

Time-Scale Structure of the Heat/Vapor Flux over the Tibetan Plateau revealed by Orthogonal Wavelet Transform

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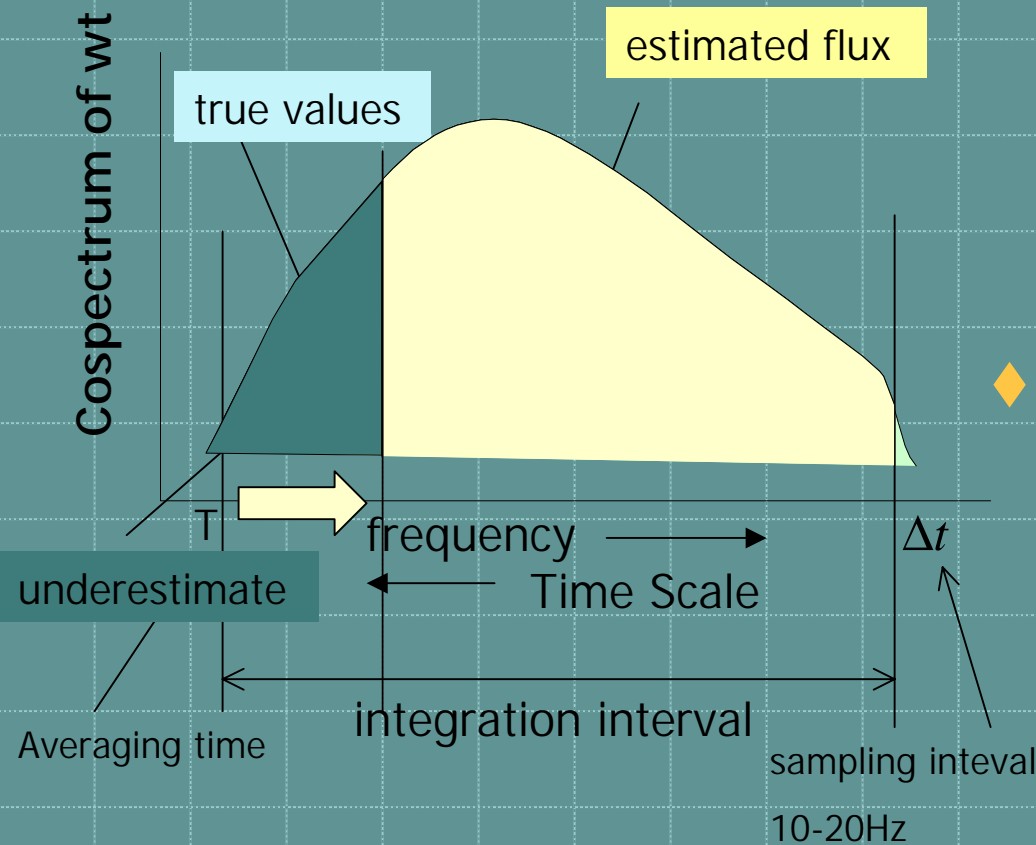
Background

- ◆ Many researchers reports “surface imbalance” at surface flux sites in

$$R_n > H + E + G$$

- ◆ GAME regions (AAN, regional flux groups)
- ◆ Worldwide projects (FIFE, BOREAS, Washita, etc)
- ◆ Possible causes (e.g. Mahrt, 1998)
 - ◆ Sensor errors, measurement problems?
 - ◆ Unmeasured terms in heat budget eqn ?
 - ◆ Averaging time problem for eddy correlation technique (heat transfer at larger scale)

Eddy correlation technique



$$H = \rho C_p \overline{w' \theta'}$$

$$= \rho C_p \int_{\Delta t}^T w' \theta' dt$$

♦ Averaging Time, T

- ♦ usually taken between 10 and 60 min.
- ♦ if too short, there is a flux that cannot be captured by with above integration.



Study Purpose

- ◆ To identify scales (frequencies) relevant to the turbulence heat transfer using **wavelet transforms**
- ◆ To determine an appropriate time for averaging time of eddy correlation
or
to evaluate the effect of too-short-averaging-time on the estimated flux values.

Data set analyzed

- ◆ GAME-Tibet IOP '1998
- ◆ Flux site near Naqu city (BJ site)
 - ◆ 4580m ASL, 31N, 92E
 - ◆ Period: 1998.5.14 ~ 9.15
 - ◆ Cooperative work between Korean, Chinese, Japanese scientists.
 - ◆ Full measurements of heat budget components and turbulence measurements
- ◆ 9 consecutive turbulence data (20Hz) observed with a sonic anemometer are selected as “run”

Runs analyzed

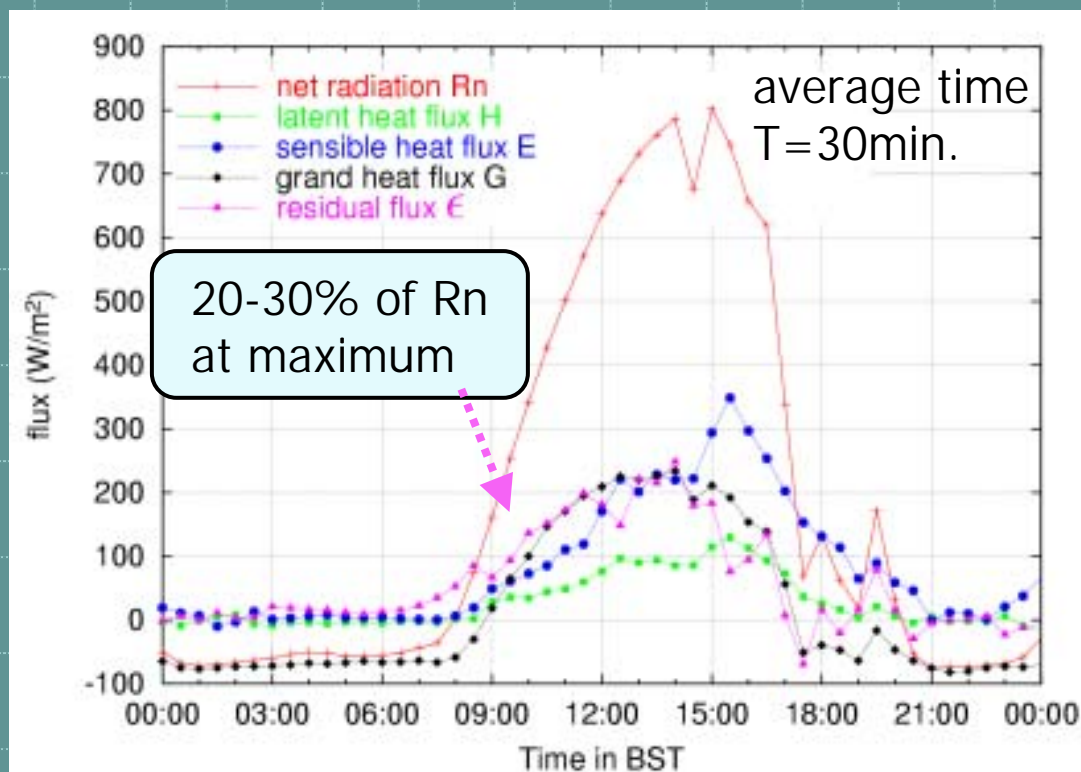


Run	Date	Time in BST
1	7/28	10:10 - 17:17
2	8/03	10:07 - 17:24
3	8/16	10:09 - 17:25
4	8/22	10:09 - 17:25
5	8/30	09:59 - 17:16
6	9/06	10:01 - 17:18
7	9/12	08:01 - 15:18
8	9/13	10:09 - 17:25
9	9/14	10:07 - 17:24

all runs are 7.3 hr

Flux imbalance @ Naqu Flux Site

- ◆ 30% of R_n is not closed with EC measured fluxes
- ◆ It has been proved that there is no technical problem.
 - ◆ Comprehensive investigation on the energy partitioning by Kim (S1-05)
 - ◆ Intercomparison with the mobile turbulence measurements (Asanuma et al., P1-16)
- ◆ The problem is not technical but scientific.

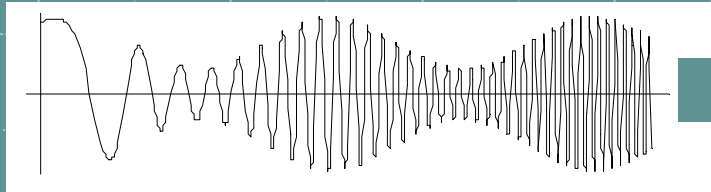
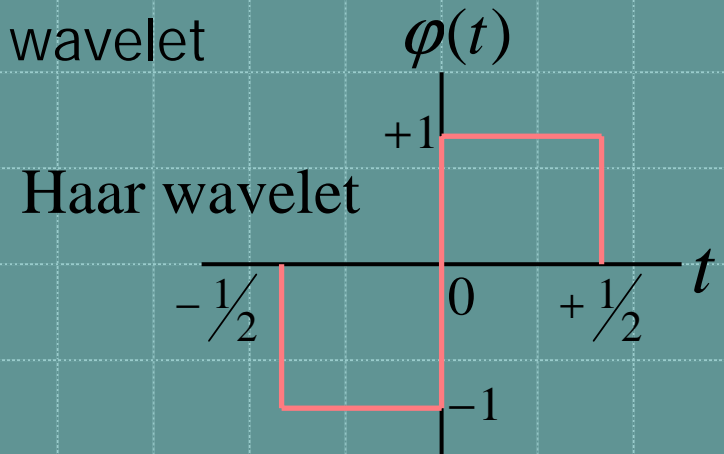


Wavelet Transforms

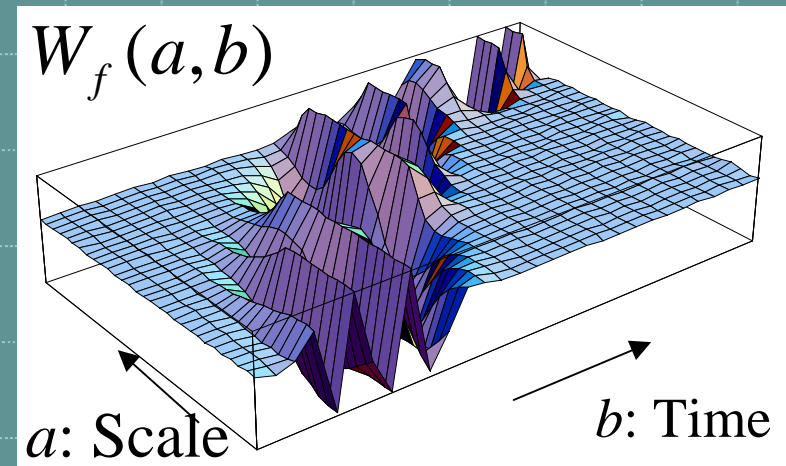
◆ Definition

$$W_f(a, b) = \int_{-\infty}^{+\infty} f(t) \varphi\left(\frac{t-b}{a}\right) dt$$

a : scale
 b : time
 $f(t)$: original time series
 $\varphi(t)$: mother wavelet



turbulent data is decomposed
into localized eddies
as a function of scale (a) and time (b)

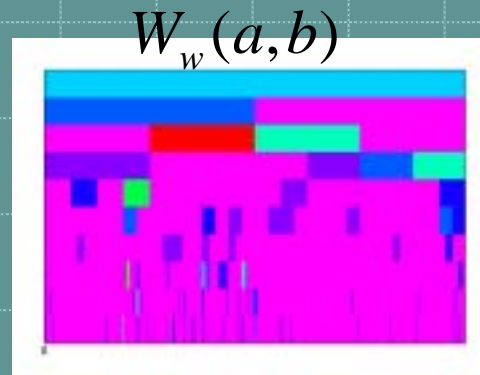
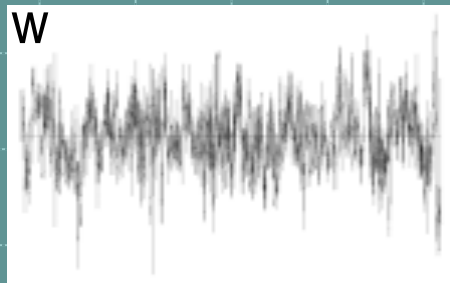


Method of Analysis 1

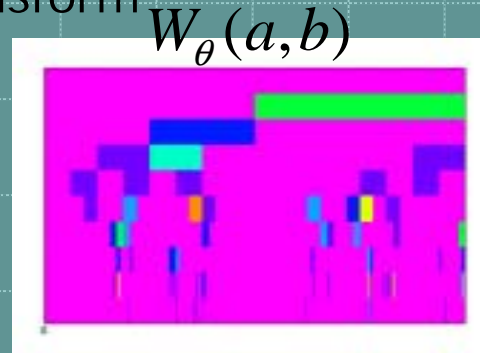
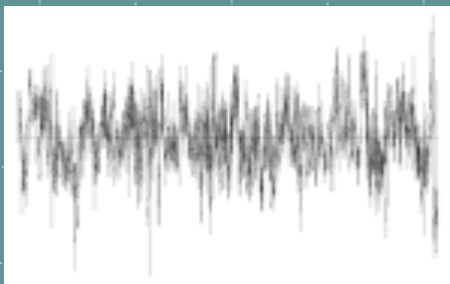
- ◆ Scale analysis of sensible heat flux
- ◆ Orthogonal scheme by Howell and Mahrt(1994)

$$H = \rho C_p \overline{w'\theta'}$$

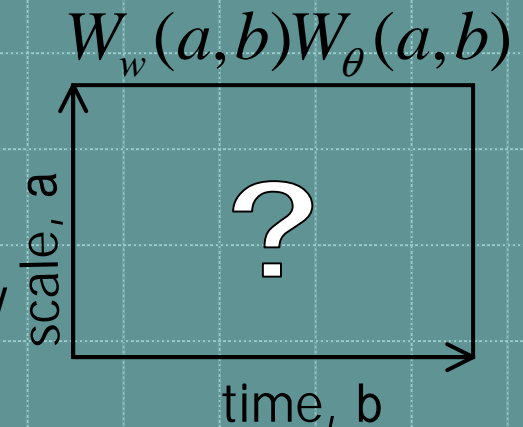
Time series



wavelet transform

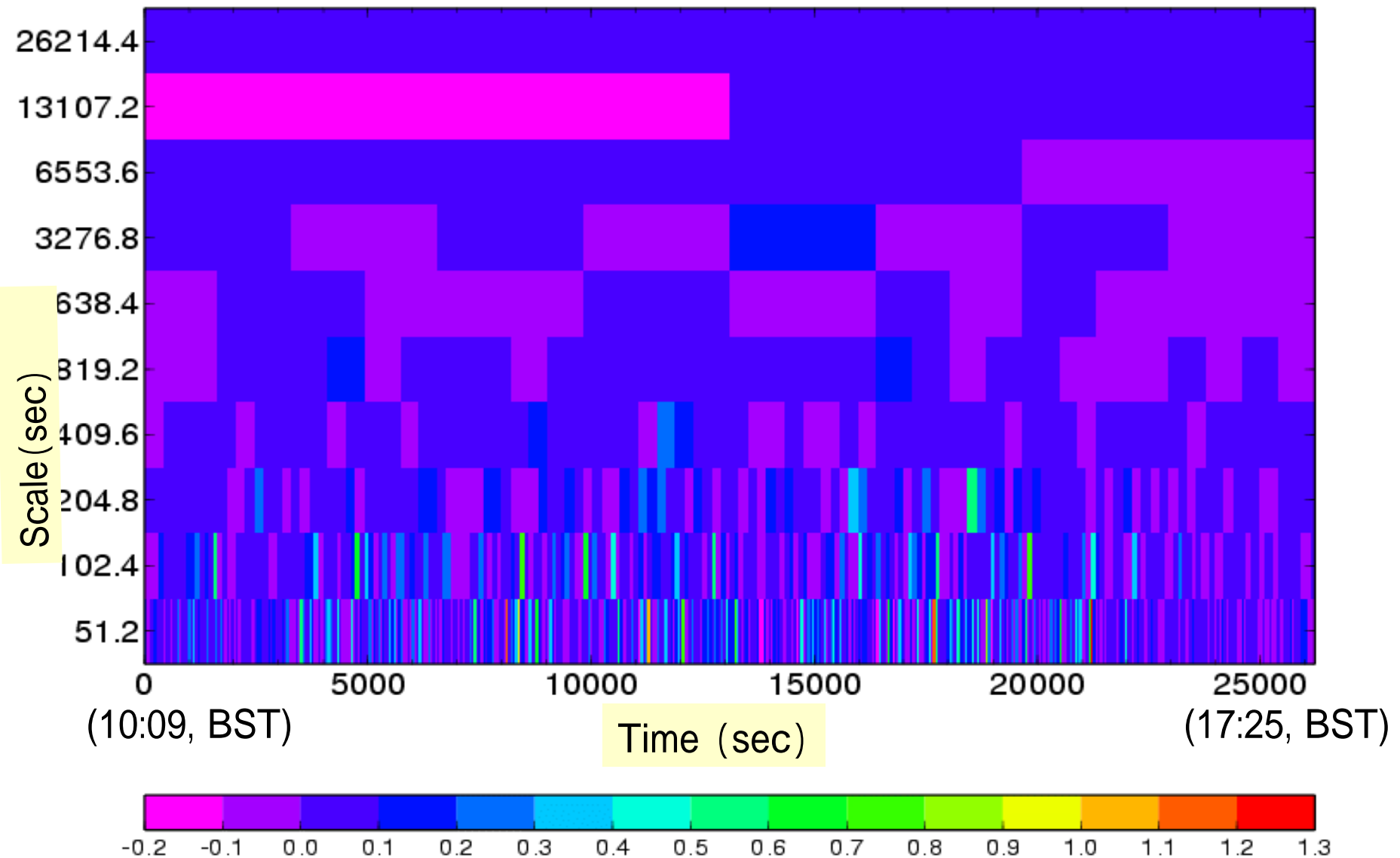


multiply



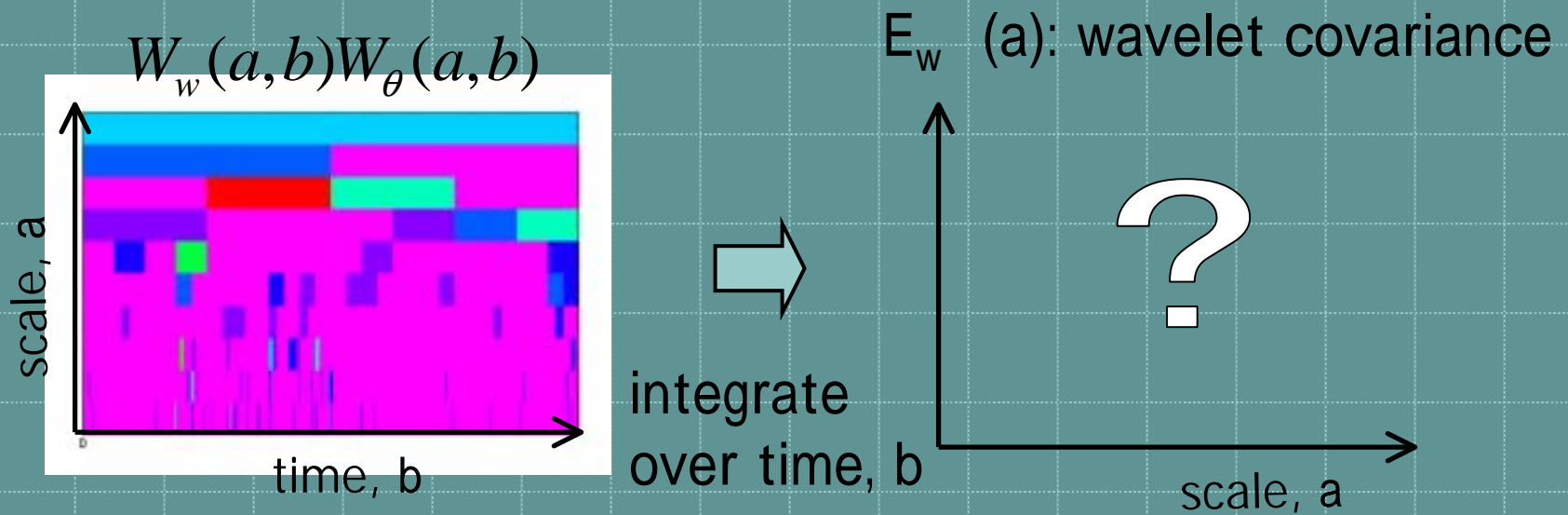
“sensible heat flux associated with a eddy of a certin scale at a certain time location”

Time-scale diagram of the sensible heat flux (Run 4)



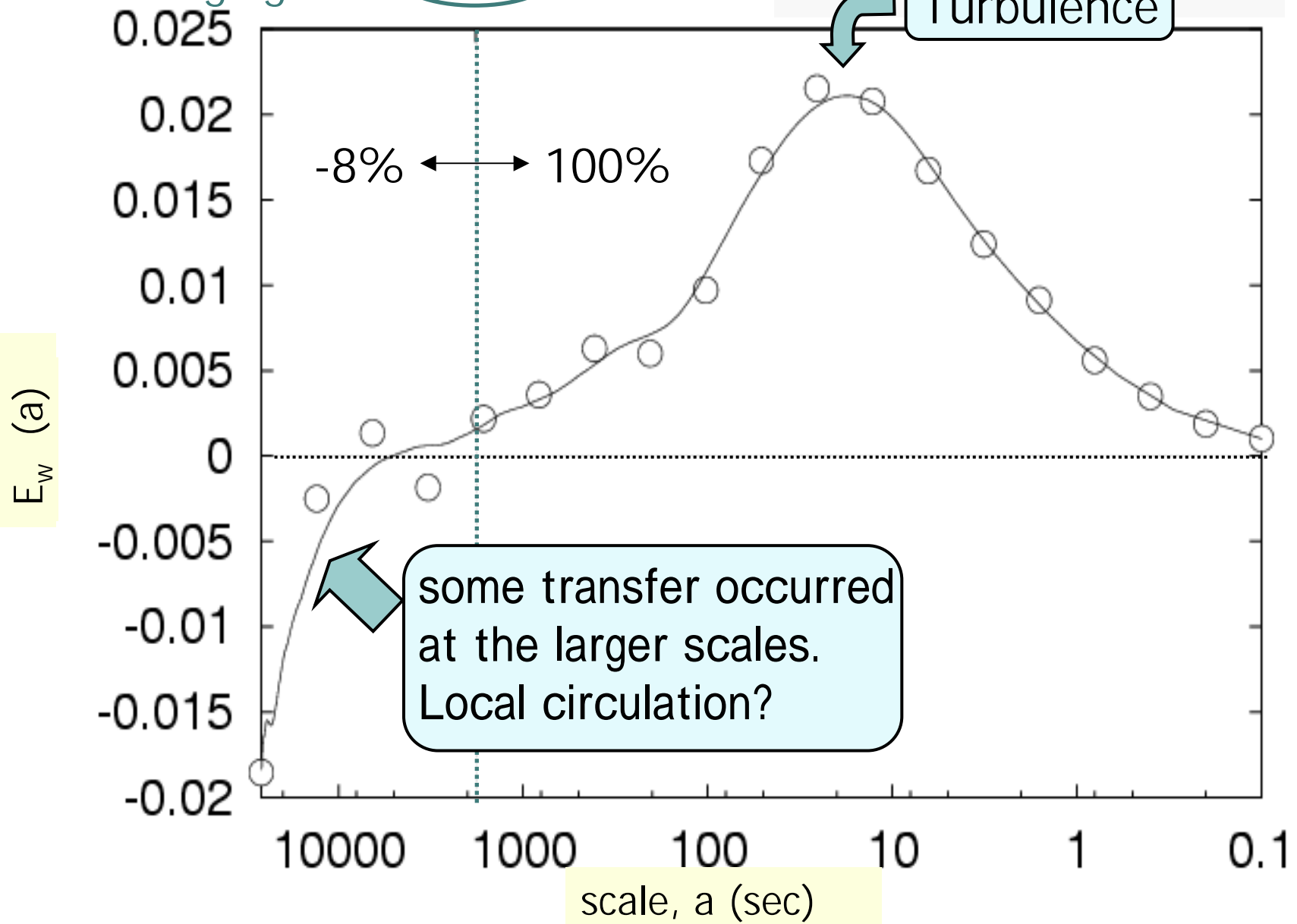
Method of Analysis 2

◆ Wavelet covariance of heat fluxes



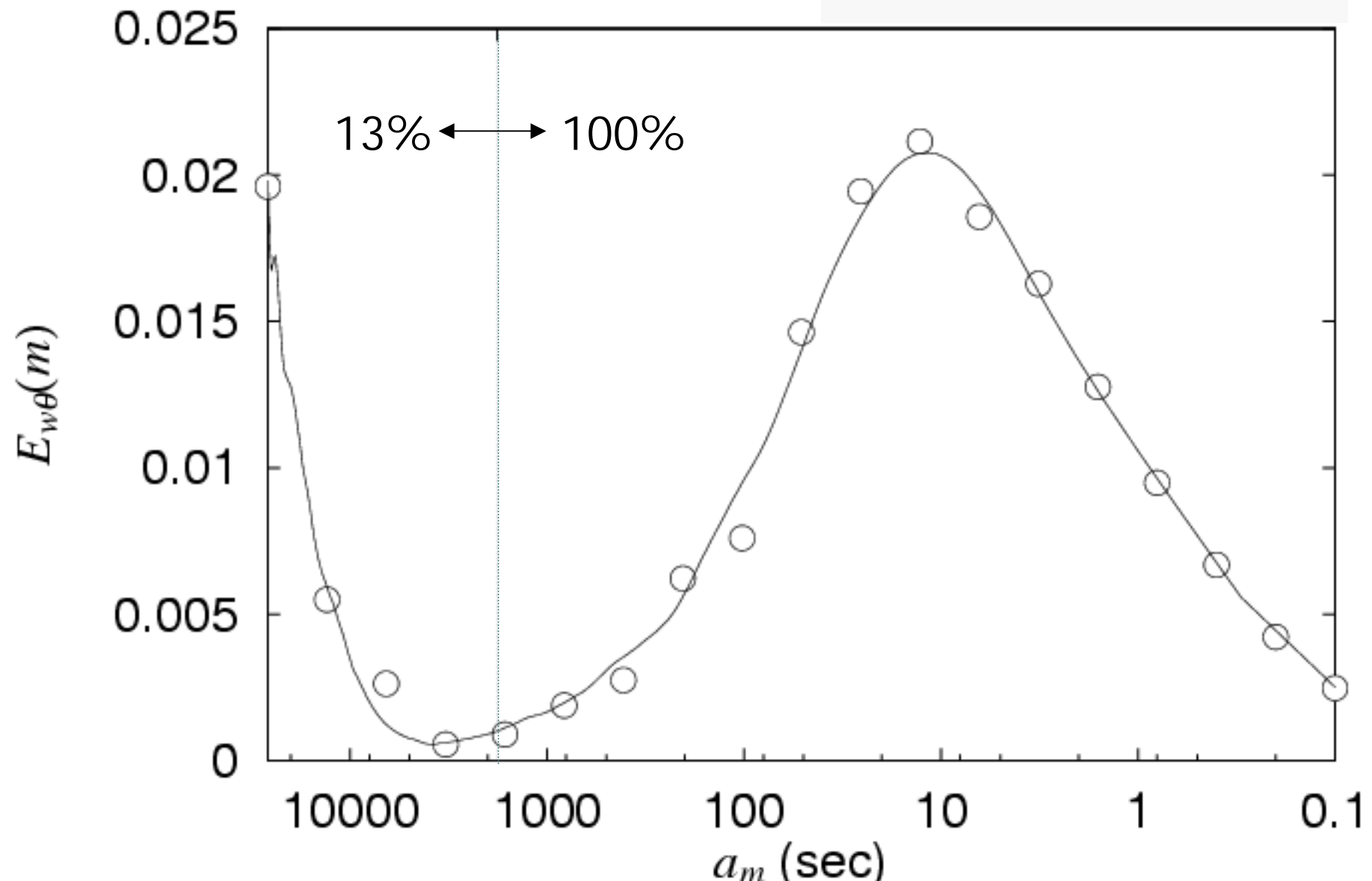
Wavelet covariance of sensible heat flux (Run4)

averaging time 30min



Wavelet cospectrum of sensible heat flux (Run3)

30min



Underestimates due to the selection of averaging time

Run	(above 30min)/(below 30min)
1	1%
2	-2%
3	13%
4	8%
5	-11%
6	4%
7	-14%
8	-4%
9	-6%



Summary

- ◆ Wavelet transform was successfully applied to the turbulence data acquired over Tibetan Plateau.
- ◆ Wavelet covariance gives clear pictures of behavior of heat transfer at larger scales.
- ◆ There is a clear scale gap around 1-2 hrs, which separates the turbulence and the larger-scale phenomena.
- ◆ There is a heat transfer at the larger scale upto 7 hrs (and more), which may be caused by This was not found for the evaporation.
- ◆ The choice of averaging time can be a cause of “the imbalance problem”, but does not explain all of the imbalance.



Things to do

- ◆ Investigate the time variation of the large scale heat transport.
- ◆ Investigate the large scale variation of T and w