GC35K-0805: Developing Multi-scale Modeling Over Australia for the 2019/2020 Extreme Wildfire Season

R. R. Buchholz[1], W. Tang[1], L. K. Emmons[1], S. Tilmes[1], P. Callaghan[1], H. Worden[1], D. Jo[1]

[1]Atmospheric Chemistry Observations & Modeling Laboratory, National Center for Atmospheric Research, USA

Motivation

The unprecedented 2019/2020 Australian fire season resulted in devastating consequences for lives and property. In addition to the direct impact of fires, fire pollution can be detrimental to human health, and affect not only those close to the fire, but also at great distances. In 2019/2020 there were large local Australian fire emissions (Fig. 3), with wide-scale impacts across the southeast of the continent, where smoke and haze hung around for many days. Hemispheric transport of fire pollution at low and lofted altitudes also occurred, creating atmospheric signatures over New Zealand and South America (Fig. 2).

MUSICA framework

The NCAR Community Earth System Model version 2 (CESM2, [1]) has a new capability of regional refinement, including the development of modeling atmospheric chemistry across scales with the **Multi-Scale Infrastructure for Chemistry and Aerosols** (MUSICA, [2, 3]). MUSICA is the next generation of global atmospheric chemistry models that enables variable spatial resolution within one model simulation. This development allows for simulation at emission and exposure relevant scales at the same time as hemispheric and global-scales. High resolution regions can be fully customized by the user. MUSICA is built with the Community Atmosphere Model using a spectral element dynamical core, with elements on a cube-face sphere [4], and is known as an unstructured grid.

Australian Regional refined grid (Fig. 1):

- ∼14km over the Australian continent
- ∼1 degree global resolution
- Tapering boundary of increasing grid sizes between 14 km and 1 degree

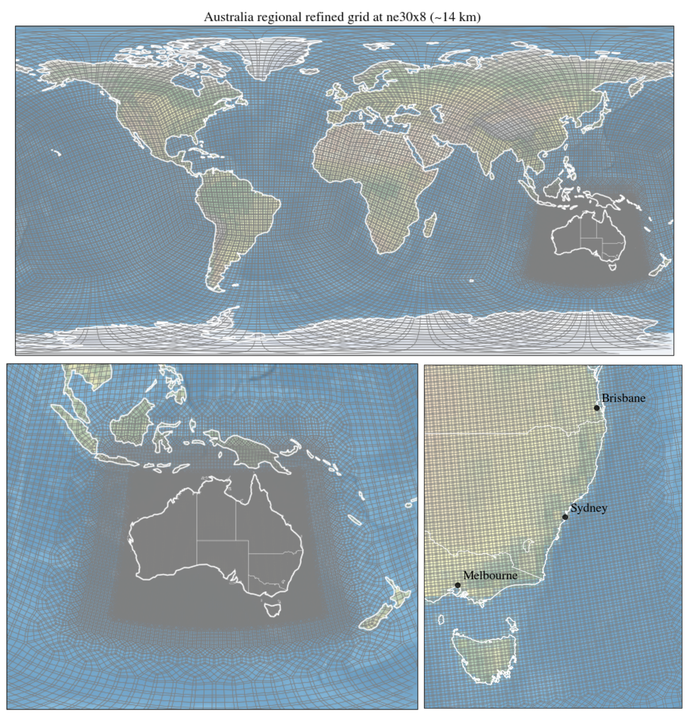

Figure 1 : Visualization of the variable grid edges for MUSICA, regionally refined over Australia.

The anomalous Australian fire season in 2019/2020

Carbon monoxide (CO) is emitted from fires in large amounts and is useful for tracking pollution transport [5]. MOPITT CO measurements, taken from space [6], show how anomalous the 2019/2020 fire season was compared to the 2002-2019 average (Fig. 2). During December 2019 to January 2020, 40% more than the normal average CO was observed over many parts of Eastern Australia, as well as in regions down wind over the Pacific Ocean and South America.

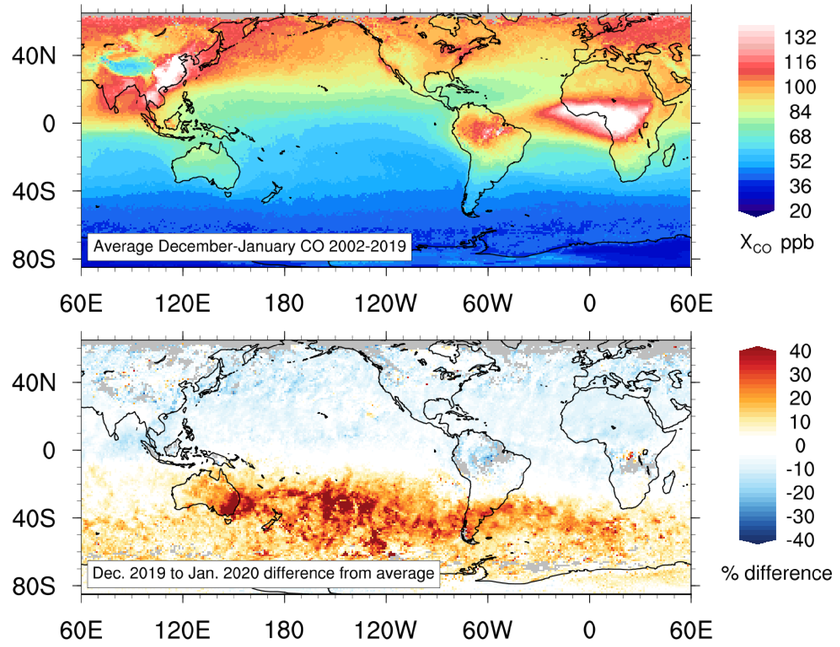

Figure 2 : Satellite-measured CO from the Terra/MOPITT [6] instrument. The top image shows the 2002–2019 mean column average mixing ratio over December–January. The bottom plot shows the percent difference of December, 2019–January, 2020 compared to the 2002–2019 mean.

- The multiple-scale impacts from wildfire in the Australian region during 2019/2020 make it a valuable test of the new multi-scale modeling capabilities at NCAR.

According to the Global Fire Emissions Database (GFED, [7]), the 2019/2020 fire season in East Australia (lat: 20° to 50° S, lon: 142° to 180 ° E) produced carbon monoxide emissions substantially above the last ∼two decades (Fig. 3).

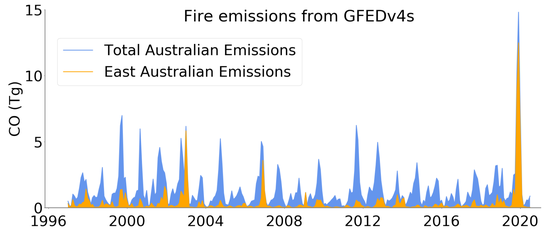

Figure 3 : Monthly average GFED cumulative fire emissions over Australia (lat: 10° to 50° S, lon: 110° to 180 ° E).

References

[1] Danabasoglu, G., et al. (2020), *J. Adv. Model. Earth Syst.*, 12, D14312, e2019MS001916

[2] The NCAR/MUSICA Web page, https://www2.acom.ucar.edu/sections/multi-scale-chemistry-modeling-musica

[3] The MUSICA Wiki, https://wiki.ucar.edu/display/MUSICA

[4] Lauritzen, P.H., et al. (2018), *J. Adv. Model. Earth Sys.*, 10, 1537–1570

[5] Edwards, D.P., et al. (2006), *J. Geophys Res-Atmos*, 111(D14), D14312

[6] Deeter, M.N., et al., (2019), *Atmos. Meas. Tech.*, 12(8), 4561–4580

[7] van der Werf, G.R., et al., (2017), *Earth Syst. Sci. Data*, 9, 697–720

[8] Darmenov, A. and da Silva, A., (2015), *NASA//TM-2015-104606*

[9] Granier, C., et al., (2019), *Copernicus Atmosphere Monitoring Service (CAMS) report*

[10] Guenther, A.B., et al., (2012), *Geosci. Model Dev.*, 5, 1471–1492

[11] Buchholz, R. R., et al., (2019), *NCAR Research data Archive*, https://doi.org/10.5065/NMP7-EP60, Accessed 7 Dec 2021

[12] Emmons, L.K., et al., (2020), *J. Adv. Model. Earth Syst.*, 12, e2019MS001882

Initial regionally refined simulations

MUSICA emissions setup: QFED fire [8]; CAMS-GLOB-ANT v5.1 anthropogenic [9]; MEGAN biogenic [10]. Comparison of instantaneous output with CAM-chem simulations [11] (Fig. 4 & 5). Both experiments use T1 chemistry [12].

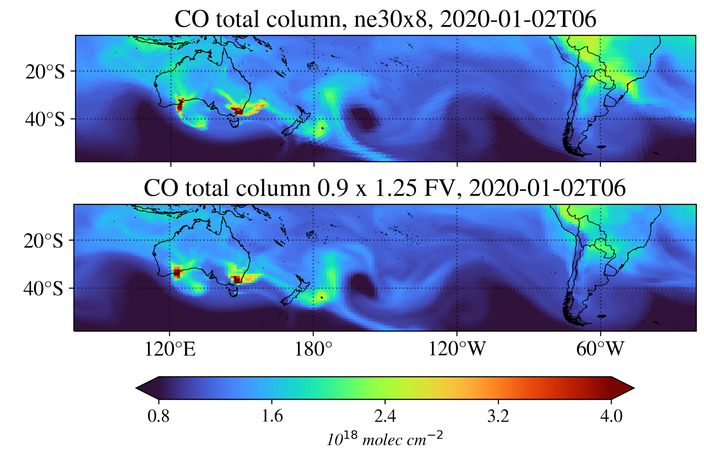

Figure 4 : Instantaneous output on January 2, 2020, 06:00 UTC from simulations using top: MUSICA with Australian regional refinement (ne30x8, ∼14 km); bottom: the finite volume (FV) 0.9°×1.25° CAM-chem [11].

- The MUSICA simulation produces higher resolution over the Australian region of interest, while maintaining transport downwind (Fig. 4).
- Transport can vary substantially between MUSICA and CAM-chem simulations, with regional refinement showing more complex regional transport patterns than CAM-chem (Fig. 5).

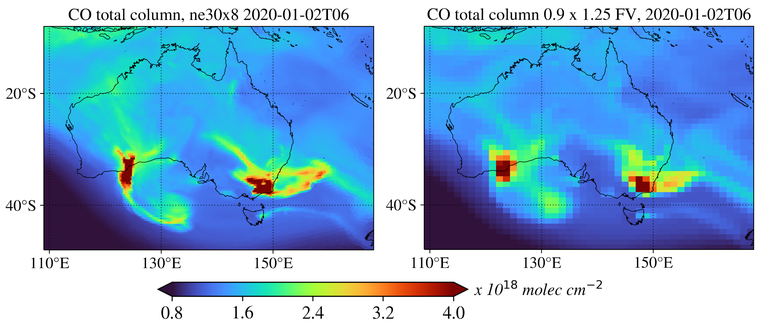

Figure 5 : Same as Fig. 4, zoomed in on Australia.

Summary and future directions

This study successfully created a numerically stable Australian regional refined MUSICA grid to study the 2019/2020 wildfire season. Future work will update emissions and investigate fire properties such as diurnal cycle and plume rise. The CESM2 framework allows interaction between model components – chemistry and climate relationships will also be investigated in future work.

Acknowledgements

• NCAR is sponsored by the National Science Foundation • HPC Cheyenne (doi:10.5065/D6RX99HX) provided by NCAR's Computational and Information Systems Laboratory • MOPITT support provided by NASA Earth Observing System (EOS) Program and the Canadian Space Agency (CSA) •

Mail: buchholz@ucar.edu