Innovative Remote Sensing: Flood Monitoring using GNSS Reflectometry

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- WP within the WISDOM project
- Experimental Setup
- Data Analysis
- Latest Results
- Conclusion and Outlook

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WP within the WISDOM Project:

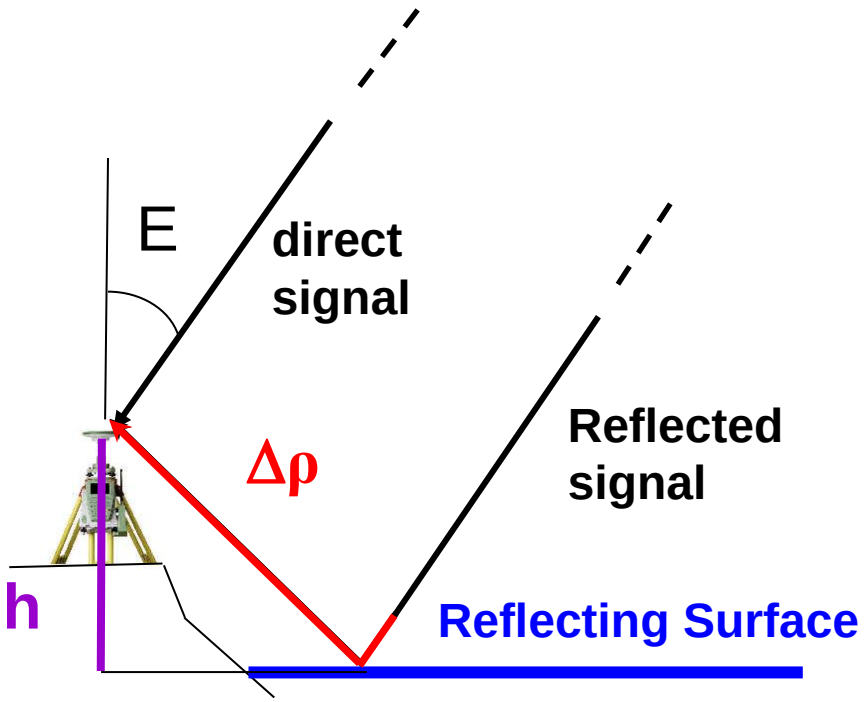
- Severe changes could be observed in the Mekong Delta:
  - extreme flood events
  - important to monitor coastal area with dense population

- Test the possibility of using low elevation GNSS-Reflectometry for flood monitoring of the Mekong Delta

- Develop and implement algorithms to process GPS signals into water levels

GNSS Reflectometry Principle:

- GNSS signals scatter off the reflecting surface
  - information on the reflecting surface
- The reflected signal has to travel a longer path w.r.t. to the direct signal
  - Relative time delay Δt
    - Incoherent GNSS-R
  - Phase offset Δϕ
    - Coherent GNSS-R



GNSS Reflectometry Principle:

- Main advantages of GNSS:
  - Large and increasing number of available GNSS signals
  - Signals for civilian use without fee
  - High quality signals: dual frequency, long-term availability and stability
  - Inexpensive: passive system
  - Dense global coverage

- Multiple simultaneous measurements with high temporal and spatial resolution

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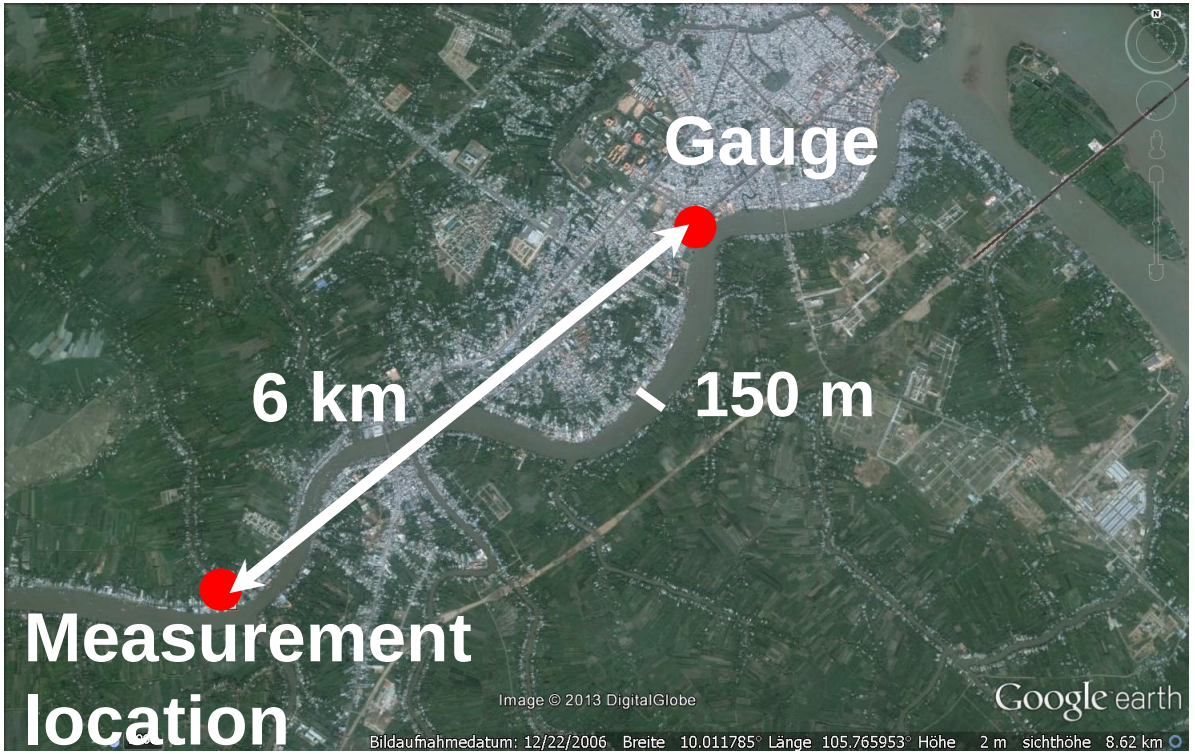
Experimental setup:

www.online-reisefuehrer.com



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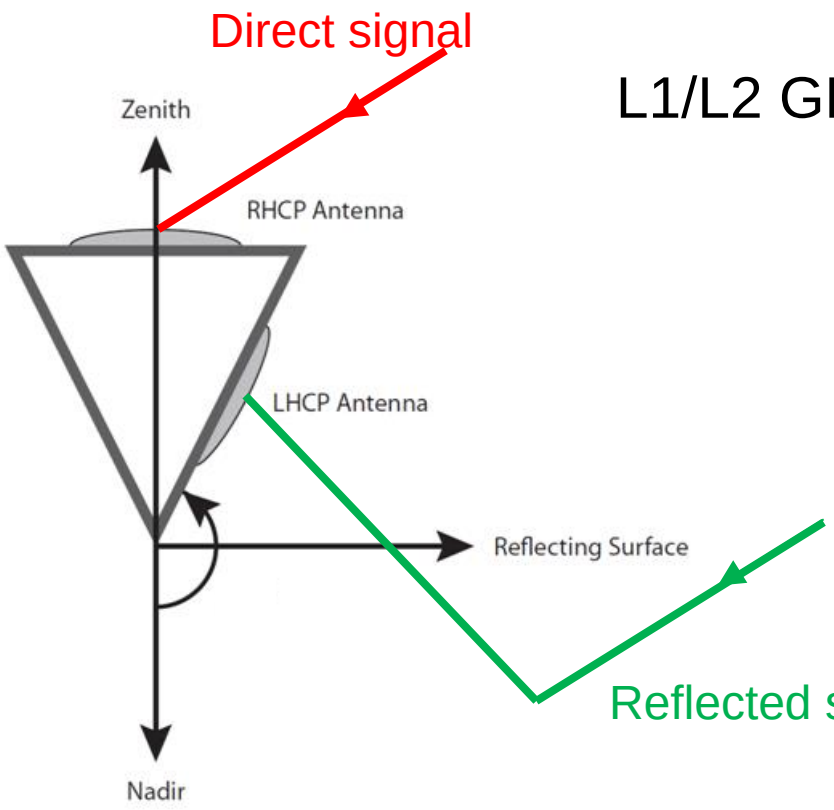
Experimental setup:

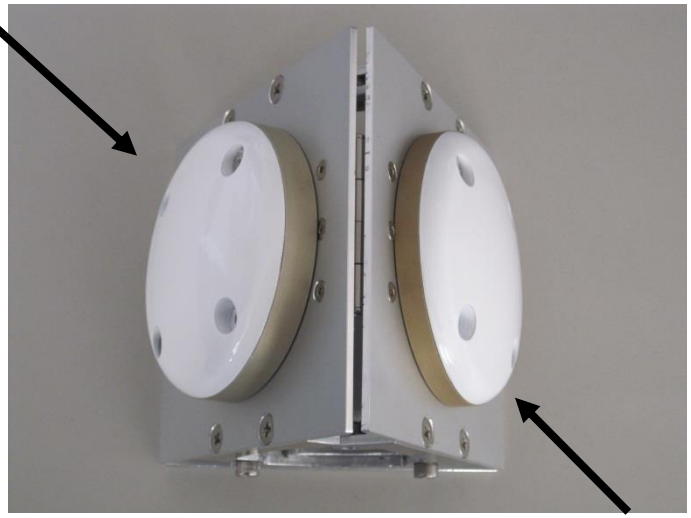
- Two time series with two different antenna heights above the reflecting surface:
  - Terrace with ~10 m
  - Roof with ~20 m

Experimental setup:

- Two antennas (Antcom):
  - RHCP oriented to the zenith (direct signal)
  - LHCP tilted to the reflecting surface (reflected signal)



L1/L2 GPS RHCP



RHCP/ LHCP
L1/L2 GPS

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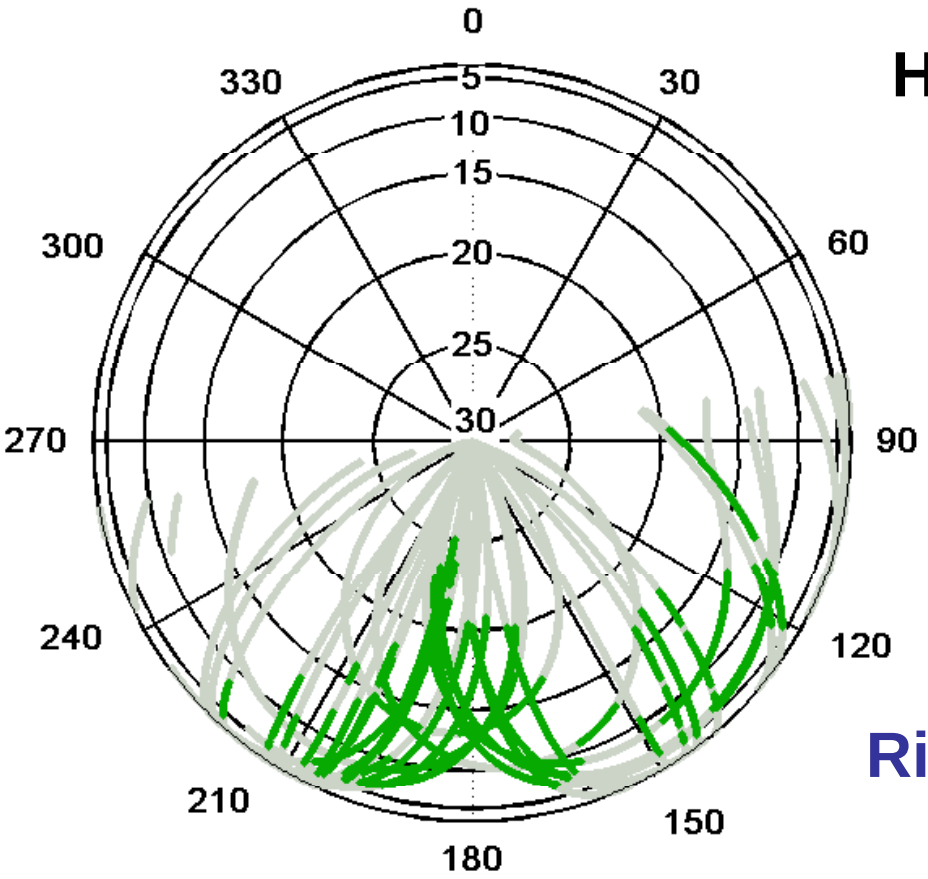
Data Analysis:

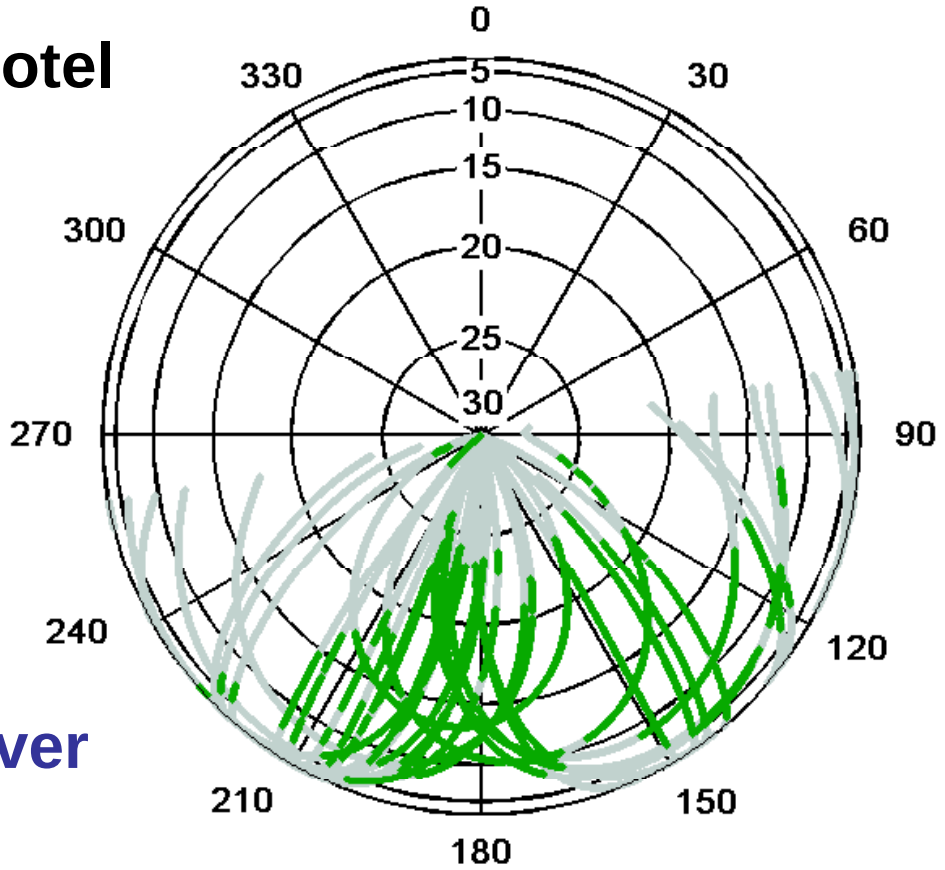
- Incoherent Observations
- Coherent Observations



Terrace (~10 m)

Hotel

River



Roof (~20 m)

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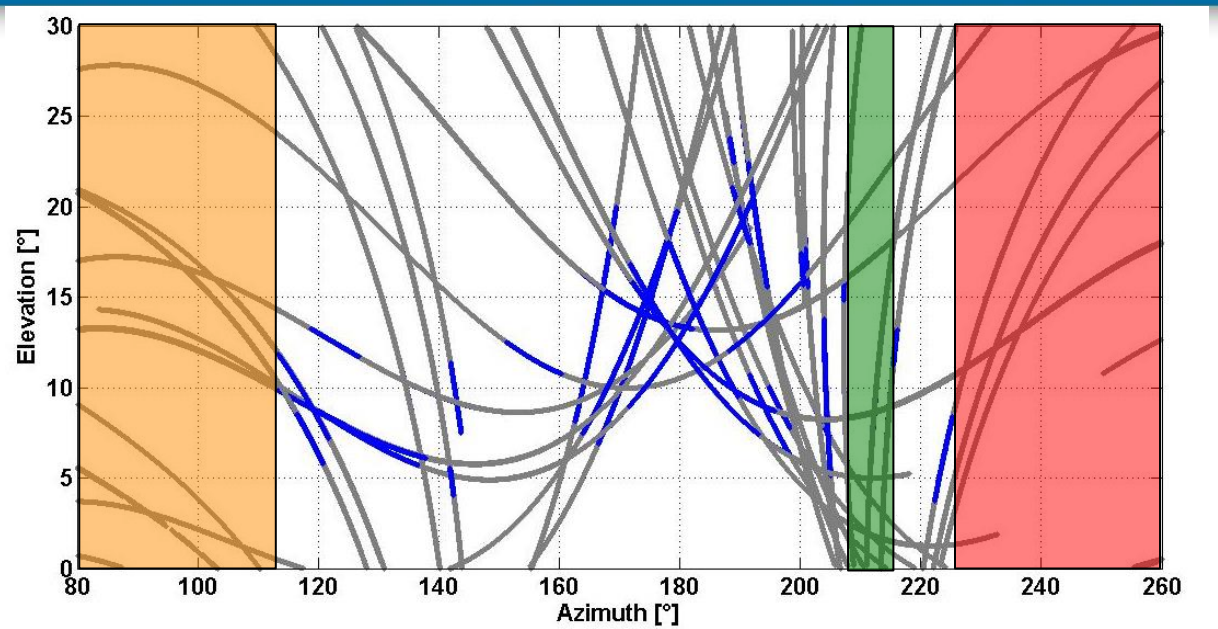
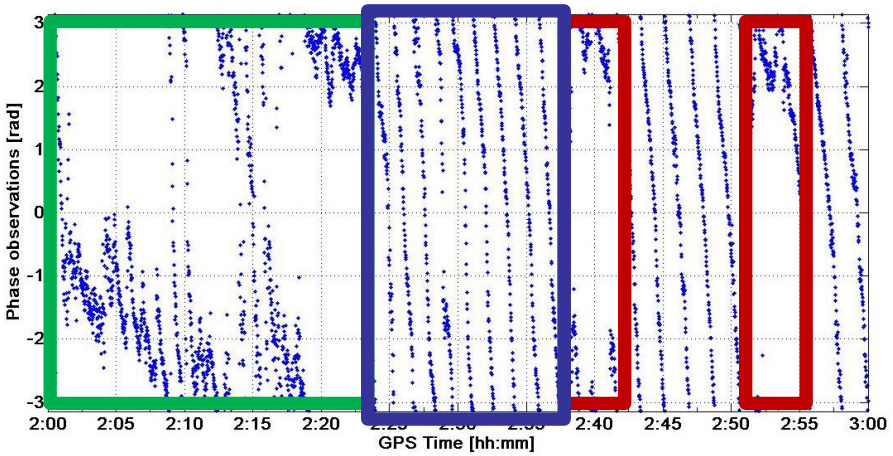
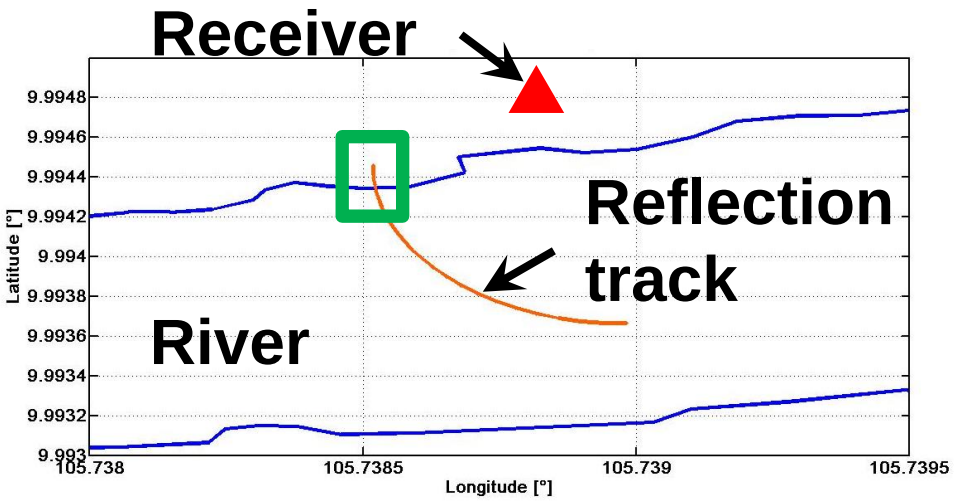
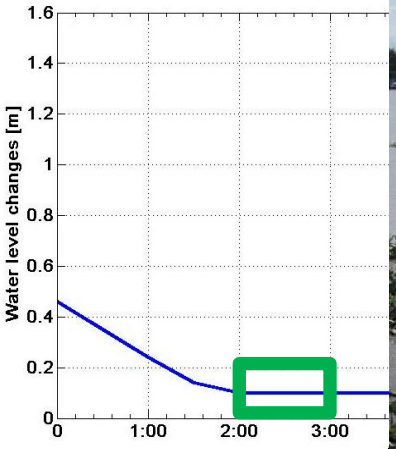
Data Analysis:



Data Analysis:







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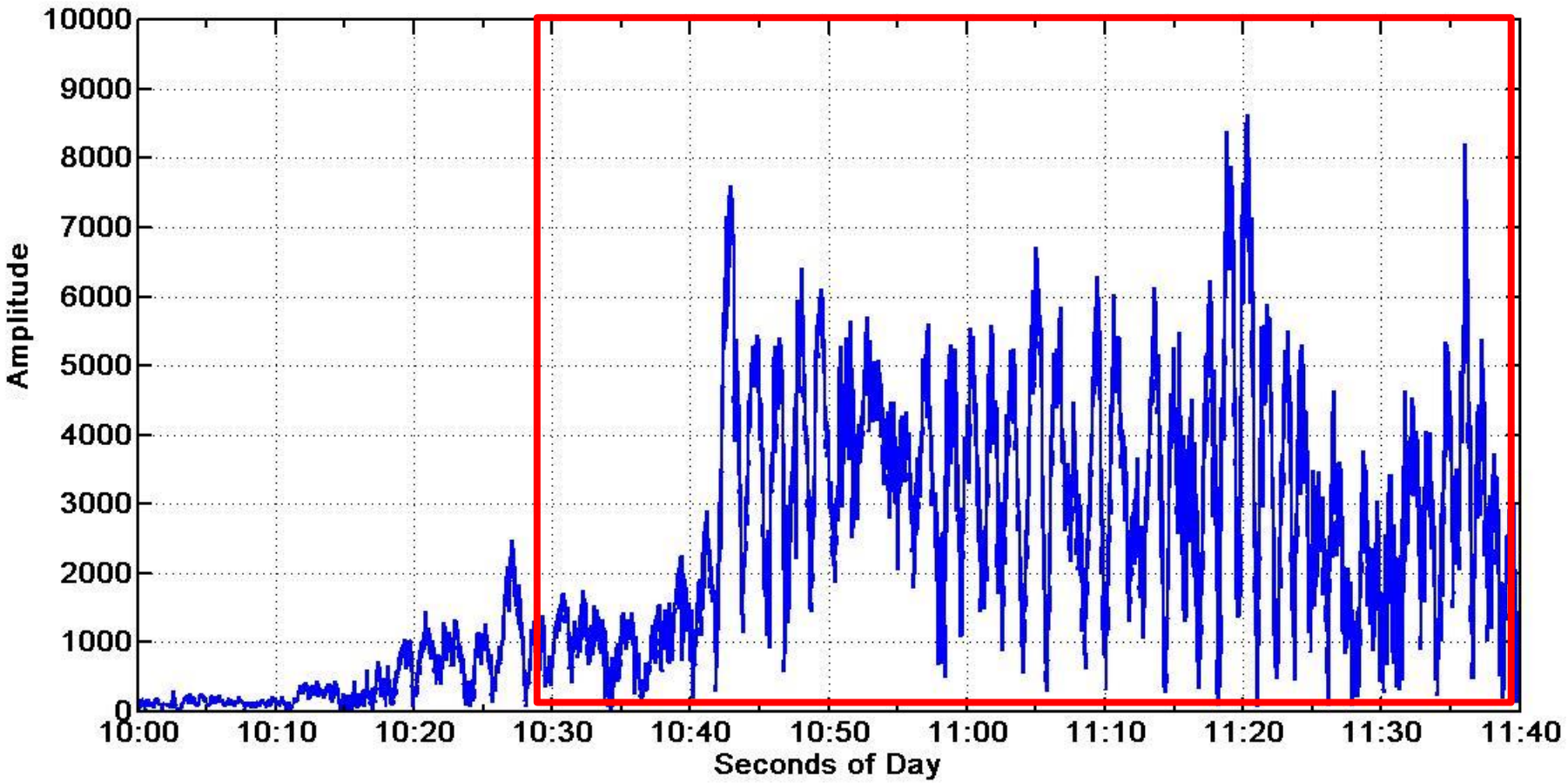
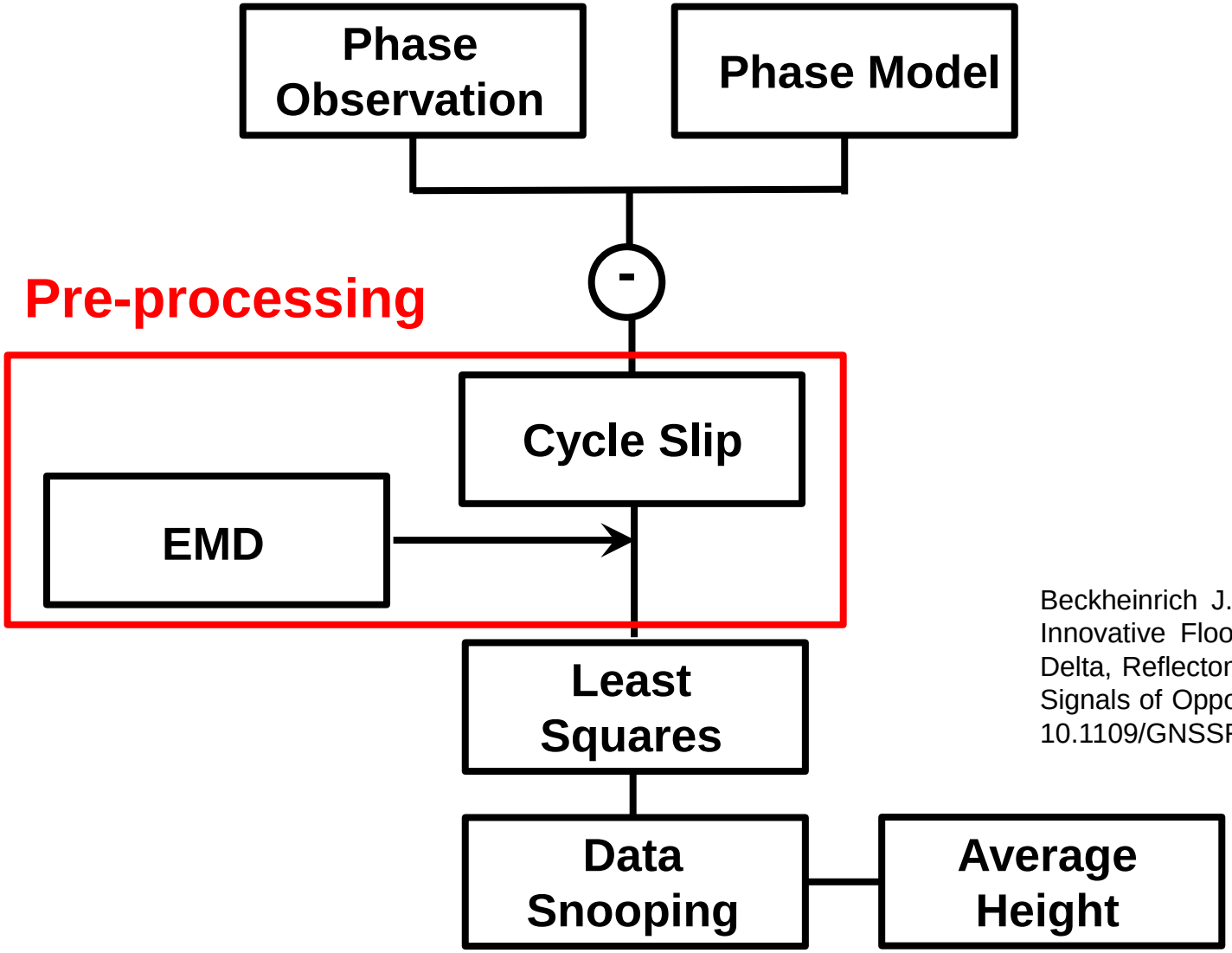


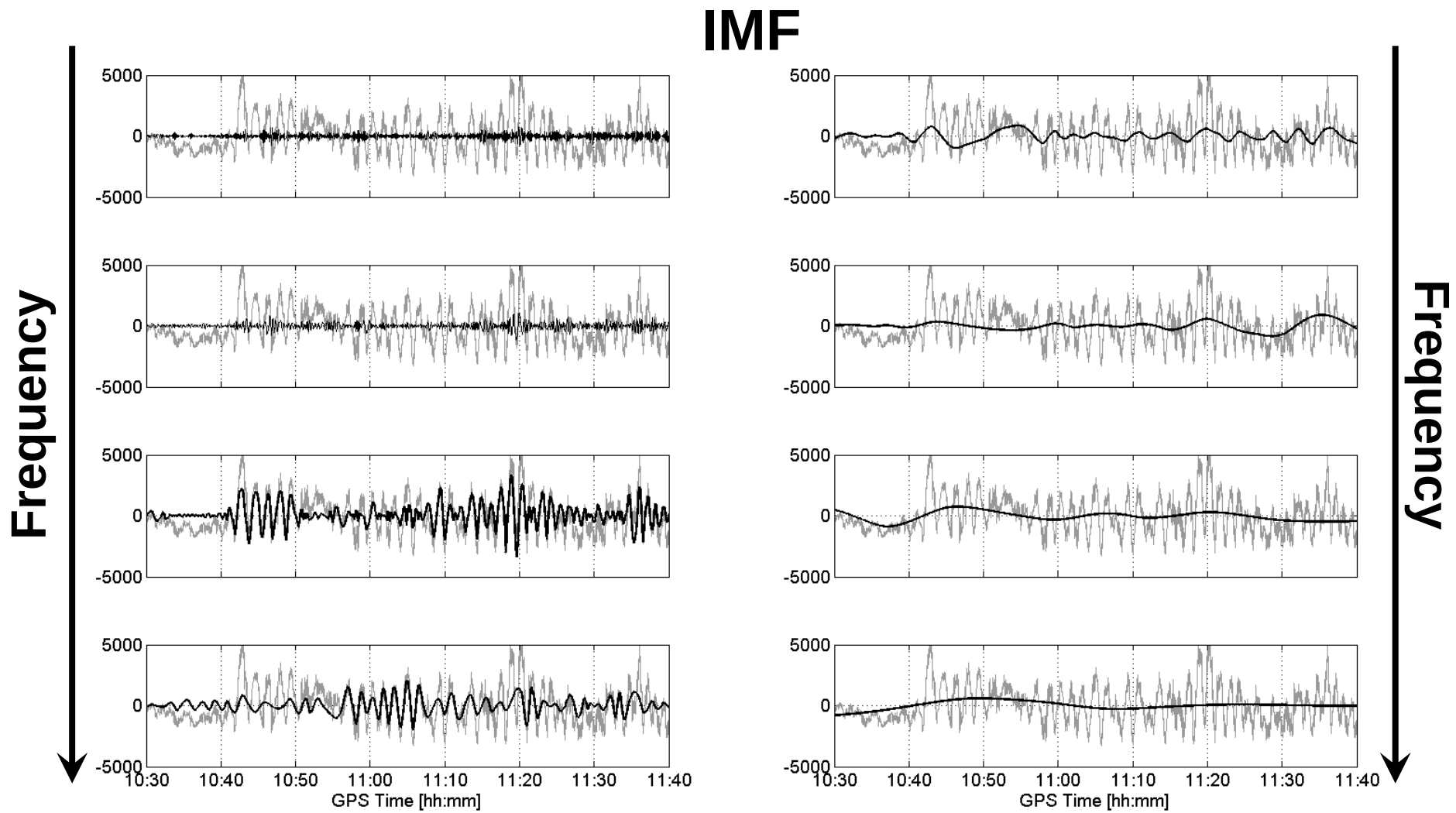


Beckheinrich J. et al, GNSS Reflectometry: Innovative Flood Monitoring at the Mekong Delta, Reflectometry Using GNSS and Other Signals of Opportunity (GNSS+R), 2012, doi: 10.1109/GNSSR.2012.6408257

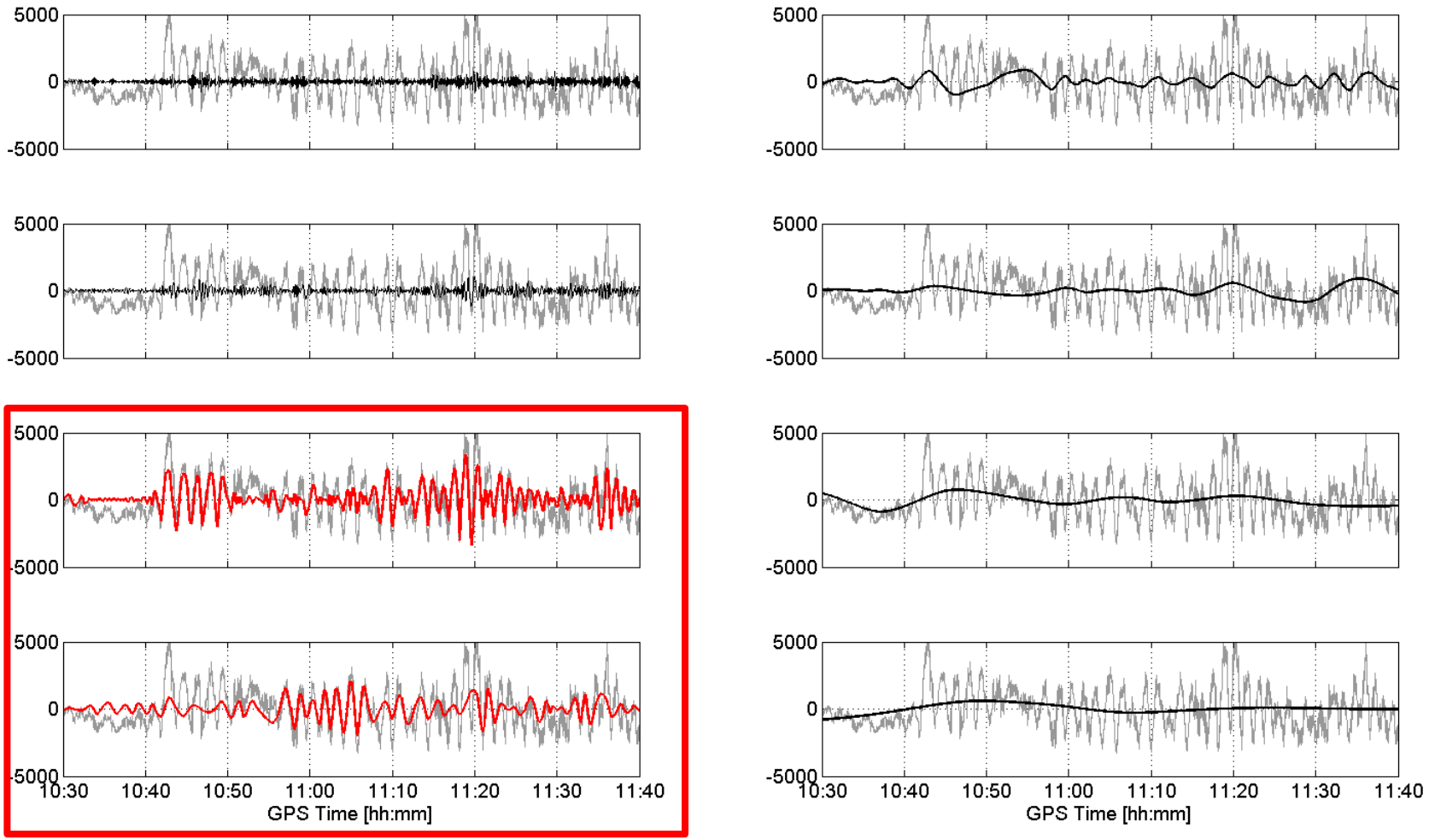
Data Analysis:

- Empirical Mode Decomposition (EMD)
  - 1998 Huang et al. [1]
  - 2013 Hirrle et al. [2]
- Motivation:
  - EMD is a fully data-driven signal analysis
  - No need of an a priori base
- Idea:
  - Signal superposition of amplitude and frequency modulated subsignals
  - Subsignals determined by shifting process

Data Analysis:



Data Analysis:



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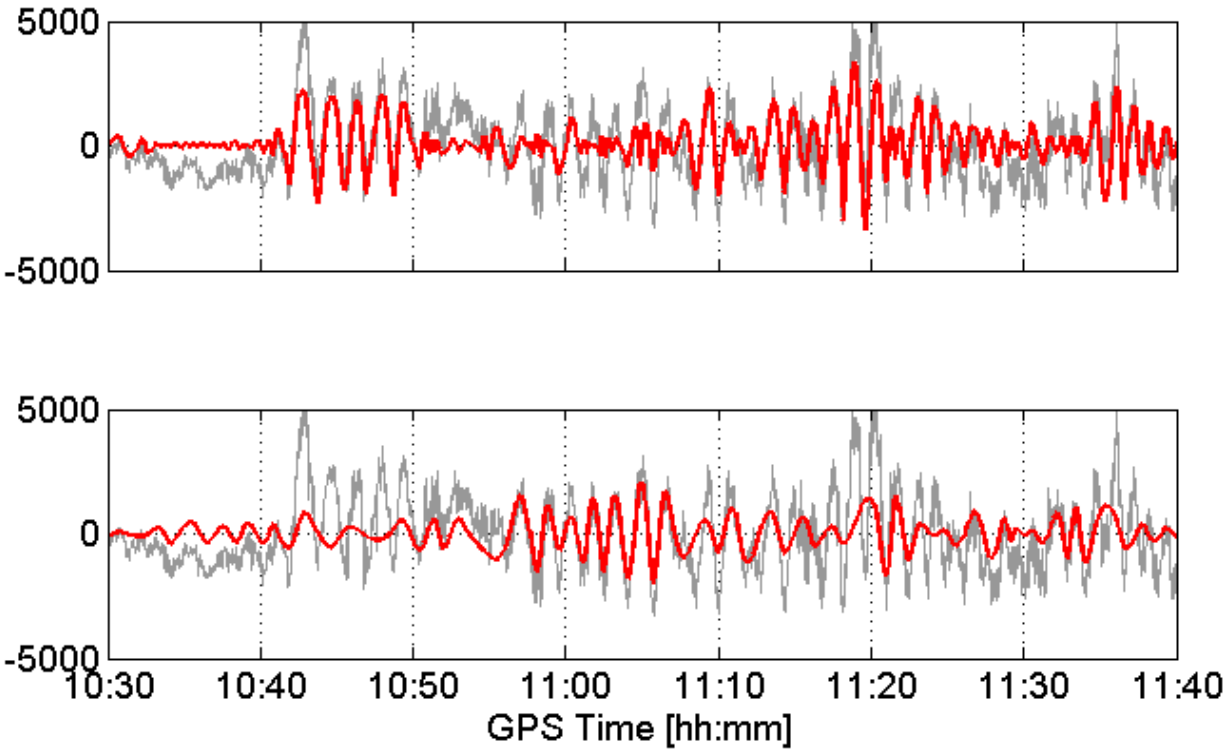

Subsignals representing reflections on water surface

Hirrle A. et al., *Estimation of Multipath Parameters using Hilbert Huang Transform*, ION GNSS, Nashville, Tennessee, USA, 2012

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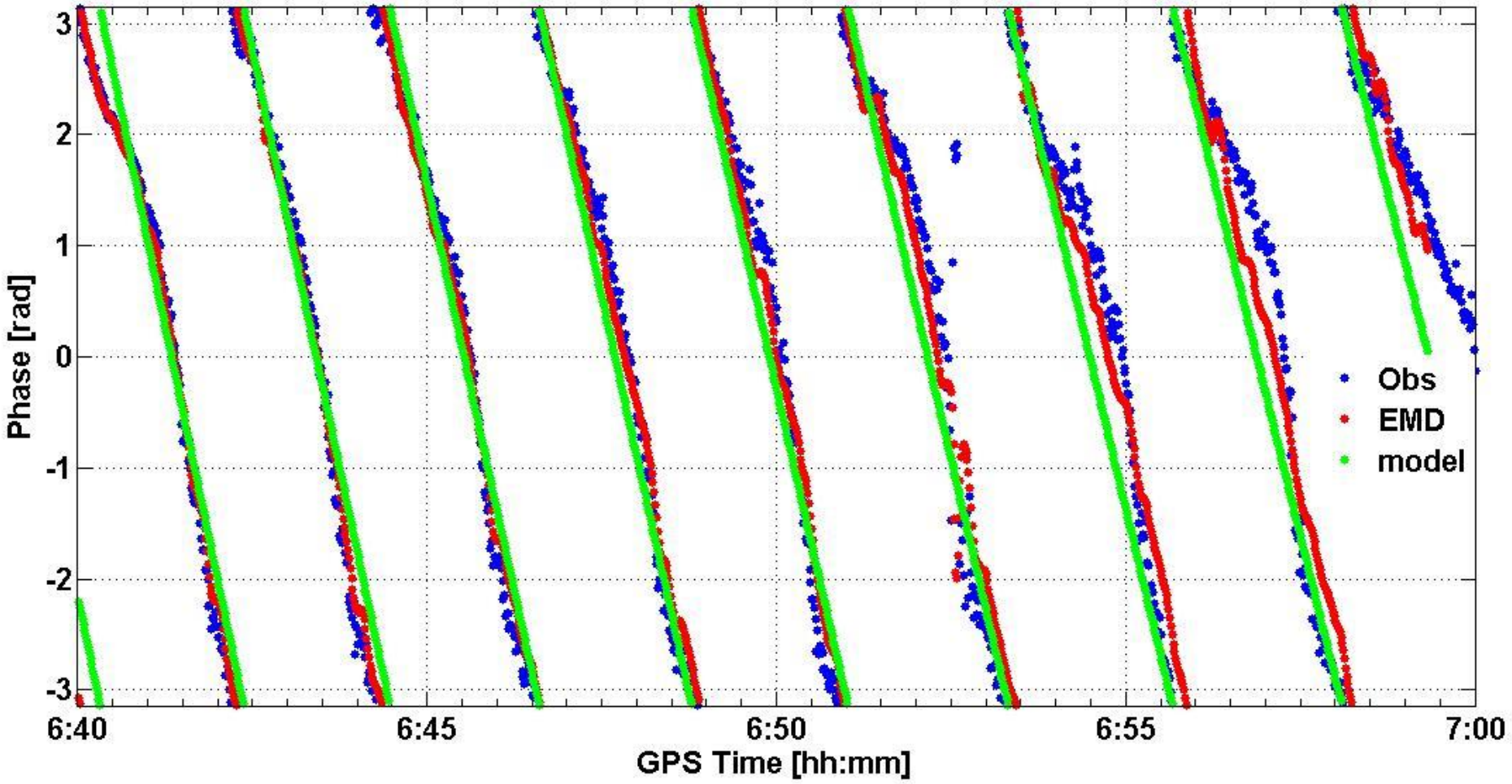
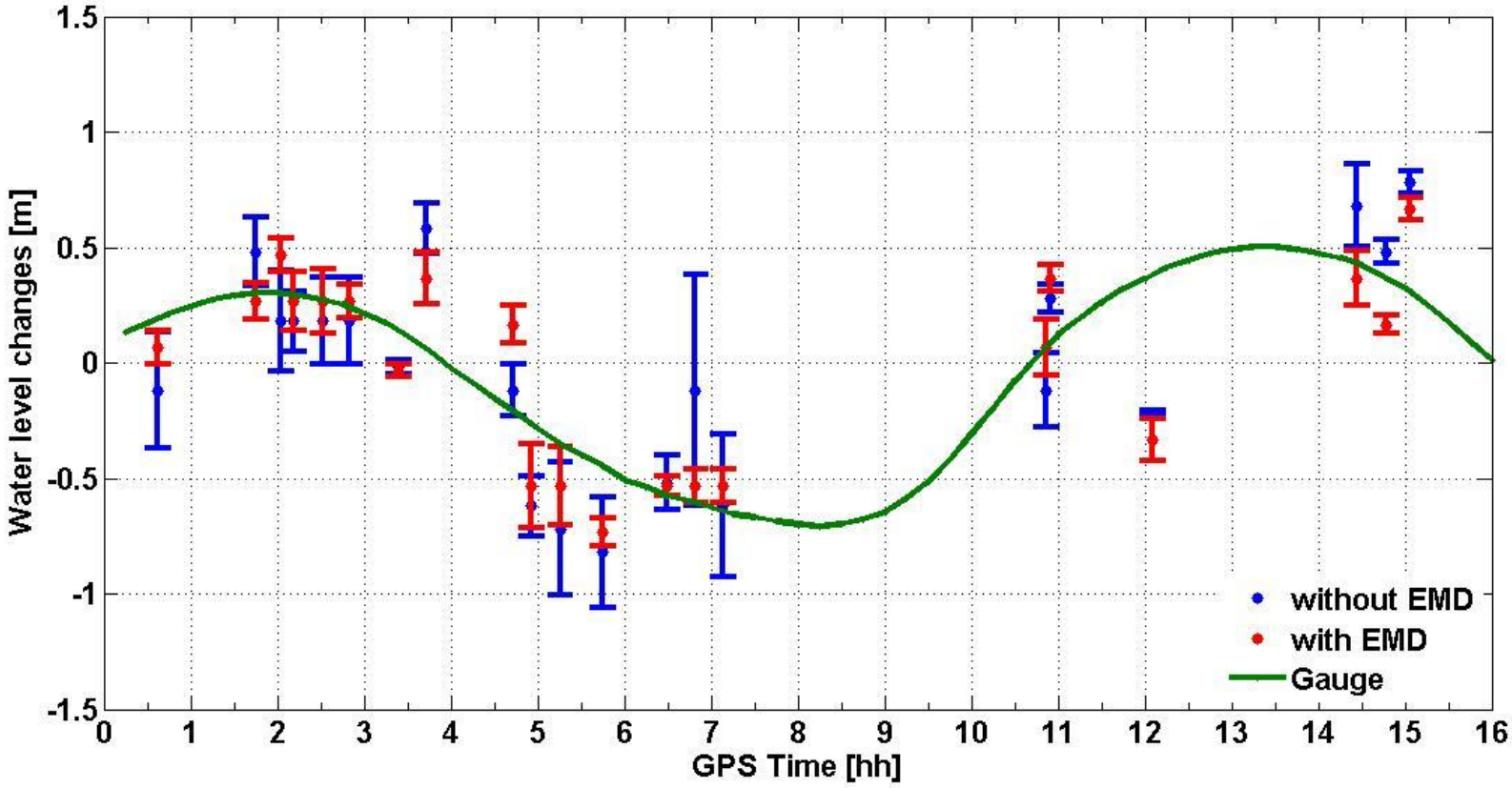
First results: EMD Observations



Latest Results:

Vietnam, Can Tho City, 29th February 2012



With EMD: std (1σ) = 0.05 m
Without EMD: std (1σ) = 0.12 m

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Conclusion and Outlook:

- Although the measurement were made under challenging conditions we could reach a correlation of 0.84 with the data recorded from a gauge instrument
- GNSS-R could contribute to monitor water level changes of the Mekong Delta
  - Placement of the antenna
- Improvement of stochastic and functional model
  - Determination of the reflected signal's sigma (Experiment)
  - Include Phase Wind up effect

Thank you for your attention

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References:

[1] Huang N.E. et al., *The Empirical Mode Decomposition and the Hilbert Spectrum for non linear and non-stationary time series analysis*, Proc. R. Soc. London A, (1998), pp. 903-995

[2] Hirrle A. et al., *Estimation of Multipath Parameters using Hilbert Huang Transform*, ION GNSS, Nashville, Tennessee, USA, 2012

[3] Beckheinrich J. et al, *GNSS Reflectometry: Innovative Flood Monitoring at the Mekong Delta*, Reflectometry Using GNSS and Other Signals of Opportunity (GNSS+R), 2012, doi: 10.1109/GNSSR.2012.6408257