# Evaluating aerosols impacts on Numerical Weather Prediction: 4th Report

Saulo Freitas
Saulo.freitas@cptec.inpe.br
Presenter: Ariane Frassoni dos Santos
Ariane.frassoni@cptec.inpe.br

With inputs from: Julliana Larise, Maurício Zarzur, Arlindo Silva, 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

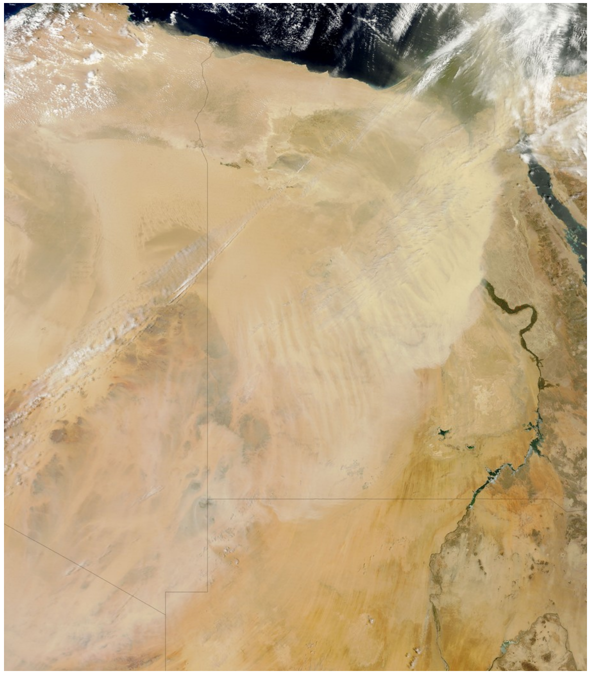
# Goals of the Exercise

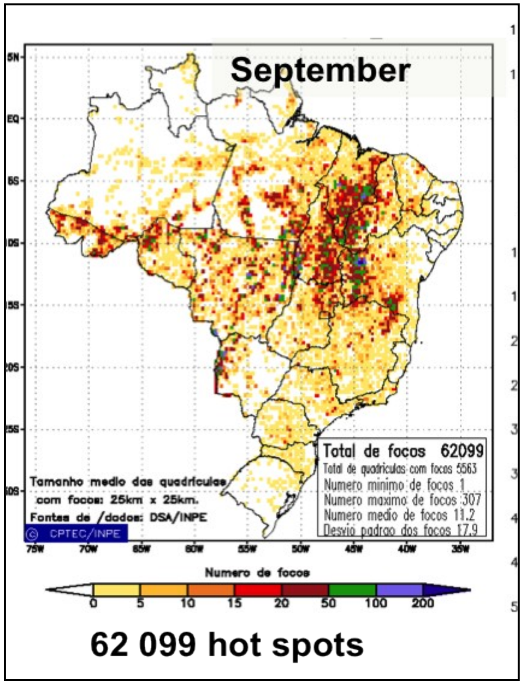
- This project aims to improve our understanding about the following questions:
- How important are aerosols for predicting the physical system (NWP, seasonal, climate) as distinct from predicting the aerosols themselves?
- How important is atmospheric model quality for air quality forecasting?
- What are the current capabilities of NWP models to simulate aerosol impacts on weather prediction?

# 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 |
| 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 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 Studies






1) Dust over Egypt: 4/2012

2) Pollution in China: 1/2013

3) Smoke in Brazil: 9/2012

# What is new?

- New datasets
  - ECMWF sent a new dataset for the DUST case
  - JMA produced new dataset as they found problems with the first run. Data was sent to CPTEC on end of July 2015 and was re-processed
  - NOAA/ESRL sent a dataset using WRF-Chem model for the SAMBBA case
  - CPTEC/Brazil provided the dataset with BRAMS model for the SAMBBA case

- Performed quantitative model evaluation

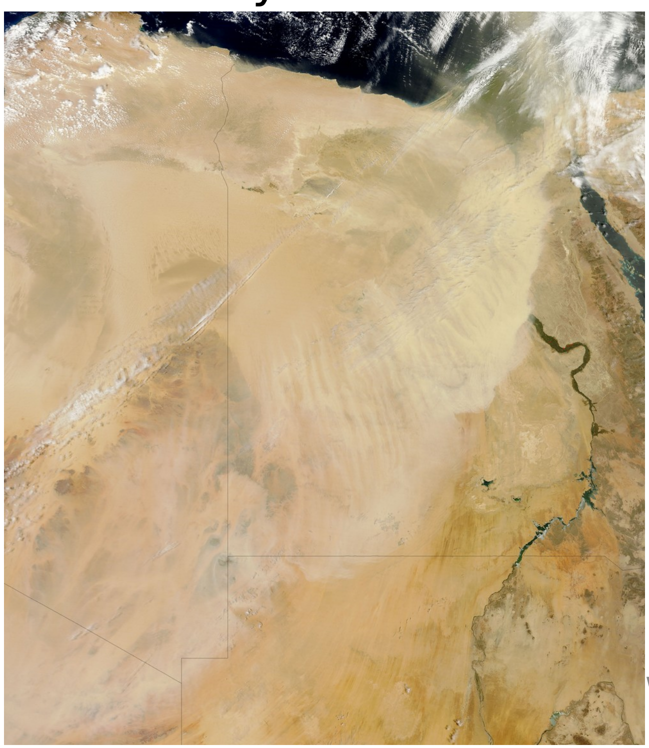
# Case 1: Dust Plume over Egypt

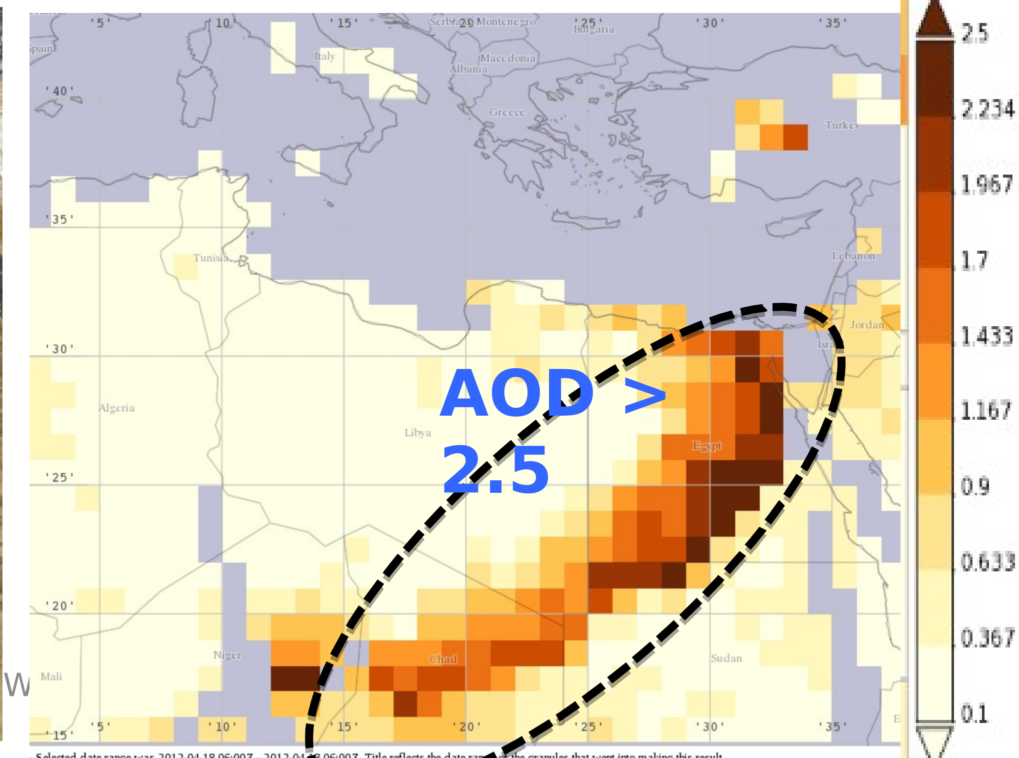
## With updates from ECMWF and JMA

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

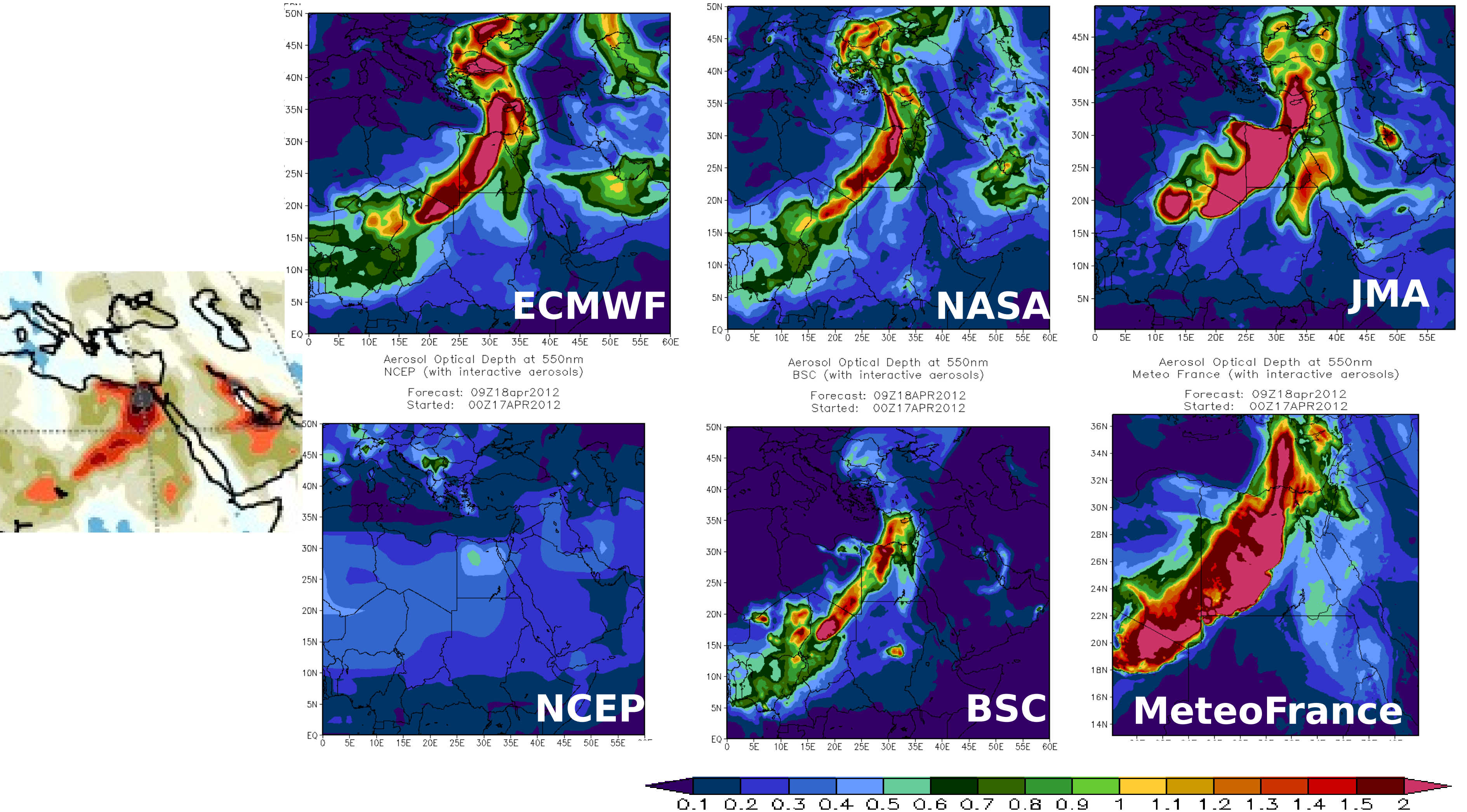
Model configuration: same as for NWP
Direct effects only

**MODIS AOD @ 550nm 18 April 2012**





# AOD at 550nm: Forecast 09UTC18apr2012
# Init: 00UTC17apr2012




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

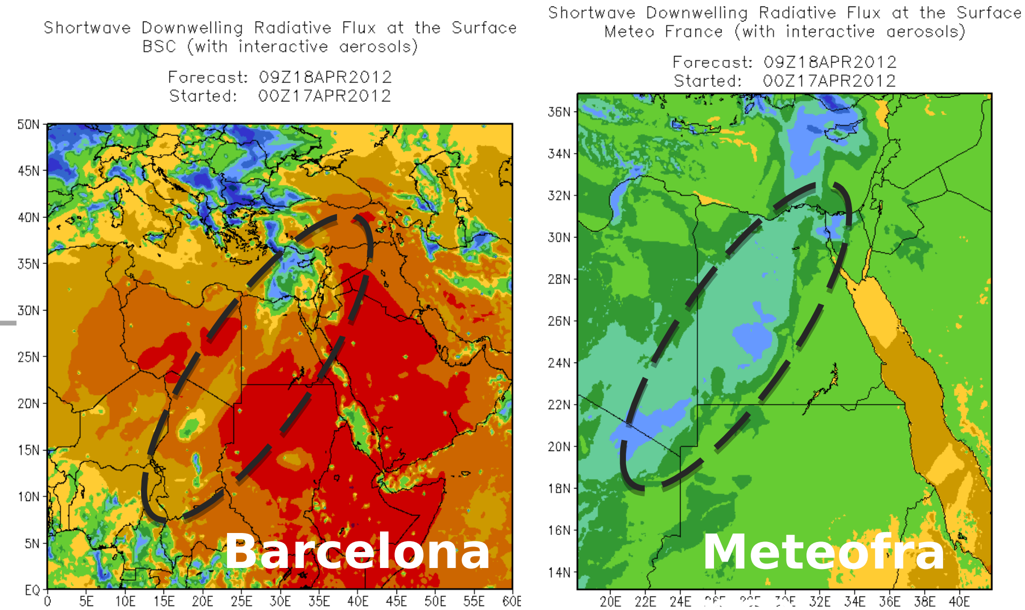
# Impacts on weather forecasting

- Radiative shortwave flux at surface
- Air temperature at 2m

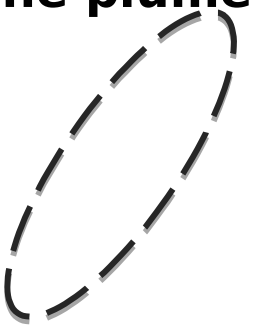
With updates from ECMWF and JMA

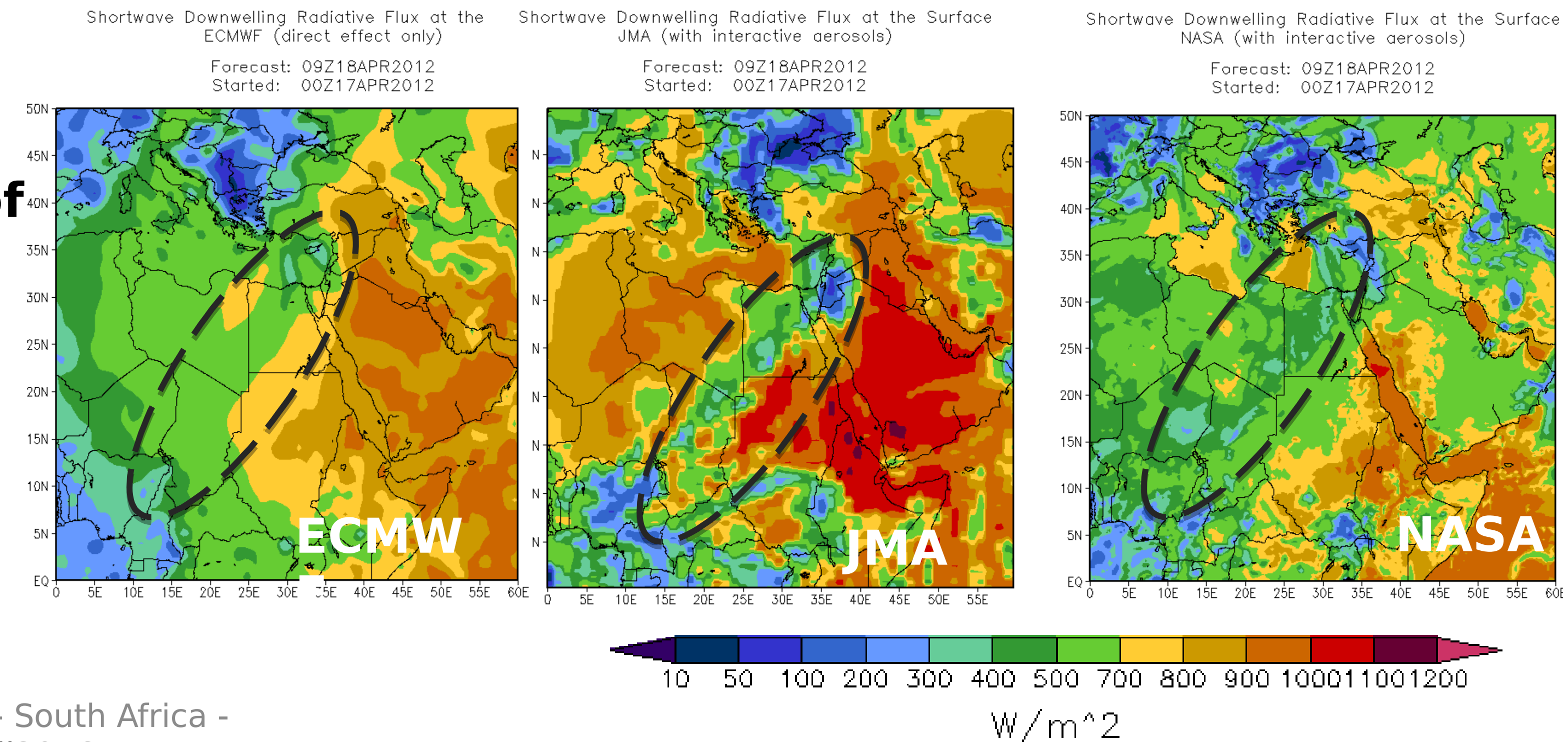
# SW Rad @ Sfc Intercomparison

- 9 UTC (morning)
- Large discrepancies among centers

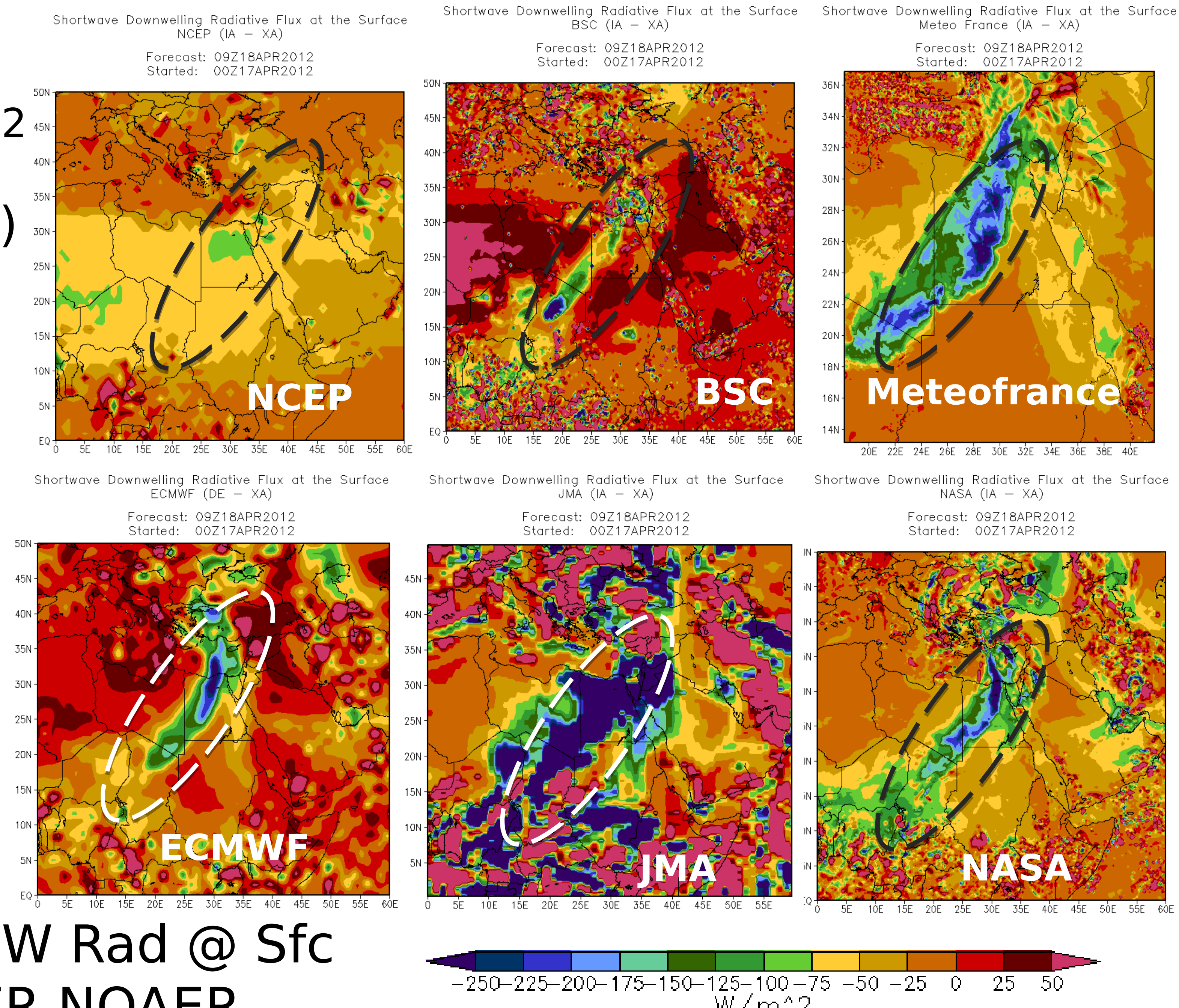



**Location of the plume**





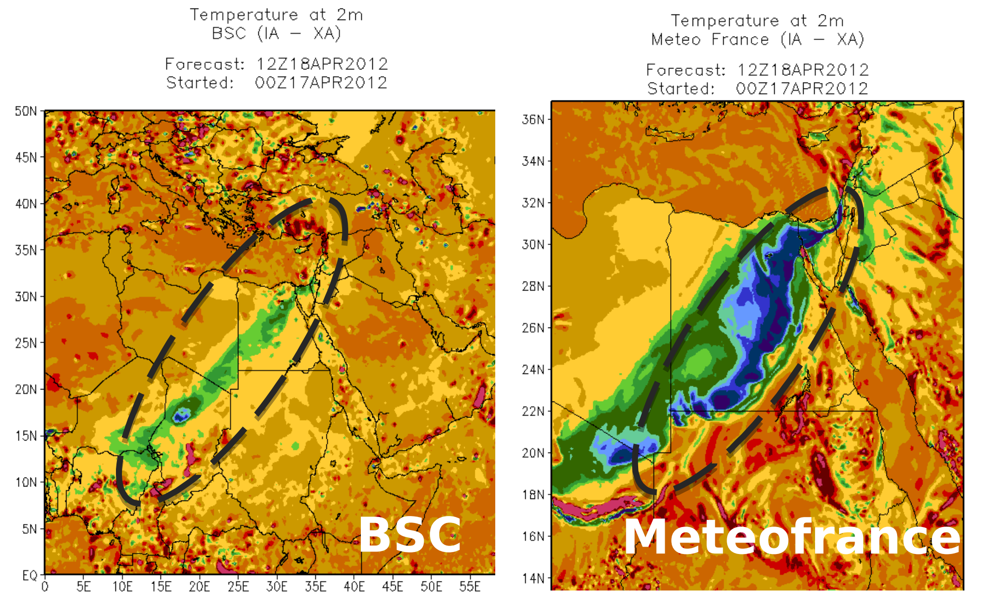
18APR2012
09 UTC
(morning)

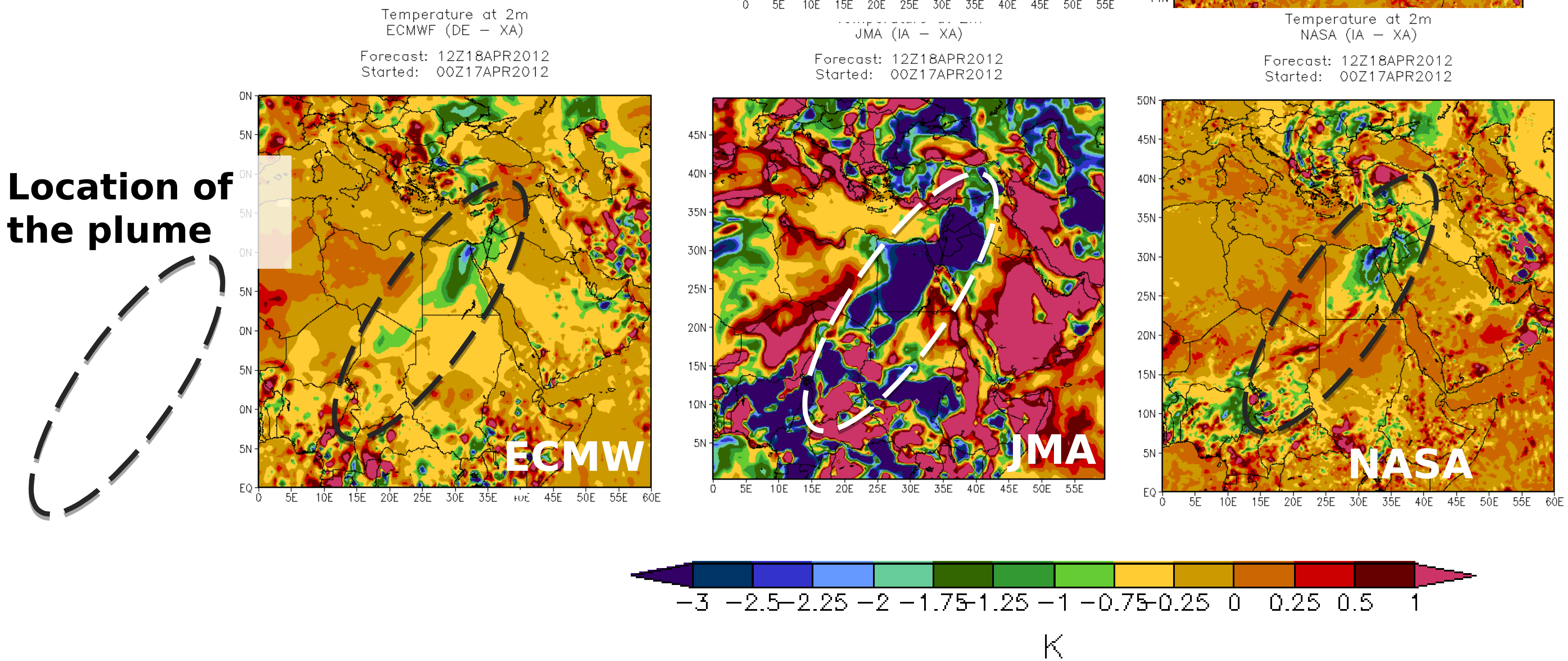



# DIFF of SW Rad @ Sfc
# AER-NOAER

# DIFF of Temp @ 2-m AER-NOAER

- 12 UTC (morning)
- Large discrepancies among centers

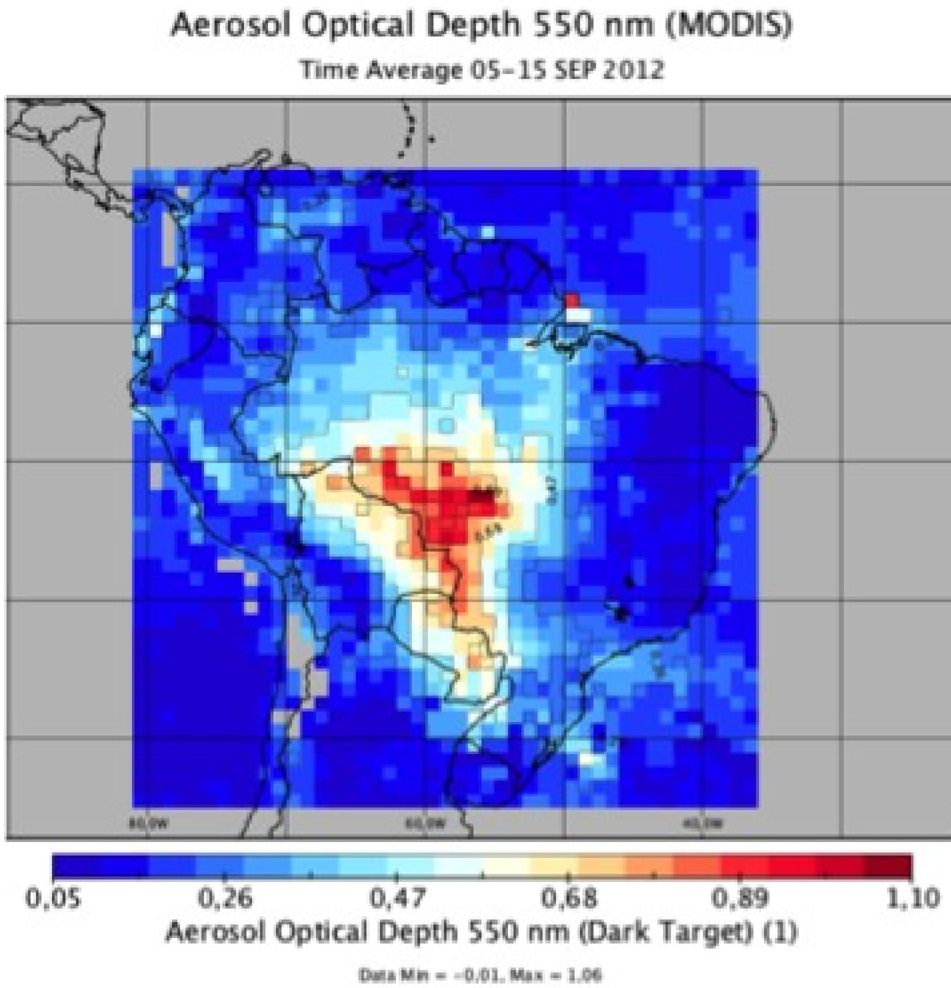


# Case 3: Persistent Smoke in Brazil

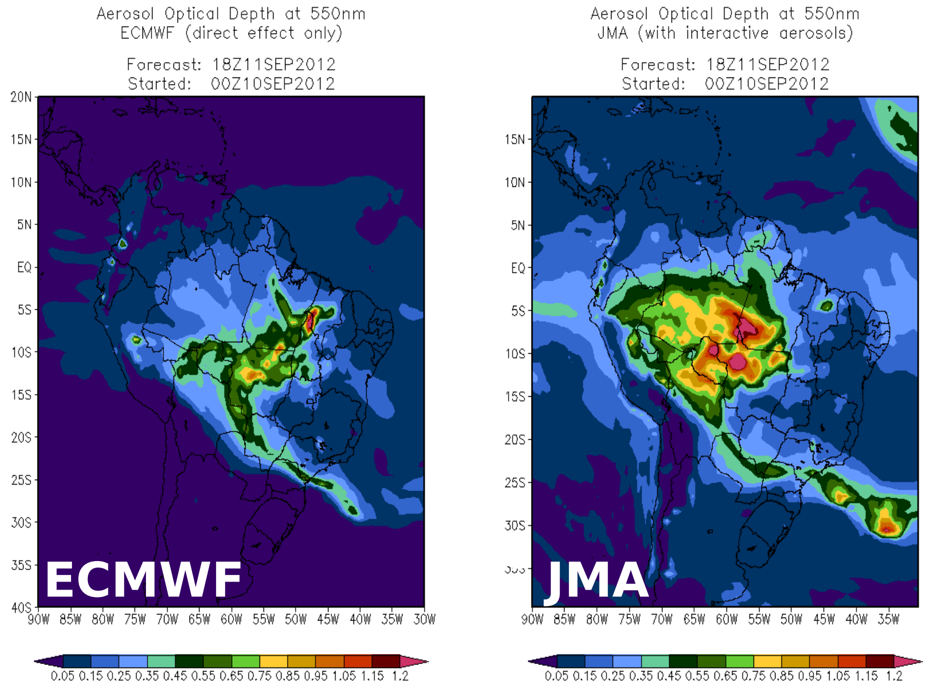
**With updates from JMA, NOAA and CPTEC**

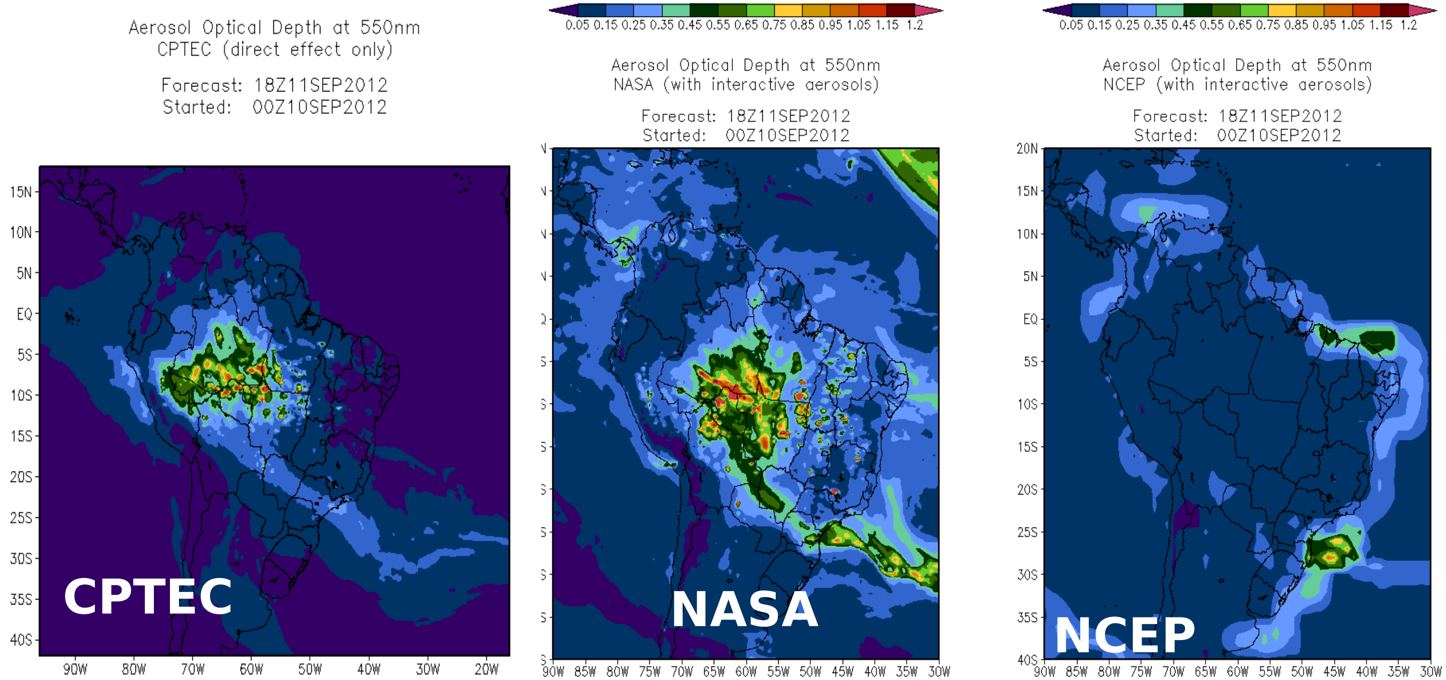
- September 2012
- Forecasts
  - September 5-15, 2012
  - From 0 or 12 UTC
  - 10 day forecasts
- Center of domain
  - 116E, 40N
- Model configuration
  - Same as for NWP
- **Direct & Indirect effects**

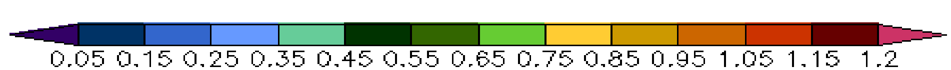


# AOD at 550 nm Forecast for 18UTC11SEP

Init.: 00UTC10SEP

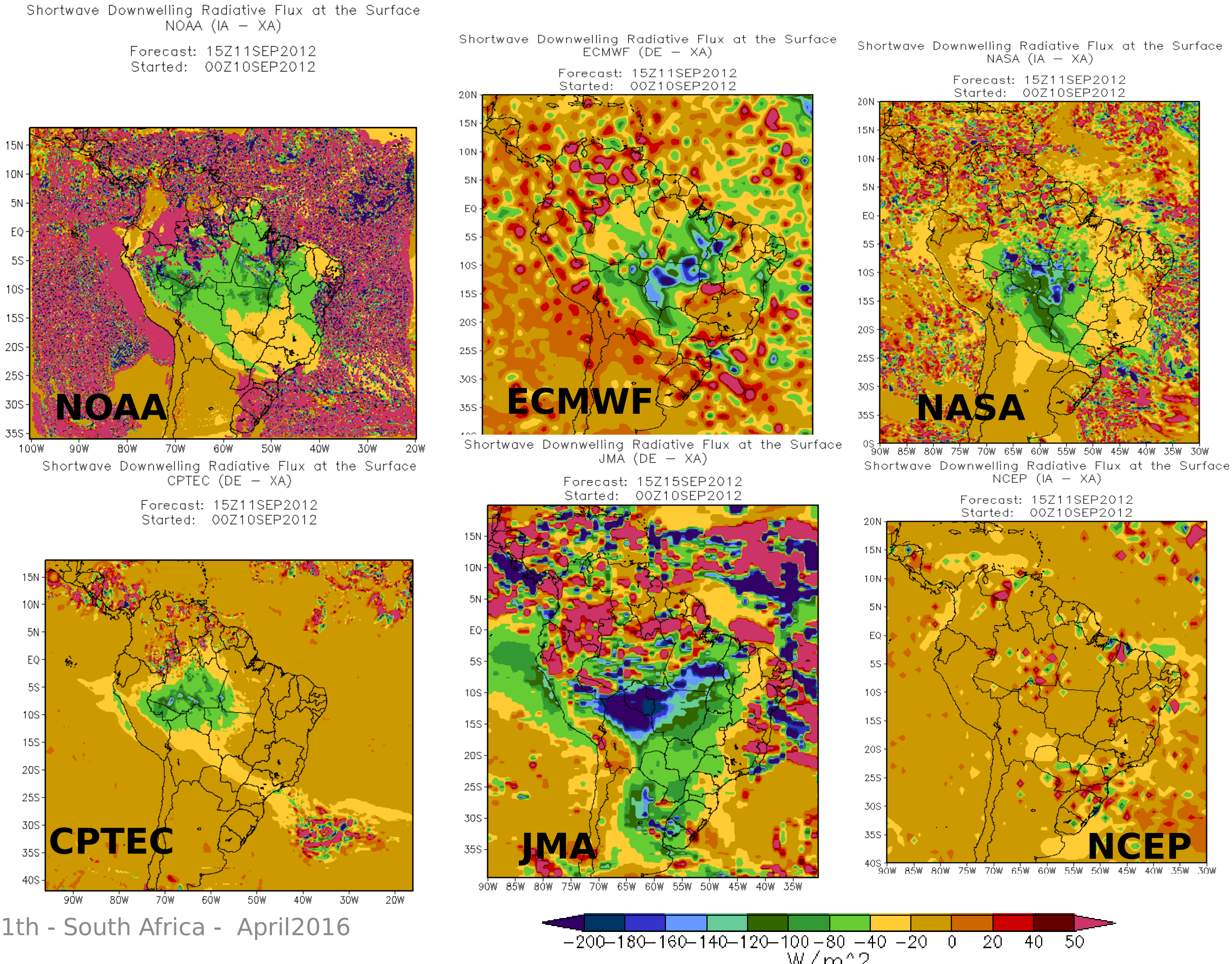


# SW down Radiative Flux (AER-NOAER)

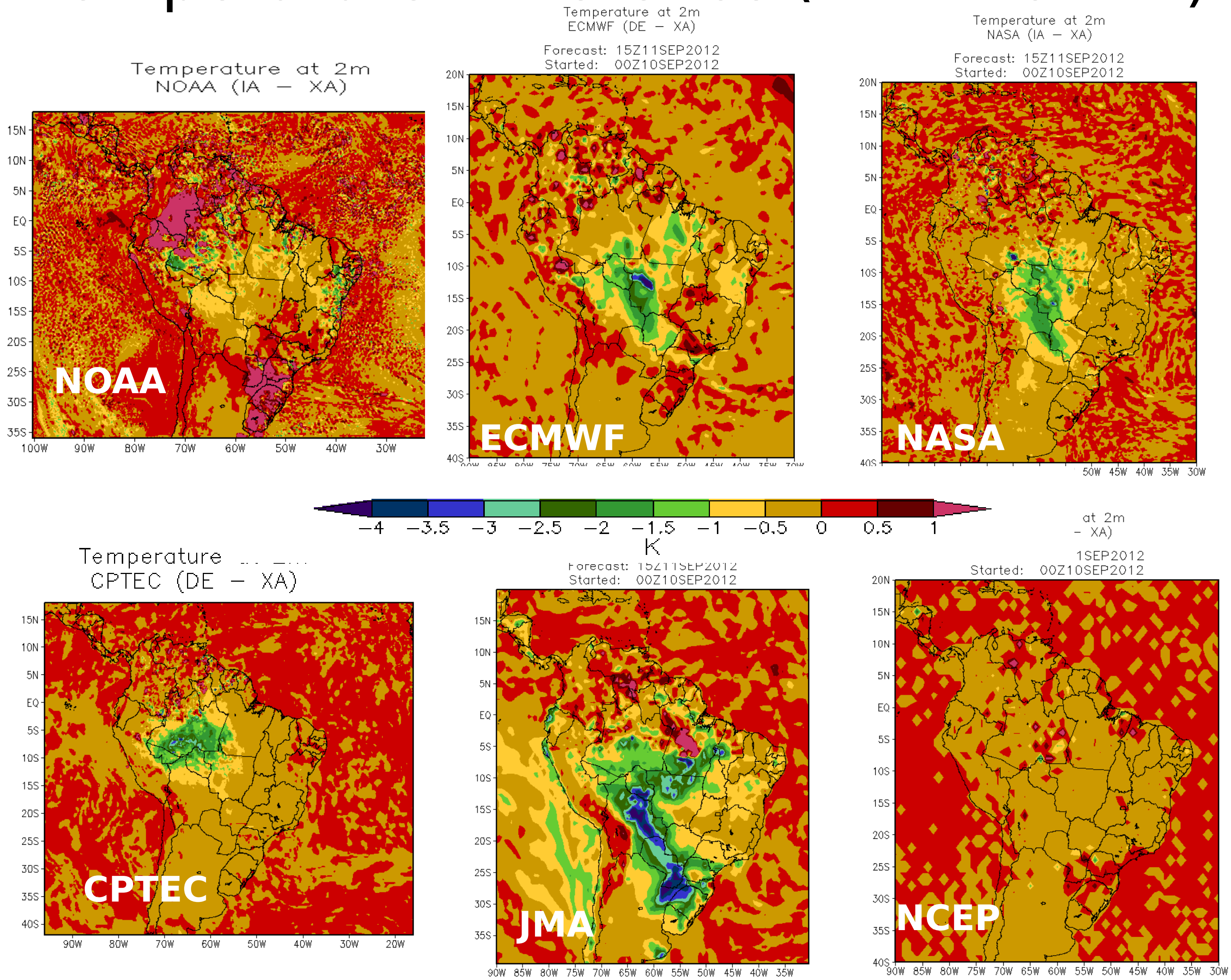
Forecast for 15UTC11SEP
Init.:00UTC10SEP




WGNE 31th - South Africa - April2016

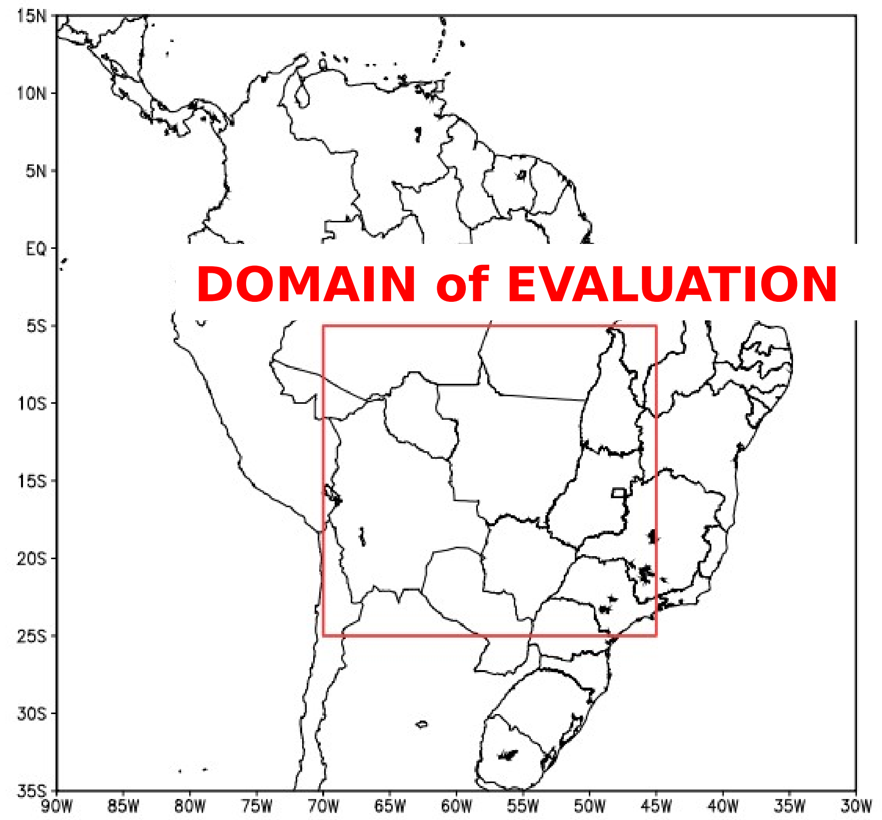
# 2-m Temperature Difference (AER-NOAER)

Forecast for 15UTC11SEP
Init.:00UTC10SEP

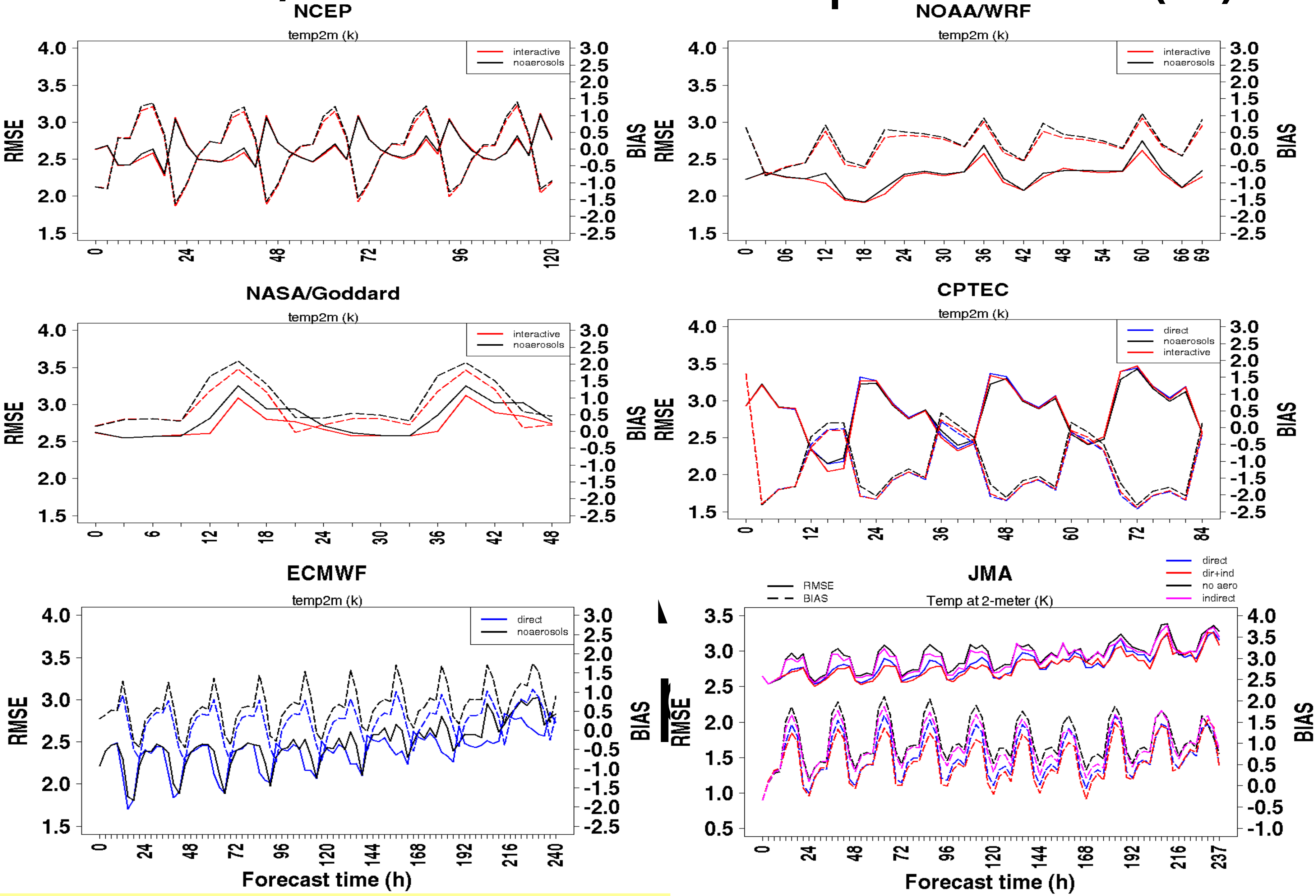


# Quantitative evaluation for the SAMBBA case

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



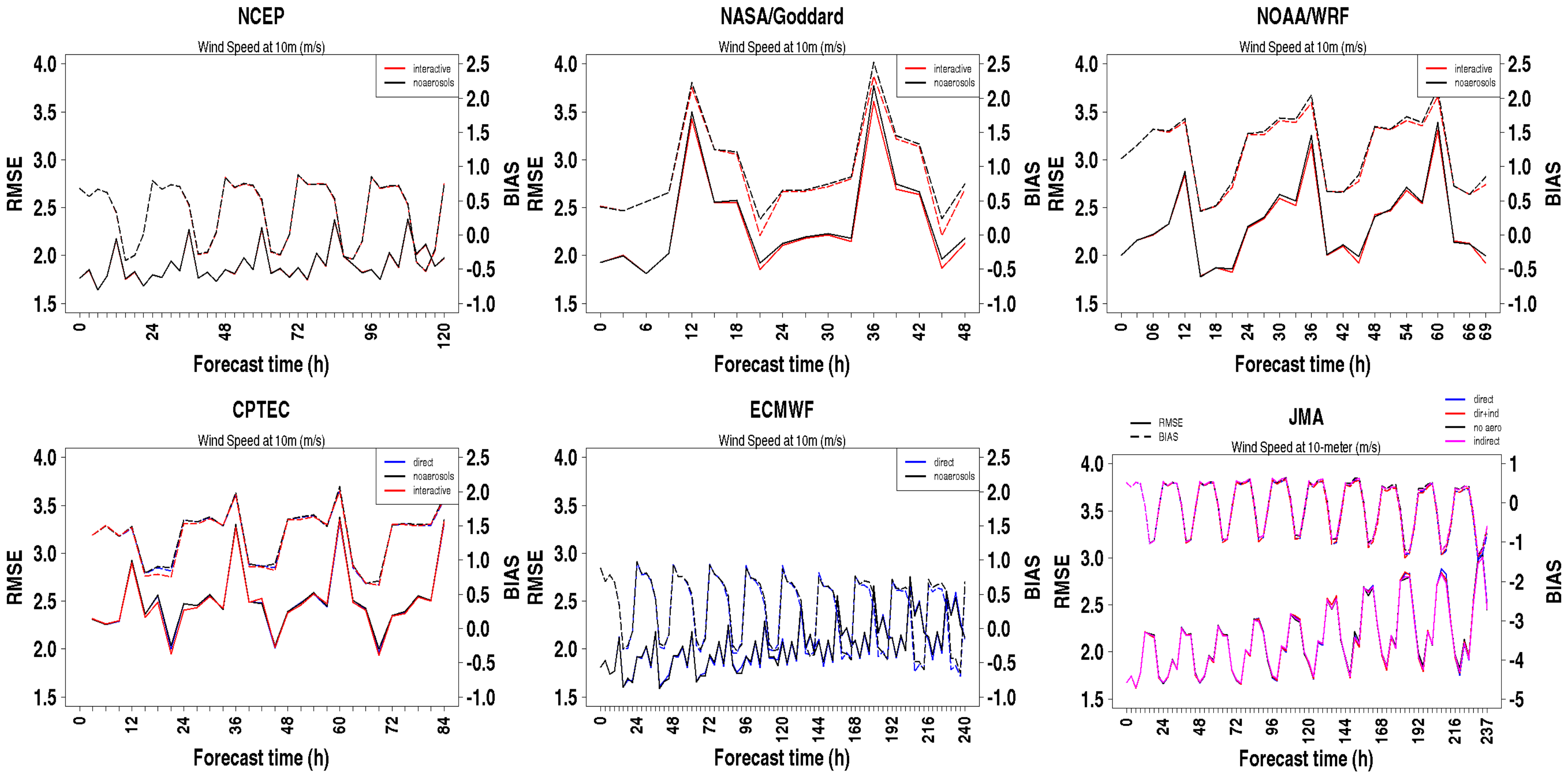
# RMSE/BIAS: 2-m Temperature (K)




**BIAS: dashed line**

**RMSE: continuous line**

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




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

# General overview of impacts on the prediction skill

| Variable | ECMWF | | JMA | | NASA | | NCEP | | NOAA | | CPTEC | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skill score | RMSE | BIAS | RMSE | BIAS | RMSE | BIAS | RMSE | BIAS | RMSE | BIAS | RMSE | BIAS |
| 2-m temp | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 10-m wind speed | ✗ | ✗ | ✗ | ✗ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ |
| 10-m wind direction | ✓ | ✓ | ✗ | ✓ | ✗ | ✓ | ✗ | ✗ | ✗ | ✓ | ✓ | ✓ |
| rainfall | ✓ | ✓ | | | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ | ✓ | ✓ |

| | |
|---|---|
| ✗ | Negligible impact |
| ✓ | Significant impact |
| | Skill is degraded |
| | Skill is improved |
| | Mixed improvement/degradation |

# Case 2

# Extreme Pollution in Beijing

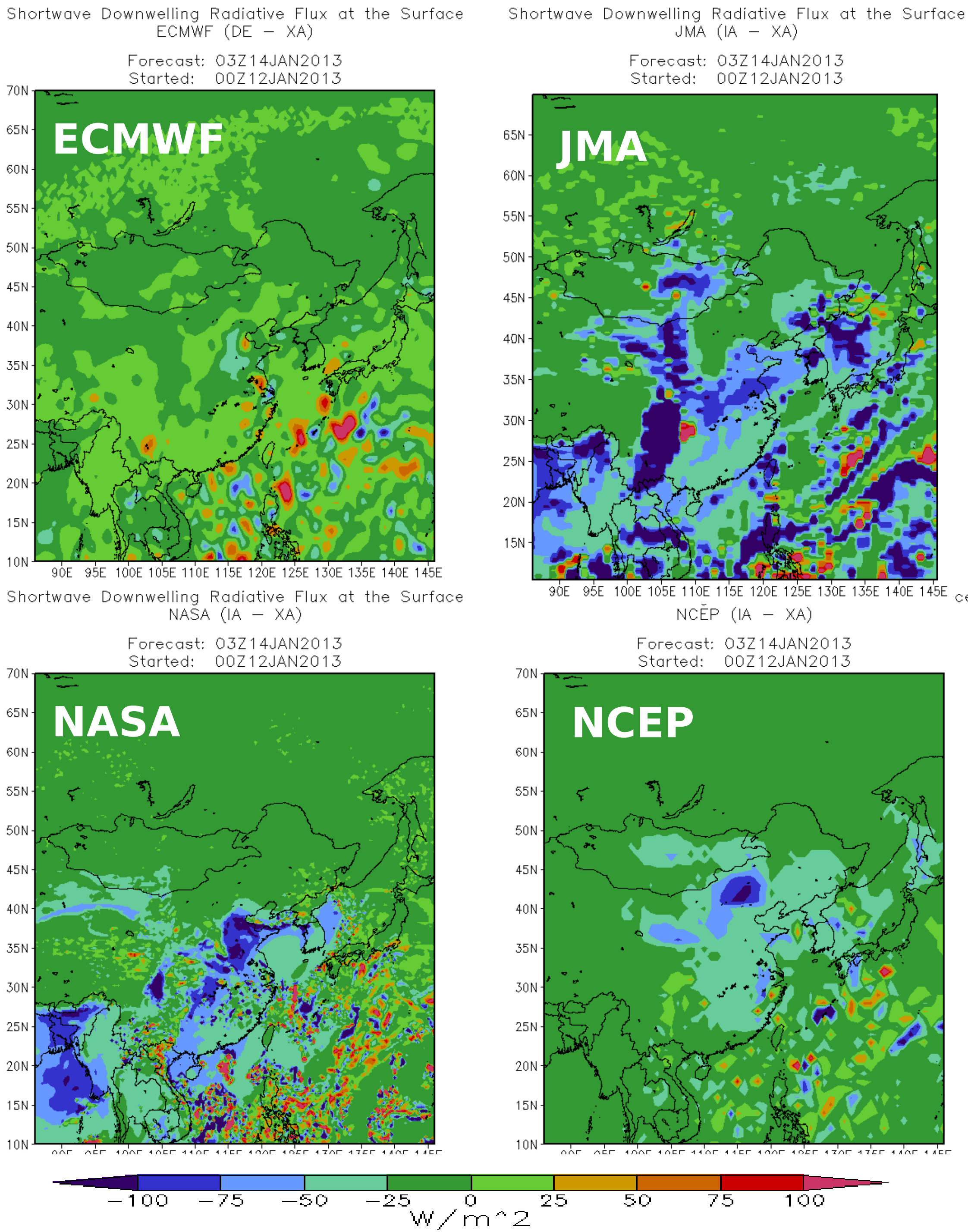
**With updates from JMA**

- 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

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

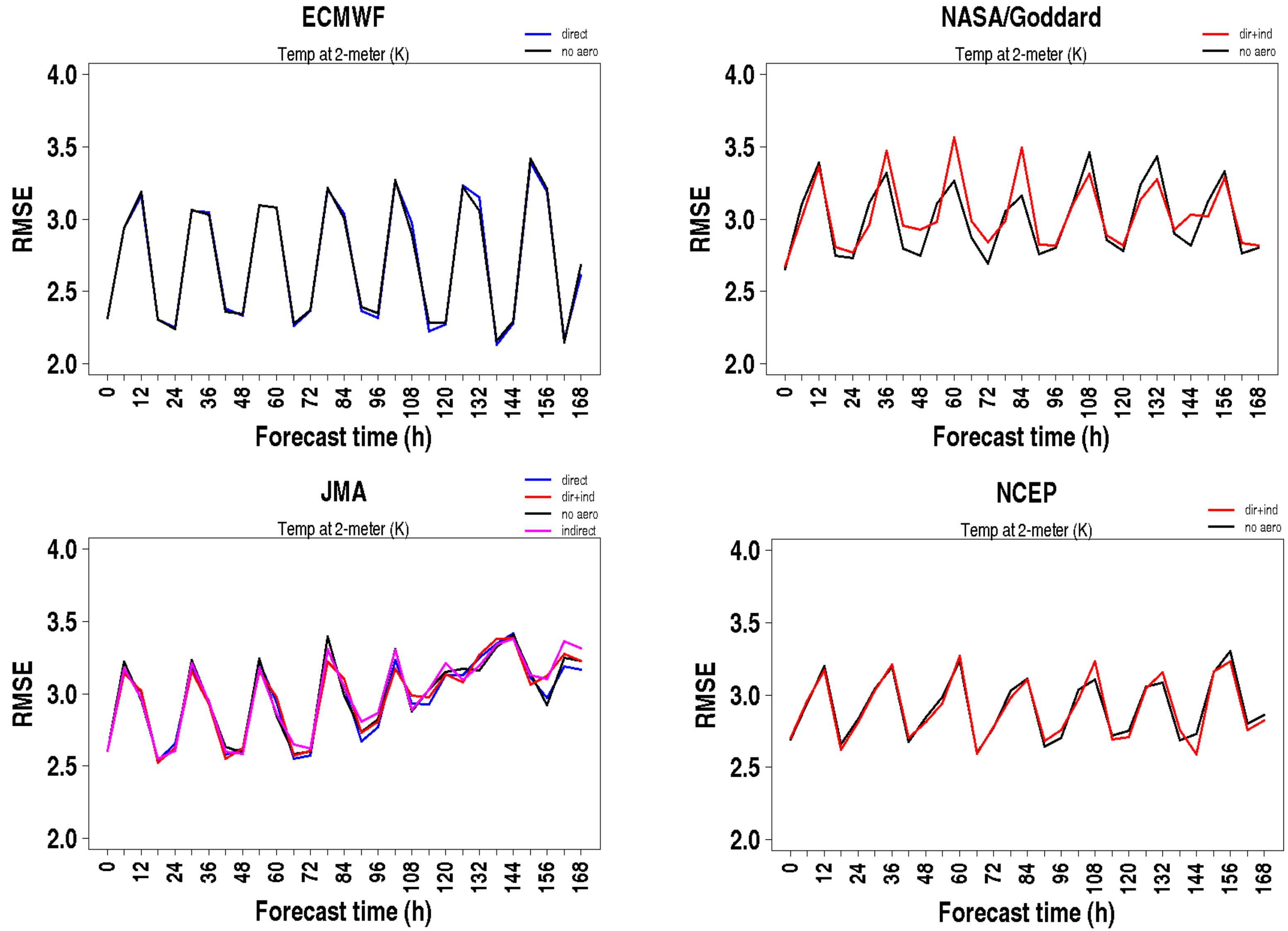
- 3 UTC (day time)



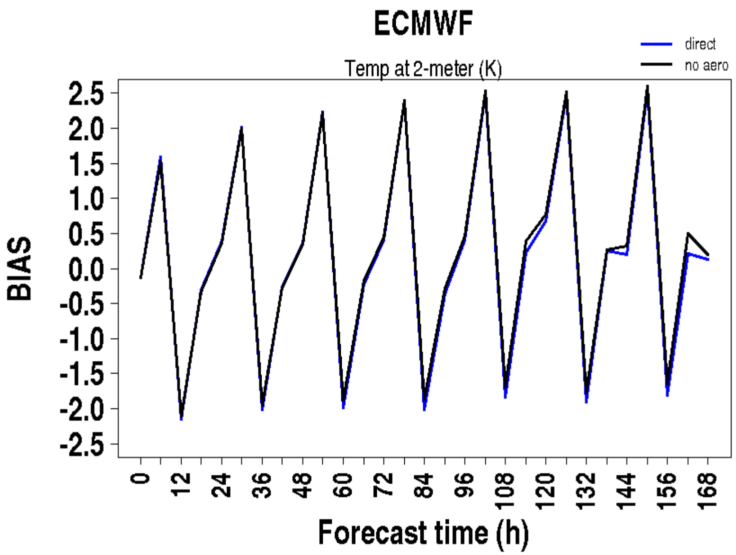
# Quantitative evaluation for the Beijing case

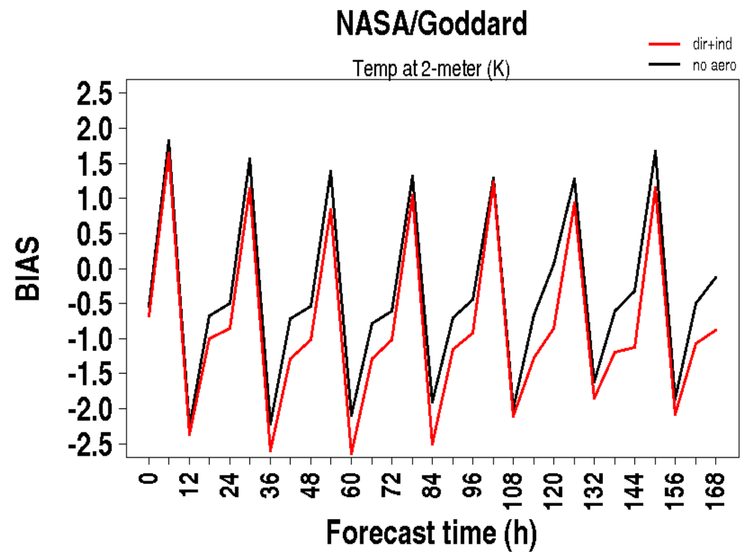
- Parameters:
  - 2-meter temperature
  - 10-meter wind (mag and direction)
  - rainfall
- Observational data: meteo surface stations over China
- Evaluated time period: January 7-2,  up to 7-day forecast

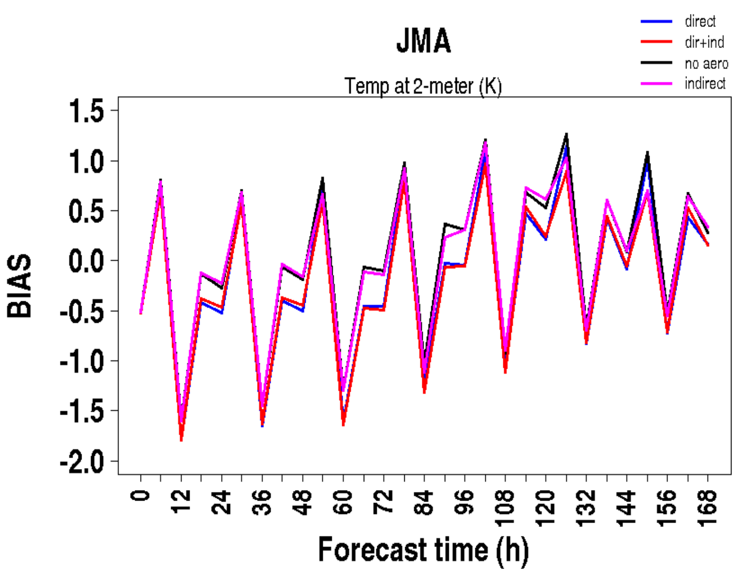
# RMSE: 2-m Temperature (K)

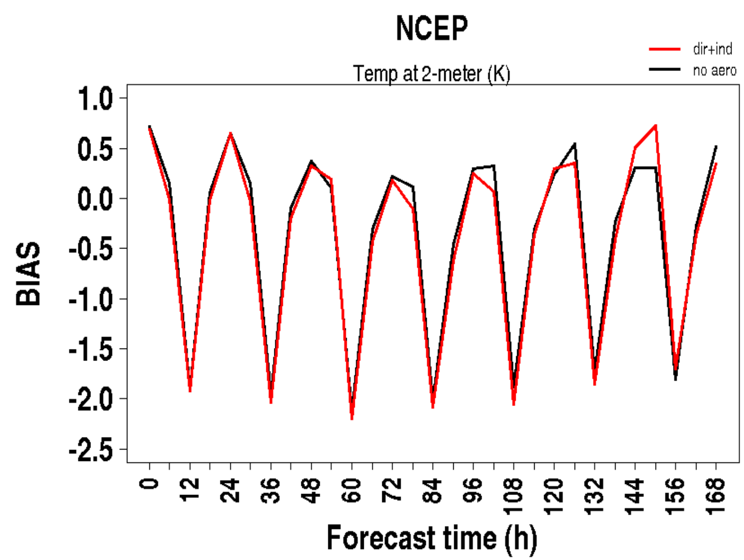


# BIAS:  2-m Temperature (K)



# General overview of impacts on the prediction skill

| Variable | ECMWF | | JMA | | NASA | | NCEP | |
|---|---|---|---|---|---|---|---|---|
| Skill score | RMSE | BIAS | RMSE | BIAS | RMSE | BIAS | RMSE | BIAS |
| 2-m temp | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 10-m wind speed | ✗ | ✓ | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ |
| 10-m wind direction | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ |
| rainfall | ✗ | ✗ | | | ✓ | ✓ | ✗ | ✗ |

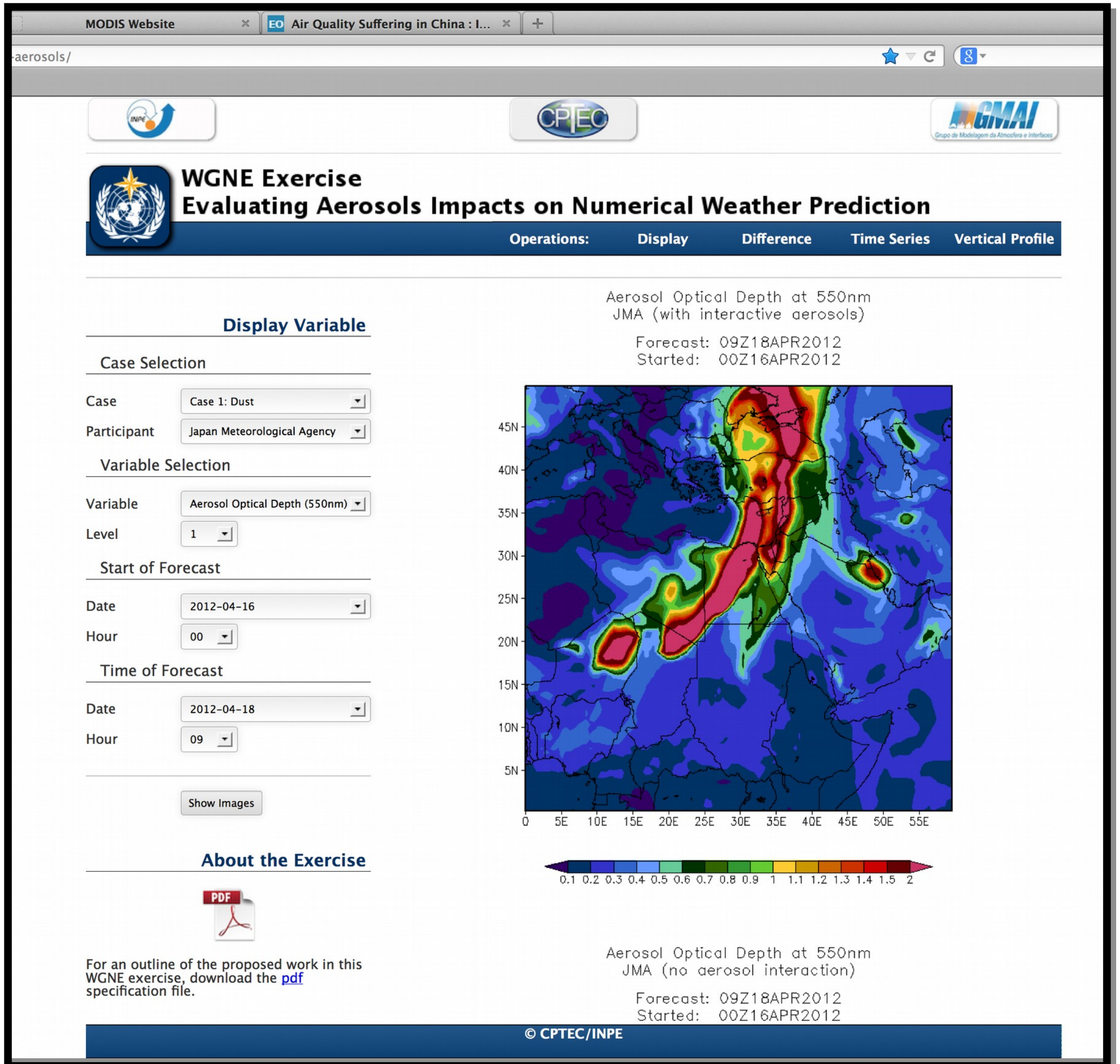
| | |
|---|---|
| ✗ | Negligible impact |
| ✓ | Significant impact |
| | Skill is degraded |
| | Skill is improved |
| | Mixed improvement/degradation |

# Next Steps

- Finish the quantitative model evaluation
- Produce a report and submit to the centers
- Propose a paper with the most relevant results for ACP/EGU or BAMS

# 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

- Thanks for your attention!
- Questions ?

# 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. )

# Current status of observational data

| Case | Surface* | Radiosonde | TRMM | Merge | MODIS/ AERONET AOD |
|---|---|---|---|---|---|
| Case 1 | ** | | | | X |
| Case 2 | CMA | CMA | | | X |
| Case 3 | CPTEC | CPTEC | CPTEC | CPTEC | X |

X – data set has already been downloaded

X – data set is available but has yet to be downloaded

- *Pressure, temp, dew-point temp, wind, AOD, PM2.5, 24-h accumulated rainfall
- **Will Contact S. Remy (ECMWF) for sharing the data used on his recent submitted paper (ACP)

# Appendix 1

Centers participants and
a general description of their modeling systems

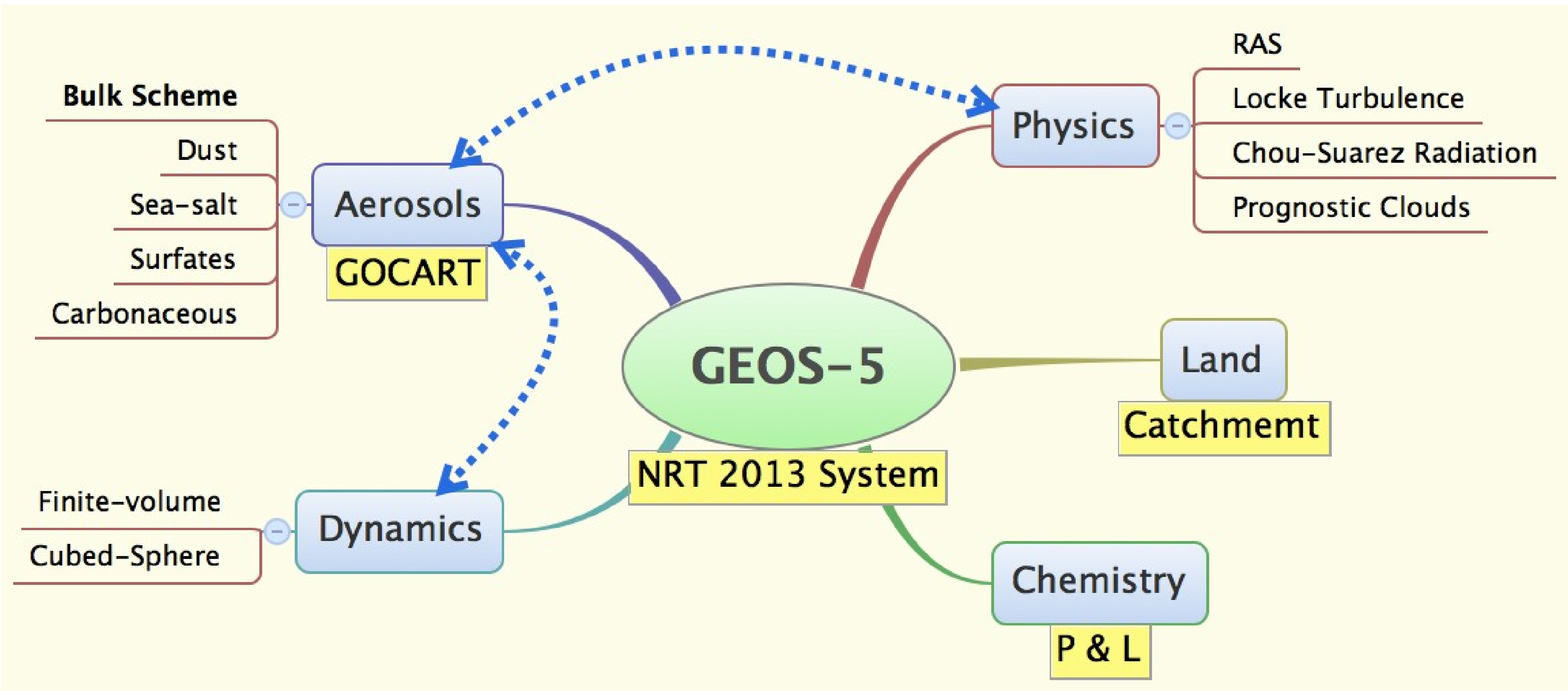
# Centers participants and a general description of their modeling systems: Global Scale

- 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

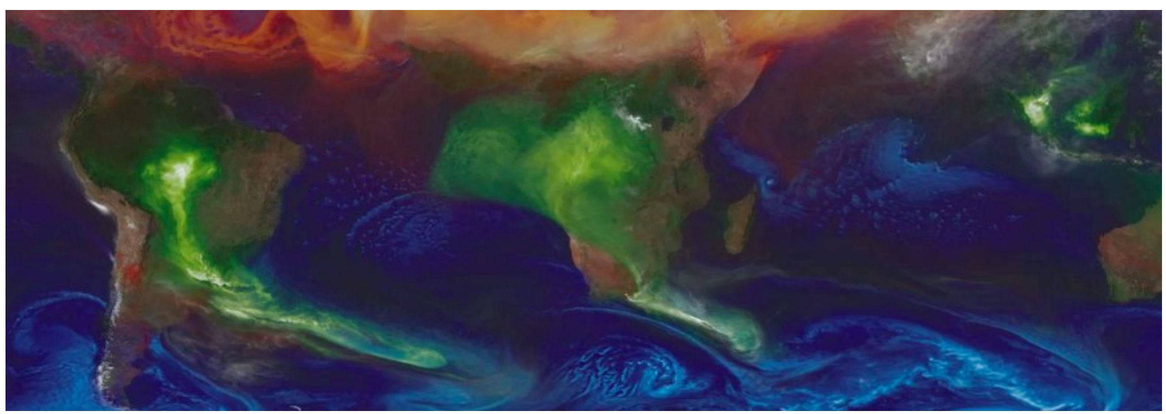
# 2013 NRT GEOS-5 Configuration




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

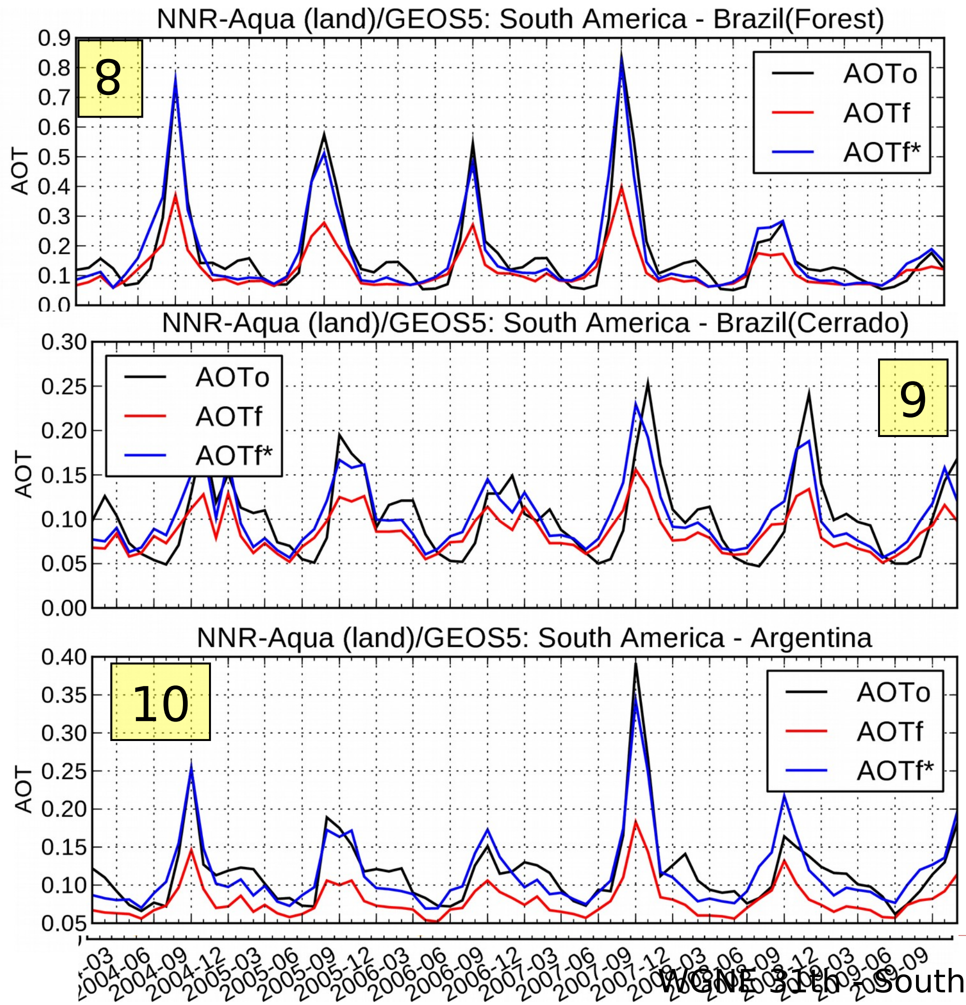
# *Q*FED: Quick Fire Emission Dataset

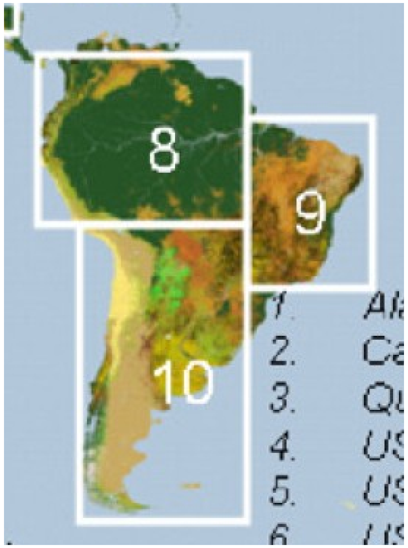
- Top-down algorithm based on MODIS Fire Radiative Power (AQUA/TERRA)
- FRP Emission factors tuned by means of inverse calculation based on MODIS AOD data.
- Daily mean emissions, NRT (thanks to LANCE)
- Prescribed diurnal cycle



JCSDA: inclusion of geo-stationary information

# QFED Calibrated by MODIS AOD




*GEOS-5 Aerosol Optical Depth*

__ QFED (GFED Calibrated)

__ QFED (MODIS Calibrated)

__ MODIS Retrievals

# P’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

# P'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

# JMA/MRI: Model description

- Model: MRI/JMA Global model MRI-AGCM3 (dynamics) + MASINGAR mk-2 (aerosol)
  - Grid resolution: TL319L40 (horizontal: 640x320, Vertical $\eta$-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

# 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

# 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)

# Meteo-France and Meteo-Service of Algeria

## 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°

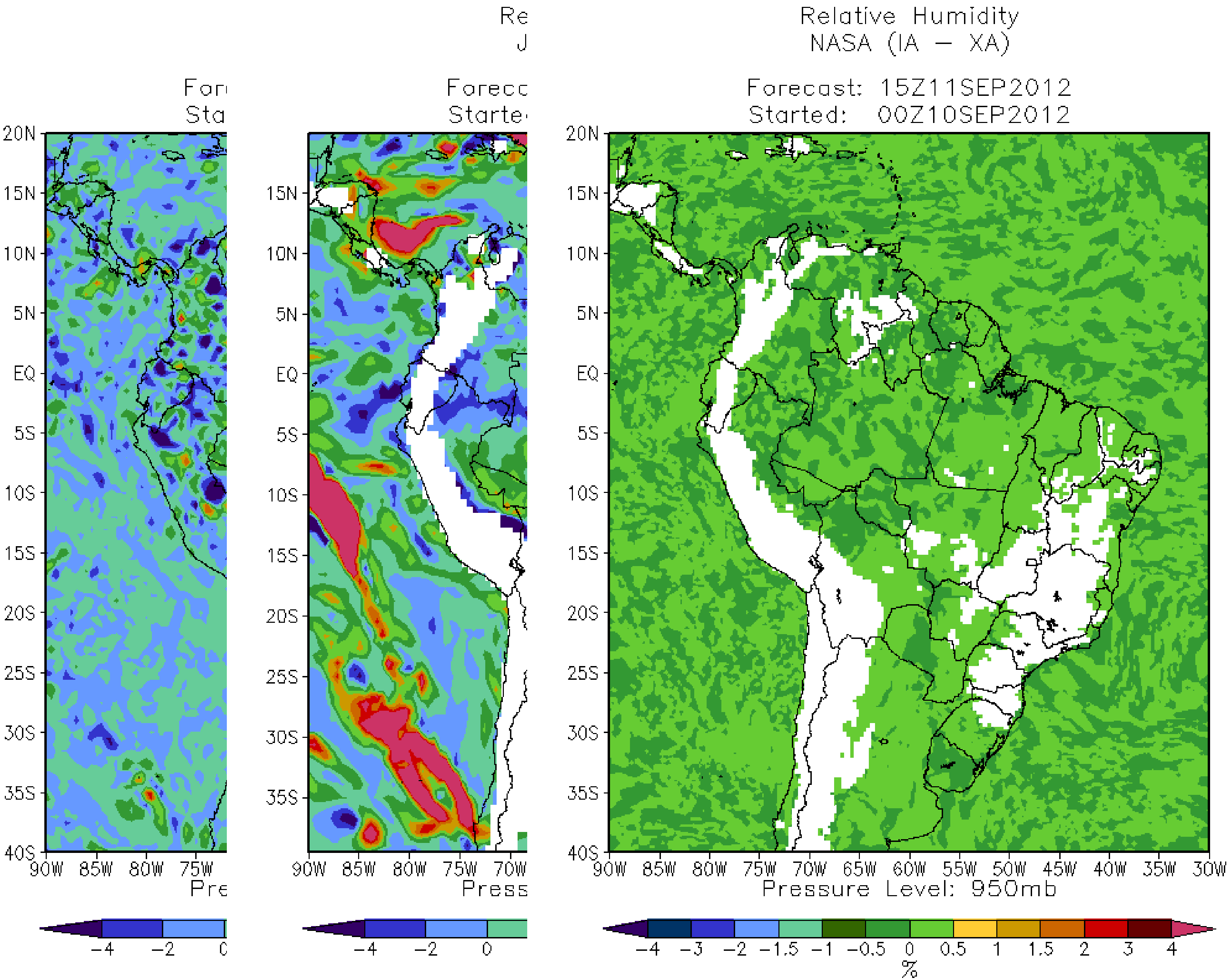
- Latmin=13.135, Latmax=36.86, Lonmin=18.135, Lonmax= 41.86
- Centre of domaine: (lat, lon) = (25°N,30°E)

# Ongoing work at NOAA/ESRL

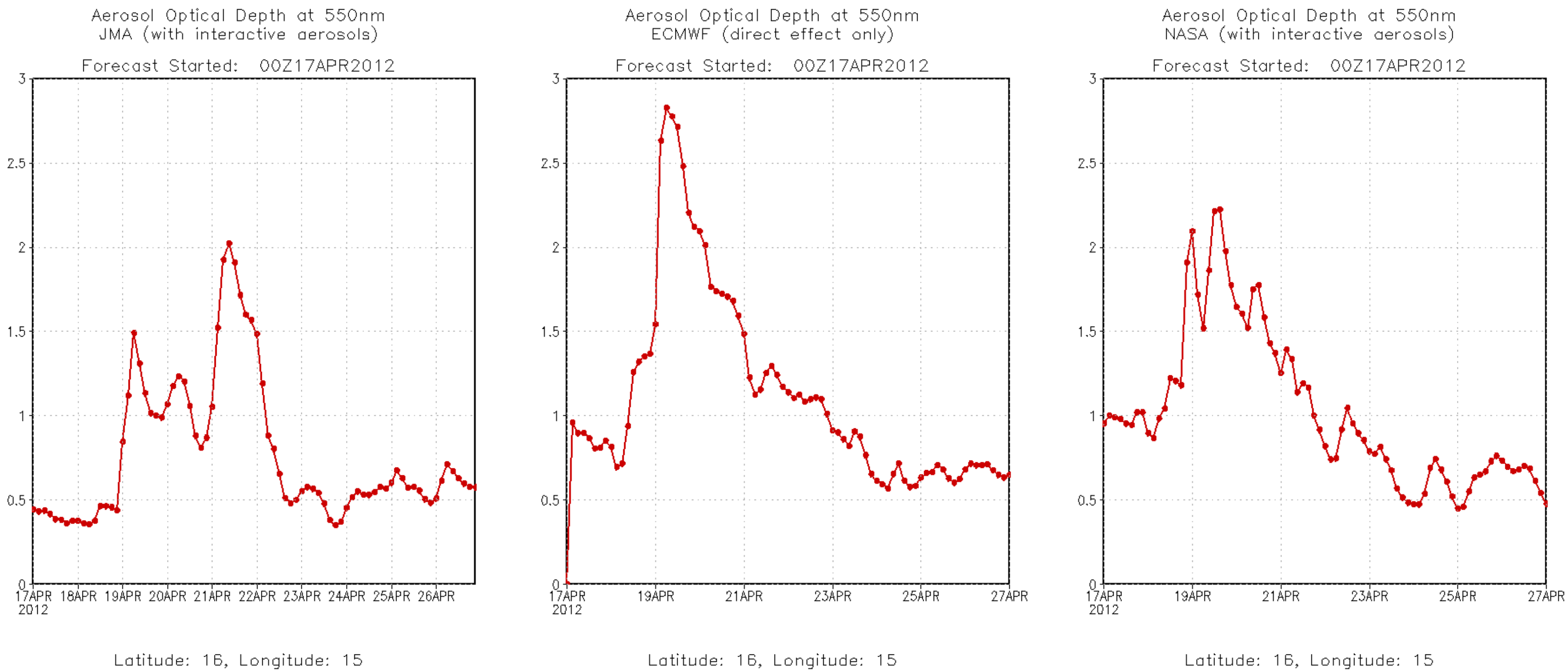
- Georg Grell’s group is applying WRF-Chem model for SAMBBA and Beijing cases

- 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

# Backup slides



Relative Humidity
NASA (IA — XA)
Forecast: 15Z11SEP2012
Started: 00Z10SEP2012
Pressure Level: 950mb
%

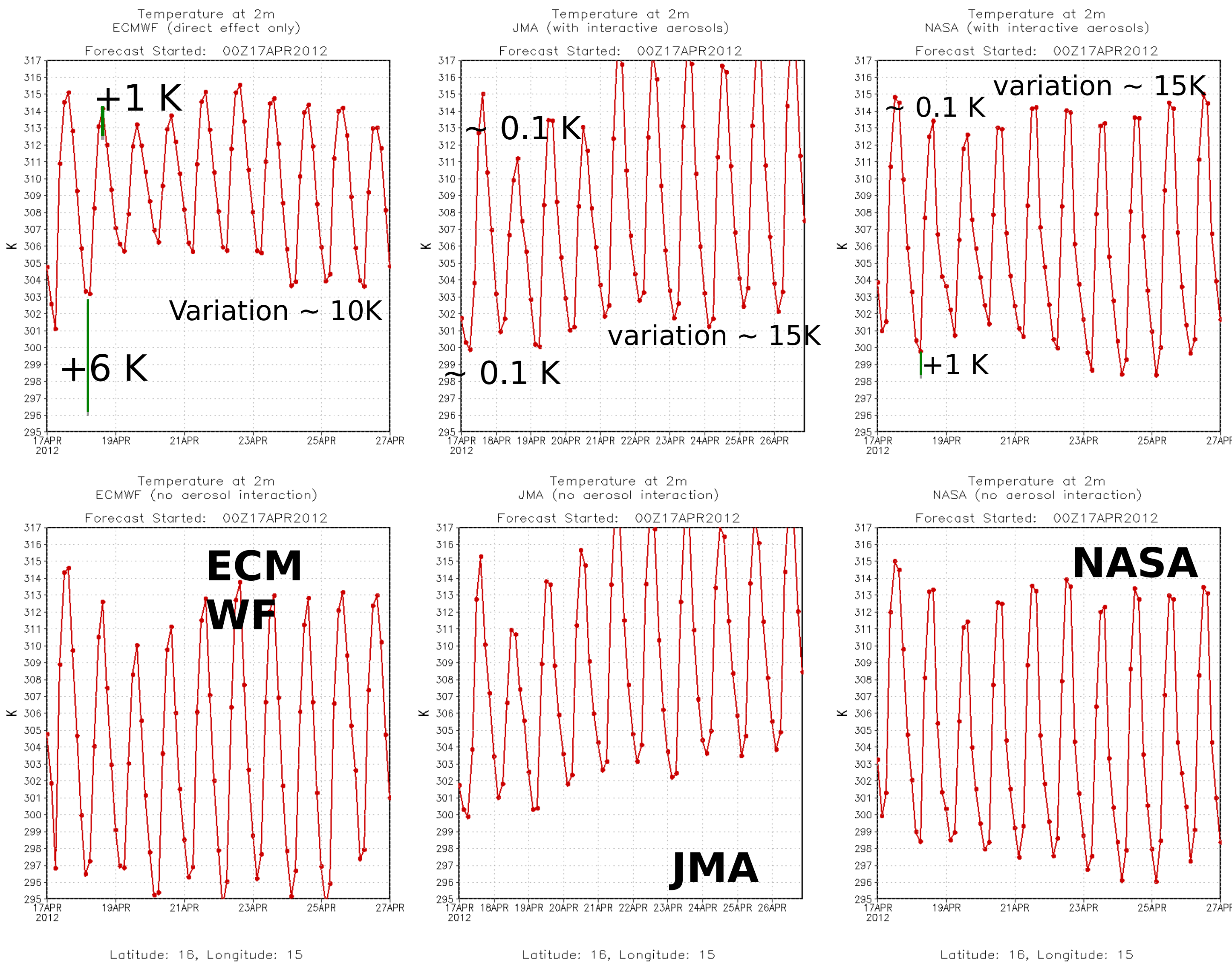

Aerosol Optical Depth at 550nm
JMA (with interactive aerosols)
Forecast Started: 00Z17APR2012
3
2.5
2
1.5
1
0.5
0
17APR 2012
18APR
19APR
20APR
21APR
22APR
23APR
24APR
25APR
26APR
Latitude: 16, Longitude: 15
Aerosol Optical Depth at 550nm
ECMWF (direct effect only)
Forecast Started: 00Z17APR2012
3
2.5
2
1.5
1
0.5
0
17APR 2012
19APR
21APR
23APR
25APR
27APR
Latitude: 16, Longitude: 15
Aerosol Optical Depth at 550nm
NASA (with interactive aerosols)
Forecast Started: 00Z17APR2012
3
2.5
2
1.5
1
0.5
0
17APR 2012
19APR
21APR
23APR
25APR
27APR
Latitude: 16, Longitude: 15

# 2m-Temp

## 10 days forecast (start:00UTC17APR2012)

**AER**

**NO AER**



# Grell-Freitas Convective Param

- **Scale-aware/Aerosol-aware (Grell and Freitas, 2014, ACP)**
  - Stochastic approach adapted from the Grell-Devenyi scheme (Grell and Devenyi, 2002, GRL; but many of the more computationally expensive ensembles have been cut for efficiency)
  - Scale awareness through Arakawa approach (2011) or spreading of subsidence
  - transitions to precipitating shallow-cumulus scheme as grid spacing decreases (can even use it at dx=1km!)
    - First temperature & moisture tendencies decrease as resolution increases
    - At very high resolution (dx < 3km) parameterized convection becomes much shallower – cloud tops near 800 mb (down from 200-300 mb).
    - Tendencies in general become very small,

# Aerosol awareness

**Constant autoconversion rate id changed to aerosol (CCN) dependent Berry conversion**

**Evaporation of raindrops is changed (Jiang and Feingold) based on empirical relationship**

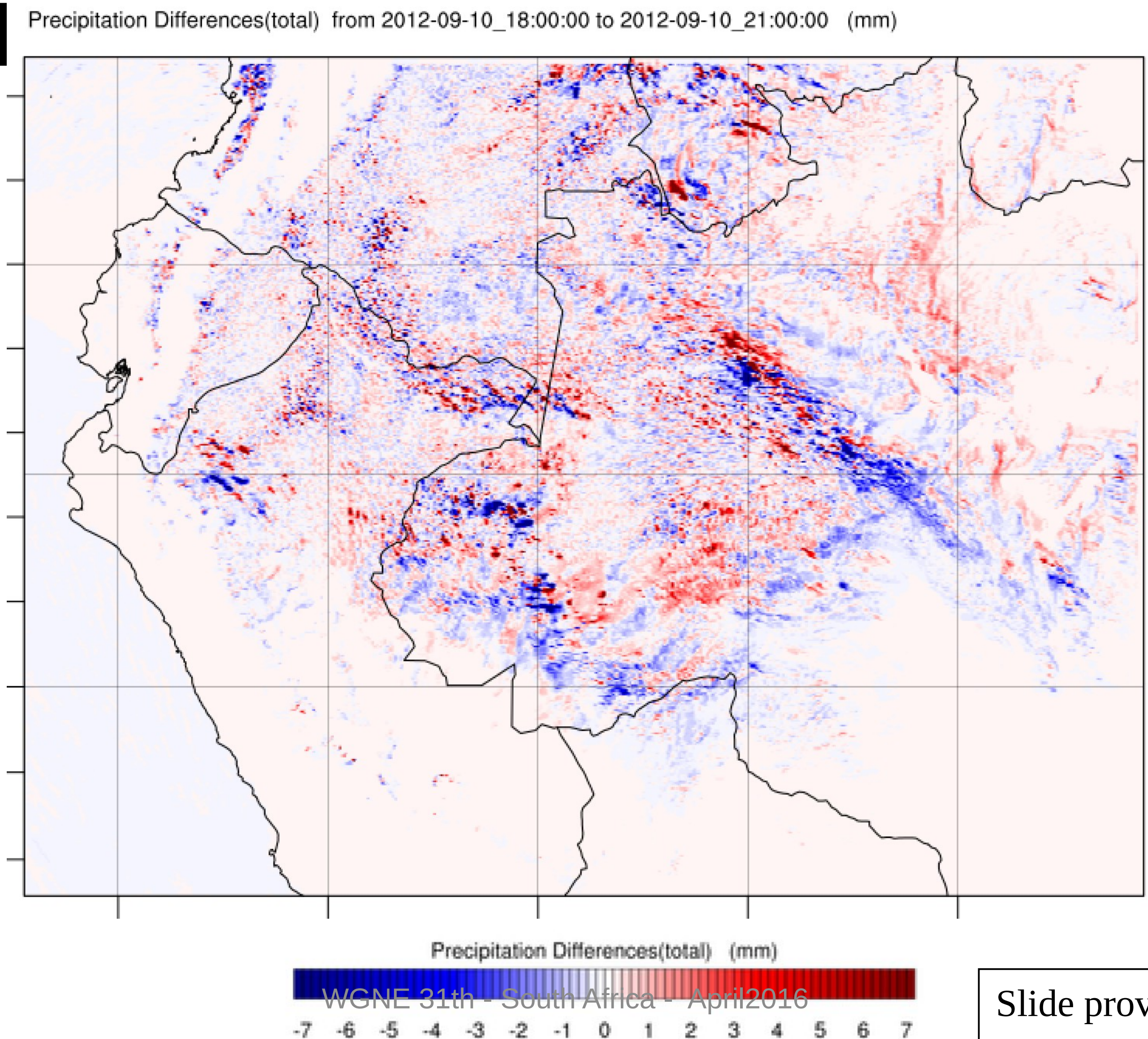
$$\left(\frac{\partial r_{rain}}{\partial t}\right)_{\text{autoconversion Berry, 1968}} = \frac{\left(\rho r_c\right)^2}{60\left(5 + \frac{0.0366\ CCN}{\rho r_c m}\right)}$$

$$PE \sim (I_1)^{\alpha_s - 1}(CCN)^{\zeta} = C_{pr}(I_1)^{\alpha_s - 1}(CCN)^{\zeta}$$

**CCN can be from complex model results (WRF-Chem), or simply from observed AOD (global or regional analysis)**

Evaporation effect will have a strong impact on downdrafts, but is limited by other environmental conditions (e.g., If the precipitation efficiency is already very low, it cannot get much lower, and vice versa)

# 3-hourly precipitation differences at Sep 10, 21Z (M

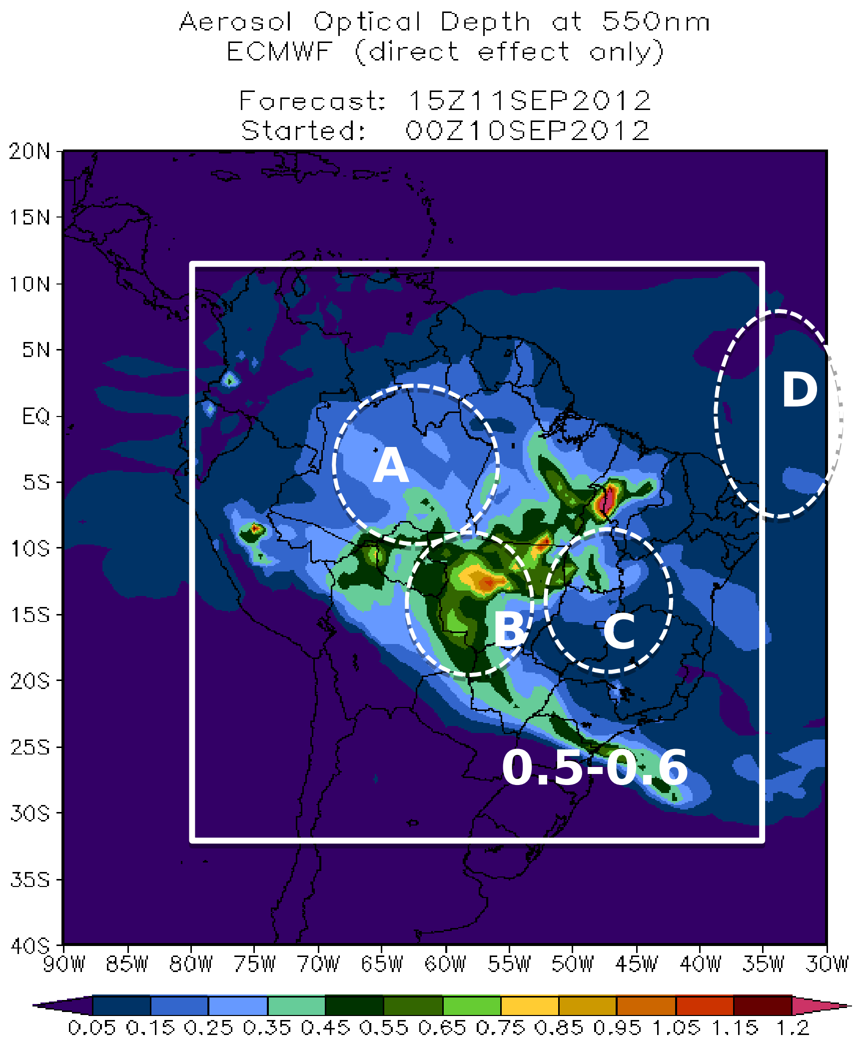


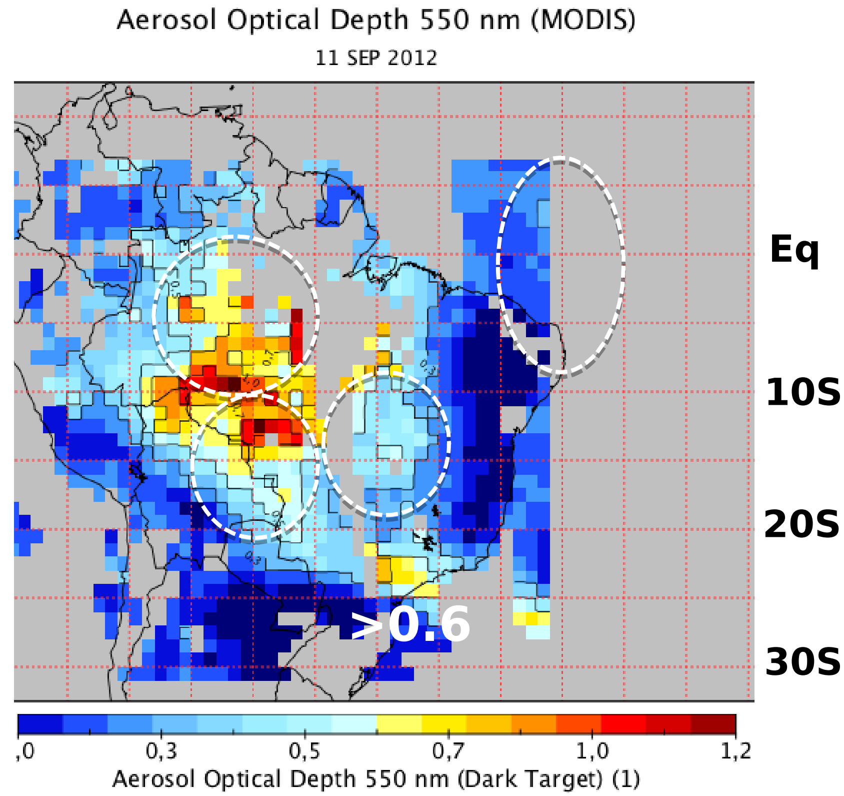



Slide provided by G. Grell

# ECMWF : AOD at 550 nm

## Forecast for 15UTC11SEP - Init.: 00UTC10SEP




A: AOD is underestimated in the interior of Amazon basin (underwood fires?)

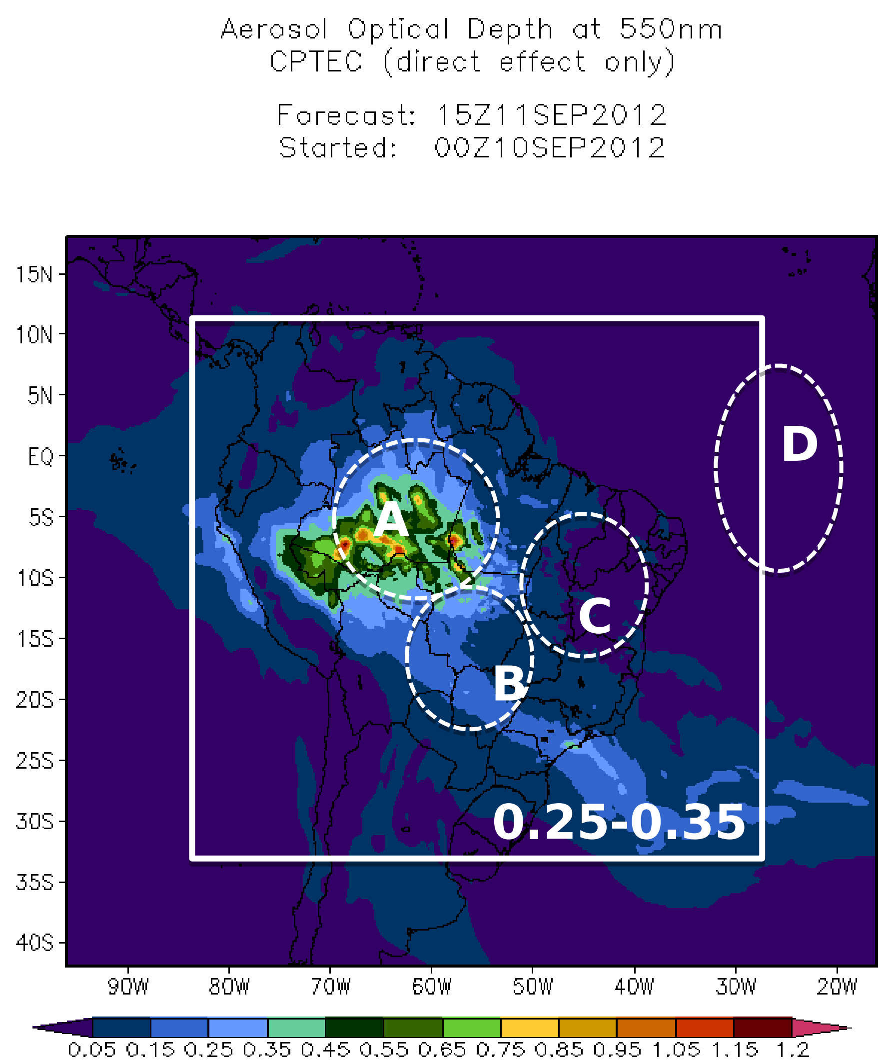
B: gradient from NW-SE is well represented, but with lower AOD

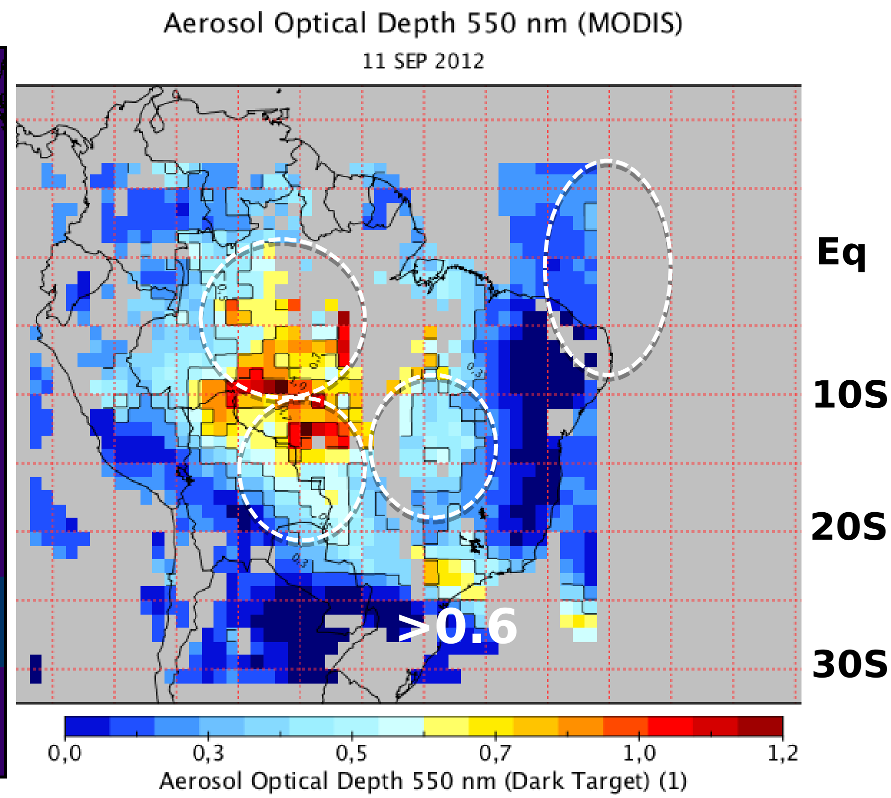
C: AOD is also underestimated (might be related to missing fires, savanna area)

D: Smoke inflow from African fires looks also underestimated

# **CPTEC:** AOD at 550 nm

## Forecast for 15UTC11SEP - Init.: 00UTC10SEP

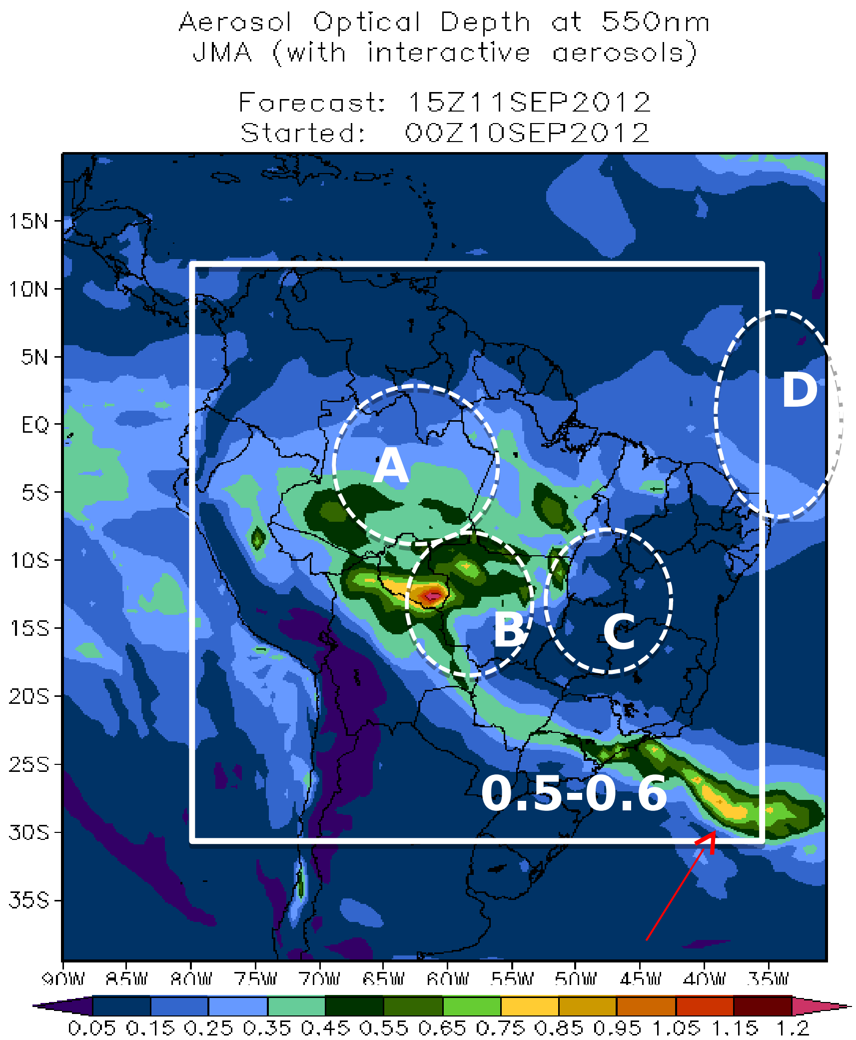


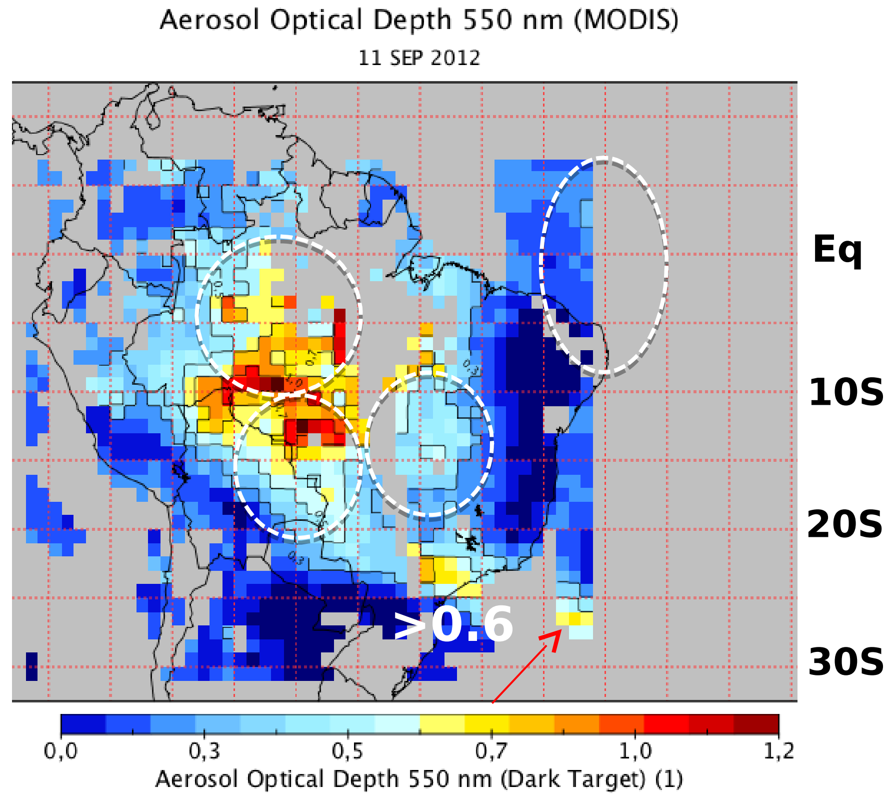




A: AOD is underestimated in the interior of Amazon basin (underwood fires?)
B: gradient from NW-SE is well represented, but with lower AOD
C: AOD is also underestimated (might be related to missing fires, savanna area)
D: Smoke inflow from African is underestimated

# JMA : AOD at 550 nm

## Forecast for 15UTC11SEP - Init.: 00UTC10SEP

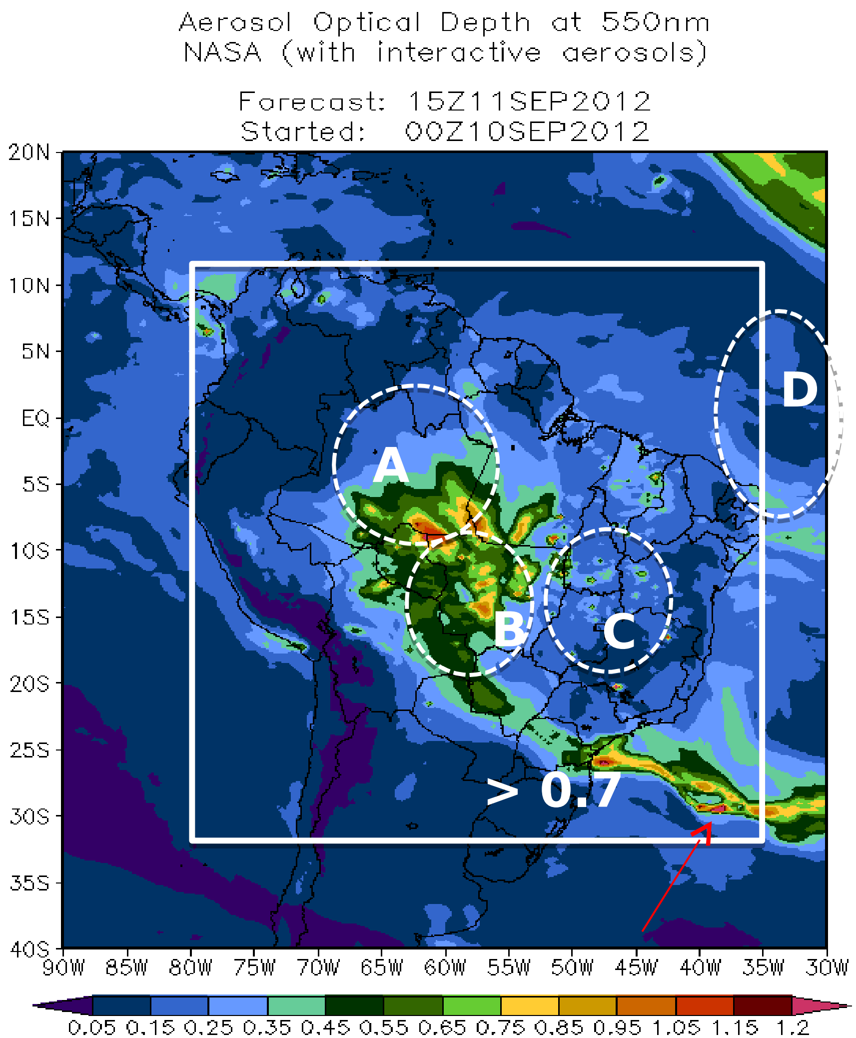


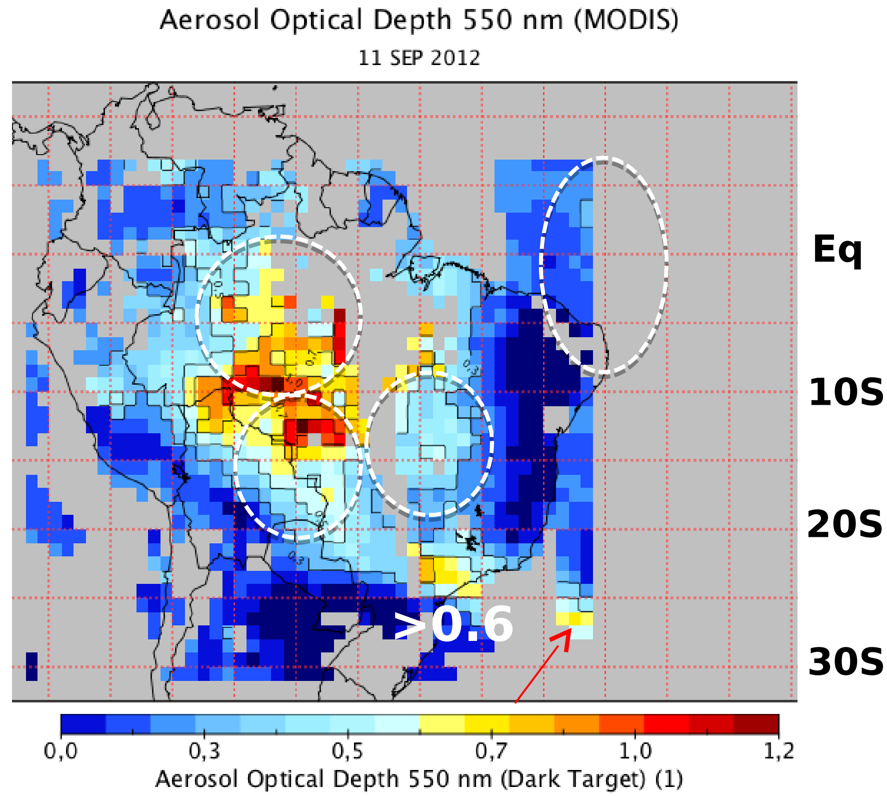




A: AOD is underestimated in the interior of Amazon basin (underwood fires?)
B: gradient from NW-SE is well represented, but with lower AOD
C: AOD has the larger underestimation
D: Smoke inflow from African fires looks fine
E: SE outflow looks fine (mag and location)

# NASA : AOD at 550 nm

## Forecast for 15UTC11SEP - Init.: 00UTC10SEP

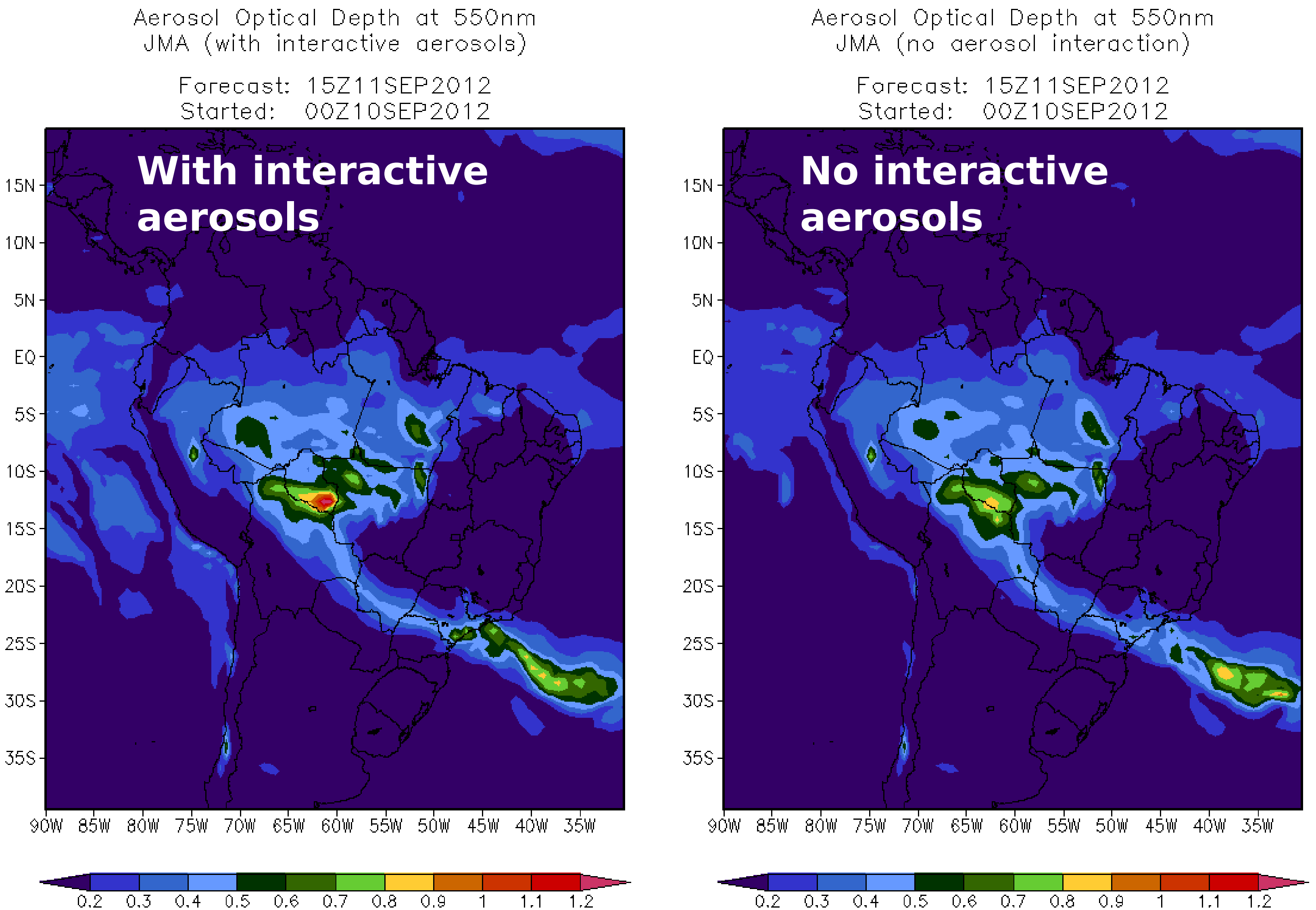



A: AOD is better represented in the interior of Amazon basin
B: gradient from NW-SE is well represented, but with lower AOD
C: AOD is also underestimated (might be related to missing fires, savanna area)
D: Smoke inflow from African fires looks better represented
E: SE outflow looks fine (mag and location)

# AOD @550 nm Forecast from JMA  model

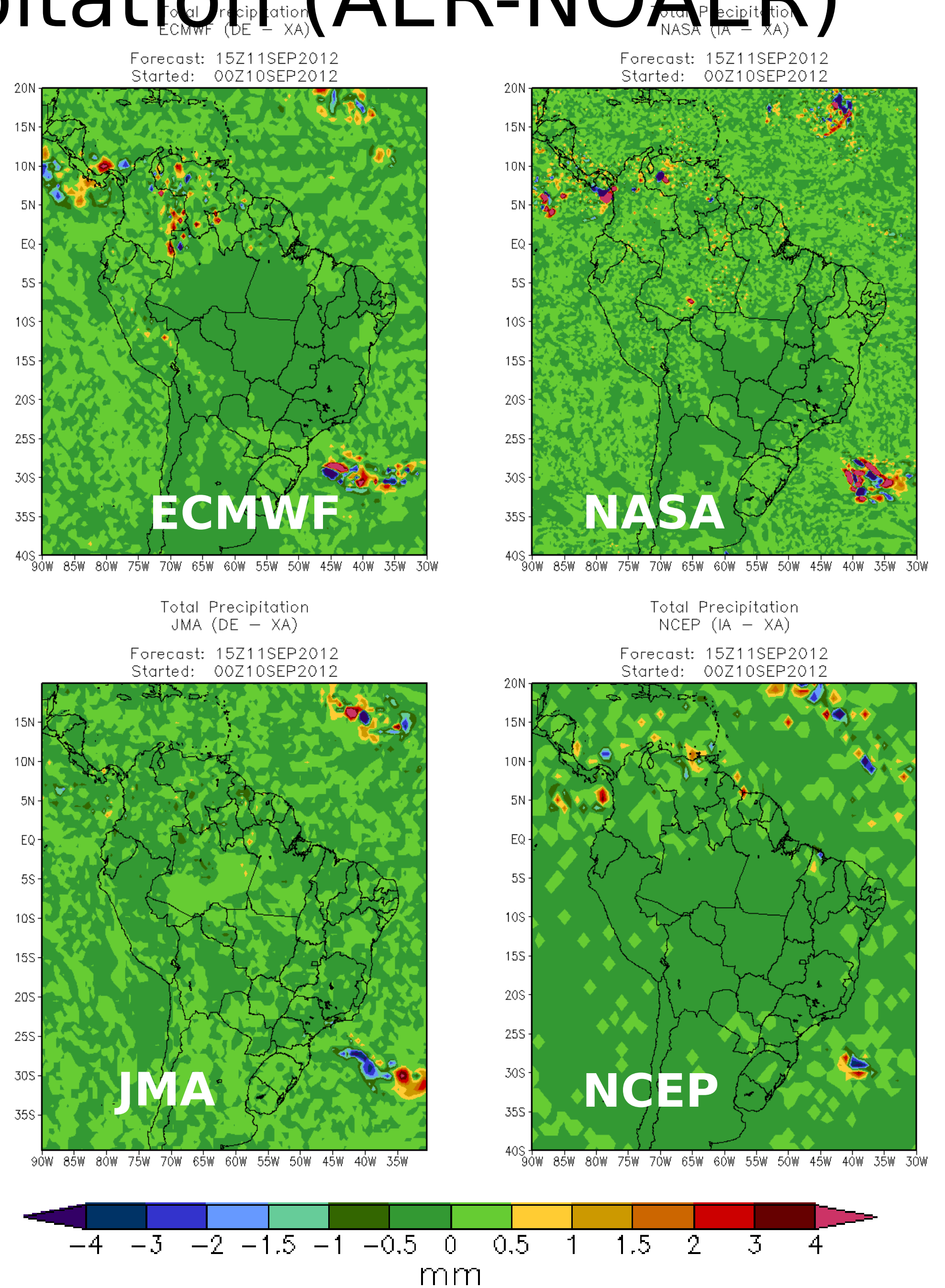
## Forecast 15UTC11SEP  - Init.:00UTC10sep



# Grid-scale Precipitation (AER-NOAER)

## Forecast for 15UTC11SEP - Init.:00UTC10SEP

- The differences are related to the clouds position only.
- The same holds for convective precip.



# The general approach 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 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 |

# 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, SO4 | EDGAR 4. 3BEM | bulk | 2-mom | no |
| JMA MASINGAR | Global TL319L40 | Dust, Sea-Salt, BC, OC, SO4 | 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-Chem | 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, SO4 | EDGAR 4.1 QFED 2.4 | Bulk | Bulk or 2-mom MG | yes |
| NCEP NGAC+GOCART | Global T126 | Dust, Sea-Salt, BC, OC, SO4 | Climatological Aerosols | Bulk | Bulk | no |