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 BAromatic 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

350 km landfall error reduced to < 100 km

Min et al., 2014
Lawrence et al., 2012
Atmospheric attenuation

Max: 2-way 50dB

Frequency (GHz)

Attenuation (dB)
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

Measurement Concept

Calibrated $P_{\text{Rec}}$ 

$P_{\text{Rec}}$ 

$1/f$ 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
PoC Instrument Development

Agilent 8362B PNA

50-56 GHz Transceiver

Port 1

10 MHz Ref

5-11 GHz IF

5-11 GHz IF

5-11 GHz PLO

15 GHz PLO

50-56 GHz

Transmit Antenna

Receive Antenna

Network Analyzer Converter

Antenna (underneath)

Shock Absorber

O2-Band Radar integration

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

![Graphs showing spectral scanning data](image-url)
DiBAR Flight Test

Flight Test Results

- Differential absorption was measured for 1000 – 6000 ft.
- Results are consistent with O₂ absorption model
- Sensitivity to surface barometric pressure has been demonstrated

\[ \Delta P_{\text{surface}} = 10 \text{ mb} \]

+ Ri(2000)/Ri(500)  
+ Ri(3000)/Ri(500) 

\[ R_i(3000)/R_i(500) = \frac{P_s - 1028 \text{ mb}}{1018 \text{ mb} - P_s} \]

\[ P_s = 1018 \text{ mb} \]

\[ P_s = 1028 \text{ mb} \]
Satellite Concept

$T_{\text{orbit}} \sim 98 \text{ min}$

LEO (705 km)

DiBAR

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

$\pm 10^\circ$

$\sim 1/6^\circ$

2 km

$\leftarrow 250 \text{ km} \rightarrow$
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 $O_2$ absorption approach will provide the first remote sensing barometric data over tropics!
- The accuracy of instantaneous sea surface air pressure measurements from $O_2$-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.