Arctic Radiometer Modifications

Sara Crepinsek

Special Thanks: Chuck Long, Emiel Hall, Jim Wendell, Rob Albee
Goal(s) of Independent Study

• Investigate previous Storm Peak experiment
• Analyze mitigation strategies
  • Assess how radiometer modifications (i.e. heat and fan) impact measurements
  • Determine what changes should be made to instruments for future research installations to mitigate rime and precipitation events
Agenda

- **Part I**
  - State of the field - Overview
  - Alert station evidence and investigation
    - Experimental radiometer
  - Storm Peak experiment

- **Part II**
  - Independent study experiment
    - Installation details
  - IS experiment results and discussion
  - Future modifications
Part I – Previous Experiments and Overview
- **PSP – Pyranometer/shortwave**
  - Two domes
    - Reduce IR loss
    - *Small* IR loss to sky at night
      - Causes underestimation or negative irradiance signal at night
    - Designed to get rid of IR loss – *smaller* magnitude signal at night
- **PIR – Pyrgeometer/longwave**
  - One dome
    - Reflect sunlight, monitor negative signal
    - *Large* IR loss to sky at night
      - Causes underestimation or negative irradiance signal at night
    - Designed to measure IR emission of the sky – *larger* magnitude signal at night
Historic Rime/Snow Issues at Alert

Photo: Matt Okraszewski

Photo: Sara Crepinsek
Experimental Radiometer On-Site

- Modifications Intact:
  - Modified base plate
  - Modified housing
  - Fan (type unknown)
  - Air intake hosing
- Installed 2014 - 2016
Experimental Radiometer at Alert

After Installation – 2014

Before Disassembly – 2016
Storm Peak Experiment

Photo: Robert Albee
<table>
<thead>
<tr>
<th>Instrument ID#</th>
<th>SPL #6</th>
<th>SPL #5</th>
<th>SPL #4</th>
<th>SPL #3</th>
<th>SPL #2</th>
<th>SPL #1</th>
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<tbody>
<tr>
<td>Radiometer Manufacturer</td>
<td>Kipp&amp;Zonen</td>
<td>Kipp&amp;Zonen</td>
<td>Eppley</td>
<td>Eppley</td>
<td>Eppley</td>
<td>Eppley</td>
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<td>Radiometer Model/Type</td>
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<td>CM22</td>
<td>PSP</td>
<td>PIR</td>
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<tr>
<td>Radiometer Serial #</td>
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<td>060130</td>
<td>36763F3</td>
<td>34309F3</td>
<td>15953F3</td>
<td>15952F3</td>
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<td>$8.45 \times 10^6$ V/Wm²</td>
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<td>GMD stock</td>
<td>modified: ebmpapst VarioPro 3212 J/2HP</td>
<td>none</td>
<td>modified: ebmpapst VarioPro 3212 J/2HP</td>
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<td>80 CFM</td>
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<td>12V, DC 4, 2A, 50W, 164CFM</td>
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<tr>
<td>Heater type (stock, modified, none)</td>
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<td>50W heater ring inside case, around dome</td>
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<td>50W heater ring inside case, around dome</td>
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<td>AC, 130CFM</td>
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<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Storm Peak Experiment

• Data from January 26, 2014 – September 11, 2015
  • No details of modification implementation
• Experimental Complications
  • No standard
  • Several modifications per radiometer
  • Not calibrated, not leveled
• Installation Complications
  • One fan installed backward
  • Spray system solution unknown
  • External pump blower broken

Photo: Robert Albee
Part II – Independent Study Experiment
Independent Study (IS) Experiment
October 28 – November 21
<table>
<thead>
<tr>
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<tr>
<td>Radiation Measured</td>
<td>Shortwave Pyranometer</td>
<td>Shortwave Pyranometer</td>
<td>Shortwave Pyranometer</td>
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<td>Shortwave Pyranometer</td>
<td>Shortwave Pyranometer</td>
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<td>Radiometer Model/Type</td>
<td>CM22</td>
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<td>Modified Housing (y/n)</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
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<td>none</td>
<td>stock</td>
<td>GMD stock</td>
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<td>12V, DC 4, 2A, 50W, 80CFM</td>
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<td>12V, DC 4, 2A, 50W, 164CFM</td>
</tr>
<tr>
<td>Heater Type (stock, modified, none)</td>
<td>none</td>
<td>stock</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>modified</td>
</tr>
<tr>
<td>Modified Heater Details</td>
<td>none</td>
<td>stock</td>
<td>none</td>
<td>none</td>
<td>none</td>
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<td>Radiometer Calibration History</td>
<td></td>
<td></td>
<td></td>
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IS Experiment Modifications

- Calibrate radiometers, leveled radiometers
- Radiometers placed next to NOAA/GMD standard
- Modifications tested: aspiration type, heat
- Lifted fan and radiometer within the housing
  - Generate more air flow
  - Issues with fan back pressure
- Housing no longer secure to base plate with fan lift
  - Used putty to fill gap between housing and base plate
- Only apply heat to one radiometer (#1 with 164cfm fan)
  - Did not test on #2 with 80cfm fan since not enough air flow to dome
- Did not test spray or blower systems
  - Not feasible for Arctic platforms
  - Spray system introduces spray solution issues: freezing of solution, solution residue, environmental impacts
Aspiration/Fan Analysis

SPL modification:
Limited air intake and expulsion

Base plate air intake

Modified Lift

Modified Lift
Fan Analysis

- **Modified Domes:**
  - Fan aspiration has *large* influence on measurement

- **Traditional Domes:**
  - Fan aspiration has *little* influence on measurement
  - Allows for air flow regardless of fan aspiration

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![Graph showing IS Experimental Analysis for Fan Experiment]

- **No Aspiration Time Period**
Overview

- **PSP – Pyranometer/shortwave**
  - Two domes
    - Reduce IR loss
    - Small IR loss to sky at night
      - Causes underestimation or negative irradiance signal at night
    - Designed to get rid of IR loss – smaller magnitude signal

- **PIR – Pyrgeometer/longwave**
  - One dome
    - Reflect sunlight – estimate IR emission of the sky
    - Large IR loss to sky at night
      - Causes underestimation or negative irradiance signal at night
    - Designed to measure IR loss – larger magnitude signal

**PSP/PIR relationship**

- **PSP can’t completely remove IR loss so…**
  - Use PIR detector signal to correct PSP night time offset
    - Derive night time relationship using the PIR to correct day & night PSP signals
  - Therefore, both instruments should be operated the same way – i.e. apply same mitigation techniques to both the PIR & PSP
  - Difficult to apply correction if instruments not operated in same way
Fan Analysis: PIR standard, PSP modified

164 cfm aspiration  
- Linear relationship  
  - PIR/PSP operated in similar manor

80 cfm aspiration  
- Relationship spreads  
  - PIR/PSP operated in slightly different manor

No aspiration  
- No relationship  
  - PIR/PSP operated in completely different manor

Note: Plots include both “dry” and “moist” modes of relationship between the PSP and PIR
Fan Analysis: PIR & PSP modified

164 cfm aspiration: Linear relationship - PIR/PSP operated in same manor

80 cfm aspiration: Relationship spreads - PIR/PSP operated in slightly different manor

No aspiration: No relationship - PIR/PSP operated in same manor

Note: Plots include both “dry” and “moist” modes of relationship between the PSP and PIR
Fan Analysis: Conclusion

• Need aspiration across dome and within housing
  • Contributes to relationship between PIR detector irradiance and PSP night offset
• Housing and base plate impact relationship & measurement
  • Need to assess flow dynamics of modified housing and base plate
  • Need to address air intake and expulsion
  • Need to assess how air is mixing within the modified housing
Heater Analysis
Heater Analysis

Radiometer #1 Housing vs Dome Temp

Radiometer #2 Housing vs Dome Temp

Radiometer #3 Housing vs Dome Temp

Radiometer #4 Housing vs Dome Temp

Radiometer #5 Housing vs Dome Temp

Radiometer #6 Housing vs Dome Temp

External Housing/Dome Temps
Heater Analysis: Results

- Instrument #1 only, due to airflow
- When heat is applied, dome becomes hotter than housing
- Heat influences system, housing impacts how heat is distributed
- Heat impacts detector irradiance and night offset relationship

**Conclusion:** Heat **DOES** affect measurement... and it is likely **not** good for the instrument thermopile
Mitigation: Snow day!

#1 164 cfm
#2 80 cfm
#3 164 cfm
#4 Stock E 100 cfm
#5 Stock KZ 80 cfm
#6 80 cfm
Future Modification Recommendations

• New housing, base plate
  • Taller housing to accommodate fan intake and expulsion
  • Base plate needs to allow for more air inflow
• Avoid using heater
  • If heater is used, then use *less* heat than 50W
• Need more airflow/aspiration
  • Allow for more air intake
  • Use DC fans
• Assess flow of modified housings and base plates
• PIR & PSP should have identical modifications applied – otherwise can’t correct for IR loss
Future Analysis

• Overall, radiometers are sensitive to mitigation modifications

• BSRN – Cold Climate Issues Working Group (CCIWG) “bake-off”
  • Winter 2017/2018
  • Assess manufacturer/technician modifications in Arctic conditions
  • Cross-collaboration campaign
References


Institute, D. R. Storm Peak. Retrieved October 4, 2016, from https://www.dri.edu/stormpeak


Thank you!
Fan Analysis: IR Loss Correlated to Aspiration

Fans ON – closer relationship

Fans OFF