SIMULATIONS OF *X*-BAND THUNDERSTORMS RADAR OBSERVATIONS

PUJOL O[1]., N. BON[2], C. COSTES[2], H. SAUVAGEOT[1], J.-P. ARTIS[2]
1 *Université Paul Sabatier, Laboratoire d'Aérologie, Toulouse, France*
2 *Thalès Systèmes Aéroportés, Brest, France*

Civil aviation uses *X*-band (f = 10 GHz) airborne radar with large aperture ($\theta_{3\ dB} > 1°$) to identify precipitating system at very long distance (r > 100 km) and estimate the hazard.
QUESTION: What would see such a X-band airborne radar?

Simulation of radar observations and theoretical considerations

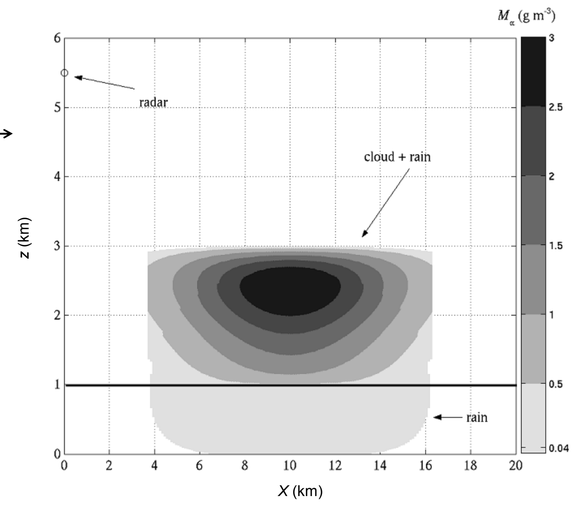
Thunderstorm modeling

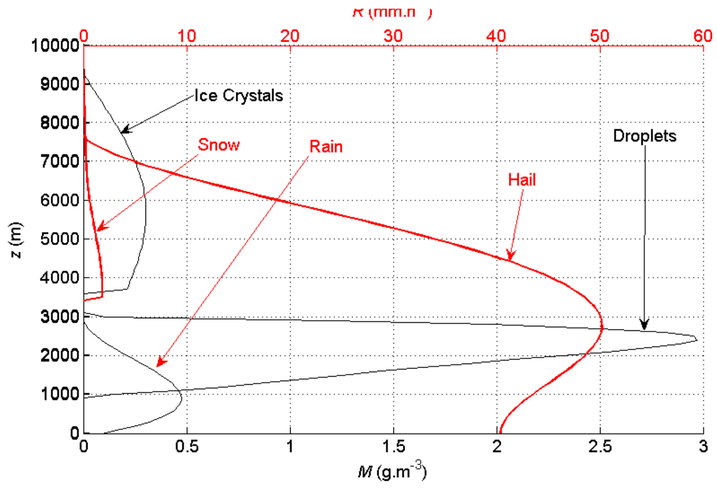
We extend to ice phases the model developed for warm clouds (*Pujol et al., 2007a, 2007b*):

1) $\boldsymbol{X(x, z) = X(z)G(x)}$ where :
- $X \equiv R$ (mm.h^{-1}) for precipitation,
- $X \equiv M$ (g.m^{-3}) for droplets and crystals,
- $G = \exp(-x^2/L^2)$ with L the horizontal extension of the modeled thunderstorm.

2) $\boldsymbol{N(D) = N_0(D)\ D^{\mu}\ \exp(-\Lambda D)}$ is the size distribution used:
- D is hydrometeor diameter and N the volumic concentration per class of diameter,
- $\mu > 0$
- Hail: $\mu = 0$, $N_0 = 115\Lambda^{3.63}$, and $\Lambda = \ln(88/R)/3.45$ (*Cheng and English 1983*)
- Hydrometeor characteristics are in the Table (*Pruppacher and Klett 1997*).

	$D_{min} - D_{max}$ (mm)	ρ (g.cm^{-3})
Ice crystal	0.1 – 2	0.9
Snow	1 – 5	< 0.2
Graupel	0.5 – 5	0.2 – 0.8
Hail	5 – 50	> 0.8
Rain	0.5 – 5	1
Droplet	1 – 50 (µm)	1





Radar observation simulations

The radar characteristics are:
1) frequency f = 10 GHz (*X*-band),
2) large aperture of 3°dB

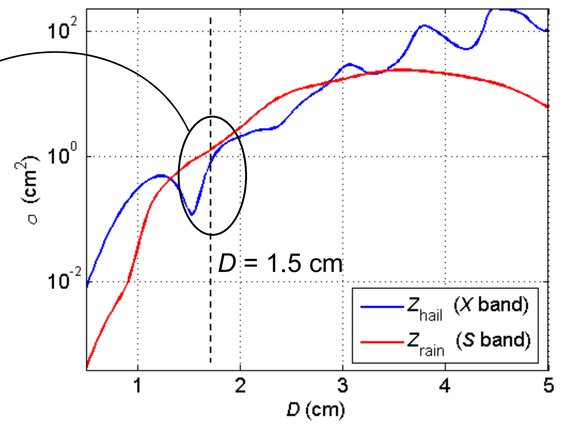
The simulation is fully completed when the whole target has been covered.

Theoretical considerations

Some ideas relative to *X*-band observations should be kept in mind:
1) Although undetectable, cloud droplets are a non negligible source of attenuation (*Pujol et al. 2007a*),
2) Hail reflectivity in *X*-band can be lower than rain reflectivity in *S*-band because of the first Mie mode (*Sauvageot 1992*)

Z_{hail} (*X*) < Z_{rain} (*S*)

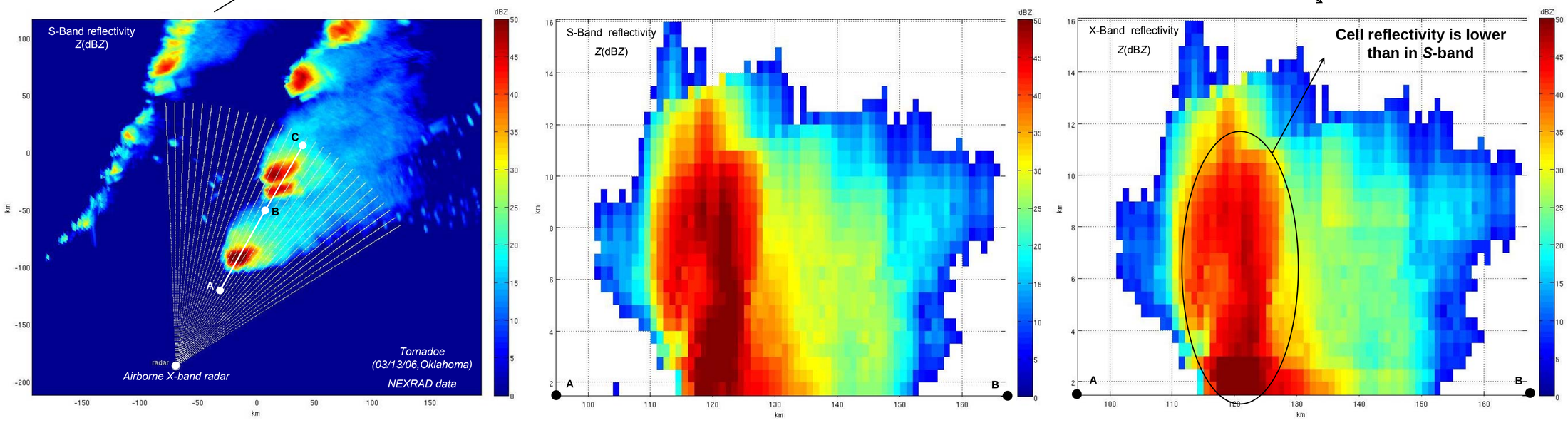
⇒ A signal coming from hail can be assimilated to a signal coming from rain !



⇒ **Hazard can thus be underestimated by pilots, which could be dramatic !**

Case of real data

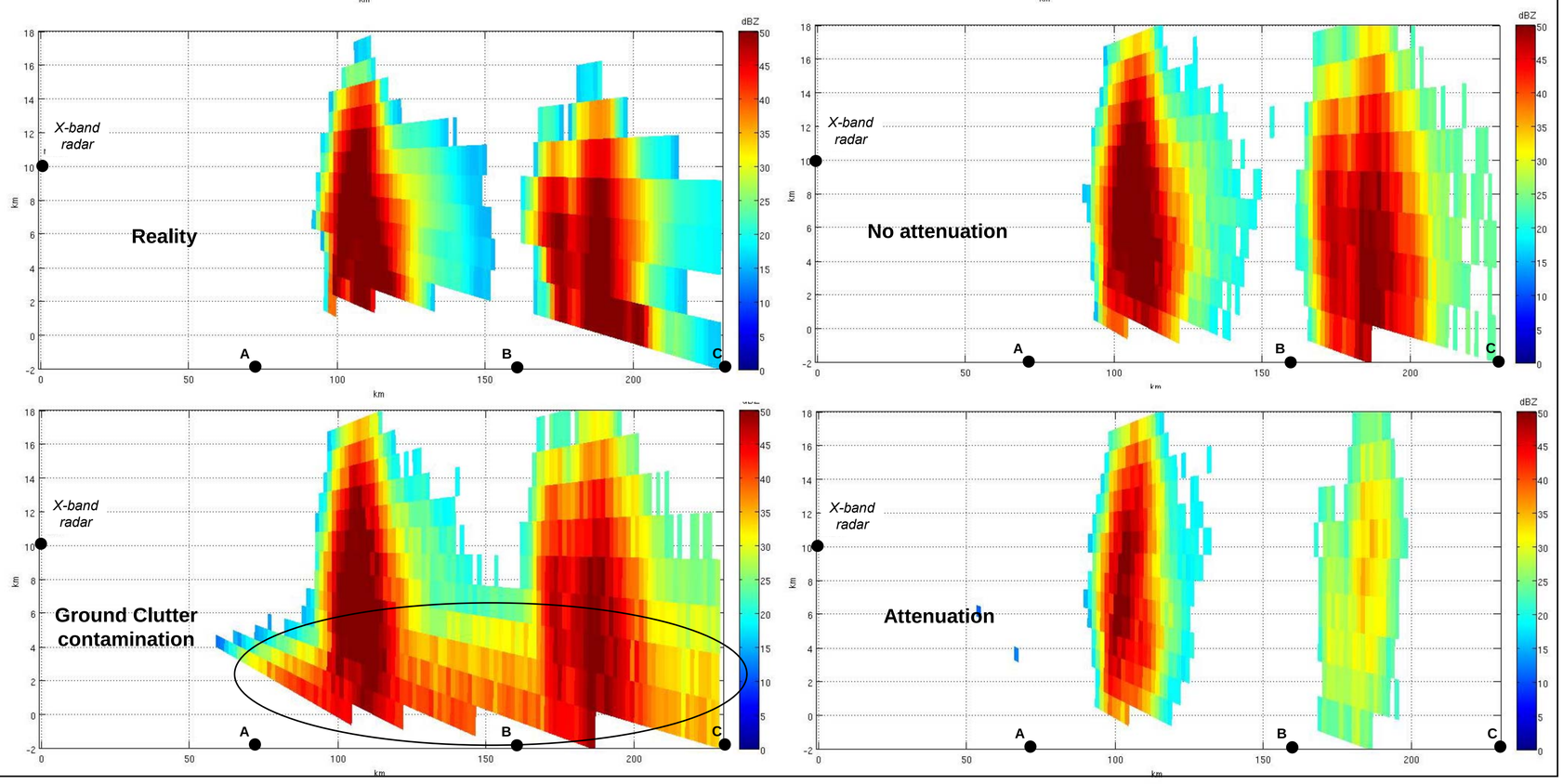
1) Discrimination convective/stratiform profile → 2) Hydrometeor identification → 3) Deduction of *X*-band reflectivity



A *X*-band radar with large aperture ($\theta_{3\ dB}$ = 3°) which observes precipitating systems at long distance (r > 200 km) causes other problems:

1) attenuation (precipitation + cloud) weaken the reflectivity of the meteorological target. Cloud is undetectable but attenuates greatly (Pujol et al. 2007),

2) Ground clutter contaminates the signal of reflectivity from the precipitating system observed; if r > 200 km, beamwidth is greater than 10 km.



CONCLUSION

X-band observation and hazard estimation by pilots are problematic since:
1) reflectivity *Z*(dB*Z*) is degraded by attenuation due to cloud and precipitation,
2) Hail detection is limited due to the first Mie Mode, so that $Z_{hail} < Z_{rain}$

An other problem arises from long distance (r > 200 km) with large aperture ($\theta_{3\ dB}$ = 3°) observations:
3) ground clutter ontaminates greatly the reflectivity.

PERSPECTIVES

The importance of civil aviation justifies such study and the further ones:
1) unambiguous hail detection method is necessary,
2) ground clutter contamination has to be corrected ,
3) squall lines and mesoscale systems should be investigated,
4) a time component should be added in our static model.

Should *X*-band be avoided and replaced by S-band?

REFERENCES

Cheng L. and English M., 1983: A relationship between hailstone concentration and size. *J. Atmos. Sci.*, 40, 204 - 213.
Pruppacher H. and Klett J.D., 1997: Microphysics of clouds and precipitation. Kluwer Academic Publisher, 943 pp.
Pujol O., F´eral L., Sauvageot H., and Georgis J.F., 2007a: Degradation of radar reflectivity by cloud attenuation at microwave frequency. *J. Atmos. Oceanic Technol.*, 24, 640 - 657
Pujol O., Sauvageot H., and Georgis J.F., 2007b: Influence of drizzle on *Z-M* relationships in warm clouds. *Atmos. Res.*, in press.
Sauvageot H., 1992: Radar Meteorology, Artech House, 366pp.