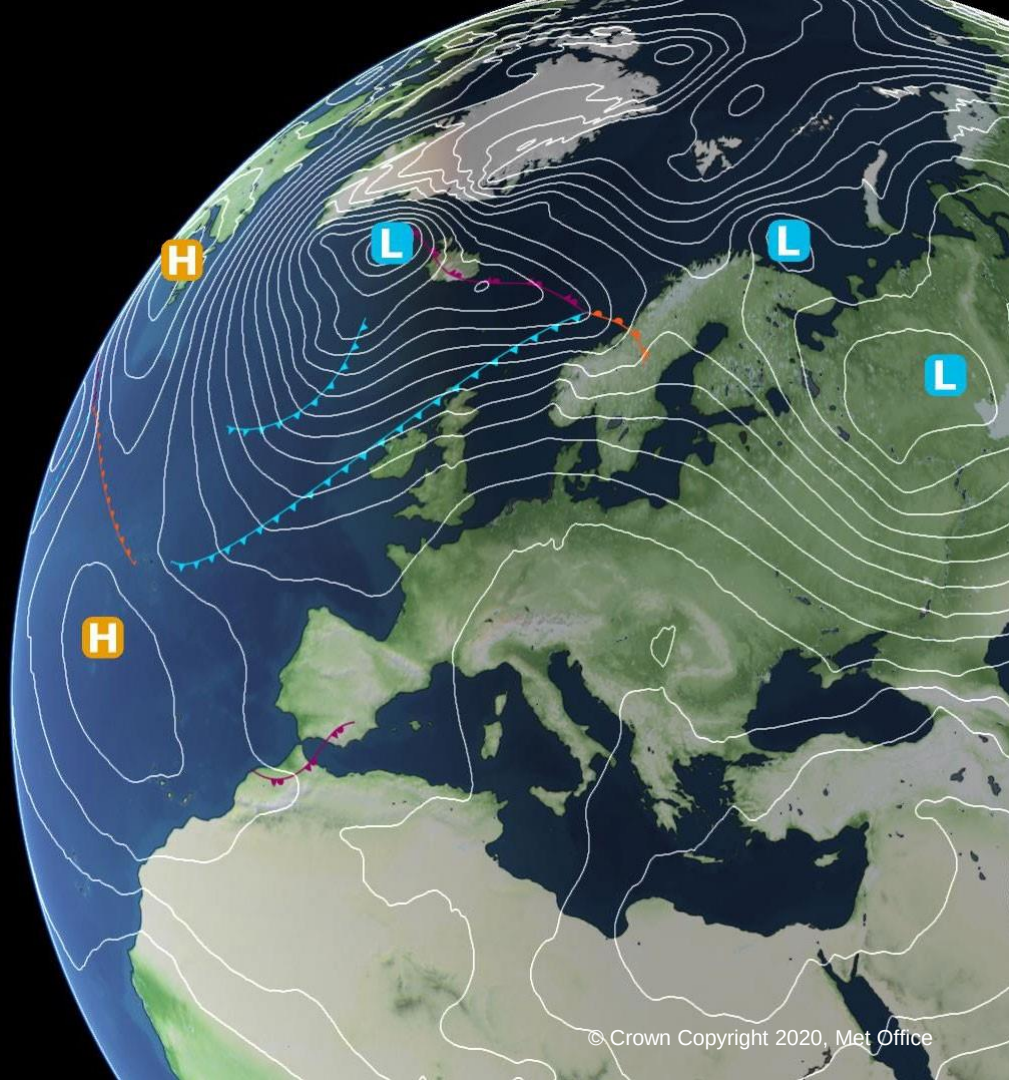
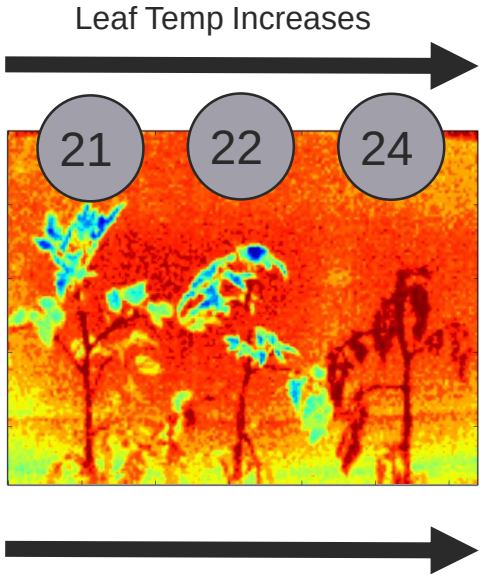
Met Office
Hadley Centre

Vegetation “LST-Air Temperature Difference” Stress in UKESM

Robert King

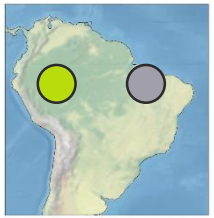


Leaf Temperature and Moisture Stress

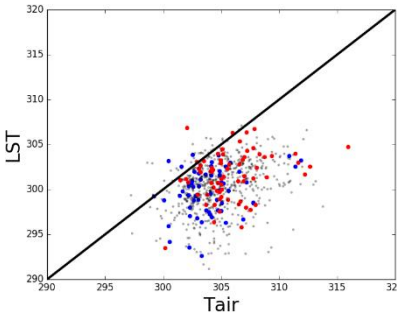


Air: 22

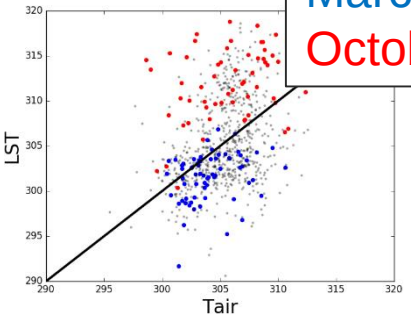
Effect visible at leaf-level and satellite/grid box scales



March
October



North West



North East

Met Office
Hadley Centre

Outline

This time I'm looking at UKESM (with JULES as the land surface component) and the LST-Tair difference behaviour within

- UKESM – how I am using it's results
- C3 & C4 grasses – the difference
- LST – Air Temperature Difference
  - C3 and C4 regions of China
  - Compare to model Soil Moisture

Met Office
Hadley Centre

UKESM

- Earth System Model
  - JULES land surface component
- UKESM historic data
- 9 ensembles
  - Kelley et al. UKESM land processes paper in prep.
- Using monthly averaged output
  - LST, Air Temperature, Soil Moisture, PFT Fraction
- Concentrating here on 2003-2014 ‘MODIS ERA’
  - Initial comparison to observations – not presented here

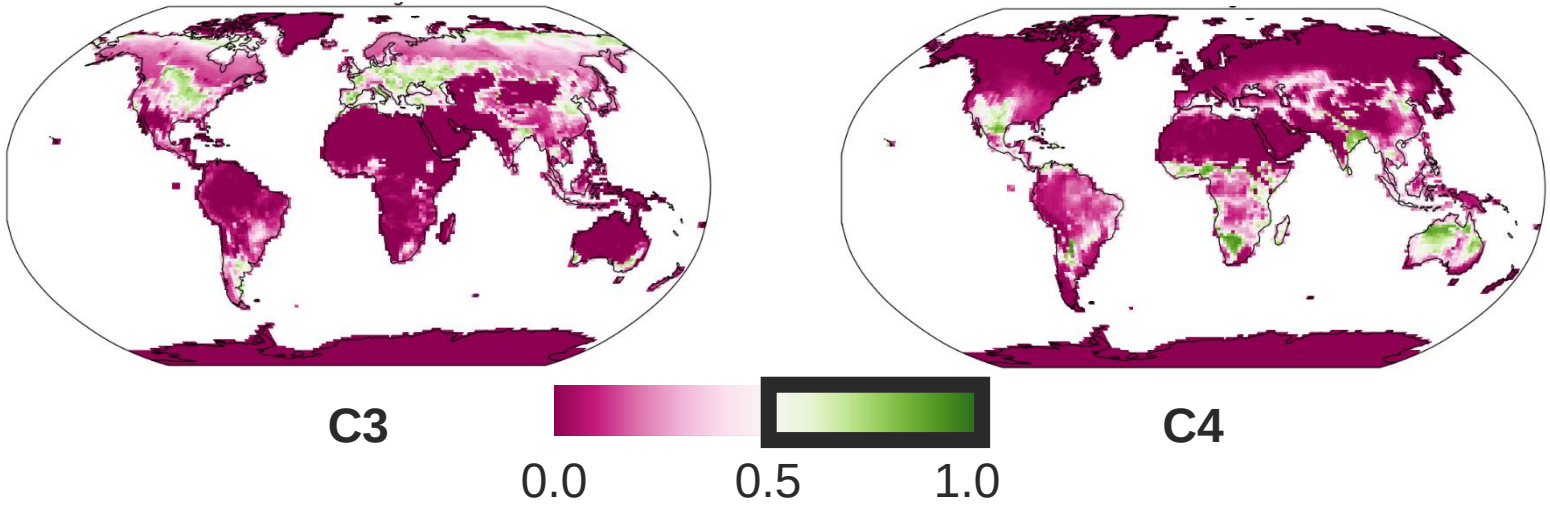
Met Office
Hadley Centre

C3 & C4 Photosynthesis

- Two different ways photosynthesis ‘works’ in plants
  - Chemical reactions take different routes
  - Stomata behaviour is different
- C4 adapted to warmer, drier climates
  - Transpiration timing through the day is different
- Several important crops are C4 grasses : maize, sugar cane
- JULES implements different restrictions on photosynthesis rates for C3 and C4 pathways
  - Different Rubisco, Light and PEP limitations in total photosynthesis calculation
- Active area for JULES research, e.g. Williams, K. E et al. GMD 2019

Met Office
Hadley Centre

C3 & C4 Photosynthesis



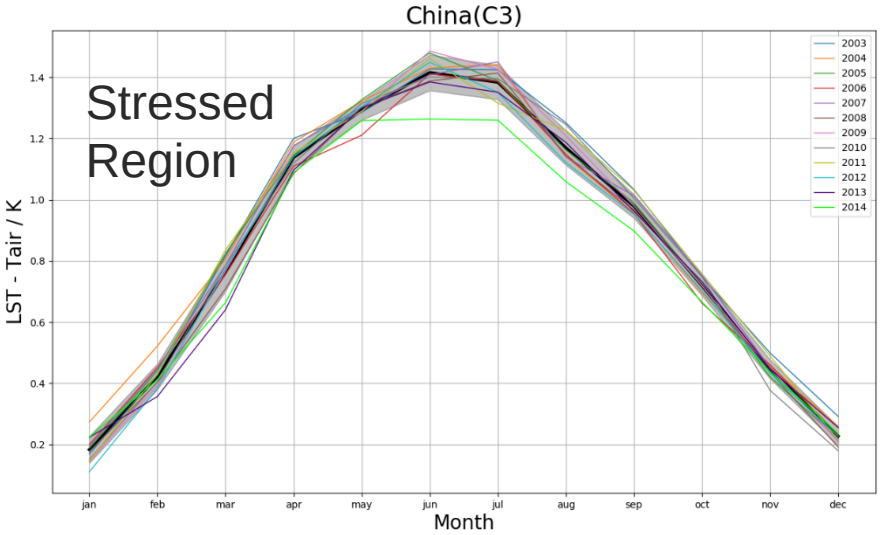
Grid box fraction of C3/C4 grass – UKESM ensemble average

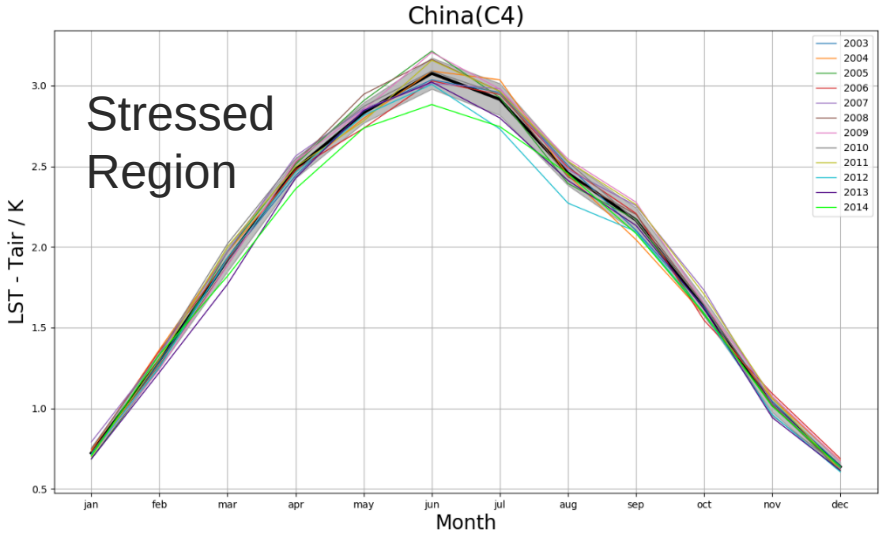
Define a grid box as C3 (C4) grass if the ensemble average fraction > 0.5

Met Office
Hadley Centre

China LST-Tair Difference

Mean + Std
Mean
Mean - Std

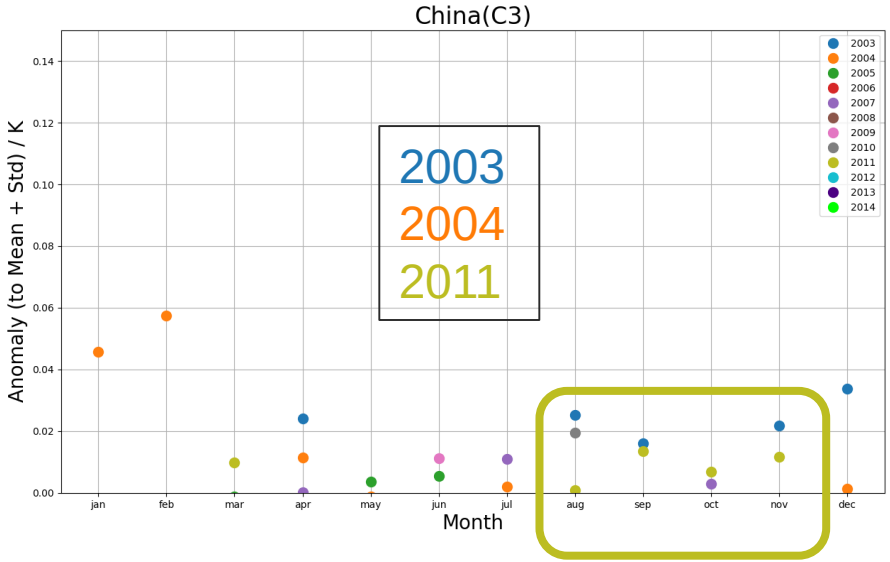


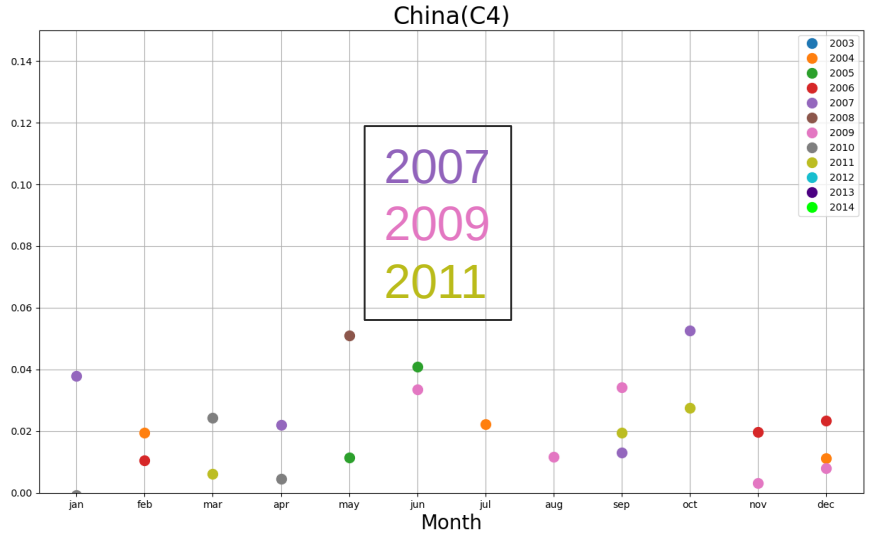


Met Office
Hadley Centre

China LST-Tair Anomaly

LST-Tair > Climatology Mean + Standard Deviation





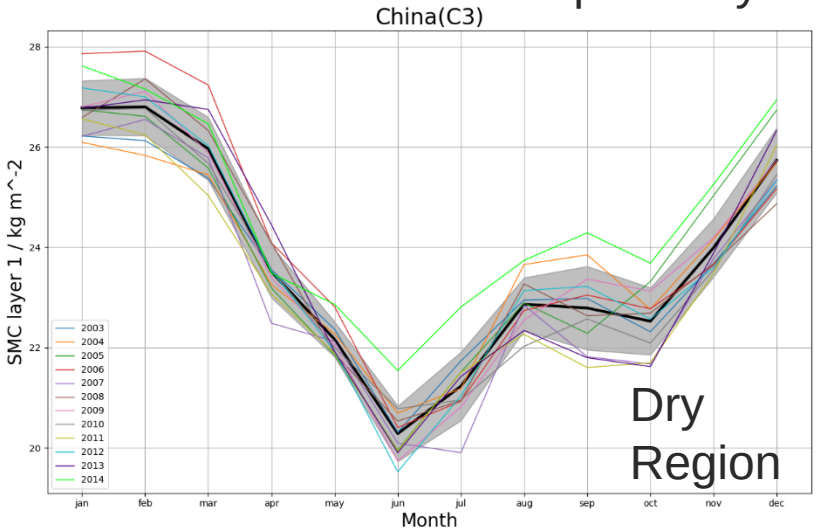
Aug-Nov 2011

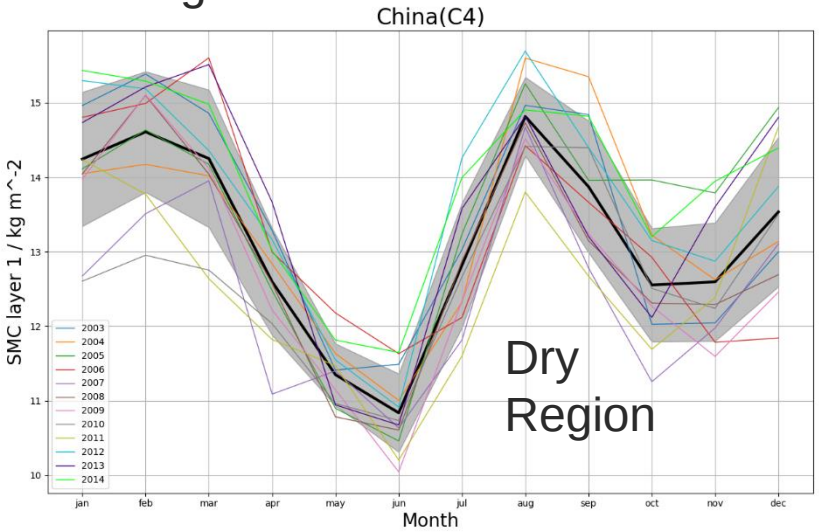
Met Office
Hadley Centre

China Soil Moisture

Mean + Std
Mean
Mean - Std

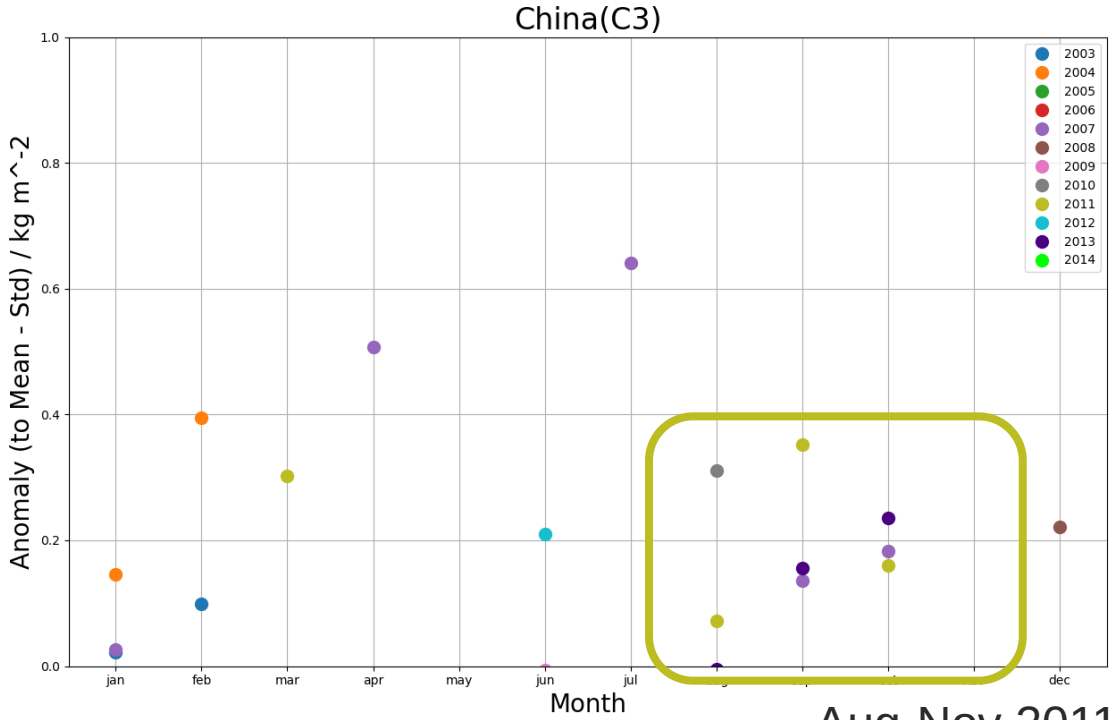
Top soil layer: 0-0.1m Units : kg m^{-2}





Met Office
Hadley Centre

Soil Moisture < Climatology Mean - Standard Deviation

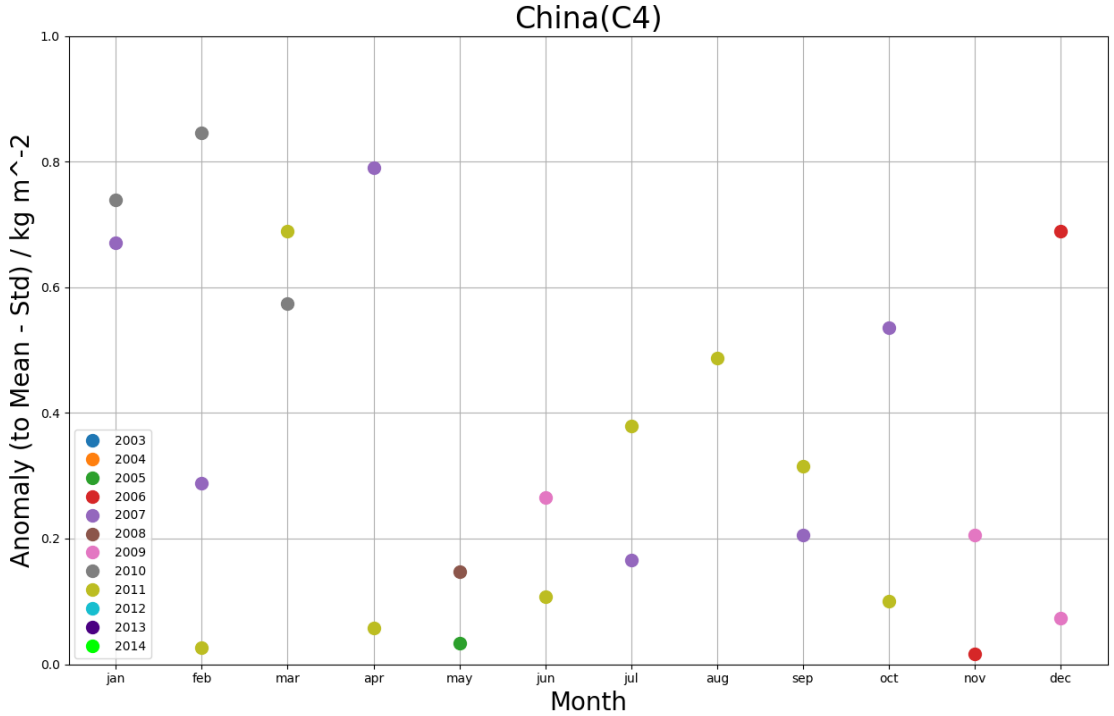


2003 ?
2004 ✓
2011 ✓
Additionally:
2007
2013

Aug-Nov 2011: November Dry yet Stressed

Met Office
Hadley Centre

Soil Moisture < Climatology Mean - Standard Deviation



2007 ✓
2009 ✓
2011 ✓
Additionally:
2010

Met Office
Hadley Centre

Stress events

- Drier soil moistures corresponding to larger LST-Tair differences
  - In several cases LST-Tair anomaly when Soil Moisture anomaly
- Consider recovery time as measure of vegetation resilience to moisture stress
  - This is not limited to C3 v C4 but also species, weather conditions, other factors…

- C4 grass shows larger variation in LST-Tair
  - Limited daytime transpiration limits latent heat
  - One less cooling term constraining the overall heat flux

- A lot of averaging of data occurring here
  - Monthly UKESM output, ensemble average, area average, climatology production
  - Expect a wider variation when looking at the area average distribution; transpiration constraining and cooling C3, contrasting to C4 behaviour

Met Office
Hadley Centre

Summary

- LST – Air Temperature difference responds to vegetation moisture stress
  - Driven by changes in transpiration
- C3 and C4 grass show different behaviour in this metric
  - Again driven by transpiration
- Variations in this temperature difference compared to climatologies give evidence of stress events occurring
  - At grid box (and hence satellite) scales

- Use this to investigate the cooling effect of C3 and the moisture stress tolerance of C4 in future climates with UKESM predictive results
- Detect in observation and models where/when to investigate soil moisture, stress calculations, land cover, …
- Define vegetation resilience to moisture stress
  - Time taken to recover to pre-stress LST-Tair values