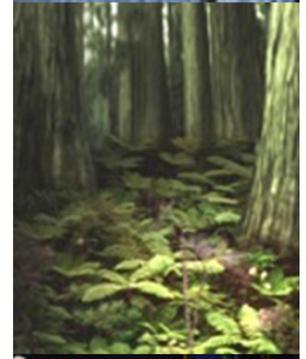
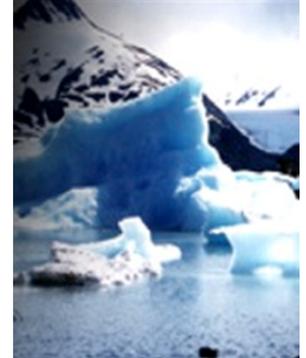
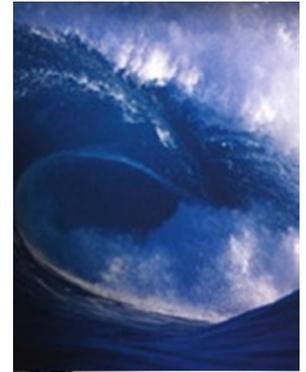


Earth Science at JPL

Dr. Duane Waliser
Chief Scientist
Earth Science and Technology Directorate
Jet Propulsion Laboratory/
California Institute of Technology

Presentation to
NTU/Taiwan Delegation
September 1, 2011



Outline

- **Satellite Assets**
- **Thrust Areas**
 - Water Cycle
 - Carbon Cycle
 - Sea Level
 - Natural Hazards
- **Integration**
 - Center for Climate Science



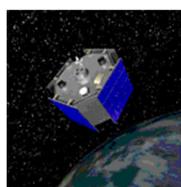
JPL Earth Science Flight Projects - 2011



Operational



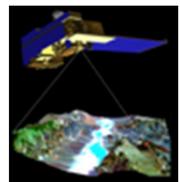
QuikSCAT
(1999)



ACRIMSAT
(1999)



Jason-1
(2001)



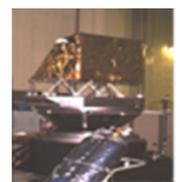
ASTER
(1999)



MISR
(1999)



GRACE
(2002)



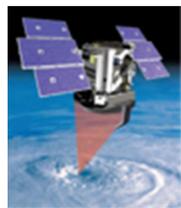
AIRS
(2002)



TES
(2004)



MLS
(2004)

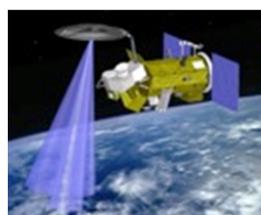


CloudSat
(2006)



Ocean Surface
Topography
Mission
(2008)

Proposed Development/Formulation



Aquarius
(2011)



GRACE-FO
(8/2016)



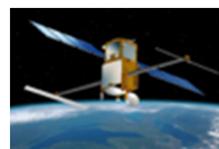
Jason 3*
(2013)



DESDynI
(2017)



OCO-2
(2/2013)



SWOT
(2019)

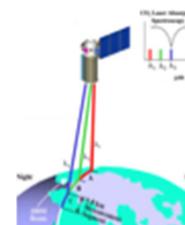


SMAP
(11/2014)



OCO-3
(NLT 2015)

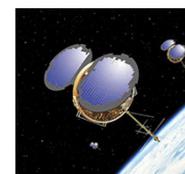
Mission Studies



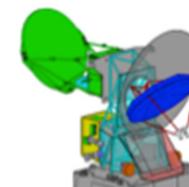
ASCENDS CO₂



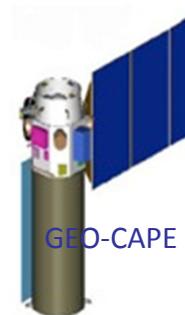
HyspIRI



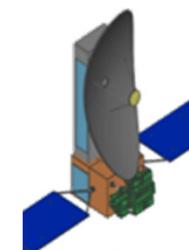
GPSRO*



Ocean Vector
Winds*



GEO-CAPE



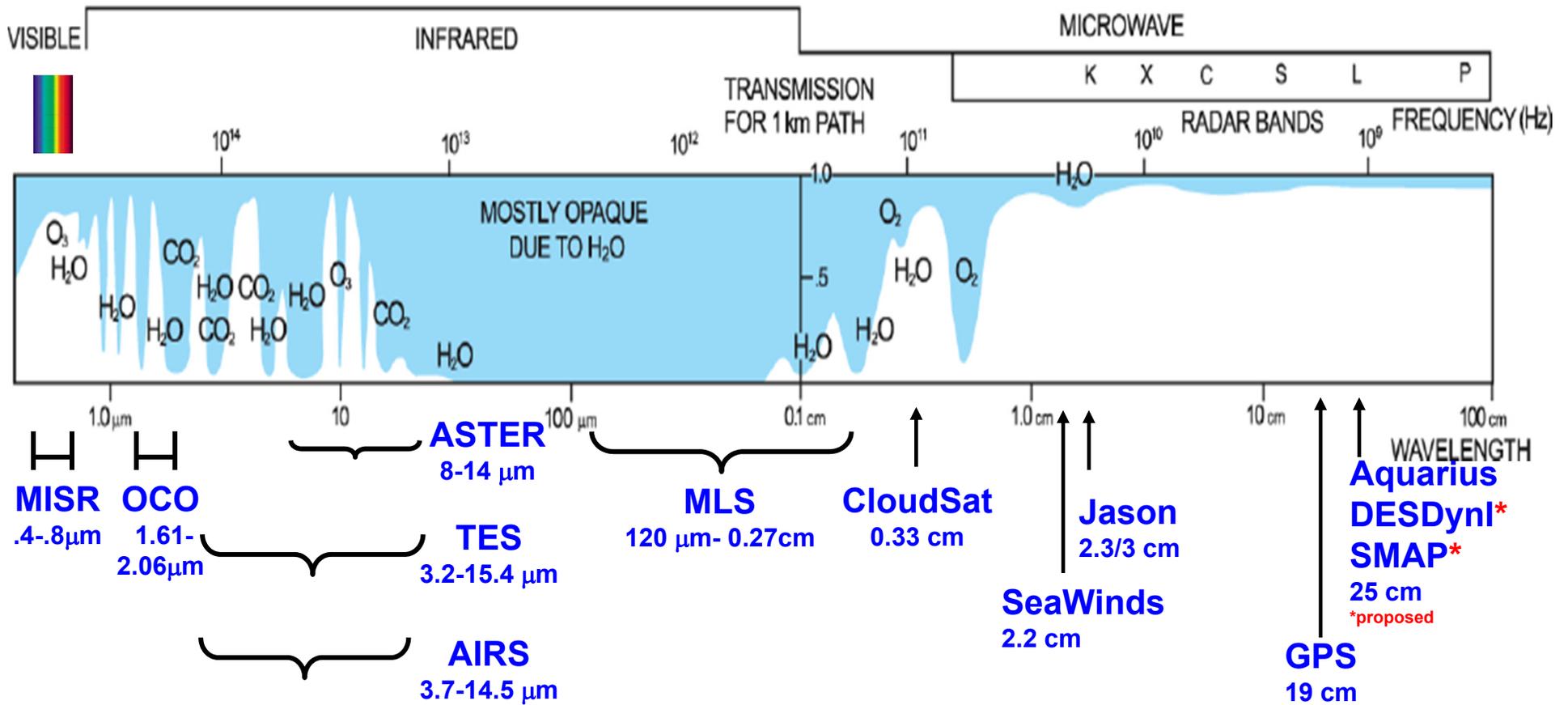
ACE

*NOAA

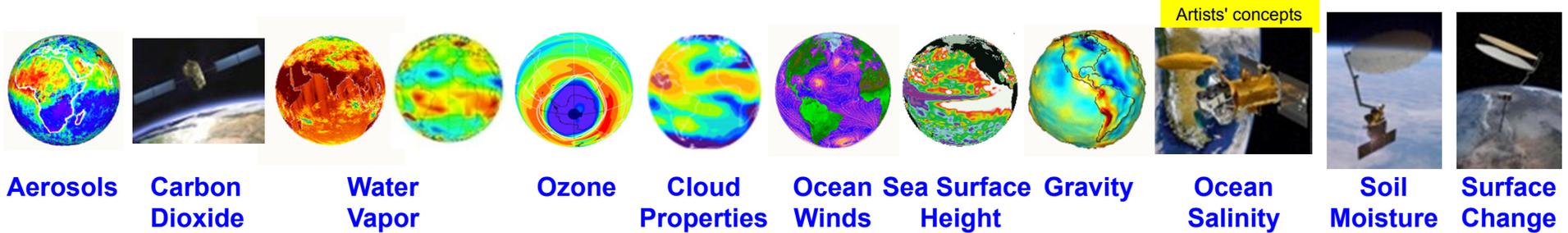
Artists' concepts

Pre-decisional Material - for Planning and Discussion Purposes Only

Seeing Earth in a New Way



Pre-decisional - for Planning and Discussion Purposes Only

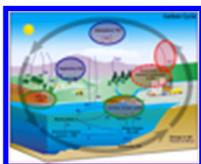


Earth Science Research Thrust Areas

Observations -> Research -> Applications -> Decision-Support



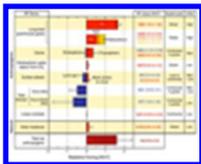
Carbon & GHGs



Water Cycle



Clouds, Vapor & Aerosol



Sea Level



Natural Hazards



Consider:
Need

Expertise

Resources

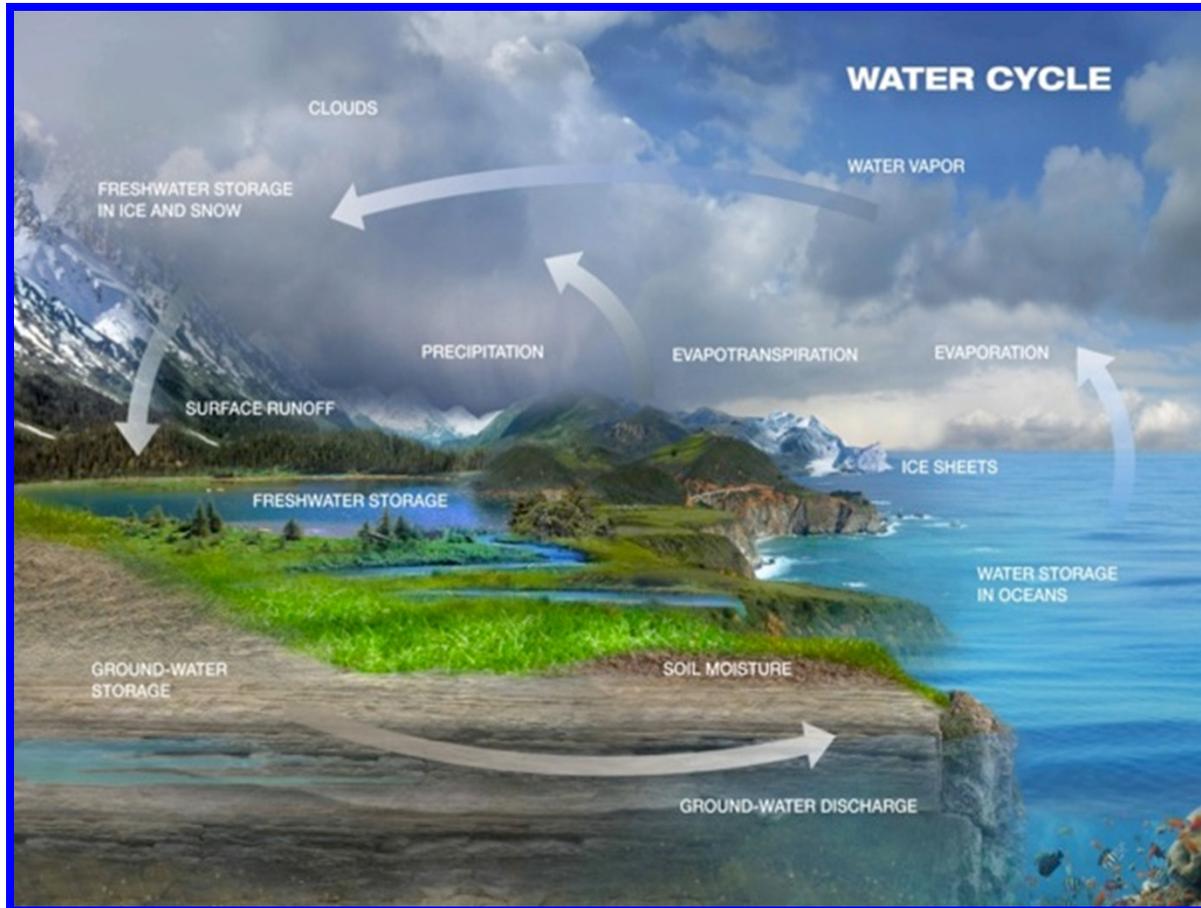
Funding

Potential

Outline

- Satellite Assets
- Thrust Areas
 - Water Cycle
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The Water Cycle



GRAVITY

Groundwater, ice sheets

RADAR

Ice sheets, lake, river & ocean levels, cloud mass, salinity

RADIOMETER

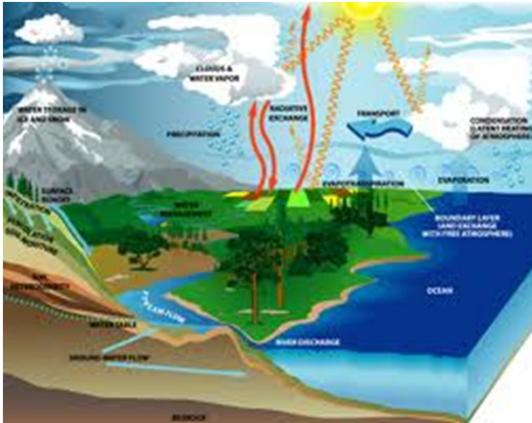
Soil moisture, sea ice, clouds, water vapor, salinity

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.



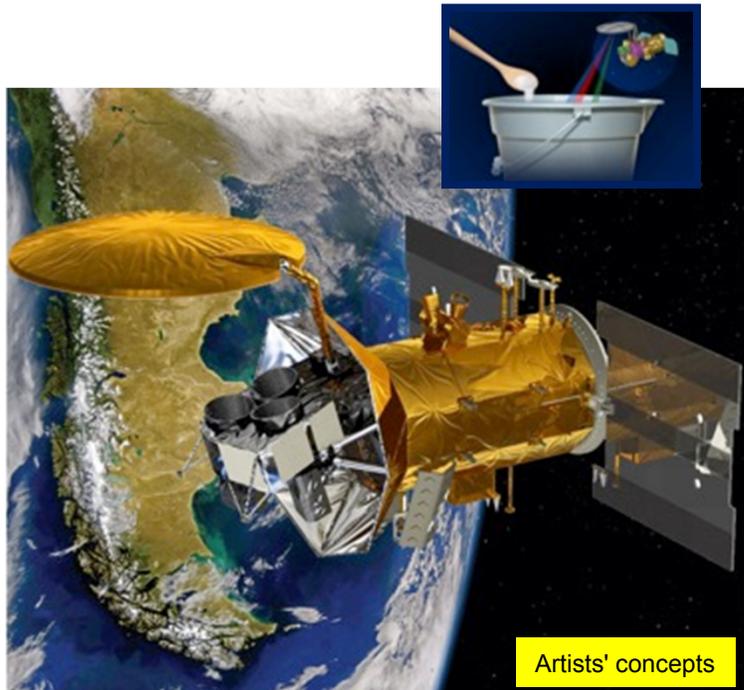
JPL Assets and Expertise



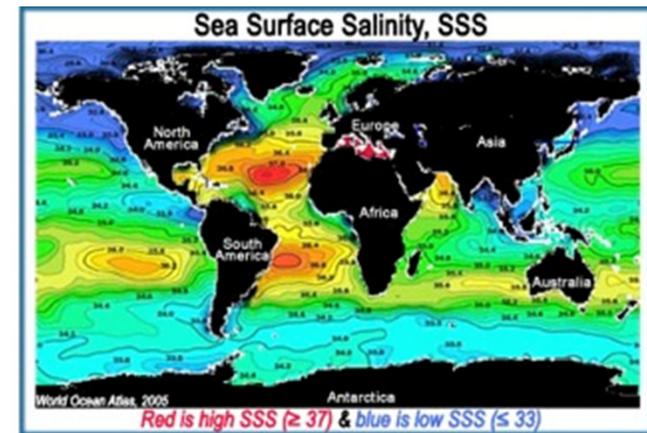
GRACE, MODIS/SNOW, AMSR-E, AVIRIS, SMAP*, SWOT*, UAVSAR, etc., *proposed missions

Measuring Sea Surface Salinity

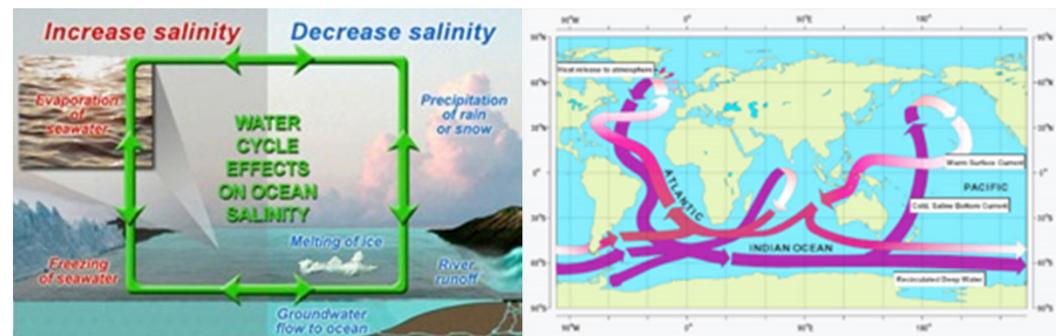
Aquarius (Launched June 2011)



Important roles in global water budget and helping drive ocean circulation



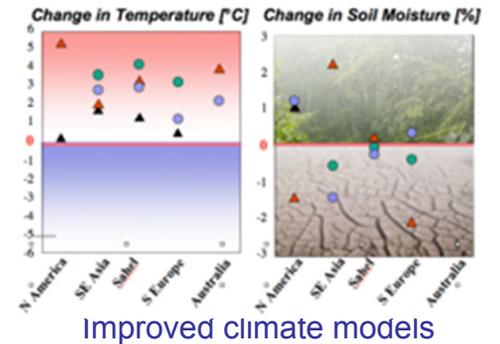
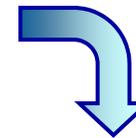
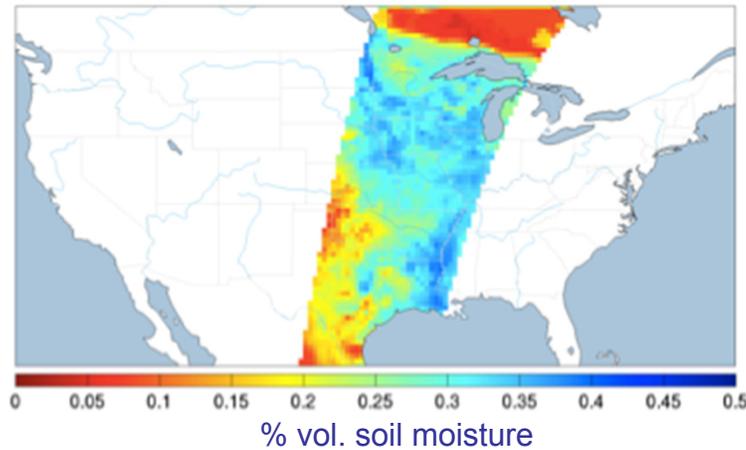
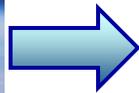
Aquarius will use an L-band radar and radiometer to make monthly maps of sea surface salinity with precision of .2 PSU and resolution of 150 x 150 km.



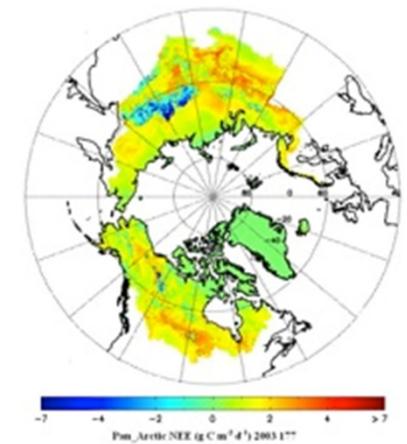
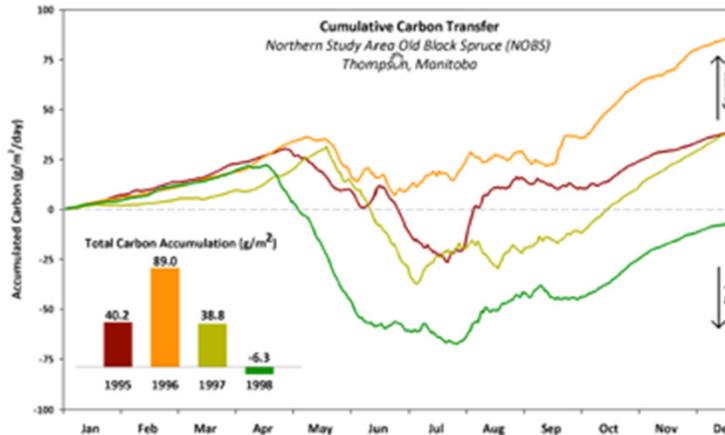
Measuring Soil Moisture

Proposed Soil Moisture Active and Passive (SMAP)

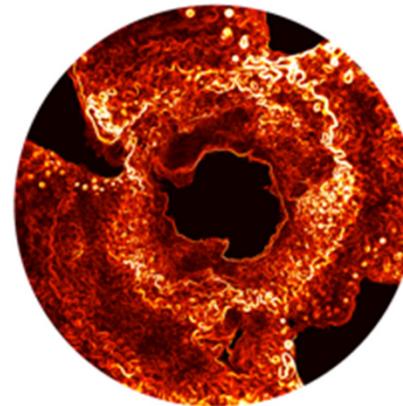
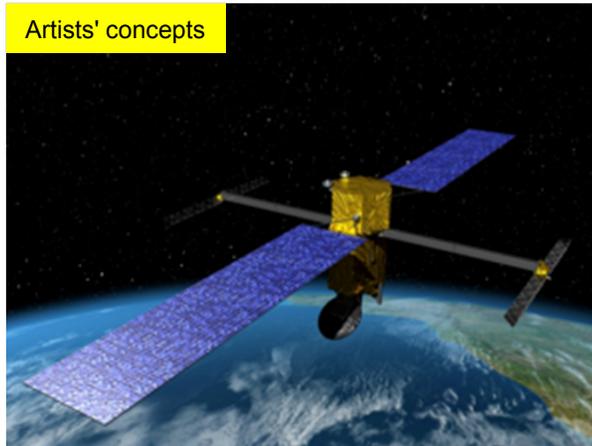
Vital information for weather forecasts and evaluating climate models



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

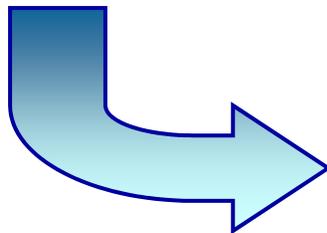


Proposed Surface Water and Ocean Topography (SWOT)

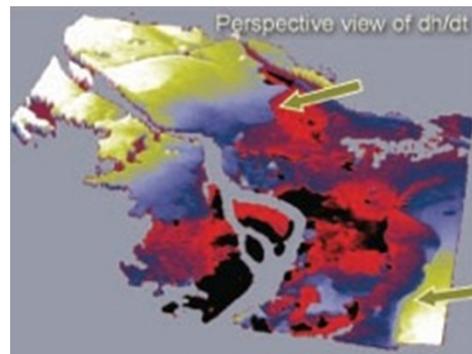


Ocean Circulation

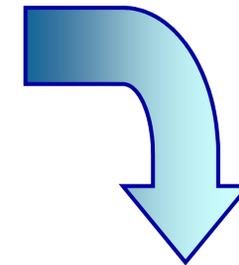
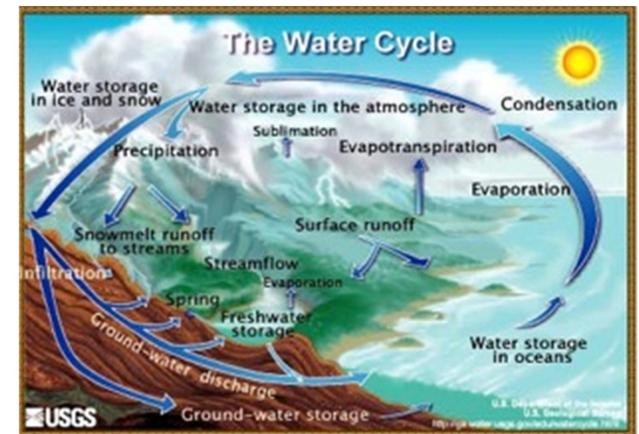
SWOT measurements would be critical to determining surface water availability and the ocean's capacity to absorb heat and carbon from the atmosphere.



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.



Fresh Water Storage



Partners: CNES, CSA

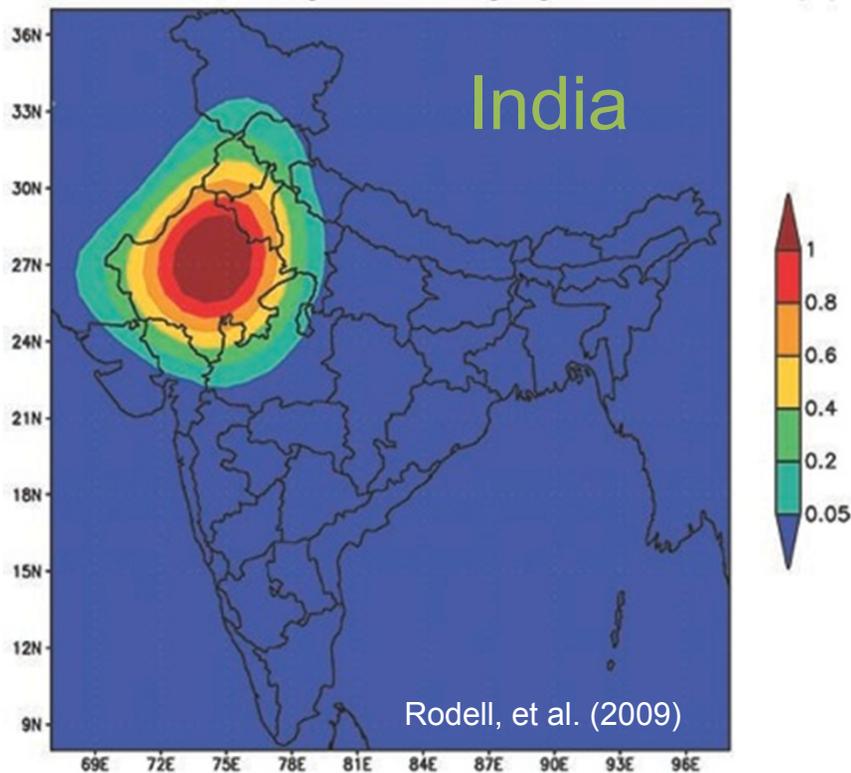
LRD: 2019

Ground Water Depletion Observed by GRACE

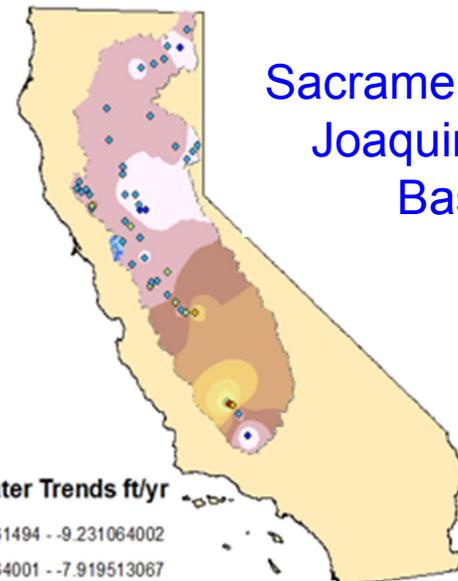
Artists' concept



GRACE (2002-Present)



Groundwater levels declining by about 1 – 5 meters every 3 years



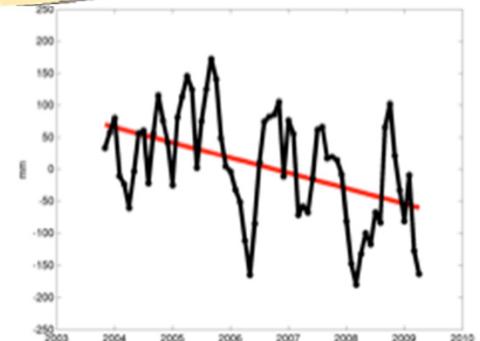
Sacramento - San Joaquin River Basin

Ground Water Trends ft/yr

Dark Green	-10.54261494 - -9.231064002
Green	-9.231064001 - -7.919513067
Light Green	-7.919513066 - -6.607962132
Yellow-Green	-6.607962131 - -5.296411196
Yellow	-5.296411195 - -3.984860261
Orange	-3.98486026 - -2.673309326
Brown	-2.673309325 - -1.361758391
Pink	-1.36175839 - -0.050207456
Light Pink	-0.050207456 - 1.261343479

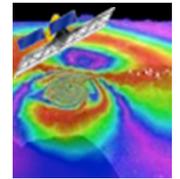
Groundwater levels declining by 1 meter every 3 years.

More than 109 cubic km of groundwater disappeared between 2002 and 2008

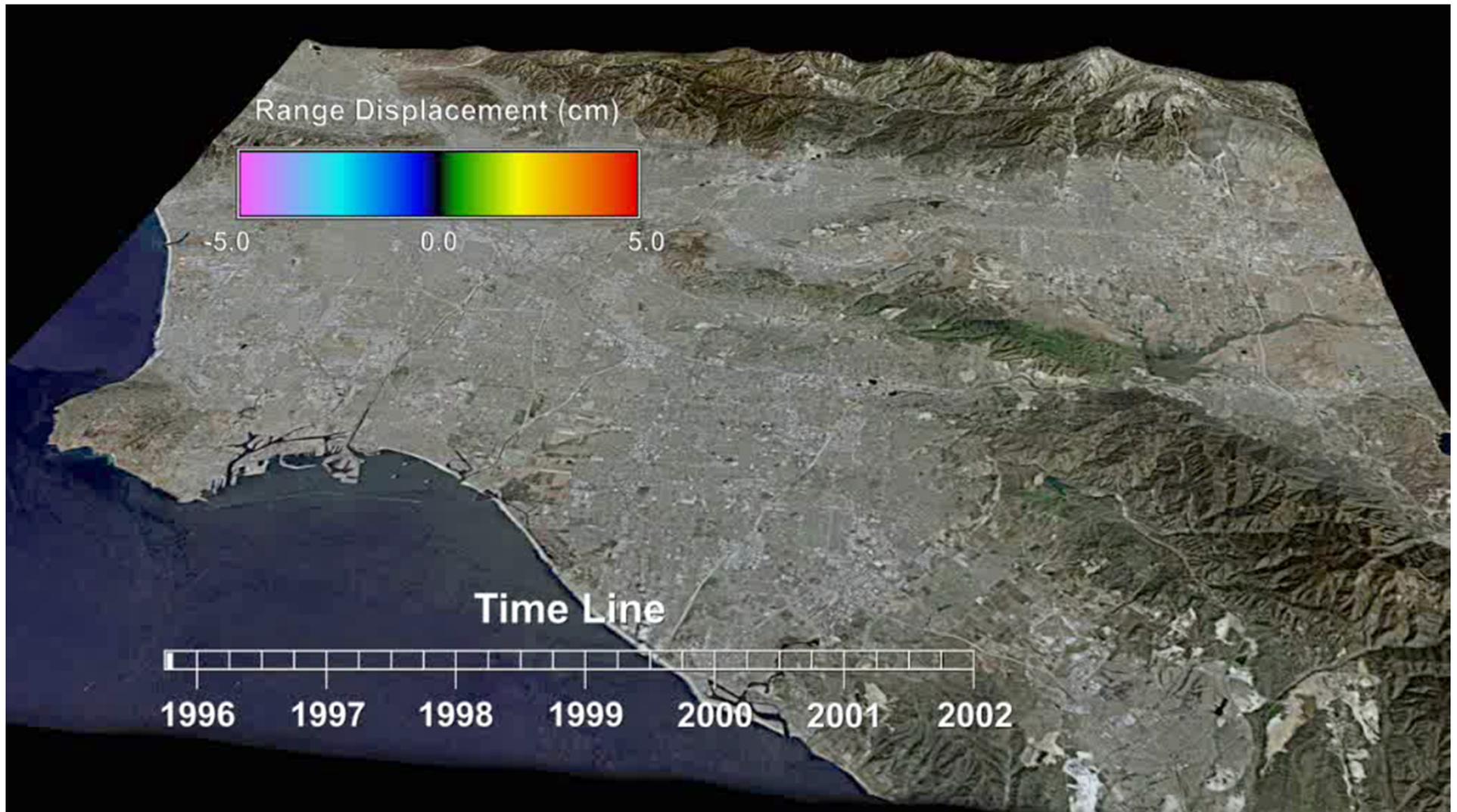


Measuring Surface Deformation Aquifers in the LA Basin

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



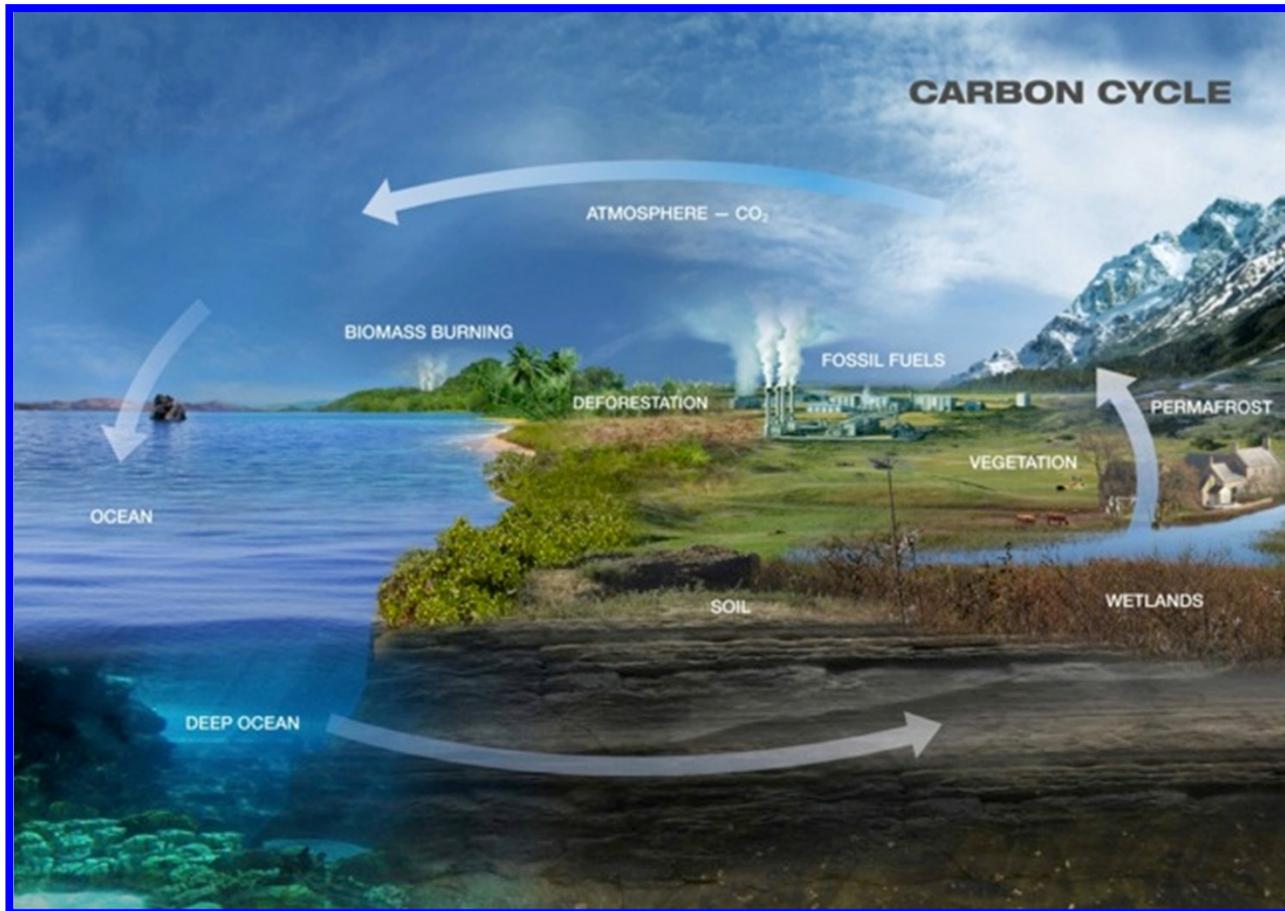
DESDynI



Outline

- Satellite Assets
- Thrust Areas
 - Water Cycle
 - Carbon Cycle
 - Sea Level
 - Natural Hazards
- Integration
 - Center for Climate Science

Carbon Cycle



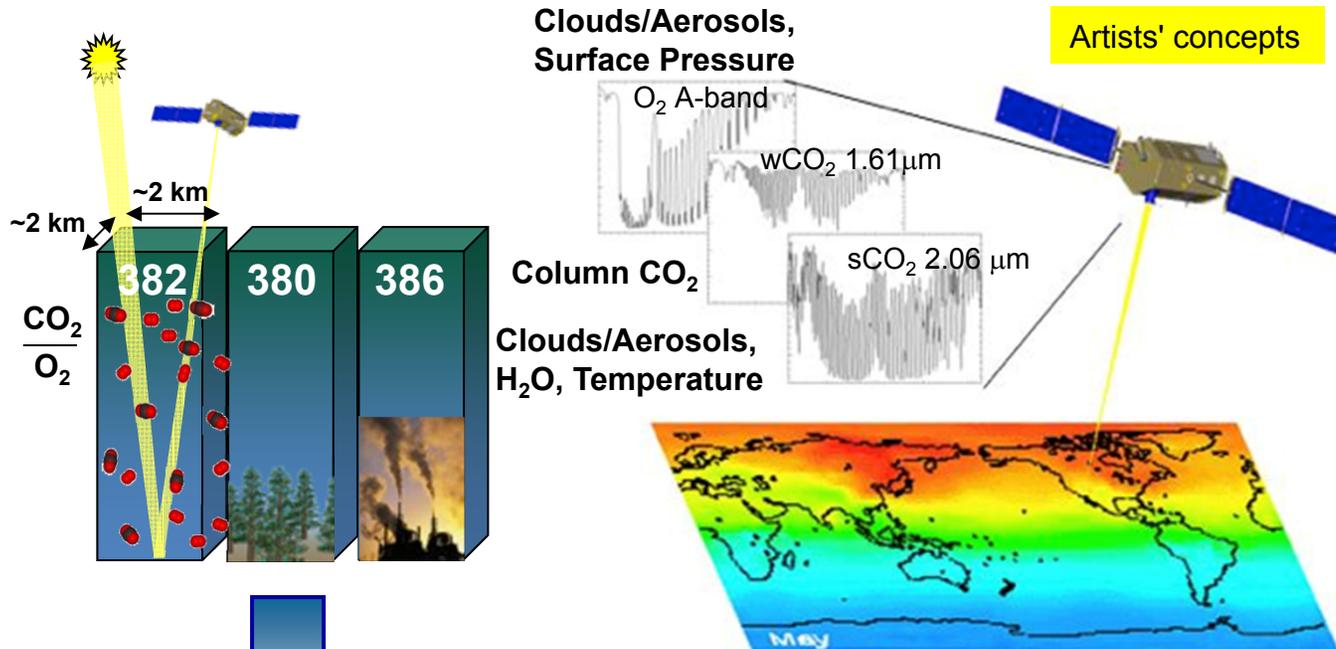
Spectrometer
CO₂, CO, Methane

RADAR
Freeze/Thaw
Biomass

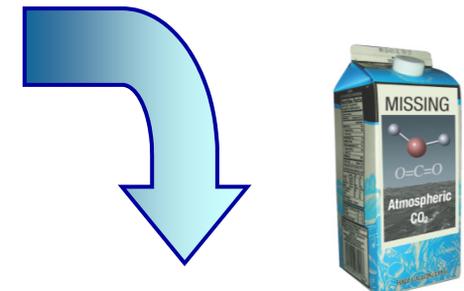
Lidar
Vegetation Structure

Optical
Land Cover Change
Ocean Color

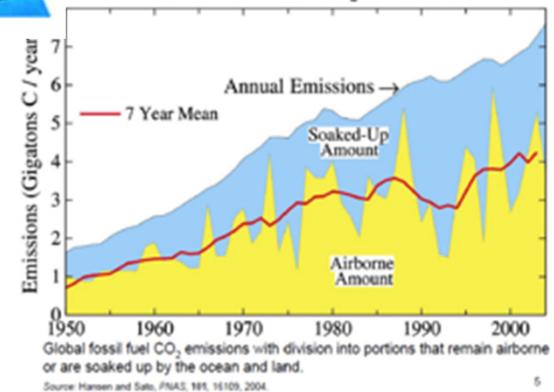
Orbiting Carbon Observatory (OCO-2)



Only ~58% of the >200 Gt C humans have added to the atmosphere since 1958 is staying in the atmosphere



Global Fossil Fuel CO₂ Emissions



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

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?

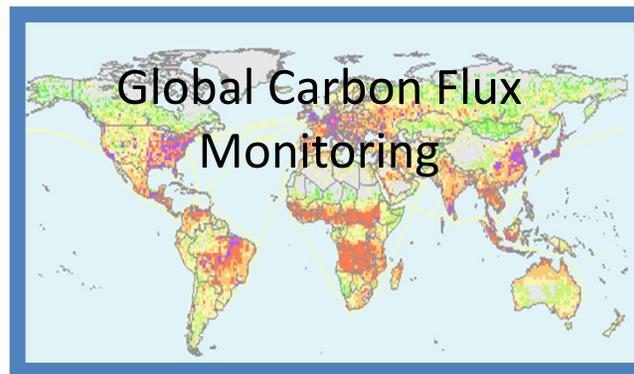
Is Country-A meeting emission stabilization commitments (or more business-as-usual)?

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)?



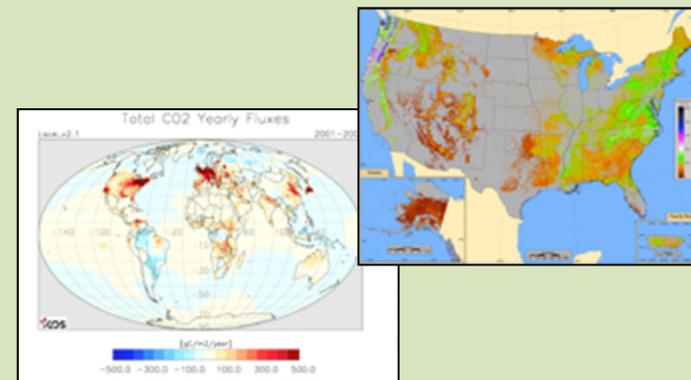
JPL: In The Vanguard of Two National Efforts



- 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)

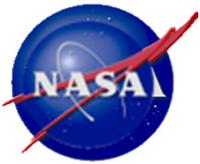
- New congressional mandate for sustained decision support
- 2 Pilot Projects
- FY' 11 Science Definition Team Call
- Scoping/Design Study



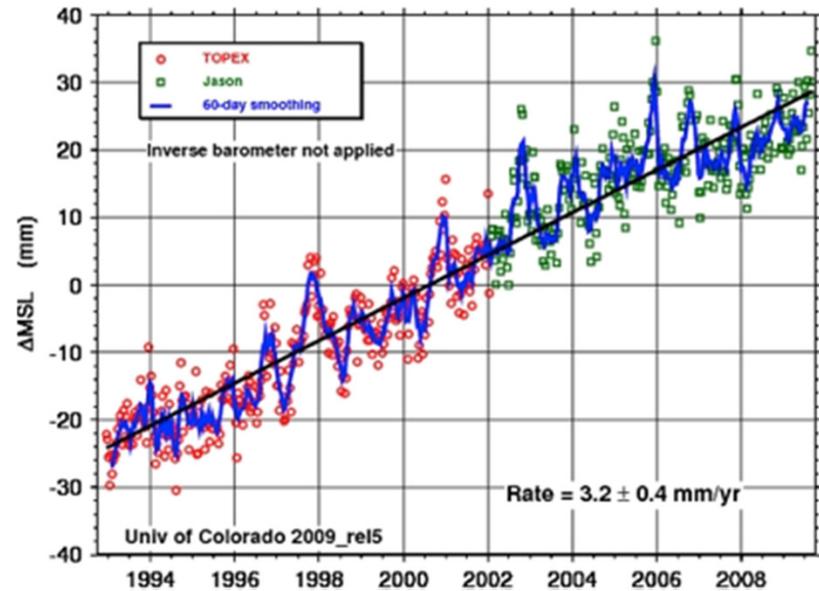
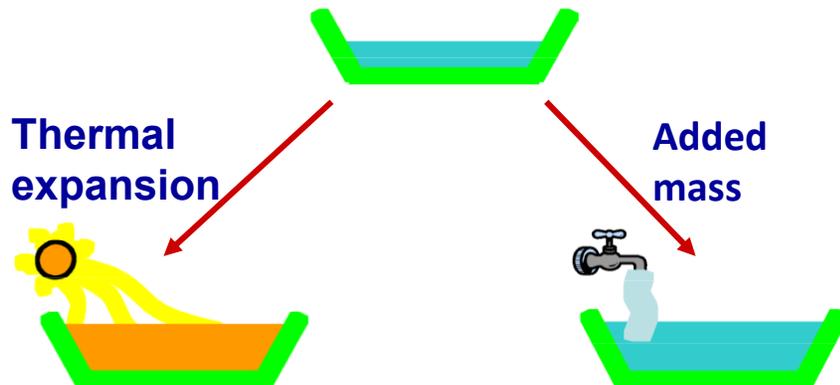
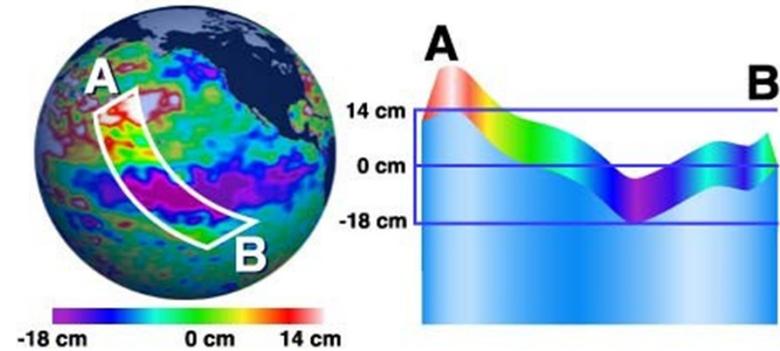
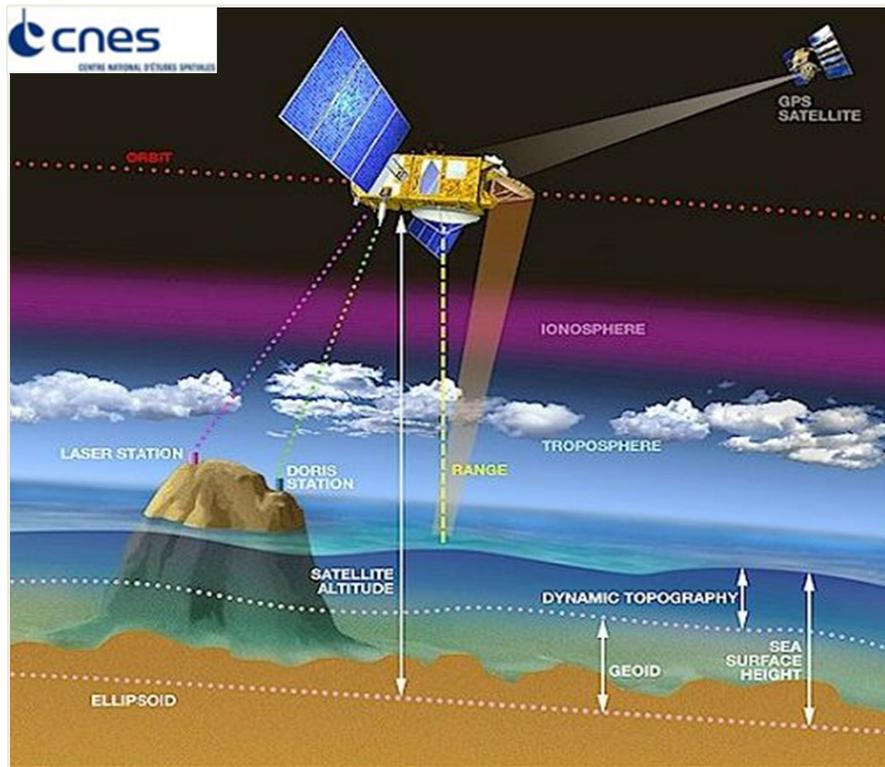
Outline

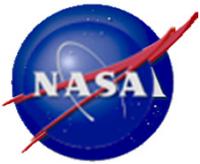
- Satellite Assets
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 - Water Cycle
 - Carbon Cycle
 - **Sea Level**
 - Natural Hazards
- Integration
 - Center for Climate Science



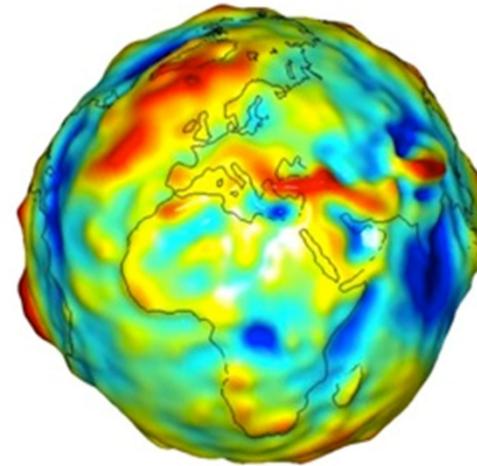
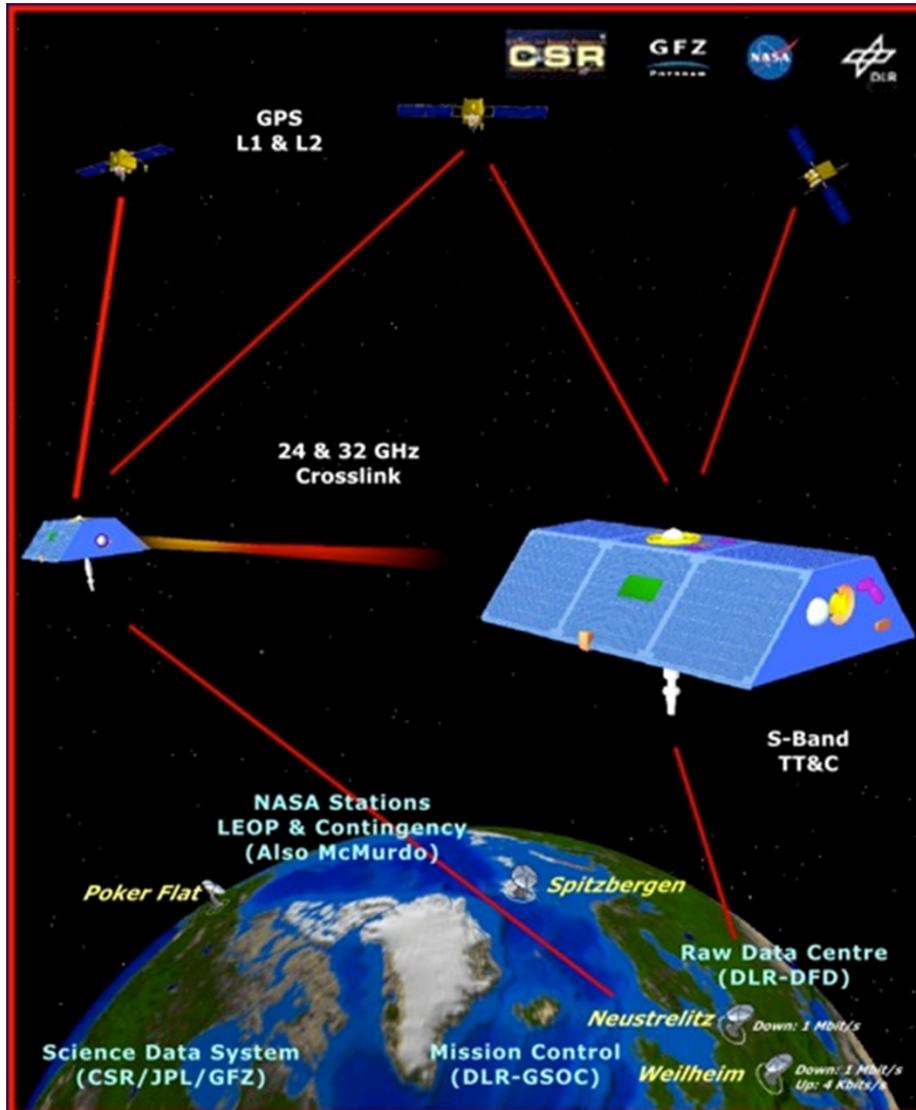


Measuring Changes in Sea Level

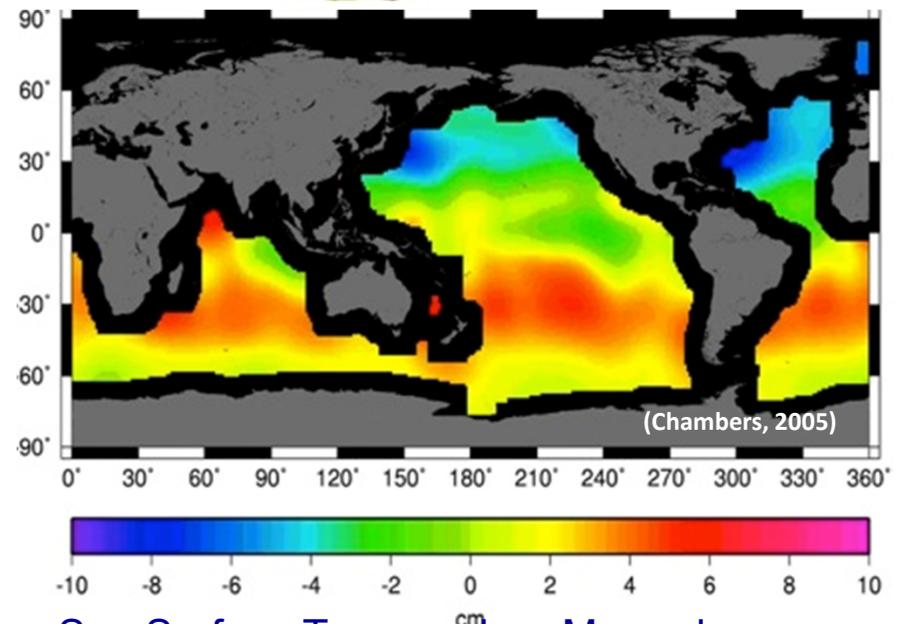




Gravity Recovery and Climate Experiment (GRACE)

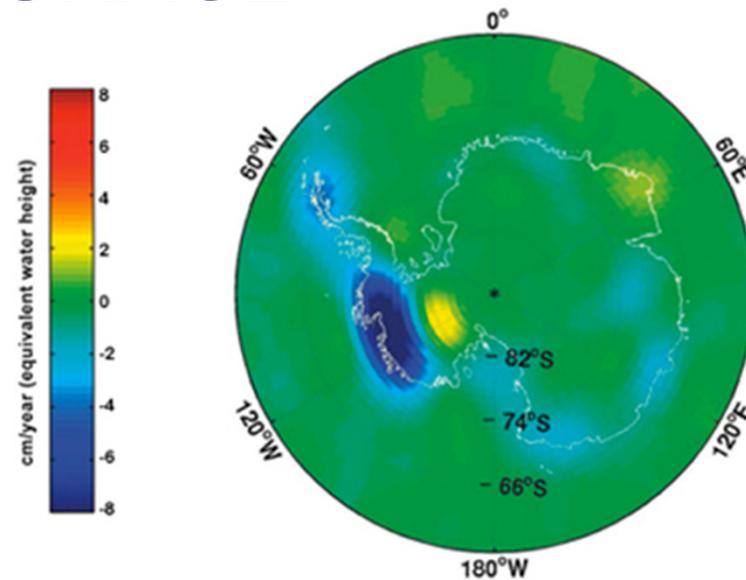
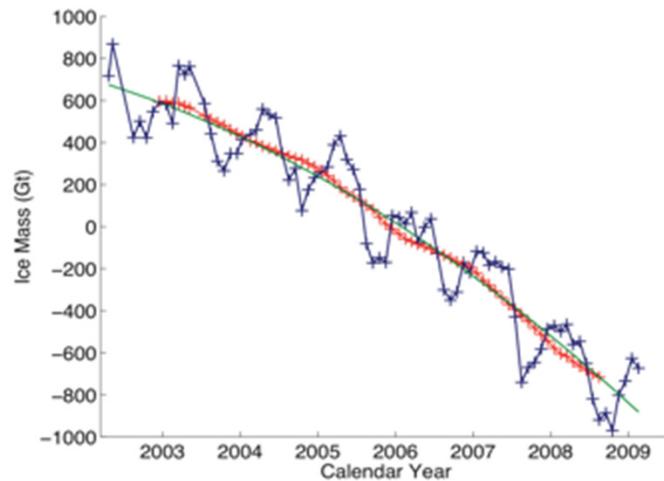
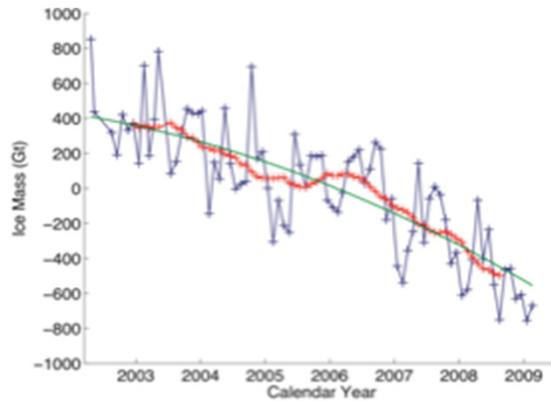


GRACE Gravity Model



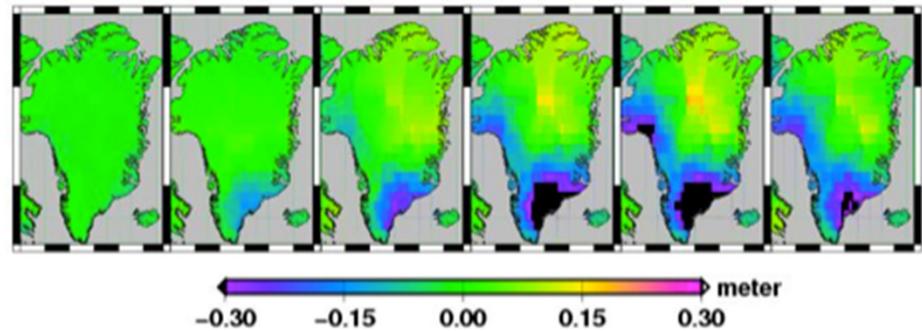
Sea Surface Topography - Mass change = Thermal Expansion of the ocean

Measuring Changes In Ice Mass with GRACE



University of Texas at Austin Center for Space Research

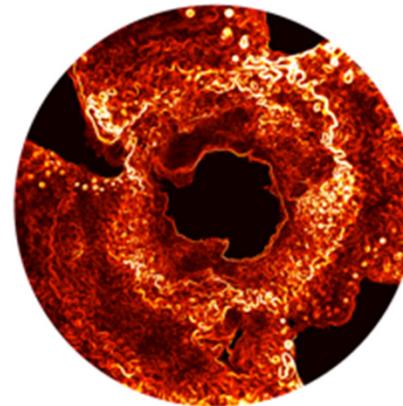
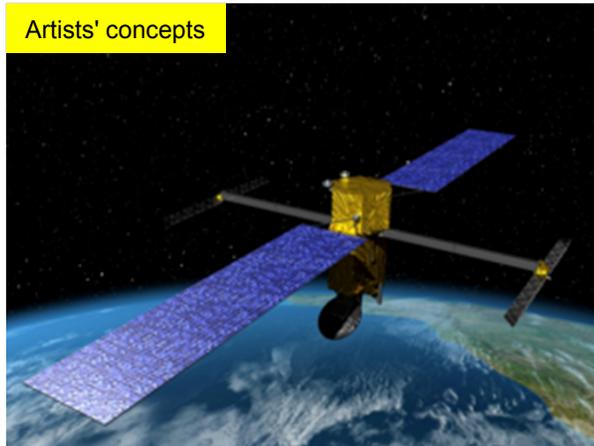
2004 2005 2006 2007 2008 2009



(from Velicogna et al, 2009)

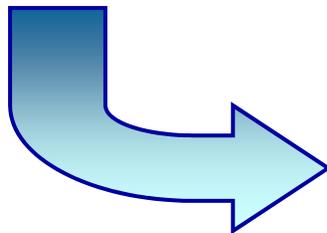
From Watkins et al, 2009

Proposed Surface Water and Ocean Topography (SWOT)

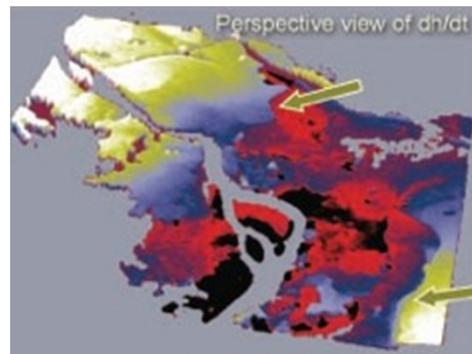


Ocean Circulation

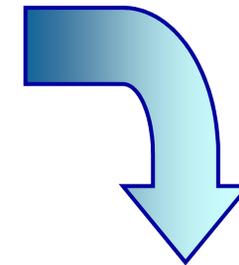
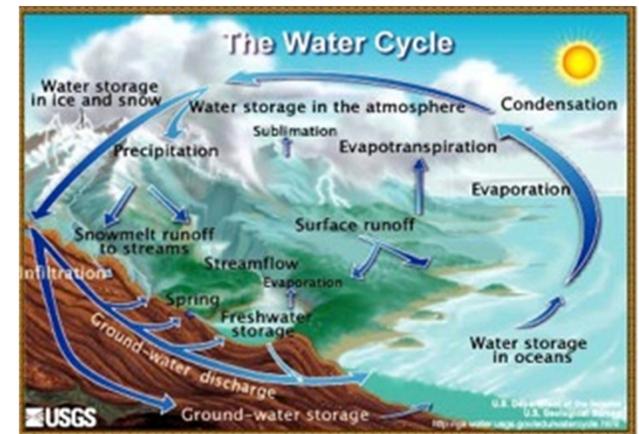
SWOT measurements would be critical to determining surface water availability and the ocean's capacity to absorb heat and carbon from the atmosphere.



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.



Fresh Water Storage



Partners: CNES, CSA

LRD: 2019

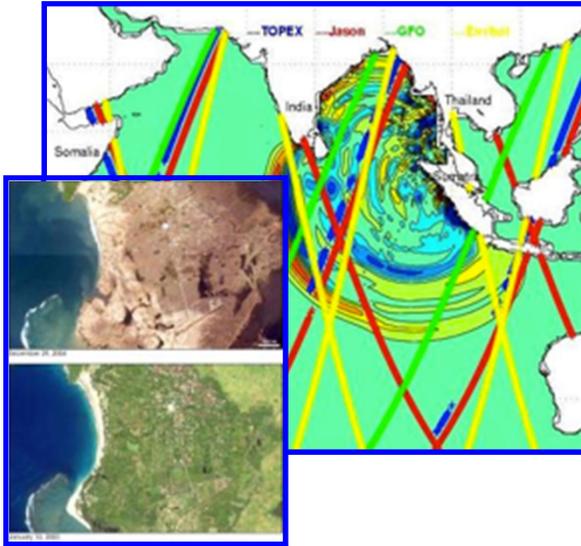
Outline

- Satellite Assets
- Thrust Areas
 - Water Cycle
 - Carbon Cycle
 - Sea Level
 - Natural Hazards
(Earthquake, Volcano, Tsunami)
- Integration
 - Center for Climate Science



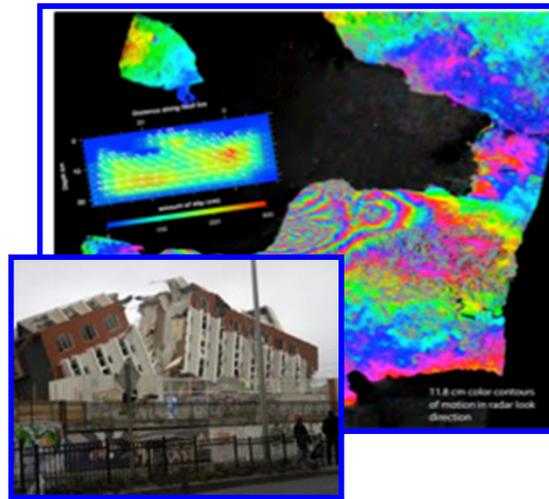
Contributions To Natural Hazard Applications & Partnerships

Tsunamis



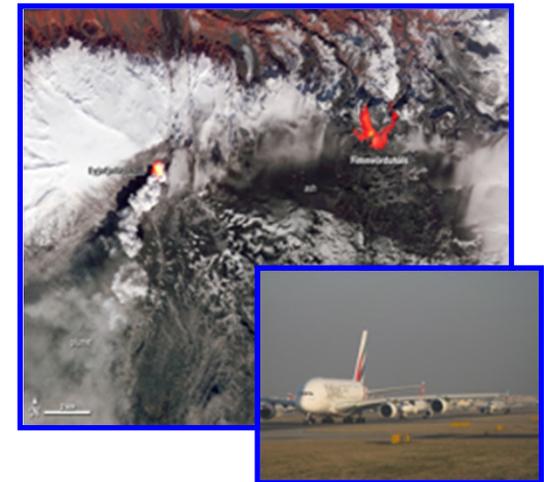
GREAT Warning System
(Obs Assets: JASON, GPS)

Earthquakes



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

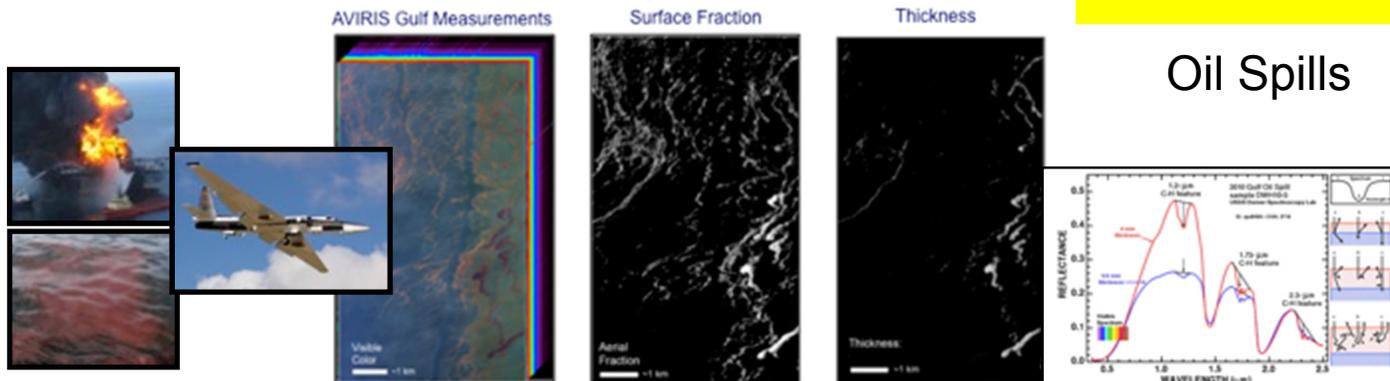
Volcanoes



(Obs Assets: ASTER,
GPS, SAR)

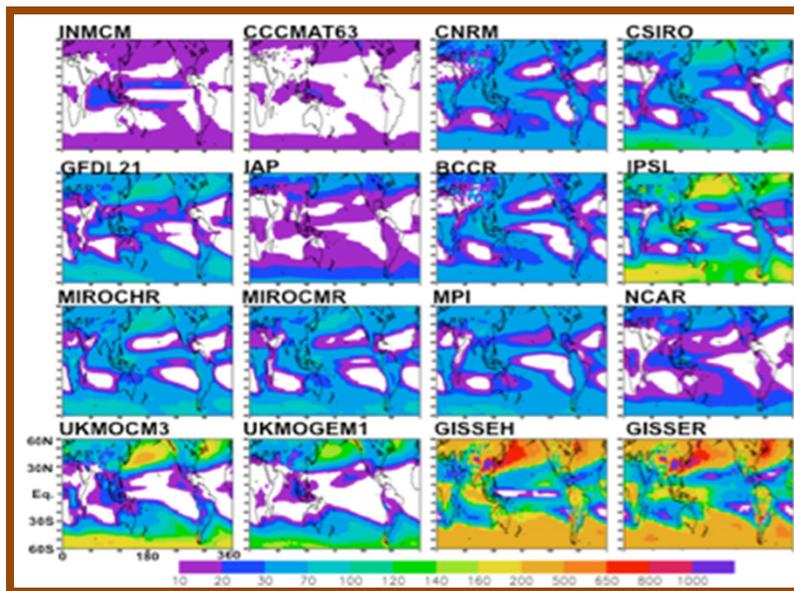
Pre-decisional - for Planning and Discussion Purposes Only

Oil Spills

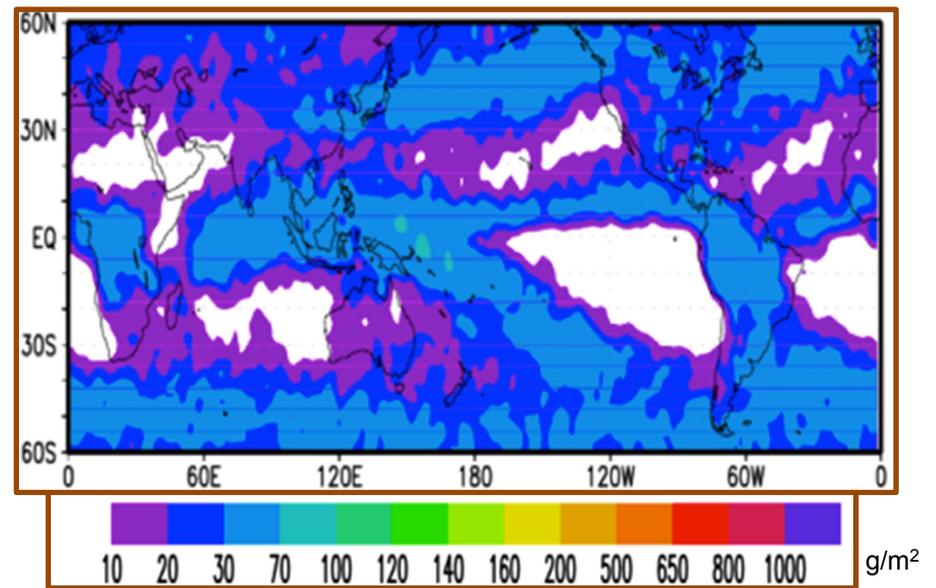


(Obs Assets:
AVRIS,
Imaging
Spectrometer)

Model-Data Comparisons for IPCC Assessment (AR5)

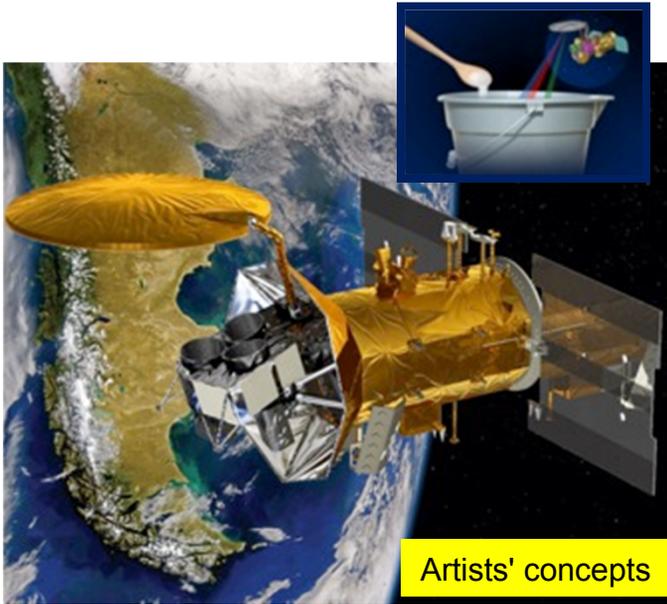


Estimates of Cloud Ice Concentrations from Models Used in the IPCC 4th Assessment



Actual Global Ice Concentrations Observed by CloudSat

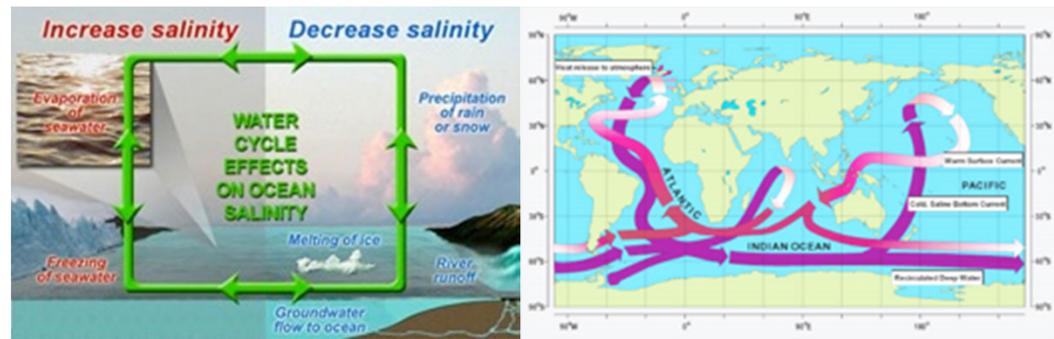
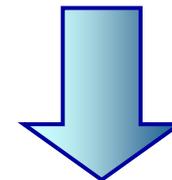
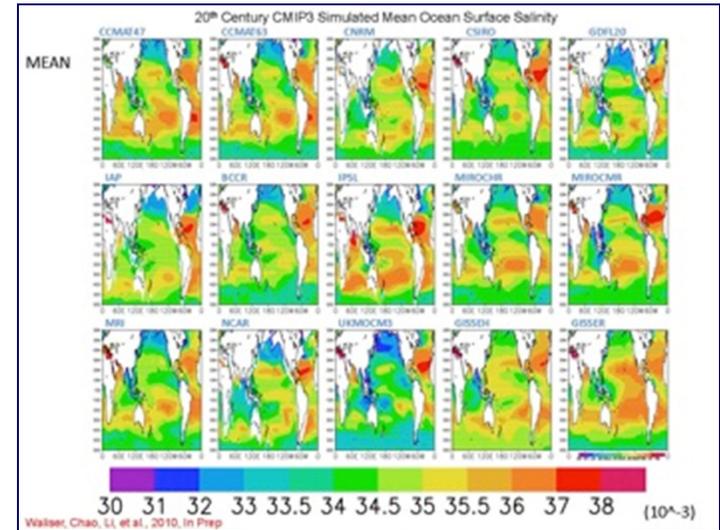
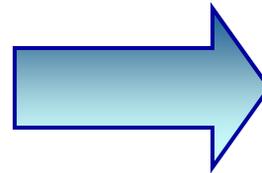
Aquarius



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 ($.2 \text{ gkg}^{-1}$) and resolution of $150 \times 150 \text{ km}$



Environmental testing underway in Brazil



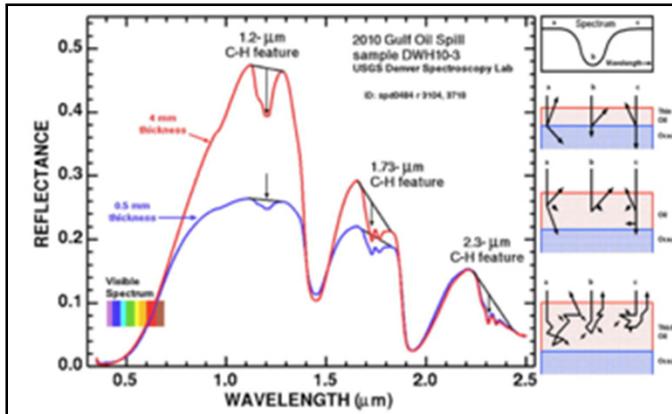
Partners: CONAE (INPE, ASI, CNES, CSA)

LRD: 06/09/2011

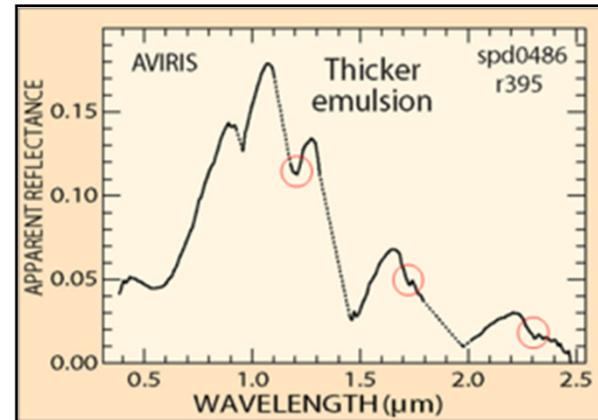
Imaging Spectroscopy Used by NASA, USGS, and NOAA to Estimate Thickness and Volume of Surface Oil



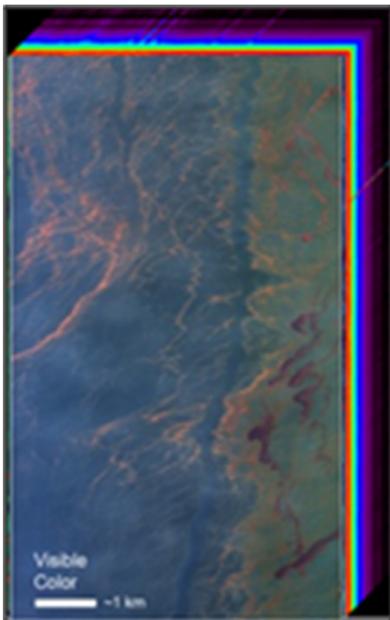
Spectroscopic Basis: Infrared C-H Bond Absorptions



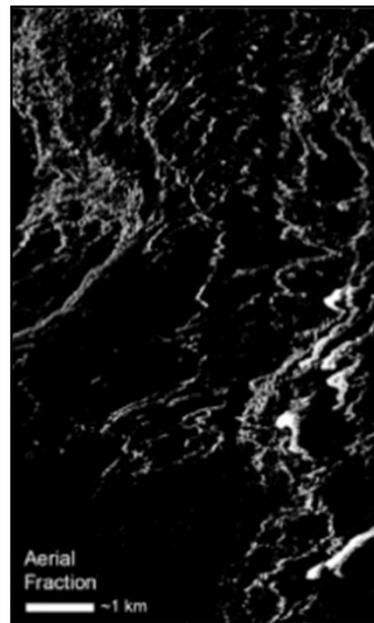
NASA AVIRIS Spectra from the Gulf



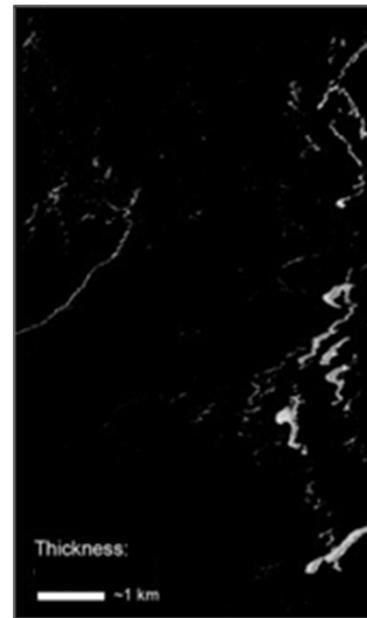
AVIRIS Gulf Measurements



Surface Fraction



Thickness



Quantitative Volume Estimates

Colno	Thicknes (mm)	Volume (liters/px)	Pixel
820 0	0.00 0.00 0.00	1109.7 1109.7 1109.7	171
820 0	0.00 0.00 20.00	10714.7 10714.7 428806.0	609
820 0	0.00 1.00 20.00	129812.3 291382.9 3064300.3	2447
820 0	2.00 6.00 20.00	8229.2 19408.6 82291.9	72
80020	0.00 1.00 20.00	330680.6 696120.9 6813411.9	7841
78025	0.00 1.00 20.00	28007.7 28007.7 379436.1	855
60040	0.00 0.00 0.00	2.2 4.5 6.5	9
60040	0.00 0.00 0.00	47.5 95.0 95.0	123
60040	0.00 0.00 0.00	69.2 69.2 69.2	65
60040	0.00 0.00 0.00	14560.4 14560.4 14560.4	2042
60040	0.00 1.00 1.00	37030.2 44904.9 64924.3	2892
60040	0.00 0.00 20.00	122919.2 245936.4 122919.2	5127
60040	0.00 0.00 0.00	0.0 0.0 0.0	0
60040	0.00 0.00 0.00	2.1 2.1 2.1	8
60040	0.00 0.00 0.00	289.9 289.9 289.9	208
60040	0.00 0.00 0.00	879.5 1108.9 1108.9	150
60040	0.00 0.00 20.00	5824.9 11353.2 5824.9	822
23077	0.00 0.00 0.00	0.0 0.0 0.0	0
23077	0.00 0.00 0.00	0.4 0.4 0.4	7
23077	0.00 0.00 0.00	6.2 6.2 6.2	23
23077	0.00 0.00 0.00	4505.3 4505.3 4505.3	3413
23077	0.00 1.00 1.00	12498.6 15931.5 15931.5	2845
23077	0.00 0.00 20.00	2449.6 5299.2 2449.6	450
0094	0.00 0.00 0.00	3511.4 3934.2 3934.2	3334
0099	0.00 0.00 0.00	2.4 2.4 0.0	170
0099	1.00 20.00 20.00	284.5 3490.9 3490.9	720
0099	0.00 0.00 0.00	110.1 110.1 110.1	6948 low level
60040	0.00 0.00 0.00	34080.3 68160.7 68160.7	19295 low level
60040	0.00 0.00 0.00	285113.0 570226.1 570226.1	188491 track

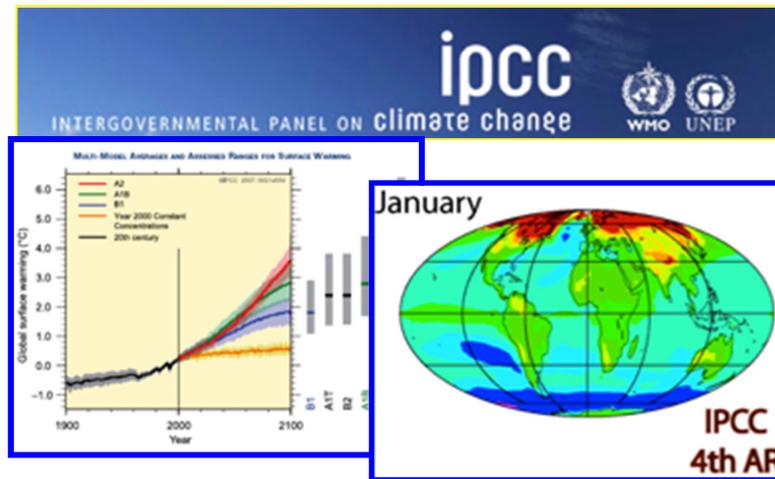
Total volume (liters):
 1143797 liters (conservative) = 7194 barrels
 1046038 liters (aggressive) = 6594 barrels
 1266667 liters (optimal) = 7964 barrels

Courtesy Rob Green (JPL)

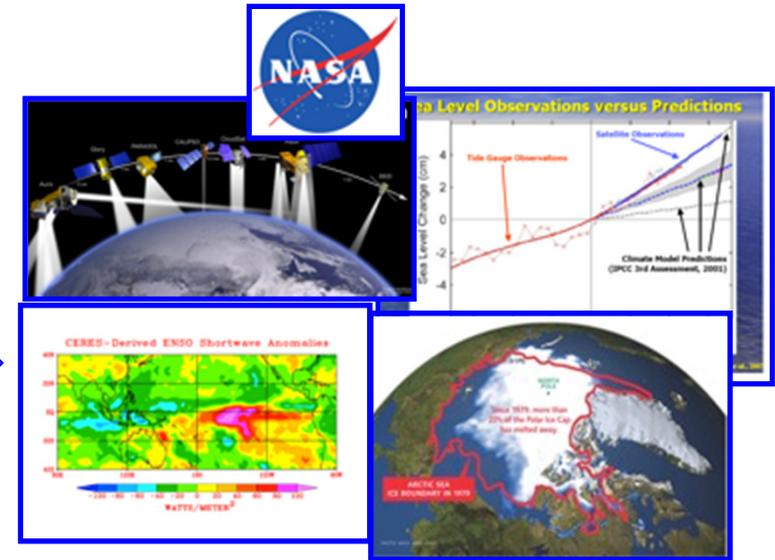
Outline

- Satellite Assets
- Thrust Areas
 - Water Cycle
 - Carbon Cycle
 - Sea Level
 - Natural Hazards
- Integration
 - Center for Climate Science

NASA and CMIP/IPCC: Better Linkage



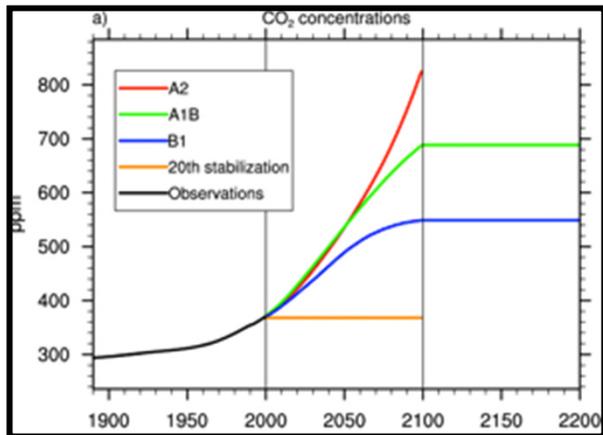
How to bring as much observational scrutiny as possible to the IPCC process?



How to best utilize the wealth of NASA Earth observations for the IPCC process?

IPCC AR5 - New Emphases, Opportunities, & Needs: Emission-Based Scenarios & Coupled Carbon

IPCC Projections



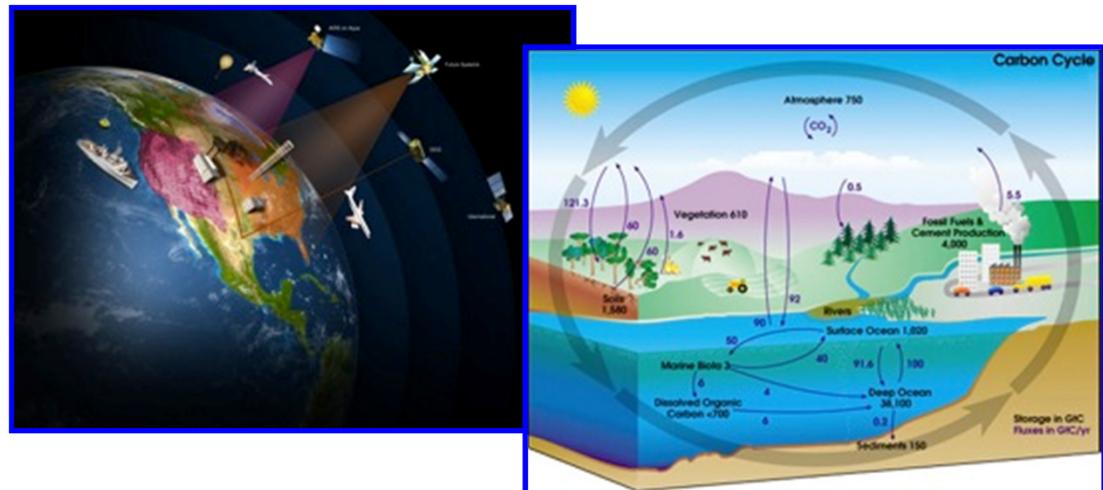
Carbon-Climate Models are in their infancy and need significant evaluation and verification

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

EOS-Era: AIRS, TES, MODIS

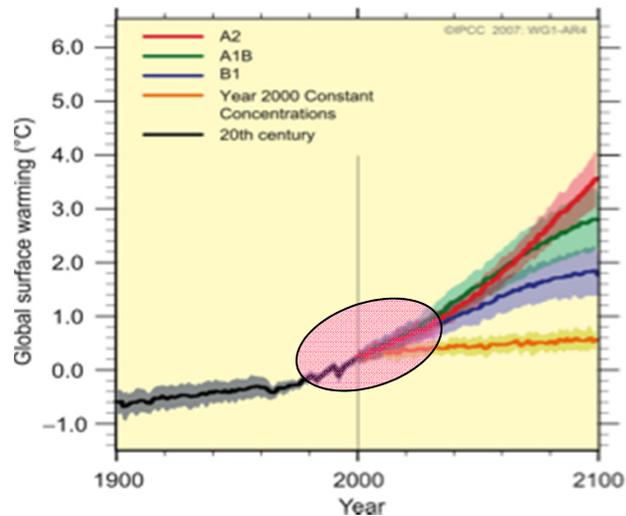
Decadal Survey/Climate Continuity/Ventures: OCO-2, DESDynI-R*, OCO-3*, ACE*, Ascends*, CARVE

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



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

IPCC Projections

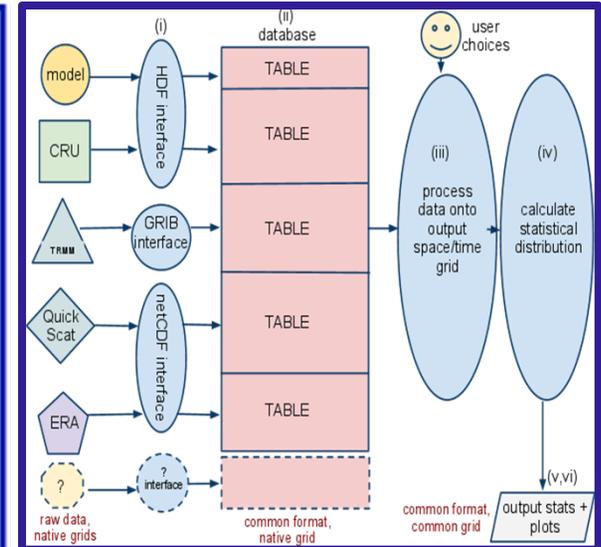
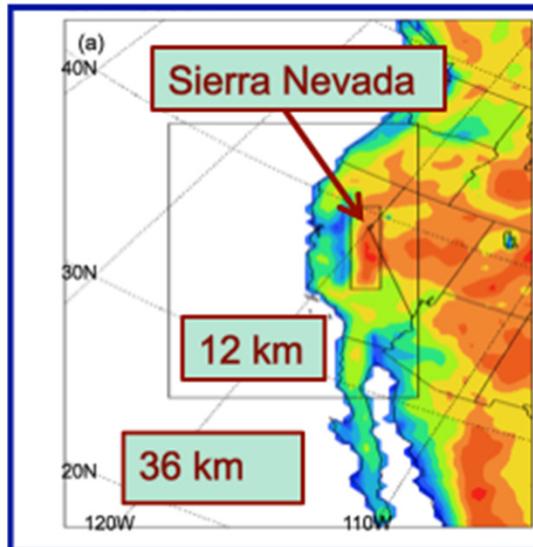


Decadal Predictions:

- *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

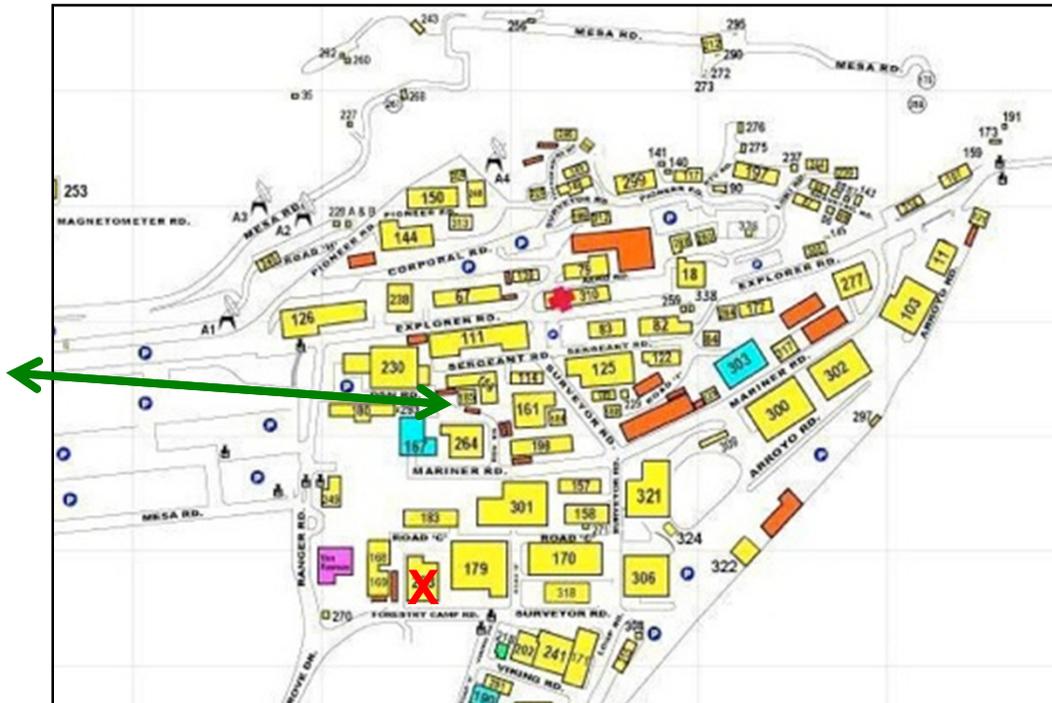
JPL/UCLA are Constructing a Regional Climate Model Evaluation System Based on Cutting Edge Satellite Observations



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.

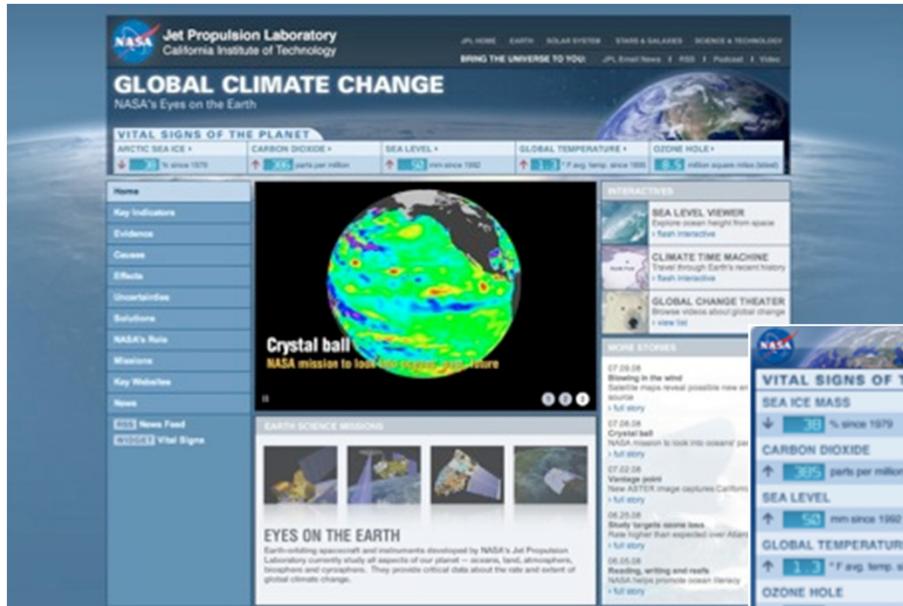


Global Climate Change Website

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'



Vital Signs Widget



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

CNN.com, Oct. 13, 2008

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



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



Five-word Webby
speech:
'Earth: Your future,
our mission'



