Measuring Divergence & Mean Vertical Velocities During the Afternoon Transition

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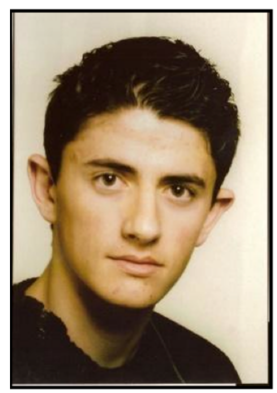


Divergence Estimate - Triple Sonde Launches

Site 1: Main super-site

Site 2: Meteo-France frequency sounding site

Site 3: Capvern Sodar Site

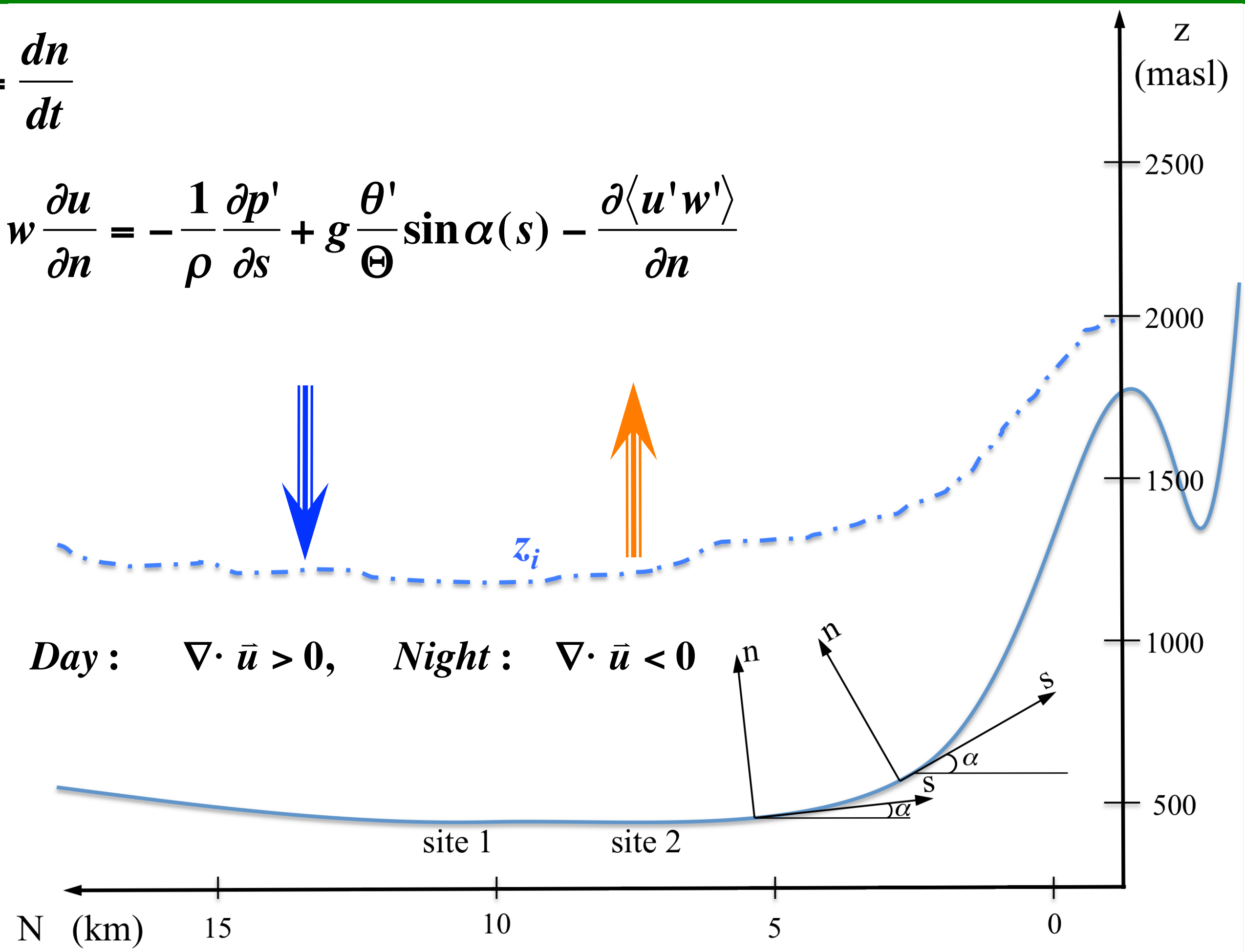
<u>Hypothesis:</u>

Simultaneously launched sondes can measure the wind field divergence accurately enough to estimate vertical velocity at the top of the ABL by continuity.

Slope Winds & Vertical Motion

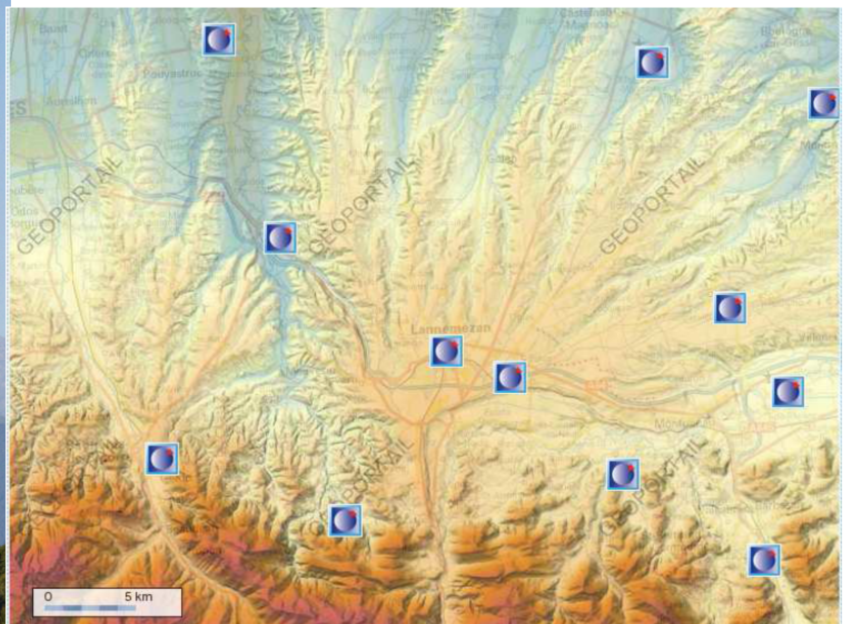
$$u = \frac{ds}{dt}, \quad w = \frac{dn}{dt}$$

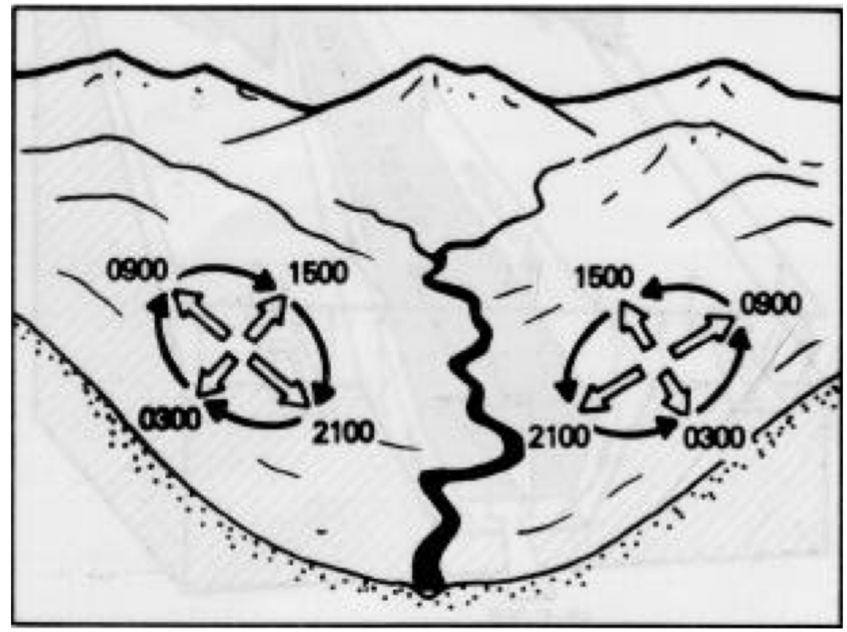
$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial s} + w\frac{\partial u}{\partial n} = -\frac{1}{\rho}\frac{\partial p'}{\partial s} + g\frac{\theta'}{\Theta}\sin\alpha(s) - \frac{\partial\langle u'w'\rangle}{\partial n}$$



Daytime buoyant acceleration has a magnitude dependent on the inclincation angle, a, and thus in principle could naturally generate near surface *divergence*, with *convergence* generated in the evening.

Flow Influence of N-S Valley





[Whiteman, 1990]

Slope winds and valley winds will generate daytime *divergence,* and evening *convergence* especially near the mouth of the N-S valley due south of the experiment.

The Budget for the ABL Height

Because the observations of boundary layer height, defined by the inversion base, z_i, are usually at a fixed location, its rate of change may have an advective component especially in the complex terrain of BLLAST.

We begin with a complete budget equation for the local inversion height, z_i:

$$\frac{\partial z_i}{\partial t} = W(z_i) + w_e - \left(U \frac{\partial z_i}{\partial x} + V \frac{\partial z_i}{\partial y} \right)$$

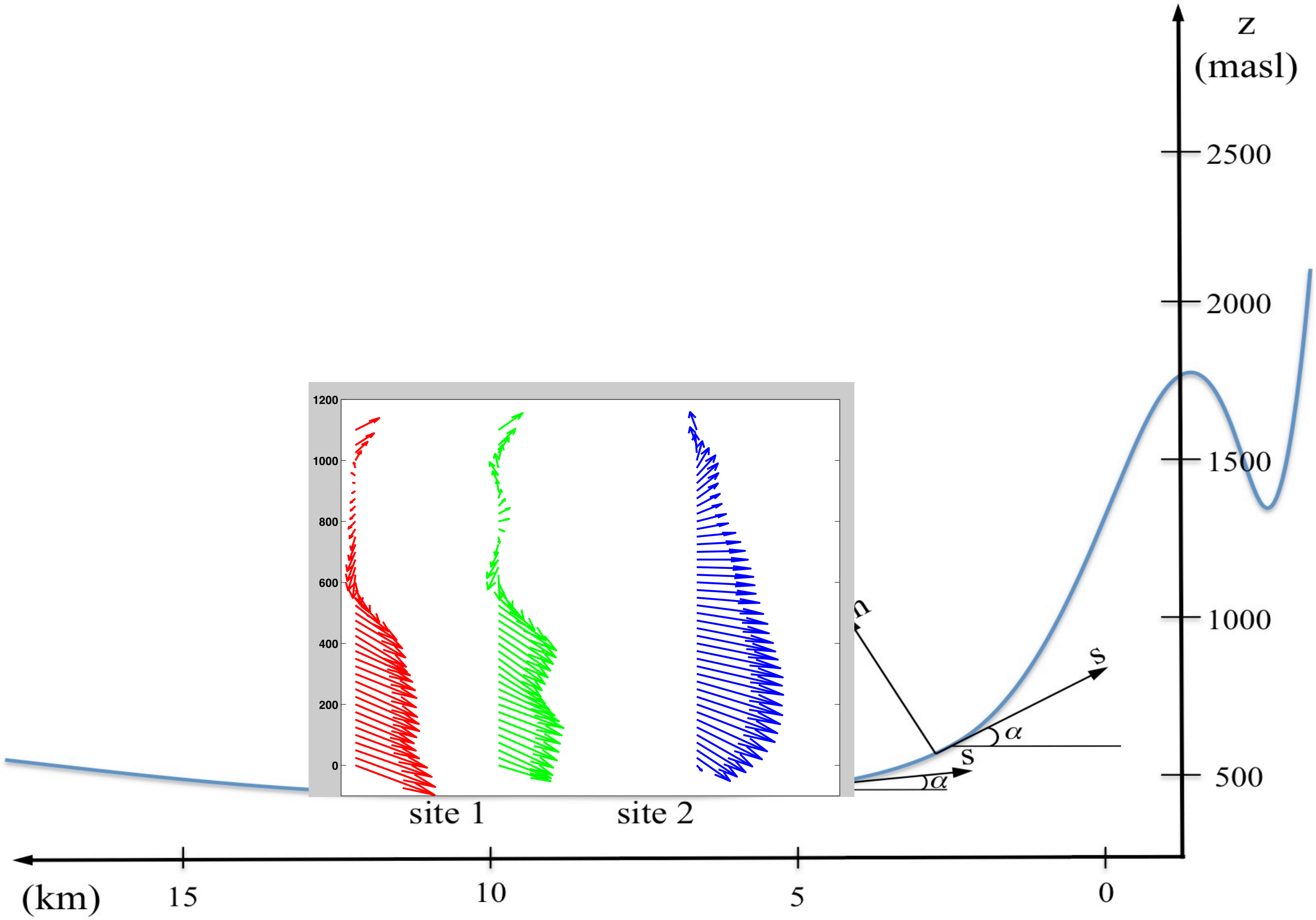
~ (-2 cm/s) ~ (-3 cm/s) ~ (10 cm/s) ~ (-8 cm/s)

$\frac{\partial z_i}{\partial t}$ Trend can be observed by UHFs *or* frequent radiosondes

$W(z_i) = \int_{z_i}^{0} \left(\frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} \right) dz$ by the triple sonde launches

$U \frac{\partial z_i}{\partial x} + V \frac{\partial z_i}{\partial y}$ Advection may be observed with 3-radiosondes *or* aircraft

Winds Relative to Terrain - IOP11 (05/07)



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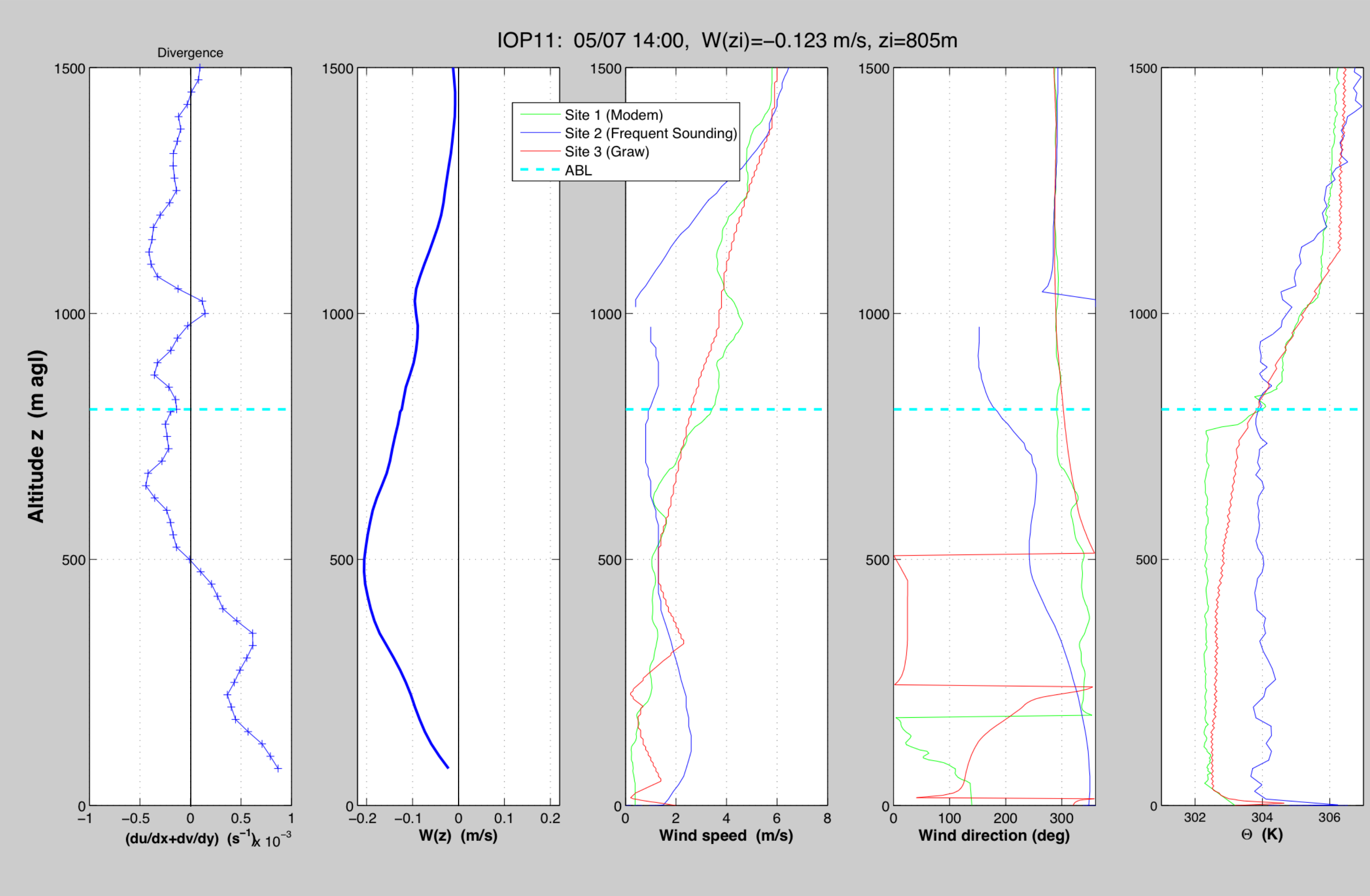
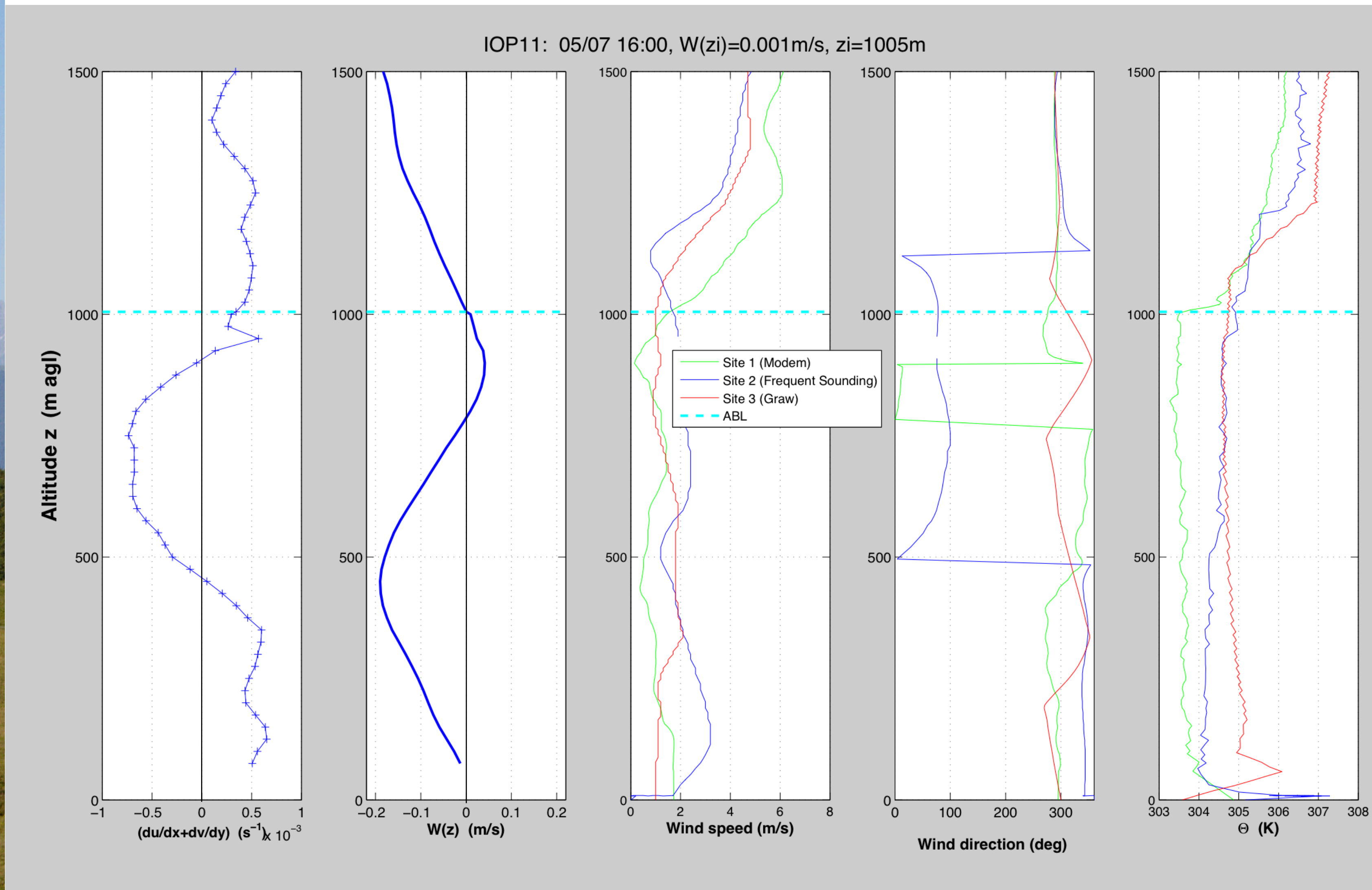
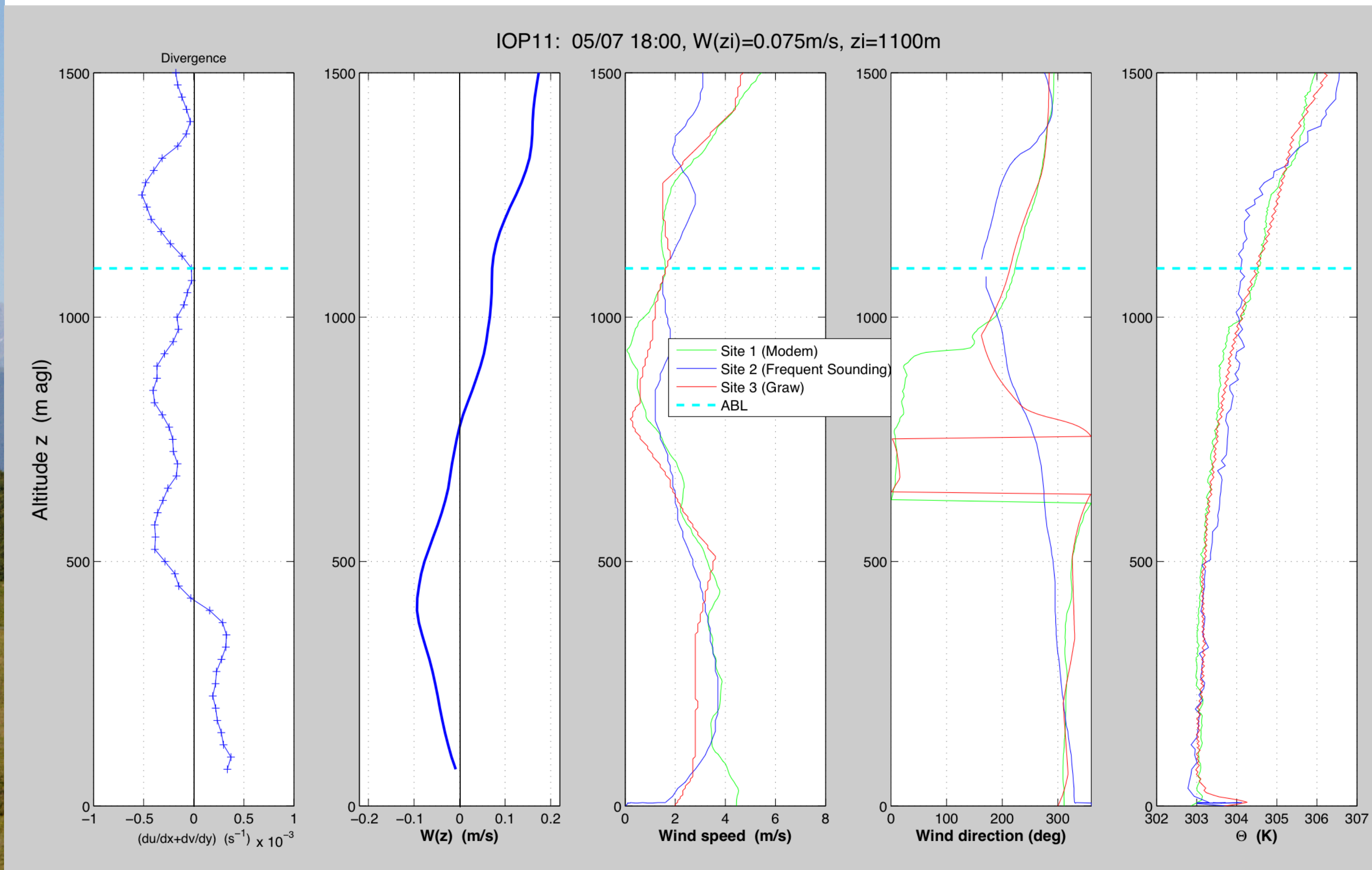
Divergence/Subsidence IOP11, 14:00



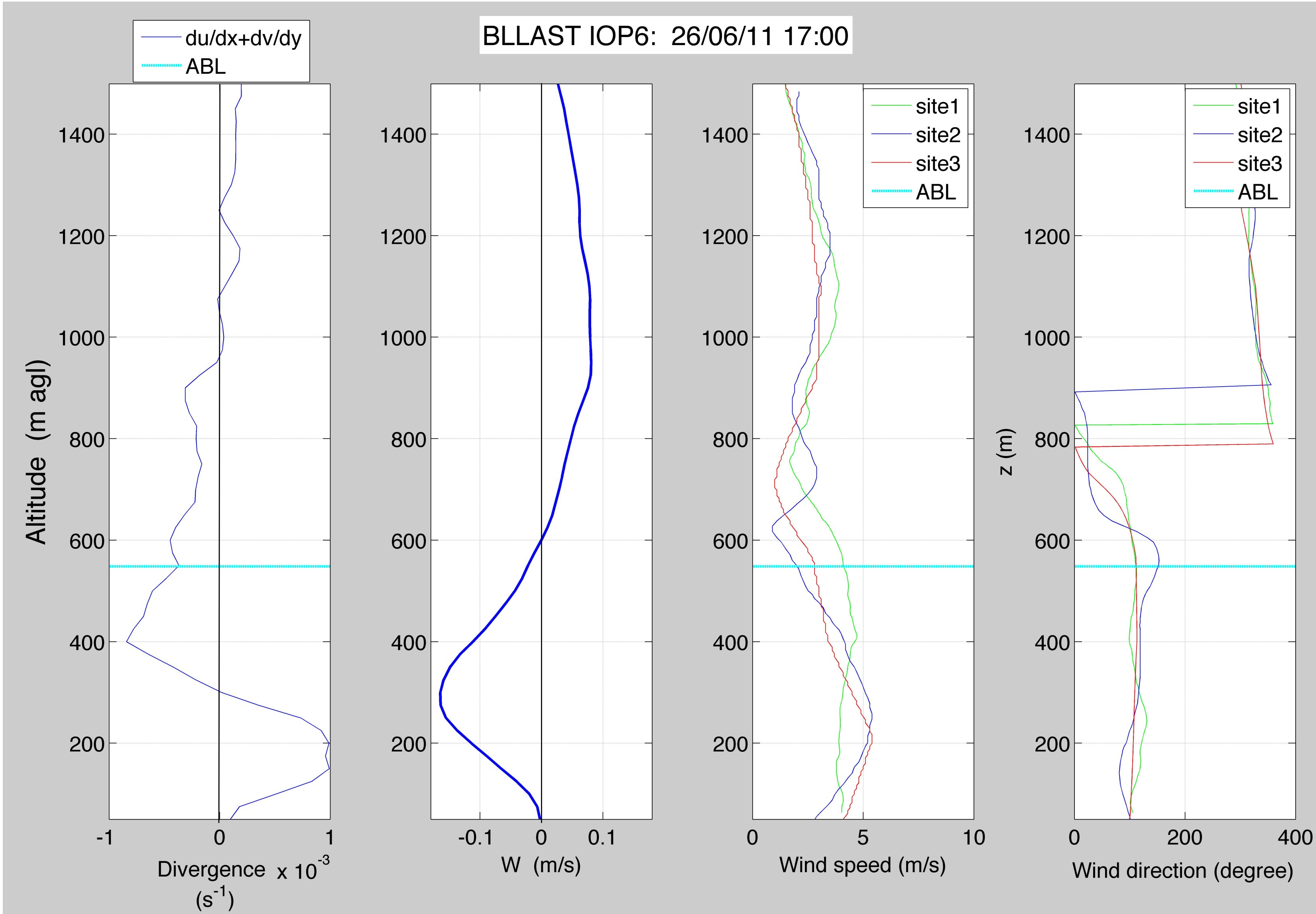
Divergence/Subsidence IOP11, 16:00



Divergence/Subsidence IOP11, 18:00

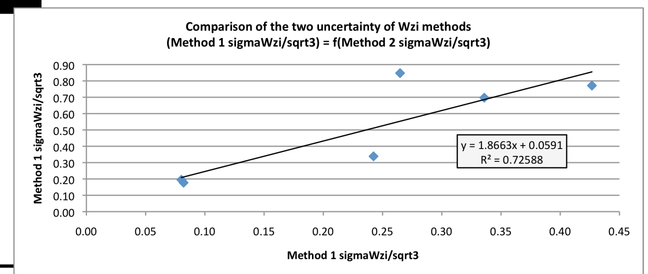


Divergence/Subsidence Measurements



Estimates of Error in W(z)

Date	H Ref	Observed Fits Uncertainty	Integral Scale Uncertainty
0626	17	0.0801	0.1950
0627	14	0.3358	0.6973
0627	17	0.0820	0.1772
0705	14	0.2424	0.3386
0705	16	0.4267	0.7715
0705	18	0.2648	0.8477
Averages :		0.2386	0.5045



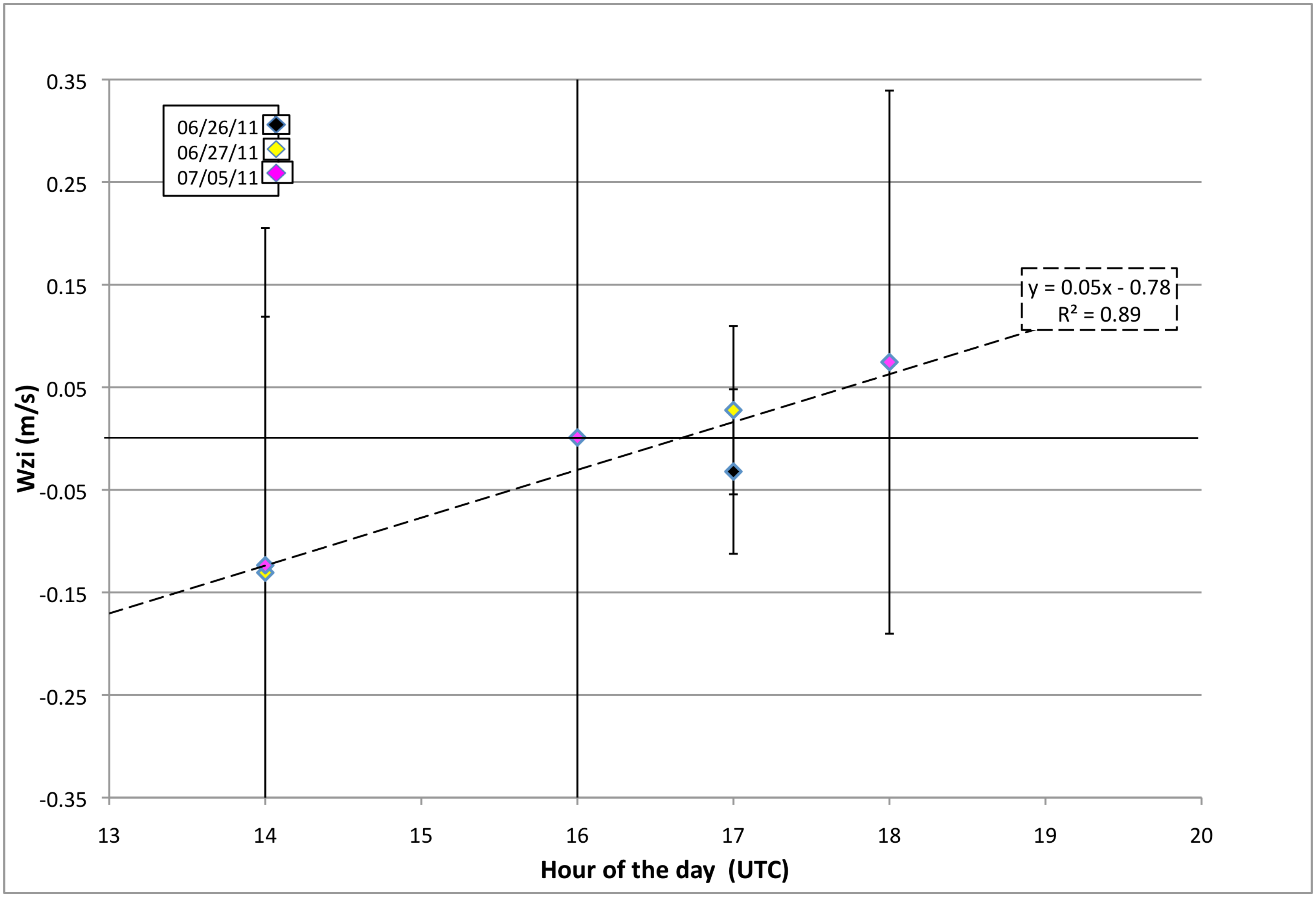
Method 1: Uncertainty due to limited sampling time, ***T*** (~3 min of balloons in ABL), relative to Eulerian integral time scale, ***τ***, (~0.5 z_i/U, [Lenschow & Stankov, 1986])

$$\sigma^2 \cong \frac{2\langle u^2 \rangle \tau}{T}, \quad \tau = \int_0^\infty \rho(t)\,dt$$

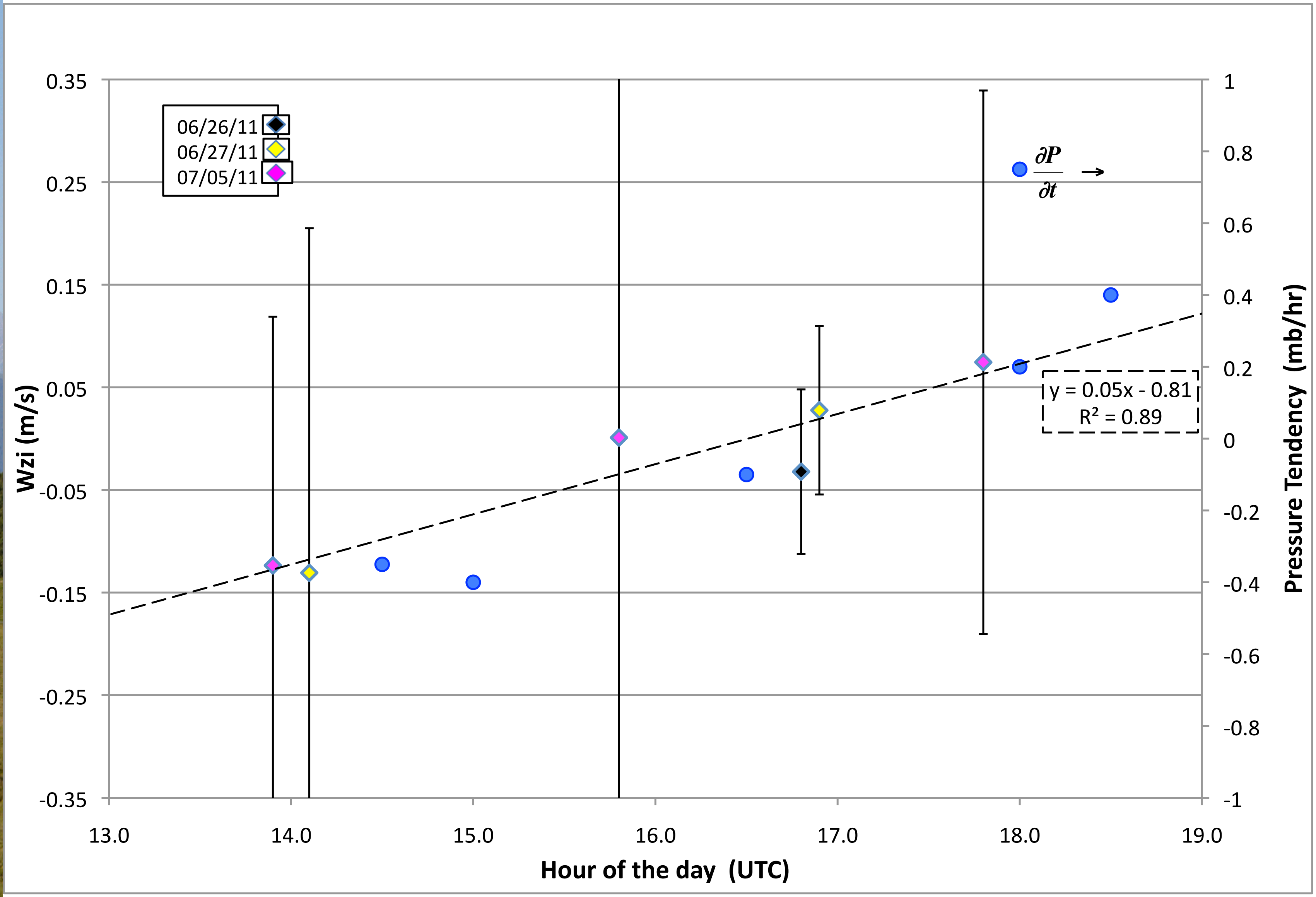
Method 2: Uncertainty associated with the linear regression of gradient from three points of the balloons

$$\sigma^2 \cong \sigma^2_{\frac{\partial u}{\partial x}} + \sigma^2_{\frac{\partial v}{\partial y}}$$

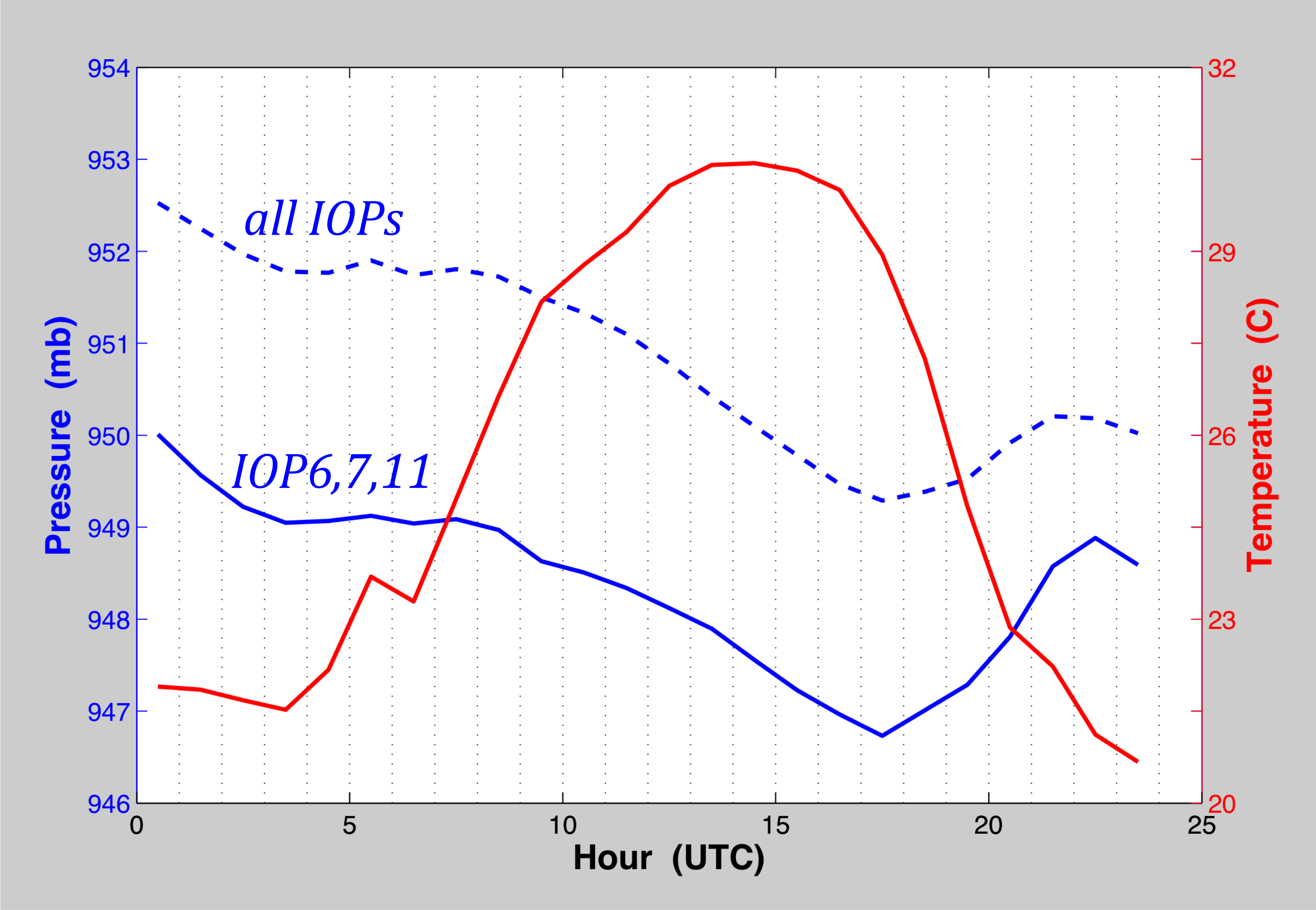
Late Afternoon Trend in Subsidence



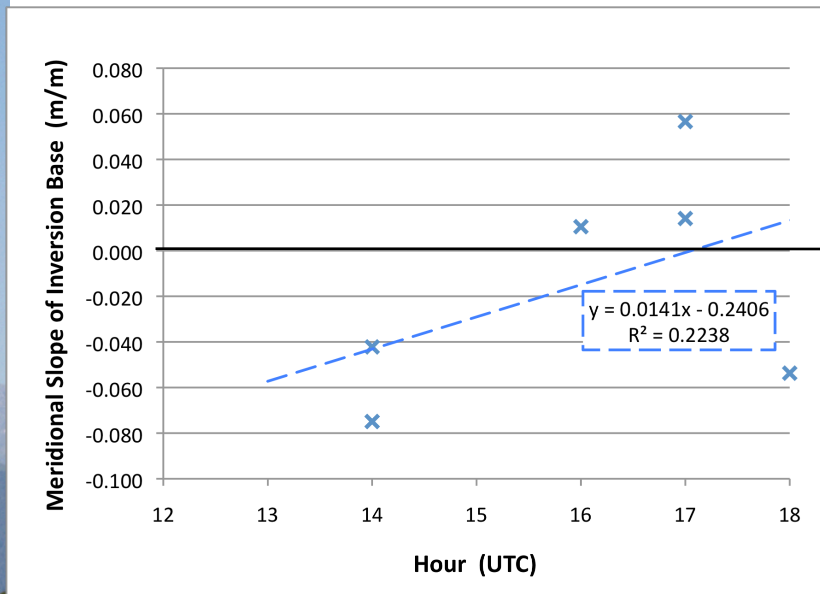
Concurrent Trend in Surface Pressure

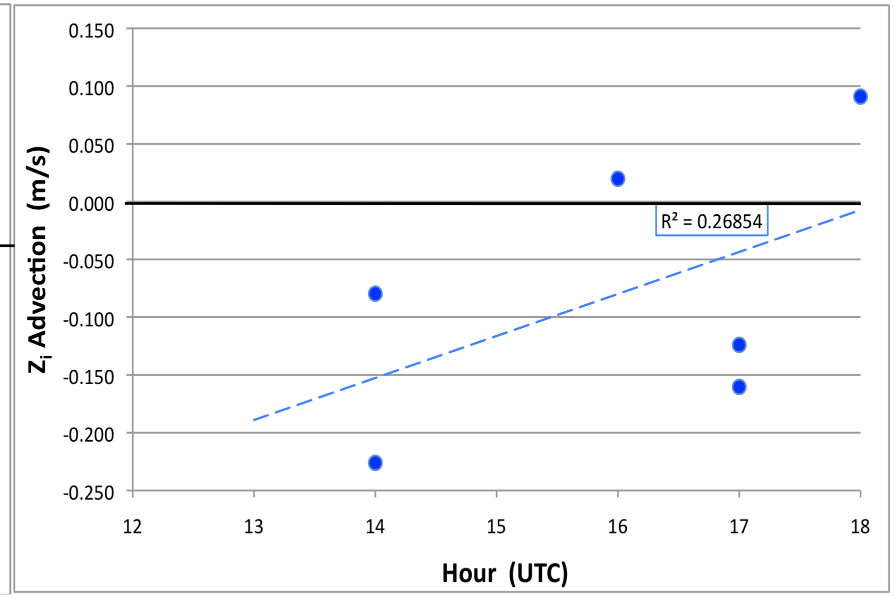


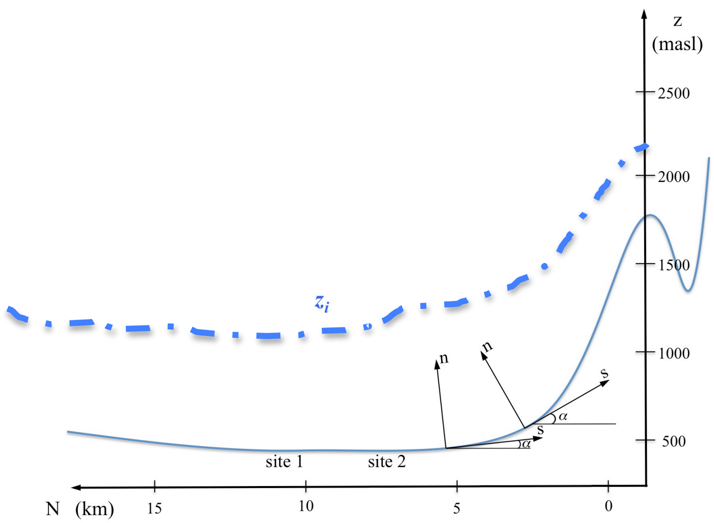
Late Afternoon Pressure Tendency

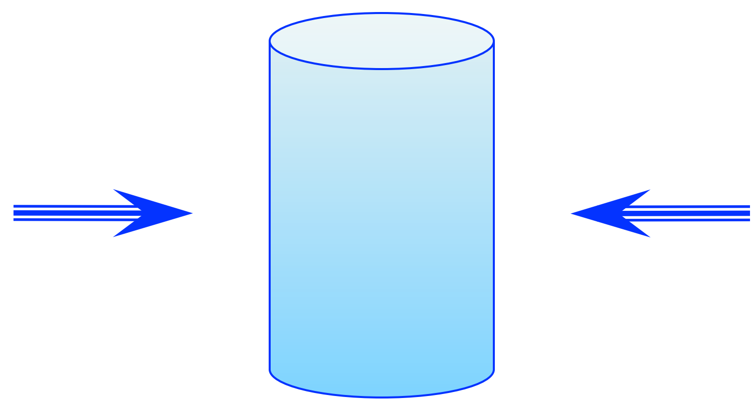


Other Late Afternoon Trends?





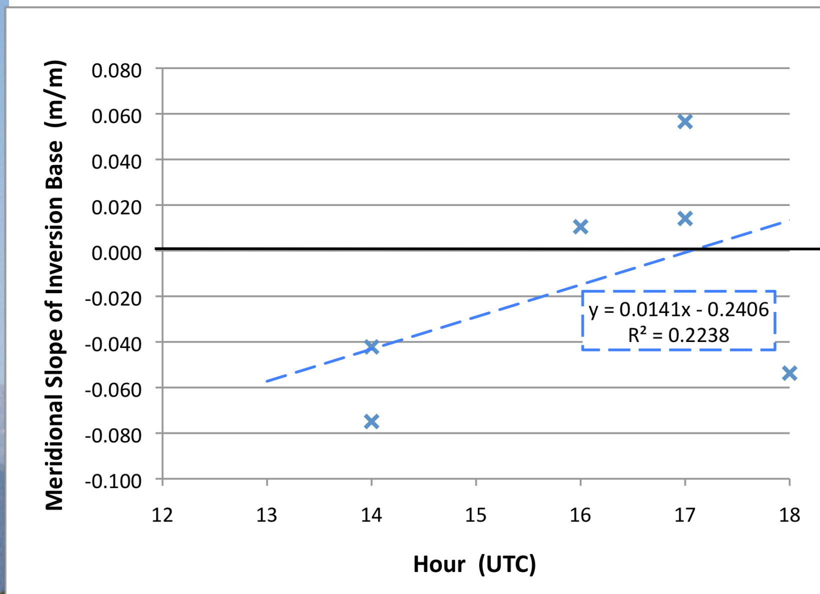


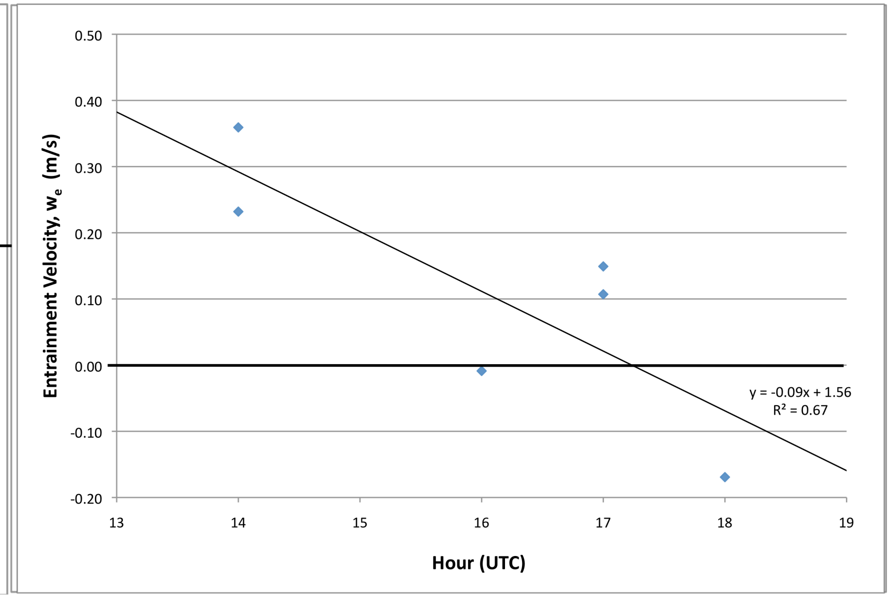


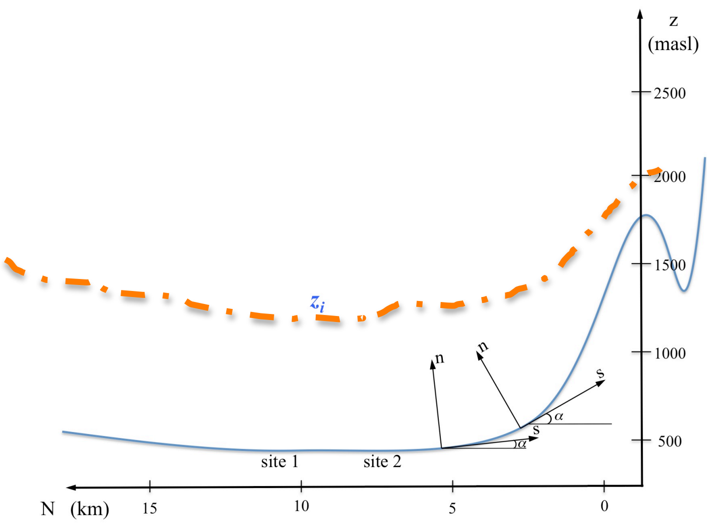
BLLAST Science Meeting

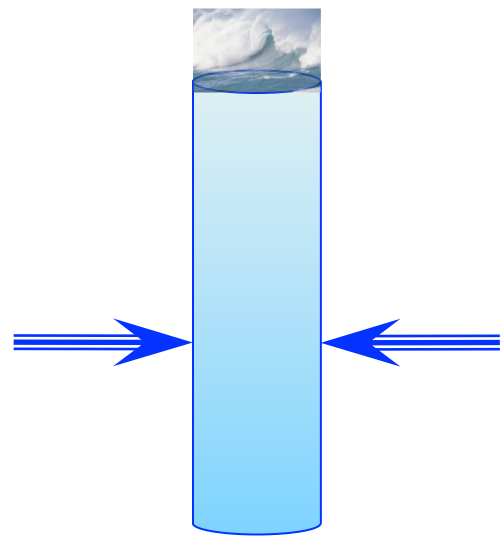
Bergen, Norway Aug 14-16, 2013

Other Late Afternoon Trends?









Other Evidence in the Literature?

✧ From the TRACT field campaign in the Rhine Valley, *Kossmann et al. (1998)* estimate z_i advection by aircraft (-0.2 to -0.8 m/s), leading to required $W(z_i) \sim 10$ cm/s.

✧ *Myrup et al. (1983)* used four theodolites in the Sacramento Valley to observe divergence in an analagous manner, deriving -.05 to -10 cm/s during the day, and + 2 in the evening.

✧ *Li et al. (2009)* studied 1000 diurnal harmonics of surface pressures in the US and found the strongest amplitudes (~ 200 Pa) in deep valleys of the mountainous Western states.

Concluding Summary and Directions

- Can we investigate the z_i advection term more closely with WRF or AROME runs for IOPs 6, 7, and 11?

- Can enthalphy budgets of the transition period help constrain what the adiabatic cooling from this proposed compensatory uplift need be?

- How might this cycle of subsidence affect the TKE decay, and the composition, stability, and elevation of the residual layer? Is this late afternoon convergence 'glass off'?

- Could we decrease the ascent rate of the balloons to better sample the divergence within the turbulent boundary layer and reduce the errors in this type of measurement in future studies?