Evaluating aerosols impacts on Numerical Weather Prediction: 5th Report - 2017

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Global Modeling and Assimilation Office, NASA/GSFC

With inputs from: Julliana Larise, Maurício Zarzur, Angela Benedetti, Georg Grell, Oriol Jorba, Morad Mokhtari, and WGNE Members Participants

outline

- Brief introduction and description of the proposed case studies and protocols and centers participants.
- Some highlighted results
- Quantitative evaluation
- Conclusions

Goals of the Exercise

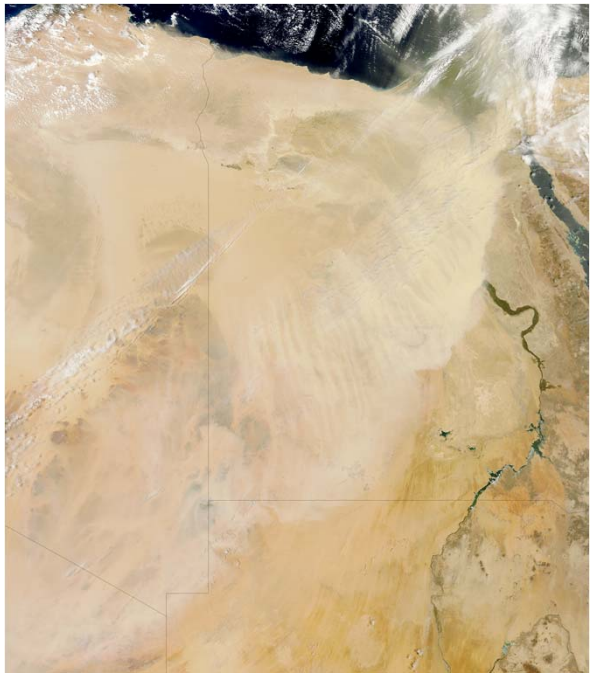
- This project aims to improve our understanding about:

- 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?

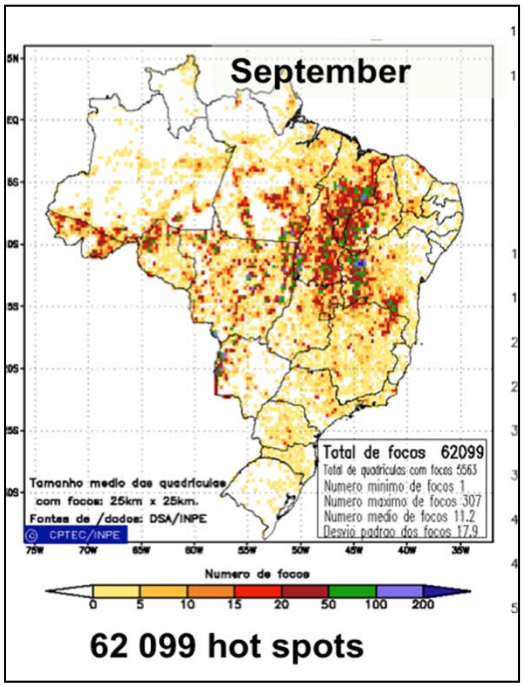
- What are the current capabilities of NWP models to simulate aerosol impacts on weather prediction?

Case Studies



1) Dust over Egypt: 4/2012

2) Pollution in China: 1/2013



3) Smoke in Brazil: 9/2012

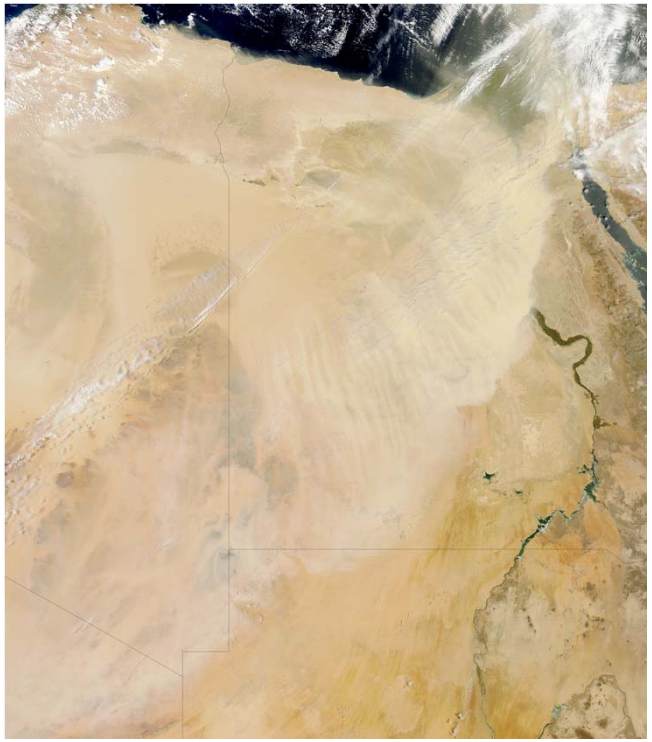
Participants

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

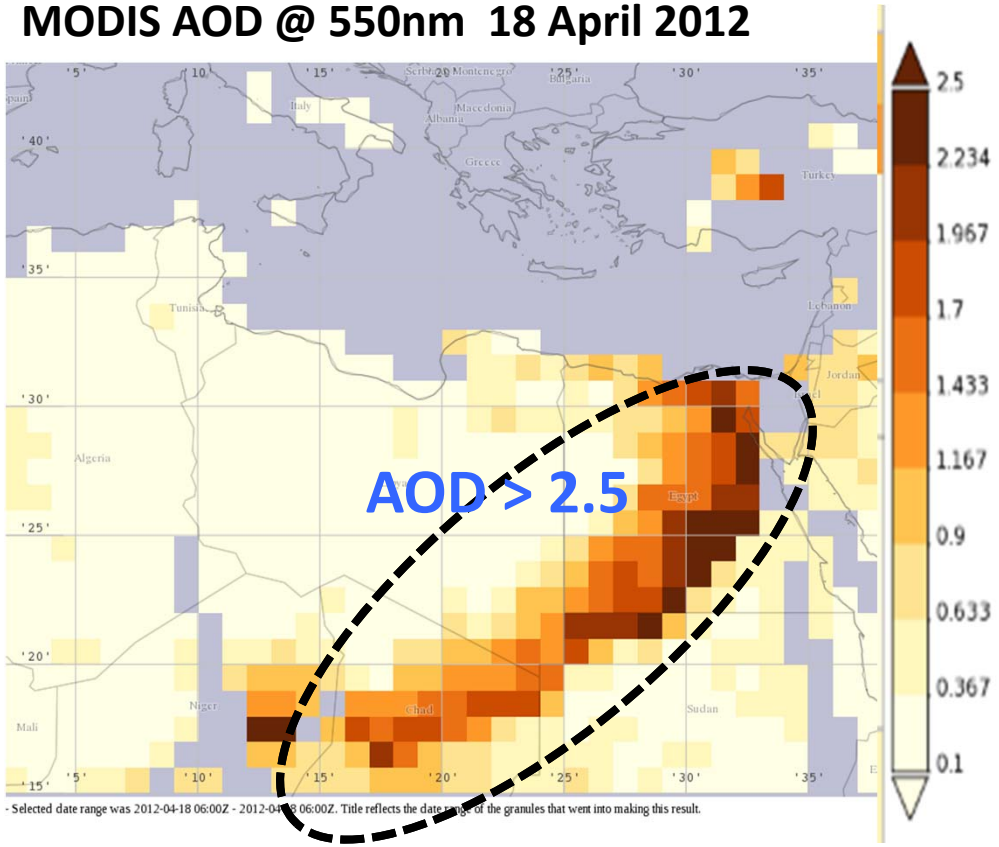
Case 1: Dust Plume over Egypt

- Forecasts
  - April 13-23 2012
  - From 0 or 12 UTC
  - 10 day forecasts

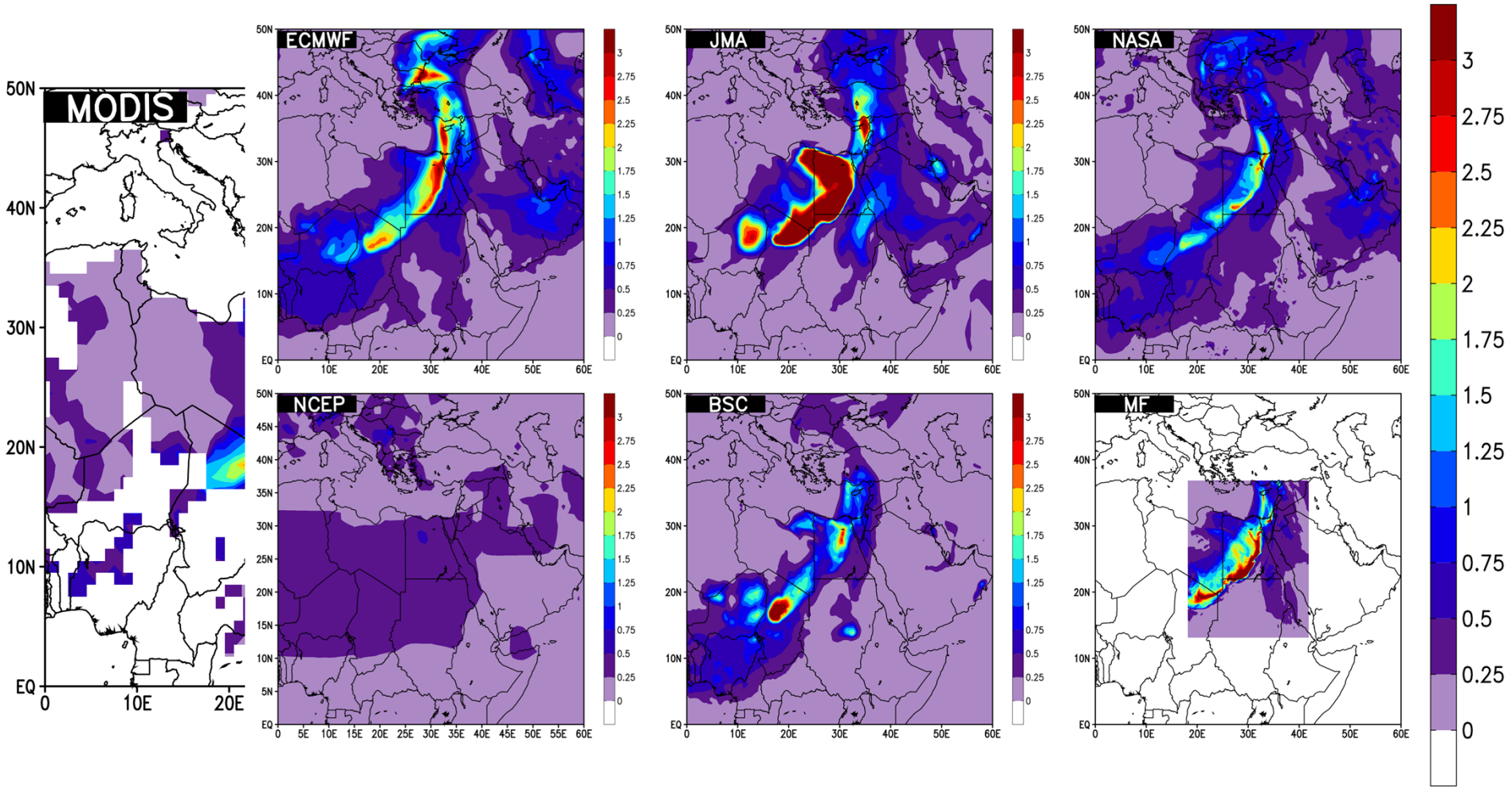
Model configuration : same as for NWP
Direct effects only



MODIS AOD @ 550nm 18 April 2012



AOD at 550nm:
Init: 00UTC17APR2012 – Forecast: 12UTC18APR2012

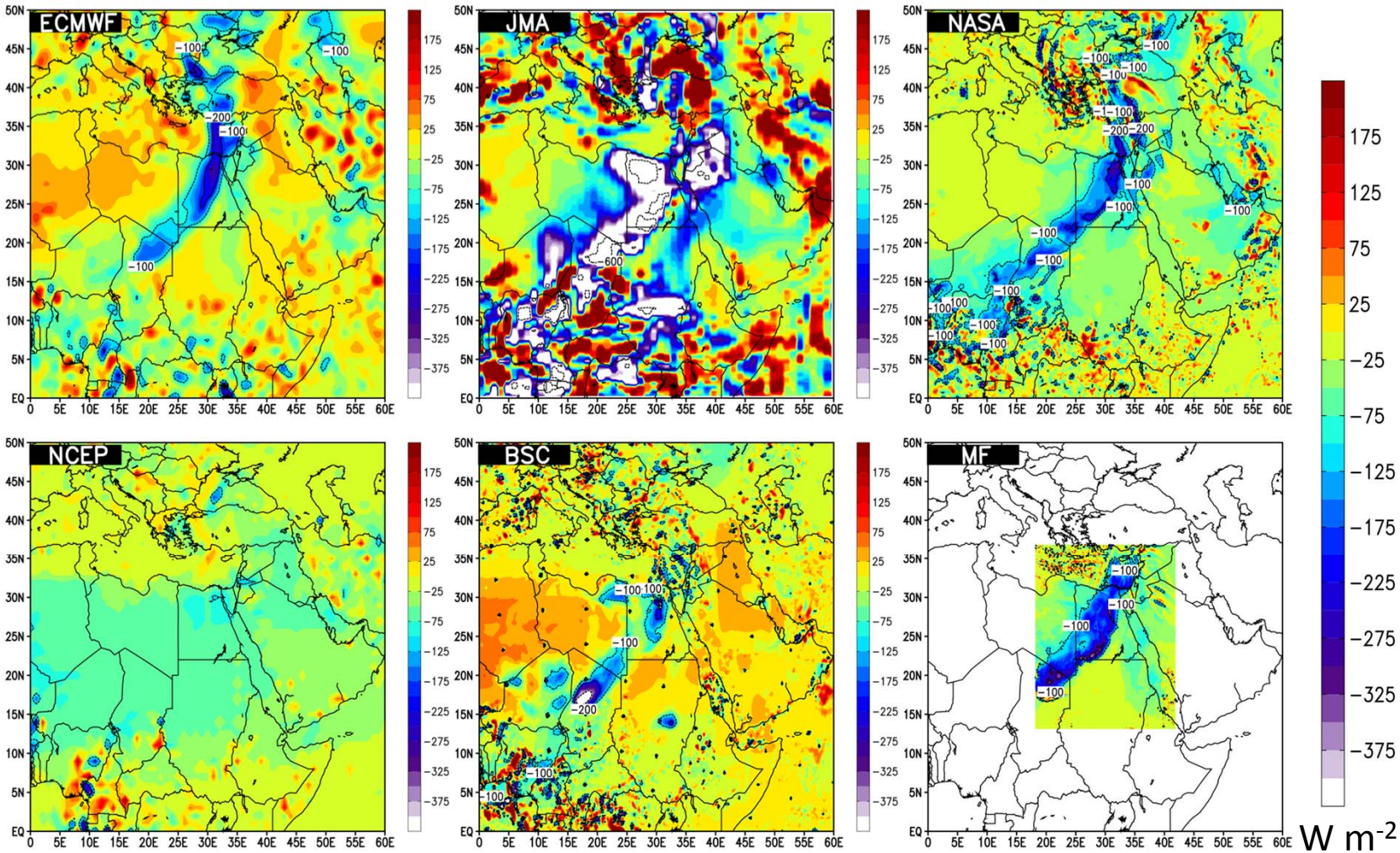


- NCEP : climatology aerosol field does not capture this transient/strong event (as expecte
- The other centers have similar pattern in terms of spatial distribution.
- AOD values : MF > JMA ~ ECMWF > NASA ~ BSC

Impacts on weather forecasting

- Radiative shortwave/longwave fluxes at surface
- Air temperature at 2m

Shortwave Downwelling radiative flux @ surface (AER – NOAER)
Init: 00UTC17APR2012 – Forecast: 12UTC18APR2012



Longwave downwelling radiative flux @ surface (AER – NOAER)
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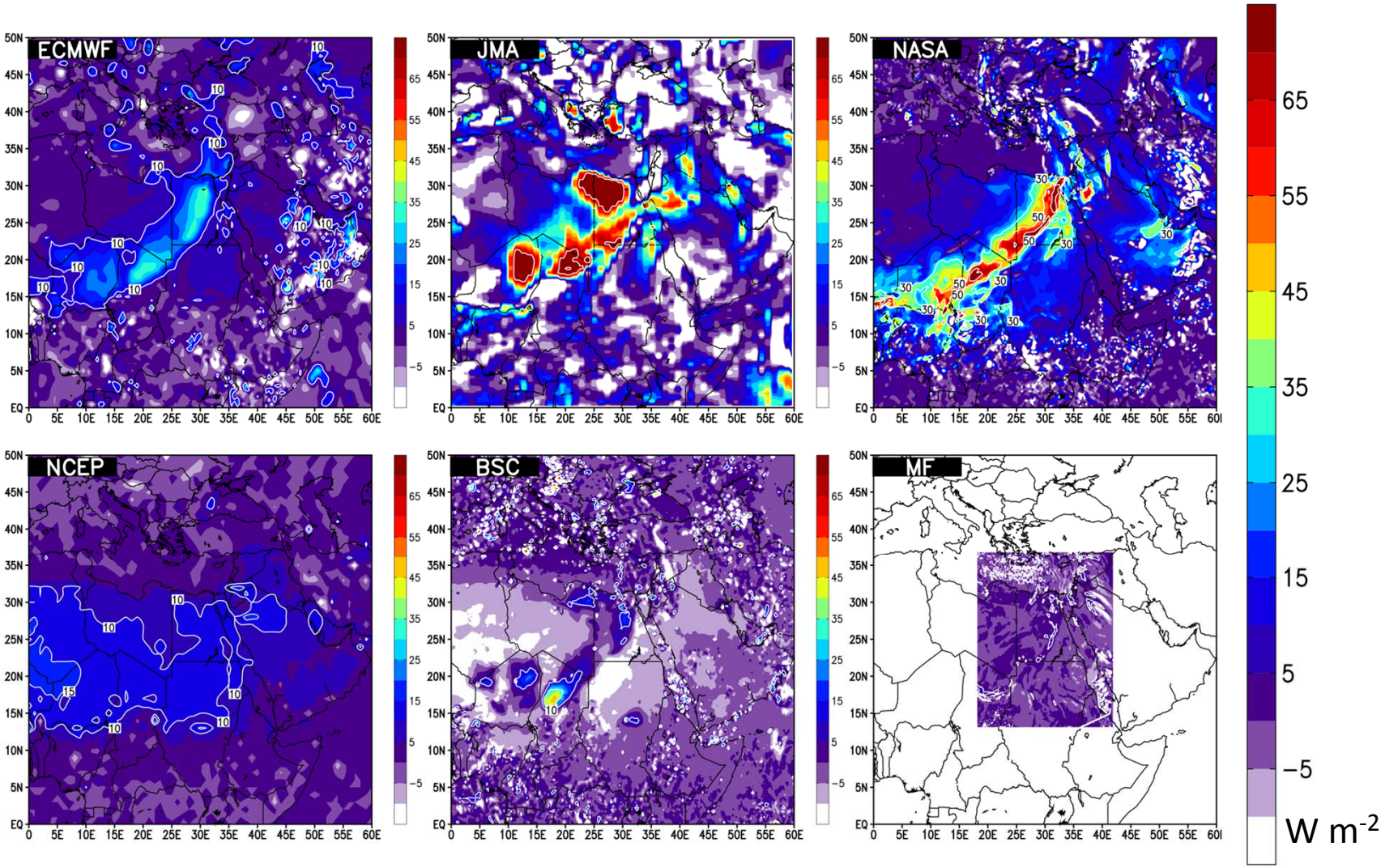
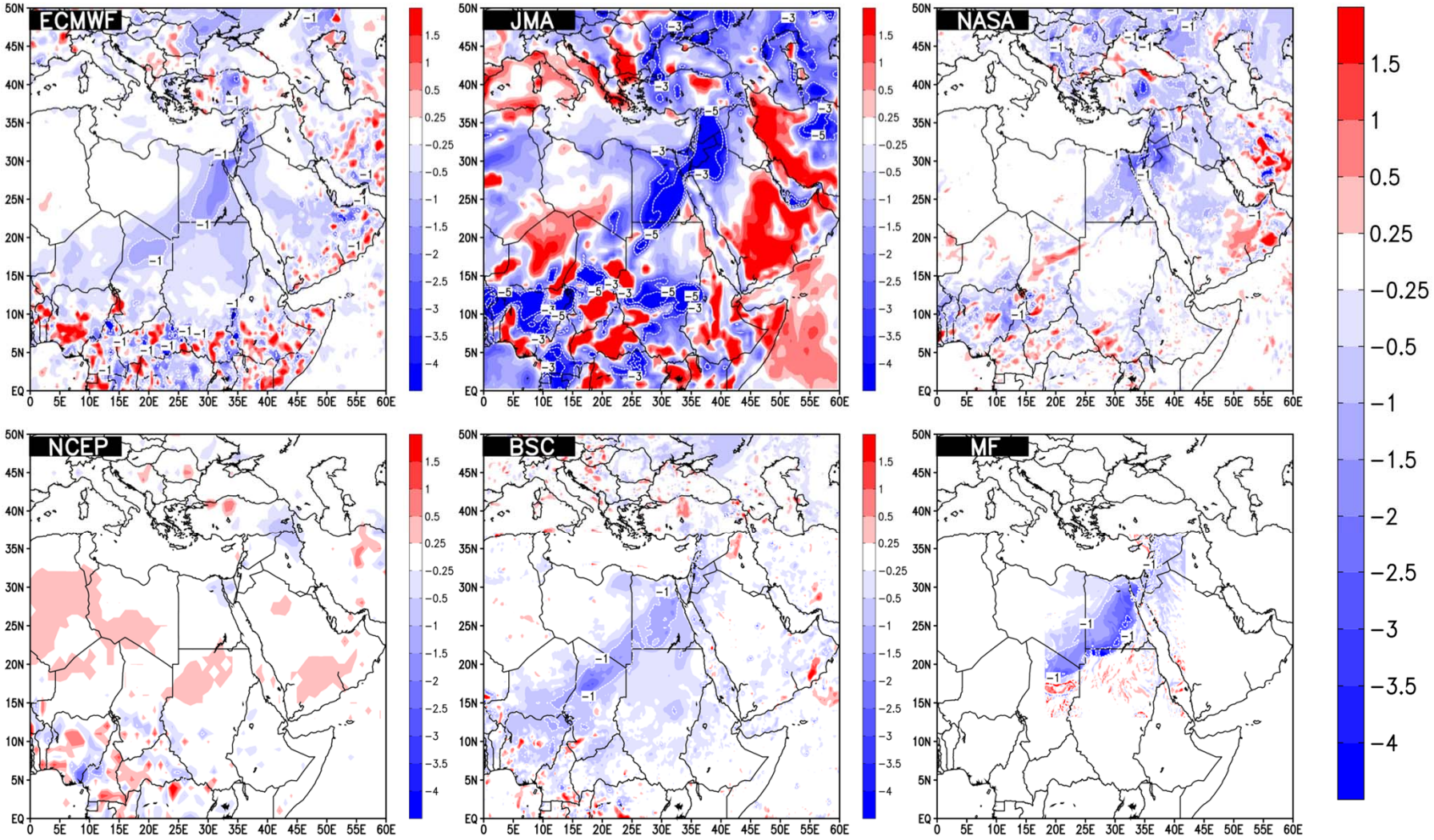


2-meter air temperature (AER – NOAER)
Init: 00UTC17APR2012 – Forecast: 15UTC18APR2012

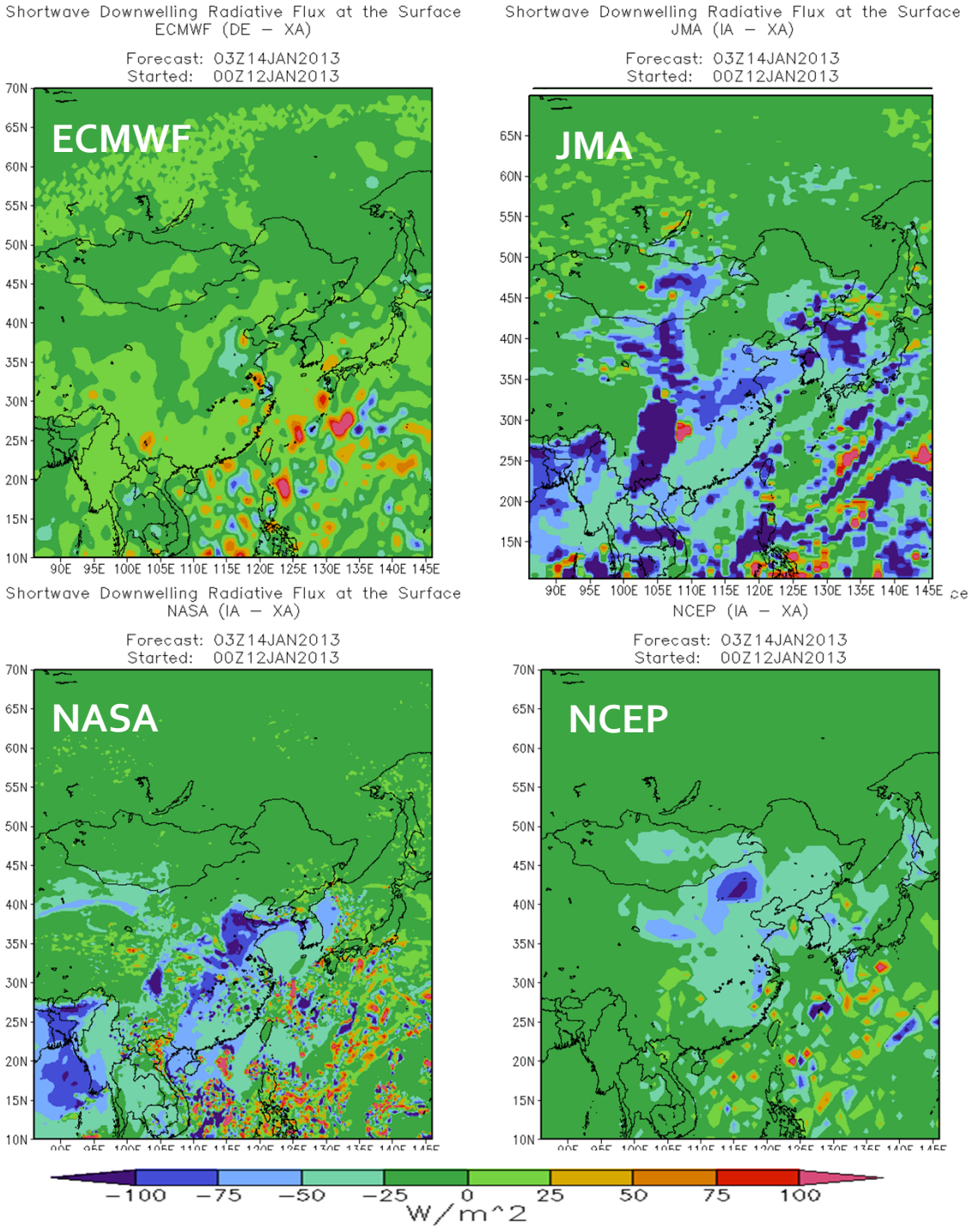


Case 2
Extreme Pollution in Beijing

- 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

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

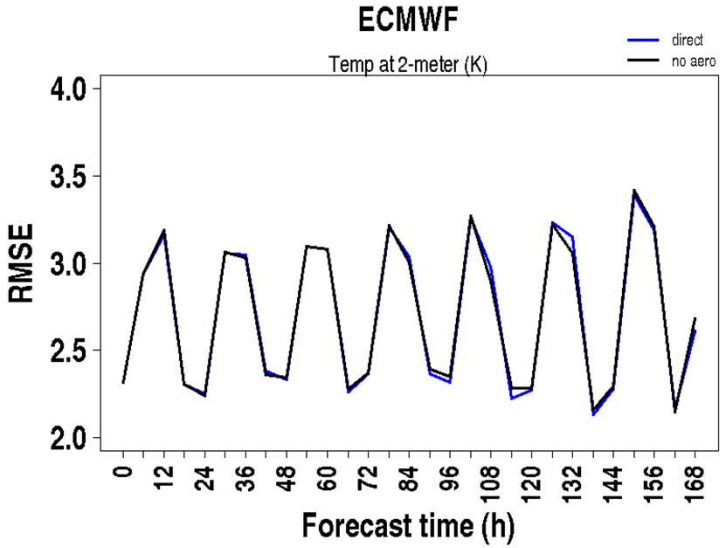
- 3 UTC (day time)

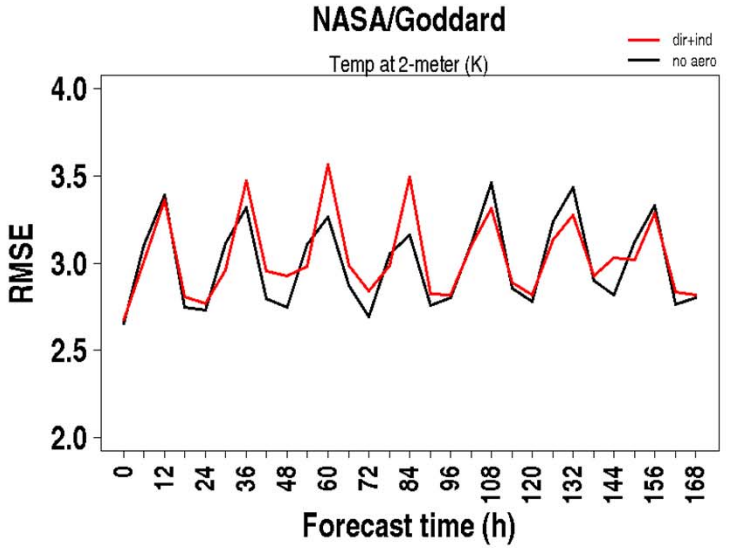


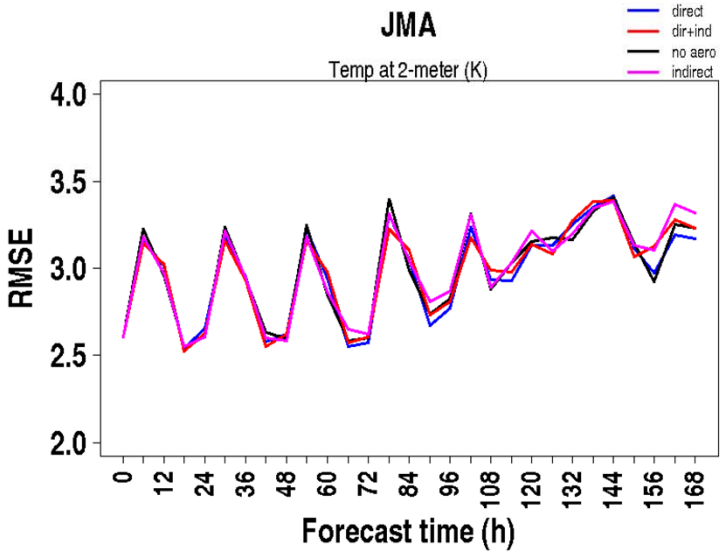
Quantitative evaluation for the Beijing case

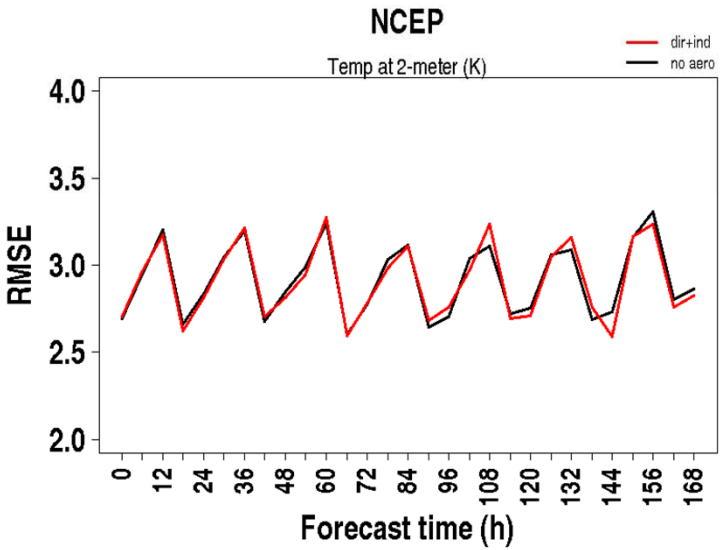
- Parameters:
  - 2-meter temperature.
  - 10-meter wind (mag and direction)
  - rainfall
- Observational data: meteo surface stations over China
- Evaluated time period: January 7-2, up to 7-day forecast.

RMSE: 2-m Temperature (K)

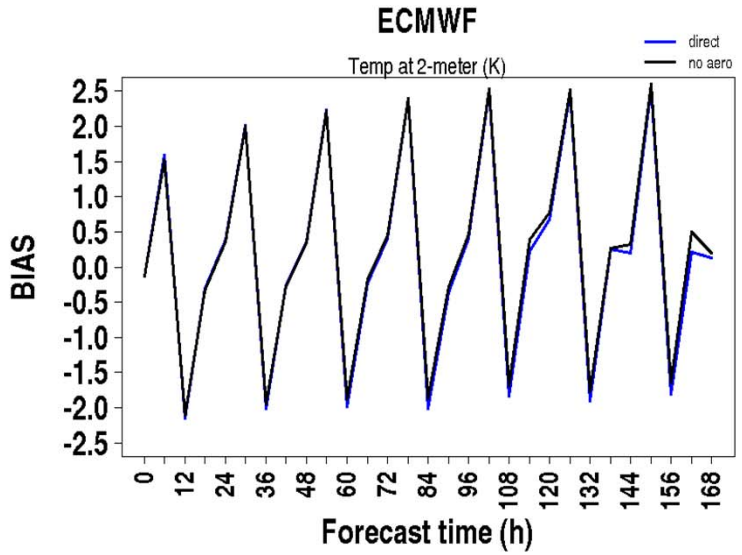


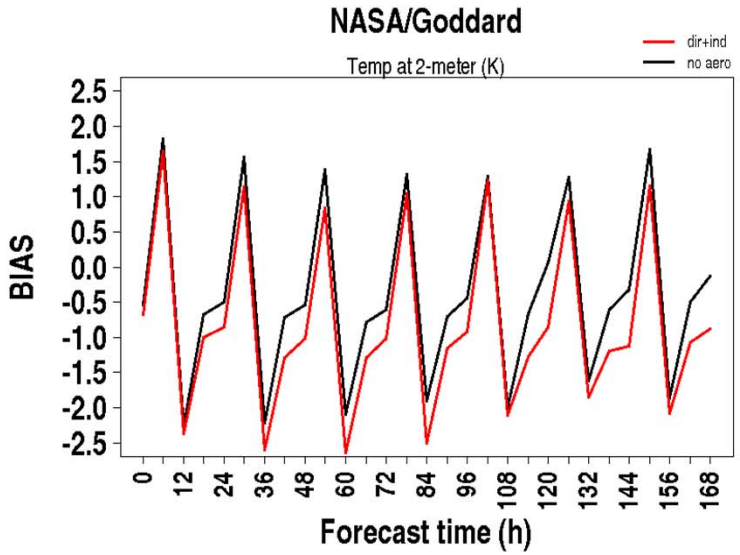


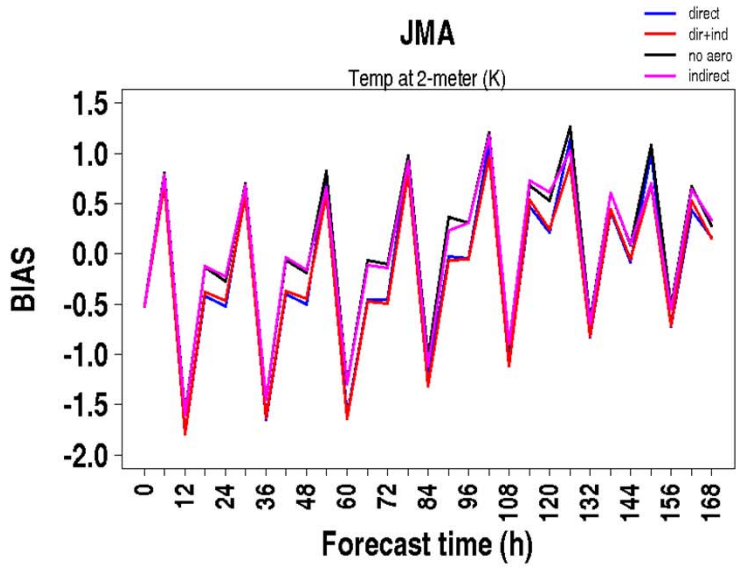


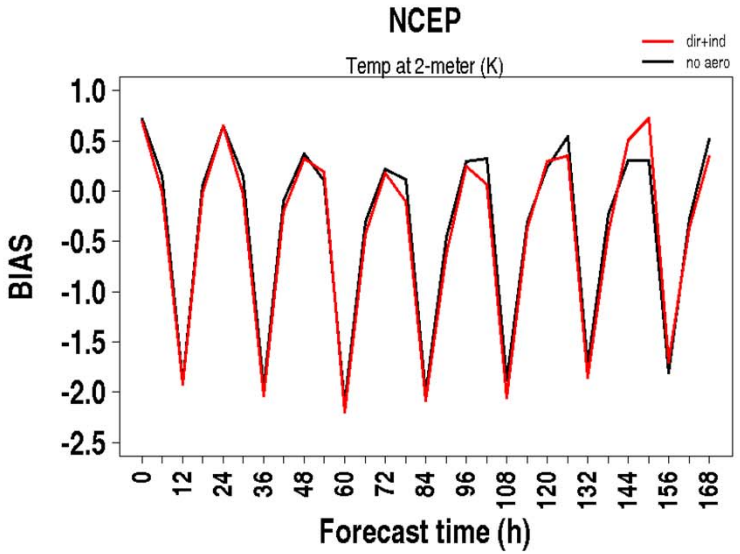


BIAS: 2-m Temperature (K)



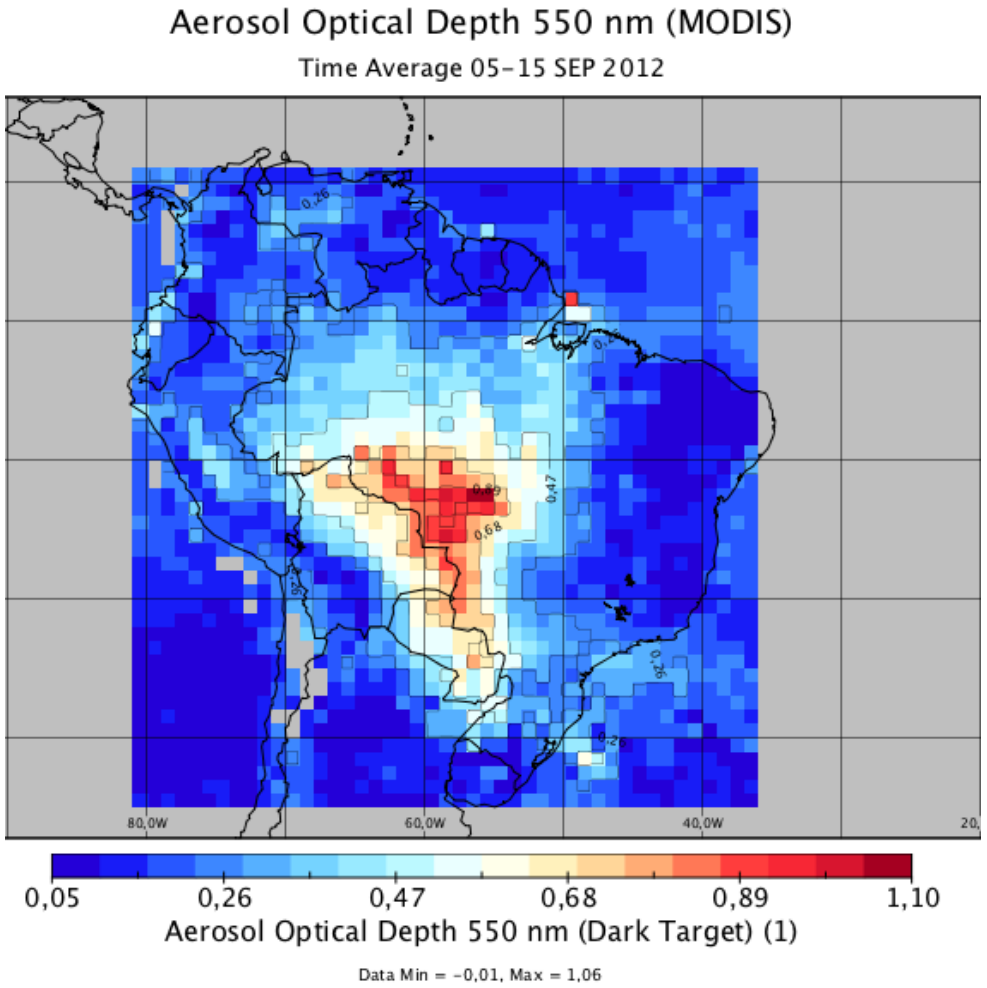




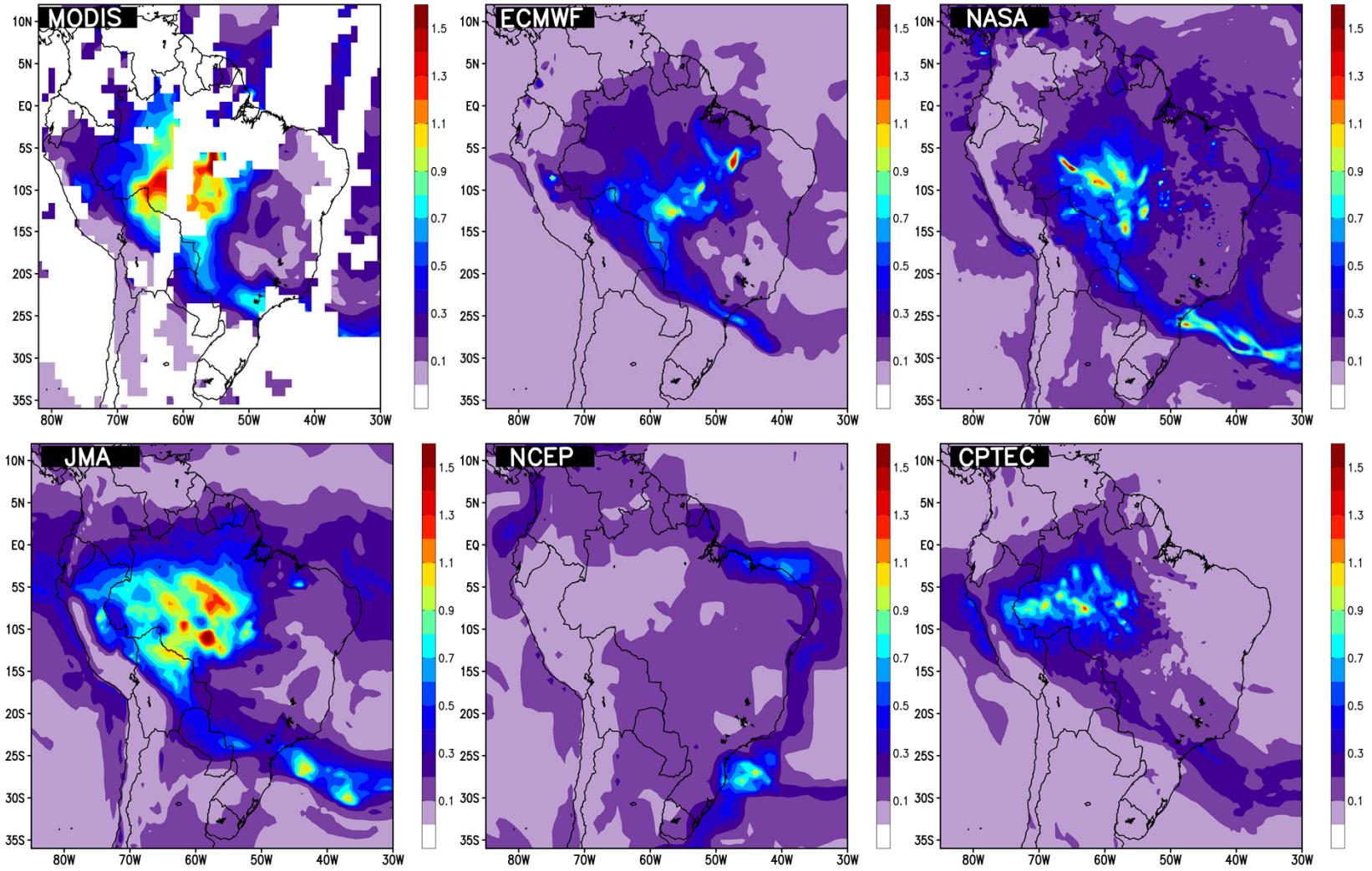


Case 3: Persistent Smoke in Brazil

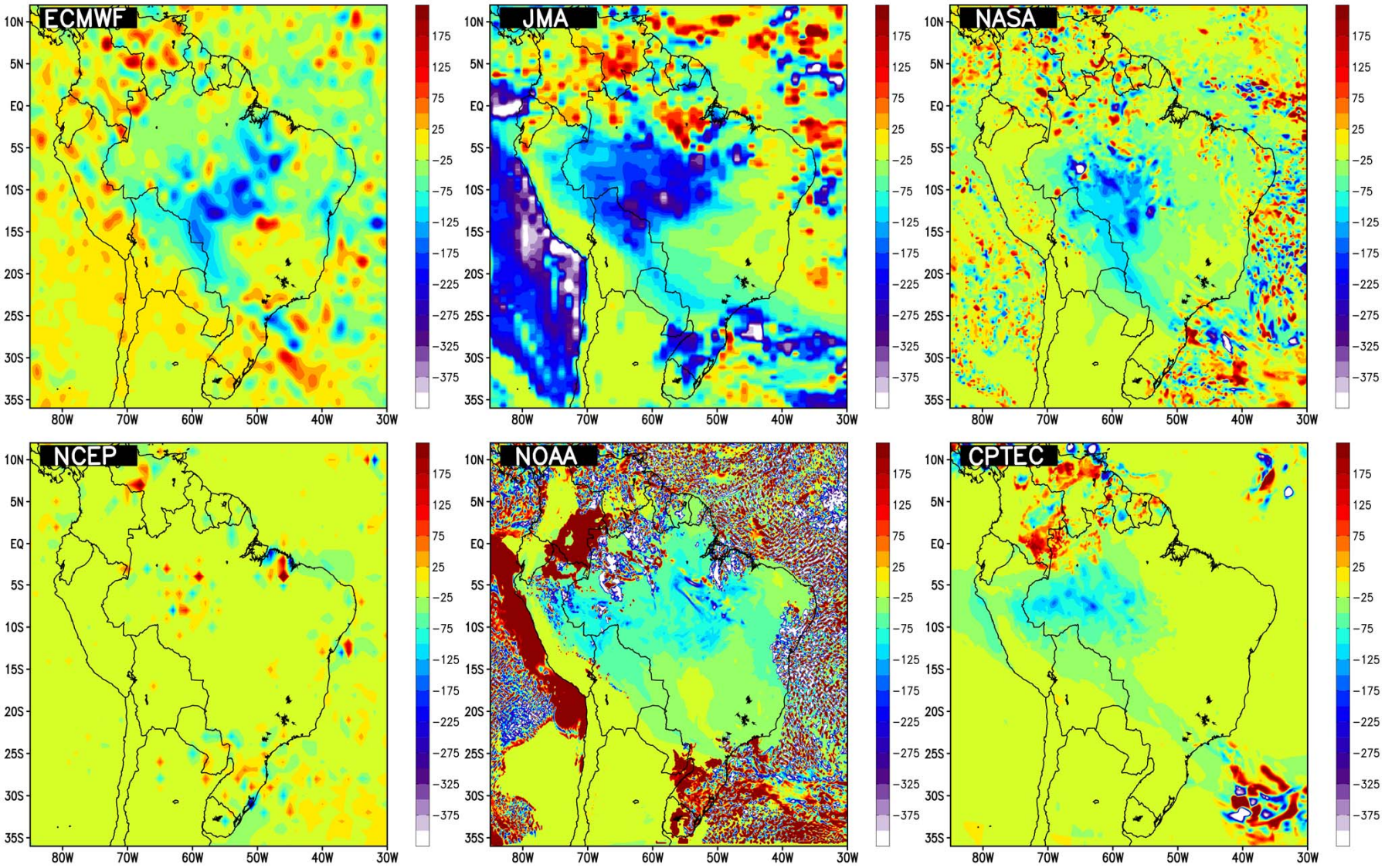
- September 2012
- Forecasts
  - September 5-15, 2012
  - From 0 or 12 UTC
  - 10 day forecasts
- Center of domain
  - 116E, 40N
- Model configuration
  - Same as for NWP
- Direct & Indirect effects



AOD at 550 nm
Init.: 00UTC10SEP – Forecast:15UTC11SEP

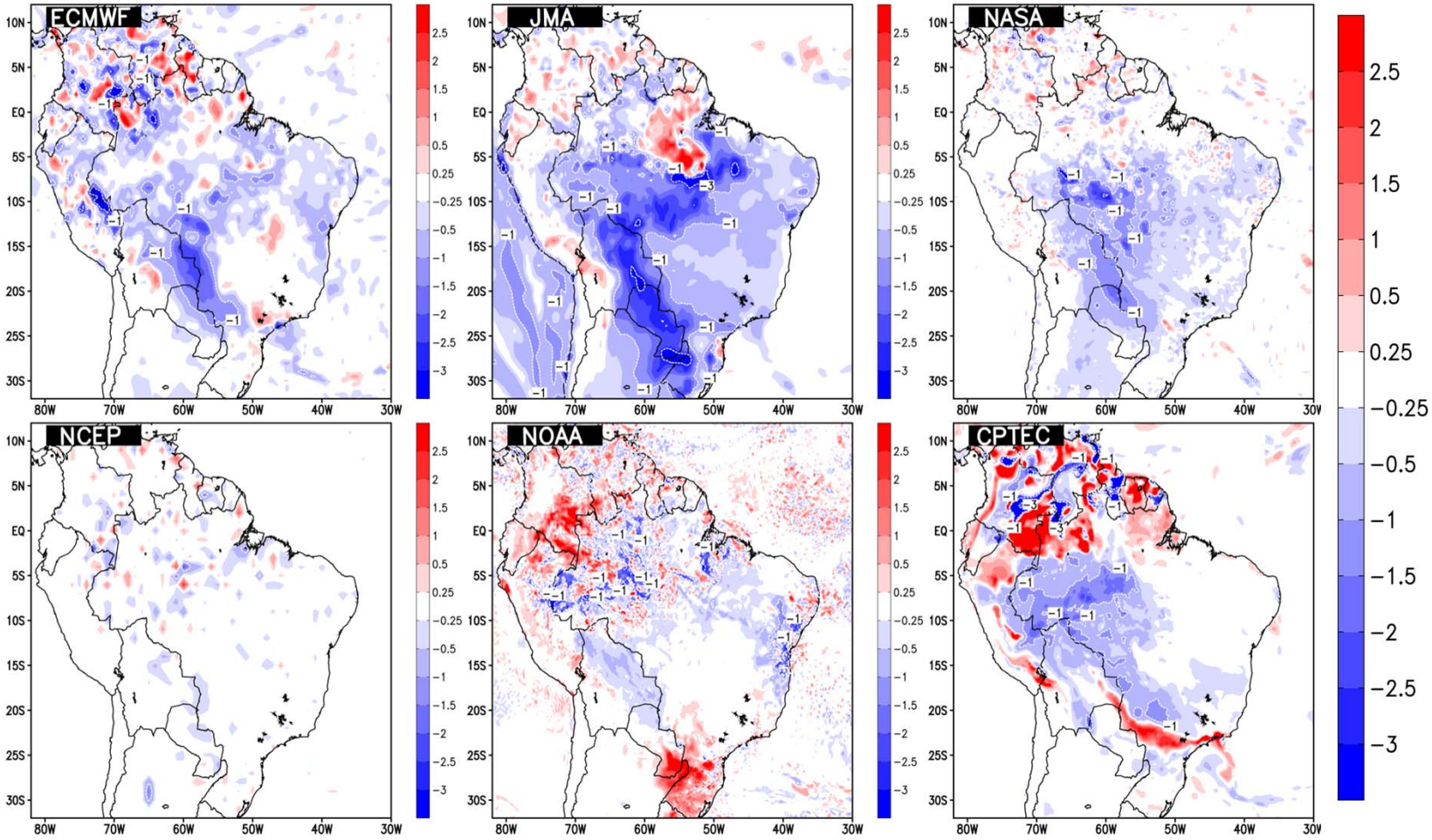


SW downweling radiative flux at surface (AER-NOAER)
Init.: 00UTC10SEP – Forecast:15UTC11SEP



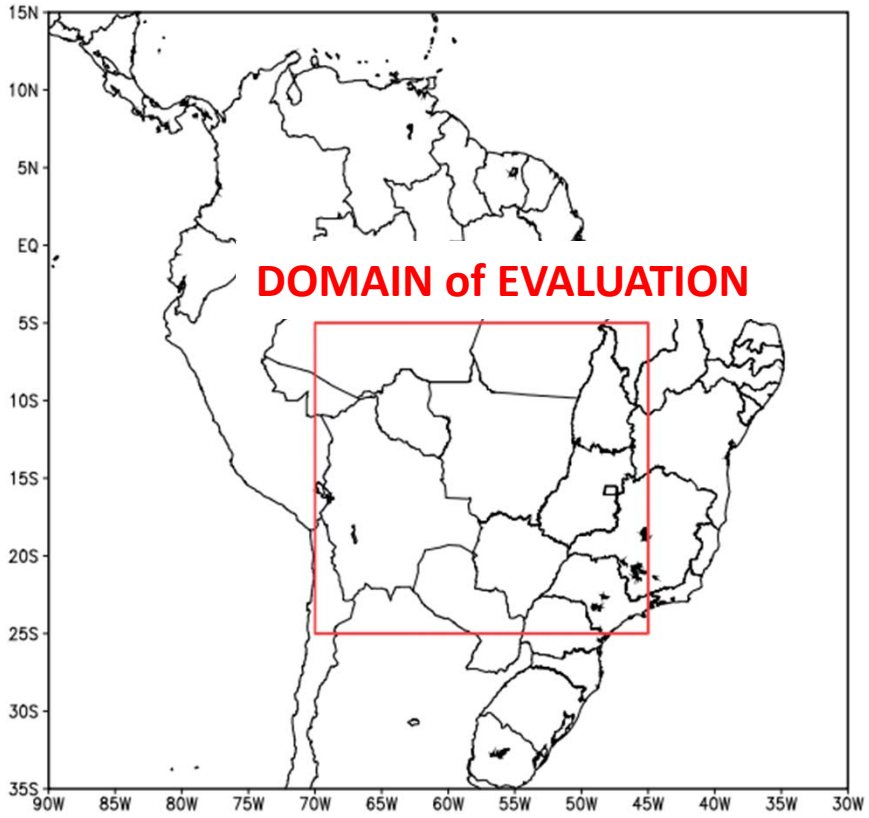
2-m Air Temperature Difference (AER-NOAER)

Init.:00UTC10SEP – Forecast: 18UTC11SEP



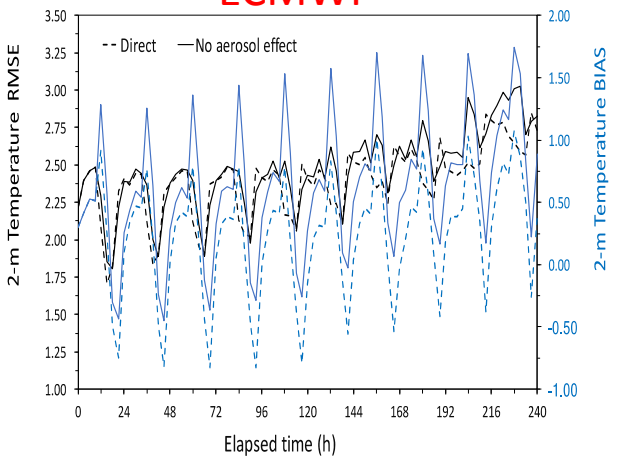
Quantitative evaluation for the SAMBBA case

- Parameters:
  - 2-meter temperature.
  - 10-meter wind (mag and direction)
- Observational data: meteo surface stations over S. America.
- Evaluated time period: 5 – 14 SEP, up to 240-hour forecast.

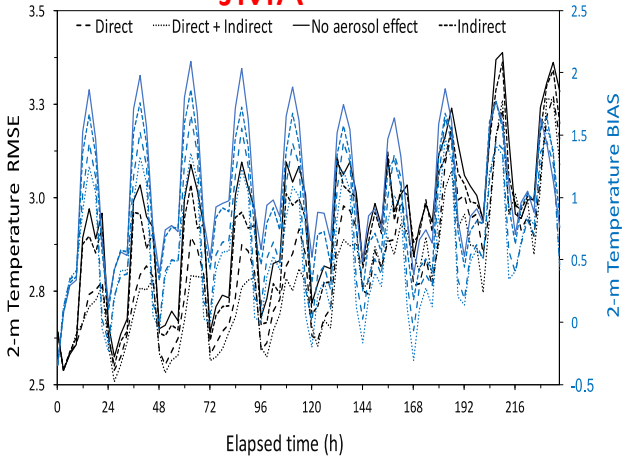


RMSE/BIAS: 2-m Temperature (K)

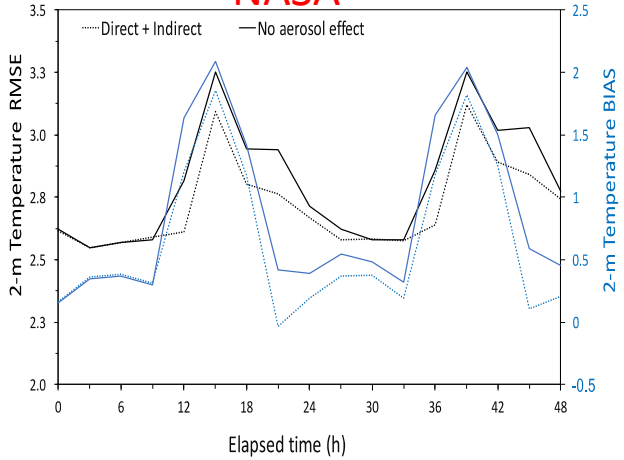
ECMWF

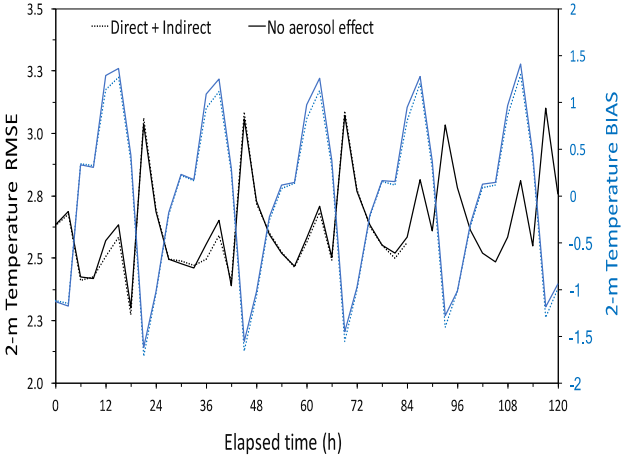


JMA

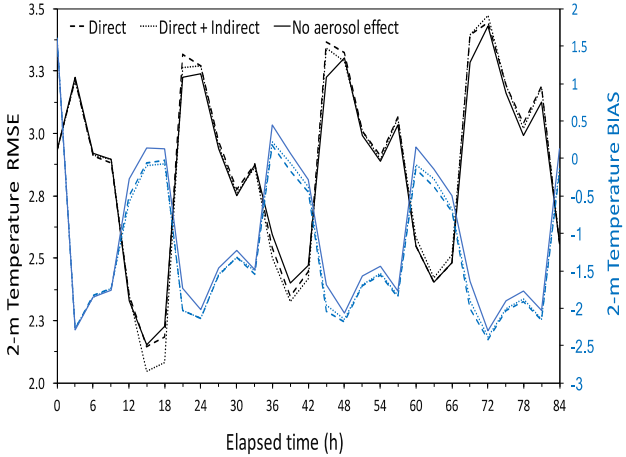


NASA

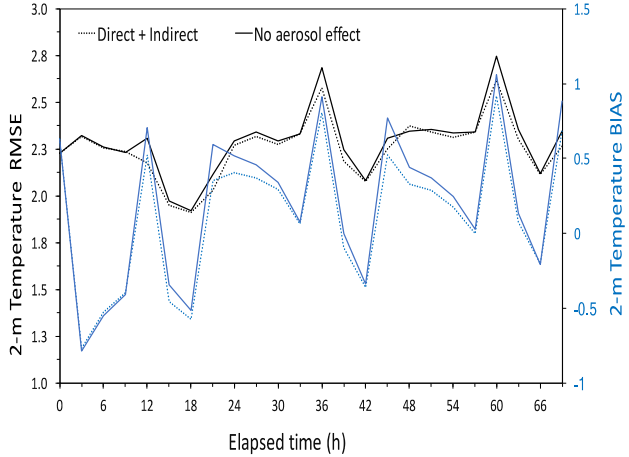




NCEP



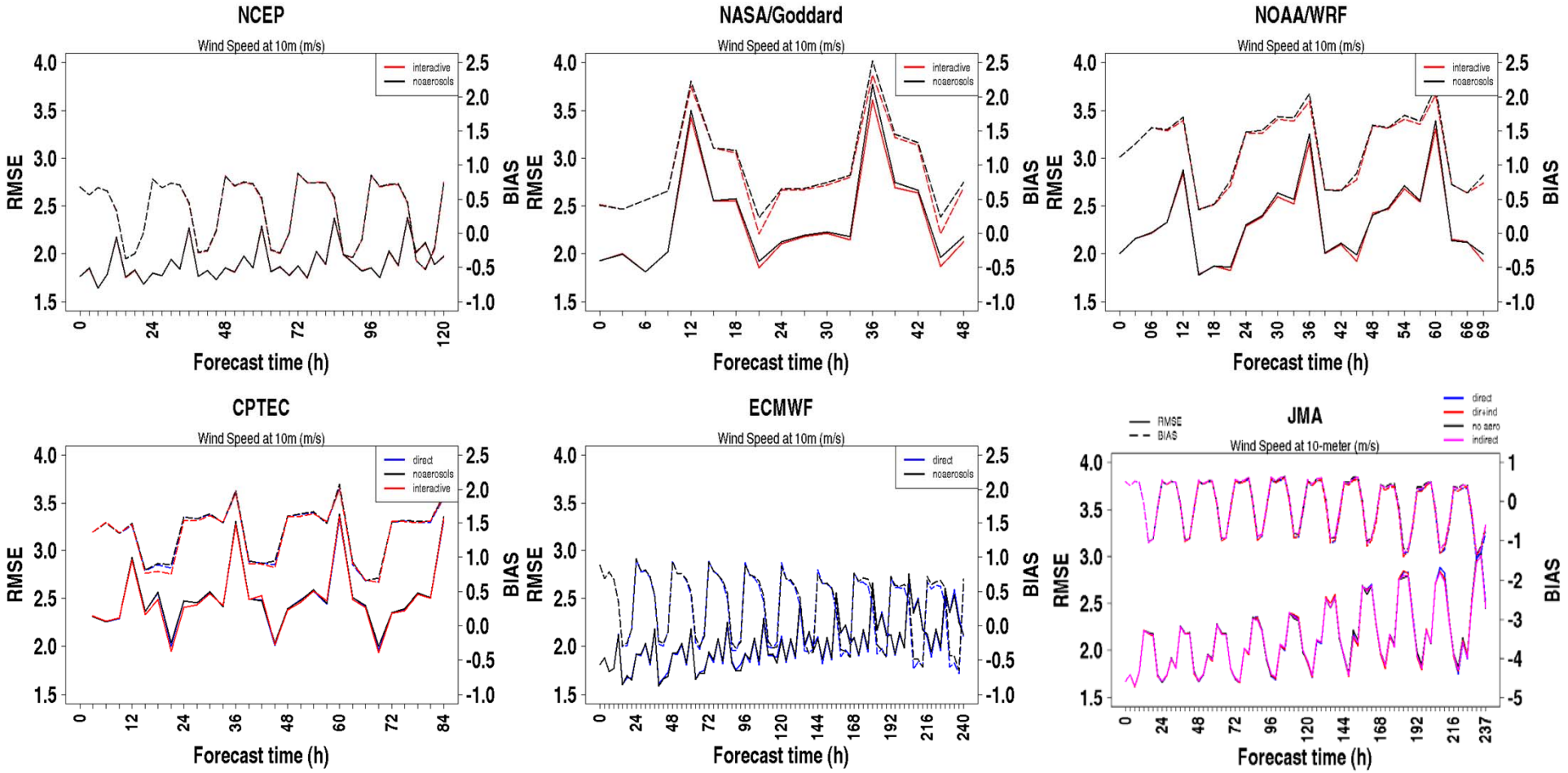
CPTEC



NOAA

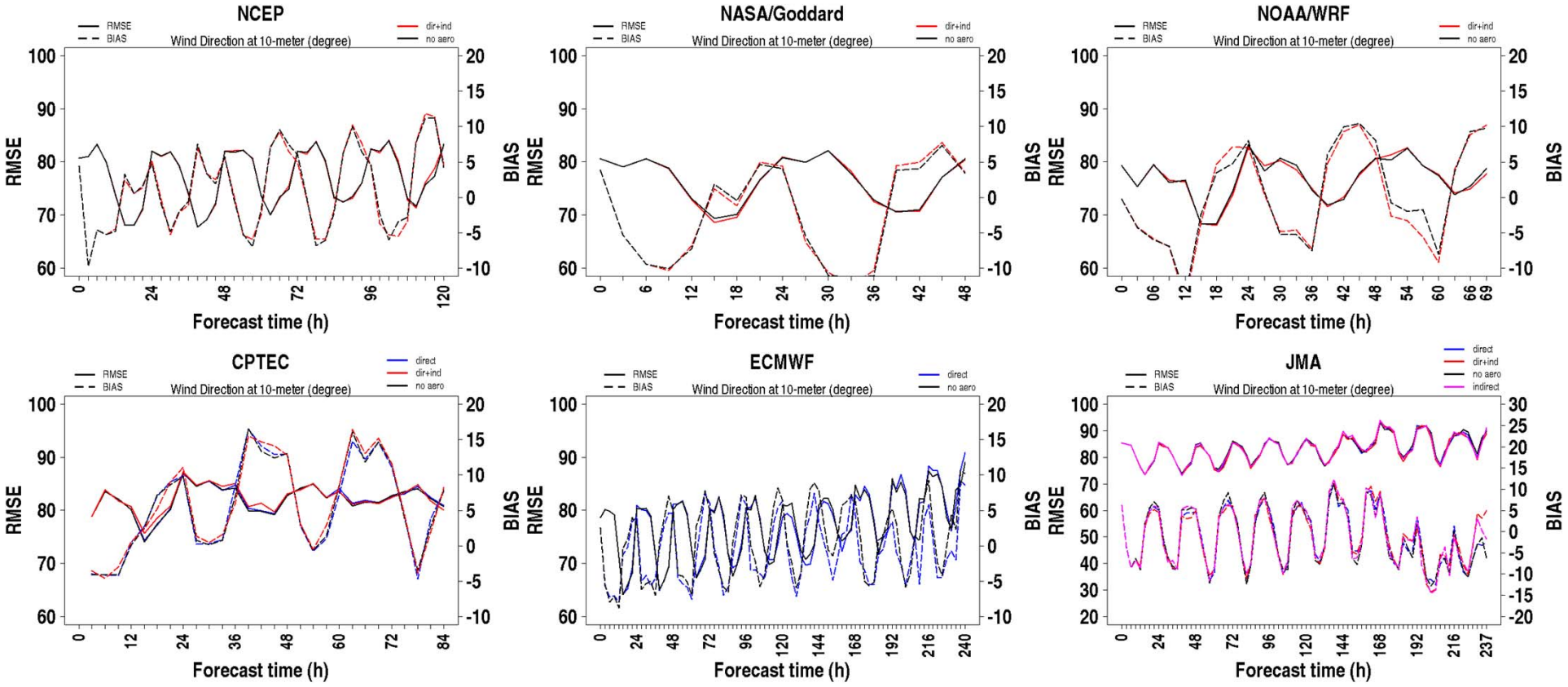
RMSE: BLACK line **BIAS: BLUE line**

RMSE/BIAS: 10-m wind magnitude (m/s)



BIAS: dashed line **RMSE: continuous line**

RMSE/BIAS: 10-m wind direction (degree)



BIAS: dashed line **RMSE: continuous line**

Summary
Quantitative evaluation for the SAMBBA case

- Parameters:
  - 2-meter temperature: more significant impact
  - 10-meter wind (mag and direction): low impact
  - Precipitation : low impact

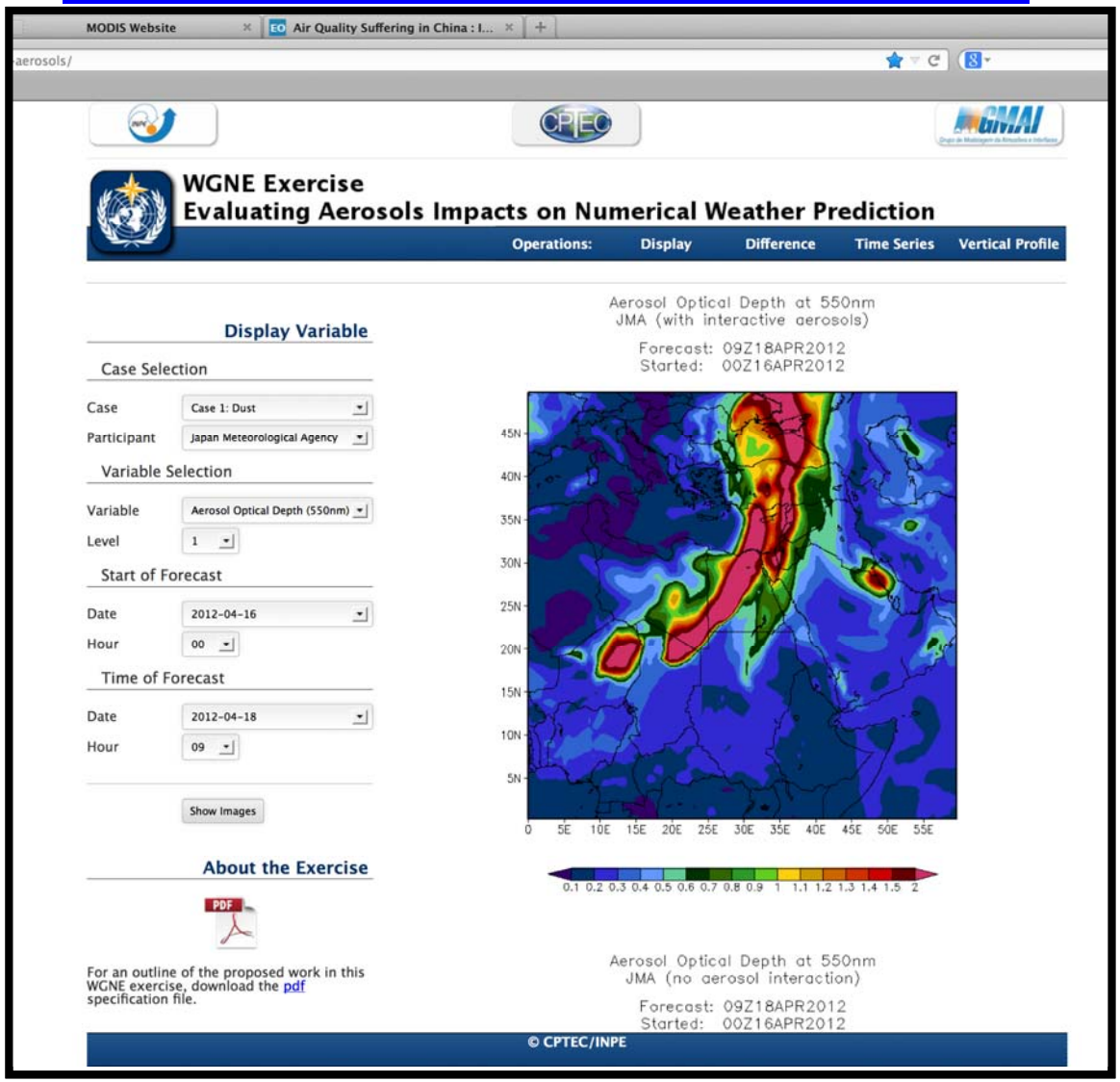
Next Steps

- A paper with the most relevant results is being prepared for JAMES/AGU, ACP/EGU or BAMS.
- Discussion whether a follow on study is necessary.

Analyzing the data with GrADS Online

Webpage hosted by CPTEC/Brazil for data analyzing and visualization

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



Developed by M. Zarzur

- Backup Slides

Next Steps

- Perform data evaluation using
  - Atmospheric observational data from CPTEC/Brazil, CMA/China, ECMWF(?).
  - Retrieved/Analyzed/Observed AOD data from NASA/Goddard provided by A. Silva and from AERONET.
  - TRMM/meteo station rainfall data.
- Produce a report and a paper.
- Propose a second phase (?):
  - Revised runs and datasets (if needed).
  - Constrain initial and boundary conditions using a unified data/procedure by data assimilation.
  - Improves the diagnostic approach of indirect effect (e.g. clear definition of the physical process(es) being represented, more detailed information about the representation of aerosols (e.g. speciation, extinction coefficients, etc.)

Appendix 1

Centers participants and
a general description of their modeling systems

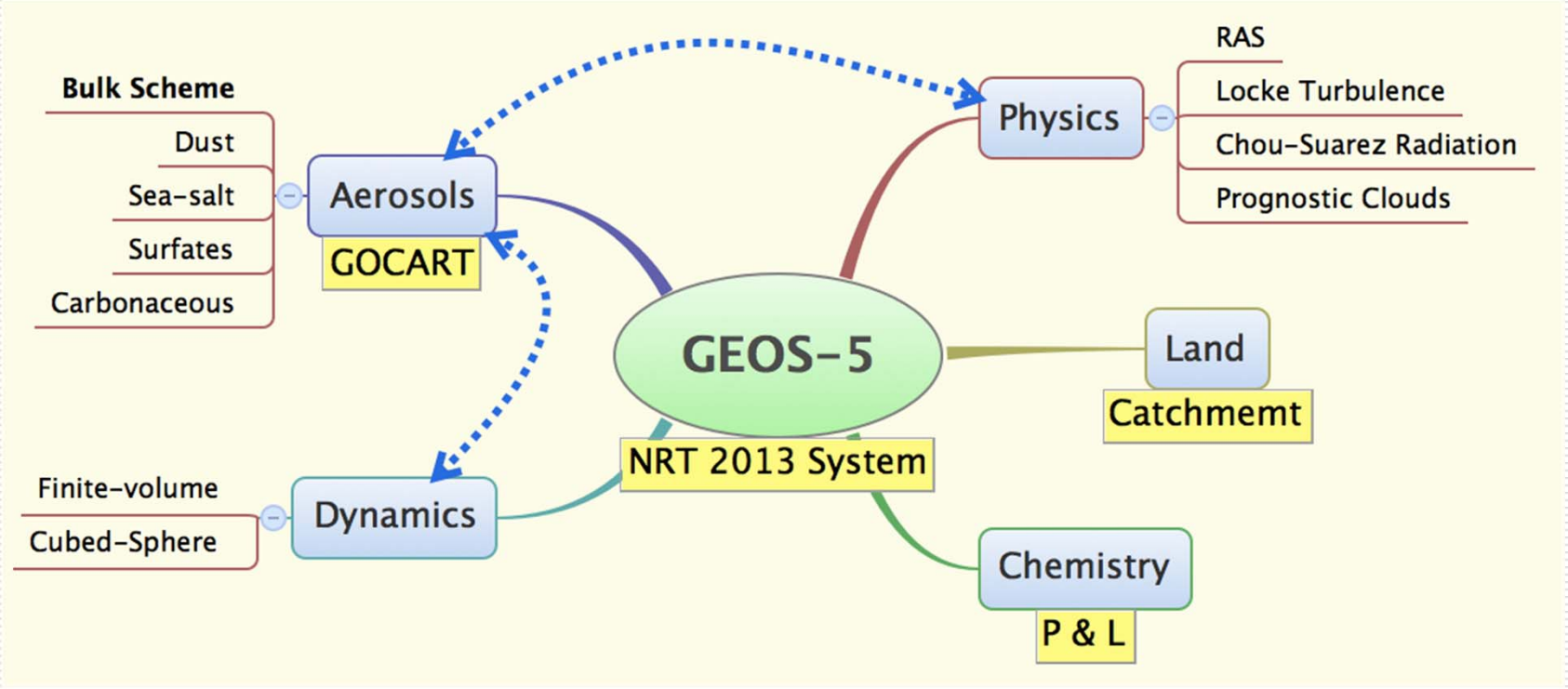
Centers participants and a general description of their modeling systems: Global Scale

- NASA/Goddard
  - GEOS-5 with GOCART aerosol model.
  - GOCART bulk model for dust, sea-salt, sulfates, carbonaceous
  - Global, 25 km, 72 levels, top at 0.01hPa
- JMA
  - MASINGAR mk-2 aerosol model + MRI-AGCM3 (dynamics)
  - 2-moment bulk cloud model w/ explicit aerosol effects
  - Interactive components: sulfate, BC, organics, sea-salt and dust.
  - Prescribed emissions from MACCity and GFAS 1.0
  - Global TL319L40, top at 0.4 hPa
- NCEP
  - NOAA/NCEP Global Forecast System (GFS)
  - Radiation based on Rapid Radiative Transfer Models (RRTM)
  - A climatological aerosol distribution at 5° resolution (Hess et al., 1998)
  - Only consider direct radiative effect.
  - Global model T574L64, top at 0.32 hPa.

Centers participants and a general description of their modeling systems: Limited Area Models

- Meteo-France and Met. Service of Algeria
  - ALADIN LAM coupled with Dust Entrainment and Deposition (DEAD) model.
  - Dust transport and optical properties are calculated using the three-moment Organic Inorganic Log-normal Aerosol Model (ORILAM) (Tulet et al. 2005)
  - Radiation RRTM for LW and FMR for SW.
  - Only direct effect.
  - Resolution 7.5 x 7.5 km and 70 levels
  - IC/BC from ARPEGE global model.
  - Case 1 only.
- CPTEC/Brazil
  - BRAMS LAM coupled with the CCATT aerosol-chemistry model.
  - Focus on biomass burning aerosol (Case 3)
  - Brazilian biomass burning emission model coupled with an interactive plumerise model
  - Direct effect using CARMA radiation parameterization
  - Indirect effect included at 2-moment bulk cloud scheme (under development)
  - Indirect effect included at cumulus convection scheme
  - Resolution: 10 x 10 km, 50 levels
  - IC/BC from GFS + MACC

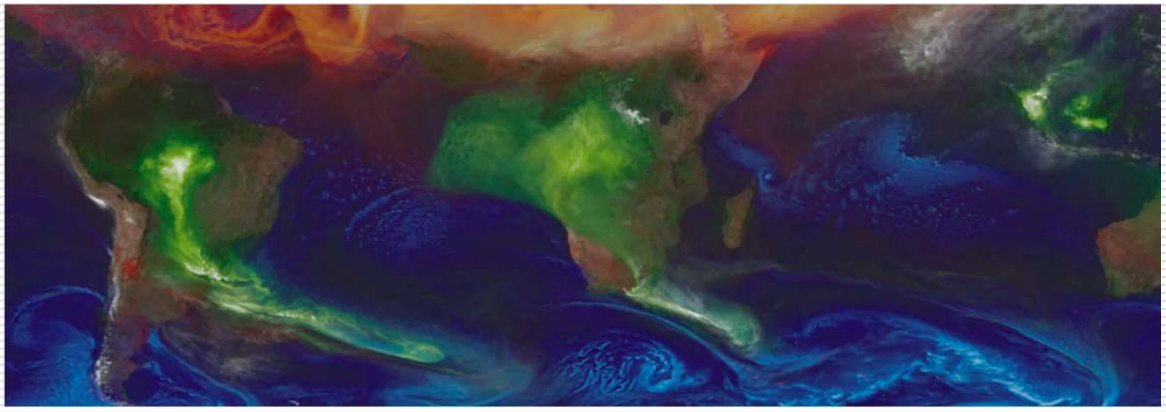
2013 NRT GEOS-5 Configuration



Global, 25 km, 72 Levels, top at 0.01 hPa

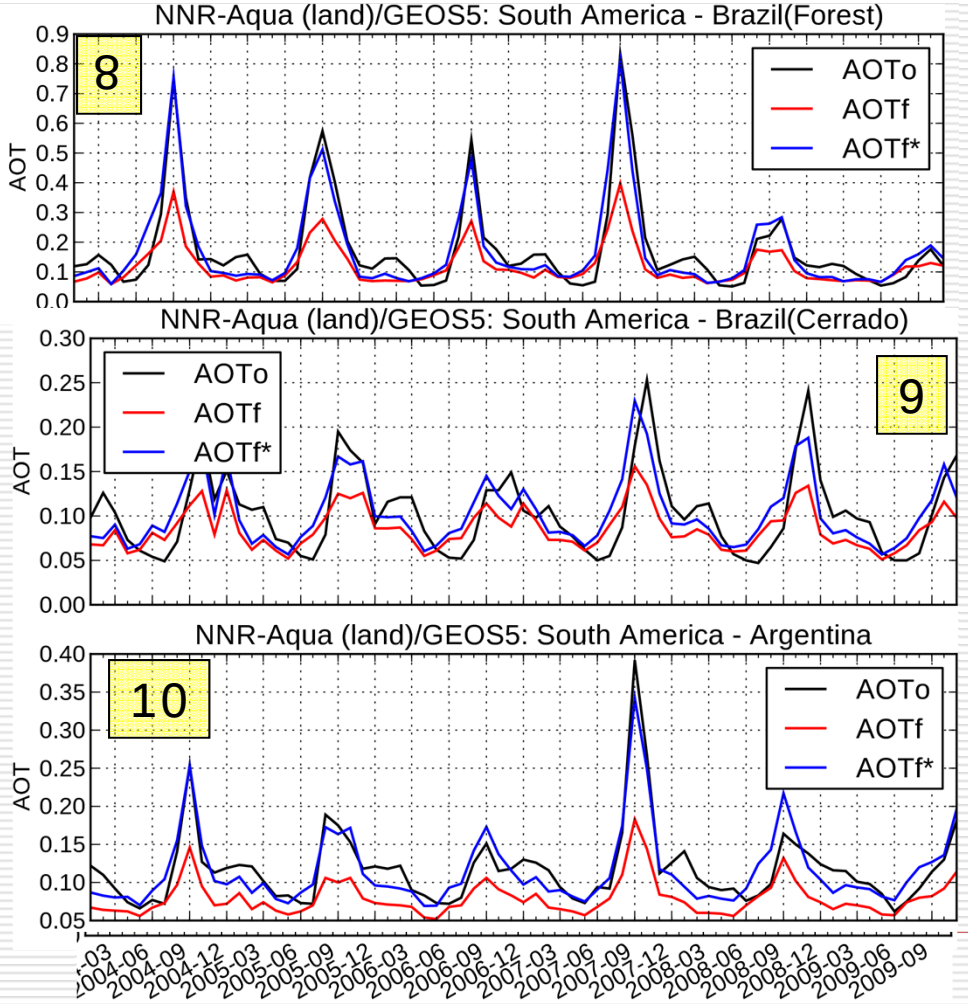
QFED: Quick Fire Emission Dataset

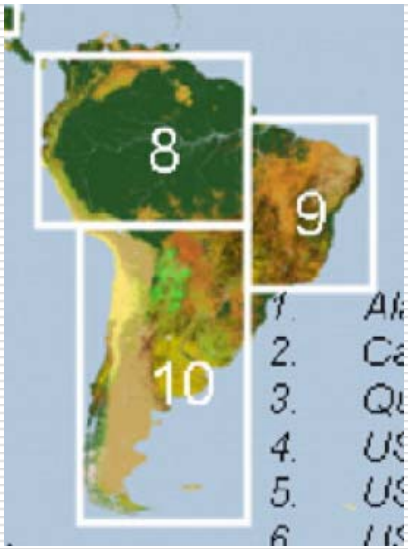
- Top-down algorithm based on MODIS Fire Radiative Power (AQUA/TERRA)
- FRP Emission factors tuned by means of inverse calculation based on MODIS AOD data.
- Daily mean emissions, NRT (thanks to LANCE)
- Prescribed diurnal cycle



JCSDA: inclusion of geo-stationary information

QFED Calibrated by MODIS AOD





GEOS-5 Aerosol Optical Depth

__ QFED (GFED Calibrated)

__ QFED (MODIS Calibrated)

__ MODIS Retrievals

NCEP's contributions to the WGNE aerosol-NWP experiment

- NOAA/NCEP Global Forecast System (GFS):
  - The cornerstone of NCEP's operational production suite, providing deterministic and probabilistic guidance out to 16 days over a global domain, four times daily at 00, 06, 12, and 18 UTC
  - Global spectral model with a comprehensive physics suite (http://www.emc.ncep.noaa.gov/GFS/doc.php)
- GFS Configuration (current operation → planned FY14 upgrade)
  - Eulerian dynamics → Semi-Lagrangian dynamics
  - T574 Eulerian (~ 27 km) out to 8 days; T190 Eulerian (~ 70 km) from 8 to 16 days → T1534 SLG (~ 13 km) out to 10 days; T574 SLG (~ 35 km) from 10 to 16 days
  - 64 vertical levels up to 0.32 mb
- GFS physics relevant to this WGNE experiment
  - Radiation parameterizations are based on Rapid Radiative Transfer Models (RRTMG_LW v2.3 and RRTMG_SW v2.3) with NCEP's modification and optimization
  - A climatological aerosol distribution at 5° resolution (Hess et al., 1998) is used.
  - Cloud microphysics is based on Zhao and Carr (1997)
  - Only consider direct radiative effect

NCEP's contributions to the WGNE aerosol-NWP experiment

- GFS experiment setup:
  - Use the latest GFS source code (targeted for the FY14 upgrade)
  - Same configuration as the operational GFS (e.g., T574 L64, Eulerian dynamics) except for output/zero-out frequency
  - Output every 3 hour, with the same 3-hourly interval for time averaging and accumulation
  - Initialized from 00Z analysis from Global Data Assimilation System (GDAS)
- Experiments conducted at NOAA R&D supercomputer (Zeus)
  - CTRL: with radiation feedback using climatological aerosols
  - EXPT: without radiation feedback
- Three cases are completed:
  - Dust: 10-day forecast for the 2012-04-13 to 2012-04-23 period
  - Pollution: 10-day forecast for the 2013-01-07 to 2013-01-21 period
  - Smoke: 5-day forecast for the 2012-09-05 to 2012-09-15 period
- GFS output (in GRIB1 format) are mapped from Gaussian grids to 1x1 deg
- The NCEP/EMC team contributing to this experiment: Sarah Lu (the NCEP POC), Yu-Tai Hou, Shrinivas Moorthi, and Fanglin Yang

JMA/MRI: Model description

- Model: MRI/JMA Global model MRI-AGCM3 (dynamics) + MASINGAR mk-2 (aerosol)
  - Grid resolution: TL319L40 (horizontal: 640x320, Vertical η-coordinate from the ground to 0.4 hPa)
  - Dynamics framework: conservative semi-Lagrange method.
  - Tiedtke-like cloud convection scheme
  - 2-moment bulk cloud scheme that explicitly represents aerosol effects on liquid and ice clouds
  - Optical properties of aerosols: OPAC (Hess et al., 1998).
  - Hygroscopic growth factors: Chin et al. (2002).
  - Interactive aerosol components: sulfate, BC, OA, Sea salt and Dust

References

- Yukimoto et al., 2012, *J. Meteorol. Soc. Jpn.*, doi:10.2151/jmsj.2012-A02
- Yukimoto et al., 2011, *Technical Reports of the Meteorological Research Institute*, No.64, ISSN 0386-4049.

JMA/MRI: Model configurations

- Anthropogenic emissions: MACCity emissions
- Biomass burning emissions: GFAS v1.0 (Kaiser *et al.*, 2012)
- Analysis:
  - Horizontal wind components are nudged toward the JMA global analysis fields.
  - SST: COBE-SST (Ishii *et al.*, 2005)

Submitted outputs are cropped to the region of the interest.

Case 1: 0 – 60 E, 0 – 50 N

Case 2: 86 – 146 E, 10 – 70 N

Case 3: 270 – 330 E, 20 – 40 S

Meteo-France and Meteo-Service of Algeria

ALADIN: **A**ire **L**imitée, **A**daptation dynamique, **D**éveloppement **I**nter**N**ational
(Limited Area, dynamical Adaptation, InterNational Development)

- ❑ Primitive equations model using a two-time-level semi-Lagrangian semi-implicit time integration scheme and a digital filter initialisation (Bubnová et al. 1995; Radnóti 1995)
- ❑ Lambert conformal projection with a bi-Fourier spectral representation and elliptical truncation.
- ❑ Coupled with ARPEGE global model every 3 hours

Physics:

- ❑ Prognostic TKE turbulence « CBR » (Cuxart, Bougeault, Redelsperger, 2000)
- ❑ Non local mixing length « BL89 » (Bougeault and Lacarrere, 1989)
- ❑ Mass flux shallow convection based on CAPE closure (Bechtold et al., 2001)
- ❑ Mass flux deep convection based on moisture convergence closure (Bougeault, 1985)
- ❑ RRTM (Rapid Radiative Transfer Model) scheme for long wave radiation (Mlawer et al. 1997)
- ❑ FMR (Fouquart-Morcrette Radiation) scheme for shortwave radiation with the 6 spectral bands (Fouquart et al. 1980, Morcrette 1991)
- ❑ Lopez microphysics with four prognostic hydrometeors (auto-conversion, collection, evaporation, sublimation, melting, freezing and sedimentation) (Lopez, 2002)
- ❑ Surface processes are calculated by the externalized surface scheme SURFEX (Masson et al., 2013) which includes the Interaction Soil Biosphere Atmosphere (ISBA) scheme (Noilhan and Planton 1989, Noilhan and Mahfouf 1996)

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Dust emission and transport model

- Dust fluxes are calculated using the Dust Entrainment And Deposition (DEAD) model (Zender et al. 2003a) coupled to SURFEX scheme by Grini et al. (2006) and recently improved by Mokhtari et al. (2012).
- Saltation flux is calculated following the Marticorena and Bergametti (1995) scheme
- Vertical flux is done using the Shao (1996) relationship
- Erodible soil fraction is represented by the covers COVER004 and COVER005 derived from the global 1 km ECOCLIMAP database relating to bare and rock soil, respectively (Masson et al. 2003)
- Mass fractions of clay, sand and silt are provided from the global 10 km FAO soil database (Masson et al. 2003)
- Soil texture is classified following the USDA (1999) (United States Department of Agriculture) textural classification with 12 basic textural definitions
- Dust transport and optical properties are calculated using the three-moment Organic Inorganic Log-normal Aerosol Model (ORILAM) (Tulet et al. 2005)

Model configuration

- Horizontal resolution: 7.5 x 7.5 km
- Vertical resolution: 70 levels
- Number of points: 400 x 400
- Georeference information for post processing:

- Number of points is 340x340
- Resolution lat/lon (deg): 0.07° x 0.07°
- Latmin=13.135, Latmax=36.86, Lonmin=18.135, Lonmax= 41.86
- Centre of domaine: (lat, lon) = (25° N,30° E)

NOAA/ESRL

- WRF-Chem model for SAMBBA
- WRF-Chem 3.6.1 version
  - 590 * 420 grid cells @ 15km resolution (similar for 5km resolution runs), 50 vertically stretched levels
  - 1-way nested domain with 5km resolution, similar number of grid points
  - ERA Interim Daily meteorological data
  - MACC reanalysis data – Boundary and Input conditions
  - MEGAN biogenic emissions, EDGAR & RETRO anthropogenic emissions, MODIS & WF-ABBA Fire emissions
  - For full chemistry run: Modal aerosols, gas-phase chemistry (RACM), aqueous phase chemistry (aqchem, and transport of all aqueous phase species)
  - RRTMG short and long wave radiation
  - Morrison double moment microphysics
  - GF for convection, one run with aerosol awareness turned on, always scale-aware, also used on 5km resolution domains