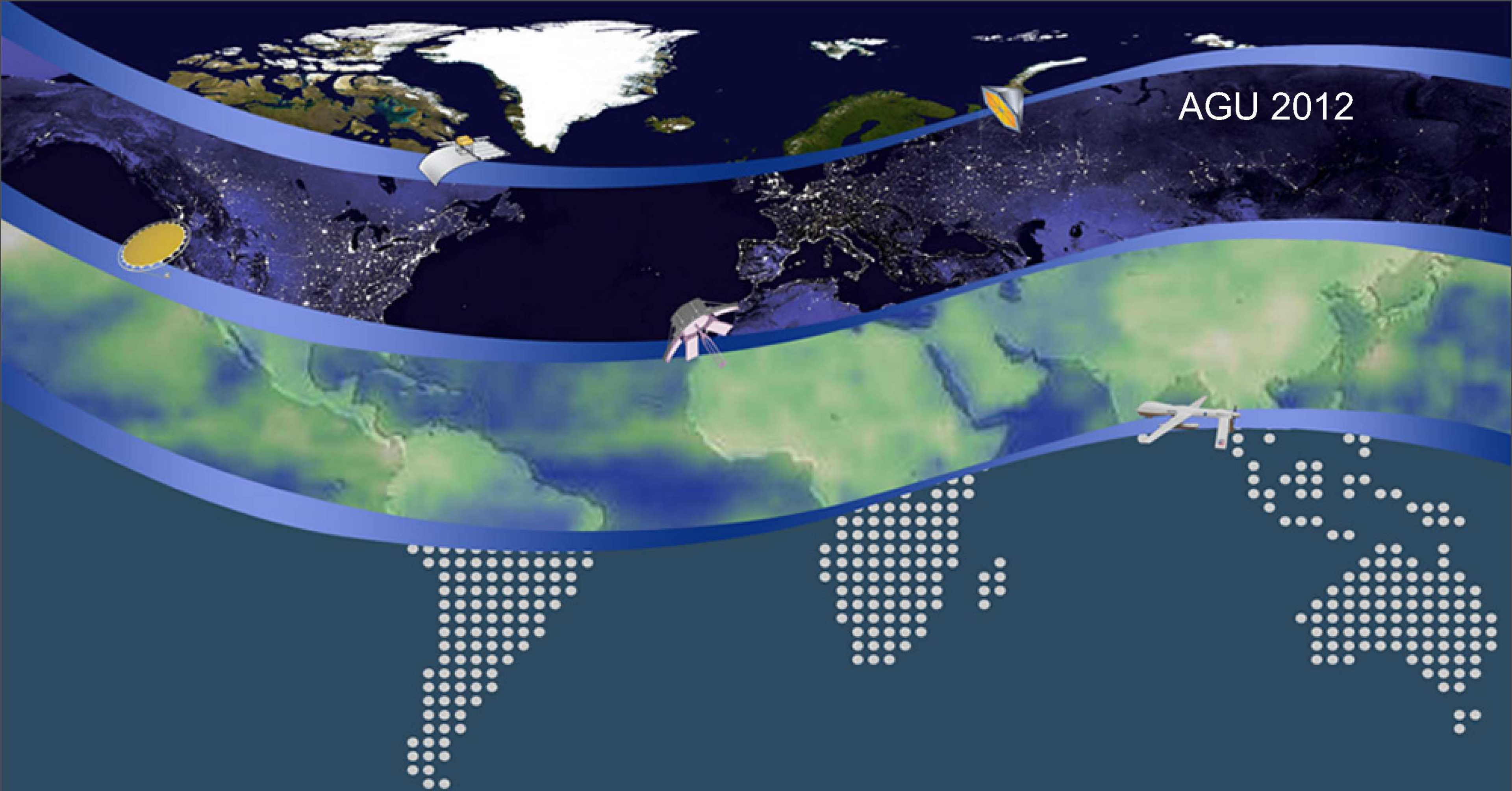


Advanced Information Technology Investments at NASA's Earth Science Technology Office (ESTO)

Michael Seablom, NASA ESTO – December 2012

The NASA Science Portfolio

Science Mission Directorate

- **Earth Science Division**
- Heliophysics Division
- Astrophysics Division
- Planetary Sciences Division

Earth Science Division:

Research

- Atmospheric Composition
- Ecosystems
- Land Cover / Land Use
- Biological Oceanography and Biodiversity
- Solid Earth
- Modeling, Analysis, Prediction
- High End Computing

Flight

- Program management of current & planned satellite missions (Tier I & II Decadal Survey missions; Climate Continuity missions)

Applied Sciences

- Health & Air Quality
- Water Resources
- Disasters
- Ecosystems

Technology

- **Advanced Information Systems Technology Program**
- Instrument Incubator Program
- Advanced Component Technology Program

ESTO's Advanced Information Systems Technology (AIST) Program

Overarching Goal

Identify, develop, and demonstrate advanced information systems technologies (TRL 2-6) that reduce the risk, cost, size, and development time for Earth Science information systems, increase the accessibility and utility of science data, and enable new observations and information products.

Data Collection & Handling | Transmission & Dissemination | Data & Information Production | System Management | Search, Access, Analysis & Display

Solicitation History

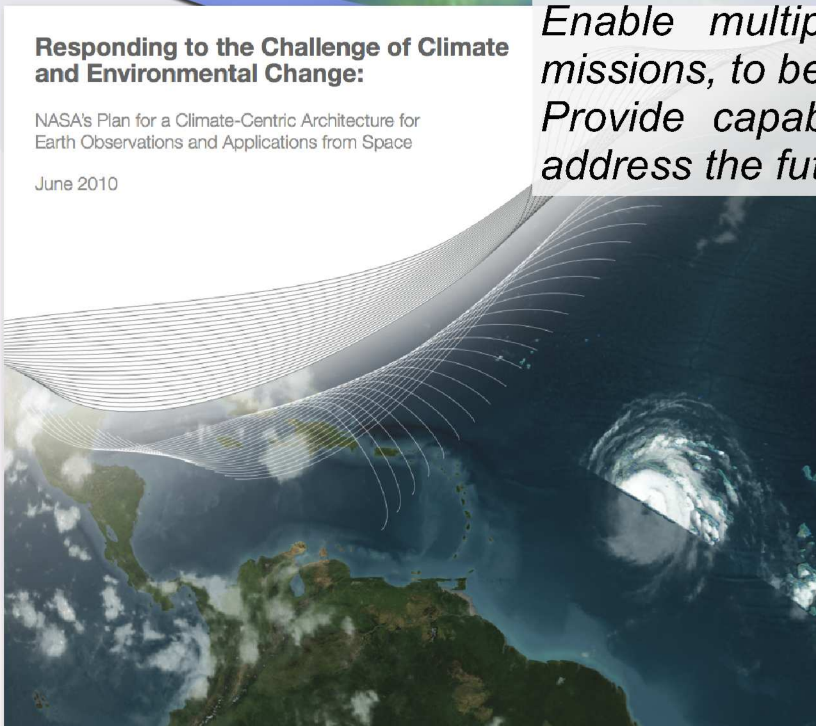
AIST-02 On-Board Processing & Communications Focus → **AIST-05** Sensor Web Focus → **AIST-08** Sensor Web & Decadal Survey Focus → **AIST-11** Multiple Focus Areas → **AIST-14** (Planning)

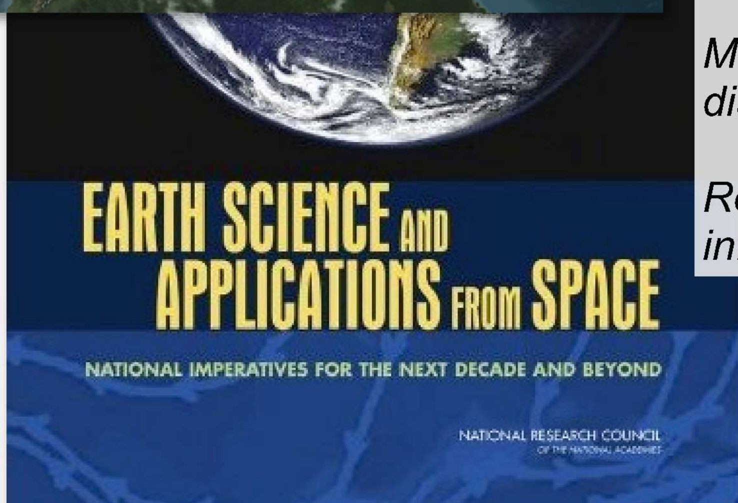
ESTO
Earth Science Technology Office

2011 Solicitation Topic Areas

Topic	Examples
Advanced Data Processing	Tools for multi-source data fusion Tools for data mining and visualization Exploitation of graphical processing units (GPUs) Re-usable Observing System Simulation Experiment (OSSE) frameworks
Data Management Services	Scientific workflows Tools to support the management of large simulation experiments w/data Software architectures & frameworks Techniques to discover shared services for use of science data.
Sensor Web Systems	Sensor web technologies for science applications Spacecraft operations and decision support Tools for adaptive targeting Tools to manage sensor calibration across satellites
Operations Management	Technologies for reducing operational costs Techniques for enhancing new capabilities (near real-time operations, direct downlink, operations autonomy) Flight operational concepts Optimization of science returns from routine vs. episodic events On-board processing systems

Recent Updates to Earth Science Strategic Plan – Info Tech Impacts





Enable multiple measurements, from different sources and missions, to be effective synthesized
Provide capabilities to combine data and models together to address the future evolution of the Earth system

Support scientific breakthroughs resulting from new observations and new ways of using those observations

Provide methods for deriving data and information from multiple observations and sensors

Support use of data in models and data assimilation

Manage data and information to enable low cost distribution to users

Reduce the risk and cost of evolving NASA information systems to support future missions

Proposals Help Identify Needs

Original Grouping (based on 2011 solicitation)

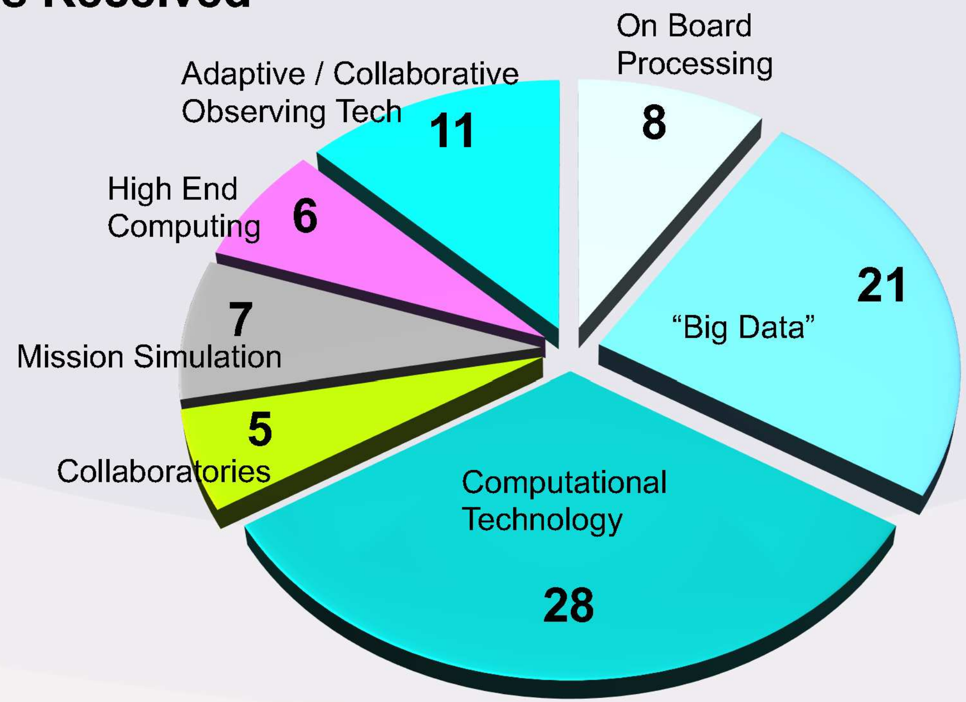
- Advanced Data Processing
- Data Services Management
- Sensor Web Systems
- Operations Management

"Natural" Grouping (based on proposals)	Description
Adaptive / Collaborative Observing Technologies	Techniques to optimize data collection; e.g., one measurement changes the observing state of another
"Big Data" Projects	New techniques to analyze the voluminous Earth Science data anticipated over the next ten years
"Collaboratory" Projects	Information technologies to allow the sharing of analysis tools and data to support seamless scientific collaboration
Computational Technologies	New, high-performance algorithms for large scale science problems
High End Computing Technologies	New software technology to help scientists make the most effective use of high-end computing systems
Mission Simulation Environments	Tools to reduce the cost and risk of planning missions
On Board Processing Projects	Hardware and software to enable the generation of low-latency data products

Proposals Received & Topic Areas

Topic Area	Total
Advanced Data Processing	45
Data Services Management	18
Sensor Web Systems	12
Operations Management	6
Uncategorized	5
Total	**86**

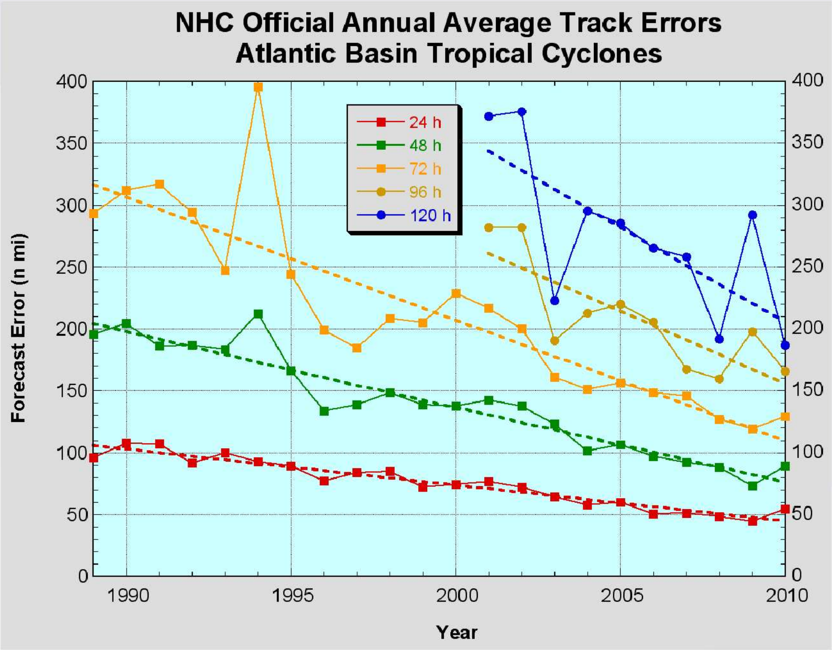
Proposals Received



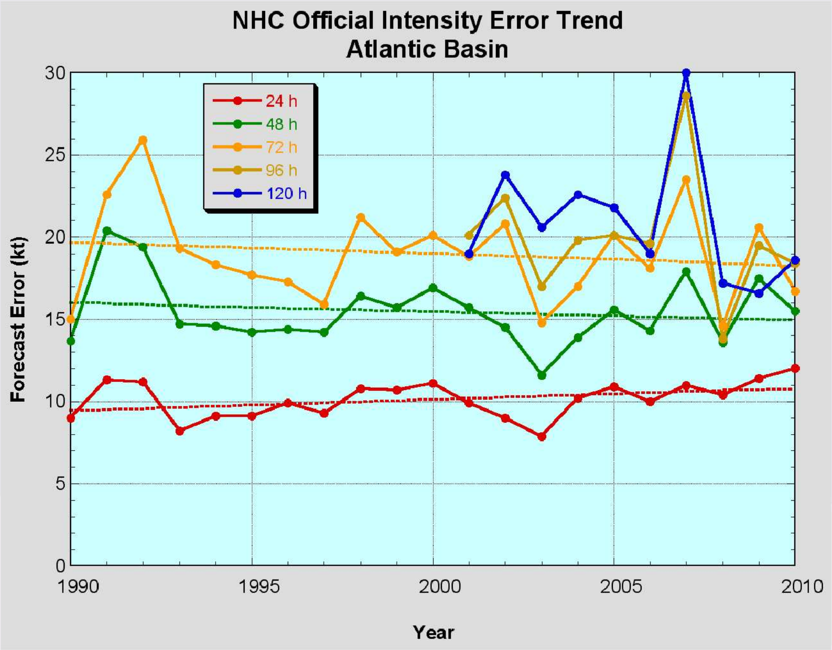
Sample AIST Investment: Predicting Hurricanes

Track Errors (1989-2010)

better



Intensity Errors (1990-2010)



http://www.nhc.noaa.gov/verification/verify5.shtml

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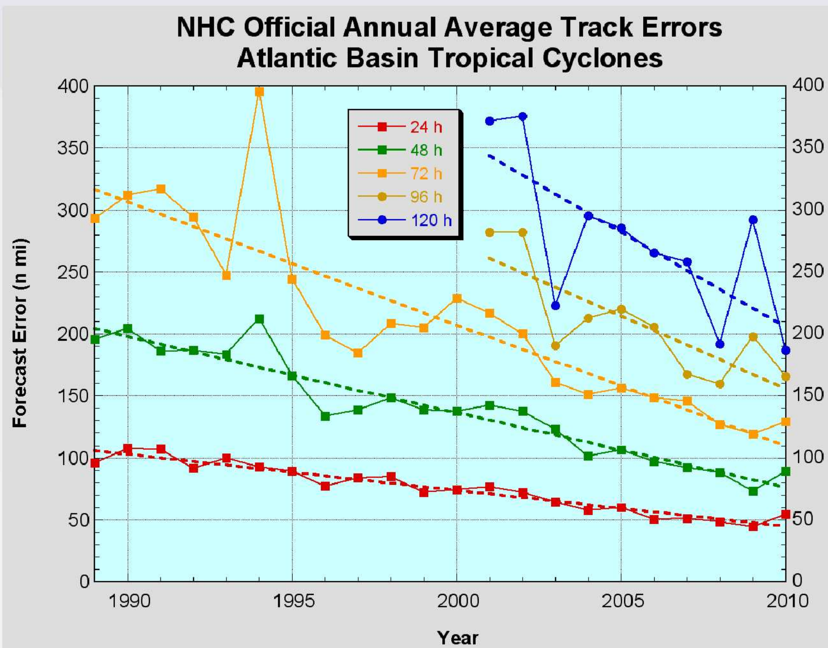
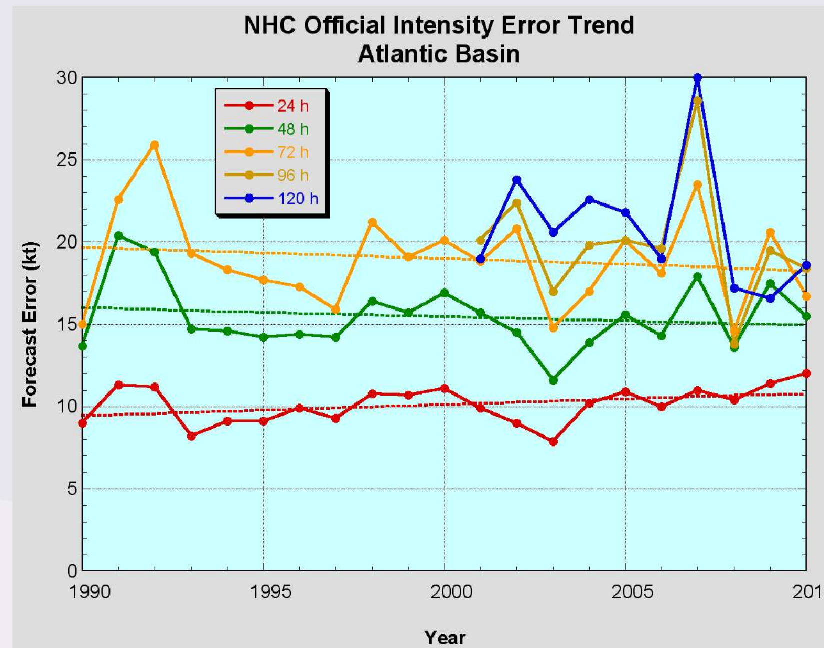




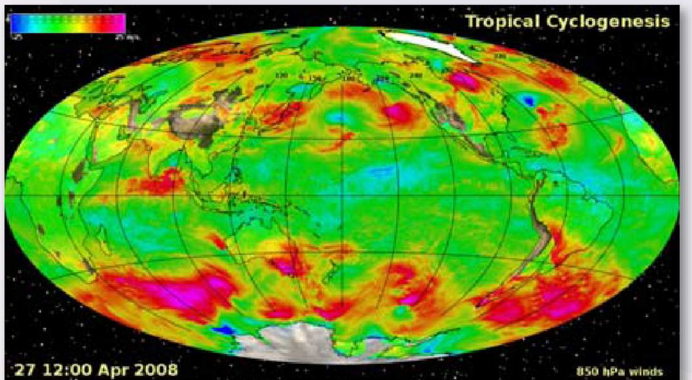
Progress of hurricane forecasts by National Hurricane Center 1990-2010. Vertical axis shows forecast errors. Lines depict different forecast intervals. *During the past twenty years, track forecasts have been steadily improving (left panel), but Intensity forecasts have lagged behind (right panel).*

http://www.nhc.noaa.gov/verification/verify5.shtml

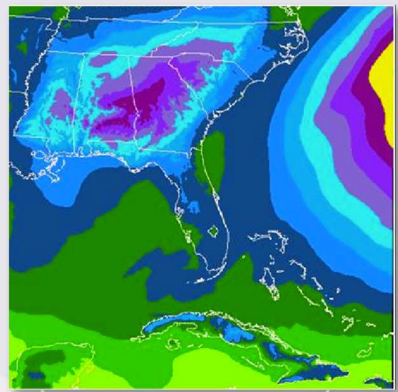
CAMVIS Tropical Cyclone Prediction Project

Bo-Wen Shen,
University of Maryland

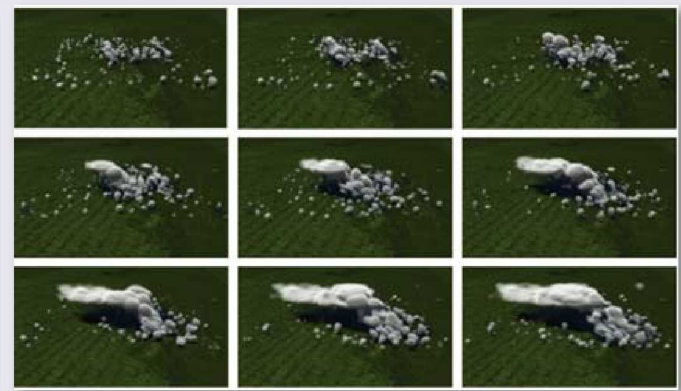
Global Model
Ex: Madden-Julian Oscillation, tropical waves



Regional Model
Ex: Vortex merger



Cloud Model
Ex: Precipitation and convection



Downscaling → ← Upscaling

Full simulation that accurately captures scale interactions: large-scale environment (deterministic), to mesoscale flows, down to convective-scale motions (stochastic).

Shen, Bo-Wen, B. Nelson, S. Cheung, W.-K. Tao, 2012d: Scalability Improvement of the NASA Multiscale Modeling Framework for Tropical Cyclone Climate Study. (submitted to CiSE in April, 2012)

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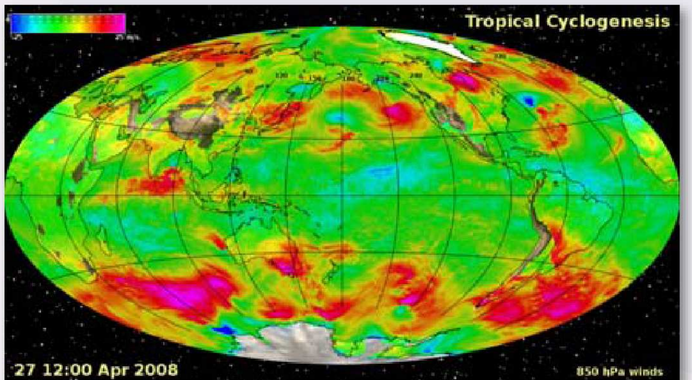

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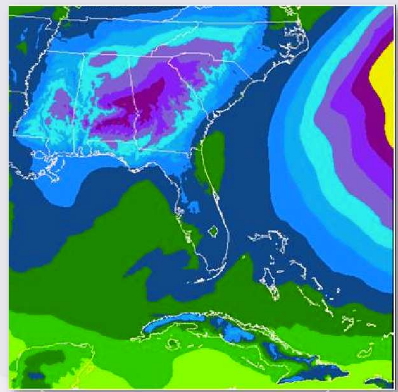

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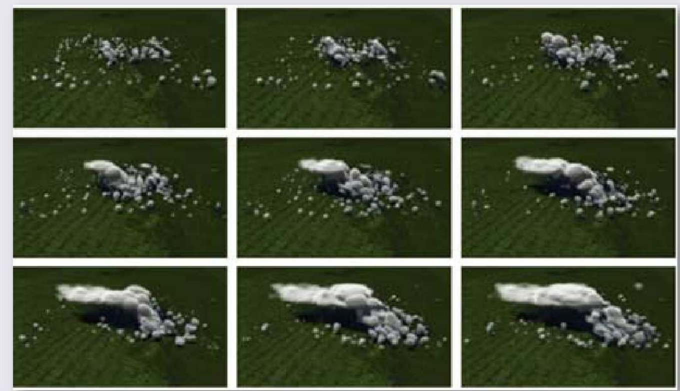

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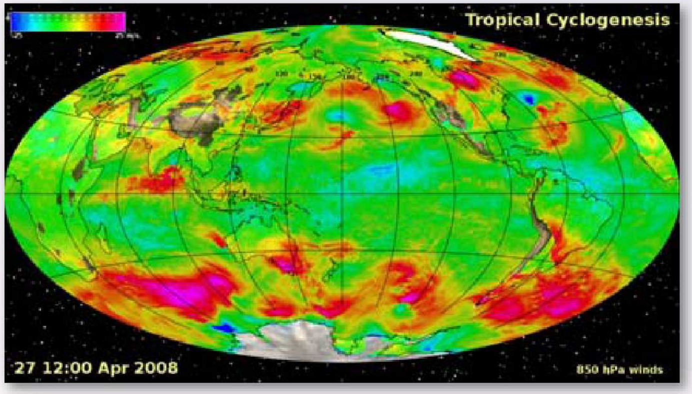

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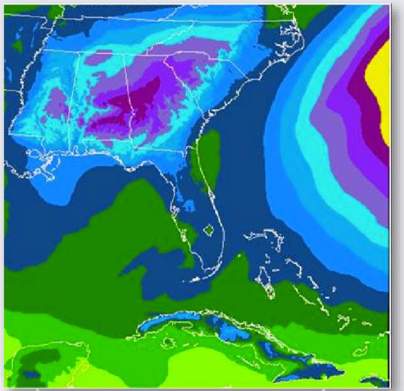


Cloud Model
Ex: Precipitation and convection

Downscaling →

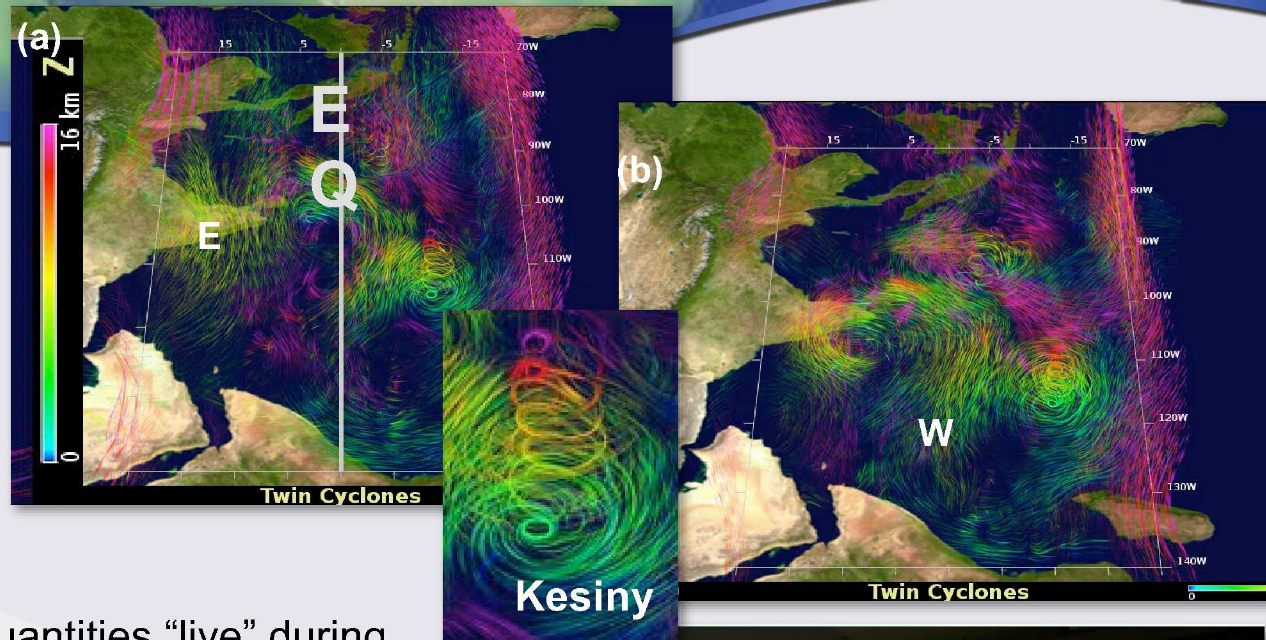
← Upscaling

Super-parameterization
(multi-scale modeling framework, MMF)

Full simulation that accurately captures scale interactions: large-scale environment (deterministic), to mesoscale flows, down to convective-scale motions (stochastic).

Shen, Bo-Wen, B. Nelson, S. Cheung, W.-K. Tao, 2012d: Scalability Improvement of the NASA Multiscale Modeling Framework for Tropical Cyclone Climate Study. (<u>submitted</u> to CiSE in April, 2012)

CAMVIS Concurrent Visualizations



EXTRACT DATA from running simulations to graphics processors

AVOID SLOW DATA WRITES to disk (>100X improvement in performance)

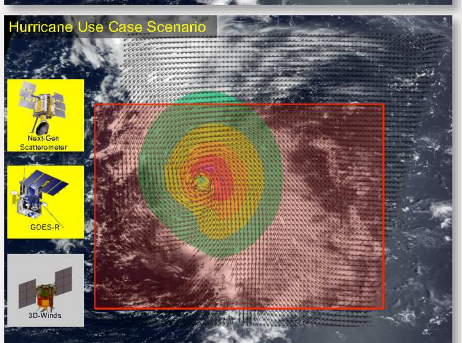
VISUALIZE many different quantities “live” during the active simulation

GENERATE MOVIES of the simulation that can later be played back

This method has a proven ability to discover features of interest that exist at very fine temporal scales

Green, B., C. Henze, B.-W. Shen, 2010: Development of a scalable concurrent visualization approach for high temporal- and spatial-resolution models. AGU 2010 Western Pacific Geophysics Meeting, Taipei, Taiwan, June 22-25, 2010.

The Need for Mission Simulation Experiments



Simulation is a powerful tool for planning future missions

- Generation of synthetic observations based on science requirements and anticipated operations concepts
- Allow for "what if?" scenarios and engineering trade studies to address cost and risk

Process is computationally expensive

- "Nature run" is generated from a high-resolution operational atmospheric model (proxy for the true atmosphere)
- Error characteristics and response functions are defined for the synthetic observations
- Impact studies are performed

Currently such experiments are being performed by multiple missions independently

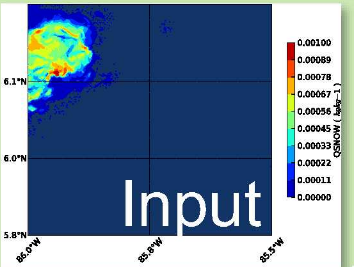
Can the process be generalized to reduce costs and improve consistency across mission?

Earth Science Technology Office

Mission Simulation Environments

Simone Tanelli,
NASA Jet Propulsion Laboratory

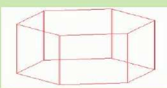
Model Input Reconditioning



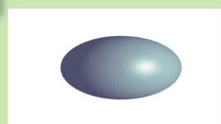
Rayleigh/Mie

Mie

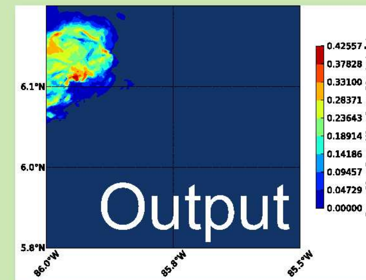
Discrete-Diapole



Total Scattering Matrix/
Geometric Optics/ Discrete-Diapole

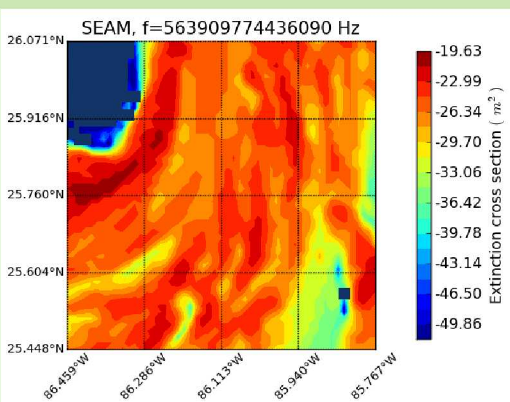


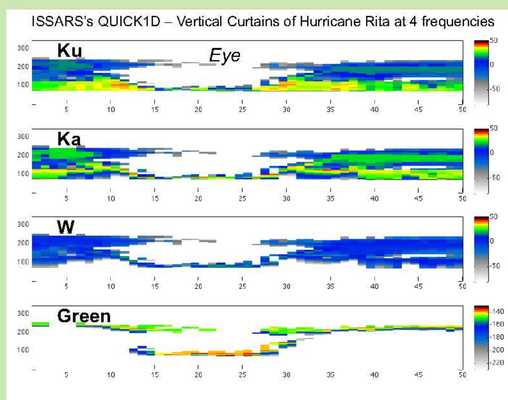
Total Scattering
Matrix/
Geometric Optics

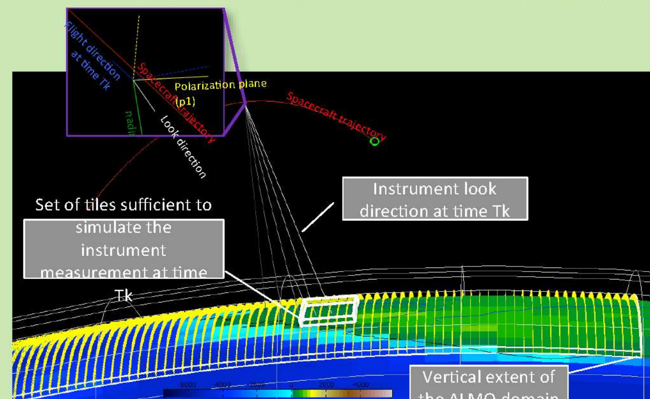


Instrument Simulation

Orbit Propagator, Scanning Strategy,Instrument Beamwidths, Range Resolutions, etc.







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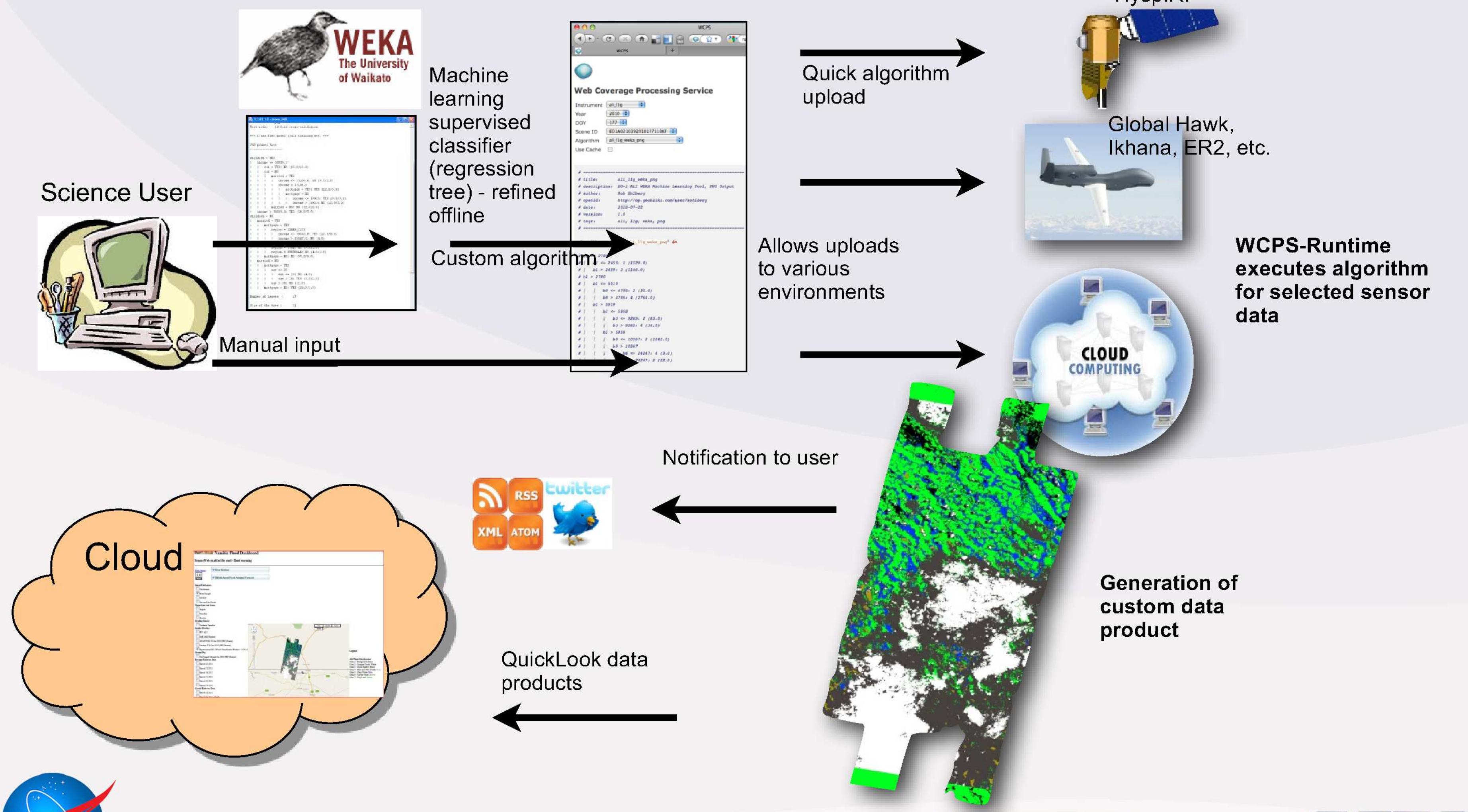
Enhanced Operations for HyspIRI Mission

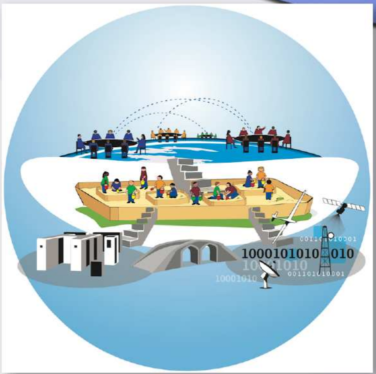
Dan Mandl,
NASA Goddard
Space Flight Center

Web Coverage Processing Service (WCPS)



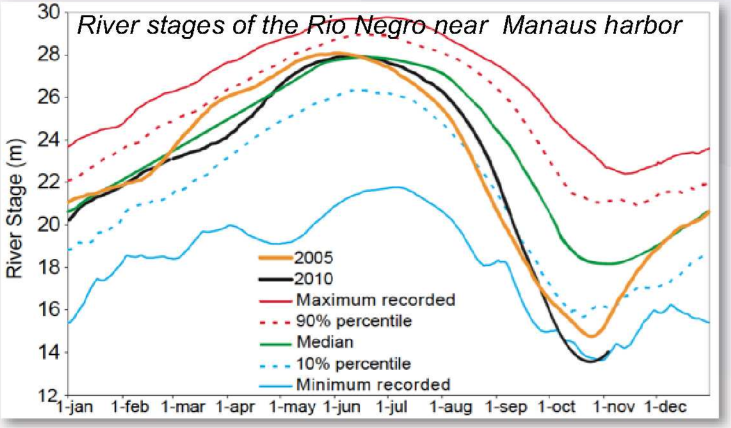
NASA Earth Exchange (NEX)

Rama Nemani, NASA / ARC

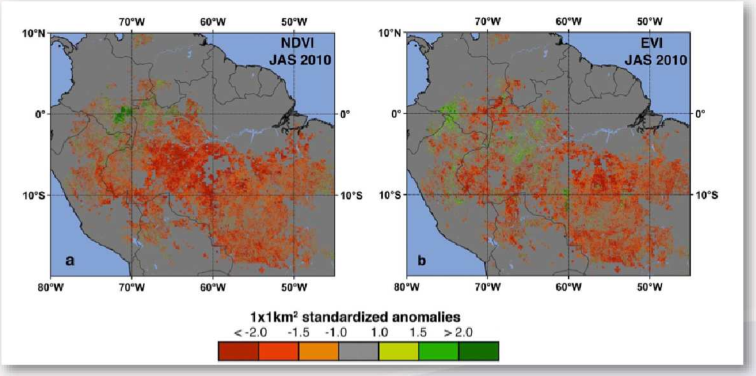


NASA's First Collaboratory brings computing and large data stores together to engage and enable the Earth science community address global environmental challenges

Current capability: 10K+ cores, 1PB online data
new paradigm in "big data" analysis and scientific discovery



Samanta et al., 2010 and Xu et. al, 2011 used NEX to process large amounts of data to examine the 2005 and 2010 severe Amazon droughts Rapid turnaround of results: 2010 data analyzed and paper published in March, 2011



Work begun in 2012 will build semi-automated workflows for science analysis

Primary funding for NEX is provided by NASA's High End Computing Program with support from ESTO

ESTO Earth Science Technology Office

To Learn More...

If you have ideas on how advanced information technology could enable future NASA missions or for general questions, please contact our team!

Mike Seablom	**Michael.S.Seablom@nasa.gov**	**202-358-0442**
Karen Moe	**Karen.Moe@nasa.gov**	**301-286-2978**
Marge Cole	**Marjorie.C.Cole@nasa.gov**	**301-286-9803**