Downwelling longwave flux over Summit, Greenland, 2010-2012:

Analysis of surface observations and evaluation of ERA-Interim using wavelets

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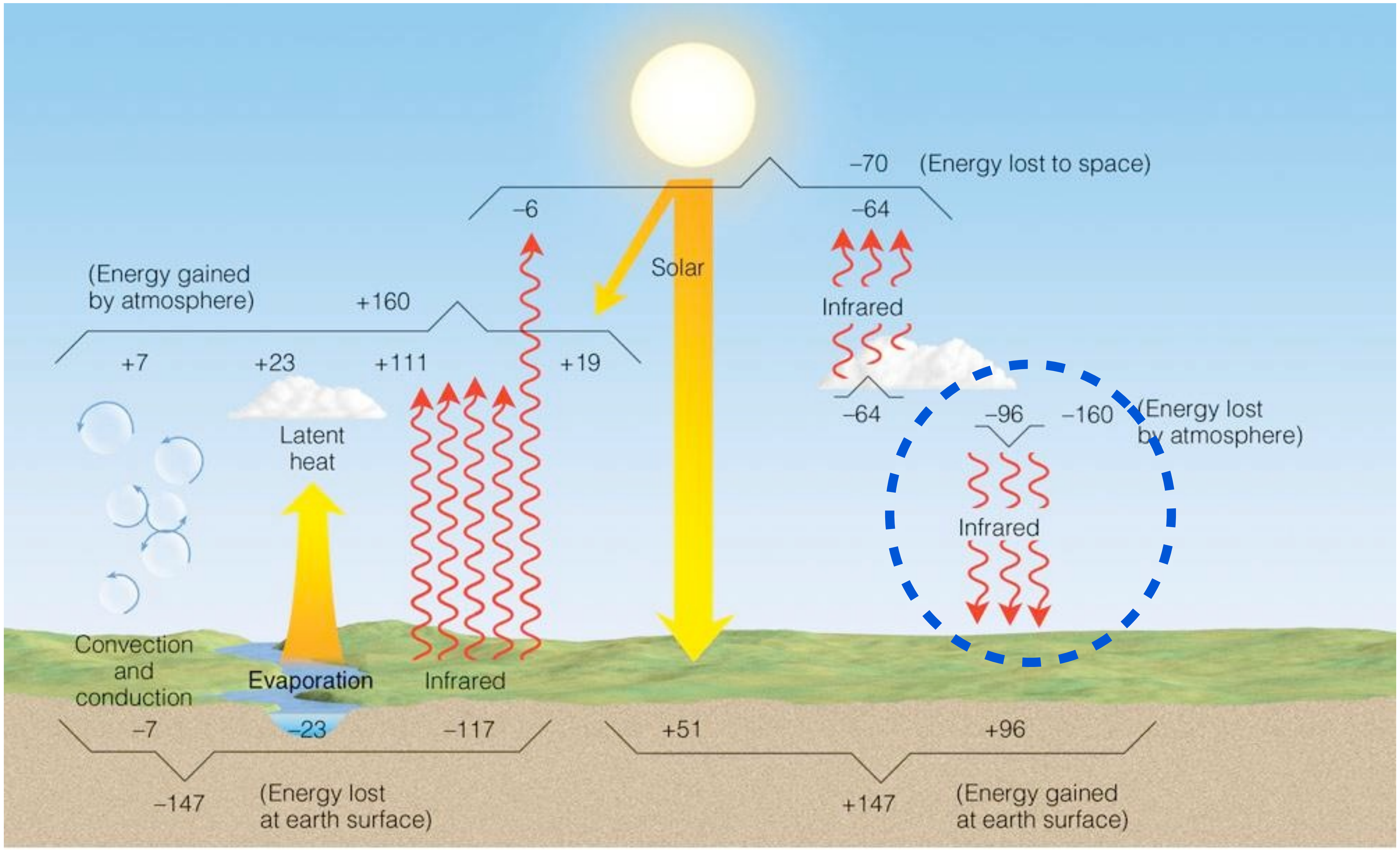
Motivations and Research Questions

- Downwelling longwave flux (DLW) is an important energy budget parameter in the Arctic.
  - Sea ice (Francis et al. 2005)
  - Greenland Ice sheet surface melt (Bennartz et al., 2013)
  - Changing Arctic clouds and DLW (Francis and Hunter, 2007)
- Variability in DLW due to clouds, temperature and atmospheric gases at many scales.
- Surface observations can measure DLW well, but network is sparse.
- Surface observations should be combined with reanalyses, but reanalyses must be validated.

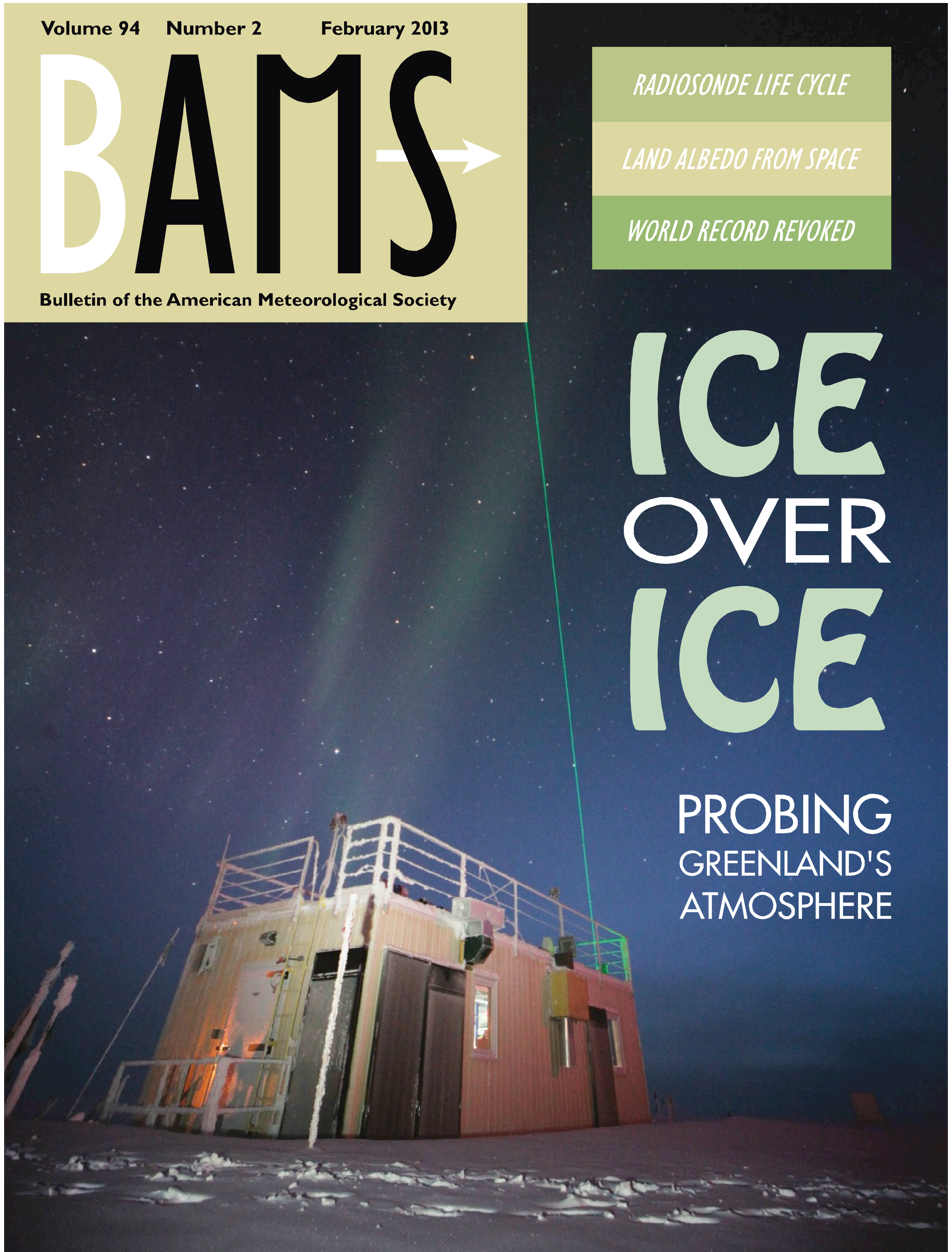
How well do reanalyses represent DLW at various scales?

How can gridded data be compared to point observations?

Downwelling Longwave Flux (DLW)



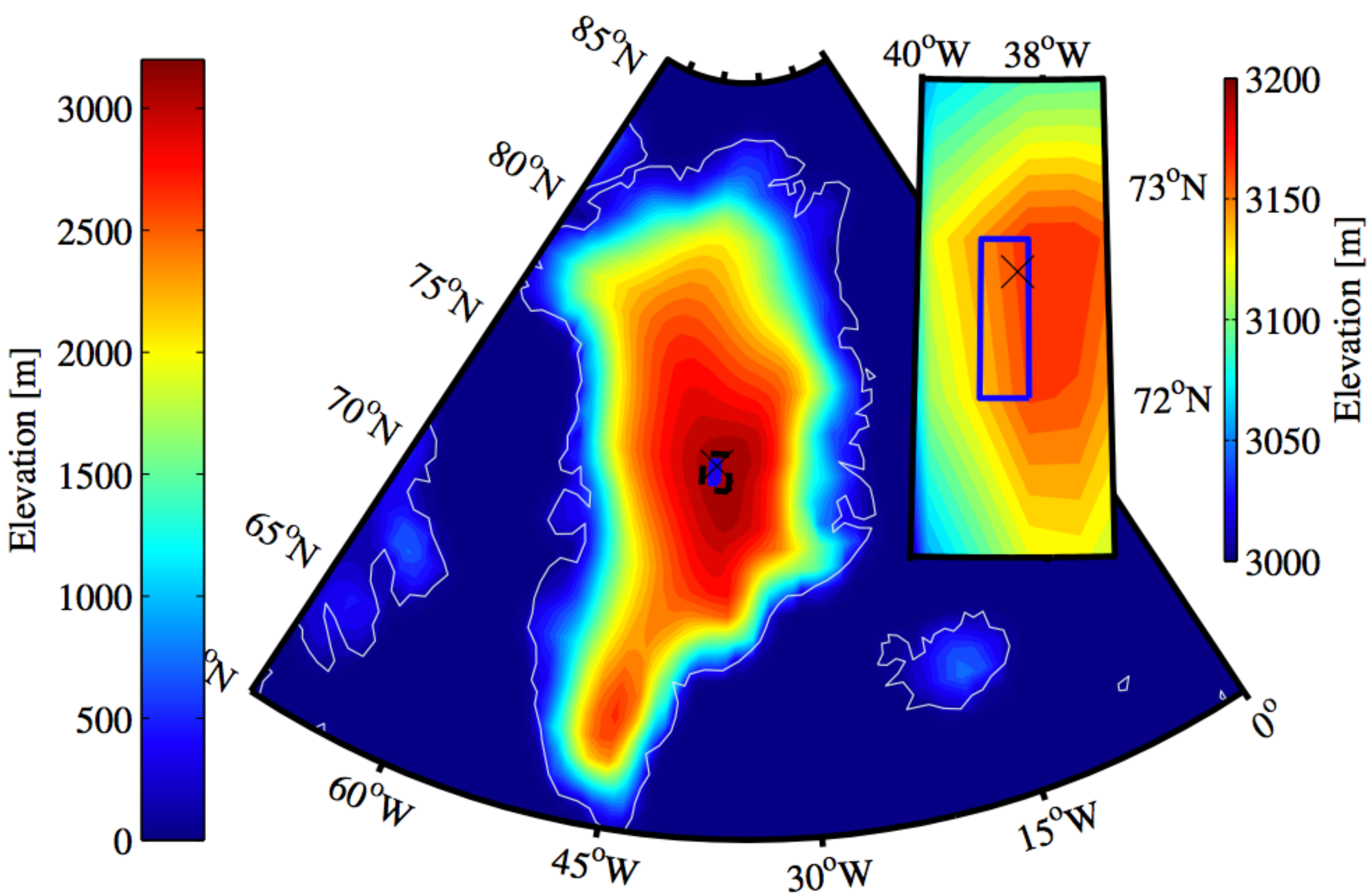
ICECAPS



Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit

Summit Station, Greenland

ERA-Interim



X Summit: 72N, 38W, 3200 m (10500 ft)

Validate ECMWF Interim Reanalysis
3-hour forecasts of DLW 0.75° grid

<u>Good location for Reanalysis Validation</u>

- Ground-observations
  - ICECAPS
  - NOAA
- Homogeneous terrain and surface type
- Distant from assimilation locations
- Unique environment

Surface Observations

Two independent observations of DLW from Summit:

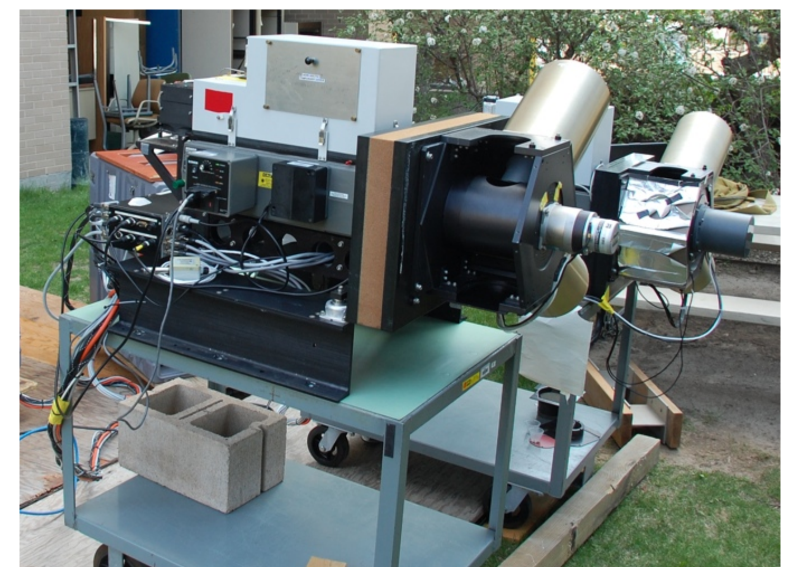
1) Derived from infrared radiances measured by the ICECAPS Atmospheric Emitted Radiance Interferometer (**AERI**) (Cox et al. 2012).
2) Broadband measurements from a pyrgeometer (**PIR**).

Time period:
  July 2010 through August 2012 (26 months)

Temporal resolution:
  3-hour averages

Missing data:
  5.5% missing from AERI
  0.7% missing from PIR
  No overlapping data gaps.

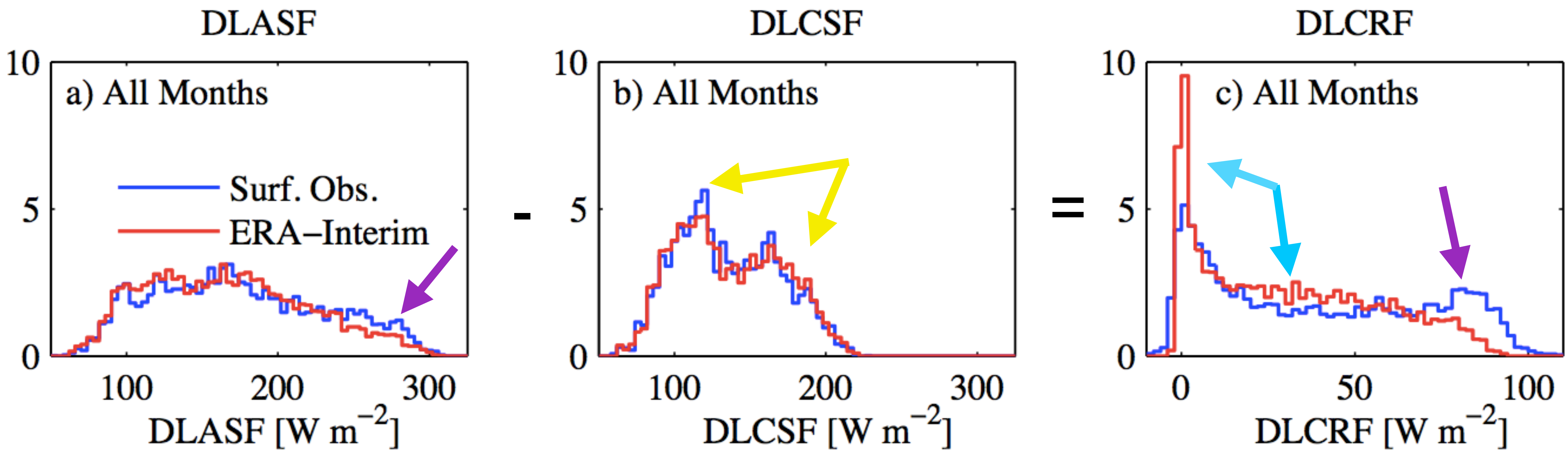
<u>AERI missing data filled with PIR as a proxy</u>



AERI

PIR (Photo: NOAA/ESRL/GMD)

Data Comparison - Surf. Obs vs ERA-I



	DLASF	DLCSF	DLCRF
Mean Error	-7.5	0.9	-8.4
σ	25	6	24
r	0.80	0.97	0.46

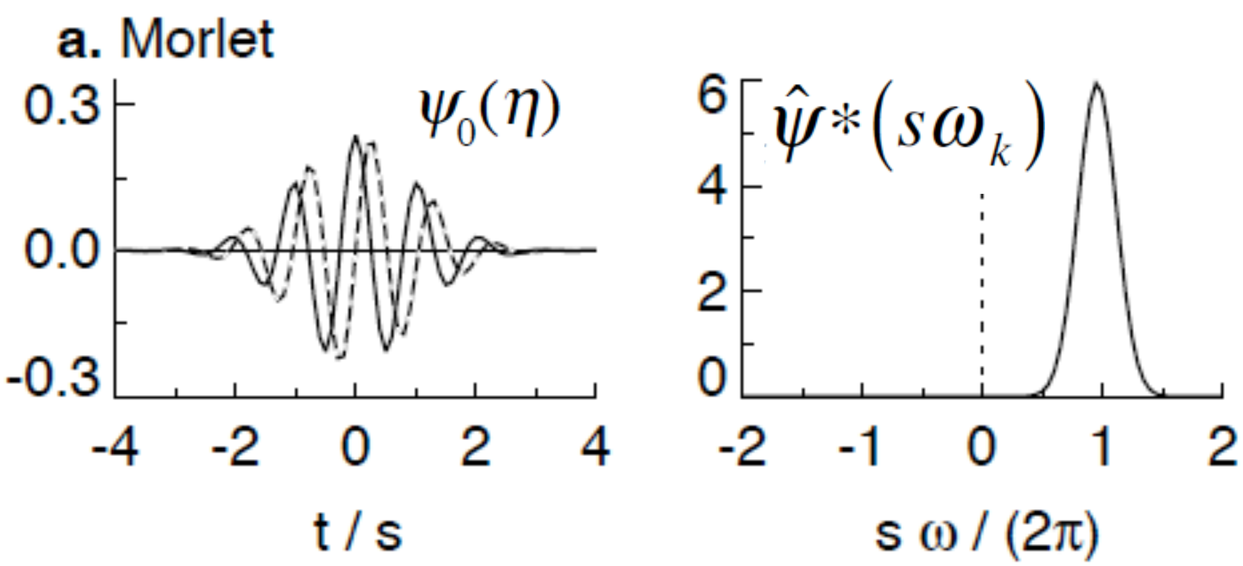
ERA-Interim

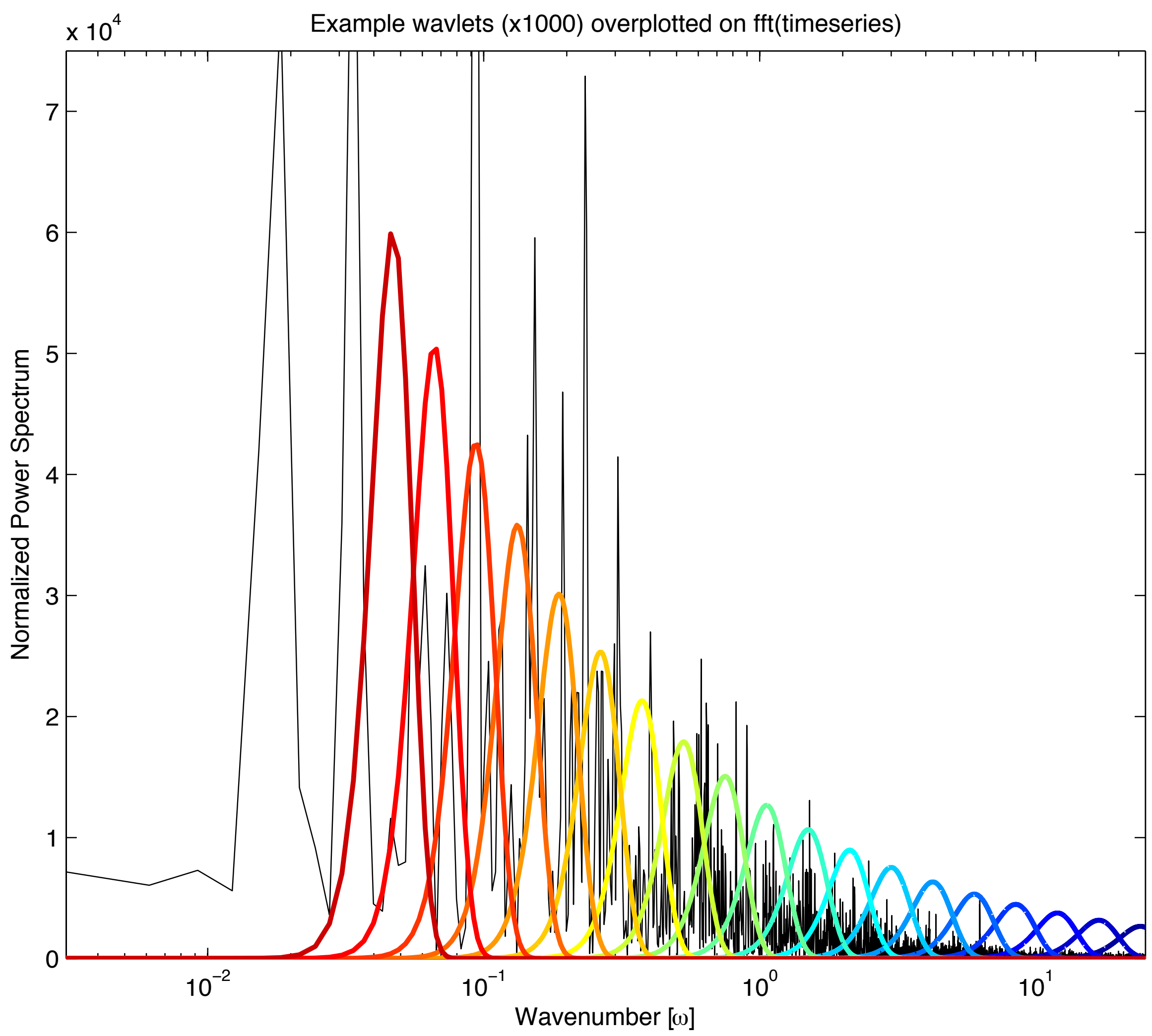
- represents DLCSF very well
- underestimates thick clouds
- overestimates frequency intermediate thicknesses and clear-sky

Wavelet Analysis

Time-Frequency signal decomposition

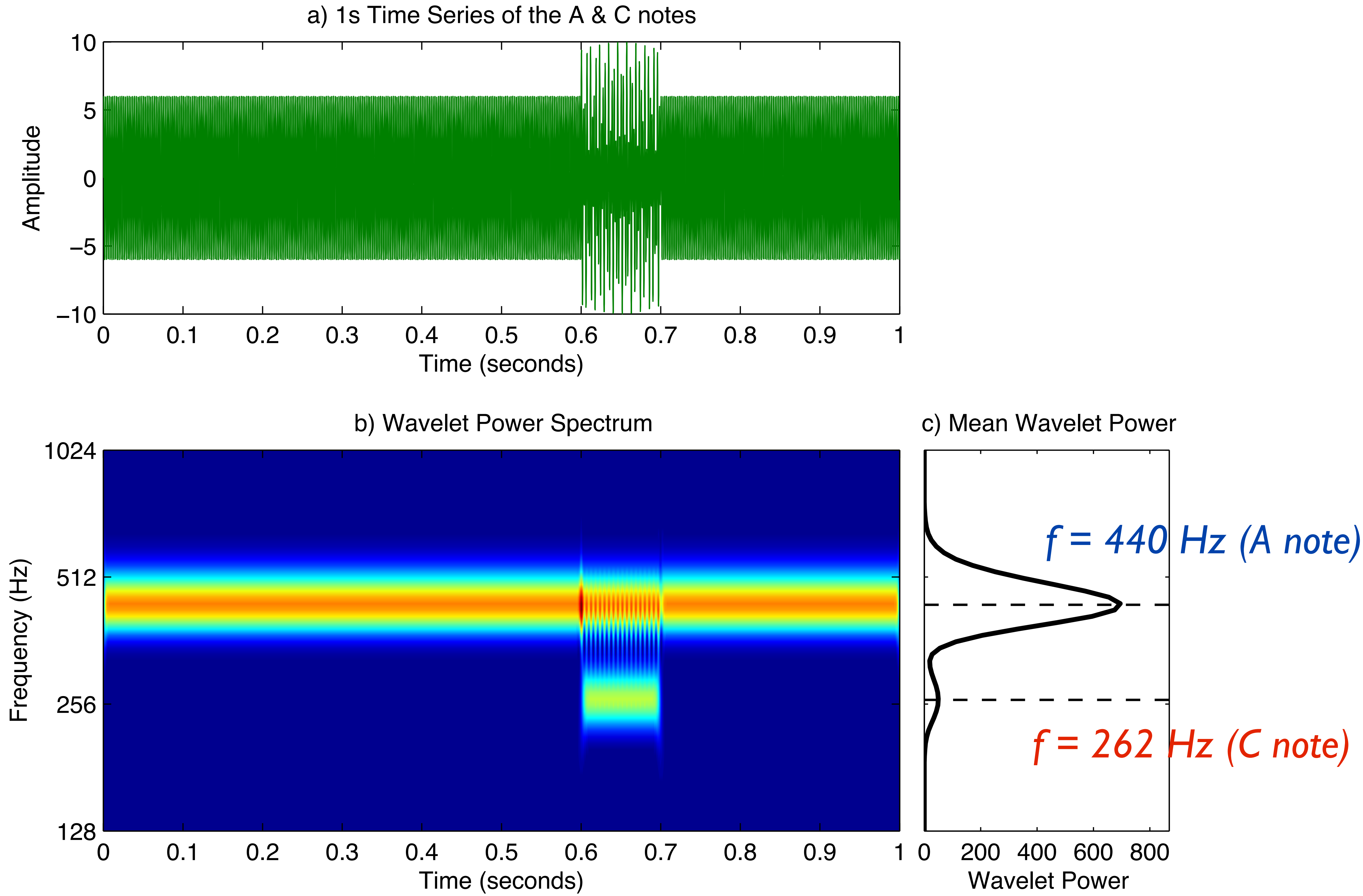
$$W_n(s) = \sum_{k=0}^{N-1} \hat{x}_k \hat{\psi}^*(s\omega_k) e^{i\omega_k n\delta t}$$



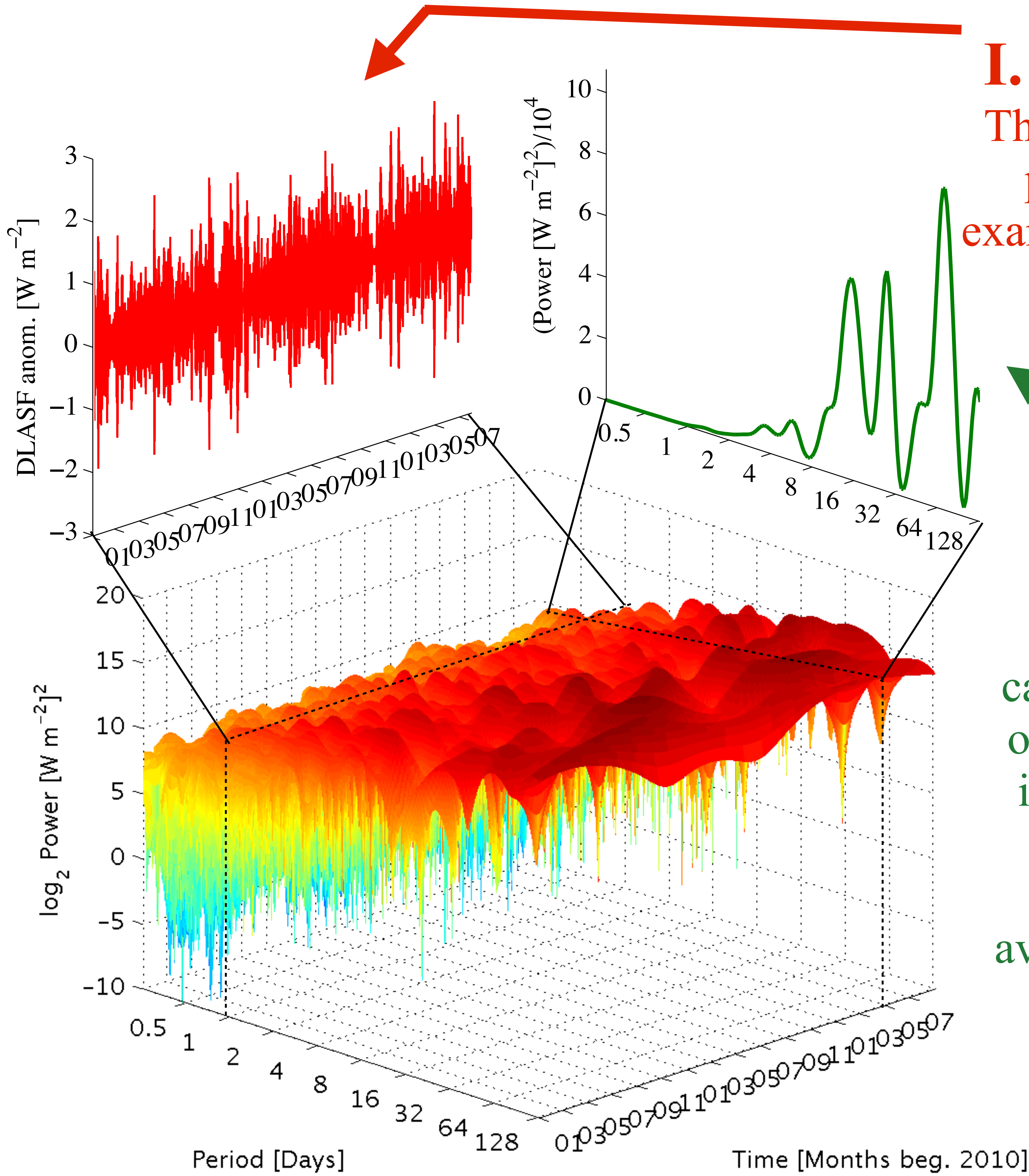


Torrence and Compo (1998)

Wavelet Analysis



Wavelet Analysis



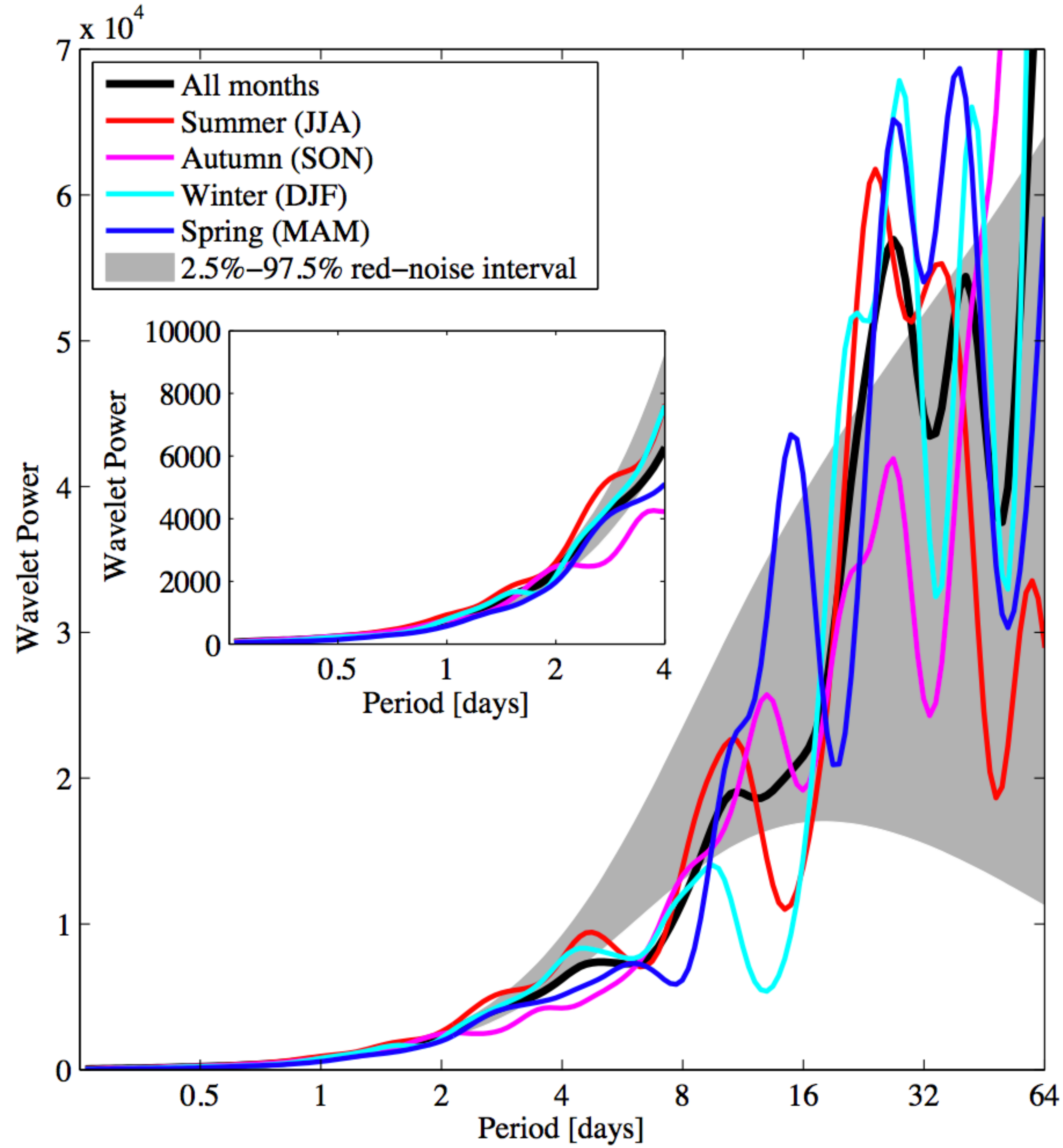
I. Reconstruction at Scale

The time series can be reconstructed partially for a set of scales. The example here shows the reconstruction of the diurnal scale.

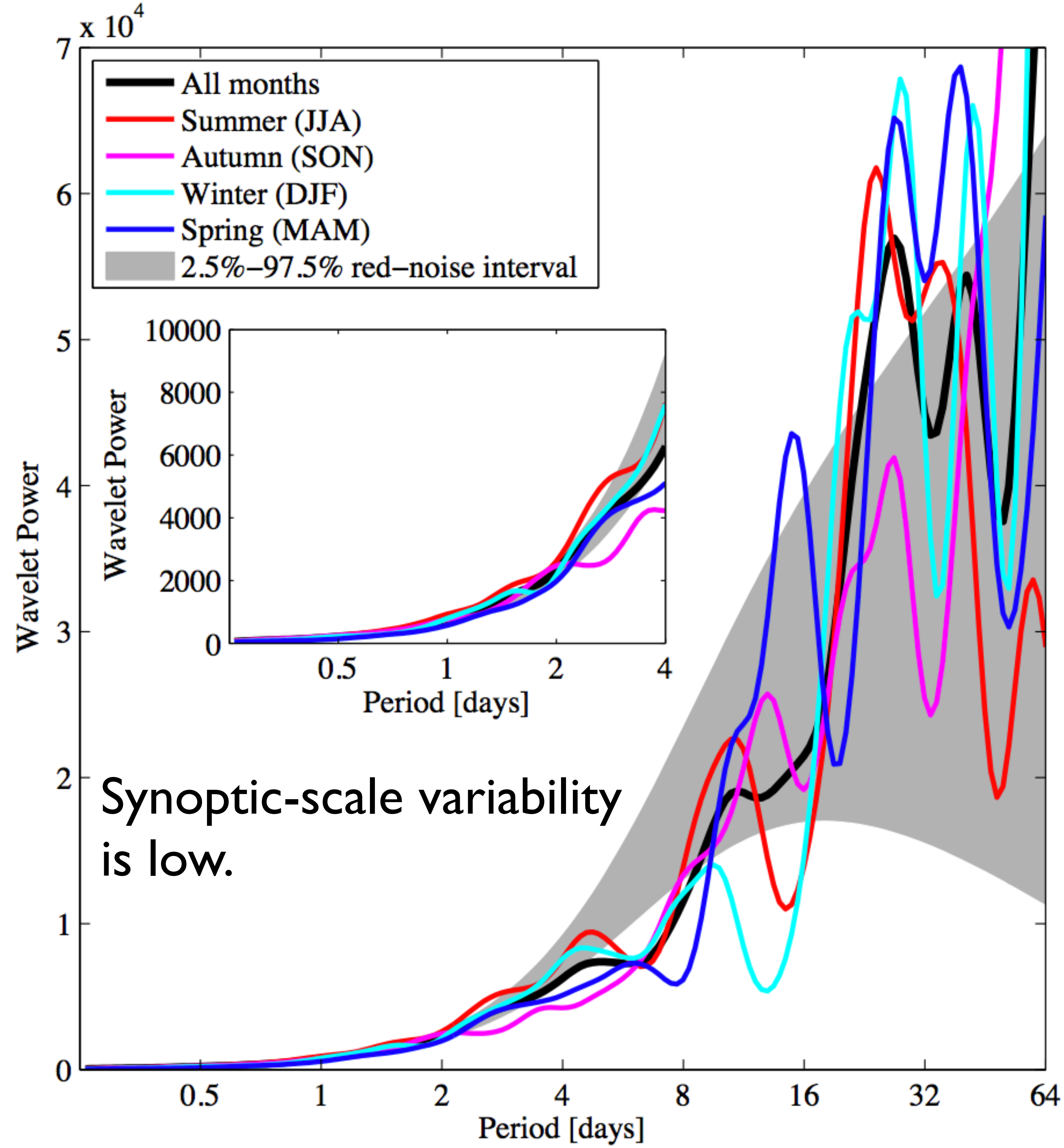
II. Average in Time

Wavelet power from selected times can be averaged together. The average of all the wavelet power through time is the same as the Fourier Transform of the time series smoothed by the wavelet. The example here is the average wavelet power in March 2012.

Wavelet Analysis of Surface Observations

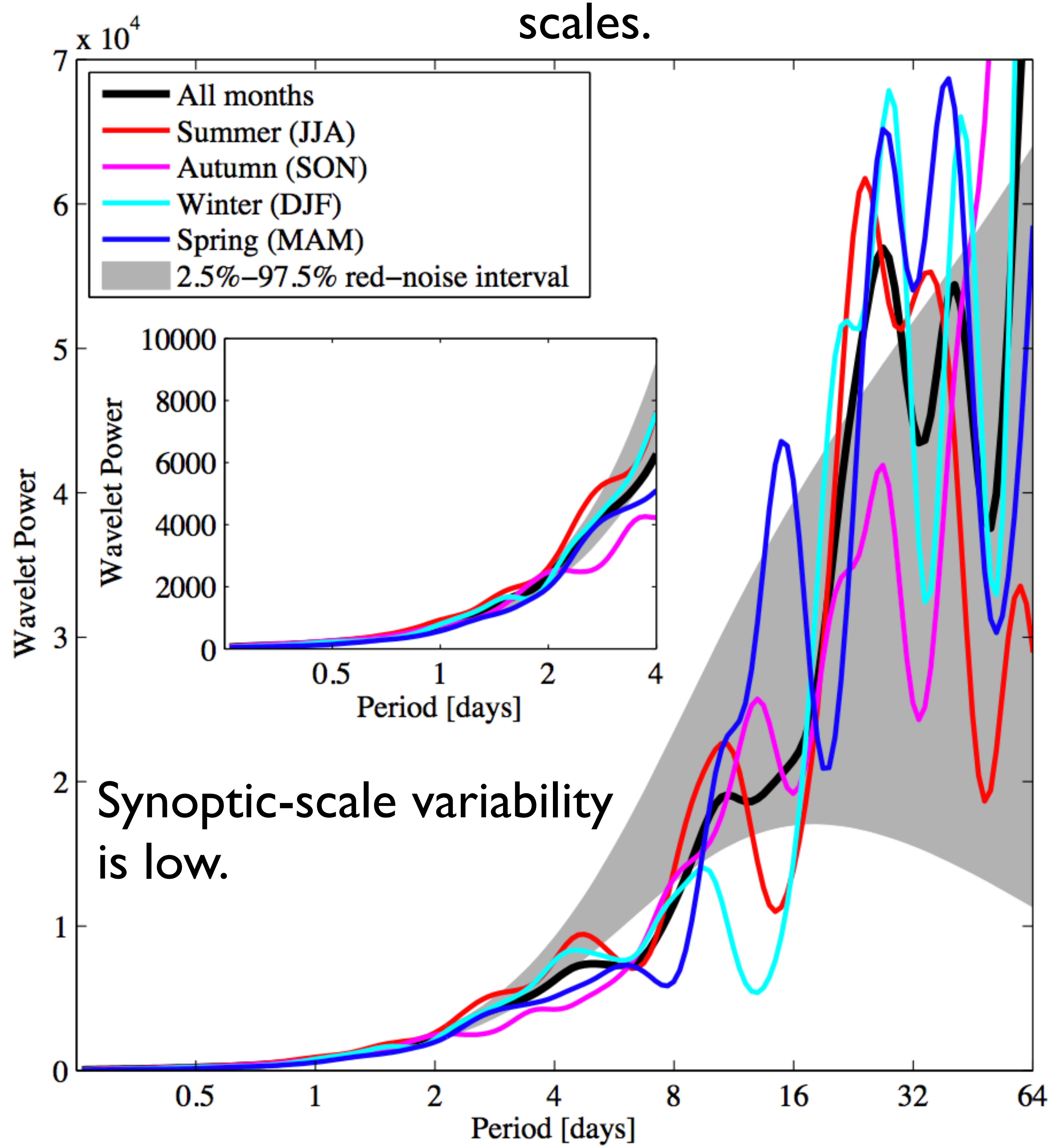


Wavelet Analysis of Surface Observations



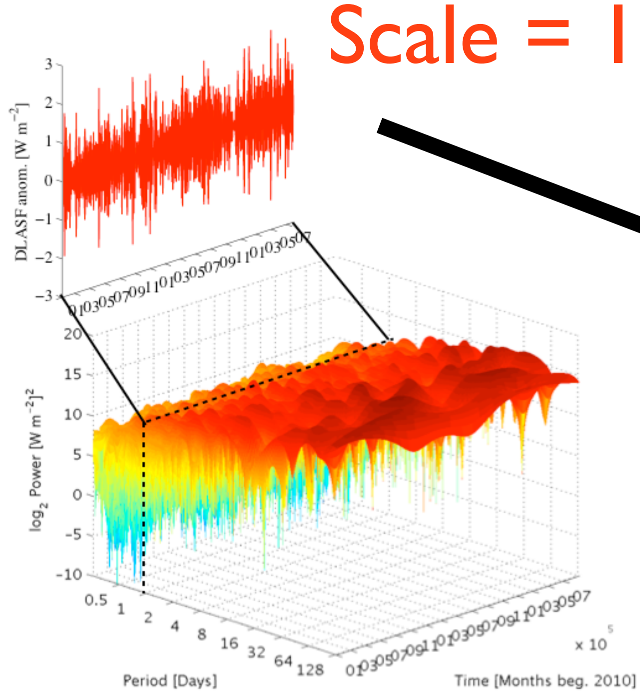
Wavelet Analysis of Surface Observations

Seasonal variability is complicated; long time scales.



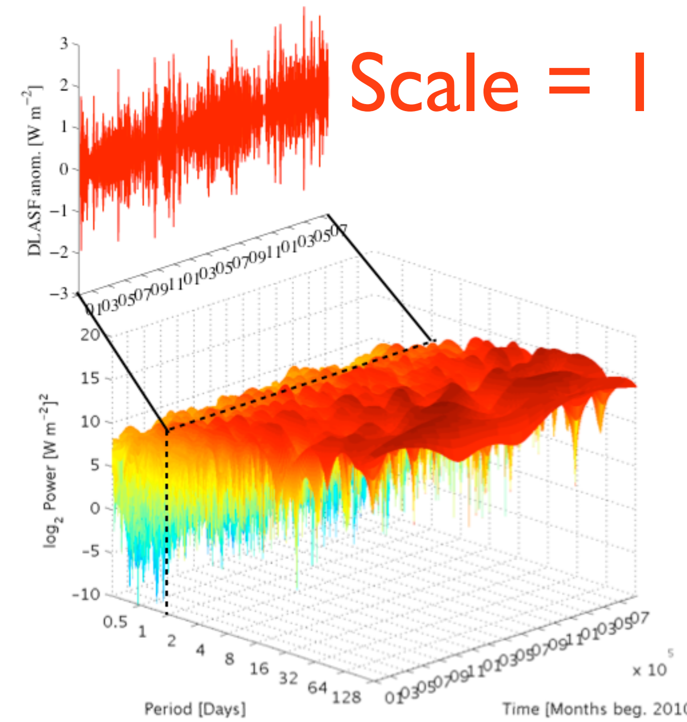
Wavelet Analysis - Evaluation of ERA-Interim

Scale = 1 day



AERI

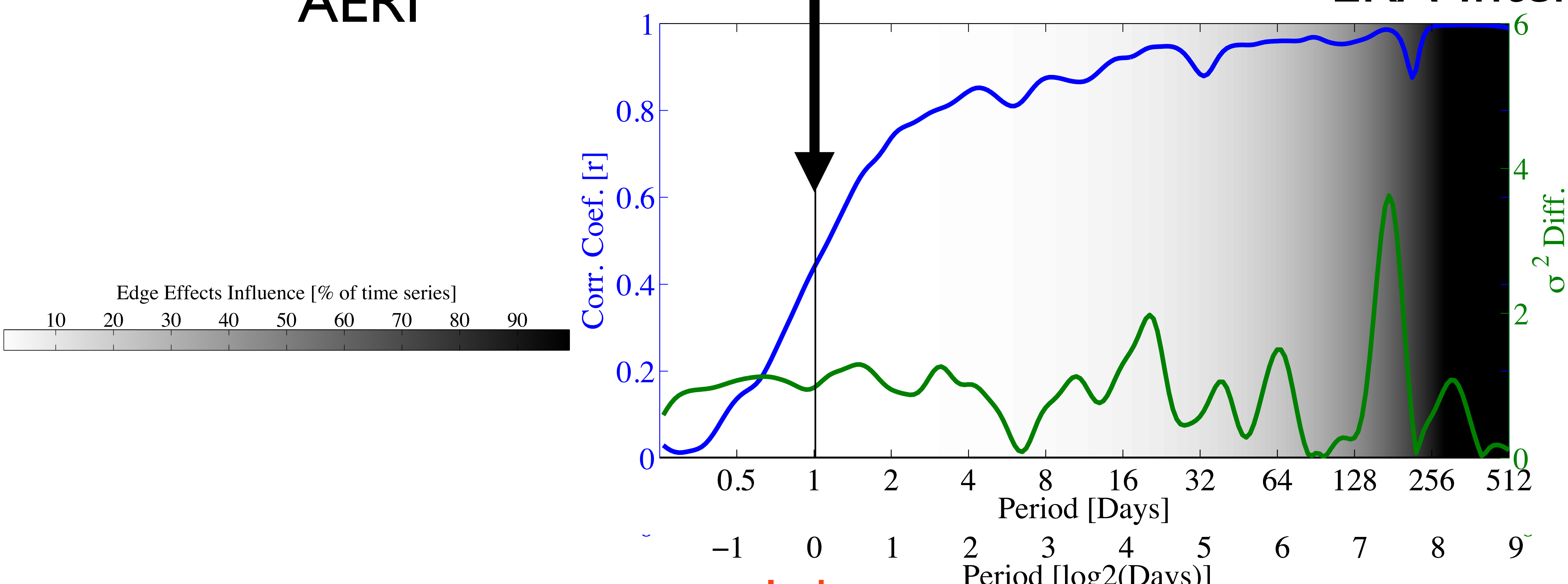
Scale = 1 day



ERA-Interim

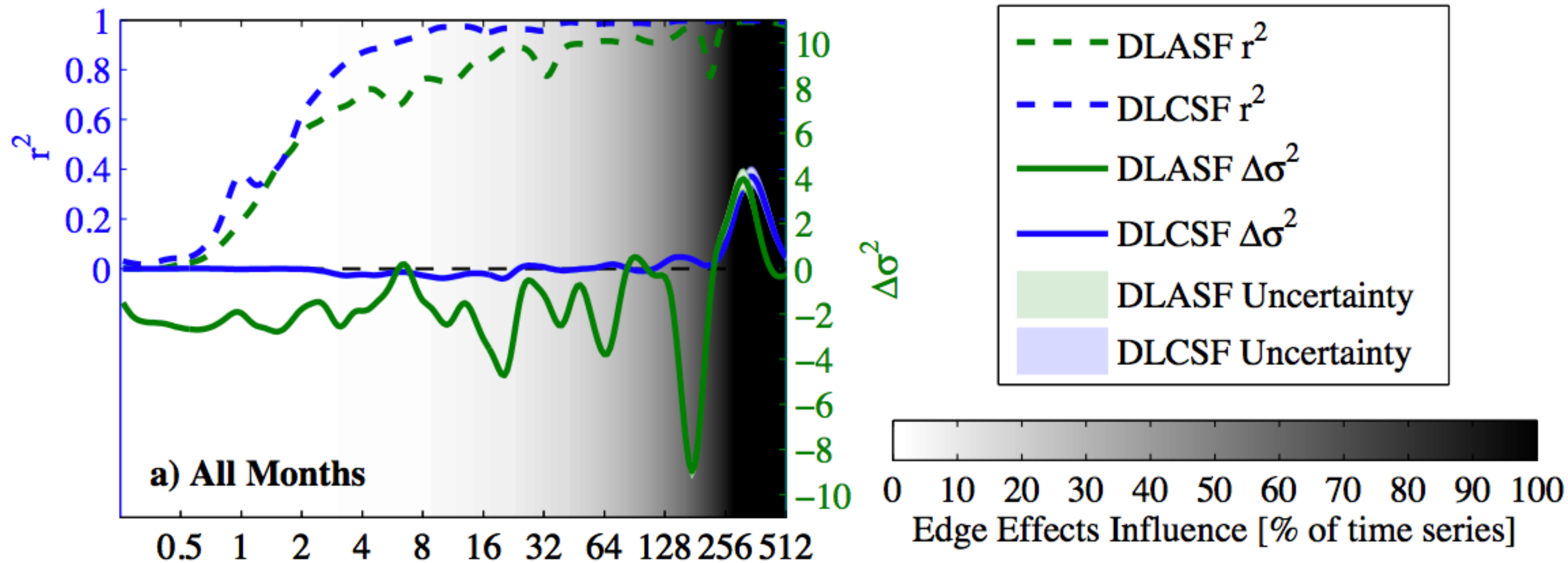
Correlation

& σ² difference



1 day

Evaluation of ERA-Interim



Surface observations and ERA-Interim show low correlation at time scales less than 4 days; **Point observations versus grid cell**.

DLCSF is well represented.

DLASF is biased low. (Underestimation of thick clouds; overestimation thin)

Semi-annual and annual time scales differ a lot.

Evaluation of ERA-Interim

Most seasons exhibit similar results.

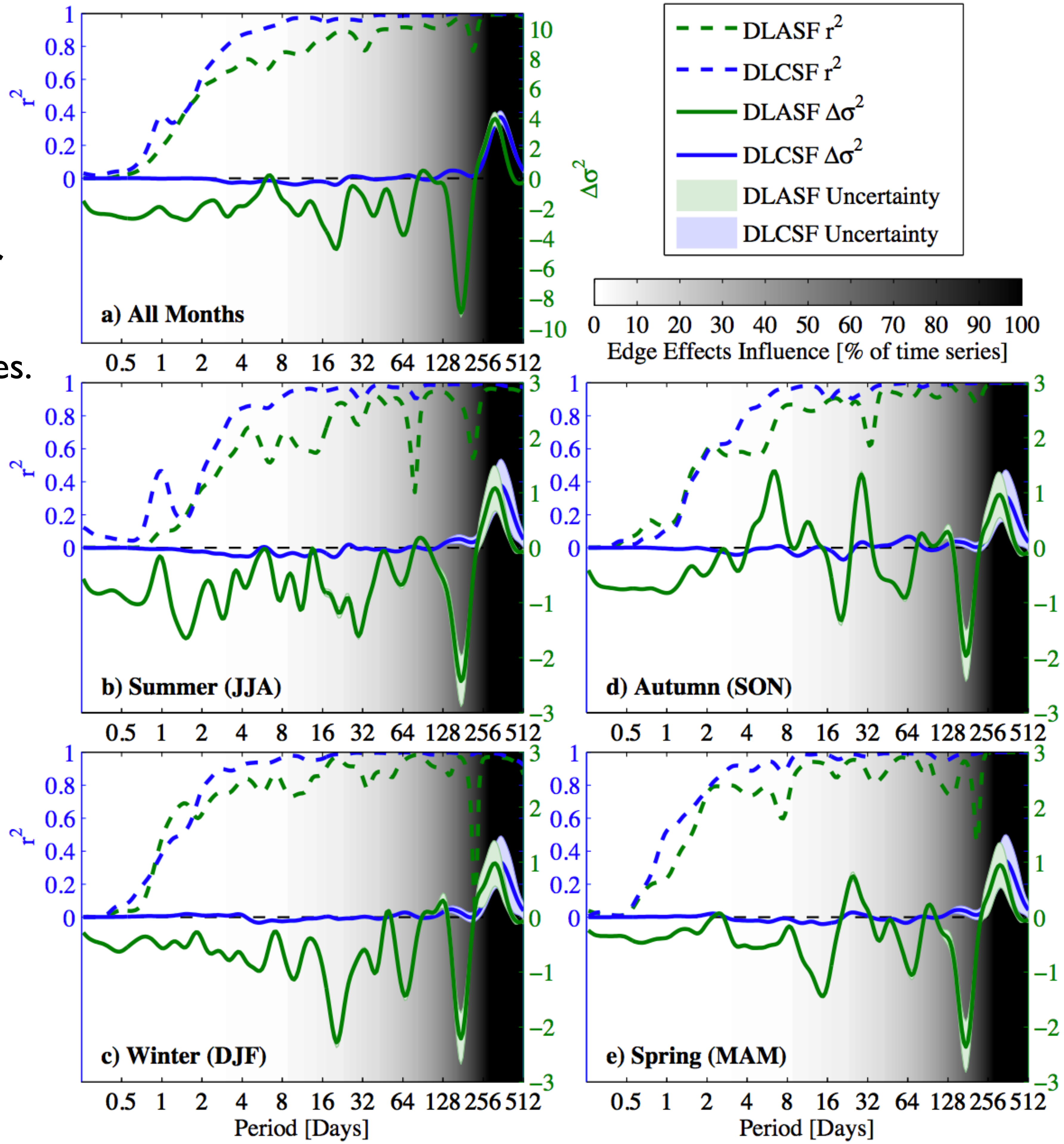
1) Lack of correlation; small times.
2) DLCSF is well represented.
3) DLASF is biased low.

Bias is independent of time scale:

1) Cloud generation
2) Position of air masses

Summer DLCSF varies diurnally

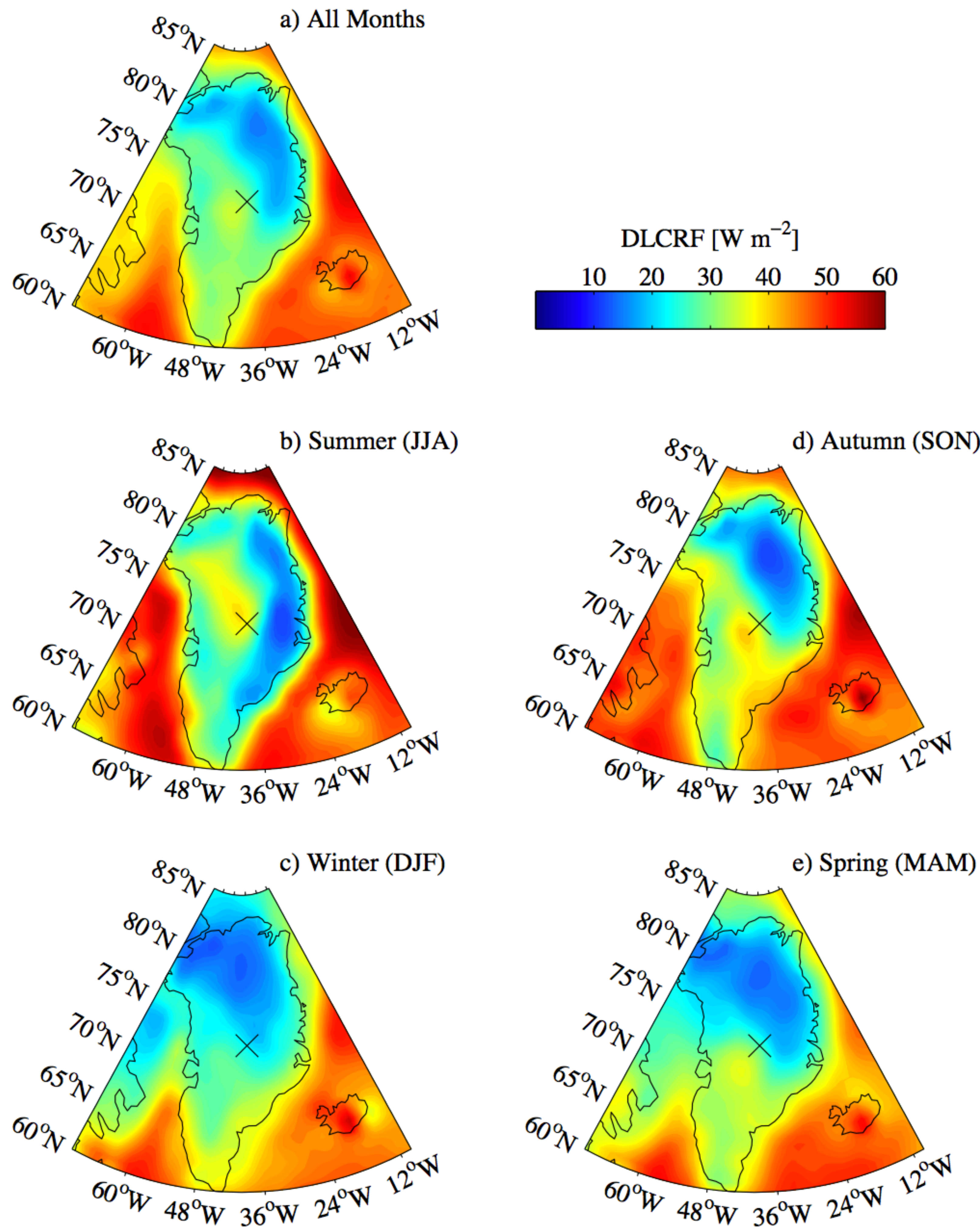
Autumn shows two large peaks at about one week and one month.



Evaluation of ERA-Interim

Summit Station is located is a transition zone between low DLCRF to the North and high DLCRF to the West.

Pattern is most complex in autumn when ERA-I exhibits competing biases in cloud variability at different time scales.



Conclusions

Wavelet analysis is useful for:

1) **Evaluating reanalysis performance**

and

2) **Comparison of gridded data sets with point locations.**

- DLW in ERA-Interim is well represented for time periods greater than about 4 days.
- ERA-Interim under estimates thick clouds and over estimates thin clouds (cloud generation processes).
- Wavelet analysis illustrates a complicated picture of how time scales of variability vary with season.
- Summit Station is situated in a transition zone of cloud variability.

Photo by Chris Cox

References

Cox, C.J., V.P. Walden, G. Compo, P.M. Rowe, M.D. Shupe and K. Steffen, 2014: Downwelling longwave flux at Summit, Greenland, 2010-2012: Analysis of surface-based observations and evaluation of ERA-Interim using wavelets, *J. Geophys. Res.*, submitted.

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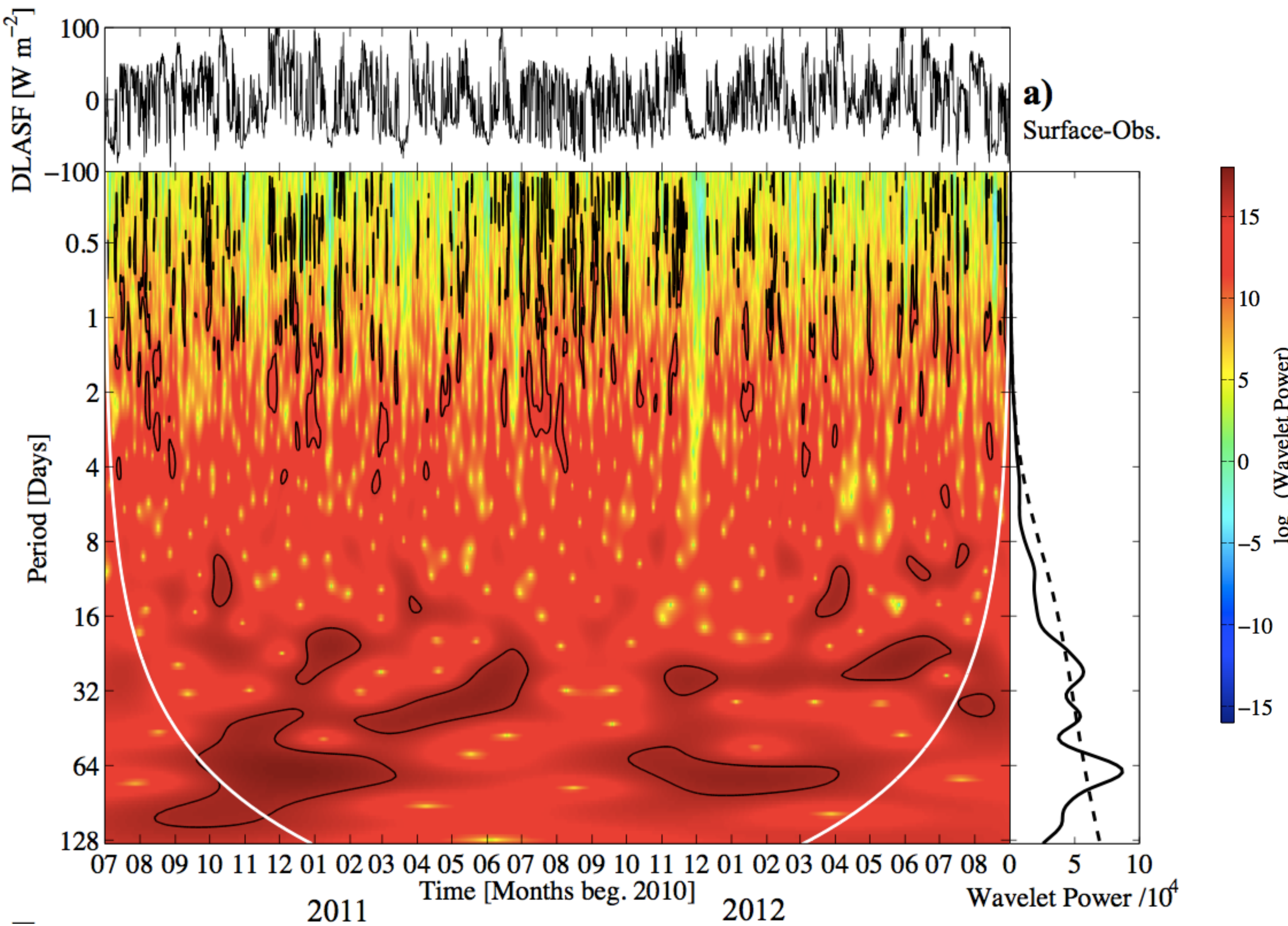
Wavelet Power (sfc obs)



Wavelet Power (ERA-I.)