THE INTERACTION BETWEEN NOWCASTING AND NWP FOR QPF FOR COASTAL LOCATIONS

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ABSTACT

The operation of a combined Nowcast/forecast rainfall presents a number of opportunities for the development of innovative hybrid techniques. As NWP is primarily an initial value problem, there is a reasonable expectation that by assimilating high-resolution observations of rainfall, cloudiness and wind speed the short-term skill of model predictions should be increased allowing a change over to NWP from Nowcasting at an earlier stage. Important work is underway in many groups who are attempting to assimilate radar observations of reflectivity and radial Doppler winds into convective scale models. For an island nation such as New Zealand the particular problem is that the radar reflectivity and radial velocity data are only available within a hundred kilometers or so of the coast meaning that the time ahead for relevant data to be assimilated into the air mass resident over the area of interest at the forecast time is quite limited. Possible solutions to this problem are the use of satellite data over the surrounding ocean regions to estimate rainfall and cloudiness, which in turn can be used in Nowcasting models the output of which can be used for direct assimilation into the NMP system. However, the optimum way to achieve this is not clear. We present some results and illustrate some problems for quantitative precipitation forecasts (QPF) obtained using WRF initialized with VAR using both directly derived radar and satellite rainfall and wind speed estimates and those obtained by Nowcasting.

1. BACKGROUND

Nowcasting based on radar is now established as a powerful technique for the short term prediction of rainfall although schemes to extend the range of such forecast by including second order. On the other hand Numerical Weather Prediction (NWP) models, such as the Weather Research Forecast Model (WRF), have advanced to a stage where the research and operational community is beginning to have confidence that most of the meteorologically important physical processes are included in the model dynamics. This confidence is limited by an understanding that the resolution (grid spacing) at which a model operates determines the scale of physical processes which can possibly be represented. At a given resolution, with given expectations about the scales of processes which the model can be expected to resolve, NWP is to a large extent an initial value problems- the skill of the model at making forecasts at a scale appropriate to the model resolution is mostly dependent on the quality of the specification of the atmosphere at a start time.

This dependence of model skill on the correct specification of initial conditions is especially true for precipitation and convective processes which may be most correctly regarded as statistically initialized phenomena. Until convective cells are observed (and hopefully introduced into the model state) the ultimate stochastic nature of some atmospheric processes makes it almost impossible to make forecasts about the time and locations that convective showers will develop, since their initiation is in many cases not driven from the large scale flow and/or orographic processes. This lack of predictability is more or less problematic depending on the requirements of the end user of forecast products. In the management of river catchments then the specific location of rainfall from thunderstorms over an afternoon may be of little relevance or of extreme importance depending on the size and hydrological response of the catchment. Large catchments and rivers can be in some sense considered integrators, responding to first order to the total amount of rainfall over periods of days or weeks. However, In urban locations with small catchments which respond quickly to localized heavy rain, knowledge of the future location and intensity of storms on very small scales may be very important, particularly if this information can be obtained quickly and then employed for the generation of flash flood warnings.

2.RADAR

For high resolution convection permitting model runs with grid lengths of a few kilometers or less but horizontal extents covering whole countries, the only observing systems which can provide high resolution observations relatively continuously in space and time are weather radar networks. Even at more modest resolutions the spatial coverage and ready availability of radar observations mean they can complement existing observational systems.

Many National radar networks, such as the very large network operated by NOAA in the United States, similar systems in Europe or the modest networks in Australia or New Zealand (Crouch 2003), provide reflectivity (**Z**) and radial Doppler Velocity ($\mathbf{V_r}$) measurements over a range of scan elevations with sampling periods as frequent as every 5 minutes. While the networks do not provide complete spatial coverage in their respective countries, they are sufficiently complete to sample a large proportion of the meso-scale precipitation features and certainly exceed the observation density of any other national observing system.

A number of related data assimilation techniques have been developed to include observations, including radar data, in the estimation of atmospheric state. The ensemble Kalman filter (**EnKF**) and n dimensional variational assimilation (**VAR**) have been implemented across NWP platforms and have been shown to improve the extent to which the model represents the true state of the atmosphere and the skill for forecasts. The widely used variational assimilation schemes include MM5/WRF 3D VAR (Barker et al. 2004), UKMet as well as others (COSMO etc). The details of the assimilation techniques will not be extensively discussed here, with the exception to note that all involve the use of an observational operator to convert the model state vector into the observation space (in this work only a Doppler Velocity operator is considered) for comparison to actual measurements. The correct specification of the error associated with these observational operators and adequate estimation of model error statistics is also important as it affects the relative magnitude to which a set of observations modify the model fields.

The impact of variational assimilation of weather radar observations on model skill has been extensively investigated over the last 5 years. Case studies have demonstrated improvements in position of model rain structures and intensities following variational assimilation of Doppler velocity alone, reflectivity and both Doppler velocity and reflectivity observations.

3. DIFFICULTIES

The spatial extent of the observing radar network will also certainly have some bearing on the maximum horizon of skill improvements. The large and almost contiguous NEXRAD network, for example, should be expected to have a longer lasting effect on model QPF skill over its main domain of the continental US than most other radar networks have over their respective countries. This is particularly the case for island or coastal situations where the radars will only be able to give useful data out to 200km or so thus limiting the modification of air masses subsequently advected over the forecast region. In this case it seems desirable to assimilate the satellite data over the oceans to extend the properly initialised forecasts out to times beyond radar coverage.

3.PROCEDURES

The traditional Approach to putting both radar and satellite data into NWP models is to do by getting the model to estimate what it thinks the clouds and radar data should look like and the use a variational (VAR) scheme to move the model in the direction of the data. It our view it is much preferable to process the radar and satellite data outside the model to produce the best possible estimates of rainfall, wind and cloud thickness by minimising calibration errors using ground truth, removing Doppler unfolding errors and calculating the precise height and location of the data and only applying it there. Certainly if the quality of the data including its location is bad enough it could make the situation worse.

We present results for novel unfolding method that works in the innovation increment space of VAR, the Doppler winds are integrated into the WRF framework in a way suitable for operational use. The filtering procedure, whereby relaxation of the maximum allowable disagreement between the model background and observations over a number of outer loop cycles allows for robust treatment of the Nyquist ambiguity without resort to manual quality control of radar observations is validated. An automated system for Doppler unfolding, like this one, essential for small operational forecast centres like the New Zealand Meteorological service, where human QC of radar data would be too expensive.

An interesting by product of this procedure is a map showing the difference between the high resolution unfolded Doppler data and the model winds. What is obtained is a map of regions of convergence and divergence. We have done some preliminary work to try to establish whether this data is useful in predicting the illusive areas of growth and decay in a Nowcasting system. The question, of course is whether the convergence precedes or follows the development of raining systems.