Quantifying Sensible Weather Forecast Variability

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LONG-TERM GOALS

The long-term goal of this research is to examine the tactical scale environmental predictability and provide a methodology by which it may be operationally assessed or monitored.

OBJECTIVES

Sensible weather occurs on small scales and the development and evolution of these small scale features depends strongly on the larger scale environment. Synoptic scale variability is represented by the individual members in a well-designed ensemble modeling system. The objective of this research is to quantify the local scale variations in sensible weather elements, like fog, due to larger scale variability. The sensitivity of selected weather elements to synoptic scale background variance will be quantified to identify when local scale predictability may be high or low.

APPROACH

The basic approach that is used to investigate the tactical-scale sensible weather forecast sensitivity is to conduct a variety of numerical model experiments. The time range of interest is the 0-48h forecast of sensible weather elements of operational interest.

Sensible weather elements are generally not explicitly forecast by numerical models but will be derived algorithmically if needed by using appropriate combinations of explicitly forecast variables. These algorithms are applied across a set of ensemble forecasts to determine the ensemble-based probability of occurrence for a particular weather element.. The NCEP GFS-based ensemble provide the basis for generating probabilistic forecasts of a variety of sensible weather elements in the 0-48 h time period. Deterministic mesoscale forecasts for the region are available from a 3km resolution forecast from COAMPS and are used to derive mesoscale sensible weather forecasts that are tuned to this model. Additional COAMPS model runs are conducted using the NCEP ensemble members to initiate COAMPS forecasts to produce a mesoscale ensemble based on the predicted synoptic scale variance. Since the NCEP ensemble represents synoptic variability, the mesoscale forecasts vary due only to the local forcing differences that arise from slightly different synoptic conditions. These experiments are used to systematically quantify the mesoscale variance that is driven by larger scale processes.

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WORK COMPLETED

Work completed during the past year has primarily to run and analyze the COAMPS ensemble model forecasts for 10 representative cases to assess the uncertainty information in the mesoscale sensible weather forecasts. The COAMPS model was compiled and is running on the NPS High Performance Computing facility. The model can be initialized with larger scale model fields obtained from NCEP. Deterministic runs from the NCEP GFS analyses can be done with the inner nest of the COAMPS model at 3km resolution. In addition, NCEP GFS Ensemble members are being collected and used to initiate COAMPS forecasts with slightly perturbed sysnoptic scale initial states. The ensemble runs of COAMPS are used to generate mesoscale forecasts of low clouds and visibility for the Monterey Bay region in order to assess the sensitivity of these sensible weather elements to the background synoptic scale forcing. The model has been run on 10 cases where low clouds either initially formed or evolved over the day to assess the ability of COAMPS to generate the evolution under a range of reasonable synoptic forcings.

The COAMPS ensemble forecast output requires tools to extract useful cloud and visibility forecast parameters at specific locations. A method to extract point forecast profiles for specified verification sites has been developed. This tool is used to generate forecast statistics to use in developing algorithms as well as to assess the variability in the prediction of these parameters.

RESULTS

To characterize the impact of synoptic scale variance on fog/low cloud forecasts, ten sample days were used to conduct detailed analysis of the high-resolution deterministic and ensemble model forecasts. The ten days selected for this initial part of the study came from the summer of 2010 and represented days when significant marine stratus transitions occurred over the course of a 24-hour period. These days were characterized by both clear to cloudy and cloudy to clear transitions at a variety of times during the day. A series of satellite images from June 7, 2010 illustrates the complex evolution of low clouds over the Monterey Bay region. For this case, the late afternoon (0000UTC) produced clear skies over most of the bay at the model start time. The satellite image shows a complex evolution of marine stratus from mostly clear the afternoon before, into complete cloud cover by the AM, followed by clearing over the northern portion of the bay through the day. While conceptually this evolution is relatively well understood, the ability to numerically predict the detailed evolution at any particular location is exceedingly difficult and the primary focus of this study.

To a first order approximation, the development and evolution of marine stratus depends largely on the synoptic scale forcing of the marine boundary layer (MBL) depth and low-level wind and thermodynamic structure. A comparison of the sounding from Monterey at the clear initial time (0000UTC) and the cloudy period in the AM (1200UTC) from the model analyses at these times reveal differences in MBL depth and degree of saturation at these two times. The degree to which synoptic scale evolution accounts for these changes varies from case to case but can be represented by considering the MBL evolution for a given synoptic forecast. Uncertainty in the synoptic evolution that forces the marine boundary layer can be sampled using the ensemble forecasts of the synoptic scale fields, such as the 850 mb wind at Monterey. The amount of spread in 850 mb wind direction and speed over the 24 h forecast period for June 7 is rather small, which is expected from the standpoint of the larger scale forecast fields for this short of a forecast interval.

To show the performance of the ensemble and a single high-resolution cloud forecast from COAMPS, the cloud fields explicitly predicted by COAMPS are compared directly to surface observations from available sites. The ceiling height forecasts for Monterey and Watsonville are compared to the observations over the 24 hour forecast period. An examination of the single deterministic model forecasts reveals several important aspects of the model performance. First, when the model explicitly forecasts a ceiling, it is very close to that observed, especially at Monterey with more prevalent cloud cover. This suggests that the synoptic scale factors that determine ceiling height are reasonably accurate in COAMPS. Second, the ability of COAMPS to correctly capture the diurnal evolution at these two location is rather limited. The Monterey forecast with more extensive clouds is generally better than the Watsonville forecast where COAMPS severely under predicts the cloud cover. Other cases show similar behavior but no consistent forecast error is evident that would allow simple bias correction of the forecast fields.

The central question in this study is whether use of the synoptic scale uncertainty or variability is sufficient to accurately depict the variability in the cloud or other sensible weather elements. Examining the ensemble mean forecast of ceiling height shows very similar behavior to the deterministic forecast. The ensemble mean shows a slightly longer period cloudiness at Monterey and a few periods of cloudiness at Watsonville that were not suggested by the deterministic forecast. In addition, the spread in ceiling height (not shown) tends to be small when clouds are present and extremely large during transition times from cloudy to clear or vise versa. These suggest that synoptic scale variance is not sufficient to realistically produce the local scale variations in the COAMPS forecasts necessary to give ceiling height probabilities much above zero unless a ceiling is forecast by nearly all members. This may be due to the synoptic scale mean fields not being sufficiently close to the true atmosphere to produce the correct mesoscale ensemble variance.

Other cases have been examined as well and reveal similar behaviour in th ensemble forecasts of ceiling heights. There is a lack of ensemble spread once a ceiling develops in the model but there is spread around the times of burn-off and formation. This is true when the spatial variations in the ensemble are examined as well. These results suggest little additional value in these sensible weather forecasts or their uncertainty is gained by using the synoptically forced ensemble. Smaller scale perturbations may be necessary to assess the small scale uncertainty both in time and space. The results are similar for the three primary synoptic patterns that typically occur during the warm season along the California coast.

IMPACT/APPLICATIONS

Potential impacts of this research are the development of tools to assess tactical scale sensible weather uncertainty using a model based ensemble. The synoptic scale variability may not capture all the variance but should still be a useful first cut at assigning mesoscale uncertainty information to applications of COAMPS battlefield forecasts in data denied regions.

RELATED PROJECTS

None.