Cloud Bursting to Augment On Premise Resources - ADAPT

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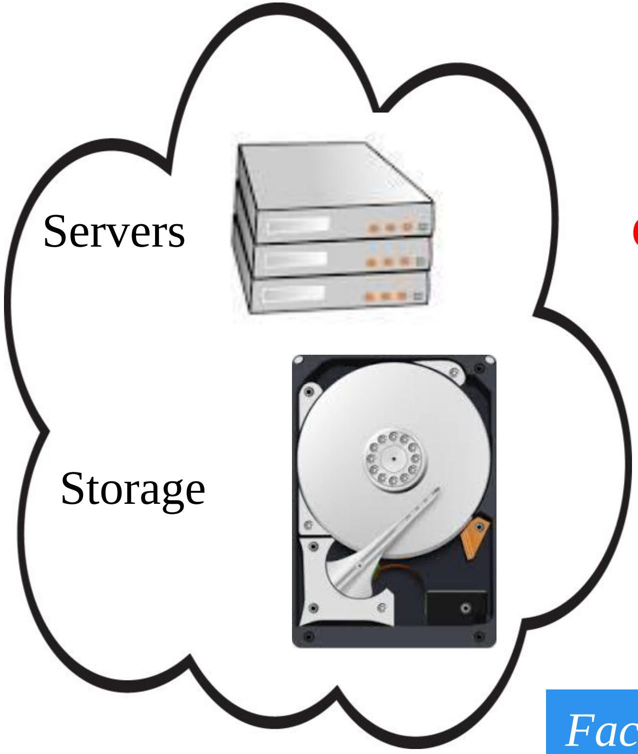
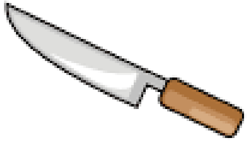
Cloud – A Simple Definition

Lots of …



Carve it up and deliver ….



Into what looks like …

> Personal virtualized workstations

- User defined
  - Operating system (OS)
  - Performance
  - Capacity
- Capacity/time based billing

> Even more personal storage units

- User defined
- Multi-device data syncing
- Capacity/time based billing

Facilitated By Virtualization and High-Speed Networking

Genesis Of ADAPT

Discover HPC System

- ~3400 compute nodes
- ~50 petabytes shared storage
- 70+ petabytes tape storage
- MPI/batch environment
- Bare metal processing

Knowledge
Hardware

ADAPT 1.0

- 300+ hypervisors
- 10+ petabytes shared storage
- Virtual machines (VM)
- Custom management scripts

ADAPT 2.0

- 200+ hypervisors
- VMs
- OpenStack cloud software

Started life as the Science Cloud, latter rebranded the Advanced Data Analytics Platform

ADAPT Highlights

Combination of new and old hardware

- New equipment for storage and management
  - ~8PBs of file system storage
- Over 500 hypervisors
  - Mix of Westmere, Sandy Bridge, Ivy Bridge and Broadwell processors
- High-speed interconnect
- GPUs K40s now, V100s soon

Both Linux and Windows virtual machines (VM)

- Shell access to Linux VMs
- Desktop (Guacamole) access to Windows VMs
- Dual authenticated, NCCS LDAP
- Script and OpenStack managed

ADAPT Target Users

- Use large amounts of distributed observation and model data to generate science – OR – perform multiple numerical iterations for engineering (small data)
- Launch loosely coupled processes requiring little to no synchronization
- Require more agile development with many small runs; utilization can be low on average (cloud like)
- Leverage third party tools – Python, IDL, MATLAB, custom code
- Need a flexible environment – jobs run in custom user space, latest libraries
- Concentrate on non-ITAR applications

Shared Directories and Common Datasets

Shared Directories

- $HOME
- $NOBACKUP

Common Datasets

- Available for direct use
- Individual investigators don't have to invest time to locate and transfer data into system
- Avoids duplications of large datasets on system
- Additional datasets can be added, including generated data

Software Stack

External License Servers

Open Source Tools
Python, NetCDF, GDAL, R, etc.

Commercial Tools
Intel Compiler (C, C++, Fortran), IDL (4 seats)

Operating Systems
Linux (Debian, CentOS) and Windows Server2012

Open source tools:

- Very flexible
- If the open source tool does not need elevated privileges to install, the user can install the software in their home or scratch directories
- Commonly used tools may be installed in a shared directory for multiple users
- If the tool requires elevated privileges, users should submit a ticket to the NCCS for assistance.

Job management:

- Parallel ssh – pdsh
- SLURM batch queuing

Virtual machines can be customized based on the end user application needs. The NCCS will work with you to create customized VMs specific to meet your needs.

ADAPT Use Cases

Science

- Arctic Boreal Vulnerability Experiment (ABoVE)
- High Mountain Asia (HMA)
- Head in the Clouds
- ArcGIS Activities
- *Ice, Cloud, and Land Elevation Satellite-2 (ICESAT-2)*
- *Goddard's LiDAR, Hyperspectral & Thermal Imager (G-LiHT)*

Remote Sensing, Big Data

Engineering

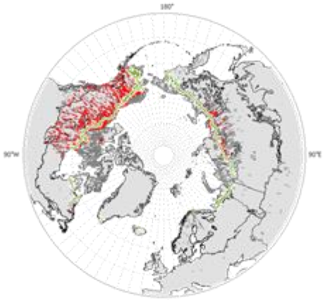
- CALET (CALorimetric Electron Telescope for ISS)
- Asteroid Hunters – Near Earth Objects
- Laser Communications Relay Demonstration (LCRD) Project – ITAR FPGA simulations
- *Wide Field Infrared Survey Telescope (WFIRST)*

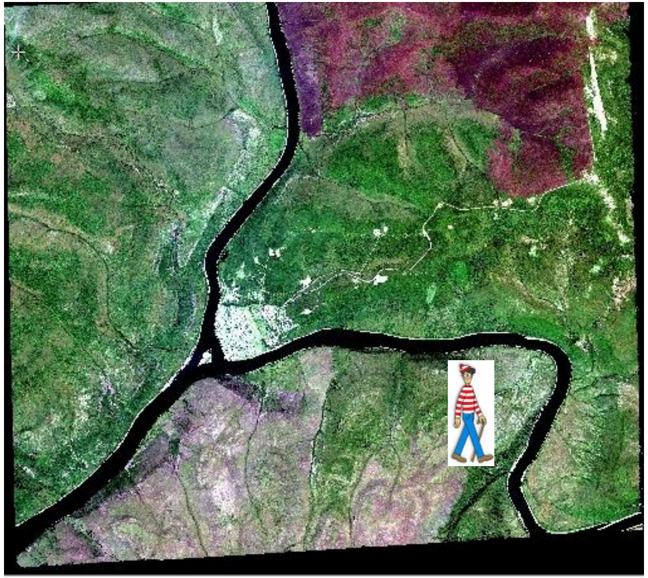
Numerical Iterations, Small Data

New users in italics

Forest Canopy Surface Elevations

- Understanding forest patterns using DigitalGlobe high-resolution satellite imagery
- Using multiple VMs and Ames Stereo Pipeline (ASP) on ADAPT to process Digital Elevation Models

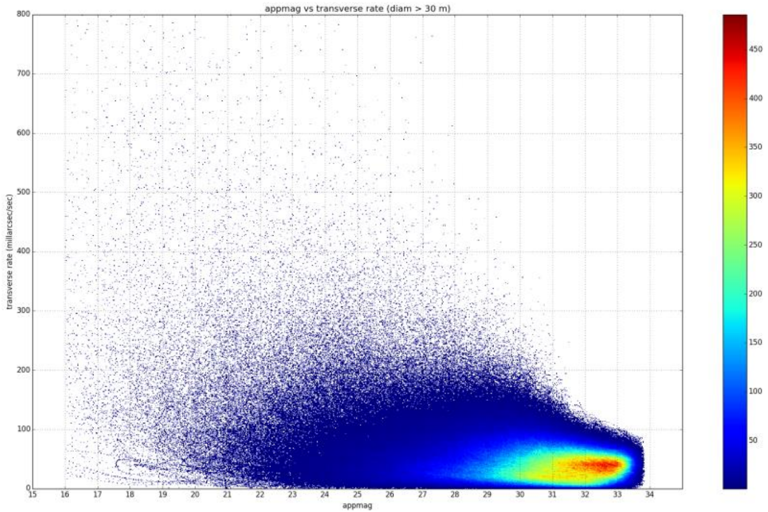




NEO Survey Simulations

New NEO survey simulations and studies facilitated by the ADAPT system help meet a number of GSFC and NASA NEO research needs

- NEODAC simulation models the performance of both GSFC and NASA proposed survey missions
- Supports modelling of a complex sky survey and exploration of the duty-cycle/pointing-scheme trade space
- Supports rapid testing of various detection models
- With ADAPT, a sim with 60~ million objects propagating at time-steps of a 5-15 seconds over a few months can be completed in 2-4 days. Outputs can be processed with new detection models and scan patterns in minutes.



Heatmap of synthetic NEO population's brightness and speed over a few days

Changes Coming To ADAPT

Convert InfiniBand network to Ethernet

- Better utilization of container-based hypervisors

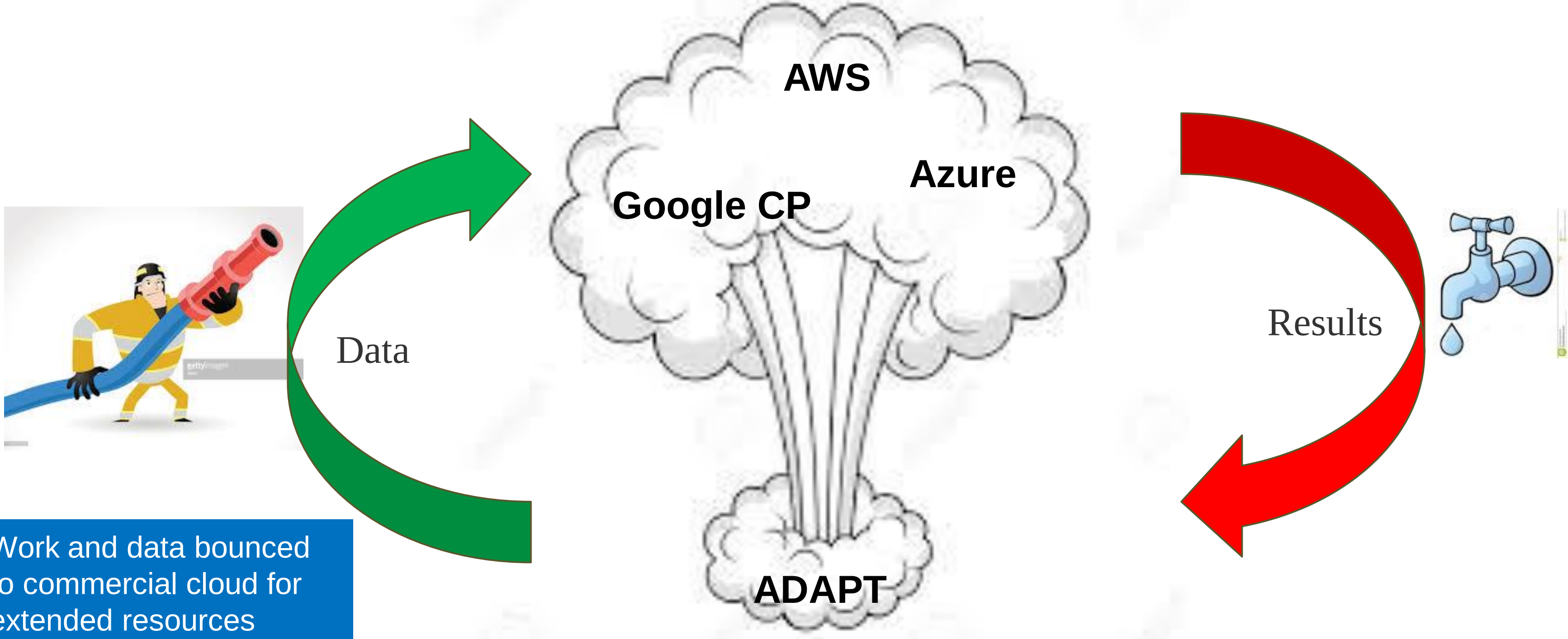
Fold ADAPT 1.0, where feasible, into OpenStack control

- Facilitate a self-service model

Introduce Cloud Bursting

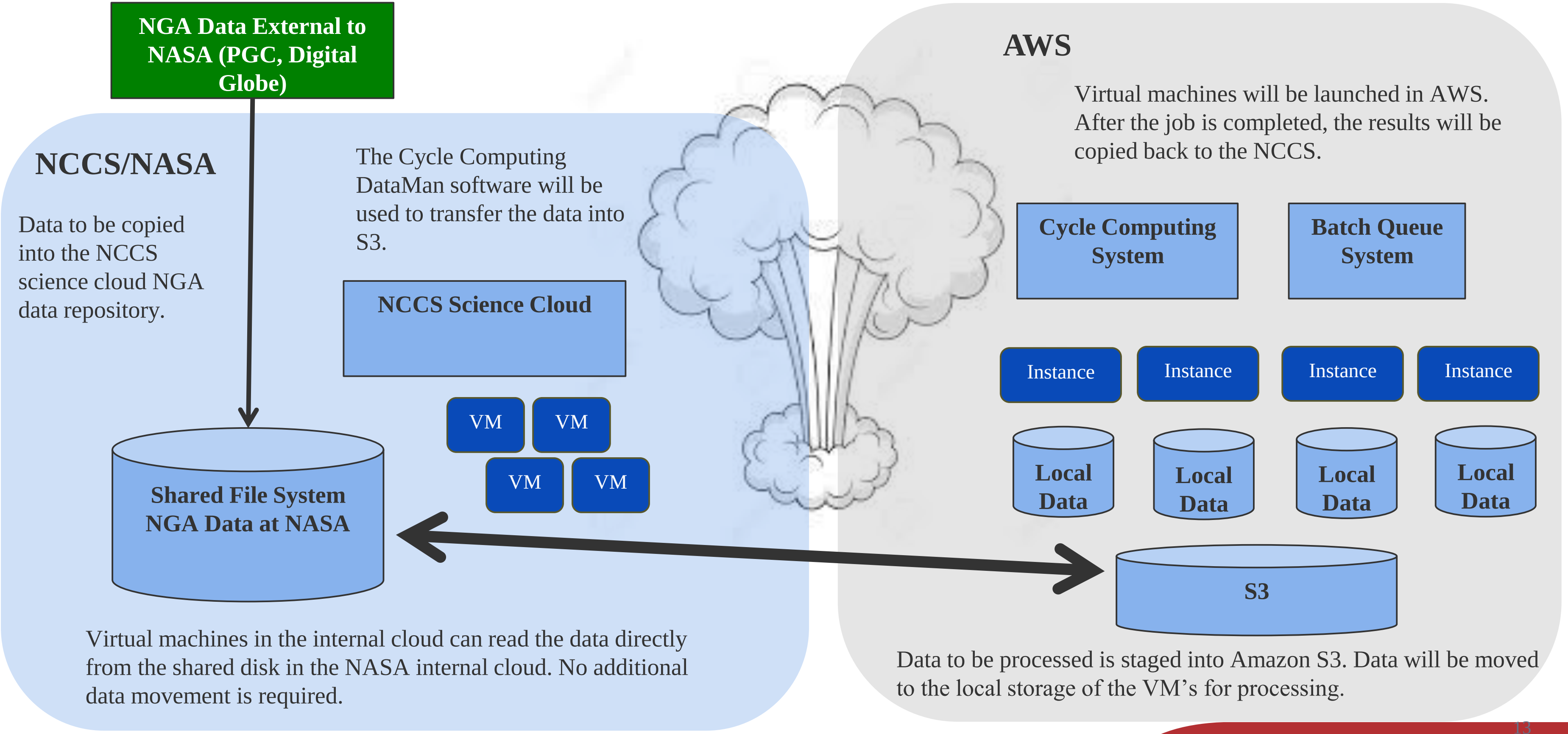
- Leverage commercial clouds to augment processing

Cloud Bursting – Head In The Clouds



- Work and data bounced to commercial cloud for extended resources
- Commercial cloud cost covered by project

Workflow – Managed By Cycle Computing



Initial Test Runs – AWS Spot Instances

Ran about 1/3 of UTM Zone 32 – Quickbird data

- Data pre-staged in AWS – post mosaicing
- 200 instances (right sized) using AWS spot pricing
- All jobs ran successfully (5 – 6 hours) and were not preempted
- Each job consumed about 4.3 GB peak of memory using a single core
- All results were pushed to S3
- Only classifier portion of the processing
- Less than 100MB of return data per tile

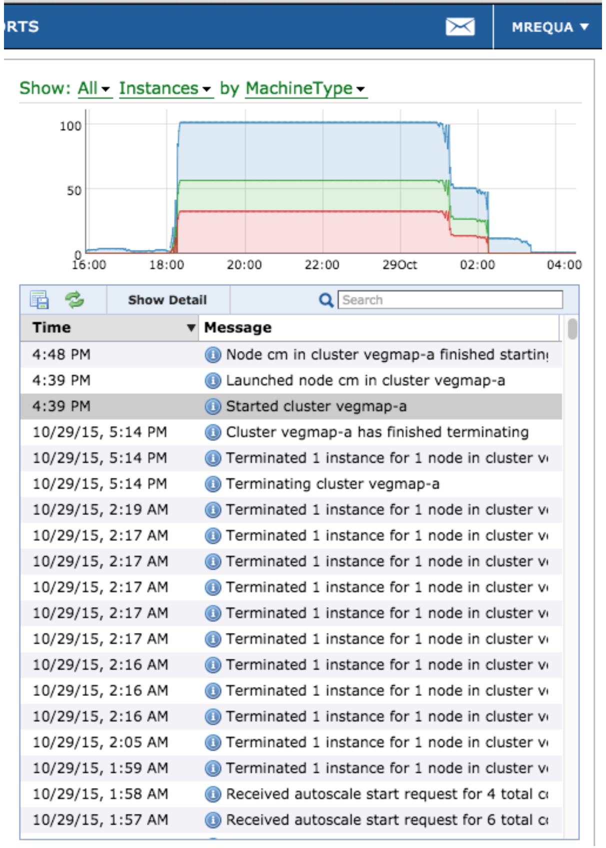
Spot Instances

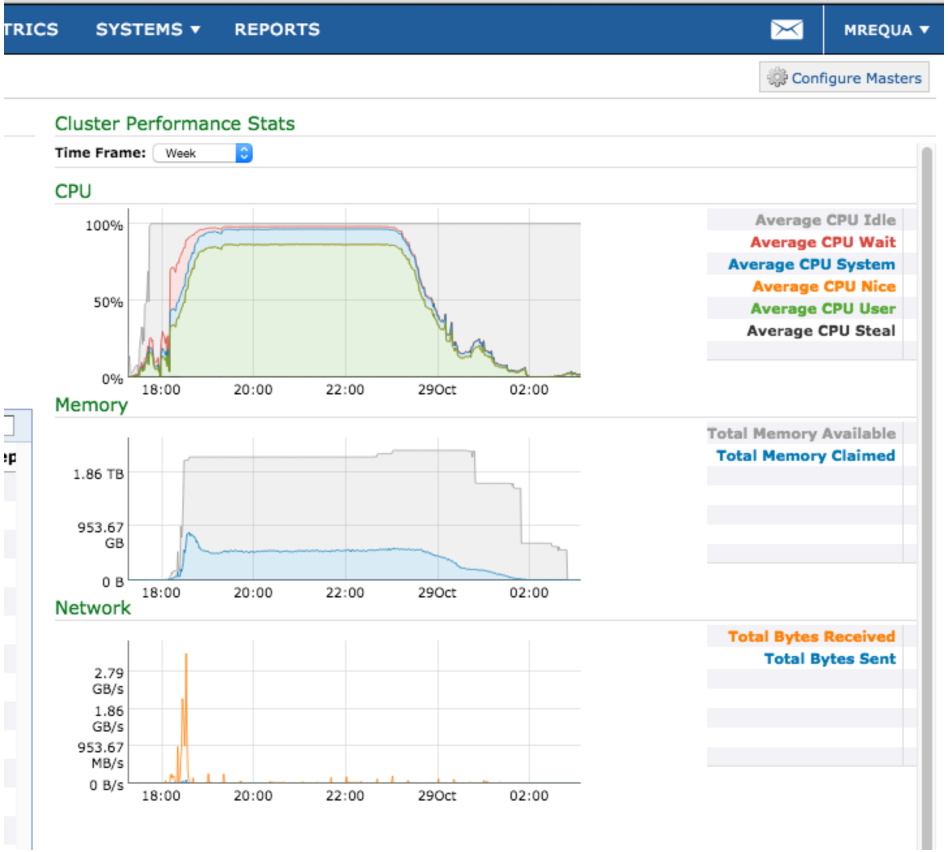
- Propose a bid price for a spot instance
- Spot instances run when your bid price exceeds the spot price
- Not guaranteed to run indefinitely
- Reduce costs by 50% to 90% from on-demand instances

Using AWS spot instances

- The entire test run cost $80
- Can do an entire UTM zone for ~$250
- Cost for all 11 UTM Zones ~$2,750
- Cost for all 11 UTM Zones and all 4 satellites ~$11,000

Cloud Resource Monitoring





Cloud Bursting Next Steps

Reconstitute Cycle Computing topology

- Now part of Microsoft

Perform Head in the Clouds processing with new algorithms

- Multiple commercial clouds – AWS and Azure

Devise cloud bursting benchmark

- Incorporate data flow and processing

Understand how Slurm developers are approaching problem

- Leverage existing batch system knowledge

!!! And Now A Commercial Break !!!

Genesis Of The Goddard Private Cloud

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Knowledge
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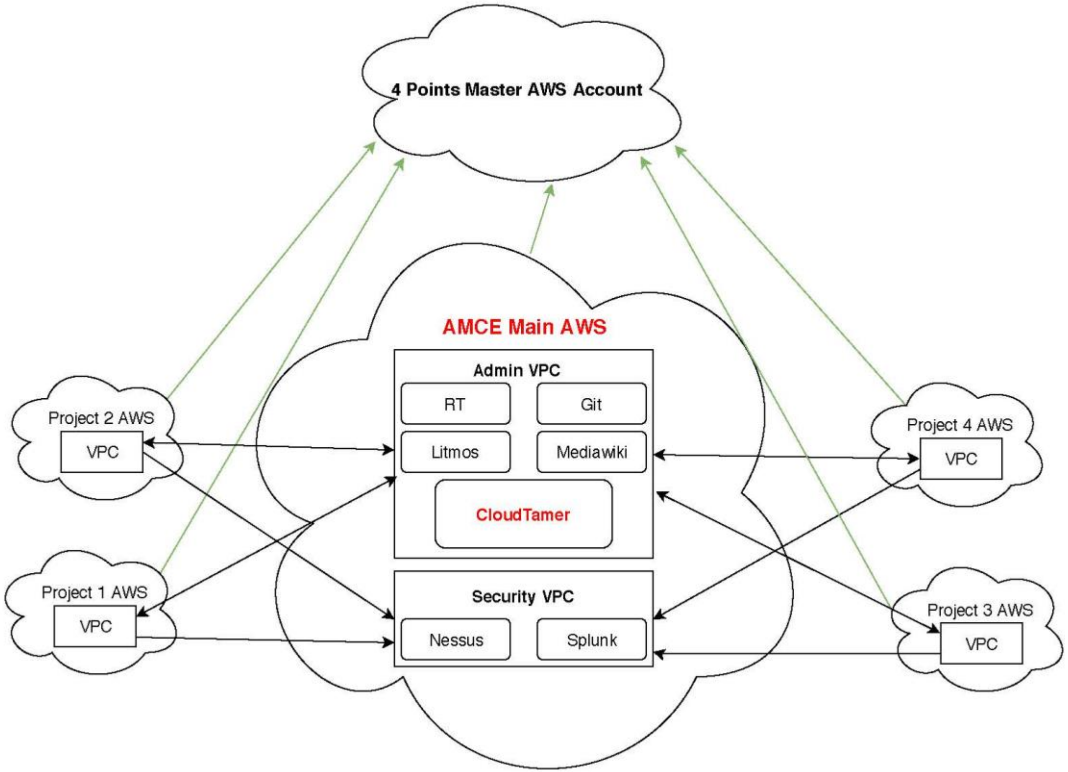
GPC Prototype

- ~35 hypervisors (VM host)
- ~700 terabytes shared storage
- OpenStack cloud software

AIAST Managed Cloud Environment




ROCK
THE
RED
2012 PLAYOFFS
STANLEY CUP PLAYOFFS

Questions??

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Head in the Clouds Counting Trees

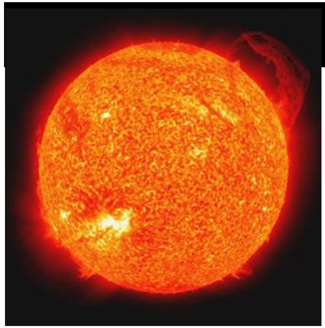
Compton James Tucker III (aka Jimmy, Jim, Jimbo, Compton, Tucker, etc.

Collaborators: Ebo David, Katie Melocik, Erin Glennie, Jorge Pinzon, Hoot Thompson, Dan Duffy, Julian Peters, Ellen Salmon, Bruce Van Artsen, Judy Strohmaier

Paul Morin, Claire Porter (University of Minnesota)

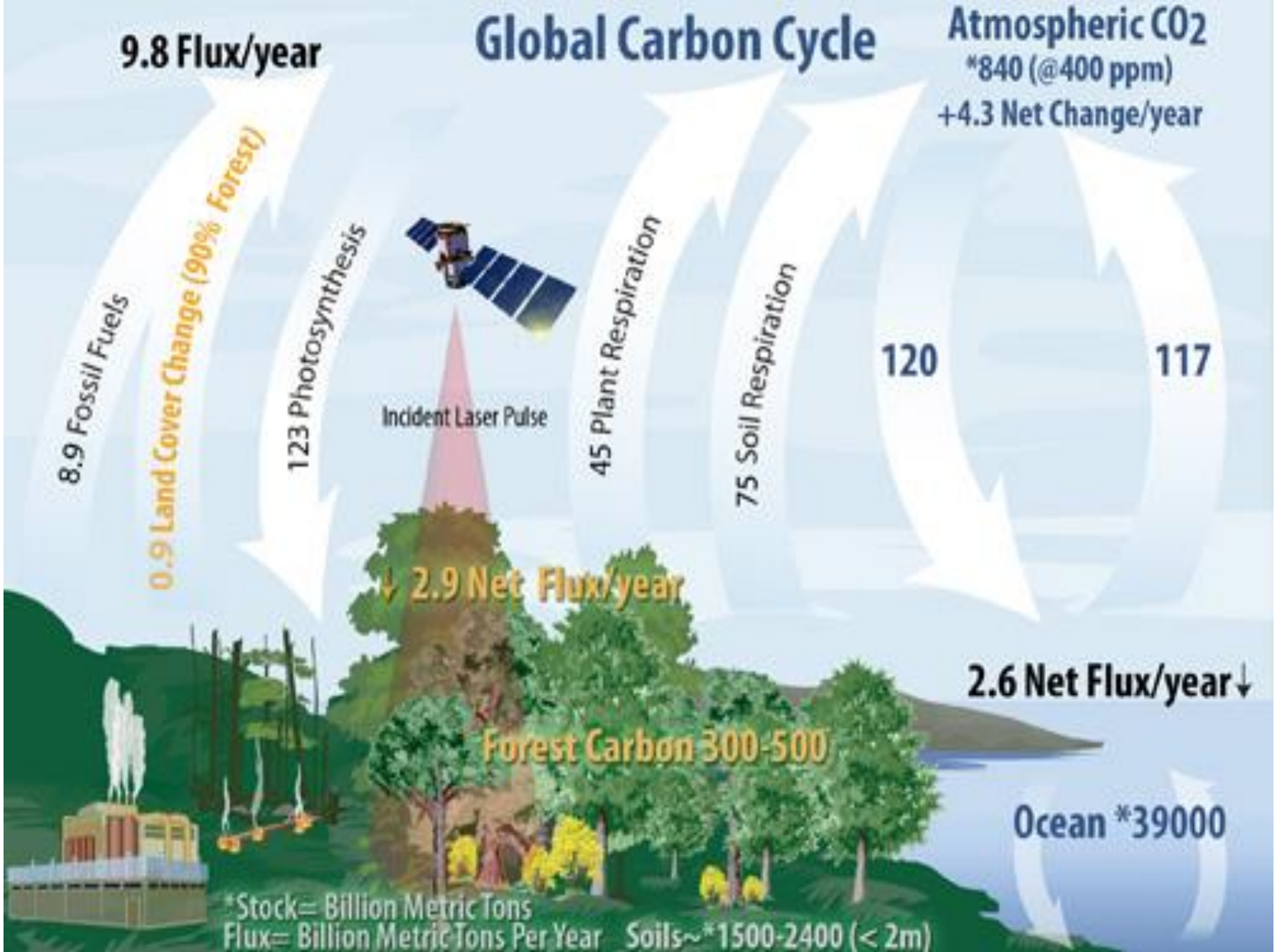
Martin Brandt, Rasmus Fensholt, Kjeld Rasmussen, Amandine Montagu, Feg Tian, Morgane Dendoncker, Caroline Vincke, Cheikh Mbow (University of Copenhagen)

Atmospheric Composition Matters

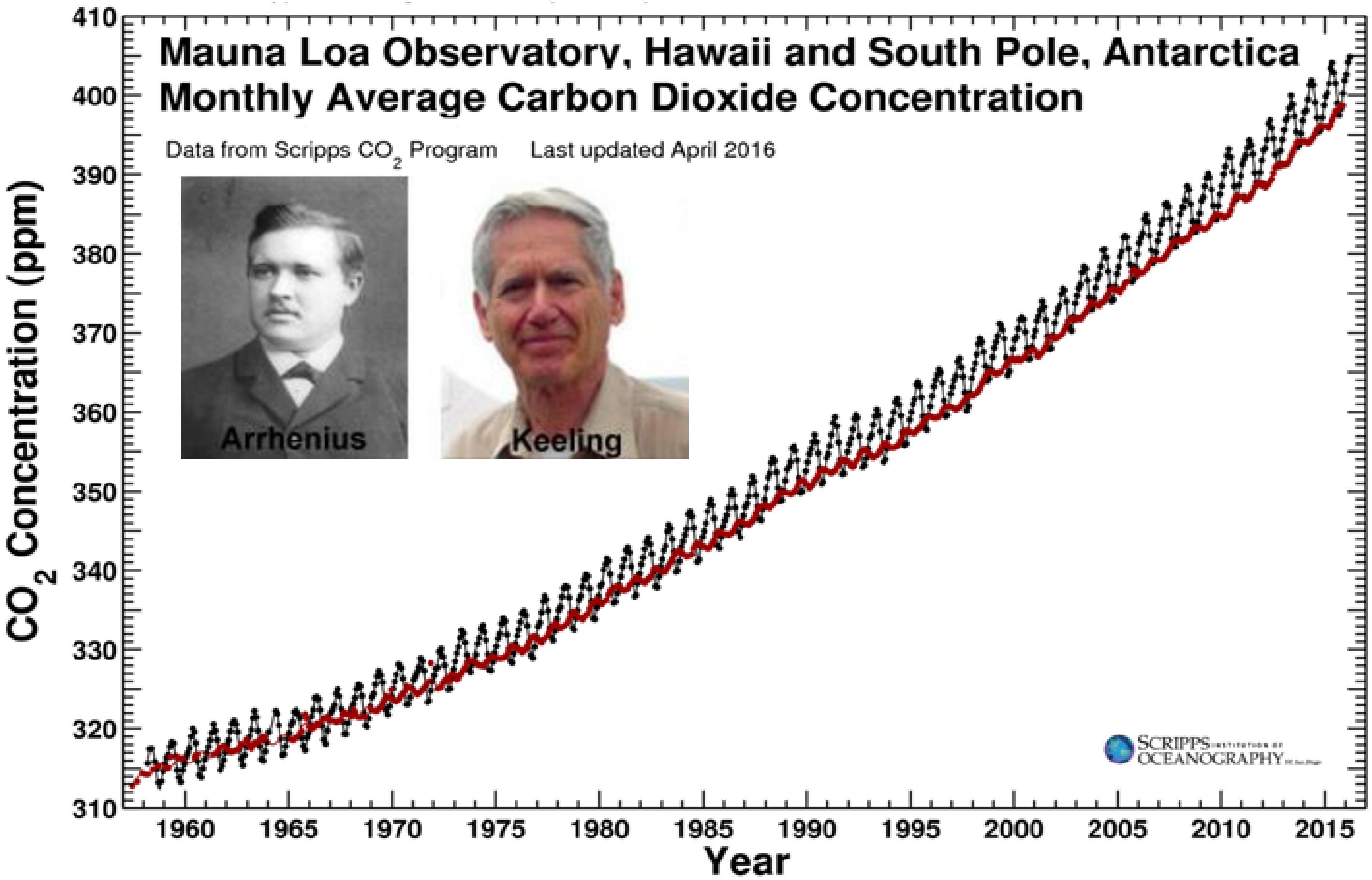


Flux: 6.78×10^{7} W/m^2

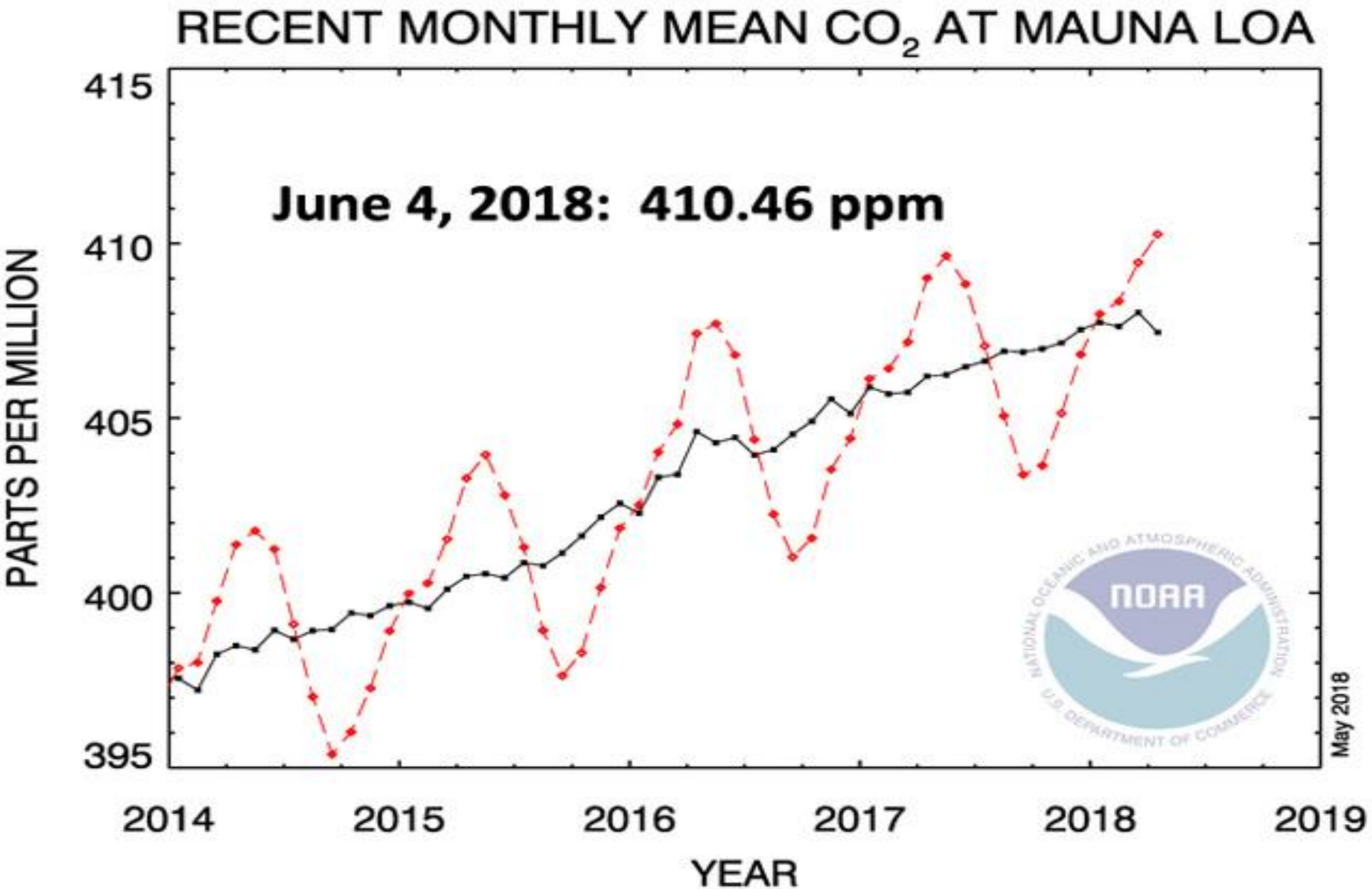
TOA flux W/m^2	**2,815**	**1,462**	**632**
Total absorbed watts:	**1.9×10^{17}**	**1.3×10^{17}**	**1.6×10^{16}**
Temp. no atmosphere (K):	**294**	**260**	**210**
Temp. no atmosphere (F):	**64**	**1**	**-89**
Actual Mean Temp. (F):	**860**	**62**	**-81**


Global Carbon Cycle
9.8 Flux/year
Atmospheric CO2
*840 (@400 ppm)
+4.3 Net Change/year
8.9 Fossil Fuels
0.9 Land Cover Change (90% Forest)
123 Photosynthesis
Incident Laser Pulse
45 Plant Respiration
75 Soil Respiration
120
117
↓ 2.9 Net Flux/year
2.6 Net Flux/year↓
Forest Carbon 300-500
Ocean *39000
*Stock= Billion Metric Tons
Flux= Billion Metric Tons Per Year
Soils~*1500-2400 (< 2m)

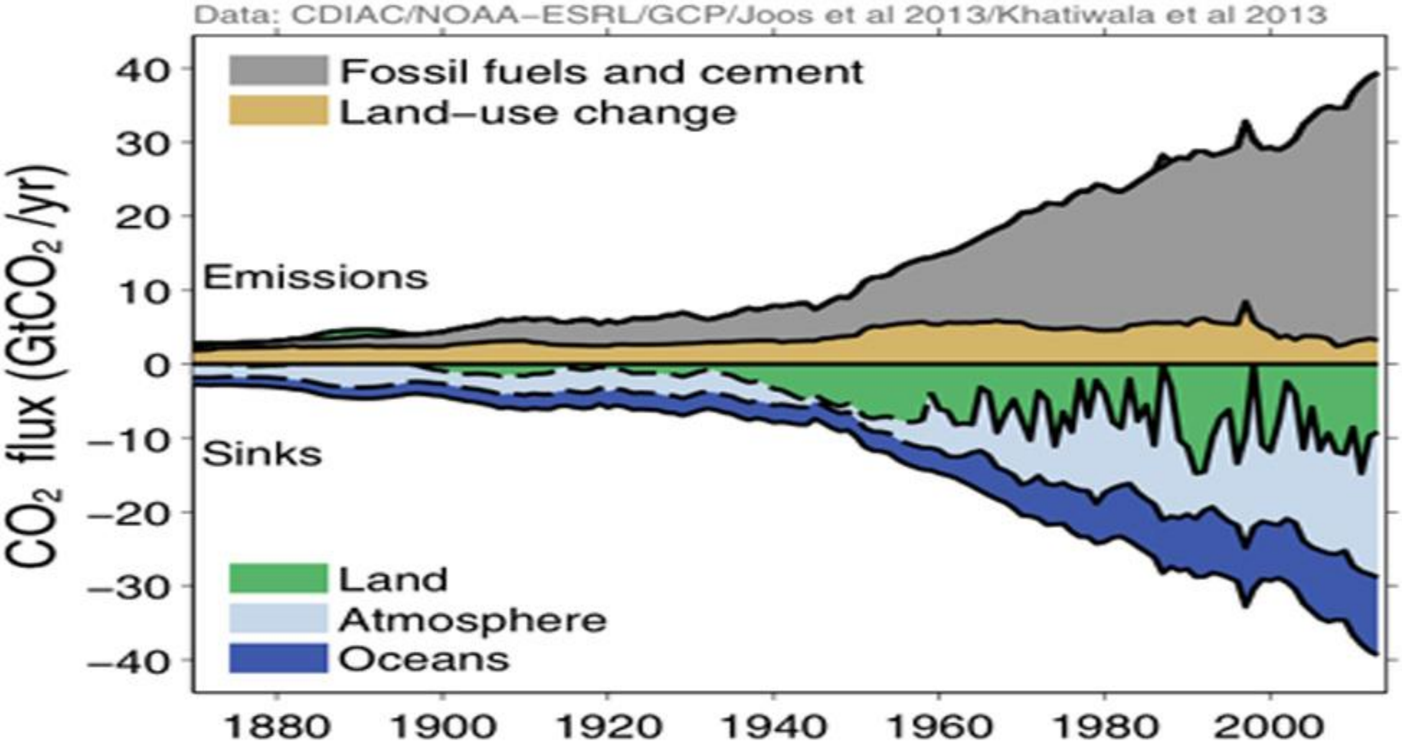
Climate & the Land Carbon Sink



Climate & the Land Carbon Sink

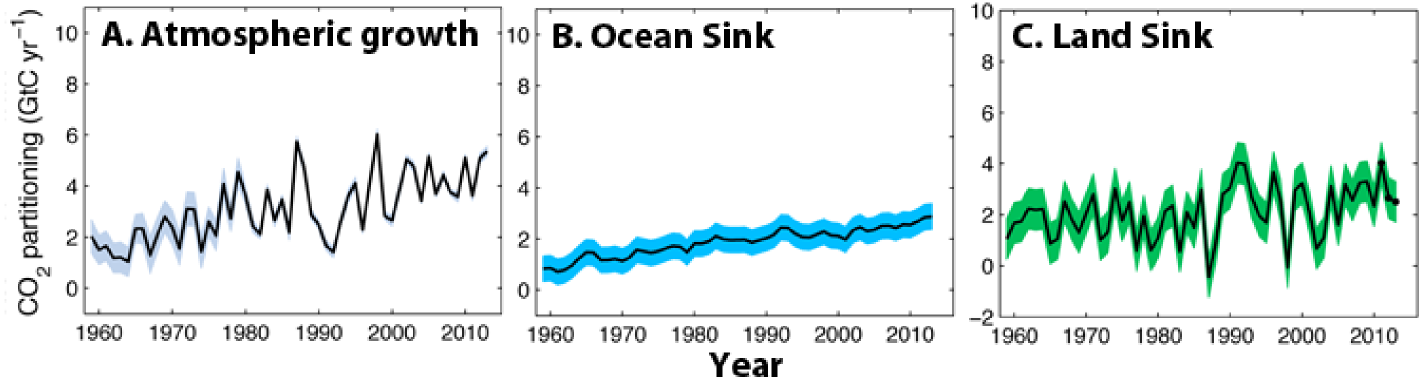


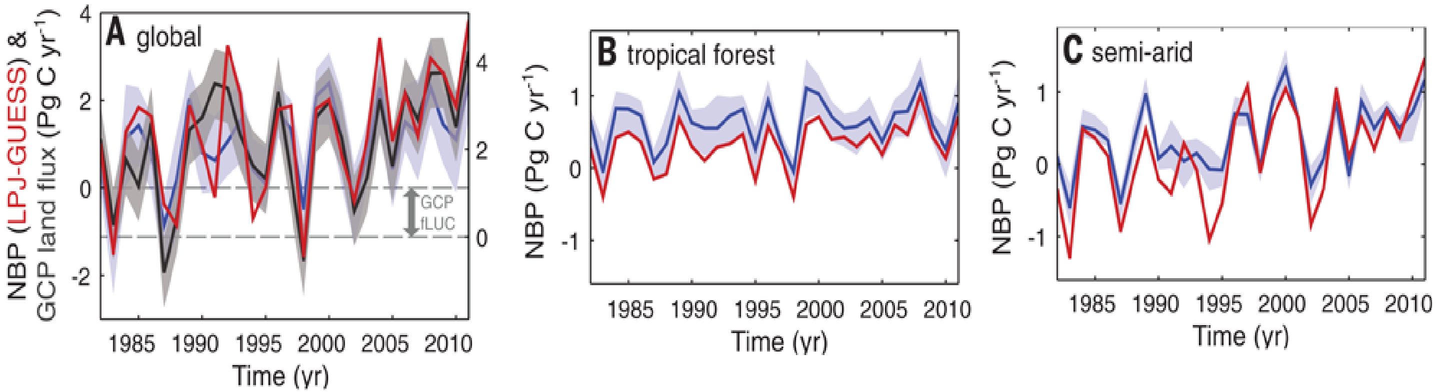
The Land Carbon Sink:
Where is the carbon going on land?

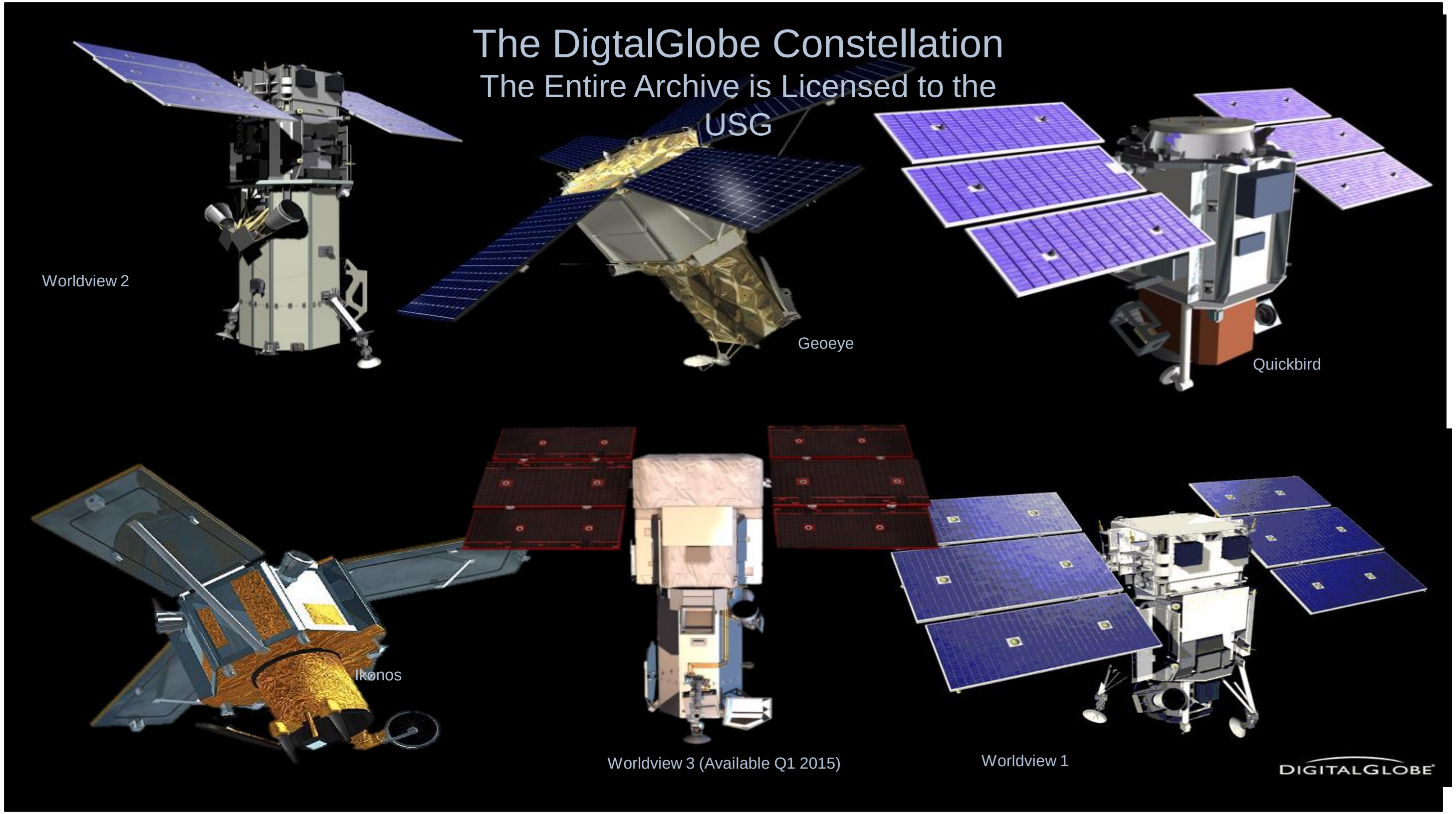


The Land Carbon Sink:

Where is the carbon going on land?

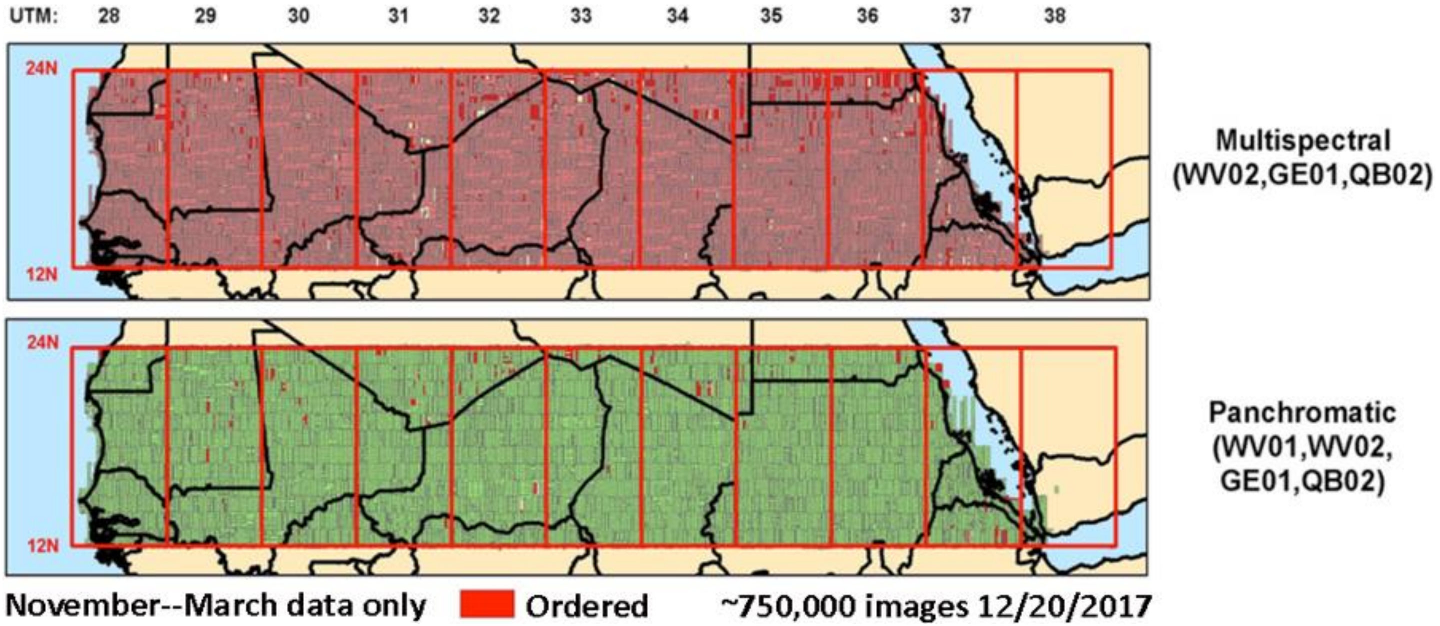




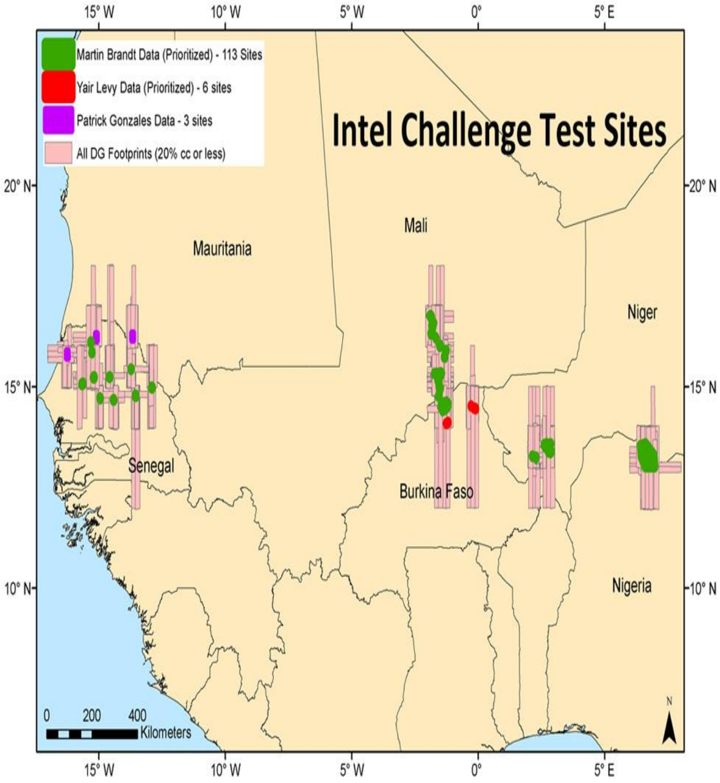

The DigtalGlobe Constellation
The Entire Archive is Licensed to the USG
Worldview 2
Geoeye
Quickbird
Ikonos
Worldview 3 (Available Q1 2015)
Worldview 1
DIGITALGLOBE

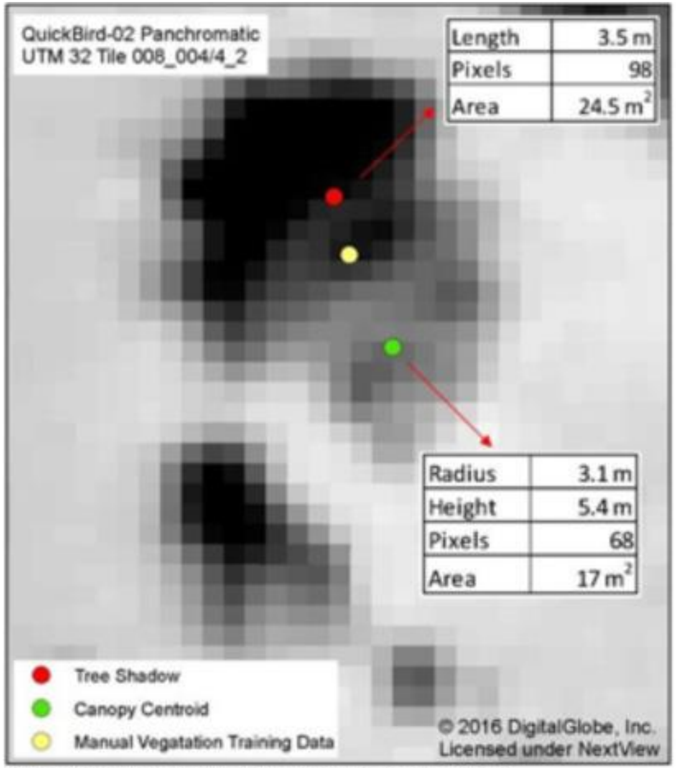
Sub-Saharan Africa

On-hand <1 m Commercial Satellite Imagery



Sub-Saharan Arid/Semi-arid Calibration Sites





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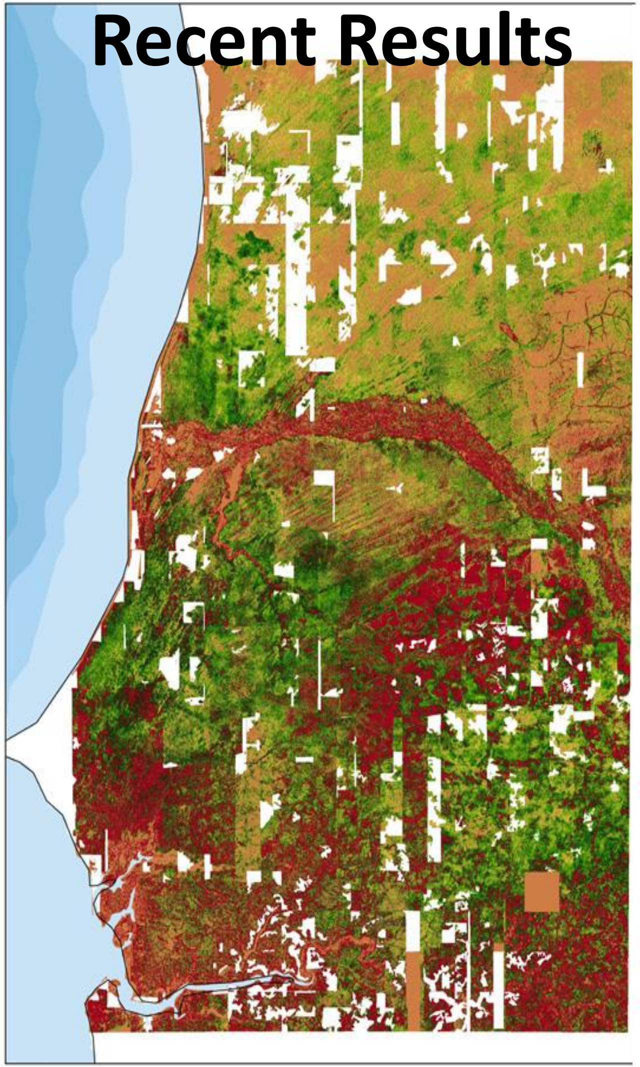
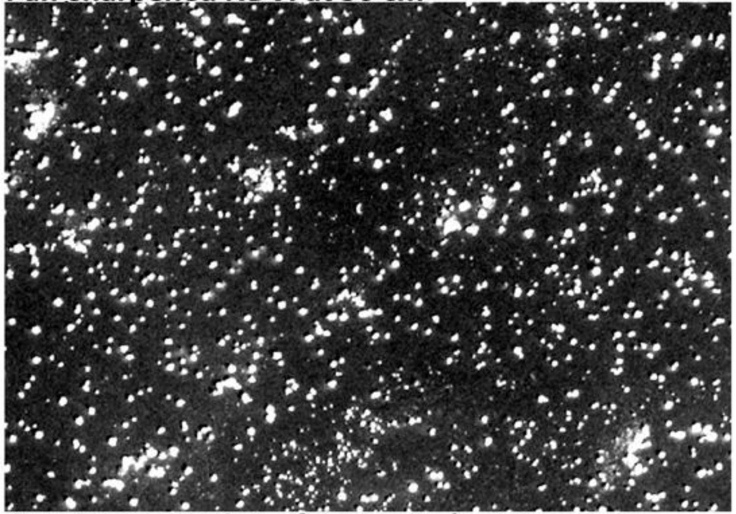
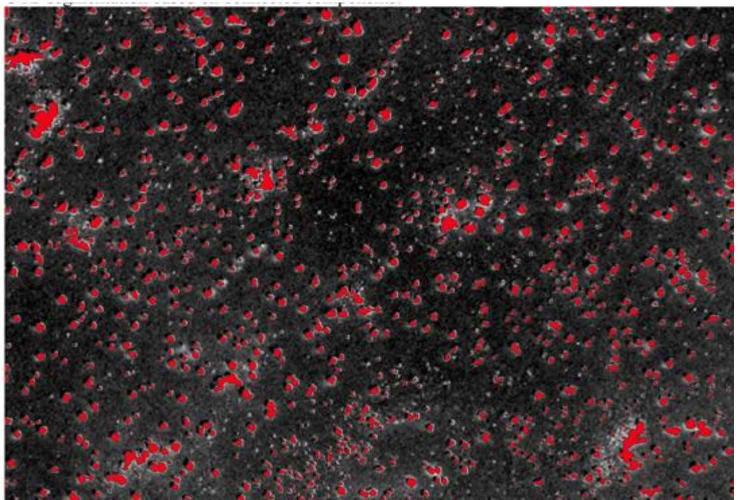
Recent Results



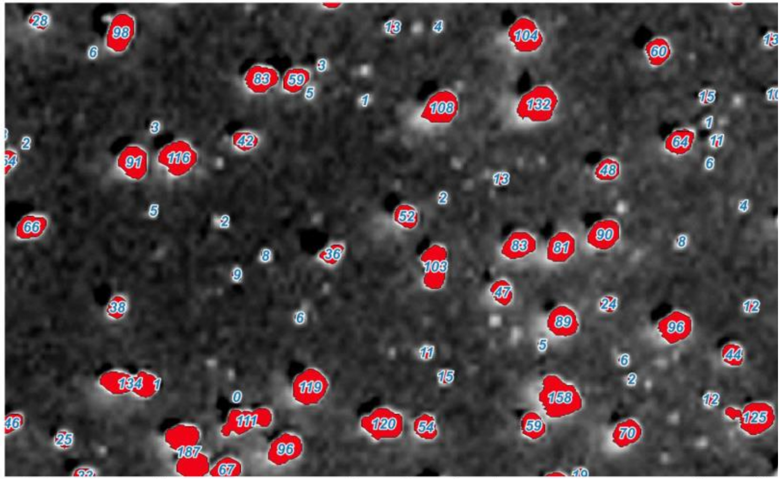
Pan-sharpened NDVI at 50 cm



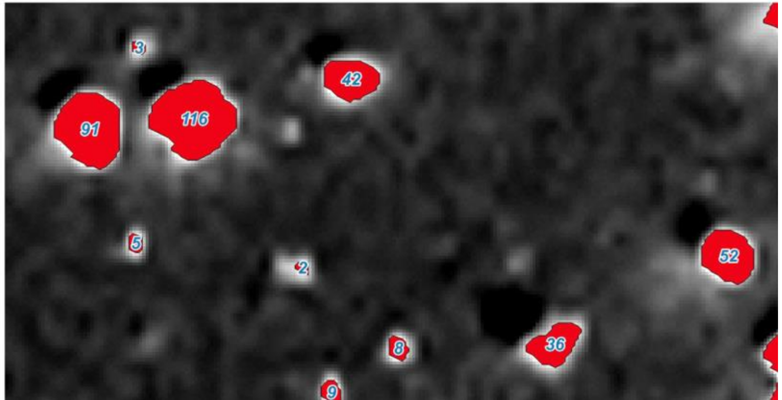
OTB Segmentation of connected components

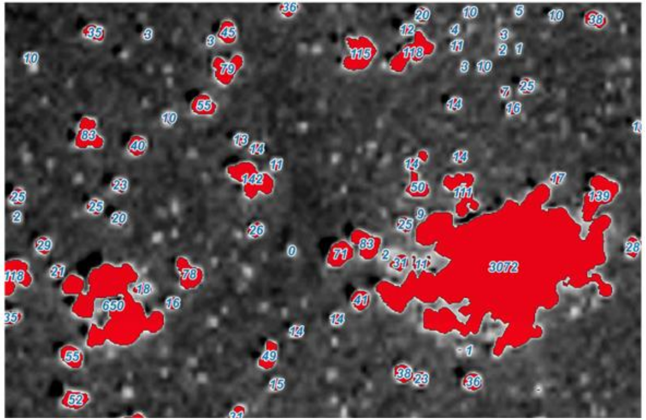


Recent results

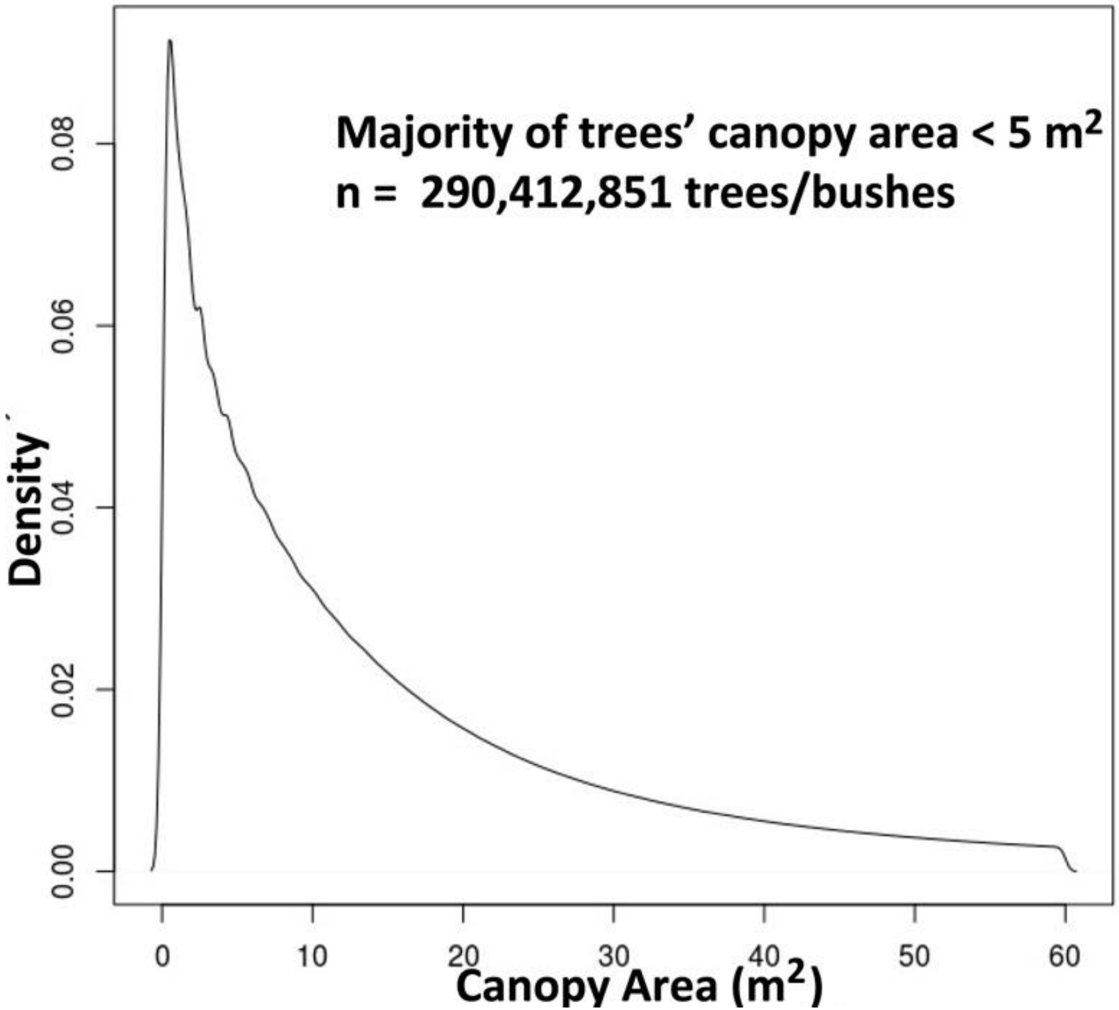


We map all green vegetation & calculate crown area in m^2



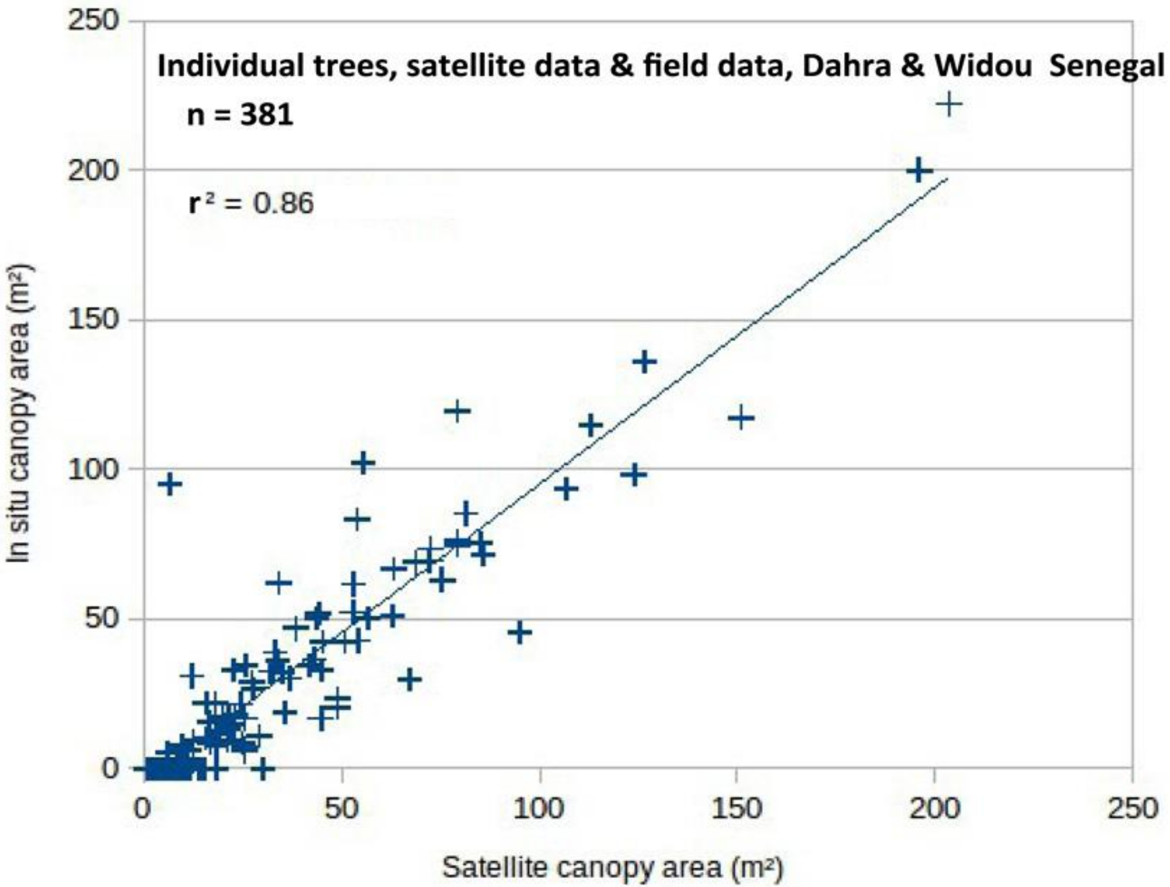


Still a problem with clumped trees

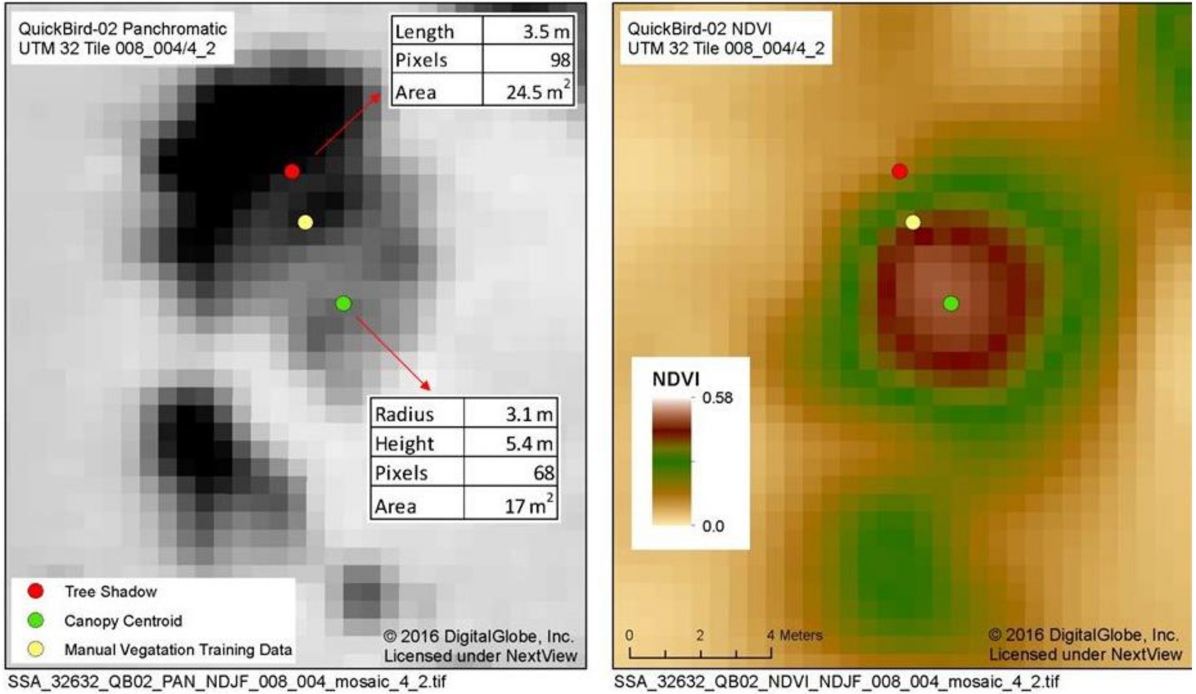


Majority of trees' canopy area < 5 m2
n = 290,412,851 trees/bushes
Density
0.00
0.02
0.04
0.06
0.08
0
10
20
30
40
50
60
Canopy Area (m2)

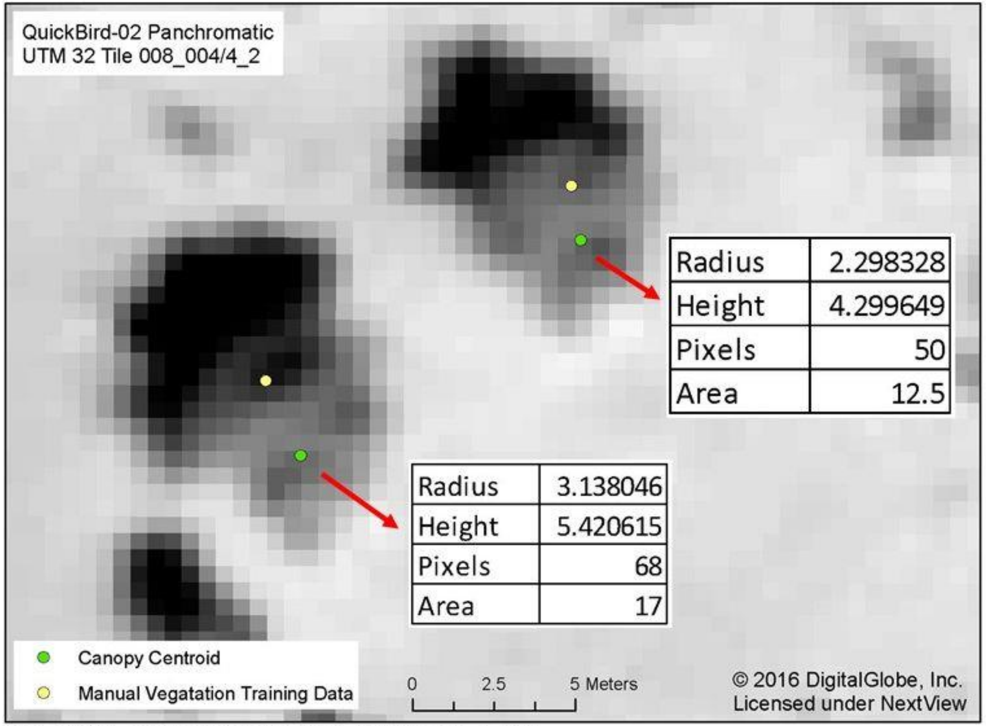
Recent results



Tree & Bush Crown & Heights at 1 - 5 m



Tree & Bush Crown & Shadow Detection in QuickBird Data



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Input Data Organization--Eliminate multiple counting

Ten UTM Zones (#28 to #37) from 12^o N to 24^o N

16 x 7 '100 km x 100 km' tiles per UTM zone = 112 tiles/UTM Zone

Each 100 km x 100 km tile broken down into sixteen 25 km x 25 km sub-tiles

112 tiles/UTM Zone X 16 sub-tiles/tiles = 1,792 sub-tiles/UTM Zone

Each 25 x 25 km sub-tile is a 2.5 x 10^9 element array at 50 cm

~1.5 hours/25 km x 25 km sub-tile/virtual machine to form processing data

1.5 hr/sub-tile X 1,792 tiles/UTM Zone X 10 UTM Zones = 1,120 days or 3 years

~5,000 strips per UTM Zone = ~4-5 M km^2 of coverage/UTM Zone

Each UTM Zone = ~1 M km^2 of area = ~10^{12} pixels per UTM Zone

100 virtual machines = ~20 cpu days for data organization

Tree & Bush Data Processing Considerations

Processing details per UTM Zone from 12 degrees N to 24 degrees N:

- **16 x 7 '100 km x 100 km' tiles per UTM zone = 112 tiles/UTM Zone**
- **1/16 of a 100 x 100 km tile = 1 sub-tile (25 km by 25 km)**
- **7 hours dedicated computer processing time per sub-tile (25 km x 25 km)**
- **Each sub-tile is an array 50,000 x 50,000 elements at a pixel size of 50 cm**

0.5 km by 0.5 km chunks or 1000 x 1000 array elements requires ~7 gb RAM (compute requires 4 gb RAM)

Tree & Bush Counting Considerations

Single Virtual Machine Niger test case for UTM Zone 32 from 12 degrees N to 24 degrees N:

- **112 tiles**
- **112 x 16 = 1,792 sub-tiles**
- **Each sub-tile takes ~7 hours computation time to completion**
- **1 UTM Zone takes 12,500 hours of compute time**
- **12,500 compute hours = 520 compute days = 17.3 compute months**

We have 10 UTM Zones:

- **10 UTM Zones x 17.3 compute months/UTM Zone = 14-15 years**
- **15 years = 180 months compute time with 1 virtual machine**
- **100 virtual machines--180 months/100 virtual machines = 1.8 months**
- **200 virtual machines--180 months/200 virtual machines = 0.9 months**