Value Added Procedures at the ARM Experiment Center

Pacific Northwest National Laboratory
Richland, Washington

Introduction

Unlike many other scientific projects, the Atmospheric Radiation Measurement (ARM) Program collects data in an ongoing, continuous manner. Because of the volume of these perpetual data streams, traditional case study methods for analyzing these data are not very effective. The concept of Value Added Procedures (VAPs) was developed to fit the need for an automatic analytical approach to ARM data streams. A VAP creates a “second generation” data stream by using existing ARM data streams as inputs and applying algorithms or models to them. A VAP is run continuously in the ARM Experiment Center, and the output generated is treated as a new ARM data stream (Figure 1).

![Figure 1. VAP data flow. Note that VAPs output new data streams, which can in turn be used as input for other VAPs.](image)

Many of the scientific needs of the ARM Program are met through VAPs. Physical models that use ARM instrument data as inputs are implemented as VAPs and can help fill some of the unmet measurement needs of the program. A special class of VAPs called Quality Measurement Experiments (QMEs) compare different data streams, allowing continuous assessment of the quality of ARM data or comparisons between instruments and models (Miller et al. 1995). Therefore, VAPs are the tools by which the ARM Program can validate and enhance both instrument and model performance.
New VAPs or suggestions for improvements or modifications to existing VAPs come from all parts of the ARM Program (e.g., science team members, instrument mentors, data and science integration team members, site scientists). A primary function of the ARM Science Applications Group (SAG) is to oversee the development of VAPs for each Geophysical Focus Area (GFA) within ARM. Each focus area has been assigned a member of SAG to work with the lead scientist to facilitate collaborations within the GFA and to coordinate intensive observation periods (IOPs), in addition to overseeing the VAP development for the GFA. Table 1 lists the lead scientists and the infrastructure liaison for each GFA. Tables 2 through 5 list the VAPs currently in production, active development, or near-term development. The symbols on the left of each VAP indicate the primary GFA(s) customers. The listed points of contact can provide more information on each VAP.

<table>
<thead>
<tr>
<th>GFA</th>
<th>Infrastructure</th>
<th>Science Team</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortwave Radiation</td>
<td>Don Slater</td>
<td>Warren Wiscombe</td>
</tr>
<tr>
<td>Longwave Radiation</td>
<td>Tim Shippert</td>
<td>Bob Ellingson</td>
</tr>
<tr>
<td>Cloud Characterization</td>
<td>Dan Rodriguez</td>
<td>Steve Krueger</td>
</tr>
<tr>
<td>Water Vapor</td>
<td>Dave Turner</td>
<td>Hank Revercomb</td>
</tr>
<tr>
<td>Aerosols</td>
<td>Ric Cederwall</td>
<td>Steve Schwartz</td>
</tr>
<tr>
<td>Surface Energy Exchange</td>
<td>Ric Cederwall</td>
<td>Chris Doran</td>
</tr>
<tr>
<td>Single-Column Models</td>
<td>Ric Cederwall</td>
<td>Dave Randall</td>
</tr>
</tbody>
</table>

**Example Flow Diagram: Raman Lidar Best-Estimate**

The data flow in the ARM Experiment Center can quickly become very complicated. For example, Figure 2 illustrates the complexity of the input processing required in order to run the Raman Lidar best-estimate (RL PROF BE) VAP. Many VAPs require input from multiple sources, including data directly from the instrument as well as other VAPs, and thus changes in a data stream can have large impacts on the downstream processing.

**Conclusion**

As the ARM Cloud and Radiation Testbed (CART) sites transition from development to operational states, the level of importance of VAPs is going to increase. The science applications group through interactions with the geophysical focus area working groups and lead scientists, are working to develop new ideas for VAPs, prioritize them, and implement them in the operational ARM environment. The process would not be possible without the feedback from the science team via the GFA working groups. More information on Value Added Producers can be found on the ARM web site at [http://www.arm.gov/docs/research/vap_homepage/vap.html](http://www.arm.gov/docs/research/vap_homepage/vap.html).
### Table 2. VAPs currently in production at the ARM Experiment Center.

<table>
<thead>
<tr>
<th>In Production</th>
<th>BE SW</th>
<th>Contacts: Shippert Wiscombe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Best-estimate shortwave radiation products: total, diffuse, direct, etc.</td>
<td></td>
</tr>
<tr>
<td>LBL ASTI</td>
<td>Contacts: Shippert Clough/Brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shortwave clear-sky radiance calculations at Absolute Solar Transmittance Interferometer (ASTI) resolution from the Line-By-Line Radiative Transfer Model (LBLRTM).</td>
<td></td>
</tr>
<tr>
<td>LBL CLOUD E</td>
<td>Contacts: Shippert Clough/Brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effective longwave cloud emissivity derived from Atmospheric Emittted Radiance Interferometer (AERI) and LBLRTM measurements.</td>
<td></td>
</tr>
<tr>
<td>LBL MWR</td>
<td>Contacts: Shippert Clough/Brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clear-sky brightness temperature calculations at Microwave Radiometer (MWR) frequencies from LBLRTM.</td>
<td></td>
</tr>
<tr>
<td>LBL RTM</td>
<td>Contacts: Shippert Clough/Brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Longwave clear-sky radiance calculations at AERI resolution from the LBLRTM.</td>
<td></td>
</tr>
<tr>
<td>LS SONDE</td>
<td>Contacts: Turner Clough/Brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radiosonde profiles where the relative humidity (RH) profile is scaled to match MWR's precipitable water vapor (PWV).</td>
<td></td>
</tr>
<tr>
<td>MWR PROF</td>
<td>Contacts: Halter Westwater</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temperature and water vapor profiles retrieved from MWR, Radio Acoustic Sounding System (RASS), &amp; Surface Meteorological Observing Station (SMOS) observations.</td>
<td></td>
</tr>
<tr>
<td>QME AERI/LBL</td>
<td>Contacts: Turner Clough/Brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Statistical analysis of AERI - LBLRTM residuals by process, bin, etc.</td>
<td></td>
</tr>
<tr>
<td>QME AERI/LBL CLOUDS</td>
<td>Contacts: Turner Clough/Brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>State of the atmosphere information to facilitate QME AERI/LBLRTM analysis.</td>
<td></td>
</tr>
<tr>
<td>QME AERI PROF</td>
<td>Contacts: Halter Feltz/Smith</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Statistical comparisons of the AERI PROF retrievals to radiosondes.</td>
<td></td>
</tr>
<tr>
<td>QME ASTI LBL</td>
<td>Contacts: Shippert Clough/Brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comparison of ASTI instrument and LBL model radiances.</td>
<td></td>
</tr>
<tr>
<td>QME MWR COL</td>
<td>Contacts: Halter Liljegren</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comparison of MWR brightness temperatures to an instrument model.</td>
<td></td>
</tr>
<tr>
<td>QME MWR PROF</td>
<td>Contacts: Halter Westwater</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Statistical comparisons of the MWR PROF retrievals to radiosondes.</td>
<td></td>
</tr>
<tr>
<td>RWP TEMP</td>
<td>Contacts: Christy/Shippert Coulter</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Merged virtual temperature profiles from the 915-MHz RASS and 50-MHz RASS.</td>
<td></td>
</tr>
<tr>
<td>TWR MR</td>
<td>Contacts: Turner Turner</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water vapor mixing ratio at surface, 25-m, and 60-m tower heights.</td>
<td></td>
</tr>
<tr>
<td>W RE SONDE</td>
<td>Contacts: Yio Cederwall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Processed wind data from radiosondes.</td>
<td></td>
</tr>
</tbody>
</table>
Table 3. VAPs currently in production at the ARM Experiment Center, but which are also undergoing further development. The development cycle for a VAP typically includes many such revisions.

<table>
<thead>
<tr>
<th>In Production and Development</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(G)AERI PROF</strong> Contacts: Halter/Feltz Feltz/Smith</td>
</tr>
<tr>
<td>Temperature and water vapor profiles physically retrieved from AERI radiance.</td>
</tr>
<tr>
<td><strong>LANGLEY</strong> Contacts: Shippert/Halter Barnard</td>
</tr>
<tr>
<td>Total optical depths from Multifilter Rotating Shadowband Radiometers (MFRSRs) using Langley plots.</td>
</tr>
<tr>
<td><strong>LBL RSS</strong> Contacts: Shippert Clough/Brown</td>
</tr>
<tr>
<td>Shortwave radiance calculations at Rotating Shadowband Specktroradiometer (RSS) filter wavelengths from LBLRTM.</td>
</tr>
<tr>
<td><strong>MPL NOR</strong> Contacts: Turner Campbell/Hlavka</td>
</tr>
<tr>
<td>Micropulse Lidar (MPL) backscatter profiles normalized and cloud detection routine applied.</td>
</tr>
<tr>
<td><strong>QME RSS LBL</strong> Contacts: Shippert Clough/Brown</td>
</tr>
<tr>
<td>Comparison of RSS instrument and LBL model radiances.</td>
</tr>
</tbody>
</table>

Table 4. VAPs currently in development at the ARM Experiment Center.

<table>
<thead>
<tr>
<th>In Development</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ARSCL</strong> Contacts: Clothiaux/Turner</td>
</tr>
<tr>
<td>Best-estimate cloud location from active remote sensors &amp; Millimeter-Wavelength Cloud Radar (MMCR) moments data.</td>
</tr>
<tr>
<td><strong>BA EBBR</strong> Contacts: Christy/Shippert Coulter</td>
</tr>
<tr>
<td>Bulk aerodynamic estimates of sensible &amp; latent heat fluxes to complement the Energy Balance Bowen Ratio (EBBR).</td>
</tr>
<tr>
<td><strong>RL PROF MR</strong> Contacts: Turner Ferrare/Turner</td>
</tr>
<tr>
<td>Mixing ratio profiles, RH profiles, and PWV from the Raman Lidar.</td>
</tr>
<tr>
<td><strong>RL PROF ASR</strong> Contacts: Heilman/Turner Ferrare/Turner</td>
</tr>
<tr>
<td>Aerosol scattering ratio and backscattering coefficient profiles from the Raman Lidar.</td>
</tr>
<tr>
<td><strong>RL PROF DEP</strong> Contacts: Turner Ferrare/Turner</td>
</tr>
<tr>
<td>Depolarization profiles from the Raman lidar.</td>
</tr>
<tr>
<td><strong>RL PROF EXT</strong> Contacts: Turner Ferrare/Turner</td>
</tr>
<tr>
<td>Aerosol extinction profiles and aerosol optical thickness from the Raman Lidar.</td>
</tr>
<tr>
<td><strong>RL PROF BE</strong> Contacts: Turner Ferrare/Turner</td>
</tr>
<tr>
<td>Best-estimate state of the atmosphere product from the Raman Lidar and AERI+Geostationary Observational Environmental Satellite (GOES).</td>
</tr>
</tbody>
</table>
Table 5. VAPs that are planned for future development and release into production at the ARM Experiment Center. This is not an exhaustive list, but is a representative sample of the kinds of products we hope to produce in the following year.

<table>
<thead>
<tr>
<th>Future Work</th>
<th>Contacts:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CLD MICRO ICE 1(2)MACE</td>
<td>Halter</td>
<td>Mace</td>
</tr>
<tr>
<td>Liquid cloud microphysics derived from MMCR reflectivities (moments) and AERI radiances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLD MICRO LIQ 1MACE</td>
<td>Halter</td>
<td>Mace</td>
</tr>
<tr>
<td>Liquid water cloud microphysics derived from MMCR and MWR.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLD MICRO LIQ 1DONG</td>
<td>Halter</td>
<td>Dong</td>
</tr>
<tr>
<td>Liquid water cloud microphysics derived from MMCR, radiosondes, and pyranometer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MFRSR AOD 1CHENG</td>
<td>Shippert</td>
<td>Cheng</td>
</tr>
<tr>
<td>Aerosol optical depth retrievals from the MFRSR.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MWR LIQ 1LILJ</td>
<td>Halter</td>
<td>Liljegren</td>
</tr>
<tr>
<td>Cloud liquid water path retrievals from the MWR.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW F ANALYSIS</td>
<td>Shippert</td>
<td>Long</td>
</tr>
<tr>
<td>Shortwave analysis: clear-sky flux and cloud fraction estimates, albedo, and QC.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reference

Figure 2. Raman Lidar best-estimate flow diagram. Green boxes are ARM instrument data streams; the purple box (GOES-8) is an external data stream. Red circles are VAPs. The blow-up of the RLPROF ASR VAP shows the level of complexity that can exist inside each VAP.