New Observations & Use Of Models For Designing And Prioritizing (Satellite) Observing Systems

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PAN-WCRP MODELLING MEETING

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Jet Propulsion Laboratory
California Institute of Technology

DISCUSSION TOPICS

- **How to best prepare and benefit from new observations coming available in the next 5 years? e.g. golden ages for hydrology and C&E.**

- **How to identify, prioritize and design future observing systems to meet needs of the modeling community and address critical/complex science questions?**
  - The era of Earth Science "discovery" missions (put it up and it will be useful) is over.
  - The totality of new science and continuity missions requires an international fleet of complementary and synergistic contributions.
  - Multiple countries/agencies are contributing new observations & international partnerships are becoming more common.
  - Options for smaller, more economical satellites/sensors are becoming feasible:
    - Constellations of satellites/sensors (e.g. A-Train, CYGNSS)
    - Multiple observation types for complex processes
    - Tight formation flying for rapid changes (e.g. Δt = minutes)
  - Modeling/OSSE tools are sorely needed across weather, climate and other Earth Science areas, and across a range of complexity (e.g. simple sampling, hypothesis testing, forecast/projection OSSEs) to identify, prioritize & design new observing systems.
  - <u>The space agencies alone don't own/manage all the modeling expertise and resources to optimally address next generation needs.</u>

New Observations (< 2022) Relevant to Model Development and Evaluation

(non-exhaustive list)

Major programs include
ESA
- Living Planet Program/Explorer
- Copernicus/SentineL

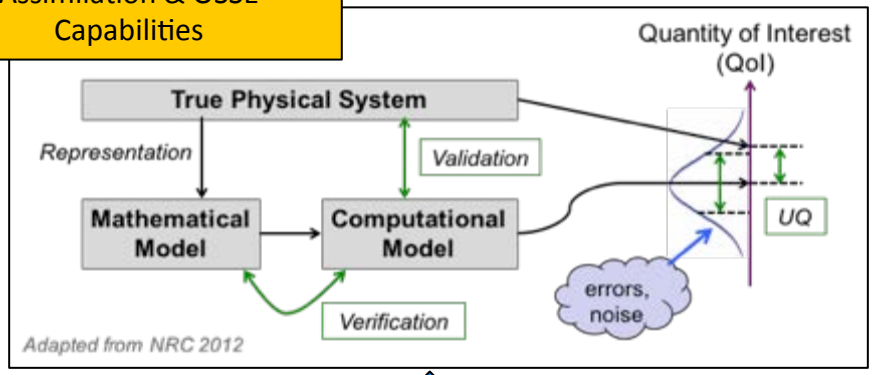
NASA
- Decadal Survey
- Earth Venture (Mission, Instrument)

ISRO, CNES, JAXA, DLR, CNSA, etc
Operational – EUMETSAT, NOAA, IMD, JMA, CMA

5 Year Horizon - Mostly Relevant to Weather/Climate Model Support						
KARI	**JAXA**	**ISRO/NASA**	**CNES/NASA**	**GFZ/NASA**	**ESA**	**NASA**
GEMS - O3, NO2, aerosol	GCOM-C - multi-spectral VisIR	NISAR - biomass and ice sheets	SWOT - mesoscale ocean topography & lake/river heights	GRACE-FO - gravity, ice-sheet, groundwater, ocean mass storage	EarthCARE - cloud radar w/ doppler	SWOT - mesoscale ocean topography & lake/river heights
ABI - IR Sounder (e.g. GOES-R, MTG)	EarthCARE - cloud radar w/ doppler				ADM-Aeolus - Winds	GRACE-FO - gravity, ice-sheet, groundwater, ocean mass/heat storage
	GOSAT-2 - CO2, CO, CH4				Biomass - biomass	NISAR - biomass and ice sheets
					Sentinel 4 - O3, NO2, aerosol	IceSat-2 - glaciers, ice-sheet
					Sentinel 5 - O3, NO2, aerosol	OCO-3 - CO2, SIF
	Composition				Sentinel 6 - Sea Level	ECOSTRESS - evapotranspiration
	Carbon & Ecosystems		**Geostationary**			GEDI - forest/vegetation structure
	Water w/ SMAP, SMOS, ECOSTRESS					TEMPO - O3, NO2, aerosol
	Atmosphere Physics w/GOES-R & MTG		**ISS**			MAIA - aersol type & size
						GeoCARB - CO2, CO, CH4

Interplay between Observations and Models for Science, Applications and Mission Formulation

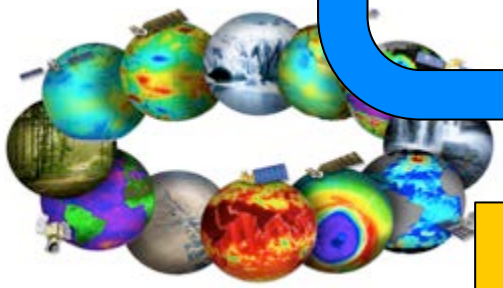
Earth System Modeling, Data Assimilation & OSSE Capabilities

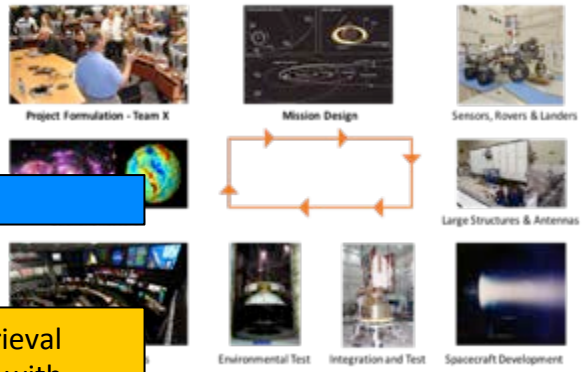


Science Outcomes & Decision Support Information with Uncertainties

Formulation: Identifying & Prioritizing New Observation Needs

Relatively new, hard yet sorely needed



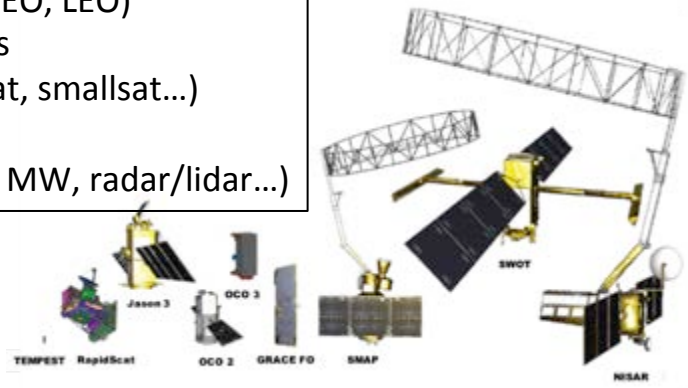


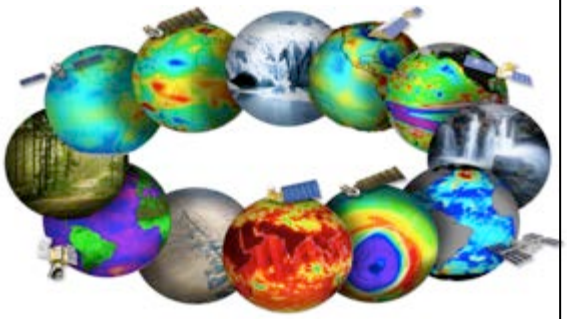
Sensor & Retrieval Development with Uncertainty Quantification

Technology Trade Space & Earth Science Complexity to be Considered is Growing / Significant

(yet $ constrained)

Orbits (GEO, LEO)
Platforms
(cubesat, smallsat…)
Sensors
(vis, IR, MW, radar/lidar…)





Atmosphere
Ocean
Land
Cryosphere
Biosphere

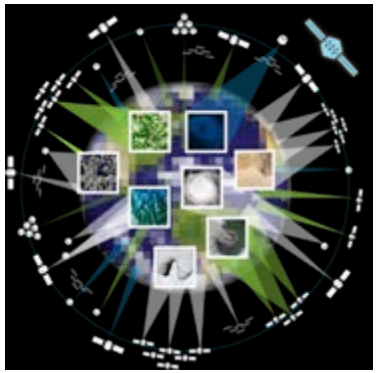
Continuity vs
New Science

Sparse, Uncoordinated LEO satellites

Coordinated observatories with high spatial and temporal sampling
Requires International/Industry partnerships and leadership

A-Train

ISS or new Science Station



Constellations

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MODELING TOOLS & RESOURCES NEEDED

- **Accessible Earth System component and coupled models are needed or trade space considerations in identifying, prioritizing and designing new observing systems:**
  - Forward satellite sensor operators embedded or software/collaborative means to readily embed new, experimental satellite sensor concepts.

  and/or
  - Realistic, high-resolution "truth" simulations from which forward satellite sensor operator calculations can be computed from model output.

  - Some constellations / processes require output with sampling of minutes
  - Some continuity mission / climate mission considerations require output of decades.
  - Model uncertainty needs to be accounted for, thus multiple models or physical ensembles of a given model are needed.

- **As new observations are being used to develop and evaluate models, and their advocacy often driven by reducing forecast/projection uncertainties (no longer "discovery"), a stronger partnership in this endeavor is needed.**