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IDEA-I: A GLOBALLY CONFIGURABLE AIR QUALITY FORECAST SOFTWARE PACKAGE APPLIED TO NUCAPS RETRIEVALS OF CARBON MONOXIDE FROM SUOMI-NPP

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Abstract

Air quality is a public health priority, particularly the effects of ozone and fine mode aerosols on respiratory and cardiovascular disease. IDEA-I (Infusion of Satellite Data into Environmental Applications-International) is a real-time system for trajectory-based forecasts of aerosol dispersion and ozone stratospheric intrusions (SI) that can be applied to other trace gases. Here we apply IDEA-I to look at carbon monoxide (CO).

The full spectral resolution (FSR) NUCAPS system is now available in CSPP, the low latency operational product distribution pathway for NOAA. This means that realistic CO concentrations are being retrieved operationally for the first time from the NOAA operational Suomi-NPP platform. Moreover, NUCAPS CO is the flagship product of the FSR CrIS instrument and this paper will demonstrate the value this product brings to fire and air quality applications. High concentration NUCAPS CO retrievals are used to initiate trajectories for IDEA-I to propagate using forecast model winds. IDEA-I is the first user application of this product. (A companion IDEA-I application forecasts smoke trajectories based on aerosol optical depth retrievals).

We will demonstrate the value of this NUCAPS CO application in monitoring mesoscale air quality transport for a specific fire case. IDEA-I is also a useful tool for evaluating the accuracy of NUCAPS CO source site identification. Tools such as this provide an understanding of satellite product utility that stretches beyond global validation statistics of bias and RMS deviation.

INTRODUCTION

2018 saw another major fire season in the Western US. Smoke from these fires not only impacted the Western US but also the Midwest and Eastern US. Predicting when and where these downwind impacts are likely to occur helps inform regional air quality management. NUCAPS CO retrievals provide some information on the altitude of air parcels high in CO, which helps to distinguish between lofted and surface plumes. This vertical information may not be available with satellite observations of smoke.

The Community Satellite Processing Package (CSPP) group have recently updated their release of the NOAA/NESDIS/STAR Unique Combined Atmospheric Processing System (NUCAPS). The NUCAPS system is for the retrieval of atmospheric profiles of temperature, moisture and trace gasses, as well as cloud-cleared radiances, using CrIS and ATMS Sensor Data Records (SDRs) from Suomi-NPP and, newly, NOAA-20. High concentration NUCAPS CO retrievals are used to initiate trajectories for IDEA-I to propagate using forecast model ½-degree Global Forecast System (GFS) winds.

SIMULATIONS

In this work we identify high CO air parcels using NUCAPS retrievals and entrain them in three-dimensional GFS winds within IDEA-I. We suggest that CO can be used in this way as a tracer of poor air quality arising from wild fires, where the fires themselves can be remote from the full extent of their health impacts. The CO levels that we detect are not at levels injurious to human health, but are indicative of smoke and other combustion products that make for poor air quality. Of particular interest to us are cases where energetic fires drive smoke aloft, but the smoke returns to the surface near to human populations that can suffer adverse health effects.

In Figure 1 you can see the active fires in Western Canada, and to a lesser extent in Northern California and Oregon. There is already a lot of smoke in North-Central Canada and down into some US Mid-Western states. In the NUCAPS CO profiles for region 1, very high CO concentrations are detected near the source of the fires, within 200 mb of the surface and higher aloft. In North-Central Canada CO concentrations above 180 ppbv are now all above 200 mb from the surface. Our interest is in whether these air parcels return to the surface to potentially adversely affect air quality.

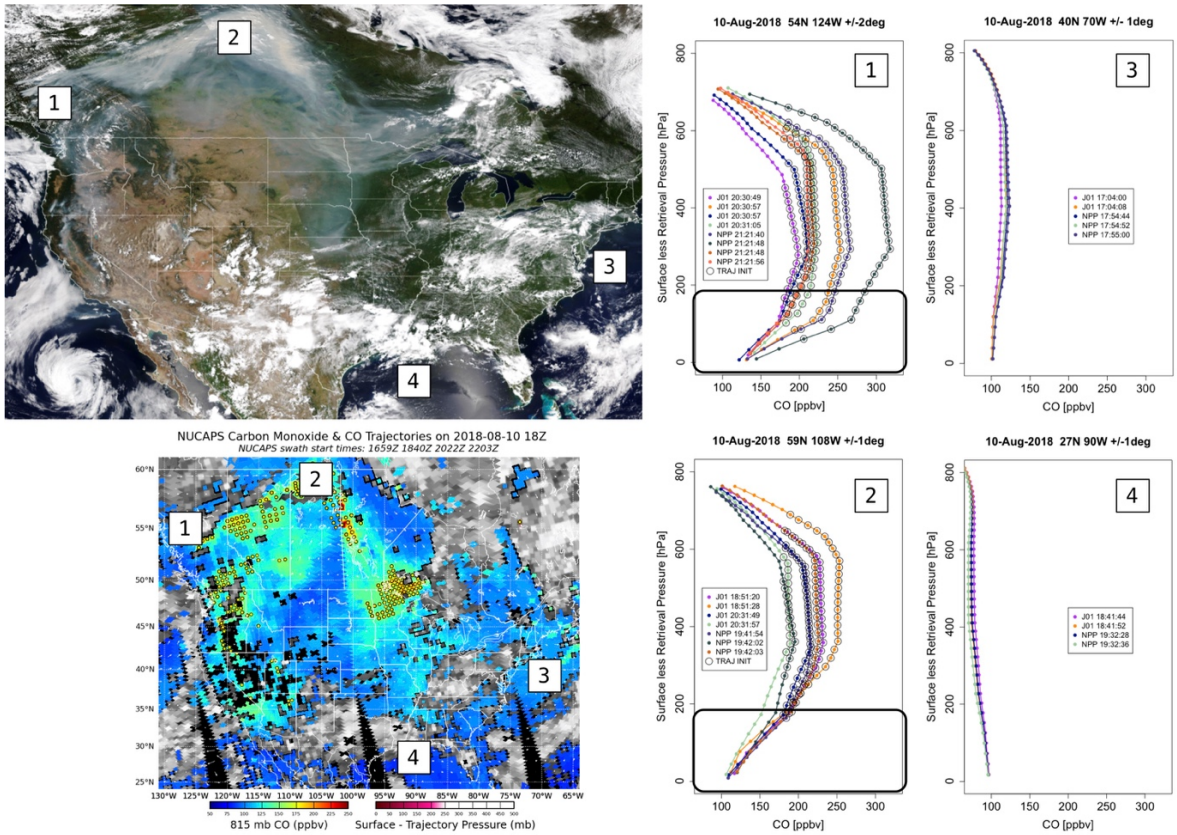

Figure 1: **Top-left is a VIIRS true color image from NOAA-20 overpasses on August 10 2018. Bottom-left is an image created by IDEA-I from NUCAPS retrievals of CO on the same day colored by CO concentration at 815 mb and marking with circles air parcels of high CO concentration (>180 ppbv) at any atmospheric level from surface to 200 mb. At right are NUCAPS CO profiles retrieved from four locations identified by number on the images at left; their vertical scale is surface pressure less retrieved air-parcel pressure, so that 0 is at the Earth's surface. On the profiles at right, we have marked with circles those air parcels with concentrations above 180 ppbv; there are many for locations 1 and 2. These are the air parcels that are to be advected by IDEA-I using GFS winds.**

IDEA-I is ostensibly a visual product. An animation in a web browser shows the location of high CO air parcels, hour-by-hour, for approximately 48 hours into the future from the last satellite overpass within a geographic domain. Figure 2 shows the IDEA-I web interface mid-animation; the air parcels are color-coded to turn a deep red when they descend to the surface, see the color key at bottom right of the figure. To get a sense of flow, the last 6 hourly positions of each air parcel is shown.

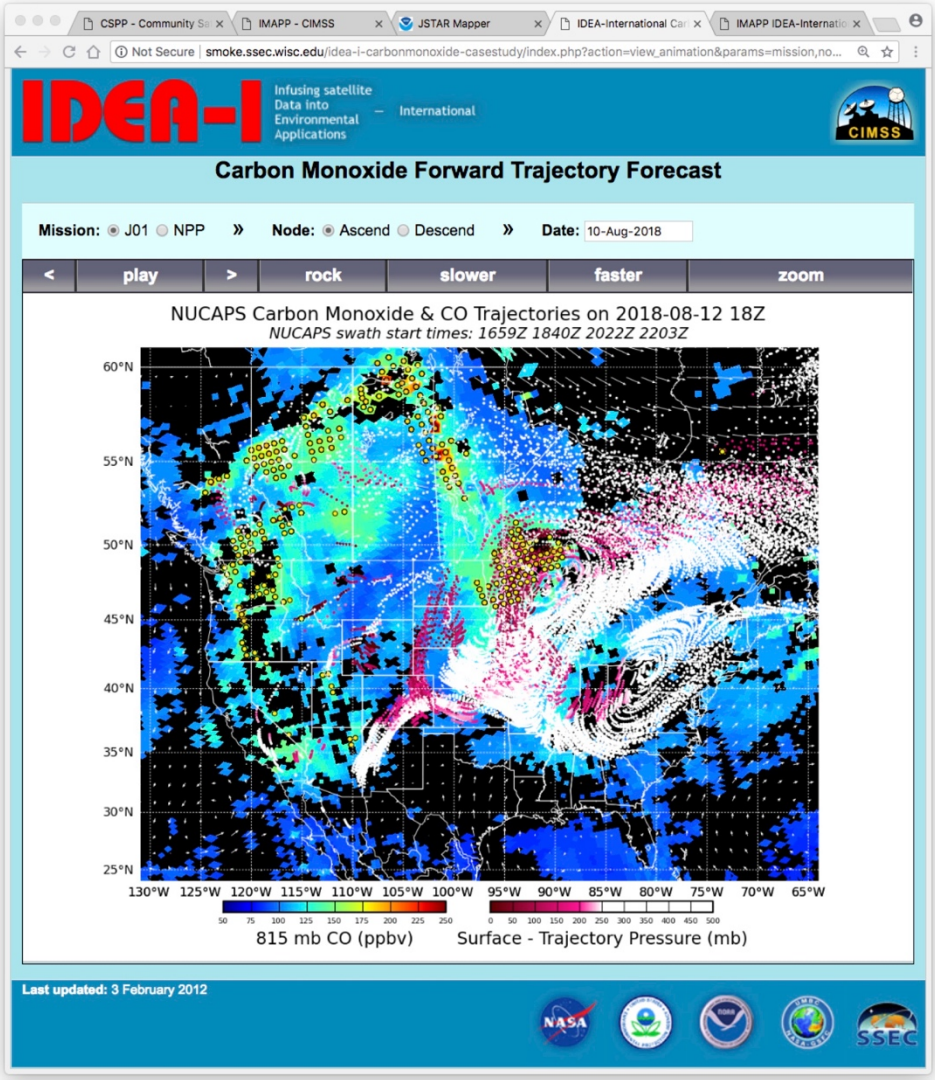

Figure 2: **IDEA-I web interface. In this instance we have buttons for both Suomi-NPP (NPP) and NOAA-20 (J01) for both day-time (Ascend) and night-time (Descend) overpasses. The background basemap is the daily NUCAPS carbon monoxide retrieval at 815 mb. Typically, IDEA-I is executed automatically once all overpasses in the domain have been processed by NUCAPS. High CO (>180 ppbv) air parcels, in the vertical range 200 mb to surface, are selected for advection by GFS winds in IDEA-I to generate animations which show where the high CO air is expected to move in the next approximately 48 hours. The case above is for NOAA-20 observations on 10 August 2018 with the simulation running forward until 18Z on 12 August 2018.**

The mosaic of images that form Figure 3 show a series IDEA-I images for both Suomi-NPP and NOAA-20. The large images at left show the 815 mb NUCAPS CO retrievals from daytime satellite overpasses on 11 August 2018 and showing good agreement between the two platforms. The “cloud optical thicknesses” in grey are a surrogate made from NUCAPS cloud fraction assessments to give context to missing data. On the right are the same base images (less the cloud surrogate) with forecast trajectories run for 24 (“August 12 at ~18Z”) and 48 hours (“August 13 at ~18Z”) and beneath each are the NUCAPS CO retrieval IDEA-I images for those days. At least qualitatively, there is a sense that the trajectories move high CO air parcels to where they are observed by NUCAPS on subsequent days. We are interested particularly where tracked high CO air parcels come down to surface, where they display as deep red. The lowest lying air parcels are plotted last to aid in visualization.

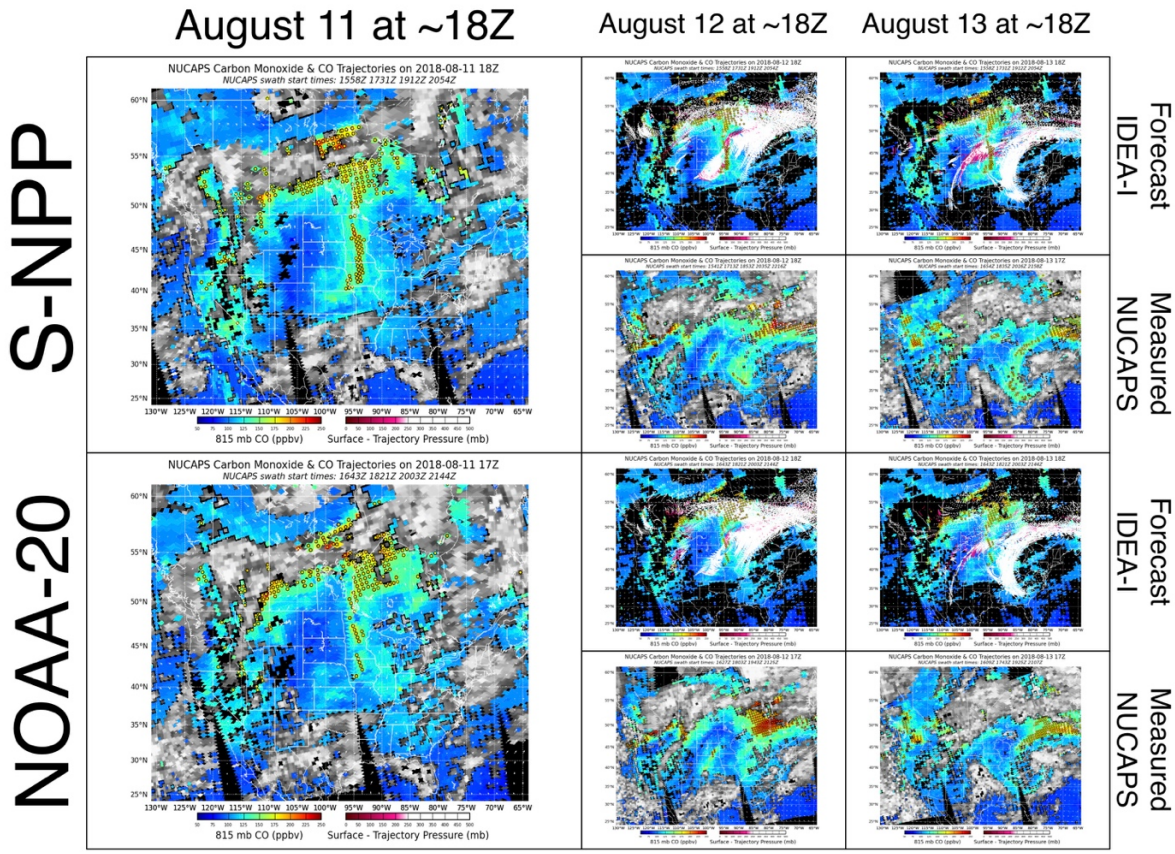

Figure 3: **Large images at left show the 815 mb NUCAPS CO retrievals from daytime satellite overpasses on 11 August 2018 and showing good agreement between the two platforms, Suomi-NPP and NOAA-20. At right are the same base images (less clouds) with forecast trajectories run for 24 and 48 hours and beneath each are the NUCAPS CO retrieval IDEA-I images for those days. There is a sense that the trajectories move high CO air parcels to where they are observed by NUCAPS on subsequent days.**

TOWARDS AIR QUALITY FORECAST

In addition to animations, IDEA-I also generates pairs of NetCDF files containing image data (gridded GFS and satellite) and trajectory data. These can be further processed to arrive at different visualizations, ones that can comprise high CO air parcel trajectories from both missions and also, potentially, from both day and night overpasses. Whilst a benefit of using CO as a trace of air quality is that NUCAPS affords us some information on vertical position at source, the enduring difficulty in using these data in air quality forecasts are temporal limitations in coverage by polar orbiting systems over mid-latitudes and missing NUCAPS retrievals down to surface due to clouds.

Figure 4 shows, at left, the AirNow surface air quality index (AQI) analyses for 10-13 August 2018. The AQI is an amalgam of ground-level ozone, particle pollution (also known as particulate matter, including PM2.5 and PM10), carbon monoxide, sulfur dioxide, nitrogen dioxide. At right are the results of binning into 1x1 deg boxes any advected high CO air parcels that are within 100 hPa of the surface during that 24-hour period. We have used IDEA-I simulations for both Suomi-NPP and NOAA-20 and for both day and night. IDEA-I simulations were started on Friday 10, so on that day we have fewer air parcels, only those initialized during the course of the day. Then next day we have more (the 24 hour forecast from the day before) and the next day more still (trajectories from the previous 2 days). The darker the 1 deg pixel, the more air parcels found within its bounds. So this is a qualitative start to using these simulations in air quality forecasts.

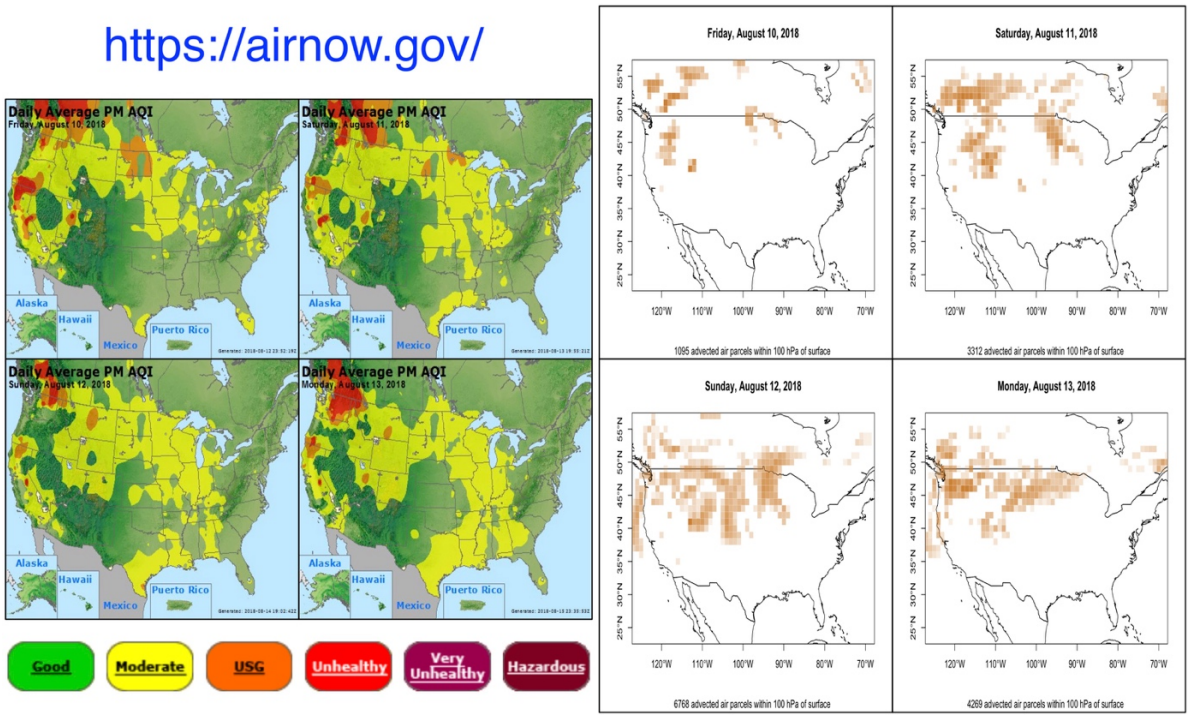

Figure 4: **AirNow surface air quality index (AQI) analyses for 10-13 August 2018 (left) alongside high CO air parcels transported by GFS winds to within 100 hPa of surface pressure (right). CO air parcels are binned into 1x1 deg boxes if they are within 100 hPa of the surface during each 24-hour period.**

LONG RANGE TRANSPORT

Regions of high CO that can be detected with NUCAPS can be of significant size, sufficient indeed to extend beyond the CrIS and ATMS instrument swath width and clearly visible at different atmospheric levels even on maps at global scale (Figure 5). Using CO as a tracer of pollutants thus affords an opportunity to study inter-continental pollutant transport.

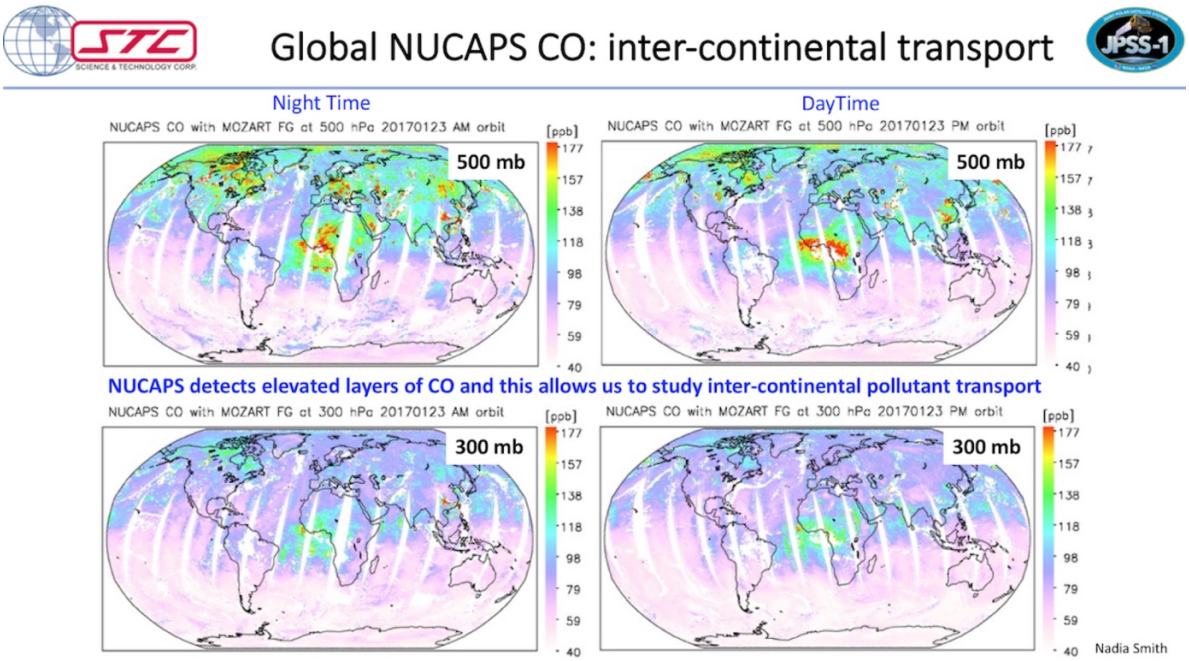

Figure 5: **High CO concentration features from NUCAPS retrievals using Suomi-NPP. Clearly visible at two atmospheric levels, both day and night, are high CO regions large enough to be contiguous across two or more neighboring swaths.**

SUMMARY

Air quality is a public health priority, particularly the effects of ozone and fine mode aerosols on respiratory and cardiovascular disease. We applied IDEA-I to look at advection of high carbon monoxide retrieved by NUCAPS as a tracer of parcels of poor air quality. Potentially this can be applied at regional and at inter-continental scales. To use as part of an air quality forecast requires more work into visualizing time and space binned high CO air parcels that return to near the Earth's surface. Run routinely as part of a direct broadcast stations' product suite, IDEA-I could be a useful tool for evaluating the accuracy of NUCAPS CO source site identification. Tools such as this can provide an understanding of satellite product utility that stretches beyond global validation statistics of bias and precision.
