# Examining the effect of seasonal changes in canopy structure on biosphere-atmosphere $CO_2$ exchange.

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# Changes in

# the phenology of trees

Climate is changing, and so are seasonal cycles.

But how much, and what does this mean for C cycling?

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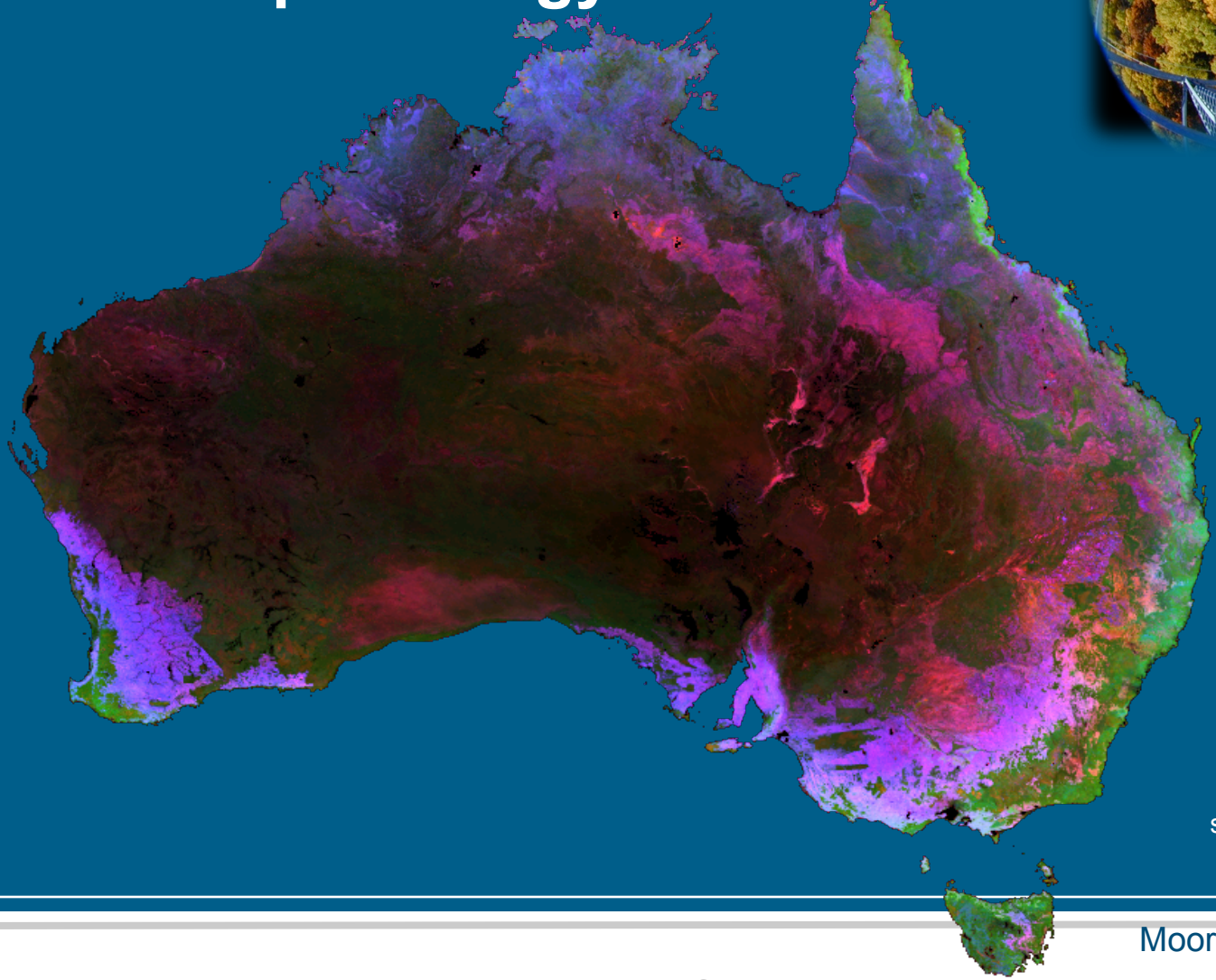
Vol 451|3 January 2008|doi:10.1038/nature06444 nature

LETTERS

## Net carbon dioxide losses of northern ecosystems in response to autumn warming

Shilong Piao[1], Philippe Ciais[1], Pierre Friedlingstein[1], Philippe Peylin[2], Markus Reichstein[3], Sebastiaan Luyssaert[4], Hank Margolis[5], Jingyun Fang[6], Alan Barr[7], Anping Chen[8], Achim Grelle[9], David Y. Hollinger[10], Tuomas Laurila[11], Anders Lindroth[12], Andrew D. Richardson[13] & Timo Vesala[14]

# Changes in the phenology of trees




Moore et al. (in review)

Image credit: Albert van Dijk

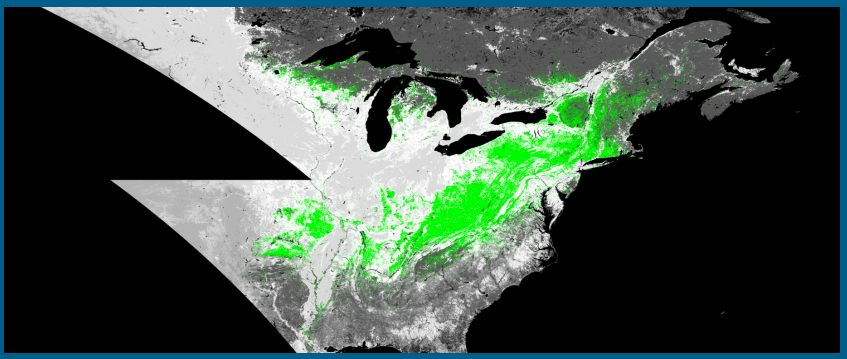
# Changes in the phenology of trees

Climate is changing, and so are seasonal cycles.

But how much, and what does this mean for C cycling?

Examine diverse **datasets** at different scales, **and** land surface **models**

- Satellite observations (MODIS reflectance)
- Eddy-covariance data at 7 sites in the northeastern US
- Ground observations of individual trees
- 21 land surface models



# Data caveats 1

## MODIS – 8-day and daily:

- All DBF pixels in the eastern US @ 500m$^2$ res.
- MODIS daily reflectance of R,G,B,NIR
  1. EVI
  2. NDVI
  3. GCC
- Two date estimation methods:
  1. Greendown logistic model (Elmore et al., 2012 Global Change Biology)
  2. Robust smoothing spline approach (Keenan et al., 2014 Ecological Applications)

# Data caveats 2

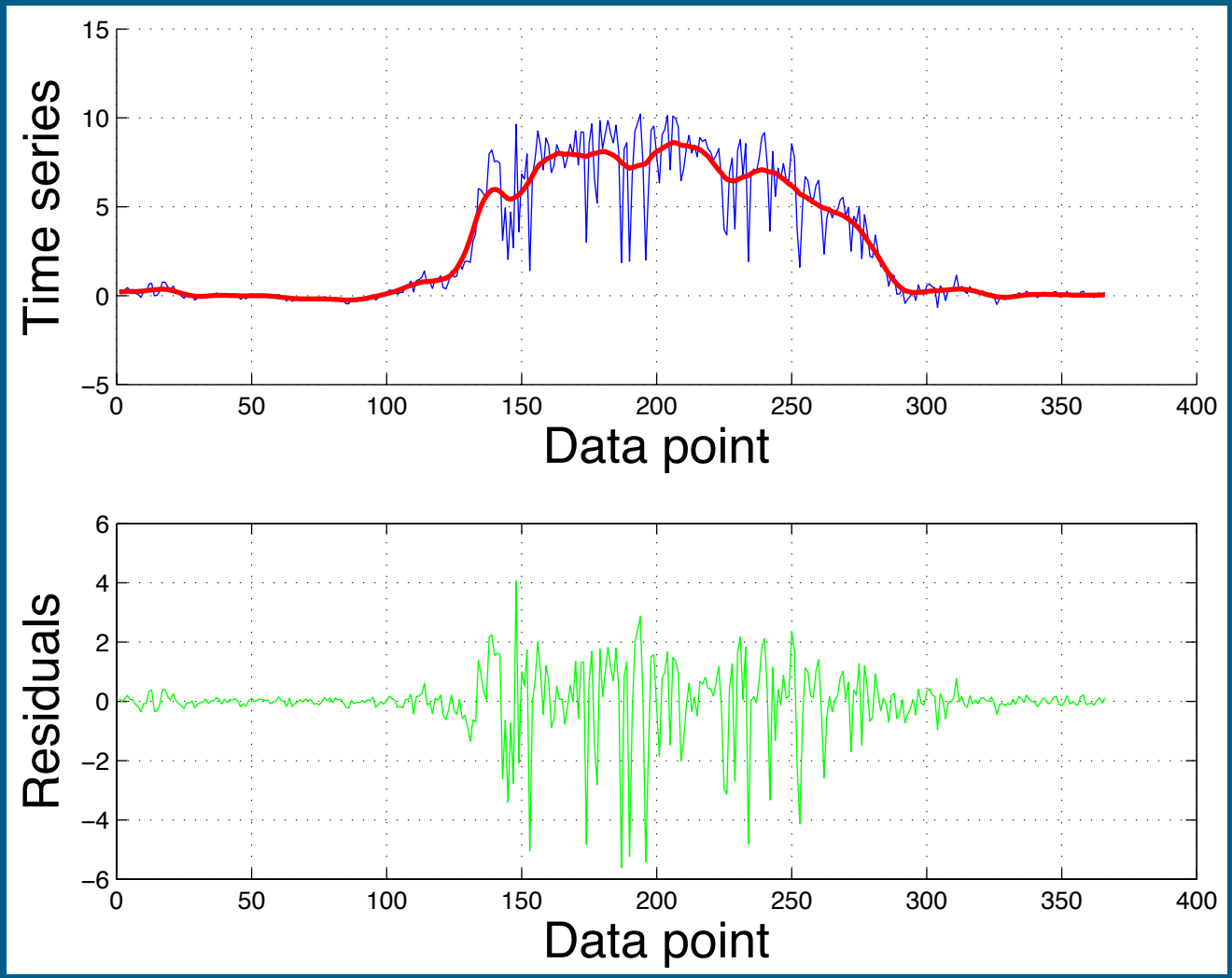
## Phenology from eddy-covariance flux data:

Developed a new method based on singular spectrum analysis

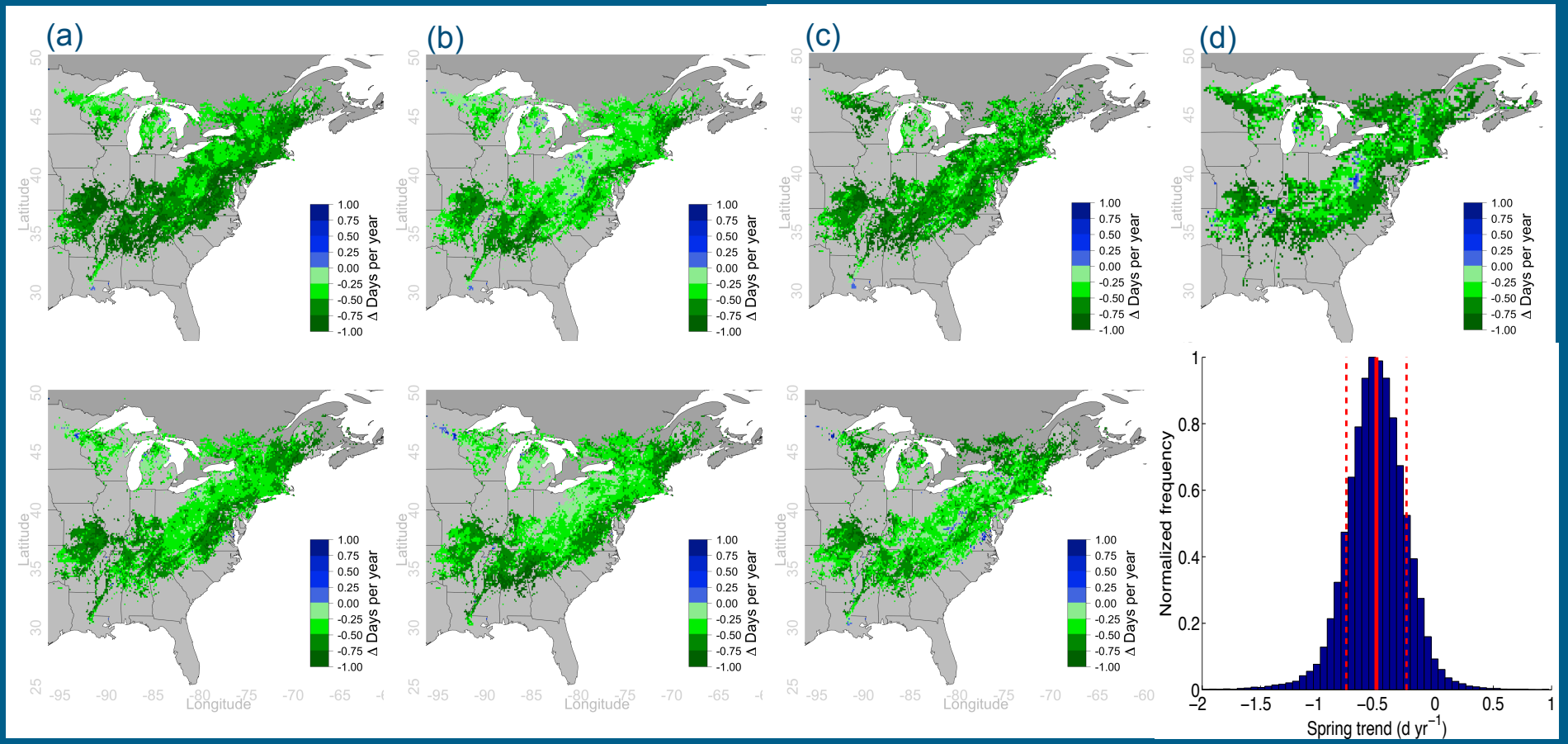
1. Decompose the time series into different modes of variability
2. Extract the underlying seasonal cycle of each year
3. Identify phenology dates on a threshold of annual amplitude basis

This approach greatly reduces the impact of random variability on phenological date estimation.

# Identifying seasons:



# **Results**: Long-term changes in satellite estimates of phenology



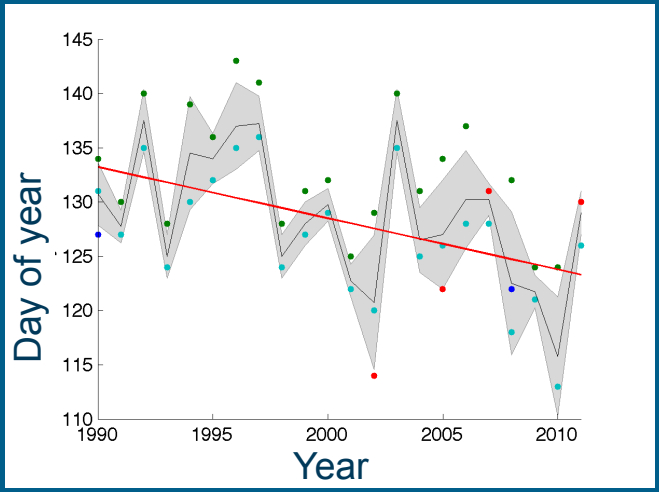

*Keenan et al. (2014) Nature Climate Change*

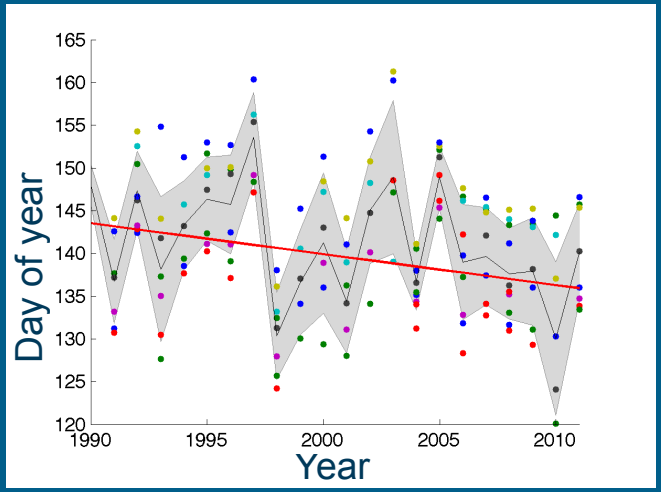
# **Results:** Ground observations of phenology

Hubbard Brook

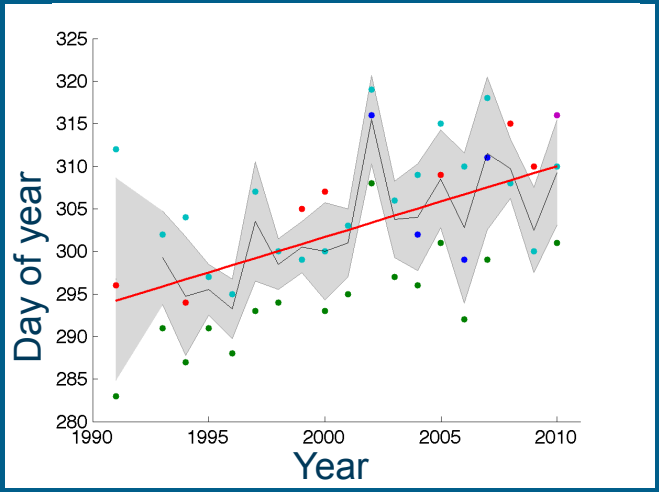
Harvard Forest

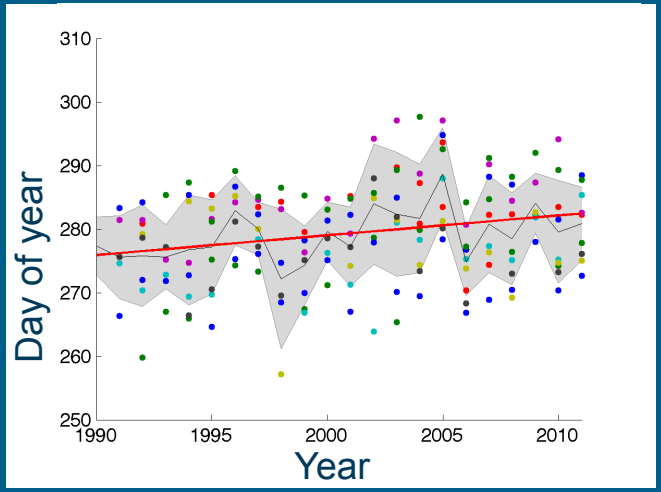
Spring is getting earlier



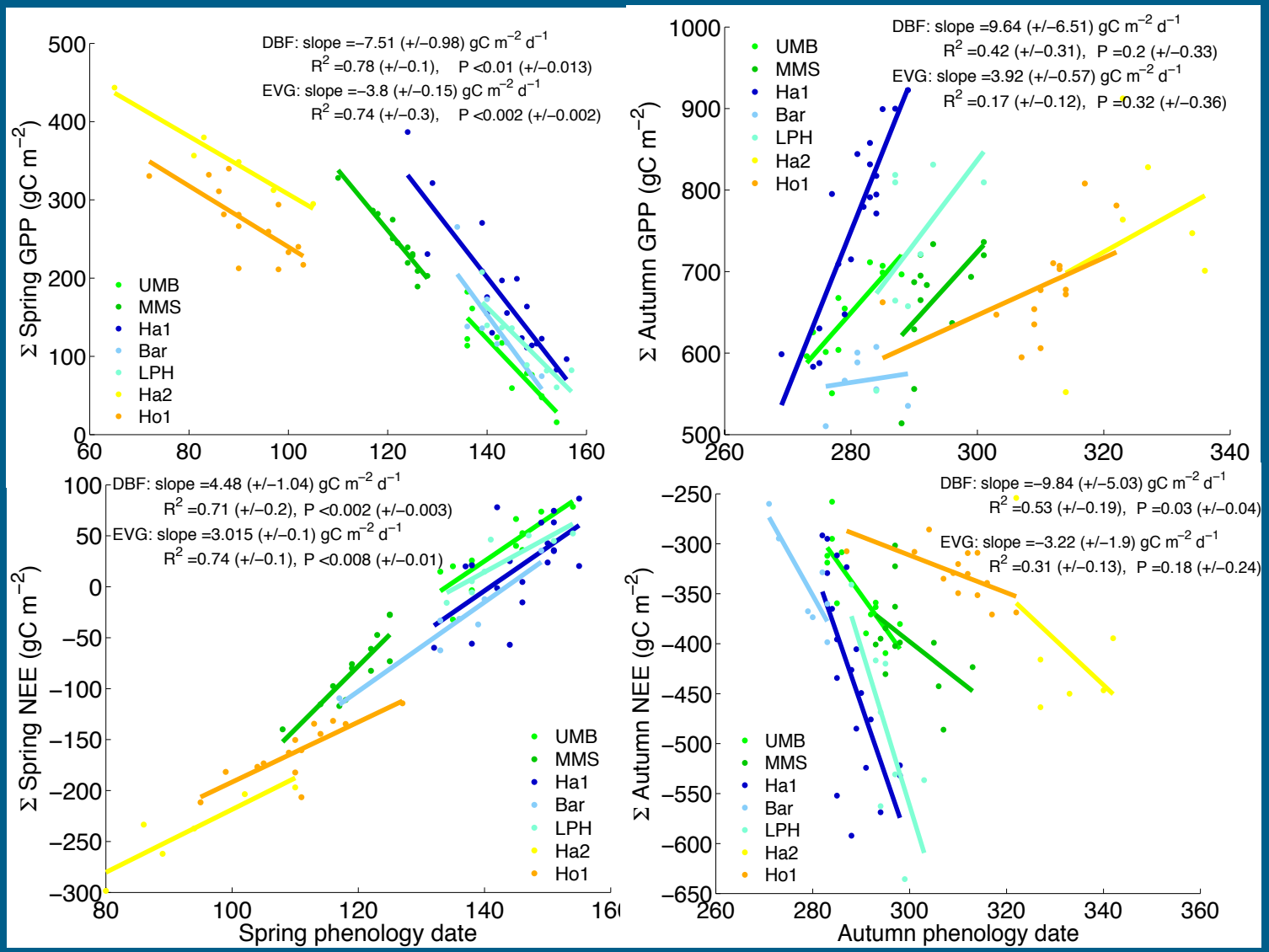

Autumn is getting later




*Keenan et al. (2014) Nature Climate Change*

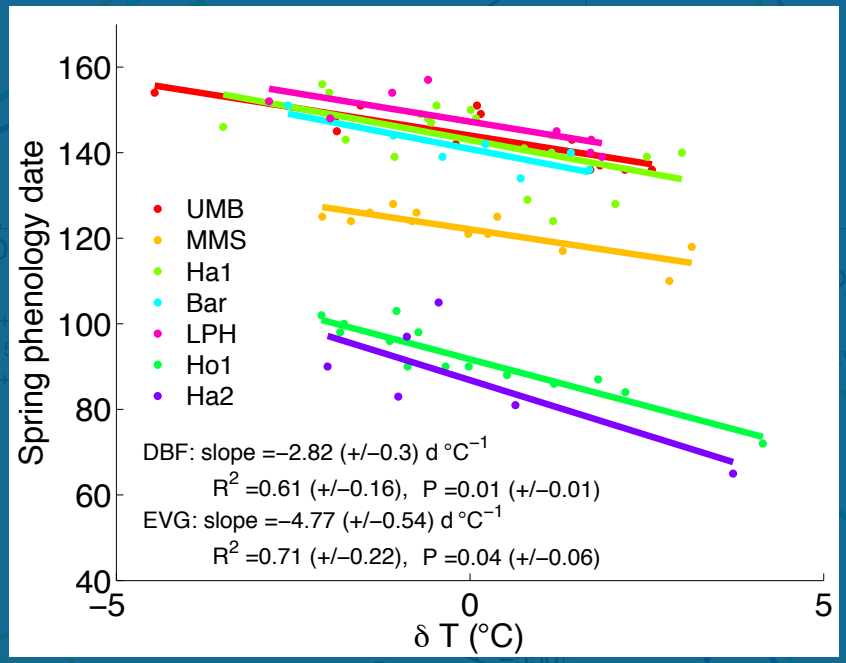
# **Results:** The impact on carbon cycling




*Keenan et al. (2014) Nature Climate Change*

# **Results:** The impact on carbon cycling

## The temperature sensitivity of phenology

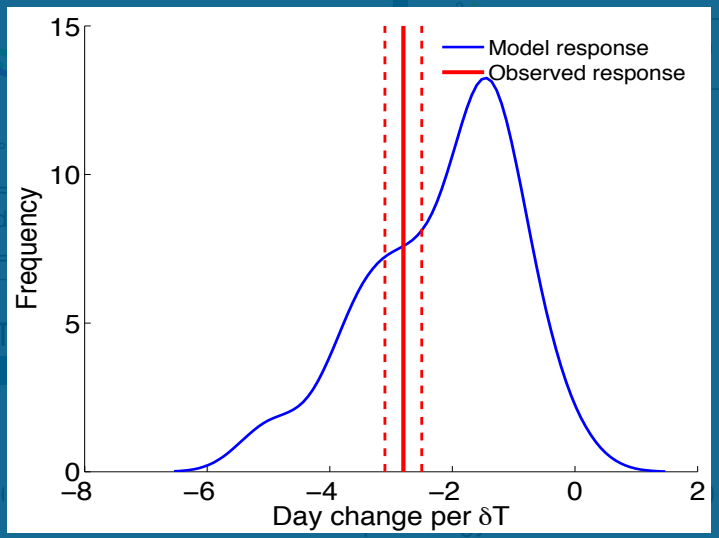



*Keenan et al. (2014) Nature Climate Change*

# **Results:** The impact on carbon cycling

The temperature sensitivity of phenology

The performance of land surface models

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## Conclusions:

1. Consistent changes in phenology can be identified in datasets at different scales
2. Changes in phenology are leading to increased carbon uptake, both in spring and autumn
3. The temperature dependence of phenology is highly conserved across sites
4. Models do not get this temperature dependence right

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# Thank you!

Andrew Richardson
Mark Friedl
Josh M Gray
Michael Toomey
Gil Bohrer
David Hollinger
Bill Munger
HaPe Schmid
Ian Sue Wing
Bai Yang
Amey Bailey - Hubbard Brook Experimental Forest
NOAA, DOE, Macquarie University Fellowship
FLUXNET PIs, AMERIFLUX, NACP