Terrestrial and Martian Dust Devils

Study of the translational motion and resolution of the size/distance degeneracy of the meteorological time series

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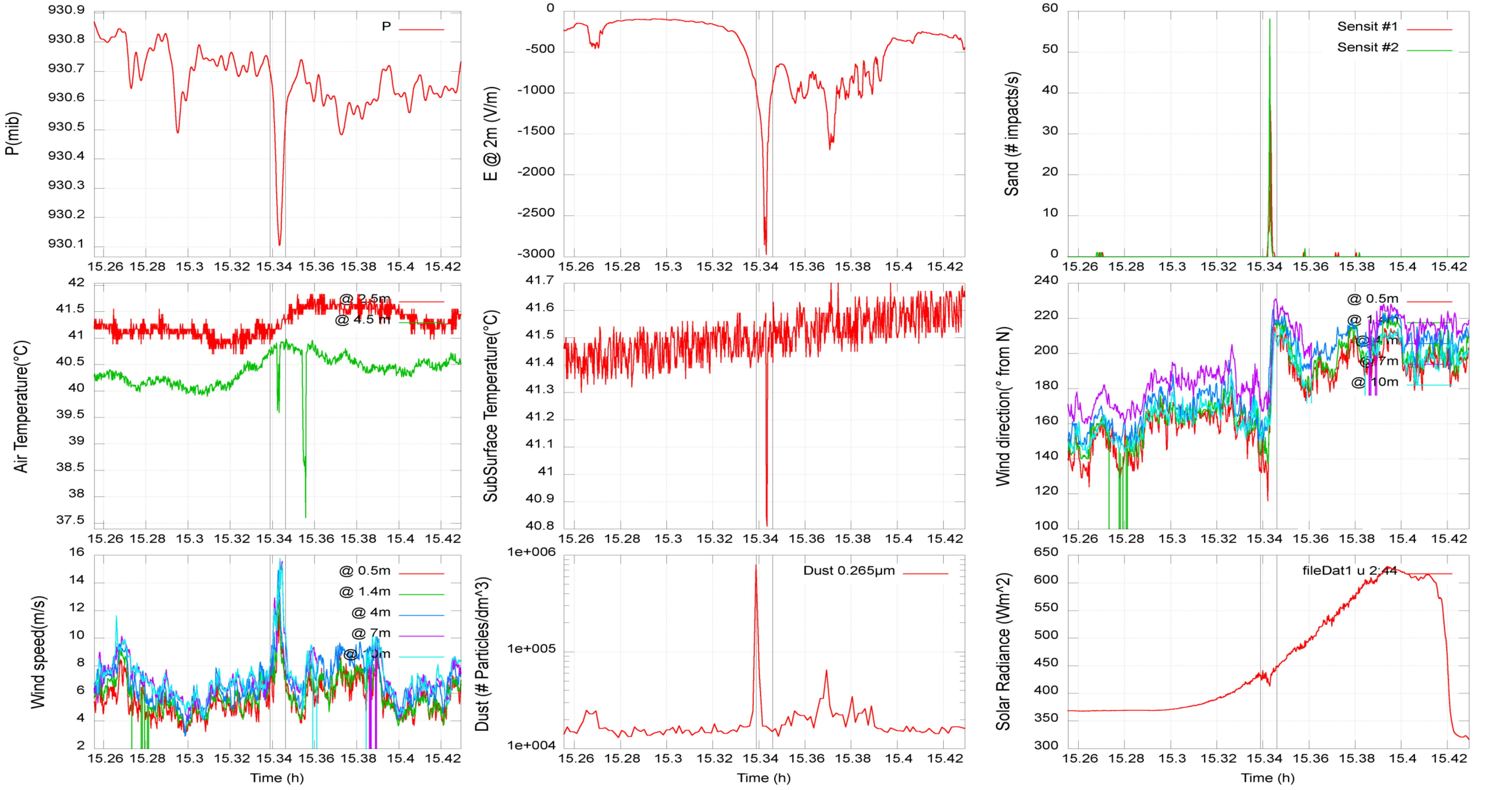
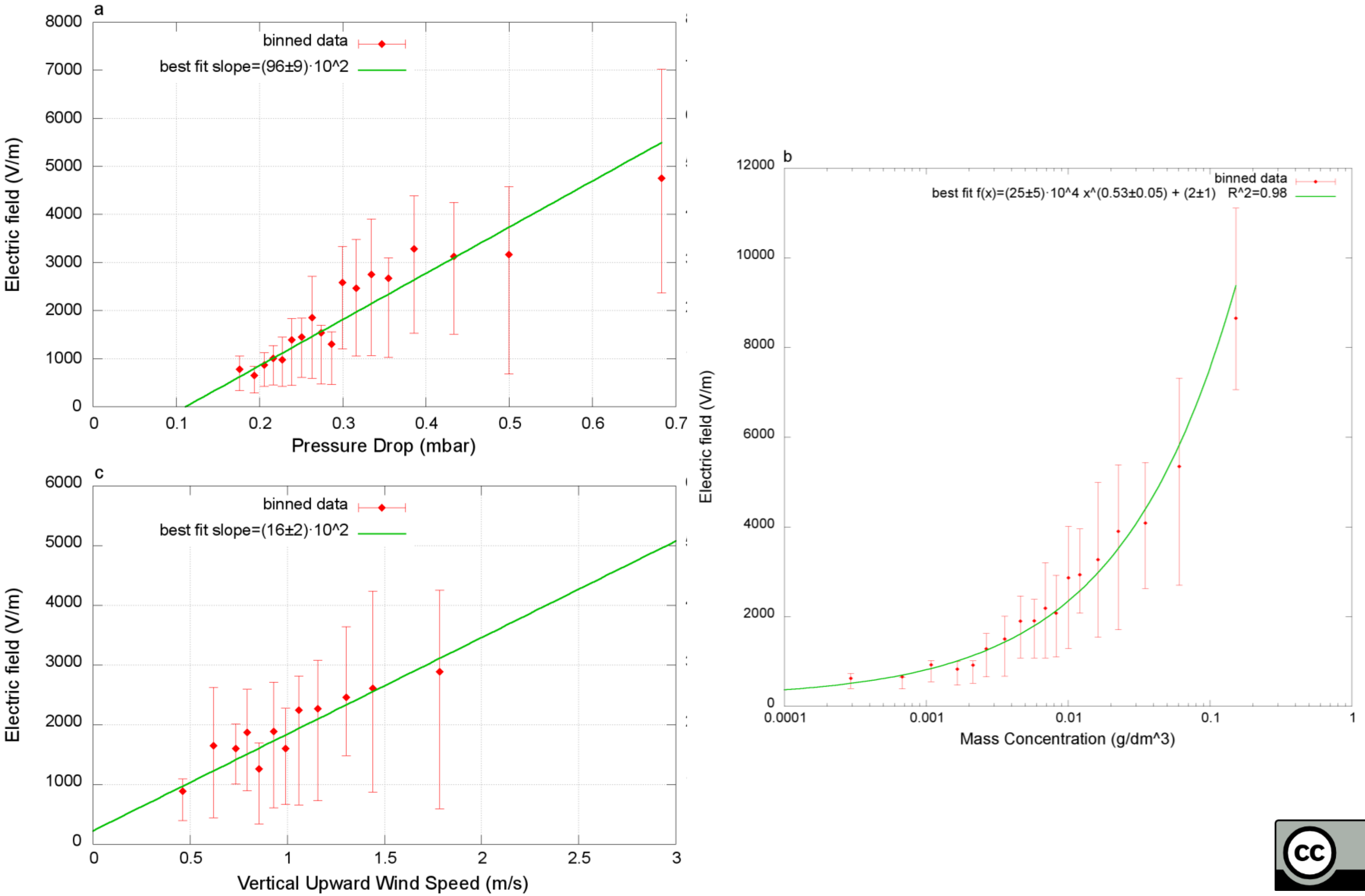
Sensor	Height 2014 (m)
Temperature	At surface 2.5 4.5
2-D sonic anemometer	0.5 1.41 4 7 10
3-D anemometer	4.5
Pressure	2
Humidity	At surface 2.5
Sensit (sand and dust impact)	At surface
Sand catcher	0.12 0.25 0.40
Dust concentration rate	1.5
Electric field	2
Solar irradiance	4

08_08_2014



P(mib)
P
E @ 2m (V/m)
Sand (# impacts/s)
Sensit #1
Sensit #2
Air Temperature(°C)
@ 2.5m
@ 4.5 m
SubSurface Temperature(°C)
Wind direction(° from N)
@ 0.5m
Wind speed(m/s)
@ 0.5m
@ 1.4m
@ 4m
@ 7m
Dust (# Particles/dm^3)
Dust 0.265μm
Solar Radiance (Wm^2)
fileDat1 u 2:44
Time (h)

Correlation between the meteo parameters

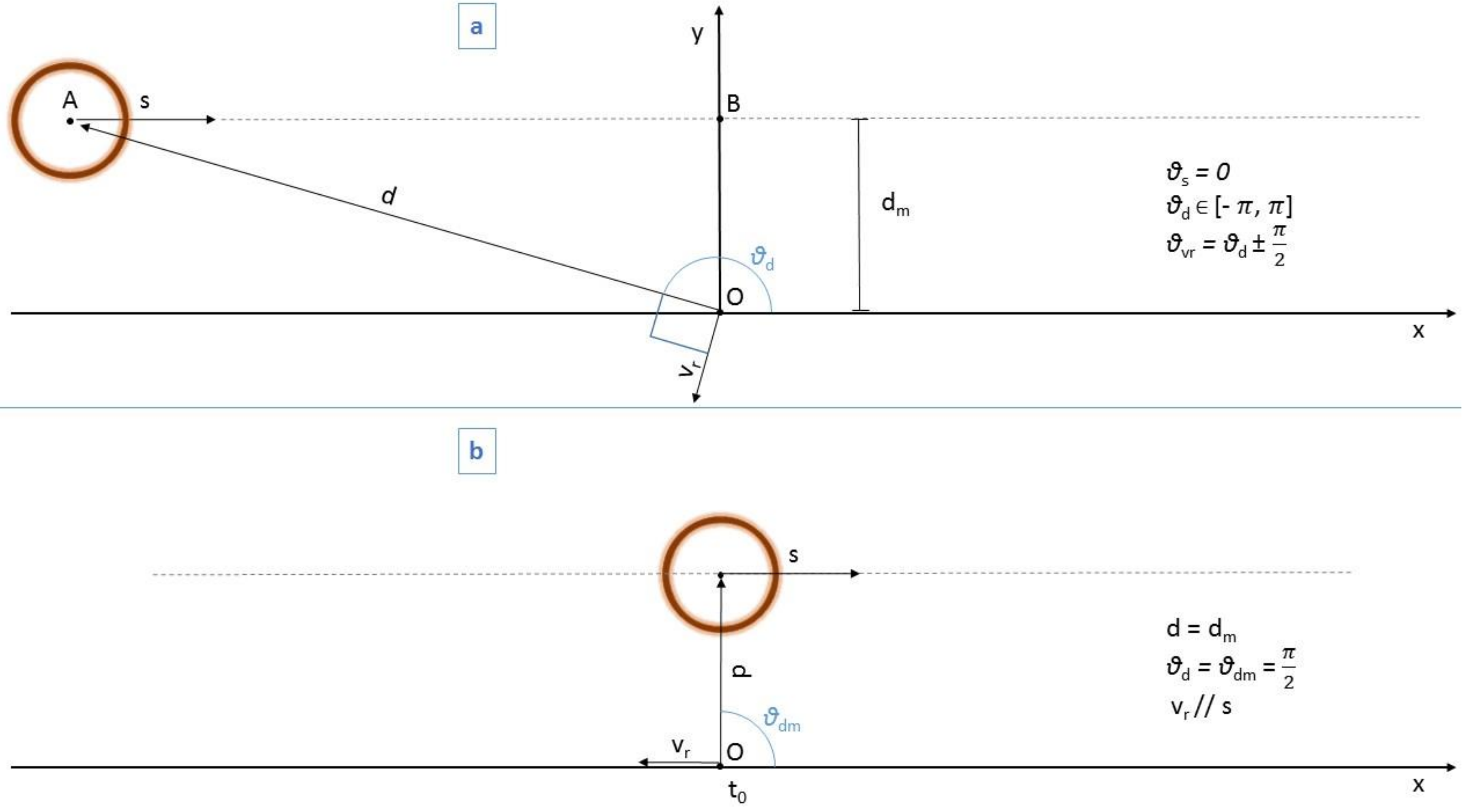


The large error bars shown are probably mainly due to the different dependence of plotted quantities on the distance between the vortex and the station

F.i. we expect:

$$dP \propto \frac{1}{d^2} \qquad dE \propto \frac{1}{d^3}$$

Impact parameter



R
vortex radius

d_m
impact parameter

s
translational speed

Vr
rotatory speed

d
distance

$$\theta_{vr} = \theta_d - \frac{\pi}{2}$$

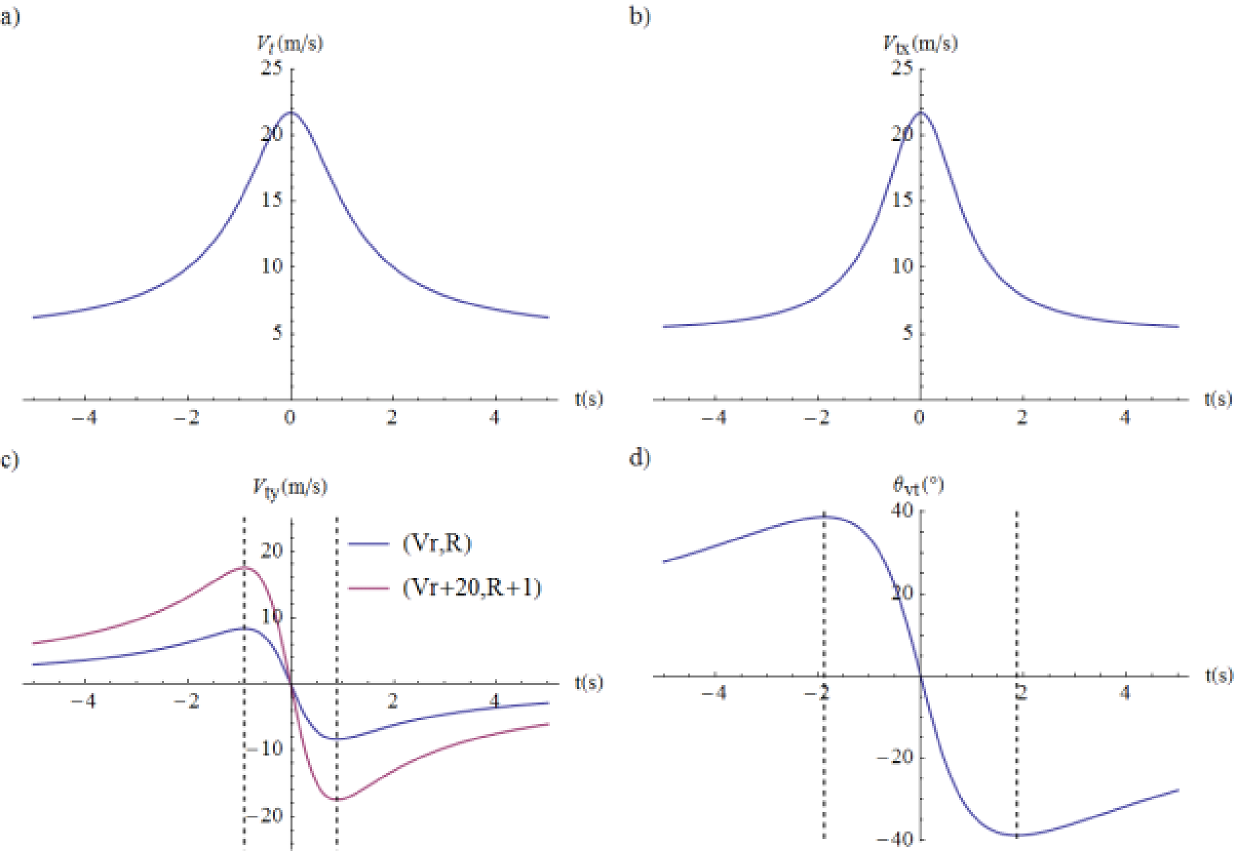
$$\mathrm{v}_{tx}(d) = s + \mathrm{v}_r(d)\,\frac{d_m}{d}$$

$$\mathrm{v}_{ty}(d) = \mathrm{v}_r(d)\,\sqrt{1 - \left(\frac{d_m}{d}\right)^2}$$

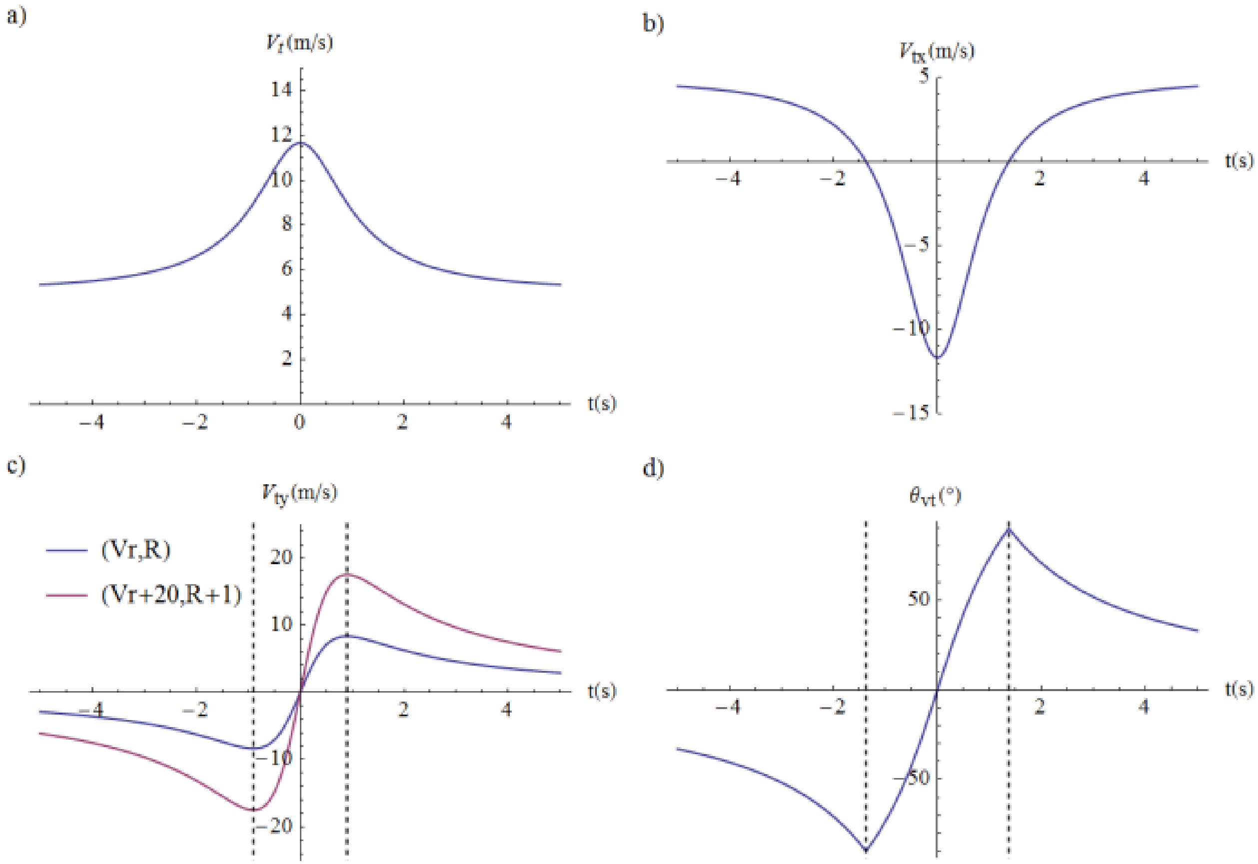
Rankine Vortex Model

$$t = \pm \frac{d_m}{s}$$

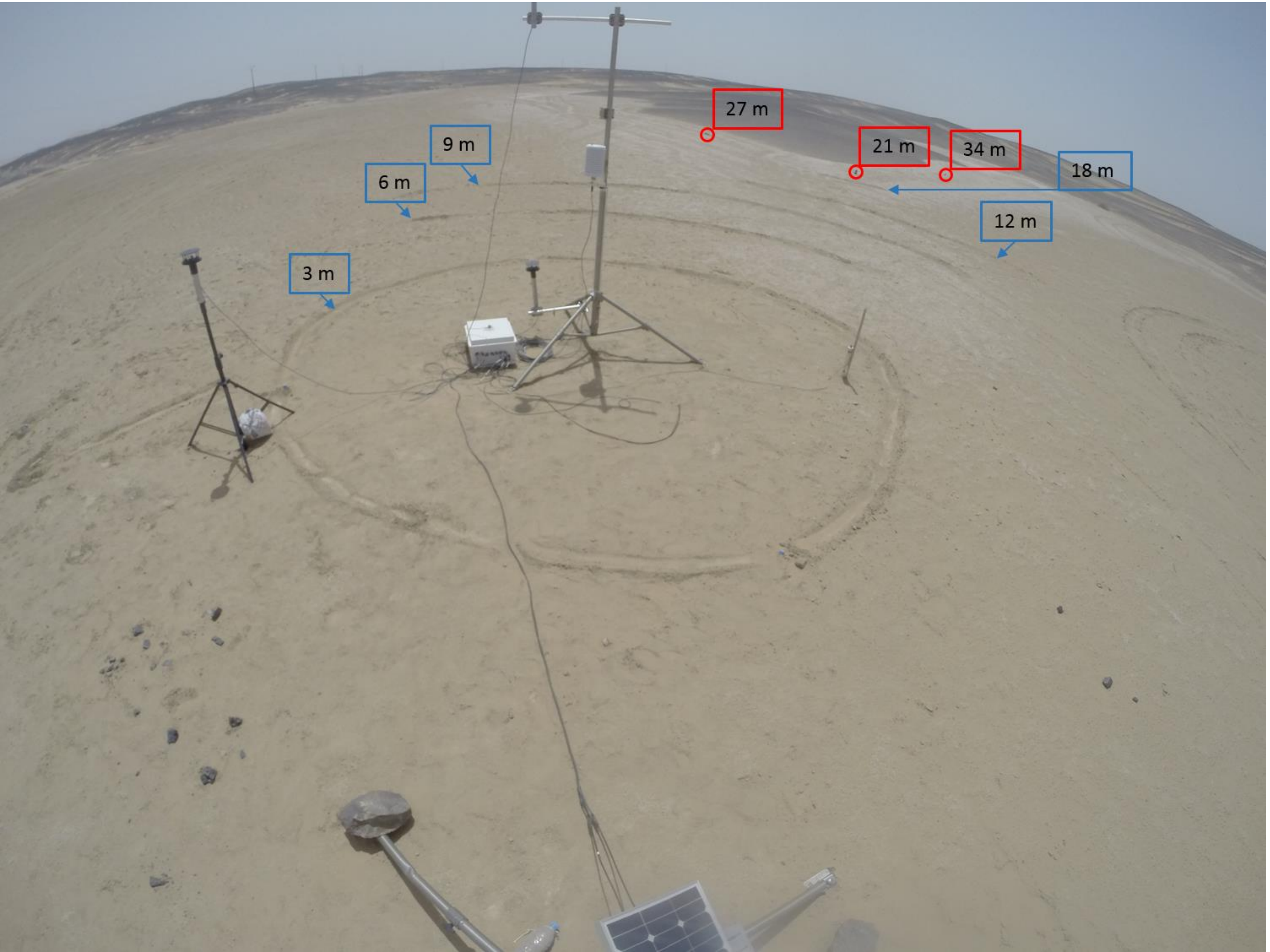
Concordant rotation



Discordant rotation

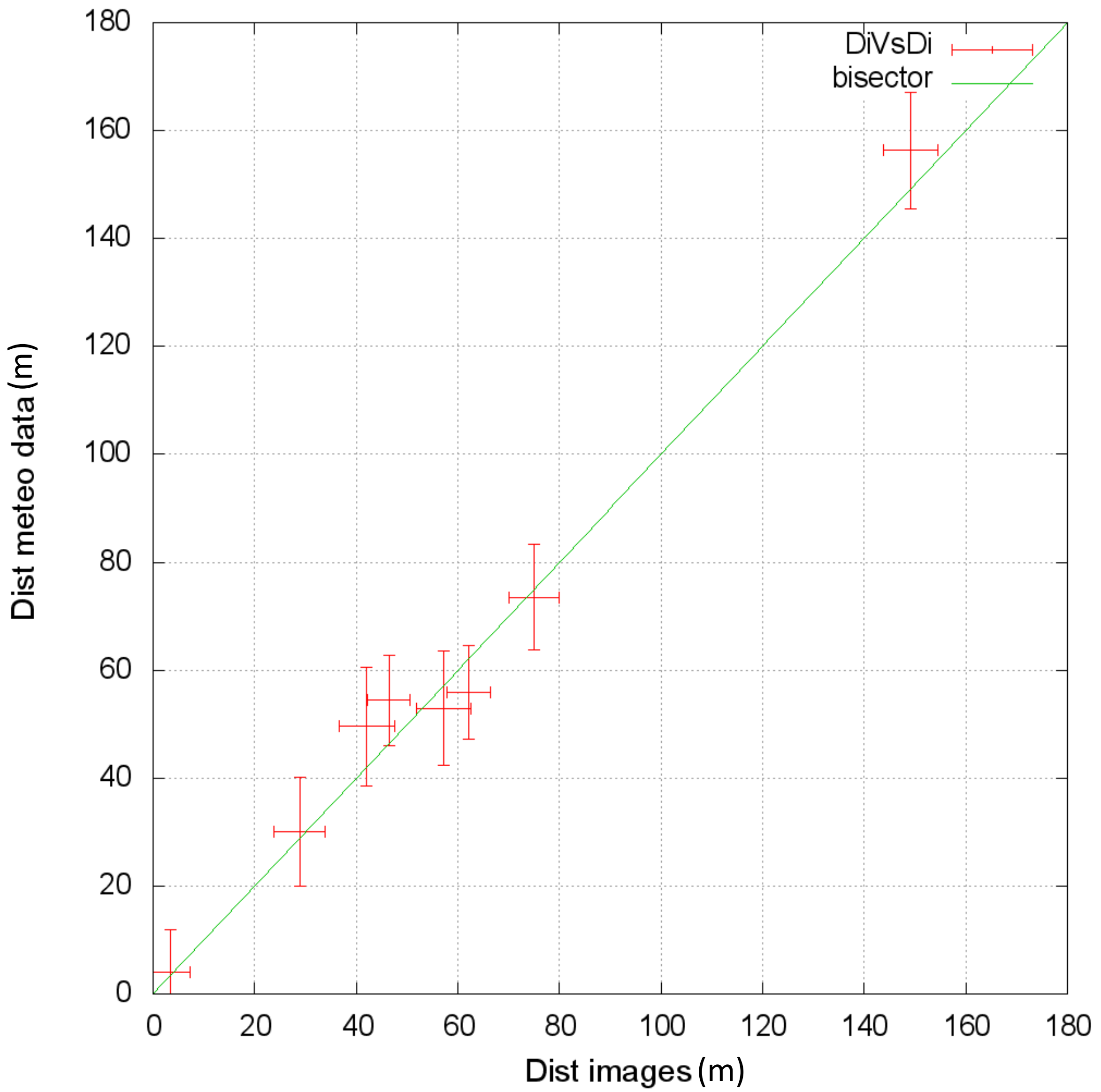


2017 Sahara field Campaign

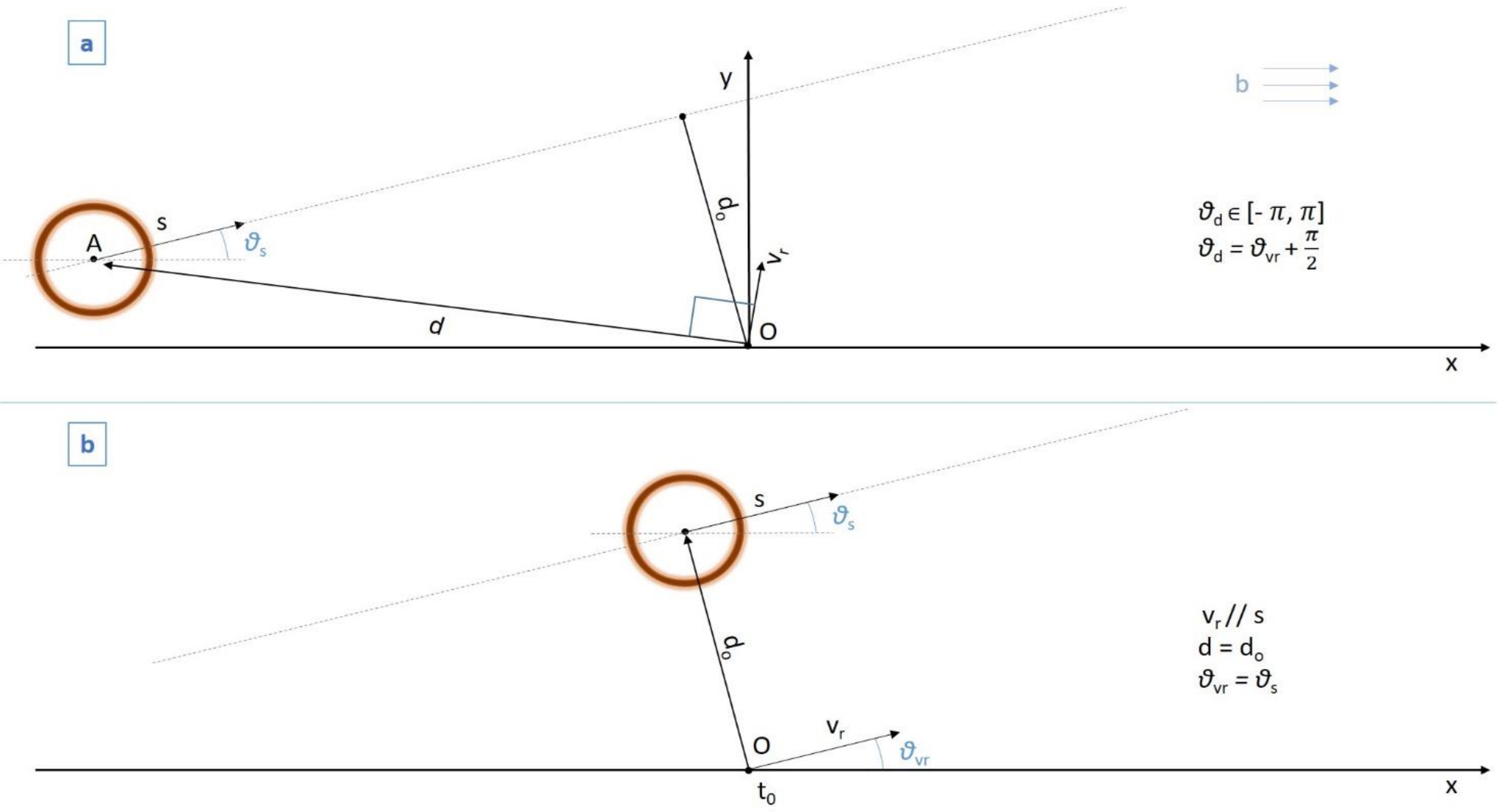


Sensors
Temperature
2-D sonic anemometer
Pressure
Humidity
Sensit (lifted sand and dust impact)
Solar irradiance
Camera Imaging System

Test of the model



Translational speed



$$\theta_{vr}(t_o) = \theta_s$$

d_o at $t=t_o$
impact parameter

total wind that
we measure

$$\mathbf{V_t}(t) \equiv (u, v)$$

$$b \equiv (\bar{u}, \bar{v})$$

relative velocity of the
vortex

$$\boldsymbol{w}(t) = \mathbf{V_t}(t) - \boldsymbol{b}$$

operatively:

$$w(t) = \sqrt{(u(t) - \bar{u})^2 + (v(t) - \bar{v})^2}$$

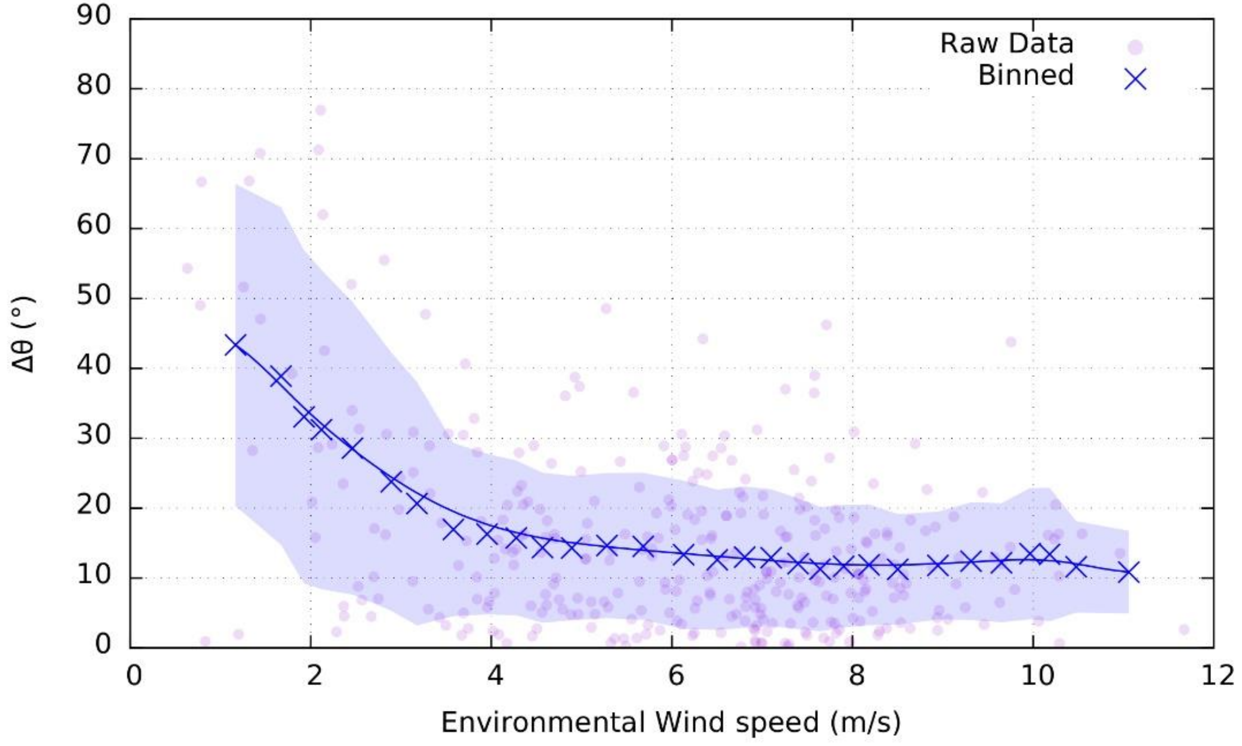
w is the composition of the vortex
translational and rotation

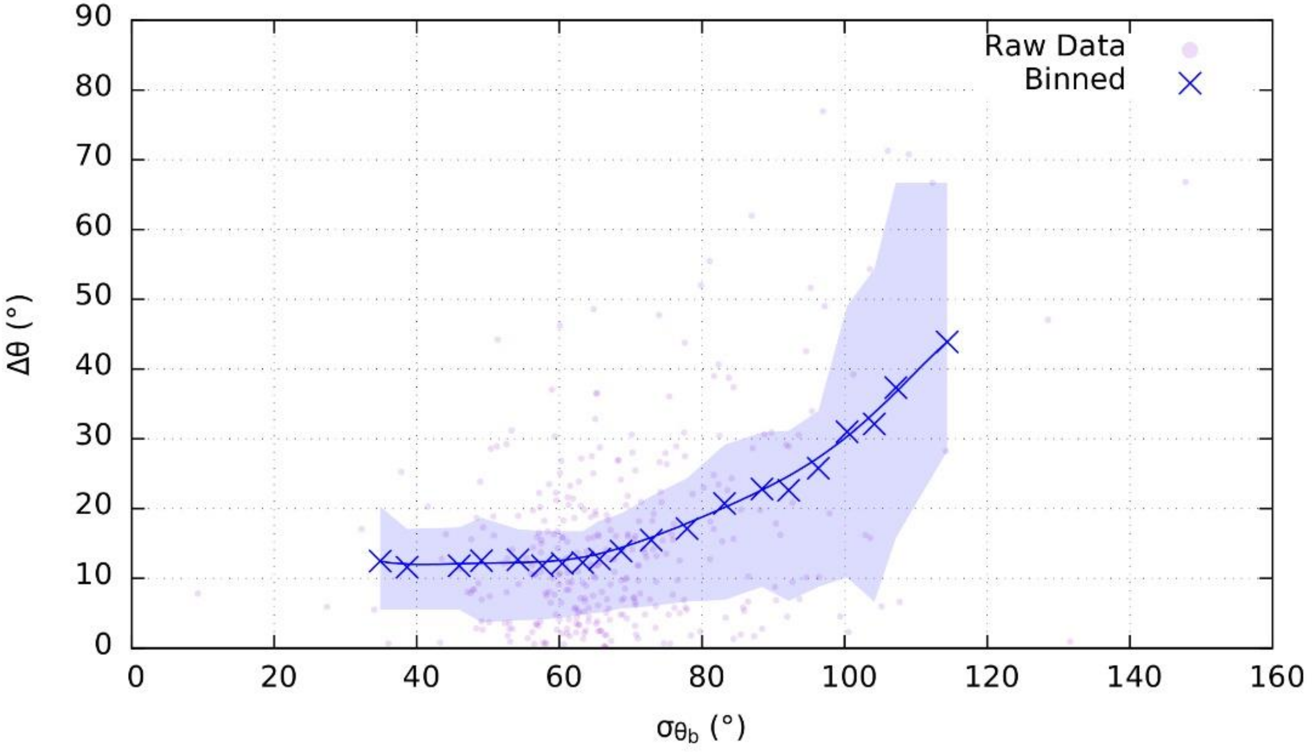
$$\boldsymbol{w}(t) = \boldsymbol{v_r}(t) + \boldsymbol{s} - \boldsymbol{b}$$

we define the 2 component:
|| and ⊥ to b

$$w = (v_{r||} + b, s_\perp + v_{r\perp})$$

Deviation from the environmental wind





Conclusions

during various field campaign in the Sahara desert
we acquired a **meteorological** and **electric field** data for hundreds of dust devils

we focused on the study of dust devils physics as an analogue of the Martian case

we studied:

- the electric proprieties of the events
- methodologies to retrieve the intrinsic vortex parameters through the resolution of the geometrical parameters of the encounters

the study of the encounters impact parameter

the study of the dust devils translational motion

Next

comparison of the translational motion model results with the one retrieved using the dust devils images

study of the relations between the dust devils deviation from the environmental wind direction and the vortex meteorological characteristics

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Electric properties of dust devils

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ABSTRACT

Dust devils are one of the most effective phenomena able to inject dust grains into the atmosphere. On Mars, they play an important role to maintain the haze and can significantly affect the global dust loading, especially outside the dust storm season. Despite dust devils having been studied for a century and a half, many open questions regarding their physics still exist. In particular, the nature of the dust lifting mechanisms inside the vortices, the development of the induced electric field and the exact contribution to the global atmospheric dust budget are still debated topics. In this paper, we analyze the dust devil activity observed in the Moroccan Sahara desert during a 2014 field campaign. We have acquired the most comprehensive field data set presently available for the dust devils: including meteorological, atmospheric electric field and lifted dust concentration measurements. We focus our attention on the electric field induced by vortices, using this as the principal detection parameter. We present, for the first time, the statistical distribution of dust devil electric field and its relationships with the pressure drop, the horizontal and vertical vortex velocity and the total dust mass lifted. We also compare the pressure drop distribution of our sample with the ones observed on the martian surface showing the similarity of the dust devils samples and the usefulness of this study for the next martian surface missions.

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Resolution of the size/distance degeneracy of the dust devils signals observed with a stationary meteorological station

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ABSTRACT

The monitoring of dust devils using only a meteorological station is limited by the size/distance degeneracy that affects the acquired time series. It is not possible to retrieve directly information on their morphology, translational motion, distance of passage and vortex intrinsic parameters as the core pressure drop and maxima rotational speed.

We propose a simple model to estimate the distance of passage (commonly referred to as *impact parameter*) of the dust devils encounters from the station, monitored using a 2D anemometer. Our technique is based on the study of an easily recognizable feature of the signal trend, univocally connected to the vortex distance of passage.

In order to test the model, we have analyzed the measurements acquired during a Sahara field campaign. Our meteorological station was equipped with a camera, to compare the modeled distances with the ones obtained from the images. For all the acquired events the experimental results are in good agreement with the model. Overall, we observed dust devils passing between 3 m and 150 m from the station, assessing the reliability of the technique over a wide range of distances.

The evaluation of the impact parameter allows to fully characterize the meteorological encounters and to retrieve the vortex intrinsic parameters. The simplicity of the procedure makes it a powerful tool in the study of the relations among different vortex features (e.g., dust concentration and induced electric field) and their dependence on the distance from the station, easily applicable to past and future terrestrial and martian surveys.