FIRO 2017 Field Campaign: Observations of landfalling atmospheric rivers in Northern California during early 2017

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FIRO Science Task Group Workshop
30 May 2017
FIRO 2017 - Background

All Cases 2005-2016 WYs; R² 0.69

Updated from Ralph et al. 2013

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Field deployment 6 Jan – 30 Mar 2017
Launch frequency during AR conditions: every 3 hours, increasing to every 1.5 hours during storm peak
164 balloons launched from Bodega Bay over 13 events
111 balloons launched from Ukiah over 8 events
NRT radiosonde profiles provided to NWS at WFOs Monterey and Eureka – working with WCMs and SOOs
Continuous data collection from ground instruments as of mid-Jan - present
Outreach opportunities: SR Press Democrat, Potter Valley Elementary
<table>
<thead>
<tr>
<th>Start (UTC)</th>
<th>End (UTC)</th>
<th>Duration (hrs)</th>
<th>Max IWV (cm)</th>
<th>Max IVT (kg/m/s)</th>
<th>BBY Pcp (mm)</th>
<th>CZC Pcp (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Jan 1900</td>
<td>9 Jan 0600</td>
<td>35</td>
<td>3.74</td>
<td>1101.9</td>
<td>56.9</td>
<td>125.5</td>
</tr>
<tr>
<td>10 Jan 0000</td>
<td>11 Jan 0300</td>
<td>27</td>
<td>2.99</td>
<td>788.6</td>
<td>41.1</td>
<td>153.7</td>
</tr>
<tr>
<td>18 Jan 0600</td>
<td>19 Jan 0600</td>
<td>24</td>
<td>2.95</td>
<td>817.6</td>
<td>30.5</td>
<td>63.5</td>
</tr>
<tr>
<td>20 Jan 0600</td>
<td>20 Jan 1400</td>
<td>8</td>
<td>2.18</td>
<td>416.1</td>
<td>18.8</td>
<td>25.4</td>
</tr>
<tr>
<td>22 Jan 0300</td>
<td>22 Jan 1200</td>
<td>9 (0)</td>
<td>2.27 (1.87)</td>
<td>616 (444.8)</td>
<td>24.1</td>
<td>35.6</td>
</tr>
<tr>
<td>2 Feb 0600</td>
<td>4 Feb 0600</td>
<td>48 (15 cont.)</td>
<td>2.62 (2.37)</td>
<td>489 (413.7)</td>
<td>60.7</td>
<td>76.7</td>
</tr>
<tr>
<td>6 Feb 0000</td>
<td>8 Feb 0300</td>
<td>51 (18 cont.)</td>
<td>3.79 (3.29)</td>
<td>1183.1 (997.8)</td>
<td>28.7</td>
<td>97.5</td>
</tr>
<tr>
<td>8 Feb 0300</td>
<td>10 Feb 0000</td>
<td>45 (39 cont.)</td>
<td>3.68 (3.33)</td>
<td>902.4 (740)</td>
<td>55.4</td>
<td>73.7</td>
</tr>
<tr>
<td>15 Feb 2100</td>
<td>16 Feb 1200</td>
<td>15 (15)</td>
<td>3.2 (3.2)</td>
<td>910.5 (875.8)</td>
<td>22.1</td>
<td>43.2</td>
</tr>
<tr>
<td>17 Feb 1200</td>
<td>17 Feb 1800</td>
<td>8 (6)</td>
<td>2.7 (2.0)</td>
<td>550.9 (310.5)</td>
<td>25.9</td>
<td>37.3</td>
</tr>
<tr>
<td>19 Feb 1500</td>
<td>21 Feb 0300</td>
<td>36 (18 cont)</td>
<td>2.9 (2.6)</td>
<td>706.1 (571.6)</td>
<td>34.3</td>
<td>99.3</td>
</tr>
<tr>
<td>20 Mar 1500</td>
<td>21 Mar 1300</td>
<td>22 (18 cont)</td>
<td>2.93 (2.7)</td>
<td>484.8 (473.5)</td>
<td>10.7</td>
<td>47.2</td>
</tr>
<tr>
<td>24 Mar 0600</td>
<td>24 Mar 1800</td>
<td>12 (12)</td>
<td>2.95 (2.5)</td>
<td>664.3 (561.6)</td>
<td>18.1</td>
<td>29.8</td>
</tr>
</tbody>
</table>
IVT – BBY vs. UKI

Simultaneous Sonde Launches

# of Sondes = 103

UKI IVT [kg/m/s] vs. BBY IVT [kg/m/s]

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Maximum Water Vapor Flux – BBY vs. UKI

Water Vapor Flux = Specific Humidity (g/kg) * Wind Speed (m/s)

BBY and UKI Radiosondes - Jan - Mar 2017

- Maximum water vapor flux observed by BBY radiosondes was on average 22% higher than max flux observed by UKI radiosondes
Maximum Water Vapor Flux – BBY vs. UKI

Water Vapor Flux = Specific Humidity (g/kg) * Wind Speed (m/s)

- The majority of BBY radiosondes measured the height of maximum water vapor flux to be below the controlling layer
  - BBY
    - Below CTL = 52 (53%)
    - In CTL = 14 (14%)
    - Above CTL = 32 (33%)
  - UKI
    - Below CTL = 6 (6%)
    - In CTL = 12 (12%)
    - Above CTL = 80 (80%)
- Max WV flux was lower at BBY than UKI in 83% of radiosondes

*N = 98
*Dashed lines represent the “controlling layer” (0.75-1.25 km agl)
IWV Flux - IVT Correlations

• Controlling layer varied but still correlates well with total IVT up to ~4 km at Bodega Bay

• Computations done entirely with radiosonde data – total WV flux = IWV throughout column * winds in 500m thick controlling layer
Comparison of water vapor flux and integrated water vapor transport (IVT)

Using CW3E dropsondes and radiosondes a comparison between water vapor flux and IVT can be made:

- IWV-Flux = IWV*Ave Wind (0.75–1.25 km agl)
- Ralph et al. 2013 catalog uses upslope flux threshold of 15 cm(m/s)
  - IWV-Flux = 15 cm(m/s) ~ IVT = 190 kg m⁻¹ s⁻¹
  - IWV-Flux = 25 cm(m/s) ~ IVT = 270 kg m⁻¹ s⁻¹
  - IWV-Flux = 19.91 cm(m/s) ~ IVT = 250 kg m⁻¹ s⁻¹
BBY Atmospheric River Observatory Catalog

Foundational ARO catalog methodology from Ralph et al. 2013

- Based on dropsondes and radiosondes a threshold of 19.91 cm(m/s) of total water vapor flux corresponds with IVT of 250 kg/m/s

- Many AR Detection Tools in the literature do not consider direction: what is the effect on the ARO catalog using water vapor flux as opposed to upslope water vapor flux?

- Several new catalogs were developed using an 8 hour minimum, with 1 hour below threshold ending event. Criteria used (all ≥ 2 cm Integrated Water Vapor):
  - Water Vapor Flux ≥ 15 cm(m/s)
  - Water Vapor Flux ≥ 25 cm(m/s)
  - **Water Vapor Flux ≥ 20 cm(m/s)**
  - Upslope Water Vapor Flux ≥ 15 cm(m/s)
  - Upslope Water Vapor Flux ≥ 25 cm(m/s)
  - Upslope Water Vapor Flux ≥ 20 cm(m/s)

<table>
<thead>
<tr>
<th>Number of ARs detected (Nov 2004 – May 2017)</th>
</tr>
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<tbody>
<tr>
<td>Threshold/Variable</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>15 cm(m/s)</td>
</tr>
<tr>
<td>25 cm(m/s)</td>
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<tr>
<td>20 cm(m/s)</td>
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</tbody>
</table>
Summary/Conclusions

• FIRO 2017 – unique dataset of high resolution observations during historic year for CA precipitation
  – Valuable for NRT uses as well as advancing research goals
  – Preliminary results show great promise for addressing relevant science questions
7 - 9 Jan BBY Observations

- Over 9 hours with >940 kg/m/s IVT observed during this event
- 5 radiosondes observed IVT >1000 kg/m/s
- Strong AR core observed at BBY ~11-21Z 8 Jan
6-8 February BBY/UKI Observations

--- 75% IVT Level --- Freezing Level

Max WV Flux

Figures provided by Reuben Demirdjian and F. Martin Ralph