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# Advances in weather forecast by assimilation of surface observations and GPS data


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## Introduction

For a good forecast to a certain time, numerical weather models require an initial state (given by the analysis) as close as possible to the real atmospheric one. To achieve this, all available data from model, observation and climatology are merged, leading to the concept of data assimilation.
An analysis requires the assimilation of a vast number of observation data (including data from ground based stations, satellites, radar, ships, buoys, aircrafts etc.) which are of different complexity and of temporal and spacial resolution. In a first step towards full data assimilation additional SYNOP data are assimilated to provide the operational weather model ALADIN with surface fields (soil moisture and temperature) of higher accuracy. The effect on the weather forecast is investigated and in a further step the upper-air fields will be corrected in the framework of 3DVar.

## Optimal Interpolation, Verification

The basic equation in data-assimilation can be deduced from minimisation of an appropriate cost function yielding an analysis with the smallest possible deviation from the true state in dependence of background and observation errors. Where the fit between model and observation data is optimised according to data accuracy. One of the simplest univariate methods used to analyse surface fields provides the optimal interpolation (OI), where the analysis $X_a$ can be deduced from

$$X_a = X_g + BH^T \left(HBH^T + R\right)^{-1} \left(Y - HX_g\right),$$

with $X_g$ the first guess vector given by previous model forecasts, $H$ the linear observation operator (maps model data to observation space), $Y$ the observation vector, $B$ and $R$ the covariance matrices for model and observation errors. Where the determination of the covariances in $B$ is crucial for the quality of the analysis.

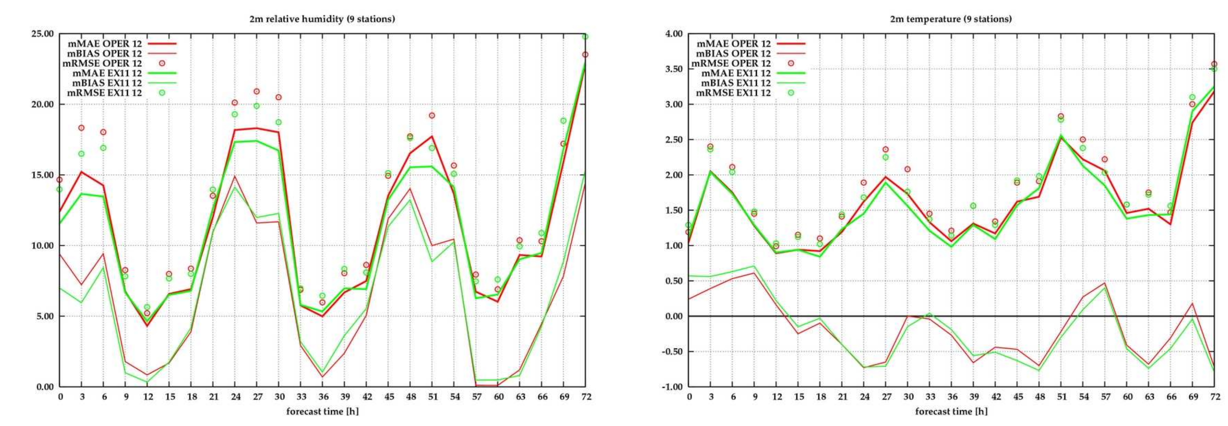

Figure 1: Verification of the $2m$ relative humidity (left) and the $2m$ temperature (right) for selected SYNOP stations in Austria.

One has to take into account that the surface fields are adapted rather slowly to the additional SYNOP data, what means it needs a certain period till the analysis without this SYNOP information differs remarkable from the one deduced by data assimilation. The verification was carried out after a two weeks cycling period, calculating MAE, BIAS and rmse for $2m$ temperature and relative humidity for the last two weeks in July (longer more reliable verification periods will be regarded as soon as data is available). Despite this short cycling period one can see an impact on the forecast (Figure 1). The relative humidity performs better than the temperature. Especially during the day, when the humidity distribution is highly inhomogeneous, the SYNOP information becomes important. For the temperature one expects an improvement in winter, as in summer the ALADIN temperature is already in rather good agreement with the observations.

## Introduction

The water vapour content of the atmosphere is highly changeable spatially and in time and therefore difficult to model. Especially in mountainous regions, where there is no radio-sounding the atmospheric moisture distribution is badly represented. A rather new method to measure the PW (precipitable column water) with high accuracy and temporal resolution provides GPS. There is evidence that assimilation of GPS PWs into the nowcasting tool INCA (Integrated Nowcasting through Comprehensive Analysis) enhances the moisture profiles and precipitation forecast. INCA developed by ZAMG Vienna gives hourly updated 3D humidity and temperature data (analysis and nowcast) with 1 $km$ resolution in the horizontal and 200 $m$ in the vertical, where the numerical weather model ALADIN serves as first guess.

## Precipitable water, Humidity profiles

In the PW time-series Figure 2 one can recognise weather phenomena like passages of frontal systems (on the $5^{th}$ or the $18^{th}$) or weak perturbations (f. e. on the $12^{th}$) indicated by high or medium peaks.

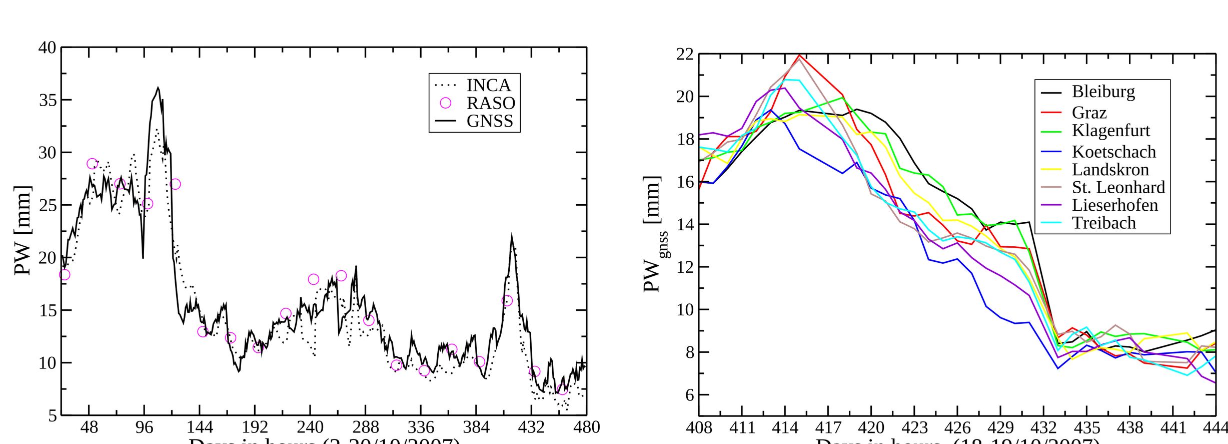


Figure 2: Comparison of GPS precipitable water with INCA and radiosounding (RASO) at Graz in October 2007 (left), PW at 8 GPS stations during passage of a frontal system on 18/10/2007 (right).

The time resolution of rapidly changeable weather systems (see Figure 2 right panel) is improved with respect to INCA. A frontal system indicated by a remarkable descent in the GPS PW is visible up to 3 hours earlier than in the model. Moreover, statistical comparison of INCA and GPS data with PWs found in radiosounding (RASO) measurements shows lower MAE and BIAS for the satellite data than for the model ones.
The GPS PWs are assimilated by applying a simple relative correction to the INCA (ALADIN) moisture profiles. Where correction factors are deduced from the proportion of GPS to INCA PW at the respective sites and then mapped onto the INCA grid. Figure 3 gives examples for good agreement between radiosounding, weather station (TAWES) and GPS corrected INCA moisture profiles in the boundary layer above Graz. The improvement of the specific humidities above the ground with respect to INCA amounts up to 1.3 $g/kg$ (see Figure 4).

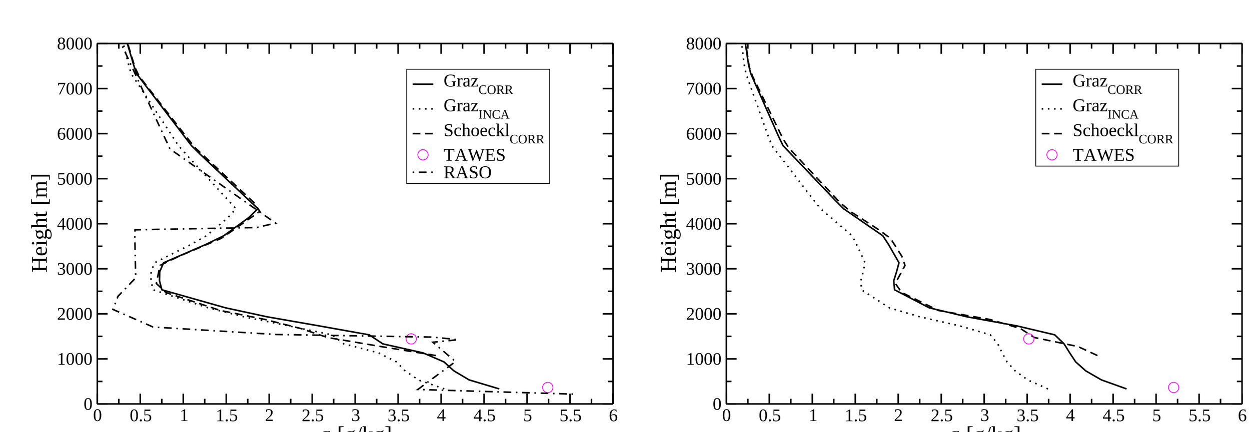


Figure 3: Humidity profile above Graz on 14/10/2007 3 am and 6 pm UTC

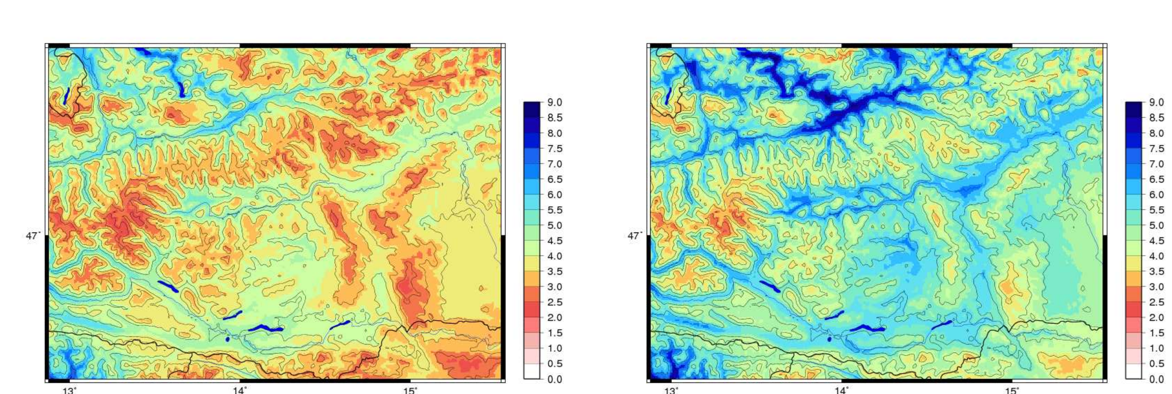

Figure 4: INCA (left) and GPS corrected (right) $2m$ specific humidity on a $1 \times 1$ $km$ grid above Carinthia, 14/10/2007 at 6 pm UTC