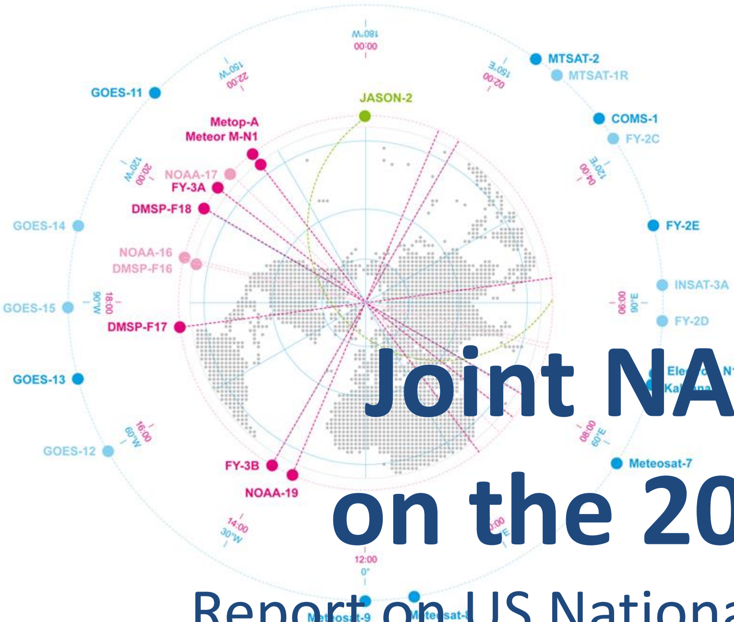


Joint NASA-NOAA Briefing on the 2017 Decadal Survey

Report on US National Academies of Science, Engineering, and Medicine Report: “Thriving on our Changing Planet: A Decadal Strategy for Earth Observations from Space”

Presented to CGMS-46 Plenary Session, Agenda Item D

Jack Kaye, NASA
Steve Volz, NOAA

7 June 2018
ISRO Headquarters

Coordination Group for Meteorological Satellites

Quick Summary: Recommendations

2

SCIENCE & APPLICATIONS

Address **35 key science/applications questions,** from among hundreds suggested. Those with objectives prioritized as most important fell into **six categories**:

- Coupling of the Water and Energy Cycles
- Ecosystem Change
- Extending & Improving Weather and Air Quality Forecasts
- Sea Level Rise
- Reducing Climate Uncertainty & Informing Societal Response
- Surface Dynamics, Geological Hazards and Disasters

1

VISION & STRATEGY

"Thriving on our Changing Planet"

3

OBSERVATIONS

Augment the **Program of Record** with **eight priority observables**:

- **Five** that are specified to be implemented:
  - *Aerosols*
  - *Clouds, Convection, & Precipitation*
  - *Mass Change*
  - *Surface Biology & Geology*
  - *Surface Deformation & Change*
- **Three** others to be selected competitively from among seven candidates
- Structure **new NASA mission program elements** to accomplish this
- Methods for new NASA capabilities to be **leveraged by NOAA and USGS**

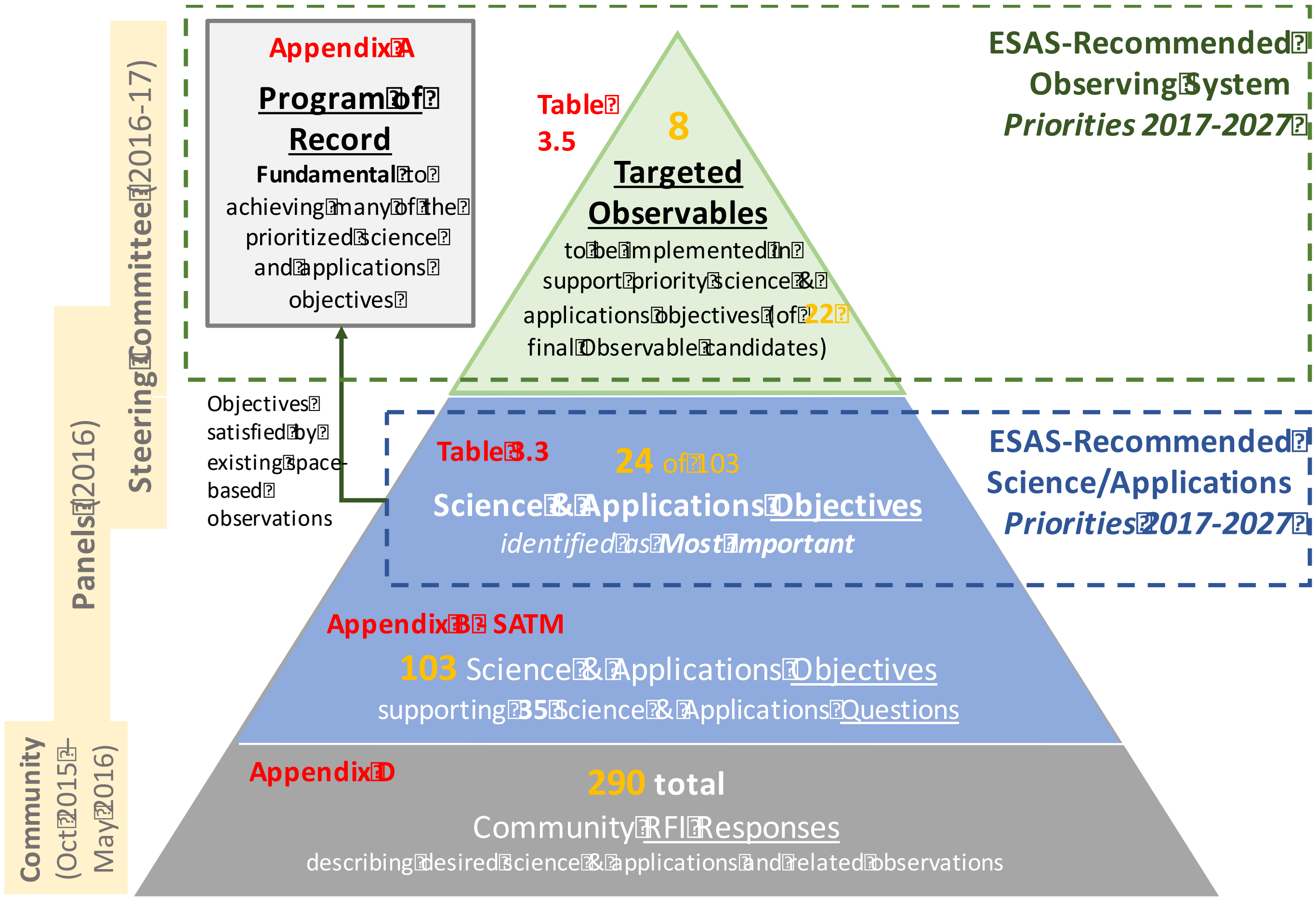
4

PROGRAMMATICS

- CROSS-AGENCY
- NASA
  - Flight
  - Technology
  - Applications
- NOAA
- USGS

Path from Science & Applications to Observational Priorities

Blue: Science & Applications; Green: Observables



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NASA Observation System Priorities

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Aerosols	**Aerosol properties, aerosol vertical profiles, and cloud properties** to understand their direct and indirect effects on climate and air quality	Backscatter lidar and multi-channel/multi-angle/polarization imaging radiometer flown together on the same platform	X		
Clouds, Convection, & Precipitation	**Coupled cloud-precipitation state and dynamics** for monitoring global hydrological cycle and understanding contributing processes	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	X		
Mass Change	**Large-scale Earth dynamics** measured by the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology & Geology	**Earth surface geology and biology,** ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR	X		
Surface Deformation & Change	**Earth surface dynamics** from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	X		
Greenhouse Gases	**CO_2 and methane fluxes and trends,** global and regional with quantification of point sources and identification of source types	Multispectral short wave IR and thermal IR sounders; or lidar**		X	
Ice Elevation	**Global ice characterization** including elevation change of land ice to assess sea level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar**		X	
Ocean Surface Winds & Currents	**Coincident high-accuracy currents and vector winds** to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift.	Radar scatterometer		X	
Ozone & Trace Gases	**Vertical profiles of ozone and trace gases** (including water vapor, CO, NO_2, methane, and N_2O) globally and with high spatial resolution	UV/IR/microwave limb/nadir sounding and UV/IR solar/stellar occultation		X	
Snow Depth & Snow Water Equivalent	**Snow depth and snow water equivalent** including high spatial resolution in mountain areas	Radar (Ka/Ku band) altimeter; or lidar**		X	
Terrestrial Ecosystem Structure	**3D structure of terrestrial ecosystem** including forest canopy and above ground biomass and changes in above ground carbon stock from processes such as deforestation & forest degradation	Lidar**		X	
Atmospheric Winds	**3D winds in troposphere/PBL** for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		X	X
Planetary Boundary Layer	**Diurnal 3D PBL thermodynamic properties and 2D PBL structure** to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights.	Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar** for PBL height			X
Surface Topography & Vegetation	**High-resolution global topography** including bare surface land topography ice topography, vegetation structure, and shallow water bathymetry	Radar; or lidar**			X

**Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables

Other ESAS 2017 Targeted Observables, not Allocated to a Flight Program Element	
Aquatic Biogeochemistry	**Radiance Intercalibration**
Magnetic Field Changes	**Sea Surface Salinity**
Ocean Ecosystem Structure	**Soil Moisture**

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Programmatics - NASA

Rec 4.6 Apply **decision rules** (included) to maintain programmatic balance (programmatic balance was a high priority)

Rec 4.7 Small scope changes to **applications & technology programs**

Rec 4.8 Reevaluate **Ventures structure** at mid-term

Rec 3.3 **Avoiding cost growth** is critical to program's success (capability and reliability are where the flexibility must be found)

NASA Activities in Support of Decadal Survey Implementation

- Weekly meetings of Earth Science Division Leadership Team to plan implementation
- Initial focus has been on closing out prior pre-formulation work and beginning transition to new efforts in support of designated observations, begin development of approach to Earth Venture continuity, incubator, and explorer lines
- Weekly internal meetings at HQ to receive questions from staff and discuss considerations
- Monthly discussions with Earth Science leadership at NASA centers
- Periodic community fora (WebEx) – first one was May 10, 2018
- Develop “90-day letter” response to National Academies

NOAA Observation System Opportunities

EXPECTED NOAA "UNSATISFIED PRIORITIES"	EXPECTED NOAA PRIORITY AND RATIONALE	RELATED ESAS 2017 PROGRAMS OR TARGETED OBSERVABLES
Instrument Cost Reduction	HIGH – Reducing cost of any system element enables greater system capability. NOAA has limited capacity to invest in development activities that eventually reduce production cost.	Incubation program element NASA ESTO
3D Winds in Troposphere and Lower Stratosphere	HIGH – High cost and low technology readiness impede inclusion in NOAA operational system.	*Atmospheric Winds*
Global Precipitation Rate	HIGH – High cost and low technology readiness impede inclusion in NOAA operational system.	*Clouds, Convection, & Precipitation*
Seasonal Forecasting	MEDIUM – Multiple new and often difficult observations needed, notably upper ocean and ocean-atmosphere coupling, along with assurance of continuity and ongoing cost reduction for existing observations.	Many ESAS 2017 Targeted Observables
Ocean Surface Vector Winds	MEDIUM – Coverage is likely to be less than desired, with high-volume coverage presently costly.	*Ocean Surface Winds & Currents*
Global Atmospheric Soundings	MEDIUM – Expect future systems to have more soundings of at least moderate precision/accuracy levels as compared to today, but high precision/accuracy IR and microwave soundings may be lacking.	*Planetary Boundary Layer*
GEO-based Regional IR and Microwave Sounding	LOW to MEDIUM – Useful for forecaster nowcasting, but generally considered less valuable than global sounding.	*Planetary Boundary Layer*

Programmatics - NOAA

Rec 4.9 Make it easier to extend use of satellite data for **NOAA purposes beyond weather**

Rec 4.10 Further leverage US and international government **partner observations,** allocating budget as needed to do so

Rec 4.11 Be a leader in exploiting **commercial observations**

Rec 4.12 Establish with NASA a flexible framework to **co-develop technology** that will be used by NOAA

NOAA Activities in Support of Decadal Survey Implementation

- Working on several fronts to make NOAA data more accessible to non-weather users, including the “One Stop” discovery interface
- Through NOAA’s budget process, working to gain additional resources to leverage international partner data
- Continue to implement the Commercial Weather Data Pilot, including issuing an RFP for Round 2 in May 2018
- Continue to identify additional areas of collaboration with NASA
  - RBI Follow-on planned as the first Venture Continuity mission
  - Seek to use NOAA budget to fund a NASA venture call to support NOAA mission areas

Backup

Statement of Task

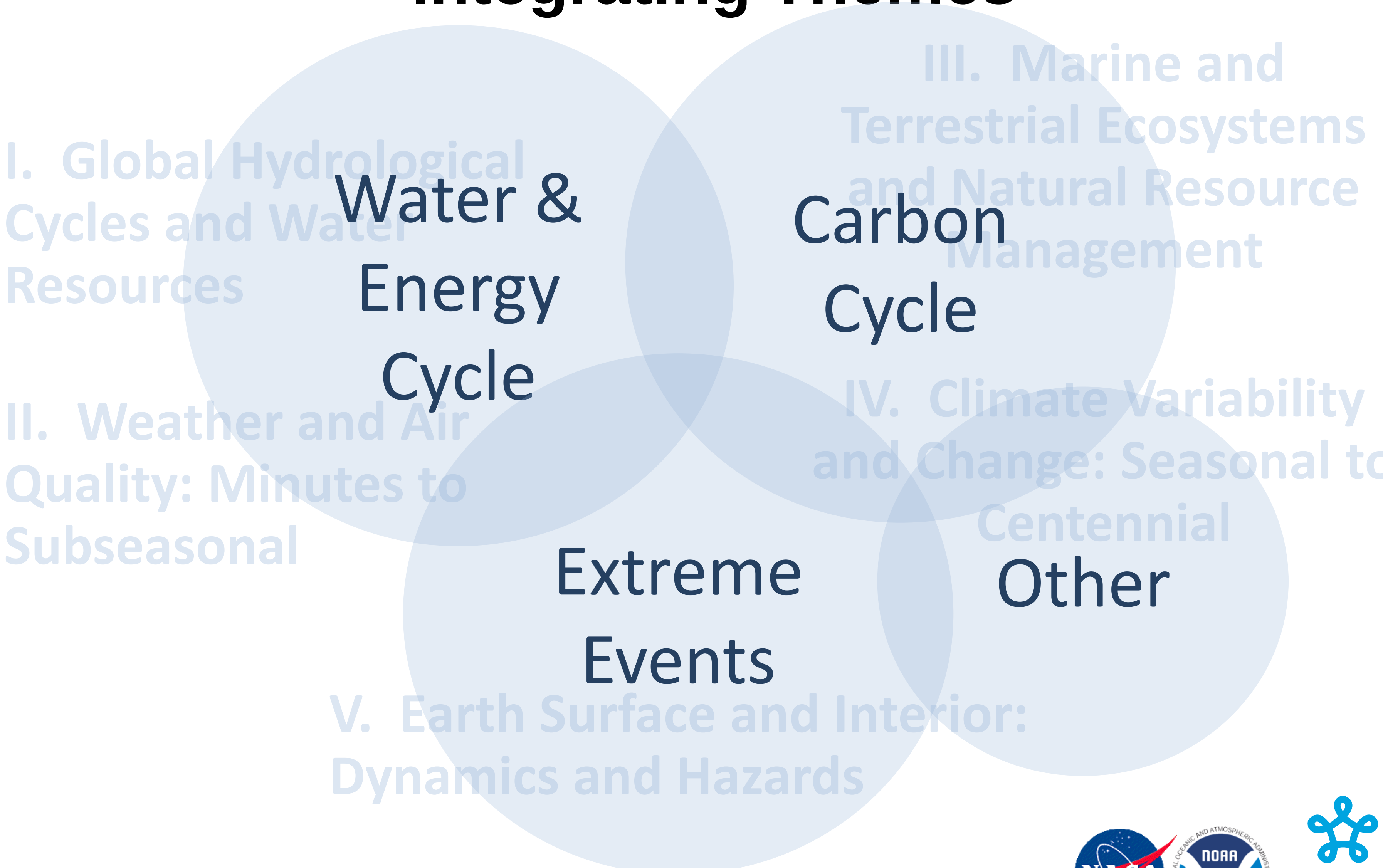
OVERARCHING TASKS

- Assess **progress from 2007**
- Develop a prioritized list of top-level **science and application objectives** for 2017-2027
- Identify gaps and opportunities in the **programs of record** at NASA, NOAA, and USGS
- Recommend approaches to facilitate the development of a robust, resilient, and appropriately balanced U.S. **program of Earth observations** from space

GENERAL & AGENCY-SPECIFIC TASKS

- **Cross-Agency**
  - Enabling activities
  - Partnerships & synergies
- **NASA**
  - Program balance and scope
  - Ventures flight element
  - Decision principles and measurement continuity
- **NOAA and USGS**
  - Non-traditional observation sources
  - On-ramp of scientific advances
  - Research-to-operations
  - Technology replacement/infusion

Integrating Themes



Strategic Framework for Leveraging Resources & Advancing

ELEMENTS OF DECADAL STRATEGY

1. Commit to **Sustained Science and Applications**
2. Embrace **Innovative Methodologies** for Integrated Science/Applications
3. Amplify the **Cross-Benefit of Science and Applications**
4. Leverage **External Resources and Partnerships**
5. Institutionalize **Programmatic Agility and Balance**
6. Exploit **External Trends** in Technology and User Needs
7. Expand Use of **Competition**
8. Pursue **Ambitious Science**, Despite Constraints

Prioritization Criteria

AREA	DESCRIPTION
Science Questions	Science objectives that contribute to answering the most important basic and applied scientific questions in Earth System science. These questions may span the entire space of scientific inquiry, from discovery to closing gaps in knowledge to monitoring change.
Applications & Policy	Science objectives contributing directly to addressing societal benefits achievable through use of Earth System science.
Interdisciplinary Uses	Science objectives with benefit to multiple scientific disciplines, thematic areas, or applications.
Long-Term Science and/or Applications	Objectives that can support scientific questions and societal needs that may arise in the future, even if they are not known or recognized today.
Value to Related Objectives	Science objectives that complement other objectives, either enhancing them or providing needed redundancy.
Readiness	Are we in a position to make meaningful progress to advance the objective, regardless of measurement?
Timeliness	Is now the time to invest in pursuing this objective? Examples include recently occurring phenomena that require focused near-term attention and the existence of complementary observing assets that may not be available in the future.

Summary of Top Science & Applications Priorities*

Science & Applications Topic	Science & Applications Questions addressed by **MOST IMPORTANT** Objectives
Coupling of the Water and Energy Cycles	**(H-1)** How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods? **(H-2)** How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?
Ecosystem Change	**(E-1)** What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space? **(E-2)** What are the fluxes (of carbon, water, nutrients, and energy) *between* ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing? **(E-3)** What are the fluxes (of carbon, water, nutrients, and energy) *within* ecosystems, and how and why are they changing?
Extending & Improving Weather and Air Quality Forecasts	**(W-1)** What planetary boundary layer (PBL) processes are integral to the air-surface (land, ocean and sea ice) exchanges of energy, momentum and mass, and how do these impact weather forecasts and air quality simulations? **(W-2)** How can environmental predictions of weather and air quality be extended to seamlessly forecast Earth System conditions at lead times of 1 week to 2 months? **(W-4)** Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do? **(W-5)** What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?
Reducing Climate Uncertainty & Informing Societal Response	**(C-2)** How can we reduce the uncertainty in the amount of future warming of the Earth as a function of fossil fuel emissions, improve our ability to predict local and regional climate response to natural and anthropogenic forcings, and reduce the uncertainty in global climate sensitivity that drives uncertainty in future economic impacts and mitigation/adaptation strategies?
Sea Level Rise	**(C-1)** How much will sea level rise, globally and regionally, over the next decade and beyond, and what will be the role of ice sheets and ocean heat storage? **(S-3)** How will local sea level change along coastlines around the world in the next decade to century?
Surface Dynamics, Geological Hazards	**(S-1)** How can large-scale geological hazards be accurately forecasted and eventually predicted in a socially relevant timeframe?

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* Complete set of Questions and Objectives in Table 3.3

CGMS

NASA Portfolio Balance

- Earth Science research and analysis: *maintain* at approximately 24% of the ESD budget (22-26%)
  - Includes 18% for openly competed research and analysis
  - Includes approximately 3% each for computing and administration
- Flight program (including Venture): *maintain* at 50-60% of the ESD budget
- Mission operations: *maintain* at 8-12% of the ESD budget
- Technology program: *increase* from current 3% to about 5% of the ESD budget
- Applications program: *maintain* at 2-3% of the ESD budget

NOAA Operational System Advances

- Clear science & technology on-ramp opportunities
- Programmatic structures that enable development of those on-ramps jointly with NASA
- Enhanced partnerships to leverage external resources, international and commercial
- Improved internal access to observing assets