

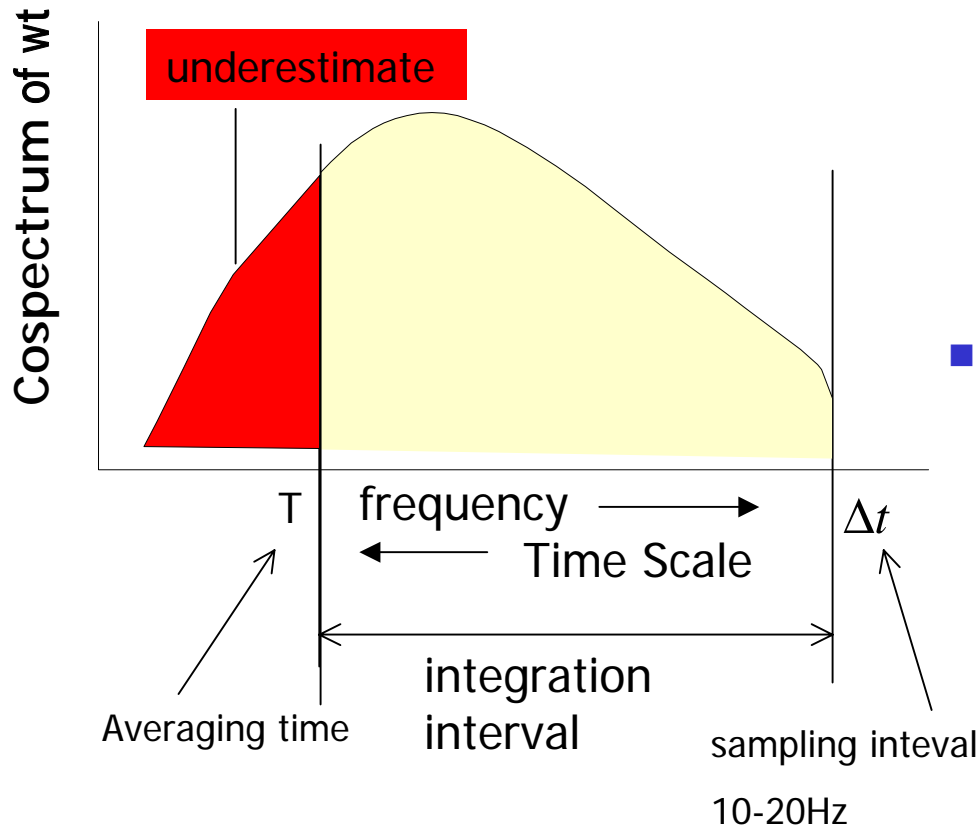


# Background

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- Many researchers reports “surface imbalance” at surface flux sites in  $Rn > H + E + G$ 
  - GAME regions (AAN, regional flux groups)
  - Worldwide projects (FIFE, BOREAS, etc )
- Possible causes (e.g. Mahrt, 1998)
  - Sensor errors, measurement problems?
  - Unknown terms in heat budget eqn ?
  - Averaging time problem for eddy correlation technique

# 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

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- To identify scales (frequencies) relevant to the turbulence heat transfer with **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.



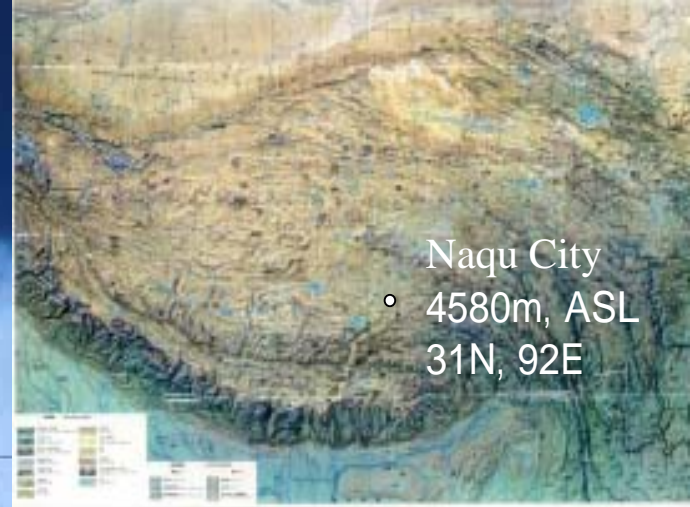
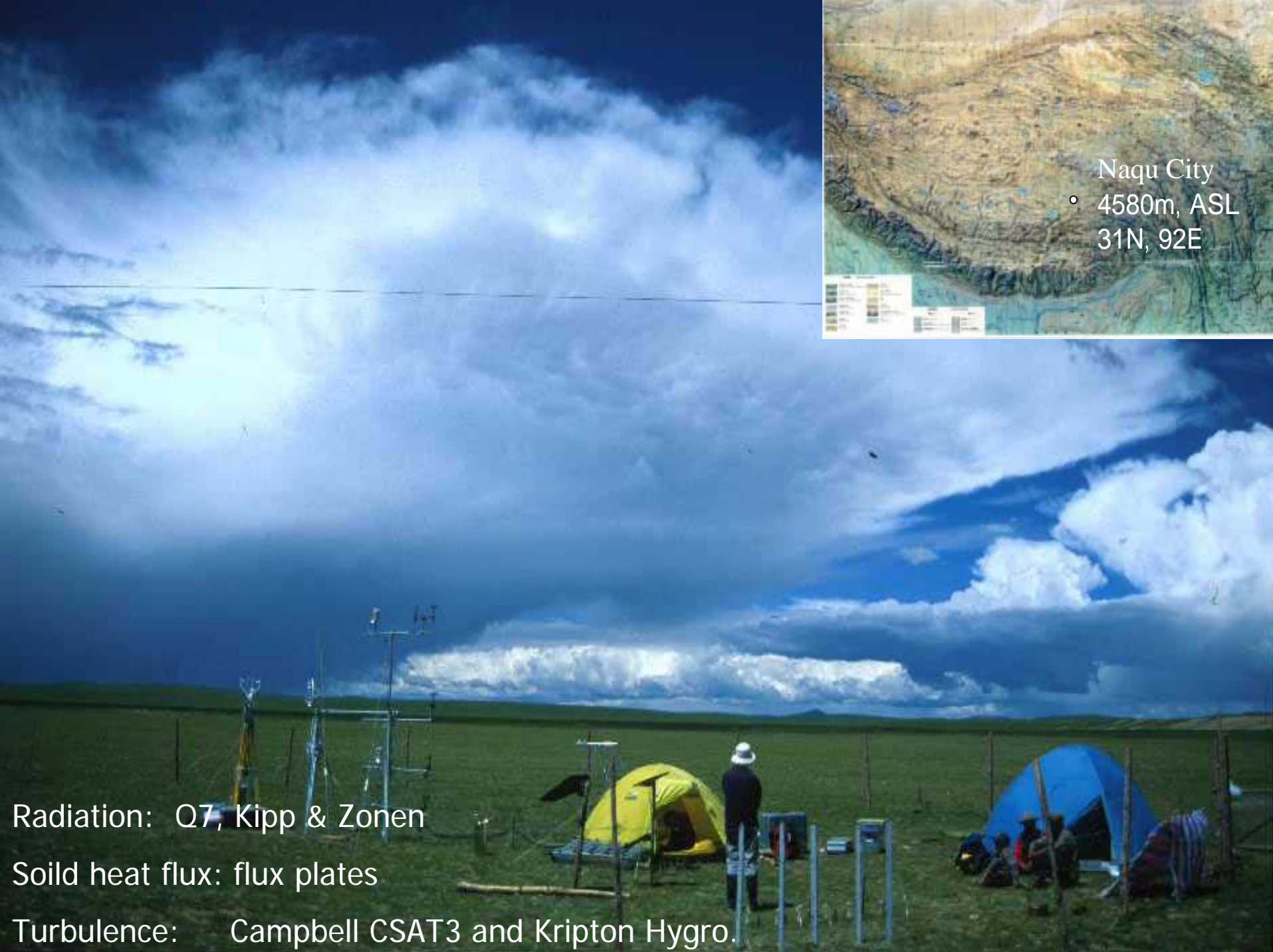
# Data set analyzed

- 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
  - Turbulence measurements
  - 9 consecutive data 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




Radiation: Q7, Kipp & Zonen

Soild heat flux: flux plates

Turbulence: Campbell CSAT3 and Krypton Hygro.

# Time-Scale Analysis of the Sensible/Latent Heat Transfer over the Tibetan Plateau Using Orthogonal Wavelet Transform



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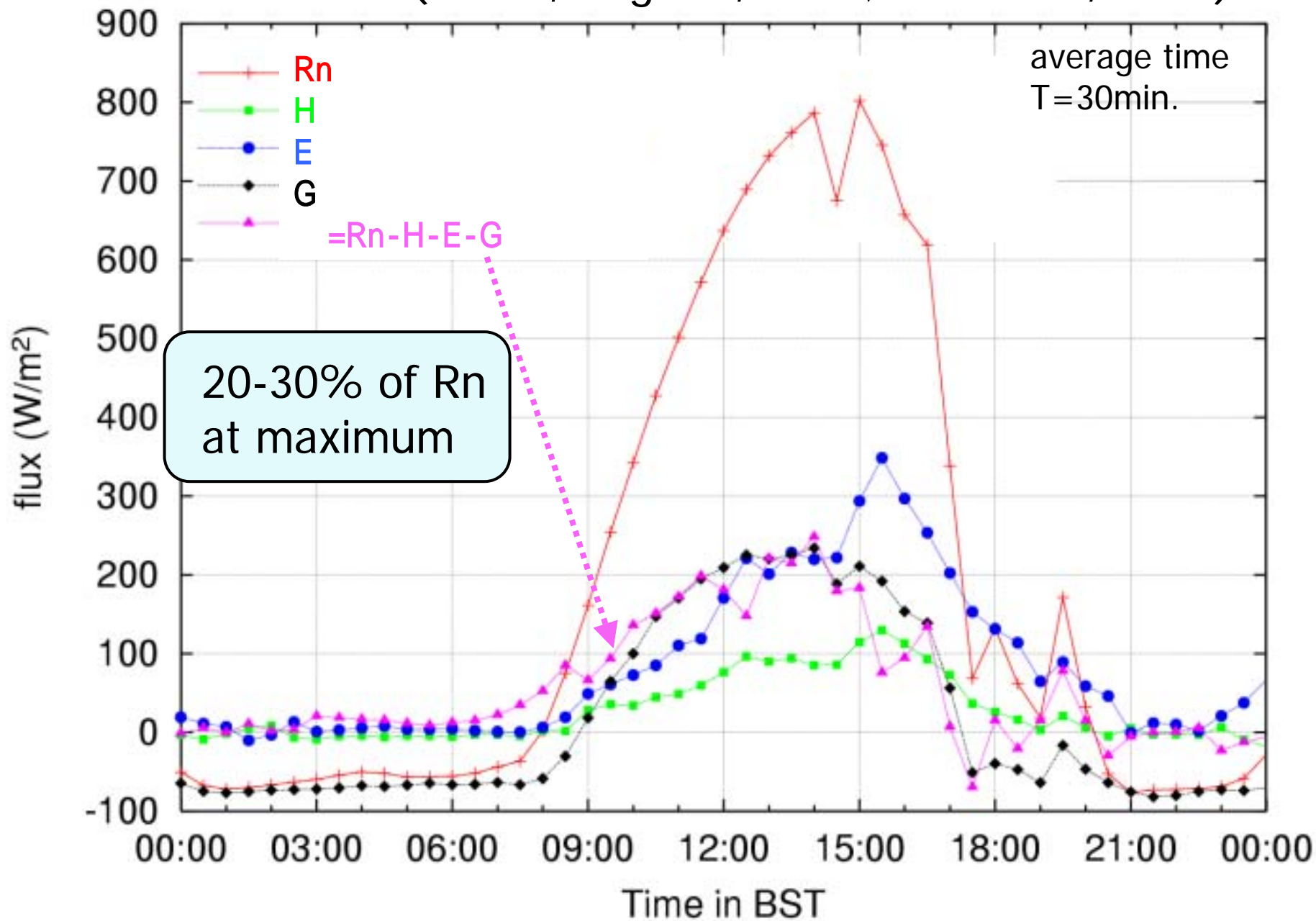
J. Asanuma (TERC, Tsukuba Univ.)

S. Aoki (Nagaoka Univ. Tech)

J. Kim, T. Choi, H. Lee (Yonsei Univ)

Z. Gao, J. Wang (Chinese Academy Sci.)

# Diurnal variation of surface heat balance at Naqu flux site (Run 4, Aug. 22, 1998; Choi et al, 2001)



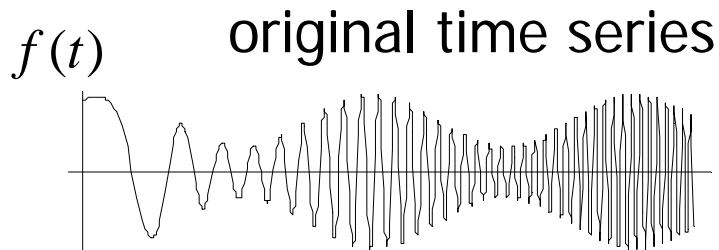


# Wavelet Transforms

## ■ Definition

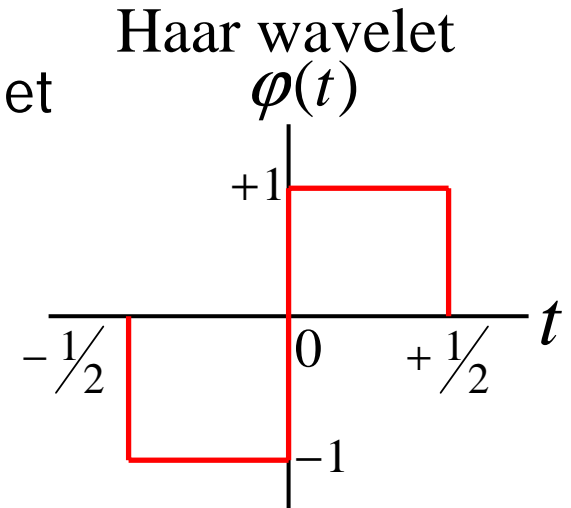
$$W_f(a, b) = \int_{-\infty}^{+\infty} f(t) \varphi\left(\frac{t-b}{a}\right) dt$$

scale      time      mother wavelet

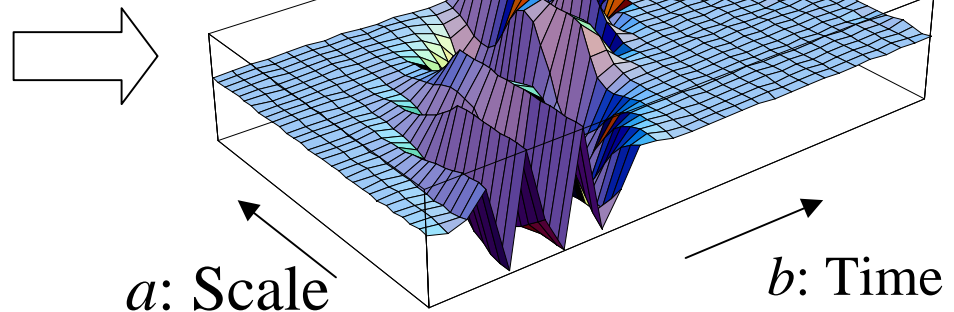


turbulent data is decomposed  
into localised eddies

as a function of scale (a) and time (b)



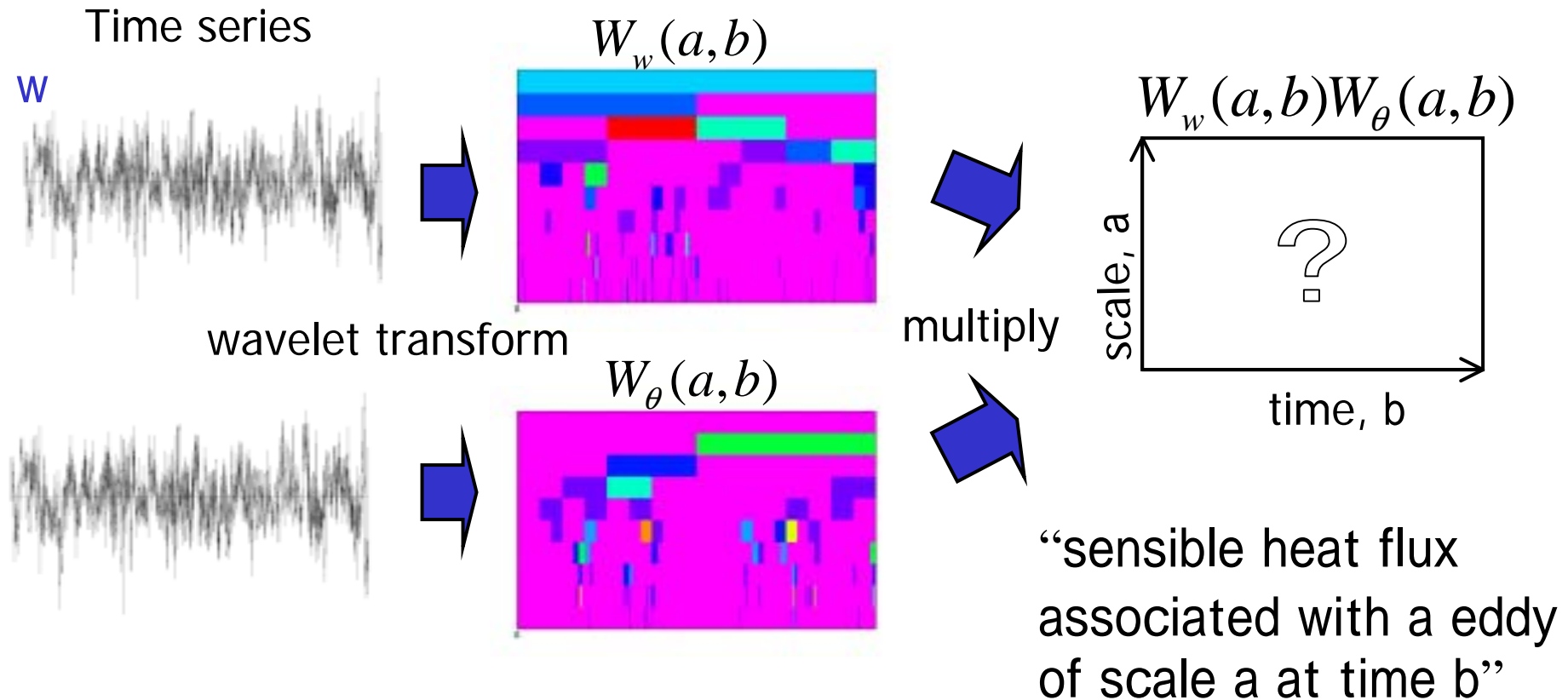
$W_f(a, b)$



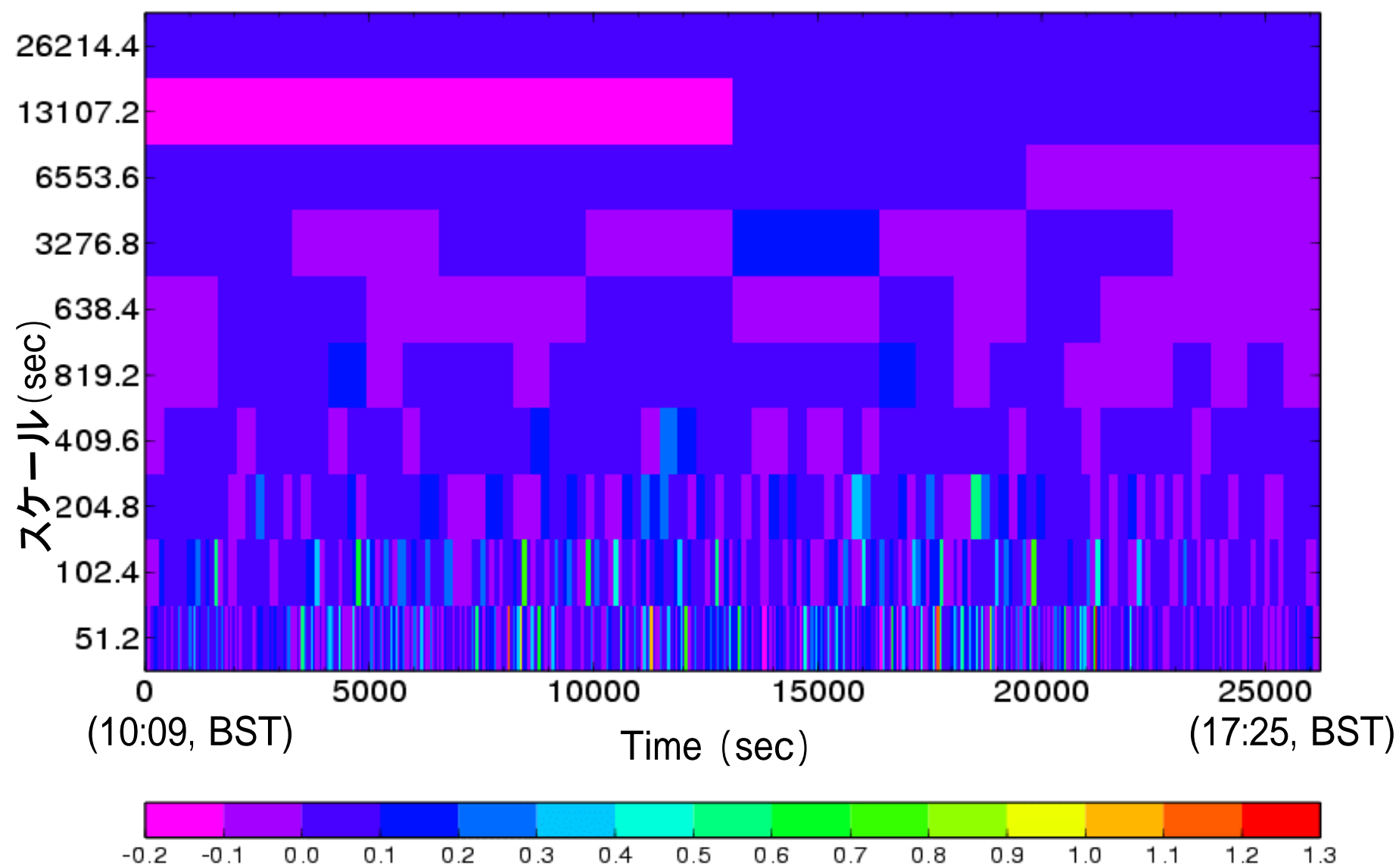


# Method of Analysis 1

- Scale analysis of sensible heat flux  $H = \rho C_p \overline{w'\theta'}$
- Orthogonal scheme by Howell and Mahrt(1994)

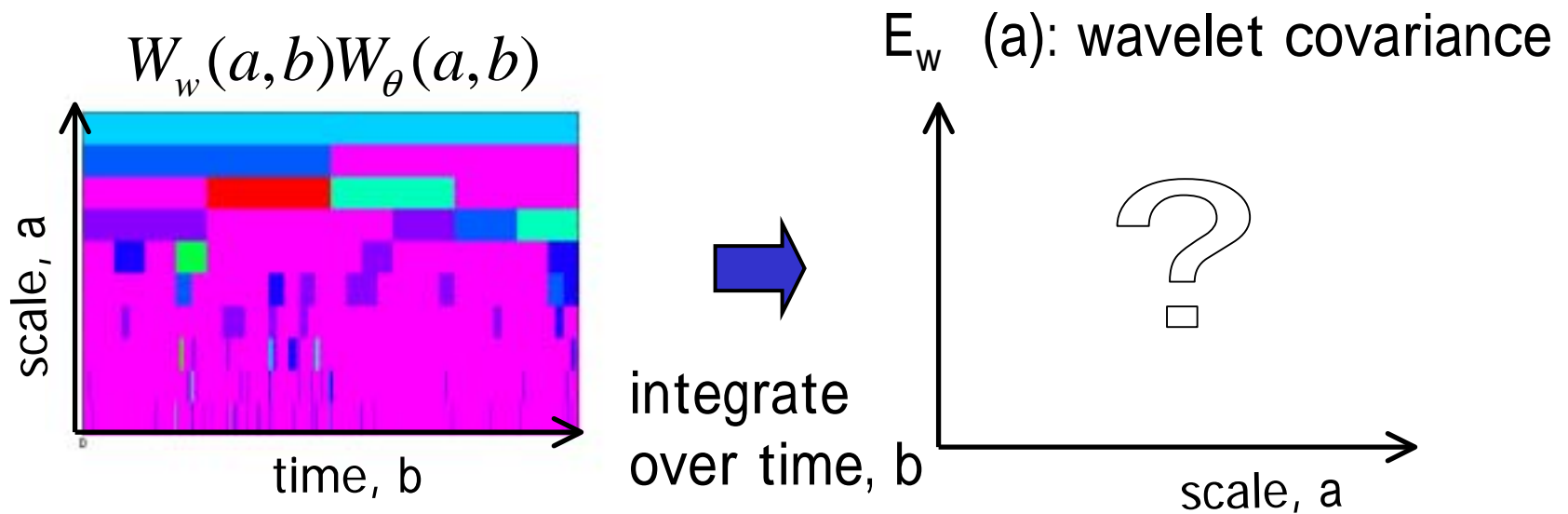


Time-scale diagram of the sensible heat flux (Run 4)



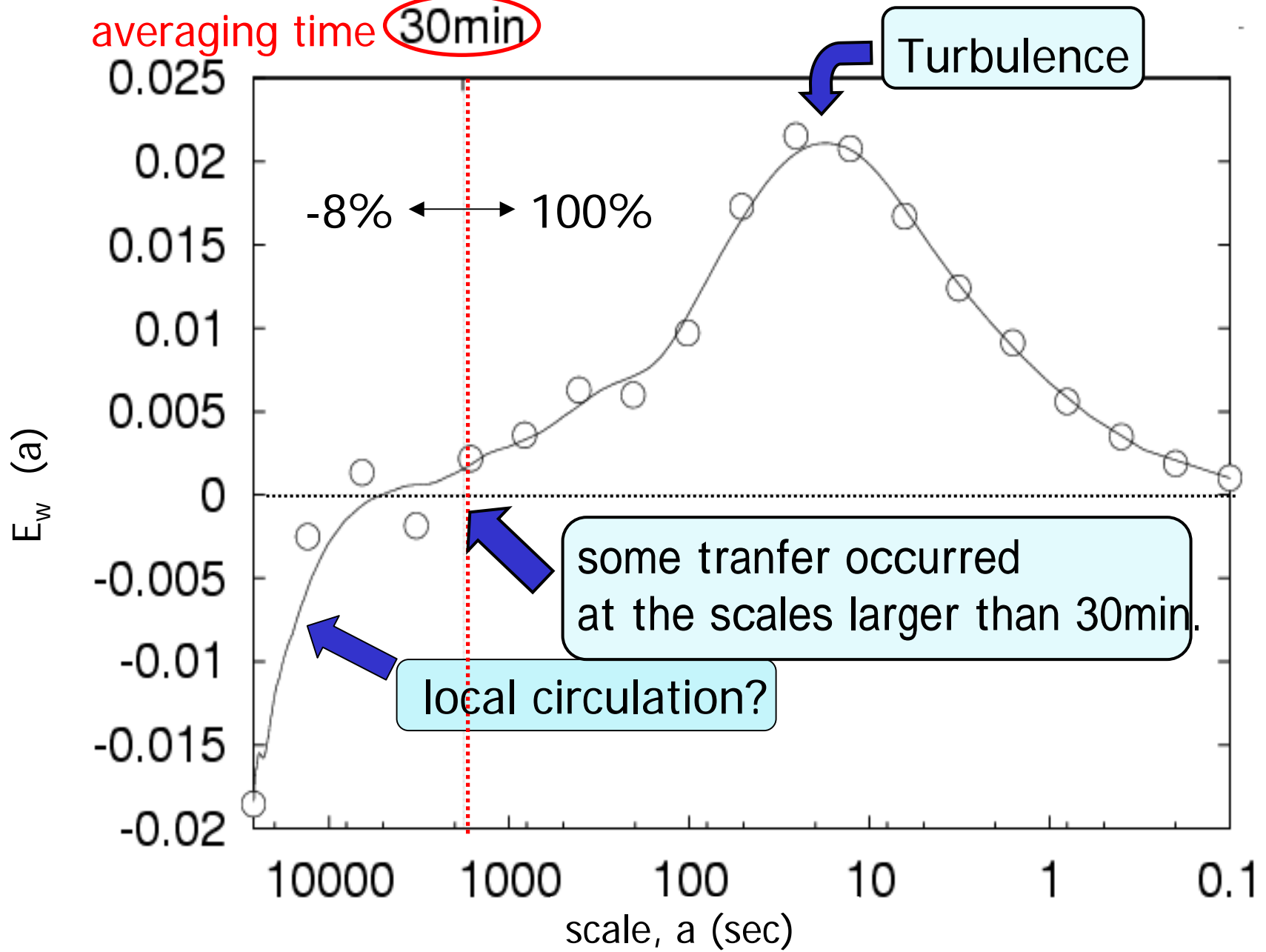
## Method of Analysis 2

- Wavelet covariance of heat fluxes

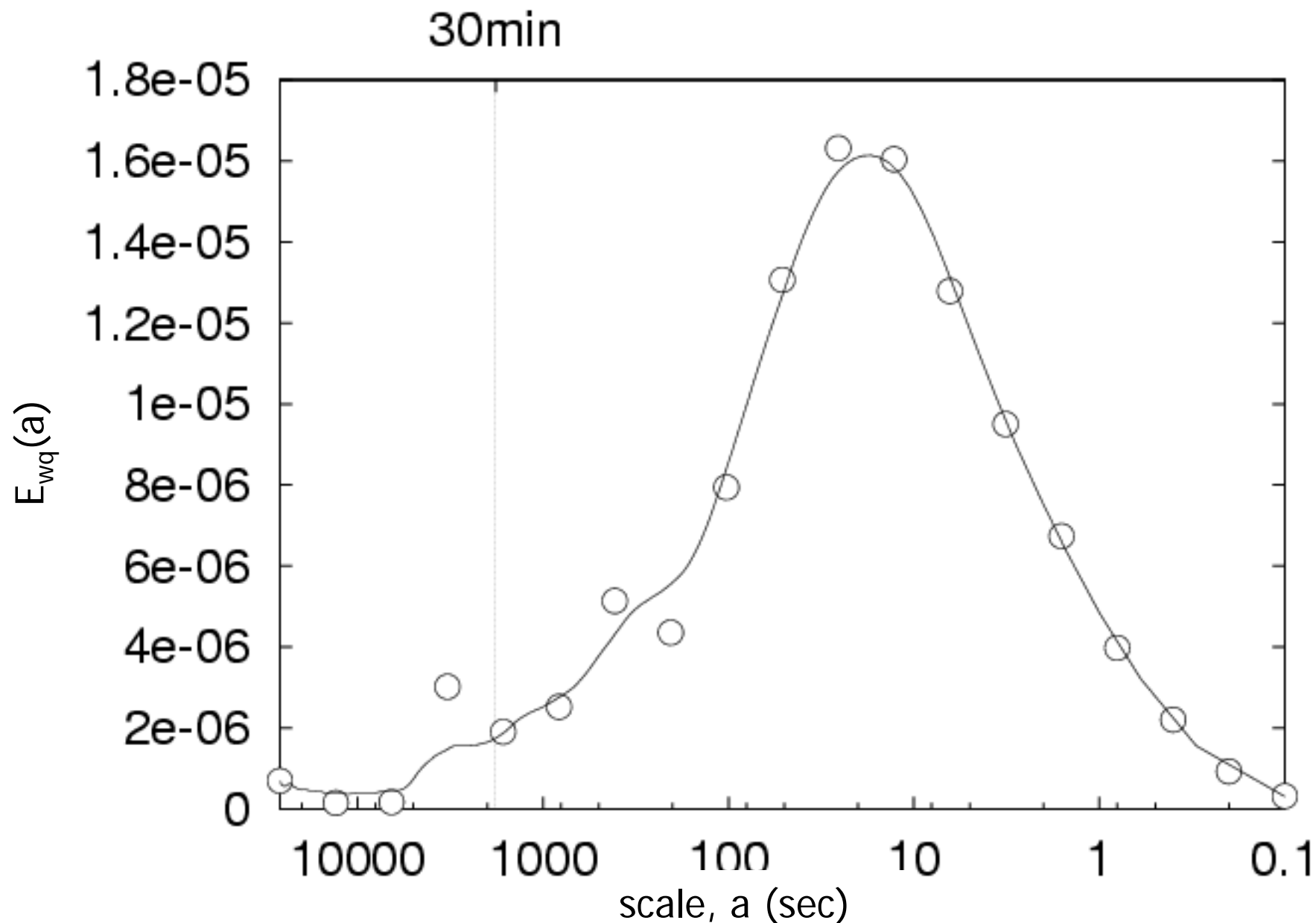


# Wavelet covariance of sensible heat flux (Run4)

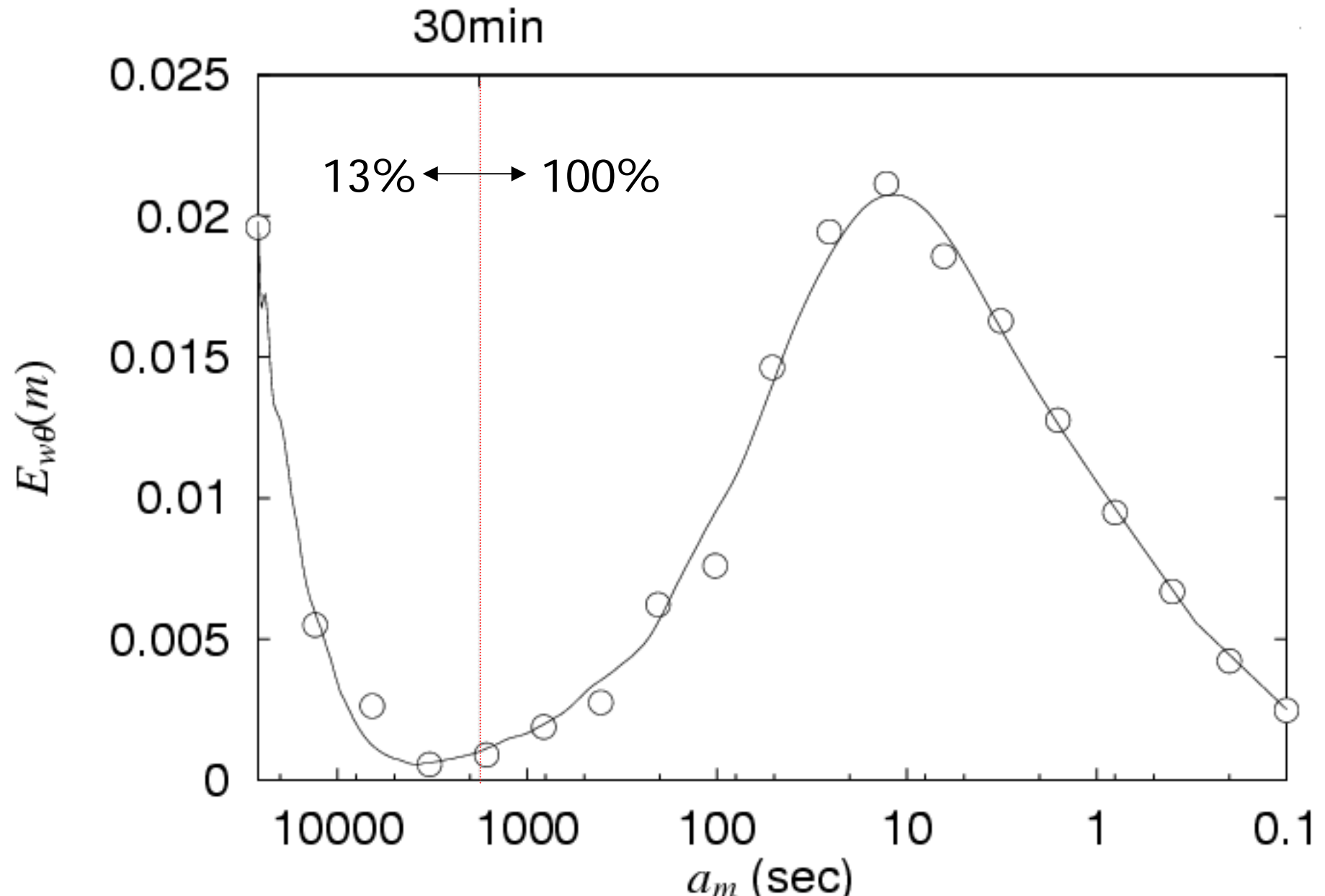
averaging time 30min

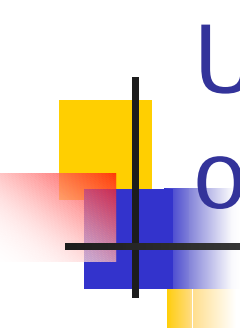


# Wavelet covariance of latent heat flux (Run4)



# Wavelet cospectrum of sensible heat flux (Run3)





# 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

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- Wavelet transform was successfully applied to the turbulence data acquired over Tibetan Plateau.
- There is a heat transfer at the scale larger than 2-3 hrs, which can be caused by mesoscale motions.
- There is a clear “scale gap” between the turbulence and mesoscale motions around 1-3 hrs.
- The heat transfer associated with the large scale motion can be a cause of “the imbalance problem”, but does not explain all of the imbalance.