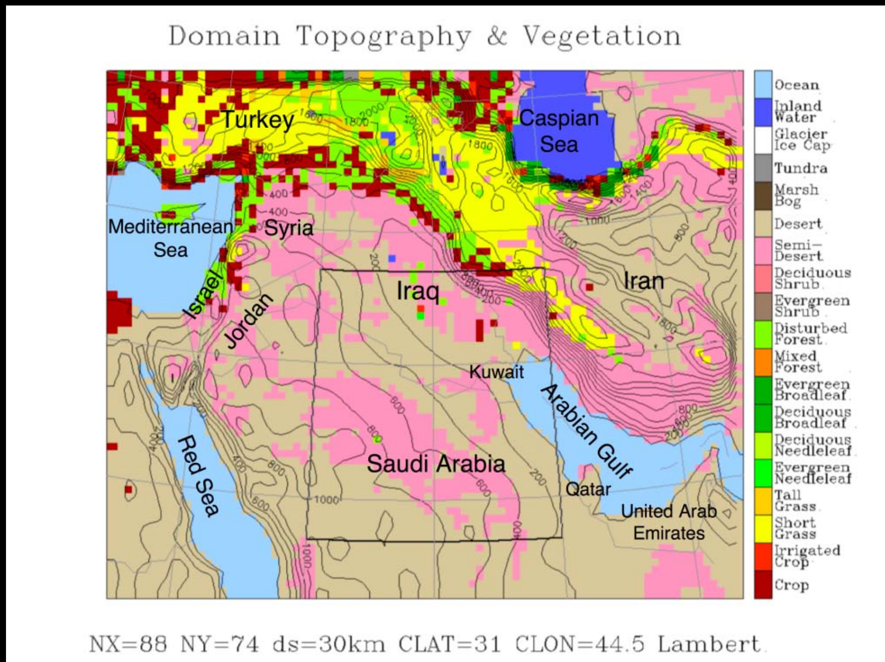
1. Motivation
2. Implementation of sub-grid surface variability
   - Wind gustiness
   - Land cover/roughness length
3. The role of dust concentration boundary conditions
4. Future work

# Motivation - Impacts of Dust Emissions

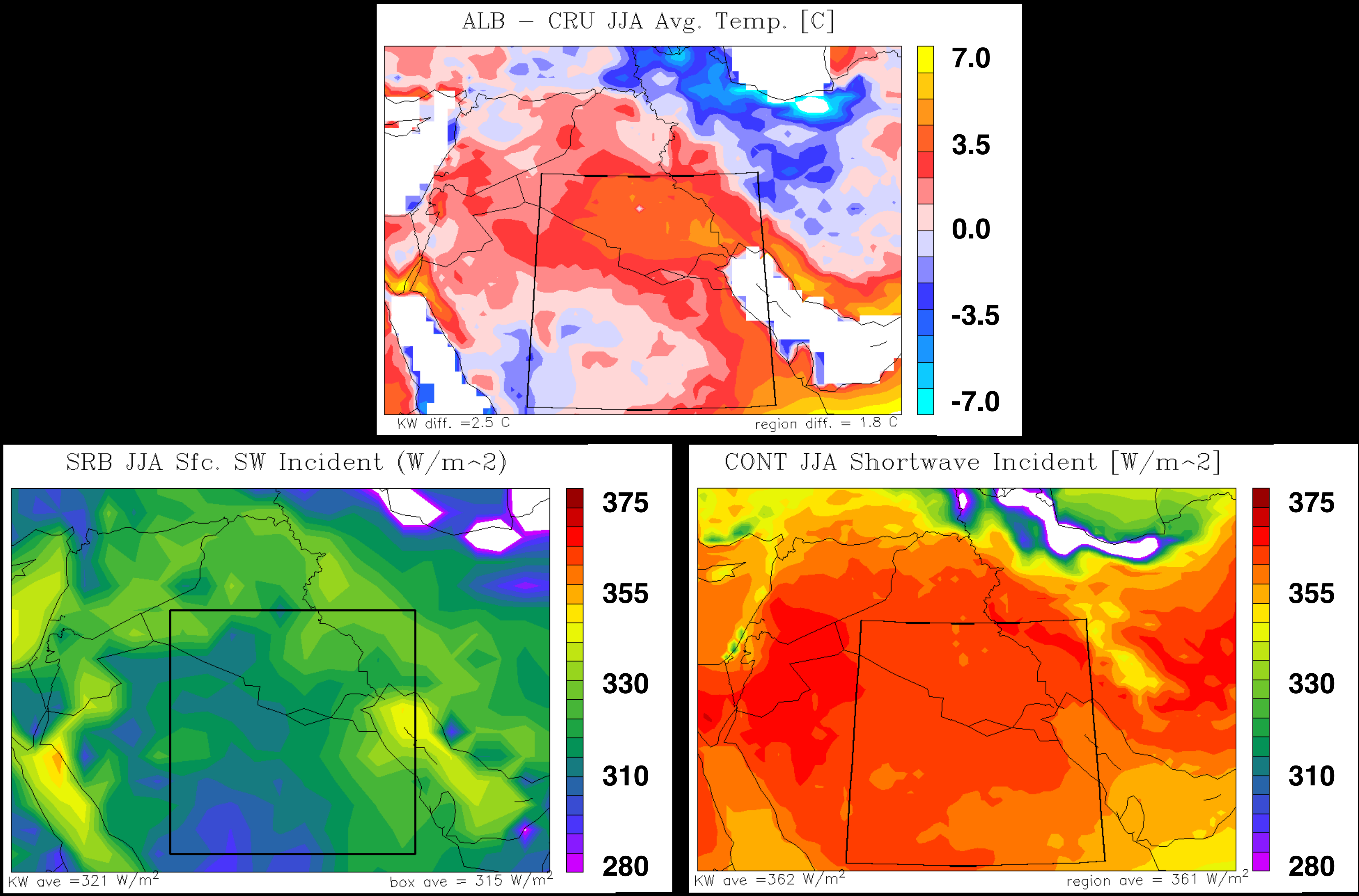
- Dry seasons bring dust storms that dramatically alter landscape and habitability
- Mineral aerosols have profound effects on climate (Miller & Tegen 1998, Sokolik 2001)
- Significant biases in surface temperatures and shortwave incident radiation

# Motivation - Area of Interest

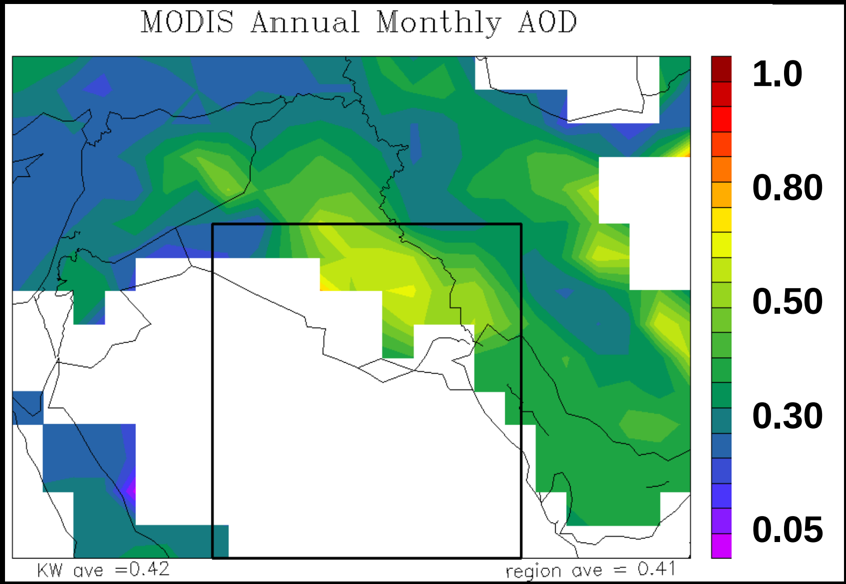
- SW Asia - strong seasonality in precipitation and therefore dust emissions (April - September)
- RegCM3 simulations - 5 year, 30 km resolution, NNRP2, OISST, Modified Kuo (Marcella & Eltahir, 2008)

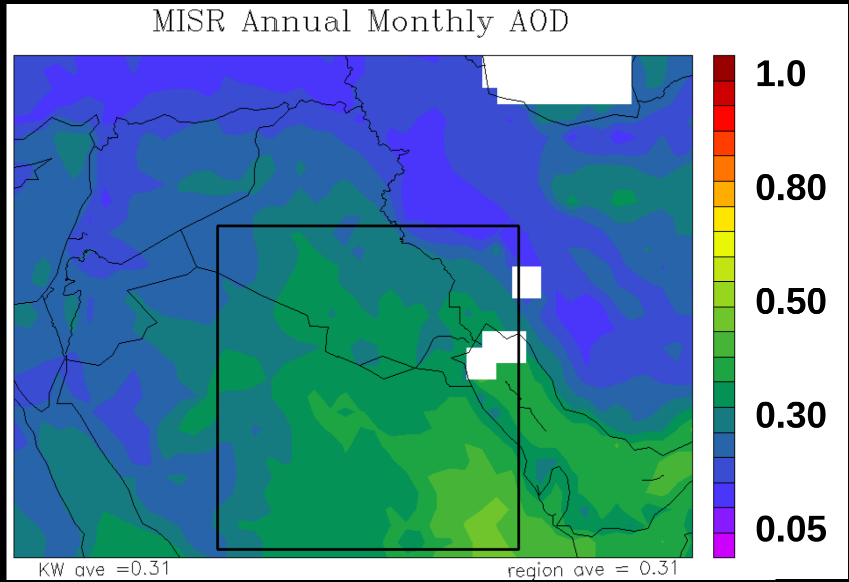


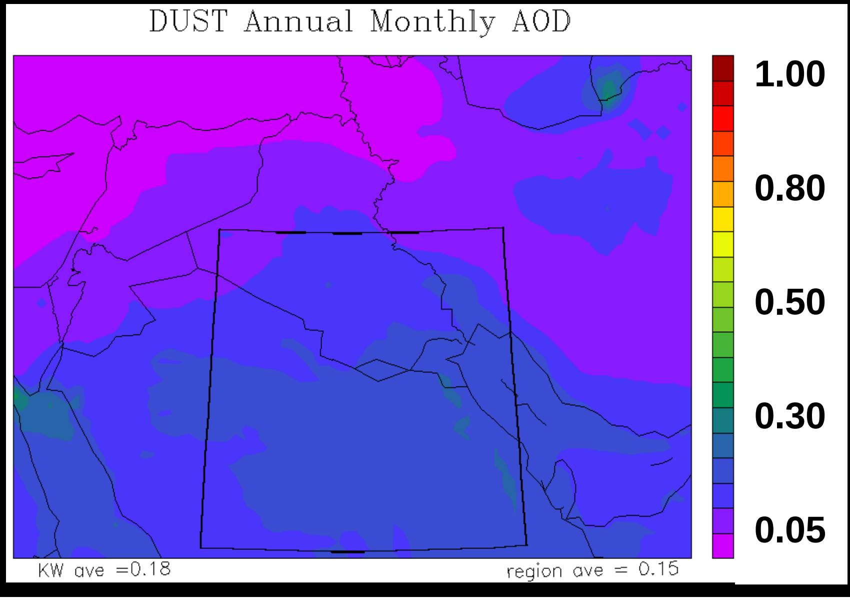
# Motivation - Surface Biases



# Motivation - AOD Bias



# Quantifying wind variability

- Assume a normal distribution of wind speed in a given grid-cell with model resolved mean value (Cakmur, et al 2004)

- Assume variance in grid-cell can be described by model meteorology: the dry convective scale---kinematic heat flux
    - dry convective eddies by strong surface heating in the vertical are proxies for horizontal fluctuations of wind within the PBL (Wyngaard, 1985)

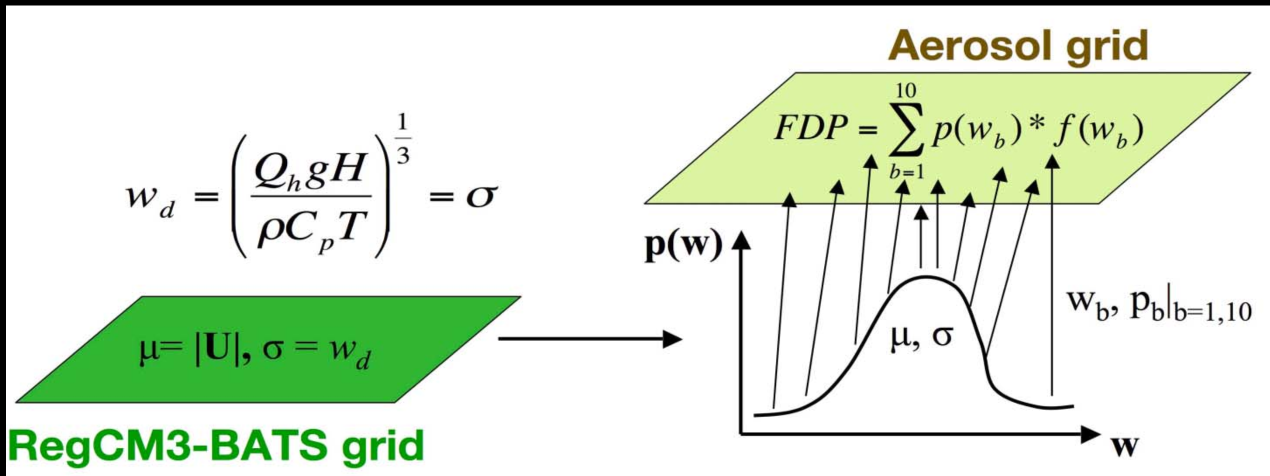
- Binned values for wind distribution within the dust model are run through entire emissions equations & integrated based on probability of wind (bin) value



Marcella and Eltahir, *JGR*, 2010

# What wind variability looks like

- Assume a normal distribution for surface wind using RegCM3/BATS surface mean winds for gridcell, and dry convective scale (kinematic heat flux) as standard deviation
  - create 10 wind bins (user chooses, covers 99% CL) with corresponding probability, passed to aerosol model to compute emissions




Marcella and Eltahir, *JGR*, 2010

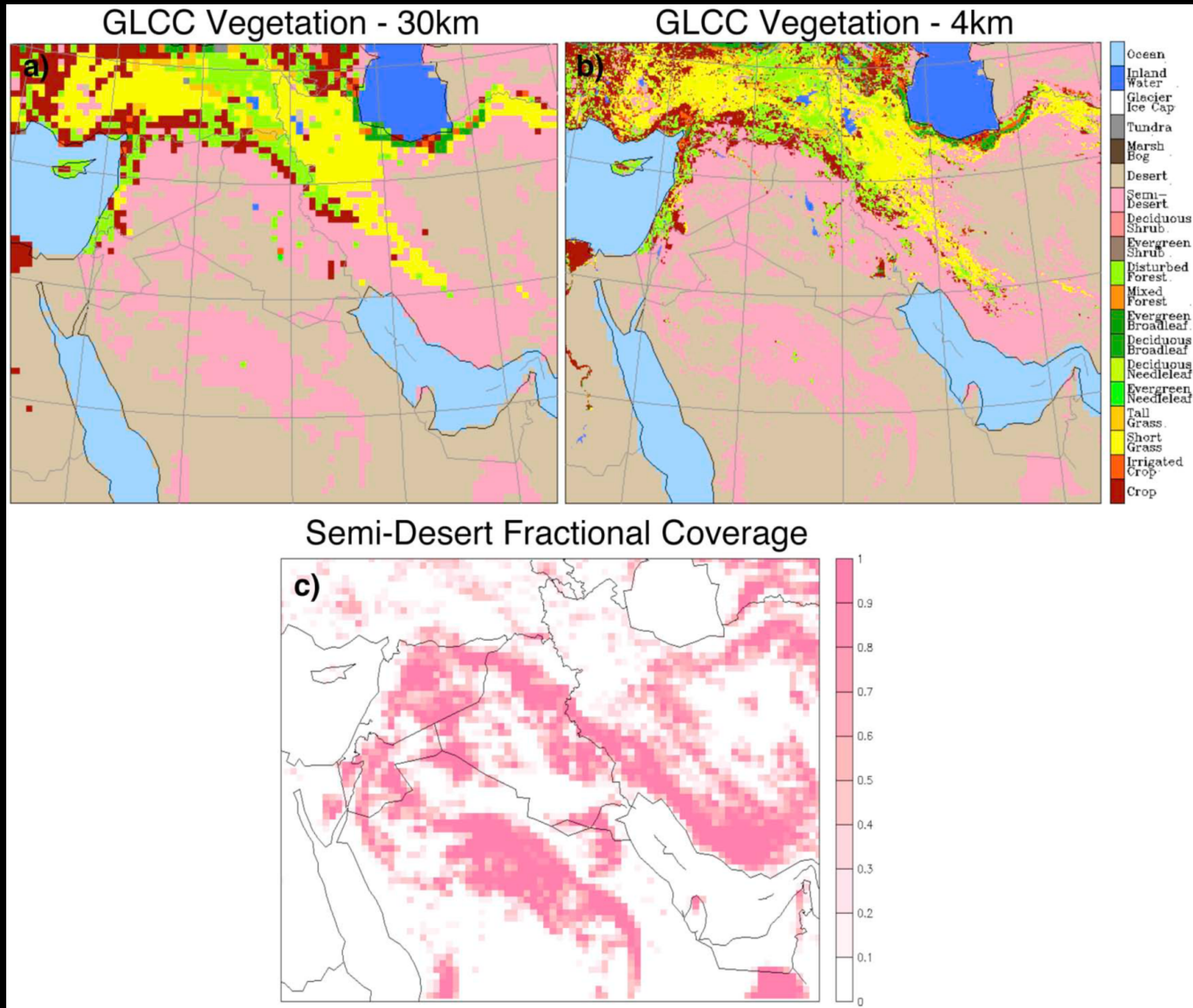
# Roughness Length Variability

- Use GLCC land cover (4km dataset) to fit empirical distribution of roughness length over a given model (i.e. 30km) grid-cell
- Bin for each land cover the possible emissions given its roughness length value (new values for wind threshold and friction velocity)
- Integrate over the percentage of each grid-cell covered with the respective land cover to get total emissions

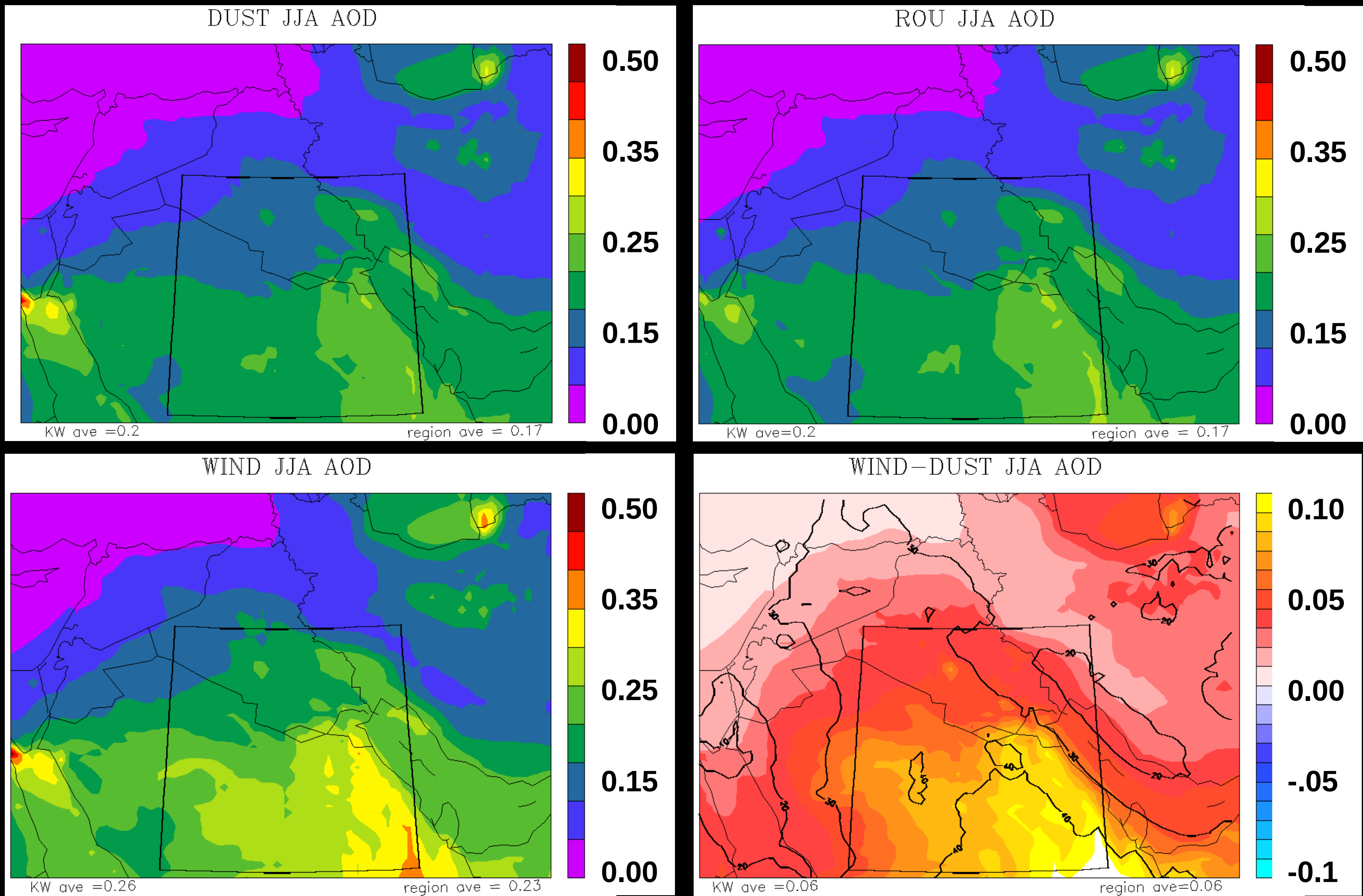


Marcella and Eltahir, *JGR*, 2010

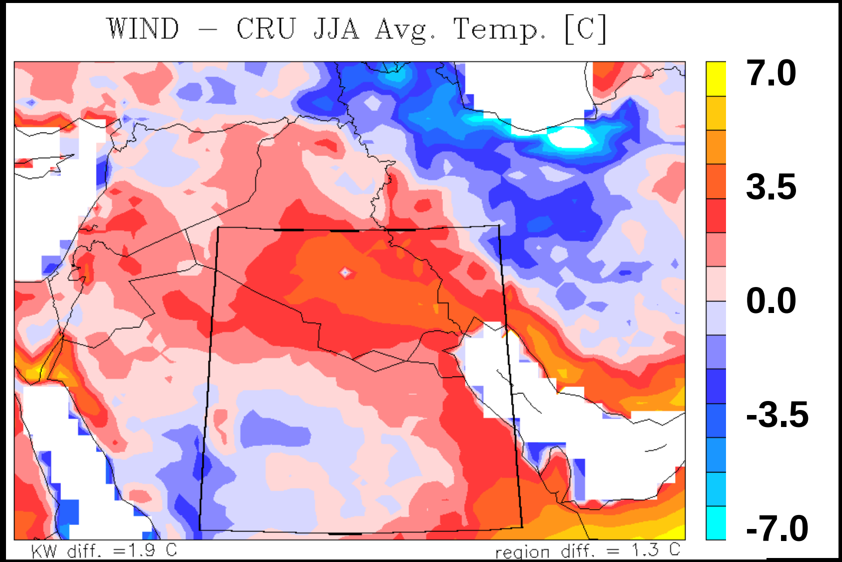
# What Roughness Variability Looks Like

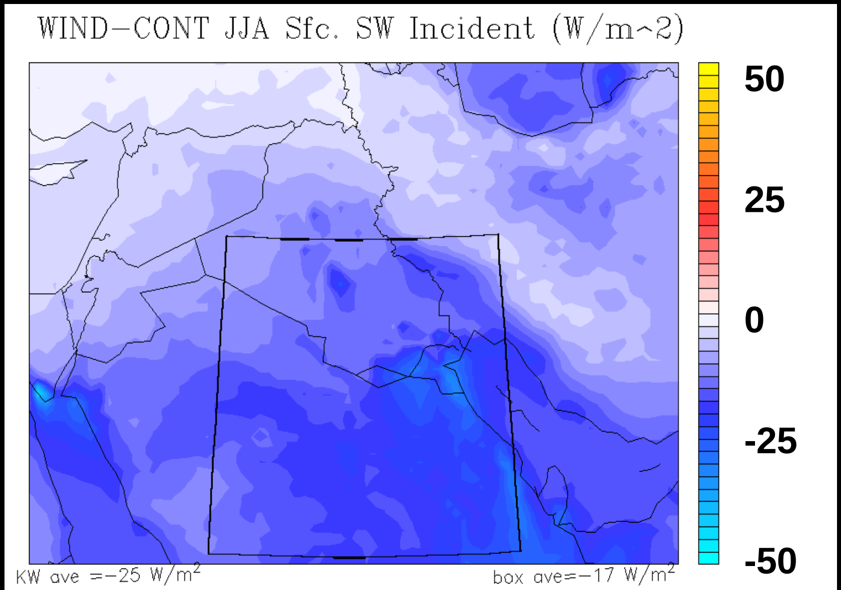


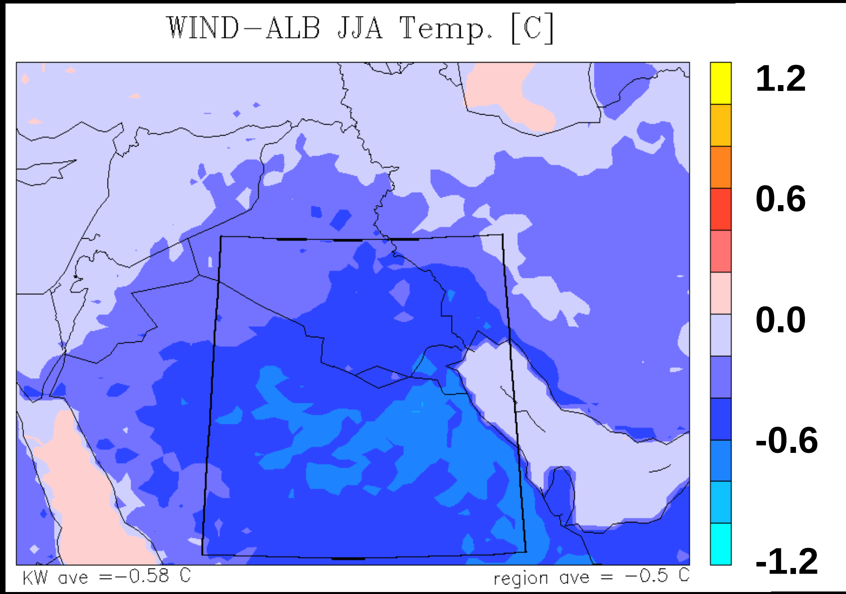
# Effects of sub-grid variability on AOD



# Impact of Dust on Surface Climate



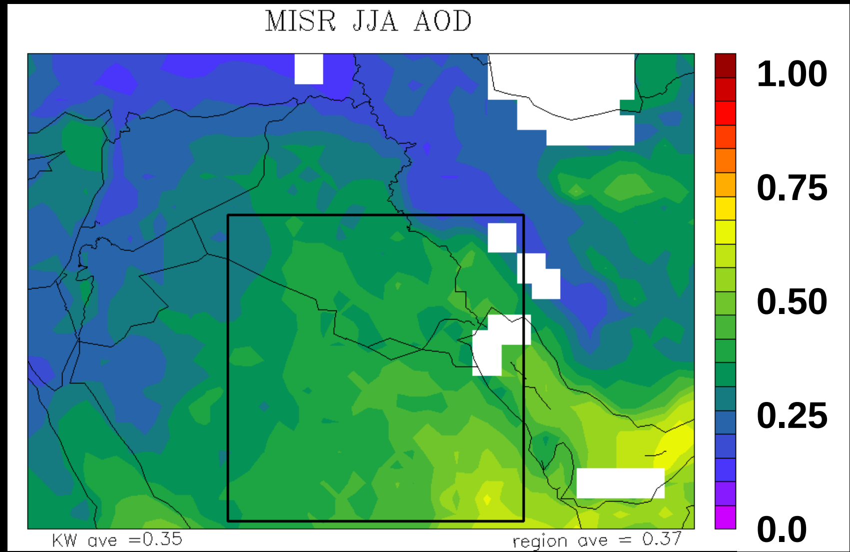
# Conclusions from Dust & Sub-grid Variability

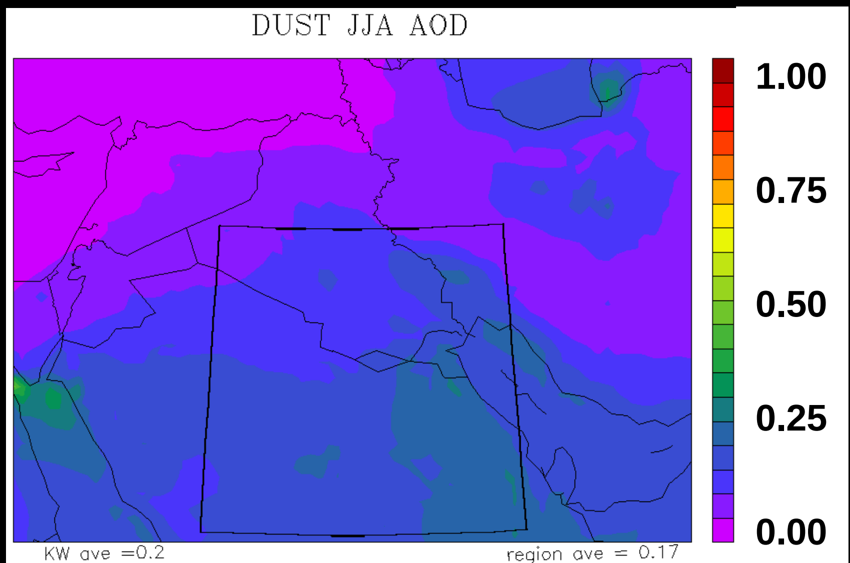
- Average daily surface cooling from dust ranges from 0.5°-1°C across the Arabian Peninsula.

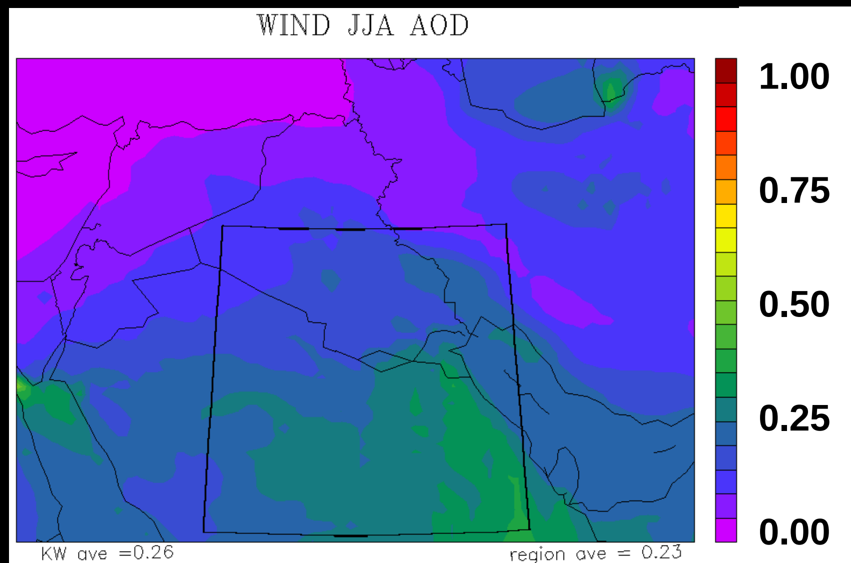
- Incident shortwave attenuation of nearly 30 $W/m^2$ occurs throughout the region with most reduction occurring in the sensible heat flux.

- Model shows strong response to including sub-grid variability for wind but not roughness length---modeled AOD values closer to observations particularly MISR estimates.

# Still a bias in AOD...



# Dust at the boundaries

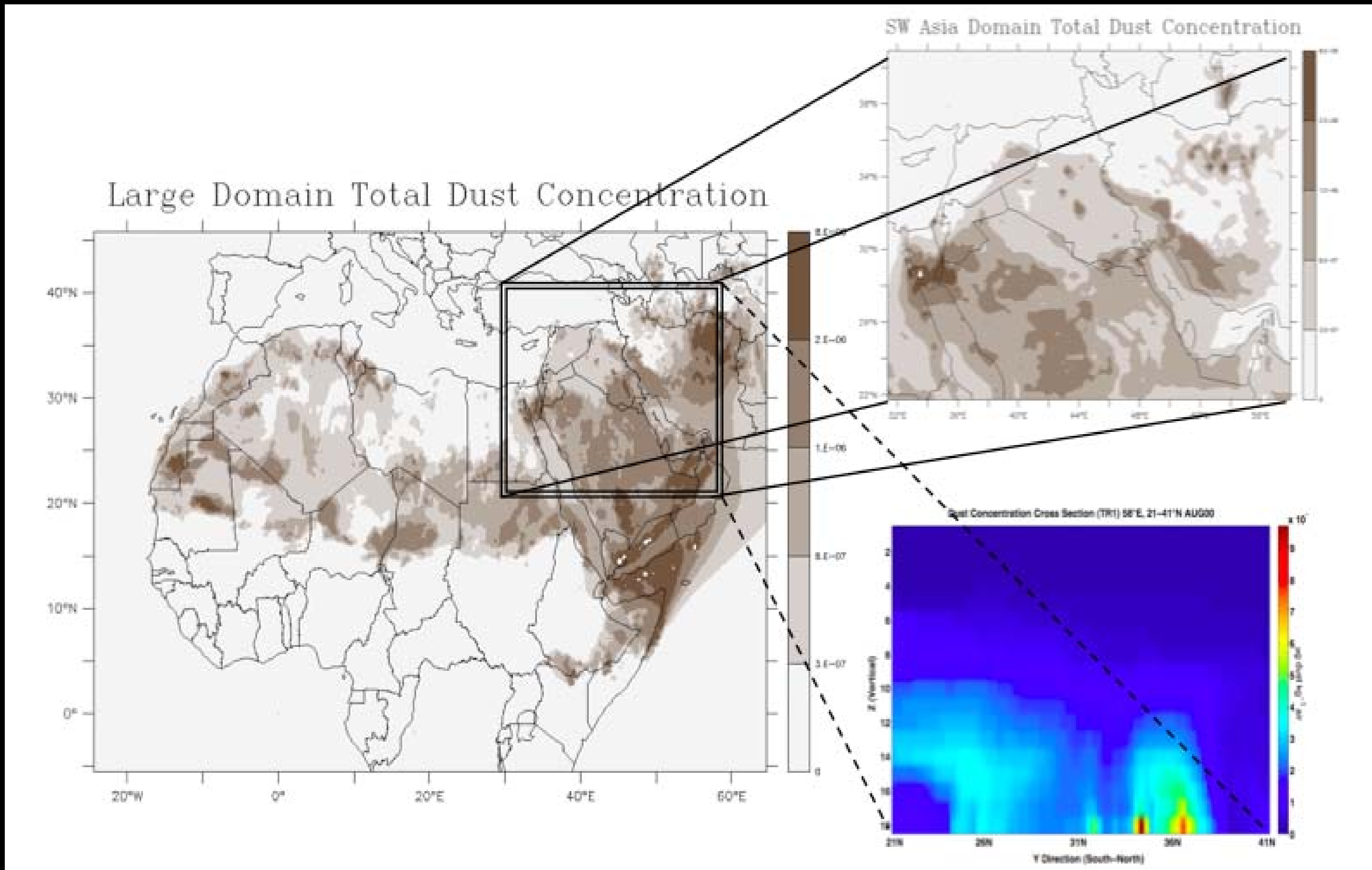
- Currently RegCM3 aerosol and dust model operates over interior of model, setting the boundaries to zero and allowing only transport of dust from the interior to the boundary slices.

- Use dust output from larger RegCM3 output to fix the boundaries (in bdyval.f) in x-z and y-z slices to average dust concentrations for each tracer bin.

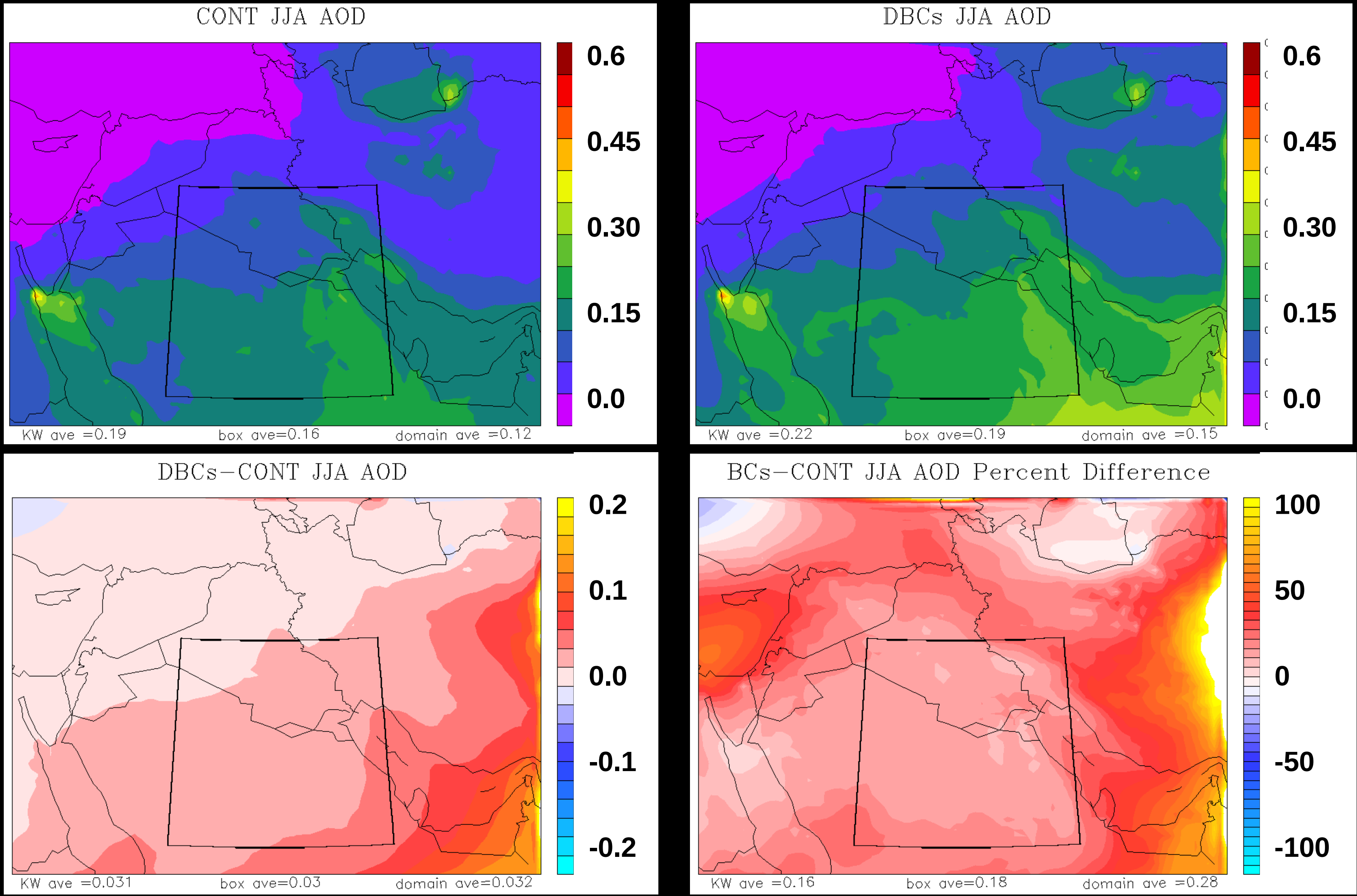


Marcella and Eltahir, *Climate Dynamics*, *in review*

# Boundary conditions schematic

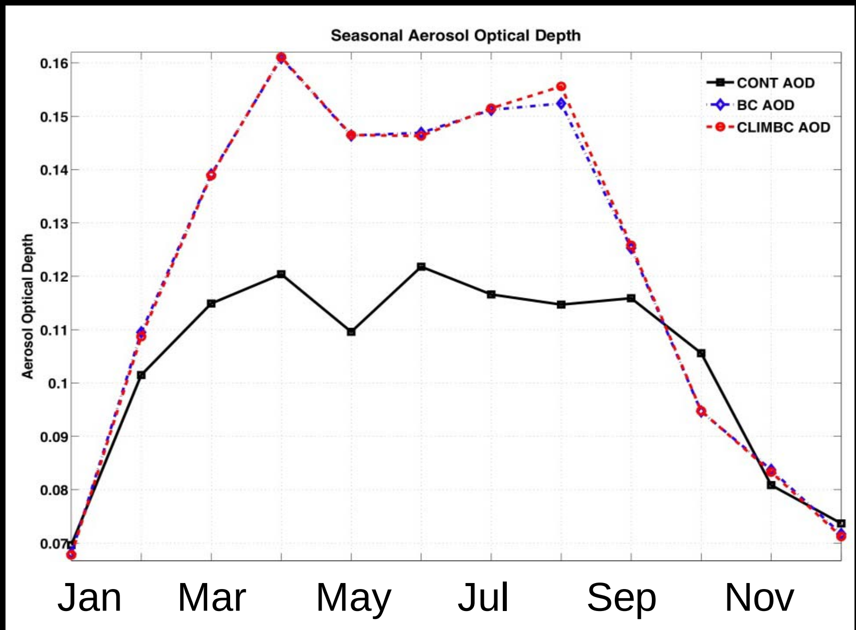


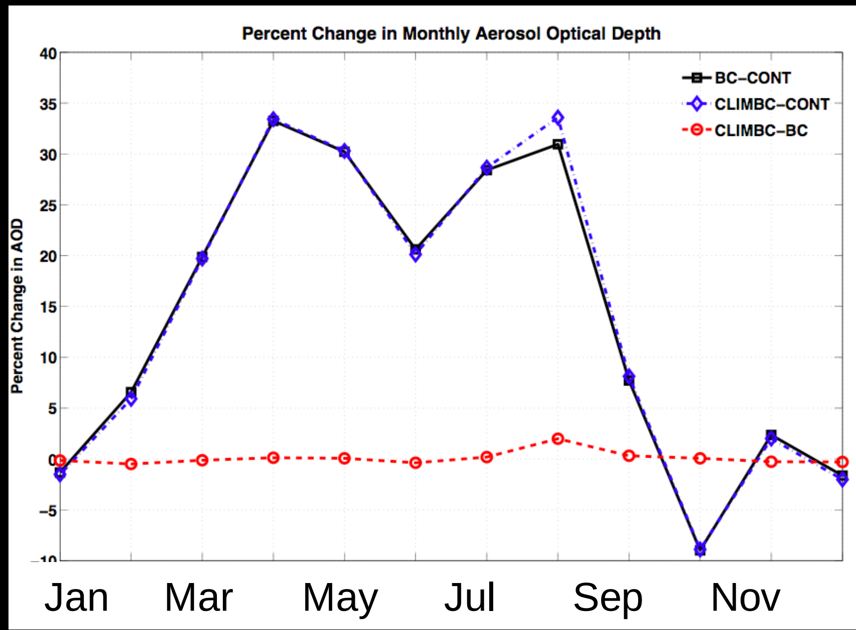
# Impact of boundary conditions on AOD



# Effects on dust seasonality

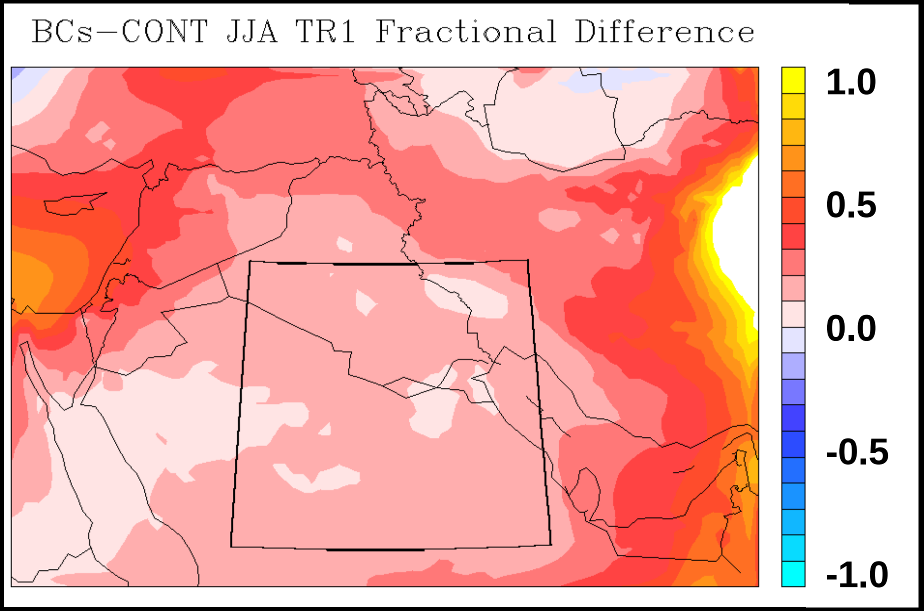
- Increase in seasonality with summer months 20-30% larger dust loading with boundary conditions implemented

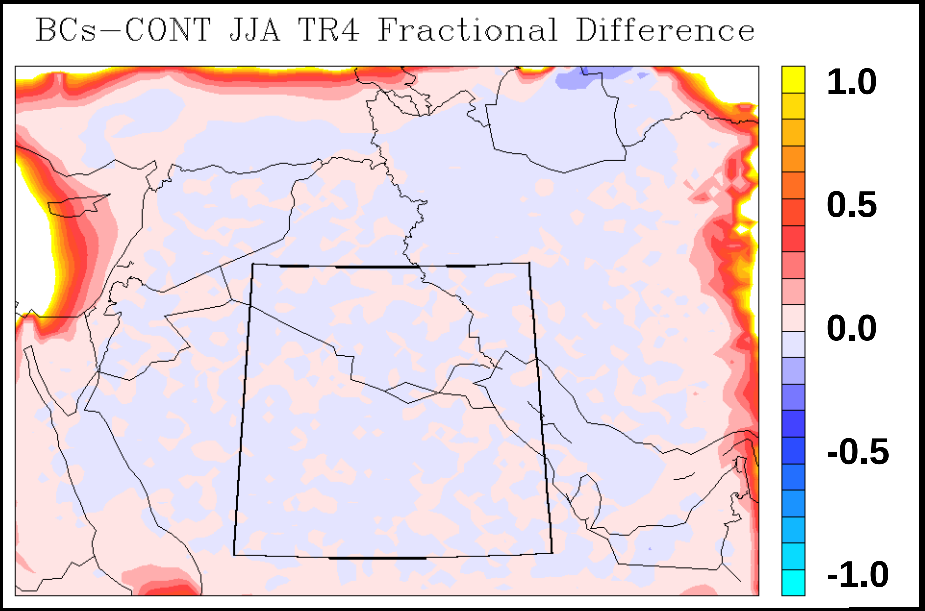


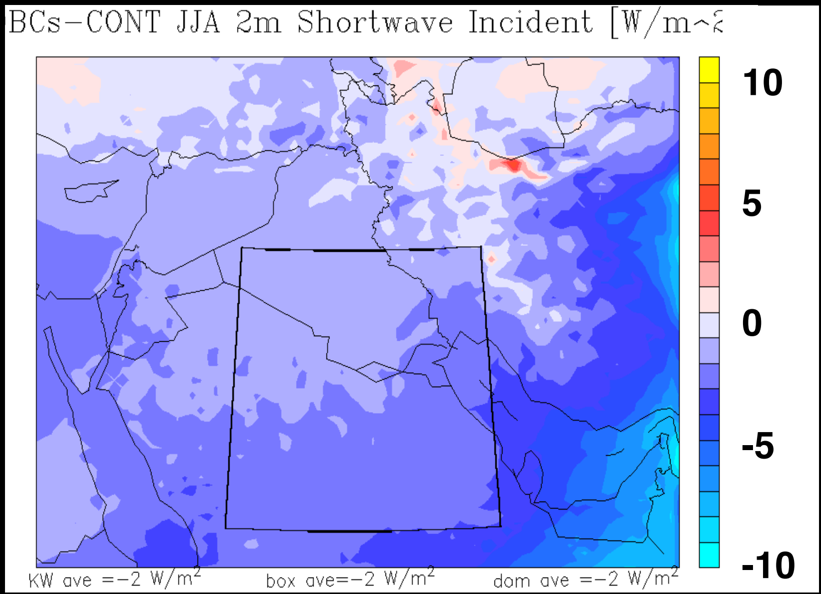
# Tracer size dependent

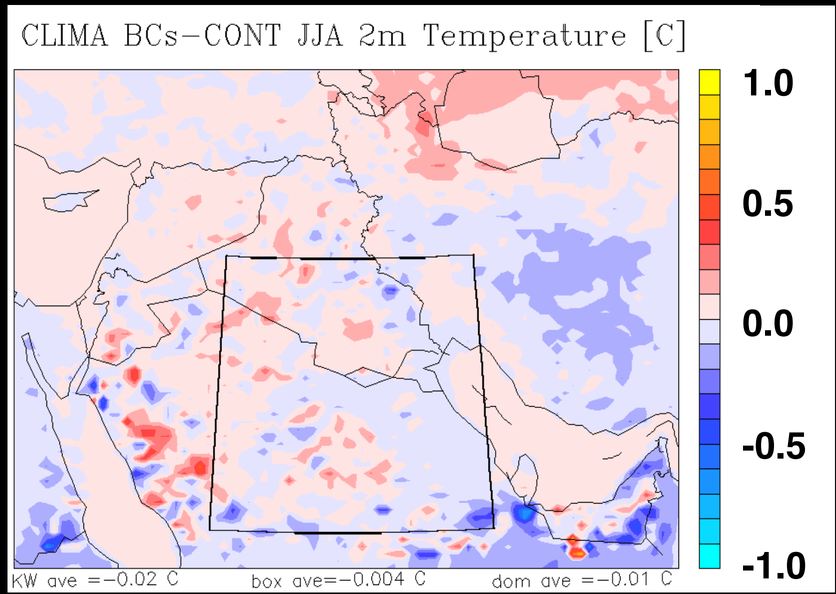
- At the boundaries, smaller tracers (e.g. tracer 1) are transported further into the domain, and therefore are more important as boundary conditions.



# Impact of boundary conditions



# Boundary condition conclusions

- Including boundary conditions has a significant impact on the mean (magnitude and spatial) summertime dust loading over SW Asia (20-30% increase) as well as seasonal variation.
- The eastern border experiences increase in dust loading due to advection into the domain while the southern boundary sees increases due to diffusion.
- At the boundaries, lighter or small dust particles are more important as boundary conditions than larger particles.

# Future work

- Sub-grid representation for variability in soil moisture
- Still underestimating dust loading (missing sources in N. Iraq, fall out too quickly)
- Use of a climatology dataset for dust concentration boundary conditions (from GCM-tracer model output, observations, etc.)
- Investigate changes in extremes and daily maximum temperatures caused by dust emissions