WRF Microphysics Validation with HMT Observations: Simulations of Winter Storms Impacting the Complex Terrain of Northern California

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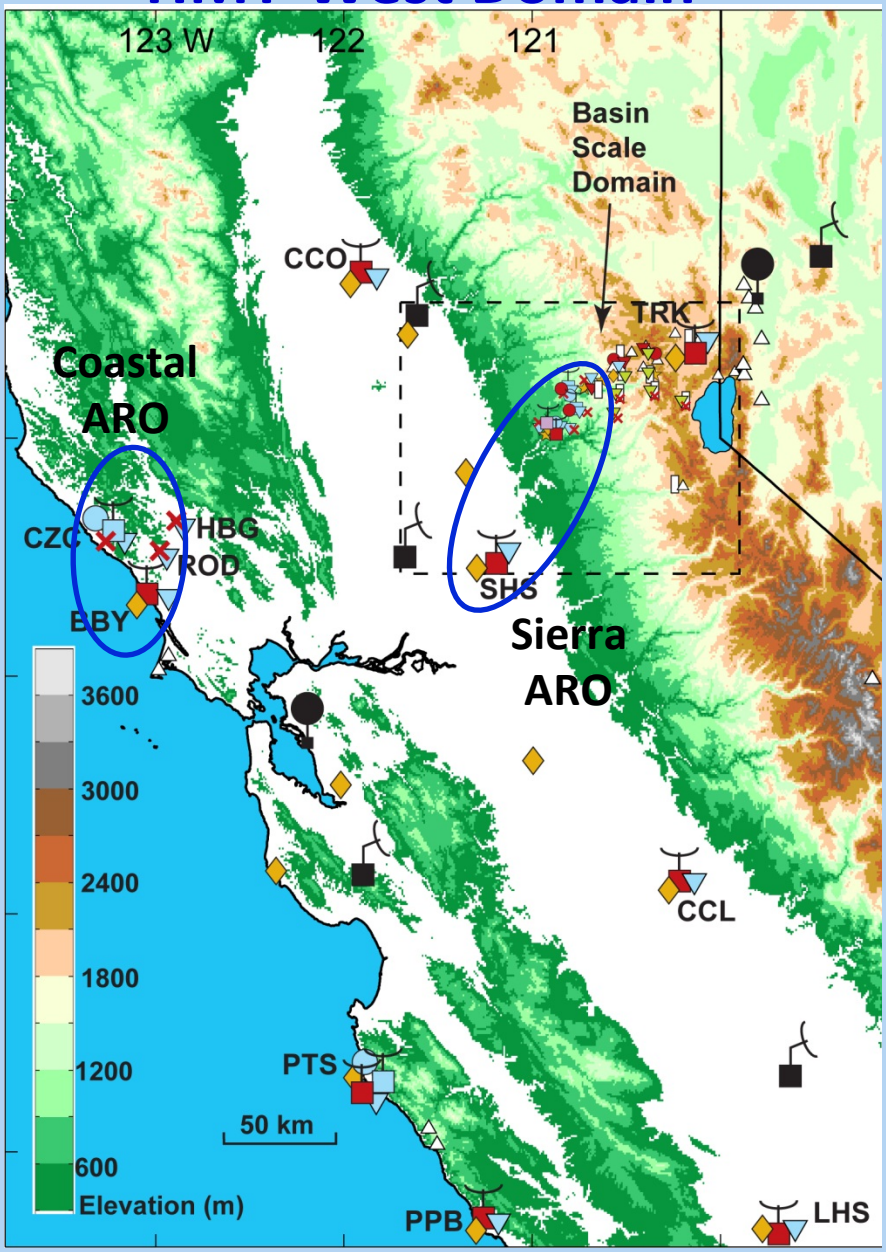
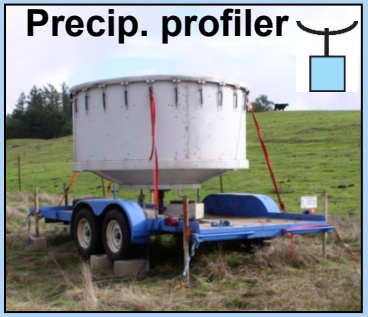
Motivation

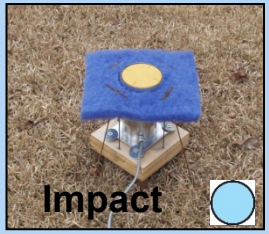
- Statistical validation approaches are a necessary but insufficient element of NWP model validation.
- Physical validation aims to examine the key physical processes represented in the NWP models and determine their validity using a variety of detailed observational datasets.
- It is important to understand why NWP models often do not produce the correct answer, but it is equally important that the NWP models get the ***correct answer for the correct reason***
- One of the factors that contribute to inaccurate QPF is deficient parameterizations of physical processes in the forecast models.
- A particularly problematic parameterization involves cloud and precipitation microphysics.

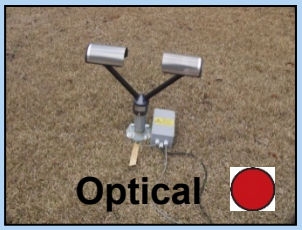
HMT-West Domain



- Observations from 16 largest precipitation events during HMT-West field campaigns in northern California during the 2005-2006 through 2011-2012 seasons
- Emphasis on data collected at two different Atmospheric River Observatories (ARO's)



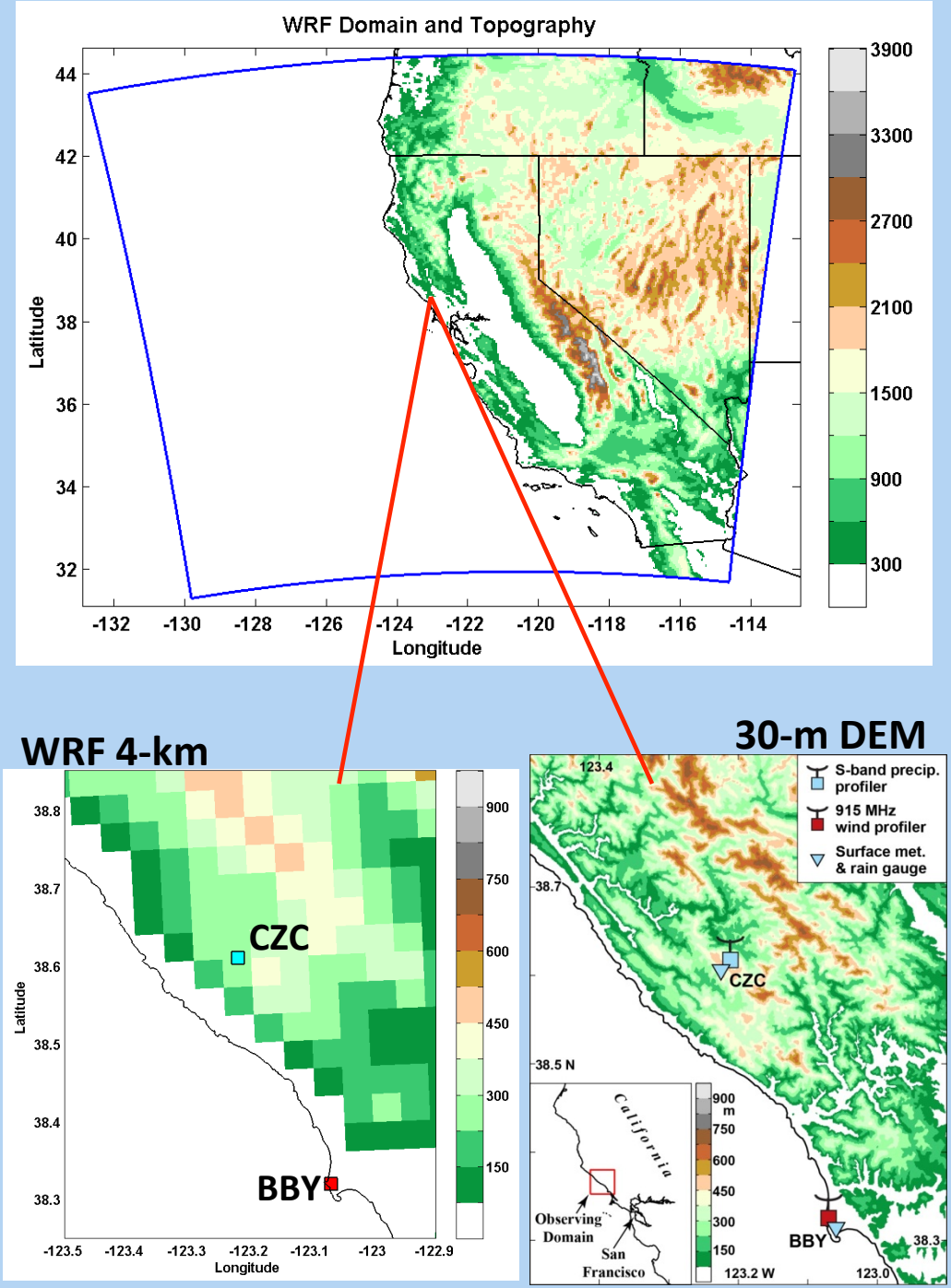




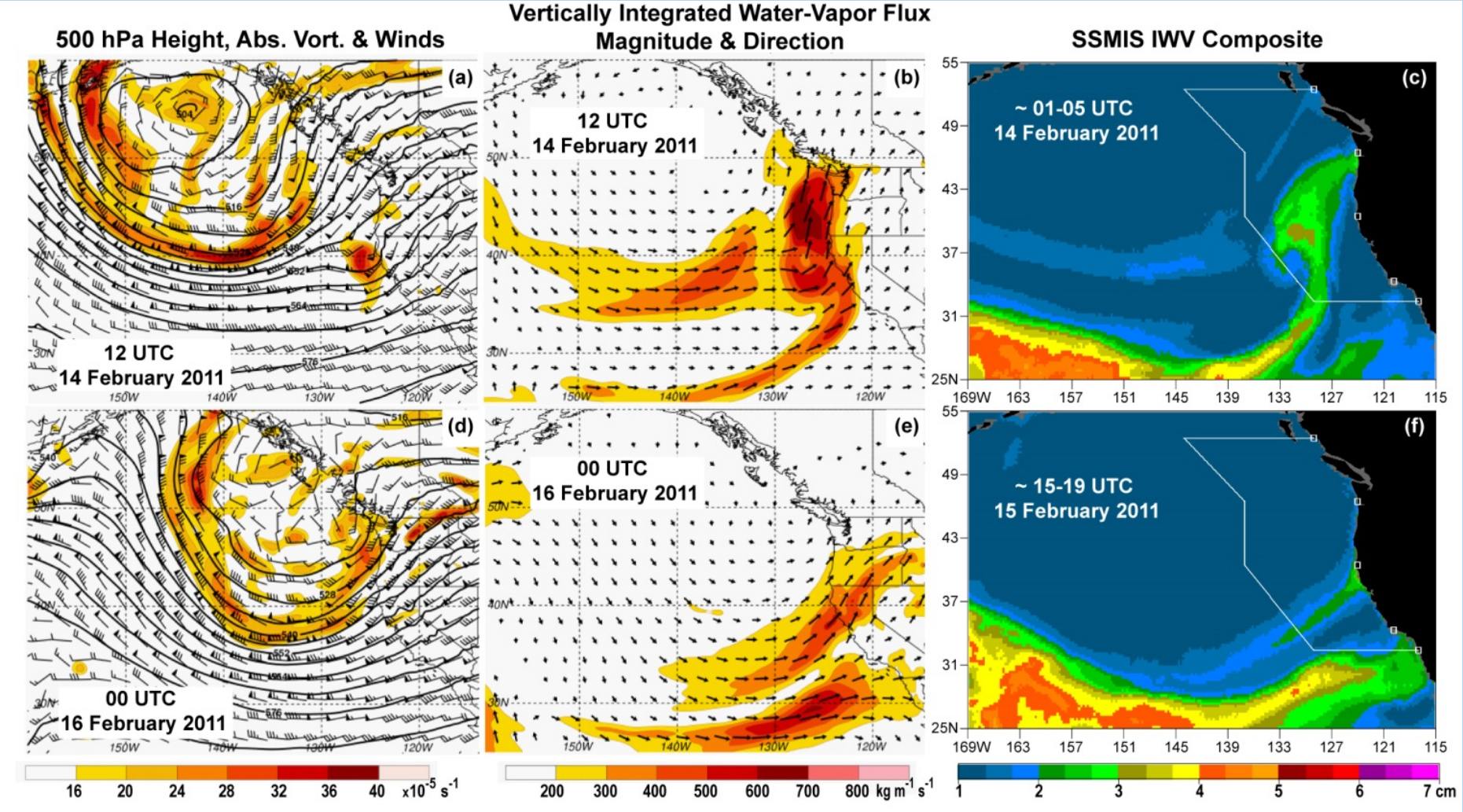
Initial focus on a single event at the Coastal ARO

Model Setup

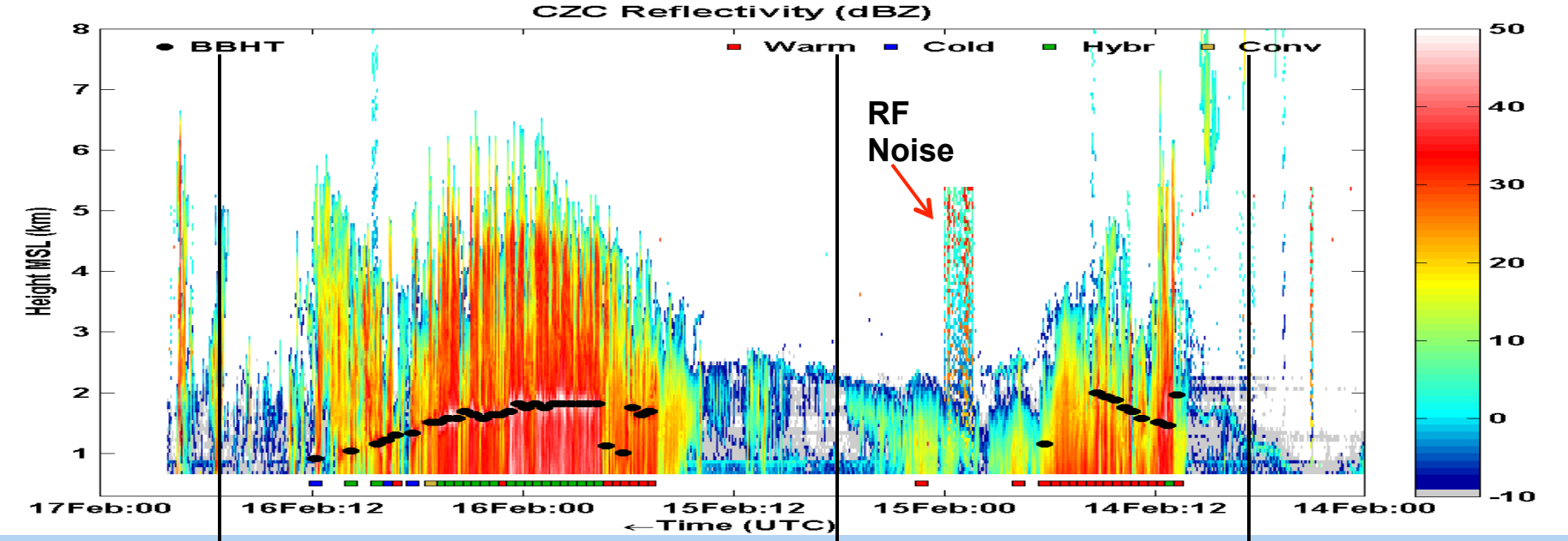
- WRF ARW and NMM dynamic cores
- 4 km horizontal grid spacing; no inner nest
- 60 vertical levels with a model top of 30 mb
- IC/Lateral BC: NAM analyses
- Microphysics options: ARW (**Ferrier**, **WSM6**, **Morrison**, Thompson, WSM3), NMM (Ferrier)
- Simulations initialized at 6 h intervals during events and run for 24-36 h
- Output stored at 15 m intervals

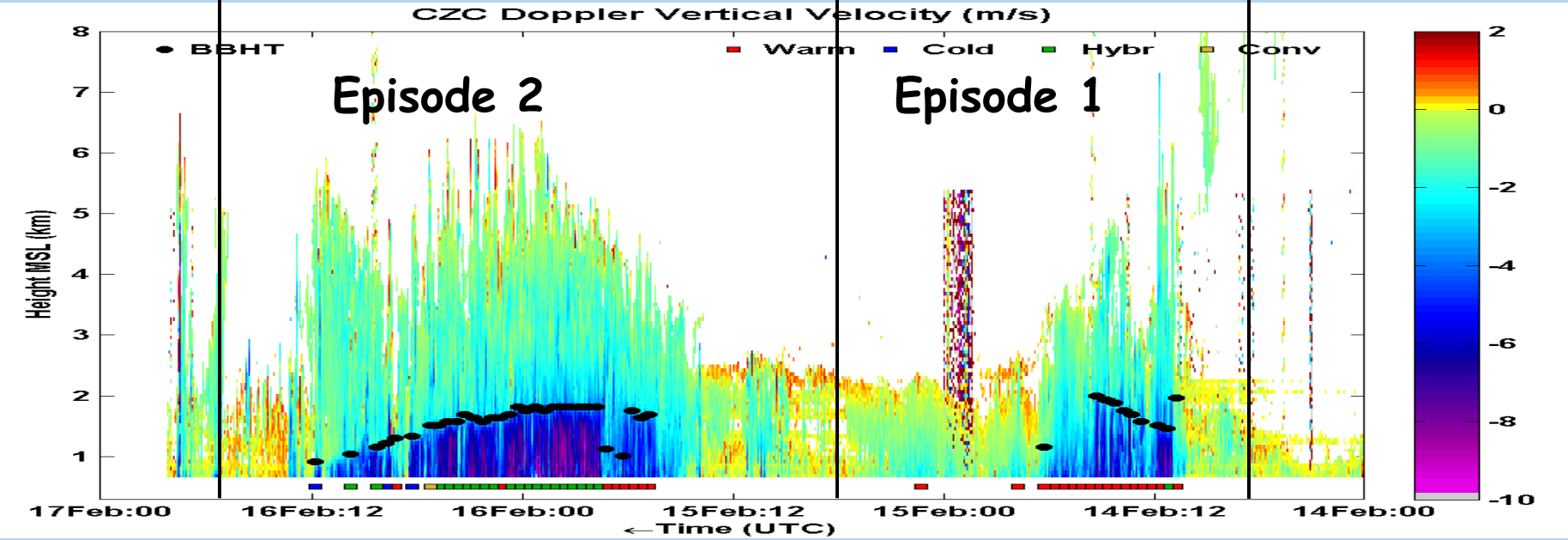


Synoptic Context for 14-17 February 2011

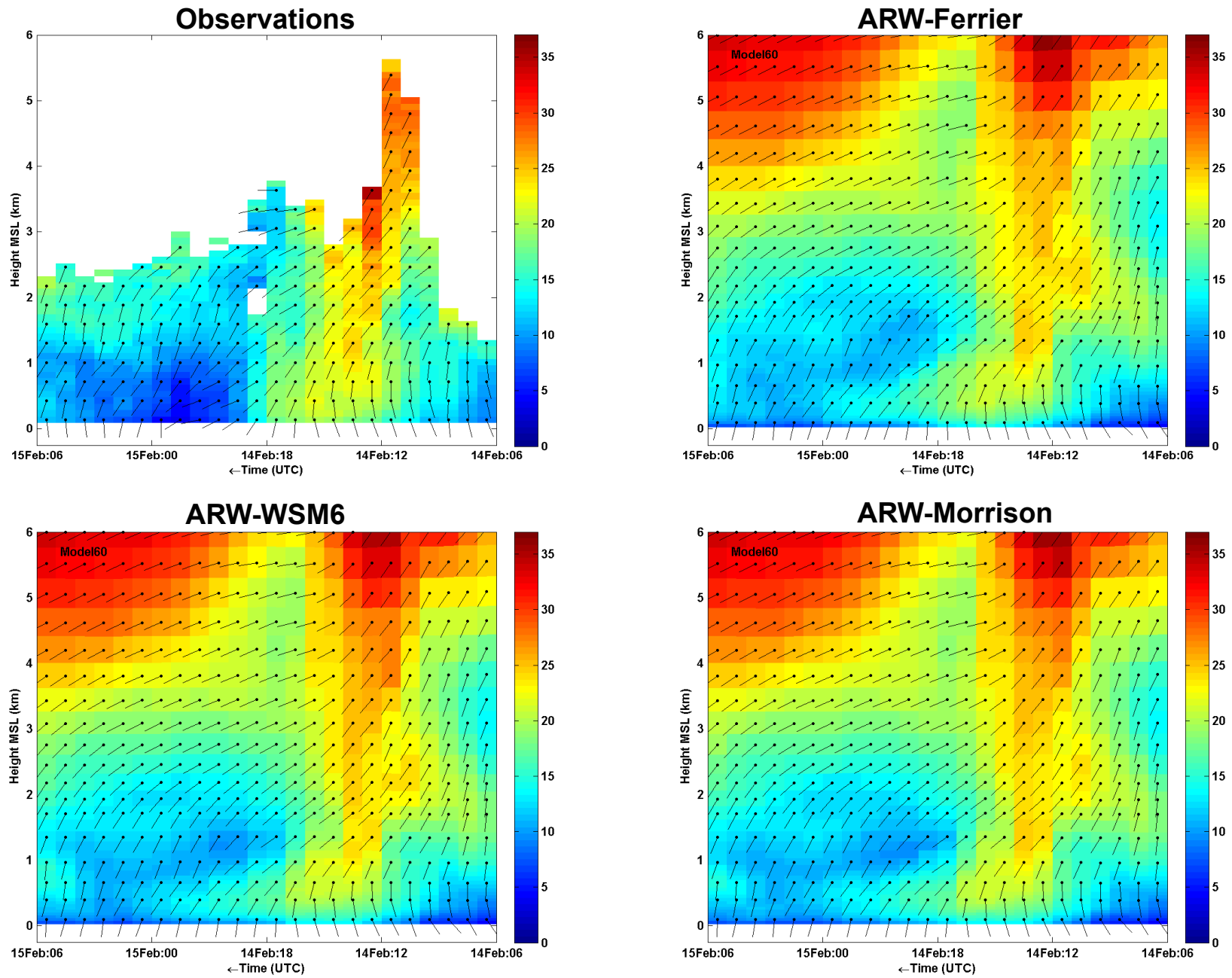


Observed Refl. & Doppler Vert. Vel. at CZC

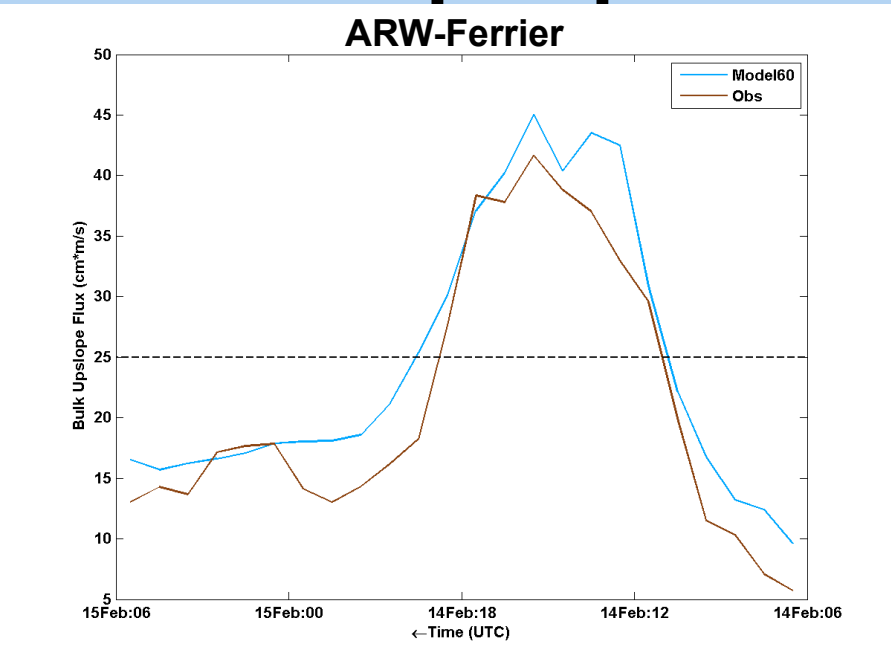


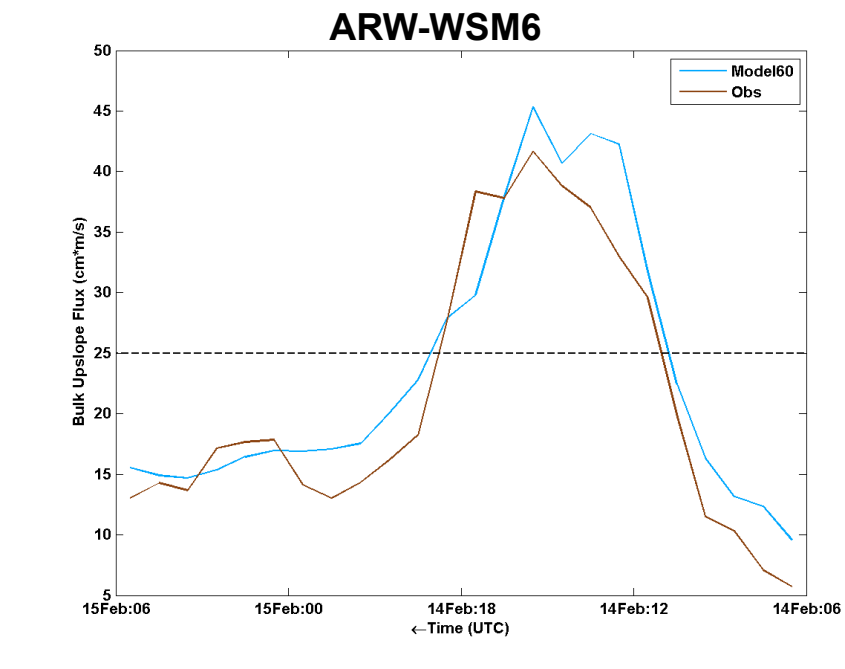


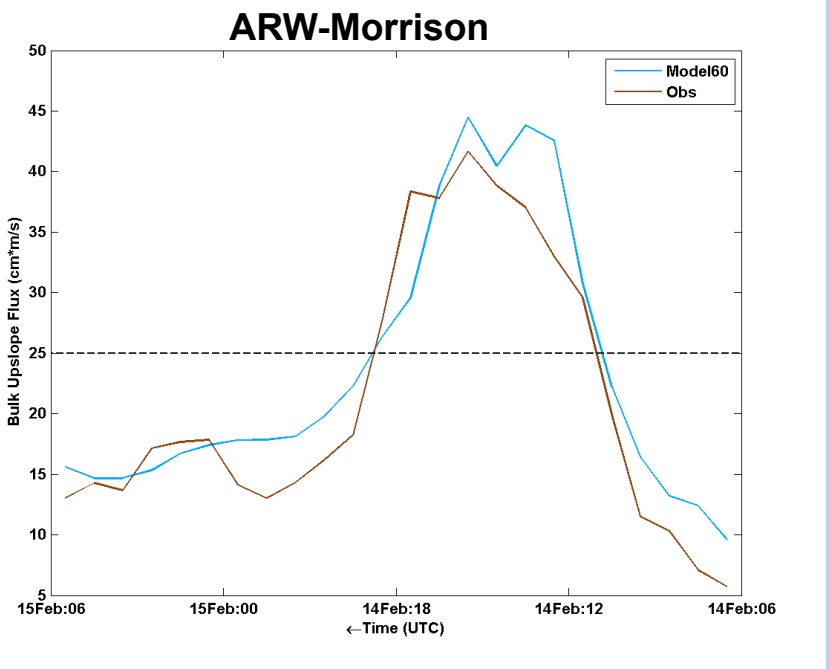
Episode 1: Total Wind Speed at BBY



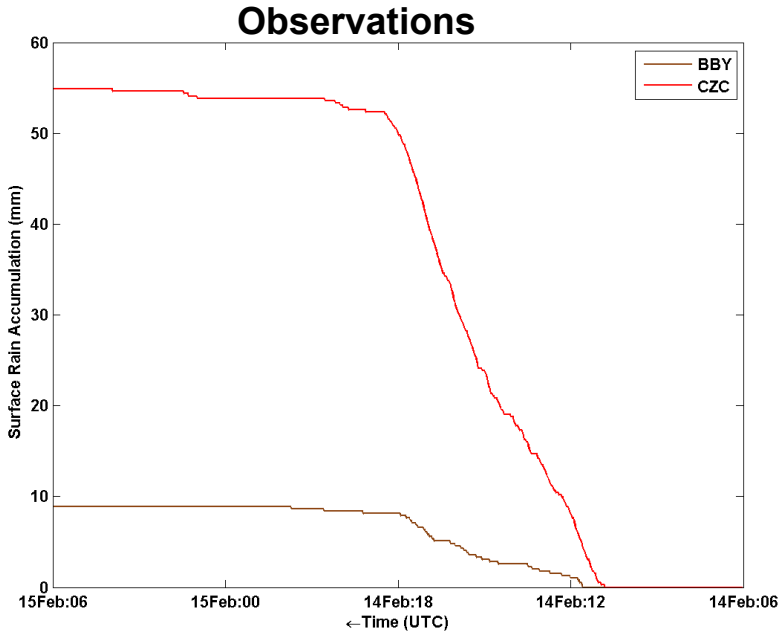
Episode 1: Bulk Upslope Flux at BBY

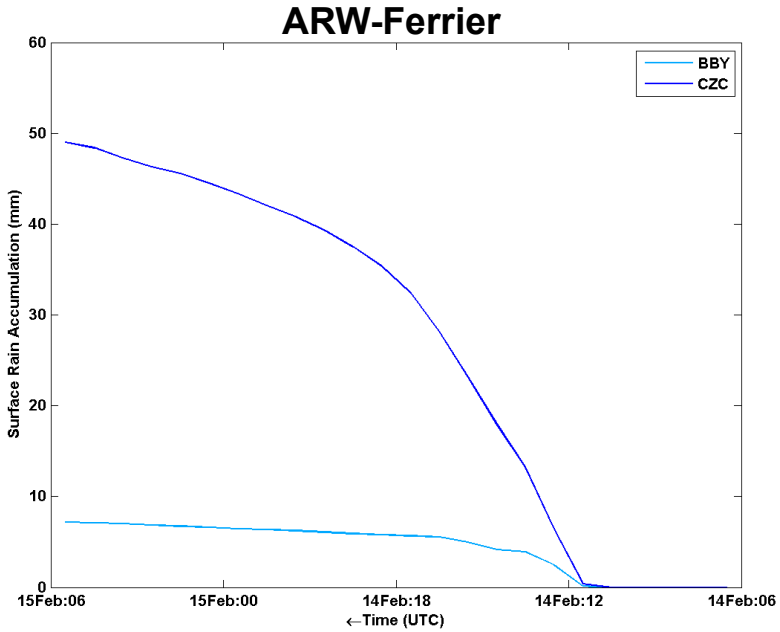


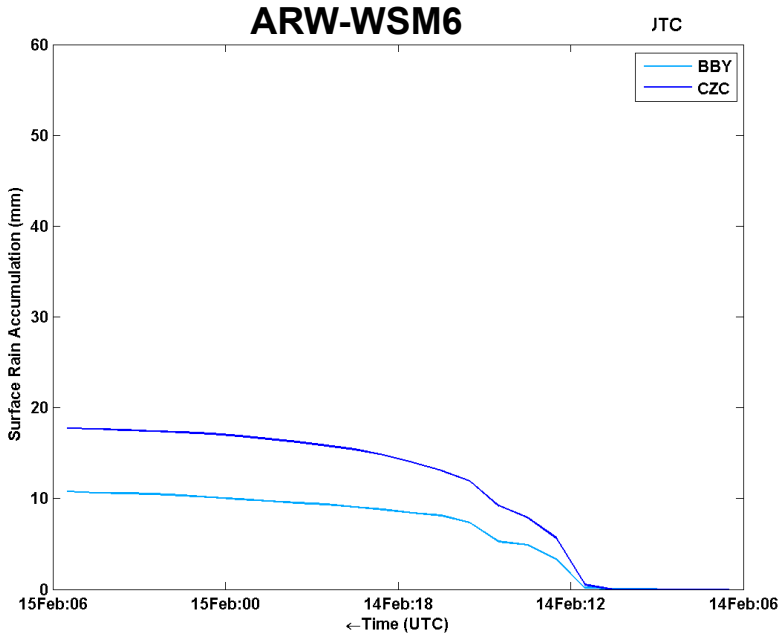


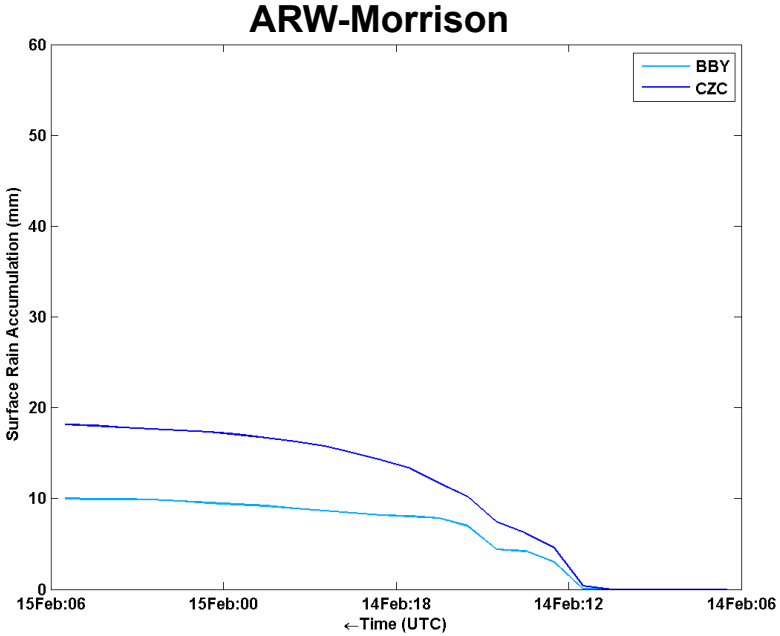


Episode 1: Surface Rain Accum. at BBY&CZC

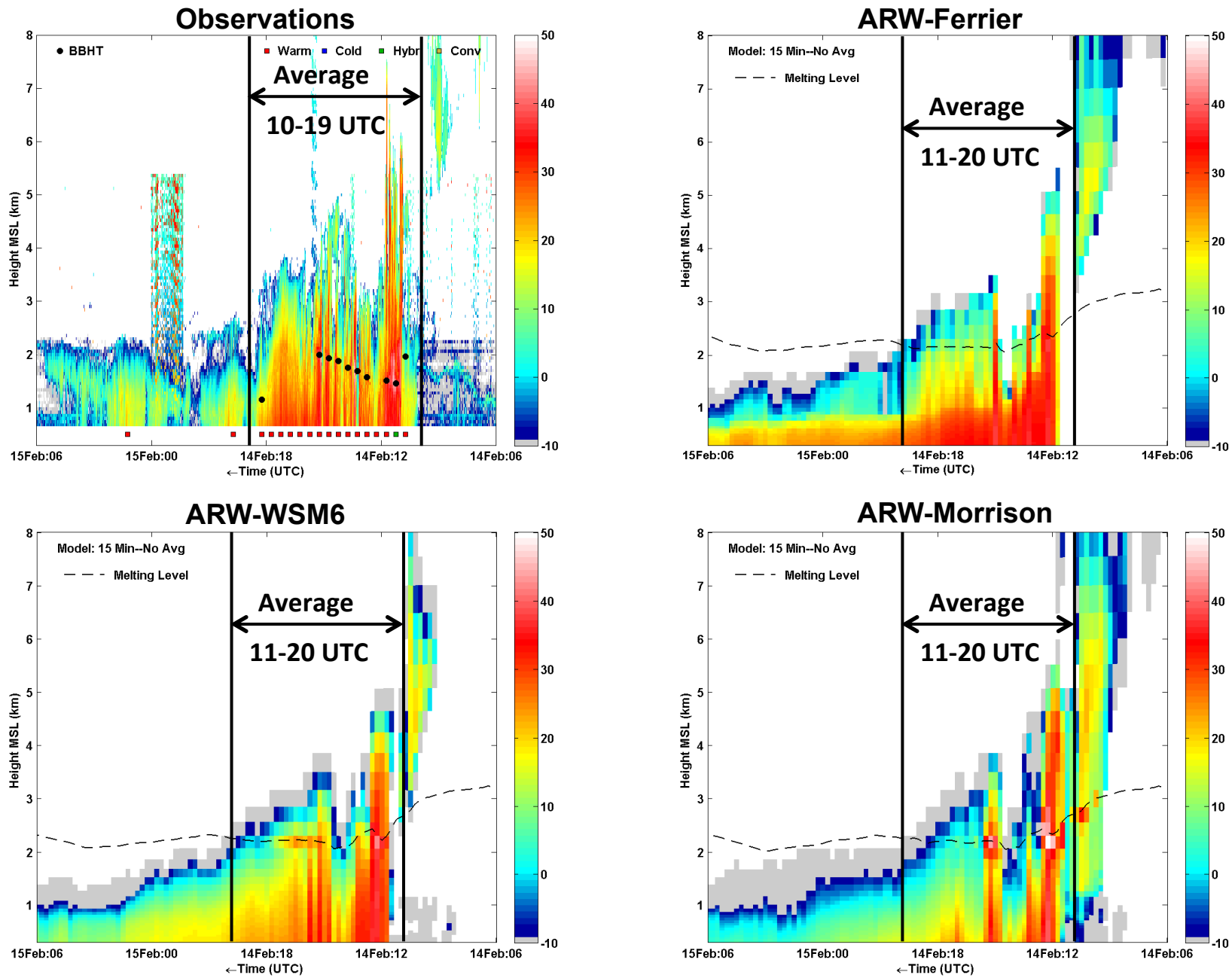








Episode 1: Reflectivity at CZC



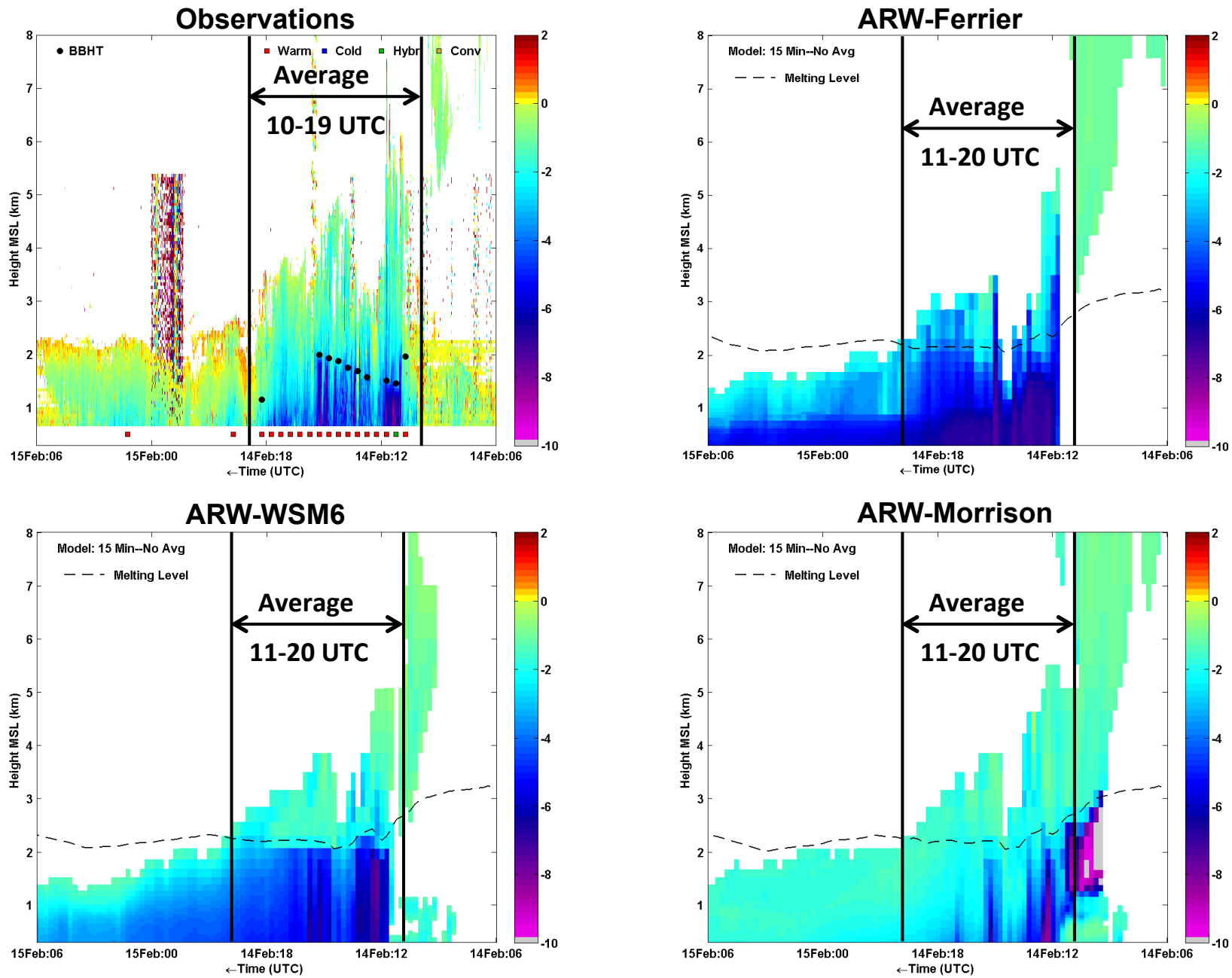
Episode 1: Avg Refl. & RWC at CZC

	Observations	ARW Ferrier	ARW WSM6	ARW Morrison
700 m Avg Refl. (dBZ)	29.9	31.4	28.2	26.5
700 m Avg RWC (mg m^{-3})	(NBB) 386 (BB) 191	198	108	159
700 m Avg Inv λ (mm)	(NBB) 0.14 (BB) 0.27	0.29	0.23	0.15

Rainwater Content (M) vs Reflectivity (Z) Relationships

- Cazadero Joss-Waldvogel disdrometer dataset from 2003-2004 season (Martner et al. 2008)
  - 1221 10-minute average DSD's
- Brightband Rain (BB): $M(mg\ m^{-3})=5.7Z^{0.51}$
- Non-Brightband Rain (NBB): $M(mg\ m^{-3})= 39.8Z^{0.33}$

Episode 1: Hydrometeor Vertical Velocity at CZC



Episode 1: Avg. HVV, VTdBZ, W at CZC

	Observations	ARW Ferrier	ARW WSM6	ARW Morrison
700 m Avg HVV ($m\ s^{-1}$)	-4.2	-6.4	-5.2	-3.3
700 m Avg VTdBZ ($m\ s^{-1}$)	(NBB) -4.8 (BB) -5.8	-6.3	-5.1	-3.2
700 m Avg w ($m\ s^{-1}$)	(NBB) ~+0.6 (BB) ~+1.6 [HVV-VTdBZ]	-0.1	-0.1	-0.1
500 m Avg RR ($mm\ h^{-1}$)	5.8	4.1	1.7	1.6

Fall Speed (V_T) vs Reflectivity (Z) Relationships

- Cazadero Joss-Waldvogel disdrometer dataset from 2003-2004 season (Martner et al. 2008)
- Brightband Rain (BB): $V_T(m\ s^{-1})=3.1Z^{0.09}$
- Non-Brightband Rain (NBB): $V_T(m\ s^{-1})= 1.3Z^{0.19}$

Conclusions

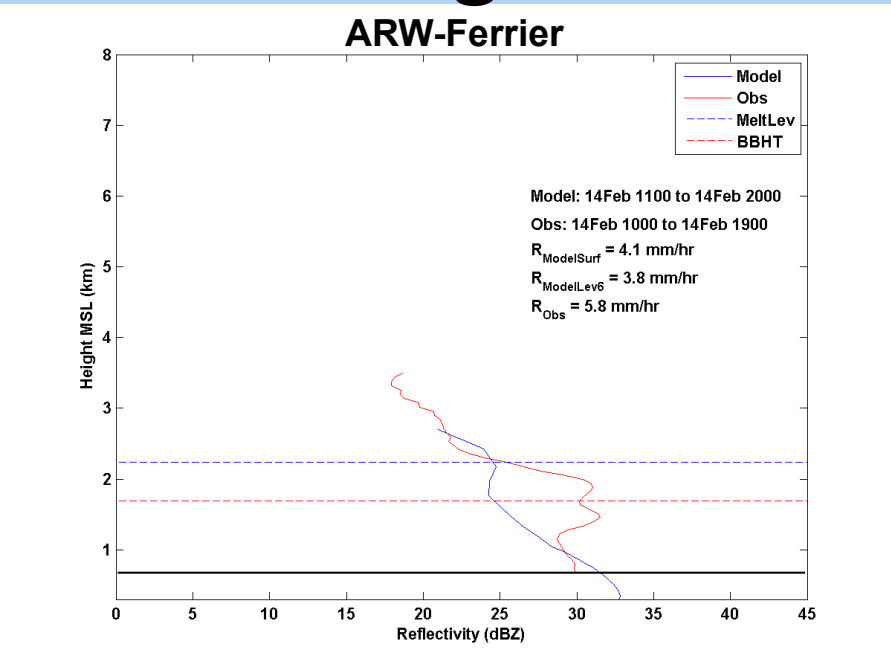
- Forcing (horizontal water vapor flux) is well represented by the models.
- BBY QPF relatively accurate (+/- 10-20% of observations). However, CZC QPF is low by a factor of 2-3 for all but ARW-FER, which was only low by ~15%.
- Models capture the gross features of echo pattern, but differences are evident in the detailed structures.
- Model rainwater content at 700 m (first good gate of SPROF) is low by a factor of 2-4 (ARW-FER closest). Inverse λ varies from 0.15 (NBB character) to 0.29 (BB character), with ARW-FER the largest.
- Model average downward hydrometeor vertical velocity is 10-50% too large (ARW-FER largest) for all except ARW-MOR, which was ~20% too small.
- Model average vertical air velocities were near zero but slightly negative, while the observations suggest that there should be an average updraft on the order of 0.5 m/s.
- Despite ARW-FER RWC being low by a factor of 2, ARW-FER rain rate only low by about 30% since the ARW-FER HVV is high by about 50%.
- ARW-FER QPF closest to correct answer, but for wrong reasons?

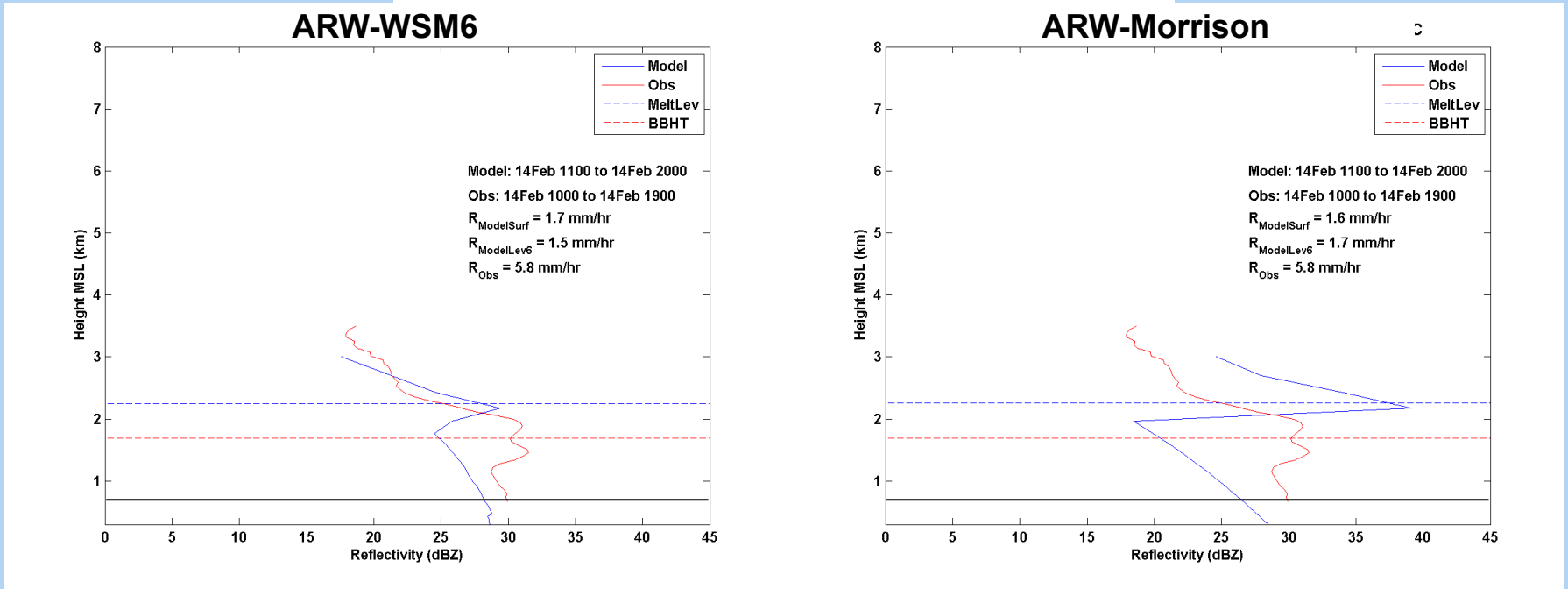
Backup Slides

Cases

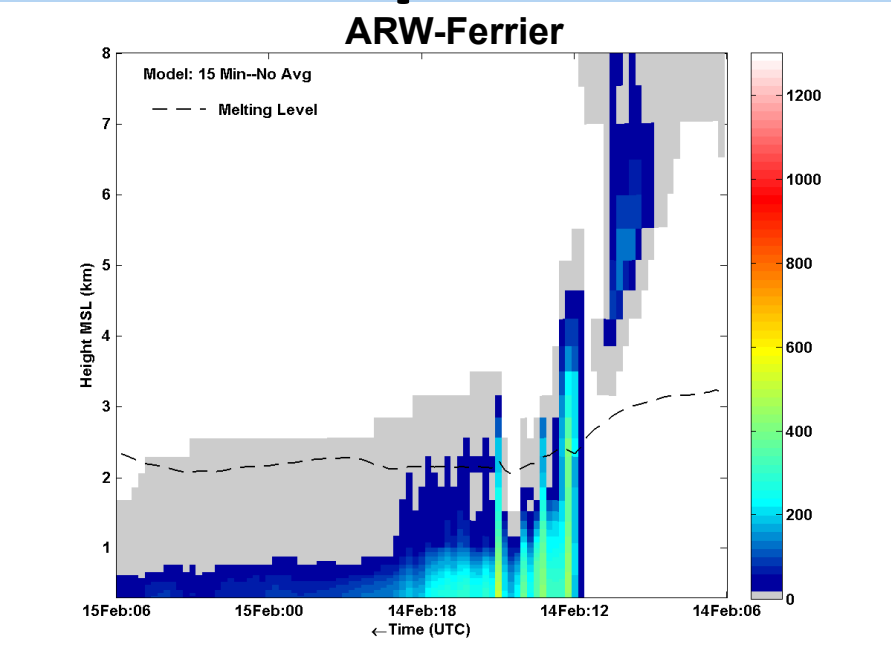
	Start of Case				End of Case				Duration (h)	Coast (CZC) + Sierra (ATA or SPD) Total Liquid Precip (mm)
	Y	M	D	H	Y	M	D	H		
	2005	12	30	00	2005	12	31	20	44	439.4
	2007	02	08	18	2007	02	11	12	66	438.4
	2008	01	03	12	2008	01	05	05	41	357.4
	2012	03	13	04	2012	03	17	10	102	343.4
	2009	02	22	05	2009	02	24	06	49	335.0
	2005	12	20	13	2005	12	23	11	70	273.8
	2005	12	27	11	2005	12	28	21	34	271.3
	2011	**02**	**14**	**10**	**2011**	**02**	**16**	**16**	**54**	**256.8**
	2012	01	19	16	2012	01	21	16	48	235.6
	2010	12	17	10	2010	12	19	19	57	223.3
	2012	03	27	00	2012	03	28	20	44	192.5
	2010	01	17	20	2010	01	19	00	28	191.0
	2008	02	23	17	2008	02	25	10	41	189.5
	2010	12	28	10	2010	12	29	16	30	184.2
	2008	02	02	12	2008	02	04	05	41	162.56
	2006	12	26	14	2006	12	27	23	33	161.29
						Mean			48.9	266.0

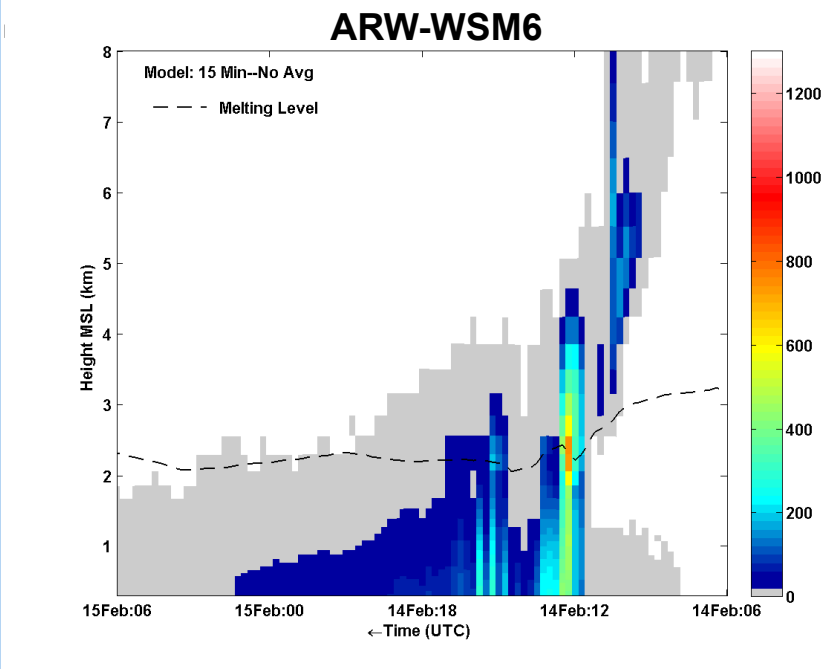
Episode 1: Avg Refl. at CZC

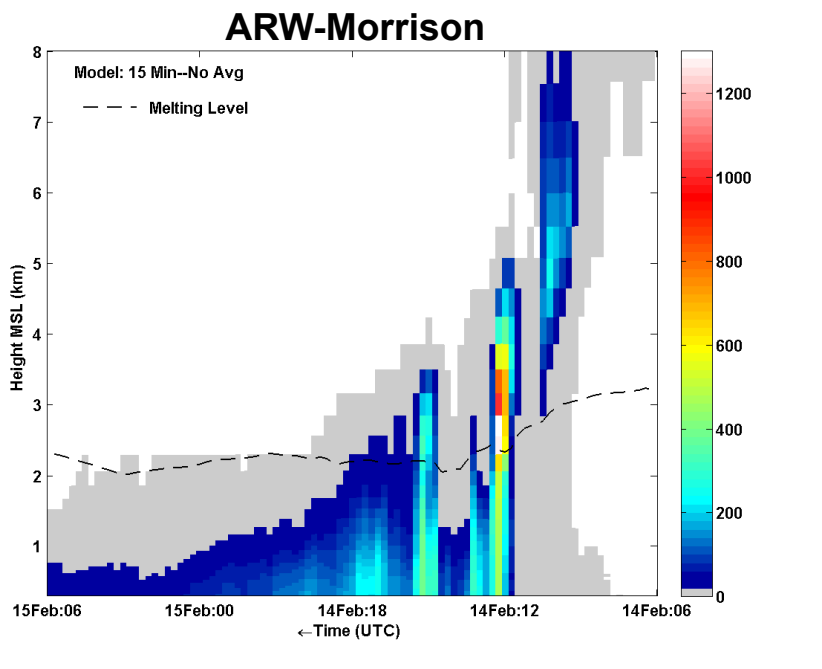




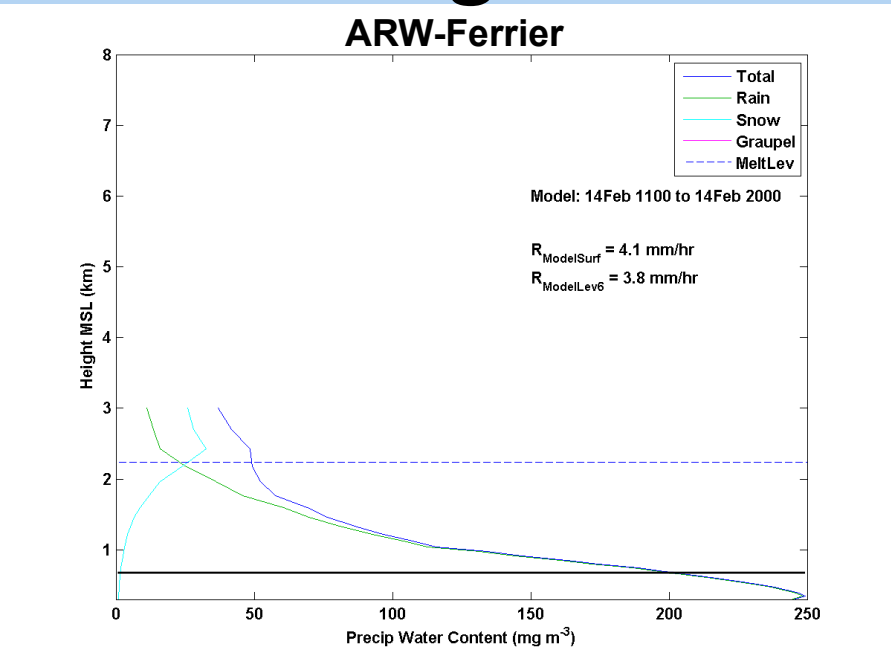
Episode 1: Total Precip. Water Content at CZC

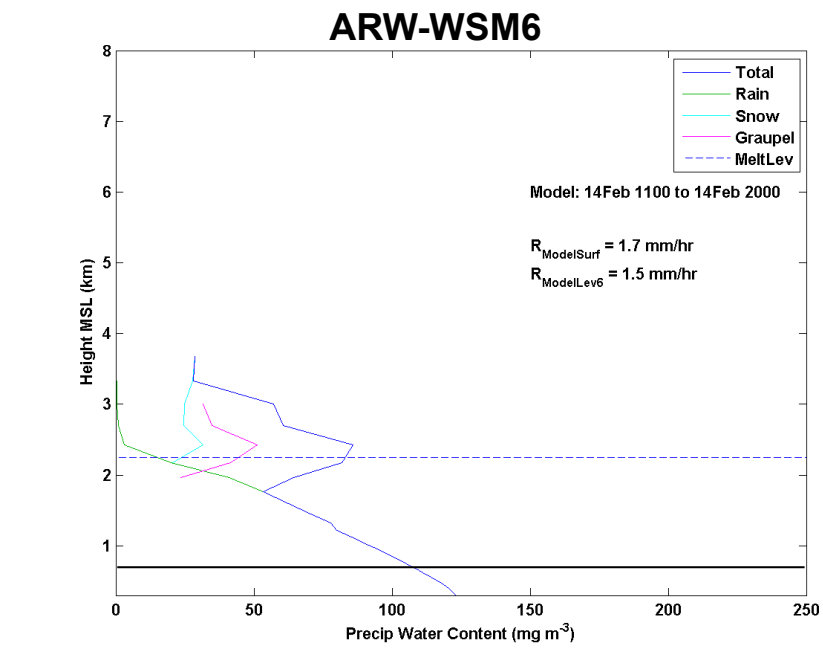


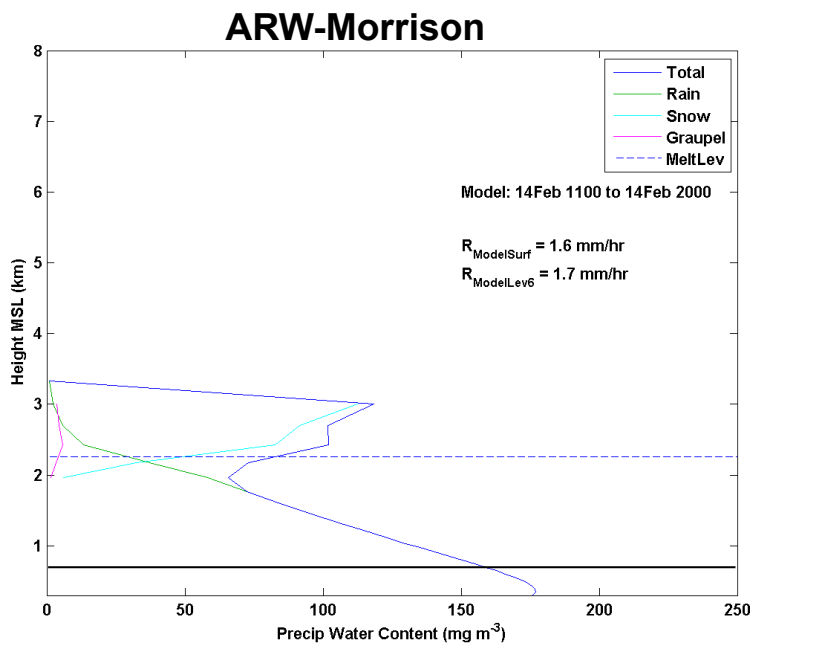




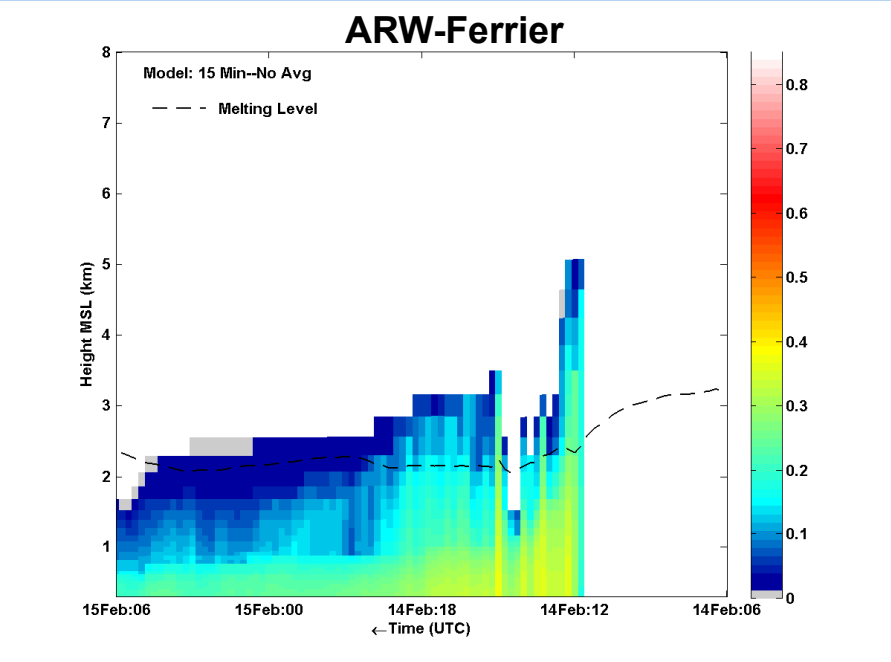
Episode 1: Avg PWC at CZC

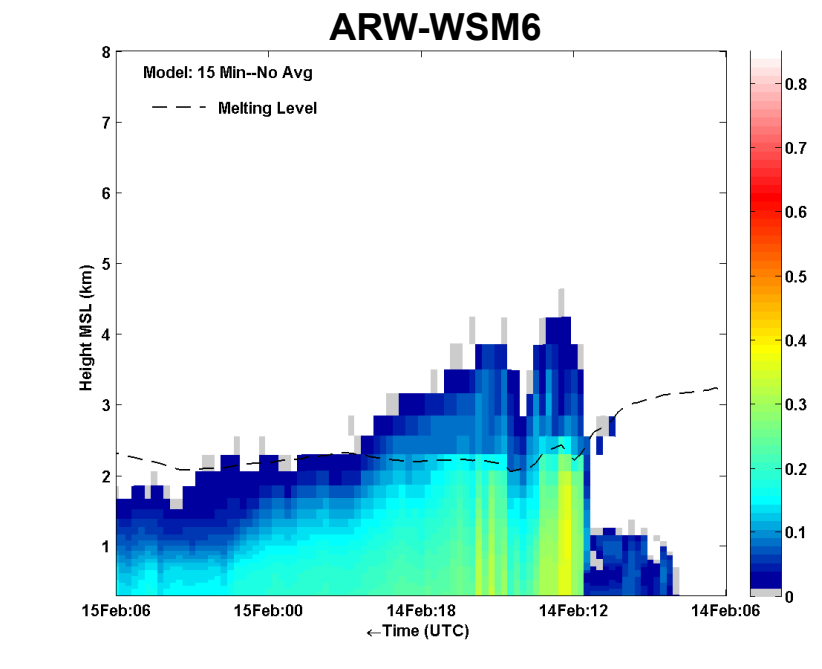


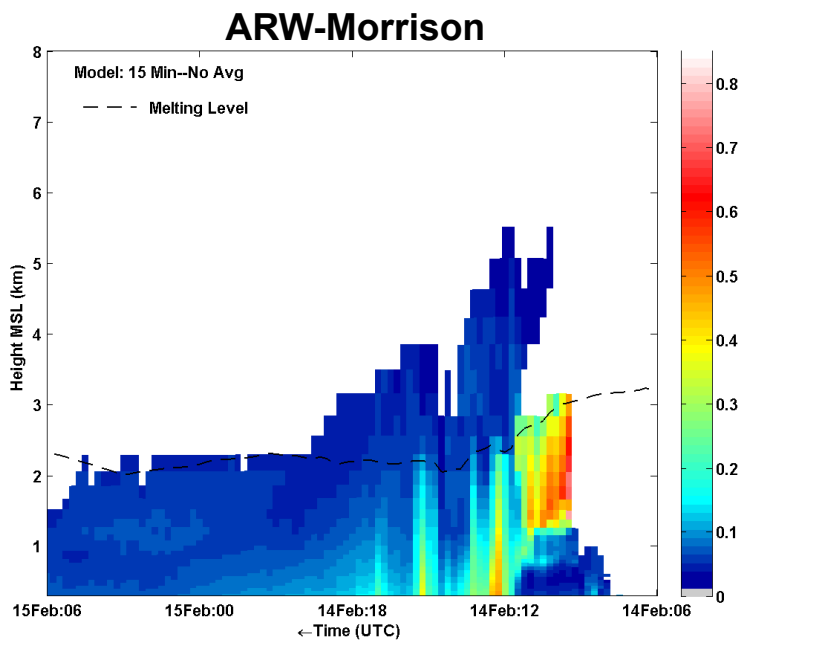




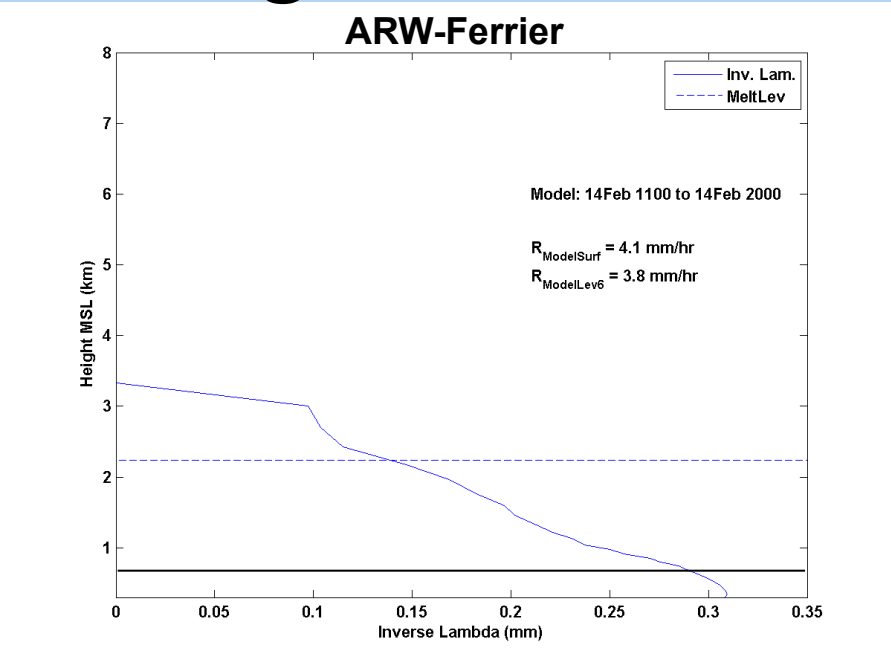
Episode 1: Rain Inverse λ at CZC

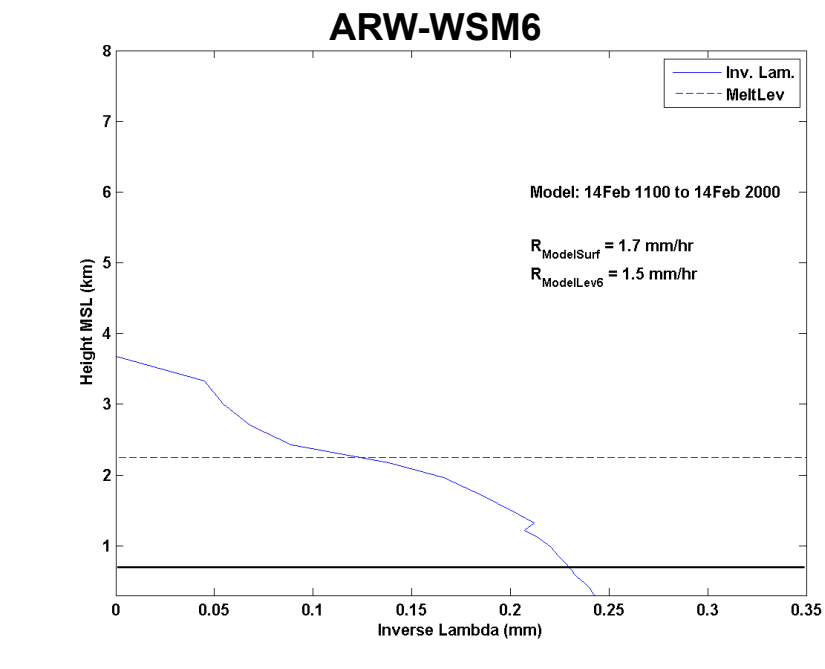


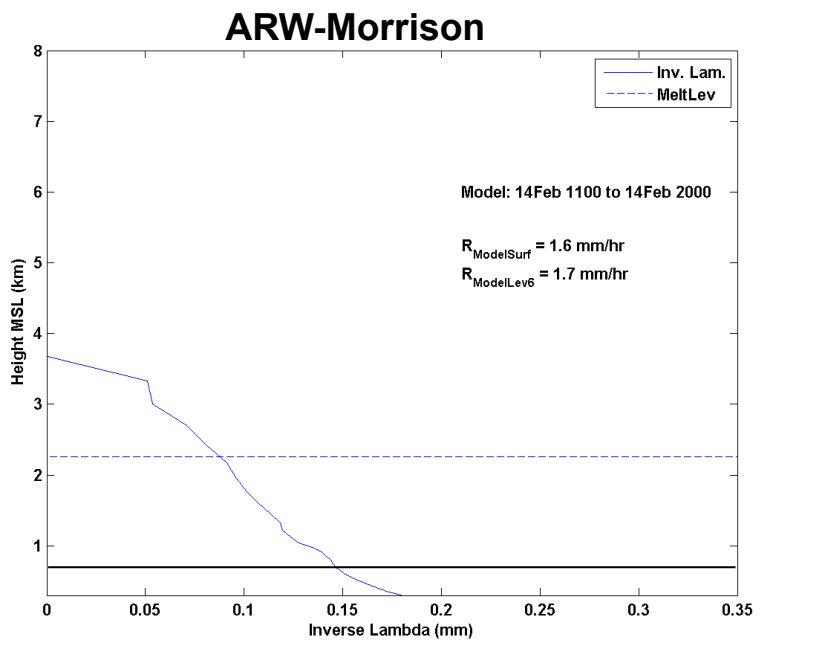




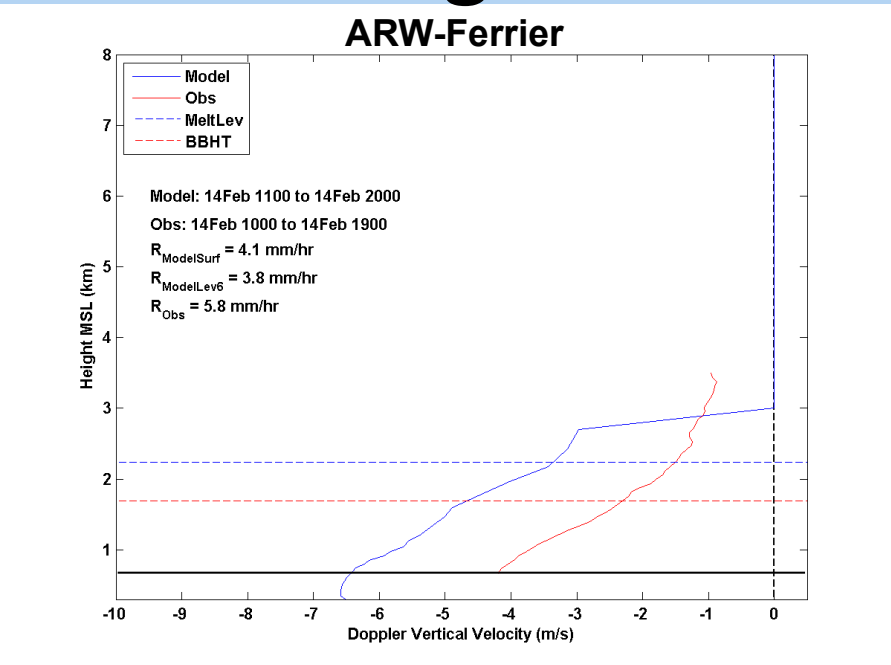
Episode 1: Avg Rain Inverse λ at CZC

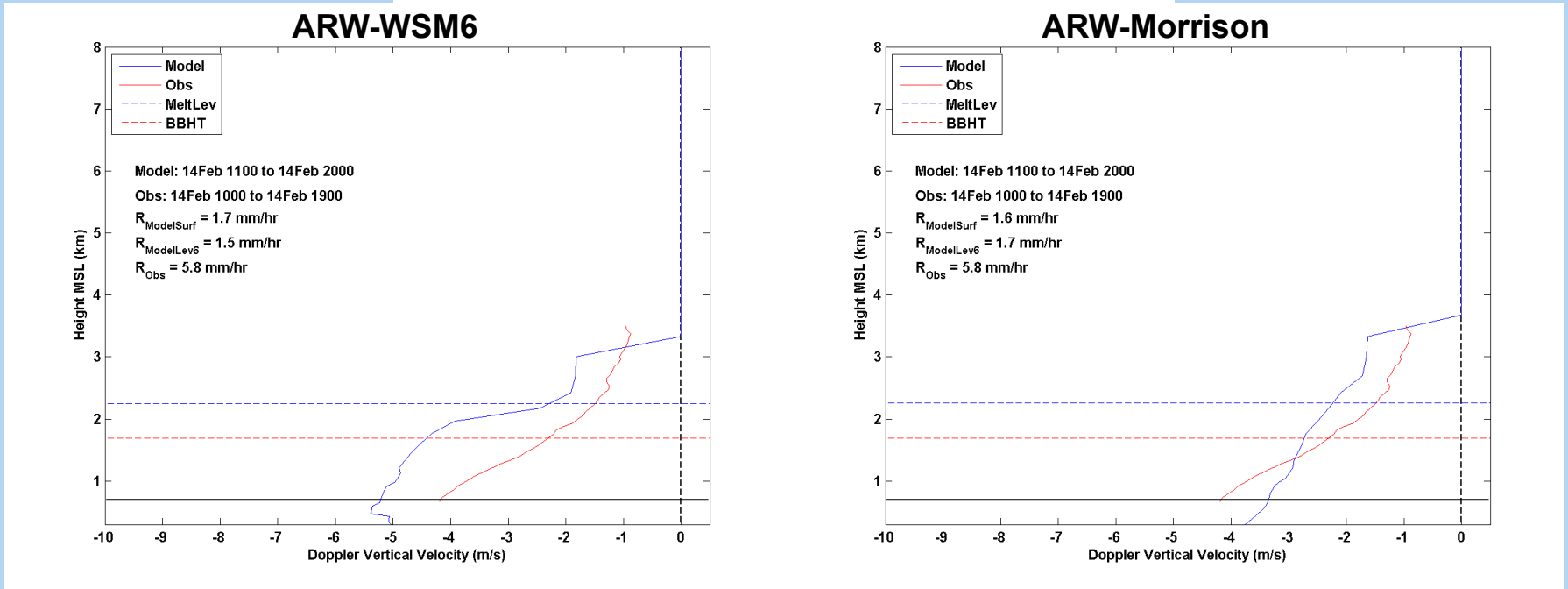




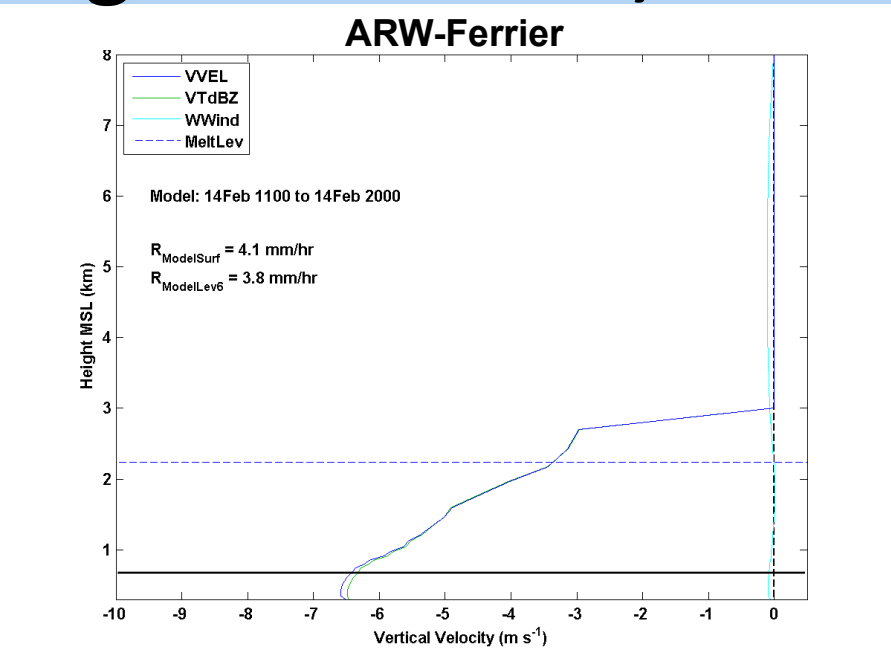


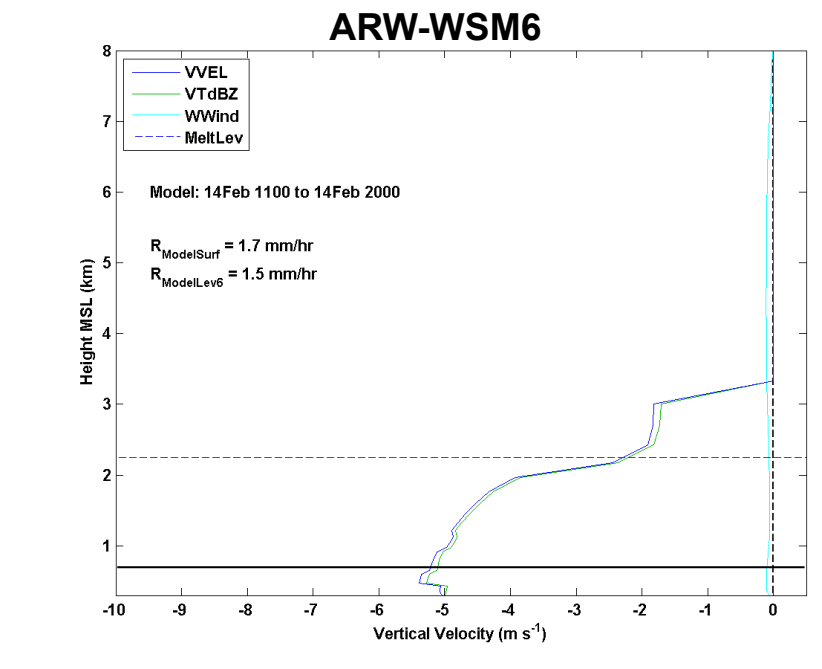
Episode 1: Avg. HVV at CZC

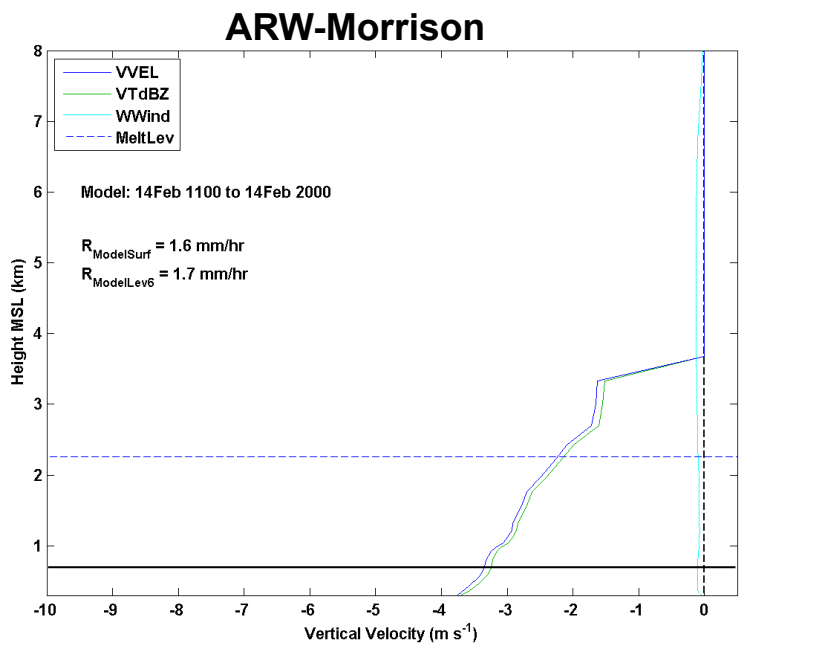
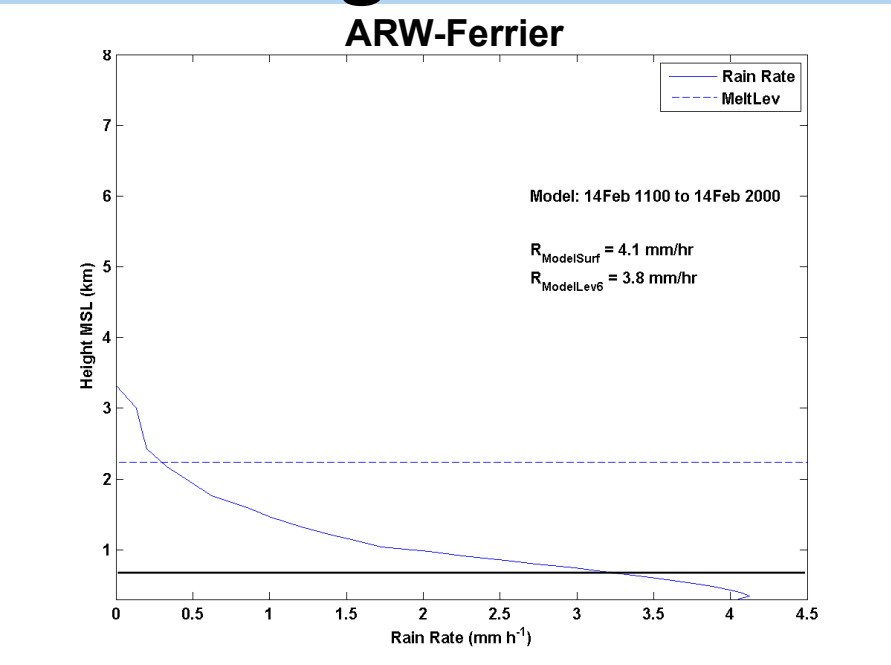
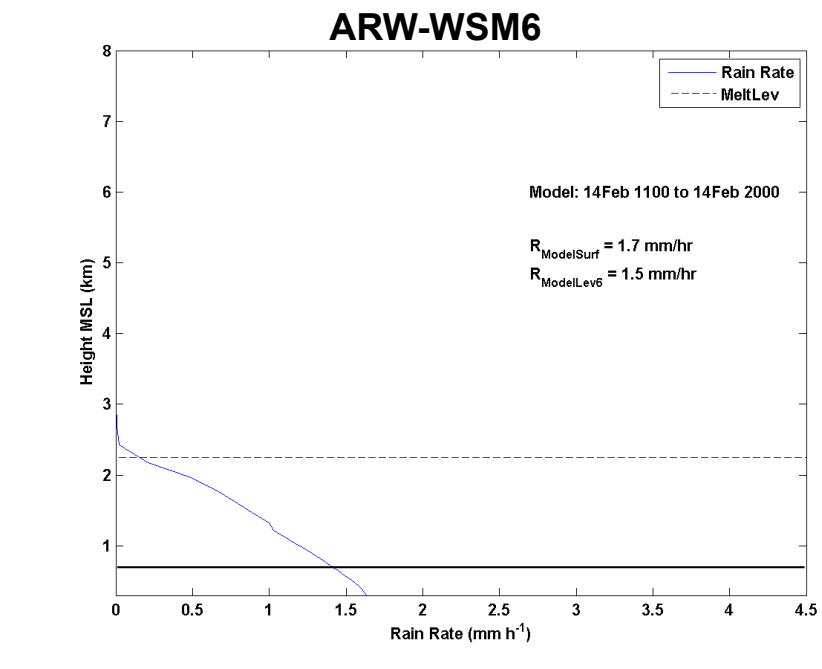
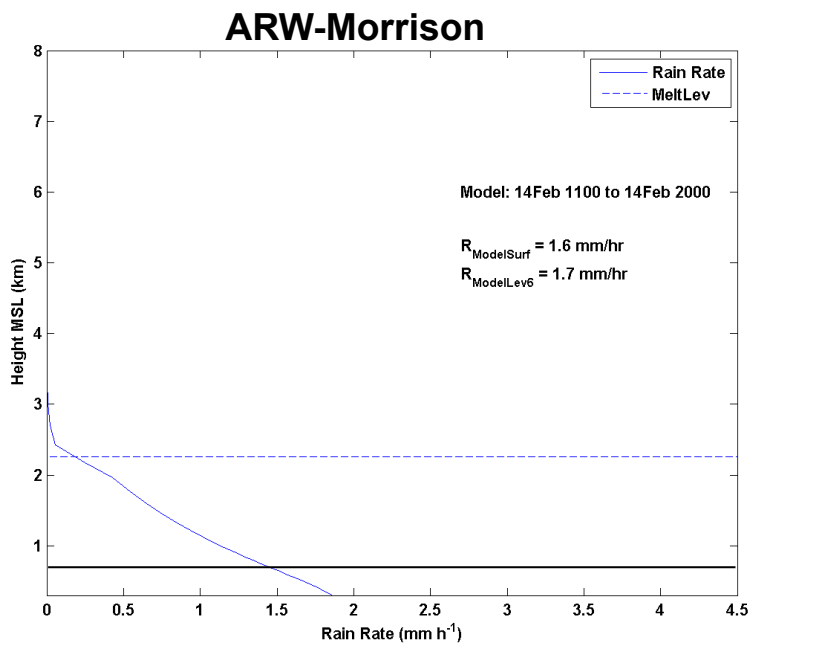




Episode 1: Avg. Model HVV, VTdBZ, W at CZC







Episode 1: Avg. Rain Rate at CZC