The Vapor/Ice Profiling Radar (VIPR)

Matt Lebsock¹, Luis Millán¹, Ken Cooper¹, Raquel Monje¹, Jose Siles¹, Andrew Brown²

¹Jet Propulsion Laboratory, California Institute of Technology
²Raytheon

Copyright 2016. California Institute of Technology
Government sponsorship acknowledged
What is it?

• Differential Absorption Radar (DAR)
  – Microwave analogue of DIAL

• An emerging concept to profile water vapor within the cloudy atmosphere.
  – Complements existing water vapor observations
Weather Measurement Need

One of the critical atmospheric variables that are **not adequately measured** by current or planned system is temperature and **humidity profiles** of adequate vertical resolution **in cloudy areas**.

[Andersson (2014) – Statement of guidance for numerical weather prediction, WMO report.]
Vapor / Ice Profiling Radar

VIPR

Development supported by NASA ESTO

2013: ACT (Advanced Component Technology)
PI: Ken Cooper
- Develop a 183 GHz source
- Integrate into a transceiver
- Entry TRL = 2, Exit TRL = 4

2016: IIP (Instrument Incubator Program)
PI: Matt Lebsock
- Build airborne VIPR radar
- Demonstrate and validate
- Entry TRL = 3, Exit TRL = 6
Frequency Modulated Continuous Wave (FMCW) radar.
- 183 GHz with 10 GHz frequency sweep
- Heritage in high frequency radar development for security applications
- All solid state components are compact
- ~1W transmit power.
Near the 183 GHz absorption line the difference in reflectivity between two frequencies is a linear function of the atmospheric water vapor content.
## Filling an Observation Gap

<table>
<thead>
<tr>
<th>Existing Sounding Techniques</th>
<th>DAR Provides</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR Sounding</td>
<td>• In cloud sounding</td>
</tr>
<tr>
<td>Microwave Sounding</td>
<td>• High resolution (~500 m x 2 km²)</td>
</tr>
<tr>
<td>Radio Occultation</td>
<td></td>
</tr>
<tr>
<td>Limb Sounding</td>
<td></td>
</tr>
<tr>
<td>Differential Absorption Lidar</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Existing Column Integral Techniques</th>
<th>DAR Provides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microwave imagery</td>
<td>• All surface types</td>
</tr>
<tr>
<td>Near-IR imagery</td>
<td>• All weather conditions</td>
</tr>
<tr>
<td></td>
<td>• High resolution (~2 km²)</td>
</tr>
<tr>
<td></td>
<td>• Improved precision</td>
</tr>
</tbody>
</table>
Instrument Simulations

CloudSat:
Observed

DAR:
Simulated

A) Cloud H₂O

B) Vapor H₂O

C) VIPR online

D) VIPR online-offline

Lat: -35 -34 -33 -32 -31 -30 -29

dBZ

Z₁₈₈, Z₁₉₃ [dBZ]
- DAR can provide CWV over all surfaces and cloud conditions with high accuracy
• Attenuation provides the differential radar signal

BUT

• Attenuation limits penetration depth (sampling)

Analysis guides frequency selection considerations. Probing high-altitude clouds requires different frequency-pairs than does low-altitude clouds.
DAR Capabilities

DAR water vapor measurements can provide:

In-cloud water vapor profiles
- Resolution possible at cloud scale (~500 m by 2 km)

Continuous column water vapor
- ~2 km horizontal resolution
- All surface types
- All weather conditions

Publications:
Millán (2014) – 10.5194/amt-7-3959-2014
Cooper (in preparation)
First VIPR Observations

[Image of equipment labeled with parts like Tx horn, Rx horn, wire grid, beam path, grating, paraboloid]

[Graph showing frequency vs. attenuation with measurements, initial guess, and retrieved values plotted]

[Legend indicating measurements, initial guess, and retrieved values]
Science Scenario 1: Convective Mixing

• How efficiently does moist convection transport moisture to the upper troposphere?
Science Scenario 3: Water Vapor Variance

- Cell width ~ 15-25 km (Order ~ microwave imagers).
- High resolution CWV would enable quantifying the variance.

Different cloud regimes have very different water vapor variability

Larson et al., 2002