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

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All ECMWF, 2 KNMI, 3 Hygeos, 4 Eumetsat
Development of atmospheric composition in the ECMWF model (IFS)

2000 - 2020

- GEMS
  - Stratospheric O₃

- MACC
  - Coupled chemistry

- CAMS
  - Integrated chemistry

Aerosol & GHG

- Upgrades of CO₂, CH₄ & O₃ climatologies
- Upgrade of aerosol climatology
- Prognostic interactive aerosols & O₃ in the CAMS configuration

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
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.
**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

**Day 1**

**Daily Maximum**

**Day 5**

**Daily Minimum**
Day 5
Largest daily T increase

Day 5
Largest daily T decrease
How large are differences between prognostic aerosols and aerosol climatology?
Mean Difference between climatological and prognostic aerosols (Total column mass) JJA 2019

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

Note:
No Nitrates and NH4 in climatology
What is the spatial correspondence between 2m T differences and prognostics aerosol anomalies and biases w.r.t climatology?
Aerosol anomalies vs 2m T anomalies

OM-> BB anomaly
-> T decrease

DD2-> DD bias
-> T increase
Are the 2m T forecast using prognostic aerosol (PROG) better than the forecast using the aerosol climatology (CLIM)?
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)**

**Against own reference**

- Blue: PROG has lower RMSE
- Red: PROG has higher RMSE

**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 (?)
**Difference in STD (iver)**

**Against own reference**

Blue: PROG has lower STD

**Against ERA5**

red: PROG has higher STD
**Difference in Mean (i.e.,)\**

Against own reference

Blue: PROG has lower Mean

red: PROG has higher Mean

Plots are identical because the reference is “cancelled out”
CLIM (base line) 96 h

PROG (base line) 96 h
Blue: PROG has lower Mean

red: PROG has higher Mean
Blue: PROG has lower RMSE

Red: PROG has higher RMSE

H 96 (00 UTC)

Imagery 4.2.0 (2019) - Issued at - Map - Sun May 3 15:30:40 2020

Improvement by accounting for biomass plumes

Degradation by systematic bias of desert dust
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 extent 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.