NASA Earth Science Division Report

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Earth Science Division
Science Mission Directorate

NASA Headquarters

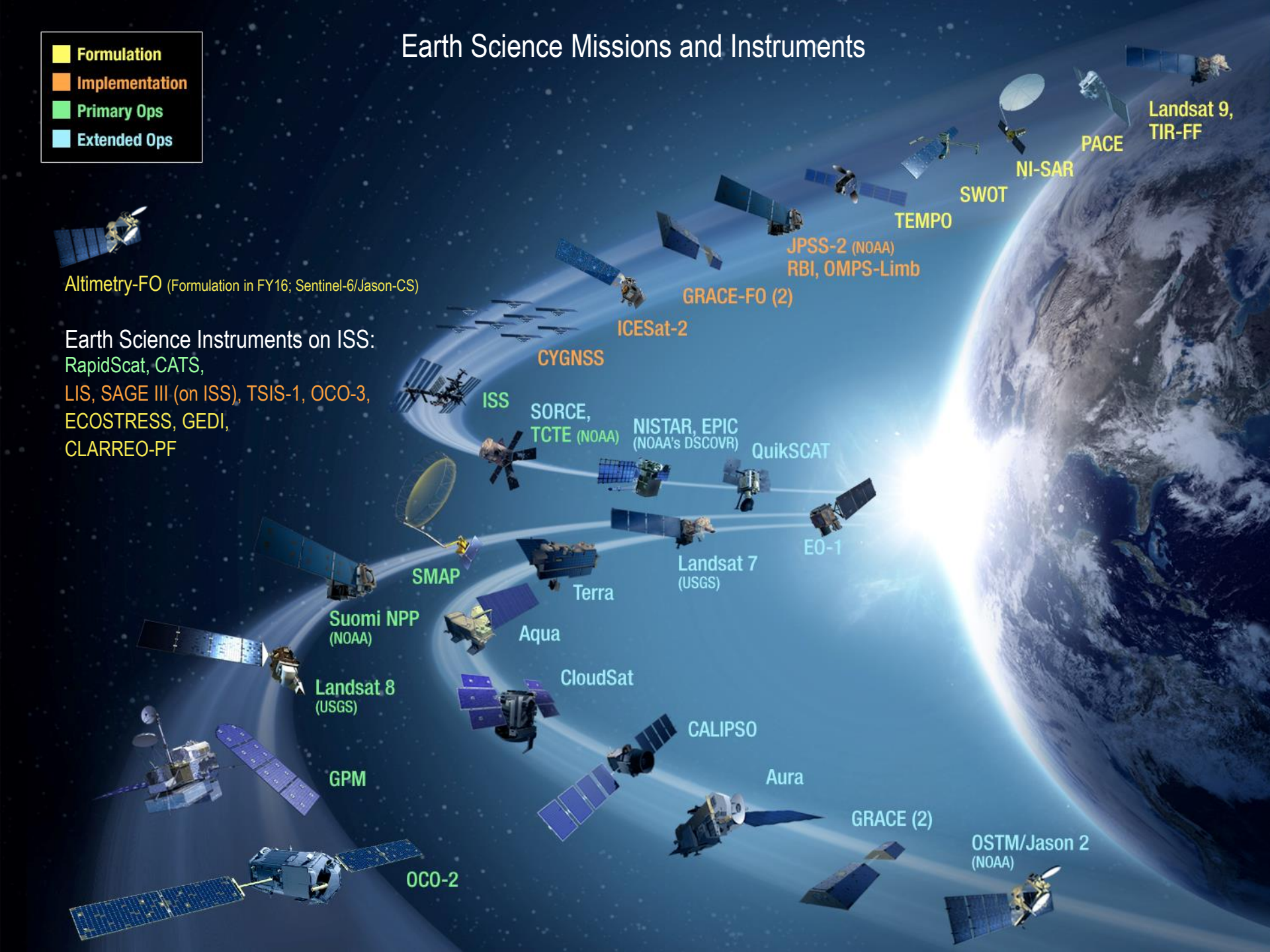
*** This talk is prepared with input and assistance from numerous colleagues at NASA HQ, NASA centers, and the broader research community!**

November 2, 2015

Summary of Talk

- Flight Program
  - Mission Status Chart
  - Venture Class Launch Services
- Field Work
  - ABoVE campaign
  - Airborne missions
- Technology – InVEST (U-Class Satellites)
- Some Recent Results
- Interagency Coordination Highlights
- Some Final Imagery

Earth Science Missions and Instruments



Accomplishments/Plans

- Recent Accomplishments
  - Release of second Earth Venture Mission (EVM-2) Announcement of Opportunity
  - Initial release of SMAP data; radar Mishap Investigation Board initiated
  - Mechanical and Electrical Integration of ICESat-2 ATLAS Instrument lasers
  - SAGE III on ISS Environmental Test Program successfully completed
  - GRACE FO Systems Integration Review/KDP-D
  - CYGNSS Systems Integration Review/KDP-D
  - GEDI Systems Requirements Review/KDP-B
  - ECOSTRESS Preliminary Design Review/Instrument KDP-C

- Upcoming Plans
  - Selection from the third Earth Venture Instrument (EVI-3) solicitation
  - SAGE III on ISS, shipment to KSC planned before the end of CY 2016; launch delayed to June 2016 due to SpaceX-10 readiness
  - SWOT Preliminary Design Review/KDP-C
  - GEDI Preliminary Design Review/KDP-C
  - ECOSTRESS Critical Design Review
  - PACE Mission Concept Review/KDP-A
  - Planning for initiation of Jason-CS/Sentinel 6 and CLARREO Pathfinder

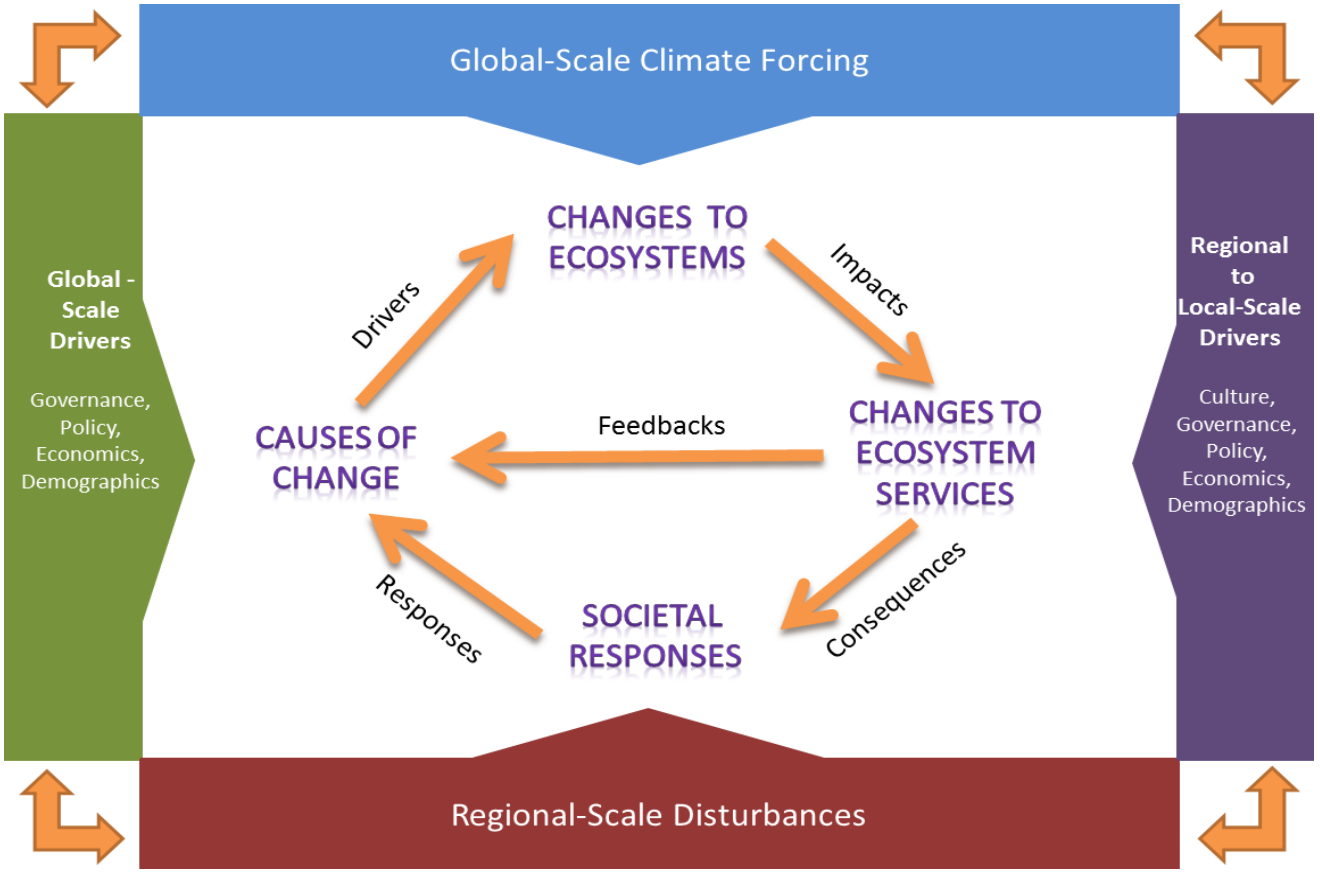
Venture Class Launch Services (VCLS)

- Joint ESD/NASA Launch Services Program initiative
- RFP released 12 June 2015; Selections announced 14 Oct 2015
- Funded with $10M from ESD
  - Selected launches will:
    - Accommodate 132 pounds (60 kilograms) of CubeSats on 1 or more launches
    - Launch(es) must occur by April 15, 2018

- Selectees:
  - Firefly Space Systems, Inc.
  - Virgin Galactic LLC
  - Rocket Lab USA, Inc.

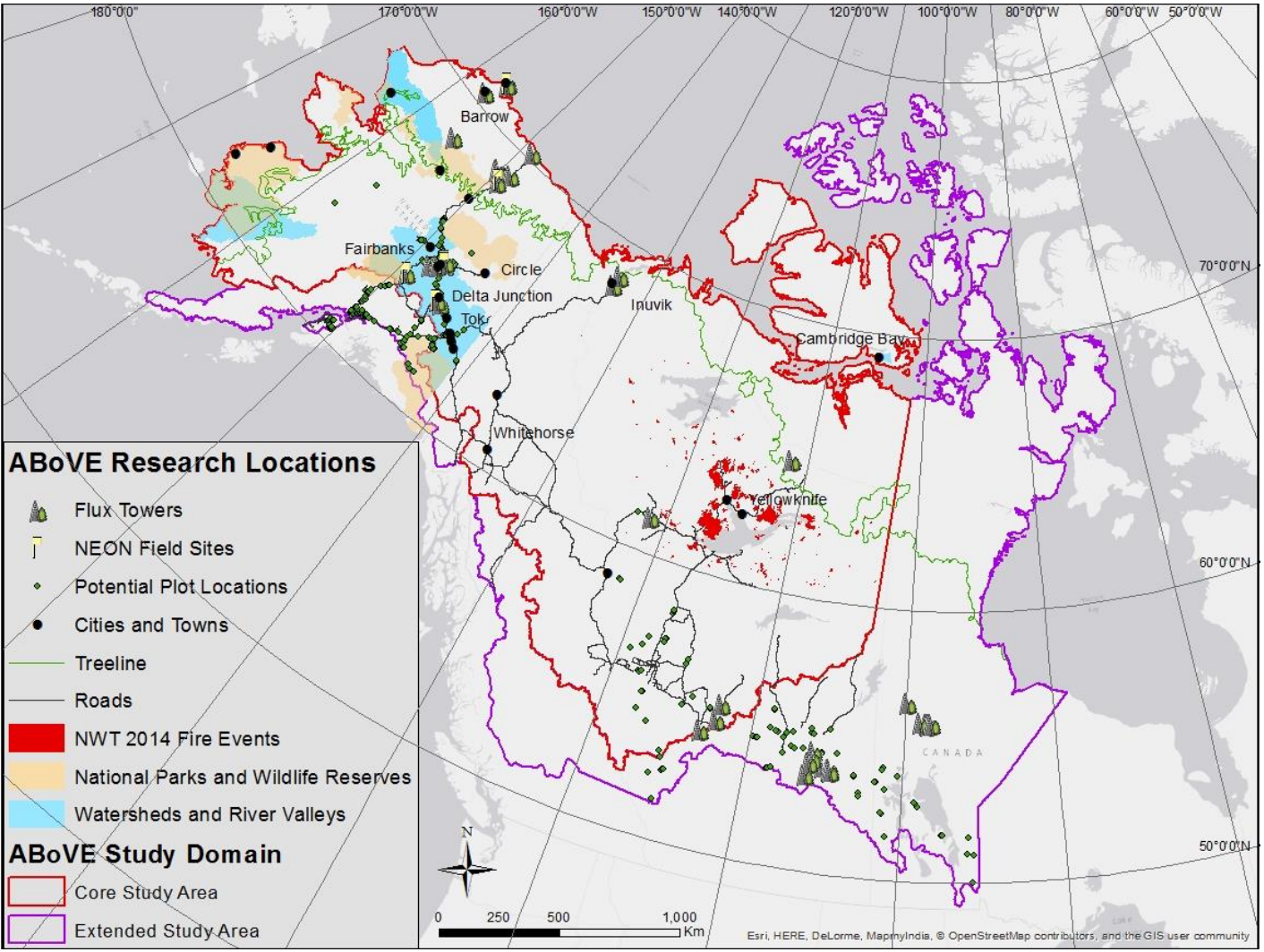
Tangible and substantial ESD investment in small launch vehicles

Conceptual Diagram of the Vulnerability/Resilience Framework Used for Organizing the ABoVE Science Questions and Objectives



ABoVE's Overarching Science Question:

How vulnerable or resilient are ecosystems and society to environmental change in the Arctic and boreal region of western North America?


180°0'0"
170°0'0"W
160°0'0"W
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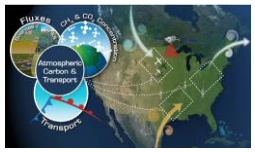
140°0'0"W
120°0'0"W
100°0'0"W
80°0'0"W
60°0'0"W
50°0'0"W
70°0'0"N
60°0'0"N
50°0'0"N
Barrow
Fairbanks
Circle
Delta Junction
Tok
Inuvik
Cambridge Bay
Whitehorse
Yellowknife
CANADA
ABoVE Research Locations
Flux Towers
NEON Field Sites
Potential Plot Locations
Cities and Towns
Treeline
Roads
NWT 2014 Fire Events
National Parks and Wildlife Reserves
Watersheds and River Valleys
ABoVE Study Domain
Core Study Area
Extended Study Area
N
0
250
500
1,000
Km
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

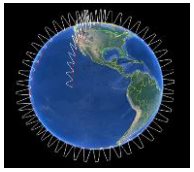

Arctic-Boreal Vulnerability Experiment
ABoVE

Airborne Science Program (ASP) Selected Missions - Past and Upcoming

EVS-2 Investigations

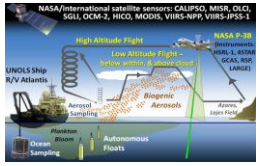


ACT-America (*Atmospheric Carbon and Transport – America*): Quantify the sources of regional carbon dioxide, methane, and other gases, and document how weather systems transport these gases

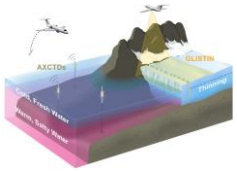


ATom (*Atmospheric Tomography Experiment*): Study the impact of human-produced air pollution on certain greenhouse gases

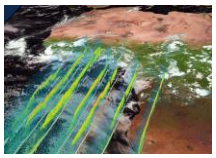
CORAL *(COral Reef Airborne Laboratory)*: Provide critical data and new models to analyze the status of coral reefs and predict their future



NAAMES (*North Atlantic Aerosols and Marine Ecosystems Study*): Improve predictions of how ocean ecosystems would change with ocean warming



OMG (*Oceans Melting Greenland*): Investigate the role of warmer, saltier Atlantic subsurface waters in Greenland glacier melting



ORACLES (*ObseRvations of Aerosols Above CLouds and Their IntEractionS*): Probe how smoke particles from massive biomass burning in Africa influences cloud cover over the Atlantic

Eight NASA Centers; Five US government agencies; 32 educational institutions; Two non-profit institutions; Three industry partners

EVS-2 Key Dates

Investigation	Aircraft	Investigation Start	Kickoff Meeting	Science Team Meeting	Current Status
ACT-America	**C-130**	1 Feb 15	3 Feb 15	12-13 Aug 15 Newport News, VA	Preparing for first airborne campaign Feb 16
ATom	**DC-8**	1 Apr 15	6 Feb 15	22-24 Jul 15 NASA AFRC	Preparing for first airborne campaign Aug 16
NAAMES	**C-130**	15 Jan 15	19 Feb 15	25-27 Aug 15 NASA LaRC	Preparing for first airborne campaign 9 Nov 15
OMG	**GIII**	1 Apr 15	6 Mar 15	30 Apr 1 May 15 Jet Propulsion Lab	Completed two of three Greenland bathymetry surveys, preparing for first airborne campaign Mar 16
ORACLES	**P-3**	1 Feb 15	22 Jan 15	9-11 Sep 15 NASA ARC	Conducted Namibia site survey, preparing for first airborne campaign Aug/Sep 16
CORAL	**TBD (GV/IV/ER-2)**	12 Aug 15	30 Jul 15	8-9 Oct 15 Jet Propulsion Lab	Integrating instrument on NSF GV for ORCAS mission, prepares instrument for a variety of platforms to perform investigation, preparing for first airborne campaign Feb 16

NASA GPM GV Field Campaign
OLYMPEX: *Olympic Mountains Experiment in the Pacific NW*

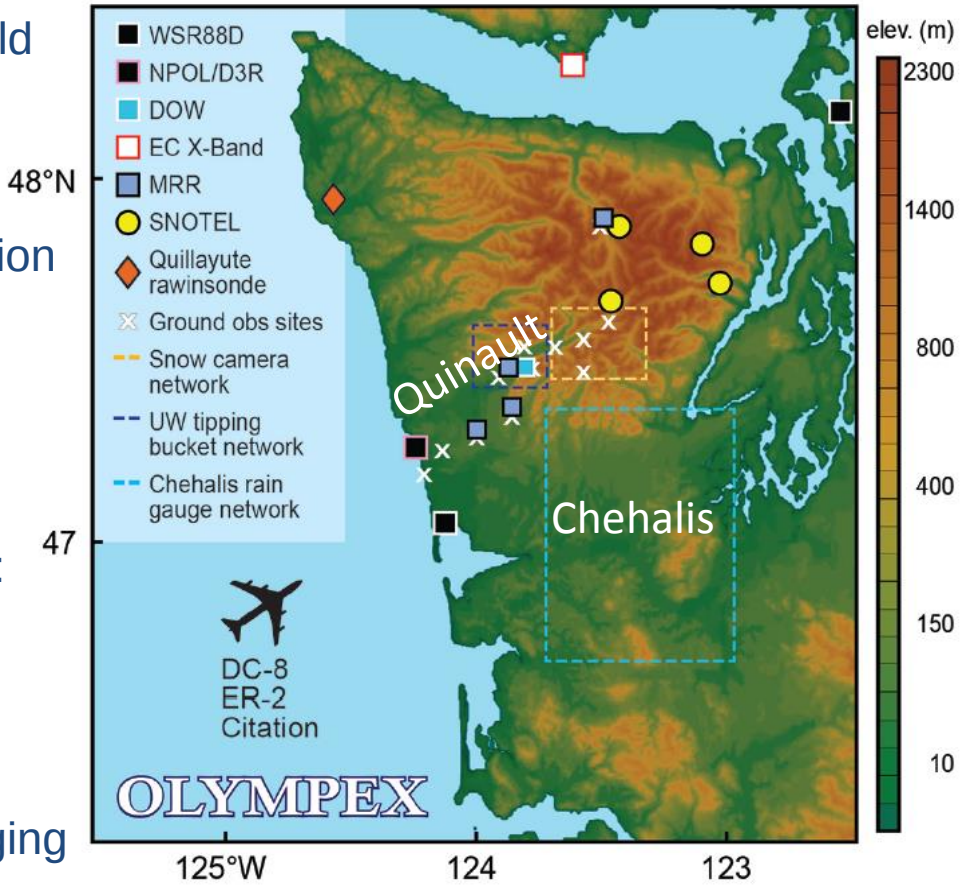
Nov 2015 – Jan 2016

Science Datasets for:

- GPM algorithm and product validation in cold season mid-latitude frontal system rain and snow events over ocean, coastal zone, and mountainous topography
- Approaches to GPM Level-IV product creation
- Testing of GPM hydrologic applications
- ACE/RADEX instrument testing for cloud physics

Instrumentation:

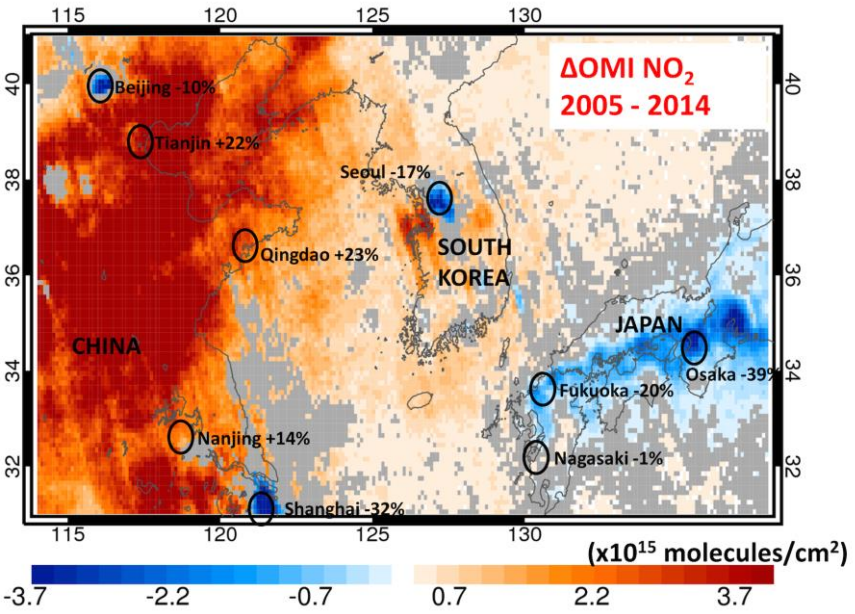
- Aircraft: DC-8, ER-2 (RADEX) and Citation: multi-frequency radars, radiometers, lidar
- Ground Radars: NASA NPOL, D3R; Env. Canada X-Band, NSF DOW, NOAA KLGX(88D)
- Surface: Rain/Snow gauge networks, imaging and sizing instrumentation, snow cameras
- Soundings: AVAPS (DC-8) and Ground-based
- Airborne Snow Observatory: 3 SWE flights



Participants: NASA, U. Washington, Environment Canada, NSF, Quinault Nation, NPS, USFS

KORUS-AQ: An International Cooperative Air Quality Field Study in Korea

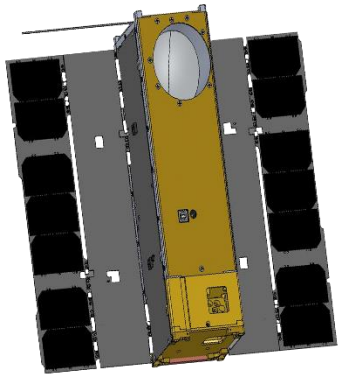
- A joint air quality field study led by NASA and the Korean National Institute for Environmental Research (NIER). The field study (30 April to 15 June 2016) will focus on the links between satellite and ground-based measurements of air quality over the Republic of Korea.
- NASA selected investigators will make observations on the NASA DC-8 and B-200 aircraft as well as on the ground. NIER funded projects include five Korean instruments on the DC-8, a Korean B-200 aircraft, and enhanced ground-based measurements. NASA and NIER will work together to provide air quality and meteorological forecasts to aid flight planning activities.
- Korea already has a geostationary ocean color and aerosol optical depth satellite (GOCI) and is building a GEO air quality satellite similar to NASA's TEMPO, call GEMS.
- The Korean peninsula and surrounding waters provide an advantageous experimental setting for distinguishing local and trans-boundary pollution.



In-Space Validation of Earth Science Technology (InVEST)-2012

U-Class satellites advancing TRLs for Earth science measurements – all 3U

MiRaTA
MIT / MIT-LL



3 Frequency Radiometer and GPSRO

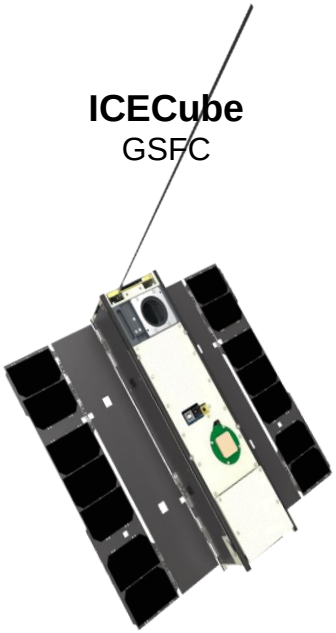
Validation of new microwave radiometer and GPSRO technology for all-weather sounding

RAVAN
APL/JHU

Vertically Aligned Carbon Nanotubes (VACNTs)

Validate VACNTs as radiometer absorbing material and calibration standard for total outgoing radiation

ICECube
GSFC



883 GHz submm-Wave radiometer

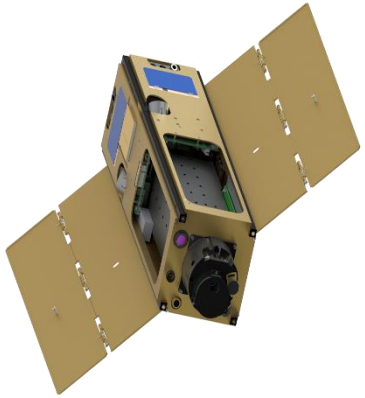
Validation of submm radiometer for spaceborne cloud ice remote sensing

HARP
UMBC

Wide FOV Rainbow Polarimeter

Validation of 2-4 km wide FOV hyperangular polarimeter for cloud & aerosol characterization

LMPC
The Aerospace Corporation



Photon Counting InfraRed Detector

Validation of linear mode single photon detector at 1, 1.5, and 2 microns in space environment

Targeting launch dates (for all) in 2016-17 timeframe primarily utilizing the CubeSat Launch Initiative

InVEST 2015 Program

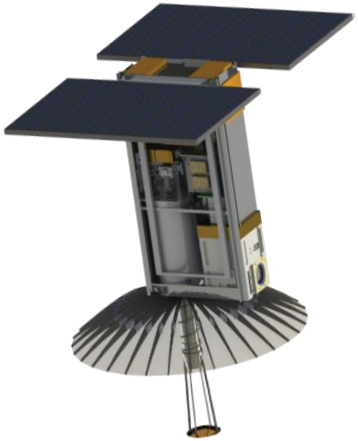
U-Class satellites advancing TRLs for Earth science measurements - ***all 6U***; selected Sept. 17 2015

CIRAS
JPL

Infrared Atmospheric Sounder

Demonstrate ability to measure spectrum of upwelling infrared radiation in 4-5 micron spectral region

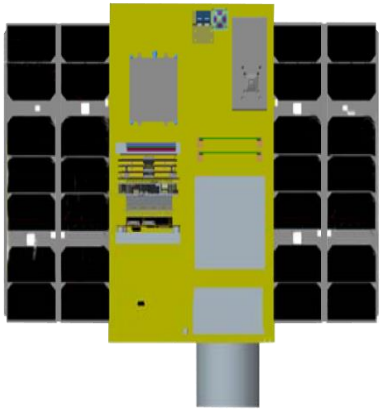
RainCube
JPL



Precipitation Profiling Radar

Validate Ka-band (35.75 GHz) radar payload using new deployable antenna and processing technologies

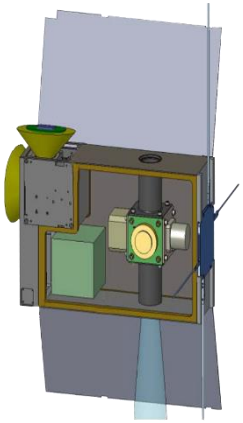
CubeRRT
The Ohio State University



Radiometer Radio Frequency Interference

Demonstrate wideband RFI mitigation technologies vital for future space-based microwave radiometers

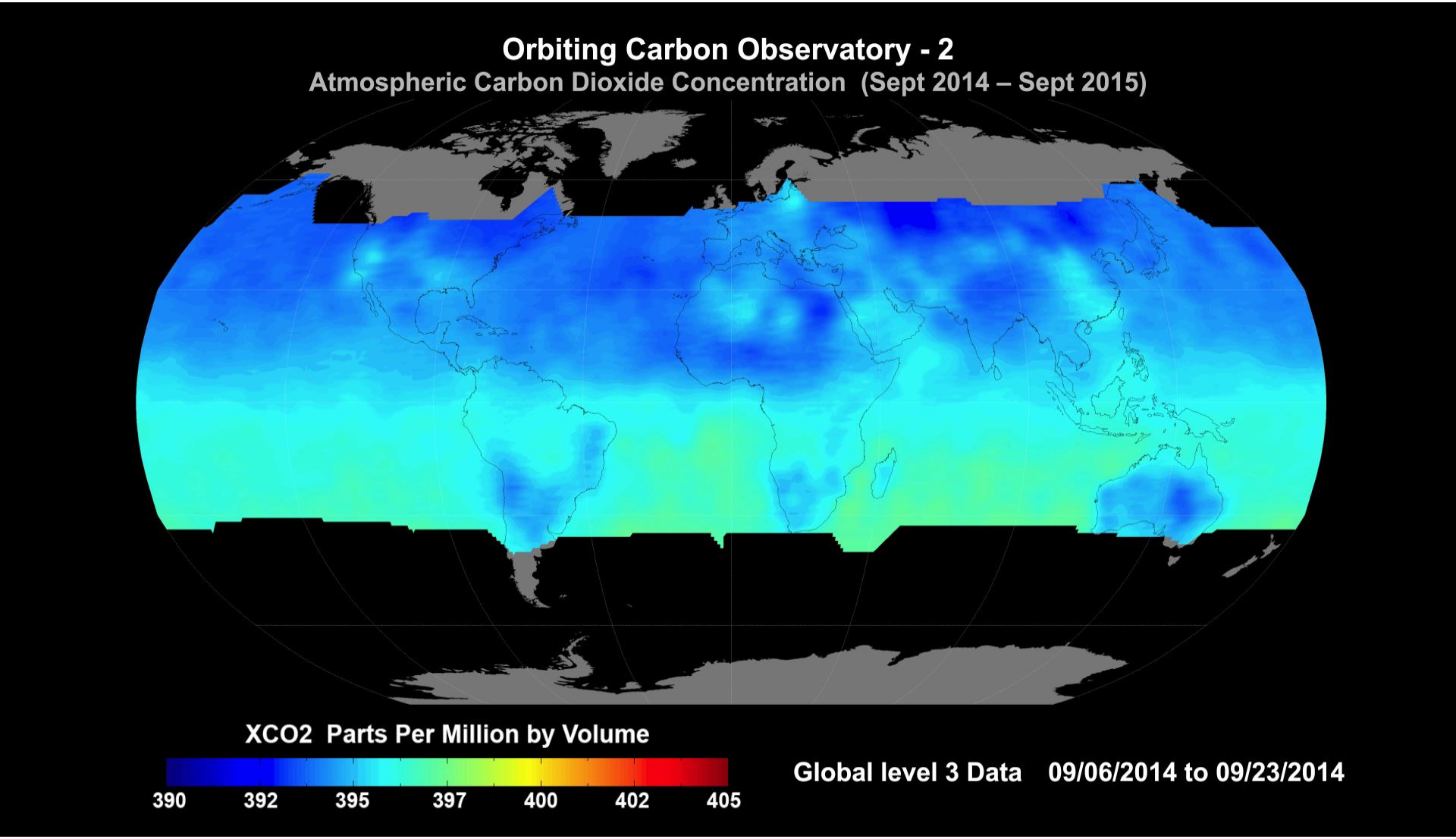
CIRIS
Ball Aerospace



Infrared Radiometer

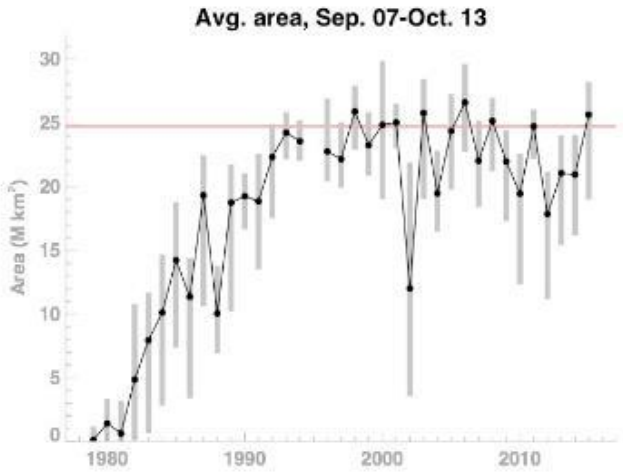
Validation of an uncooled imaging infrared (7.5-13 um) radiometer for high radiometric performance in LEO

OCO-2's First Year of Measurements

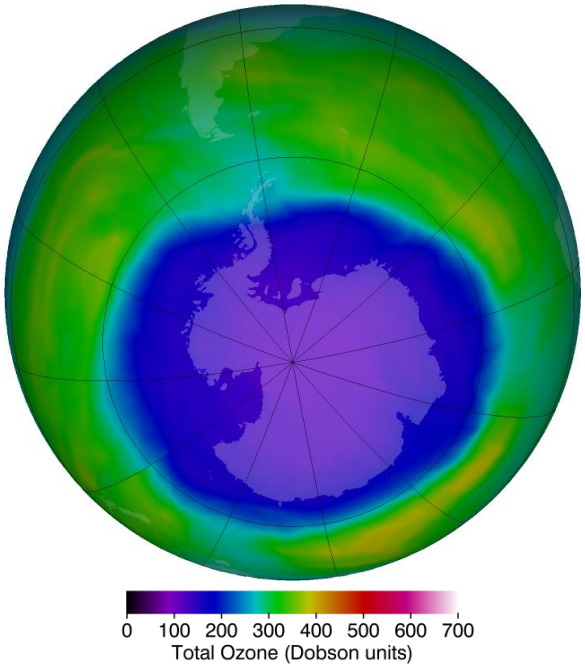


2015 Antarctic Ozone Hole

- **On Oct 2, NASA and NOAA scientists indicated that the 2015 Antarctic ozone hole approached its annual maximum. This is the 4th largest ozone hole in the 24 years since 1991.**
- The hole formed more slowly this year, because the polar vortex was so symmetric around the pole – later solar exposure of the perturbed chemical region. The hole is slowly declining this year because of the weak dynamical forcing.
- While the current ozone hole area is large, this area is consistent with our understanding of ozone depletion chemistry and weaker than average stratospheric dynamical (weather) conditions. This "weak" dynamics colder than average stratospheric temperatures – which strongly modulates ozone depletion.



Average size of the Antarctic ozone hole derived from daily estimates between Sep. 7 and Oct. 13 of each year. The surface area of N. America is 24.7 M km^2 (red line). 2015 is the 4th largest ozone hole.



Oct 2, 2015 False-color view of total ozone over the Antarctic pole. The purple and blue colors are where there is the least ozone, and the yellows and reds are where there is more ozone.

2015 Arctic Sea Ice Summertime Minimum Is Fourth Lowest on Record

- **Analysis by NASA and NASA-supported National Snow and Ice Data Center (NSIDC) showed the annual minimum extent was 1.70 million square miles on Sept. 11. This year's minimum is 699,000 square miles lower than the 1981-2010 average.**
- Sea ice decline has accelerated since 1996. The 10 lowest minimum extents in the satellite record have occurred in the last 11 years.
- The 2014 minimum was 1.94 million square miles, the seventh lowest on record.
- This year, the **Arctic sea ice cover experienced relatively slow rates of melt in June**, which is the month the Arctic receives the most solar energy.
- However, **the rate of ice loss picked up during July, when the sun is still strong. Faster than normal ice loss rates continued through August**, a transition month when ice loss typically begins to slow.
- **A big "hole" appeared in August in the ice pack in the Beaufort and Chukchi seas, north of Alaska, when thinner seasonal ice surrounded by thicker, older ice melted**. The huge opening allowed for the ocean to absorb more solar energy, accelerating the melt.

This animation shows the evolution of the Arctic sea ice cover from its wintertime maximum extent, which was reached on Feb. 25, 2015, and was the lowest on record, to its apparent yearly minimum, which occurred on Sept. 11, 2015, and is the fourth lowest in the satellite era. https://youtu.be/OpwM6PfcIbg

Eastern China Emissions Offset 43% of the Expected Reduction in Mid-Tropospheric Ozone over the Western US from 2005-2010

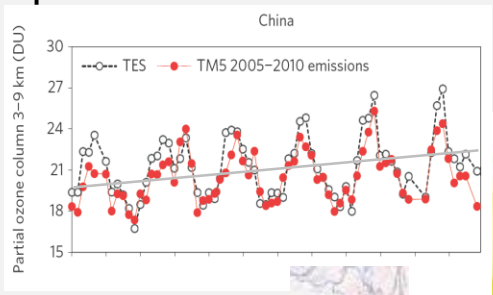
Verstraeten et al., *Nature Geosci*., 2015

Over the past decade, China has undergone rapid population growth and industrialization. At the same time, the US experienced an economic recession and implemented increasingly strict emissions controls.
What do satellite measurements tell us about how these differences in development and policy have manifested in terms of changes in tropospheric ozone, a harmful pollutant and potent greenhouse gas?

We combine Aura measurements with a model to quantify and attribute observed ozone changes to: Regional emissions; Long-range transport; and downward transport from the stratosphere. We find that natural stratospheric variability played a surprisingly large role in tropospheric ozone trends and that Chinese emissions offset a large portion of the reduction in mid-tropospheric ozone that should have occurred over the Western US due to emission reduction policies. The absolute impact of Chinese emissions has thus far been small, but its future trajectory is highly uncertain.

Aura's Microwave Limb Sounder: Temporary increase in downward transport from the stratosphere partly due to 2009-2010 El Nino.

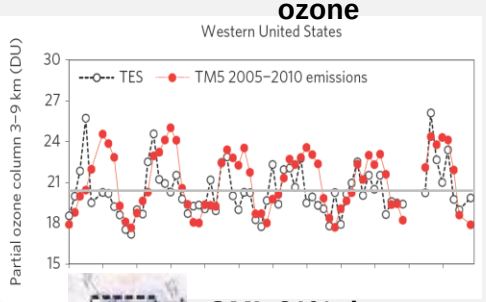
Aura's Tropospheric Emission Spectrometer (TES): 7% Increase in mid-tropospheric ozone



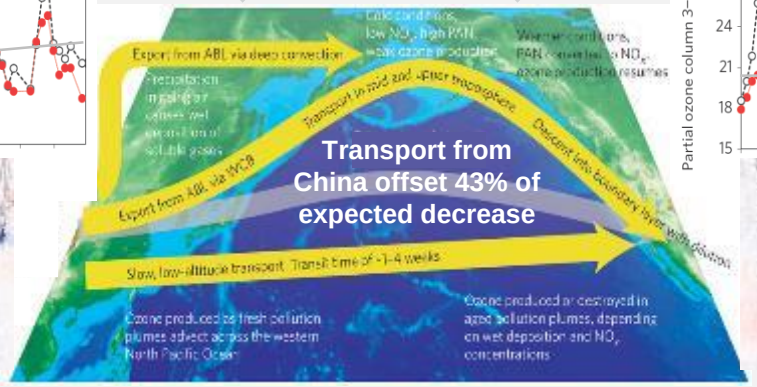
Explains 50% of the ozone increase

Offset 57% of expected ozone decrease

TES: No change in mid-tropospheric ozone



OMI: 21% increase in NO_x emissions. Explains 50% of the ozone increase.



Transport from China offset 43% of expected decrease

OMI: 21% decrease in NO_x emissions. Should have given a 2% decrease in ozone

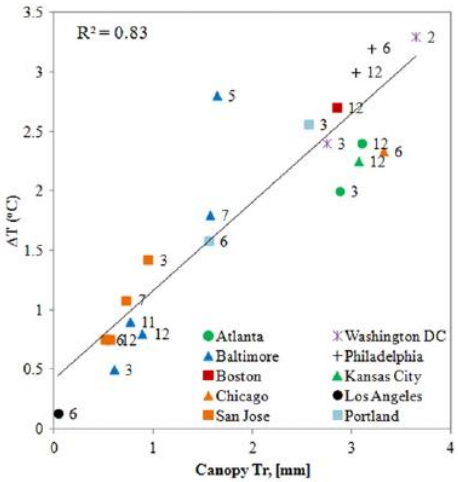
Model-derived increases in surface ozone are ~2x mid-tropospheric ozone changes

Model-derived impact of Chinese emissions at the surface <1/2 their impact in the mid-troposphere

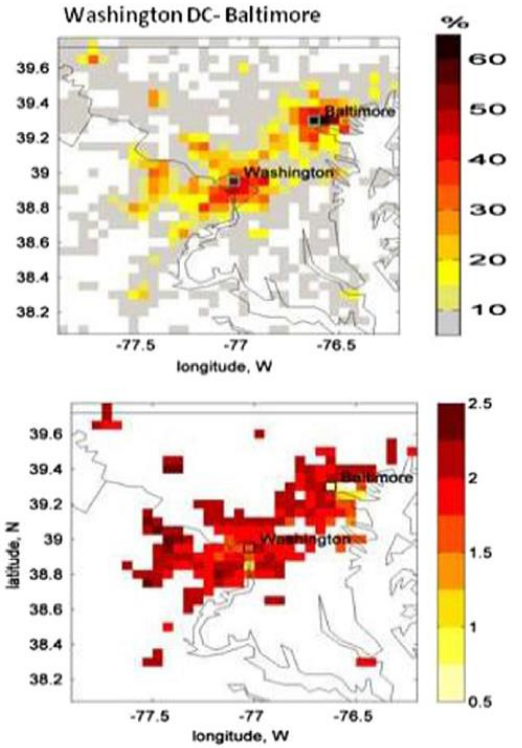
Impact of Urbanization on US Surface Climate

L. Bounoua, P. Zhang, G. Mostovoy, K. Thome, J. Masek, M. Imhoff, M. Shepherd, D. Quattrochi, J. Santanello, J. Silva, R. Wolfe and A.M. Toure. August 2015. Environmental Research Letters. Vol 10; 8.

- **The NASA-funded study completed the first assessment of urbanization impacts for the continental U.S. and quantified how vegetation regulates the urban heat effect**.
- The scientists combined impervious surface and vegetation data from Landsat 7 Enhanced Thematic Mapper Plus sensor and MODIS sensors on Terra and Aqua with NASA's Simple Biosphere model to recreate the interaction among vegetation, urbanization, and the atmosphere.
- Cities built within forests had higher daytime urban land surface temperature than that of vegetated lands.
- Cities built within arid lands, were cooler than surrounding areas.
- Type and amount of tree species plays a critical role in modulating city land surface temperature.
- Once urban impervious surfaces surpassed 35% of the city's land area, then temperature began increasing as the area of urban surfaces increased, reaching 1.6° C warmer by 65% urbanization.



Left: Relationship between daytime mean surface temp difference between urban and vegetation classes within selected CMGs v canopy transpiration for June-July-Aug. #s next to markers indicate vegetation class.



Above: Spatial distribution of impervious surface area (ISA) (upper panel) and temp difference (C) between urban and vegetation classes co-existing within each climate modeling grid (CMG).

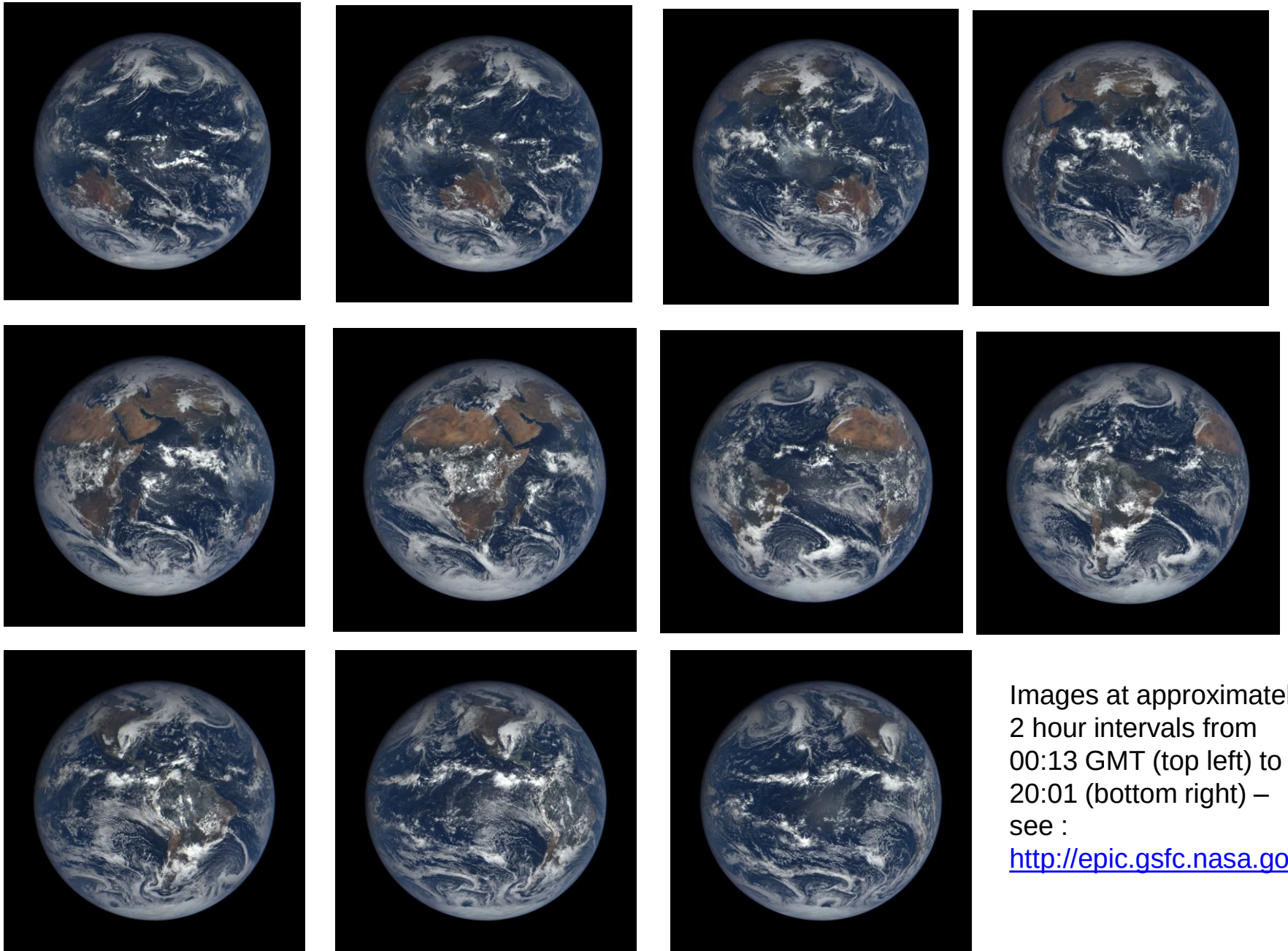
Major Interagency Activities

- **Climate**
  - NASA took on responsibility for new USGCRP office lease with GSA (1800 G St.) and for support services contract for National Coordination Office (ICF, Inc.)
  - NASA continues to be largest contributor to USGCRP
  - NASA provided lead for team developing USGCRP Updated Strategic Plan
  - NASA scientists and managers participate in and provide leadership to many USGCRP Interagency Working Groups
  - NASA provides support for sustained assessment through funding of enabling tools and competitive grants on indicators (first round of tasks are complete, second have selection imminent)
  - NASA participating in annual UNFCCC COP meeting (COP-21 in Paris – 111-12/15) by bringing hyperwall and scientists to narrate, as well as lead side events
- **Oceans**
  - Our Ocean Conference - was held October 5-6, 2015, in Viña del Mar with NASA exhibiting in support
  - SOST - is focused on implementation of the *SOST Operating Principles*, including developing FY18 ocean S&T priorities and SOST Transition document; NASA personnel participate and provide leadership to multiple groups
  - National Ocean Council -- adopted a new implementation structure for the National Ocean Policy (NOP), calling for development of annual work plans and a Longer-term Guidance document
- **Arctic**
  - IARPC – Active participation in multiple groups, providing data through Distributed Biological Observatory and NASA Satellite Observations of Arctic Change
  - National Arctic Strategy – NASA participates in activities and groups
  - Arctic Executive Steering Committee – NASA participates in meetings and activities; Executive Director Adm. Brzezinski to visit GSFC 11/6
  - NASA participated in GLACIER Conference (8/31) organized through Arctic Executive Steering Committee
  - NASA has supported NSF in development of Science Cooperation Task Force within Arctic Council (which US chairs from 2015-2017)
- **USGEO**
  - NASA provides overall co-chair for US GEO (and mechanism for engagement in international GEO)
  - NASA provides a co-chair for Earth Observation Assessment and numerous scientists for the multiple writing teams
- **Climate Action Plan**
  - NASA is lead for Climate Data initiative and contributes to Climate Resilience Tool Kit

DSCOVR – EPIC (Lunar Transit movie)

Daily EPIC Imagery: http://epic.gsfc.nasa.gov

DSCOVR EPIC Images – 10/25

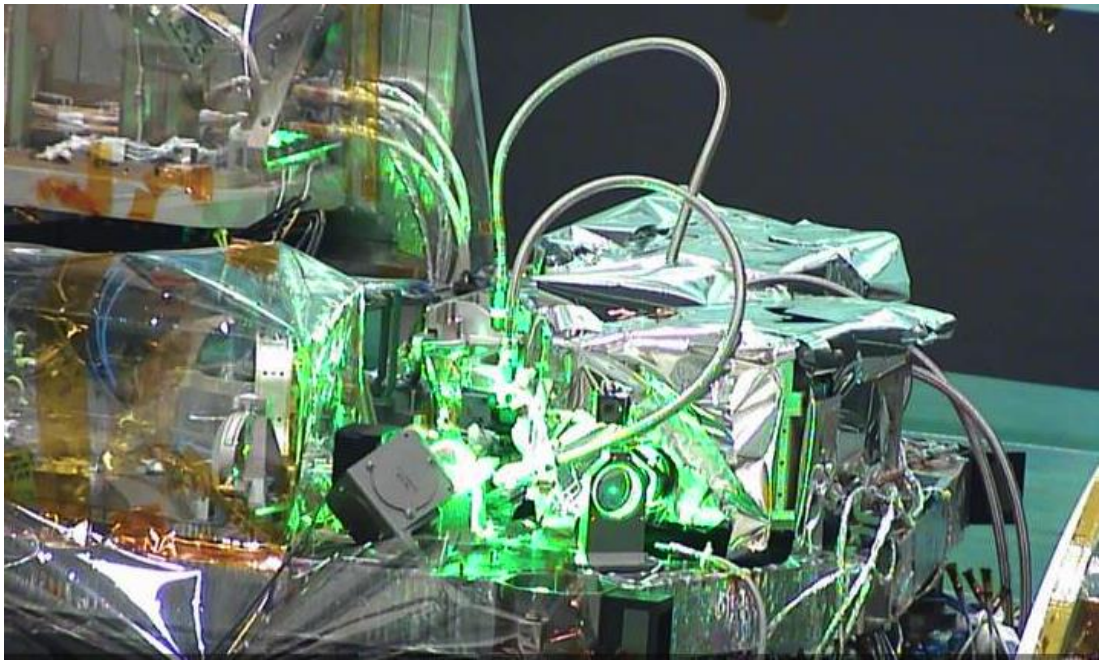


Images at approximately 2 hour intervals from 00:13 GMT (top left) to 20:01 (bottom right) – see : http://epic.gsfc.nasa.gov

Backup Slides

ICESat 2 – Integration of Flight Lasers

First Light!



ABoVE Science Team Membership Selection

	Investigators	Organizations
Principal Investigators	35	23
Funded Investigators	101	59
Collaborators	131	55
Total	232	104

	U.S.	Canada	Europe	Japan	Total
University	43	10	3		56
National Agencies/Labs	18	6	4	1	29
State/Provincial/Territorial	2	8			10
Private	4	2			6
Native Organizations	2	1			3
Total	69	27	7	1	104

ESD Airborne Science Accomplishments

- Ongoing campaigns
  - Operation IceBridge Arctic and Antarctic
  - HyspIRI cal/val flights in CA
- Completed campaigns
  - Operation IceBridge Arctic
  - UAVSAR Mexico earthquake and deployment to Central and South America
  - UAVSAR and AirSWOT deployments to the Mississippi River delta
  - CalWater-2 CA flights
  - GPM cal/val (Polar Winds) deployment to Iceland
  - ICESat-2 cal/val deployment to Greenland
  - HyspIRI cal/val flights in CA
  - Suomi-National Polar Orbiting (SNPP) cal/val deployment to Iceland
  - PECAN deployment to KS
  - HIWC campaign in support of NASA ARMD
  - Harmful Algal Bloom flights over Great Lakes
  - NOAA operational evaluation of Global Hawk aircraft (SHOUT) mission
- Completed/ongoing airborne instrument development activities (AirSWOT, Rotating PALS, SLAP, PRISM on ER-2)
- Earth Venture Suborbital (EVS)
  - Initiated six new EVS-2 investigations (Act-America, ATOM, CORAL, NAAMES, OMG, & ORACLES)
  - OMG completed sonar survey of sea floor along Greenland coast
  - Modifying 2 C-130's and 2 G-III's for EVS-2
  - Completed almost all EVS- 1 data collection (CARVE finishes in Nov 15), investigations completing data analysis and closeout activities
- Completed Student Airborne Research Program (7th year of program) – 32 students this FY
- P-3 major maintenance (rewing) ongoing to provide another 18 years (or so) of ESD support

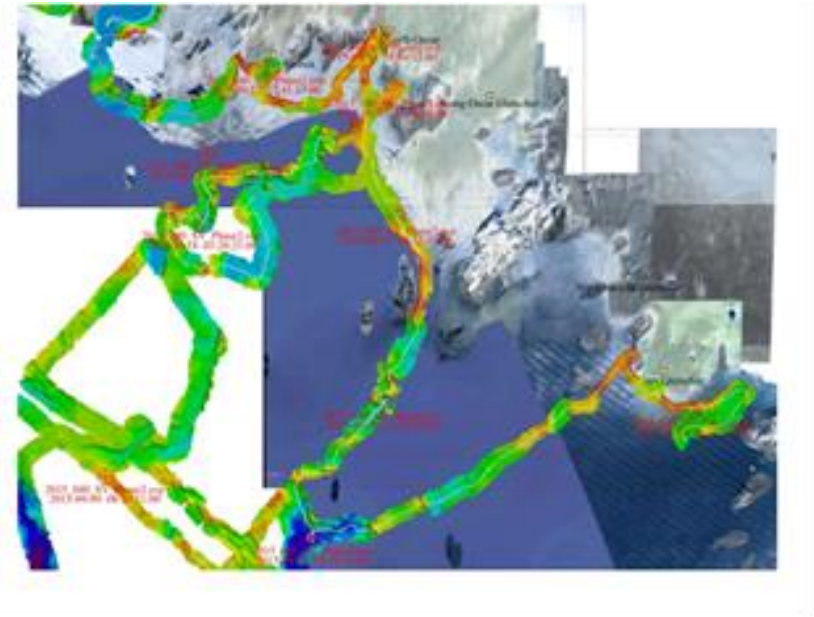
ESD FY16 Airborne Science Upcoming Activities

- Upcoming deployments/campaigns
  - GPM cal/val (Olympex) campaign (Dec 15)
  - ACE mission concept development (RADEX) campaign (Dec 15)
  - SWOT cal/val (AirSWOT) deployment to the Gulf Coast (Dec 15 – Jan 16)
  - Korean air quality mission (KORUS – AQ) deployment (25 Apr – 13 Jun 16)
  - Joint NASA ESA Gabon Africa (AfriSAR) deployment (Feb or Apr/May 16)
  - ASCENDS mission development campaign (Jan – Feb 16)
  - NOAA operational evaluation of Global Hawk aircraft (SHOUT) mission (Feb – Mar 16, Aug – Nov 16)
  - HyspIRI Tropical (HI) deployment (Apr 16)
  - UAVSAR flights (variety of programs (earthquakes, levy monitoring, AfriSAR) and dates throughout FY16)
- Earth Venture Suborbital (EVS)
  - NAAMES deployment to Canada/Azores (Nov 15, Apr – May 16)
  - Complete GIII modifications for OMG (Dec 15)
  - OMG deployment to Greenland (Apr 16)
  - Complete C-130 modifications for Act-America (Dec 15)
  - Act-America deployment to Central US (Jul – Sep 16)
  - ORACLES Namibia deployment (Aug – Sep 16 dependent upon Namibian clearances)
  - Closeout all EVS-1 investigations (TBD 16)
- Student Airborne Research Program FY16 (Jun – Aug 16)
- Complete P-3 major maintenance (Apr/May 16)

EVS-2 OMG summary status

➢ Activities

- Both phases of the bathymetry sonar survey from Cape Race ship are complete. The ship completed a total of 4,250 nautical miles of survey lines. The final NETCDF product will be sent to JPL by January 15.
- Work continues in fabrication of the Airborne eXpendable Conductivity, Temperature, and Depth (AXCTD) rack hardware for the JSC Gulfstream-III aircraft. Last week, the assembly of the four rackmount AXCTD receivers was begun.



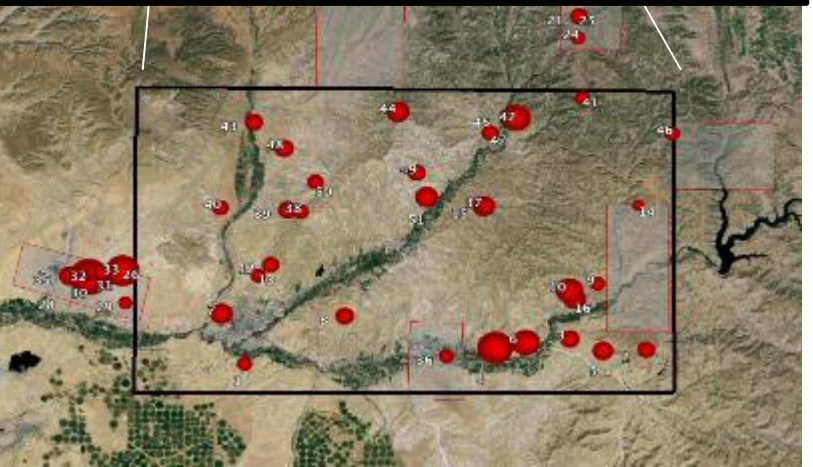
AXCTD probes

Oceans Melting Greenland OMG

4-Corners Methane Campaign: April 2015

SCIAMACHY Satellite data indicated largest US methane hotspot (Kort et al) -> emissions about 0.5Tg/yr

Airborne Campaign with AVIRIS-NG and HyTES detected more than 50 large point sources in this areas, most related to coalbed methane extraction

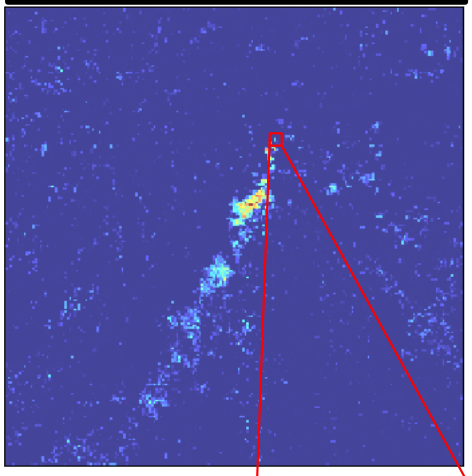


AVIRIS-NG and HyTES on Twin Otter aircraft imaged entire area at about 2x2m resolution

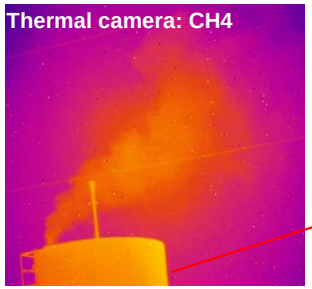
One example (out of >50)

RGB Image

Methane Plume



Typical methane plume from tank, confirmed on ground

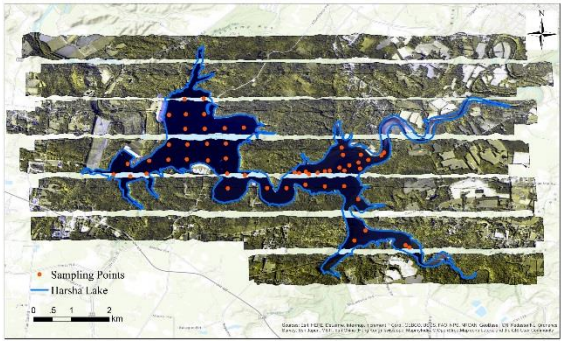


2015 Harmful Algal Blooms Campaign
August 31 – October 22

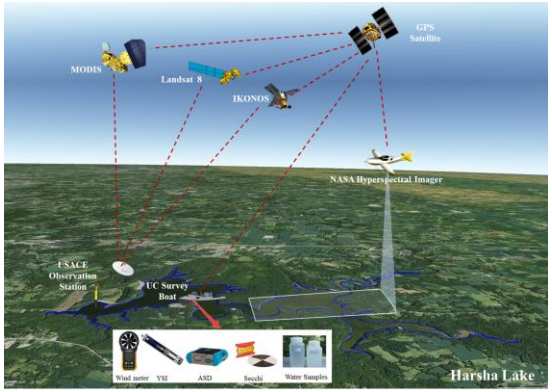
- Glenn Research Center's Twin Otter continued to make ~weekly flights over Lake Erie to study algae concentrations and their contributions to Harmful Algal Blooms that may affect drinking water quality and availability. Additional coverage included Ohio River, etc. where significant blooms occurred
  - Total flight hours accrued: 80 hours
  - All instruments & systems have functioned properly

- Relevant MODIS and LANDSAT satellite data were referenced and in-situ calibration were collected on ground and water by partners: Michigan Tech Research Institute, NOAA, University of Toledo, Kent State University, Bowling Green State University, Ohio State University, and University of Cincinnati, with calibration support from MSFC and South Dakota State Univ.
- Data have been shared within 2 business days with regional entities and archived for public access
- Coordinated a coincidental flight with the NOAA hyperspectral sensor flight
- NASA Flights are now put on standby as the blooms subside
- First campaign data workshop November 12-13 @ Lake Erie Center, Oregon, Ohio
- Draft of first NASA TM scheduled for February 2016

Severe blooms in Ohio River this year



Swaths over Harsha Lake 10/05/15

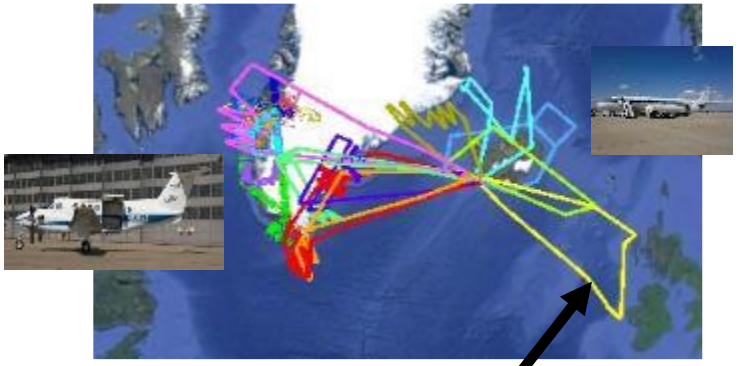


Collaborate with University of Cincinnati to develop algorithm

PolarWinds and ADM Cal/Val Preparatory Campaigns

Campaign 1: 10/26 – 11/14/14; LaRC's UC-12B; Kangerlussuaq, Greenland
Campaign 2: 05/11 – 05/29/15; NASA DC-8; Keflavik, Iceland

Leads: NASA LaRC (DAWN PI); Simpson Weather Associates (Science PI)
Science Team: Colorado University, Ohio State University, University of Washington, NASA LaRC, and Simpson Weather Associates

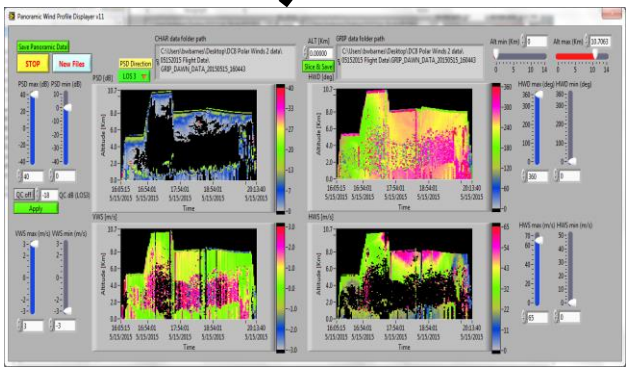


Campaign Objectives

- PolarWinds
  - Mesoscale model validation/development
  - Stable boundary layers; katabatic flows; marginal ice zone dynamics
- ADM Cal/Val
  - Obtain DWL LOS observations that mimic those expected with ADM
  - Co-fly with DLR Falcon in Campaign 2 to calibrate Aeolus simulator (A2D)

Instrumentation

Campaign 1: DAWN only
Campaign 2: DAWN, Yankee dropsondes, TWiLiTE and German Falcon with 2 wind lidars



AfriSAR Science Objectives

Overall Objective:

Internationally coordinated campaign (**ESA**, **DLR**, **NASA and AGEOS**) to acquire well calibrated SAR, Lidar, and *in situ* datasets in dense tropical forests using aircraft and field measurements in support of the **ESA BIOMASS**, **NASA NISAR** and **NASA GEDI** mission requirements to develop biomass and forest structure inversion algorithms.

This effort will leverage **the high quality forest inventory data collected** in **one of the least studied** and **unique forest ecosystems** in the world; thereby providing excellent data for **scientific research**, **technology demonstrations** and **Calibration/Validation activities**.

Specific Objectives:

1. Using NASA's **LVIS** and **UAVSAR** instruments to **measure forest canopy height, canopy profiles and biomass density**, under a variety of **Forest conditions** (including tropical rainforests, mangrove forests, forested freshwater wetlands and savannah) and **topographic and surface conditions** (including flat, mountainous).

2. Acquire detailed measurements of **airborne SAR data (at L and P band)** and **Lidar** data for **cross calibration** of NASA and ESA/DLR instruments and for **CAL/VAL support** of the **BIOMASS**, **NISAR, GEDI** and **TanDEM-X** missions

3. Generate a time-series **of L- and P-band SAR data** covering varying soil moisture and atmospheric conditions (including dry and rainy seasons).

4. Conduct **Technology demonstrations** such as **Lidar-Radar Fusion**

Assessment of Precipitation Anomalies in California Using TRMM and MERRA Data

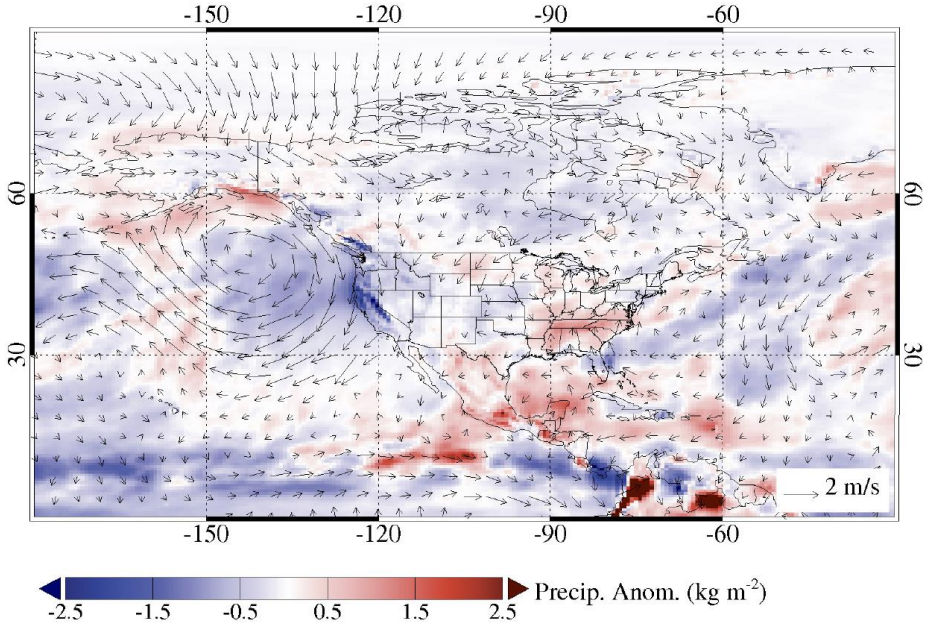
A. K. Savtchenko, G. Huffman, B. Vollmer, *Journal of Geophysical Research: Atmospheres*, July 2015.

- **Using satellite precipitation data from the TRMM** (Tropical Rainfall Measuring Mission,1998-2014) and model reanalysis **from MERRA** (Modern-Era Retrospective Analysis for Research and Applications 1979-2015), **NASA scientists found that California accumulated a debt of about 20 inches of precipitation between 2012 and 2015** -- the average amount expected to fall in the state in a single year. The deficit was driven primarily by a lack of air currents moving inland from the Pacific Ocean that are rich in water vapor.

- While El Niño (the warm phase of the El Niño Southern Oscillation) is frequently cited as the natural forcing expected to bring a relief, this **assessment is that ENSO has been driving at best only 6% of precipitation variability in California in the past three decades.**

- Using fractional risk analysis of precipitation populations during normal and dry periods, this **study shows that the likelihood of losing the most intensive precipitation events drastically increases during the multi-year drying events.**

- Storms delivering up to 50% of precipitation in California are driven by atmospheric rivers making landfall. However, they can be suppressed and blocked by persistent ridges of atmospheric pressure in the northeast Pacific.



Above: Anomalies of MERRA winds at 850 hPa (vectors), and precipitation (shades) in 2013.

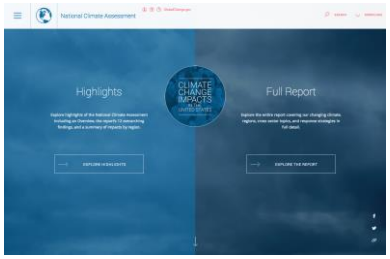
ESD's Interagency Coordination Efforts

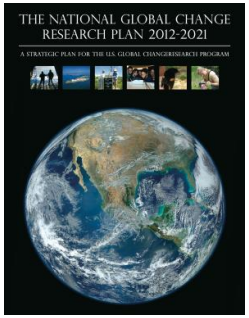
National Science And Technology Council (NSTC)

Committee on Environment, Natural Resources and Sustainability (CENRS)

Subcommittee on Global Change Research (SGCR)

U.S. Global Change Research Program (USGCRP)





CENRS Sub-Committees, WGs, & Task Forces
Air Quality Research (AQRS)
Critical and Strategic Mineral Supply Chains (CSMSC)
Interagency Arctic Research Policy Committee Interagency Working Group (IARPC)
Integration of Science and Technology for Sustainability Task Force
National Earth Observations Task Force (NEO)
Disaster Reduction (SDR)
Ecological Services (SES)
Global Change Research (SGCR)
Ocean Science & Technology (SOST)
Water Availability & Quality (SWAQ)
Toxics & Risks (T&R)
US Group on Earth Observations (USGEO)