Remote Sensing Global Surface Air Pressure using Differential Absorption BARometric Radar (DiBAR)

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Objectives

(Dynamic fields, hurricanes)

- 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
Benefits of sea surface barometry

Hurricane Katrina

Aug 26, 2005
Aug 29, 2005

Min et al., 2014

Fran’97

350 km landfall error reduced to < 100 km

with P data

actual track

Aug 26, 2005
Aug 29, 2005
Current Capability

In-Situ Sea Surface Air Pressure Measurements for Weather Forecasts and Atmospheric Dynamics

Existing techniques: in-situ

- Spatial coverage: very limited
- Costs: high
- Buoy: uncertain in hurricanes
- Uncertainty: ~1 mb

No remote sensing technique is available.
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.
Simulated barometry results

Lin and Hu, 2005

Global weather conditions
PoC Instrument developed

Agilent 8362B PNA

SpaceK Labs 45GHz Up/Down Converter

Quinstar 24" Cassegrain Antennas
DiBAR flight results

The measured differential loss validated the predicted frequency dependence and was clearly correlated with surface level pressure.

- Increased O\textsubscript{2} absorption loss vs. frequency evident for all flight measurements.
- Differential absorption, or Ri, shows correlated with increasing SLP for the flight campaign data.
DiBAR Flight Test

- Differential absorption was measured for 0 – 2 km altitudes.
- Results are consistent with $\text{O}_2$ absorption model.
- Sensitivity to surface barometric pressure demonstrated.

\[
\begin{align*}
+ \frac{R_i(2000)}{R_i(500)} & \quad P_s = 1018 \text{ mb} \\
\triangle R_i(3000) / R_i(500) & \\
- \frac{R_i(2000)}{R_i(500)} & \quad P_s = 1028 \text{ mb} \\
\triangle R_i(3000) / R_i(500) & \\
\end{align*}
\]

\[\Delta P_{\text{surface}} = 10 \text{ mb}\]
Radar Sea Level Pressure Remote Sensing for Improvements in Hurricane Predictions

**Satellite Concept**

- **T_{orbit}** ~98 min
- **LEO (705 km)**

**DiBAR**

- Design Est.:
  - Mass: 250 kg
  - FY -- TBD

- ±10°
- ~1/6°
- 2 km

← 250 km →

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Image NASA © 2007 Europa Technologies
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Summary

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

- The differential $O_2$ absorption approach will provide the first remote sensing barometric data over the globe!
- The accuracy of instantaneous sea surface air pressure measurements from $O_2$-band sensors could be as high as $\sim 4$ 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 storm and precipitation events such as tropical storms, and has both weather and climate applications.