Cross-spectral evaluation of JULES energy fluxes and soil moisture using half-hourly observations at the Met Office Research Unit, Cardington Bedfordshire.

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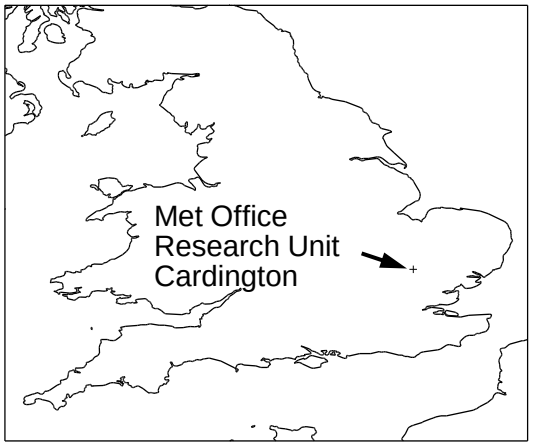
[1] = Met Office, [2] = CEH Wallingford, [3] = Anemos-Jacob GmbH, Germany



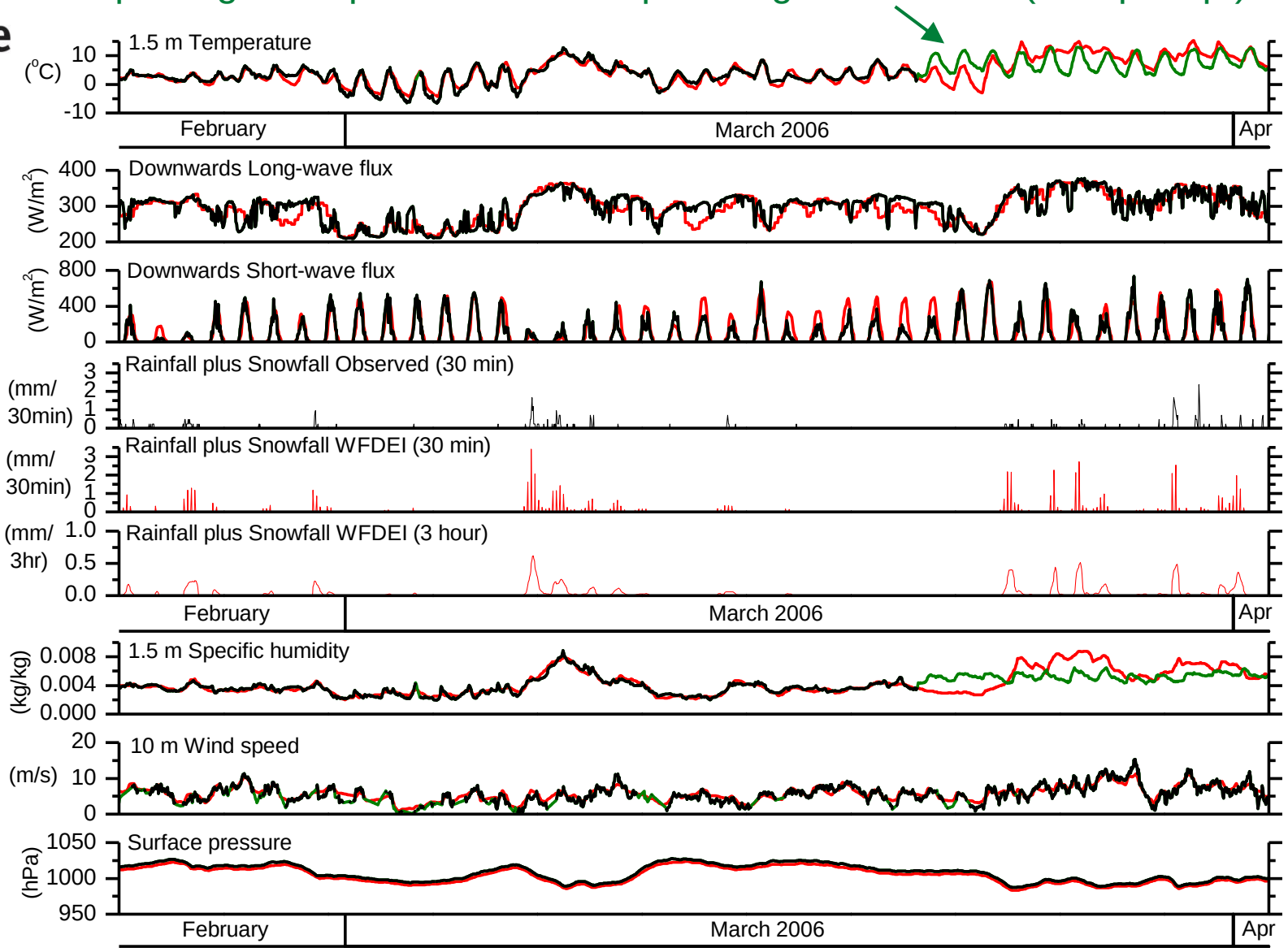
<u>30 min surface observations 2005-2012:</u>
(N = about 140,000 time steps)

Meteorology:
1.5 Air temperature; specific humidity; air pressure; 10 m wind speed; rainfall rate; snowfall rate; downwards shortwave flux ; downwards longwave flux

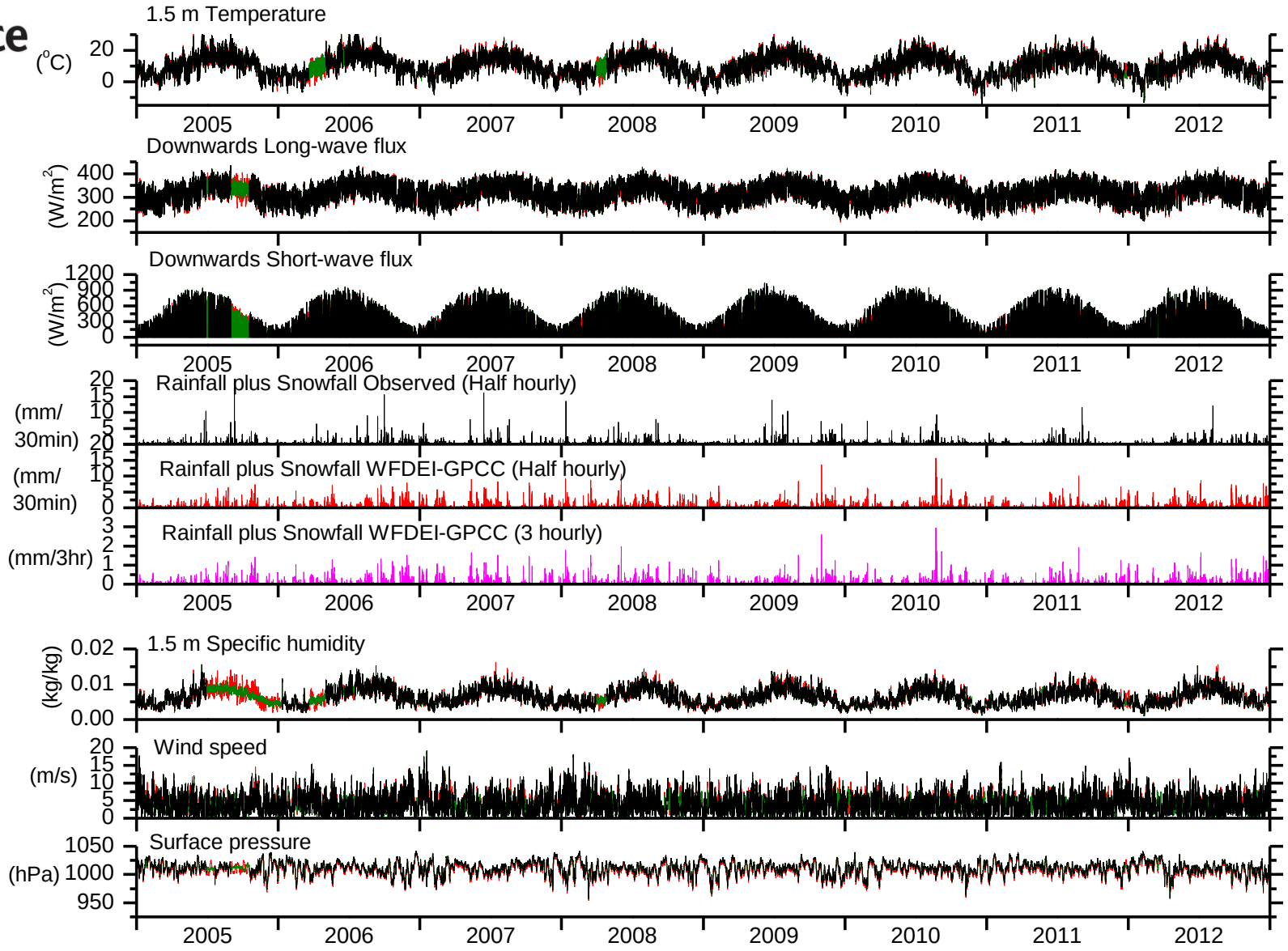
Energy fluxes and soil measurements:
Latent heat; sensible heat; 0-10 cm soil saturation

Cardington Meterological **Observations** v. **Gap-filled observations** v. **WFDEI**

Gap-filling with specific time-stamp average 2005-2012 (exc. precip.)

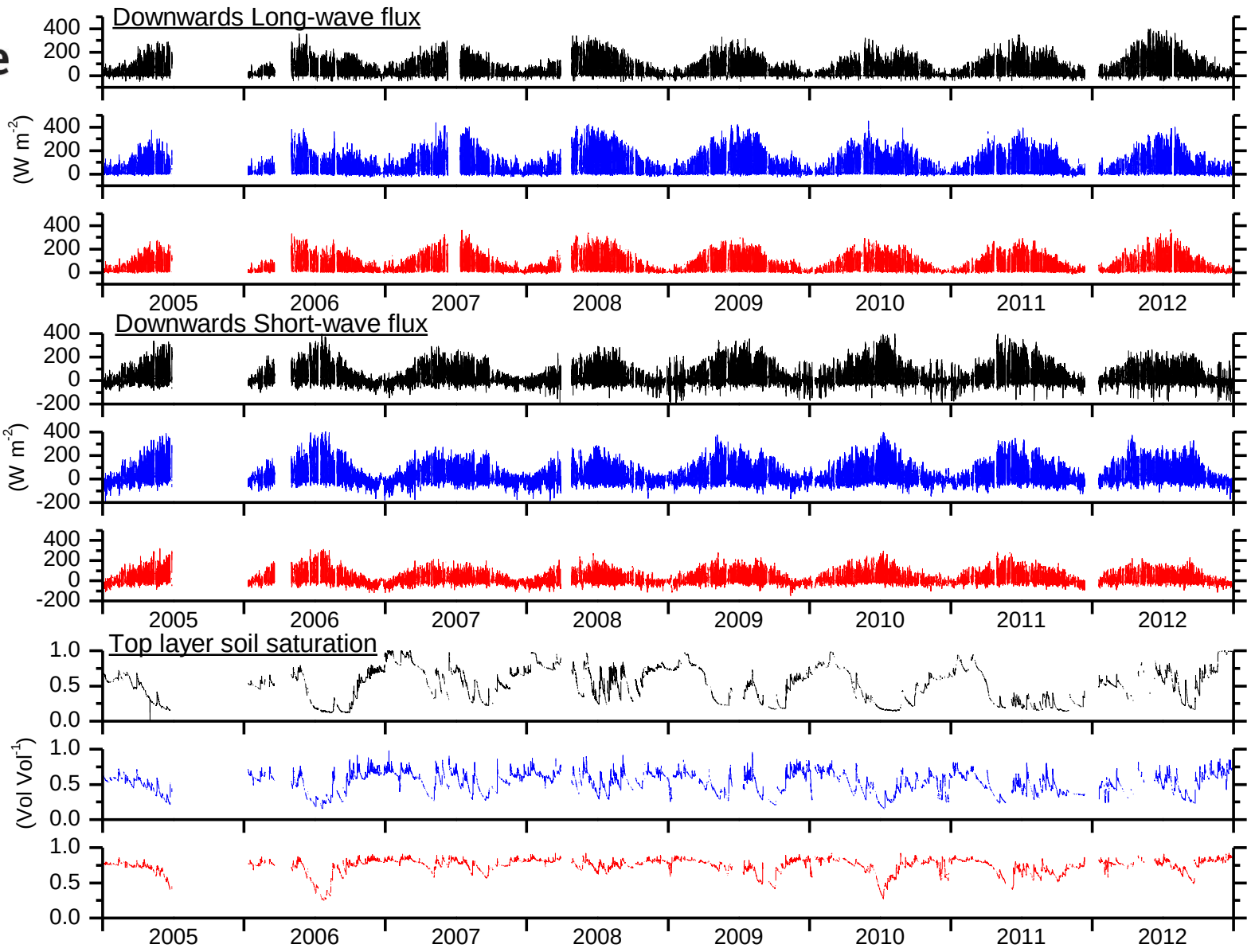


Cardington Meterological **Observations** v. **Gap-filled observations** v. **WFDEI**



Cardington Fluxes and soil saturation

Observations v. **JULES-Card-Obs** v. **JULES-WFDEI**



Cross-spectral analysis of Cardington time series:

Met Office

Basics:

Frequency = 1/period. **Amplitude** = max. deviation from the mean. **Phase** indicates timing of oscillations. Simplifying, the **power spectrum** plots ***average*** amplitude^2 (i.e. variance) v. frequency. The **phase spectrum** plots ***average*** phase v. frequency.

Applications:

1) **Frequency response** of JULES compared to frequency response of observed environment.
2) **Evaluation of mis-matches** between observed variable and JULES output.

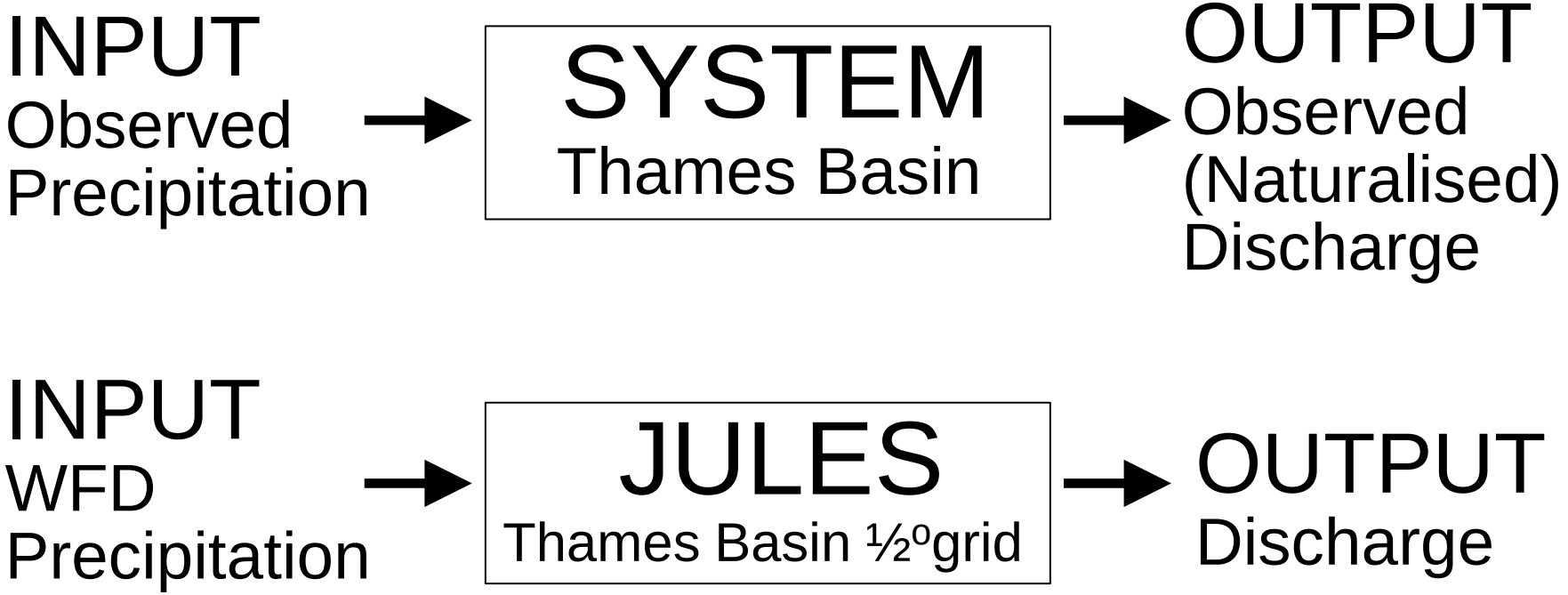
Restrictions:

- Analysis only at time steps where **all meteorological variables** and relevant **fluxes/soil saturation are observed** (about 70% of possible time steps).
- Lomb-Scargle algorithm > “periodogram”-based spectral estimates.
- JULESv4.3 using out-of-the-box (not optimised) configuration (e.g. C3 grass 1.5 m tall not ~0.1 m tall).

Methodology:

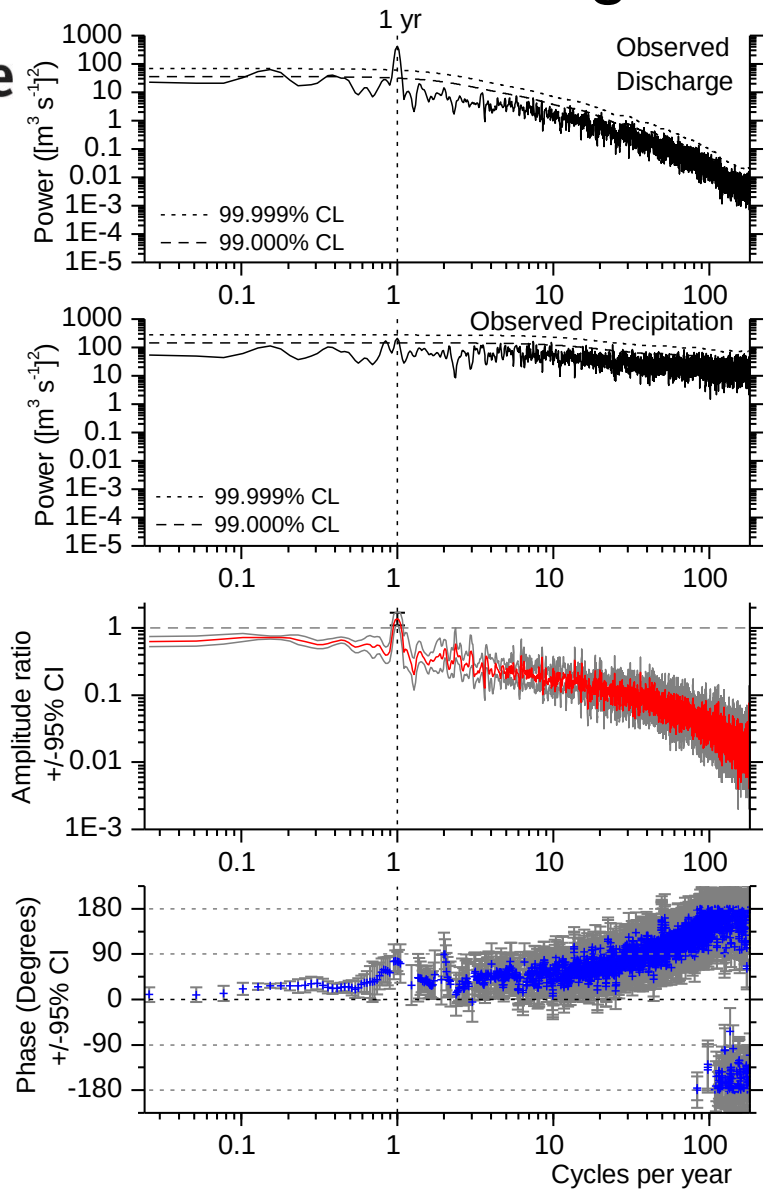
Weedon et al., 2015. Evaluating the performance of hydrological models via cross-spectral analysis: Case study of the Thames Basin, United Kingdom. *J. Hydrometeorology*, doi: 10.1175/JHM-D-14-0021.1

Frequency response from the spectral transfer function

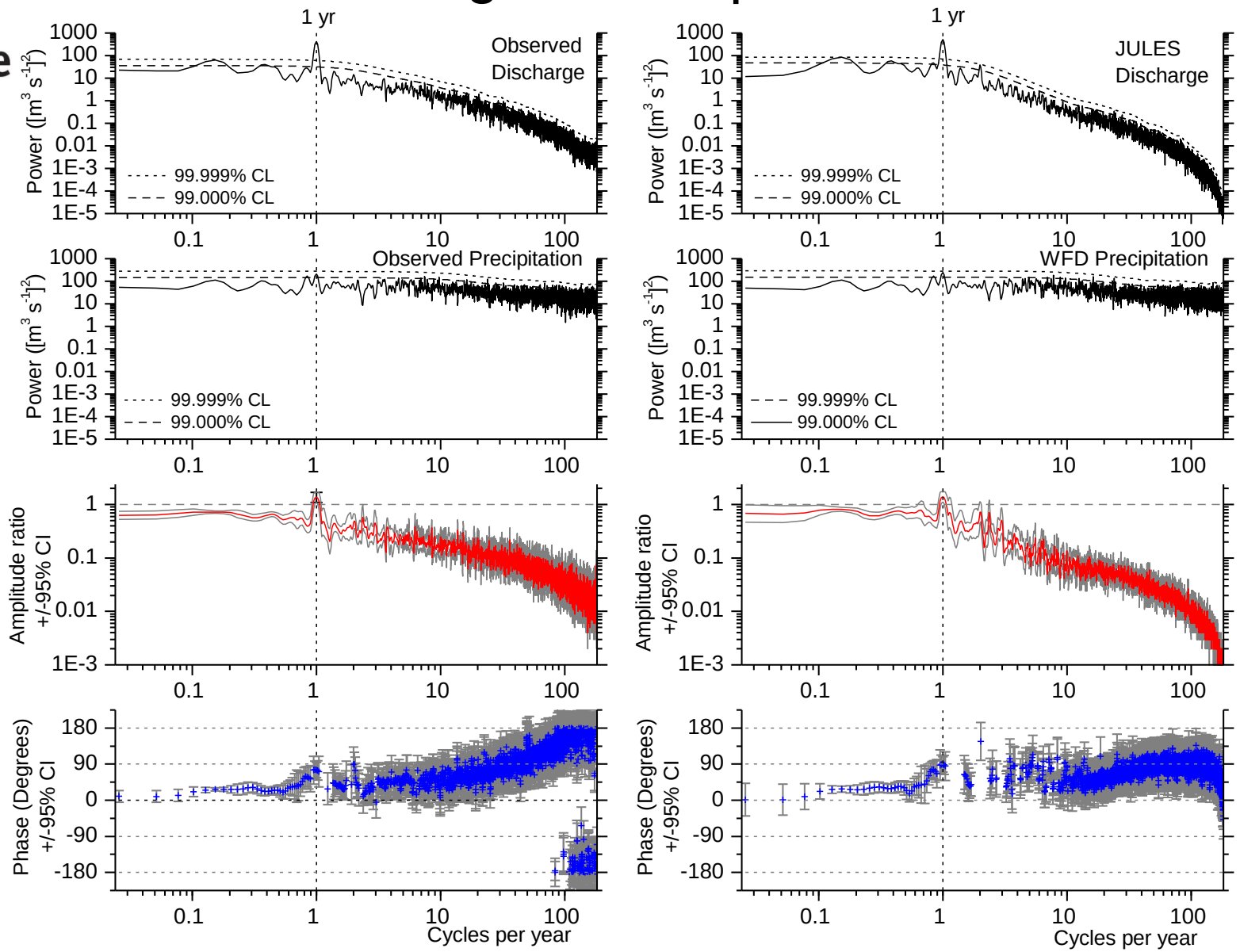


The frequency response for linear, time-invariant systems without feedbacks, can be estimated by comparing output time series with input time series.

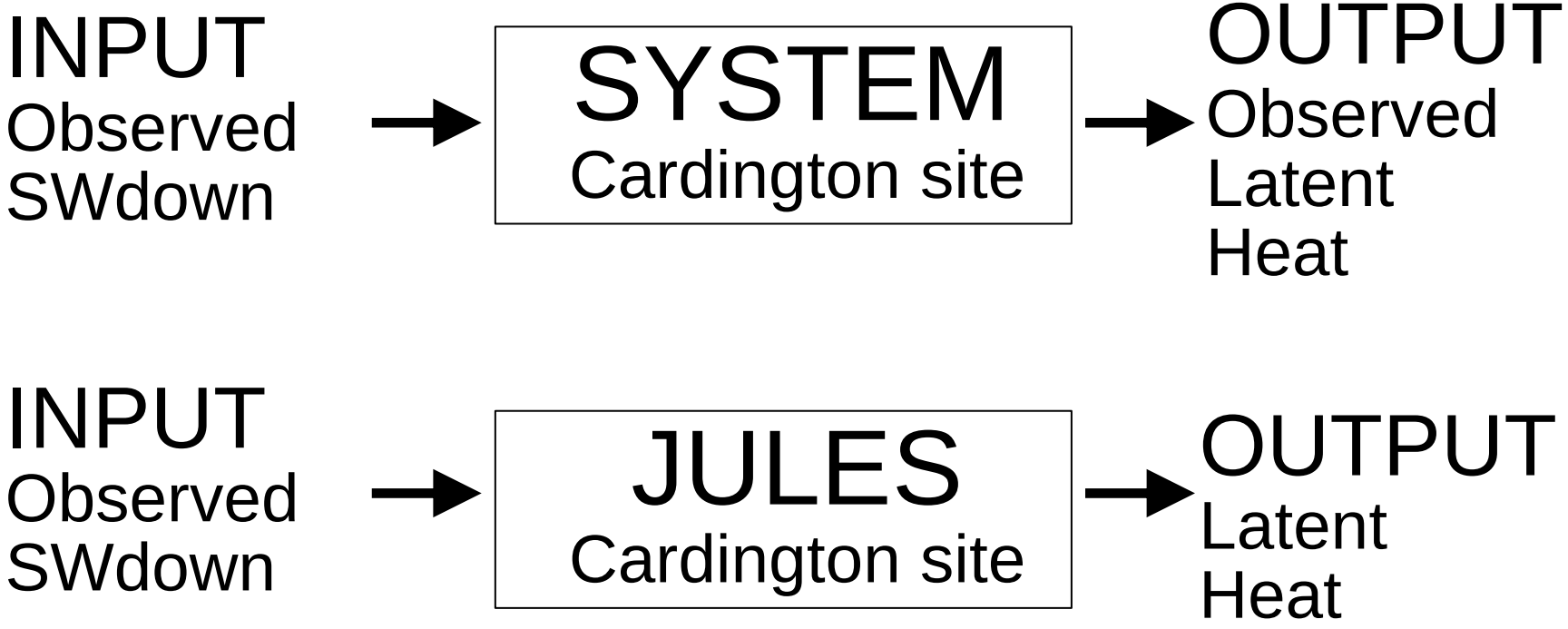
Thames Basin Transfer functions
Discharge v Precipitation



Thames Basin Transfer functions
Discharge v Precipitation

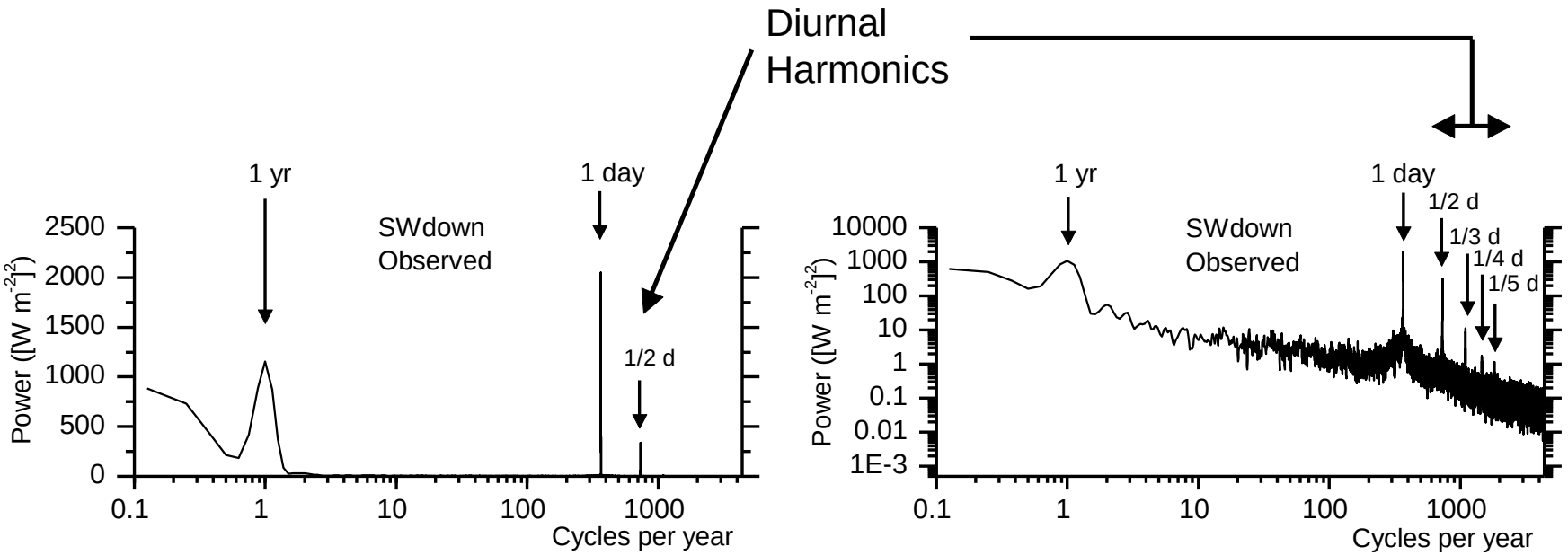


Frequency response from the spectral transfer function



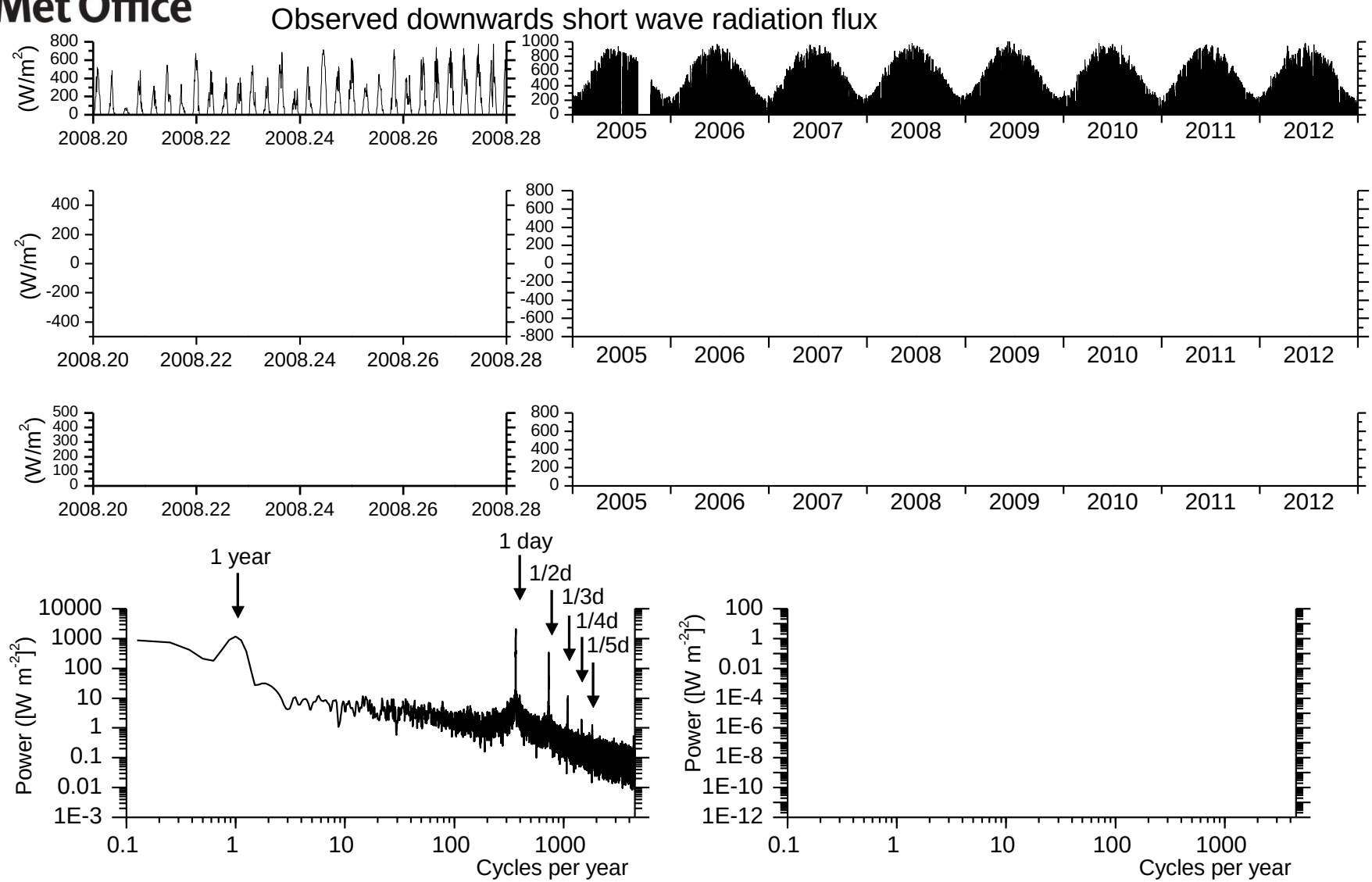
Most of the variance of downwards shortwave flux is concentrated near the annual and diurnal frequencies.

In this case these two spectral peaks alone represent 42.8% of the total variance concentrated within just 0.07% of the available frequency positions.



Simulating downwards shortwave spectral characteristics

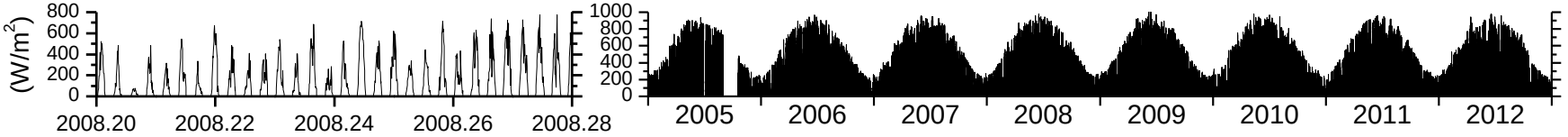
Met Office



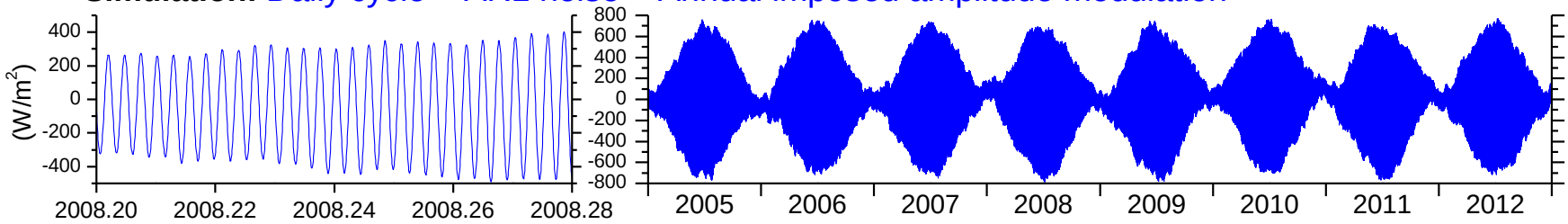
Simulating downwards shortwave spectral characteristics

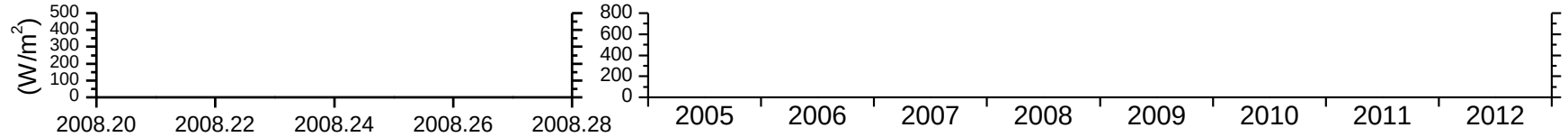
Met Office

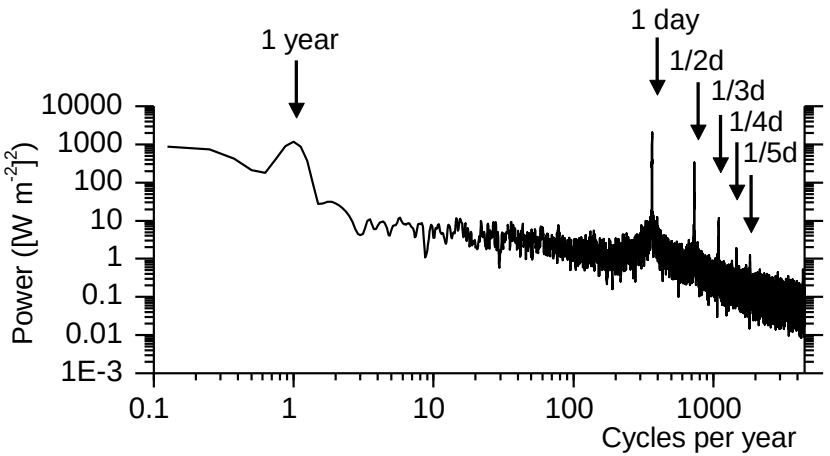
Observed downwards short wave radiation flux

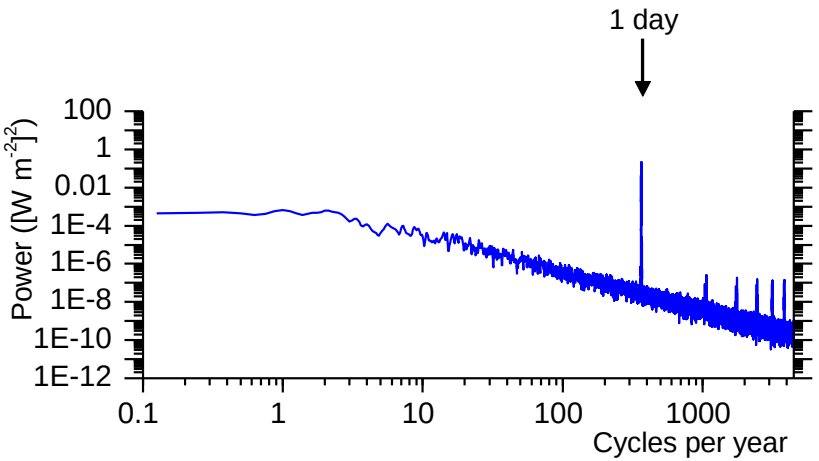


Simulation: Daily cycle + AR1 noise + Annual imposed amplitude modulation









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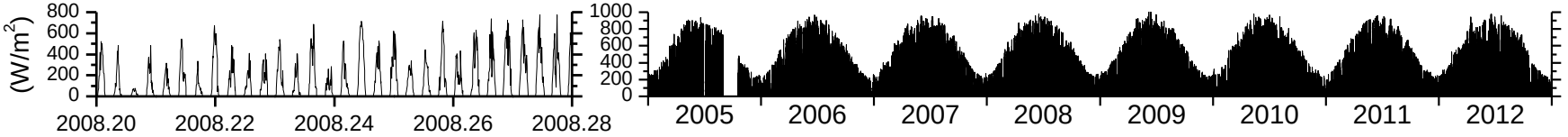
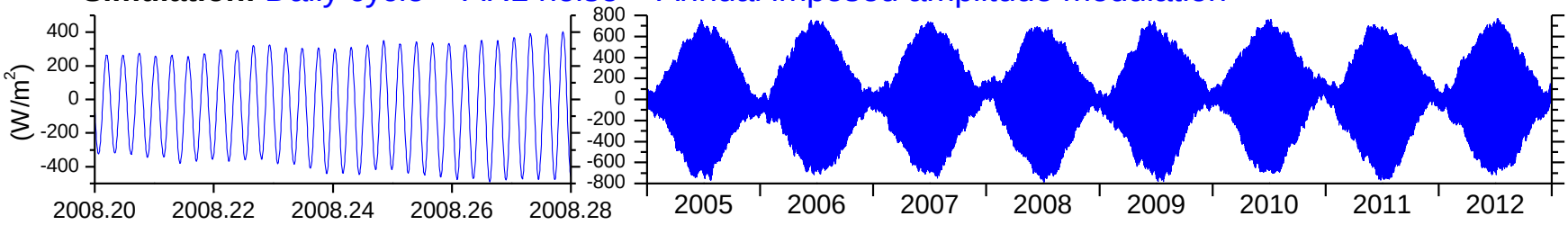
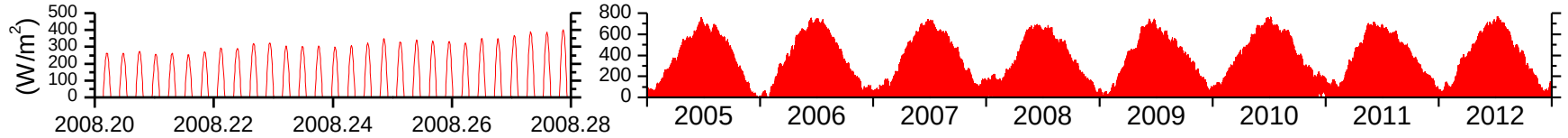
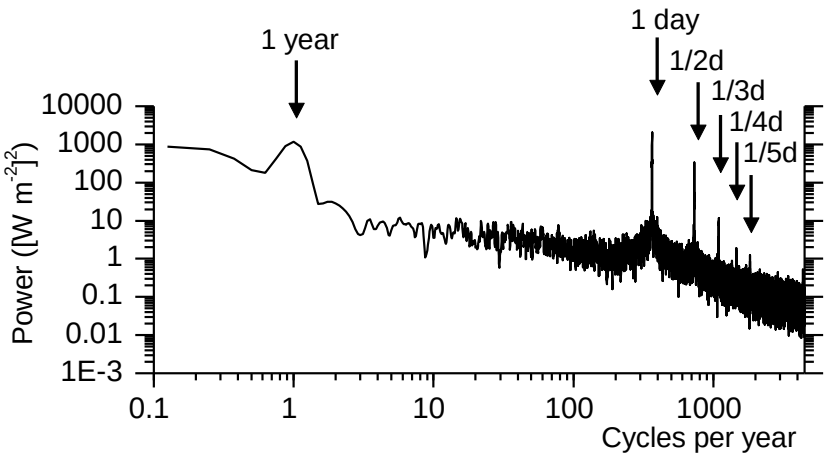


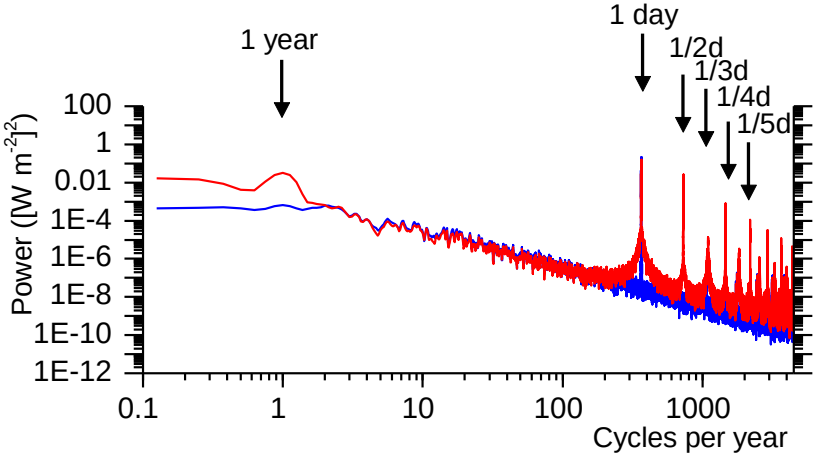
Simulation: Daily cycle + AR1 noise + Annual imposed amplitude modulation



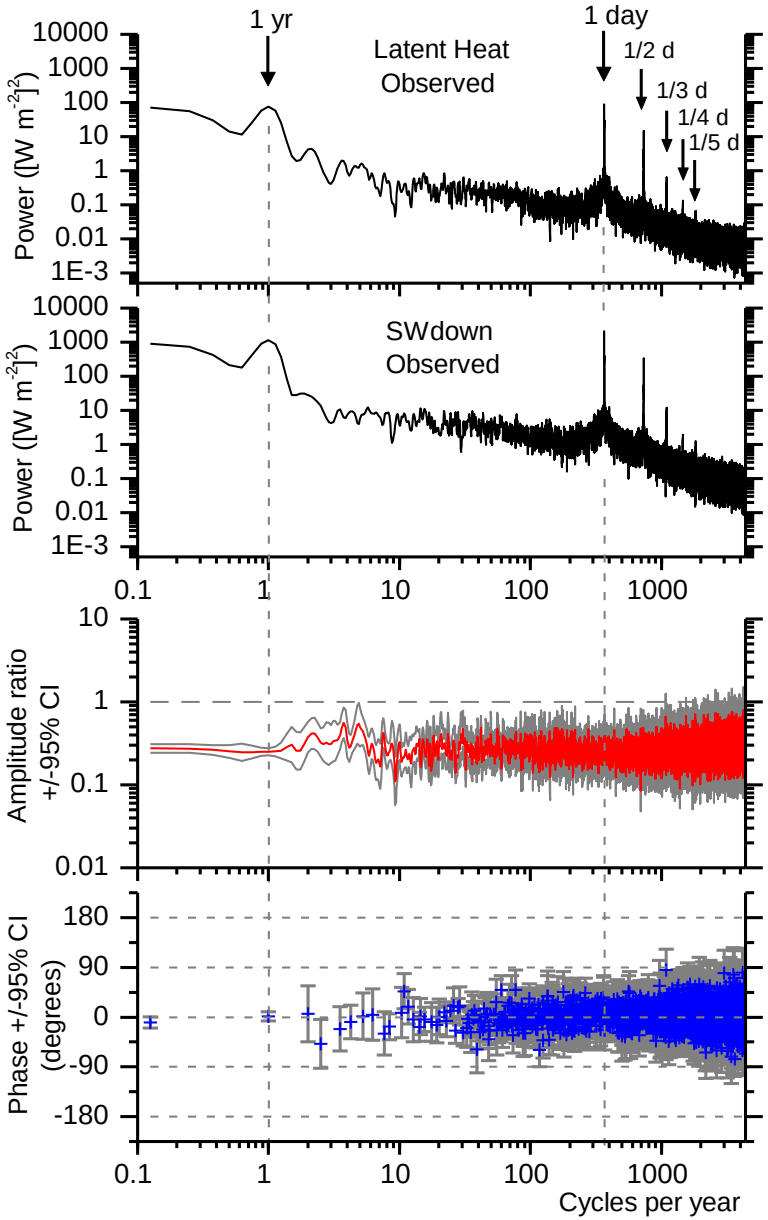
Simulation: Half-wave Rectified:[Daily cycle + AR1 noise + Annual imposed amplitude modulation]







Cardington Transfer functions
Latent Heat v Downwards shortwave flux



Cardington Transfer functions
Latent Heat v Downwards shortwave flux