

Advancing Quantitative Precipitation Forecasting by means of Data Assimilation

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Rapidly developing mesoscale convective systems (MCS) are usually responsible for the heaviest and most destructive rainfall and flood events worldwide. Rainfall from an MCS is spatially heterogeneous such that convective cells (typically associated with lightning activity) would produce areas of intense rain rates imbedded within larger precipitation regions. This pattern can persist over several hours and cover large areas producing large accumulations of rain and often result in flash floods and other problems of surface water drainage. To moderate these hazards, systems have been developed for issuing short-range (up to 48 hrs) quantitative precipitation forecasts (QPF) on the basis of numerical weather prediction (NWP) models and observational inputs (e.g., synoptic observations, surface and remotely sensed data). Due to the rapid progress in computing performance and atmospheric modeling, NWP models can run nowadays with grid resolutions down to a few kilometres and can be used to predict weather operationally at local scales. The refinement in the model resolution did not prevent QPF from exhibiting large uncertainties at forecasting highly variable convective precipitation events. Clearly, the high non-linearity in modeling atmospheric processes causes sensitivities to even small perturbation in the atmospheric initial state, the quality of which dictates the accuracy of QPF. An aspect that has shown convincing signs of improving numerical weather prediction is data assimilation. Data assimilation aims at obtaining the optimal initial state of the atmosphere in order to define a better starting point for model integration.

Collective evidence from past studies indicates that improved initialization of the local environment in NWP models (particularly this of the atmospheric moisture distribution) is an avenue for potentially improving QPF as it relates to simulated convective precipitation.

The talk will review techniques aimed at the improvement of local and regional atmospheric model analyses and forecasts through the assimilation of ground-based and satellite observations related to atmospheric moisture as well as cloud and precipitation parameters.

In particular, we will first examine the impact of data forced land surface conditions (soil moisture and temperature) on the simulation of thunderstorm development in warm-season environments. The study is facilitated by a weather forecasting system that uses a modified version of the NCEP/Eta model. We consider two modes of atmospheric model operations: coupled and uncoupled with a land data assimilation system (LDAS). LDAS uses hourly gauge-calibrated radar rainfall fields and satellite-retrieved radiation fields, and other near surface atmospheric parameters (winds, temperature, pressure and relative humidity) obtained from the global ECMWF analysis dataset to force the NCAR Community Land Model version 3.0 (CLM3) for simulating the evolution of land surface

parameters. In the coupled mode, for the definition of the initial soil state (soil moisture and temperature distributions) we use (a) the global ECMWF analysis dataset and (b) the output obtained from a land surface scheme forced by Eta predicted fields. In the uncoupled mode, the CLM3 soil moisture and temperature fields are used to dynamically update the Eta land surface boundary conditions during model simulations. Results from the numerical experiments are evaluated against measured radar rainfall fields and in-situ observations of soil moisture.

Second, we will review a strategy to directly assimilate satellite observations of precipitation into a cloud-resolving-model. The assimilation is based on an Ensemble Kalman Filter methodology. The cloud resolving model to be used is the Advanced Regional Prediction System (ARPS) developed at the University of Oklahoma. The model features several microphysical schemes, turbulent parameterizations, and surface sub-models. An “a priori” covariance term, based on independent radar-radiometer observations, is included in functional form associated with the assimilation process. This “a priori” covariance term constrains the model state variables to values consistent with independent observations. The methodology is evaluated using radar and satellite radiometer observations. That is coincident real radar and radiometer data are assimilated into the model. Assimilations of radiometer only observations with and without the “a priori” covariance term are performed. The retrieved/forecasted state variables are compared to those derived in from the combined radar and radiometer observations, and the impact of the “a priori” covariance term on the assimilation is thus assessed.

The talk will conclude with a discussion about a coordinated effort in Europe (named WATERSAT) targeting the advancement of weather and hydrologic forecasting by means of improving cloud and precipitation observations and data assimilation techniques.