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

Aug 26, 2005

350 km landfall error reduced to < 100 km

Fran'97

Aug 29, 2005

Control

with P data

actual track

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.

**Measurement Concept**

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

\[ P_{\text{Rec}} \]

**Calibrated \( P_{\text{Rec}} \)** w/o Attenuation

f or \( 1/\lambda \) (50~56GHz)
Radar Simulated Results

Lin and Hu, 2005

Millan et al., 2014
PoC Instrument Development

Agilent 8362B PNA

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 with labels for observations and simulations at different altitudes.]

- Red: simulation
- Black: observation

Altitudes:
- 1219m
- 1524m

Frequency (GHz) vs. Difference Abs (dB)
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

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

\[ + \text{Ri}(2000)/\text{Ri}(500) \]
\[ + \triangle \text{Ri}(3000)/\text{Ri}(500) \]

\[ \text{P}_{s} = 1018 \text{ mb} \]

\[ + 2000 \text{ ft} \]
\[ \triangle 3000 \text{ ft} \]

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

\[ \text{SLP}=1028 \text{ mb} \]
**Satellite Concept**

- **Orbit**: ~98 min
- **LEO**: (705 km)

**DiBAR**

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

- **±10°**
- **~1/6°**
- **2 km**
- **250 km**
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 $\sim4$ 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.