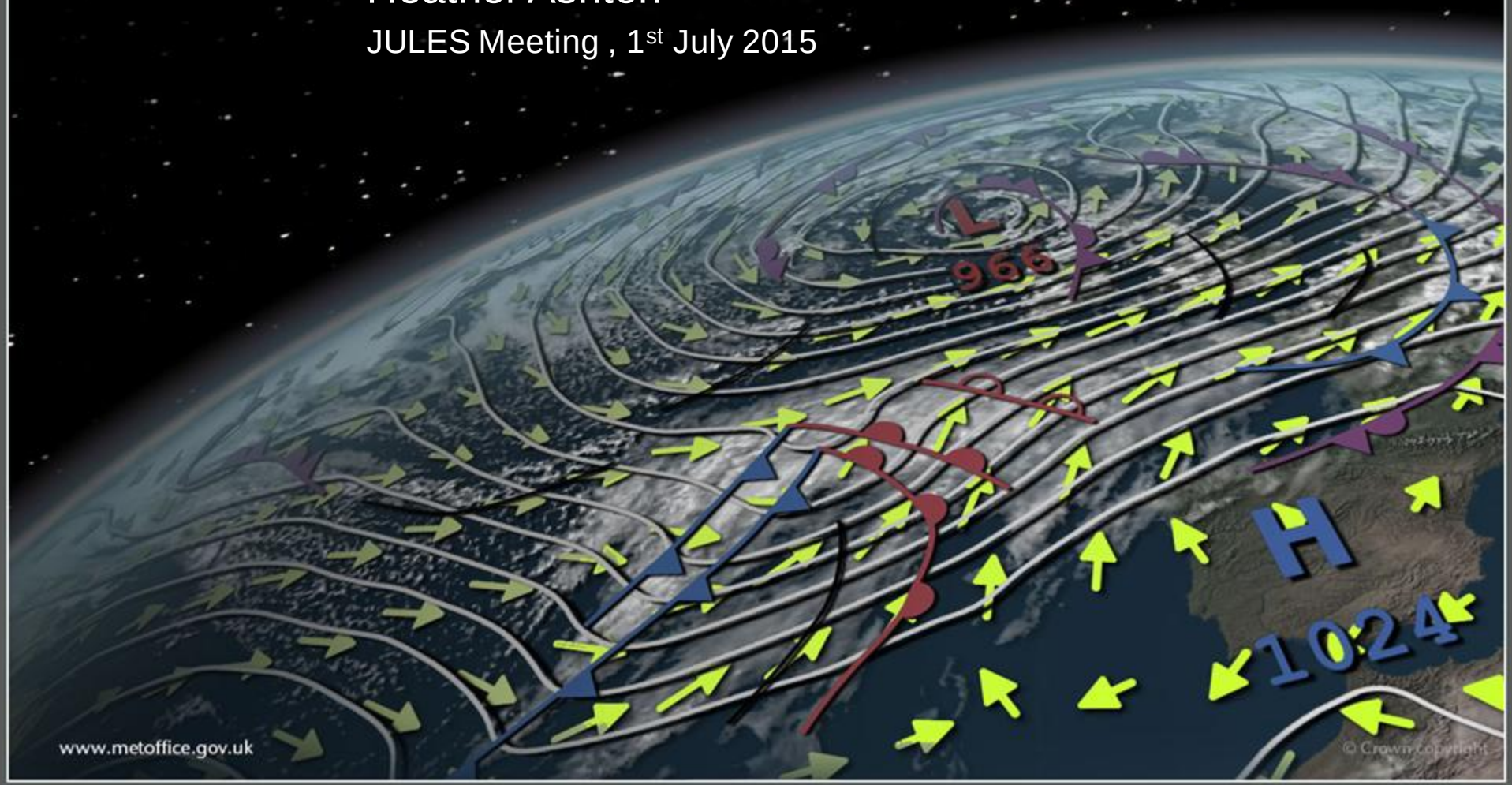
Evaluation of the CHESS data within JULES for UK Environmental Prediction

Heather Ashton

JULES Meeting , 1st July 2015



Outline

- Purpose of the evaluation
- CHESS, WFDEI & observations
- Evaluation studies
    - Daily
    - 3 hourly
    - Single site
- Key conclusions
- Future plans

Met Office

UKEP - UK Environmental Prediction

Purpose

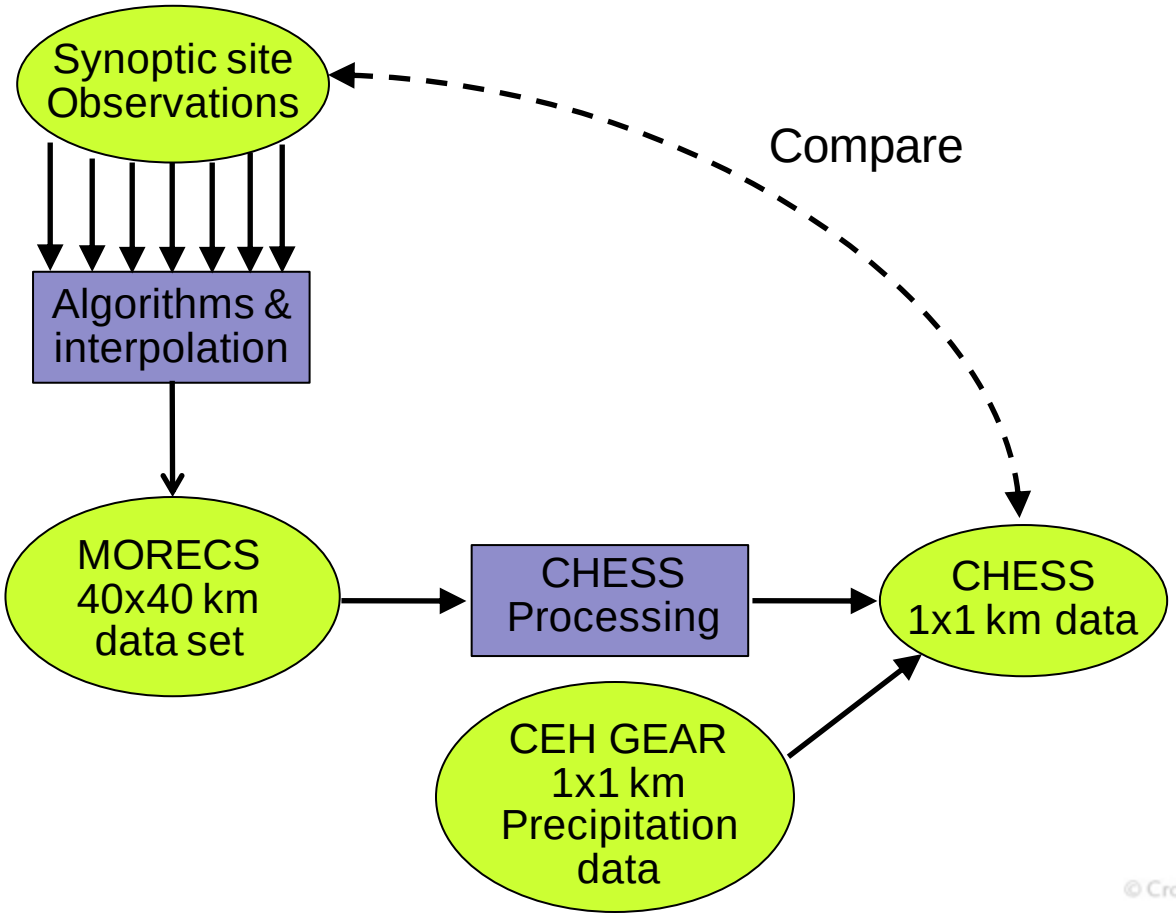
1. **Aims:**
   - **To extend, test and implement new hydrological capabilities into JULES in a fully coupled system.**
   - **To provide realistic simulations of river discharge into the oceans and represent feedbacks to the atmosphere.**
2. **The CHESS dataset is required to drive JULES for offline evaluation of the hydrological components.**
3. **It is essential to evaluate the CHESS dataset for this purpose, especially the disaggregator.**

What is CHESS?

- Climate Hydrology Ecology Support System
- 30 year (1961 – 2013), daily 1km UK forcing dataset.

Data Product

Model/ Algorithm

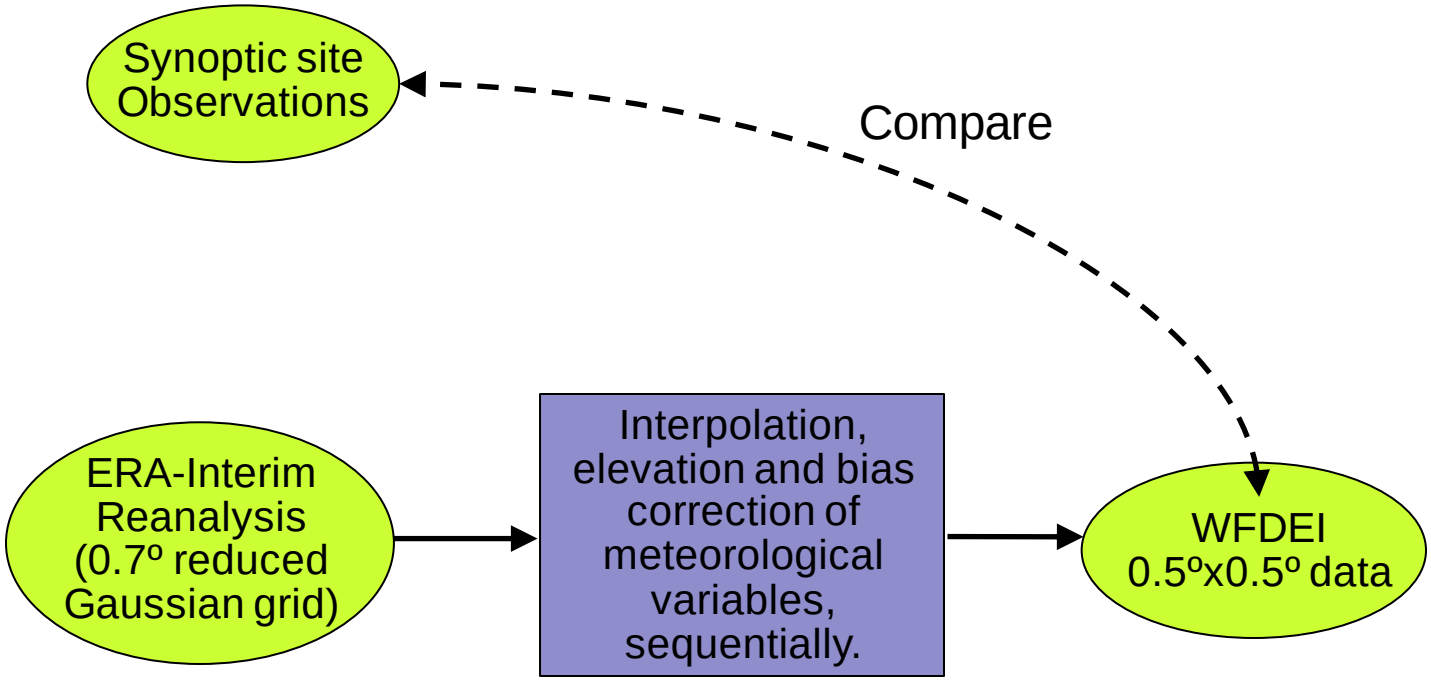


What is WFDEI?

Data Product

Model/ Algorithm

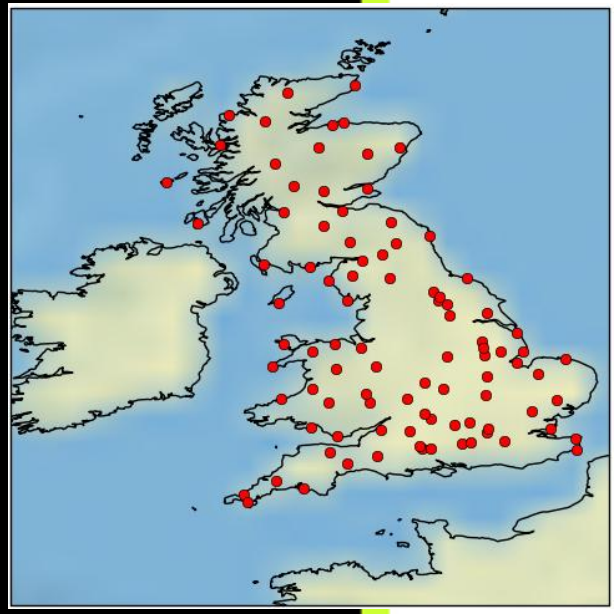
- WATCH Forcing Data (WFD) methodology applied to ERA Interim reanalysis data.
- 33 year (1979 – 2012), 3 hourly, half-degree (~ 50 x 50 km) global forcing dataset.



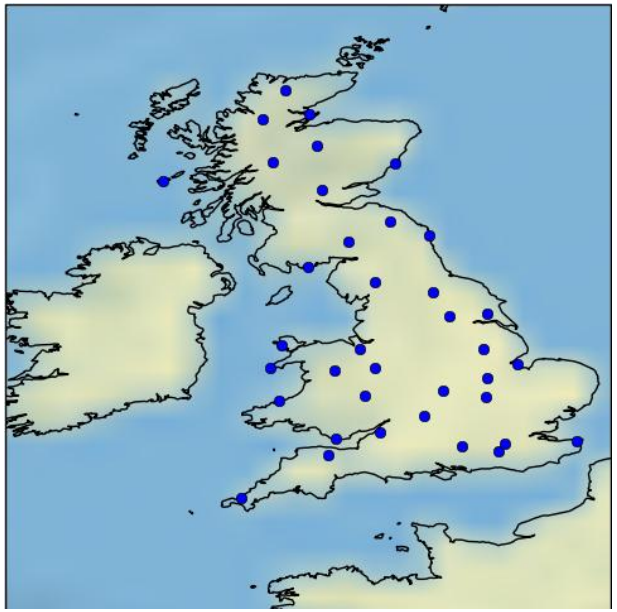
Weedon *et al.*(2014), The WFDEI meteorological forcing data set: WATCH Forcing Data methodology applied to ERA-Interim reanalysis data, Water Resour. Res., 50, 7505–7514

Observations

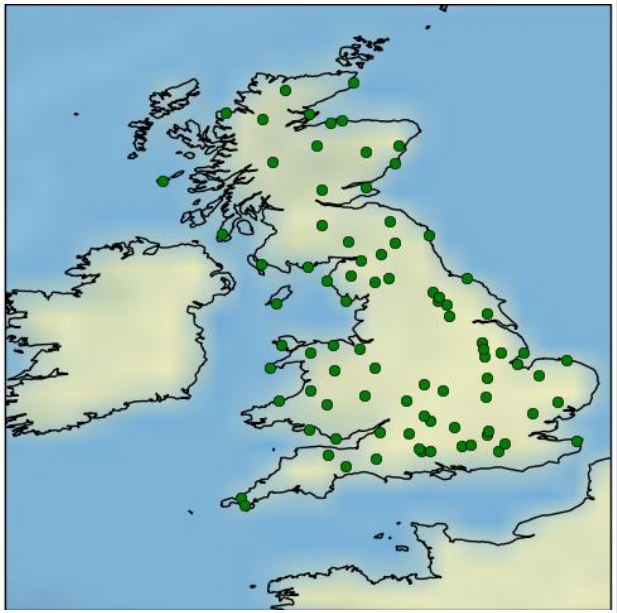
- Met Office Land Synoptic Stations over UK
- Hourly observations.



Air Temperature, Relative Humidity & Wind Speed
94 sites



Down-welling shortwave radiation
37 sites



Precipitation
86 sites

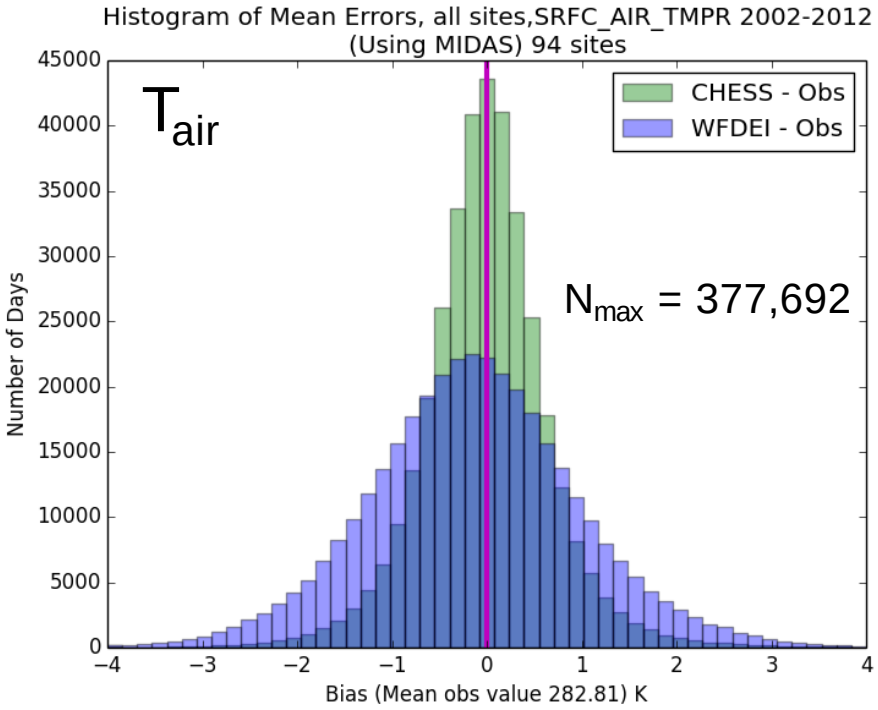
Evaluation

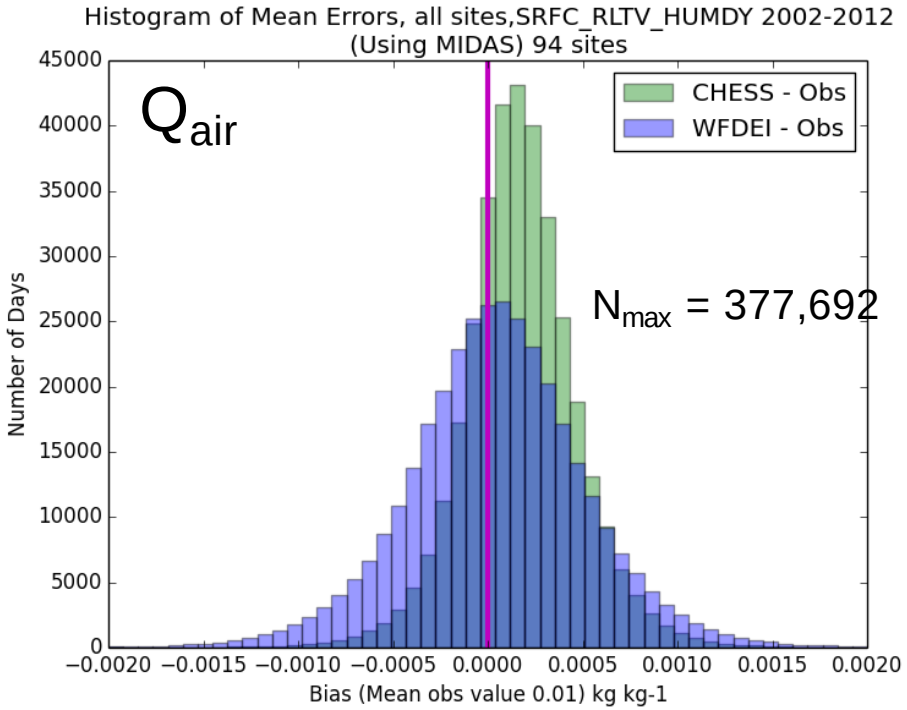
- 10 years, 2002 - 2012.
- Mean absolute biases.
- Daily and 3 hourly means - T_{air}, Q_{air}, Wind, SW down.
- Daily and 3 hourly accumulations for total precipitation.
    - Subdivided into wet, dry, false wet and missed wet days.
    - Analysis of 09hr to 09hr (daily only) and 00hr to 00hr accumulations.
- Single site analysis – Cardington
    - 3 hourly biases
    - Cross spectral analysis on fluxes (Graham Weedon)

Met Office

Daily Analysis

Daily Temperature & Humidity

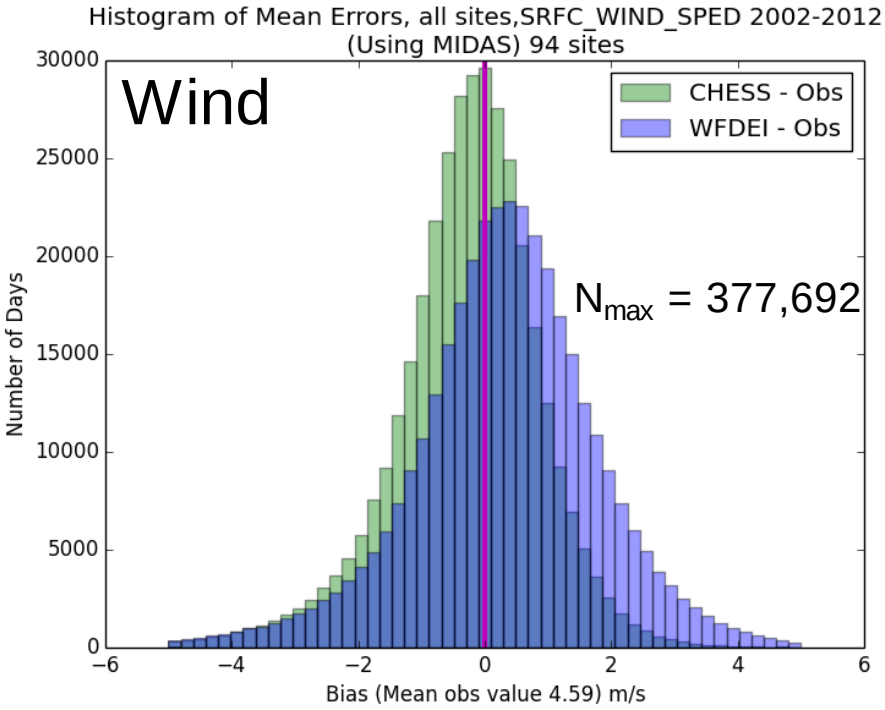


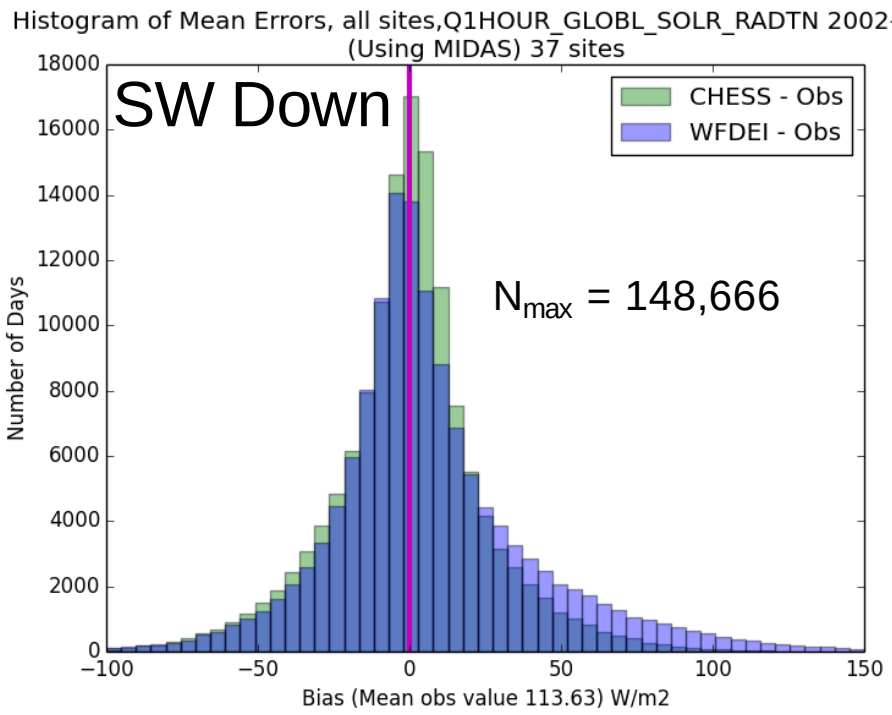


T_{air}	WFDEI	CHESS
Mean (K)	-0.1302	-0.0115
Std Dev	1.1431	0.6911
Skewness	0.2186	0.1844
Kurtosis	1.5971	5.9697

Q_{air}	WFDEI	CHESS
Mean (kg kg^{-1})	0.00005	0.00020
Std Dev	0.0005	0.0003
Skewness	-0.0165	-0.0263
Kurtosis	1.3561	2.6676

Daily Wind Speed & Down-welling Shortwave Radiation





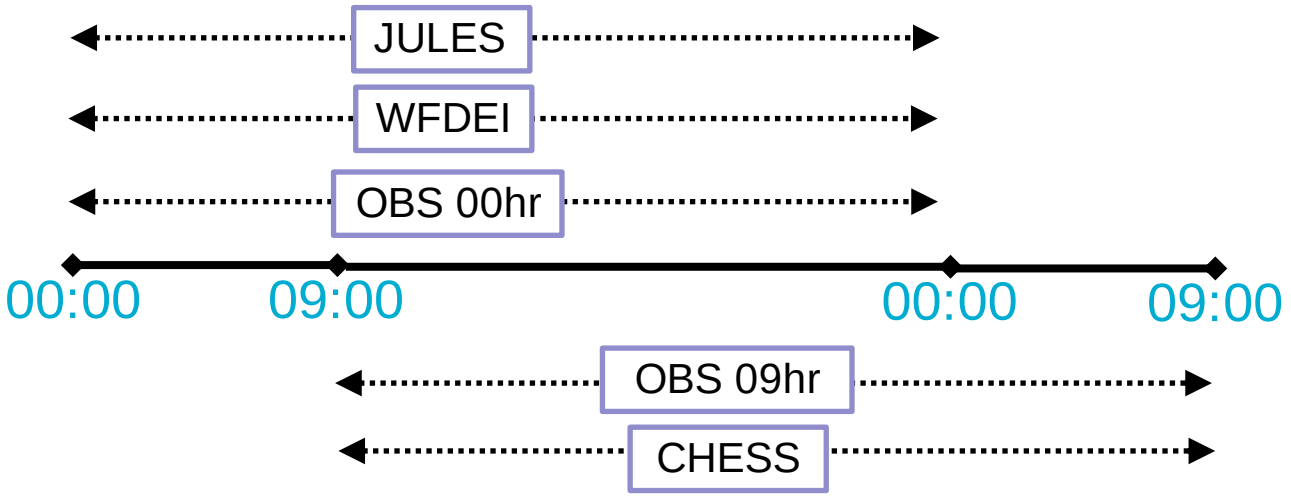
Wind	WFDEI	CHESS
Mean ($m\ s^{-1}$)	0.2929	-0.3041
Std Dev	1.5401	1.2114
Skewness	-0.4681	-0.8281
Kurtosis	2.0403	3.2377

SW down	WFDEI	CHESS
Mean ($W\ m^{-2}$)	6.9696	-0.5219
Std Dev	35.2463	26.2369
Skewness	0.8427	-0.0326
Kurtosis	2.6417	2.4689

Precipitation - timeline

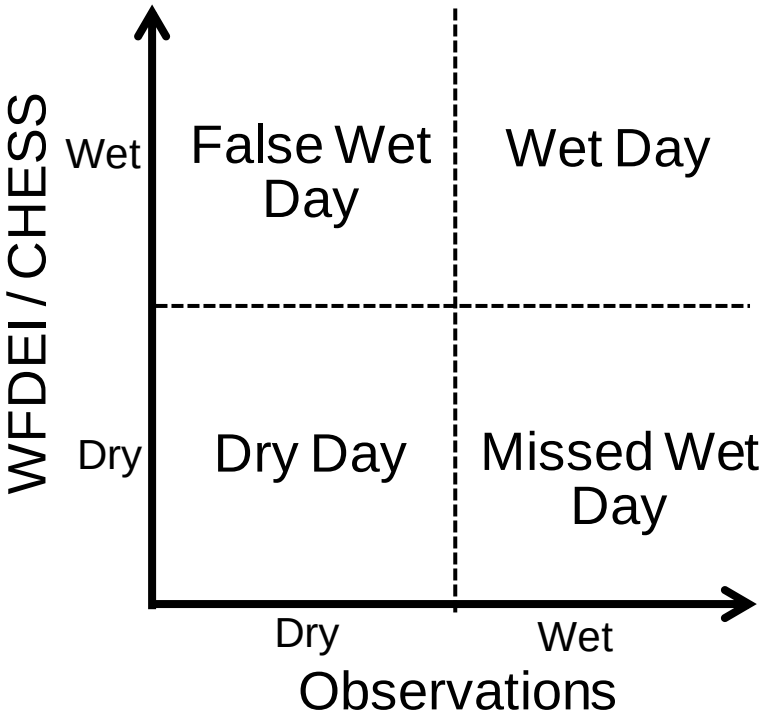
• UK hydrological convention - precipitation on a given day refers to accumulation between 09:00 on the day and 09:00 on the next day.

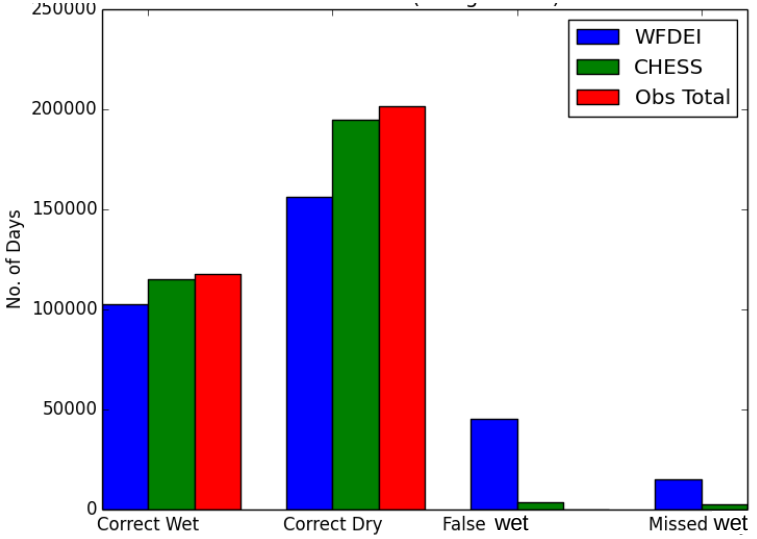
• Modelling convention (and JULES) – precipitation accumulated from 00:00 to 00:00.



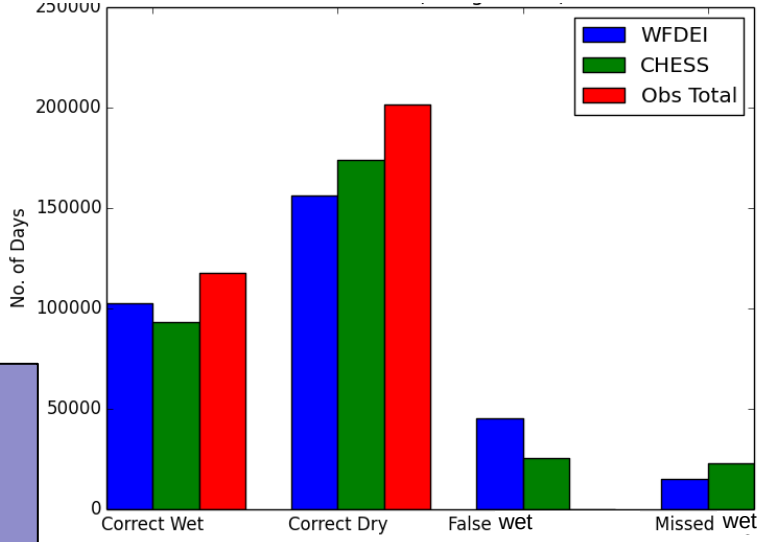
Comparing:
• WFDEI & OBS 00hr
• CHESS & OBS 00hr
• CHESS & OBS 09hr

Daily Precipitation – Rain days





CHESS 09hr

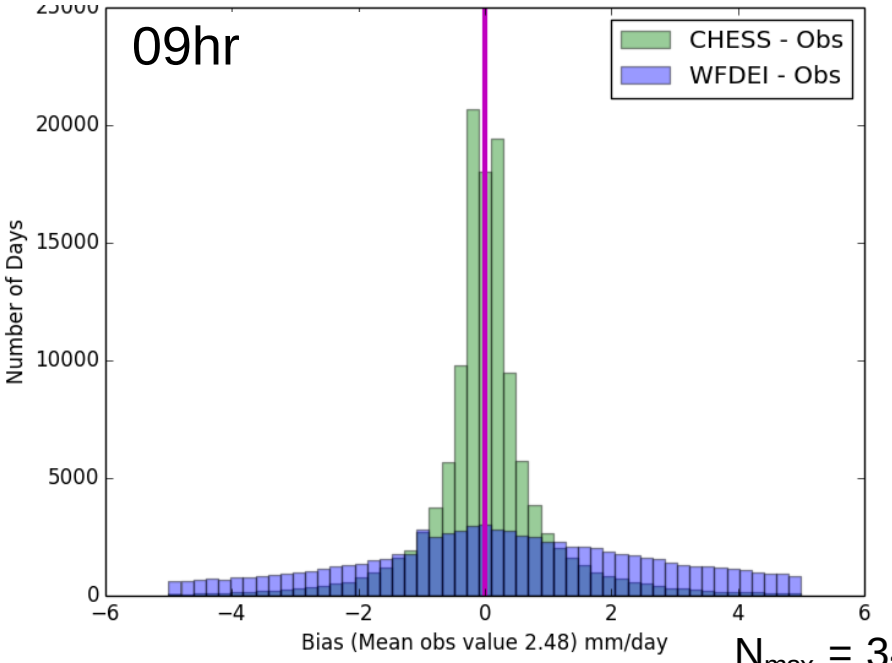


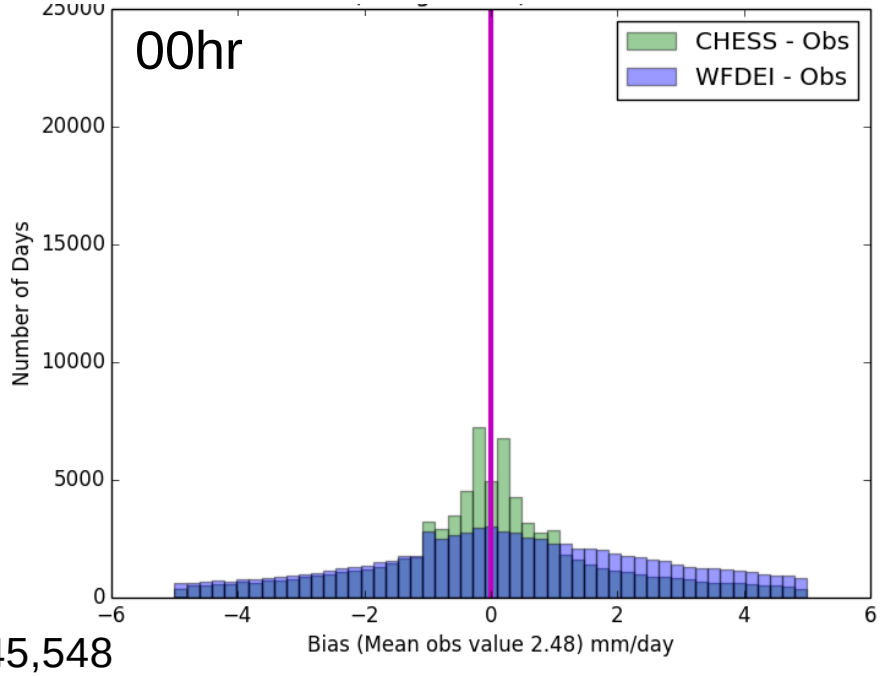
CHESS 00hr

Rain day ≥ 1mm/day

(National Climate Information Centre definition)

Daily Precipitation – Wet days



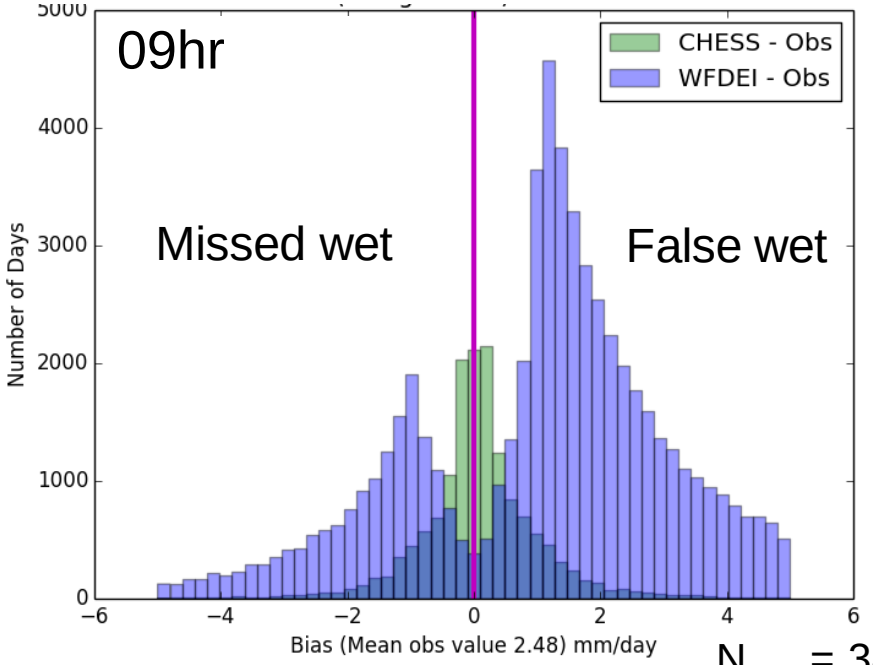


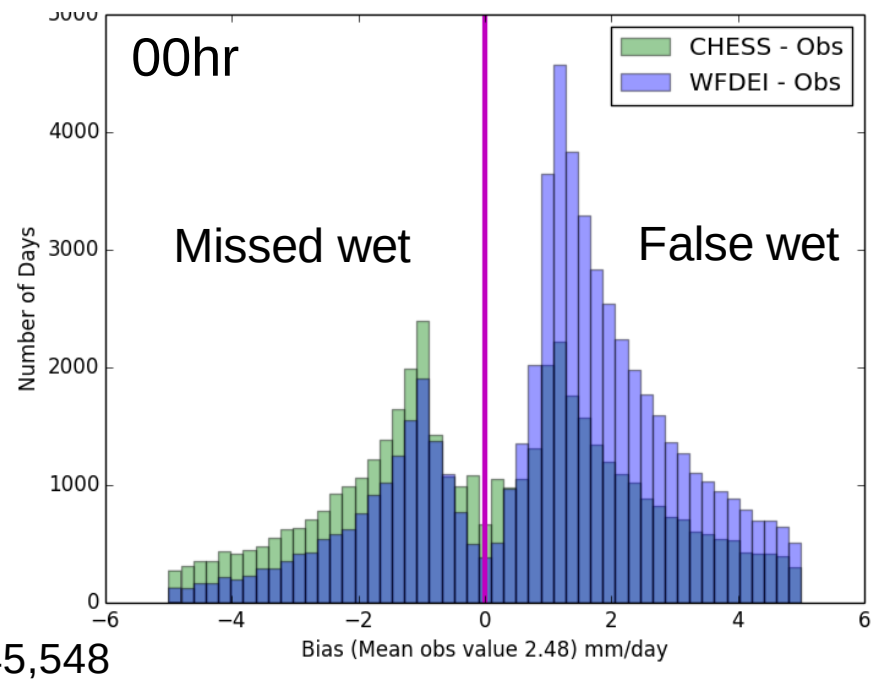
N_{max} = 345,548

0900 Wet	WFDEI	CHESS
Mean (kg m^{-2} s^{-1})	0.4488	0.0351
Std Dev	6.4431	1.3039
Skewness	-0.8132	0.7621
Kurtosis	14.7848	35.0069

0000 Wet	WFDEI	CHESS
Mean (kg m^{-2} s^{-1})	0.4488	-0.0422
Std Dev	6.4431	5.6746
Skewness	-0.8132	0.1795
Kurtosis	14.7848	11.1932

Daily Precipitation – False/Missed





N_{max} = 345,548

0900 False/Missed	WFDEI	CHESS
Mean (kg m^{-2} s^{-1})	1.4203	0.1471
Std Dev	3.3140	1.3313
Skewness	-0.0369	2.9130
Kurtosis	12.4863	37.2676

0000 False/Missed	WFDEI	CHESS
Mean (kg m^{-2} s^{-1})	1.4203	0.2373
Std Dev	3.3140	4.9552
Skewness	-0.0369	-0.0926
Kurtosis	12.4863	7.7350

3 Hourly Analysis

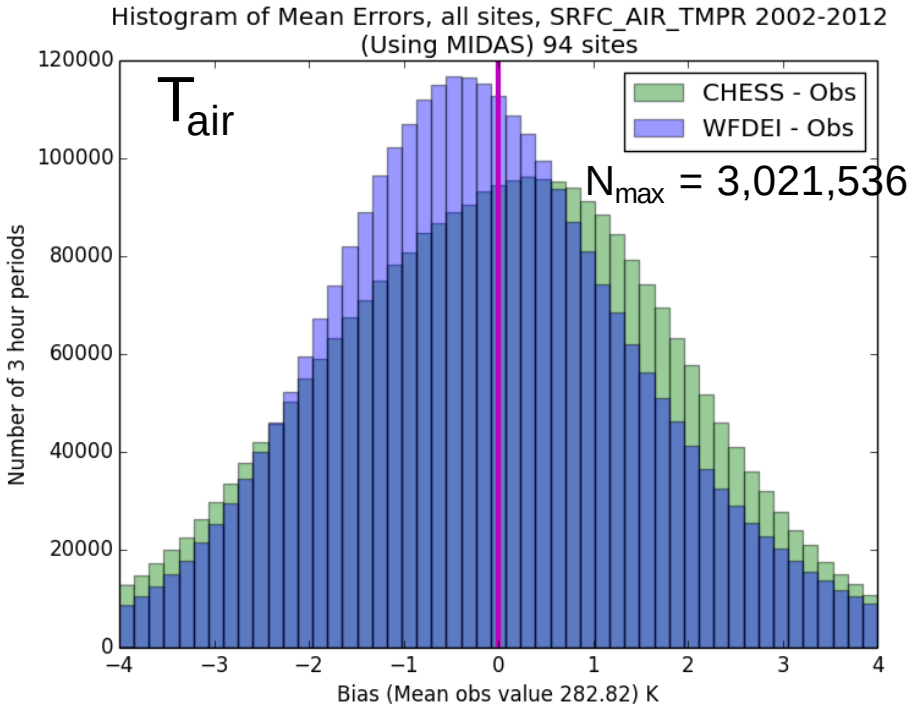
The JULES Disaggregator

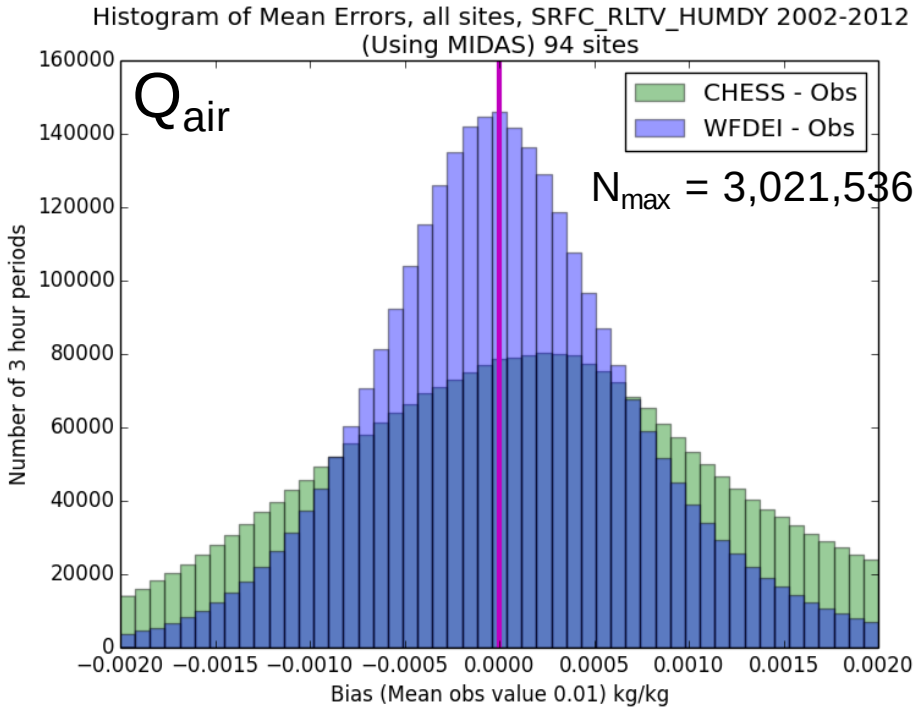
- JULES version 4.0 and later.
- Disaggregation of daily forcing data to JULES model time steps
- Switched on using the `l_daily_disagg` flag in `&JULES_DRIVE`
- Imposes a diurnal cycle on temperature and radiation.
- Allocates the precipitation to a continuous series of model time steps within the day.
- Pressure and wind values are unchanged by the disaggregation code
- Specific humidity is kept below the specific humidity at saturation.
- Used ‘out the box’ settings for this evaluation work.

More details see:

Williams, Karina; Clark, Douglas. 2014. Disaggregation of daily data in JULES. Exeter, Met Office, 26pp. (Hadley Centre Technical Note 96)

3 hourly Temperature & Humidity

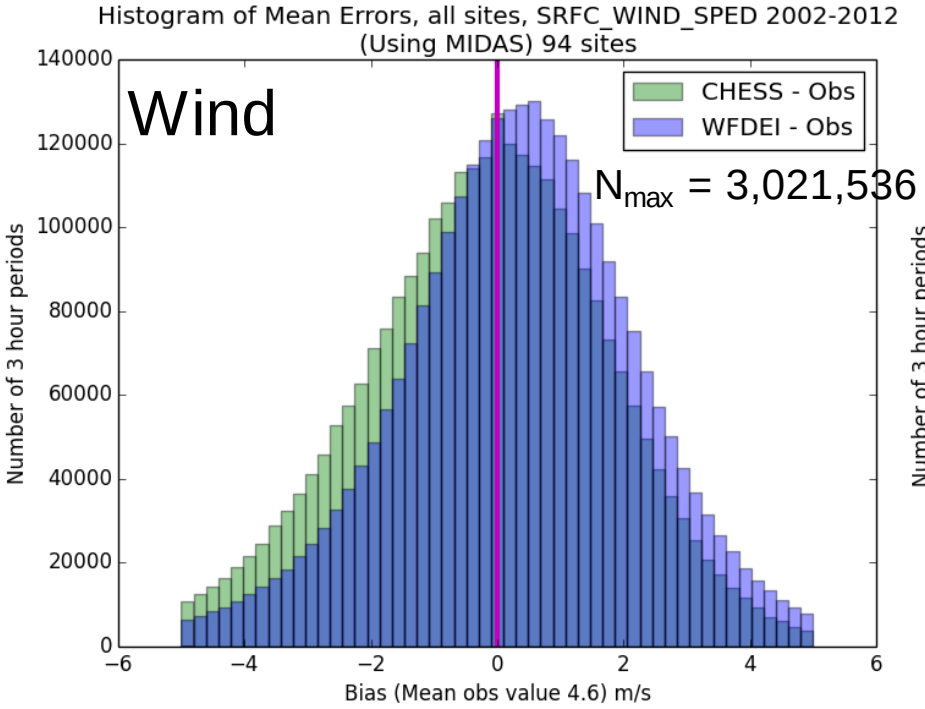


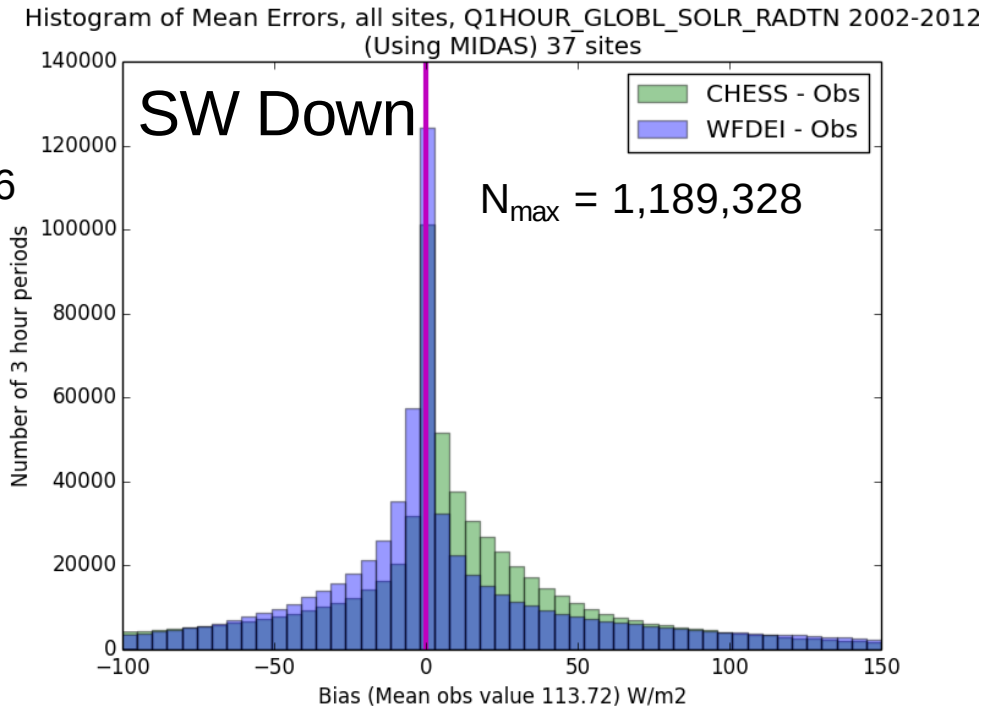


T_{air}	WFDEI	CHESS
Mean (K)	-0.1294	-0.0114
Std Dev	1.7948	1.9790
Skewness	0.3758	-0.0942
Kurtosis	1.1706	0.3949

Q_{air}	WFDEI	CHESS
Mean (kg kg^{-1})	0.00004	0.00030
Std Dev	0.0007	0.0013
Skewness	0.4275	0.3776
Kurtosis	2.1439	0.7287

3 hourly Wind Speed & Down-welling Shortwave Radiation



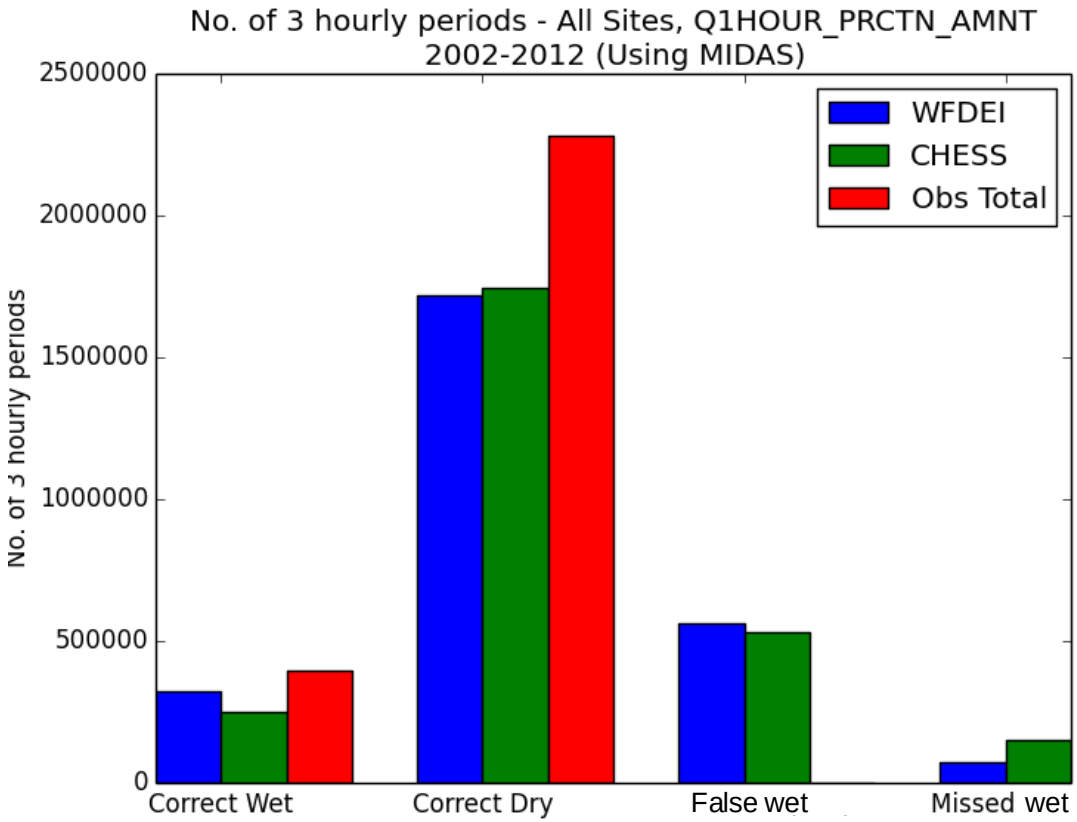


Wind	WFDEI	CHESS
Mean ($m\ s^{-1}$)	0.2899	-0.3047
Std Dev	2.0860	2.1652
Skewness	-0.3487	-0.5505
Kurtosis	1.5682	1.5222

SW Down	WFDEI	CHESS
Mean ($W\ m^{-2}$)	6.9862	-0.8020
Std Dev	68.3318	74.5428
Skewness	1.5341	-0.6569
Kurtosis	9.6768	3.8807

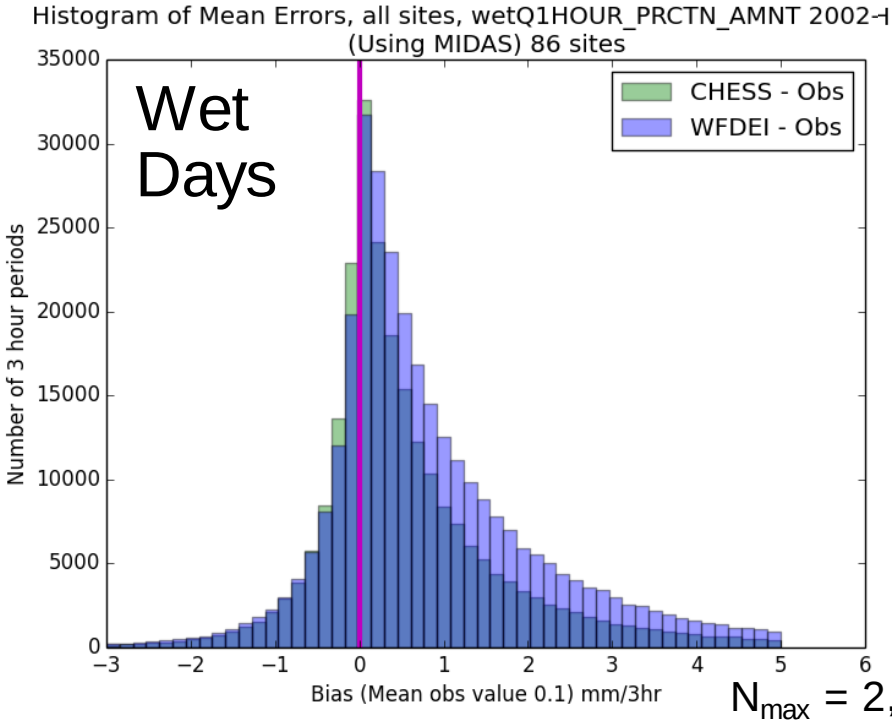
3 hourly Total Precipitation – wet periods

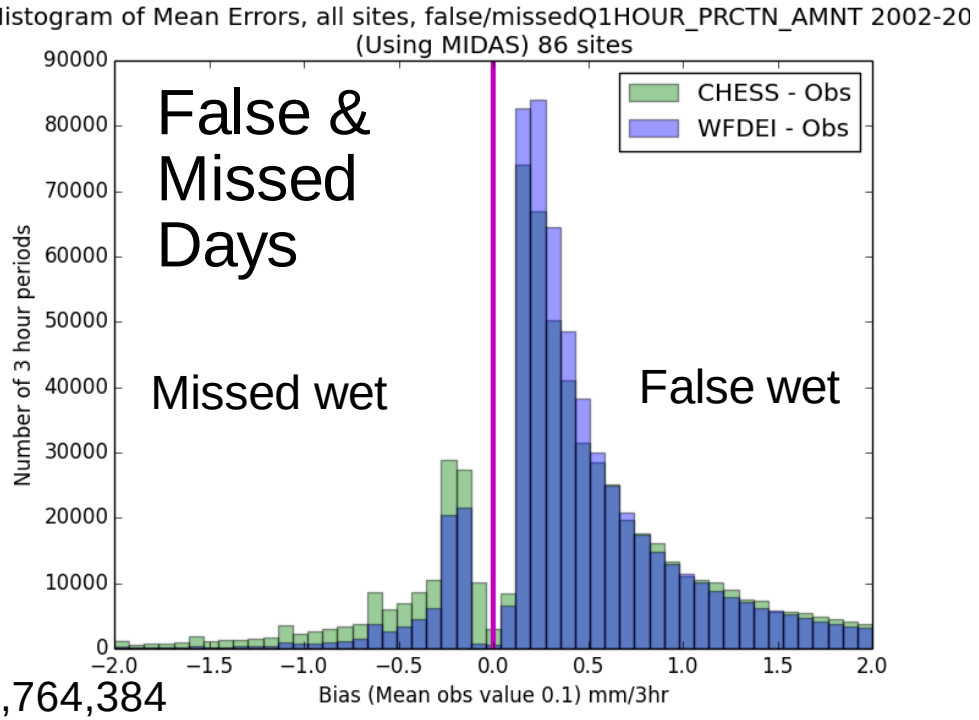
Rain period defined as:
≥ 0.125 mm / 3 hourly period



- Comparing midnight to midnight values.
- CHESS and WFDEI have very similar numbers of wet, dry, false and missed periods.

3 hourly Total Precipitation



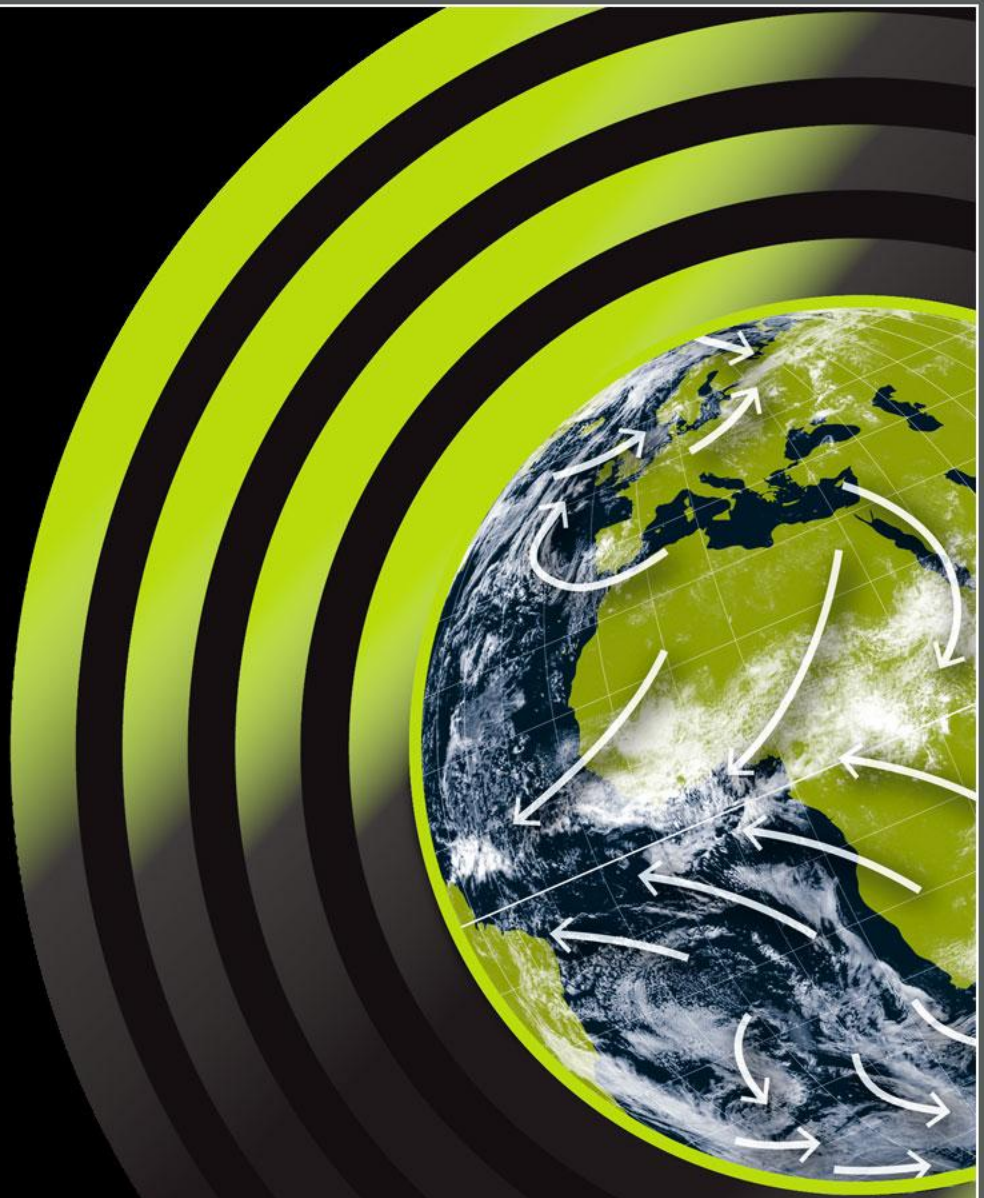


N_{max} = 2,764,384

Wet	WFDEI	CHESS
Mean (kg m^{-2} s^{-1})	1.04989	0.7106
Std Dev	1.8271	1.6388
Skewness	2.3435	3.5874
Kurtosis	11.6220	29.9125

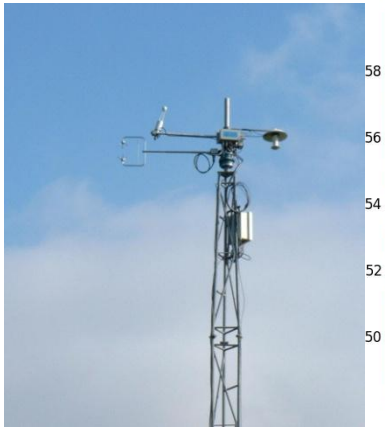
False/Missed	WFDEI	CHESS
Mean (kg m^{-2} s^{-1})	0.5730	0.5480
Std Dev	0.8444	1.2164
Skewness	2.7972	2.9893
Kurtosis	22.9355	37.1549

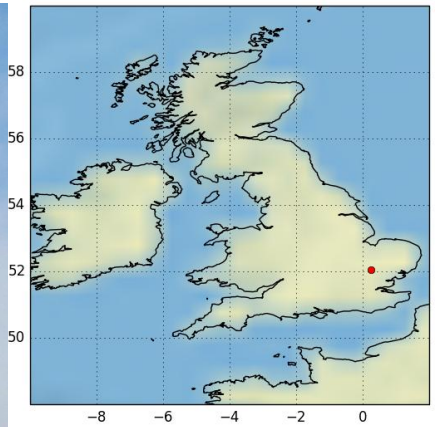
Single Site Analysis



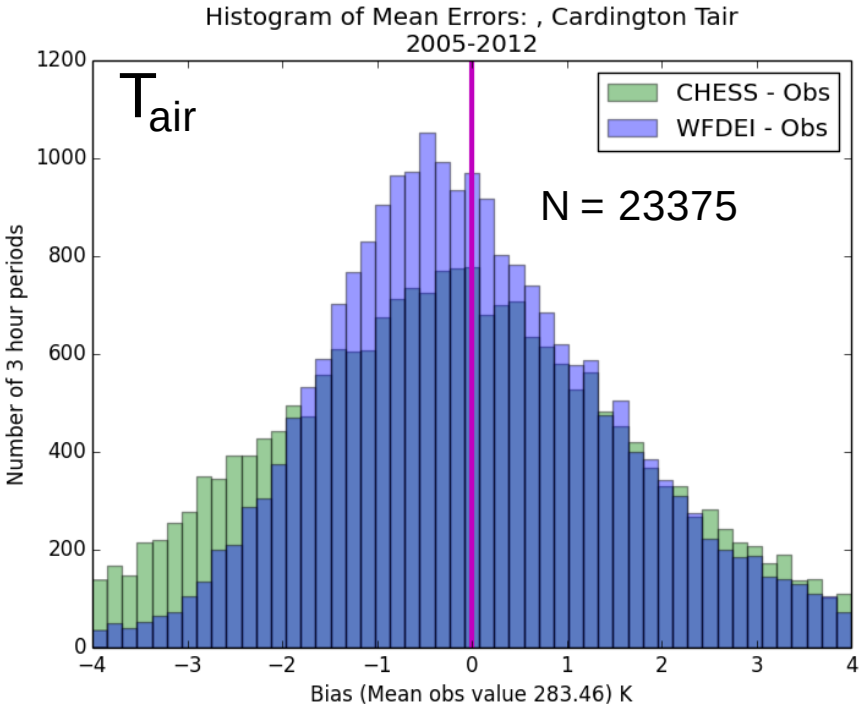
Single Site - Cardington

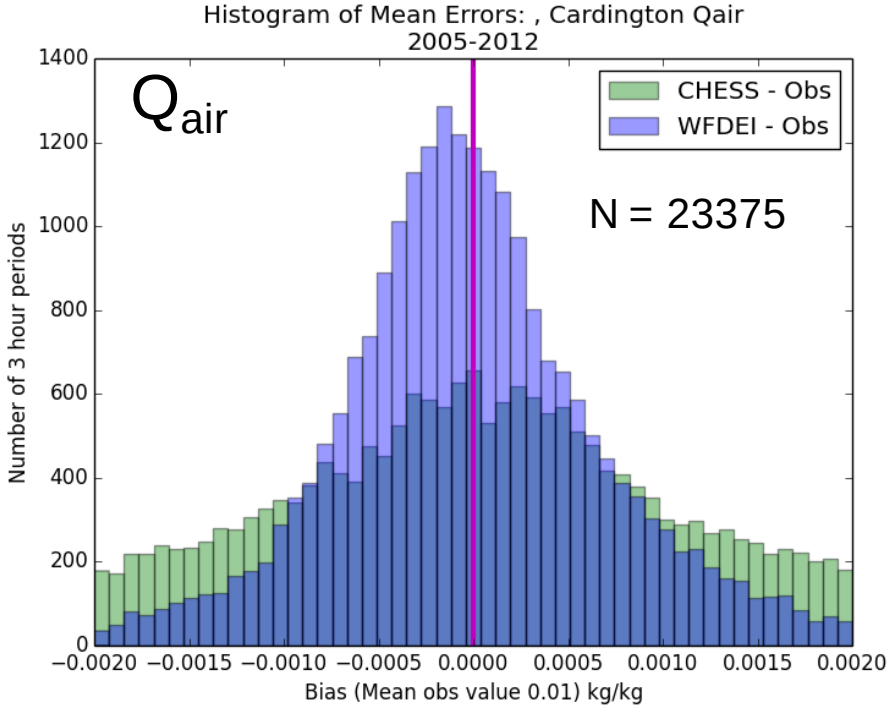
- Meteorological Research Unit, Cardington
- Comprehensive suite of surface and mast-mounted instrumentation:
  - Wind and turbulence (incl. Fluxes)
  - Temperature & humidity
  - Radiation (incl. global incoming, diffuse, and reflected solar irradiance & incoming and outgoing long wave irradiances)
  - Sub-soil sensors
  - Tipping bucket rain gauge





3 hourly Temperature & Humidity

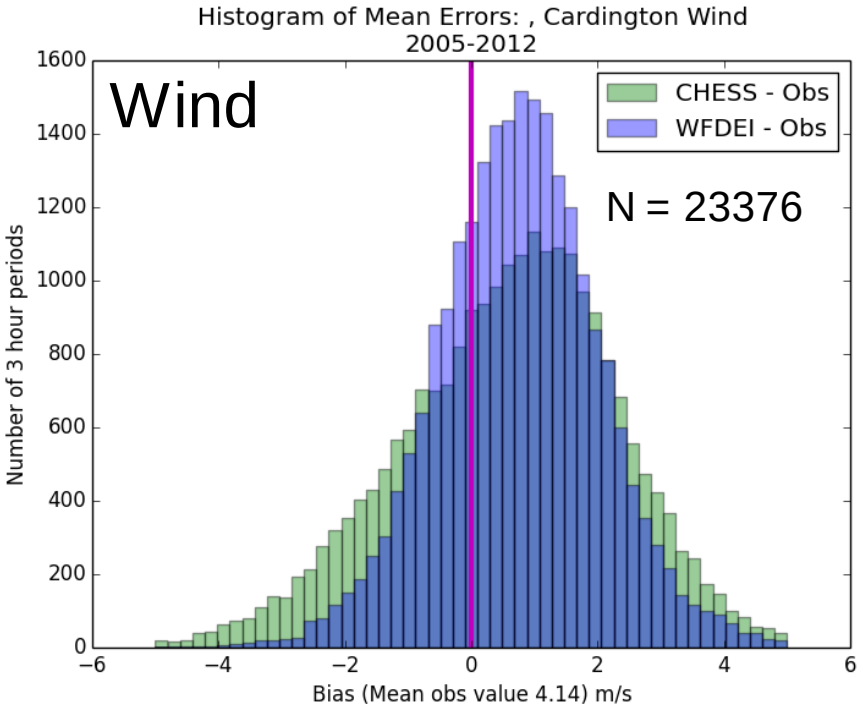


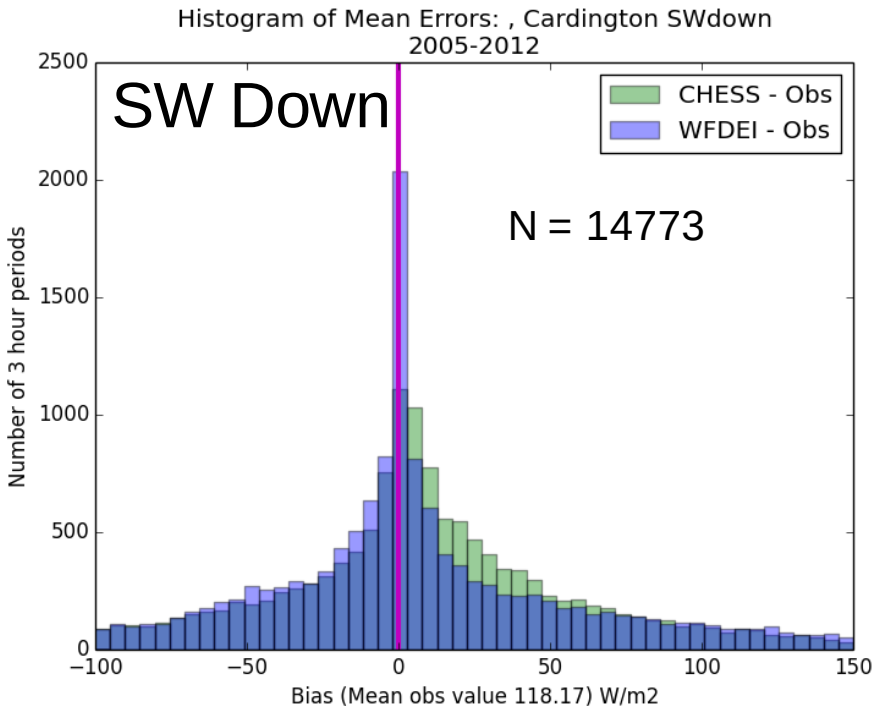


T_{air}	WFDEI	CHESS
Mean (K)	0.0898	-0.2076
Std Dev	1.7705	2.1842
Skewness	0.5268	0.0590
Kurtosis	1.5515	0.6590

Q_{air}	WFDEI	CHESS
Mean (kg kg^{-1})	2.666e-07	0.0002
Std Dev	0.0009	0.0015
Skewness	0.4521	0.4174
Kurtosis	3.1985	0.6150

3 hourly Wind Speed & Down-welling Shortwave Radiation

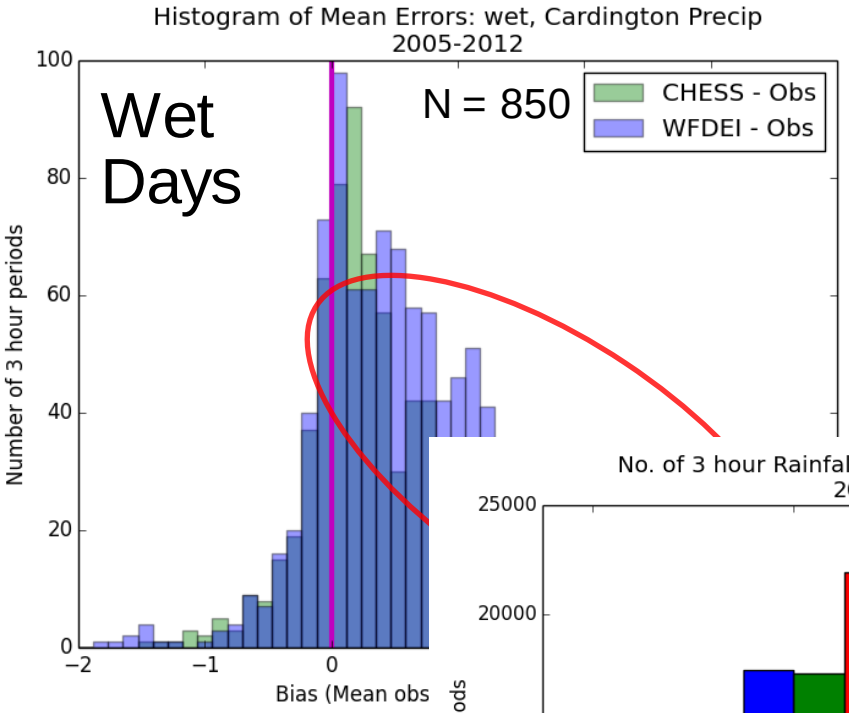


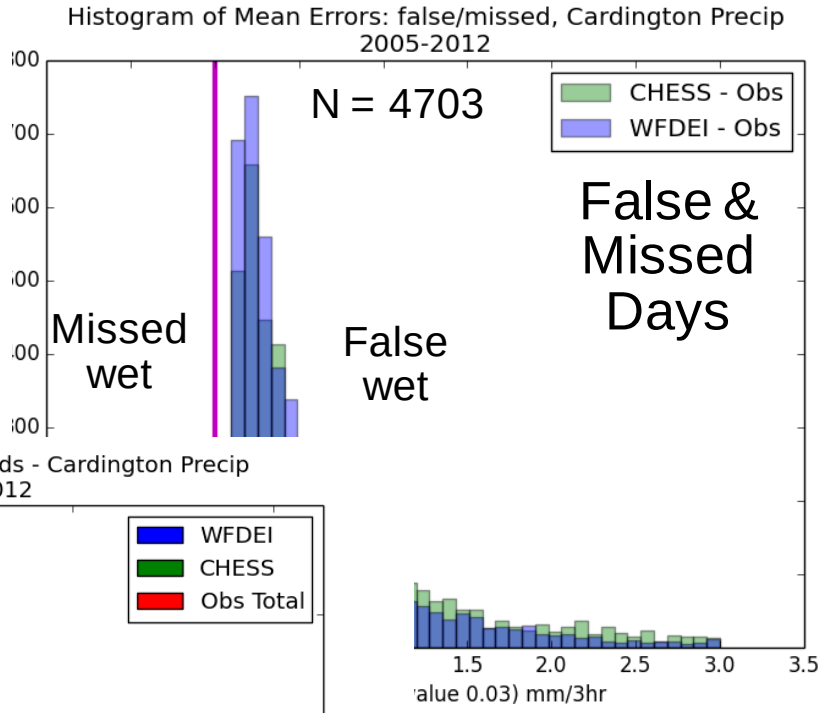


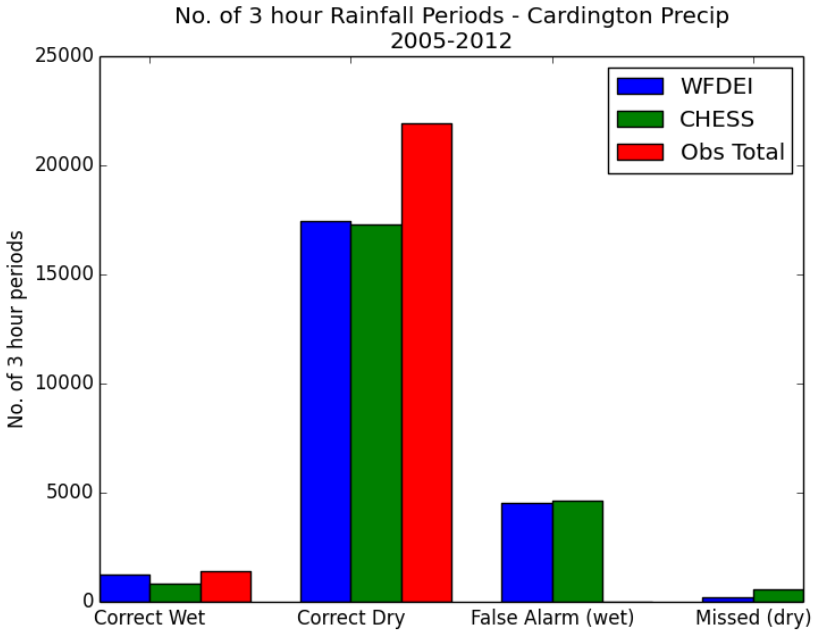
Wind	WFDEI	CHESS
Mean ($m\ s^{-1}$)	0.7534	0.5877
Std Dev	1.3112	1.7845
Skewness	0.0989	-0.2993
Kurtosis	0.9666	0.4136

SWdown	WFDEI	CHESS
Mean ($W\ m^{-2}$)	13.2032	0.5330
Std Dev	81.5894	73.0194
Skewness	1.0581	-0.3222
Kurtosis	4.2315	2.5455

3 hourly Total Precipitation





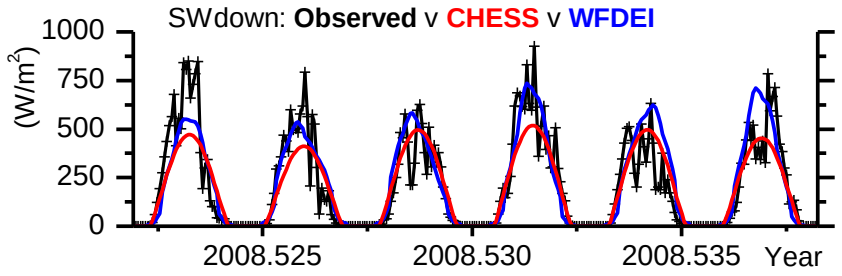


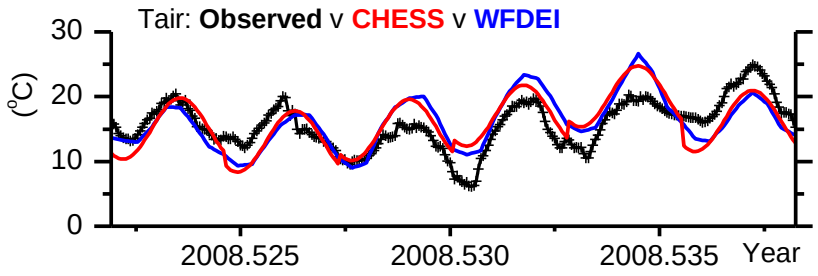
Precip Wet		WFDEI	CHESS
Mean (kg m^{-2} s^{-1})		.5825	0.6527
Std Dev		.7634	0.9819
Skewness		.6328	2.9870
Kurtosis		7.9418	18.9052

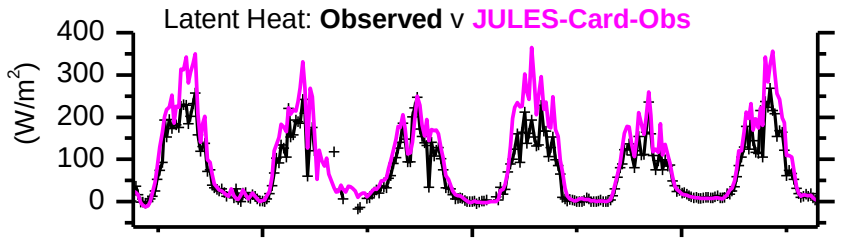
Time series

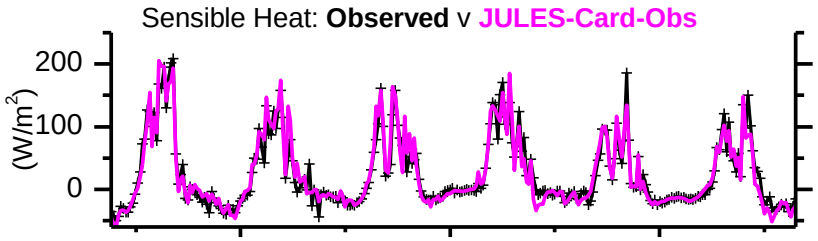
JULES v4.3 "out-of-the-box" parameters at 30-min steps for 2005-2012, same Rose Suite using:
Cardington observed meteorology (30 mins), **CHESS (daily)** and **WFDEI (3 hourly)**

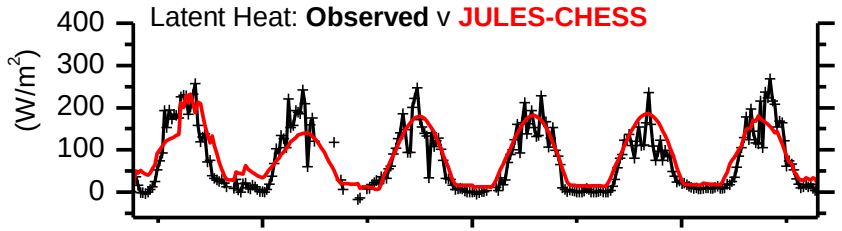
10th - 15th July 2008 at MRU Cardington, Bedfordshire, UK

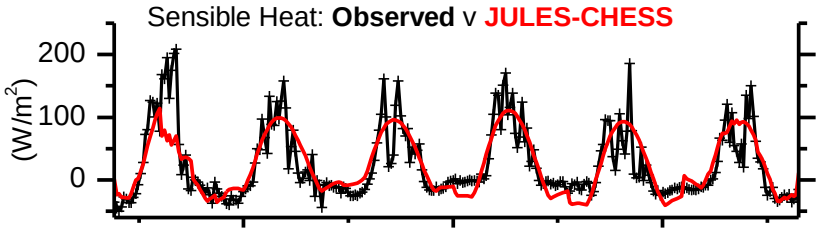


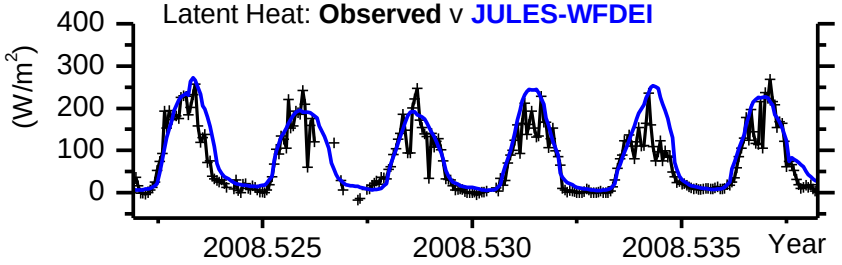


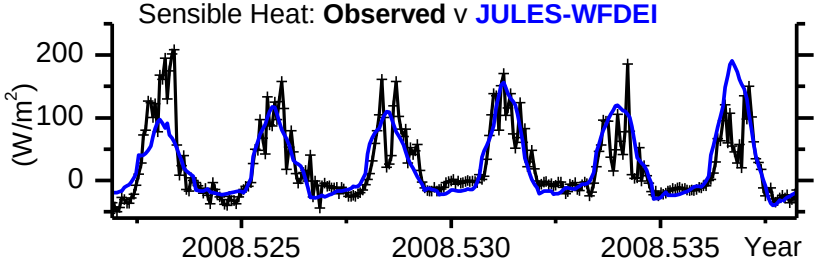










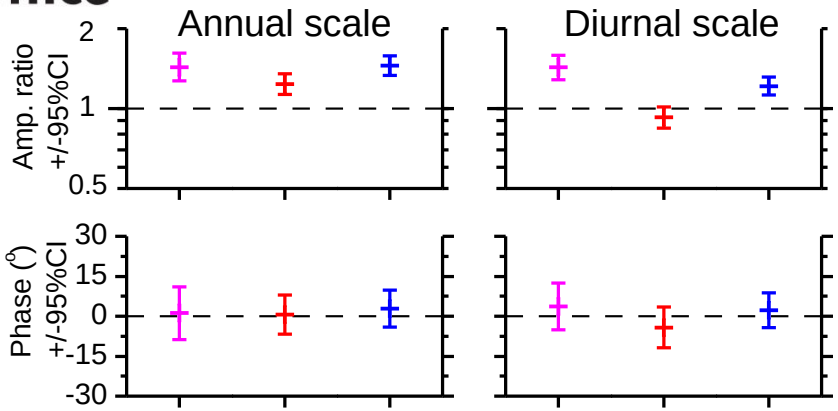


(Graham Weedon)

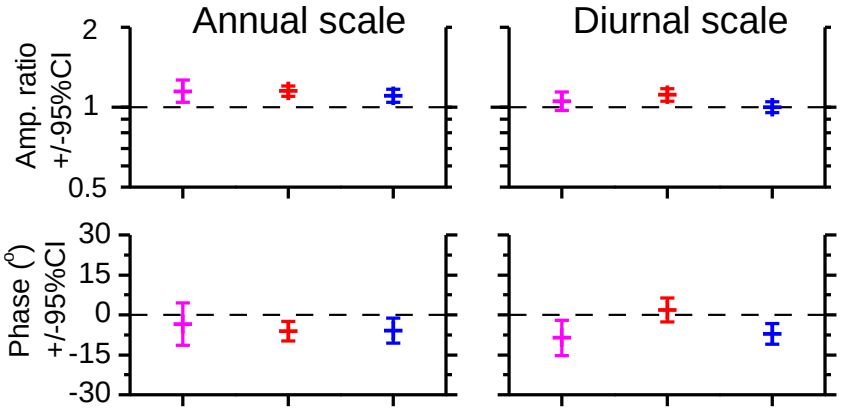
Cross Spectral Analysis

JULES v4.3 "out-of-the-box" parameters at 30-min steps for 2005-2012, same Rose Suite using:
Cardington observed meteorology (30 mins), **CHESS (daily)** and **WFDEI (3 hourly)**

Latent Heat: Observed v JULES

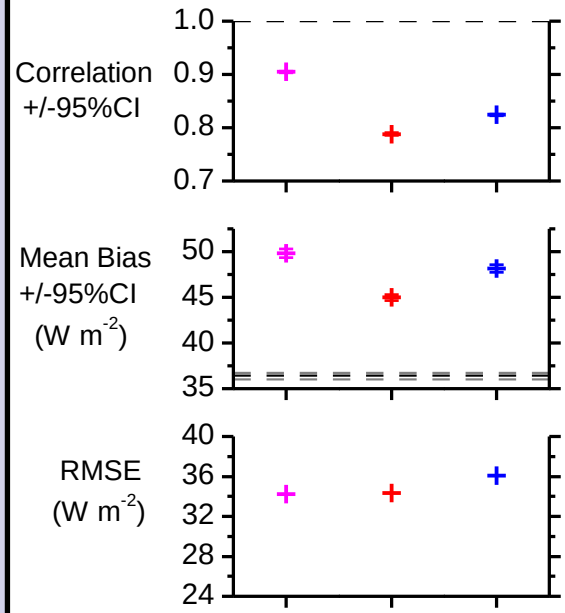


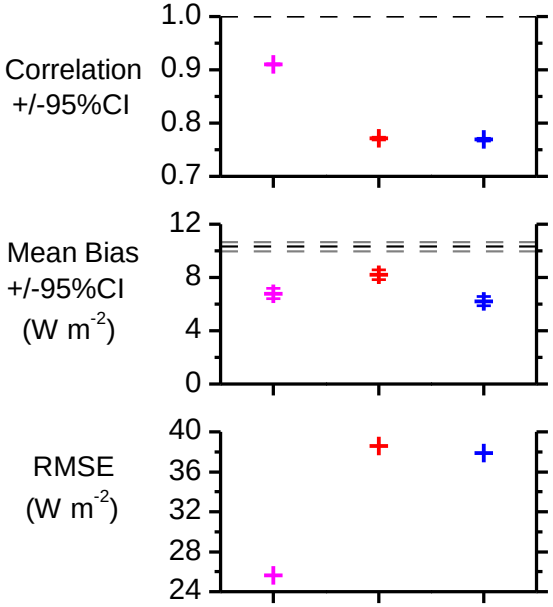
Sensible Heat: Observed v JULES



Amplitude ratio = Model Amp/ Obs Amp (> 1 means amplification, obs < model)

Phase = Phase difference Negative phase means model is early compared to obs, positive means model is late compared to obs.





(Graham Weedon – to be continued later...)

Conclusions

- On the whole CHESS performs well.
- However some technical issues using CHESS with JULES
  - Precipitation accumulation period
  - Disaggregator assumptions
- This site-wise broad comparison shows little difference between CHESS and WFDEI as used in JULES.
- There may be features specific to site and variables that are not evident in the average distribution plots.

Conclusions 2

- 3 hourly analysis Cardington broadly shows the same as site wide comparisons.

- WFDEI in general is much closer to JULES run with observed data than CHESS, especially on diurnal timescales.

- Improved parameter sets should generate an improved and more realistic simulation for all three JULES runs.

Future Work

• Complete the analysis by looking at the relative impacts from individual variables.

• How can we improve the hydrological processes within JULES?

- Improve our parameter sets (Alberto Martínez, CEH)
- Combine JULES with a hydrology model – e.g. SHETRAN (Newcastle University)

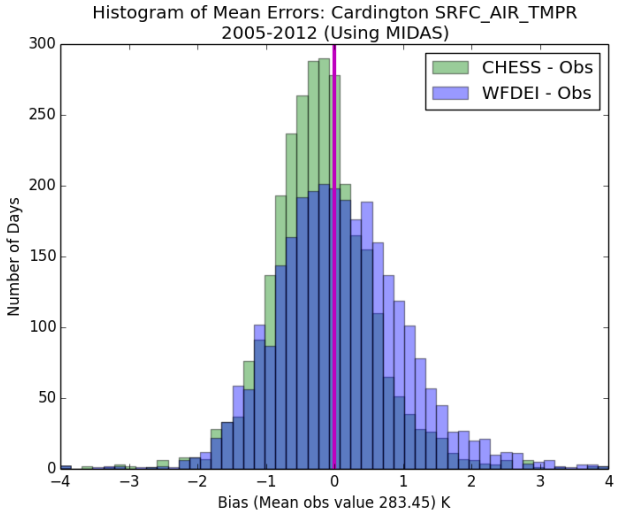
Met Office

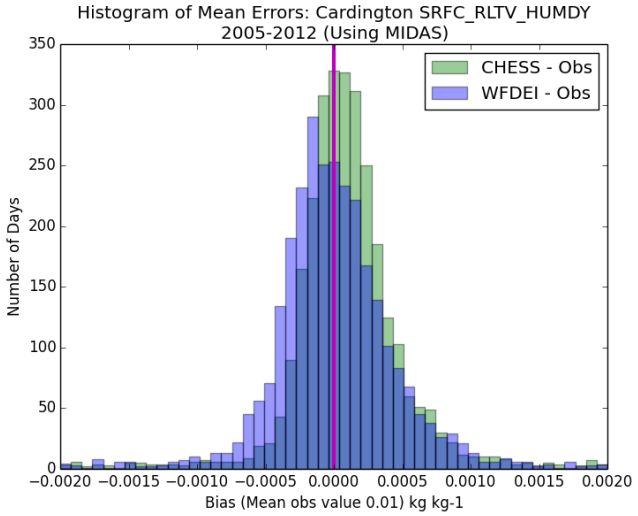
Any questions?

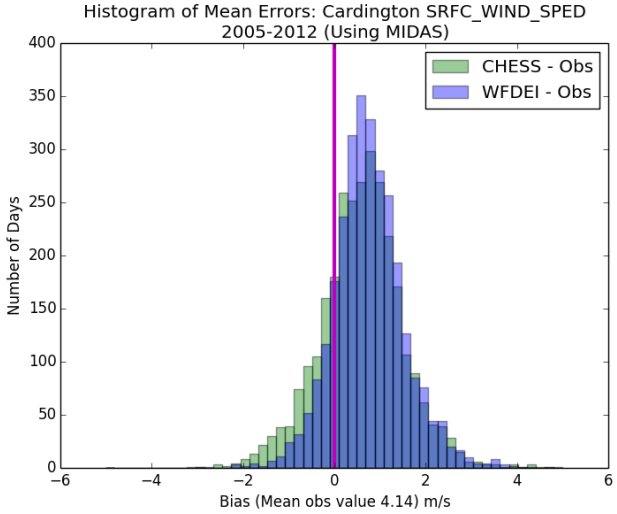
The JULES Disaggregator

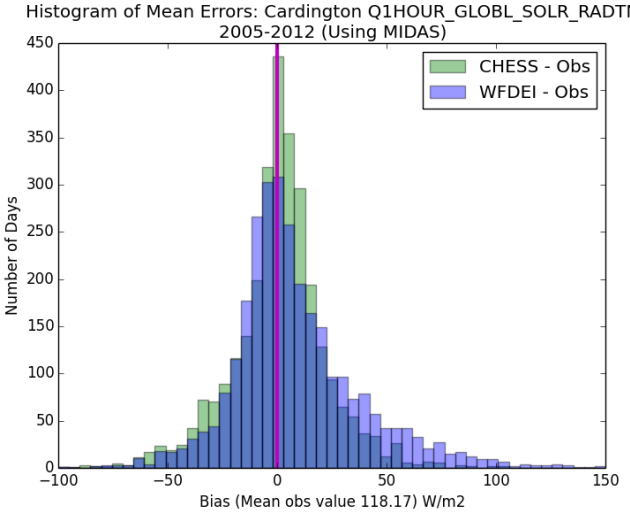
```
&JULES_DRIVE
  data_start  = '1961-01-01 00:00:00'
  data_end    = '2014-01-01 00:00:00'
  data_period = 86400,
  l_daily_disagg = T
  l_disagg_const_rh = T
  precip_disagg_method = 4
  diff_frac_const = 0.4
  t_for_snow = 275.15
  t_for_con_rain = 288.15
  dur_conv_rain = 7200.0
  dur_ls_rain = 18000.0
  dur_ls_snow = 18000.0
```

Daily biases - Cardington









Daily Biases - Cardington