Talking points for Boundary forced convection

1. Title
2. Learning objectives
3. The first type of boundary we'll discuss is the sea-breeze boundary, in this example centered on the coast of South Carolina in June 2018. We select a 4 panel display useful for analyzing the sea-breeze boundary. In the upper left we have the visible imagery, in the upper right the day cloud phase distinction RGB, both of these are useful for identifying the sea-breeze boundary and convective initiation along the boundary. In the lower left we have the day convection RGB which is useful in identifying relatively stronger or young convection. In the lower right we have the METARs along with the GOES SST baseline product to assess the temperature difference between the land and water, as well as wind direction for sea-breeze passage. Once the difference between the water temperature and land temperature exceeds a threshold under quiescent synoptic conditions, the sea-breeze boundary begins moving inland which can clearly be seen as a line of cumulus in the visible and day cloud phase distinction RGB moving inland. Soon thereafter congestus develops along the central South Carolina coastline and convective initiation is indicated by glaciation of cloud tops as the colors transitions from light blue to green to yellowish red. The day convection RGB shows this new convection in orange to yellow colors which indicate more vigorous convection than convection that is more red in color.
4. Similar to a sea-breeze boundary, we may observe a lake-breeze boundary around the Great Lakes under quiescent synoptic conditions during the summer. This case occurred in early July, thus lake surface temperatures are relatively cool while the unstable air mass resides on the inland side of the lake-breeze boundary which is clearly supported by the presence of cumulus streets versus clear skies on the lake side of the boundary. Monitoring storm motion relative to the boundary is an effective use of the GOES imagery knowing that storms that cross the boundary and move towards the stable side of the boundary, in this case towards the lake, will weaken as less CAPE is available over the cooler lake surface.
5. We switch gears to a severe weather event that affected the Northeast on May 15, 2018. There are multiple boundaries where thunderstorms developed and became severe. The most obvious boundary is a cold front coming in from the west where convection develops across Pennsylvania midway through the loop. The other boundary of note is an outflow boundary produced from morning convection that moved from near Binghamton, NY to south of Albany and into Massachusetts. By later in the afternoon with daytime heating, congestus develops along this outflow boundary and soon thereafter thunderstorms develop rapidly and go on to produce all modes of severe weather.
6. We move on to a different case from April 16, 2017 over western Oklahoma into the eastern Texas panhandle. In this visible loop we observe multiple boundaries where convection initiates. Probably the most obvious boundary is a westward moving dryline late in the day in the eastern Texas panhandle where multiple discrete storms develop by the end of the loop. We see another boundary from the extreme northeast Texas panhandle stretching eastward

into northwest Oklahoma with an enhanced cumulus field. North of the cumulus field we observe stable wave clouds while south of the field we observe cumulus streets. Thunderstorms develop along a segment of this boundary in northwest Oklahoma late in the loop. We see additional thunderstorm development in west central Oklahoma as well as southwest Oklahoma along an outflow boundary. Using surface observations in tandem with the visible satellite imagery provides the most complete way to identify various boundaries that may lead to new convection.

7. We switch to a case over central Iowa from July 19, 2018. Surface observations show a well defined boundary with westerly winds *over here* and southeast winds *over here*. The highest temperatures and dewpoints are in the south and extend northward along the boundary, however the warm sector gets narrower further north. The visible imagery depicts cumulus streets further south in the warm sector. Stable wave clouds exist northeast of there. The boundary of interest is clearly seen as a line of enhanced cumulus that grows into congestus followed by towering cumulus and then thunderstorm development. The width of the warm sector narrows as we move south to north along the boundary.
8. What additional information can we get by looking at other bands and RGB products? In the lower left panel, the day cloud phase distinction RGB can be quite useful for convective initiation along a boundary, where we look for colors to transition from light blue to green to yellow. The transition in colors is not that fast, and most of the storms further north do not transition from green to yellow, rather they stay green or even go back to light blue. This is consistent with what we're seeing in the 10.3 micron IR band in the upper right panel in that cloud top temperatures do not get that cold, with the exception of the southernmost storm. Also, the day convection RGB depicts convection in the red colors, not so much the yellow to brighter colors like we see on the southern storm. This goes along with our earlier impression that the warm sector was greatest in magnitude and areal extent further south, and narrowed as you move northward.
9. What occurred were numerous landspouts with the central and northern storms in the first half of the loop, while the larger more intense looking convection in the later half of the loop produced supercell tornadoes. The GLM Flash Extent Density gridded data identifies storms with higher flash rates that are supercells in the later portion of the loop, while earlier storms further north in the narrow warm sector had less lightning activity associated with them. Note how the southernmost storm has access to the more robust warm sector further to the south and may even be propagating along a northwest to southeast oriented boundary, east of Des Moines.
10. Another type of boundary to be concerned with are terrain induced boundaries. In this example from August 9, 2018 we are looking over a mountain range in northern New Mexico, as shown in the terrain map in the upper right panel. Early in the loop in the visible imagery and the day cloud phase distinction RGB, we observe lines of cumulus oriented along 2 major ridge lines with a valley between the two ridges as seen in the topo map. With daytime heating and sufficient moisture, convection develops along both of these boundaries. By late in the loop we see convection develop rapidly along the easternmost boundary, perhaps interacting with an

outflow boundary from a storm to its south, this storm grows rapidly as can be seen in the IR imagery and a landspout tornado is reported.

11. Time for an interactive exercise, for this loop I want you to identify as many boundaries as you can. There are numerous different types of boundaries in the scene. Remember to use the surface observations in tandem with the visible imagery. I'll give you some time for analysis.
12. There are many boundaries during this loop to consider, perhaps the most obvious boundary stretches from northwest Wisconsin through southern Minnesota to northern Iowa and into Nebraska. The convection that develops early on across southern Minnesota results in multiple rounds of outflow boundaries that spawn new convection from Minnesota into Iowa. Further west we see a similar situation with multiple rounds of convection that spawn outflow boundaries and new convection. Most of the convection we've discussed so far is associated with either the cold front or outflow boundaries, or both interacting. Further south in Illinois under more quiescent synoptic conditions we see convection that develops, does not last long but outflow boundaries are easily seen. In fact there is not much strength to the downdrafts compared to convection further northwest, so you can actually see the mesoscale high pressure regions as circular areas of clearer skies left in the wake of the convection that dissipates. New convection spawns along the arc shaped outflow boundaries. We also have a lake-breeze boundary associated with Lake Michigan where convection develops, but does not persist due to storm-motion being towards the stable air mass. West of the lake-breeze boundary more in central Wisconsin we have a convergence zone oriented north-northeast to south-southwest that initiates new convection late in the loop. Lastly, a somewhat more subtle feature can be seen downstream of Lake Winnebago which is located here. In the southerly flow off the relatively cooler water of Lake Winnebago we get a stable clear area that extends northeastward. This creates 2 smaller scale boundaries. As the lake breeze pushes inland it intersects the eastern boundary resulting in enhanced convection that later dissipates as it moves to the stable side of the boundary.
13. In summary, identification of boundaries will be much improved in the GOES-R era, primarily due to greater temporal and spatial resolution but also RGB products that are now possible with some new bands.