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Jean-Marie Bettems

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MeteoSchweiz
Krähbühlstrasse 58
Postfach 514
CH-8044 Zürich

Telefon +41 1 256 91 11
Telefax +41 1 256 92 78
info@meteoschweiz.ch
www.meteoschweiz.ch

EUCOS impact study using the limited-area non-hydrostatic NWP model in operational use at MeteoSwiss

JEAN-MARIE BETTEMS

jean-marie.bettems@meteoswiss.ch
Swiss Federal Office of Meteorology and Climatology (MeteoSwiss)
CH-8044 Zurich, Switzerland

Abstract

The EUCOS program aims to optimize the ground segment of the European observing system. A drastic reduction of the number of radiosondes has been proposed, compensated by a higher observing frequence of the remaining stations and additional AMDAR platforms. To assess the impact of such a scenario, sensitivity studies have been done with aLMo, the COSMO limited area NWP model in operational use at MeteoSwiss.

This non-hydrostatic model, in operational use at MeteoSwiss, is integrated on a 2700km×2300km mesh covering occidental and central Europe, with a 7km mesh size. A continuous assimilation cycle based on the nudging technique is used to assimilate all conventional observations. A 27day test period has been defined (19.10.1999–14.11.1999) and daily 24hour forecasts have been calculated to measure the impact of the proposed radiosonde network modification and to assess the effect of the additional AMDAR platforms on the model analysis and forecast quality.

A significant degradation of the model quality is associated with the reduction of the number of radiosonde stations at analysis time and in the very short range; the increased observation frequency does not compensate for the reduced horizontal resolution of the observing system. On the other side, the additional AMDAR platforms bring a clear local improvement of wind, temperature *and humidity*; however this improvement does not compensate the quality loss brought by the radiosonde network degradation. An improved horizontal coverage by AMDAR observations and additional information about local structures in the humidity field could be a necessary addition to the EUCOS scenario.

I Context and Objectives

The main goal of the EUMETNET Composite Observing System program (EUCOS) is to define the optimum ground based observing system for the support of short range numerical weather prediction (NWP) over Europe. The current ground segment of the European observing system is quite dense over the continental area, but sparse over the ocean. A preliminary study [Pailleux et al., 1997] indicated that a significant reduction of the number of radiosondes over the data dense area and the addition of profiles over the Atlantic Ocean and the Mediterranean could optimize the NWP quality for the available financial resources. Based on this study two EUCOS network scenarios have been proposed: a *first configuration* using half the number of radiosonde stations over continental areas (about 40 remaining stations) but with higher sampling rate at these remaining stations (4 ascents a day) and additional aircraft observations, and a *second configuration* which extends the first one by introducing new observations over sensitive areas of the Atlantic Ocean and Mediterranean.

In order to better evaluate the impact of these scenarios on NWP quality, it has been decided to perform observing system experiments (OSE) with both global and limited area NWP models. A special observing campaign took place from 20 September to 14 November 1999. 27 uniformly distributed radiosonde stations have been activated four times a day over the continent and 116 supplementary aircraft platforms providing wind and temperature were added. The set of all available observations collected during this period is the base for conducting EUCOS OSE[1].

[1] It has to be noted, that this EUCOS campaign coincided with the Special Observing Period of the Mesoscale Alpine Programme [Bougeault et al., 2001], whose data set offers a large potential for additional OSE's.

A first impact study has been done with the ECMWF global model [Cardinali, 2000]: the observed impact on the short and medium range forecast was very small. It was also shown that during the two months of the EUCOS observing period the most sensitive areas where errors are fast growing were not located over Europe but over the North Pacific. However, this does not preclude an impact at smaller horizontal and shorter time scale (the ECMWF model used a T319 spectral truncation corresponding to a resolution of about 60km over Europe). Two countries committed to do OSE with their high resolution limited area models: the Danish Meteorological Institute with the HIRLAM model and its optimum interpolation analysis and MeteoSwiss with aLMo - its current operational model - and its associated continuous assimilation scheme. The results of the first study have been published [Amstrup, 2000], this report presents the results obtained with aLMo.

II The NWP model

In the frame of the Consortium for Small-scale Modelling (COSMO), the National Weather Services of Italy, Greece and Switzerland under the lead of the National Weather Service of Germany have developed a new non-hydrostatic meso-scale model called the Local Model. This model is based on the primitive hydro-thermodynamical equations describing non-hydrostatic flow in a moist atmosphere, without any scale approximations. The model equations are solved numerically using the finite difference method on a Arakawa C-grid with generalized terrain-following vertical coordinates. A thorough description of the Local Model itself can be found on the COSMO web site at www.cosmo-model.org or in the first COSMO newsletter [Doms, 2001].

The version of the Local Model running at MeteoSwiss is named aLMo (for *al*pine *mo*del). Two daily 48h forecasts are calculated since the first of July 2000, and the model is used operationally since the first of April 2001. It is calculated on a 385×325 mesh, with a 1/16° mesh size (about 7km), on a domain covering most of western Europe (see figure 2-1). In the vertical a 45 layers configuration is used; the vertical resolution in the lowest 2km of the atmosphere is about 100m (see figure 2-2). A filtered (smoothed) orography has been

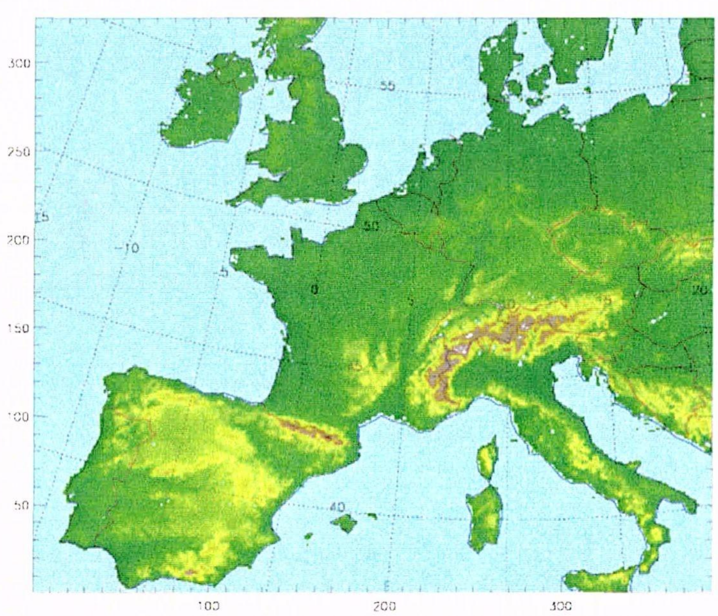


FIGURE 2-1. Domain and orography of aLMo (min: -5m, max: 3109m).

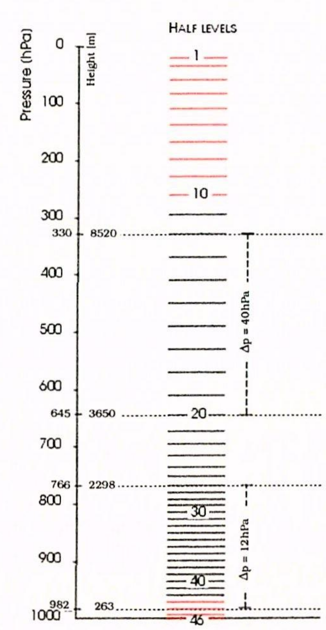


FIGURE 2-2. Vertical distribution of layers in aLMo.

introduced in order to reduce the unrealistic forcing of $2\Delta x$ waves produced by a mean orography. Lateral boundary conditions are assimilated by a 1-way nesting procedure according to Davies [Davies, 1976]. Rayleigh damping is applied in the 8 upper model layers, starting at 11km, with a top boundary condition set by the driving model.

The model configuration defined for the OSE performed in this study is based on the operational configuration just described. The only differences are the driving model (the Global Model of the German Weather Service is used for production, the ECMWF model for the OSE) and the initialization procedure (an interpolation of the driving model analysis is currently used in production, the nudging scheme is used for the OSE).

III The assimilation scheme

Data assimilation with the Local Model is based on the nudging or Newtonian relaxation method. This technique has been implemented using relaxation of model dynamical fields towards direct observations [Schraff, 1997].

The observations being assimilated are horizontal wind, temperature, and relative humidity at all levels, and pressure at the lowest model level. Currently only conventional observing systems are used: surface observations (SYNOP, SHIP, DRIBU), aircraft observations (AIREP, AMDAR) and vertical soundings (TEMP, PILOT). The conditions defining the use of a specific observation are summarized in table 3-1.

TABLE 3-1. Conditions for assimilation of a specific observation.

	Surface observation (SYNOP, SHIP, DRIBU)	Vertical profile (TEMP, PILOT)		Aircraft (AIREP, AMDAR)
		Standard level	Significant level	
Surface pressure	Height diff.[a] < 100m > -400m	Yes		No
Horizontal wind	Obs. height < 100m a.s.l.	Yes	Yes if > 100hPa	Yes
Temperature	No	Yes	Yes if > 100hPa	Yes
Relative humidity	Abs(height diff.) < 160m	Yes if > 300hPa		No

[a] Difference between model orography and station height.

During aircraft ascent and descent phases, the aircraft observations are grouped together to form piecewise vertical profiles. All observations from the same aircraft are first collected and a base report is defined by selecting the report with the highest pressure. All observations within 15 minutes and 20 kilometers of the base report are then grouped in a multi-level report. This procedure is then repeated with the remaining reports. Finally each multi-level report is assimilated in a way similar to a TEMP profile (in particular a multi-level report is associated to a single location, neglecting any horizontal drift). As a result of this scheme, most aircraft observations are assimilated as part of multi-level reports below 700hPa – with a vertical resolution of about 10 to 20hPa – and as original single-level reports above 400hPa.

The nudging weight (main coefficient of the nudging term in the model equations) is set to 6×10^{-4} s^{-1} which corresponds to an e-folding time of about half an hour. The temporal influence of a vertical profile extends from 3h before the observation time to 1h after, and the influence of surface and upper air single level observations extends from 1.5h before the observation time to 0.5h after. The typical half-width of the horizontal influence radius of an observation is between 120km and 220km, with smaller values near the ground and larger values aloft.

The conservation of the specific humidity is enforced when assimilating any temperature report. In order to better assimilate surface pressure information, a temperature and a partly geostrophic wind correction is associated with any surface pressure increment; hydrostatic upper-air pressure increments balancing the total analysis increments are also added. Because no soil model analysis is currently available at MeteoSwiss, the fields describing the soil state, including snow related quantities and sea surface temperature, are updated twice a day from the driving model analysis. A simple quality control is regularly performed by comparing the observation increments (difference between an observation and the corresponding model value) with predefined thresholds.

Since the first of March 2001, a continuous data assimilation cycle based on the configuration described above is in pre-operational mode at MeteoSwiss. Systematic subjective and objective verification, covering a 5 months period, has shown a consistent behaviour of this assimilation scheme and a clear positive impact on the forecasts.

The data assimilation scheme defined for the OSE performed in this study is based on the pre-operational scheme just described.

IV The experimental set-up

Due to time constraints it was not possible to calculate EUCOS OSE for the whole EUCOS observing period. I chose the same four weeks as the one defined by the Danish Meteorological Institute, namely *from 19 October 1999 00UTC to 15 November 1999 00UTC*. This period includes 2 of the 3 case studies presented in the ECMWF report [Cardinali, 2000], and seven MAP heavy precipitation events (MAP is the Mesoscale Alpine Program, see the web site at www.map.ethz.ch or [Bougeault et al., 2001]); this last fact is of interest because we can anticipate a larger impact of the proposed EUCOS scenario on "wet" weather regimes due to the reduction of humidity observations.

Three observing systems called S1, S2 and S3 have been considered. S1 is the observing system which uses the same radiosonde and aircraft data as before the EUCOS campaign; S2 has 37 radiosonde stations less, but 13 more stations measuring every 6 hours; S3 has the same radiosonde configuration as S2, but is complemented by 121 more AMDAR platforms. The blacklists used to define the different observing systems are available in the annex (supplementary soundings by stations which changed their operations during EUCOS observation campaign have not been included in S1, contrary to the ECMWF study). The typical number of bulletins assimilated by aLMo during a 24h period for each of these observing systems is listed in table 4-1, and the typical daily coverage of AMDAR platforms in observing system S3 is displayed in figure 4-1.

TABLE 4-1. Typical number of observations assimilated by aLMo during a 24h period (the active stations number differs from the blacklist derived value because only the stations inside aLMo domain are considered).

		TEMP	PILOT	AIRCRAFT	SYNOP	DRIBU
S1	active stations	55	12	135	1078	6
	active reports[a)]	202	24	4671	18542	146
S2	active stations	25	12	135	1078	6
	active reports	110	24	4671	18542	146
S3	active stations	25	12	216	1078	6
	active reports	110	24	21261	18542	146

[a)] all observations influencing the model flow during the considered 24h period.

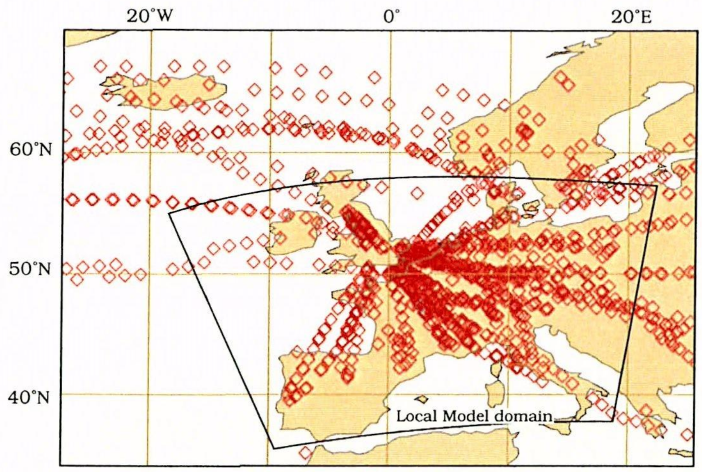


FIGURE 4-1. Typical daily coverage of activated AMDAR platforms in observing system S3 (red boxes).

A 27 days assimilation has been run with the Local Model for each of S1, S2 and S3. These three assimilation cycles have been started the 19 October 1999 at 00UTC from the ECMWF operational 4d variational analysis[2)]. This same ECMWF analysis stream has been used to update the lateral boundary conditions every 6hours, and to update the soil model once a day at 00UTC (no soil model analysis is available at MeteoSwiss).

Daily 24hour forecasts starting at 12UTC have been run with aLMo for each of S1, S2 and S3. Initial conditions for these forecasts were obtained from the corresponding assimilation cycle, described in the previous section. Observations were still assimilated during the first forecast hour, in order to mirror the (pre-) operational configuration used at MeteoSwiss. Lateral boundary conditions were updated every 6hours from the ECMWF operational deterministic forecast[3)].

I would like to stress that all three experiments S1, S2 and S3 have been calculated with the same set of ECMWF lateral boundary conditions. Although EUCOS OSE dataset were available at ECMWF for both assimilation and forecast, it was not possible to use them: the liquid water field – required by aLMo – was missing in the ECMWF archive. However, in view of the weak impact observed in the ECMWF EUCOS OSE, this should not significantly alter the conclusions of this study.

V Impact on forecast quality

The impact of the observing system modifications *on aLMo forecast quality* has been evaluated with two verification packages in operational use at MeteoSwiss: a package for the verification of the vertical structure of the atmosphere over the whole aLMo domain (5.1) and a package for the verification of near-surface weather parameters over Switzerland (5.2). One of the three cases presented in the ECMWF study [Cardinali, 2000] is also briefly presented (5.3).

5.1 Vertical structure of the atmosphere

A statistical verification of the vertical structure of the model atmosphere against radiosonde data for a set of 28 stations regularly distributed over the whole aLMo domain has been applied. The reference stations are Hemsby (03496), Crawley (03774), Camborne (03808), Long Kesh⁻ (03920), Valentia (03953), Payerne⁺ (06610), Brest⁻ (07110), Trappes⁻ (07145) , Nancy⁻ (07180) , Lyon⁻ (07481), Bordeaux⁺ (07510), Nimes⁺ (07645), Ajaccio⁻ (07761), La Coruna (08001), Madrid⁻ (08221), Mallorca⁺ (08301), Schleswig (10035), Emden⁻ (10200), Lindenberg⁰ (10393), Essen⁻ (10410), Stuttgart⁻ (10739), Muenchen⁻ (10868), Wien (11035),

[2)] the MARS retrieval parameters are: stream *oper*, class *od*, type *4v*, expver *001*.
[3)] the MARS retrieval parameters are: stream *oper*, class *od*, type *fc*, expver *001*.

Innsbruck° (11120), Prag (11520), Udine (16044), Milano⁻ (16080), San Pietro⁻ (16144), Roma⁻ (16245) and Cagliari (16560) (a "+" means increased observing frequency in S2, a "-" means not present in S2, a "o" means neither present in S1 nor in S2). A quality assessment in the frame of MAP [Häberli, 1998] has shown good observation scores for these stations. Bias and standard deviation for temperature, relative humidity (over water), wind direction and wind speed are calculated for the whole set of available forecasts and for different forecast times (+00h, +06h, +12h, +24h).

The main results of this verification can be summarized by the four statements presented below, and are illustrated by the statistical scores displayed in figures 5-1 to 5-5:

- Decreasing the spatial density of radiosondes and increasing the observing frequency of some (from S1 to S2) results in a significant increase of the standard deviation of both dynamical and thermodynamical fields *at analysis time* (+00h). For instance, in the middle troposphere a 50% increase in variance of relative humidity is observed (fig. 5-2).
  This fact reflects a degradation of the mesoscale structures due to the modification of the observing system. This is consistent with one of the conclusion of an earlier observing system simulation experiment (OSSE), which showed that a high temporal resolution of wind profiler observations does not compensate for a poor horizontal resolution of the observing system [Bettems, 1999].
  One can argue that the observed impact is maximized by the applied verification method, the scores being (partly) calculated at the exact locations where the observing network is modified. This is certainly true, but a relevant impact is also observed at locations where no observing system modification is applied, as shown in figures 5-6 and 5-7.
- Increasing the number of aircraft observations does not compensate for the quality loss observed by going from S1 to S2. In fact the global impact of a fourfold increase

All stations, temperature +00h (12UTC)

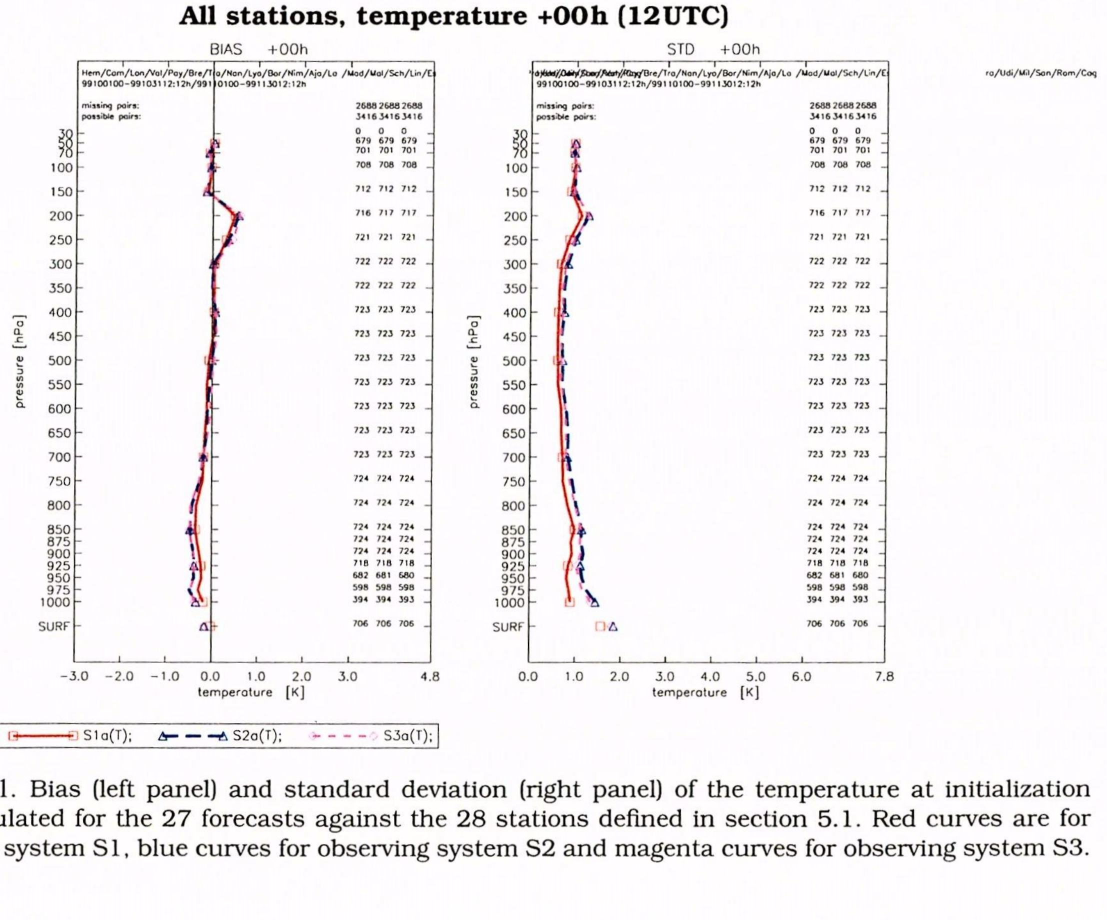


FIGURE 5-1. Bias (left panel) and standard deviation (right panel) of the temperature at initialization time calculated for the 27 forecasts against the 28 stations defined in section 5.1. Red curves are for observing system S1, blue curves for observing system S2 and magenta curves for observing system S3.

All stations, relative humidity +00h (12UTC)

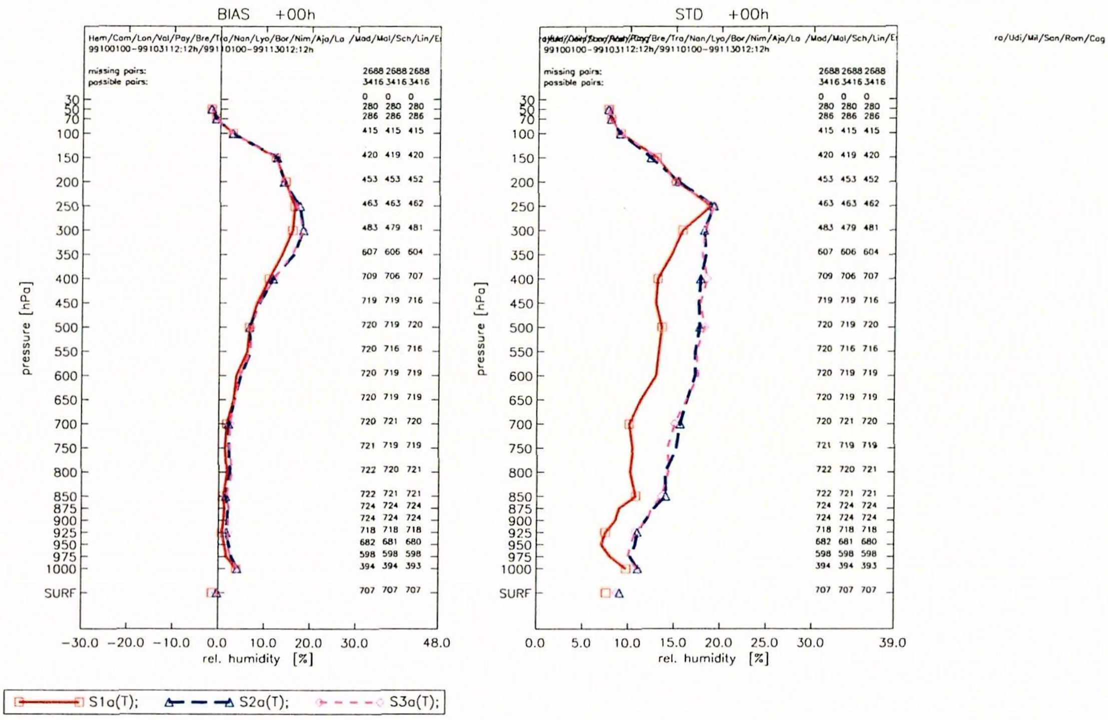


FIGURE 5-2. Bias (left panel) and standard deviation (right panel) of the relative humidity at initialization time calculated for the 27 forecasts against the 28 stations defined in section 5.1. Red curves are for observing system S1, blue curves for observing system S2 and magenta curves for observing system S3.

All stations, relative humidity +12h (00UTC)

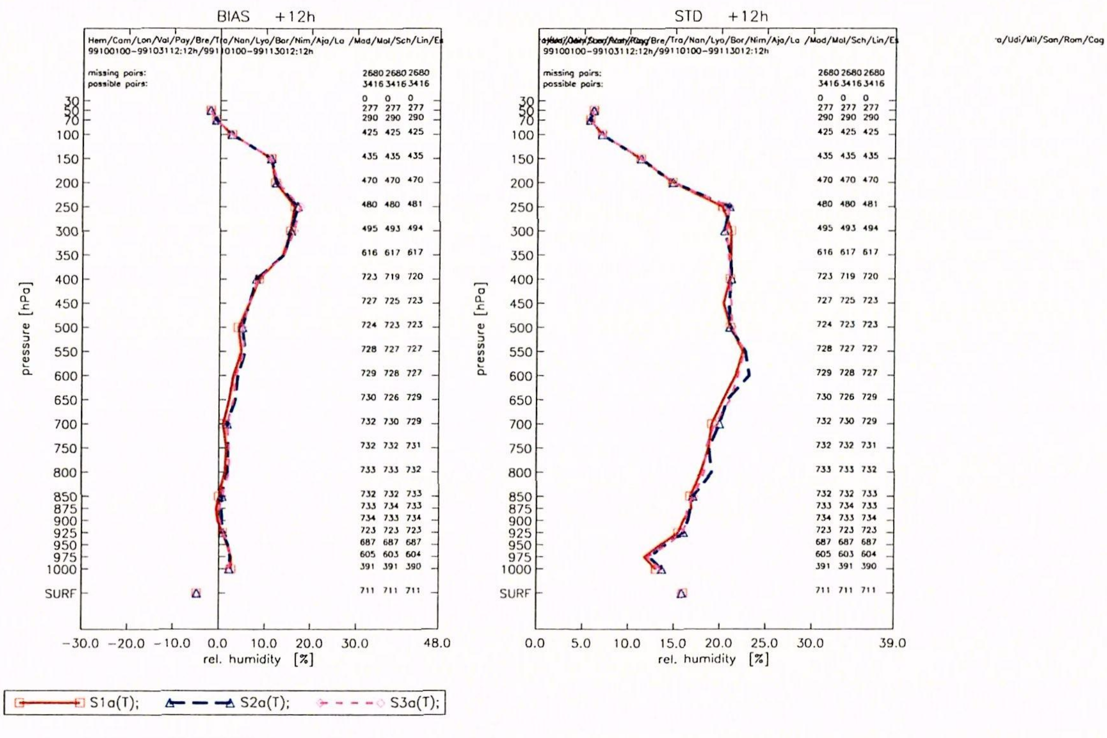


FIGURE 5-3. As figure 5-2, after 12hour forecast.

All stations, wind speed +00h (12UTC)

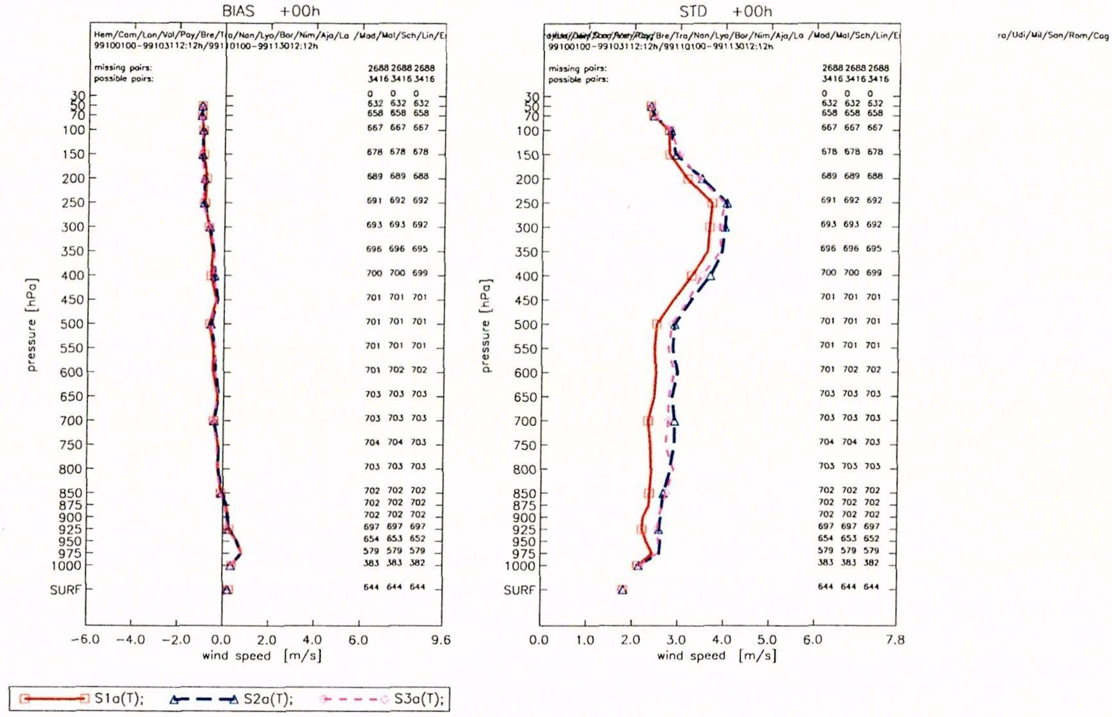


FIGURE 5-4. Bias (left panel) and standard deviation (right panel) of the wind speed at initialization time calculated for the 27 forecasts against the 28 stations defined in section 5.1. Red curves are for observing system S1, blue curves for observing system S2 and magenta curves for observing system S3.

All stations, wind direction +00h (12UTC)

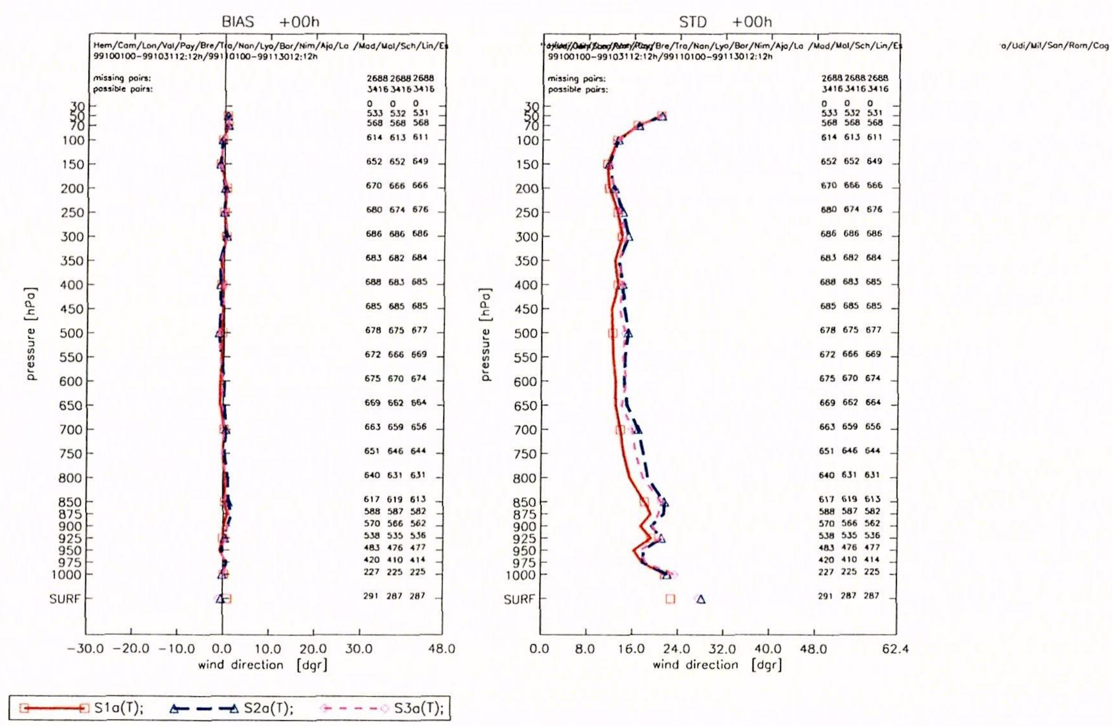


FIGURE 5-5. As figure 5-4, for the wind direction.

Innsbruck, wind speed +00h (12UTC)

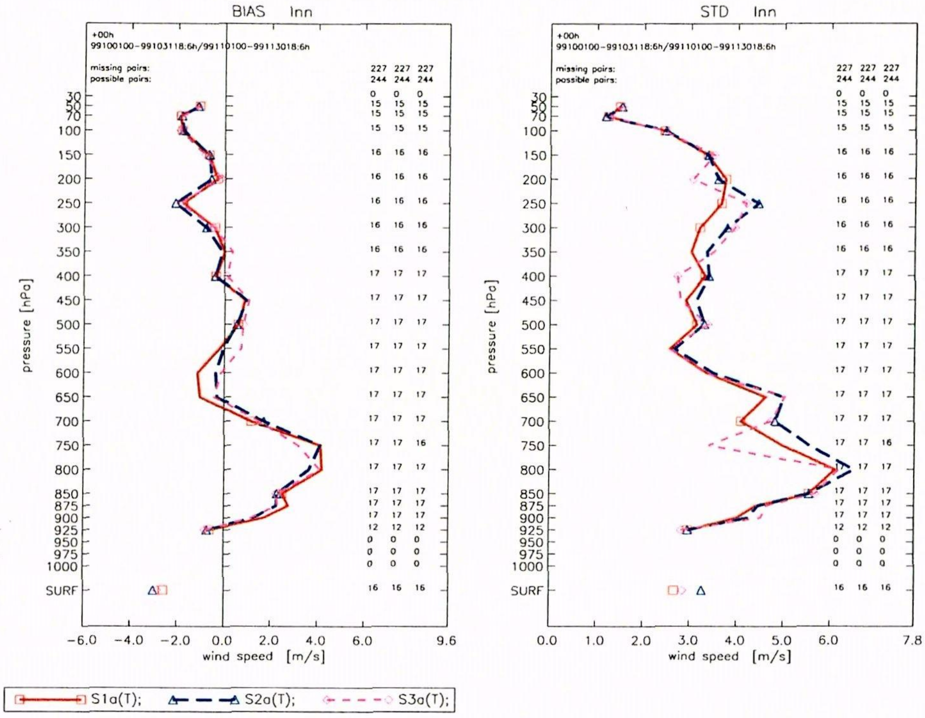


FIGURE 5-6. Bias (left panel) and standard deviation (right panel) of the wind speed at initialization time calculated for the 27 forecasts against the vertical sounding at Innsbruck. Red curves are for observing system S1, blue curves for observing system S2 and magenta curves for observing system S3. Innsbruck is a radiosonde station which is not used in our OSE.

Innsbruck, wind speed +06h (18UTC)

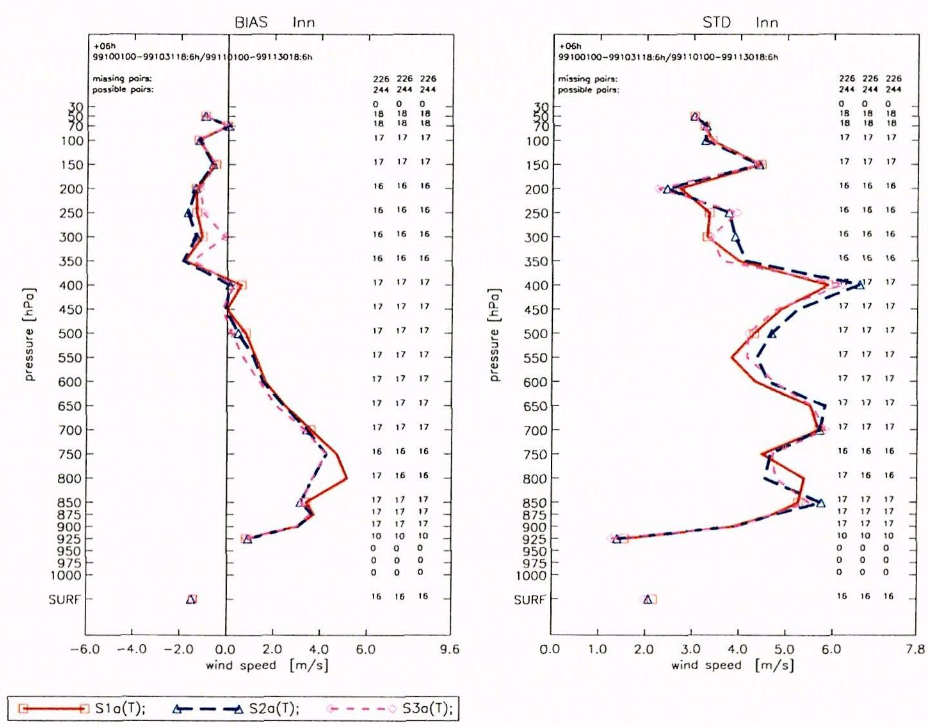


FIGURE 5-7. As figure 5-6, after 6hour forecast.

Stuttgart, relative humidity +00h (12UTC)

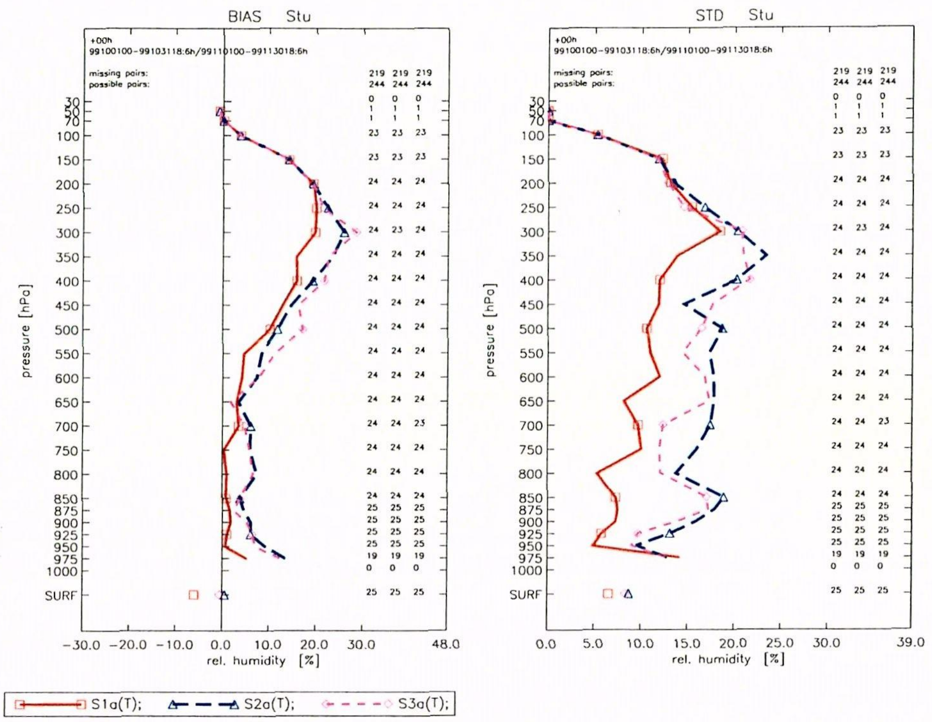


FIGURE 5-8. Bias (left panel) and standard deviation (right panel) of the relative humidity at initialization time calculated for the 27 forecasts against the vertical sounding at Stuttgart. Red curves are for observing system S1, blue curves for observing system S2 and magenta curves for observing system S3. Stuttgart is a radiosonde station which is blacklisted in S2 and S3, and is a location with many AMDARs data.

Stuttgart, wind speed +00h (12UTC)

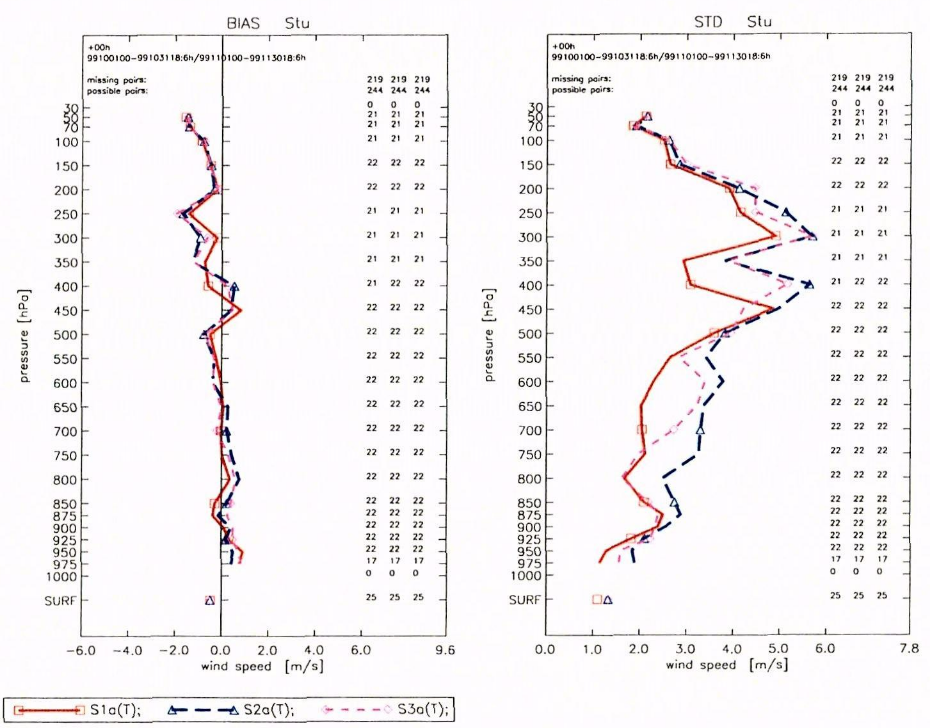


FIGURE 5-9. As figure 5-8, for wind speed.

of AMDAR bulletins is only marginally positive on all verified parameters. This is not surprising for the humidity field – AMDAR do not contain humidity information – but such a weak impact on the wind field was not anticipated.
However one should note the highly non-uniform distribution of AMDAR observations in the model domain (see figure 4-1) which could partly explain this fact. A look at figures 5-8 and 5-9 shows that AMDAR data have at least locally a remarkable impact, and are even able to improve the humidity field.

- All differences observed at analysis time have vanished *after 6 to 12 hours forecast*. This is again consistent with our experience, that for a limited area model similar to aLMo the impact of the initial conditions does not generally extend more than 12 to 18 hours into the forecast.
- A verification with a higher spatial granularity (Alpine region, the four quadrants west, north, east and south of the Alps) presents the same patterns.

Another comment can be made about the figure 5-2: in all three experiments the humidity *bias* in the lower troposphere is about zero, meaning that the global water vapour budget is correct and very similar for all experiments (this is consistent with the fact that fluxes through lateral boundaries and soil model state are identical in S1, S2 and S3). What is clearly degraded by the reduction of the number of radiosonde stations is *the distribution* of humidity in the integration domain, resulting in the observed increase of standard deviation.

5.2 Near-surface weather parameters over Switzerland

A statistical verification of 2m-temperature, 2m-dewpoint depression, 10m-wind, hourly sums of precipitation and cloud cover *over Switzerland* against data from the 72 stations of the Swiss automatic surface stations network (ANETZ) has been applied. Precipitation scores have also been calculated. To interpret these results it is important to realize that the observing system modifications associated with S2 resulted in a local increase of the number of radiosonde observations (Payerne station, on the Swiss Plateau, going from 2 to 4 daily soundings).

The results of this verification can be summarized by the three following statements and are illustrated by the statistical scores of figures 5-10 to 5-13:

- The sensitivity of the near-surface parameters to the modifications of the observing system is weaker than what has been observed in the verification of the vertical structure of the model atmosphere (e.g. compare the sensitivity of the wind speed standard deviation in fig. 5-4 and in fig. 5-10).
- Over Switzerland the modification of the radiosonde network results in a small degradation of the 10m wind speed and direction (fig. 5-10), but induces a significant reduction in variance of precipitation, which even persists up to the end of the forecast (fig. 5-12). The cloud cover bias is also slightly improved (fig. 5-11).
The small degradation of the 10meter wind field associated with the increased sounding frequency probably reflects a weakness of our near-surface wind assimilation algorithm in presence of strong orographic forcing.
The observed improvement of cloudiness and precipitation reflects the better three-dimensional fields over Switzerland, due to the increased number of assimilated soundings. In contrast, this confirms the negative impact a reduction of the number of radiosonde observations can locally have on wet weather elements.
- One observes a small but clearly positive impact of AMDAR observations on the temperature standard deviation (compare in fig. 5-13 the impact on the 2m temperature near an airport, at Kloten, and further away at Bern) and on the wind speed and direction (e.g. look at the wind speed standard deviation in fig. 5-10). This improvement is visible in the analysis *and* in the first 6 to 12h forecast.

Wind speed **Wind direction**

All representative stations associated to grid points below 800m

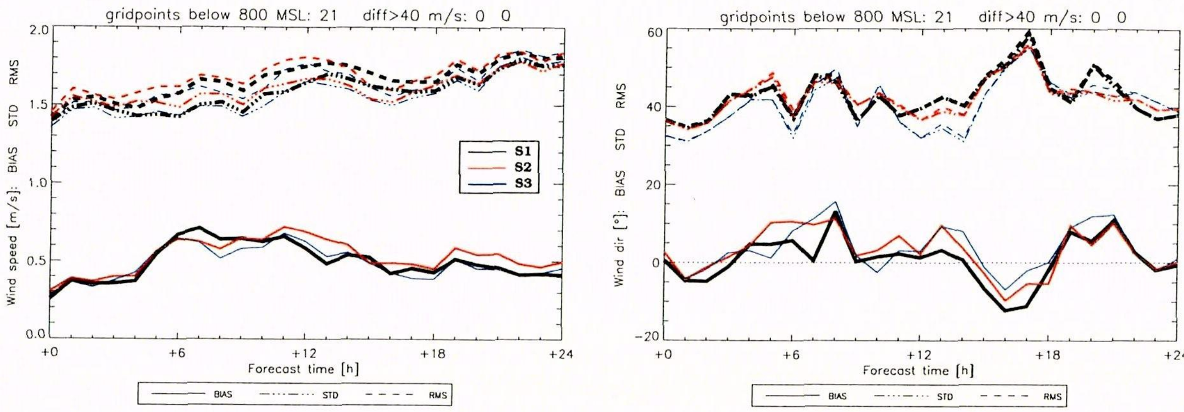


FIGURE 5-10. Hourly variation of some statistical scores for the 10m wind speed (***left panel***) and for the 10m wind direction (***right panel***), verified against the 21 representative ANETZ stations associated to a model grid point below 800m. Black curves are for observing system S1, red curves for observing system S2 and blue curves for observing system S3. The plain lines represent the bias, the dotted lines represent the rms and the dash/dotted lines represent the standard deviation.

Total cloud cover

All active stations associated to grid points below 800m

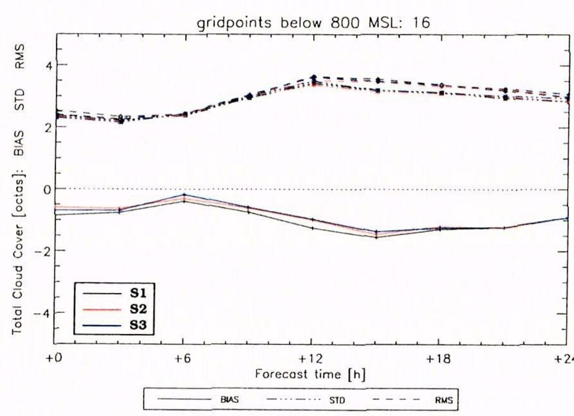


FIGURE 5-11. As figure 5-10, for the total cloud cover verified against the 16 active ANETZ stations associated to a model grid point below 800m. All grid points within 30km of an observation location are considered when calculating the scores.

Total precipitation

All active stations

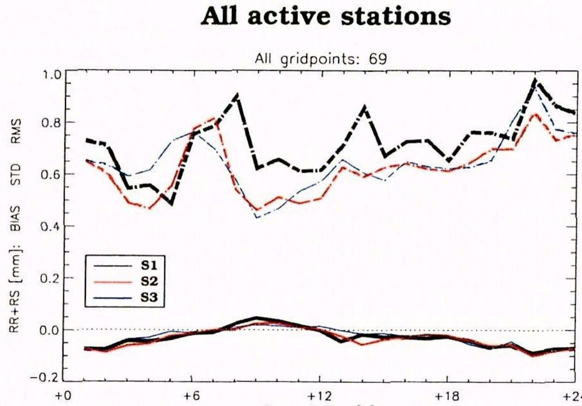
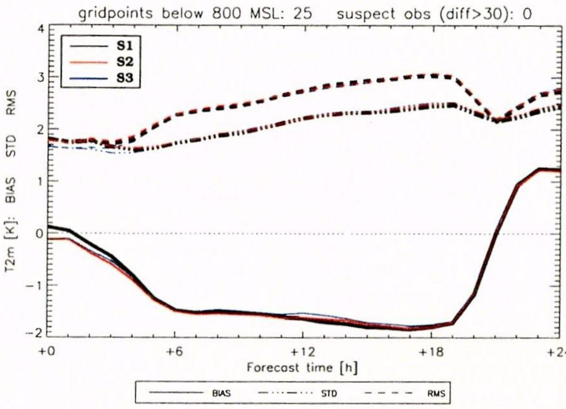
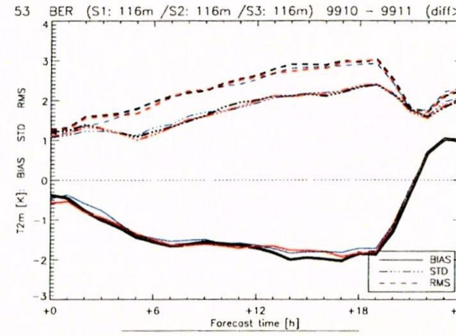


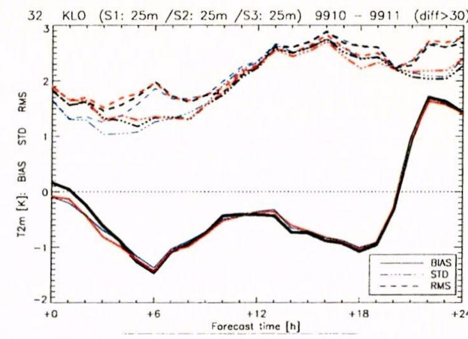
FIGURE 5-12. As figure 5-10, for the hourly total precipitation verified against all 69 active ANETZ stations. The plain lines represent the bias, the dash/dotted lines the standard deviation. A mean of 5 grid points around an observation is done before calculating the scores.

2m temperature
All active stations associated to grid points below 800m





Station Bern



Station Kloten

FIGURE 5-13. ***Upper panel***: hourly variation of bias (solid line) and standard deviation (dashed line) for the 2m temperature, verified against the 25 active ANETZ stations associated to a model grid point below 800m. Black curves are for observing system S1, red curves for observing system S2 and blue curves for observing system S3. ***Right panels***: same as upper panel but for a single ANETZ station. Both Bern and Kloten are on the Swiss Plateau, the latter one is also at an international airport location.

5.3 Case study

A study of the forecast based on the 6th November 1999 12UTC analysis has been done. This case is characterized by a blocking situation over the Western edge of the continent with a cut-off low over the South of Europe. Heavy precipitation - partly convective - has been observed in the Southern part of the Alps (Tessin, Lago Maggiore).

This case has been investigated at ECMWF [Cardinali, 2000] and it has been found that the synoptic situation was better described by forecast based on the observing system S1, the information from all the stations over the Atlantic border being very important for this particular meteorological situation.

No such synoptic scale differences are observed by looking at the high resolution short range forecast produced by aLMo; this is consistent with the fact that the synoptic structures are forced by the driving model, which is the same ECMWF operational deterministic forecast in all three experiments. However smaller scale structures do exhibit significant differences, and a clear improvement of the location and the spread of the heavy precipitation region is brought by the additional AMDAR observations (see figure 5-14). The negative impact due to the suppression of Nancy and Stuttgart radiosondes - north of Switzerland - is also well visible.

Total precipitation over Switzerland, the 6th November 1999

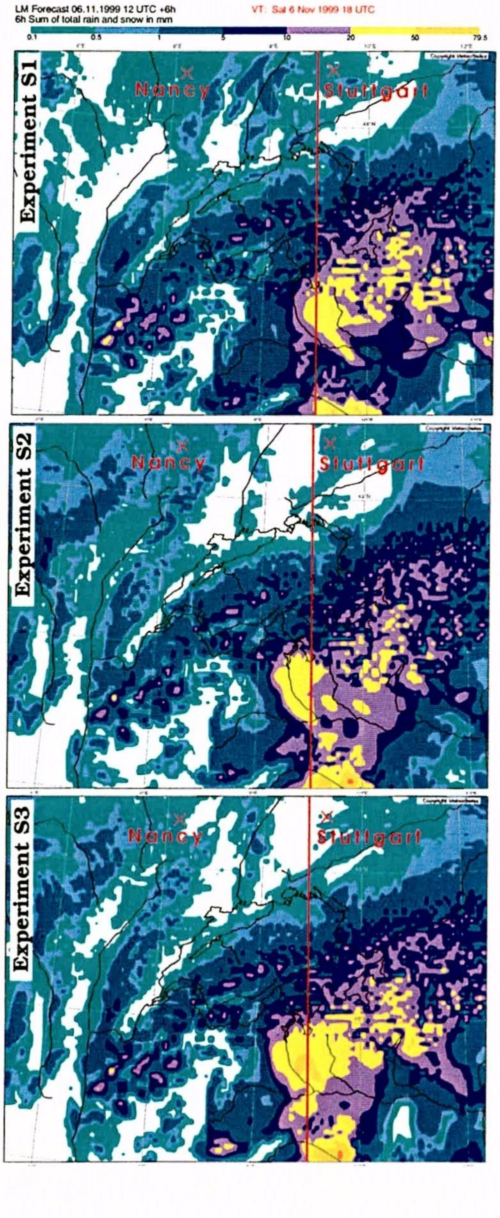
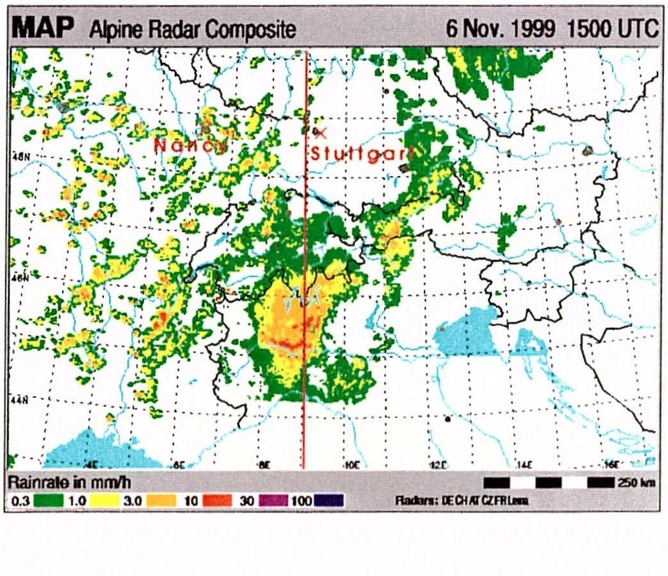


FIGURE 5-14. Sensitivity of an heavy precipitation event over Southern part of the Alps to the observing system. ***Left panels***: 6hours sum of total precipitation forecast over Switzerland, evaluated on the 6th November 1999 between 12UTC (analysis time) and 18UTC. ***Lower panel***: Total precipitation rate observed by the MAP Alpine Radar Composite on the 6th November 1999 at 15UTC (data for the whole MAP period are available on-line at www.map.ethz.ch).
Yellow areas in the left panels can be compared with light orange areas in the lower panel, and correspond to about 20 to 50mm precipitation in 6 hours.



VI Conclusion

The motivation of all EUCOS observing system experiments done at ECMWF [Cardinali, 2000], DMI [Amstrup, 2000] and MeteoSwiss was the evaluation of the impact of the proposed EUMETNET observing system modification on the quality of numerical weather forecast. It has been shown that a reduction of the number of active radiosonde stations had a very small but slightly negative impact on both the global ECMWF model and the DMI-HIRLAM-G limited area model, and the additional AMDAR data have been found to slightly degrade the quality of the forecast. The results obtained with aLMo differ substantially. To understand this fact, one should keep in mind that the two other models have a coarser horizontal resolution (50 to 60km instead of 7km), and that the DMI-HIRLAM-G is integrated over a much larger domain than the EUCOS region and uses an intermittent data assimilation scheme. In the present study we have found:

- A *significant* degradation of the model quality at analysis time and in the very short range is associated with the reduction of the number of radiosonde stations. This degradation is mainly visible in the distribution of the 3-dimensional fields inside the model domain (meso-β structures).The quality of precipitation is also degraded. The increased observation frequency of the remaining stations does not compensate for the reduced horizontal resolution of the observing system, except in the surrounding of an upgraded station. This is consistent with previous OSSEs [Bettems, 1999].
- Measured over the *whole model domain* the impact of the additional AMDARs is positive but very small. However, a clear improvement of wind, temperature *and humidity* fields is *locally* observed, in regions well covered by AMDAR platforms. This improvement is significant, but does not compensate the quality loss brought by the radiosonde network degradation.
- Even in *regions well covered by radiosonde observations*, the AMDAR data bring a clear improvement of the forecast quality (e.g. see fig. 5-10).

These results suggest a degradation of the (mean) quality of high resolution short range numerical weather forecast associated with the introduction of one of the proposed EUCOS scenario, if no compensatory actions are taken. AMDAR observations have a clear potential, and an improved horizontal coverage (e.g. using regional flights) would certainly mitigate the expected quality loss. However additional information about local structures in the humidity field are needed.

Annex

This annex gives the blacklists defining the observing systems S1, S2 and S3. These lists have been provided by Mrs. Carla Cardinali from ECMWF and complemented by the information listed in table 1 of the document EUCOS-SPC-003 (radiosonde stations whose operating mode changed during EUCOS observing period).

Blacklist for TEMP, observing system S1:

All synoptic times (53 elements)

"11010", "11120", "07690", "11240", "06400", "06496", "06060", "07137", "07255", "07503", "10304", "10437", "10828", "10962", "06242", "03023", "03130", "03213", "03377", "03414", "03590", "03693", "03696", "03743", "11036", "11105", "11123", "07112", "07453", "07613", "07614", "07615", "07616", "07664", "10393", "11394", "10722", "06348", "01010", "06792", "03501", "03608", "03807", "03840", "16087", "16113", "16121", "06831", "06832", "06833", "06842", "06843", "06844"

00UTC (3 elements)

"16754", "01152", "08579"

06UTC (12 elements)

"11350", "07510", "07645", "10350", "16622", "16754", "01415", "08579", "08100", "08301", "06610", "08495"

12UTC (2 elements)

"01152", "08579"

18UTC (12 elements)

"11350", "07510", "07645", "10350", "16622", "16754", "01152", "01415", "08100", "08301", "06610", "08495"

Blacklist for TEMP, observing systems S2 and S3 (90 elements):

"06447", "06181", "02836", "07110", "07145", "07180", "07481", "07761", "10184", "10200", "10238", "10410", "10486", "10548", "10618", "10739", "10771", "10868", "16716", "16080", "16144", "16245", "16429", "01384", "01400", "08023", "08160", "08221", "08430", "02365", "03005", "03502", "03882", "03920", "11010", "11120", "07690", "11240", "06476", "06400", "06496", "06060", "07137", "07255", "07503", "10304", "10437", "10828", "10962", "06242", "03023", "03130", "03354", "03213", "03377", "03414", "03590", "03693", "03696", "03743", "11036", "11105", "11123", "07112", "07453", "07613", "07614", "07615", "07616", "07664", "10393", "11394", "10722", "06348", "01010", "02591", "06792", "03501", "03608", "03807", "03840", "16087", "16113", "16121", "06831", "06832", "06833", "06842", "06843", "06844"

Blacklist for AMDAR, observing systems S1 and S2 (121 elements):

"EU0088", "EU0123", "EU0143", "EU0175", "EU0201", "EU0204", "EU0221", "EU0245", "EU0249", "EU0254", "EU0263", "EU0274", "EU0285", "EU0291", "EU0300", "EU0312", "EU0332", "EU0341", "EU0347", "EU0354", "EU0357", "EU0363", "EU0372", "EU0385", "EU0393", "EU0405", "EU0482", "EU0574", "EU0720", "EU0807", "EU0934", "EU0947", "EU0961", "EU0985", "EU1002", "EU1222", "EU1495", "EU1593", "EU1673", "EU1688", "EU1692", "EU2378", "EU2399", "EU2547", "EU2578", "EU2590", "EU2618", "EU2630", "EU2634", "EU2689", "EU2845", "EU2890", "EU2896", "EU2912", "EU2978", "EU2984", "EU3056", "EU3268", "EU3321", "EU3654", "EU3684", "EU3689", "EU3908", "EU4002", "EU4003", "EU4021", "EU4278", "EU4387", "EU4409", "EU4529", "EU4587", "EU4656", "EU4838", "EU5098", "EU5167", "EU5182", "EU5349", "EU5590", "EU5673", "EU6287", "EU6386", "EU6524", "EU6723", "EU6893", "EU6923", "EU7082", "EU7285", "EU7521", "EU7634", "EU7865", "EU7866", "EU8264", "EU8431", "EU8478", "EU8598", "EU8605", "EU8632", "EU8736", "EU8789", "EU8891", "EU8943", "EU9023", "EU9356", "EU9378", "EU9589", "EU9678", "EU9692", "EU9734", "EU9967", "EU0041", "EU0043", "EU0047", "EU0050", "EU0052", "EU0059", "EU0061", "EU0106", "EU0154", "EU0158", "EU0167", "EU0185"

Blacklist for PILOT, observing systems S1, S2 and S3 (20 elements):

"11036", "11105", "11123", "07112", "07453", "07613", "07614", "07615", "07616", "07664", "10393", "11394", "10722", "06348", "01010", "06792", "03501", "03608", "03807", "03840"

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