AMGI

Turbulence averaging scale for bora flows at the NE Adriatic coast

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CONTENT

I. RECENT FINDINGS ON THE BORA RELATED TURBULENCE

- Belušić et al. (2004) ➔ observed gust pulsations in strong bora flows at T ϵ [3 - 10] min
- Belušić et al. (2006) ➔ arbitrarily defined the total bora turbulence as the variability at T ϵ [2 s - 10 min] ➔ included gust pulsations into the total turbulence
- variance at T ϵ [2 s - 1 min] ➔ highly correlated with the mean wind speed ➔ turbulence is locally produced (mechanical shear, surface roughness)
- variance at T ϵ [1 - 10] min ➔ increases without increasing mean wind speed ➔ turbulence is non-locally produced (gust pulsations)
- “local turbulence” ➔ T ϵ [2 s - 1 min]
- “non-local turbulence” ➔ T ϵ [1 - 10] min

II. GOAL

- To find a proper turbulence averaging scale (TAS) for definition of turbulence fluctuations (e.g. Stull 1988):

  ➔ decomposition: $$q = \overline{q}_{(\lambda,\tau)} + q' \qquad (1)$$

- Too short/long TAS ➔ under-/overestimation of turbulence (e.g. Večenaj et al. 2011)

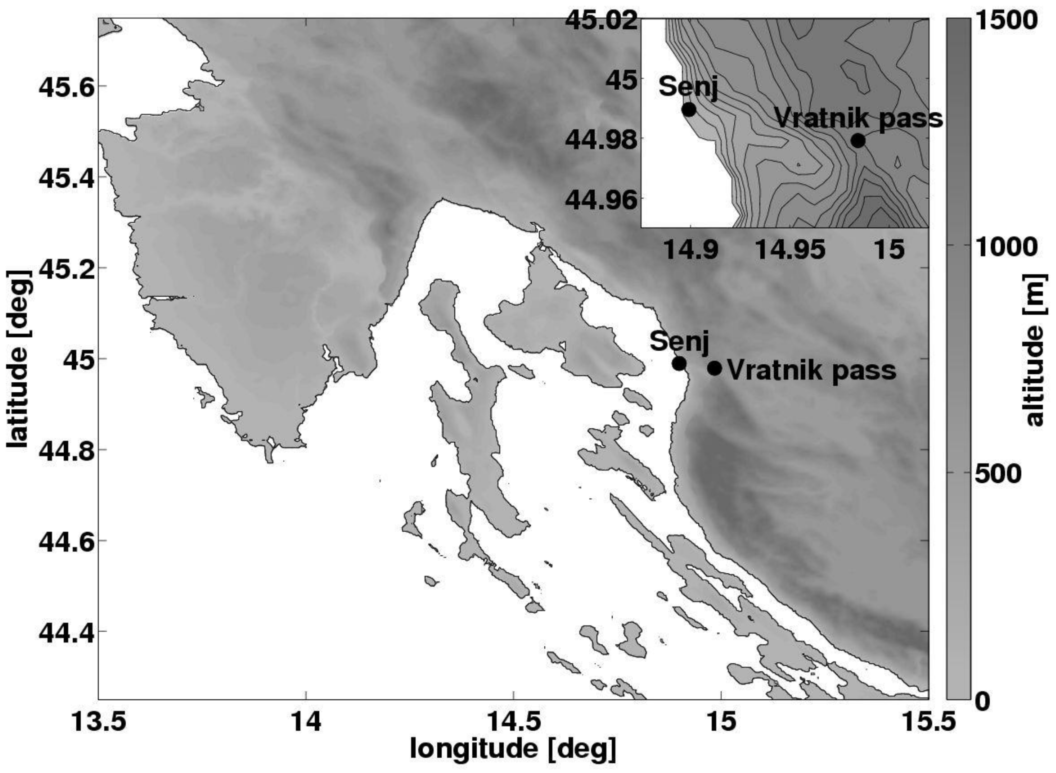
- Two independent tools:

  a) Fourier spectral analysis

  b) Multiresolution flux decomposition (MFD)

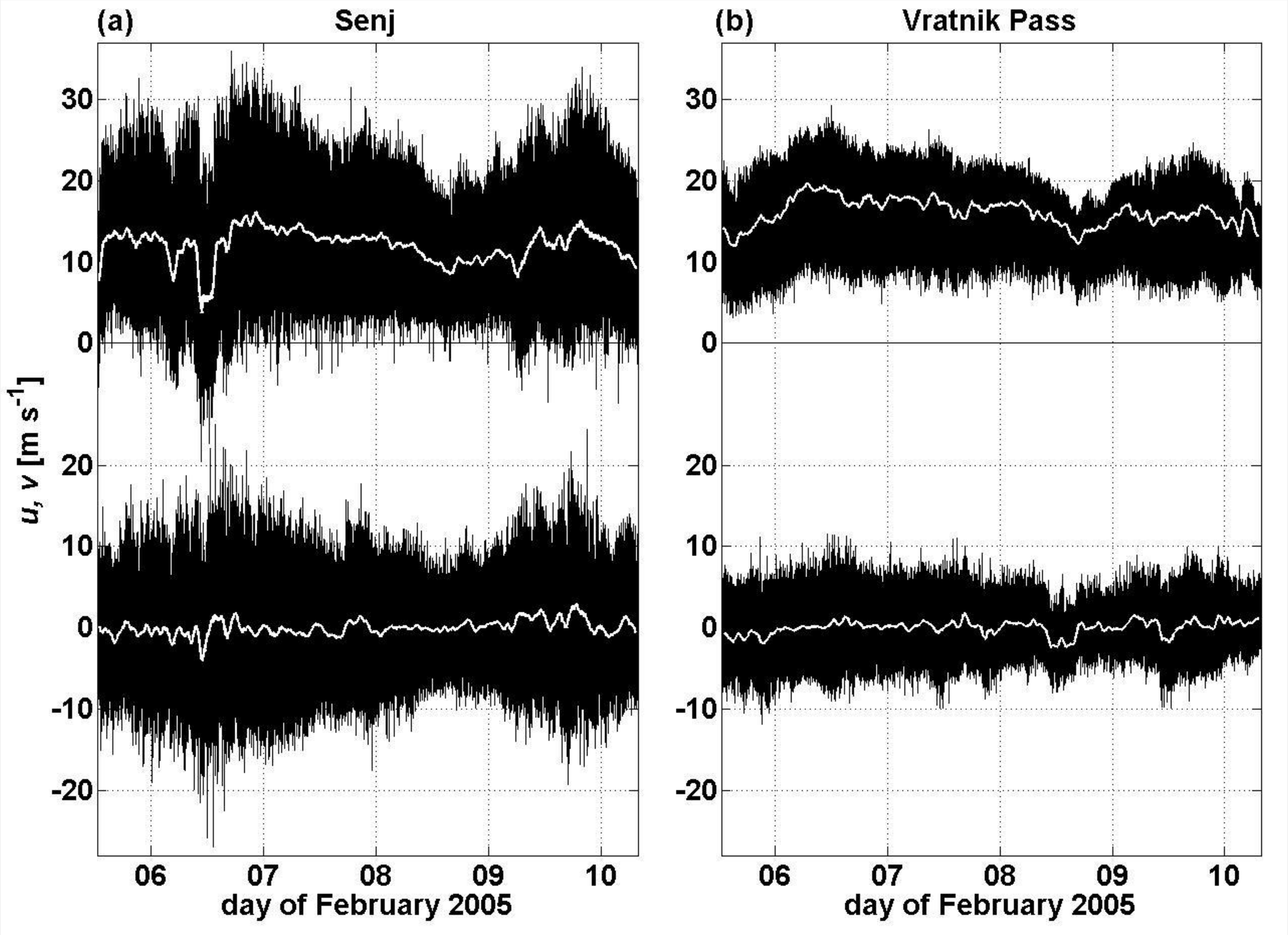
III. OBSERVED DATA

- 3D wind speed single point measurements – Gill ultrasonic anemometers – 4 Hz
- Senj ➔ 44.99°N, 14.90°E, 2 m ASL, 13 m AG
  - observation periods: (i) Mar 2004 – Jun 2005
  (ii) Sep 2005 – Jun 2006
- Vratnik Pass (VP) ➔ 44.98°N, 14.98°E, ~ 700 m ASL, 10 m AG
  - observatio period: Oct 2004 – Sep 2005



- Definition of a bora episode: "*wind of azimuth between 30° and 90° blowing at least for 3 h*"
- 341 bora episodes in Senj with cumulative duration of ≈ 6400 h
- 153 bora episodes in VP with cumulative duration of ≈ 4700 h

III.1. Demonstration case study – a severe winter bora event



IV. DETERMINATION OF THE TURBULENCE AVERAGING SCALE

- Two averaging scales to be distinguished in turbulence analysis:

  a) turbulence averaging scale (TAS); λ or τ:

$$\bar{q}_{(\lambda,\tau)} = \frac{1}{(\lambda,\tau)} \int_{(x,t)-(\lambda,\tau)/2}^{(x,t)+(\lambda,\tau)/2} q d(x,t) \qquad (2)$$

  b) averaging scale for statistical moments (Reynolds averaging scale); L or T:

$$\overline{q'^2}_{(L,T)} = \frac{1}{(L,T)} \int_{(x,t)-(L,T)/2}^{(x,t)+(L,T)/2} \left(q - \bar{q}_{(\lambda,\tau)}\right)^2 d(x,t) \qquad (3)$$

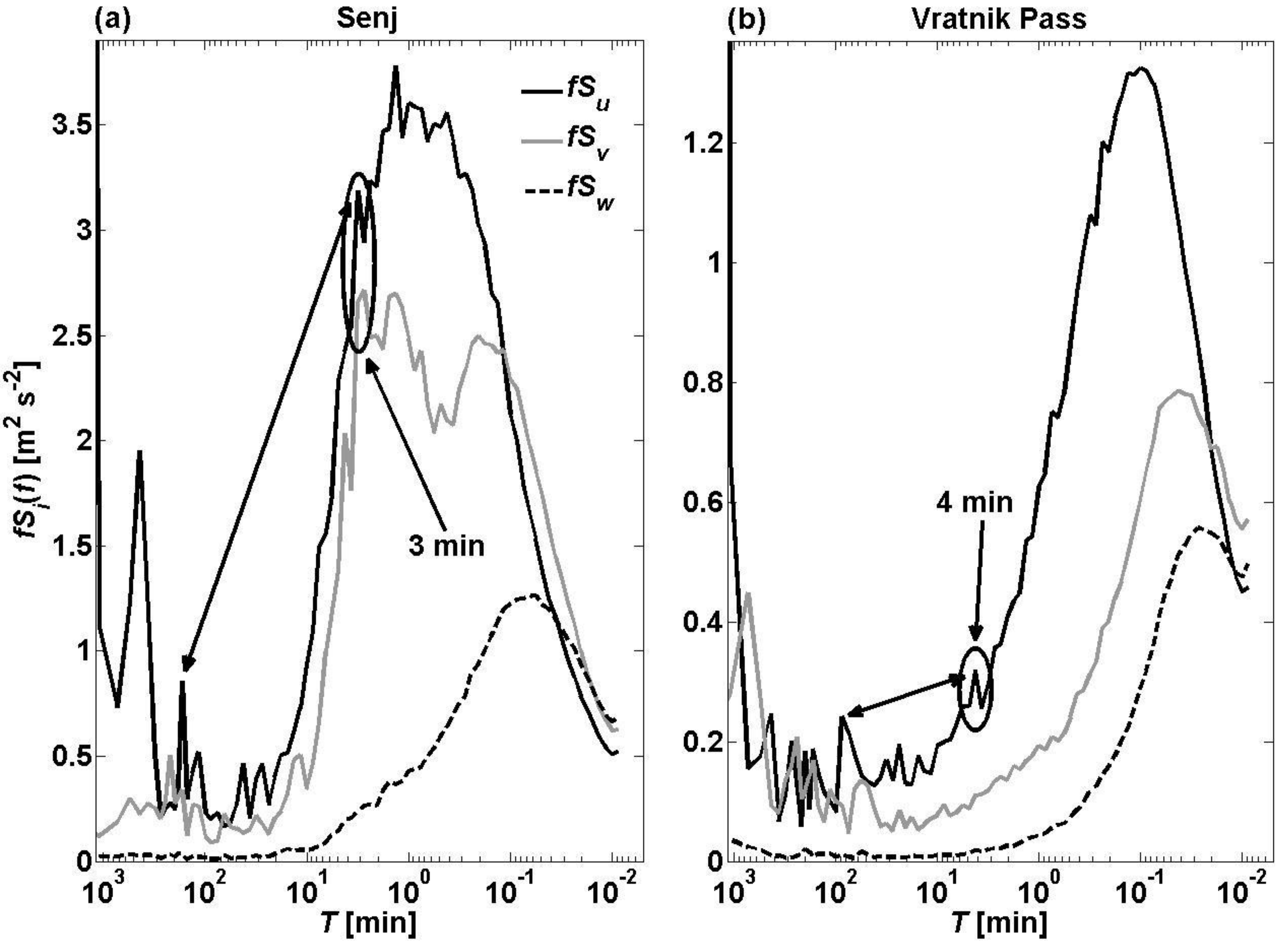
- usually $(L, T) \geq (\lambda, \tau)$
- λ and τ ➔ moving average
- L and T ➔ block average

IV.1. Fourier spectra and the *energy gap*

- Mesoscale motions should not significantly influence turbulence generation in ABL ➔ idealizezed case ➔ clear boundary in Fourier spectra between large (synoptic) scale and microscale (e.g. Fiedler & Panofsky 1970) ➔ *energy gap* at mesoscale.

- For the time series, large and small scale peaks occur at scales of several hours (or even days) and several minutes (or even several 10 of minutes), respectively

- TAS should be settled in the *gap*



(a)
Senj
fS_u
fS_v
fS_w
3 min
fS_i(f) [m^2 s^-2]
T [min]
(b)
Vratnik Pass
4 min
T [min]

IV.2. Multiresolution flux decomposition (MFD)

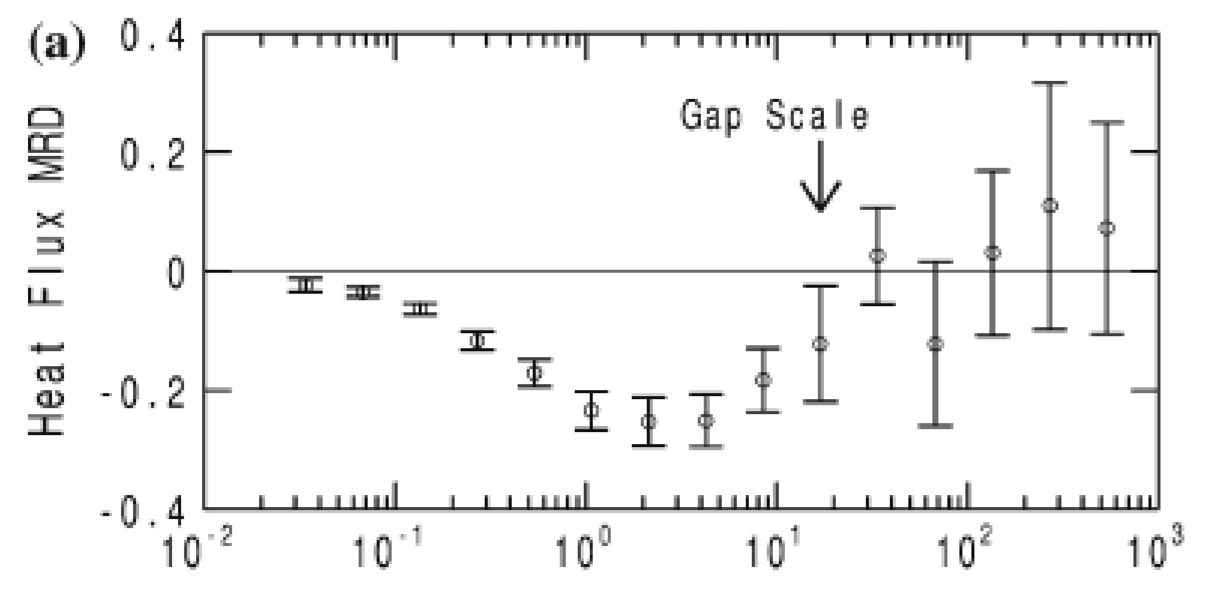
- MFD decomposes (co)variances locally ➔ periodicity is not required for the identification of peaks/gaps
- MFD cospectrum (flux):

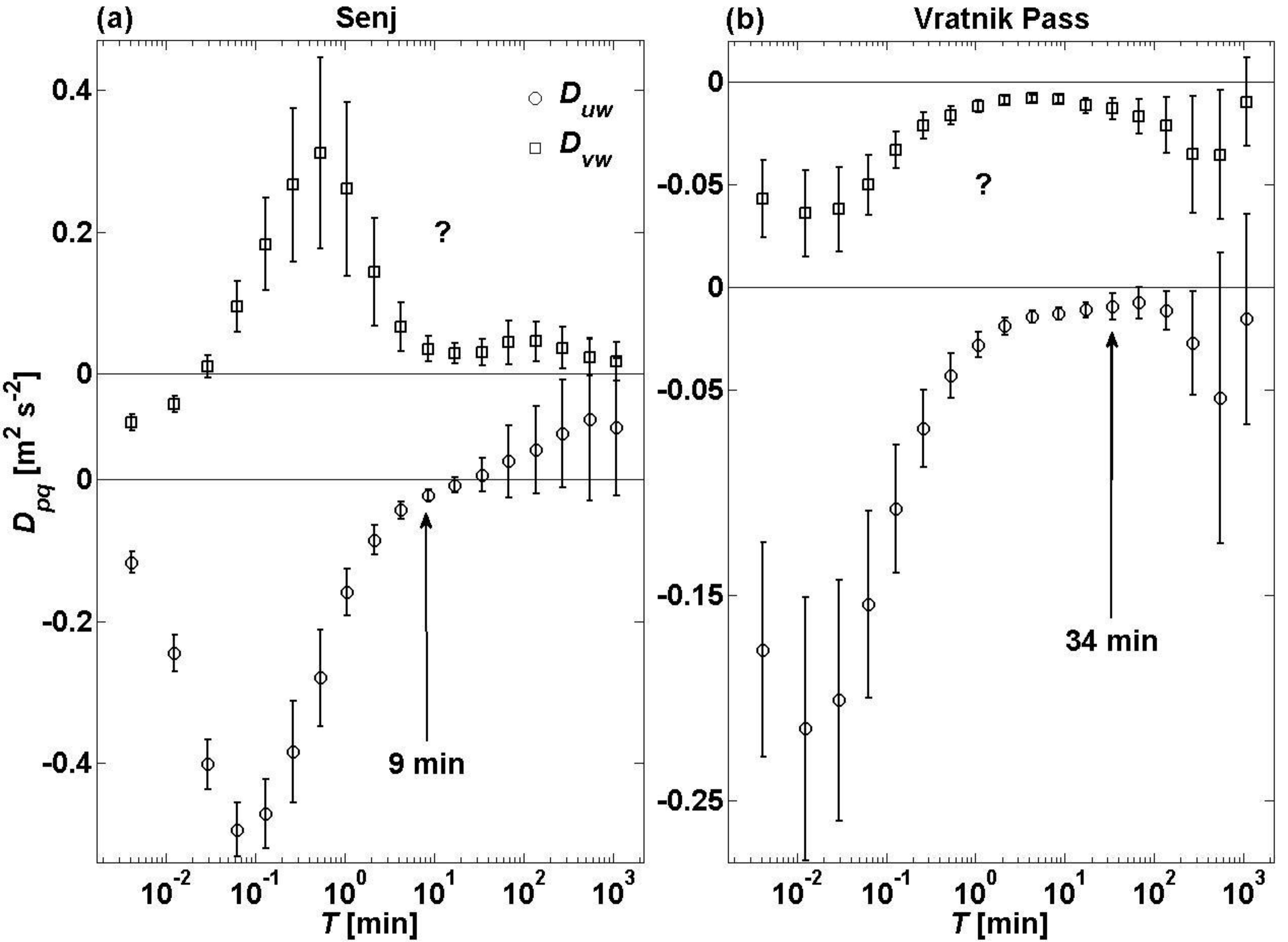
$$D_{pq}(m+1)=\frac{1}{2^{M-m}}\sum_{n=1}^{2^{M-m}}\overline{p}_n(m)\overline{q}_n(m), \qquad (4)$$

where

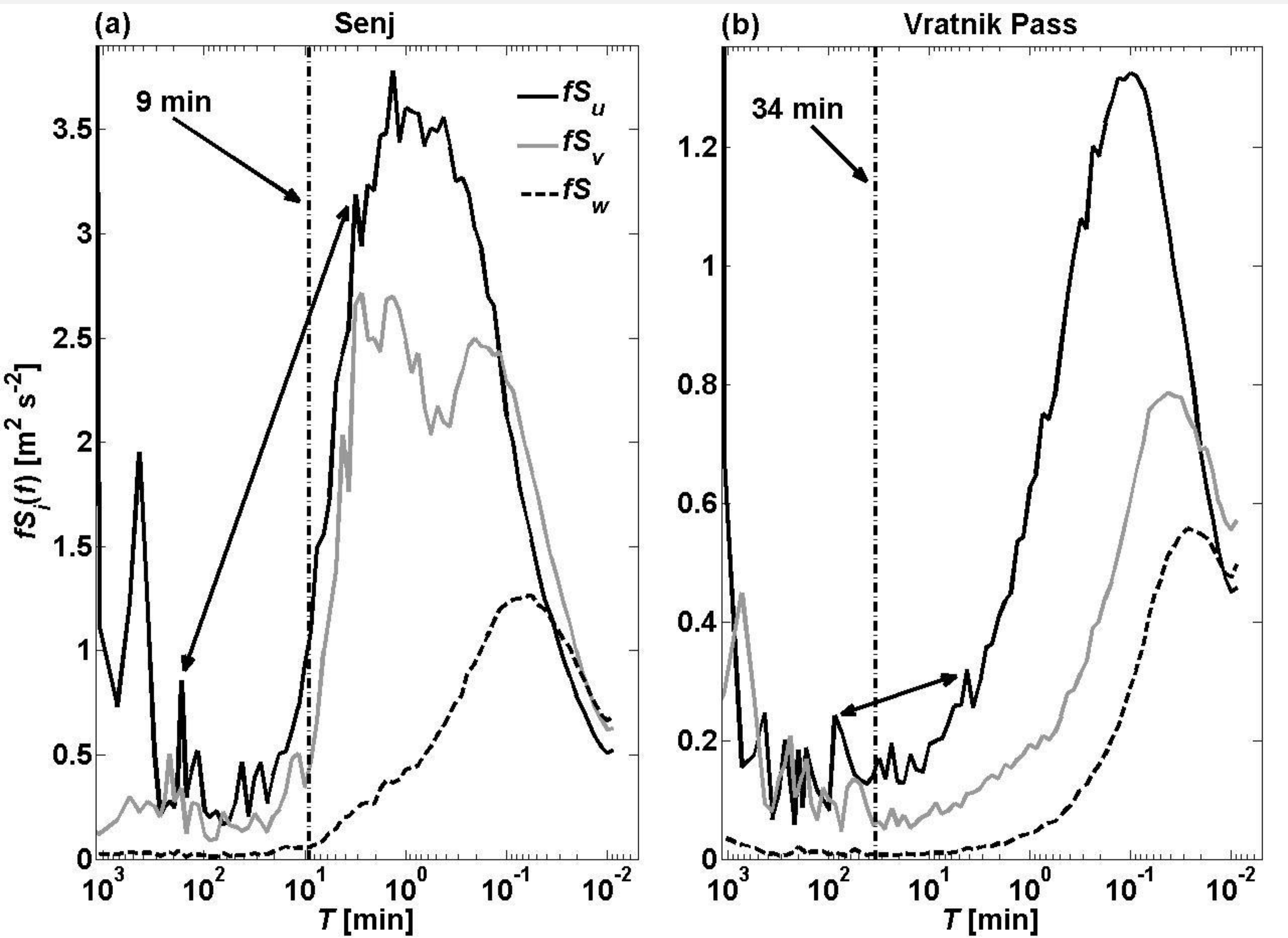
$$\left(\overline{p},\overline{q}\right)_n(m)=\frac{1}{2^m}\sum_{i=(n-1)2^m+1}^{n2^m}\left(p_r,q_r\right)_i(m). \qquad (5)$$

- Vickers and Mahrt (2006) ➔ TAS ➔ the last consecutive scale (from smaller to larger scales), for which the composite D_{pq} doesn't change sign



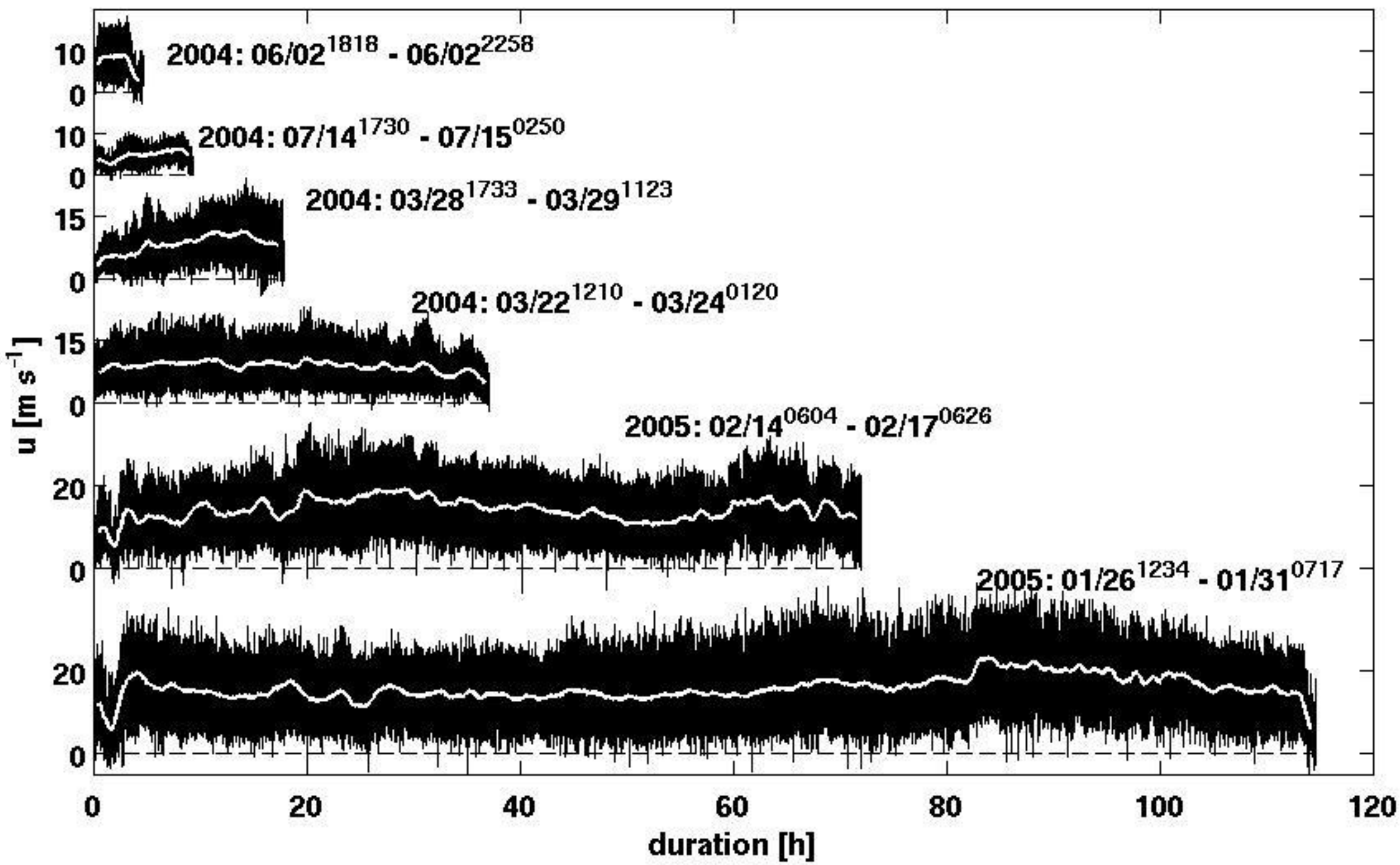


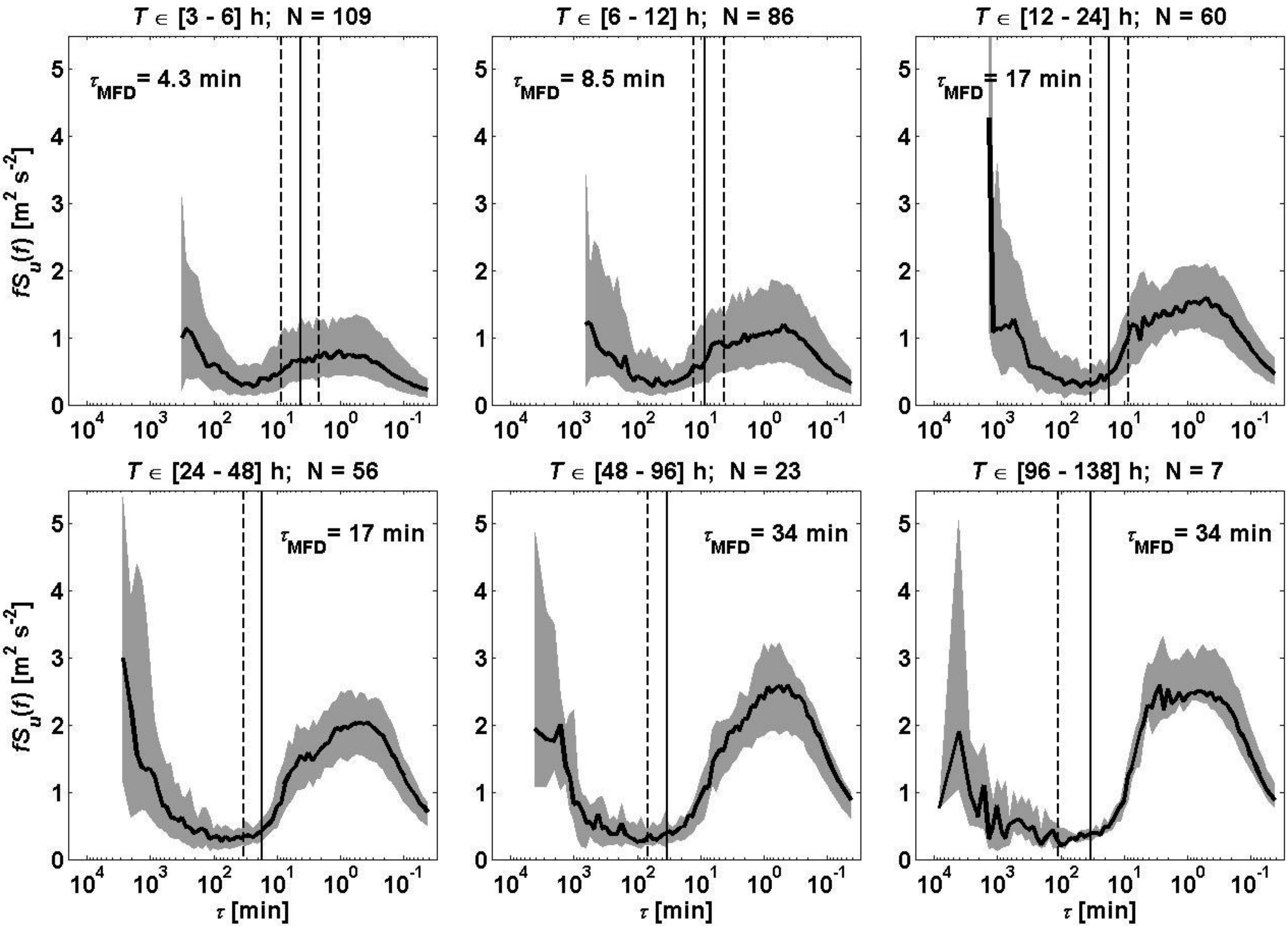
(a)
Senj
(b)
Vratnik Pass
D_{uw}
D_{vw}
?
?
9 min
34 min
D_{pq} [m^2 s^{-2}]
T [min]
T [min]
0.4
0.2
0
0
-0.2
-0.4
0
-0.05
0
-0.05
-0.15
-0.25
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}


(a)
Senj
9 min
fSu
fSv
fSw
fSi(f) [m2 s-2]
T [min]
(b)
Vratnik Pass
34 min
T [min]

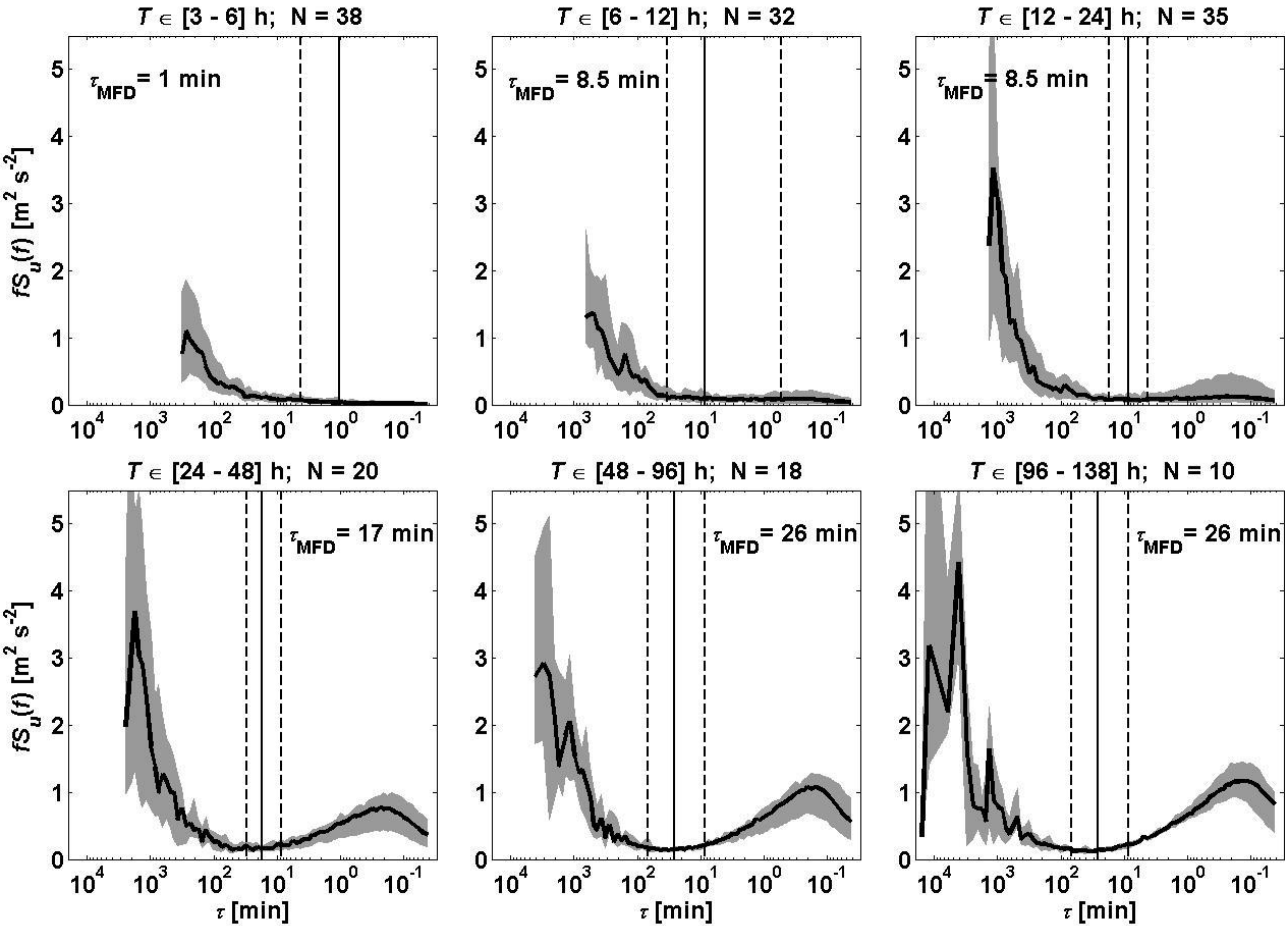
IV.3. Application to all bora events

- Clasification according to durration ➔ „*Quasi-logaritmic*“ partition to 6 classes: [3 – 6] h; [6 – 12] h; [12 – 24] h; [24 – 48] h; [48 – 96] h; >96 h





T ∈ [3 - 6] h; N = 109
T ∈ [6 - 12] h; N = 86
T ∈ [12 - 24] h; N = 60
T ∈ [24 - 48] h; N = 56
T ∈ [48 - 96] h; N = 23
T ∈ [96 - 138] h; N = 7
τMFD = 4.3 min
τMFD = 8.5 min
τMFD = 17 min
τMFD = 17 min
τMFD = 34 min
τMFD = 34 min
fSu(f) [m2 s-2]
τ [min]



T ∈ [3 - 6] h; N = 38
τMFD = 1 min
T ∈ [6 - 12] h; N = 32
τMFD = 8.5 min
T ∈ [12 - 24] h; N = 35
τMFD = 8.5 min
T ∈ [24 - 48] h; N = 20
τMFD = 17 min
T ∈ [48 - 96] h; N = 18
τMFD = 26 min
T ∈ [96 - 138] h; N = 10
τMFD = 26 min
fSu(f) [m2 s-2]
τ [min]

V. CONCLUSIONS

- Determination of turbulence averaging scale for bora ➔ a non-trivial task

- Fourier spectra show the existence of the *energy gap* and gust pulsations in the ground based measurements

- Combination of the Fourier spectral analysis and MFD method might provide an information about the proper TAS for bora

- It appears that TAS increases with the duration of bora epizodes in both Senj and Vratnik Pass