The sensitivity of high-latitude transport modeling to the choice of WRF model configuration

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Introduction

•NASA's CARVE mission is a multi-year (2012-2015 field observations), multi-platform field study that provides insight into Arctic carbon cycling

•Overarching scientific goal is to provide a baseline of GHG observations against which effects of climate change can be quantified

•NASA aircraft observes both near-surface and lower troposphere GHG concentrations between thaw-freeze (April-November)

•High-resolution modeling characterizes the transport of carbon from source to observation location

•WRF and Stochastic Time-Inverted Lagrangian Transport (STILT) models are coupled in an offline-manner and form the basis of the CARVE science analysis

•This poster presents the initial findings from a study to determine the sensitivity of transport fields to the choice of model physics

•Are differences in typical model validation summary statistics reflected in spatial features of transport fields?

WRF Model

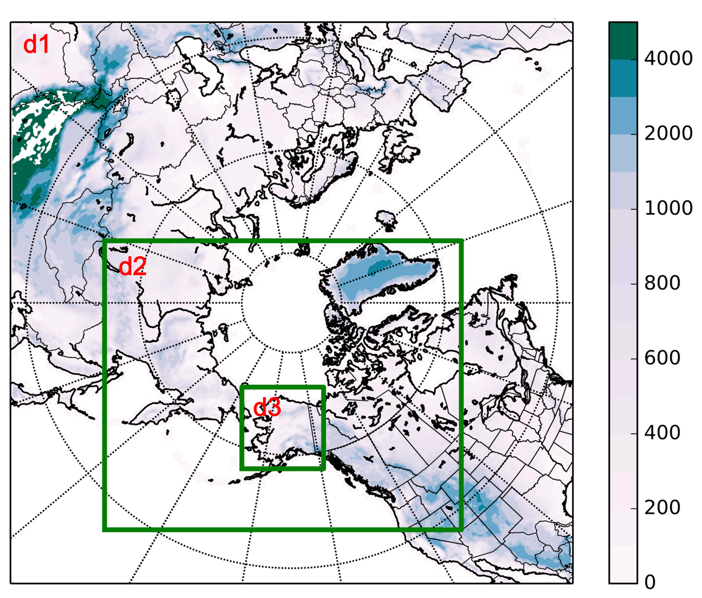

Fig. 1 – WRF v3.5.1 nest configuration for CARVE simulations. Grid spacings are 30, 10 and 3.3 km for domains 1, 2 and 3, respectively.

•Polar variant of WRF-ARW v3.5.1 with supplemental PIOMAS (University of Washington) snow/ice datasets and sea ice melt/freeze times (OSU)

•Baseline physics: MYNN 2.5 TKE PBL, Morrison 2-moment microphysics, Noah LSM, RRTMG LW/SW, 41 vertical levels, Grell-Devenyi ensemble cumulus (d1+d2)

•Triply-nested domain (Fig. 1) enables the substantial orography of Alaska to be represented by the underlying high-resolution model topography

•Daily 30-h WRF runs initialized from NASA MERRA reanalysis with first 6-h removed for model spinup

WRF Sensitivity Runs and Validation Statistics

•Sensitivity study utilized popular physics combinations, including those from the literature:
- Run WRF using the six combinations of MYNN, MYJ and GBM PBL schemes and Morrison and Thompson microphysics
- Experiment names: **mynn-morr, mynn-thom, myj-morr, myj-thom, gbm-morr** and **gbm-thom**
- Periods of interest in 2015 between thaw-freeze: 1-15 May, 23 May-6 June and 1-15 October

•Results:
- Sensitivity to PBL scheme is larger than sensitivity to microphysics scheme (Fig. 2)
- CARVE baseline PBL selection (MYNN and Morrison) exhibited largest negative temperature and largest negative wind speed biases
- Smallest bias overall seen in GBM PBL
- Bias smallest for temperature and dewpoint temperature overnight (LT=UTC-8h) across all physics combinations; time of smallest wind speed bias varies

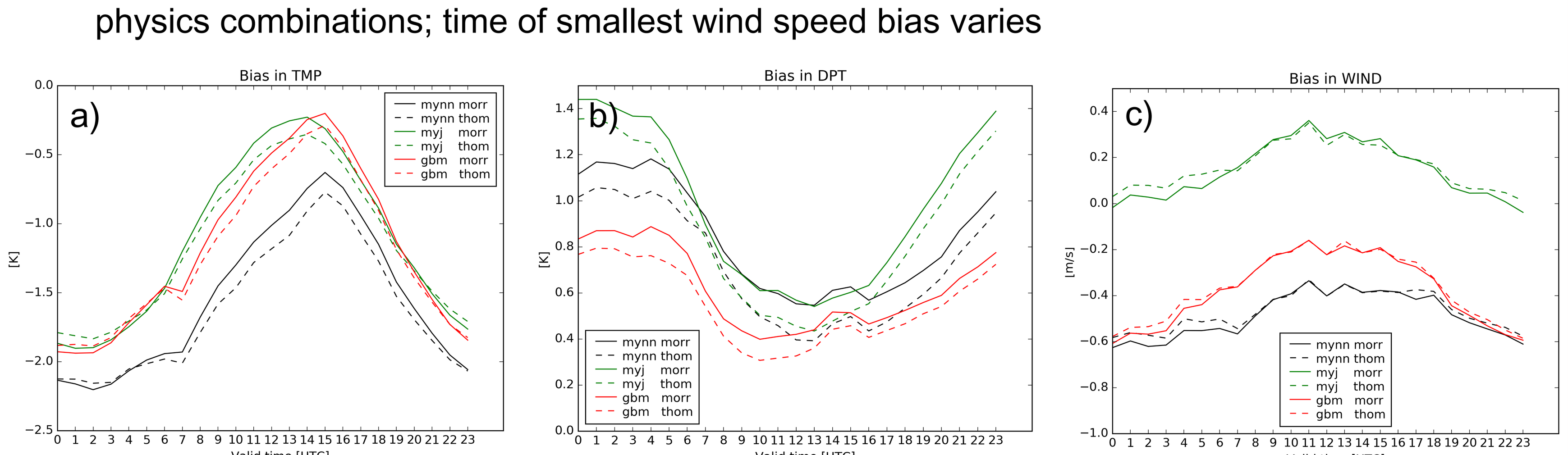

Fig. 2 – Bias by hour of day (UTC) at sites in d3 during 1-15 May, 23 May-6 June and 1-15 October 2015 for a) temperature (K), b) dewpoint temperature (K) and c) wind speed (m s^{-1})

STILT Transport Model

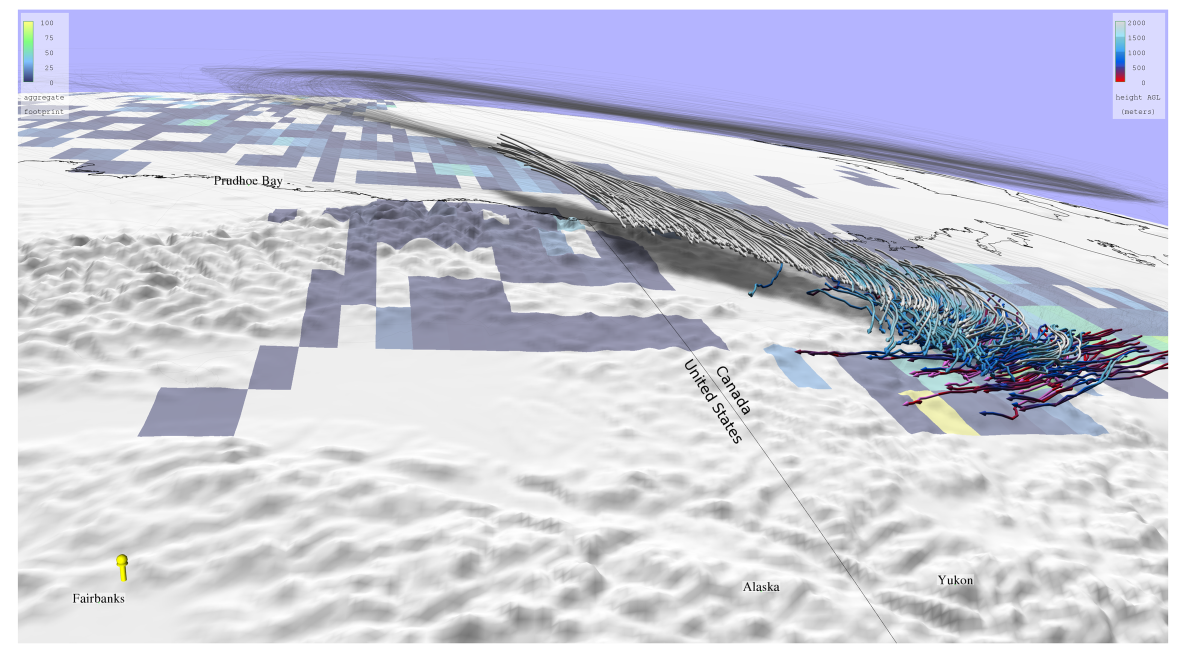

Fig. 3 – STILT particle motion over 4-h period (colored vectors) toward receptor (yellow peg) located 301 m AGL in Fox, AK (near Fairbanks) at 2208 UTC 25 August 2013 and aggregate footprint (shaded boxes) with contributions from particles in lower part of the PBL (pink vectors)

•STILT, a Lagrangian particle dispersion model (LPDM), is well-suited to characterize atmospheric transport from *in situ* observations and can be applied to a wide range of science topics, such as satellite applications and monitoring of anthropogenic CO_2 emissions

•Customized meteorological fields (time-averaged mass fluxes and convective mass fluxes) are used from WRF and particles are advected by the mean wind and a turbulent velocity component

•Particles accumulate fluxes from the surface, when residing in the lower half of the PBL, along the back-trajectory from the observation

•STILT computes the adjoint of the transport model in the form of a "footprint" field [units of mixing ratio / (micromole m^{-2} s^{-1})] that quantifies the influence of upwind surface fluxes on measured concentrations (Fig. 3)

•When multiplied by an *a priori* flux field (units of micromole m^{-2} s^{-1}), the footprint gives the associated contribution to the mixing ratio (units of ppm) measured at the observation location (receptor)

Sensitivity of STILT Footprints to WRF Model Physics

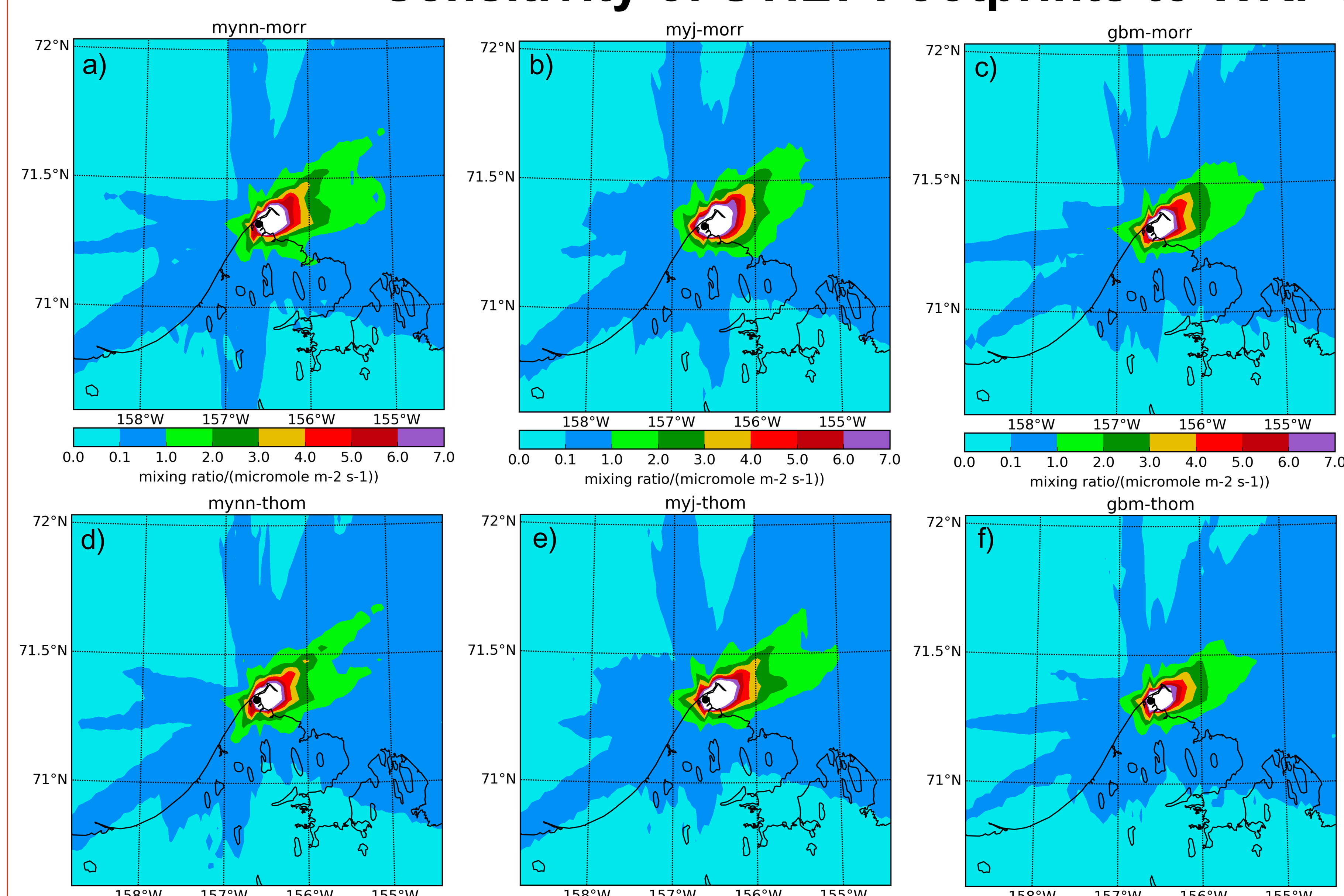

Fig. 4 – Five-day aggregates of hourly STILT footprints on 0.05-degree grid for Barrow, AK, tower receptors from 6-14 May, 28 May-5 June and 6-14 October 2015 using the wind field from WRF configured with a) mynn-morr, b) myj-morr, c) gbm-morr, d) mynn-thom, e) myj-thom and f) gbm-thom. The black circle near the center of the grid indicates the location of the Barrow tower. Receptor height is 28 m AGL.

•Run STILT using model fields from the six WRF simulations

•For each WRF simulation, five-day backward trajectories were generated using 6134 receptors from:
- Tower sites: CARVE (near Fox, AK) and Barrow
- CARVE aircraft flights: three single-day 2015 flight loops (6 June, Yukon-Kuskokwim Delta; 13 July, Yukon Flats NWR; 11 November, North Slope) replicated for each day of WRF fields

•Hourly aggregates of high-resolution footprint fields from 417 tower receptors at Barrow (Fig. 4) exhibit some variation at distances from the receptor site

•Signal is dominated by surface fluxes in close proximity to tower

•The sensitivity is higher in regions of substantial orography for individual receptors (not shown), including those at low levels from aircraft flights

Conclusions and Future Work

•Validation against standard meteorological observations of WRF fields indicates appreciable sensitivity to model physics, especially the choice of PBL scheme. Future work will attempt to identify spatial regions, time periods and synoptic flow patterns where STILT is most susceptible to differences in the meteorology.

•The current investigation will next *quantify* the variation in footprint fields due to differences in meteorology and also elicit the response to changes in the configuration of the STILT model

•A multi-year (2012-2015), self-consistent library of footprints derived from the baseline high-resolution WRF simulations, available at **ilma.jpl.nasa.gov/portal**, enables ongoing scientific investigations for the CARVE mission, including these recent papers:

-Zona, D., B. Giolic, R. Commane, J. Lindaas, S. C. Wofsy, C. E. Miller, S. J. Dinardo, S. Dengel, C. Sweeney, A. Karion, R. Y.-W. Chang, J. M. Henderson, P. C. Murphy, J. P. Goodrich, V. Moreaux, A. Liljedahl, J. D. Watts, J. S. Kimball, D. A. Lipson, and W. C. Oechel, 2016: **Cold season emissions dominate the Arctic tundra methane budget**, *Proceed. National Academy Sci.*, doi:10.1073/pnas.1516017113.

-Henderson, J. M., Eluszkiewicz, J., Mountain, M. E., Nehrkorn, T., Chang, R. Y.-W., Karion, A., Miller, J. B., Sweeney, C., Steiner, N., Wofsy, S. C., and Miller, C. E.: **Atmospheric transport simulations in support of the Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE)**, *Atmos. Chem. Phys.*, 15, 4093-4116, doi:10.5194/acp-15-4093-2015, 2015.

-Chang, R. Y.-W., Miller, C. E., Dinardo, S. J., Karion, A., Sweeney, C. S., Daube, B. C., Henderson, J. M., Mountain, M. E., Eluszkiewicz, J., Miller, J. B., Bruhwiler, L. M. P., and Wofsy, S. C., 2014: **Methane emissions from Alaska in 2012 from CARVE airborne observations**, *Proceed. National Academy Sci.*, doi:10.1073/pnas.1412953111.