# **HIGH-RESOLUTION PHASED ARRAY RADAR OBSERVATIONS OF AN OKLAHOMA HAILSTORM PRODUCING EXTREMELY-LARGE HAIL**

## Introduction

- Severe storms in central OK on 31 May 2013 produced hail up to 160 mm in diameter
- The Phased Array Radar (PAR) in Norman, OK collected data on these storms
- The 160 mm hailstone is a new record-large size for OK and the fifth largest in the U.S.; it fell on the west side of El Reno, OK at ~2305 UTC (106 min after first echo)
- This study presents high-resolution PAR observations of the storm that produced the 160 mm hailstone

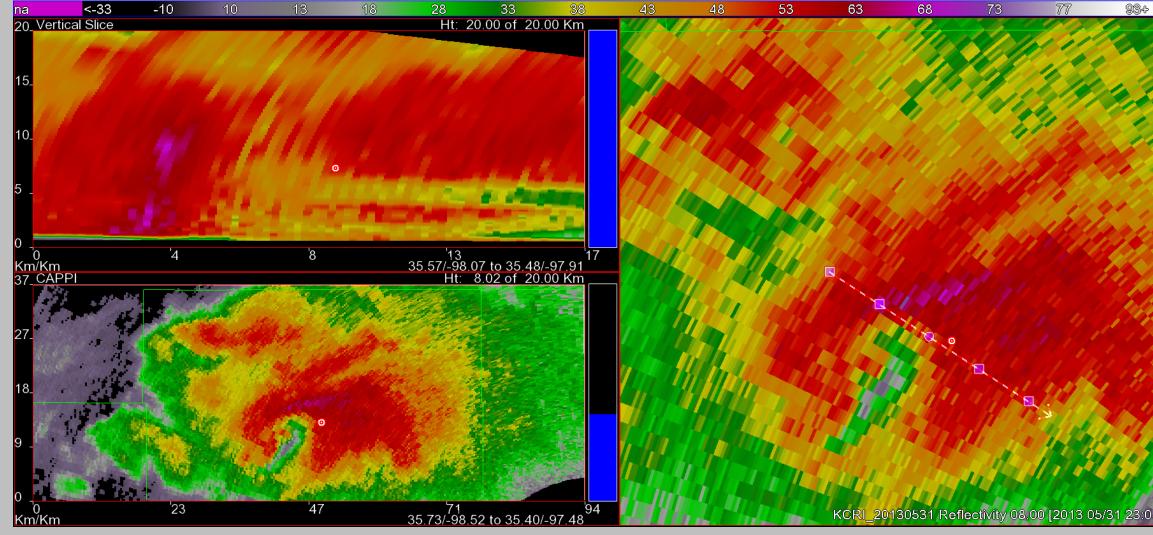


## Radar parameters examined

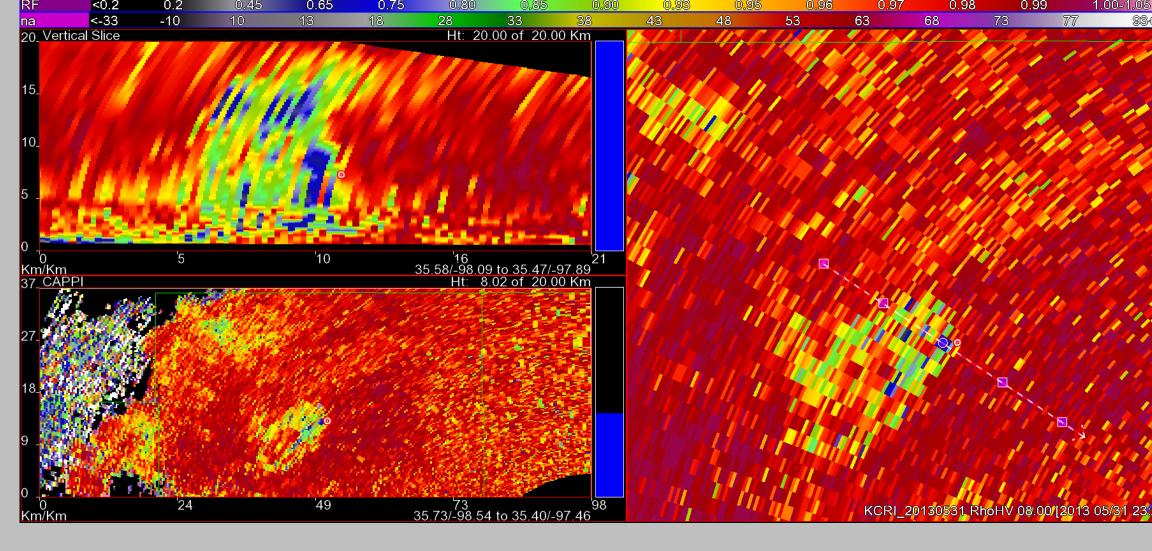
- Maximum reflectivity at the -20°C height (Z<sub>253K</sub>)
- Vertically integrated liquid (VIL)
- Maximum expected size of hail (MESH)
- Storm-top divergence (STD)
- Mid-altitude rotational velocity (MRV)

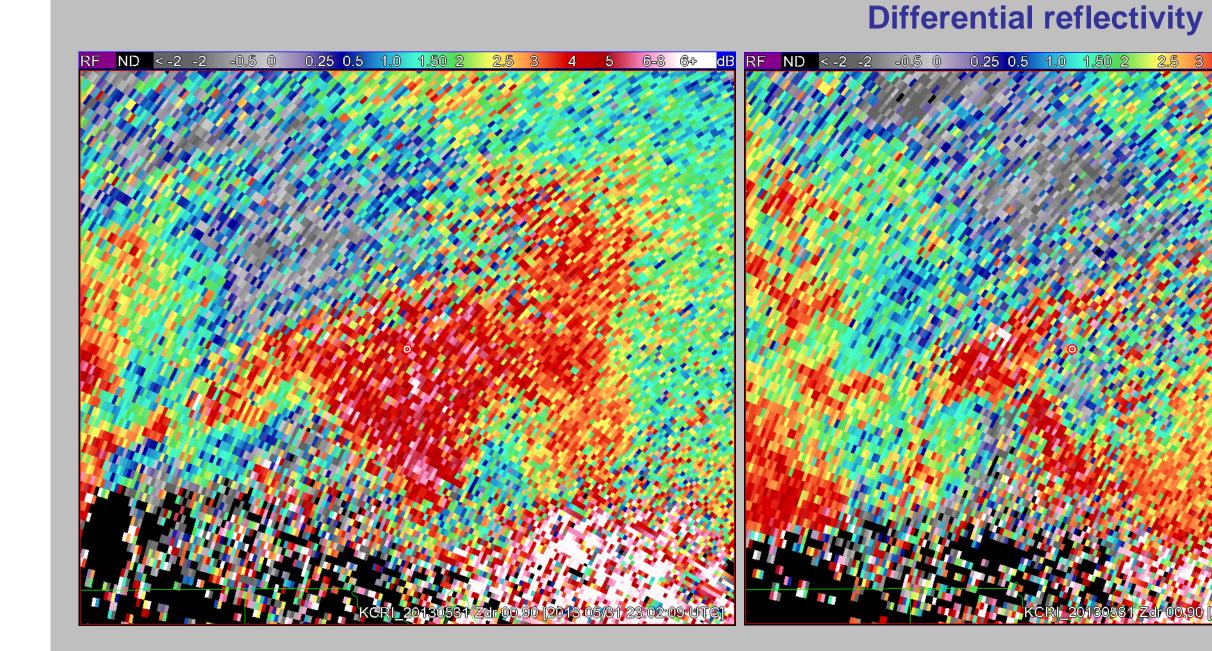
## **Dual-polarization data from KCRI**

### Reflectivity

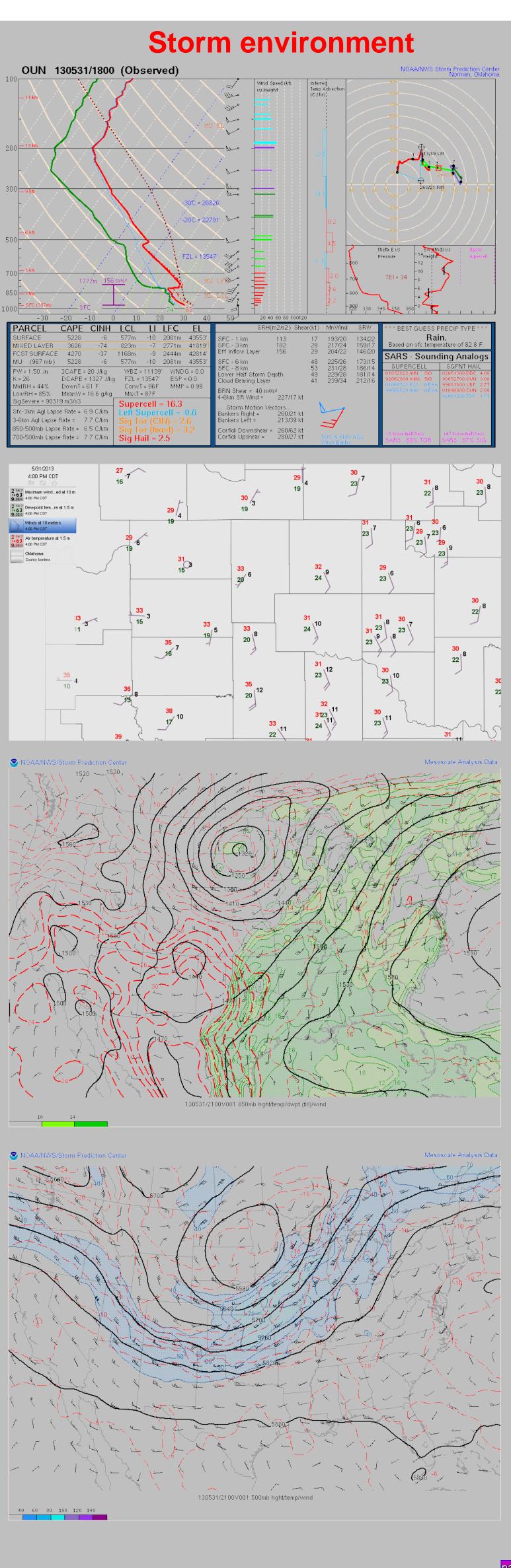


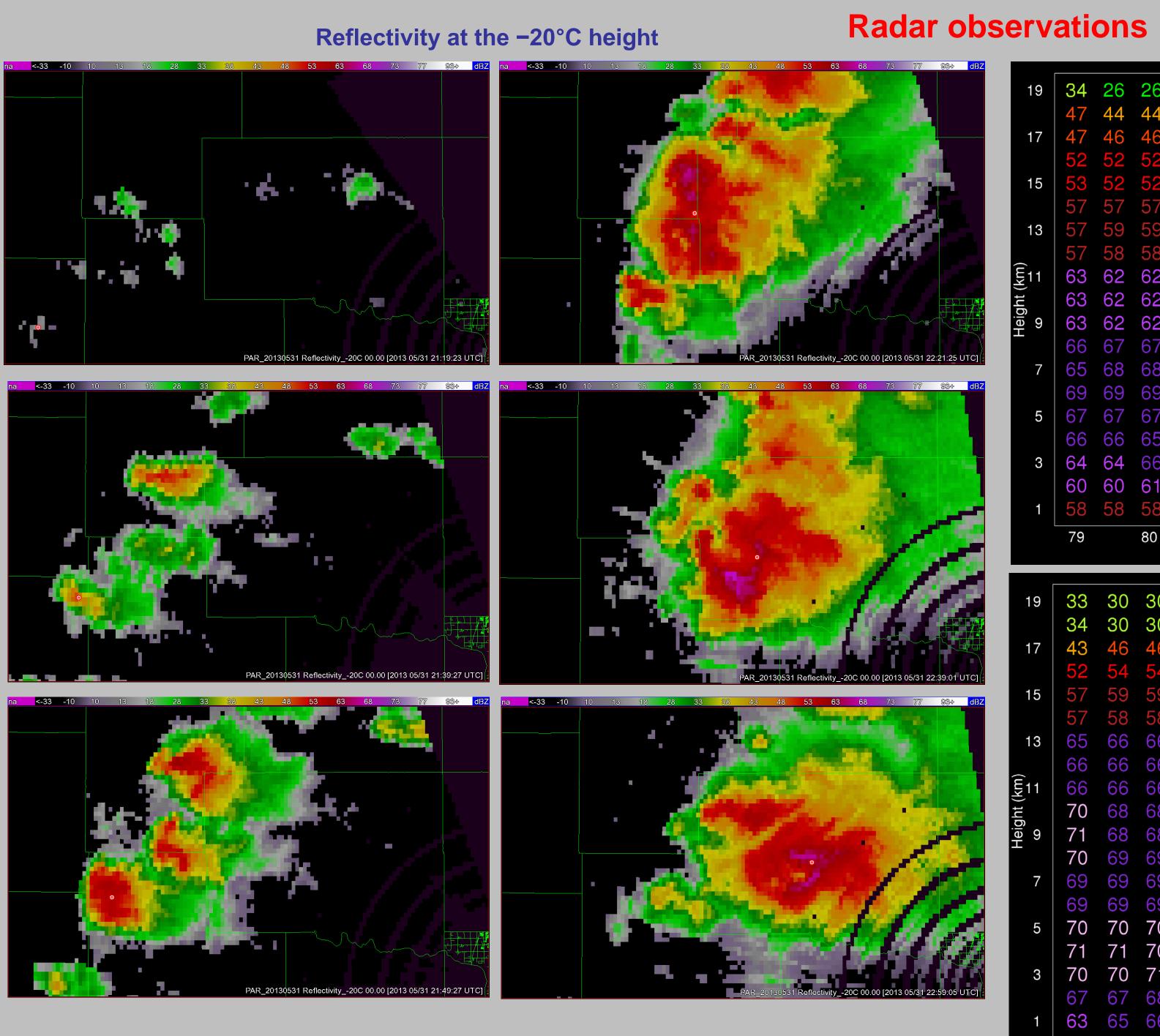
**Cross-correlation coefficient** 

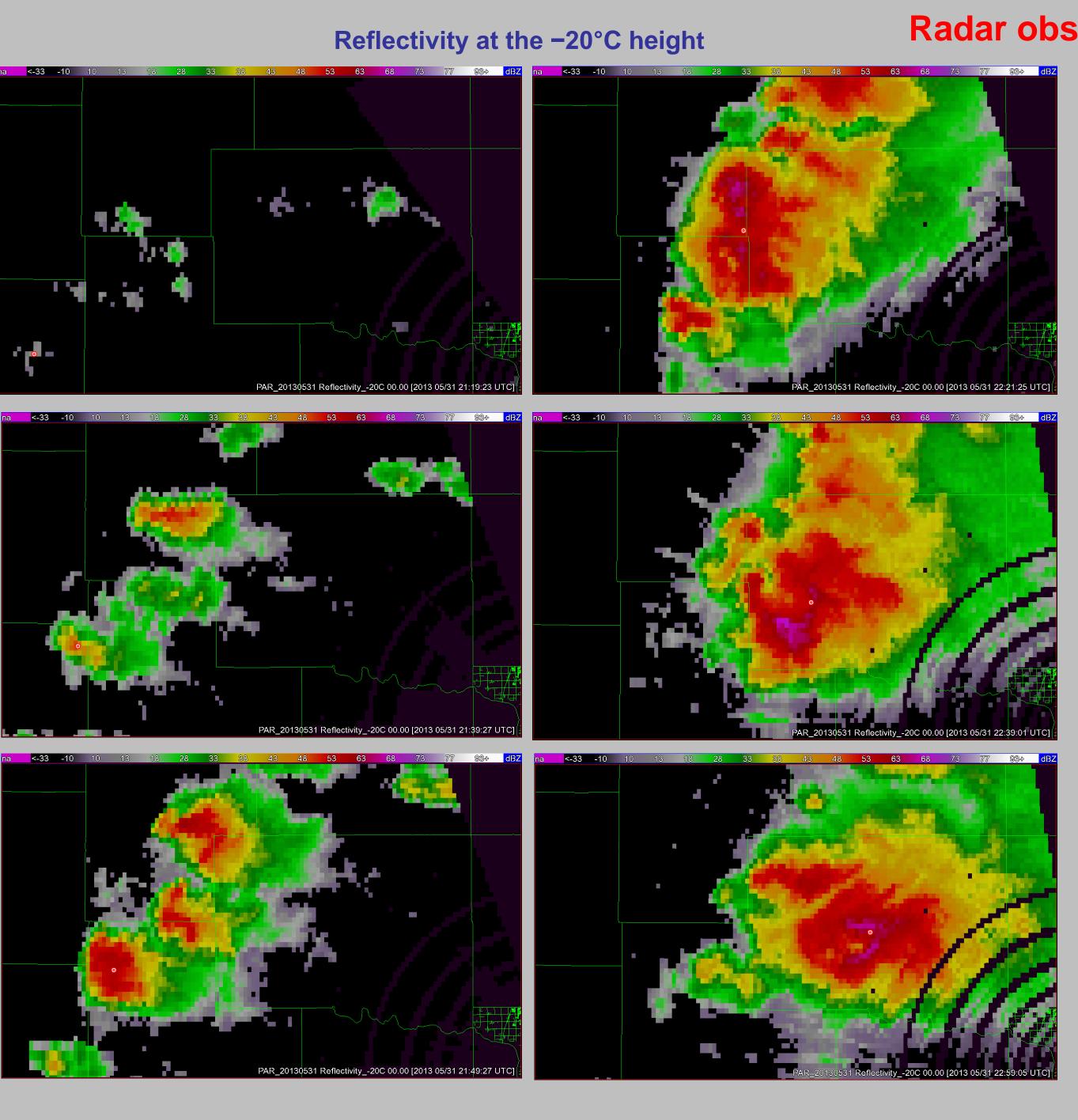


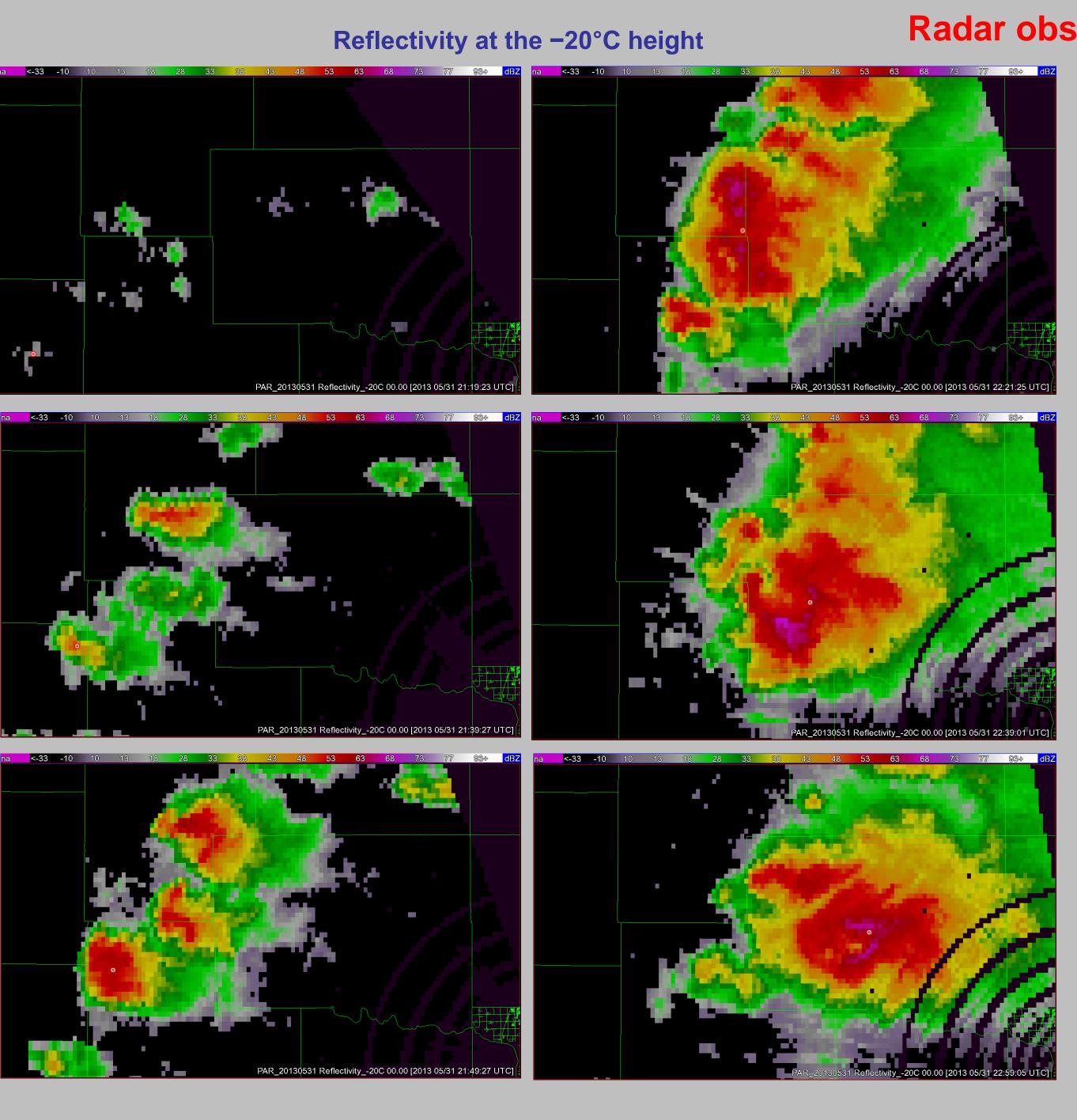


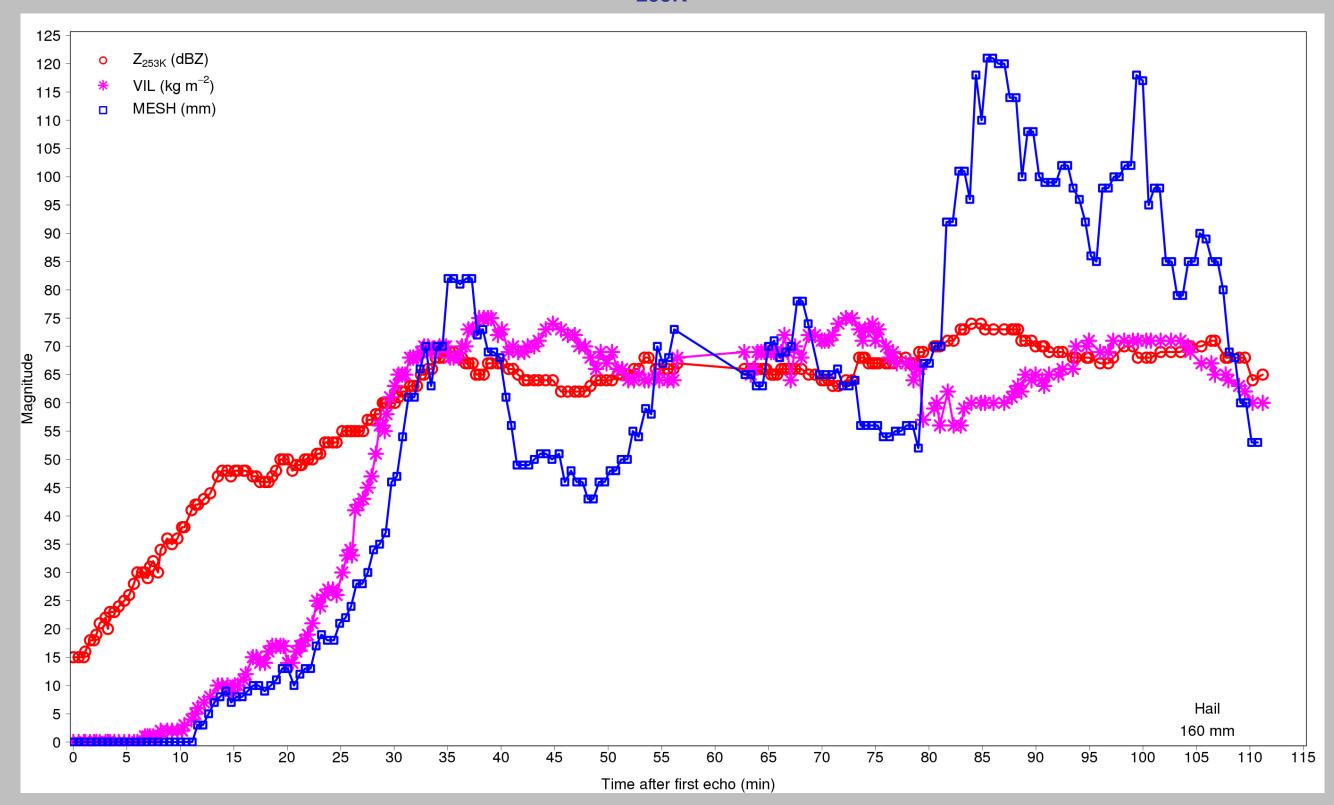
Arthur Witt **NOAA/National Severe Storms Laboratory** 

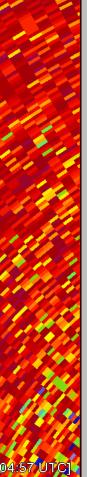




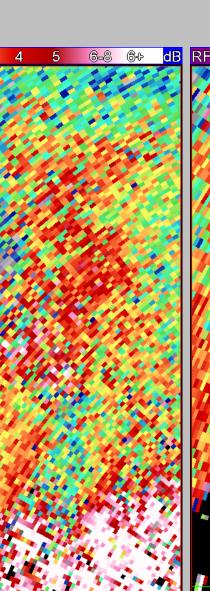


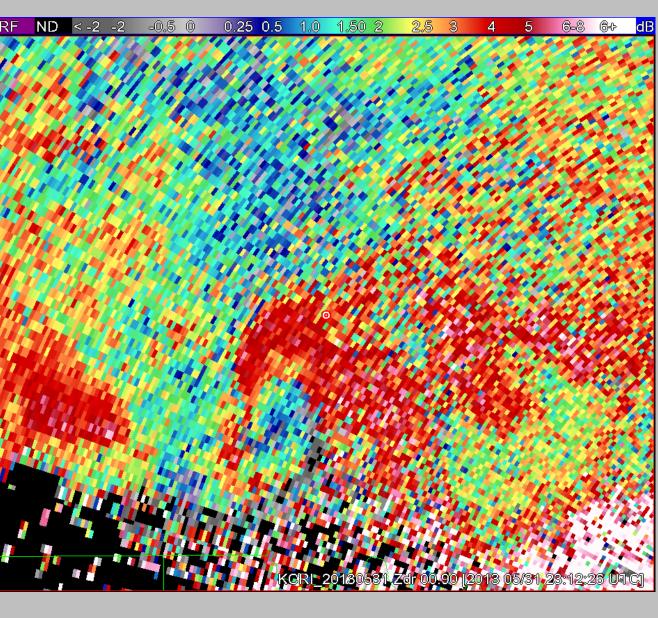


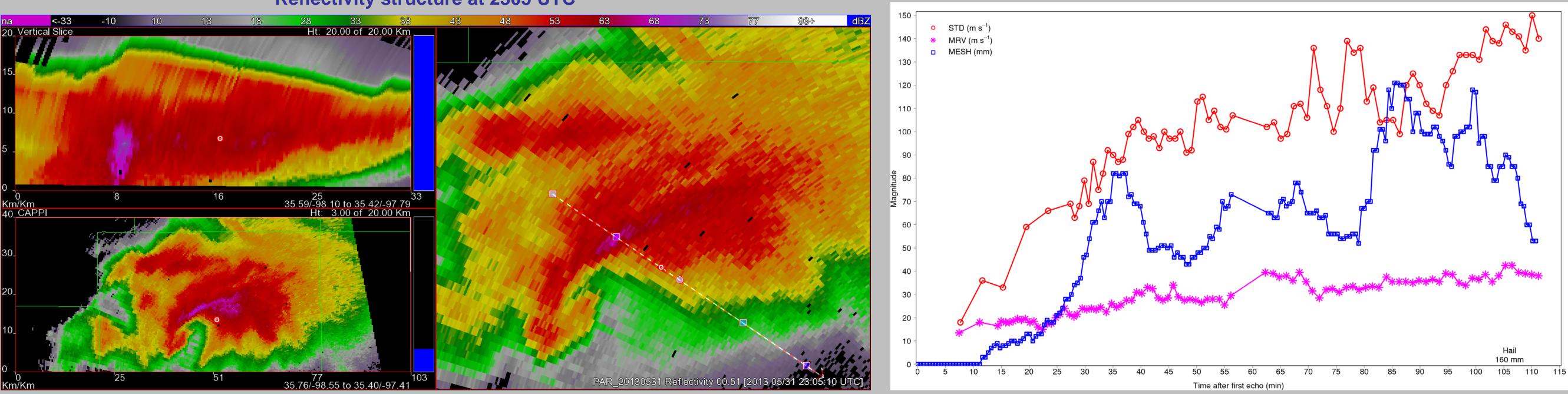












• Given the damage potential and threat to life and property from extreme severe weather events, adequate warning is vital • The PAR's ability to rapidly scan a storm's full 3-D volume allows for additional warning lead-time • During the 20-30 min prior to occurrence of the 160 mm hailstone, the storm exhibited exceptional supercell features and radar-measured intensities • The maximum STD of 150 m s<sup>-1</sup> is the second largest documented, and had an inbound velocity of 104 m s<sup>-1</sup> • The STD of 150 m s<sup>-1</sup> is more than double the 72 m s<sup>-1</sup> median STD for storms producing hail  $\geq$  102 mm in Blair et al. (2011), with the MRV of 42.5 m s<sup>-1</sup> nearly double the median MRV of 24 m s<sup>-1</sup> in Blair's study

Time series of Z<sub>253K</sub>, VIL and MESH

**Reflectivity structure at 2305 UTC** 

## Conclusions

• Although the maximum MESH of 121 mm was less than the observed size, such a high MESH gives adequate indication of the extreme threat • The higher time resolution data from the PAR is most evident in the MESH and STD time-series, with some periods of rapid increase and decrease in magnitude • More frequent observations of STD and MRV signatures provide greater confidence in the accuracy of their measured strength, especially when extremely high velocities and extensive aliasing are involved



	VC			3		Vertical reflectivity profile (dBZ)															
1	9	34	26	26	33	33	33	22	22	25	25	24	24	25	25	27	27	27	29	29	33
		47	44	44	44	44	44	39	39	36	36	33	33	27	27	35	35	35	32	32	34
1	7	47	46	46	48	48	48	46	46	45	45	43	43	44	44	41	41	41	40	40	43
1	5	52 53	52 52	52 52	48 47	48 47	48 48	48 48	48 48	48 49	48 49	47 47	47 47	51 52	51 52	48 48	48 48	51 51	51 52	51 52	<b>52</b> 57
		57	57	57	58	58	56	56	53	53	53	50	50	52	52	48	48	55	55	55	57
1	3	57	59	59	58	58	58	58	62	62	62	61	61	59	59	60	60	65	65	65	65
(E1	1	57 63	58 62	58 62	57 60	57 60	58 63	58 63	62 68	62 68	62 68	62 63	62 63	59 67	59 67	60 69	60 69	65 68	65 68	65 65	66 66
Height (km)	•	63	62	62	61	61	63	63	68	68	68	68	68	68	68	69	69	69	69	70	70
Heig	9	63	62	62	66	66	70	70	69	69	69	71	71	71	71	69	69	70	70	71	71
	7	66 65	67 68	67 68	67 69	67 69	70 71	70 71	70 73	70 73	70 74	72 74	72 74	73 73	73 73	72 73	72 73	70 73	70 73	70 71	70 71
	<b>′</b>	69	69	69	69	69	70	70	71	71	73	73	71	73	73	72	72	73	73	71	71
	5	67	67	67	68	68	70	70	70	70	72	72	72	72	72	72	72	71	71	71	71
	0	66 64	66	65	67 66	67 64	68 67	68 66	69 67	69 67	70	70	69 66	69 66	69 67	71	71	70	70	70	70
	3	64 60	64 60	66 61	бб 61	64 61	б7 61	66 61	67 61	67 60	66 61	66 61	60 62	60 62	67 62	67 62	68 64	68 64	68 64	69 65	69 65
	1	58	58	58	58	58	58	59	59	59	59	60	60	61	62	62	61	61	61	61	63
		79		80		81	6	32	8		84 fter fir:		85 (min	\ \	86		87		88	8	39
1	9	33	30	30	32	32	36	36	36	38	38	31	31	30	30	41	41	43	43 49	43 49	39
1	7	34 43	30 46	30 46	36 45	36 45	42 43	42 43	42 43	46 48	46 48	46 47	46 47	41 53	41 53	46 54	46 54	48 54	48 54	48 54	48 53
		52	54	54	55	55	56	56	56	56	56	56	56	55	55	58	58	57	57	57	59
1	5	57	59	59	59	59	61	61	61	60	60	59	59	60	60	62	62	60	60	60	60
1	3	57 65	58 66	58 66	59 65	59 65	62 64	62 64	62 64	62 64	62 64	62 64	62 64	60 65	60 65	63 65	63 65	65 65	65 65	65 65	63   64
		66	66	66	65	65	67	67	69	69	69	66	66	69	69	69	69	68	68	70	70
(km)	1	66	66	66	66	66	66	66	68	68	68	66	66	69	69	68	68	69	69	70	70
Height (km)	a	70 71	68 68	68 68	68 68	68 68	69 69	69 69	69 69	69 69	69 69	69 69	69 69	69 69	69 69	70 70	70 70	70 69	70 69	71 71	71   71
He	9	70	69	69	70	70	69	69	68	68	67	67	67	68	68	68	68	70	70	71	71
	7	69	69	69	68	68	69	69	67	67	67	67	67	67	67	68	68	70	70	68	68
	5	69 70	69 70	69 70	69 70	69 70	69 69	69 69	68 68	68 68	67 68	67 68	67 67	67 67	68 68	67 68	67 66	67 66	67 66	67 68	67 68
	5	71	71	70	70	70	69	69	69	69	68	68	67	67	68	68	68	68	68	67	67
	3	70	70	71	71	71	71	70	70	70	69	69	68	68	68	68	68	68	67	67	67
		67 62	67 65	68 66	68 66	68 67	68 67	69 67	68 67	68 67	68 67	68 67	68 67	68 67	67 68	67 68	67 67	67 67	68 66	68 66	66
		63 9	65 0	66 9	66	67 92	67	67 93	67	67 94	67	67 95	67 c	67 96	68 9	68 7	67 98	67	66 99	66	65 100
										Time a	fter firs		o (min)	)							
1	9	39	37	37	34	34	40	40	36	36	36	42	42	38	38	34	34	30	30	34	34
		48	45	45	48	48	51	51	51	51	51	52	52	51	51	50	50	46	46	47	47
1	7	<b>53</b>	52 57	52 57	50 57	50 57	53 57	53 57	55 56	55 56	55 56	55 56	55 56	56 50	56 50	55 57	55 57	56	56	<b>53</b>	<b>53</b>
1	5	59 60	57 61	57 61	57 62	57 62	57 61	57 61	56 61	56 61	56 61	56 58	56 58	58 60	58 60	57 58	57 58	56 60	56 60	56 58	56 58
		63	64	64	62	62	63	63	64	64	64	62	62	60	60	63	63	60	60	60	60
1	3	64	64	64	65	65	65	65	64	64	64	62	62	60	60	63	63	62	62	60	60
Ê1	1	70 70	67 70	67 70	68 68	68 68	68 68	68 68	64 64	64 64	65 66	65 66	65 66	66 66	66 66	63 62	63 62	62 62	62 62	62 64	62   64
ght (km)		70	70	70	70	70	69	69	68	68	67	67	65	65	65	64	64	63	63	60	60
Heig	9	70	70	70	70	70	69	69	68	68	67	67	65	65	65	63	63	63	63	62	62
	7	70	70 68	70	69 68	69 68	69 69	69 69	70	70	68 68	68 68	69 69	69 69	69 69	66 66	66 66	64 64	64 64	64 64	64
	7	68 67	68 67	68 69	68 69	68 69	69 69	69 69	69 70	69 70	68 70	68 70	69 71	69 71	69 68	66 68	66 68	64 68	64 68	64 64	64 64
	5	67	67	67	67	68	68	68	69	69	70	70	72	72	68	68	68	68	68	66	66
		68	68	68	68	67	67	67	67	67	69	69 69	70	70	70	70	69	69	69	68	68
	3	68 66	68 66	69 67	69 67	69 68	69 68	67 67	67 67	67 66	68 66	68 67	69 67	69 67	70 67	70 67	68 67	68 67	67 66	67 66	66 66
	1	65	65	65	66	67	67	66	66	65	65	67	67	66	66	66	66	66	65	65	65
	L		101		102		103	1(	04	10	5	106		107		108		109	1	10	 111

Time series of STD, MRV and MESH

Time after first echo (mir