AMGI

Separation of the turbulence from the mean bora flows at the NE Adriatic coast

[1]Željko Večenaj

[2]Danijel Belušić and [1]Branko Grisogono

[1]University of Zagreb, Faculty of Science, Department of Geophysics (Andrija Mohorovičić Geophysical Institute – AMGI), Zagreb, Croatia

[2]School of Mathematical Sciences, Monash University, Melbourne, Victoria, Australia

Email: zvecenaj@gfz.hr

CONTENT

- I. Recent findings on the bora related turbulence
- II. Goal
- III. Observed data
- IV. Determination of the turbulence averaging scale
- V. Conclusions

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

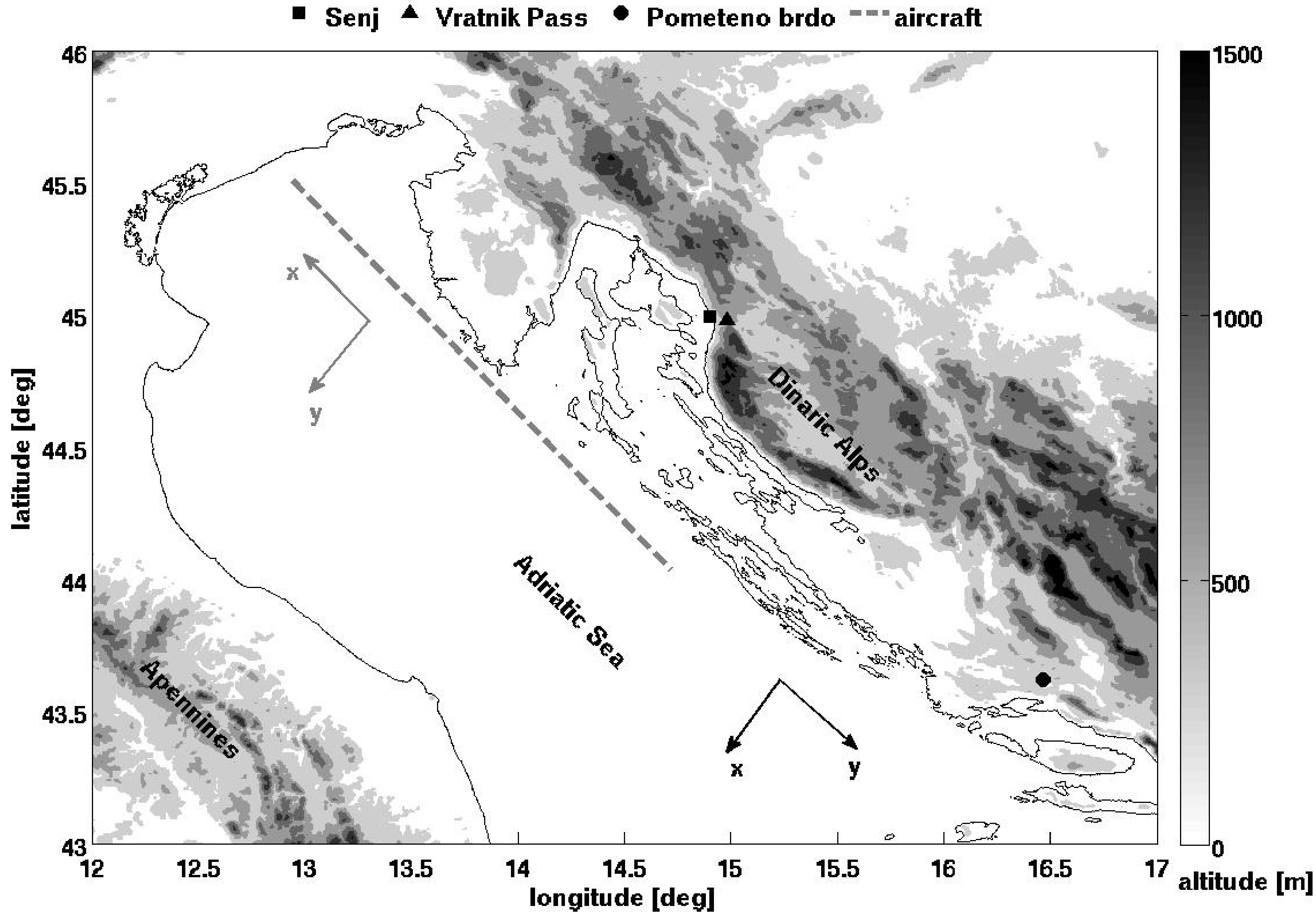
- Too short/long TAS ➔ under-/overestimation of turbulence (e.g. Večenaj et al. 2011)

- Two independent tools:

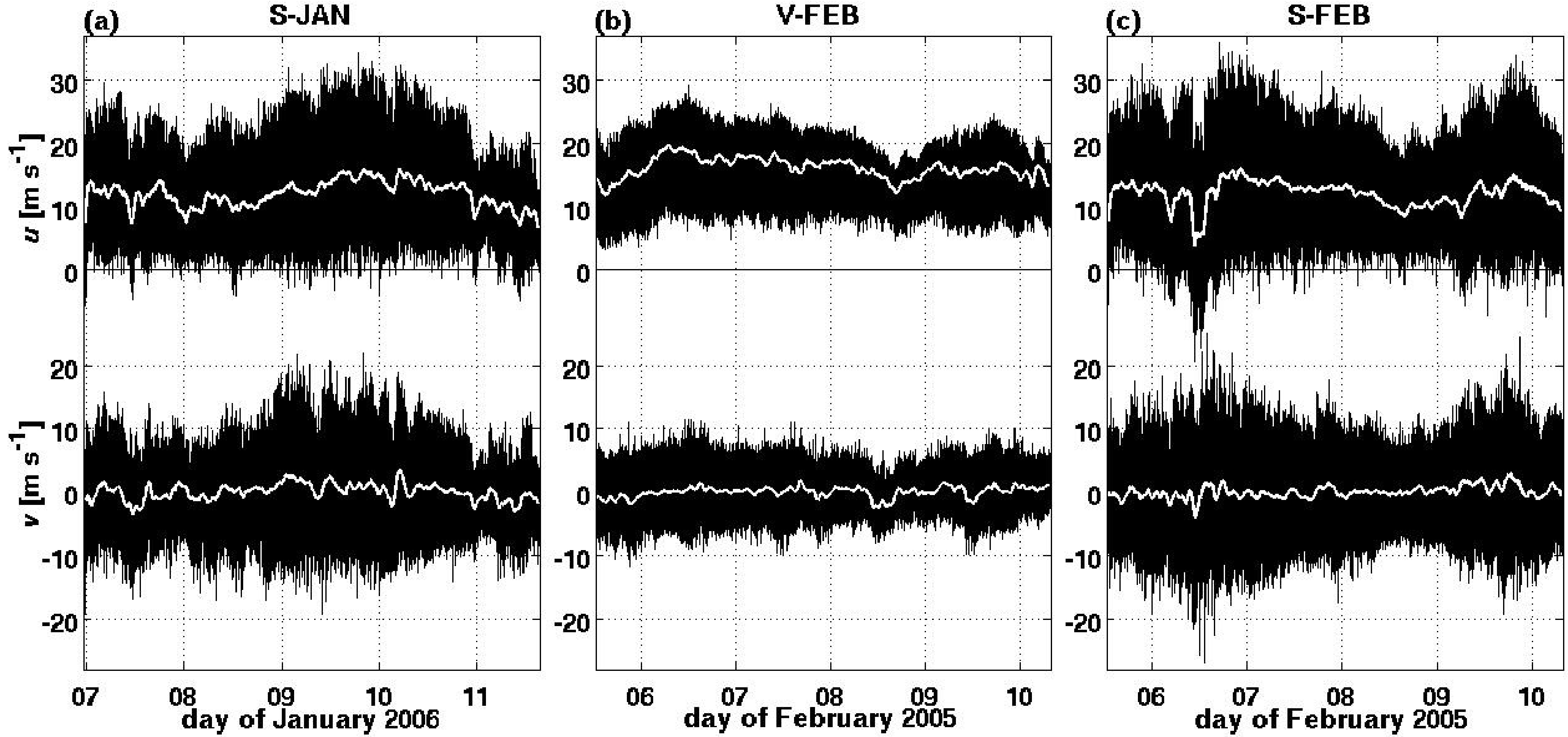
  a) Fourier spectral analysis

  b) Multiresolution flux decomposition (MFD)

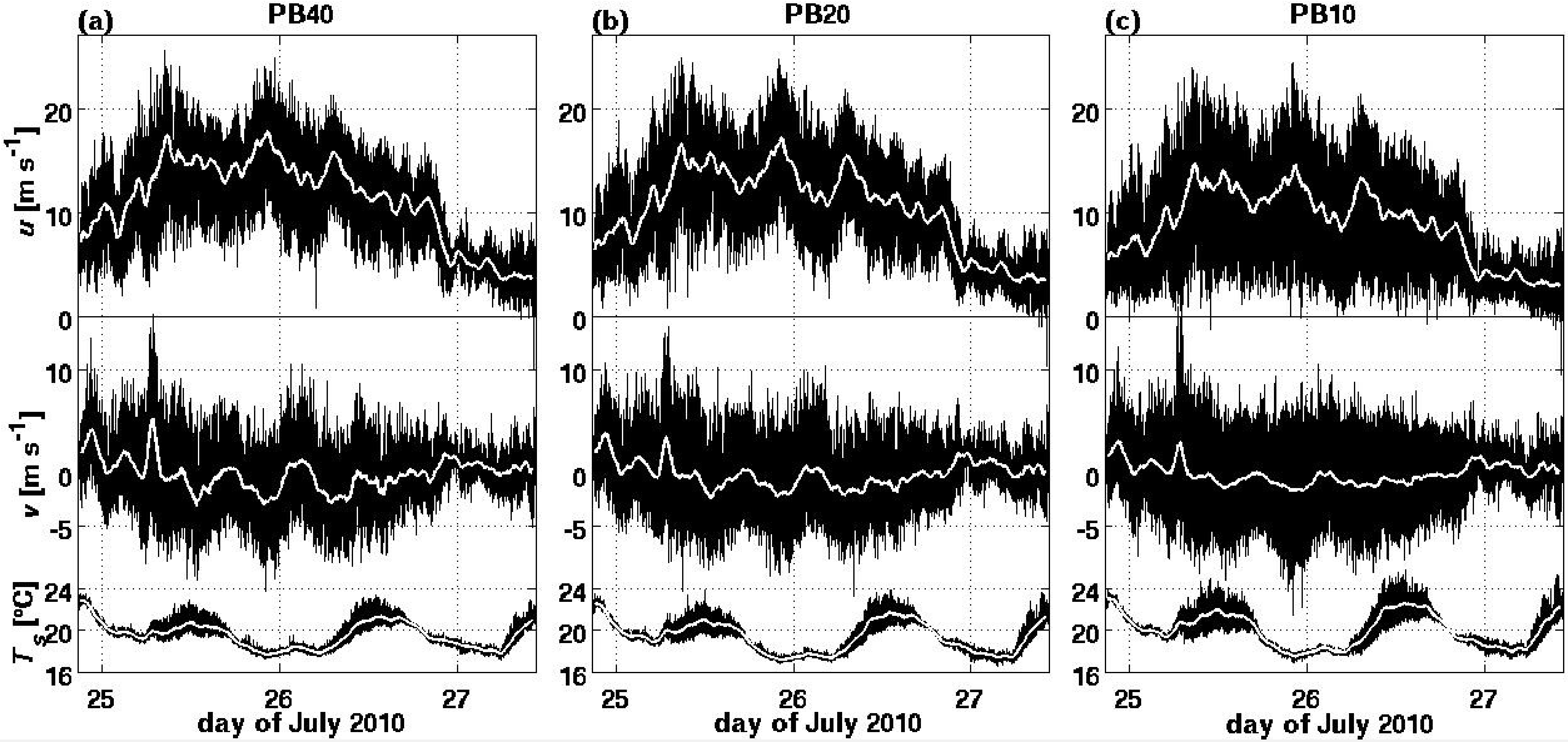
III. OBSERVED DATA



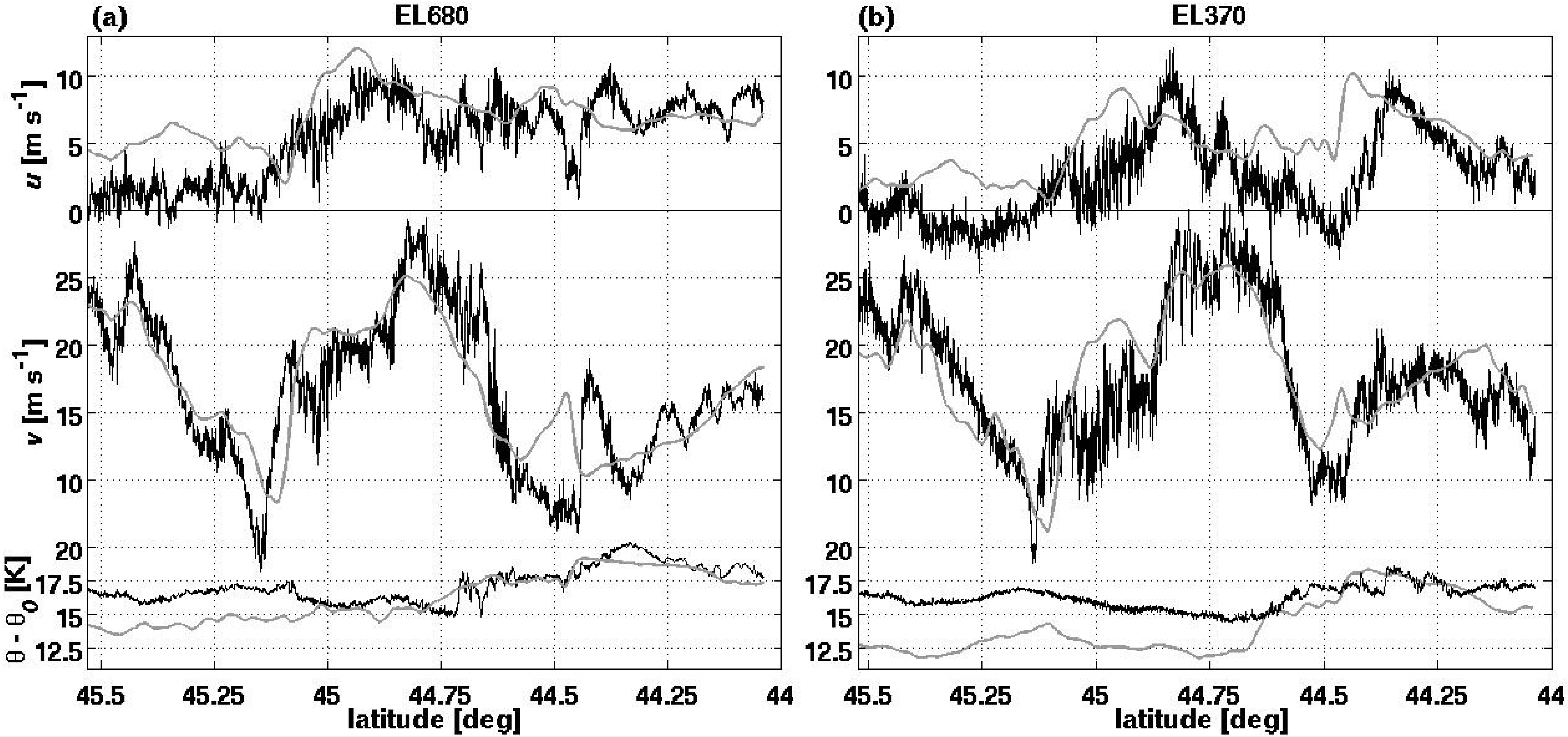
III.1 Winter bora events in the town of Senj and Vratnik Pass



III.2 Summer bora event on Pometeno brdo



III.3 Winter bora event above N Adriatic Sea



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

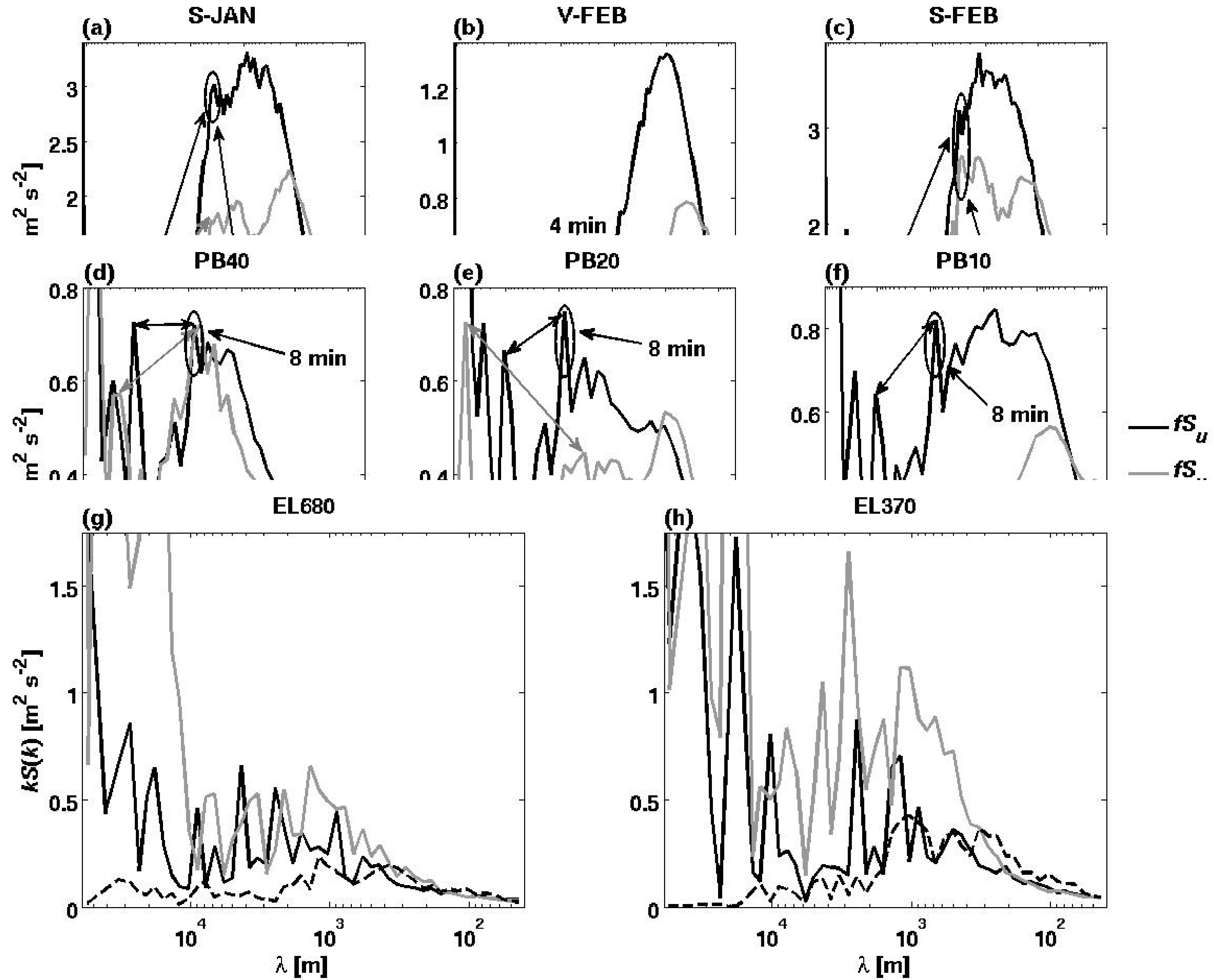
IV.2 Fourier spectra and the *energy gap*

- 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

- For the high resolution measurements in space, i.e. aircraft measurements, the *gap* is usually settled between the scales of few tens (or even hundreds) of kilometers and few hundreds of meters (or even several kilometers)

- TAS should be settled in the *gap*



(a) S-JAN
(b) V-FEB
(c) S-FEB
4 min
(d) PB40
(e) PB20
(f) PB10
8 min
8 min
8 min
(g) EL680
(h) EL370
m2 s-2
kS(k) [m2 s-2]
λ [m]
fSu

IV.3 Multiresolution flux decomposition (MFD)

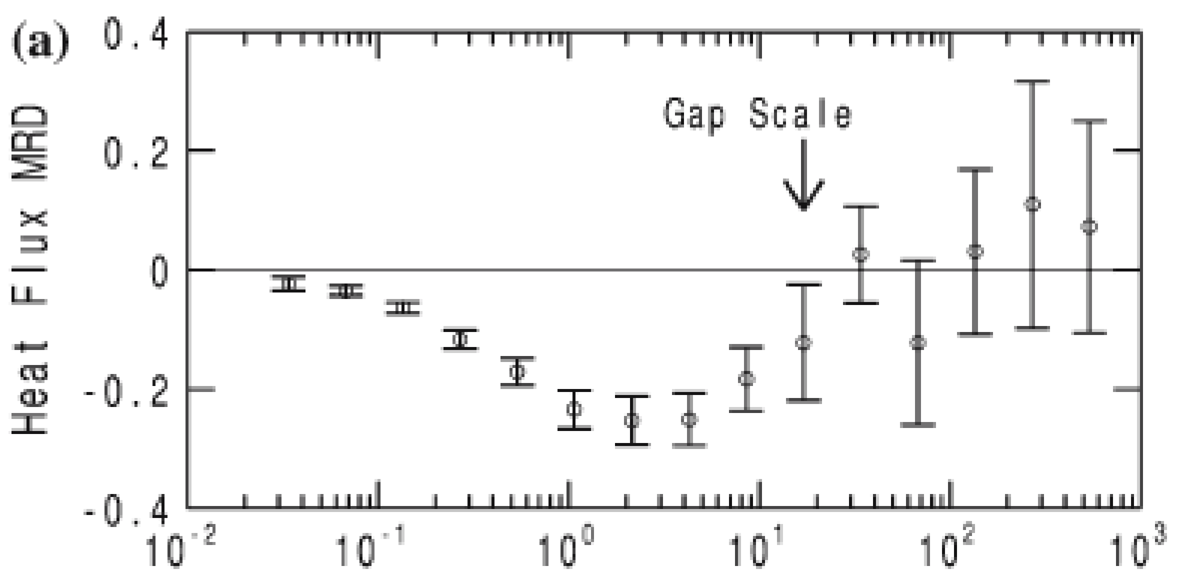
- MFD decomposes (co)variances locally ➔ periodicity is not required for the identification of peaks/gaps
- MFD cospectrum (flux):

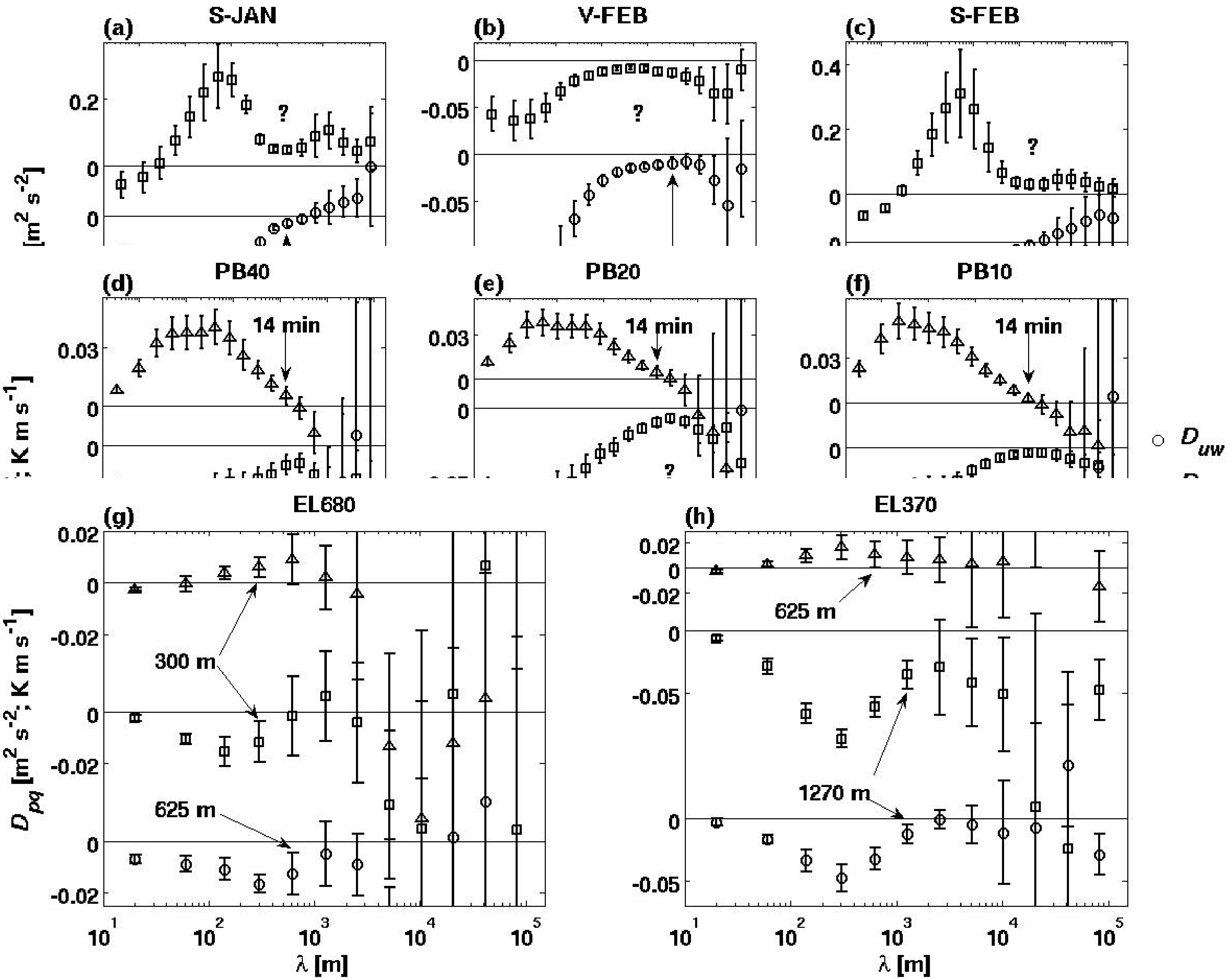
$$D_{pq}(m+1)=\frac{1}{2^{M-m}}\sum_{n=1}^{2^{M-m}}\overline{p}_n(m)\overline{q}_n(m), \qquad (4)$$

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

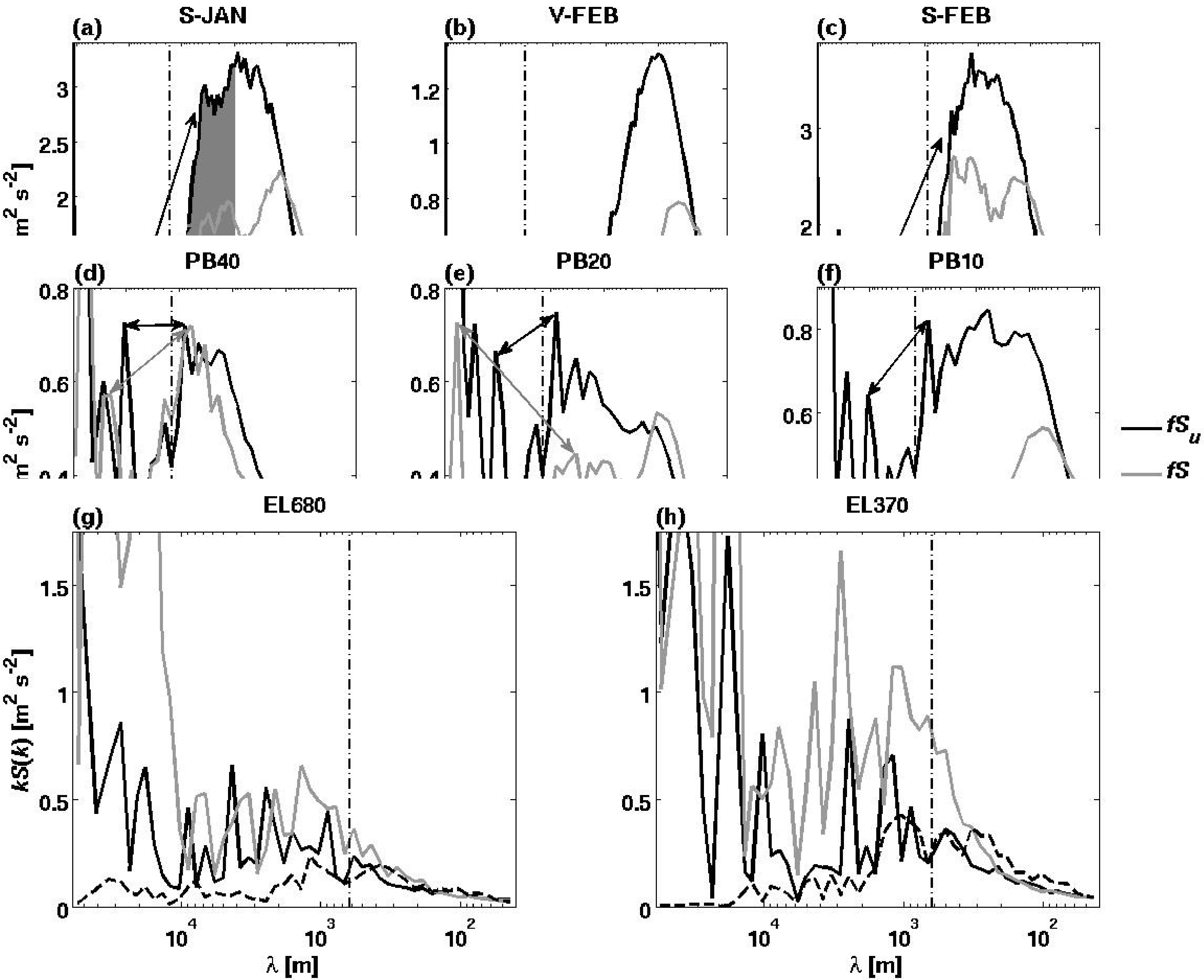




S-JAN
(a)
V-FEB
(b)
S-FEB
(c)
PB40
(d)
PB20
(e)
PB10
(f)
14 min
EL680
(g)
EL370
(h)
300 m
625 m
1270 m
?
D_{uw}
D_{pq} [m^2 s^{-2}; K m s^{-1}]
λ [m]

- ground based data ➔ scales closest to the small-scale peaks in the Fourier spectra are chosen for TAS ➔ in order to minimize possible influence of the mesoscale motions to the turbulence structures:
  - S-JAN ➔ $\underline{\tau = 17\ \text{min}}$; V-FEB ➔ $\underline{\tau = 34\ \text{min}}$; S-FEB ➔ $\underline{\tau = 9\ \text{min}}$
  - PB40, PB20, PB10 ➔ $\underline{\tau = 14\ \text{min}}$
- aircraft data ➔ TAS of $\underline{\lambda = 625\ \text{m}}$ is chosen for EL680 and EL370 ➔ scale at which Fourier spectra of all three wind speed components on both flight legs simultaneously exhibit a small gap

		Senj – Vratnik (τ [min])			Pometeno brdo (τ [min])			Electra (λ [m])	
method	(co)spectrum	S-JAN	V-FEB	S-FEB	PB40	PB20	PB10	EL680	EL370
Fourier spectra	S_u	4–170	4–90	3–170	8–110	8–110	8–110	?	?
	S_v	3–240	?	12–220	6–190	3–580	3–270	?	?
	S_w	?	?	?	?	?	?	?	?
MFD cospectra	D_{uw}	$\boxed{17}$	$\boxed{34}$	$\boxed{9}$	27	27	27	$\boxed{625}$	1270
	D_{vw}	?	?	?	?	?	?	300	1270
	$D_{w\theta}$	/	/	/	$\boxed{14}$	$\boxed{14}$	$\boxed{14}$	300	$\boxed{625}$
Cumulative MFD cospectra	ΣD_{uw}	34	?	17	55	55	27	?	1270
	ΣD_{vw}	?	?	?	?	?	?	625	?
	$\Sigma D_{w\theta}$	/	/	/	14	14	14	1270	2560
Ogives	Og_{uw}	150	?	90	250	200	150	2000	?
	Og_{vw}	?	?	?	?	?	?	2000	?
	$Og_{w\theta}$	/	/	/	160	120	90	300	1780


S-JAN
V-FEB
S-FEB
PB40
PB20
PB10
EL680
EL370
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
$kS(k)$ [$m^2 s^{-2}$]
λ [m]
fS_u
fS

VI. 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

- Analysis of more bora events is needed to get general conclusions