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# Statistical database from existing data sets to assess the performances of a dynamics and microphysics studies-oriented mission: DYCECT

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# DYCECT context

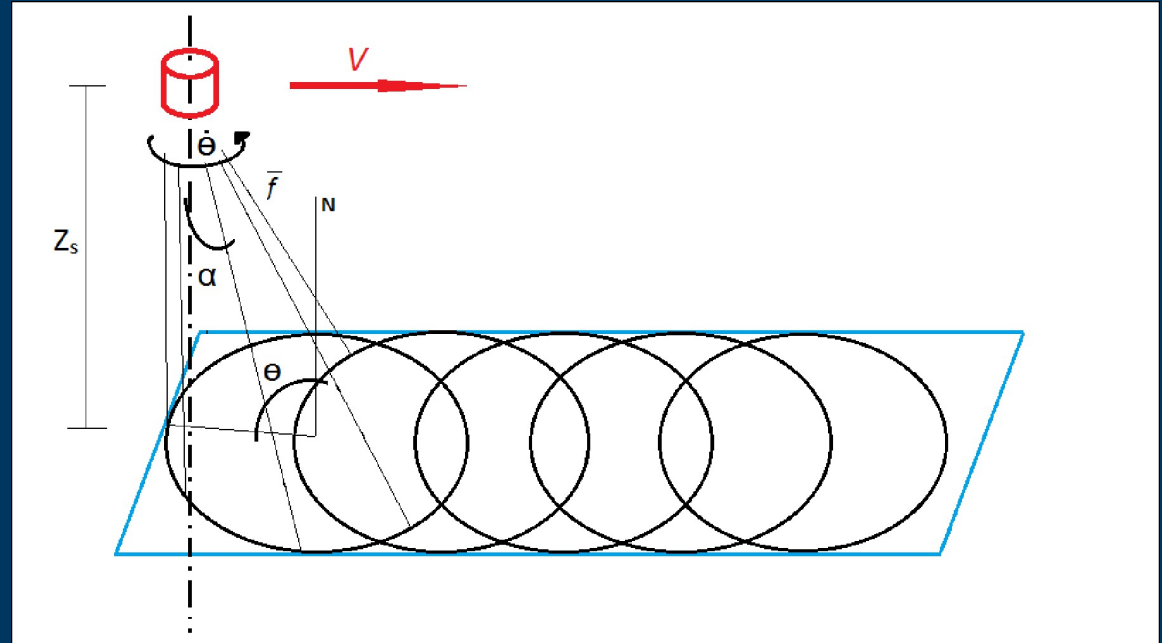
(DYnamique, énergie et Cycle de l'Eau dans la Convection Tropicale)  
(Dynamics, energy and water cycle in tropical convection)

- **Post-Global Precipitation Measurement concept => 2025-2030**
- **Retrieve a 3D wind field (u,v,w) and microphysical classifications in cloud systems:**
  - **Convection studies and climatology**
  - **Convection parameterization**
  - **Microphysical processes**
- **Focused on processes rather than rain retrieval**
- **Originally aimed at the Tropics but appropriate for higher latitudes**



# Concept 1 example

Similar to PMR imager: rotation of the antenna combined with motion of the satellite makes the beam describe a spiral-shaped projected track => non-linear measurements

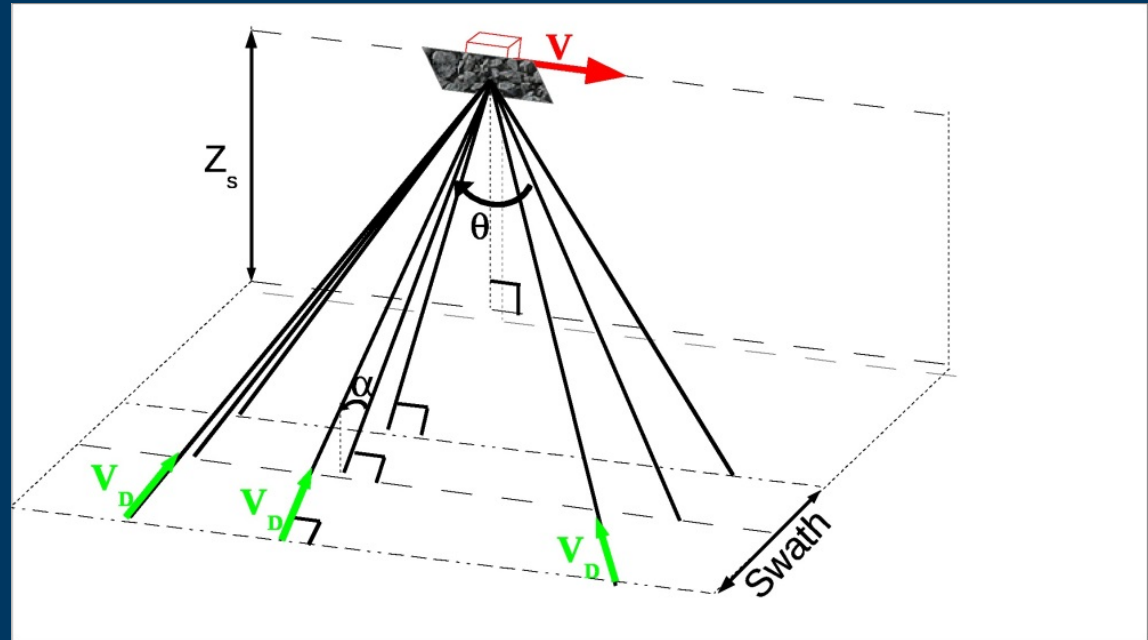


- More interesting at 95 GHz.
- Elevation  $\sim 35^\circ - 45^\circ$  (TBD) depending on retrieval constraints.
- Rotation of antenna between 10 and 30 rpm (TBD).
- Resulting swath about 800 km (450-500 km altitude) but retrieval is very inhomogeneous.



# Concept 2 example

Agility in Azimuth and Elevation provides the scanning. Three Azimuth angles are envisioned.

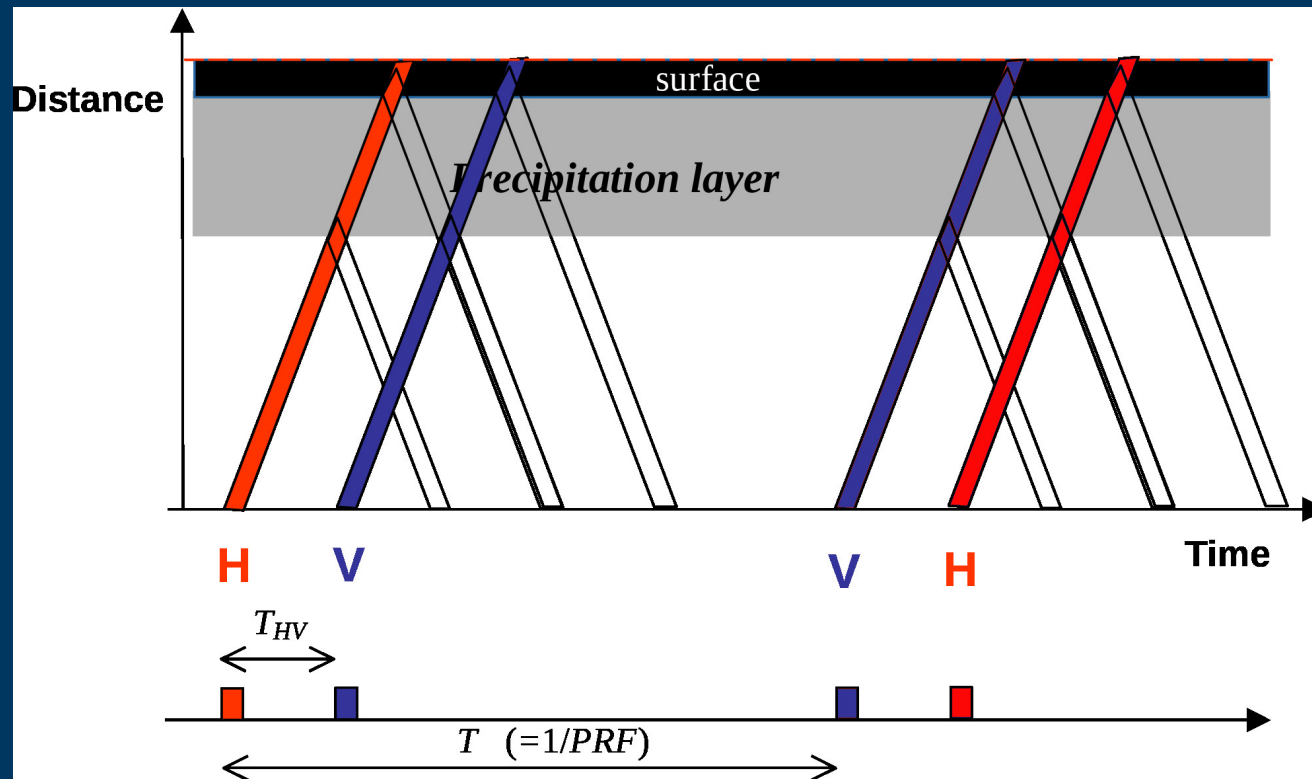


- More realistic option for 35 GHz.
- Elevation  $\sim 20$  to  $40^\circ$
- A lot more independent samples.
- Resulting swath about 400 km (450 -500 km altitude).





# Polarimetric Interleaved Pulses (Pazmani 1999)



**This makes  $V_{Amb}$  and  $D_{Amb}$  independent.  
Data are processed using Pulse Pair technique.**



# Most critical aspect: NUBF

- Satellite velocity is  $7.5 \text{ km.s}^{-1}$  !!
- Target velocities range from a few  $\text{cm.s}^{-1}$  to a few  $\text{m.s}^{-1}$

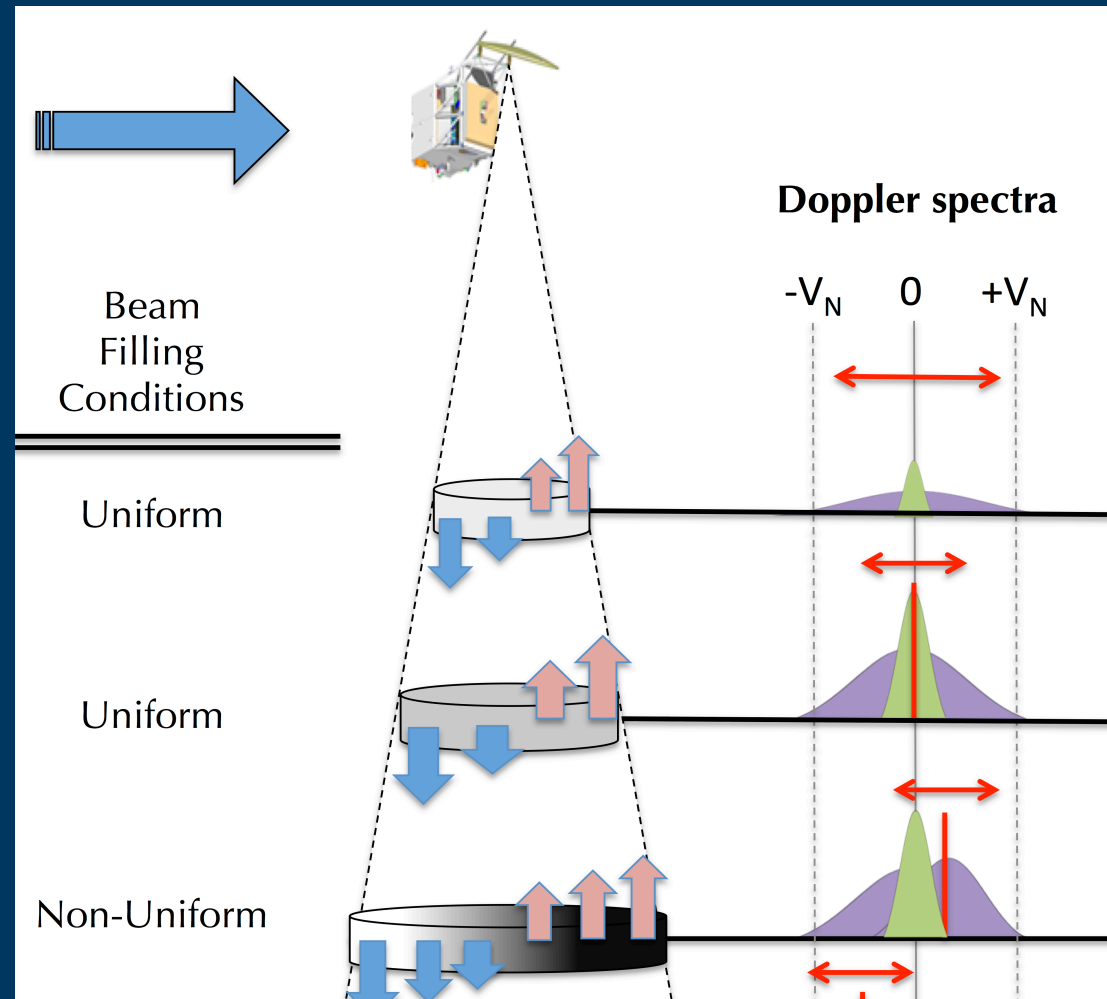


Figure borrowed from WIVERN presentation by A. Illingworth



# General characteristics

At 95 GHz, mechanical sampling, rotation is 10 rpm => 45 km between scans

Frequency	F	95	35	GHz
Antenna size	$D$	2.9	9.0	$m$
Antenna type		Mecan.	Electro.	
Satellite altitude	$Z$	450		$km$
Onboard elev. angle	$\theta$	46.	20 – 40	$deg$
Half swath	$S_w$	485	200	$km$
One-way beam aperture	$\theta_0$	0.08	0.07	$deg$
3dB one-way cross resolution <b>IFOV</b>	$L$	1.6	1.1-1.4	$km$
Pulse duration	$\tau$	3.3		$\mu s$
Range resolution		500		$m$
Peak power	$P_e$	1.8		$kW$
Pulse repetition frequency	$PRF$	3750	variable	$Hz$
H/V & V/H interpair time	$T_{HV}$	267.		$\mu s$
H & V interpulse time	$T_{pair}$	9.6		$\mu s$
Receiver noise	$Noise$	-119		$dBm$
0 dB SNR detection threshold	$Z_{0SNR}$	-7.35		$dBZ$
10 dB SNR detection threshold	$Z_{10SNR}$	2.65		$dBZ$
PP error at 10 dBZ <b>IFOV</b>	$\sigma_{10dBZ}$	6.62	59.1	$m.s^{-1}$
PP error at 0 dBZ <b>IFOV</b>	$\sigma_{0dBZ}$	22.46	319.5	$m.s^{-1}$
Ambiguous distance	$D_{Amb}$	40		$km$
Ambiguous velocity	$V_{Amb}$	82	223	$m.s^{-1}$



# General characteristics

- Using approximated formula from Doviak and Zrnic 1993

At 95 GHz, mechanical sampling, rotation is 10 rpm => 45 km between scans

Frequency	F	95	35	GHz
Antenna size	D	2.9	9.0	m
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Satellite altitude	Z	450		km
Onboard elev. angle	$\theta$	46.	20 – 40	deg
Half swath	$S_w$	485	200	km
One-way beam aperture	$\theta_0$	0.08	0.07	deg
3dB one-way cross resolution IFOV	L	1.6	1.1-1.4	km
Pulse duration	$\tau$	3.3		$\mu s$

$$\sigma_{PP} = \frac{(1 + 1/SNR)^2 - \rho(mT)^2}{32\pi^2 M \rho(mT) T^2}$$

0 dB SNR detection threshold	$Z_{0SNR}$	-7.35		dBZ
10 dB SNR detection threshold	$Z_{10SNR}$	2.65		dBZ
PP error at 10 dBZ IFOV	$\sigma_{10dBZ}$	6.62	59.1	$m.s^{-1}$
PP error at 0 dBZ IFOV	$\sigma_{0dBZ}$	22.46	319.5	$m.s^{-1}$
Ambiguous distance	$D_{Amb}$	40		km
Ambiguous velocity	$V_{Amb}$	82	223	$m.s^{-1}$



# General characteristics

- At 35 GHz to get acceptable perf we need 1024 integrations...

## Integrating over 50 pairs of H-V pulses

Frequency	F	95	35	GHz
Antenna size	$D$	2.9	9.0	$m$
Antenna type		Mecan.	Electro.	
Satellite altitude	$Z$	450		$km$
Onboard elev. angle	$\theta$	46.	20 – 40	$deg$
Half swath	$S_w$	485	200	$km$
One-way beam aperture	$\theta_0$	0.08	0.07	$deg$
3dB one-way cross resolution Integ. 50 pairs	$L$	5.3	variable	$km$
Pulse duration	$\tau$	3.3		$\mu s$
Range resolution		500		$m$
Peak power	$P_e$	1.8		$kW$
Pulse repetition frequency	$PRF$	3750	variable	$Hz$
H/V & V/H interpair time	$T_{HV}$	267.		$\mu s$
H & V interpulse time	$T_{pair}$	9.6		$\mu s$
Receiver noise	$Noise$	-119		$dBm$
0 dB SNR detection threshold	$Z_{0SNR}$	-7.35		$dBZ$
10 dB SNR detection threshold	$Z_{10SNR}$	2.65		$dBZ$
PP error at 10 dBZ Integ. 50 pairs	$\sigma_{10dBZ}$	0.91	8.36	$m.s^{-1}$
PP error at 0 dBZ Integ. 50 pairs	$\sigma_{0dBZ}$	3.17	45.0	$m.s^{-1}$
Ambiguous distance	$D_{Amb}$	40		$km$
Ambiguous velocity	$V_{Amb}$	82	223	$m.s^{-1}$

- @ 95 w/ slow rotation and @ 35 w/ "smart" scanning

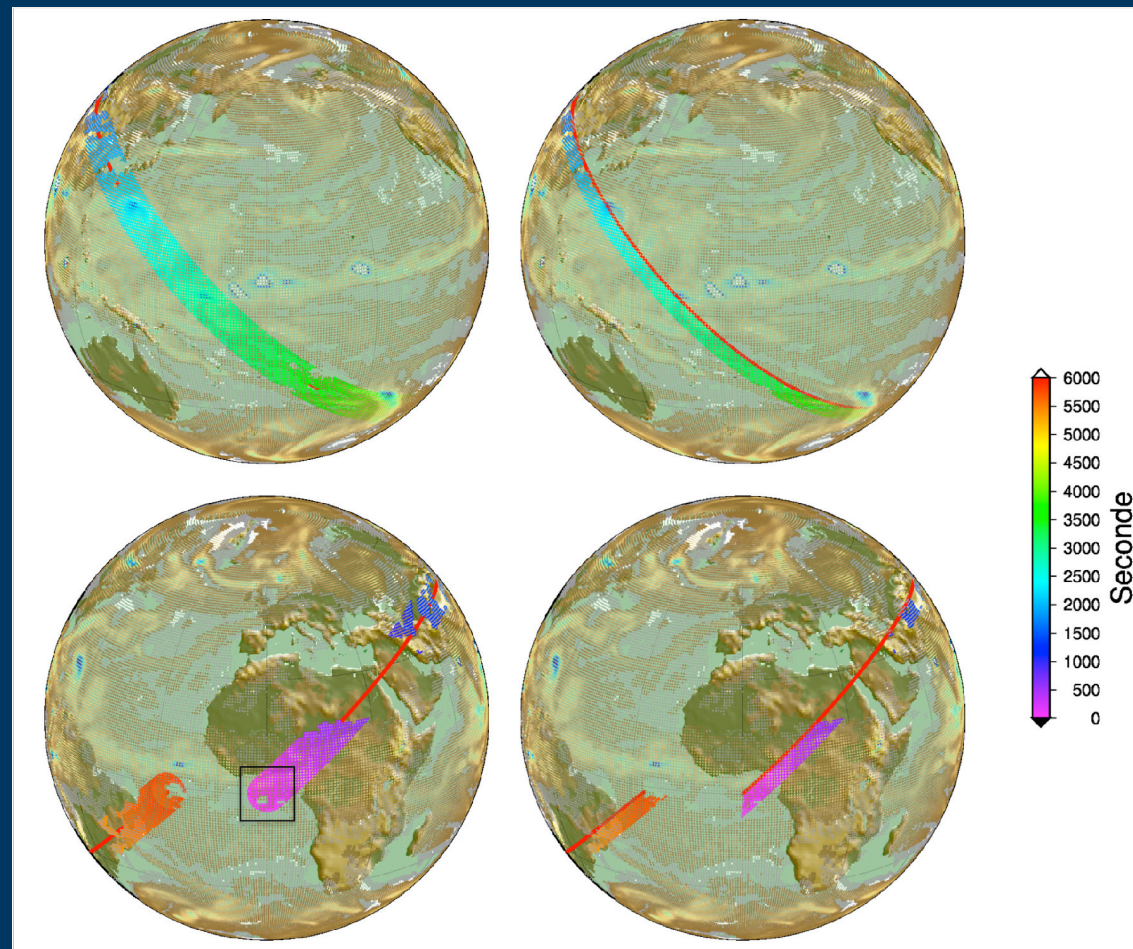


# Sampling illustration

- ERA simulation on September 13, 1975
- Good to get an idea but does not resolve convection...

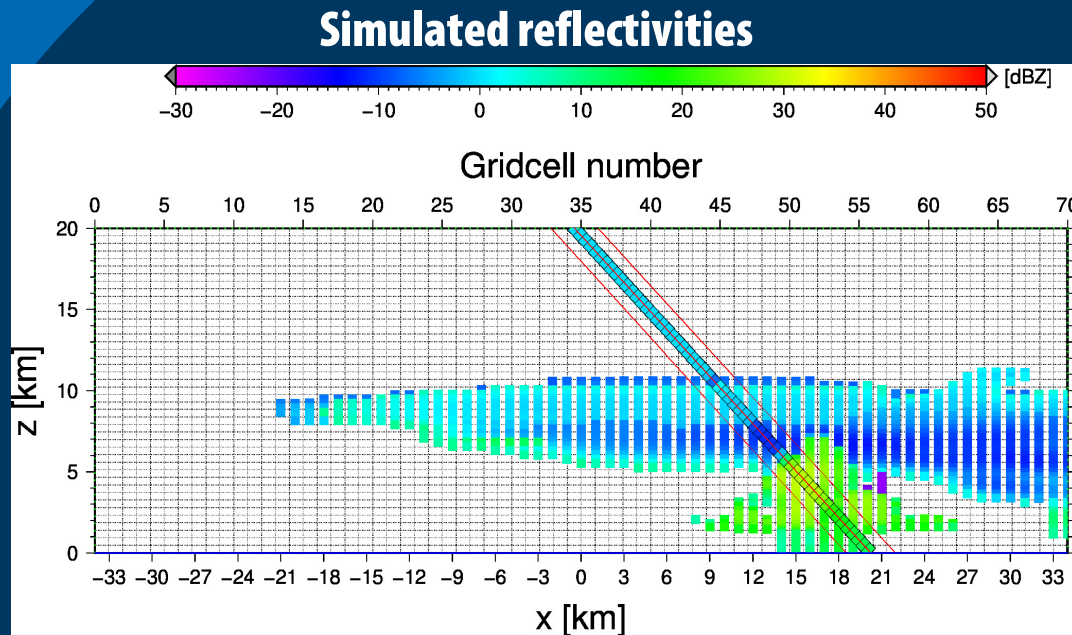
Conical

Side view



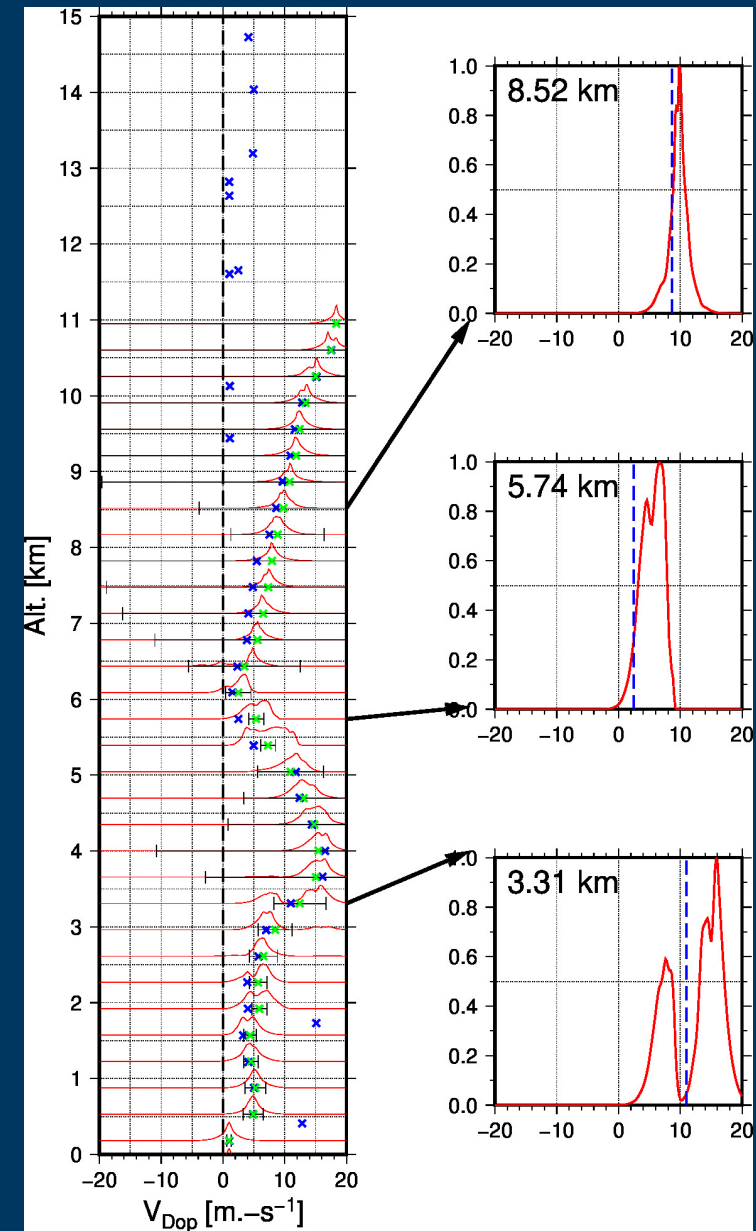


# Example W band, conical



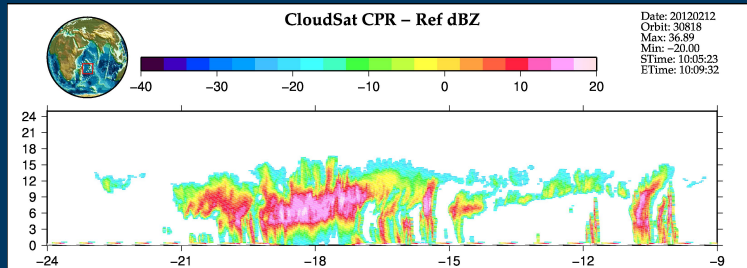
- WRF simulation (S. Bastin, LATMOS)
- Full 3D
- Single scattering
- Pulse-Pair Processing errors (Doviak and Zrnic)

## Simulated spectra

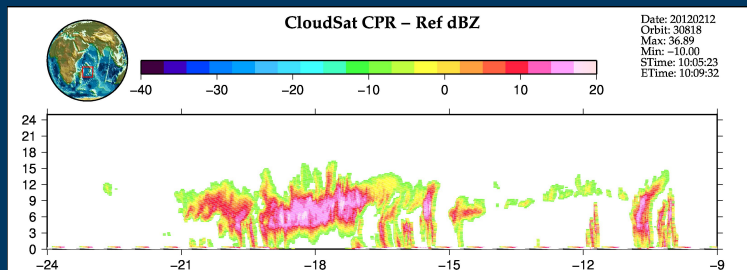


# Expected sensitivity

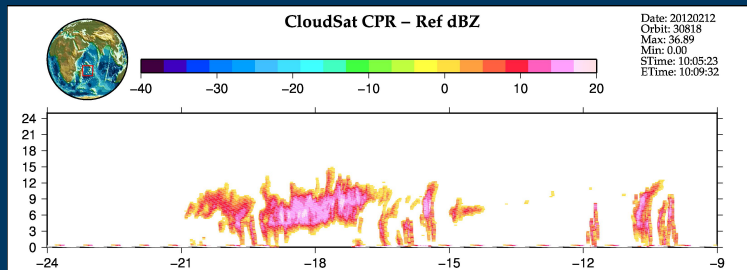
-20 dBZ



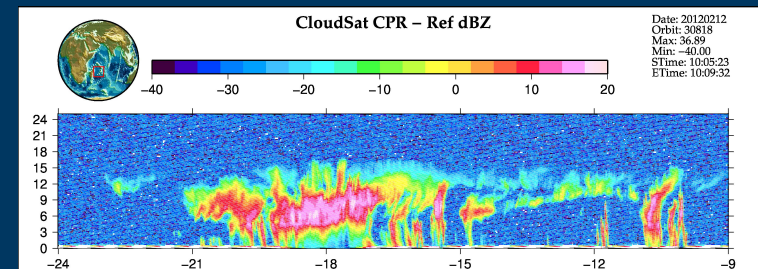
-10 dBZ



0 dBZ



Original CPR ~ -35 dBZ



Just to set up ideas, we expect that the nominal sensitivity should be near 0 dBZ...





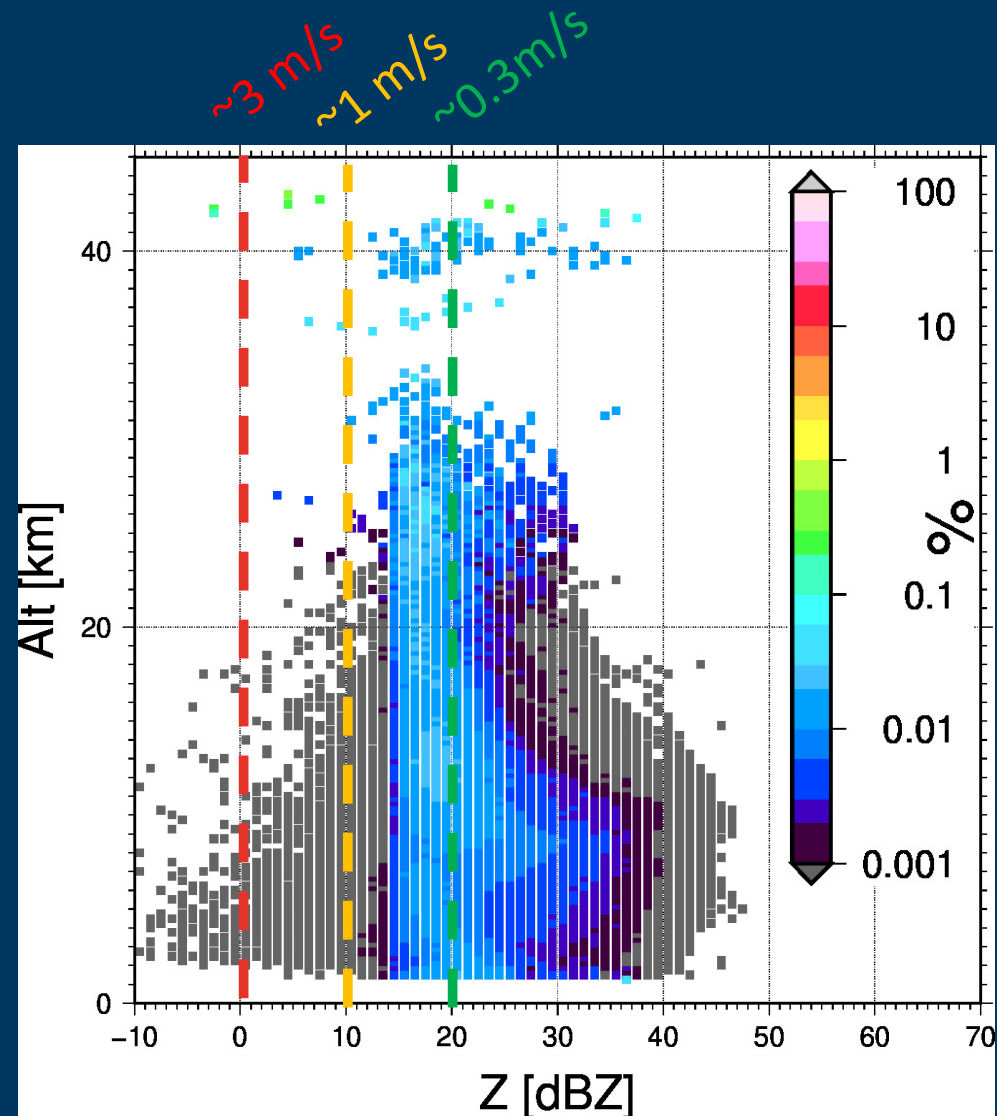
# Building a database from existing sensors

- **In order to assess the radar potential, we are building a database from**
  - **GPM DPR in order to have 3D structure of reflectivity at Ku and Ka band**
  - **Cloudsat to access higher sensitivity (but has only 2D structure of reflectivity)**
  - **EarthCare when available will also be a great asset with 2D Z and  $V_{Dop}$  !**
- **We use standard flags from the said products to select “rainy” pixels**
- **We compute 2D histograms of altitude vs. reflectivity**
- **We will also make use of the reflectivity 3D structure to assess a more detailed wind retrieval**



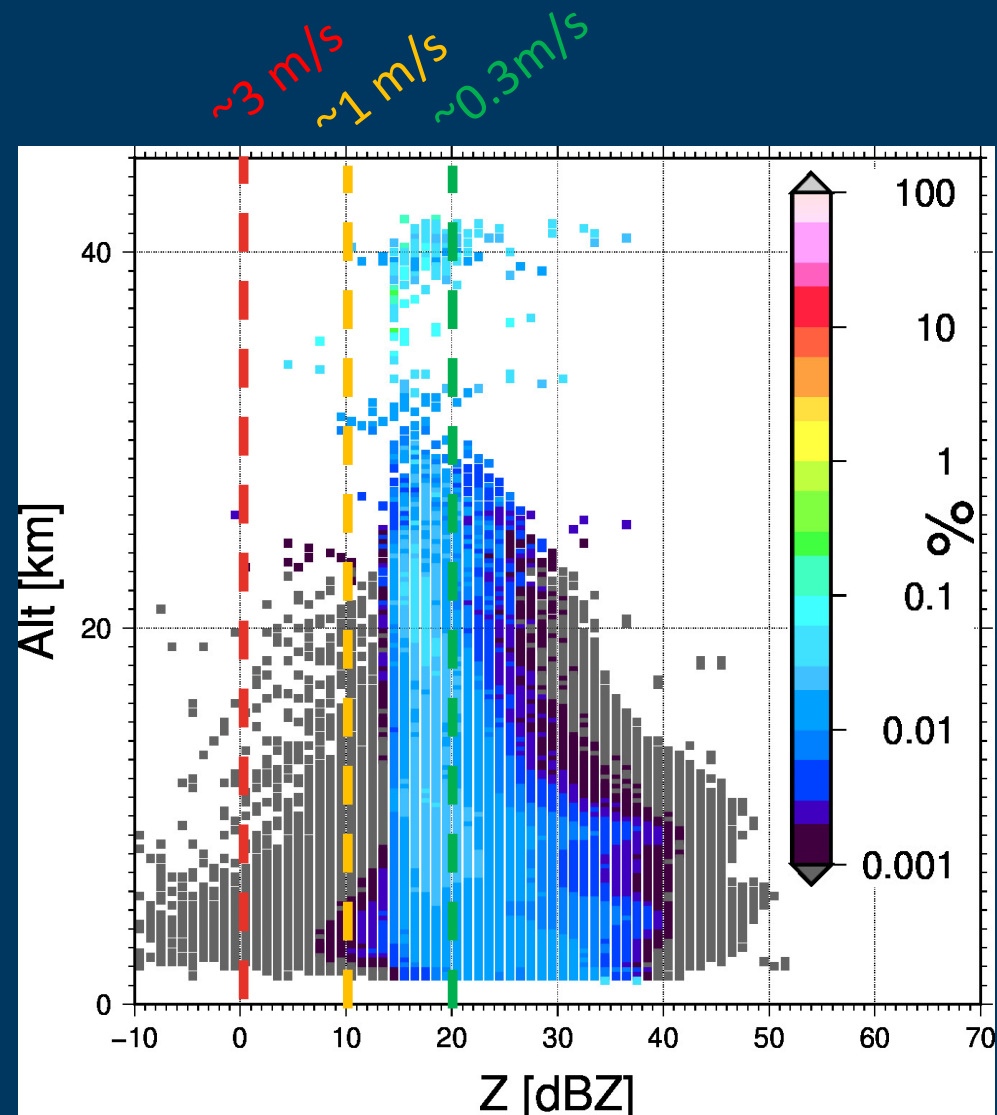
# Average rainy Z at Ku Band from GPM DPR: June

- For 95 Ghz
- Same hypotheses as before, 50 pulses integration
- 2D histogram of Z occurrence per altitude
- This is GPM Ku Band, we miss a lot of the clouds where  $Z < 0$  dBZ!



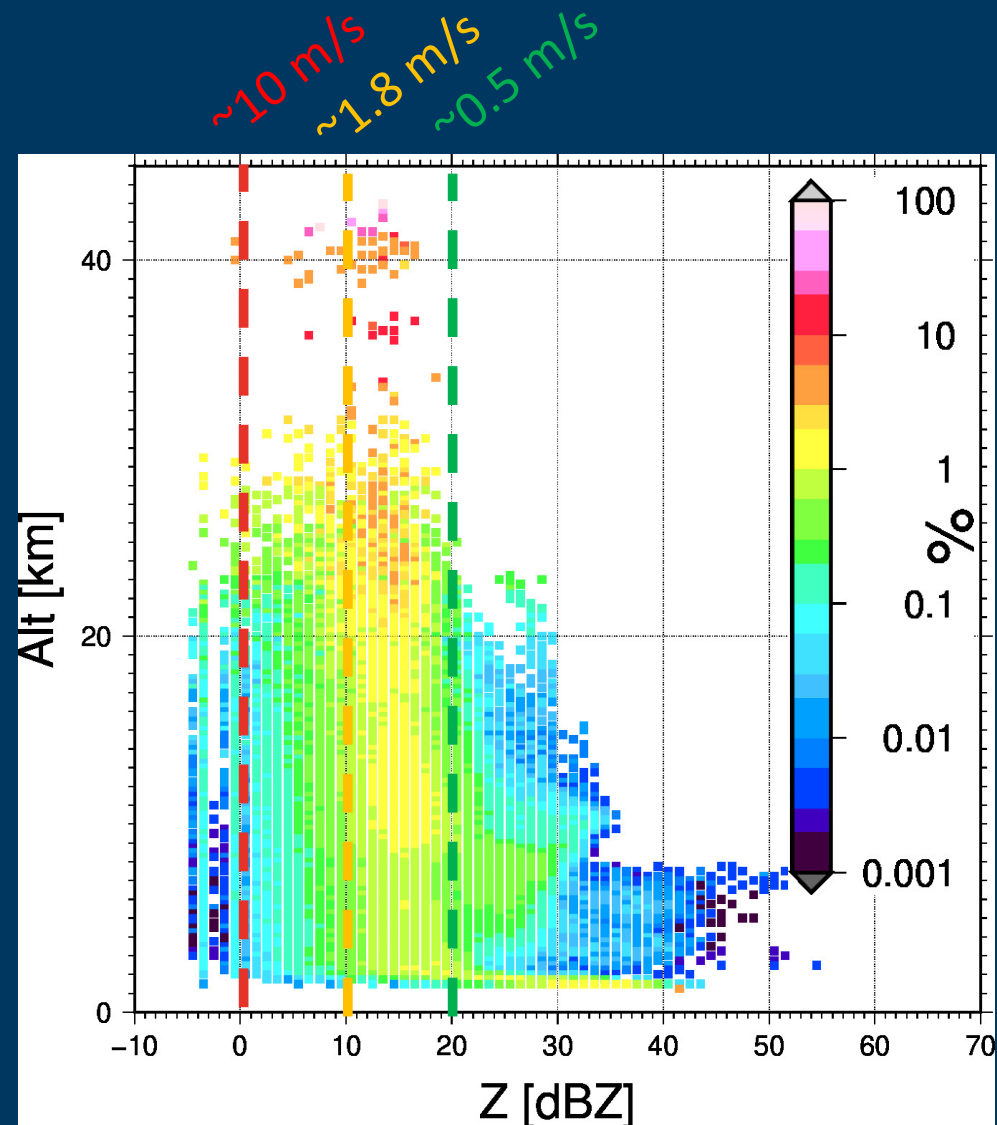
# Average rainy Z at Ku Band from GPM DPR: October

- For 95 GHz
- Same hypotheses as before, 50 pulses integration
- 2D histogram of Z occurrence per altitude
- This is GPM Ku Band, we miss a lot of the clouds where  $Z < 0$  dBZ!



# Average rainy Z at Ka Band from GPM DPR: June

- For 35 GHz
- **1024 pulses integration**
- **2D histogram of Z**
- **occurrence per altitude**



# Conclusions & Perspectives

- **95 GHz offers better performances**
  - **Mechanical design is simpler but density of pixels is less favorable due to slow rotation for improved independent samples**
  - **Majority of ice precipitations would be observed with an error on Doppler  $< 1\text{m.s}^{-1}$  but clouds are much more critical**
  - **Study with ClouSat database needs to be made**
- **35 GHz option is better for rain**
  - **Electronic antenna offers great flexibility but much more complex technically**
  - **$1\text{ m.s}^{-1}$  error threshold on  $V_{\text{Dop}}$  is closer to 20 dBZ so we would miss a substantial fraction of precipitations and clouds**





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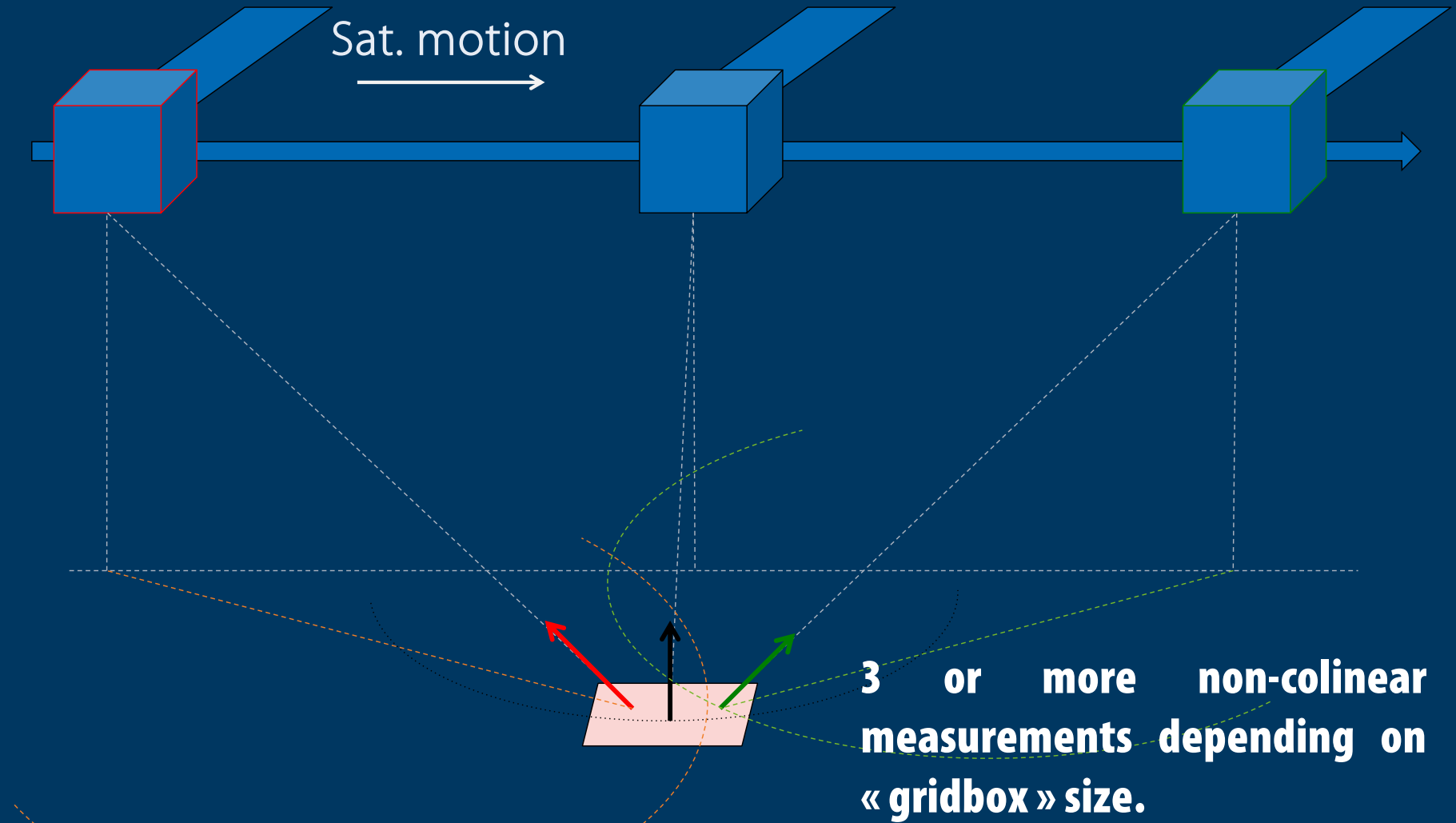


# Thank you



[www.latmos.ipsl.fr](http://www.latmos.ipsl.fr)

# Measurement principle



# Interleaved H and V pulses (Pazmani 1999)

Ambiguous velocity and distance

$$V_a = \frac{\lambda}{4T_s} = \frac{\lambda PRF}{4} \quad D_a = \frac{cT_s}{2} = \frac{c}{2PRF}$$

Pulse-Pair Processing:

$$\hat{v}_R = -\frac{\lambda}{4\pi T_s} \arg(\langle E_H(t) \cdot E_V^*(t + T_s) \rangle)$$

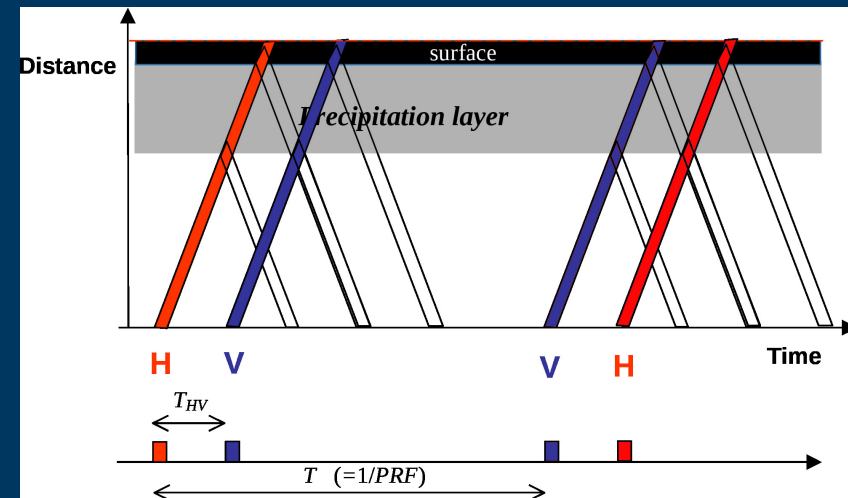
Decoupling of velocity and distance:

$$V_a = \frac{\lambda}{4T_{HV}} = \frac{\lambda PRF_V}{4} \quad D_a = \frac{cT}{2} = \frac{c}{2PRF}$$

Handling differential phase effects:

$$\hat{v}_R = -\frac{\lambda}{8\pi T_{HV}} \left[ \arg(\langle E_H(t) \cdot E_V^*(t + T_{HV}) \rangle) + \arg(\langle E_V(t) \cdot E_H^*(t + T_{HV}) \rangle) \right]$$

$$\Phi_{DP} = \left[ \arg(\langle E_H(t) \cdot E_V^*(t + T_{HV}) \rangle) - \arg(\langle E_V(t) \cdot E_H^*(t + T_{HV}) \rangle) \right]$$





# Monte-Carlo simulation at 95 GHz

(with F. Szczap, LaMP)

SS: Single Scattering

MS: Multiple Scattering

