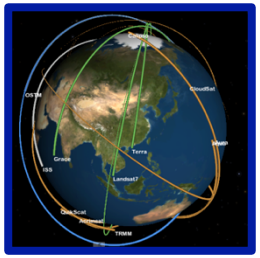
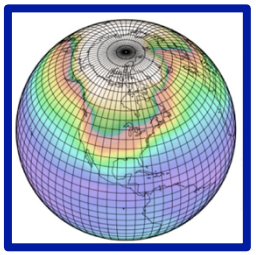
Observations Supporting Models & Forecasts

- Process knowledge
- Initial conditions
- Evaluate models and guide development & improvement

Community activities are extensive and helpful

(Satellite) Observations





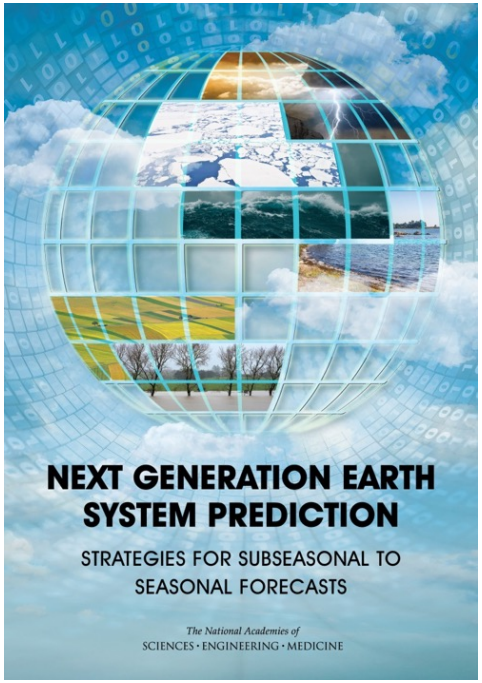
Models

Models Supporting Observations

- Reanalysis – synthesis and gap filling
- Guide observing system development and prioritization???

- *Community activities are very limited and/or of very limited practical value – lack quantitative justifications and comparisons*

Sources of S2S Predictability



1) **Natural Modes of Variability**
   ENSO,
   MJO,
   QBO
   etc
2) **Slowly Varying Surface Processes**

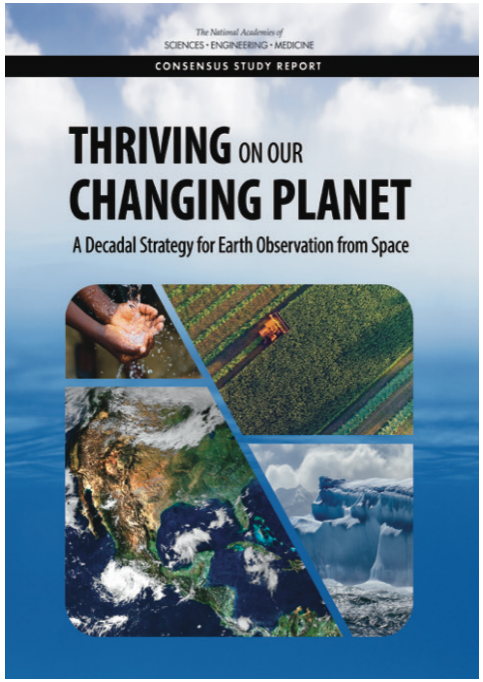
snowpack - only have cover, not SWE
sea ice– only have cover, not thickness or snow vs ice
soil moisture – have near surface but not root zone
vegetation & VWC – limited quantitative information
ocean mixed-layer – have SST, but not MLD except ARGO
etc

Need observations to improve process knowledge, modeling and forecast capabilities.

U.S. National Academy of Sciences Study 2016: Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts

Supported by NASA, ONR and Heising-Simons Foundation

Observations for Science & Applications



Prioritized Earth science and applications questions across:

- Global Hydrological Cycles and Water Resources
- Weather and Air Quality: Minutes to Subseasonal
- Marine and Terrestrial Ecosystems and Natural Resources
- Climate Variability and Change: Seasonal to Centennial
- Earth Surface and Interior: Dynamics and Hazards

Recommended a program for accomplishing a subset of high priority science through a suite of directed and competitive mission elements.

U.S. National Academy of Sciences Study 2017: Thriving on Our Changing Planet A Decadal Strategy for Earth Observation from Space

Supported by NASA, NOAA and USGS

U.S. Decadal Survey Recommended Science Priorities and Program

Designated

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		

Total Water Storage

Vegetation

Explorer

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
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	

Sea Ice

Ocean Currents

Snowpack

Vegetation

3 "Missions" to be selected out of 7 considerations

US $350 Million cost capped for each

<u>International partnerships anticipated</u>

Likely a total of over $1.5B to be spent by broader community

Incubation

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
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

Planetary boundary layer

Ocean Ecosystem/Mixed-Layer Depth

Soil Moisture

Better & Practical Uses of Model Experimentation for Observing System Development

- Our modeling community is very adept at, and willing to undertake, systematic model experimentation (e.g. CMIP, GASS-YOTC, S2S, GLACE, etc).
- Typically, the objective of these experiments are posed with only a science objective in mind.
- In some limited cases, community experimentation has been done to examine the utility of an observation (e.g. GLACE soil moisture experimentation for role in subseasonal variations).
- Little or no experimentation is done that quantitatively compares the utility of one observing system over another for one or more S2S (or other time scales) prediction measures.

Better & Practical Uses of Model Experimentation for Observing System Development

- The observation development / space agency communities would welcome more quantitative justifications for new (or continued) observing systems.
- The observation development community does not have the time/expertise to develop such justification(s) – *so often hand wave the perceived value*.
- The modeling community has the wherewithal and opportunity to significantly influence these prioritizations and choices by objectively and quantitatively demonstrating the impact.
- **$Bs of international investment** is involved in these observing systems, we need to make judicious choices.
- These observing systems are critical to implementing and improving our environmental prediction systems – **that save lives and property**.
- We should try to **be more practical and systematic** in the development of our model experimentation objectives.

Recommendation

Within our 2nd Phase of S2S, including in our ocean and land initialization subprojects, and in concert with GEWEX, develop our model experimentation with the above sorts of considerations and observing systems more overtly and concretely in mind.