Monitoring Changes of Tropical Extreme Rainfall Events Using Differential Absorption Barometric Radar (DiBAR)

introduction, measurement approach: O₂ absorption, technology development, space application, summary

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Water and Energy cycles in the Tropics
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Objectives and Progresses

- Develop satellite capability of Surface Level Pressure (SLP) observations, especially over oceans
- Global SLP measurements will:
  - greatly improve hurricane forecasts (intensification & track predictions)
  - advance severe weather forecasts
  - directly measure the fundamental variable of meteorological dynamics
- Current: develop Proof-of-Concept (PoC) system, demonstrate the Differential absorption BArometric Radar (DiBAR) technology using PoC system for SLP measurements
- Existing capability: limited obs from buoy & dropsonde over oceans
Benefits of sea surface barometry

Hurricane Katrina

Aug 26, 2005

Aug 29, 2005

350 km landfall error reduced to < 100 km

Min et al., 2014

Lawrence et al., 2012

With P data

Actual track

Fran'97
Atmospheric attenuation

Max: 2-way 50dB
Oxygen in the atmosphere attenuates the transmitted signal — less at lower freq. and more at higher freq.

The amount of attenuation is directly related to barometric pressure and altitude.

Aircraft/Spacecraft-Based Q-Band (50-56GHz) Radar

Calibrated $P_{\text{Rec}}$

$P_{\text{Rec}}$

$f$ or $1/\lambda$ (50~56GHz)

The amount of attenuation is directly related to barometric pressure and altitude.
Radar Simulated Results

Lin and Hu, 2005

Millan et al., 2014
Agilent 8362B Network Analyzer

SpaceK Labs 45GHz Up/Down Converter

Quinstar 24" Cassegrain Antennas simplified to a small horn during flights
Stability (short- and long-term)

- Characterization of the end-to-end spectral response and linearity
- Repeatability suggests calibrations will be stable both short and long terms.
- Flight tests will use measurements at low altitudes to verify spectral calibration.

repeating tests in 30 minutes and 6 months

Besides lab tests, tests in open fields and over bridges were also conducted.
Flight Test: Spectral Scanning

![Graph showing spectral scanning data with frequency on the x-axis and difference in absorption (dB) on the y-axis. The graph includes two sets of data distinguished by red and black lines, with labels for observed (obs) and simulated (simu) data at different altitudes (1219m and 1524m).]
Flight Test Results

- Differential absorption was measured for 1000 – 6000 ft.
- Results are consistent with $\text{O}_2$ absorption model.
- Sensitivity to surface barometric pressure has been demonstrated.

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\Delta P_{\text{surface}} = 10 \text{ mb}
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\begin{align*}
+ \frac{\text{Ri}(2000)}{\text{Ri}(500)} \\
\Delta \frac{\text{Ri}(3000)}{\text{Ri}(500)}
\end{align*}
\]

\[
\begin{align*}
P_s = 1018 \text{ mb} \\
P_s = 1028 \text{ mb}
\end{align*}
\]
Satellite Concept

T_{\text{orbit}} \sim 98 \text{ min}
LEO (705 \text{ km})

DiBAR

\pm 10^\circ

\sim 1/6 \,^\circ
2 \text{ km}

\leftarrow 250 \text{ km} \rightarrow

Design Est.:
Mass: 250kg
Power: 250W
& DL Comm.
FY -- TBD
Summary

The SLP measurement approach will dramatically extend the current, limited-point barometric measurements for tropical storm observations when spaceborne instruments are available.

- The differential O₂ absorption approach will provide the first remote sensing barometric data over tropics!
- The accuracy of instantaneous sea surface air pressure measurements from O₂-band sensors could be as high as ~4 mb.
- DiBAR technology will lead significant improvements in predictions of hurricane intensities and tracks and provide great benefits for the public.
- Operational capability of DiBAR approach potentially enables the monitoring of changes in the extreme precipitation events such as tropical storms over tropics, and has both weather and climate applications.