Input to NRC Decadal Survey from a Broad Audience of Remote Sensing Scientists – Air Quality-Fire Themes

Q.1 What are the key challenges or questions for Earth System Science in the coming decade?

Key challenges/questions identified by respondents not-associated with a particular geographic region are presented below (not listed in order of priority). Responses are presented verbatim, with minor editing to improve understanding and to combine similar comments.

Air Quality / Atmosphere

1. Atmospheric forcings
2. Atmospheric chemistry at all layers of the atmosphere (ozone chemistry in particular)
3. Atmospheric chemistry at 10 km anywhere in the world, 50 vertical levels
4. Subtle changing efficacy of the oxidizing capacity in micro climes/sprawling urban areas
5. How is the atmospheric composition changing?
6. Understanding the role of black carbon in reducing climate change
7. How will climate affect air quality and environmental planning?
8. How do changing emissions of methane and other pollutants impact regional and global air quality, climate, and energy decision-making?
9. Impact of greenhouse gases on climate and health
10. Air quality in a rapidly changing societal environment
11. How can we quantify changing air and climate pollutants to understand the effect of regulatory decisions?
12. What contributions do internationally-transported air pollution components have each day on ground-based air quality observations, compared to U.S. emissions?
13. What are the quantities and chemical signatures of emissions from quasi-natural systems with minimal direct/day-to-day anthropogenic influences?
14. What are the proportions, quantities, and chemical signatures of "direct emissions contributions" and "post-direct emissions atmospherically-transformed gases/aerosols" transported into and out of the U.S.?

Fires

15. Can we model wildfires so that communities and land management agencies can reduce fire risk?
16. Are wildfires increasing in frequency, size and severity?
17. How to detect wildfires, prescribed fires, ag fires, grassland fires?
18. What is the structure of the vegetation?
19. How much fuel is in a given area?
20. How does the landscape change relative to vegetation fuel moisture over a growing season?
21. Regional haze due to wildfires and air pollution
22. How do invasive species change the landscape and increase wildfires?
23. How will climate affect biomass burning in the Southern Hemisphere?
24. How is climate change affecting individual species recovery and distribution (plant and animal) post-disturbance?

25. What is the carbon footprint of large-scale wildfires vs prescribed fire or other fuels reduction treatments vs wildfire suppression?

Q.2 Why are these challenge/questions timely to address now especially with respect to readiness?

Respondents were not asked to comment on the timeliness of proposed key questions/challenges. Considering the extended time horizon of the Decadal Survey (2017-2027), timeliness of proposed key questions/challenges was not considered a critical factor.

Q.3 Why are space-based observations fundamental to addressing these challenges/questions?

To address proposed key challenges/questions, respondents offered several suggestions for continuing existing satellite observations or implementing new ones.

<u>Existing observations that should be continued to support decision-making or application development include</u>:

- Landsat – Number 1 priority would be to ensure the continuity of Landsat.
    - The world now relies on Landsat for the bulk of Earth observations including mapping and monitoring.
    - Critically important for understanding change through time.
- MODIS
    - A 'must-have'
    - To maintain fire detection and mapping capabilities
    - To help our understanding of emissions into the atmosphere on a large scale (gas and aerosol) and their impact on human health.
- Suomi-NPP, Terra, Aqua (workhorses of NASA)
    - Support an extremely wide range of applications: climate, forest fires, energy, catastrophic event decision-making, etc.
- OCO – important for measuring atmospheric CO_2 given climate change
- SMAP and other soil moisture at high resolution and high accuracy – a critical variable for health, weather, soils, and fire.
    - As the climate changes and wildfires grow, soils need to be better understood.
- The NASA A-train is proving to be one of the best satellite platforms for scientific and applied research communities. The use of multiple sensors so close together in temporal space has proven to be a distinct advantage for ocean, land, and atmospheric measurements, which can be applied together to provide a more complete picture than any one sensor can provide.
- High temporal, moderate resolution (<=250 meters) multi-spectral observations of the globe (e.g., MODIS, VIIRS) to support land, atmosphere and ocean science applications and information needs.
- High temporal thermal observations (multiple times daily) at moderate to high resolution to support active fire detection, monitoring and characterization.
- Fire-related variables – thermal anomalies, radiative power and burned area
    - These benefit public health/air quality as they serve as critical inputs for both real-time smoke modeling and retrospective emissions inventory development.

- Any and all data/observations which provide valuable soils, atmospheric, oceanographic, vegetation, climatic, geologic, hydrologic, etc. information that can help decision makers face the environmental and social challenges ahead.

Air Quality

- Tools that allow us to better characterize pollution in the atmosphere, and to detect fires and land use changes – to do a better job modeling emissions and air quality and to see changes over time.
- Measurements of air pollutants, including ozone, CO, formaldehyde, aerosol properties and abundance, nitrogen oxides. These correspond to OMI and MOPITT observations, with improved algorithms to refine near-surface abundances.
    - Chemical weather models use the atmospheric tracer CO to separate near-surface concentrations from pollution aloft; MOPITT multi-spectral data are the paradigm for this vertical information.
    - OMI data and the upcoming (not NASA) TROPOMI data, plus upcoming TEMPO data over North America are absolutely necessary for air quality decision support.
- In the stratosphere a sensor similar to the MLS instrument would be invaluable for continuing long-term measurements. Integral validation schemes should be in place to corroborate satellite measurements and to bridge gaps between satellite missions.

<u>Suggestions for additional investments include</u>:

Air Quality

- Air quality (near-surface air pollutant) observations, particularly those with co-benefits for mitigating climate change, leading with methane.
    - These observations (methane, CO [not CO_2], NO_2, aerosol, and others) with dual benefits to climate and air quality are under-represented or absent in NASA's portfolio.
    - The communities involved are generally capable of using the large datasets produced by satellites.
    - The direct impact of this information on national and international climate and air quality policy is enormous.
    - On a 20-year, policy-relevant timeframe, methane's global warming potential is 86 times that of CO_2. Satellite methane measurements are needed to support methane reductions.
- Modeled near-surface atmospheric fields at high resolution could enhance understanding of heat stress experienced by urban dwellers and improve linkages between urban form and health outcomes.
- Global geostationary air quality monitoring (including the Southern Hemisphere)
    - High time-resolved air quality measurements of atmospheric gases and aerosols – AOD, NO_2, CO, NH_3, and ozone retrievals for the troposphere.
    - Will help understand the evolution of pollution plumes and lead to insights about diurnal variations and the impact of pollutants on human health.
- Anthropogenically forced environmental changes are an unknown.

- Changing energy production, chemical feedstocks, population concentration effect the air environment.
- Focused measurements of urban air quality, targeting the oxidizing capacity, help to understand the effect of the gross pollution production in dense human environments.

Wildfires

- Fire detections, fire emissions, and their impact on regional air quality.
- Improved wildland fire monitoring during fire season in the US at both strategic and tactical levels.
- Replace and improve the MODIS and VIIRS instruments that detect fire.
- Higher spatial resolution satellite (about 10 m) with weekly temporal resolution to support wildfire management – weather, erosion, soil moisture/temperature, vegetation moisture, and species-level vegetation data to answer post-fire/post-disturbance vegetation and soil stabilization recovery and treatment effectiveness questions.
- Dedicated satellite for all stages of fire management/applications:
    - Moderate to high spatial resolution
    - Thermal bands with appropriate saturation thresholds to support characterizations of active fire properties
    - VIS, NIR and SWIR bands for post-fire burn area mapping, severity characterization and assessing live fuel conditions
    - High temporal frequency
- More frequent collection for fire and other emergency responses for daily thermal monitoring at 1 m resolution.
    - Every other day cover is needed for Landsat.
    - Two collections each month coverage is an issue for event coverage, due to cloud cover.
- NDVI products directly from Landsat. Improved land fire data with increased accuracy and annual refresh.
- Carbon-identifying services or sensors would be huge in the wildfire community to understand carbon released or trapped by fires.