Exploring differing definitions of congestions and analytic techniques for evaluating and identifying congestion

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Defining Congestion

The Evolution of Internet Congestion

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Abstract

This paper discusses the evolution of the congestion controls that govern all Internet traffic. In particular we chronicle and discuss the implications of the fact that the most significant "congestion signals" are increasingly coming from network operators, not the TCP stack. Providers now nudge users into different traffic patterns using a variety of new technical and non-technical means. These 'network-based congestion management' techniques include volume-based limits and active traffic management of best effort traffic. The goal and effect of these techniques differs from the historically coveted flow-rate fairness of TCP, provoking some in the technical and policy community to question the appropriateness of such deviations, and feeding

Bauer, S., Clark, D., Lehr, W. (2009), The Evolution of Internet Congestion, Massachusetts Institute of Technology, 37th Research Conference on Communication, Information and Internet Policy (www.tprcweb.com), Arlington, VA, September 2009

Queuing theory definition of congestion

- **Formula 1:** arrival rate > service rate

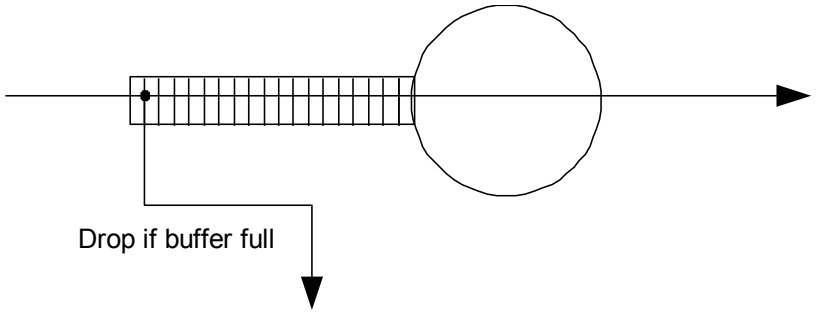
$$\lambda > \mu$$

- **Formula 2:** congestion = arrival rate / service rate

$$p = \lambda/\mu$$

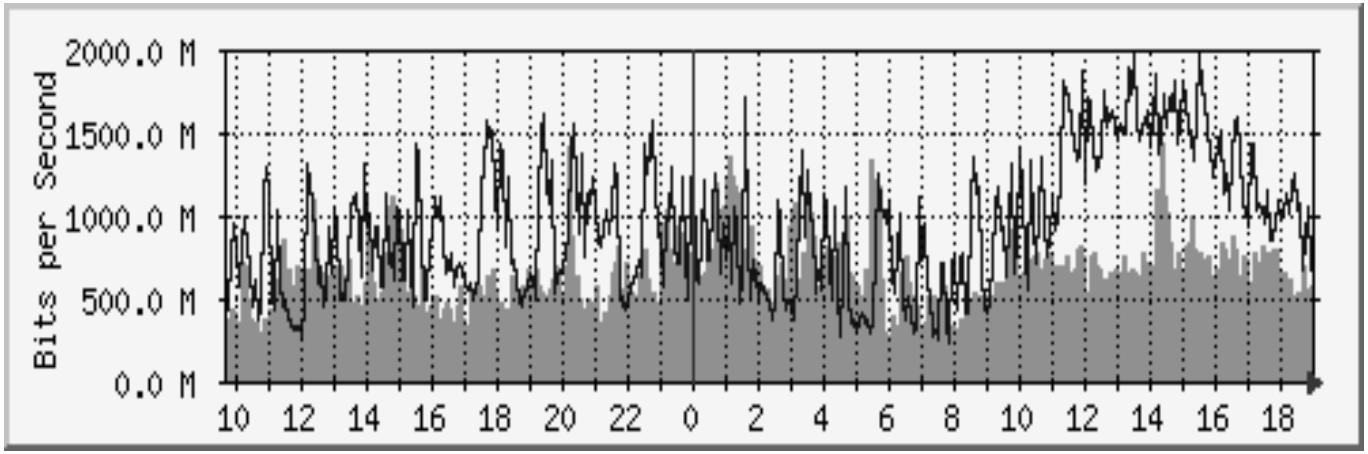
Networking text book definitions

- **Congestion:** router runs out of buffer space and must start dropping packets if more arrive.
- **Contention:** the buildup of packets in a queue



Network provider definitions of congestion

- Average link/network utilization of some period of time



One economic definition of congestion

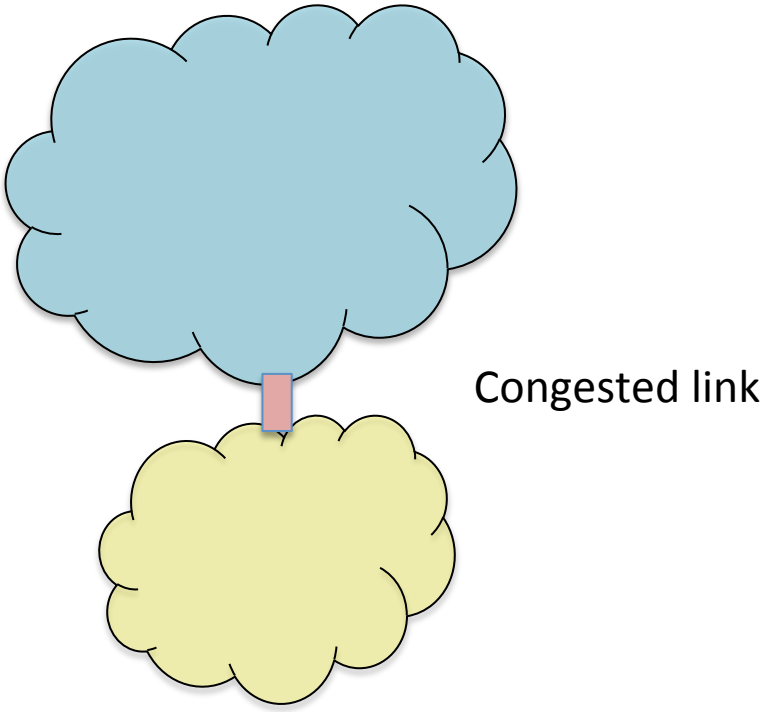
- MIT Dictionary of Modern Economics:

"*When an increase in the use of a facility or service which is used by a number of people would impose a cost (not necessarily a monetary cost) on the existing users, that facility is said to be 'congested'.*

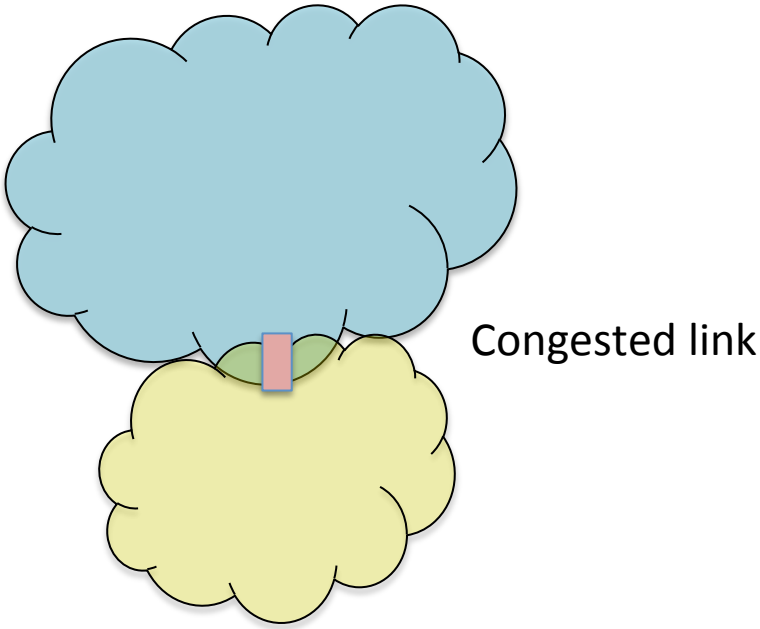
Application centric definitions of congestion

User centric definitions of congestion

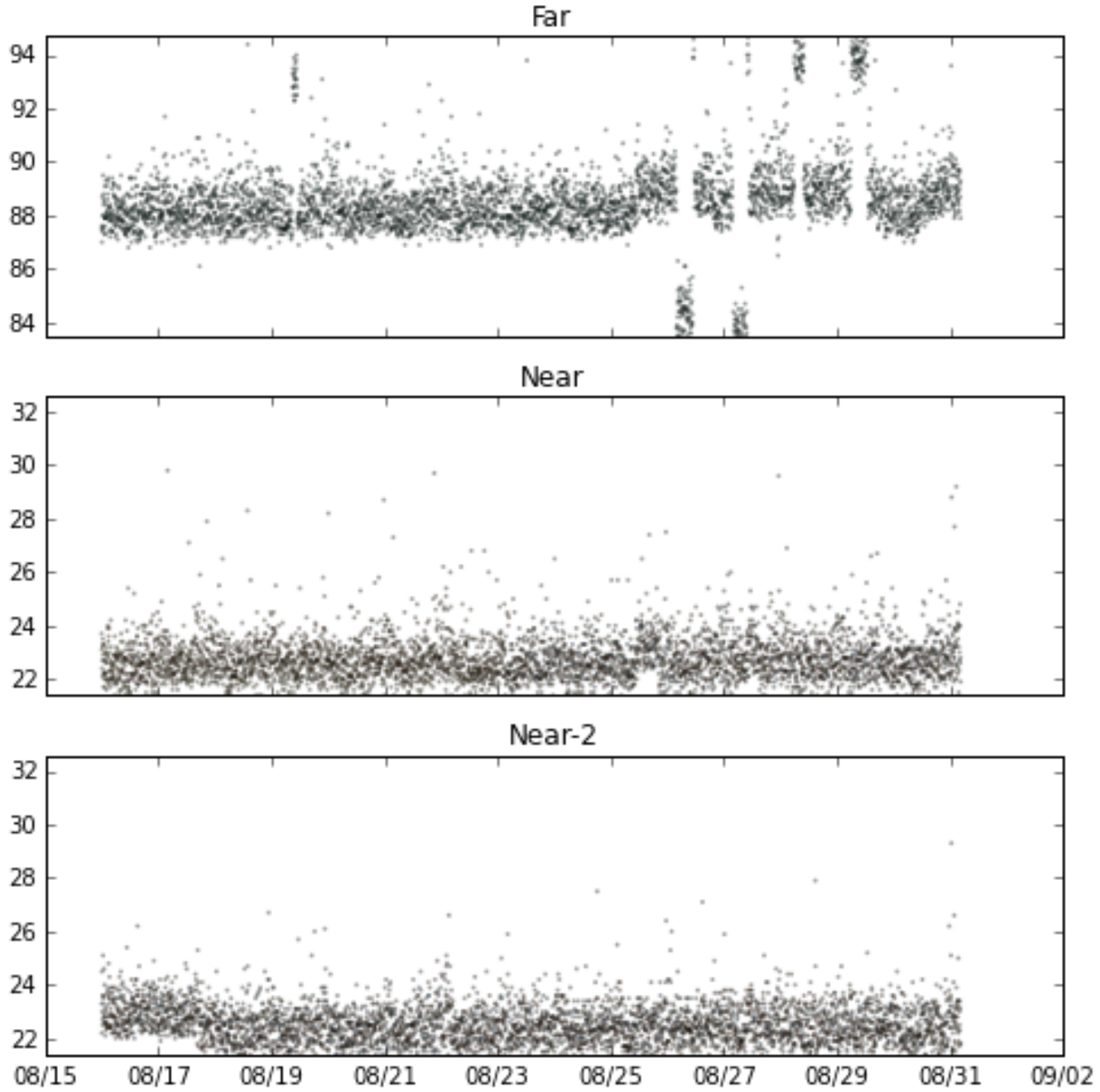
Uncongested Networks
Congested Internet

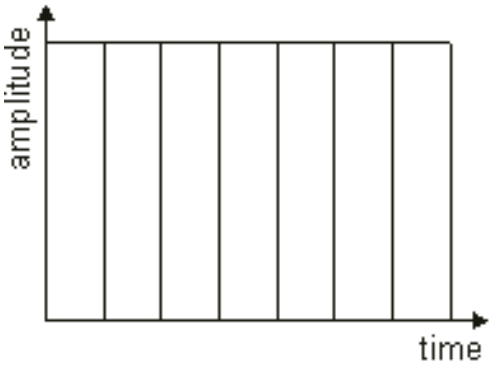


Congested Networks
Congested Internet

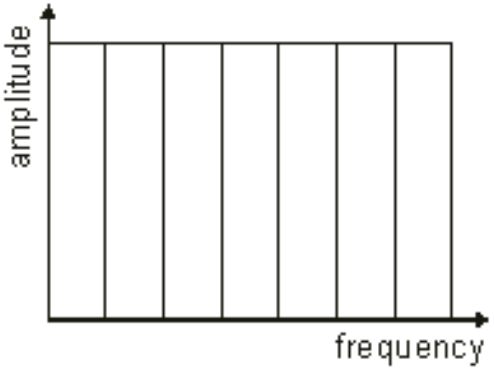


Analyzing congestion data with wavelets


Far
94
92
90
88
86
84
Near
32
30
28
26
24
22
Near-2
32
30
28
26
24
22
08/15
08/17
08/19
08/21
08/23
08/25
08/27
08/29
08/31
09/02

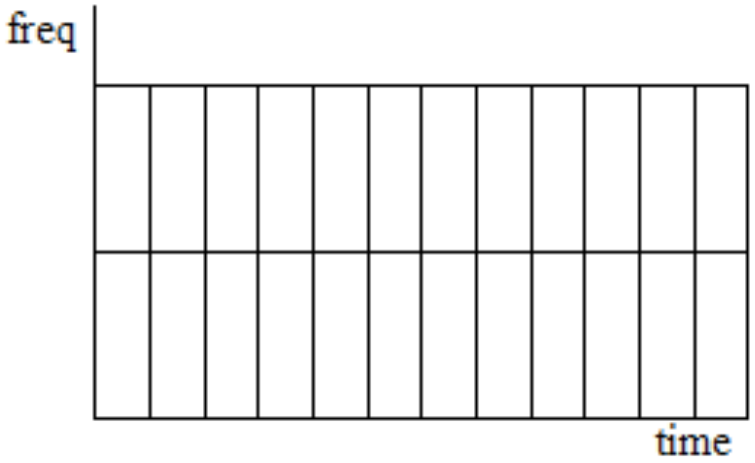


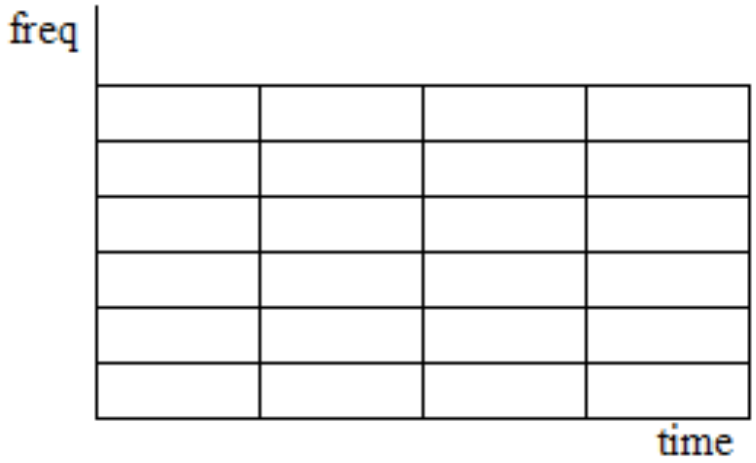
signal-domain



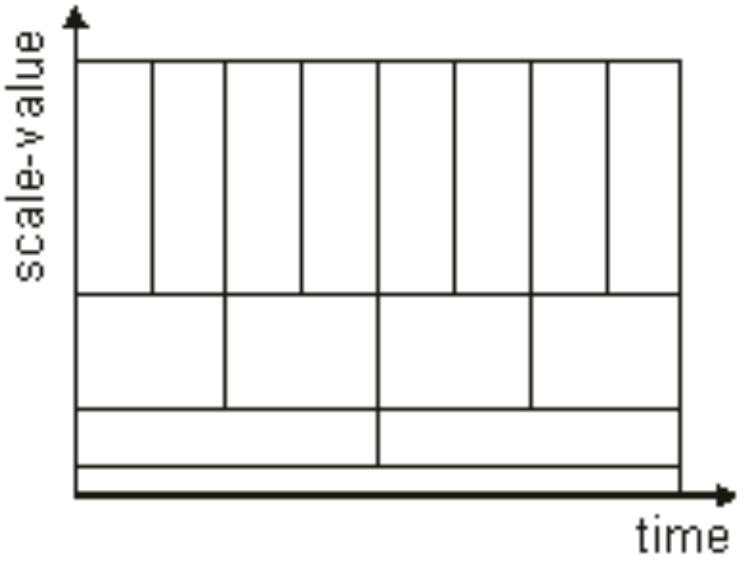
frequency-domain (FT)

Short-time Fourier transform



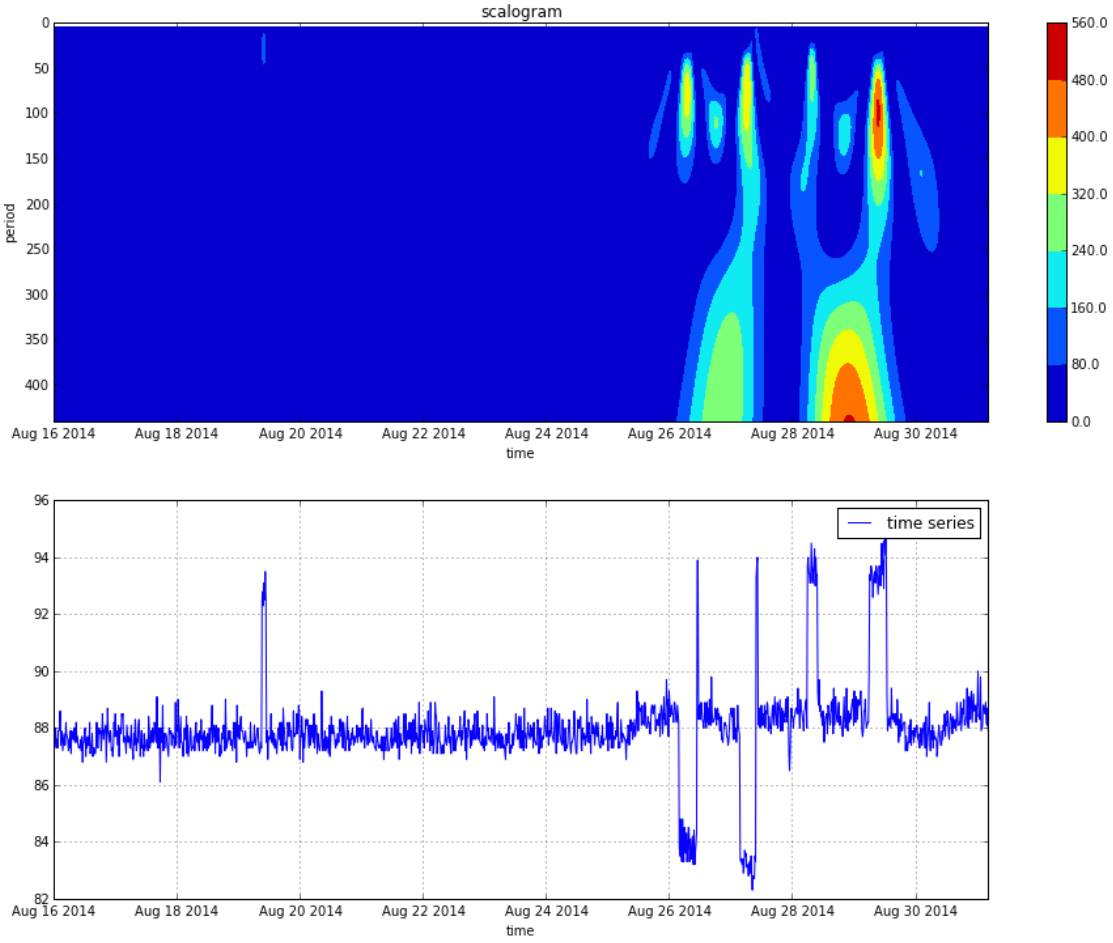


Wavelet analysis

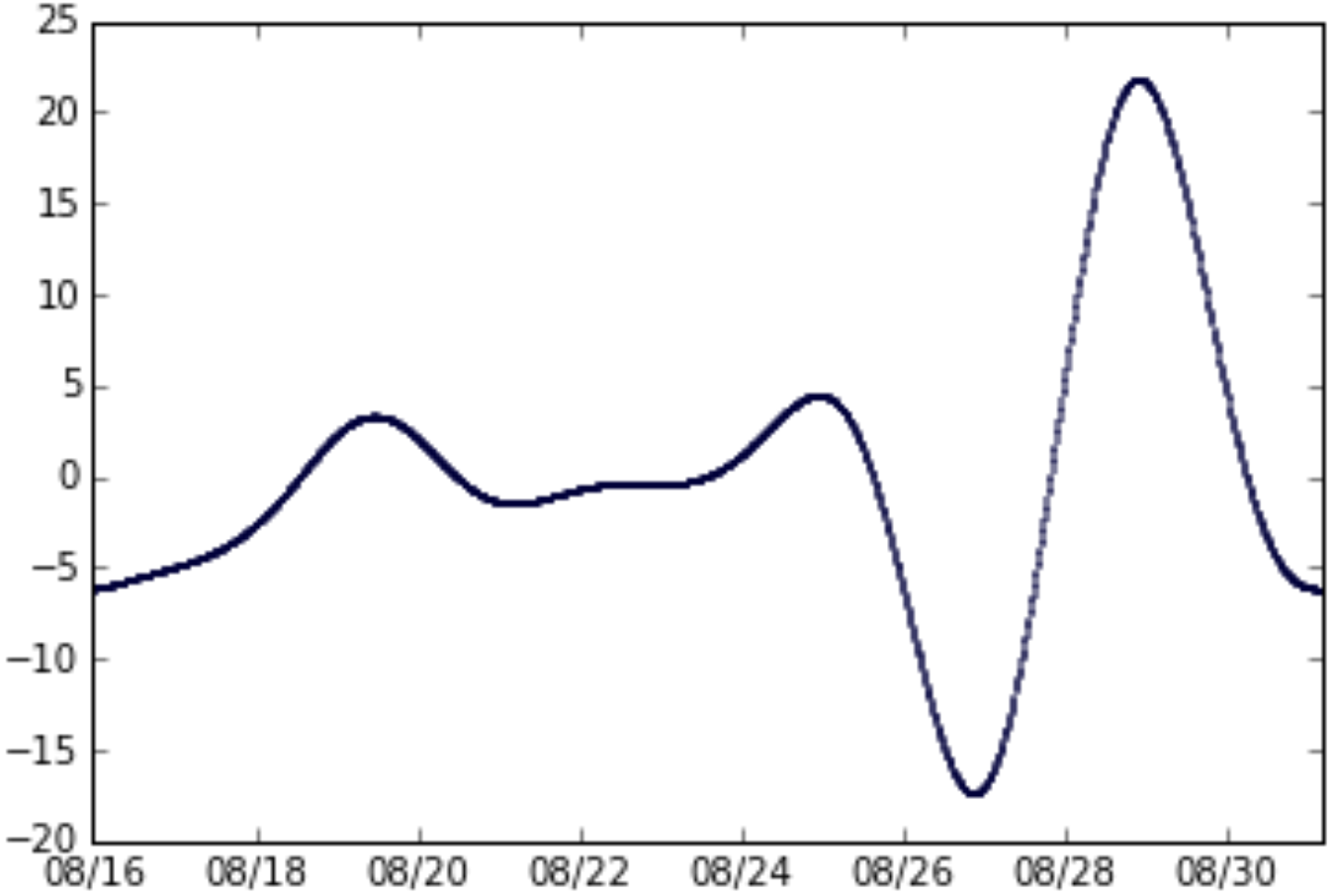


Wavelet-analysis

Far


scalogram
period
0
50
100
150
200
250
300
350
400
Aug 16 2014
Aug 18 2014
Aug 20 2014
Aug 22 2014
Aug 24 2014
Aug 26 2014
Aug 28 2014
Aug 30 2014
time
560.0
480.0
400.0
320.0
240.0
160.0
80.0
0.0
time series
96
94
92
90
88
86
84
82

Wavelet coefficients for daily signal



Far link power spectrum