Quantitative Precipitation Estimation from MultiSensor Observations

The general framework

Quantitative Precipitation Estimates (QPE) is a crucial information for improving the forecast skill of models both developed for flood forecasting purposes and for forest fire predictions.
Rainfall is characterised by a high degree of variability at all scales in both time and space. This can be formalised in the power-law expressions typical of a fractal quantity. A consequence is that there is no minimum scale below which the rainfall intensity distribution becomes smooth and point measurements can be taken as representative of larger areas.
Time structure analysis of ground precipitation shows the typical behaviour of a noise signal: not random noise, but noise with a memory. Such structure means that the phenomenon (system) moves between events (rainfall) in a complex way. In addition to this, spectral analysis and fractal analyses show typical fractal characteristics, i.e. infinite repetition at both small and large scales. This characteristic is not critical for time continuous integrated observations like those made by classical direct instruments (rain gauges), but it leads to serious limits for instantaneous time sampling observations like those which can be retrieved by remote sensing systems using electromagnetic radiation. In this case we have the problem of the error (underestimation) in reconstructing the total amount of precipitation at ground.
Raingauges measure directly the rainfall at the ground with very high temporal resolution but provide very coarse information (if combined in a network) about spatial distribution of rainfall structures. On the other hand ground-based meteorological radar provide reliable estimates of spatial structure of precipitation field but have larger uncertainties about QPE since the estimates derive for indirect measurements and do not measure continuously in time. Satellite measurements (e.g. HSAF PR-OBS 5 – accumulated rainfall) can guarantee a very good spatial coverage but with very low reliability about QPE and with a temporal resolution that ranges from 3h to 24 hours.
In-situ networks are generally preferred operationally, because the accuracy of gauge observations is still considered to be the best and most reliable. Radar data, preferably in combination with gauge information, are considered important for obtaining a better idea of the spatial distribution of precipitation. The value of satellite data will be highest for areas for which no radar data are available, and where the network of rain gauges is sparse or not representative. Most importantly, ground-based networks do not cover precipitation occurring over sea. Hydrometeorologists in the Mediterranean countries have emphasized the need for precipitation information overseas, for the purposes of nowcasting. Secondly, ground-based networks have problems in observing precipitation in mountainous areas. Satellite observations can help fill these two types of gaps, provided that they are of sufficient and reliable accuracy. Also there is a need for some redundancy in precipitation observations. For civil protection application gaps in operational networks at critical moments due to e.g. instrument failure cannot be afforded. In severe weather conditions and during floods, frequently ground measurements are not available due to damage of equipment is considered to be very useful as a means to assess their quality. For example, at large distances from a radar site, the radar beam may be at too high elevation to detect precipitating low clouds, or the beam may be attenuated by nearby precipitation; likewise, rain gauges may be faulty for a variety of reasons. Satellite precipitation in such cases can be used to aid quality control of ground-based data. The high quality estimates of both absolute values of precipitation and of its variability in time and space is crucial both for research and operational purposes.
Satellite precipitation observations are presently practically not used in operational hydrology (with some exceptions), but this is expected to change once products become available on an operational basis which either are comparable in accuracy and resolution to ground-based observations, or which clearly fill gaps in the existing networks.
To fully meet the requirements of rainfall mapping for civil protection applications, it is thus necessary to combine the observation deriving from different measurement techniques. A combined approach that uses all available sensors is the most promising research direction for estimation of high resolution precipitation fields.

Progress beyond the state of the art

CIMA Research Foundation manage, on behalf of Italian Civil Protection, a large database that contains data from a network of about 2000 raingauges, a meteorological radar network (more than 15 C-band doppler radar and X-band polarimetric systems) and satellite data deriving from MSG and HSAF platform.

The PhD candidate is expected to:

1) Analyze data deriving from different measurement available in order to define their characteristics and uncertainties;
2) Develop a framework to combine data from different sensor in order to deliver a multisensor Quantitative Precipitation Estimate and its uncertainty.
3) Evaluate the reliability of QPE obtained when ground measurements are unavailable and/or of poor quality.