Revisiting the First ISLSCP Field Experiment to evaluate water stress in JULES 5.0

Karina Williams, Anna Harper, Chris Huntingford, Lina Mercado, Camilla Mathison, Pete Falloon, Peter Cox, Joon Kim,

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Motivation

- The 'soil moisture stress on vegetation' JULES Process Evaluation Group is collecting together lots of site runs (see JPEG session tomorrow)
- FIFE data was used to develop the original soil moisture stress scheme in MOSES (Cox et al 1998).
- So, it makes sense to revisit the FIFE dataset for the JPEG evaluation work.

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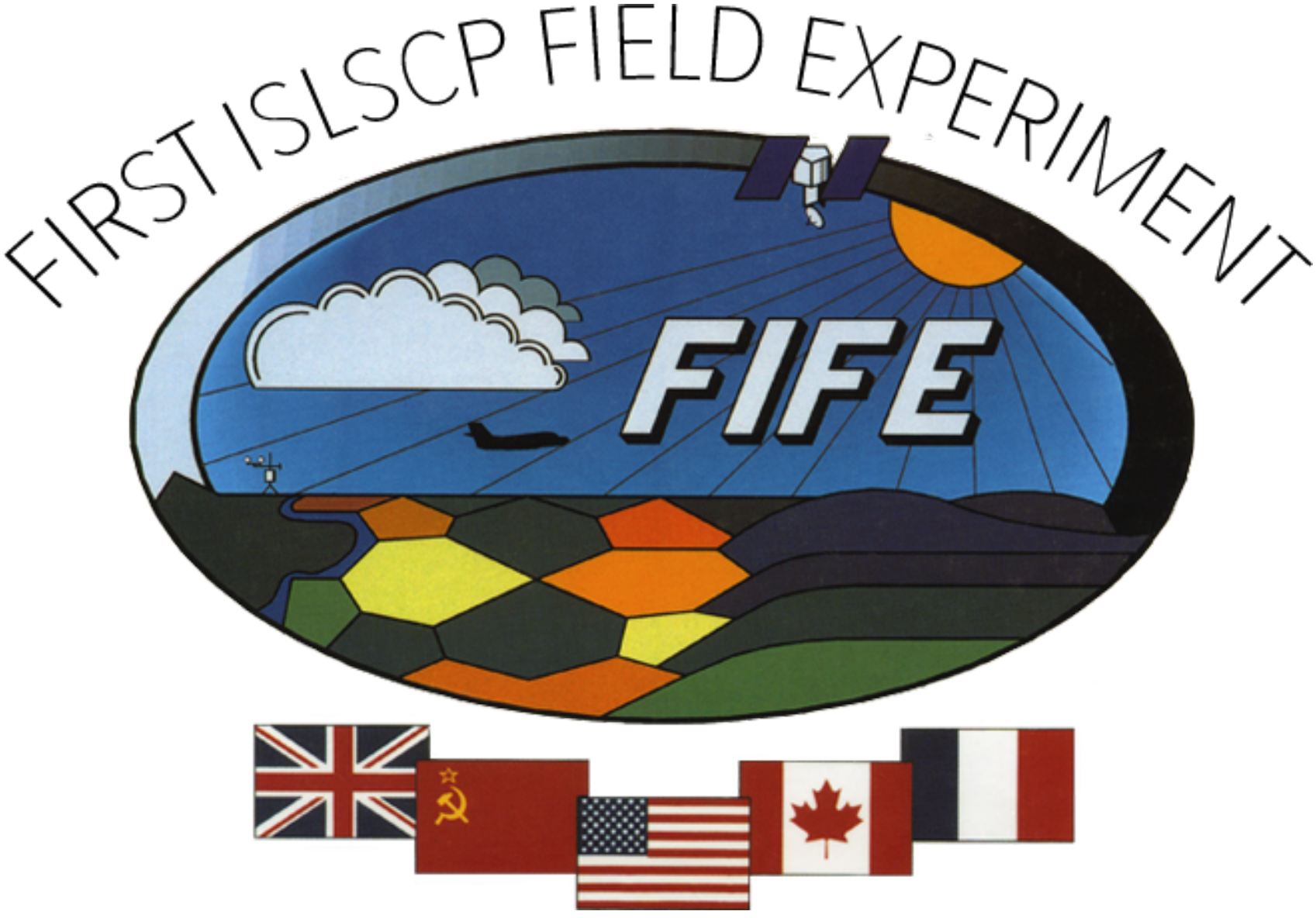
FIRST ISLSCP FIELD EXPERIMENT
FIFE

First ISLSCP Field Experiment

- The International Satellite Land Surface Climatology Project (ISLSCP) was formed in 1983.

- Their first field experiment, FIFE, aimed to
  - improve the representation of land surface-atmosphere interactions in GCMs
  - develop new methods for using satellite data to initialise and validate the improved parameterizations.

'The FIFE experiments are at the center of NASA's plan to develop a physically based approach to the use of satellite remote-sensing systems and a key component of ISLSCP'

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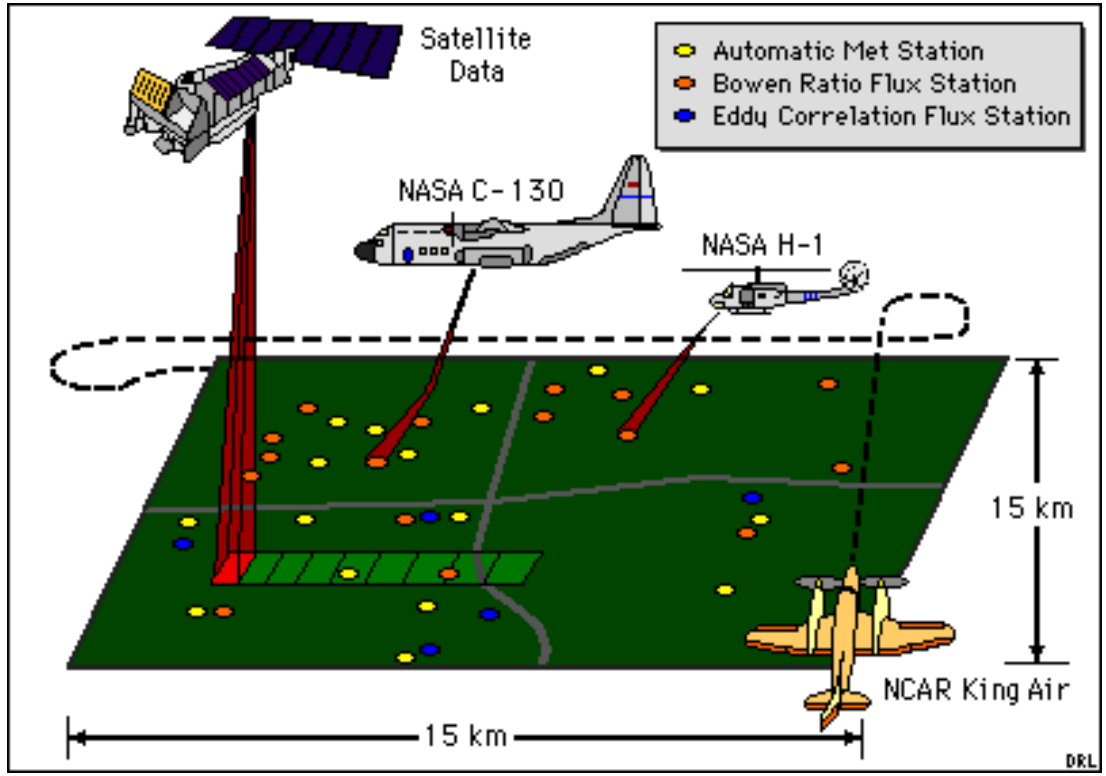
FIFE campaigns 1987-9

- Study area: 15km x 15km tallgrass prairie, Kansas, US.
- Involved around 150 scientists, aircrew and students, 8 aircraft, 16 automated met stations.
- Gravimetric soil moisture surveys, streamflow data and biometric measurements.
- AVHRR, Landsat, SPOT, GOES satellite data



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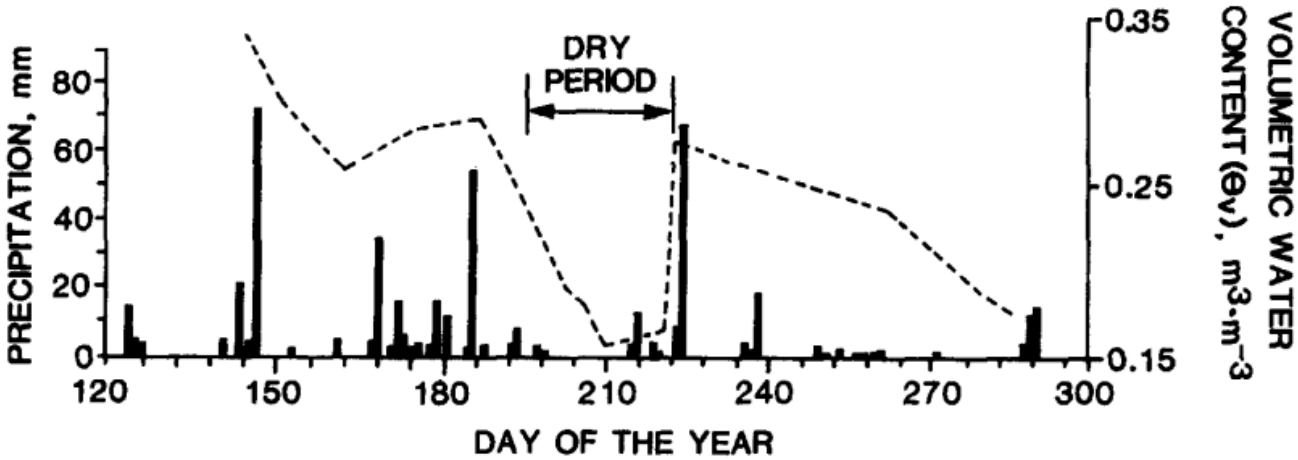
FIFE site 4439

- The original soil water stress parameterisation in JULES is based on data taken at one of the FIFE sites (4439) in 1987.
- This site was
  - burned April 1987
  - mostly (>80%) C4 grass
  - ungrazed
  - intensively measured and modelled



Plot: *Kim and Verma 1990*

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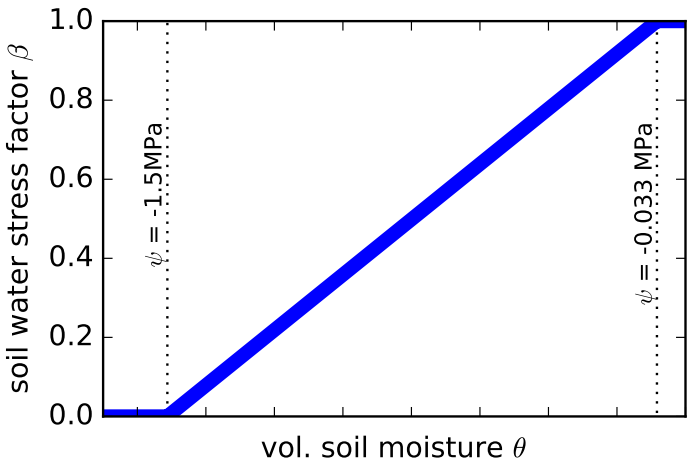
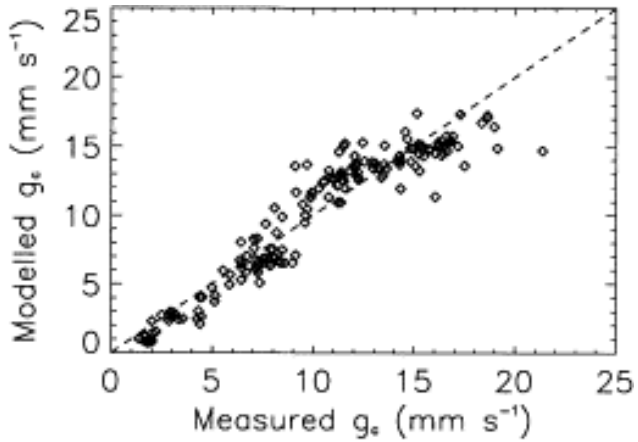
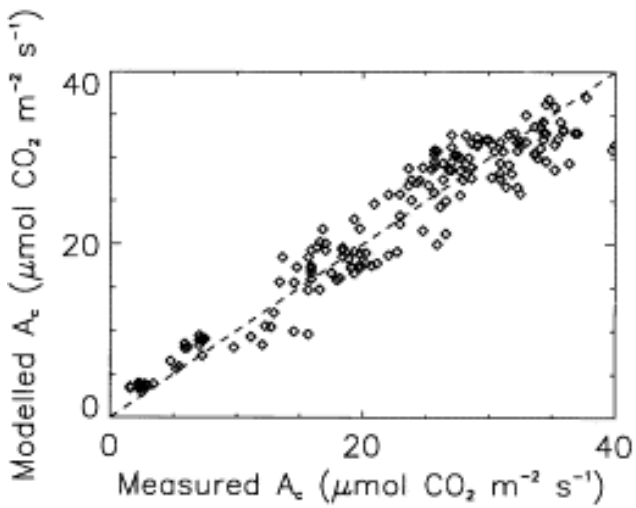
FIFE site 4439 and Cox et al 1998

- Cox et al 1998 used data from this site to develop the original soil moisture stress parameterisation used in JULES: a factor β that scales net leaf photosynthesis.







Plot: *Cox et al 1998*

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FIFE site 4439 and JULES 5.0

We tried 3 different configurations:

- `repro-cox-1998`: reproduces the original Cox et al 1998 study as closely as possible. 'Big leaf' canopy, prescribed LAI and soil moisture, β from the top 1.4m of soil.
- `global-C4-grass`: uses Harper et al 2016 configuration but with prescribed LAI and soil moisture. Site is modelled as 100% C4 grass.
- `tune-leaf`: as above, but using FIFE leaf observations to calibrate the JULES leaf parameters.

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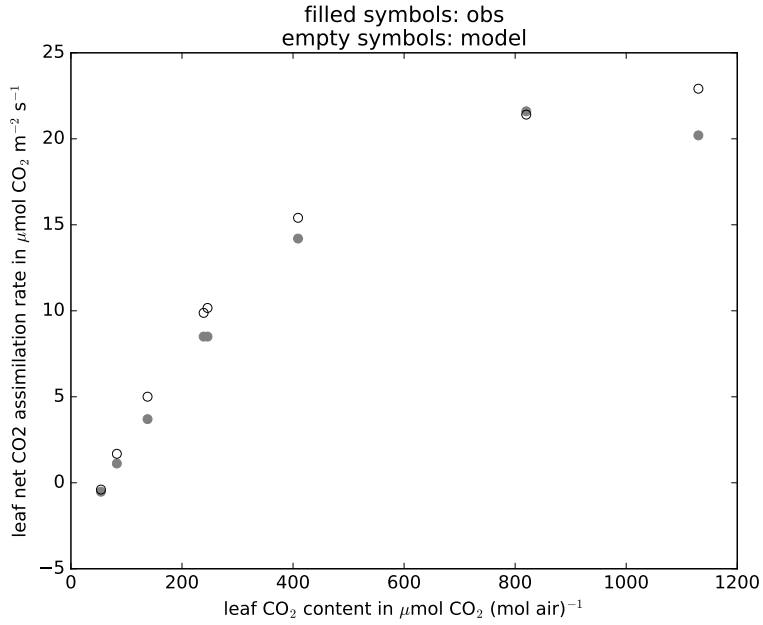
Leaf Simulator

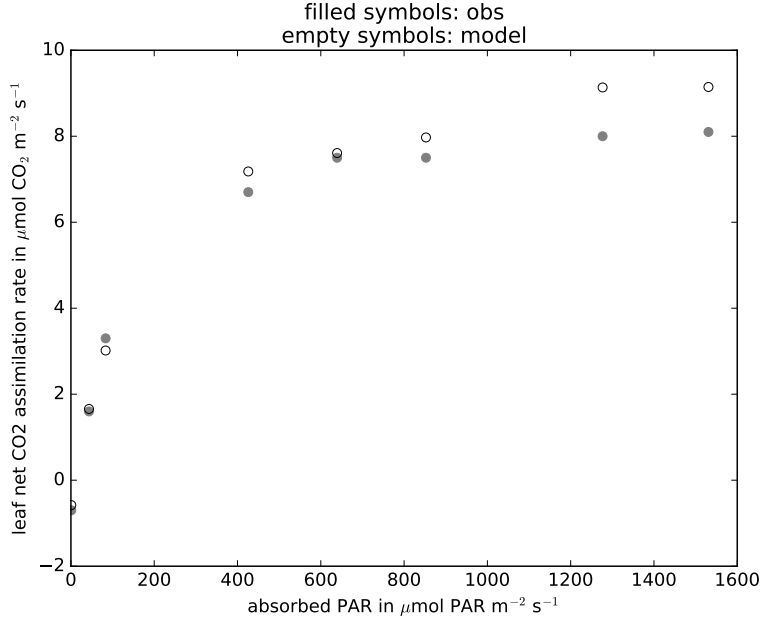
- We used the Leaf Simulator python package to calibrate the JULES leaf photosynthesis parameters to LICOR gas exchange chamber measurements.
- It can be called from the command line, or imported into python scripts.

Leaf Simulator

Karina Williams, Debbie Hemming, Anna Harper, Lina Mercado

https://code.metoffice.gov.uk/trac/utils/wiki/leaf_simulator





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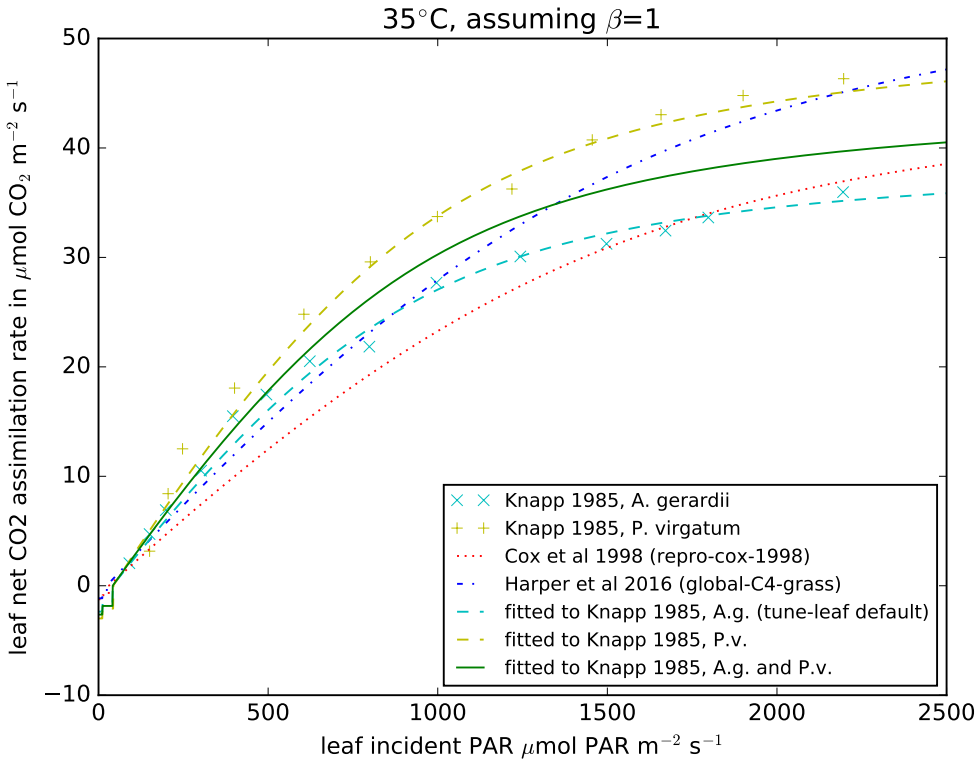
Calibrating to observed light curves



Andropogon gerardii (Big bluestem)

Panicum virgatum (Switchgrass)

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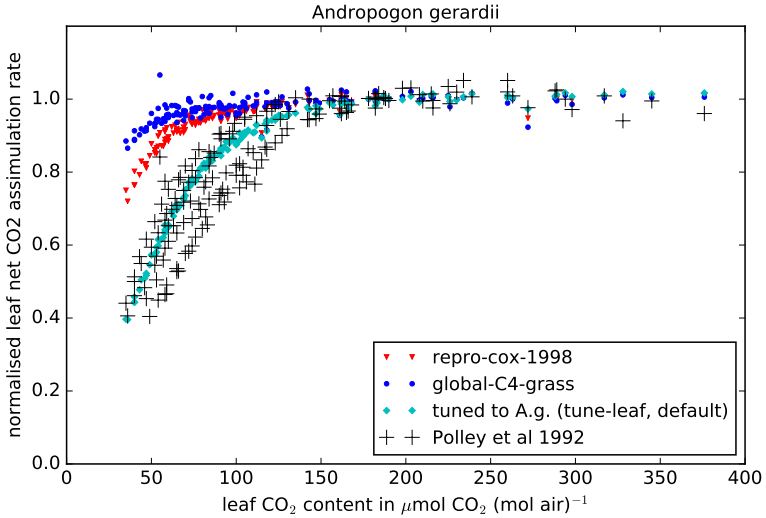
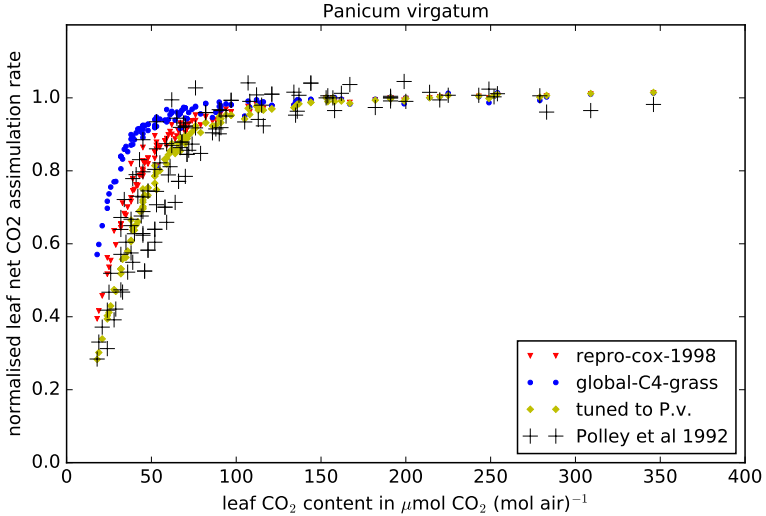
Calibrating to observed CO_2 curves



Andropogon gerardii (Big bluestem)



Panicum virgatum (Switchgrass)

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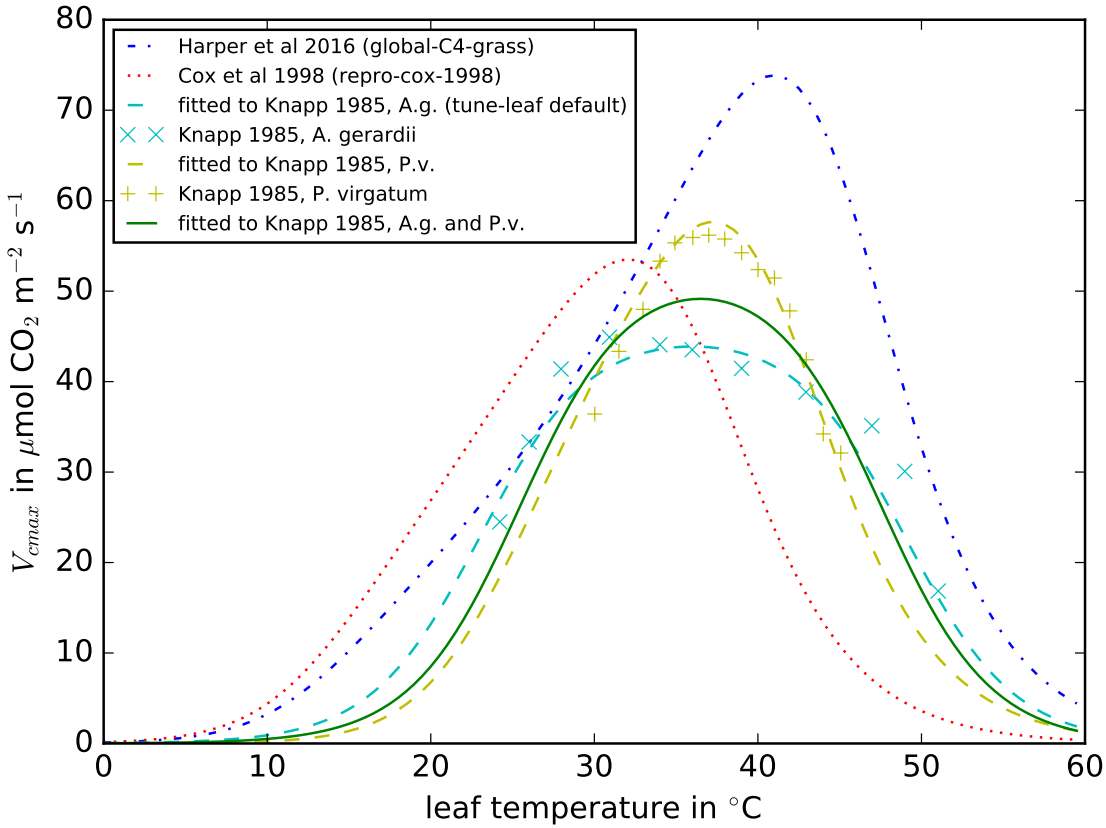
Calibrating temperature dependence



- In JULES, the temperature dependence of net leaf assimilation for C4 plants is via the maximum rate of carboxylation of Rubisco V_{cmax}

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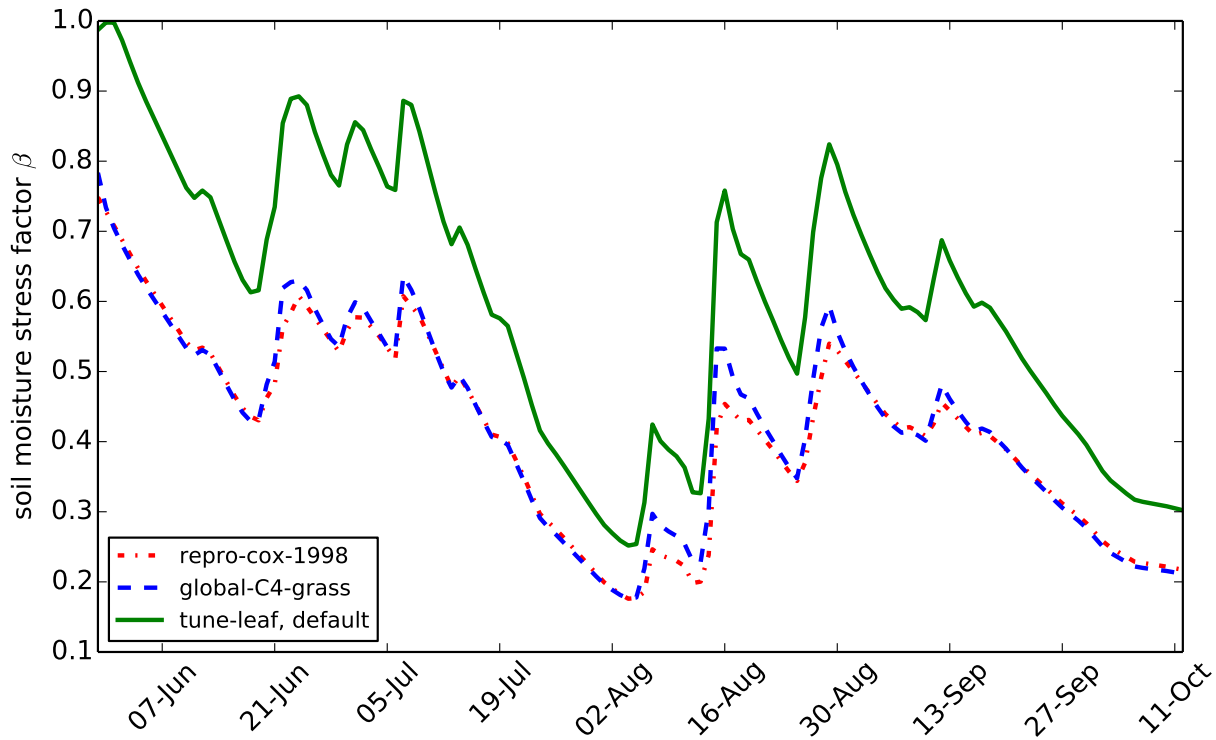
Calibrating early season stress

- Other studies and leaf potential observations indicate that the grasses are not under much stress in early June 1987
- So, for tune-leaf, we reduce the threshold for soil moisture stress



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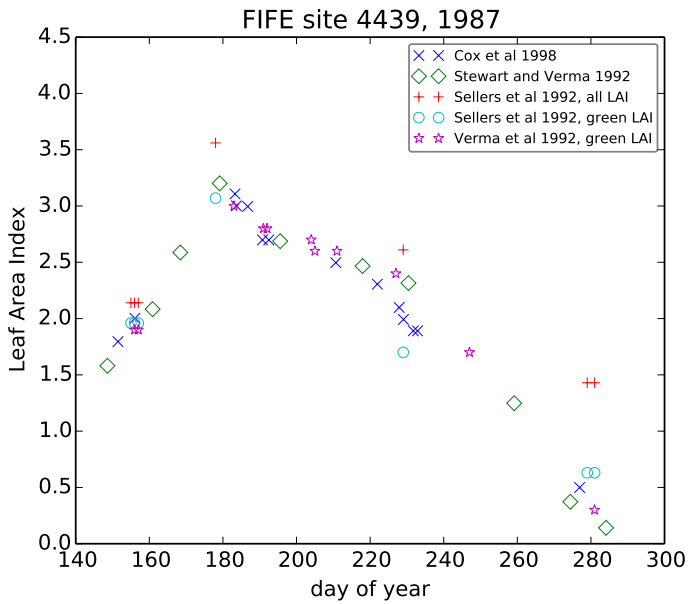
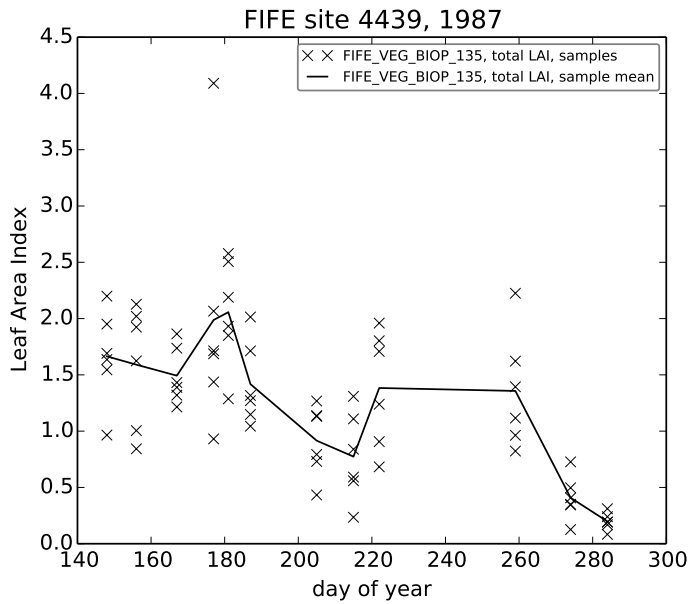
Uncertainty in prescribed data

- LAI and soil moisture was prescribed in all runs.
- There's a large spread of soil moisture, soil properties and LAI obs. even with a site as well measured as this, by independent teams.
- For example, LAI at the site was estimated to have an error of about 75%.





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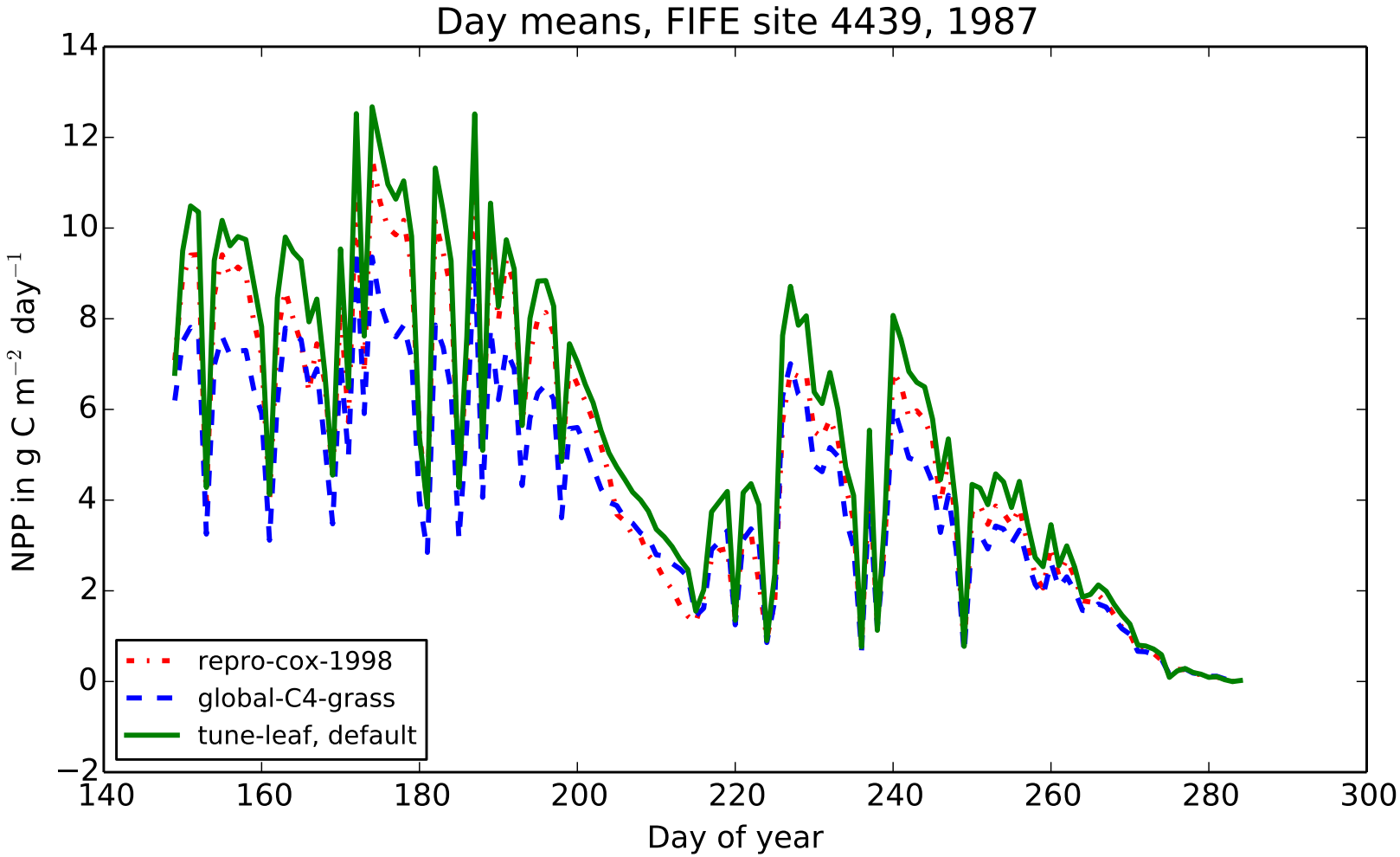
Results



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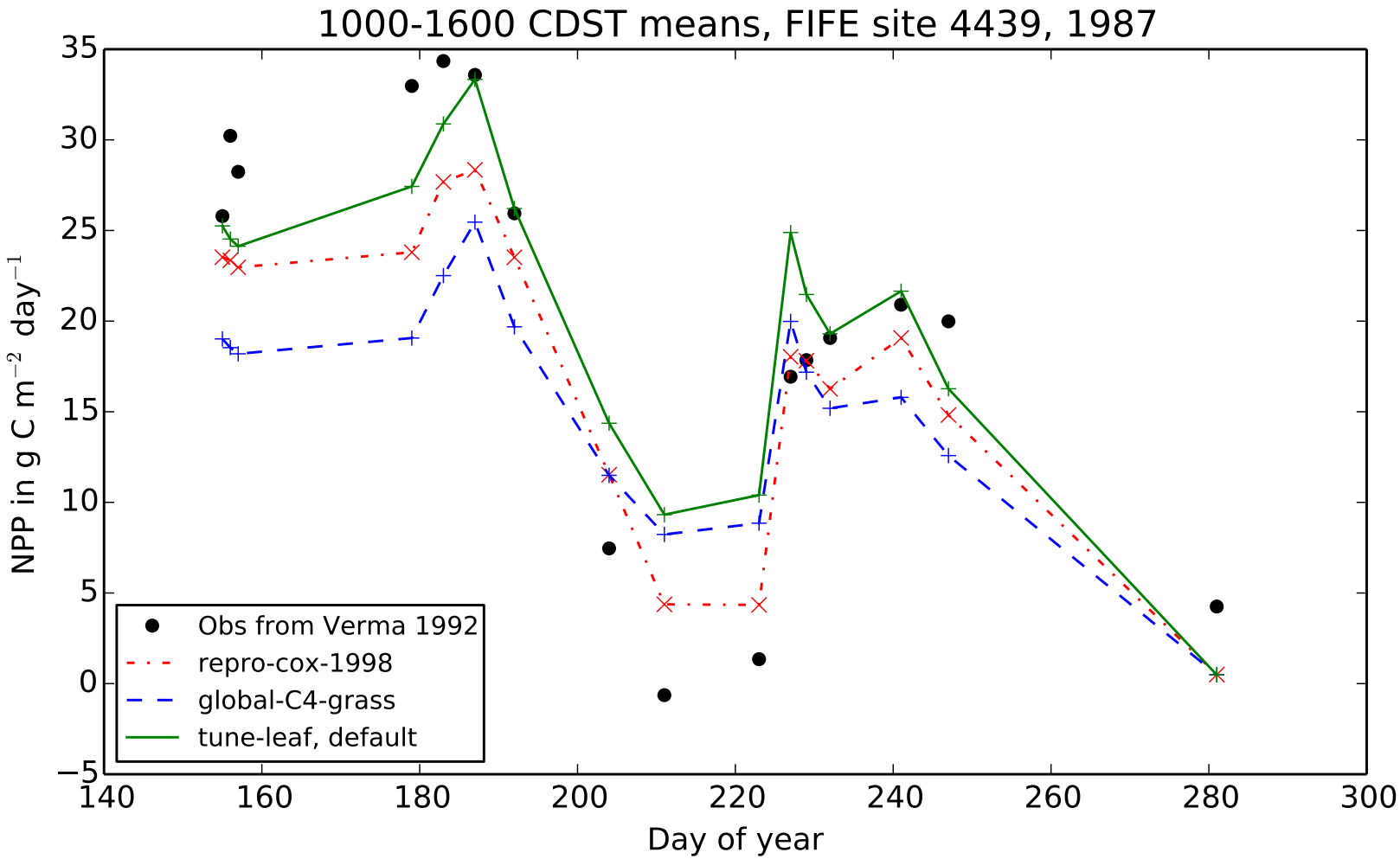
Results



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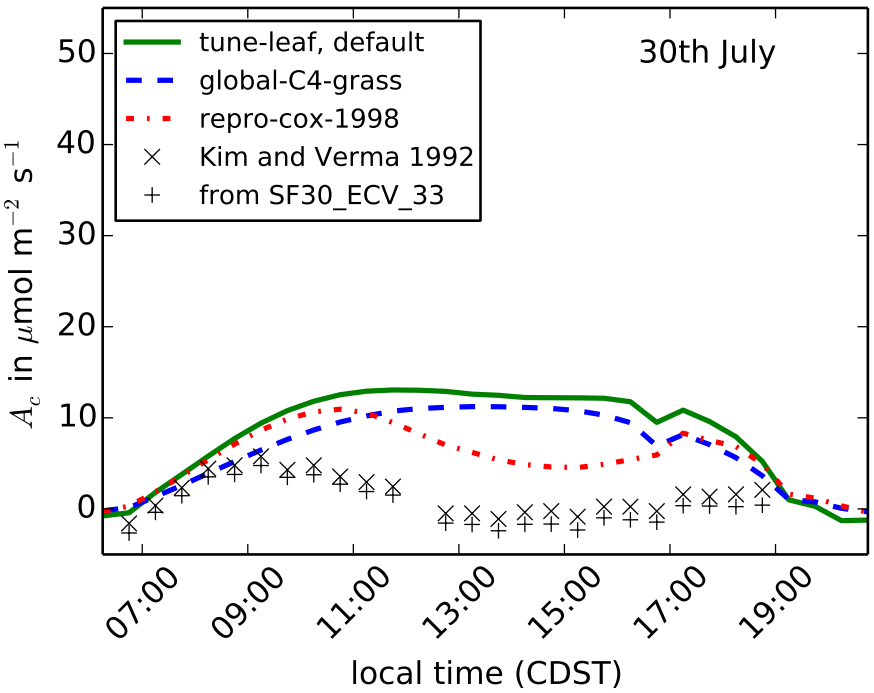
Results



- repro-cox-1998 decreases during the middle of the day because of the V_{cmax} temperature dependence, which conflicted with the leaf observations.
- Other studies captured this dip in the middle of the day at this site by including an explicit dependence on leaf water potential.
- See JPEG session tomorrow for JULES extensions that add a calculation of leaf water potential.

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Summary

- The First ISLSCP Field Experiment was a major landmark in land-surface science.
- Observations collected at FIFE are still useful for validating land surface models today. ORNL-DAAC has 115 available FIFE datasets.
- We would like to build a community of JULES users who run the model with FIFE data.
- As a start, we have created configurations that can be used to look at water stress, as part of the 'soil moisture stress on vegetation' JPEG evaluation dataset.
- We hope that this work will continue to be built on by successive studies in the future - a JULES 'golden site'.

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