A Case of Dry Lightning?

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Every year Fire Weather forecasters are faced with the difficult task of forecasting lightning events accompanied by little or no precipitation. Damage from these episodes, if the episodes can be identified in advance, can be greatly reduced as land management agencies position their resources to deal with fire starts. By the same token, false alarms can cost land management agencies a great deal. So what are the key ingredients that result in dry lightning and how can the Fire Weather forecaster successfully predict its onset? These are questions for which there are no complete answers, but only a set of guiding principles.

First, and most obviously, there must be a very dry sub-cloud layer to evaporate thunderstorm rains before they reach the ground. This is most commonly established by an eastward moving ridge. The "classic" cases of dry lightning in the Medford OR Fire Weather district have each been preceded by an eastward moving ridge as contrasted with a retrograding southwest U.S. ridge. In the former case, the subsidence side of the ridge moves over an area following the passage of a trough. Dry air gradually descends from aloft over the entire region resulting in a very dry (and often very warm) air mass. The later produces very warm conditions, but not the extraordinarily dry conditions.

Secondly, it appears that the cloud bases during a dry lightning outbreak are 2-4,000 feet higher than during a "normal" lightning event. Not a lot of research has gone into this hypothesis, however, the 2 "classic" dry lightning cases over the Medford district occurred with cloud bases in the 15,000 to 16,500 feet range. This contrasts with the "garden variety" thunderstorm cases where the cloud bases range from 10,000 to 12,000 feet. Inasmuch as this is intuitive, I would tend to believe that this is an ingredient one should look for when deciding whether or not to forecast a dry lightning event.

Thirdly, lapse rates above 700 mb must be nearly dry adiabatic. This high level instability is an absolute requirement. As you increase in altitude, the moist adiabat becomes nearly parallel to the dry adiabat. The lapse rate must increase for there to be significant CAPE above the level of free convection. Thus, as the altitude of the cloud bases increase, a greater lapse rate is required to support convection. The Medford cases of dry lightning showed a temperature difference between 700 MB and 500 MB of 22 to 24 degrees C. Higher elevation inland areas to the east of Medford would likely require even greater values. It should be noted that values of 22 to 24 degrees C at Medford exceed what is normal during "garden variety" thunderstorm activity.

Lastly, dry lightning events require SIGNIFICANT upper level forcing. If all that is present is surface heating, the storms will be wet. The low level moisture that is required to produce late day thunderstorms by heating alone is sufficient to ensure that the rain produced will be only partially evaporated as it descends below the base of the storm. Upper level forcing in the form of a migratory shortwave trough or an area of deformation serves two purposes. It further destabilizes that portion of the atmosphere above 700 mb allowing convection to occur with a relatively dry sub-cloud layer, and it "carries" the convection along ensuring that the storms don't linger over areas until the sub-cloud layer becomes saturated.

Armed with these crude tools, let us examine a recent case of convection across Oregon. Prior to this event, considerable debate took place as to whether or not the storms of July 7, 2003 would be wet or dry. Let's see how things match up as we compare this event with the 4 ingredients above. From the Medford morning sounding preceding this event the following data was gleaned (figure 1) :

Mean dewpoint depression 850 mb - 650 mb 14 degrees C
Temperature difference 700 mb - 500 mb 16 degrees C
Estimated cloud base (CCL) 10,500 feet

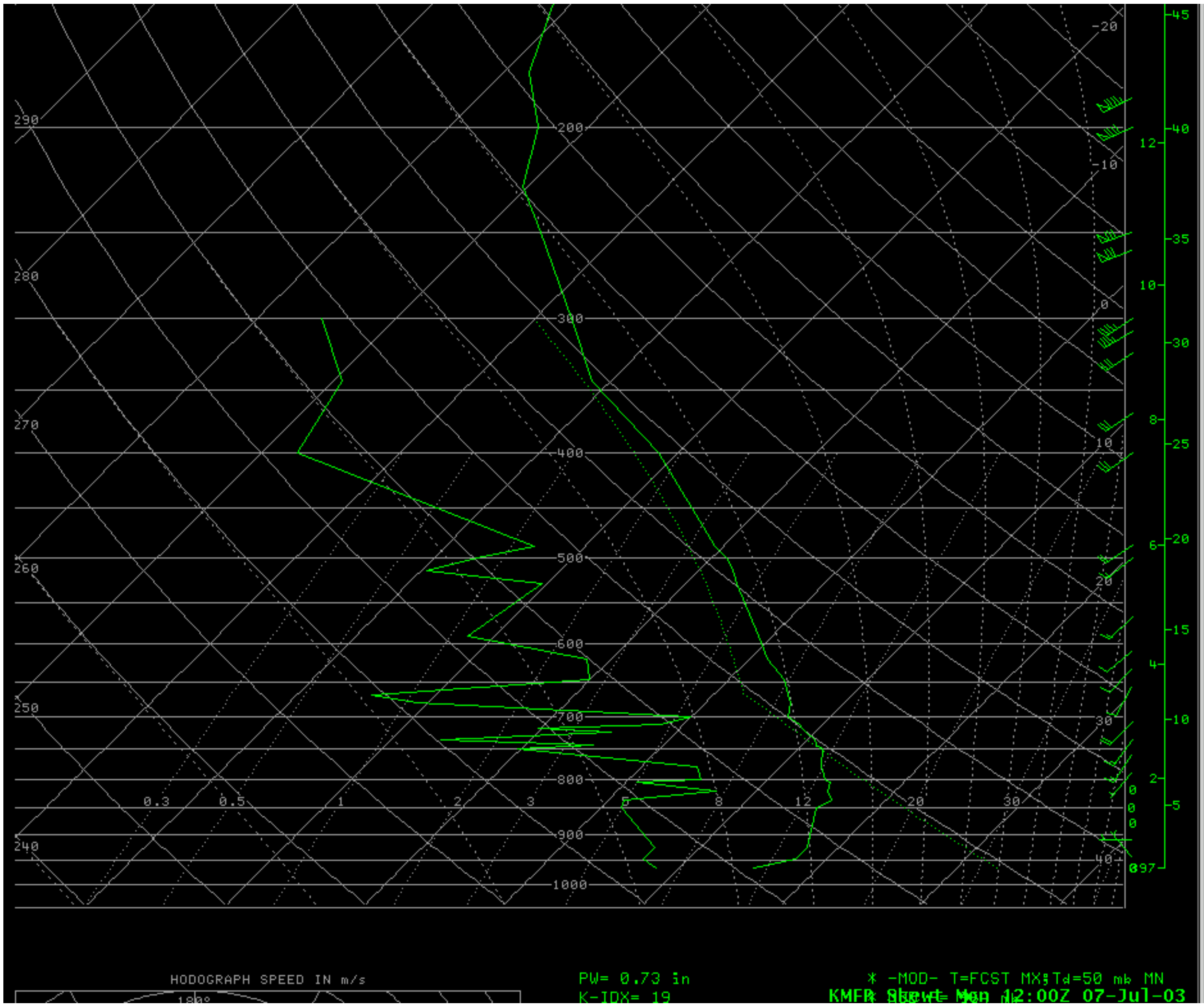
Since the thunderstorm activity was expected to be east of the Cascades, we can derive the same indices from the MesoEta using a point centered east of the Cascades (figure 2).

Mean dewpoint depression 850 mb - 650 mb 13 degrees C
Temperature difference 700 mb - 500 mb 16 degrees C
Estimated cloud base (CCL) 12,000 feet

Looking at a portion of the Eta model run from 07/12z for 07/21z, it is obvious that a significant shortwave is approaching the region and will move across the area this evening (figure 3). Thus significant upper level forcing is definitely present. Scanning the other indices, however, leads us to believe that the storms that are produced will easily be wet. None of the indices are even close to those that were present during the other significant dry lightning outbreaks in Medford's district. Thus the correct forecast in this case was to predict wet thunderstorms.

In looking over the data following the storms, those sites in the direct path of the storms received between .35 and .65 inches of precipitation. Lesser amounts were reported by sites on the fringe of the activity.

Figure 1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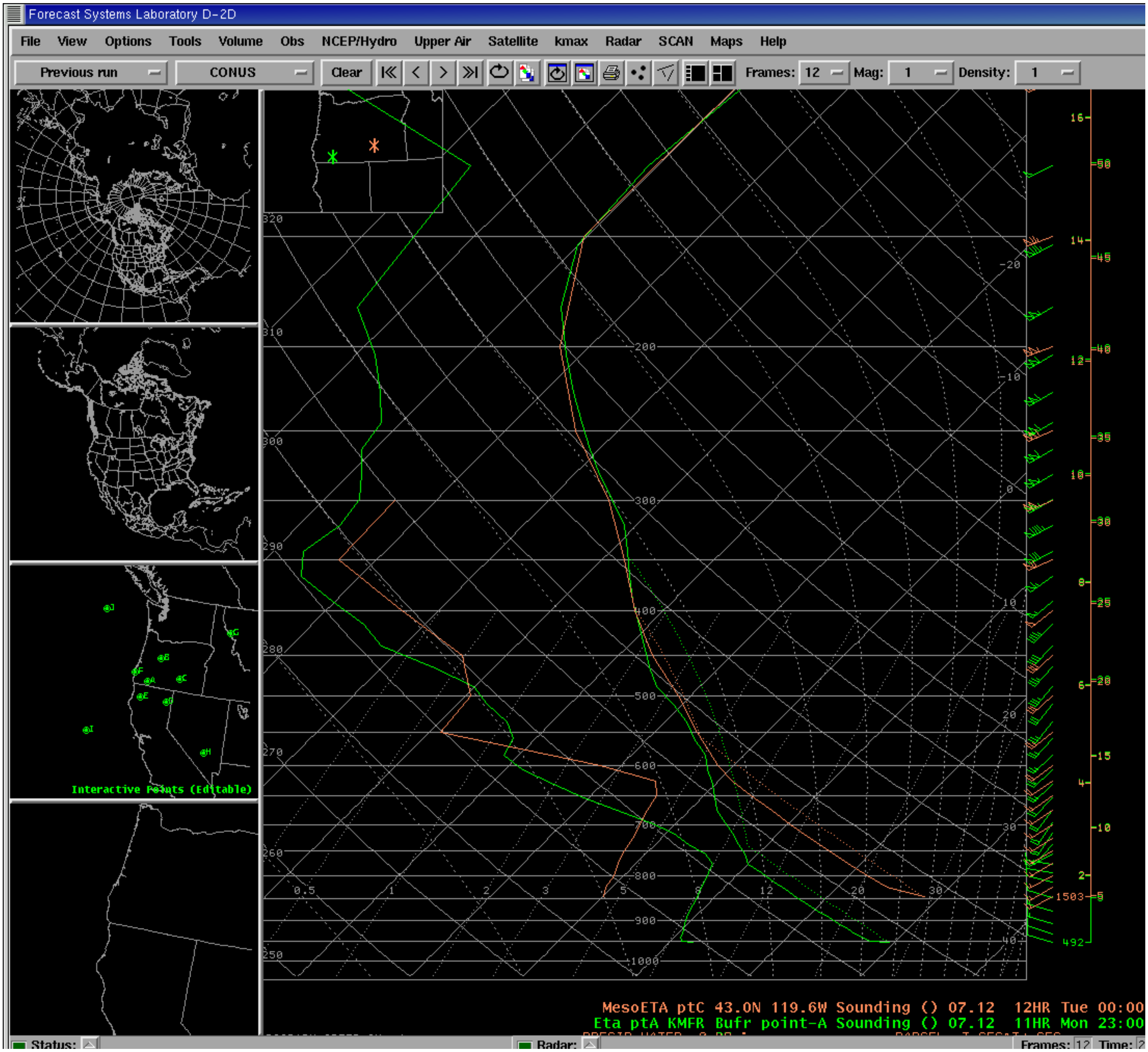
K-IDX= 19
* -MOD- T=FCST MX;Td=50 mb MN
12:00Z 07-Jul-03

Figure 2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File View Options Tools Volume Obs NCEP/Hydro Upper Air Satellite kmax Radar SCAN Maps Help
Previous run
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Frames: 12
Mag: 1
Density: 1
Interactive Points (Editable)
MesoETA ptC 43.0N 119.6W Sounding () 07.12 12HR Tue 00:00
Eta ptA KMFR Bufr point-A Sounding () 07.12 11HR Mon 23:00
Status:
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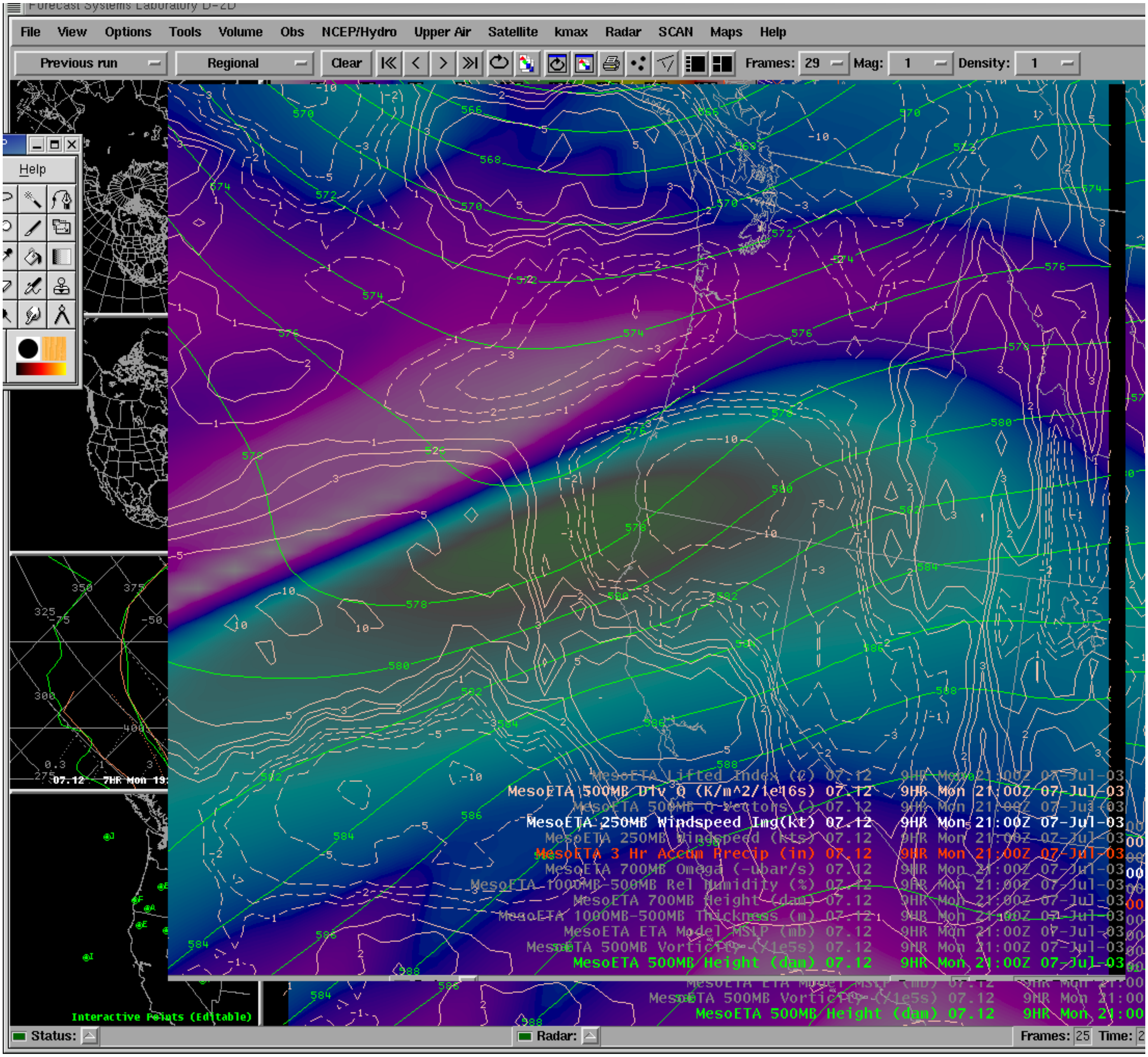
Frames: 12
Time:

Figure 3


Forecast Systems Laboratory D-2D
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Help
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MesoETA 500MB Div Q (K/m^2/1e16s) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 500MB Q-Vectors () 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 250MB Windspeed Img(kt) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 250MB Windspeed (kts) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 3 Hr Accum Precip (in) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 700MB Omega (-ubar/s) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 1000MB-500MB Rel Humidity (%) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 700MB Height (dam) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 1000MB-500MB Thickness (m) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA ETA Model MSLP (mb) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 500MB Vorticity (/1e5s) 07.12 9HR Mon 21:00Z 07-Jul-03
MesoETA 500MB Height (dam) 07.12 9HR Mon 21:00Z 07-Jul-03
07.12 7HR Mon 19:
Interactive Points (Editable)
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