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

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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.
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’
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
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, and intensively measured and modelled.
Cox et al 1998 used data from this site to develop the original soil moisture stress parameterisation used in JULES: a factor $\beta$ that scales net leaf photosynthesis.
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, $\beta$ 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.
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

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https://code.metoffice.gov.uk/trac/utils/wiki/leaf_simulator
Calibrating to observed light curves

$35^\circ C$, assuming $\beta=1$

Andropogon gerardii (Big bluestem)

Panicum virgatum (Switchgrass)

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Calibrating to observed CO$_2$ curves

Andropogon gerardii

Panicum virgatum

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In JULES, the temperature dependence of net leaf assimilation for C4 plants is via the maximum rate of carboxylation of Rubisco $V_{cmax}$
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.
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%.
Day means, FIFE site 4439, 1987

NPP in g C m$^{-2}$ day$^{-1}$

Day of year

- repro-cox-1998
- global-C4-grass
- tune-leaf, default

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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.
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’.