Utilizing Medium Range Ensemble Forecasts (MREF) in the Forecast Process:
Application of MREF to the October 26, 2003 Forecast Period

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Introduction
The availability and utilization of ensemble forecast products have continuously increased over the past few years. The amount of ensemble forecasts products will continue to increase in the future at a rapid pace and this valuable data source needs to be incorporated into daily forecast operations. Both the number of members and the model resolution will increase dramatically through 2010. NCEP currently has plans to incrementally increase the MREF suite from its current resolution of 115 km (T126) with 28 levels and 10 members to 70 km with 64 levels and 50 members in 2010. This data can be utilized in producing the traditional "deterministic" forecasts, but also will be a key component for producing "probabilistic" forecast products.

This case deals with a medium range forecast and demonstrates how to utilize specific ensemble forecast products for evaluating model performance and uncertainty. Several runs of the GFS and ECMWF from October 18th through October 21st are reviewed for the forecast period of 12Z October 26, 2003 over the Desert Southwest and the Las Vegas County Warning Area (CWA) specifically. We will examine the model evolution of the long wave pattern over the eastern Pacific and western half of the U.S. and the development of a closed low or lack thereof over the Desert Southwest.

Overview
The western U.S. was under the influence of a strong ridge of high pressure over the first three weeks of October. The GFS began predicting a significant shift in the pattern for the Desert Southwest with the 00Z run on October 19th, developing a closed low near the Four Corners region on Oct. 25 and retrograding the low into the Desert Southwest during the period of interest (Oct. 26).

Ensemble Products
This case utilizes the 500-mb height normalized ensemble spread, the 500-mb height ensemble mean, and the 500-mb height ensemble spread from the NCEP MREF product suite. The normalized ensemble spread is computed by averaging the spread values for every individual grid point over the past 30 days and for each lead time (forecast time). The current run of ensembles is then divided by the average spread over the past 30 days for each grid point and lead time. Normalized spread values above one indicate areas where the current ensemble's spread is above the 30-day average and values below one indicate areas that are below the 30-day average. This enables one to easily locate regions of above and below average levels of model forecast uncertainty.

October 18, 2003
The 500-mb height field from the 00Z run of the GFS indicated a strong ridge of high pressure (597 dm) across the eastern Pacific centered at 38N 145W with a trough axis located over the central U.S. along the Mississippi River Plain (Fig. 1). The GFS began exhibiting a retrograding long wave pattern on October 25th and continued the retrogression of the low through 240 hours. The Las Vegas CWA was predominantly under dry northwesterly flow with no significant sensible weather expected.

The ECMWF run only extended through 12Z on October 25, 2003 but was consistent with the GFS maintaining the strong ridge of high pressure across the eastern Pacific. The ECMWF's placement of the long wave trough axis was slightly further west, along the front range of the Rockies.

October 19, 2003
The 500-mb height field from the 00Z run of the GFS continued to indicate a strong ridge across the eastern Pacific (Fig. 2) centered at 40N 136W (594 dm). The ECMWF had a similarly placed but slightly stronger ridge (601 dm). There was good agreement between the models with the positioning of the trough over the central U.S. from Minnesota southward into central Texas. However, the GFS introduced dramatic changes across the southwest U.S. at 12Z on October 25th with the development of a closed low just west of the Four Corners region (not shown). The low forms at the base of the trough and then retrogrades to the west and develops into a sub-540 dm cut-off low centered over southern California by 12Z on October 26 (Fig 2). The ECMWF at the same time period hinted at the development of a much weaker closed low over central Texas. The GFS's development of the cutoff low would provide significant implications to the sensible weather across the entire southwest and specifically the Las Vegas CWA.

The NCEP MREF 500-mb height normalized ensemble spread also indicated a cutoff low over the southwest U.S. (Fig. 3), but was much weaker (570 dm). The normalized spread was very large across the entire southwest with values near the cutoff low (across the southern portions of the CWA) as high as 4 times the 30-day average spread. The 500-mb height ensemble mean also indicated a closed low over the Desert Southwest (Fig. 4) with a height of 552 dam and anomalously large ensemble spread of 200 m. Concurrently, the ridge over the eastern Pacific indicated much lower values across the board, including below normal spread in the normalized 500-mb heights and actual spread generally less than 50 m throughout the ridge axis.

By taking into account the various degrees of the uncertainty in the NCEP MREF ensemble data, one can apply a level of confidence in the current operational run of the GFS model. The ensemble data indicates a low uncertainty/high confidence in the ridge across the eastern Pacific and a very high level of uncertainty/low confidence in the development of the intense cutoff low over the southwest U.S. Additionally, the GFS forecast is a significant deviation from the previous GFS run, the previous ECMWF run and the current ECMWF run. By incorporating the ensemble data into the forecast process one would appropriately discount the development of the cutoff low (particularly for a day 6 forecast).

October 20, 2003
The 500-mb height field from the GFS (00Z run) and the 12Z run of the ECMWF (Fig. 5) maintained the strong ridge over the eastern Pacific centered at 42N 131W with the ECMWF slightly stronger. Both models had similar placements of the long wave trough across the north central U.S., but the GFS continued the development and retrogression of a cutoff low into the Desert Southwest, while the ECMWF continued with an open long wave trough that stretched southward into the central Texas. The GFS however, did indicate a weaker cutoff low (556 dm) in comparison to the previous run.

The NCEP MREF 500-mb height normalized ensemble spread continued to produce a 570 dm closed low over the Desert Southwest (Fig. 6). The normalized spread remained very large (4-5+ times the average 30-day spread) in the Desert Southwest and near the position of the closed low. The 500-mb height ensemble mean (Fig. 7) was slightly weaker from the previous run with a 558 dm closed low. The spread also remained very high near the position of the low and across the Las Vegas CWA with values predominantly between 175 and 200 m. Meanwhile, the ridge over the eastern Pacific continued to indicate low spread (below average normalized spread) and therefore low uncertainty. Accepting the operational GFS solution would have significant effects on the Las Vegas CWA sensible weather forecast. Again, utilizing the normalized ensemble spread and the ensemble mean 500-mb products would highlight the uncertainty with the cutoff low over the Desert Southwest and lead one to lean toward a solution similar to the ECMWF with better run to run consistency and lower uncertainty.

October 21, 2003
The operational run of the 00Z GFS depicted the ridge of high pressure centered over the eastern Pacific at 40N 130W with a height of 598 dm and the axis of the long wave trough over the central U.S. (Fig. 8) stretching from Minnesota to central Texas. The GFS no longer exhibited the development of a retrograding closed low over the Desert Southwest.

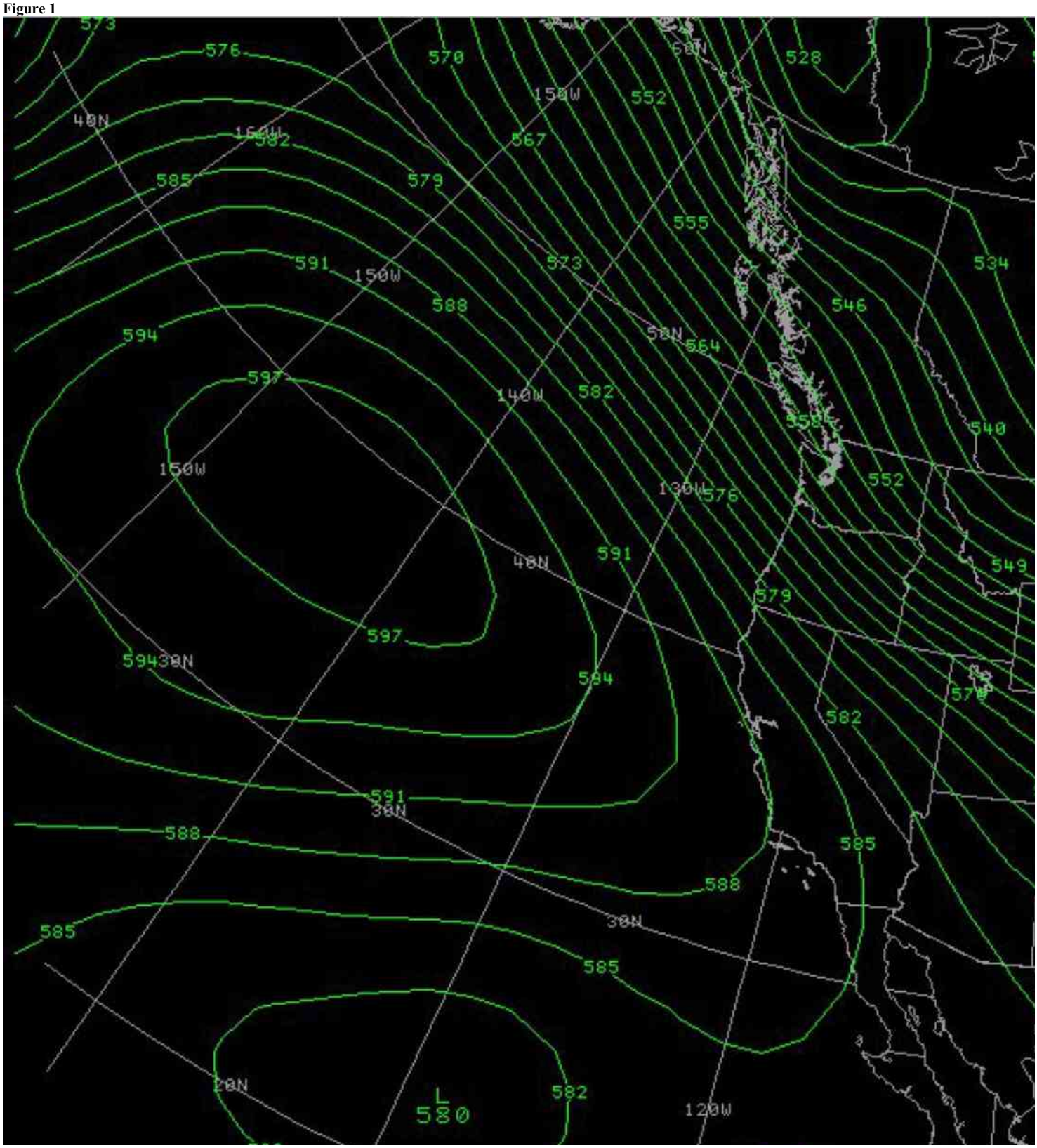
The normalized ensemble mean spread indicated very low values (below average uncertainty) over the eastern Pacific and the west coast of the U.S. with

the continued support of a strong ridge (Fig. 9). The 500-mb height ensemble maintained a strong ridge over the eastern Pacific and western U.S. and produced spreads of only 5-20 m (high predictability) among the ensemble members (Fig. 10). The latest operational run of the GFS has returned to the solution with the lower uncertainty, now resembling the GFS solution from Oct. 18 and the ECMWF solutions from Oct. 19 and 20. Utilizing the NCEP MREF ensemble would have reduced the likelihood of following the anomalous GFS solutions from the Oct. 19 and Oct. 20 and would have enabled a more consistent forecast product.

The ridge over the eastern Pacific and western U.S. persisted through the remainder of the month and produced the warmest October on record at McCarran International Airport in Las Vegas and no precipitation for the month tying the previous record.

Summary
There are ever increasing amounts of ensemble data available to the operational meteorologist and this trend will continue throughout the rest of the decade. This case dealt with a small subset of this data and is only one example of how this data can be utilized to help improve medium range forecasts.

Figure 1



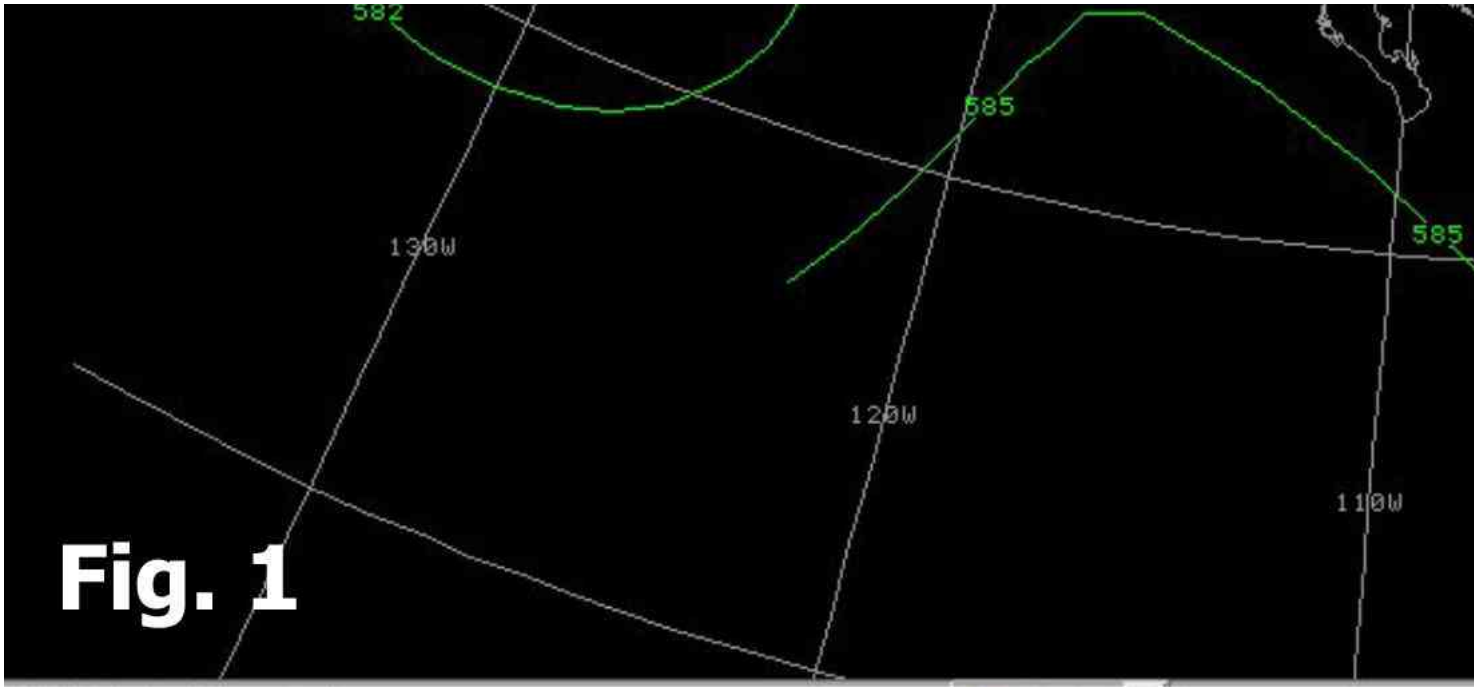

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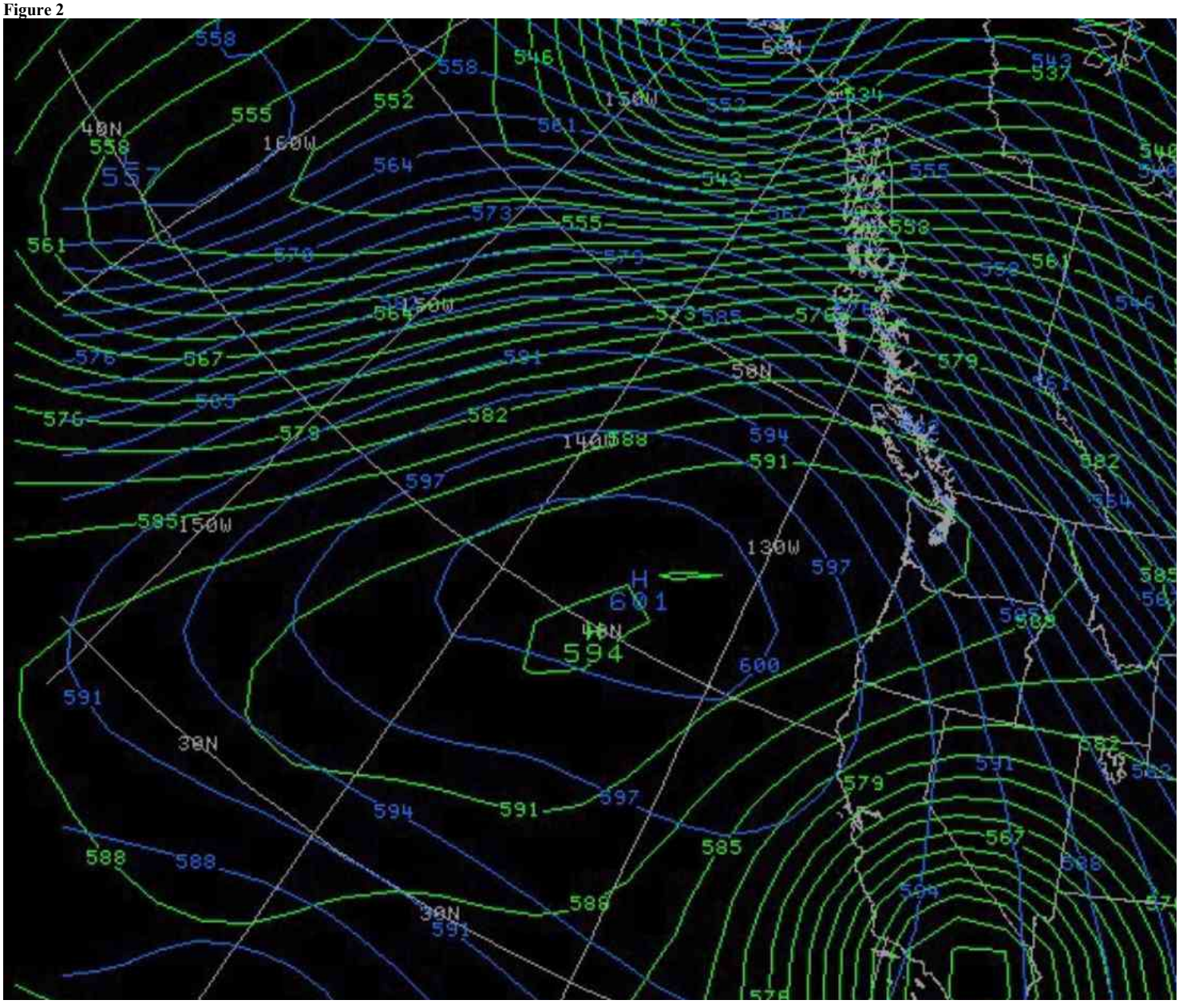
Fig. 1

Figure 2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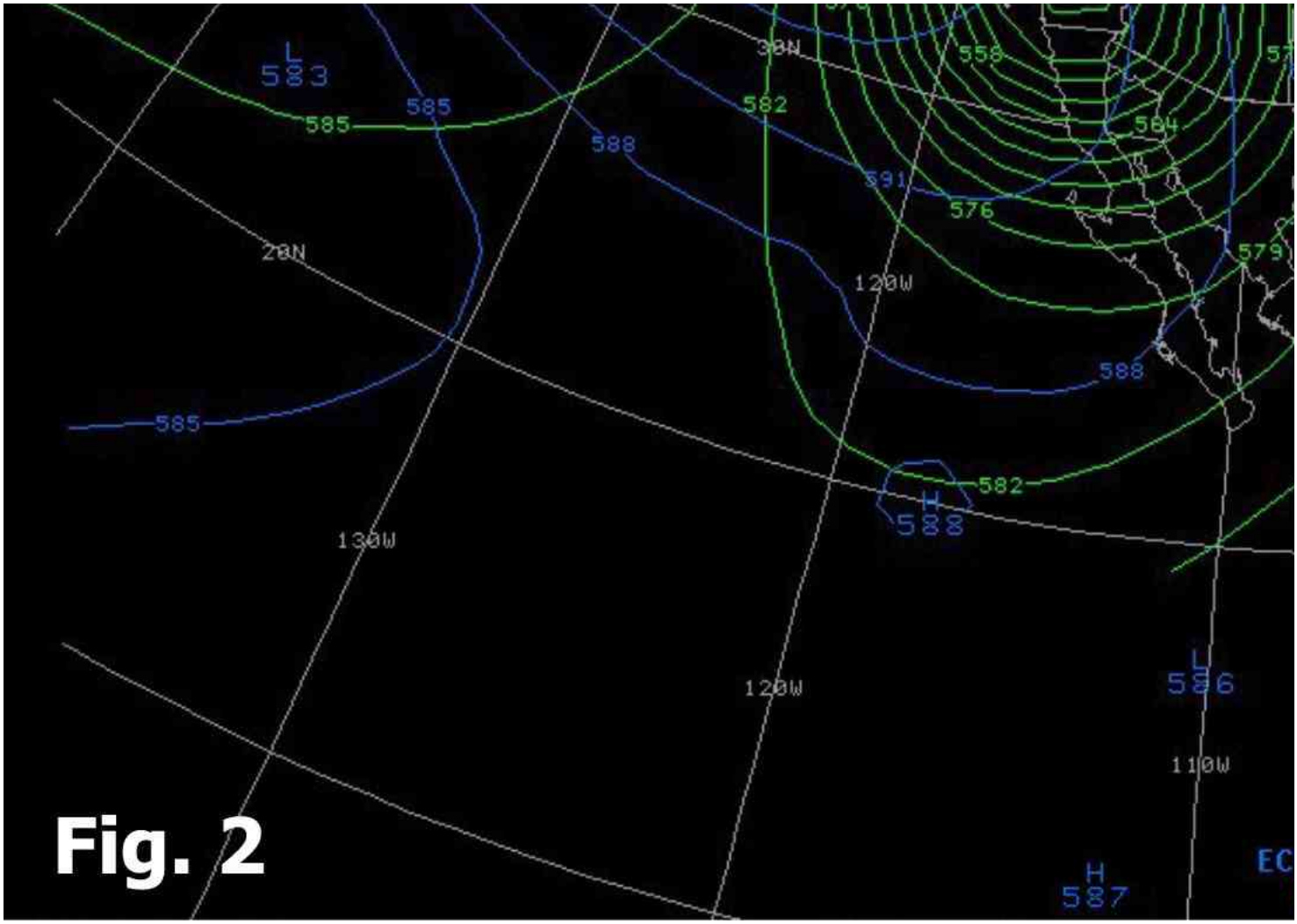
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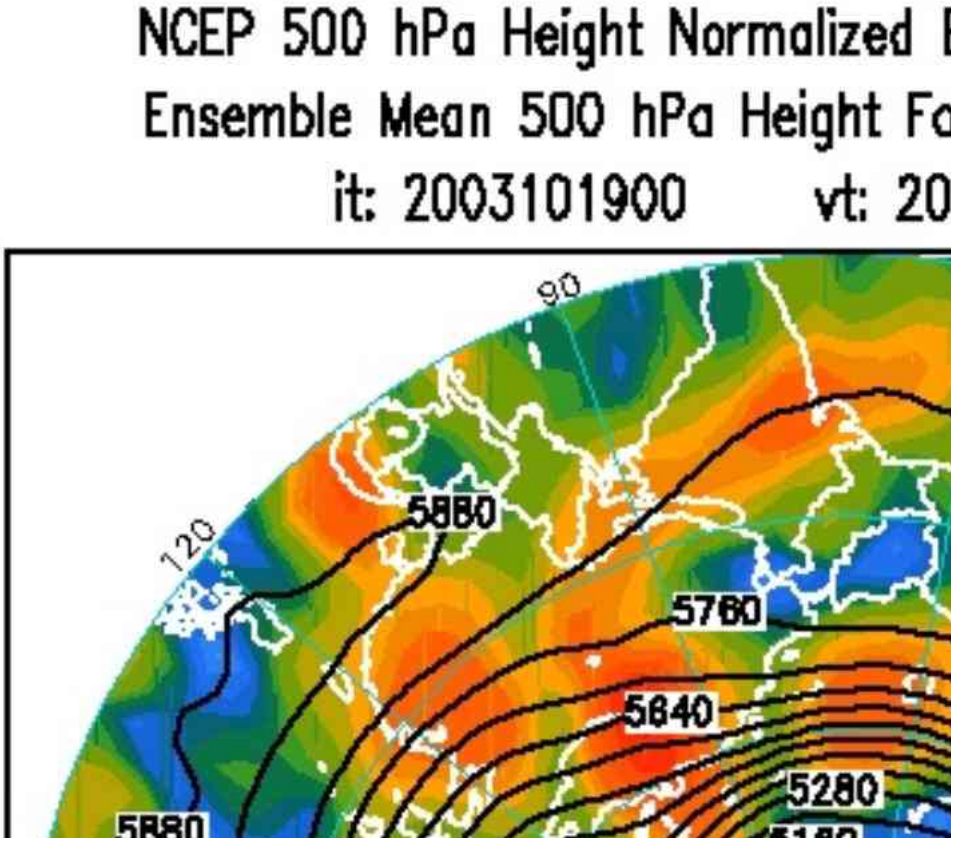
Figure 3


NCEP 500 hPa Height Normalized
Ensemble Mean 500 hPa Height Fo
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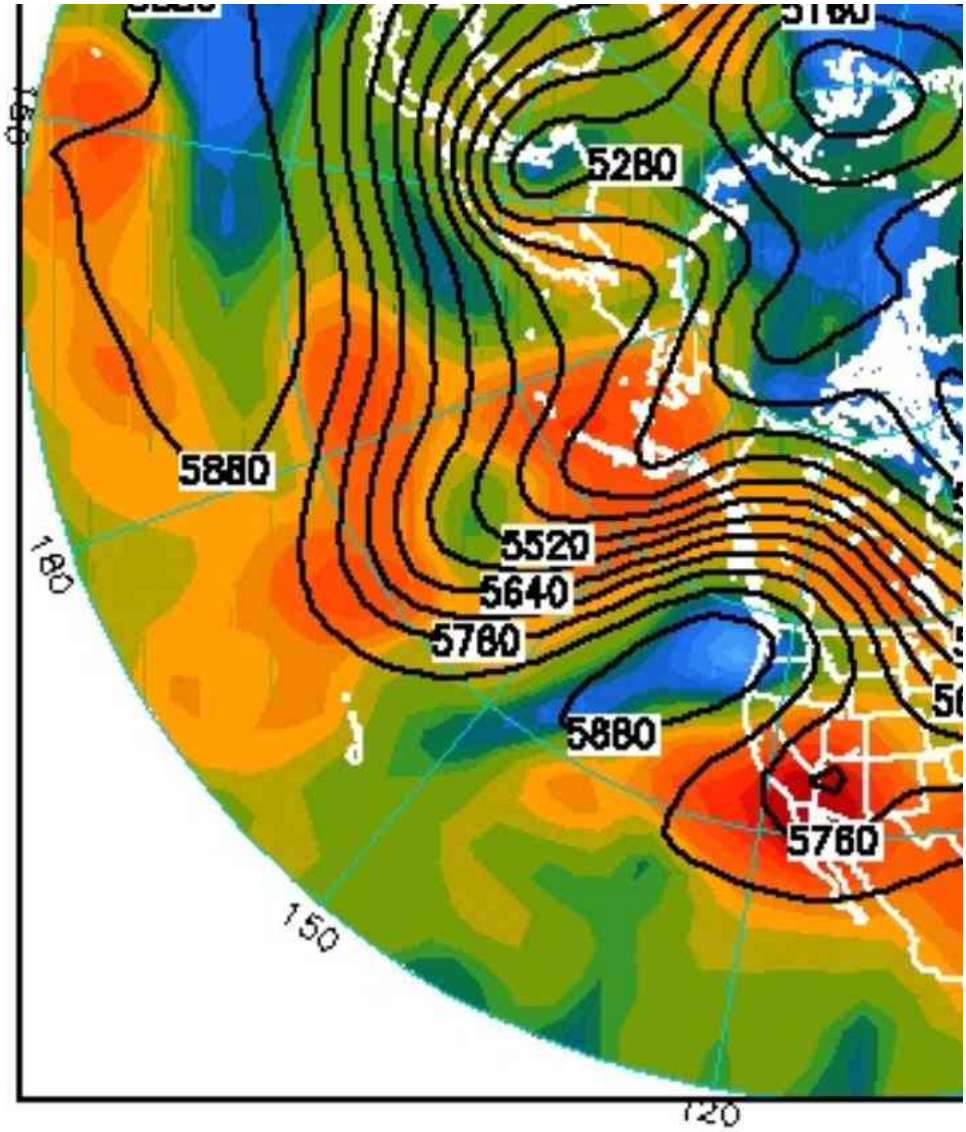
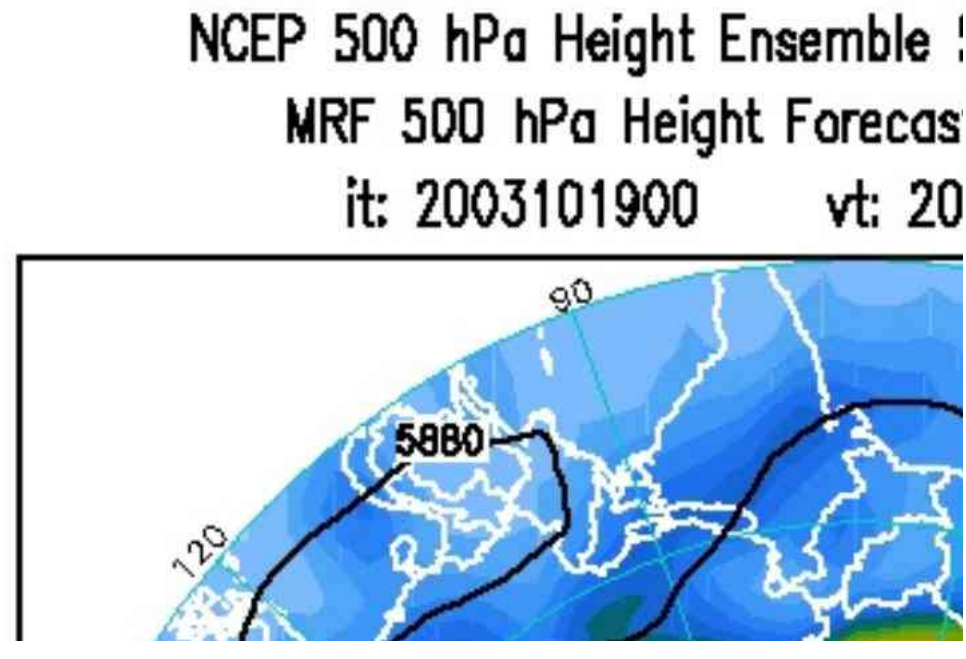


Fig. 3

Figure 4



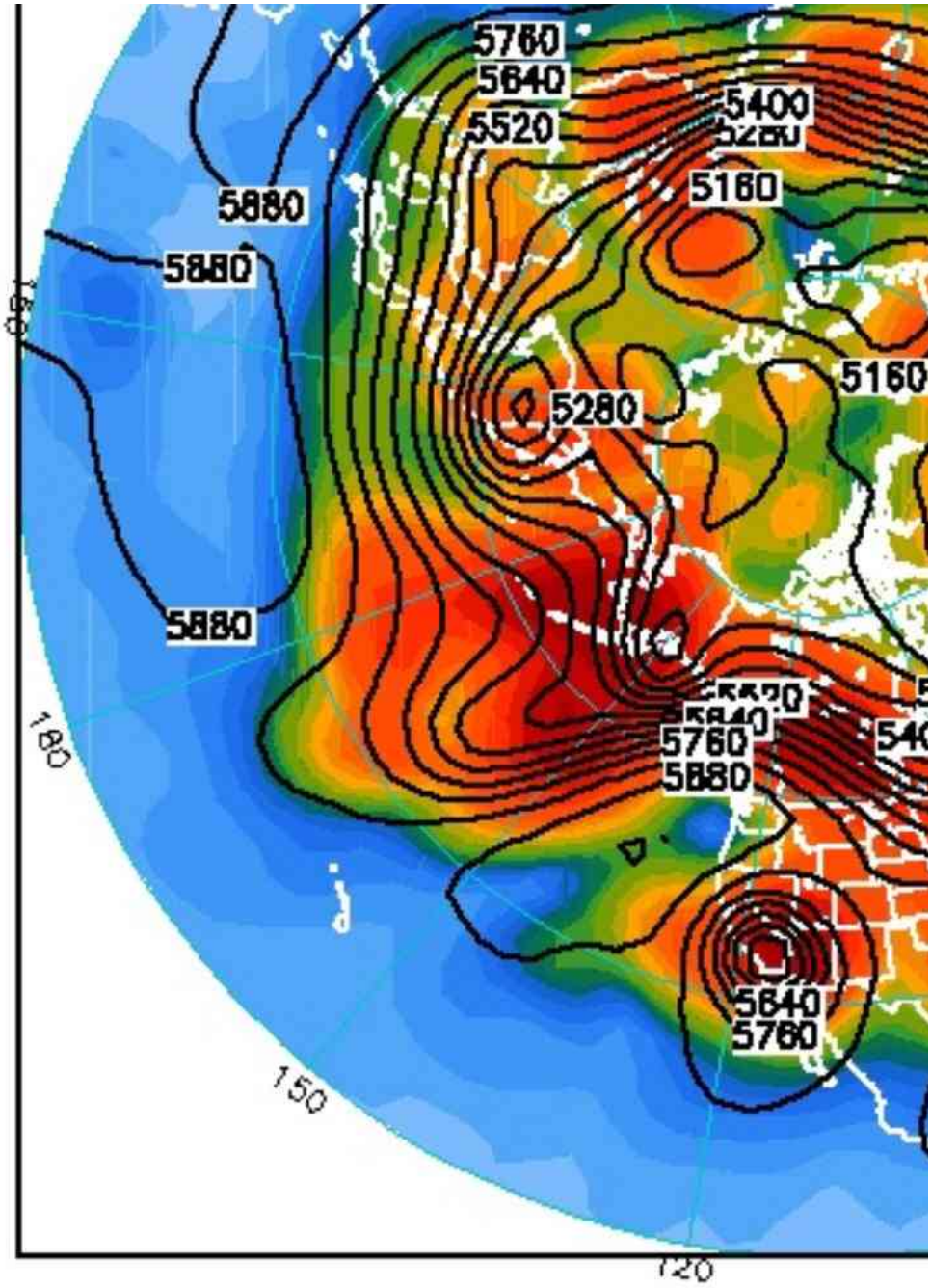


Fig. 4

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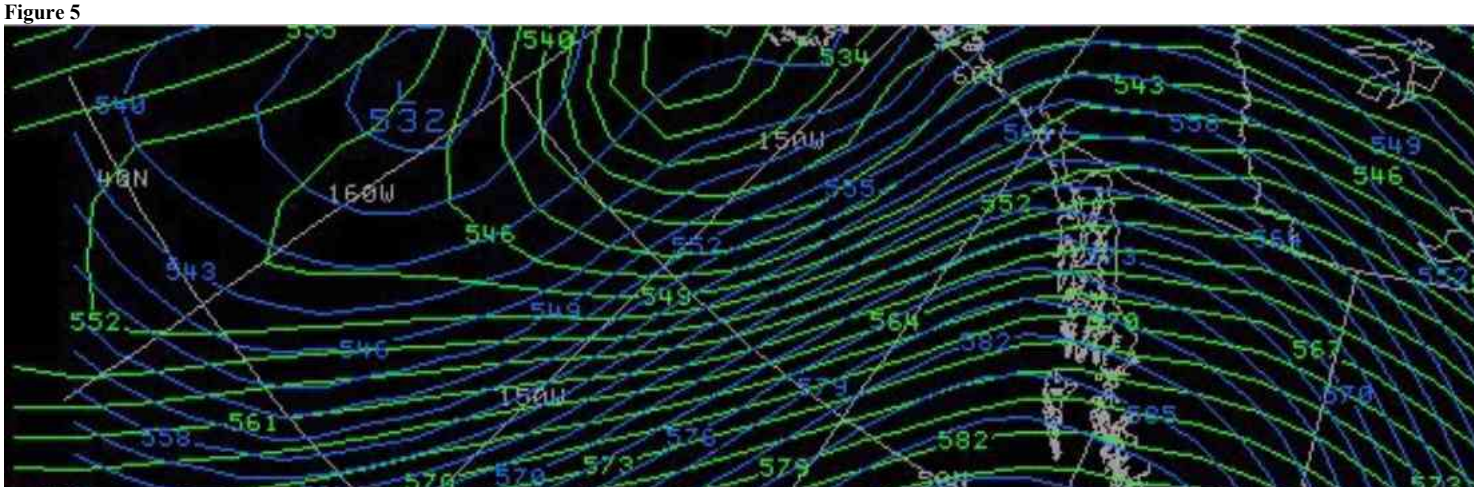

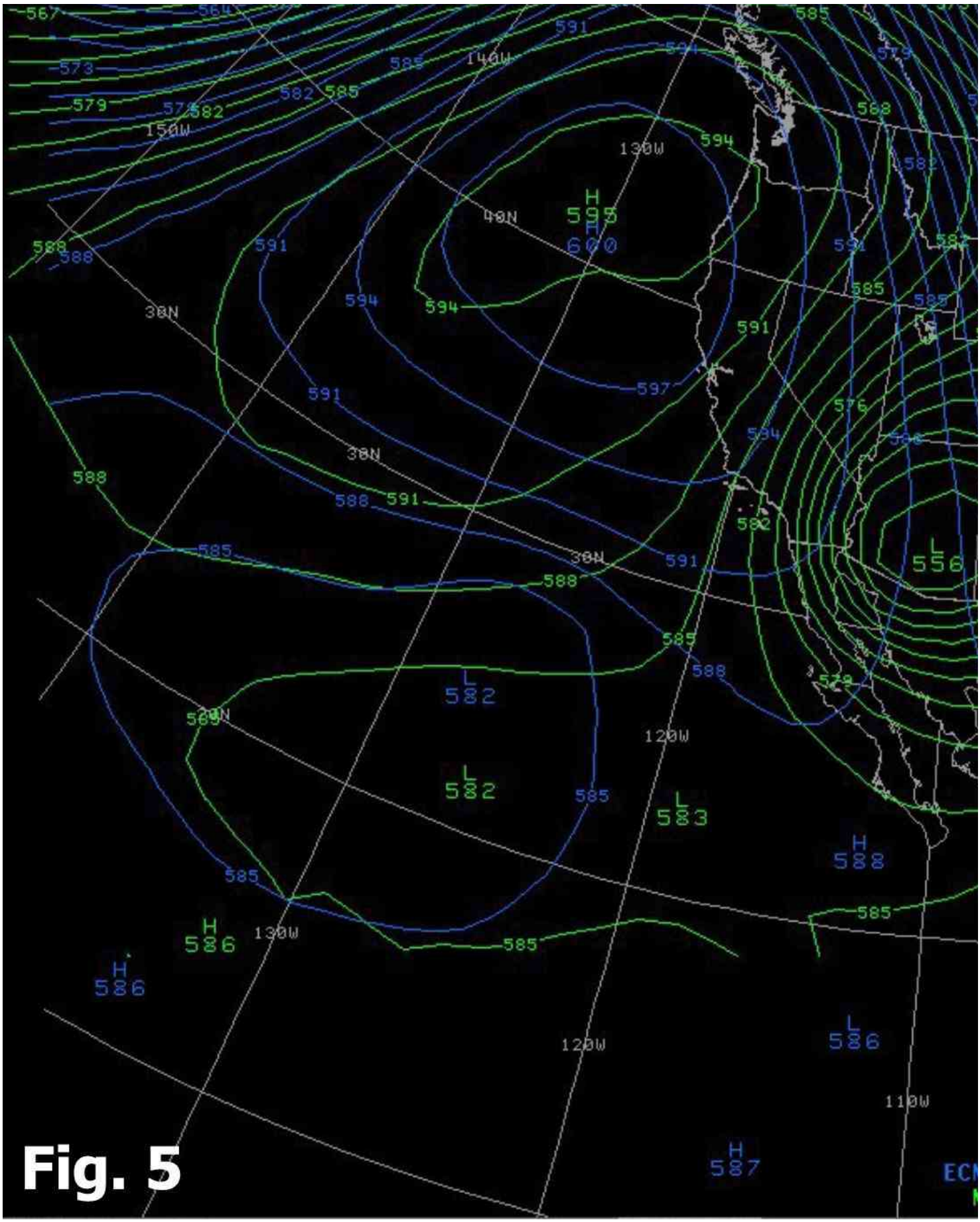

Figure 6

NCEP 500 hPa Height Normalized

Ensemble Mean 500 hPa Height Fo

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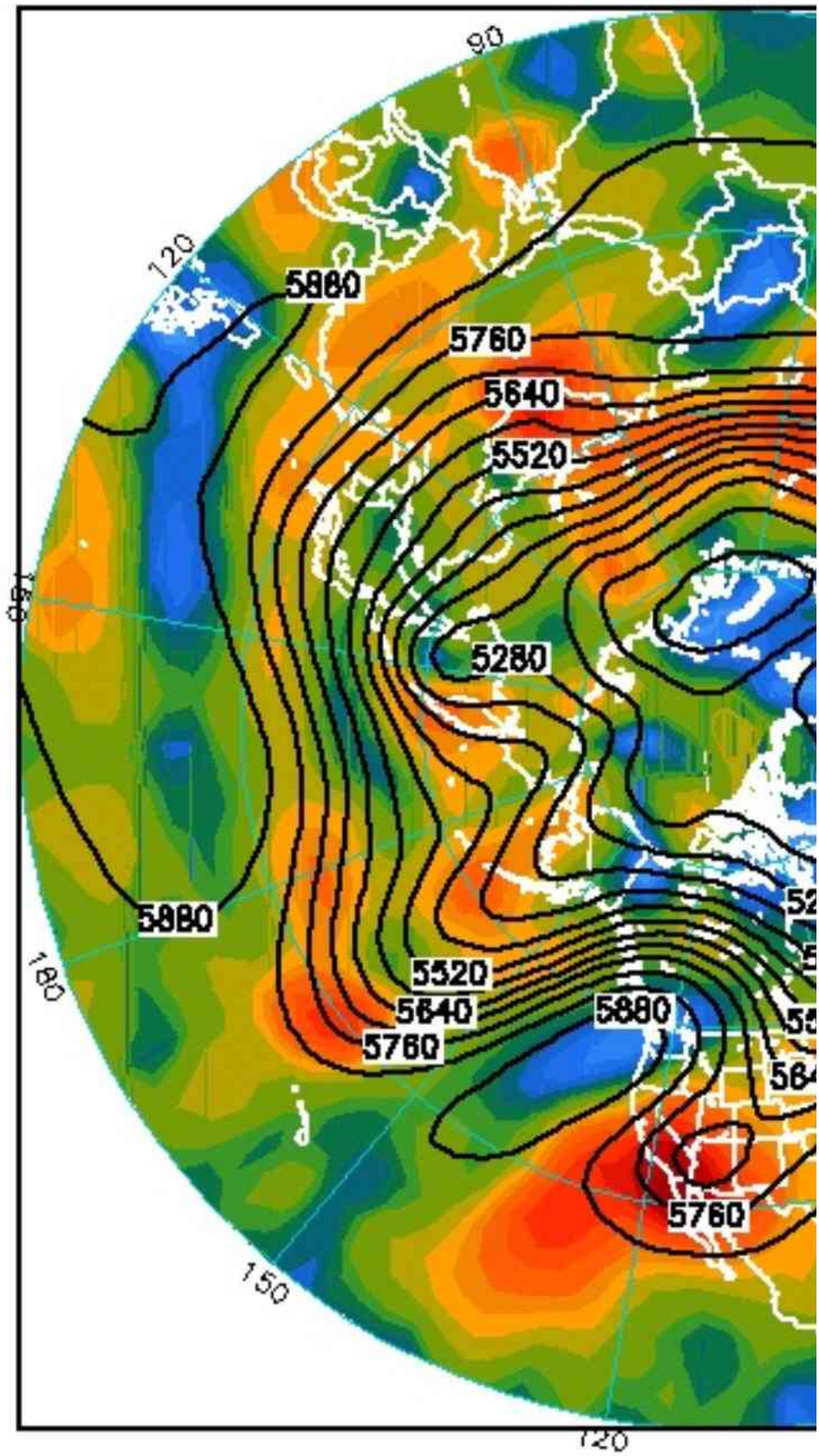


Fig. 6

Fig. 6

Figure 7

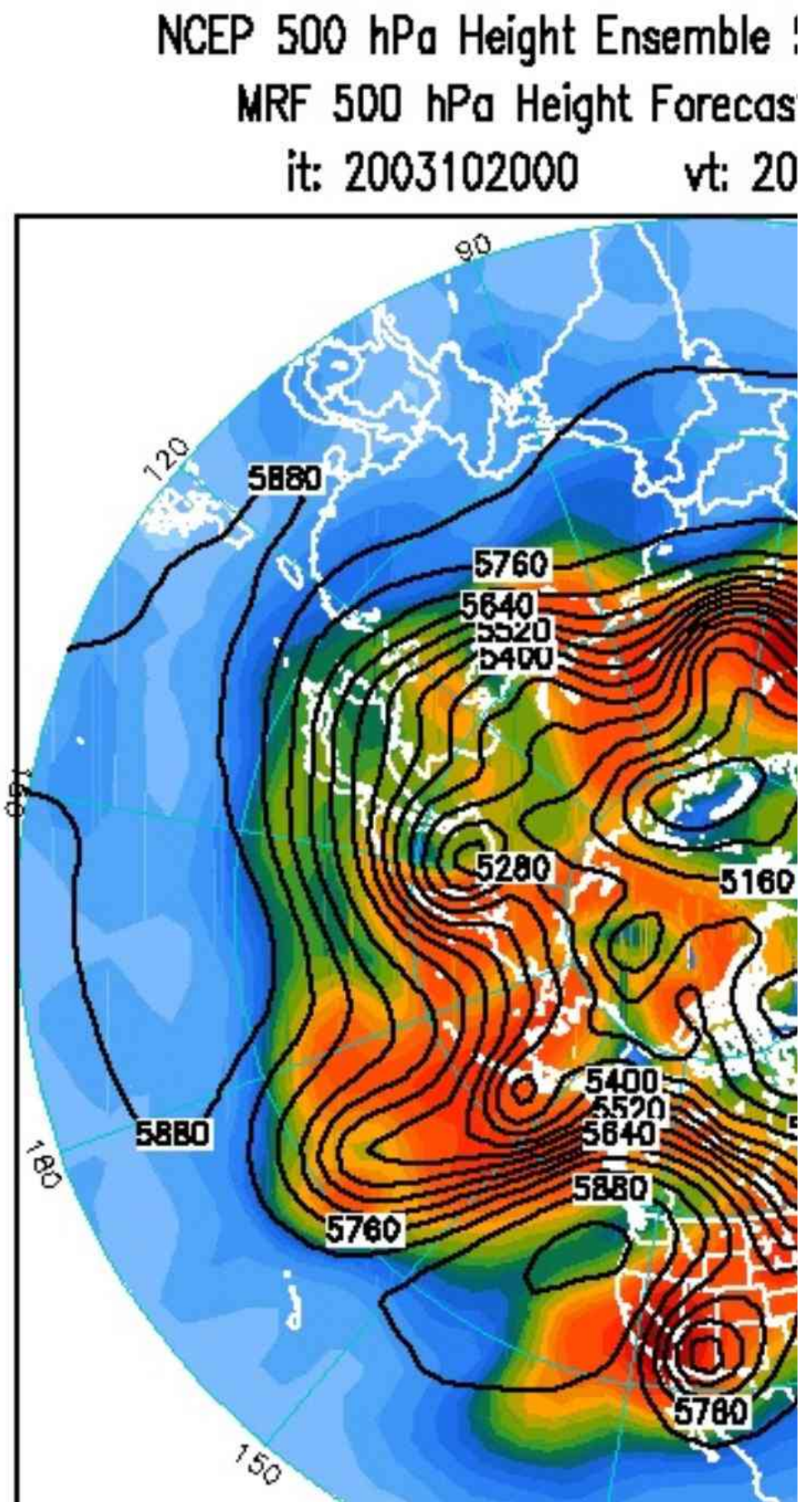
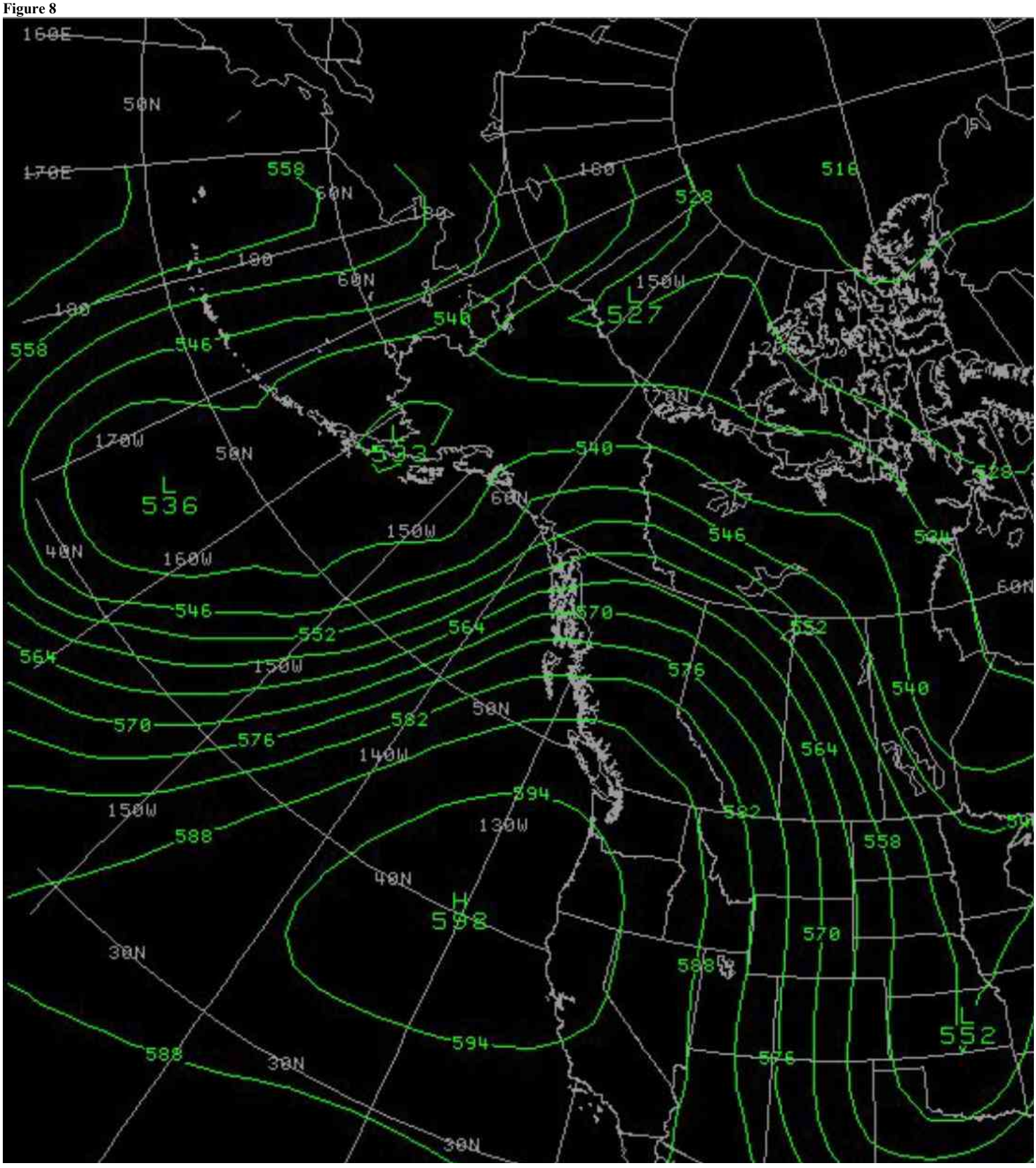


Fig. 7

Figure 8



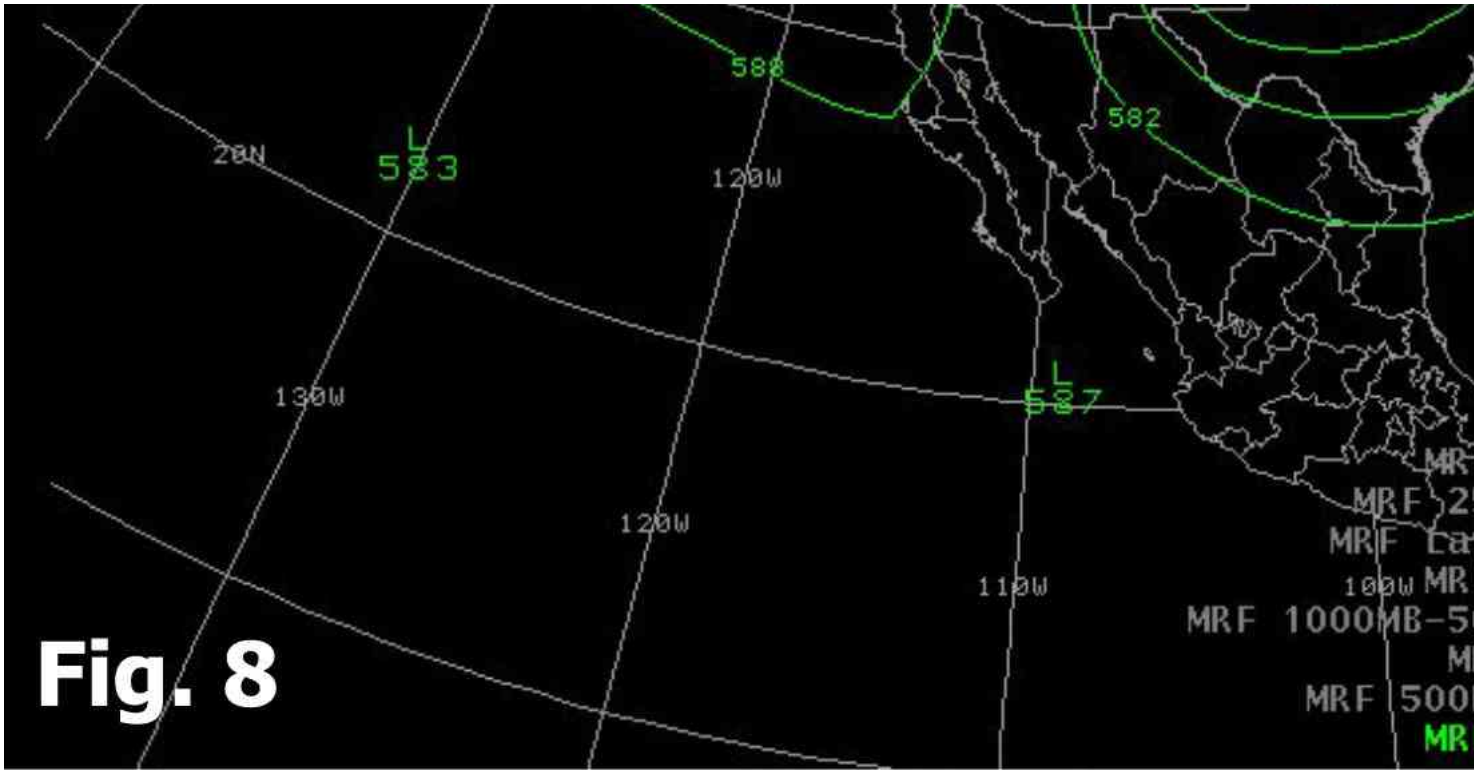

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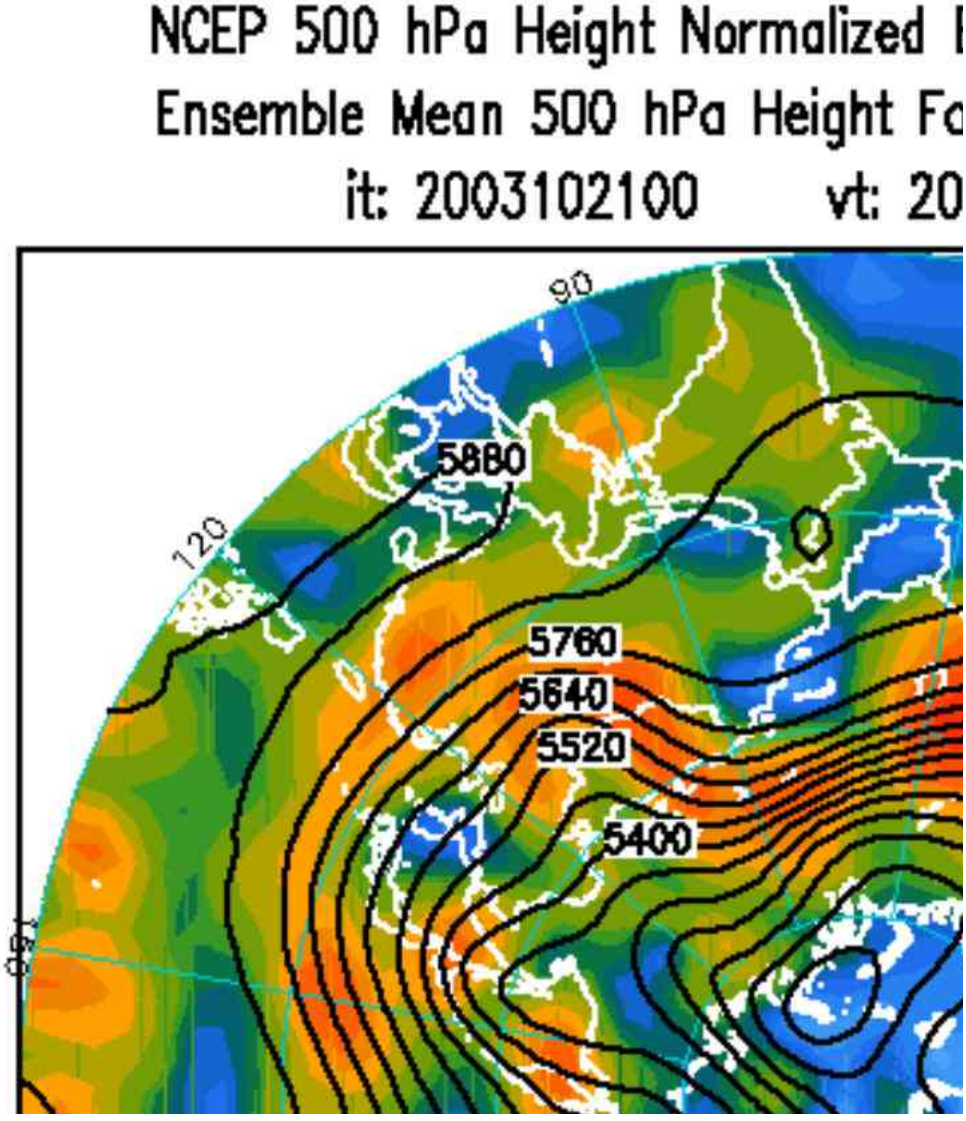
Fig. 8

Figure 9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Ensemble Mean 500 hPa Height Fo
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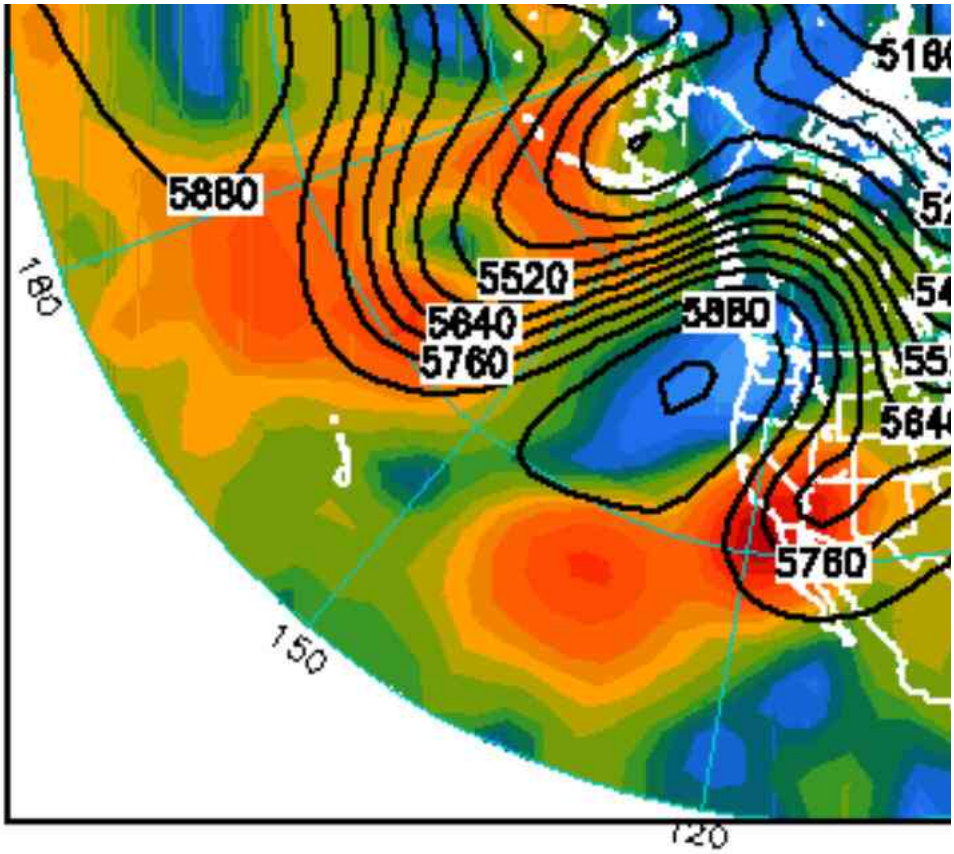
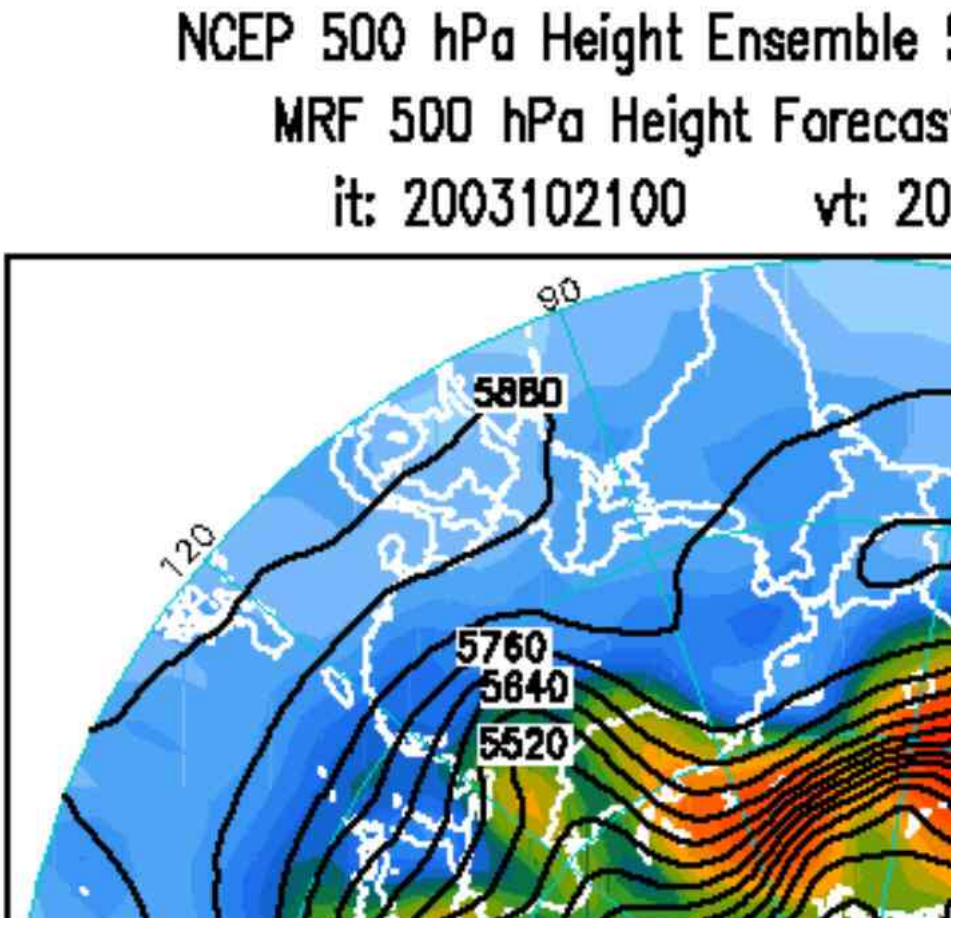


Fig. 9

Figure 10



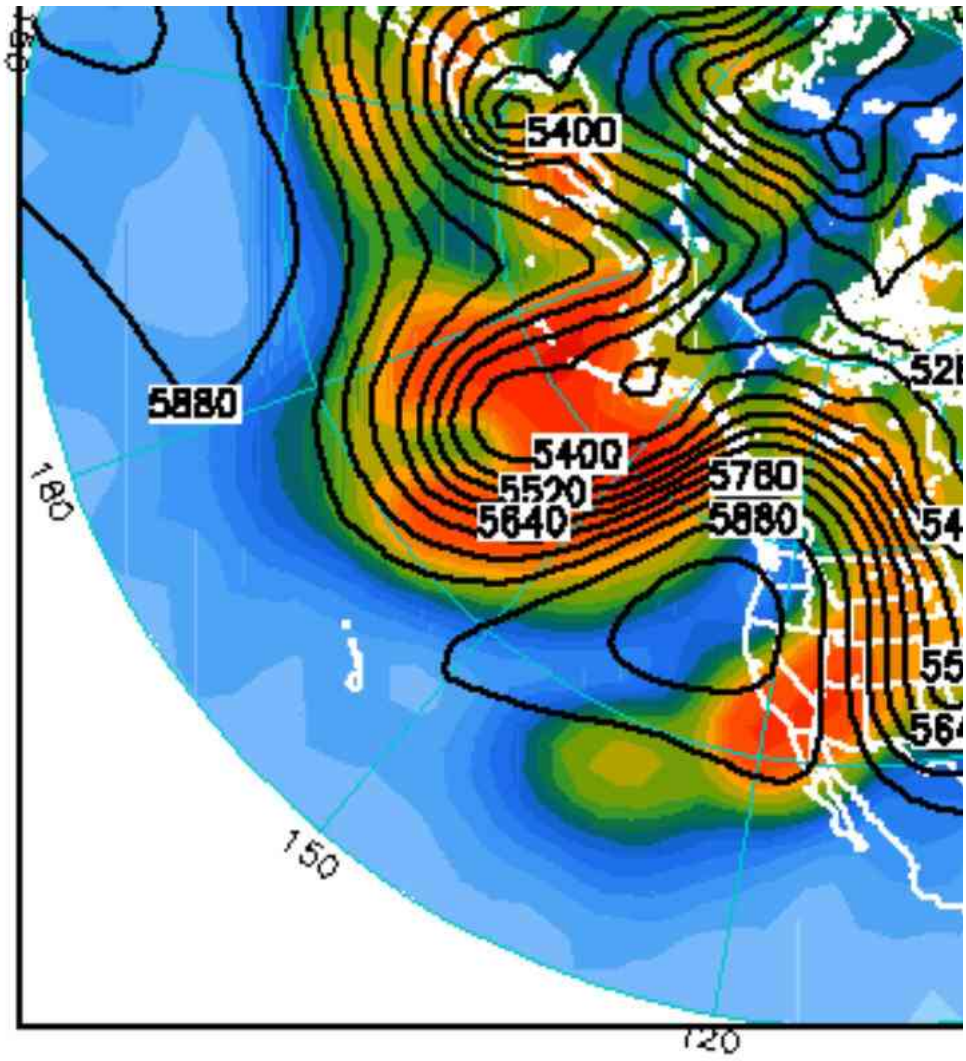


Fig. 10