Mobile Turbulence Measurements of Heat Fluxes over Tibetan Plateau

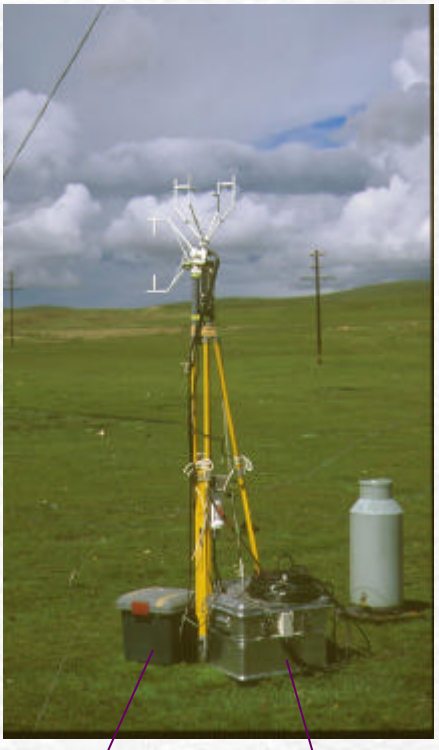
J. Asanuma — Terrestrial Environment Research Center, Tsukuba Univ.

H. Ishikawa — Disaster Prevention Research Institute, Kyoto Univ

I. Tamagawa — Civil Eng., Gifu Univ.,

And

GAME-Tibet Boundary Layer Group



battery loggers

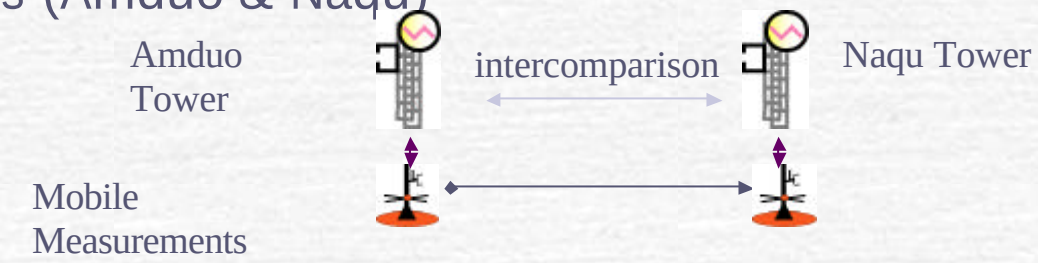
Kaijo SAT

AIR Humair

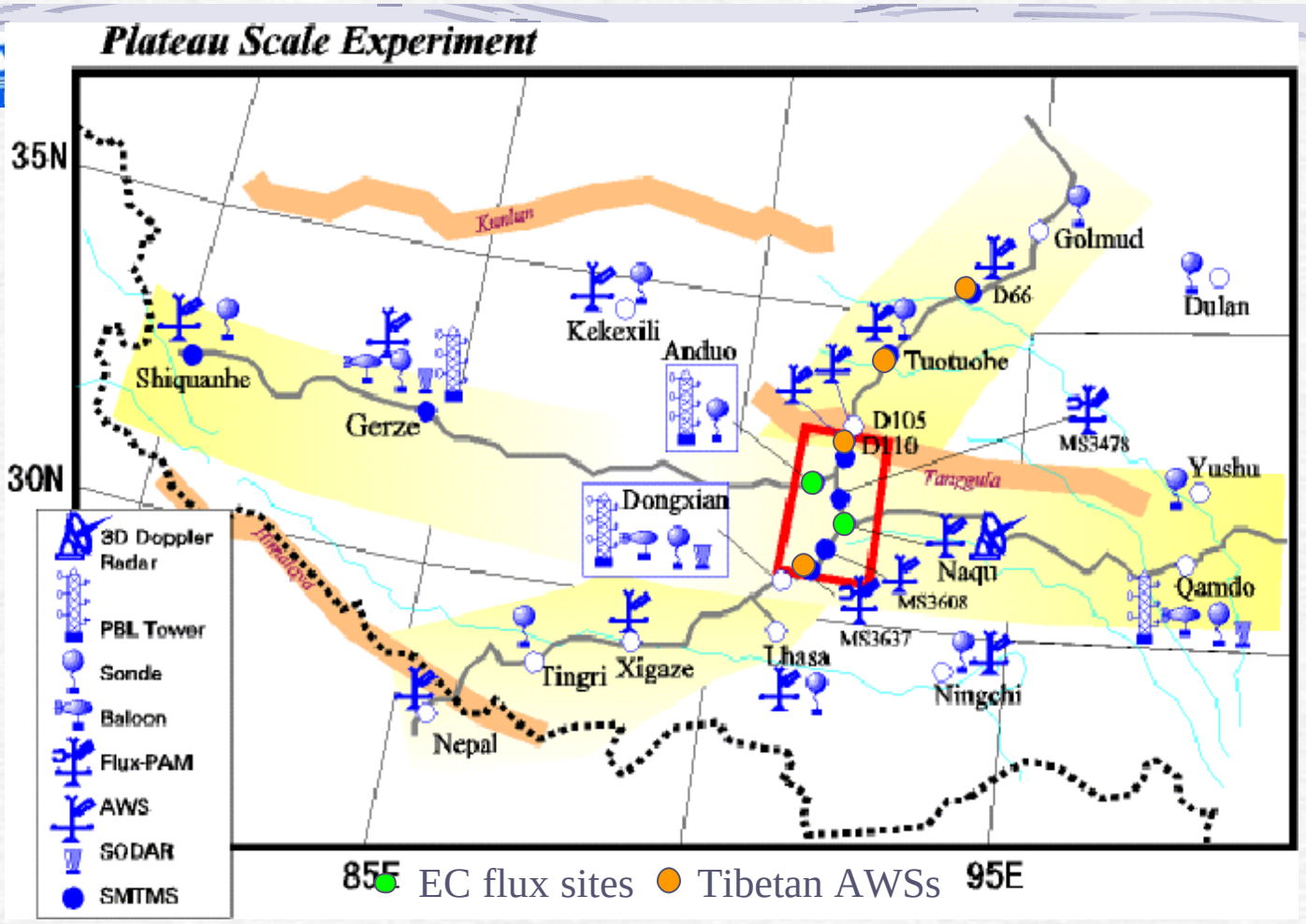
Vaisala Humicap

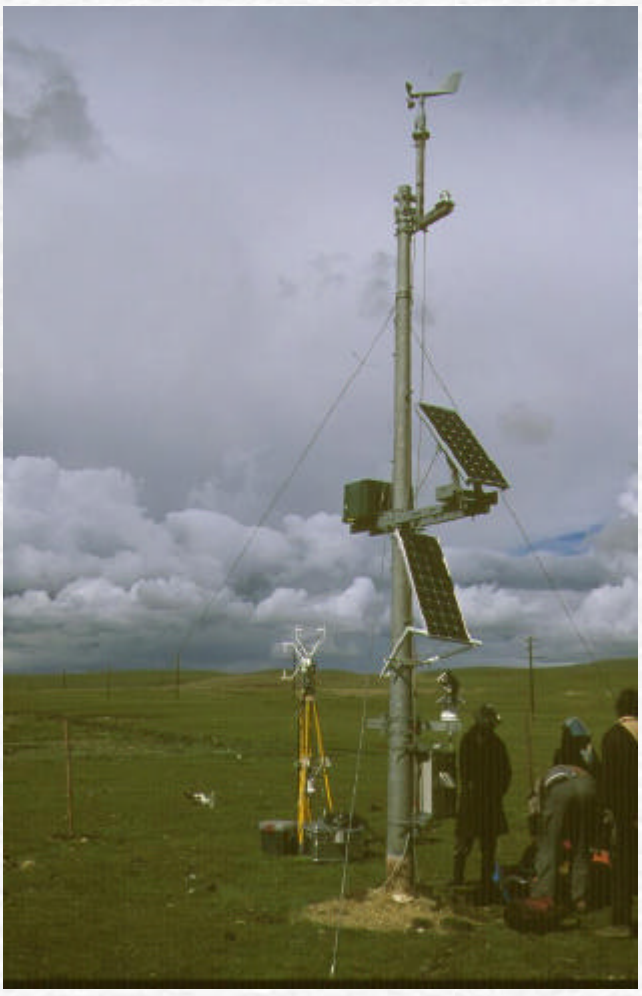
Mobile Turbulence Measurements

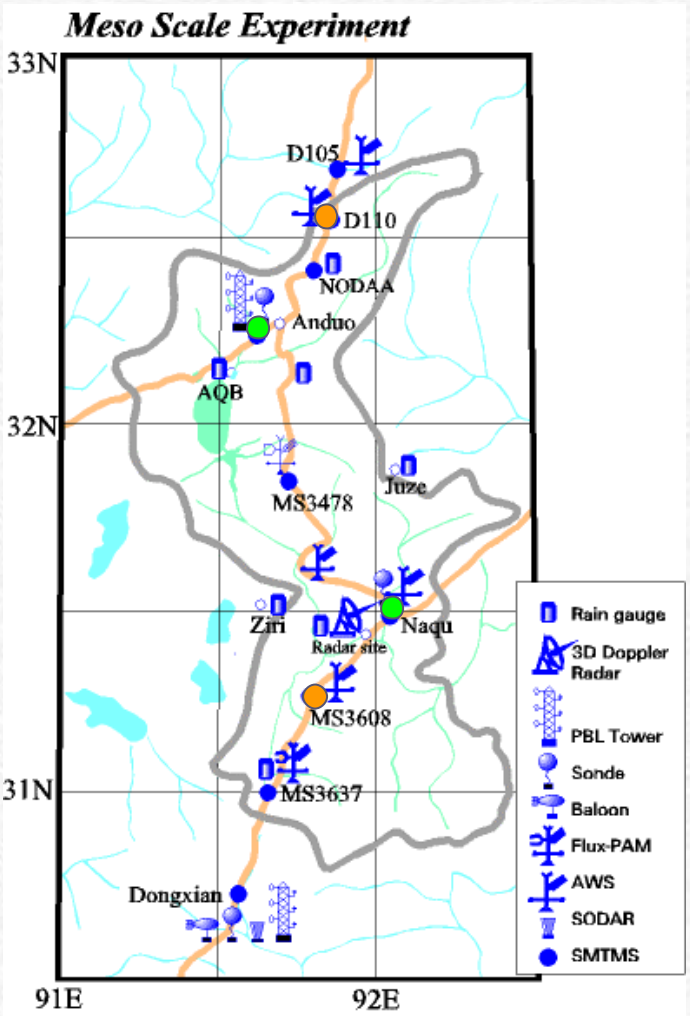
- Motivation
  - Tibetan-AWS (Automated Weather Station)
    - Objective: capture spatial heat flux distribution over the plateau
    - Sensors: T, q, u at one height and radiational Ts
    - need calibration of the bulk coeff. with reference flux values to estimate H and E
  - Many flux sites in GAME-Tibet region w/ different sensors
    - need intercomparison between them
- Objectives
  - Calibration of the AWSs to derive bulk coefficients
  - Work as a reference for the intercomparison of the two flux sites (Amduo & Naqu)



- Sensors deployed
  - 3D SAT (Kaijo)
  - Capacitive humidity sensors
    - Vaisala Humicap (slower but reliable)
      - Absolute value reference
    - AIR Humair (faster upto 10 Hz)
      - Fluctuation measurements
  - else
    - Tripods, special logger, large battery


Plateau Scale Experiment
35N
30N
85E
95E
Kunlun
Golmud
D66
Dulan
Kekexili
Anduo
Tuotuohe
Shiquanhe
Gerze
D105
D110
MS3478
Yushu
Tanggula
Dongxian
Naqu
MS3608
Qamdo
MS3637
Lhasa
Tingri
Xigaze
Ningchi
Nepal
3D Doppler Radar
PBL Tower
Sonde
Baloon
Flux-PAM
AWS
SODAR
SMTMS
EC flux sites
Tibetan AWSs




Meso Scale Experiment
33N
32N
31N
91E
92E
D105
D110
NODAA
Anduo
AQB
MS3478
Juze
Ziri
Radar site
Naqu
MS3608
MS3637
Dongxian
Rain gauge
3D Doppler Radar
PBL Tower
Sonde
Baloon
Flux-PAM
AWS
SODAR
SMTMS

Summary of Measurements

- Place and Periods
  - Amdo1: 05/23 11:50 - 05/24 06:50 19.0hrs
  - Amdo2: 07/31 14:50 - 08/02 13:50 45.8hrs
  - Naqu1: 08/05 17:10 - 08/06 10:40 16.6hrs
  - Naqu2: 08/08 11:40 - 08/09 16:00 27.6hrs
  - D110: 06/01 12:50 - 06/03 10:40 46.0hrs
  - MS3608:08/11 16:40 - 08/12 17:10 24.5hrs
  - Total 179.8hrs

(Time in BST)

Order of the Whole Analysis with AWSs

- Calculating H and E with the Mobile System
  - 1. Eddy correlation (EC) technique, H
  - 2. Bandpass Covariance Technique, E
- Comparison with the towers
- Calibration of AWSs
- Calculating H and E with AWSs

2. Bandpass Covariance (BC) Technique

- Principles
  - Covariance is divided into 3 frequency ranges

$$\overline{w'q'} = \overline{w'q'}_{lp} + \overline{w'q'}_{bp} + \overline{w'q'}_{hp}$$

    such that
    - hp: humidity sensor cannot capture the actual fluctuation
    - bp: humidity sensor capture the actual fluctuation and the similarity between q and T hols, so that

$$\frac{\overline{w'q'}_{bp}}{\overline{w'q'}_{bp}} = \frac{\overline{w'q'}_{hp}}{\overline{w'q'}_{hp}}$$

  - Then, the defected covariance can be compensated as

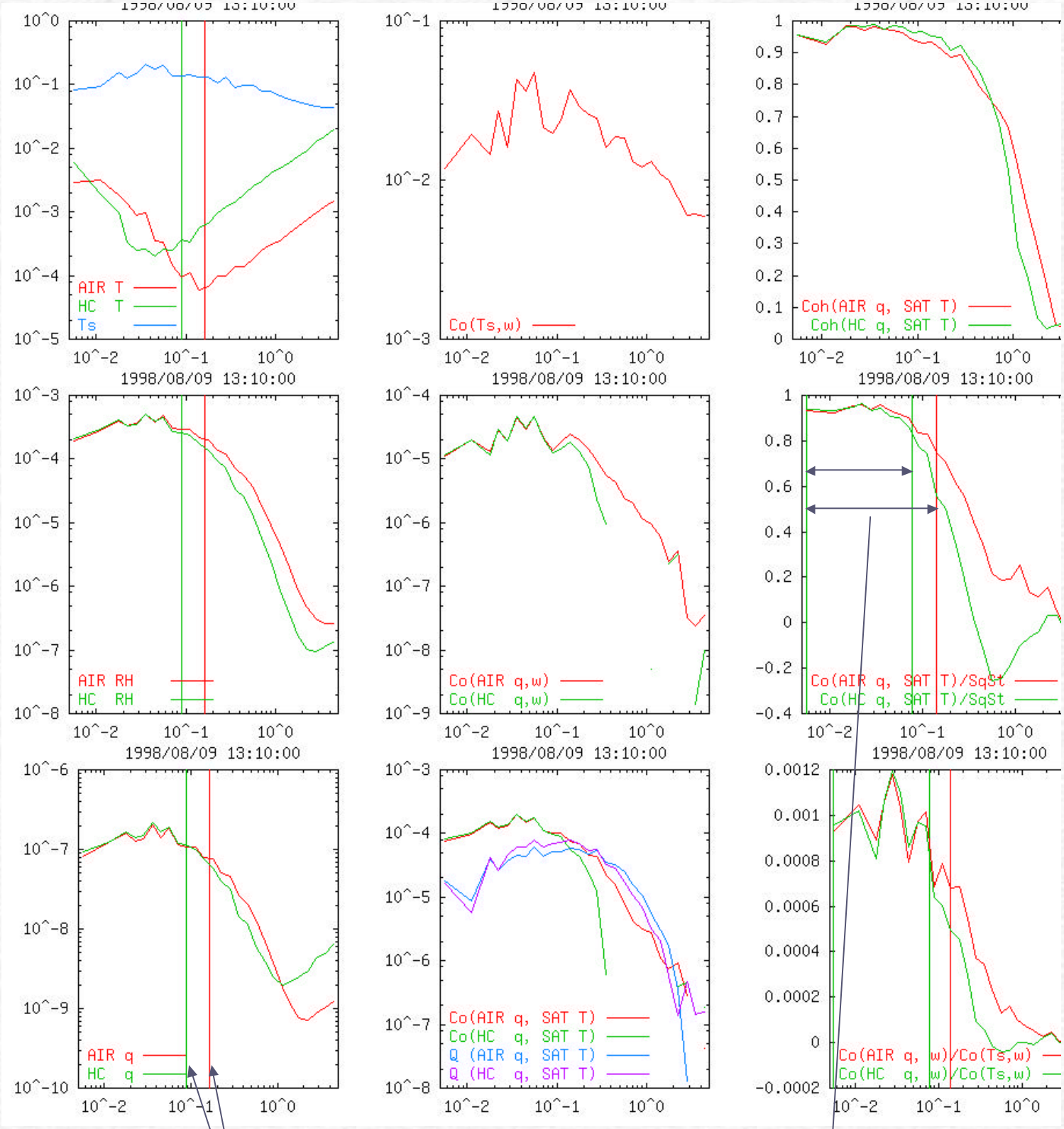
$$\overline{w'q'} = \overline{w'q'}_{lp} + \overline{w'q'}_{bp}\left(1 + \frac{\overline{w'q'}_{hp}}{\overline{w'q'}_{bp}}\right)$$

- Implementation
  - Bandpass Covariance with both of HumAIR and Humicap
  - Frequency range determination for bp
    - bp frequency range does not contain significant noise.
      - "noise separation frequency" can be identified in the "fS(f)-f" plot of T and q spectrum.
    - Similarity between T and q holds in bp frequency range

$$\frac{Co_{tq}(f)}{\sqrt{S_t(f)S_q(f)}} \geq 0.8$$

Example of spectrum and cospectrum

ectrum, cospectrum x f



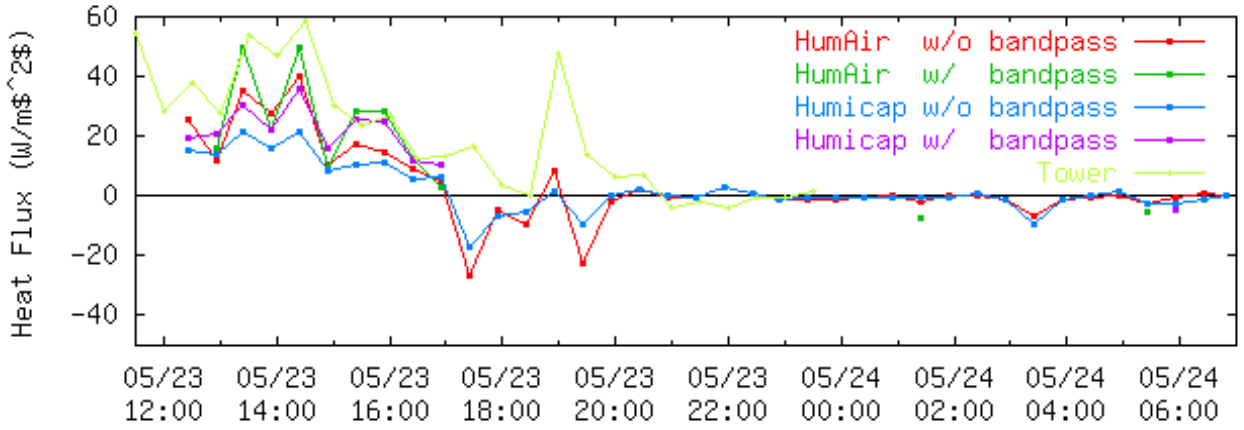
Frequenc y

Noise separation frequency

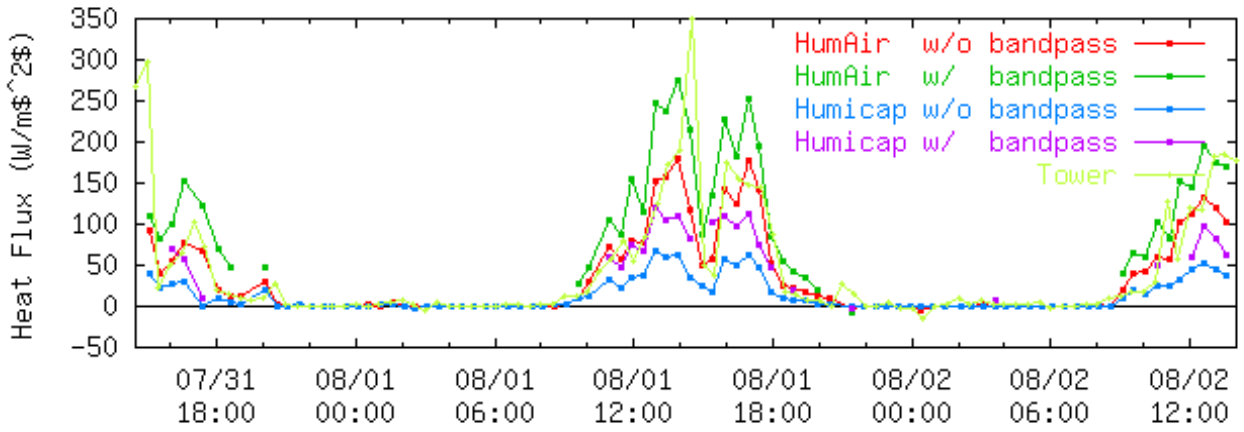
Similarity range

Result of BC technique

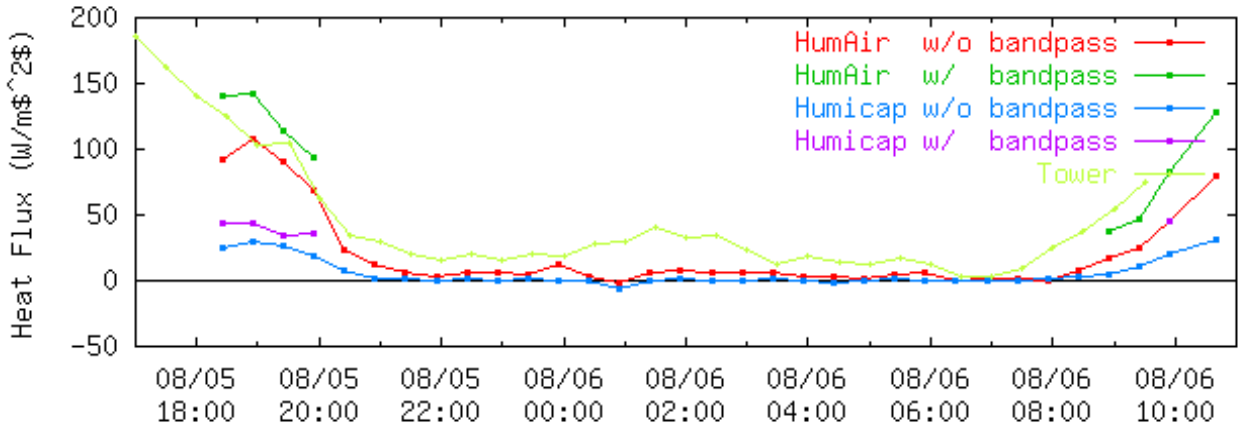
Amdo1



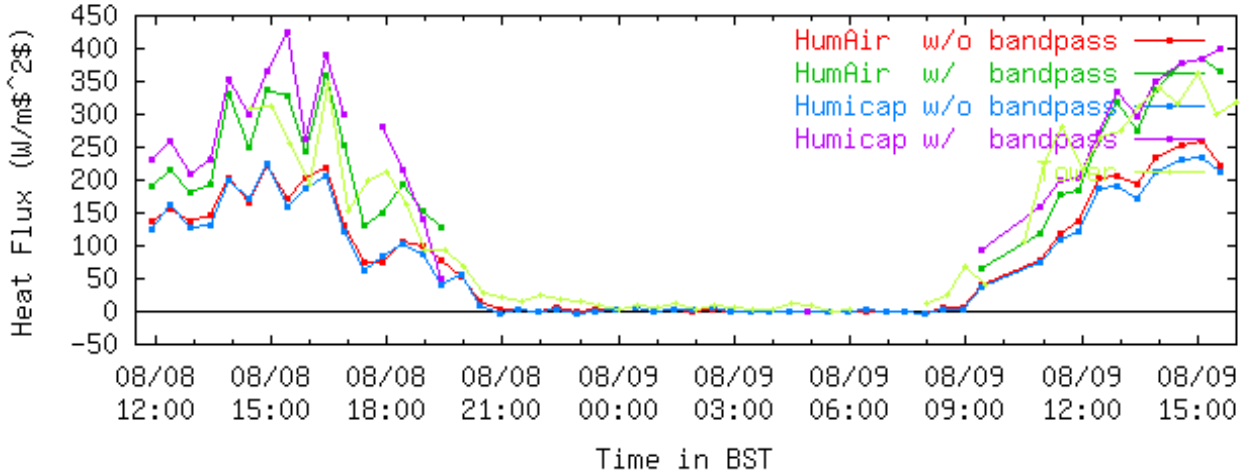
Amdo2



Naqu1

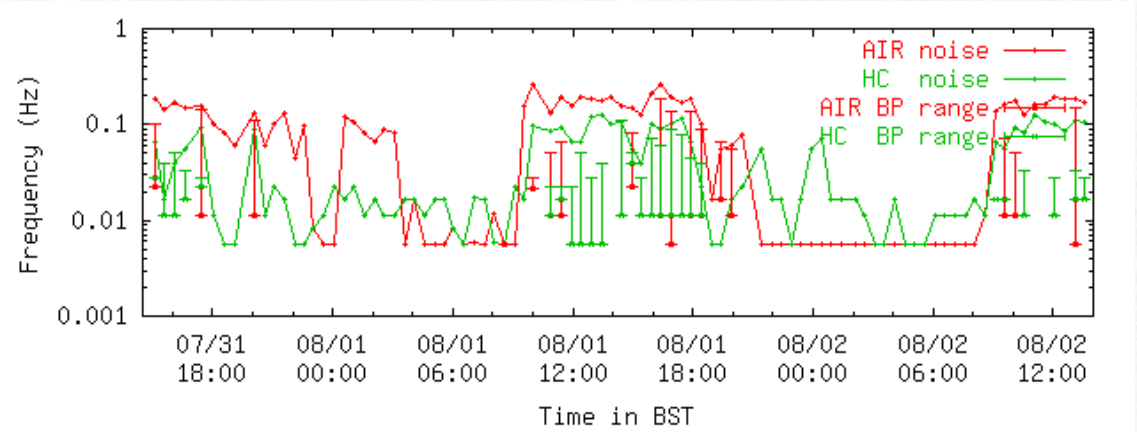


Naqu2

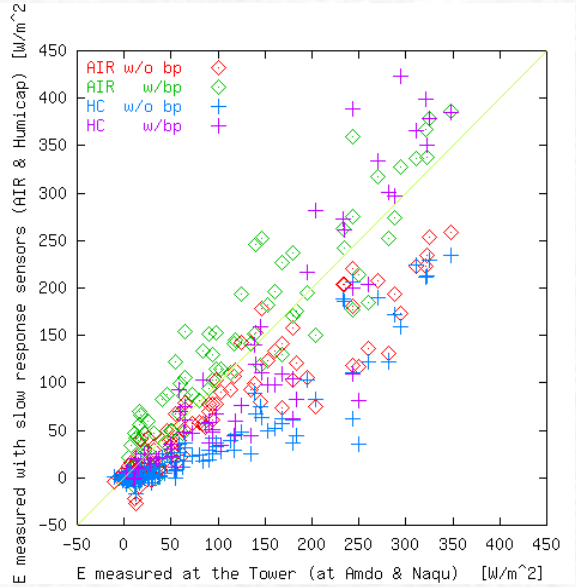


Evaluation of BC technique

Bandpass frequency range



Comparison with Towers



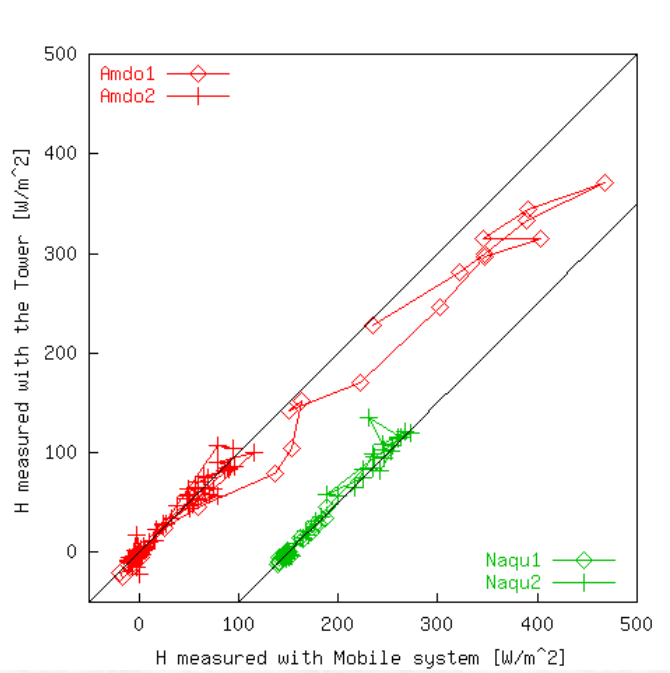
Summary

- Both of the slow response humidity sensor, HumAIR and Humicap, are capable of measuring humidity fluctuations that is enough when used in the BC technique for the latent heat flux.
- In spite of their different frequency response, the latent heat flux values estimated through the BC technique are almost equivalent.
- Some overestimations in BC technique are found, and is under investigation.
- Objective method to determine the bandpass range is necessary.

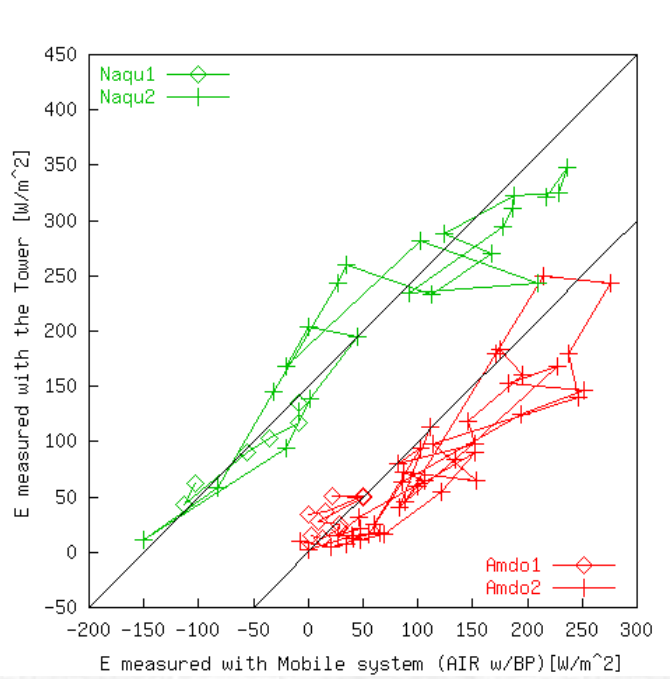
Intercomparison between Towers

- Intercomparison between the Tower fluxes are possible through the mobile measurements.

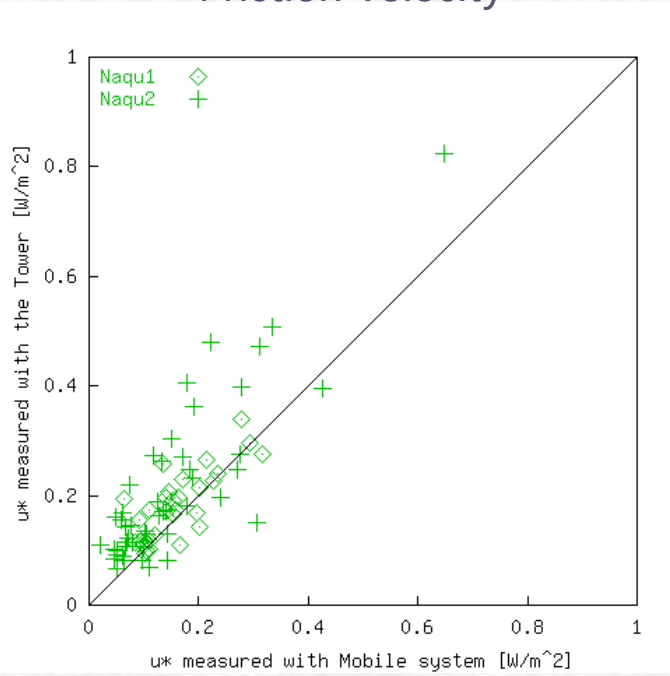
Sensible heat flux



Latent heat flux



Friction velocity



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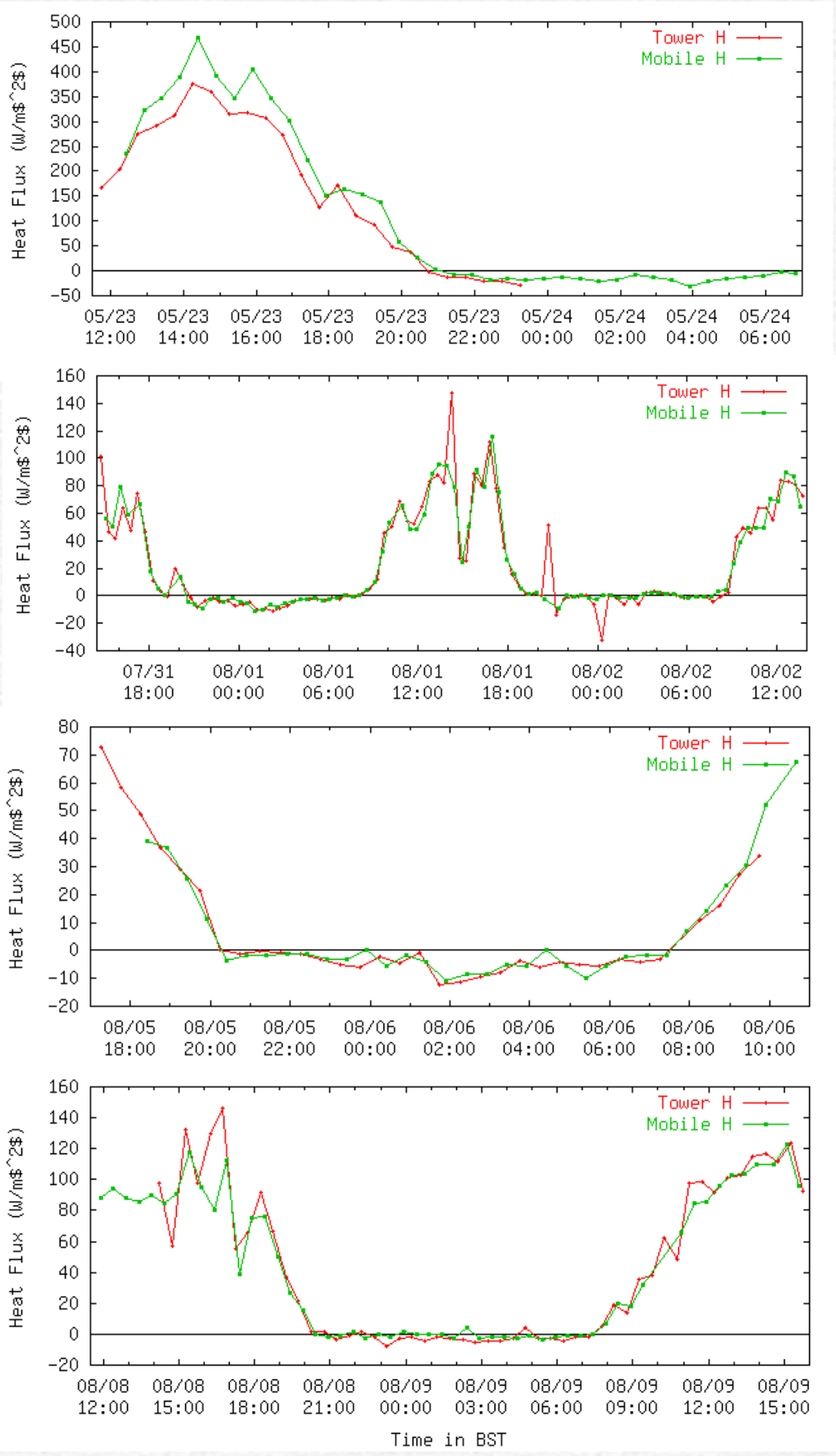
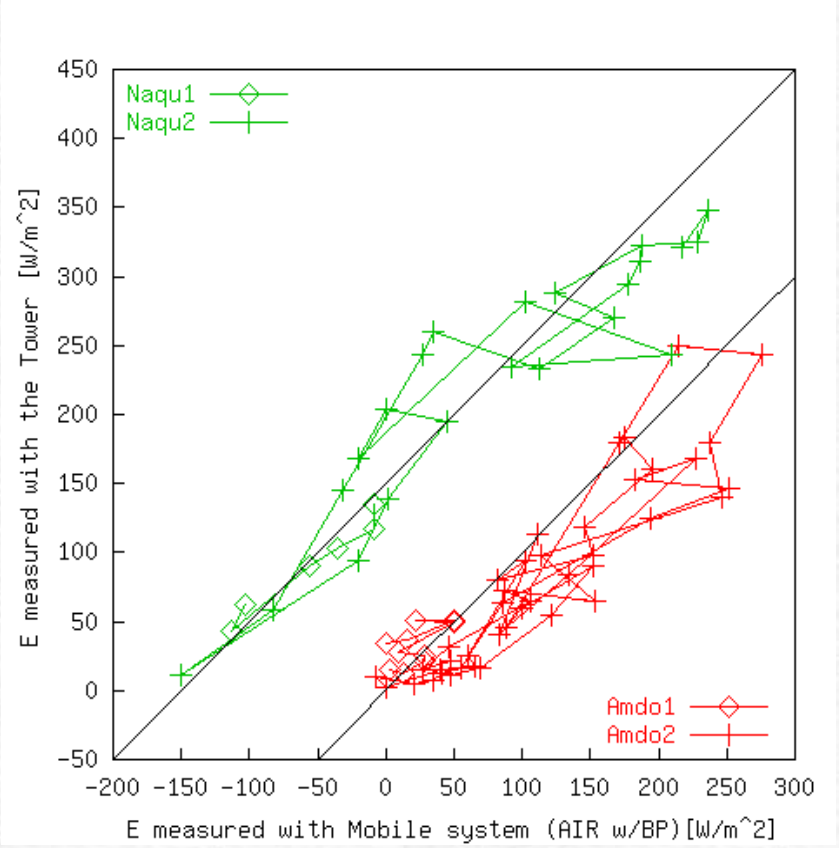
1.Eddy Correlation comparison with Tower Measurements



Evaluation of the BC criteria

$$\frac{Co_{tq}(f)}{\sqrt{S_t(f)S_q(f)}} \geq 0.8$$



$$\frac{Co_{tq}(f)}{\sqrt{S_t(f)S_q(f)}} \geq 0.9$$