URBAN CLIMATOLOGICAL PARAMETERS DERIVED FROM MULTISENSOR SATELLITE DATA OF ERS-1 AND LANDSAT-TM

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ABSTRACT

The urban climate is a locally limited man-made climate modification, which becomes more and more important since urban population is increasing and urban agglomerations are growing. A more striking fact is that this climate modification directly influences people's living and working sphere. In Germany 32 % of the total population is living in 73 cities with more than 100.000 inhabitants. Including the huge amount of smaller cities of 10.000 to 50.000 inhabitants one can expects that 60 to 75 % of the Central European population lives in urbanised areas. In many European countries there is a growing awareness on urban climate which leads to legal controls and the implementation of aspects of urban climate into planning strategies. By means of high resolution satellite data of ERS-1 and LANDSAT-TM many climatologically relevant parameters can be elaborated and can be used as input or validation data for mesoscale models of wind fields, ventilation and human bioclimate like cold stress in winter respectively heat stress in summer. Examples are presented from two testsites in the Upper Rhine Valley for the computation of aerodynamic roughness from ERS-1 data, a very detailed landuse classification with special emphasis to urban classes by using a multi-sensor approach with ERS-1 and LANDSAT-TM as well as meteorological informations of surface broadband albedo, surface temperature and net radiation from LANDSAT-TM.

1. INTRODUCTION

Planning our environment - be it urban or rural - means an anthropogenic impact on natural or semi-natural conditions. In urban agglomerations man's activities result in a complete and not invertible change of various environmental factors like climate, hydrology, vegetation, biodiversity, air chemistry etc. These changes directly influence the living and working spheres of mankind. Up to now there is an increasing pressure on the urbanized regions not only in industrial nations but also in developing countries. Keywords to be mentioned are urbanization, rural exodus, industrialization and urban heat island. Depending on the relevant environmental laws, which differ among the countries, urban planning demands for improved and more detailed analysis of the urban climate in scales which can only be carried out by using sophisticated numerical models and simulations. Besides many basic research needs to understand the complexity of the climate system, to an increasing extend climate models need a lot of spatially distributed data with the best spatial resolution available. This is both the challenge and the potential for remote sensing to make these data available to solve the important questions and to elaborate expertise of practical applications. Data extracted from remotely sensed data are characterized by their

- high spatial resolution,
- spatial availability over large areas,
- physical nature,
- temporal homogeneity even across national boundaries and
- potential easily to be updated.

2. MULTISENSOR APPROACH

Within the ERS-1 Pilot Study ERSCLiP (ERS based Climate Project) satellite data from ERS-1 and Landsat-TM are used to extract climatological parameters relevant for urban climate studies. The study was carried out at two testsites in the Southern Upper Rhine Valley at Freiburg/FRG and Basel/Switzerland. ERSCLiP was closely connected to the running climate project REKLIP, an international cross-border regional climate project (Parlow 1992, 1995; Fiedler 1992; IGBP 1993).

The conceptional framework of the multisensor analysis was to compute primary data sets of

Primary dataset	Sensor used
Aerodynamic roughness length	ERS-1
Landuse	ERS-1, Landsat-TM
Surface albedo	Landsat-TM
Surface temperature	Landsat-TM

Proceedings of the Second ERS Applications Workshop, London, UK, 6–8 December 1995 (ESA SP-383, February 1996)

In a further step a second set of derived data is extracted

- All wave net radiation which is the key factor of energy budget,
- Storage heat flux and
- Available energy.

The various resulting data can be integrated in numerical models like

- windfield models or
- bioclimatic models to compute heat stress conditions during summer.

An example of ERS-1 and Landsat-TM composites of the Basel testsites, which were used as input data for further analysis, are presented in figures 1 and 2. For the multitemporal ERS-1 composite data from 7th June 1992, 5th May 1992 and 4th September 1991 are used. The Landsat-TM composite is from 11th July 1991. So a temporal correspondence of multisensor data is guaranteed.

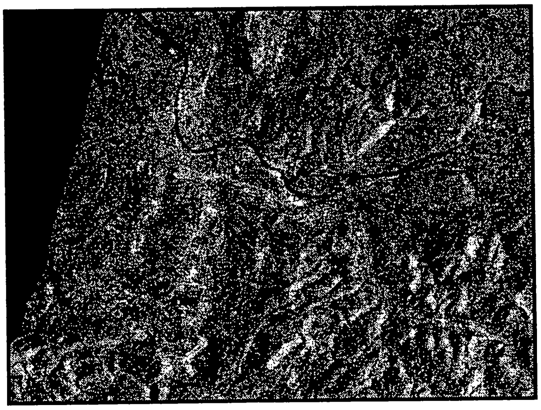

Fig. 1 : Multitemporal ERS-1 Composite Basel

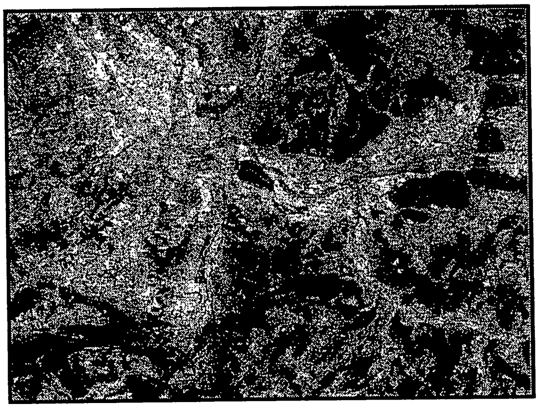

Fig. 2 : Multispectral Landsat-TM Composite Basel

For classification purposes a principal component analysis (PCA) was carried out with ERS-1 data from 22nd of May 1991 and Landsat-TM data from 11th July 1991. So a temporal correspondence of satellite data was guaranteed. No data were available in the top right corner of ERS-1 due to frame limitation. Therefore this area is only represented by Landsat-TM data and the information growth can easily be detected. Information of ERS-1 is nearly completely stored in the 3rd PC which increases the variance by 10 %. PCs 1-3 have a total variance of 98 %. Fig. 3 shows the RGB-composite of ERS-1 and Landsat-TM.

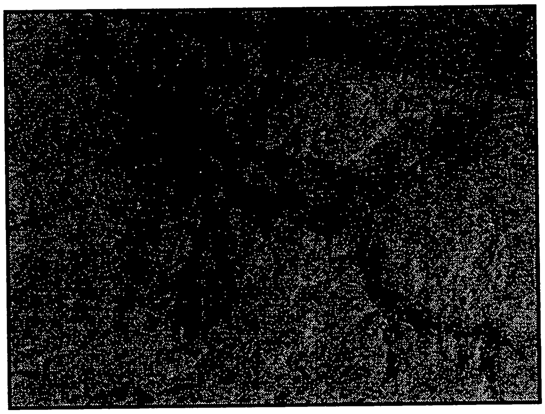

Fig. 3: Principle component RGB-composite of ERS-1 and Landsat-TM data fusion. Red colours correspond to ERS-1 information.

3. URBAN LANDUSE CLASSIFICATION

A detailed landuse classification of the testsite Basel was carried out by combining data from multitemporal ERS-1 and Landsat-TM. A total of 35 classes could be separated with 17 urban/industrial classes. The accuracy of the classification was 90.5 % and the improvement of the multisensor classification versus a pure Landsat-TM approach was +5 % in general and up to +7 % for some urban classes. Landsat-TM data was corrected from terrain induced illumination effects (Parlow 1996a). Fig. 4 shows the result of the landuse classification of the urban agglomeration of Basel/Switzerland. The accuracy and spatial resolution is appropriate enough to be applied for several planning purposes and climate analysis studies of the local authorities. Class definition was made according to the urban climatological relevance and the needs and definitions of the planning authorities (Scherer et al. 1996b, Beha et al. 1996). The integration of ERS-1 data helped especially to separate the various settlement types and industrial areas, because their structural physiognomy was better detected from ERS-1 as compared to Landsat-TM. Urban classes are presented in red and orange colours, forests in green, water in blue and arable land in brown colours.

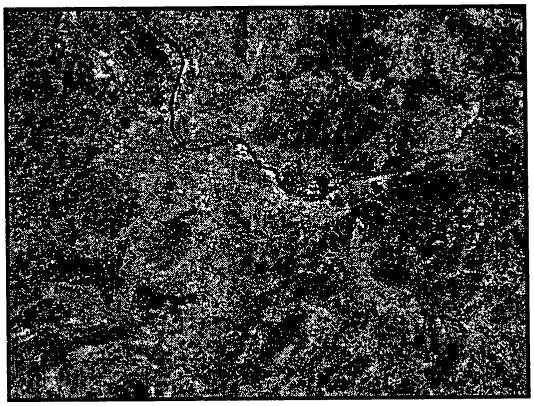

Fig. 4: Multisensor landuse classification of the urban agglomeration of Basel

4. METEOROLOGICAL DATA LAYERS DERIVED FROM LANDSAT-TM

Landsat-TM data was used in combination with numerical radiation models to compute various meteorological radiation fields which are relevant to urban climate. The methodological steps are summarized briefly. For more detailed information it is referred to Parlow (1996b). From illumination corrected optical data surface solar albedo was calculated. A digital terrain model gave the input parameters to compute solar irradiance with respect to inclined surfaces in mountainous areas. An arithmetic combination of albedo times solar irradiance results in the shortwave net radiation. After correction of atmospheric influences channel 6 of Landsat-TM corresponds to surface temperature and terrestrial longwave emission. By using vertical temperature and humidity profiles from weather station the atmospheric counter radiation can be parametrized quiet easily. Finally spatially distributed shortwave and longwave radiation fluxes are existing and the net radiation can be calculated. Fig. 5 and 6 give an information of albedo, shortwave radiation balance, surface temperature and all wave net radiation.

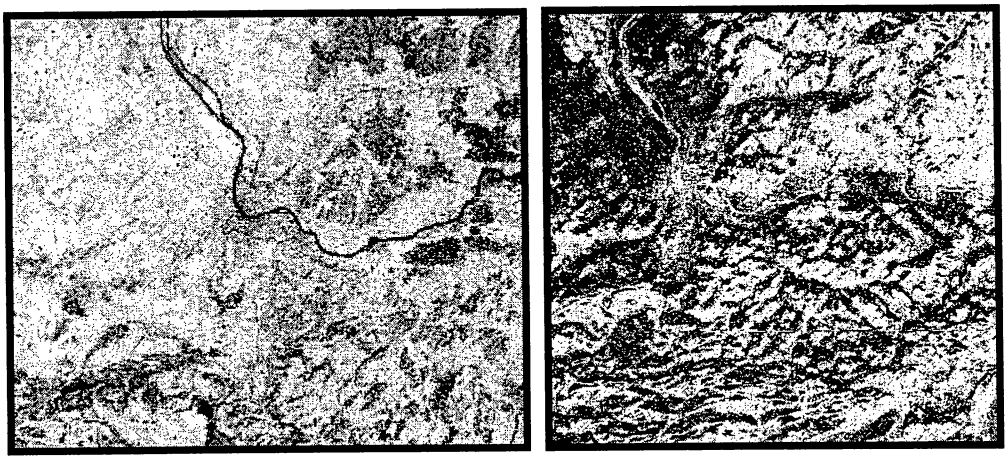

Fig. 5 : Surface albedo (left) and shortwave net radiation (right) of the agglomeration of Basel/Switzerland computed from Landsat-TM data and numerical radiation models for the time of Landsat-TM overflight.

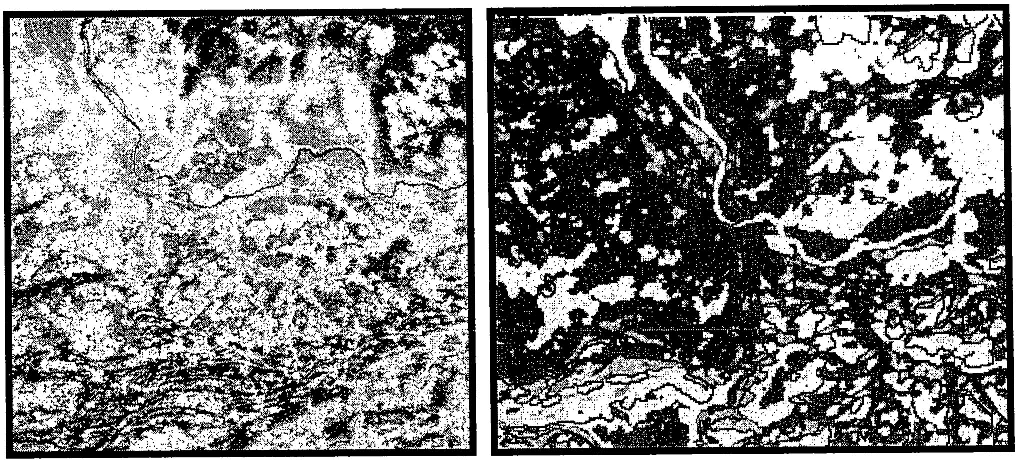

Fig. 6 : Surface temperature (left) and net radiation (right) of the agglomeration of Basel/Switzerland computed from Landsat-TM data and numerical radiation models for the time of Landsat-TM overflight.

5. AERODYNAMIC ROUGHNESS LENGTH FROM ERS-1 DATA

Modeling of wind fields is a standard application of urban climatology. The flow pattern of wind is an important information for the propagation of air pollutants, for temperature distribution and bioclimatic parameters like heat stress. Wind speed and turbulence structure is influenced directly by aerodynamic surface roughness. In micrometeorology this parameter is called aerodynamic roughness length (z_0). It determines the vertical wind profile. Aerodynamic roughness length was derived from ERS-1 data for non-forested areas in the Basel testsite. Roughness lengths of forests could not be calculated form SAR data because normally they have a high roughness length but low digital counts in SAR imagery. So forests had to be treated separately. Fig. 7 shows aerodynamic roughness length. For further methodological informations it is referred to Scherer et al. 1996a.

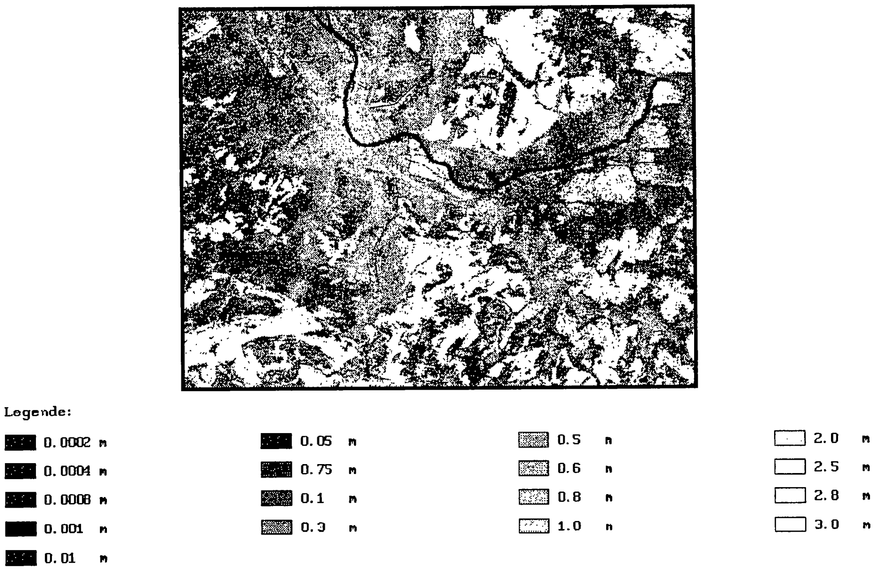

Fig. 7 : Aerodynamic roughness length z_0 of the city of Basel derived from ERS-1 data

The vertical wind profile can be written as:

$$\bar{u}(z) = \frac{u_*}{k} \ln \frac{(z-d)}{z_0}$$

with $u(z)$ = windspeed at height z
u_* = friction velocity
k = von Karman's constant (0.4)
z = height
d = zero plane displacement
z_0 = aerodynamic roughness length

The application of a windfield model for planning purposes is shown in fig. 8. Using the model FITNAH the local wind field was computed for the ERSCLiP testsite Freiburg/FRG. Results of windfield models can be improved if better input data of aerodynamic roughness, landuse and radiation fluxes are made available. Satellite data have the potential to fill this gap.

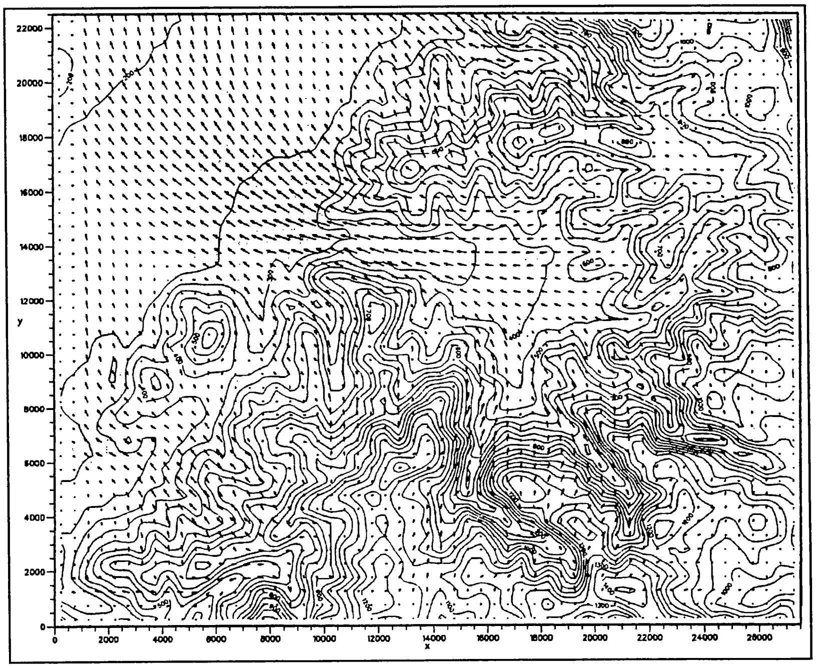

Fig. 8 : Result of a windfield modeling of ERSCLiP testsite Freiburg/FRG during nighttime. A local mountain-valley wind system is blowing from the Black Forest to the Upper Rhine Lowland (top left). .

6. MODELING OF URBAN HEAT STRESS

In many European countries bioclimate maps are an important tool for planning. The thermal influence on man which results e.g. in summer heat stress is an extremely complex meteorological process. Heat stress is an important parameter in medicine especially during rehabilitation of people with coronar deseases. During days with heat stress the mortality rate increases significantly.

Heat stress is impossible to be measured because in addition to air temperature there are a lot of other variables like air humidity, wind speed, net radiation and the human metabolism rate which have to be considered. The only possibility to compute and map heat stress conditions is by using bioclimate models. The model used computes the total energy budget of man including heat production as a result of his acticity, his heat release due to transpiration etc. and the insulation effects of the cloths. The model again needs a variety of spatially distributed input data like landuse with its vertical structure, aerodynamic roughness, terrain conditions etc. The German Weather Service created a sophisticated bioclimate model to compute summer heat stress and winter cold stress, taking the variables mentioned into account (Jendritzky 1991; 1992). This model was used to compute the number of days with heat stress conditions during summer for the city of Basel (Jendritzky 1995). Fig. 9 shows the result of modeling of the days with heat stress during summer for the study area of Basel. Comparing the image with fig. 4 the influence of urban landuse can be seen. In the city of Basel several urban heat islands can be identified and correlated to densely built-up areas.

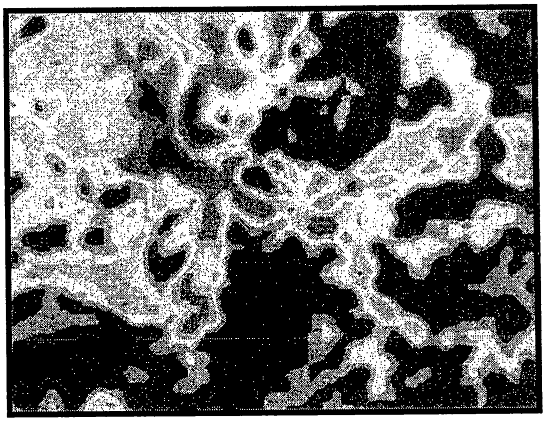

Fig. 9 : Number of days with heat stress during summer for Basel/Switzerland

7. CONCLUSIONS

Data from high resolution satellites like ERS-1 have a enormous potential to be used in urban climatological studies. The fusion of microwave data of ERS-1 data with optical data from Landsat-TM offers a lot of possibilities to elaborate spatially distributed data sets which directly contribute to urban climate or can be used as input variables of mesoscale models. The spatial resolution is appropriate enough that both data and results can be integrated in planning activities of the official authorities and other applications. The pilot study ERSCLiP successfully showed the potentials of ERS-1 and Landsat-TM data in the study areas of Basel/Switzerland and Freiburg/FRG.

8. REFERENCES

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