Case of 20 June 2011 : LES set-up and addressed issues

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David Pino, Jordi Vila,
and BLLASTers

Motivations

- Use of a simplified LES for the study of key issues of the LAT : evolution of the turbulence (Turbulent kinetic energy, lengthscales, spectral structure)
- LES : complementary tool between the mesoscale simulation and the observations
- Resolves small scales down to 10 m resolution that allows the study of turbulence, but within a small domain that cannot resolve the mesoscale effects

  ($\rightarrow$ forcing)
- Simplified surface and forcings based on observations

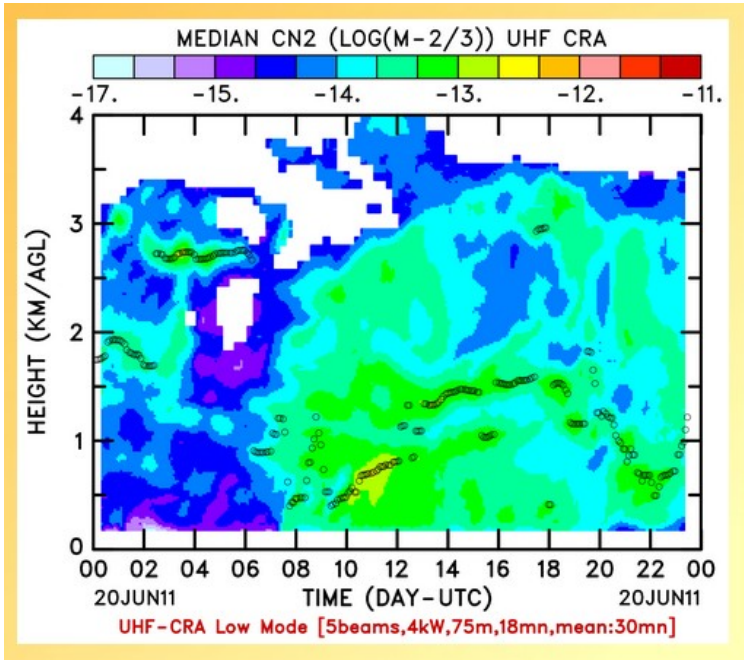
Outline

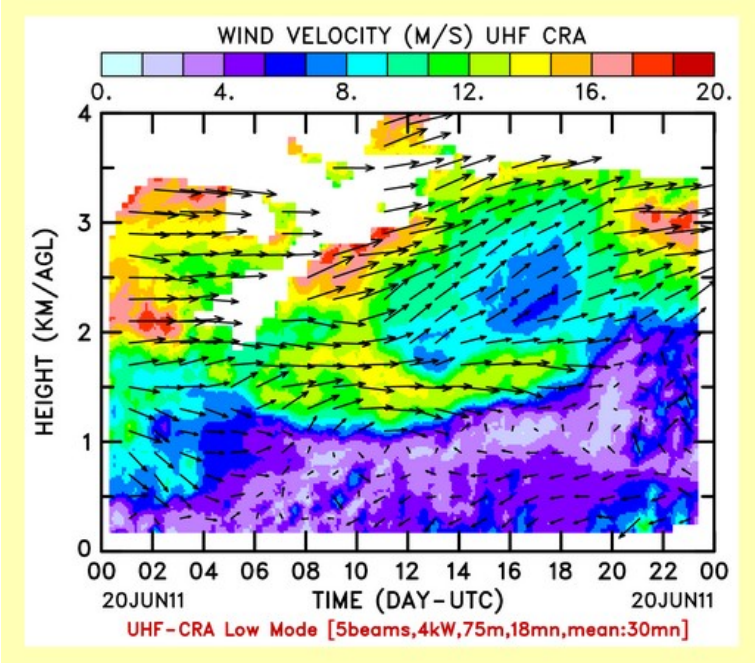
- Study case : 20 June 2011
  - Description of the case, and motivations for choosing this day
- LES set-up, and sensitivity study to
  - Initial profiles
  - Surface flux
  - Advection
  - Resolution and domain size
- Addressed issues

Choice of 20 June

- Conditions (low wind, surface fluxes, PBL growth, synoptic forcing)
- Data coverage (dense aircraft exploration)
- Other case studies (25, 26 June, 1st July)

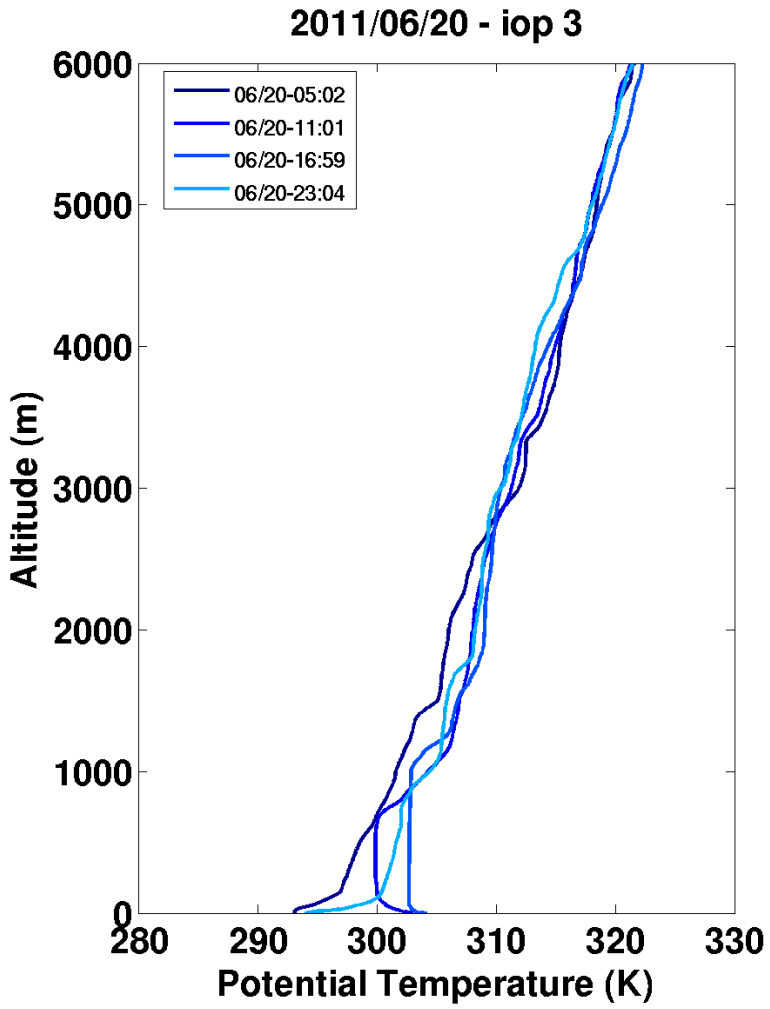
  → 20 June 2011 selected

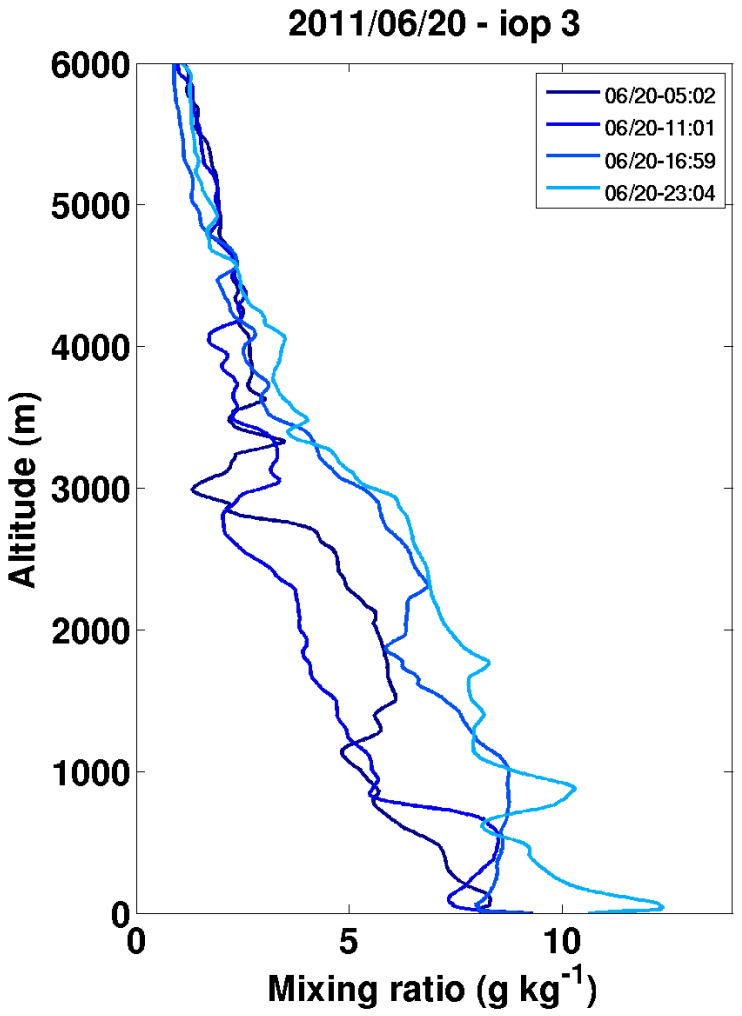




20 June – Observed mean structure

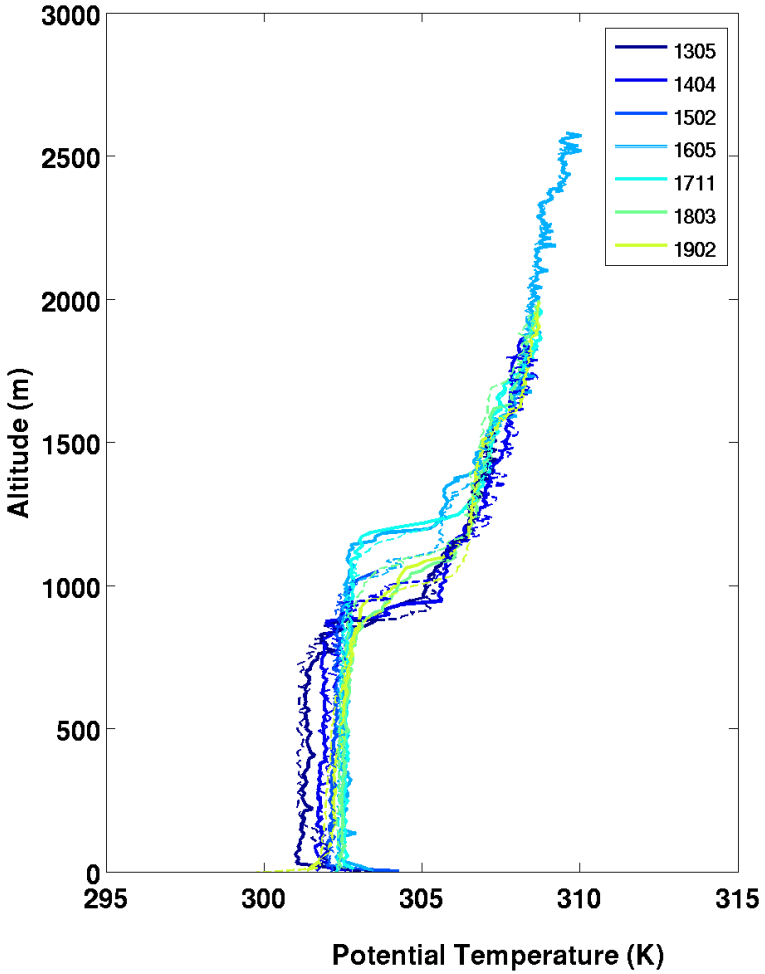
Diurnal cycle – Site 1

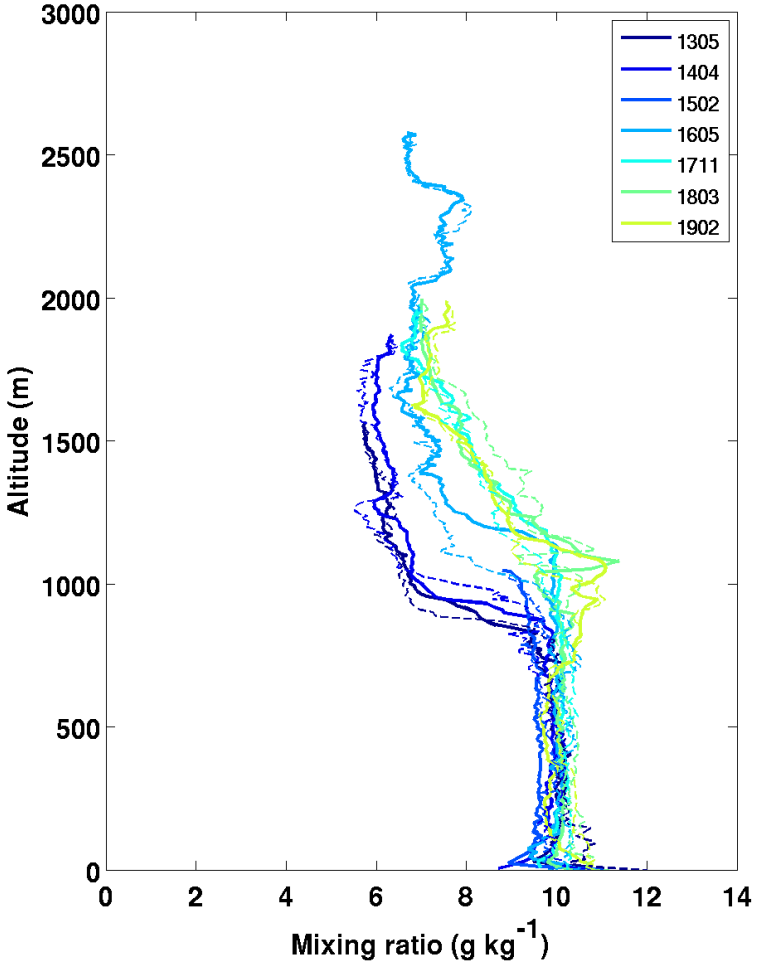




20 June – Observed mean structure

Afternoon – Site 2





20 June – Observed mean structure

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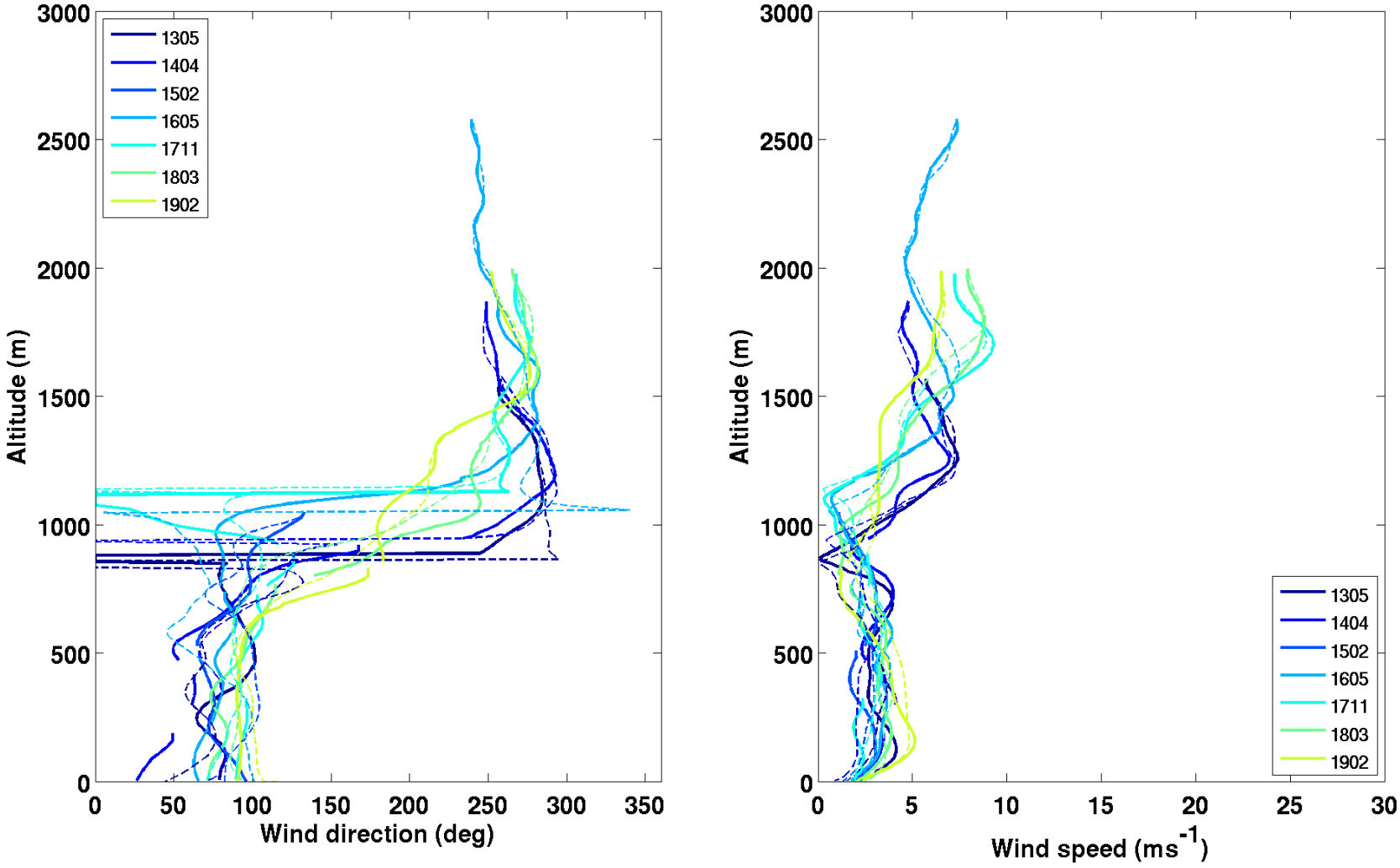


LES 20 June - Characteristics

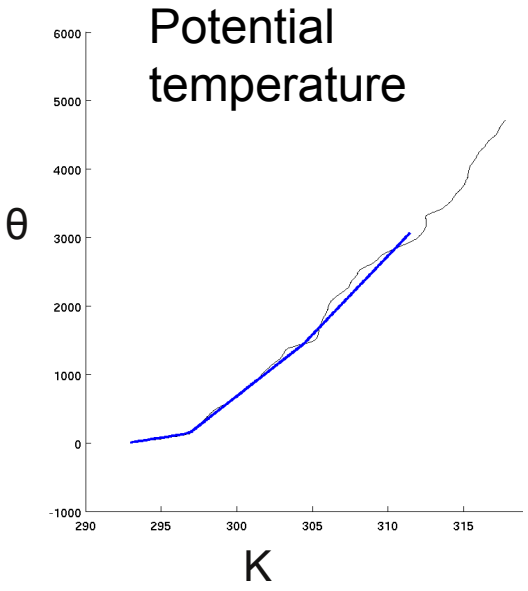
Study case : BLLAST, 06/20/2011 (IOP 3)
Timerun : from 0515UTC to ~2100UTC
LES model : NCAR (Moeng et al 1984, 1986 ; Sullivan et al. 1996 ; Patton et al. 2005)
Cyclic lateral conditions, dry air, W=0 at top of box
Imposed surface flux / homogeneous surface

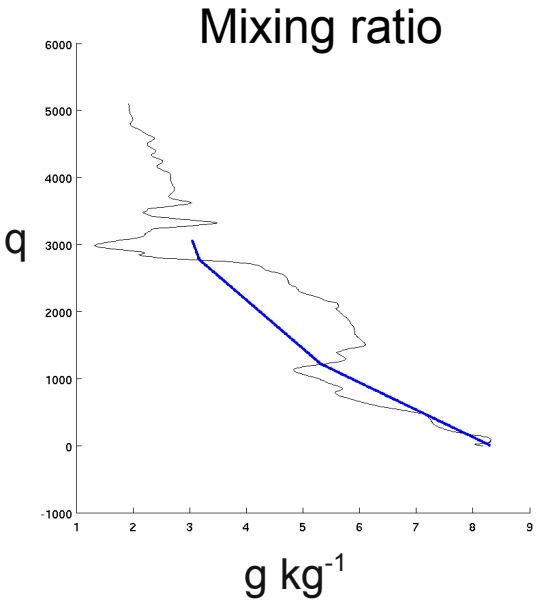
Initial profiles : simplified profiles based on observations
Advection prescribed
Subsidence : included in advection
No geostrophic wind
No radiation

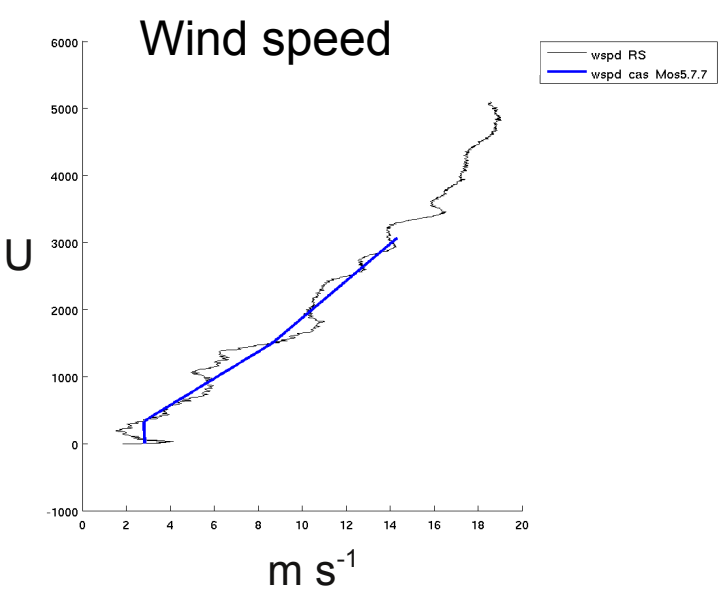
Domain size : 10 km*10 km* 3 km
Resolution : 40 m*40 m*12 m

20 June – LES set up : Initial profiles

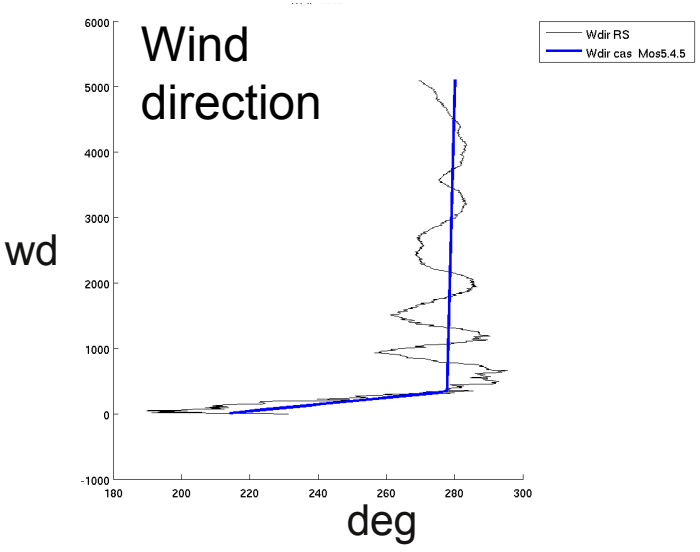
0515UTC initial profiles





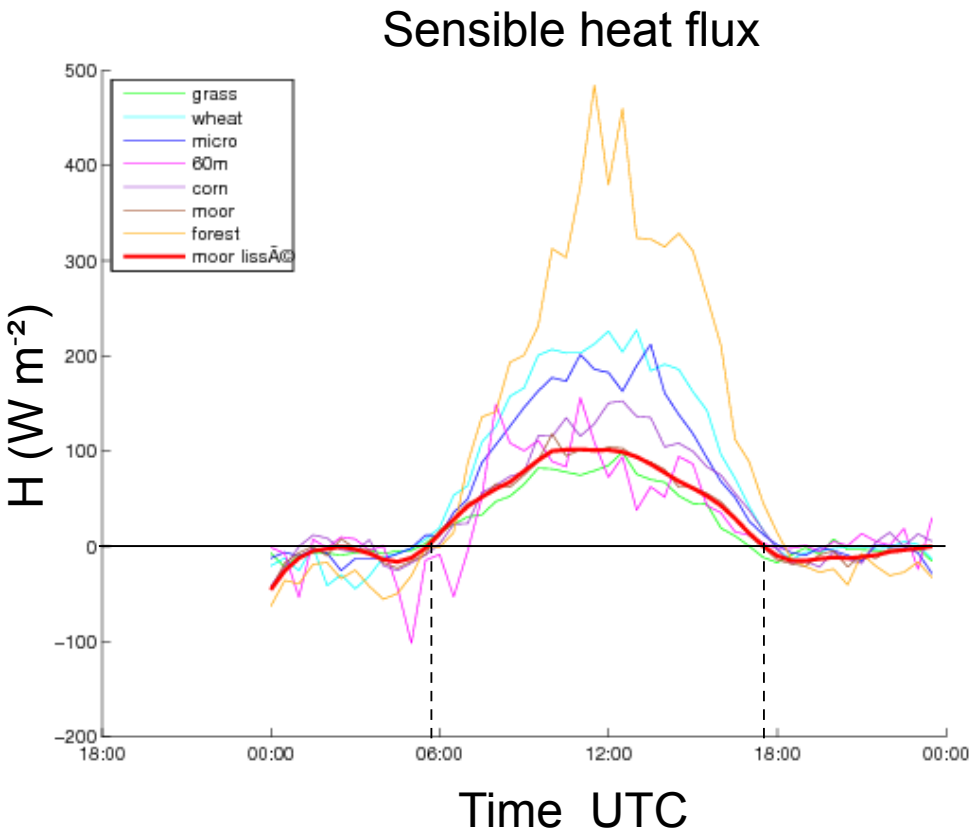


Sensitivity analysis on complexity of initial profiles
Choice of simplest profiles



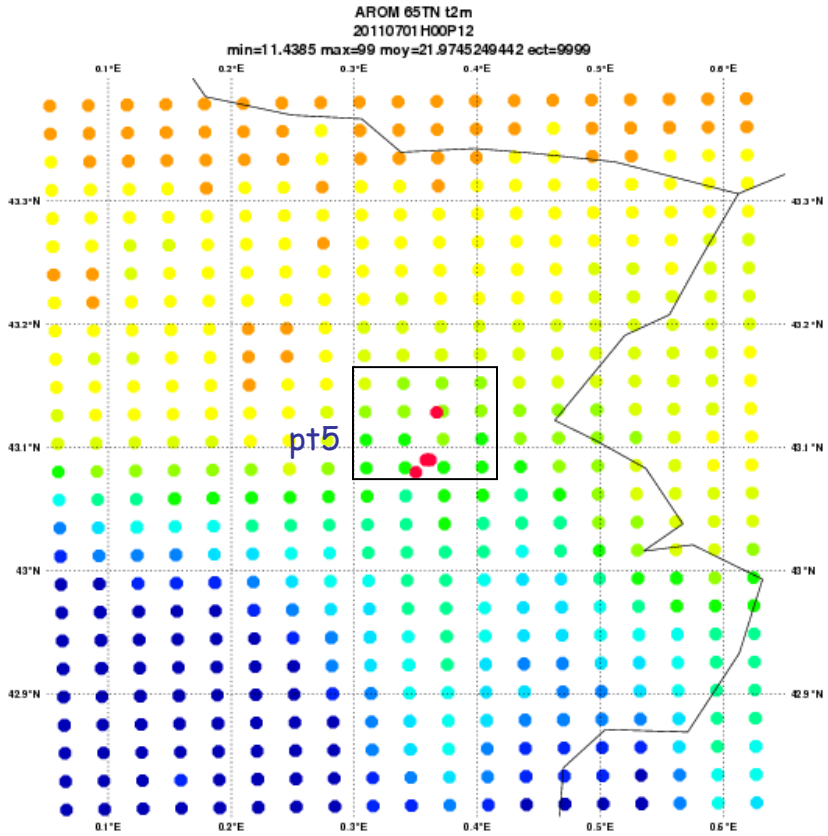
20 June – LES set up : Surface flux

Sensitivity analysis on surface flux
Choice of flux based on flux measured over moor

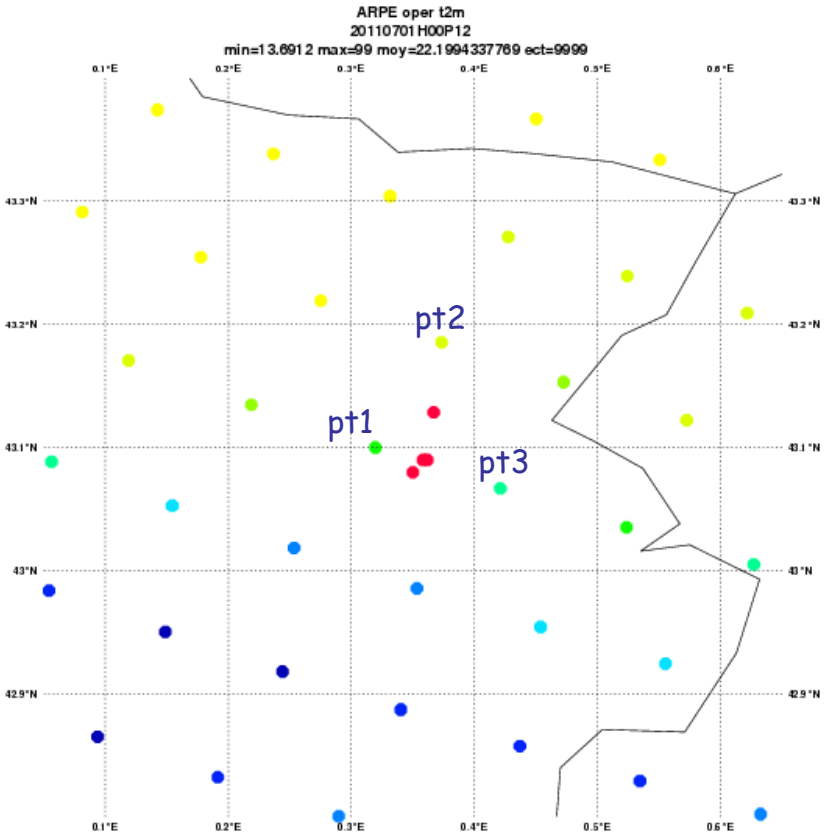


Advection : 2 models, 2 methods

AROME



ARPEGE



- Method 1 : diagnostic on each grid point. Total advection. No distinction of the three components

$$\frac{\partial T}{dt} + \sum_i u_i \frac{\partial T}{\partial x_i} + \frac{\partial \overline{w'T'}}{\partial z} = 0$$

- Method 2 : direct a posteriori calculation at the faces of a box around the experimental area : adv(q)= <u>dq/dx+<v>dq/dy+ <w>dq/dz

@ Fleur Couvreux

Advection study : main conclusions

- Zonal advection is predominant in the morning, especially in ARPEGE. More complex in AROME.

  Vertical advection becomes predominant after 11 UTC.
- Method 2 reveals a large variability of vertical advection from point to point, and more difference between the 2 models.

  Nb : role of the mountain / model levels
- The 2 methods correctly agree in AROME,less in ARPEGE

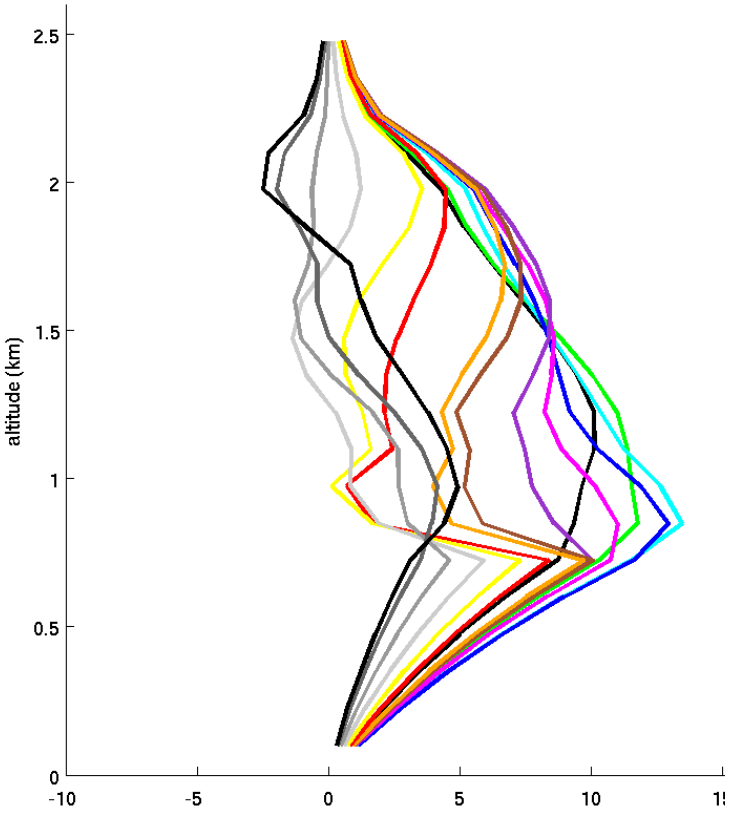
→ Use of Method 1 with AROME

Total advection from AROME

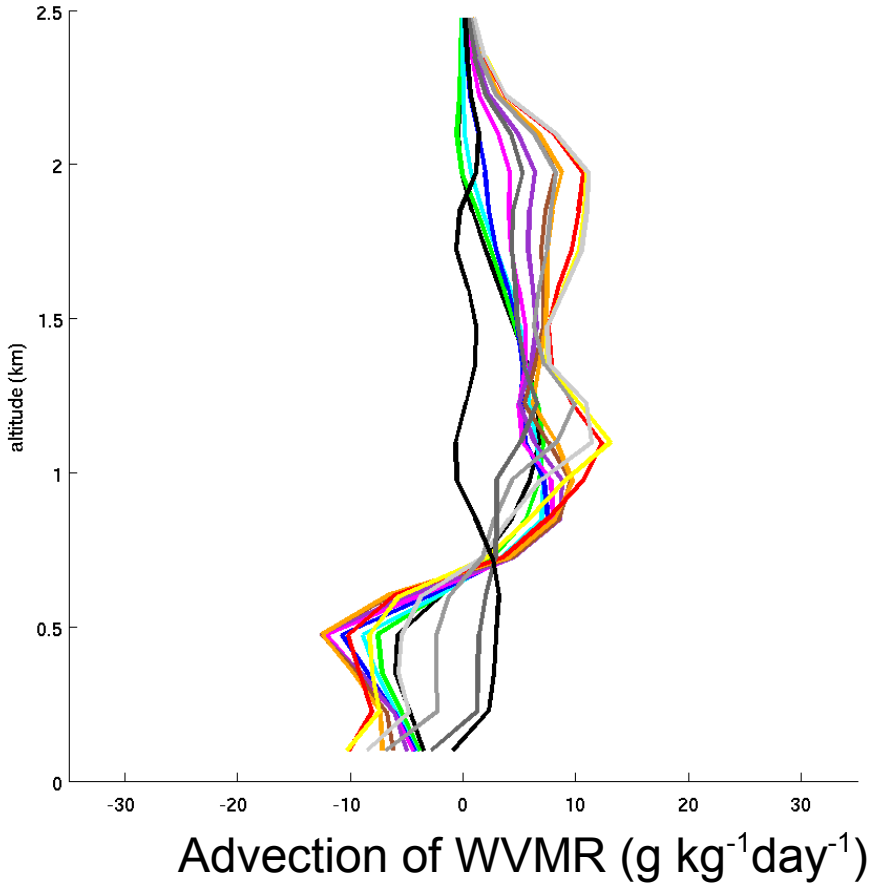
$$\frac{\partial T}{dt} + \sum_i u_i \frac{\partial T}{\partial x_i} + \frac{\partial \overline{w'T'}}{\partial z} = 0$$

$\sum u_i \frac{dT}{dx_i}(z,t)$ exponentially decreasing under 600m

$\sum u_i \frac{dq}{dx_i}(z,t)$



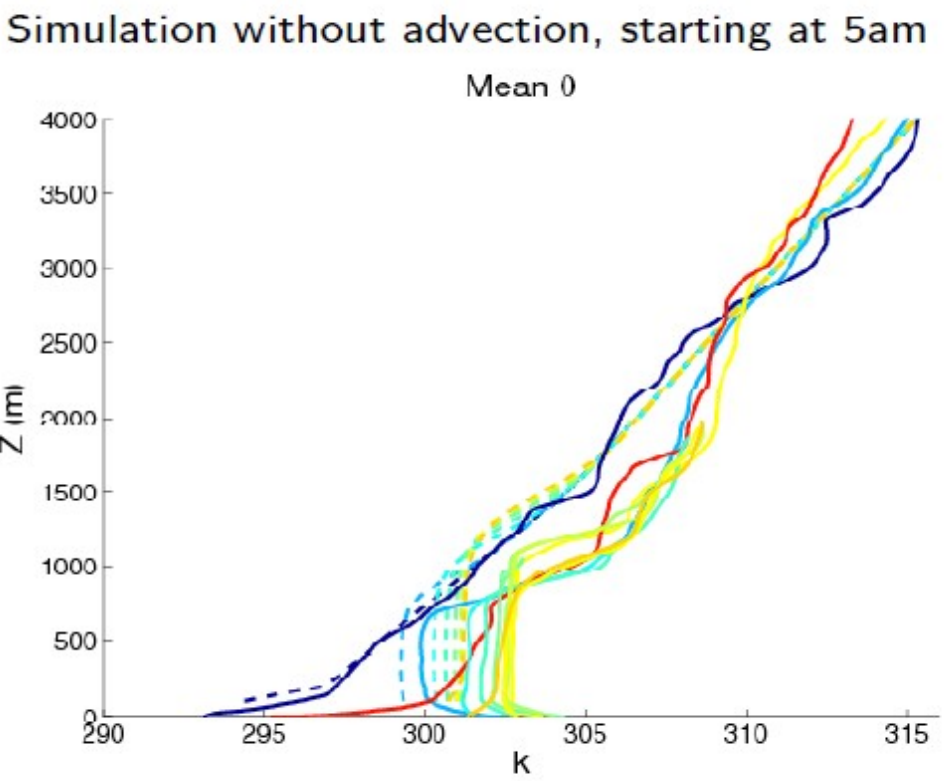
Advection of temperature (K day^{-1})

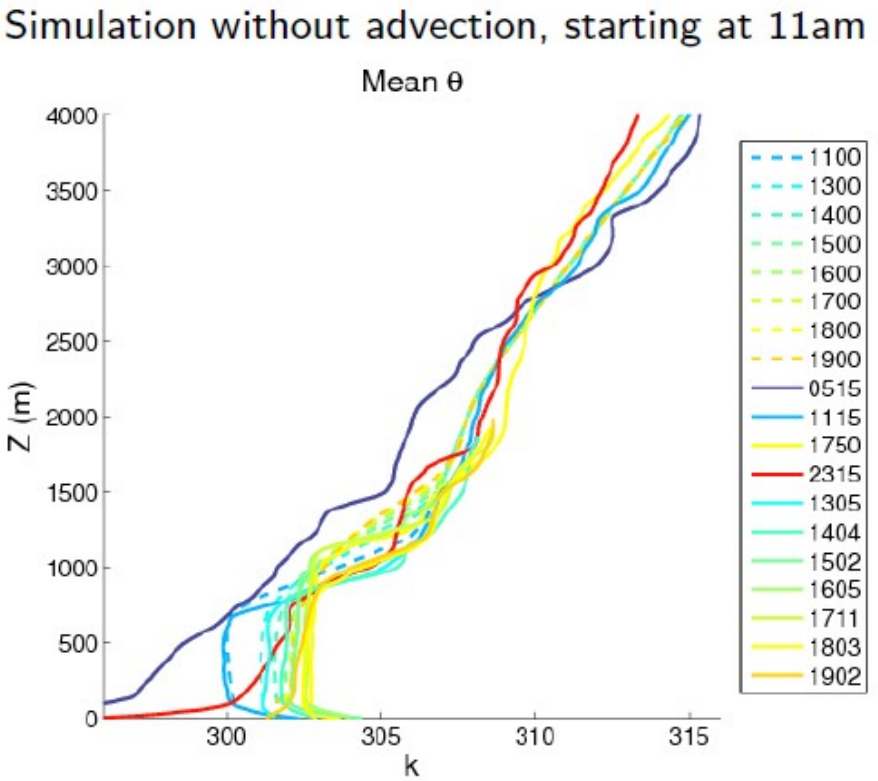


Advection of WVMR (g kg^{-1}day^{-1})

Sensitivity to starting time / advection

Simulations without advection

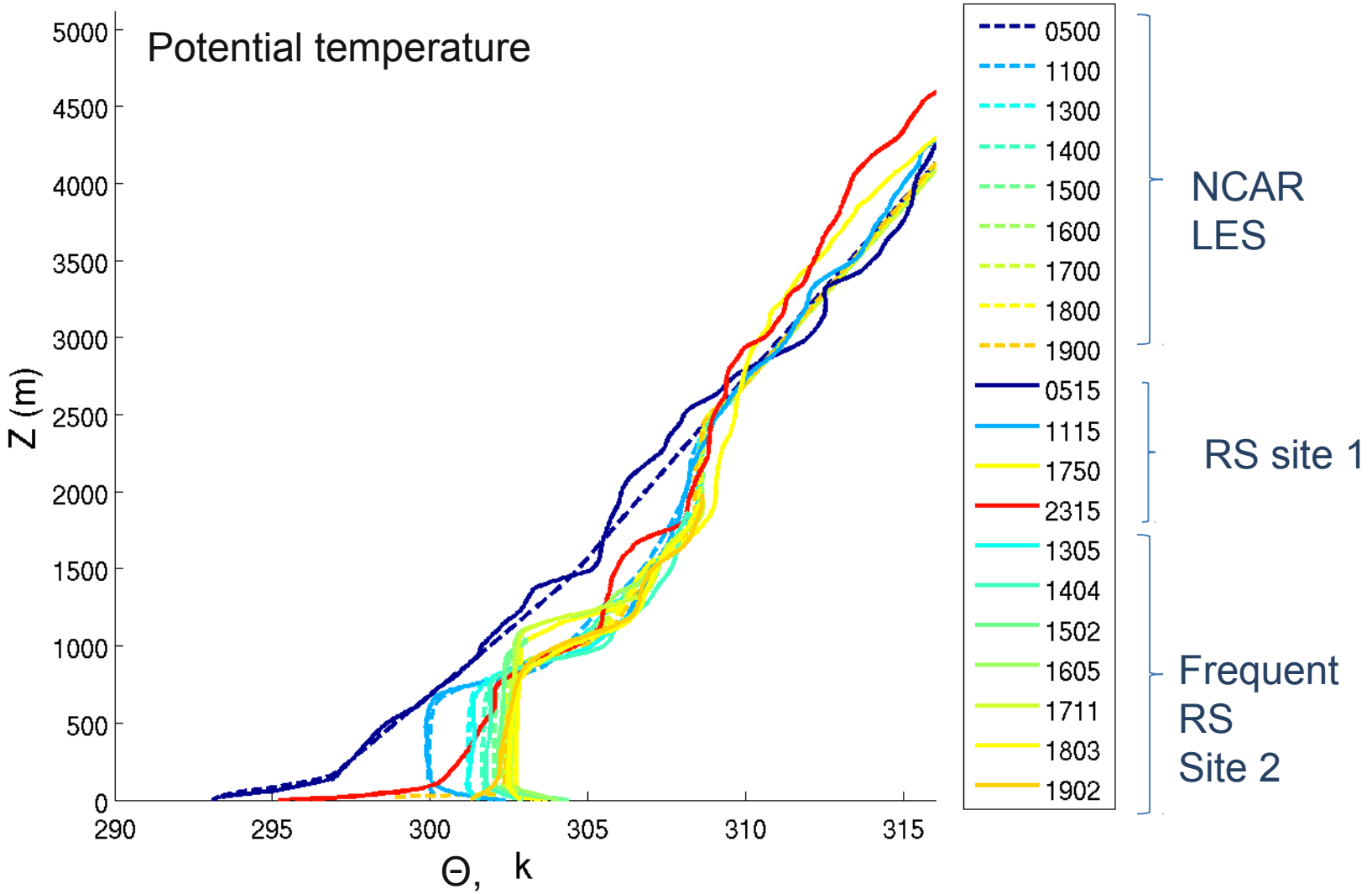




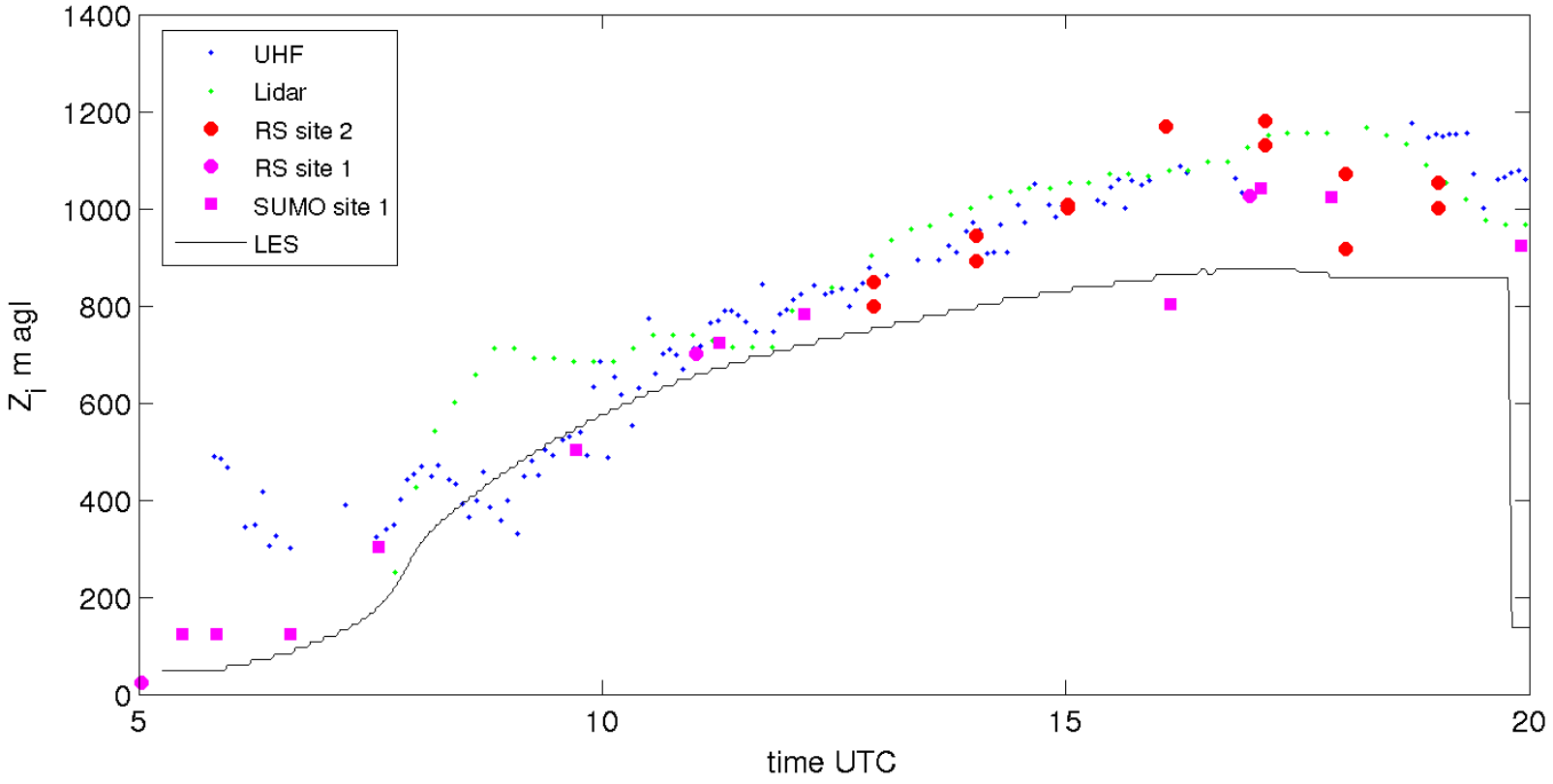
Advection is not predominant during the afternoon of 20/06

Results - mean thermodynamical structure

Simulation with advection starting at 0515UTC



Results – Growth of the CBL



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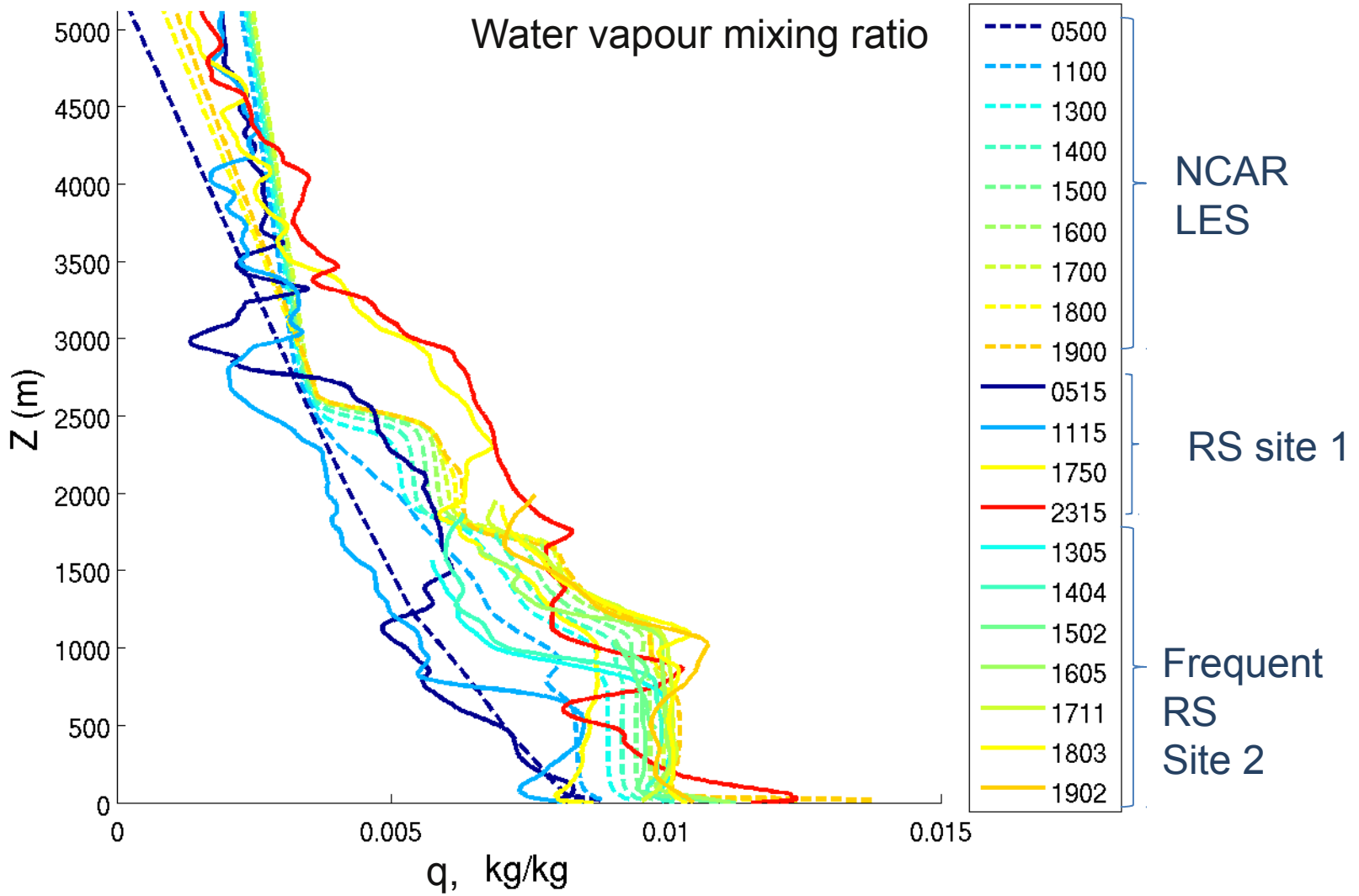
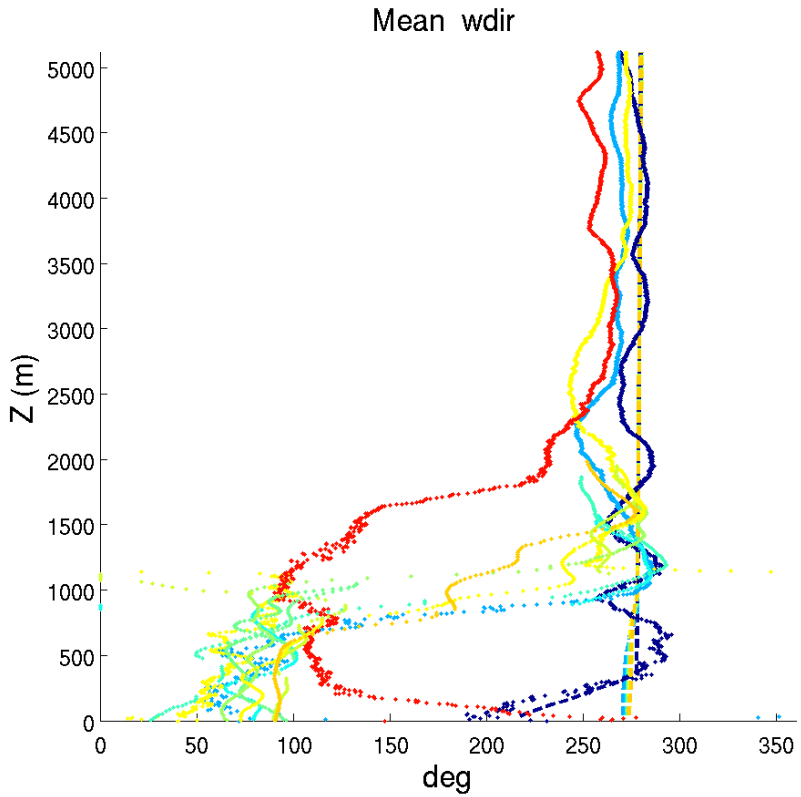
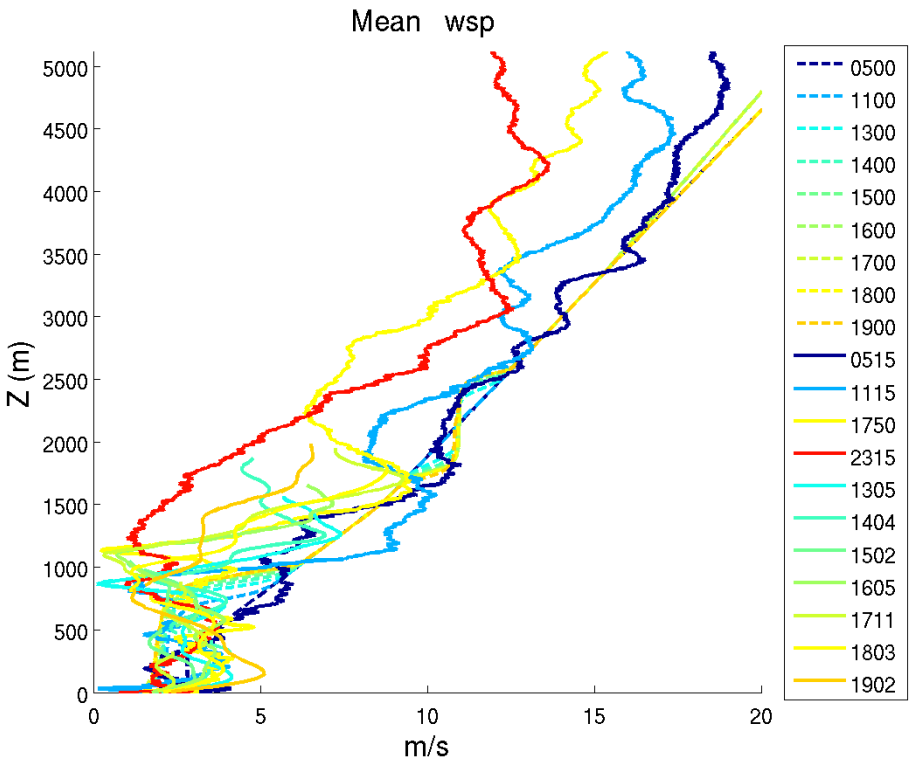


Results - mean wind profiles





Intermediate conclusions

Complexity of the advection term, and difficulty of taking it into account.
But not significant after 11 UTC on 20 June.

Good representation of the mean structure evolution for temperature

Complex structure in humidity, much more difficult to simulate with a simplified LES

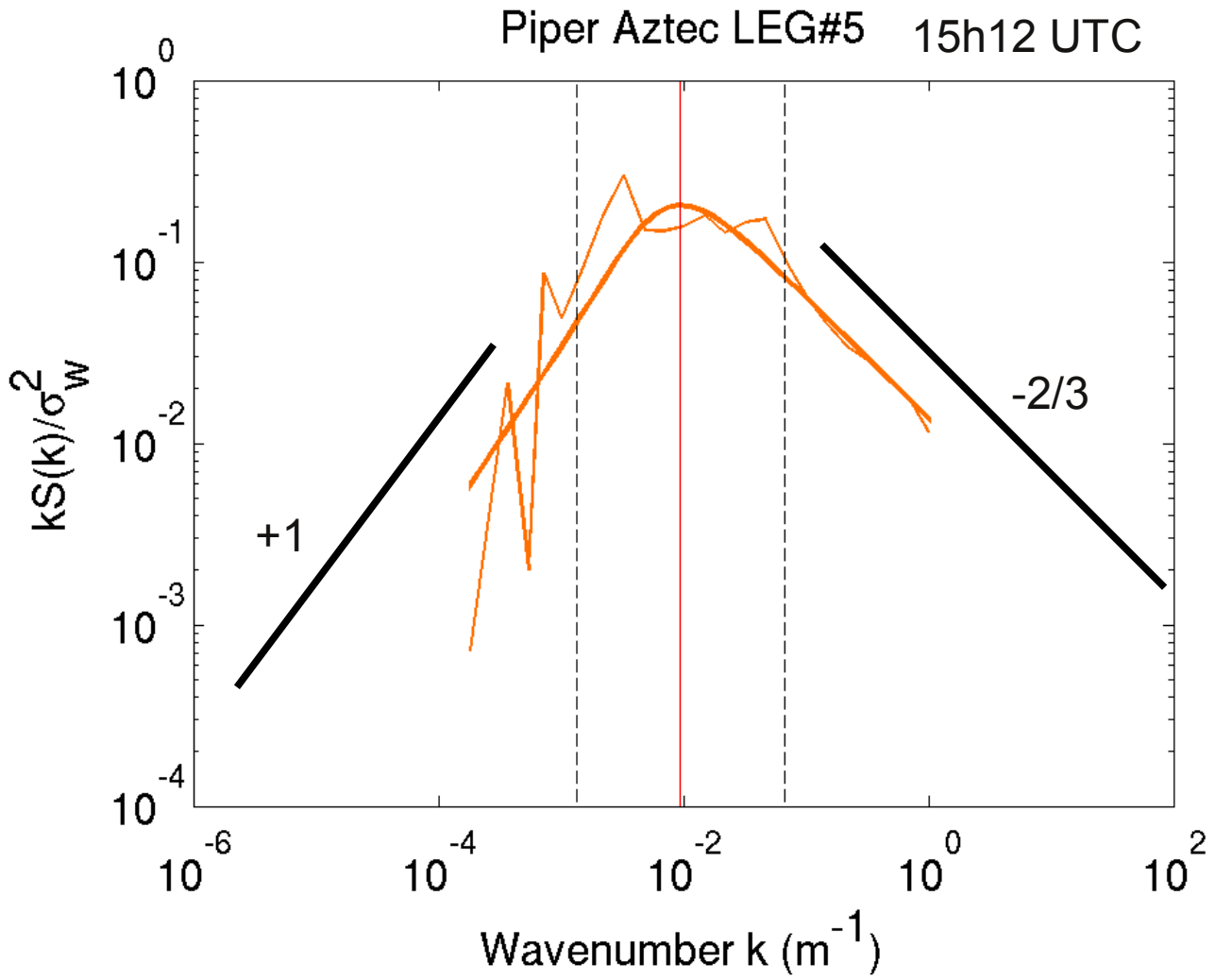
Idealized wind profiles : correct windspeed, still needs more realistic profiles for the representation of shear and its effects

What about the turbulence structure ?

Is it sensitive to the domain size and resolution ?

Is it sensitive to the starting time / duration of the simulation ?

Example of observed W spectrum

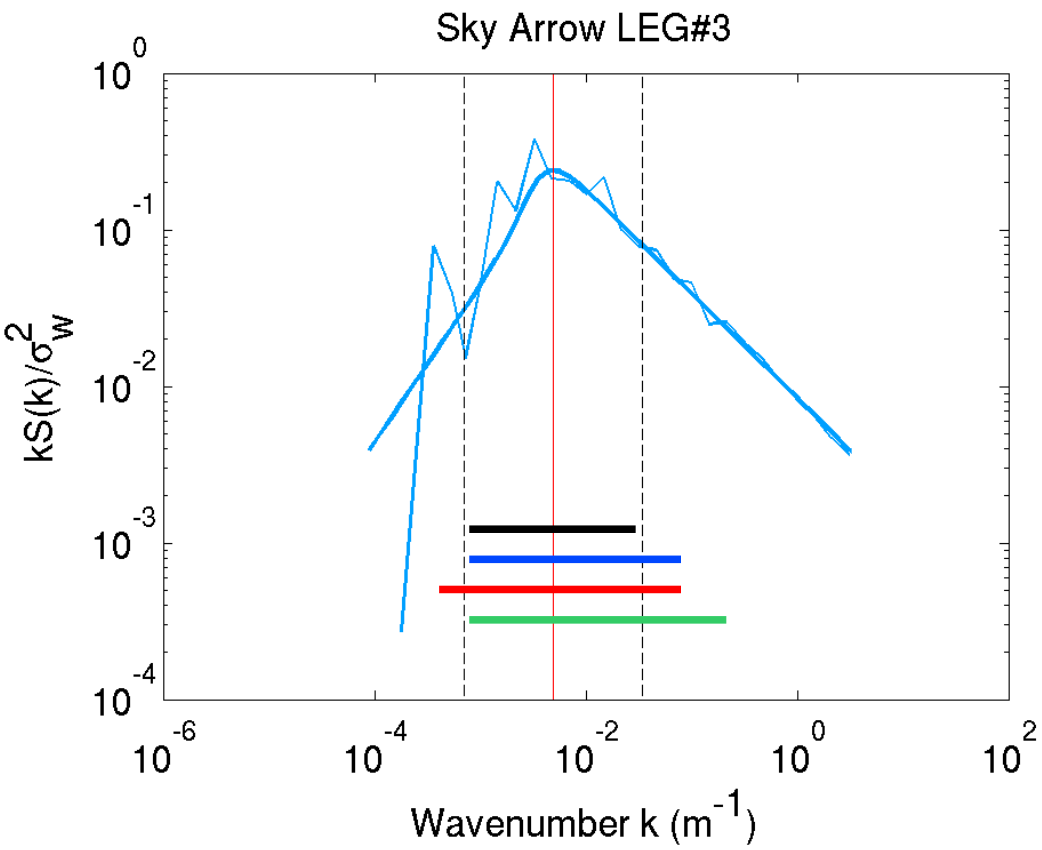


Piper Aztec
TAS=70 ms^{-1}
Fr=25 Hz
Dx=~3 m

Sky Arrow
TAS=40 ms^{-1}
Fr=50 Hz
Dx=~1 m

Length of legs ~40 km

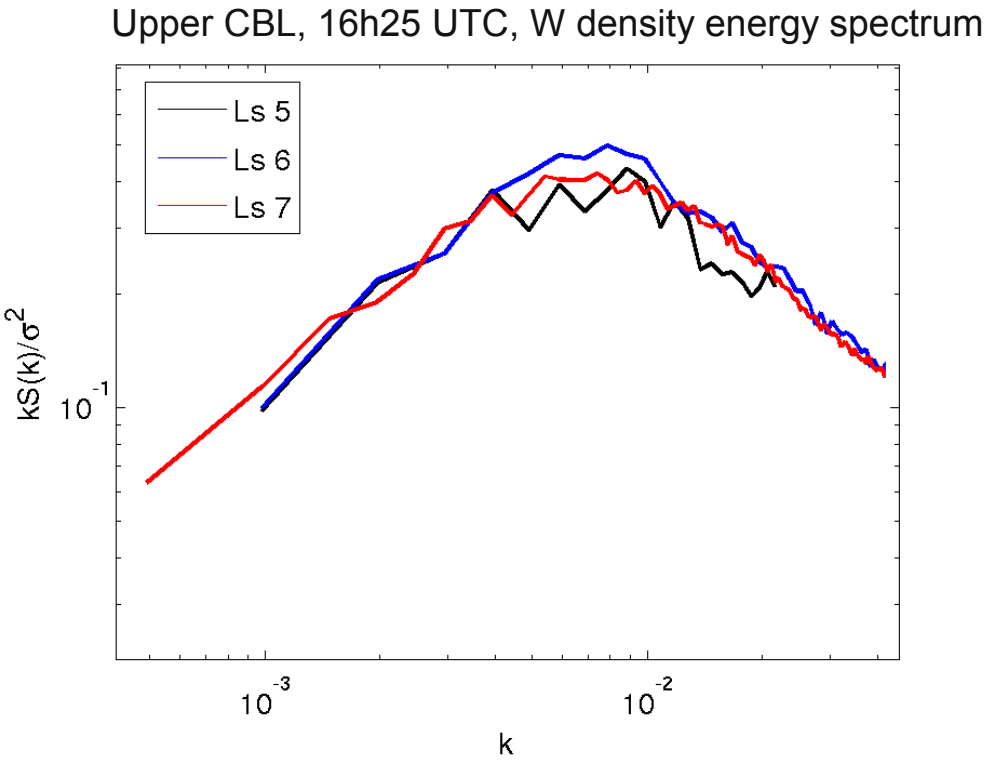
20 June – LES set up :
Sensitivity to domain size and resolution



Tests	Resolution/Domain size
Ls5	100m*100m*40m 6.4km*6.4km*5.12km
Ls6	50m*50m*20m 6.4km*6.4km*5.12km
Ls7	50m*50m*20m 12.8km*12.8km*5.12km
Ls8	12.5m*12.5m*10m 6.4km*6.4km*5.12km
Ls1	25m*25m*10m 12.8km*12.8km*5.12km
Ls2	40m*40*m*12m 10.24km*10.24km*3.072km

20 June – LES set up :
Sensitivity to domain size and resolution

No significant change in the mean structure
Effect on turbulence structure



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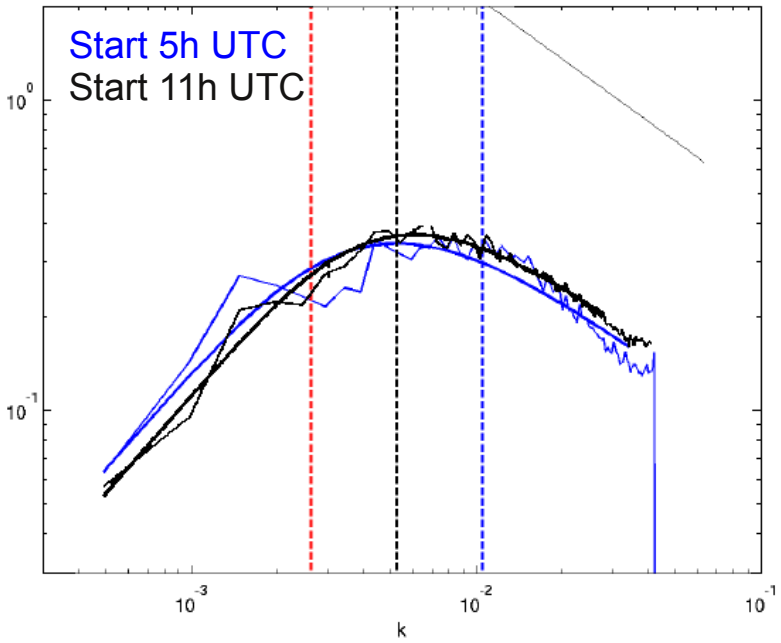
20 June – LES set up :
Sensitivity of spectra on starting time

18h15 UTC, lower CBL



Starting time of the simulation
changes the characteristics of the spectra
- shape
- associated lengthscales

Needs time to « build » the larger scales

« Turbulence can remember »

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Questions addressed and working plan

How do the turbulent kinetic energy, spectra and scales evolve during the LAT, according to observations ?

Is there a decoupling with height, as the surface flux gets close to zero ?

→ Analysis of aircraft and surface observations, TKE decay and spectra studies

Does the NCAR LES simulate the same evolution ?

→ Analysis of the LES, comparison with observations, link from surface to within the CBL

Do different LES models represent the afternoon transition in the same way ?

→ Intercomparison study DALES/Meso-NH/NCAR (initiated)

What are the limitations of both observations and LES ?

Further steps

How to go through/beyond those limitations

More realism in the simulation (in forcings understood from mesoscale studies and observations)

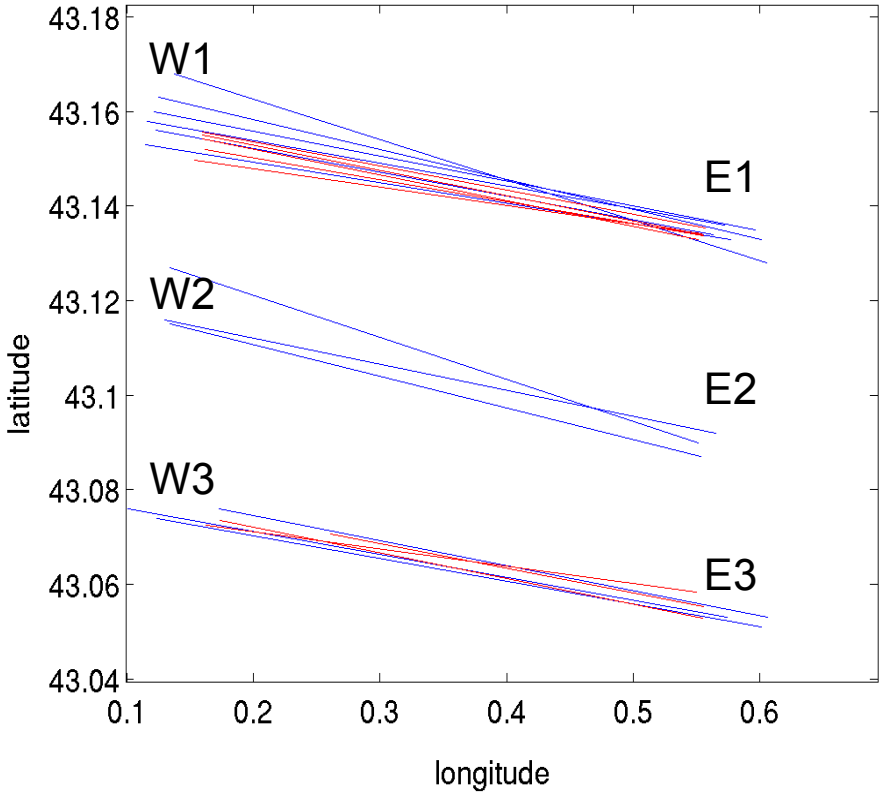
Sensitivity studies, that can cover conditions encountered on other cases, and allow to study the role of shear, entrainment, surface heterogeneity,...

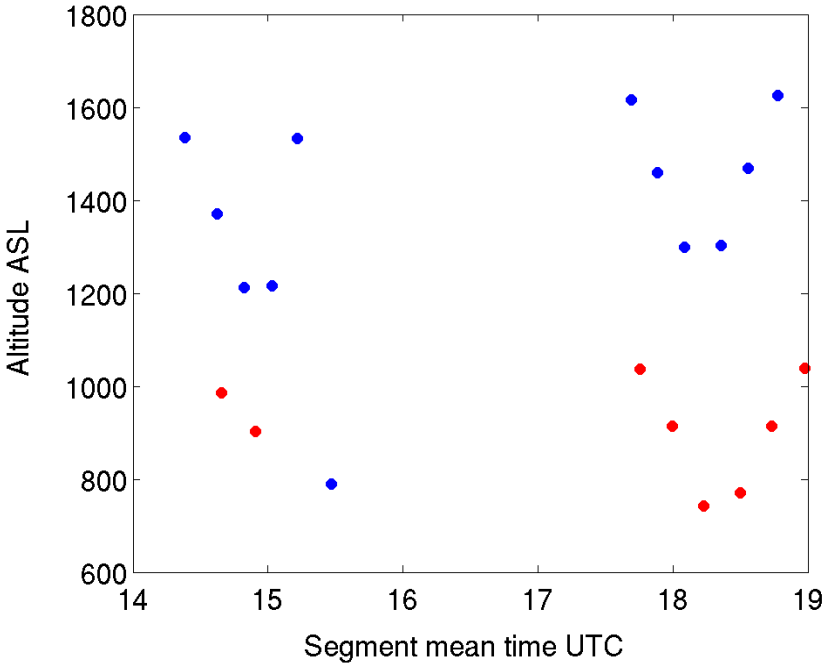
The simulations are available to all !

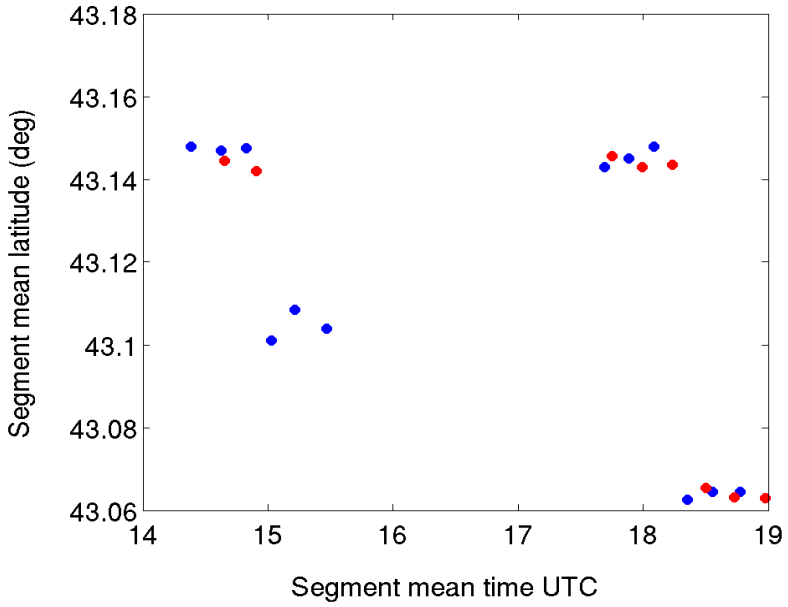
Thank you

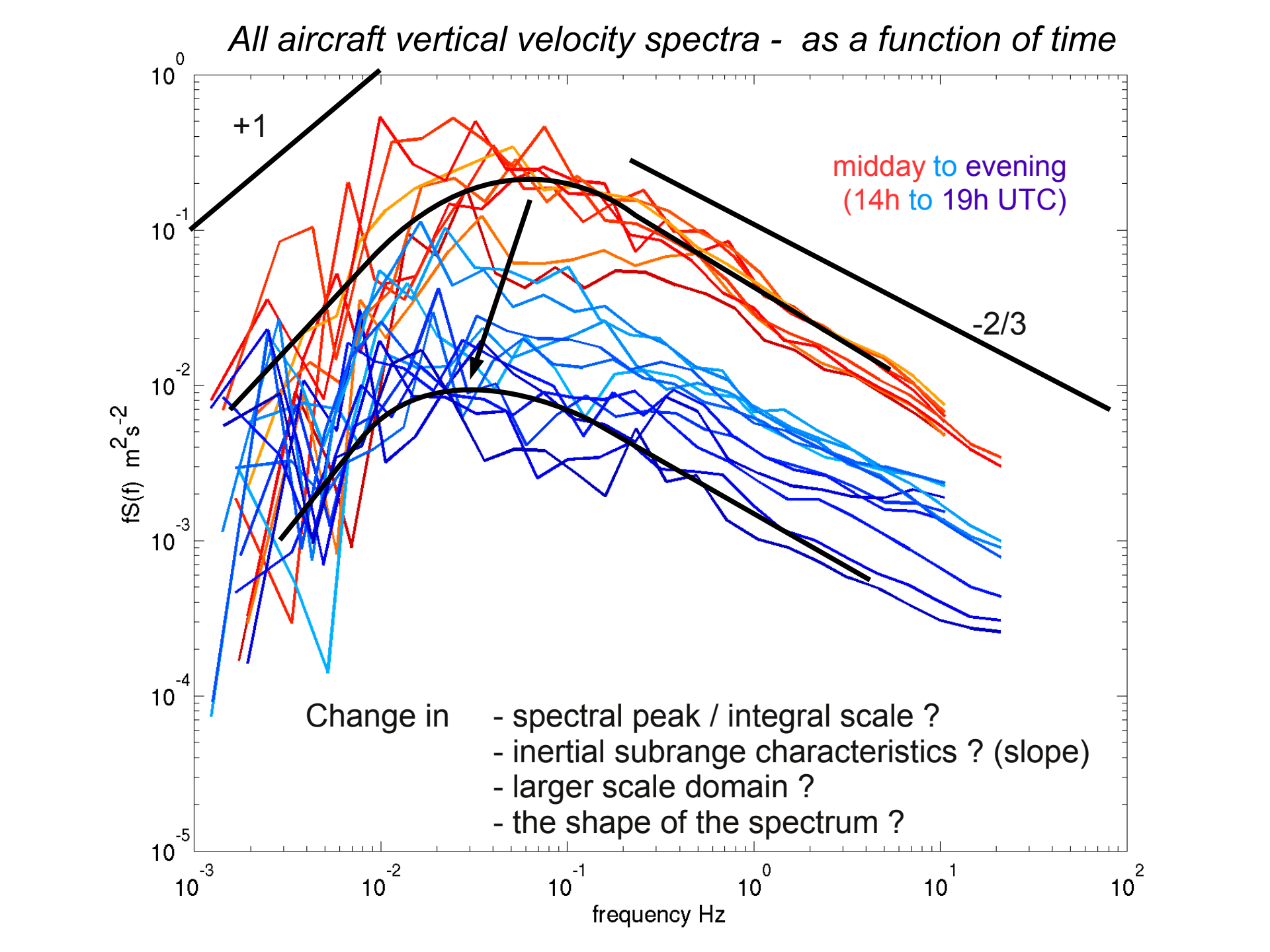
Flight patterns of Piper Aztec and Sky Arrow airplanes on 20 June 2011

Three // legs, 6 heights, 3 latitudes



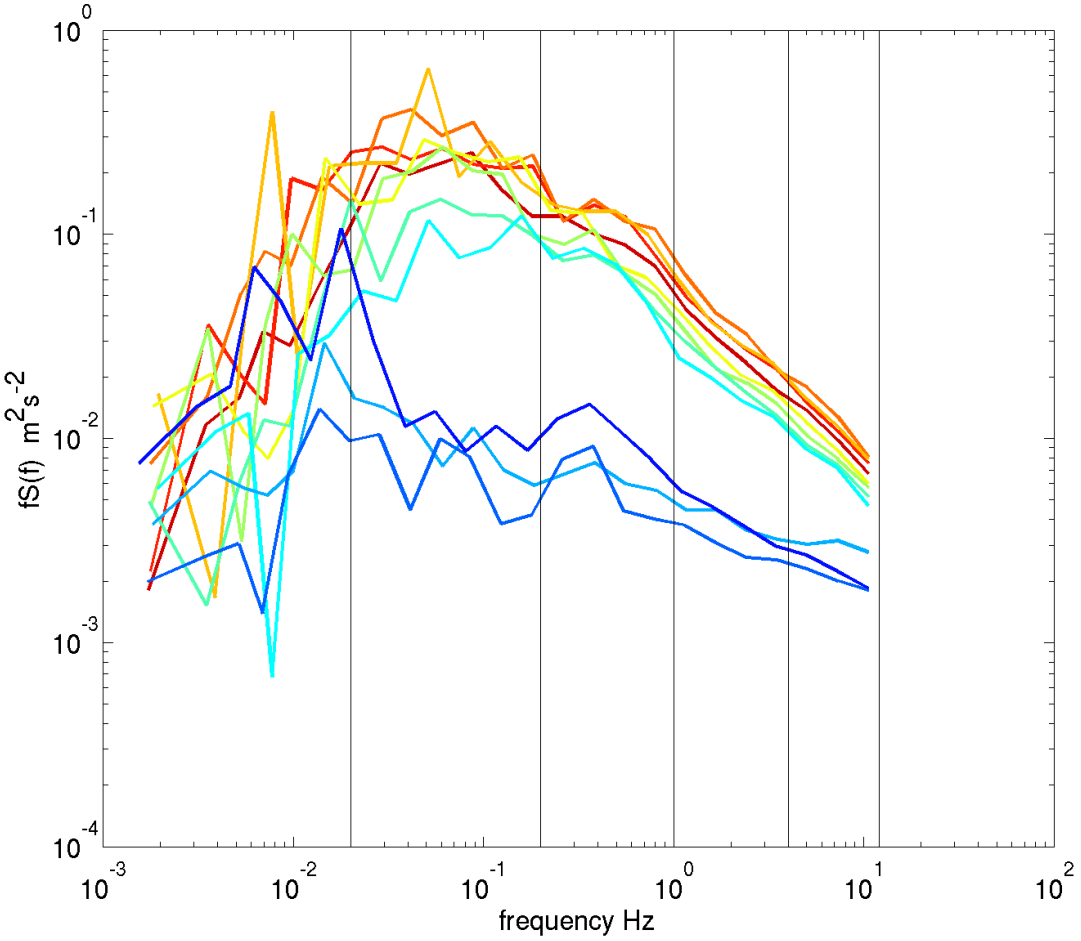





All aircraft vertical velocity spectra - as a function of time
+1
-2/3
midday to evening
(14h to 19h UTC)
Change in
- spectral peak / integral scale ?
- inertial subrange characteristics ? (slope)
- larger scale domain ?
- the shape of the spectrum ?
fS(f) m2s-2
frequency Hz
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-3
10^-2
10^-1
10^0
10^1
10^2

Motivations

Piper Aztec aircraft - 5 Jul 2011 - Vertical velocity spectra



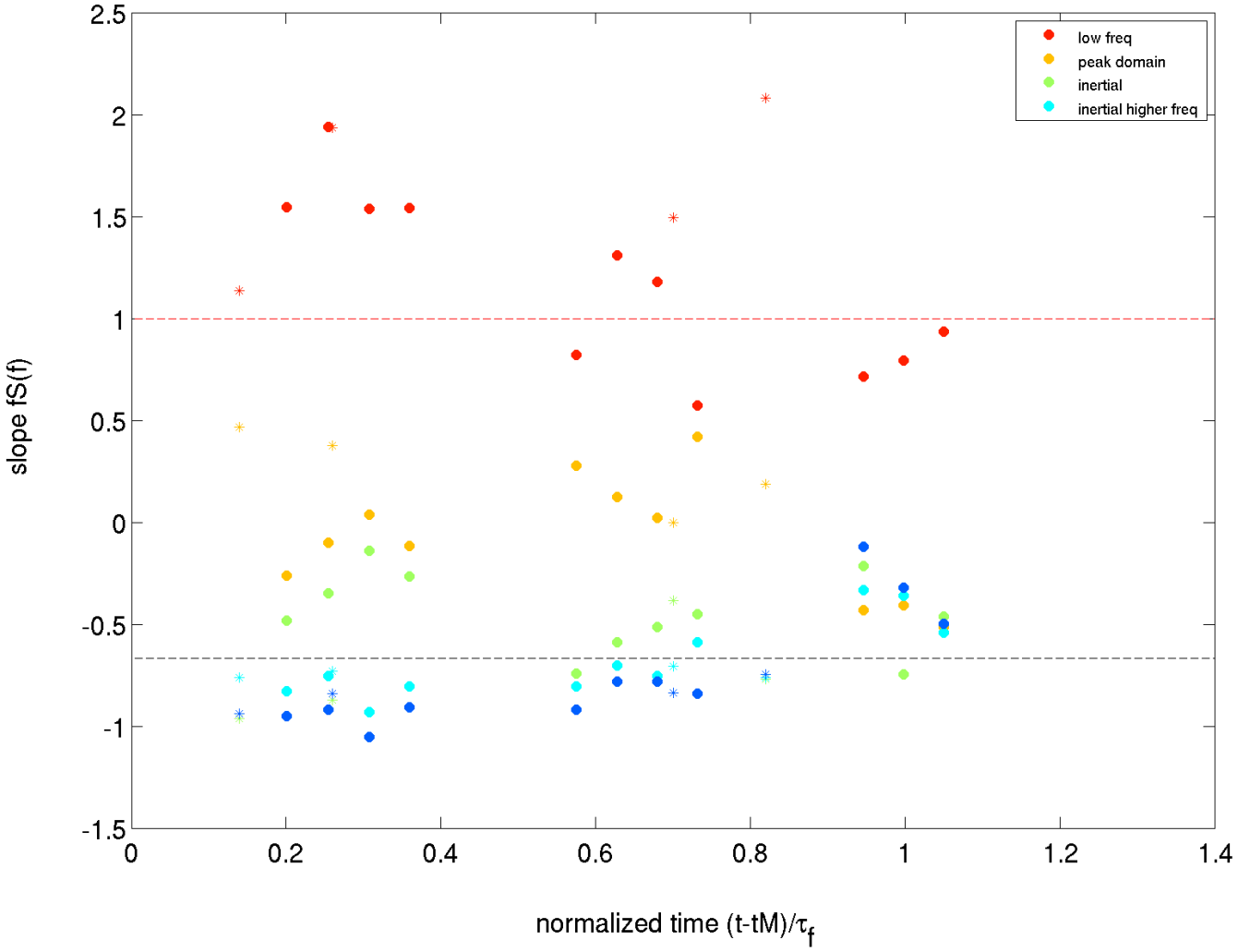
Z*=~0.2

(f x S(f) plotted here)

Same one 40-km leg flown at different times

From midday (darker red) to sunset (darker blue)

Evolution of the slopes of the spectra



5 and 1 July

Observed ratio l_w/λ_w (Piper aztec legs)