

Comparison of a Global Fleet of Triton Wind Profilers to Collocated Met Towers

Windergy India, New Delhi

25 April 2017

VAISALA

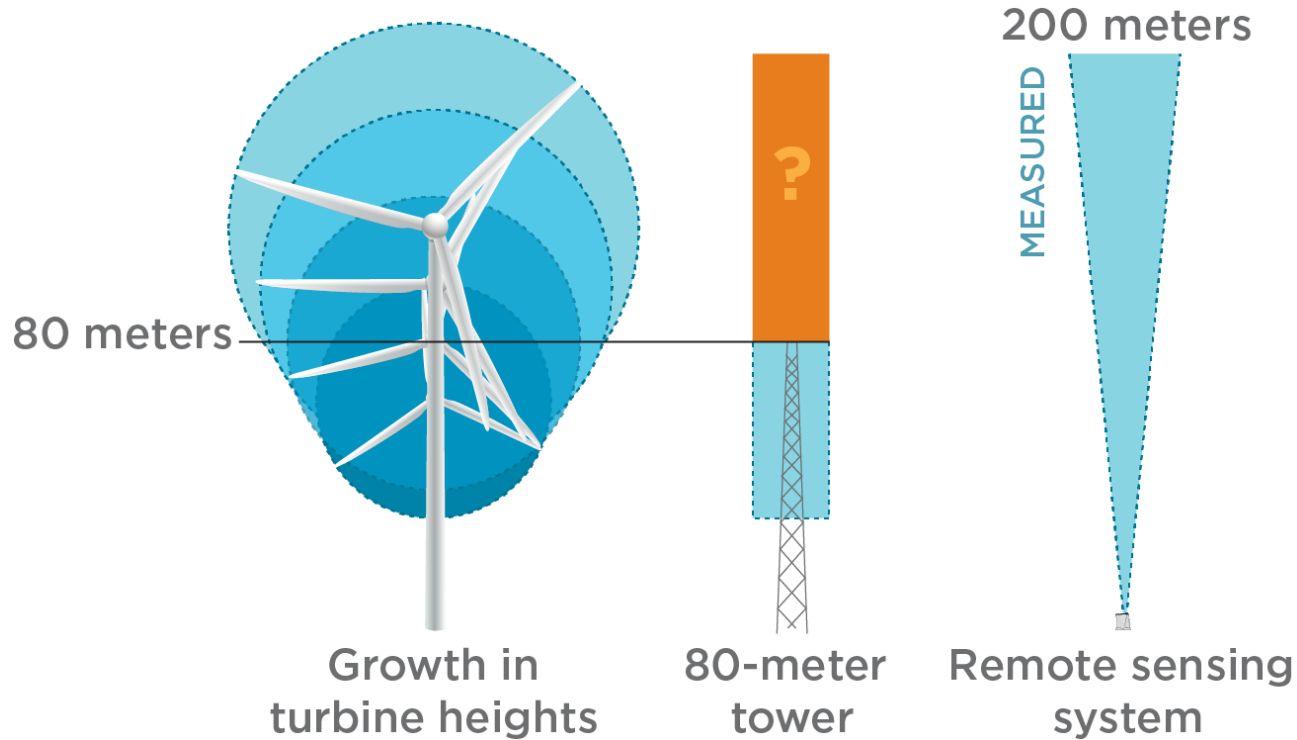
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Umakanthan

Dr. Mark
Stoelinga

Dr. Pascal
Storck

Matthew
Hendrickson

Why Remote Sensing? *Higher height data*



Triton[®] Wind Profiler



- Easy to install
- No permitting delays
- Easy to move, relocate, and service

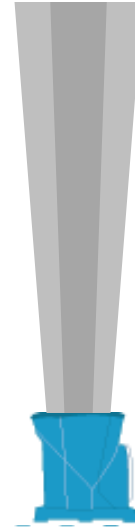
How Does It Compare to a Met Tower?

“TRUE” WIND SPEED

?



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



Triton[®] Validation Study

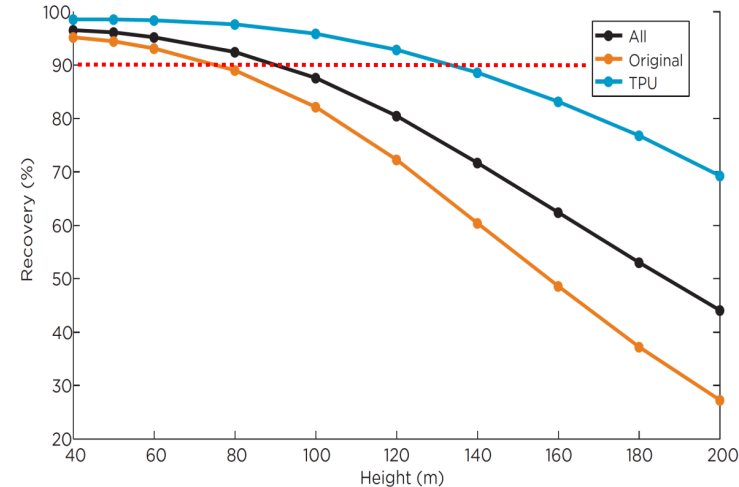
- Measured Quantities:
 - Wind speed, direction, shear @ 10min periods
 - Data recovery w/ height, unit up-time
- Study Size and Attributes:
 - 30 Triton/Tower deployments; 100 sensor heights
 - Shortest: 34m; Tallest: 120m
 - Triton/Tower distance: 70m-220m (avg: 134m)
 - Triton/Tower elevation differences: <6m (most <2m)
 - 18 units original speaker array; 12 upgraded (TPU)
 - Data periods: 4-25 weeks from 11 different users
 - Environmental distribution:
 - 4 continents (N. AMER., S. AMER., EUR, S. AFR)
 - Limited terrain complexity (flat to slightly rolling terrain)
 - Locations without frequent heavy rain



Triton[®] Validation Study: Data Recovery

“All Tritons (both original units and those with the upgraded speaker array, or “TPU” units) exhibit high data recovery ($\geq 90\%$) 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.”*



How well does Triton work in India?

Primary concern: Triton measurements are negatively affected by heavy rain. Will this significantly decrease the data recovery during the Monsoon?

Test: Collocated Triton and Met Tower

- Tamil Nadu
- Flat terrain
- Triton and 120-m Met Tower separated by 140 m distance
- 10-minute measurements for 1 year (2015)

Quality Control

- Triton:

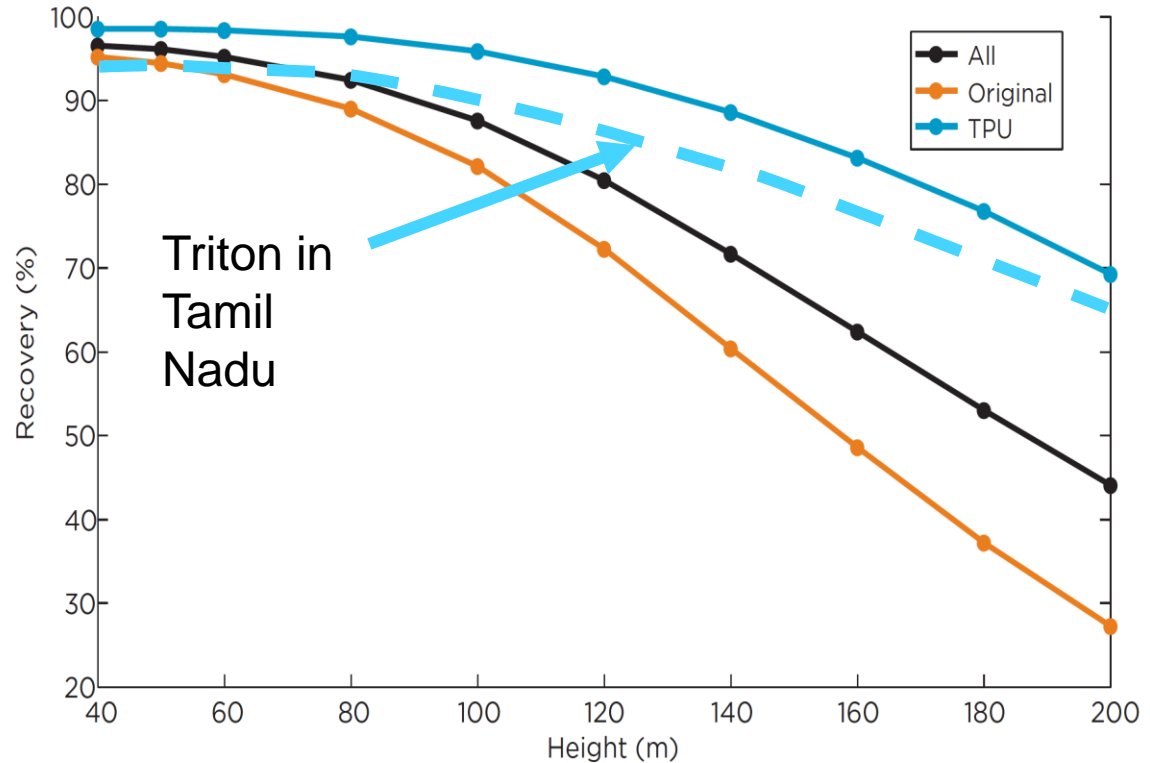
- Quality factor threshold
 - Quality Factor is Triton's "self assessment" of the quality of each measurement (SNR, sound characteristics, etc.)
- Vertical velocity threshold
 - Filters periods of heavy rainfall
- Wind ramp threshold
 - Unrealistically large 10-minute wind speed changes can be filtered out.

- *Met Tower:*

- *standard techniques*
 - Flow distortion filtered out
 - Sensor degradation filtered out

Data Recovery

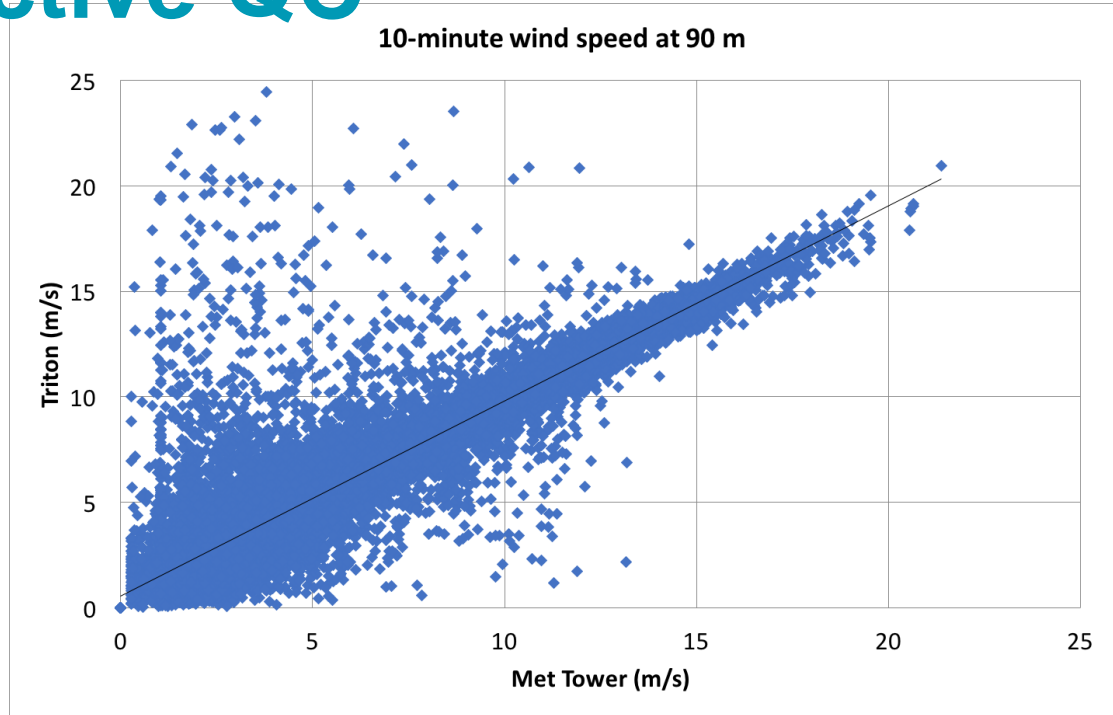
- Standard QC: Quality Factor Threshold = 90%
- Vertical Velocity Threshold = -1.5 m/s
- (No ramp filtering)
- Recovery rate: slightly lower than global average, but still very high, considering Monsoon rain



Comparison Plots with Progressively More Restrictive QC

QF Thresh.	Vert. Vel. Thresh.	Ramp Thresh.
none	none	none
90%	none	none
90%	1.5 m/s	none
90%	1.5 m/s	5 m/s

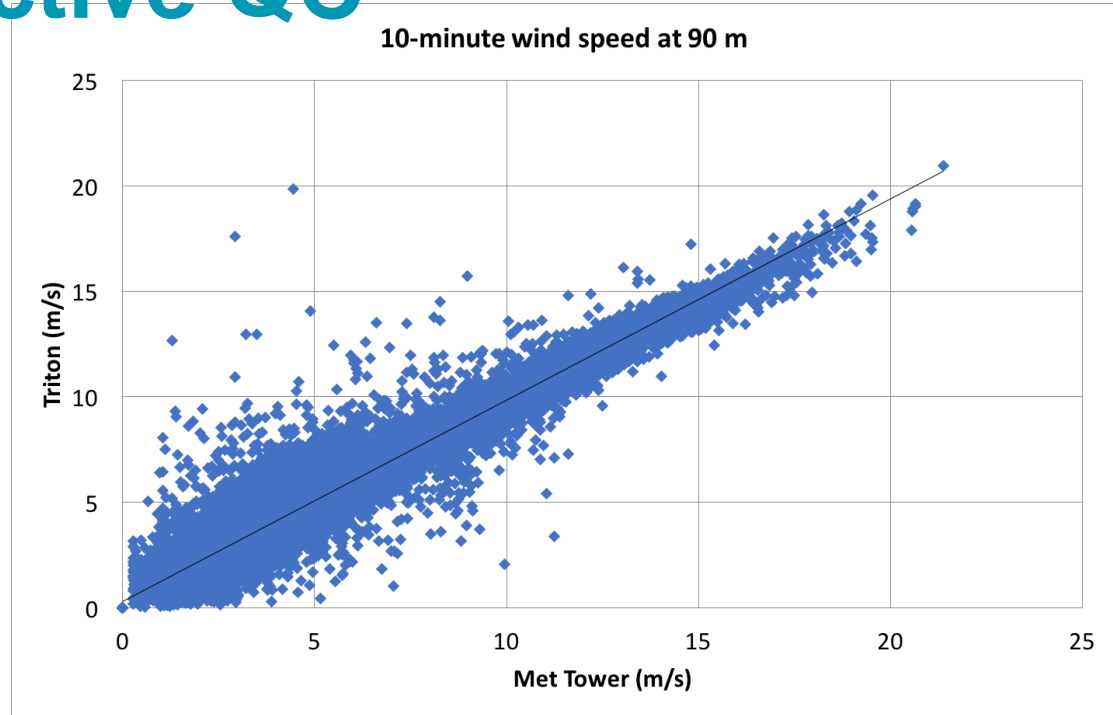
R ²	Bias (%)	Data Recov. (%)
0.88	+2.0	99.0
0.96	+0.5	92.1
0.96	+0.2	90.6
0.97	+0.2	90.0



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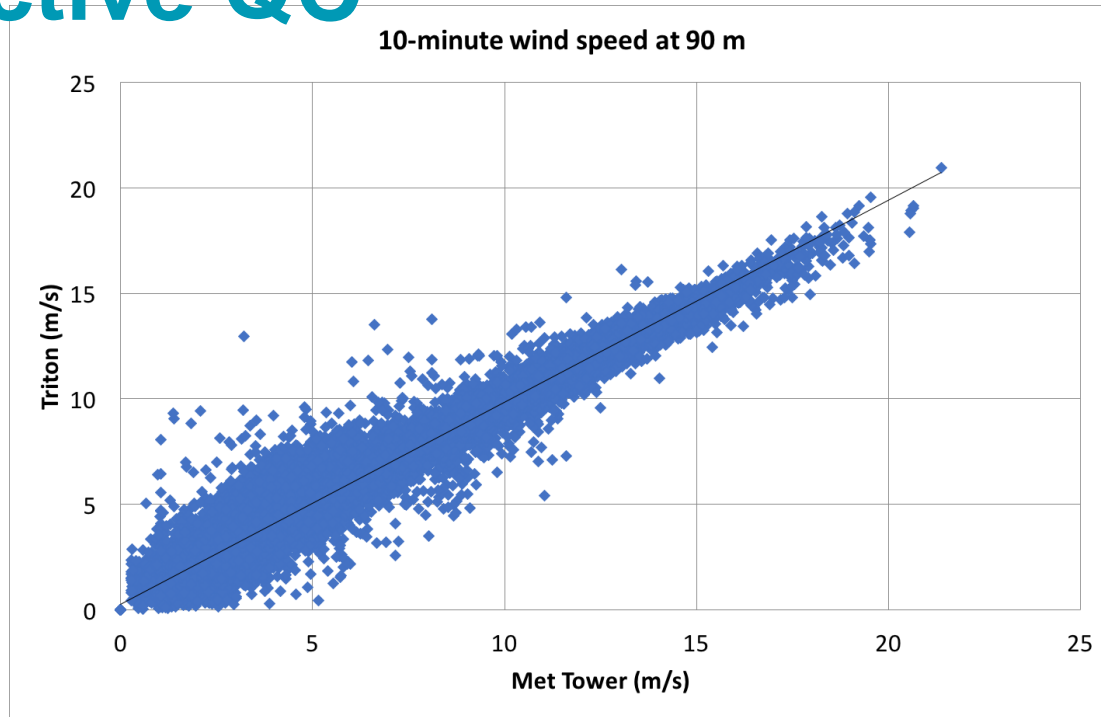
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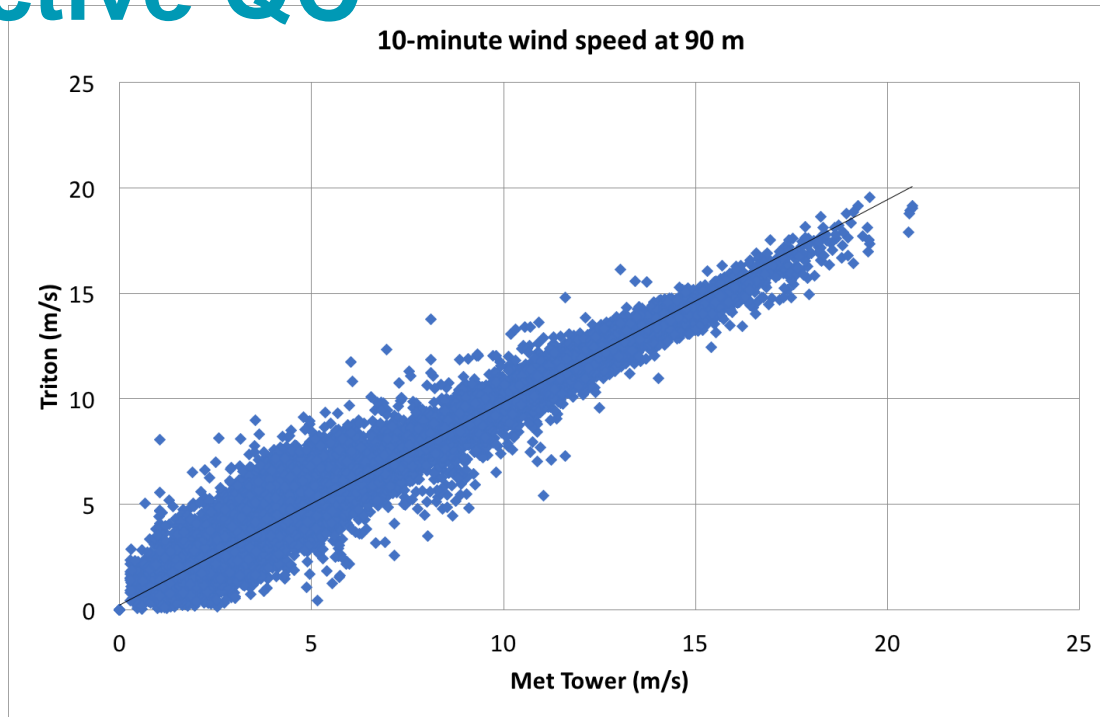
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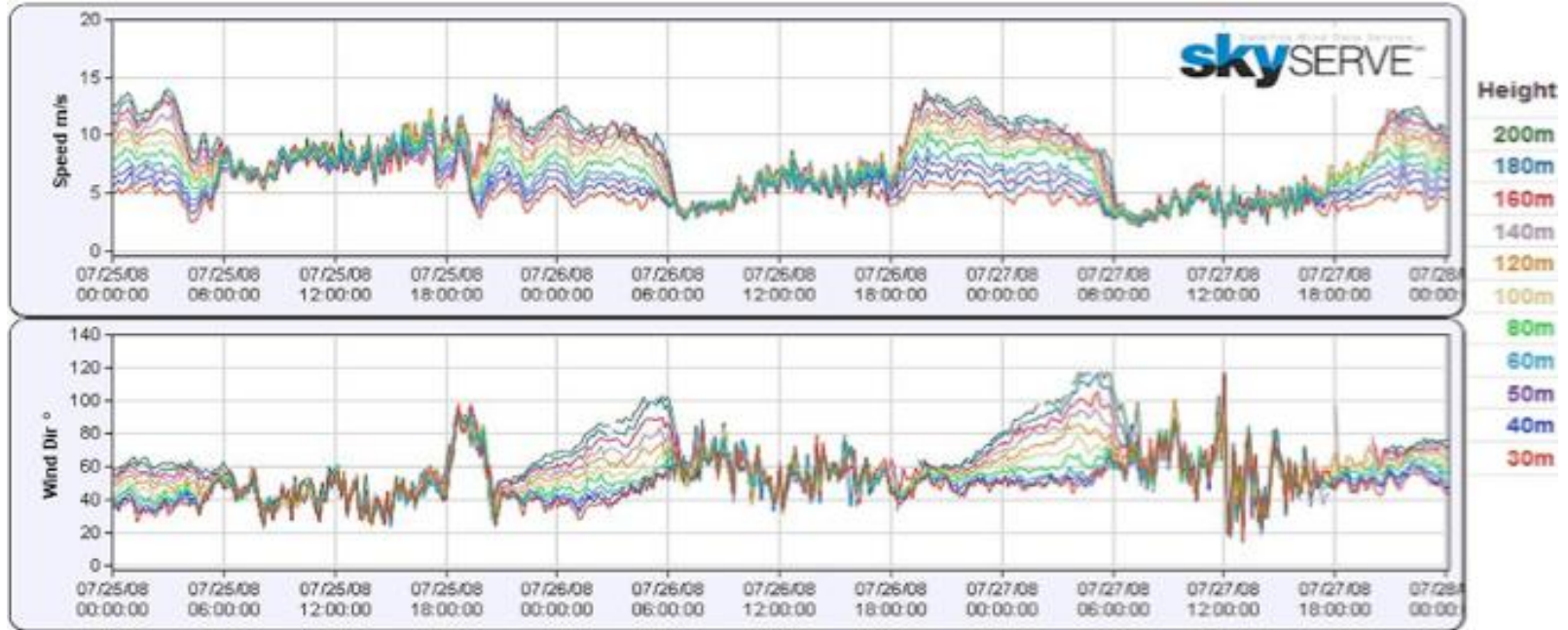
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Wind Shear Comparison

- Can Triton accurately capture wind shear at and above hub height?

Wind Shear / Wind Veer Measurement



Remote sensing reveals anomalies in the wind that can skew annual energy production estimates and affect turbine performance.

Conclusions

- Triton provides a mobile, versatile, reliable remotely sensed wind measurement at hub height and above
- Global validation suggests error in long-term mean wind speed of around 1.0%
- QC is straightforward with thresholding techniques
- In India, data recovery is strong and results are accurate, in spite of monsoon rain
- Triton can accurately quantify changes in shear from lower heights to hub height and above.

Ongoing Validation Studies

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



China
Hydroelectric
Corporation



नीवे NIWE



Vaisala's Unique Position



MANY DEPLOYMENTS HAD
COLLOCATED TOWERS

MANY LEADING CUSTOMERS
VOLUNTEERED DATA FOR
A GLOBAL STUDY

IN-HOUSE WIND RESOURCE
ASSESSMENT EXPERTISE