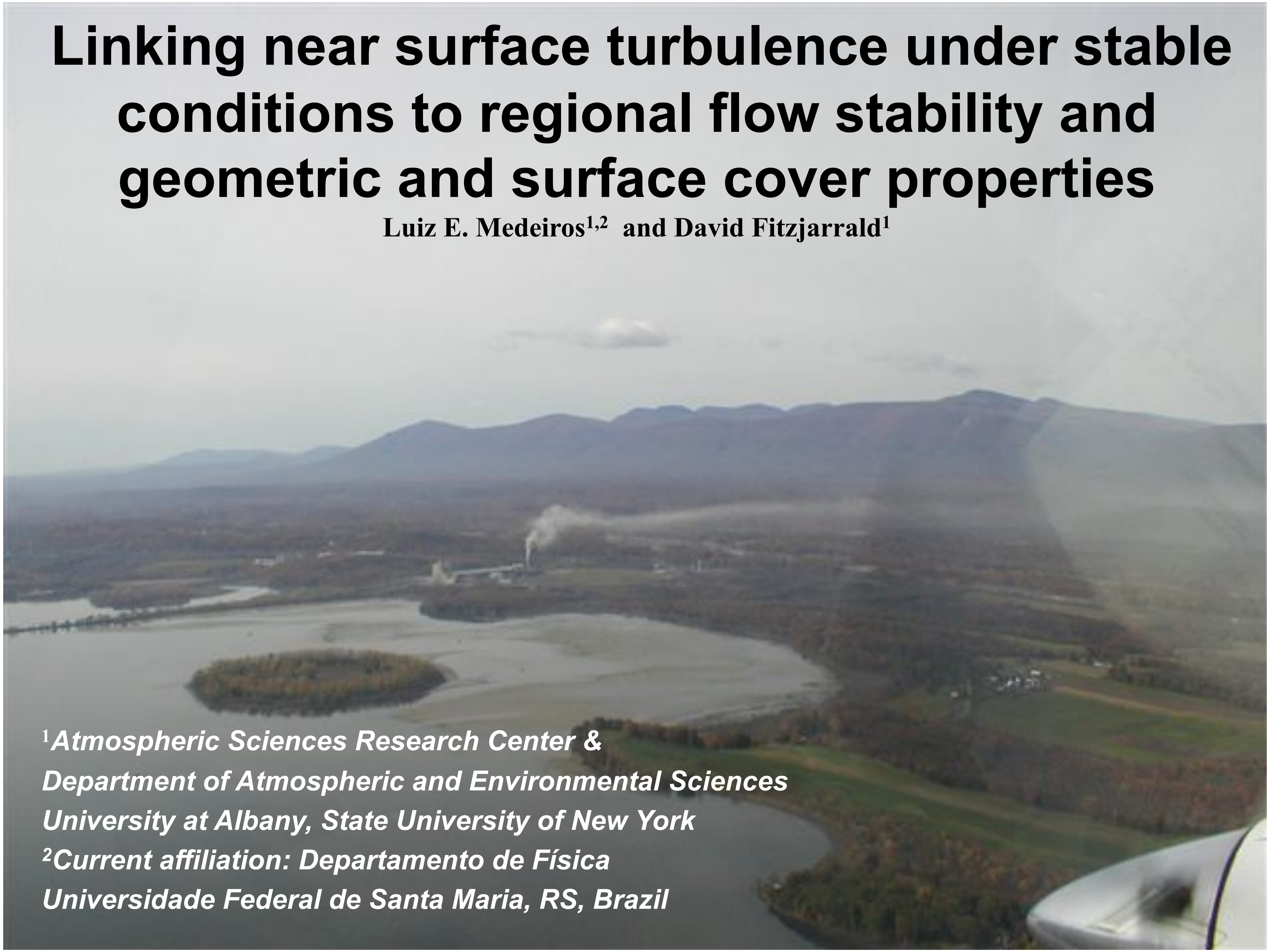

Linking near surface turbulence under stable conditions to regional flow stability and geometric and surface cover properties

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Outline

- 1. Introduction
- 2. Data
- 3. Results – Regional Richardson number (Ri_{br})
- 4. Results – Mixing and Landscape
- 5. Conclusions
- 6. Suggestion for future work

Introduction - I

➢Under very stable conditions numerical weather predictions (NWP) models have problems to forecast surface minimum temperatures, the height and strength of low level jets, the temperature inversion of SBL, the height of the SBL, and life-time of low pressure systems (low surface drag) (Viterbo et al. 1999; McCabe and Brown 2007; Steeneveld et al. 2008; Sandu et al. 2013).

➢ The very SBL usually happens under clear sky and light wind.

➢It has been shown that in the very SBL

a)Turbulence can be intermittent (Salmond and McKendry, 2002; Mahrt, 1998; Poulos et al., 2002; Nappo, 1991)

b)Turbulence can be localized (Acevedo and Fitzjarrald 2003; Nakamura and Mahrt, 2005)

c) Features of the landscape (e. g. topography and land cover) affect the distribution of surface turbulence, winds, temperatures and scalars (Acevedo and Fitzjarrald 2003; LeMone et al., 2003; Mahrt, et. al. 2001).

Introduction - II

- In most NWP models a K-Theory is used to describe the fluxes (MacCabe and Brown, 2007)

$$\overline{w'\chi'} = -K_{\chi}\left(f(\overline{Ri_b}) \right) \frac{\partial \overline{\chi}}{\partial z}$$

where

$$Ri_b = \frac{g \cdot \left(\Delta\theta / \Delta z \right)}{\theta_{ref} \cdot \left[\left(\Delta U / \Delta z \right)^2 + \left(\Delta V / \Delta z \right)^2 \right]}$$

- Different types of stability functions to adjust the amount of mixing:
  - *no mixing when $Ri_b > 1/4$ – Short tails*;
  - *artificial mixing when $Ri_b > 1/4$ – Long tails*.

$$f(Rib) = \frac{1}{1 + 10Rib}$$

Met office global model (McCabe and Brown, 2007)

- Mahrt (1987) suggested that spatial heterogeneity can be one of the reasons to justify unphysical extra mixing to occur. – Localized pockets of mixing attenuated by averaging process.

Main goals

- Try to find out if the practice of keeping unrealistic mixing above Ri_{cr} in models can be supported by real observations
- Link turbulent mixing to surface terrain characteristics

HVAMS – Intense Observational Period (IOP) - From 09/15/03 to 11/01/03

NOAA wind profiler (SCH)

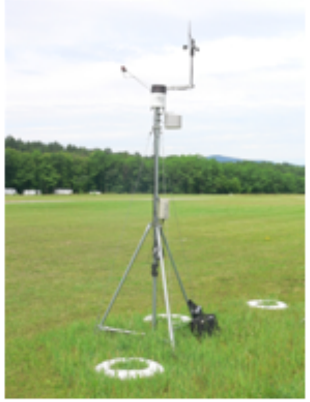
ASOS st. (ALB, POU)

Wind, temp., q and pressure every 1h. 00z and 12z soundings at ALB.

Sodar (S)

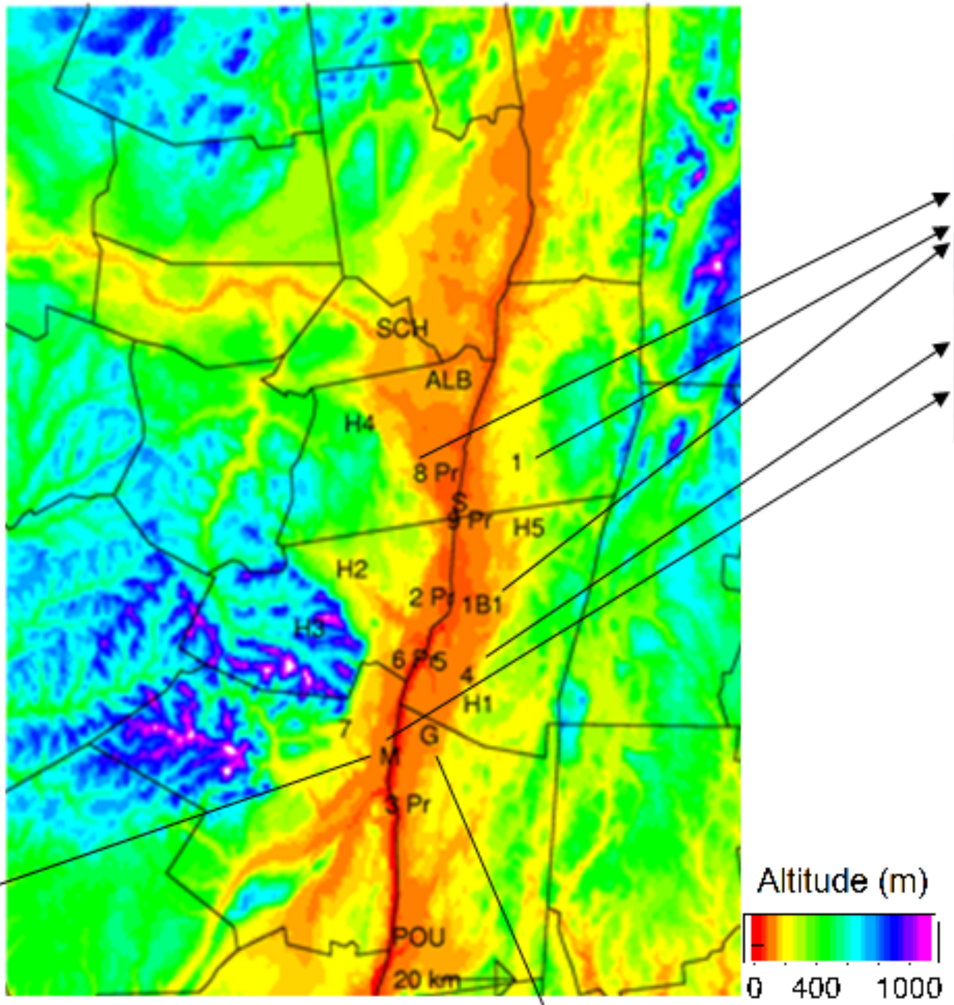
Acoustic wind profiler

HOBO weather st.



(H1 – H5)

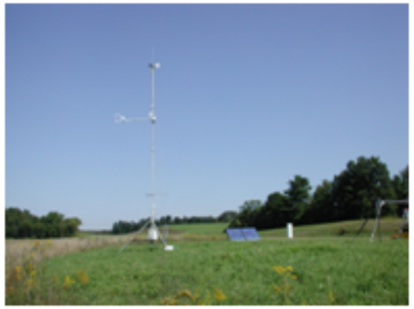
wind, temp., q, and pressure every 1 minute.



Soundings done by aircraft UWKA

vertical profiles of wind, temp., q, CO2 and O3 at 5 small airports

PAM flux st. (1 – 9)



Eddy-correlation system 10Hz, wind, temp., q, pressure and radiation. Some had CO2 and O3.

MIPS

(Microwave passive radiometer, wind profiler)

Tethered Balloon

(Wind, temp., humidity prof. w/ 5 levels)

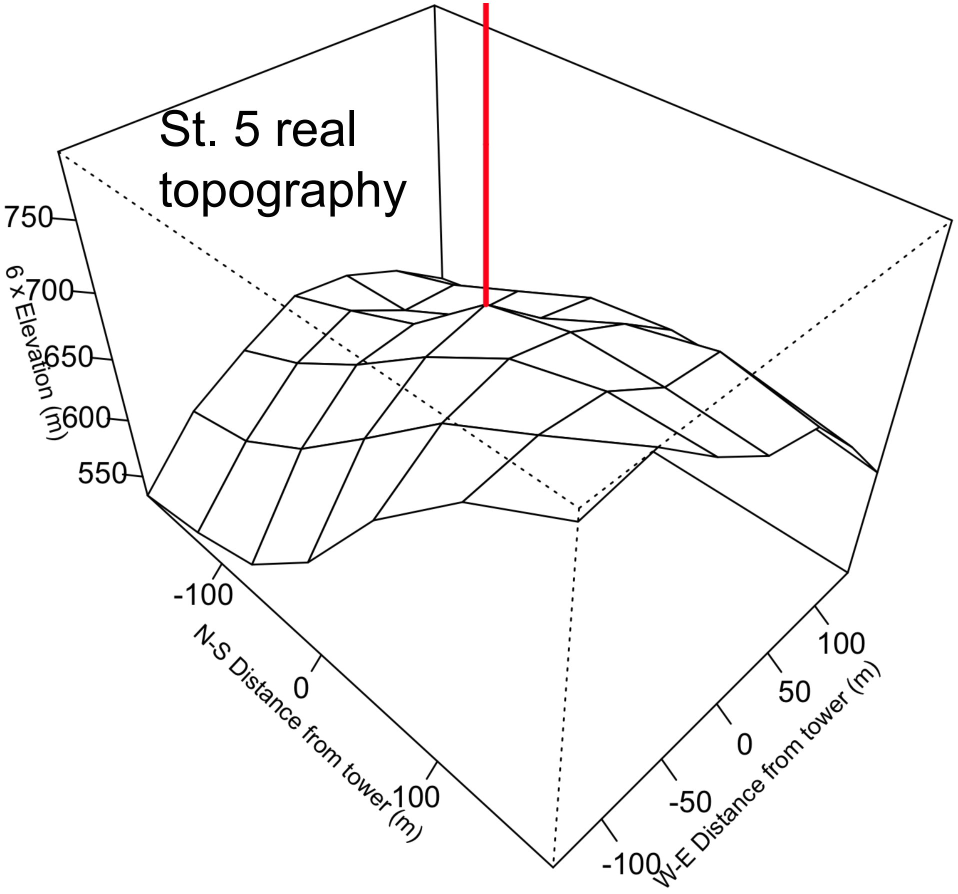
Anchor st. or st. 10

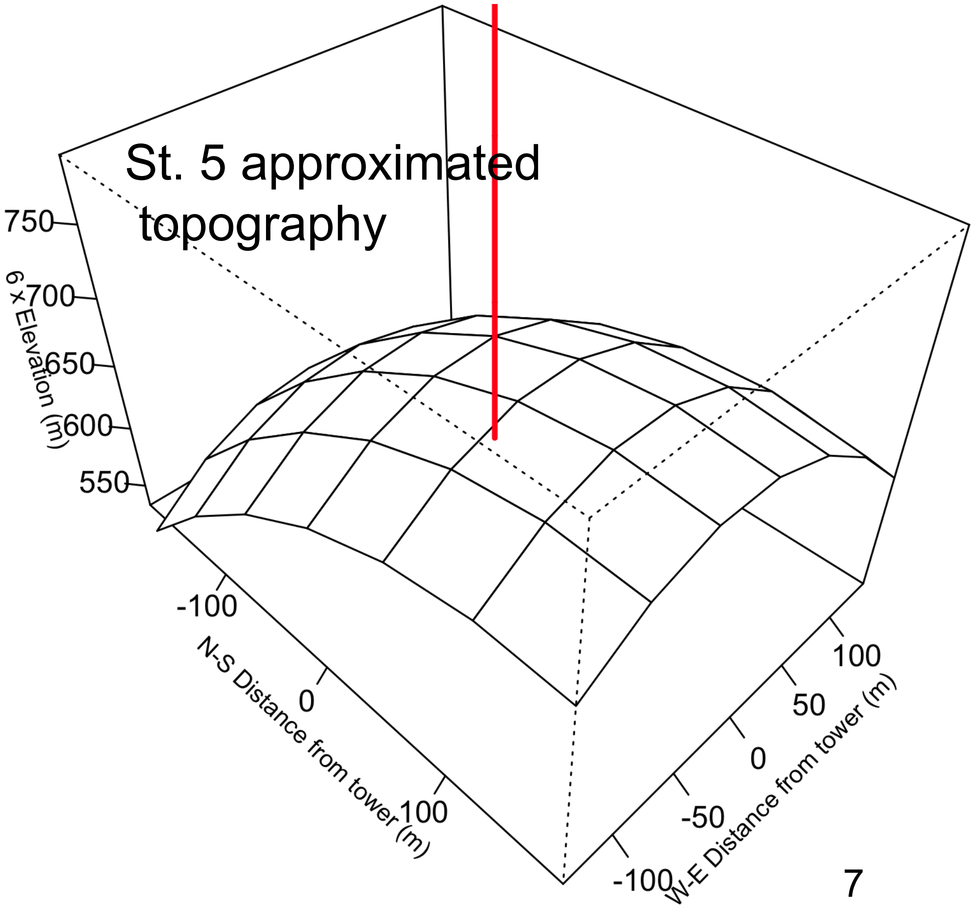
Micromet tower with eddy-correlation system 10Hz, profiles of wind, temp., and q, pressure, radiation, CO2, and O3.

2. Topographic site characteristics

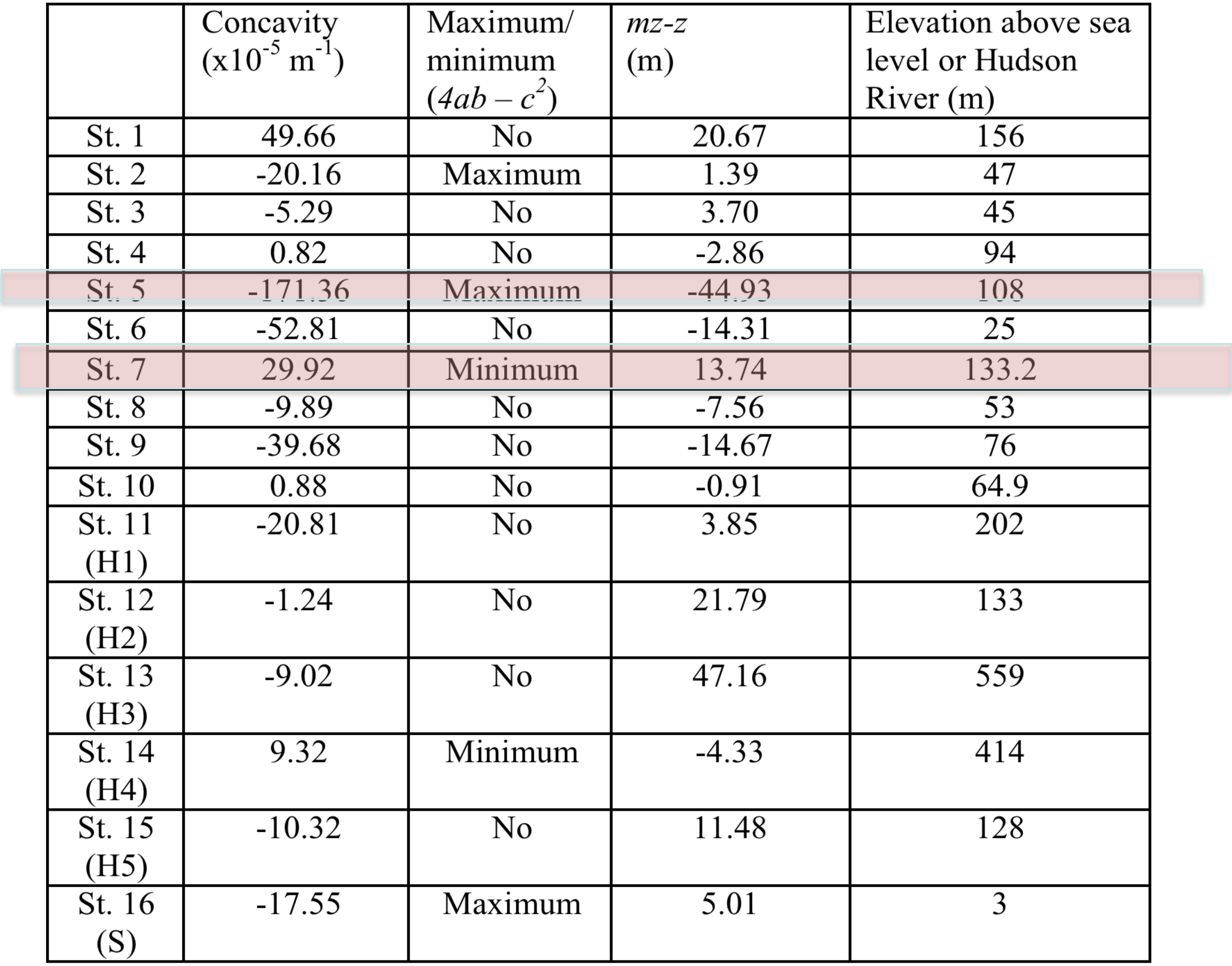
To determine local topographic characteristics of all the sites we used USGS topographic map with a ~ 30m x 30m resolution.

- Elevation (z)
- Local concavity: $\nabla^2 z(x,y)$, where $z(x,y) = ax^2 + by^2 + cxy + dx + ey + f$


St. 5 real topography


St. 5 approximated topography

2. Results - Topographic site characteristics



	Concavity (x10^{-5} m^{-1})	Maximum/ minimum $(4ab - c^2)$	*mz-z* (m)	Elevation above sea level or Hudson River (m)
St. 1	49.66	No	20.67	156
St. 2	-20.16	Maximum	1.39	47
St. 3	-5.29	No	3.70	45
St. 4	0.82	No	-2.86	94
St. 5	-171.36	Maximum	-44.93	108
St. 6	-52.81	No	-14.31	25
St. 7	29.92	Minimum	13.74	133.2
St. 8	-9.89	No	-7.56	53
St. 9	-39.68	No	-14.67	76
St. 10	0.88	No	-0.91	64.9
St. 11 (H1)	-20.81	No	3.85	202
St. 12 (H2)	-1.24	No	21.79	133
St. 13 (H3)	-9.02	No	47.16	559
St. 14 (H4)	9.32	Minimum	-4.33	414
St. 15 (H5)	-10.32	No	11.48	128
St. 16 (S)	-17.55	Maximum	5.01	3

- $(4ab-c^2) > 0$ there is local maximum (a and b < 0) or minimum (a and b > 0). When is local minimum there is possibility of cold air pooling.

- $(4ab-c^2) \leq 0$ no maximum or minimum might be hyperbolic parabaloid (saddle point) or parabolic cylinder .

2. Sheltering

$TF(\phi) = U_{st}(\phi) / U_{max\ network}(\phi)$

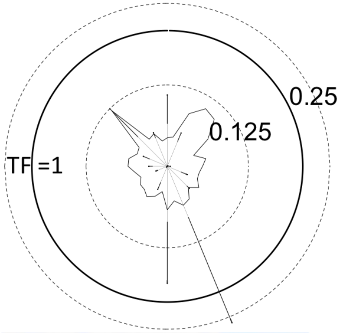
ϕ = wind direction

North

Local landscape/Sheltering

Station 7
-Small agricultural clearing
-Site with worst exposure
in the network

West

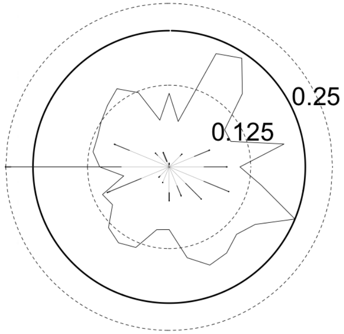


East

South

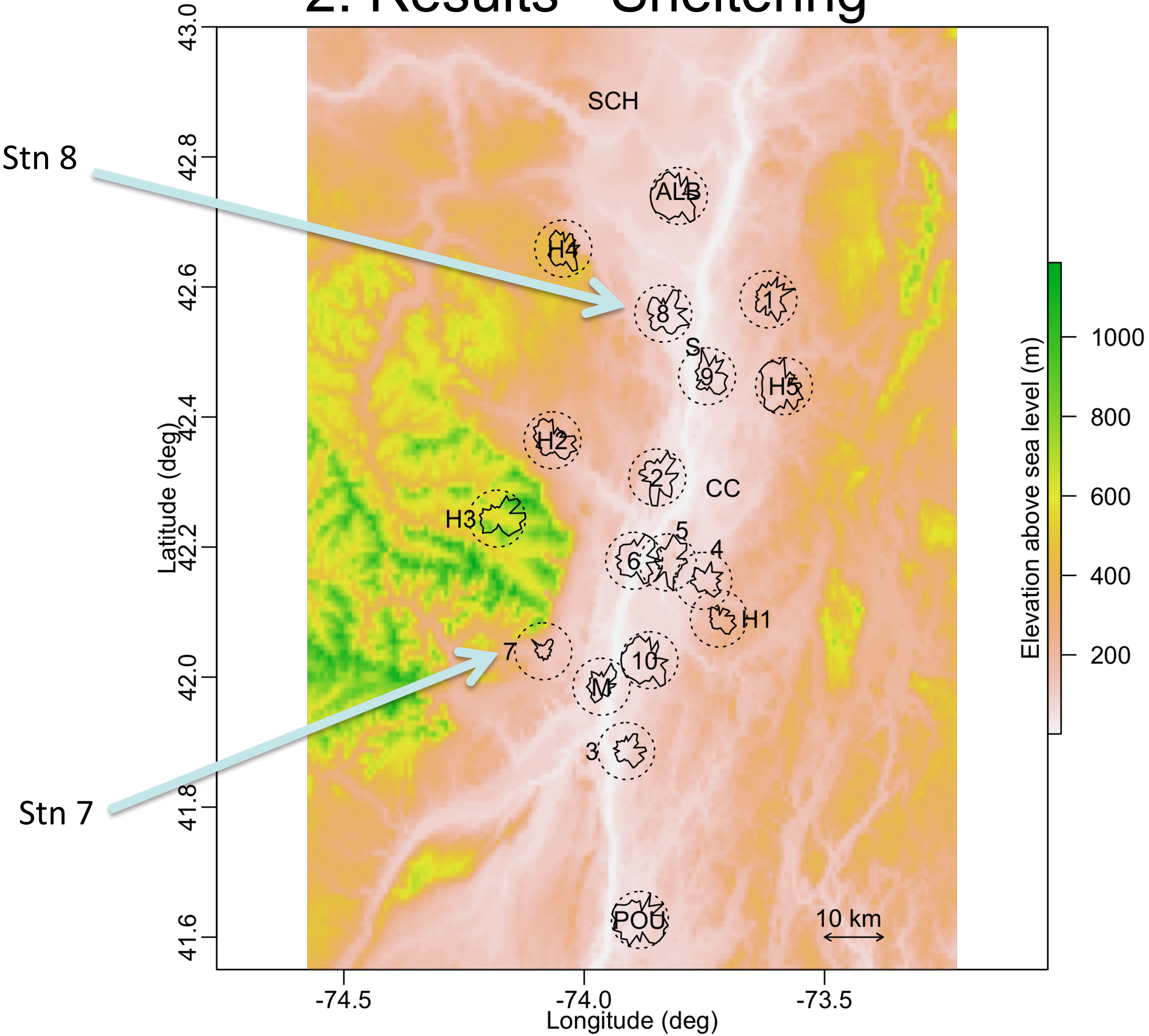
Station 8
-Field surrounded by small
sparse trees
-One of the sites with best
exposure among the flux
stations

Facing unknown direction

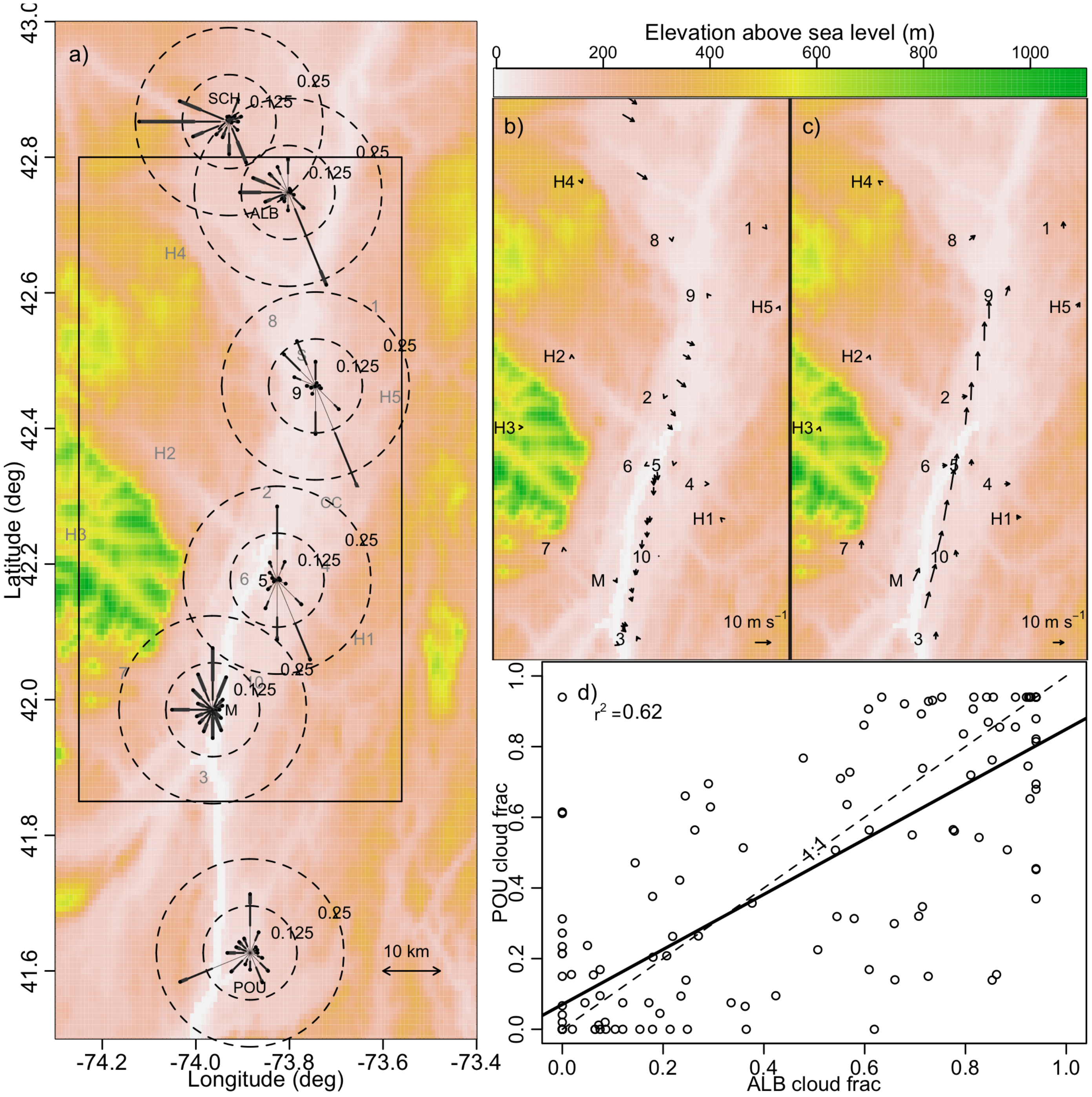


Facing unknown direction

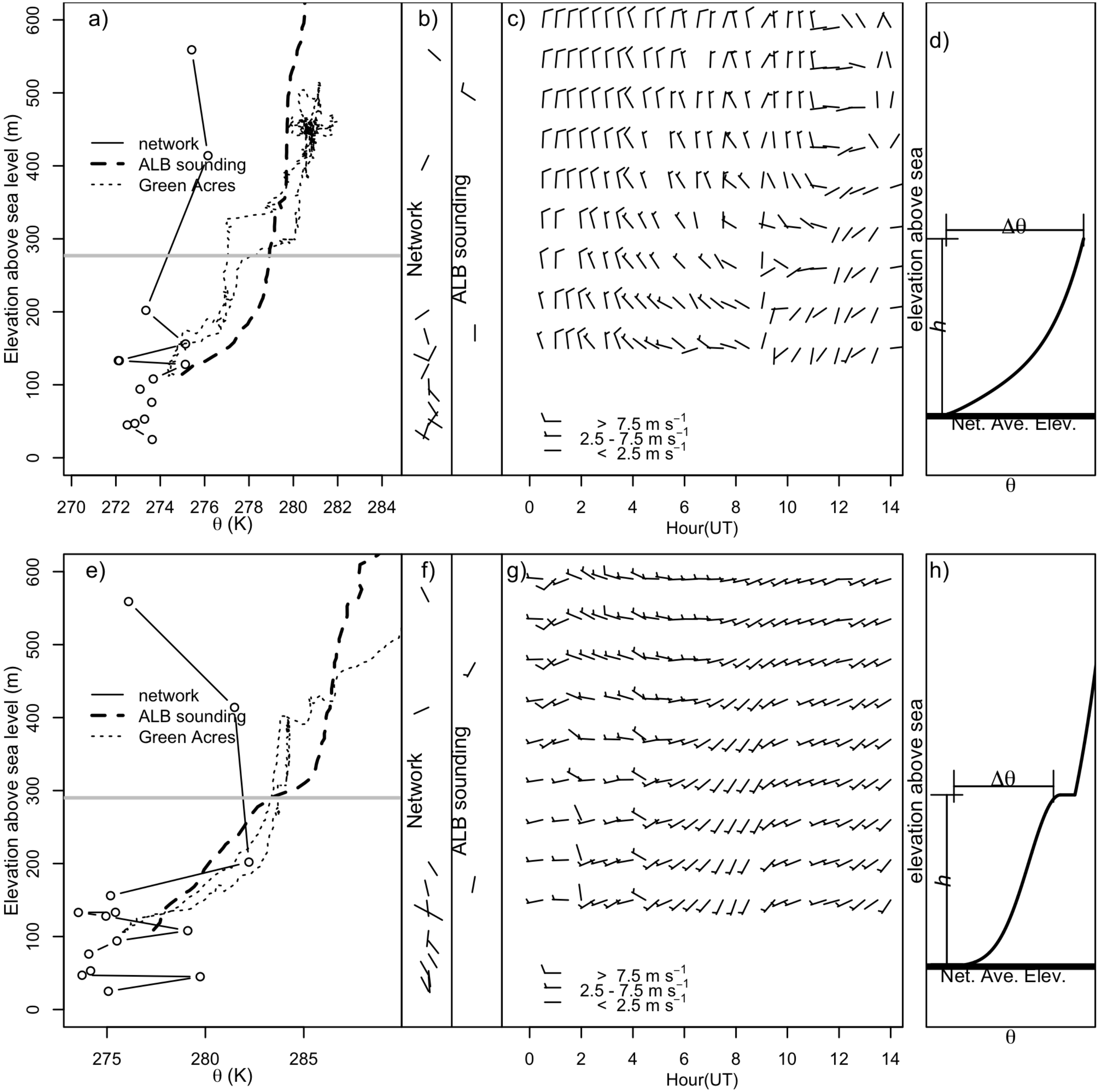
2. Results - Sheltering



3. Mesoscale influences


a)
SCH
ALB
POU
M
H1
H2
H3
H4
H5
CC
0.25
0.125
10 km
Latitude (deg)
Longitude (deg)
43.0
42.8
42.6
42.4
42.2
42.0
41.8
41.6
-74.2
-74.0
-73.8
-73.6
-73.4
Elevation above sea level (m)
0
200
400
600
800
1000
b)
c)
10 m s^{-1}
d)
r^2 =0.62
1:1
POU cloud frac
ALB cloud frac
0.0
0.2
0.4
0.6
0.8
1.0

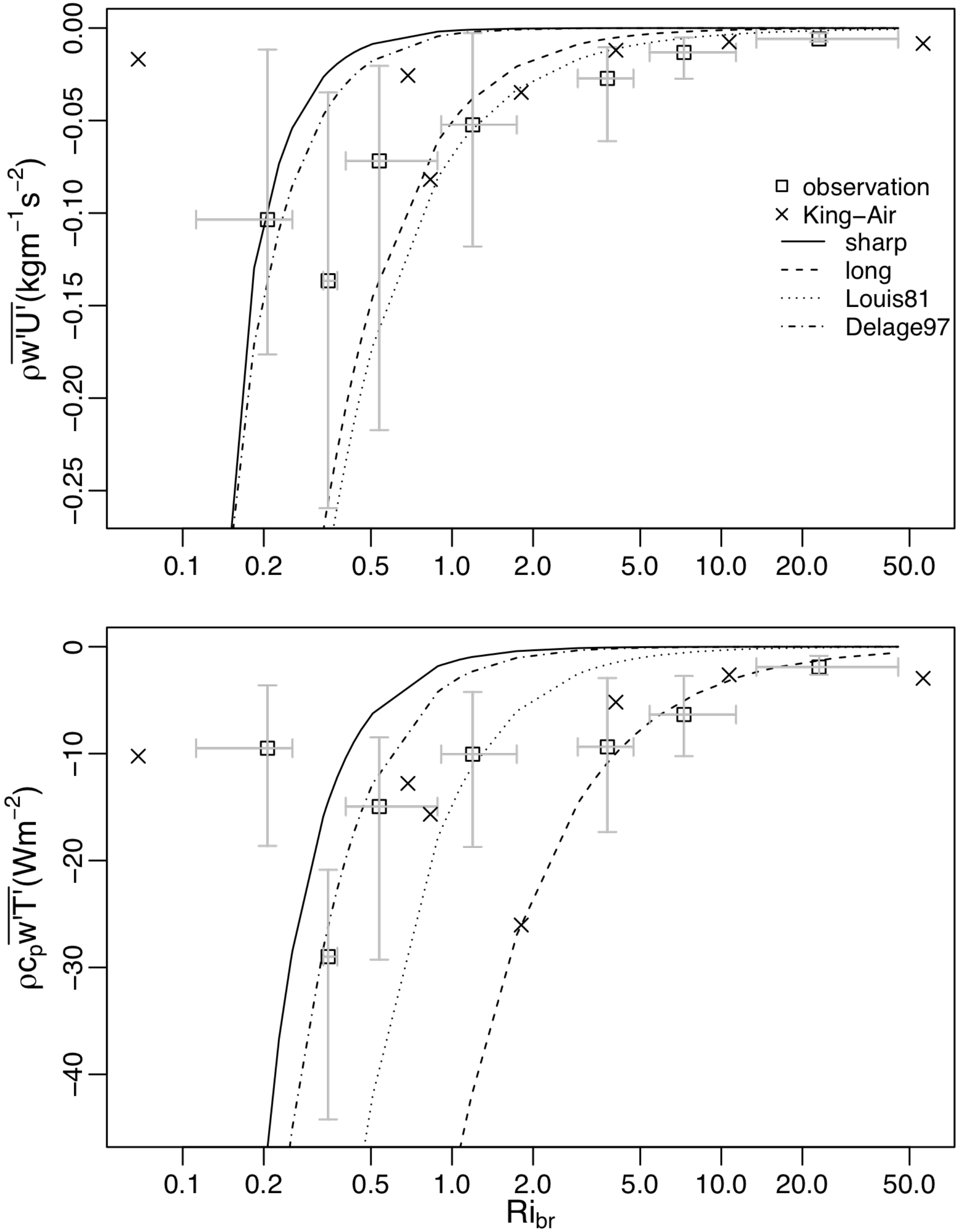
3. Seeking a regional Ri_b (Ri_{br})



- We need an upper and lower potential temperatures θ and winds U, and a height h .

$$Ribr = \frac{g}{\theta_{ref}} \frac{h(\theta_{sbl} - \theta_{\min}(network))}{U^2}$$

3. Results - Mesoscale influences



$$\overline{w'\chi'} = -l^2 \left(\frac{\Delta\overline{U}}{\Delta z}\right)\left(\frac{\Delta\overline{\chi}}{\Delta z}\right) f_a(\ Ribr\ )$$

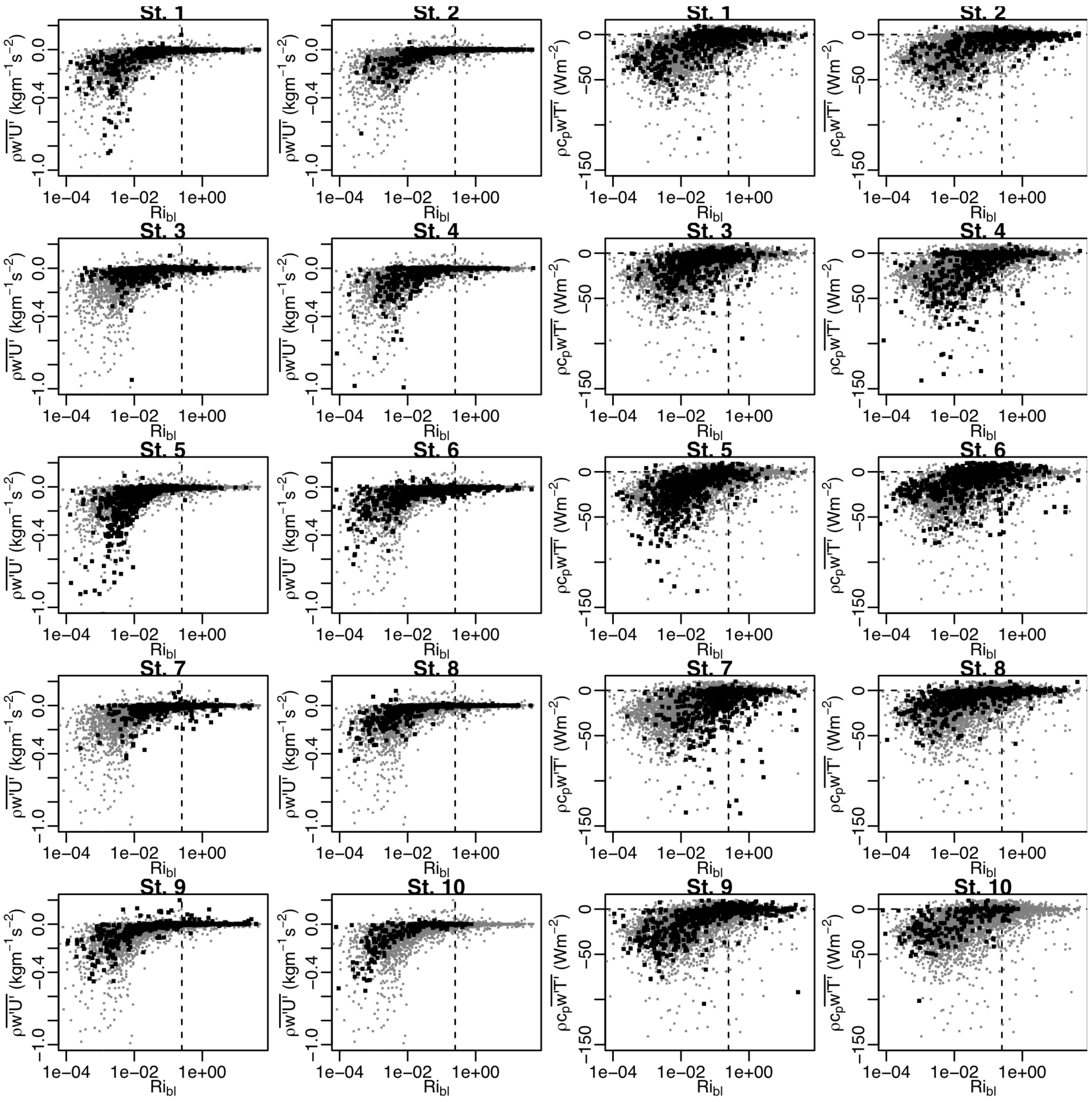
- There is still flux for $Ri_{br} > Ri_{cr} = 0.25$

- Sharp-tail and Delage97 underestimate fluxes $Ri_{br} > 1/4$.

- Long-tail and Louis81 overestimate fluxes when stability is weak.

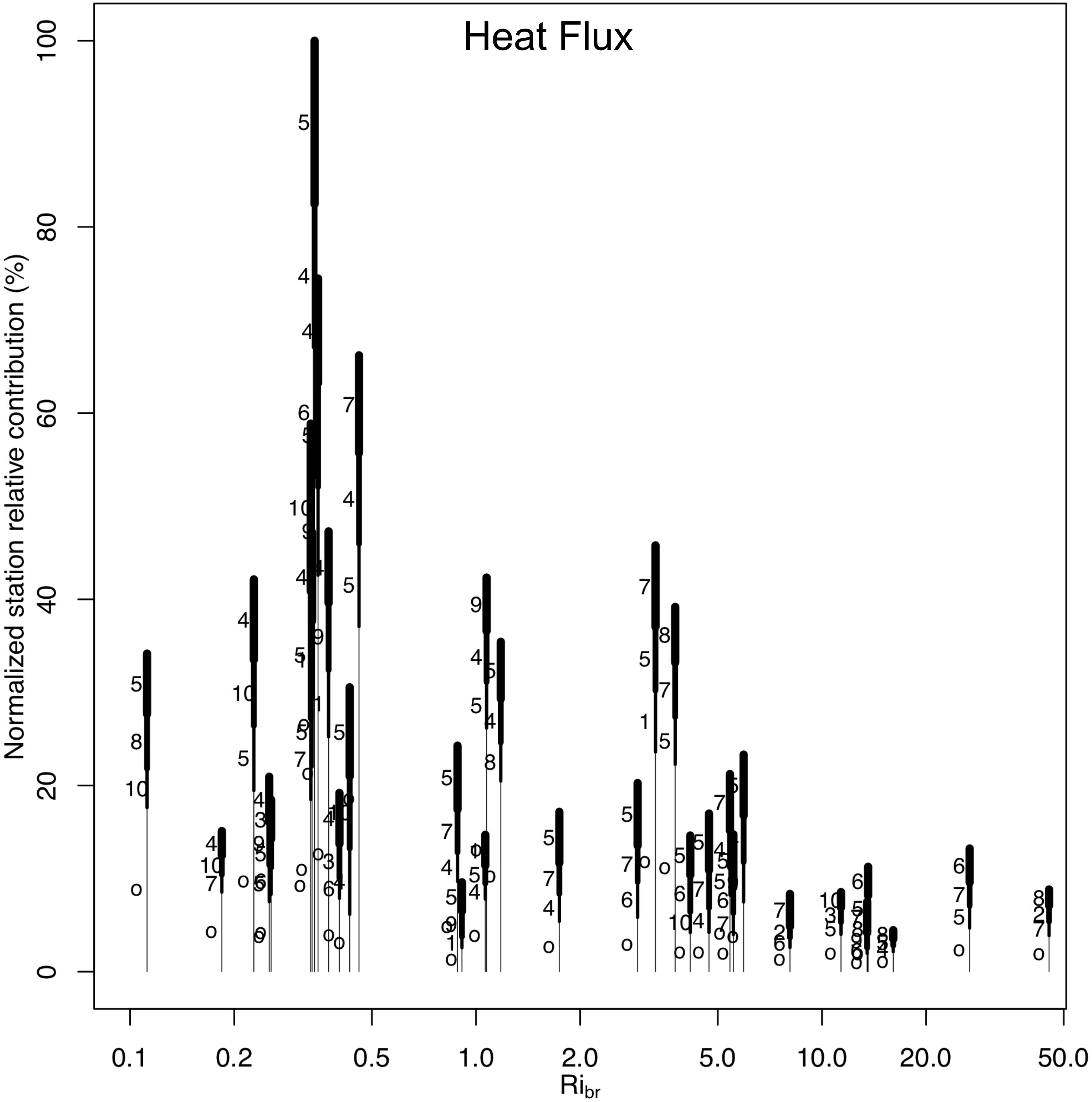
- No common model flux parameterization is consistent with HVAMS

4. Fluxes and the local bulk Ri_b (Ri_{bl})

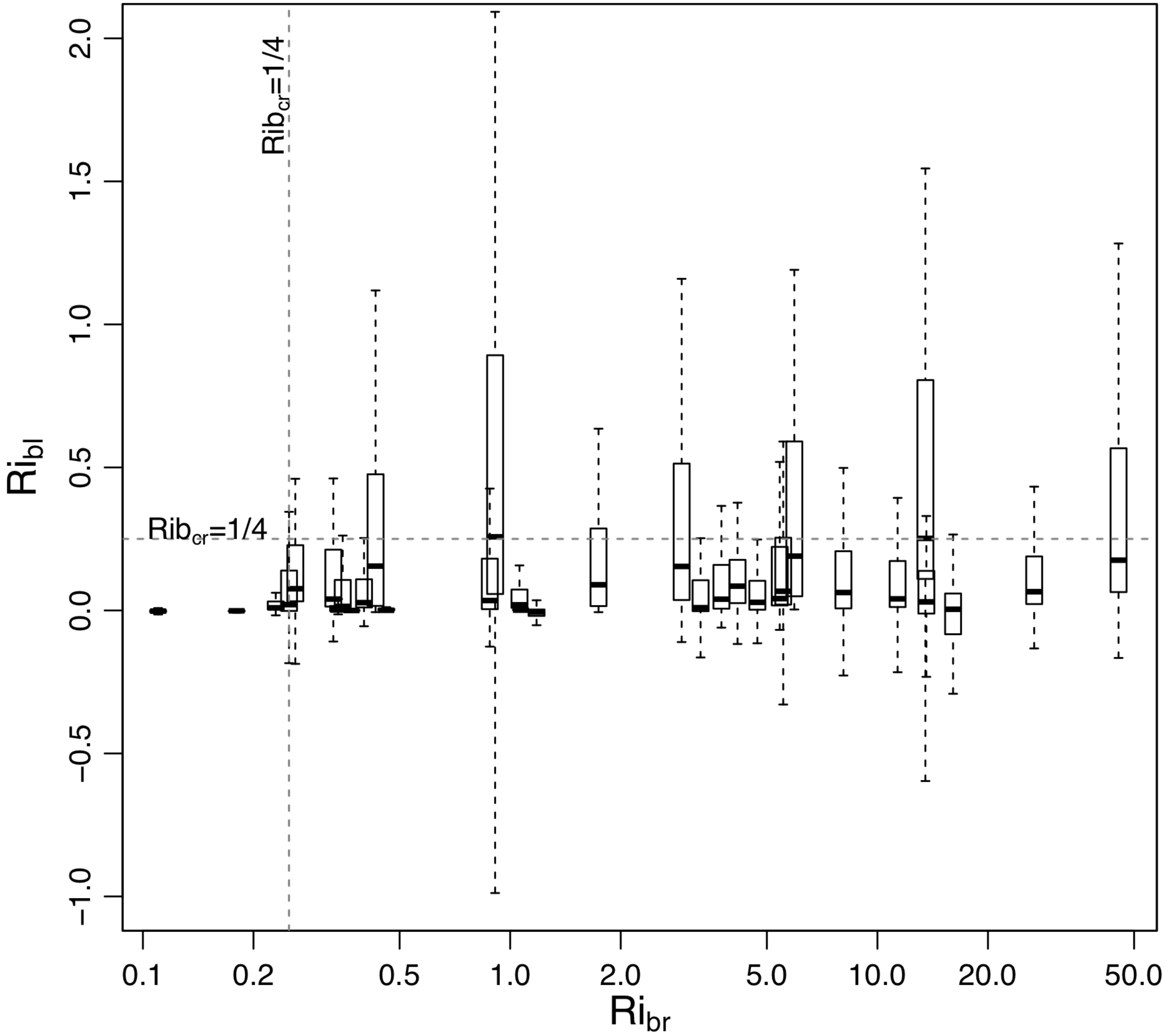


The critical value of ¼ for “on and off” turbulence still approximately works for the poorly sited HVAMS stations. However, there is no guarantee that in a same night all places in region will have same local stability.

4. Local flux contribution to regional flux

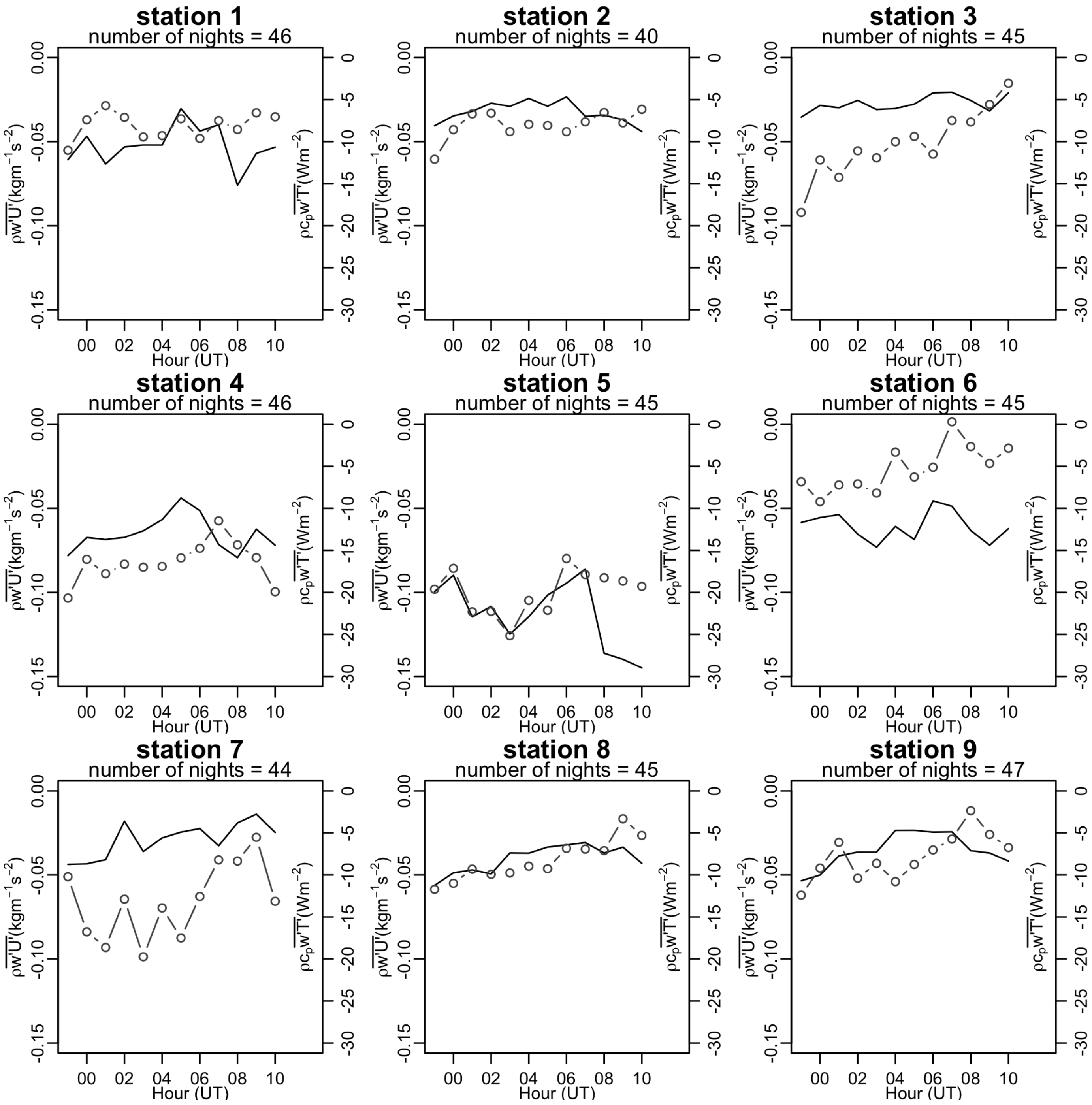


4. Local stability in terms of regional stability



Considering only nights with $Ri_{br} > 2$ the network average momentum and heat fluxes are, respectively, -0.012 kg m^{-1} s^{-2} and -4.32 W m^{-2}. The contribution of local fluxes at supercritical stability account to only 6 % and 8 % of the *exceeding* network momentum and heat fluxes, respectively. This is clearly not a serious concern.

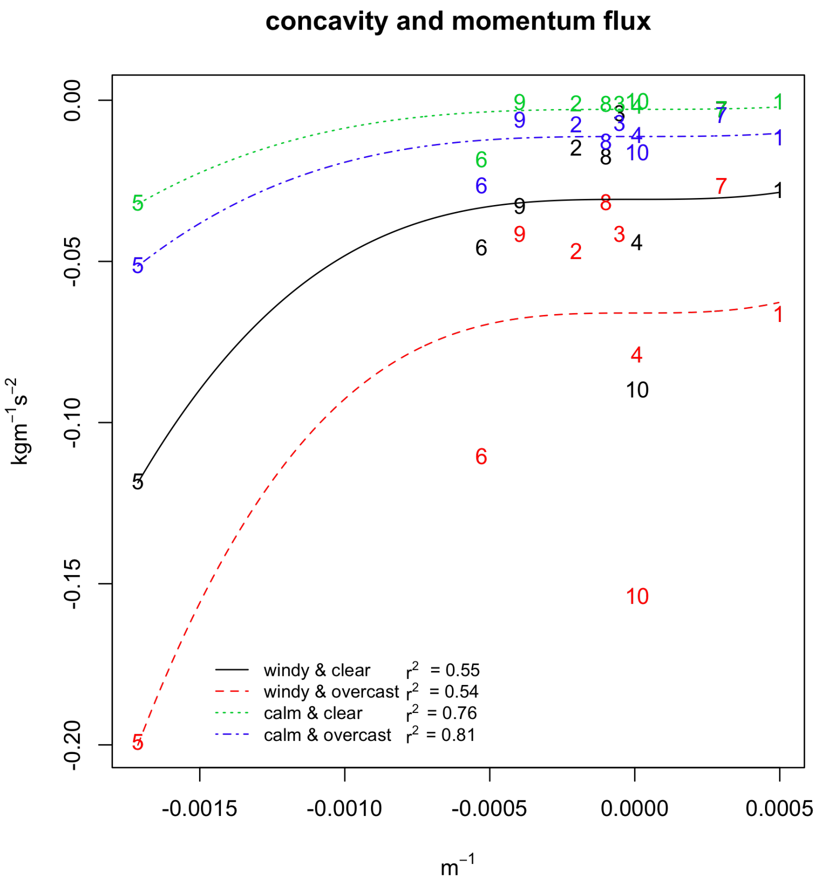
4. Results – Nocturnal average fluxes for all IOP



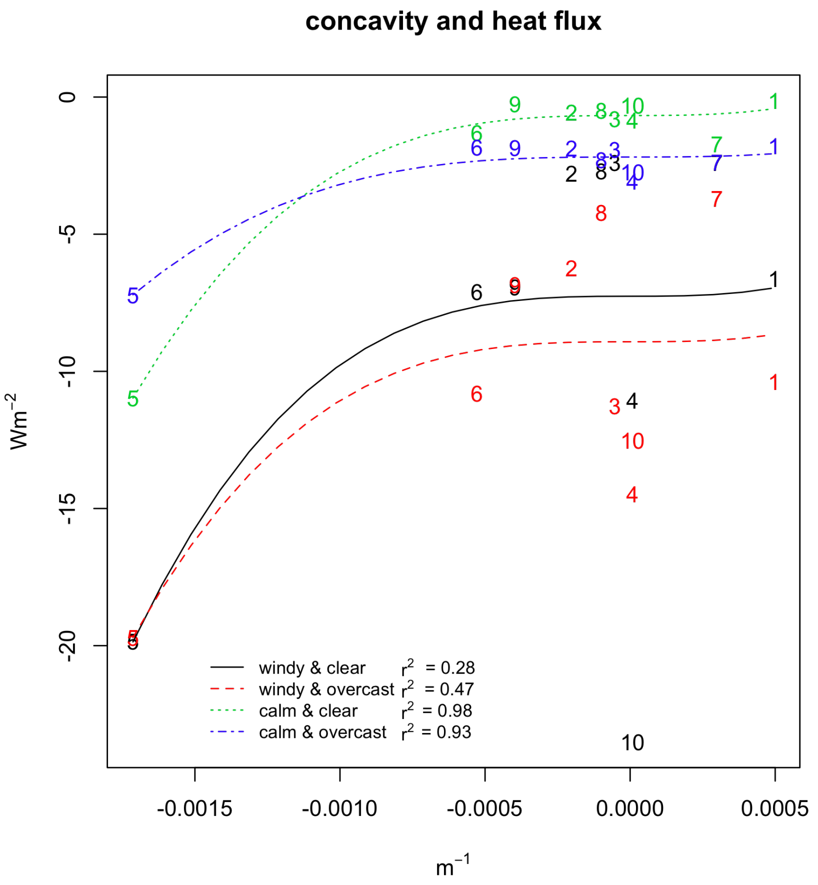
Hour binned averaged periods for momentum and heat flux during the IOP (50 nights). Black solid line = momentum flux (left axis)
line & circles = heat flux (right axis).

4. Results – Landscape and mixing

Fluxes and concavity



concavity and momentum flux



concavity and heat flux

$r^2 \sim 0.8$ for windy conditions

$r^2 \sim 0.5$ for calm conditions

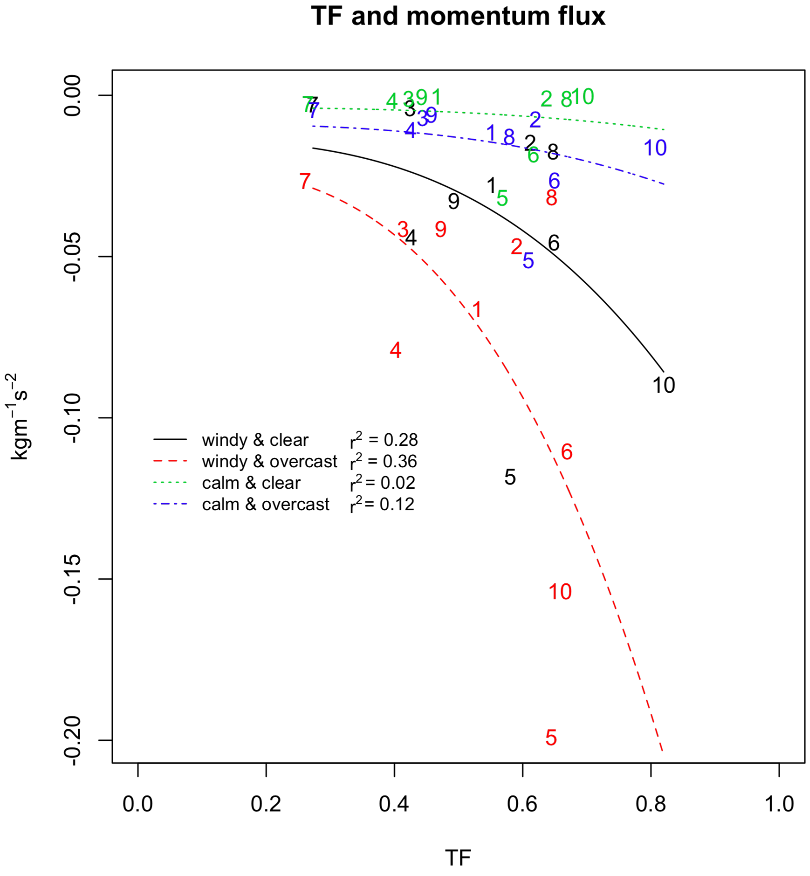
$r^2 \sim 0.9$ for windy conditions

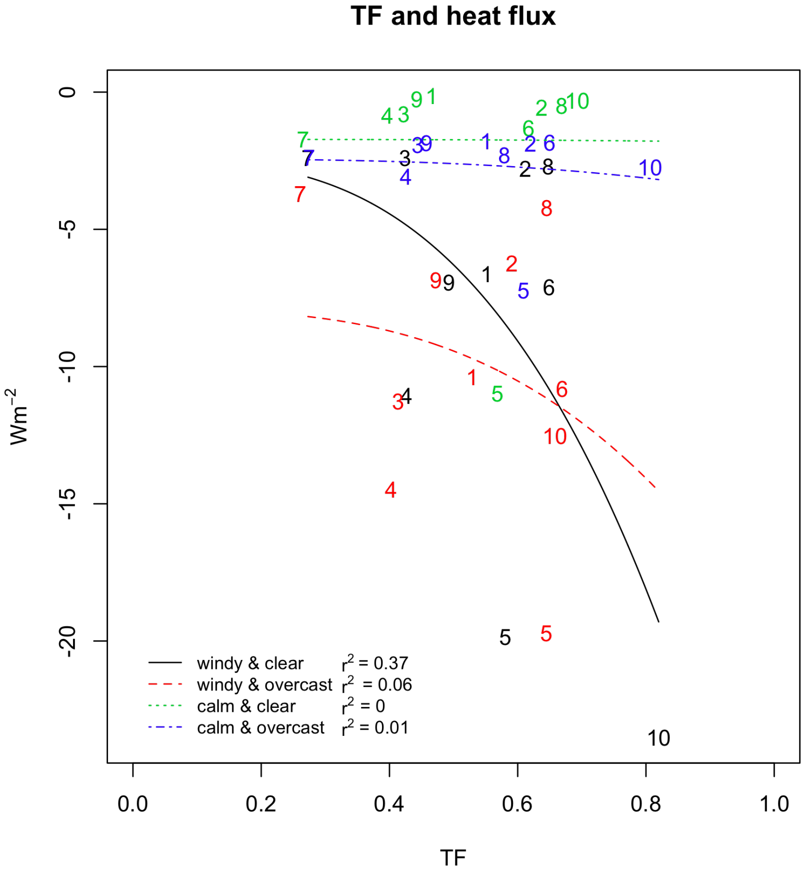
$r^2 \sim 0.3$ for calm conditions

No distinction between overcast and clear

4. Results – Landscape and mixing

TF and Fluxes


TF and momentum flux


TF and heat flux

r^2 ~ 0.3 for windy conditions
r^2 ~ 0.1 for calm conditions

r^2 ~ 0.2 for windy conditions
r^2 ~ 0 for calm conditions

No distinction between clear and overcast

5. Conclusion

a) Mesoscale influences

- Observations show that the need for extra mixing above Ri_{cr} in NWP models is a result of spatial averaging.

- Model formulations for $f(Ri_{br})$ do not describe the HVAMS results.

The short-tail and Delage 97 stability functions perform better when the stability is weak, but underestimate otherwise. The long-tail and Louis81 perform well for stronger stability but overestimate otherwise.

5. Conclusions

b) Turbulent fluxes, concavity and TF

•Local surface concavity is more important for conditions of calm winds and less important for windy conditions.

•In contrast to concavity effects, *TF* tends to be more influential in windy conditions than in calm winds. During windy conditions the overall fluxes are higher and differences in the fluxes due to obstructed and open direction are therefore higher too. These results perhaps would be clearer if there were a wider range of *TF* with many more stations.

Suggestions for future work

- With 100 stations (such as the proposed NCAR CentNet; Oncley et al., 2010), the effects of local curvature, *TF*, and other surface parameters on mixing.

- It is extremely important to do an assessment of these landscape indices before siting surface stations, to isolate the effects of a particular landscape parameter.

Thank You!