



Second FORALPS Conference

Contributions for a wise management
of water resources from meteorology
and climatology

Programme and Contents

Salzburg, 28 November 2007

Max Gandolf Bibliothek
Salzburg University

Hosted by



Central Institute for Meteorology and Geodynamics,
Regional Office for Salzburg and Oberösterreich

In connection with



ACQUA ALTA ALPINA 2007
www.acqua-alta-alpina.at



This project has received
European Regional
Development Funding
through the INTERREG III B
Community Initiative



Interreg III B

INDEX



INDEX

Conference Programme	5
TALKS	
Assessment of climatic trends at regional scale (WP5)	
• Ingeborg Auer, Reinhard Böhm, Anita Jurkovic, Eva Korus: <i>The FORALPS dataset: Application on the question of regional climate change</i>	10
• Mojca Dolinar, Boris Pavčič, Mateja Nadbath, Gregor Vertačnik: <i>The FORALPS Project in Slovenija</i>	11
• Jonathan Spinoni, Gianluca Lentini, Michele Brunetti, Maurizio Maugeri: <i>Construction of a 1961-1990 temperature climatology field for the “Greater Lombardy Area”</i>	12
• Angela Sulis, Alessia Marchetti: <i>Assessment of Lombardy’s climate in the last century: data analysis, methodologies and indices</i>	13
• Anita Jurkovic, Ingeborg Auer, Reinhard Böhm: <i>Digitalisation and interpolation of daily snow data</i>	14
Innovative instruments for rainfall monitoring (WP6)	
• Marco Gabella, Giovanni Perona, Stefano Turso, Marco Zambotto, Giulio Contri: <i>Quantitative precipitation estimation in Aosta Valley using the portable, low-cost, X-band radar developed within FORALPS</i>	15
Assessment of costs and benefits deriving from improved meteorological information (WP9)	
• Bernhard Niedermoser, Markus Ungersböck, Martin Ultz, Michael Staudinger: <i>Optimization of meteorological forecasts and evaluation of the economic consequences in an Austrian riverbasin</i>	16
Weather and water resources availability forecasting (WP7)	
• Irene Gallai, Dario B. Giaiotti, Fulvio Stel: <i>The onset of deep moist convection on areas characterized by complex orography: the case of Friuli Venezia Giulia</i>	17

- Marta Salvati, Cristian Lussana, Francesco Uboldi: *Verification of worded areal forecast of temperature extremes using a high resolution mesoscale analysis field*..... 18
- Michele Tarolli: *Verification of forecasts in Trentino*..... 19
- Arturo Pucillo, Fulvio Stel: *Verification and skill assessment of operational ECMWF EPS - based forecasts under different weather conditions*..... 20
- Alexandre Lanciani, Stefano Mariani, Marco Casaioli, Nazario Tartaglione, Christophe Accadia: *Combined approach to verification and intercomparison of precipitation fields modelled by LAMs: Multiscale, objective and subjective*..... 21

Sustainable management of water resources (WP8)

- Gianluca Vignoli, Ilaria Todeschini, Martino Salvaro, Roberto Dinale: *Hydrological modeling in the Ridanna river basin: Application of the GEOTRANSF model*..... 22
- Roberto Dinale, Gianluca Vignoli: *Sustainable water resource management in small alpine catchments: An effective scheme for resource availability analysis*..... 23

POSTERS

Assessment of climatic trends at regional scale (WP5)

- Mateja Nadbath, Boris Pavčič, Gregor Vertačnik: *Long term climate reconstruction and analysis in Ljubljana*..... 26
- Michele Andrighetti, Massimiliano de Franceschi and Dino Zardi: *A method to estimate daily maxima and minima based on single daily air temperature readings*..... 27
- Michele Tarolli, Roberto Rea, Dino Zardi: *Reconstruction and climatological analysis of the temperature and precipitation series of Fiemme Valley (Trento)*..... 28

Innovative instruments for rainfall monitoring (WP6)

- Paolo Battistutta, Andrea Bellan, Alessio Brezigar, Ivan Chiusso, Alessandro Gimona, Davide Pascolo, Furio Pieri, Mauro Trevisan: *Do We Really Need to Improve the Weather Monitoring Networks?*..... 29

Weather and water resources availability forecasting (WP7)

- Cristian Lussana, Marta Salvati, Francesco Uboldi: *Spatial analysis of observations from high resolution automatic meteorological networks*..... 30
- Cristian Lussana, Maria Ranci, Marta Salvati, Francesco Uboldi: *Automatic data quality control using spatial interpolation with statistical methods*..... 31
- Michela Calza, Luciano Lago, Marco Monai, Arianna Tardelli: *Tools for studying climatology of convective activity*..... 32
- Paul Rainer: *Verification of Precipitation Forecasts*..... 33
- Marco Casaioli, Stefano Mariani, Alexandre Lanciani, Christophe Accadia, Nazario Tartaglione: *Backtracking the forecast error from precipitation to mesoscale dynamics: Some qualitative conjectures*..... 34

Sustainable management of water resources (WP8)

- Michela Munari, Roberto Dinale, Christoph Oberschmied, Andrea Di Lullo: *Glaciological surveys on the Malavalle glacier*..... 35

Assessment of costs and benefits deriving from improved meteorological information (WP9)

- Francesca Predicatori, Federica Giacomazzi, Paolo Frontero, Elisa Montesor: *Agriculture and climate change: an evaluation of the willingness to pay for improved weather forecast*..... 36

CONFERENCE PROGRAMME



CONFERENCE PROGRAMME

OPENING – Chair: Michael Staudinger

10:00 Arrival and registration

10:30 Welcome and introduction

Local host and invited authorities

10:45 **Dino Zardi**, University of Trento
“An overview of the project FORALPS”

11:00 **Anuska Stoka**, Alpine Space Joint Technical Secretariat
“The new Territorial Cooperation Programme Alpine Space 2007-2013”

11:30 First invited lecture

Dr. Reinhard Böhm

*Central Institute for Meteorology and Geodynamics (ZAMG), Vienna
Department of Climatology / Climatological Survey and Hydro-
Climatology*

“Climate reconstruction in the instrumental period: problems and solutions for the greater Alpine region”

12:00 Second invited lecture

Dr. Ludwig Braun

Head of the Glaciological Commission of the Bavarian Academy of Science

“Runoff from high mountain regions as affected by global change”

12:30 Lunch break



CONFERENCE PROGRAMME

FIRST SESSION – Chair: Gregor Gregorič

13:30 – Assessment of climatic trends at regional scale (WP5)

Ingeborg Auer, Reinhard Böhm, Anita Jurkovic, Eva Korus: *The FORALPS dataset : Application on the question of regional climate change*

Mojca Dolinar, Boris Pavčič, Mateja Nadbath, Gregor Vertačnik: *The FORALPS Project in Slovenija*

Jonathan Spinoni, Gianluca Lentini, Michele Brunetti, Maurizio Maugeri: *Construction of a 1961-1990 temperature climatology field for the “Greater Lombardy Area”*

Angela Sulis, Alessia Marchetti: *Assessment of Lombardy’s climate in the last century: data analysis, methodologies and indices*

Anita Jurkovic, Ingeborg Auer, Reinhard Böhm: *Digitalisation and Interpolation of daily snow data*

14:45 – Innovative instruments for rainfall monitoring (WP6)

Marco Gabella, Giovanni Perona, Stefano Turso, Marco Zambotto, Giulio Contri: *Quantitative precipitation estimation in Aosta Valley using the portable, low-cost, X-band radar developed within FORALPS*

15:00 – Assessment of costs and benefits deriving from improved meteo-hydrological information (WP9)

Bernhard Niedermoser, Markus Ungersböck, Martin Ultz, Michael Staudinger: *Optimization of meteorological forecasts and evaluation of the economic consequences in an Austrian riverbasin*

POSTER SESSION – Chair: Franz Stockinger

15:15 – Poster Introduction

Coffee break + poster viewing



CONFERENCE PROGRAMME

SECOND SESSION – Chair: Mauro Valentini

16:00 – Weather and water resources availability forecasting

Irene Gallai, Dario B. Giaiotti, Fulvio Stel: *The onset of deep moist convection on areas characterized by complex orography: the case of Friuli Venezia Giulia*

Marta Salvati, Cristian Lussana, Francesco Uboldi: *Verification of worded areal forecast of temperature extremes using a high resolution mesoscale analysis field*

Michele Tarolli: *Verification of forecasts in Trentino*

Arturo Pucillo, Fulvio Stel: *Verification and skill assessment of operational ECMWF EPS - based forecasts under different weather conditions*

Alexandre Lanciani, Stefano Mariani, Marco Casaioli, Nazario Tartaglione, Christophe Accadia: *Combined approach to verification and intercomparison of precipitation fields modelled by LAMs: Multiscale, objective and subjective*

17:15 – Sustainable management of water resources (WP8)

Gianluca Vignoli, Ilaria Todeschini, Martino Salvaro, Roberto Dinale: *Hydrological modeling in the Ridanna river basin: Application of the GEOTRANSF model*

Roberto Dinale, Gianluca Vignoli: *Sustainable water resource management in small alpine catchments: An effective scheme for resource availability analysis*

17:45 – Conclusions

TALKS

The FORALPS dataset: Application on the question of regional climate change

Ingeborg Auer, Reinhard Böhm, Anita Jurkovic, Eva Korus

Central Institute for Meteorology and Geodynamics - Vienna, Austria

Mankind is currently experiencing a significant change of one of the most important factors controlling general living conditions in the Alpine region - climate change. A number of recent studies have shown that the Alps are among the regions of the world most sensitive to climate, pressurised by an increase of temperature roughly twice as strong as for the global mean during the past 150 years. ZAMG-W's FORALPS daily climate data set allows for detailed regional climate change studies, concerning changes in mean as well as extreme climate. Climate Change Indices developed by the WMO's "Expert Team on Climate Change Detection, Monitoring and Indices" turned out to be a useful tool to investigate into climate trends and variability during the 20th century.

Carefully tested time series of temperature show a quite uniform behaviour over the Eastern Alps. At the same time precipitation and snow, however, show quite remarkable regional differences.

ZAMG-W's FORALPS daily climate data set will allow for a number of future studies beyond the FORALPS project phase. Especially, collaborative studies within the climate impact community will reward the enormous amount of time and manpower spent into data recovery and rescue, quality checks and data correction, meta data studies, homogeneity testing and soft homogenising procedures.

The FORALPS Project in Slovenia

Mojca Dolinar⁽¹⁾, Boris Pavčič⁽²⁾, Mateja Nadbath⁽¹⁾, Gregor Vertačnik⁽¹⁾

(1) Environmental Agency of the Republic of Slovenia - Ljubljana, Slovenia

(2) University of Ljubljana, Faculty of Mathematics and Physics, Department of Physics, Chair of Meteorology - Ljubljana, Slovenia

FORALPS is an INTERREG Project (extended name Meteo-Hydrological Forecast and Observations for improved water Resource management in the ALPS). Environmental Agency of the Republic of Slovenia (EARS) is a project partner since its beginning in 2005.

In the framework of working group 5, which addresses meteorological and hydrological data in the broadest meaning, the aim of Slovenian partner was to extend and improve the quality of national climatological database.

High quality climatological data is the primary basis of a reliable climatological analysis. Long, validated and homogenous climatological data series are essential for the analysis of climate variability and change, since different errors and inhomogeneities in data series could produce false signals, with magnitude comparable or even larger than climate variability or climate change signals. Long, homogenous data series are also very important for climate predictions, since only a good knowledge of past climate can lead us to good predictions, especially on local scale.

Digital archives of Slovene meteorological data contain records from 1961 onwards for the majority of the stations. In the frame of FORALPS the resources of historical climatological data were searched and the data for longer data-series have been digitised. As for the purpose of homogenisation and climatological analysis, the history of measurement site and the instruments must be well documented. Therefore EARS has performed activities to restore metadata archive and transfer it into digital form. Thanks to additional metadata on extended data series we found new facts about past climate in Slovenia, especially about extreme values and trends.

Construction of a 1961-1990 temperature climatology field for the “Greater Lombardy Area”

Jonathan Spinoni⁽¹⁾, Gianluca Lentini⁽²⁾, Michele Brunetti⁽²⁾, Maurizio Maugeri⁽¹⁾

(1) Institute of General and Applied Physics, University of Milan - Milan, Italy

(2) National Research Council, Institute of Atmospheric Sciences and Climate - Bologna, Italy

Constructing a climatology means extrapolating the information from individual station values to the whole area under examination; in other words, it implies the shift from a discrete domain to a continuous field, by means of the creation of a geographical model and the construction of a regular grid. Such procedure is often referred to as “data spatialization”.

A database of 240 thermometric stations was recovered for the Greater Lombardy Area (GLA, 44 to 47°N, 7 to 12°E): such database was deemed as adequate in order to properly describe the wide range of climatological features (sketchily summarized by the terms “Mediterranean, Continental and Alpine”) encompassed by the GLA.

A geographical spatialization model for the GLA was created by investigating the dependence of 1961-1990 monthly temperatures on a set of several geographical and morphological parameters: such dependence was studied by means of regression analysis and by evaluating the amplitude and distribution of monthly residuals for every station. The parameters whose contribution was evaluated were the latitude, longitude, distance from the (Adriatic and Ligurian) seas, presence of large lacustrine water basins, continentality in terms of Po-Plain-basin effect, morphology and orientation of mountain valleys, position at the valley bottom or mountain top, presence of urban heat island.

Given the geography of the GLA, it was first found that the dependence on longitude was entirely encompassed by both the distance from the Adriatic sea and the continentality (Po-Plain-basin) effects. Such dependence on longitude was therefore neglected as a result.

The individual effects of all the other geographical and morphological parameters, evaluated in terms of monthly residuals of linear regressions, were embodied in the geographical spatialization model, resulting in extrapolated 1961-1990 monthly temperature values over a 1 km x 1 km resolution grid encompassing the whole GLA.

Assessment of Lombardy's climate in the last century: data analysis, methodologies and indices

Angela Sulis, Alessia Marchetti

Regional Agency for Environmental Protection of Lombardia, Hydrographic Office - Milano, Italy

A huge work of data rescue, collection from several sources and data organization enables now ARPA Lombardia to count on 20 long term daily series of rainfall and 11 series of temperature in the Greater Lombardy Area (GLA, 44 to 47°N, 7 to 12°E). All the collected data (raw, validated and homogenized) and metadata are stored in a database with geographical information. The same system stores also calculated indices.

With this tool the time series are easily managed and the datasets have been used to provide some first analysis of last century climate in the GLA.

According to the time resolution (daily, monthly, seasonal or annual) the data features are different, and so are the indices meanings: they can show trends, changes in the extremes or the persistence of some weather conditions (wet or dry periods, heat waves or cold waves). Twenty seven indices based on daily data, chosen within the FORALPS WP5 team, were calculated with a common tool written in R language (Rclimindex, available on the web). Some simple indices based on monthly, seasonal and annual data were calculated and stored too.

Monthly data were homogenized, so all the long term series could be used for the analysis. Since the daily data homogenization is still an open matter, daily time series can be used only in homogeneous periods. We found 5 daily data series longer than a century, with at least 100 years of homogeneous data, and made a comparison between the trends in the indices calculated using all the data period and using the last homogeneous period. The first results show some interesting points:

1. the climate isn't really stationary, at least in the last half century.
2. some indices seem not to be sensitive to data homogenization.
3. only good continuous measurements provide good climate analysis.

Digitalisation and interpolation of daily snow data

Anita Jurkovic, Ingeborg Auer, Reinhard Böhm

Central Institute for Meteorology and Geodynamics - Vienna, Austria

Snow is a significant parameter in our climate system and reacts immediately on temperature and precipitation anomalies. Hence it is a good indicator for the omnipresent catchword “Climate Change”. Especially the warm winter 2007 demonstrated us the impact of temperature increase on snow cover, a sensible climate element. The small amount of snow during the winter season had fatal consequences for Austrian tourism and economy. Therefore it is necessary to evaluate and in further steps to homogenise daily snow data.

The digitalisation and interpolation of long-term daily snow series is one of the final aims of the FORALPS project WP5. Out of historical hydrological Yearbooks (1895-1915), data of more than 800 stations were digitalised, corrected and finally completed.

To demonstrate the great variability of the element snow and the effects of the main global warming of the 20th century, a second recent timeslice (1980-2000) was selected and compared with the historical one. After some quality tests and criterias only 98 (10%) out of 800 stations were chosen for further statistically evaluations, interpolations and significant tests.

Special parameters, as number of days with/without snow cover, begin and end of snow cover and duration of winter cover were evaluated and pictured. Interpolations of extreme years like 1989 (only a few days with snow especially in the South of Austria) and trend analysis of long term (100 years) time series should round off this presentation.

Quantitative precipitation estimation in Aosta Valley using the portable, low-cost, X-band radar developed within FORALPS

Marco Gabella⁽¹⁾, Giovanni Perona⁽¹⁾, Stefano Turso⁽¹⁾, Marco Zambotto⁽¹⁾, Giulio Contri⁽²⁾

(1) Department of Electronics, Politecnico di Torino - Torino, Italy

(2) Civil Protection Meteorological Office, Autonomous Region Valle d'Aosta - Aosta, Italy

The concept of portable, low-cost, X-band radar for monitoring precipitation inside valleys in complex terrain has been developed within the EC INTERREG project FORALPS. The first prototype has been installed at the Aosta airport in March 2007. This letter describes the preliminary results obtained in spring 2007. Radar-derived estimates using echoes 700 m above the radar site are in good agreement with two in situ measurements within 3 km from the radar site. The two nearby gauges have also proved to be useful for the adjustment of the radar itself. The overall adjustment factor (Gauge-to-Radar total) related to twelve (half-day) rainy periods results to be 1.5 dB. After the adjustment, which forces the radar to measure a total amount of rainfall equal to the average of the two nearby gauges (45.1 mm), the Root Mean Square Error (RMSE) between Radar and the (average of the two) nearby Gauges is 1.9 mm. (Thanks to the adjustment, the RMSE is coincident with the standard deviation of the differences). The Weighted Standard DEVIation (WSDEV) of the fractional differences is 55%. Given the high spatial variability of the precipitation field, it is not surprising that the agreement with two farer gauges (within 13 km range) is worse: RMSE is 3.0 mm and WSDEV is 68%. These preliminary results have to be completed with many more cases (stratiform and convective events) originating from different seasons. Future steps include also detailed analyses of the vertical radar reflectivity profile. Without this remotely sensed information, which obviously no rain gauge can give, the three-dimensional description of the precipitating clouds is impossible.

Optimization of meteorological forecasts and evaluation of the economic consequences in an Austrian riverbasin

Bernhard Niedermoser, Markus Ungersböck, Martin Ultz, Michael Staudinger
Central Institute for Meteorology and Geodynamics - Salzburg, Austria

Water management in Austrian River basins can be very cost related specially during extreme weather events. As the zonal planning and the usage of the land is determined by extreme usage of the urban and suburban landscape, every flooding causes relatively large damages depending on the river height.

For the city of Steyr and the upstream river basin area an optimisation for the forecast procedures was undertaken during the FORALPS project. With the help of a Graphic Forecast Editor (GFE) model fields for the parameter of precipitation from different models (ECMWF and Aladan) could be merged, modified and optimized according to the needs of the current synoptical situation. The results showed the influence of the forecaster on the current estimation of the precipitation development over an area of approx 3000 km².

With the help of these optimised forecasts a coupling to hydrological models is possible and will be undertaken for the Steyr/Enns river basin in the year 2008 operationally. The hydrological model will allow a better water management in this basin by the water authorities and the hydro power plant operators.

As the city of Steyr is located directly at the river shores and flooding is frequent here, every improvement of forecast quality in the meteo / hydro chain is directly related to a mitigated economic damage.

In order to assess the amount of this mitigation, an areal assessment of the exposed property values for the local topography has been made. With this area / height / property value relationship the cost efficiency ration of the improved forecasts could be determined for the inner city and the surrounding of the Steyr city.

The results showed a considerable improvement of the meteo / hydro model chain and a cost / efficiency ratio of the meteorological forecasts by an order of magnitude.

The onset of deep moist convection on areas characterized by complex orography: the case of Friuli Venezia Giulia

Irene Gallai, Dario B. Giaiotti, Fulvio Stel

Regional Agency for Environmental Protection of Friuli Venezia Giulia, Meteorological Office - Palmanova, Italy

The onset of deep moist convection (hereafter DMC) is studied in Friuli Venezia Giulia region, an area characterized by a complex orography, by way of the WRF non-hydrostatic numerical model. In particular, several sensitivity tests have been performed on the Valcanale flash flood (29th August 2003) and are here presented looking for the elements that might be considered the most important for the observed evolution of that event. The first result obtained through these sensitivity cases is that the Valcanale event could not be correctly foreseen by the current available numerical models, this essentially because of the parametrization of convection (in particular the Kain-Fritsh parametrization) which misplaces the positioning of the precipitation maxima, producing the largest amounts of rain on the lee-side of the Prealps in spite of the inner Alpine area. With a fully resolved convection, the maxima of precipitation are correctly placed and the parameter which seems to play the major role for the onset and stationarity of DMC is relative humidity. In particular, low values of relative humidity in the lowest levels near the ground are fundamental for the onset and stationarity of DMC in the inner part of Alps, as it was in the case of Valcanale flash flood. Relatively high values of relative humidity, on the contrary, favour the onset of DMC on the foothills as well as the propagation of DMC cells on the relieves through the “mother-daughter” mechanism. Moreover, particularly high values of relative humidity in a context of convective instability can favour the onset of deep moist convection on the plain of Friuli Venezia Giulia, relatively far from the mountain range, in some peculiar synoptic situations characterized by a cold advection aloft and by a moist Scirocco at the ground. All these results are summarized in a look-up table that can be used by weather forecasters for their operational purposes.

Verification of worded areal forecast of temperature extremes using a high resolution mesoscale analysis field

Marta Salvati⁽¹⁾, Cristian Lussana⁽¹⁾, Francesco Uboldi⁽²⁾

(1) Regional Agency for Environmental Protection of Lombardia, Regional Meteorological Office - Milano, Italy

(2) Consultant - Novate Milanese, Italy

The present work tackles the messy problem of verifying worded forecasts issued over an area. The difficulties lie in unambiguously and consistently translating forecasts in quantitative and verifiable statements, and in choosing the non-obvious observational “truth” to verify against. Main justification of this effort is the numerous user community of worded forecasts, often the most consulted and less verified forecast product of many weather services.

Temperature has been chosen as first parameter to verify, mainly because an analysis method was available with known error, but also because it is the easiest to quantify and its spatial distribution tends to be regular even in complex terrain.

Through discussions with forecasting staff carried out before and during first data analysis, unambiguous and objective criteria to translate forecasts have been formulated; these are necessary for verification but have been found to be useful also for expressing homogeneous and objective analysis and forecasts.

The quantified forecasts have been verified against the areal temperature distribution obtained from the analysis field, which in turn has been checked against the distribution of pointwise observation in the same area. Forecasts have good skill over persistence in estimating the mean of the spatial temperature distribution, but lower skill on the spread.

Verification results prompted the discussion of forecast formulation and the planning of new objective analysis tools in support of forecasting activity.

Verification of forecasts in Trentino

Michele Tarolli

Autonomous Province of Trento - Office for Forecasts and Organization

The study concerns the verification of both objective and subjective weather forecasts. The area considered in this analysis is the territory pertaining to the Autonomous Province of Trento.

Regarding the subjective forecasts the study is focused on the verification of the probabilistic bulletins daily issued by Meteotrentino. In these bulletins the codes that vary from 0, which is associated with the minimum probability, to 3, which guarantees the maximum probability - are assigned to events of interest for the Civil Protection, describing the probability of occurrence of any particular meteorological event. The codes are verified with the data obtained from the weather stations, and the results report the percentage related to each code for every season of the year. The selection of the set of stations to be used in the verification is the most critical point, and depends on the variable in exam. The results, illustrated to the forecasters last January (2007), were used to calibrate a new scale of probabilities to associate to the events, improving the overall quality of the forecasts.

Meanwhile, regarding the objective forecasts, the attention is focused on the verification of the meteorological models used by the forecasters. The variables of interest are temperature and precipitation. The study allows a direct comparison between models characterized by different grid resolutions (global models and local models); this is of particular interest for a Region like Trentino as it presents a complex orography. Different techniques have been adopted to interpolate values (grid points and stations points). Finally the study evaluates the accuracy of the forecasts generated by each single model for the first three days and in the different seasons of the year. The indexes used to assess the quality of the forecasts are the MAE (Mean Average Error) for the series of temperatures, and the ETS (Equitable Threat Score) for the levels of precipitation.

Verification and skill assessment of operational ECMWF EPS - based forecasts under different weather conditions

Arturo Pucillo, Fulvio Stel

Regional Agency for Environmental Protection of Friuli Venezia Giulia, Meteorological Office - Palmanova, Italy

This work aims at providing a multicategorical statistical analysis of the ECMWF Ensemble Probabilistic System forecasts issued by a forecaster according to the Table for Scenario Identification. It has been implemented to deal with seven different weather categories observed in Friuli Venezia Giulia region (the target area) and chosen according to the experience of OSMER forecasters. The verification scheme adopted is a nonprobabilistic scheme for multicategorical discrete predictands implemented for all the scenarios and the precipitation scenario alone.

The ECMWF EPS dataset at OSMER ARPA FVG provides information about clustering in geopotential field over Europe, showing the mean of each cluster and the standard deviation; the rainfall probability over Europe; the time series over a single grid point of forecast rainfall, ground temperature and wind, with indication of the cluster mean and the percentiles. The Table of Scenario Identification describes seven different types of weather: convective activity, stratiform rain (with or without convection embedded), snowfall, ice at ground (or rime or icing rain), fog, wind (of dangerous or at least meaningful intensity with respect to the land over which it blows), stability (even though not sunny). The forecast scenario is selected according to a fixed scheme that follows a checklist over the available model outputs: the first step is the evaluation of geopotential cluster mean over Europe at 500 hPa, then the temperature at 850 hPa, last the geopotential height at 1000 hPa. The second step is the evaluation of the time series over a single grid point (in particular 46°N 13°E grid point) for the rainfall mean amount of each cluster, the ground temperature mean, the number and population of clusters. The latter is used to assess the probability of occurrence of that scenario, being 100% the one-cluster probability.

Combined approach to verification and intercomparison of precipitation fields modelled by LAMs: Multiscale, objective and subjective

Alexandre Lanciani⁽¹⁾, Stefano Mariani⁽²⁾, Marco Casaioli⁽¹⁾, Nazario Tartaglione⁽³⁾, Christophe Accadia⁽⁴⁾

(1) Agency for Environmental Protection and Technical Services - Rome, Italy

(2) Department of Mathematics, University of Ferrara - Ferrara, Italy

(3) Department of Physics, University of Camerino - Camerino, Italy

(4) EUMETSAT - Darmstadt, Germany

Forecast verification is an important component of both meteorological operational and research activities. Results presented here refer to two selected events (16-20 Nov. 2002 and 8-10 Sep. 2005) when significant rainfall over the eastern Alpine range was observed. Objective and subjective verification techniques were employed: the former can provide a quantitative basis to subjective verification, while the latter can suggest a physical interpretation of the quantitative verification achievements. However, traditional skill scores (measuring point-to-point match) are sensitive to small displacement errors, due to double penalty effect. Higher order moments must be studied to assess if the fields being compared are defined on grids with the same real resolution and if they have the same amount of small scale detail. Multiscale methods such as the power spectrum are suitable tools to this end. Three LAMs were considered for this study: ALADIN operational at EARS; QBO-LAM operational at APAT; and WRF running in a research configuration at OSMER. Models have different domain sizes and differ in the parameterization schemes and initial and boundary conditions. For precipitation comparisons, forecast data have been post-processed on two common grids (grid size of 0.1° and 0.5°) by remapping and by bilinear interpolation. Using the spectra, we found that, as grid transformation, the former is to be preferred to the latter since bilinear interpolation tends to smooth the structure of the original field. We also found that skill scores' intercomparison ought to be performed over the 0.5° grid where the models' structure is comparable, whereas over the 0.1° grid the smoother fields are privileged. Moreover, we showed how the capacity of the models to predict precipitation well for all thresholds may change from model to model. Finally, we showed the importance of the CRA analysis to identify and quantify location errors of modelled precipitation patterns.

Hydrological modeling in the Ridanna river basin: Application of the GEOTRANSF model

Gianluca Vignoli⁽¹⁾, Ilaria Todeschini⁽¹⁾, Martino Salvaro⁽²⁾, Roberto Dinale⁽³⁾

(1) CISMA S.r.l. - Bolzano, Italy

(2) Department of Civil and Environmental Engineering, University of Trento - Trento, Italy

(3) Autonomous Province of Bolzano, Hydrographic Office - Bolzano, Italy

The GEOTRANSF hydrological model uses morphological (DEM, landuse, soil types, geology) and meteorological (temperature and rainfall) data and reproduces the entire hydrological cycle at catchment scale: discharge, evapotranspiration, snow cover and snow melt. The model is applied partitioning the study area into several geomorphological elements suitably interconnected. The building block of the model is a nonlinear runoff generation model applied to the unchanneled portion of the catchment. The hydrological response of the catchment depends on the soil water content, which is continuously evaluated in every element by solving the mass balance equation.

To investigate the model capability of reproducing hydrological cycles at different spatial scales, the model has been applied to the Ridanna catchment, located in the East-Central part of the Alps, at the border between Italy and Austria, and to four subcatchments, which range from 13 km² to 208 km². The model was run for 10 years at catchment scale and for 2.5 years at sub-catchment scale. Results were obtained and evaluated in terms of simulated discharge versus measured discharge and in terms of the Nash index, a dimensionless index of the results quality. Nash index equal to one indicates an excellent agreement between simulated and measured discharge. Applications at the catchment scale simulations show good results with a Nash index up to 76%. Results for the sub-catchment scale simulations show a good agreement with the measured data, with a Nash index slightly lower with respect to the catchment scale case. In particular, for three of the sub-basins we obtain a Nash index up to 66%, while for the fourth of them model performances are lower, showing a Nash index close to 45%.

Sustainable water resource management in small alpine catchments: An effective scheme for resource availability analysis

Roberto Dinale⁽¹⁾ , Gianluca Vignoli⁽²⁾

(1) Autonomous Province of Bolzano, Hydrographic Office - Bolzano, Italy

(2) CISMA S.r.l. - Bolzano, Italy

In the Alps sustainable water resources management is a need because of the quite high level of urbanisation of the region and the growing requirements of people and industries living and operating there. The EU Water Framework Directive underlines the importance of water management by river basins and identifies the River Basin Management Plan as the tool to describe the state of all surface and ground waters and to define the measures to reach a “good status” for all waters by a set deadline. A good level of knowledge of river basin hydrology is propedeutical to all this, both for big and small river basins, as often is the case in the Alpine area. For this reason an effective methodology to study the water resource availability at river basin scale was developed and tested on the Ridanna river catchment. This pilot is located in the northern part of Italy, in the Trentino Alto Adige/Sudtirolo region, and has a total area of 208 km² and a mean elevation of 1926 m. The total annual rainfall amount is about 1000 mm. Snow and ice hydrology also affect the water balance of this river basin. An integrated approach composed by basin macro analysis, monitoring, field work and modelling has been tested and proved to be useful for a better comprehension of the hydrological phenomena and, as a consequence, to support water management planning and decision makers.

POSTERS

Long term climate reconstruction and analysis in Ljubljana

Mateja Nadbath⁽¹⁾, Boris Pavčič⁽²⁾, Gregor Vertačnik⁽¹⁾

(1) Environmental Agency of the Republic of Slovenia - Ljubljana, Slovenia

(2) University of Ljubljana, Faculty of Mathematics and Physics, Department of Physics, Chair of Meteorology - Ljubljana, Slovenia

EARS is a partner of the INTERREG project FORALPS (an acronym for Meteorological Forecast and Observations for improved water Resource management in the ALPS). Within working group 5, Dataset: assessment of climatic trends at regional scale, EARS wants to improve the quality of climatological database with long, homogenous data series. Meteorological data for Ljubljana were first in process.

In this task several steps were done. Firstly, the history of measurements in Ljubljana and related metadata were reconstructed as detailed as possible. Secondly, the digitalisation of meteorological data from the first years of measurements at the meteorological station of Ljubljana and at neighbour stations was made. These two first steps were the basis for homogenisation of meteorological data. Afterwards, some climate analyses for Ljubljana were done.

Instrumental measurements in Ljubljana have begun in March 1850. From the beginning till year 1948 the main problems were:

1. several locations of meteorological station (from 1850 till 1948 meteorological station changed seven locations);
2. non-standard observation time;
3. non-standard measurement units (Paris line for precipitation);
4. insufficient documentation of metadata.

From 1948 onwards the meteorological station in Ljubljana has been in the same location, but problems arose as its immediate surroundings have changed, due to the growth of the city.

Homogenisation has been done on average monthly temperature. Craddock homogeneity test was used and its results were downscaled to daily adjustments. Several inhomogeneities were found and adjusted. On such data series climate indices were computed and compared with nonhomogenised data. Results were quite different.

A method to estimate daily maxima and minima based on single daily air temperature readings

Michele Andrighetti, Massimiliano de Franceschi, Dino Zardi

(1) Atmospheric Physics Group, Department of Civil and Environmental Engineering, University of Trento - Trento, Italy.

A problem specifically affecting series composed from measurements taken before the introduction of modern standards about observation timing and instruments (e. g. maximum and minimum thermometers) is the availability of only one daily observation, often taken at varying hours. Even when the observer used to record at least the daily hour at which measurements were recorded, the effective diurnal timing of measurements have to be reconstructed if the adopted timing system was an older one. Indications about the state of the weather at the time of observations, which usually were recorded as side information as well, are a very useful reference to classify the days into some weather categories. The paper proposes a method to estimate daily temperature maxima and minima when only such single daily readings are available, taking advantage of all the available information. The method requires the availability of a representative diurnal temperature cycle (for each weather category), determined for instance on the basis of sample of high frequency temperature measurement in the same area (of course, in more recent times). Based on linear regression, a best fit line is obtained, which provides the basis for the relationship between the single-hour reading and daily extremes. The outcoming parameters of the best fit line provide the basis for the evaluation of maxima and minima from single daily readings. The methods provides also an estimate for the intrinsic error of the estimate. A preliminary application of the method to the series of data from temperature measurements taken in Verona (Italy) from 1768 to 1774 is presented.

Reconstruction and climatological analysis of the temperature and precipitation series of Fiemme Valley (Trento)

Michele Tarolli⁽¹⁾, Roberto Rea⁽²⁾, Dino Zardi⁽³⁾

(1) Autonomous Province of Trento, Office for Forecasts and Organization - Trento, Italy

(2) Municipality of Campitello di Fassa - Italy

(3) Atmospheric Physics Group - Department of Civil and Environmental Engineering, University of Trento - Trento, Italy

The Fiemme Valley is one of the most remarkable valleys in the north-eastern part of Trentino, delimited northward by the Dolomites and furrowed by the Avisio River, a tributary of the Adige River.

Various weather stations were installed at the main centres of the valley at the end of the 19th century. In the present work the series of temperature and precipitation from four stations in the above centres, namely Predazzo, Cavalese, Paneveggio and Passo Rolle, are presented.

Data obtained from hydrological yearbooks were collected and minor gaps filled by means of suitable correlation with reference series (Trento, Bolzano/Bozen, Riva del Garda, Rovereto, Bressanone/Brixen, Belluno, Innsbruck, Mantova and Monte Maria/Marienbergl). Outliers have been removed after careful check.

The Standard Normal Homogeneity Test has been applied and inhomogeneities detected and removed.

After climatological analysis, the resulting series display a clear tendency towards increasing temperature, whereas the identification of clear trends in precipitation regimes is questionable.

Do We Really Need to Improve the Weather Monitoring Networks?

Paolo Battistutta, Andrea Bellan, Alessio Brezigar, Ivan Chiusso,
Alessandro Gimona, Davide Pascolo, Furio Pieri, Mauro Trevisan

Regional Agency for Environmental Protection of Friuli Venezia Giulia, Meteorological Office -
Palmanova, Italy

Weather monitoring networks reach an incredibly high density on the Alpine area, nevertheless almost every EU Project referring to the Alpine Space includes in its foreseen activities the improvement of those networks. These improvements are necessary at least for three main reasons:

1. Alpine Space is characterized by an extreme orographic variability and the current monitoring networks do not have a sufficient resolution;
2. every monitoring network works with its own “monitoring strategy”, to optimize the data collection and diffusion which, indeed, produces constraints in the monitoring procedure itself;
3. every monitoring network is usually developed and tuned for a restricted set of phenomena/variables.

Keeping in mind these three aspects of the monitoring activity, in the frame of FORALPS WP6, ARPA OSMER installed a set of experimental weather stations to:

1. cover previously uncovered areas of Friuli Venezia Giulia and to
2. collect data in quasi-real-time mode, to be
3. used in conjunction with the already available and newly developed RADAR systems.

These weather stations, based on the GPRS transmission system, are currently integrated in the pre-existing network (their data are homogeneous with respect to the “old” weather stations) and have a working-cost (essentially related to the data-transmission) roughly one order of magnitude lower than that of the “old” weather stations. Moreover, thanks to their quasi-real-time (5’ time-lag) they can be used for the real-time calibration of RADAR rain estimates and for nowcasting purposes.

Spatial analysis of observations from high resolution automatic meteorological networks.

Cristian Lussana⁽¹⁾, Marta Salvati⁽¹⁾, Francesco Uboldi⁽²⁾

(1) Regional Agency for Environmental Protection of Lombardia, Regional Meteorological Office - Milano, Italy

(2) Consultant - Novate Milanese, Italy

Local observational networks of automatic weather stations are characterized, in Northern Italy, by high temporal and spatial resolution, often over complex orography and land-use. Even so, this wealth of meteorological information is only partially exploited in operational centers. In fact, point-wise observations are rarely combined to produce reliable analysis maps, and almost never integrated with other sources of meteorological information, such as model fields or remote sensing measurements.

Mostly for practical reasons, producing objective analysis maps of such observations can be of interest even independently from the availability of model fields. On the other hand it is appropriate to combine observations with model information, if this is available with sufficient resolution. Optimal interpolation, a basic step in many data assimilation methods, can be used in both cases.

An Optimal Interpolation scheme has been implemented with Lombardia's network, accounting for the high observational density and with three-dimensional correlations.

Depending on the analysis variable, local characteristics of the area (as elevation, land-use, slope and aspect) have been included in the correlation functions used to specify covariances. The parameters of these functions have then been optimized through the innovation statistics.

The method is presently applied to temperature and relative humidity observations. The algorithm has been coded to compute the analysis value on a regular 1.5km grid, the cross-validation analysis on station locations, and diagnostic parameters useful for performance evaluation and data quality control.

Work is under way to extend the interpolation scheme to other variables. The general goal is to progressively integrate the local network measurements with other sources of information (remote sensing, model fields, physical constraints) to produce multi-variate analysis fields by means of data assimilation techniques.

Automatic data quality control using spatial interpolation with statistical methods

Cristian Lussana⁽¹⁾, Maria Ranci⁽¹⁾, Marta Salvati⁽¹⁾, Francesco Uboldi⁽²⁾

(1) Regional Agency for Environmental Protection of Lombardia, Regional Meteorological Office - Milano, Italy

(2) Consultant - Novate Milanese, Italy

Data quality control (DQC) is a fundamental step for any kind of data analysis; in particular it is important to have a reliable automatic DQC for numerical elaboration purposes, objective analysis included.

The automatic high resolution meteorological network managed by Lombardia 's Regional Weather Service is distributed over complex terrain in orography and land use. Furthermore, station sites are not optimized and observations are differently affected by representativity errors.

For these reasons there is a strong need of robust, reliable, automatic DQC procedures. Simple tests based on climatology and on increments or persistence thresholds have been implemented successfully.

Additionally, statistical interpolation methods (as Optimal Interpolation) provide a valuable tool for spatial consistency test in automatic DQC. Simple analytical representation of a-priori error covariances allows for analysis estimates with satisfactory cross-validation scores. A-posteriori evaluation of error probability density functions can be used to estimate representativity errors of the observations and to reject data affected by gross errors through appropriate DQC tests.

This automatic DQC is an operational tool for the Regional Weather Service and it is used both as a filter for numerical procedures and as a support for the daily human DQC.

Tools for studying climatology of convective activity

Michela Calza, Luciano Lago, Marco Monai, Arianna Tardelli

Regional Agency for Environmental Protection of Veneto, Meteorological Center of Teolo - Teolo, Italy

Forecasting thunderstorm activity during the convective season is one of the major challenges in the operational activity of the Centro Meteorologico di Teolo (CMT), the regional met service of Veneto belonging to Regional Environmental Agency (ARPAV). CMT has a long tradition in using radar for monitoring convection, but a systematic thunderstorm climatology has never been constructed. The purpose of this study, performed in the framework of FORALPS, is to take a first step in filling this gap by means of radar imagery. More precisely, the records of the Storm Cell Identification and Tracking (SCIT) are exploited, an algorithm developed by NSSL and available in the Hydromet Decision Support System (HDSS). Such a characterization of convective activity is the basis for the evaluation of numerical weather prediction guidance related to severe weather.

To this end, the SCIT cell table, updated while the real time radar system of Mt. Grande monitors the weather, has been transformed into a data base. A web interface for data extraction has been created to allow the user to select cells identified by the SCIT with specified characteristics for selected periods of time. The set of parameters managed by SCIT (about 40) characterizes the strength of the cells, like maximum dBZ, probability of hail and severe hail, height of max dBZ and others. This makes the tool rather versatile, in that it makes possible to stratify all the cells, according to a number of criteria. The graphical outputs, available on the web browser, include interactive density and trajectories maps, and histograms useful for a systematic analysis of convective activity in the radar domain. For the present study, data for the warm seasons (May-Sep) 2005, 2006 and 2007 were analyzed. For example, the convective activity was depicted in terms of the average frequency of occurrence, preferred genesis regions, times of the day, and cell tracks depending on the various months of the convective seasons.

Verification of Precipitation Forecasts

Paul Rainer

Central Institute for Meteorology and Geodynamics - Klagenfurt, Austria

A tool has been created for online verification for seven regions in Carinthia. This tool is used in operational work and it is available in Internet, <http://wetterbox.kso.ac.at> (username: vop, password: vop). Verification in classes (very weak 0.1-1.0 mm, weak 1.0-5.0 mm, moderate 5.0-15.0 mm and abundant precipitation >15mm) make it possible to find a ranking of models - ECMWF, GME, AUSTROMOS, ALADIN (LAM), LM(LAM+forecast) - for seven regions in Carinthia. Case studies have been performed to investigate the snowfall line in case of very heavy precipitation in the area of Carinthia and to check an application implemented in ACUVIS from Alfred Neururer (ZAMG Innsbruck). In the project a comparison of stability indices and the correlation with thunderstorm activity has been made, for a better estimation of convective precipitation. One result of the project is an intensification of the cooperation and a better data exchange with HYDRO service in Carinthia and the Hydro Power Corporation (AHP).

The results of the FORALPS project bring an improvement for the input to quantitative precipitation forecasts for hydro power corporations, and to the forecast of extreme precipitation issued by the Hydrographic Department of the Carinthian government, used to alert civil protection agencies and inform media to give a flood warning.

Backtracking the forecast error from precipitation to mesoscale dynamics: Some qualitative conjectures

Marco Casaioli⁽¹⁾, Stefano Mariani^(1,2), Alexandre Lanciani⁽¹⁾,
Christophe Accadia⁽³⁾, Nazario Tartaglione⁽⁴⁾

(1) Agency for Environmental Protection and Technical Services - Rome, Italy

(2) Department of Mathematics, University of Ferrara - Ferrara, Italy

(3) EUMETSAT - Darmstadt, Germany

(4) Department of Physics, University of Camerino - Camerino, Italy

Precipitation forecasting in the Mediterranean regions suffers from different sources of uncertainty which are not easy to determine, but can depend both on the model and on the complexity of the involved phenomena. For instance, initial analysis could be too coarse to fully describe all the scales which contribute to the evolution of the weather system and, eventually, to the precipitation space-time distribution. When comparing models in a case-study approach, the combined use of different subjective and objective verification methods allows characterising the performance of the competing models. However, starting from such results, one would wish to reach some reliable physical statement about the origin and the growth of the diagnosed errors. Within the FORALPS activity, a wide set of verification methodologies have been previously applied on two selected case studies, simulated with three operational limited area models: the Slovenian version of the ALADIN model operational at EARS; QBOLAM operational at APAT; and WRF running in a research configuration at OSMER. Here, verification results about the first event (16-20 Nov. 2002) are assumed as a starting point for conjectures about the possible origin of the forecasting error, on the basis of further subjective verification of the models and the initial and boundary fields coming from global models and analyses.

Glaciological surveys on the Malavalle glacier

Michela Munari⁽¹⁾, Roberto Dinale⁽¹⁾, Christoph Oberschmied⁽¹⁾,
Andrea Di Lullo⁽²⁾

(1) Autonomous Province of Bolzano, Hydrographic Office - Bolzano, Italy

(2) University of Trieste - Trieste, Italy

Glaciers are a peculiar characteristic of many Alpine catchments. In an inventory dated 1997, the surface of south-tyrolean glaciers was of about 110 km². Their progressive retreat is on the one side a very confident climate change indicator, and on the other side it represents a considerable contribution to the water cycle of this region. In the frame of the FORALPS project the Ridanna river pilot catchment was studied. This basin is covered by glaciers for 4.6% of its surface, which strongly affect the catchment hydrology, in particular during the summer months. To support the hydrological analyses, on the most important glaciated area - the Malavalle glacier - mass balance studies were carried out by the direct glaciological method, based on in situ measurements. At a number of individual points the change in surface level is measured to evaluate the glacier mass gain or loss on that point. Extrapolating the punctual results to the entire glacier surface it is possible to refer the results to the whole glacier. The results of the surveys were yearly resumed in terms of specific net winter, summer and yearly mass balance, Equilibrium Line Altitude (ELA) and Accumulation Area Ratio (AAR). The poster shows the field activities performed, the weather stations, which has been installed to support the glaciological surveys, and the results of the measuring campaigns. The geomorphological evolution of the glacier and its proglacial lake are described as well.

Agriculture and climate change: an evaluation of the willingness to pay for improved weather forecast

Francesca Predicatori⁽¹⁾, Federica Giacomazzi⁽¹⁾, Paolo Frontero⁽¹⁾,
Elisa Montresor⁽²⁾

(1) Regional Agency for Environmental Protection of Veneto, Department of Verona - Verona, Italy

(2) Department of Economics, University of Verona - Verona, Italy

Improved weather forecasts can contribute to preserve hydrological resources. A survey on weather forecast service use held in the Verona province showed that the most relevant end users there are fruit farmers. A workshop was organized, regarding new technologies in weather forecast and agrometeorological information and culture defense. A general questionnaire was submitted to the participants (mainly farmers and insurers). A new questionnaire was then submitted individually to the fruit farmers who agreed to collaborate during the conference, to estimate the farmers' "willingness to pay" for weather forecast.

The cost benefit analysis for no-market goods, as weather forecast is, can be dealt with "direct methods". One of these methods is the contingent valuation, that aims at defining how much specific users are "willing to pay" (WTP) for direct or indirect benefits. Interviewing the farmers at their homes, first we asked the current use of weather forecasts regarding the phytosanitary treatments, early and late frost, extreme events (hail, strong wind, excess rain), irrigation and the general degree of satisfaction about actual weather forecast information. Second we asked their WTP for improving every specific aspect of weather forecast proposing different expenses ranges. The main results of the survey are listed below.

1. a specialised and aimed weather forecast information is particularly useful in the agricultural sector: farming costs are increased by lost of crop and by the expenses for repeated phytosanitary treatments if weather forecast services are inaccurate.
2. farmers are highly willing to pay for improved weather forecast, especially for higher spatial and timing reliability: the higher proposed expenses range was most often selected.
3. farmers would like more information about specific weather forecast aspects, and expressed interest in specialized training about current and improved forecast.

FORALPS Partnership



University of Trento
Department of Civil and Environmental Engineering
Lead Partner



Autonomous Province of Bolzano
Hydrographic Office



Italian Agency for Environmental Protection
and Technical Services



Autonomous Province of Trento
Office for Forecasts and Organization



Regional Agency for Environmental Protection Lombardia
Regional Meteorological Service,
Regional Hydrographic Office



Valle d'Aosta Autonomous Region
Meteorological Office



Regional Agency for Environmental Protection
Veneto



Central Institute for Meteorology and Geodynamics
Regional Office for Tirol and Vorarlberg



Environmental Agency of the Republic of Slovenia

Regional Office for Carinthia

Regional Office for Salzburg and Oberösterreich

Regional Office for Wien, Niederösterreich and Burgenland



Regional Agency for Environmental Protection
Friuli-Venezia Giulia
Regional Meteorological Observatory



Organizing and Technical Committee

Michael Staudinger (ZAMG, Salzburg) - President

Marco Aniello (UniTN, Trento)

Ingeborg Auer (ZAMG, Vienna)

Tanja Cegnar (Ljubljana, EARS)

Stefano Micheletti (OSMER, Udine)

Giuseppina Monacelli (APAT, Rome)

Marina Rogato (UniTN, Trento)

Stefano Serafin (UniTN, Trento)

Fulvio Stel (OSMER, Udine)

Dino Zardi (UniTN, Trento)

Contacts



Mailing address:

University of Trento
Department of Civil and Environmental Engineering
Via Mesiano 77, I -38050 Trento



Email: foralps@unitn.it

Web: www.foralps.net



Tel: +39 0461 882649

Fax: +39 0461 881946