Talking points for Mesoanalysis Using GOES RSO session

Slide number	Talking points
1	Title slide
2	Objectives 1. RSO satellite imagery can be used to analyze differing air masses, low-level boundaries, environmental shear (via GOES derived winds) and upper air features. GOES sounder data is also discussed as a means of assessing air mass instability parameters such as evolving CAPE and CIN. 2. RSO visible imagery is particularly useful during the convective initiation phase. The imagery can be used to identify storms that form on low level boundaries, versus those that don't. This is one factor that's important in analyzing the intensity and movement of the storm throughout its lifetime. 3. RSO imagery can play an important role in diagnosing the near-storm environment during the WDM process. Answers to questions such as the nature of down stream mesoscale air masses, the existence of nearby boundaries, etc. may only be available on satellite imagery.
3	Why RSO is important (review from first RSO teletraining session)
4	Typical GOES-8 RSO Imager (review from first RSO teletraining session)
5	Time from scan start to receipt on AWIPS Normal scanning schedule calls for one image every 15 minutes. By the time this image is transmitted to AWIPS a full 26 minutes has typically gone by. With RSO scheduling images are available within 8 minutes of scan start time. Furthermore there are twice as many images available per hour.
6	Outline
7	This loop, centered on southeast Colorado, illustrates many of the benefits of using RSO satellite imagery in the Warning Decision Making (WDM) process. Important boundaries (such as the east-west stationary front in eastern Colorado and western Kansas) are often best located using satellite imagery since model analyses frequently smooth out key features. Features in the vicinity of severe thunderstorms can also provide important clues to near term changes in storm morphology. For example, the storm in southwestern Kansas intensified as it moved into the region where low-level cumulus cloud streets dominated. The large right moving supercell in eastern Colorado intensified as it intersected the stationary front. A new overshooting top can be observed as this intersection occurs (beginning at 22:42 UTC) just east of the main core. Between 22:42 and 22:45 UTC a meso-beta sized, low-level deck of strato-cumulus is seen to appear on the southern edge of theis new cell. This feature is associated with a 70 kt+ microburst at the surface. The cloud feature is seen to intersect the flanking line of the main core by 23:15 UTC. An F2 tornado touches down shortly thereafter. The outflow to the west of the main core of the supercell storm is associated with deep subsidence. A mid-level deck of clouds (shaped like the figure '7') can be seen approaching the outflow between 22:11 and 22:45 UTC. Cloud tops in this deck are at 14,000 ft AGL (determined using IR imagery and the evening DDC sounding). This deck is seen to dissipate as it travels over the outflow region. The cloud deck to its west is cirrus (height estimated at 32,000 ft), and does not dissipate. The behavior of these two decks indicates that strong subsidence is associated with the

	main cells outflow. Motions of cloud elements at storm tops can also provide useful information about storm intensity. Note the cloud top divergence at storm top seen on the storm in extreme southwest Kansas. As noted above, the storm intensified as it moved into the region where low-level cumulus cloud streets dominated.
8	During VORTEX-95, most tornado events were associated with a boundary. Of these events, most of the tornadoes occurred in the vicinity of the boundary, especially on the cool side.
9	When the storm intersects the pre-existing boundary it intensifies. Parcels containing enhanced horizontal vorticity reside on the cold side of the boundary, thus a storm must ingest inflow from the cold side if the horizontal vorticity has any relevance. When the storm moves well into the more stable air it weakens. Note, although the stable air is stated on this illustration, the air may not be very stable in all cases. An example of this may be in the central plains during the summer, when the air to the cold side of the boundary may be only slightly more stable than that on the warm side.
10	Example of the importance of boundaries, to go along with schematics presented. GOES-8 visible imagery from 16:10 UTC 23 June 2002 through 01:45 UTC 24 June 2002. An outflow boundary becomes evident on the imagery with daytime heating in northeast South Dakota. The storm of interest develops in northeast South Dakota (northwest of Aberdeen).
11	KABR radar 0.5 degree tilt base reflectivity from 23:04 UTC 23 June 2002 through 02:45 UTC 24 June 2002. The tornadic storm forms at the intersection of 2 boundaries northwest of Aberdeen, SD (ABR). The storm interacts with the boundary as it moves towards the east. Also, note the storm is on the "cold" side of the boundary by a short distance. Later, the storm moves northeast further into the stable air on the "cold" side of the boundary and weakens. Radar loop courtesy of National Center for Atmospheric Research (NCAR).
12	Picture of tornado in northeast South Dakota (courtesy of David Gold and Roger Hill).
13	This is the county warning area for the North Platte, NE (LBF) WFO. This will be the area of interest for the 24 July 2000 case study.
14	Eta 00 hour forecast 500 mb Height/Vorticity valid 12:00 UTC 24 July 2000. Shortwave over north central Nebraska and a second shortwave over northeast Wyoming are analyzed. Eta 12 hour forecast 500 mb Height/Vorticity valid 00:00 UTC 25 July 2000. The shortwave that was over northeast Wyoming at 12:00 UTC has now moved over the area of interest.
15	Eta 00 hour forecast 850 mb Height/Dewpoint valid 12:00 UTC 24 July 2000. Eta 00 hour forecast 850 mb Height/Dewpoint valid 00:00 UTC 25 July 2000. Low-level winds have backed, and dewpoints increased in the area of interest.
16	24 July 2000 12:00 UTC surface analysis. A reflection of the 850 mb trough can be seen in advance of the surface cold front. There is a low pressure center (1007 mb) in the northwest Nebraska panhandle. This low was forecast to drift eastward.
17	Loop of surface observations from 12:00 - 18:00 UTC 24 July 2000. The observations show dewpoints increasing and low-level winds backing in and near the area of interest.
18	North Platte, NE sounding at 12:00 UTC 24 July 2000. Note the dry adiabatic lapse rate from ~850

	mb to 500 mb. Low-level moisture is shallow, but expected to increase. Winds are veering with height. Low-level flow was expected to increase and back with the approaching trough and upper level winds were expected to increase.
19	GOES IR 10.7 um loop from 10:02 - 18:02 UTC 24 July 2000. Early morning convective activity stretches from North Dakota through central Nebraska in association with shortwave shown on 500 mb analysis. Through the morning hours the activity consolidates into an MCS over eastern South Dakota. However, notice that residual convection is keeping eastern Nebraska under SCT/BKN cloud cover.
20	GOES Visible imagery 13:25 - 18:02 UTC 24 July 2000. The BKN/SCT cloud cover in eastern Nebraska referred to in the IR loop will result in a slightly cooler air mass than that in western Nebraska. The resulting baroclinic zone can be seen in later imagery and analyses. The MCS has produced significant rainfall but during this loop period an arc cloud line has not formed. This region should be monitored for the development of clouds along the outflow boundary.
21	RUC surface divergence analysis valid 20:00 UTC 24 July 2000. Divergence associated with the MCS covers portions of southeastern South Dakota, Minnesota and Iowa. The convergence to the south of this region is in northeastern Nebraska. Also notice the north-south axis of convergence associated with cloudy versus clear boundary in central Nebraska.
22	Eta 6 hr forecast LI valid 18:00 UTC 24 July 2000 showing a tongue of instability stretching northward from western Kansas to central Nebraska, then northestward into eastern North Dakota.
23	Eta 6 hr forecast LI valid 18:00 UTC 24 July 2000 overlaid on GOES-11 DPI LI valid 17:46 UTC 24 July 2000. The analyses agree through western Kansas and central Nebraska, however the MCS in eastern South Dakota has stabilized the air mass.
24	GOES-11 DPI PW minus Eta first guess PW field valid 17:46 UTC 24 July 2000. The analysis finds more moisture present than expected by the Eta model. This holds true for most of the area shown, however, the area west of the MCS is drier than expected due to subsidence behind the convection.
25	Identification Questions
26	Try to determine the time of initiation for towering cumulus AND for thunderstorm initiation. This is the regular 15 minute schedule and will be available on AWIPS about 25 minutes after the image start time.
27	Once again, try to determine the time of initiation for towering cumulus AND for thunderstorm initiation. This is the RSO schedule and will be available on AWIPS about 8 minutes after the image start time.
28	The values shown in the table are consensus estimates. Note that due to the more frequent imaging, features are seen in earlier imagery AND that the images appear on AWIPS much sooner when using RSO.
29	This is the SRSO schedule. Now the high temporal resolution makes detection of towering cumulus AND thunderstorm initiation easier. The primary storm develops only at the intersection of the n-s oriented baroclinic boundary, the e-w oriented old MCS boundary and the se-nw oriented convergence boundary where we intitally observed Tcu that dissipated.
30	Loop of GOES-11 sounder LI from 14:46 - 21:46 UTC 24 July 2000. Notice that the instability increases through western Kansas and central Nebraska but that the air mass stabilizes in eastern South Dakota.

31	KLNX radar 0.5 degree tilt base reflectivity from 21:57 - 22:23 UTC 24 July 2000. Notice that the large thunderstorm in southern South Dakota (northwest of KSFD) appears to be splitting with the left mover travelling northward while the main core remains quasi-stationary. The circulation around the surface low may be seen in the ground clutter near KLNX radar site.
32	GOES-11 visible satellite loop from 21:45 - 22:30 UTC 24 July 2000. The large thunderstorm in southern South Dakota is developing a well defined flanking line and overshooting tops. The split is not readily discernable at this time. Convection has developed along eastern portions of the MCS outflow boundary. Notice that only a few small cumulus have developed in the CWA. It is clear that this area remains capped.
33	KLNX radar 0.5 degree tilt base reflectivity from 22:28 UTC 24 July 2000 through 01:54 UTC 25 July 2000. The storm has begun moving southward. At 23:04 UTC new convection forms on the southwest flank of the main core and merges by 23:19 UTC. No outflow boundary can be seen due to the range from the radar (90 miles). Tornadoes are reported at 22:50, 23:05 and 00:47 UTC. By 00:53 UTC a low-level outflow boundary can be seen. This boundary has probably been there all along, but the storm has finally reached a range such that it appears on radar. The maximum hail diameter reports were close to the tornado times (i.e. the hail size reports went down at the SD/NE border).
34	GOES-11 visible satellite loop from 22:20 24 July 2000 - 00:55 UTC 25 July 2000. It is evident at this time that the storm split is a result of a northward moving outflow boundary and not shear dynamics alone. This is important because classical shear induced left-movers normally weaken and die within 30 minutes due to a dynamically induced high pressure area aloft. In this case the left mover does NOT weaken. It survives for more than 2 and a half hours and produces hail. By 22:40 UTC large flanking lines (cumulus forming above the RFD) are seen to develop on the west side of the right mover. Ten minutes later a tornado is reported. This phenonemona has been observed several times and been documented in the literature (Weaver and Purdom, 1995, Weaver and Lindsey 2004). A second tornado is observed at 23:05 UTC. The flanking towers dissipate quickly between 23:10 and 23:15 UTC. No tornadoes are reported over the next hour and a half. Flanking towers again develop by 00:30 UTC and a tornado is reported at 00:47 UTC. The cumulus that develops above the RFD is a sign of storm intensification, why they form is a topic of future research.
35	Photographs of the storm showing new towers developing (on the left in the earlier pictures) and moving into the main updraft (towards the right on the picture), proving that discrete propagation was occuring at least during this time period during the storms life cycle. This series of photos shows that discrete propagation continued into the evening hours as the storm continued to propagate south.
36	Loop of GOES-11 sounder derived CAPE and CIN from 22:16 UTC 24 July 2000 to 02:16 UTC 25 July 2000. Data are shown as Single Field of View (SFOV) images. This product is experimental and sophisticated cloud clearing algorithms have not been applied. Thus cloud edges are poorly defined, appearing gray in the CAPE imagery and black in the CIN. The loop shows the right moving storm travelling southward along the high CAPE axis and propagating into areas of zero CIN. This loop explains why the supercell is isolated and also implies (through the lack of synoptic scale effect on the low-level cap) that the shortwave trough is having little effect at this time. Notice that the minimum CIN axis has developed along the convergence boundary referred to earlier.
37	Storm Reports for 24 July 2000
38	Conclusions to 24 July 2000 case
39	This is the county warning area for the Norman, OK (OUN) WFO. This will be the area of interest for the 8

	June 1998 case study.
40	8 June 1998 Upper air analyses 300 mb 8 June 1998 12:00 UTC 300 mb analysis heights and isotachs (knots). The analysis depicts a jet over New Mexico and the Texas panhandle with southwest flow over the area of interest. 500 mb 8 June 1998 12:00 UTC 500 mb analysis. A well-defined shortwave trough over Colorado and northeastern New Mexico. Relatively strong southwest flow exists over the area of interest and upwind. 700 mb 8 June 1998 12:00 UTC 700 mb analysis. Advection of drier air to the west of the area of interest is the key feature for this case. 850 mb 8 June 1998 12:00 UTC 850 mb analysis. A well defined trough extends from western Nebraska to west Texas. At the time of the analysis a low-level jet stretched fromwestern Texas into southern Nebraska advecting low-level moisture over the area of interest.
41	GOES IR 6.7 um loop from 12:45 - 18:15 UTC 8 June 1998. Early morning convective activity can be seen in eastern Oklahoma. There is a strong jet extending from southeast Arizona, across central New Mexico into west Texas.
42	GOES IR 10.7 um loop from 12:45 - 15:55 UTC 8 June 1998. An MCS over eastern Oklahoma can be seen moving eastward leaving behind a cooler air mass. Note that the MCS is not affecting a small region in extreme southeast Oklahoma. There is a well defined circulation center in northwestern Kansas associated with a surface low. Note the cirrus clouds forming in southern New Mexico in association with the upper jet discussed in the previous loop.
43	Norman, OK sounding at 12:00 UTC 8 June 1998. Note the saturated stable layer from 900 to 700 mb that was caused by the stratiform rain associated with the morning MCS. There is a conditionally unstable layer from 650 to the equilibrium level. The wind profile veers and increases in speed with height.
44	Eta 00-hr forecast MSLP, surface winds (knots) and dewpoint (F) valid 12:00 UTC 8 June 1998. A dryline is evident over eastern New Mexico with strong southerly flow from the Gulf of Mexico advecting low-level moisture into the area of interest. Eta 6-hr forecast MSLP, surface winds (knots) and dewpoint (F) valid 18:00 UTC 8 June 1998. The low deepens and moves northeast into western Kansas. The dryline is now in the eastern Texas panhandle. The low-level moisture advection into Oklahoma continues. Eta 12-hr forecast MSLP, surface winds (knots) and dewpoint (F) valid 00:00 UTC 9 June 1998. The dryline has now moved into western Oklahoma and central Kansas. The 70 F isodrosotherm is expected to move north to the OK/KS border.
45	Eta 00-hr forecast CAPE and surface winds (knots) valid 12:00 UTC 8 June 1998. The analysis shows relatively high instability over the Texas panhandle. Eta 6-hr forecast CAPE and surface winds (knots) valid 18:00 UTC 8 June 1998. The analysis shows that the maximum instability is now in western Oklahoma. Eastern Oklahoma has much less CAPE due primarily to the morning MCS.

	Eta 12-hr forecast CAPE and surface winds (knots) valid 00:00 UTC 9 June 1998. A narrow axis of higher CAPE is situated between the dryline and the more stable air associated with the old MCS. Maximum forecast values were around 3000 J/kg. Note that the model output suggested air mass destabilization from west to east in eastern Oklahoma.
46	Loop of GOES Visible imagery 15:45 - 17:15 UTC 8 June 1998. The northeastern 2/3 of Oklahoma are overcast while there is partial clearing in extreme southeast Oklahoma south of the MCS. Note the clearing trend in western Oklahoma. A cumulus line along the western Oklahoma border into western Kansas delineates the position of the dryline. Jet cirrus can be observed over the central Texas panhandle and southwest Oklahoma. Northwestern Oklahoma appears to be less cloudy than the area to its south. Finally notice the boundary between wave clouds and cumulus streets in west central Oklahoma.
47	Oklahoma Mesonet surface observations 14:45 - 18:00 UTC 8 June 1998. Temperatures in northeast Oklahoma are not warming up due to the cloud cover behind the MCS. Temperatures south of the MCS in southeast Oklahoma, however, are warming into the upper 70's. The area of most substantial clearing in western Oklahoma is warming into the mid to upper 80's leading to a rapid increase in CAPE. The position of the dryline is evident in the Oklahoma panhandle.
48	Composite of WSR-88D radar reflectivity from 3 radars (KTLX, KVNX, KINX). Loop covers the period from 17:54 - 18:42 UTC 8 June 1998. Stratiform cloud cover observed in visible imagery over northeast Oklahoma show up as weak echoes from the Tulsa (KINX) radar. Weaker echoes southeast of Norman confirm the satellite observations that show broken cloud cover. New thunderstorms can be seen forming along the dryline shown in satellite imagery.
49	Loop of GOES Visible imagery 17:45 - 19:30 UTC 8 June 1998. The circulation around the low can be seen in northwestern Kansas. Several thunderstorms are now forming along the dryline from Kansas into western Oklahoma. Ahead of this activity in Oklahoma we can see relatively clear skies with scattered cumulus cloudiness. This is the narrow tongue of high CAPE we have been expecting to develop. Note the clearing line is gradually moving eastward as the MCS exits Oklahoma. The boundary separating the stable from the unstable air is now evident as wave cloudiness versus scattered cumulus (note the wave clouds near the north central Oklahoma border). The near storm environment ahead of the southern storm is seen to be filled with cumulus congestus while the storm in northwest Oklahoma is moving into a cloud free region. This area evidently has a drier boundary layer even though the mesonet observations alone would suggest there is little if any difference in air mass characteristics throughout western Oklahoma.
50	Questions
51	Severe reports in the period 19:30 to 20:30 UTC. Green dots indicate hail with diamater stated. Blue + indicates severe wind reports.
52	Loop of GOES Visible imagery 19:30 - 21:59 UTC 8 June 1998. The large storm that moved into the cumulus rich air mass in southwestern Oklahoma has become the largest storm in the CWA. However, notice that this storm is now approaching the stable region in eastern Oklahoma dominated by wave clouds. Notice also that the storm in northwest Oklahoma remained small as it crossed the cloud free area then intensified around 20:30 UTC as it reached the low-level cumulus field. This cumulus field is very narrow in north central Oklahoma, so there is only a short window of opportunity for the storm to persist before it reaches the stable air mass. There is also an apparent storm merger with a small cell that develops to its south. Also notice during this time period substantial clearing develops in southeastern Oklahoma.
53	Oklahoma Mesonet surface observations 19:15 - 22:00 UTC 8 June 1998. Narrow axis of instability can be seen to gradually move eastward. This axis is bounded by a dryline pushing into western Oklahoma and the stable air mass created by the old MCS. Notice that significant heating is now occuring in southeast Oklahoma where the clearing had been noted on satellite imagery.
54	KTLX 0.5 degree tilt radar reflectivity 19:29 - 22:01 UTC 8 June 1998. The large storm moving into

	central Oklahoma remains intense throughout the period. The storm in northwest Oklahoma can be seen to intensify as discussed in the correpsonding satellite loop. The merger referred to is confirmed by the reflectivity data. Note that the larger storm intensifies following this merger. A new line of storms is developing in southwest Oklahoma.
55	KTLX 0.5 degree tilt radar velocity 19:29 - 22:01 UTC 8 June 1998.
56	Questions
57	Severe reports in the period 22:00 to 00:00 UTC. Green dots indicate hail with diamater stated. Blue + indicates severe wind reports.
58	Loop of GOES Visible imagery 21:59 - 23:45 UTC 8 June 1998. The two storms we had been following both rapidly weaken once they reach the more stable air mass as had been tracked on visible imagery and mesonet observations through the afternoon. A new storm intensifies throughout this period in central Oklahoma. Notice that a well defined east-west cloud boundary has appeared ahead of this new convection. This boundary separates the region which remained persistently stable throughout the afternoon from the region that cleared out early in the afternoon. Unstable cloud streets can be seen south of this boundary feeding into the storm. The anvil shadow may be playing a role in intensifying the baroclinicity (and consequent horizontal vorticity) along this boundary. Markowski et. al 1998 have shown that temperatures can cool at a rate of 3 to 4 C over a period of 45 minutes to an hour. This is sufficient to produce horizontal vorticity on the order of 10 **(-2): the same order of magnitude as the vertical vorticity in an updraft with a mid-level mesocyclone.
59	KLX 0.5 degree tilt radar reflectivity 22:01 8 June 1998 - 00:02 UTC 9 June 1998. Radar shows the two storms previously discussed RAPIDLY dissipating. Note that as the southern storm intensifies it turns right and develops an appendage on its southern flank. The storm is now apparently traveling along the boundary discussed in the previous satellite loop. It is unknown whether this right turn is a result of propagation along this baroclinic boundary, or a more classical dynamically induced pressure deficit on the right flank. Regardless of the cause, the storm is now able to directly access the more unstable air.
60	KTLX 0.5 degree tilt radar velocity 22:01 8 June 1998 - 00:02 UTC 9 June 1998.
61	Questions
62	Severe reports in the period 00:00 to 02:00 UTC. Tornado tracks in red with Fujita scale stated. Green dots indicate hail with diamater stated. Blue + indicates severe wind reports.
63	KLX 0.5 degree tilt radar reflectivity 00:00 9 June 1998 - 02:00 UTC 9 June 1998. The storm is tornadic during portions of this time period and also produces 4.5" hail. The storm is travelling along the baroclinic boundary at the south end of the old MCS. Note the temperature change north of the storm versus south of the storm.
64	Conclusions