Royal Netherlands Meteorological institute

Eindhoven University of Technology

Characterisation of wind and wind-shear profiles for ADM-Aeolus: High-res radiosondes vs ECMWF-SRF

Karim HOUCHI
PhD Weather observations

Promoter: Hennie Kelder
Supervisor: Ad Stoffelen
Gert-Jan Marseille
Jos De Kloe

Plan

1. ADM-Aeolus mission:Doppler wind Lidar (DWL)

2. Vertical Aeolus measurement positioning(VAMP)

3. High resolution Radiosondes analysis vs ECMWF SRF

   - Spatial and temporal coverage
   - Collocation with ECMWF fields: short-Range Forecast

4. wind and wind shear variability

   - Climate regions (Polar, midlatitudes and tropics)

   - Period (yearly)

5. Radiosonde windfinding systems

6. Conclusions

1. ADM-Aeolus mission: Overview

➢ Fourth Explorer mission to be developed within ESA`s living programme (launch in 2010)

➢ADM- Aeolus: Atmospheric Dynamic Mission, Aeolus " *Keeper of the Winds*" in Greek mythology.

➢ First-ever satellite to directly observe the 3D wind.

➢ Aeolus satellite carry an Instrument named ALADIN (Atmospheric Laser Doppler Instrument).

➢ ALADIN probe the lowermost 30 km of the atmosphere from an orbit of 400 km above the earth's surface

➢ ALADIN fires laser pulses towards the atmosphere and measures the Doppler shift of the collected return signal, backscattered at different levels in the atmosphere.

➢ 120 wind profiles measurement per hour (1 profile each 30 sec).

Aeolus in action

1.ADM-Aeolus mission: Features

•Sun-synchronous, Polar orbiting at 400 km altitude (3 year life time)

• Direct detection near UV, 355nm laser wavelength

with two receivers Mie (clouds/aerosol), Rayleigh (molecules)

• Single line of sight (LOS) measurement

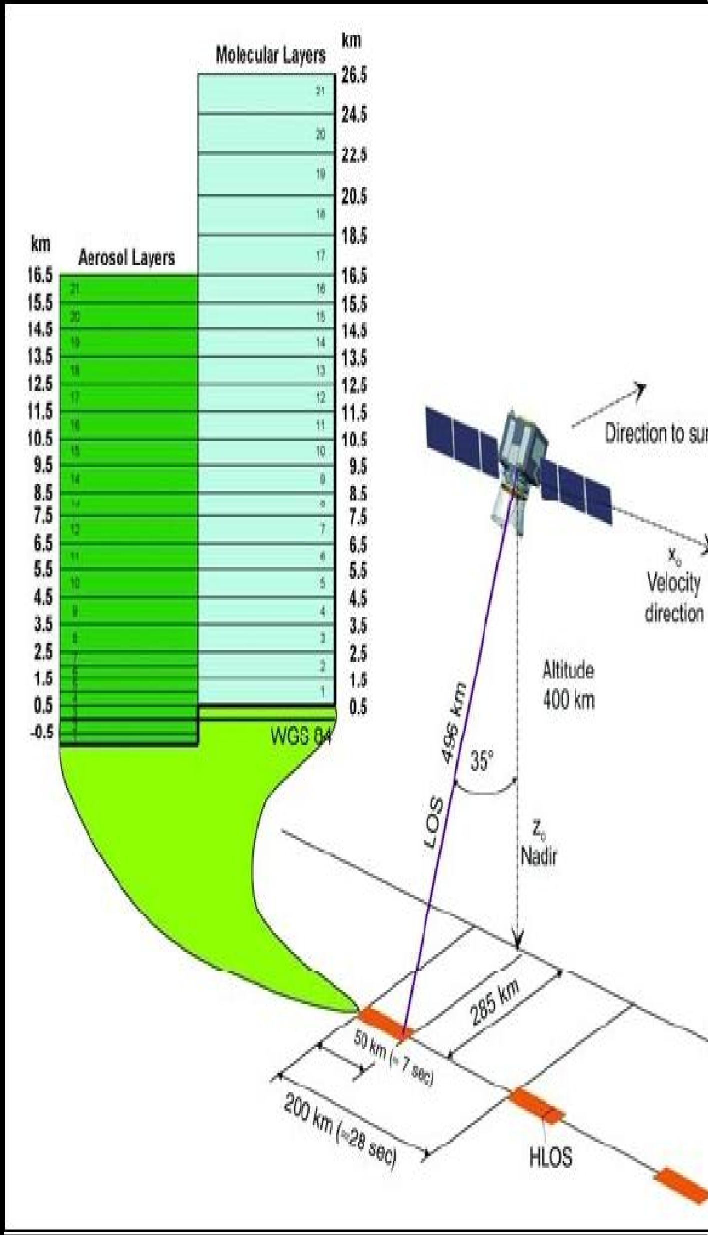
• Looking angle: 35° with the nadir

• Average wind velocity over 50 km tracks

• Vertical resolution programmable (range bins) in steps of 250m =>adjustable in flight

eg. 250-500m in the lower troposphere, 1000m in the free troposphere and 2000m higher up (WMO).

• Wind accuracy of 1m/s in the planetary boundary layer (up to an altitude of 2 km) & 2 m/s in the free troposphere (up to an altitude of 16 km)



Baseline Aeolus Measurement geometry

1. ADM-Aeolus mission: Doppler wind lidar (DWL)

Lidar use Light waves (Laser) instead of radiowaves (RADAR) or Sonic waves (SODAR) => **Direct measurement technique**

$$v_{LOS}(Z)=\frac{\lambda_0}{2}[f_s(z)-f_0]$$

f_0 : transmitted frequency

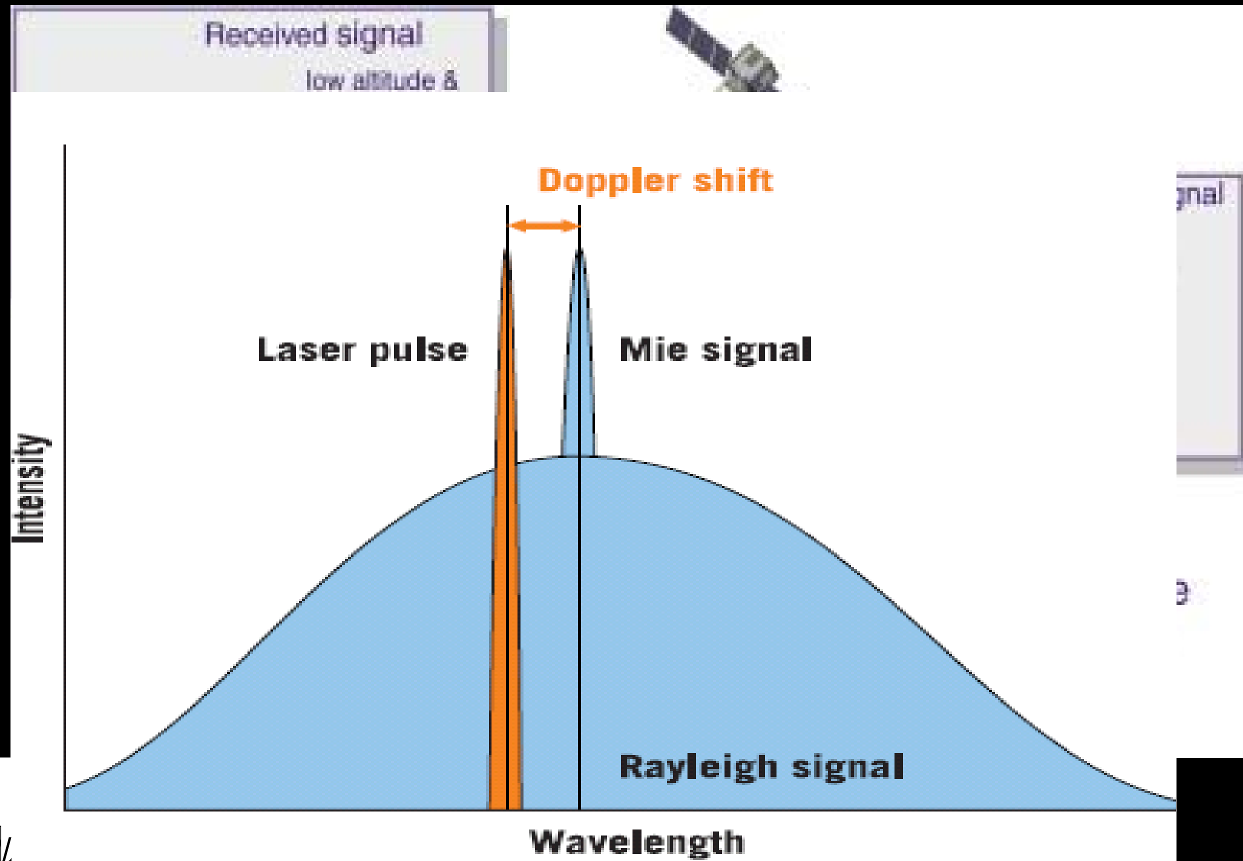
f_s : detected Doppler Shifted f

$V_{HLOS} = V_{LOS}/\sin$ □□ □

□ : incidence angle

$V_{HLOS} = -U\sin\psi - V\cos\psi$

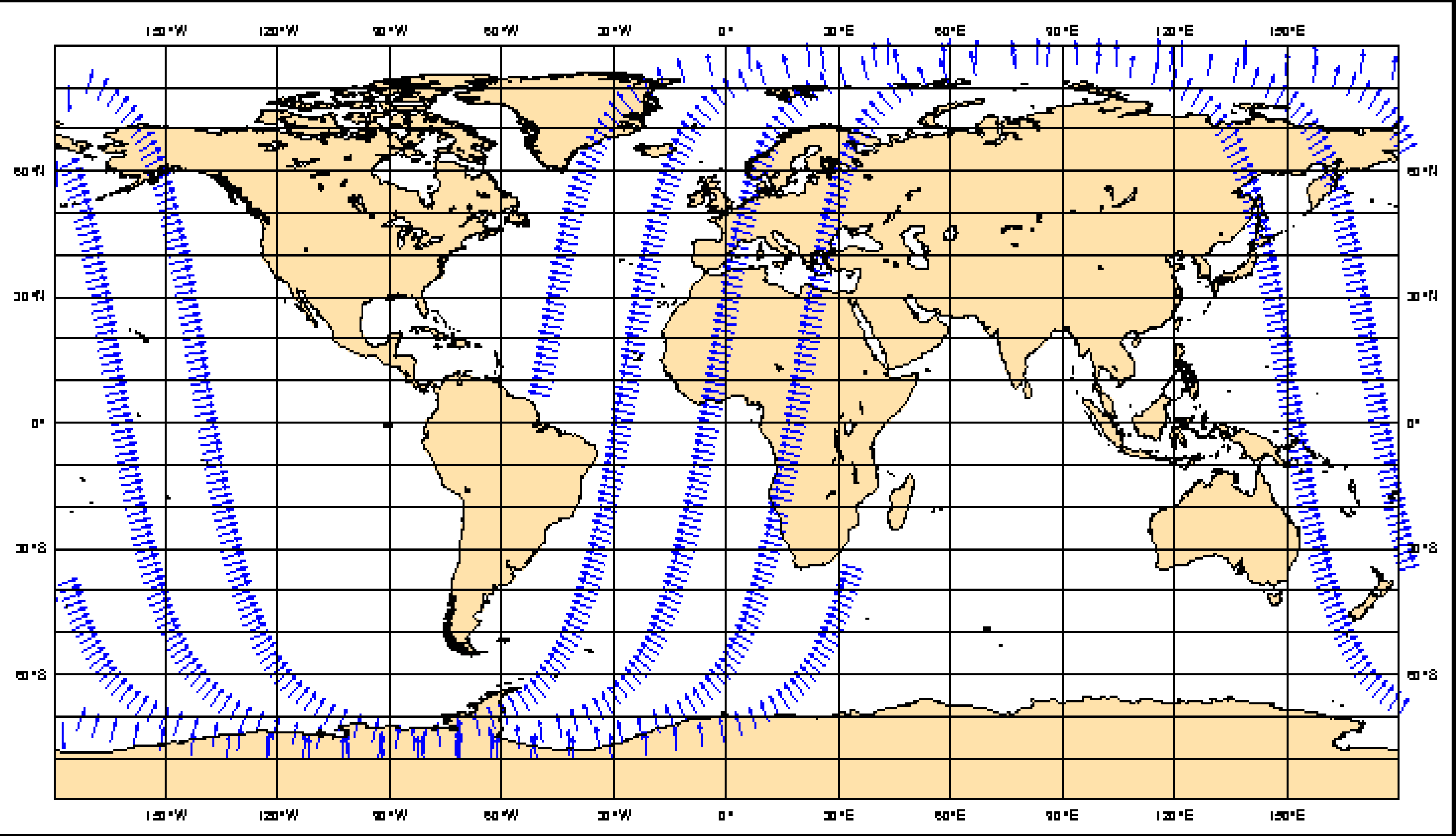
ψ : azimuth angle



- Range (bin distance) known from the travel delay between the transmitted and the received signal

- **Rayleigh** Refers to scattering of light (blue & viole by molecules , **O2 & N2** =>**blue sky** in the sunny day
- **Mie** scattering refers to scattering of light (**all**) by (cloud/aerosols)=> **White Clouds**

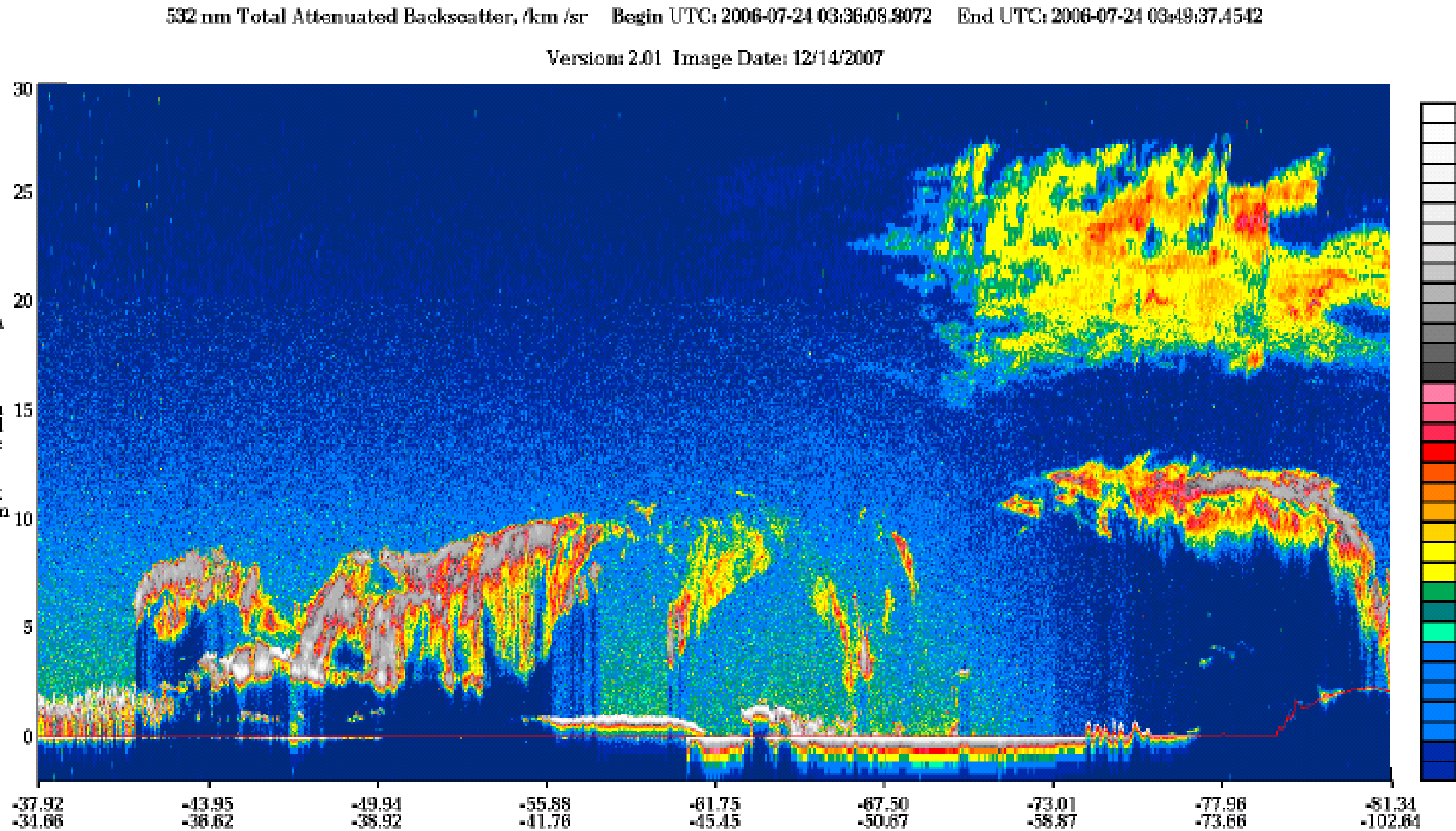
1.ADM-Aeolus mission: Coverage



- direction 7º from zonal at equator
- 6 hour coverage

2.VAMP(Cal/val project for ESA): Vertical Sampling

ADM-Aeolus's Mie and Rayleigh channels are limited to 24 Range bins for each



2. VAMP: Vertical sampling: Wind bin estimation

The most useful vertical bins distribution/sampling depends strongly on the **optical/dynamics heterogeneity** knowledge of the atmosphere

- Wind estimation over bins:

$$V_m(i) = \frac{\int_{z_i}^{z_{i+1}} s(z) V_t(z) dz}{\int_{z_i}^{z_{i+1}} s(z) dz}$$

V_t : true wind

V_m : measured

S : return signal energy (photons)

Jet stream

Main situations

➢ Homogeneous atmosphere:

$S(z) = S_0$ → $V_m(i) = \frac{1}{z_{i+1} - z_i} \int_{z_i}^{z_{i+1}} V_t(z) dz$ → Mean wind in bin

➢ Heterogeneous atmosphere:

$V(z) = V_0 = \text{cste/bin}$ → $V_m(i) = V_0$ → Mean wind in bin

➢ Heterogeneous atmosphere+ Wind shear:

$V_m(i) \neq V_{bin}$ → Estimated wind # Mean wind in bin → **Wind errors**

2. VAMP: Vertical sampling: Wind errors

Wind errors measurement in the range bins depends on:

- **optical (cloud/aerosol) variability and their location inside the bin**
- **Wind shear over the bin (vertical)**

VAMP studies:

- **CALIPSO backscatter/ECMWF wind collocation ; (Gert-Jan Marseille,KNMI)**
- **Cloud resolving model (KAWEX, models) (Heiner Körnich, MISU,Stockholm)**
- **High resolution radiosonde /ECMWF wind collocation (Karim, KNMI)**

Characterization of the wind and wind shear

Vertical wind shear

$$sh(i) = \frac{\left|V(i+1) - V(i)\right|}{z(i+1) - z(i)}, \qquad i = 1, \cdots, n$$

2. Hi-Res vs ECMWF SRF: Data coverage

SPARC data features

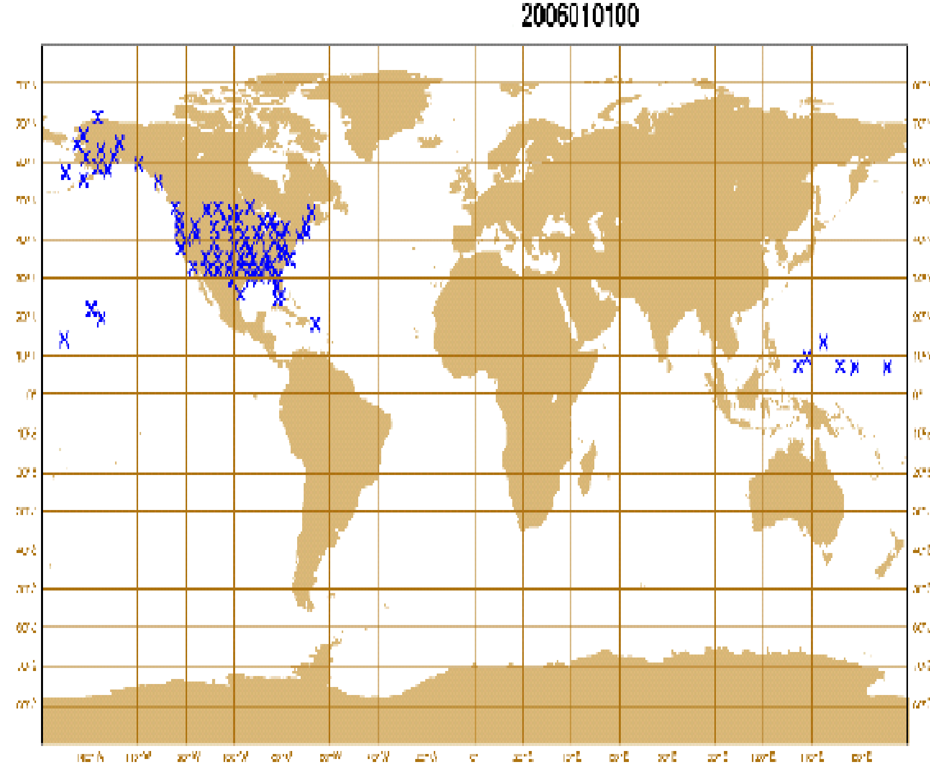
• 6 second time resolution(~30m, vm=5m/s)

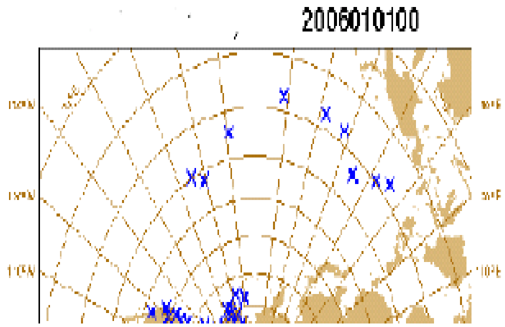
•Spatial coverage (map)

• Temporal coverage: 1998 till 2006

• Windfinding system based on the radiothedolite

Others data(met-Office (UK), Fastex…)



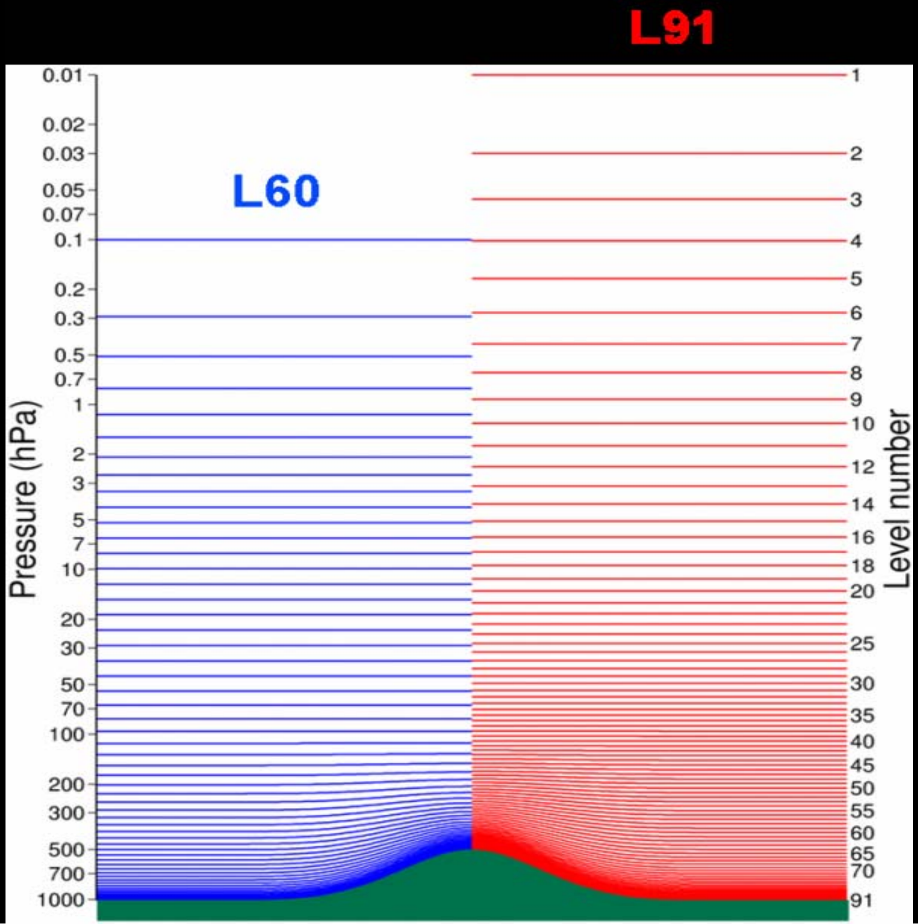


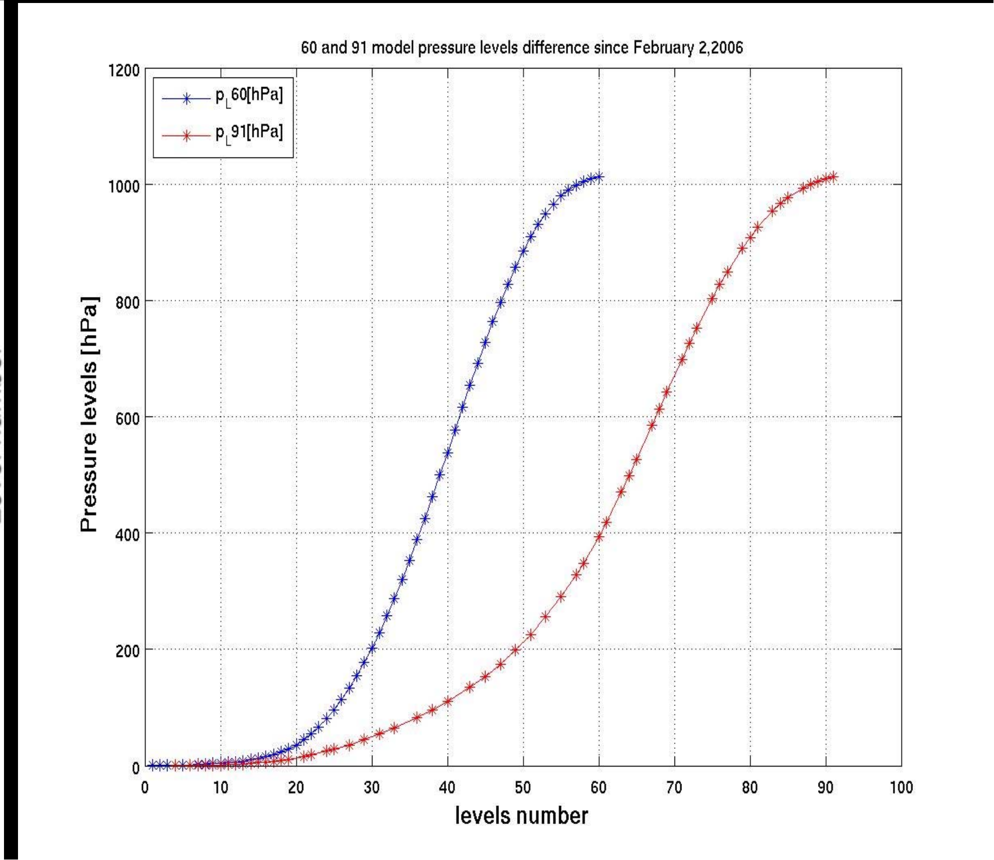
3. Hi-Res radiosonde vs ECMWF SRF: Model levels/changes

ECMWF Short-Range Forecast (SRF)

• 1 year SPARC(2006) data are collocated with ECMWF-SRF => data correspondence in terms of time and space

Note: Model level change from 61 to 90 since 02/02/2006



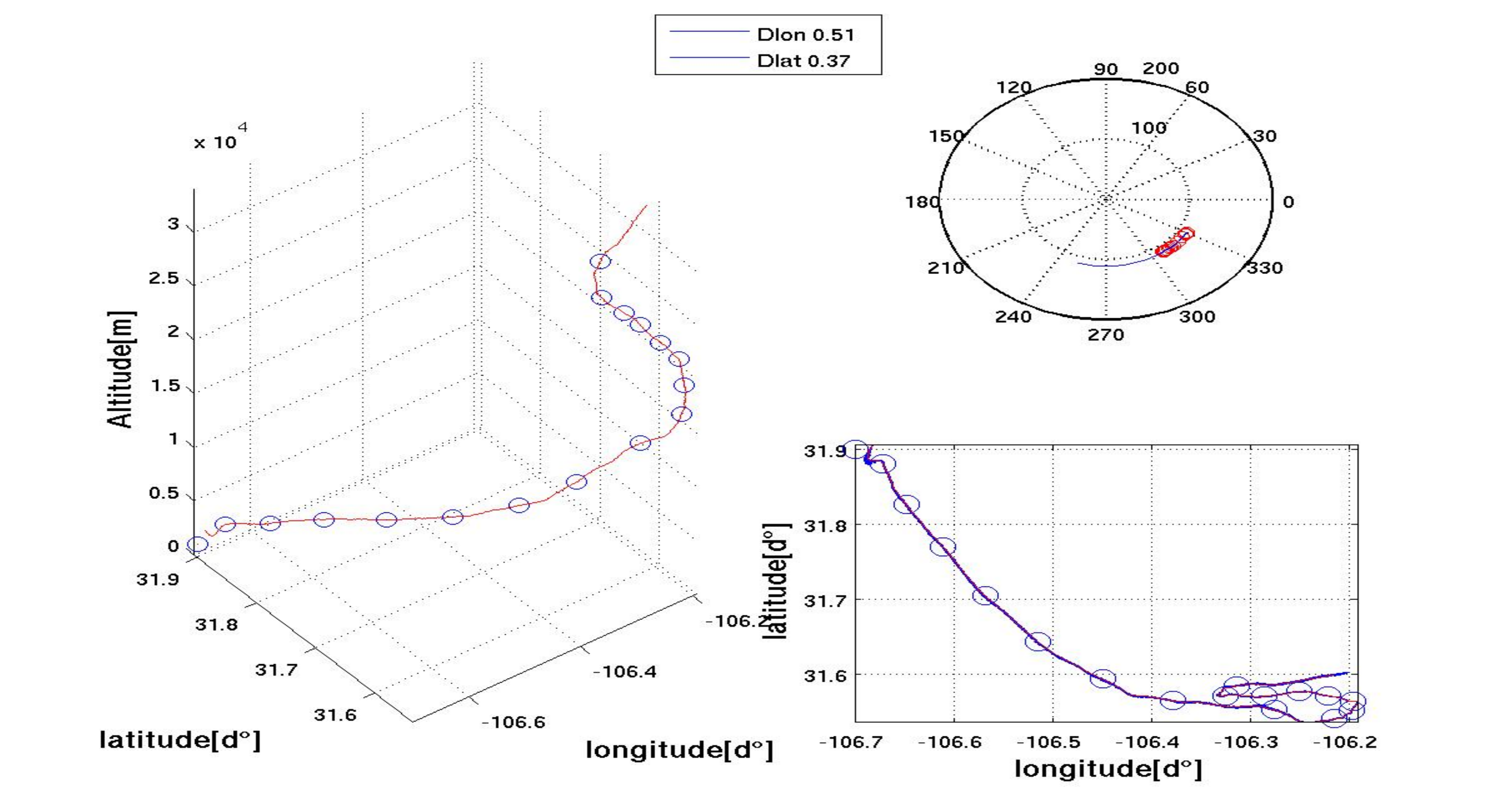


3.Hi-Res Radiosonde vs ECMWF-SRF: rad trajectory/drift

- Radiosonde drift can goes to **hundreds** of Km

  e.g: At the equator, the circumference of the earth ~ 40076 km

1 degree lon=40076/360 = 111.32 km/degree



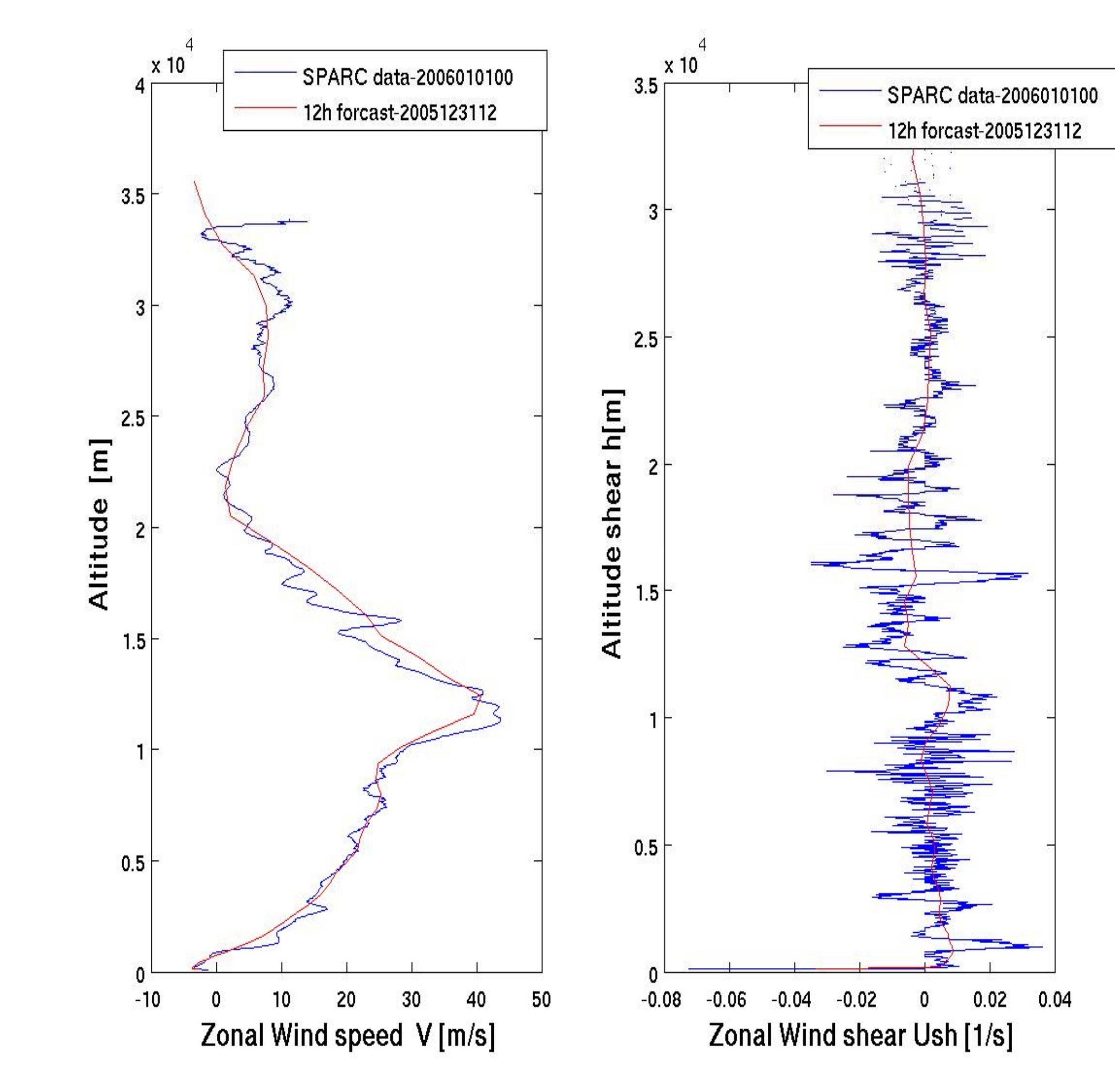
Radiosonde ascent trajectory (movie) and radiosonde position.

3. Hi-Res radiosonde vs ECMWF SRF : collocation

- **ECMWF wind profile resembles in Shape to the Hi-Res radiosonde**

- **ECMWF-SRF miss quite important structures (underestimation of height assignment and HLOS wind errors)**

- **Wind shear variability in the radiosonde is higher than the ECMWF wind model (ECMWF is smoother)**



Wind collocation of the Hi-res resolution radiosonde with the ECMWF-SRF

2.Hi-Res radiosonde vs ECMWF-SRF:Resolution effect

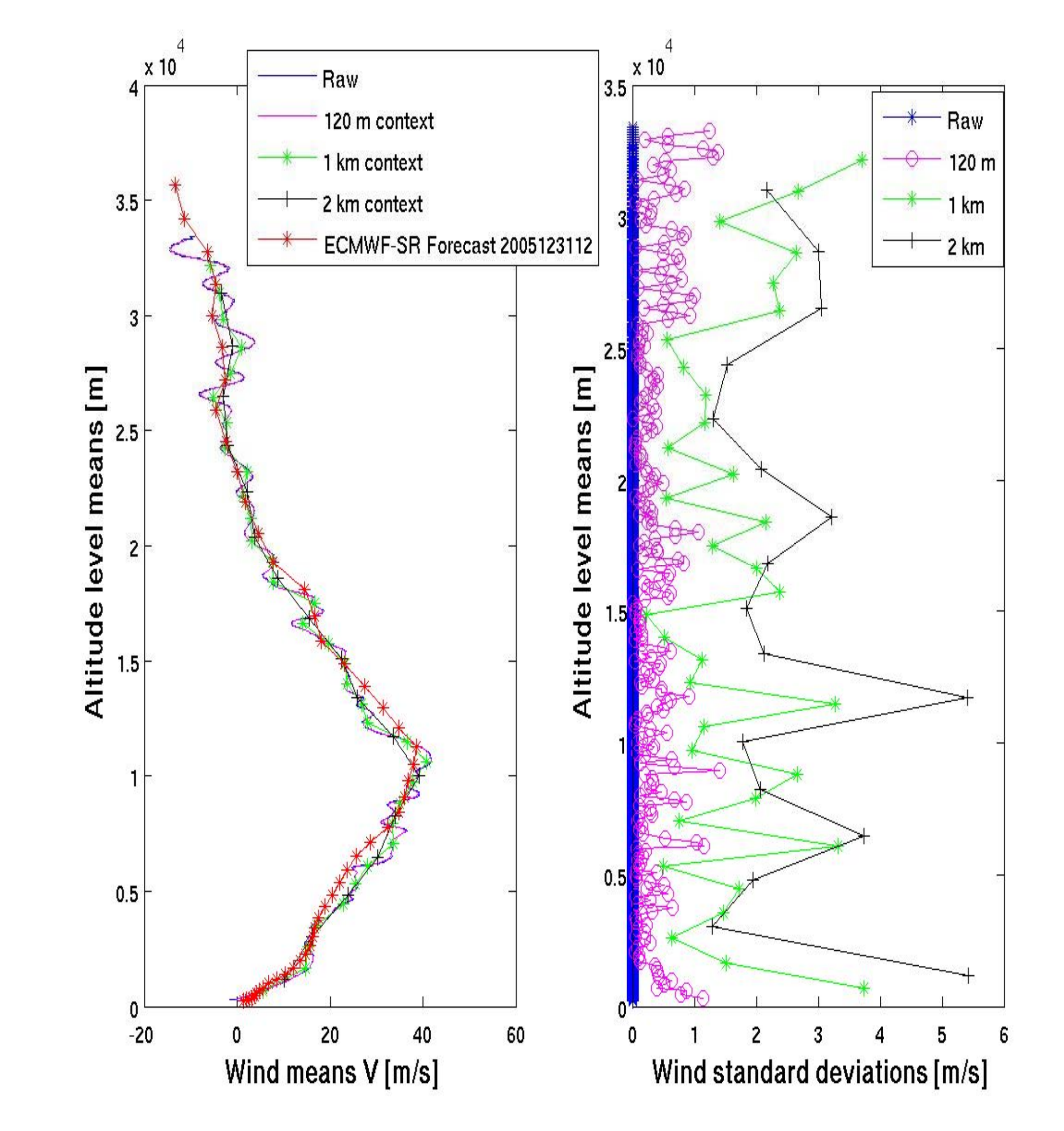
Averaging/stds over different ranges bins:120m,1km and 2km

- **For larger range bins the Hi-Res radiosonde compares better to the ECMWF wind profile of 2km context**

- **the SDs (errors) increases by reducing the resolution**

- **the larger the range, the more wind variability is confined in it**

==> smooth ECMWF wind profile lacking a wind variability in of 2 to 3 m/s



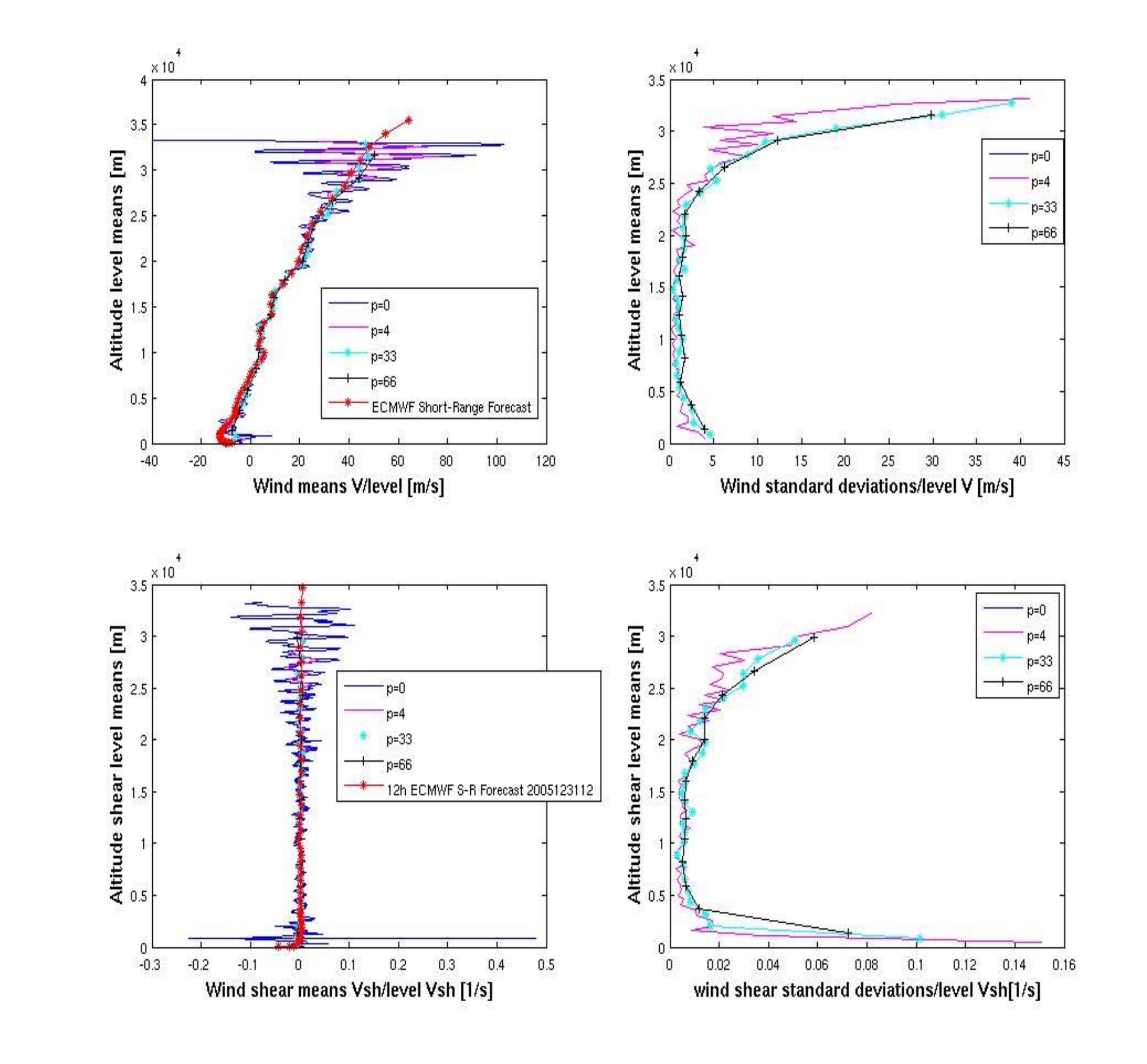
Effect of reducing the resolution of raw radiosonde on wind and wind shear

3. Hi-Res radiosonde vs ECMWF-SRF: gravity waves, outliers

- **From 120m resolution context and Up, the gravity waves vanish (not detected!)**

- **persistent problem near the surface, due the Radiothedolite wind finding system (el<17°)used for collecting this data.**

Data Quality control



Effect of reducing the resolution of raw radiosonde on wind and wind shear

3. Hi-Res radiosonde vs ECMWF-SRF: Quality control

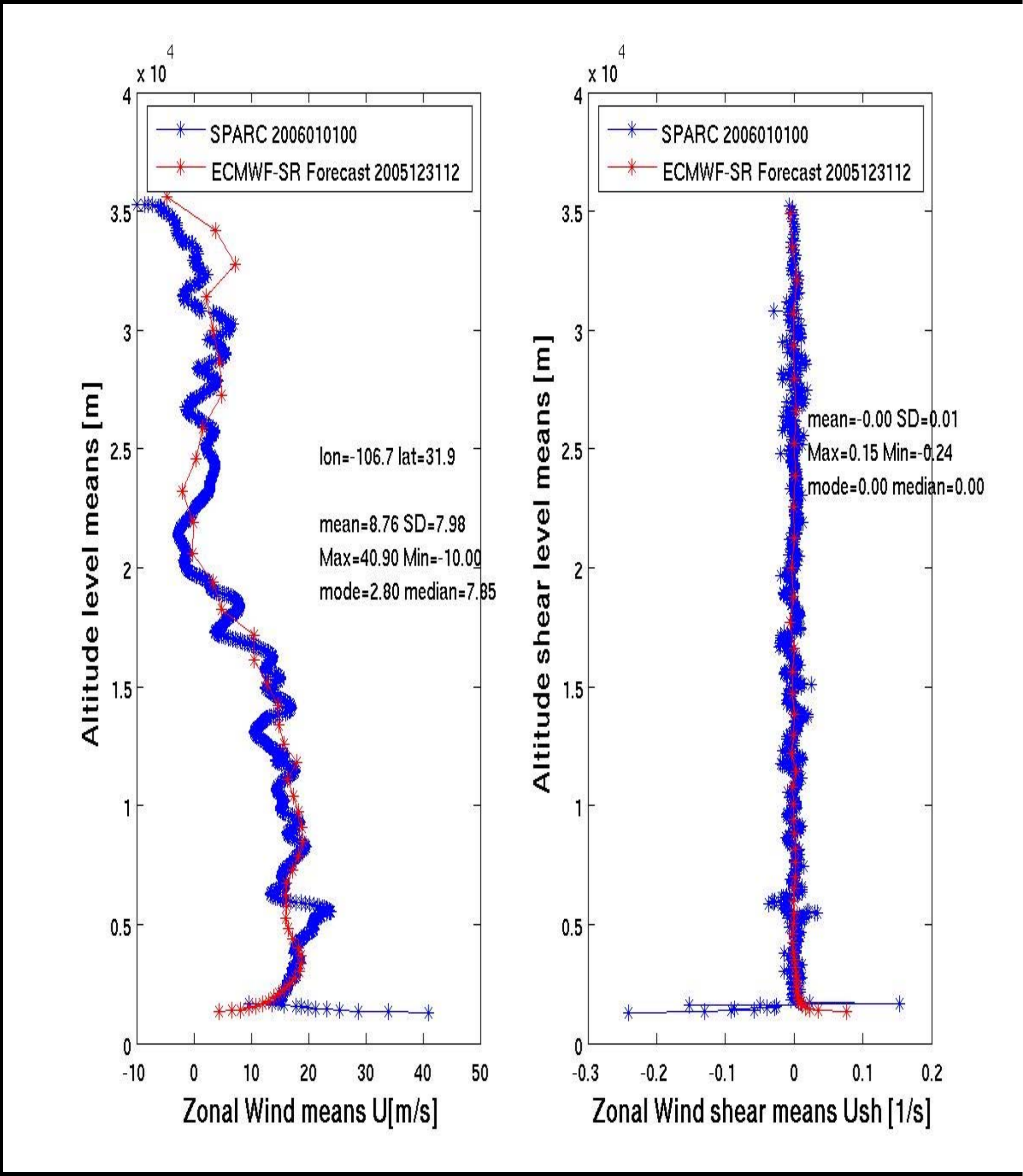
QC is the necessary procedure to distinguish the outliers (unrepresentative)
from the representative observations; generally done in 2 steps (levels) :

- ***QC level 1: Validity check*** *Eliminate the unreasonable extreme world values (table of Tolerance limits of the extreme values), and Hydrostatics check (Schwartz, B. & all, 1992)*

- ***QC level 2: : Super adiabatic lapse rate check & Wind shear check*** *(DiMego, & all, 1985)*

Vamp QC: *Control first deltaZ then QC below in color)*

Typical e.g. of wind shear control (deltaZ~mean delta Z ascent here)



4. Wind and wind shear variability: Tropics

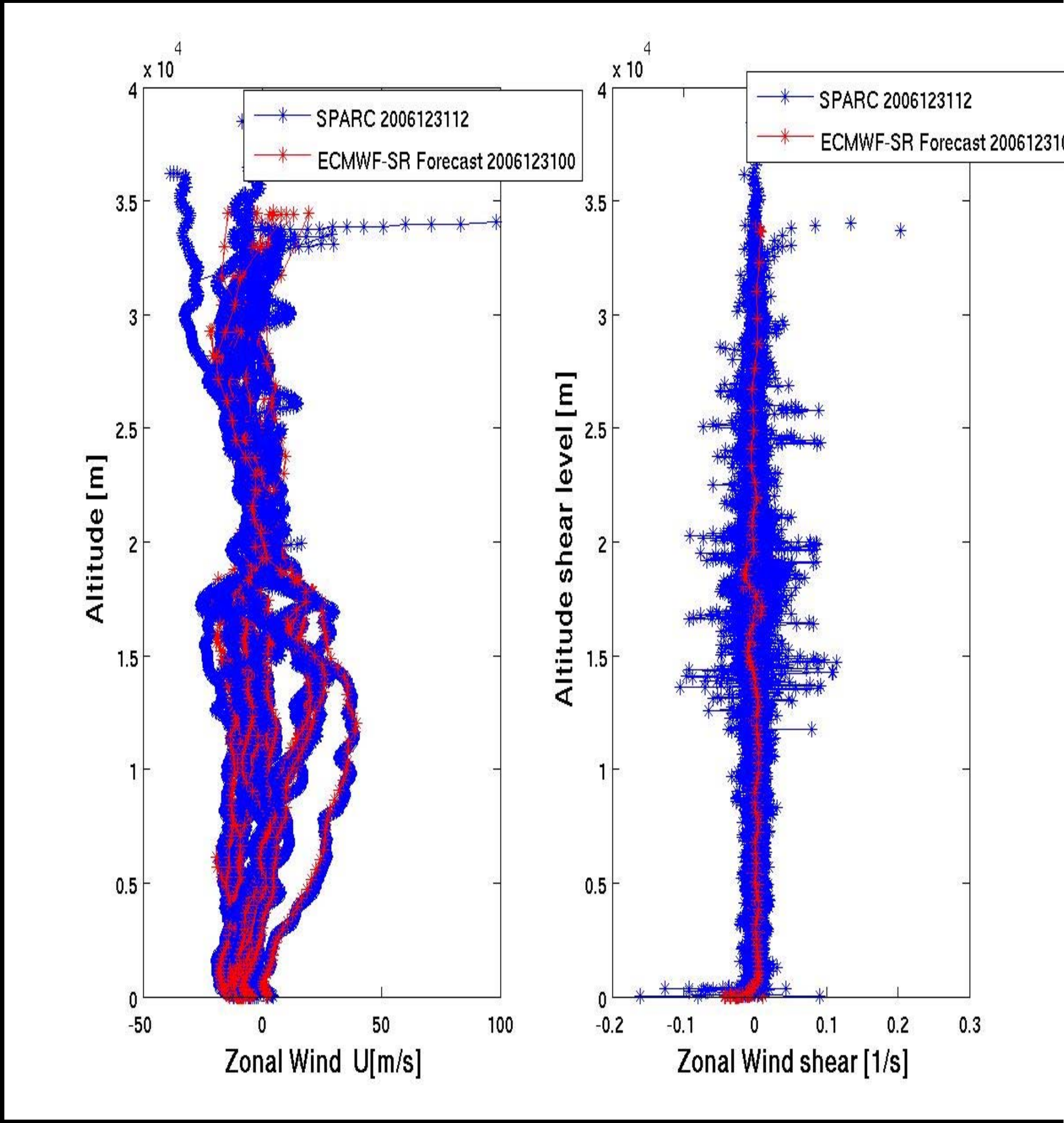
- Maximum wind values reached 48m/s, mainly near the tropopause and upper stratosphere.

- The mean wind is small in the tropics (15 m/s) and it is mainly **easterly**

- Large value of the wind shear found in the stratosphere

- The threshold of the QC wind shear of 0.4 1/s fixed here is too excessive,

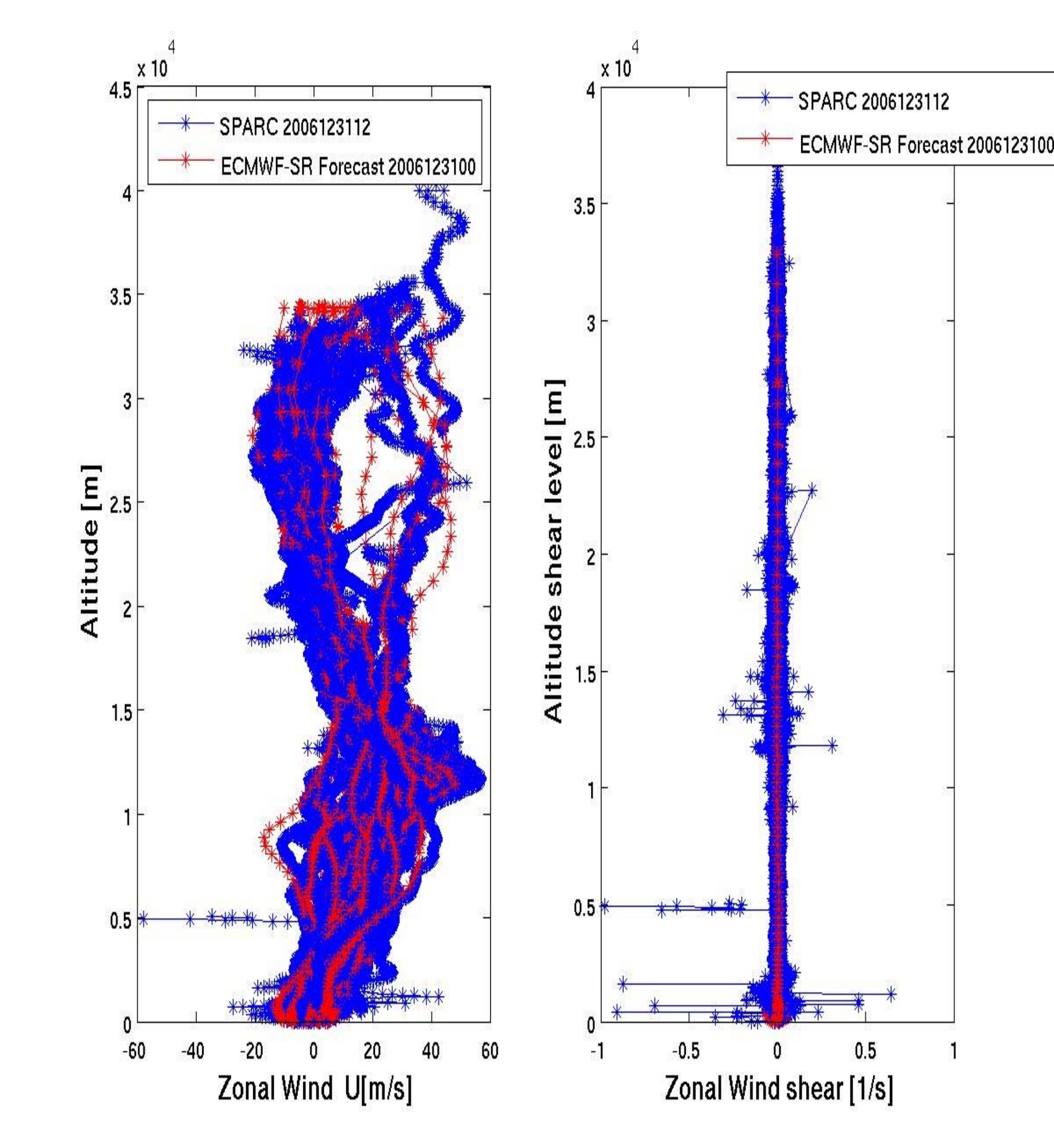
- A threshold of 0.10 or 0.12 should be enough to validate the representative data in the tropics.



Zonal Wind and wind shear over 15 tropical locations with restriction on the wind shear (WS-QC=.0.4 (s−1))

4. Wind and wind shear variability:Mid-latitudes

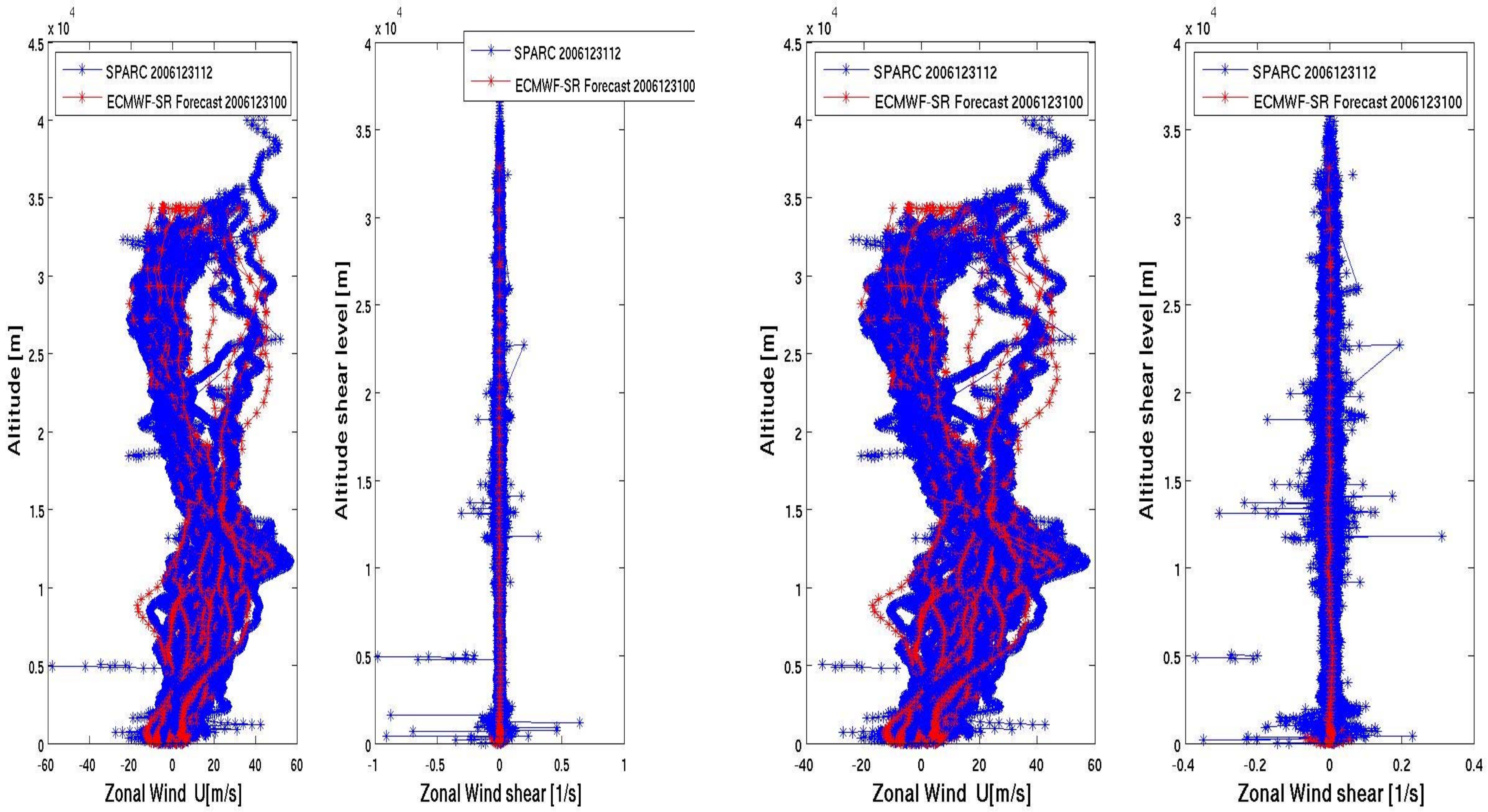
- Maximum wind values reached 60 m/s, mainly near the tropopause(westerly) and less in (30m/s)upper stratosphere (Easterly).
- Large values of the wind shear found near the tropopause(jet stream) and the boundary layer
- Suspicious values near the surface due probably to the limitation of the radiotheodolite for elevation angle under 17°



Zonal Wind and wind shear over 61 mid-latitudes locations with No QC- wind shear (0.s−1)

4. Wind and wind shear variability: Wind shear QC

- About 6 points only are rejected and near the surface with 0.4 WS-QC
- But, still have some suspicious values?
- Can say at least that Its value should be greater than in the tropics, means around 0.2 (1/s).

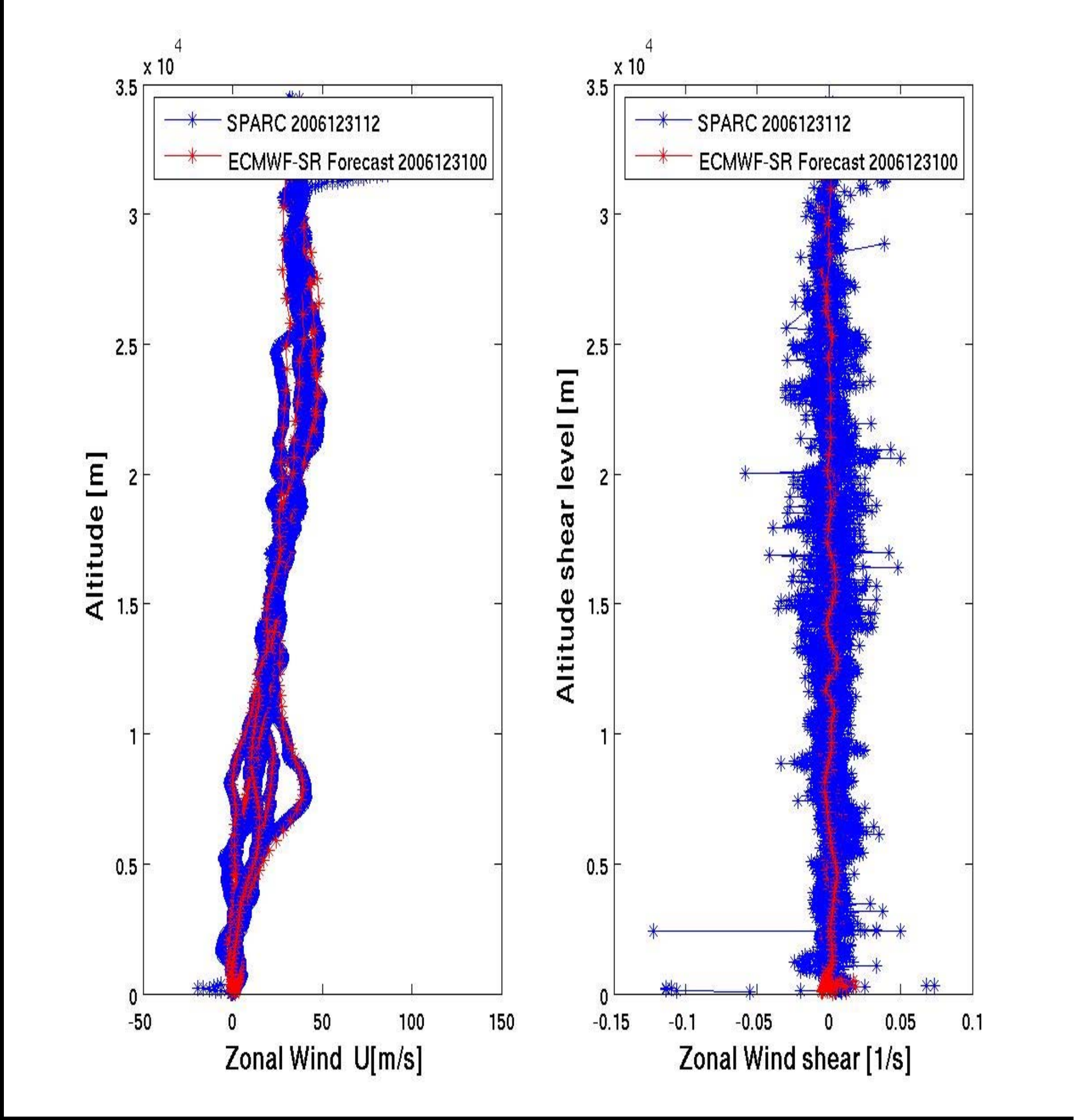


4. Wind and wind shear variability:Polar

• Maximum wind values can reach even more than 100m/s in the upper stratosphere and a mean of ~50 m/s in the lower stratosphere(stratospheric jets) mainly Westerly

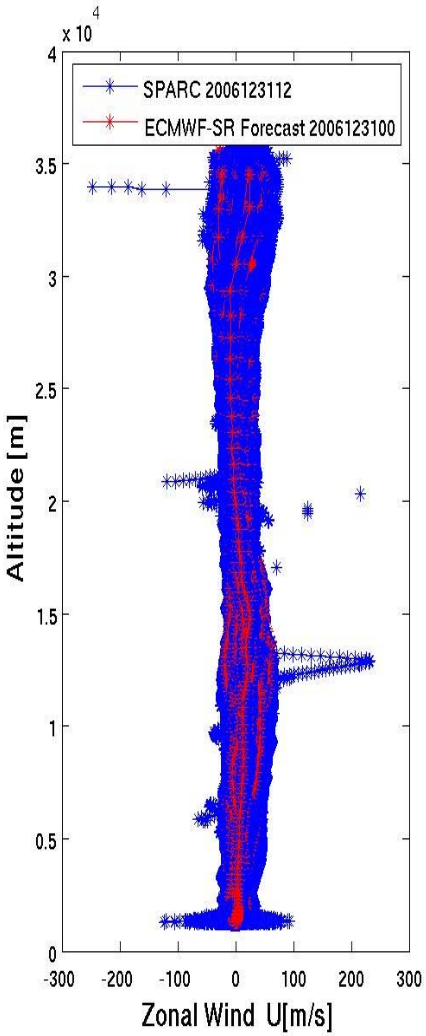
• Large values of the wind shear found , mainly near the tropopause and the stratosphere But not larger than what we have seen in th tropics and midlatitude

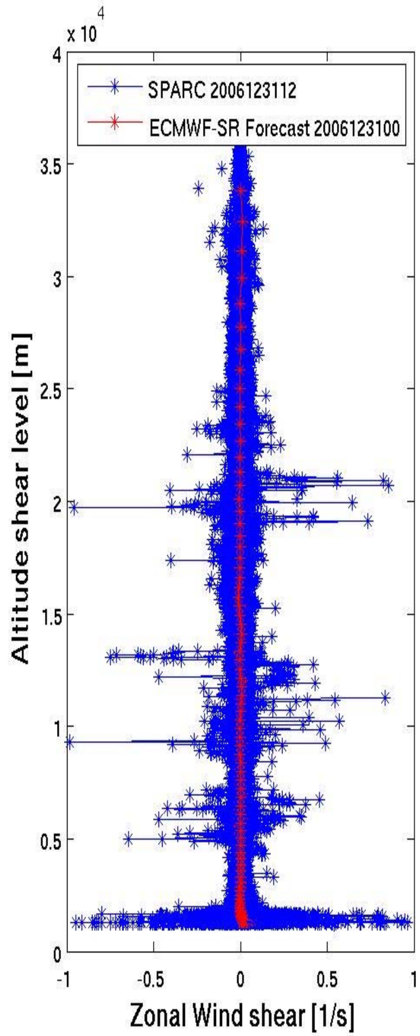
• Suspicious value near the surface due probably to the limitation of the radiotheodolite for elevation angle under 17°

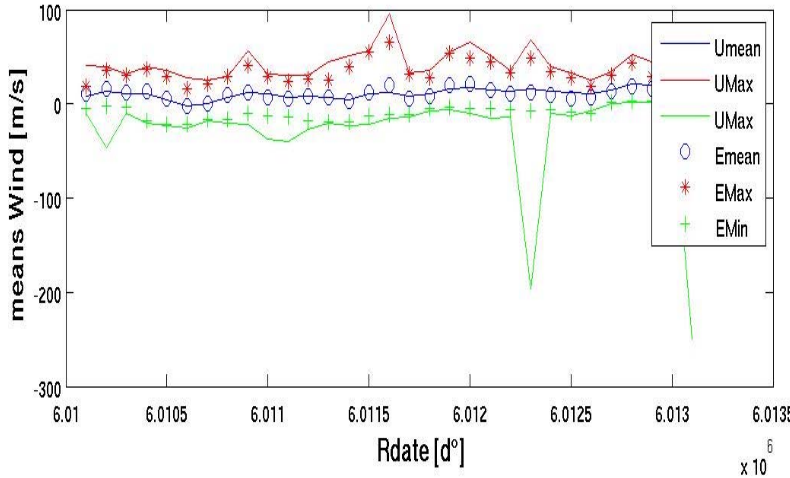


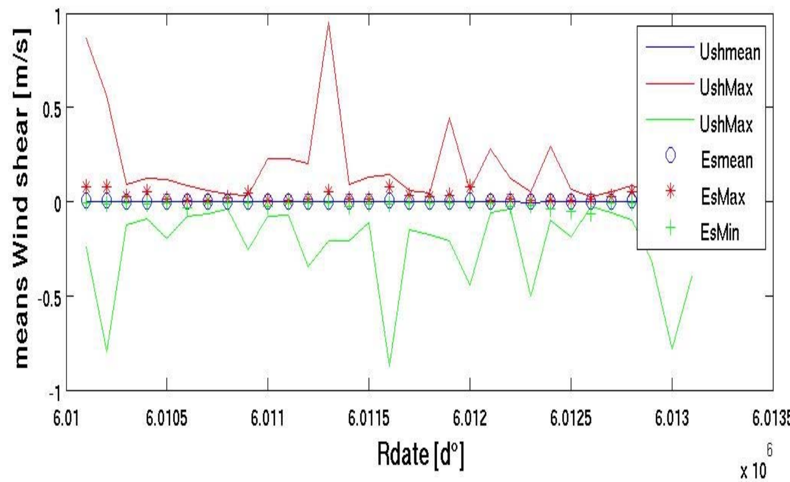
Zonal Wind and wind shear over 7 polar locations, wind shear (WS-QC=1.0 (1/s)

4. Wind and wind shear variability: yearly variability









Zonal Wind and wind shear over one 1 year period, 2006 with WS-QC=.1.0 1/s)

Means (blue), MAXs (red) and MINs (green), b) Variations radiosonde data and ECMWF model period, January 2006 with WS-QC=.1.0 (1/s)

5. Windfinding system(radiotheodolite,Loran and GPS)

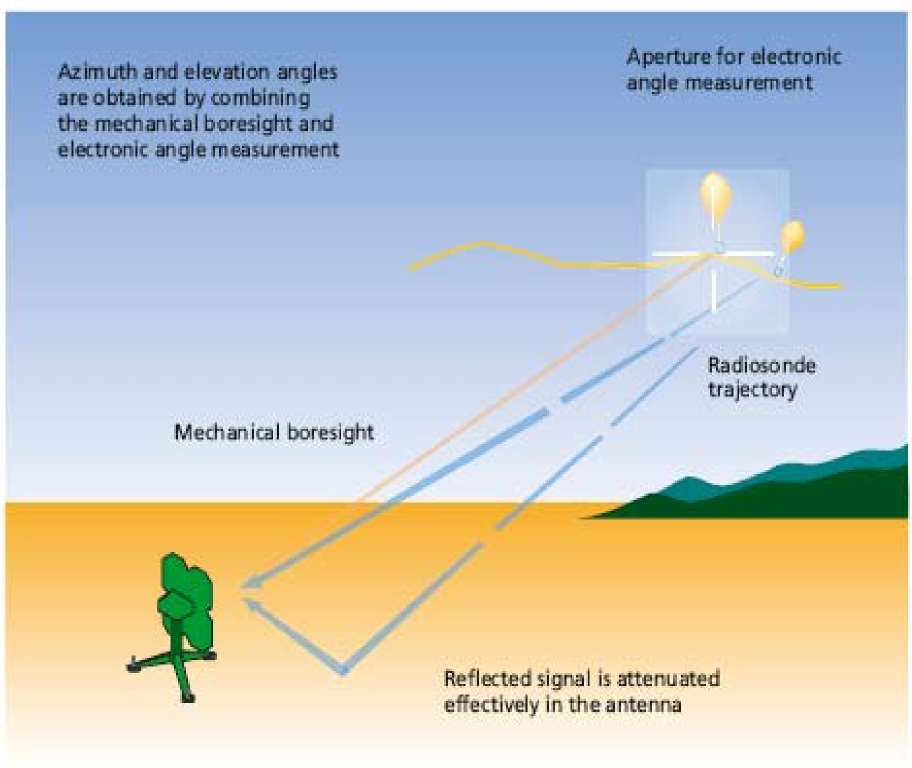
The radiosonde wind data is derived from the successive positions of the balloon ascent, using one or more of the 3 type of the windfinding systems

- Radiotheodolite: follow the balloon by a radar and determine the azimutha and elevation angle and also the range (if equipped with radar reflector); the position is determined by using a simple spherical coordinate

- LOng Range Navigation(Loran-c (US,),Chakya(Russia)):based on the trilateration methods

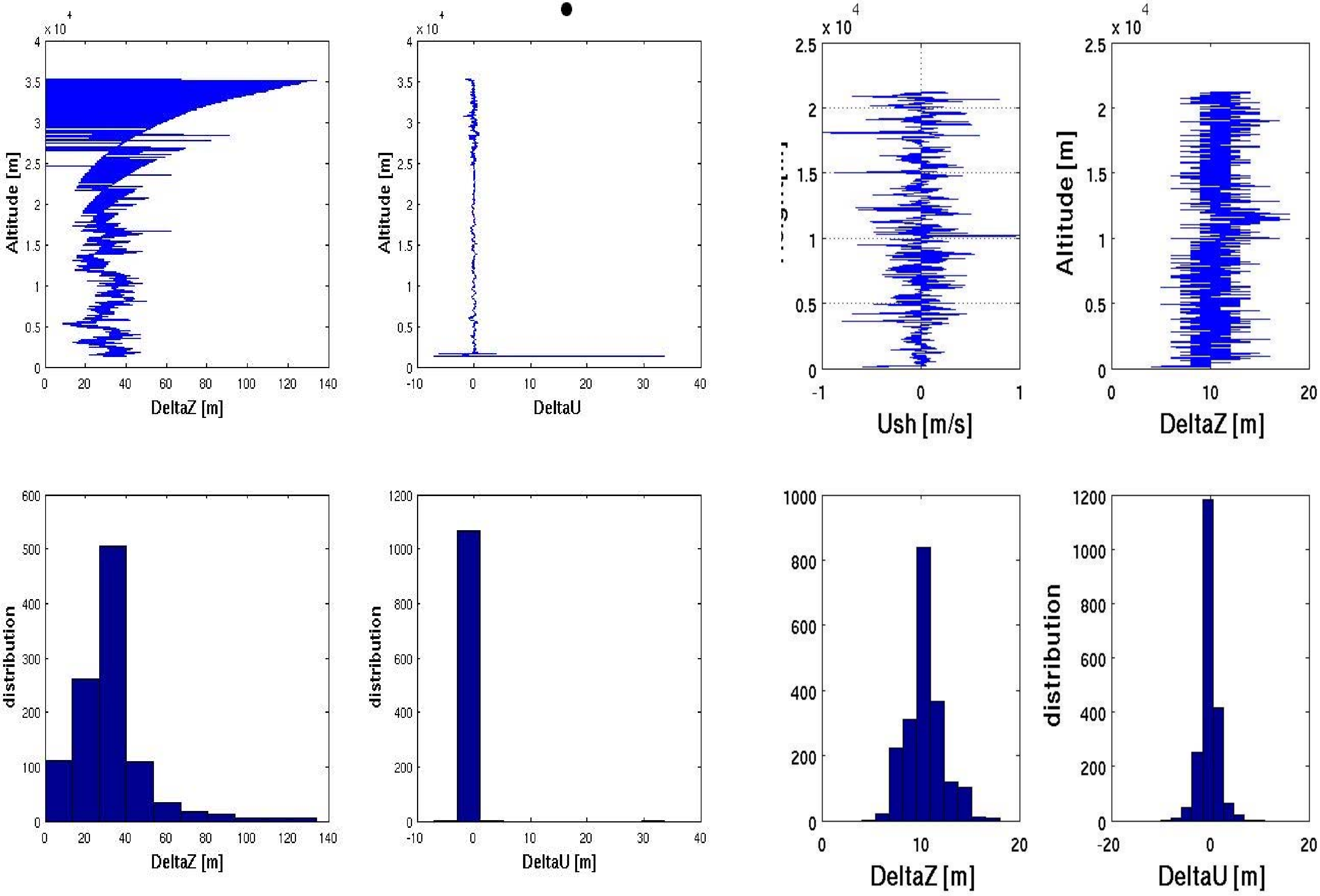
- GPS (at least four satellites needed)

=> The quality of wind data depends on position accuracy measurement of the these systems



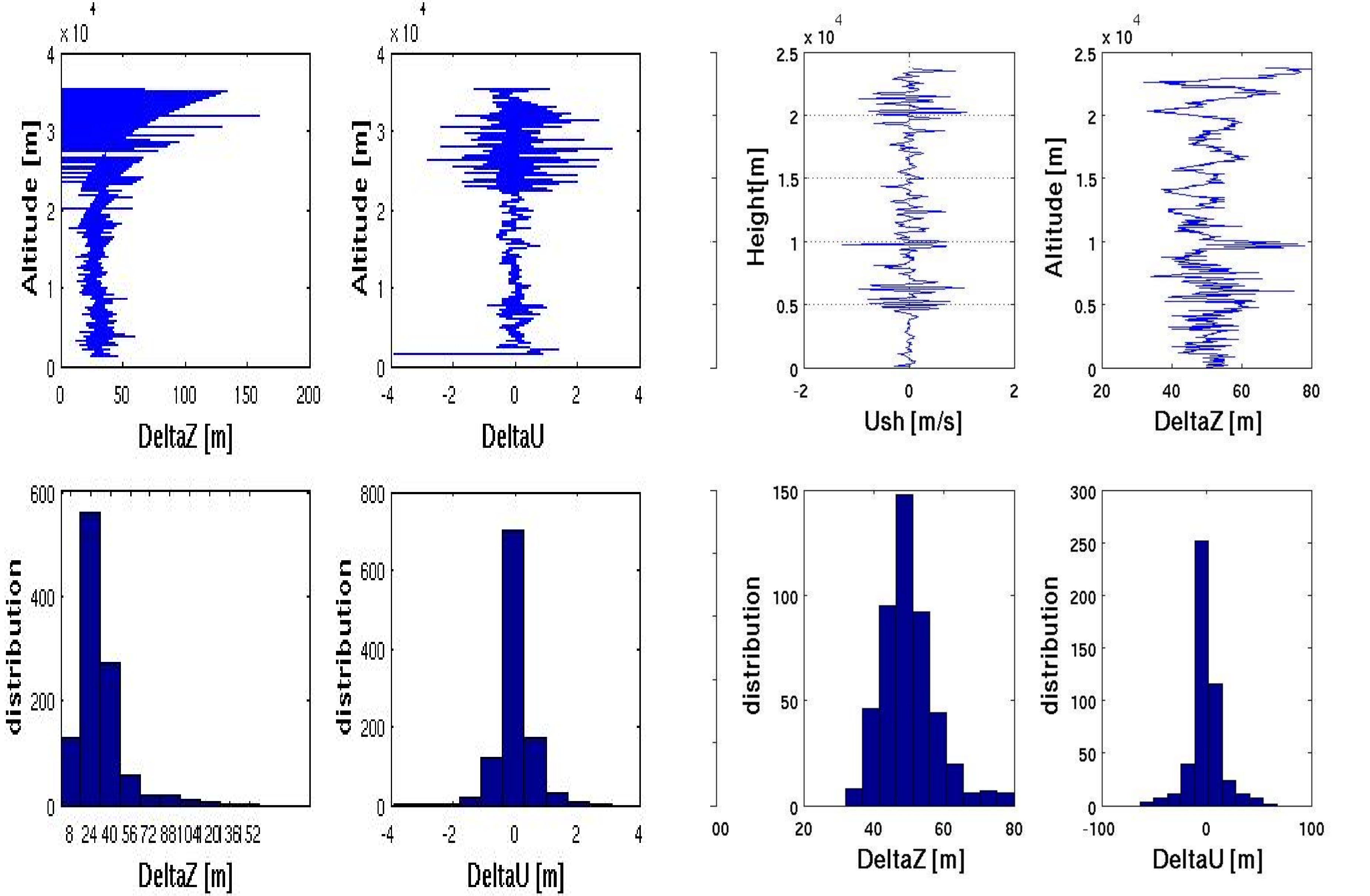
Radiotheodolite windfinding system

5. Windfinding system: radiotheodolite(6sec) vs Loran-C(2sec)



windfinding systems comparison

5. Windfinding system: Radiotheodolite(6sec) vs GPS(2sec)



Windfinding systems comparison

6.Conclusions

- Hi-Resolution radiosonde (at small scales) exhibits a strong

Wind/~ shear variability compared to ECMWF model levels

- Radiosonde data is still an important component of the observing network, despite the large amount of nowadays satellites.

- The quality of radiosondes wind data depends on the used

windfinding systems (radiotheodolite, Loran GPS ...) for data retrieval

⇒ Get a good model wind (at small scales)=> require a good quality of the data.

But since,

- SPARC (radiotheodolite) data: a wide coverage low quality data
- GPS and Loran-C data: better quality but a limited coverage

hence, the extensive comparison of the data from the different windfinding systems will give a idea whether possible to continue modelling with these SPARC data?

Thanks…