Input to NRC Decadal Survey from a Broad Audience of Remote Sensing Scientists – General Issues

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

Key challenges/questions identified by approximately 53 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 combine similar comments.

Data Accessibility, Dissemination, and Challenges

1. How to create or improve data infrastructures using cloud-based computing
2. How to improve resolution
3. What's NASA's contribution to the big data challenge and opportunities?
4. How can we improve the latency of new missions?
5. How can we enhance data interoperability across sensors and platforms?
6. How can we make data access easier, including products accessed through a Distributed Active Archive Center (DAAC)?
7. How can we improve partnerships with other agencies?
8. Near-real-time (NRT) all-weather surveillance of the land surface without cloud cover obscuration
9. Synergy of remotely sensed signals (e.g., reflectance, thermal, LIDAR, microwave)
10. Can Landsat be funded to avoid data gaps?

Integration with End Users

11. How best to involve local communities in NASA-funded application projects to provide actionable information needed on the ground?
12. How can we better bridge the gap between science and real needs applications?
13. How can NASA best support resilience-building around the globe?
14. How can satellite-based data be a regular resource for policy makers?

Weather / Climate Change

15. Climate change observation, detection, modeling/prediction
16. What are the primary sources of seasonal climate predictability and how does predictability change with time?
17. Which mitigation efforts impact climate change in positive ways?
18. How much can we improve weather and climate simulation (on subseasonal to interannual scales) through higher spatial resolution observations and simulations?
19. What are the full impacts of dust on local and regional precipitation, and can we simulate coupled hydrological-dust dynamics realistically at regional scale?
20. How is climate change affecting site-level weather variables (e.g., precipitation) both spatially and temporally?

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, and facilitating the use of satellite data.

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

- Aquarius – Helpful in El Niño prediction
- CloudSat – Relevant to climate, weather
- DEMs – Topography mission such as the proposed LIST to provide much needed better vertical DEMs for building stronger resilience.
- GCOM-W1
- GEOS (All) – Relevant to climate, weather
- GPM – Relevant to precipitation, weather, climate, etc.
- Ensuring GRACE-FO and GRACE2 is critical for climate
- Landsat – Number 1 priority would be to ensure the continuity of Landsat.
    - The world relies on Landsat for the bulk of Earth observations including mapping and monitoring.
    - Critically important for understanding change through time.
- MODIS – A ‘must-have’
- Near-surface humidity and air temperature – Important weather drivers
- OCO – Important for measuring atmospheric CO_2 given climate change
- Radar
- Suomi-NPP, Terra, Aqua (workhorses of NASA) – Support an extremely wide range of applications
- SMAP and other soil moisture at high resolution and high accuracy – Critical variable for health, weather, etc.
- SWOT – Relevant to global water cycle, climate, etc.
- Thermal missions, moderate to high-resolution – Important for climate monitoring
- The TRMM/GPM legacy is critical for all manner of applications areas and needs to be continued.
- Tropospheric chemistry species such as MOPITT, TES, MLS, AIRS – Relevant to human health, energy and climate
- Visible, near-infrared and thermal
- The 30-odd Essential Climate Variables (ECVs) are key to continue measuring.
- Articulating the value of NASA Earth Science supported research to end users and the general public, and/or enabling them to discover the value of this research for themselves, should remain a top priority.

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

Data Accessibility, Dissemination, and Challenges

- An archiving data system or open cloud computing service that provides easy access to data and imagery.
- Emphasize continuity. It is critical that capabilities of sensors for the last 20-30 years be maintained on future sensors to ensure continuity of data records.
- Improved NRT access to data products to support disaster response, science and application needs:
    - Use infrastructures similar to LANCE and Worldview.
    - NRT information measured against averages or baselines to identify/predict trends can support operational decisions and influence major strategy and policy decisions.
    - Most A-train sensors have provided NRT capability which end user communities have been able to use to study their thematic interests. The availability of NRT satellite sensor datasets has often provided results not necessarily intended by the original sensor design.
    - Continue direct broadcast capabilities on future instruments, and/or design/optimize data streams to support availability of key science data products to end users with very low latency.
- 4-16 pt sq/m NIR or green LIDAR satellite; high density p-band ifsar satellite; constellation of 20cm-5m 8-16 band (b-TIR) satellites.
- Latency and format of user friendly products are key to their infusion into decision-making and use in chemical and meteorological models.
- Geospatial metadata that enables the use of ArcGIS products to readily fit into application tools without a lot of reformatting and re-projection work on the user's dime.
- Software infrastructure similar to Google Earth Engine that allows for more rapid processing of satellite products without the need to transfer large quantities of data.
- Hyperspectral with thermal because the number of resultant data products would enable broad science advancement across numerous areas.
- Build and launch additional MODIS sensors
    - Beyond what VIIRS is currently providing
    - With higher resolution on thermal sensor
    - Include two sensors flying simultaneously in a morning/afternoon orbit like Terra and Aqua do now.
    - Critical to maintain the long-term continuity of the calibrated MODIS record
    - The MODIS suite of sensors has provided one of the most complete sets of value-added products for the entire remote sensing community.
- Fine-resolution images without cloud cover or little cloud cover, which renders some images useless, especially images taken close to the ocean and during wet seasons.
- High temporal and spatial resolution land products – to examine changes in Earth’s surface, from vegetation to fires. This can be used as input to weather/climate, air quality, emissions models; and for land development and management actions.

- To obtain near-continuous (daily) monitoring of the water and energy balance globally, it is essential that a satellite system be implemented that has a sensor package spanning the visible to microwave wavelengths.
    - Critical to many applications in climate and weather forecasting.
- For research applications, a satellite with very high resolution would be very beneficial. Many research plots are much smaller than currently available resolution, which limits possibilities of research projects using remote sensing.
- A data fusion product at 20 to 30 m spatial resolution with bands similar to Landsat but augmented spectrally. Most importantly, have FREQUENT overpasses so that the product reliably has value in a 5-day composite period.
- Currently it appears that the geostationary ABI (or ABI like) sensors are the future direction for most of the remote sensing community. Much of the scientific and applied research communities will be applying their resources to the channels, temporal scale, and effective field of view of these sensors.
- Build and launch additional Landsat sensors
    - Have multiple Landsat sensors flying at one time in order to provide temporal resolution of ~4 days.
    - Possibly two sensors up at the same time for both redundancy and more frequent collections.
    - Additional thermal bands.

Climate Change

- Tools to improve cities' resilience
- High-resolution spatial (km) and temporal measurements (hourly) to determine regional levels of CH_4 from natural and anthropogenic sources (e.g., fracking) to inform policy. CH_4 emissions can have an impact within a 20-year timeframe that is even greater than that of CO_2.

Weather / Atmosphere

- Vertically resolved, hourly observations of the chemical and meteorological characteristics of the atmosphere, with the ability to track diurnal/weekly/monthly variation and trends across North America.
- Geostationary hyperspectral sounding capability to advance our ability to predict weather events on short time scales.
- Ozone measurements in the troposphere.
- Real-time accurate precipitation measurement of fine resolution, especially over Africa.
- Microwave temperature and humidity sounder instrument capable of resolving variability in the lowest 1 km of atmosphere over the ocean.
- Satellite-informed model of high-resolution intra-urban air temperature (and other near-surface fields) – important for better representation of environmental conditions relevant to human energy budget.
- Reliable profiles of temperature, humidity, and other variables in the lower troposphere would be extremely useful, contributing to studies of land-atmosphere interactions, evaluation of climate models, and novel data assimilation techniques.

- Air temperature and humidity profiles in the lowest 1 km planetary boundary layer (PBL)
    - PBL is a critical component of the atmosphere that is not well observed.
    - Important to countless applications, from modeling of atmospheric convection to atmospheric chemistry and Earth's energy and water cycles. For example, evapotranspiration over land is dependent on turbulence within the PBL.

To increase the value of data and enable end users to fully understand satellite data and how it can be used, it would be useful to provide:

- Metadata (geographic scope, time series length)
- Information on the uncertainty of satellite data
- Data latency
- GIS-ready imagery (orthorectified)
- Models – Much data is available, but many people lack knowledge of how to turn data into information.