# DYCECT MISSION : Preliminary studies

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## CONTEXT AND OBJECTIVES

The access to information about the dynamics of convection, even at moderate spatial and temporal resolution is probably the next big challenge for space-borne remote sensing. A space-borne measurement of the Doppler velocities would allow us to improve our knowledge on the mass and energy budget of convection. EarthCare (ESA-JAXA) is the first step in that direction but the measurements (94 GHz radar) will be limited to the satellite nadir, giving access only to the vertical wind component, w. ADM-AEOLUS (ESA, side-looking lidar ALADIN) will also provide some wind profiling but will be quickly attenuated in the presence of deep clouds or precipitation. More generally, the community interested in rain retrievals and rain estimates should ask itself if the post-GPM system should be made of passive radiometers, radars or a balanced mix of both.

## RADAR CONCEPT

Measurement of Doppler velocities of the order of 1m.s$^{-1}$ on a satellite moving at about 7km.s$^{-1}$ is a challenging task. Complex effects of contamination of the satellite motion within the radar beam have to be accounted for and the first constraint is to keep the said beam as narrow as possible. In order to keep the antenna size within the 1 – 1.2m range, the only possible frequencies for the radar are either Ka (35 GHz) or W (94 GHz). Both frequencies are attenuated to some extent. The 35 GHz less so, but it would offer a larger beam width for the same dish size, which would increase the platform velocity contamination effect and the Non-Uniform Beam-Filling (NUBF). On the other hand, the 94 GHz is very good for small ice crystal detection and ice cloud studies but it can be affected by more multiple scattering in regions where ice is highly concentrated and it is very much attenuated in the warm cloud part. This last drawback of the 94 GHz has to be considered keeping in mind that the radar will have a blind region of about 2 to 4 km anyway near the surface (ground clutter and H/V surface echo disambiguation). In the studied concept, trains of interlaced H and V pulses are used in a pulse-pair processing.

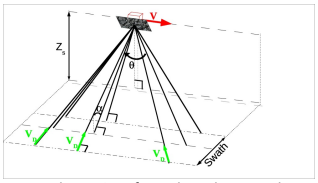


Figure 1: Schematic of a phased-array electronic scanning configuration where Doppler measurements ($V_D$) are made for various elevation (corresponding to various incidence angles θ). One measurement is perpendicular to the satellite displacement (V), one is forward (+θ) and the last one is backward (−θ). The satellite flies at altitude $Z_S$ (Concept Thales Alenia Space).

### INNOVATIVE CONCEPT / NEW CHALLENGE

**Objectives**:

1) Retrieve a 3-Dimensionnal wind field (u, v, w components) in a ~200 km swath from surface to the tropopause. This will be accomplished with a scanning Doppler radar looking off-nadir.

2) Deduce from the wind field and from polarimetric measurements, the microphysical properties of the observed systems.

**Challenge**:

1) The off-nadir configuration increases the surface contamination effects and the satellite velocity contamination in the Doppler

2) The high frequency required for a very narrow beam increases the multiple scattering effects

3) The scanning reduces the number of independent samples thus increasing the noise.

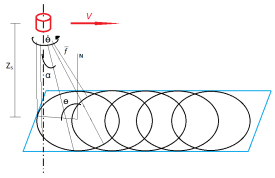


Figure 2: Same as Fig. 2 but for a mechanical scanning system. The antenna is a classical dish rotating around a vertical axis, which gives a constant incidence angle at the surface. The combination of the satellite motion and the antenna rotation lead to a spiral-like pattern of the beam at the surface.

## PHASED-ARRAY ELECTRONIC SCANNING CONFIGURATION @ 35 GHz

In this example PRF is 3750 Hz, with a scanning at 90° and 90+/-45° from the satellite motion. The elevation at 90° go from 5° to 45° with an step of 0.025° and are adjusted accordingly for the other two azimuth. The minimum pixel size is 5.8x5.8 km2 and the maximum one is 8.8x14.4 km$^2$. The blind region (ground clutter) goes from 0.3 to 3.5 km altitude. The swath is 425 km.

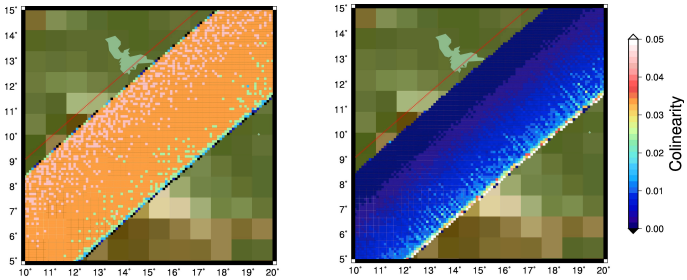


Figure 3: Number of pixels per square of 10x10 km$^2$ (left-hand side) and variance of the dot products between the $V_{Dop}$ (right-hand side) used as a proxy to measure co-linearity.

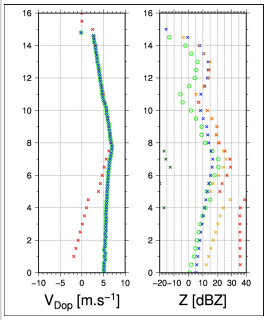


Figure 5: Effects of multiple scattering on an arbitrary profile of cloud/rain content for both the Doppler Velocity ($V_{Dop}$, left-hand side) and the reflectivity (Z right-hand side):

- multiple scattering (VV and VH) with randomly oriented spheroids (e=a/b=1.2) computed with T-Matrix method in a Monte-Carlo simulation.
- multiple scattering with Mie phase function in a Monte-Carlo simulation
- unattenuated single scattering performed with Mie computation on spheres
- attenuated single scattering performed with Mie computation on spheres

The results are for 35 GHz looking at Nadir and after correction of the platform motion on a plan parallel atmosphere.

## MECHANICAL (CONICAL) SCANNING CONFIGURATION @ 94Ghz

In this example PRF is 3750 Hz, and the onboard elevation angle is 40°. 80 % overlap of the pixels (3x4 km$^2$) is required which sets the rotation speed of the antenna at 37.6 rpm. The blind region due to ground clutter is 1.3 km. The swath is 1100 km.

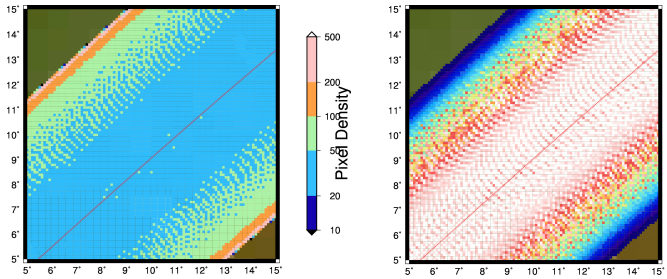


Figure 4: Idem Fig. 3 but for the conical scanning at 94 GHz.

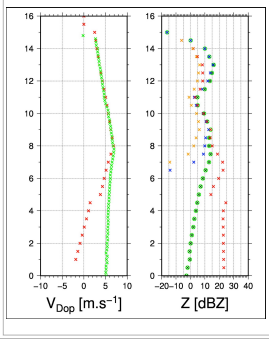


Figure 6: Idem Fig. 5 but for 94 GHz :

- multiple scattering with randomly oriented spheroids (e=a/b=1.2) computed with T-Matrix method in a Monte-Carlo simulation.
- unattenuated single scattering performed with Mie computation on spheres
- attenuated single scattering computed with T-Matrix on spheroids (e=a/b=1.2)
- attenuated single scattering performed with Mie computation on spheres

The results are for 94 GHz looking at Nadir and after correction of the platform motion on a plan parallel atmosphere.

## Conclusions

These are new results on the ongoing feasibility study of the DYCECT radar. An end-to-end simulator is being developed at LATMOS in cooperation with Thales-Alenia-Space and CNES to further asses the performances of the system. The two considered options both have pros and cons. The 35 GHz electronically-scanning radar offers more flexibility and probably better performances but is far more complex to develop and will be more affected by NUBF. The 94 GHz mechanically-scanning system is simpler but much more sensitive to both attenuation and multiple scattering and marginally less affected by NUBF.

Note that the radar should be part of a system similar to the TRMM/GPM mother-sat concept (or the A-Train concept) where the radar will come in support to passive microwave instruments.

Acknowledgements

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