Remote Sensing Global Surface Air Pressure using Differential Absorption BAromatic 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 BARometric 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

350 km landfall error reduced to < 100 km
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 50 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 (50-55GHz) Radar

Measurement Concept

Calibrated $P_{\text{Rec}}$ w/o Attenuation

Attenuation

$P_{\text{Rec}}$

$f$ or $1/\lambda$ (50~55GHz)

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

50-56 GHz Transceiver

Port 1

Port 2

10 MHz Ref

5-11 GHz IF

15 GHz PLO

5-11 GHz IF

50-56 GHz

Transmit Antenna

Receive Antenna

Agilent 8362B Network Analyzer

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 O₂ 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 O_2 absorption model.
- Sensitivity to surface barometric pressure demonstrated.

\[ \frac{\text{Ri}(2000)}{\text{Ri}(500)} \]
\[ \frac{\Delta \text{Ri}(3000)}{\text{Ri}(500)} \]

\[ P_s = 1018 \text{ mb} \]
\[ P_s = 1028 \text{ mb} \]

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

**Satellite Concept**

- **T<sub>orbit</sub>**: ~98 min
- **LEO (705 km)**

**DiBAR**

- **DiBAR Coverage**: ±10°
- **Field of View**: ~1/6°, 2 km
- **Range**: 250 km

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