1. The remote sensors

1.1 The Meteosat

The European Space Agency (ESA) initially launched a geostationary satellite in 1977 that orbited at 36.000 km from the earth's surface at 0° lat S and at 0° lon. The satellite can see Europe, Africa and the Atlantic Ocean. Thereafter, other Meteosats have been launched carrying a renewed sensor package. The data used in the present work come from Meteosat 7 that carries a Visibile and Infrared Spin Scan Radiometer (VISSR), with four channels and three high resolution wave lenghts: Visible/near infrared (VIS) from 0.4 to 1.1 mm, thermic infrared (IR) from 10.5 to 12.5 mm and water vapour absorption band (WV) from 5.7 to 7.1 mm.

The nominal image resolution at nadir is 2.5 km for VIS and 5 km for the other sensors. At 45° N the resolution goes down to 3.5 and 7 km respectively. Data is available every half an hour.

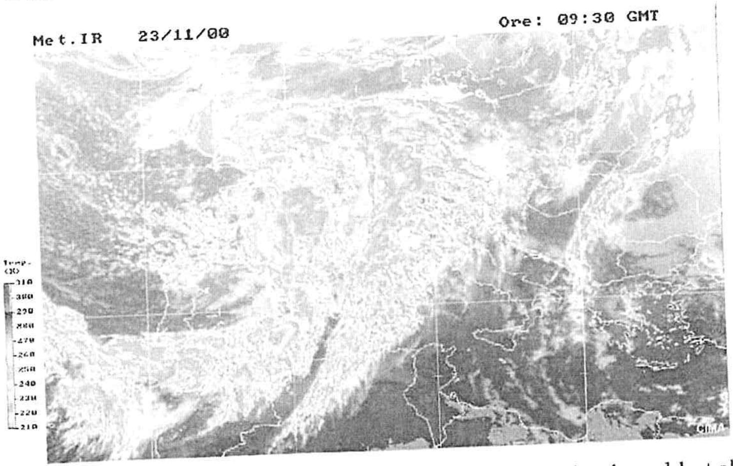

Figure 1. IR band image from Meteosat filtered so as to pin point the coldest cloud tops.

The images received regularly from the PDUS primary station by *Centro Interuniversitario di ricerca in Monitoraggio Ambientale* (CIMA), are cut over Europe (from 30° to 60° N in latitude and from 20° W to 30° E in longitude) and transformed so to refer to terrestrial coordinates allowing further reference to land marks. The three high-resolution bands of VISSR can only measure cloud top radiance emission since the sensed radiation is absorbed by water vapor making clouds opaque. Many techniques have been developed to use cloud top radiance temperature to reveal the precipitation intensity below cloud top but results are still very unreliable due to the difficulty encountered in cloud type interpretation. This work uses IR radiance temperature only to determine the overall movement and features of cloud formation without involving any rainfall estimate. The perceptive color filter is used only to pinpoint the highest cloud tops and cut out the less significant background (below 253 K). An example of such a filter can be seen in Fig. 1, where it is possible to notice some very high cloud tops that could be of convective origin.

1.2 The Defence Meteorological Satellite Program

The satellite-based retrieval of surface rainfall rates turned out to be a reliable outcome of the satellite-based measurements on June 1987 when the first Special Sensor Microwave / Imager (SSM/I) was launched onboard the polar orbiting F–8 satellite of the Defense Meteorological Satellite Program (DMSP). It was continued by the launch of F–10 in December 1990, F–11 in November 1991, F–12 in August 1994, F–13 in March 1995, F-14 in April 1997, and F-15 in December 1999. The sensor measures vertically and horizontally polarized radiances at 19.35, 37, and 85.5 GHz and vertically polarized radiances at 22.235 GHz emitted from below by scanning conically at a nadir angle of 45°. The spatial resolution of the footprints decreases with frequency from about 13 km x 15 km at 85.5 GHz to 43 km x 69 km at 19.35 GHz. Microwave radiometry from space has great potential for estimating rainfall because the upwelling radiation over the cloud is responsive to precipitation microphysics.

Many SSM/I-based retrieval algorithms have been proposed ranging from simple regressive formulas to complex physical profile-based approaches (Smith et al., 1998). The profile-based rainfall retrieval algorithm adopted in this paper raised as a consequence of a series of theoretical studies (i.e. Mugnai et al., 1993 and Smith et al, 1994). It is based on the use of cloud-radiation databases, whose cloud portion is generated by means of time dependent, three-dimensional cloud/mesoscale model, specifically the University of Wisconsin –Numerical Model System (NMS) developed by Prof. G.J.Tripoli that explicitly produces six species of hydrometeors (cloud drops, rain drops, graupel particles, pristine ice crystals, ice aggregates and snowflakes) as a function of space and time. The corresponding radiation database is generated by using these cloud model data as an input to a radiative transfer model. Making use of this cloud-radiation database, the multi-frequency SSM/I measurements are associated to simulated cloud structures and then to surface rainfall rates.

1.3 The Tropical Rainfall Measuring Mission (TRMM)

The TRMM was developed in joint venture among US NASA and Japanese NASDA. The satellite was launched in 1997 and carries sensors aimed at the study of precipitation fields and sensible and latent heat exchange over tropical and subtropical regions. The satellite orbits at about 350 km from earth with an inclination of 35° with respect to the equator.

The precipitation sensors are:

Microwave radiometer (TMI) with the five frequencies of 10.7, 19.4, 21.3, 37 and 85.5 GHz (dual polarized except for 21.3 V-only) that have a resolution going from 5 to 41 km with a 790 km. swath;

Precipitation Radar (PR) at 13.8 GHz, that is the first radar to be carried by a satellite, with a footprint of 4.3 km, a vertical resolution of 0.25 km and a 215 km swath;

Visible Infrared Scanner (VIRS) at 5 different wave lengths (0.63, 1.6, 3.75, 10.8 e 12 mm) with nadir resolution of 2 km and ground mark of 720 km.

TRMM data are elaborated in real time by the TRMM Science Data and Information System (TSDIS). The resulting official TRMM products are freely distributed by the Distributed Active Archive Center (DAAC) at Goddard Space Flight Center. TRMM flies in a quasi equatorial orbit so that it covers only tropical regions (Fig. 2), while the polar SSM/I orbit allows to observe almost the whole globe.

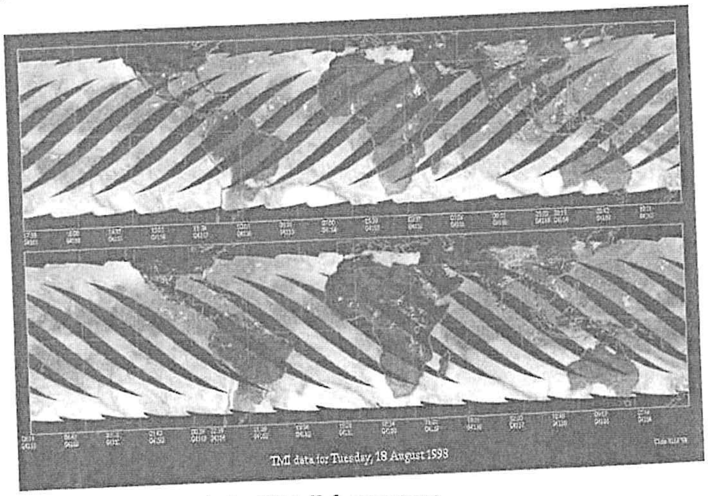

Figure 2. Example of the daily TRMM coverage

1.4 The Meteorological Radar

Rainfall estimation is the most known radar quantitative meteorological measurement and it is typically obtained by using an appropriate reflectivity-rainfall (Z-R) relationship. Recently, the rain rate estimation has been improved using polarimetric measurements.

Reliable rainfall radar estimations can be performed over a square grid having a resolution of 1x1 km and covering about 50000 km^2. Temporal sampling can be get in 5-10 minutes.