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Refinements in INCA with special emphasis on humidity and precipitation

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Abstract

The meaning of highly resolved meteorological analysis of the alpine atmosphere has risen in importance within the last years. Local heavy rain falls can cause flooding, wet land slides or avalanches. A more detailed analysis of the moisture and the precipitation fields is therefore essential to provide a better forecast. INCA is steadily enhanced to meet this requirements. Here the influence of assimilated GNSS and radar data into INCA is studied as regards an improvement in the humidity and precipitation analysis, where the investigations are conducted in the alpine regions of Carinthia and Salzburg.

Introduction

The water vapour content of the atmosphere is highly changeable spatially and in time and therefore difficult to model. It is very important for atmospheric dynamics through the release of huge amounts of latent heat associated with condensation. The amount of water vapour in a vertical column of air is given by the total precipitable water (PW), defined by the water depth produced by condensation of all the water vapour in the column.
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 with high accuracy and temporal resolution provides GPS. There is evidence that assimilation of GPS PWs into INCA enhances the moisture profiles and precipitation forecast.

The second part of the poster deals with the changes conducted in INCA to improve the precipitation analysis. First of all the assimilation of 2-d radar data has been meliorated. Moreover the increase in precipitation intensity with height in the mountains has been taken into account, as well as a wind correction for the rain gauge measurements which was assumed to be a constant value for temperatures below zero. In addition the possible improvement due to an area-wide precipitation field including 3-d radar information has been studied.

Precipitable water

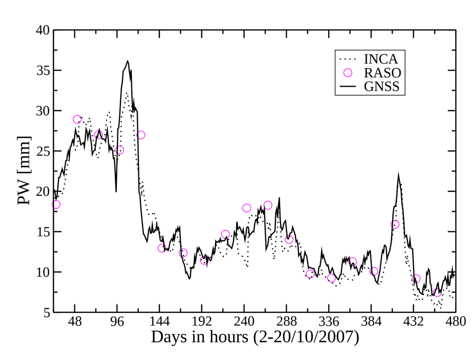

Figure 1: Comparison of GNSS precipitable water with INCA and radio-sounding at Graz in October 2007.

In the PW time-series Figure 1 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. At the frontal passage on the 18^{th} the PW drops by 12 mm in less than 12 hours.
Statistical comparison of INCA and GNSS PW (see Table 1) shows a slightly better agreement of satellite data with PWs found in radio-sounding measurements.

	MAE	BIAS	CORR
PW_{Inca}	1.95	-1.74	0.95
PW_{Gnss}	1.73	-1.51	0.91

Table 1: Statistical comparison of INCA and GNSS precipitable water with radiosonde-data at station Graz

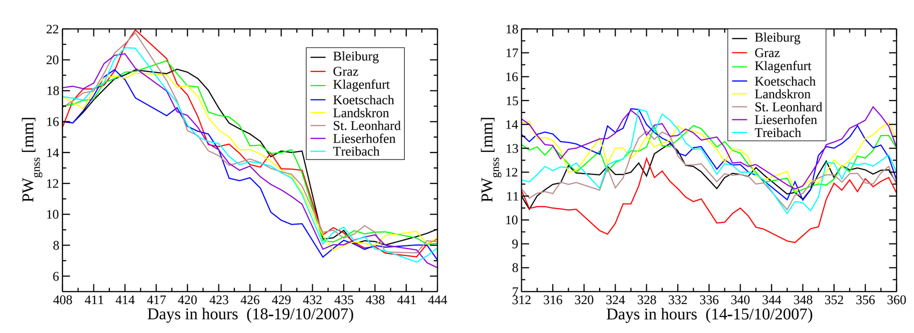

Figure 2: PW at 8 GNSS stations during passage of a frontal system on 18/10/2007 (left) and during stable high pressure weather on the 14^{th} (right).

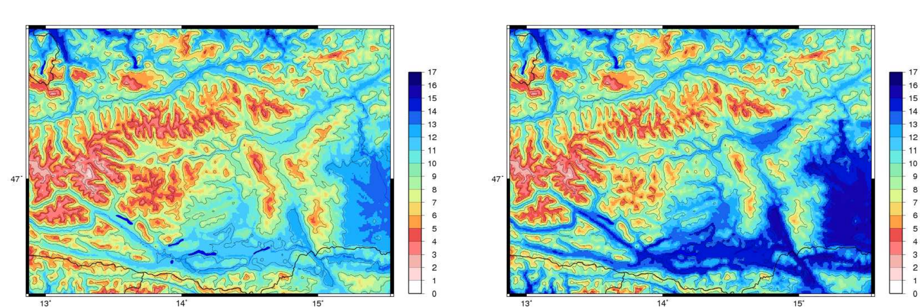

Figure 3: INCA (left) and GNSS (right) PW on a 1×1 km grid above Carinthia, 13/10/2007 at 3 am UTC

The time resolution of rapidly changeable weather systems (see Figure 2) is improved with respect to INCA. A frontal system indicated by a remarkable descent in the GNSS PW is visible up to 3 hours earlier than in the model. At stable high pressure weather the PW shows the typical S-shape diurnal trend. Regions in western styria and in the valleys of Carinthia become more moist in the morning hours, compared to the INCA PW (see Figure 3).

Humidity profiles

The GNSS PWs are assimilated by applying a simple relative correction to the INCA (ALADIN) moisture profiles. Where correction factors are deduced from the proportion of GNSS to INCA PW at the respective sites and then mapped onto the INCA grid. Figure 4 gives examples for good agreement between radio-sounding, weather station and GNSS corrected INCA moisture profiles in the boundary layer above Graz. The improvement of the specific humidities at the ground with respect to INCA amounts up to 1.3 g/kg (see Figure 5).

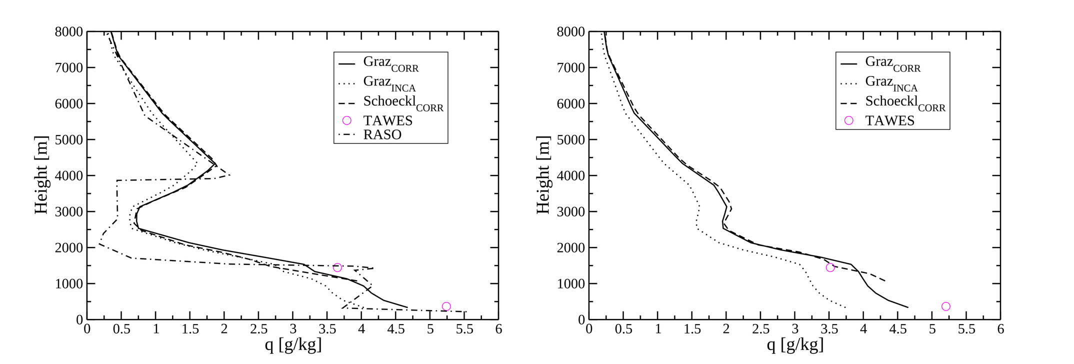

Figure 4: Humidity profile above Graz on 14/10/2007 3 am and 6 pm UTC

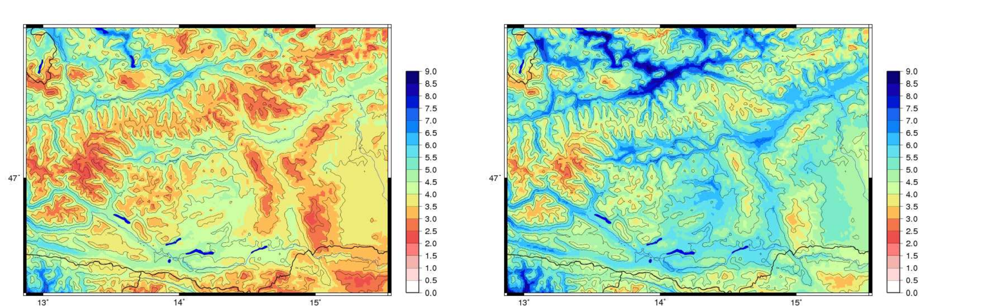

Figure 5: INCA (left) and GNSS corrected (right) $2m$ specific humidity on a 1×1 km grid above Carinthia, 14/10/2007 at 6 pm UTC

Precipitation

It has been shown before that radar data can complement and improve precipitation measurements in regions where there is no station information available. While in the convective case the radar precipitation field agrees rather well with the respective rain gauge measurements, because of damping effects in the stratiform case the radar field has to be heavily up-scaled to meet the station values. It turned out that one has to be very careful not to overshoot the scaling in certain regions.

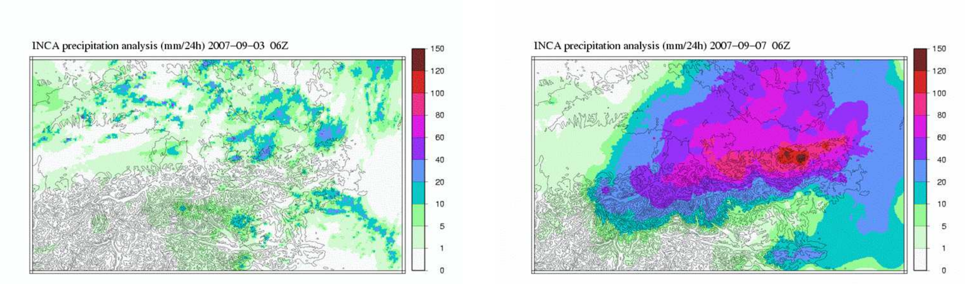

Figure 6: Convective (left) (16% improvement) and stratiform (right) (3% improvement by using 2-d radar) precipitation analysis in INCA including 2-d radar.

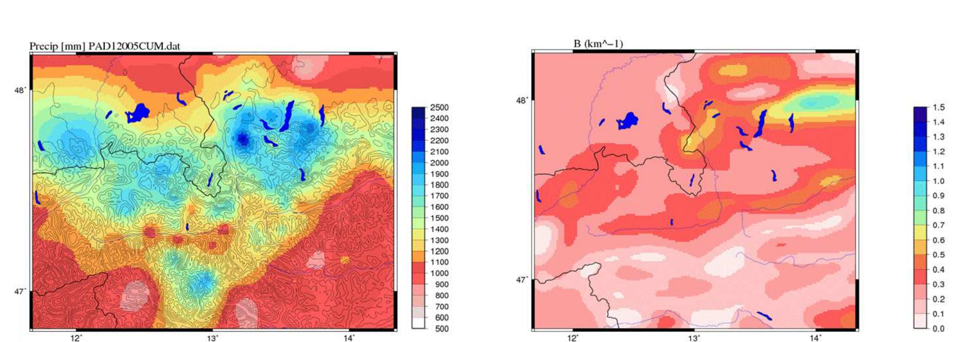

Figure 7: Annually accumulated rain-gauge measurements (left), relative increase of annual precipitation with height (right).

Statistical studies carried out with data of the last 10 years have shown a clear height dependence of precipitation intensity in alpine regions. In Figure 7 one sees the relative increase of the annual precipitation per km height together with the interpolation of the annual rain gauge measurements above Salzburg. Taking the height dependence into account leads to the precipitation field in Figure 8 which matches well with the climatological annual precipitation averaged over the last 30 years.

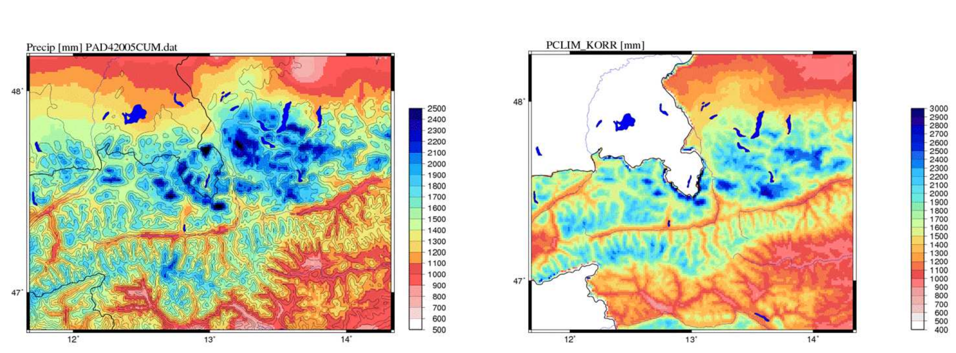

Figure 8: Annually accumulated height corrected rain-gauge measurements (left), averaged climatological annual precipitation (right).

Radar

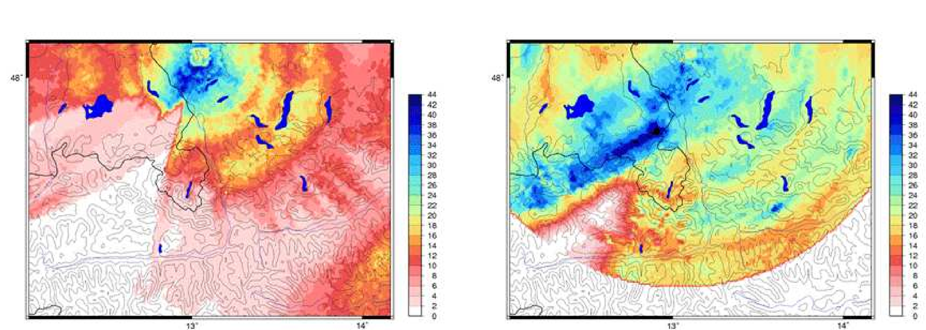

Figure 9: Comparison of 2-d radar- with 3-d radar field.

Especially in the stratiform case the 2-d radar field is of poor quality f. e. in Figure 6 it reduced the MAE of the pure rain gauge field only by 3%. Heavy rain fall causes strong attenuation of the radar signals in the horizontal as well as in the vertical as shown in Figure 9 by a vertical section at height 2500 m. 3-d radar analysis with a vertical resolution of 1 km was applied to enhance and complete the radar signals near the ground by using the information of the layers above and assuming a multiplicative increase of the precipitation from top to bottom.

Conclusions, Outlook

Although the GNSS PW is closer to radio-sounding than the INCA one, there can be problems to meet the correct moisture distribution with respect to height. This is mainly due to the insufficent fit made in the relative correction. Moreover the quality of the profile strongly depends on the weather situation and the time of day. But despite of its simplicity, the correction leads in many cases to a significant improvement of the moisture profile. So far we only worked with ALADIN profiles as first guess without assimilating station moistures. This has to be left to another project as one has to be rather careful with the incorporation of ground data, especially during sunny periods when the station values can deviate extremely from the free atmospheric ones.

As precipitation analysis is concerned height and wind correction have brought the annual precipitation closer to its climatological average. The corrections are therefore expected to improve the analysis. The constant factor for the snow correction is still subject of further investigations. As is the utility of the inclusion of 3-d radar information which should at least improve the ground radar-field in that way to make the overshooting in the scaling procedure obsolete.
Both precipitation analysis and GNSS PW especially through its high temporal resolution can contribute to a better rain forecast.