Triton Remote Sensing Systems: Comparing Accuracy with Collocated Met Towers

11.11.2015 Juha Paldanius

SECONDWIND by Vaisala | 3TIER by Vaisala | VAISALA

Introduction toTriton® SODAR

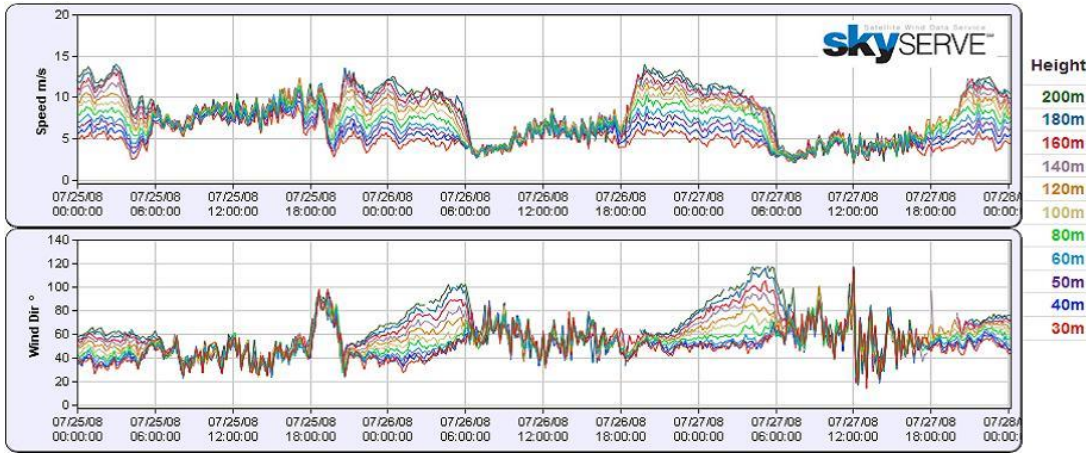
SECONDWIND by Vaisala | 3TIER by Vaisala | VAISALA

Triton® Sonic Wind Profiler

- Triton Sonic Wind Profiler is the most widely used and trusted remote sensing system in the wind industry
  - Over 500 units deployed, more than 14 million hours of data collected
  - Designed to add value at all stages of development and operation
  - Reliable hub-height data
  - Unattended operation
  - **Low Total Cost of Ownership**

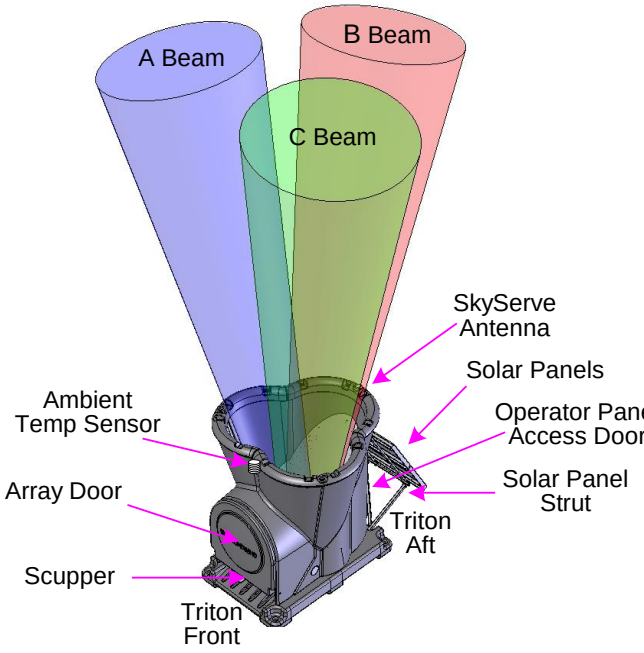
Triton® Sonic Wind Profiler – Key Features

- 40m to 200m wind speed, direction, TI, vertical wind speed
- Temperature, pressure, humidity
- Online data access
- GPS for locational accuracy, time stamp
- Satellite or GPRS communications



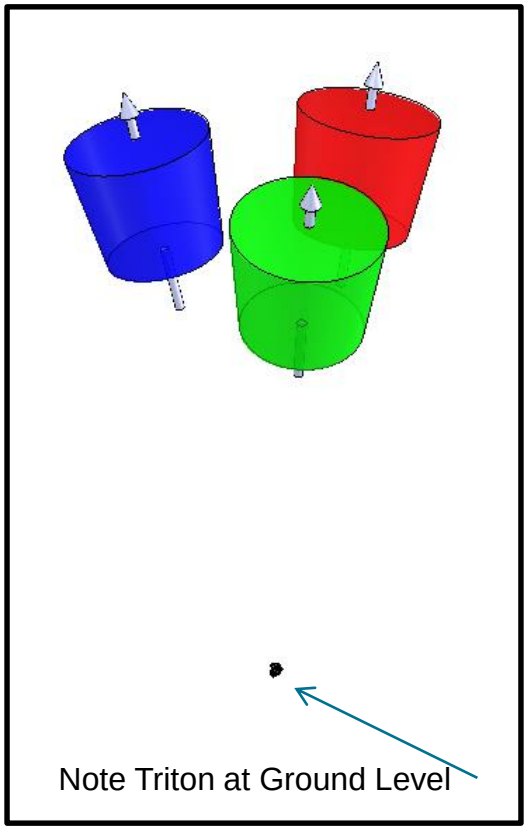
How Triton® Works - Overview

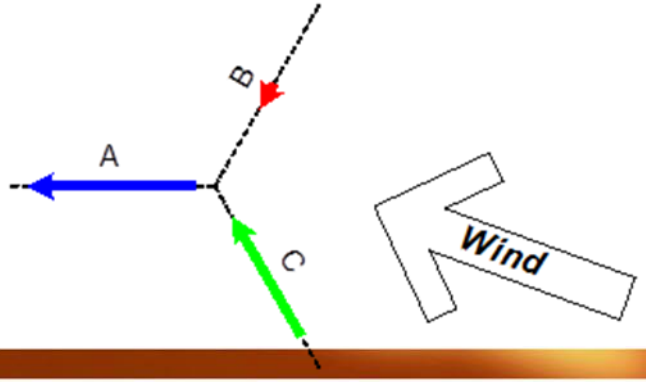
- Triton uses SODAR – Sonic Detection and Ranging technology
- Triton emits sound pulses then “listens” for reflections from turbulent eddies
- The along the beam wind changes the returned signal frequency -- Doppler shift
- The wind either “stretches” or “compresses” the beam
- The larger the wind speed, the larger the Doppler shift



How Triton® Works – Graphical View

- Triton measures averages wind speed over a volume and not a point in space
- For 100 m wind speed, Triton listens for beam reflections that start at 90 m and end at 110 m (also referred to as the range-gate)
- The red, green and blue bottle cork-shaped beam segments display the entire volume of air from which reflections are detected
- The recorded sample of backscattered sound the Triton hears along a particular beam direction and segmented by station height is called a shot





Overview of Beam and Measurements

[Name]

Triton Remote Sensing Systems: Comparing Accuracy with Collocated Met Towers

Largest worldwide study ever conducted

SECONDWIND by Vaisala | 3TIER by Vaisala | VAISALA

Independent Validation Studies

- Triton® Wind Profiler has been independently evaluated and verified for accuracy by:

ECN Your energy. Our passion.

NREL

NATIONAL INSTITUTE OF WIND ENERGY
नीवे NIWE

GL Garrad Hassan

KEMA DNV

res

China Hydroelectric Corporation

Studies in progress – 2015:

ECOFYS

ECN

Why a *Global* Validation Study?

- Despite widespread adoption, you still want to know: **"Are remote sensing systems as accurate as met tower systems?"**

TRITON BROUGHT TO MARKET IN **2008**

PERFORMANCE UPGRADE **2013**

550+ TRITONS SHIPPED

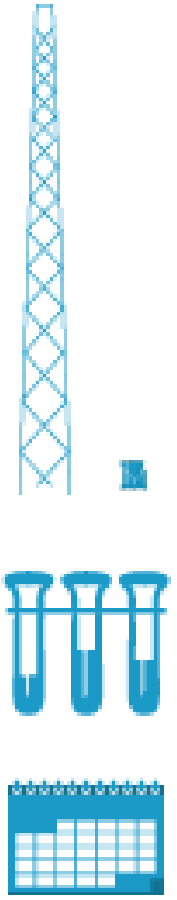
19 WIND DEVELOPERS OWN MORE THAN FIVE TRITONS. FOUR HAVE TRITON FLEETS OF **15+**

14m+ HOURS OF WIND DATA

2500+ LOCATIONS IN **30+** COUNTRIES

Traditional Comparison Studies

- Are an important step in establishing the validity of remote sensing systems
- Measure one remote sensing system against one tower
- Are done in as carefully controlled an environment as possible
- Are done for as short a time period a possible
- Answer the question: **“Is this remote sensing system technology capable of being as accurate as a met tower system?”**



Vaisala's Unique Position

MANY DEPLOYMENTS HAD COLLOCATED TOWERS

MANY CUSTOMERS VOLUNTEERED TO SHARE DATA FOR A GLOBAL STUDY

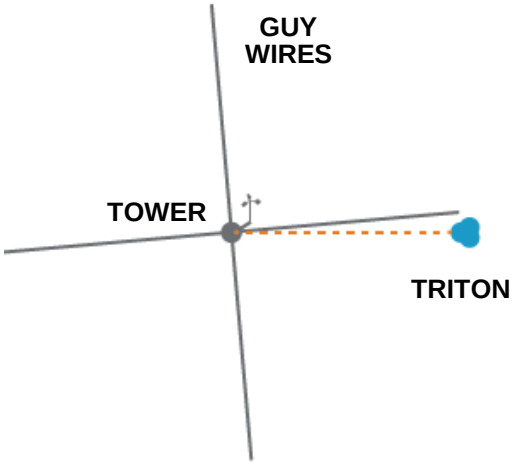
IN-HOUSE WIND RESOURCE ASSESSMENT EXPERTISE

Met Towers and Anemometers

- The “Industry Standard”
  - The cup anemometer is currently the standard instrument used for wind speed measurement in the wind energy industry
  - Despite inherent limitations, vast numbers of cup anemometers have been deployed around the world for wind resource assessment
  - The cup anemometer is also used for certified power performance measurements for turbine power output verification purposes.
- Triton is automatically compared to the imperfect, but well known met tower / anemometer technology
  - At some point, nearly every Triton customer asks “is Triton as accurate as my met towers?”
  - The short answer is **YES** (probably more accurate), but…

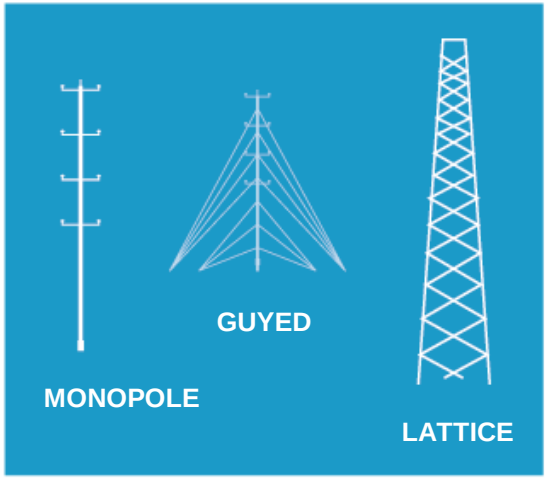
Caveats of Comparison

LOCATION



Met towers take up a lot of space; it's physically impossible to locate Triton in the exact same place

CONFIGURATION



The tower can have major impacts on the data – wind bounces off or flows around and over tower, booms, etc.

THE IDEAL

A perfect instrument on an invisible tower

Caveats of met tower data

DESIGN	OVER-SPEEDING	VERTICAL SPEED	10%!
			
ANEMOMETERS…			
REACT MORE QUICKLY TO INCREASES IN WIND SPEED	USUALLY READ TOO HIGH AT HIGHER WIND SPEEDS, ESPECIALLY WITH GUSTS	OFTEN MIS-INTERPRET VERTICAL COMPONENT OF WINDSPEED, CAUSING HIGHER READINGS	CAN SOMETIMES DIFFER UP TO 10% FROM AN ANEMOMETER AT SAME HEIGHT ON SAME TOWER

Caveats of Analysis Methods

- **Data Analysis Methods**
  - The process of “cleaning and screening” met tower data is excruciating and manually labor intensive
  - There are no published specifications on exactly how to do it and many difficult choices and decisions are made by the meteorologists
  - No two teams of meteorologists will come up with exactly the same results when handed the same set of raw met tower data

Our Main Questions to Ourselves

- Is Triton as accurate as a met tower system, in actual commercial use?
- How does Triton and met tower data compare?
- What is the advantage of Triton on evaluating wind shear with incomplete data yield?

The Data Set

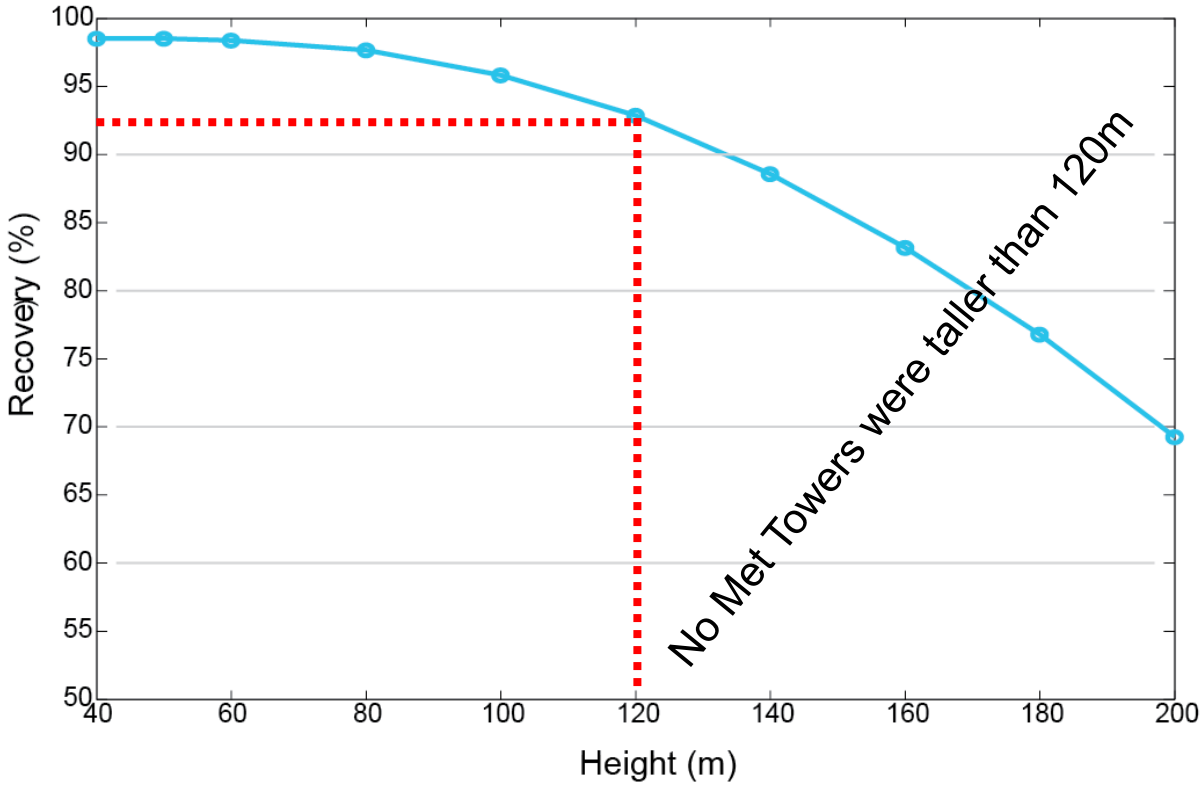
- 30 Triton / Tower data sets included in the study:
  - Triton data came from 24 different units manufactured between 2008 and 2014
    - 11 different Triton users
  - A total of 100 correlation pairs (heights) were used
    - Shortest tower measurement height was 34m
    - Tallest tower measurement height was 120m
    - Average tower to Triton distance was 134m (70…220m)
    - Most Triton / tower elevation differences were less than 2m, and all were within 6m
  - All Tritons were deployed as they were shipped from the factory
    - 18 had an original Triton sonic array (built: 2008-2012)
    - 12 Tritons were TPU-equipped (built: 2012-2014)

Data Recovery

"All Tritons (both original units and those with the upgraded speaker array, or "TPU" units) exhibit high data recovery (>=90%) up to 80m. Data recovery for the newer TPU units is considerably improved compared to that of original units at higher heights:

- *17% higher at 100 m,*
- *47% higher at 140 m, and*
- *106% higher at 180 m."*

Data Recovery



- On average, across all Tritons in the study, TPU equipped Tritons had >90% data recovery at 120 meters

The Vaisala Study

- 30 Triton/met tower pairs from six years of commercial deployments:
  - Triton placed near a well-instrumented met tower
  - Minimal height / elevation differences between Triton and tower
  - Mostly – **but not exclusively** – simple terrain
  - Well distributed geographically
  - Wide variety of weather and climate regimes

Key Take-aways

- **Accuracy:** Triton is as accurate as a met tower
  - Not just in one experiment, but over 10's of 1000's of data-hours
  - Measuring with Triton cuts shear extrapolation error in half
- **Repeatability:** You can expect continued, repeatable performance from one Triton to another
- **Longevity:** Study included data collected over 6 years – if you have an original Triton, you can affordably upgrade it to improve your data recovery rates at higher heights

Conclusion: Wind speed

"When the mean wind speed differences at all 100 qualifying anemometer measurement heights within the 30 Triton/met tower pairs are aggregated, ***the average relative difference is +0.09%****, and the percent* ***root mean-square of the differences is 1.27%****. This is consistent with an estimated uncertainty of the Triton of approximately 1%, if the met tower measurement uncertainty is assumed to be independent and approximately 1% as well, a reasonable assumption for a large set of met towers maintained by many different Triton users."*

Reducing Shear Extrapolation Uncertainty

- When mean winds directly measured by Triton (under a perfect data recovery scenario), or filled-in with values based on Triton-measured shear (under a real data recovery scenario), are compared with estimates sheared up from lower met tower heights, **the Triton mean wind speed estimates exhibit uncertainties less than half that of estimates sheared up from met towers**.

- Under the real data recovery scenario, **the reduction is from 2.7% uncertainty for met tower extrapolation down to 1.3%** uncertainty for Triton measurement with filled-in values.

So what is the “Truth”?

“TRUE” WIND SPEED

?

TOWER UNCERTAINTY SOURCES:

CALIBRATION | TURBULENCE & OFF=-HORIZONTAL FLOW | SENSOR DEGRADATION | TOWER FLOW DISTORTION | TO NAME A FEW!

Summary

- Vaisala and our Triton customers have accumulated a large dataset of measurements from collocated pairs of Tritons and met towers, deployed at diverse locations across the globe:
  - Data were taken from real-world projects
  - ***Differences in mean wind speed and direction measured by tower-mounted anemometers and wind vanes and by Triton are virtually indistinguishable from each other***
- The findings point the way to additional applications of Triton that you may not have considered, including the use of Triton as a stand-alone alternative to met towers in many situations.

Thank you!

SECONDWIND by Vaisala | 3TIER by Vaisala | VAISALA