Potential for Satellite and Aircraft Remote Sensing Within a Joint Urban Test Bed

Michael F. Jasinski
NASA Goddard Space Flight Center

Outline

1. Satellite data products
2. Land Data Assimilation products
3. Future missions
4. Aircraft Data Products

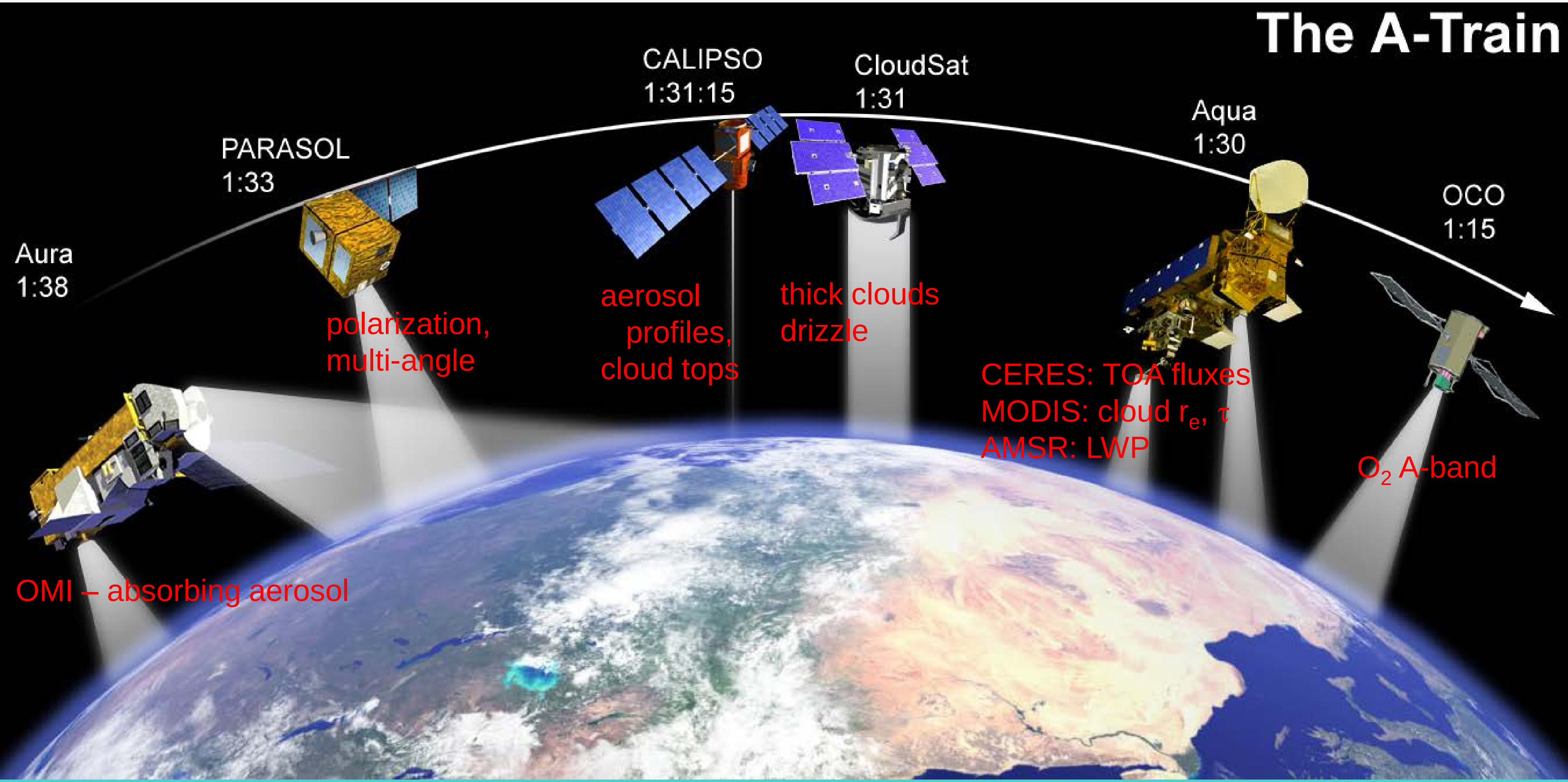
Atmospheric Transport and Dispersion Modeling Conference
George Mason University
July 17, 2007

NASA Earth Science Research Objectives
(from 2007 NASA Science Plan)

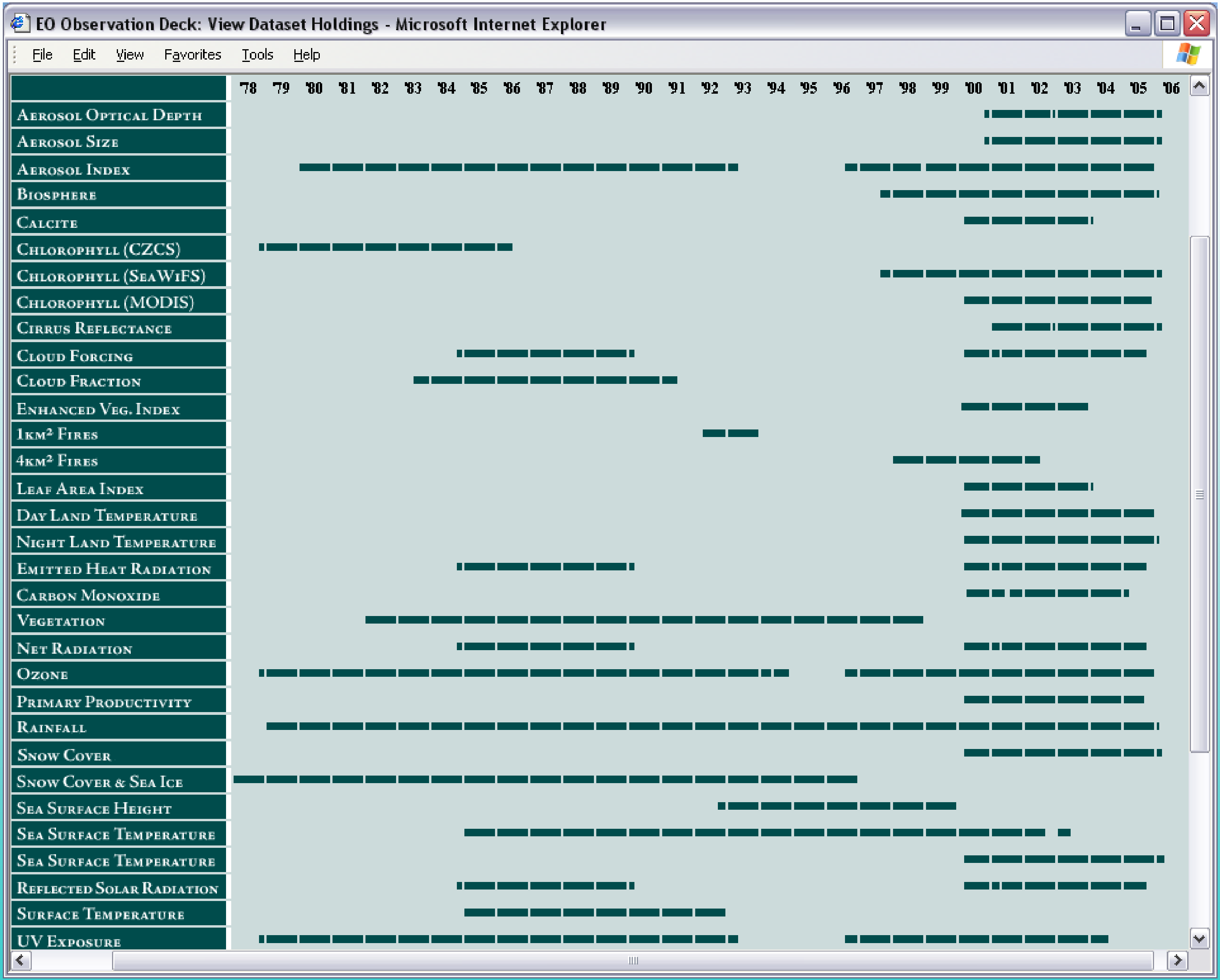
Science Area	Science Questions	Research Objectives [multiyear Outcomes, 2006 NASA Strategic Plan—Appendix 1]
Earth Science: Study planet Earth from space to advance scientific understanding and meet societal needs.	• How is the global Earth system changing? • What are the primary causes of change in the Earth system? • How does the Earth system respond to natural and human-induced changes? • What are the consequences for human civilization? • How will the Earth system change in the future?	1. Understand and improve predictive capability for changes in the ozone layer, climate forcing, and air quality associated with changes in atmospheric composition 2. Enable improved predictive capability for weather and extreme weather events 3. Quantify global land cover change and terrestrial and marine productivity and improve carbon cycle and ecosystem models 4. Quantify the key reservoirs and fluxes in the global water cycle and improve models of water cycle change and fresh water availability 5. Understand the role of oceans, atmosphere, and ice in the climate system and improve predictive capability for its future evolution 6. Characterize and understand Earth surface changes and variability of Earth's gravitational and magnetic fields 7. Expand and accelerate the realization of societal benefits from Earth system science

NASA Observing Spacecraft for Earth System Research

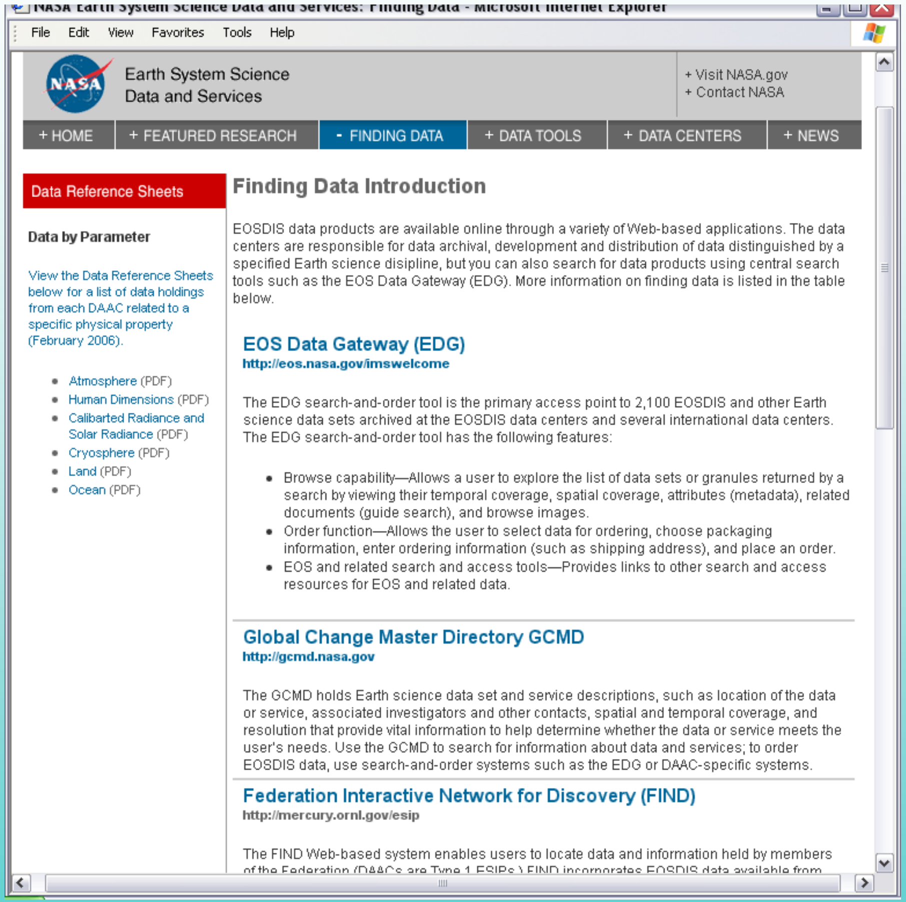
Earth Observation System A-Train: Aerosol/Clouds/Radiation



EOS Data Products



Data and Information Services



NASA Earth System Science Data and Services: Finding Data - Microsoft Internet Explorer

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Earth System Science
Data and Services

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Data Reference Sheets

Data by Parameter

View the Data Reference Sheets below for a list of data holdings from each DAAC related to a specific physical property (February 2006).

- Atmosphere (PDF)
- Human Dimensions (PDF)
- Calibrated Radiance and Solar Radiance (PDF)
- Cryosphere (PDF)
- Land (PDF)
- Ocean (PDF)

Finding Data Introduction

EOSDIS data products are available online through a variety of Web-based applications. The data centers are responsible for data archival, development and distribution of data distinguished by a specified Earth science disipline, but you can also search for data products using central search tools such as the EOS Data Gateway (EDG). More information on finding data is listed in the table below.

EOS Data Gateway (EDG)

http://eos.nasa.gov/imswelcome

The EDG search-and-order tool is the primary access point to 2,100 EOSDIS and other Earth science data sets archived at the EOSDIS data centers and several international data centers. The EDG search-and-order tool has the following features:

- Browse capability—Allows a user to explore the list of data sets or granules returned by a search by viewing their temporal coverage, spatial coverage, attributes (metadata), related documents (guide search), and browse images.
- Order function—Allows the user to select data for ordering, choose packaging information, enter ordering information (such as shipping address), and place an order.
- EOS and related search and access tools—Provides links to other search and access resources for EOS and related data.

Global Change Master Directory GCMD

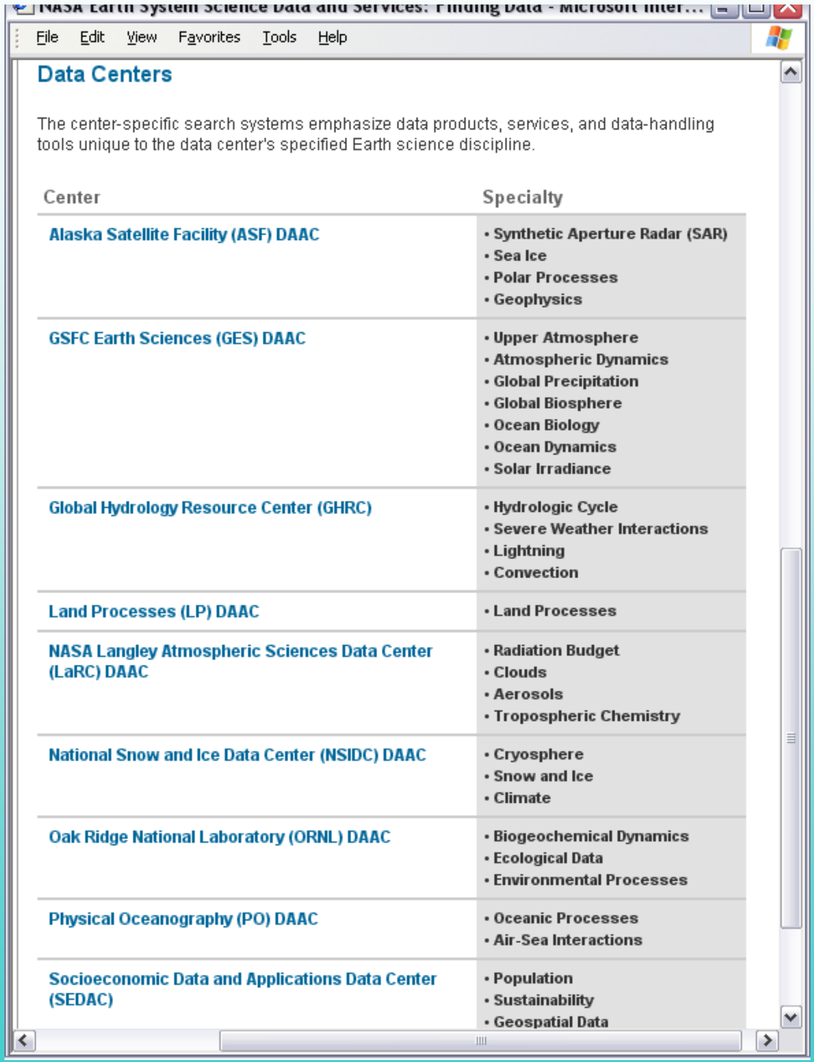
http://gcmd.nasa.gov

The GCMD holds Earth science data set and service descriptions, such as location of the data or service, associated investigators and other contacts, spatial and temporal coverage, and resolution that provide vital information to help determine whether the data or service meets the user's needs. Use the GCMD to search for information about data and services; to order EOSDIS data, use search-and-order systems such as the EDG or DAAC-specific systems.

Federation Interactive Network for Discovery (FIND)

http://mercury.ornl.gov/esip

The FIND Web-based system enables users to locate data and information held by members



NASA Earth System Science Data and Services: Finding Data - Microsoft Inter...

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Data Centers

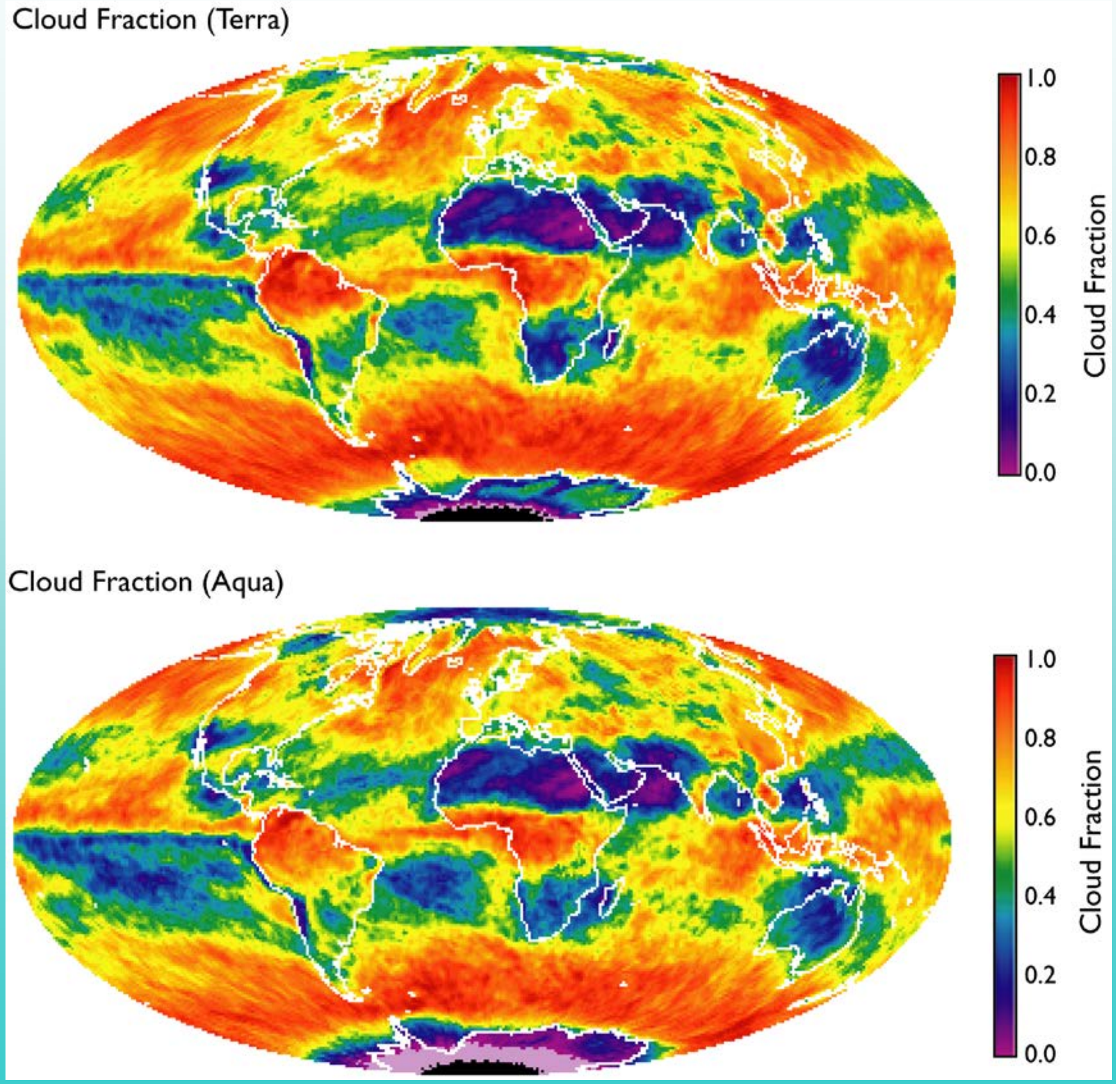
The center-specific search systems emphasize data products, services, and data-handling tools unique to the data center's specified Earth science discipline.

Center	Specialty
Alaska Satellite Facility (ASF) DAAC	• Synthetic Aperture Radar (SAR) • Sea Ice • Polar Processes • Geophysics
GSFC Earth Sciences (GES) DAAC	• Upper Atmosphere • Atmospheric Dynamics • Global Precipitation • Global Biosphere • Ocean Biology • Ocean Dynamics • Solar Irradiance
Global Hydrology Resource Center (GHRC)	• Hydrologic Cycle • Severe Weather Interactions • Lightning • Convection
Land Processes (LP) DAAC	• Land Processes
NASA Langley Atmospheric Sciences Data Center (LaRC) DAAC	• Radiation Budget • Clouds • Aerosols • Tropospheric Chemistry
National Snow and Ice Data Center (NSIDC) DAAC	• Cryosphere • Snow and Ice • Climate
Oak Ridge National Laboratory (ORNL) DAAC	• Biogeochemical Dynamics • Ecological Data • Environmental Processes
Physical Oceanography (PO) DAAC	• Oceanic Processes • Air-Sea Interactions
Socioeconomic Data and Applications Data Center (SEDAC)	• Population • Sustainability • Geospatial Data

Monthly Mean Cloud Fraction during Daytime

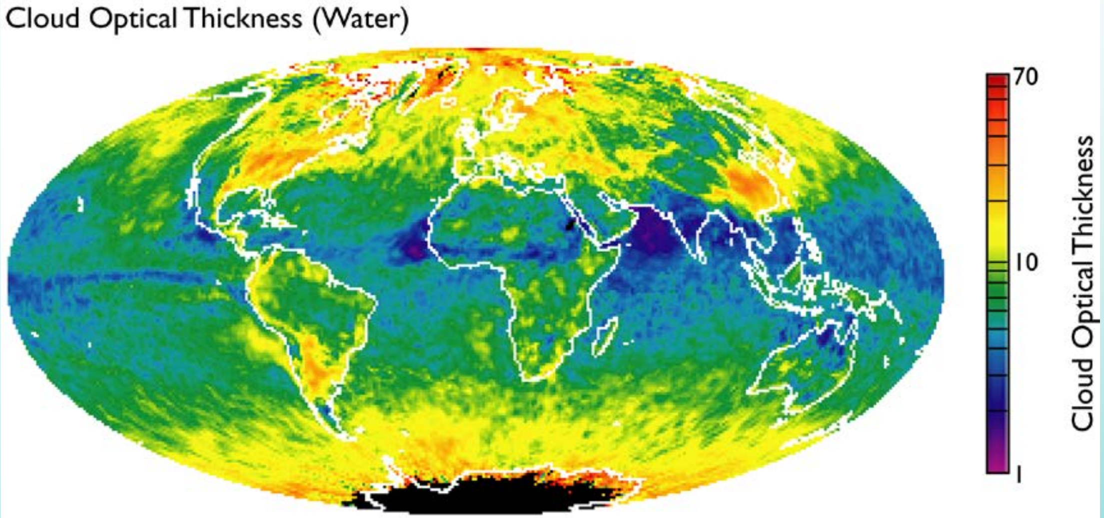
(M. D. King, S. Platnick, S. A. Ackerman et al. – NASA GSFC, U Wisc.)

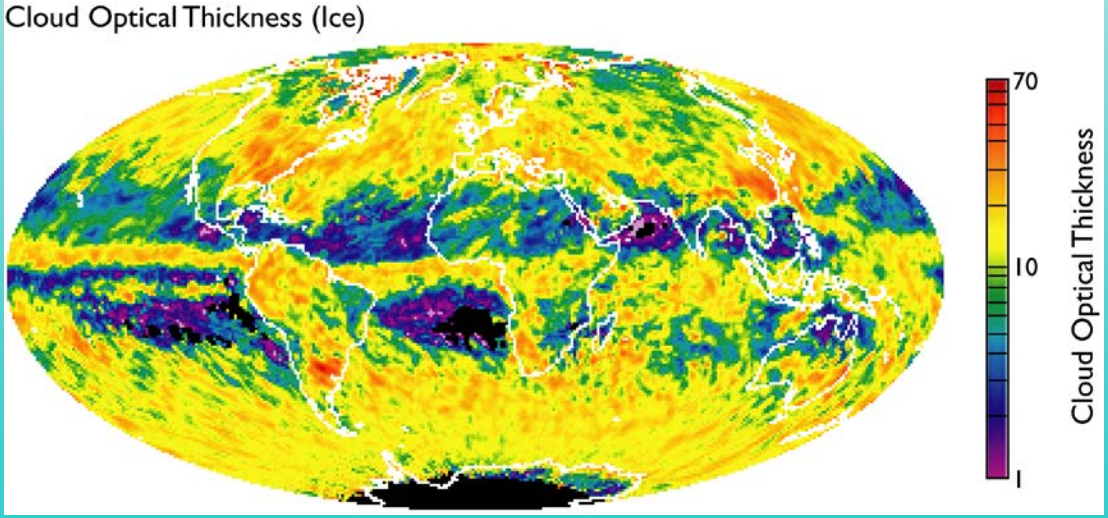
April 2003 (Collection 4)



Monthly Mean Cloud Optical Thickness
(M. D. King, S. Platnick et al. – NASA GSFC)

April 2003
(Collection 4)



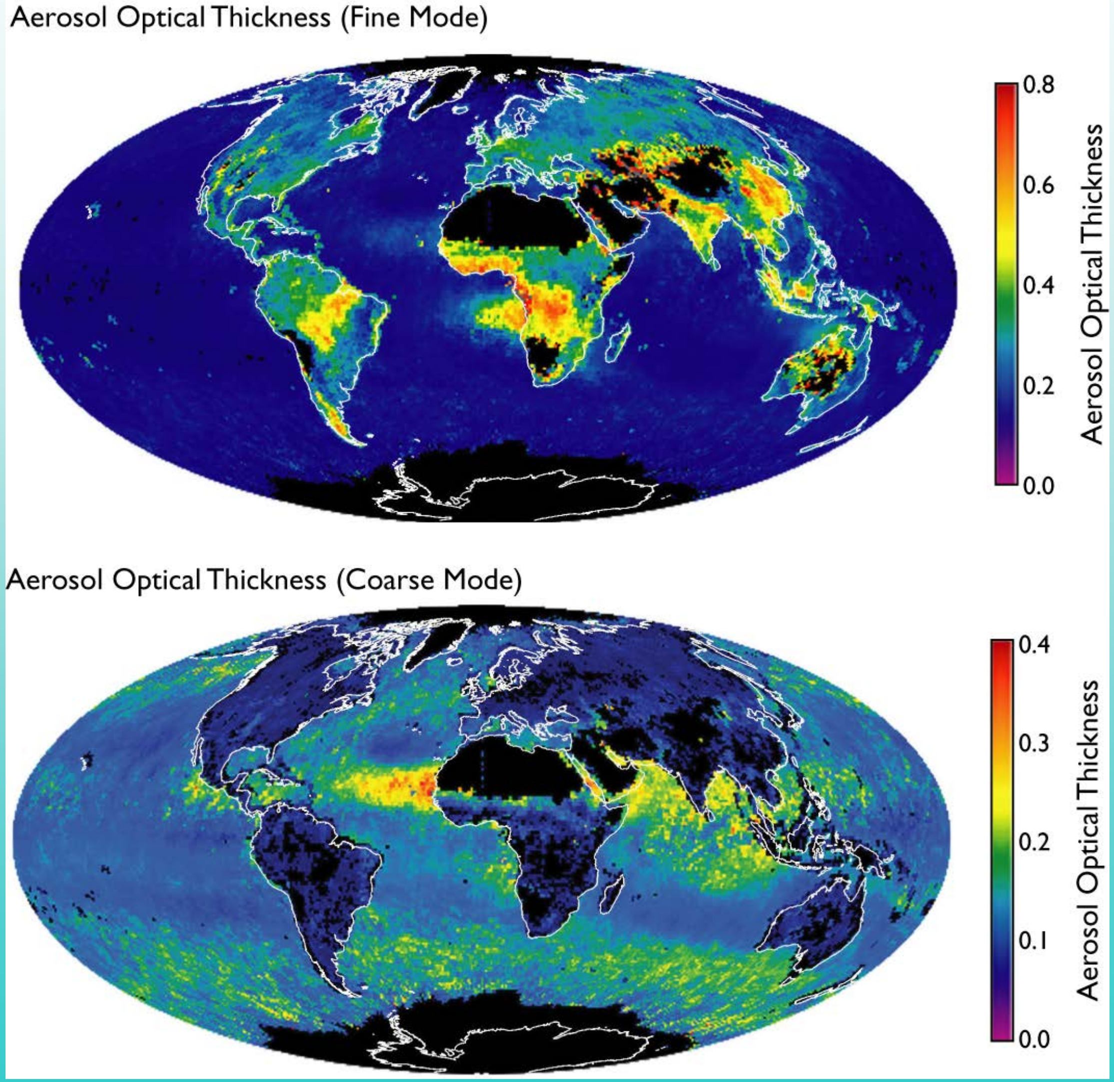


MODIS Monthly Mean Aerosol Optical Thickness

(Y. J. Kaufman, D. Tanré, L. A. Remer – NASA GSFC, Univ. of Lille)

Terra
September 2000

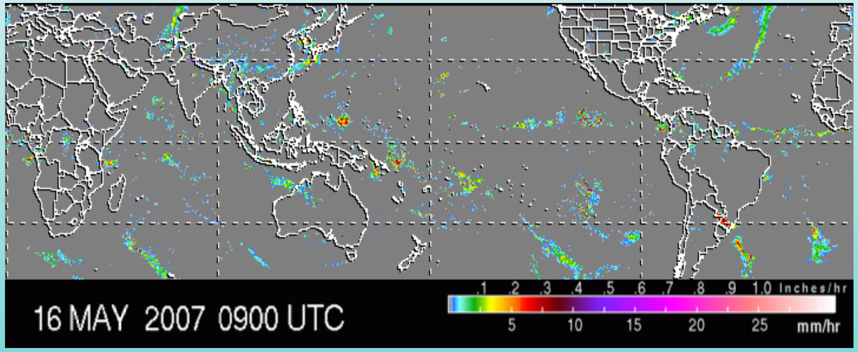
- Fine Mode
  - ➢Industrial pollution
    - – China, India, US, Europe
  - ➢Smoke from biomass burning
    - – Brazil and Bolivia
    - – southern Africa (DRC, Angola, Zambia)
    - – Australia, Borneo
- Coarse Mode
  - ➢Desert dust
    - – Sahara, Arabian Sea
  - ➢Sea salt
    - – Southern ocean

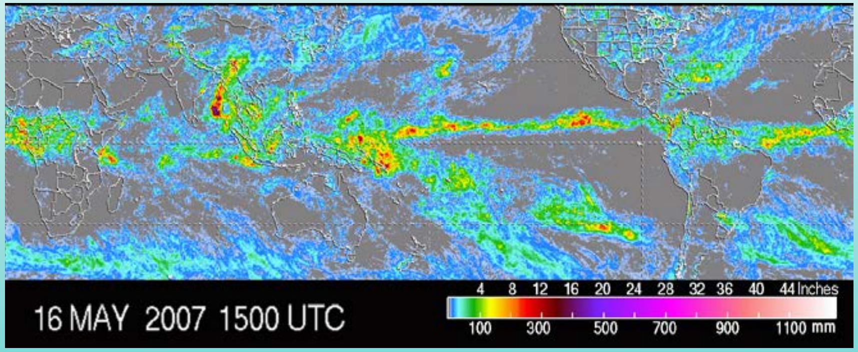


TRMM Rainfall

3-hourly merged “real-time” global

7-day global





Snow Water Equivalent (AMSR-E)

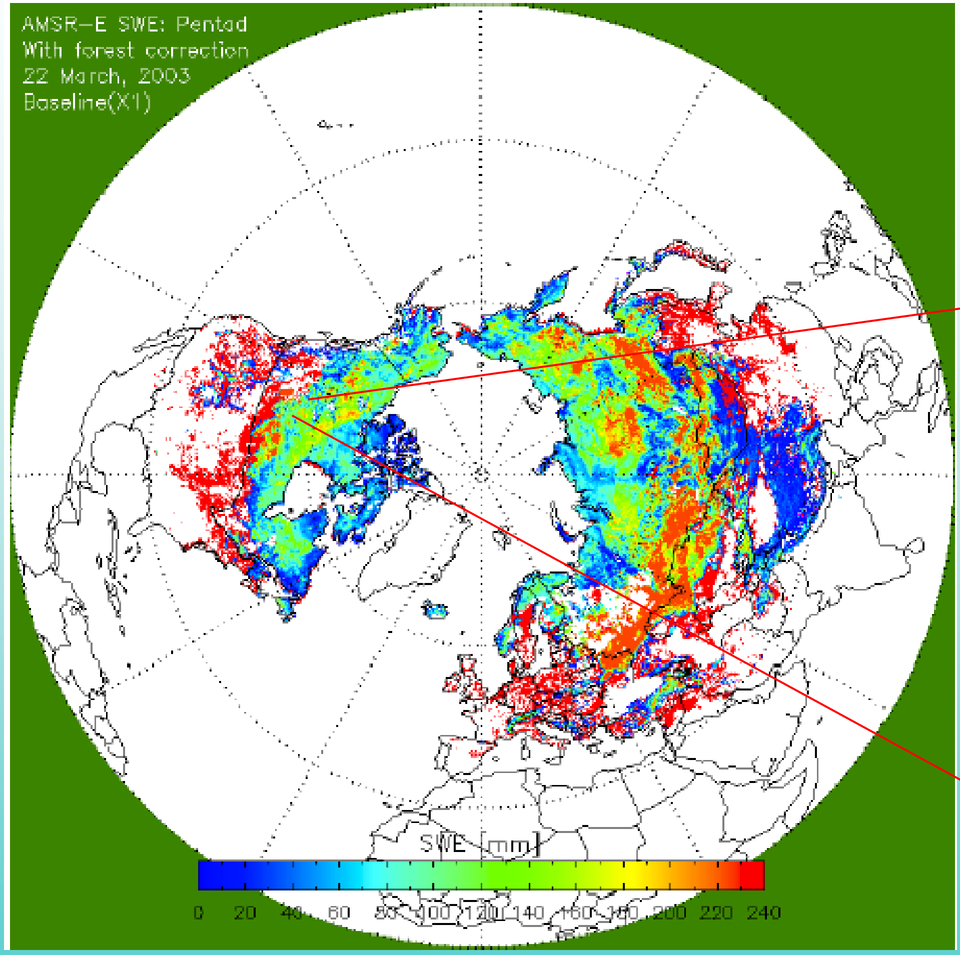


Figure 1. 22 March 2003 Pentad SWE from AMSR-E X1 calibrated data. A forest correction has been made. After Chang et al,, 2003, IEEE TGRS.

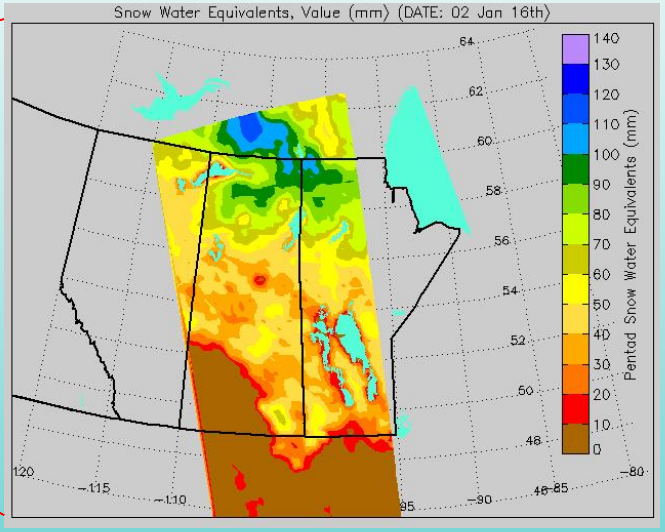
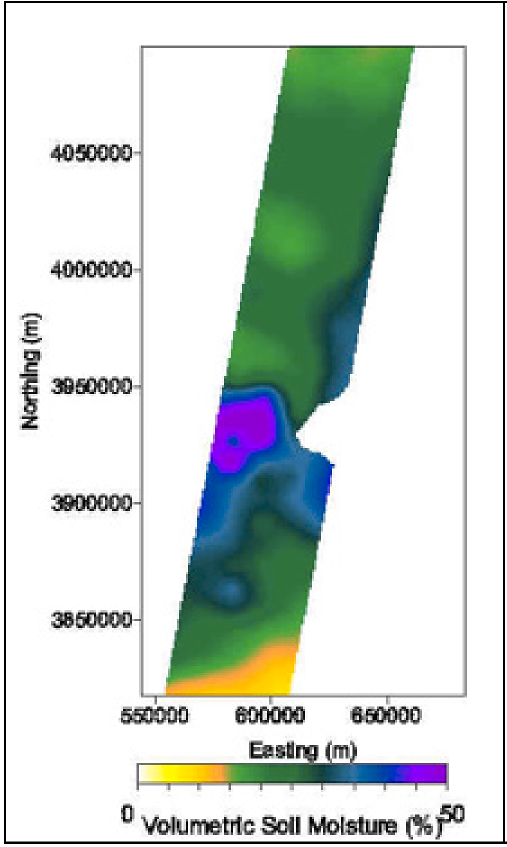


Figure 2. Jan 16, 2002 SWE, after Kelly

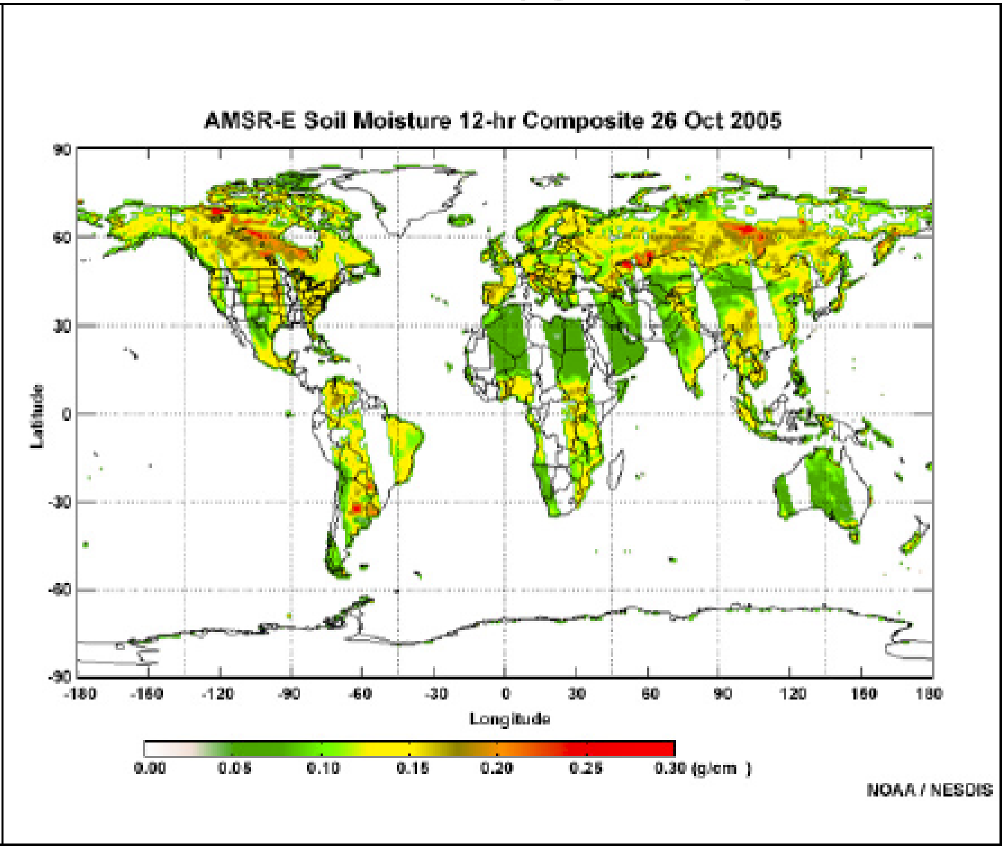
Soil Moisture (TMI and AMSR-E)

TRMM/TMI: TRMM Microwave Imager
Aqua/AMSR-E: Advanced Microwave Scanning Radiometer

TMI (Jackson et al.)

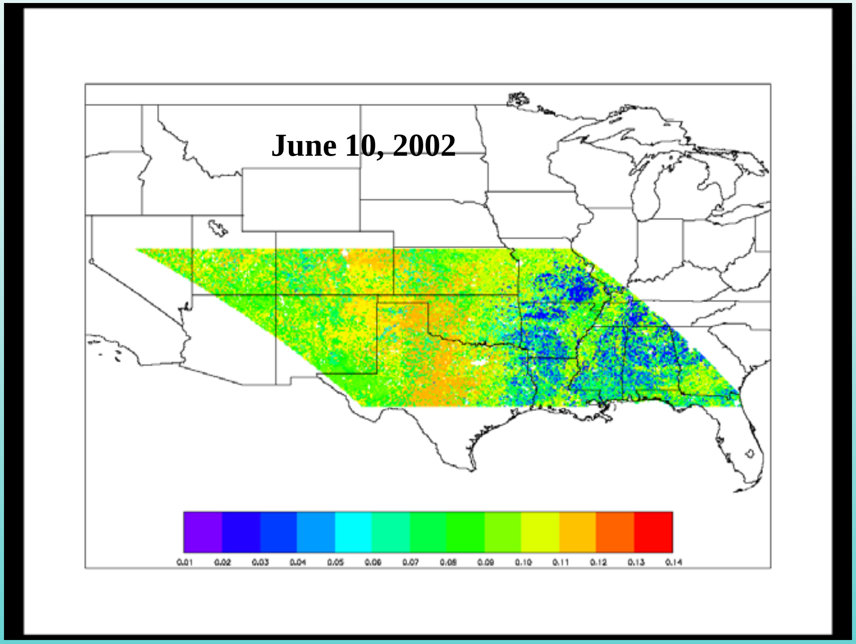


AMSR-E (Njoku et al.)



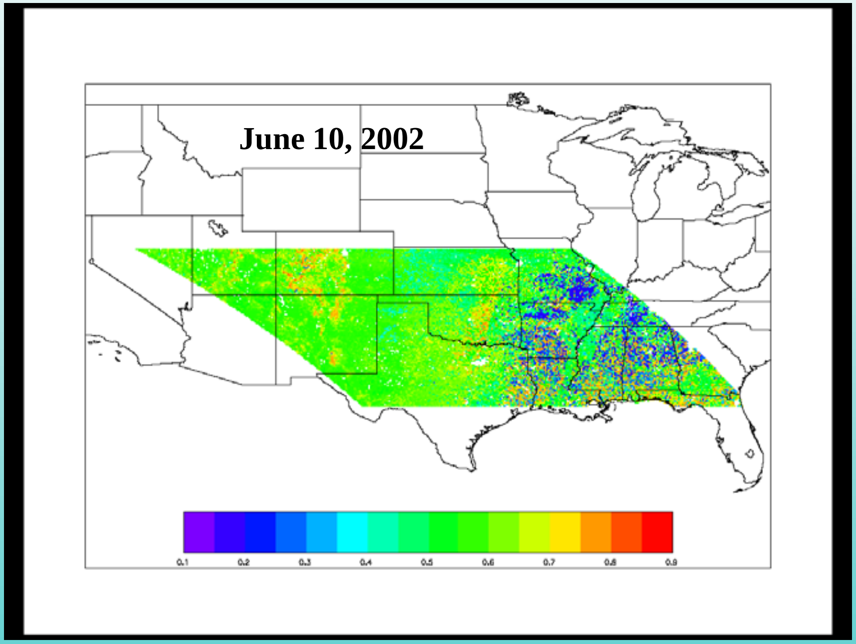
Vegetation aerodynamic roughness from MODIS

Zero-plane displacement height



d_0/h

Normalized roughness length

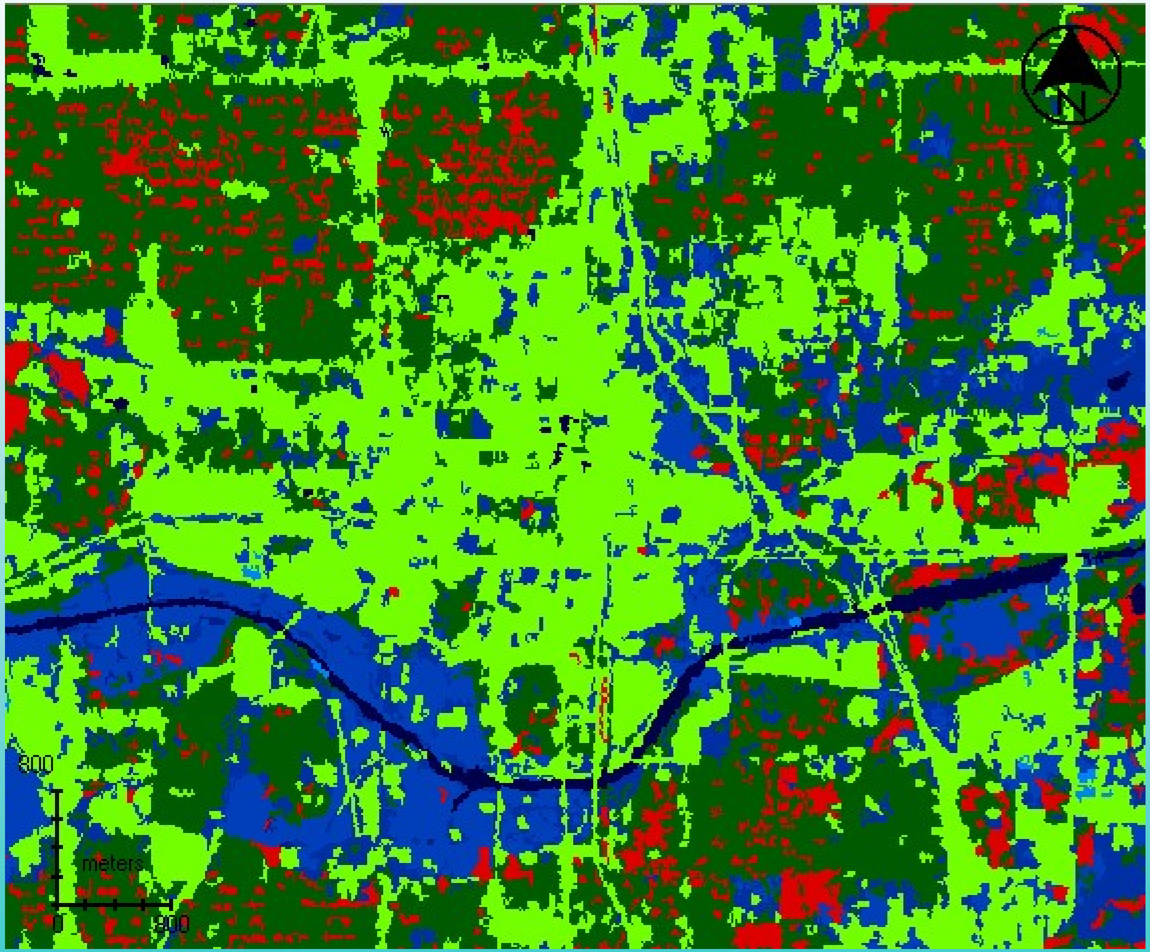


z_0/h

Jasinski, Borak and Crago, Agriculture and Forest Meteorology, 133(2005), 55-68

Oklahoma City Surface Roughness (ASTER)

Map derived from ASTER LULC classification with HAZUS-MH lookup table (z_0 LUT, in meters)



Color	z0 LUT	Class Description
	0.010	Open Water
	0.040	Grasslands/Herbaceous Upland
	0.050	Urban/Recreational Grasses
	0.060	Small Grains
	0.101	Bare Rock/Sand/Clay
	0.339	Low Intensity Residential
	0.373	Commercial/Industrial/Transportation
	0.736	Deciduous Forest

- **Tall-building areas (Central Business District, CBD) with high surface roughness (> 2 m) are still grouped into a catch-all class "commercial, industrial, transportation" with the z_0 value of 0.373 m which is too low.**
- **Efforts are underway to separate the CBD areas using the ASTER LULC classification and elevation data.**

Contributed by S. Blonski, J. Spruce, J. Bergland, Stennis Space Center

Summary
Space-Based Hydrologic Observations - Current Capability

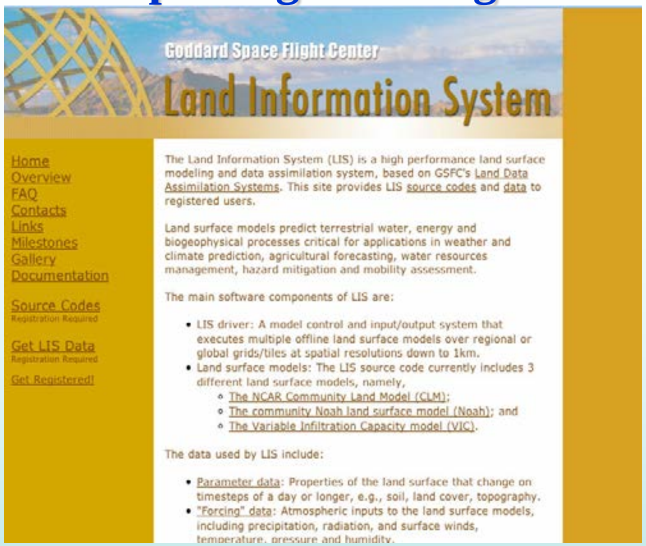
		Sensor	Technology	Horizontal Resolution	Repeat Frequency		Swath Width		
Precipitation		TRMM	Precip Radar (JAXA) TMI, VIRS	5 km 0.25x0.25deg	daily		247 km 878 km		
Soil moisture		SSMI AMSR-E	Multifrequency Radiometers	12-56 km	5-day		1445 km		
Groundwater		GRACE	gravity	100,000 km2	30 days		-		
Lake/reservoir levels		Topex/ Poseidon Jason-1	Altimetric radar	350 m	10 day		Single track		
Evaporation		MODIS	Visible/NIR	250-1000m	1-2 days				
Stream discharge		Topex Poseidon Jason-1	Altimetric radar	350m	10-day		Single track		
Snow water equivalent		SSMI AMSR-E	Multifrequency Radiometers	12-56 km	5-day		1445 km		
Snow cover		MODIS	Vis/NIR	250-1000m	1-2 days		2330 km		
roughness		MODIS		1 km	monthly				

Land Data Assimilation Products

Land Information System
Global Land Data Assimilation System
(LIS/GLDAS)

- Data assimilation capability
- Regional to Global; 1 km to 0.25 degree
- Offline or coupled modes

http://lis.gsfc.nasa.gov



Goddard Space Flight Center
Land Information System

Home
Overview
FAQ
Contacts
Links
Milestones
Gallery
Documentation
Source Codes
Registration Required
Get LIS Data
Registration Required
Get Registered!

The Land Information System (LIS) is a high performance land surface modeling and data assimilation system, based on GSFC's Land Data Assimilation Systems. This site provides LIS source codes and data to registered users.

Land surface models predict terrestrial water, energy and biogeophysical processes critical for applications in weather and climate prediction, agricultural forecasting, water resources management, hazard mitigation and mobility assessment.

The main software components of LIS are:

- LIS driver: A model control and input/output system that executes multiple offline land surface models over regional or global grids/tiles at spatial resolutions down to 1km.
- Land surface models: The LIS source code currently includes 3 different land surface models, namely,
  - The NCAR Community Land Model (CLM);
  - The community Noah land surface model (Noah); and
  - The Variable Infiltration Capacity model (VIC).

The data used by LIS include:

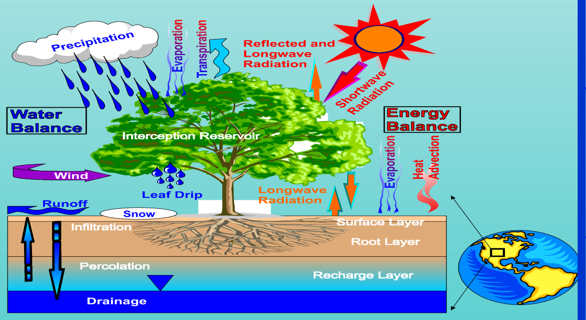
- Parameter data: Properties of the land surface that change on timesteps of a day or longer, e.g., soil, land cover, topography.
- "Forcing" data: Atmospheric inputs to the land surface models, including precipitation, radiation, and surface winds, temperature, pressure and humidity.

Inputs

- Topography, Soils
- Land Cover, Vegetation Properties
- Meteorological Forecasts, Re-Analyses, and/or Observations
- *Satellite Snow Soil Moisture Temperature*

Physics

Land Surface Models (CLM, Noah, VIC)



Data Assimilation Modules

Outputs

- Soil Moisture & Temperature
- Evaporation Sensible Heat Flux
- Runoff
- Snowpack Properties

Applications

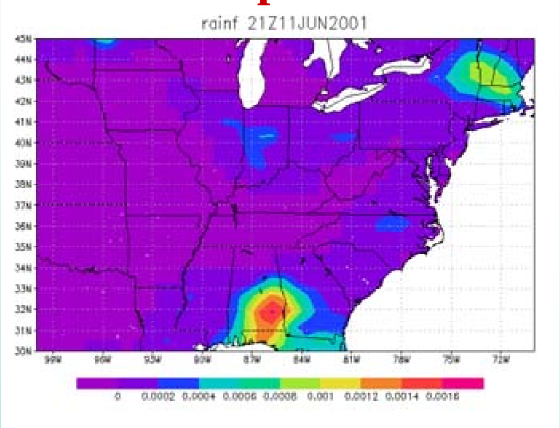
- Weather/ Climate
- Water Resources
- Homeland Security
- Military Ops
- Natural Hazards

Peters-Lidard, NASA GSFC

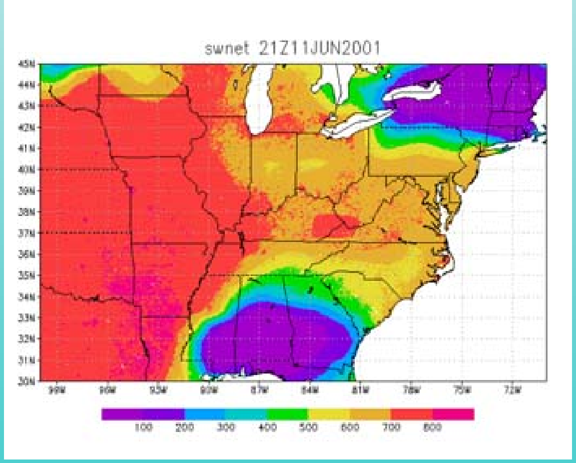
LIS/GLDAS Typical Results

Eastern United States, June 12, 2001, 3 PM

Input

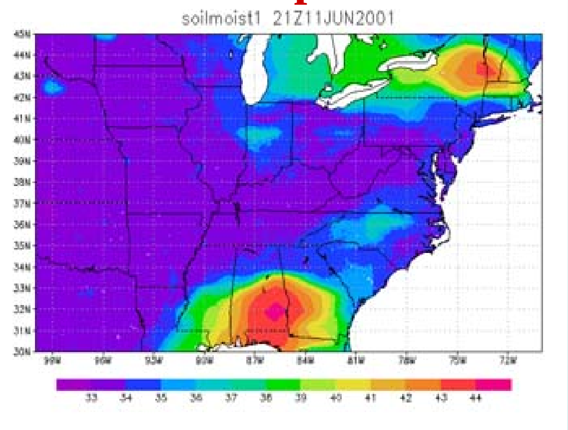


Precipitation

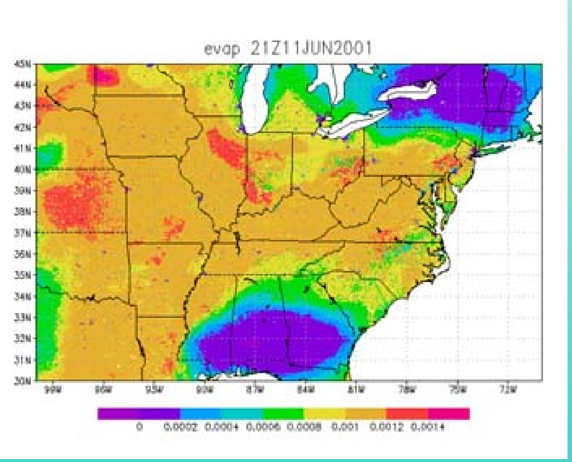


Net shortwave radiation

Output



Surface evaporation



Root-zone soil moisture

Future Missions

Currently Planned NASA Missions

Earth Science Mission Priorities	
Missions	**Priority Rationale**
NPOESS Preparatory Project [2009] Strategic mission - Systematic measurement	Required for continuity of several key climate measurements between the Earth Observing System and NPOESS. Implementation of the NPOESS Presidential Decision Directive of 1994. Joint mission with the NPOESS Integrated Program Office
Landsat Data Continuity Mission (LDCM) [2010] Strategic mission - Systematic measurement	Required for continuity of long-term global land cover change data; post-LDCM land imagery acquisition by an operational agency is planned. Mandated by the Land Remote Sensing Policy Act of 1992. Joint mission with USGS
Ocean Surface Topography Mission (OSTM) [2008] Strategic mission - Systematic measurement	Required for continuity of ocean altimetry; planned as part of a transition to operational agencies. Joint mission with CNES, NOAA and EUMETSAT
Glory [2008] Strategic mission - Initializes a systematic measurement	Addresses high priority objective of the U.S. Climate Change Science Program. Measure global aerosols and liquid cloud properties and solar radiation. Mandated by the President's Climate Change Research Initiative of 2001
Orbiting Carbon Observatory (OCO) [2008] Competed mission - Earth System Science Pathfinder	Nearing completion of development. First global measurement of CO_2 from space; small Earth science mission
Aquarius [2009] Competed mission - Earth System Science Pathfinder	In advanced stage of development. First global measurement of sea-surface salinity from space; small Earth science mission. Joint mission with Argentina
Global Precipitation Measurement (GPM) [2012] Strategic mission - Initializes a systematic measurement	Recommended by 2005 interim report of decadal survey committee; extend spatial coverage to global and temporal coverage to every 3 hours with constellation

Additional NASA Missions Recommended in NRC Decadal Survey

Timeframe 2010-2013

CLARREO (NASA portion)	Solar and Earth radiation, spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter

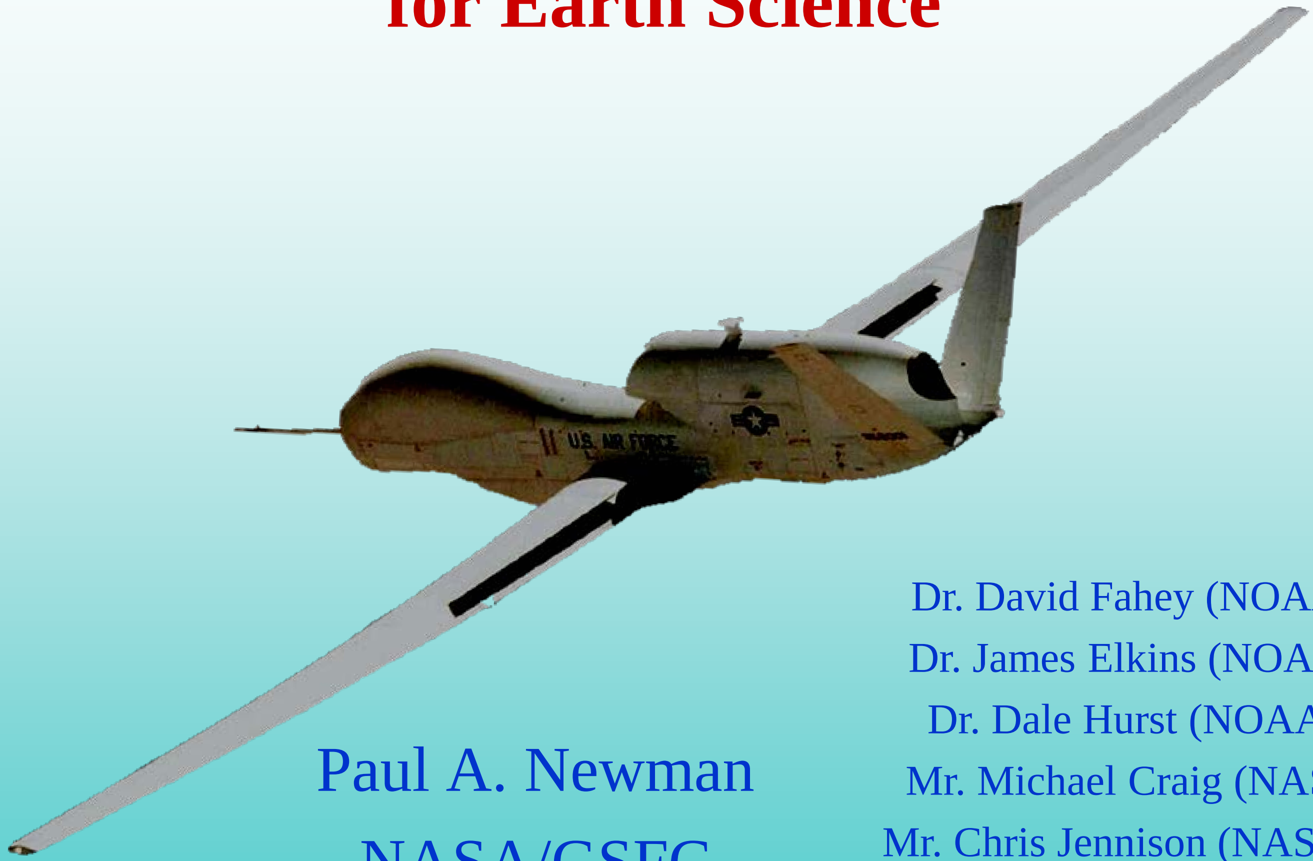
Timeframe 2013-2016

HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar

Timeframe 2016-2020

LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar

Unmanned Aircraft Systems (UAS) for Earth Science



Paul A. Newman
NASA/GSFC

Dr. David Fahey (NOAA/ESRL)
Dr. James Elkins (NOAA/ESRL)
Dr. Dale Hurst (NOAA/ESRL)
Mr. Michael Craig (NASA/ARC)
Mr. Chris Jennison (NASA/Dryden)
Mr. Robert Curry (NASA/Dryden)
Col. Andrew Roberts (NASA/HQ)
Ms. Cheryl Yuhas (NASA/HQ)

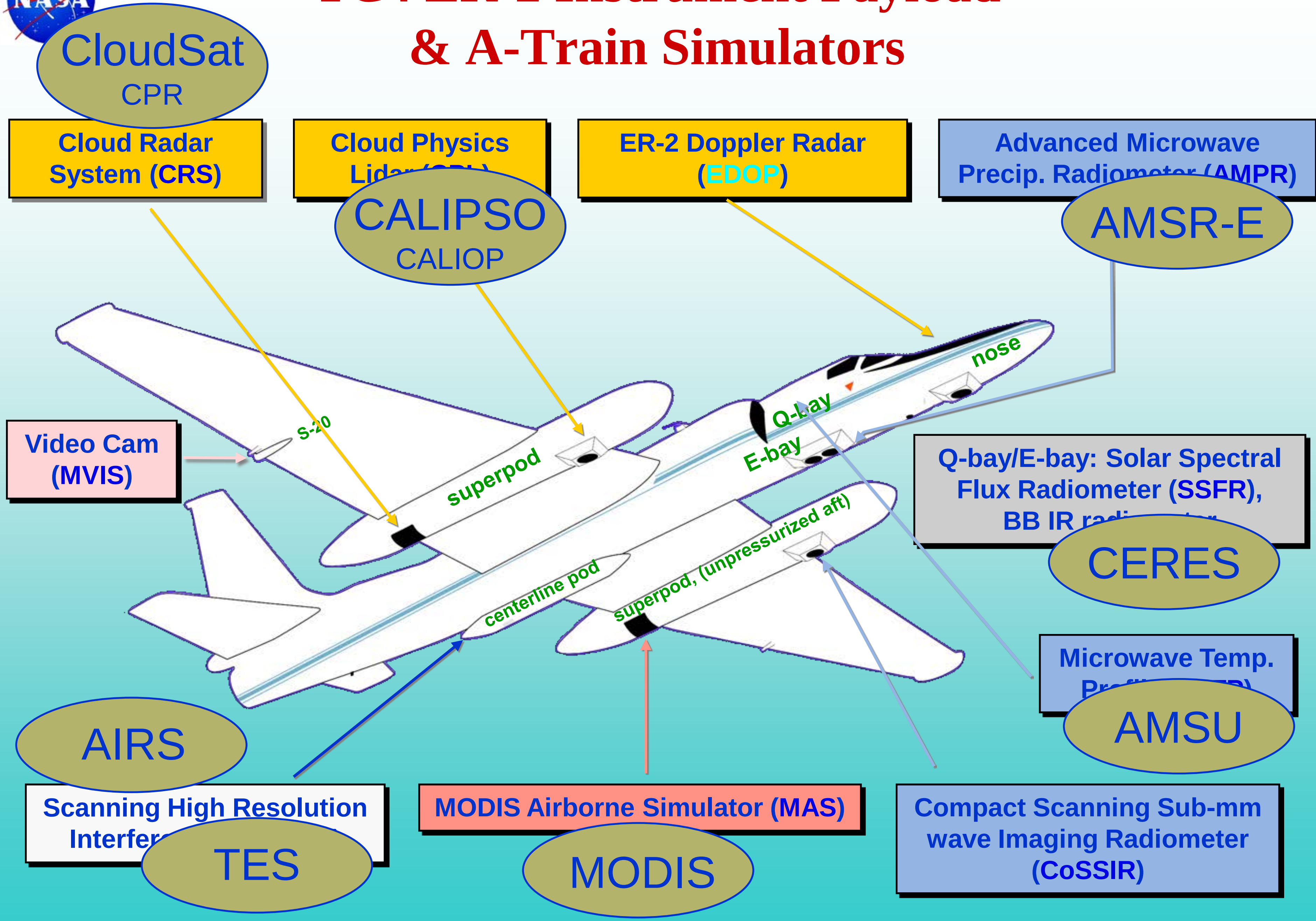
Role of aircraft

- Prototype instrument test-beds, algorithm development
- Process studies for focused science questions
- Satellite validation
- Monitoring and Applications

Validation Example: Tropical Composition, Cloud and Climate Coupling (TC^4) (2007)

- Coordinated science mission to both validate A-train instruments and to investigate tropical clouds and the tropical transition layer
- 3 aircraft: NASA's ER-2, DC-8, and WB-57f
- Dr. David Starr (Branch Head, 613.1) as project scientist
- San Jose, Costa Rica (July 14-August 11, 2007)

TC4 ER-2 Instrument Payload
& A-Train Simulators



Some UAS examples

Aerosonde Ltd.'s Aerosonde

Range:	3000 km
Endurance:	30 hrs.
Max. Alt.:	5 km
Payload:	2.3 kg
Length:	2.1 m
Wingspan:	2.9 m
Speed:	70 kph
Engine:	24 cc fuel injection
Launch:	Car roof

UAV facility at Wallops Flight Facility supports and coordinates Aerosonde operations for NASA sub-orbital program

AeroVironment's Heilos

Range:	**150 km**
Endurance:	**Daylight (<15 hrs.)**
Max. Alt.:	**30 km**
Payload:	**16 kg**
Weight:	**600 kg**
Length:	**3.6 m**
Wingspan:	**76.8 m**
Speed:	**17-21 mph**
Power:	**Bi-facial solar cells ~ 270 m^2**
Engine:	**8 DC electric motors (1.5 kW)**
Launch:	**Wheeled**

Altair UAS

In September 2005 the FAA granted it the first experimental Airworthiness Certificate for a one year "file and fly" for use in commercial missions. The certification came with restrictions on weather conditions and altitudes and Visual Flight Rules are in effect at all times.

Altair Specifications

Wingspan:	86 ft (26.21m)
Fuselage:	36 ft (10.97m)
Weight:	7,000 lb (3175 kg)
Altitude:	> 47,000 ft
Endurance:	> 24 hr.
Payload:	
Internal -	660 lb (300 kg)
External -	3,000 lb (1361 kg)
Powerplant:	Honeywell TPE 331-10T
Air Speed:	200 kts

- Built by GA-ASI for NASA's Environmental Research Aircraft and Sensor Technology (ERAST) Program
- Currently leased by NASA
- Purpose: High-altitude Earth science missions
- First flight: March 2003

Gray Butte Airfield, CA

Ikhana (Predator B)

A NASA Unmanned Aerial System
Supporting Long-Duration Earth Science Missions

'Mission ready' in July, 2007

Capabilities

- Endurance > 24 hours
- Altitude < 28,800 ft (RSVM restricted)
- Payload > 2,000 lbs (750 in pod)
- Range 3,500 nautical miles

- Highly reliable UAS
  - Standard MQ-9 w/digital engine control
  - Triple redundant flight control systems, dual redundant power & networks
  - Predator family has logged over 200,000 hours

Northrop Grumman's Global Hawk

Range: 13,500 nm
Endurance: > 30 hrs.
Max. Alt.: 65,000 ft.
Payload: > 1500 lbs.

Platform Requirements

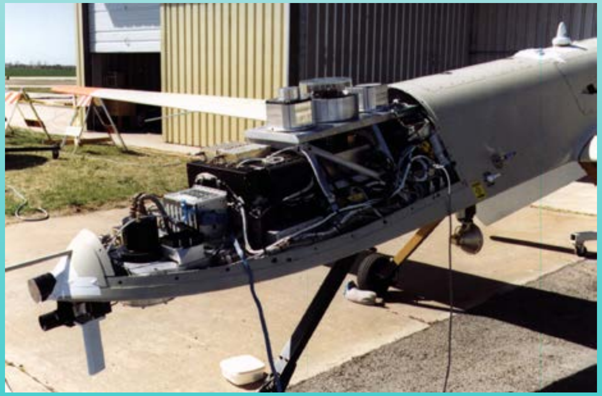
- **Reliable, heritage, rapid turnaround**
- **Payload capability**
  - 40 ft^3 pressurized
  - 62 ft^3 un-pressurized
  - Can accommodate wing pods
  - Access (attended instruments, proper sampling)
- **Good altitude and/or range**
  - **4000 nm@20 km**

NASA now owns 2 Global Hawks
- unfunded

DOE Atmospheric Radiation Measurement (ARM) ARM Aircraft Program (1996)

- 1993-2002: 4 campaigns (1 Gnat, 3 Altus)
- For measurements at the top of the troposphere in the tropics - long endurance UAV for altitudes > 60 kft (18 km)
- 1st science flights using a UAV in 1994
- 1st use of an unescorted UAV in general use airspace in 1996
- Development of a GPS-based system that allows precise vertically stacked flight of a UAV and a piloted aircraft for cloud absorption measurements
- A flight of over 26 hours in duration over the CART site (5 Oct. 1996)
- Development of several compact instruments suitable for UAV applications.

General Atomics Gnat



USCG Alaskan Maritime Surveillance (Summer, 2004)

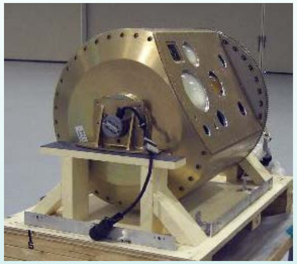
- Objective: Evaluate use of a UAS for intelligence, surveillance, and reconnaissance (ISR) operations

- Objective: Evaluate use of a UAS for intelligence, surveillance, and reconnaissance (ISR) operations

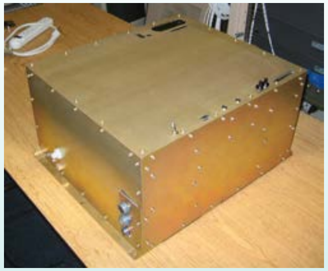
- Overview
  - United States Coast Guard (USCG), NASA, GA, and others
  - General Atomics Altair (high-altitude Predator B derivative)
  - Payload
    - surface surveillance radar, . . .
    - internal integration
  - Flight Operations: Summer, 2004
    - Self deployment from California to Alaska
    - Launch and recovery team operating remote from mission operations center in Juneau
    - Over the horizon shore to ship communications relay

NOAA/NASA UAV Demonstration Project (2005)

- Objective: Evaluate the use of a UAV for future science and operational requirements
  - Atmospheric research
    - sample low-level Eastern Pacific jets
  - Atmospheric research
    - coastal mapping, wildlife monitoring, marine enforcement



Ocean Color & Passive Microwave Vertical Sounder



Gas Chromatograph & Ozone Sensor

- Overview
  - NOAA, NASA joint project
  - General Atomics Altair
  - Internal payload integration
  - Flight operations
    Spring, 2005 and Fall, 2005
    - Flights in National Air Space (NAS) under Certificate of Authorization (COA)
      - primarily at FL430
      - descents below 18,000 ft escorted by chase plane

Altair integrated with NOAA science payload

The Altus Cumulus Electrification Study (ACES) (August 2002)

- Science objectives
  - Lightning Imaging Sensor (LIS) validation
    - Lightning type, cloud-top optical energy, and power statistics
  - Lightning-storm relationships
  - Storm electric budget
- August 2002: 13 flights, 30 hours of data
- NASA MSFC, PI: Richard Blakeslee

Western States Fire Mission
(Fall, 2006)

- Objective: Identify and monitor wildfire events throughout the Western United States and provide near real-time products to field units

- Overview
  - NASA, USFS, NOAA, GA partnership
  - General Atomics Altair with centerline pod
  - Payload
    - Wildfire sensor – Developed at NASA Ames
      - 13 spectral bands optimized for fire characterization
      - Fully autonomous
    - near real-time data transfer
      - on-board processing (geo-rectification)
      - overlaid with Google-Earth imagery
      - internet access by end users
    - in-situ atmospheric sampling
    - experiment command and control from ground
  - Flight operations: Fall, 2006
    - 5 from base at Grey Butte, CA; primarily in military airspace
    - Only 1 flight into National Air Space (NAS), always at FL430


Ames Research Center
WRAP
Wildfire Research and Applications Partnership
PI - V. Ambrosia, ARC
Terra & Aqua MODIS imaging fires
UAV Platform Fire Imaging
COMSAT Telemetry & Platform C&C
GOES Weather Data
Asset Tracking
Remote Observer NASA HQ
NIFC NIC
USFS RSAC
IC Fire Camps
Wide Area Network
Telemetry / C&C Downlink
Aircraft Operations
Payload Operations
Define aircraft ops
Intelligent Mission Management / CDE
Tactical Fire Information DSS
Direct Broadcast Receiving Station USFS RSAC
Active Fire Maps
http://activefiremaps.fs.fed.us
Three times / day
Tactical Fire Products
GeoTiff & Perimeter File
WRAP Project Webpage
http://geo.arc.nasa.gov/sge/WRAP

Hurricane Ophelia: Aerosonde (September 2005)

- NASA, NOAA and Aerosonde North America
- Sep. 16, 2005
- Launched from Wallops
- Payload:
  - GPS dropwindsonde
  - Temp., press., RH, winds
  - IR KT11 - sea surface temp.

The UAS Coffee Project
(September 2002)

- Application objective
  - imaging over the Kauai Coffee Company's for the detection of differences in coffee field ripening.
  - RGB photographs, narrow band imaging
- September 2002: 1 flight
- AeroEnvironment Pathfinder Plus
- Clark University, PI: Stanley Herwitz

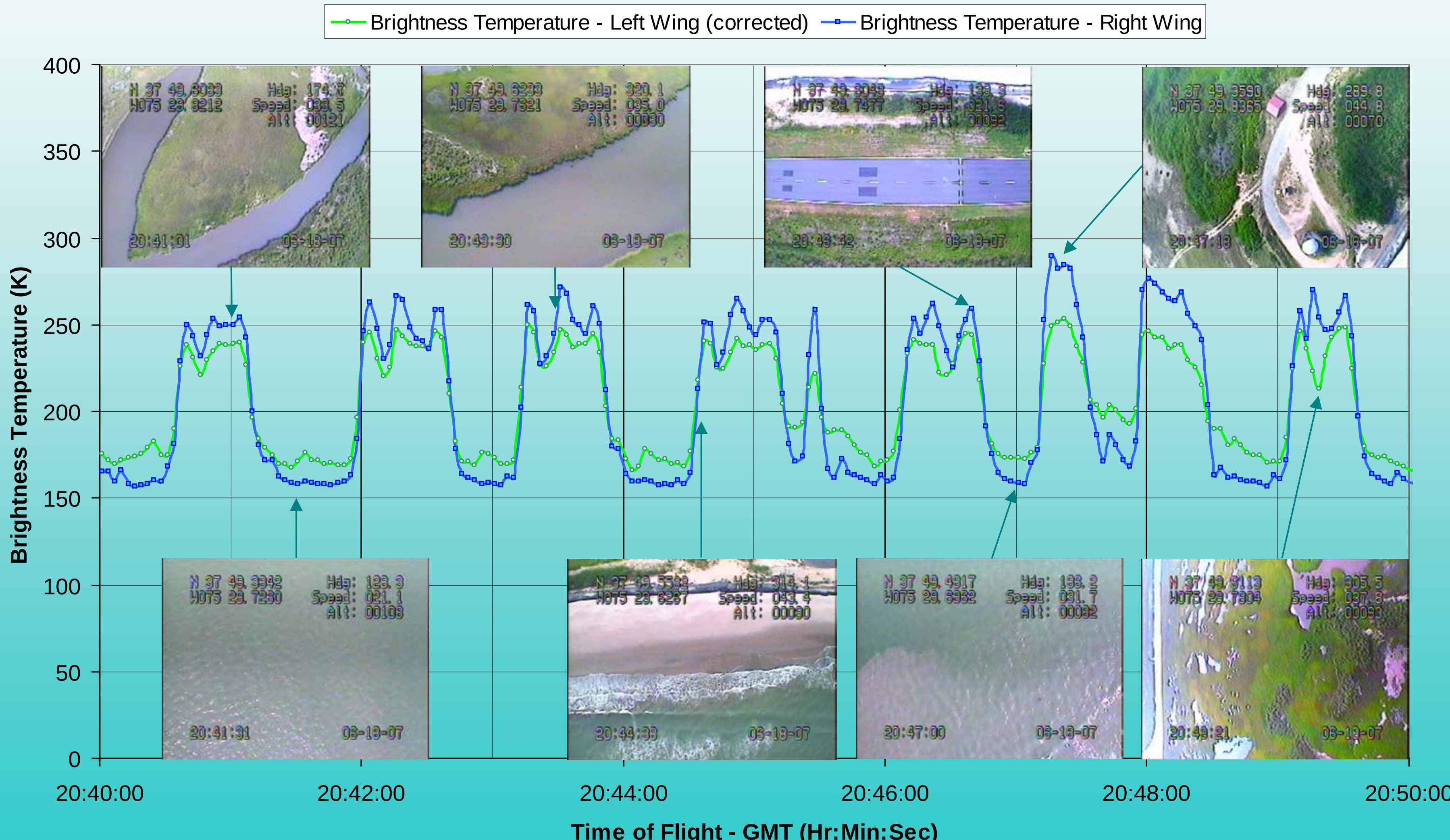
Aerotenna

Small Unmanned Aerial Vehicle (UAV) with Integrated L-Band Radiometer

- Light Weight Passive (~1.4 GHz) Instrument System Developed by GSFC (555/Hillard, et al), for Measurements of Soil Moisture, Sea Surface Salinity, and Snow Depth
- Miniature Airborne System will Enable Fine-Scale Observations for Detailed Hydrological Process Studies

Experimental 12 lb UAV with Electric Propulsion, Instrument, and Data Systems, Developed and Flown at the Wallops Flight Facility (614.6/Bland, 569/Miles)

Success Represents a Major Milestone in the Evolution of Small UAVs for Earth Science Related Observations



Summary
Opportunties for NASA participation in JUTB

- Satellite observations
    - -Current sensors focus on regional to global science
    - -Future sensors w/improved resolution
- LIS/GLDAS extends observations & assists in model initialization
- Feasibility established for UAS in local to regional scale studies
    - Hi resolution
    - frequent repeat
    - more acurate targeting
- Potential for JUTB for satellite calibration
- NASA data archiving and storage facilities