Abstract

By increasing the resolution of numerical weather prediction (NWP) models the lack of high resolution measurements of the atmosphere is becoming more and more critical. The quality of the initial conditions for numerical weather forecast provided by data assimilation is highly dependent on the amount of available observations. The number of observations in the limited area mesoscale models with horizontal resolution of a few kilometers is a few orders of magnitude less than of the model points.

One of the main sources of observations for NWP is air traffic. Aircraft are equipped with instruments to measure temperatures and winds with aim to improve flight safety and efficiency. The development of meteorological system AMDAR (Aircraft Meteorological Data Relay) which has provided aircraft measurements for many years is coordinated by the World Meteorological Organization. The system requires the installation of additional communication equipment on the aircraft and the maintenance of data stream. Consequently, a very small, almost negligible proportion of all potentially available observations can then be collected. This thesis introduces an new approach for the delivery of wind and temperature data provided through air traffic control system. This data, known as Mode-S MRAR (Meteorological Routine Air Report), was acquired by Slovenia Control and was made available to the Slovenian meteorological office for the validation and application in NWP. Because the applied data transfer requires minimal additional costs, Mode-S MRAR is a very inexpensive source of meteorological measurements compared to other observing systems.

The usefulness of Mode-S MRAR data for numerical weather prediction is investigated with a limited area model ALADIN (in French Aire Limitée Adaptation dynamique Développement INternational), which is used for operational weather forecasting in Slovenia. An important prerequisite for successful application of new measurements is their quality control. An inter comparison study of Mode-S MRAR data against radiosondes and AMDAR observations over the common area is performed. It is found that Mode-S MRAR are of the same quality as AMDAR and that differences with respect to radiosondes are not greater than in the other similar studies. A more complete insight to the quality of the measurements is possible by the comparison with the short-term model forecasts. This validation reveals that some sensors are considerably biased, mainly on smaller aircraft. This provides basis for a list of aircraft with high-quality measurements to be used for assimilation.

Impact of the new data on analyses and forecasts is investigated by two

separate assimilation cycles, one of them assimilating Mode-S MRAR observations in addition to all the other measurements. Since the impact on forecast is expected mainly over Slovenia due to the geographical limitations of the data coverage, the verification of forecast is possible only with the local measurements. With the exception of a single radiosonde measurement per day there is no high-quality observations in the lower troposphere, so the impact on the forecast has to be mainly checked against Mode-S MRAR observations.

Data assimilation experiments include the summer and the winter period. A significant impact of new measurements on the local analysis is detected. In the winter period, a positive impact is observed on the local temperature profile of the atmosphere and also the overall positive impact on the first few hours of temperature and wind forecasts. During a stable anticyclonic situations, the impact is even longer close to the ground, up to 24 hours in the forecast. In summer, the impact on forecast is much more mixed. In addition to a general positive impact on very short-term forecast (2-3 hours), a negative impact on the temperature forecast is observed in the planetary boundary layer. It is found that the experiment with assimilated Mode-S MRAR observations is systematically too warm and too dry. Because humidity is not available through Mode-S, the influence on humidity caused by multivariate couplings with other observed variables is studied. When the impact of the observations of other atmospheric variables on the humidity through multivariate couplings in the background error covariances is not allowed, the systematic errors in temperature field disappear. This illustrates the importance of direct humidity information and its consistency in the analysis with the other variables in the mesoscale data assimilation, possibly by application flow-dependent background error covariances. On the case of the strong freezing rain in the beginning of 2014 it is demonstated how Mode-S MRAR observations improve the initial temperature profile and thus enable a better diagnosis of freezing rain.

The presented results have contributed the wide European initiative for a broader application of Mode-S data in the meteorological practice in Europe. With a groving network of such observations, a considerable impact on mesoscale numeric weather prediction can be expected.

Keywords: Mode-S MRAR, aircraft observations, data assimilation, mesoscale processes, ALADIN, NWP, limited-area modeling, variational assimilation, multivariate coupling

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