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

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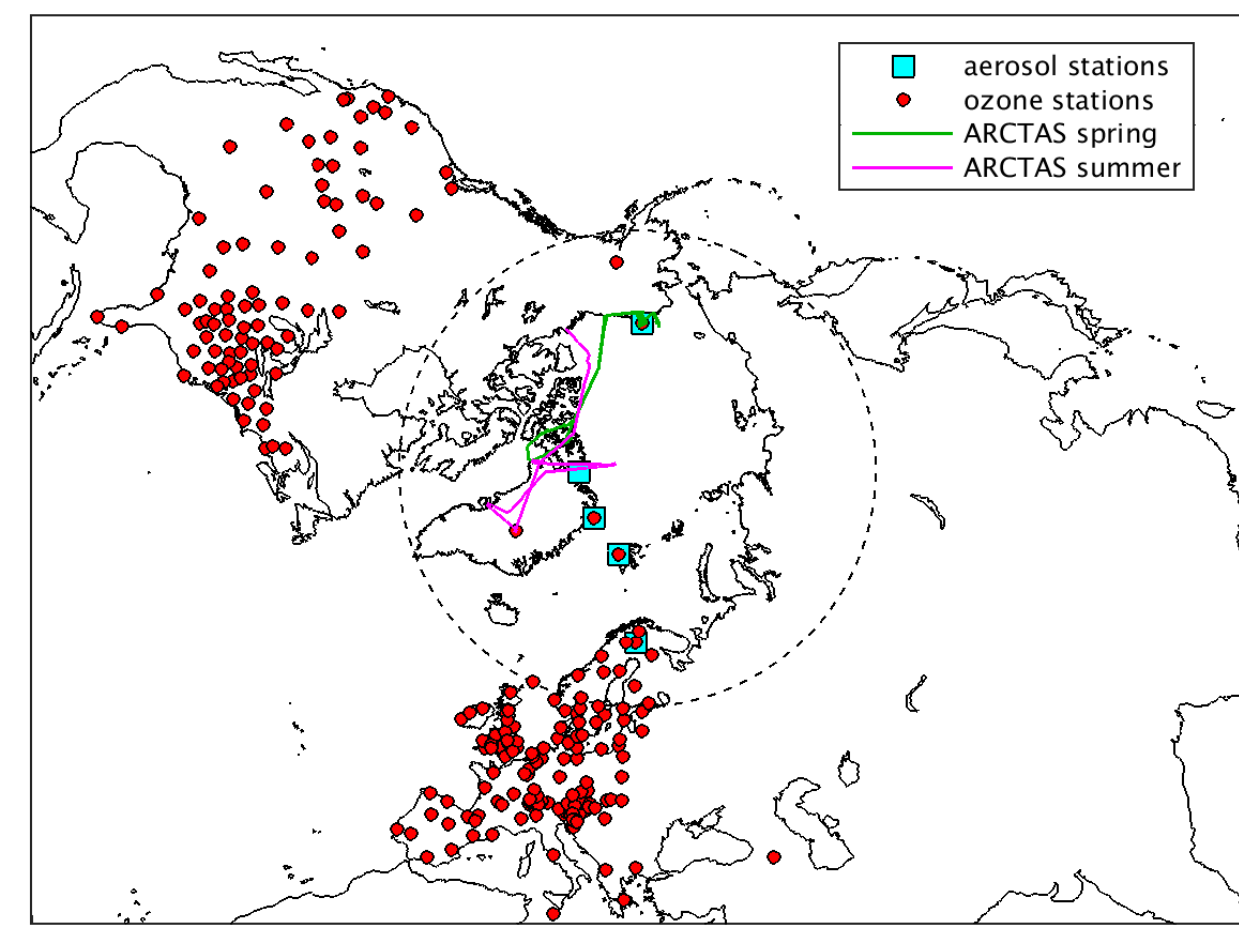
## Motivations

- 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

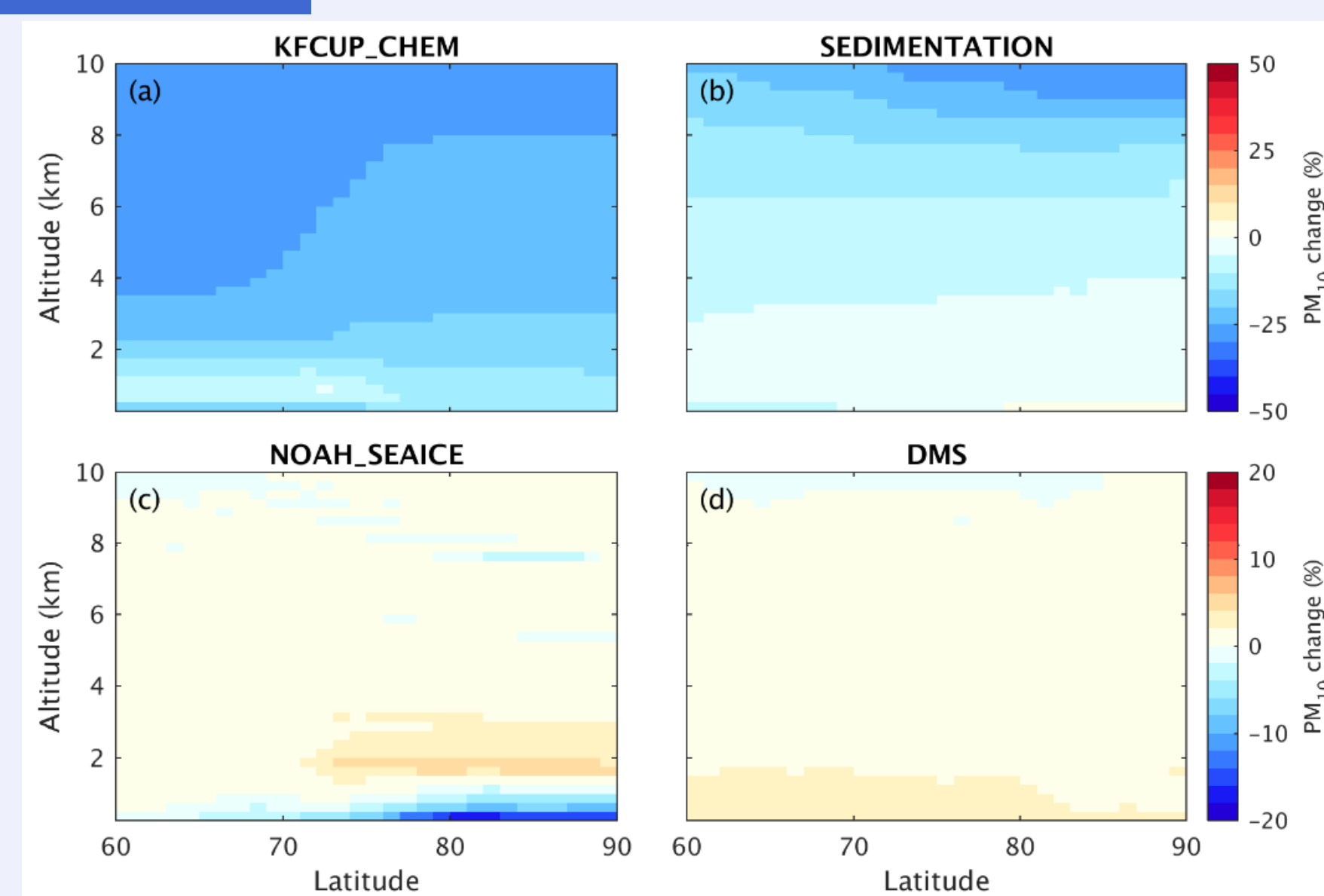
Update name	Description
<b>SEDIMENTATION</b>	Aerosol sedimentation above the first model level.
<b>DMS</b>	Dimethylsulfide (DMS) oceanic emissions (Nightingale et al., 2000) and simple gas-phase chemistry (Chin et al., 1996).
<b>SNOWDEP</b>	Force reduced « wintertime » dry deposition of trace gases over seasonal snow.
<b>SNOWPHOT</b>	UV-albedo dependence on snow and ice cover for photolysis calculations.
<b>NOAH_SEAICE</b>	Correct skin temperatures over melting ice in the Noah Land Surface Model.
<b>KFCUP_CHEM</b>	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 individual updates one by one.
- We also perform **NO\_UPDATES** and **ALL\_UPDATES** simulations.

## Results - aerosols in the Arctic

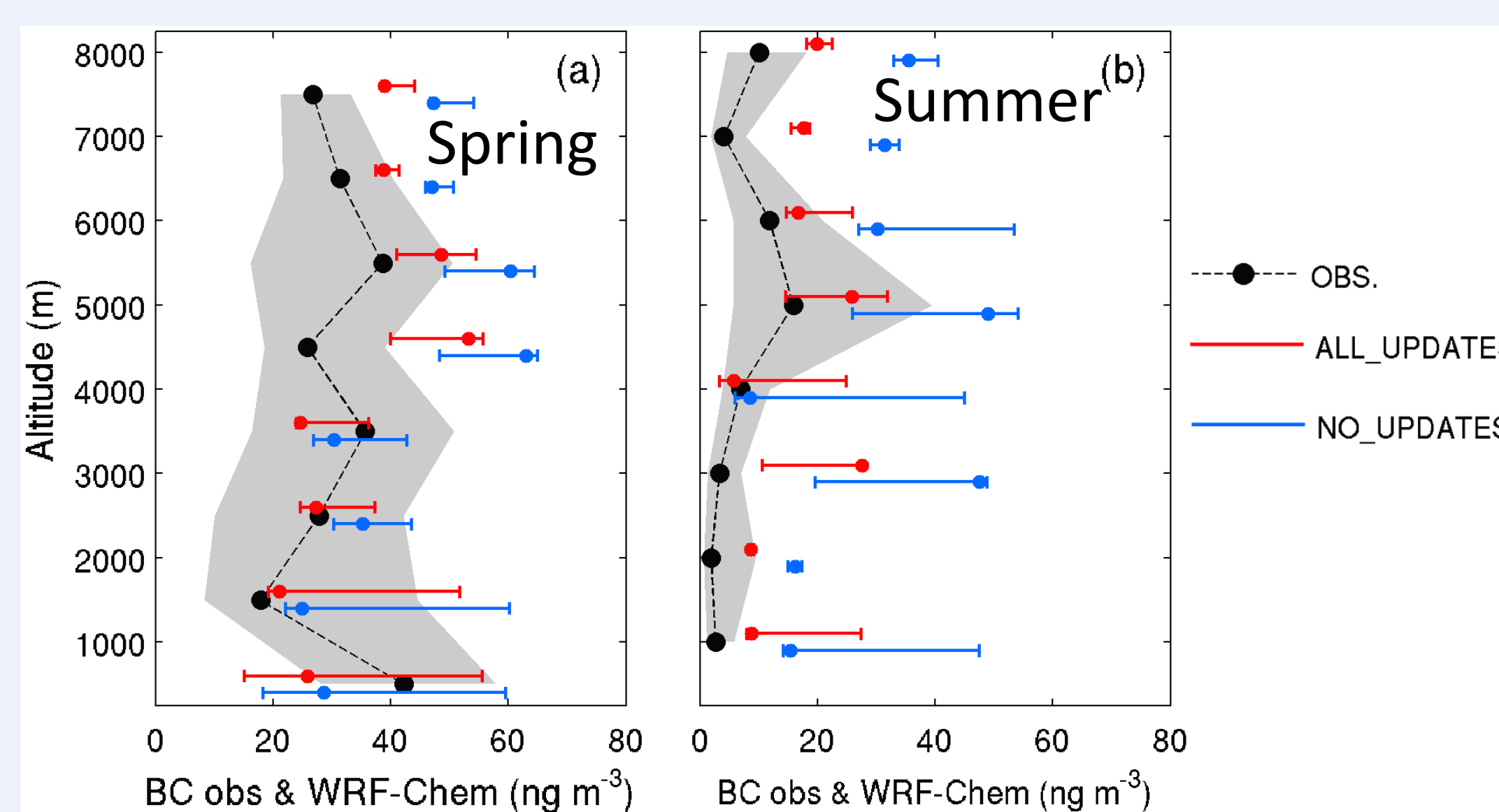
### Effect of the updates on zonal mean $PM_{10}$ in the Arctic (60°N – 90°N, April-July average)

- 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.

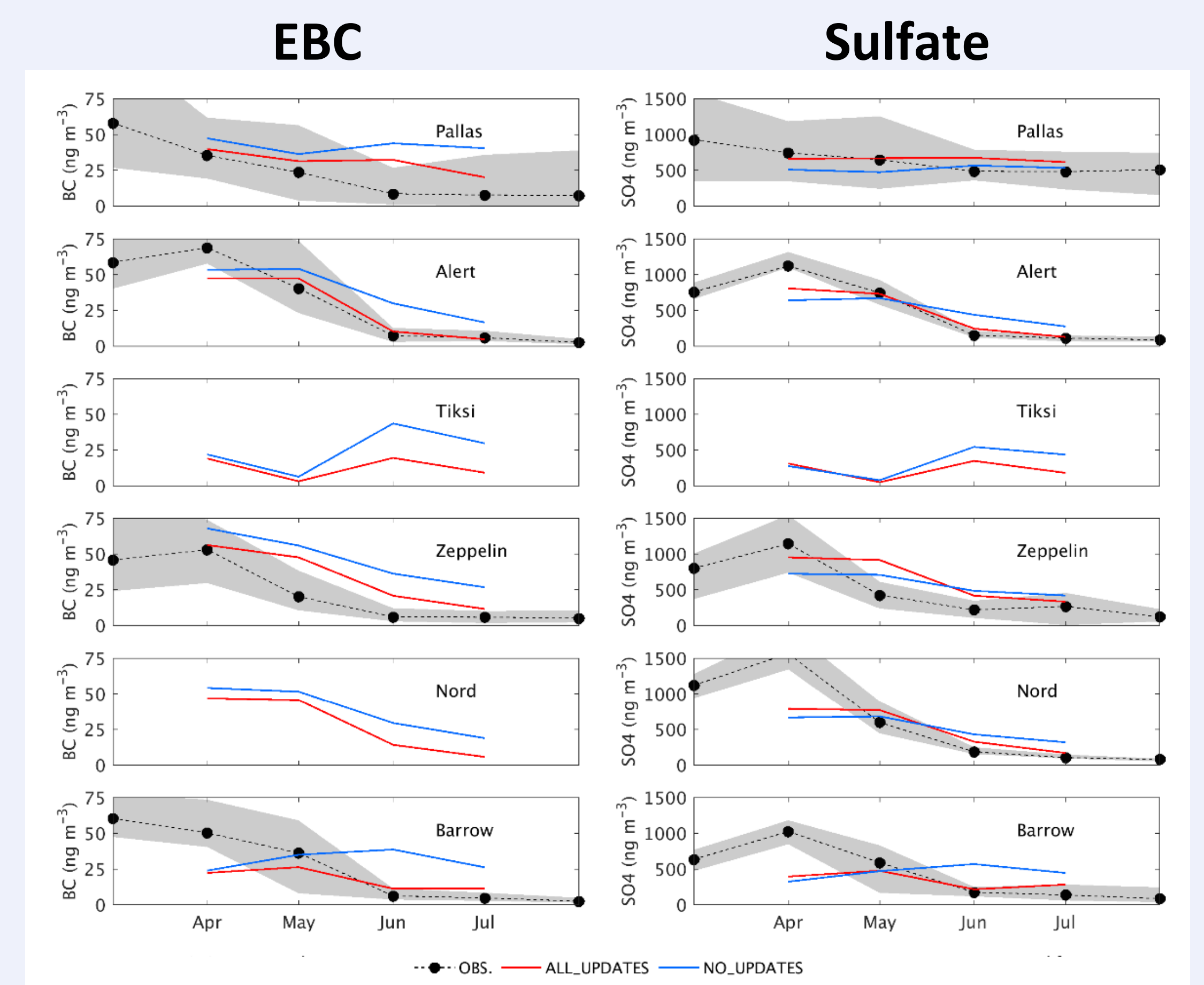


### Evaluation against mean rBC profiles from the ARCTAS campaigns (2008)

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



### Evaluation against surface measurements in the Arctic

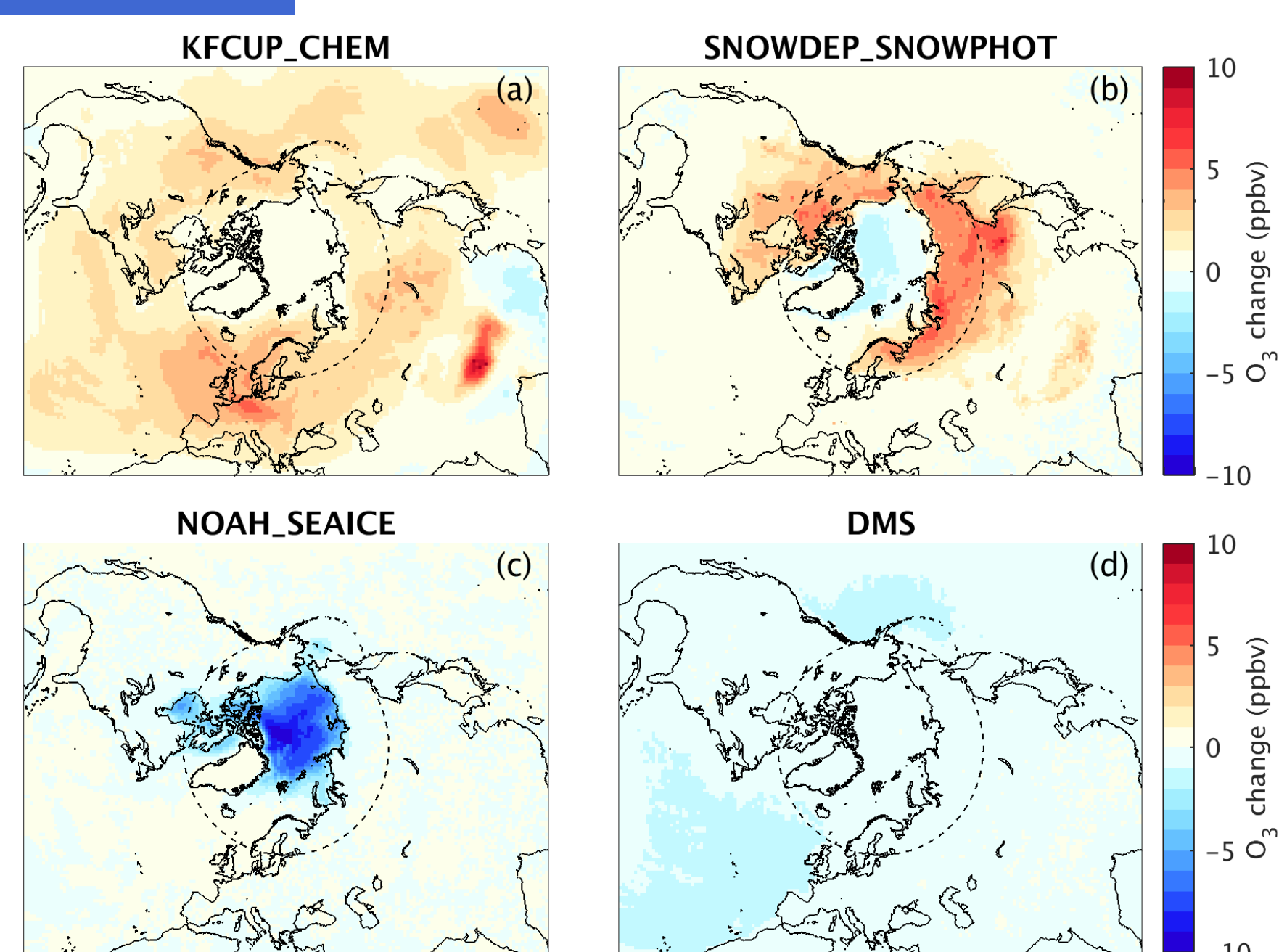


- BC RMSE reduced by 38 %, sulfate RMSE by 21 %.
- KFCUP\_CHEM and NOAH\_SEAICE have the largest impact
- DMS improves RMSE at all stations except Zeppelin

## Results - ozone in the Arctic

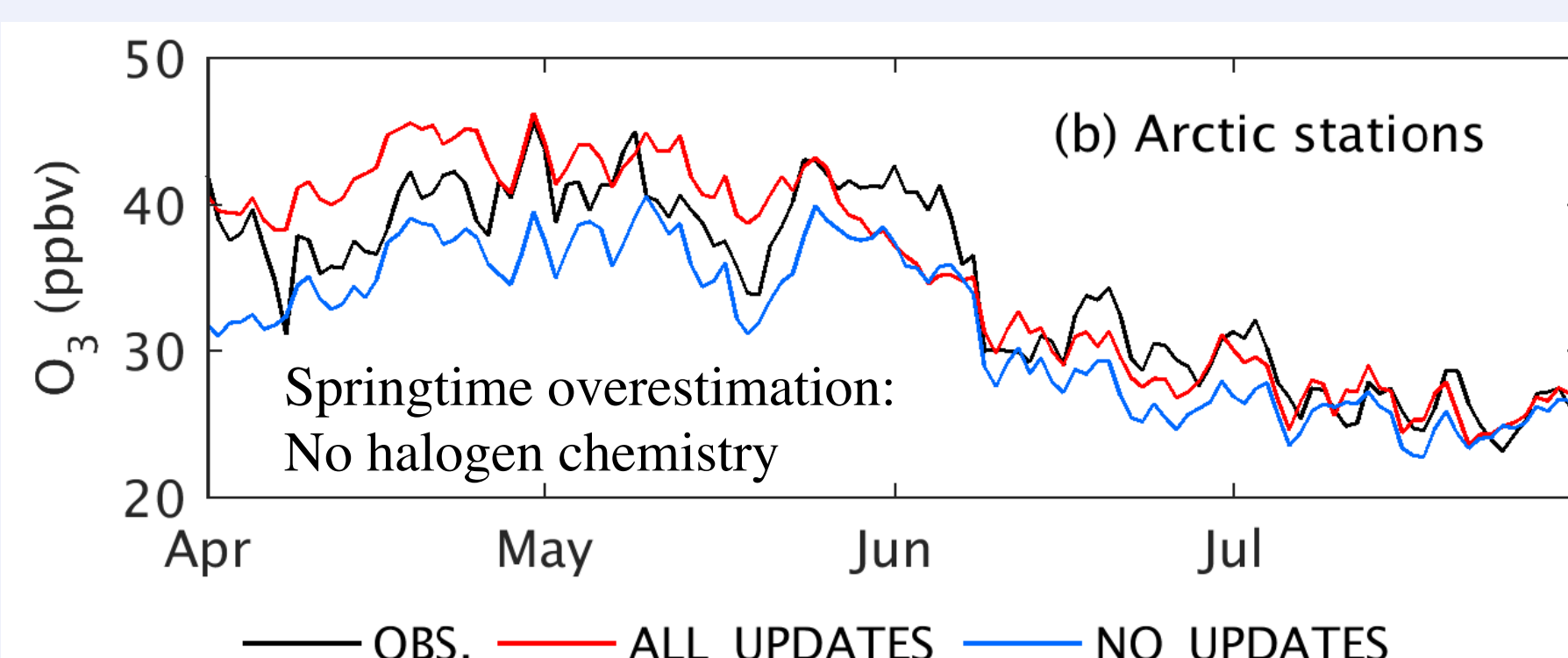
### Effect of the updates on surface $O_3$ (April-July average)

- 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 photolysis 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 well as higher resolutions are needed to improve results further.

### References:

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