Changing CO_2 seasonal amplitude: A synthesis

Ralph Keeling
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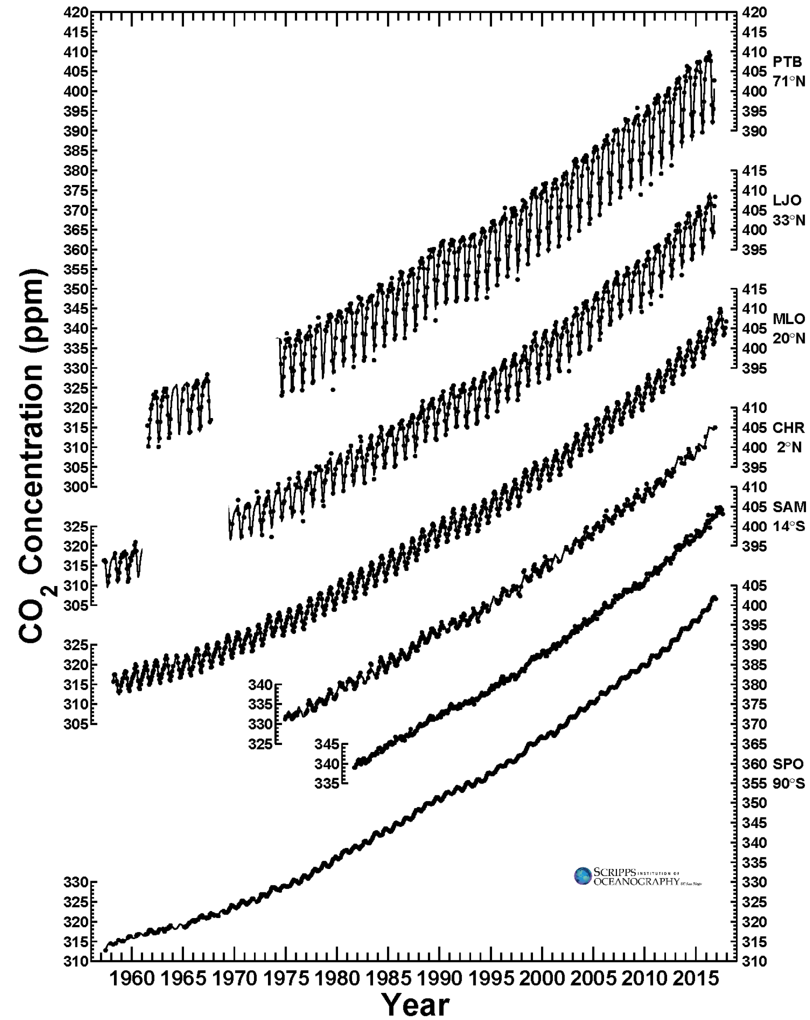
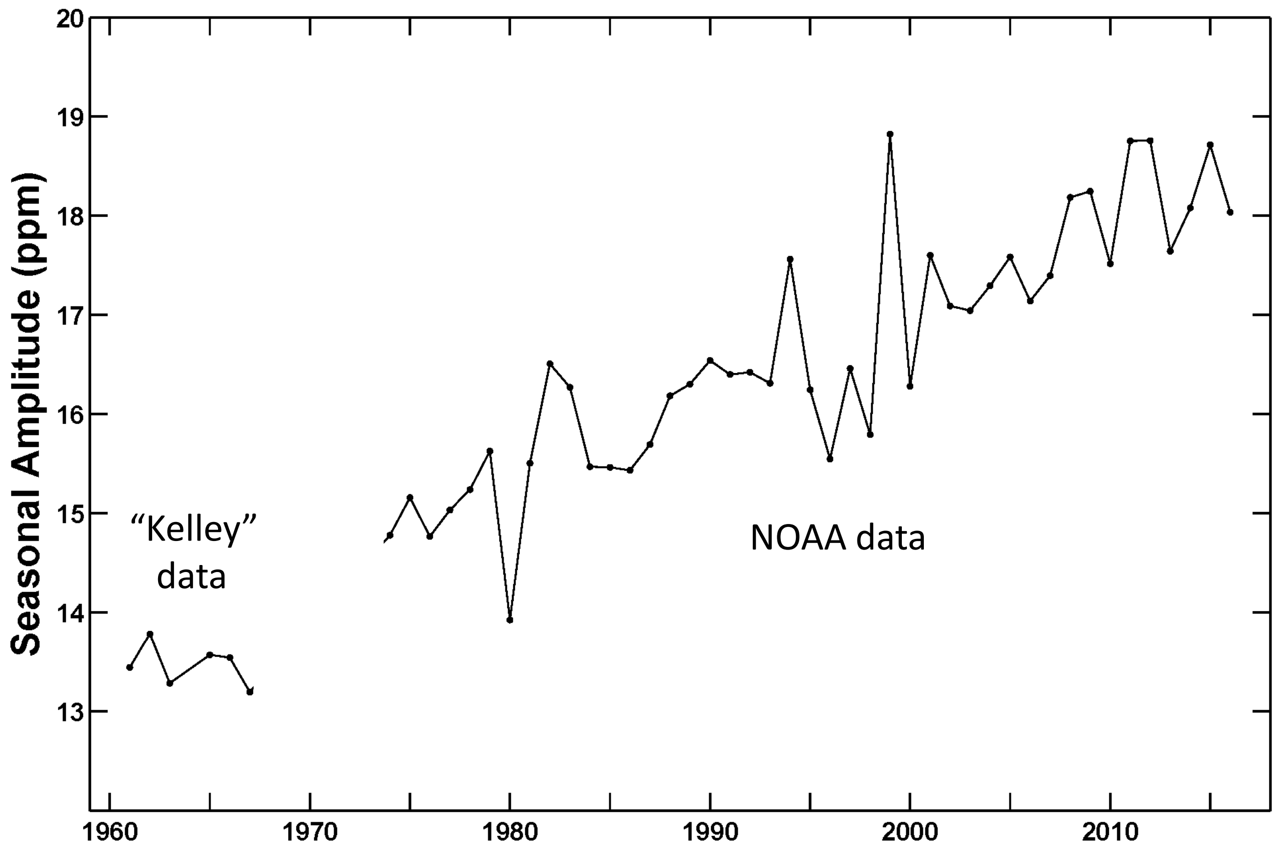


Barrow seasonal amplitude trend



Fall/winter bump, evidence for increased respiration (Piao et al., 2008, Nature)

Ciais/Piao et al next paper?

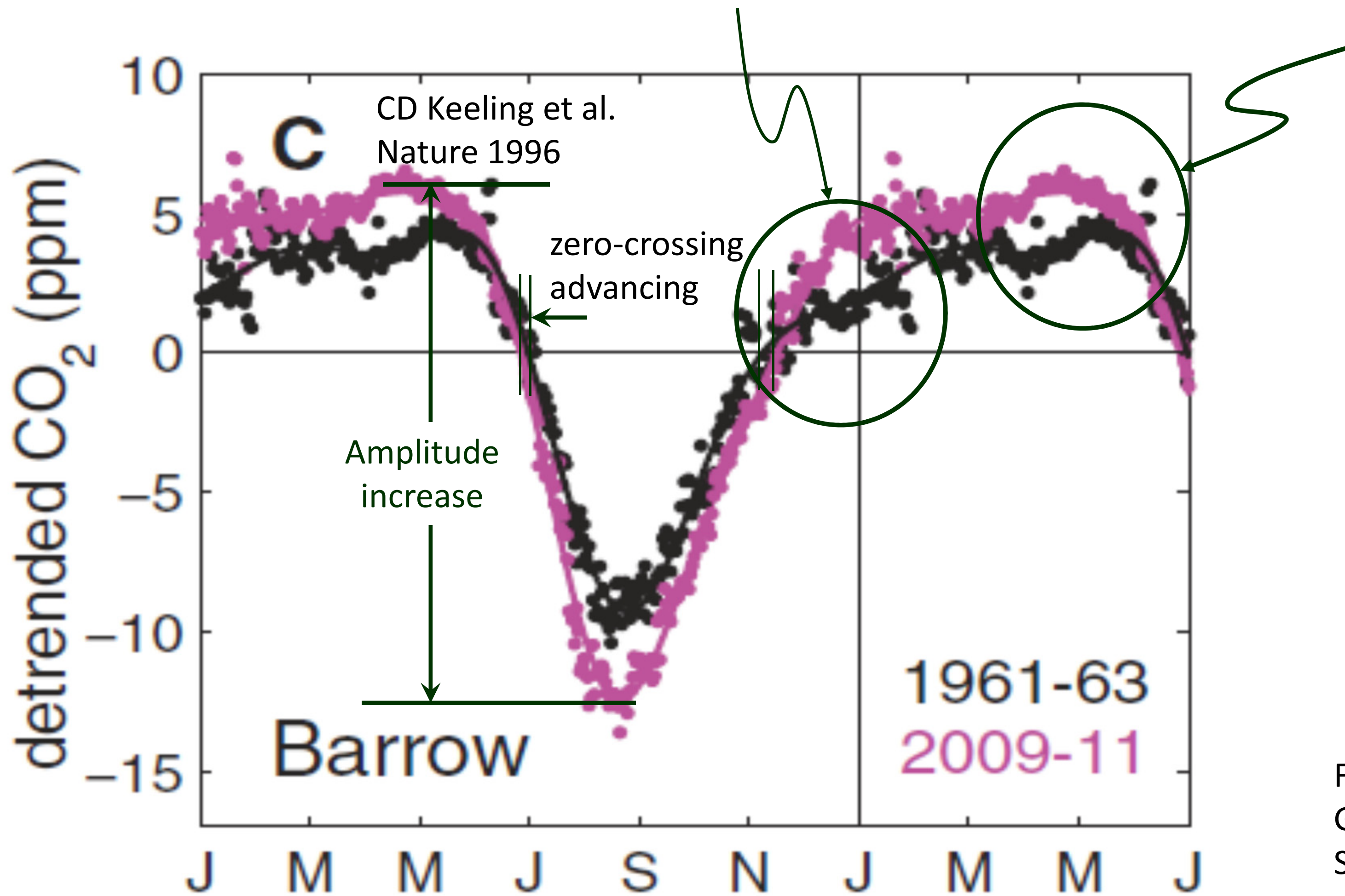
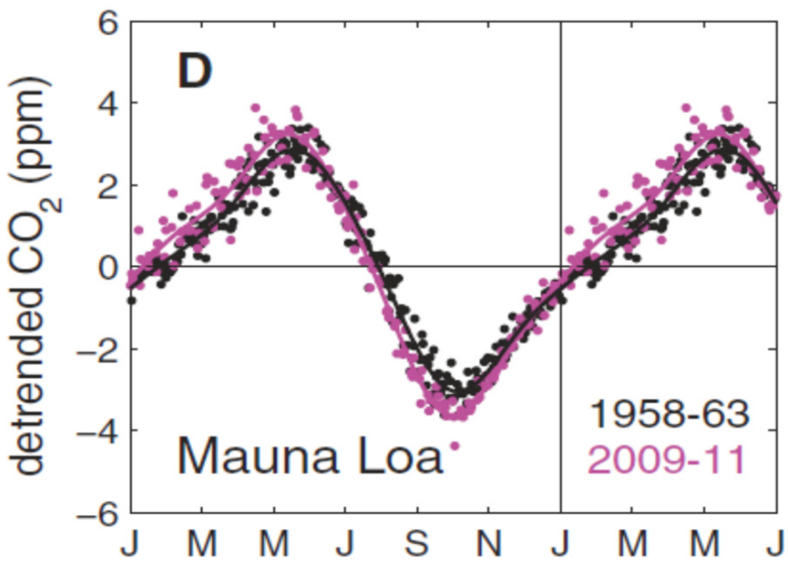


Figure from Graven et al Science 2013

~15% increase in 50 years



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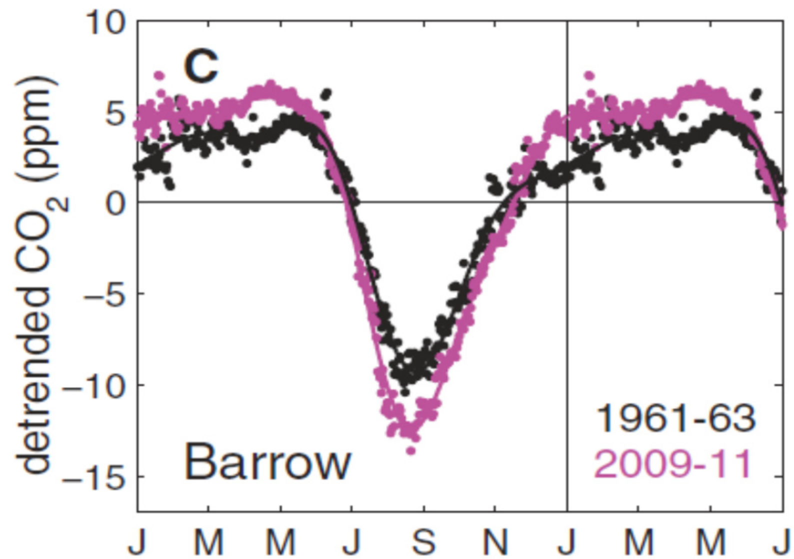
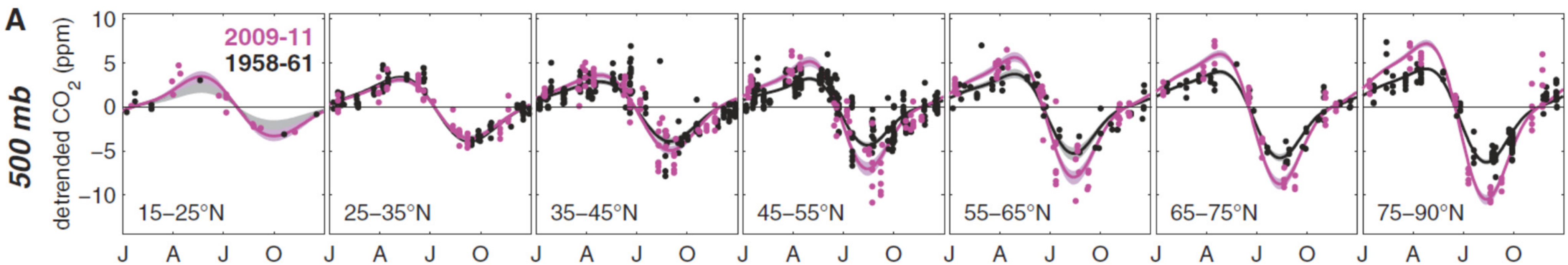
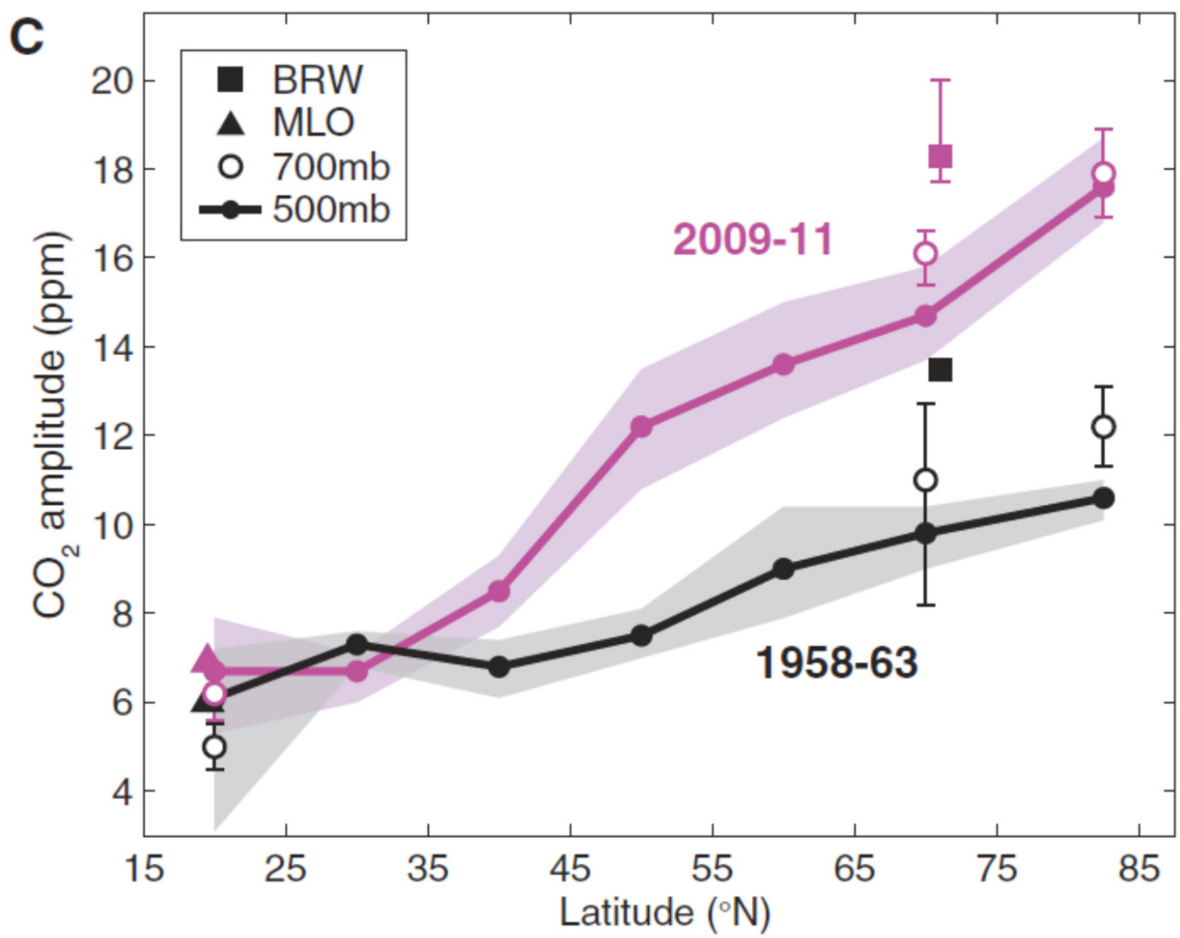


Figure from Graven et al.
Science 2013

Graven et al 2013, Science study

Compared airborne campaign data from ~1960 (IGY) and ~2010 (HIPPO)





Major conclusions:

% Changes in middle troposphere were larger than at either Barrow or Mauna Loa!

Longer growing season alone cannot explain changes. Uptake in mid summer must also have increased.

Relevance of crop changes

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Agricultural Green Revolution as a driver of increasing atmospheric CO_2 seasonal amplitude

Ning Zeng[1], Fang Zhao[1], George J. Collatz[2], Eugenia Kalnay[1], Ross J. Salawitch[1], Tristram O. West[3] & Luis Guanter[4]

Crop trends account for ~50% of amplitude trend at Mauna Loa and global average CO2

Direct human influence on atmospheric CO_2 seasonality from increased cropland productivity

Josh M. Gray[1], Steve Frolking[2], Eric A. Kort[3], Deepak K. Ray[4], Christopher J. Kucharik[5], Navin Ramankutty[6]† & Mark A. Friedl[1]

Account for 17 to 25% of amplitude trend detected from airborne data

How do models compare?

It depends on what signal is compared to!

(1) Mid-troposphere 50-year trend

(2) Surface stations in network since ~1980 (satellite era)

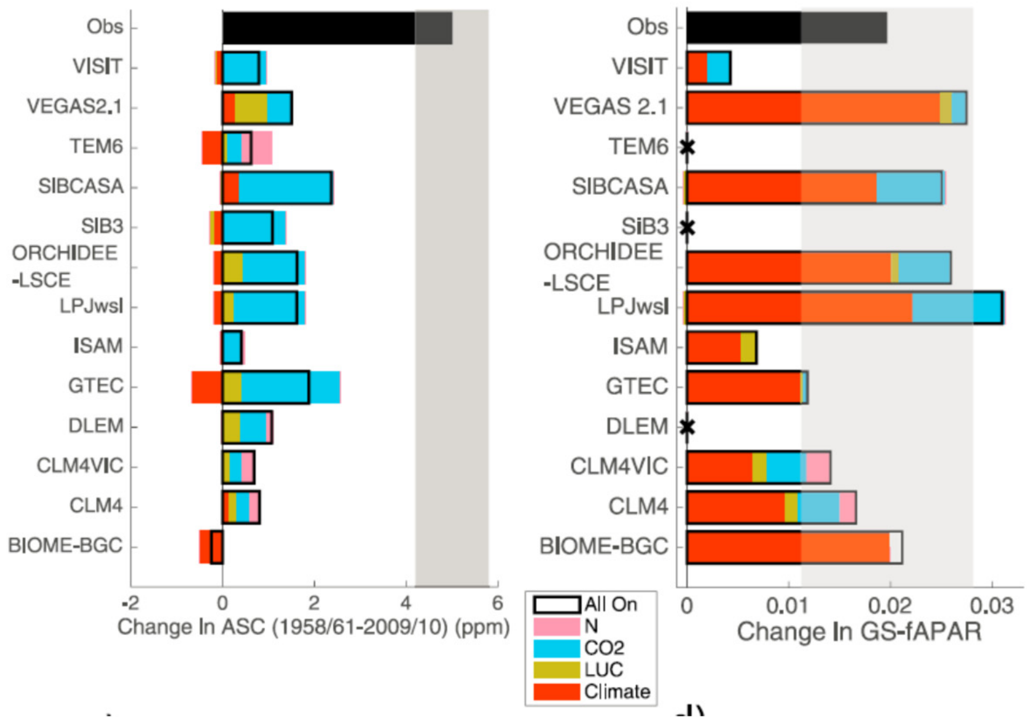
(3) Mauna Loa or global average CO_2

How do models compare?

Publication	Model(s)*	Mid trop 1960-2010	Surface stations since ~1980	Mauna Loa or global avg.
Graven et al. (2013)	CMIP5	All models too low		
Forkel et al. (2016)	LPJml		partial success	
Thomas et al. (2016)	MsTMIP	All models too low		
Wenzel et al. (2016)	CMIP5		partial success	
Ito et al. (2017)	MsTMIP			partial success

*All model studies suggest a larger role for changes in photosynthesis than respiration in driving amplitude changes

Models capture greening but not amplitude increases (Thomas et al., 2016)



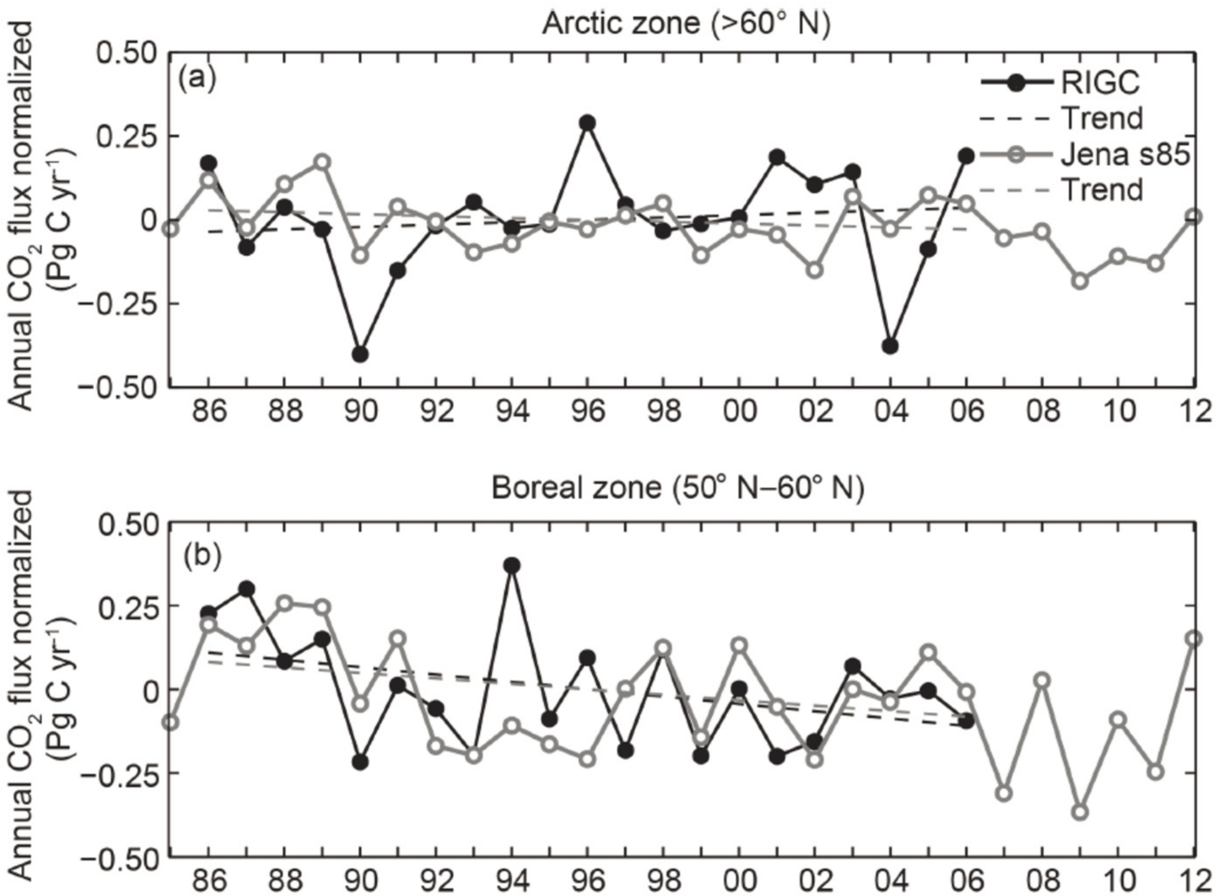
How is amplitude change related to northern land sink?

- Randerson (GBC, 1997) Amplitude increase consistent with ~2 Pg northern sink if driven by increase in NPP and passive respiration response.
- Welp et al. (Biogeosciences, 2016) resolve changes in amplitude and sink from inversions, 1985-2012.

  Boreal zone: strengthening annual sink (0.2 Pg/yr over 25 yrs)

  Arctic: No annual trend (to within 0.1 Pg yr).
- Commane et al. (PNAS, 2017) show Alaska trending towards stronger net source.

Welp et al (Biogeosciences, 2016)



Possible drivers of increases in June/July net CO_2 uptake:

(1) Warming-effect on photosynthesis (growing season, nitrogen, etc.)
(2) Leaf-level CO_2 fertilization effect
(3) Changes in vegetation: cover, structure, leaf area (woody encroachment, treeline migration)
(4) Changes in disturbance, especially fire
(5) Shifts in evergreen/deciduous

Some needs/objectives

Datasets:

- maps of deciduous vs evergreen fractions over time
- tree & understory cover over time
- snow depth over time
- stand age over time
- consistent long-term fire databases/records

Modelling:

- robust long-term inversions
- better constraints on long-term CO_2 fertilization responses
- warming effects on nutrient availability
- better representation of drought stress (esp. late summer)
- better phenology

Ongoing ABoVE efforts

Brendan Rogers et al. - Develop data driven model of seasonal amplitude changes

Colm Sweeney et al. - Atmospheric measurements and synthesis

Welp/Keeling et al. – Relationship between seasonal changes in CO_2 and $\delta^{13}C$

Roedenbeck/Keeling et al – Synthesis inversion from 1955 using T-based regression

Emily Wilson et al. – Miniaturized CO_2 and CH_4 column measurements (laser heterodyne)

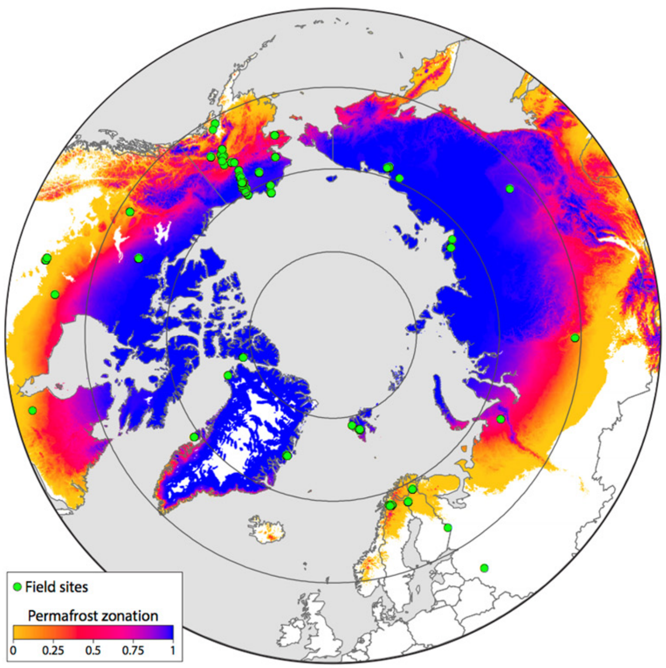
Ongoing research by Brendon Rogers et al

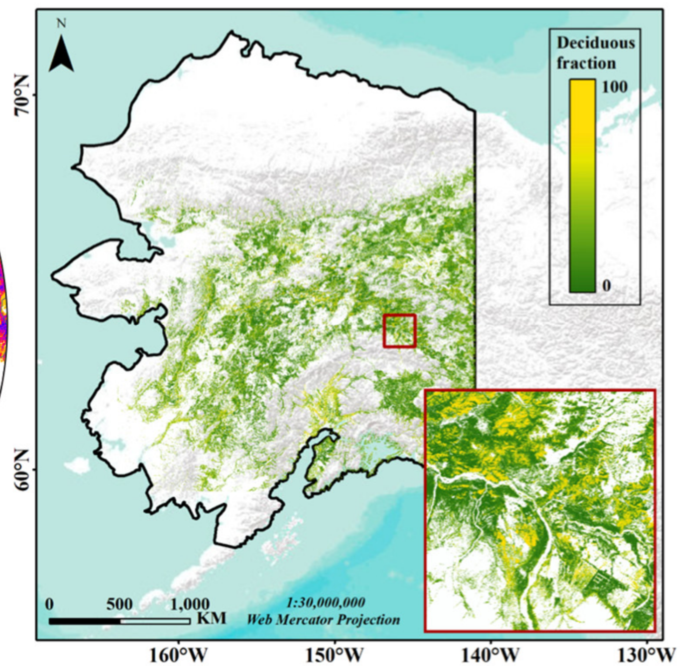
Provide a bottom-up, data-constrained, hypothesis-driven modeling assessment of increasing CO_2 amplitudes

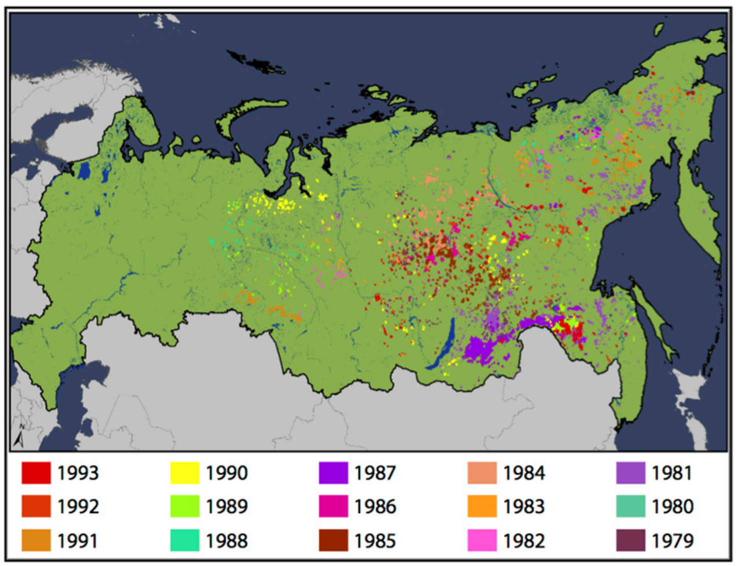
Synthesis of *in situ* CO_2 fluxes → Gridded monthly flux products

Landsat-based deciduous fraction → Time series of Plant Functional Types

AVHRR-based fire history for Siberia → Circumpolar records of fire disturbance







Mini-LHR Update

For more info contact: Emily Wilson/614
Emily.L.Wilson@nasa.gov, 301-614-6730

Overview: The mini-LHR is a miniaturized laser heterodyne radiometer that measures column CO_2 and CH_4 (precision 1 ppm CO_2, 10 ppb CH_4 for one hour data products for clear sky conditions)

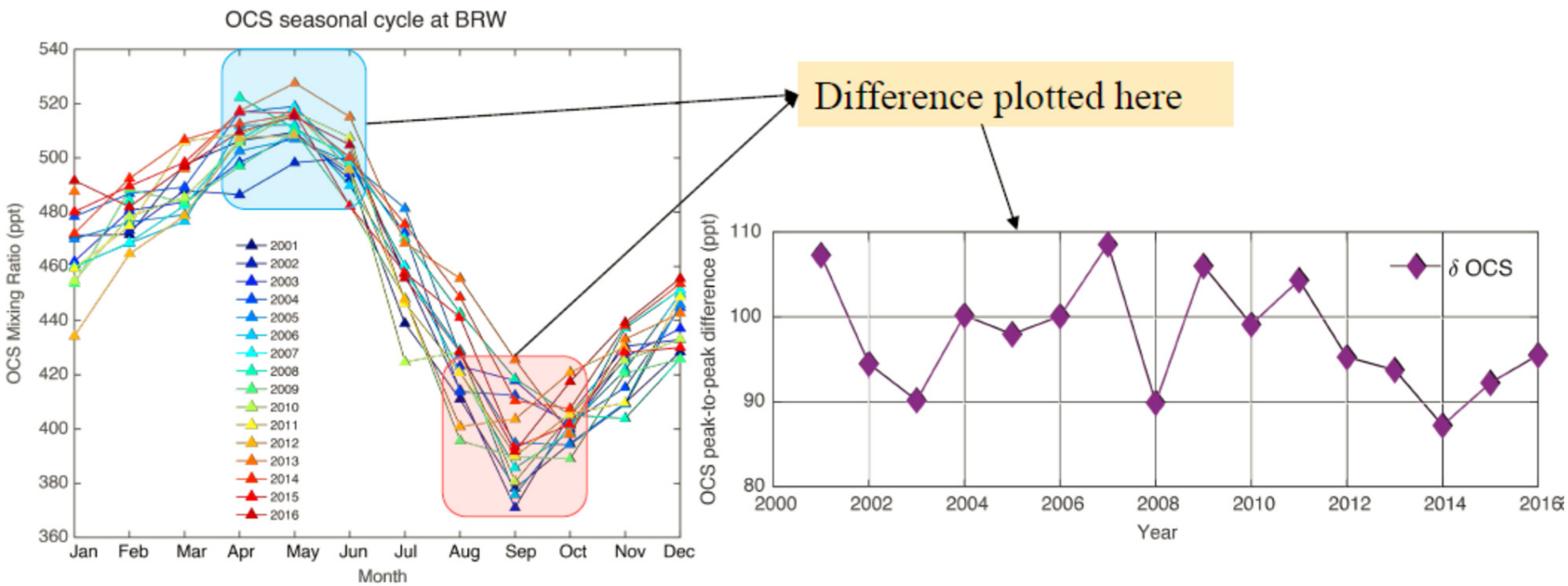
Status:

- Analysis software uses Planetary Spectrum Generator and MERRA data. More info: https://psg.gsfc.nasa.gov, contact Geronimo Villanueva, geronimo.l.villanueva@nasa.gov).
- Mini-LHR is now completely solar powered and fits on a backpack for access to remote areas.
- Side-by-side comparison with TCCON at Armstrong planned late spring 2018.
- **Current instrument cost is ~$10K.** It is not commercially available yet – but we are building the first 20 for teams to test.

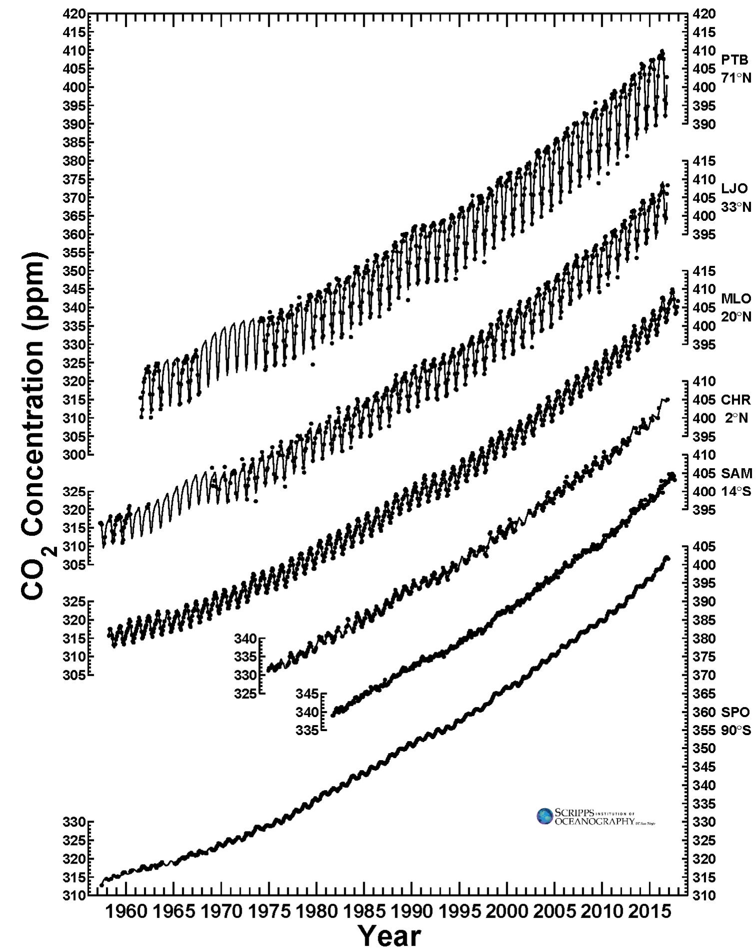
Look for column CO_2 and CH_4 data sets coming to our webpage (https://mini-lhr.gsfc.nasa.gov/) in Spring 2018:

- Hi-SEAS (https://hi-seas.org/), & MLO
- Bonanza Creek Research Forest
- Edinburgh Scotland (Royal Observatory)
- Amazon river basin

OCS seasonal cycles - work in progress by Abhishek Chatterjee



Thank You



PTB 71°N
LJO 33°N
MLO 20°N
CHR 2°N
SAM 14°S
SPO 90°S
CO_2 Concentration (ppm)
Year
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