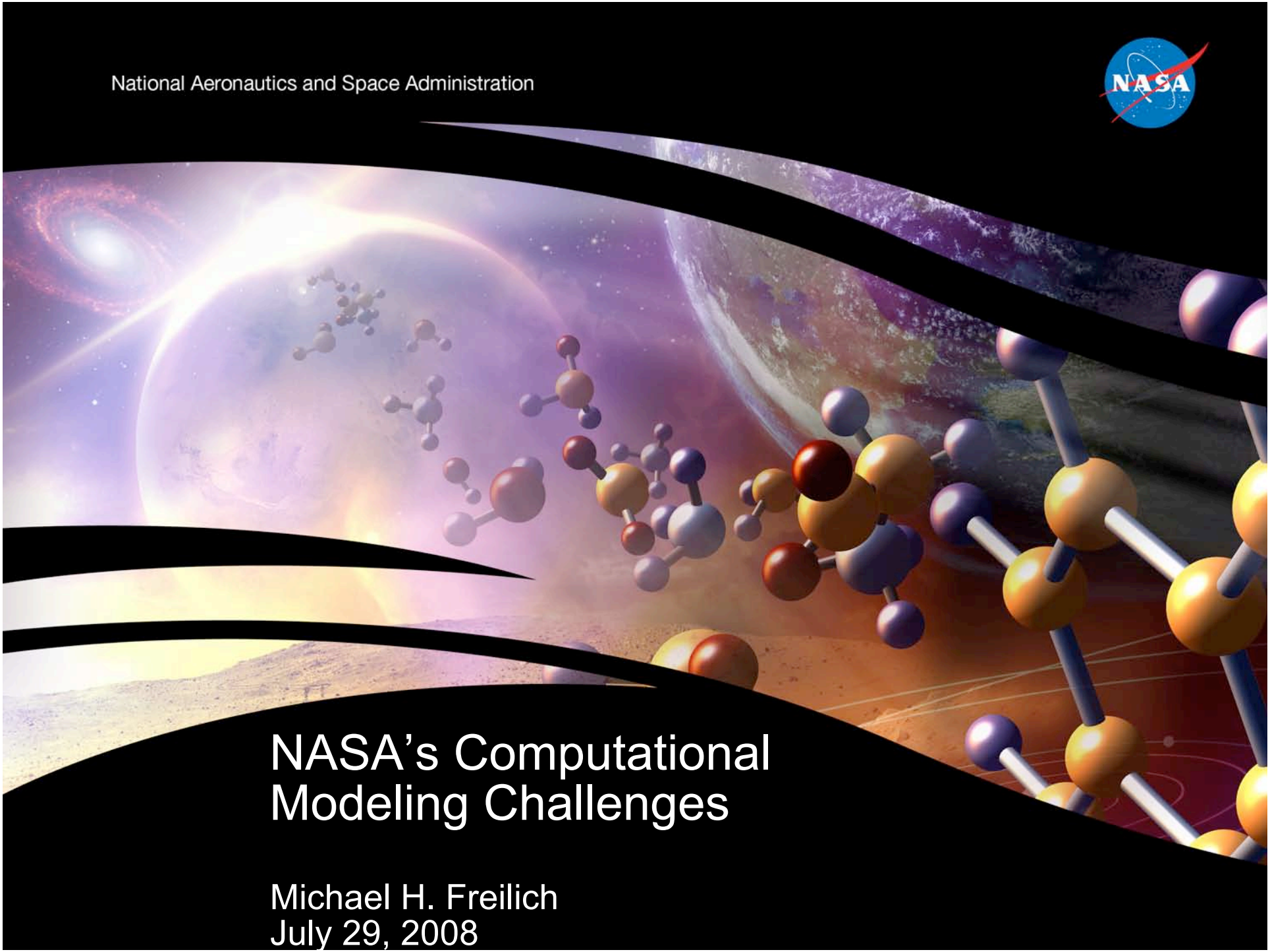
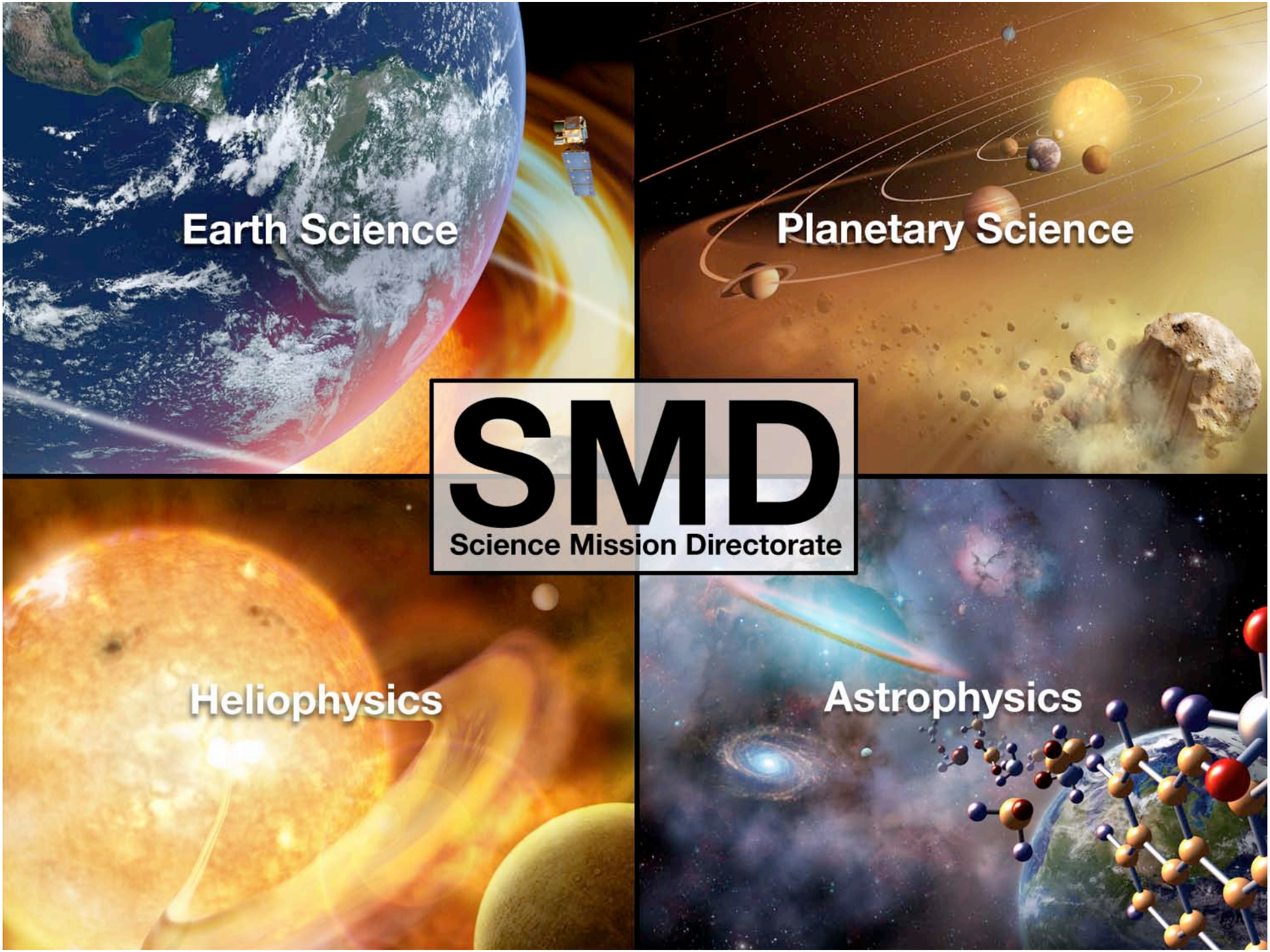
National Aeronautics and Space Administration

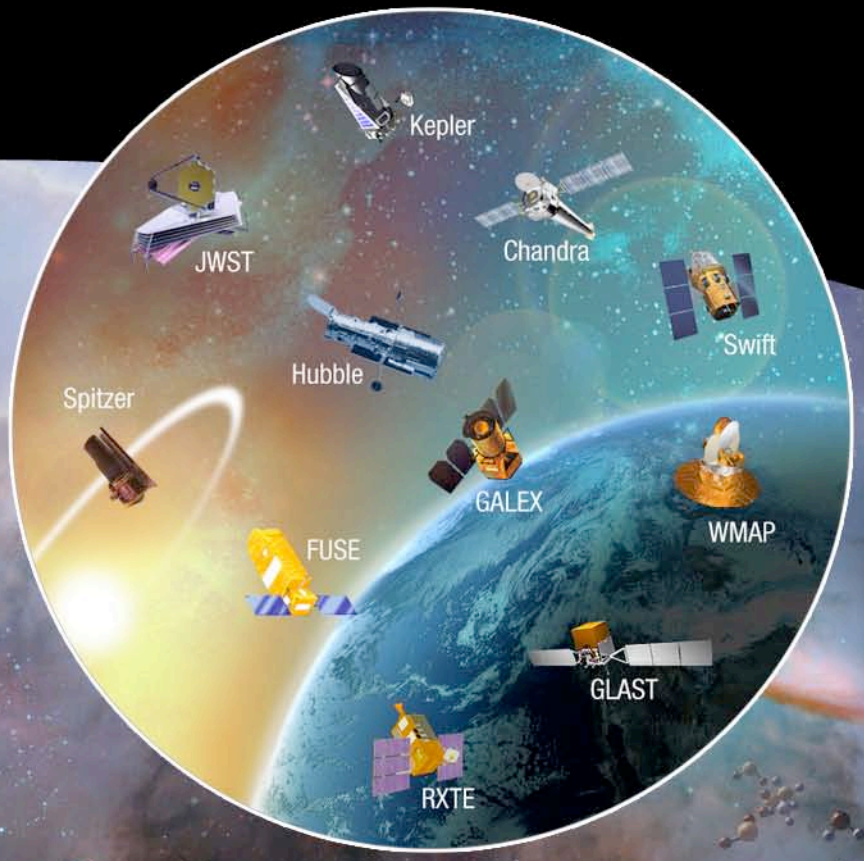


NASA's Computational Modeling Challenges

Michael H. Freilich
July 29, 2008

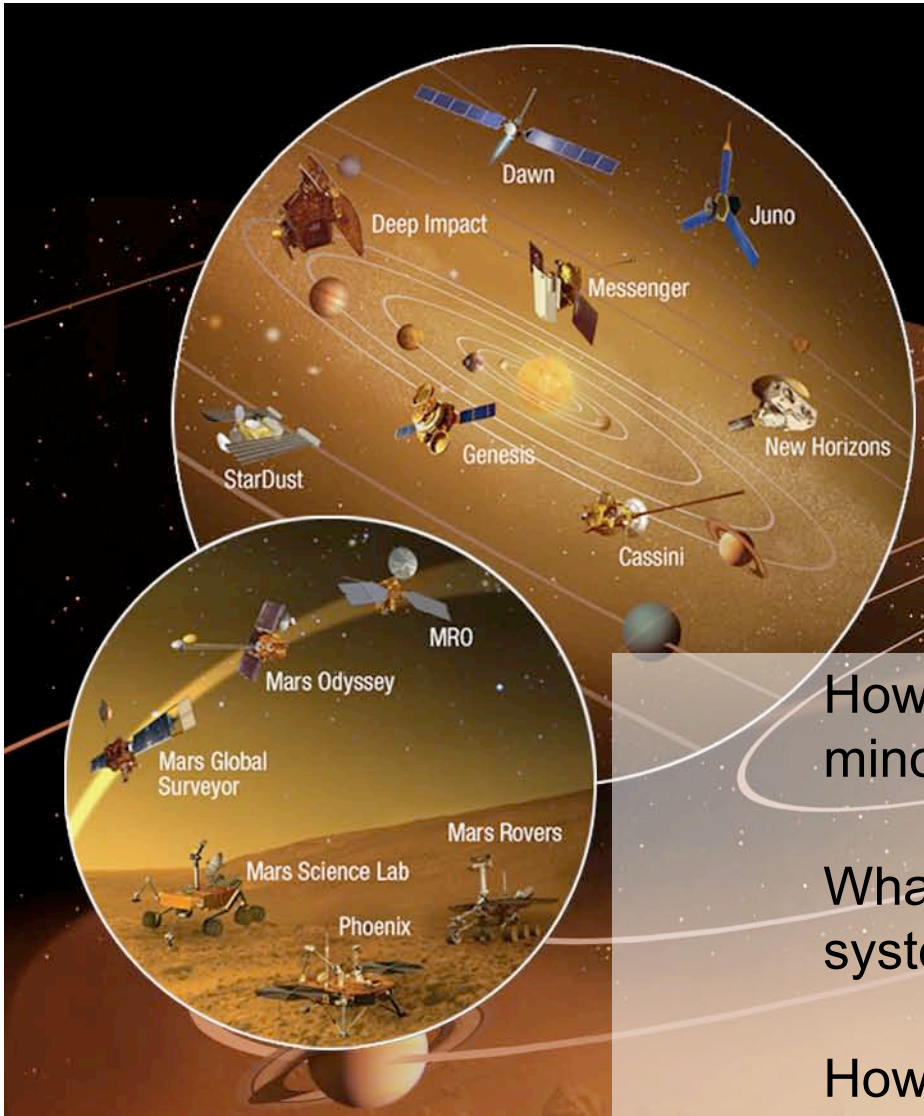

Earth Science
Planetary Science
SMD
Science Mission Directorate
Heliophysics
Astrophysics

Astrophysics



What are the origin, evolution, and fate of the universe?
How do planets, stars, galaxies, and cosmic structure come into being?
When and how did the elements of life and the universe arise?
Is there life elsewhere?

Planetary Science



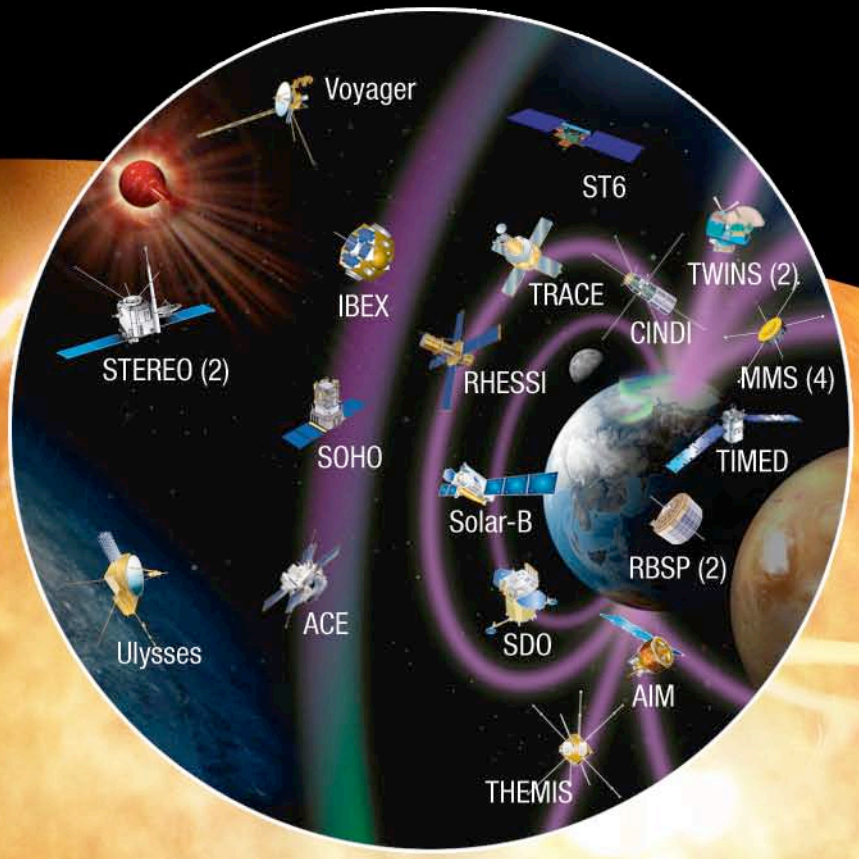
How did the Sun's family of planets and minor bodies originate and evolve?

What are the characteristics of the solar system that lead to the origin of life?

How did life begin and evolve on Earth and has it evolved elsewhere in the solar system?

What solar system hazards and resources will affect the extension of human presence of human presence in space?

Heliophysics

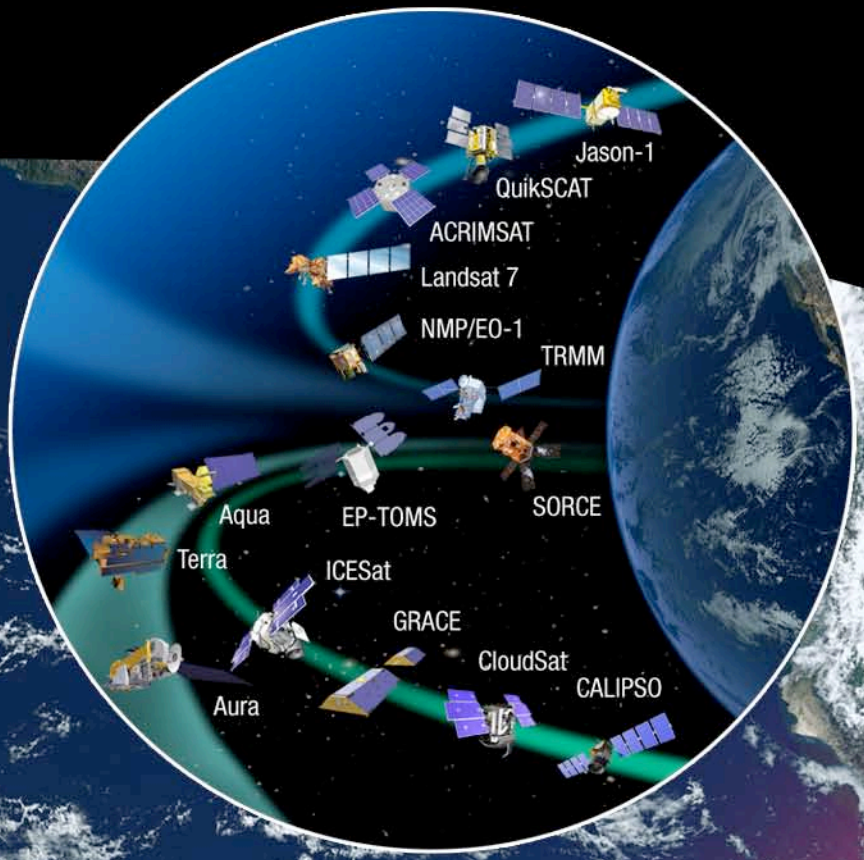


How and why does the Sun vary?

How do the Earth and planetary systems respond?

What are the impacts on humanity?

Earth Science



How and why is the global Earth system changing?

How does the Earth system respond to natural and human-induced changes?

What are the consequences and opportunities for human civilization?

How will the Earth system change in the future?

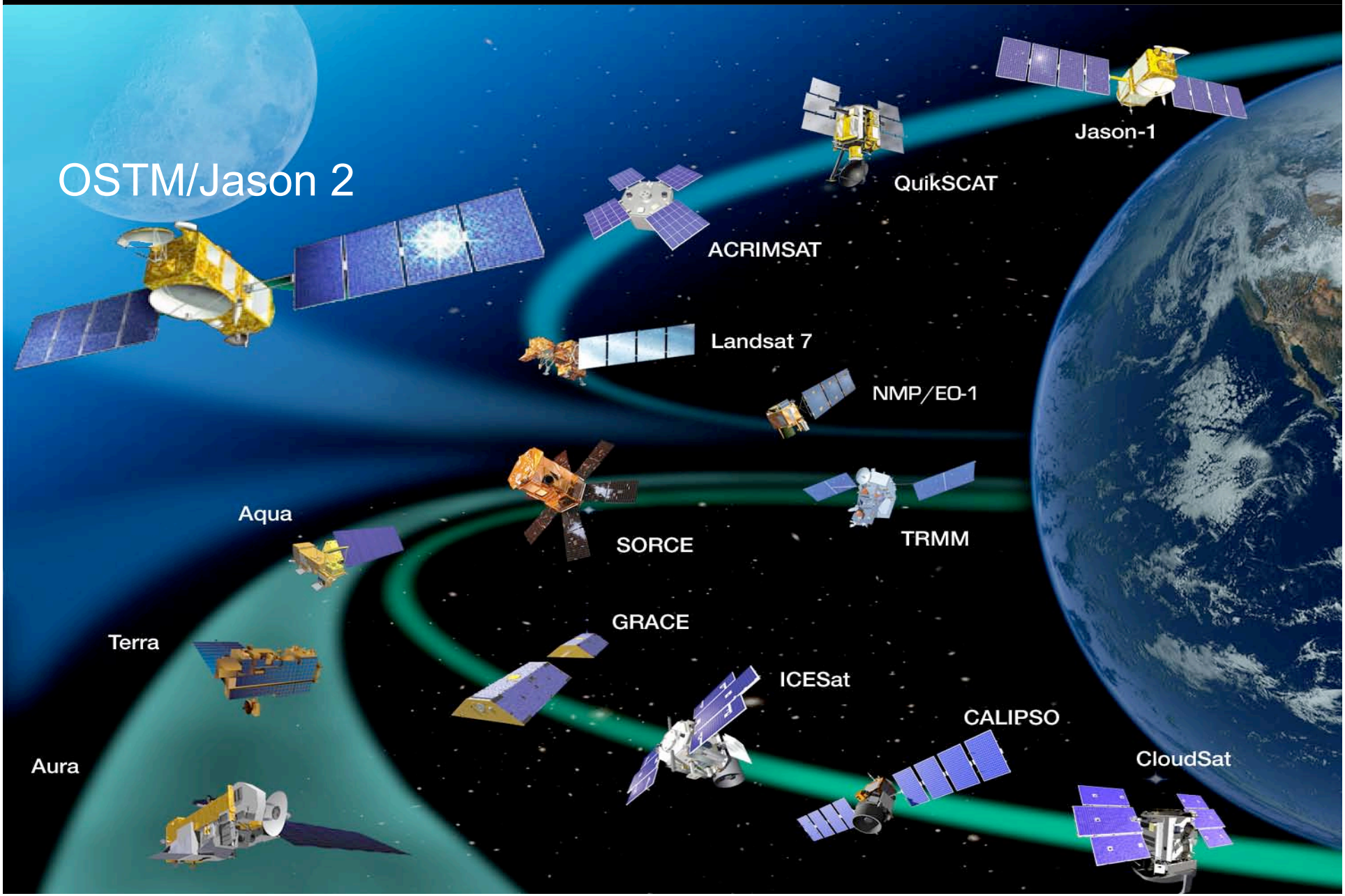
The Earth System Science Endeavor

- The Earth is an integral, complex system
  - Many processes, with varying time and spatial scales
  - Quantitatively describing the ***interactions between processes*** is key
- ***Measurements*** must span all important variables, and all important scales
- ***Research*** leads to greater understanding, which is codified in numerical models – ***prediction***
- Societal benefits result when ***understanding*** is combined with ***measurements*** to generate ***useful information products***

Earth Science Division Overview

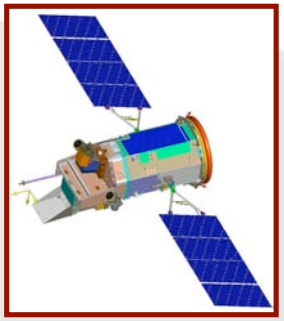
- Overarching goal: to advance Earth System science, including climate studies, through spaceborne data acquisition, **research and analysis, and predictive modeling**
- Six major activities:
  - Building and operating Earth observing satellite missions, many with international and interagency partners
  - Making high-quality data products available to the broad science community
  - **Conducting and sponsoring cutting-edge research in 6 thematic focus areas**
    - Field campaigns to complement satellite measurements
    - **Modeling**
    - Analyses of non-NASA mission data
  - **Applied Science**
  - **Developing technologies to improve Earth observation capabilities**
  - Education and Public Outreach

NASA Operating Research Missions (15)

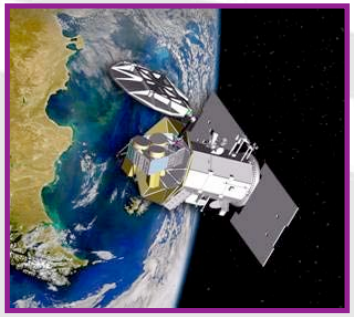


Missions in Formulation and Implementation

OCO
1/2009

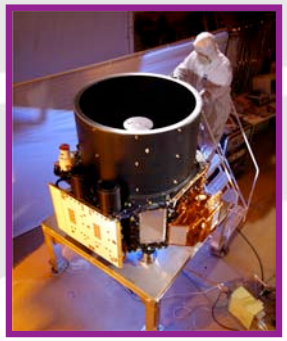


GLORY
6/09



AQUARIUS
5/2010

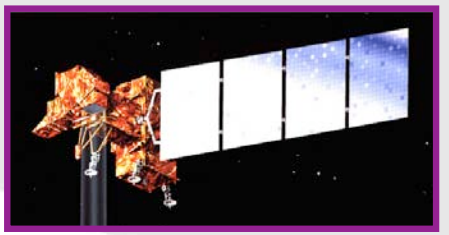
NPP
6/2010



ICESat-II
2015

SMAP
2012

GPM
6/2013, 11/2014



LDCM
likely late 2012

Earth Science Division Overview

- Overarching goal: to advance Earth System science, including climate studies, through spaceborne data acquisition, **research and analysis, and predictive modeling**
- Six major activities:
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  - Making high-quality data products available to the broad science community
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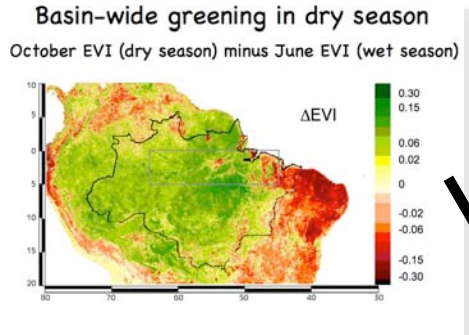
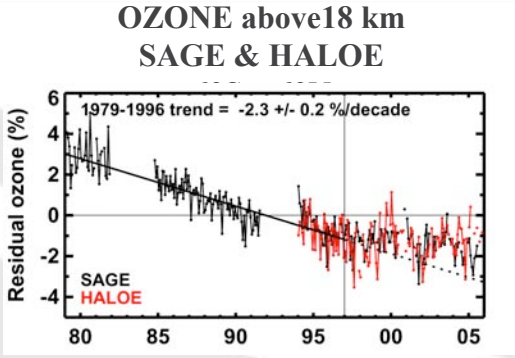
    - Field campaigns to complement satellite measurements
    - **Modeling**
    - Analyses of non-NASA mission data
  - **Applied Science**
  - **Developing technologies to improve Earth observation capabilities**
  - Education and Public Outreach

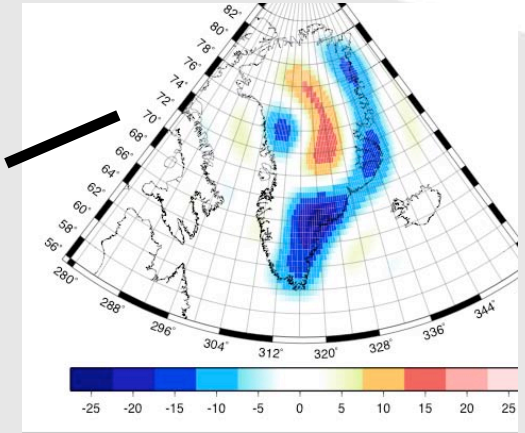
Earth **SCIENCE** Division Focus Areas



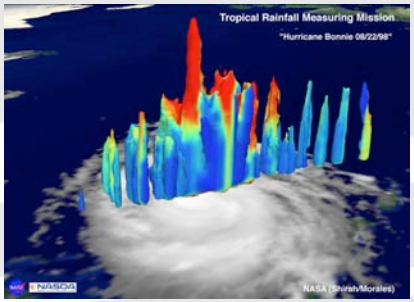
Atmospheric Composition



Carbon Cycle and Ecosystems

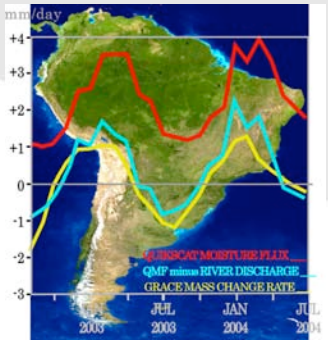


Climate Variability and Change

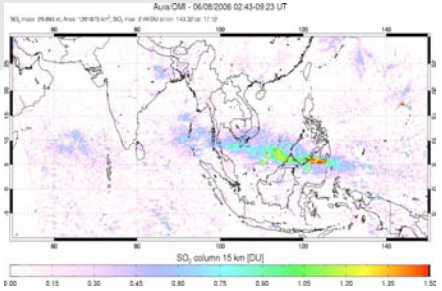


Weather

Water and Energy Cycle



Earth Surface and Interior



Observations and Model Predictions of Arctic Sea Ice Extent

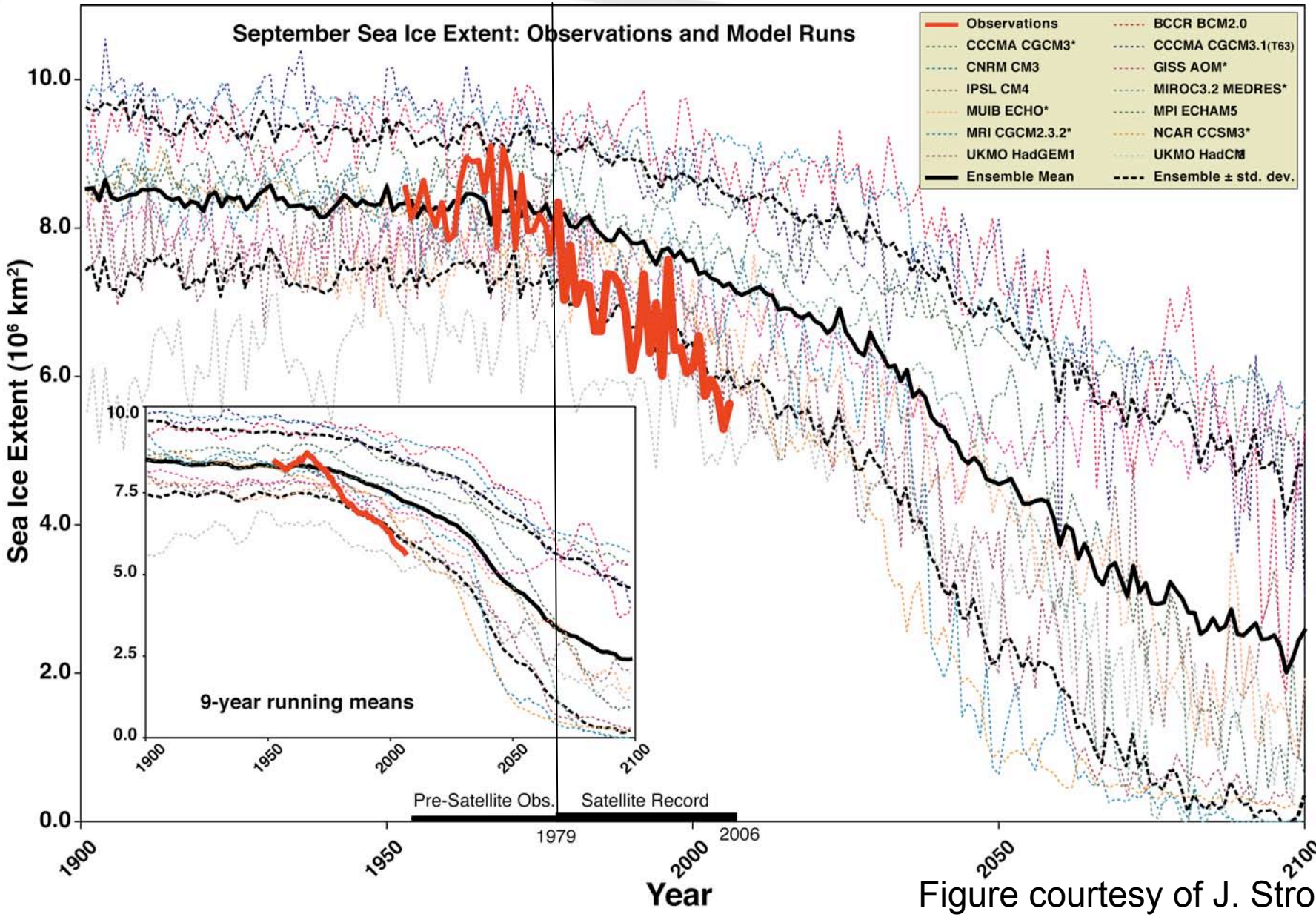
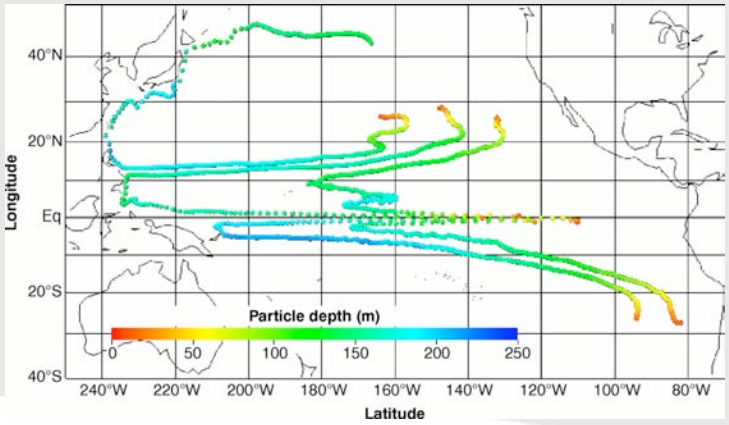


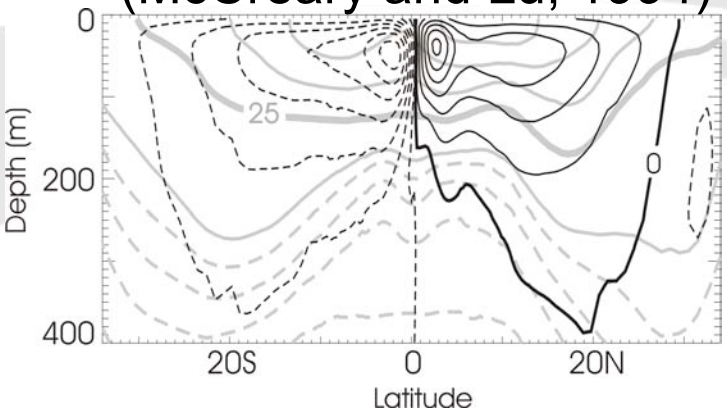
Figure courtesy of J. Stroeve

Origin, pathway & fate of "El Niño Water"

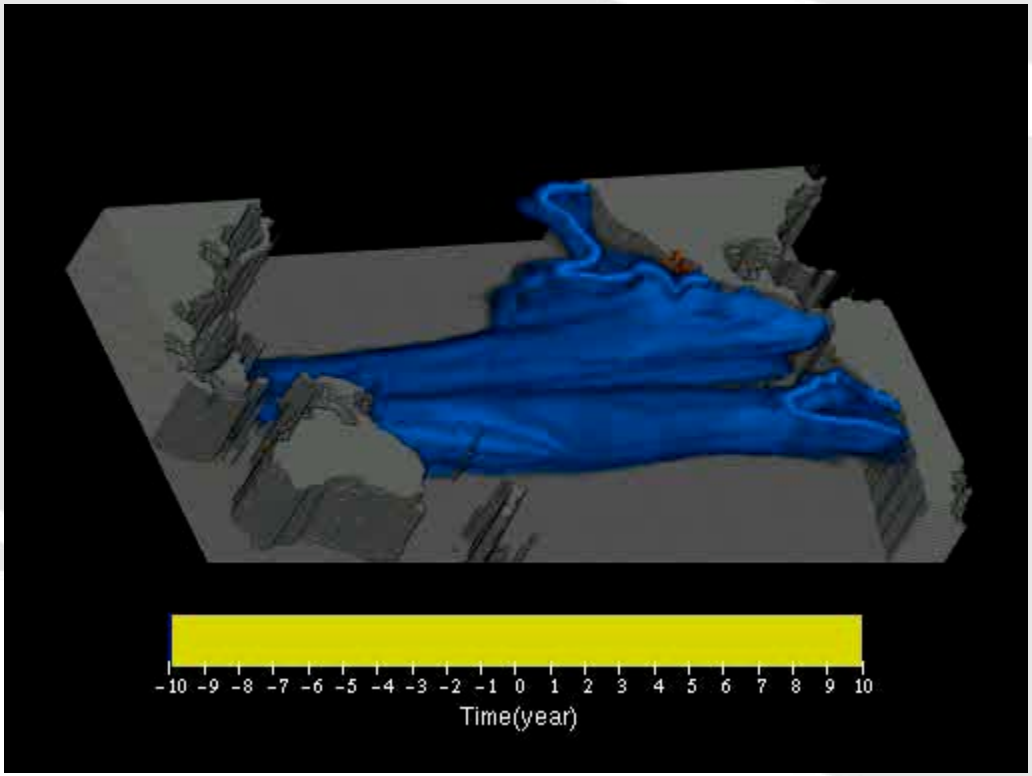
Particle trajectory
(Gu and Philander, 1997)



Subtropical Cell (STC)
(McCreary and Lu, 1994)

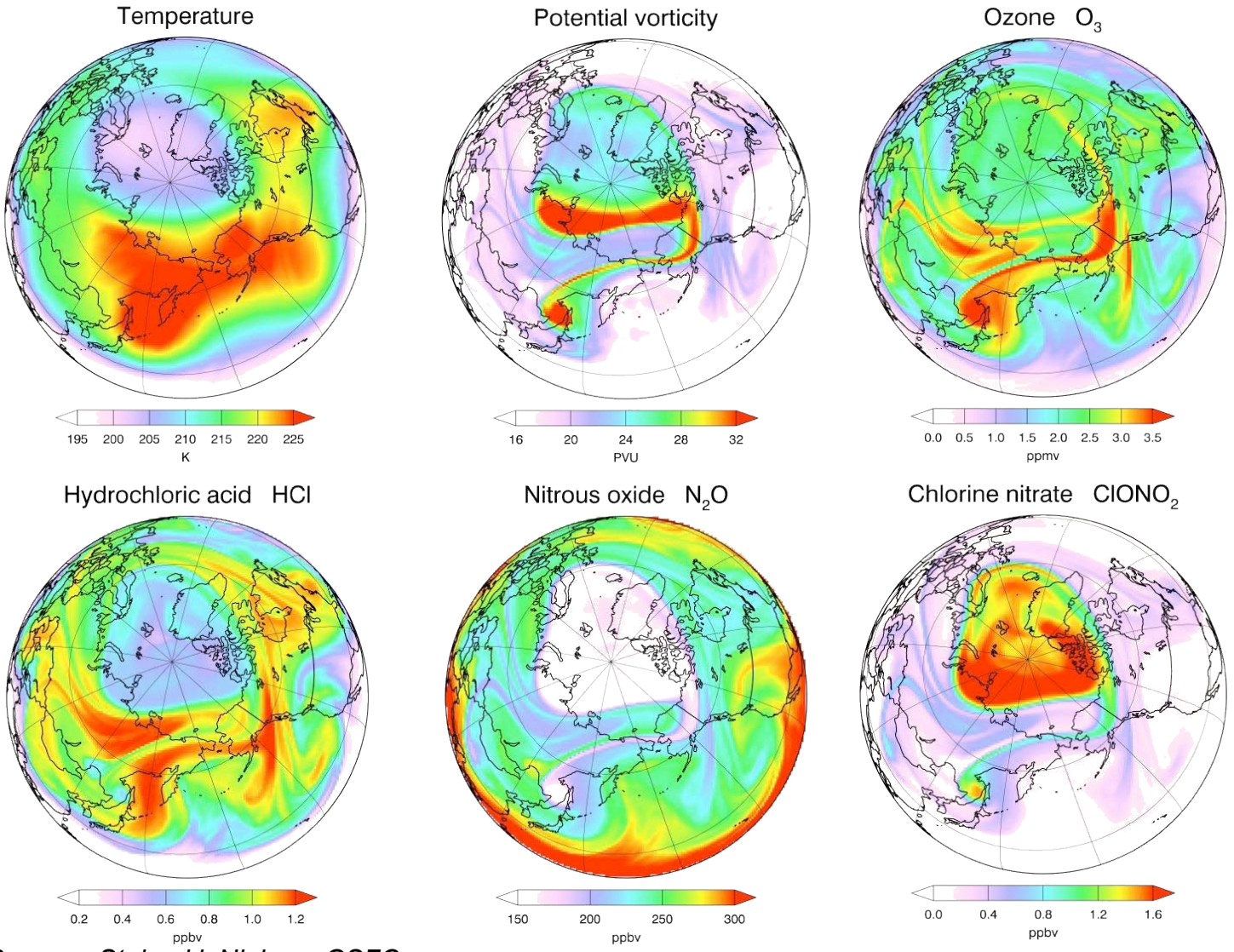


Animation of Nino3 water pathway using a passive tracer (yrs 0~10) and its adjoint (yrs -10~0)



(Fukumori et al., 2004, J. Phys. Oceanogr.)

GEOS-5 AGCM with Stratospheric Chemistry

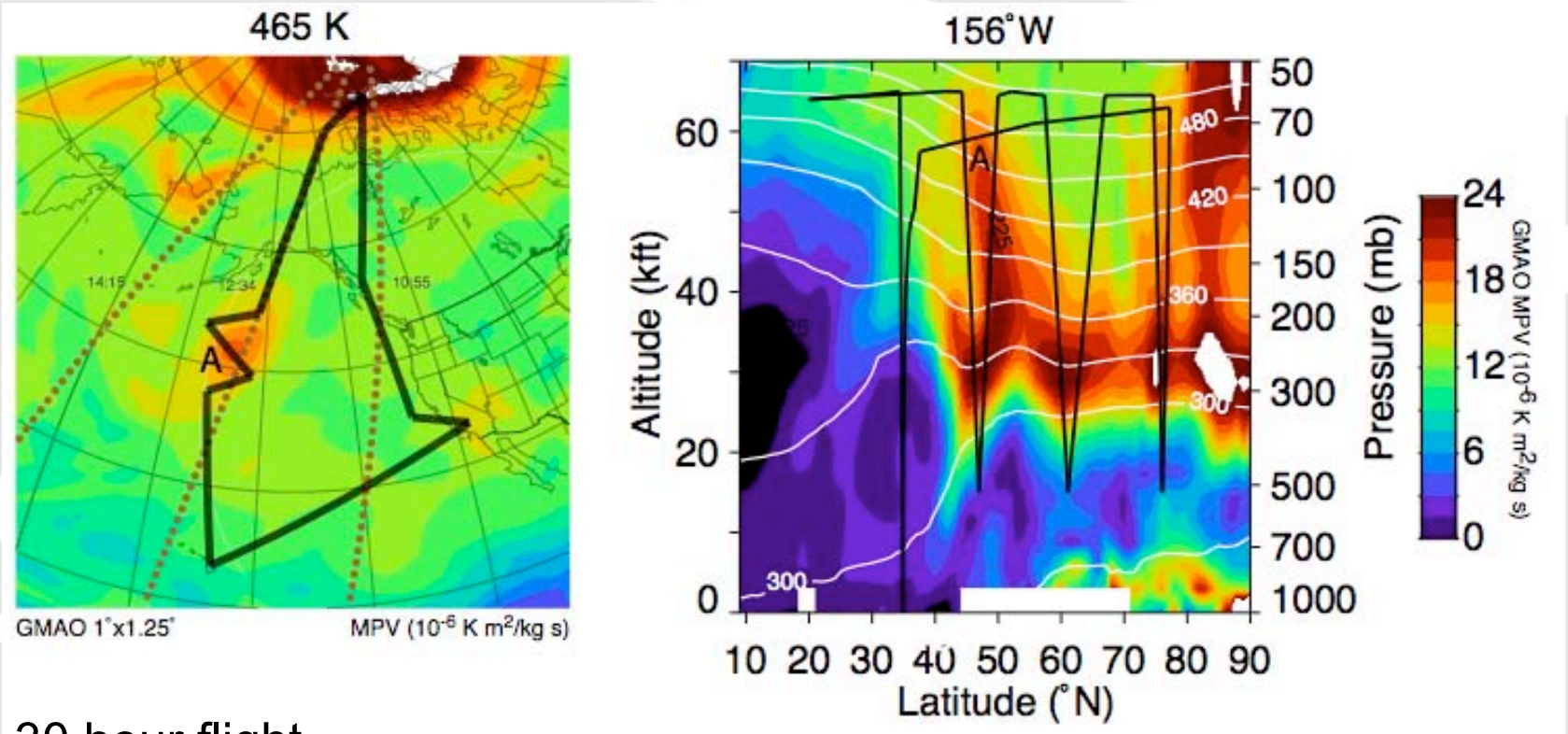


Pawson, Stolarski, Nielsen, GSFC

Coherent filaments are peeled from the edge and interior of the polar vortex

Columbia supports coupled stratospheric chemistry-climate model simulations at unprecedented resolutions

Planned (2009) GH UAS-AVE vortex fragment flight



30 hour flight

Objective 1: sample remaining polar vortex for ozone depleted air

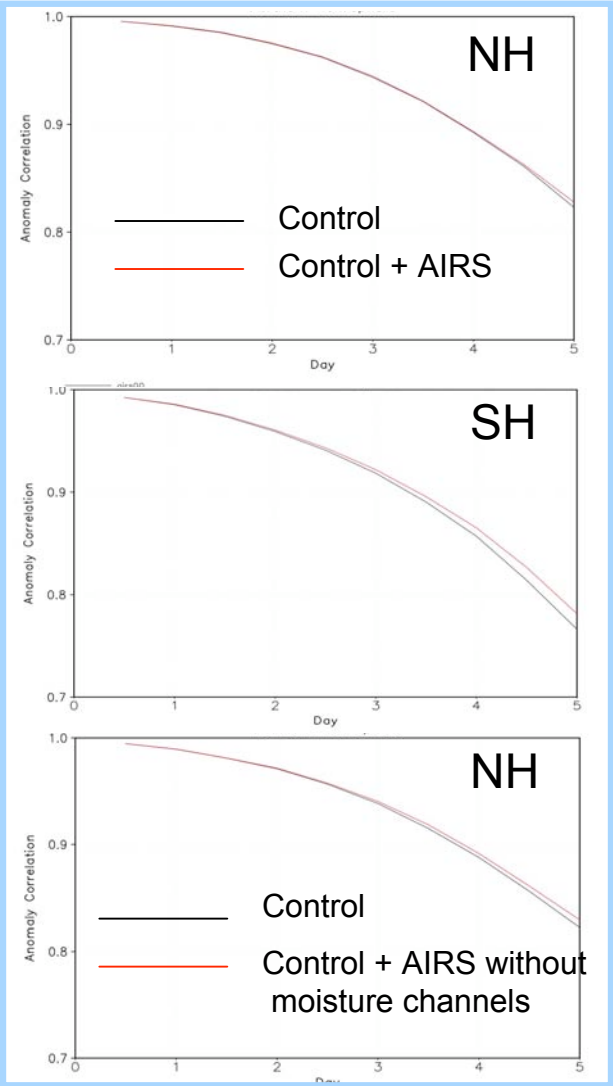
Objective 2: sample polar fragment over Pacific

Objective 3: Coordination with Aura satellite overpass

Objective 4: Pole-to-tropics sampling of air masses

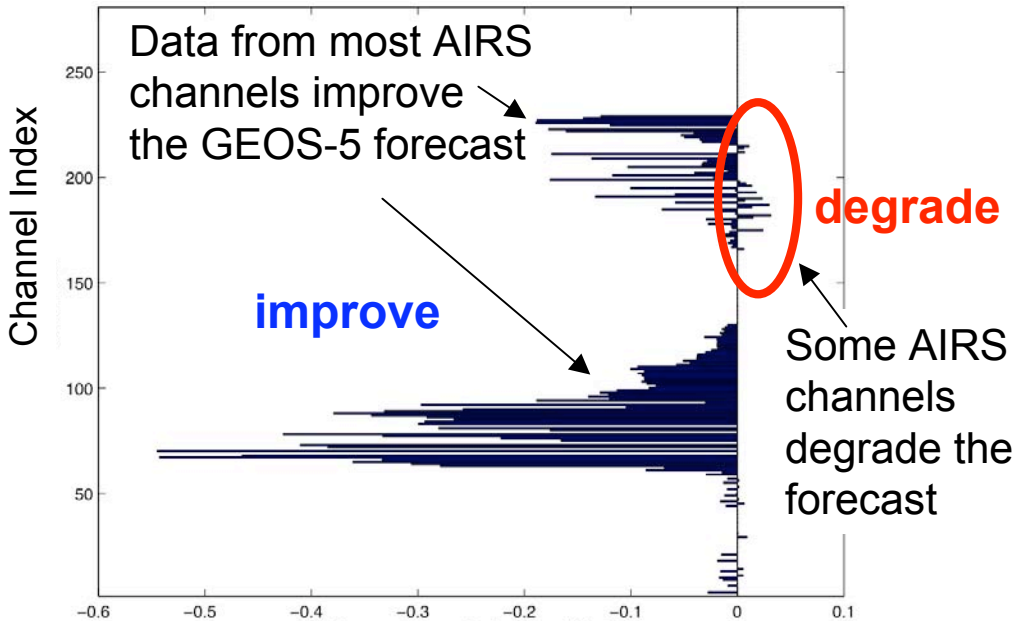
GEOS-5 Used to Evaluate Impact of AIRS in NWP

Traditional Data Impact Studies



Forecast Skill vs. Time

Observation Adjoint Tool



24-hr Forecast Error Reduction vs. Channel

AIRS brings slightly positive impact on forecast skill in Northern Hemisphere; clear positive impact in Southern Hemisphere. Currently, forecast skills are increased when moisture channels from AIRS are not included…

KEY QUESTIONS

- What High-End Computing capabilities are ***essential*** to advance SMD science in the next 5-10 years?

- What science and applications demonstrations could be accomplished over the next decade with:
  - Our present HEC capabilities
  - An ***evolutionary increase*** in our present capabilities
  - A realistic, but ***revolutionary*** change in capabilities

- Advice on the cost/benefit/schedule "sweet spot" for HEC in the 5-year time frame