Assessing the Ability of IR Sounders in Detecting Extreme Weather Events and Predicting Extreme Floods

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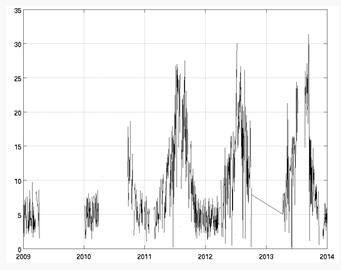
Abstract

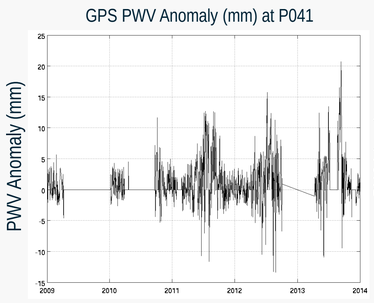
The IPCC 4th Assessment found that changes in the frequency of extreme events, such as droughts, heat waves, and floods, are expected to increase. Extreme PWV events are predicted to increase by a factor of 5-50 between 2000-2025 and 2075-2100, depending on the season and region. This paper investigates the ability of IR sounders to retrieve PWV during extreme weather events. Additionally, a cumulative sum method will be used to examine the predictability of PWV for extreme flooding cases. Results are presented that highlight the extreme moisture during extreme flooding events through case studies, and quantify the differences and agreement between satellite retrievals and ground-based observations. In addition, the probability of extreme rain given extreme moisture will be examined.

Boulder, CO USA Flood: September 2013

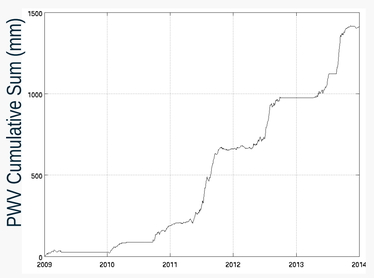
GPS Daily PWV (mm) at P041



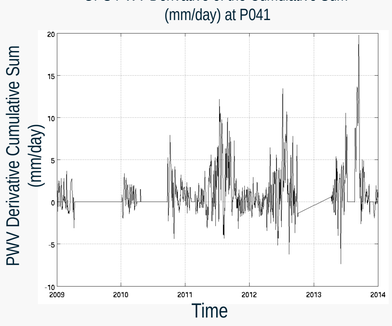
GPS PWV Anomaly (mm) at P041



GPS PWV Cumulative Sum (mm) at P041



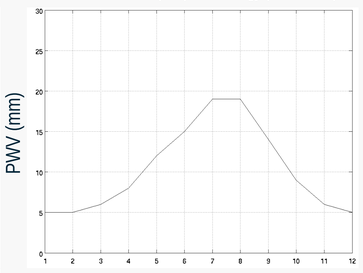
GPS PWV Derivative of the Cumulative Sum (mm/day) at P041



- This study makes use of a quantity called the Derivative of the Cumulative Sum; a value that describes the rate of moisture flux. The steps below describe the method to obtain this value.

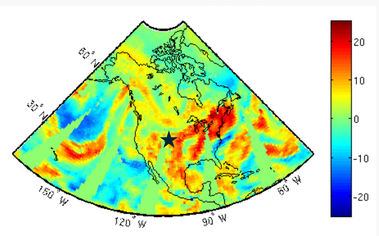
1) Pick a PWV timeseries
   - For this example, we will look at the GPS PWV timeseries at P041, near Boulder, CO. The timeseries shows daily PWV starting in 2009 running through the end of December 2013.

ERA Interim PWV (mm) Climatology (1979-1999)

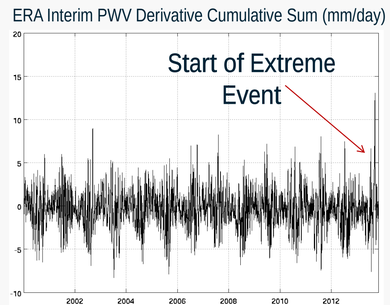


2) Choose a reanalysis/model/or climatological dataset; it should be as long as possible.
   - We will be using the ERA-Interim daily PWV data at the closest point to the GPS station from 1979-1999.
3) Calculate the mean climatology of the dataset chosen above for each month.
4) Calculate an anomaly for the GPS PWV based on the previous climatology.
5) Next, calculate the cumulative sum, a sequential analysis that is used to monitor change detection, by adding the anomalies together consecutively. This value shows an overall change in the moisture at a given location and is useful for climate studies.
6) Pick a time step and calculate the derivative of the cumulative sum.
   - For this example, we choose three days as our time step. We take a point in time and subtract the cumulative sum of that point with the cumulative sum three days ago. Next we divide this value by 3 (the number of days), to get a value of mm/day.

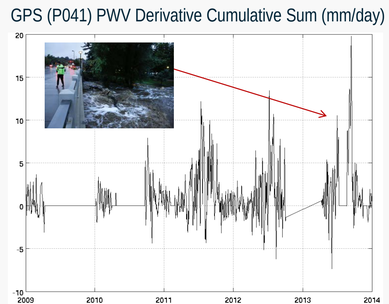
AIRS L3 D PWV Anomaly (mm) 9/11/2013



ERA Interim PWV Derivative Cumulative Sum (mm/day)

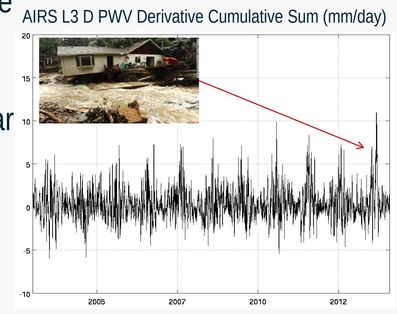


GPS (P041) PWV Derivative Cumulative Sum (mm/day)

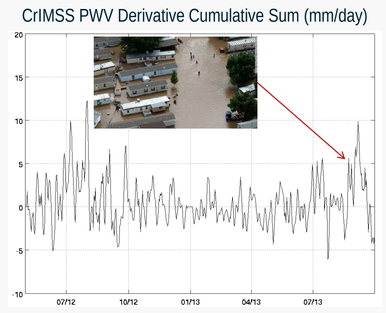


- The figures show the derivative of the cumulative sum for different observations for Boulder, CO (shown as the star in the figure above)
- Each observation was able to capture the intensity of the moisture in the area

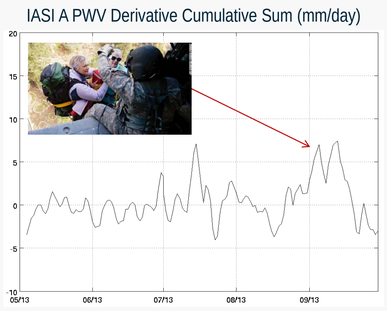
AIRS L3 D PWV Derivative Cumulative Sum (mm/day)



CrIMSS PWV Derivative Cumulative Sum (mm/day)



IASI A PWV Derivative Cumulative Sum (mm/day)



IASI B PWV Derivative Cumulative Sum (mm/day)

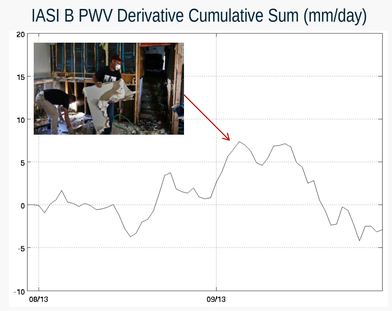


Table of Daily Precipitation (inches) and Derivative of Cumulative Sum (mm/day) for Boulder, CO

Date	Precipitation (inches)	AIRS L3 A (mm/day)	AIRS L3 D (mm/day)	GPS (mm/day)	CrIMSS (mm/day)	IASI A (mm/day)	IASI B (mm/day)	ERA Interim (mm/day)
9/1/13	0.03	5.5289	6.3141	10.9728	5.4254	2.8874	2.609	3.8398
9/2/13	0	6.2531	5.6007	12.3604	6.8686	3.893	3.9077	4.656
9/3/13	0	7.403	7.1101	13.6293	5.798	5.2834	5.6592	6.9344
9/4/13	0	7.4382	7.6218	13.0751	6.5018	6.1221	6.4539	5.4729
9/5/13	0	8.6257	10.9421	13.5196	9.1198	7.0031	7.3536	6.4453
9/6/13	0	7.2624	10.9304	13.0702	9.8642	4.9658	6.9836	5.6925
9/7/13	0	6.1023	8.9656	11.014	8.25	3.6233	6.2497	4.5118
9/8/13	0	4.1687	5.739	9.0314	5.4857	2.5089	4.9352	2.4322
9/9/13	0.25	6.2624	5.3445		4.3066	4.674	4.6085	2.3631
9/10/13	1.02	7.1648	7.5711	9.6432	3.6337	5.7346	5.4557	4.5191
9/11/13	1.92	8.7546	9.2078	13.6716	3.8559	6.9055	6.8558	8.2268
9/12/13	9.08	6.6101	9.5399	17.5855	1.9111	7.2009	6.92	11.4331
9/13/13	2.44	3.9119	5.9159		2.0654	7.4225	7.1249	13.0686
9/14/13	0.01	3.5486	5.4706		1.8335	5.0969	6.7498	10.7411
9/15/13	1.94	3.9432	4.3182		2.3813	4.2071	4.9148	9.4334

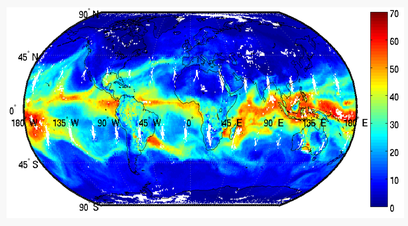
- The high values for the derivative of the cumulative sum days before the flooding event (shown in the table) suggest that extreme moisture transport was occurring and moisture was continuously accumulating in the region, suggesting the usage of this variable for predictability
- Blue shading represents derivative values that have exceeded the 99th percentile based on the ERA-Interim (~5.5 mm/day)
- Red shading represents precipitation values above the climatological mean for September (~1.9 inches)

United Kingdom Floods: January 2014

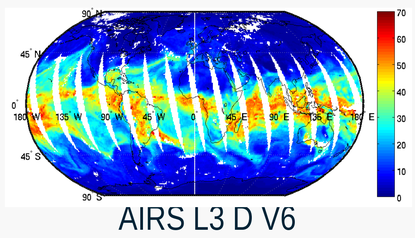
- Starting at the end of October 2013 the United Kingdom and Europe have been hit with a series of flooding events. Below is a list of key dates
  1) October 27th-28th 2013 the St. Jude Storm hit that started the flooding
  2) December 23rd -31st 2013 continuous storms hit the United Kingdom
  3) Rain keeps coming on and off again through January
  4) January 24th-27th a Major Incident is declared for the United Kingdom
- Some studies in the past have shown the cause of these storms to be Atmospheric Rivers (ARs)
  - ARs are elongated bands of of moisture that transport 90% of poleward bound atmospheric water vapor
  - These bands usually are in the lower-troposphere correlated with the warm sector of an extra-tropical cyclone and located in areas of strong winds
  - Typically PWV values are greater than 20 mm
- Transport of large amounts of water vapor, like from these ARs, can lead to extreme precipitation when these ARs reach land

- These figures show PWV (mm) for January 1st 2014

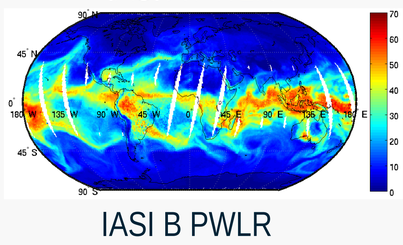
CrIMSS



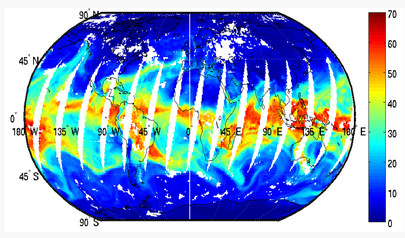
AIRS L3 A V6



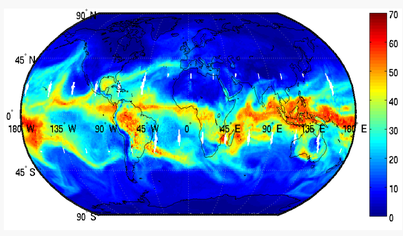
IASI A PWLR



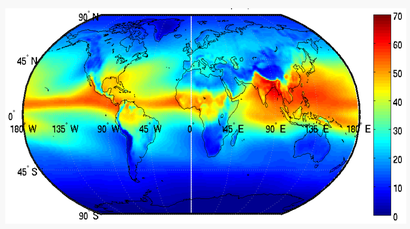
AIRS L3 D V6



IASI B PWLR



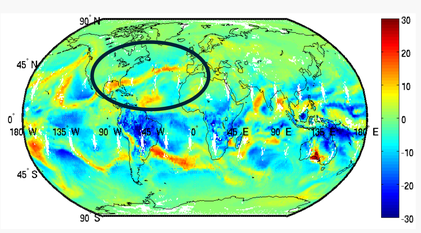
ERA Interim Climatological PWV (mm) for January (1)



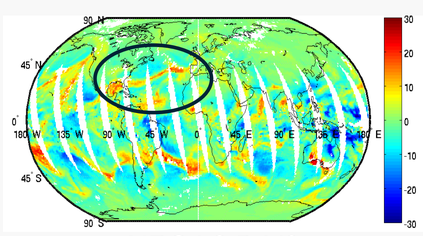
- The figure to the left shows the ERA-Interim Climatological PWV(mm) for January based on daily PWV values from 1979-1999
- This is used to calculate the anomaly by subtracting the ERA-Interim from the observations

- These figures show PWV Anomaly (mm) for January 1st 2014 based on the ERA-Interim Climatology

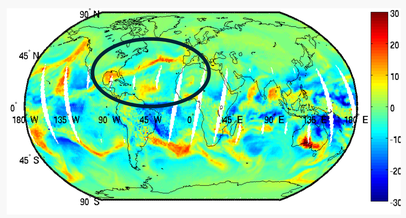
CrIMSS



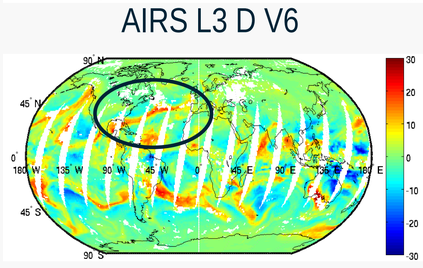
AIRS L3 A V6



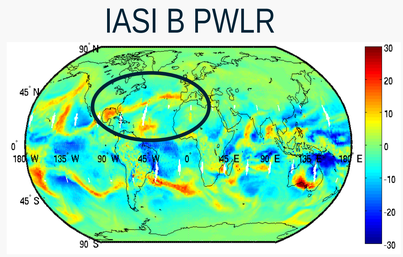
IASI A PWLR



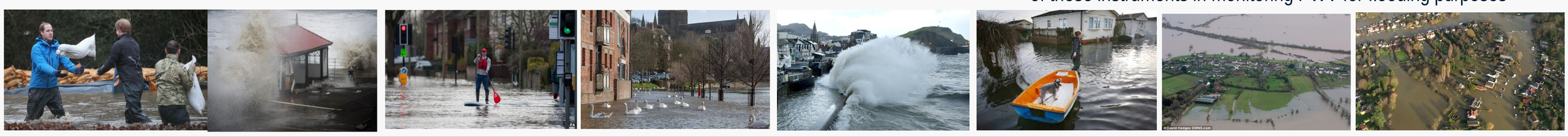
AIRS L3 D V6



IASI B PWLR



- The figures above clearly show an anomalously high transport of moisture from the Gulf of Mexico across the Atlantic Ocean to Europe
- Throughout January (figures not shown) a similar AR was seen every couple of days suggesting this might be the mechanism that has brought the enhanced moisture needed for the heavy precipitation to Europe
- All observations were able to capture the moisture suggesting the use of these instruments in monitoring PWV for flooding purposes



Conclusions

- A new method for monitoring the rate of moisture transport, called the derivative of the cumulative sum; was utilized for the Boulder, CO flooding event of September 2013.
- Prior to the extreme flooding event in Boulder, CO, all observations successfully showed the extreme rate of moisture entering and accumulating in the region, implying a potential to incorporate these observations into now-casting or prediction of floods.
- Atmospheric Rivers (ARs) have previously been determined as the cause of flooding in the United Kingdom.
- This study has shown the high probability that the ARs are the reason behind the extreme moisture in the region that has led to the precipitation and flooding during 2014.
- All observations were able to capture the AR suggesting the need to incorporate these instruments into monitoring techniques for floods.

Acknowledgements And Contact

- We would like to acknowledge and thank Thomas August and Tim Hultberg at EUMETSTAT for supplying the IASI A and IASI B PWLR data for this study

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