Improvements to the WRF-Chem model for quasi-hemispheric simulations of aerosols and ozone in the Arctic

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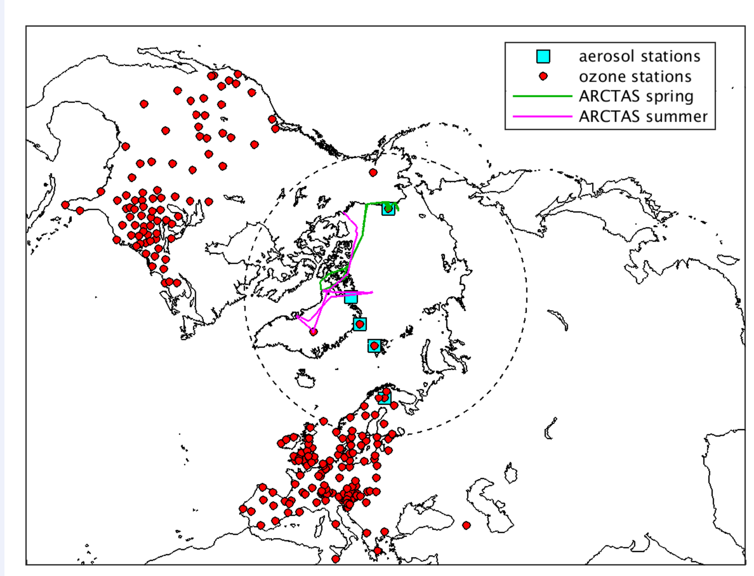
Motivations

- Improve WRF-Chem's performance compared to recent intercomparisons (AMAP, 2015) in order to study aerosols and ozone in the the Arctic (long-range transport, local sources).
- We identify missing processes in WRF-Chem 3.5.1, update the model, and evaluate the corrected model in the Arctic.

WRF-Chem model setup

WRF-Chem 3.5.1 simulations, 1 March 2008 to 1 August 2008

- MOSAIC aerosols (cloud chemistry and SOA), SAPRC-99 gas-phase chemistry
- Morrison 2-moment microphysics
- KF-CuP cumulus parameterization
- Noah Land Surface Model
- MOZART boundary and initial conditions
- Nudging to NCEP FNL



Domain (100 x 100 km resolution) and location of the measurements

Description of the model updates

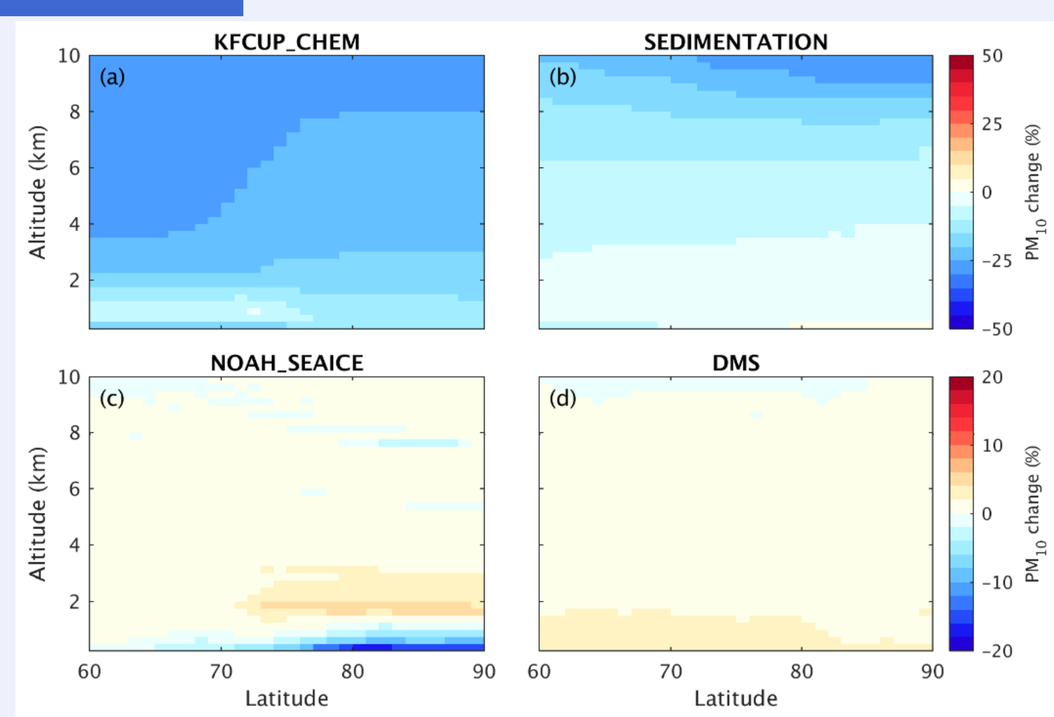
Update name	Description
SEDIMENTATION	Aerosol sedimentation above the first model level.
DMS	Dimethylsulfide (DMS) oceanic emissions (Nightingale et al., 2000) and simple gas-phase chemistry (Chin et al., 1996).
SNOWDEP	Force reduced « wintertime » dry deposition of trace gases over seasonal snow.
SNOWPHOT	UV-albedo dependence on snow and ice cover for photolysis calculations.
NOAH_SEAICE	Correct skin temperatures over melting ice in the Noah Land Surface Model.
KFCUP_CHEM	Include the recent KF-CuP cumulus parameterization (Berg et al., 2015) including the effect of cumulus clouds on aerosols and trace gases (removal, transport, cloud chemistry)

- Updates are evaluated by turning off indivual updates one by one.
- We also perform **NO_UPDATES** and **ALL_UPDATES** simulations.

Results - aerosols in the Arctic

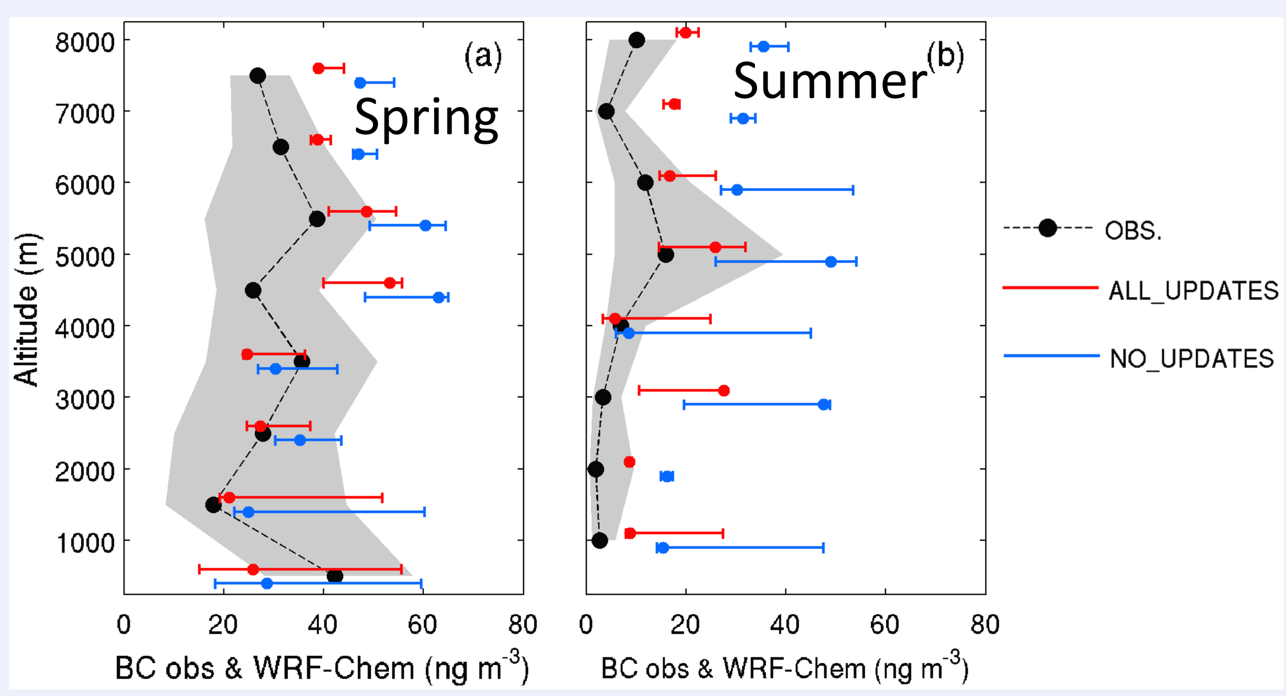
Effect of the updates on zonal mean PM_{10} in the Arctic (60°N – 90°N, April-July average)

- KFUP_CHEM decreases are mostly due to increased wet removal by cumuli
- NOAH_SEAICE reduces sea ice skin temperatures, increasing stability over sea ice, reducing vertical mixing.



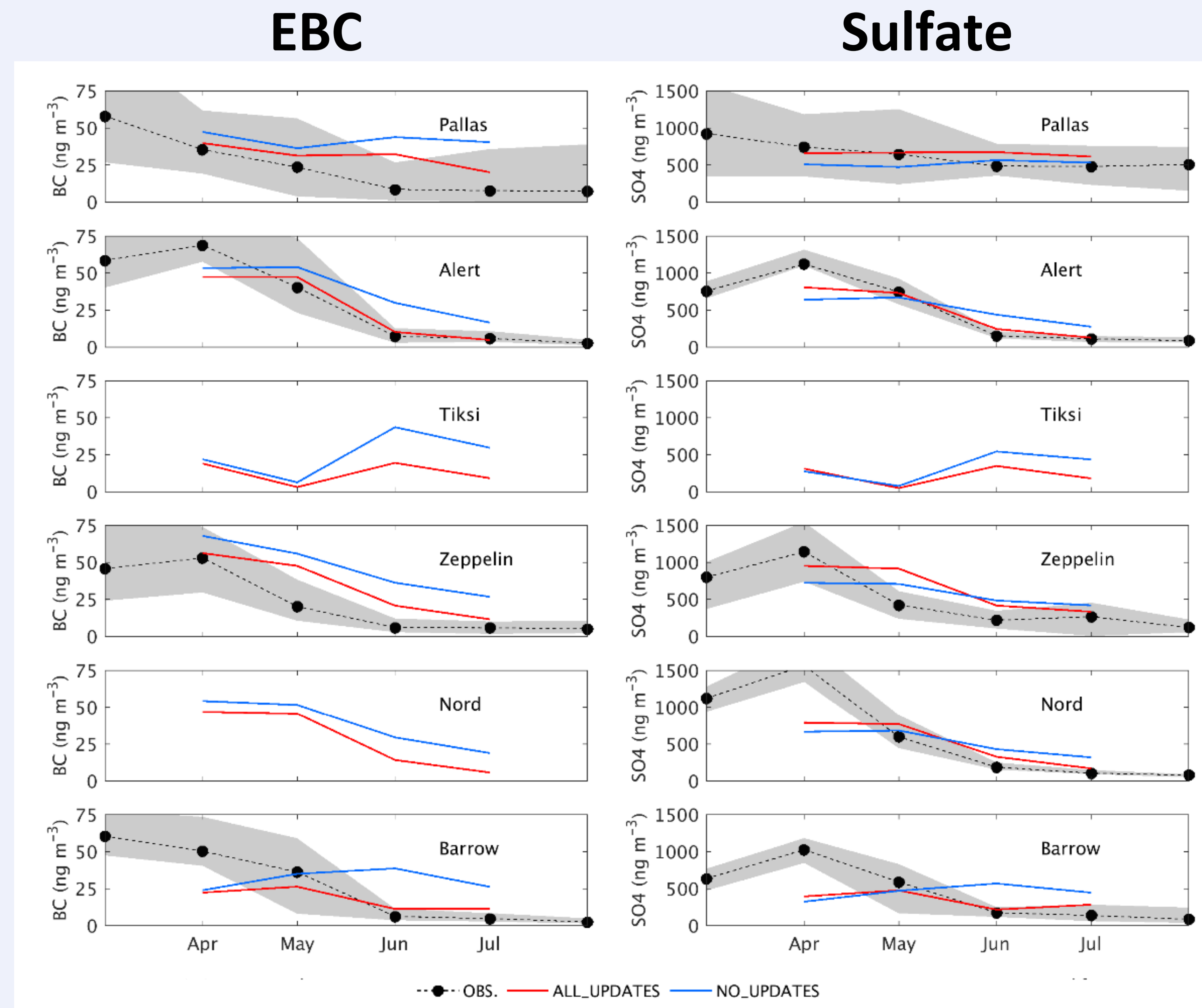
Evaluation against mean rBC profiles from the ARCTAS campaigns (2008)

- BC RMSE reduced by 28 % (spring) and 50 % (summer), due to KFCUP_CHEM.



Evaluation against surface measurements in the Arctic

EBC Sulfate

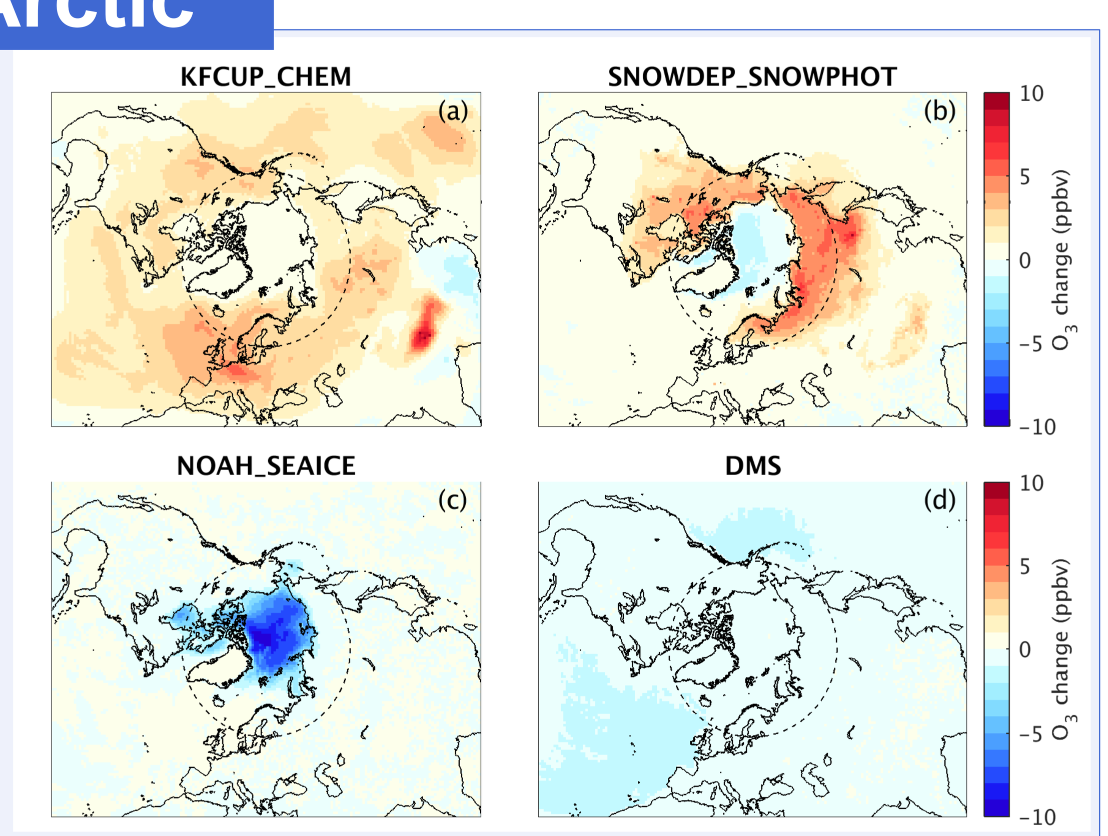


- BC RMSE reduced by 38 %, sulfate RMSE by 21 %.
- KFCUP_CHEM and NOAH_SEAICE have the largest impact
- DMS improves RMSE at all stations except Zeppelin

Results - ozone in the Arctic

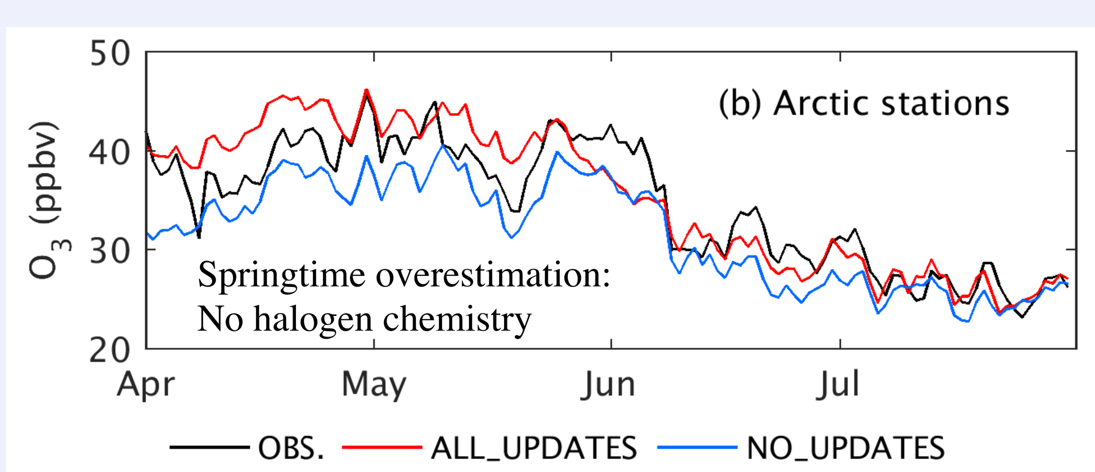
Effect of the updates on surface O_3 (April-July average)

- KFCUP_CHEM: increased vertical mixing of O_3 and precursors, higher surface O_3
- NOAH_SEAICE: reduced vertical mixing, lower surface O_3
- SNOWDEP & SNOWPHOT: reduced dry deposition and increased photolyis rates, higher O_3.



Evaluation for surface O_3 in the Arctic (17 stations, lat > 60°N)

- RMSE reduced by 15 % (mostly due to SNOWDEP, SNOWPHOT and KFCUP_CHEM).



Main conclusions

- Model updates **reduce RMSE significantly** (-10 % to -50 %) for all datasets. Large improvements for **BC**, especially during summer.
  - NOAH_SEAICE (improving **skin temperatures over ice** and stability) and KFCUP_CHEM (Including **cumulus cloud interactions with aerosols and gases**) have the largest effect on aerosols.
  - Improved **deposition and photolysis over snow** (SNOWDEP & SNOWPHOT) have a large effect on ozone.
- Halogen chemistry and detailed DMS gas-phase chemistry, as wells as higher resolutions are needed to improve results further.

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