Observations Supporting Models & Forecasts
• Process knowledge
• Initial conditions
• Evaluate models and guide development & improvement

Models Supporting Observations
• Reanalysis – synthesis and gap filling
• Guide observing system development and prioritization???

Community activities are extensive and helpful

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
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
<table>
<thead>
<tr>
<th>Targeted Observable</th>
<th>Science/Applications Summary</th>
<th>Candidate Measurement Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerosols</td>
<td>Backscatter lidar and multi-channel/multi-angle/polarization imaging radiometer flown together on the same platform</td>
<td>X</td>
</tr>
<tr>
<td>Clouds, Connection &amp; Precipitation</td>
<td>Radar(s), with multi-frequency passive microwave and sub-mm radiometer</td>
<td>X</td>
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<tr>
<td>Mass Change</td>
<td>Large-scale earth dynamics measured for the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets</td>
<td>X</td>
</tr>
<tr>
<td>Surface Biology &amp; Geology</td>
<td>Earth surface geology and biology, Ground water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass</td>
<td>X</td>
</tr>
<tr>
<td>Surface Deformation &amp; Change</td>
<td>Earth surface dynamics from earthquakes and landfills to ice sheets and permafrost</td>
<td>X</td>
</tr>
<tr>
<td>Greenhouse Gases</td>
<td>Multispectral short wave IR and thermal IR sounders, or lidar**</td>
<td>X</td>
</tr>
<tr>
<td>Ice Elevations</td>
<td>Lida**</td>
<td>X</td>
</tr>
<tr>
<td>Ocean Surface Winds &amp; Currents</td>
<td>Radial scatterometer</td>
<td>X</td>
</tr>
<tr>
<td>Ocean &amp; Trace Gases</td>
<td>UV/R/microwave limb/hadr sounding and UV/R solar/lidar occultation</td>
<td>X</td>
</tr>
<tr>
<td>Snow Depth &amp; Snow Water Equivalent</td>
<td>Radar (Ka/Ku band) altimeter, or lidar**</td>
<td>X</td>
</tr>
<tr>
<td>Terrestrial Ecosystem Structure</td>
<td>Lida**</td>
<td>X</td>
</tr>
<tr>
<td>Atmospheric Winds</td>
<td>Active sensing (lidar, radar, scatterometer), passive imagery or radiometry-based atmosphere vectors (AIRS) tracking, or lidar**</td>
<td>X</td>
</tr>
<tr>
<td>Planetary Boundary Layer</td>
<td>Microwave, hyperspectral IR sounder(s), e.g., in geo or small set constellation, GPS radio occultation for diurnal PRN temperature and humidity and height; water vapor profiling DAS lidar, and lidar** in PRN height</td>
<td>X</td>
</tr>
<tr>
<td>Surface Topography &amp; Vegetation</td>
<td>Radar, or lidar**</td>
<td>X</td>
</tr>
<tr>
<td>** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**U.S. Decadal Survey Recommended Science Priorities and Program**

- **Total Water Storage**
- **Vegetation**
- **Sea Ice**
- **Ocean Currents**
- **Planetary boundary layer**
- **Ocean Ecosystem/Mixed-Layer Depth**
- **Soil Moisture**

3 “Missions” to be selected out of 7 considerations

US $350 Million cost capped for each

International partnerships anticipated

Likely a total of over $1.5B to be spent by broader community
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.
- *$B$s 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 2\textsuperscript{nd} 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.