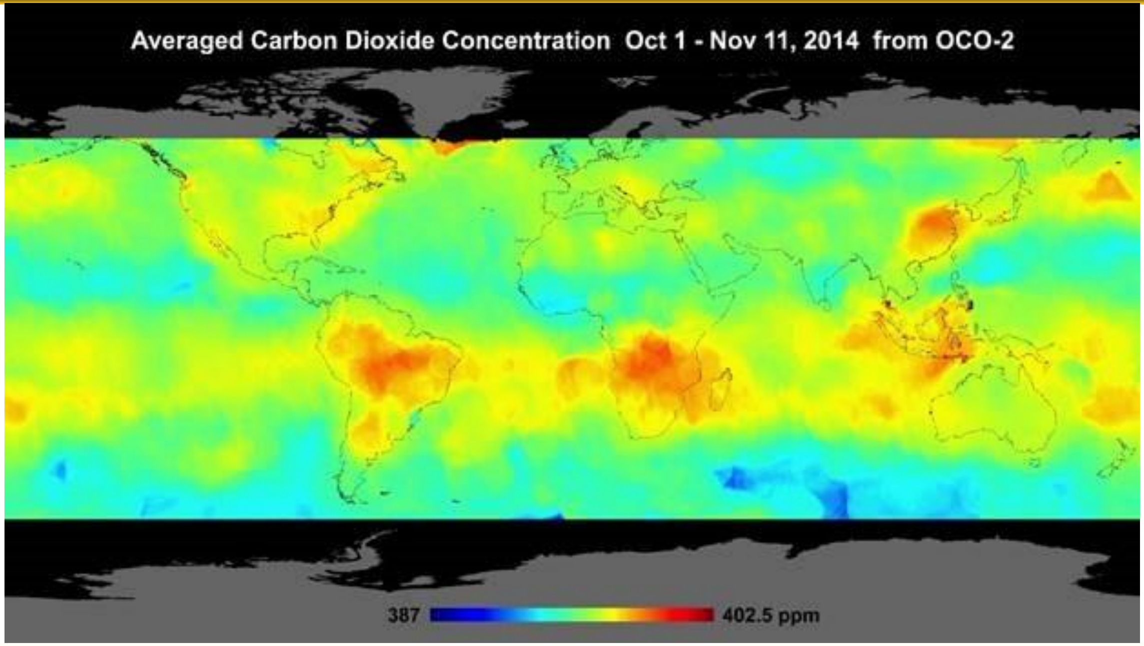
New data sets from OCO-2: What can we learn?

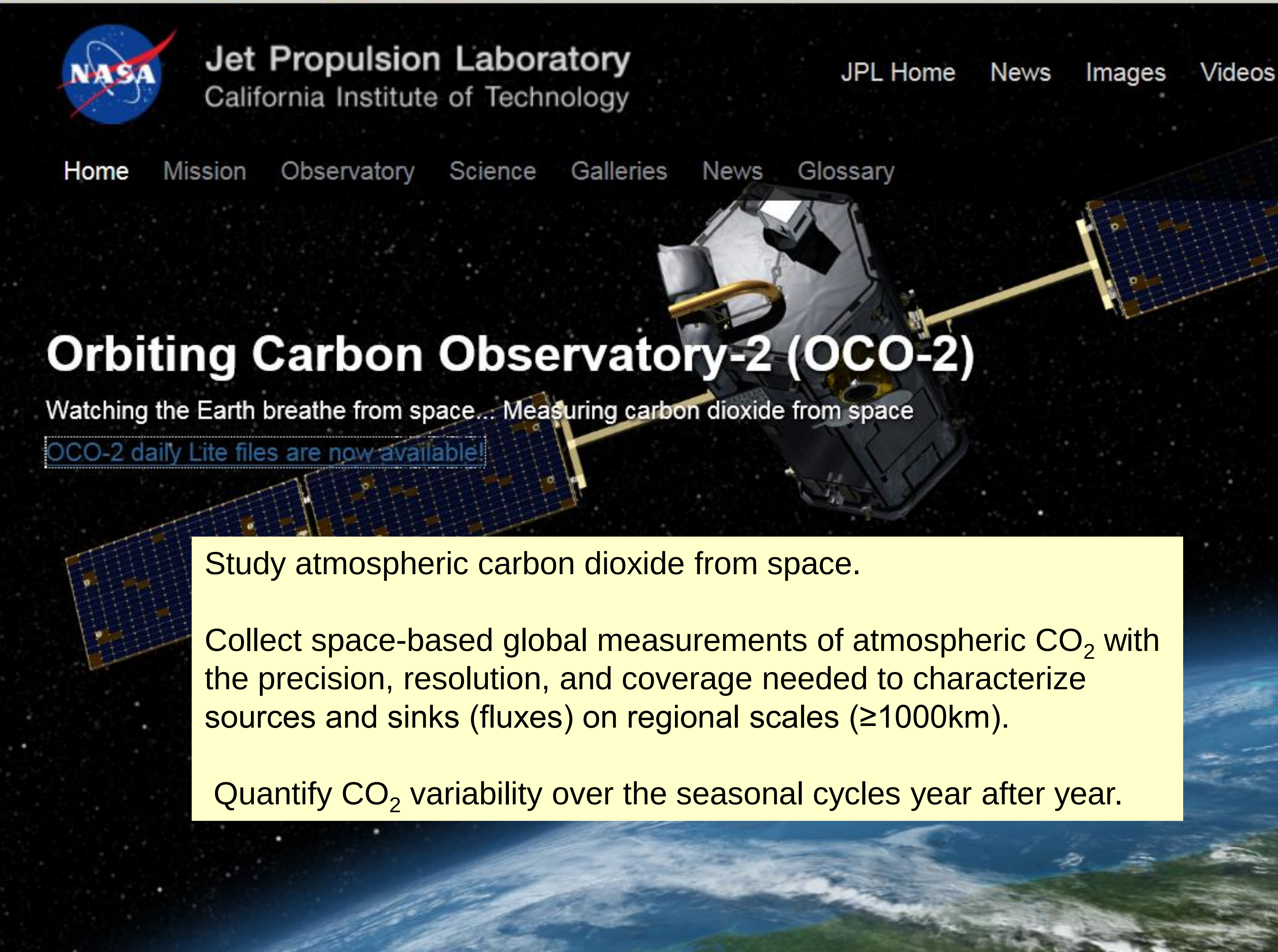


Bob Endlich

bendlich@msn.com

Updated 31 October 2015

Cruces Atmospheric Sciences Forum



Study atmospheric carbon dioxide from space.

Collect space-based global measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize sources and sinks (fluxes) on regional scales (≥1000km).

Quantify CO_2 variability over the seasonal cycles year after year.

Outline and Background Materials

Keeling Curve: increasing <CO2> in the atmosphere

Annual progression of the <CO2> data

Background Information on China and Southern Hemisphere, using Satellite Maps

Carbon Cycle and CO2 budget analyses

Anthropogenic Source Estimates

Orbiting Carbon Observatory

OCO-1: Failed to achieve orbit after launch from Vandenberg AFB, Feb, 2009

OCO-2: Launched 2 July 2014; the source for visualizations here.

Acknowledgement:
Bernie McCune, for suggestions and technical references in the presentation.

References:

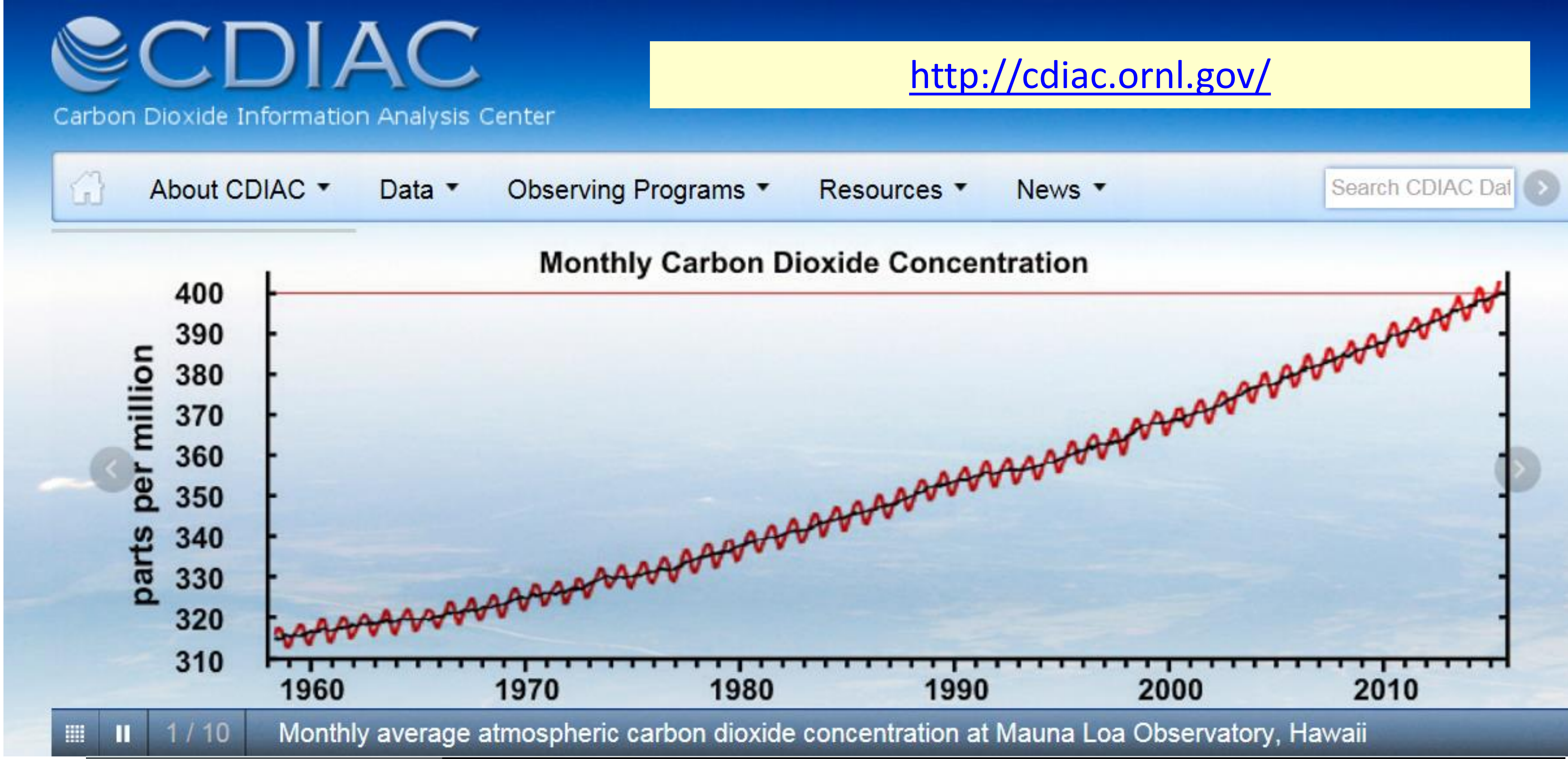
Data visualizations of OCO-2:
http://wattsupwiththat.com/2015/10/04/finally-visualized-oco2-satellite-data-showing-global-carbon-dioxide-concentrations/

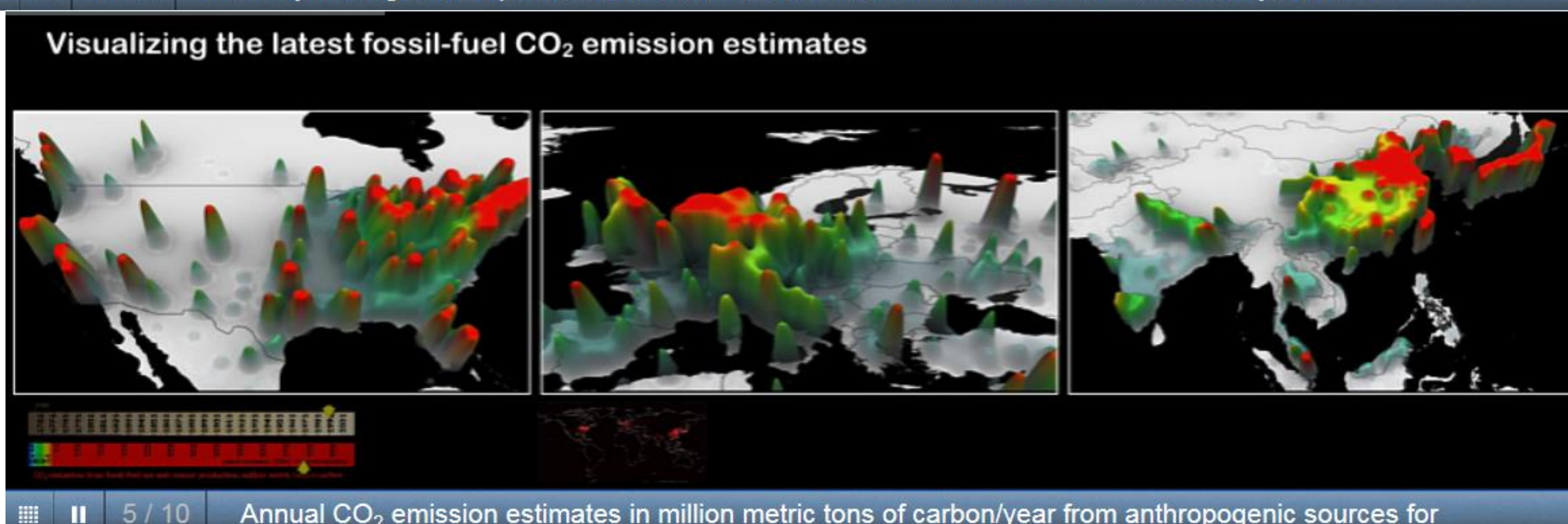
Launch of OCO-2
http://wattsupwiththat.com/2014/06/13/nasa-to-attempt-launching-another-carbon-observatory-the-last-one-burned-up/

Failed Launch of OCO-1 in Feb 2009
http://wattsupwiththat.com/2009/02/24/bad-week-for-hardware-orbiting-carbon-observatory-satellite-burns-up/

Additional background materials, especially fire data are also included in the body of the presentation.

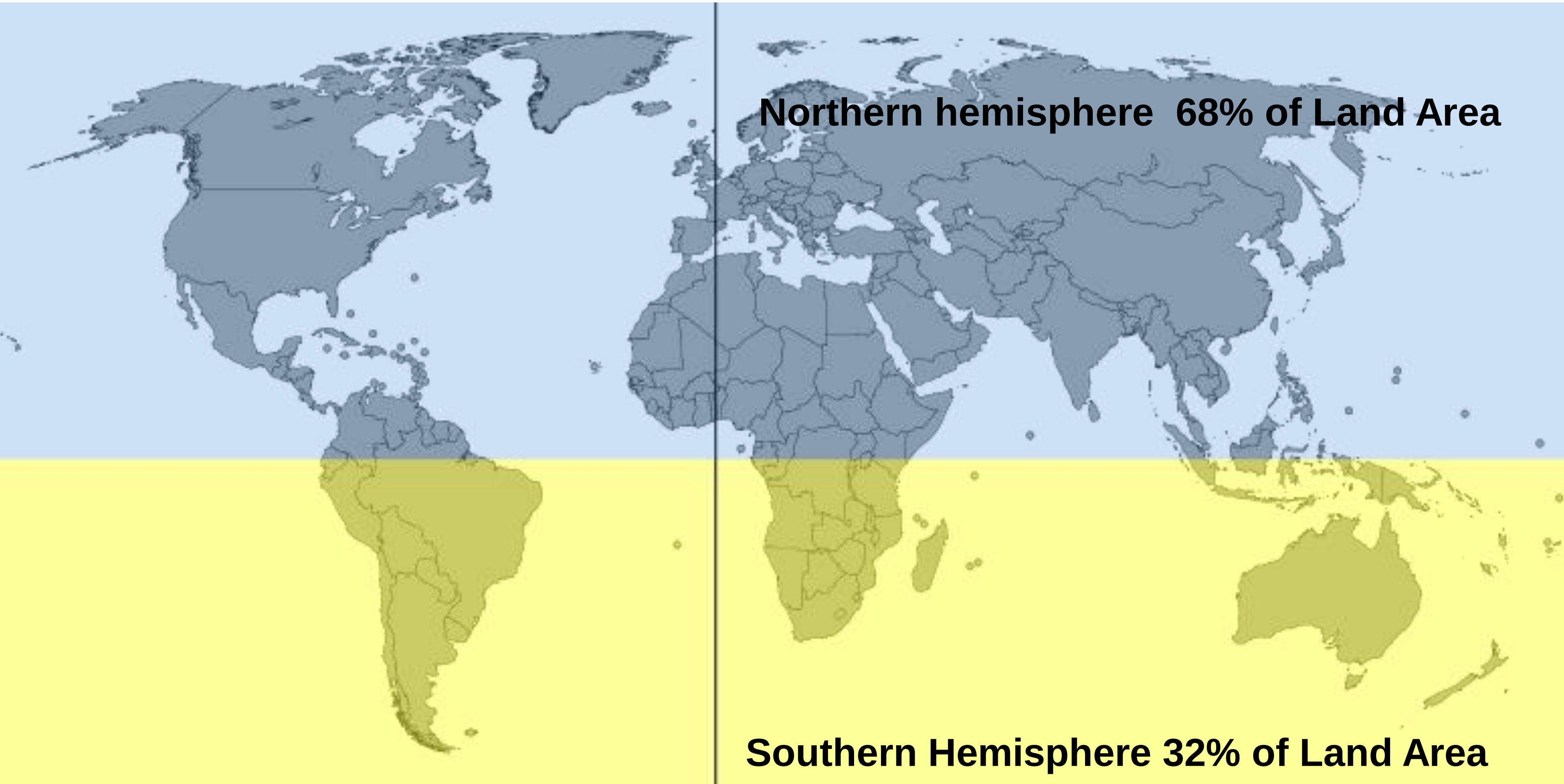
http://cdiac.ornl.gov/





Oceans have 71% of all of earth surface area
Land has 29% of all of earth surface area

Plant growth cycle in Northern Hemisphere drives annual variation of <CO_2>

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Salvador
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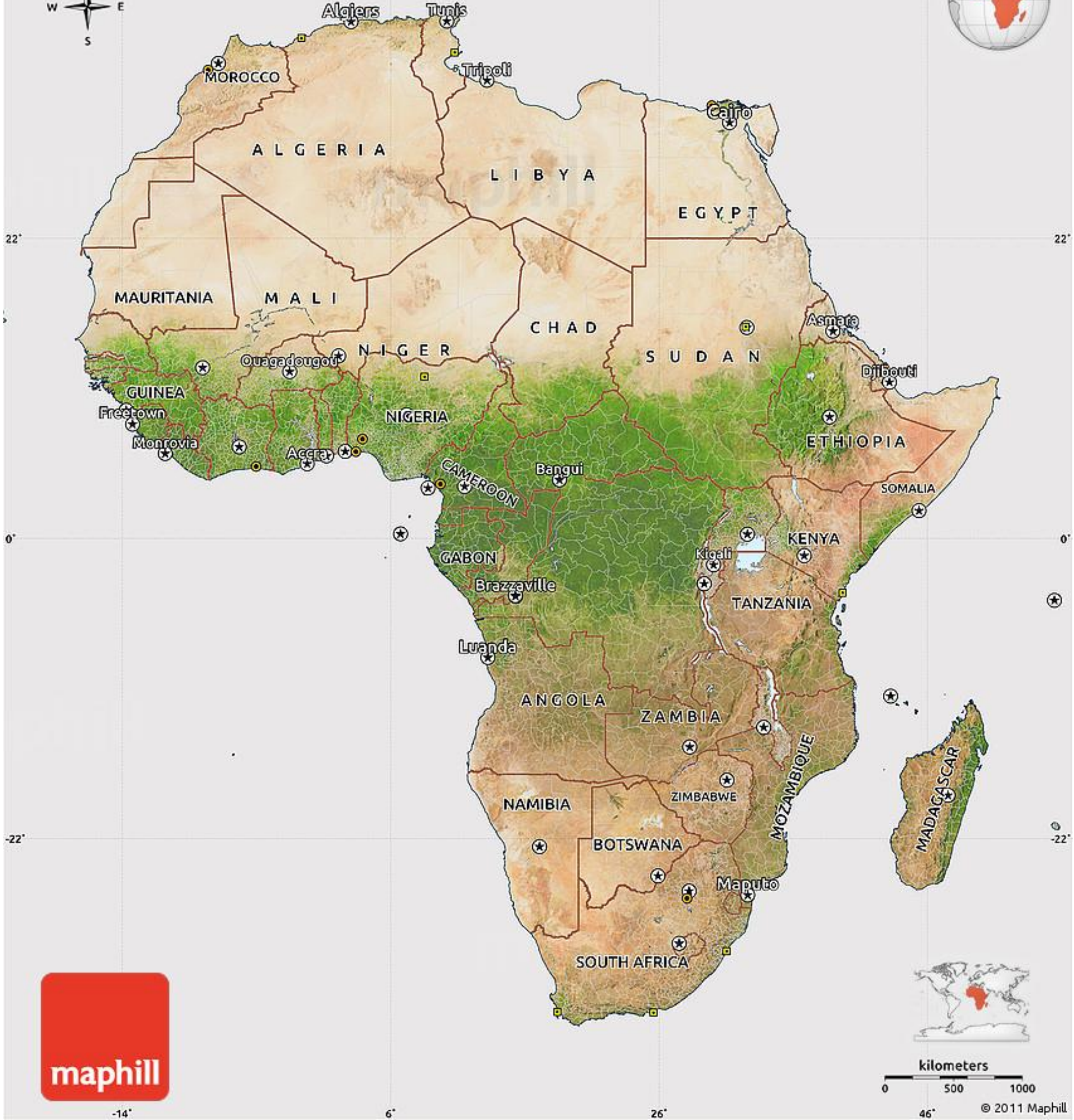
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SUDAN
Asmara
Djibouti
Ouagadougou
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kilometers
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26°
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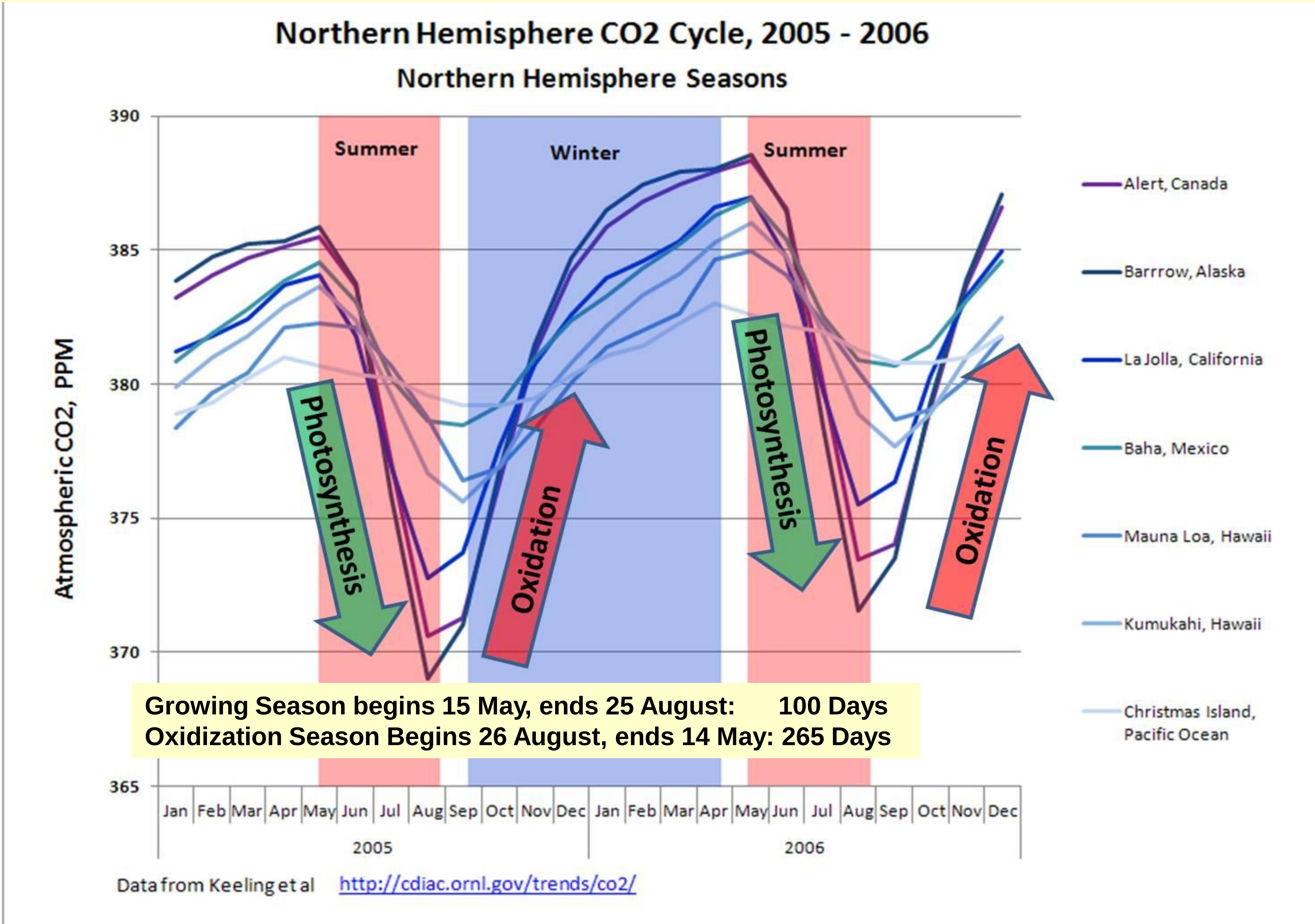
http://www.vmapas.com/Asia/China/Map-Agricultural-Regions-China-1986.jpg/maps-en.html?map_viewMap=1

Graphic from Bernie McCune

http://dougrobbins.blogspot.com/2013/05/the-keeling-curve-seasonal-co2-cycles.html



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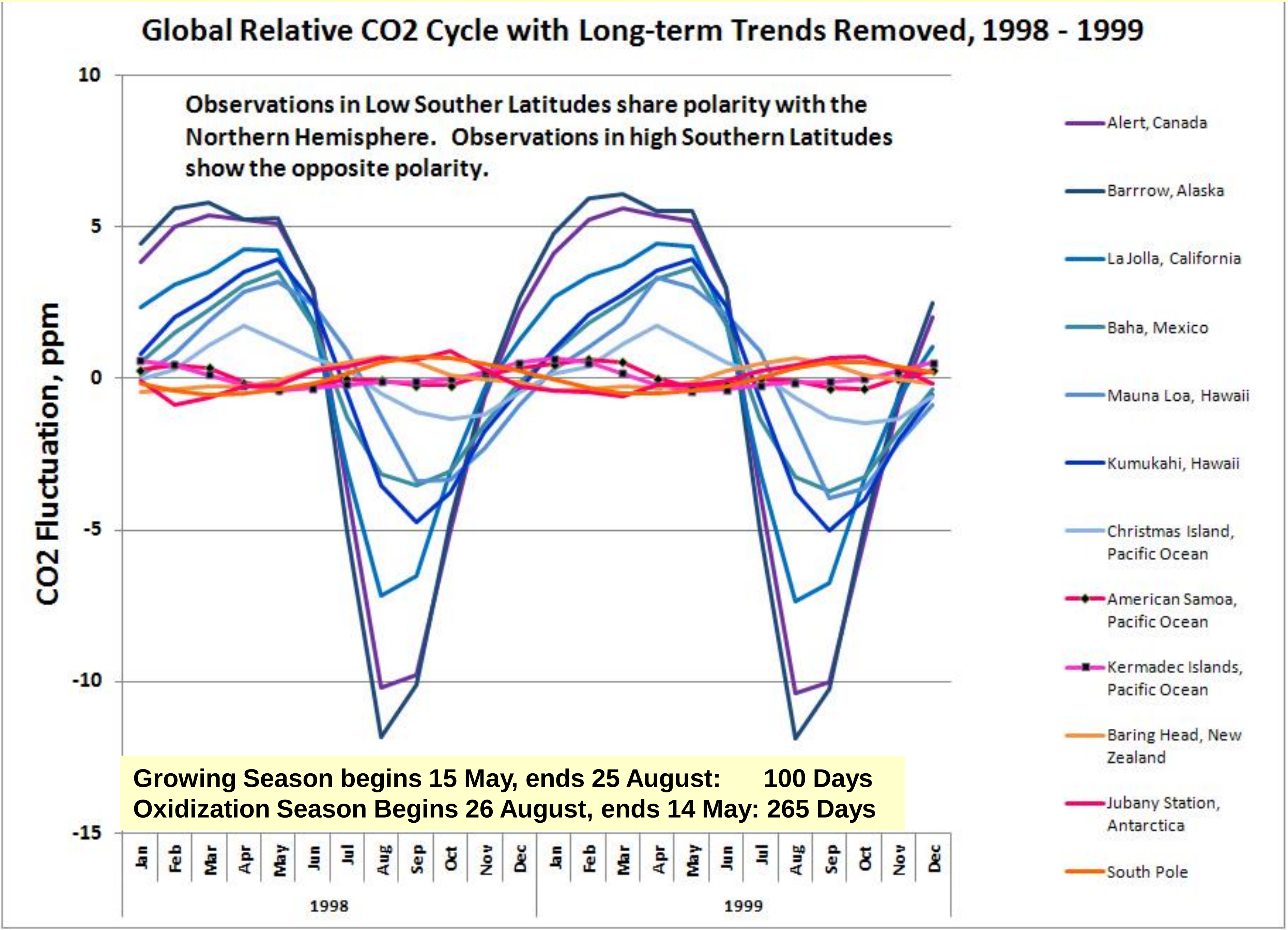


Source:
Dr. David Bice, 1994.

Doesn't include new estimate of global tree numbers

The Global Carbon Cycle

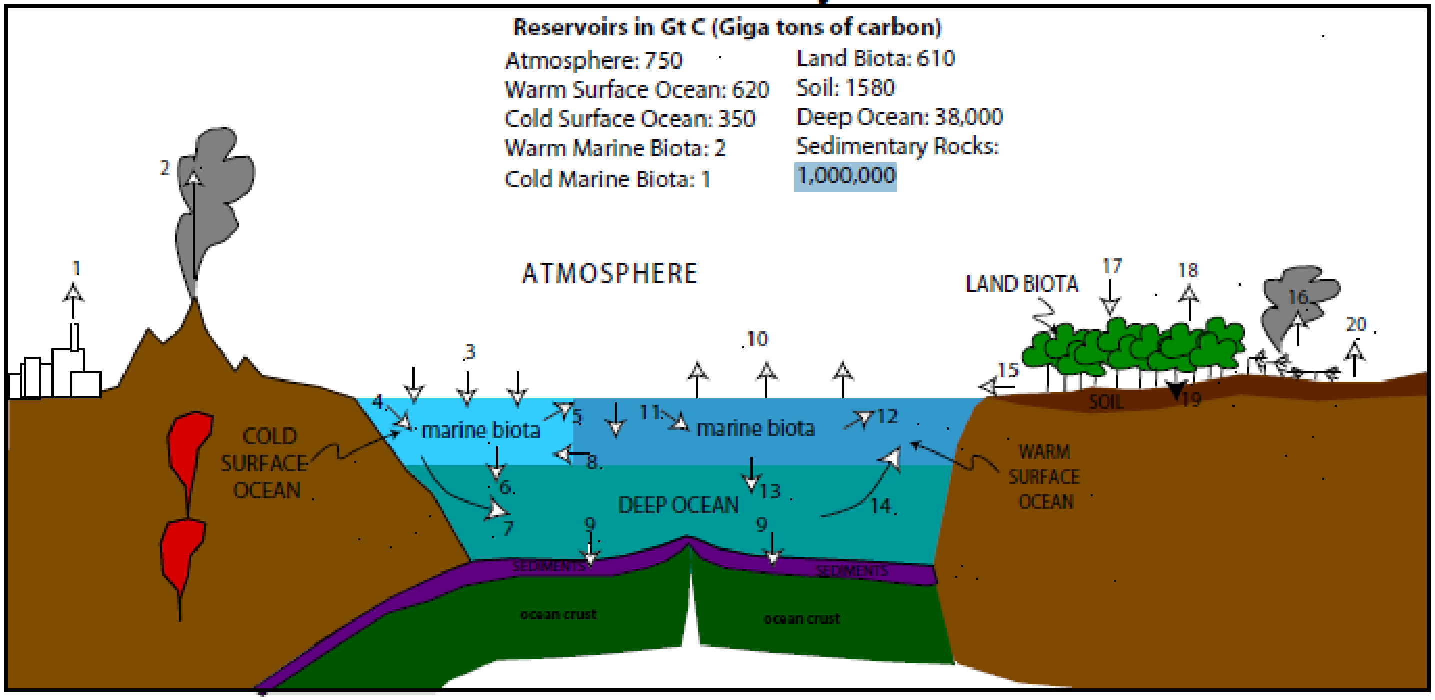


Figure 1. The global carbon cycle, as best estimated, in 1994. Data slightly modified from Siegenthaler and Sarmiento, 1995; Kwon and Schnoor, 19

Largest Fluxes, GT Carbon:

Cold Ocean Uptake :	90
Polar Oceans Downwelling	96.2
Cold Ocean Upwelling	105.6
Warm Ocean Release	90
Land Photosynthesys	110
Land biota Respiration:	50
Bugs in Soil Respiration	59.4
…	
Fossil Fuel Burning	5

Key to Flows:

1) Fossil Fuel Burning — 5 Gt C/yr
2) Volcanic Emissions — 0.6 Gt C/yr
3) Uptake of CO_2 by cold surface waters of the oceans — 90 GtC/yr
4) Photosynthesis of marine biota in cold surface waters — 18 GtC/yr
5) Respiration of living marine biota and rapid recycling of dead biota in cold surface waters — 14 GtC/yr
6) Sinking of dead marine biota (both organic and inorganic carbon) from cold water into deep water — 4 GtC/yr
7) Downwelling of cold surface water (mainly near the poles) — 96.2 GtC/yr
8) Advection (horizontal transfer) from warm to cold surface water — 10 Gt C/yr
9) Sedimentation on sea floor (both organic and inorganic carbon) stores carbon in sedimentary rocks — 0.6Gt C/yr
10) Release of CO_2 by warm surface waters of the oceans — 90 GtC/yr
11) Photosynthesis of marine biota in warm surface waters — 32 GtC/yr
12) Respiration of living marine biota and rapid recycling of dead biota in warm surface waters — 26 GtC/yr
13) Sinking of dead marine biota (both organic and inorganic carbon) from warm water into deep water — 6 GtC/yr
14) Upwelling of deep water (at equator and along edges of continents) — 105.6 GtC/yr
15) River runoff transfers carbon from the land to the sea — 0.6 Gt C/yr (2/3 to warm ocean, 1/3 cold)
16) Deforestation and land clearing releases CO2 into the atmosphere — 1.5 Gt C/yr
17) Photosynthesis of land biota — 110 Gt C/yr
18) Respiration of land biota — 50 Gt C/yr
19) Litter fall and below-ground loss from plant roots transfers carbon to the soil — 60 Gt C/yr
20) Respiration of micoorganisms in the soil releases CO2 into the atmosphere — 59.4 Gt C/yr

Anthropogenic CO2 Emissions

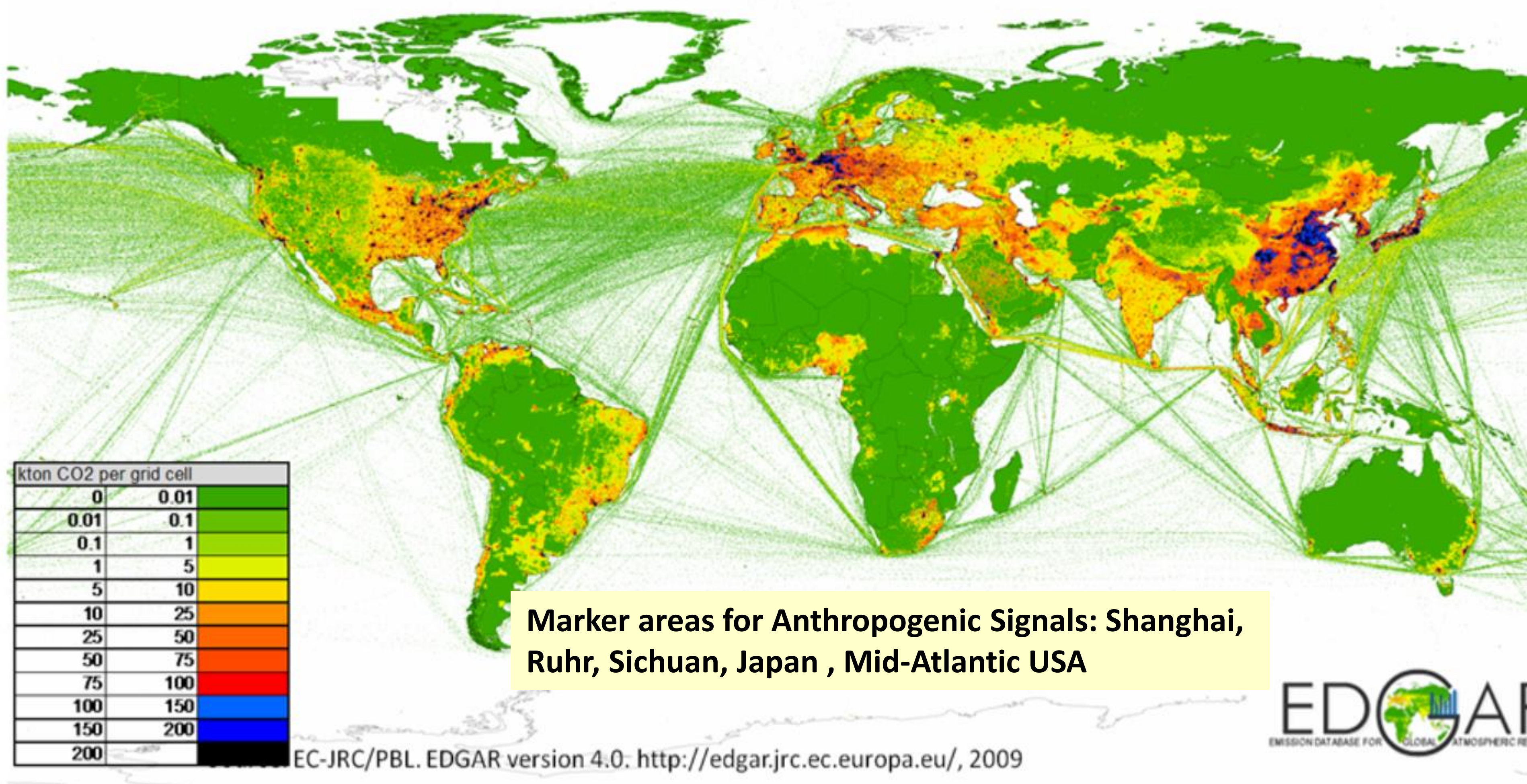
http://edgar.jrc.ec.europa.eu/part_CO2.php

Global Gridded carbon dioxide emissions in the year 2005 <tons of CO2 per grid cell>

Grid cells are <0.1 Deg x 0.1 Deg>

Includes Fossil Fuels and other anthropogenic emissions

Does not include aviation and organic sources



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

Figure 6: Global gridded carbon dioxide emissions in the year 2005 (unit ton CO2 per grid cell).

press x to

Anthropogenic CO_2 Emissions

http://edgar.jrc.ec.europa.eu/methodology.php

1.2 Source categories

List of EDGARv4 standard reporting codes (IPCC codes). By clicking on the IPCC code (first column) a factsheet describing the methodology and data for each main source category can be viewed.

IPCC code	Source name	Comment
1. Energy: Fuel Combustion (1A) and Fugitive emissions from fuel (1B)		
1A1a	Public electricity and heat production	Including autoproducers of electricity and heat
1A1bc	Other energy industries	
1A2	Manufacturing industries and construction	
1A3a	Domestic aviation	
1A3b	Road transportation	
1A3c	Rail transportation	
1A3d	Domestic navigation	
1A3e	Other transportation	
1A4	Residential and other sectors	
1B1	Fugitive emissions from solid fuels	
1B2	Fugitive emissions from oil and gas	Including venting and flaring
1C1	Memo: International aviation	
1C2	Memo: International navigation	
2. Industrial Processes (non-combustion) and 3. Product Use		
2A	Production of minerals	
2B	Production of chemicals	

NASA's and Eric Swenson's Visualizations of <CO2>

NASA has visualized only two periods:

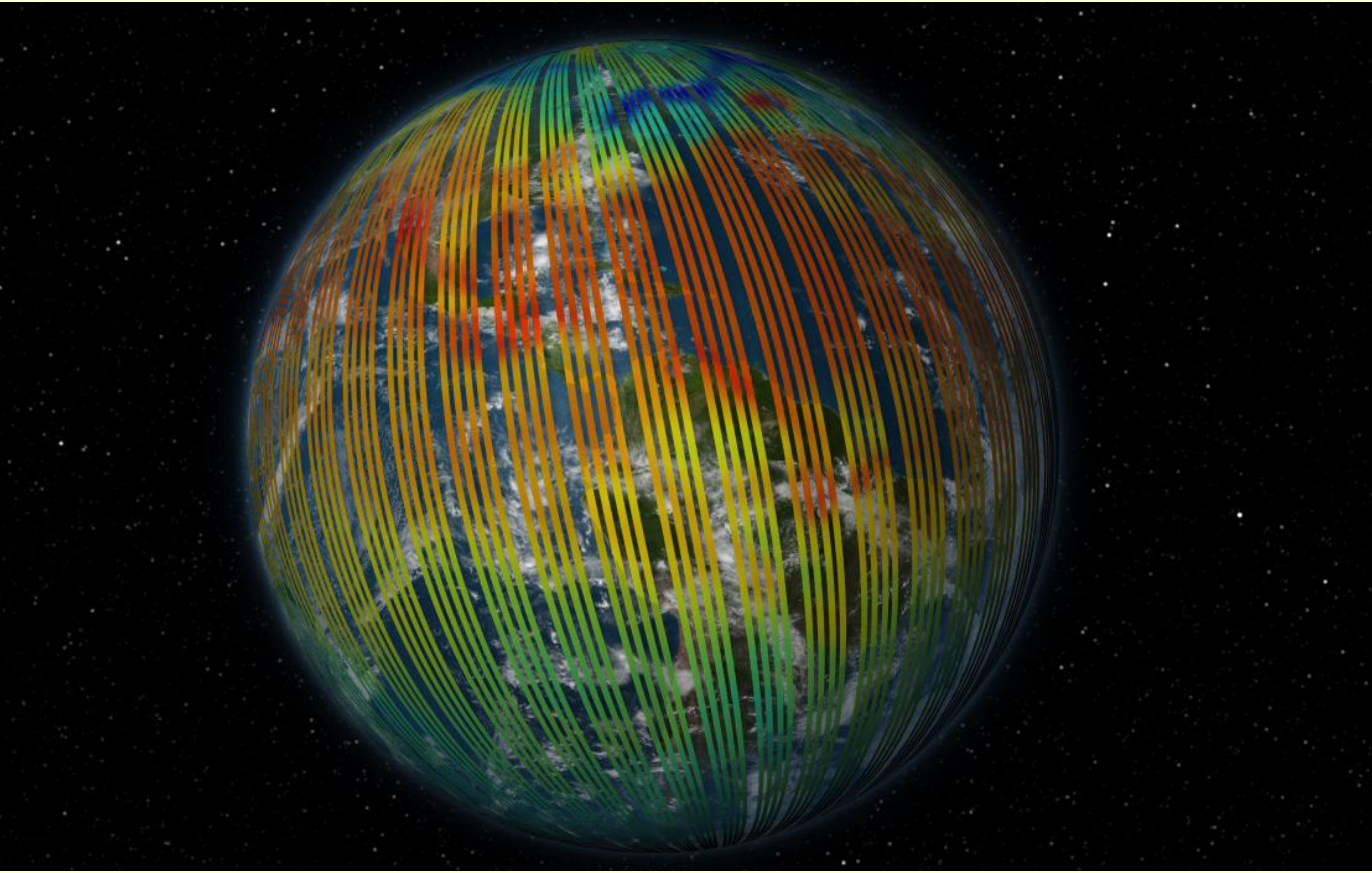
1 October 2104--- 11 November 2014
and
21 November 2014---27 December 2104

NASA put processed data on-line with data quality indicators, but NASA has not released other OCO-2 data visualizations themselves.

The NASA data are in HDF file format, but not a convenient or user-friendly method.

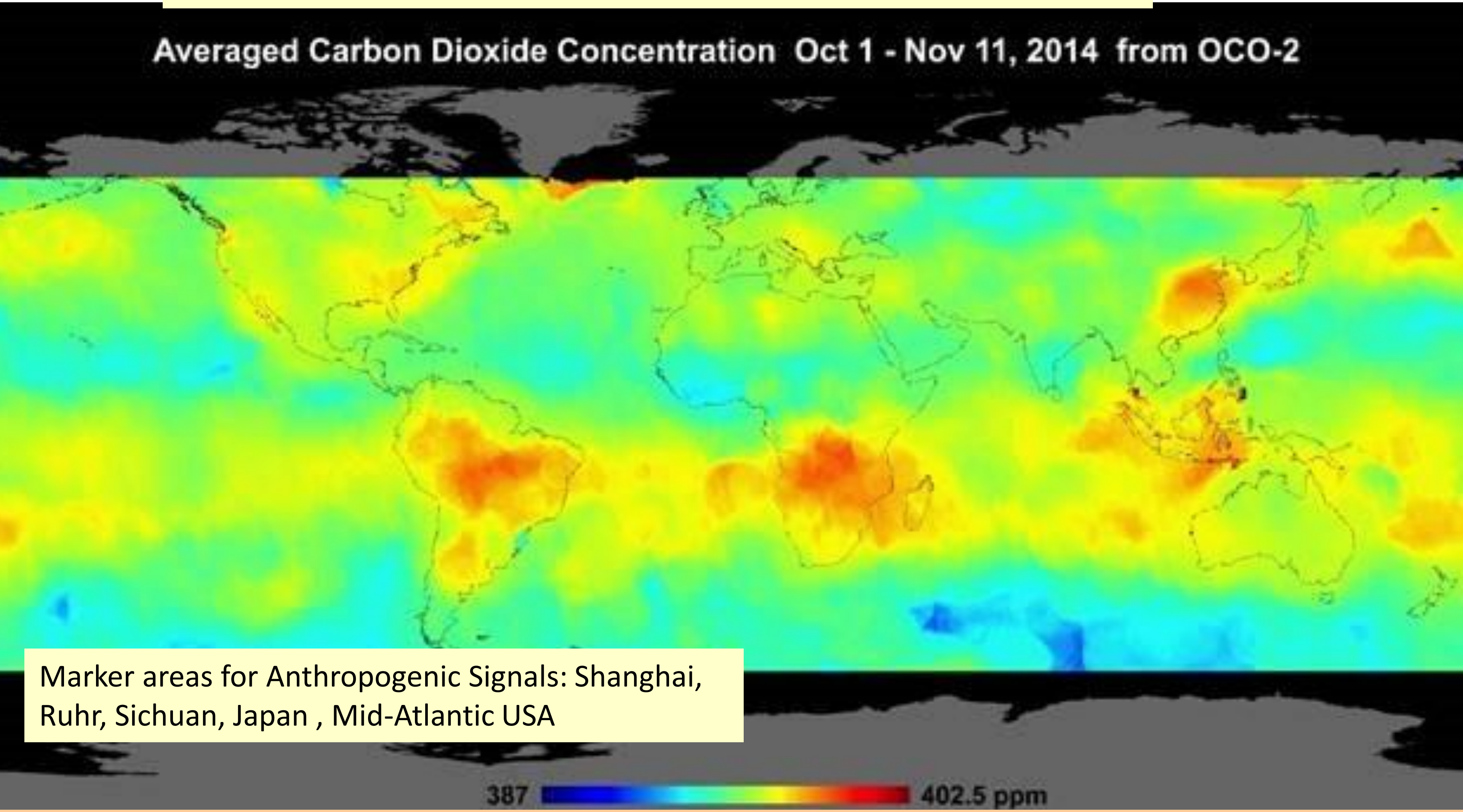
Erik Swenson processed the data and made visualizations available on WUWT

Takes ~16 days and 233 orbits to collect a single visualization – if everything goes correctly -- communication systems, data collection, processing routines (next graphic) https://wattsupwiththat.files.wordpress.com/2015/10/oco2-orbits.jpg



From NASA: "It takes 16 days and 233 orbits for the satellite to produce a complete global picture of carbon dioxide."

NASA's first visualization. 1 October 2014 – 11 November 2014
First Month of Autumn in NH, First Month of Spring in SH



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

Southern Hemisphere: Spring's large CO2 Hot Spots: Amazon of South America, Congo, Africa.
Early spring still shows plant vegetation decay and CO2 sources.
Southern Ocean "blue" seems to be CO2 uptake from cold waters there, ➔ low <CO2.>
NH: Eastern USA & Canada: China & Russia: Post-frost vegetation decay? But N Atl & Pacific?


Maracaibo
Caracas
VENEZUELA
Medellin
Bogota
COLOMBIA
GUYANA
Paramaribo
ECUADOR
Belem
Manaus
B R A Z I L
Recife
P E R U
Salvador
Brasilia
B O L I V I A
Belo Horizonte
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Sao Paulo
Asuncion
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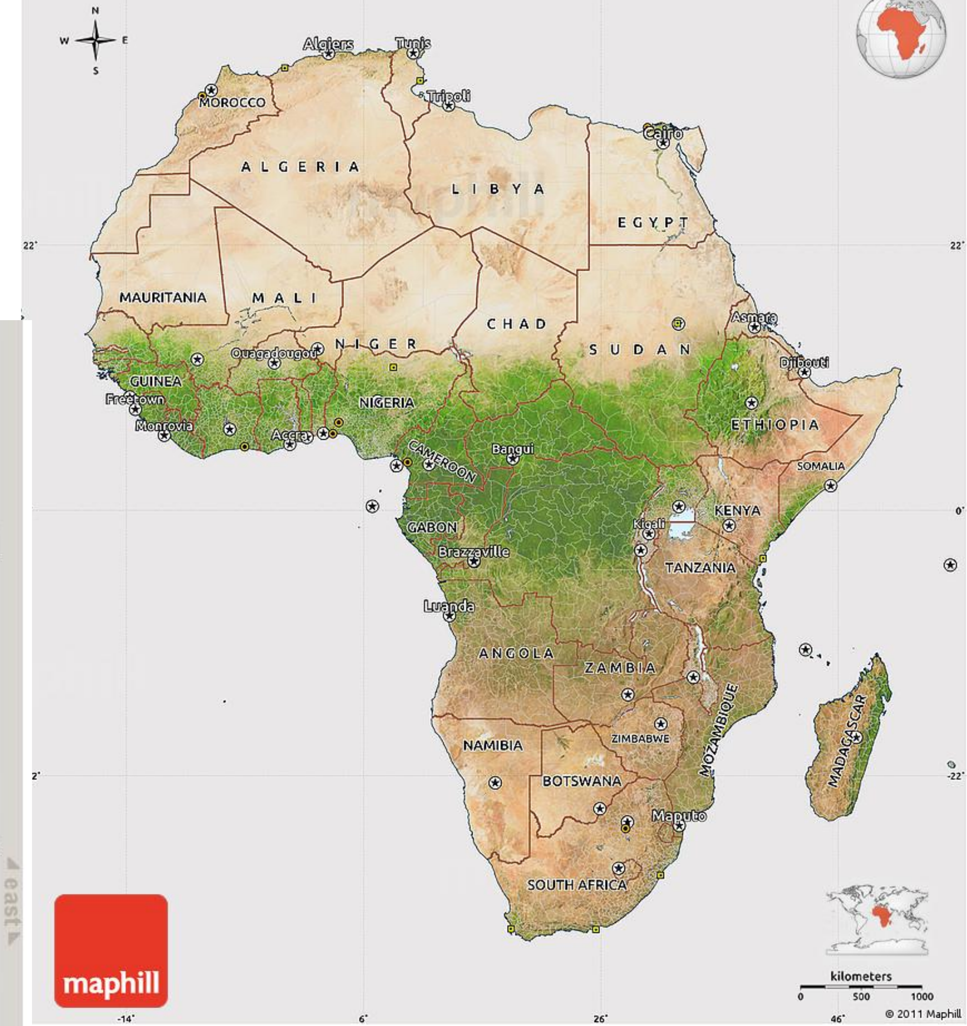
Algiers
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Ouagadougou
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GABON
Kigali
Brazzaville
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Luanda
ANGOLA
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MOZAMBIQUE
MADAGASCAR
NAMIBIA
ZIMBABWE
BOTSWANA
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Anthropogenic CO2 Emissions

http://edgar.jrc.ec.europa.eu/part_CO2.php

Global Gridded carbon dioxide emissions in the year 2005 <tons of CO2 per grid cell>

Grid cells are <0.1 Deg x 0.1 Deg>

Includes Fossil Fuels and other anthropogenic emissions

Does not include aviation and organic sources

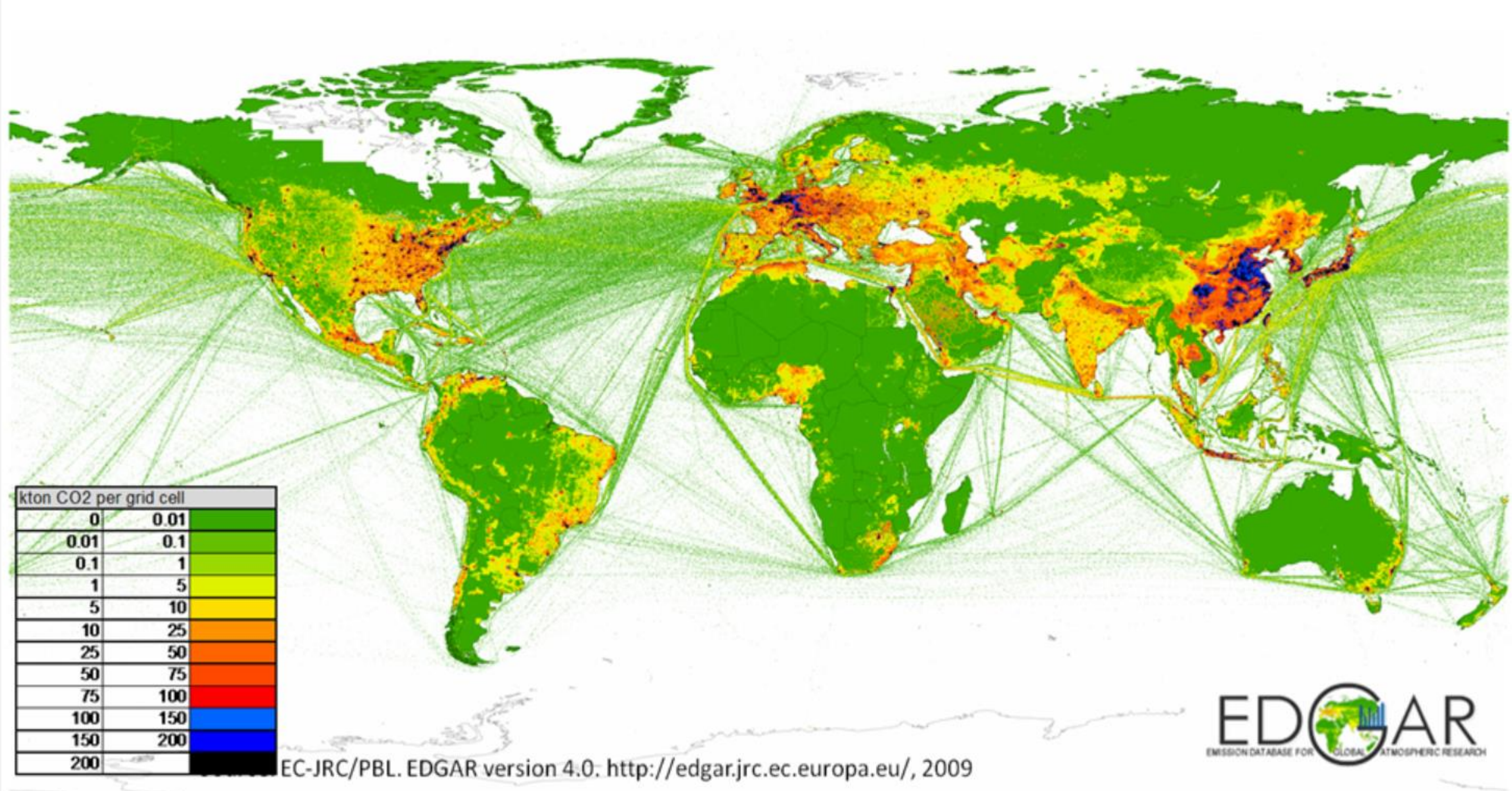
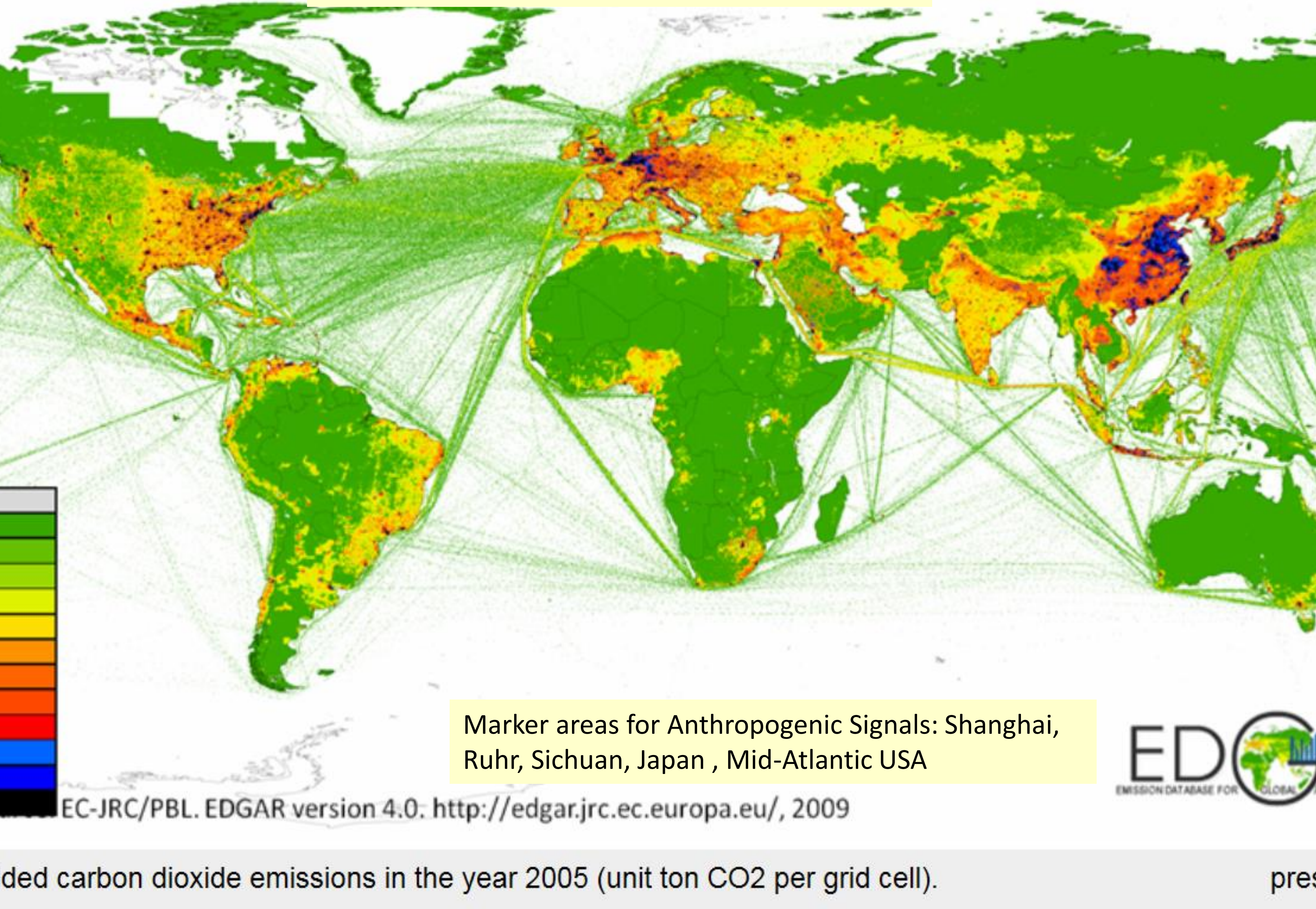


Figure 6: Global gridded carbon dioxide emissions in the year 2005 (unit ton CO2 per grid cell).

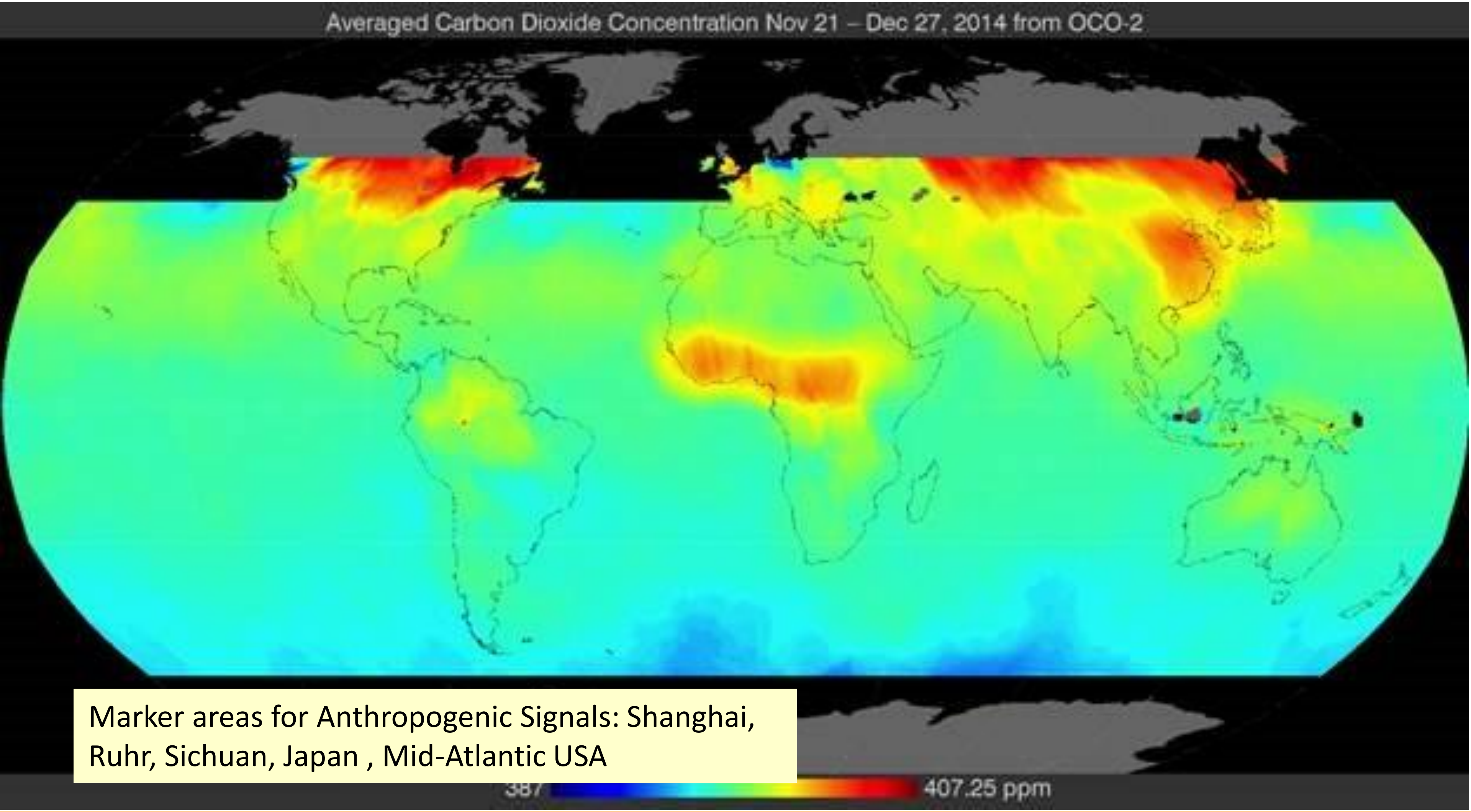
press x to close

Marker Areas Defined



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

NASA's second OCO-2 visualization. 21 November 2014 – 27 December 2014
Northern Hemisphere Autumn Southern Hemisphere Spring



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

Rotting Vegetation is source for CO2 hot spots in North America Brittany, Ukraine, Central Asia.
Fires most likely sources for hot spot in Africa.
Ruhr Valley is a sink? Sinks in Caspian, Aral Seas? Sinks in Indonesia and Rabaul?
Southern Ocean: CO2 Sink leading to decreased atmospheric <CO2>.

Erik Swenson provided the rest of the visualizations

from Erik's Implementation Notes:

data from each sample are put into an array.

Each point is added to the array as a circular blob.

…center point of the circle has a weight of 1 for the averaging function.

…remaining points in the circle are weighted in a decreasing manner from the center.

…images from NASA… show circular artifacts.

All of the images use the same min/max scale of 380 – 415 ppm.

…present(s) a good range over all of the images.

…NASA images are chopped beyond 60 degrees N and S latitude.

… show(s) whatever data is there.
All data points are plotted from the OCO-2-Lite files regardless of warn_level.

Warn_level is used to judge the quality of the sample.

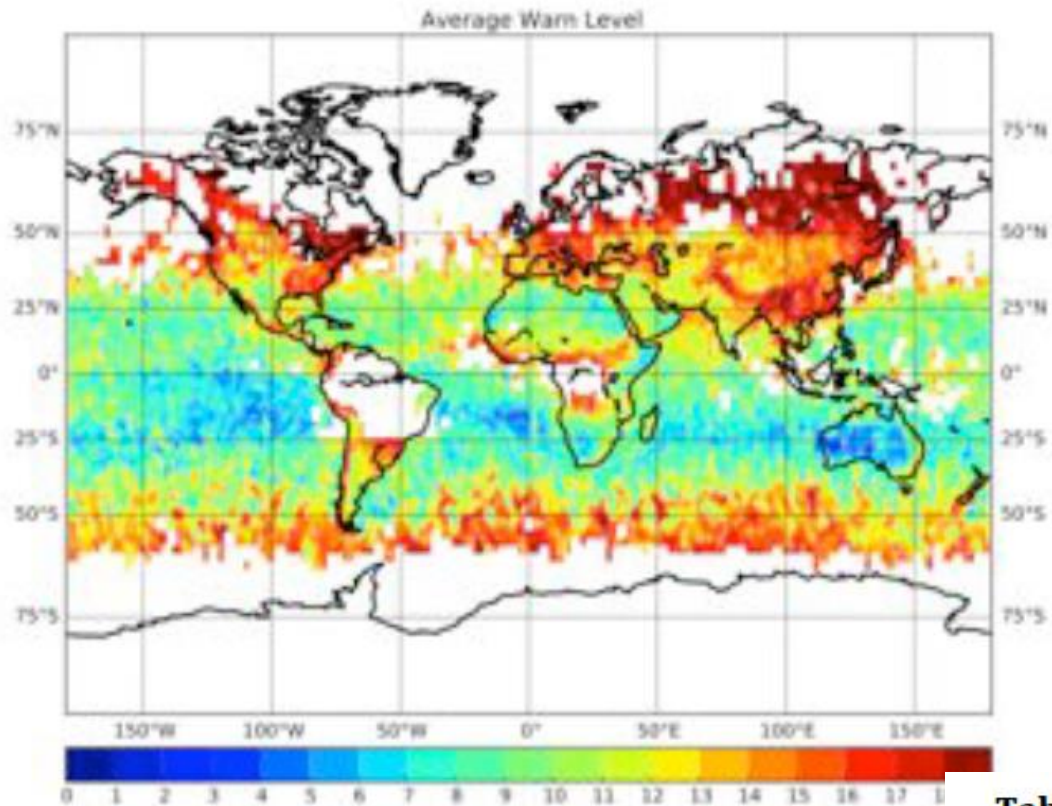


Figure 5 – Average Warn Level Map

Warn Levels:

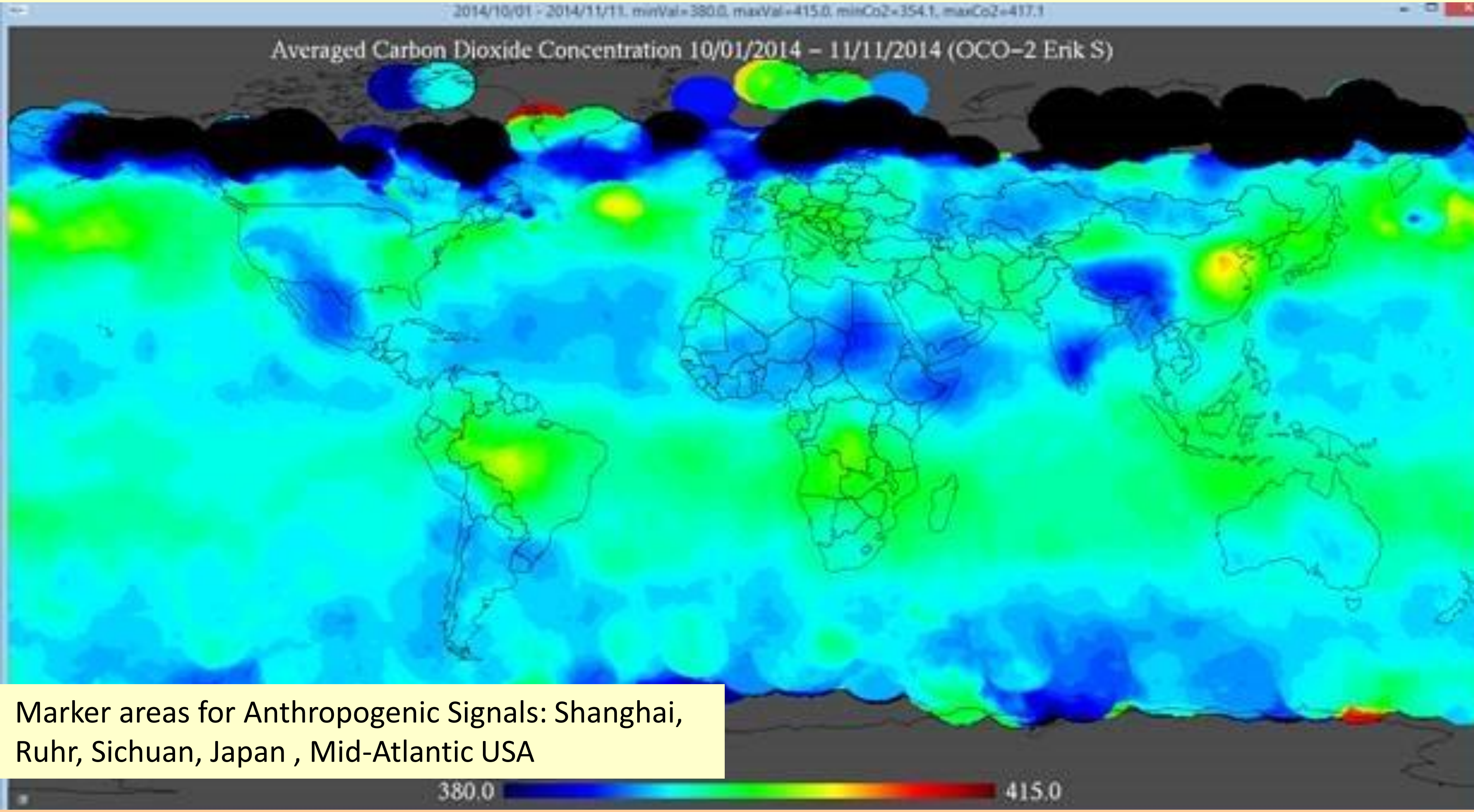
Data quality warnings from JPL (NASA) User Manual

Table 2: Basic Procedure for Warn Level Usage

1	Decide requirements beforehand: how much data volume / coverage or scatter / error is needed / tolerable?	
2	Begin admitting WL=0, 1, 2, ... into project. Monitor above statistics.	
3	Stop when data volume / coverage are acceptable, or when scatter / error become intolerable (then back off).	

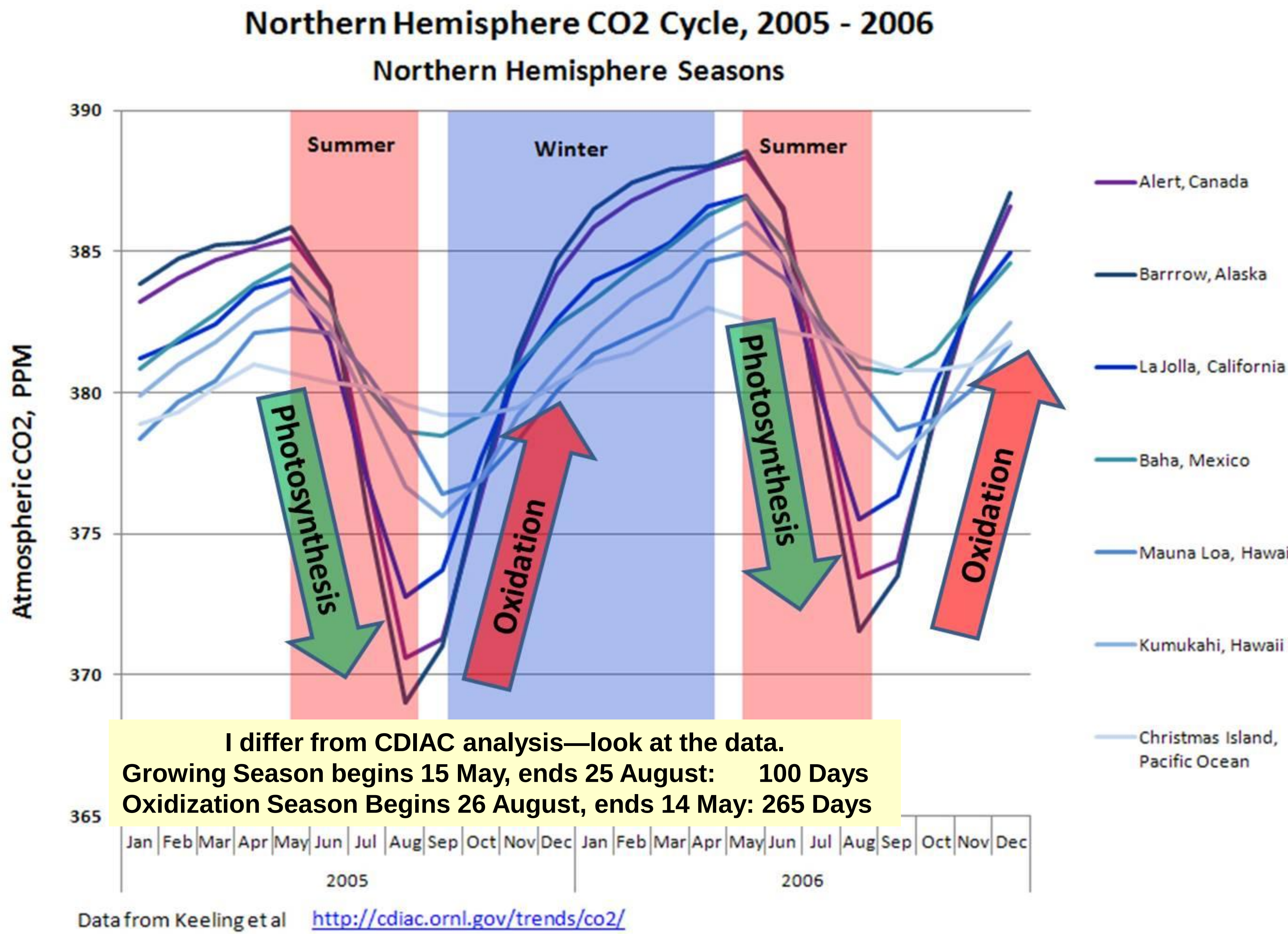
1 October 2014 – 11 November 2014 Erik Swenson

NH: First full month of Autumn. SH: First full month of Spring.



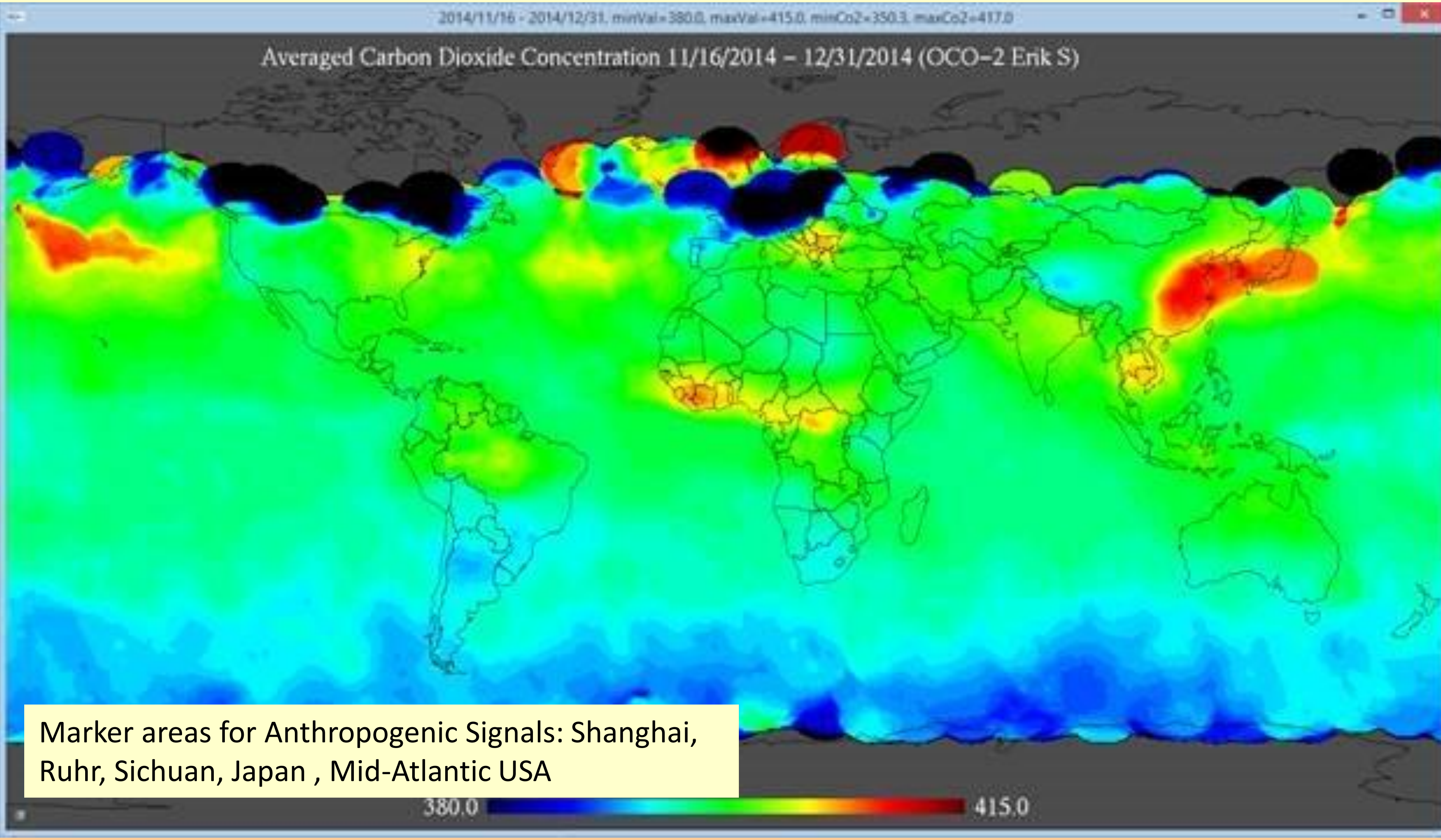
Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

Warmest emission sites from North Atlantic and North Pacific Oceans?
Growth of grasslands? Tibetan Plateau, S ahel, Chad, Horn of Africa, India
Below average or CO_2 autumn sinks in Corn and Wheat-growing regions of North America?
Cold Southern Ocean a continuing sink caused by CO_2 uptake.

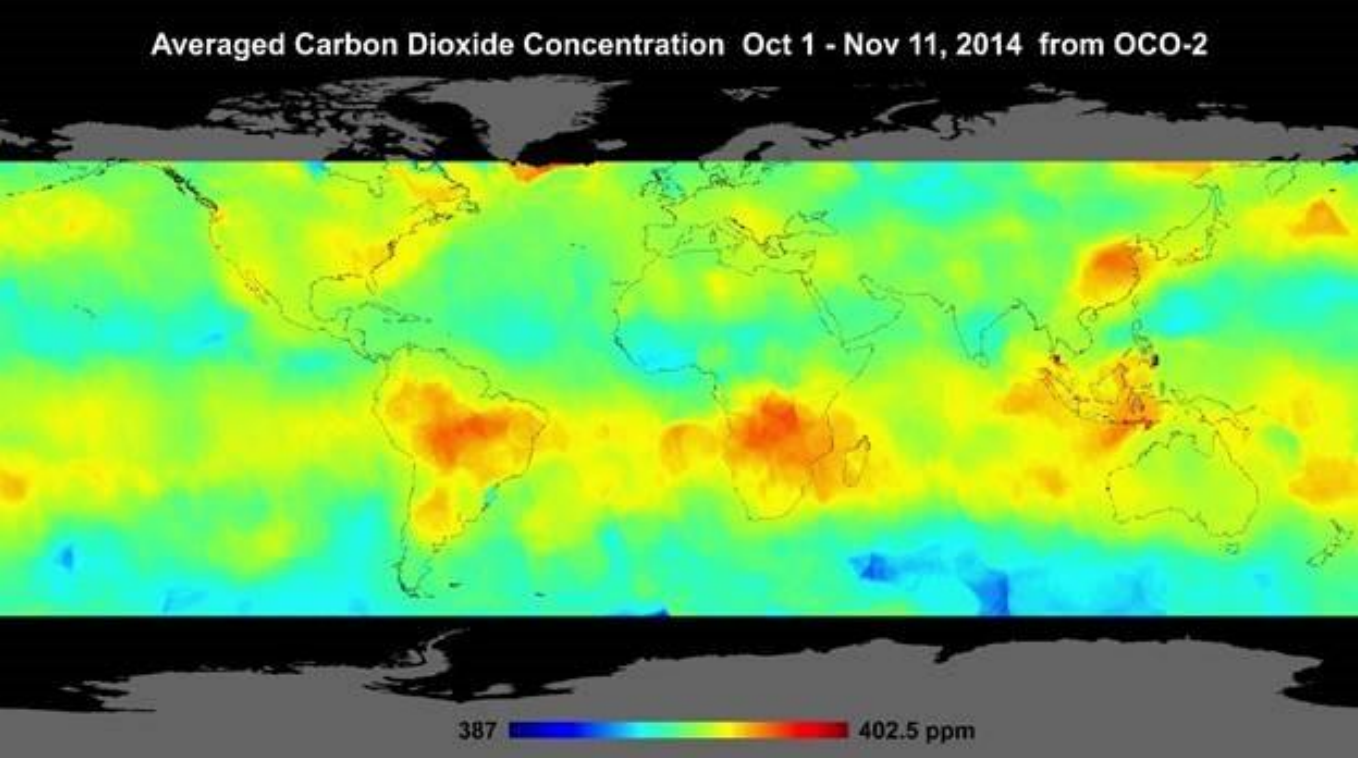

Northern Hemisphere CO2 Cycle, 2005 - 2006
Northern Hemisphere Seasons
Summer
Winter
Summer
Atmospheric CO2, PPM
390
385
380
375
370
365
Photosynthesis
Oxidation
Photosynthesis
Oxidation
Alert, Canada
Barrrow, Alaska
La Jolla, California
Baha, Mexico
Mauna Loa, Hawaii
Kumukahi, Hawaii
Christmas Island, Pacific Ocean
I differ from CDIAC analysis—look at the data.
Growing Season begins 15 May, ends 25 August: 100 Days
Oxidization Season Begins 26 August, ends 14 May: 265 Days
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2005
2006
Data from Keeling et al http://cdiac.ornl.gov/trends/co2/

16 November 2014---31 December 2014 Erik Swenson

Near NH Winter Solstice and SH Summer Solstice.



Southern Ocean CO2 Sink.   Why the large CO2 emission from the North Central Pacific Ocean?
Why the CO2 emission sources in Atlantic Ocean?   SEA: Slash and burn agriculture source?`
Winter Solstice in Northern Hemisphere; why large source in E, NE Asia?

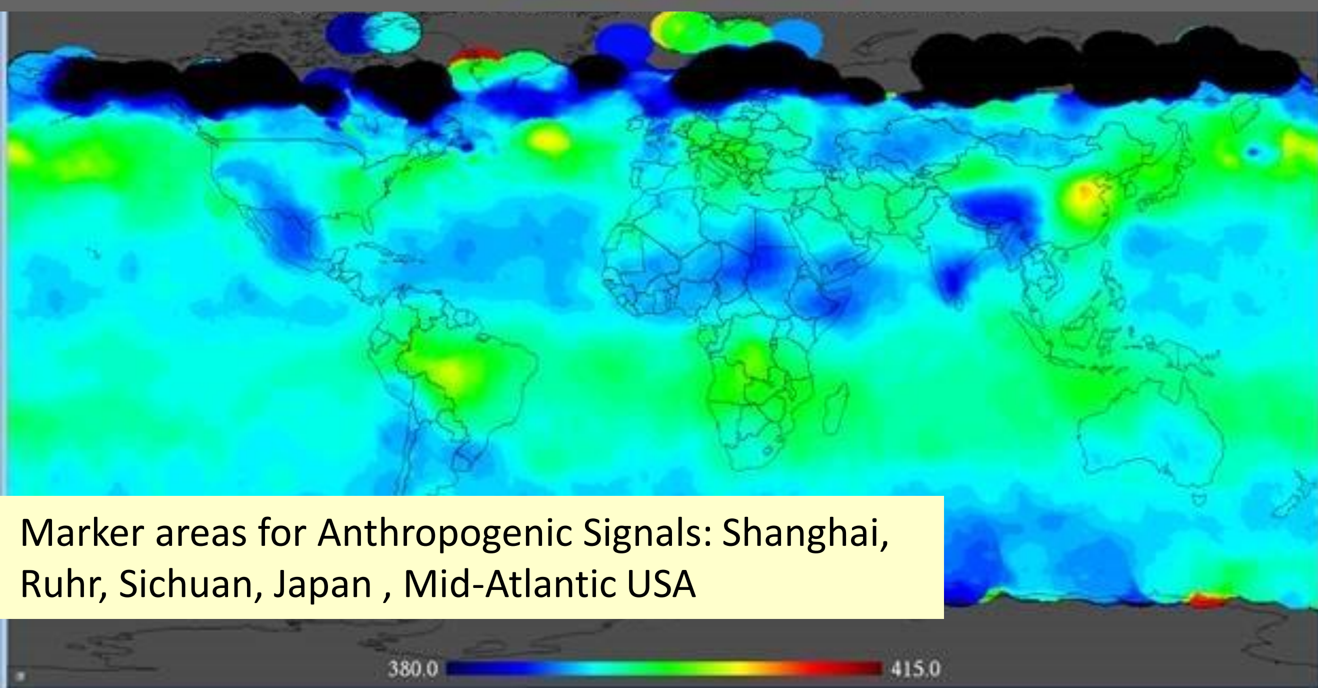


1 October 2014
11 November 2014
NASA
NH-First Month Autumn

SH-First Month Spring

Different Pictures!
Same Time Periods

Slightly different color scales.



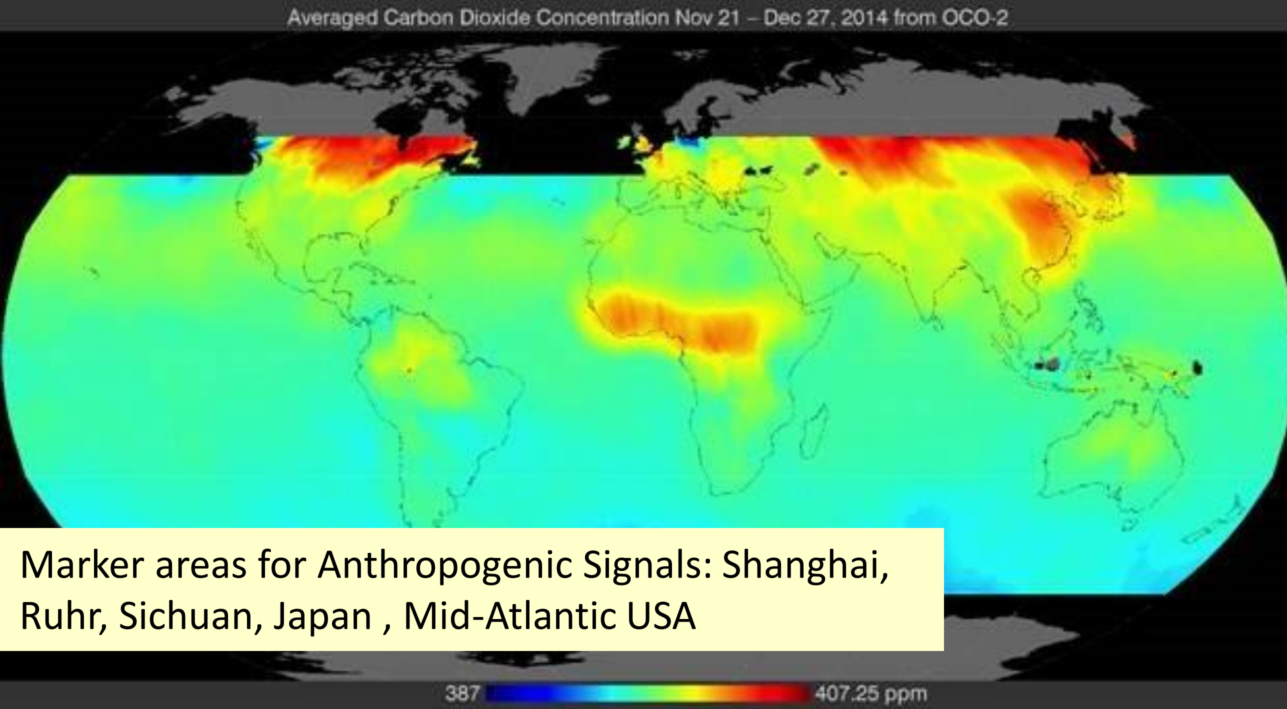
Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

NH- First Month Autumn

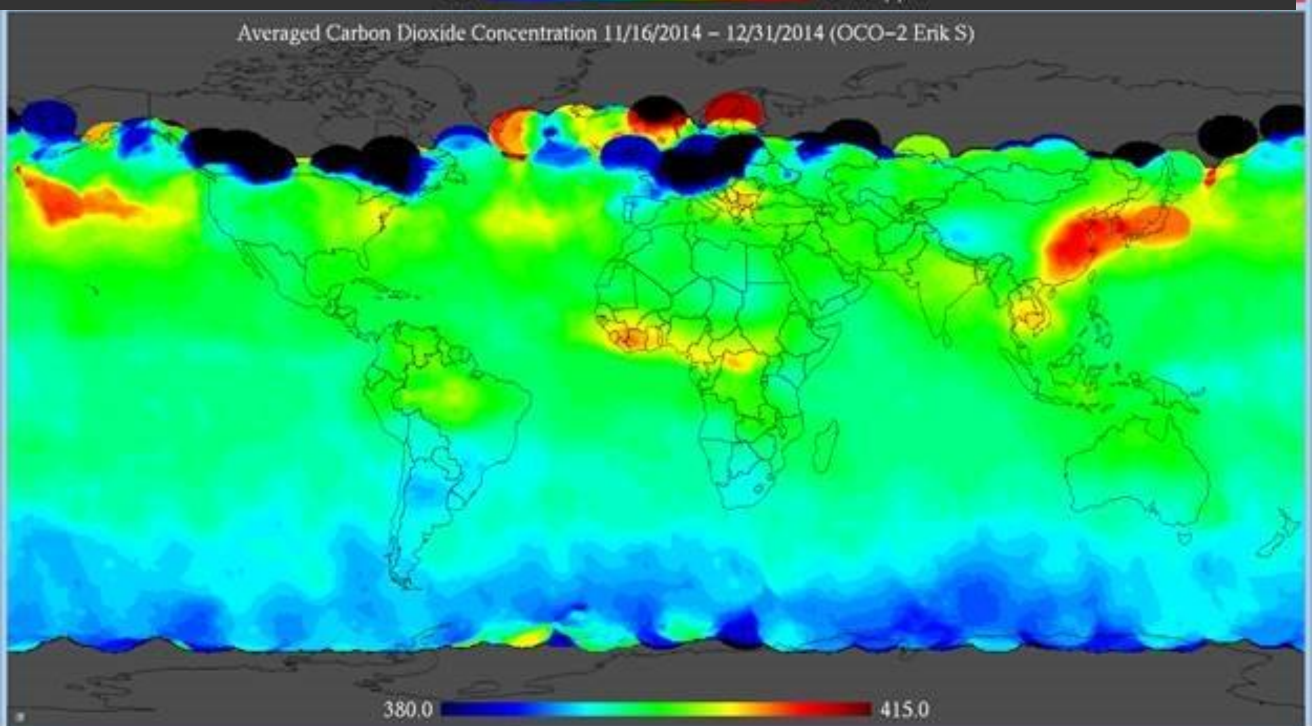
SH-First Month Spring

1 October 2014-
11 November 2014

Erik Swenson



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA



21 November 2014-
31 December 2014
NASA
NH – "Winter Solstice"

SH – "Summer Solstice"

Slightly different time periods.

Slightly different color scales.

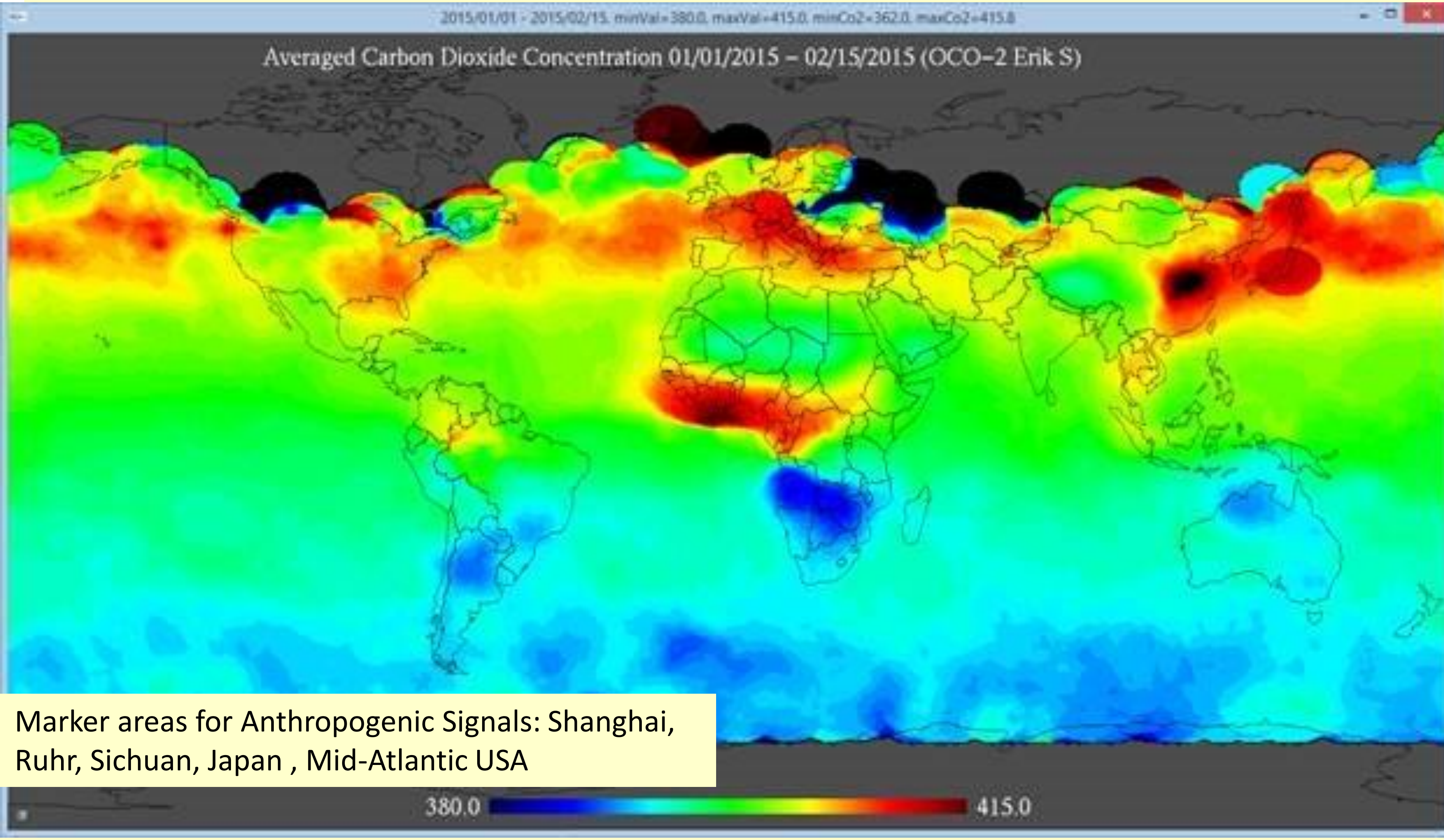
NH – "Winter Solstice"

SH – "Summer Solstice"

16 November 2014-
31 December 2014

Erik Swenson

1 Jan 2015- 15 Feb 2015 Erik Swenson NH: Mid-Winter SH: Mid-Summer



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

Summer growing season in SH => CO_2 cool spots S America, Southern Africa, Australia.
Huge Southern Ocean Cool Spot CO_2 uptake into cold water. ITCZ furthest south now.
NH Hot plume: W Great Lakes-East USA-N Atlantic-Cent- S Europe. Lg Hot spot N China- Japan – Sakhalin- N Pacific- Pac NW. **Dry Season Hot Spot Equatorial Africa: Drying /burning Jungle?**

NASA: Global Tour of Fire

https://www.youtube.com/watch?feature=player_embedded&v=CDEfXCHMQWs

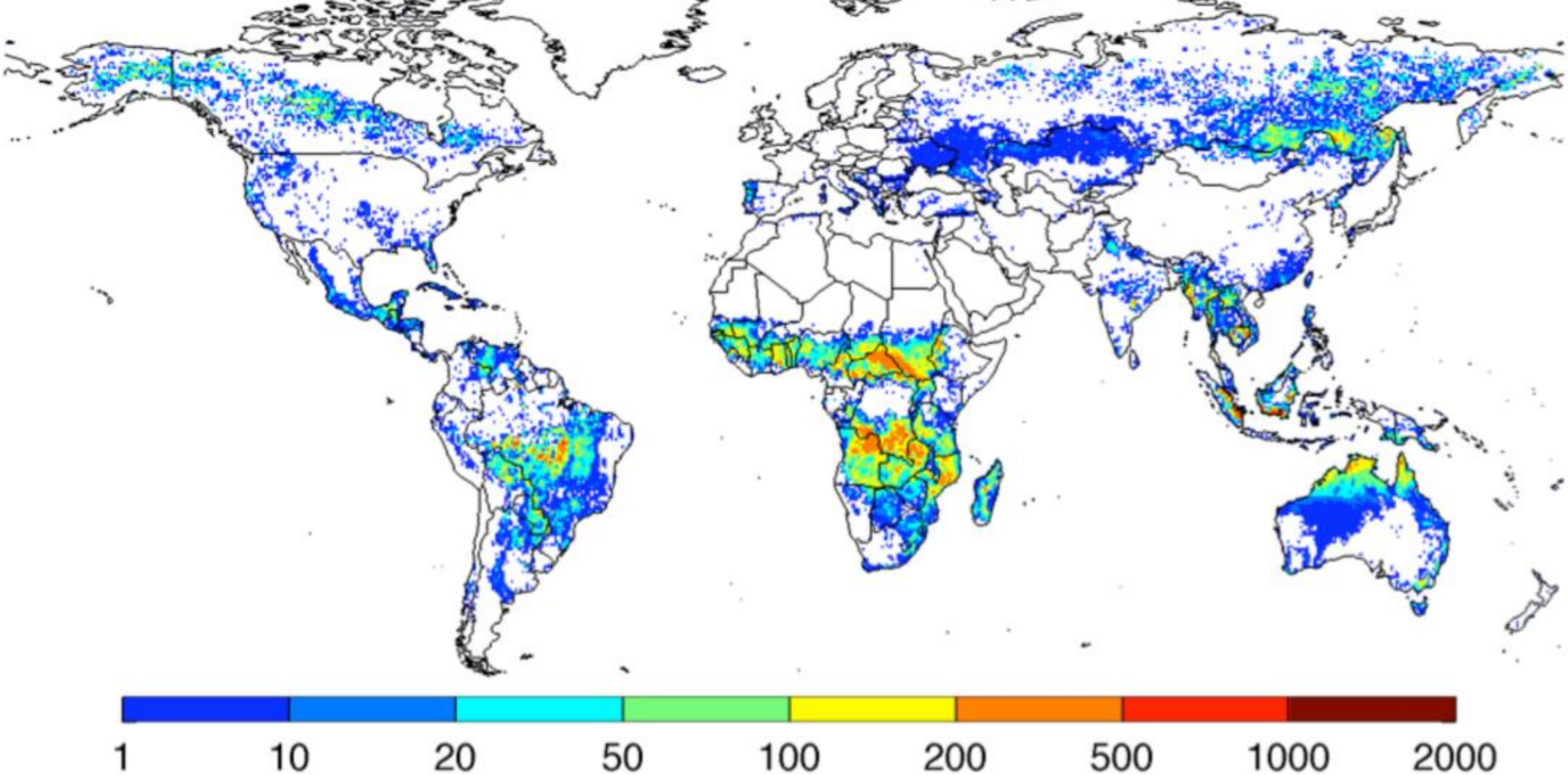
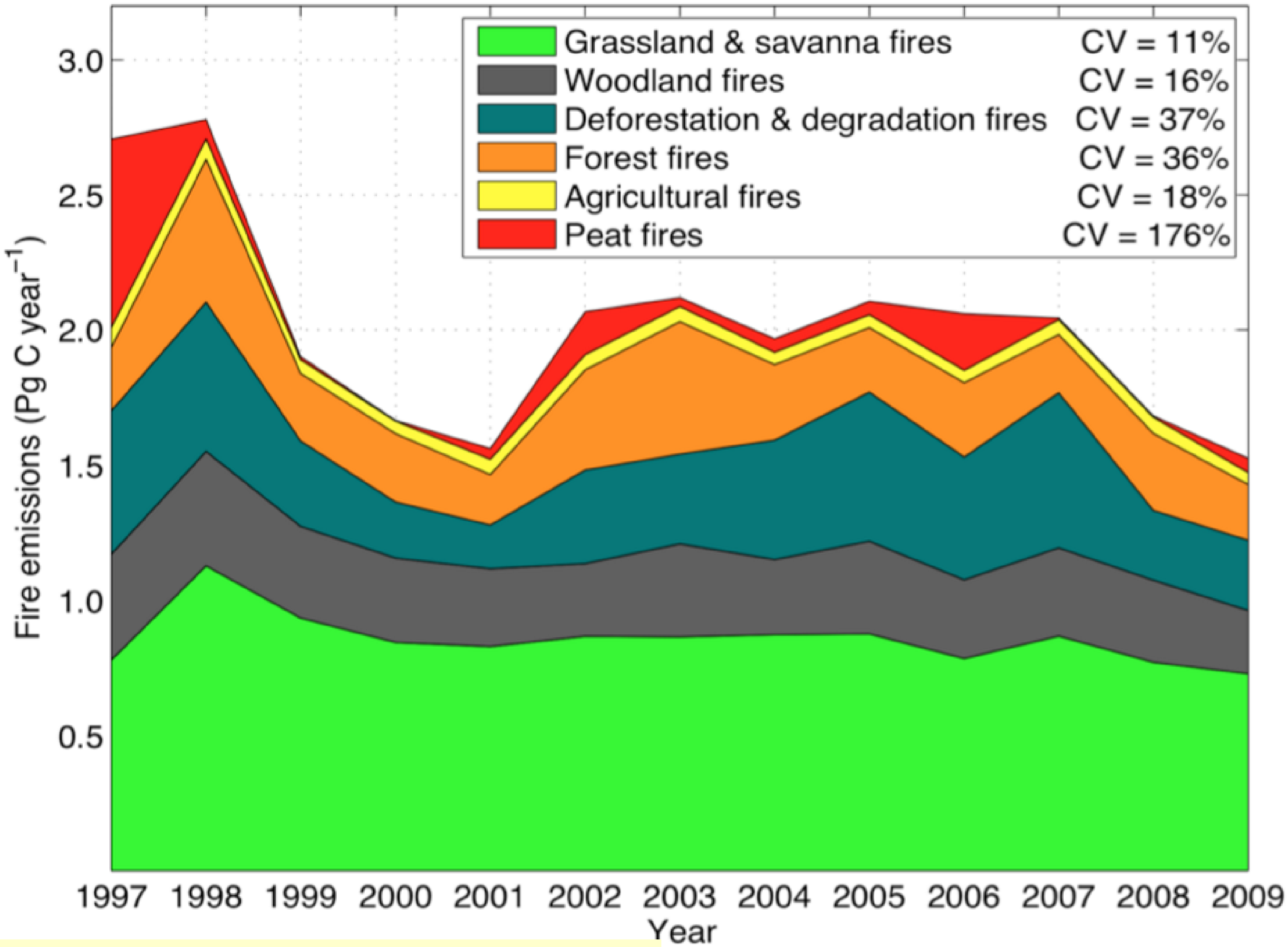


Fig. 11. Mean annual fire carbon emissions ($g\,C\,m^{-2}\,year^{-1}$), averaged over 1997–2009. This quantity is the product of the fuel consumption (e.g., Fig. 6) and the burned area within the grid cell, divided by the total area of the grid cell.

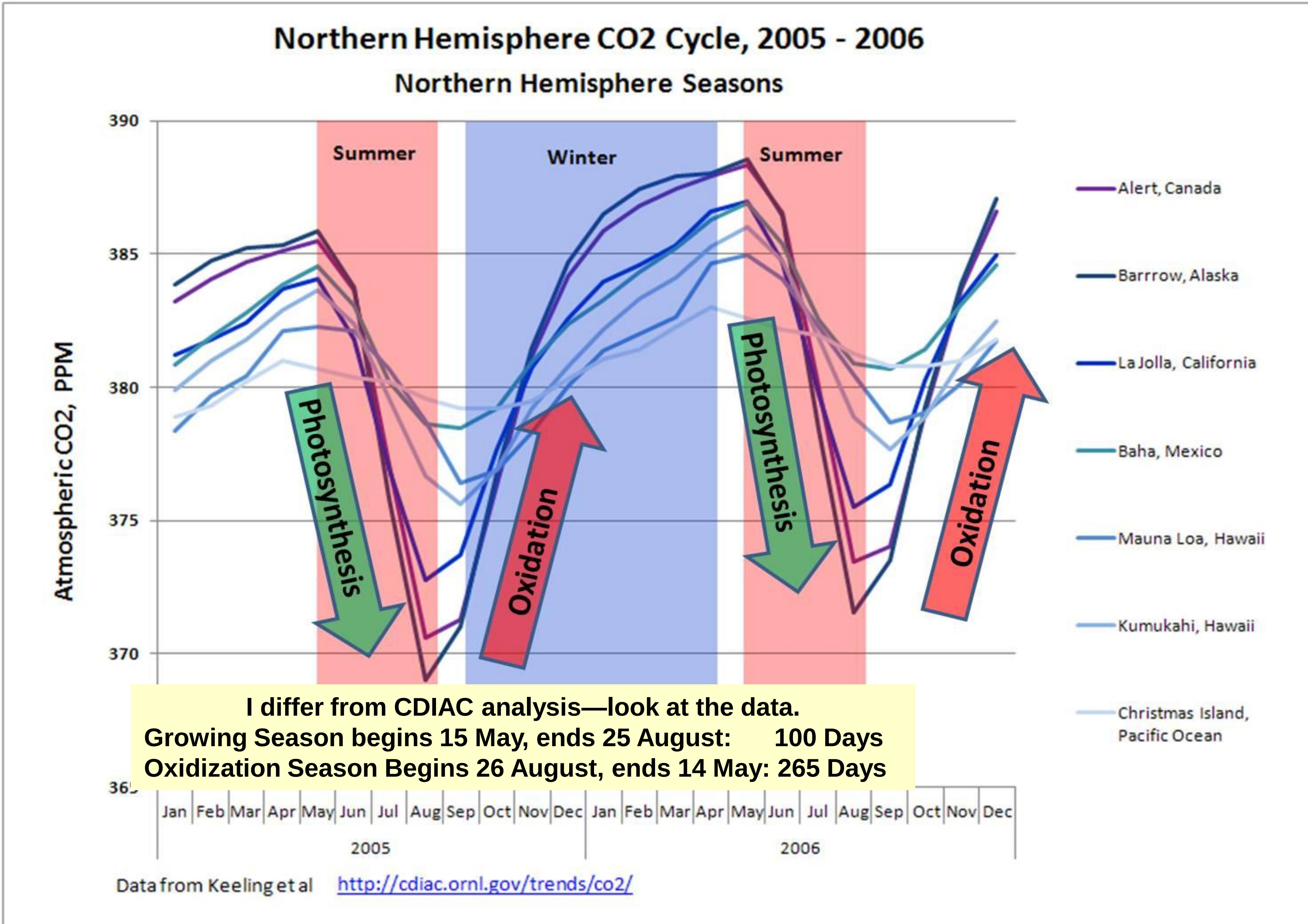
G. R. van der Werf, et al, **Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires** (1997–2009) Atmos. Chem. Phys., 10, 11707–11735, 2010
www.atmos-chemphys.net/10/11707/2010/ doi:10.5194/acp-10-11707-2010



Pg C per year is the same as Gt C per year

Fig. 8. Cumulative annual carbon emissions from different fire types and their coefficient of variation (CV) during 1997–2009.

G. R. van der Werf, et al, **Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires** (1997–2009) Atmos. Chem. Phys., 10, 11707–11735, 2010
www.atmos-chemphys.net/10/11707/2010/ doi:10.5194/acp-10-11707-2010


Northern Hemisphere CO2 Cycle, 2005 - 2006
Northern Hemisphere Seasons
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Winter
Summer
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Atmospheric CO2, PPM
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365
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
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2006
Alert, Canada
Barrrow, Alaska
La Jolla, California
Baha, Mexico
Mauna Loa, Hawaii
Kumukahi, Hawaii
Christmas Island, Pacific Ocean
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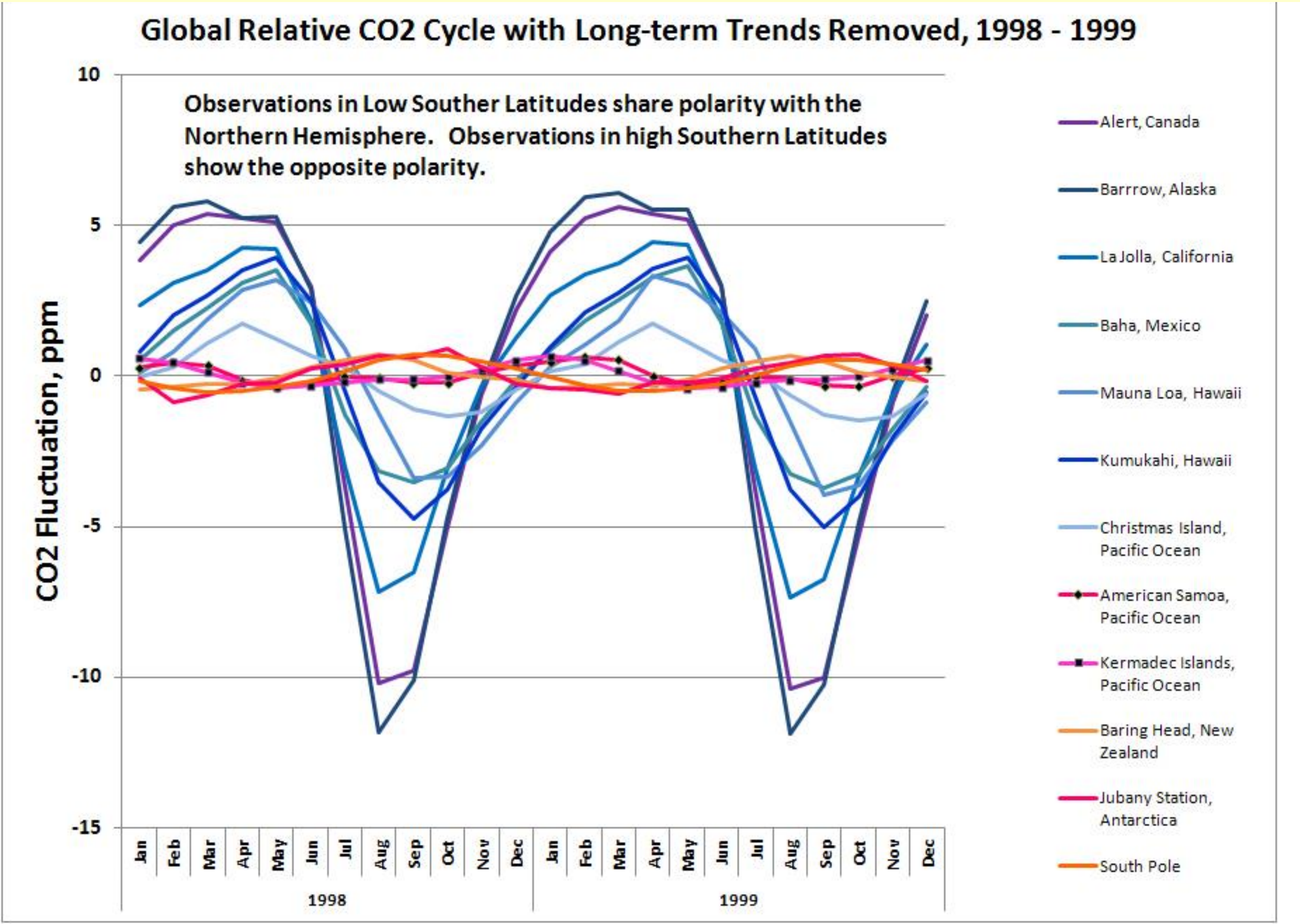
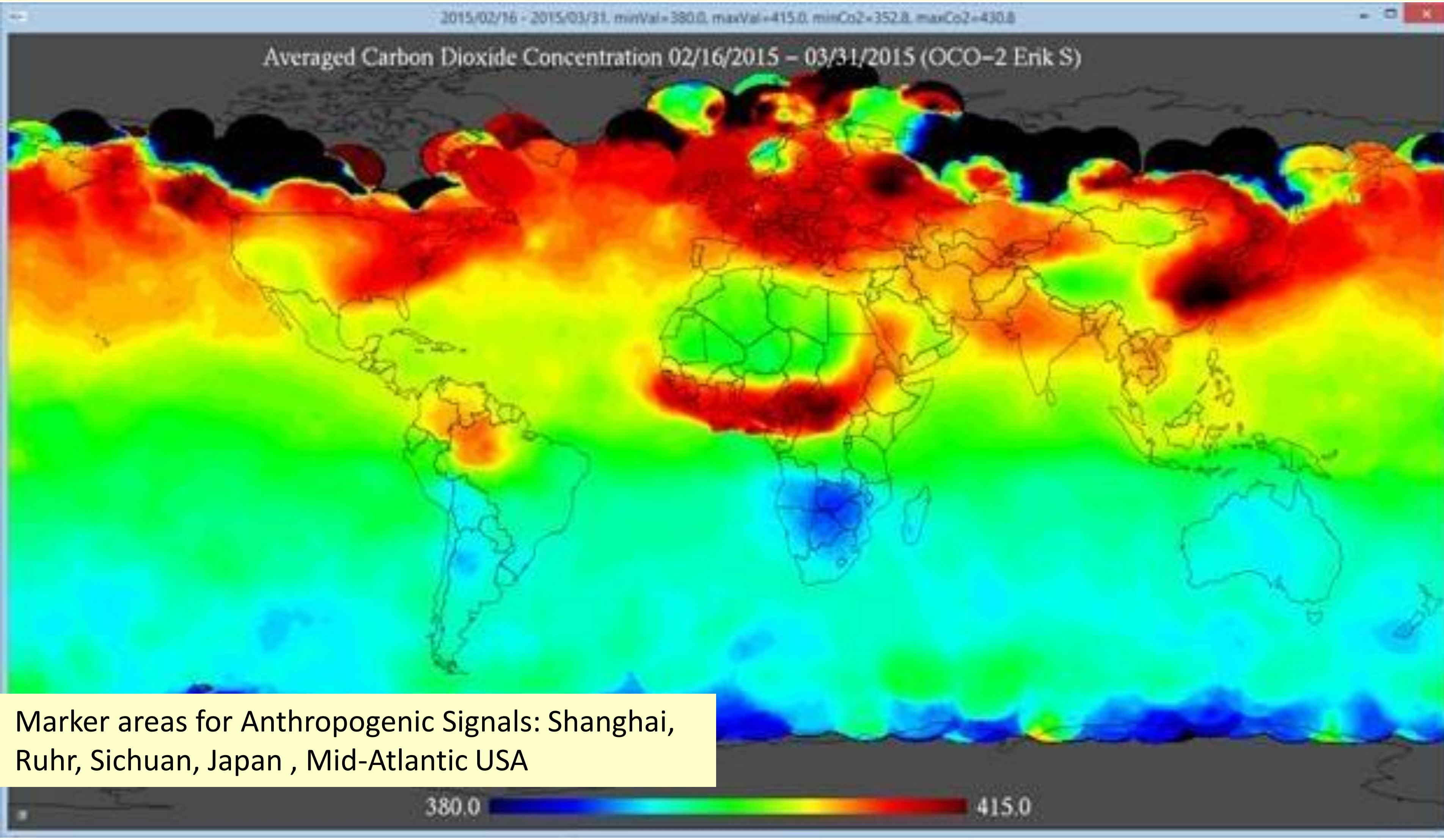
http://dougrobbins.blogspot.com/2013/05/the-keeling-curve-seasonal-co2-cycles.html



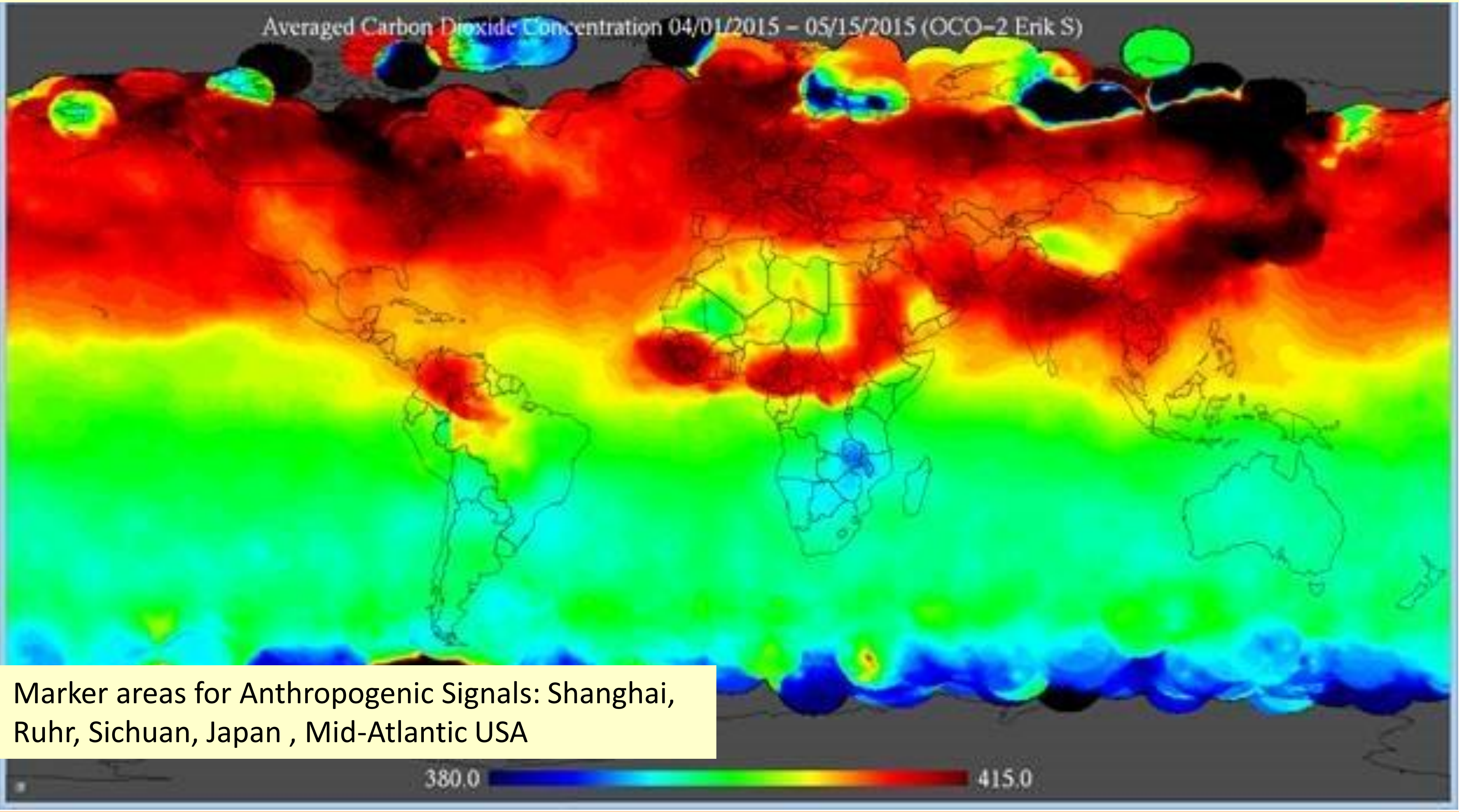
16 February 2015 – 31 March 2015 Erik Swenson NH- Spring Equinox SH Autumnal Equinox



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

SH CO_2 Cool spots in S America, Southern Africa, Australia:plants still growing, removing CO_2 .
Equatorial Africa-rotting plants, fires, giving up CO_2
NH Hot Plume: NE Asia-N Asia-N Pacific-Gulf Alaska, E USA+ S Canada-N Atlantic-Europe-NW Russia! Warming earth, rotting vegetation; spring growth not yet started.

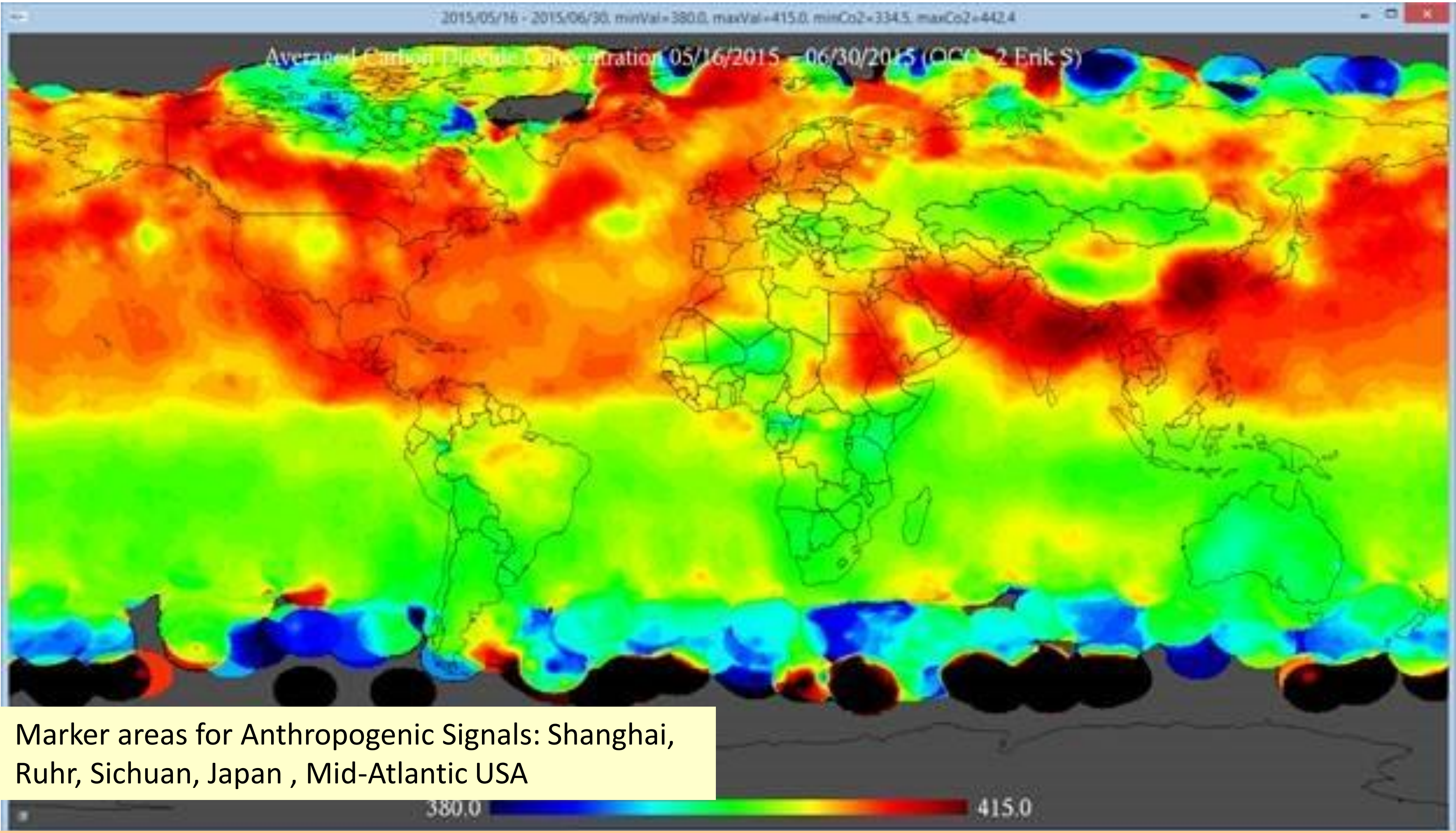
1 Apr 2015-15 May 2015 Erik Swenson NH- Onset of Spring. SH- Onset of Autumn



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

NH CO_2 hot plume almost everywhere. End of April and the first couple of weeks of May plant rot is still yielding CO_2 to the air. Spring growth has not started in earnest.
Southern Ocean uptake: Cool spots are confined to most poleward parts Southern Ocean.
SH Land Areas: S. America, Africa, Australia: CO_2 uptake from plants nearing harvest.

16 May 2015-30 June 2015 Erik Swenson.   Summer Solstice in NH. Winter Solstice SH



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

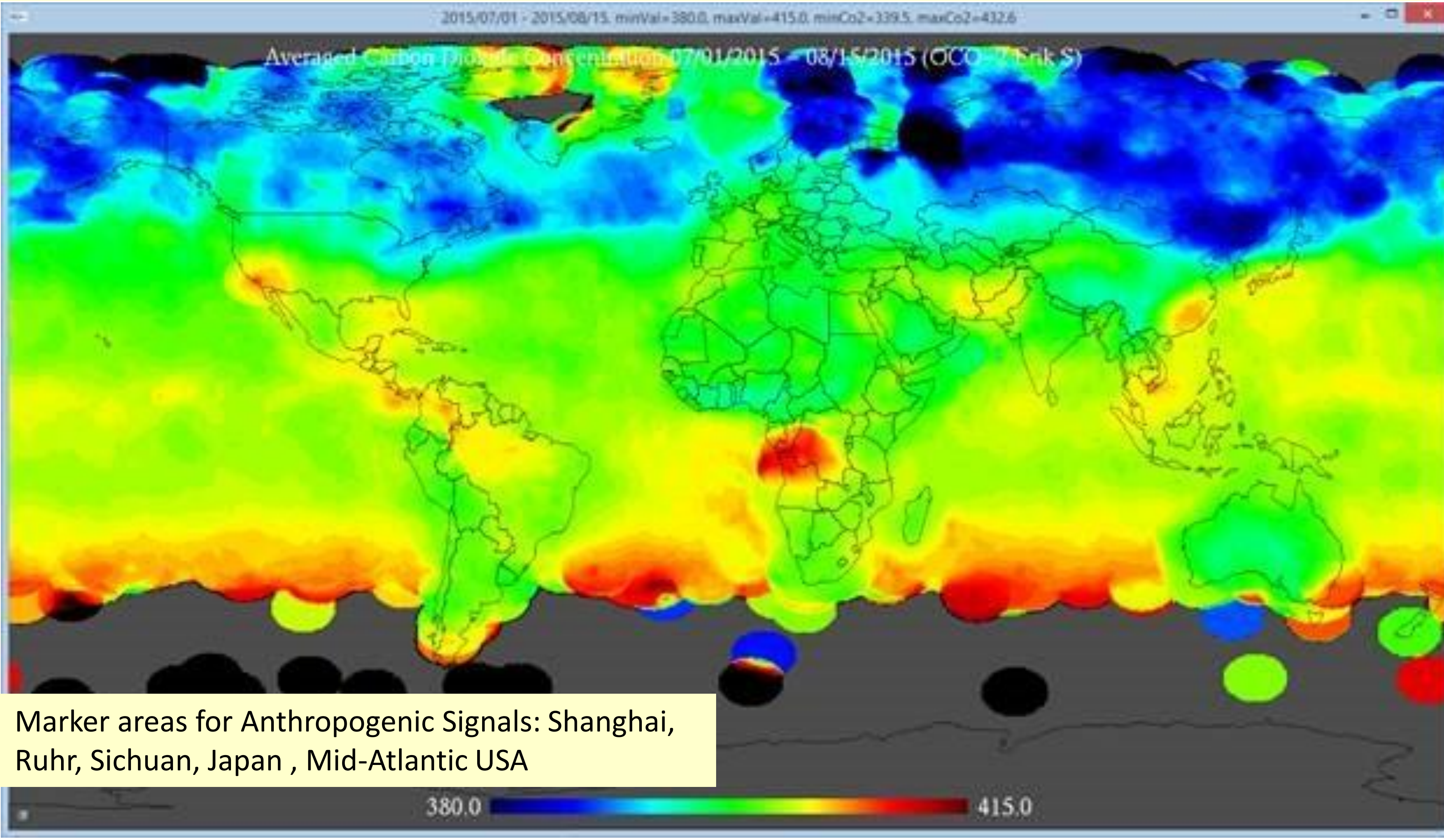
CO_2 Hot Plume NH: N Pacific Ocean, Beaufort Sea, Mid-Canada, all of USA except Nebraska? Hot Spots: NE Africa, Bangladesh, NE Asia. Hot plume and spots: soil warms, rotting plants give off CO_2; new growing season becoming established in northernmost areas (~24 hour sunlight) Veg. source of CO_2 emissions from N Atlantic & N Pacific Oceans?   **S Ocean: cold uptake CO_2**.

Arctic Reference Map

Nat’l Snow Ice Data Center

https://nsidc.org/sites/nsidc.org/files/images//arctic_map.gif

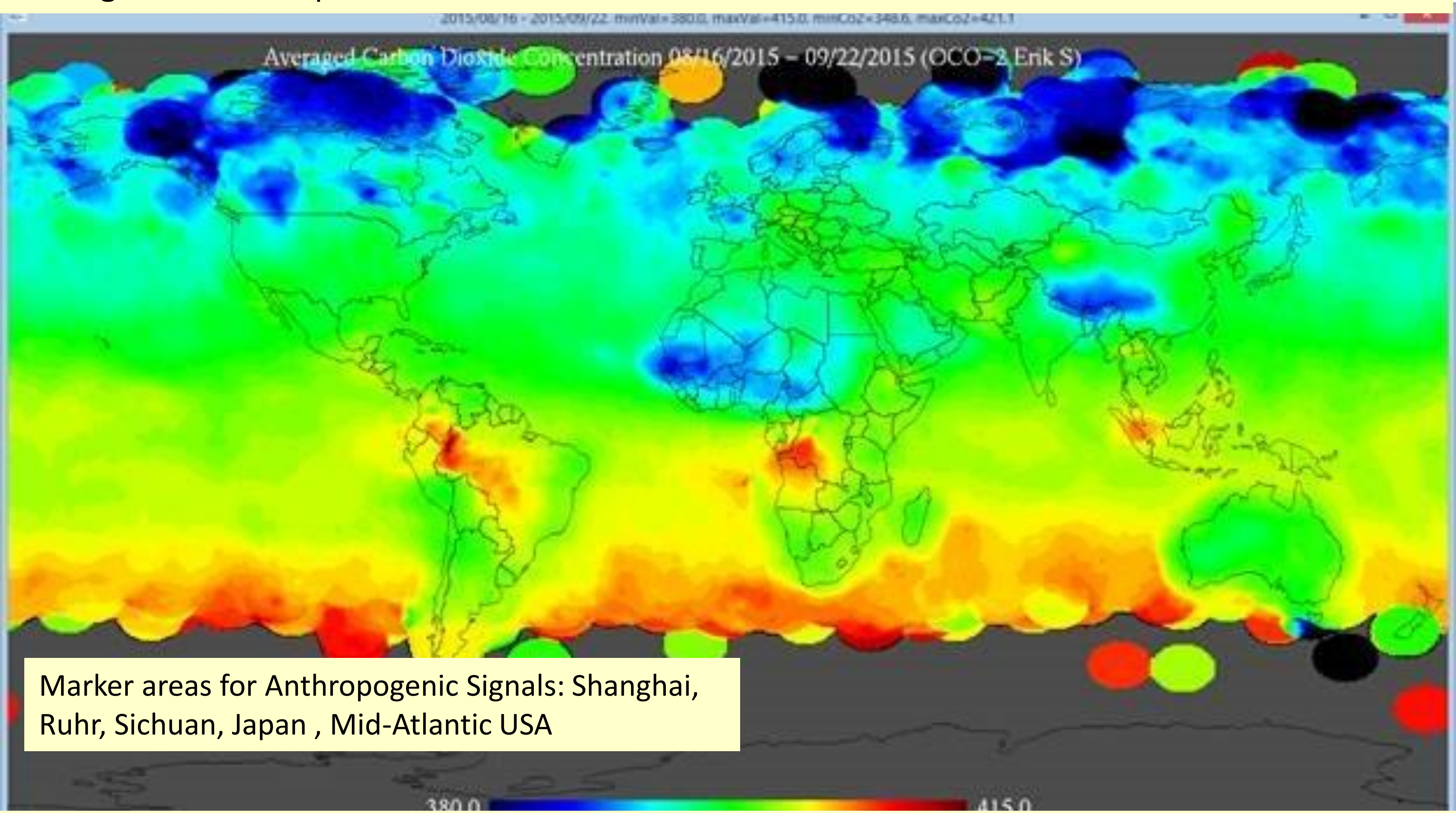
1 July 2015- 15 August 2015 Erik Swenson Mid Summer NH and Mid-Winter SH



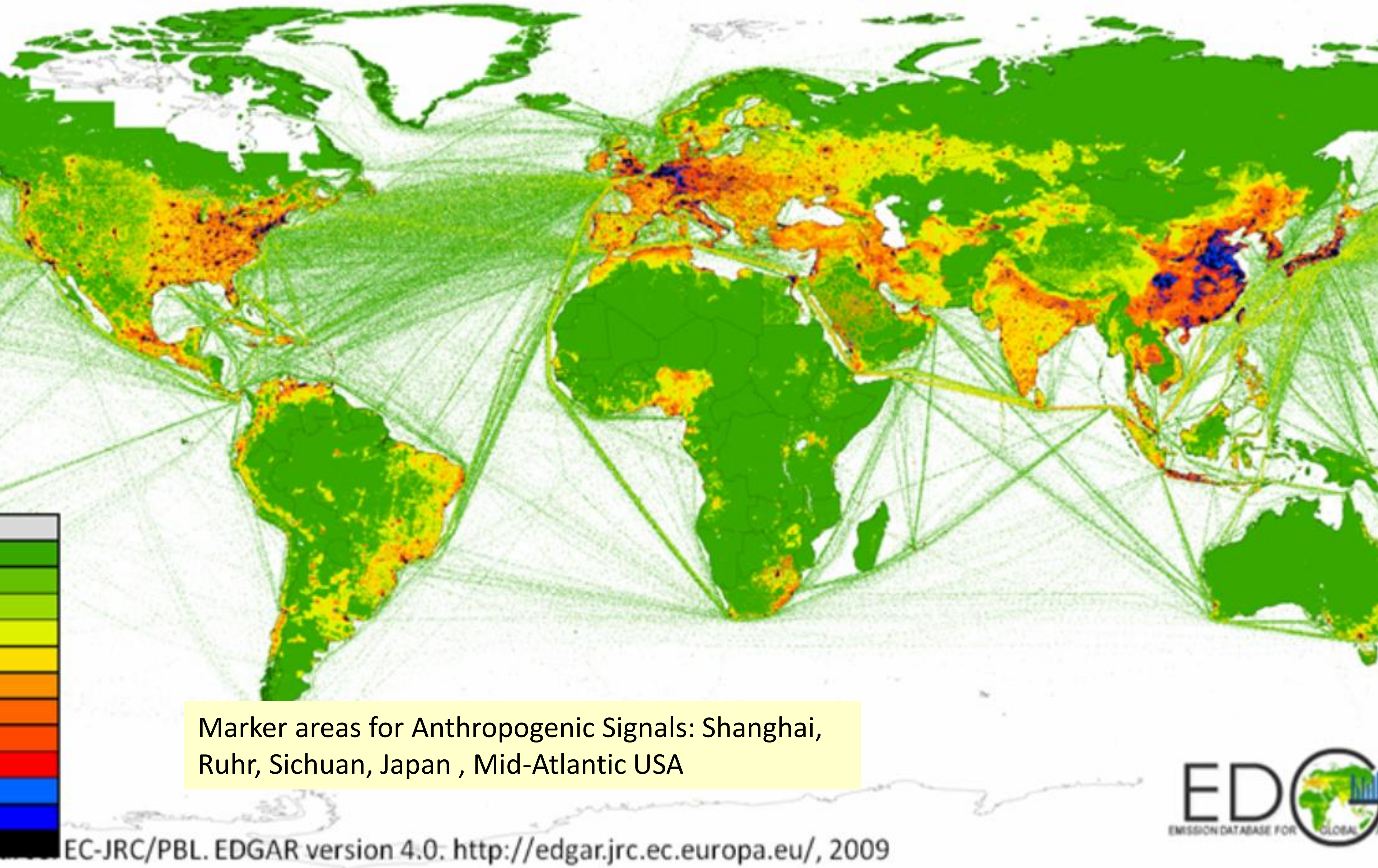
Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

Mid Summer in NH and plants gobbling up CO2 all across the NH: Alaska, Canada, Europe, Russia, and North Atlantic , Pacific Oceans.
Mid-Winter in SH, oceanic plants seem to be giving off CO2 from South Atlantic, South Indian and south Pacific, but not over any land in SH except Congo in Africa; this follows CDIAC curve.

16 Aug 2015 – 22 Sept 2015 Erik Swenson End of Summer NH and End of Winter SH



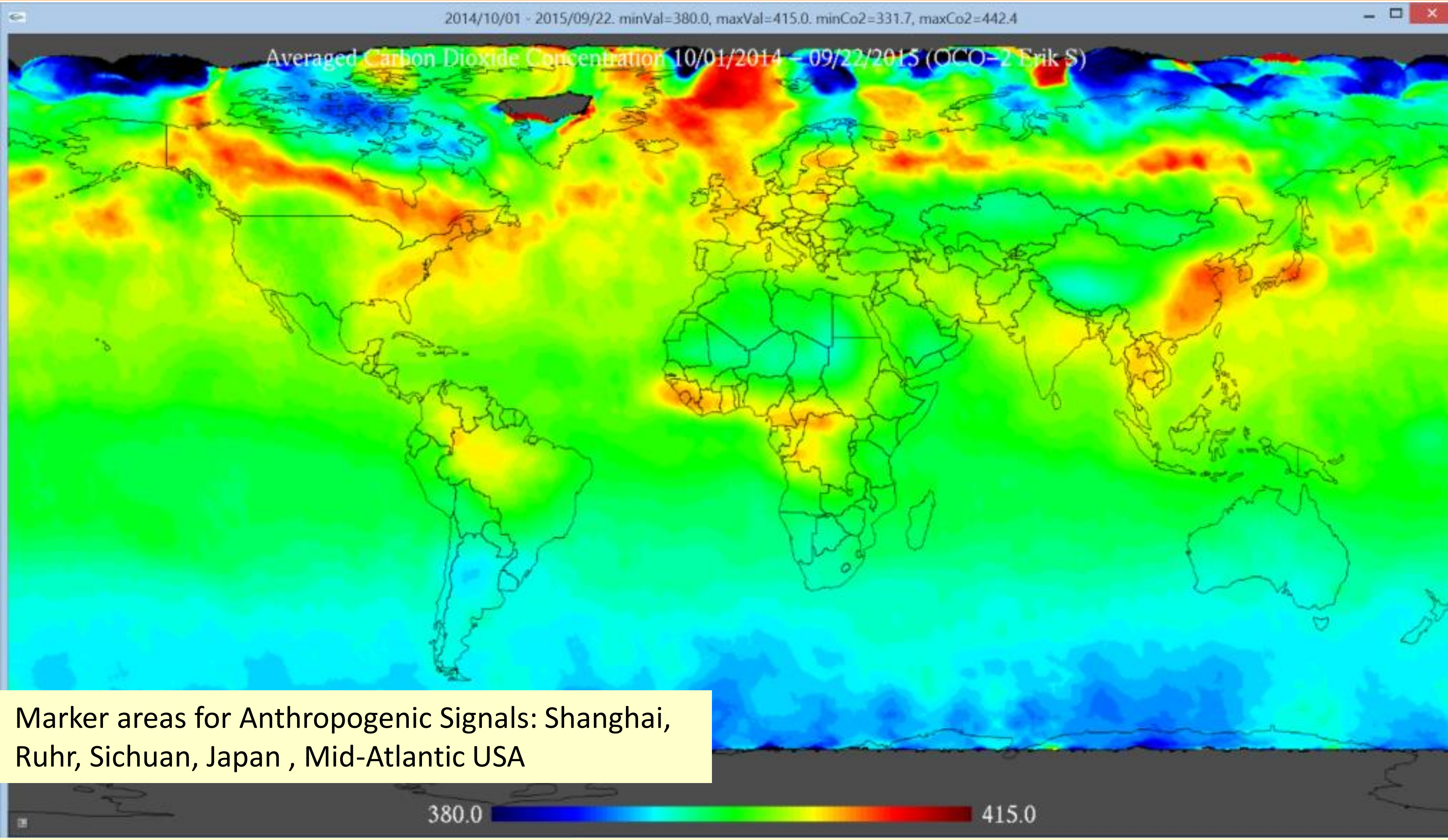
Last image set from Erik Swenson; paucity of data from the Southern Ocean.
NH -- end of summer, but plants ingesting large amounts of CO2, ➔ CO2 cool spots or CO2 slight deficits as plants in final growing spurt. Tibet: Grasslands growth spurt produces CO2 deficit. AFRICA: Sahel, blue indicates a growth spurt and a deficit of <CO2;> may not be typical (Sahel expansion and desertification cycles.) SH: Rotting Plants show CO2 hot spots Congo, Amazon.



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

ded carbon dioxide emissions in the year 2005 (unit ton CO2 per grid cell). pres

ANNUAL 1 Oct 2014 – 22 Sept 2015 Erik Swenson



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

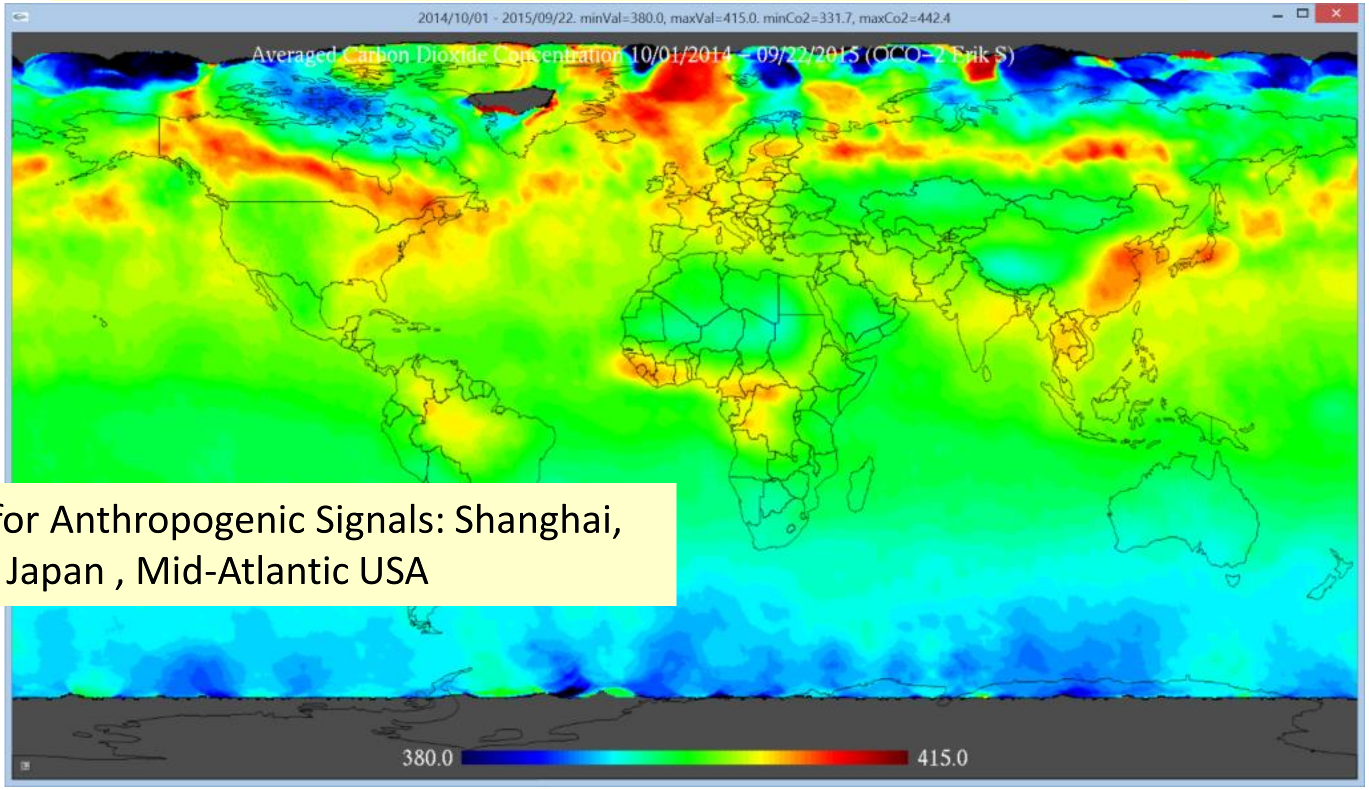
Arctic and Southern Oceans CO_2 sinks. Queen Elisabeth Islands to Repulse Bay, Canada –Sinks.

CO_2 sources: Beaufort Sea Mid Canada –Gaspe' Peninsula:.

Franz Joseph Land to Faroe, Shetland Islands CO_2 emissions (!) sources. (?)

North Pacific and NW Pacific, central Russia, CO_2 source areas.

What have we learned?   Annual chart , below



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

No large anthropogenic source areas indicated on the OCO-2 maps, because the marker signature is missing from Sichuan, Ruhr, Mid-Atlantic USA.

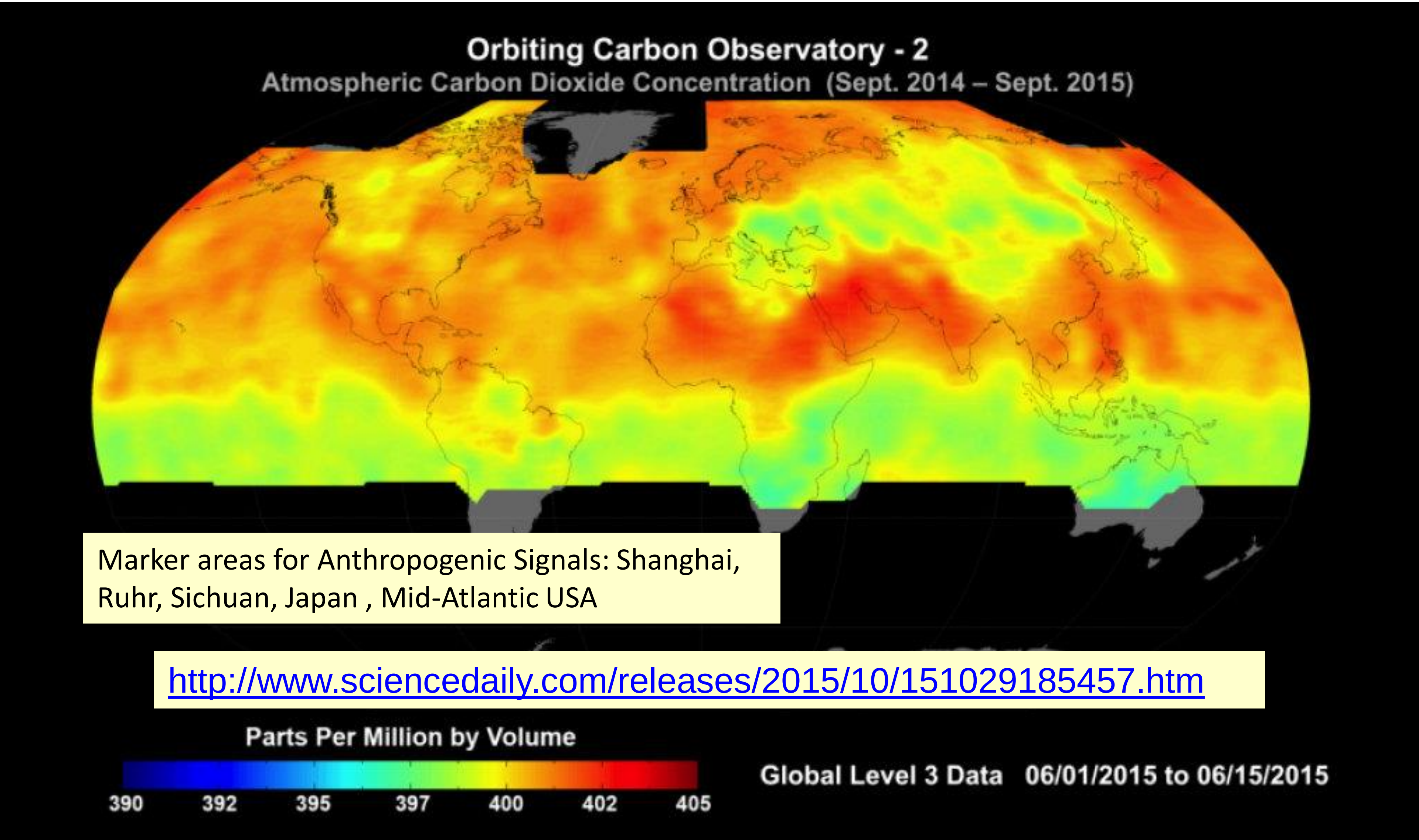
This result might have been expected if magnitude of anthropogenic sources, 5 GT C/ year

…was compared, e.g., with the natural sources from the oceans, 90 GT C/year.

…we saw these data in the Carbon Cycle diagrams from Dr. David Bice.

NASA's Visualization 1-15 June 2015

Downloaded 29 Oct 2015
Marker areas for Ruhr, Sichuan, Mid-Atlantic USA and Japan missing; Shanghai seems small WRT Arctic sources near Svalbard, Franz Josef Land, far East Russia.



Marker areas for Anthropogenic Signals: Shanghai, Ruhr, Sichuan, Japan , Mid-Atlantic USA

http://www.sciencedaily.com/releases/2015/10/151029185457.htm