LA Megacity: A Land-Atmosphere System for Urban CO_2 Emissions

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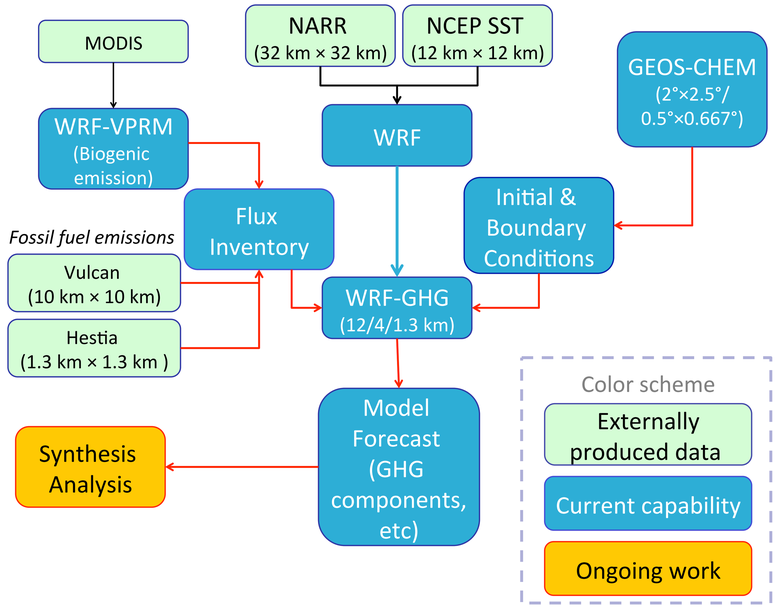
GREENHOUSE GAS MODELING FRAMEWORK

OBJECTIVES: To improve understanding of localized, high-flux elements of the carbon cycle associated with the significant spatial and temporal variability in the carbon exchange of urban landscapes and to support efforts by local stakeholders to evaluate actions intended to stabilize urban GHG emissions. Here are the scientific questions we want to answer:

- How do the fossil fuel emissions impact CO_2 simulations?
- How do the atmospheric CO_2 fields associated with the LA megacity vary spatially across the complex urban to rural gradient?



MODEL CONFIGURATION & EXPERIMENT

WRF-GHG configuration	
Option	Description
Domains	12 km (D01), 4 km (D02), 1.3 km (D03)
Vertical Setup	50 layers (29 layers below 2 km AGL)
Longwave Radiations	RRTMG
shortwave Radiations	RRTMG
Land Surface	Noah LSM
Microphysics	WSM5
Cumulus (d01 & d02)	Grell 3D

Experimental Design	
Option	Description
Urban Surface	UCM, BEP, None
PBL Scheme	MYJ, MYNN2.5, BouLac
Model Res.	4 km (d02), 1.3 km (d03)
$FFCO_2$	Vulcan (10 km x 10 km), Hestia (1.3 km x 1.3 km)

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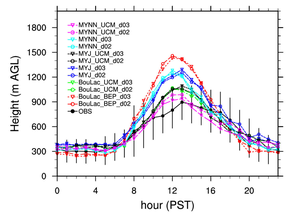
MODEL EVALUATION

- **Sensitivity of model physics and resolutions**

*Absolute difference between the aircraft-determined and modeled PBL height for each profile, P01, P02, P03, ...

- No mode physics systematically better than others
- Four configurations (highlighted) discarded

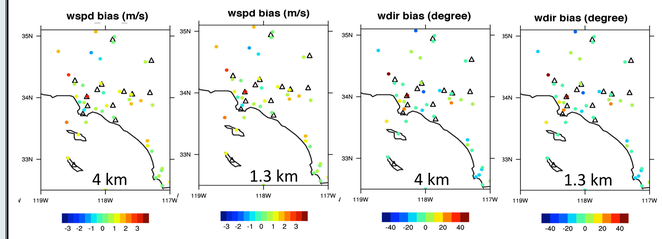
Optimal model physics for LA: MYNN_UCM



*Average diurnal variation of the ceilometer measured and modelled PBL heights at Caltech

- MYNN_UCM agrees with ceilometer the best
- BouLac_BEP differ with ceilometer the most

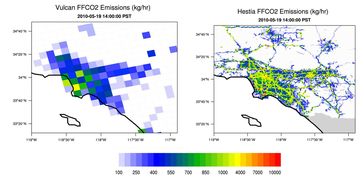
- **Model performance over complex terrain**



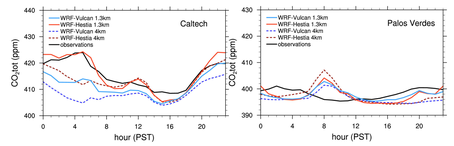
*Bias maps of WRF simulations vs. National Weather Stations. Δ – GHG observation sites.

- Horizontally, no clear difference between 4- and 1.3-km resolution simulation performances evaluated at various surface stations

- **Comparison to in-situ CO_2**



*Snapshots of the Vulcan and Hestia $FFCO_2$ emissions (unit: kg/hr) over the LA megacity at 14:00 PST on 15 May, 2010. *Vulcan quantifies national $FFCO_2$ emissions at 10 km x 10 km; Hestia-LA specifies $FFCO_2$ emission to the individual building, road segments, and point sources*



*Average diurnal variation of modeled and observed CO_2 concentration for Caltech and Palos Verdes during CalNex-LA.

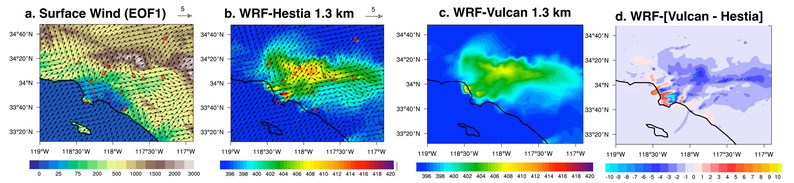
- For Caltech site, WRF-Vulcan runs considerably lower CO_2 then WRF-Hestia runs
- Smaller discrepancy between WRF-Vulcan runs and WRF-Hestia runs during daytime
- 1.3-km WRF-Hestia captures diurnal variation of surface CO_2 well
- For Palos Verdes site, no configuration matches the observations (coastal site)

CONCLUSIONS

- A high-resolution greenhouse gas modeling system was developed to understand the carbon exchange over L.A.. The optimal model physics and resolution was defined based on a combined meteorological and CO_2 concentration evaluation.
- No clear difference were shown between 4- and 1.3-km resolution simulation performances in terms of meteorology; however, large difference were shown in terms of the simulated CO_2 fields
- No uniform "urban dome" in atmospheric CO_2 due to orography, coastal circulation, and fine spatial structures $FFCO_2$ emissions
- A high-resolution emission product such as Hestia (km resolution) coupled to WRF is required in order to disaggregate CO_2 sources over LA and identify optialm locations for a high density network of towers

RESULTS

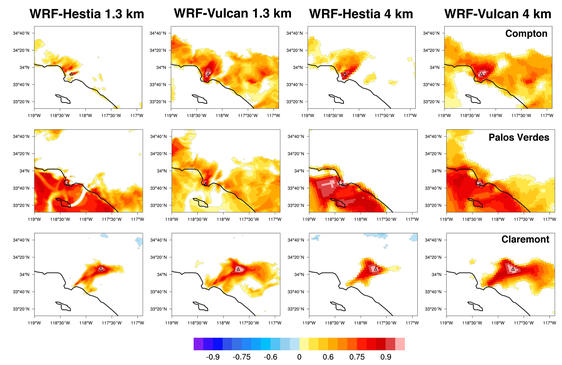
- **Spatial pattern of surface CO_2 over LA**



*(a and b) The first empirical orthogonal function (EOF 1) for the surface wind pattern simulated by MYNN_UCM_d03 at 1400 PST during CalNex-LA. EOF 1 accounts for 48.1 % of the variance in the average winds. Contours: (a) terrain height (unit: m); (b) modeled surface CO_2 concentration (unit: ppm) driven by WRF-Hestia 1.3km. The red triangles indicate the locations of the measurement sites. (c) The modeled CO_2 concentration from the 1.3-km WRF-Vulcan run (unit: ppm). (d) The difference of the modeled CO_2 concentration between the 1.3-km WRF-Hestia and WRF-Vulcan runs (unit: ppm). Δ – GHG observation sites.

- No uniform "urban dome" in atmospheric CO_2 due to orography, coastal circulation, and fine spatial structures in $FFCO_2$ emissions
- High CO_2 plumes from point sources missing in Vulcan, replaced by wide areas of elevated CO_2

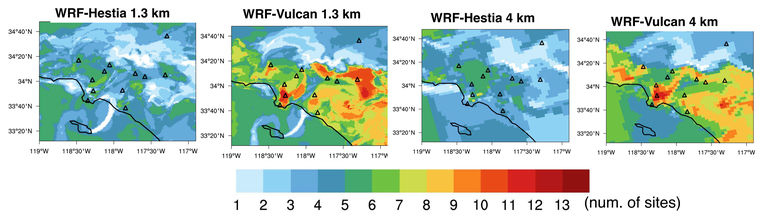
- **Sensitivity of the coverage of the measuring site to the $FFCO_2$ emission products**



*Correlation maps of three observations from different runs. The correlation map was constructed by calculating the simultaneous correlation of the site CO_2 to the CO_2 over rest of the LA megacity. Note that only those pixels that pass the t-test at the significance level of 0.01 ($|R| \geq 0.46$) are colored.
*Reference: WRF-Hestia 1.3 km

- WRF-Vulcan runs overestimate the area of correlation maps for each site due to relatively coarse resolution of the original emission product

- **Composite maps of spatial correlation upon LA GHG network**



The composite maps of spatial correlation for four runs. Specifically, white cells indicate that no sites are correlated well at the location; dark red cells indicate that all 14 sites have good correlation at the location. Δ – GHG observation sites.

- LA covered by up to six sites in WRF-Hestia runs but over 12 sites in WRF-Vulcan runs
- Using low resolution Vulcan overestimates the data density with artificially wide CO_2 structures