Weak-wind SBL

Only problems, or solutions in sight?

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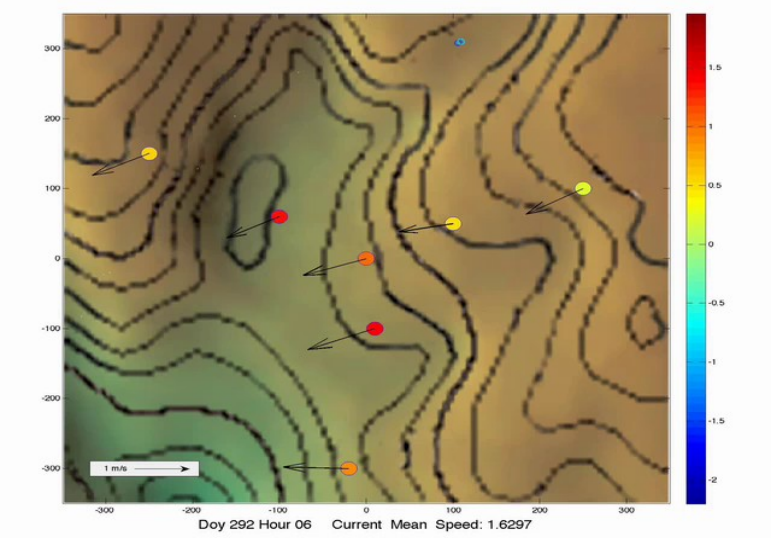
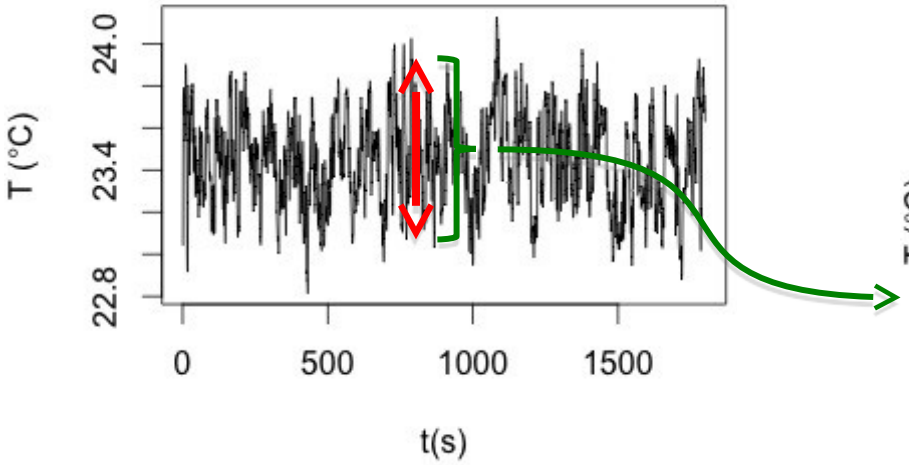
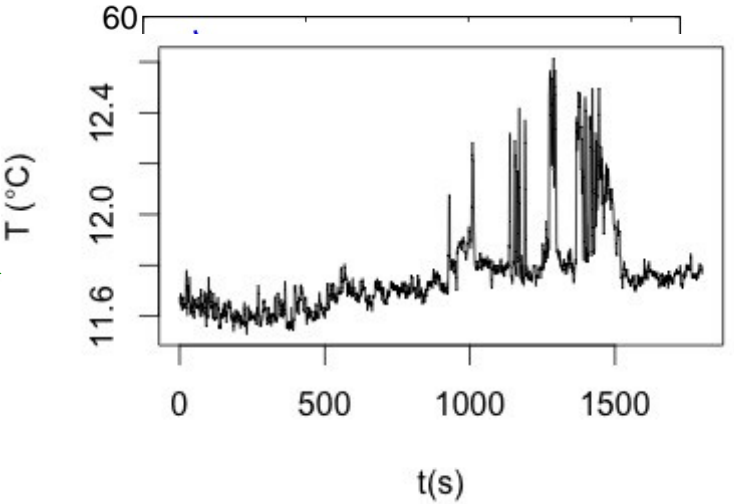
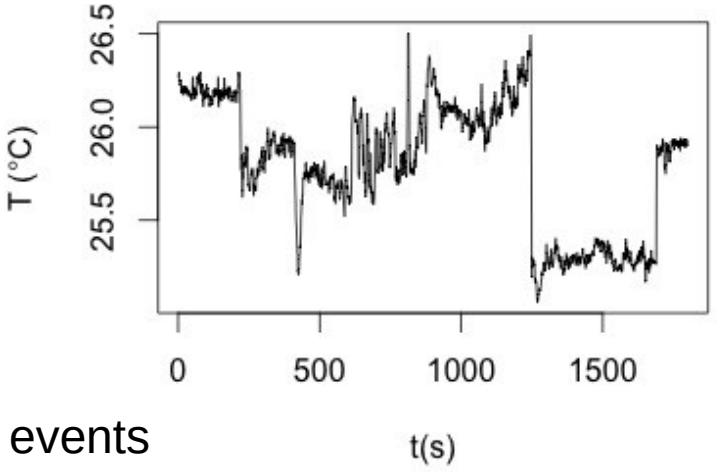
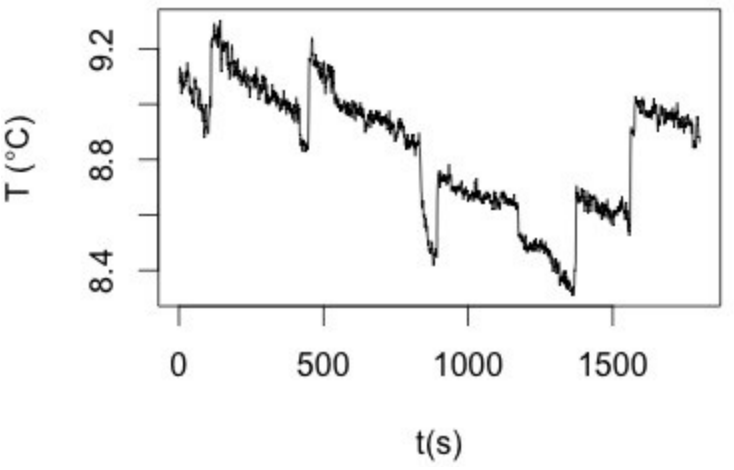

300
200
100
0
-100
-200
-300
-300
-200
-100
0
100
200
300
1 m/s
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Doy 292 Hour 06 Current Mean Speed: 1.6297

Where is the problem?









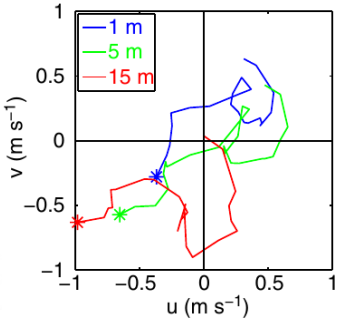
HH&S vs
intermittent events

Weak winds

- Nothing works:
  - **Anemometers** have weak-wind thresholds, but even if they work, then
  - **Assumptions** (e.g. Taylor's "frozen turbulence", S, HH) are invalid
  - **Models** have numerical diffusion, (dirty) fixes, and are based on hardly-applicable theories (e.g. M-O)

- Luckily, this is an overstatement...

Events

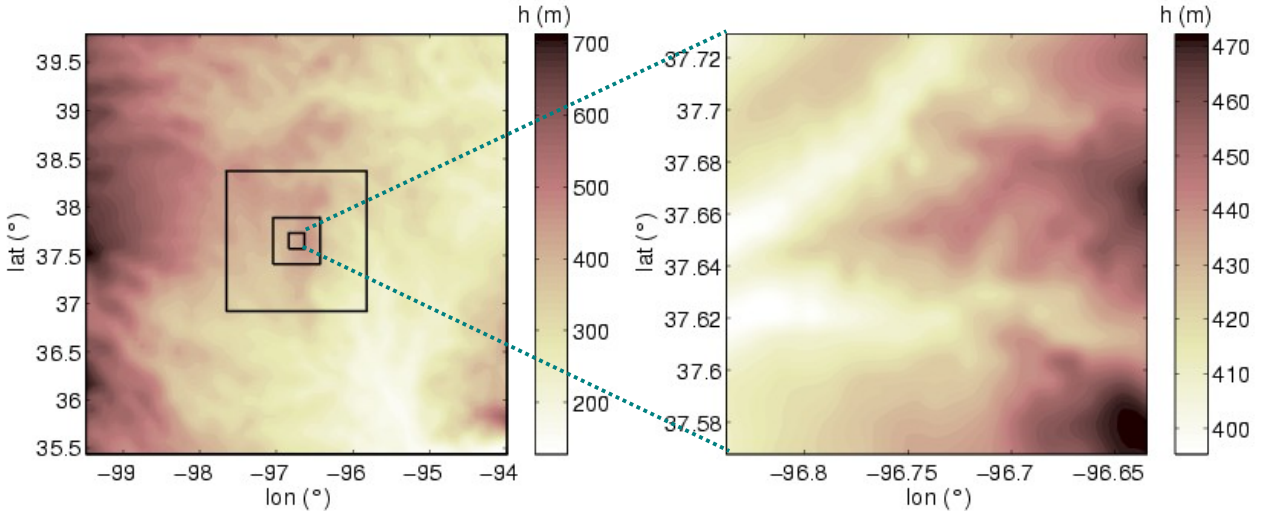


Kang, Belušić & Smith-Miles, QJ2015

Modelling submeso?

Horizontal resolution vs dynamics

WRF-ARW, CASES99 night 18/19 October



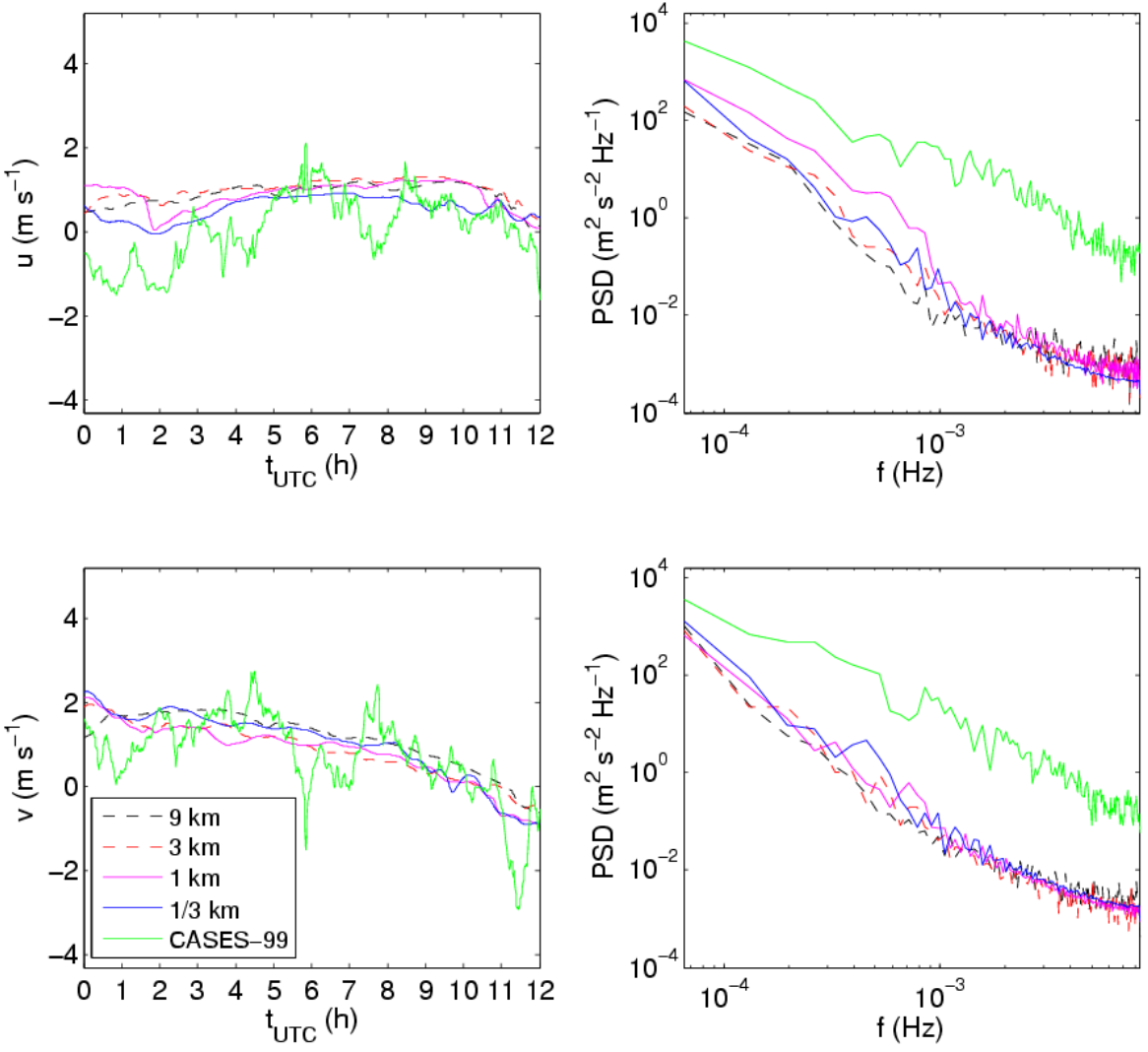
Horizontal: 9, 3, 1, 1/3 km

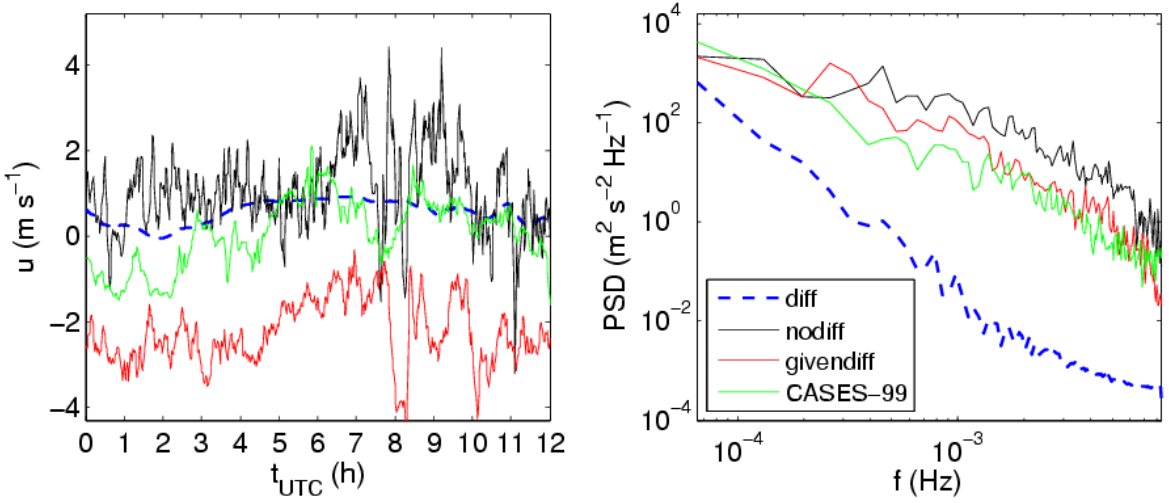
Vertical: 80 levels up to 50 hPa

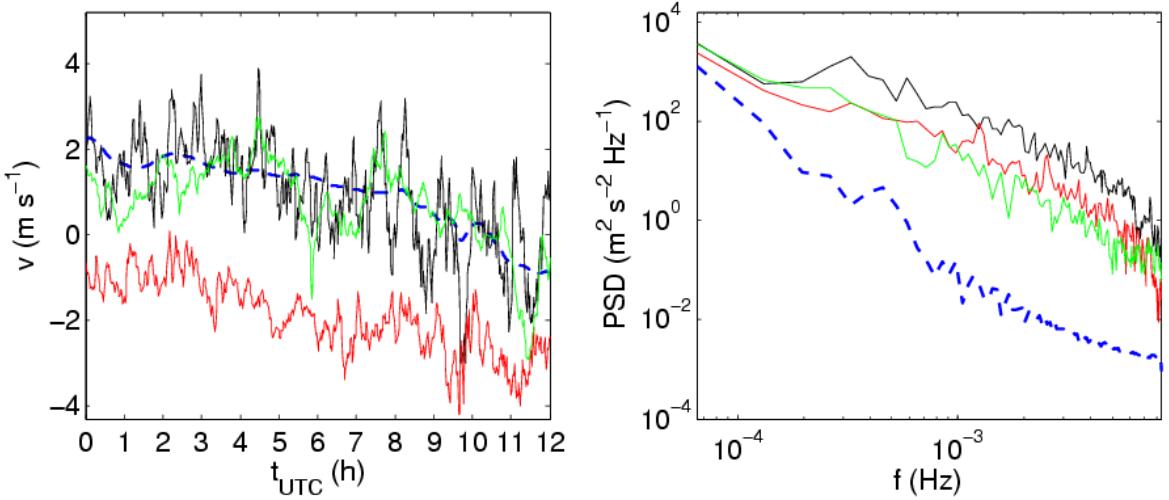
Mellor-Yamada-Janjic vertical mixing

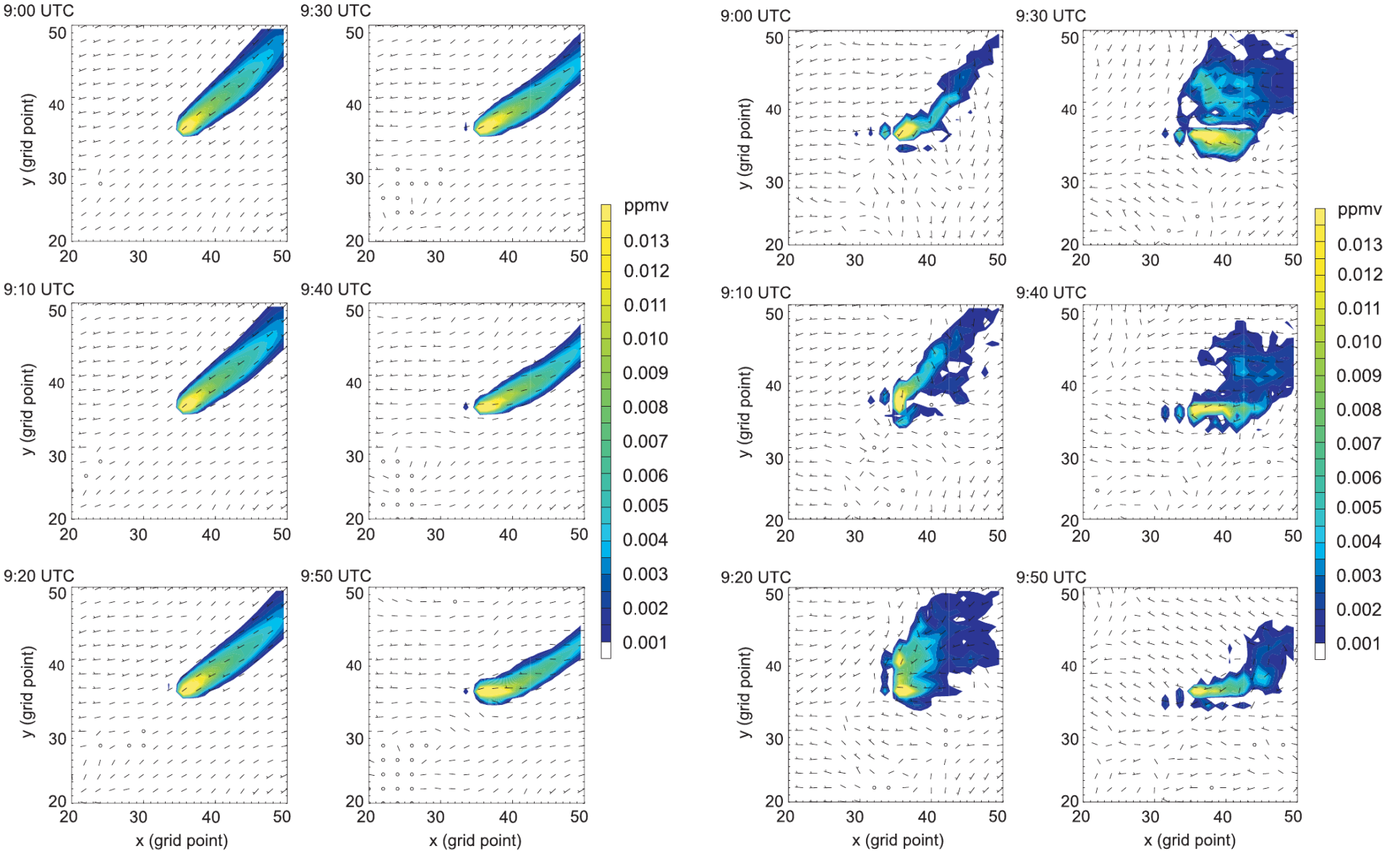
ECMWF initial & boundary conditions

Belušić & Güttler, QJ 2010
Güttler & Belušić, ASL 2012


u (m s^{-1})
t_{UTC} (h)
PSD (m^2 s^{-2} Hz^{-1})
f (Hz)
v (m s^{-1})
9 km
3 km
1 km
1/3 km
CASES−99


u (m s^{-1})
t_{UTC} (h)
PSD (m^2 s^{-2} Hz^{-1})
f (Hz)
diff
nodiff
givendiff
CASES–99


v (m s^{-1})
t_{UTC} (h)
PSD (m^2 s^{-2} Hz^{-1})
f (Hz)


9:00 UTC
9:30 UTC
9:10 UTC
9:40 UTC
9:20 UTC
9:50 UTC
y (grid point)
x (grid point)
20
30
40
50
ppmv
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001

Observations: Spatial wind variation

Horizontal heterogeneity

Table 1 Description of the networks

Site	sfc	wk	N	σ_{Zsfc}	τ	z	L_D	Citations
SCP	Grass	8	21	4.7	1	1	0.8	Mahrt et al. (2014)
CASES-99	Grass	4	7	3.0	1	5	0.5	Poulos et al. (2001)
DUMOSA	Grass	95	3	1.3	1	3	1.0	Lang et al. (2018)
Iowa	Crops	3	12	3	1	2	15	Kustas et al. (2004)
Pedras Altas	Mixed	8	10	10.0	2	2.5	0.95	Guerra et al. (2018)
Perdigão	Mixed	13	19	49	1	10	2	Fernando et al. (2017)
HVAMS	Mixed	9	7	14.2	5	7	65	Freedman and Fitzjarrald (2017)
FOG-82	Mixed	9	26	8	1	4	23	Acevedo and Fitzjarrald (2003)

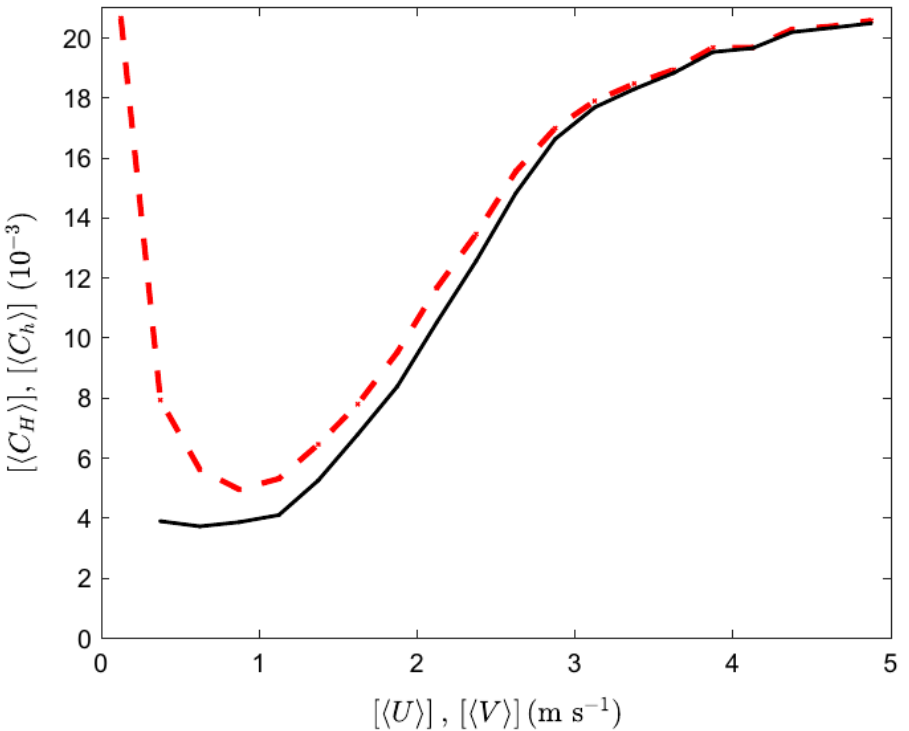
Spatial wind variation

Horizontal heterogeneity

$$\langle U \rangle^2 \equiv \langle V \rangle^2 + V_{sm}^2$$

Scalar-averaged speed

Vector-averaged speed (aka model-resolved speed)



Mahrt, Belušić & Acevedo, BLM 2021

Spatial wind variation

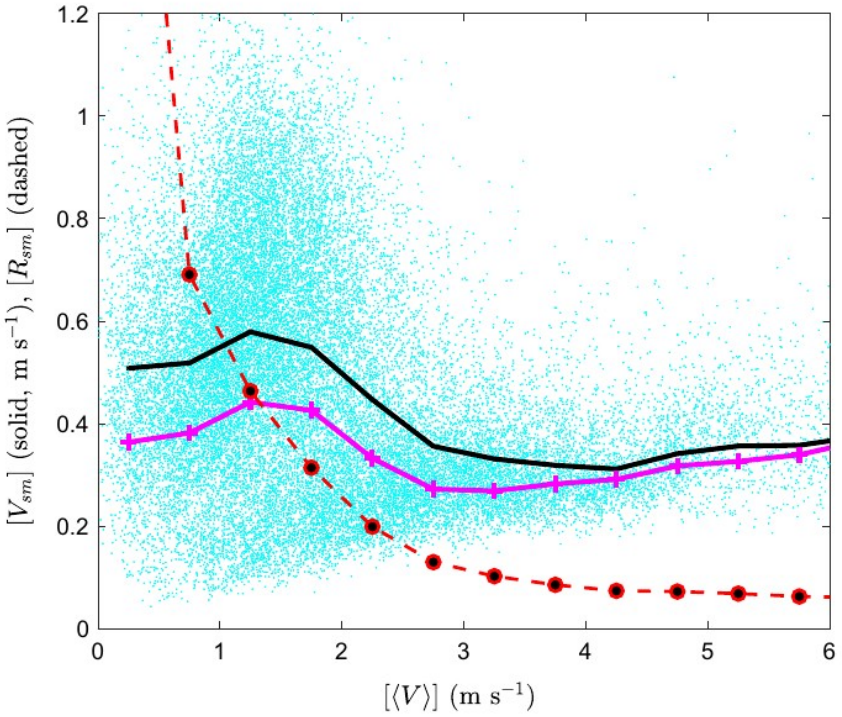
VSBL vs WSBL?

$$\langle U \rangle^2 \equiv \langle V \rangle^2 + V_{sm}^2$$

Scalar-averaged speed

Vector-averaged speed

VSBL vs WSBL:
“self-organised”

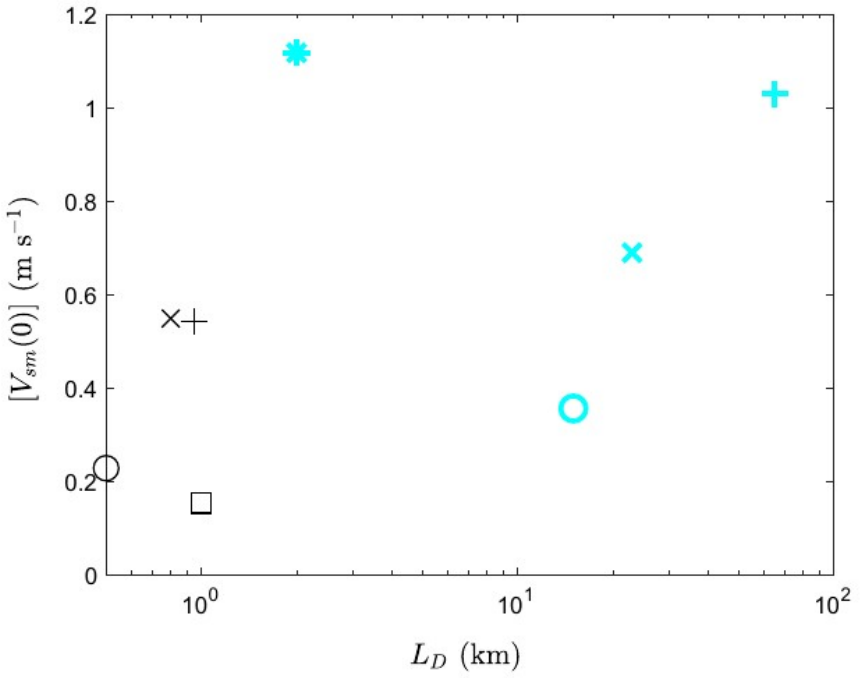


Mahrt, Belušić & Acevedo, BLM 2021

Spatial wind variation

Horizontal heterogeneity

- L_D – domain width



Mahrt, Belušić & Acevedo, BLM 2021

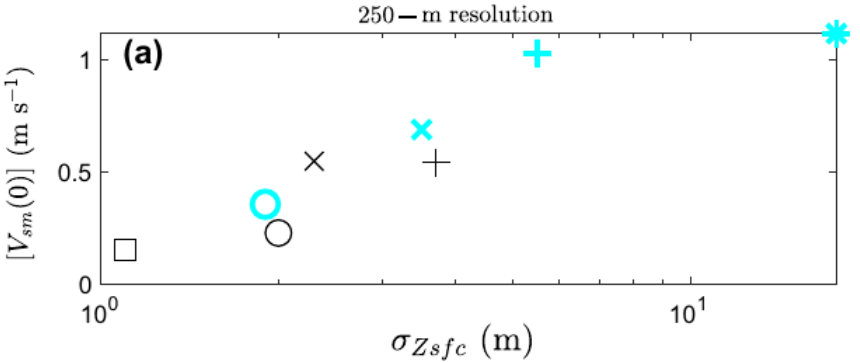
Spatial wind variation

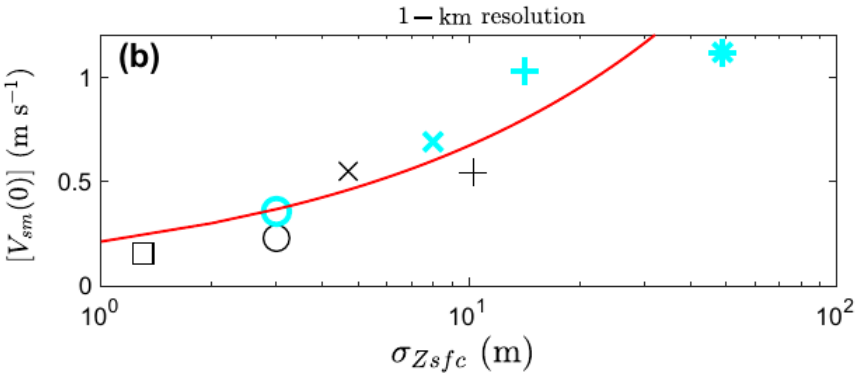
Horizontal heterogeneity

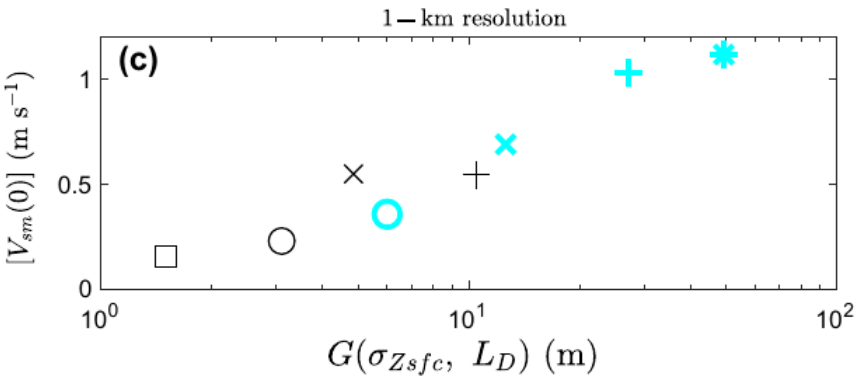
σ_{Zsfc} – terrain std between
33 m and 250 m / 1 km

$$[V_{sm}(0)] = 1.5(\sigma_{Zsfc}/50)^{0.5}$$

$$G(\sigma_{Zsfc}, L_D) = \sigma_{Zsfc} + L_D/C$$







Mahrt, Belušić & Acevedo, BLM 2021

Spatial wind variation

Horizontal heterogeneity

Consider:

$$\langle \overline{w'\theta'} \rangle \equiv -\langle C_H \rangle \sqrt{\langle V \rangle^2 + V_{sm}(0)^2}\ \langle \delta_z \theta \rangle$$

where:

$[V_{sm}(0)] = 1.5(\sigma_{Zsfc}/50)^{0.5}$ or simply $[V_{sm}(0)] = 0.5$ m/s

Mahrt, Belušić & Acevedo, BLM 2021

Concluding remarks

- In weak-wind SBL (i.e. VSBL) the usual theories and hypotheses are not applicable → events
- Models cannot properly reproduce VSBL variability
- Effects of horizontal heterogeneity on wind variability appear through terrain complexity (σ_{Zsfc})
- Distinction between VSBL and WSBL occurs automatically