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SPACE RESEARCH IN BELGIUM

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INTRODUCTION

This report has been prepared on behalf of the Belgian National Committee on Space Research of the Académie Royale de Belgique and the Koninklijke Academie van België, for presentation at the XXVIIth Plenary Meeting of the Scientific Committee on Space Research (COSPAR) at ESPOO, Finland, 18-29 July 1988.

It summarizes basic and applied space research undertaken by Belgian teams in various research institutes and universities. The names of these institutions are listed in Appendix of this report. The work of these groups is made possible by the funds almost entirely supplied by the government.

A. BELGIAN INSTITUTE FOR SPACE AERONOMY

1. EURECA-ORA PROJECT

The ORA (Occultation Radiometer) project is a collaborative program between the Belgian Institute for Space Aeronomy and the Department of Atmospheric Physics of the University of Oxford. The major scientific objective of this program is the determination of minor constituents (O_3 , NO_2 , H_2O and CO_2) and aerosols in the upper atmosphere through occultation measurements in different wavelength domains from the European satellite EURECA 1. The ORA instrument has been accepted by ESA for the first flight of EURECA, which will be launched by the shuttle. Due to the shuttle accident, the launching has been postponed and is now tentatively scheduled in 1990.

The contribution of the Oxford team consists of the development of the infrared optical part of the instrument.

The Belgian Institute for Space Aeronomy is responsible for the management, the mechanical structure, the optics for the visible wavelengths (8 optical modules with interference filters), the complete electronics, the software and the additional technical studies (thermal analysis and mechanical models). The activities concerning these points are summarized briefly hereafter.

- The Engineering model (EM) of the mechanical structure has now been completed, based on a mathematical mechanical model. Previous problems encountered with the prototype structure during vibration tests will hopefully be avoided by special surface treatments of the mounting contact surfaces (tungsten carbide plasma spray). A final vibration test including the total EM of the complete instrument is foreseen in 1988.

- Final EM models of both the visible and infrared modules of the optics have been realized and tested to a full extent. A special stimuli box has been designed and manufactured to allow a final check before flight.
- The EM of the electronic boxes have been completed, along with a great part of the associated software. PTF (Payload test facility) tests to check the compatibility with the EURECA carrier hard- and software have been executed in MBB Bremen and were successful.
- A thermal mathematical model has been developed to predict the thermal behavior of the instrument in flight. As a result of this heat-pipes have been designed and constructed to assure a safe thermal conduct of the payload.

Presently the EM of the radiometer is completely assembled and the final qualification tests (vibration, thermal vacuum and EMC) will be finalized in the first half of 1988.

A set up for calibration of the flight model (FM) of the ORA radiometer is under preparation.

In the meanwhile the construction of some parts of the FM has started. Delivery of the FM is foreseen by the end of 1988.

2. GRILLE SPECTROMETER

The grille spectrometer was successfully flown during the first Spacelab mission in November 1983. The second flight was planned for August 1986 and the instrument was already mounted on the EOM earth observation payload when the Challenger accident in January 1986 led NASA to replace the earth observation missions (EOM) by the ATLAS program (Atmospheric and Terrestrial Laboratory in Space). In this program the grille spectrometer is only scheduled for the first flight, which will not be earlier than the middle of 1990, and which will be

without a pressurized module, requesting thus changes in the configuration of the payload compared to Spacelab 1 and to EOM.

These modifications are currently under study. The scientific program will remain the same as defined for the EOM flight and takes into account the Spacelab 1 experience, emphasizing latitude variations of atmospheric composition.

The interpretation of the data of the first flight has been entirely remade using an automatic fitting of the observation with synthetic spectra, this technique was highly successful for all gases : CO, CO₂, CH₄, NO, NO₂, N₂O, H₂O. However, in the case of O₃, discrepancies between the observed and calculated results lead to wide uncertainties. This can be either attributed to the present state of knowledge of the ozone spectrum, instrumental noise in the 9.6 μm window or even to a misunderstanding of the ozone absorption processes in the mesosphere.

The next flight will address these issues using an extended set of spectral windows together with upper atmospheric studies of infrared emissions which could not be performed during the Spacelab 1 flight due to a failure of the Spacelab horizon sensor. The grille spectrometer activity will then be continued after the ATLAS 1 flight, if requested by Nasa, either in the ATLAS serie, or with a modernized and simplified model on other space platforms.

As part of the American Space Station Programme, a space platform could be set on a heliosynchronous orbit and the opportunity to conduct atmospheric measurements by absorption spectrometry from such an orbit cannot be neglected. The possibilities for occultation and the resulting latitude coverage of the observations have been analysed.

3. SOLAR ULTRAVIOLET IRRADIANCE MEASUREMENTS

New solar irradiance values obtained between 200 and 360 nm with

an accuracy of $\pm 5.2\%$ at 200 nm and $\pm 4.0\%$ at 300 nm during the Spacelab 1 mission have been published by Labs et al. (1987). This experiment has been selected by ESA to be flown on-board the EURECA-1 project, scheduled in 1990 for a six months mission. The platform will be recovered after the end of the mission. The main purpose of this observation will be the study of short term variations at the maximum of solar activity, in the ultraviolet. The same instrument has also been selected by NASA in the frame of the ATLAS programme, for a one week mission using the Space Shuttle. This flight will give one of the first opportunities (with UARS) to compare two different solar spectrometers dedicated for solar ultraviolet irradiance measurements, at the same time and on the same platform. The main purpose is to measure the absolute value of solar ultraviolet irradiance at the maximum of solar cycle 22. The flight is currently scheduled for 1991.

4. OZONE ASSESSMENT REPORTS

The WMO-NASA report on "Atmospheric Ozone, 1985" has been published in 1986 with contributions of Belgian scientists to several sections (e.g. Radiative Processes, Frederick et al., 1986).

A new NASA-WMO Ozone Trends Panel has been set up in 1987 in order to solve the controversy about ozone trend observations as those deduced by means of the SBUV spectrometer on board satellite Nimbus 7. The participation of P.C. Simon (IASB) to the "satellite instrument calibration and stability" working group has to be mentioned. The report of this panel will be published in 1988.

5. STUDY OF THE ION COMPOSITION OF THE STRATOSPHERE AND RELATED TRACE

GAS DETECTION

The objective of this program is to determine through in situ measurements with balloon-borne ion mass spectrometers positive and negative ion composition of the stratosphere between 20 and 45 km. The

final goal of these measurements is to obtain a better understanding of the ion-molecule chemistry of the stratosphere and to deduce concentration profiles of trace gases such as acetonitrile (CH_3CN) and sulfuric acid vapour, playing an important role in this chemistry.

In the period 1986-1987 no new balloon flights have been performed, but nevertheless a critical study of previously obtained results was continued.

Recent derivations of acetonitrile concentration from ion spectra obtained with airplane borne instruments by the group of the Max Planck Institute in Heidelberg have shown a discrepancy with our results obtained with balloon borne instruments below 30 km altitude.

Experimental studies in our laboratory have shown that these discrepancies are due to experimental problems encountered with the balloon borne instruments. These difficulties result from cluster break-up effects due to electric field induced collisional dissociations in the mass spectrometer. Presently a theoretical as well as experimental study of these cluster break-up effects is planned. To avoid such effects in the future more sensitive instruments will be required which can work with lower electric fields.

A feasibility study has been performed to check whether such instruments can be realized using magnetic mass filters combined with simultaneous detection techniques. A collaborative program has been started together with the University of Bern and the CNRS in Orléans with the aim of building a balloon borne magnetic mass spectrometer (Mattauch-Herzog type) equipped with a simultaneous ion detection device (micro channel plate + photocathode + reticon). The new cryopumping system and part of the microprocessor unit for this instrument have been developed in our institute, whereas the construction of the magnetic mass filter is being done in Bern.

6. STUDY OF THE IONOSPHERE

The concept of chemical fluctuations associated with electron attachment and detachment processes in the terrestrial D-region implies the existence of scale times and scale lengths over which these phenomena can be observed. An extension of Chapman's definition of scale times and scale lengths to fluctuating quantities leads to an eigenvalue problem which can be solved numerically, and for which simple analytical approximations are obtained. Two scale times associated with negative ion chemistry and with neutralization, respectively, differ by several orders of magnitudes. One scale length indicates how the classical Debye length is modified by the presence of negative ions. Two other scale lengths are the spatial correspondence of the scale times. The scale length associated with negative ion chemistry ranges from 10 to 80 cm, and the scale length corresponding to recombination processes ranges from 5 to 10 m.

7. STUDY OF THE SOLAR WIND PLASMA

The modeling of current sheets in the solar wind is one aspect of the Interdisciplinary Study of Directional Discontinuities with the Ulysses Mission. The internal structure of a typical current sheet in the solar wind has been simulated numerically by means of a computer program based on the Vlasov-Maxwell theory of tangential discontinuities.

The quasi-neutrality approximation is satisfied with a very high degree of accuracy in the solar plasma. Minute departures are however expected in thin current sheaths (directional discontinuities) at the interface of two plasmas with widely different physical parameters. The departure from charge neutrality in a kinetic model of Tangential Discontinuities has been studied by solving Poisson's equation with two alternative numerical methods. The results confirm that when the thickness of the current sheath and double layers is larger than several Debye lengths the quasi-neutrality ($\sum Z_n = 0$) is always a very good approximation.

8. A CORRELATION STUDY BETWEEN SOLAR WIND PARAMETER AND GEOMAGNETIC ACTIVITY

The tri-hourly Aa geomagnetic activity indices are correlated with solar wind parameters (from NSSDC's OMNITAPE).

It was possible to confirm that Aa is well correlated with

$$S = BV(NV^2)^{1/3} (1 + 3\cos^2\psi)^{-3/2}$$

which is a non linear function of the average IMF (B), the average solar wind velocity (V), the average solar wind density (N), the angle ψ of the Earth dipole with respect to the Sun-Earth direction; a correlation coefficient of $r = 0.82$ has been obtained. This statistical result indicates that the solar wind convection electric field (BV), its momentum density flux (NMV^2), and the inclination of the Earth dipole are all controlling factors for the response of the magnetosphere to perturbations of the solar wind momentum flux.

Furthermore, it was shown that the ratio Aa/S is an increasing function of $(\sigma_B)/B$, where σ_B is the standard deviation of the interplanetary magnetic field intensity B, over the tri-hourly periods of time; the correlation coefficient between Aa/S and σ_B/B is equal to $r = 0.98$. This latter statistical result supports the contention that geomagnetic perturbations, characterized by enhanced values of Aa, are triggered by the small scale plasma and field irregularities carried by the supersonic solar wind flow. This latter conclusion also supports the non stationary theory for Impulsive Penetration of solar wind plasma irregularities into the magnetosphere.

9. STUDY OF THE INTERACTION BETWEEN THE SOLAR-WIND AND THE MAGNETOSPHERE

According to the Impulsive Penetration (IP) theory, solar wind plasmoids penetrate predominantly in the two lobes of the magnetotail when the Interplanetary Magnetic Field (IMF) has a northward B_z .

Momentum density of the penetrating solar wind plasma element is transferred to the surrounding plasma and to the central polar cap ionospheric regions, which, as a matter of consequence, is dragged over the poles in the sunward direction. This transient magnetotail plasma convection and the associated non stationary polar cap convection can be added and compared to steady state convection patterns predicted by earlier stationary interaction models.

In the northern hemisphere, the region of preferred penetration is shifted towards dusk for a positive B_y , and towards dawn for $B_y < 0$. The direction of these shifts is reversed in the southern hemisphere. The polar cap convection pattern associated with impulsive penetration of solar wind plasma irregularities is therefore also shifted towards dusk or dawn, according to the value of B_y as mentioned above.

Furthermore, the NBZ Birkeland currents driven at the interfaces between the penetrating plasmoids and the ambient geomagnetic field are downwards (upwards) in the dusk (dawn) side for both hemispheres. The amplitudes of NBZ currents are expected to be larger when B_z is larger (and positive). The region of reversal of the NBZ currents is also shifted towards dawn or dusk depending on the sign of B_y as described above. These transient field aligned currents, driven upwards and downwards, are associated with the non-zero field aligned component of curl \underline{B} (i.e. with magnetic shears) in the vicinity of the penetrating diamagnetic plasmoids.

10. ELECTROMOTIVE FORCE GENERATOR IN THE MAGNETOSPHERE

The interface between two magnetospheric plasma clouds with different densities, temperatures, and/or bulk velocities can be modeled in the framework of a collisionless theory for tangential discontinuities. From this modeling, it has been shown that an electric potential difference of several kilovolts exists across thin unstable electron layers. It has been suggested that these unstable electron layers are the seat of strong pitch angle scattering for the primary auroral electrons.

11. CASSINI SPACE MISSION : MICROWAVE RADIOMETER

The Cassini spacecraft will be designed and operated jointly by ESA and NASA for a deep space mission to Saturn and its satellite Titan, there are plans for a lander which would sound the atmosphere and surface of Titan while the orbiter would stay in the Saturnian system and perform repeated observations of the planet and its satellites, the earliest launch window occurs in 1995 for an arrival at Saturn around 2002 and about 15 years of observation. A microwave spectrometer would allow to investigate CO and HCN from the orbiter instrument platform at each Titan encounter. Simulations of the signal have been already performed and contacts have been initiated with industrial companies to build an instrument.

At this point, strong chances exist that a spectrometer corresponding to the studies presented to ESA and NASA will be present in the model payload for which an announcement of opportunity will be issued in 1990.

12. PLANETARY INSOLATIONS

The combined effect of global dust storms, characterized by optical depths ranging from 0 to 3, and the oblateness on the mean seasonal daily insulations at the martian surface has been studied as a function of latitude. It has been found that the variations in the solar radiation distributions over a season or a year are strongly dependent on the optical thicknesses.

The seasonal and latitudinal variation of the daily insolation and the latitudinal variation of the mean summer, winter or annual daily insulations at the top of Saturn's atmosphere and taking into account both the oblateness of the planet and the shadow of the ring system have also been investigated. This theoretical study clearly demonstrated that the major rings (A, B and C) of the planet cause significant differences in both the planetary-wide distribution and the intensity of the daily and the mean daily insulations.

The direct solar radiation incident at the top of the atmosphere of Uranus and Neptune has been recalculated based on updating values for the period of axial rotation and the oblateness.

Finally, it was shown that the elevation of the sun and, as a consequence, the solar radiation at the warm pole of Mercury depend markedly on the orbital eccentricity which may create abrupt changes in the insolation at the perihelion or at a few days symmetric with respect to the perihelion passage.

13. PUBLICATIONS

ARIJS, E. and BRASSEUR, G., Acetonitrile in the stratosphere and implications for positive ion composition, *J. Geophys. Res.*, 91, 4003-4016, 1986.

ARIJS, E., NEVEJANS, D. and INGELS, J., Stratospheric positive ion composition measurements and acetonitrile detection : a consistent picture? *Int. J. Mass Spectrom. Ion Processes*, 81, 15-31, 1987.

BALOGH et al., Columbus Solar-Terrestrial Physics (CSTP), Science Team Report, *ESA Sci.* (86)2, December 1986.

BERTAUX, J.-L. and SIMON, P.C., Composition and temperature measurements with a spectral camera in the middle atmosphere and thermosphere, *Proceedings of the ESA/BNSC/CNES Workshop on Solar-Terrestrial Physics on Space Station/Columbus*, RAL, Chilton Didcot (U.K.), 139-142, 1986.

BURROWS, J., HARRIES, J.E., LEE, A.C.L., MORGAN, J., RASCHKE, E., READINGS, C.J., REES, D., SIMON, P.C. and TESTUD, J.C., COPE (Co-orbiting Platform Elements), "Atmosphere" Panel Report, *Proceedings of an ESA workshop held at ESTEC*, ESA SP-1093, 41-45, 1987.

DECREAU, P., LEMAIRE, J., CHAPPELL, C.R. and WAITE, J.R., Nightside plasmopause positions observed by DEL as a function of geomagnetic indices : comparison with whistler observations and model calculations, in *Proceedings of COSPAR Symposium : Physics of the thermal plasma in the magnetosphere*, Toulouse, France, July 6-12, 1986, *Adv. Space Res.*, vol. 6, n° 3, pp. 209-214, 1986.

- EVANS, D.S., ROTH, M. and LEMAIRE, J., Electric potential distributions at the interface between plasmashet clouds : a source of EMF. In : Double Layers in Astrophysics. Edited by A.C. Williams and T.W. Moorehead, NASA Marshall Space Flight Center, Alabama, NASA Conference Publication, 2469, 287-294, 1987.
- FREDERICK, J., LEOVY, C., ANDERSON, D.E., ANDERSON, Jr., DICKINSON, G.P., DRAYSON, R.E., S.R., FELS, S., HALL, L.A., KIEHL, J., MENTALL, J.E., MOUNT, G.H., NICOLET, M., RODGERS, C.D., ROTTMAN, G. and SIMON, P.C., Radiative processes. In atmospheric ozone 1985 : assessment of our understanding of the processes controlling its present distribution and change, WMO global ozone research and monitoring project report n° 16, NASA Earth Sciences and Applications Division, Washington, D.C., 349-392, 1986.
- INGELS, J., NEVEJANS, D., FREDERICK, P. and ARIJS, E., Stratospheric positive ion composition measurements between 22 and 45 km - An updated analysis, J. Geophys. Res., 91, 4017-4024, 1986.
- INGELS, J., NEVEJANS, D., FREDERICK, P. and ARIJS, E., Acetonitrile and sulfuric acid concentrations derived from ion composition measurements during the MAP-Globus 1983 campaign, Planet. Space Sci., 35, 685-691, 1987.
- KOCKARTS, G. and WISEMBERG, G. : Scale times and scale lengths associated with charged particle fluctuations in the lower ionosphere, Planet. Space Sci., 34, 979-985, 1986.
- LABS, D., NECKEL, H., SIMON, P.C. and THUILLIER, G., Ultraviolet solar irradiance measurement from 200 to 358 nm during Spacelab 1 mission, Solar Phys., 107, 203-219, 1987.
- LAURENT, J., BRARD, D., GIRARD, A., CAMY-PEYRET, C., LIPPENS, C., MULLER, C., VERCHEVAL, J. and ACKERMAN, M., Middle atmospheric water vapor observed by the Spacelab One grille spectrometer, Planetary and Space Science, 34, 1067-1071, 1986.
- LEMAIRE, J., Du vent solaire vers la magnétosphère, Physicalia Mag., 8, 31-59, 1986.

- LEMAIRE, J., The quiet and disturbed plasmasphere, in Proceedings of AGARD 38th Meeting of Electromagnetic wave propagation panel : The aerospace environment at high altitudes and its implications for charging and communications, 1.1-1.7, 1986.
- LEMAIRE, J., Plasma transport in the plasmasphere, in Proceedings of COSPAR symposium : Physics of the thermal plasma in the magnetosphere, Toulouse, France, July 6-12, 1986, Adv. Space Res., vol. 6, n°3, 157-175, 1986.
- LEMAIRE, J., The plasmopause formation, in Proceedings of STP symposium, Toulouse, June 30-July 5, 1986, Eds. Hultqvist, B., Rees, D. and von Zahn, U., Physica Scripta, vol. T18, pp. 111-118, 1987.
- LEMAIRE, J., The solar wind plasma : problems and perspectives. Review paper presented at the General Assembly of the Société belge de Physique, Hasselt, Belgium, June 4-5, 1987.
- LEMAIRE, J., Interpretation of the northward Bz (NBZ) Birkeland current system and polar cap convection patterns in terms of the impulsive penetration model, in Magnetotail Physics, ed. Lui, A.T.Y., Johns Hopkins University Press, pp. 83-90, 1987.
- MATTHEWS, W.A., AIMEDIEU, P., MEGIE, G., PELON, J., ATTMANNSPACHER, W., KOMHYR, W., MARCHE, P., de La NÖE, J., RIGAUD, P., SIMON, P.C. and ROBBINS, D.E., General comparison of ozone vertical profiles obtained by various techniques during the 1983 MAP/GLOBUS campaign, Planet. Space Sci., 35, 603-608, 1987.
- POMMEREAU, J.-P., FABIAN, P., FLENTJE, G., HELTEN, M., PÄTZ, H.W., EHHALT, D.H., KARCHER, F., FROMENT, G., ARMAND, G., MATTHEWS, W.A., OFFERMANN, D., RIPPEL, H., RIGAUD, P., NAUDET, J.P., HUGUENIN, D., SIMON, P.C., PEETERMANS, W., VANDENEDEE, P., ZANDER, R. and ROLAND, G., Intercomparison of stratospheric NO₂ and NO₃ measurements during MAP/GLOBUS 1983, Planet. Space Sci., 35, 615-629, 1987.
- ROTH, M., A computer simulation study of the microscopic structure of a typical current sheet in the solar wind. In : The Sun and the heliosphere in three dimensions, Eds. Marsden, R.G., Astrophysics and Space Science Library, D. Reidel Publ., Dordrecht, Holland, 167-171, 1986.

- ROTH, M., EVANS, D.S. and LEMAIRE, J., A model for an electromotive force generator in the magnetosphere : a source of discrete auroral arcs. In : The aerospace environment at high altitudes and its implications for spacecraft charging and communications. NATO-AGARD Conference Proceedings, The Hague, The Netherlands, CP-406(3), 1-22, 1987.
- ROSTOKER, G., BAKER, D.M., LEMAIRE, J. and VASYLIUNAS, V., Dialog on the relative roles of reconnection and the "viscous" interaction in providing solar wind energy to the magnetosphere, in Magnetotail Physics, Ed. Lui, A.T.Y., Johns Hopkins University Press, Baltimore, pp. 409-414, 1987.
- SHIZGAL, B., WEINERT, U. and LEMAIRE, J., Collisional kinetic theory of escape of light ions from the polar wind, in Proceedings of the 15th International Symposium on Rarefied Gas Dynamics, vol. II, edited by Boffi, V. and Cercignani, C., Teubner, Stuttgart, pp. 374-383, 1986.
- SIMON, P.C., Advances atmospheric physics platforms, Proceedings of the ESA/BNSC/CNES Workshop on Solar-Terrestrial Physics on Space Station/Columbus, RAL, Chilton Didcot (U.K.), 57-58, 1986.
- SIMON, P.C., PEETERMANS, W., PLATEAU, E., RIGAUD, P., NAUDET, J.-P., HUGUENIN, D., OFFERMAN, D. and RIPPEL, H., Remote sensing ozone measurements from stratospheric balloon during MAP/GLOBUS Campaign 1983, Planet. Space Sci., 35, 595-601, 1987.
- VAN HEMELRIJCK, E., The oblateness effect on the mean seasonal daily insolarations at the martian surface during global dust storms, Earth, Moon and Planets, 38, 209-216, 1987.
- VAN HEMELRIJCK, E., The effect of Saturn's rings on the upper-boundary insolation of its atmosphere, Earth, Moon and Planets, 38, 217-235, 1987.
- VAN HEMELRIJCK, E., The solar radiation incident at the top of the atmosphere of Uranus and Neptune, Aeronomica Acta A 317, 1987.
- VERCHEVAL, J., Latitude coverage of solar absorption spectrometry observations of the middle atmosphere from a heliosynchronous orbit, ESA Journal, 11, 233-238, 1987.

VERCHEVAL, J., LIPPENS, C., MULLER, C., ACKERMAN, M., LEMAITRE, M.-P.,
BESSON, J., GIRARD, A. and LAURENT, J., CO₂ and CO vertical
distribution in the middle atmosphere and lower thermosphere
deduced from infrared spectra, Annales Geophysicae, Series A -
Upper Atmosphere and Space Sciences, 4, 161-164, 1986.

B. ASTROPHYSICAL INSTITUTE OF THE UNIVERSITY OF LIEGE

1. INTERNATIONAL ULTRAVIOLET EXPLORER SPECTRA

From IUE high resolution spectra the behaviour of different ions has been investigated concerning their respective profiles as well as their radial velocities (see Brandi, Gosset and Swings, 1987). A large number of ionization stages are actually simultaneously present. The ultraviolet spectrum is dominated by absorptions, mainly of FeII, but emissions are also present in some lines of OI, MgII, FeII. The absorption line widths increase with the ionization stages. No correlation appears between the radial velocities and the excitation potential whereas some correlation exists between the former and the ionization potentials. A Bowen mechanism is responsible for the observed emission (P Cygni type profile) of the resonance triplet of OI as well as for the resonance doublet of MgII. In the far UV, FeII is characterized by the presence of absorption lines with the remarkable exception of multiplet 191 which shows P Cygni profiles : these are explained as being due to a radiative pumping mechanism. In the near UV, FeII is characterized by double absorption lines with sometimes a complex emission feature on the redward side. It is also shown that resonance fluorescence is the main excitation of the FeII emission in the near ultraviolet, in the optical and in the infrared regions.

From IUE low resolution data, a value of the B-V excess of $E_{B-V} = 0.52 \pm 0.04$ (2σ) has been proposed. The continuum of GG Carinae from the UV to the visible is rather well represented by the theoretical flux of a $T_{\text{eff}} = 18000$ K Kurucz standard model atmosphere. They also investigated the ultraviolet lightcurve, which is essentially similar to the one observed in the visible.

Identifications of the very numerous lines (absorption, emission, P Cygni) that GG Carinae exhibits between 1392 and 3196 Å are given in Brandi and Gosset (1987).

The ultraviolet extinction and element depletions in the circumstellar envelope of the M-supergiant binary system, α Sco, have been investigated by using the IUE, Copernicus, and ANS data of the B-dwarf companion, α Sco B, which can be seen in absorption through the cool-star envelope (see Snow et al., 1987). After assessing the interstellar, circumstellar, and atmospheric column densities toward α Sco B, they have estimated the circumstellar reddening, the circumstellar depletions, and the circumstellar spectral-extinction toward α Sco B.

They find that the amounts of circumstellar hydrogen and interstellar hydrogen are approximately equal, and that the circumstellar refractory depletions appear to follow the same depletion pattern as both the Scorpius and general interstellar depletions. The circumstellar depletions, however, are less than the interstellar depletions, except for the aluminium depletion, which is the same in the general interstellar medium and in the α Sco B circumstellar medium. They interpret this as evidence that the B-star has inhibited grain formation in the circumstellar envelope but has not greatly altered the composition of the circumstellar grains. The evidence for a siliceous composition is substantiated by the absence of a circumstellar 2175 Å bump in the spectral extinction. Also, with some uncertainty, the far-ultraviolet rise appears to be absent from the α Sco B circumstellar extinction. Thus, the spectral extinction and the element depletions toward α Sco B suggest that the circumstellar grains are not tiny and are not carbonaceous, but are large and siliceous.

2. INFRARED SPECTROSCOPIC INVESTIGATIONS

Infrared spectroscopic investigations have been pursued in three ways :

a. Balloon observations

Three flights have been carried out successfully from the National Scientific Balloon Facility, Palestine, Texas. The main emphasis was placed on accurate measurements of the molecules HCl and HF, between 10 and 40 km altitude. Compared to earlier column abundances determinations, the recent results indicate a slight increase (maximum of 1%/year) of the hydrogen chloride amount above 25 km, while the integrated abundance of hydrogen fluoride above the same altitude has increased by about $7.5 \pm 2.5\%$ /yr. The lower parts of the retrieved profiles obtained during both sunsets and sunrises in the sun-occultation mode have been well established too, and their gradients below 18 km are directly related to the height of the tropopause. A peculiar inflexion in the HCl profile between 22 and 35 km has been observed systematically on the measurements made in 1985 and 1987; it is the consequence of the existence between these altitudes of the important chlorine reservoir species ClONO₂ (chlorine nitrate), the total amounts of HCl and ClONO₂ giving a good indication of the Cl-atoms budget in the upper stratosphere.

The emphasis on HCl and HF measurements was further justified due to the fact that similar measurements were made during the 1986-87 Antarctic campaigns aimed at studying the "ozone hole"; the HCl and HF species are good indicators of the amounts of chlorofluorocarbons (mainly CF₂Cl₂ and CFCl₃) being photodissociated after diffusion above 20 km.

CH₄ was also retrieved between 14 and 40 km altitude from balloon observations; the volume mixing ratio profiles indicate a strong "anomaly" between 28 and 38 km where that ratio remains practically constant; whether or not this is a "new and persistent feature" in the methane distribution in the stratosphere needs to be assessed by future measurements.

b. ATMOS-SL3-Data investigations

The first mission (April-May 1985) of the ATMOS-Fourier transform spectrometer onboard Spacelab 3 provided over 1000 atmospheric IR-transmission spectra recorded in the occultation mode during 12 sunsets and 8 sunrises, which occurred near 30°N and 47°S, respectively. These observations have allowed to study the volume mixing ratios of more than 25 atmospheric constituents, some of them, e.g. CO₂, NO, CO, having been detected to well above 100 km altitude.

As a co-investigator (C.B. Farmer from the Jet Propulsion Laboratory, Pasadena, Calif. is the principal investigator of the ATMOS project), we have participated in the analysis of the ATMOS/SL3 data base and contributed to the publication of various results. The list of papers published so far is given hereafter and demonstrates the efficiency of the ATMOS instrument for telluric investigations. While the program awaits further reflights as soon as the shuttle platform becomes operational again, the 1985 mission will become an important milestone against which future results can be compared to evaluate variability and trends on various time scales.

c. Jungfraujoch observations

Series of high quality infrared solar observations have been made over the last years at the Jungfraujoch Station (Swiss Alps, 3580 m altitude), in support of the ATMOS/program, e.g. to characterize the stability of the atmosphere through studies of temperature insensitive lines of N₂ and CO₂. Other recordings have been analysed within the context of coordinated campaigns in Europe; the column abundances of various species such as NO, NO₂, O₃,... determined from ground-based observations can contribute to the validation of integrated abundances derived by other observational methods, e.g. by balloon, aircraft,...

TABLE 1 : Summary of Jungfrauoch investigations.

Observations :

Easy : H₂O, CO₂, N₂O, CO, CH₄, O₃, NO, NO₂, HNO₃, HCl, HF, ClONO₂,
CF₂Cl₂, CFC1₃, CHF₂Cl, C₂H₂, C₂H₆, H₂CO₂, OCS, HCN.

Difficult : CH₃Cl, HBr, ClO, HOCl, HO₂, H₂O₂, HO₂NO₂, CCl₄, COF₂, CF₄.

Findings :

| MOLECULE | PERIOD | TREND %/yr. | ACTUAL COLUMN mol./cm ² | REMARKS |
|---------------------------------|---------|----------------|---------------------------------------|---|
| HCL | 1977-87 | .75 | 2.9xE15 | variability; tropopause relation |
| HF | 1977-87 | 8.5 | 7.5xE14 | " " " |
| HF/HCL | | | | .15 in 1977-79; .25 in 1985-87 |
| CH ₄ | 1951-87 | .75 | 2.15xE19 | tropopause relation |
| CO | 1951-87 | .85 | 1.1xE18 7.0xE17 | in March-April in summer |
| N ₂ O | 1951-87 | | | in progress |
| HNO ₃ | 1986-87 | - | 1.15xE16 7.50xE15 | in Feb.-March; variab. in summer; |
| NO ₂ | 1985-87 | - | 2.0xE15 4.0xE15 | in winter; large variab. in summer; " " " diurnal evolution |
| NO | 1985-87 | - | 3.0xE15 3.6xE15 | in winter in summer; variab. diurnal evolution |
| ClONO ₂ | 1986-87 | - | 1.15xE15 | absolute value remains? |
| COF ₂ | 1986 | - | 6.5xE13 | weak absorption |
| HBr | 1986-87 | - | <1.0xE12 | upper limit |
| ClO | 1985-87 | - | <1.0xE14 | insufficient sensitivity |
| HOCl | 1986-87 | - | <2.5xE13 | upper limit |
| CFC1 ₃ | 1986 | - | 2.4xE15 | absolute values remain |
| CF ₂ Cl ₂ | 1986 | - | 4.1xE15 | unsatisfactory; pseudo |
| CHF ₂ Cl | 1986 | - | 9.5xE14 | continua; trends in progress |
| C ₂ H ₆ | 1986 | - | 8.3xE15 | variability or seasonal ? trend 1951-86 in progress |
| C ₂ H ₂ | 1986 | - | | column + trend in progress |

Furthermore, our long-term ground-based observations (time span of over 35 years) are being further investigated to derive secular trends of species of importance within the frame of the evolution of our environment. Table 1 gives a list of those molecules "looked" at in Jungfraujoch observations and preliminary information about their behaviour throughout the integrated atmosphere.

3. THE DISTRIBUTION OF ATOMIC NITROGEN IN VENUS' ATMOSPHERE

The vertical distribution of the major positive ions, electrons, N(4S), N(2D) and NO has been calculated for comparison with data obtained with the Pioneer Venus ion and neutral mass spectrometer instruments (OIMS-ONMS). A model extending from 80 to 200 km has been developed to solve the coupled continuity and flux equations. The neutral temperature and major constituent distributions are adopted from Hedin's empirical model. The calculated vertical profile and time dependence is found to be in good agreement with the measurements for most ions and for N(4S) atoms. The diurnal variation of nitrogen atoms near periapsis and its asymmetry is also correctly predicted. It is found that the global production of atoms on the day side is large enough to account for the UV recombination airglow observed on the night side of the planet with the PV ultraviolet spectrometer.

4. ROLE OF NO IN THE ENERGY BALANCE OF THE THERMOSPHERE

A model of the odd nitrogen distribution previously developed for solar minimum activity conditions has been adapted for more active solar cycle periods.

The general features of the 5.3 μ m cooling by nitric oxide are found to be qualitatively similar in both cases. However, the cooling term due to infrared radiation of NO is larger in solar maximum conditions as a result of the increased temperature and nitric oxide density prevailing near the peak of the solar cycle.

5. PUBLICATIONS

- BEER, R., FARMER, C.B. and ZANDER, R., Observational evidence for anomalous CO and CO₂ depletion above 90 km, Proceedings of the workshop on "Atmospheric spectroscopy applications", Rutherford Appleton Laboratory, Chilton, 1-3 Sept. 1987, Ed. J. Ballard, paper 13-2, RAL-88-009, 1987.
- BRANDI, E., GOSSET, E. and SWINGS, J.P., Astron. Astrophys., 175, 151, 1987.
- BRANDI, E. and GOSSET, A., Astron. Astrophys. Suppl. Series, 68, 283-293, 1987.
- GERARD, J.C. and ROBLE, R.G., The role of nitric oxide on thermospheric dynamics and composition : solar minimum activity conditions, Planet. Space Sci., 34, 131-144, 1985.
- GERARD, J.C. and TAIEB, C., The E-region electron density diurnal asymmetry at Saint-Santin : observations and role of nitric oxide, J. Atmos. Terr. Phys., 48, 471-483, 1985.
- GERARD, J.C. and NOEL, C.E., AE-D measurements of the NO geomagnetic latitudinal distribution and contamination by N⁺(5S) emission, J. Geophys. Res., 91, 10136-10140, 1986.
- PARK, J.H., ZANDER, R., FARMER, C.B., RINSLAND, C.P., RUSSELL, J.M. III, NORTON, R.H. and RAPER, O.F., Spectroscopic detection of CH₃Cl in the upper troposphere and lower stratosphere, Geophys. Res. Lett., 13, 765-768, 1986.
- POMMEREAU, J.P., FABIAN, P., FLENTJE, G., HELTEN, M., PAETZ, H.W., EHHALT, D.H., KARCHER, F., FROMENT, G., ARMAND, G., MATTHEWS, W., OFFERMANN, D., RIPPEL, H., RIGAUD, P., NAUDET, J.P., HUGUENIN, D., SIMON, P.C., PEETERMANS, W., VANDENEDE, P., ZANDER, R. and ROLAND, G., Intercomparison of stratospheric NO₂ and NO₃ measurements during MAP/GLOBUS 1983, Planet. Space Sci., 35, 615-629, 1987.
- RAPER, O.F., FARMER, C.B., ZANDER, R. and PARK, J.H., Infrared spectroscopic measurements of halogenated sink and reservoir gases in the stratosphere with the ATMOS instrument, J. Geophys. Res., 92, 9851-9858, 1987.

- RINSLAND, C.P., ZANDER, R., BROWN, L.R., FARMER, C.B., PARK, J.H., NORTON, R.H., RUSSELL, J.M. III and RAPER, O.F., Detection of carbonyl fluoride in the stratosphere, *Geophys. Res. Lett.*, 13, 769-772, 1986.
- RINSLAND, C.P., ZANDER, R., FARMER, C.B., NORTON, R.H., BROWN, L.R., RUSSELL, J.M. III and PARK, J.H., Evidence for the presence of the 802.7 cm^{-1} band Q branch of HO_2NO_2 in high resolution solar absorption spectra of the stratosphere, *Geophys. Res. Lett.*, 13, 761-764, 1986.
- RINSLAND, C.P., ZANDER, R., FARMER, C.B., NORTON, R.H. and RUSSELL, J.M. III, Concentration of ethane (C_2H_6) in the lower stratosphere and upper troposphere and acetylene (C_2H_2) in the upper troposphere deduced from Atmospheric Trace Molecule Spectroscopy/Spacelab 3 spectra, *J. Geophys. Res.*, 92, 11951-11964, 1987.
- SNOW, T.P., BUSS, R.H. Jr., GILRA, D.P. and SWINGS, J.P., *Astrophys. J.*, 321, 921-936, 1987.
- ZANDER, R., Ground-based infrared solar observations for early detection of stratospheric changes, NASA-report of workshop on "Network for Early Detection of Stratospheric Changes", Boulder, Colo., March 5-7, 1986.
- ZANDER, R., RINSLAND, C.P., FARMER, C.B., BROWN, L.R. and NORTON, R.H., Observation of several chlorine nitrate (ClONO_2) bands in stratospheric infrared spectra, *Geophys. Res. Lett.*, 13, 757-761, 1986.
- ZANDER, R., RINSLAND, C.P., FARMER, C.B. and NORTON, R.H., Infrared spectroscopic measurements of halogenated source gases in the stratosphere with the ATMOS instrument, *J. Geophys. Res.*, 92, 9836-9850, 1987.
- ZANDER, R., RINSLAND, C.P., FARMER, C.B. and NORTON, R.H., Telluric infrared continuum absorptions observed with the ATMOS instrument, Proceedings of the workshop on "Atmospheric spectroscopy applications", Rutherford Appleton Laboratory, Chilton, 1-3 Sept. 1987, Ed. J. Ballard, paper 9-5, RAL-88-009, 1987.

- ZANDER, R., ROLAND, G., DELBOUILLE, L., SAUVAL, A., FARMER, C.B. and NORTON, R.H., Monitoring of the integrated column of hydrogen fluoride above the Jungfraujoch station since 1977 - the HF/HCl column ratio, *J. Atmos. Chem.*, 5, 385-394, 1987.
- ZANDER, R., ROLAND, G., DELBOUILLE, L., SAUVAL, A., FARMER, C.B. and NORTON, R.H., Column abundance and long-term trend of hydrogen chloride (HCl) above the Jungfraujoch station, *J. Atmos. Chem.*, 5, 395-404, 1987.
- ZANDER, R., ROLAND, G., DELBOUILLE, L., SAUVAL, A.J., MARCHE, P., KARCHER, E., AMOUDEI, M. and DUFOUR, B., Concentrations of hydrogen chloride and hydrogen fluoride measured during the MAP/GLOBUS campaign of September 1983, *Planet. Space Sci.*, 35, 665-672, 1987.

C. IAL SPACE

1. SPACE TELESCOPE - PHOTON DETECTOR ASSEMBLY (PDA)

Due to delay in the launch of the Space Telescope, ESA has decided to calibrate two new detectors in order to replace, if necessary, the actual integrated ones.

This has induced a reconduction of the initial contract, the calibration of the two models being planned in 1988.

Modifications to the calibration facility and absolute calibration of it have been performed end of 1987.

2. VACUUM OPTICAL BENCHES (FOCAL 5 AND FOCAL 2)

a. Focal 5

This facility was successfully used during the thermal-vacuum and calibration test of the Hipparcos payload.

Thermal stability has been of the order of 0.05 deg.C per 5hr (average) with vacuum conditions of around 10^{-7} mbar.

Moreover, the first calibration results indicate good correlation with the predicted ones.

Additionally, the adaptation of the facility for the tests on the ISO telescope has started. The planned date for the start of the tests is mid 1988.

In order to achieve the tests (cooling of the items down to 5 deg.K) an He liquefier has been ordered (1 LHe and 2 GHe outputs for the feeding of the dedicated shrouds.

b. Focal 2

This facility, located earlier in another building, has been transferred in 1987. This facility presents the same characteristics as the larger one. A concrete seismic bloc has been developed in order to support the optical bench installed in the chamber.

This latter must be ready in the same time as the large one in order to be usable as a redundant chamber for the ISO tests. Preliminary tests have been performed in December 1987, in order to analyse the behaviour of specific items, when cooled down to 5 deg. K.

3. GIOTTO SPACE PROBE : HALLEY MULTICOLOR CAMERA (HMC)

The Giotto Spacecraft has been launched on the 2nd July 1985 and the probe has reached the Halley comet on the 13-14th March 1986. The mission has met a full success with many thousands pictures sent to the earth. HMC worked nominally up to 2000 km from the nucleus when the contact has been lost with the probe as a result of an impact with high speed cometary dust. Data reduction has been pursued in 86 and 87.

4. THERMAL VACUUM TEST OF THE HIPPARCOS PAYLOAD

The Hipparcos astrometry satellite requires a structural stability which is related to its objectives : define the relative position of 120.000 stars with an accuracy of 2 milliarcsec during 2.5 years. This goal implies mechanical stabilities which are also of the order of milliarcsec for the angle and tenth of nm for the distances between different optical components.

This instability is measured in a realistic vacuum thermal environment in Focal, making full use of the inherent stability of the facility. Three models of the Hipparcos payload have been tested during 86-87. The structural, the engineering and the flight models have successively been tested. The optical performances were evaluated in a thermal balance and thermal vacuum environment. The results gave full satisfaction.

5. PUBLICATIONS

KELLER, H.U., JAMAR, C., CUCCHIARO et al., The Halley multicolour camera, J. Phys. E : Sci. Instrum., 20, 807-820, 1987.

KELLER, H.U., JAMAR, C., MALAISE, D. et al., First Halley multicolour camera imaging results from Giotto, Nature, 321, 320-326, 1986.

MACAU-HERCOT, D., CUCCHIARO, A., MACAU, J.P., JAMAR, J. and JAMAR, C., The Liège vacuum optical bench "Focal 5", Jour. of Env. Sc., 17-20, 1987.

SCHMIDT, W.K.H., KELLER, H.U., ARPIGNY, C., JAMAR, C., MALAISE, D. et al., The Giotto Halley multicolour camera, ESA SP-1077, 149-172, 1986.

1. ALFVEN WAVE PLASMA TURBULENCE DURING SOLAR WIND-COMET INTERACTION

As evidenced from plasma observations during the encounter missions to comets Giacobini-Zinner and Halley, ions of cometary origin were detected at distances of up to 10^7 km from the nucleus. Having escaped, due to the comet's low gravity, as neutral molecules from the inner coma, they are picked up at ionization by the ambient solar wind plasma. The newly created ions are accelerated by the combined action of the solar wind electric and magnetic fields to the perpendicular velocity of the solar wind. At the same time, their parallel velocity along the solar wind magnetic field would remain equal to the gas outflow velocity, typically of the order of 1 km/s. Thus the cometary ion distribution function forms a ring in velocity space drifting parallel to the solar wind magnetic field.

This distribution function contains two sources of free energy, namely the ring in velocity space and the relative drift between the solar wind protons and the cometary ions, which can excite various kinds of plasma instabilities. In previous treatments of these instabilities both effects were included, but not in a selfconsistent way, as the influence of the cometary ions on the solar wind plasma was not taken into account. The picked-up cometary ions were thus treated as a low-density, high-speed but non-neutral beam shot through an otherwise undisturbed solar wind plasma. As one knows that the solar wind is indeed mass-loaded by the cometary ions, close to the nucleus so substantially that it leads to a bow shock, a selfconsistent description of the Alfvén instabilities was given, at first restricted to the parallel drift effects only, without incorporating the ring-current distribution.

Subsequently, a selfconsistent way to deal with both effects at the same time was under study. In this, the ring-current effects will amount to a sort of temperature anisotropy for the cometary ions, and in the subsequent treatment will lead to a firehose part of the instabilities.

Both sources of free energy can excite Alfvénic mode instabilities in different parameter regimes. For the purely growing, nondispersive modes the parallel drifts are destabilizing, whereas the ring current has a stabilizing influence.

2. PUBLICATIONS

- LAKHINA, G.S. and VERHEEST, F., Alfvén wave instabilities and ring current during solar wind-comet interaction, *Astrophysics and Space Science*, in press, 1988.
- VERHEEST, F., Nonlinear Alfvén instabilities in the solar wind, *Bulletin of the American Physical Society*, 30, 1366, 1985.
- VERHEEST, F., Alfvén mode instabilities during solar wind-comet interaction, *Bulletin of the American Physical Society*, 32, 1725, 1987.
- VERHEEST, F., Alfvén wave plasma turbulence during solar wind-comet interaction, *Astrophysics and Space Science*, 138, 209-215, 1987.

E. ROYAL OBSERVATORY OF BELGIUM

I. SPACE GEODESY - EARTH ROTATION

1. Observations

The Royal Observatory of Belgium has a tracking station of the NNSS TRANSIT satellites currently used for terrestrial navigation, monitoring of the polar motion and deployment of geodetic networks. BEACON satellites are also observed in support of missions for Earth gravity field improvement. TRANSIT and BEACON satellites are observed on a permanent basis, 30.011 passes were observed during the years 1986 and 1987.

The station is part of the TRANET network managed by DMAHTC (Defense Mapping Agency Hydrographic and Topographic Center).

2. Analysis

- The Royal Observatory of Belgium is part of the European Consortium taking in charge the analysis of the African Doppler campaign (ADOS) organized by the Commission "International Coordination of Space Techniques for Geodesy and Geophysics (IAG and COSPAR)". Computations of the networks, it means the determination of the coordinates of 299 stations, were ended in 1987.
- The first order geodetic net of Burundi (65 stations) has been computed in Brussels on the basis of Doppler observations performed on TRANSIT satellites.
- Aiming to test the stability of the TRANSIT system, on the basis of the observations of the TRANSIT satellites performed in Brussels, the station coordinates were recomputed from each consecutive 10 days of observation.

- Simulations were conducted to estimate the interest of the Global Positioning System (GPS) to monitor the short term ($\leq 24h$) variations of the Earth Rotation.
The precision obtained led to the conclusion that, for this purpose, GPS could compete with the best systems presently available (SLR, VLBI).
- The 50-day fluctuations observed in the Earth Rotation and in the Atmospheric Angular Momentum were correlated to the solar activity. Same fluctuations were identified in other geophysical and solar activity phenomena : Geomagnetic Field, Sunspots, Interplanetary Magnetic Field, Solar Wind.
- A study to estimate the ionospheric perturbation acting on time transfer with the GPS system has been undertaken. Results are expected in mid- 1988.

3. PUBLICATIONS

- DEHANT, V. and PAQUET, P., Summary of the IAU International Symposium n° 128 on Earth Rotation and Reference Frames, Manuscripta Geodetica, Symposia in review, vol. 12, n° 1, pp. 65-66, 1987.
- DJUROVIC, D. and PAQUET, P., Short term variations of the Earth Rotation and the Solar Activity, Proceed. of the IAU Symposium n° 128 on "Earth Rotation and Ref. Frames", Reidel, Ed. A. Babcock and G. Wilkins, 1987.
- DJUROVIC, D. and PAQUET, P., On the solar origin of the 50 day fluctuation of the Earth Rotation and Atmospheric Circulation, Astronomy and Astrophysics (to be published).
- HIEBER, S., PAQUET, P. and PETIT, M., SESAME Workshop, Summary report, Proceed. of the Workshop on Solid Earth Science and Application Mission for Europe, ESA Workshop, SP-1080, pp. IX-XVIII, 1986.
- MURIGANDE, C., PAQUET, P. and TOINT, PH., Two new methods for solving large scale least squares in geodetic surveying computations, Bull. Géodésique, vol. 60, n° 4, pp. 311-328, 1986.

- PAQUET, P., Monitoring the Earth Rotation Parameters by space experiments, Proceed. of the SESAME Workshop, ESA, SP-1080, pp. 65-68, 1986.
- PAQUET, P. and DEHANT, V., Improvement of the NOVA satellite data for positioning and monitoring of polar motion, Proceedings of the 4th International Symposium on Satellite Positioning, Austin, Texas, USA, Apr.-May 1986, Proceedings publ. in 1987, vol. 2, pp. 861-872, 1987.
- PAQUET, P. and LOUIS, L., Simulations to recover Earth Rotation parameters with GPS system, Proceedings of Symposium U5, 19th General Assembly of the IUGG, Vancouver, Canada, 1987 (to be published).

II. THE ASTROMETRIC MISSION OF THE HIPPARCOS SATELLITE

The contribution of the Royal Observatory of Belgium to the programme HIPPARCOS (High Precision Parallax Collecting Satellite) consists since 1981 in the participation of the Department of Astrometry and Celestial Mechanics to the tasks of the INCA consortium, in charge of the preparation of a list of 100.000 stars (the Input Catalogue) that will be observed by the satellite. There are two aspects to this participation :

1. the representation of Belgium within the Steering Committee of the consortium, and,
2. the coordination of the tasks of the Working Group "Double Stars" within the same consortium (Executive Committee).

The Working Group "Double Stars" consists of two groups :

- one group, formed by three persons of the Royal Observatory of Belgium, is working at the realization of a catalogue of double and multiple stars with a specific astrometric orientation;
- a second group of some fifteen international participants is in charge of the processing of various problems related to the collection of the astrometric and photometric data.

The catalogue realized at Uccle ("Catalogue des Composantes d'étoiles Doubles et Multiples" or C.C.D.M.)^(*) contains 62.237 systems of which 13.223 are contained in the Input Catalogue. Though insufficiently accurate and incomplete for the pursued purposes, the INDEX CATALOGUE OF DOUBLE STARS OF USNO at Washington was used as a starting base for the catalogue in 1979. Its establishment comprised the search of unknown identifications for about 4700 stars during 1986-1987. Thus completed, the C.C.D.M. allowed the selection of 22.660 entries of double and multiple star systems of the INCA DATA BASE (210.000 stars). This data base, of which the INPUT CATALOGUE (100.000 stars) is a subset, was established at the "Observatoire de Meudon" (France) from the lists of stars proposed for observation by the astronomical community.

The C.C.D.M. catalogue also led to the "cleaning up" of the INCA Data Base by the deletion of overabundant entries or by the adjunction of ignored components. More than 30.000 accurate positions ($\pm 0.1''$) were extracted from existing catalogues or furnished by the members of the international collaboration group and were inserted in it.

The most important data, essential to the observation of the double and multiple systems of the INPUT CATALOGUE by the satellite, will have been collected within some months, i.e. approximatively one year before the satellite launch foreseen for april 1989.

The Working Group "Double Stars" has gathered at the University of Bonn and at the Royal Observatory of Belgium, in February 1986 (fourth annual meeting) and September 1987 (fifth annual meeting), respectively. Eight detailed tri-monthly reports about the progressing works were issued to the intention of the European Space Agency during the period 1986-1987.

(*) J. DOMMANGET, Un Catalogue des Composantes d'étoiles Doubles et Multiples (C.C.D.M.), Bulletin d'Information du Centre des Données Stellaires, Strasbourg, 24, pp. 83-90, 1983.

PUBLICATIONS

- BACCHUS, P. et NYS, O., Identification par leurs numéros DM ou par une position semi-précise d'étoiles doubles du catalogue Index (1976,5), Bulletin d'Information du Centre de Données Stellaires, Strasbourg, 29, 43-55, 1985.
- DOMMANGET, J., Hipparcos astrometric binaries, Astrophysics and Space Science, 110, 47-63, 1985.
- DOMMANGET, J., Concerns, realisations and prospects of the Sub-Group Double Stars of the Hipparcos Inca Consortium, Scientific Aspects of the Input Catalogue Preparation, Aussois, 3-7 June 1985, ESA SP-234, 153-159, 1985.
- DOMMANGET, J., Observabilité par Hipparcos des étoiles doubles spectroscopiques, Scientific Aspects of the Input Catalogue Preparation, Aussois, 3-7 June 1985, ESA SP-234, 165-171, 1985.
- DOMMANGET, J., L'exploitation des observations d'étoiles doubles, issues de la mission Hipparcos, Inca News, 6, 27-35, 1985.
- NYS, O., New wide double stars in the Hipparcos input catalogue, Scientific Aspects of the Input Catalogue Preparation, Aussois, 3-7 June 1985, ESA SP-234, 161-163, 1985.

F. ROYAL MILITARY ACADEMY

The Global Positioning System (GPS) is a very promising system which will cause fundamental changes in landsurveying and kinematic positioning and navigation.

The research and applications at the RMA are aimed at two fields of applications :

1. kinematic positioning and navigation
2. utilization of GPS information in the photogrammetric bundle adjustment.

1. KINEMATIC POSITIONING AND NAVIGATION

- In 1986 a number of tests were conducted in order to investigate the capabilities of GPS absolute positioning with a ROCKWELL-COLLINS receiver.
- In collaboration with the "Institut Géographique National de France" a static relative GPS-test has been executed in 1987. The purpose of the test mainly consisted in evaluating the accuracy of GPS as a function of time for baselines in triangulation networks and the consequences for the landsurveying.
- Now we will extend the tests to kinematic relative GPS positioning in collaboration with the FAF-University of Munich.

2. UTILIZATION OF GPS INFORMATION IN THE PHOTOGRAMMETRIC BUNDLE

ADJUSTMENT

The theoretical models are concerned with 3-dimensional instantaneous camera positioning providing a set of homogeneous control coordinates at flying height.

This means that the block triangulation could be repeated at any time with the same accuracy without reference to a fixed set of control points on the ground.

The incorporation of GPS-information in a photogrammetric bundle adjustment makes aerotriangulation without ground control a distinct possibility for medium to small scale mapping projects.

The exposure station coordinates must be determined with a standard error of 1 to 2 m and the full deployment of the GPS-system is necessary.

PUBLICATIONS

VAN TWEMBEKE, U., La photogrammétrie comme intégrateur de la télé-détection spatiale et de la cartographie terrestre et planétaire, Bull. Soc. Belge Phot., partie I n° 157-158; partie II n° 159-160, 1986. - Géomètre (France) n°6 (1986).

VAN TWEMBEKE, U., Etat de l'art de la photogrammétrie à buts cartographiques et métrologiques, Bull. Soc. Belge Phot., n° 165-166, 1987; Géomètre (France), (1987).

G. ROYAL METEOROLOGICAL INSTITUTE OF BELGIUM

1. SOLAR CONSTANT AND EARTH'S RADIATION BUDGET

Due to the accident with CHALLENGER the delivery of the new version of experiment 1ES021 Solar Constant (SOLCON) which is part of the core payload of the Earth Observation Mission Series (EOM) of NASA, has been delayed to August 1989 for launch in September 1990 on COLUMBIA with the now renamed mission "Atmospheric Laboratory for Applications and Science" (ATLAS).

The construction of the experiment Solar Variability (SOVA) payload of the European Retrievable Carrier has been pursued. The delivery is planned for end of 1988 for a shuttle launch end of 1990 or beginning 1991.

The scientific objectives of experiment SOVA is the measurement of the absolute value of the solar irradiance and its variations together with the observation of Sun oscillations with dedicated total and spectral irradiances channels.

EURECA will stay a minimum of six months in space. Experiment SOVA is a collaboration between the Royal Meteorological Institute of Belgium (RMIB), the World Radiation Center Davos (WRCD) and the Space Science Department of ESA (SSD).

The Royal Meteorological Institute continues its collaboration with the Langley Research Center of NASA in the framework of the Earth Radiation Budget Experiment (ERBE) and is currently participating in the preparation of an Earth Observation System (EOS) proposal named Clouds and the Earth Radiant Energy System (CERES). The ERBE activities proceed as planned.

The RMIB has participated in the definition of the experiment Variability of Solar Irradiance and Gravity Oscillations (VIRGO) in the framework of the SOHO programs.

2. PUBLICATIONS

BRUSA, R.W., CROMMELYNCK, D. and DOMINGO, V., Results of the Solar Constant Experiment onboard Spacelab 1, Solar Physics, 107, 1-9, 1986.

H. DEPARTMENT OF METALLURGY AND MATERIALS ENGINEERING

OF THE CATHOLIC UNIVERSITY OF LEUVEN

1. MELTING AND SOLIDIFICATION OF METALLIC COMPOSITE MATERIALS

Our activities aim at contributing to a better understanding and control of the melt metallurgical production of composite materials, in which ceramic or metallic particles are combined with a metallic matrix into a microscopically homogeneous structure.

Two flight experiments (D1-Spacelab, TEXUS 14bis) have successfully been performed, two others (TEXUS 14 and 16) gave no results due to the failure of the sounding rockets.

During the D1-mission, six copper matrix composite samples have been melted and solidified according to the requested temperature-time profile. In the field of particulate metal-metal composite (Cu-W, Cu-Mo), several particle redistribution mechanisms, such as particle agglomeration could be observed. A model based on interfacial energy and geometrical considerations has been proposed.

It further appears that an oxide dispersion strengthened alloy can be kept stable and quite homogeneous during liquid phase processing in space. A limited particle growth is observed and the hardness of the flight sample is substantially higher than that of the lg-reference sample. The latter showed a pronounced agglomeration of the oxide particles.

The TEXUS 14bis experiment aimed for a better understanding of sedimentation and the formation of a particle skeleton in a Al-SiC composite material during melting and solidification. The main results

are the development of a new sample-crucible design with a highly improved thermal control and the qualitative confirmation of expectations based on a new particle-solidification front interaction model. This confirmation could only be obtained in a μg -environment.

2. PUBLICATIONS

DELANNAY, F., FROYEN, L. and DERUYTTERE, A., The wetting of solids by molten metals and its relation to the preparation of metal-matrix composites, Journ. of Mat. Sci., 22, 1-6, 1987.

DERUYTTERE, A. and FROYEN, L., Space research on materials, Proc. Materials Processing in Space : the New Frontier, Relaspar, Brussels, May 28th, 1986.

DERUYTTERE, A., FROYEN, L. and DE BONDT, S., Melting and solidification of metallic composites in space, Adv. Space Res., 6, n°5, 101-110, 1986.

FROYEN, L. and DERUYTTERE, A., Melting and solidification of metallic composite materials, Naturwissenschaften, 3, 384-386, 1986.

FROYEN, L. and DERUYTTERE, A., Melting and solidification of copper matrix composite materials, Proc. D1, symposium, Norderney, 27-29 August 1986 (ed. P.R. Sahm), WPF, Köln, 315-321.

I. DEPARTMENT OF CHEMICAL PHYSICS OF THE UNIVERSITE

LIBRE DE BRUXELLES

1. MARANGONI CONVECTION AROUND A SURFACE TENSION MINIMUM

The Spacelab D1 mission results have been evaluated. The good collaboration with Astronaut F. FURRER yields very important results. The related publications are listed at the end of this report.

The continuation of this work is presently seriously disturbed by the Challenger accident and by a series of troubles in sounding rocket campaigns in the frame of the Texus programme.

| | |
|----------|-----------------------------|
| Texus 13 | APR 1986 : hardware failure |
| Texus 15 | MAY 1987 : rocket failure |
| Texus 16 | DEC 1987 : rocket failure |

ESA has accepted our proposal to continue this investigation with an improved hardware using a bidirectional differential interferometer. This new instrument is presently under development in a collaboration between the "Service de Physique des Milieux Continus" - Prof. Ebbeni, ULB, Verhaert Design and Development, Antwerpen and Pedeo Techniek, Oudenaarde and will be integrated in the platform produced by MBB-ERNO. It is foreseen to use this new instrument in fall 1988.

New results have also been obtained in the Marangoni convection field during short duration experiments performed during KC 135 parabolic flights with NASA in August 1987. The hardware used for these investigations contained the observation cells used during the Spacelab D1 mission.

2. HYDRODYNAMIC INSTABILITY PROBLEMS (Bénard Problem)

Our proposal to ESA to study the heat and the mass transfers in a fluid layer heated transversally has been accepted. This experiment will be performed during the Spacelab D2 mission foreseen in 1992 and, Dr. D. Schwabe from Giessen University (RFA) and Dr. J. Koster from Colorado University Boulder (USA) will be co-investigators.

It is planned to investigate the heat flux around the critical value of the Marangoni number and to accurately observe the hysteresis behaviour which is foreseen in the absence of gravity field.

Preliminary results have been obtained during two NASA KC 135 parabolic flight campaigns (1986-1987) and during parabolic flights performed in Fouga-Magister aircraft of the BAéF in collaboration with the company Bio Space Technology.

3. THE SORET COEFFICIENT MEASUREMENTS

The Eureka 1 mission during which we shall perform our Soret coefficient measurements is presently planned for 1990.

The engineering model has been tested and the flight model is ready for testing. The description of this experiment and the associated hardware have been published (see the list at the end of this report).

The evaluation of the disturbing effect of the residual $10E-5g$ level has been completed.

The reference ground tests which are presently progressing consist in :

- redetermination of the Soret coefficient values in the flight conditions.

(30-40°C) by direct measurements using the flow cell technique.

- determination of the influence of the Soret coefficients of the proposed solutions on the hydrodynamic stability of the liquid layer heated from below.

4. PUBLICATIONS

- LEGROS, J.C., Problems related to non-linear variations of surface tension, Acta Astronautica, 13, n° 11-12, 697-703, 1986.
- LEGROS, J.C., Double diffusive instabilities and the Soret coefficient measurement under microgravity conditions, Acta Astronautica, 15, 455-461, 1987.
- LEGROS, J.C. and LIMBOURG-FONTAINE, M.C., Liquid/gas interfaces under microgravity conditions, ESTEC EWP, 1457, 28-41, 1986.
- LEGROS, J.C., LIMBOURG-FONTAINE, M.C. and PETRE, G., Surface tension minimum and Marangoni convection, Fluid Dynamics and Space, VKI-ESA-SP, 265, 137-143, 1986.
- LEGROS, J.C., LIMBOURG-FONTAINE, M.C. and PETRE, G., Surface tension induced convection in presence of a surface tension minimum, Results of the German Spacelab Mission D1. Ed. by BPFT, 1986.
- LEGROS, J.C., LIMBOURG-FONTAINE, M.C. and PETRE, G., Surface tension induced convection presence of a surface tension minimum, Physico-chemical Hydrodynamics : Interfacial Phenomena, (2 vol) Plenum Press (to appear).
- LEGROS, J.C., LIMBOURG-FONTAINE, M.C., SCHWABE, D., LICHTENBELT, J. and FRIMOUT, D., Some results from parabolic flights, Adv. Space Res., 6, n° 5, 93-95, 1986.
- LIMBOURG-FONTAINE, M.C., LEGROS, J.C. and PETRE, G., The influence of a surface tension minimum on the convective motion of a fluid in microgravity (D1 mission results), Adv. Space Res., 6, n° 5, 35-39, 1986.
- LIMBOURG-FONTAINE, M.C., LEGROS, J.C. and PETRE, G., Marangoni convection around a surface tension minimum - D1 mission results, IAF, 274, 1987.

- LIMBOURG-FONTAINE, M.C., LEGROS, J.C. and PETRE, G., Marangoni convection induced in a fluid presenting a surface tension minimum as a function of the temperature, ESA-SP, 256, 245-249, 1987.
- LIMBOURG-FONTAINE, M.C., PETRE, G. and LEGROS, J.C., Thermocapillary movements under microgravity at a minimum of surface tension, Naturwissenschaften, 73, 360-362, 1986.
- LIMBOURG-FONTAINE, M.C., PETRE, G., LEGROS, J.C. and VAN RANSBEECK, E., Thermocapillary movements around a surface tension minimum under microgravity conditions (part I. Technical description of the stem experiments. D1 mission of Spacelab), Acta Astronautics, 13, n° 4, 197-208, 1986.
- VAN VAERENBERGH, S.R. and LEGROS, J.C., Kinetic of the Soret effect and its measurement under microgravity conditions, AIAA (Progress in Astronautics and Aeronautics Series) (to appear).

STUDY OF BONE DEMINERALISATION IN MICROGRAVITY

1. INTRODUCTION

The different aspects of our research were defined in previous reports to COSPAR. These are :

- "in vivo" bone strain measurements in microgravity;
- study of bone remodelling after space flight;
- preventive therapy.

Because of the overall delay in the schedule of the space programme, only the third objective was pursued in 86-87 (cf.: references).

However, to improve the technology of our devices used for "in vivo" bone strain measurements and to explore a new field of bone pathology in microgravity, we developed a new programme to be used on KC-135 parabolic aircraft flights entitled :

- in vivo monitoring of the mechanical environment of fractures in microgravity.

The influence of the local mechanical environment on bone remodelling has been well known since 1982 (Wolff). An increase in bone strain produces an increase in bone formation and reversely.

Microgravity offers an exceptional environment where the only remaining strain on bone is the muscular contraction required to mobilize or fix the joints without any resistance except the forces of inertia.

Modification of the mechanical environment has an even more determinant action on fracture healing. Moreover, this effect is more sensitive and magnified on a broken bone. This justifies the interest of the quantitative and qualitative evaluation of the mechanical strain even during short periods of microgravity (15" to 20").

On earth the relative unloading is always subject to the gravity vector of force. Only microgravity or its simulation during parabolic flight will allow an absolute unloading (except the residual muscular forces) and the evaluation of the mechanical forces occurring during the mobilization of a fractured limb in microgravity. Until now this data has been ignored.

Besides the fundamental interest they represent in the study of bone healing, these measurements are indispensable in establishing a therapeutic attitude in case of a bone fracture during space flight.

2. ON GROUND PRELIMINARY STUDIES

These measurements were started in 1965 by Professor Burny on long bone fractures to assess an objective follow-up of the functional recovery of the injured limb and to adapt the physical revalidation to the mechanical resistance of callus in formation. At the present time this technique is used routinely and mostly for humeral and tibial fractures treated by external fixation (500 cases) and for pertrochanteric fractures treated with an internal implant (nail plate : 200 cases). This represents a unique data base in the world.

This technique has proved to be useful in preventing secondary displacement and implant failure but also unnecessary delay in functional rehabilitation. Moreover the information on the mechanical rigidity of the callus has allowed the establishment of a new theory on fracture healing and the improvement of the surgical techniques and materials used.

3. EXPERIMENT PROPOSAL FOR KC-135 PARABOLIC AIRCRAFT FLIGHT

The measurements will be taken on a human tibial fracture treated by external fixation and measured routinely on earth.

The measurements were obtained from strain gauges fixed on the bridging rod of the external fixation. The strain gauges are connected by wires to an analogic/digital interface and recorded with an IMB compatible PC.

The recordings are on line during level flight 30" before, during and 30" after each procedure of parabolic trajectory flight.

Six types of measurements were proposed :

1. Subject lying on the floor or on a stretcher.
Static recording during 30" level flight, during microgravity and over loading period and 30" level flight afterwards.
2. Subject standing up.
Static recording during 30" level flight, during microgravity and over loading period and 30" level flight afterwards.
3. Subject lying.
Recording during active flexion of the hip, limb in extension during microgravity period.
4. Subject lying.
Recording during active flexion of the knee during microgravity period.

5. Subject lying.

Recording during active flexion of the hip, limb in extension during microgravity period. Study of the influence of different speeds in motion.

6. Subject lying.

Recording during rebound from the wall into the measured limb during microgravity period.

4. PUBLICATIONS

BURNY, F. and DONKERWOLCKE, M., Elastic fixation of fractures : Biomechanics of fracture healing. In : Fracture Healing (Ed. : J. Lane), Churchill Livingstone : 123-137, 1987.

BURNY, F., DONKERWOLCKE, M., BOURGEOIS, R. and HINSENKAMP, M., Twenty years experience of clinical measurement of bone implants deformation with strain gauges, In : Monitoring of fracture healing by vibration analysis and other mechanical methods (Eds. : G. Van Derre, A.B. Christensen) : 145-162, 1986.

HINSENKAMP, M., ROOZE, M. and TUERLINCKX, B., Biophysical and biological intervention. Future directions, In : Fracture Healing (Ed. : J. Lane), Churchill Livingstone, 267-275, 1987.

K. INSTITUTE OF INTERDISCIPLINARY RESEARCH

OF THE UNIVERSITE LIBRE DE BRUXELLES

THE RESPIRATORY SYSTEM UNDER WEIGHTLESSNESS : PREPARATION OF ANTHRORACK

EXPERIMENT B-55 FOR MISSION D-2

1. GROUND STUDIES

The study of the respiratory system in microgravity will be a very important part of biomedical space research during next flights of Spacelab. Some of the experiments selected consist of single and multiple inert gas washouts to study the ventilation distribution during one week in microgravity.

1.1. Single breath washout

One of the simplest non-invasive tests in pneumology is particularly appropriate to study the gravity dependence of the distribution of ventilation : the single breath washout. In its conventional form, this test consists of an inspiration of O_2 , the N_2 concentration being recorded during the following expiration. We have shown that the role of gravity on the distribution of ventilation can be better studied by using a gas mixture containing a high diffusive (He) and a low diffusive gas (SF_6).

1.2. Multibreath washout

The astronauts will be asked to perform 30 one liter breaths when inspiring a gas mixture containing O_2 with He and SF_6 as tracers. From ground studies and computer modelling techniques we have optimized the procedure to follow, in order to obtain a maximal information on the role of gravity on ventilation distribution.

2. CHEST WALL SHAPE AND MOTION IN MICROGRAVITY (5th ESA PARABOLIC FLIGHT
CAMPAIGN - OCT 1987)

The knowledge of the lung volume of the astronauts is important for the determination of many respiratory parameters. The spontaneous end expiratory lung volume (FRC) also determines the length of the respiratory muscles during normal breathing. However, previous attempts to perform these measurements have given conflicting results and to the best of our knowledge, there is no published information of the astronauts FRC during orbital missions.

Four different respiratory maneuvers were performed in five subjects and repeated in one of them during the fifth ESA campaign of parabolic flights. The maneuvers were performed during and between the parabolae and six variables were recorded on tape and hard disc : 1) vertical acceleration, 2) atmospheric pressure in the plane, 3) respiratory flow, 4) abdomen and 5) rib cage contribution to total volume measured by an external device (Respitrace) and 6) the sum of 4) and 5) which enables the estimation of chest wall volume. The main observations from a preliminary analysis of the results are that during the microgravity periods a) FRC decreases significantly in all the subjects, this decrease resulting primarily from an inward movement of the ventral abdominal wall; b) the contribution of the abdominal compartment to tidal volume increases and c) the abdominal expansion predominates over the rib cage expansion relative to the relaxed thoraco-abdominal configuration, the so-called relaxation line.

During quiet breathing, normal subjects follow the relaxation line which corresponds to the more economical way of breathing. This is a consequence of a very complex coordination of the different respiratory muscles. The knowledge of the relaxation line and of the pattern of breathing establishes a framework for the computation of the work of breathing in weightlessness. There is evidence that some activities have

proved to be unexpectedly demanding. This may be partly due to a disadvantageous change in chest wall mechanics. However, during long periods of weightlessness, the situation is much more complex due, for example, to the increase in the inter disc distances of the spine and consequently of the rib insertions. We will follow the adaptation of the astronauts during the D-2 mission, measuring how the breathing pattern changes with respect to the relaxation line. This will bring a link between the nervous and the respiratory systems.

3. PUBLICATIONS

- CRAWFORD, A.B.H., MAKOWSKA, M., PAIVA, M. and ENGEL, L.A., Convection- and diffusion-dependent ventilation maldistribution in normal subjects, *J. Appl. Physiol.*, 59, 838-846, 1985.
- PAIVA, M., Theoretical studies of gas mixing in the lung. In : "Gas Mixing and Distribution in the Lung". L.A. Engel & M. Paiva eds. Marcel Dekker, New York, 221-285, 1985.
- PAIVA, M., Perspectives for studying the respiratory system in microgravity, *Bull. Europ. Physiopath. Resp.*, 23, 413-415, 1987.
- PAIVA, M. and ENGEL, L.A., Model analysis of intra-acinar gas exchange, *Respir. Physiol.*, 62, 257-272, 1985.
- PAIVA, M. and ENGEL, L.A., Theoretical studies of gas mixing and ventilation distribution in the lung, *Physiol. Rev.*, 67, 750-796, 1987.
- PAIVA, M., ENGEL, L.A., HUGHES, J.M.B., GUY, H.J., PRISK, G.K. and WEST, J.B., The respiratory system under weightlessness, *ESA SP-271*, 41-45, 1987.
- PAIVA, M., VAN MUYLEM, A., RAVEZ, P. and YERNAULT, J.C., Preinspiratory lung volume dependence of the slope of the alveolar plateau, *Respir. Physiol.*, 63, 327-338, 1986.

L. LABORATORY FOR SPACE PHYSIOLOGY (RUCA)

BRAIN ELECTROPHYSIOLOGY IN ZERO-G

The past two decades have seen an increasing recognition of the impact of environmental factors in determining the performance capability of man, and of the need to monitor a number of central nervous systems (CNS) and other parameters on a non-interference basis in space. Developments in bio-instrumentation have materially assisted in achieving these goals. Therefore the study of the brain activity as a function of zero-G was performed during two parabolic flights organised by ESA and NASA in Houston in October 1987.

The limited duration of the parabolic flights have restricted the investigation of the electrical activity of the brain as a function of zero-G to the study of the EEG during wakefulness only. Nevertheless, parabolic flights have allowed to identify, among the number of factors which influence the activity of the brain in orbital conditions, the factor responsible for some of the observed effects. In orbit, there is the period of severe booster accelerations and vibrations with pressures up to 10 G, whereas during the parabolas they reach 2 G only, immediately before the zero-G acrophase. In orbit, there is the non negligible factor of irradiation facts in the brain and the CNS generally; or alternatively, the question of irradiation of the whole body and its secondary effects on the CNS. This factor is absent in parabolic flights.

For these reasons, the EEG has been monitored in three subjects during the various phases of the parabolas.

Results showed that the increase in the power of the 4 to 8 Hz. EEG theta waves was again the main feature of the in-flight recordings.

The results confirm the findings of the 1983 parabolic flights. The theta waves showed a 90 sec. periodicity similar to the period of the parabolas. An increase in the theta waves has been documented earlier in the Gemini flights during early exposure to weightlessness and interpreted as a physiological response to the weightless environment. It entitles us to assume that the periodicity in the theta waves corresponds to the zero gravity acrophase of the parabolas. Increase in the theta waves may result from an augmented orienting response to a quite unusual experience. They may be considered as a biological measure of the periodicity of the parabolas. It has been interpreted as related to a strongly focused attention.

The increase in the theta frequency band stands in sharp contrast with the decrease in power after landing in these subjects. Laboratory studies have indicated that, as in the present case, the decrease is correlated with a more relaxed attitude following a challenging experience.

The increased densities in the theta band broadened to include the 8 to 12 Hz. alpha frequencies in-flight. A parallel between the evolution of the spectra in both classes of frequencies can be seen. It may seem a paradox at first sight because alpha waves are associated with relaxed wakefulness. They probably correspond to the period immediately following the zero-G acrophase.

The data show a slight increase in the amplitude spectrum of the beta waves which range from 12.5 to 16 Hz. We hesitate to put too much physiological significance on this finding, particularly as some mixture of muscle potentials could not always be excluded.

The man-space program obviously insists on the aspects "productivity" and "autonomy" of the astronauts. The monitoring of EEG data during performance tasks in zero-G aims at establishing a data base. Aberrant neurophysiological changes should serve as early warning signs indicating intervention as counter measures for health related problems.

M. LABORATORY FOR REGIONAL GEOGRAPHY AND LANDSCAPE SCIENCE

OF THE STATE UNIVERSITY OF GHENT

1. INTEGRATED INTERPRETATION

Visual and digital interpretation techniques are complementary for the interpretation of remote sensing data. A combined use of both interpretation techniques will provide the best results.

To the classical tools of the visual processing at the Laboratory for Regional Geography and Landscape Science belong stretching by high gamma films, preparation of false colour composites, density slicing, etc... The processed photographic products are used for different kinds of interpretation work, including e.g. the photomorphic unit (PMU) classification. By this technique B&W negatives or false color composites (FCC) are analyzed and units with the same spectral, textural and structural characteristics are mapped.

Digital processing is also done at the Laboratory for Regional Geography and Landscape Science. The CCT's (computer compatible tapes) are read by the main frame computer, the processing itself is done on a microcomputer using both commercial and indoor software.

The integration of digital and visual interpretation data and information derived from maps, statistics and field work can be done either manually or computer assisted. The latter uses geographical information systems (GIS) and computer assisted cartography (CAC). A part of the staff is developing further the use of such techniques.

Last but not least the Laboratory for Regional Geography and Landscape Science offers large possibilities of integrated research in collaboration with other faculty laboratories, including pedologists, geologists and botanists.

2. THE STUDY OF LINEAMENTS ON SATELLITE IMAGES IN ALGERIA

The study of lineaments on satellite images can contribute to the understanding of regional structural geology. Such an analysis was performed in North-East Algeria.

In the region of Constantine 338 lineaments were visually recognized on an enlarged print. An important amount of the observed lineaments exceeds 20 km. Three modal orientations can be distinguished. A comparison was made with the faulting orientations, indicated on the geological map. The principal lineament orientation is perpendicular to the SW-NE Auresian faulting direction; an explanation for the perpendicularity of the lineaments to the mapped faulting, can probably be found in regional differences inside the studied area and in the detection of hidden faulting or fracturing. As the lineaments cross different structural units and as they are perceptible in spite of a thick Pliocene and Quaternary cover, questions about the importance of recent regional tectonic movement arise.

Comparisons were also made between mining sites on topographical maps and lineament distribution. To allow such comparisons, transformations to the Lambert Algerian North rectangular coordinate system was made using indoor cartographic software.

3. SPOT : LAND USE PROJECT

The interpretation of land use is one of the common activities at the Laboratory for Regional Geography and Landscape Sciences. In 1986 a land use project for Flanders, with the use of SPOT imagery was started. In Flanders, the great diversity of the landscape and their complex fine structures cause important regional variations in the interpretation accuracy of satellite images for this purpose. Consequently it is necessary to make first of all a classification of structural characteristics of the landscape. Therefore 14 test sites were chosen, located in the different regional areas of Flanders.

During several months terrain inventories were made using the method and guidelines used during the SAR 580 campaign in 1982. Following parameters were especially recorded : crop type, growing height coverage, the occurrence of enclosures, the soil colour, the soil moisture, and the topographical situation.

After a visual and digital treatment of these data, in combination with the imagery data, an interpretation key was proposed. With the use of these interpretation techniques it is possible to detect regional differences in the landscape and it will be possible to make estimations about the yield of the different crops in the different regions.

4. MONITORING OF ENVIRONMENTAL DEGRADATION IN ARID AND SUBARID REGIONS USING SATELLITE IMAGES

The desertification of the Sahel zone is probably the most discussed present day environmental degradation phenomenon. There are different kinds of degradation, and some are studied at the Laboratory of Regional Geography. Desertification is the result of the disturbance of the ecological balance. In most regions, the cause for this disturbance is the human activity. Also in the Sudan-Sahelian zone, the moving of the Sahelian border finds a cause in overgrazing. The reason for this overgrazing can either be the growing or the local concentration of the cattle stock above the carrying-capacity of the environment. This kind of overgrazing happens around dwellings. Each overgrazed zone extends in a concentric way and they will sooner or later, join. When there is no vegetation, soils erosion will be accelerated. The desertification phenomena are followed in a multi-temporal way, this means that the satellite images of different dates are interpreted and compared. The final product of these analyses is a map with indications about the evolution of the degradation phenomena. With the use of satellite images, the environmental degradation can be detected very early : in the beginning, the degradation manifests itself only in the

infrared part of the spectrum. By making the wright choice of the spectral bands of the Landsat and/or SPOT images, it is possible to make a diagnosis of these phenomena.

Also other phenomena, such as dune movement, change of river beds... etc., can be detected by using satellite images.

Special attention is paid to the study of the salinization of the soils of Northern Africa. The appearances of salt affected soils is a natural phenomenon (chotts, sebkhas, guerrahs...), but, on a smaller scale, it may be the result of irrigation with (salty) water. From the agricultural point of view, it is important to map these zones and to prevent their expansion. This can be done by mapping the natural salt affected soils as well as the "man-made" salt affected soils. After the development of an interpretation key it is possible to indicate the endangered zones for the agriculture. When this is done in a multi-temporal way, it is even possible to estimate the rate of the salinization process.

Other objects of the Laboratory are the evaluation of the vegetation conditions in neglected oases, the follow up of new agricultural zones and the study and cartography of land use in general.

5. DETECTION OF SOIL DRAINAGE CONDITIONS USING SATELLITE IMAGES

At the laboratory for Regional Geography and Landscape Science, several studies about soil drainage detection have been executed. The test sites are mainly located in Belgium and partly in France.

The used images came from different passive sensors as there are, Landsat MSS, Landsat TM, and multispectral SPOT-images.

The aim of this study field is to have a better understanding of the influence of the ground water table on the reflection of grassland. Recent research is also concentrating on the influence of the ground water table on the reflection of naked arable land.

For some regions, "Haspengouw" the "Pays de Herve" (Belgium) and Picardy (France), interpretation keys could be developed, allowing the distinction of poorly and well drained soils. The application of these interpretation keys allows the mapping of general soil drainage conditions. The elaborated interpretation keys could be extrapolated to similar areas for which soil maps are not available.

More recent research is emphasizing on small test sites, homogeneously covered by pasture land. This research is concerned with detailed analysis of the digital values. Small differences in digital values could be correlated with differences in soil drainage conditions. The spectral response of the pasture land shows a correspondence with the soil drainage conditions.

The investigation of soil drainage detection over naked arable land showed clearly the influence of the winter ground water table on the (surface) reflection of the bare soils. It was estimated that the closer the ground water table is to the surface, the lower is the surface reflection.

6. THE USE OF SATELLITE IMAGES FOR THE STUDY OF SOIL CHARACTERISTICS AND LAND USE (APPLIED UPON SOUTH EVVIA, GREECE)

The aim of this study is to investigate how remote sensing documents can be used for the detection of soil characteristics and land use.

The study area is situated in the southern part of the island EVVIA. EVVIA is the second largest island of the Greek archipelago. It is located in the Aegean Sea, along the eastcoast of Central Greece.

Three types of satellite images are used : Landsat MSS, Landsat TM and SPOT. The study mainly deals with the multiconcept, in which documents of different nature are compared. The combination of the different images, registered by the different sensors (each with its

own spectral, spatial and temporal resolution), allows a better interpretation. A visual interpretation as well as a digital approach is executed.

According to the SOIL SURVEY MANUAL (1962) "soil" is defined as follows : "Soil is the collection of natural bodies occupying portions of the earth's surface that support plants and that have properties due to the integrated effect of climate, living matter, acting upon parent material as conditioned by relief over periods of time".

In most cases, the soil is not visible, and the soil characteristics have to be deduced from visible landscape elements, which are interrelated with the soil conditions. Thus, a thematic study of these elements, such as relief, hydrographic network, geology, natural vegetation land use and human influence is needed. Each of these landscape elements is characterized by its own spectral signature.

In fact, this study consists of the delineation of spectral differences, which have to be correlated with differences in soil conditions. The soil characteristics, which we try to detect, are : texture, soil humidity, soil drainage, organic matter content, erosion, salt accumulation,...

It is to distinguish five different soil types in South EVVIA, by means of a visual interpretation. These are : alluvial soils, colluvial soils, terra rossa, lithosols and hydromorphic soils.

7. ZAIRE PROJECT

The Zairese authorities, in charge of the improvement of the agriculture, insisted on Belgian cooperation for the up-dating of the agricultural statistics of Zaire.

The first period of investigation was started in December 1984, for a period of six months and was completely carried out in Belgium. This stage was merely preparatory and included a review of existing literature and a first visual interpretation of Landsat images. Following units were mapped : Traditional environment occupied by agriculture and the most common regional vegetation units. This mapping based on 20 test cases, covers a big part of Southern Zaire.

The first stage was executed in collaboration with other Belgian universities : RUG, KUL, UCL and the Agriculture faculty of Gembloux. With this view-mapping, made by means of Landsat images (resolution 79 x 79 m). 16 units could be detected. Out of these units some test cases were selected and will be further investigated.

The second stage was started in January 1987 and will be carried out partly in Belgium and Zaire. This stage will lead to a method to determine the agriculture areas very accurately. Satellite images used for this purpose have a finer texture than those used in stage one namely : 30 x 30 m for TM-images and 10 or 20 m for SPOT images. The aim is also to investigate the yield of several cultures through the combination of satellite images and terrain studies.

The results of those two stages of investigation will also be used in other parts of Zaire, in order to provide the basic data which can be used for the interpretation of the traditional agriculture.

8. PUBLICATIONS

ANTROP, M., Structural information of the landscape as ground truth for the interpretation of satellite imagery, Proc. 7th Int. Symp. ISPRS, Enschede, 25-29 August 1986, 3-8.

ANTROP, M., Satellieten voor aardobservatie : wat kunnen ze echt zien van ons milieu., Milieu-Aktief, 6, 17-20, 1986.

ANTROP, M., Geographical site analysis : a review of the possibilities, Proc. 2e Inter. Symp. van het CIRA, Brussel, C. Leva, Luchtfotografie en geografische prospecties in de archeologie, 1987.

- ANTROP, M., Analyse géographique des sites utilisant des modèles de dispersion spatiale, *Archéologie*, 2 (in press).
- ANTROP, M. and MARTENS, M., Spot : Een nieuwe manier om de aarde te observeren, *De Aardrijkskunde*, 10, 1, 63-75, 1986.
- DAELS, L., DE MAEYER, P. and GOOSSENS, R., Milieuinventarisatie aan de hand van satellietgegevens Landsat MSS en SPOT simulaties in het Dongola District (Soedan), *De Aardrijkskunde*, 87/2 (in press).
- DAELS, L., DE MAEYER, P. and GOOSSENS, R., An environmental study using satellite imagery of the Dongola district (Sudan) including crop inventory of soil degradation monitoring and mapping of the morphographic changes of the River Nile, *AVRUG* (in press).
- DE MAEYER, P., Van computergesteunde cartografische informatiesystemen : mogelijkheden op een microcomputer, *De Aardrijkskunde*, 87/2 (in press).
- DE MAEYER, P. and HANSSENS, E., Lineaments in N.E.-Algeria, Poster session, BGRG, University of Reading, U.K, 1986.
- DE MAEYER, P. and HANSSENS, E., Analysis of lineaments. Distribution patterns of NE-Algeria, *IGARSS'87 Michigan* 18-21 May, 1309-1313, 1987.
- DE MAEYER, P. and ONGENA, T., Integration of a GIS and Remote sensing for land use, *Willi Nordberg Symposium*, Graz, September 7-9, 1987.
- GAD, A. and DAELS, L., Assessment of desertification in the lower Nile Valley (Egypt) by an interpretation of Landsat MSS-colour composites and aerial photographs, *Proc. 7th Int. Symp. ISPRS*, Enschede, 25-29 August 1986, 599-606.
- GAD, A. and DAELS, L., Assessment of wind and fluvial action by using Landsat MSS-colour composites in the lower Nile Valley (Egypt), *Proc. ISCS CP Conference*, Rome, 2-6 December 1985, ESA SP-248, 473-476, 1986.
- GOOSSENS, R., Image interpretation of soil drainage conditions in the Land of Herve, Poster session, BGRG, University of Reading, U.K., 1986.

- GOOSSENS, R., Detection of soil drainage in "pays de Herve" - Belgium - on Landsat MSS imagery, ESA/EARSEL Symp., June 1986, pp. 2, 1986.
- GOOSSENS, R. and DE DAPPER, M., The use of B&W aerial pictures for the detection of supposed ancient conservation terraces (Southern Evvia-Greece), Archeologia, (in press).
- GOOSSENS, R. and DE MAEYER, P., Visuele en digitale beeldanalyse en interpretatie van Landsat MSS en TM beelden voor de detectie van waterhuishouding in zout en zout-geaffecteerde gronden in NE-Algerije, Intern Rapport, RUG en Ministerie van Wetenschapsbeleid, 1986.
- GOOSSENS, R., DE MAEYER, P. and ANTROP, M., Interpretatie van milieu-degradatie en evolutie aan de hand van Landsat MSS en SPOT-simulatie, Dongola district (Soedan) preliminair rapport, Intern rapport, RUG en Ministerie van Wetenschapsbeleid, pp. 17 + 4 kaarten B.T., 1986.
- GOOSSENS, R. and VAN CAMP, L., The detection of soil drainage by using Landsat MSS and TM (Belgian test zones), IGARSS'87, Michigan 18-21 May, 871-876, 1987.
- LARNOE, G., Drie benaderingswijzen in landschapsanalyse, toegepast op een aantal gebieden in Frankrijk. Deel 2 : een geïntegreerde studie van de landschapsbouw en transformatie in het binnenland van de Provence, De Aardrijkskunde, 87/2 (in press).
- LARNOE, G., Study of some connecting landscape structures and their evolution in the basin of Montméyan, 2e IALE-Seminar, Münster 19-24 July, Pro Poster session, 1987.
- LARNOE, G., Drie benaderingswijzen in landschapsanalyse, toegepast op een aantal gebieden in Frankrijk. Deel 4 : Analyse van de bezitsstructuren en de impact hiervan op de sociaal economische situatie in de Grande Champagne (Pays Charentais), De Aardrijkskunde, 4 (in press).
- VAN CAMP, L. and GOOSSENS, R., A multi source image set for the study of soil texture and drainage as observed from TM in Northern Belgium, IGARSS'87 Michigan, 18-21 May, 221-226, 1987.

1. REMOTE SENSING PROJECTS

The research activities were further developed in the framework of the Belgian scientific research program in the field of spatial remote sensing.

a. Satellite inventories and field radiometry

European Remote Sensing efforts in the agricultural domain concentrate on the improvement and timely acquisition of agrostatistical information. In particular, much is expected from the complementary use of Remote Sensing data, together with collateral sources providing topographic, soil, climatic, administrative... information.

In a case-study performed in the Gembloux test area (Central-Belgium), the following data sources were integrated :

- Six satellite images of the growing season 1986 (4 SPOT-HRV, 2 Landsat-TM);
- A dataset of easily recognizable ground control points, used for the geometric correction and numerical overlay of the different images;
- A Digital Terrain Model providing heights and slopes, both in vector and raster format;
- A detailed crop inventory map of a sub-zone, used for the supervised classification and/or verification;
- A dataset of ground-measured irradiances and reflectances, acquainted on some test fields at regular time intervals;
- A Geographical Information System with the administrative boundaries, which permits the extraction of crop statistics per municipality;

- Existing statistics, gathered by the National Institute of Statistics, allowing the comparison of our results on a municipal base.

In a preliminar atmospherical correction, all original image data were rescaled into pixel reflectance factors, which represent a better ground for pixel identification and extraction of crop parameters (biomass, LAI, ...). An integrated remote sensing approach for regional agrostatistics and land monitoring is under development.

b. Agriculture statistics in Zaire with the support of remote sensing satellite data

The tasks of the project are the following : Collection of local terrain data and other collateral information. Execution of field radiometry on tropical crops and soils. The field work is done in collaboration with Zaire. Interpretation of satellite data : optically oriented colour composites and digital image processing. Derivation of crop and land cover types, acreage and assessment of actual land use patterns for land management. Production of thematic maps and ground verifications. Demonstrations of the use of remote sensing from space with respect to applications in forestry management, land degradation, urban growth, etc. Training of Zaire collaborators in remote sensing techniques in Belgium and in Zaire.

2. PUBLICATIONS

DEPUYDT, F., GOMBEER, R. and STEENMANS, C., Satellietkartografie : De schijnbare thermische inertiekaart van België. Kaartblad op schaal 1/500.000 met begeleidende tekst. (Kaartauteurs : R. Gombeer en C. Steenmans), Nederlands Kartografisch Tijdschrift, 4, 10, 1986.

EERENS, H., ROEKAERTS, M. and GOMBEER, R., Crop inventorying of small parcelled areas using SPOT and TM-data in conjunction with field radiometric measurements, Proceedings of IGARSS'87 Symposium, Ann Arbor (USA), 227-232, 1987.

- EERENS, H., ROEKAERTS, M. and GOMBEER, R., Absolute recalibration of satellite recorded digital numbers into Pixel reflectances at optical wavelengths, Notes de Recherches de la Société Géographique de l'Université de Liège. (Groupe FNRS). Numéro spécial "Télédétection et Espaces Urbains" n° 9, 17-32, 1987.
- GOMBEER, R., Application of Meteosat data for remote sensing of earth resources. Recommendations and outlook, Proc. ESA/EARSEL Symposium on Europe from Space, Lyngby (Denmark), ESA SP-258, 109-115, 1986.
- ROEKAERTS, M., DELCOURT, A., EERENS, H., DEVOS, W. en GOMBEER, R., Multitemporele bodemgebruiksklassifikatie van satellietbeelden, gebruik makend van een atmosferische en geometrische correctie, Proc. studiedag : Resultaten van toepassingen van satellietbeelden bij milieu en landschapsonderzoek, Koninklijk Nederlands Aardrijkskundig Genootschap, 45-48.
- ROEKAERTS, M., VAN DAELE, R. and GOMBEER, R., Landsat-TM multitemporal crop and land-use mapping over small parcelled areas in Belgium. NPOC Pilot Project, Final report to ESA/EARTHNET, 77 pages, 1987.
- ROSEMA, A. and GOMBEER, R., Results of the Group Agromet Monitoring Project (GAMP), ESA Journal, 10, 17-41, 1986.
- WILMET, J., OZER, A., DAUTREBANDE, S. and GOMBEER, R., Quelques résultats de l'interprétation agro-pédologique et du paysage rural des données SPOT en Belgique, Colloque International Spot-1, Paris, 383-385, 1987.

O. LABORATORY FOR AERO-SPATIAL REMOTE SENSING OF THE
ROYAL MUSEUM FOR CENTRAL AFRICA

1. CURRENT RESEARCH

a. Development of geology-oriented image processing soft-and hardware

Programs allowing the superposition of multiple source data and the interpretation thereof are applied to the comparison of geophysical, geochemical and remotely sensed data. This method is used as an aid to geological mapping on the ground in Rwanda.

The possibilities of image processing apparatus prototype are in constant development.

b. Enhancement of geological features in space imagery

Image processing is currently used for geological application. Two thematic fields are developed : discrimination of lithology and structural analysis. Both rely on remotely sensed data. The variables used in the multivariable processing are either original satellite data or derived ones. Most of the applications of the last year have been done in the frame of the GARS (Geological Applications of Remote Sensing) program of UNESCO/IUGS and the PEPS program of SPOT image. The region concerned are western Tanzania (1986-1987) and Burundi (1987-1988).

c. Interference between objects radiance and atmosphere

Measurement of the radiance/reflectance of natural objects (mainly rocks and soils) have been made in the field in tropical regions

(W. Tanzania, Burundi) in order to obtain parameters for image analysis and subsequent thematic classifications. The radiometer used have been the CIMEL 3 bands (SPOT bands) radiance/reflectance radiometer, the IRIS IV 940 channels reflectance spectroradiometer as well as laboratory spectroradiometers. Specific atmospheric correction algorithms are developed for the use of these data in connection with space imagery.

2. PUBLICATIONS

BARDINET, C., KLERKX, J., LAVREAU, J., LE PAGE, A., ROGGERI, I., TREFOIS, Ph., WEBER, C. and Yu ZHENG, First results of the IUGS-UNESCO programme on Geological application of Remote Sensing (GARS) in Eastern Africa, COSPAR meeting, Toulouse, Adv. Space Res., 7, 19-23, 1986.

BARDINET, C., LAVREAU, J., LE PAGE, A., ROGGERI, I. and TREFOIS, Ph., Image analysis and lithological classifications of the Karema area using LANDSAT TM data. In : Remote sensing applied to geological problems in tropical Africa (LAVREAU, J. and BARDINET, C., eds), Ann. Mus. Roy. Afr. Centr., Tervuren, Sc. géol., (in press).

BARDINET, C., LAVREAU, J., ROGGERI, I. and TREFOIS, Ph., Recognition of lithologies favourable to base metals and mineral commodities in tropical conditions using TM data in the Karema region, W. Tanzania. Workshop on Remote sensing and mineral exploration, CEE, June 1986, (in press).

BARDINET, C., LAVREAU, J., TREFOIS, Ph., LE PAGE, A., ROGGERI, I., RUDANT, J.P., and TAMAIN, G., Lithology discrimination in tropical conditions using TM data supplemented with a radiometric ground survey in western Tanzania. In : Current Research in African Earth Sciences (MATHEIS, G. and SCHANDELMEIER, H., ed.). A.A. Balkema, Rotterdam, 333-336, 1987.

KLERKX, J., LADMIRANT, H., LAVREAU, J., THEUNISSEN, K. and TREFOIS, Ph., Apport de SPOT (XS) à la cartographie géologique du Burundien (Précambrien moyen) au nord-ouest du Burundi (résumé). CNES/SPOT IMAGE, Coll. Int. SPOT 1. Utilisation des images, Paris, 23-27 nov. 1987. Abstract volume, 423-425.

- LAVREAU, J., Mise au point et utilisation en géologie d'un système de traitement numérique d'images, Bull. Soc. belge Photogrammétrie et Télédétection, 167-168, 51-60, 1987.
- LAVREAU, J., Le traitement d'images satellitaires en géologie au M.R.A.C., Tervuren. De bewerking van satellietbeelden in de geologie door het K.M.M.A., Tervuren Satellite News, (in press).
- LAVREAU, J., Discrimination of natural objects in the Karema area, Tanzania, using a SPOT-calibrated radiometer. In : Remote sensing applied to geological problems in tropical Africa (LAVREAU, J. and BARDINET, C., eds.), Ann. Mus. Roy. Afr. Centr., Tervuren, Sc. géol., (in press).
- LAVREAU, J., ROGGERI, I., RUDANT, J.P., TAMAIN, G., TEMU, E. and TREFOIS, Ph., Radiometric survey of the Karema area (W. Tanzania) as a tool for geological applications. In : Remote sensing applied to geological problems in tropical Africa (LAVREAU, J. and BARDINET, C., eds.), Ann. Mus. Roy. Afr. Centr., Tervuren, Sc. géol., (in press).
- LAVREAU, J., RUDANT, J.P. and TREFOIS, Ph., Rocks and soils discrimination using a SPOT-calibrated radiometer. 4th Int. Coll. Spectral Signatures of Objects in Remote Sensing. ESA publication, (in press).
- ROGGERI, I. and TREFOIS, Ph., Texture analysis of a LANDSAT TM scene of Western Tanzania : enhancement of the structures and textural signatures. In: Remote sensing applied to geological problems in tropical Africa (LAVREAU, J. and BARDINET, C., eds), Ann. Mus. Roy. Afr. Centr., Tervuren, Sc. géol., (in press).
- TAMAIN, G., LAVREAU, J., NANYARO, J. and YANDA, P., Regional metallogenic analysis in W. Tanzania : Mineralization during the first stages of the lower proterozoicum. In: Remote sensing applied to geological problems in tropical Africa (LAVREAU, J. and BARDINET, C., eds.), Ann. Mus. Roy. Afr. Centr., Tervuren, Sc. géol., (in press).

- TAMAIN, G., LAVREAU, J., NANYARO, J. and YANDA, P., Regional metallogenetic analysis in W. Tanzania : Mineralization during the first stages of the lower proterozoicum. In : Remote sensing applied to geological problems in tropical Africa (LAVREAU, J. and BARDINET, C., eds.), Ann. Mus. Roy. Afr. Centr., Tervuren, Sc. géol., (in press).
- THEUNISSEN, K., TREFOIS, Ph. and LAVREAU, J., Analyse du contenu multi-spectral et exploitation en mode stéréo-panchromatique de sous-scènes SPOT dans deux régions du Burundi. Interprétation lithologique et tectonique (PEPS 286). CNES/SPOT IMAGE, Actes du Coll. Int. SPOT 1, Paris 1987, CEPADUES-EDITIONS, Toulouse, 881-6, 1988.
- TREFOIS, Ph., Correlation and principal components analysis of a LANDSAT TM scene. In : Remote sensing applied to geological problems in tropical Africa (LAVREAU, J. and BARDINET, C., eds), Ann. Mus. Roy. Afr. Centr., Tervuren, Sc. géol., (in press).
- VANOUPINES, P., An atmospheric correction algorithm for Landsat TM, suitable for general applications. In : Proceedings of the International Meeting on Atmospheric transparency for Satellite Applications, Capry, (in press).
- VANOUPINES, P., Atmospheric corrections : theory and applications. In : Remote sensing applied to geological problems in tropical Africa (LAVREAU, J. and BARDINET, C., ed), Ann. Mus. Roy. Afr. Centr., Tervuren, Sc. géol. (in press).
- VANOUPINES, P., Atmospheric corrections, a processing technique for satellite images, Mus. Roy. Afr. Centr., Tervuren, Belg., Dép. géol. et min., Rapp. ann. 1985-1986, 191-201, 1987.
- VANOUPINES, P., Ware kleurcomposieten, Tijds. Belg. Vereniging Tele-detektie, Kartografie en Fotogrammetrie, 167-168, 21-30, 1987.

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