A Combined GPS-RO and WindCam System for PBL Remote Sensing

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Synergy of GPS RO, WindCam, and ??? on I-Train

- **Climate**
  - PBL cloud, humidity, height, and winds
  - Climate monitoring (e.g., Temperature and humidity)
  - Clouds dynamics and feedback processes

- **Weather**
  - Severe weather forecast (e.g., Tropical cyclone and convection)
  - Dispersion of pollutants and toxic/trace gases (e.g., CO2) in PBL

- **Challenges for PBL remote sensing**
  - Technical readiness
  - Vertical resolution: ~100 m
  - Horizontal resolution: 100-1000 m
  - Shallow layer, diurnal cycle, and global coverage
GPS RO: A Limb Technique for PBL Height and Humidity
GPS RO: High Vertical Resolution

- Enhanced reflectivity sensitivity to PBL inversion
- 50 Hz (~20 m) sampling
- Insensitive to clouds
- Day and night

\[ \theta \]
\[ q_t \]

Bending angle (Deg)

Courtesy of F. Xie
Ratnam and Basha [2010]
WindCam: A Stereo Technique for Cloud Height and Winds
Stereoscopic Viewing Technique

Multiangle Imaging Spectroradiometer (MISR)

9 view angles at Earth surface:
Nadir ±26°, ±46°, ±60°, ±70°

4 bands at each angle:
446, 558, 672, 866 nm

Daylight pole-to-pole coverage with 400-km swath

275 m - 1.1 km resolution

7 minutes to observe each scene at all 9 angles

Global data since March 2000
MISR High-Resolution Cloud Top Height and Winds

MISR Flight Direction

-46 s 46 s

Stereo Technique

-26° +26°

Cloud Top Height

Cross Track

Ground Track

Parallax
MISR High-Resolution Cloud Top Height and Winds

MISR Flight Direction

Stereo Technique

Along Track wind precision
± 3-4 m/s

Ground Track

Cross Track wind
~ ±1 m/s
Hurricane Earl
8/30/2010
(orbit 37285)

Boundary layer wind field

High-level outflow

Courtesy of Kevin Mueller
Boundary-Layer Clouds inside Tropical Cyclone’s Eye

- Tangential wind speed at 1.1 km resolution
- Detailed angular rotation and structures
- Monitoring and forecasting cyclone intensity

Hurricane Alberto (2000)

Radial Distance from Center (km)
What is the correlation between cloud top height and the wind divergence?

How are cellular structures related to wind convergence/divergence?

What determine cloud height variations?

PBL Height-Wind Relationship

Courtesy of Matt Scholes

- What is the correlation between cloud top height and the wind divergence?
- How are cellular structures related to wind convergence/divergence?
- What determine cloud height variations?
Clouds from Ship Tracks (Aerosol-Cloud Interactions)

Height Precision:

< 50 m
Arctic Roll Clouds

- Arctic cold air outbreak on Oct 17, 2007 over Beaufort Sea
- Cloud rolls originated from sea ice edge
- Retrievals from MINX showing cloud height increases from 200 m to 800 m in 150 km with increasing wind speed
Meridional Winds

MISR (0-3 km)  
NCEP/NCAR reanalysis (0-3 km)


m/s

Courtesy of Jae N. Lee
## WindCam: A Concept for Small Satellite

<table>
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<tr>
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<th>MISR</th>
<th>WindCam</th>
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<tr>
<td>Camera Configuration</td>
<td>9 narrow angle cameras, 4 VNIR bands</td>
<td>1 wide angle camera, 1 red band</td>
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<td>View Angles</td>
<td>Nadir, 26°, 46°, 60°, 70°</td>
<td>Nadir, 40°, 60°, 70°</td>
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<tr>
<td>Resolution</td>
<td>Resolution preserved by varying the camera focal lengths vs. angle</td>
<td>Resolution preserved by varying the detector sizes vs. angle</td>
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<tr>
<td>Mass</td>
<td>150 kg</td>
<td>17 kg</td>
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<tr>
<td>Power</td>
<td>75 W</td>
<td>23 W</td>
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<tr>
<td>Data Rate</td>
<td>7 Mbps</td>
<td>&lt;3 Mbps</td>
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<td>Spatial Resolution</td>
<td>275 m</td>
<td>250 m</td>
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<td>Swath</td>
<td>400 km swath</td>
<td>1000 km swath</td>
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<td>Global Coverage</td>
<td>- 9 days</td>
<td>Daily global coverage from 3 platforms</td>
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</table>

Diner et al. (2008)
WindCam: Twin Satellite Formation

Flight direction

WindCam
- Cloud height
  - Precision < 100 m
- Wind vector
  - Precision < 1 m/s

Cloud winds

parallax
GPS RO

9 min

WindCam

9 min

WindCam

9 min

???

Swath ~1000 km

Swath ~1000 km
GPS RO on Iridium-NEXT

Multi-freq tracking
High gain antenna
Mass: ~10 kg
Power: 10-35 W

Courtesy of Tom Meehan