# Potential of polarimetric observations for aircraft icing detection?

**Clotilde Augros**, Mathieu Lecocq, Nicolas Gaussiat

Météo-France, DSO/Radar Center (CMR), Toulouse, France – clotilde.augros@meteo.fr

## 1. Motivation

- **Polarimetric radar** can provide information on hydrometeor shapes and sizes. At Météo France, they are used to identify the hydrometeor types (Al-Sakka et al 2013)
- However, the presence of **Supercooled Liquid Water (SLW)** that can cause **aircraft icing** is not yet available in the classification algorithm.
- Previous studies have examined the characteristics of polarimetric observations in case of aircraft icing and suggest that
  - SLW is often associated to very low values of Kdp and Zdr (Plummer 2010)
  - But the coexistence of SLW and ice particles can also be characterized by relatively large Kdp and Zdr values due to the riming on oblate crystals (Williams 2011, Grazioli 2015)
- An icing algorithm has already been developed at NCAR (Serke et al 2015)

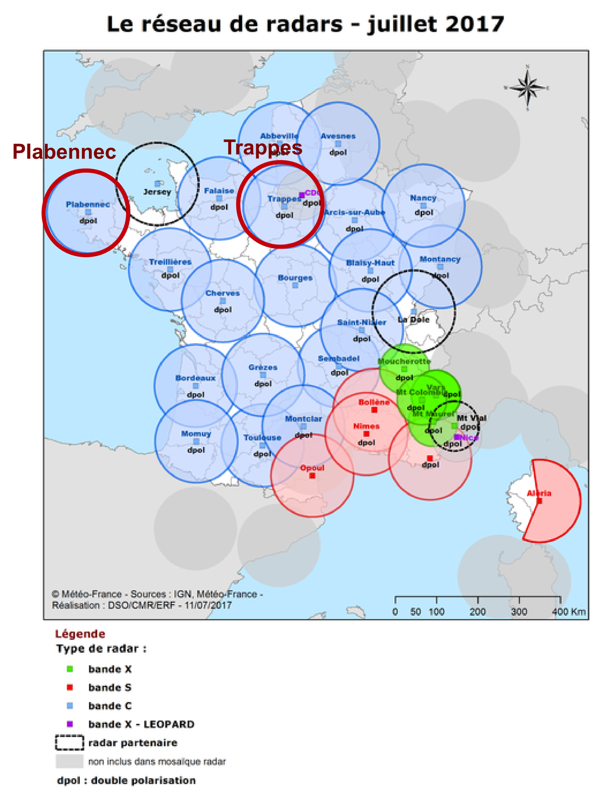
**Our aim: evaluate the potential of operational radar polarimetric observations for icing detection**

- Do light snow and SLW really exhibit distinct polarimetric signatures?
- Can the operational polarimetric radar observations reach a sufficient accuracy to represent distinct signatures in case of icing versus non icing?
- To what extent can radars improve model based algorithms to detect icing regions ?

## 2. Data

### In situ measurements: 2 aircraft icing databases

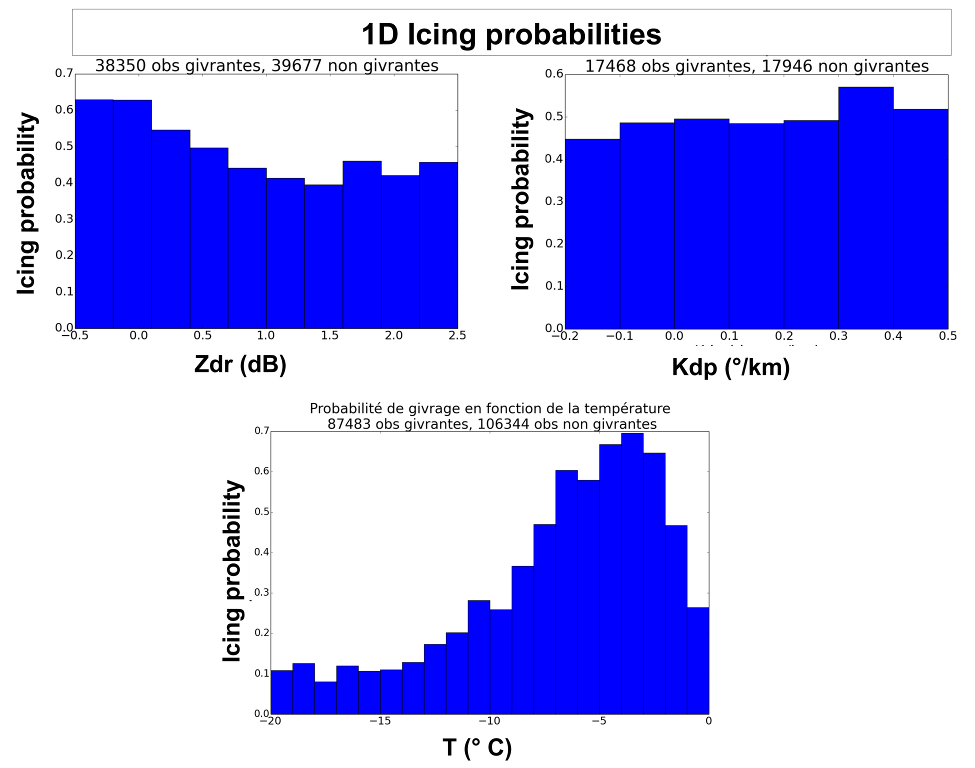
- Brittany, winter 2015 / 2016: icing certification campaign => predominant icing conditions
  - 26 flights lasting about 2 to 4 hours
  - In-situ observations : **Temperature (T), Liquid Water Content (LWC)**, Mean Volume Diameter
- France, 2013 / 2015: commercial airline flights => all types of weather conditions
  - 24 000 hours of flight
  - In-situ observations : **Temperature, Icing occurrence (binary signal: yes/no)**

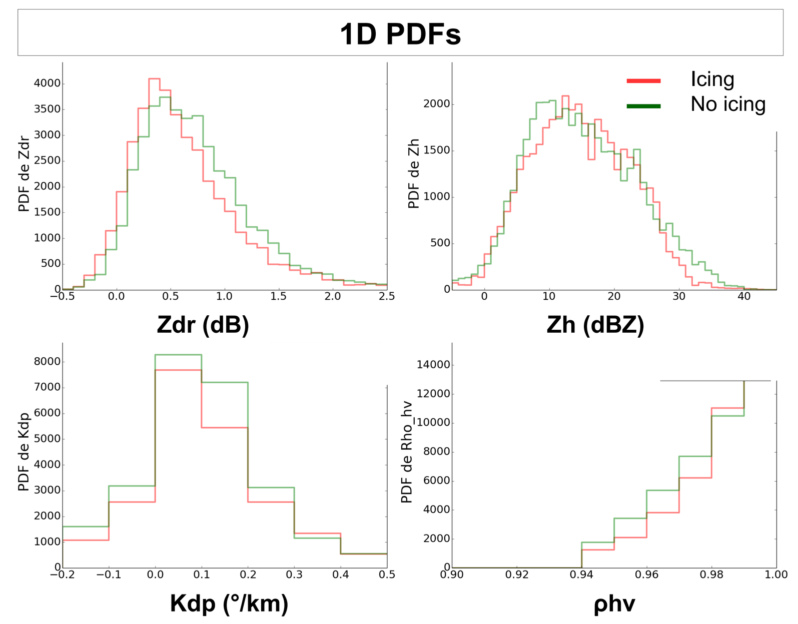



### Polarimetric radar observations

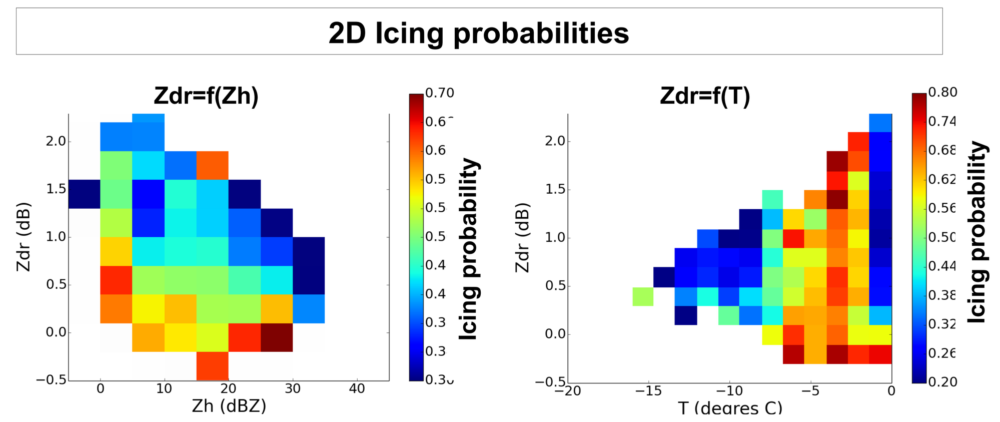
- Use of polarimetric observations from **Plabennec** and **Trappes** radars (C band): **Zh , Zdr , ρhv , φdp, Kdp**
- Data selection: SNR> 8 dB, -25 < T < 0°C, φdp < 25°, ρhv > 0.94, $d_{beam-aircraft}$ < 250m

## 3. Distributions of Zdr and Kdp in icing/non icing conditions

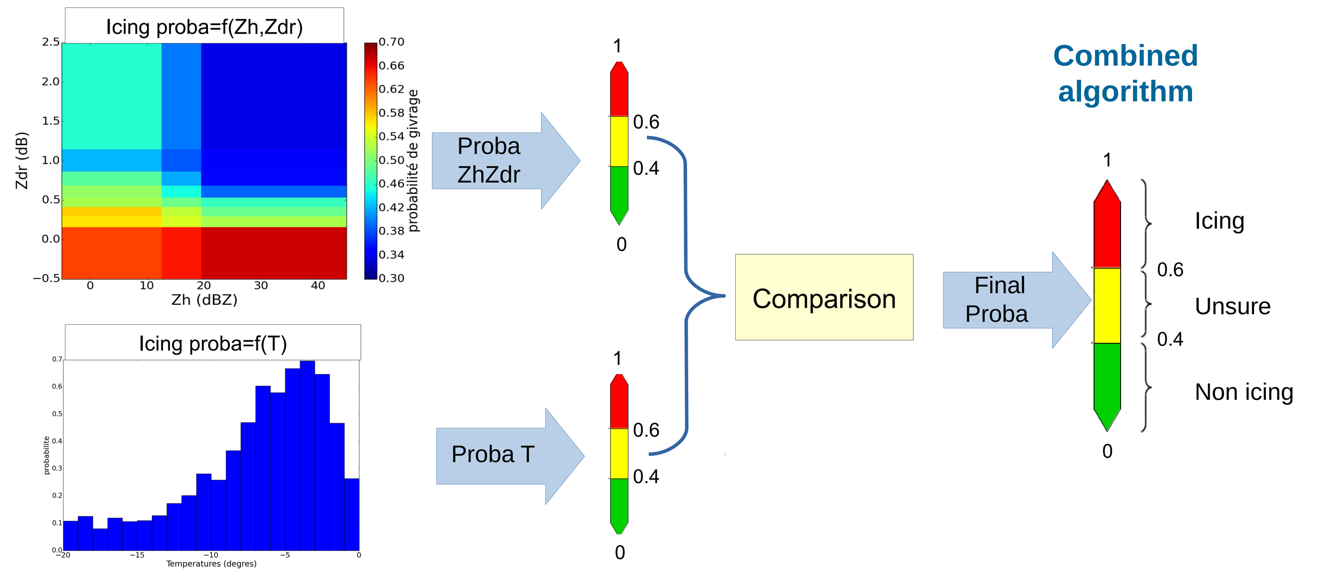



- For Kdp: Icing and Non Icing PDF are very close => Kdp not relevant for icing prediction?
- Slight increase of the icing probability for low Zdr (consistent with Plummer et al 2010)
- Strong increase of the icing probability for T around – 4°C



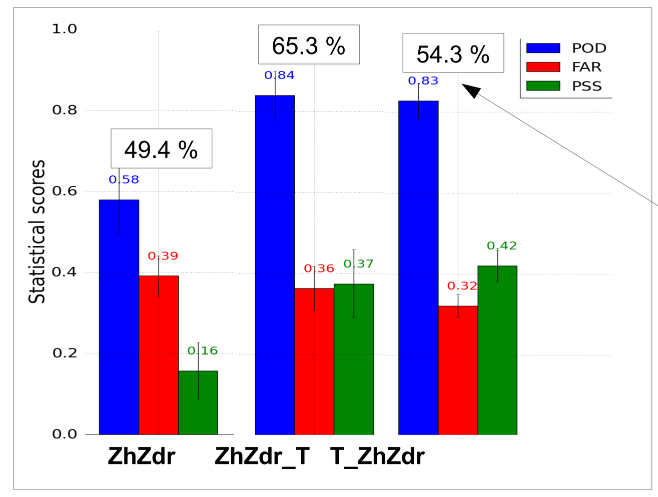

## 4. Icing detection algorithm



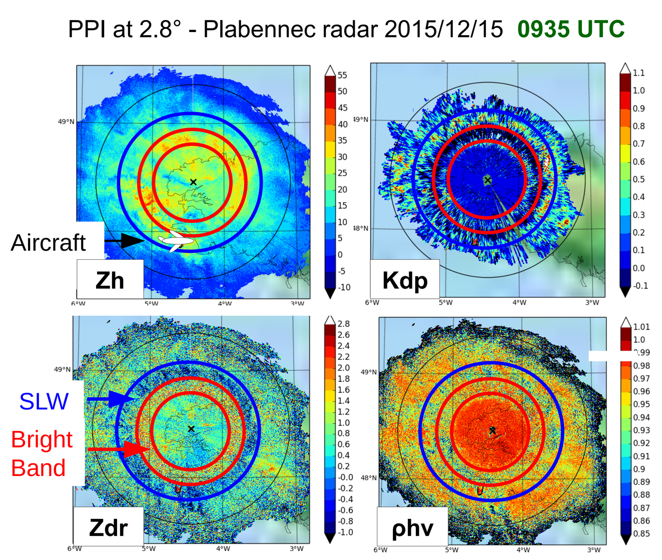

- Selection of the most useful PDF for icing prediction: **ZhZdr** and **T**
- Both PDF are combined as follows:
  - P(ZhZdr) & P(T) / P(ZhZdr) & P(T) / P(ZhZdr) & P(T) → Pfinal=P(T) for **T_ZhZdr**; Pfinal=P(ZhZdr) for **ZhZdr_T**
  - P(ZhZdr) & P(T) / P(ZhZdr) & P(T) / P(ZhZdr) & P(T) → Pfinal=P(T) for **T_ZhZdr**; Pfinal=P(ZhZdr) for **ZhZdr_T**
  - If [ P(ZhZdr) & P(T) ] or [ P(ZhZdr) & P(T) ] → **Pfinal=0.5**

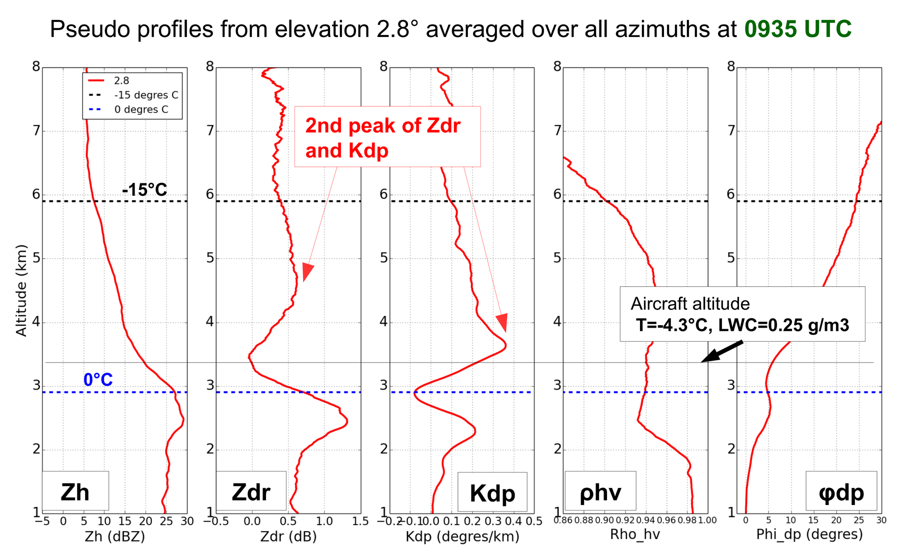
### Results

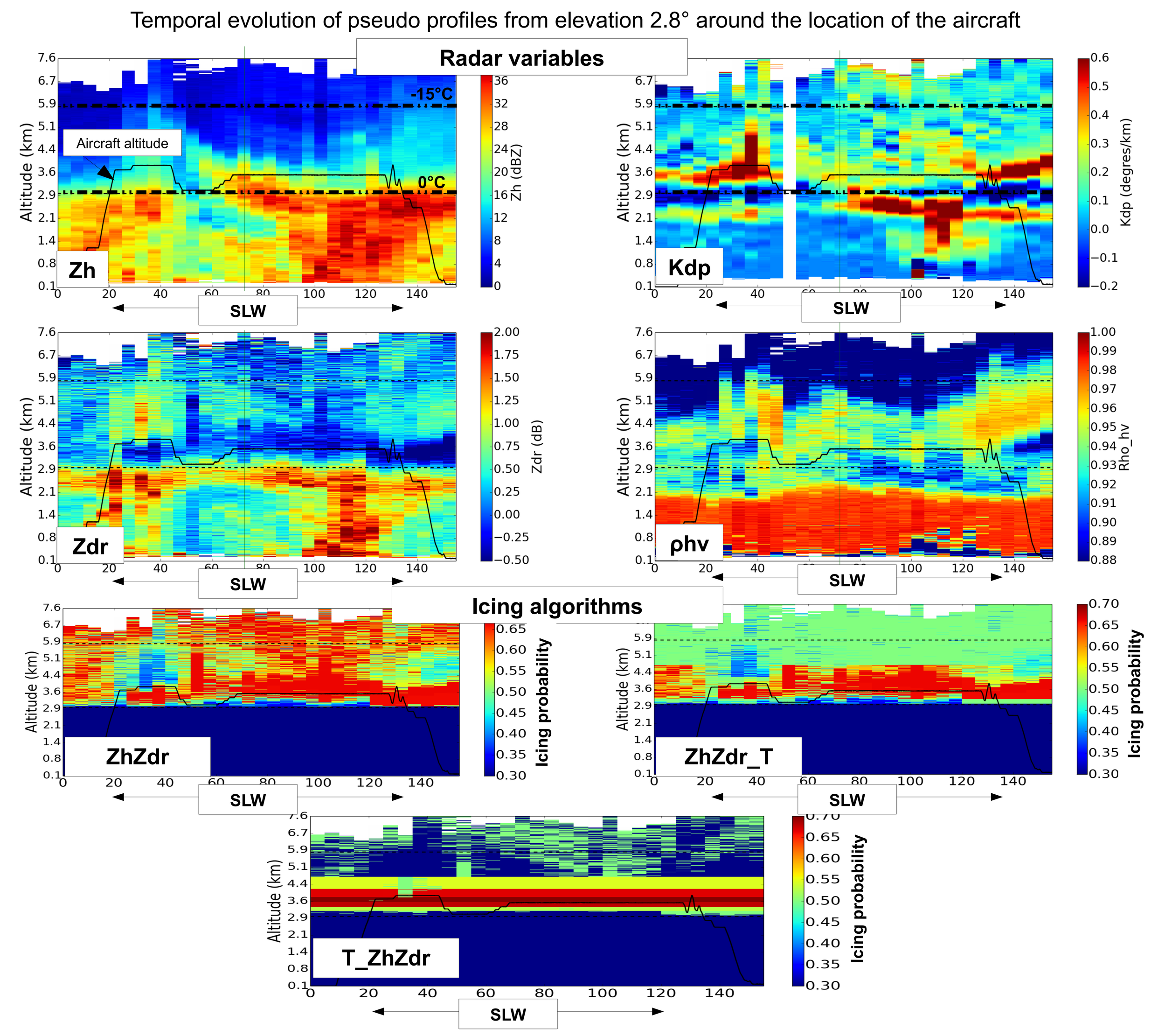
- Half of the data was used to build the PDF and scores (POD, FAR, PSS) were computed on the other half
- When using only ZhZdr the PSS is very low (0.16) but positive
- High POD when using both T and ZhZdr and moderate FAR
- But: the ratio of points for which the icing proba is « unsure » is very high (> 50%)




## 5. Case study with strong icing conditions




- The aircraft remains in the low Zdr area (~ 0 dB) corresponding to SLW in-situ observations (> 0.1 g/m3)
- A 2nd maximum of Zdr and Kdp is present above the bright band: due to riming on oblate crystals?
- ZhZdr: unrealistic high probability values of riming are predicted at high altitudes
- ZhZdr_T: this high icing probabilities are suppressed when using the temperature information (T)
- T_ZhZdr : the high icing probability diagnosed thanks to the temperature information at the aircraft altitude is consistent with the in situ observations of SLW

## 6. Future work

- Need for more in-situ observations !!! LWC, IWC, freezing drizzle occurrence ...
- Attempt new strategies to build the icing detection algorithm (test other PDF combinations)
- Take into account new parameters : vertical wind field estimated through the 3D Doppler wind retrieval from Bousquet et al 2015 / vertical gradients of radar variables ?
- Improve Zdr and Kdp quality in case of low SNR: new signal processing?
- Combine the radar parameters with the icing algorithm estimated from NWP model data

=> **Final aim**: use the polarimetric radar observations within the operational icing detection algorithm of Météo-France to increase its accuracy

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