Landscape-Scale Heat Flux Measurements Using Scintillometry Over Complex Terrain

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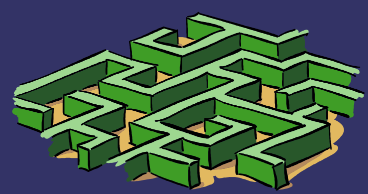
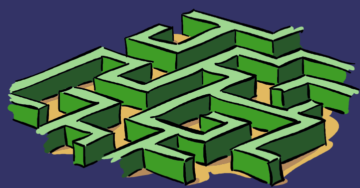


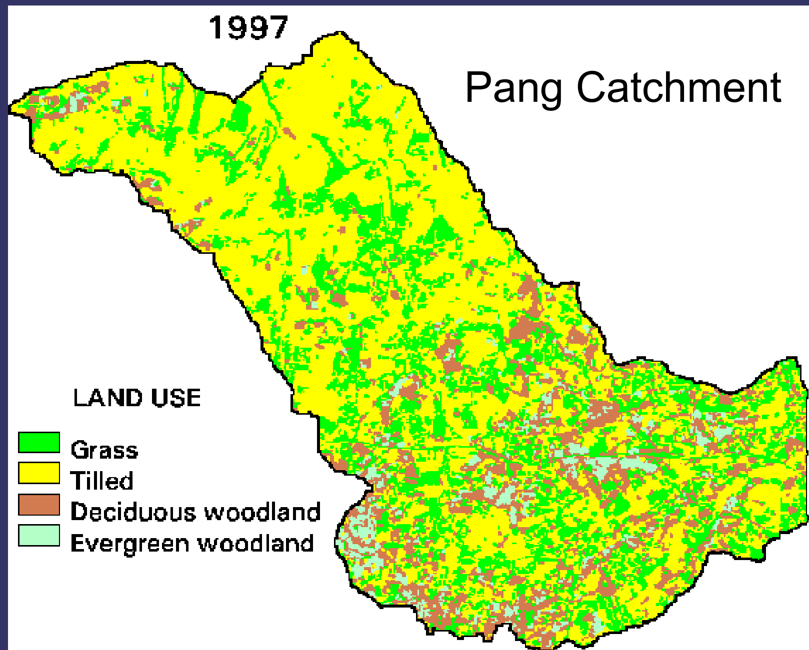
Introduction

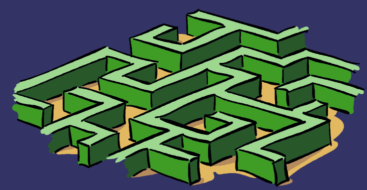
- Motivations for this work
- Landscape-scale measurements of H with a Large Aperture Scintillometer (LAS)
- ..... and LE using a LAS in combination with a new millimetre-wave scintillo-meter (mws)
- Discussion of results
- Future work.



New Methods to Estimate Grid or Catchment Area-Average Evaporation

- **Overall Project Objectives:** to assess new methods of estimating landscape-scale evaporation
- Require up-scaled measurements over mixed vegetation and non-ideal (hilly) terrain.
- **Methods:**
- Scintillometry
- Eddy Correlation
- Energy Balance
- Satellite net radiation
- Comparison based on the extrapolation of point measurements, and footprint analyses.





Location of Field Site

Sheepdrove Organic Farm,

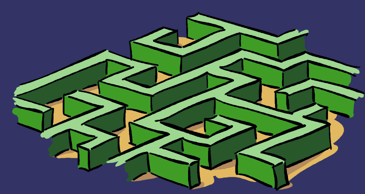
Lambourn Catchment,

West Berkshire,

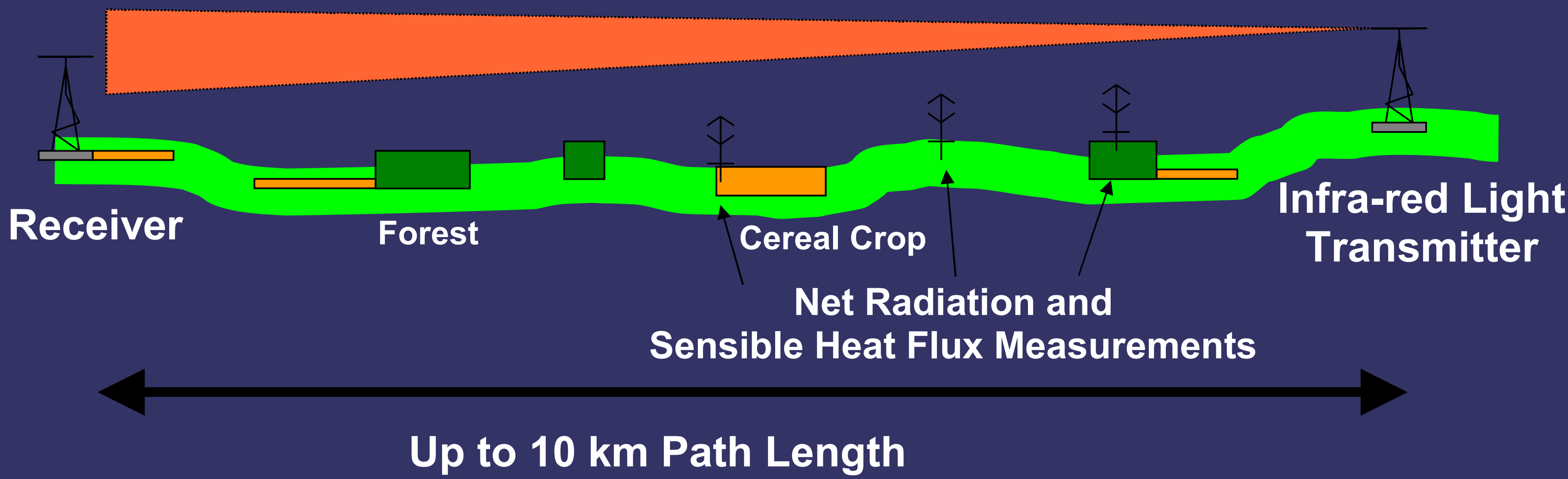
Southern England

51° 31’ 49” North

1 ° 28’ 55” West



LAS Measures Sensible Heat Flux

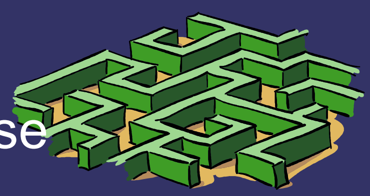


- From LAS measurements, path-averaged Sensible Heat Flux, H, can be calculated, using additional measurements of mean temperature and wind-speed or friction velocity.

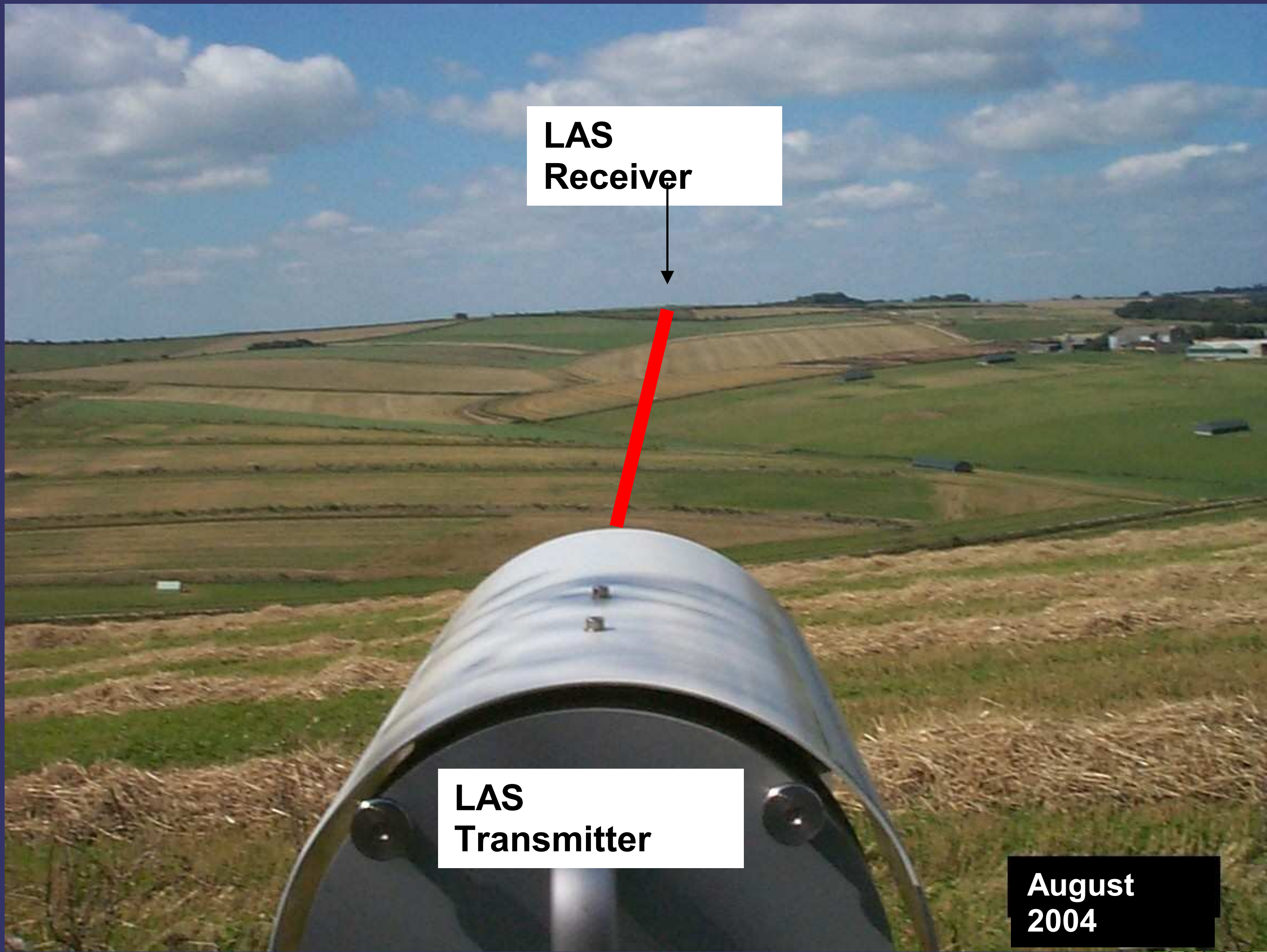
- Evaporation is derived by the Surface Energy Balance

- Area-averaged Net Radiation is required, from ground point measurements or satellite grid estimates – Imperial College London

- Measurements over complex topography and mixed land use



2004-7 Measurements: LAS 2.4 km Path Set-up

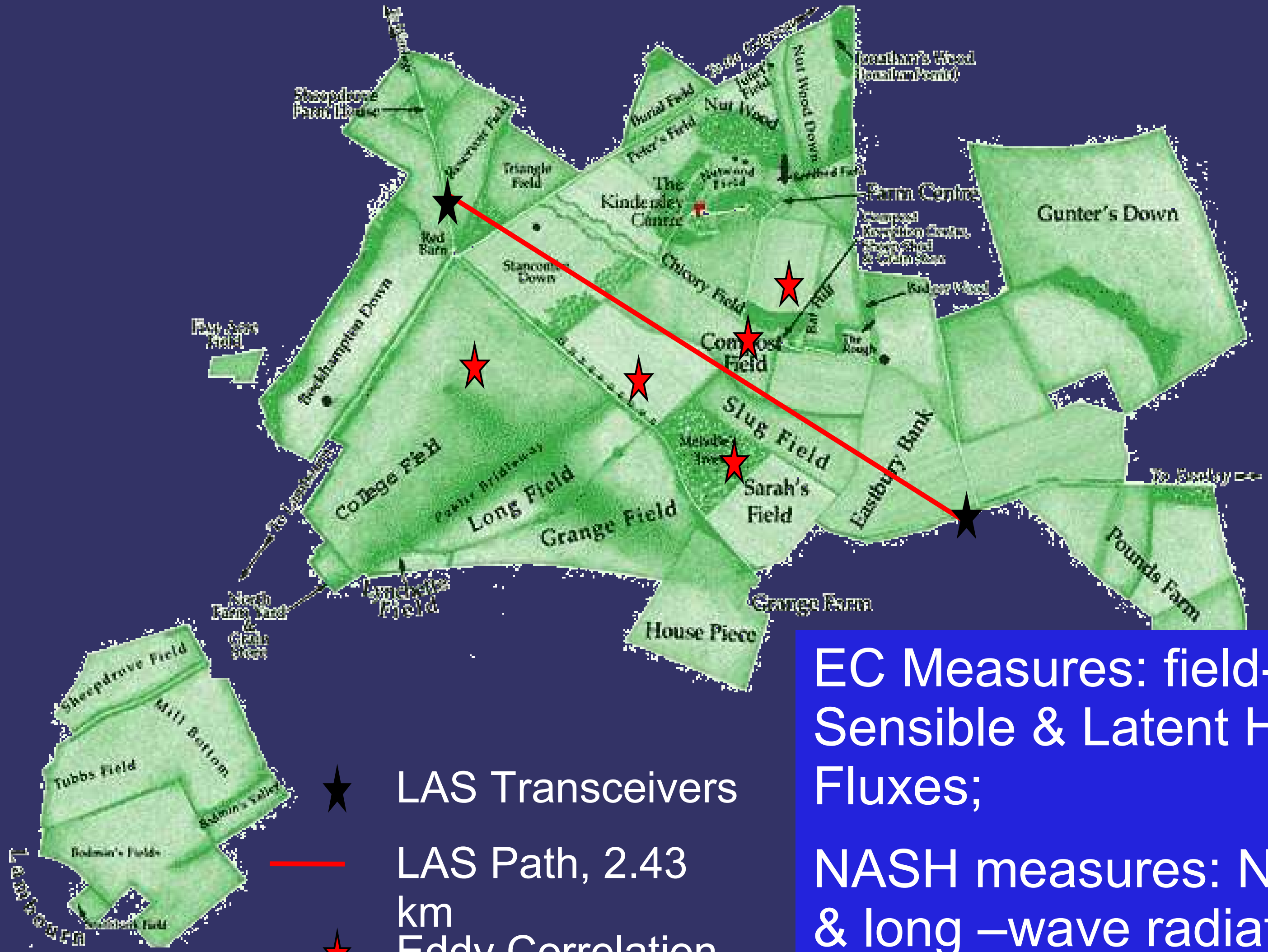



June 2004


June 2004

View from LAS Receiver at Stancombe Reservoir

2004 Field Measurements at Sheepdrove Organic Farm



LAS Transceivers

LAS Path, 2.43 km

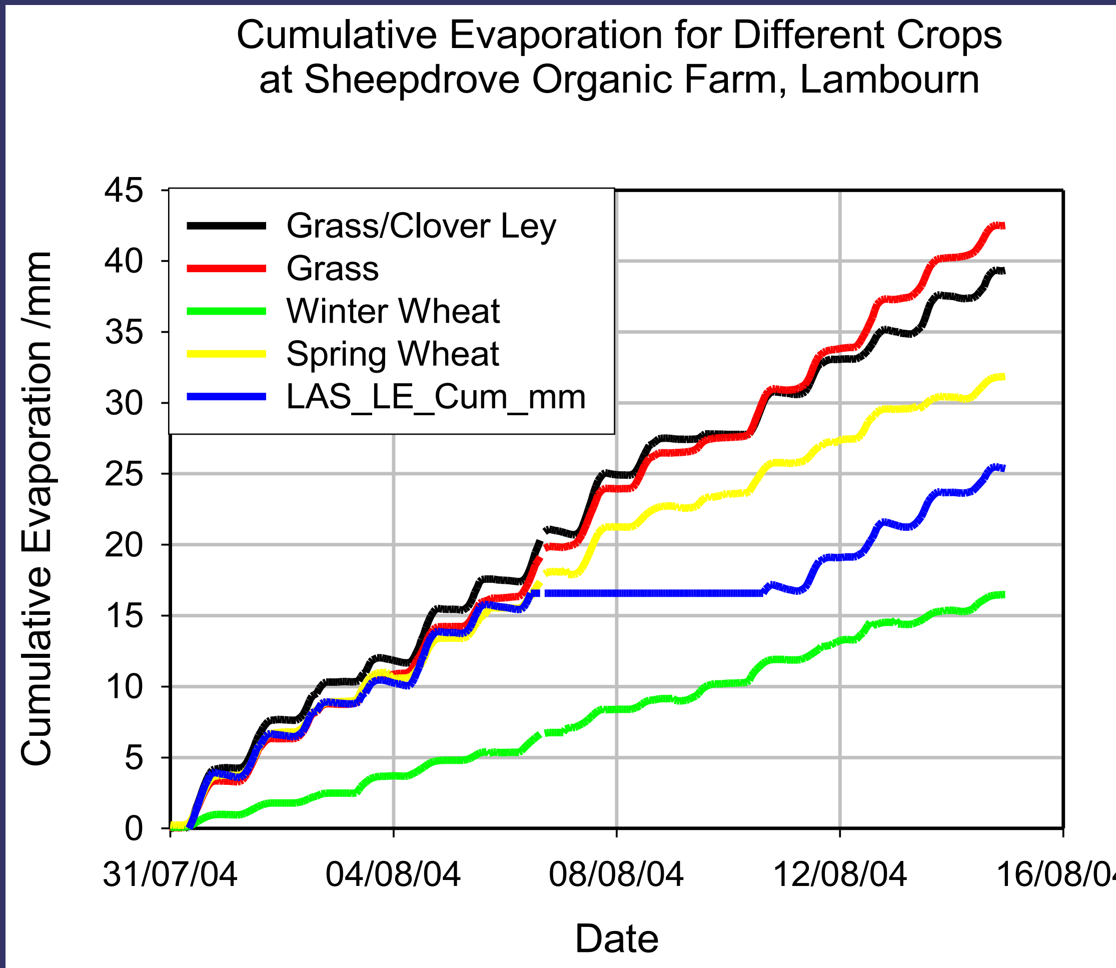
Eddy Correlation (EC)

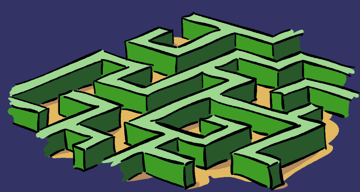
& NASH Stations

EC Measures: field-scale Sensible & Latent Heat Fluxes;

NASH measures: Net, short & long –wave radiation Surface Temperature, Soil Heat Flux, Soil Temperature & Soil Moisture.

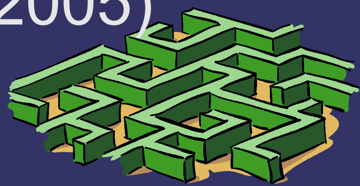
R3 Sonic + Li7500


Cumulative Evaporation for Different Crops
at Sheepdrove Organic Farm, Lambourn
Grass/Clover Ley
Grass
Winter Wheat
Spring Wheat
LAS_LE_Cum_mm
45
40
35
30
25
20
15
10
5
0
Cumulative Evaporation /mm
31/07/04
04/08/04
08/08/04
12/08/04
16/08/04
Date



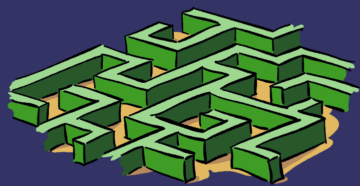
Development of a new Millimetre-Wave Scintillometer (MMWS)

- NERC funded project in collaboration with the Radio Communications Research Unit of the Rutherford Appleton Laboratory.
- To design, build & field test a robust low-power 34/36 GHz or 94 GHz MMWS for measurement of evaporation by scintillation, in combination with an infra-red scintillometer.
- Wavelength choice criteria are:
  - ➲ Sensitivity to C_{q2} , without absorption,
  - ➲ Small Fresnel zone compared to L_0 ,
  - ➲ Building on published work (e.g. Ludi et. al. 2005)
  - ➲ Cost of hardware for chosen wavelength



The RAL 94 GHz (RAL94) Scintillometer

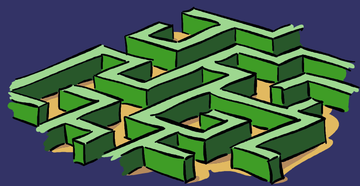
- 94 GHz was selected as low-risk (meets criteria well) and has been used successfully by Ludi et. al. (2005) in Lit-fass.
- Trade-off is high cost of components at 94 GHz (c. 50 K Euro).
- Low power (15 W) using GPS to lock frequency (no temperature contol).
- Reliable (2 years in field).



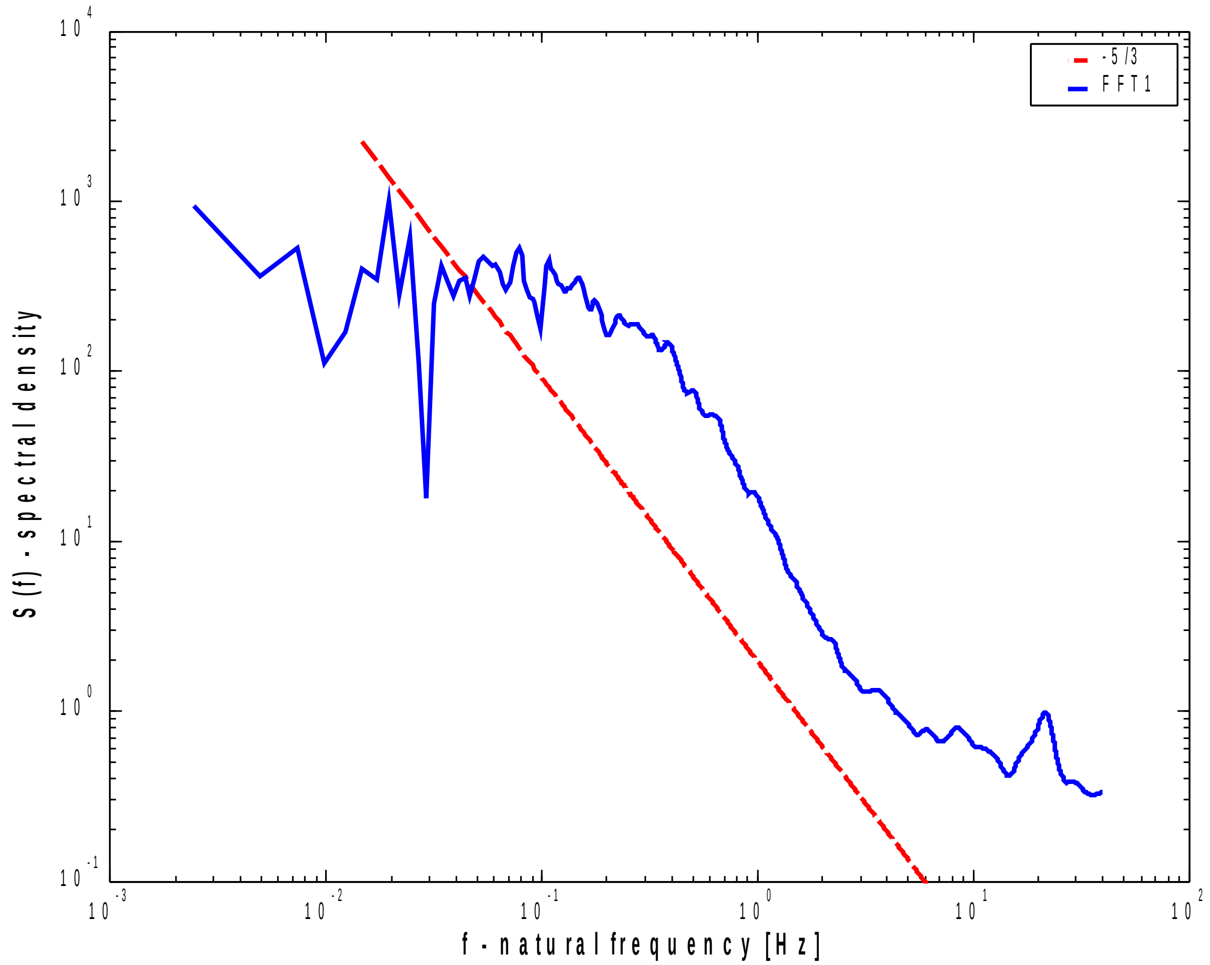
LAS & RAL94 at Sheepdrove

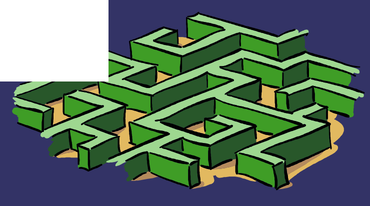
RAL94 Data Analysis

- Inspection of raw intensity spectra shows need for filtering both very low frequency (<0.1 Hz) changes in atmo-spheric opacity ....
- .... and high frequency (>10 Hz) non-turbulent (non-random 'noise')
- A Chebychev type II (flat in the pass-band) digital bandpass filter was de-signed with cut-offs of 0.05 Hz and 10 Hz.

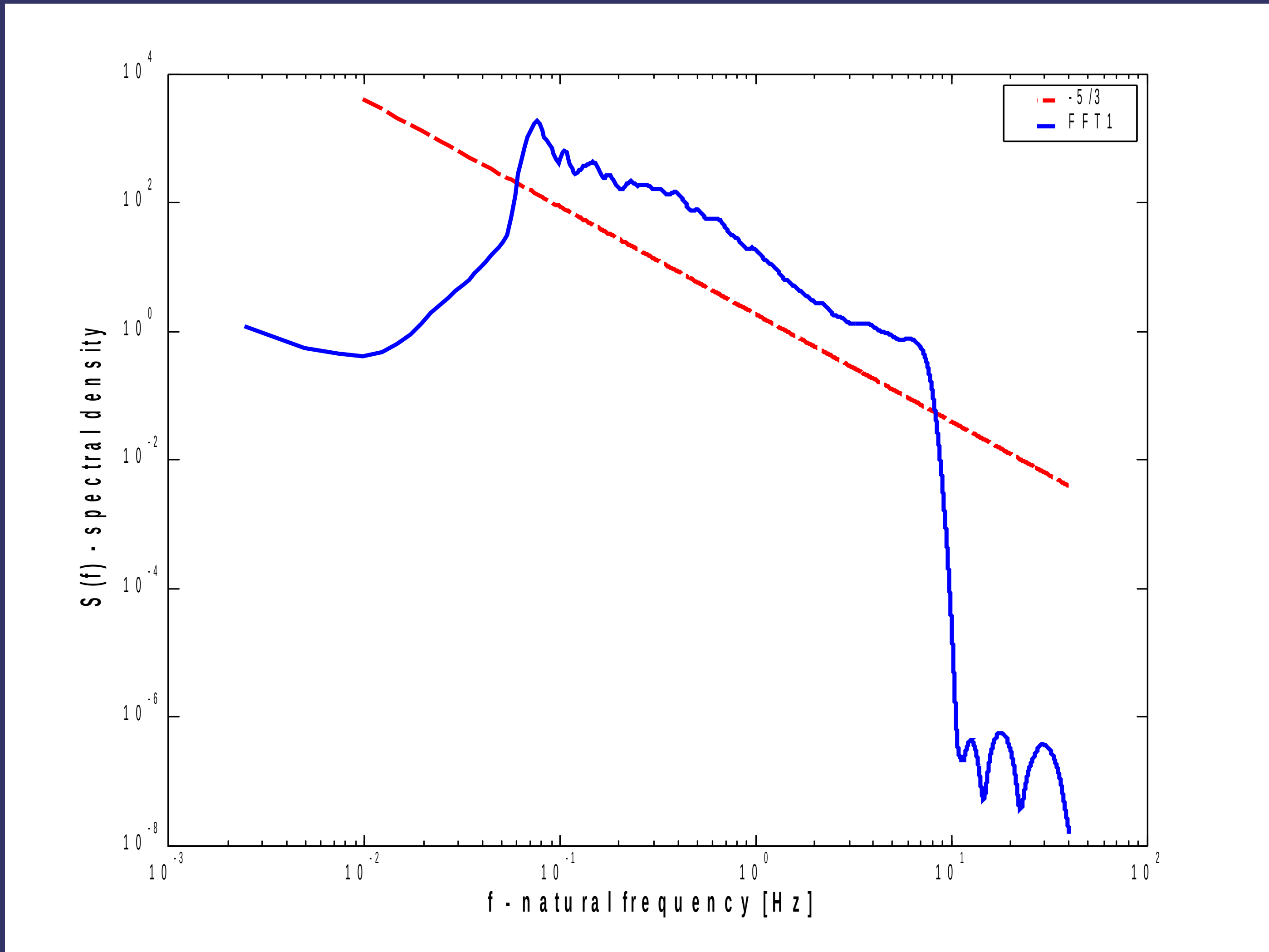


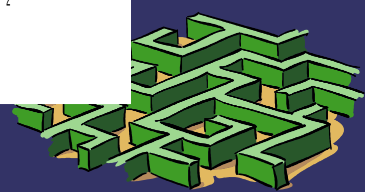
Raw RAL94 Spectrum





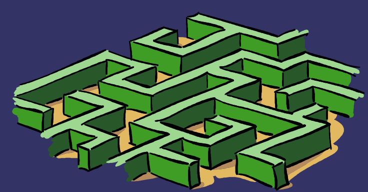
Filtered RAL94 Spectrum



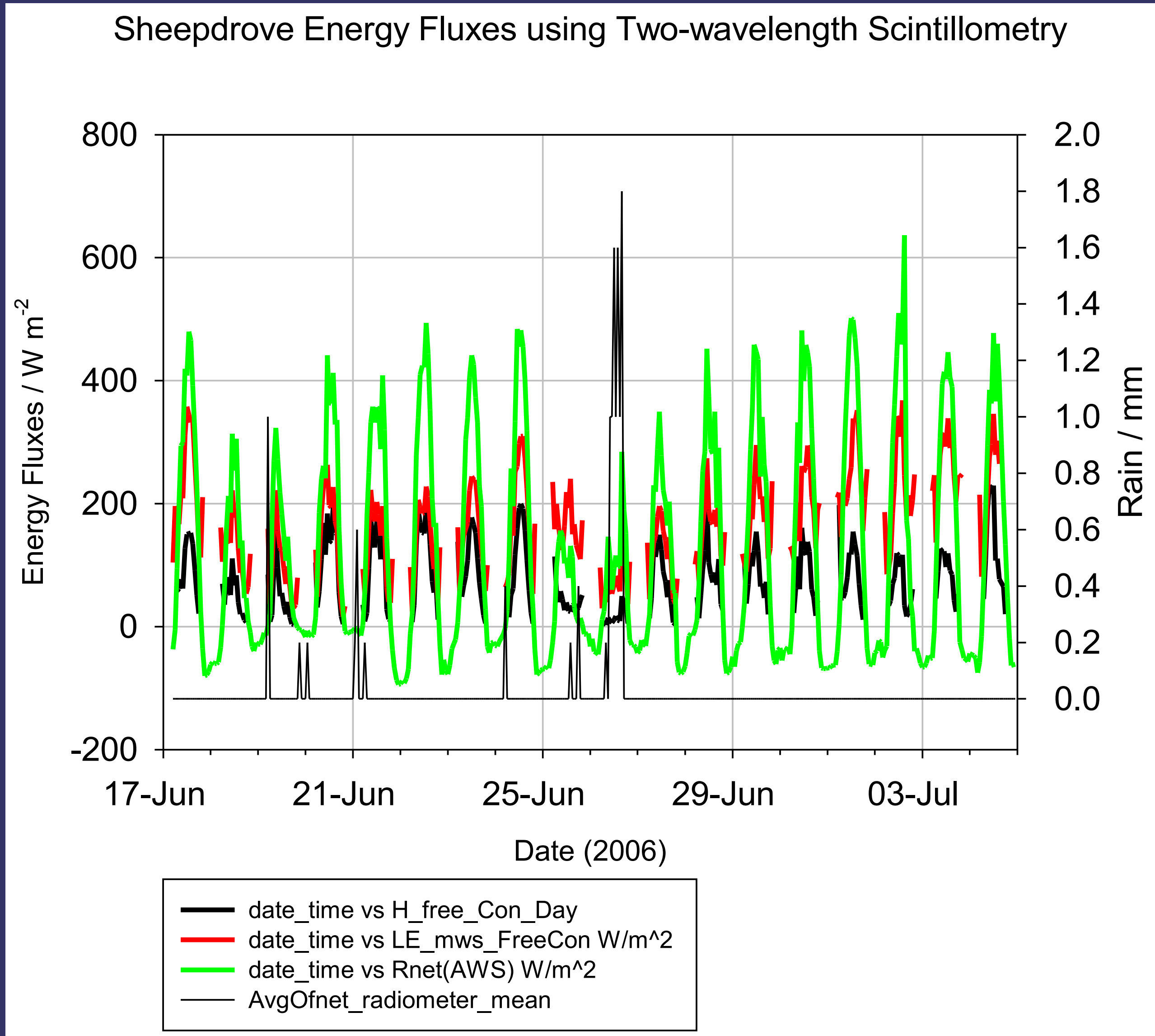


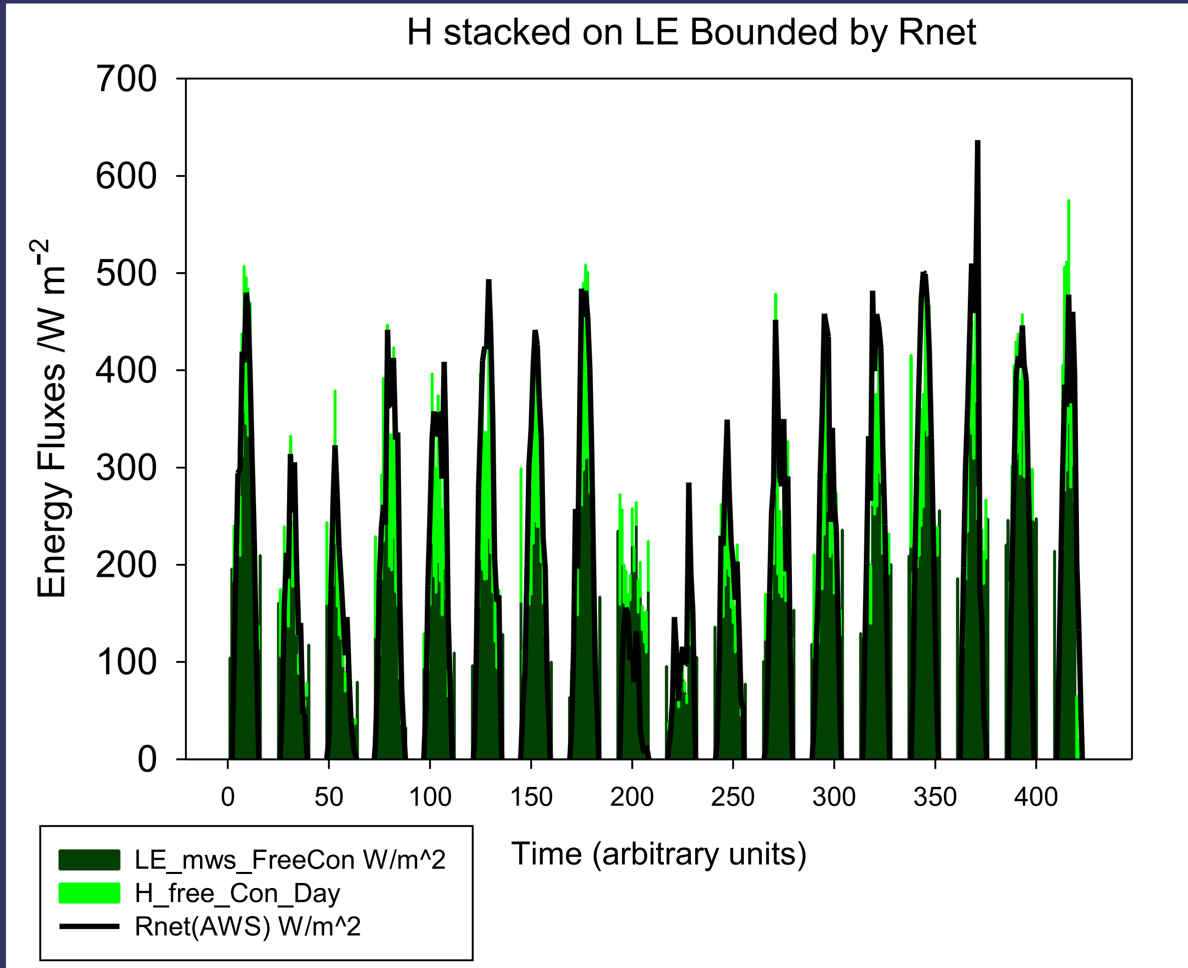
Calculation of LE

- C_{q2} was calculated from the variance of the log-intensity fluctuations (Hill *et. al.*, 1980), taking r_{Tq} = 0.6 (Ludi *et. al.*, 2005) and C_{T2} from the LAS assuming Bowen ratio = 2.
- Free convection method used to calculate LE, as $-(Z – d) / L_{ob} > 1$.



Results


Sheepdrove Energy Fluxes using Two-wavelength Scintillometry
Energy Fluxes / W m^-2
800
600
400
200
0
-200
Rain / mm
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
17-Jun
21-Jun
25-Jun
29-Jun
03-Jul
Date (2006)
date_time vs H_free_Con_Day
date_time vs LE_mws_FreeCon W/m^2
date_time vs Rnet(AWS) W/m^2
AvgOfnet_radiometer_mean


H stacked on LE Bounded by Rnet
Energy Fluxes /W m^-2
700
600
500
400
300
200
100
0
0
50
100
150
200
250
300
350
400
Time (arbitrary units)
LE_mws_FreeCon W/m^2
H_free_Con_Day
Rnet(AWS) W/m^2

Discussion

- Flux measurements appear to be good using the two-wavelength method over complex terrain (error analysis re-quired).
- High Z is beneficial, allowing the use of free convection and reducing the pos-sibility of saturation. It increases the footprint.
- Topography can provide height.