QUEST-UK EARTH SYSTEM MODEL

(Reading univ, UK Met Office, CEH, Bristol univ, Oxford univ, Cambridge univ, UEA, Sheffield univ, Leeds univ, Lancaster univ, et al.)
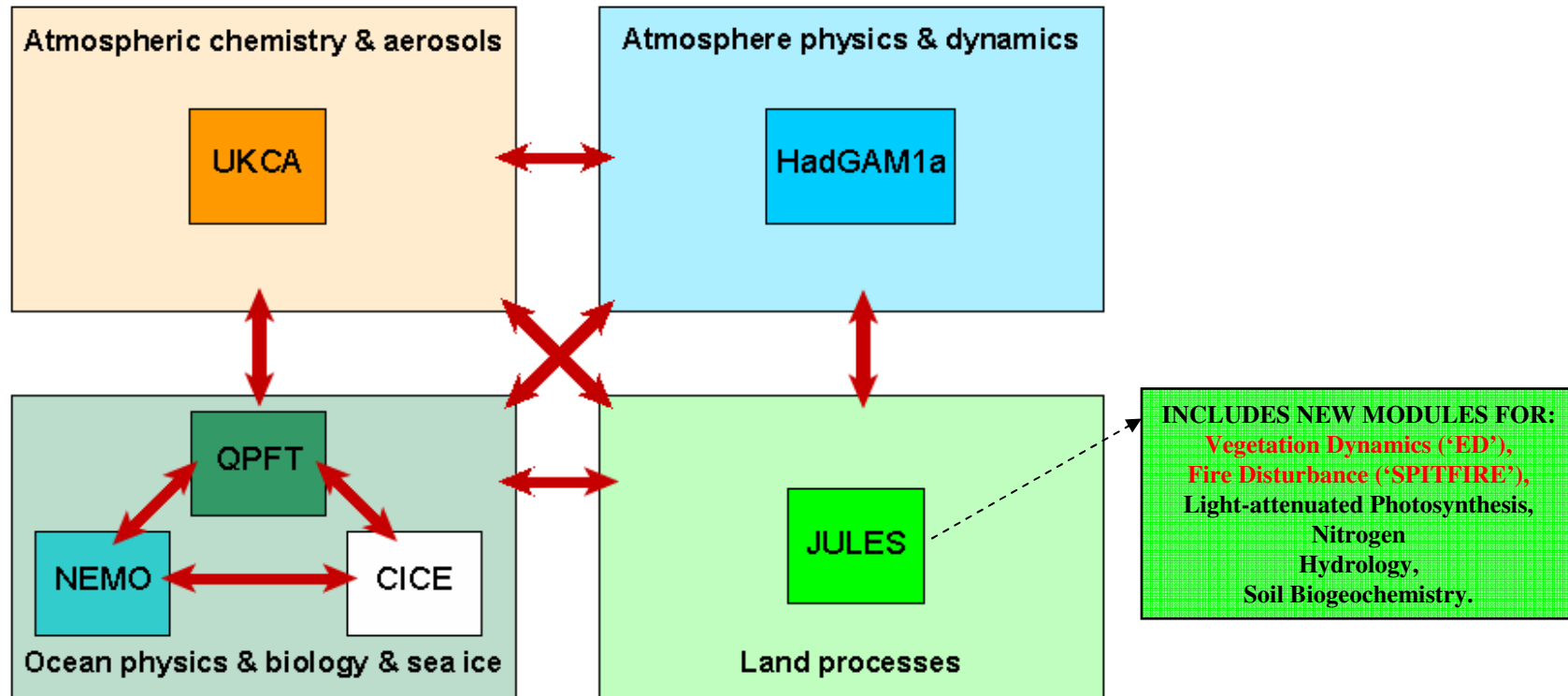
Introducing ED

- **Originally developed by Moorcroft et al. (2001 Ecological Monographs).**

- **Global version of ED: Dr Rosie Fisher, formerly Sheffield Univ., now at Los Alamos National Lab.**

- **ED is quite different from other Dynamic Global vegetation Models (e.g. TRIFFID, LPJ, SDGVM) and is based on the principles of 'gap' models.**

- **The patch structure used in most land surface models (including the TRIFFID component of JULES) is based on Plant Functional Types (PFTs).**

- **ED has 7 PFTs: C3 grass, C4 grass, Boreal Needleaved Sumergreen (larch), Temperate Broadleaved Summergreen (oaks, birch etc), Tropical Broadleaved Evergreen (rainforest), Tropical Broadleaved Deciduous (savanna trees), Temperate Needleleaved Evergreen (pine).**

- **The patch structure in ED is defined by time since disturbance by tree mortality or fire. Newly disturbed land is created every year, and patches represent stages of regrowth. Patches with sufficiently similar characteristics are merged.**

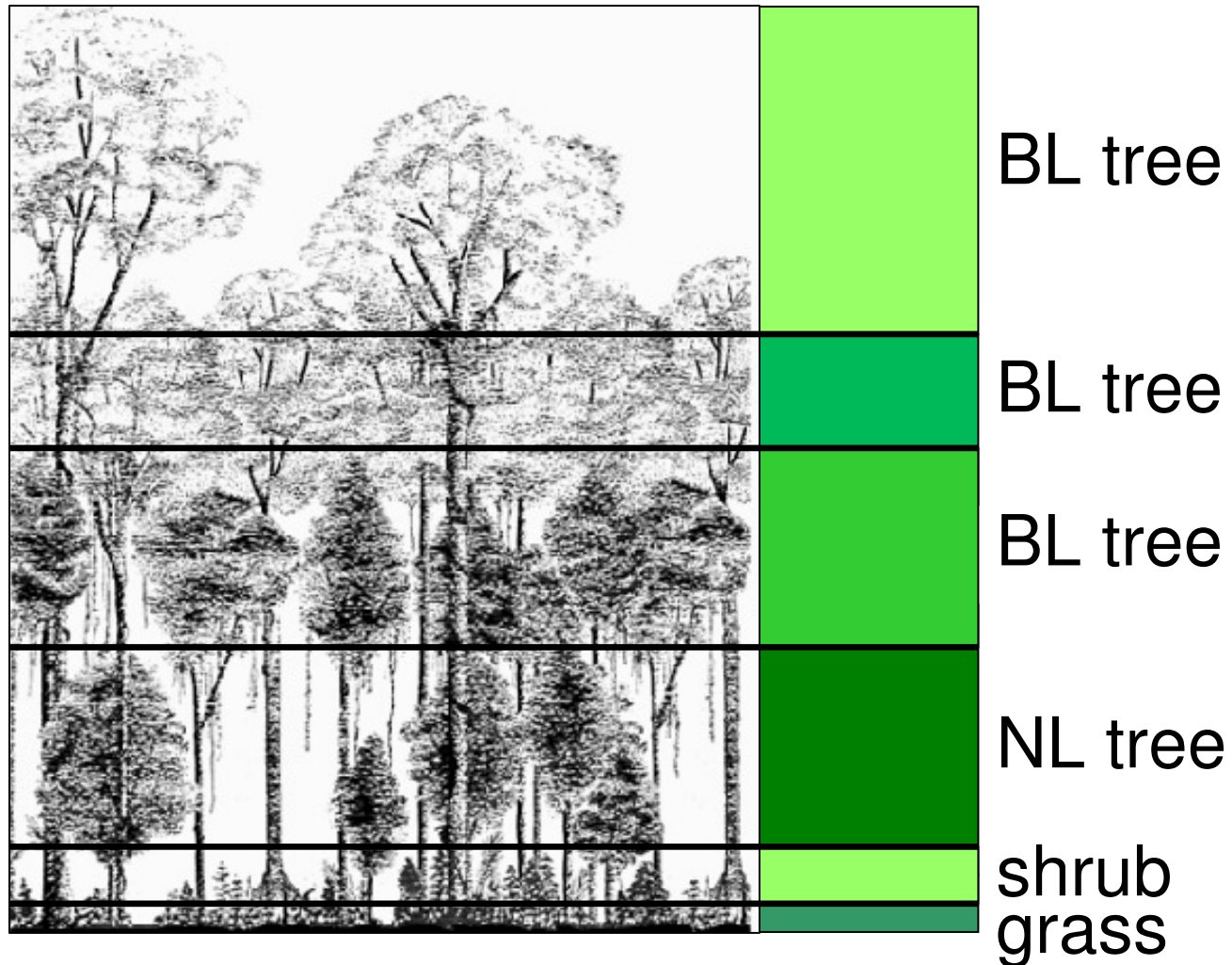PFT-based tile structure.   **TRIFFID in JULES**
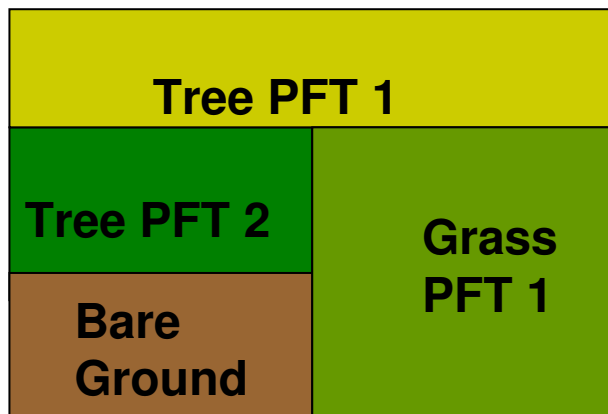
Age-based patch structure. **ED**

Introducing Cohorts

- Within each ED patch, plants of a given PFT and similar height are grouped into 'cohorts'. Cohorts compete for resources (e.g. light).

- The profile of light through the canopy is used by the JULES photosynthesis calculations.

BL tree

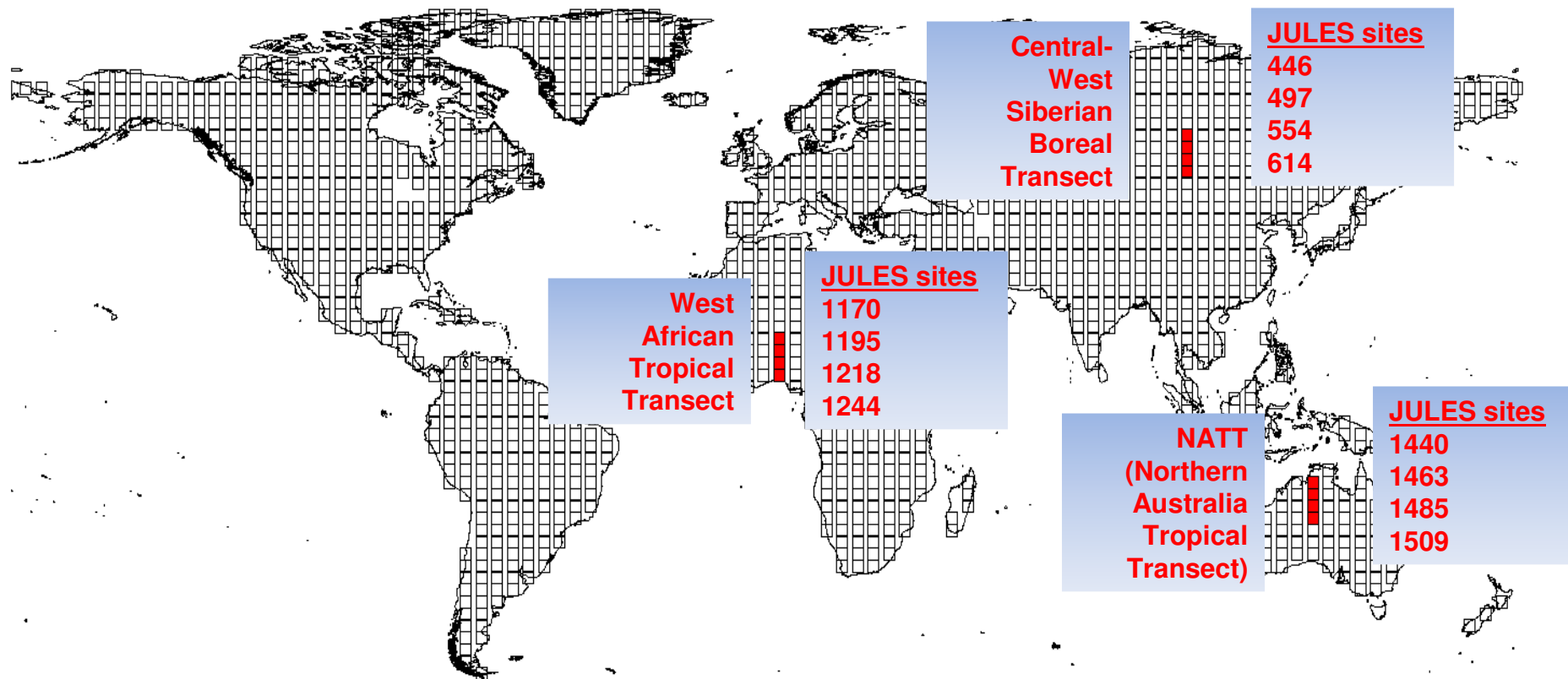BL tree

BL tree

NL tree

shrub
grass

The site/patch/cohort hierarchy in ED

- In ED, the number of patches and cohorts changes every year/month/day respectively, and is much larger for complex forest ecosystems than for simple (eg tundra) ecosystems.

- ED uses linked lists and dynamic memory allocation, available in FORTRAN 90, to permit flexible bookkeeping of simple to complex ecosystems without having to predefine arrays.

- The alternative JULES-FORTRAN 77 style approach to this problem would be to define very large arrays for all the variables, which would then mostly be empty.

- That would be inefficient.
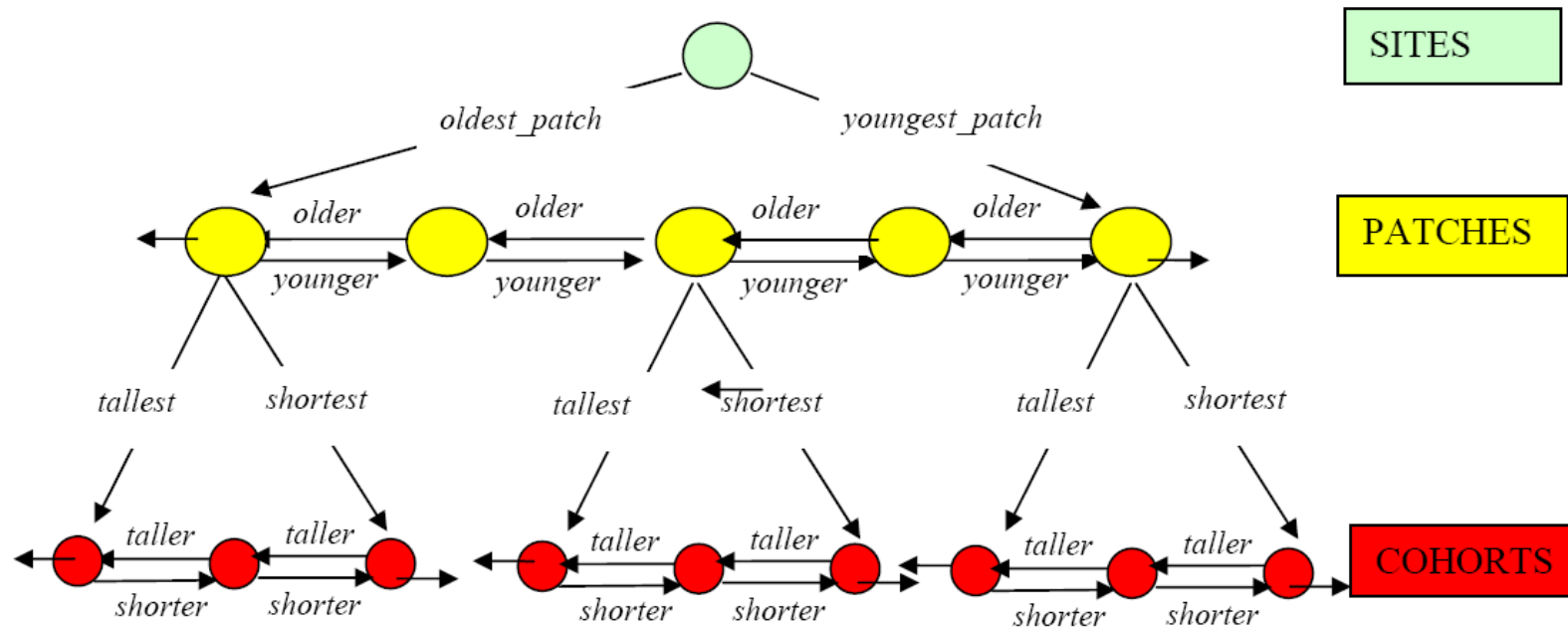
Testing and tuning global ED

- first steps… examining first order patterns in PFT distribution and productivity
- IGBP transects
- ED-IMOGEN-MOSES2.2-SPITFIRE driven by CRU TS2.1 data
- Effect of rainfall and temperature gradients
- Effect of 'fire on' versus 'fire off'

Central-West Siberian Boreal Transect

JULES sites
446
497
554
614

West African Tropical Transect

JULES sites
1170
1195
1218
1244

NATT (Northern Australia Tropical Transect)

JULES sites
1440
1463
1485
1509

5 year Moving Average Annual Rainfall

TrBlEg ('Evergreen Rainforest') trees

No fire

5 year Moving Average Annual Rainfall

C4 grass   **No fire**

TrBlRg ('Drought Deciduous Savanna' trees)

No fire

Ag biomass kgC per sqm (y-axis): 0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06

x-axis: 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

?

Legend:
- Site 1440
- Site 1463
- Site 1485
- Site 1509
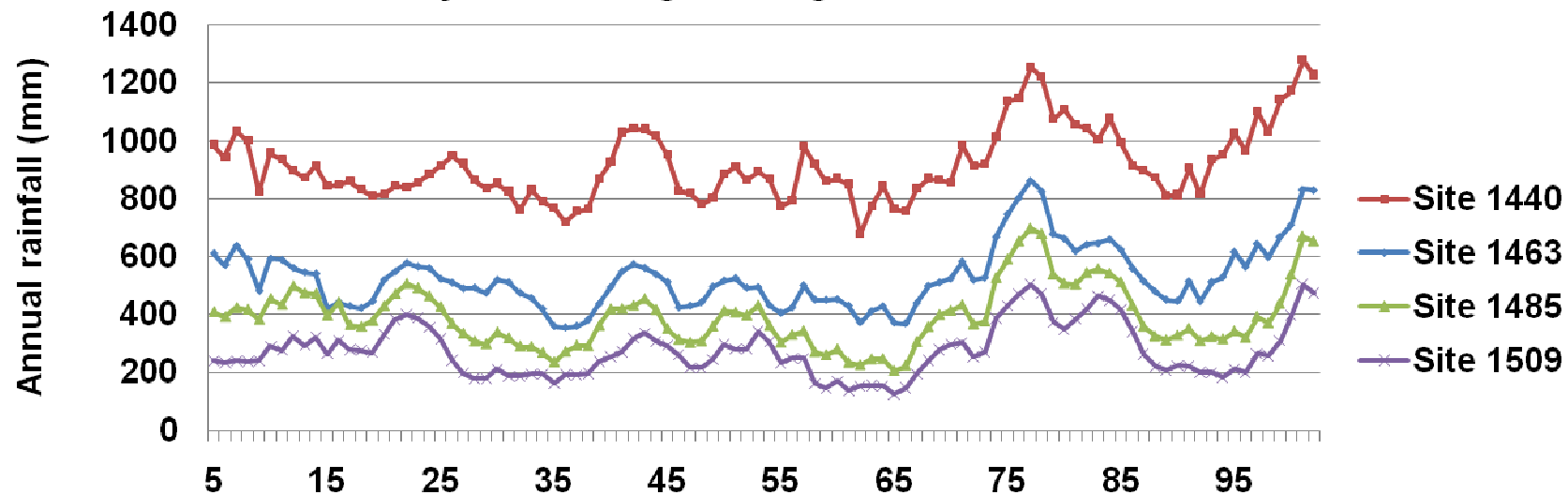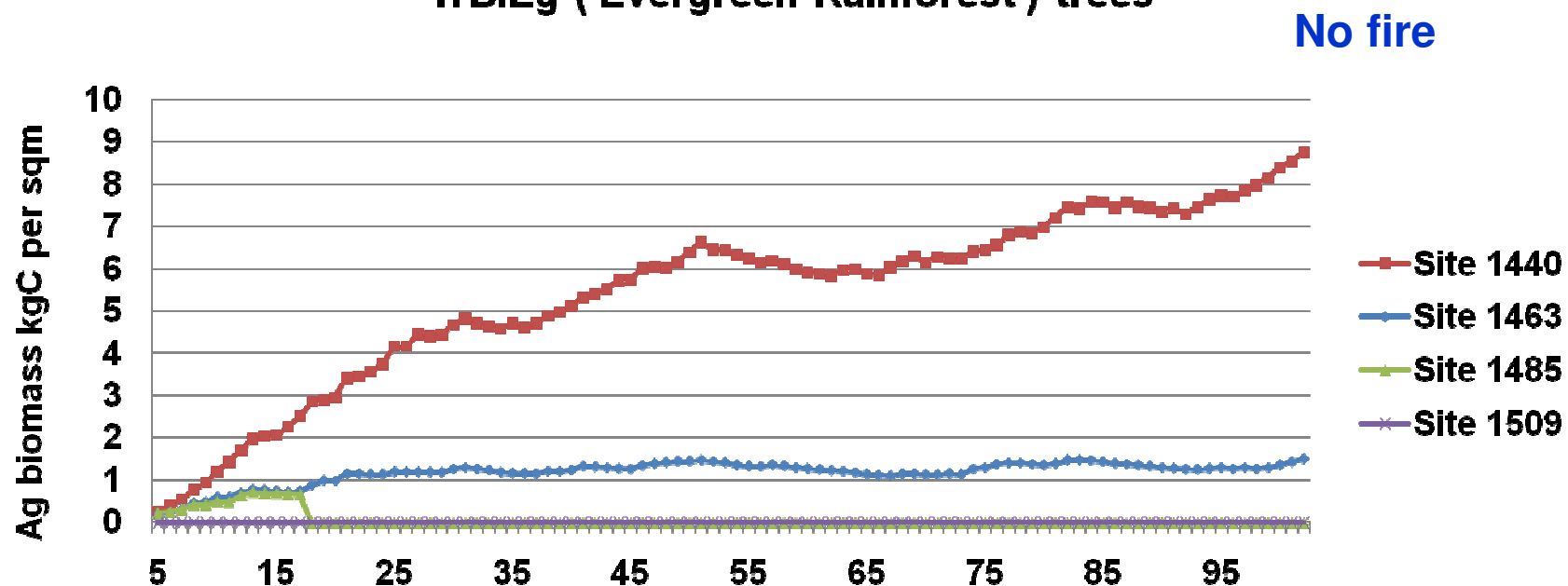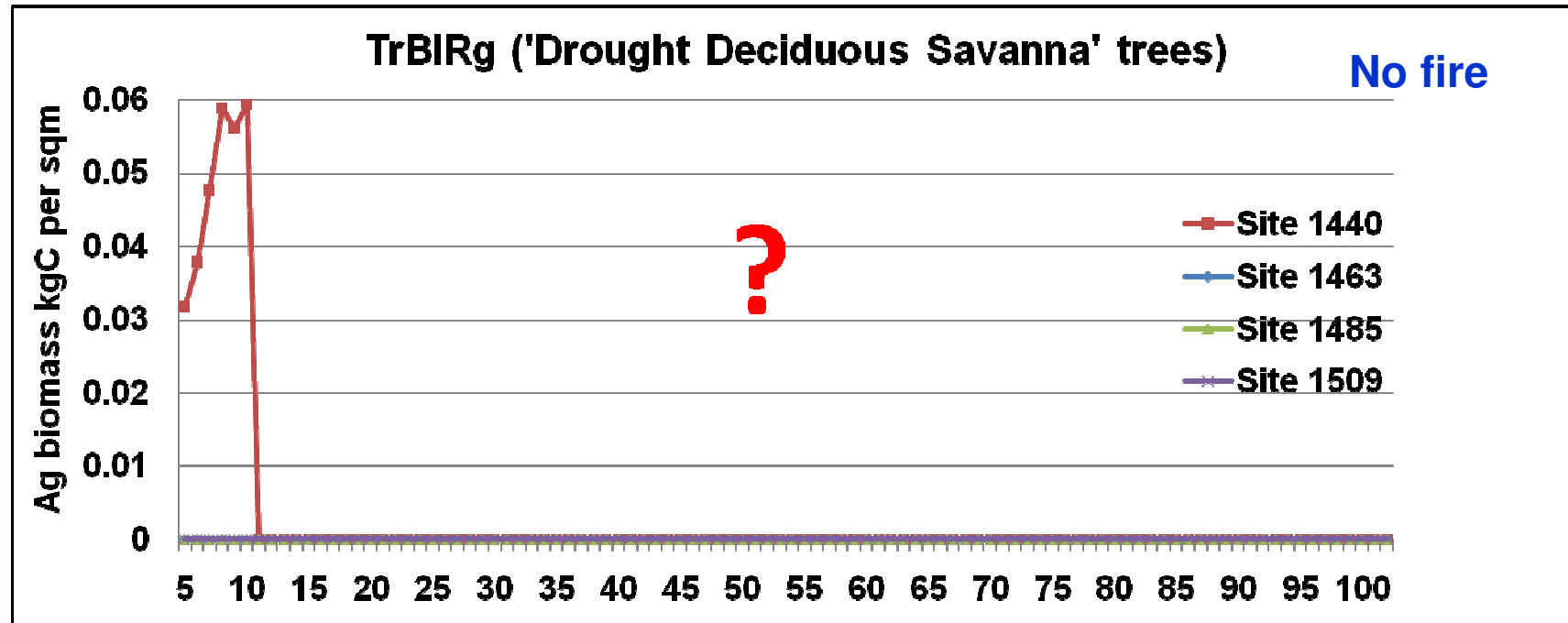
Options tried:

- Root mass proportional to leaf biomass vs root biomass proportional to leaf area.

- Introducing fires (because savanna trees are fire tolerant). Doesn't help because trees extinct *before* fuel is sufficiently great enough to carry fire.

- Altering soil moisture in JULES.

* More savanna trees in West Africa transect simulation, but overall ED currently poor at simulating savanna trees.

Testing and tuning global ED
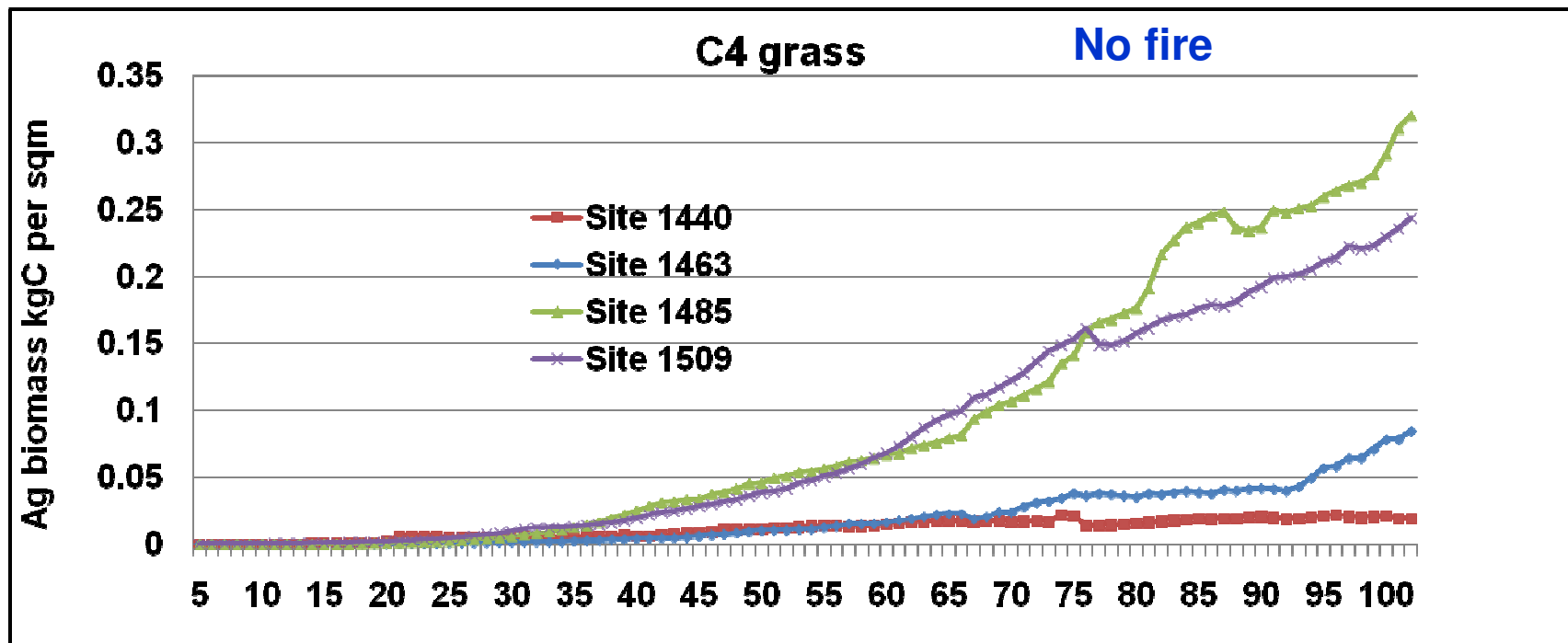
- **first steps… examining first order patterns initially**

- **IGBP transects**

- **ED-IMOGEN-MOSES2.2-SPITFIRE driven by CRU TS2.1 data**

- **Effect of rainfall and temperature gradients**
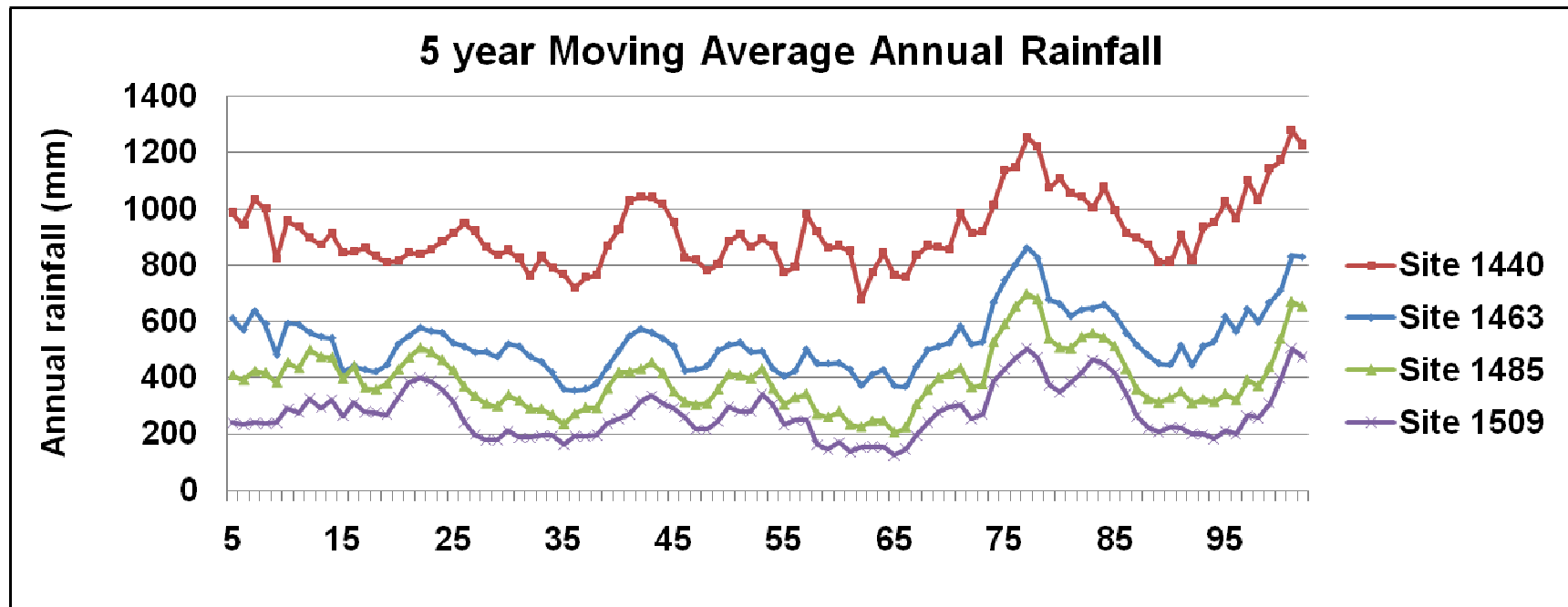
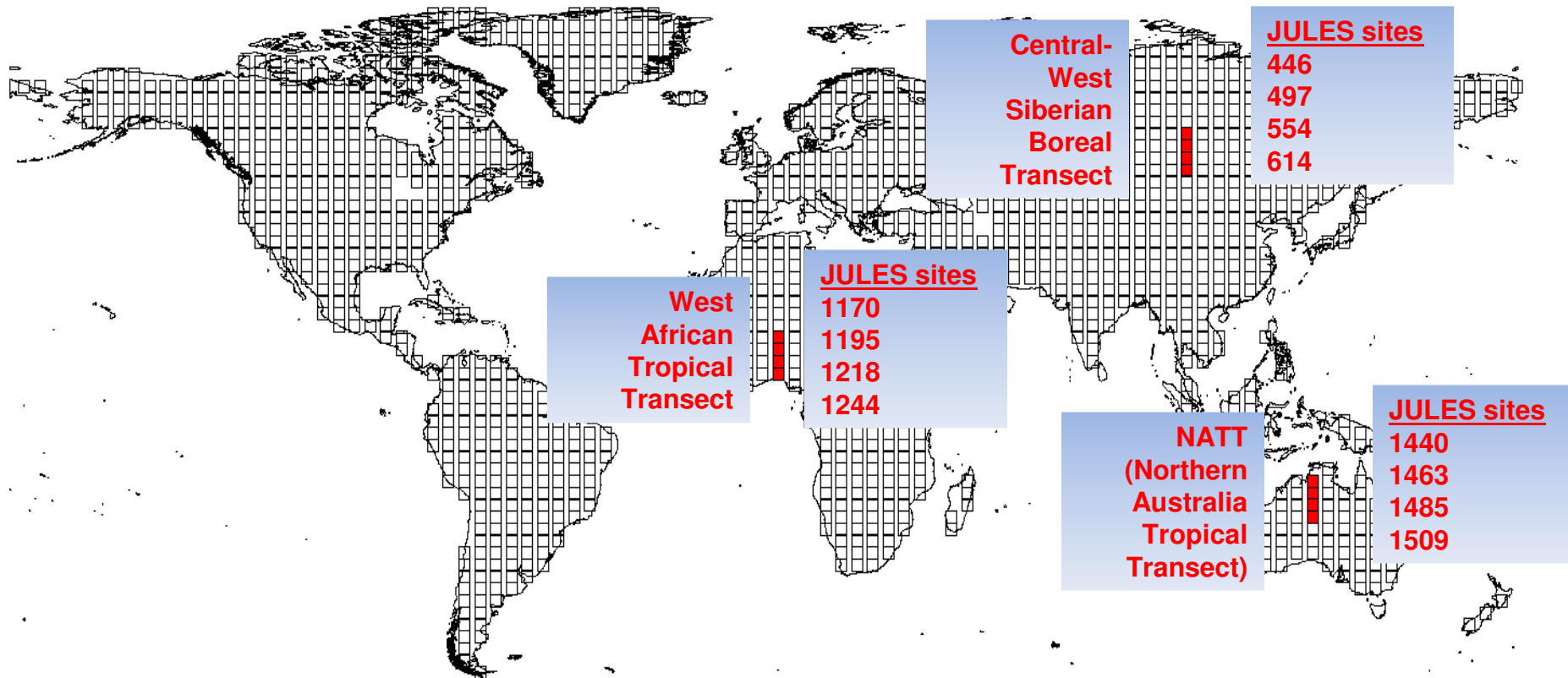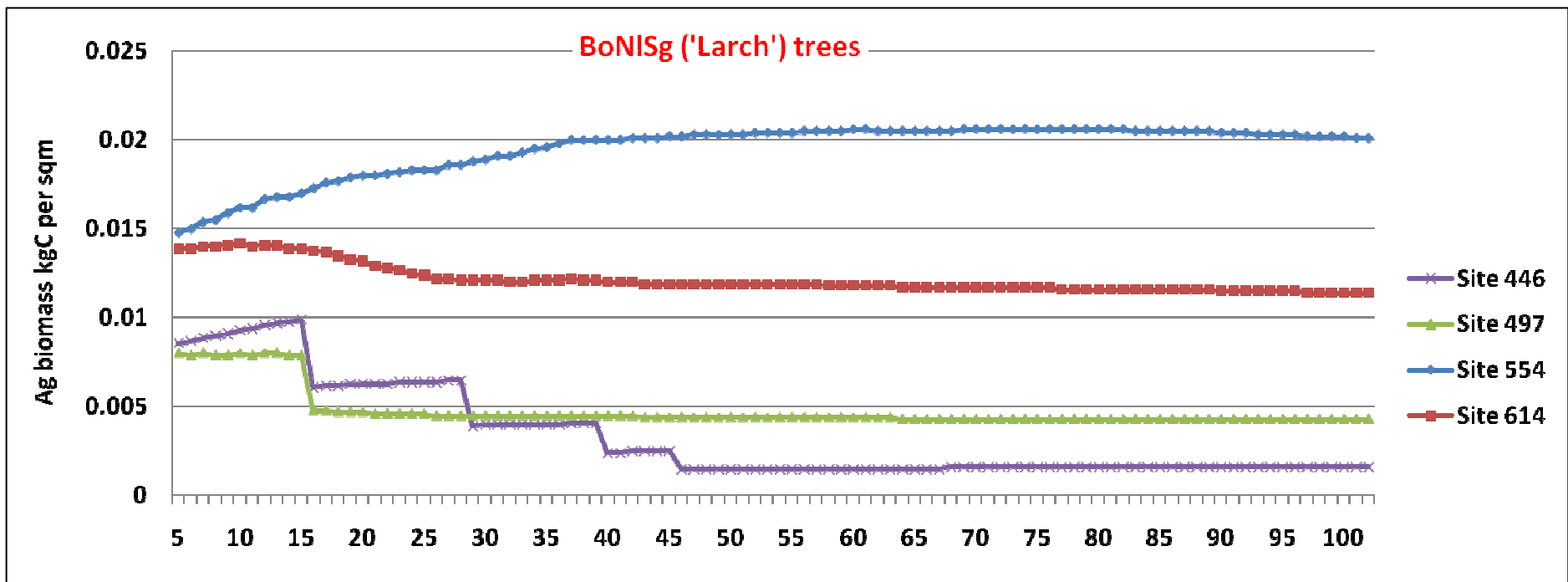- **Effect of fire on versus fire off.**

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NIEg ('pine') trees

Ag biomass kgC per sqm

- Site 446
- Site 497
- Site 554
- Site 614

BoNlSg ('Larch') trees

Ag biomass kgC per sqm

- Site 446
- Site 497
- Site 554
- Site 614
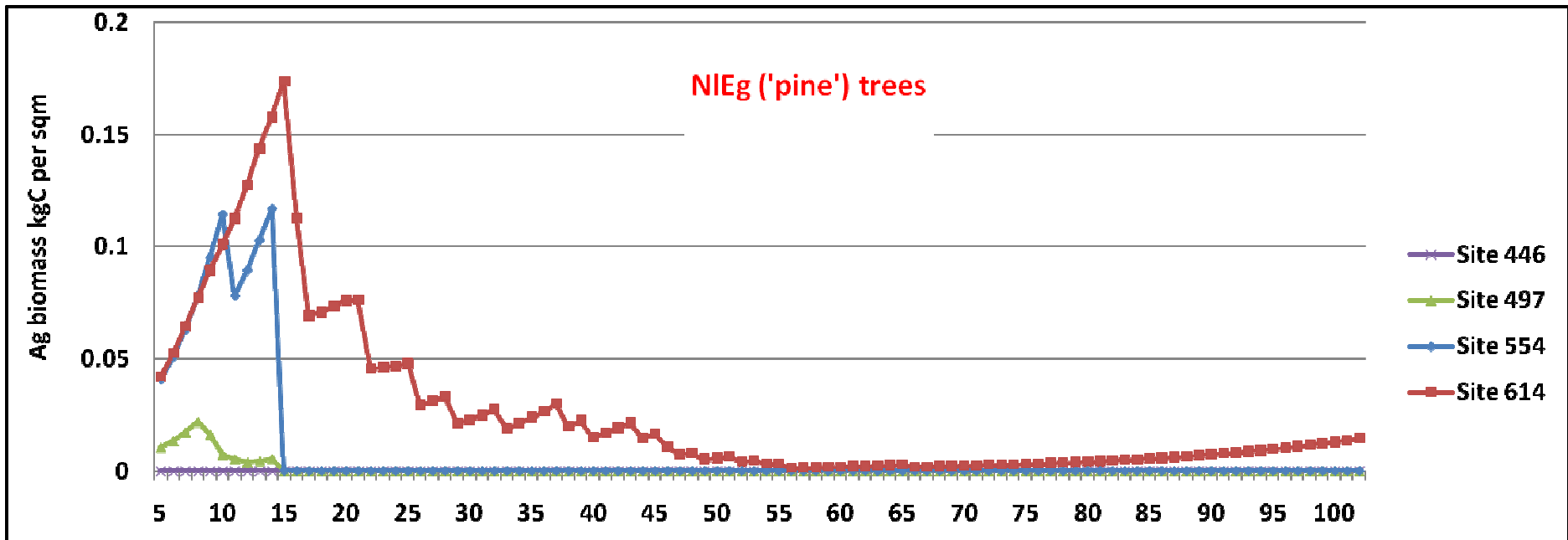
Conclusions

- **IMPACT STUDIES** using **J**ULES with **E**D, **E**COSSE, **F**UN & **S**PITFIRE.

  - How will future climate change affect the various drivers of vegetation (e.g. fire, soil moisture, nitrogen)

  - How will these drivers affect resultant vegetation patterns and productivity in future? Role for Quest Earth System Model? IMOGEN? What else?

  - What are the important climate drivers and what is their prediction uncertainty?

  - How does nitrogen availability affect CO_2 uptake by vegetation?

  - Role of droughts on vegetation productivity both directly via soil moisture, nitrogen availability and indirectly via fire?

- **MODEL CONFIDENCE… No point of impact studies if the desired model tools are not complete and/or lack rigorous validation, and as such, we or worse still, the users of the model output, lack confidence in them.**

- **THINK GLOBALLY… A global version of ED that replicates observed vegetation patterns, NPP, and biomass (so-called 'mass balance' validation) needs to be completed as soon as possible. Benefits to the Earth System Modelling Community and beyond.**

- **VERSION CONTROL…. Potential users are queueing up. How to share results and experiences with model in 'real-time', not every other JULES meeting…**

- **RESOURCES… ED needs to be properly resourced if we expect JULES to do 'world class' vegetation dynamics modelling. Past 6 months…. Allan S part time, and Rosie F part time on ED. No-one else. Things may change in future? HOPE SO!**

EXTRAS

Patch Sucession in ED.

REFER EXAMPLE BELOW... Five PFTs are represented. Grasses are light and dark green triangles. Broadleaf trees are light and dark green circles on sticks, and needleleaf trees are dark green triangles on sticks.

❖ **Figure 2a...** ED is typically spun-up from bare ground. At the start, there is only a single patch.

❖ **Figure 2b...** On this patch, seedlings of each plant functional type are 'planted'.

❖ **Figure 2c...** Over time, these seedlings grow. As an approximation, grasses grow fastest at first, due to their low construction costs.

❖ **Figure 2d...** At some point, there is a fire disturbance event. The vegetation is destroyed by the disturbance (exact amount consumed depends on litter moisture, fire intensity, fire residence time, vegetation height and bark thickness). A new patch is created.

❖ **Figure 2e...** This patch is then again seeded by cohorts of each PFT.

❖ To maintain computational efficiency, ED compares the new patch with the next oldest patch, and decides whether these two patches have similar vegetation structure. If they are only slightly different, then the two patches are 'fused' together and the combined vegetation is spread evenly around the newer larger patch.

❖ **Figure 2f...** Patches are destroyed when their area is reduced (by disturbance) to a negligible size. Eventually, the disturbance routines form a dynamic equilibrium along the successional gradient.

5 year moving average annual precipitation

5 year moving average daily temperature