Working Group on Numerical Experimentation (WGNE)
Exercise on Aerosol Impact on NWP

Evaluating the Impact of Aerosols on Numerical Weather Prediction

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with input from Saulo Freitas, Angela Benedetti and many participants

World Weather Open Science Conference
Montreal, Canada
16-21 August 2014

Outline

- Goals of Exercise
- Proposed case studies
- Participating Centers & modeling systems
- Webpage and analysis tool
- Preliminary results
  - Case 1: Dust Storm over Egypt
  - Case 2: Extreme Pollution Event in China
  - ~~Case 3: Biomass Burning~~
- Concluding Remarks

Aerosol Direct effect

Solar Radiation Scattered to Space

Mostly Scattering Aerosol

Less Solar Radiation Reaches Surface

Surface Radiative Cooling

(e.g. sulfate, sea salt aerosols)

Solar Radiation Scattered to Space

Mostly Absorbing Aerosol

Solar Radiation Absorbed by Aerosol Layer

Atmospheric Radiative Warming

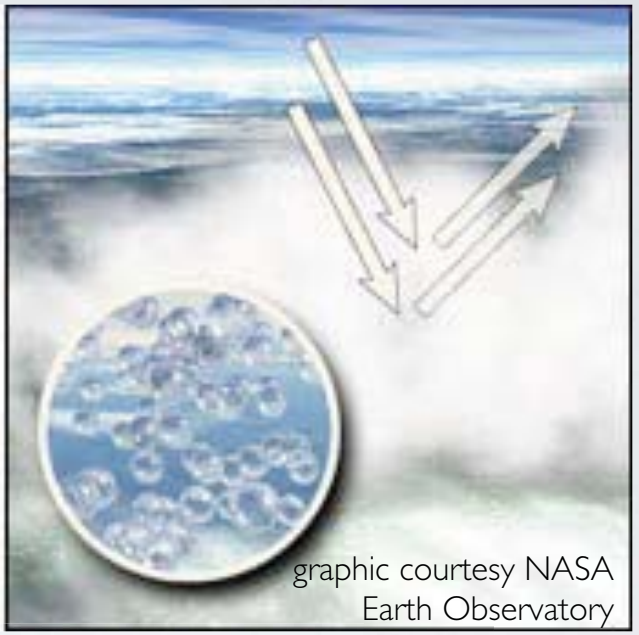
Less Solar Radiation Reaches Surface

Surface Radiative Cooling

(e.g. black carbon, dust aerosols)

Animation by C. A. Randles

Aerosol INDirect effect



Larger cloud droplets, less reflective cloud.

Twomey Effect

Smaller cloud droplets, more reflective cloud.

Less Aerosols Increased Cooling by Clouds More Aerosols

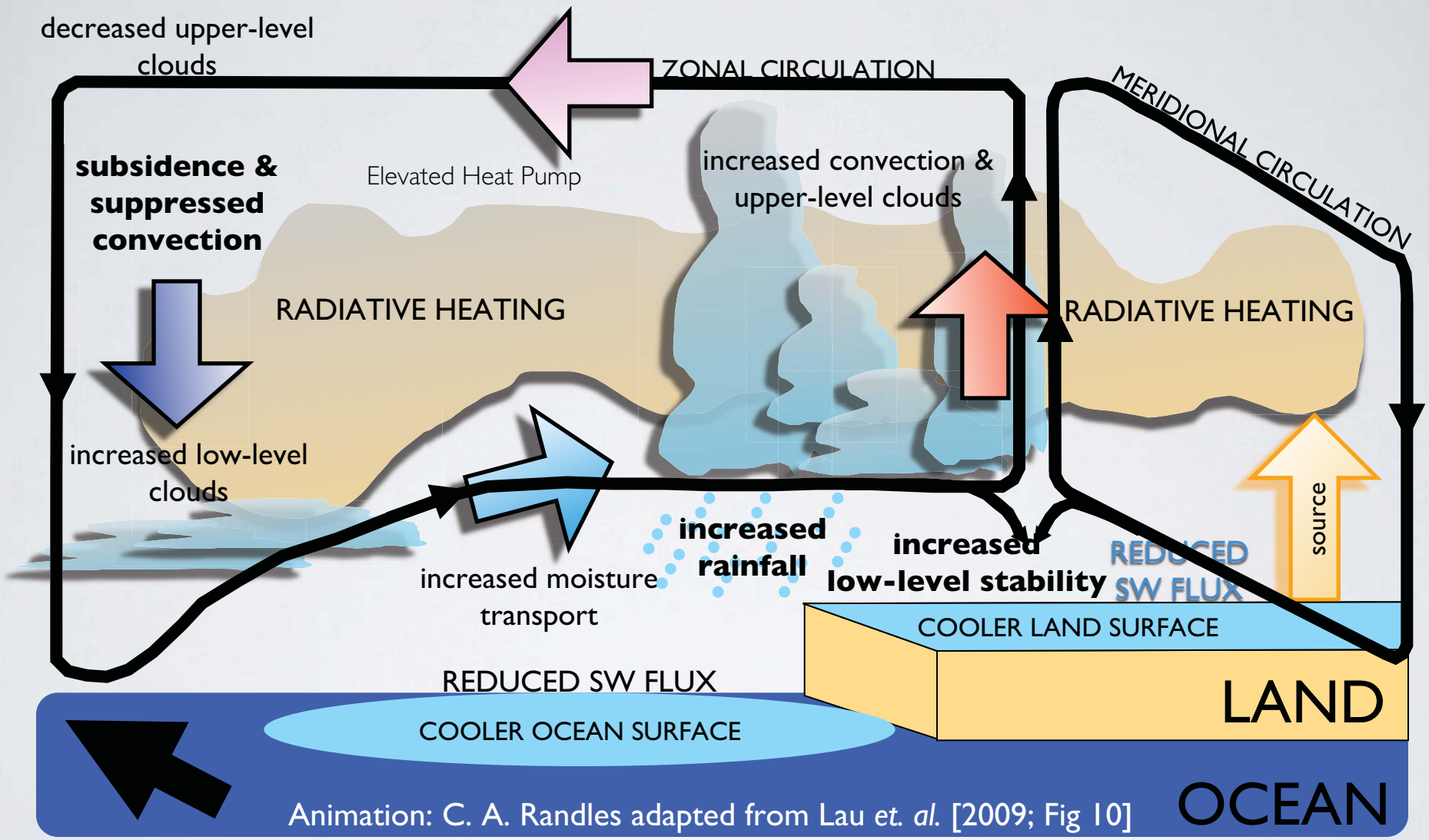
Larger cloud droplets, droplets rain out easier, clouds dissipate quicker.

Albrecht Effect

Smaller cloud droplets, droplets rain out less, longer-lived clouds.

Animation by C. A. Randles

Absorption-CIRCULATION INTERACTIONS



Widespread absorbing aerosol layers can impact large-scale circulation and precipitation patterns like the Indian Monsoon (e.g. Ramanathan and Carmichael, *Nature*, 2008).

Goals of the WGNE* Exercise

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

* WGNE is a Joint Working Group of the Commission for Atmospheric Sciences and the World Climate Research Programme.

Approach

- 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 aerosol simulation
  - AOD or related parameter
  - Verification: AERONET, MODIS, MISR
- Evaluate aerosol impact on meteorology:
  - 2-meter temperature, dew point temperature, 10-meter wind
  - rainfall, surface energy budget, etc.

Protocol: Variables

- 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 grid scale)	x,y	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	-	
Cloud drop number concentration	x,y,z	cm^{-3}	

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

Protocol: Experiments

Experiment	Direct Effect	Indirect Effect	No aerosol Interaction
1	X		
2		X	
3	X	X	
4			X

Participants

Participants	Case 1	Case 2	Case 3	Type of model	Status of the data	People Involved
CPTEC			X	R	Data being analyzed (aerosol direct effect only)	Saulo Freitas, Mauricio Zarzur
JMA	X	X	X	G	Data sent (ind, dir, ind+dir, no-aer)	Taichu Tanaka, Chiasi Muroi
ECMWF	X	X	X	G	Data sent (aerosol direct effect only)	Angela Benedetti, Samuel Remy, Jean-Noel Thepaut
Météo-France/Met. Serv. Algeria	X			R	Data sent (aerosol direct effect only)	Morad Mokhtari, Bouyssel Francois
ESRL/NOAA	X	X	X	G/R	Working on the simulations	Georg Grell
NASA/ Goddard	X	X	X	G	Data sent (direct effect only)	Arlindo da Silva
NCEP	X			G	Data sent (direct effect only)	Sarah Lu, Yu-Tai Hou, Shrinivas Moorthi, and Fanglin Yang
Barcelona Super. Ctr.	X			R	Data sent (aerosol direct effect only)	Oriol Jorba Casellas

X = data not yet available for processing or analyzed

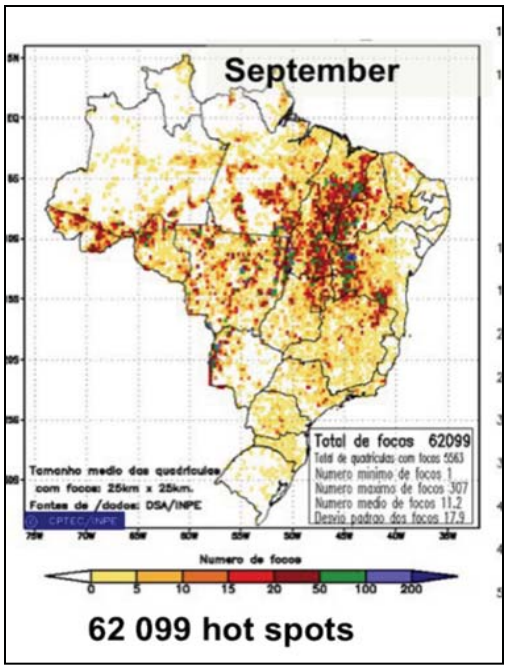
Participating Models

Institution Model	Domain Resolution	Aerosol Species	A & BB Emissions	Aerosol Physics	Cloud Physics	Aerosol Assimilation
CPTEC BRAMS LAM+CCAT	Regional 10 km	BC, Sea-Salt, OC, SO_4	EDGAR 4. 3BEM	bulk	2-mom	no
JMA MASINGAR	Global TL319L40	Dust, Sea-Salt, BC, OC, SO_4	MACCity GFAS 1.0	2-mom	2-mom	no
ECMWF Global	Global T511L60			Bulk	Bulk	yes
Météo-France ALADIN + ORILAM	Regional 7.5 km	Dust	DEAD model	3-mom log-no normal	Bulk	no
ESRL/NOAA WRF	Regional cloud res.	(many)	EDGAR 4. 3BEM	Bulk and Modal	2-mom	no
NASA/GSFC GEOS-5+GOCART	Global 25 km	Dust, Sea-Salt, BC, OC, SO_4	EDGAR 4.1 QFED 2.4	Bulk modal	Bulk or 2-mom MG	yes
NCEP NGAC+GOCART	Global T126	Dust, Sea-Salt, BC, OC, SO_4	Climatological Aerosols	Bulk	Bulk	no
Barcelona SC	regional	dust	BSC-dust model	8 dust size bins	Same as in WRF	no

Case Studies

1) Dust over Egypt: 4/2012

2) Pollution in China: 1/2013

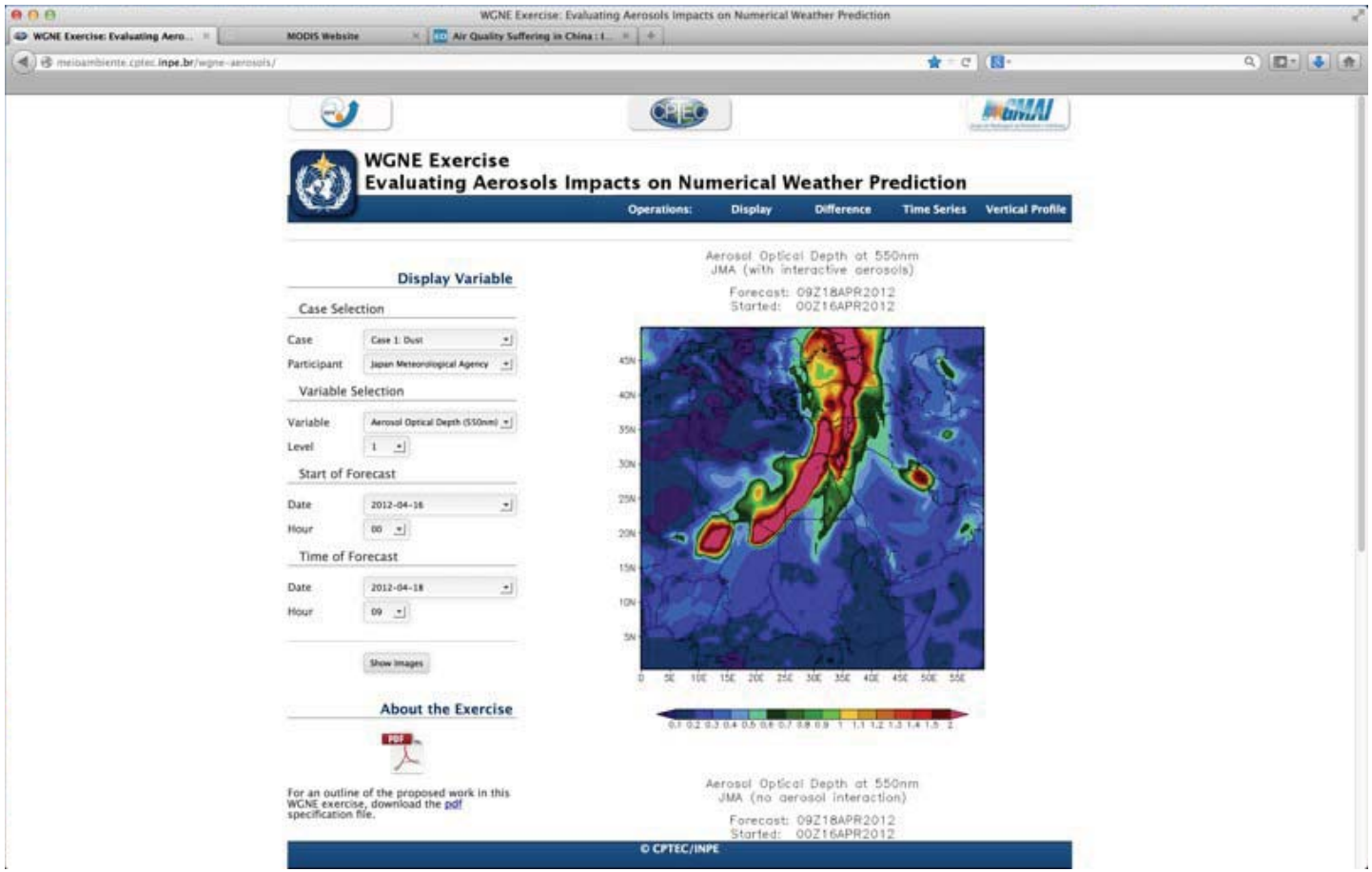


3) Smoke in Brazil: 9/2012

Website

http://meioambiente.cptec.inpe.br/wgne-aerosols/

Webpage hosted by CPTEC for data analysis and visualization

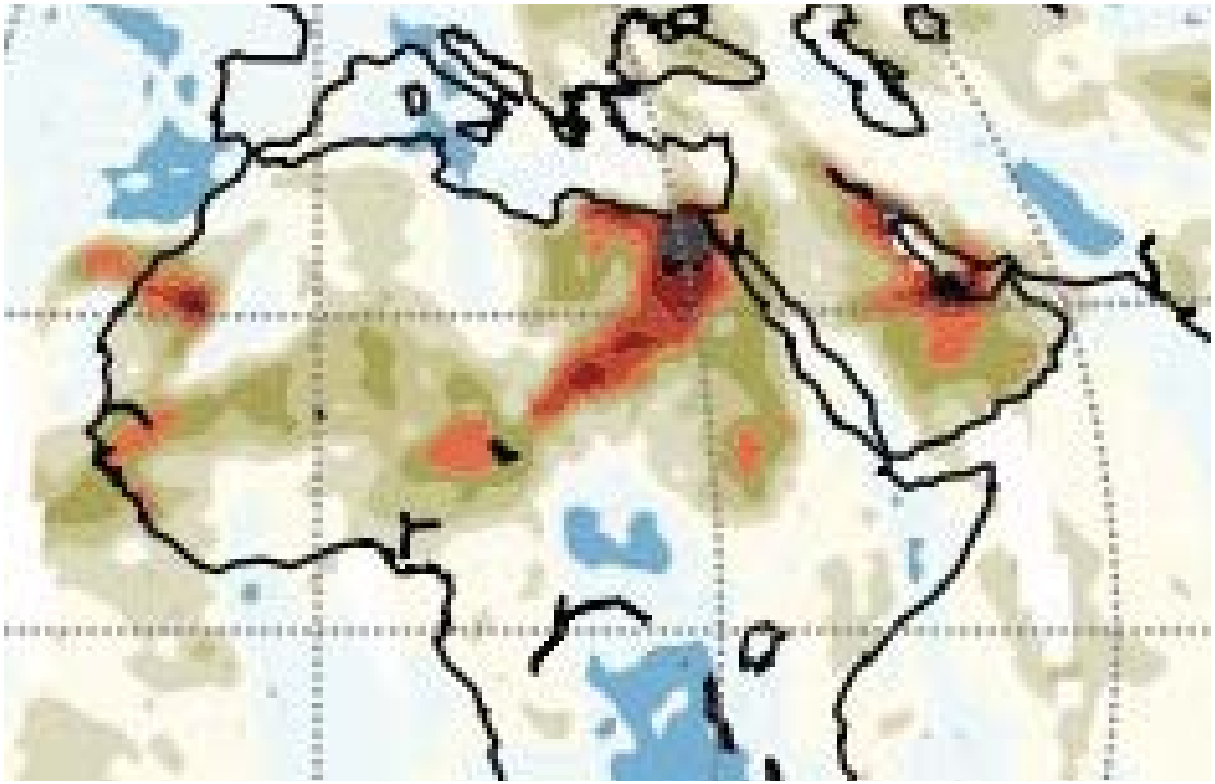


Developed by M. Zarzur

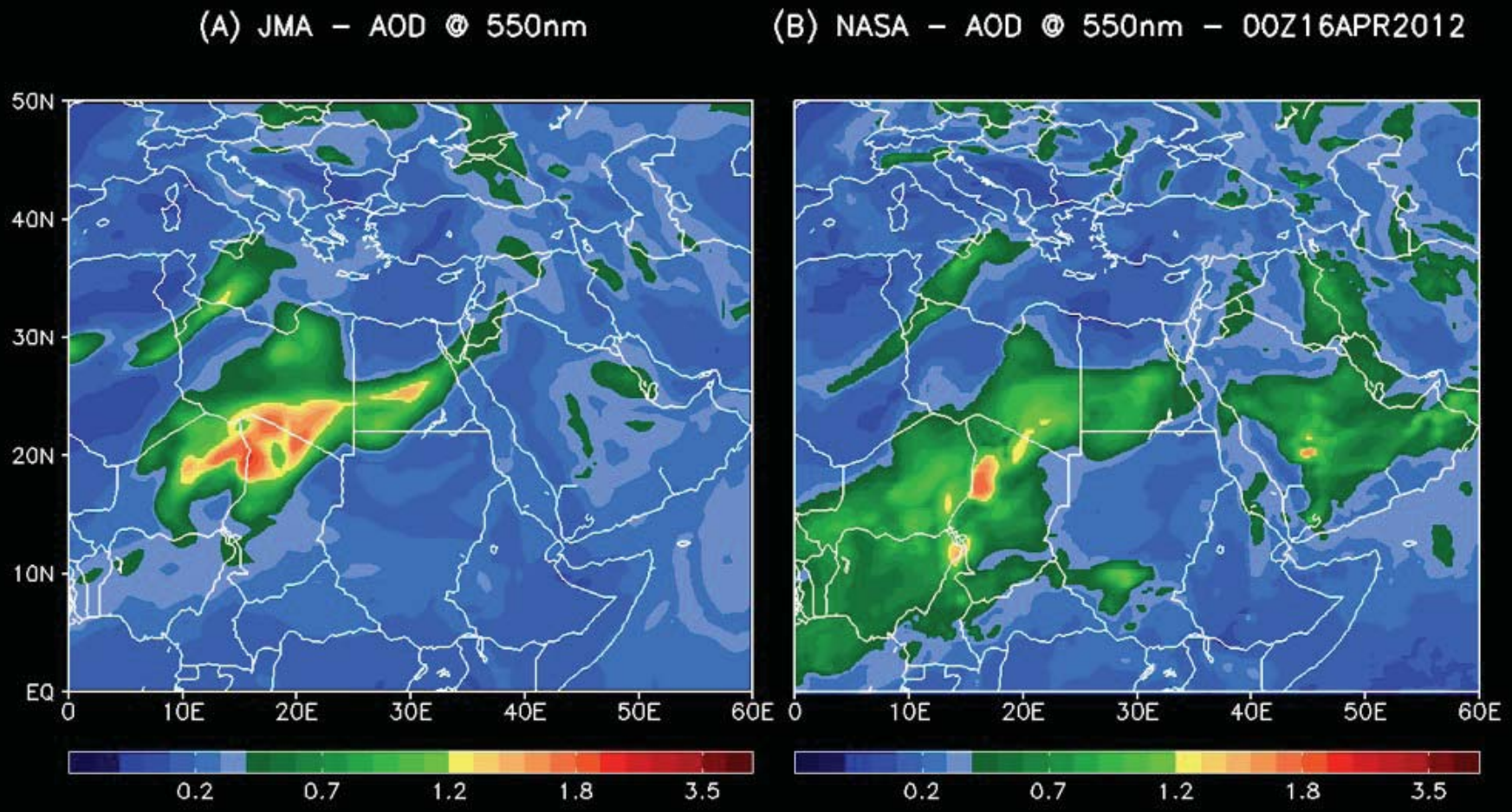
Case 1
Dust Plume over Egypt

- 18 April 2012
- Forecasts
  - April 13-23 2012
  - From 0 or 12 UTC
  - 10 day forecasts
- Center of domain
  - 30E, 25N
- Model configuration
  - Same as for NWP
- Direct effects only

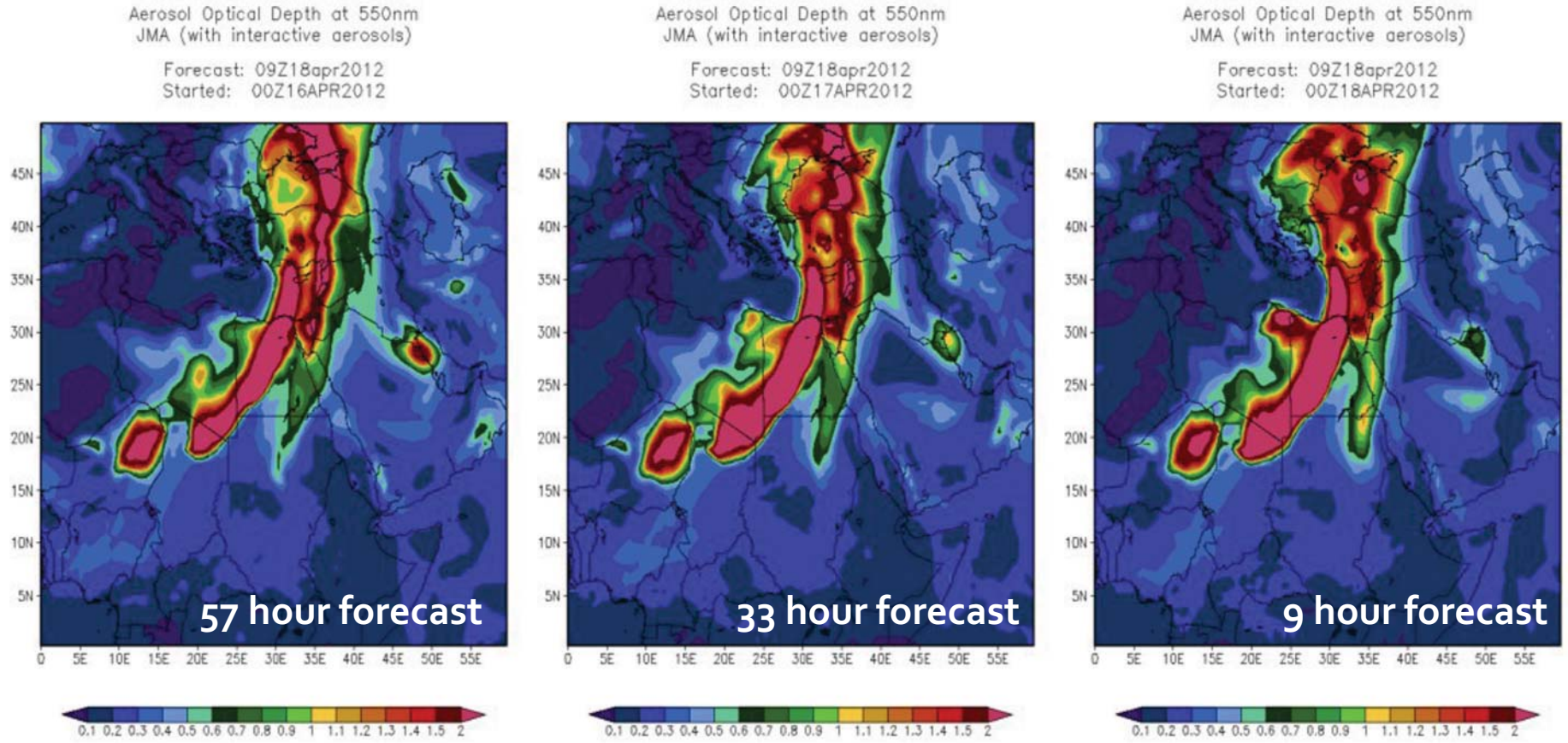
OMPS UV Aerosol Index
18 April 2012



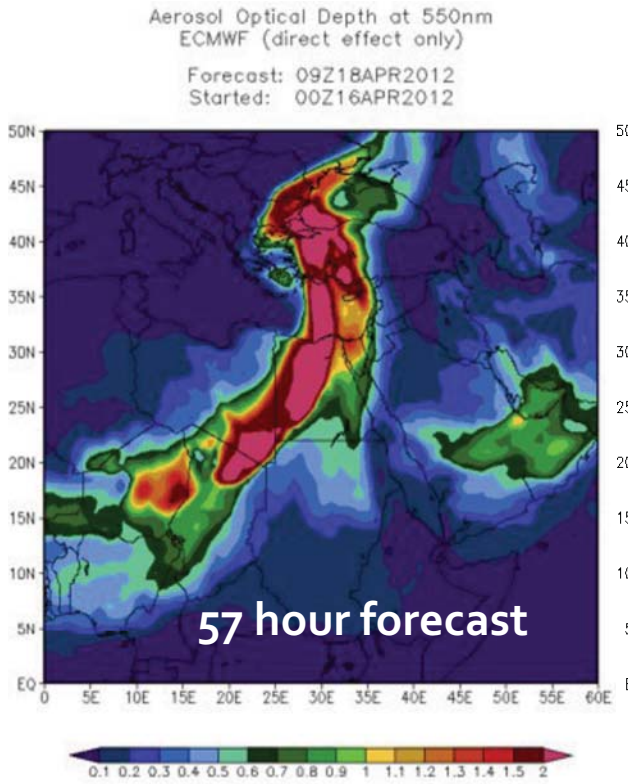
Case 1: Dust
JMA & NASA AOD Forecast

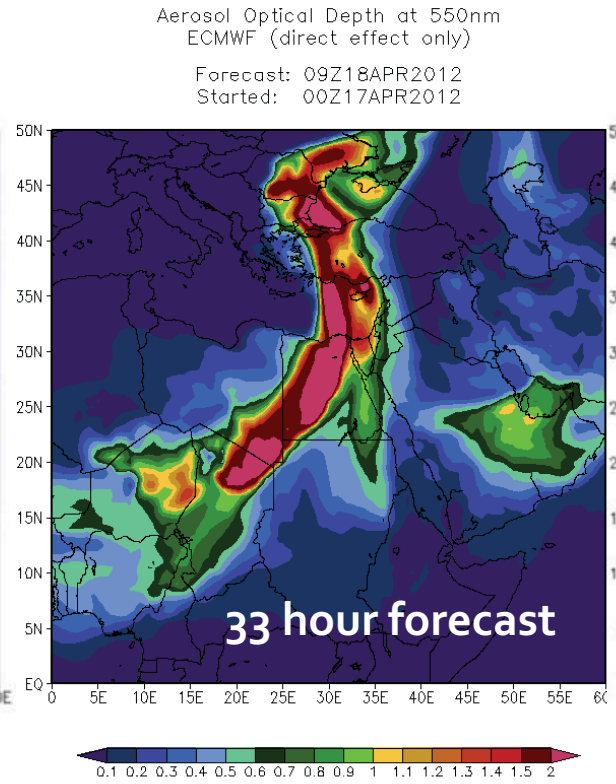


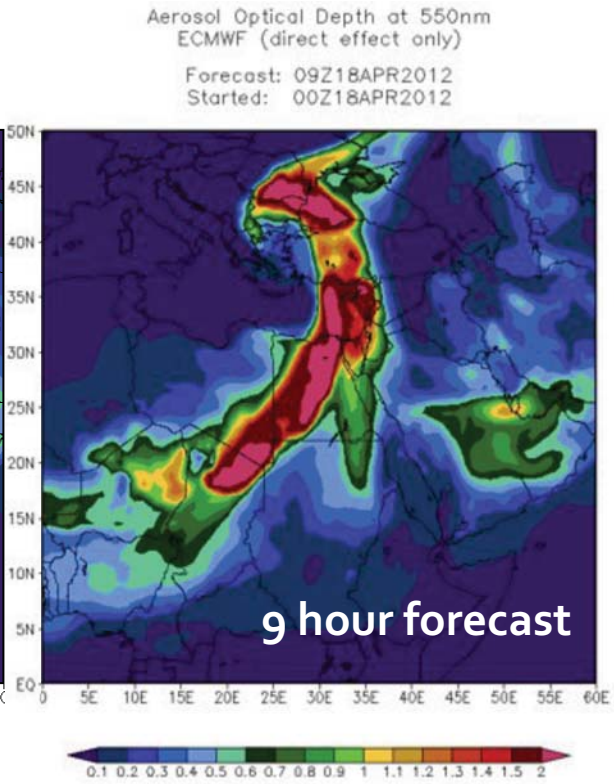
AOD Forecast (JMA) valid at 09UTC 18 April 2012



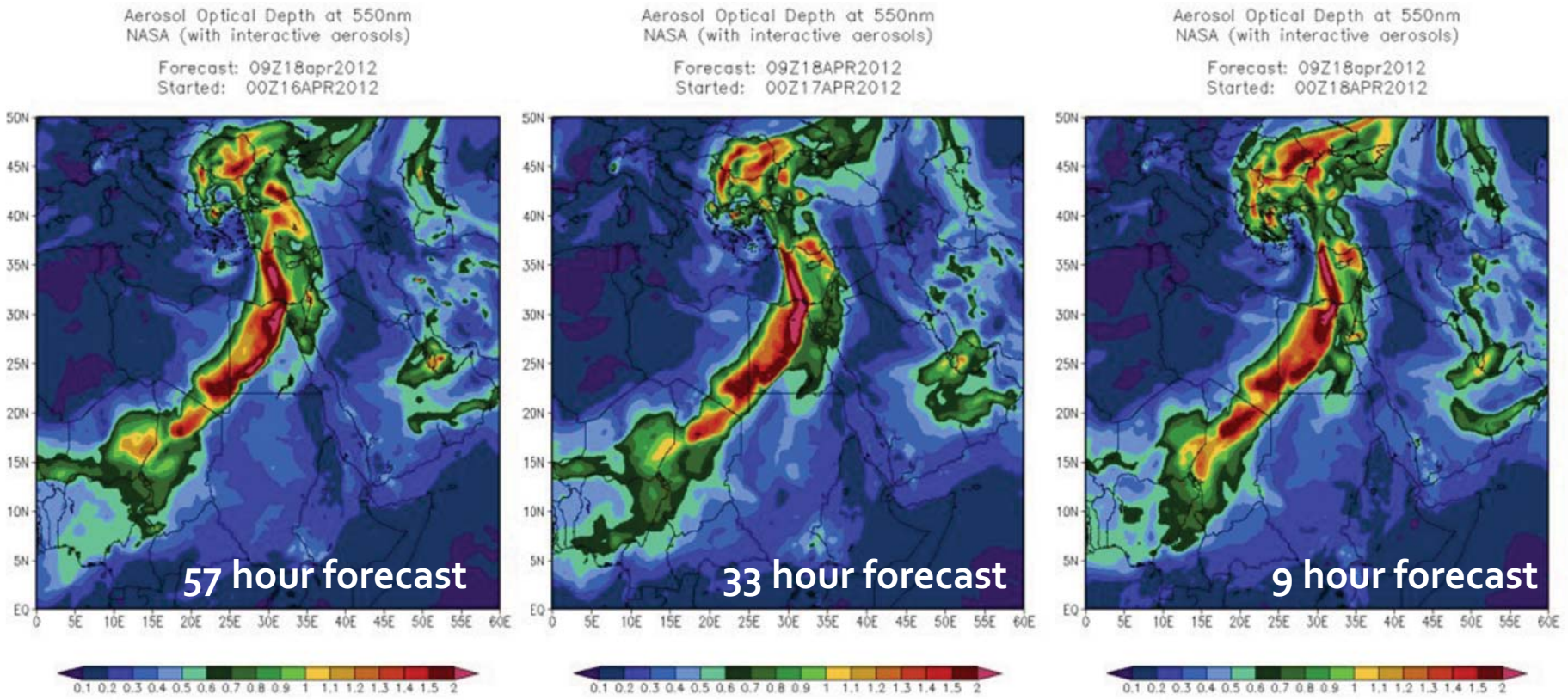
AOD Forecast (ECMWF) valid at 09UTC 18 April 2012



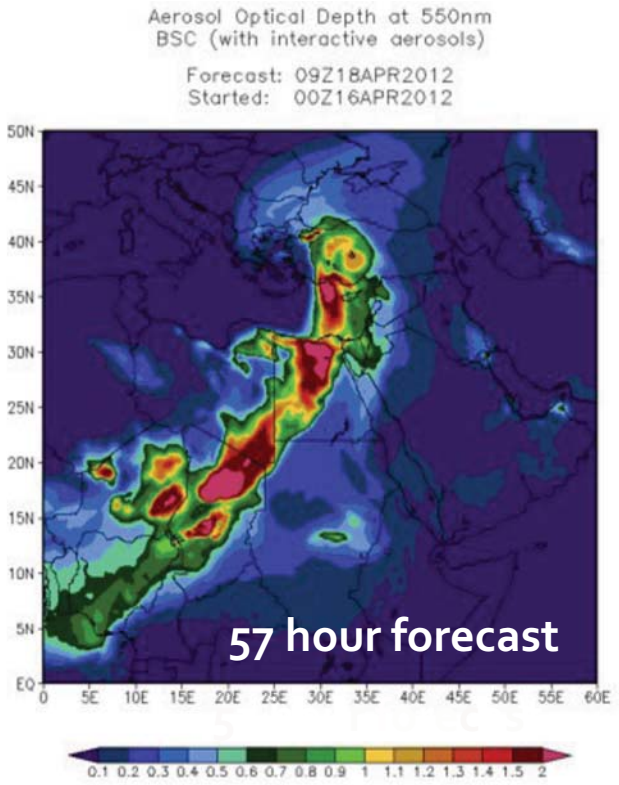


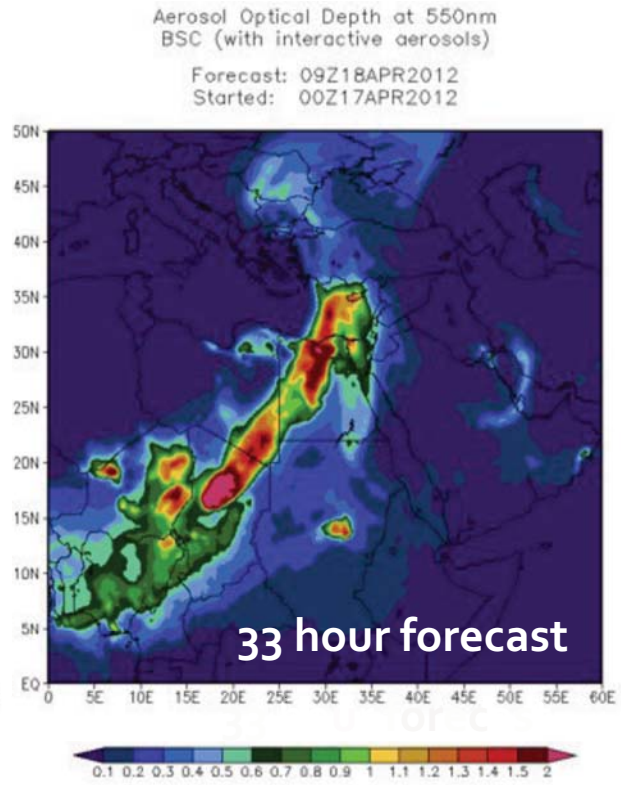


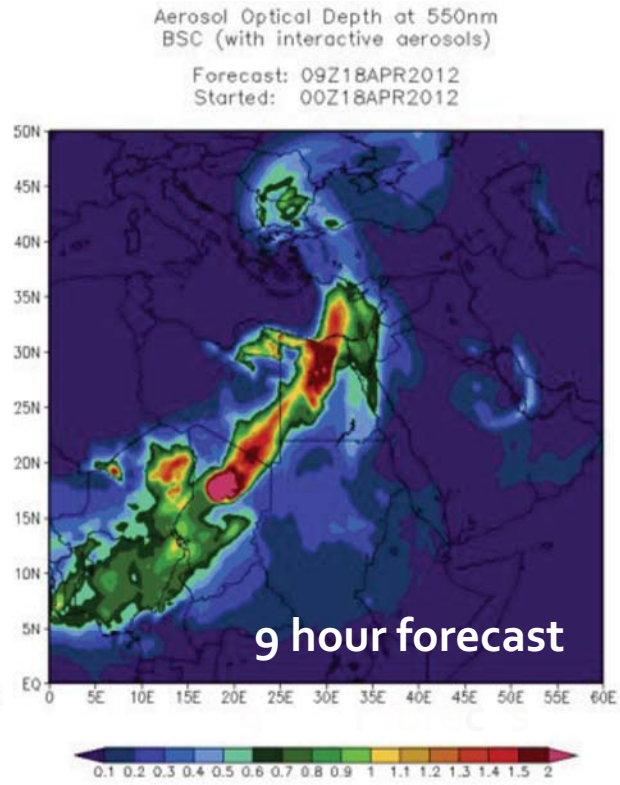
AOD Forecast (NASA) valid at 09UTC 18 April 2012



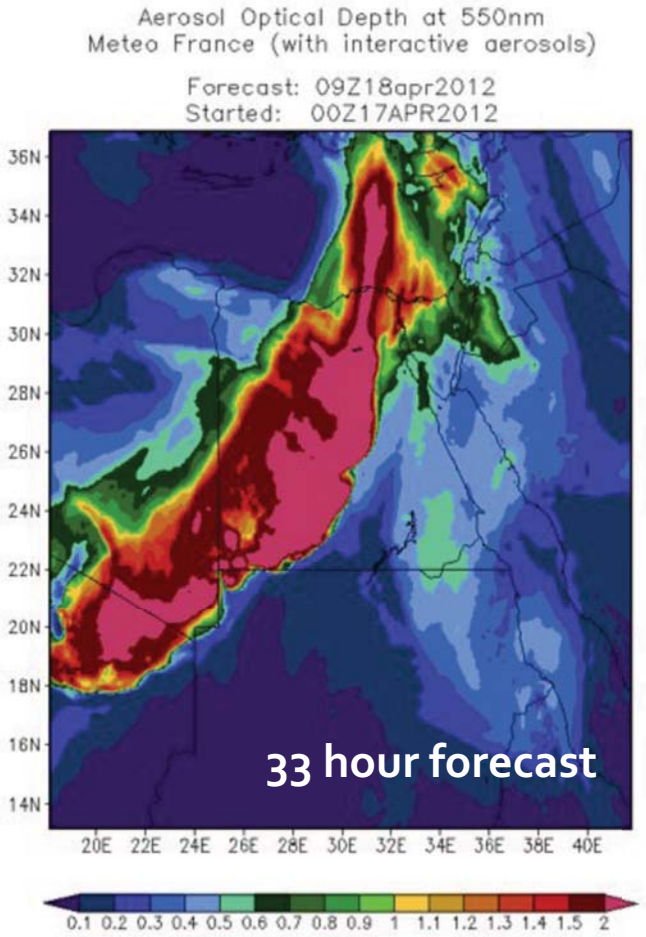
AOD Forecast (Barcelona) valid at 09UTC 18 April 2012

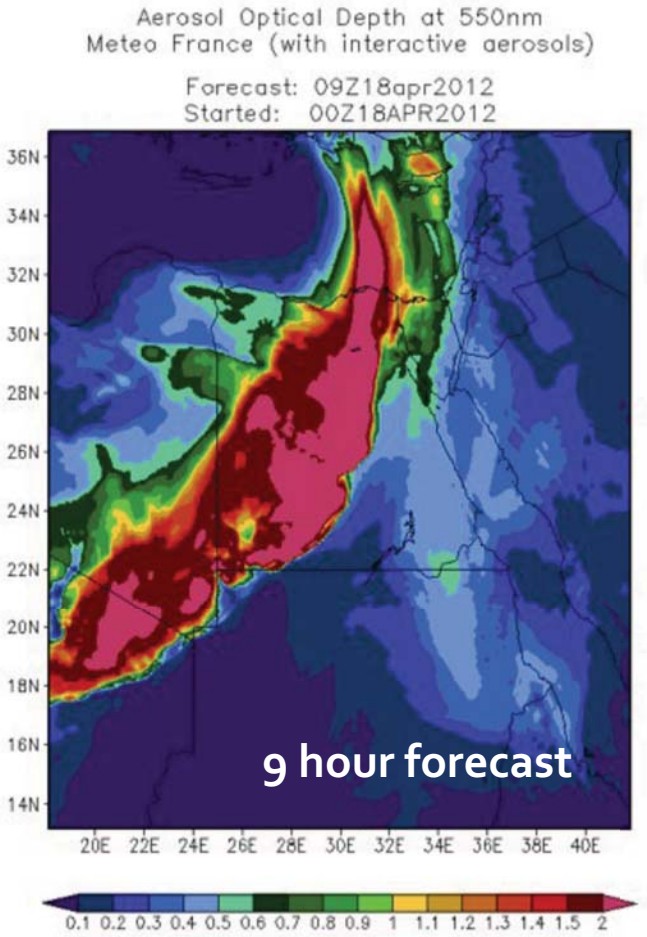






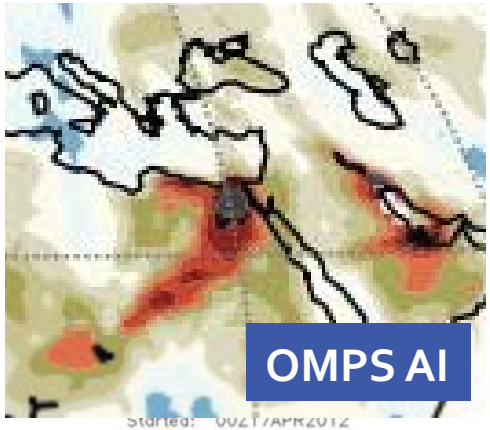
AOD Forecast (MeteoFrance) valid at 09UTC 18 April 2012

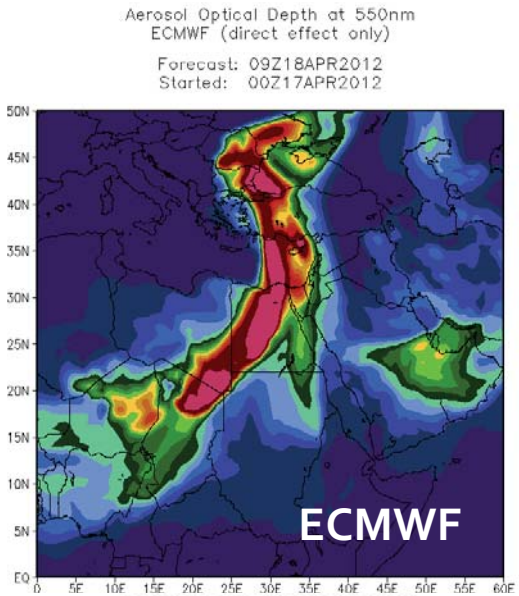


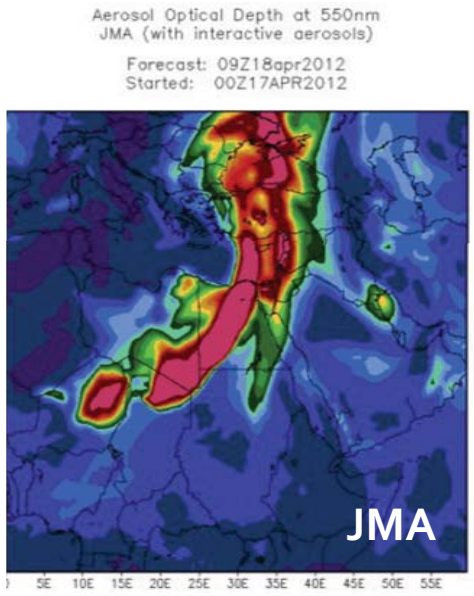


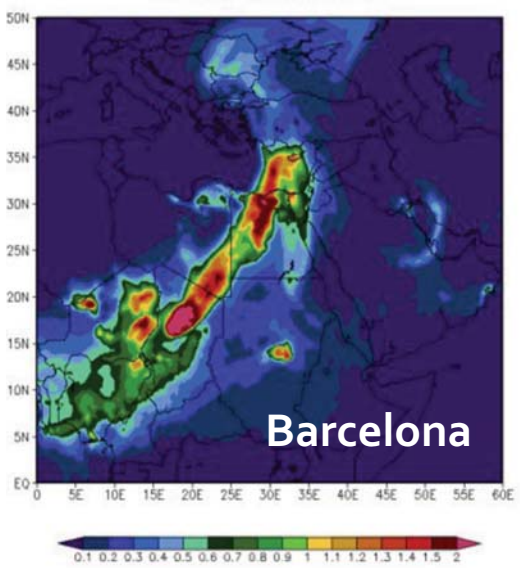
AOD 550nm Intercomparison

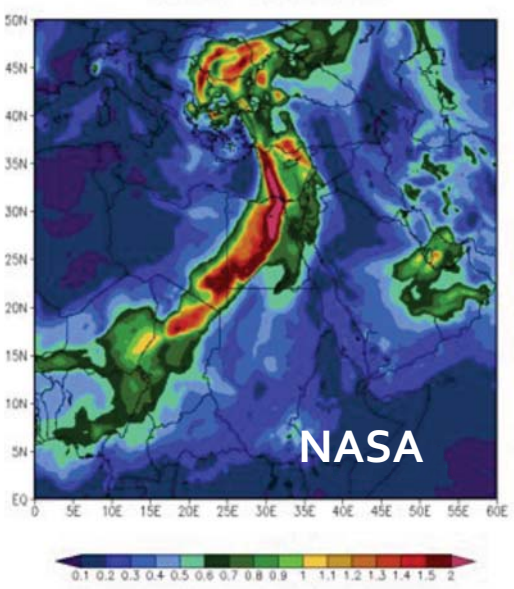
33 hour forecast

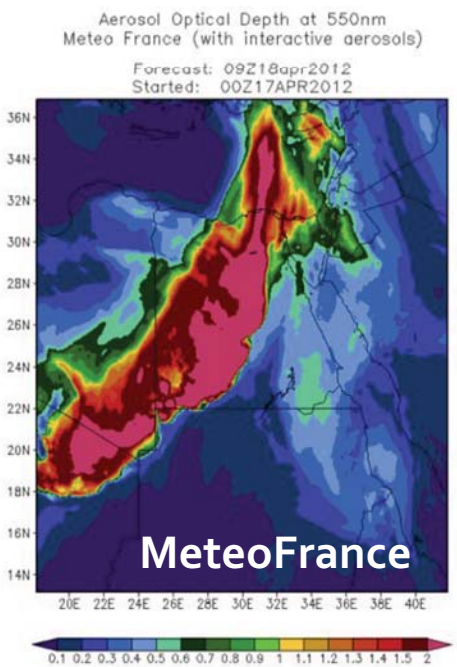








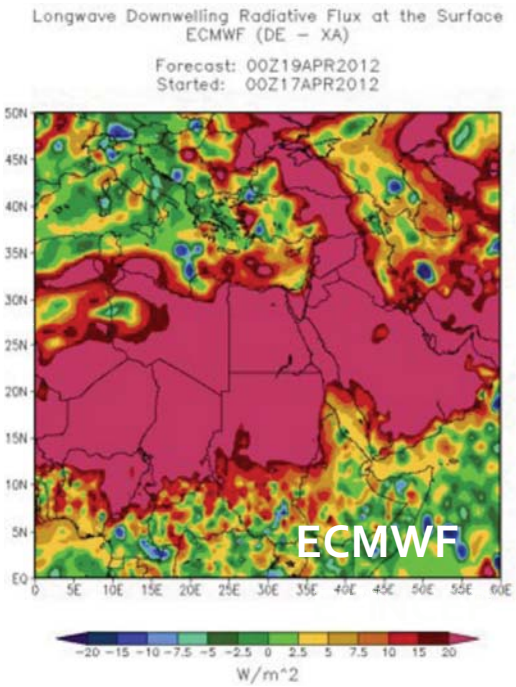


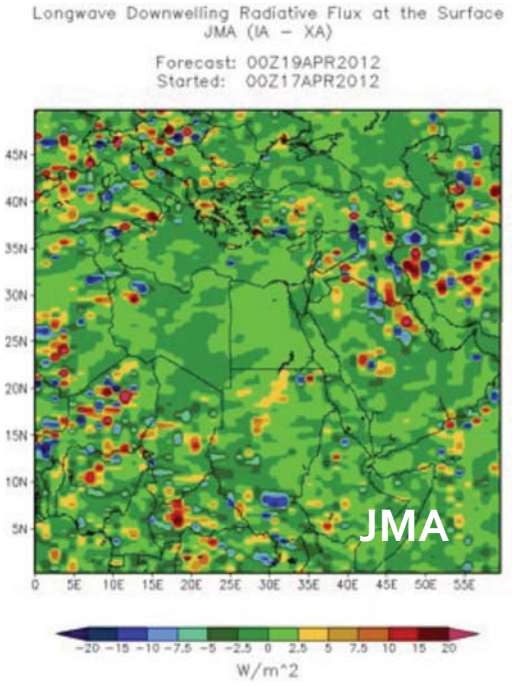


$\tau_{MF} > \tau_{JMA} \sim \tau_{ECMWF} > \tau_{NASA} \sim \tau_{Barcelona}$

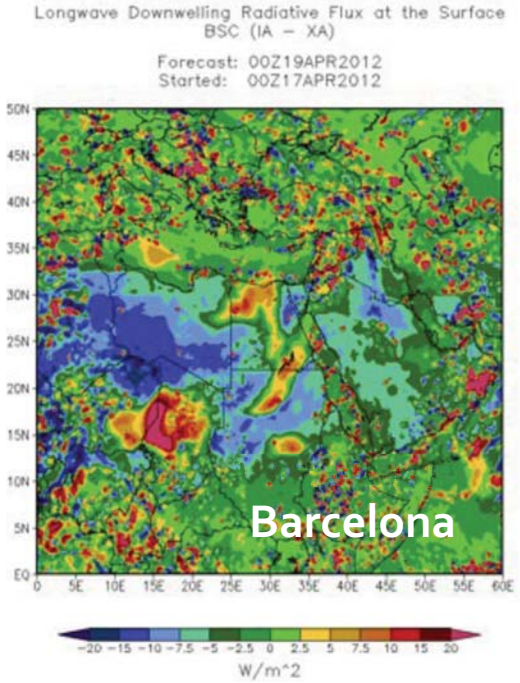
LW Rad @ Sfc
Impact (Aero-NoAero)

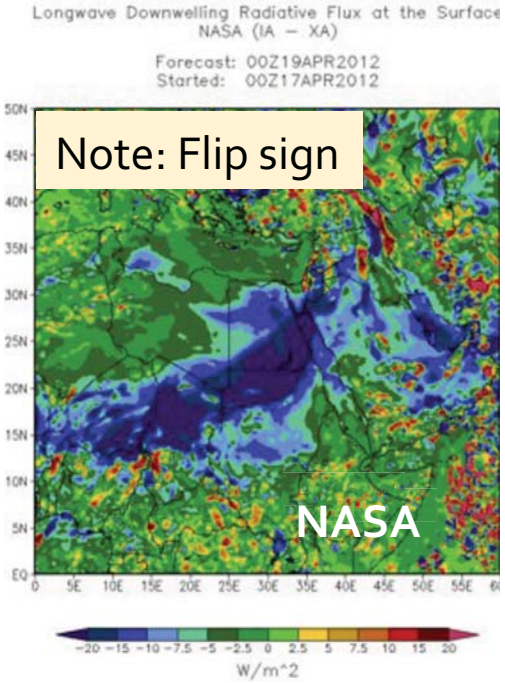
- 0 UTC (night time)
- JMA misses LW signal
- ECMWF: stronger

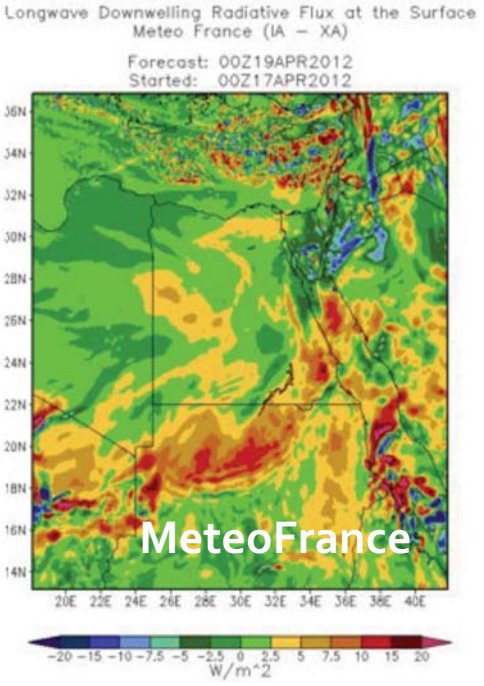




48 hour forecast



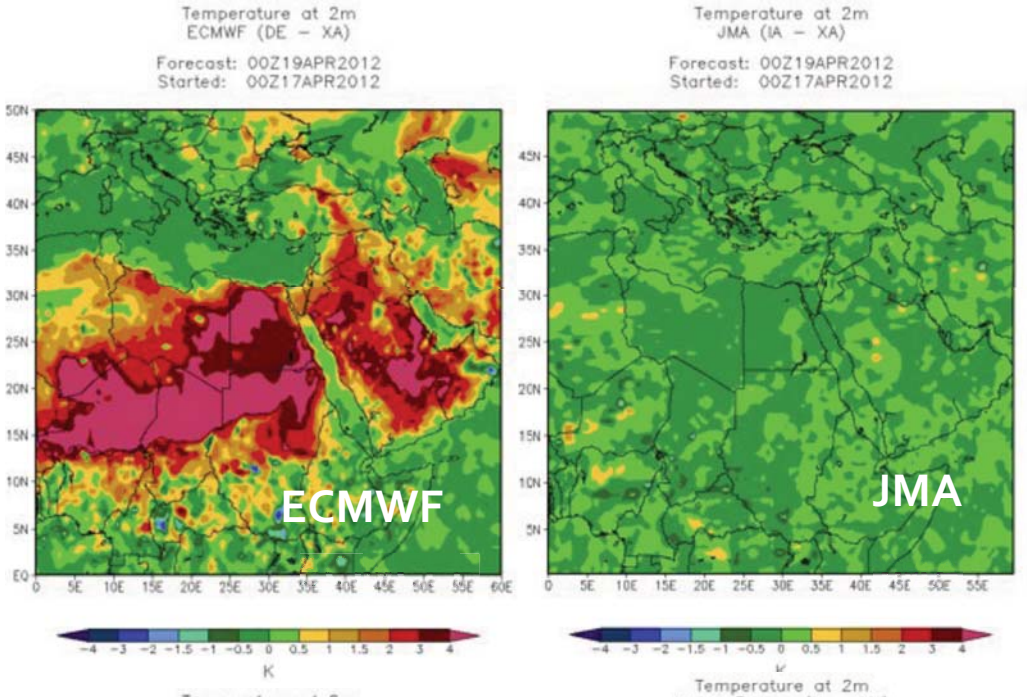


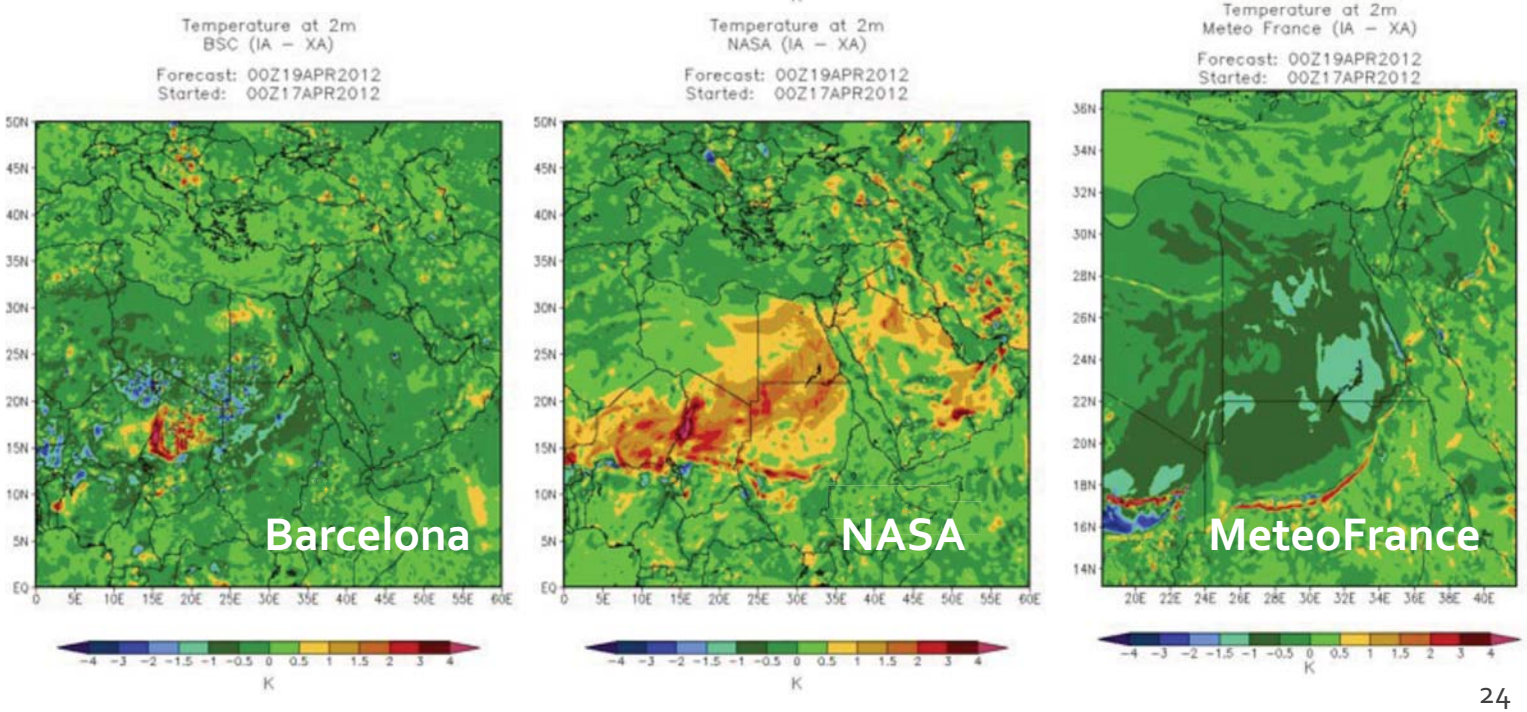


T_{2m} Impact Aero-NoAero

- 0 UTC (night time)
- ECMWF shows stronger impact

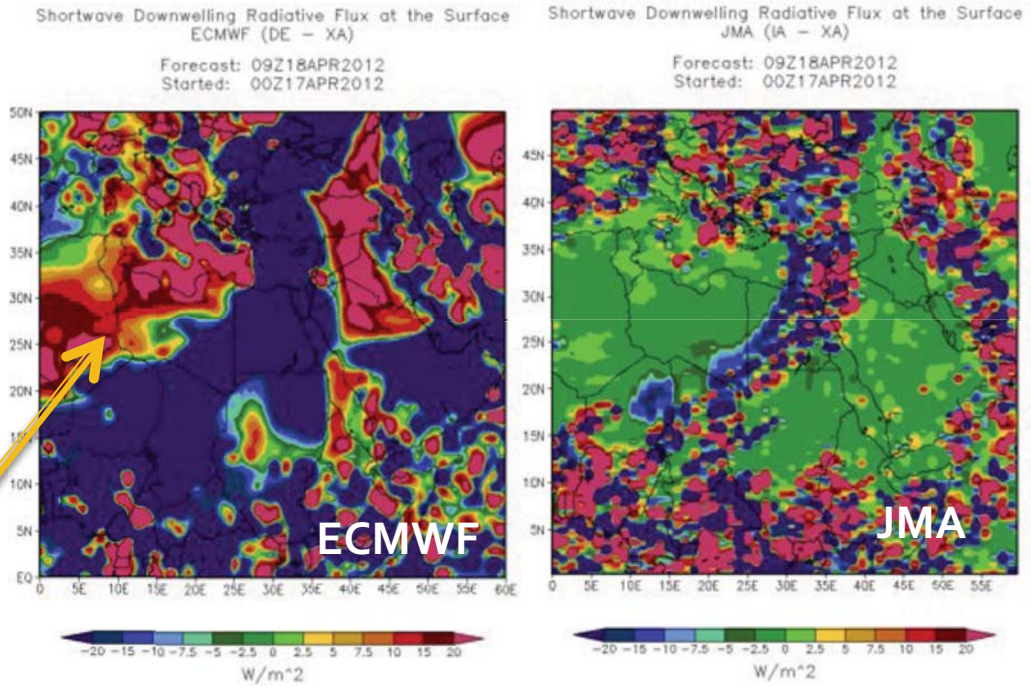
48 hour forecast

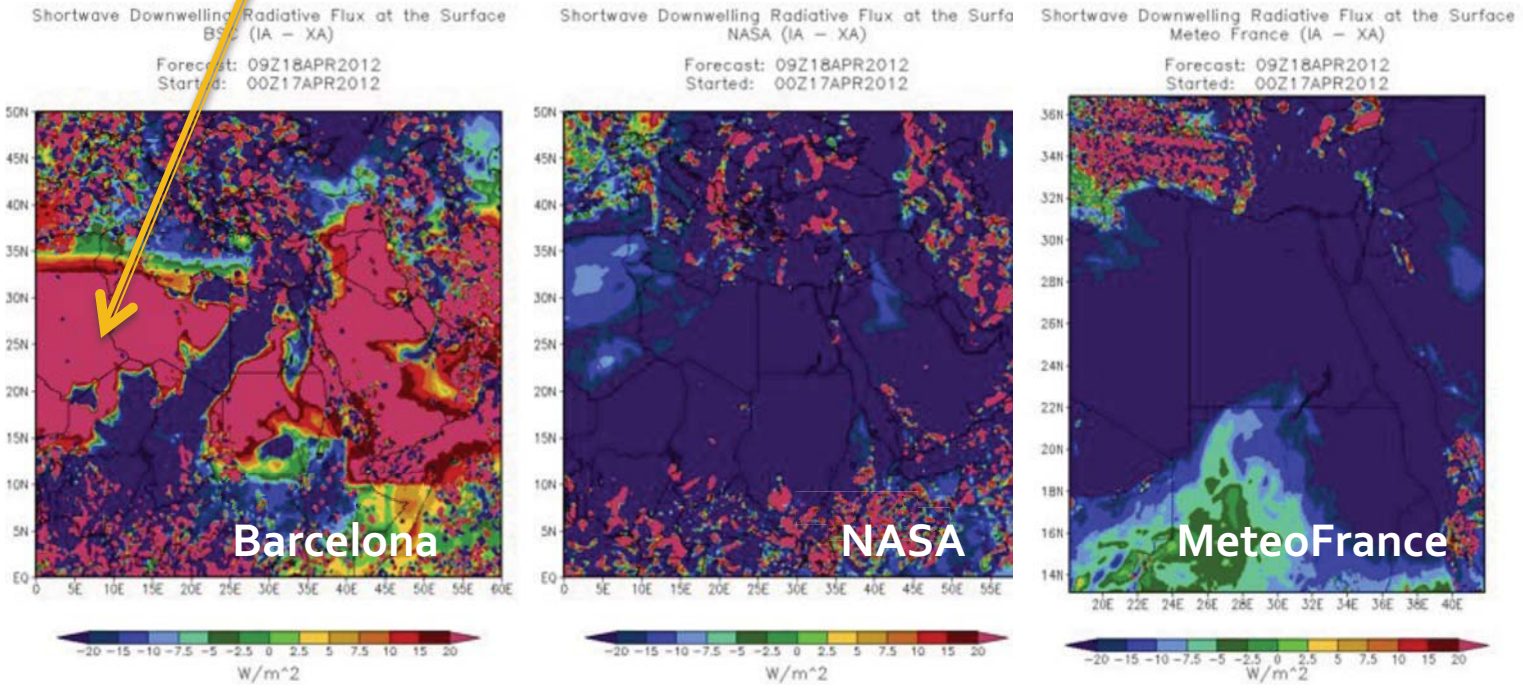




SW Rad @ Sfc
Impact (Aero-NoAero)

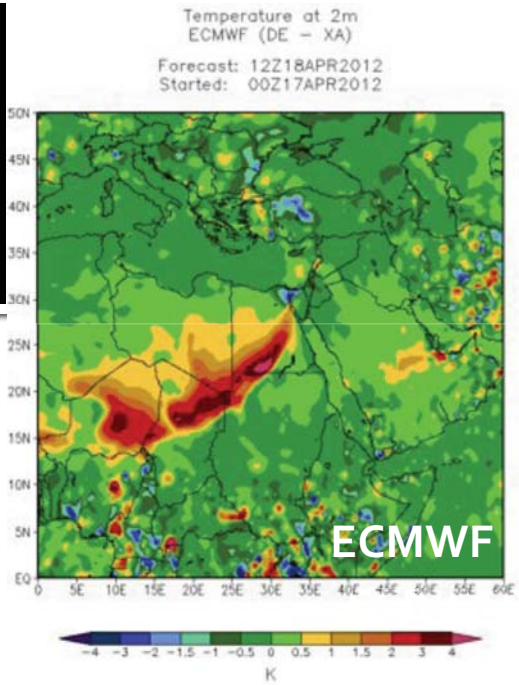
- 9 UTC (morning)
- ECMWF and BSC indicate an increase in SW around the plume

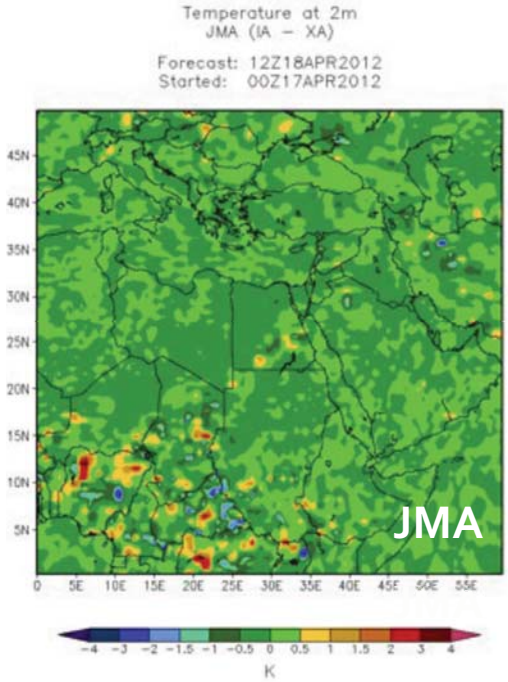




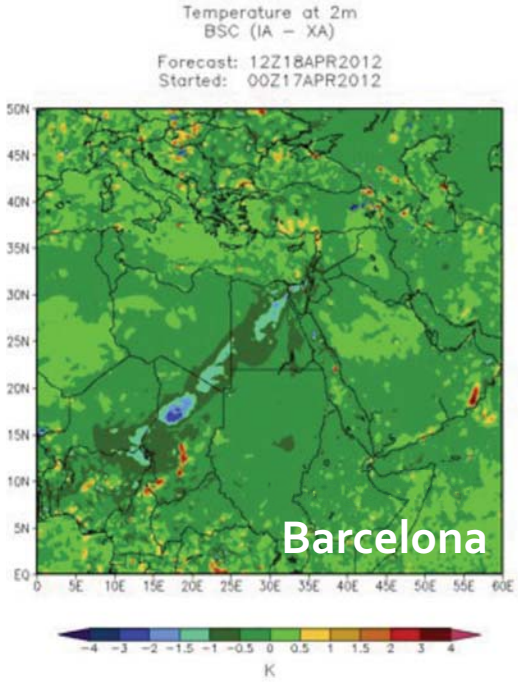
T_{2m} Impact Aero-NoAero

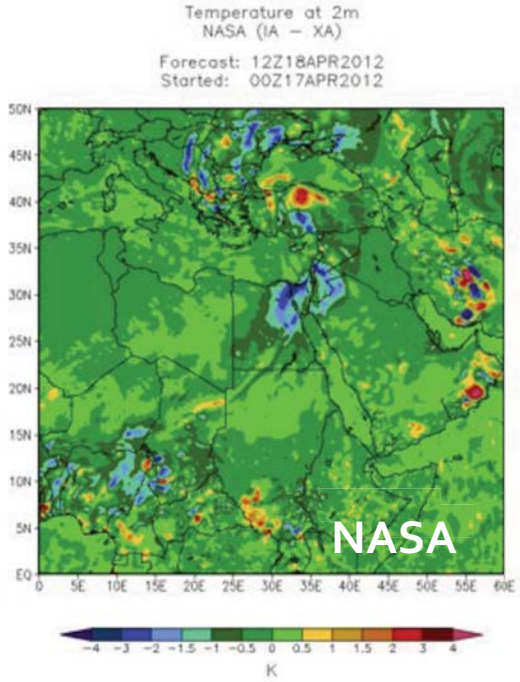
- 12 UTC (day time)
- ECMFW net warming may be a residual effect from the night

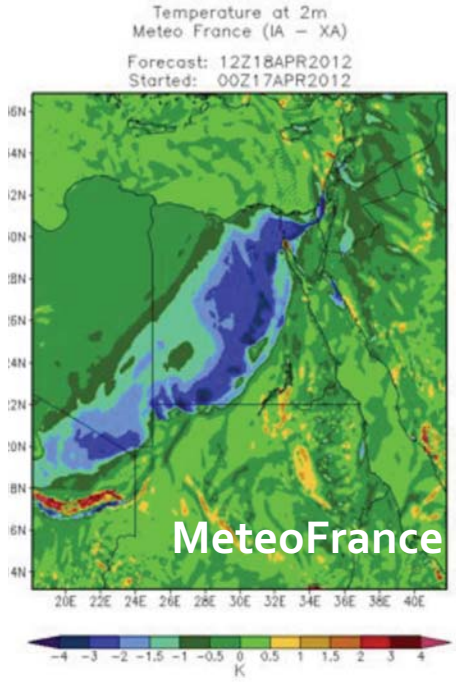




36 hour forecast



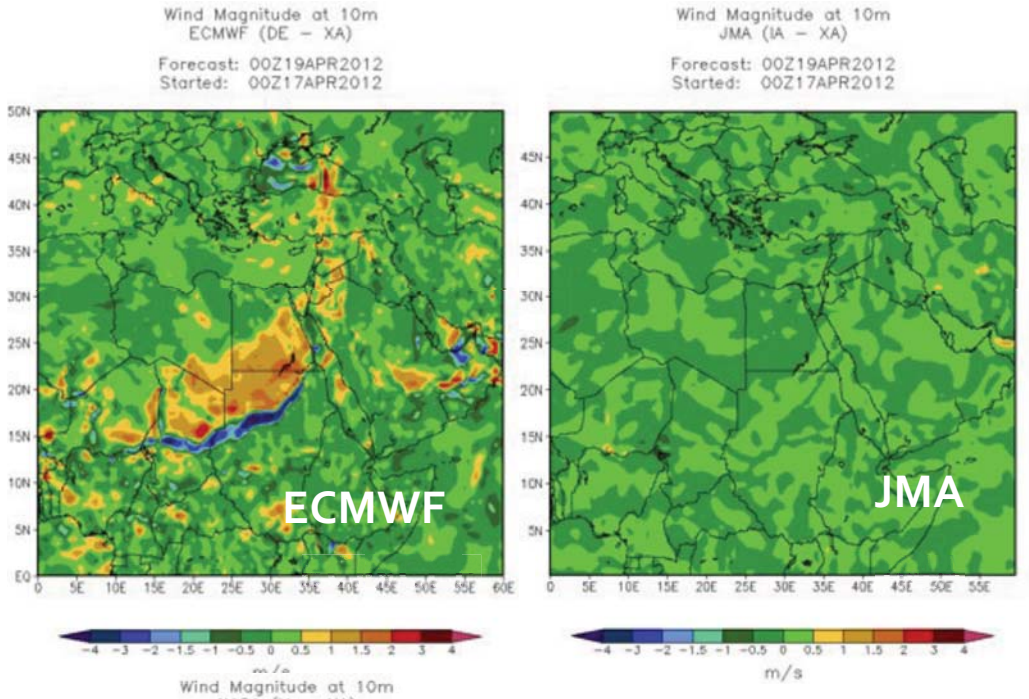


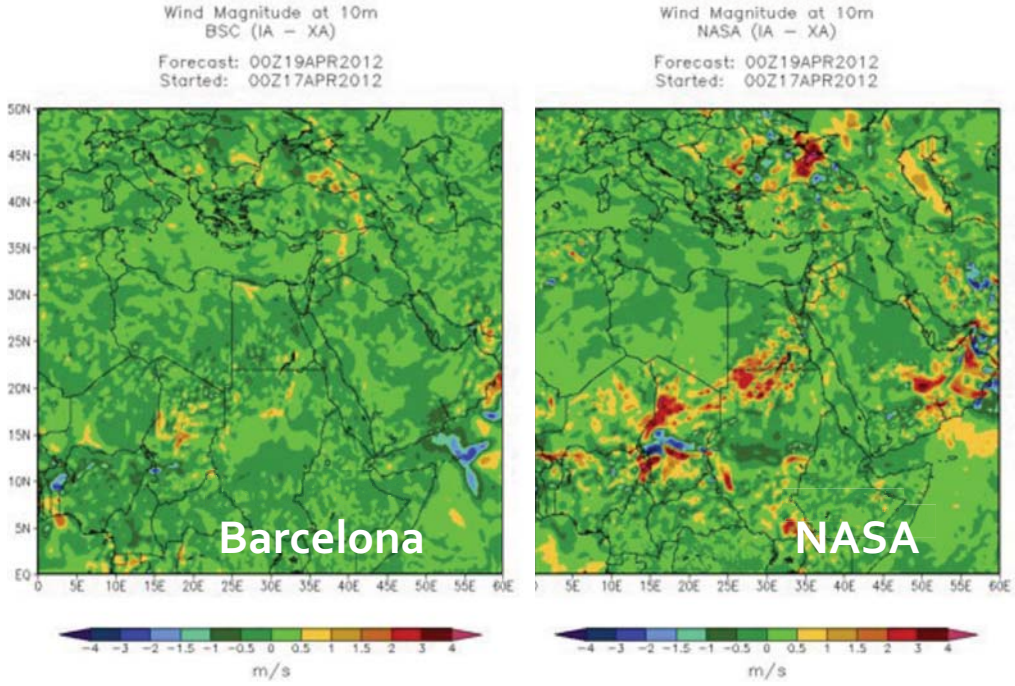


U_{10m} Impact Aero-NoAero

- 0 UTC (night time)

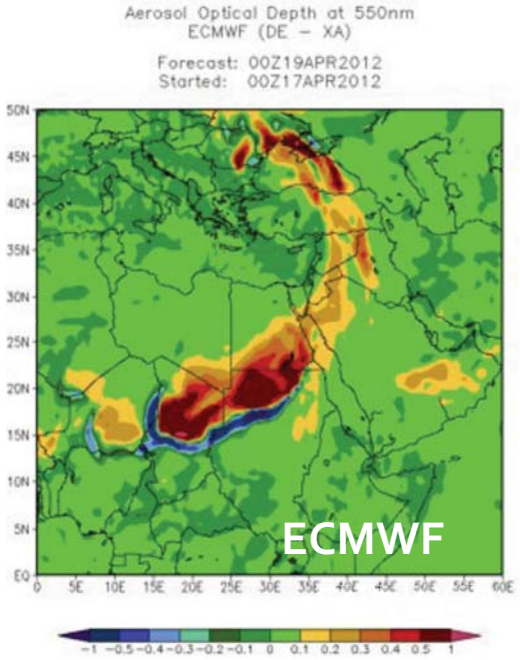
48 hour forecast

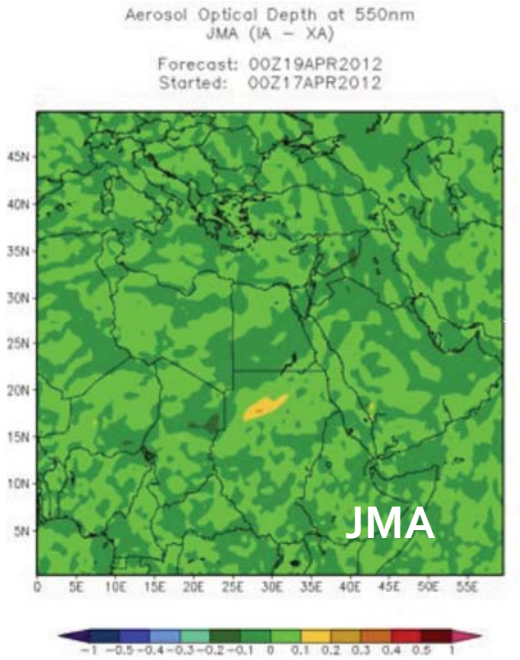




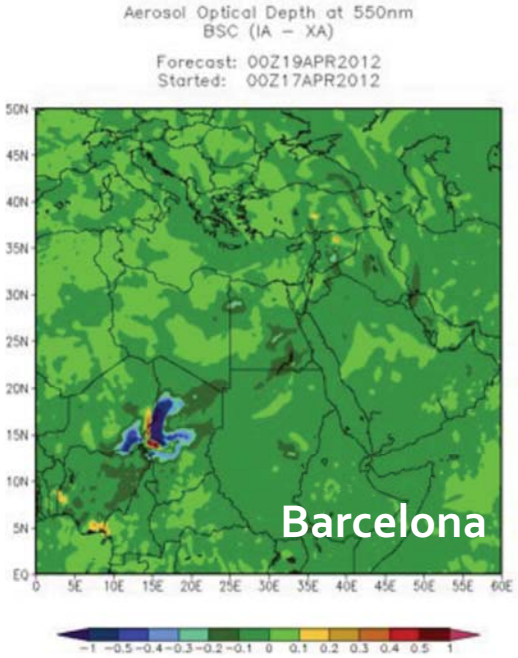
AOD Impact Aero-NoAero

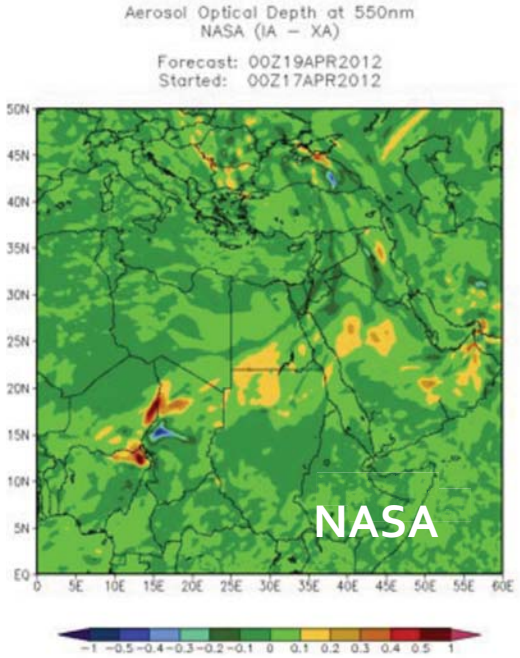
- 0 UTC (night time)





48 hour forecast



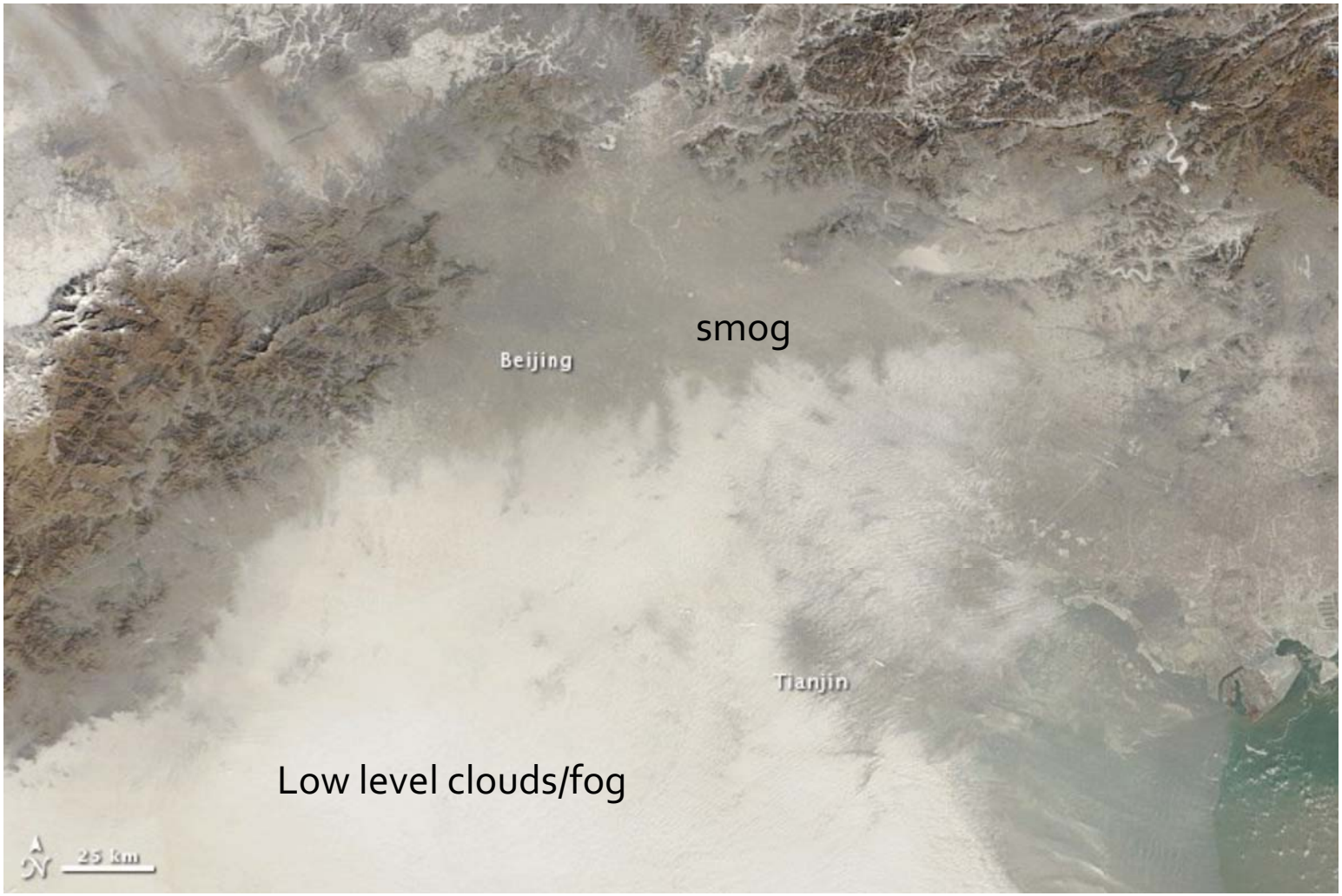


Case 2
Extreme Pollution in Beijing

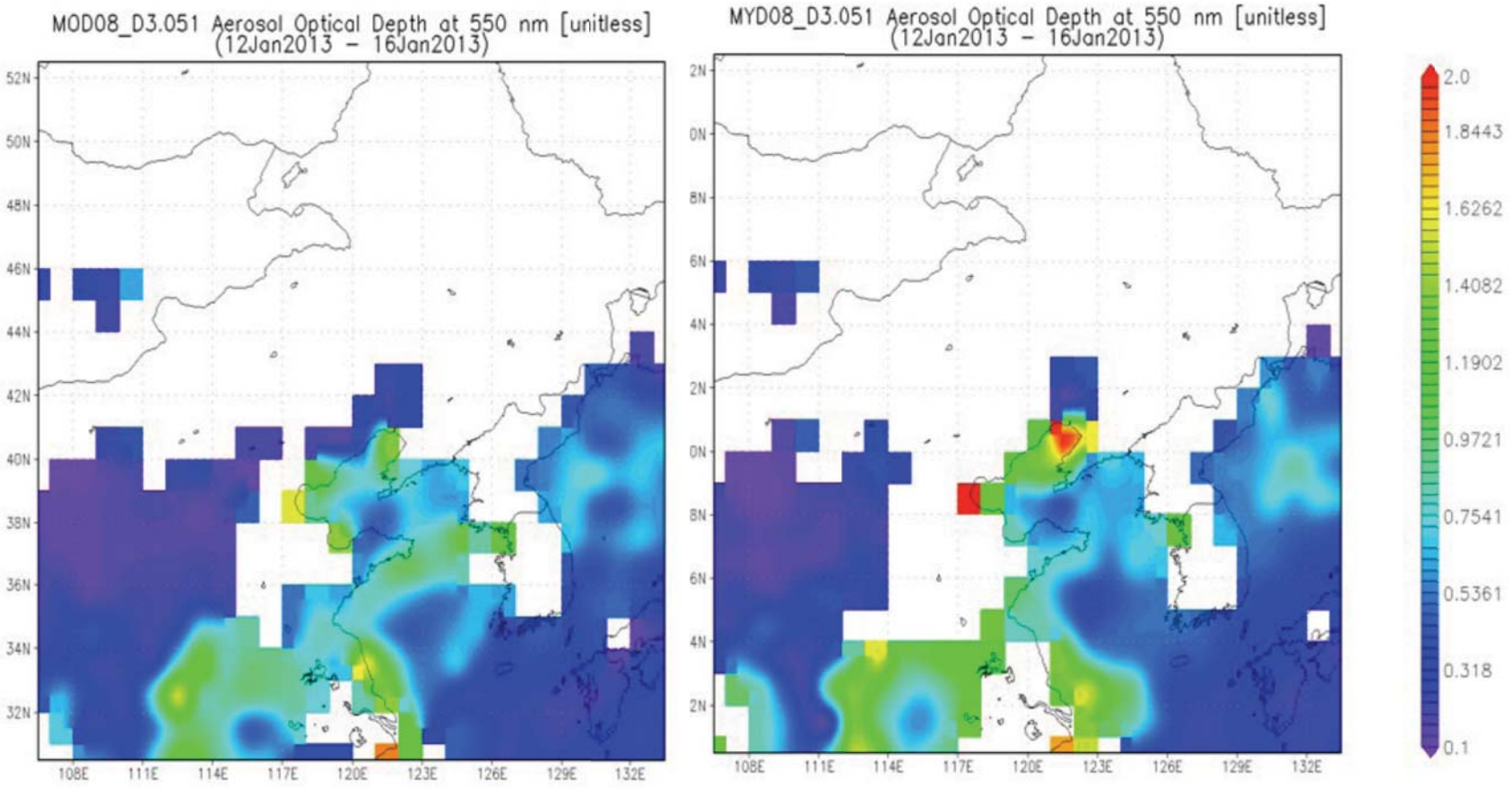
- January 2013
- Forecasts
  - January 7-21 2013
  - From 0 or 12 UTC
  - 10 day forecasts
- Center of domain
  - 116E, 40N
- Model configuration
  - Same as for NWP
- Direct & Indirect effects

So far, only JMA has submitted Indirect Effect experiments.

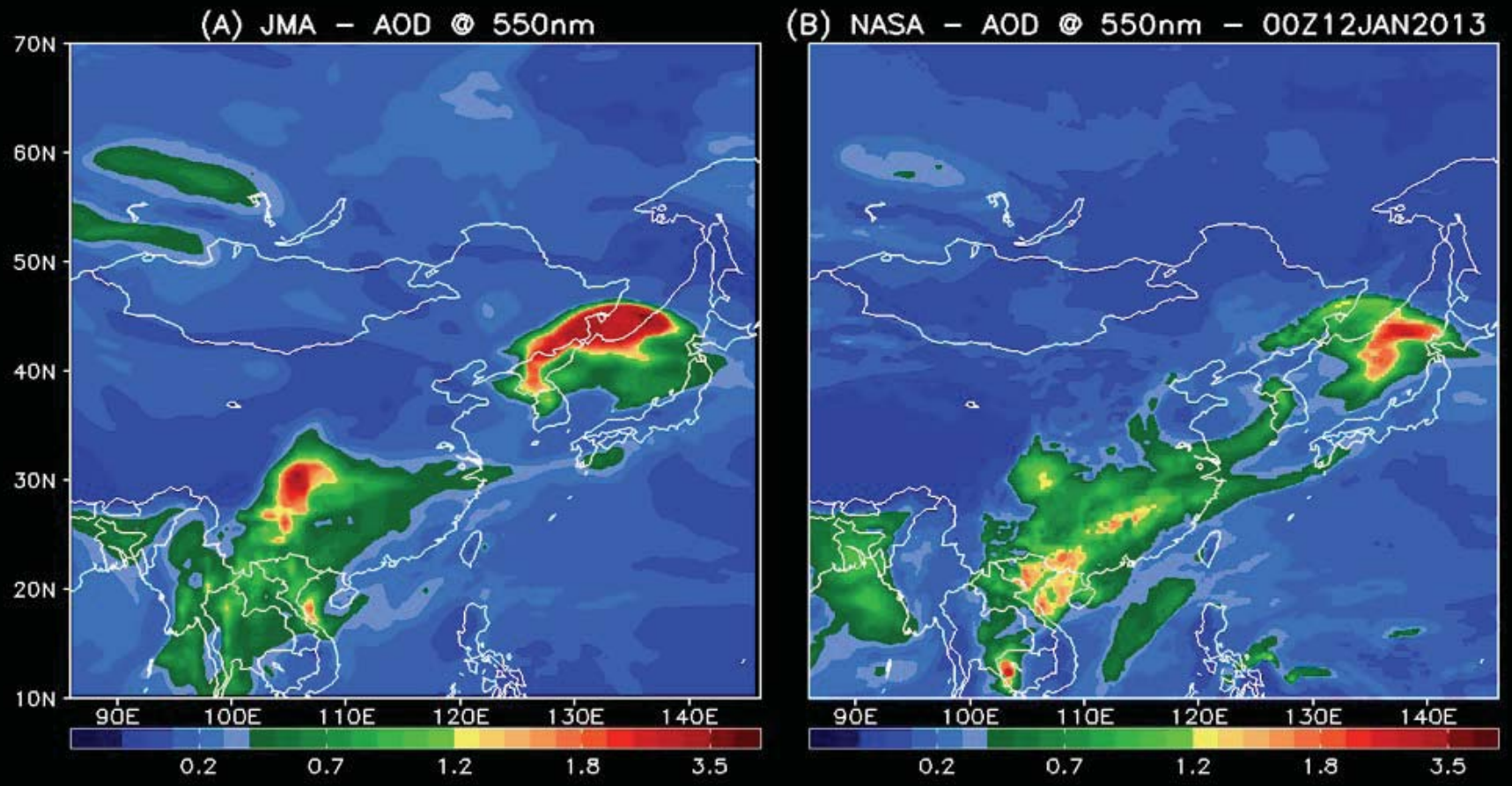
Case 2
Extreme Pollution in Beijing



AOD - MODIS Terra & Aqua
12-16 January 2013

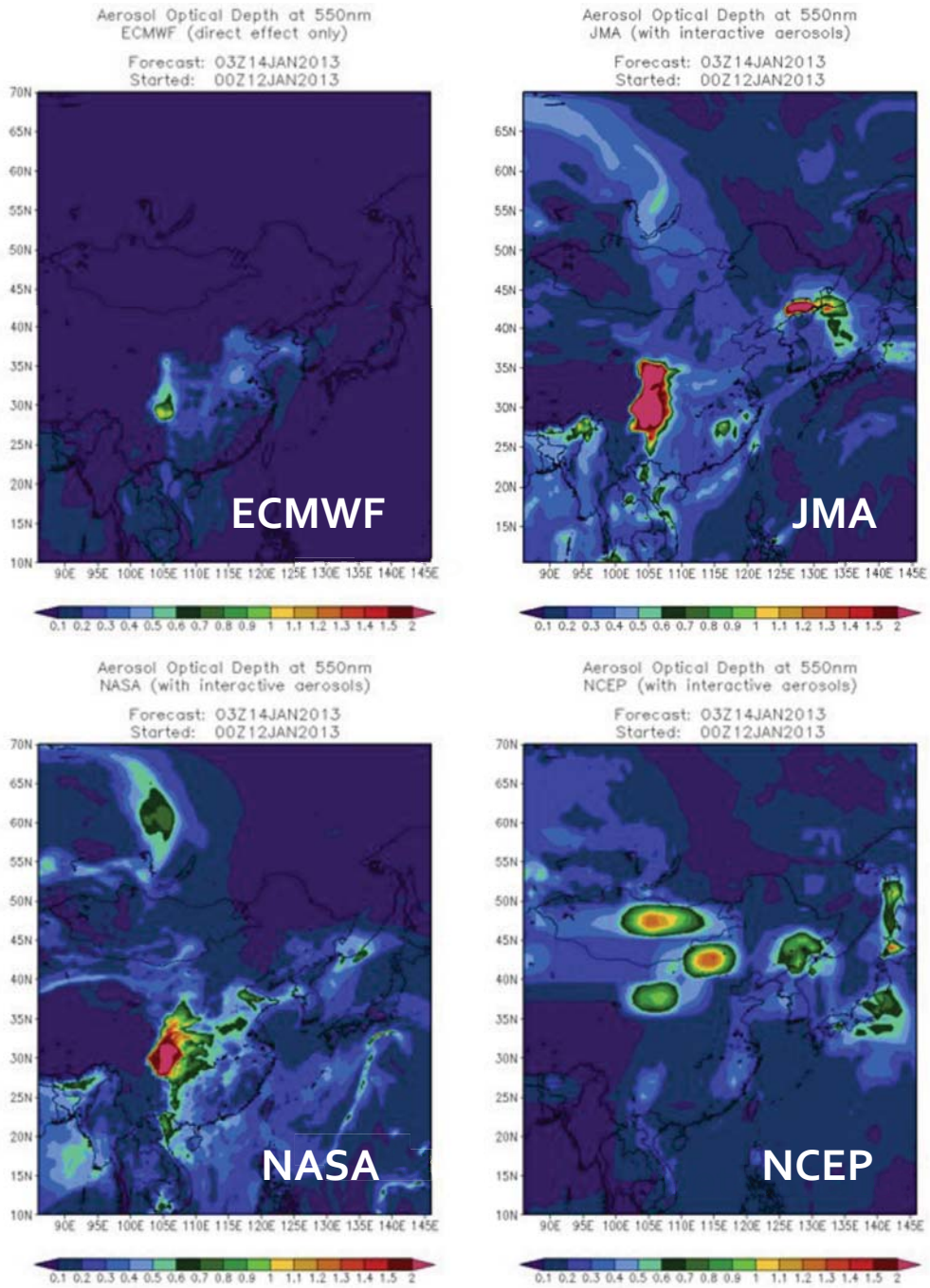


Case 2: Pollution in China
JMA & NASA Forecasts



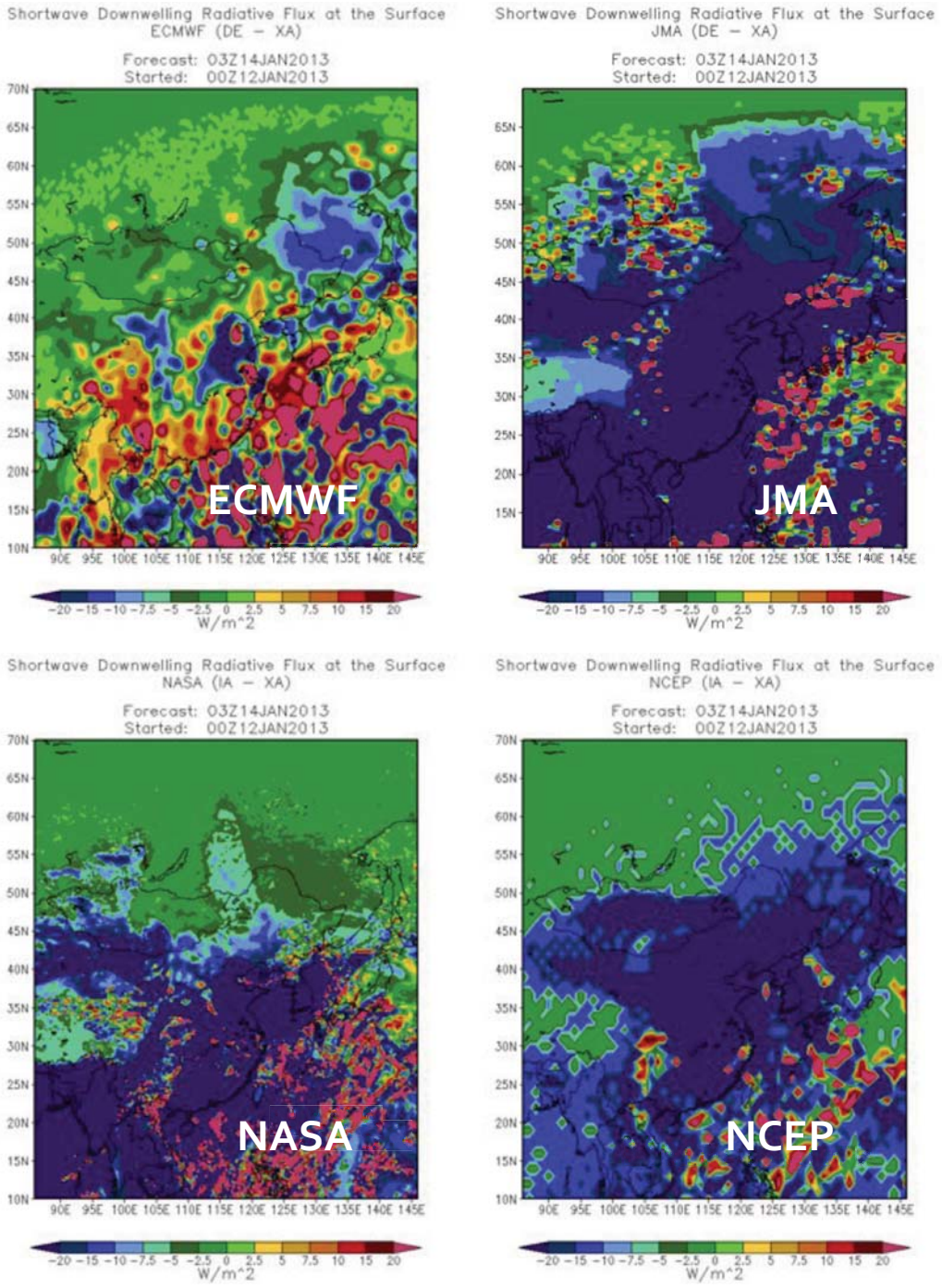
AOD 550nm Intercomparison 3 UTC 14 Jan 2013 (51h)

- NCEP Climatology does not capture this event (as expected)
- ECMWF event relatively weak compared to NASA/ JMA



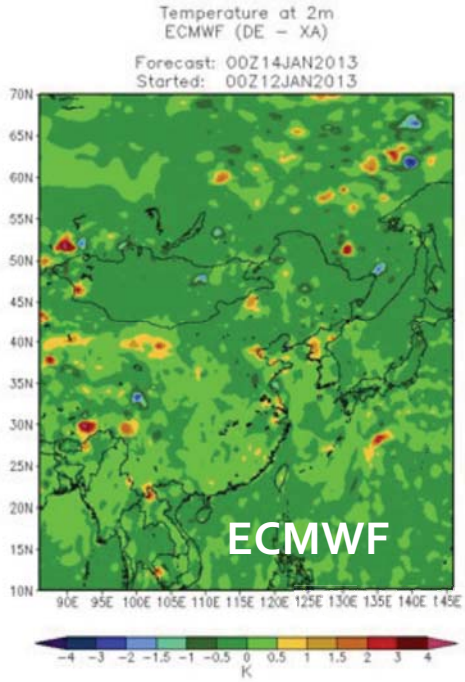
SW Radiation @ Surface Impact (Aero-NoAero) 3 UTC 14 Jan 2013 (51h)

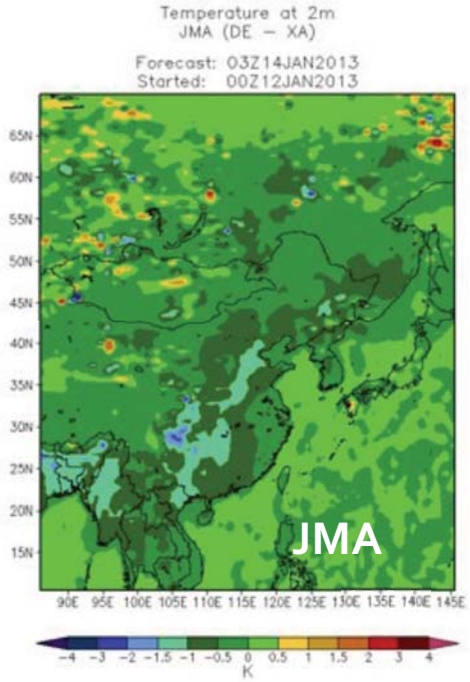
- 3 UTC (day time)
- Except for ECMWF, aerosol impact is to reduce SW in astern Asia
- The role BC/OC vs SO_4 needs to be examined (but no speciation data provided)

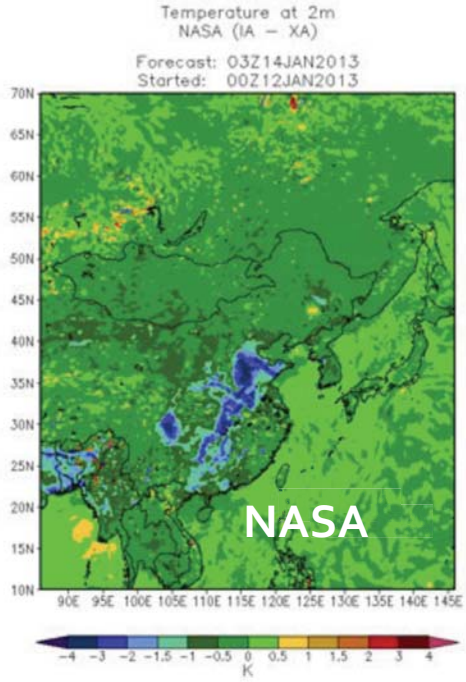


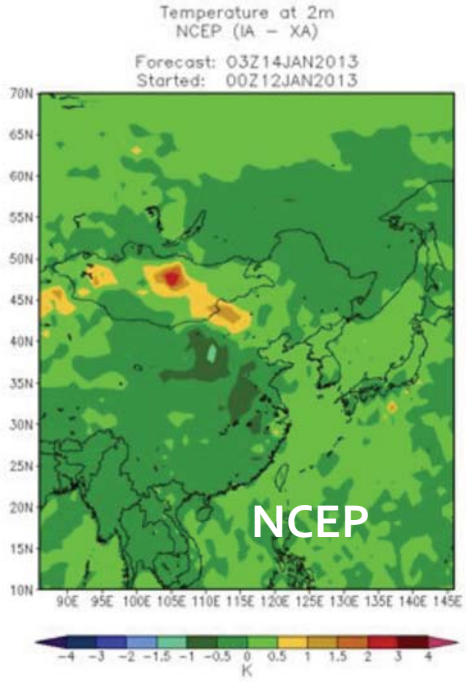
Temperature @ 2m Impact (Aero-NoAero) 3 UTC 14 Jan 2013 (51h)

- 3 UTC (day time)
- Relatively modest surface cooling, except for NASA



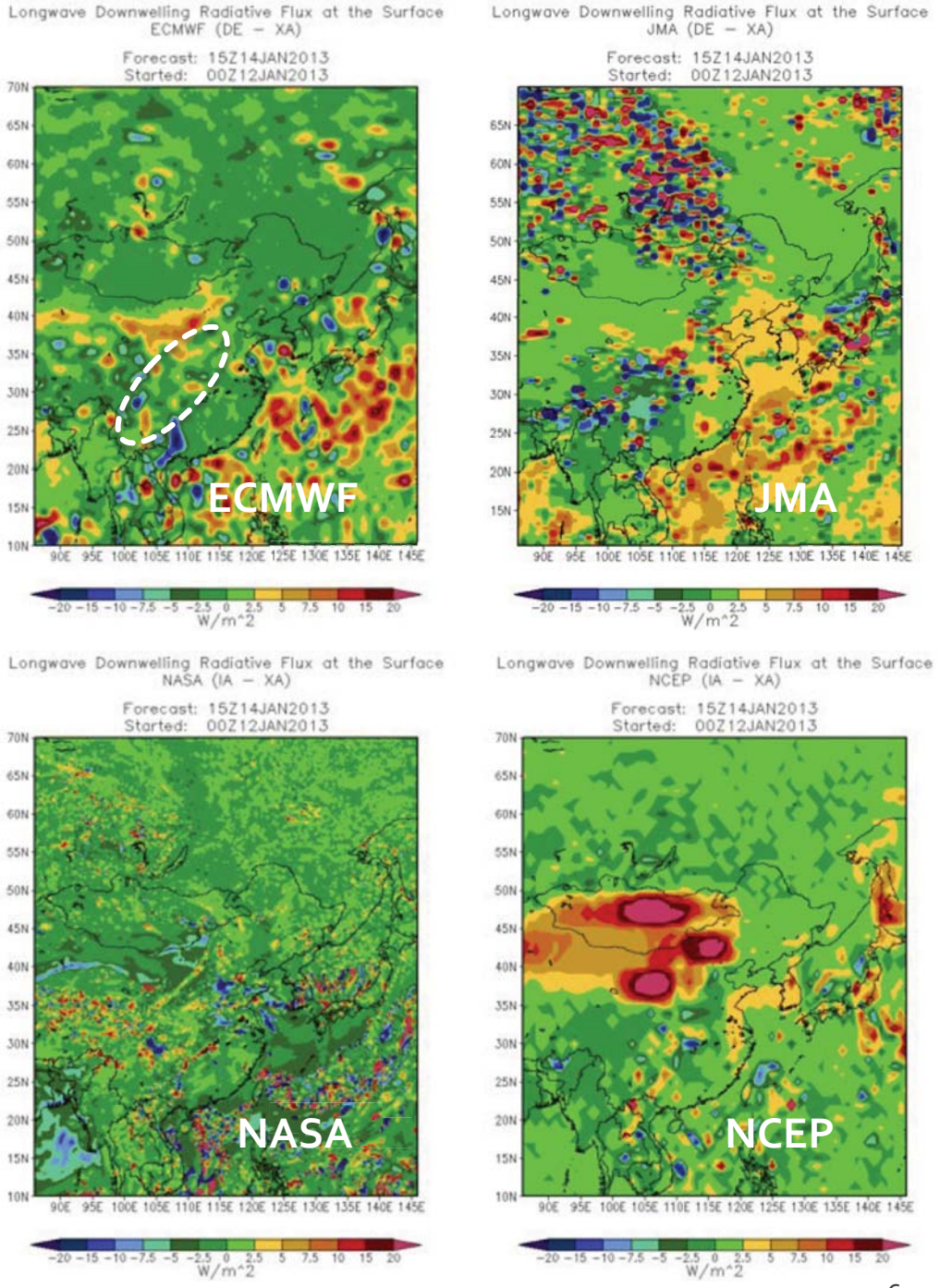






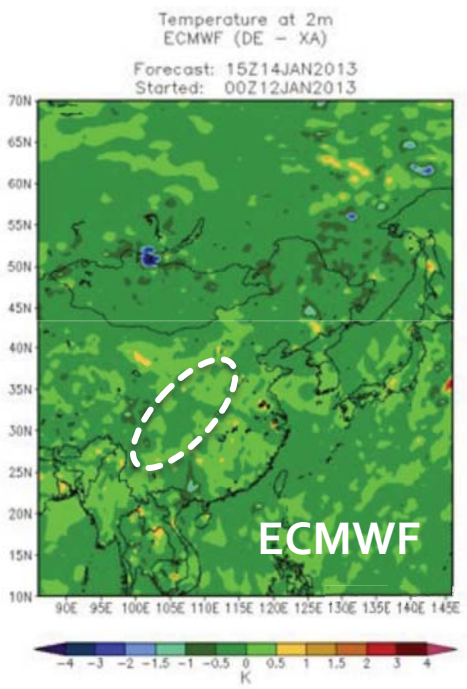
LW Radiation @ Surface Impact (Aero-NoAero) 15 UTC 14 Jan 2013 (72h)

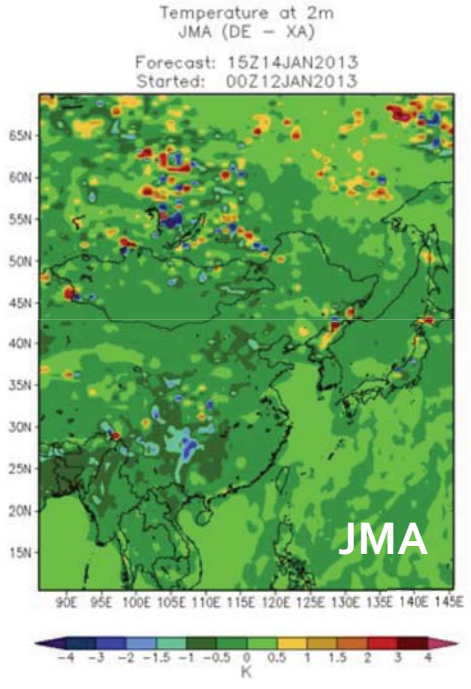
- 15 UTC (night time)
- Very little aerosol impact on surface LW along the plume.
- Predominance of non-absorbing aerosols in these models?

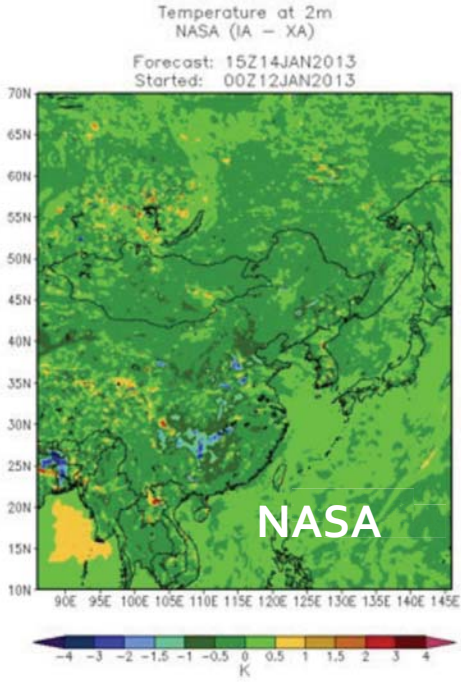


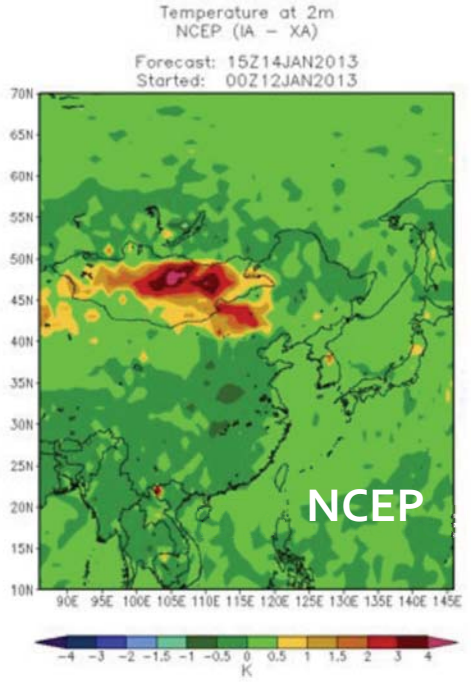
Temperature @ 2m Impact (Aero-NoAero) 15 UTC 14 Jan 2013 (72h)

- 15 UTC (night time)
- Consistently, not much of a surface temperature impact







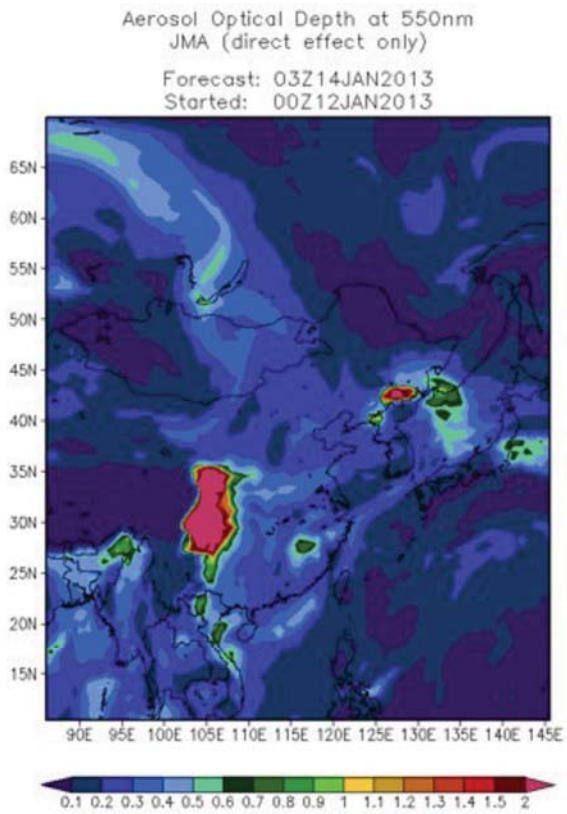


Aerosol Indirect Effect

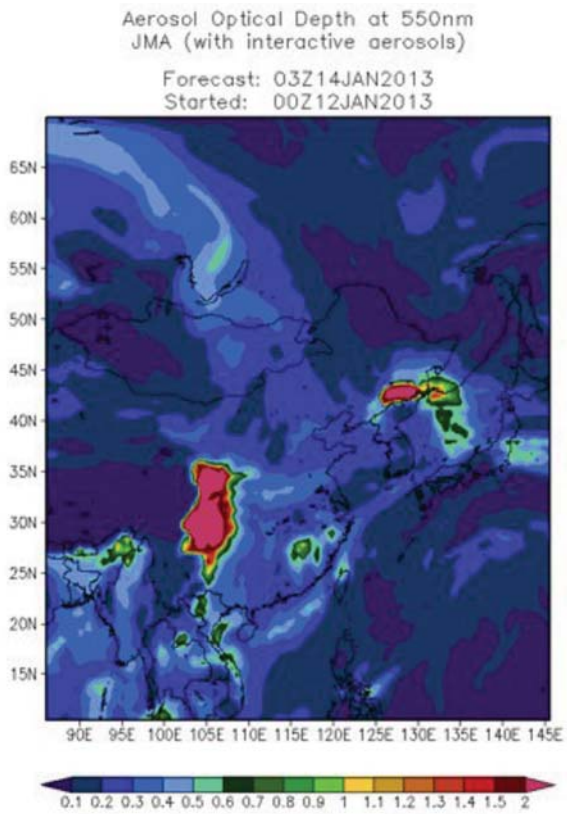
So far, only JMA has submitted these cases

AOD 550 nm (JMA)
3 UTC 14 Jan 2013

DIRECT ONLY

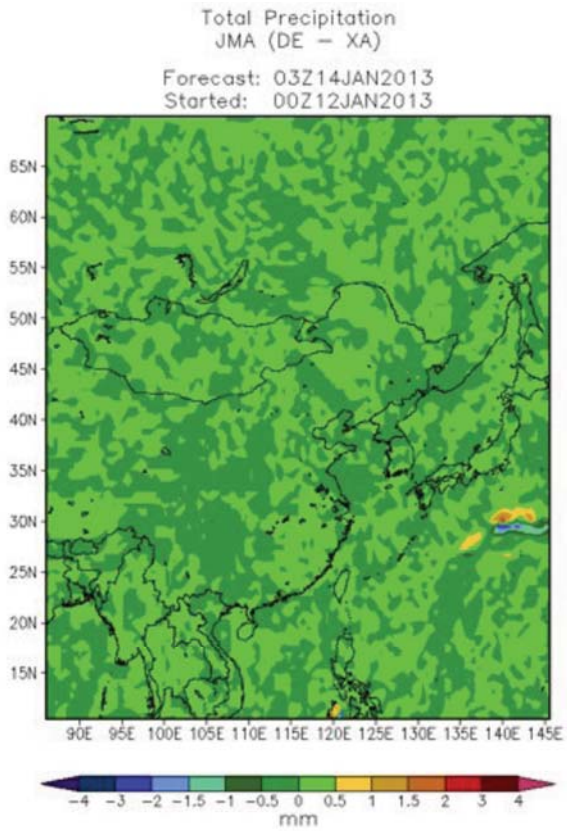


DIRECT+INDIRECT

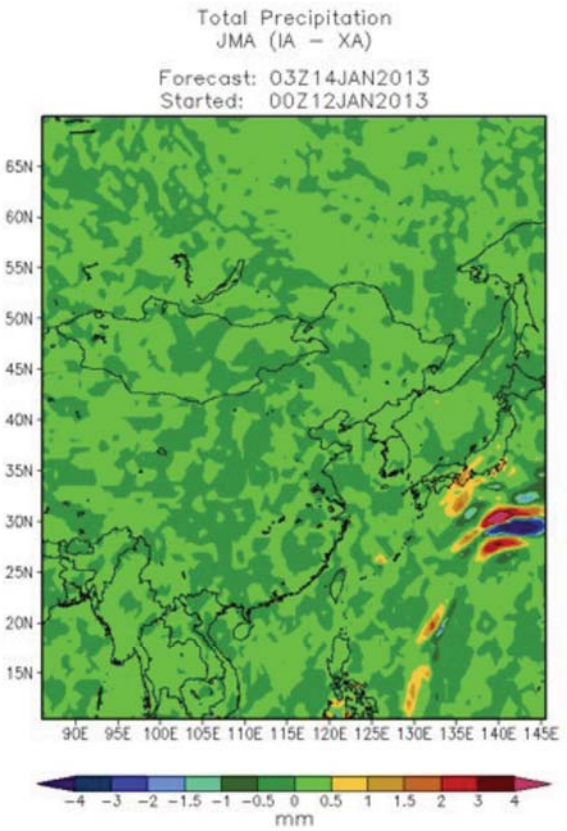


Precipitation (Cloud Microphysics) 3 UTC 14 Jan 2013

DIRECT ONLY – NO AEROSOL

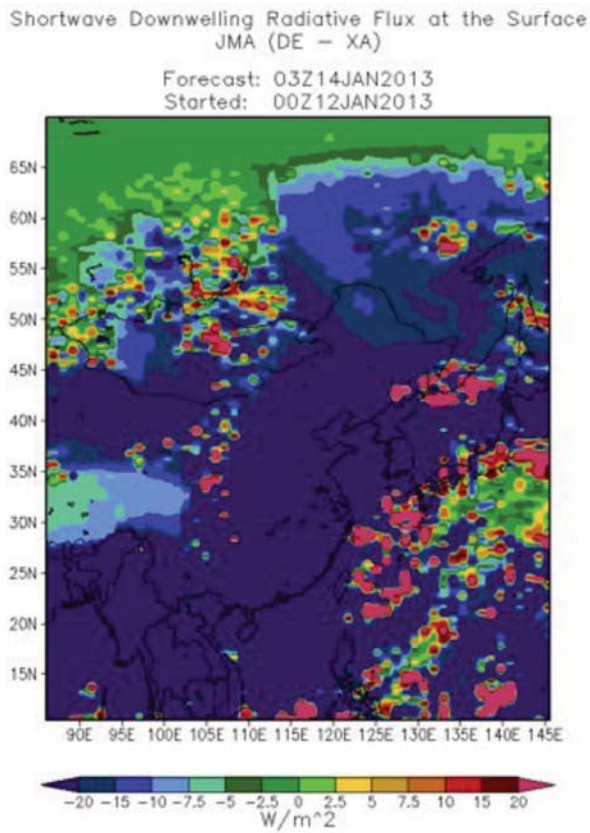


DIRECT+INDIRECT – NO AERO

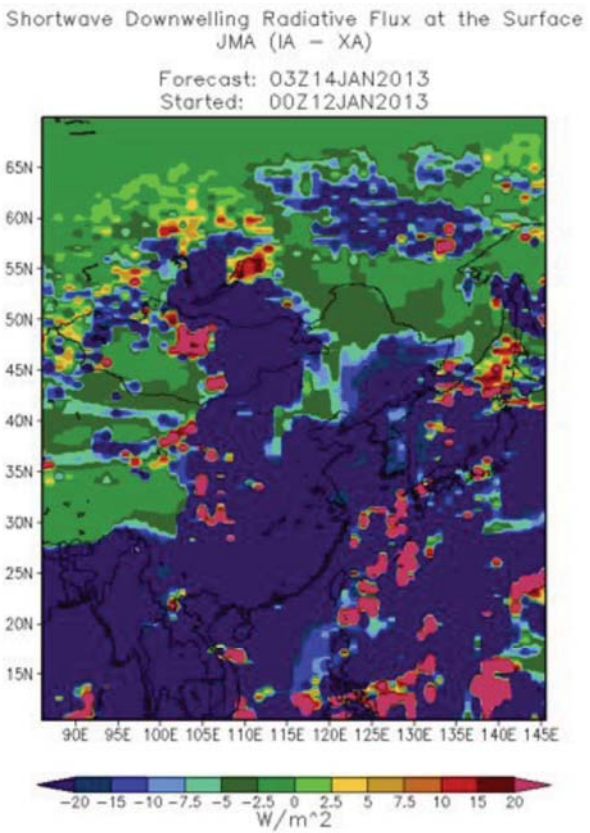


SW Radiation @ Surface (JMA)
3 UTC 14 Jan 2013

DIRECT ONLY – NO AEROSOL

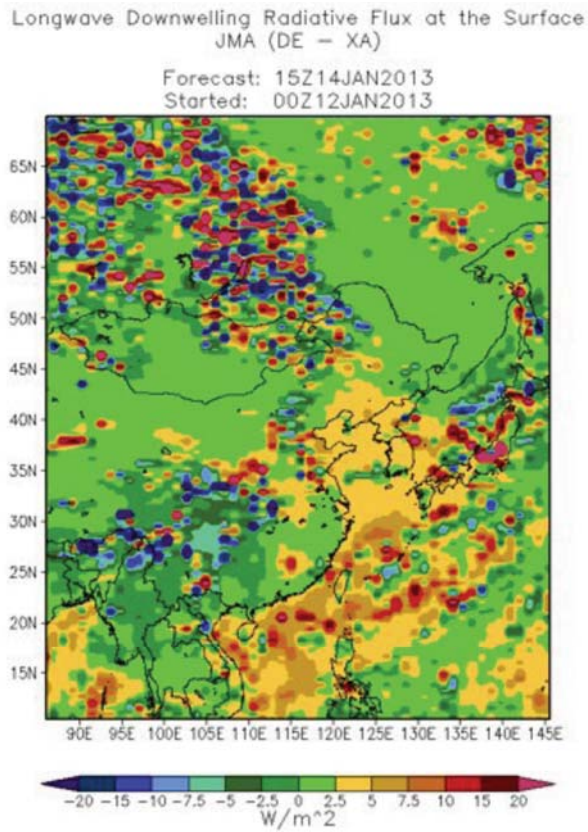


DIRECT+INDIRECT – NO AERO

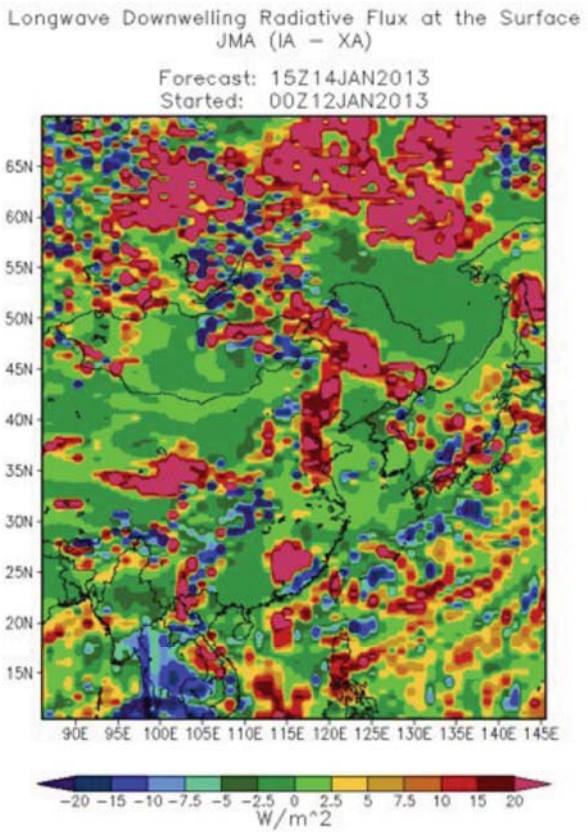


LW Radiation @ Surface (JMA) 15 UTC 14 Jan 2013

DIRECT ONLY – NO AEROSOL

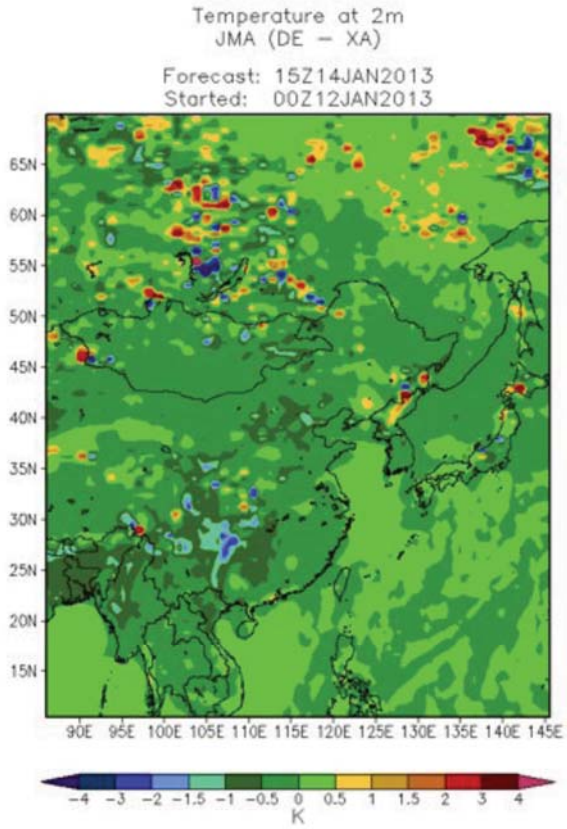


DIRECT+INDIRECT – NO AERO

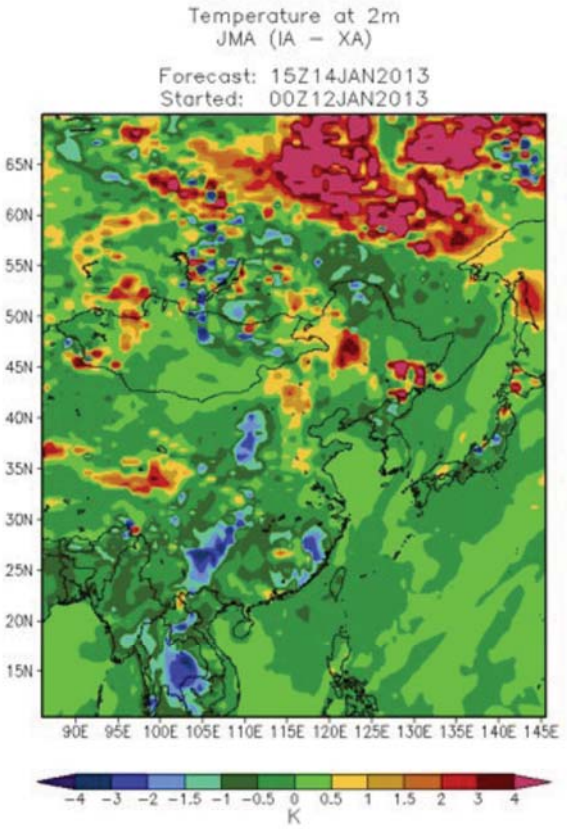


Temperature @ 2m (JMA)
15 UTC 14 Jan 2013

DIRECT ONLY – NO AEROSOL

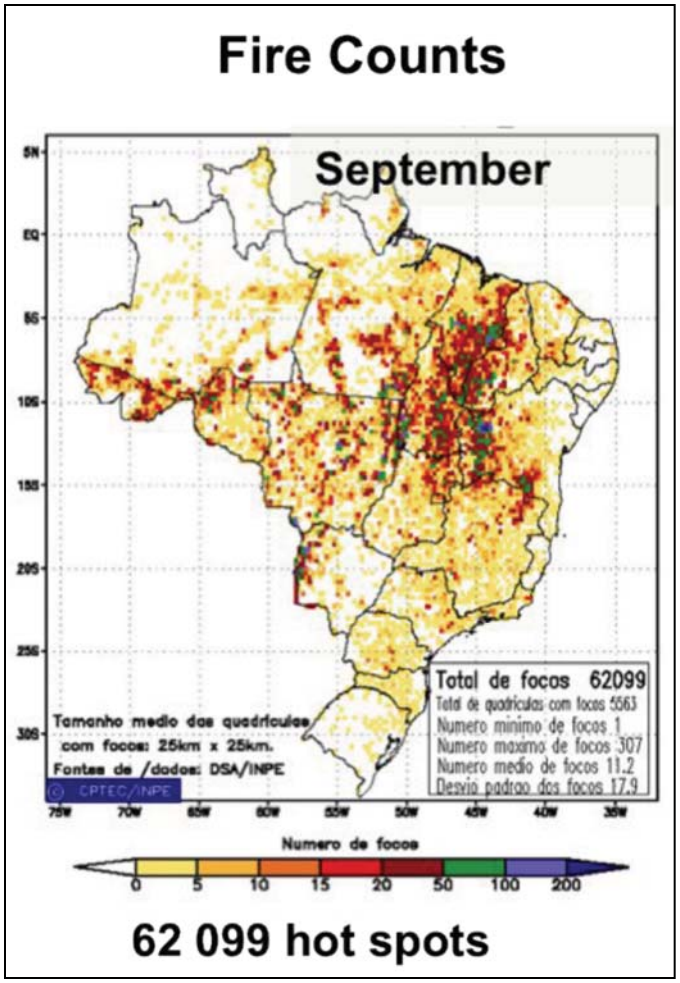


DIRECT+INDIRECT – NO AERO



Case 3
Persistent Smoke in Brazil

- September 2012
- Forecasts
  - September 5-15, 2012
  - From 0 or 12 UTC
  - 10 day forecasts
- Center of domain
  - 116E, 40N
- Model configuration
  - Same as for NWP
- Direct & Indirect effects



Concluding Remarks

- WGNE Exercise on Aerosol Impact on NWP is under way
  - Mostly direct effect cases have been submitted
  - Analysis of results progressing
    - Goal: Report by end of 2014, journal article by Q1/Q2 2014
  - There is still time for new participants!
- From these early results
  - Models show some skill in capturing aerosol events
  - Aerosol Direct Radiative forcing not consistent among all models
  - Likewise, near surface wind/temperature response vary
- Further analysis required, e.g.,
  - Validation by independent aerosol and meteorological data
  - Limited assessment of forecast skills
- Leading to refinement of the protocol for phase II.