Capabilities and Benefits of Coherent Doppler LIDARs for local weather Observation Networks

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NRGSystems

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Agenda

- Motivation
- Capabilities of Coherent Doppler LIDARs based on fiber technology
- Benefits of LIDARs for networks
- How to build LIDARs networks
- Conclusions

Motivation

- Existing observation networks were designed for **national coverage**
- Today, more and more interest to focus at **local and regional scales** where **weather risk exposure is the highest** (urban, business, industrial area)
  - Limit human, social and economical impacts
  - Develop decision making tools for local authorities
- To improve local weather monitoring (ex: severe weather)
  - More dense observation networks at local / regional scales
- To improve local weather nowcasting / forecasting
  - Development of high resolution (<5km) models requiring highly resolved observations within PBL and near the ground

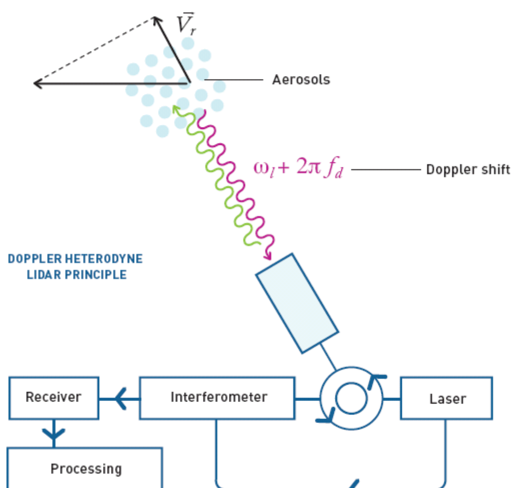
→ **Can LIDARs provide fine mesh wind and aerosol observations for local operational networks ?**

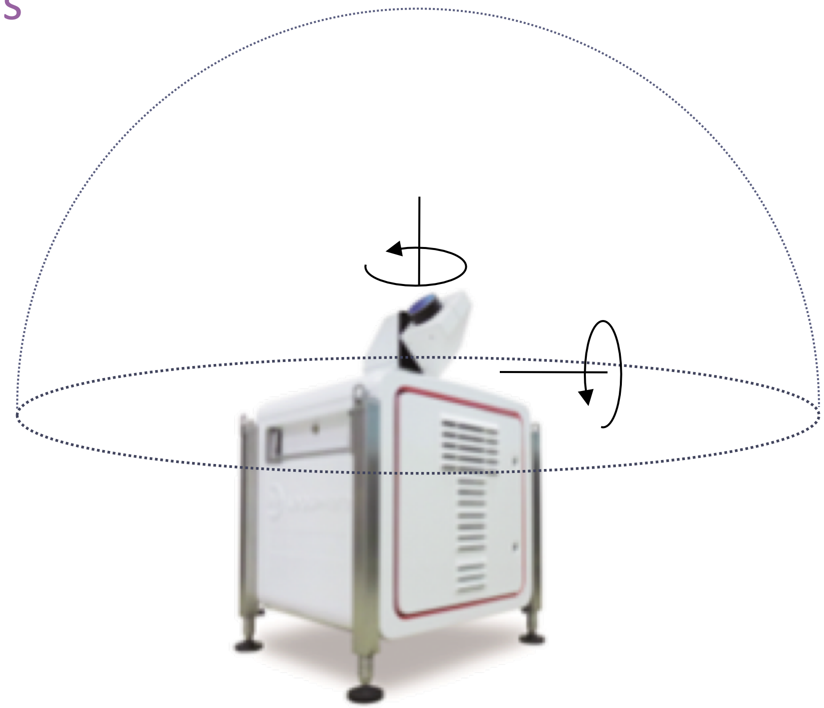
→ **How will LIDARs improve weather awareness and forecasts ?**

Capabilities of Coherent Doppler LIDARs based on fiber technology

LIDAR measurement capabilities

- Coherent Doppler Lidars become operational sensors
  - Optical fiber based CDLs ➔ Reliable and less costly
  - Today, ~1500 commercial CDLs worldwide
- Measure winds and aerosols/clouds **remotely, inside PBL** with a resolution **from 25m to 200m** under **clear air** conditions
- Flexible Scenarios PPI / RHI / DBS





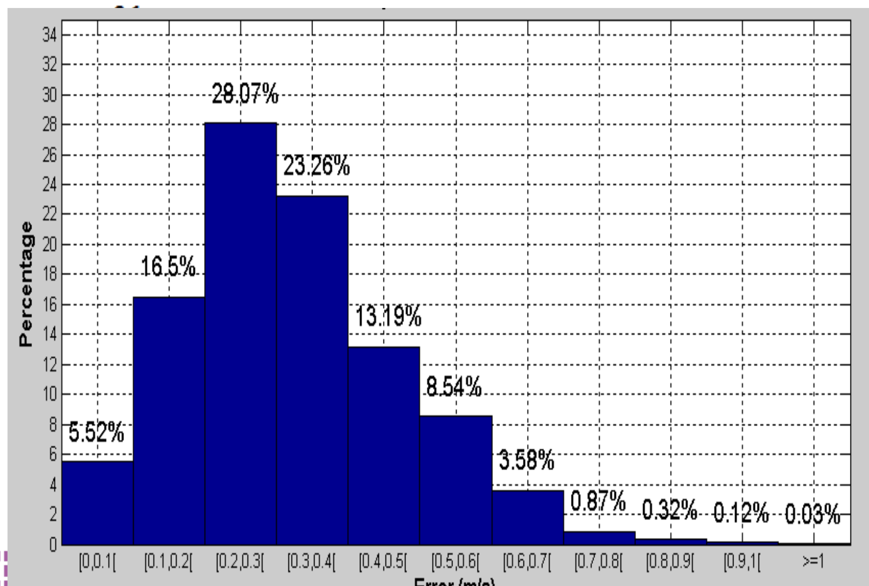
Velocity uncertainty

1. By computing Cramer-Rao Lower bound formula (pulse duration, N pulse accumulated, Npts in spectra, Bandwidth)

$$\sigma_e{}^2 = \left(\frac{\Delta v^2\sqrt{8}}{\alpha N_p}\right)\left(1+\frac{\alpha}{\sqrt{2\pi}}\right)^2, \qquad \textit{With} \qquad \alpha = \left(\frac{SNR}{\sqrt{2\pi}}\right)\left(\frac{B}{\Delta v}\right) \qquad N_p = SNR\; n\; M$$

Source O'Connor 2010, Rye & Hardesty 1993

2. By analyzing variance of wind data



- Wind precision <0.5m/s in turbulent atmosphere
- Bias against anemometers <0.2-0.3m/s
- At NRG Systems and Leosphere, specific calibration and validation procedures are performed

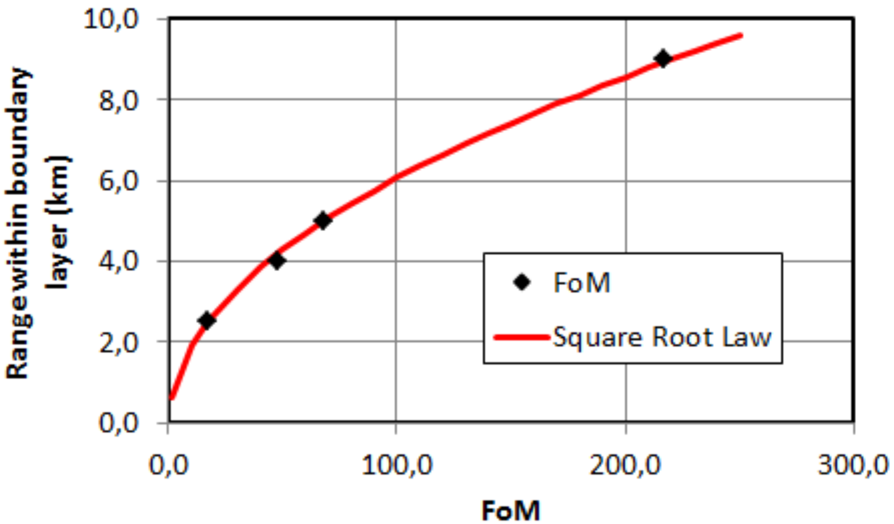
Data availability

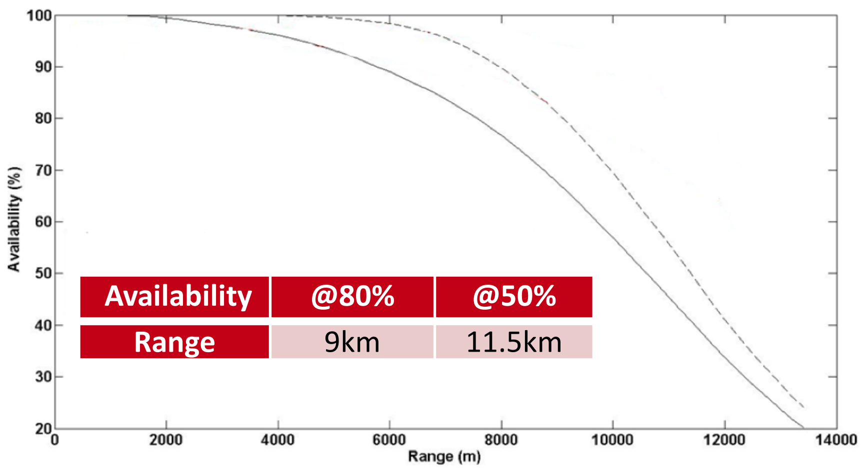
1. By computing Figure of Merit (FoM): Intrinsic performances of range based on main technical CDL specifications

$$FOM = \lambda\, E_p \tau_p\, A \sqrt{f_{PRF}}$$

Source ISO Standard on CDL

2. By analyzing data: statistical range = Maximum distance at which valid data can be retrieved for clear air conditions (visibility >10km, no rain following ISO)



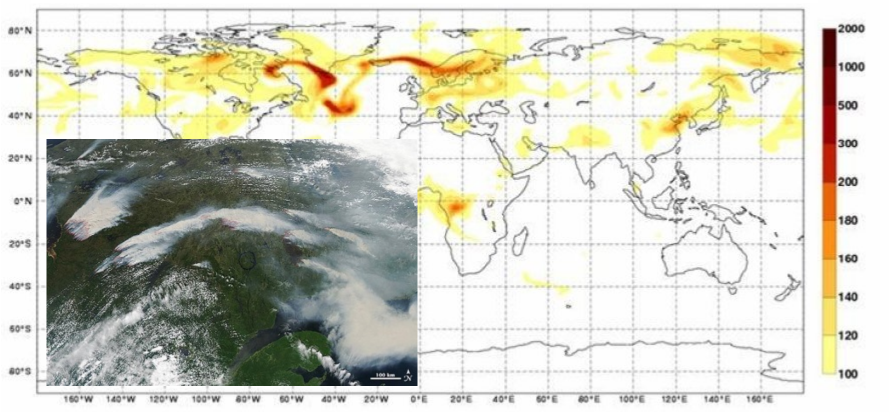


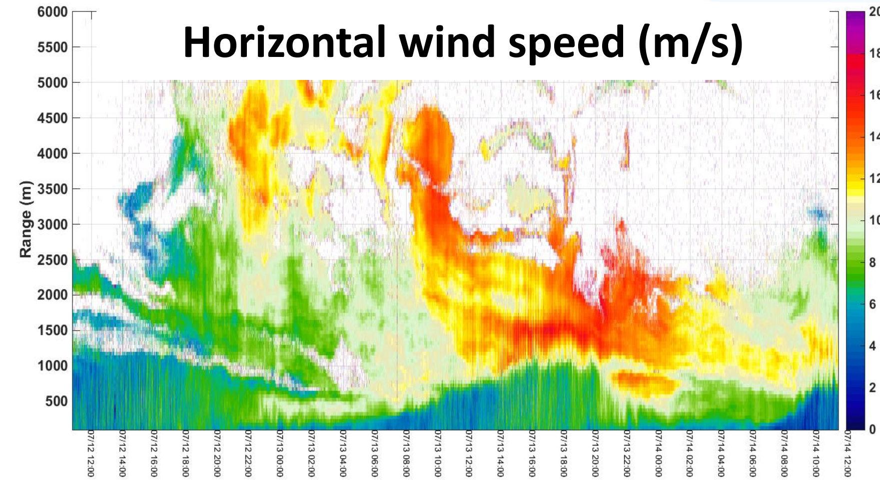
Availability	@80%	@50%
Range	9km	11.5km

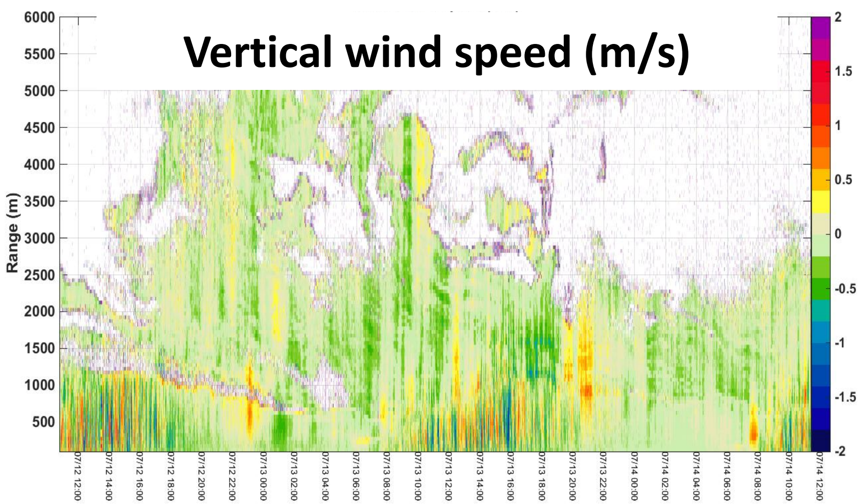
Range of a WINDCUBE400S

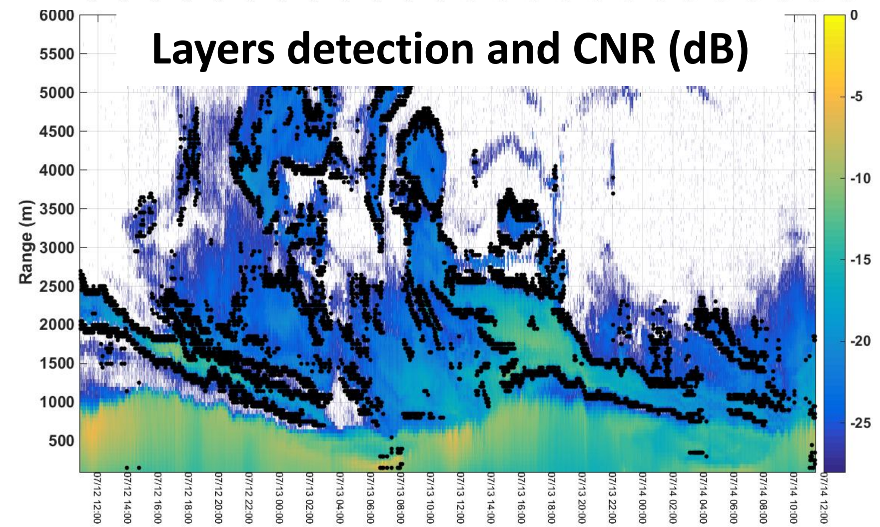
Example: Canadian forest fire observations above Paris in July 2013

MACC Forecast the 8th of July '13

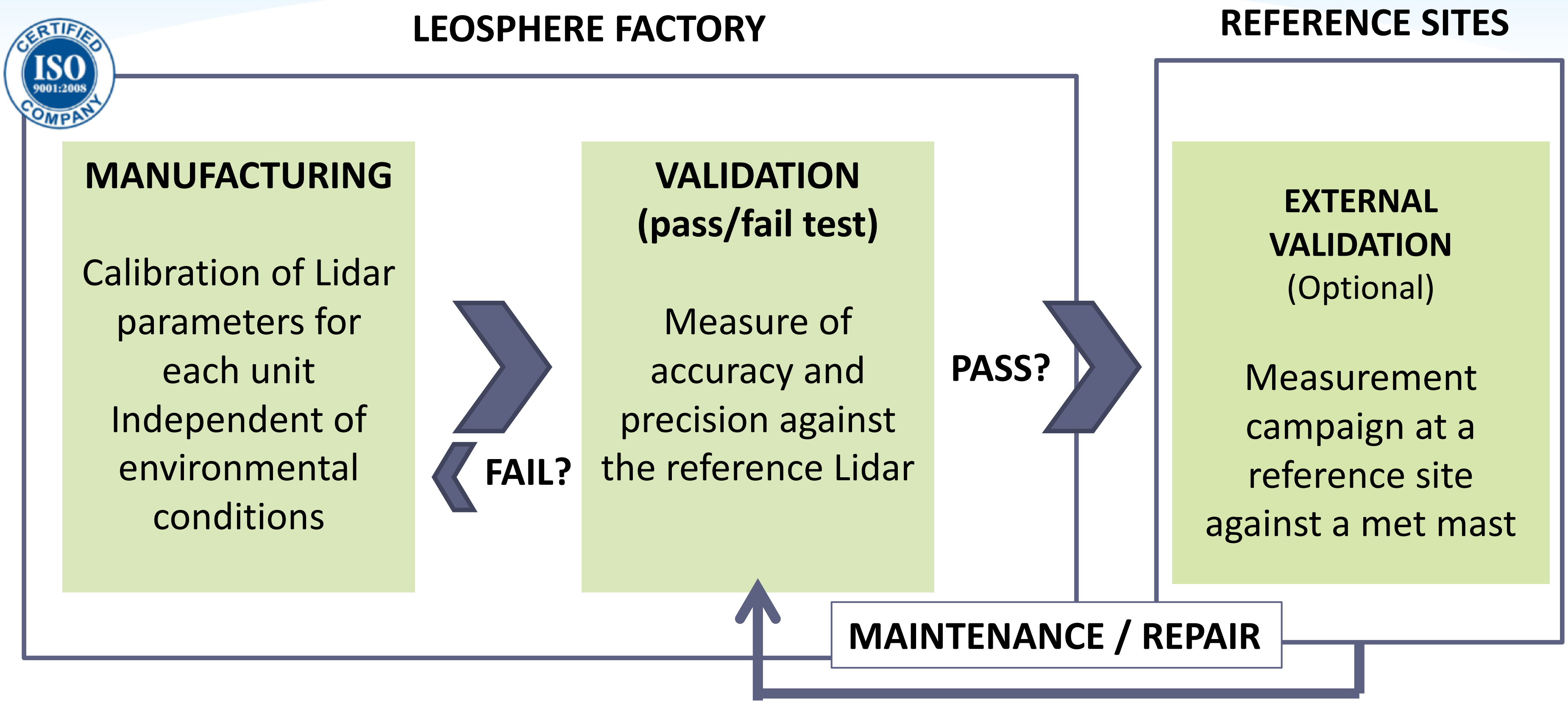








Every Lidar follows the same process to ensure repeatability and stability



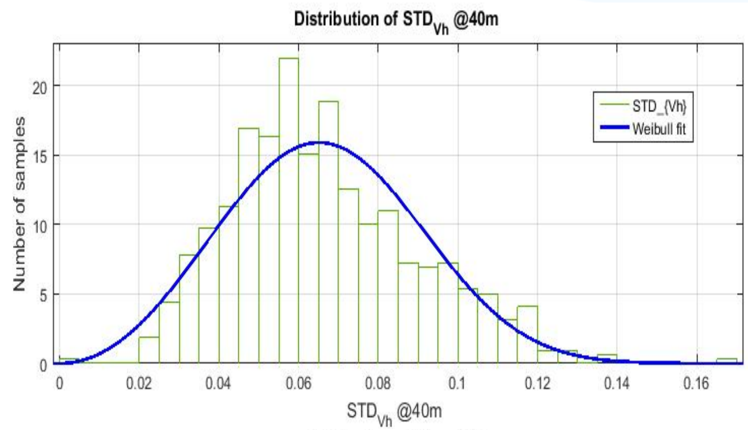
Demanding verification process

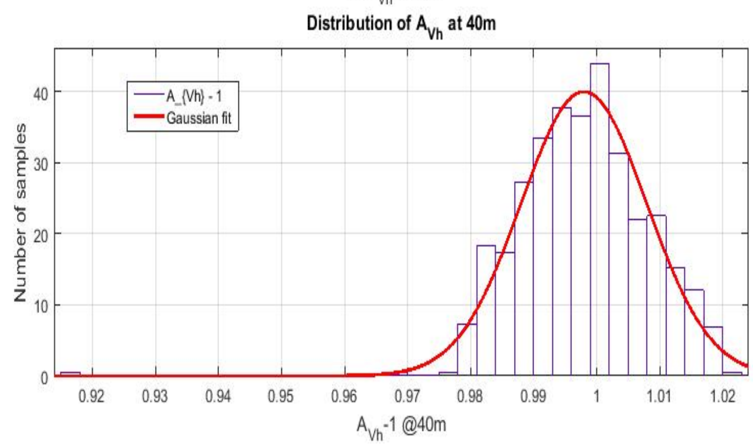
→ Consistency of data between all LIDARs

→ Verification of metrological performances with specifications

Repeatability and stability study of wind data over 850 datasets and 448 units

- Datasets collected over 5 years from 2012 to 2016
- Methodology
  - Accuracy and Precision are measured for each system for wind parameter for each height
  - Mean deviation and Standard deviation of Accuracy and Precision
- Examples of results:
  - Distribution of the standard deviation and regression slope of 10’ horizontal wind speed





For each pairing we compute Mean and Standard deviation for Accuracy and Precision

Statistics for all 850 systems			40m	80m	120m	160m	200m
Parameter	Unit						
Wind speed	m/s	Accuracy	-0,01 ±0,03	0,00±0,02	0,00±0,03	0,01±0,03	0,02±0,04
		Precision	0,07±0,02	0,05±0,02	0,05±0,02	0,06±0,03	0,07±0,03
Wind direction	°	Accuracy	0,17±1,47	0,17±1,46	0,18±1,46	0,17±1,47	0,16±1,48
		Precision	1,37±1,12	0,84±0,80	0,82±1,01	0,84±1,02	0,86±1,16
TI	%	Accuracy	-0,1±0,6	-0,1±0,3	-0,1±0,3	-0,1±0,3	-0,1±0,5
		Precision	1,6±0,7	1,0±0,8	0,9±0,6	1,0±0,7	1,1±0,8

Benefits of LIDARs for networks

Severe weather monitoring and forecasting

Courtesy of J. Soderholm / UQ

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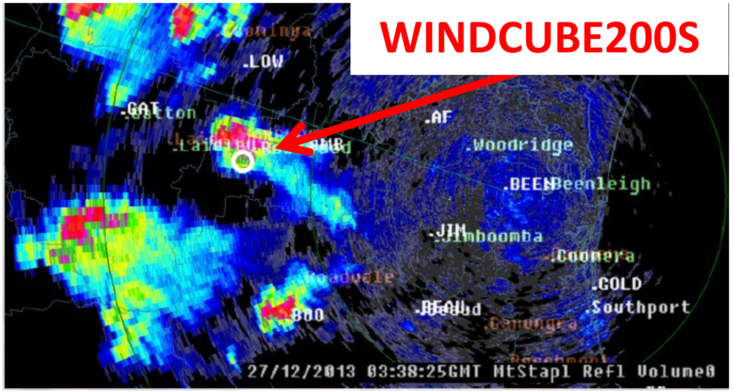
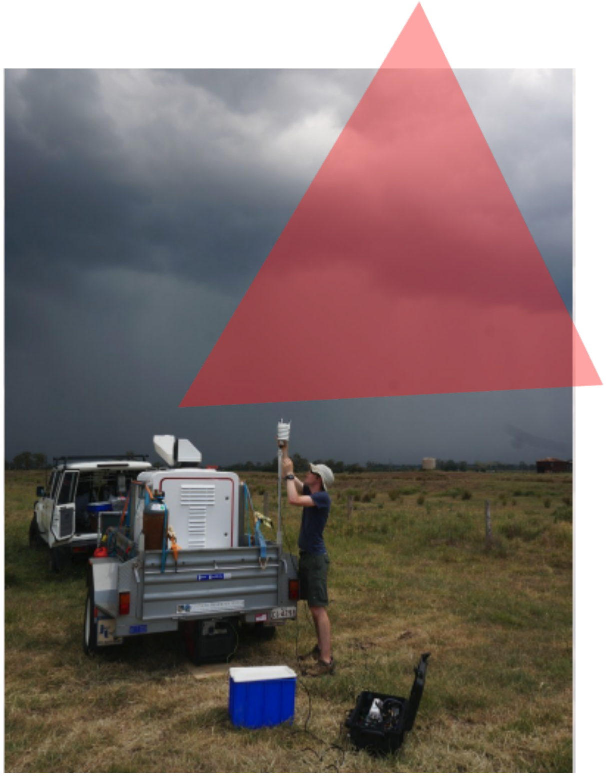
- Convective Initiation of severe storms in Queensland, Australia
- Launch of the Coastal Convective Interactions Experiment (CCIE) by UQ:
  - Quantify thunderstorm hotspot activity
  - Understand anomalous spatial behavior of thunderstorms
- Deployment of several sensors (X-Band radar, WINDCUBE200S scanning LIDAR, …) during summer'14



LIDAR Configuration:
- 25 m
- RHI scan perp. to storms
- Scan duration 90s



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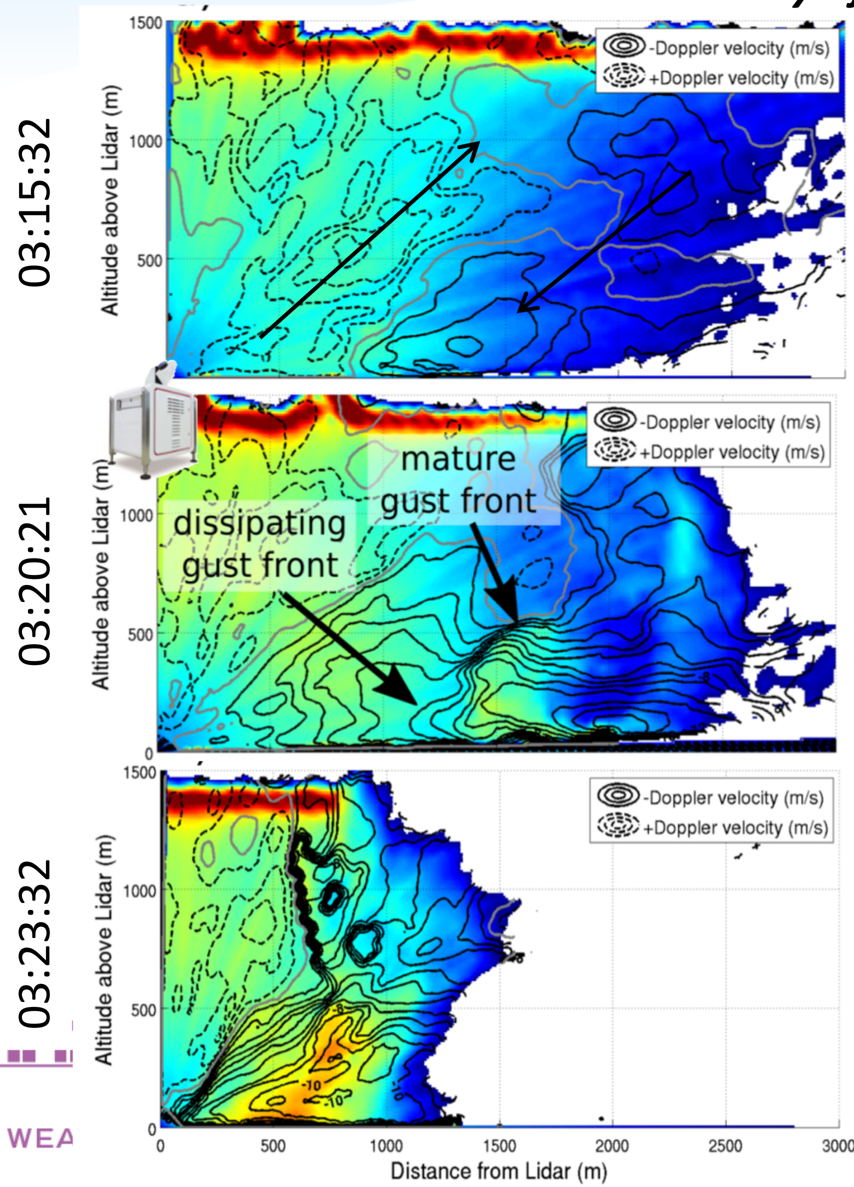
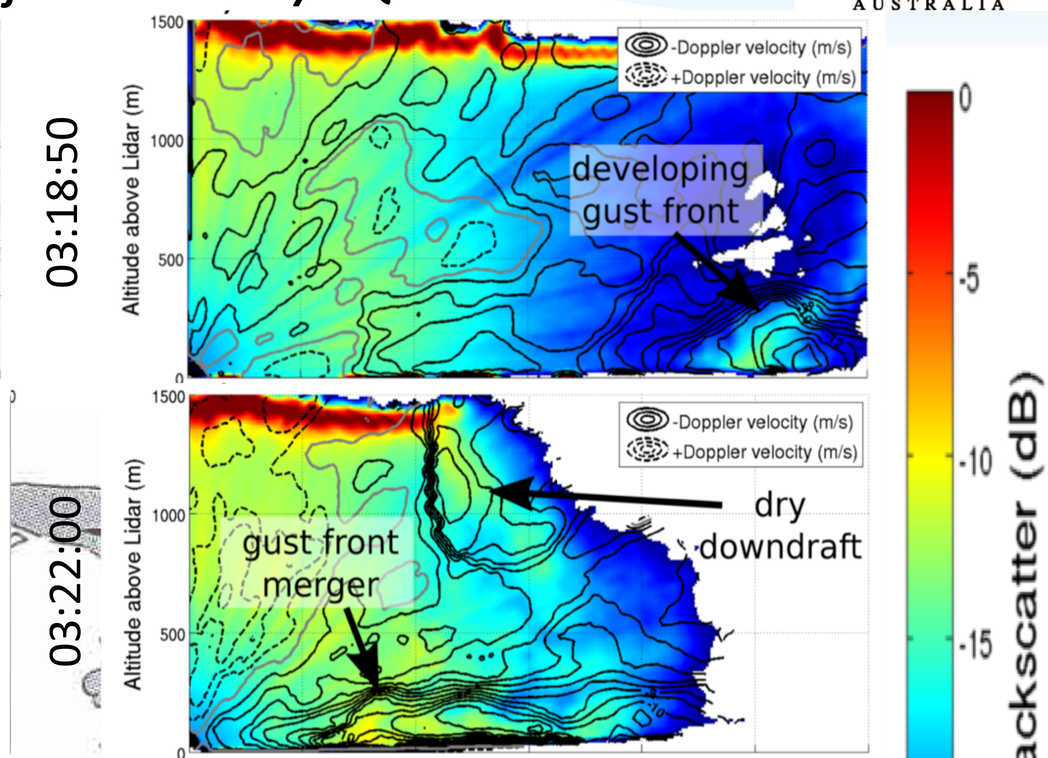
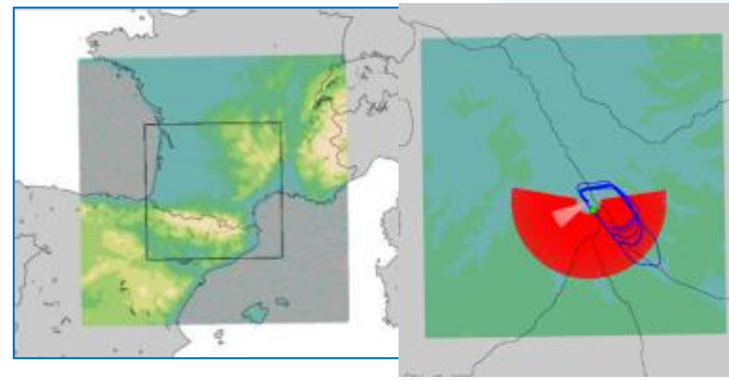




➔ **This study shows that scanning LIDARs measure local winds before the storm arrival and this helps to better understand hotspot activity in Queensland**

Assimilation of LIDAR data into NWP Model

Courtesy of S. De Haan / KNMI

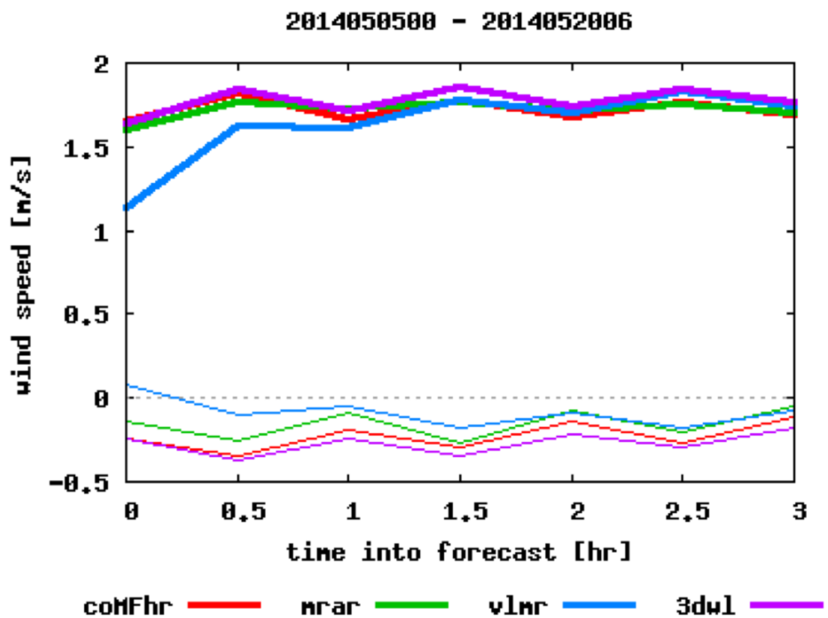


Set-up of Harmonie model domain for Toulouse

- 1km resolution: 500 x 500 grid points

Experiments

- Conventional obs MF: **coMFhr**
- + Mode-S MRAR : **mrar**
- + LEOSPHERE WindcubeV2: **vlmr**
- + LEOSPHERE 3D wind observation – **3dwl**



Results

- Best performance with assimilation of LIDAR wind profiler
- Positive impact on wind speed std and bias
- Difficulties to assimilate directly 3D Wind LIDAR data (small turbulence scales)

➔ This study shows that LIDAR data from even short range profilers can improve local wind forecasts

How to build LIDARs networks

Which CDL configuration for which networks?

Regional networks

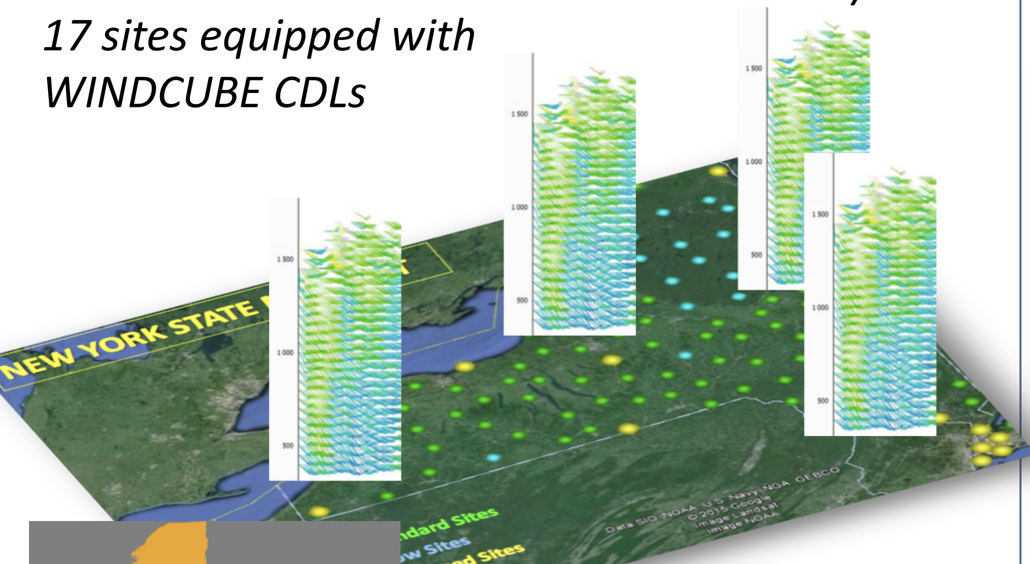
> 100 000 km^2 - Region / State
PBL LIDAR Profilers

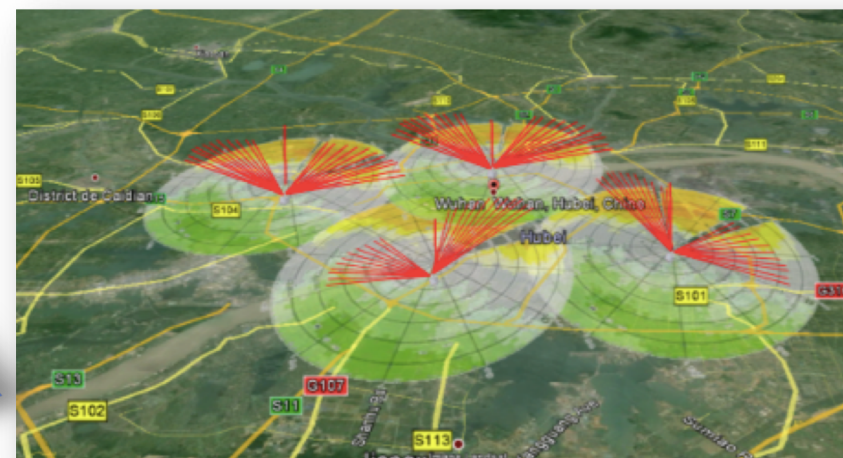
Local networks

< 5 000 km^2 - Megapole area -
Long range scanning LIDARs

1. *PBL wind, aerosol and clouds profiles assimilation into NWP models*
2. *Wind / aerosol monitoring*

17 sites equipped with WINDCUBE CDLs





NYS Mesonet UNIVERSITY AT ALBANY

http://www.nysmesonet.org/

Conclusions

- **New high resolution local observations** are needed for improving weather awareness and nowcasting/forecasting **at local and regional scales**
- WINDCUBE LIDAR sensors based on fiber technology allow to
  - Measure winds accurately to 0.1-0.3m/s inside PBL
  - Fiber-based LIDARs ensure high reliability and cost effectiveness
  - All WINDCUBE LIDARs are calibrated and verified to ensure data consistency
- Demonstrated performances over 5 years and 850 datasets
- Key projects demonstrated potential benefits of LIDARs for operational networks
- For building LIDARs networks
  - Configurations will depend on size of network (region, city…)
- On-going standardization activities on Doppler LIDARs specifications and use (ISO /TC 146/SC 5/DIS 28902-2, IEC 61400 and IEA)
- Several projects like NYS MesoNet have been launched worldwide to initiate and develop local and operational weather networks equipped with Doppler LIDARs

Questions

Thank You

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