Global Monitoring Division

Supporting Infrastructure Presentations

2013-2017 Review

May 21-24, 2018

Contents:

- Trace Gas, Ozone and Radiation Standards/Calibrations ..............2-12
- GMD Atmospheric Baseline Observatories ..................................13-20
Calibration and Standards Activities

GMD Research Themes and Applications

- Solar & Terrestrial Radiation
- Dobson Column Ozone
- Trace Gases
- Federated Aerosol Network
Solar & Terrestrial Radiation

- Calibration support for GMD observatories and Baseline Surface Radiation Network (BSRN) sites at Kwajalein, Bermuda
- GMD reference cavity radiometers - traceable to World Radiation Center (Davos, Switzerland)

IPC 2015 Results for the six NOAA Active Cavity Pyrheliometers

<table>
<thead>
<tr>
<th>Pyrheliometer</th>
<th>AWX</th>
<th>AWX</th>
<th>AHF</th>
<th>AHF</th>
<th>AHF</th>
<th>TMI</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>31114</td>
<td>32448</td>
<td>28553</td>
<td>30710</td>
<td>14917</td>
<td>67502</td>
</tr>
<tr>
<td>WRR factor</td>
<td>1.002</td>
<td>1.001</td>
<td>0.998</td>
<td>1.002</td>
<td>0.998</td>
<td>1.002</td>
</tr>
</tbody>
</table>

- WMO Region IV National Radiometric Calibration Center for the U.S.
- Expanding calibration services to include instruments in the U.S. Climate Reference Network (NOAA Air Resources Lab)
Solar & Terrestrial Radiation

Central UV Calibration Facility (CUCF)

- NIST traveling primary standards:
  - limited lifetime
  - vertical orientation only
  - high cost (~$15K)

- **Practical Solution**: Collaboration with NIST and others ....
  GMD calibrates 1000 watt standard lamps in *horizontal and vertical* orientations, traceable to the NIST scale (Yoon, et al. 2003)

![Portable Calibration Unit](image)

Solar & Terrestrial Radiation

Hierarchical Approach

**Primary**
- NIST primary standards (2001 NIST detector-based irradiance scale)

**Secondary**
- 1st Triad
- 2nd Triad

**Tertiary**
- NEUBrew field standards
- CUCF laboratory standards
- Antarctic UV field standards
- NOAA-NIWA field standards

Vertical and horizontal tracking standards
WMO/GAW Regional Calibration Center

- CUCF Activities:
  - Absolute spectral irradiance calibrations (~40 per year)
  - Laboratory facility at GMD + portable calibration system
  - Characterization (spectral response, angular response, +more)
  - Host comparison activities (Lantz et al. 2001, Lantz et al. 2008)

Performing a Field Calibration

UV Spectral Response System

Dobson Column Ozone

Dobson Total Ozone Network

World Primary Standard D083

- Hohenpeissenberg, Germany D064, D072
- Irene, South Africa D065
- Buenos Aires, Argentina D070
- Melbourne, Australia D105
- Tsukuba, Japan D116

McConville, Dobson Ozone Network (P-53)
Dobson Column Ozone

Comparison between field instruments and reference instruments

- Used to establish consistency of measurement across the network(s)
- Allows us to evaluate:
  - combined datasets
    (important for Ozone Assessment)
  - stability of new satellites (i.e. JPSS)
  - stability of new instruments (i.e. Pandora)
Recent Developments: New Software

- WinDobson (developed by the Japan Meteorological Agency)
  - Facilitates near-real-time data
  - Improved QC
  - NRT data needed to support satellites (critical in post-launch year)
  - Efficient reprocessing of archive data

Identified 1-2% errors in SMO record (overall correction, all stations ~0.1%)

from Evans et al., 2017

Federated Aerosol Network

- Calibration derived from TROPOS (Germany)
- Network support, capacity-building role
- QA/QC
Trace Gases

- Primary methods – traceable to SI (to the extent possible)
- Flexibility – compatible with measurement method
- Support instrument development, complete understanding

Gas Blending Manifold

Compressed Gas Standards

Trace Gases

<table>
<thead>
<tr>
<th>CFCs</th>
<th>HCFCs</th>
<th>HFCs</th>
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</thead>
<tbody>
<tr>
<td>CFC-11</td>
<td>HFC-22</td>
<td>HFC-134a</td>
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<tr>
<td>CFC-12</td>
<td>HFC-141b</td>
<td>HFC-365mfc</td>
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<tr>
<td>CFC-113</td>
<td>HFC-142b</td>
<td>HFC-152a</td>
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<tr>
<td>CFC-114</td>
<td>HFC-133a</td>
<td>HFC-236fa</td>
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<tr>
<td>CFC-115</td>
<td>HCFC-21</td>
<td>HFC-143a</td>
</tr>
<tr>
<td>CFC-13</td>
<td>HCFC-11</td>
<td>HFC-227ea</td>
</tr>
</tbody>
</table>

Scales Developed within GMD

<table>
<thead>
<tr>
<th>Solvents</th>
<th>Halons</th>
<th>Sulfur Gases</th>
<th>Other Halocarbons</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₂CCl₃, CCI₂HCCl₂</td>
<td>Halon-1211, Halon-1301, Halon-2402</td>
<td>COS, SO₂F₂, CS₂, CF₂SF₅, SF₆</td>
<td>CH₃Br, CH₃Cl, CH₃I, CH₂Br₂, CHBr₃, CH₂BrCl, CHBr₂Cl, CH₂I₂, CH₂BrI, CH₂ClI, CF₃</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hydrocarbons</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetylene, n-pentane, i-pentane, propane, hexane, n-butane, benzene, i-butane, toluene</td>
<td>CO₂, CH₄, N₂O, CO, hydrogen, peroxycetyl nitrate, water vapor, perfluoro-amines, NF₃</td>
</tr>
</tbody>
</table>
Designated Institute of WMO

- For select gases: CO$_2$, CH$_4$, N$_2$O, CO, SF$_6$
- ISO 17025 – Quality Management System reviewed in 2015
- Participate in Key Comparisons – BIPM, National Metrology Institutes

Whole-Air Standards

- GMD distributes whole-air standards (tertiary)
  - Related to secondary/primary standard by analysis
  - A few other labs also make whole air standards (SIO, CSIRO, ICOS, NIWA)
  - GMD makes **custom mixtures**
  - Access to un-polluted whole air is extremely valuable to GMD
**Trace Gases**

**WMO/GAW Central Calibration Laboratory**

New CO$_2$/CH$_4$ analytical system

Since April, 2016

Crotwell, Carbon Monoxide (P-21)

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**Trace Gases**

**Research Component:**

Stability of CO$_2$ in aluminum cylinders

- CO$_2$ increases as pressure drops
  - Remarkably consistent
  - ~0.04 ppm increase (1 part in 10,000)
  - (comparable to compatibility goals)

Schibig et al., 2018
**Future Directions**

### Solar & Terrestrial Radiation

- Continue to facilitate a comparison to evaluate a new standard for longwave irradiance (with NREL/PMOD) (interim standard currently in use)
- Collaborate with NREL and National Central University, Taiwan to improve shortwave irradiance calibrations regarding infrared loss from sensors
- Improve direct-sun calibrations of the Brewer spectrophotometer to improve Aerosol Optical Depth retrievals

**Stierle, AOD Retrievals (P-49)**

### Dobson Column Ozone

- Possibly move D083 to MLO (eliminate risk of transport)
- Continue Dobson/Pandora/Satellite comparisons

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**Future Directions**

### Trace Gases

- Improve uncertainty estimates
- Update CO₂ calibration scale
- Facilitate WMO Round Robin #7

**Michel, Stable Isotopes of CO₂ (P-14)**

**Miller, Uncertainties (P-18)**

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**WMO Round Robin Comparison #6 Results: (CH₄)**
Summary

- Calibration activities are an essential component of GMD
- We provide calibration links among networks (regional/global scope)
  - Including critical support for WMO/GAW
- We play an active role in improving measurements
- Activities share common aspects: Commitment to consistency
Atmospheric Baseline Observatories

Radiative Forcing
Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks
Monitoring and Understanding Trends in Surface Radiation, Clouds, and Aerosols
Guiding Recovery of Stratospheric Ozone
Climate Sensitivity
Air Quality
Arctic Processes
Standards

Observatories

Renewable Energy Support
Climate Intervention

Brian Vasel
Director of Observatory Operations

Backbone of Global Networks

Barrow (BRW)
Elevation: 11m 71.3° N Latitude

Mauna Loa (MLO)
Elevation: 3397m 19.5° N Latitude

American Samoa (SMO)
Elevation: 42m 14.2° S Latitude

South Pole (SPO)
Elevation: 2840m 90° S Latitude
Observatory Operations Philosophy

ABOs enable and support Science 📈 Science drives decisions

- **Stewardship** – Build upon foundation of high-quality observations for over 45 years, continue "national treasure" legacy

- **Customer Service** – Plug and play remote field operations for researchers

- **Resources Tool Kit** – Provide highly skilled workforce & core of supporting measurements (meta-data) at each observatory. Updated meteorology, web cams, all-sky imagery, ceilometers, etc.

- **Efficiency** – Thrifty and resourceful operations; every dollar for operations is a dollar less for science

- **Innovation** – Expand and enhance the use of renewable technology, modernize instrumentation

- **Platform for Growth** – Dependable observatory resources + co-location of measurements = increase in interagency & interdisciplinary science collaboration
  - Promotion of observatory platform to audiences external to GMD
  (Other NOAA line offices, Federal partners, & University PIs)

ABO Historical and Relational Significance

**Staff Collaboration**

- Federal
- CIRES & JIMAR (Cooperative Institutes)
- STC contractors
- NOAA Corps Officers
  - 2-3 officers assigned to GMD at any given time

**Longevity**

- MLO and SPO records date back to 1956 and 1957 (IGY)
- BRW records begin in 1973, SMO in 1974
- First Geophysical Monitoring for Climatic Change (GMCC) Summary Report (1972)
  "... data are collected by a few observatories whose location is chosen to sample representative latitudes in both hemispheres where local man-made or biota interferences are minimal. First priority is placed on the collection of impeccable measurements of trace constituents."
- WMO Global Atmospheric Watch (GAW) network modeled on ABOs
**ABOs - Home of Scientifically Renowned Records**

Barrow Snow Melt Date

Atmospheric CO₂ at Mauna Loa Observatory

South Pole Ozone Hole

Ozone Depleting Gases

Mauna Loa Apparent Transmission

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**ABO Stats**

- **Total Peer-reviewed Publications using ABO datasets:** 6,307
- **2251 Peer-reviewed Publications Since 2013 Review!**
  - GMD Data Sets: 775
  - Staff: 16
  - Vehicle Fleet: 7
  - Total Acreage: 135
  - Miles of Driveway: 19
  - Cooperative Research Projects: 70
  - Solar Power: 165 panels (SMO = 33% and MLO = 20% of daytime demand)
  - Total Structures: 67
Operational Challenges

Operating Field Sites in remote locations poses unique challenges.

- Tight procurement & shipping timelines
- Dirty power
- Cultural considerations
- Natural disasters
- Extreme climates
- Clean Air Sector management
- NEPA & State Historic Preservation Office (SHPO) requirements
- Training of observatory personnel to provide reliable science support workforce
- Infrastructure maintenance

Facility Deferred Maintenance

Facility Condition Assessments (FCAs) - NOAA OCAO effort across agency

BRW - April 2015
- "The Observatory is in poor condition and appears to have outlived its useful life." Executive Summary, Page 10

SMO - April 2017
- "The Observatory Site is in Poor condition and is rated as a D. Condition is still somewhat adequate, but the assets are heading toward the latter half of their lifecycle." Executive Summary, Page 4

MLO - June 2017
- "The Observatory is in working order, however, OAR should plan for upcoming capital costs related to component renewals." Executive Summary, Page 7

Total = $1.8M in deferred maintenance projects
Keeping the Lights On

Simple Math
• Inflation: Increasing Cost of Business
• Steady Science Mission
• Flat Observatory Budget
• Increasingly Difficult to Manage

Prioritized Investments
• Life/facility safety
• Failures/repairs
• Improvements

Critical Mass
• Infrastructure investment essential to service science & maintain quality
• Science suffers without dependable resources

Considerations for THO & SUM

Hard Decisions
No longer support Trinidad Head, CA (THD) or Summit, Greenland (SUM) as NOAA "Atmospheric Baseline Observatories". However, still have critical measurements at each site.

• Rationale for sites & impact to partners
• Current facilities & planned upgrades
• Local influences vs. background? Science requirements.
• Efficiency - logistics requirements for each project:
  • Removed cargo/staff intensive projects
  • Kept low maintenance/power projects
• Ongoing Measurements: THD | SUM
  Aircraft flasks | CCGG flasks
  HATS flasks | HATS flasks
  Ozonesondes | Aerosol suite
  Surface ozone | Meteorology
Cooperative Research Projects

• Currently 70 projects across the observatory network are supported

1. Management process redesigned for cooperative projects to leverage Google platform benefits:
   • Email, calendar, forms, drive storage, and secure sharing to field sites

2. New & improved external support webpage created to enhance information sharing with partners, to include:
   • New request/renewal process
   • Logistics
   • Site access,
   • Fee structure, etc.

• We currently bring in $250K in reimbursable funds from partners

Near Term Observatory Goals

Efficiency - Greening the Observatories:
• Renewable energy
• LED Lighting 2018 DOC Green Grant

Building on Partnerships:
• Hilo office (NWS)
• USCG flight/cargo support
• NSF Office of Polar Programs {Arctic & Antarctic}
• Cooperative Projects
• Australia BOM/CSIRO staff training & exchange

Investment in Science:
• New Barrow Observatory Main Building
• New ARO at South Pole
• Additional land buffer at Mauna Loa
• NOTAMs for CAS no-fly zones
• Increase project cost reimbursements
Observatory Take Away

- Unique to OAR and NOAA
- Effective Spending
- Collaboration
- Innovation and Evolution
- Maintenance of Global Leadership
- Expand relevance to meet societal need

*World-class science demands world-class facilities*

Our Bi-Polar Observatory Team Thanks You!

*Sunrise at the Barrow Atmospheric Baseline Observatory - Vernal Equinox*

March 21st, 2018

*Sunset at the South Pole Atmospheric Baseline Observatory - Autumnal Equinox*
Questions?

The Night Sky over South Pole Station

Observatory Relevant GMAC Presentations:
- Oral Session 3 - Morris
- Oral Session 3 - Cox
- Oral Session 4 - Johnson
- Oral Session 4 - Petropavlovskikh
- Oral Session 4 - Witte
- Oral Session 8 - Davis
- Poster 2 - Williams
- Poster 3 - Ivey
- Poster 35 - He
- Poster 43 - Barnes
- Poster 44 - Shiobara
- Poster 48 - Disterhoft
- Poster 54 - Sun
- Poster 70 - Dix
- Poster 71 - Koenig
- Poster 74 - McClure-Begley
- +14 additional