VENETO REGION CLIMATIC TRENDS IN THE PERIOD 1956-2004

(1)A. Chiaudani, (1)A.Barbi, (1)I.Delillo, A.Cagnati(2), A.Crepaz(2), M.Valt (2)

Environmental Protection and Prevention Agency of Veneto Region (ARPAV)
Regional Department for Territory Security
(1)Meteorological Centre of Teolo, (2)Arabba Avalanche Centre
www.arpa.veneto.it

1. Introduction

Climate behaviour can be entirely appreciated only adopting a scale perspective, from macro to micro and vice-versa, following an approach defined many years ago by "classical" climatology - e.g.: macro, meso and microclimatic studies carried out by in Germany by the Koeppen's school and particularly by Rudolf Geiger (1927). Examples of scale relations are given by (i) changes in land use (e.g.: substitution of crop fields with forests, disappearance of ice coverage, etc.) which give microscale consequences on surface radiation and energy balance with effects on surface air temperature and humidity, (ii) changes in frequency and persistence of mesoscale weather patterns (e.g.: foehn, anticyclonic ridges, troughs, etc.) with consequences in cloud coverage, short and long wave radiation, precipitation, air temperature, relative humidity, wind speed, etc. and (iii) changes in frequency and persistence of macroscale patterns (e.g.: monsoons, Hadley cells, NAO, PDO El Nino and so on) with consequences on wave radiation, precipitation, air temperature, relative humidity, wind speed, etc.

The scale perspective is also crucial for biometeorology and bioclimatology, because humans and most of the leaving beings of our planet live in the so called "boundary layer", which climate is the result of the interactions of the atmosphere with the surface of the planet *(Mariani, 2002).*

A clear distinction among phenomena acting at different scales and the formalisation of their quantitative relations is made difficult by the complex links existing among scales *(Zichichi, 1993)* with macroscale acting on mesoscale and microscale phenomena and, vice-versa, microscale acting on meso and macroscale. In particular, it is quite difficult to evaluate how land use changes affect boudary layer climate and how the latter dialogs with the free atmosphere and consequently affects the global climate *(Adegoke et al., 2007).* Nevertheless, the increasing availability of global analyses obtained from surface global networks or by remote sensing justify the need of more detailed studies at meso and microscale carried out on the base of available time series. These evaluations are the background of this paper, which presents some results regarding the mesoscale climatic analysis in Veneto Region and the relations with some macroscale features of circulation above Europe. This approach was made possible by the availability of high resolution data sets of temperature (max and min) and precipitation belonging to the 1956-2004 period.

Crucial for this work has also been the definition of a methodology useful to describe climatic variability and change on the base of physical (temperature, precipitation, reference crop evapotranspiration, circulation indexes) and biological determinants (crop behaviour and, more specifically, phenological phases).

A widely accepted approach to past variability of climatic variables is founded on linear interpolation methods. In this case this approach has been integrated by techniques of discontinuity analysis *(Seidel and Lanzante, 2003)* to put in evidence that an important aspect of climate evolution is represented by abrupt changes *(Sneyers et al.,1993)* with different climatic phases separated by break-points *(Bryson,1974; Lockwood,2001).* These breakpoints show one of the most characteristic features of the climatic system which is a turbulent, non linear system affected by sudden transitions from a state to another *(Lorenz, 1963; Peixoto and Oort, 1992).* These sudden variations have immediate impacts on the meteorological variables monitored at ground level (radiation, temperature, pluviometric regime etc..) *(Mariani, 2006).*

A statistical tool useful to identify sudden climatic transitions is represented by the change – point analysis. This analysis permits the identification of transitions from a climatic homogeneous phase to a new one, separating stationary sub-periods ("climatic normals"), defined by their average values.

In particular for the Veneto Region both aspects of static climatology (spatial and temporal behaviour of surface meteorological variables) and dynamic climatology (relations between macroscale circulation patterns and meteorological phenomena at surface) have been investigated. By the dynamic point of view the correlation between macroscale circulation indexes (e.g. North Atlantic Oscillation Index) and surface meteorological variables gauged for Veneto region on the period 1956-2004 was analysed. Moreover the link between atmospheric variables and biological variables (phenology of cultivated and spontaneous plants) was investigated. The availability of biological data for vegetation (e.g.: crop production, date of appearance of specific phenological phases) is an interesting proxy because green plants colonise the main part of the terrestrial boundary layers and their phenological and productive behaviour is driven by climatic variables (solar radiation, precipitation, air temperature, etc.).

2. Some Results

With reference to the meteorological variables monitored from 9 temperature and 49 rain stations belonging to the "*Ex Hydrographic service"* during the 1956-2004, precipitation showed a significant negative trend only in winter season, instead temperatures show a sensible increase in all seasons, especially during summer and winter for maximum temperatures, and summer for minimum temperatures. Also derived variables as Reference Evapotranspiration and the Hydroclimatic Balance (Prec. - ET0), useful to elaborate adaptation strategies for example in agriculture economic field, are strongly influenced by temperature trends.

The time-scale analysis of the different atmospheric variables highlights an abrupt climatic change (breakpoint) that has influenced the climatology of our Region. It is important to point out that the Veneto regional analysis is supported by homologous results and data at European level even if the local characteristics of territory (e.g. Alpine relief, pre-alpine lakes) are important factors of perturbation. Anyway, the results relative to the almost 50 years long period will be improved as soon as more complete historical data set will be available.

The change of climatic phase individuated with the discontinuity analysis *(BP test, Bai and Perron, 1998; Zeileis et al., 2003) ,* regarding min, max temperatures and winter precipitation, occurs in Veneto Region around the end of the 80'. This analysis also gives us the chance to individuate the sub periods and the last "climatic normal" that will be the reference one useful to elaborate future scenarios and elaborate decisions (adaptation strategies). This last homogeneous sub-period subsequent the 80' break-point presents the following average characteristics referred to the previous period:

- annual min. temp. 0.9 °C higher
- annual max. temp. 1.5 °C higher
- summer max. temp. 1.9 °C higher
- winter max. temp. 1.4°C higher
- winter prec. 78 mm lower

Correlated direct effects of this situation are the decrease of seasonal snow height and snow cover duration, especially at middle and low altitude *(Valt et alii, 2008)*.

Analyzing the data of four stations at different altitude stations on the Dolomites area (Lago Cavia, Andraz, Cortina d'Ampezzo, Ghirlo), snow height, both maximum and average values, and snow cover duration also decreased during the last decade of the past century. The most significant change during the period 1991/2004 is the annual snow cover duration (-18 days/-14%, compared to 1961-90 period) and the winter snow height (-39% for average snow height and -35% for maximum height compared to 1961-90 period). Due to higher temperatures and snowfall decrease, little

Dolomites' glaciers displayed a significant mass loss in the last twenty years. Since 1910 to 2004 the area of the most important Dolomites dramatically decreased (-44.7%) with an acceleration since 1980, when it decreased from 6.727 km^2 to 5.126 km^2 (-23.8%). Some little glaciers (Cristallino, Eastern Antelao,…) disappeared, while in some other areas it decreased of about 80% (e.g. Fradusta). On Marmolada, the most important Dolomitic glacier, ice front moved back for 434 m in altitude since 1924 to 2004. Moving back was almost continuous during the last century, even if during '80s there was a delay due to important snowfall during winter season.

From the agricultural and territorial point of view, comes to light a critical situation in the centre-southern plane (Polesine), where, after the break-point of the end of the 80', the reference evapotranspiration increases of 29 mm and hydroclimatic deficit of 56mm during summer season. This situation is made worse by the fact that in this area we have the most unfavourable annual average evapotranspiration and Hydroclimatic deficit. Other neighbour regions show similar trends and break-points almost coincident, strengthening the result obtained for Veneto Region.

Near the afore said information, it is important to consider the phenological proxy data information of cultivated crops and spontaneous plants at Italian and European level. Also these data put in evidence the conclusion elaborated in Veneto Region and show a substantial coincidence in the climatic and phenological breakpoints of the 80' at Italian and European level.

The dynamic climatology investigation referred to 1956-2004 period has given the chance to individuate significant correlations between the climatic variability at regional level and macroscale circulation indexes. For example the positive phase of NAO correspond in Veneto to a decrease of the winter precipitation and to a corresponding increase of winter maximum temperature as individuated by other authors at continental scale in larger European areas and Alpine sites *(Werner et al., 2000; Quadrelli et al., 2001; Ciccarelli et al. 2007).*

These evaluations show the how crucial is mid-latitudes circulation in order to determine the features of Veneto climate and confirms that it is necessary to adopt a perspective founded on dynamic climatology (e.g.: study of macro and mesoscale circulation patterns and their effect on local features of weather, study of Teleconnections). This perspective could also be useful to produce effective seasonal forecasts for a territory which is affected by some strong mesoclimatic effects produced for example by the presence of the Alps.

The results of this study show some operational rules referred to adaptation strategies; for example in agriculture field it could be necessary to optimise the management of water with long period policies and to promote the adoption of winter crops (barley, winter wheat, durum wheat) which minimise the risk of high temperature and aridity or of summer crops tolerant to water stress (e.g.: sorghum, sunflower).

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