Re-estimating the CO emissions from the Californian fires of 2018 using S5P

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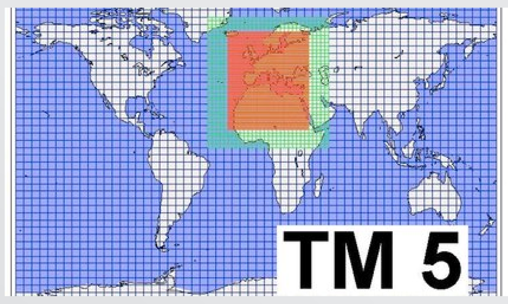
Motivation

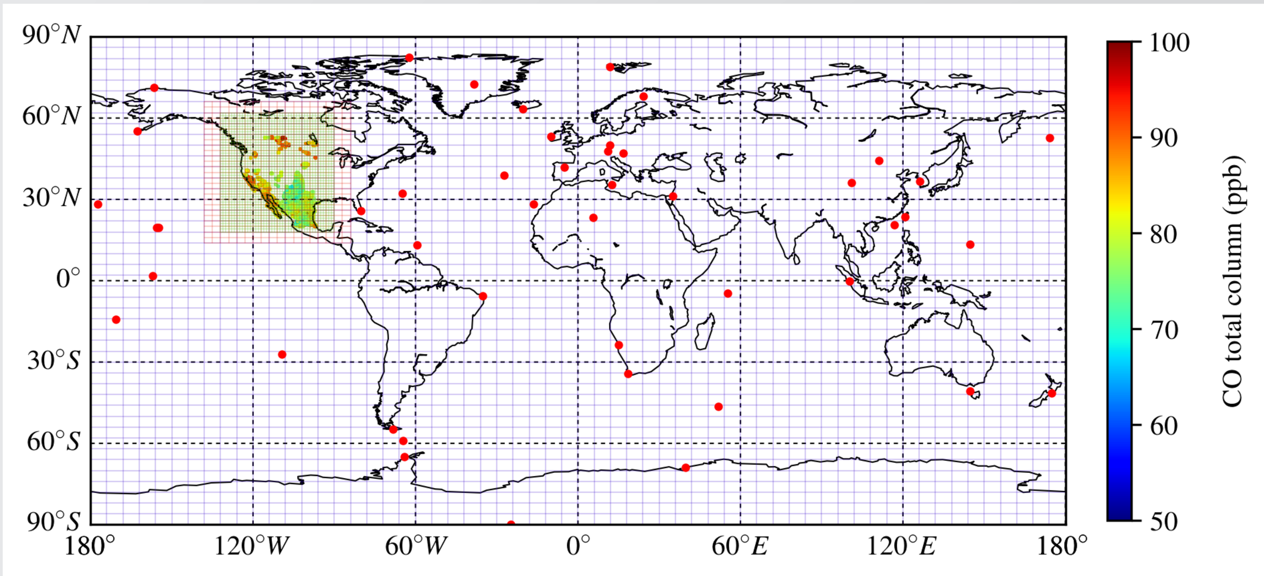
In November and December 2018, the warmer and dryer than usual weather conditions caused major burning events in California. The Woolsey and Camp fires, that started on November 8th, alone devastated a forested and inhabited area of about 1000 km^2, killing 88 people and burning land and structures forcing the evacuation of multiple towns. A different impact of these fires were the elevated pollution caused by the extensive biomass burning. Here we try to retrieve the CO emissions from these biomass burning events using TROPOMI observations in the TM54dvar model.

Model Description/Experiment Setup

The model used here is the TM5-4dvar inversion system. The transport model is the TM5-zoom [1]

- A priori emissions
  - MACCity anthropogenic [2]
  - FINN biomass burning [3]
  - NMVOC and CH_4 from TM5MP [4]
- ERA-Interim meteorology [5]
- 1 month spinup/spindown time
- Very simplified chemistry scheme: chemical production/loss based on OH climatology [6] scaled by 0.92 [4]
- Non-linear M1QN3 optimizer





Lateral gridboxes in the model for the global and the zooming regions, locations of the used NOAA flask measurements stations (red dots) and satellite data used over North America (color map).

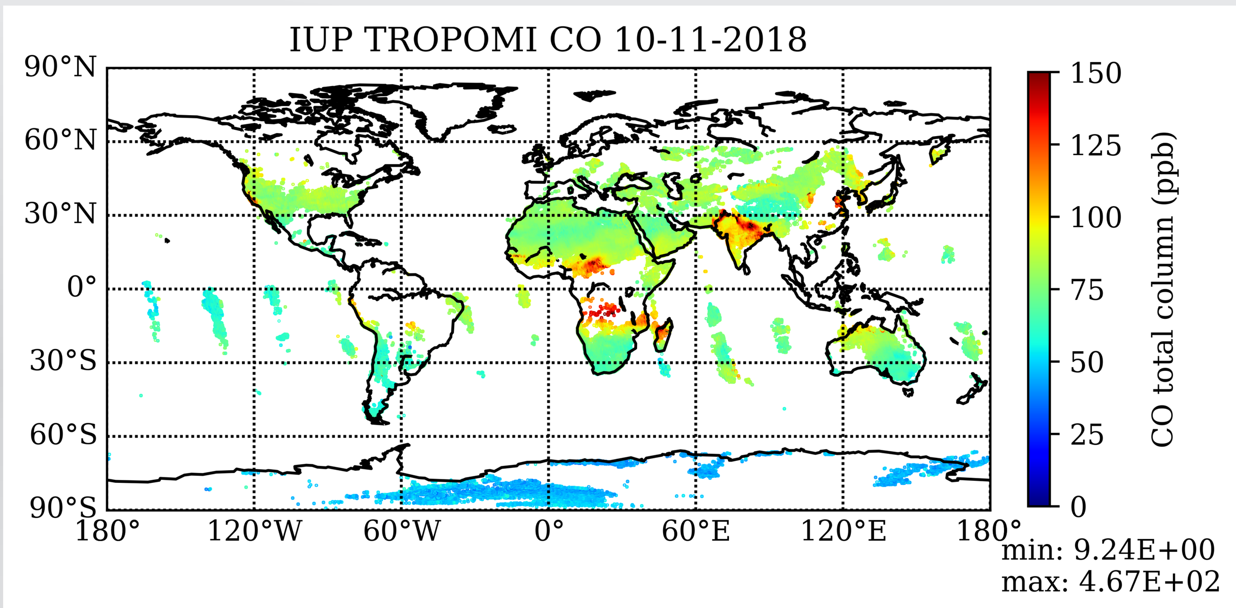
For this experiment we use the model in its coarse resolution (6°×4° longitude × latitude) globally, with a "zoom" region in 1°×1° over the area of interest. There is also a "buffer" region in 3°×2° to accommodate a smooth transition between the zooming region and the global resolution. The arrangement of these regions on the globe is demonstrated in the figure to the left.

The model is constrained globally by high confidence flask CO observations from NOAA. The global model run is done to yield proper boundary conditions for the experiment region, over which the high resolution TROPOMI satellite CO data is used to constrain the biomass burning emissions. The non-linear M1QN3 optimizer is used, which suppresses negative emissions.

Observations

Satellite observations

- **TROPO**spheric **M**onitoring **I**nstrument onboard of **S**entinel-5 Precursor
- Daily global coverage with local overpass time 13:30
- High resolution (up to 7×7 km^2)
  - → Still useful for 1°×1° model pixels: lower error, chance to have at least some cloud free pixels
- Especially sensitive to troposphere and boundary layer

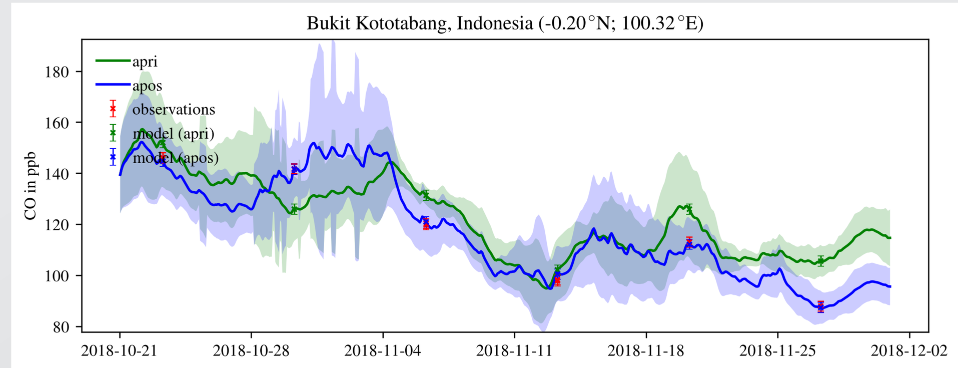


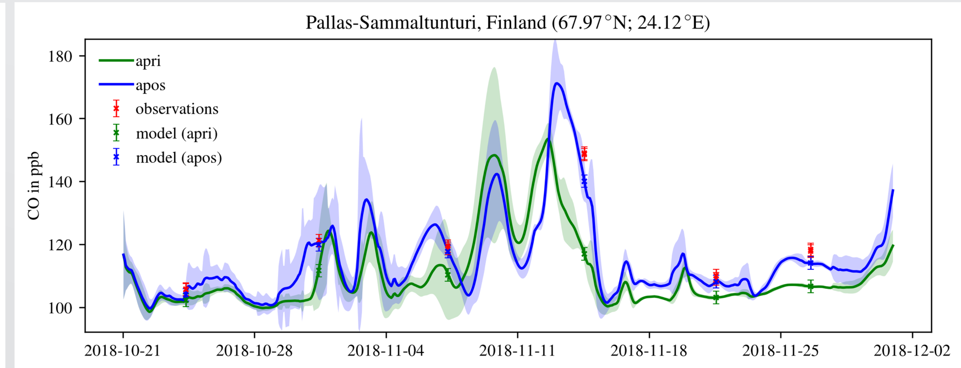
Global background flasks

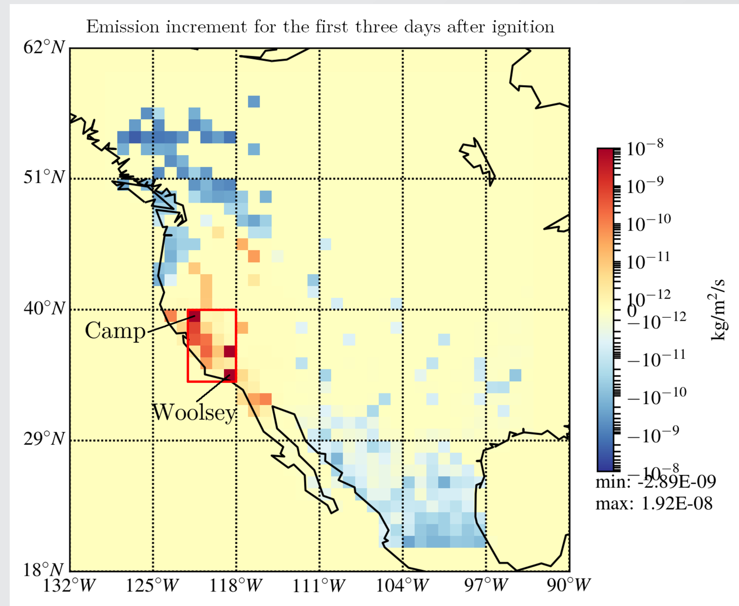
- NOAA CCGG stations
- Very high accuracy ground measurements with low temporal resolution (around weekly)
- Low coverage compared to satellites - around 60 stations to constrain the whole globe

Results

The optimizer updated the global emissions until the modeled concentrations at the background stations converged closely to the flask measurements ...

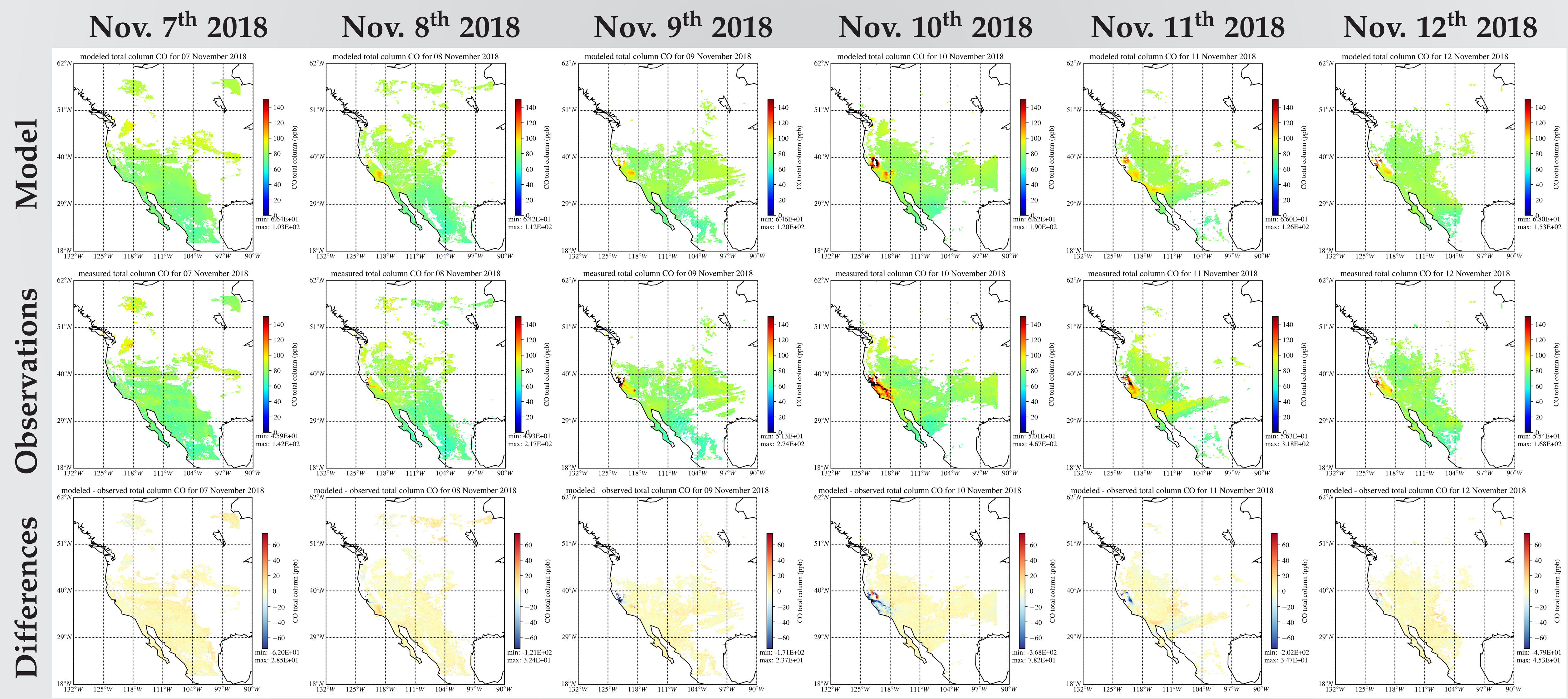






... while the local emission increments for North America were governed by the satellite observations. A clear increase in biomass burning emissions in the region of interest (118°W - 122°W, 34°N - 40°N, with the source of the Camp fire in the upper left (NW) corner and the source of the Woolsey fire in the lower right (SE) corner) is visible. This corresponds to an increase in total CO mass emitted from 18 kt to 124 kt for just those three days (November 8th to November 10th).

Below, a comparison between the fully optimized model concentrations and the observed concentrations is shown. For this, the model was sampled at and interpolated to the times and locations of the observations and had the corresponding averaging kernels of the satellite retrieval applied.



The difference plots show very good agreement for the background concentrations, which features low spatial frequencies. Only some very fine features are not captured by the limited resolution of the model. The biggest deviations are visible close to the biomass burning sources, where the gradients are steep. However, as some parts are over- while others are underestimated, the plumes correspond to the same amount of total CO.

Over the first 15 days (November 8th to November 23rd) after the fires started the inversion leads to a total CO emission of 336 kt in the region of interest, up from 59 kt in FINN. This is much closer to what is to be expected, taking into account estimated CO_2 emissions of around 5.5 million tons [7] and CO/CO_2-ratio of around 10% for wildfires.

Conclusion

The TM5-4dvar model has been used to perform an inversion of the CO emissions from the devastating wildfires in California in November 2018. Convergence to the global background stations as well as the background part of the satellite observations was achieved. The inversion shows massive emission increments for the region of interest, with more than 5 times more mass emitted compared to the FINN inventory over the first two weeks after the initial burning events. This shows how emission estimates in bottom-up inventories can benefit from the top-down approach of inversion, especially for major burning events.

Acknowledgements

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References

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