

# Lidar as ice detector

**Winterwind 2015**

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Andrea Vignaroli  
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# Lidar ice detector

- US Patent 2014/0192356
  - Arrangement and method for icing detection
    - Esa Peltola, Petteri Antikainen, Andrea Vignaroli

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- Software component that allows use of lidar to determine icing conditions

# Lidar ice detector

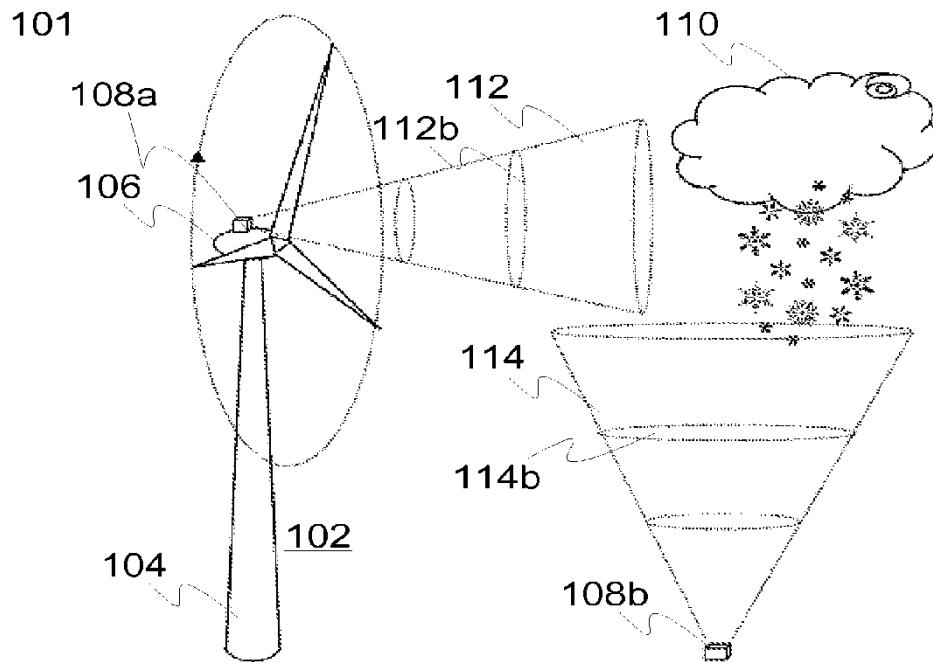
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- No changes required to the lidar

# Lidar ice detector

- US Patent 2014/0192356
  - Arrangement and method for icing detection
    - Esa Peltola, Petteri Antikainen, Andrea Vignaroli
- Software component that allows use of lidar to determine icing conditions
- No changes required to the lidar
- Works in real time
- Can be used retroactively on archived data

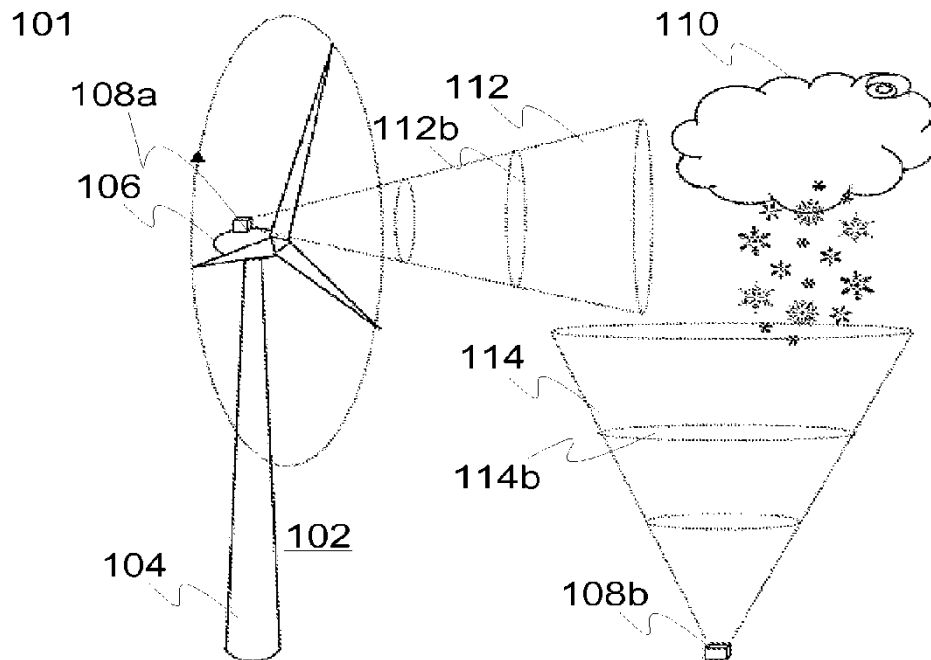
# Lidar ice detector

- Remote sensing
  - No mast required



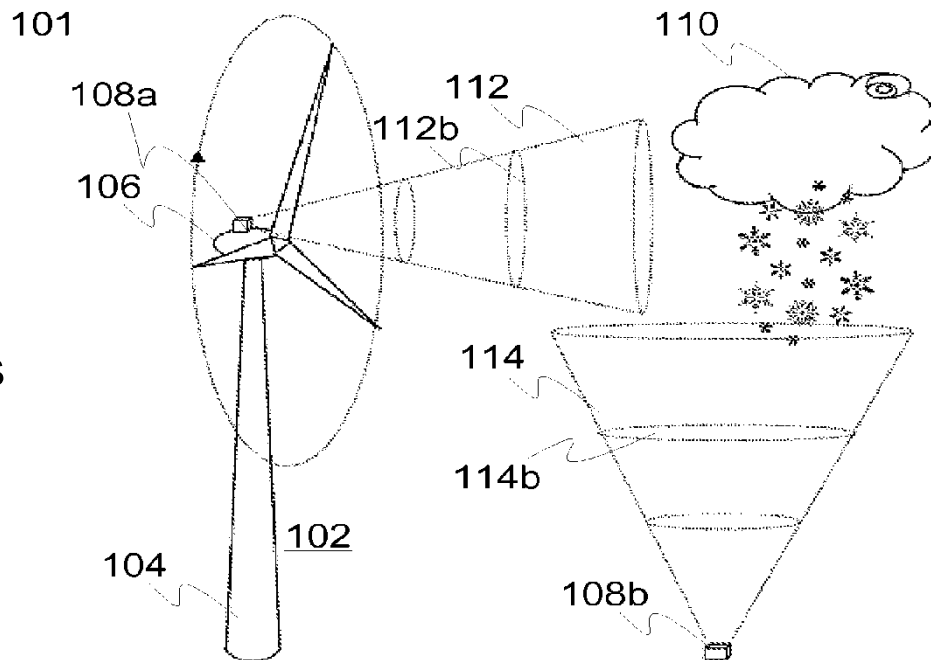
# Lidar ice detector

- Remote sensing
  - No mast required
- Portable equipment
  - Easy to setup



# Lidar ice detector

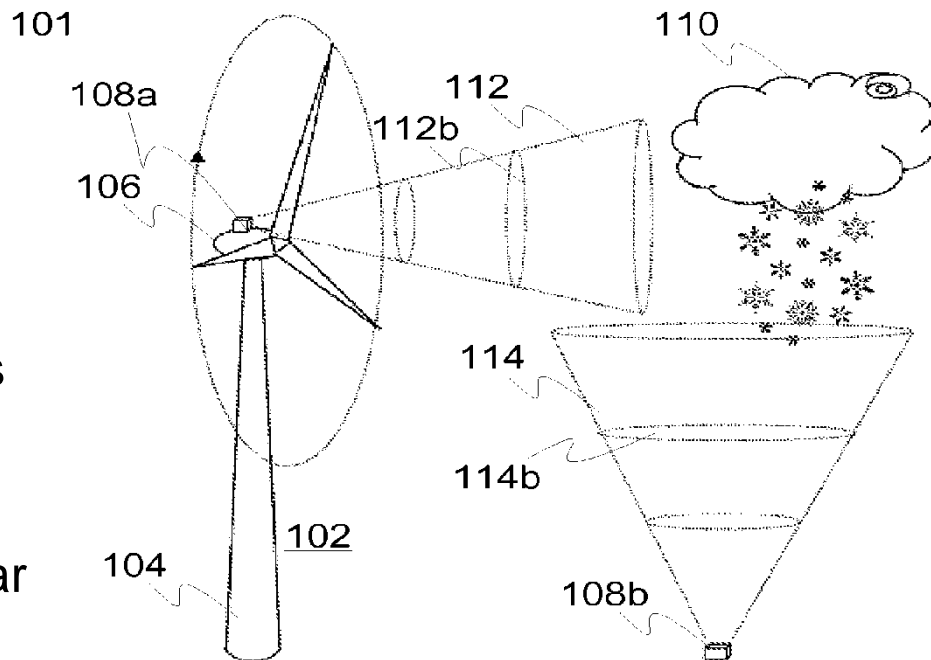
- Remote sensing
  - No mast required
- Portable equipment
  - Easy to setup
- Multiple measurement heights at the same time





# Lidar ice detector

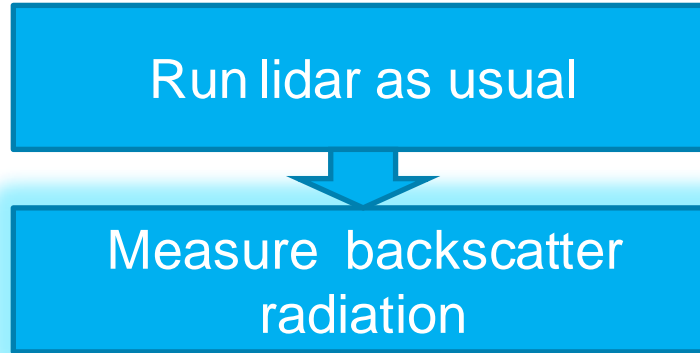
- Remote sensing
  - No mast required
- Portable equipment
  - Easy to setup
- Multiple measurement heights at the same time
- Horizontal or vertical
- Ground or nacelle-based lidar



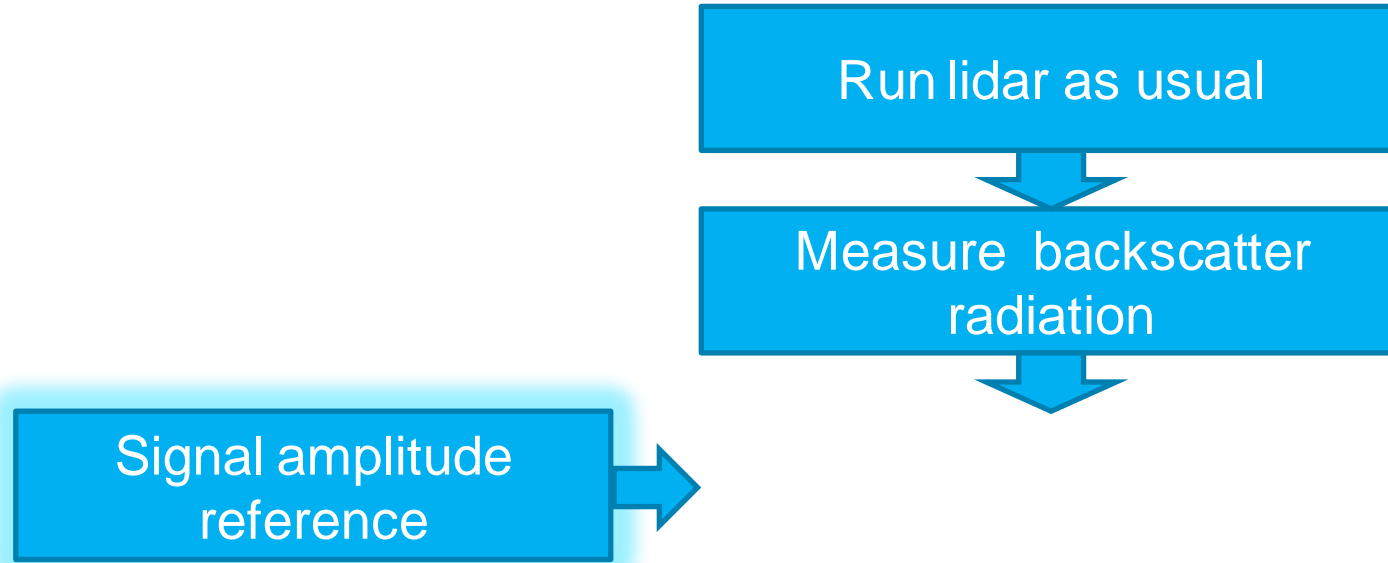
# Lidar as ice detector

Run lidar as usual

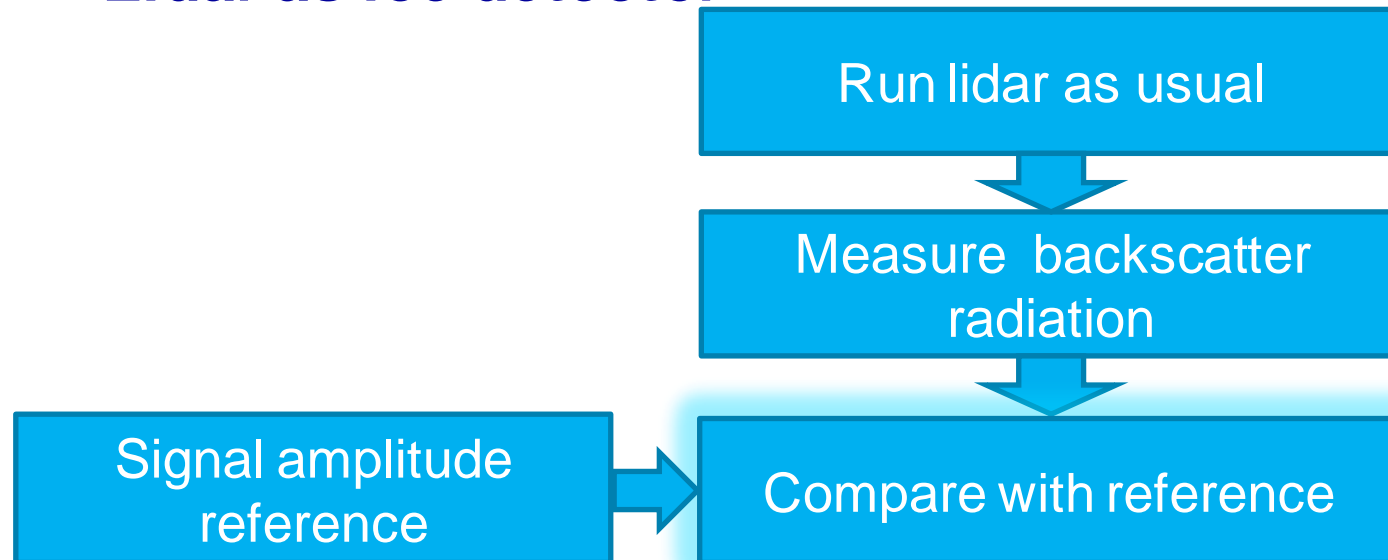
# Lidar as ice detector



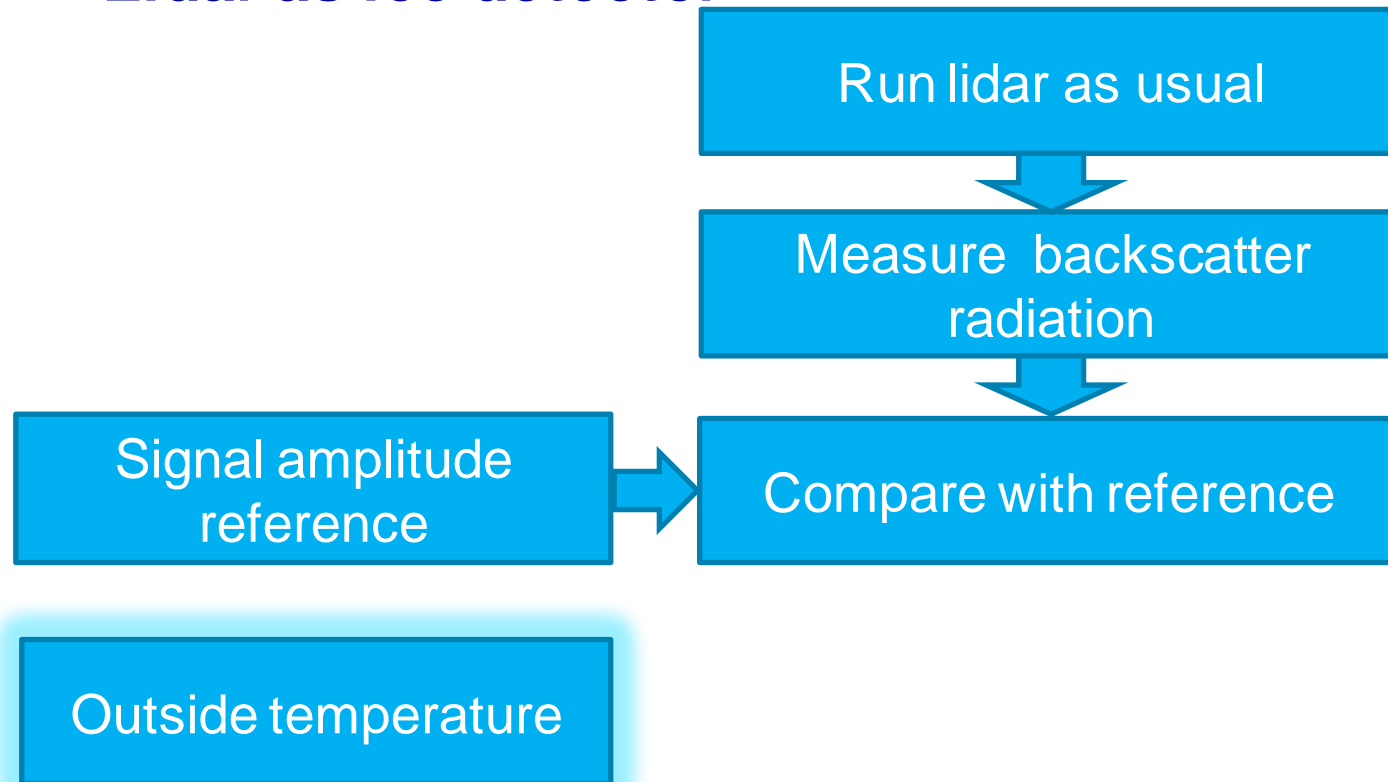
# Lidar as ice detector



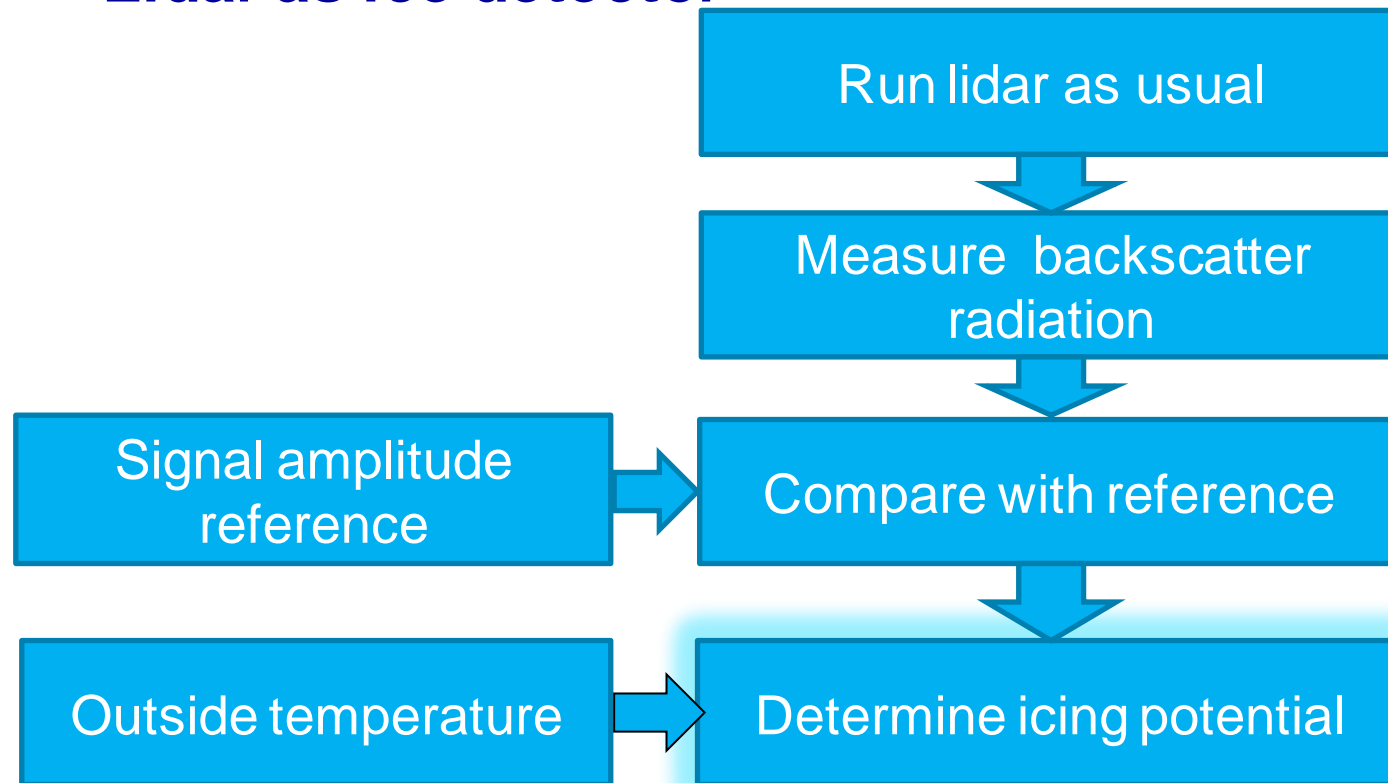
# Lidar as ice detector



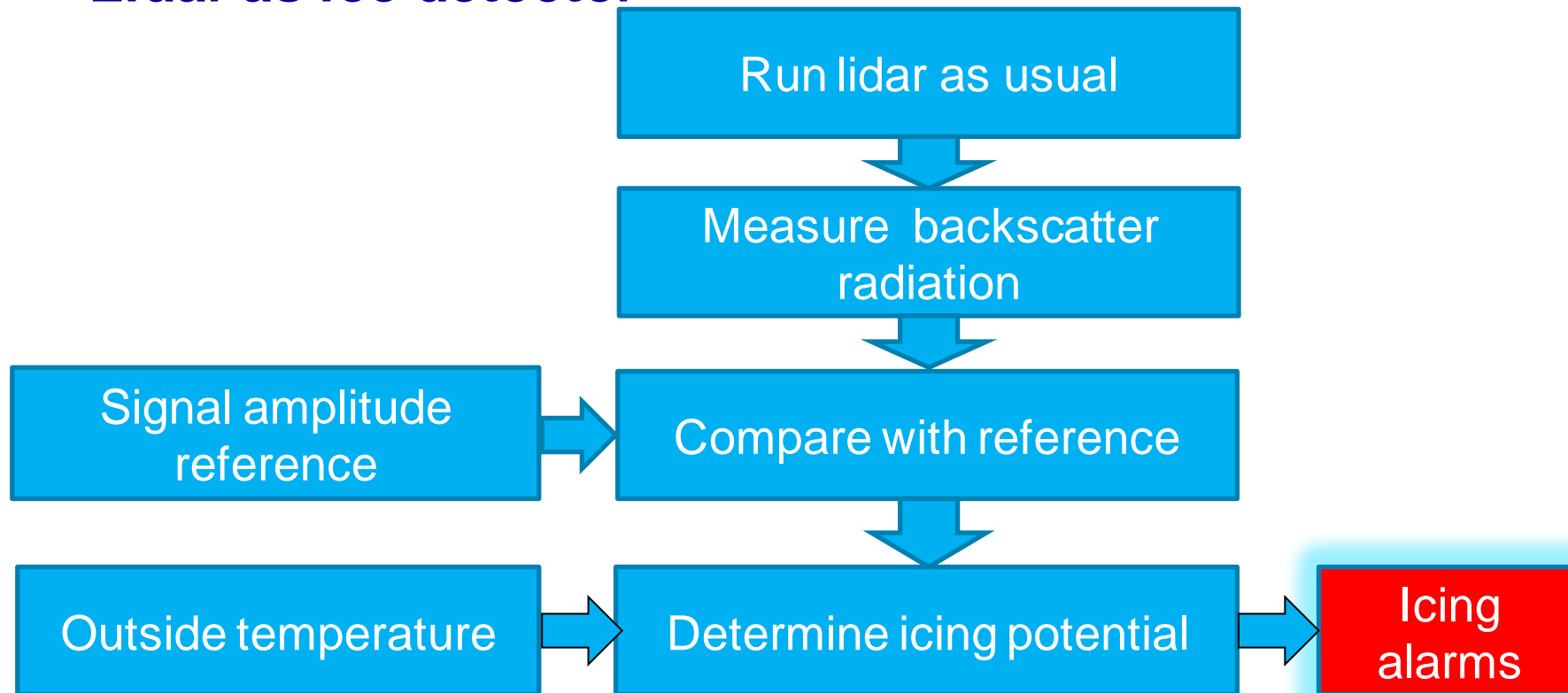
# Lidar as ice detector



# Lidar as ice detector

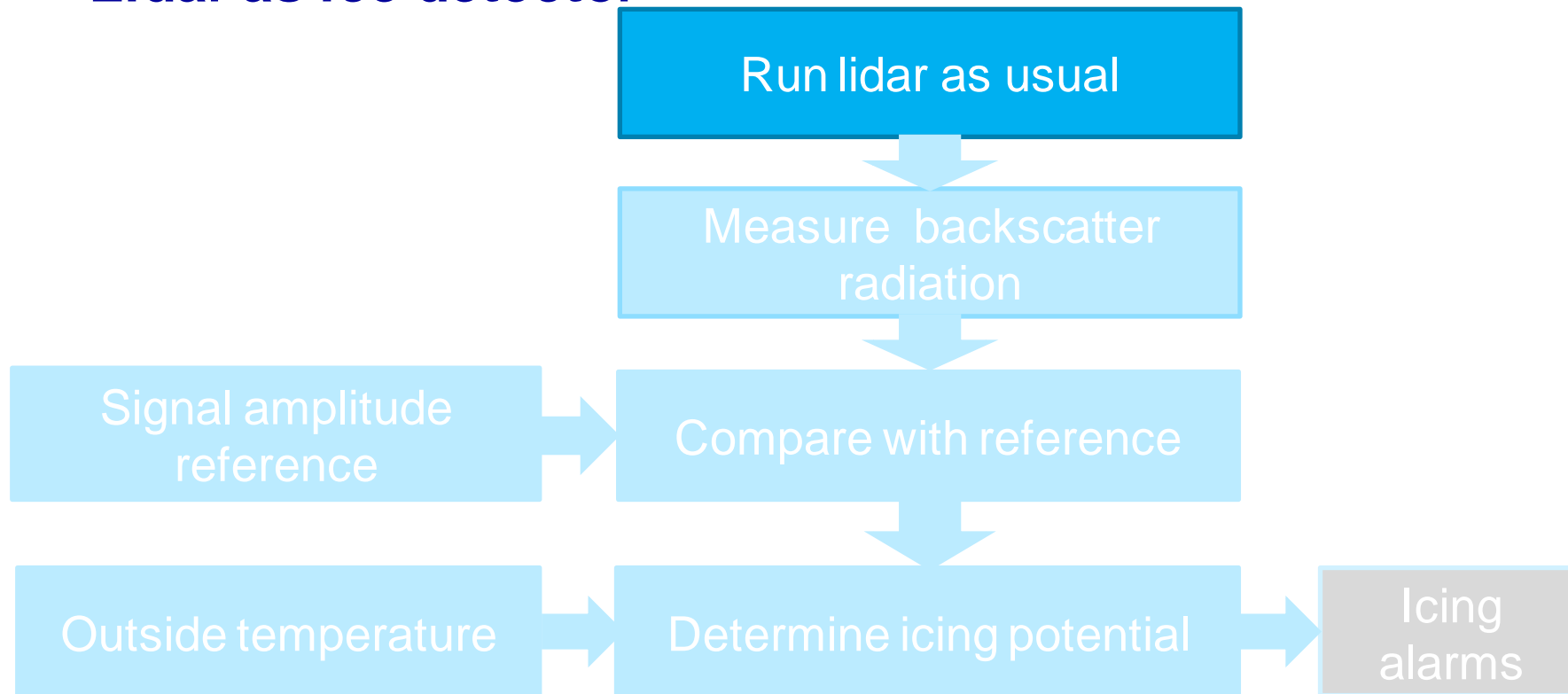


# Lidar as ice detector



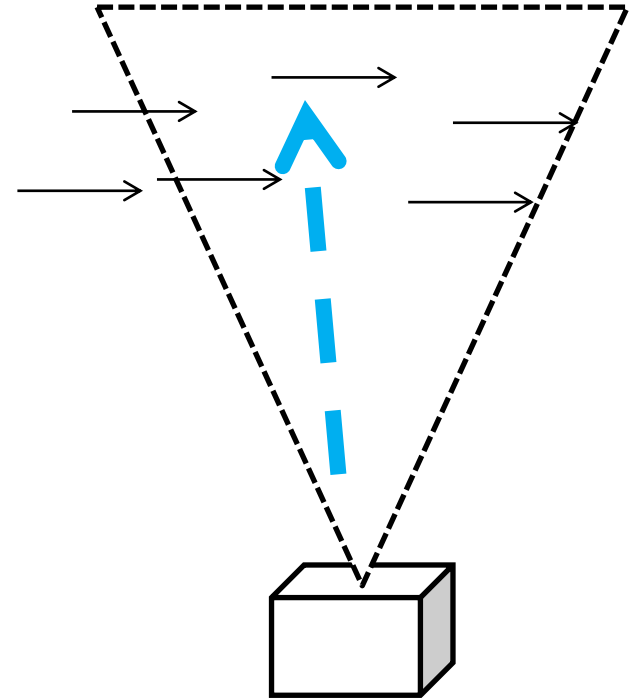


# Lidar as ice detector



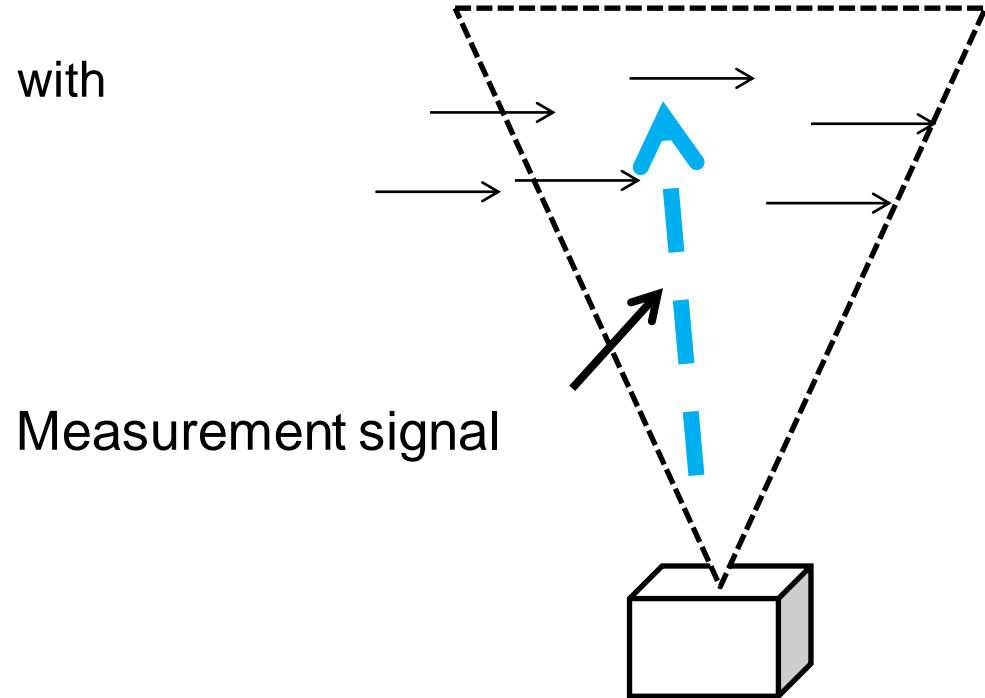
# Lidar principle

- Lidar measures wind speeds with laser



# Lidar principle

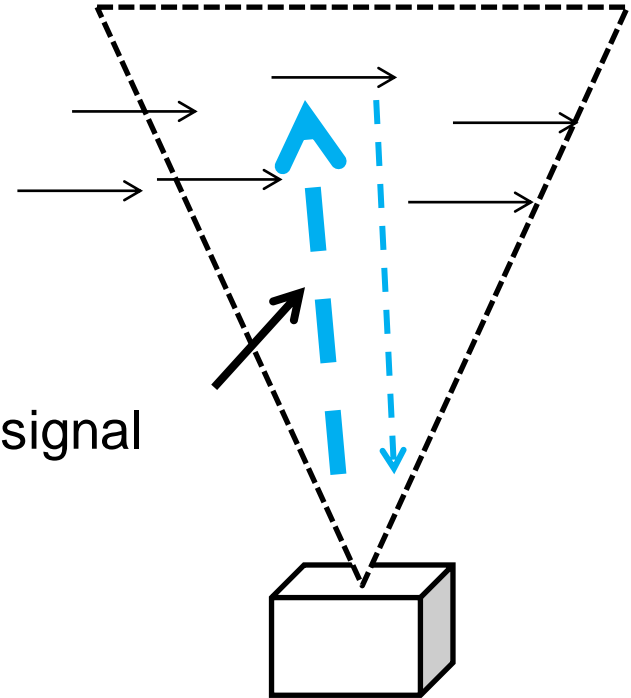
- Lidar measures wind speeds with laser



# Lidar principle

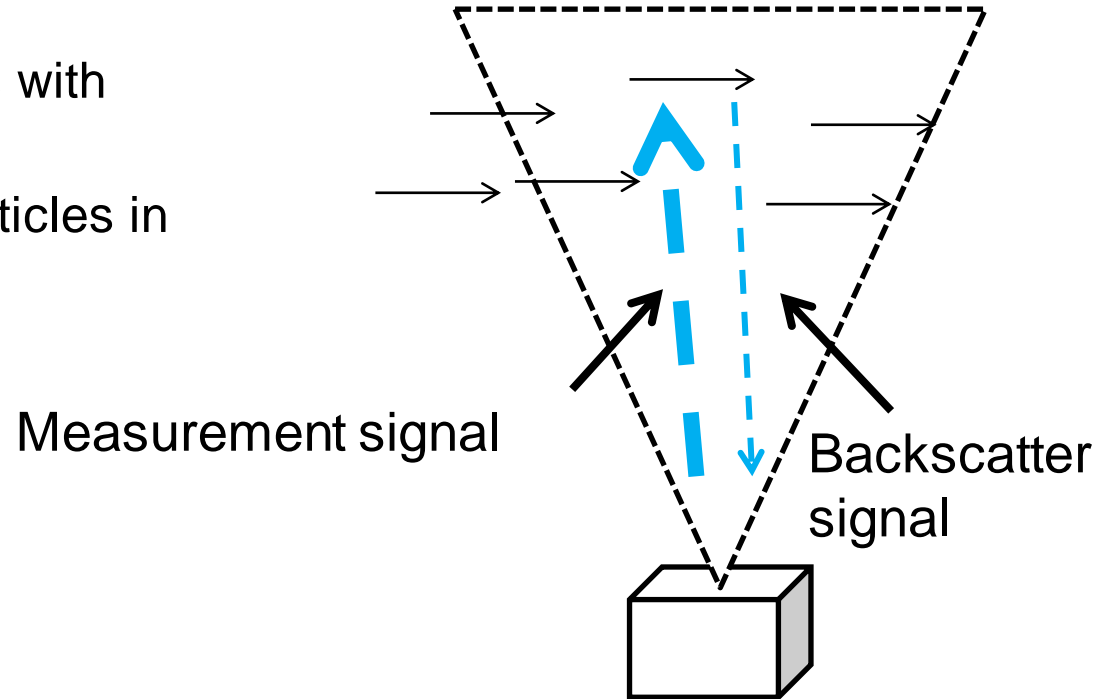
- Lidar measures wind speeds with laser
- Light reflected back from particles in air

Measurement signal



# Backscatter signal

- Lidar measures wind speeds with laser
- Light reflected back from particles in air

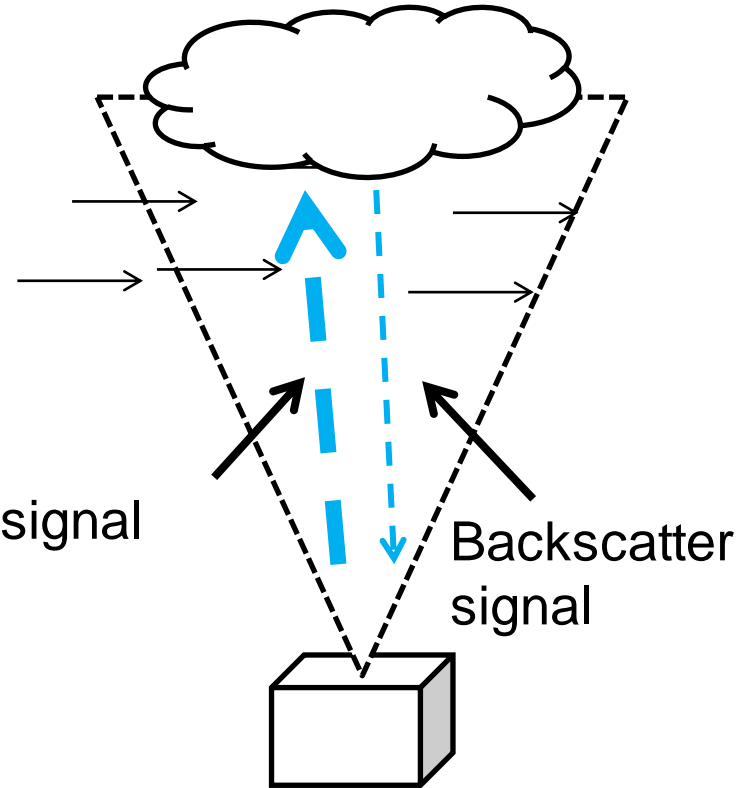


# Lidar principle

- Lidar measures wind speeds with laser
- Light reflected back from particles in air
- Cloud->more particles in air-> stronger backscatter signal

Measurement signal

Backscatter signal

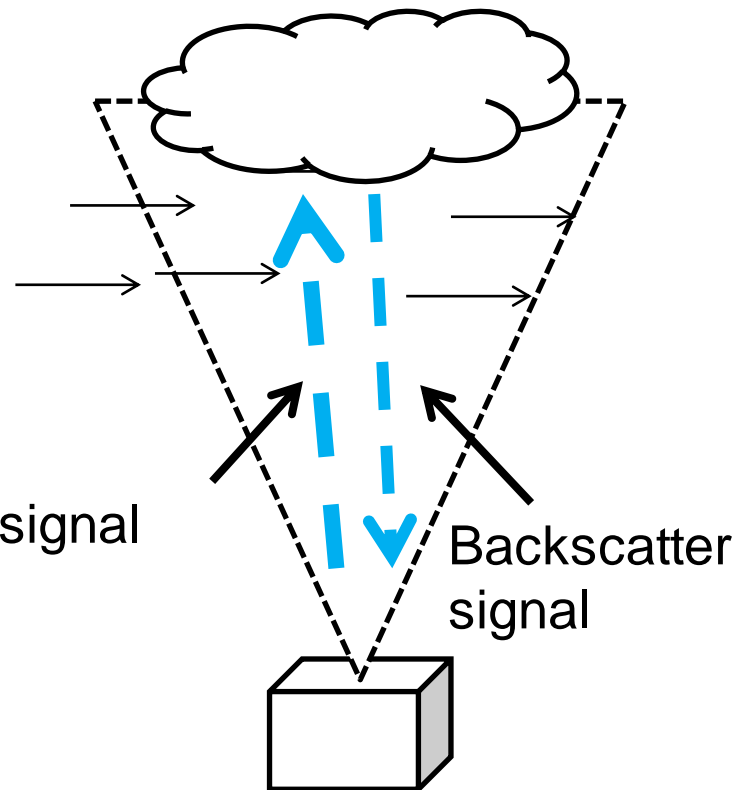


# Lidar principle

- Lidar measures wind speeds with laser
- Light reflected back from particles in air
- Cloud->more particles in air-> stronger backscatter signal

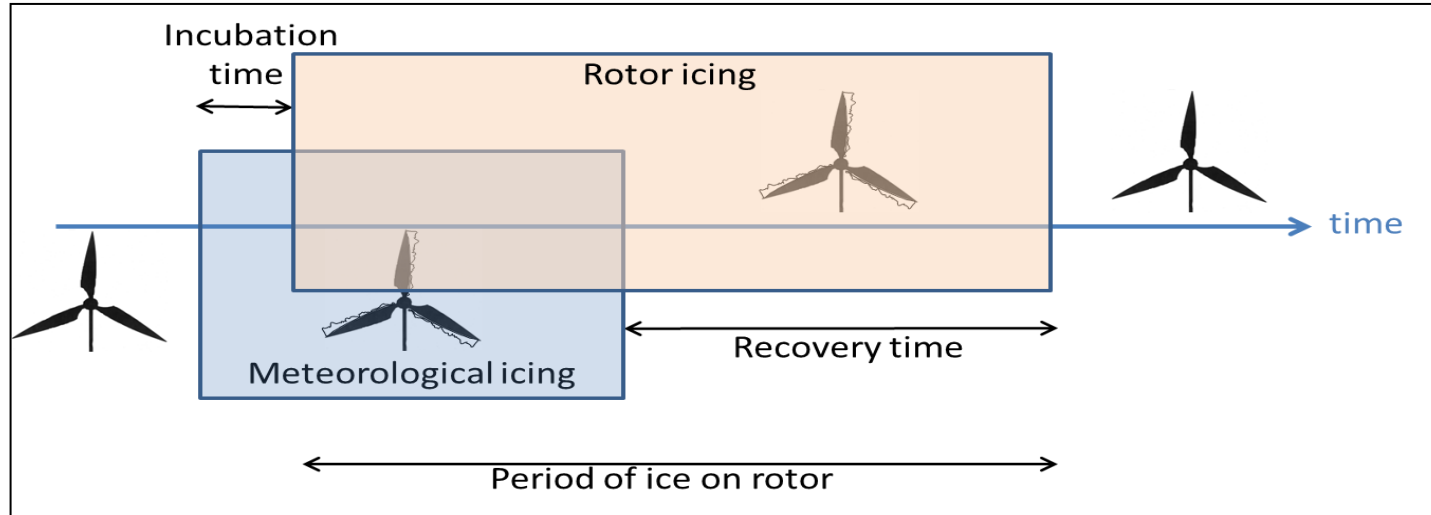
Measurement signal

Backscatter signal



# Icing conditions

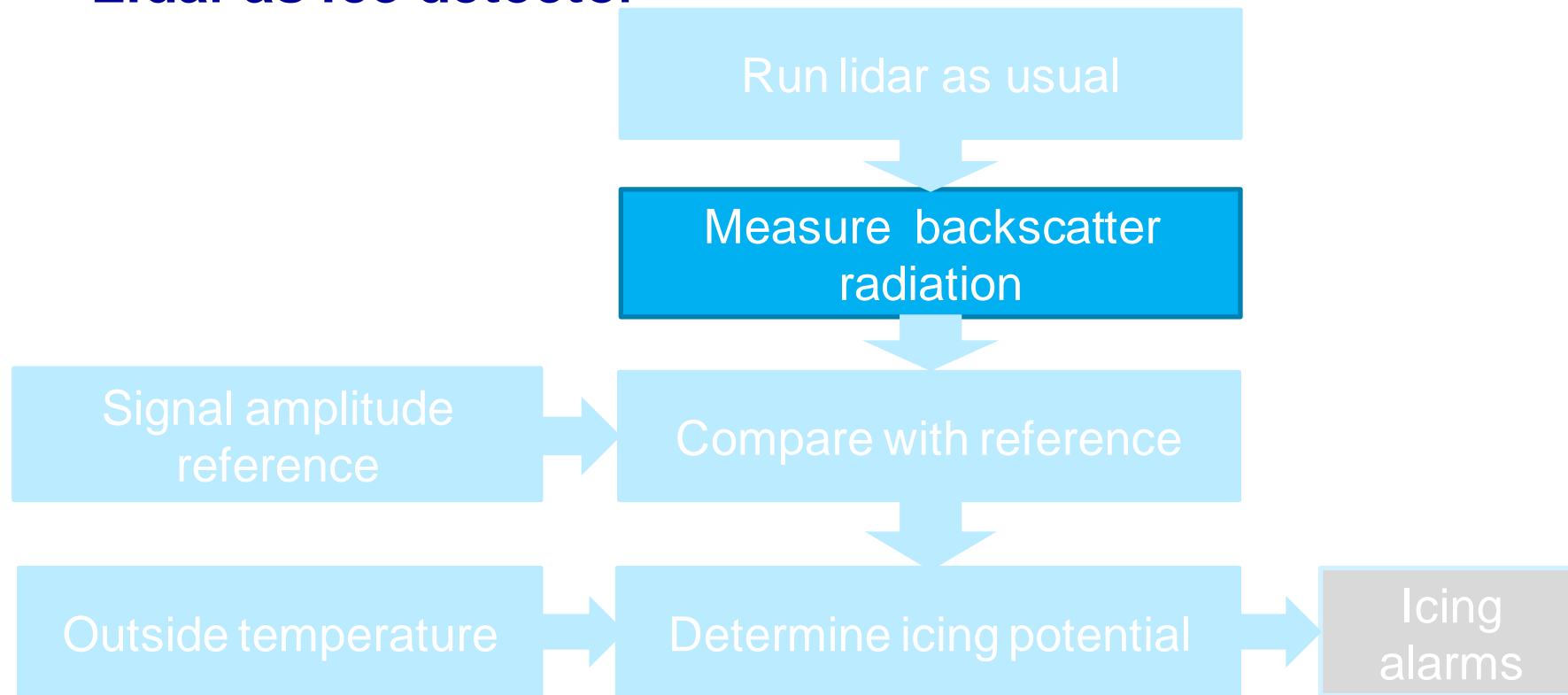
- Low level clouds &  $T < 0^{\circ}\text{C}$  = in-cloud icing (most typical)



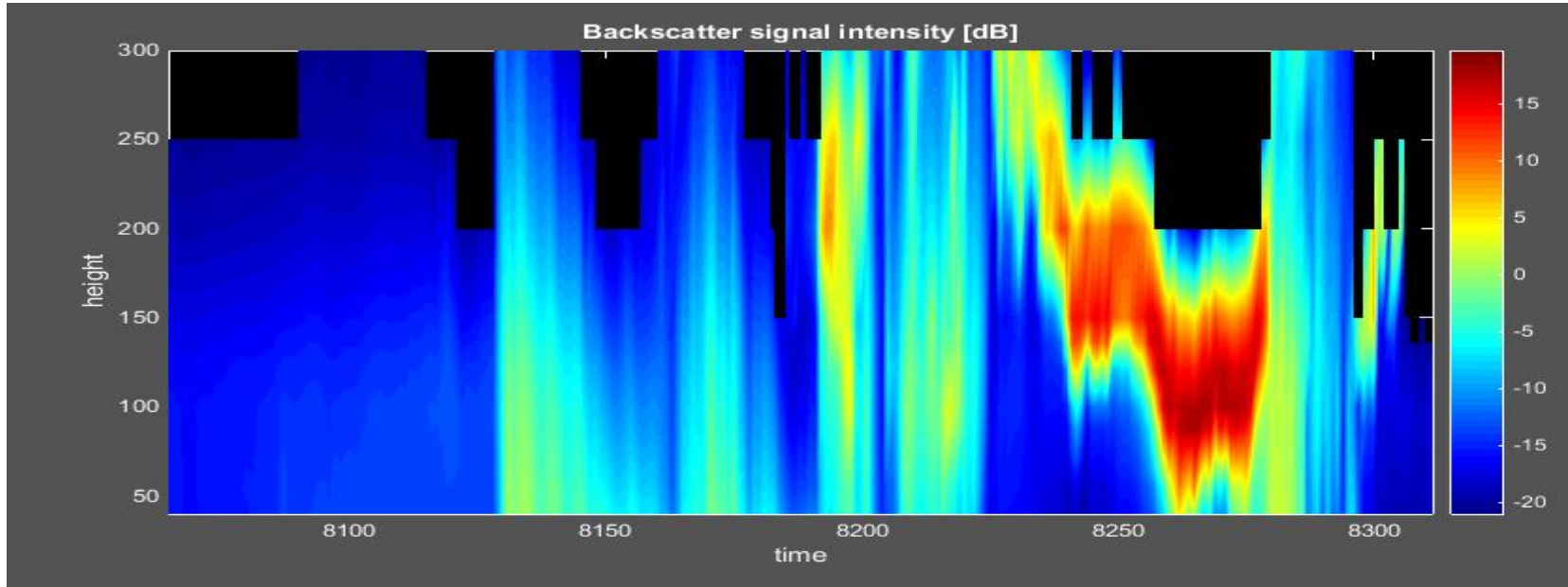
Sources:  
IEC 61400-1 ed4 CDV



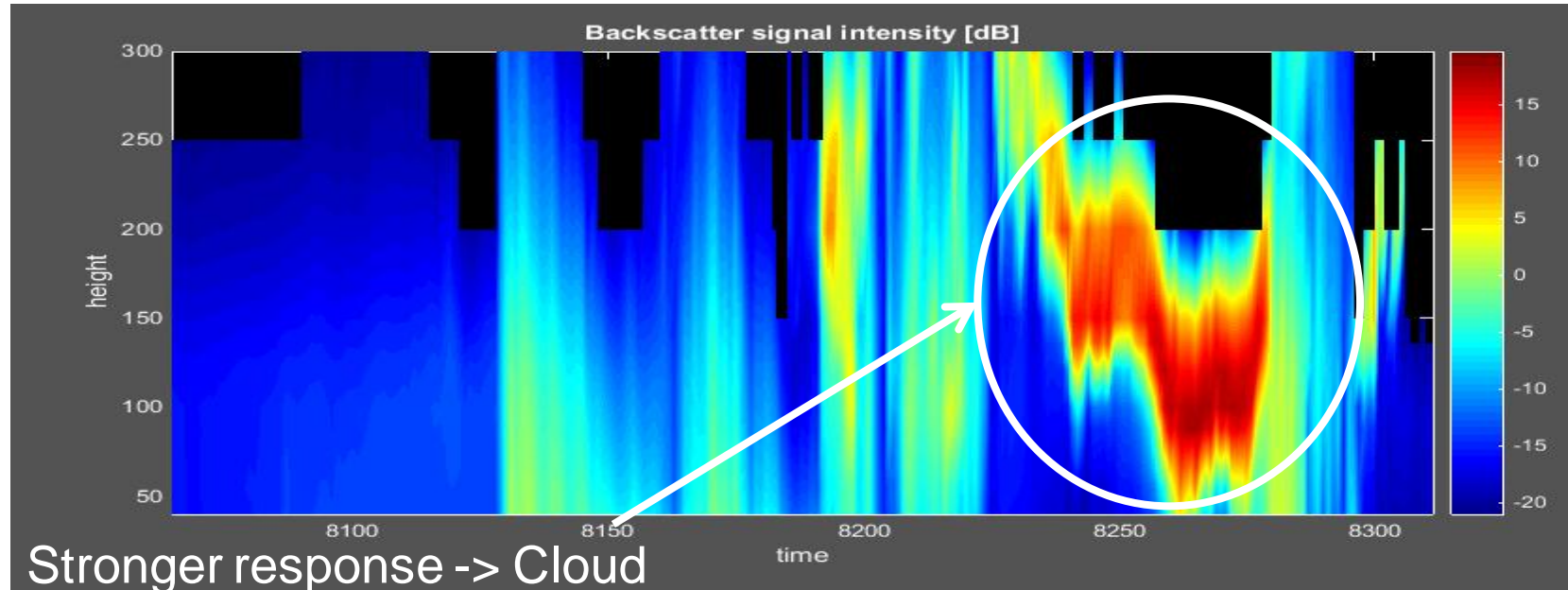
# Lidar as ice detector



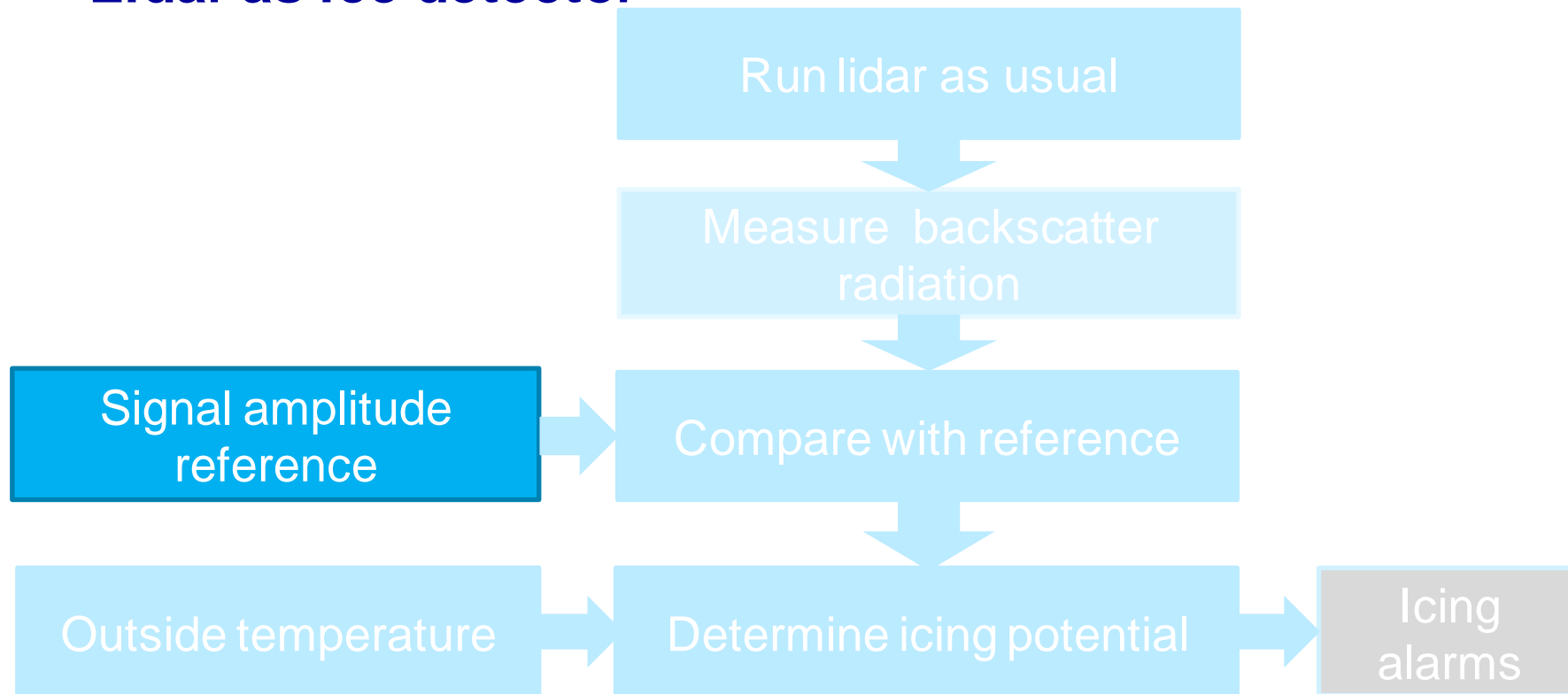
# Backscatter radiation



# Backscatter radiation

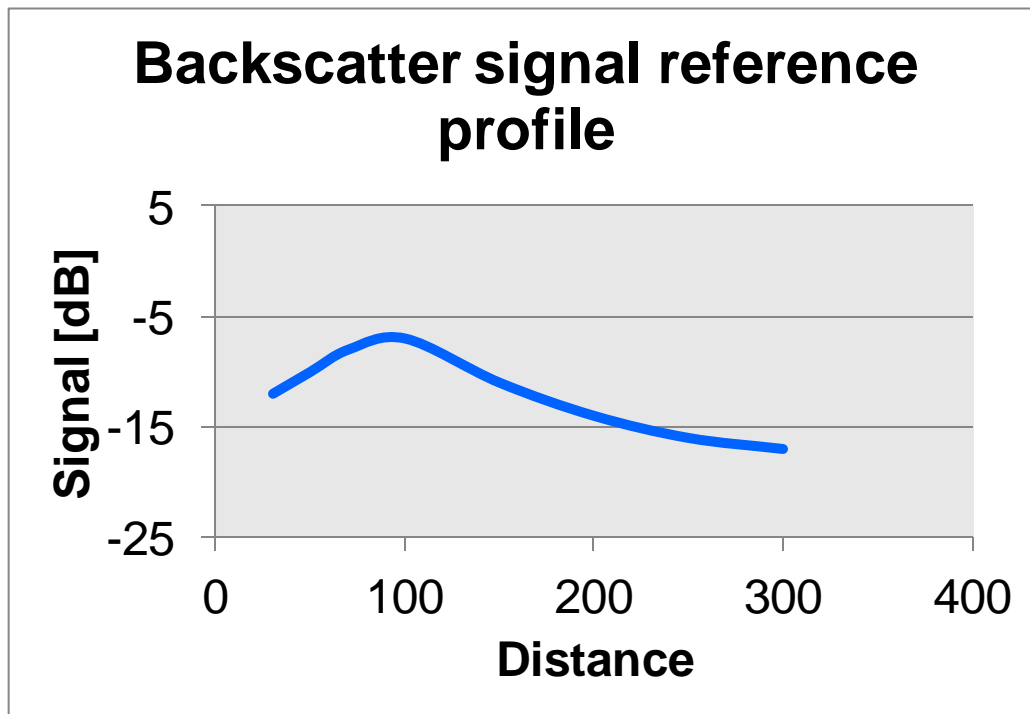


# Lidar as ice detector

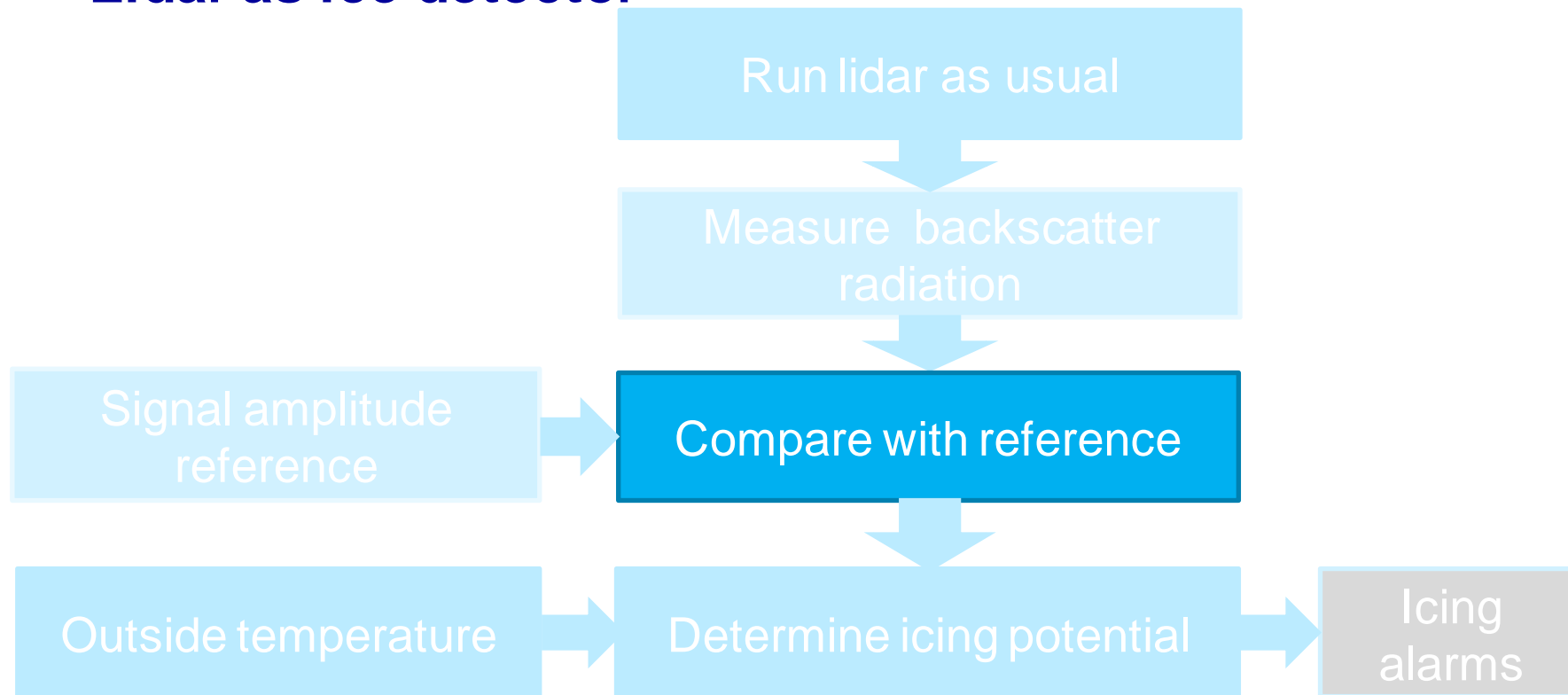


# Signal amplitude reference

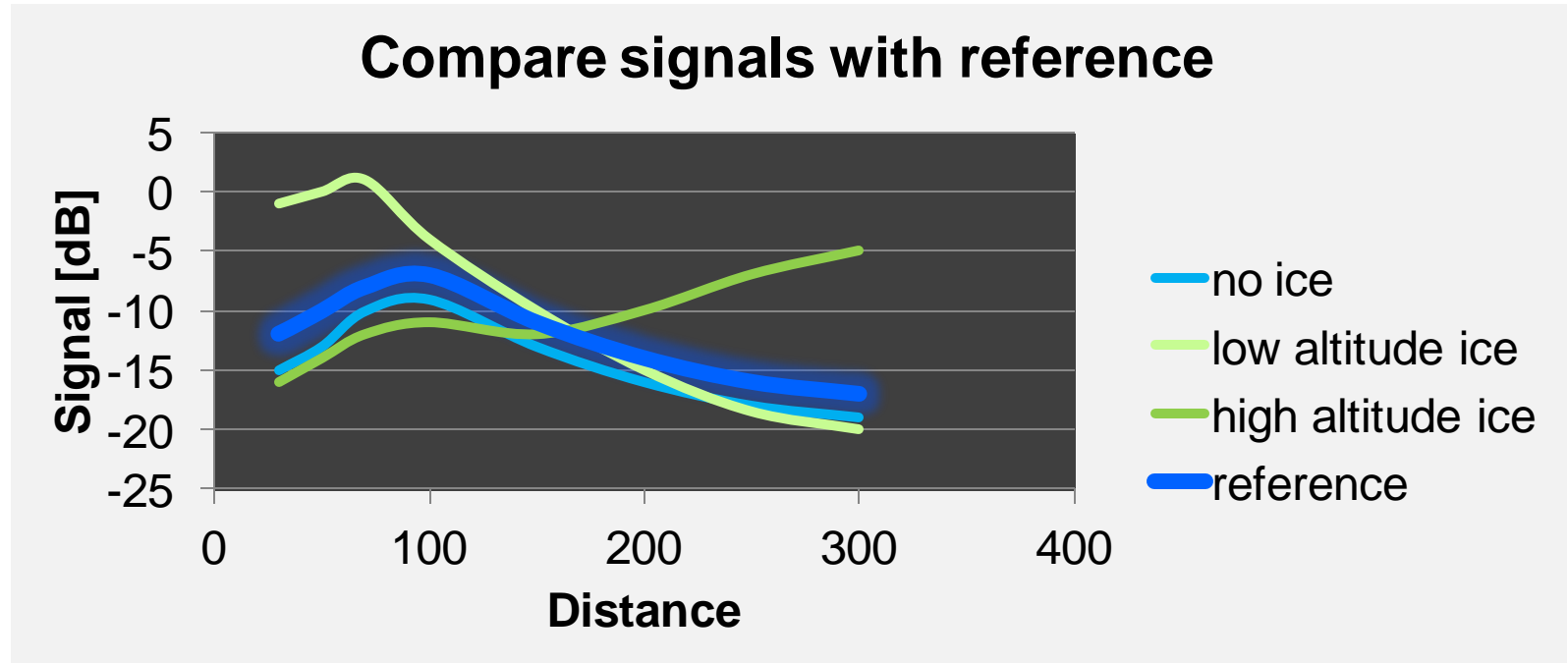
- Reference profile based on measurements
- A "clear sky" value for all heights



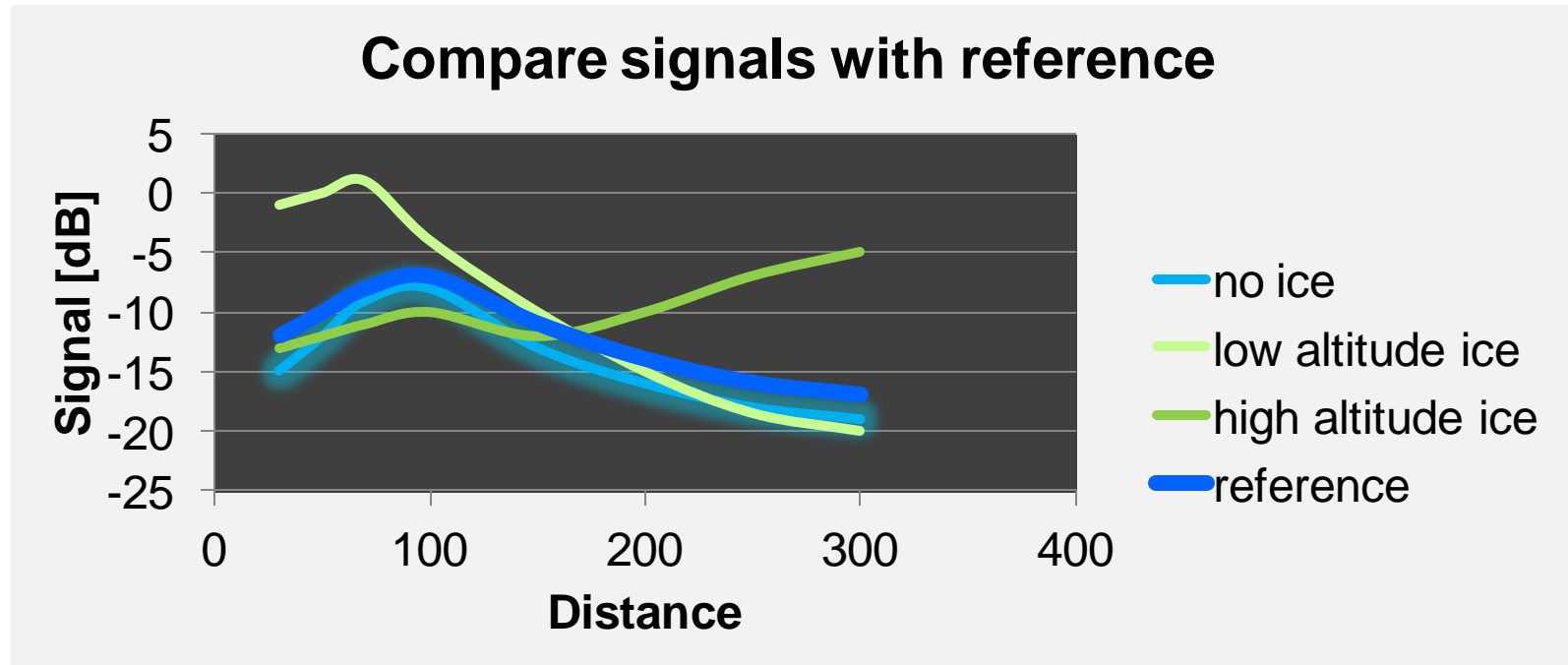
# Lidar as ice detector



# Compare with reference

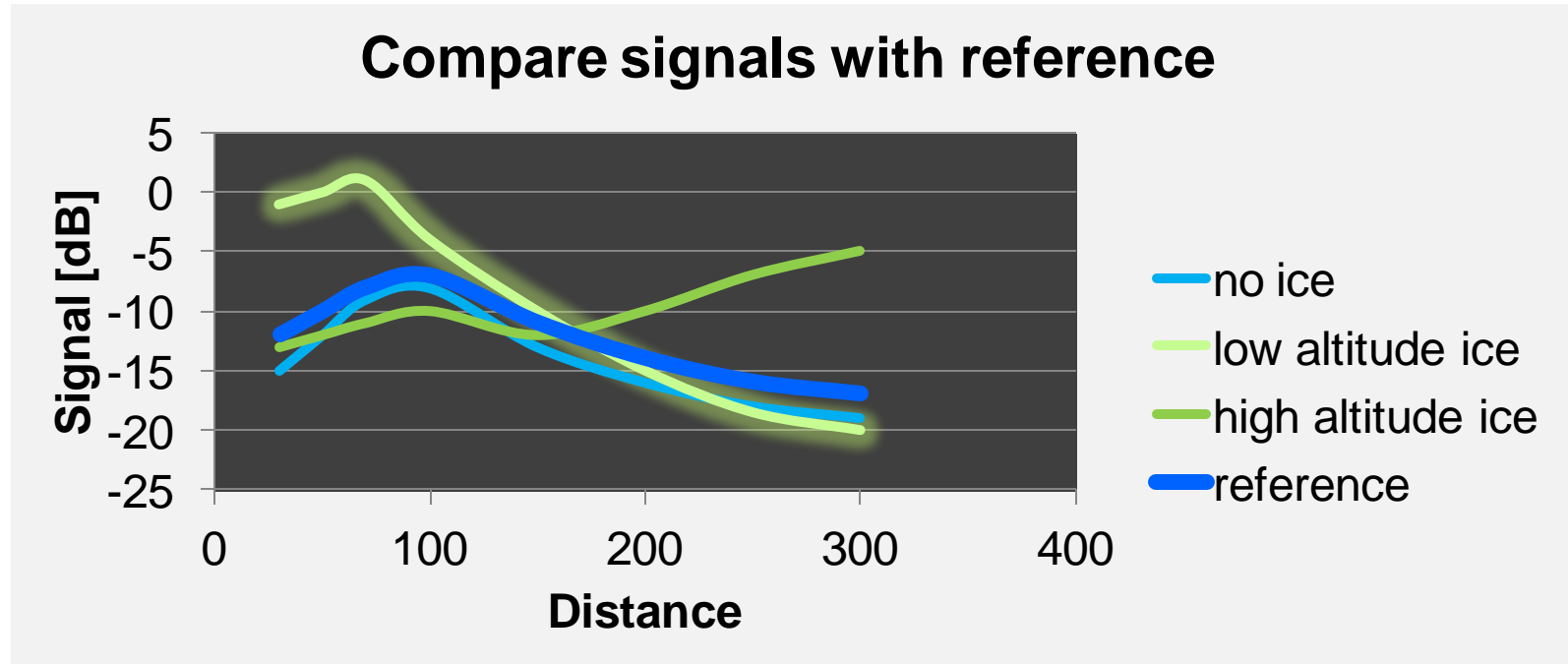


## Compare with reference, no ice

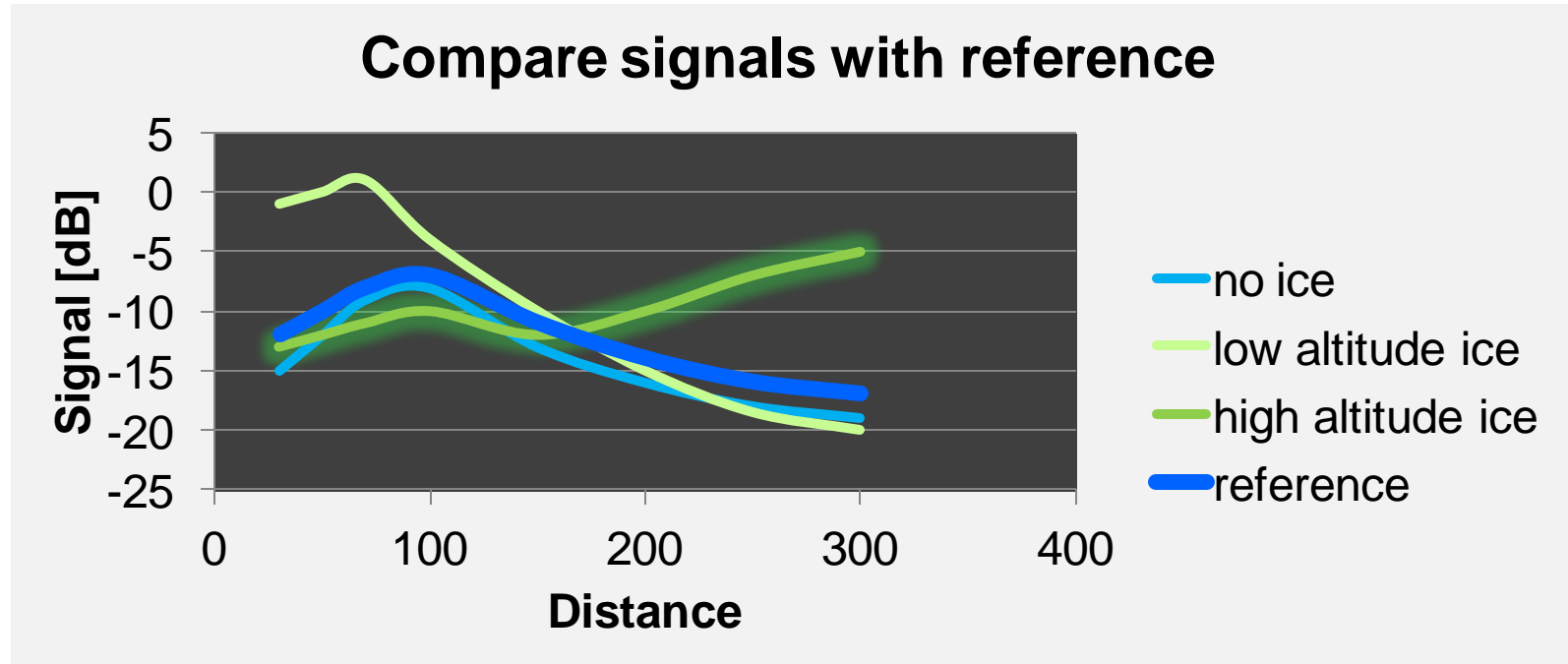




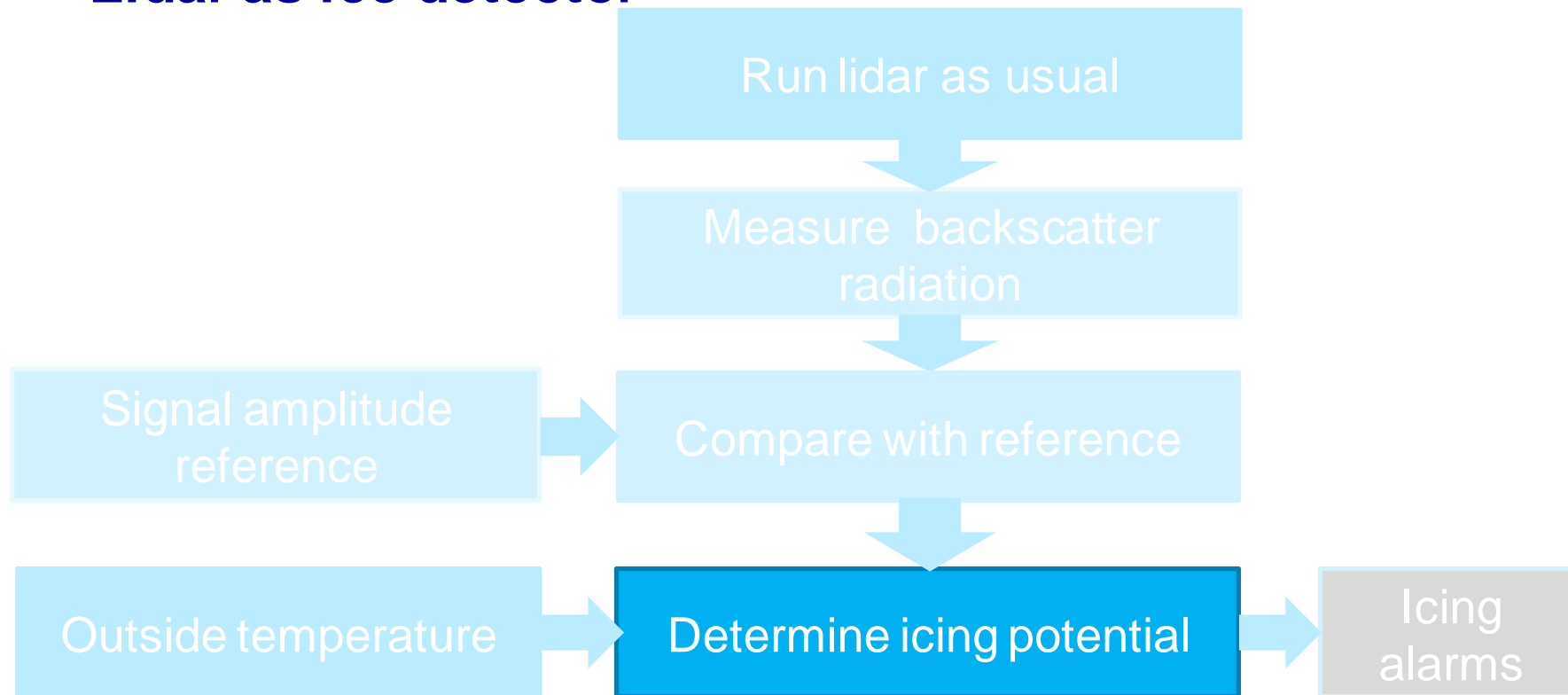
## Compare with reference, ice at low altitude



# Compare with reference, ice at high altitude



# Lidar as ice detector



# Icing potential

- Backscatter signal strength for each measurement height

# icing potential

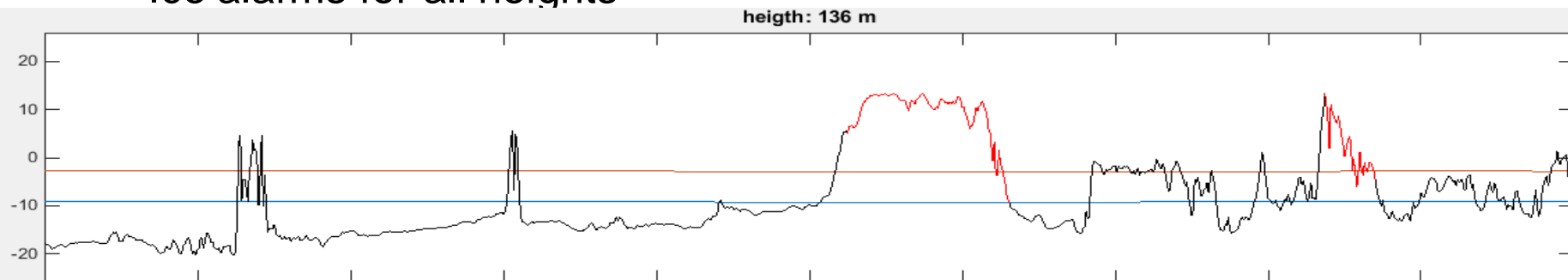
- Backscatter signal strength for each measurement height
- Combine with temperature measurements

# icing potential

- Backscatter signal strength for each measurement height
- Combine with temperature measurements
- Compare to reference alarm limit

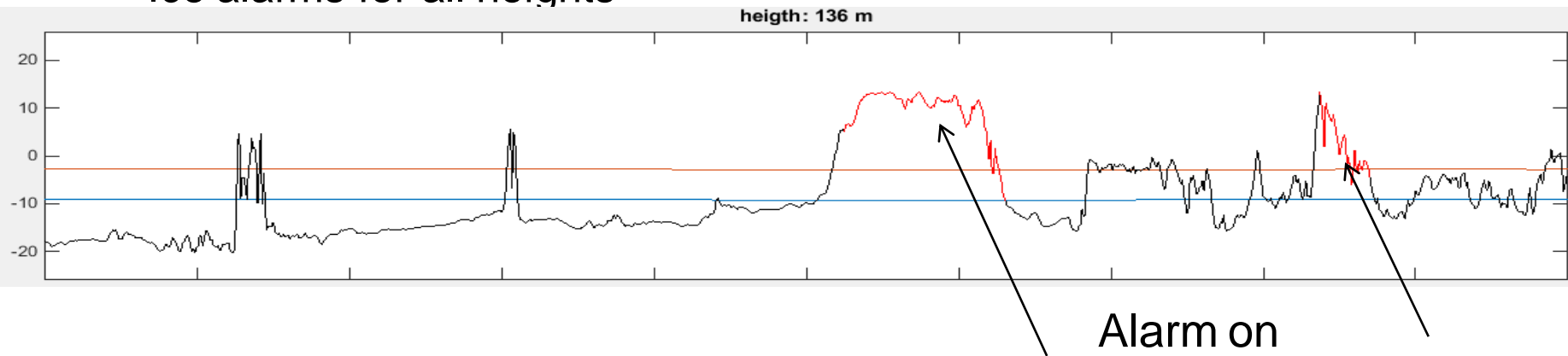
# Icing potential

- Backscatter signal strength for each measurement height
- Combine with temperature measurements
- Compare to reference alarm limit
- Ice alarms for all heights



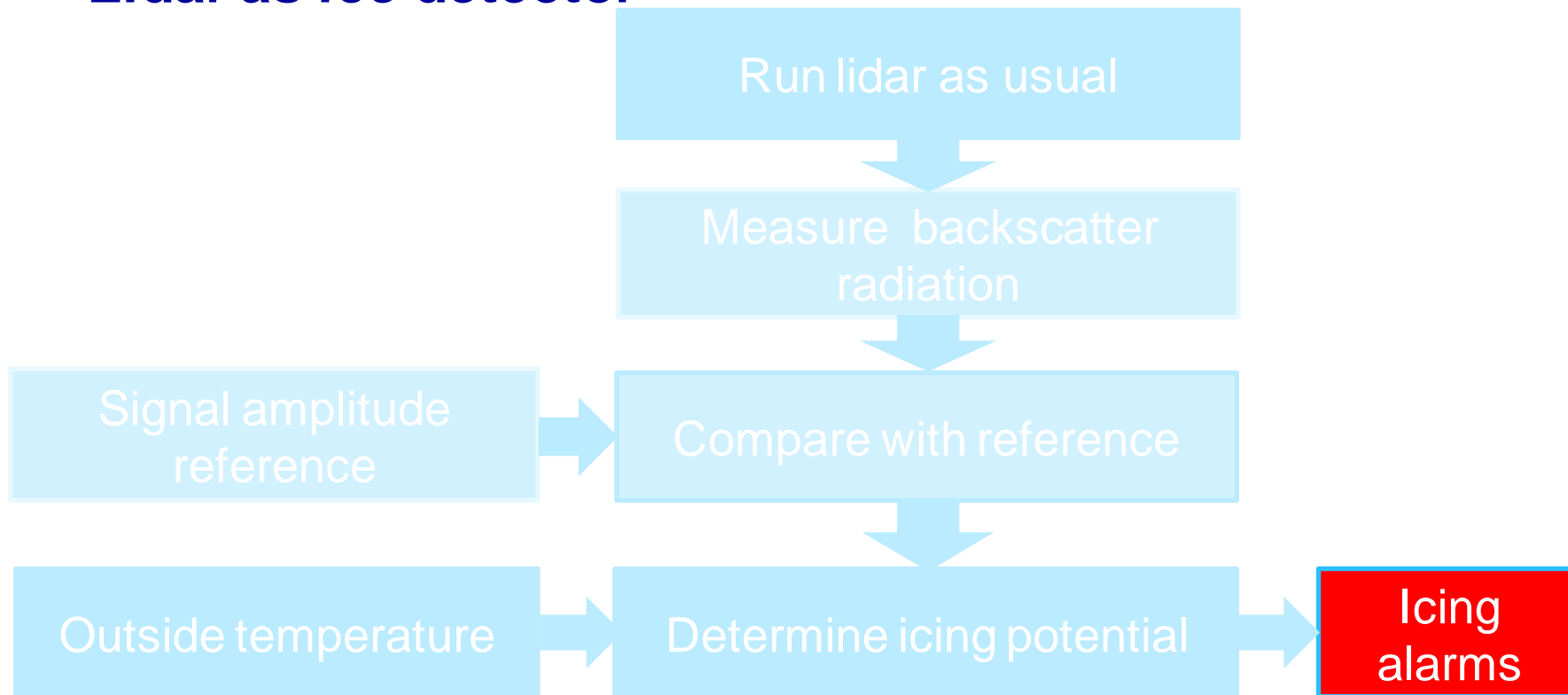
# Icing potential

- Backscatter signal strength for each measurement height
- Combine with temperature measurements
- Compare to reference alarm limit
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# Lidar as ice detector

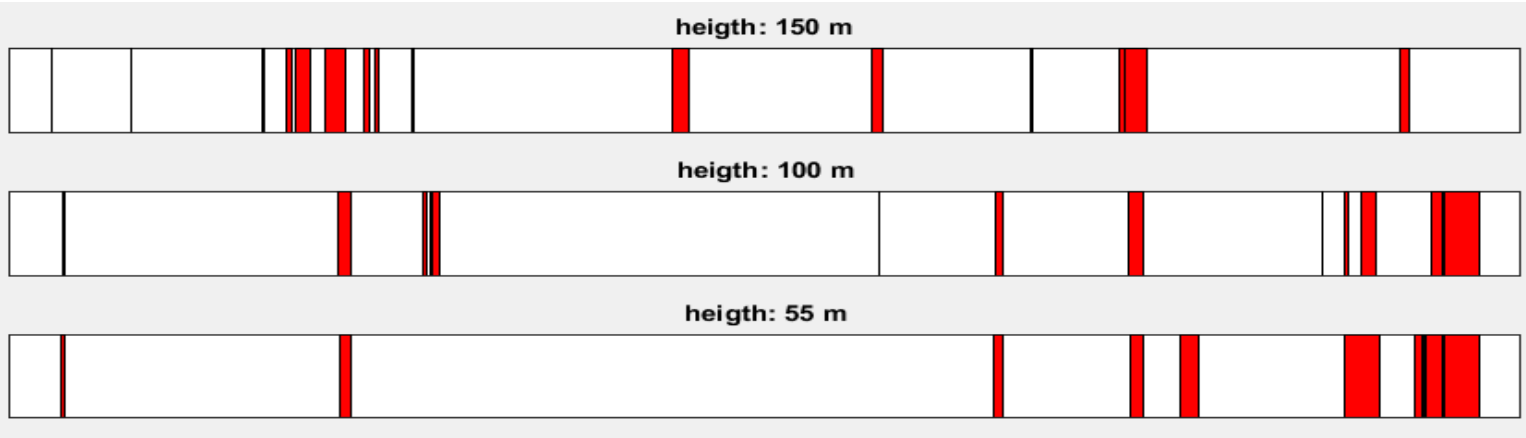


# Ice alarms

- Combine with temperature measurements
- Alarms for all measurement heights at the same time

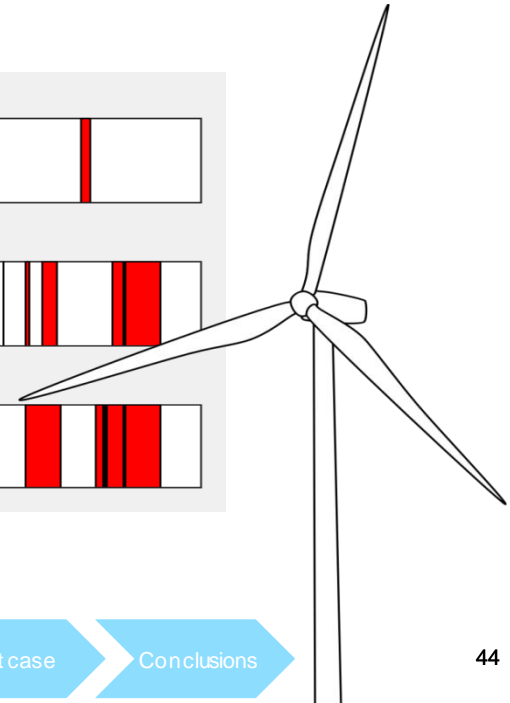
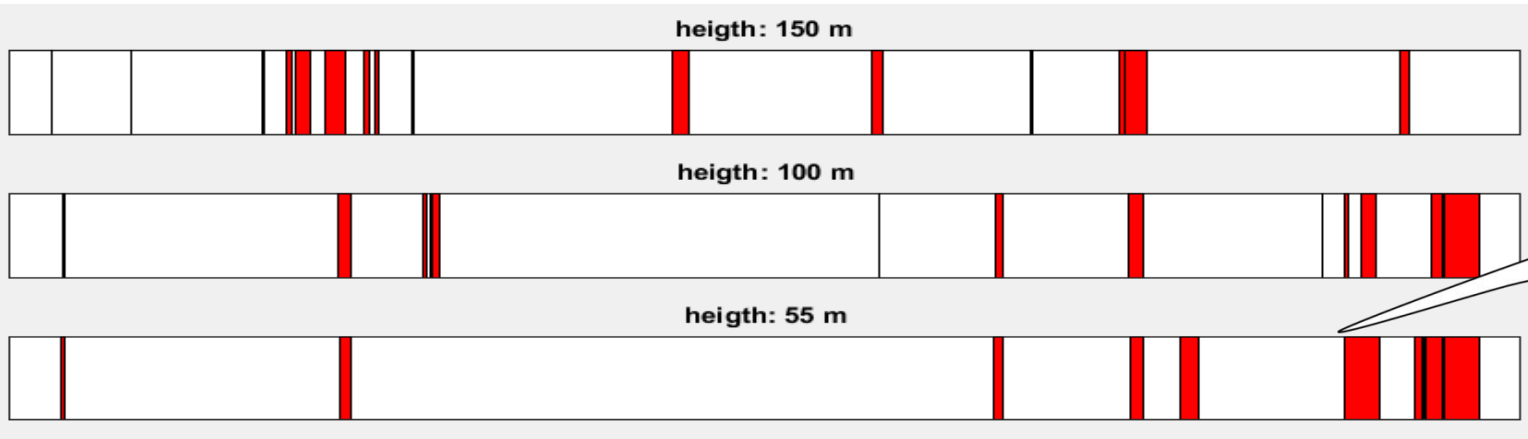
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# Compare to ice detector

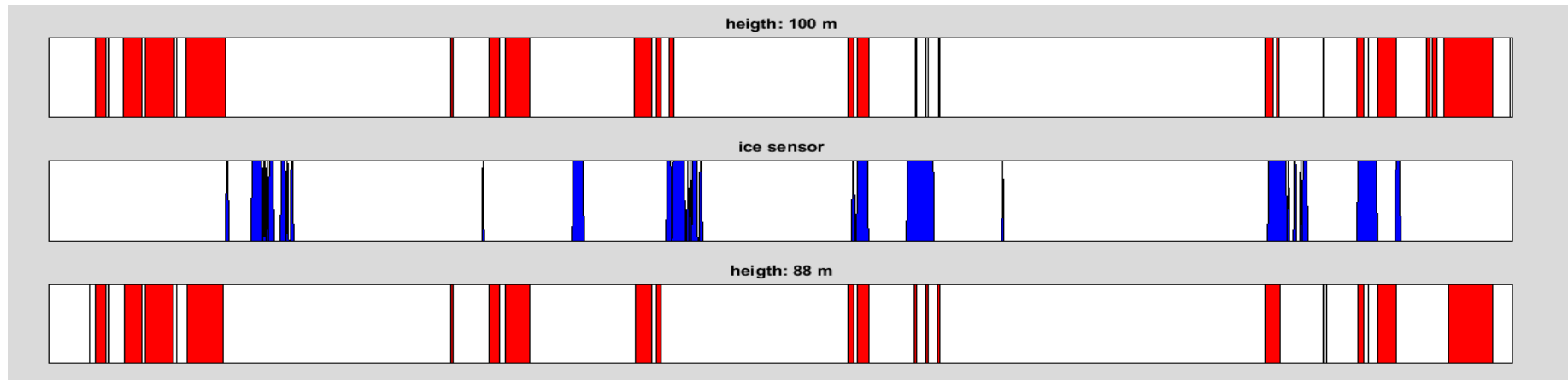
- Measurements done at a wind power site
- One winter
- Lidar next to a wind turbine

# Compare to ice detector

- Ice detector at 90m
- Sample case over a week

# Compare to ice detector

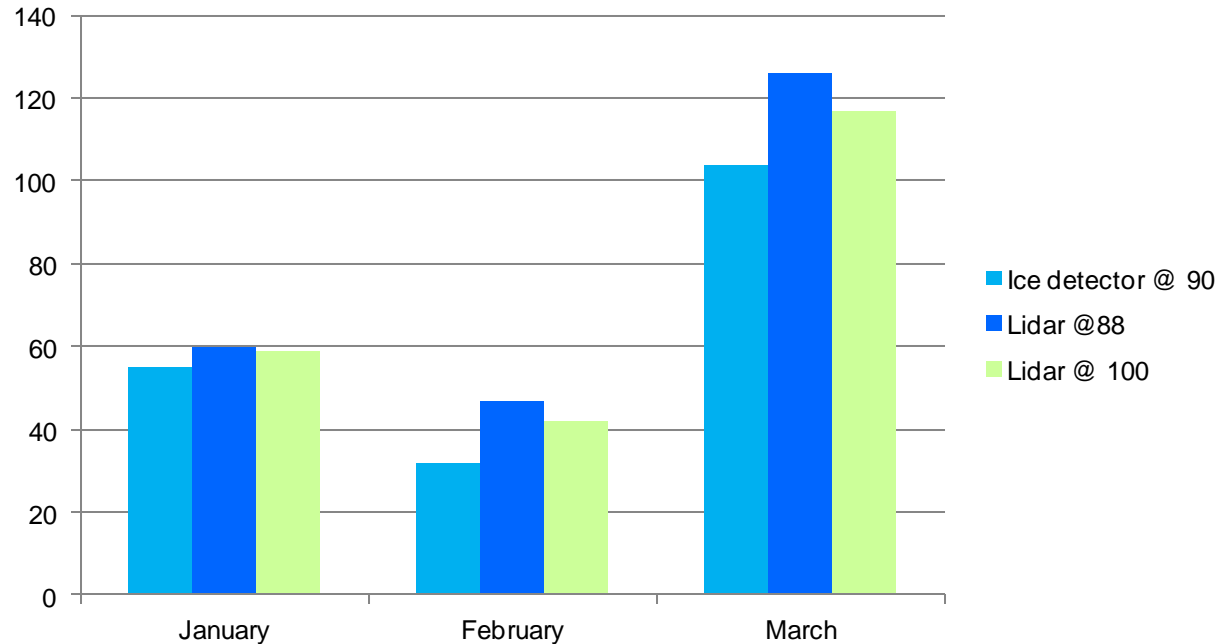
- Ice detector at 90m
- Sample case over a week



# Compare to ice detector

- Statistical comparison to ice detector
- Lidar-based detection seems more sensitive

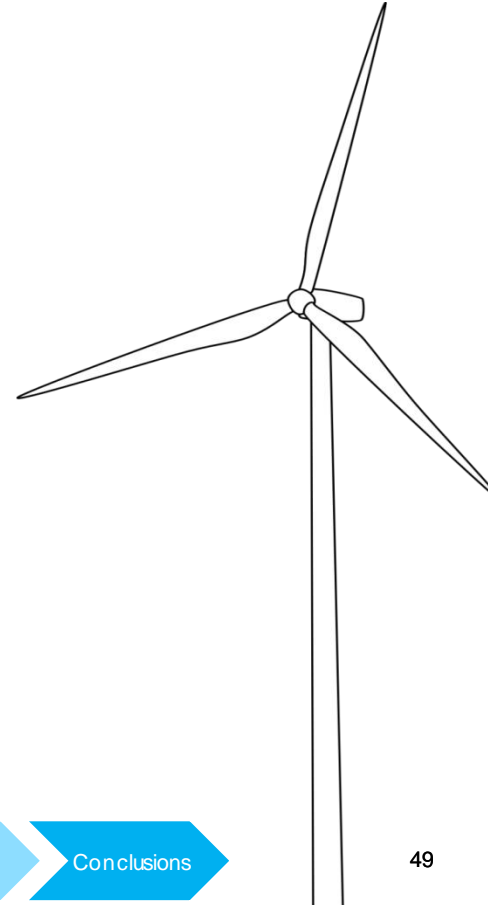
Alarm counts during test period





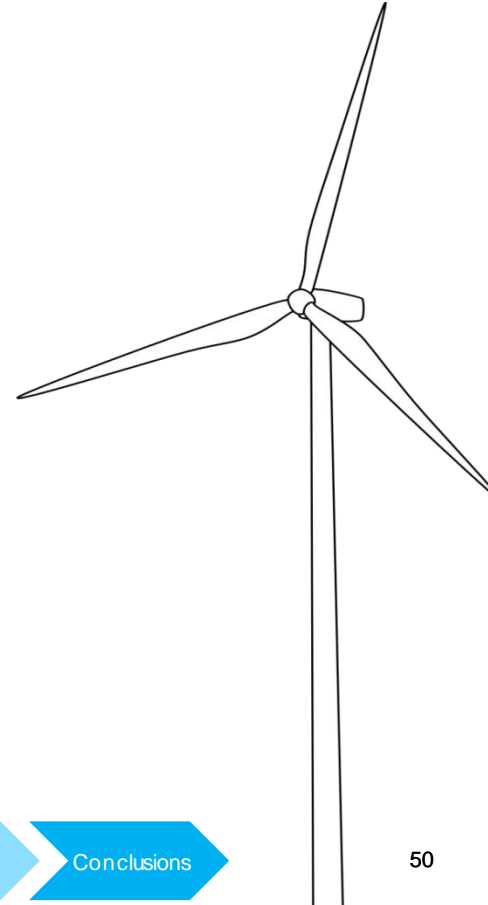
## Other solutions

- The results here were for a ground-based lidar



## Other solutions

- The results here were for a ground-based lidar
- Same method works for a turbine based horizontal lidar just as well



# Summary

- US Patent 2014/0192356
- Lidar can be used to determine icing potential in the air
  - Multiple heights
  - One lidar
  - Real time
- Done by looking at backscatter signal intensity
- Results in line with other sources as well

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**TECHNOLOGY FOR BUSINESS**

