Oklahoma Ecological Observatory:
Its Contribution to the NASA GeoCarb Mission

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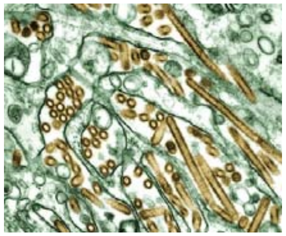

Acknowledgements

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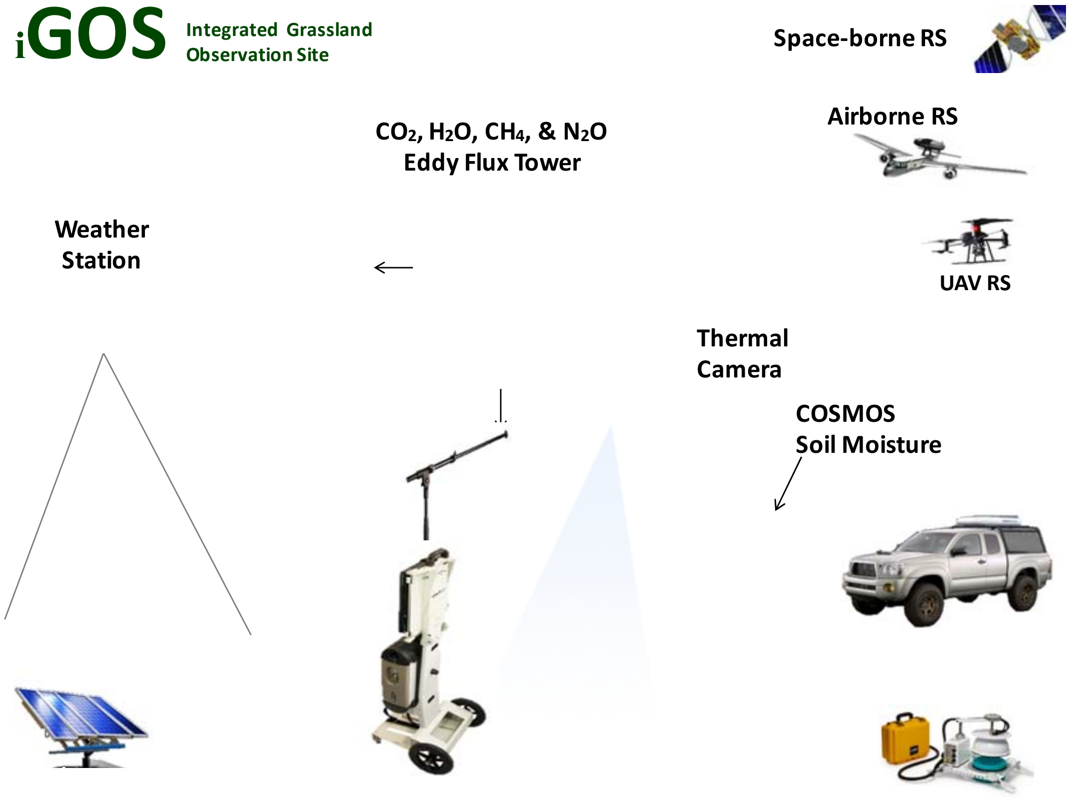
Rajen Bajgain, Jeffrey Basara, Jinwei Dong, Russell Doughty, Cui Jin, Hayden Mahan, Michael Menarguez, Yuanwei Qin, Jie Wang, Xiaocui Wu, Xiangming Xiao, Yao Zhang, Yuting Zhou, Zhenhua Zou

USDA ARS Grazinglands Research Laboratory, El Reno, OK

Jean Steiner, Pradeep Wagle

Oklahoma Ecological Observatory

Infrastructure for *In-situ* observatory



iGOS Integrated Grassland Observation Site

Space-borne RS

Airborne RS

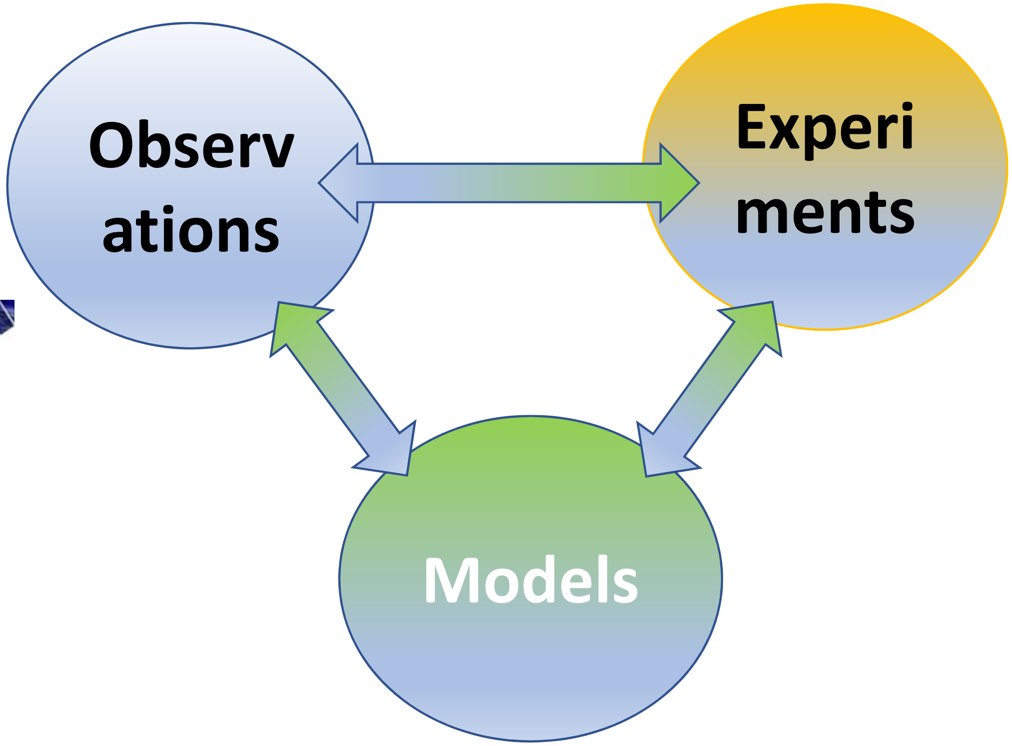
CO_2, H_2O, CH_4, & N_2O Eddy Flux Tower

UAV RS

Weather Station

Thermal Camera

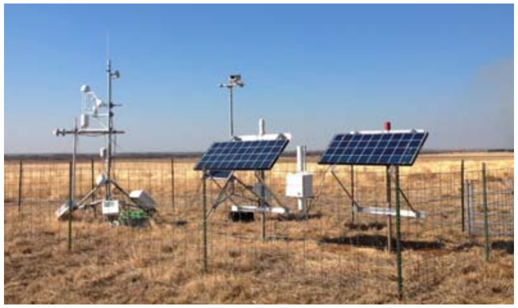
COSMOS Soil Moisture



Observ ations

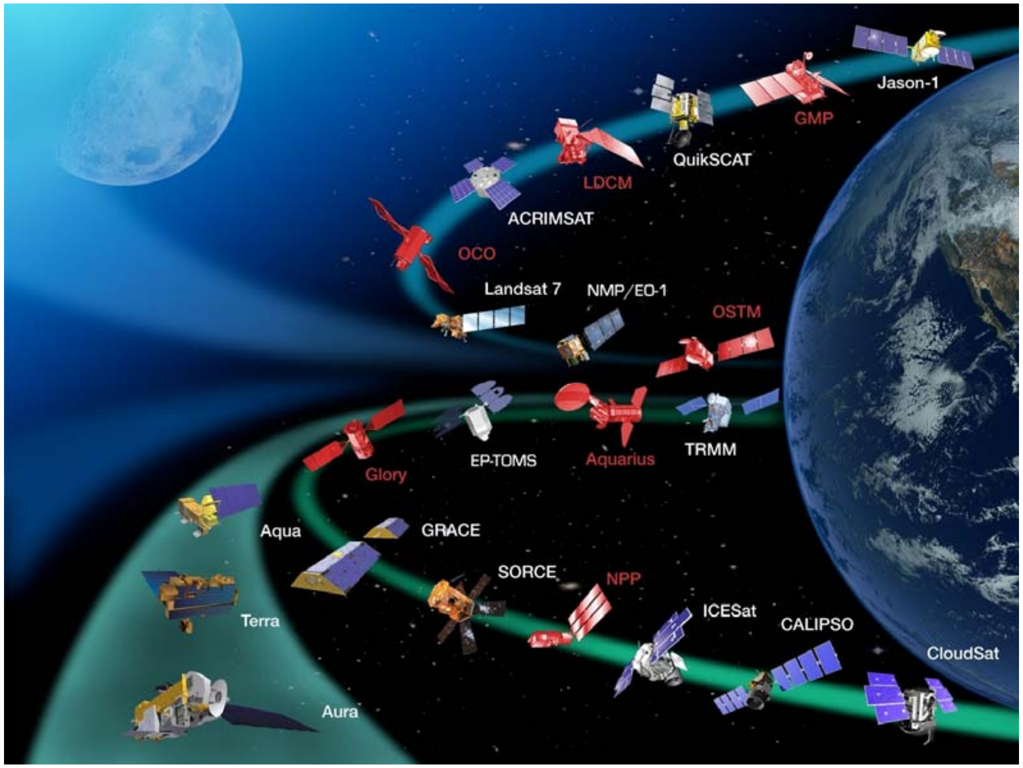
Experi ments

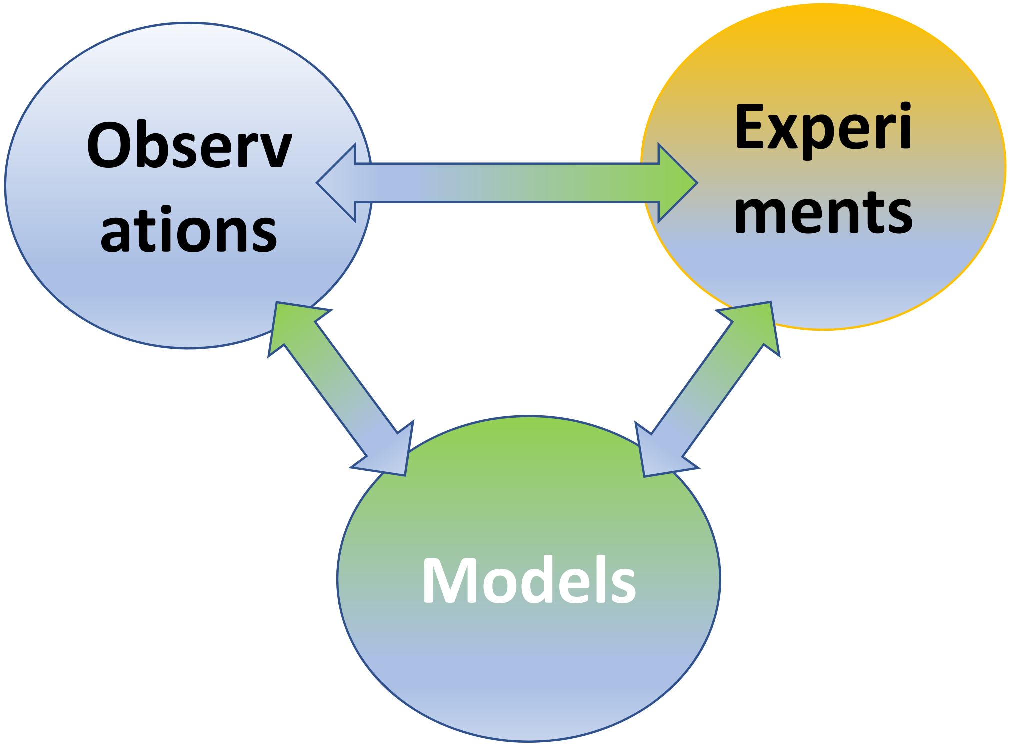
Models



Oklahoma Ecological Observatory

Infrastructure for large-scale mapping and monitoring from space



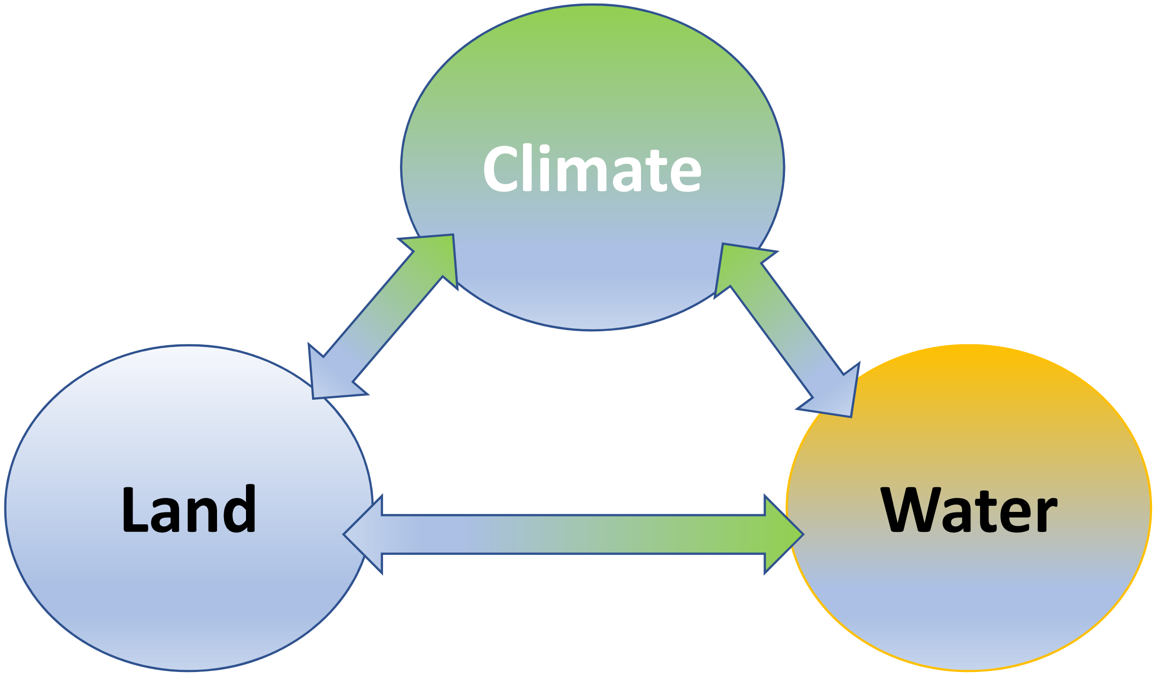


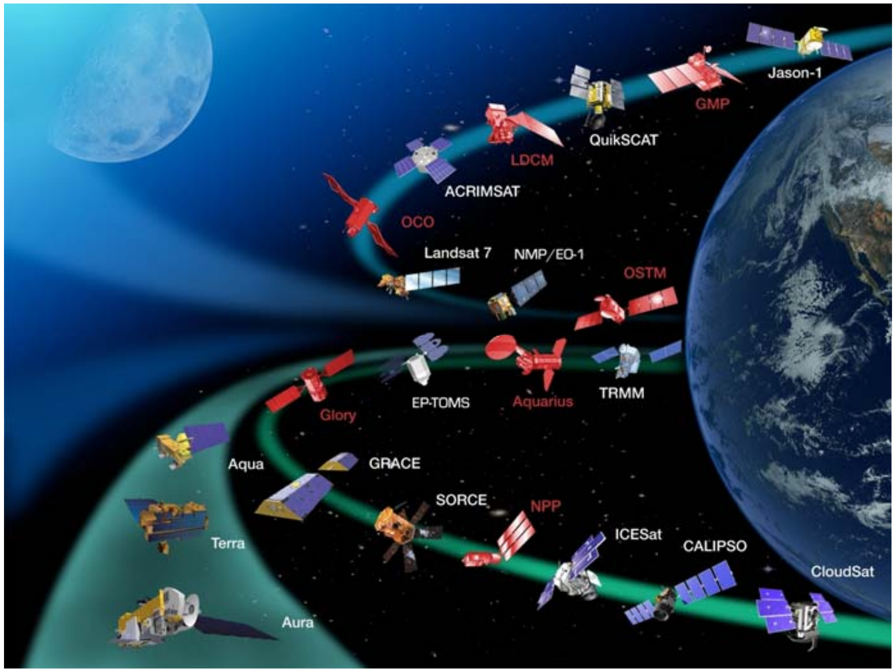
Observations

Experiments

Models

Oklahoma Ecological Observatory



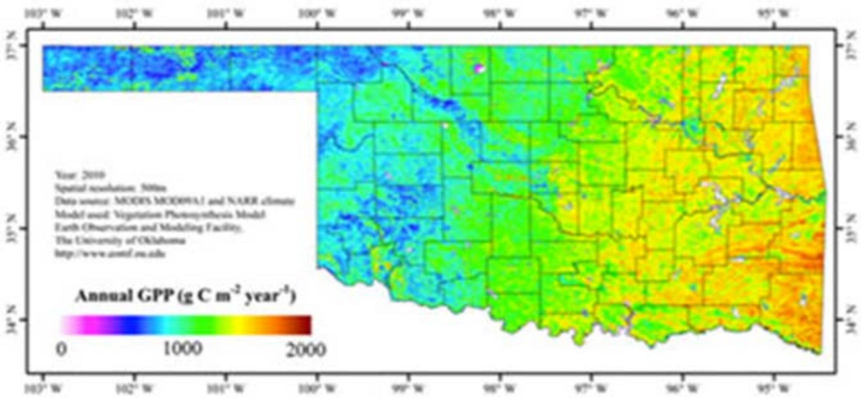


To develop state-wide geospatial data products for natural resources in Oklahoma

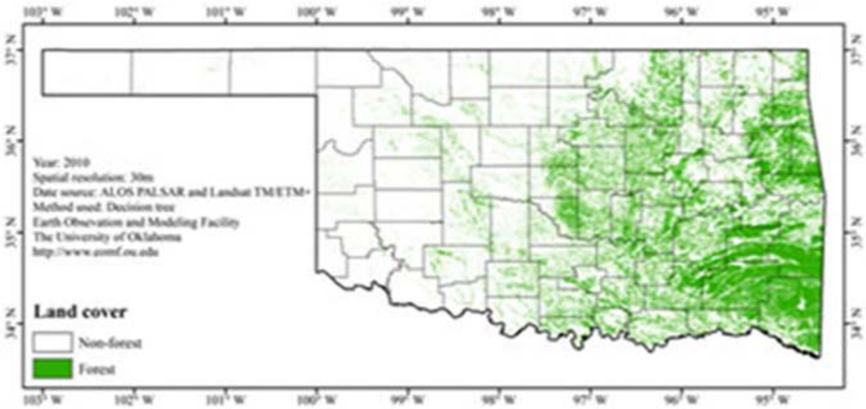
Oklahoma Ecological Observatory

Oklahoma state-wide land and water datasets from remote sensing

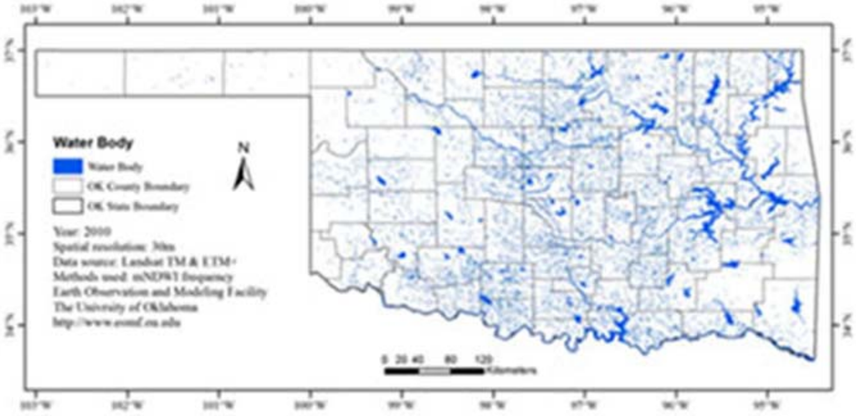
Gross primary production (2000-2015)

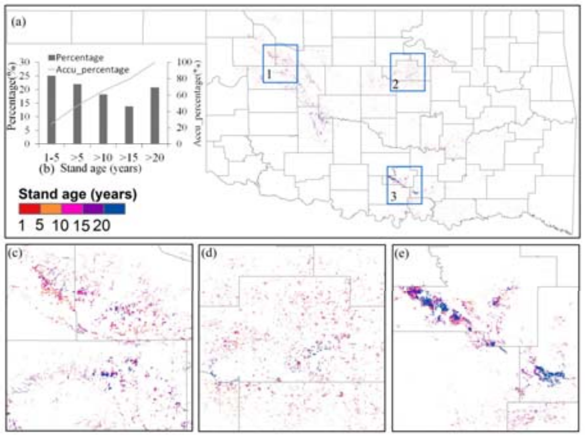


Forest cover in 2010 (Landsat, PALSAR)



Open surface water bodies (1984-2015)





Woody plant encroachment (1984-2010)

Open surface water bodies in Oklahoma

Science of the Total Environment xxx (2017) xxx-xxx

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com

Continued decrease of open surface water body area in Oklahoma during 1984–2015

Zhenhua Zou[a], Jinwei Dong[a, b], Michael A. Menarguez[a, c], Xiangming Xiao[a, d], , Yuanwei Qin[a], Russell B. Doughty[a], Katherine V. Hooker[c], K. David Hambright[e]

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ARTICLE INFO

Article history:
Received 21 January 2017
Received in revised form 27 March 2017
Accepted 28 March 2017
Available online xxx

Editor: D. Barcelo

Keywords:
Surface water body
Mapping
Landsat
Climate change

ABSTRACT

Oklahoma contains the largest number of manmade lakes and reservoirs in the United States. Despite the importance of these open surface water bodies to public water supply, agriculture, thermoelectric power, tourism and recreation, it is unclear how these water bodies have responded to climate change and anthropogenic water exploitation in past decades. In this study, we used all available Landsat 5 and 7 images (16,000 scenes) from 1984 through 2015 and a water index- and pixel-based approach to analyze the spatial-temporal variability of open surface water bodies and its relationship with climate and water exploitation. Specifically, the areas and numbers of four water body extents (the maximum, year-long, seasonal, and average extents) were analyzed to capture variations in water body area and number. Statistically significant downward trends were found in the maximum, year-long, and annual average water body areas from 1984 through 2015. Furthermore, these decreases were mainly attributed to the continued shrinking of large water bodies (> 1 km^2). There were also significant decreases in maximum and year-long water body numbers, which suggested that some of the water bodies were vanishing year by year. However, remarkable inter-annual variations of water body area and number were also found. Both water body area and number were positively related to precipitation, and negatively related to temperature. Surface water withdrawals mainly influenced the year-long water bodies. The smaller water bodies have a higher risk of drying under a drier climate, which suggests that small water bodies are more vulnerable under climate-warming senarios.

1. Introduction

Climate change and increased climate variability can strongly impact surface water resources (Aherne et al., 2006; Ferguson and Maxwell, 2012; Tulbure et al., 2016), causing dramatic intra-annual and inter-annual water variability (Hall et al., 2014; Mercier et al., 2002), which has been shown to have wide-ranging consequences on human societies and ecosystems (Bates et al., 2008; Brown and Lall, 2006). Previous studies using remote sensing approaches have documented strong relationships between water body extent (area and number) with both climate variability and anthropogenic impacts of water resources (Liu et al., 2013; Pekel et al., 2016; Tao et al., 2015; Tulbure and Broich, 2013; Tulbure et al., 2014).

Water body monitoring with remote sensing techniques has advanced along with an increase in freely available, high-resolution satellite data. Many approaches were developed primarily based on Landsat spectral bands, water indices and decision tree classification algorithms (Fisher et al., 2016; Mueller et al., 2016; Tulbure and Broich, 2013). First, many water indices were defined to delineate water bodies with emphases on different features (Bhagat and Sonawane, 2011; Boland, 1976; Crist, 1985; Gond et al., 2004; McFeeters, 1996; Rouse et al., 1974; Shine and Mesev, 2007; Xiao et al., 2002; Xu, 2006) (see supplementary online material 1 (SOM 1)). For example, McFeeters (1996) defined the Normalized Difference Water Index (NDWI) using green and near infrared band to delineate open water features. Xu (2006) modified the NDWI into mNDWI by replacing the near infrared band with short-wave infrared band to suppress the noise of built-up land. mNDWI is one of the most widely used water indices due to its good performance in water body delineation across diverse landscapes (Du et al., 2012; Feyisa et al., 2014; Hui et al., 2008; Ogilvie et al., 2015; Tao et al., 2015).

Second, previous remote sensing approaches have inconsistent capabilities of capturing water body variability. Many surface water bodies have strong intra-annual dynamics, during for example, wet and dry seasons (Alsdorf et al., 2007; Tulbure and Broich, 2013). But some studies estimated water body extent from satellite images gathered at a single time of the year, typically in the wet season (Feng et al., 2011; Homer et al., 2015; Liu et al., 2013). However, it is difficult to define the proper period due to uncertainties in intra-annual variability of climate and anthropogenic effects. Some studies compared the difference of water body area between the same time of selected years to indicate the increasing or decreasing trends of water body area among those years (Du et al., 2012; Homer et al., 2015;

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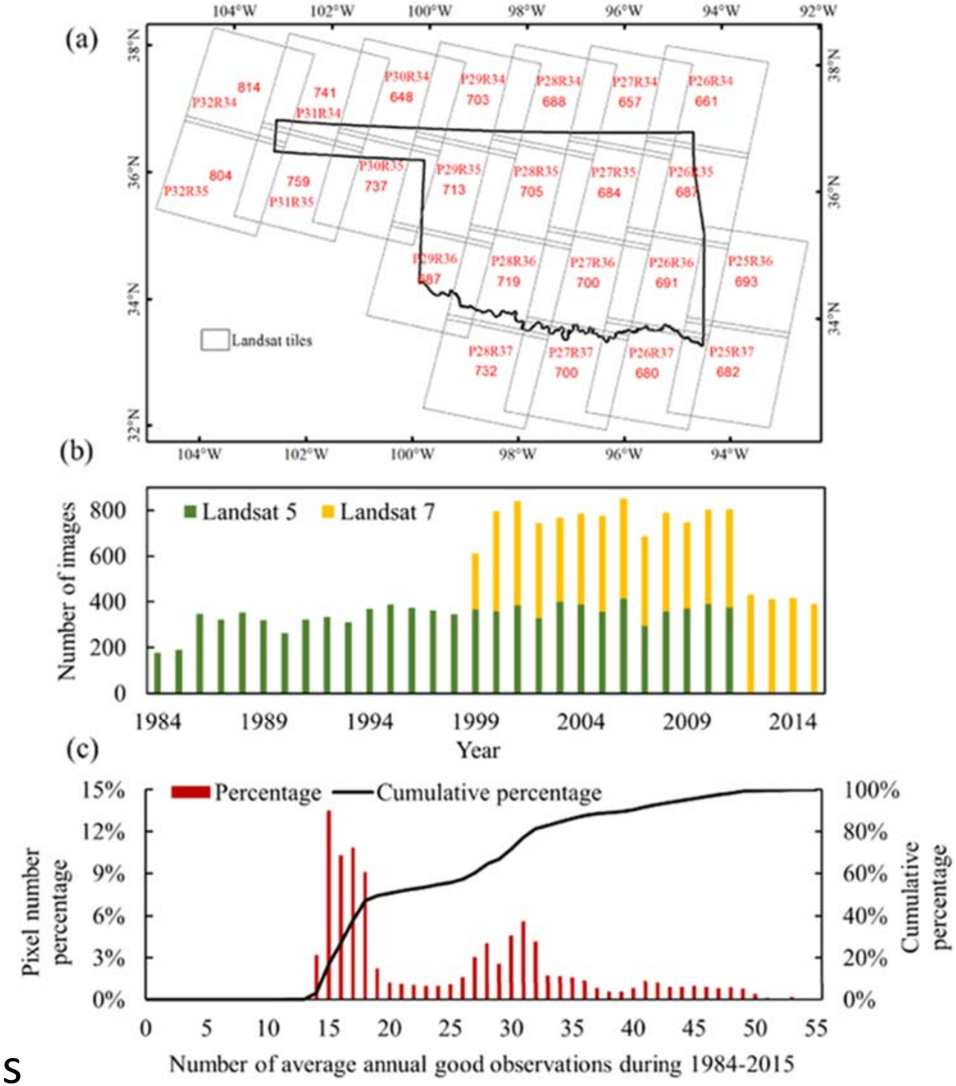
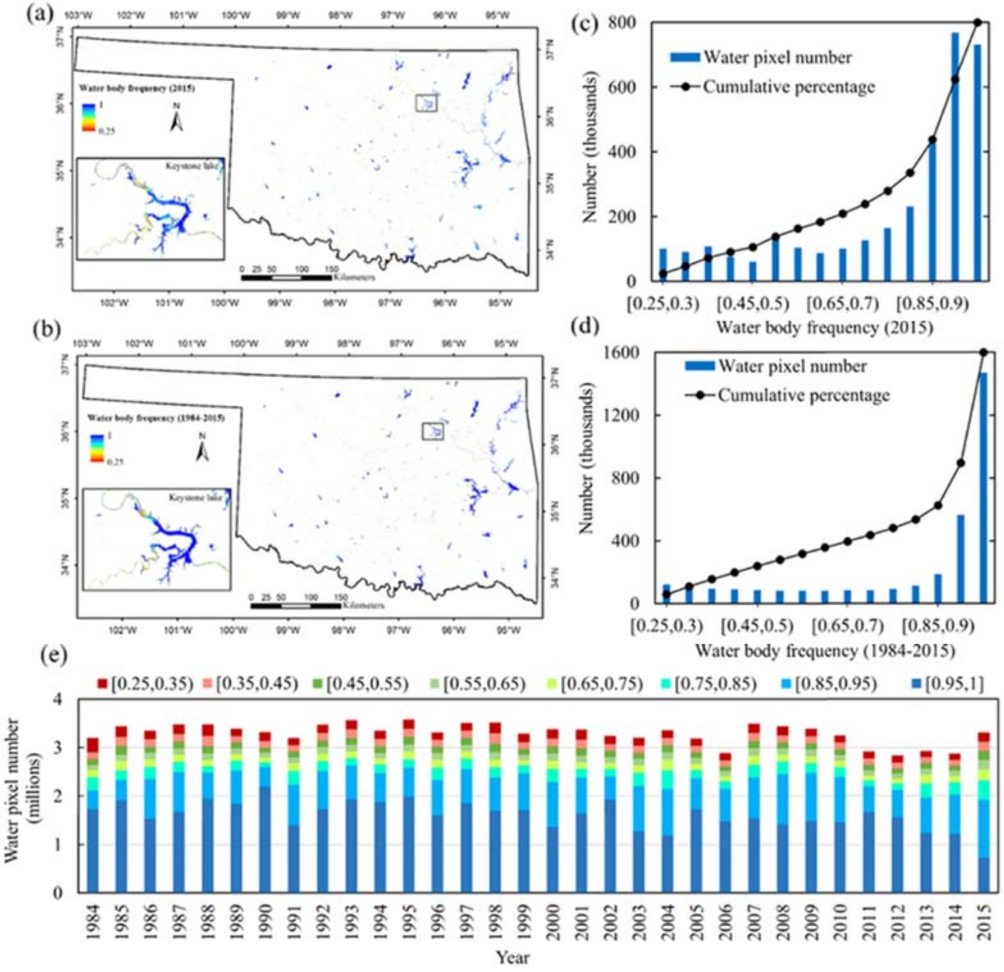
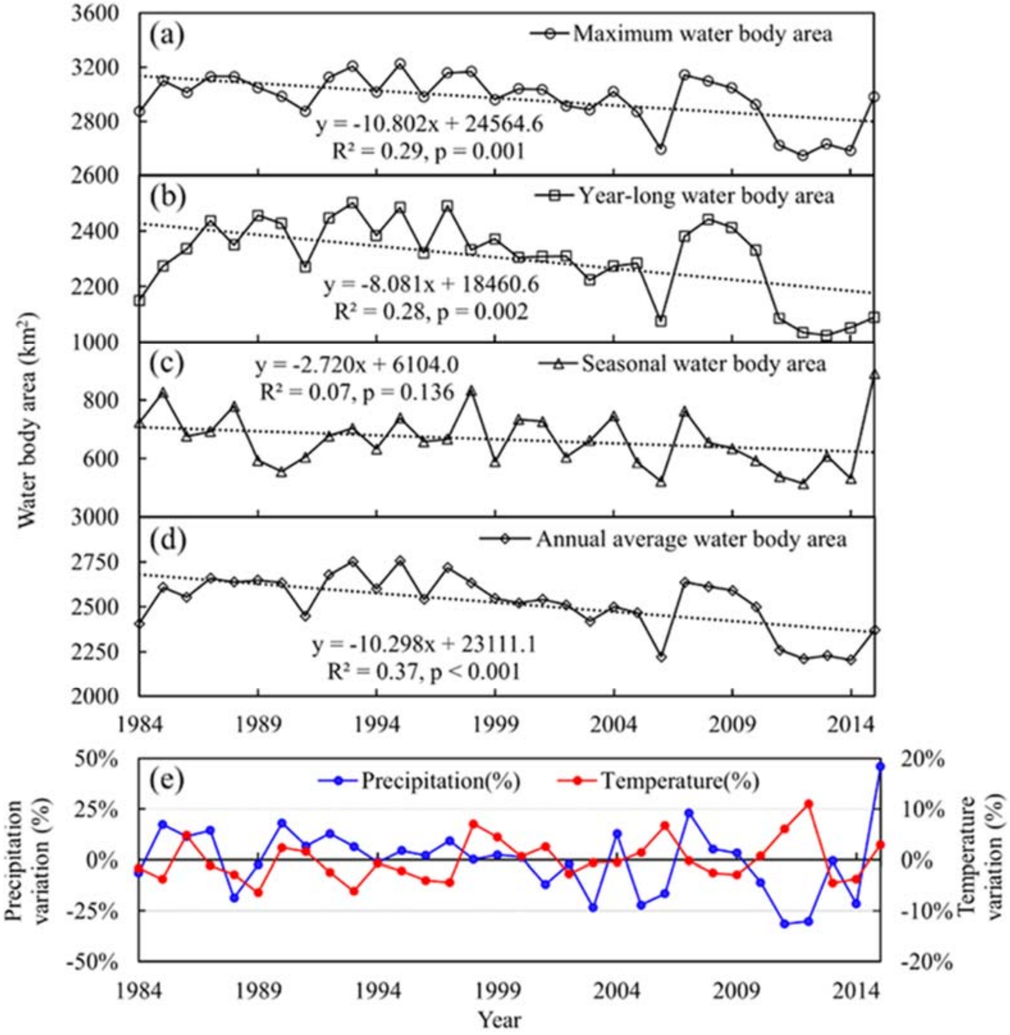
http://dx.doi.org/10.1016/j.scitotenv.2017.03.259
0048-9697/© 2016 Published by Elsevier Ltd.



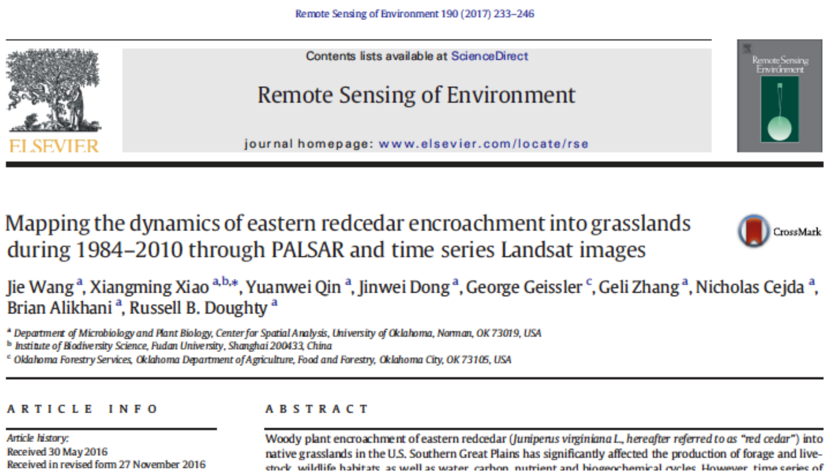
16,000 Landsat 5 & 7 images

Annual dynamics of open surface water bodies (areas and numbers) over 1984-2015 in Oklahoma





Annual dynamics of woody plant encroachment in Oklahoma during 2000-2010



Remote Sensing of Environment 190 (2017) 233–246

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Mapping the dynamics of eastern redcedar encroachment into grasslands during 1984–2010 through PALSAR and time series Landsat images

Jie Wang [a], Xiangming Xiao [a,b,*], Yuanwei Qin [a], Jinwei Dong [a], George Geissler [c], Geli Zhang [a], Nicholas Cejda [a], Brian Alikhani [a], Russell B. Doughty [a]

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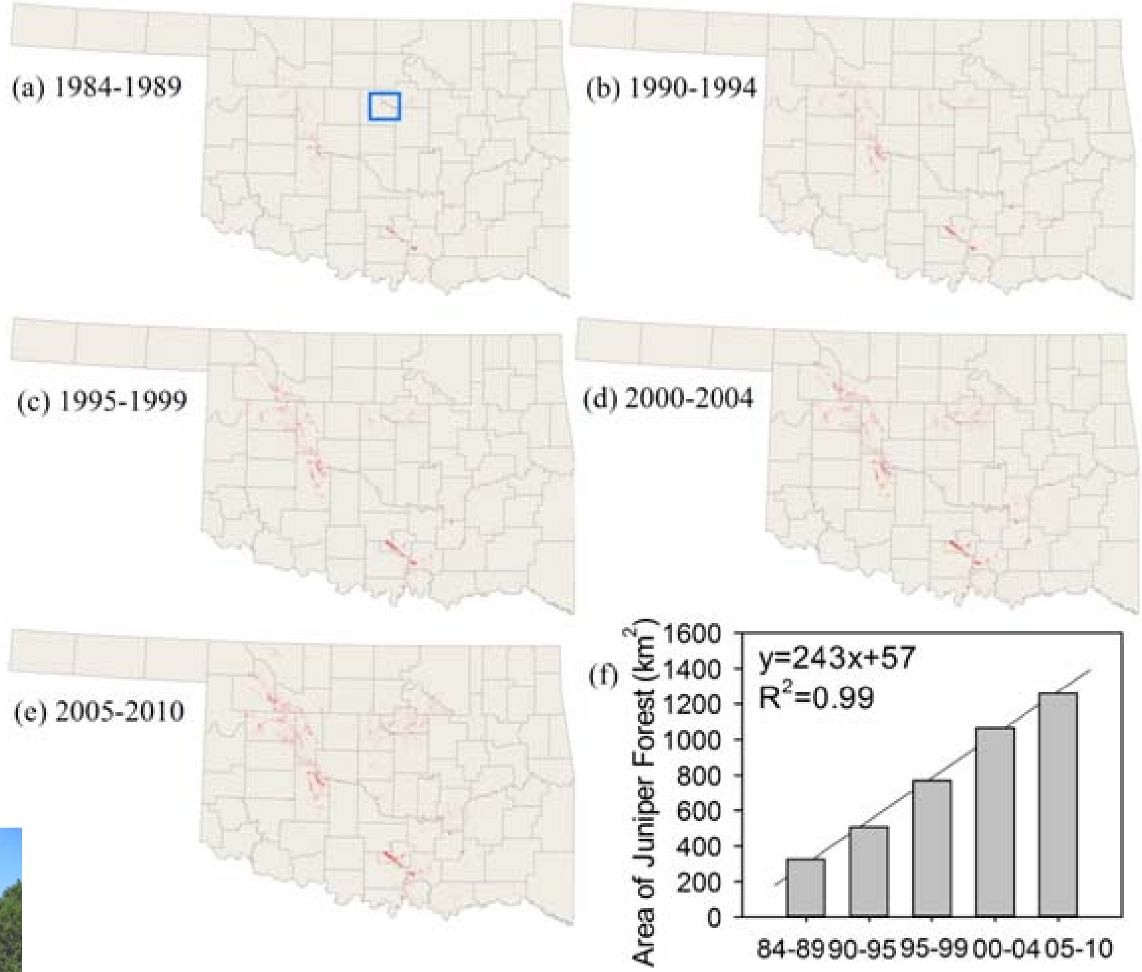
ARTICLE INFO

Article history:
Received 30 May 2016
Received in revised form 27 November 2016

ABSTRACT

Woody plant encroachment of eastern redcedar (*Juniperus virginiana L., hereafter referred to as "red cedar"*) into native grasslands in the U.S. Southern Great Plains has significantly affected the production of forage and live-

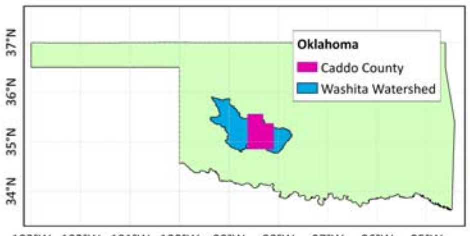


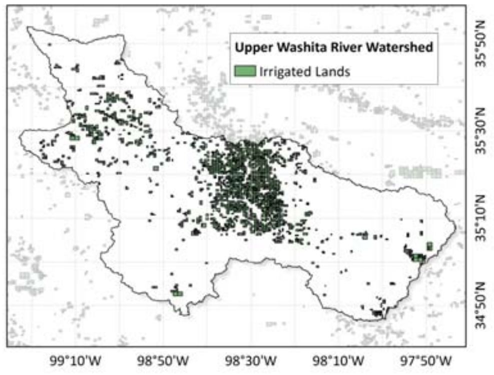
- Juniper forests in Oklahoma have expanded linearly at an annual rate of ~40 km^2/year between 1984 - 2010 with notable spatial clusters in its expansion process.

Eastern redcedar and other juniper forests

Annual dynamics of gross and net primary production (GPP and NPP) of croplands and grasslands in Oklahoma during 2000-2015

GPP, NPP --- >> forage biomass and grain yields



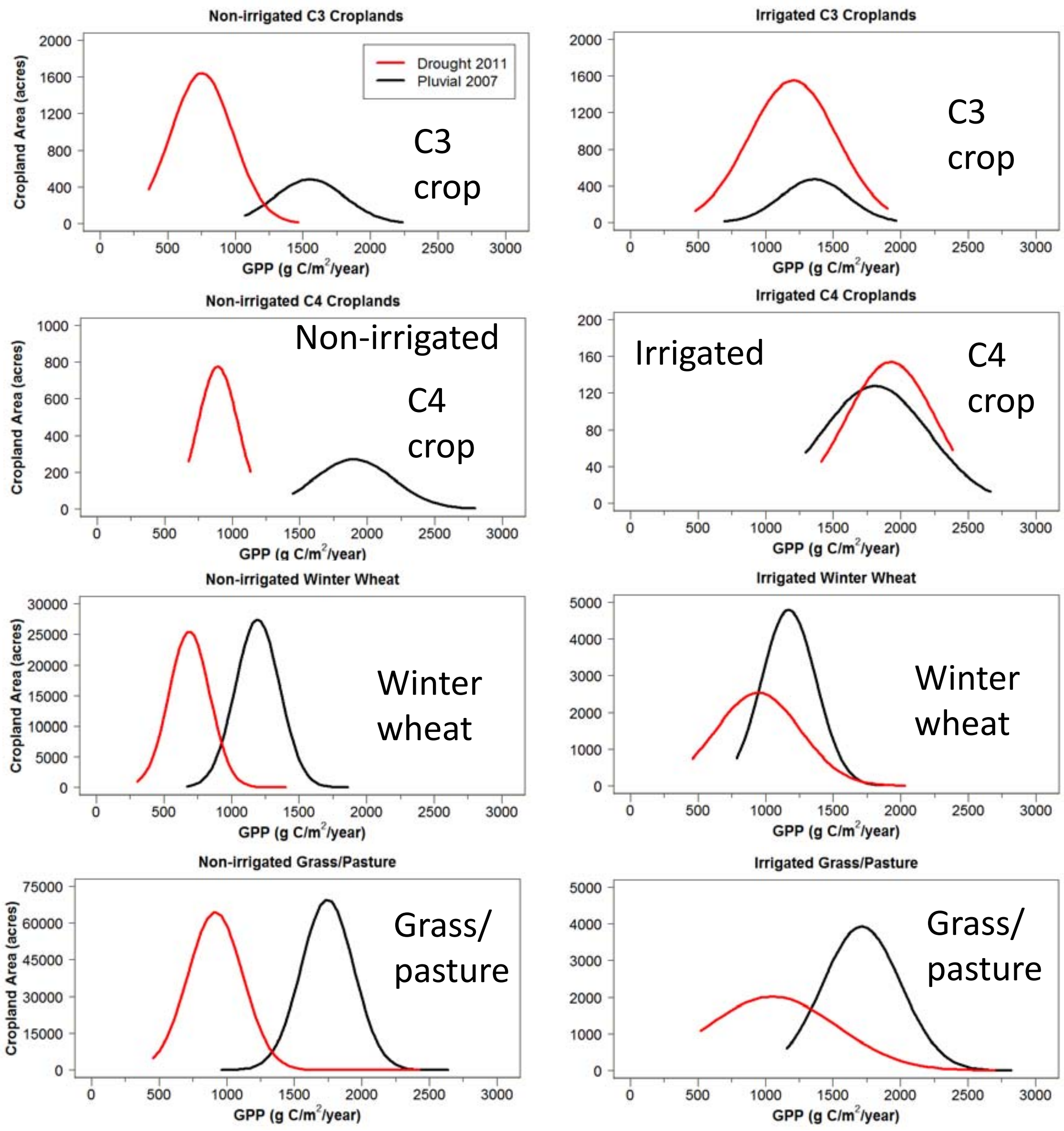


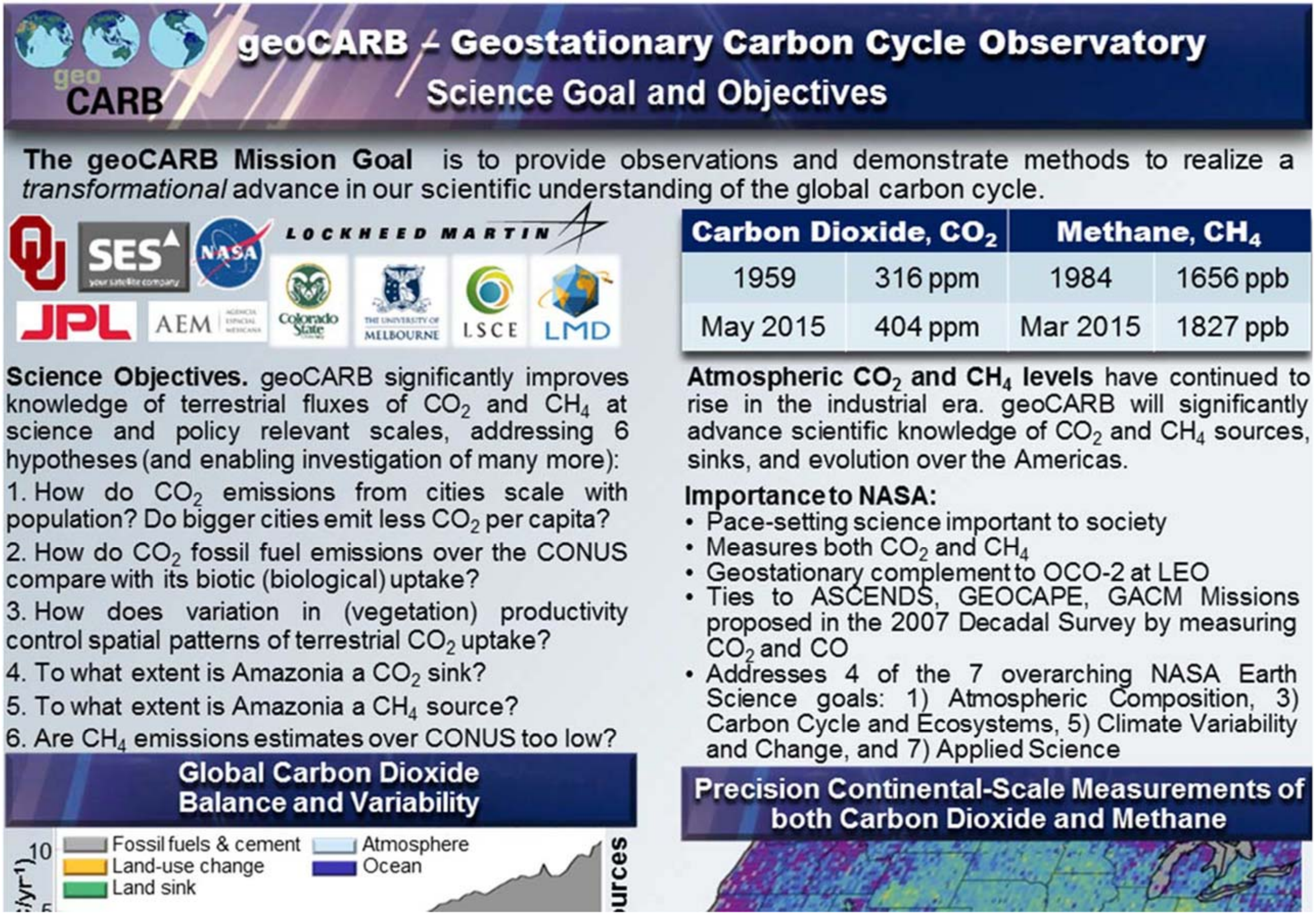
Histogram of annual GPP by crop, grass and pasture fields in Cando county

Drought year 2011 (red line)

Pluvial year 2007 (black line)

See Doughty et al., Poster#3





geoCARB – Geostationary Carbon Cycle Observatory

Science Goal and Objectives

The geoCARB Mission Goal is to provide observations and demonstrate methods to realize a *transformational* advance in our scientific understanding of the global carbon cycle.

Carbon Dioxide, CO_2		Methane, CH_4	
1959	316 ppm	1984	1656 ppb
May 2015	404 ppm	Mar 2015	1827 ppb

Science Objectives. geoCARB significantly improves knowledge of terrestrial fluxes of CO_2 and CH_4 at science and policy relevant scales, addressing 6 hypotheses (and enabling investigation of many more):

1. How do CO_2 emissions from cities scale with population? Do bigger cities emit less CO_2 per capita?
2. How do CO_2 fossil fuel emissions over the CONUS compare with its biotic (biological) uptake?
3. How does variation in (vegetation) productivity control spatial patterns of terrestrial CO_2 uptake?
4. To what extent is Amazonia a CO_2 sink?
5. To what extent is Amazonia a CH_4 source?
6. Are CH_4 emissions estimates over CONUS too low?

Atmospheric CO_2 and CH_4 levels have continued to rise in the industrial era. geoCARB will significantly advance scientific knowledge of CO_2 and CH_4 sources, sinks, and evolution over the Americas.

Importance to NASA:
- Pace-setting science important to society
- Measures both CO_2 and CH_4
- Geostationary complement to OCO-2 at LEO
- Ties to ASCENDS, GEOCAPE, GACM Missions proposed in the 2007 Decadal Survey by measuring CO_2 and CO
- Addresses 4 of the 7 overarching NASA Earth Science goals: 1) Atmospheric Composition, 3) Carbon Cycle and Ecosystems, 5) Climate Variability and Change, and 7) Applied Science

Global Carbon Dioxide Balance and Variability

Precision Continental-Scale Measurements of both Carbon Dioxide and Methane

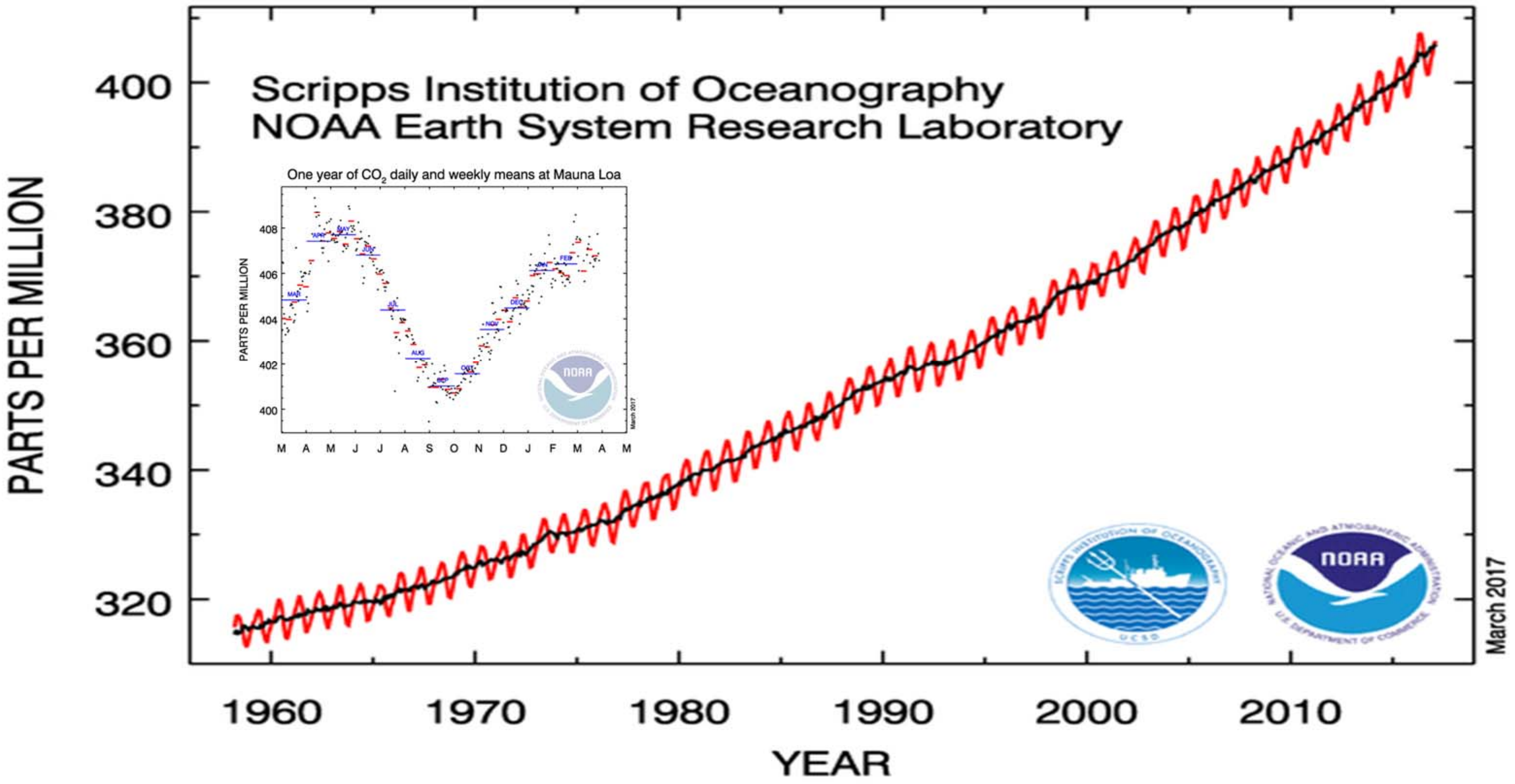
In 12/2016, NASA selected the GeoCarb mission.

It is a 5-year project and the mission is planned to be launched in late 2021 or early 2022.

$166 million investment over 2017-2022.

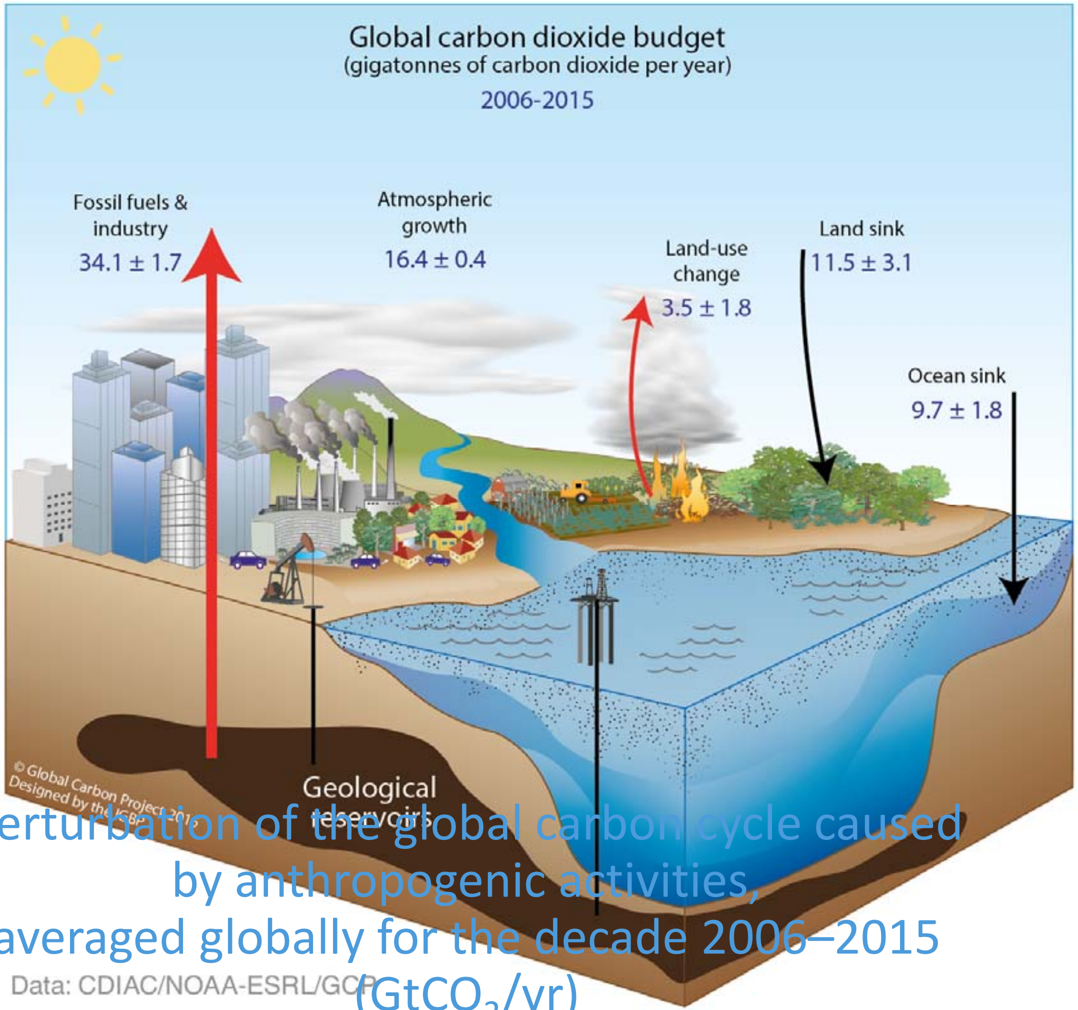
PI: Berrien Moore

Atmospheric CO_2 at Mauna Loa Observatory



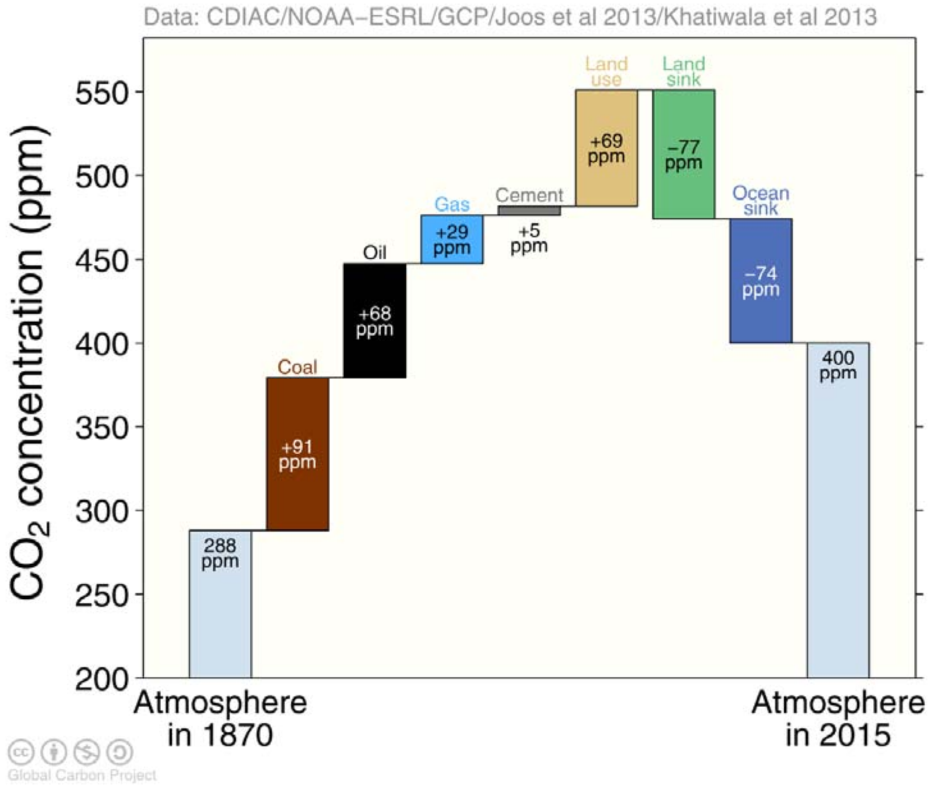
GLOBAL CARBON PROJECT

Anthropogenic perturbation of the global carbon cycle



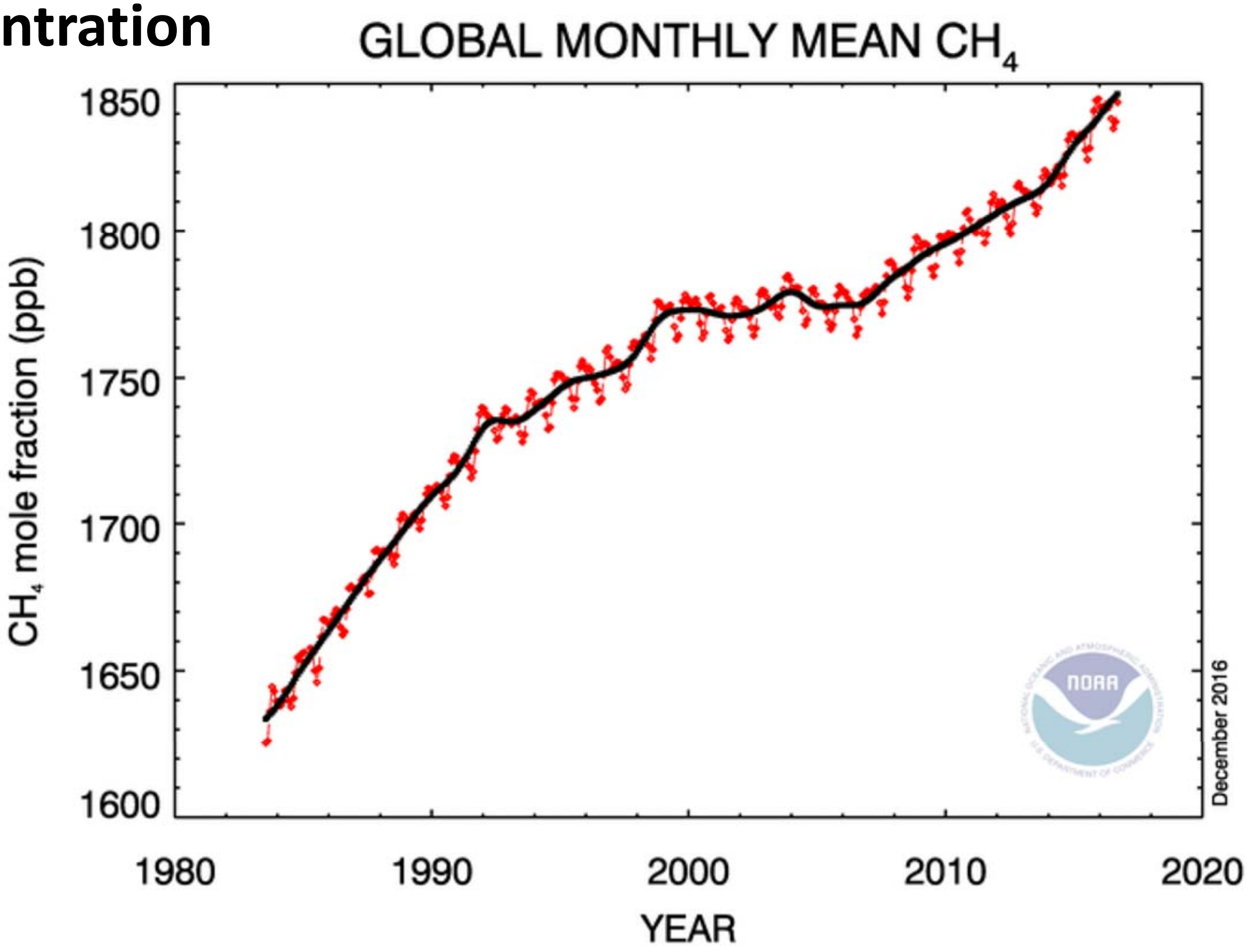
Perturbation of the global carbon cycle caused by anthropogenic activities,
averaged globally for the decade 2006–2015
($GtCO_2$/yr)

Data: CDIAC/NOAA-ESRL/GCP



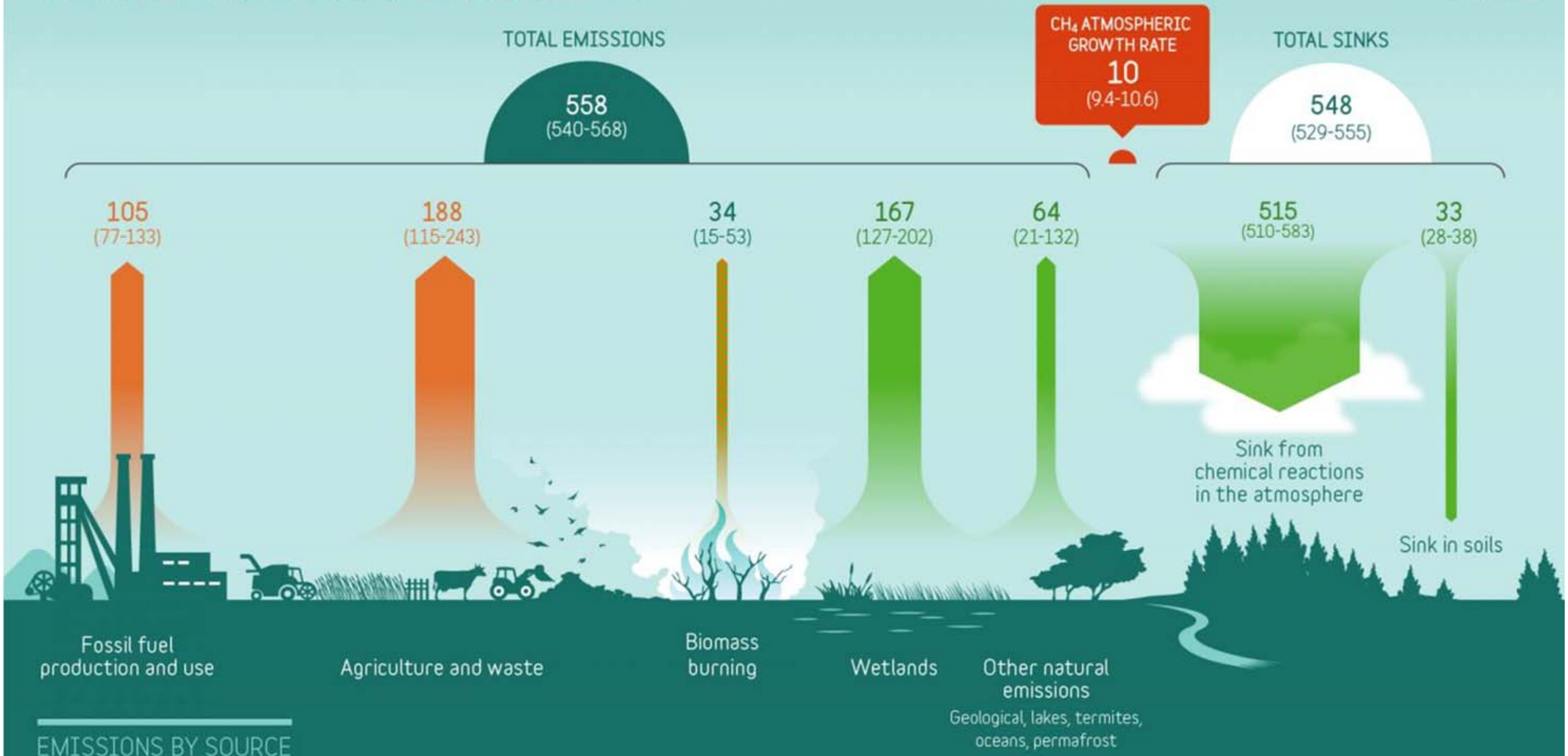
CDIAC; NOAA-ESRL; Le Quéré et al 2016; Global Carbon Budget 2016

Atmospheric CH_4 concentration



What factor(s) drove the large increases in atmospheric CH_4 concentration after mid 2000s?

GLOBAL METHANE BUDGET



TOTAL EMISSIONS

558
(540-568)

CH_4 ATMOSPHERIC GROWTH RATE
10
(9.4-10.6)

TOTAL SINKS

548
(529-555)

105
(77-133)
Fossil fuel production and use

188
(115-243)
Agriculture and waste

34
(15-53)
Biomass burning

167
(127-202)
Wetlands

64
(21-132)
Other natural emissions
Geological, lakes, termites, oceans, permafrost

515
(510-583)
Sink from chemical reactions in the atmosphere

33
(28-38)
Sink in soils

EMISSIONS BY SOURCE

In million-tons of CH_4 per year (Tg CH_4 / yr), average 2003-2012

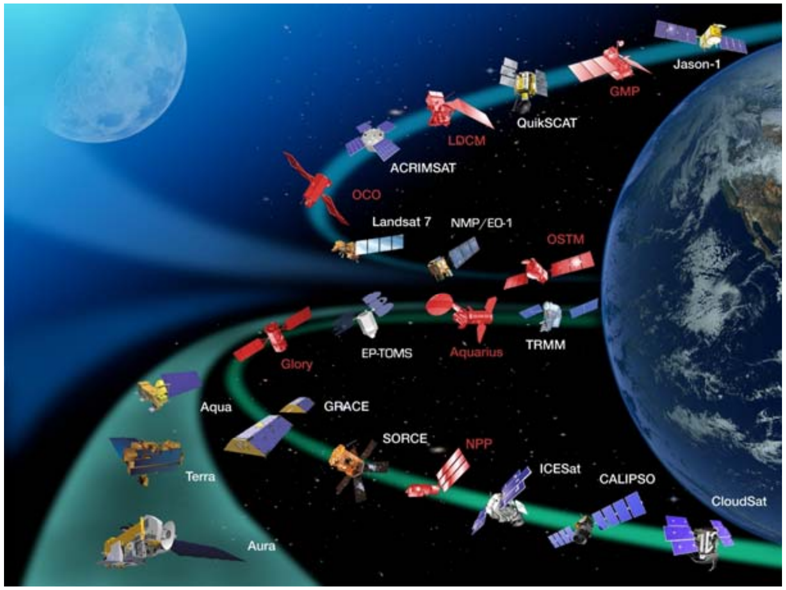
🟧 Anthropogenic fluxes 🟩 Natural fluxes ▨ Natural and anthropogenic

GLOBAL CARBON PROJECT

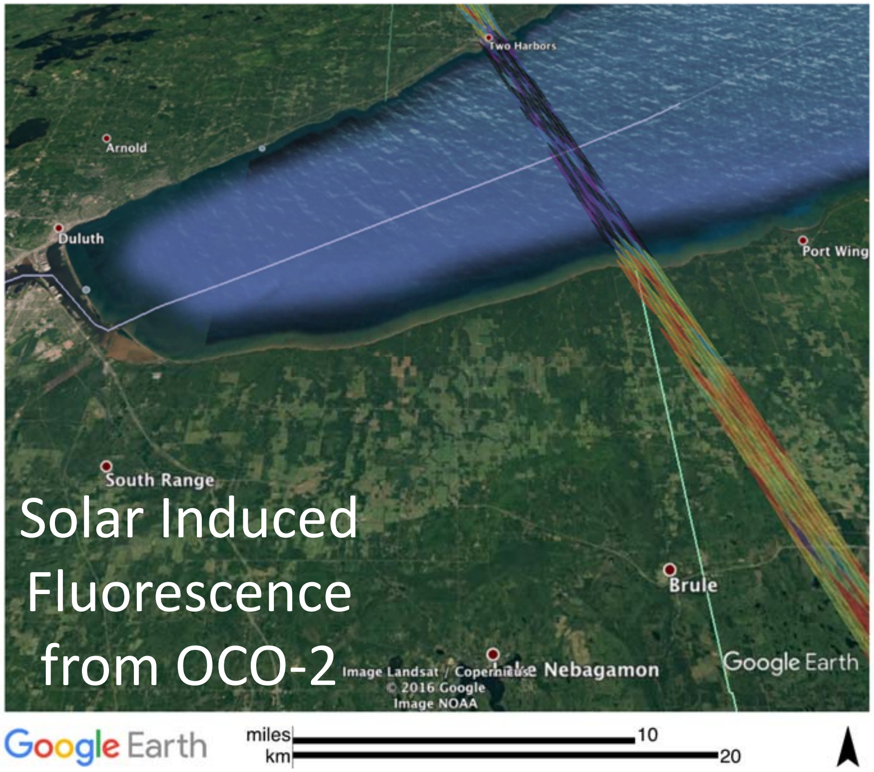
FONDATION BNP PARIBAS

Observations from space

Atmospheric CO_2, CH_4 and SIF data from analyses of satellite images and *in-situ* observations



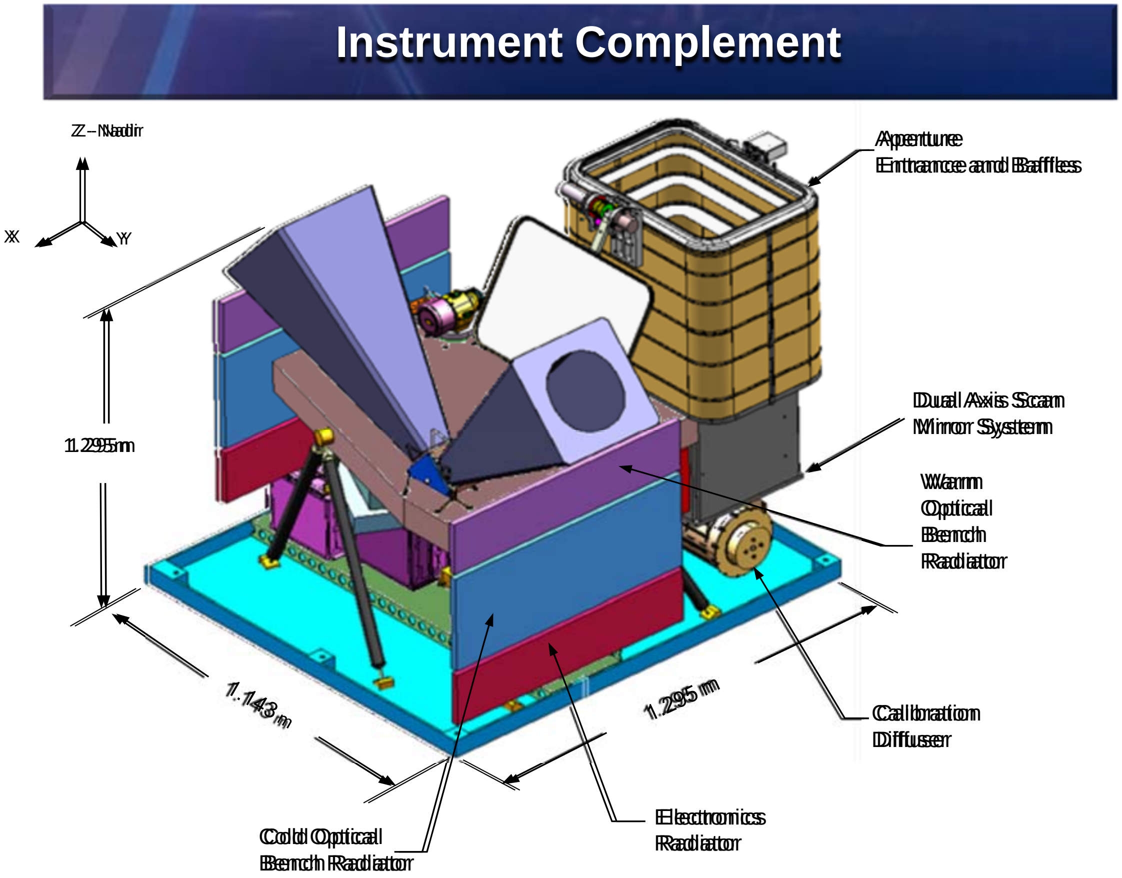
GOSAT, SCHIMARCH, OCO-2 missions
(sampling missions)



Solar Induced Fluorescence from OCO-2

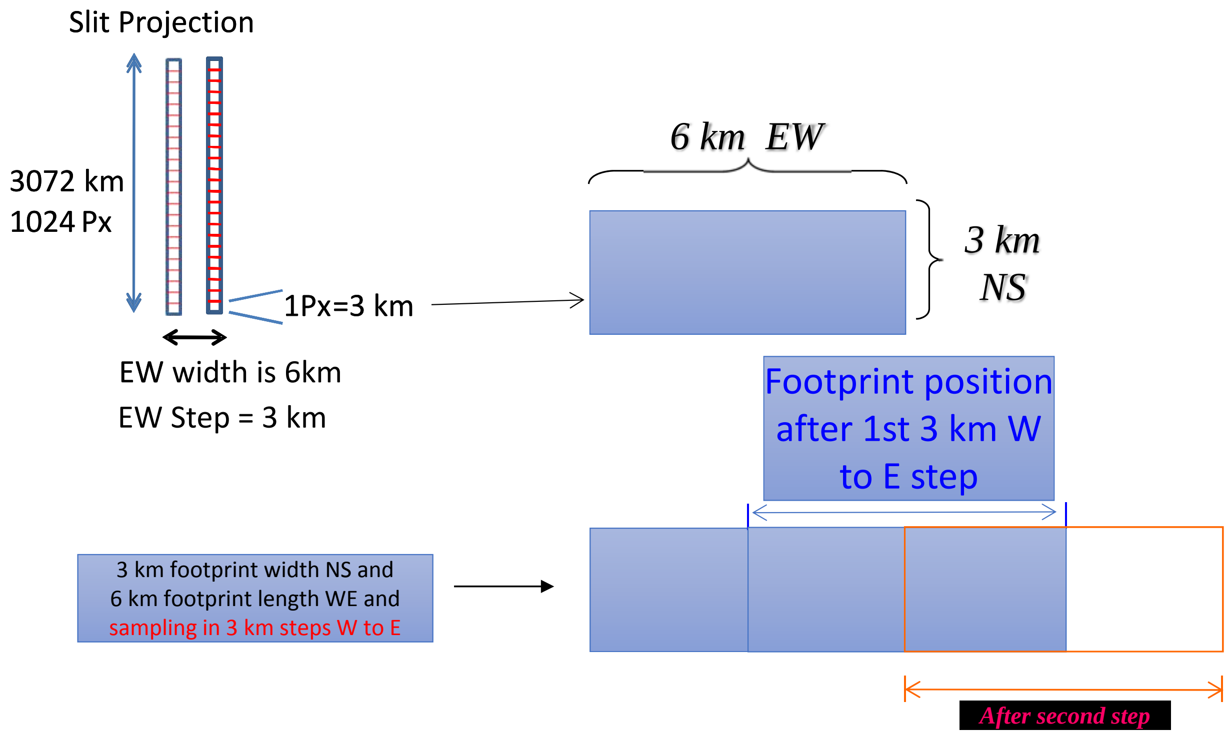
A Geostationary Solution – geoCARB

- Measures CO, CO_2, O_2, CH_4,and SIF
- Scanning IR slit spectrometer:
    - 0.76µm (O_2 and SIF)
    - 1.61µm & 2.06µm (CO_2)
    - 2.32 µm (CH_4 and CO)
- 3 km resolution (at SSP)
- Multiple Scans per day – flexible scanning strategies to meet different goals



NASA GeoCarb mission

Regional mode 3 km x 6 km footprint
– 3 km E-W sampling
– 4s integration time – 2 hr CONUS revisit



Slit Projection

3072 km
1024 Px

1Px=3 km

EW width is 6km

EW Step = 3 km

6 km EW

3 km NS

Footprint position after 1st 3 km W to E step

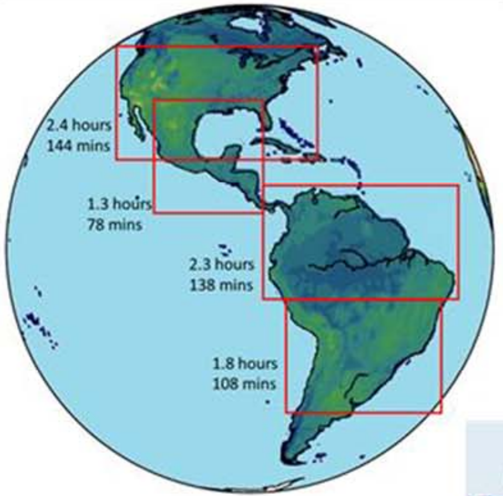
3 km footprint width NS and
6 km footprint length WE and
sampling in 3 km steps W to E

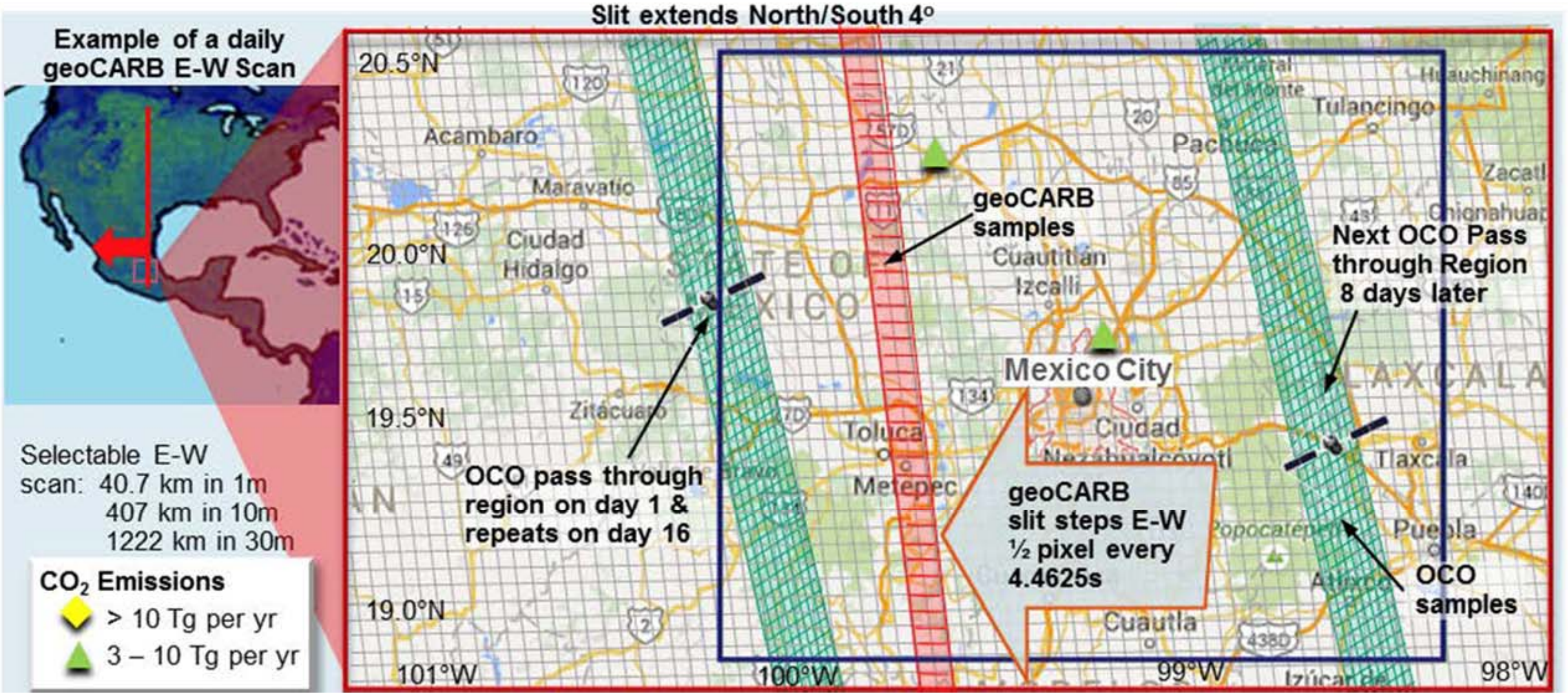
After second step

The spectrum of the 3 km x 6 km footprint is one row of pixels in the spectral direction corresponding to each of the 1024 pixels along the slit

NASA GeoCarb mission

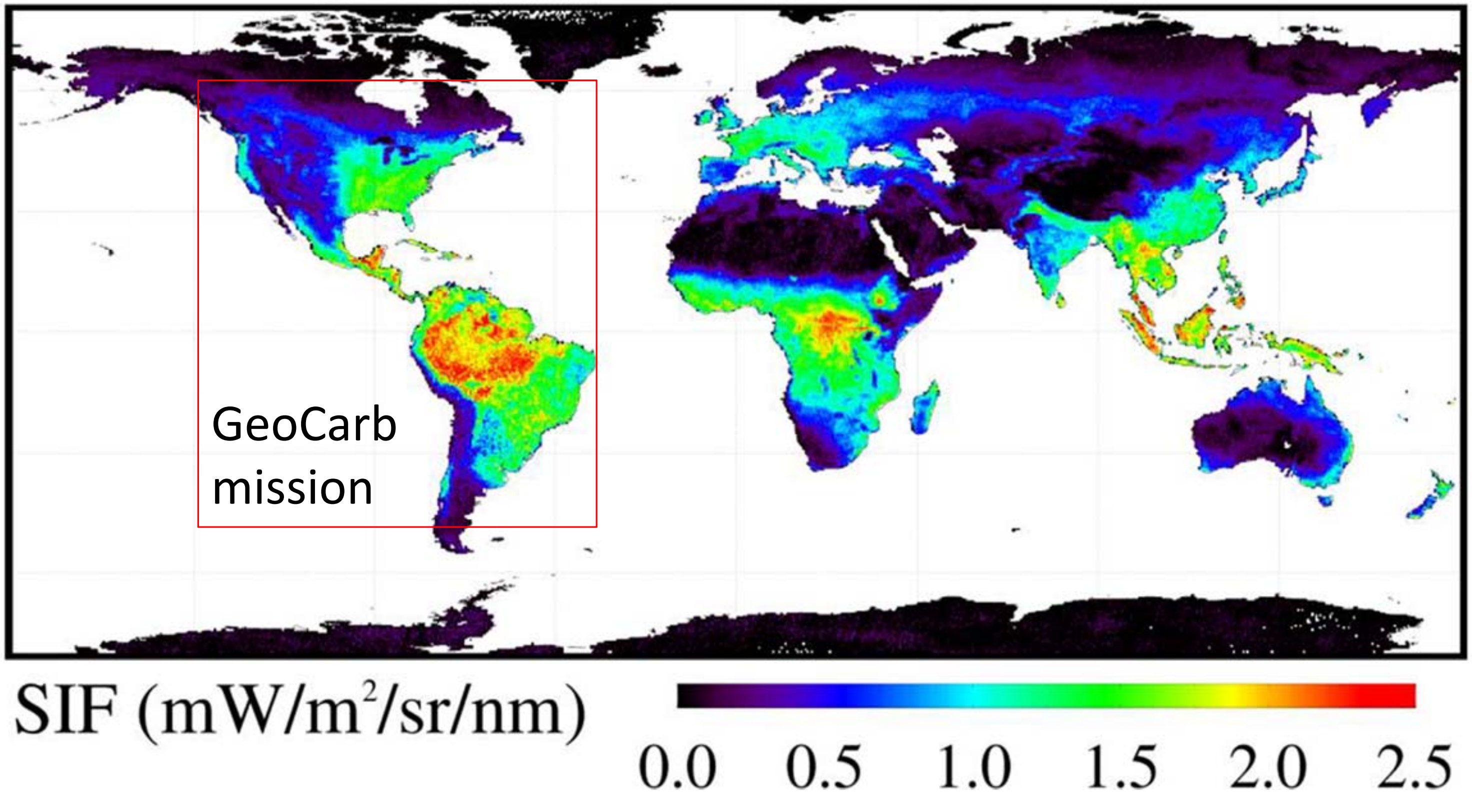
Geostationary Carbon Cycle Observatory





Monitor plant health and vegetation stress in North to South America

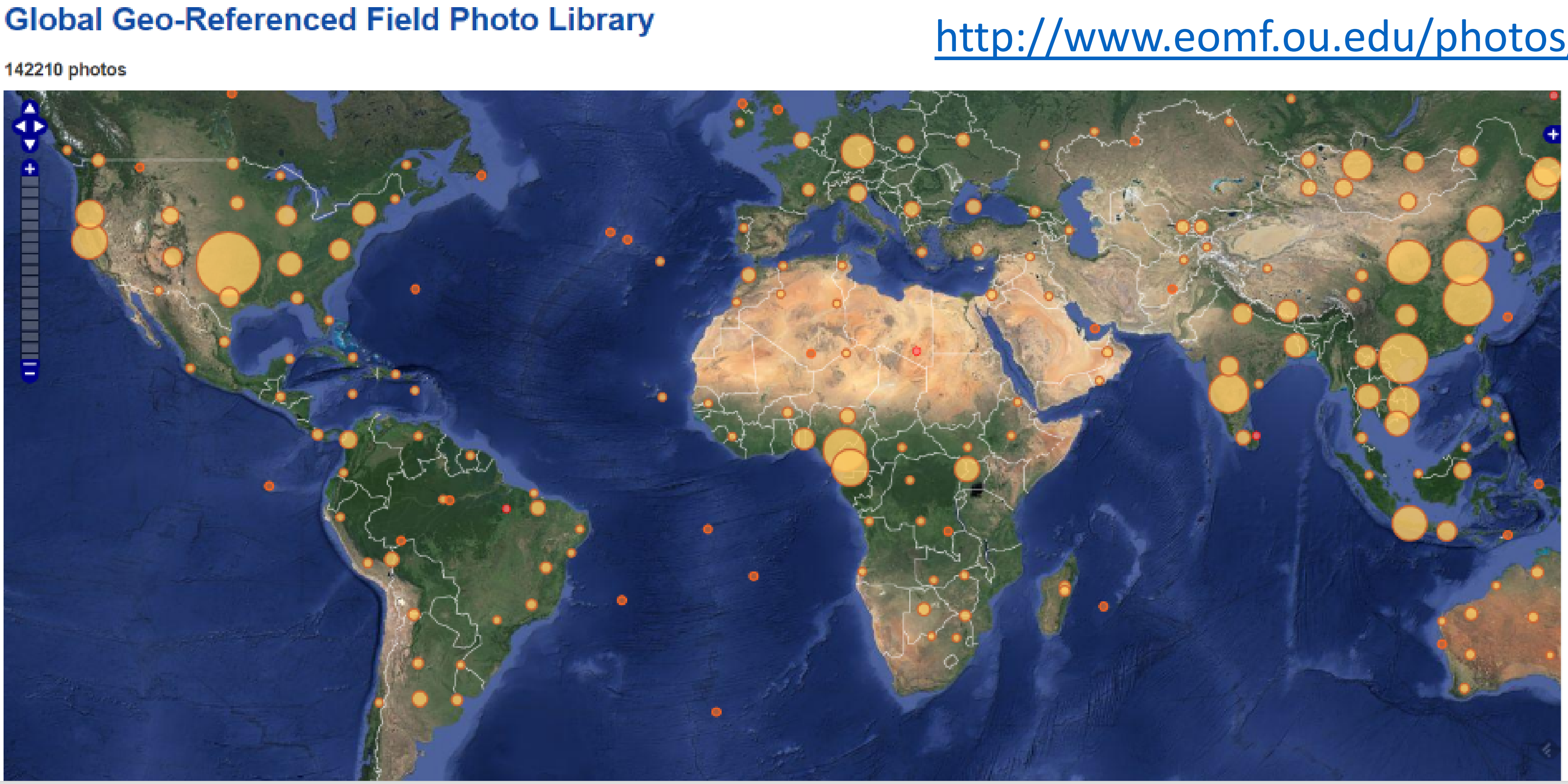
It measures solar-induced chlorophyll fluorescence (SIF), which is related to plant health and vegetation stress.



GOME-2 daily maximum SIF in 2010

FluoSpec and Eddy Flux Tower sites at KAEFS

Crowdsourcing and citizen science approach for *in-situ* georeferenced field photos



Global Geo-Referenced Field Photo Library

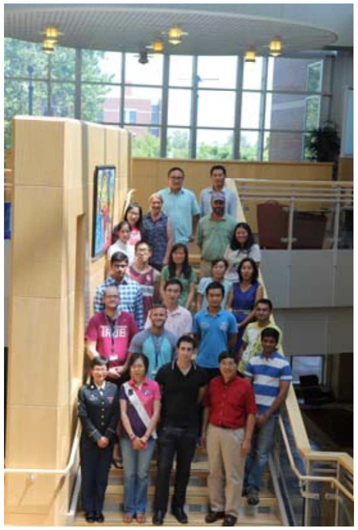
142210 photos

http://www.eomf.ou.edu/photos/

Please join thousands of citizen scientists to share your field photos that show your footprint and document our Planet Earth

Thank you

Question ?

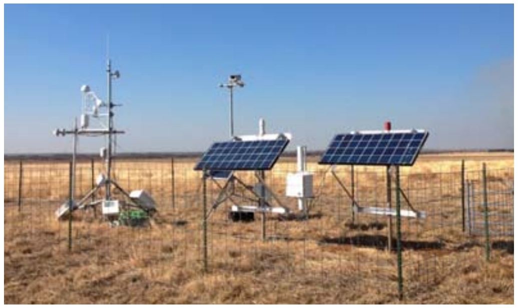


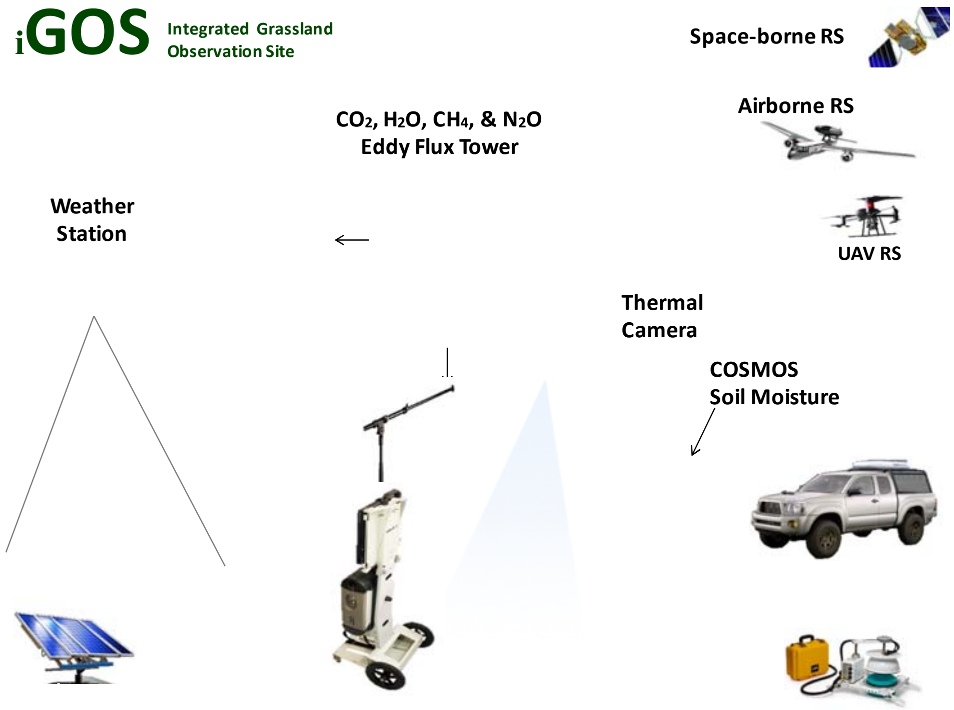
Earth Observation and Modeling Facility at the University of Oklahoma

A. Remote Sensing Laboratory

B. Spatial Ecology and Epidemiology Laboratory

C. Computation and Visualization Laboratory





iGOS Integrated Grassland Observation Site

Space-borne RS

Airborne RS

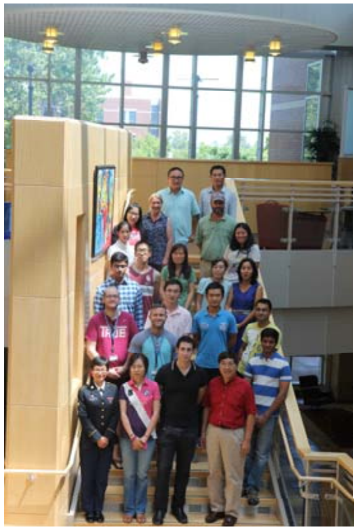
CO_2, H_2O, CH_4, & N_2O
Eddy Flux Tower

Weather
Station

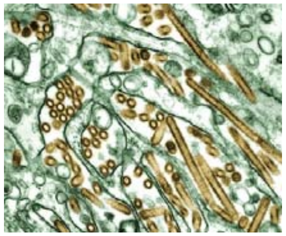
UAV RS

Thermal
Camera

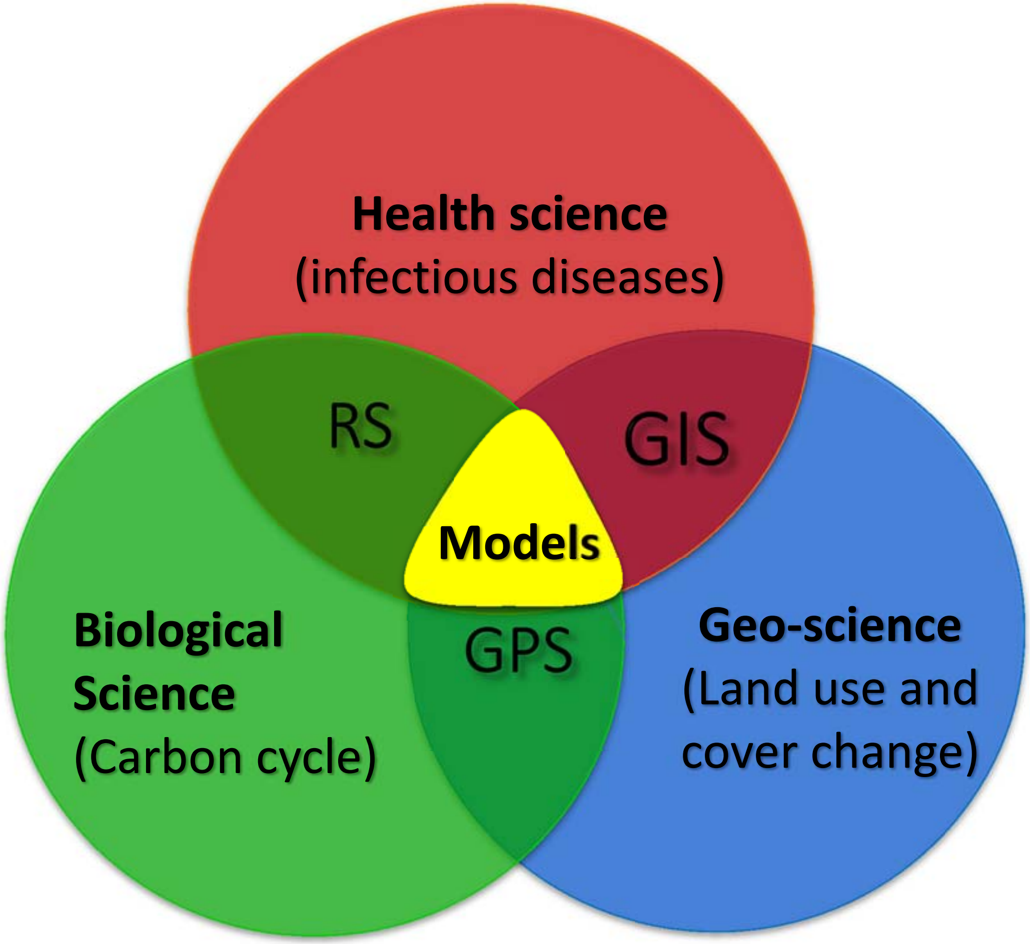
COSMOS
Soil Moisture



Earth Observation and Modeling Facility



H5N1



Health science
(infectious diseases)

RS

GIS

Models

GPS

Biological Science
(Carbon cycle)

Geo-science
(Land use and cover change)