Evaluating aerosols impacts on Numerical Weather Prediction

Introduction

This project aims to improve our understanding about the following questions:

- How important are aerosols for predicting the physical system (NWP, seasonal, climate) as distinct from predicting the aerosols themselves?
- How important is atmospheric model quality for air quality forecasting?
- What are the current capabilities of NWP models to simulate aerosol impacts on weather prediction?

The general outline of the proposed work is:

- Select strong or persistent events of aerosol pollution worldwide that could be fairly represented in the current NWP model allowing the evaluation of aerosol impacts on weather prediction.
- Perform model runs both including and not the feedback from the aerosol interaction with radiation and clouds.
- Evaluate model performance in terms of AOD simulation compared to observations (e.g. AERONET/MODIS data) or any other related aerosol observation available.
- Evaluate aerosol impacts on the model results regarding 2-meter temperature and dew point temperature, 10-meter wind direction and magnitude, rainfall, surface energy budget, etc.

Cases studies

Case 1: Dust storm on April 18, 2012

Description

After dust blew off the coast of Libya and over the Mediterranean Sea for two days, a wall of dust moved eastward over Egypt. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured this natural-color image on April 18, 2012 (Figure 1). The dust plume extended roughly north-northeast to south-southwest, and the dust was thick enough to completely hide the land surface below. On either side of the plume, skies were mostly clear—along the Libya-Egypt border, and over part of the Nile River Valley. A ghostly outline of the Nile Delta appeared through the north-eastern edge of the dust storm. Source points for the dust storm are not obvious in this image, but the dust likely arose from the rich sand seas of north-eastern Libya and north-western Egypt. A change in wind direction probably carried the dust toward the southeast after two days of moving the dust northward over the Mediterranean Sea.

Experiment set-up

- Aerosol effects: forecast with and without interactive aerosols, limited to direct effect only. Each participant defines if the aerosols fields will be climatological or prognostic.
- Duration and time period: 10 days, April 13-23 2012.
- Length: 10 days forecasts from the 00UTC or 1200UTC analysis with and without interactive aerosols.

- Center of the model domain (for limited area models): 30^0 E, 25^0 N
- Model configuration should be compatible with the configuration of the operational system used currently for NWP.
- Initial and boundary conditions for meteo fields can be provided upon demand by ECMWF (eg MACC fields including aerosols) for the limited area models.
- Variables to compare:

Variable name on 3 hours interval	Dimensio -nality	units	obs
2m-Temperature	x,y	K	
10m-wind direction and magnitude	x,y	Degree m/s	
Aerosol optical depth at 550 nm	x,y	-	
Dust aerosol mass column integrated	x,y	kg/m^2	
shortwave and longwave downwelling radiative flux at the surface.	x,y	W/m^2	
temperature tendency associated to the total radiative flux divergence.	x,y,z	K/s (or dy)	
Temperature	x,y,z	K	
Relative Humidity	x,y,z	-	

- Output should be using a lat-lon rectangular grid. The preferred format is NETCDF.

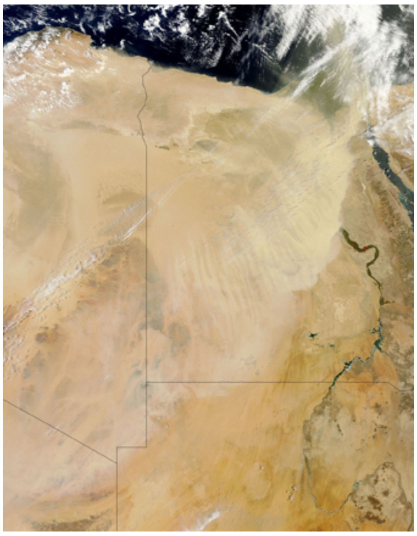

Figure 1. The dust storm case (source: http://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2012-04-22)

Case 2: Extreme pollution in Beijing on 12-16 January 2013

Description

Between January 12 and January 16 2013 an extremely severe episode of pollution in Beijing and surrounding areas was reported. Levels were above the worst Air Quality (AQ) Index ("Hazardous") as defined by the Environment Protection Agency (EPA) with levels of particulate matter smaller than 2.5 microns (PM2.5) greater than 700µg/m3. Beijing's high pollution levels were deemed to be caused by local industry and transport sector emission as well as regional impact, and were affected by weather conditions. The winter season is usually the most polluted time of the year in North China because of the significant emissions from coal combustion. The situation in January was aggravated by the poor dispersion of pollutants in Beijing and its surrounding areas, including Hebei, Henan and Shandong provinces, also due to a lingering high-pressure system. Severe pollution was also reported later in the month (Jan 29th).

Figure 2. Left: Satellite image of Beijing smog on January 14. The brightest areas tend to be clouds or fog, which have a tinge of gray or yellow from the air pollution. Other cloud-free areas have a pall of gray and brown smog that mostly blots out the cities below. (Source: http://earthobservatory.nasa.gov/IOTD/view.php?id=80152). Right: Picture of a hazy day in Beijing, China, January 14, 2013 (Source: http://news.yahoo.com/photos/china-s-air-pollution-problem-slideshow/).

Experiment set-up

- Aerosol effects: forecast with and without interactive aerosols, including direct and indirect effects. Each participant defines if the aerosols fields will be climatological or prognostic. Ideally four experiments should be performed:

Experiment	Direct effect	Indirect effect	Direct + indirect effects	No aerosol interaction
1	X			
2		X		
3			X	
4				X

- Duration and time period: 14 days, from January 7 to January 21 2012
- Length: 10 days forecasts from the 00UTC or 1200UTC analysis with and without interactive aerosols.
- Center of the model domain (for limited area models): 116^0 E, 40^0 N
- Model configuration should be compatible with the configuration of the operational system used currently for NWP.
- Initial and boundary conditions for meteo fields will be provided upon demand by ECMWF (eg MACC) for the limited area models.
- Variables to compare:

Variable name on 3 hours interval	Dimensio-nality	units	obs
2m-Temperature	x,y	K	
10m-wind direction and magnitude	x,y	Degree m/s	
Aerosol optical depth at 550 nm	x,y	-	
total aerosol mass column integrated	x,y	kg/m^2	
Precipitation (from convective parameterization)	x,y	mm	
Precipitation (from cloud microphysics at	x,y	mm	

grid scale)			
shortwave and longwave downwelling radiative flux at the surface.	x,y	W/m^2	
temperature tendency associated to the total radiative flux divergence.	x,y,z	K/s (or dy)	
Temperature	x,y,z	K	
Relative Humidity	x,y,z	-	
Cloud drop number concentration	x,y,z	cm^{-3}	

- Output should be using a lat-lon rectangular grid. The preferred format is NETCDF.

Case 3: Extreme biomass burning smoke in Brazil – the SAMBBA case

Description

The dry season (Austral winter) over South America is characterized by intense biomass burning (vegetation fires) which produces dense smoke covering large areas of over the continent, but primarily over Brazil. The 3rd case addresses the impact of biomass burning aerosol on weather over the central part of Brazil and adjacent areas. Figure 3 shows (on the left side) the location of the vegetation fires over Brazil and the total number for September 2012. On the right, the associated smoke is shown as the aerosol optical depth at 500nm from MODIS. This case study coincides with the occurrence of the South American Biomass Burning Analysis (SAMBBA) field experiment. The SAMBBA case is not a 'strong' event, but a persistent case of large area covered by smoke from biomass burning for several days.

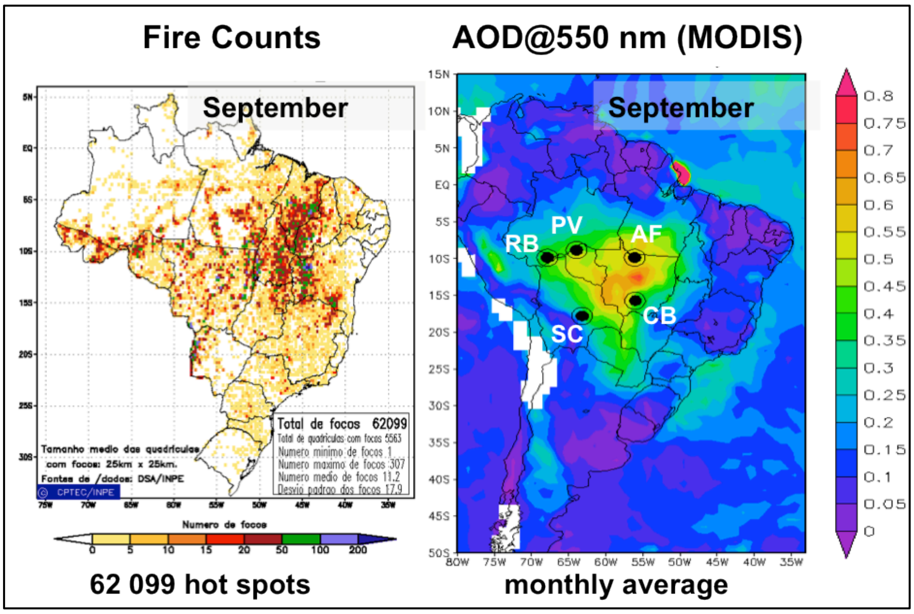

Figure 3. Left: Fire counts location and accumulated for September 2012 (source: http://www.inpe.br/queimadas/). Right: Monthly average of aerosol optical depth at 550 nm from MODIS for September 2012 (source: http://disc.sci.gsfc.nasa.gov/giovanni). The dots with the initials RB, PV, … denote AERONET site locations.

Experiment set-up

- Aerosol effects: forecast with and without interactive aerosols, including direct and indirect effects. Each participant defines if the aerosols fields will be climatological or prognostic. Ideally four experiments should be performed:

Experiment	Direct effect	Indirect effect	Direct + indirect effects	No aerosol interaction
1	X			
2		X		
3			X	
4				X

- Duration and time period: 10 days, September 05-15, 2012
- Length: minimum of 3 days forecasts from the 00UTC or 1200UTC analysis with and without interactive aerosols.
- Center of the model domain (for limited area models): 60^0 W, 10^0 S
- Model configuration should be compatible with the configuration of the operational system used currently for NWP.
- Initial and boundary conditions for meteo fields can be provided upon by ECMWF (eg MACC) for the limited area models.
- Variables to compare:

Variable name on 3 hours interval	Dimensio -nality	units	obs
2m-Temperature	x,y	K	
10m-wind direction and magnitude	x,y	Degree m/s	
Aerosol optical depth at 550 nm	x,y	-	
total aerosol mass column integrated	x,y	kg/m^2	
Precipitation (from convective parameterization)	2-d	mm	
Precipitation (from cloud microphysics at grid scale)	2-d	mm	
shortwave and longwave downwelling radiative flux at the surface.	x,y	W/m^2	
temperature tendency associated to the total radiative flux divergence.	x,y,z	K/s (or dy)	
Temperature	x,y,z	K	
Relative Humidity	x,y,z	-	

- Output should be using a lat-lon retangular grid. The preferred format is NETCDF.

General Information /Agenda

a. The deadline for providing model simulations and results is 30 January 2014.
b. The participants should fill up the table below indicating for which case they will provide the simulation data and return it as soon as possible:

Participant	Case 1	Case 2	Case 3

c. The Brazilian Center CPTEC/INPE will provide an ftp area to store all provided simulations and perform data analysis and inter-comparison.
d. The models inter-comparison and results will be discussed in the 2014 WGNE meeting in Australia.
e. The primary contact is Saulo Freitas (saulo.freitas@cptec.inpe.br).