94 GHz Doppler Wind Radar Satellite Mission Concept and Planned Demonstration Campaigns

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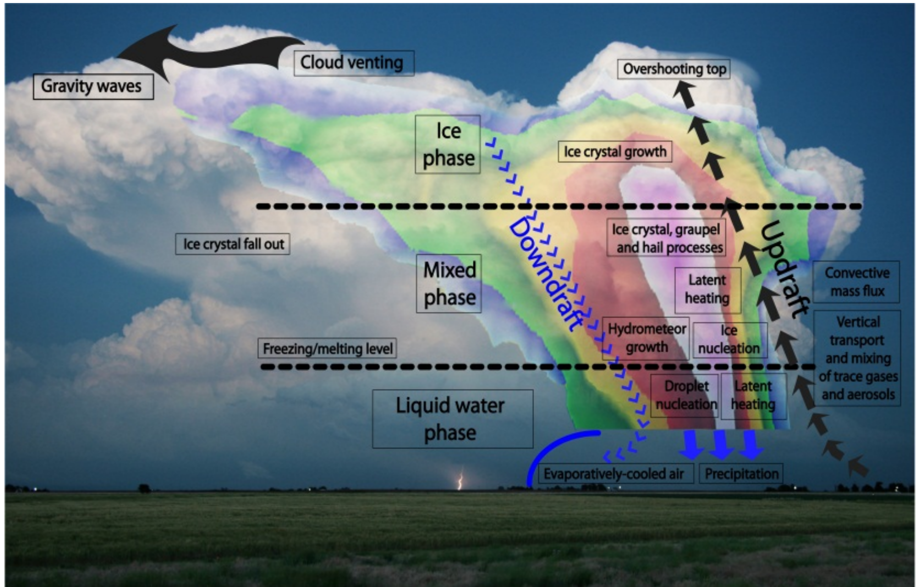
European Space Agency

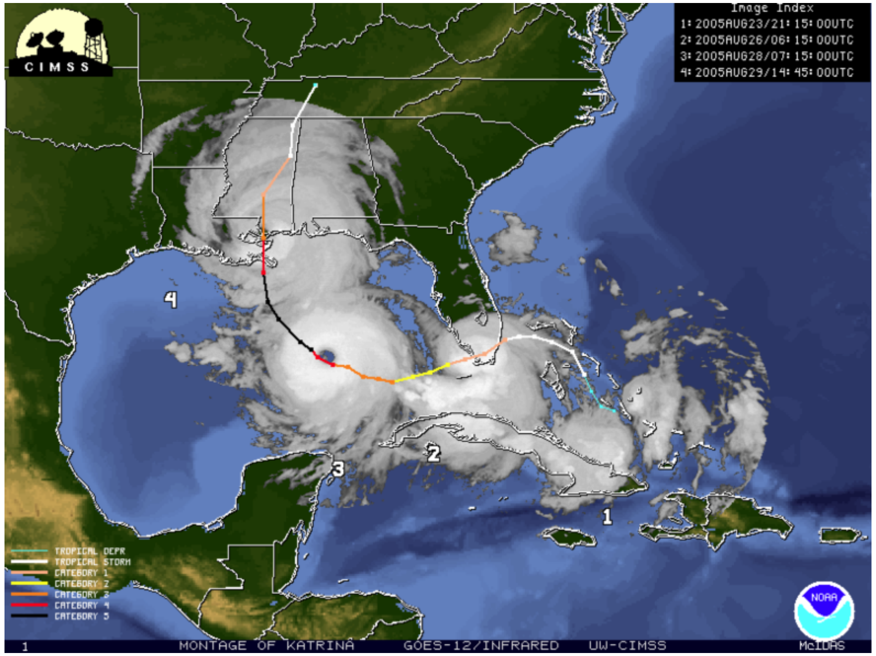
Upcoming European atmospheric missions

Scientific motivations

- What will be the storm track?
- How fast will it grow?
- How will the wind structure look like?
- How much precipitation will fall and where?
- …

Courtesy of S. Tanelli, NASA-JPL

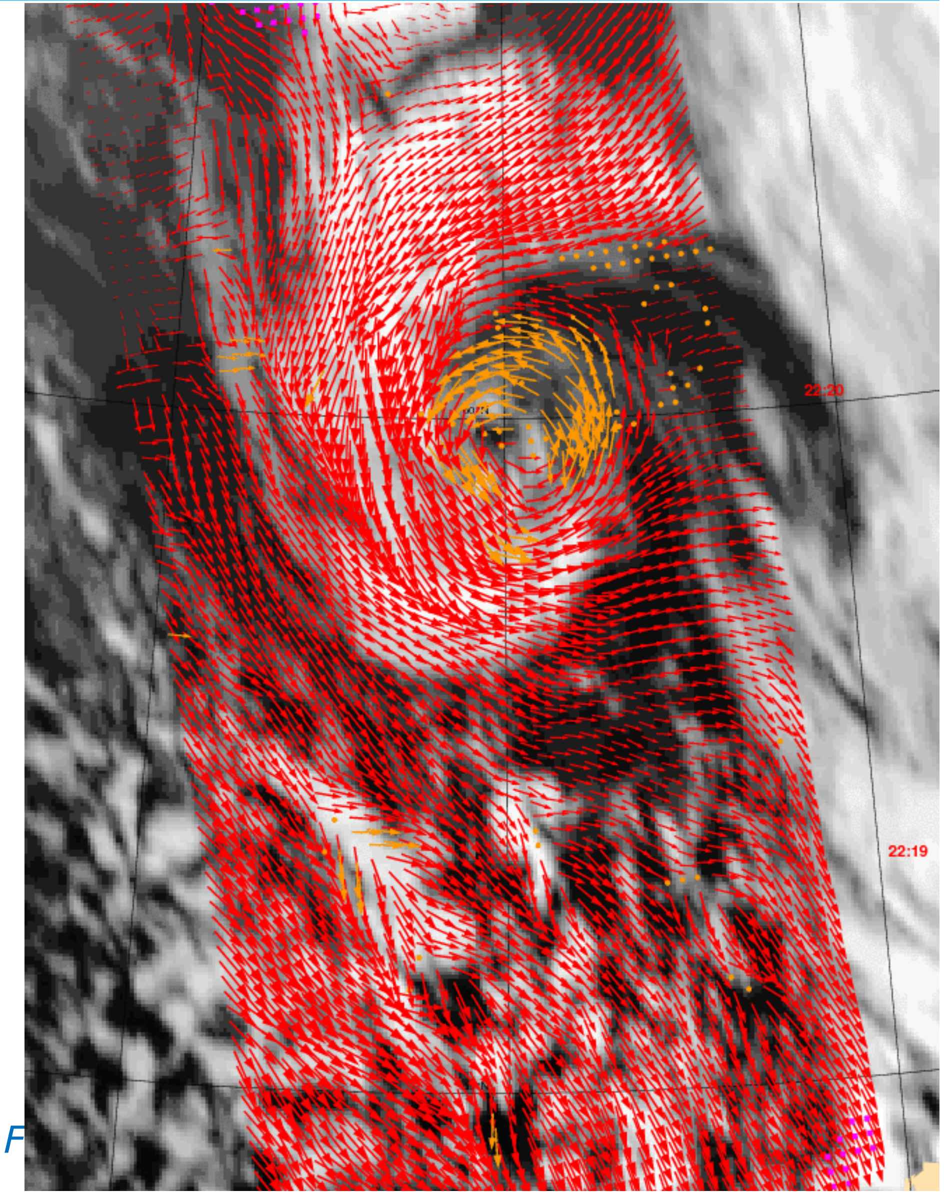




- Are the presently used parametrization schemes for convections/turbulence in NWP models adequate?
- Are all mechanisms involved in convective systems well-understood?
- How shall convective phenomena be best-represented in the NWP models?
- …

Objectives

1. Observation of detailed 3D motion of the atmosphere under (highly) convective/turbulent conditions and extreme weather events from space
2. All weather capability, especially under cloud cover
3. Complementary to the ADM/Aeolus (lidar) mission: clear sky, single 35° off-nadir cut of the atmosphere, 200 km sampling
4. Understand/quantify the 'wind-cloud-precipitation' connection



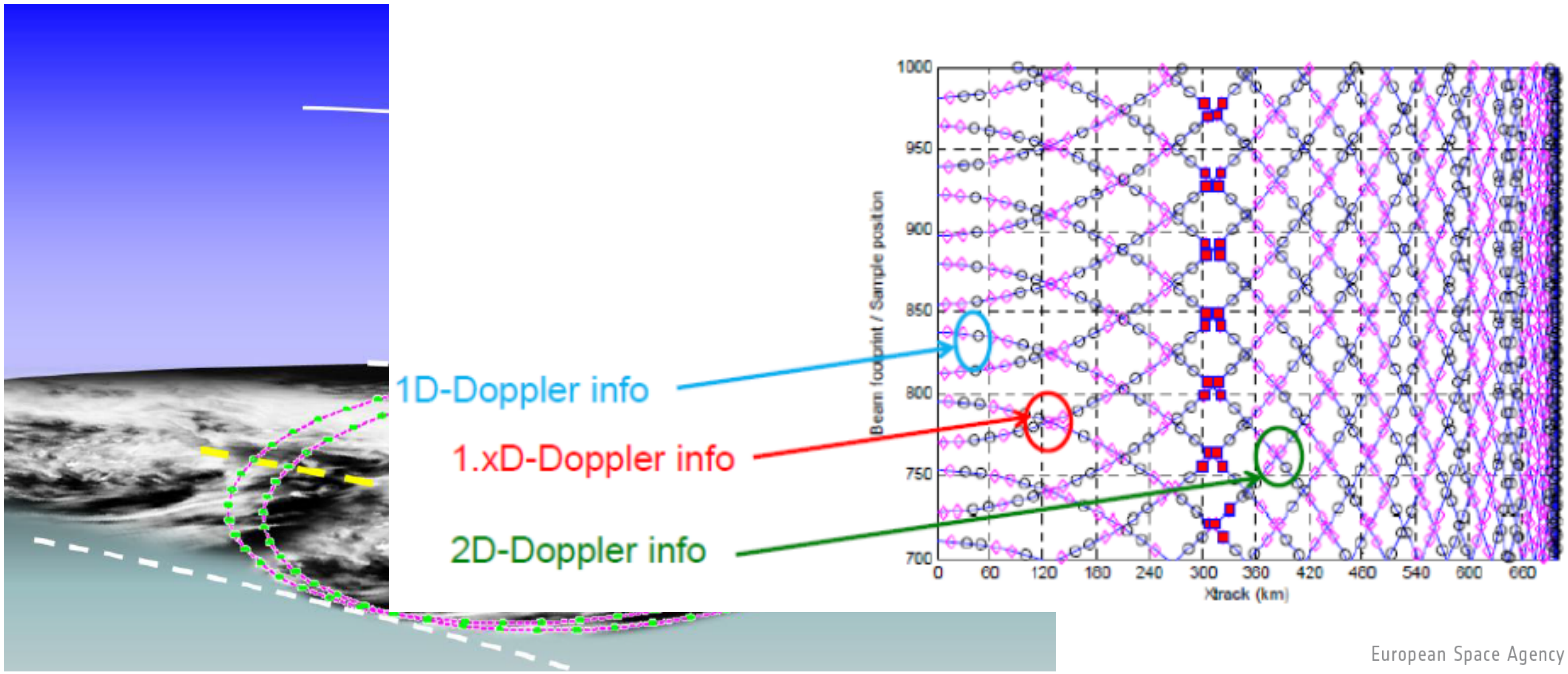
MetOp/ASCAT ocean surface vector wind observation, super-imposed onto MeteoSat imagery (Courtesy of KNMI)

Conically scanning pencil-beam concept

Trade-offs on:	- orbit height - off-nadir angle - antenna size - scan speed

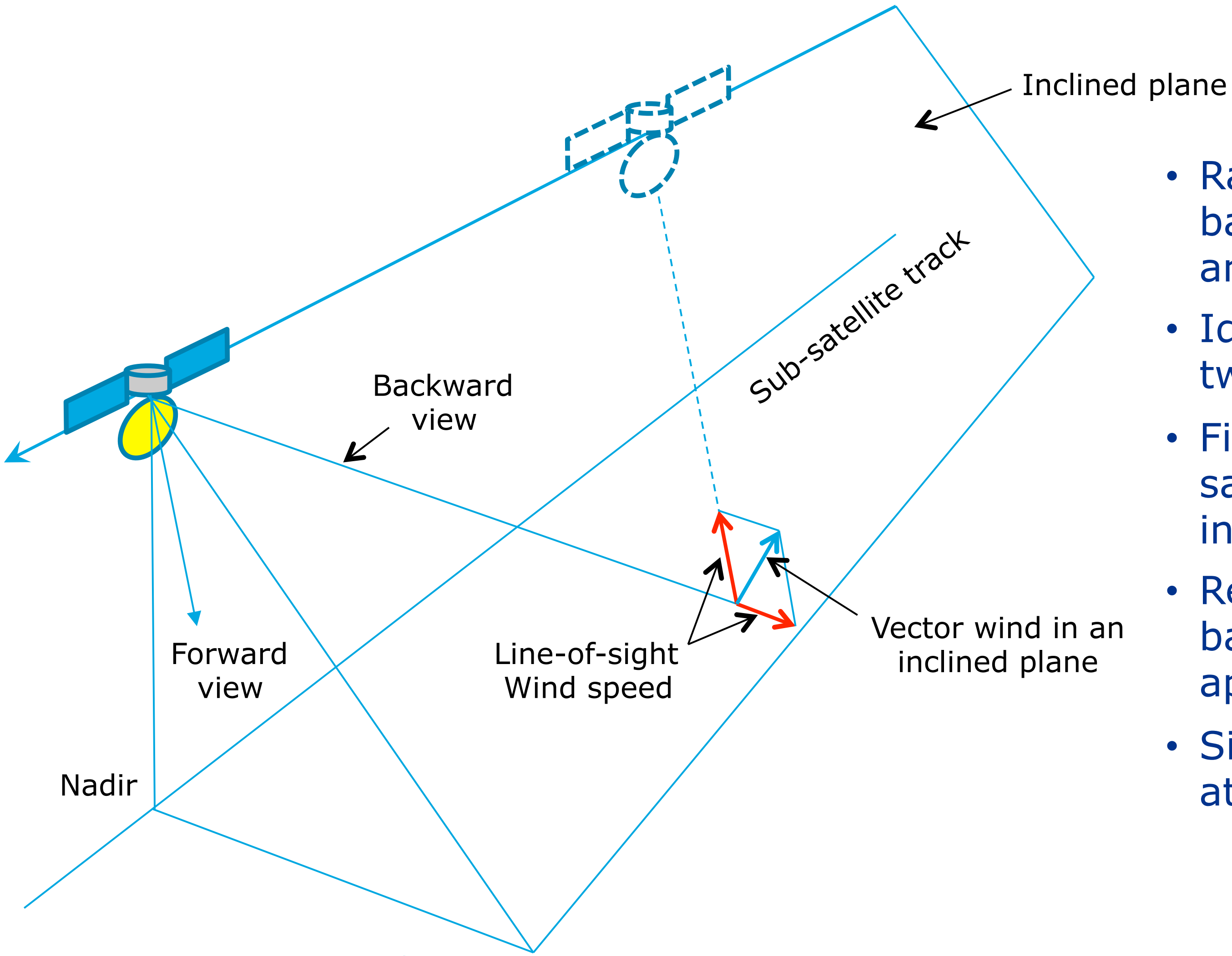
E.g.:

- ~500 km altitude
- 37.8° off-nadir (800 km swath)
- 2.9 m × 1.8 m
- 8.6 RPM (50 km per revolution)



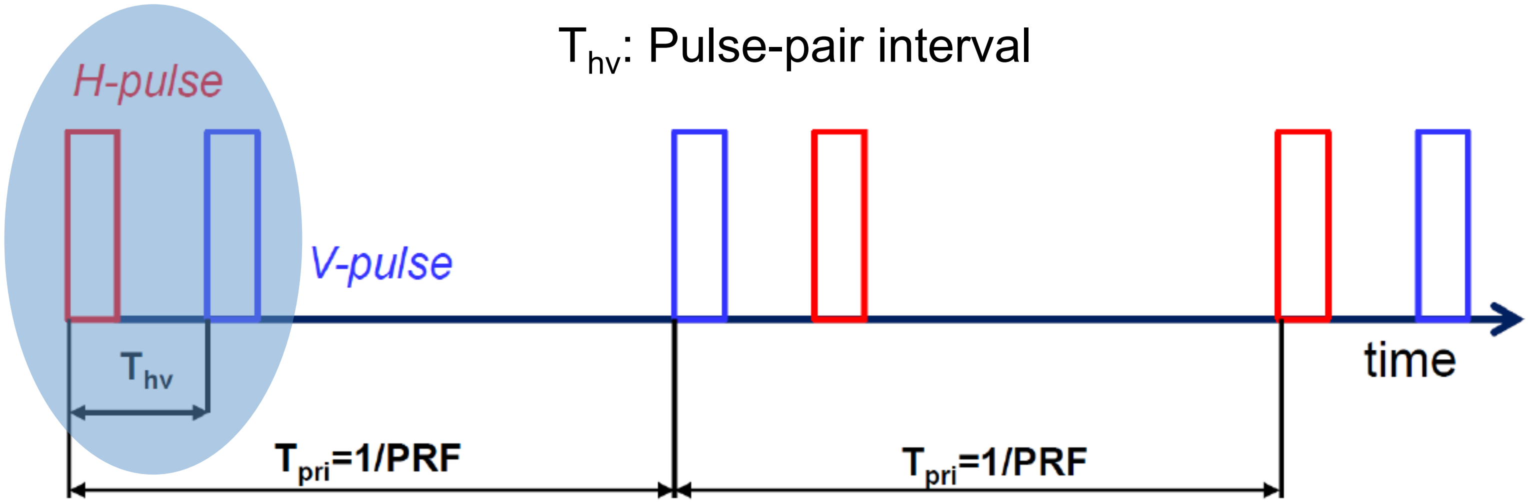
European Space Agency

Stereo radar concept



- Radar with forward and backwards views within an inclined plane
- Ideally 90° between the two views
- Fine wind vector sampling within the inclined plane
- Requires forward and backward antenna apertures
- Single cut in the atmosphere

Frequency-diversity pulse-pair (FDPP) technique (1)



Doviak and Sirmans (1973)
Pazmany et al. (1999)
Kobayashi et al., (2002)

Unambiguous range: $r_{max} = cT_{pri}/2,$

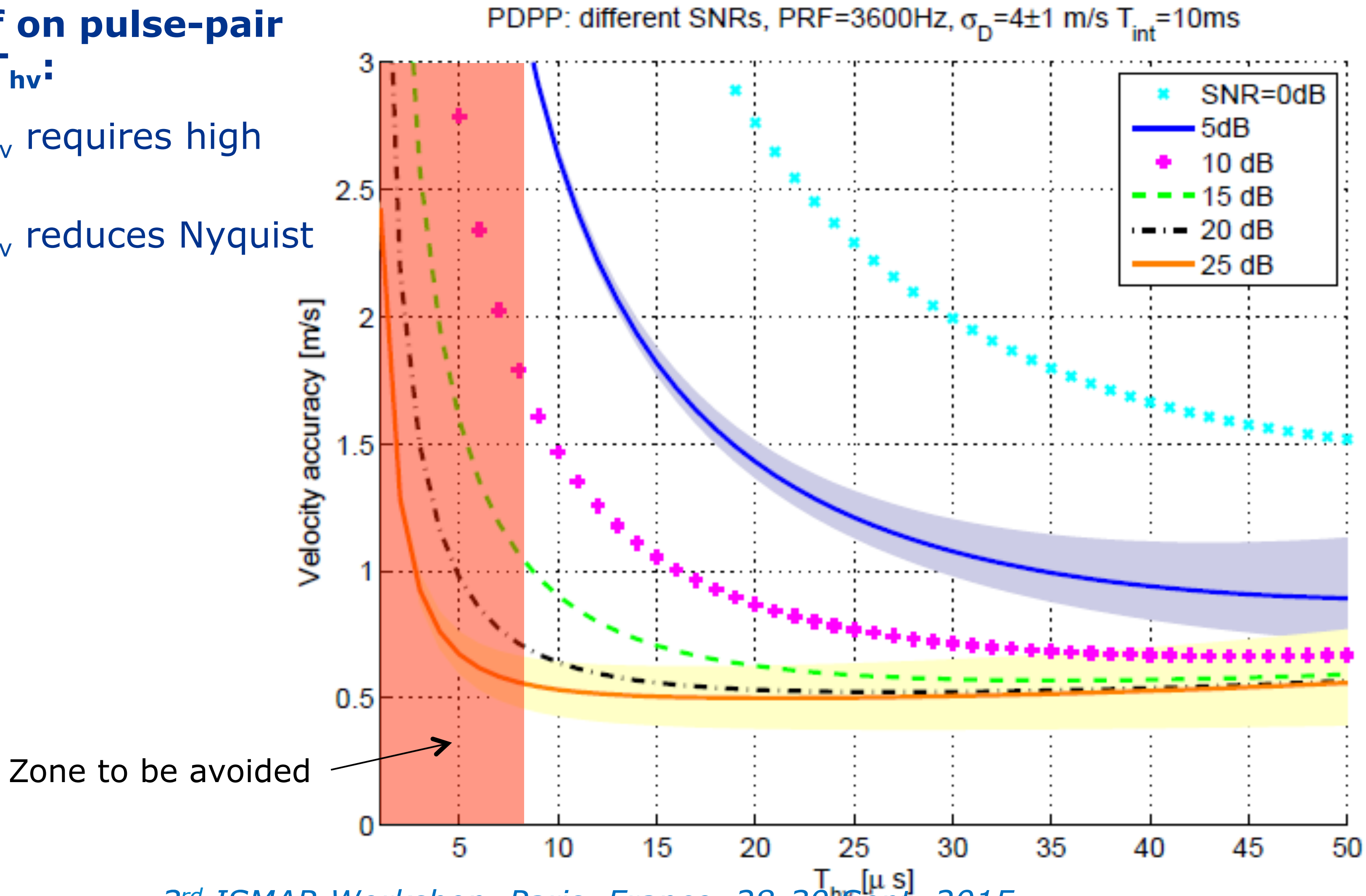
Nyquist velocity: $v_{Nyq} = \dfrac{\lambda}{4T_{hv}}$ $\begin{cases} T_{hv} = 5\,\mu s \Rightarrow v_{Nyq} = 400\,m/s @ K_a \quad 150\,m/s @ W \\ T_{hv} = 20\,\mu s \Rightarrow v_{Nyq} = 100\,m/s @ K_a \quad 37.5\,m/s @ W \end{cases}$

Basic assumption: Radar echoes between V and H channels are well-correlated

Frequency-diversity pulse-pair (FDPP) technique (2)

Trade-off on pulse-pair interval T_{hv}:

- Small T_{hv} requires high SNR;
- Large T_{hv} reduces Nyquist velocity



Vertical resolution (conical scan)

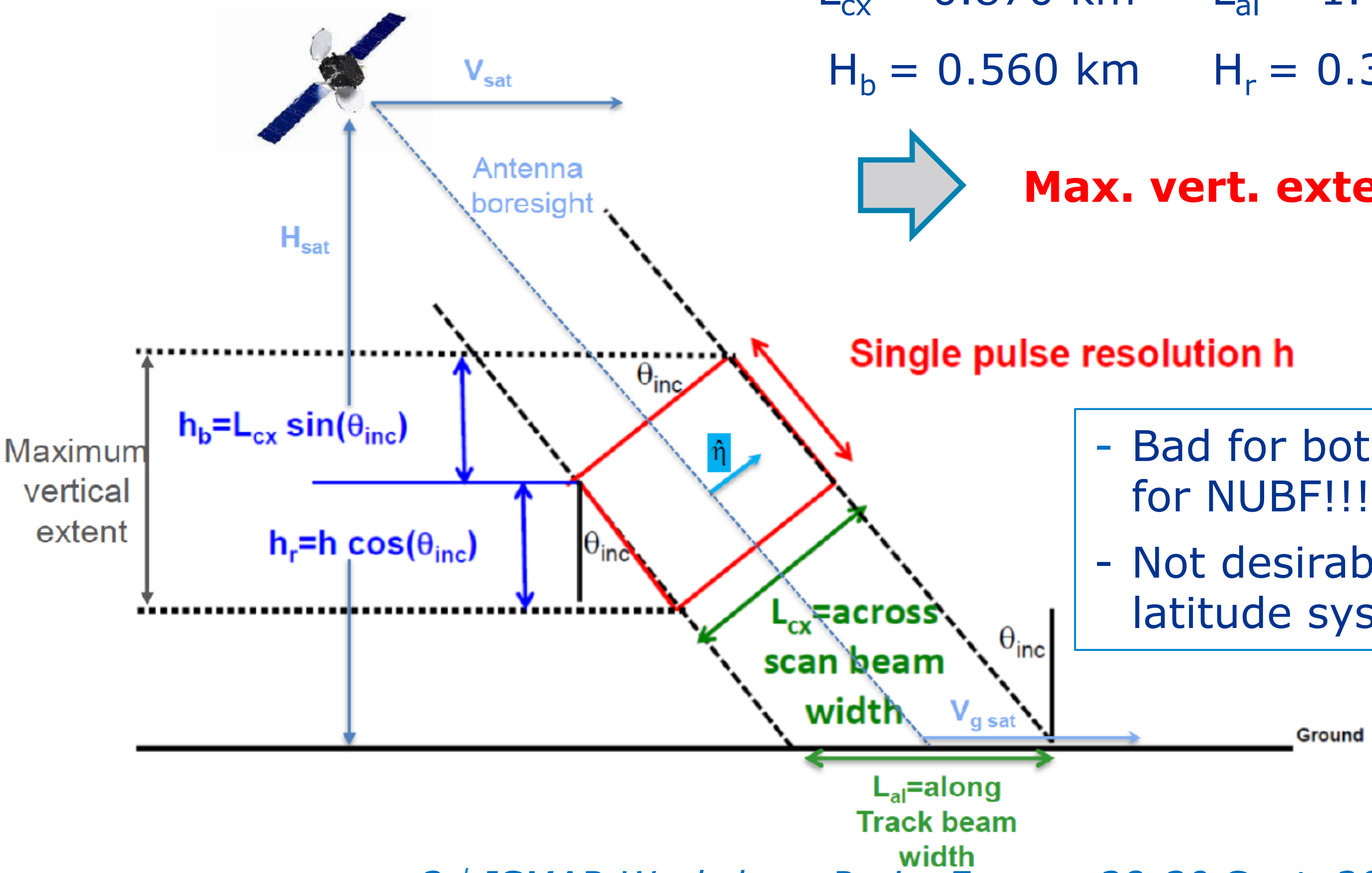
Assuming: - Cross-scan beam width=0.077º; Along-scan beam width=0.124º

- 500 km orbit altitude; 500 m range resolution

L_{cx} = 0.870 km L_{al} = 1.40 km

H_b = 0.560 km H_r = 0.375 km

Max. vert. extent = 950 m



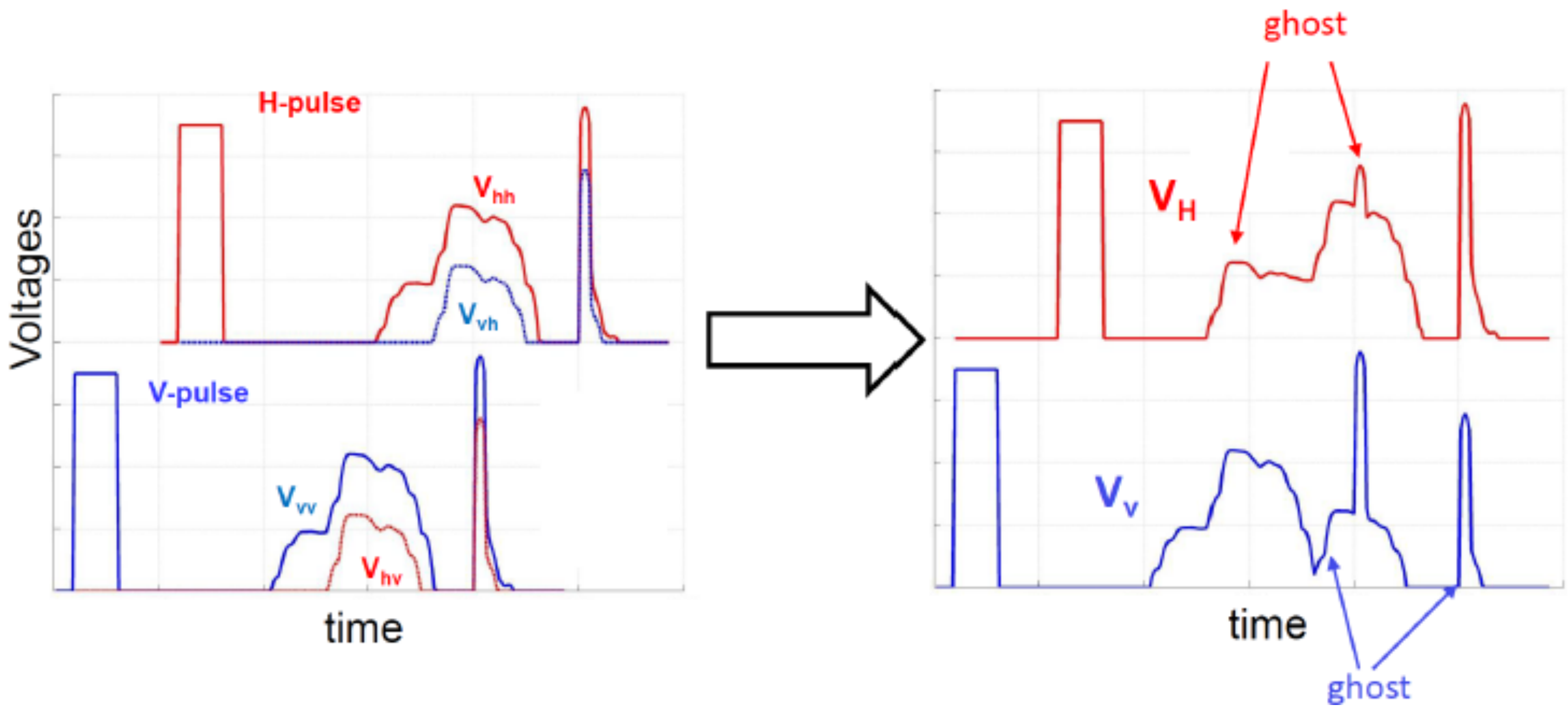
- Bad for both ground clutter and for NUBF!!!
- Not desirable especially for mid-latitude systems (shallow)

Ghost echoes due to depolarization and system cross-talk

There are two sources of ghost echoes:

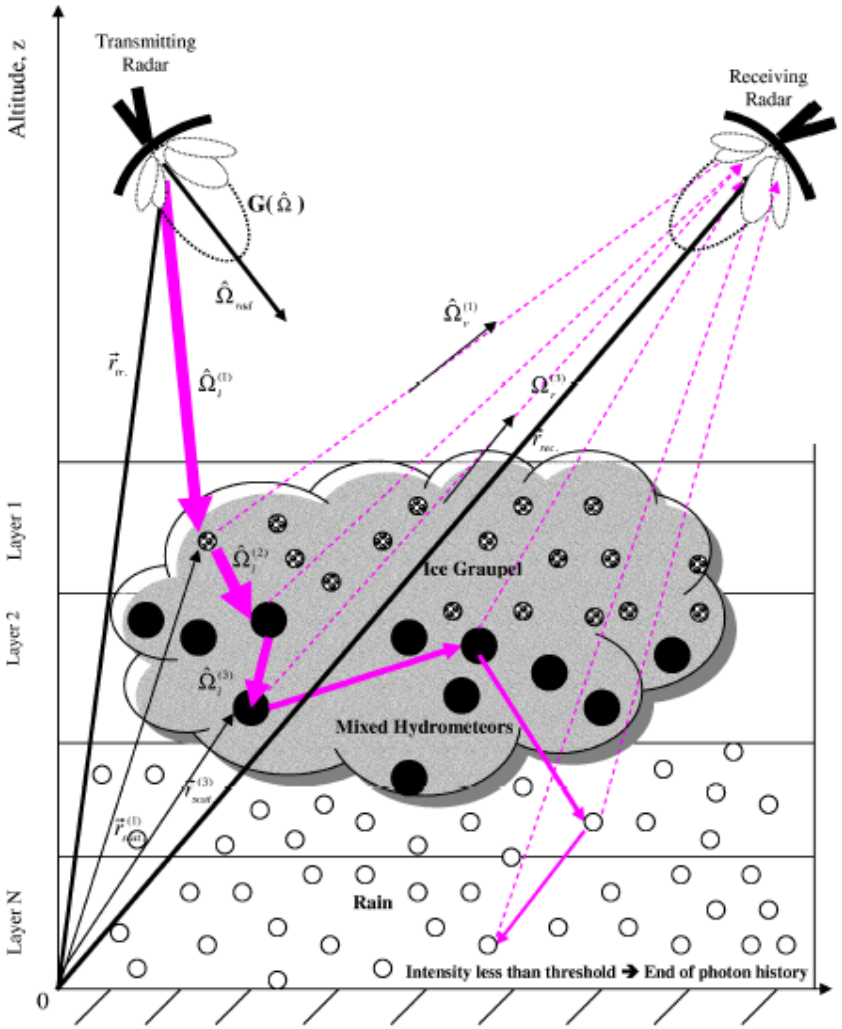
1) due to depolarizations by ice clouds and solid precipitation;

2) due to system internal polarization cross-talks.



Ghost echoes are mostly correlated?

Multiple scattering and non-uniform beam filling (NUBF)



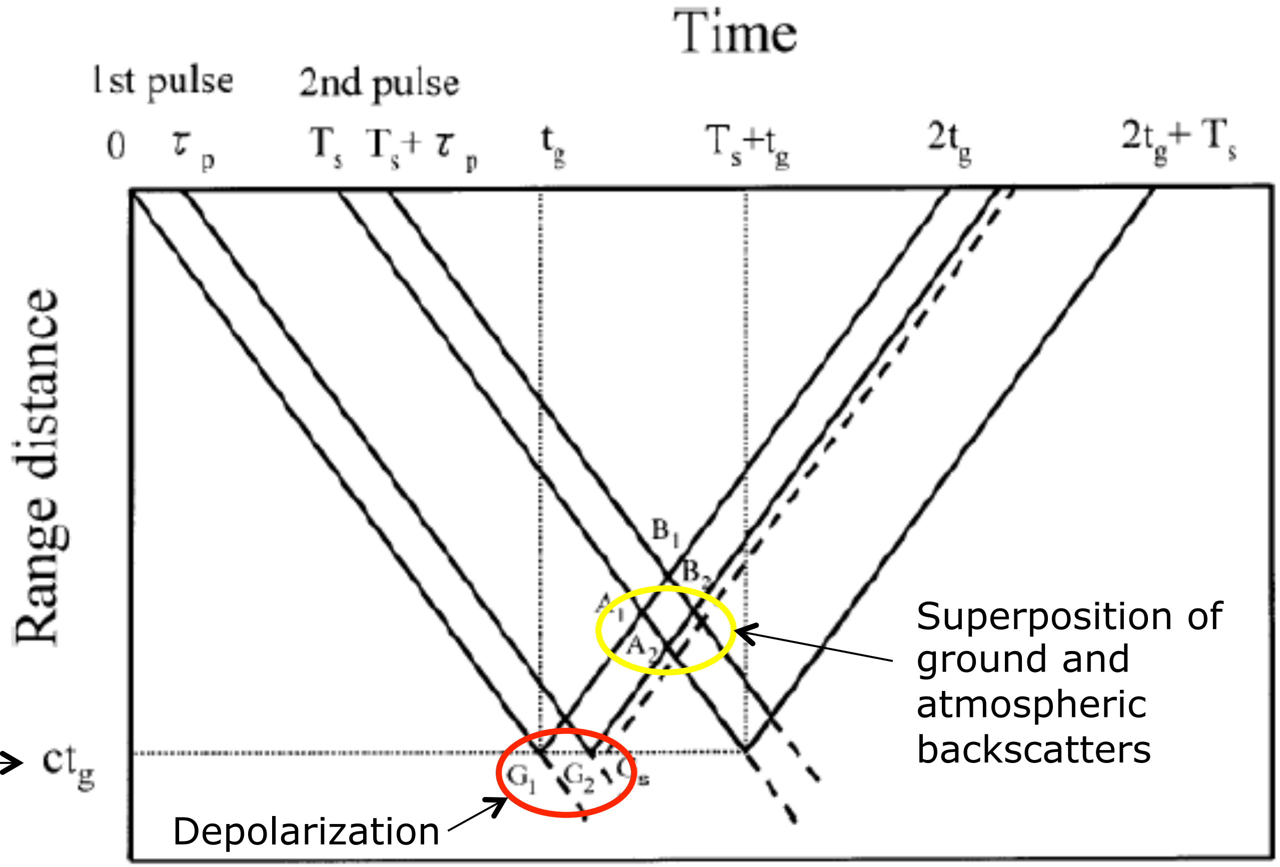
- Part of signals due to multiple scattering may be **decorrelated** between the H- and V-channels:

  ➡ No ghost Doppler, but increased noise level!

- **NUBF** gives rise to significantly erroneous Doppler estimation

A. Battaglia, M.O. Ajewole, and C. Simmer, "Evaluation of radar multiple scattering effects from a GPM perspective. Part I: model description and validation," J. Appl. Meteorol., 45(12), 206, pp. 1634–1647.

The height of the blind layer increases with the pulse-pair interval!

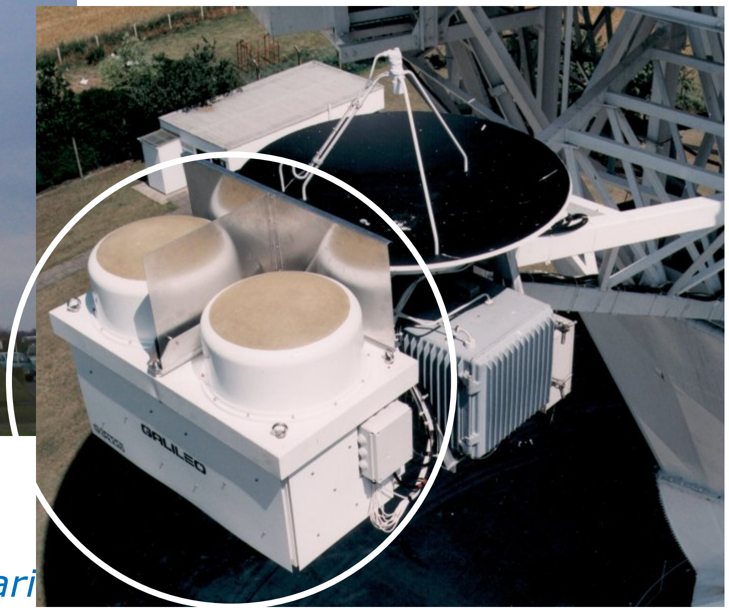


Kobayashi, S., Kumagai, H., and Kuroiwa, H. (2002). A Proposal of Pulse-Pair Doppler Operation on a Spaceborne Cloud-Profiling Radar in the W Band. J. Atmos. Ocean Technol., 19, 1294–1306. doi: http://dx.doi.org/10.1175/1520-0426(2002)019<1294:APOPPD>2.0.CO;2.

Demonstration campaigns (1)

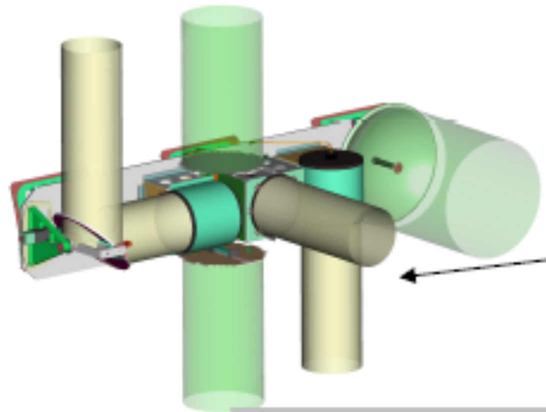
25 m antenna of the S-band weather radar at Chilbolton, UK

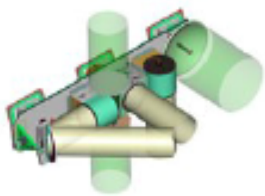
- Ground-based demonstration of the FDPP technique for Doppler retrieval with varying pulse interval
- Study effects of depolarization/particle shape and channel cross-talk
- 94 GHz Galileo radar already upgraded to support the FDPP mode of operation
- S-band radar to support calibration of the 94 GHz radar

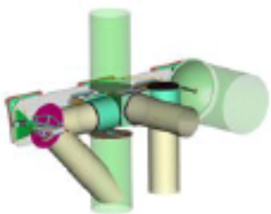


94 GHz Galileo radar and 35 GHz cloud radar

Demonstration campaigns (2)







NAWX	W-band	X-band
Transmitted Frequency (GHz)	94.05	9.41
Peak Tx Power (KW)	1.7 - typical	25 (split b/n two ports)
Polarization	Co and Cross	Simultaneous H and V
Doppler	Pulse Pair and FFT	Pulse Pair and FFT
Pulse Duration (µs)	0.1 - 10	0.11-1
Max PRF (KHz)	20	5
Ant. 3 dB BW (°)	0.75	3.5
Antenna ports	5	4
View direction	Up, down and side	Up, down and side

More details/updates: **http://www.nawx.nrc.gc.ca**

Demonstration campaigns (3)

esa

Objectives of the airborne campaign (Ottawa/Great Lake region):

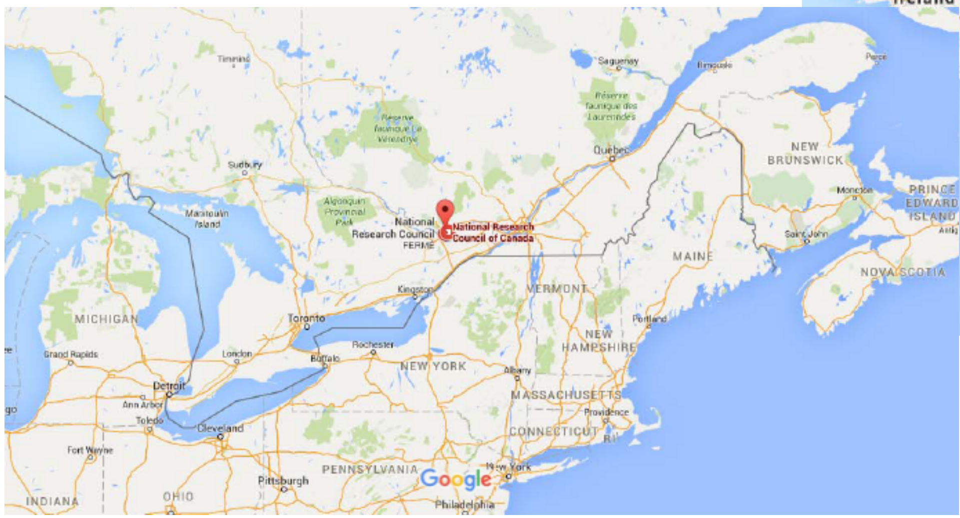
- Quantifying the spatial and temporal decorrelations between echo-signals in the two polarization channels;
- Correlating in-situ particle size distribution with radar backscatter;
- Quantifying the polarimetric backscatter properties of sea and land surfaces, and their effects on blind zone;
- Acquire high spatial resolution data for modelling non-uniform beam-filling (NUBF) effects in satellite configuration.

Remark: No multiple scattering is expected in airborne or ground-based configuration.

Cloud particle probes
(courtesy of NRC Canada)

Conclusion

- Synergy and joint campaign opportunities sought with ADM-Aeolus, EarthCARE and ICI mission preparations.
- Chilbolton (ground-based) observation campaign planned to start in Nov. 2015 for a period of 6 months.
- Convair-580 flight campaign planned in April 2016.



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