WGNE-S2S-GAW Aerosol project:
Evaluating the impact of aerosols on Numerical Weather and Subseasonal Prediction

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Thanks to: Johannes Flemming, Glicia Garcia,
Luiz F. Sapucci, Joao G. Z. de Mattos, Alexander Baklanov

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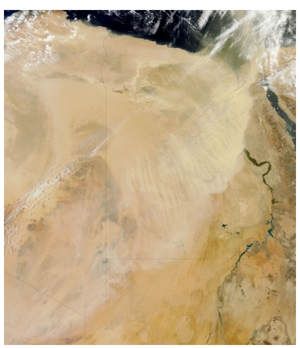
35th WGNE Session
On-line
Nov 2020

Background

Joint Initiative of WGNE, WWRP/S2S and GAW

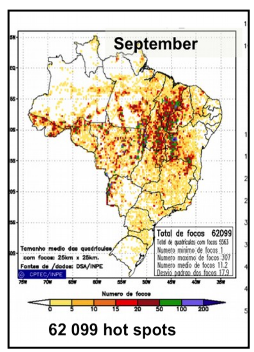
Overarching objective: *Improving model capabilities via incorporating/integrating composition, weather and climate*

The First Phase of the WGNE-Aerosol Project



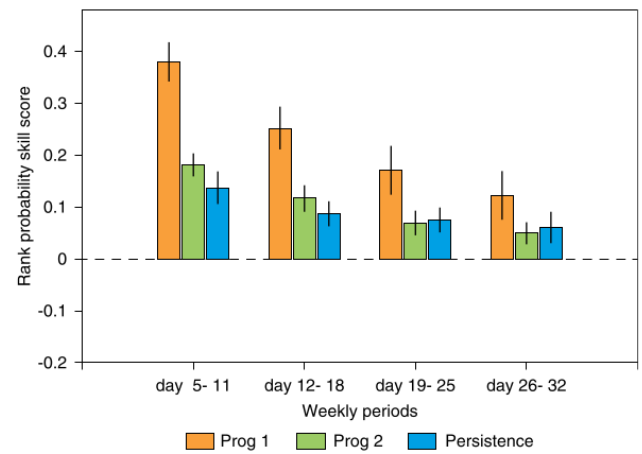
Dust over Egypt: 4/2012

Pollution in China: 1/2013



Smoke in Brazil: 9/2012

Courtesy: Saulo Freitas

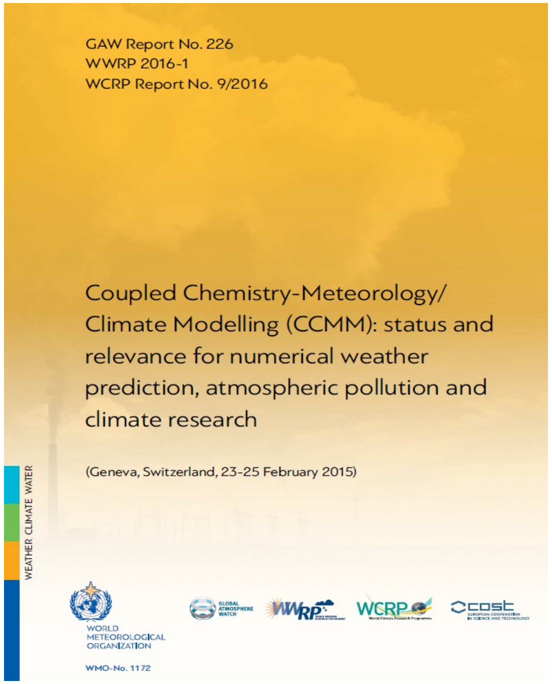


RPSS for experiments PROG1 (orange) and PROG2 (green) with respect to a persistence forecast (blue) of dust optical depth for the tropics

Benedetti and Vitart (2018, MWR)

Coupled Chemistry-Meteorology Models (CCMM) within ESP for NWP, AQ and Climate applications: *key scientific questions*

- What are the advantages of integrating meteorological and chemical/aerosol processes in coupled models?
- How important are the two-way feedbacks and chains of feedbacks for meteorology, climate, and air quality simulations?
- What are the effects of climate/meteorology on the abundance and properties (chemical, microphysical, and radiative) of aerosols on urban/regional/global scales?
- What is our current understanding of cloud-aerosol interactions and how well are radiative feedbacks represented in NWP/climate models?
- What is the relative importance of the direct and indirect aerosol effects as well as of gas-aerosol interactions for different applications (e.g., for NWP, air quality, climate)?
- What are the key uncertainties associated with model predictions of feedback effects?
- How to realize chemical data assimilation in integrated models for improving NWP and air quality simulations?
- How the simulated feedbacks can be verified with available observations/datasets? What are the requirements for observations from the three modelling communities?



GAW Report No. 226
WWRP 2016-1
WCRP Report No. 9/2016

Coupled Chemistry-Meteorology/ Climate Modelling (CCMM): status and relevance for numerical weather prediction, atmospheric pollution and climate research

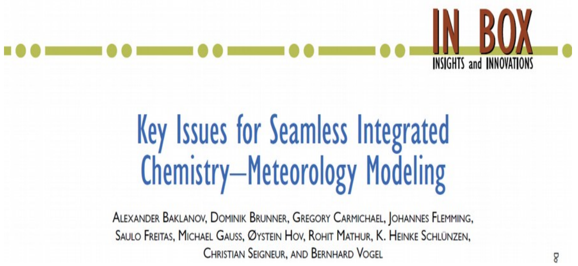
(Geneva, Switzerland, 23-25 February 2015)

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

WMO-No. 1172

https://library.wmo.int/doc_num.php?explnum_id=7938



IN BOX
INSIGHTS and INNOVATIONS

Key Issues for Seamless Integrated Chemistry–Meteorology Modeling

Alexander Baklanov, Dominik Brunner, Gregory Carmichael, Johannes Flemming, Saulo Freitas, Michael Gauss, Øystein Hov, Rohit Mathur, K. Heinke Schlünzen, Christian Seigneur, and Bernhard Vogel

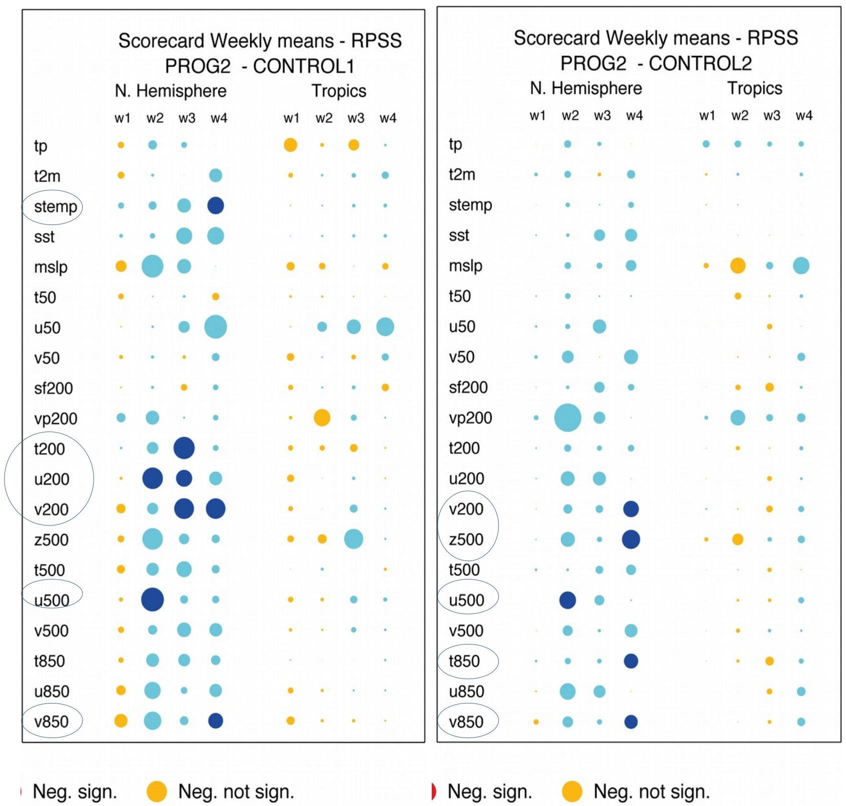
WMO OMM

Courtesy: A. Baklanov

BAMS Paper:
https://doi.org/10.1175/BAMS-D-15-00166.1

Aerosols as climate forcing

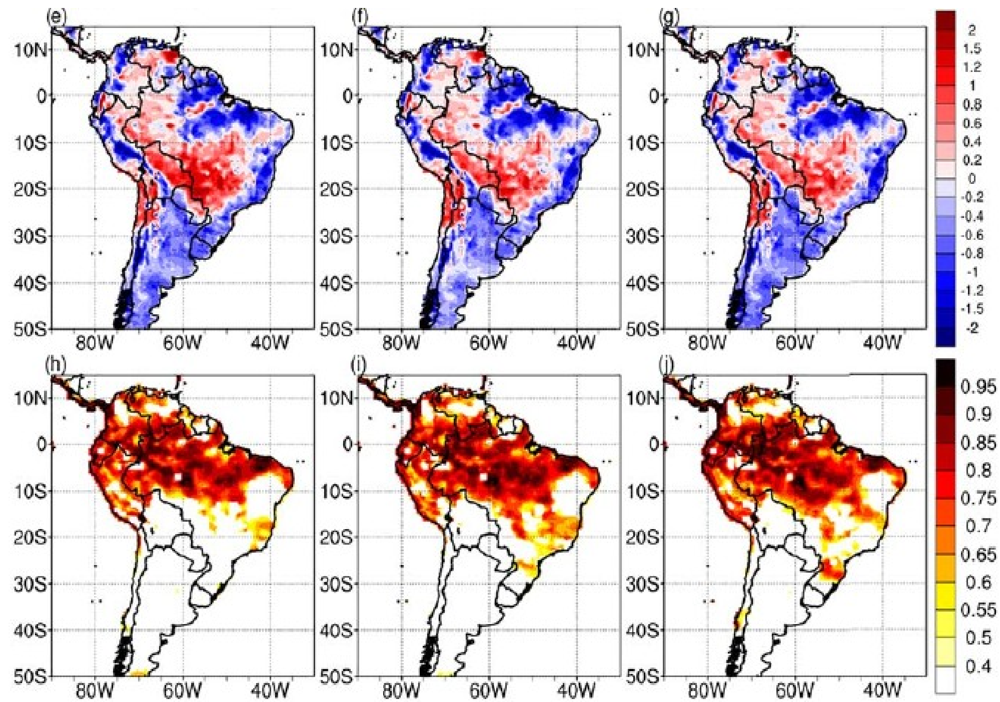
Subseasonal climate prediction



Scorecard weekly means RPSS

Benedetti and Vitart (2018, MWR)

Seasonal climate prediction



Mean bias of 2-meter temperature from GEOS-S2S-5 relative to MERRA-2

Freire et al. (2020, GRL)

Project Goals

Identify:

- *the importance of aerosols for the predictability of the atmospere in a systematic approach*

- *the atmospheric model quality for air quality forecasting*

- *Analyse capabilities of NWP models to simulate the impact of aerosols on NWP and S2S*

Experiments - Direct effect

Short-range **Regional domains**	**S2S** **Global domain**
Period of simulations: 2017-2019 (2016 optional)	**Hindcasts:** 2003-2019
Forecast lenght: 72h from 00:00 UTC	**Forecast length:** At least 32-day long simulations
Time resolution: 3h	**Time resolution:** 6h
Configuration: according with modelling groups capability	**Configuration:** Initialized by own analysis/re-analysis Minimum 5-member ensemble
Aerosols: Focus on different aerosol species according with region of interest Climatological vs interactive	**Aerosols:** Biomass Burning and Dust Climatological emissions vs prescribed observed emissions

Short-range experiments - summary

Participants	***Event/Area***	***Period***	***Domain***	***Type of the model***	***Status of the data***	***People involved***
CMA	East Asia – EA (dust & pollution)	Mar-Apr-May Jan-Feb-Mar		R	TBS	Xiao-Ye Zhang / Wang Hong
ECMWF	SAm, SAf, EA	Aug-Sep-Oct Mar-Apr-May Jan-Feb-Mar	**19°W to 95°W 60°S to 15°N**	G	2016	Johannes Flemming
INPE	S. America	Aug-Sep-Oct	**19°W to 95°W 60°S to 15°N**	R	2016	Ariane Frassoni
JMA	SAm, SAf, EA	Aug-Sep-Oct Mar-Apr-May Jan-Feb-Mar		G	Requested again	Taichu Y. Tanaka
Leibniz TROPOS	Dust in Egypt	Mar-Apr-May	80°E to 120°E 20°N to 50°N	R	TBS	Roland Schrödner
NOA/ IAASARS	**Dust transport in the Mediterrane-an**	26-28 Mar 2010 01-03 Feb 2015 21-23 Mar 2018	**20°W to 40° E 15°N to 50°N**	R	S	Christos Spyrou

Preliminary results – ECMWF contribution

Thanks to Johannes Flemming and colleagues

Data sets

PROG: Interactive prognostic aerosol (direct effect)

- 40x40 km horizontal resolution, 137 Levels (T511)
- NWP Data assimilation (00 and 12 windows)
- Data assimilation of AOD (MODIS)
- Aerosol model as described in Remy at el. 2019: 3*DD, 3*SS, 2*OM, 2*BC, SO4, 2*NO3, NH4

CLIM: Aerosol climatology (direct effect)

- 40x40 km horizontal resolution, 137 Levels (T511)
- Started at 00, NWP initialised as PROG from CAMS o-suite
- Aerosol climatology derived from CAMSRA (Bozzo et al., 2020)
- CAMSRA aerosol modelling differs from 46r1 aerosol:
    - no NO3 & NH4
    - different mean desert dust and sea salt
- meteorology initiated as PROG from CAMS o-suite

Period:

- 1.6.2019 - 31.8.2010
- Four and Five day forecast started at 00 every day

Note : CLIM forecast starts from an analysis that have “seen” prognostic aerosols

Flemming et al., 2020

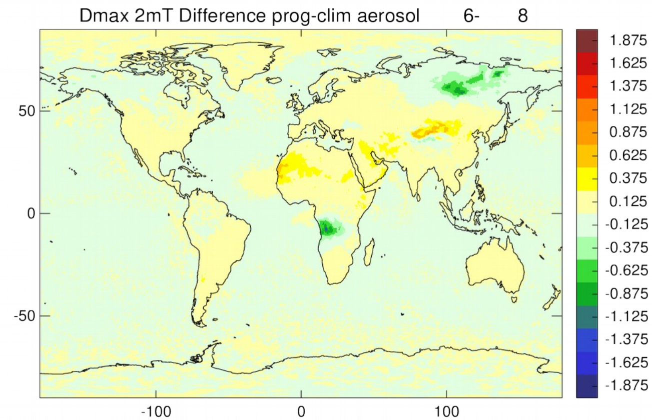
https://meetingorganizer.copernicus.org/EGU2020/EGU2020-18254.html?pdf

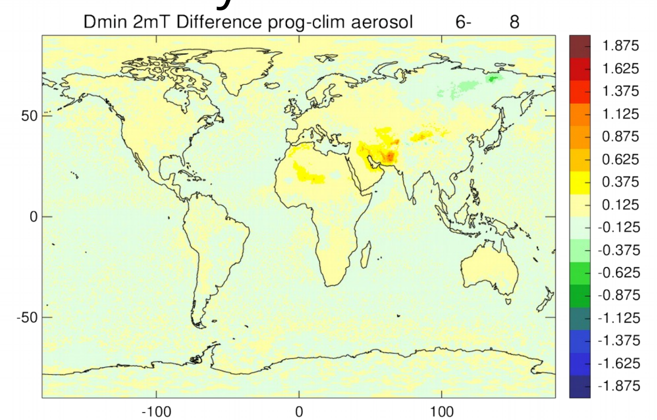
2mT Maximum differences (PROG-CLIM) JJA 2019

Daily Maximum

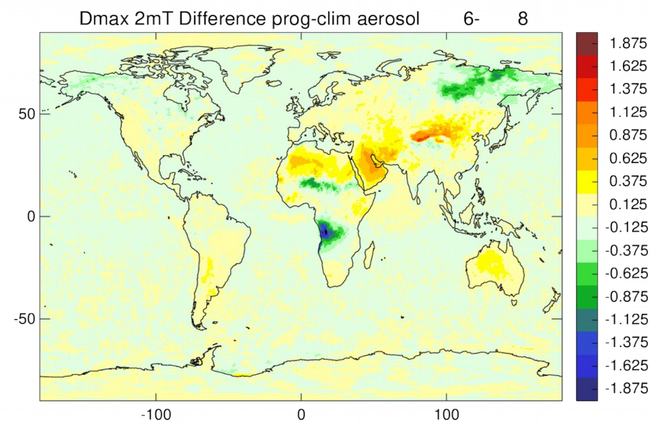
Daily Minimum

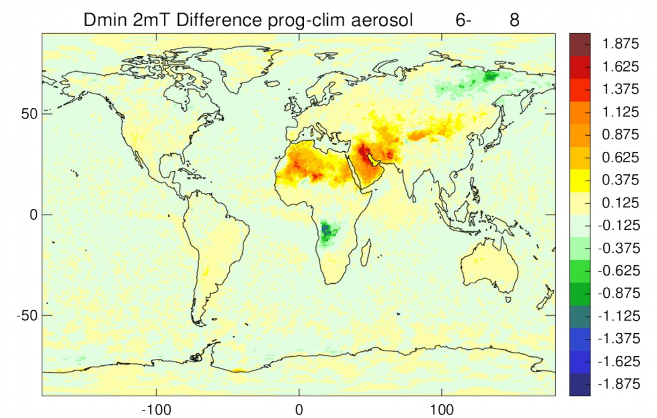
Day 1





Day 5



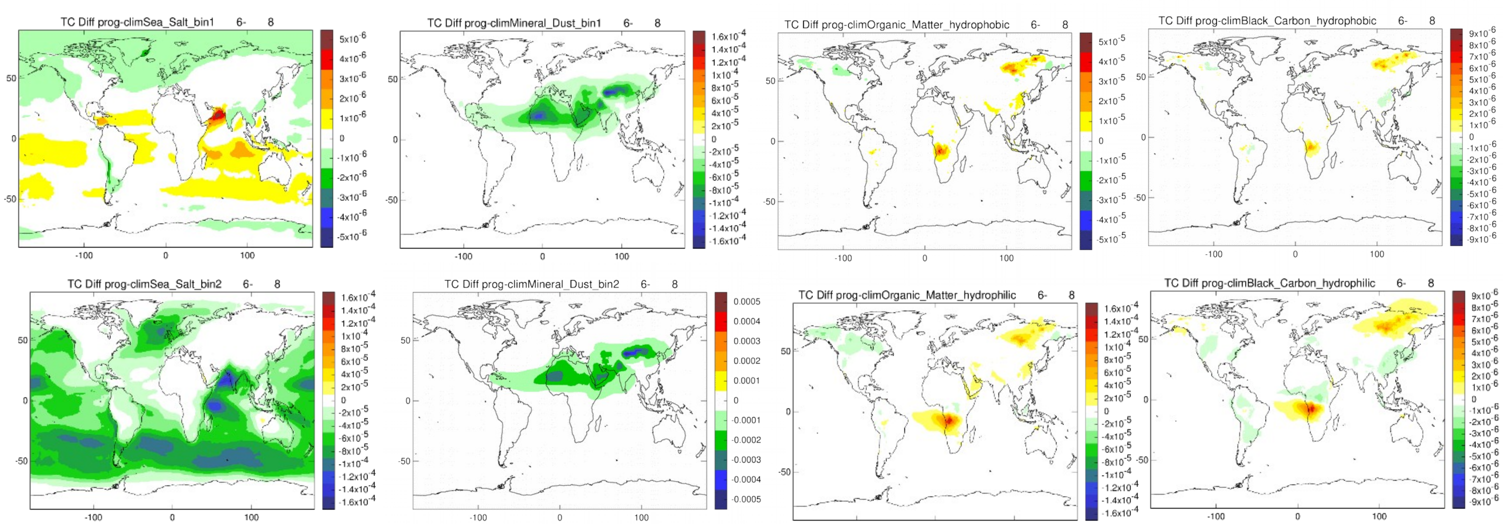


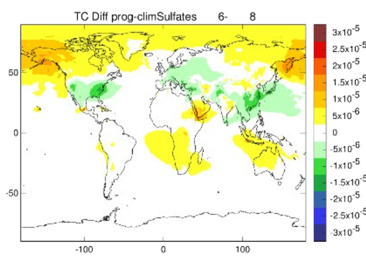
Flemming et al., 2020

https://meetingorganizer.copernicus.org/EGU2020/EGU2020-18254.html?pdf

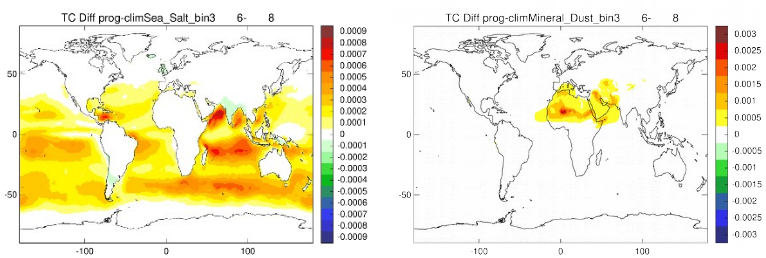
Mean Difference between climatological and prognostic aerosols (Total column mass) JJA 2019

Sea Salt Dust OM BC SO4





Note:
No Nitrates and NH4 in climatology



- Considerable mean differences for dust and sea salt
- Biomass burning signature in OM and BC
- Increased prognostic NH4 SO4 probably because of Raikoke eruption

Flemming et al., 2020

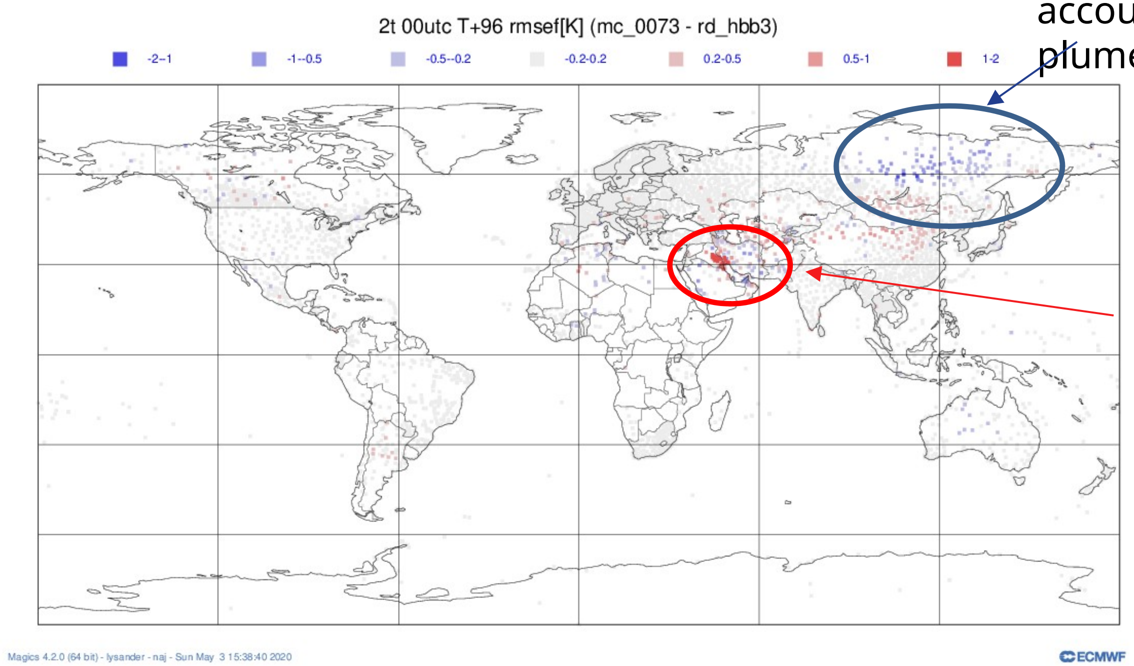
https://meetingorganizer.copernicus.org/EGU2020/EGU2020-18254.html?pdf

Difference in 2M T RMSE (JJA 2019) (PROG-CLIM) using synop data

Blue: PROG has lower RMSE

red: PROG has higher RMSE

H 96 (00 UTC)



Improvement by accounting for biomass plumes

Degradation by systematic bias of desert dust

Flemming et al., 2020
https://meetingorganizer.copernicus.org/EGU2020/EGU2020-18254.html?pdf

Summary

- ECMWF systematically compared 2m T forecast with the IFS (T511, CAMS configuration) for JJA 2019 using in the radiation scheme:
  - IFS aerosol climatology (CLIM)
  - IFS prognostic aerosol (PROG)
- Overall NWP scores were not substantially different between PROG and CLIM
- PROG 2m T differed from CLIM to a larger extend in:
  - areas affected by increased aerosol originating from wild fires (**cooling**)
  - desert dust dominated regions because the prognostic dust aerosol was systematically lower than dust aerosol in the climatology (**warming**)
- The cooling introduced by the prognostic wild fire aerosol plumes was mostly an improvement w.r.t synop observations and 2mT analysis but also depend on base line bias (CLIM already to cold)
- The warming in the dust regions was a mixed results: improved biases and degraded variability

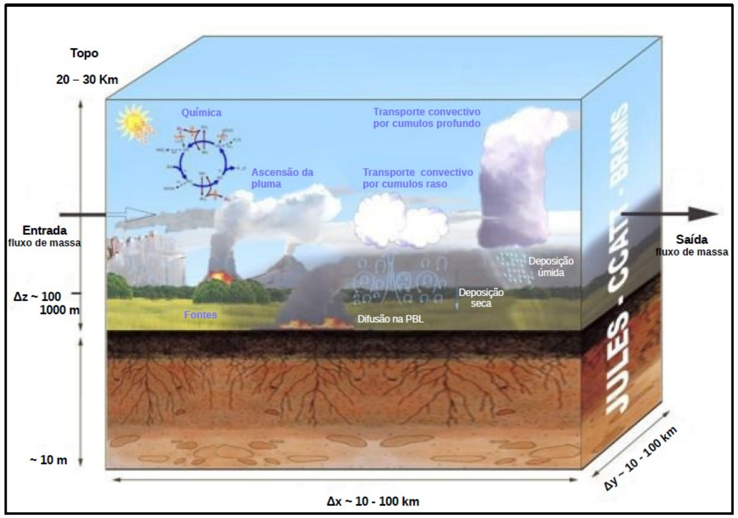
Flemming et al., 2020
https://meetingorganizer.copernicus.org/EGU2020/EGU2020-18254.html?pdf

Preliminary results – INPE contribution

Thanks to G. Garcia and Luiz F. Sapucci

Object-based evaluation of Heatwave Forecasts: case study

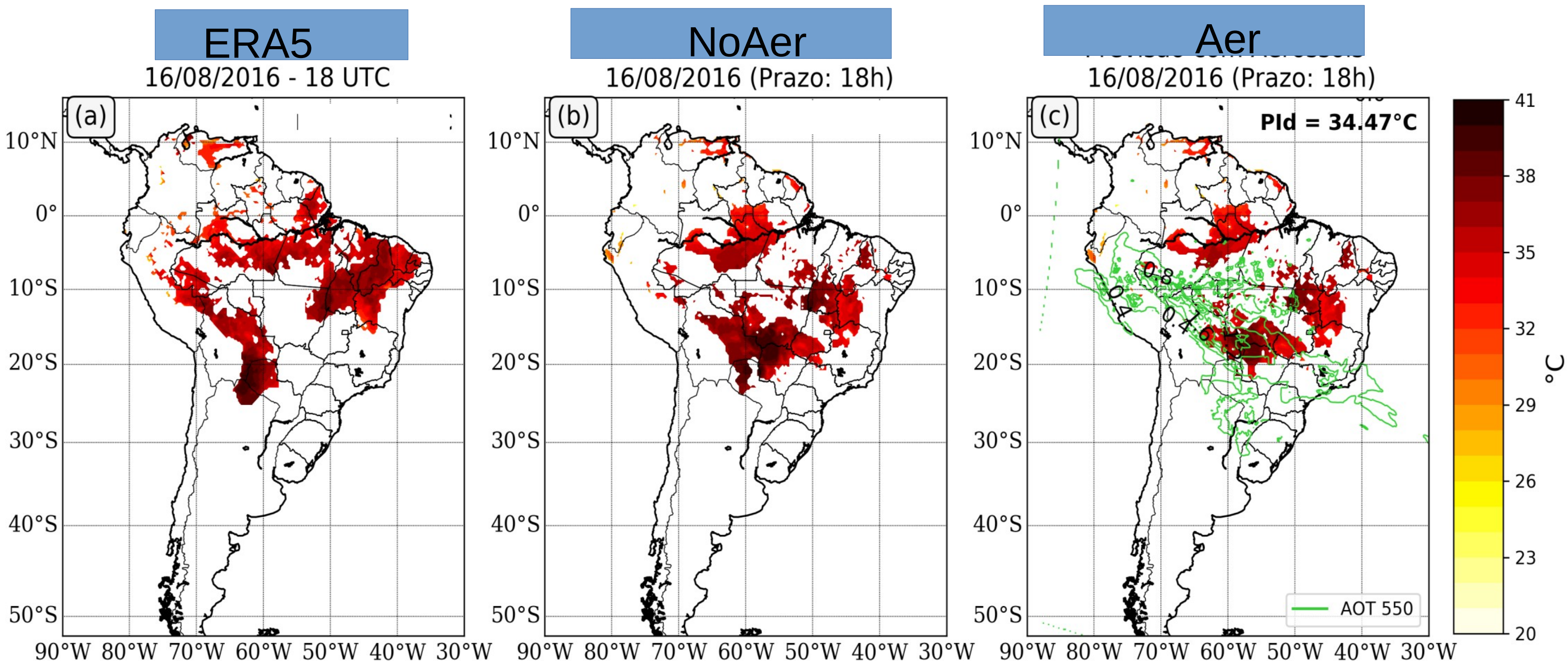
- BRAMS forecasts: fully chemistry/meteorology coupled model (Freitas et al., 2017)
- Interactive prognostic aerosol (direct effect)
  - 20X20 km horizontal resolution, 41 Levels
  - Biomass burning emissons from satellite data
- Period:
  - 13/08/2016 - 22/08/2016
  - Up to three day forecasts started at 00 every day
- ERA5 – reference 2mT



Fonte: Adaptado de Moreira et al. (2013).

Object-based evaluation of Heatwave Forecasts: case study

18h (00 UTC) BRAMS forecasts considering
Interactive Aerosols x noAer 16/08/2016

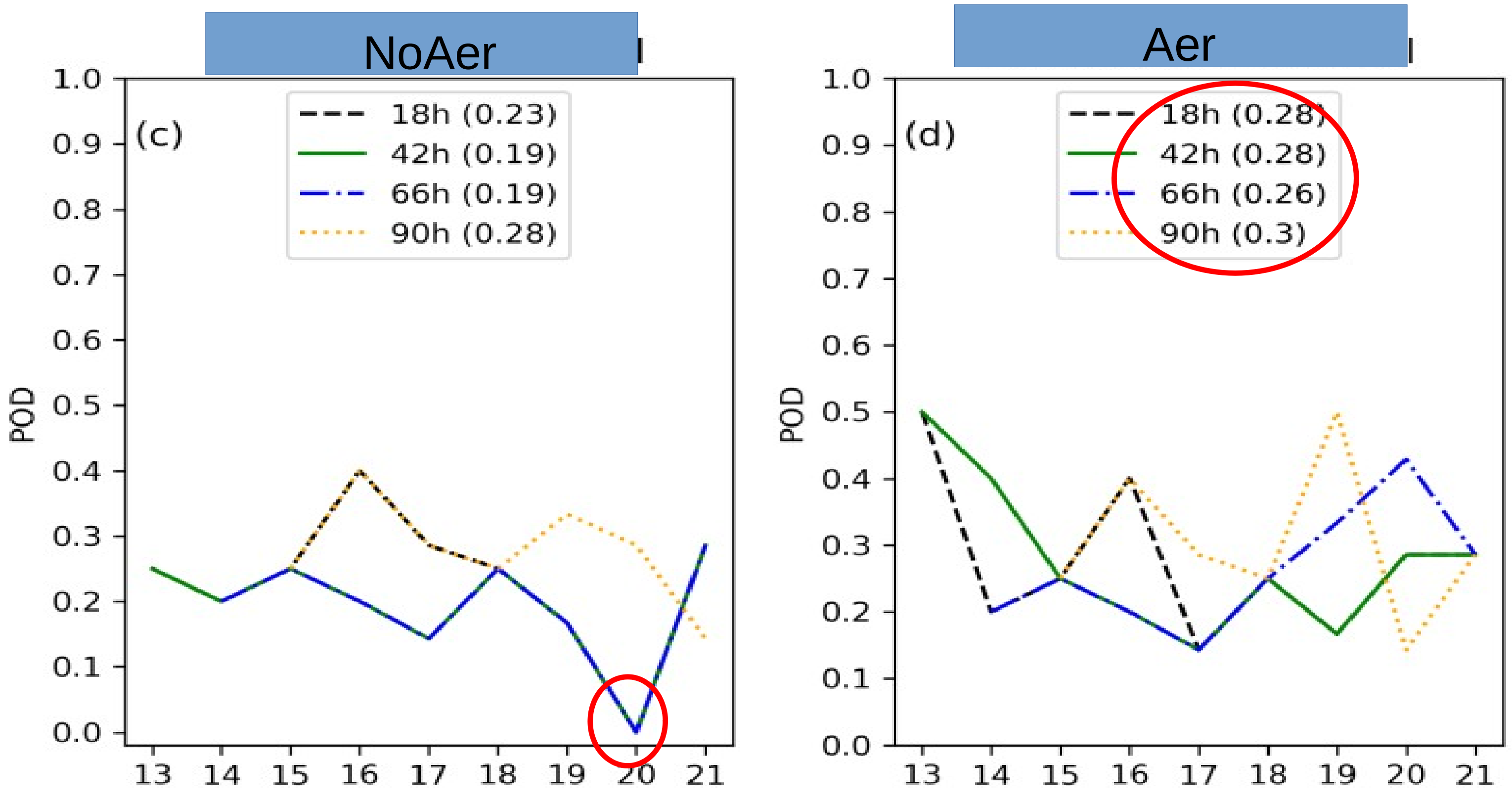


Heatwave identified between 13-22/08/2016

Glicia Garcia, Ariane Frassoni, Luiz F. Sapucci *(in prep.)*

Object-based evaluation of Heatwave Forecasts: case study

BRAMS forecasts considering noAe x Interactive Aerosol
13-21/08/2016



Glicia Garcia, Ariane Frassoni, Luiz F. Sapucci *(in prep.)*

Summary

- Heatwave areas are affected by increased aerosol loading from BB - cooling effect (reduction of HW area)

- Aerosols impact the spatial extent of the heatwave: Interactive aerosols improved spatial extent of the heatwave identified in the ERA5 reference

- In general, forecasts overestimate the number of objects w.r.t ERA5, but interactive aerosols improve the accuracy in the number of objects for all lead times

Next steps

- Apply quantitative evaluation of main meteorological fields

- Compile results, produce a report and submit to modelling groups

- Finish up the writing of the paper - compiling technical information to be provided by modelling groups participants, verification strategy and possibly preliminary results (TBD)

- Inclusion of North America domain: under discussion among modelling groups (ECCC and NOAA)

Acknowledgements

GAW

WCRP
World Climate Research Programme

WWRP
WORLD WEATHER RESEARCH PROGRAMME

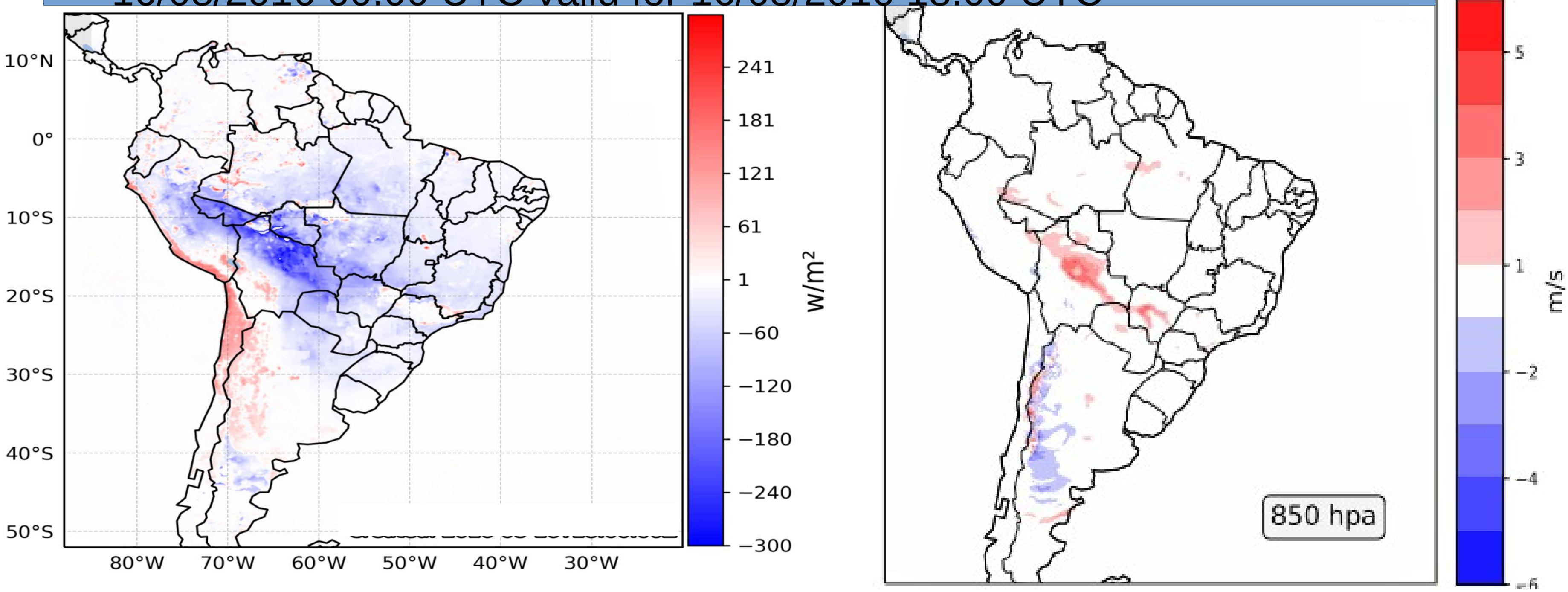
INPE
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

Subseasonal-to-Seasonal
S2S
Prediction Project

Thanks for your attention!

18h (00 UTC) BRAMS forecasts considering noAer x Interactive Aerosol 16/08/2016

Sensible heat flux (left) and wind velocity (right) : IA-noAer difference 16/08/2016 00:00 UTC valid for 16/08/2016 18:00 UTC



Glicia Garcia, Ariane Frassoni, Luiz F. Sapucci *(in preparation)*