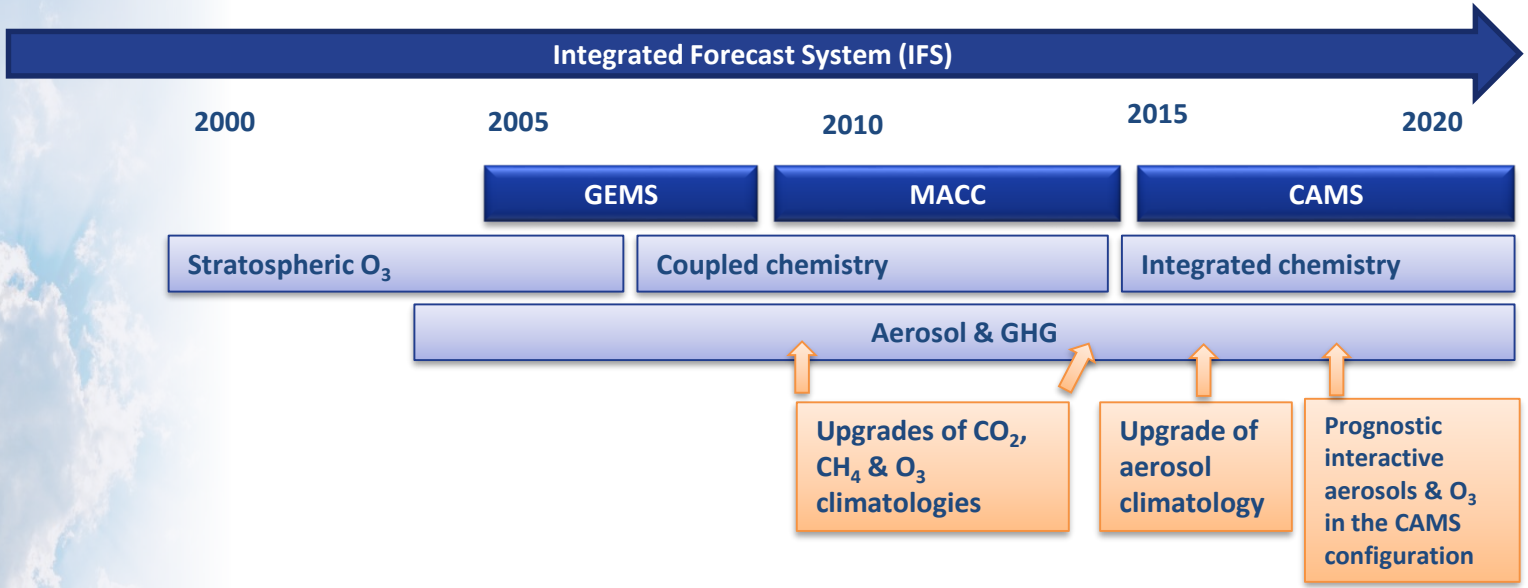
Does accounting for the direct-radiative effect of prognostic aerosols improve 5-day temperature forecast of the ECMWF weather forecast model ?

Johannes Flemming, Alessio Bozzo4, Jerome Barre, Richard Engelen, Sebastien Garrigues, Robin Hogan, Vincent Huijnen2, Antje Inness, Zak Kipling, Mark Parrington, Samuel Remy3, Ivan Tsonevsky, and Vincent-Henri Peuch

All ECMWF, 2 KNMI, 3 Hygeos, 4 Eumetsat

Atmosphere Monitoring

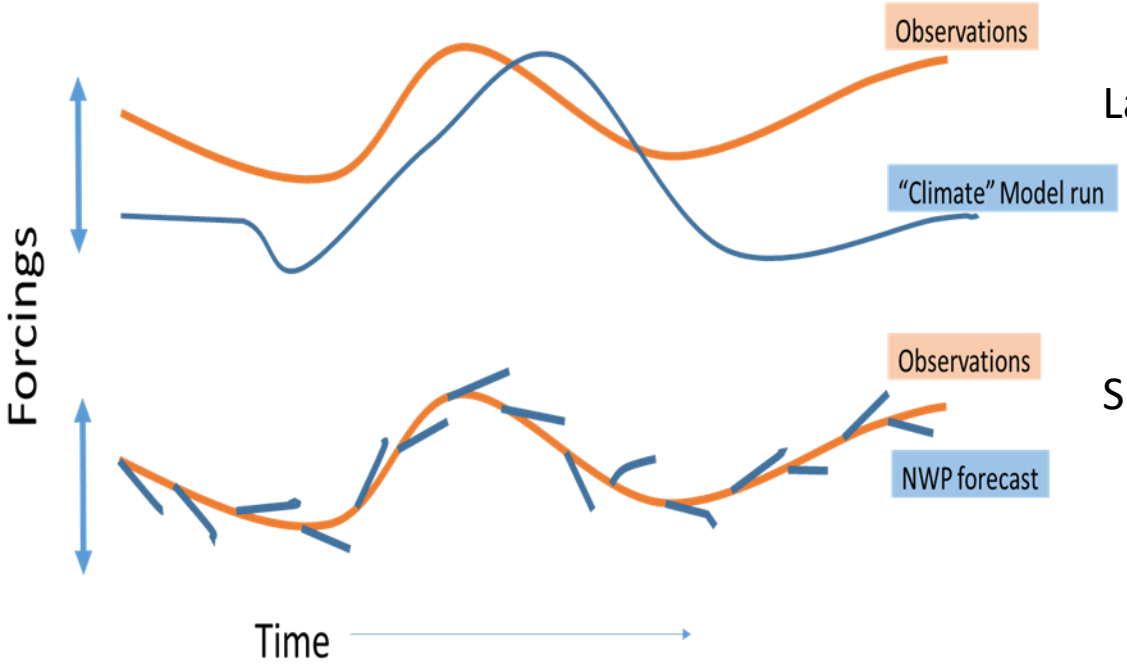
Development of atmospheric composition in the ECMWF model (IFS)



GEMS = Global and regional Earth-system (atmosphere) Monitoring using Satellite and in-situ data
MACC = Monitoring Atmospheric Composition and Climate
CAMS = Copernicus Atmosphere Monitoring System

ECMWF Copernicus Europe's eyes on Earth European Commission

Climate runs



Large impact

NWP

Small impact

The impact of AC - Weather feedback is expected to be much smaller in medium-range NWP simulation than in climate or free-running simulation because the NWP forecast are initialised at the start of every forecast.

Atmosphere Monitoring

Data sets

- **PROG:** Interactive prognostics aerosol in the radiation scheme (0073)
  - 40x40 km horizontal resolution, 137 Levels
  - NWP Data assimilation (00 and 12 windows)
  - Data assimilation of AOD (MODIS) and TC of NO2, CO and O3
  - Aerosol model (46r1) as described in Remy at el. 2019
  - 46r1 aerosol: 3*DD, 3*SS, 2*OM, 2*BC, SO4, 2*NO3, NH4
- **CLIM:** Aerosol climatology in the radiation scheme (hbb3)
  - Aerosol climatology derived from CAMS RA (Bozzo et al., 2020)
  - CAMSRA aerosol modelling differs from 46r1 aerosol:
    - no NO3 & NH4
    - different mean desert dust and sea salt
  - meteorology initiated from 0073 for PROG and CLIM
- Period:
  - 1.6.2019 - 31.8.2010
  - Four and Five day forecast started at 00 every day

How large are 2m T differences between PROG and CLIM ?

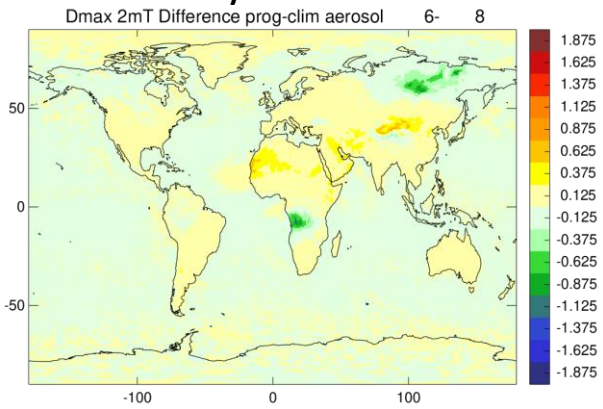
Mean Differences (PROG – CLIM) – JJA 2019

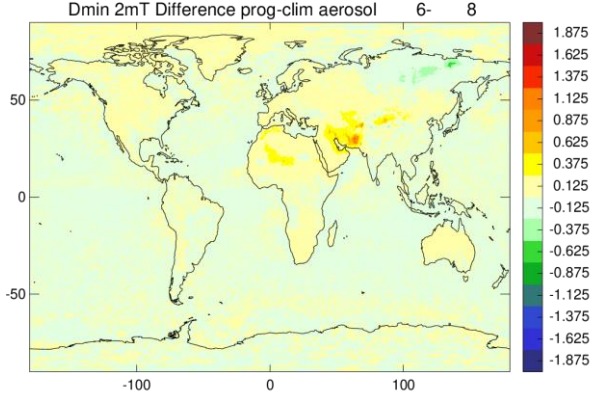
Atmosphere Monitoring

Daily Maximum

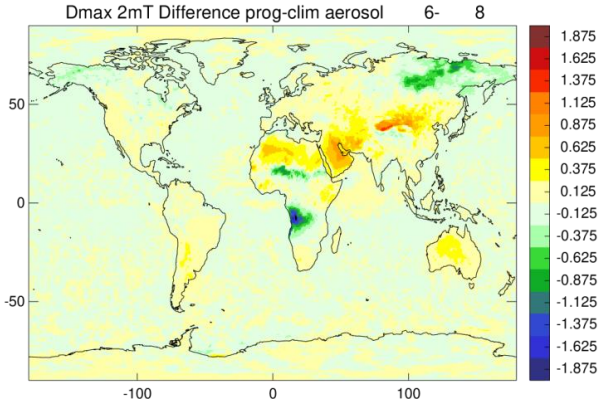
Daily Minimum

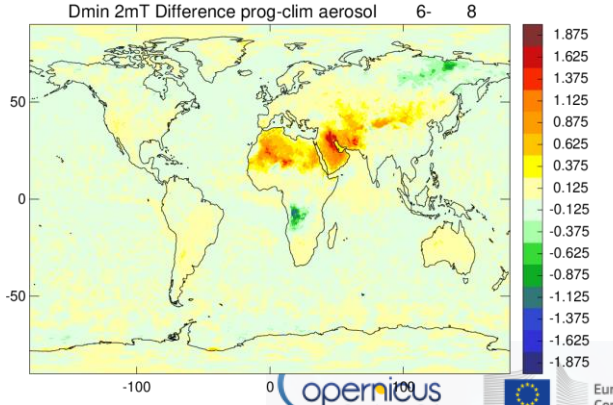
Day 1





Day 5





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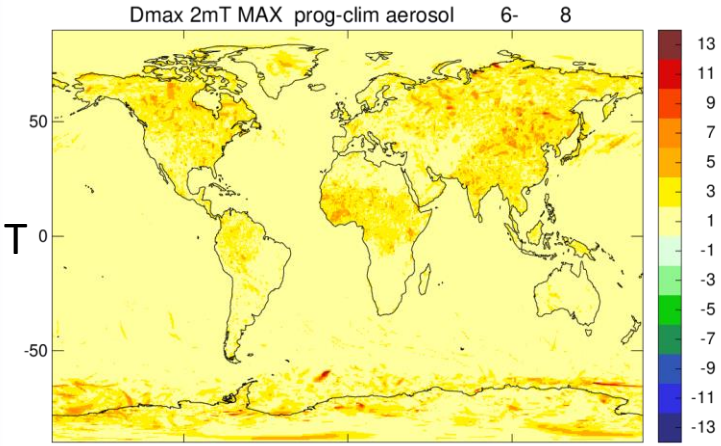
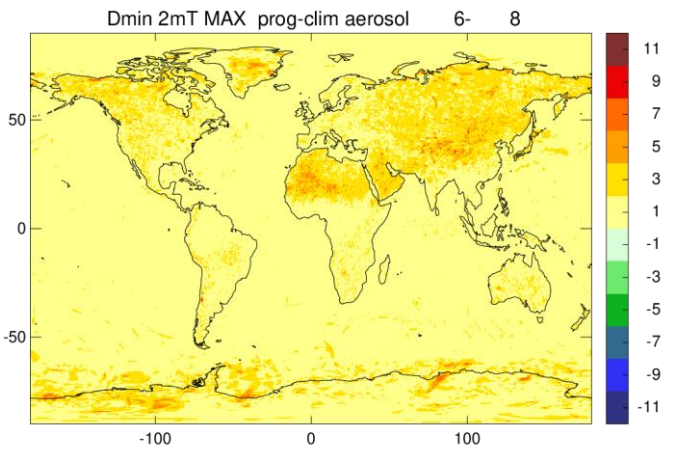
Maximum differences (PROG-CLIM) – JJA 2019

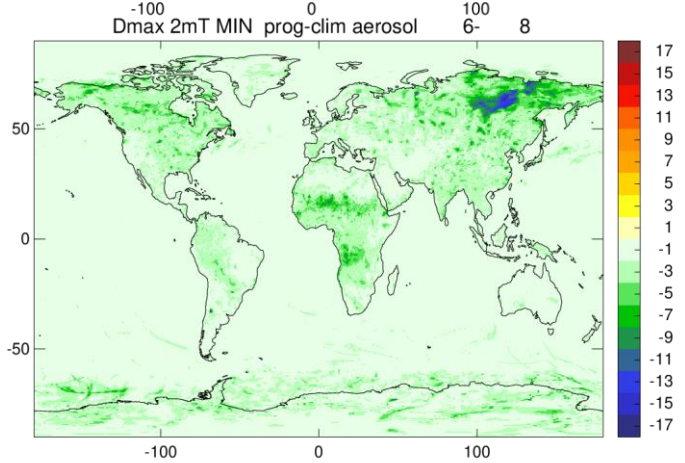
Atmosphere Monitoring

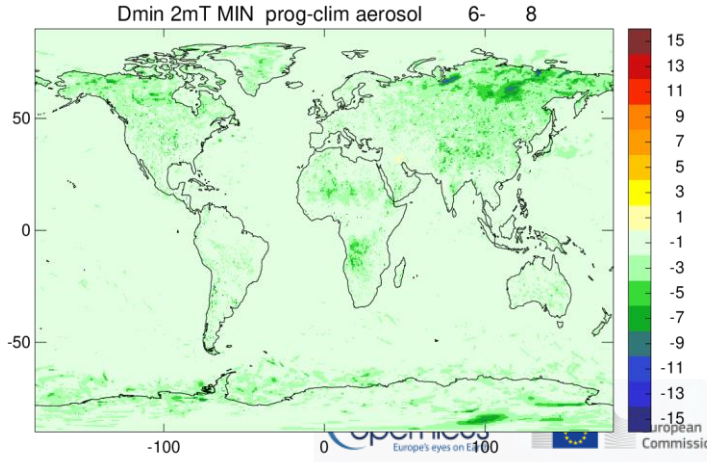
Day 5
Largest daily T increase





Day 5
Largest daily T decrease





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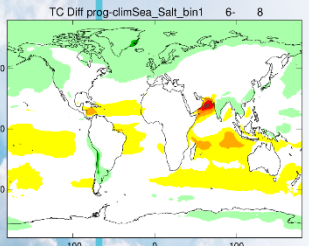
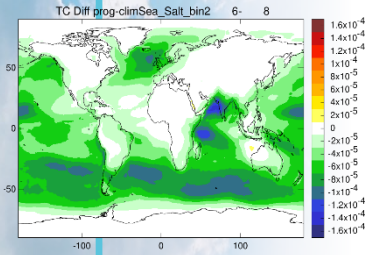
How large are differences between prognostic aerosols and aerosol climatology ?

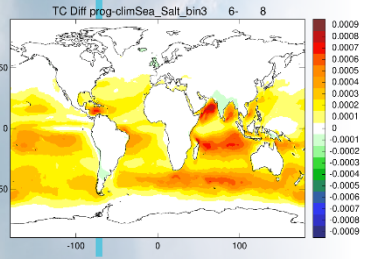
Atmosphere Monitoring

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

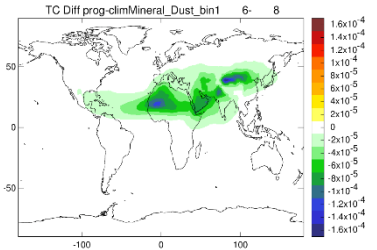
Sea Salt

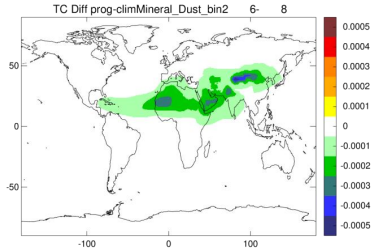


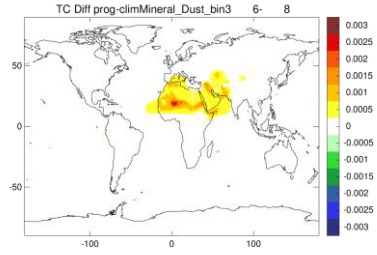




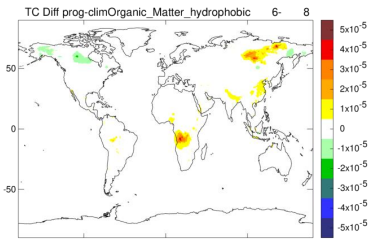
Dust

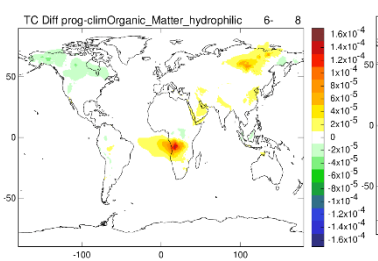




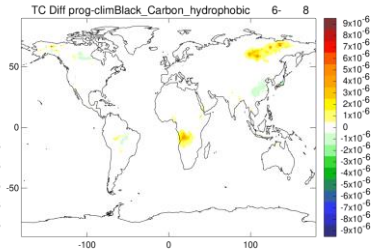


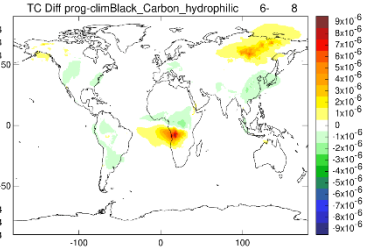
OM



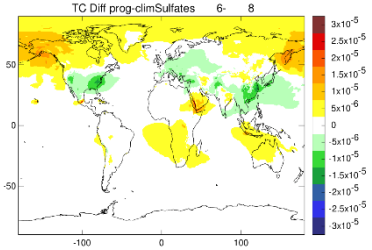


BC





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

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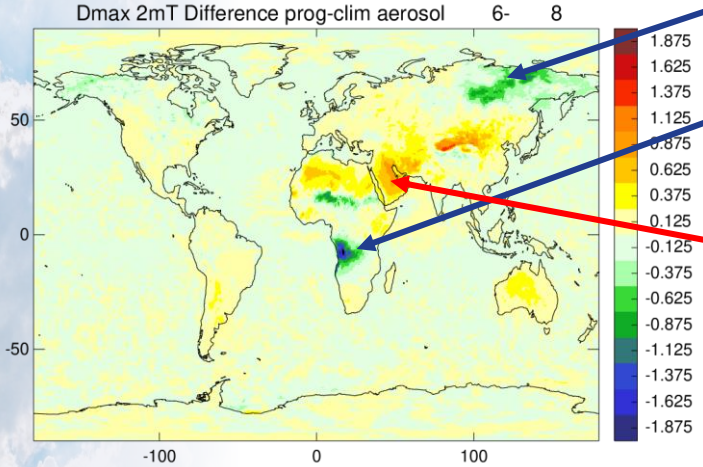
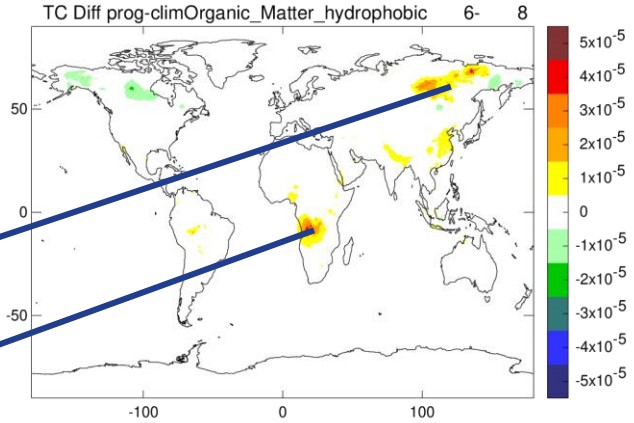
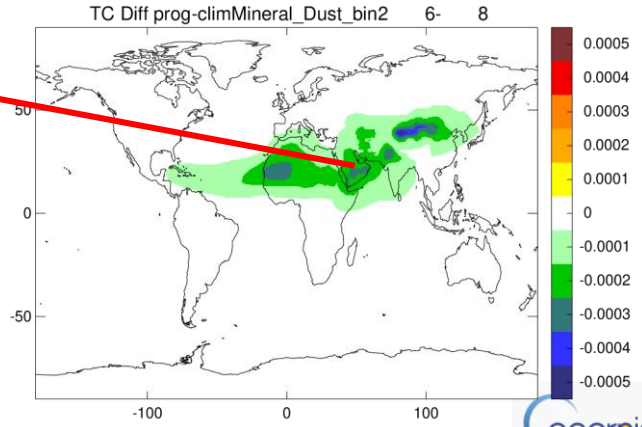
What is the spatial correspondence between 2m T differences and prognostics aerosol anomalies and biases w.r.t climatology?

Aerosol anomalies vs 2m T annomalies

Atmosphere Monitoring







OM->
BB anomaly
-> T decrease

DD2->
DD bias
-> T increase

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Are the 2m T forecast using prognostic aerosol (PROG) better than the forecast using the aerosol climatology (CLIM) ?

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Verification approaches

- Use a 2m T gridded analysis (iver)
  - Use own analysis, i.e. CAMS o-suite analysis, which used prognostic aerosol
    - Both PROG and CLIM have been initialised with CAMS o-suite analysis
  - Use ER5 2m T analysis (aerosol climatology has been used)
    - Uses climatological aerosol
    - Different cycle & resolution than PROG and CLIM
- Use synop observation of 2M T (quaver)
- Metrics:
  - Maps of the spatial distribution of error measures (iver, quaver)
  - Time series of daily error measures for specific regions (quaver)

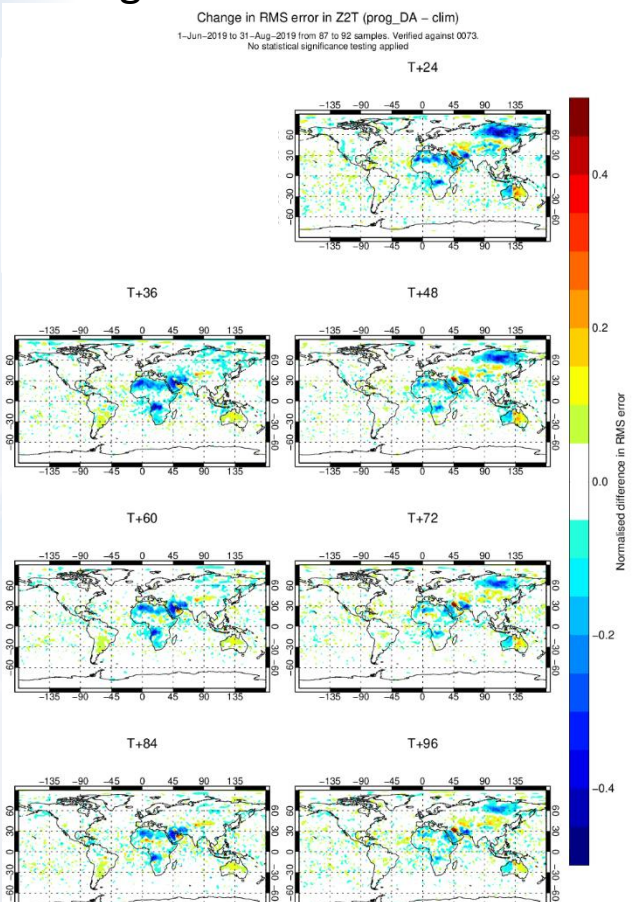
Difference in RMSE (iver)

Atmosphere Monitoring

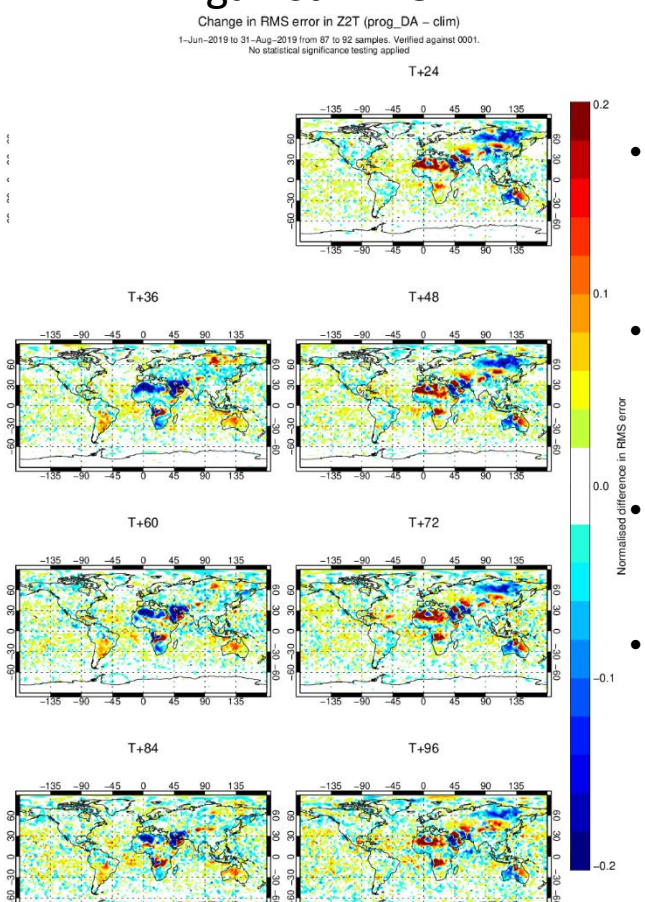
Blue: PROG has lower RMSE

red: PROG has higher RMSE

Against own reference



Against ERA5



- No gradual increase of differences with lead time
- T 12 (own analysis) response over ocean not clear
- Day and night differences (0 UTC vs 12 UTC)
- OM feature in Siberia robust improvement (?)

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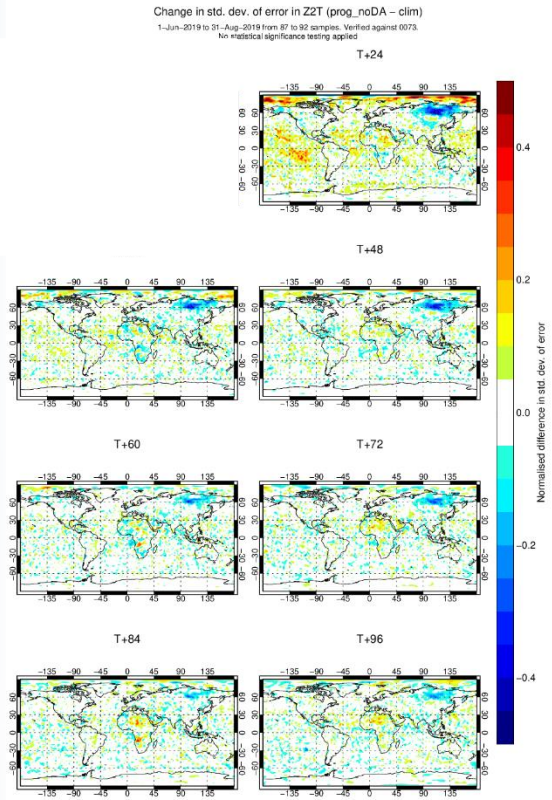
Atmosphere Monitoring

Difference in STD (iver)

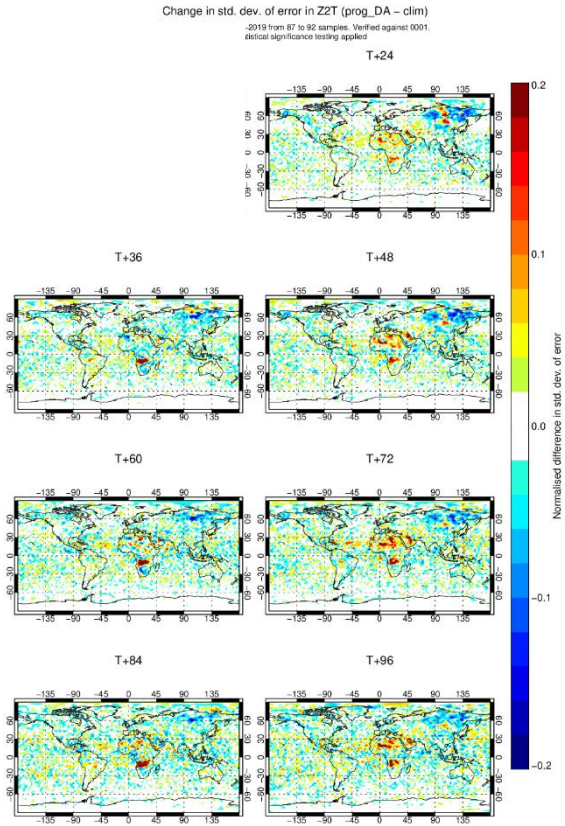
Blue:
PROG has lower STD

red:
PROG has higher STD

Against own reference



Against ERA5



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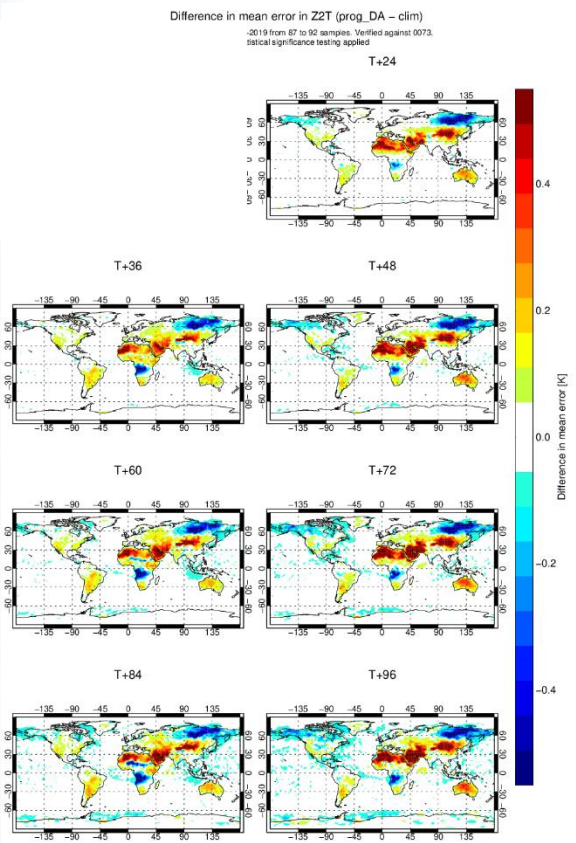
Difference in Mean (iver)

Atmosphere Monitoring

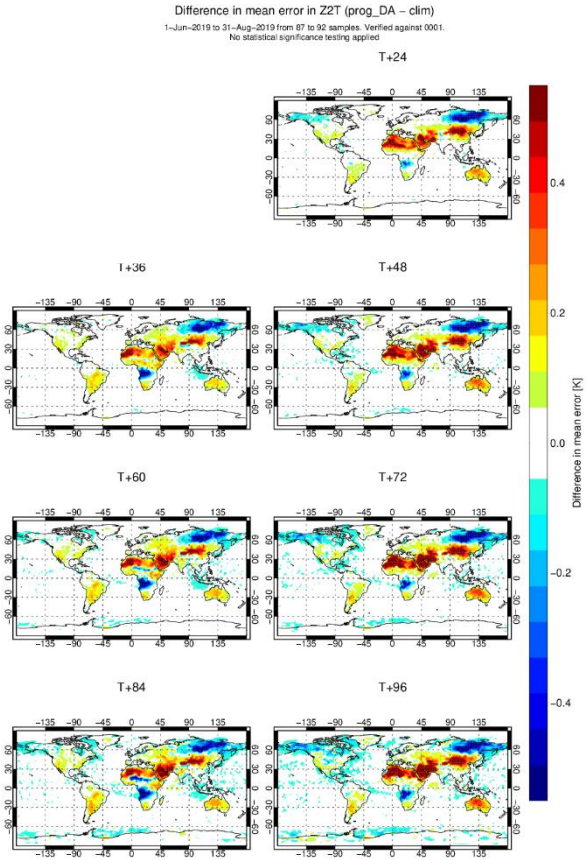
Blue:
PROG has lower Mean

red:
PROG has higher Mean

Against own reference



Against ERA5



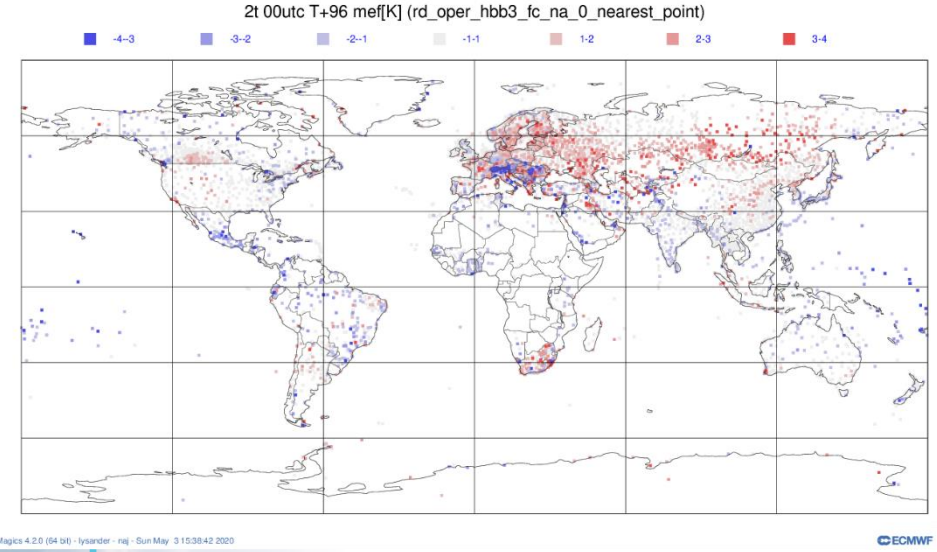
Plots are identical because the reference is “cancelled out”

European Commission

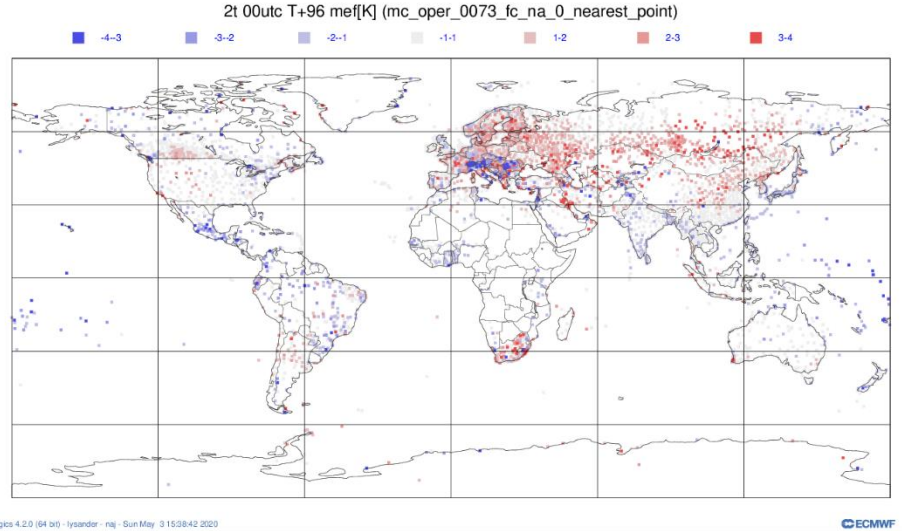
2M T Bias (JJA 2019) against synop (quaver)

Atmosphere Monitoring

CLIM (base line) 96 h



PROG (base line) 96 h



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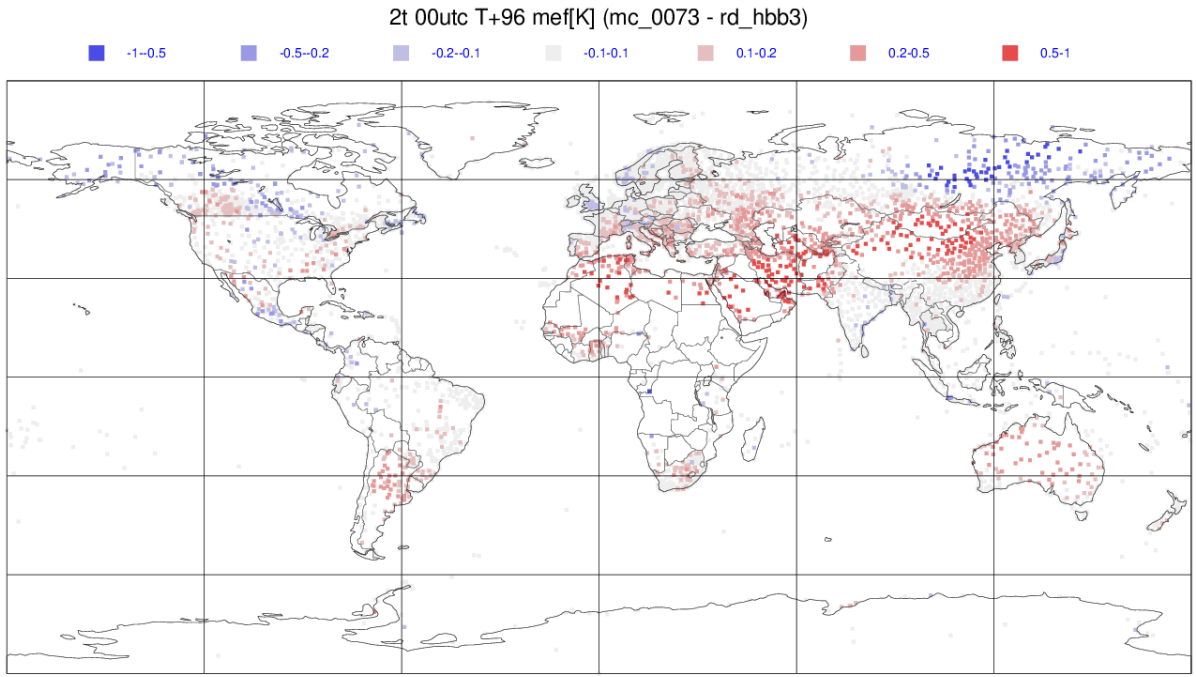
Difference in 2M T Bias (JJA 2019) (PROG-CLIM)

Atmosphere Monitoring

Blue:
PROG has lower Mean

red:
PROG has higher Mean



Magics 4.2.0 (64 bit) - lysander - naj - Sun May 3 15:38:42 2020

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European Commission

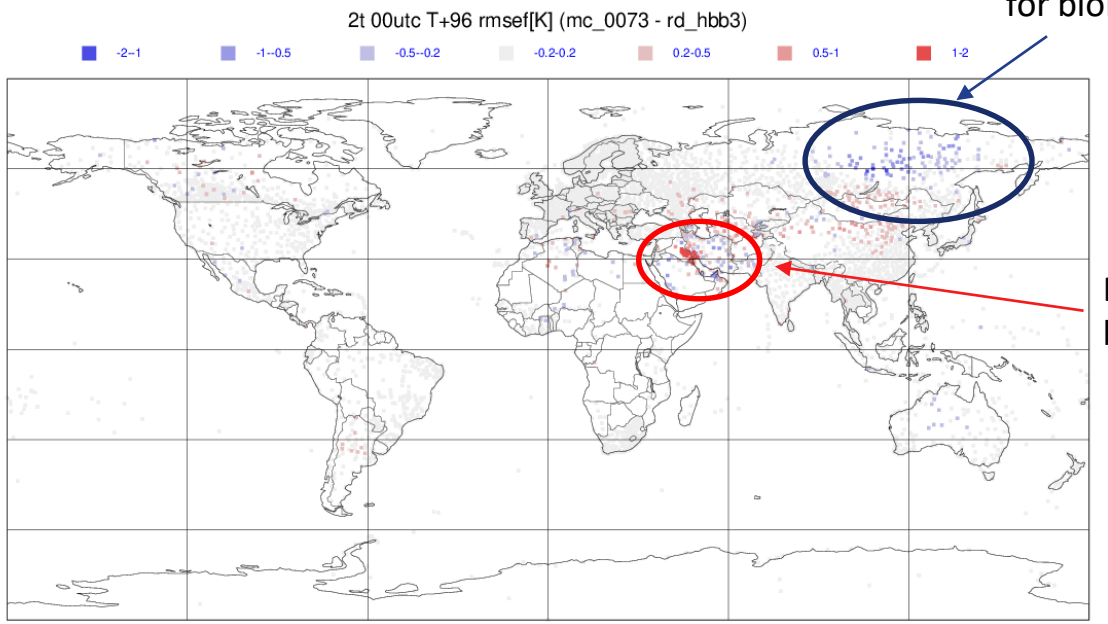
Difference in 2M T RMSE (JJA 2019) (PROG-CLIM)

Atmosphere Monitoring

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

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opernicus
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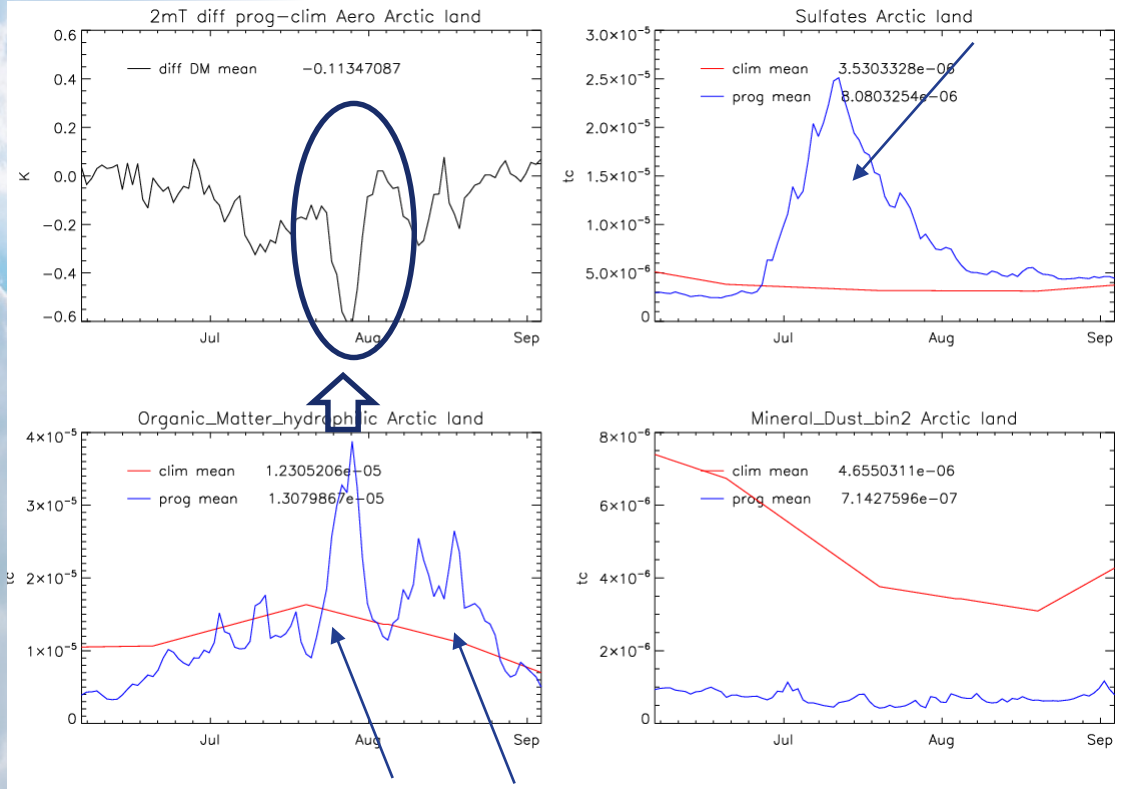
European Commission

Time series Artic Forecast Day 5 JJA 2019

Atmosphere Monitoring

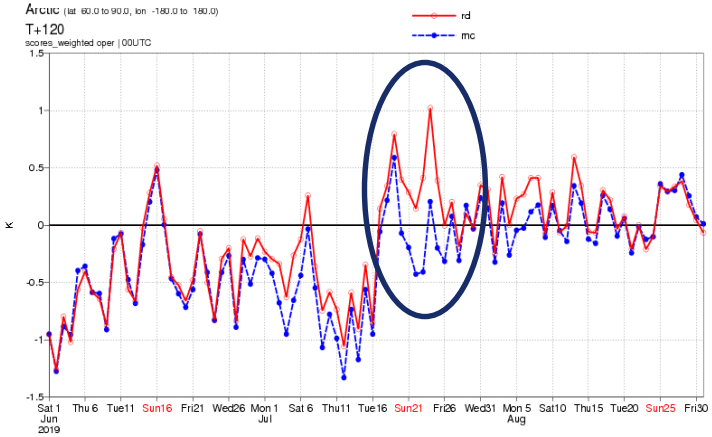
Raikoke



Bio mass burning Siberia

Clim DD Bias

Bias against synop observations



CLIM

PROG

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Summary

- We 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 an improvement w.r.t synop observations and 2mT analysis
- The warming in the dust regions was mainly a degradation (but it was not caused by the prognostic aspect)
- Consistency in the mean states of the prognostic aerosol and the aerosol climatology will be required to better identify the benefits of prognostic aerosol in NWP