Session 2P4
Neural Network and/or Remote Sensing Inversion Problems

Neural Networks for Satellite-Based Estimation of Precipitation

F. W. Chen
MIT Lincoln Laboratory, USA

This presentation provides an overview on the use of neural networks in precipitation estimation.

Neural networks provide a useful method for learning mathematical relationships using a representative sample of data. These are especially useful in situations where the relationships between variables are extremely complicated and simulations based on physical models are inadequate or computationally expensive.

Approaches to precipitation estimation can be classified into two groups: model-based and statistics-based. Model-based methods involve tuning parameters to match observations and then using the parameters to obtain precipitation rate. Statistics-based methods correlate brightness temperature observations with ground truth measurements. The physics of precipitation is extremely complicated and existing physical models do not adequately capture all of the variation of precipitation. Moreover, repeatedly running radiative transfer calculations can take a lot of time while neural net computations are much simpler.

Chen and Staelin (IEEE Trans. Geosci. Remote Sensing, 41(2), 2003) have developed a method for estimating precipitation using the passive microwave radiometer AMSU-A/B (Advanced Microwave Sounding Unit) aboard the NOAA-15, NOAA-16, and NOAA-17 satellites. The method applies spatial filtering and signal separation to extract information relevant to precipitation. The outputs of this signal processing component are then fed to a neural network. This method was trained using data from the NEXRAD ground-based radar network as ground truth and shows reasonably good agreement at 15-km resolution.

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Neural Network Retrievals of Atmospheric Temperature and Moisture Profiles from High-resolution Infrared and Microwave Sounding Data

W. J. Blackwell
Massachusetts Institute of Technology, USA

A novel statistical method for the retrieval of atmospheric temperature and moisture (relative humidity) profiles has been developed and evaluated with sounding data from the Atmospheric InfraRed Sounder (AIRS) and the Advanced Microwave Sounding Unit (AMSU). The algorithm is implemented in three stages. First, the infrared radiance perturbations due to clouds are estimated and corrected by combined processing of the infrared and microwave data. Second, a Projected Principal Components (PPC) transform is used to reduce the dimensionality of and optimally extract geophysical profile information from the cloud-cleared infrared radiance data. Third, an artificial feedforward neural network is used to estimate the desired geophysical parameters from the projected principal components.

The cloud-clearing of the infrared radiances was performed by the AIRS Science Team using infrared brightness temperature contrasts in adjacent fields of view and microwave-derived estimates of the infrared clear-column radiances to estimate and correct the radiance contamination introduced by clouds. The PPC compression technique was used to reduce the infrared radiance dimensionality by a factor of 100, while retaining over 99.99% of the radiance variance that is correlated to the geophysical profiles. This compression allows the use of smaller, faster, and more robust estimators. A single-layer feedforward neural network with approximately 3000 degrees of freedom was then used to estimate the geophysical profiles at approximately 60 levels from the surface to 20 km.

The performance of this method (henceforth referred to as the PPC/NN method) was evaluated using global (ascending and descending) EOS-Aqua orbits co-located with ECMWF fields for a variety of days throughout 2003 and 2004. Over 350,000 fields of regard (3×3 arrays of footprints) over ocean and land were used in the study. Retrieval performance compares favorably with that obtained with simulated observations from the NOAA88b radiosonde set of approximately 7500 profiles. The PPC/NN method requires significantly less computation than traditional variational retrieval methods, while achieving comparable performance.

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Ozone Profiles Retrieval: Intercomparison between Neural Networks Inversion and Other Estimation Techniques

M. Iapaolo[1], **F. Del Frate**[1], **and S. Casadio**[2]

[1]Università di Roma Tor Vergata, Italy
[2]Karl Franzens University of Graz, Italy

The Global Ozone Monitoring Experiment (GOME) is a nadir-viewing broadband spectrometer (240–790 nm) of moderate resolution (0.2–0.4 nm) on board the European ERS-2 spacecraft which has been operational since mid 1995. Its measurements allow the retrieval of global distributions of ozone and a number of chemically associated atmospheric trace gases, such as NO_2, BrO, $HCHO$, $OClO$ and SO_2. GOME is the first in a series of European space-borne ozone monitoring instruments; it has been followed by the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) on Envisat (2002) and by the Ozone Monitoring Instrument (OMI) on EOS-Aura satellite (2004), and it will be continued by GOME-2 series on the EUMETSAT Metop-1, 2, 3 satellites, planned to be launched in 2006.

Most important for climate and environmental application is the retrieval of vertical ozone profiles, which yield pertinent information on the ozone distribution in the stratosphere and the upper troposphere exploiting the spectral information of the Hartley and Huggins bands in the UV range. Recently, a retrieval methodology based on neural networks (NNs) has been proposed; such a technique is very attractive for its capability to provide a real-time accurate solution of the inversion problem, as required to process the huge volume of data that characterize the continuous observation of the atmosphere from a satellite platform. In this study all GOME spectral measurements from July 1995 to June 2003 have been successfully processed. The effectiveness of the retrieval algorithm has been tested, and the accuracy of the retrieved ozone profiles has been evaluated performing an extended inter-comparison with similar products provided by other instruments and inversion techniques. The Improved Limb Atmospheric Spectrometer (ILAS), a limb-scanning instrument boarded on the Japanese satellite ADEOS, and a series of lidar stations belonging to the Network for Detection of Stratospheric Changes (NDSC) have been considered in this work. Tropical, mid-latitude and high-latitude regions have been considered during the inter-comparison, either in the Northern or in the Southern Hemisphere, and the results have been critically analized.

Application of Artificial Neural Networks and Genetic Algorithms to the Retrieval of Snow Parameters from Passive Microwave Remote Sensing Data

M. Tedesco[1,2] and E. J. Kim[2]

[1]University of Maryland Baltimore County, USA
[2]NASA Goddard Space Flight Center, USA

Monitoring the quantity, distribution and dry/wet state of snow provides vital information for applications such as weather and natural hazards forecasting, use of water resources for domestic and hydropower applications.

The retrieval of snow parameters from microwave remote sensing data is based on the inversion of relationships between the snow parameters and electromagnetic quantities. It is rarely possible to perform this inversion in a strictly analytical way and numerical techniques are often used. In some cases, the problem of inverting these relationships is solved by using a linear regression between the snow parameter of interest and a combination of electromagnetic quantities (e.g., Chang's algorithm for the retrieval of SWE). In other cases, iterative techniques based on the solution of the radiative transfer equation can be used (e.g., the HUT iterative inversion technique).

Numerical techniques such as Artificial Neural Networks (ANN) and Genetic Algorithms (GA) can also be used for the inversion of the radiative transfer equations. In this study we separately evaluate the capabilities of both ANN- and GA-based techniques to retrieve snow parameters from space-borne brightness temperatures at 19 and 37 GHz collected by the SSM/I and/or AMSR-E radiometers, with particular emphasis on snow depth. The two techniques are applied to different datasets collected over different areas and the results are compared with ground measurements. We also evaluate the advantages and disadvantages of the two techniques in terms of computational time and potential applications to retrievals of snow parameters close for near-real-time applications. We compare the performances of the ANN- and GA-based techniques with those of the most well known algorithms described in the literature: Chang's algorithm, the Helsinki University of Technology iterative algorithm and the Spectral Polarization Difference algorithm.

On the Robustness of Neural Network Algorithms for Oil Spill Detection

E. Angiuli, **F. Del Frate**, **S. Di Giosia**, **and L. Salvatori**
Università Tor Vergata, Italy

In this paper we present the potentialities of Neural Network algorithms for detection of oil spill. Previous works have demonstrated how neural networks are a valid instrument for this type of analysis. In fact, an artificial neural network (NN) may be viewed as a mathematical model composed of many nonlinear computational elements, named neurons, operating in parallel and massively connected by links characterized by different weights. This particular structure makes neural networks very stable and robust when there are sensible input variations. For this study, multilayer perceptrons (MPL) have been considered, which have been found to have a suited topology for classification and inversion problems. The network input is a vector containing the values of a set of features characterizing an oil spill candidate. The output is a value, included between 0 and 1, representing the probability that the candidate is an oil slick. The classification performance has been evaluated on a data set of ERS-SAR and Envisat-ASAR images containing examples of oil spills and look-alikes. To test the robustness of the algorithm, we have grouped all the collected examples into different subsets considering two main factors: the different SAR instrument (ERS-SAR or Envisat-ASAR) and the natural noise characterizing the image. For this latter case the standard deviation of the backscattering values of the sea surface has been considered as a general noise index. Several nets have been designed using in turn different subsets for the training phase and the performance of each net has been tested on different subsets, either similar or dissimilar to those used in the training. The neural algorithm gives generally satisfactory results, however the performance is clearly affected by the type of examples included in the training set. This effect has been investigated throughout a systematic analysis.

Neural Network Ozone Retrieval System for Total Ozone and Ozone Profile Retrieval from Gome Uv/Vis Spectra (Nnorsy-gome)

A. K. Kaifel[1], **M. D. Müller**[2], **and J. Kaptur**[1]

[1]Zentrum für Sonnenenergie-und Wasserstoff-Forschung, Germany
[2]NASA Goddard Space Flight Center, USA

The Neural Network Ozone Retrieval System (NNORSY) was developed during the last years for total ozone and ozone profile retrieval from UV/VIS spectra of ERS-2 GOME and total ozone column retrieval from IR NOAA-TOVS satellite data. Version 1 of NNORSY GOME ozone profile retrieval was implemented for real-time processing of GOME data at the DLR-DFD up to the failure of the tape recorder of ERS-2 in July 2003 ($http://wdc.dlr.de/data_products/SERVICES/GOMENRT/inde-$ $x.html$). Latest developments for NNORSY-GOME Version 2 yielded further improvements of retrieval accuracy and was applied to the whole GOME data time range in order to generate a more than 9 year global ozone profile data set with high vertical resolution.

For training ozonesonde data are used reaching from ground up to about 25 km and satellite ozone profile measurements from SAGE, HALOE and POAM covering the height range from 60 km down to tropopause height level. This means that the neural network have to deal with incomplete target data during training. Therefore training algorithms have to be developed to handle partial training with incomplete target vector.

This paper first presents the solution we developed for partial training as well as application to ozone profile retrieval from GOME UV/VIS spectra for reprocessing whole GOME level 1 data set ranging from July 1995 to the end of 2004. These yields to a consistent global ozone profile data set stretching from ground up to 60 km height at 1 km sampling rate. Comparison with other independent satellite ozone profile data products (e.g., MLS) as well as extensive geophysical validation against ozonesonde data will also be shown.

NNORSY processing is very fast and resulting GOME ozone profile product has about the same or better accuracy as classical optimal estimation based retrieval schemes which makes NNORSY a candidate for further real-time processing on current or upcoming satellite sensors like OMI on EOS-AURA or GOME-2 on METOP.

Analysis of Urban SAR Data Using Morphological Pre-processing and Neural Networks

J. A. Benediktsson[1], S. O. Sigurjonsson[1]
G. Lisini[2], P. Gamba[2], J. Chanussot[3], and J. R. Sveinsson[1]

[1]University of Iceland, Iceland
[2]University of Pavia, Italy
[3]LIS / INPG, France

Classification of high-resolution remote sensing images from urban areas has been addressed in [1] and [2] using two main steps:

- feature extraction based on the construction of a differential morphological profile which characterizes each pixel both in terms of intensity and in terms of local geometry.
- classification based on a neural network (eventually after selection of the most significant features).

In this paper, a further evolution of [1] and [2] is presented and applied in neural network classification of an AIRSAR image of Los Angeles, California. For the feature extraction step, two different approaches are used for the construction of the morphological profile of each pixel: 1) alternating sequential filters (ASF) and 2) the applications of openings and closings with linear structuring elements under varying angles. The effect of using speckle filtering prior to the construction of the morphological profiles is also investigated. In the paper, the maps obtained from the classification of the different morphological profiles are used for classification and street tracking.

From the data, street extraction is made in two steps. The first one is aimed at trying and discarding the "blobs" that do not possess the usual characteristics of the roads such as elongation. This is made by a routine hat tries and associate each "blob" present in the filtered image to a "street prototype" database [4]. If the shape of the blob under test is too different from the ones found in the database, it will be removed from the image. It is possible to remove even only a part of the entire blob that shows too peculiar features. The second step uses modified Hough transform routine [5] for real road extraction.

To evaluate the quality of the extracted street network, quantitative indexes are computed, including the correctness and completeness indexes [5]. Both of them require the knowledge of the true network and provide a means to understand to what extent the extracted networks is similar to the reference one. In particular, completeness represents the fraction of ground truth length extracted while correctness is the fraction of segments' length belonging to actual roads.

REFERENCES

1. Pesaresi, M. and J. A. Benediktsson, "A new approach for the morphological segmentation of high-resolution satellite imagery," *IEEE Transactions on Geosciene and Remote Sensing*, No. 2, 309–321, 2001.
2. Benediktsson, J. A., J. A. Palmason, and J. R. Sveinsson, "Classification of hyperspectral data from urban areas based on extended morphological profiles," *IEEE Transactions on Geoscience and Remote Sensing*, No. 3, 480–491, 2005.
3. Acqua, F. D., P. Gamba, and G. Lisini, "Road map extraction by multipledetectors in fine spatial resolution SAR data," *Canadian J. Remote Sensing*, Vol. 29, No. 4, 481–490, Aug. 2003.
4. Acqua, F. D. and P. Gamba, "Detection of urban structures in SAR images by robust fuzzy clustering algorithms: the example of street tracking," *IEEE Trans. Geosci. Remote Sensing*, Vol. 39, No. 10, 2287–2297, Oct. 2001.
5. Wiedemann, C. and H. Ebner, "Automatic completion and evaluation of road networks," *Int. Arch. Photogramm. Remote Sensing*, Vol. 33, 976–986, 2000.

Speckle Reduction of SAR Images Using Independent Component Analysis

C. H. Chen and X. J. Wang
University of Massachuetts Dartmouth, USA

Synthetic aperture radar (SAR) images are often degraded by multiplicative speckle noises. Appearing to be randomly granular, SAR image speckle noise is resulted from phase variations of radar waves from unit reflectors within a resolution cell. Its existence is undesirable, since it degrades image quality and affects the task of human interpretation and evaluation. SAR image speckle noise reduction has been a well studied subject for over twenty years, notably by J. S. Lee, D. T. Kuan and many others.

In this paper the neural network based independent component analysis(ICA) technique is presented that shows experimentally more signficant speckle noise than those reported by other researchers. The ICA method employed makes use of fastICA algorithm for the basis images and a classification procedure to assign the basis image to signal (edge) space or the speckle (texture) space, with the assumption that the two spaces are independent. The coefficient associated with the signal space basis image is going through a nonlinear transform while the coerfficient associted with the speckle space is set to zero. The image is then reconstructed from the resulting signal space.

The SAR images considered with 250×350 pixels for the experimental comparison have nine channels with PLC bands and three polarizations. They cover the agricultural area near the village of Feltwell, UK. The comparison of ratio of standard deviation to mean clearly indicates that our method is signficantly better in most image channels.

Table 1: Ratio comparison.

	Original	Our method	Wiener filter	Lee method	Kuan method
Channel 1	0.6362	0.2723	0.5597	0.3072	0.5765
Channel 2	0.6298	0.2581	0.4358	0.3154	0.5203
Channel 3	0.5842	0.2407	0.3976	0.3018	0.5276
Channel 4	0.3682	0.2196	0.3097	0.2640	0.3437
Channel 5	0.3596	0.3087	0.3164	0.2785	0.3272

Markov Random Fields and Neural Network for Improving Multi-source Data Interpretation

P. Gamba, G. Trianni, and S. Caorsi
Università di Pavia, Italy

There is currently a big need for methods aimed at improving the exploitation of multi-source data for earth observation. This is caused by the increasing number of image sources providing different kinds of information about the earth for oceanic, meteorological, terrestrial applications. These sources may be very different in their nature, and consequently also the spatial and spectral resolution of their data sets may be also very different.

In this work we are interested to land cover analysis, especially in urban areas, where the huge spatial variability of the environment requires usually data coming from many sensors to generate a satisfactory and reliable interpretation of the scene. This process, labeled as data fusion, has been performed using various approaches, from statistical methods [1], to Dempster- Shafer theory [2], and also by means of neural networks [3]. Here we propose a basic procedure based on a Markov Random Field but with the aid of neural network for extracting the a priori probability density functions for the land cover classes. Moreover, a comparison with all neural network chains for data fusion in urban areas [4] is provided, in order to understand the advantages and drawbacks of the approach. As a matter of fact, taking into account some simple local interactions at the scale of a single pixel and its neighbors, MRF models show a complex global behavior, which is the principal reason of their popularity among the scientific community. One drawback of MRF is that they may have prohibitive computational costs. To our aim, we found out that ICM (iterated conditional mode) was the most useful algorithm. Still, neural network trained for spatial (re)classification may be equally effective, and maybe more suitable to continuously spatially changing environments. So, this work provides an interesting comparison between the two techniques, both based on a initial pixel-based classification performed by a Fuzzy ARTMAP classifier.

For our tests, the area around the town of Pavia (Northern Italy) has been chosen. The city of Pavia has already been widely analyzed for other purposes and therefore a detailed ground information, together with other results, may be used for analysis and comparison [5]. So, we collected some ERS-1/2, Envisat (ASAR) and Landsat TM and ETM images of the town and performed our classification based on the MRF and NN approaches. The multi-source data have been co-registered one to the others and to the corresponding ground truth. We want to remark here that in defining the MRF classification model, we made some choices as the energy function present in the Gibbs function, the pixel number contained in the neighborhood of each pixel, and the optimization algorithm, which are peculiar to urban areas, and thus were chosen to make the approach more suited to the target area.

REFERENCES

1. Welch, R. and M. Elehers, "Cartographic feature extraction with integrated (SIR-B) and landsat TM images," *Int. J. Remote Sensing*, Vol. 9, 873–880, 1988.
2. Lehrer, N., G. Reynolds, and J. Griffith, "Initial hypothesis formation in image understanding using an automatically generated knowledge base," *Proc. Workshop Image Understanding*, 521–537, Los Angeles, CA, February 1987.
3. Jakubowicz, O., "Autonomous reconfiguration of sensor systems using neural nets," in *Proc. SPIE: Sensor Fusion*, 197–203, Orlando, FL, April 1988.
4. Gamba, P. and B. Houshmand, "An efficient neural classification chain for optical and SAR urban images," *International Journal of Remote Sensing*, Vol. 22, No. 8, 1535–1553, May 2001.
5. Gamba, P., "A collection of data for urban area characterization," *Proc. of IGARSS04*, Vol. 1, 69–72, Anchorage (USA), September 2004.

Neural Networks for the Electromagnetic Near Field Subsurface Sensing

S. Caorsi and G. Cevini
University of Pavia, Italy

This paper is intended to give an assessment of the application of a neural network approach to the electromagnetic sensing of subsurface scenarios. The neural network approach is used to obtain a reconstruction of the geometric and dielectric properties of buried geometries. Besides, the focus is on the exploitation of aspect-limited electromagnetic data coming from near field measurements, such as those available at the terminals of a ground penetrating radar equipment. This topic is related to many practical applications in environmental and civil engineering, such as, for example, the subsurface mapping of utilities or contaminants, or the monitoring of the subsoil conditions, for buildings, roads or railroads maintenance purposes.

The problem of reconstructing the geometric and dielectric characteristics of buried scenarios is usually formulated as an inverse scattering one. Since, usually, only few parameters can be investigated in order to characterize the unknown target, learning-by-examples techniques have recently been applied to face inverse scattering problems. As a matter of fact, a neural network can be trained to approximate the functional relation between the electromagnetic available measurement data and the unknown characteristics of the scatterer, through the exploitation of a set of examples representative of the problem at hand. Thus, the a-priori information must be effectively exploited to construct a representation of the investigated problem.

The proposed approach is seen to provide a geometrical and physical characterization of buried objects by considering both frequency-domain aspect-limited data (amplitude and phase of the measured scattered field) and time-domain aspect-limited data [1–3]. Different measurement configurations have been tested (both bistatic and multi-offset setups). Besides, we have also considered the problem of reconstructing the properties of layers embedded in a host medium in order to test the potentialities of the neural network approach to reconstruct the subsoil composition. Again, different measurement configurations have been taken into account.

Numerical results will be presented assessing the capabilities of a neural network approach to exploit electromagnetic data to face the reconstruction of subsurface scenarios. Moreover, we also monitored the computational burden of the approach in order to give some indications on the computational resources requirements. The collected data will serve the purpose of underlining, on the one hand, the advantages and, on the other hand, the limitations of the proposed approach.

REFERENCES

1. Caorsi, S. and P. Gamba, "Electromagnetic detection of dielectric cylinders by a neural network approach," *IEEE Trans. on Geoscience and Remote Sensing*, Vol. 37, 820–827, 1999.
2. Bermani, E., S. Caorsi, and M. Raffetto, "Microwave detection and electromagnetic characterization of cylindrical objects from amplitude-only data by means of neural networks," *IEEE Trans. on Antennas and Propagation*, Vol. 50, 1309–1314, 2002.
3. Caorsi, S. and G. Cevini, "An electromagnetic approach based on neural networks for the GPR investigation of buried cylinders," *IEEE Geoscience and Remote Sensing Letters*, Vol. 2, 3–7, 2005.

Combination Approaches in Neural Classifiers Fusion for Image Classification

K.-S. Chen
National Central University, Taiwan

Y.-C. Tzeng
National United University, Taiwan

In this paper, three different weighting policies: variance reduction technique, rms distance weighting, and average distance weighting, in the use of multiple neural classifiers for image fusion are investigated and compared. The fusion procedures are categorized by their input/output characteristics in five categories: data in data out, data in feature out, feature in feature out, feature in decision out, decision in decision out. It is seen that data fusion are held at different levels and is divided into three levels: raw data level fusion, feature level fusion, and decision level fusion. In this paper, we take the decision level fusion. The performance of each method of combination is evaluated with fusion of multi-polarization SAR and optical images. As for classifier, a single neural network was used to classify both SAR and optical images, although different types of classifier may be used to different data sources. Experimental results show that the classification accuracy is dramatically improved by the proposed method. For weighting method that combines the pre-classification results, it indicates that the rms distance weighting and the average distance weighting perform comparatively and both outperform that of using the variance reduction technique.

Cloud Cover Assessment of Quickbird Imagery Using NEURANUS Software

Z. Bergen
Digital Globe, USA

The success of Cloud Cover Assessment (CCA) of satellite imagery is highly dependent on band coverage. We present a constrained problem where existing arvchive imagery requires assessment in a production environment and band coverage is limited. We utilitize NEURANUS software to build an artificial neural net (ANN) for creating classified images from Quickbird imagery. The advantage of ANNs for production work is that a confidence measure is inherent in the process, and low confidence images may be processed according to existing semi-automated techniques. The resulting thematic layers are translated into polygon coverages in an Oracle Spatial database. In addition, we present a current approach to cloud assessment resulting from the low confidence cases of the ANN.

Retrieving Cloud Information with Neural Network Ensembles

D. G. Loyola R.
German Aerospace Center (DLR), Germany

The global distribution and the physical properties of clouds in the Earth's atmosphere are of great importance for a number of disciplines including weather forecasting, climate change, hydrology and atmospheric chemistry/physics. An increasing number of satellite based sensors measure the backscattered solar light, which in one way or other depends on the clouds properties. The accurate and fast retrieval of clouds information solving this inverse problem is an area of active research. This paper presents a novel approach for retrieving macrophysical cloud information out of the oxygen A-Band using neural network ensembles. The absorption depth in the oxygen A-band in and around 760 nm, depends on the cloud coverage, the cloud-top height and the optical depth of the cloud. Radiative transfer models are used to simulate the oxygen A-band absorption and neural networks are trained to retrieve cloud information using these simulations. The neural networks basically compute the inverse of the radiative transfer model, but this inversion is an ill-posed problem. Therefore an ensemble of distinct inverse solvers (neural networks) is combined to produce a more robust and less sensitive retrieval algorithm. The resulting system is extremely fast, and the retrieved cloud information compares well with that of traditional algorithms and with cloud information obtained from other sensors.

Neural Networks for Tropospheric Profiling from GPS-LEO Radio Occultation

P. Basili[1], **S. Bonafoni**[1], **P. Ciotti**[2], **and E. Maltempi**[1]

[1]University of Perugia, Italy
[2]University of L'Aquila, Italy

Global Positioning System (GPS) receivers placed on a Low-Earth Orbit (LEO) satellite allow the sounding of the Earth's troposphere and ionosphere evaluating the additional delay, due to the refractivity index, of a radio signal when passing through the atmosphere.

This radio occultation technique in recent years has been exploited to obtain profiles of refractivity, temperature, pressure and humidity in the troposphere, and several investigations have demonstrated that the retrieval accuracies are comparable with traditional atmospheric sensing techniques. Even though the atmospheric refractivity profiling by radio occultation is a well-defined problem, care must be taken to analyse factors affecting the occulted signal (multipath, satellite motion etc.) and to compute the temperature, pressure and humidity profiles from the refractivity profile. The accuracy of tropospheric profile estimation is affected by the use of proper boundary conditions and by the presence of water vapour in the atmosphere, that complicates the interpretation of refractivity. In fact the recovery of tropospheric profiles in wet conditions requires knowledge of temperature derived from independent observations (i.e. radiosoundings or ECMWF data).

In this work a retrieval method based on neural networks is proposed to overcome the constraint of temperature profile availability at each GPS occultation. We have trained a neural network with refractivity profiles as input computed from the geometrical occultation parameters of the CHAMP satellite provided by the Information System and Data Center (ISDC) of GeoForschungsZendrum (GFZ) (Potsdam).

The outputs are the dry and wet refractivity profiles obtained from the contemporary ECMWF data. We have considered a feedforward neural networks with the Levenberg-Marquardt algorithm for a fast training. The output decomposition of the wet and dry refractivity allow to obtain temperature, pressure and humidity profiles without the knowledge of the temperature ones as independent source of information.