Two Prototype Hail Detection Algorithms Using the Advanced Microwave Sounding Unit (AMSU)

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Background and previous work

CICS Hail detection algorithm

MicroWave Cloud Classification (MWCC) method with hail flag

Hail Climatologies

Verification Statistics

2015 Case Studies

Conclusions and Future Work

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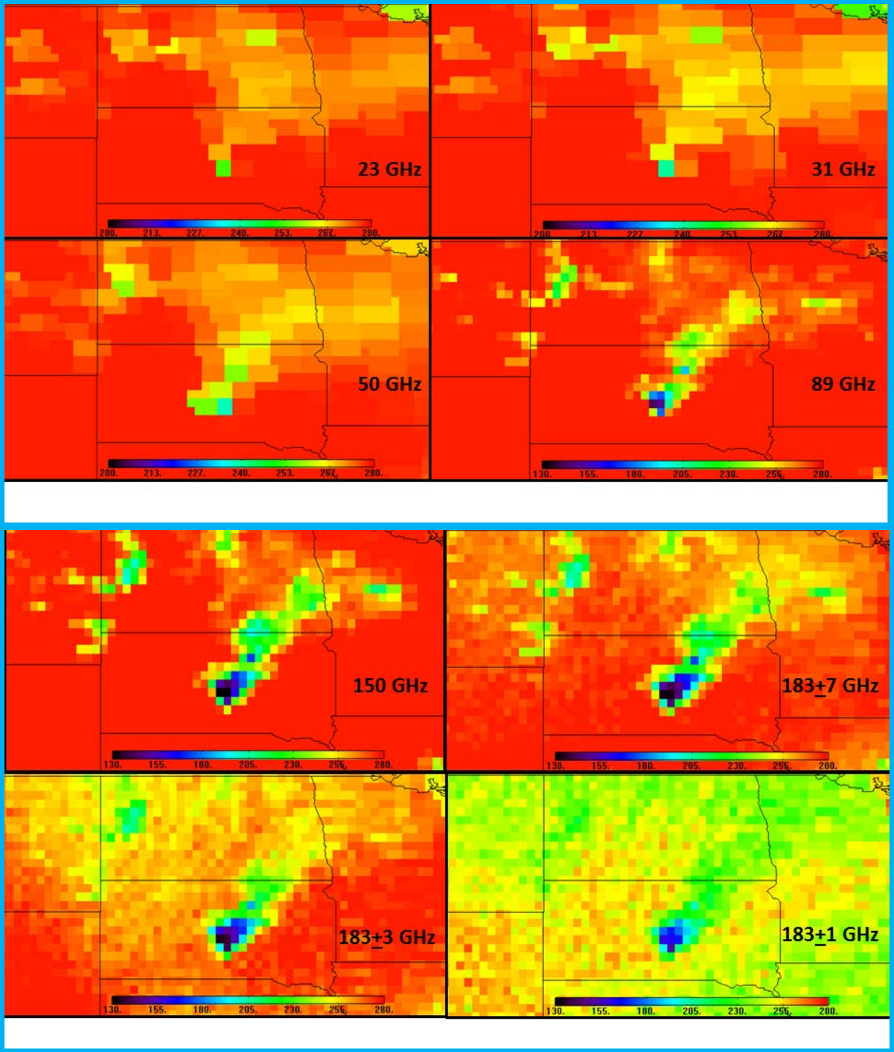
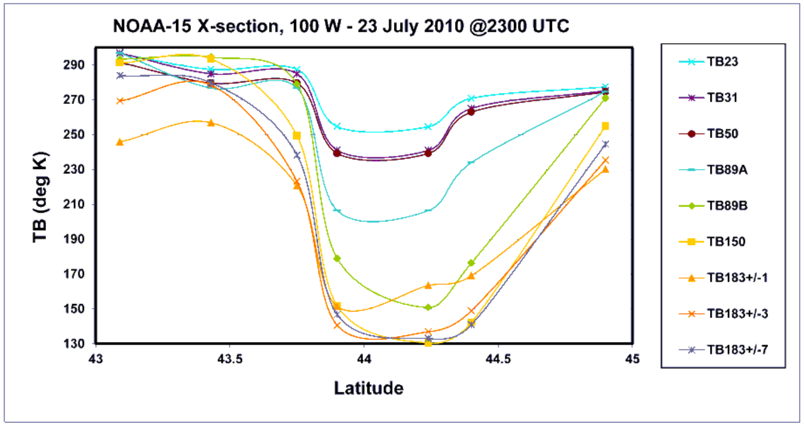
Hailstorm over Vivian, South Dakota (8 “ hail)





NOAA-15 AMSU TB’s for
2300 UTC, 23 July 2010

Previous Satellite Derived Hail Climatologies (Cecil (2009, 2011 and Cecil and Blankenship (2012)

- TRMM Microwave Imager (TMI) – limited to 35º S to 35º N

- EOS Aqua Advanced Microwave Scanning Radiometer (AMSR-E) limited by 130 am/pm local observation time

Advantages of using NOAA (NOAA-15 through NOAA-19) and EUMETSAT (MetOp-A and MetOp-B)

- 1998 to present
- Multiple satellites – near global coverage every 4 hours

Satellite / ground observation matchups

- Storm Report data from NOAA's Storm Prediction Center (SPC) Time, location, and hail size
- Satellite Data: NOAA-15 to NOAA-19, MetOp-A
- Collocate these data according to these criteria:
  5 minutes, 25 km, 25^{o} local zenith angle
- 6823 total matchups for all years

Number of matchups and satellites used

Satellite	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
NOAA-15	X	X	X	X	X	X	X	X	X	X	X	
NOAA-16		X	X	X	X	X	X	X	X	X	X	X
NOAA-17			X	X	X	X	X	X	X	X		
NOAA-18						X	X	X	X	X	X	X
MetOp-A								X	X	X	X	X
NOAA-19										X	X	X
Total Matchups	110	327	313	372	430	480	673	731	1089	922	627	749

Average brightness temperatures as a function of AMSU observation frequency and SPC hail size for 2000 – 2011. Shown in parenthesis is the standard deviation.

Hail Size	TB89	TB150	TB183±1	TB183±3	TB183±7	# Obs	% of Obs
≤1”	233.8 (33.4)	213.2 (37.9)	217.9 (21.8)	212.4 (30.1)	206.9 (34.8)	5196	76.2
>1” to ≤2”	230.7 (34.8)	209.6 (38.3)	214.0 (23.0)	207.6 (31.2)	202.5 (35.6)	1418	20.8
>2” to ≤3”	226.5 (35.9)	204.5 (38.6)	207.8 (23.3)	201.4 (30.9)	197.1 (34.9)	174	2.5
>3”	223.6 (43.6)	197.5 (43.9)	196.8 (28.0)	190.7 (36.9)	189.0 (39.5)	35	0.5

- TB’s decrease with increasing hail size for all AMSU frequencies.

- For any particular hail size, there is generally a decrease in TB with increasing AMSU frequency, especially between 89 GHz and 150 GHz. This supports the physical basis of the sensitivity to ice effective size to higher frequencies.

- Among the 183 GHz channels there is a general increase in TB as the channels peak higher in the atmosphere.

CICS Threshold Algorithm

- AMSU-B Channels (finer resolution)
- 2000 – 2009 training period
- Mean TB's for 1" or greater hail size (24 % of matchups)

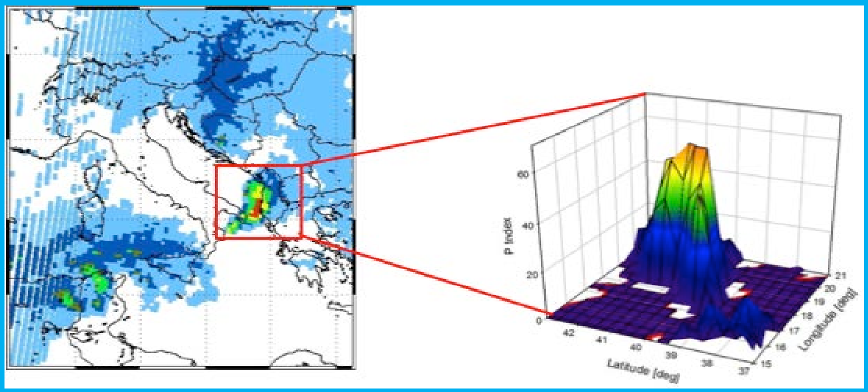
- TB89: 228.2^{o}K
- TB150: 206.9^{o}K
- TB183+/-1: 211.1^{o}K
- TB183+/-3: 204.6^{o}K
- TB183+/-7: 200.5^{o}K

Ferraro, R., J.Beauchamp, D.Cecil, G.Heymsfield, 2015, Atmospheric Research, 163, 24-35.

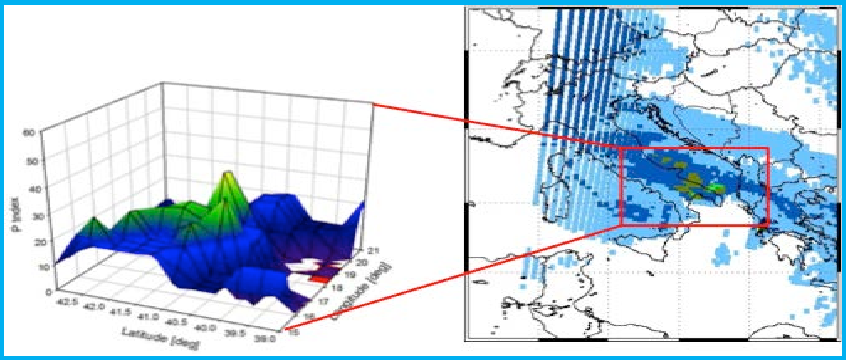
MicroWave Cloud Classification (MWCC)

- The MWCC method exploits the properties of the three water vapor (WV) channels at 183.31 GHz on board the AMSU-B/MHS radiometers.
- Due to the vertical development of the different cloud types, the typical extinction of radiation a 183.31 GHz band in clear sky conditions is *perturbed* (P_{index}) as a function of cloud type and microphysics.
- By analyzing the signal variations of different WV channels it is possible to detect and classify the cloud types in terms of convective or stratiform by assessing the altitude of cloud top.

Deep Convection



Stratiform clouds

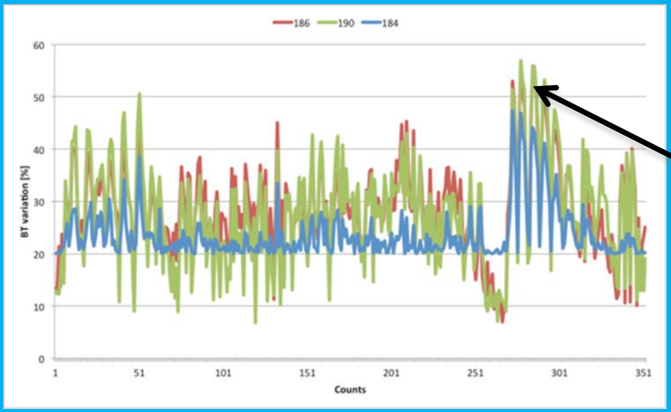


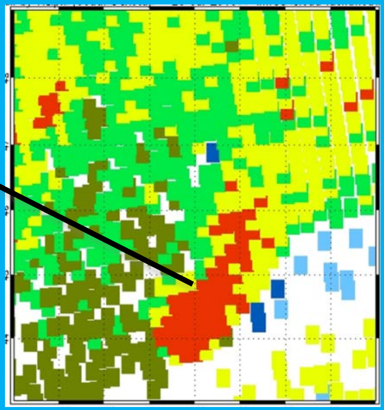
Laviola S., and V. Levizzani, 2011: The 183_WSL fast rain rate retrieval algorithm. Part 1: Retrieval design. Atmos. Res., 99, 443-461

Miglietta, M.M., S. Laviola, A. Malvaldi, D. Conte, V. Levizzani, and C. Price, 2013: Analysis of tropical-like cyclone over the Mediterranean Sea through a combined modeling and satellite approach. Geophy. Res. Lett., 40, 2400-2405, doi:10.1002/grl.50432

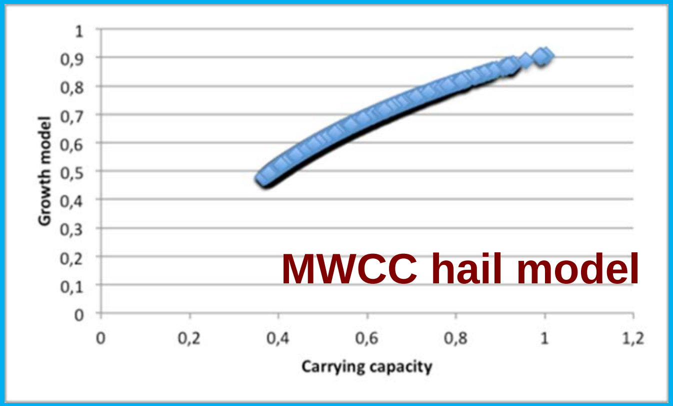
Microwave Cloud Classification (MWCC) - Hail

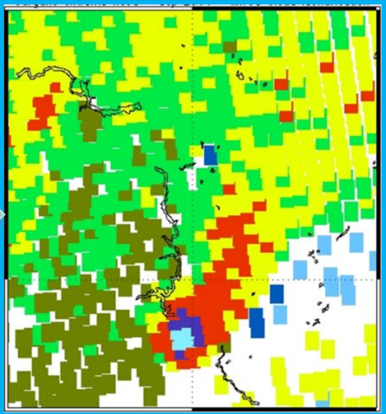
Recently, the computational scheme of the MWCC method was improved with a probability-based module for hail detection.





Hailstorm over Vivian, South Dakota NOAA-15 AMSU-B TBs for 2254 UTC 23 July 2010. Diagrams show the perturbation (%) of the 183 GHz bands (top-left) during the hailstorm classified as deep convection (top-right). The same with the hail model (bottom-left) is classified as extralarge-type hailstorm (bottom-right)





MWCC Legend

ST= Stratiform
CO= Convection
LH= Large Hail
XLH= Extra-Large Hail

Type	*P* index		Altitude [km]
ST1		10	1-3
ST2		20	3-4
ST3		30	> 4
CO1		40	4-6
CO2		50	6-8
CO3		60	> 8
LH		70	TOA
XLH		80	TOA

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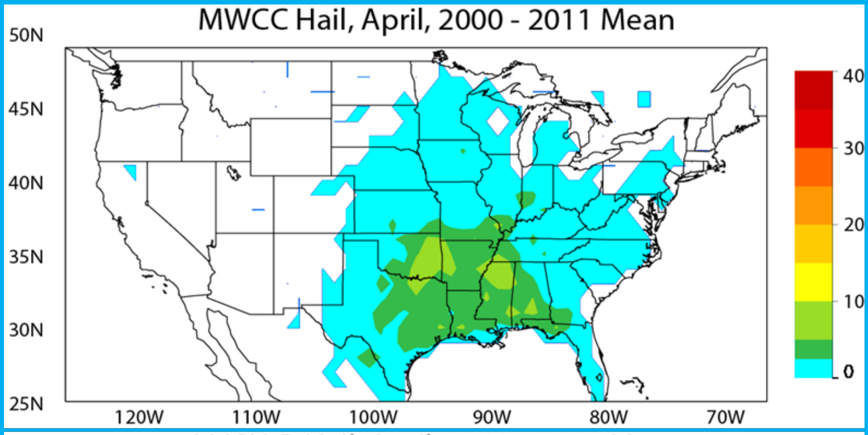

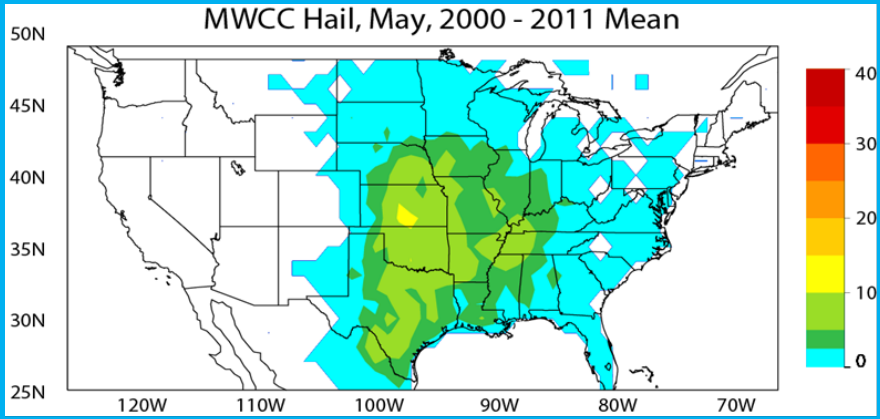

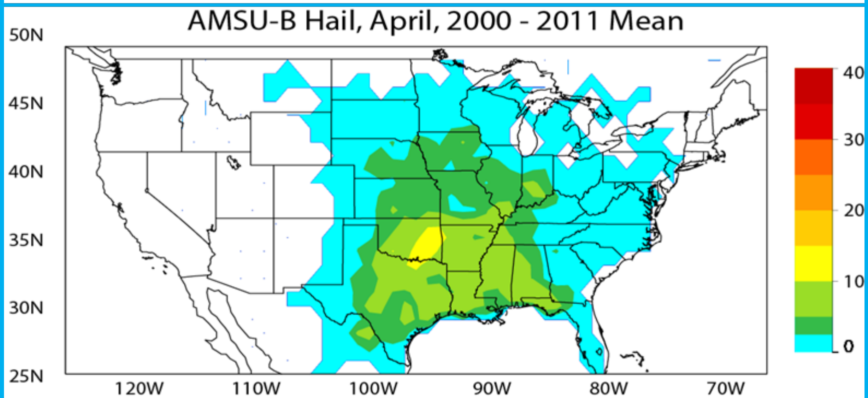

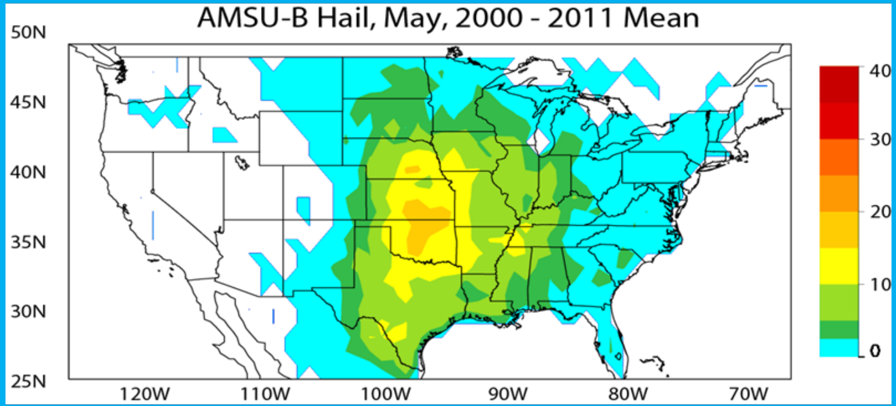

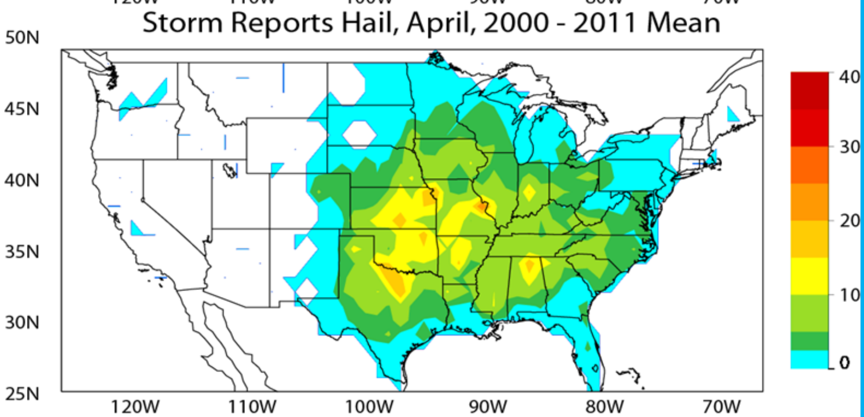

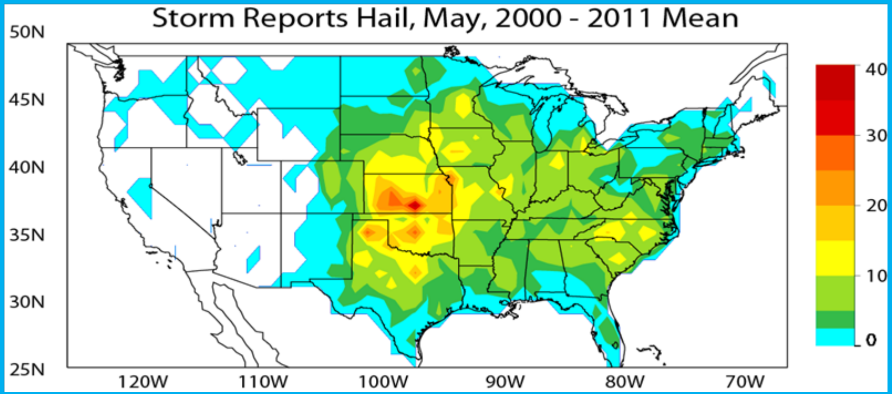

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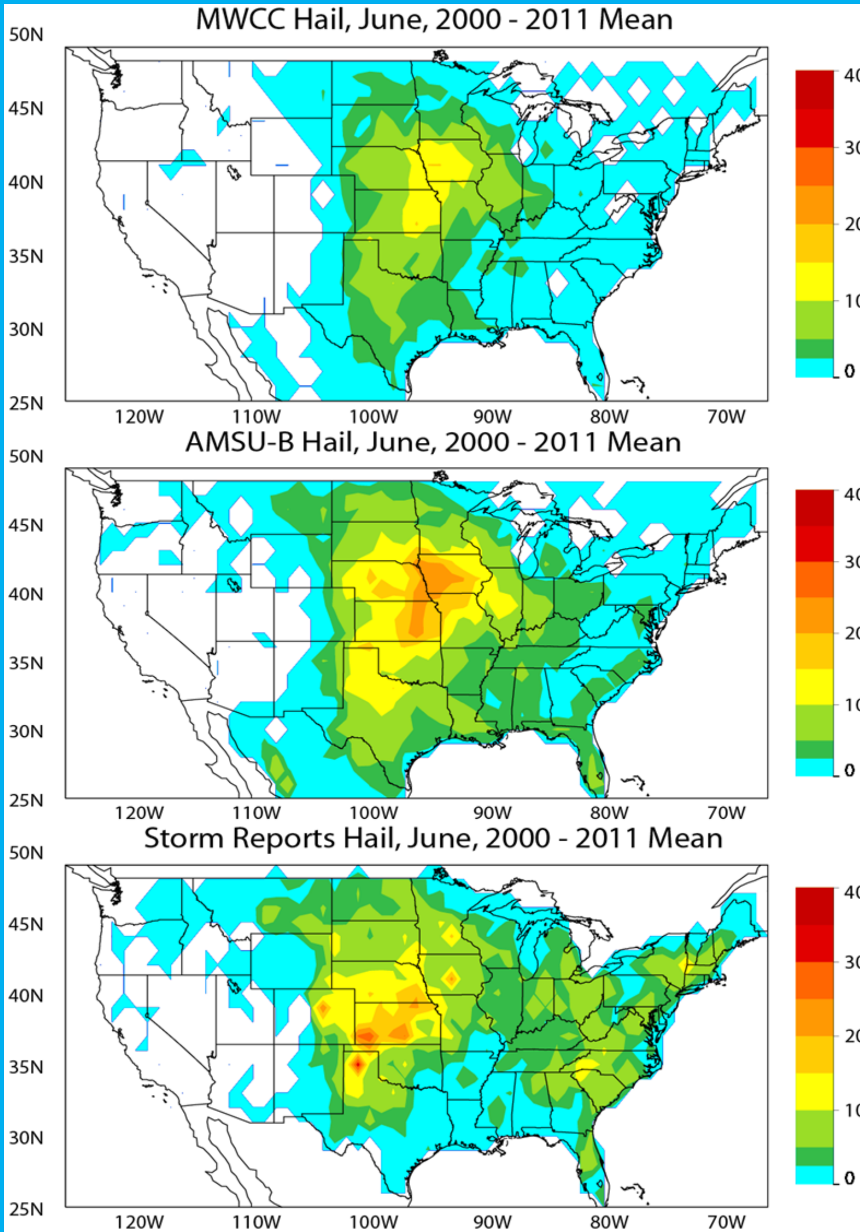
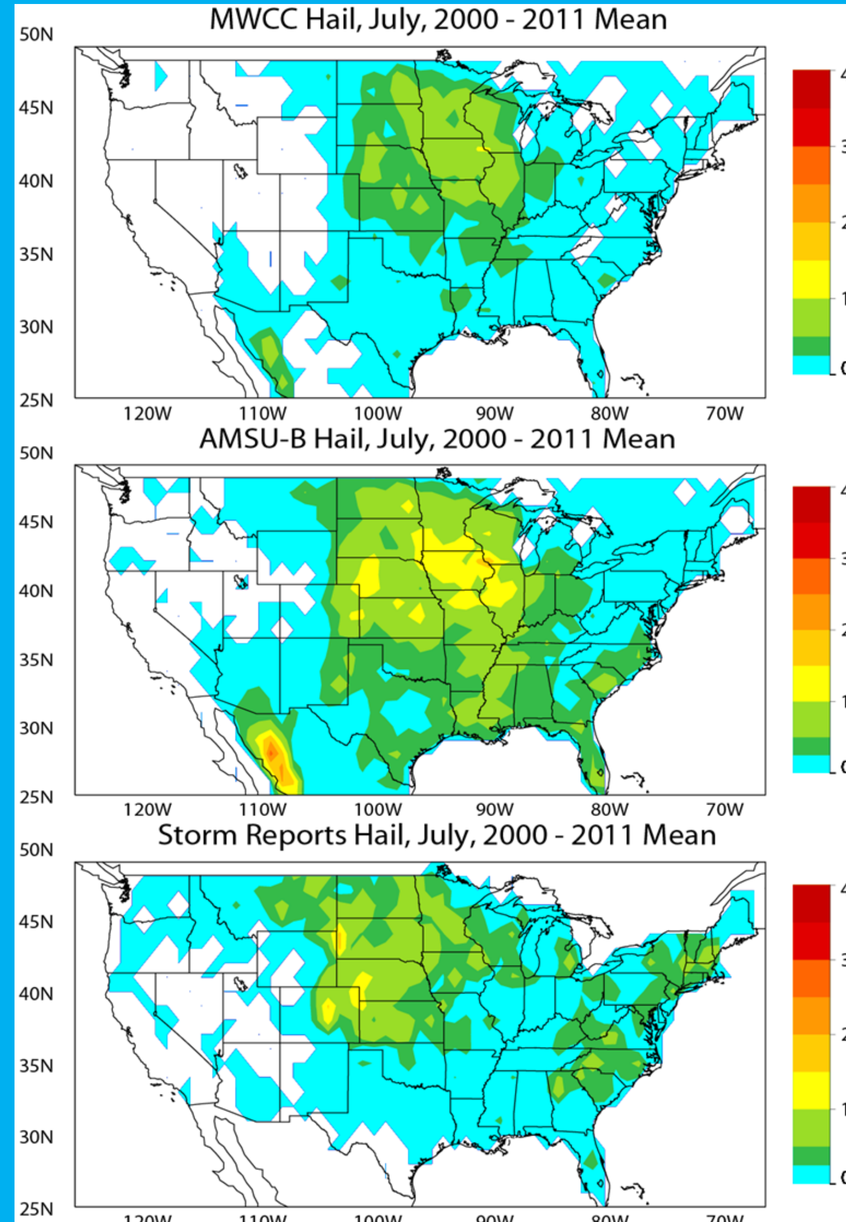
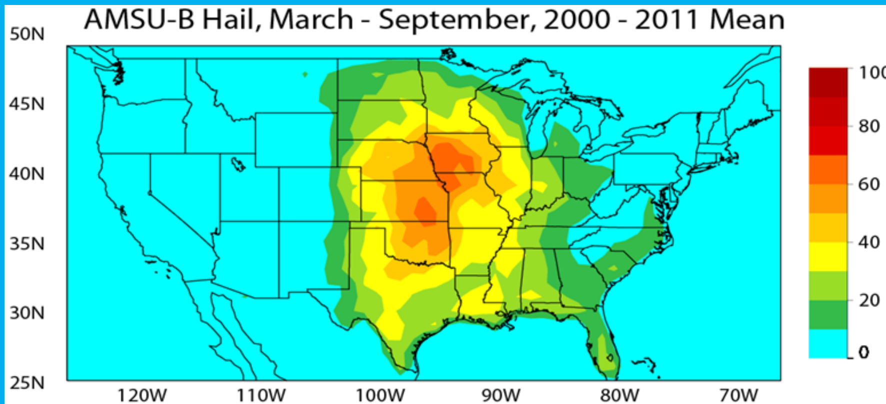
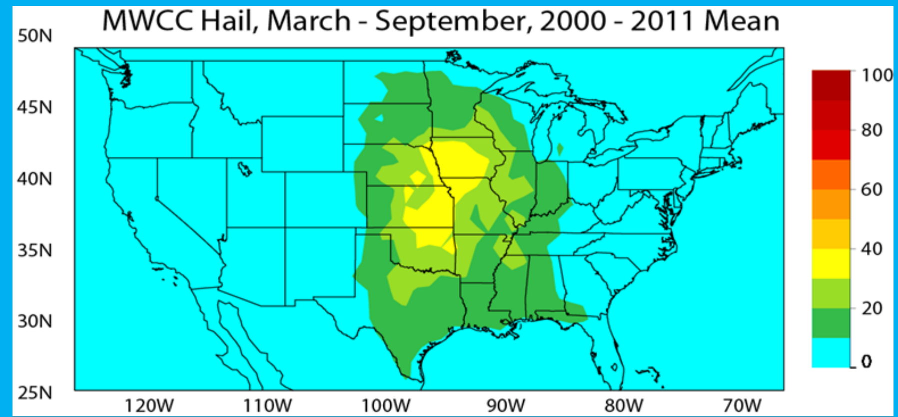
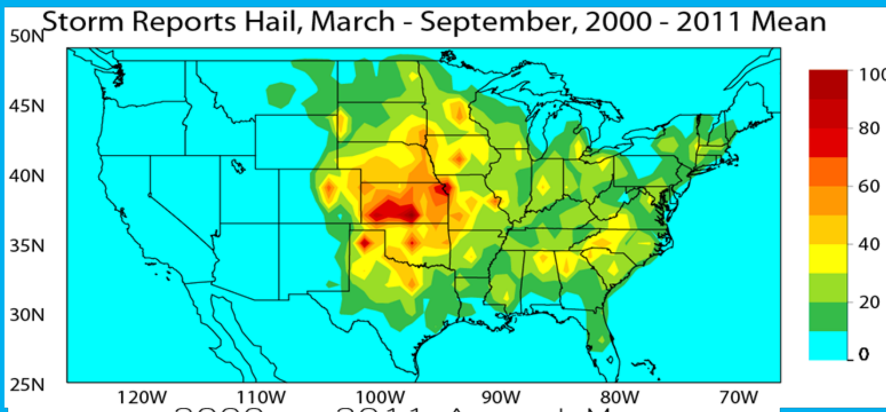
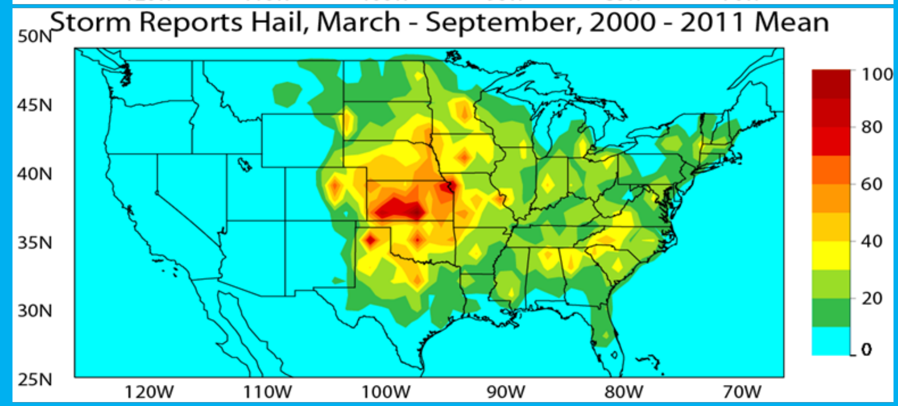


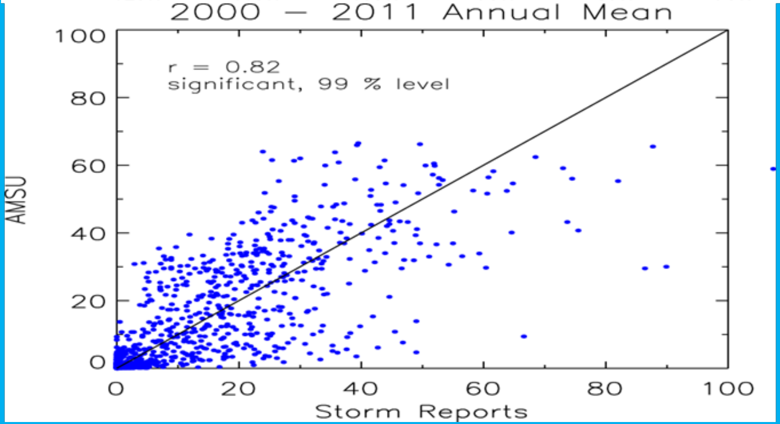


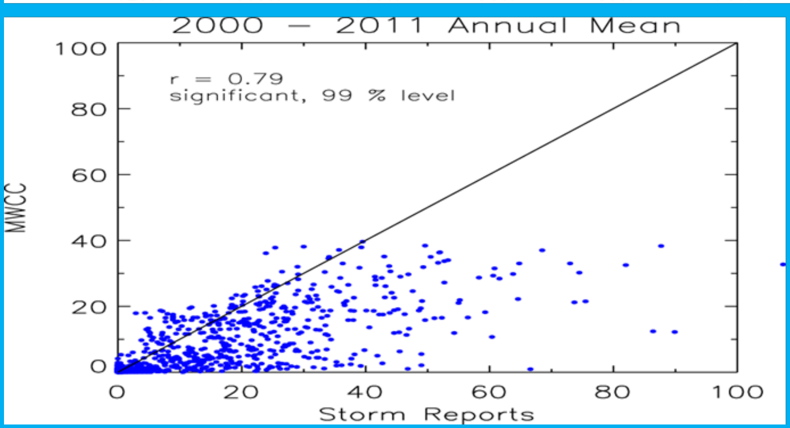

AMSU-B Hail, March - September, 2000 - 2011 Mean
50N
45N
40N
35N
30N
25N
120W
110W
100W
90W
80W
70W
100
80
60
40
20
0


MWCC Hail, March - September, 2000 - 2011 Mean
50N
45N
40N
35N
30N
25N
120W
110W
100W
90W
80W
70W
100
80
60
40
20
0


Storm Reports Hail, March - September, 2000 - 2011 Mean
50N
45N
40N
35N
30N
25N
120W
110W
100W
90W
80W
70W
100
80
60
40
20
0


Storm Reports Hail, March - September, 2000 - 2011 Mean
50N
45N
40N
35N
30N
25N
120W
110W
100W
90W
80W
70W
100
80
60
40
20
0


2000 — 2011 Annual Mean
r = 0.82
significant, 99 % level
AMSU
Storm Reports
0
20
40
60
80
100


2000 — 2011 Annual Mean
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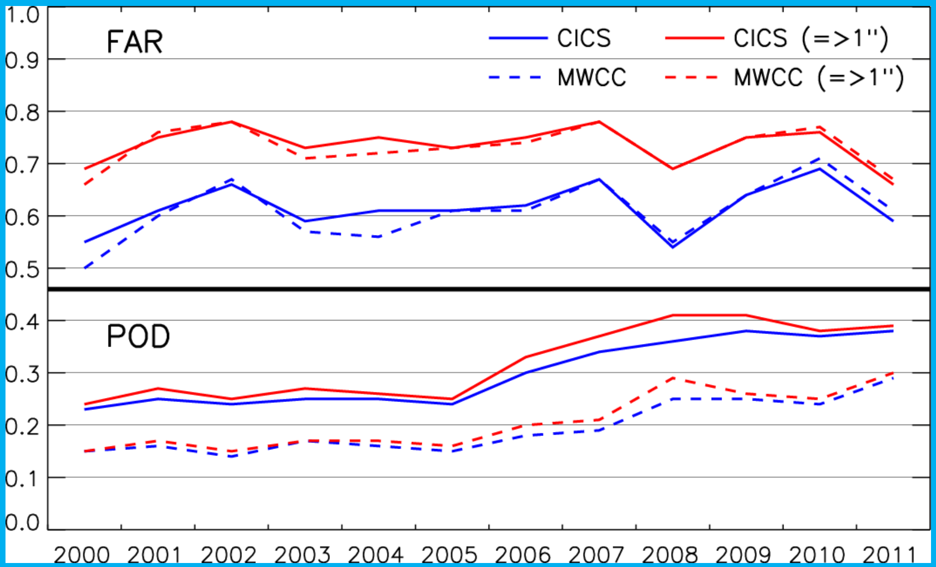
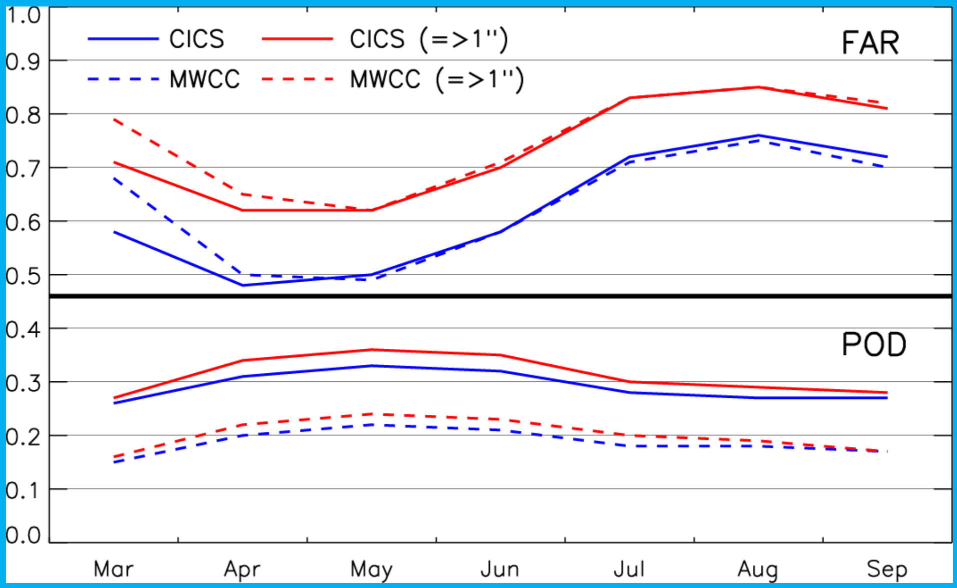
MWCC
Storm Reports
0
20
40
60
80
100

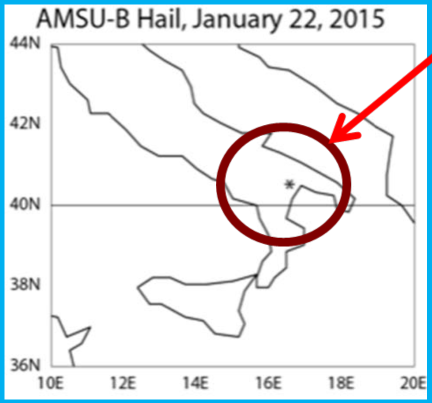
Annual



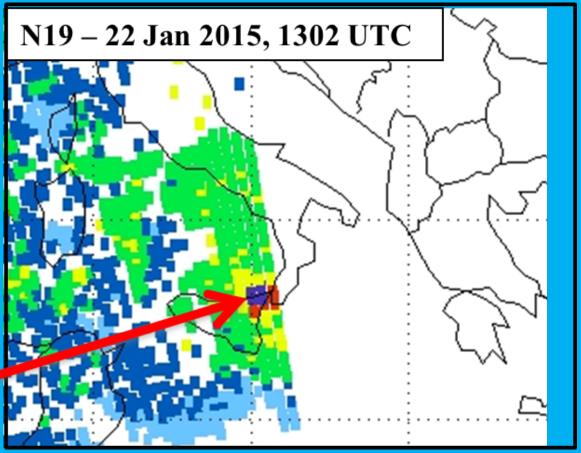
Monthly



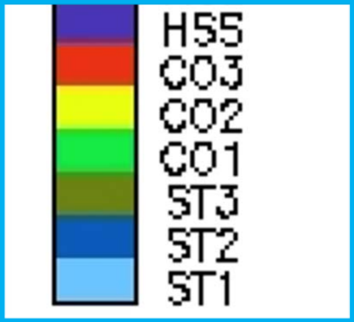
Anomalous Hailstorm over Southern Italy, Jan. 22, 2015

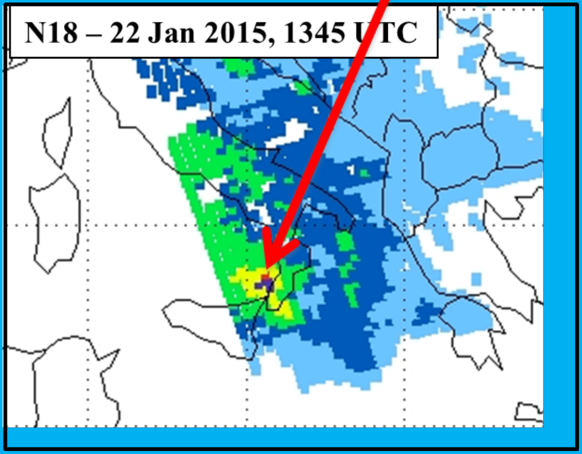


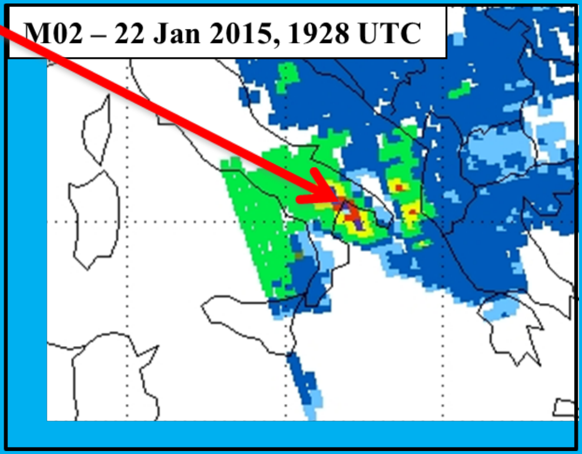
* Hail criteria met four times at 1933 UTC



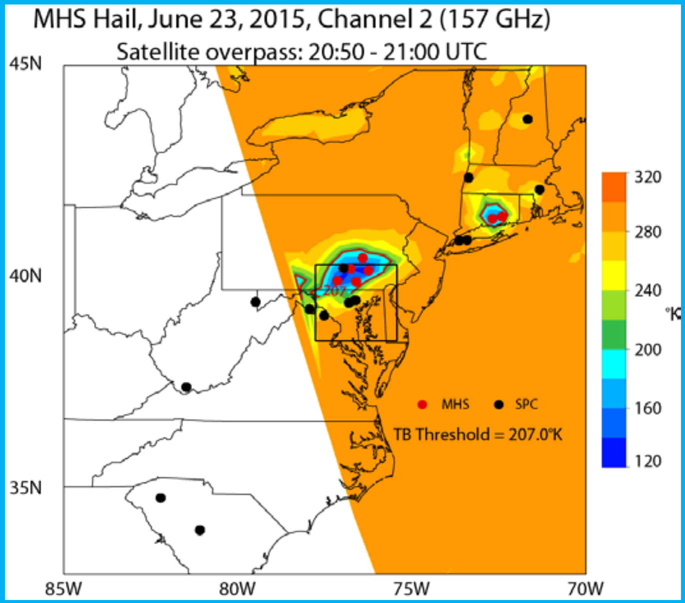
MWCC method

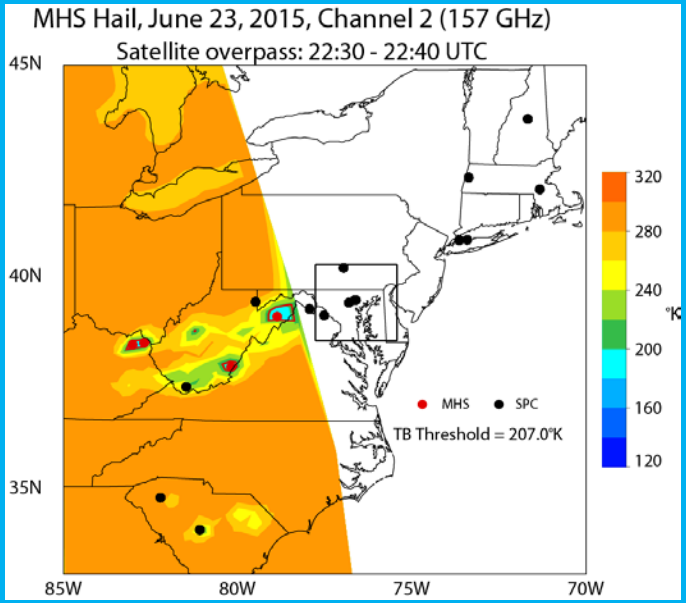






Hailstorm (4 “), Baltimore, MD June 23, 2015





State	Time (UTC)	Latitude	Longitude (W)	Hail size
NH	21:25	43.73	71.67	1.00
MA	21:39	42.07	71.33	1.00
MA	20:34	42:35	73.37	1.00
NY	22:40	40.87	73.64	1.75
NY	22:45	40.88	73.41	1.00
PA	20:05	40.22	76.96	1.00
MD	21:21	39.46	76.63	1.00
MD	21:36	39.40	76.81	1.25
MD	21:36	39.46	76.61	4.00
MD	22:07	39.46	76.64	1.75
VA	22:28	39.10	77.52	1.00
WV	20:06	39.42	79.49	1.00
WV	21:37	39.25	77.94	1.00
WV	22:55	37.41	81.48	1.00
SC	21:19	34.80	82.22	1.00
SC	22:45	34.04	81.09	1.00

Conclusions and Future Work

- AMSU/MHS measurements have the potential to detect and map hail events over the United States and even globally, using either the CICS threshold method or the MWCC with hail flag.
- Use of AMSU/MHS data allows for better temporal and global coverage, especially when these sensors are aboard several satellites with differing equator crossing times.
- POD values reach about .40 for years having the best satellite coverage. Relatively high (0.70) FAR values may be due to there being no spotter reports where there is no hail which may bias these values.
- For individual hailstorms, use of radar animations might be particularly beneficial for better understanding of similarities/differences in the timing of satellite-detected hail vs. surface reports.
- Use of regionally or temporally varying thresholds or TB depressions instead of absolute TB values.
- Incorporating freezing level data to decrease false alarms where satellite data indicate hail that melts before reaching the surface.
- Applying the CICS threshold technique to satellite intercalibrated swaths files.

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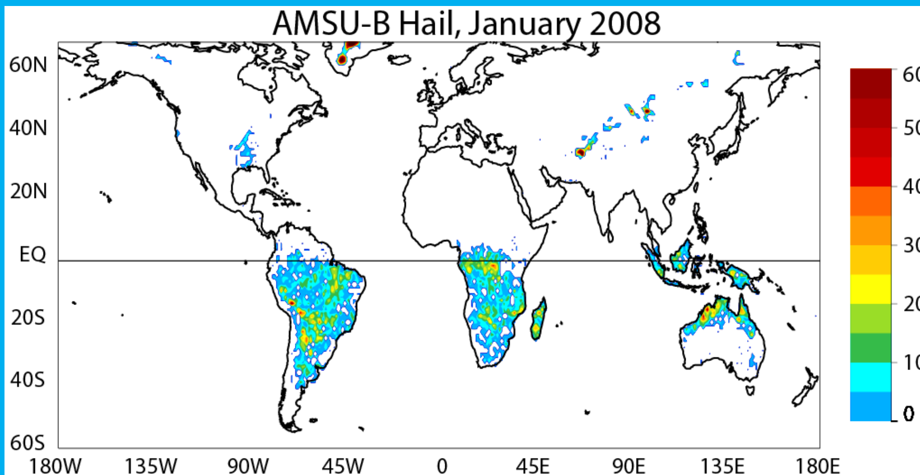
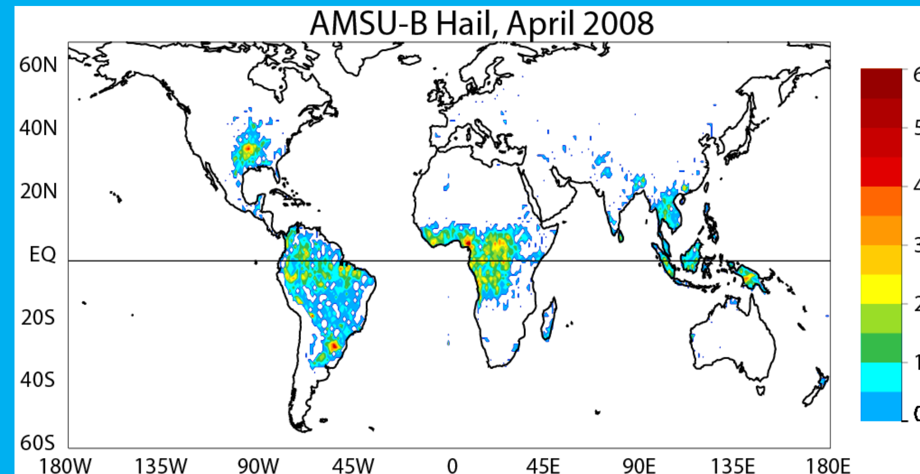
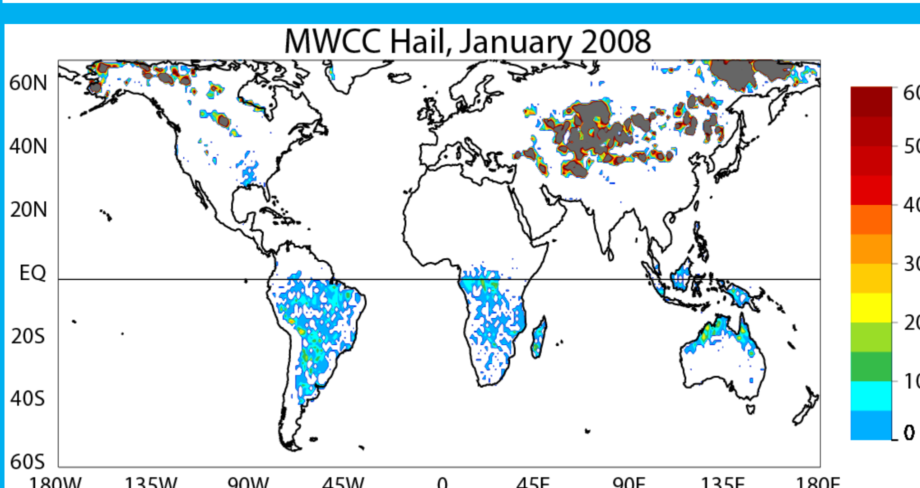
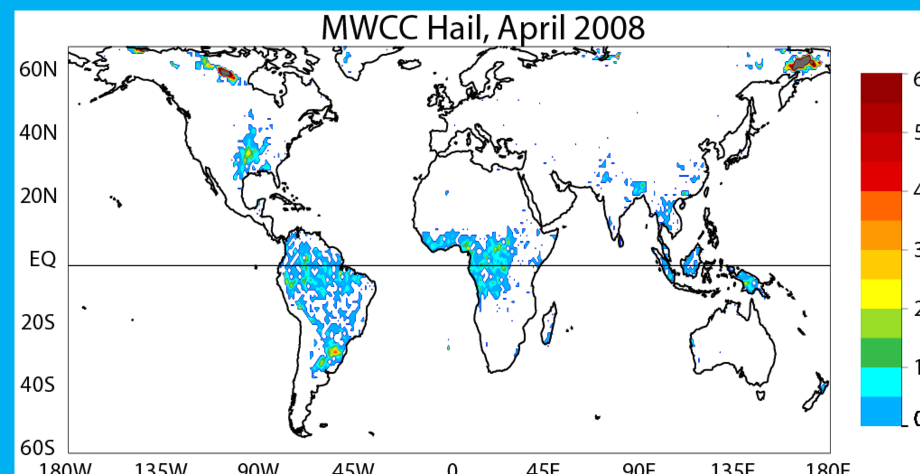
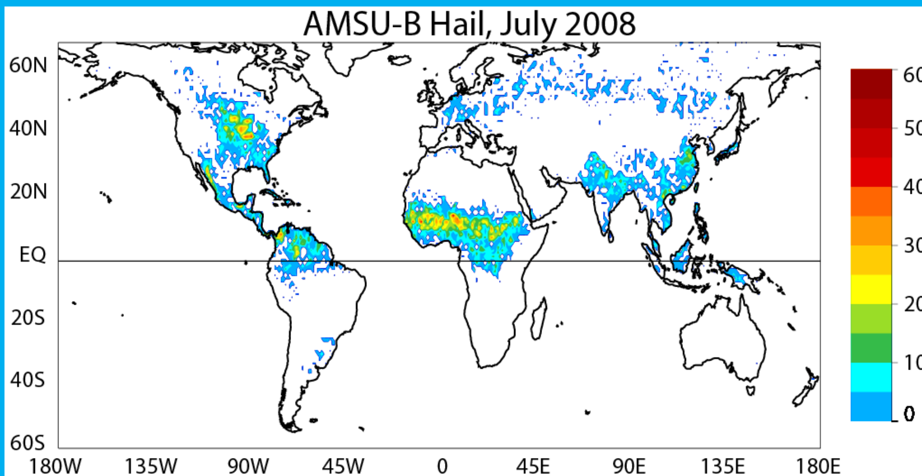
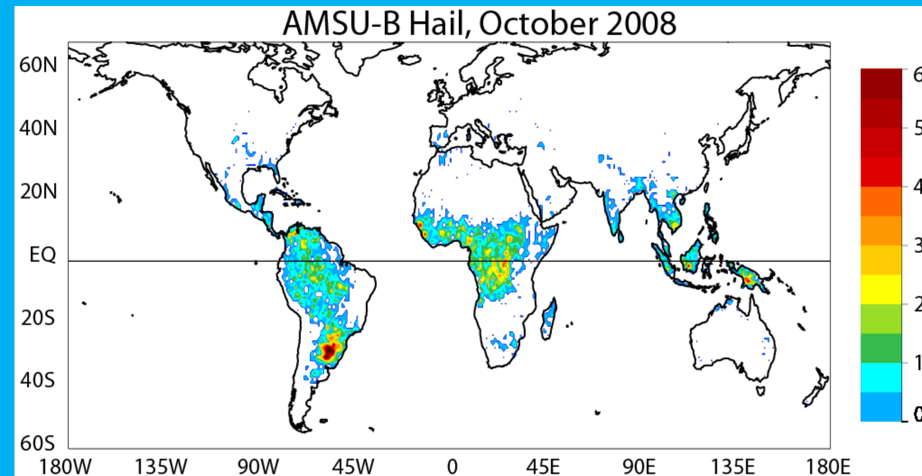









AMSU-B Hail, July 2008
60N
40N
20N
EQ
20S
40S
60S
180W
135W
90W
45W
0
45E
90E
135E
180E
60
50
40
30
20
10
0


AMSU-B Hail, October 2008
60N
40N
20N
EQ
20S
40S
60S
180W
135W
90W
45W
0
45E
90E
135E
180E
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20
10
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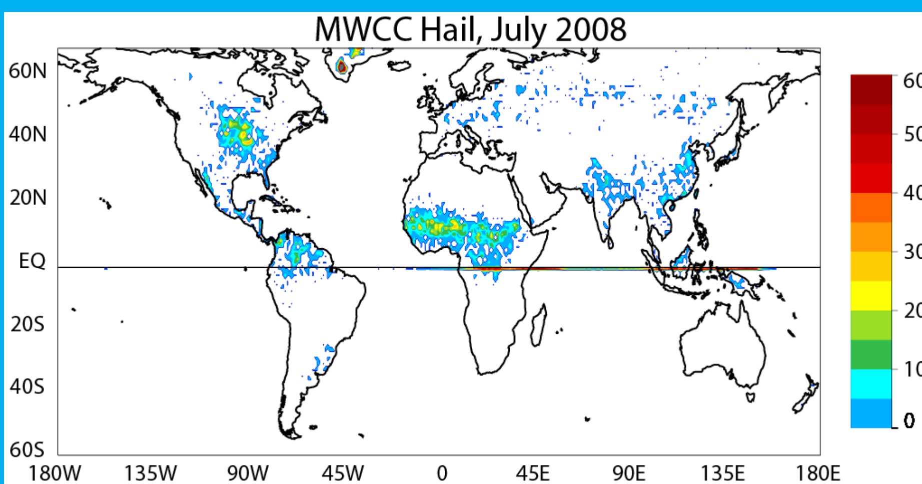
MWCC Hail, July 2008
60N
40N
20N
EQ
20S
40S
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45E
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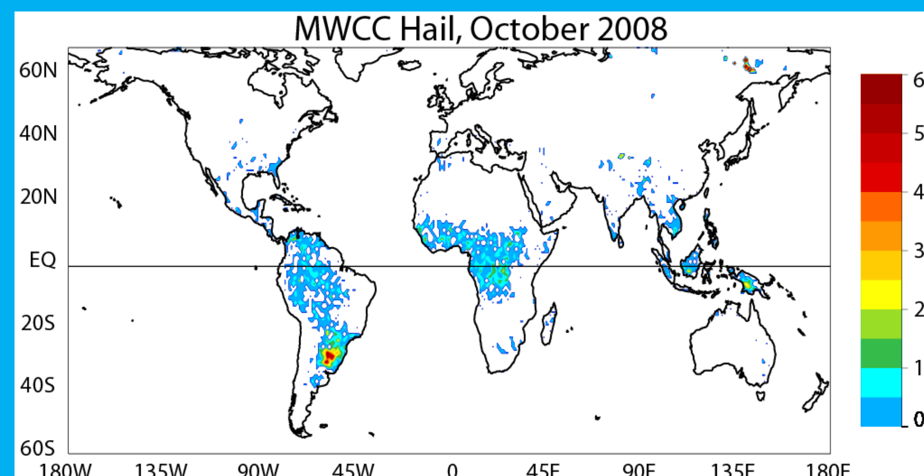
MWCC Hail, October 2008
60N
40N
20N
EQ
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