Earth Science at JPL

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Presentation to
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Outline

- Satellite Assets
- Thrust Areas
  - Water Cycle
  - Carbon Cycle
  - Sea Level
  - Natural Hazards
- Integration
  - Center for Climate Science
JPL Earth Science Flight Projects - 2011

Operational
- QuikSCAT (1999)
- ACRIMSAT (1999)
- Jason-1 (2001)
- ASTER (1999)
- MISR (1999)
- GRACE (2002)
- AIRS (2002)
- TES (2004)
- MLS (2004)

Proposed Development/Formulation
- Aquarius (2011)
- Jason 3* (2013)
- GRACE-FO (8/2016)
- Jason 3* (2013)
- OCO-2 (2/2013)
- OCO-3 (NLT 2015)
- SMAP (11/2014)

Mission Studies
- ASCENDS CO₂
- HyspIRI
- GPSRO*
- Ocean Vector Winds*
- GEO-CAPE
- ACE
- Pre-decisional Material - for Planning and Discussion Purposes Only

Artists' concepts
Seeing Earth in a New Way

- **MISR**: 0.4–0.8 μm
- **OCO**: 1.61–2.06 μm
- **ASTER**: 8–14 μm
- **TES**: 3.2–15.4 μm
- **AIRS**: 3.7–14.5 μm
- **MLS**: 120 μm - 0.27 cm
- **CloudSat**: 0.33 cm
- **SeaWinds**: 2.2 cm
- **Jason**: 2.3/3 cm
- **GPS**: 19 cm
- **Aquarius**
- **DESDynI**
- **SMAP**

Pre-decisional - for Planning and Discussion Purposes Only

Artists' concepts
Earth Science Research Thrust Areas

Consider:
- Need
- Expertise
- Resources
- Funding
- Potential
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The Water Cycle

- **GRAVITY**: Groundwater, ice sheets
- **RADAR**: Ice sheets, lake, river & ocean levels, cloud mass, salinity
- **RADIOMETER**: Soil moisture, sea ice, clouds, water vapor, salinity
- **SPECTROMETER**: Atmospheric water vapor profiles
Water Resources: Critical Need for Science-Informed Decision Making

**Motivation**

- Gaps exist in observations and research needs related to climate change and water.
- Access to better observational data will improve understanding of changes, reduce prediction uncertainties and enable adaptive management.
- The current National Climate Assessment identifies water resources as a specific, integrated resource focus area.

- Today 1.1 billion people live without access to adequate water.
- Climate change is expected to profoundly impact the world’s water supply and quality.
- Water resource challenges will manifest on regional scales, and can quickly impact political and economic stability.

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*JPL Assets and Expertise*

- GRACE, MODIS/SNOW, AMSR-E, AVIRIS, SMAP*, SWOT*, UAVSAR, etc.
  * *proposed missions*
Measuring Sea Surface Salinity
Aquarius (Launched June 2011)

Aquarius will use an L-band radar and radiometer to make monthly maps of sea surface salinity with precision of .2 PSU and resolution of 150 x 150 km.

Important roles in global water budget and helping drive ocean circulation.
SMAP would use a rotating 6-m deployable mesh antenna shared by an L-band radar & radiometer to map soil moisture and freeze/thaw state and resolution of 10 km every 3 days.
Proposed **Surface Water and Ocean Topography (SWOT)**

SWOT would use a Ka-band interferometric SAR with 2 swaths, 60 km each to characterize the ocean circulation at a spatial resolution of 10 km and provide a global inventory of terrestrial water bodies.

SWOT measurements would be critical to determining surface water availability and the ocean's capacity to absorb heat and carbon from the atmosphere.

Partners: CNES, CSA

LRD: 2019
Ground Water Depletion Observed by GRACE

Groundwater levels declining by 1 meter every 3 years.
More than 109 cubic km of groundwater disappeared between 2002 and 2008

Rodell, et al. (2009)
Measuring Surface Deformation Aquifers in the LA Basin

*Synthetic Aperture Radar (SAR) from ERS-1,2*
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Carbon Cycle

Spectrometer
CO₂, CO, Methane

RADAR
Freeze/Thaw
Biomass

Lidar
Vegetation Structure

Optical
Land Cover Change
Ocean Color
Focusing on Carbon & GHG: Science & Policy

Motivation

- Many scientific questions remain regarding the global carbon cycle (e.g. ocean uptake, permafrost).
- The next IPCC Assessment includes a more substantial focus on Earth System / Coupled Carbon-Climate Models.
- Future climate forcing scenarios of imposed GHG concentrations are giving way to imposed emission scenarios.

- Policy and investment decisions on emissions and energy will depend in part on carbon cycle knowledge, predictions, and monitoring.

JPL - Missions (OCO-2, AIRS, TES, SMAP*, DESDynI*, etc), Carbon Cycle Science (e.g. CARVE), and Systems Engineering.

*proposed missions

Pre-decisional - for Planning and Discussion Purposes Only
OCO will measure reflected sunlight with 3 bore-sighted, high resolution grating spectrometers with enough precision (1–2 ppm) to resolve sources and sinks of CO2 at a scale of 1000 km.

Only ~58% of the >200 Gt C humans have added to the atmosphere since 1958 is staying in the atmosphere.
Carbon Mitigation Policies
Questions & Monitoring Needs

What are the trends in **fossil-fuel emissions** from the largest cities?

How are individual power plants being operated?

Is Country-A meeting emission **stabilization commitments** (or more business-as-usual)?

Are reported emissions from agriculture and other land-use for a given region accurate?

If policy X isn’t meeting its ultimate objective, what needs adjustment? Where?

Is Project-Y’s claimed baseline for a forest **carbon offset credit** real?

Are disturbances occurring that impact Country-B’s avoided **deforestation commitment** (is it permanent)?

Urban Center & Power Plant Emission Monitoring

Global Carbon Flux Monitoring

Global Carbon Stock Monitoring
JPL: In The Vanguard of Two National Efforts

- Grassroots effort started in 2008 by JPL and partners at DOE labs, NOAA, and other agencies
- Concept for an integrated network of space/air/land/sea observations, modeling, & data systems
- Satellite observations expected to play a critical role.

**NASA Carbon Monitoring System (CMS)**

- New congressional mandate for sustained decision support
- 2 Pilot Projects
- FY'11 Science Definition Team Call
- Scoping/Design Study
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Measuring Changes in Sea Level

Thermal expansion

Added mass
Gravity Recovery and Climate Experiment (GRACE)

Sea Surface Topography - Mass change = Thermal Expansion of the ocean

GRACE Gravity Model

(Chambers, 2005)
Measuring Changes In Ice Mass with GRACE

(from Velicogna et al, 2009)
Proposed **Surface Water and Ocean Topography (SWOT)**

SWOT would use a Ka-band interferometric SAR with 2 swaths, 60 km each to characterize the ocean circulation at a spatial resolution of 10 km and provide a global inventory of terrestrial water bodies.

SWOT measurements would be critical to determining surface water availability and the ocean’s capacity to absorb heat and carbon from the atmosphere.

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**Partners:** CNES, CSA

**LRD:** 2019
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  – Natural Hazards (Earthquake, Volcano, Tsunami)
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Contributions To Natural Hazard Applications & Partnerships

**Tsunamis**
- GREAT Warning System (Obs Assets: JASON, GPS)

**Earthquakes**
- ARIA, eDecider, QuakeSIM (Obs Assets: GPS, Proposed SAR/DESDynI)

**Volcanoes**
- (Obs Assets: ASTER, GPS, SAR)

**Oil Spills**
- (Obs Assets: AVRIS, Imaging Spectrometer)

Pre-decisional - for Planning and Discussion Purposes Only
Model-Data Comparisons for IPCC Assessment (AR5)

Estimates of Cloud Ice Concentrations from Models Used in the IPCC 4th Assessment

Actual Global Ice Concentrations Observed by CloudSat

Waliser, Li et al. (2009)
Aquarius will use an L-band radar (JPL) and radiometer (GSFC) to make monthly maps of sea surface salinity with precision of 0.2 PSU (0.2 gkg\(^{-1}\)) and resolution of 150 x 150 km.

Environmental testing underway in Brazil.

Partners: CONAE (INPE, ASI, CNES, CSA)
Imaging Spectroscopy Used by NASA, USGS, and NOAA to Estimate Thickness and Volume of Surface Oil

Spectroscopic Basis: Infrared C-H Bond Absorptions

NASA AVIRIS Spectra from the Gulf

AVIRIS Gulf Measurements

Surface Fraction

Thickness

Quantitative Volume Estimates

Courtesy Rob Green (JPL)
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NASA and CMIP/IPCC: Better Linkage

How to bring as much observational scrutiny as possible to the IPCC process?

How to best utilize the wealth of NASA Earth observations for the IPCC process?
NASA Satellite Observations for the IPCC Process
A NASA-DOE Collaboration led by JPL & PCMDI

**MOTIVATION**
- Observation-based “metrics” are necessary for assessing and improving model capabilities, as well as for quantifying climate projection uncertainty.
- NASA has a wealth of satellite observations that have yet to be fully exploited for this purpose.

**ACTIVITY**
- Deliver a wide range of NASA satellite data relevant to IPCC AR5 quantitative model-data comparison.
- Users will have simultaneous access to model output & satellite data similarly formatted and sampled to facilitate model evaluation and improvement.
IPCC AR5 - New Emphases, Opportunities, & Needs: Emission-Based Scenarios & Coupled Carbon-Climate Models

Carbon-Climate Models are in their infancy and need significant evaluation and verification.

NASA-JPL is developing a cadre of Satellite Products/Missions to quantify the Carbon Cycle.

EOS-Era: AIRS, TES, MODIS

Decadal Survey/Climate Continuity/Ventures: OCO-2, DESDynI-R*, OCO-3*, ACE*, Ascends*, CARVE

Emission-Based GHG Scenarios
Coupled Carbon-Climate Models used to determine Atmospheric and other Concentrations

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* Proposed Missions
IPCC AR5 - New Emphases, Opportunities, & Needs: Decadal Predictions

Decadal Predictions:
• Less dependent on GHG scenario
• Afford higher resolution
• Near-term decision support

Downscaling Global Decadal Predictions with Regional Climate Models is key to providing needed local details for decision-support

JPL/UCLA are Constructing a Regional Climate Model Evaluation System Based on Cutting Edge Satellite Observations
Earth Science Outreach Center

Background:
• In fall 2009, JPL was awarded $600k in Stimulus funds for thematic Earth Science outreach support. The majority of those funds were designated to improve the visitor experience in Earth Sciences at JPL. JPL contributed an additional $300k in facilities funds.
• In the spring of 2010, building 264 was approved for the Center.
• Construction of the Center will be completed in December 2010 and opened in January 2011.
Global Climate Change Website

Launched June 15, 2008

News…key climate change indicators…interactives…videos…NASA’s role in climate science research

- Start-up funding from JPL’s Global Change and Energy Group
- 1.2 million hits/99,000 page views in first two weeks
- Quickly top 10 Google search result for ‘Global Climate Change’

“…One of the most stimulating, most thorough climate tracking sites you’ll find anywhere on the web.”

CNN.com, Oct. 13, 2008

Vital Signs Widget
Adoption by NASA HQ & 2 Webby Awards

July 2009: Site re-launched with updated look, switch to NASA URL and HQ sponsorship.

climate.nasa.gov

“The Best Science Site”
2010 (Public) & 2011 (Judges)

five-word Webby speech:
“Earth: Your future, our mission”
Thank you for visiting.