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U.S. EPA Perspective: Key Earth System Science Challenges Related to Climate Change and Air Pollution

Lead co-authors - Jim Szykman and Terry Keating

This is one of three responses formally provided by the EPA to the National Research Council in response to the Request For Information concerning the 2017-2027 NRC Decadal Survey in Earth Science and Applications from Space.

Climate change and air pollution are arguably the most significant environmental problems facing the United States and the world over the next decade. There is an urgent need to dramatically curtail emissions of greenhouse gases, including powerful short-lived forcers such as methane, to help mitigate the severest impacts of climate change. Globally, indoor and outdoor air pollution are now recognized as leading contributors to the global burden of disease, accounting for as many as 7 million deaths annually.[a] In the United States, new health research has led to a decision to tighten the National Ambient Air Quality Standard for ozone.[b] Attaining the new standard by 2025 across the United States, excluding California, is expected to cost \$1.4 B/yr and yield up to \$5.9 B/yr in quantifiable health benefits. In California, it is expected to take additional time to meet the NAAQS, leading to \$0.8 B/yr in additional costs but yielding up to \$2.1 B/yr in additional quantifiable health benefits.[c] As the standard is lowered, international and non-anthropogenic influences are becoming more significant relative contributors to NAAQS non-attainment. Simultaneously, these extra-regional influences are changing in absolute magnitude due to global development and climate change.

To develop appropriate policies, the EPA needs to understand how emissions of air pollutants (including greenhouse gases) in the United States and abroad are changing over time and how these emissions affect air quality and climate through atmospheric chemical, radiative, and dynamic processes occurring over global to local scales. Networks of ground-based air quality monitors and bottom-up emissions inventories based on limited source measurements and emission factor estimates are not adequate to provide the information needed to understand important sources of emissions or the most important atmospheric processes occurring aloft. Space-based observations can and do play important roles in informing both emissions estimation and atmospheric process understanding, ultimately contributing to better air quality management and climate change mitigation policies.

The concept of an integrated observing strategy (based on surface, airborne and space observations of atmospheric composition) was articulated in 2004 by the intergovernmental group Integrated Global Observing Strategy (IGOS) in their Integrated Global Atmospheric Chemistry Observations (IGACO)

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[a] Lim, S.S., et al. (2012), *Lancet*, 380:2224-60.

[b] EPA (2015), National Ambient Air Quality Standards for Ozone: Final Rule, *Federal Register*, 80:65291-65224.

[c] EPA (2015), *Regulatory Impact Analysis of the Final Revisions to the National Ambient Air Quality Standards for Ground-Level Ozone*, EPA-452/R-15-007.

report.[d] The EPA has increasingly recognized the need to integrate space-based observations into our research and operational work, and views space-based observations as a critical component to an integrated observation system. With respect to air quality, the use of space-based observations was highlighted in 2013 by the National Science and Technology Council,[e] which recognized such observations will be required to address the challenges we face within the United States and across the globe. The NSTC's findings complement the findings and recommendations of other NRC reports, including the first "decadal survey."[f] For space-based observations the nexus between atmospheric and carbon cycle science presents an immense transdisciplinary challenge best addressed through an integrated observation approach.

Current and planned satellite capabilities, including the planned geostationary deployment of the TEMPO instrument, provide some very valuable observations that will help address air quality management challenges within the United States.[g] In a constellation with geostationary satellites from Europe and Korea, TEMPO will also contribute to an improved understanding of the international and global flows of air pollution and their impact on climate. However, our ability to address the scientific and policy challenges of the next decade are limited by two important gaps in the Earth System Science: 1) space-based observations of some key pollutants and 2) a robust operational infrastructure to integrate surface, space, and in-situ observations, global and regional-scale atmospheric models, and emissions inventories for purposes of evaluation and assimilation.

Missing from the expected suite of satellite observations that will be available to atmospheric scientists and air quality managers in the next decade are high temporal and spatial resolution measurements of methane (CH_4) and carbon monoxide (CO). CH_4 is a potent greenhouse gas whose control targets different sources and influences climate on shorter time scales than those of carbon dioxide-abatement measures.[h] Many CH_4 sources are diffuse and difficult to measure at the point of emission, leading to significant uncertainty in current emissions estimates. CH_4 also contributes to the growing global background concentration of tropospheric ozone (O_3), influencing surface O_3. CO has been shown to be a very useful indicator of long-range transport of air pollutants from fires and anthropogenic sources.[i]

[d] Barrie, L.A., et al. (2004), *The Changing Atmosphere: An Integrated Global Atmospheric Chemistry Observation Theme for the IGOS Partnership*, GAW Report 159, WMO TD 1235.

[e] National Science and Technology Council, (2013), *Air Quality Observation Systems in the United States*, Committee on Environment, Natural Resources, and Sustainability, Air Quality Research Subcommittee.

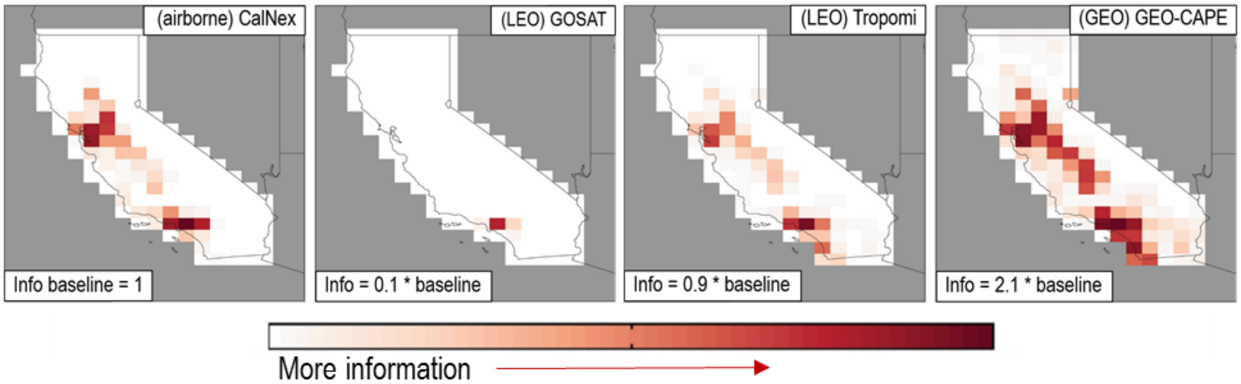
[f] National Research Council (2007), Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. Washington, DC: The National Academies Press. National Research Council (2009), Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks. Washington, DC: The National Academies Press.

[g] Zoogman, P., et al. (2014), *ACP*, 14:6261-6271

[h] Shindell, D., et al. (2012), *Science*, 335(6065):183-9, doi:10.1126/science.1210026.

[i] Heald, C.L., et al., (2003), *JGR*, 108(D24):4804, doi:10.1029/2003JD003507.

CO is also an O_3 precursor and CO from wildfires may increase with climate warming, posing challenges to implementing and attaining air quality standards.



High value of hourly methane observations (from GEO). Adapted from Wecht et al. (2014), the model inversion of assimilated CalNex aircraft campaign methane data establishes current observational capability to constrain methane emissions over California ("Info baseline"). Information content from LEO depends on sampling and revisit times (GOSAT, TROPOMI). A GEO-CAPE SWIR instrument would constrain methane emissions better than even a dedicated aircraft campaign and observations are available for years.

The technical capability to observe CH_4 and CO is well developed. Surface networks and airborne field campaigns provide very high quality data; however such data are sparse in space and time. The sparse data lead to a lack of confidence in the available CH_4 emissions inventories[j] that remains a problematic limitation to the design of efficient environmental policies. In contrast, geostationary space-based observations of CH_4 and CO can provide high quality data everywhere in North America continuously for years.[k] The measurement techniques have been proven in space, with well documented algorithms and effective validation programs to allow for an understanding of uncertainty. NASA has conducted studies of suitable observations which could address these measurement needs, most directly through the mission concept studies for the 2007 Decadal Survey mission GEO-CAPE.[l] No current or planned observing capability meets these defined EPA needs for CH_4. The Canadian MOPITT instrument on NASA's Terra platform measures CO near the surface and aloft using multi-spectral techniques that provide otherwise unavailable data to reveal vertical and horizontal air pollutant transport. However, MOPITT is in extended operations and no follow-on is presently authorized.

CH_4 observations with sensitivity near the surface from geostationary orbit could enable CH_4 emissions estimates that are consistently measured, timely, transparent, complete (over greater North America), accurate, and spatially attributed. CO observations at high temporal and spatial resolution could enable better diagnosis of long range transport of pollution from anthropogenic sources and wildfires. These observations would be valuable from both scientific and management perspectives, leading to greater understanding of key environmental processes and creating a foundation for better policies with multiple societal benefits.

The value of these observations, and other satellite-based observations, would be significantly enhanced by the development of a more robust infrastructure to support the integration of different types of observations (surface networks, satellites, ground-based remote sensing, sondes, aircraft, etc.), models,

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[j] Miller, S.M. et al. (2013), PNAS, www.pnas.org/cgi/doi/10.1073/pnas.1314392110.
[k] Wecht, K.J., et al. (2014), *ACP*, 14:8173-8184, doi:10.5194/acp-14-8173-2014.
[l] Fishman, J., et al., (2012), *BAMS*, 93(10):1547-1566.

and emissions inventories in a more tightly coupled system for both evaluation and assimilation on an operational basis. Leading researchers have demonstrated techniques for integrating multiple types of observations, for linking global and regional scale models, for evaluating emissions estimates based on observations, and for improving model estimates by assimilating observations. However, we do not have the institutional, information, and technical infrastructure to perform these operations efficiently or make these capabilities available to the broader scientific community or the air quality planning and climate policy development communities on an operational basis. Creating such an infrastructure within the United States to exploit the full value of observations and enable an improved research-to-applications paradigm would require a sustained and coordinated multi-agency, multi-government effort, such as that demonstrated by the Copernicus Atmosphere Monitoring Service[m], a large pan-European effort. A similar effort across United States could significantly enhance the Earth System Science enterprise and the societal benefit achieved by future investments in satellite observations.

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[m] https://atmosphere.copernicus.eu