History of the Sunspot Index: 25 years SIDC

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Abstract

The sunspot number is the oldest solar activity index. For a long time, it was the only index representative of the solar cycle, and many studies on the cyclical behavior of the Sun were performed using the sunspot number. The Sunspot Index Data Center (SIDC) was founded in January 1981 to continue the work of the Swiss Federal Observatory[1], when this institution decided to stop computing and publishing the sunspot number. The SIDC now also provides daily activity reports and forecasts of the status of the space environment. This 'space weather' activity is part of the International Space Environment Services (ISES, a permanent service of the FAGS) that co-ordinates 10 regional warning centers (RWC). In this paper we will give an overview of the history of the sunspot number, as well as a short overview of the 25-year history of the SIDC.

1. Introduction

The sunspot number and its 11 year cycle is the oldest and best known characterization of the solar activity. Besides solar physics, the sunspot number is used in fields as diverse as climatology, meteorology, space physics, etc. Using the digital library "The NASA Astrophysics Data System" (ADS, [1]) one can find more than 430 papers published since 2000 containing the exact phrase "sunspot number" in the abstract. The internet search engine *Google* returns more than 50000 hits for the exact phrase "sunspot cycle".

Yet, 25 years ago, it was seriously considered to discontinue the production of the sunspot number. Correlation studies had indeed proven that the solar radio flux at 2800MHz (10.7cm wavelength) was highly correlated to the sunspot number. The more objective 10cm radio flux could thus well be used as a replacement for the sunspot number. In a dramatic change of course, the Zürich Observatory decided, after more than 125 years of systematic sunspot observations, to stop its historical core business and to reorient its scientific investigations in solar physics. The World Data Center for the sunspot index was transferred to a newly created structure "the SIDC" in Brussels at the Royal Observatory of Belgium. In this paper we retrace what the motivations were of the people involved. As we will see, World War II brought Zürich and Brussels together, but also caused a schism between the internationally adopted sunspot number (Zürich/Brussels) and the American sunspot number (AAVSO). We use the upcoming 25th anniversary of the SIDC to review this early history of the sunspot number, as well as the evolution of the SIDC in the last 2 solar cycles.

In section 2, we review the highlights of the history of the sunspot index from the discovery of sunspots around 1610 and the centuries-long involvement of the Swiss Federal Observatory, up till the retirement of Max Waldmeier. In section 3, we take a look at what solar physics meant in Belgium during this same time lapse. We look for the foundations on which the SIDC was built. Section 4 focuses on the years around 1981 when the production of the sunspot index was transferred from the Zürich Observatory to the Royal Observatory of Belgium with the creation of the SIDC. The following development and maturing of the SIDC as a complete space weather monitoring institute is discussed in section 5. Concluding remarks on the future of the sunspot index are presented in section 6.

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[1] The Swiss Federal Observatory (Eidgenössische Sternwarte) was reorganized in 1981 with the creation of the Institut für Astronomie of the Eidgenössische Technische Hochschule. We will often refer to it as the "Zürich Observatory".

2. Early history of the sunspot index and the Zürich Era

Sunspots have been observed occasionally by the naked eye since ancient times in China, Greece and elsewhere [2]. Systematic observations of sunspots, however, started only in the 17th century, after the invention of the telescope. Around 1610, several Europeans independently sighted sunspots with their telescopes (Hufbauer 1991), the most famous being the Italian Galileo Galilei. His contemporaries include the English Thomas Harriot [3], who made 199 observations between 8 December 1610 and 18 January 1613, and, in the low countries, father and son Fabricius [4] who were the first to publish on such observations (1611; "Account of Spots Observed on the Sun and of Their Apparent Rotation with the Sun"). The study of sunspots as newly discovered and thus fascinating solar phenomena came to an abrupt end around 1640. During the time between 1640 and 1715 – a time now called the Maunder minimum – sunspot numbers dropped dramatically. Further investigations of sunspots had to wait till later in the 18th century.

The German pharmacist Heinrich Schwabe [5] reported in 1843 the discovery of a ten-year cycle of the number of sunspots. In 1826 he had started a daily record of sunspots as an aid to his search for an intra-Mercurial planet. As his data accumulated, he began to suspect that the number of sunspots followed a slow cyclical pattern. By the end of 1843, he had observed two maxima and two minima of what appeared to be a ten-year cycle. He was however not the first who had witnessed an effect of the variability of the solar magnetic cycle. Already in 1803, Ritter (Schroeder 1997) had pointed out that auroras ("northern lights") appear more frequently in certain time intervals, which would be later identified as solar maxima. In Ritter's time the same cycle in the solar magnetic activity –as measured by the sunspot number- had not yet been discovered, so he could not envisage a solar connection. It lasted till 1852 when Edward Sabine, the chief British promoter of magnetic studies, was informing the Royal Society in London, that "it is certainly a most striking coincidence, that the period, and the epochs of minima and maxima, which H. Schwabe has assigned to the variation of the solar spots are absolutely identical with those which have been [found for] magnetic variation".

In the same year, Rudolf Wolf [6] found after extensive observations, that the period was actually 11.1 years. (Kiepenheuer 1953). He introduced the Wolf number, defined as $R=k(10\ g\ +f)$ with g the number of groups, and f the number of spots. The choice of $10g$ must have been guided by the aim to derive R as far as possible back in time (Zelenka 1979). Wolf chose to exclude in his daily observations short-lived groups of only one small spot and or small spots that were visible only under excellent seeing conditions. This probably eased the comparison with older observations. Using scattered older data, Wolf succeeded in deriving spot numbers back to 1749 (shortly after the Maunder minimum), and the epochs of maxima and minima back even to 1610, when sunspots were first observed. From 1749 up till 1825 only daily values of irregular quality are available. Wolf needed to match past and, later, running records to his own and among themselves. For this he introduced the reduction factor k, specific for each user.

Wolf became the first director of the Swiss Federal Observatory in Zürich. His work was eventually taken over by a series of successors: Wolfer, Bruner, and, most recently, Waldmeier. Over the course of time, more observatories were enlisted in the task in order to combat the variable seeing conditions at particular locations, thereby preserving continuity in the daily counts, and the seeds of an international effort were sown. Wolfer, Wolf's successor, deviated from Wolf's counting strategy (Waldmeier 1961). With a larger and better-dispersed group of observers, *average* seeing conditions improved. The new counting strategy required observers to count *all* of the groups and *all* of the spots visible on a given day (Zelenka 1979, [7]). It was determined that, assuming a value of k=1.0 for Wolf's observations, a coefficient of k=0.6 for Wolfer's observations would place the indices on approximately the same scale, thus maintaining the desired continuity. This value of k is now referred to as the "Zürich Reduction Coefficient", and the resulting index is identified as R_Z, the Zürich Relative Sunspot Number.

Brunner published the first issue of the International Astronomical Union's 'Bulletin for Character Figures of Solar Phenomena' at the end of 1928. It reported data from 13 observatories around the globe for January-March 1928 (Hufbauer 1991). Under the impulse of Hale, a cooperative watch for "chromospheric eruptions" – sudden bursts in the chromosphere that would later be called flares was organized. The job of editing a flare list for the "Bulletin" was taken up by Lucien d'Azambuja of the Meudon Astrophysical Observatory (d'Azambuja 1934). Thanks to the recruiting efforts of Brunner and d'Azambuja, participation in the "Bulletin" continued to grow throughout the troubled 1930s. By the summer of 1939 – shortly afterward it was renamed the "Quarterly Bulletin on Solar Activity" [7] – 31 observatories around the globe were contributing to this cooperative enterprise.

During World War II, American observers started a parallel effort to circumvent long delays associated with the receipt of critically-needed data from Zürich. The interruption of communication with Europe in 1940 and the importance of the solar activity on telecommunications during the war led to the development of the American Number R_A [8]. Beginning with two observers who provided data that could be used to establish monthly trends in activity, responsibility for the effort was transferred to the Solar Division of AAVSO (American Association of Variable Star Observers) in December 1944. This resulted in an increase in the observer base of between twenty and forty. An immediate challenge faced by the AAVSO was to devise adequate means for maintaining day-to-day continuity with the Zürich index in the absence of parallel data from Switzerland. By 1949 it became apparent that the American Relative Sunspot Numbers, had drifted from the Zürich numbers. Efforts to restore conformity with R_Z, including the formulation and application of revised statistical treatments aimed at maintaining long-term quality control were undertaken at that time (Shapley 1949).

At the occasion of the International Geophysical Year, in 1957 and 1958, the Zürich Observatory became the official World Data Center (WDC), set up by the URSI, for the production and international distribution of the sunspot number [9]. More than 30 observatories around the world sent their sunspot observations to Zürich, where they were reduced together with the Swiss observations (in Zürich and Locarno) to form the Zürich Sunspot Number, carefully calibrated to a common scale. The Royal Observatory of Belgium contributed right from the start to the Zürich Sunspot Number.

Since July 1947, Brunner's successor as Director of the Swiss Federal Observatory, Max Waldmeier, resumed publication of the Quarterly Bulletin on Solar Activity. Solar observatories around the globe were once again sending periodic reports to Zürich. Waldmeier had in 1951 built a solar tower telescope in Zürich and in 1957 the *Specola Solare* in Locarno, a solar station on the southern side of the Alps, where the weather is usually complementary to that in Zürich (Stenflo 2000). Waldmeier introduced a widely used evolutionary classification of sunspot groups in nine classes A-J. He carried out a careful examination of the cycles that were at his disposal at that time (up to cycle 18) and subsequently defined classes of cycles that he used to build a set of standard curves. By shifting these curves to such that their respective maxima coincide, he remarked that all the curves were crossing each other in a very small region near R_Z =50, so that the time interval between the crossing "point" and the maximum is roughly constant (1.9 year). From this property Waldmeier derived a method for predicting the position and amplitude of the maximum (Lantos, Cugnon and Koeckelenbergh 1993).

Waldmeier was the last successor of Rudolf Wolf at the Swiss Federal Observatory. The institute was reorganized in 1981 with the creation of the *Institut für Astronomie* of the *Eidgenössische Technische Hochschule* (ETH) in Zürich. Together with the new structure came new people putting new priorities. As we will see below, the production of the Sunspot Number in Zürich would soon come to a definitive ending and the task of the World Data Center would be moved to the Royal Observatory of Belgium (ROB).

3. Early history of solar physics at the Royal Observatory of Belgium

The observatory was created in 1826, 4 years before the creation of Belgium, by King Willem I of the United Netherlands (consisting of what is now called Belgium and The Netherlands). In 1839, the observatory was officially called the "Royal Observatory of Brussels". The observatory had a slow start: In 1832 the first scientific activities started and by 1879, there were still only 15 employees. The observatory was first located close to the center of Brussels (Schaarbeeksepoort, Sint-Joost-ten-Node) and was moved in 1891 to its current position in Uccle[2], in the Southern suburbs of Brussels. From then on it is named "Royal Observatory of Belgium" (ROB).

Sunspot observations were regularly recorded from the early days of the observatory. At the end of the 19th century, Charles Fiévez joined the observatory to assist with regular observations of sunspots and prominences (Koeckelenbergh 1970). Several observations by him, dated August 1877, have been found (Sauval 1995). Jean-Charles Houzeau, who had been appointed Director in 1876, sent him for several months at Meudon under the direction of Jules Janssen, the famous solar spectroscopist and founder of the Observatory of Paris-Meudon. In 1882, Charles Fiévez published his Atlas of the Solar Spectrum, "Etude du spectre solaire" (Annales de l'Observatoire Royal de Bruxelles t. IV, nouvelle série, 5-8, 1882). Fiévez observed and drew 2400 lines in the visible part of the solar spectrum, between 450 and 660 nm. This constituted a record number of lines when compared to all the previous published atlases: e.g. only about 1000 lines were seen in Ångström's atlas (1868). In 1885, he observed in a similar fashion 360 lines of the red section, between 656nm and 760nm, "Etude de la region rouge (A-C) du spectre solaire" (Annales de l'Observatoire Royal de Bruxelles t. V, nouvelle série, 3-5, 1885). In the same year, he brings out his research on "The influence of Magnetism on the Character of Spectral Lines" (Bulletin de l'Académie Royale de Belgique 3e série, t. IX, 381-385, 1885). Fiévez observed the broadening of lines of sodium, potassium, lithium and thallium, but the intensity of the magnetic field must have been too weak, as he could not see the true decomposition of the lines, a characteristic effect which was to be observed eleven years later by the Dutch physicist Pieter Zeeman (1896, 1897). From his experiments, Fiévez concluded too quickly and mistakenly that the influence of magnetism on the lines was the same as the influence of temperature. He died in 1890, at the age of 45.

Around 1908, Mgr. Eugène Spée (1843-1924), a Jesuit priest, who had studied at the "Specola Vaticana" and was a student of Secchi, started photographic observations of the photosphere at the ROB solar dome using a Grubb heliograph (Koeckelenbergh, oral communication). This refractor is still in use now for the visual sunspot drawings of the Uccle station. This photographic program was not systematic and went to a halt in 1909 with the nomination of Georges Lecointe as Director of the ROB. Lecointe, who had followed a military career, had also served on board of the "Belgica" polar expedition to Antarctica, together with De Gerlache. Lecointe was a classical astronomer (mathematician) and considered that astrometric programs ("Carte du Ciel" program) were more important that the developing astrophysical techniques. In a rather dogmatic fashion, he thus stopped authoritatively the nascent solar observations. In 1910 (Annales de l'Observatoire Royal de Belgique, vol XII, p. V and VI.), the Director G. Lecointe explained the reasons for the cessation of this type of observation: *"Considering that this type of work is already performed in other observatories, with special care, great regularity and a much improved method of photography; considering that we can use for more scientific and more justified research the large resources of our observatory and the intellectual capacities of its staff, we decided that starting 1909, these statistics will no more be included in our program.."*

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[2] Uccle is a suburb in the South of Brussels. Brussels has a bilingual status (French/Dutch), in what follows we will use the French spelling of Uccle (Dutch: Ukkel).

However, Director G. Lecointe was often on sick leave and, when the World War I broke out, he joined the Belgian Army as a volunteer. During those absences, Stroobant and Warzée, an assistant, carried out again solar observations. An anonymous book has 264 plates of the sun between 1913 and 1919. Finally, in 1924, Stroobant succeeded to Lecointe as Director, and systematic solar observations take their real start at the ROB. In 1939 and during World War II, Gaston Coutrez was appointed as a technician to further implement a systematic and standardized solar observing program (Koeckelenbergh 1971). He began systematic spot observations and their reduction with a projected image of 25cm diameter in collaboration with Profs. Brünner and Waldmeier. Because of the war, communications were difficult with observatories in other countries, in particular in the USA. The mail exchange with the Zürich Observatory was the foundation of the close personal relationship and mutual trust between Brussels and Zürich that continued long after the war and led to the current SIDC. From 1940 onwards, we have at Uccle a homogeneous series of uninterrupted observations of spots, and observation reports are regularly edited by the revue Ciel et Terre, by Communications and the Bulletin Astronomique (Koeckelenbergh 1971).

The son of Gaston Coutrez, Raymond Coutrez, was hired at the observatory in 1945 after many years of voluntary work (Gonze 1998). Under the direction of Director Bourgeois, R. Coutrez undertook the modernization of the solar apparatus. In 1949, he starts a new field of research at the ROB: radio astronomy. In collaboration with "Ecole Normale Supérieure de Paris" and "IRSAC" simultaneous radio-astronomical observations of the total solar eclipses of 1952 and 1954 are carried out from 3 different sites. This allows defining the relation between solar coronal activity in metric wavebands and active chromospheric and photospheric plages. R. Coutrez founded in 1954 the radio-astronomy station in Humain (near Marche-en-Famenne, Belgium). Two radio telescopes (169MHz and 600MHz) were used for the International Geophysical Year. He finally conceives a radio interferometer in Humain consisting of 48 parabolic antennas.

In 1952, A. Koeckelenbergh started working as a trainee (assistant volontaire) in the solar physics group, where he was invited by G. Coutrez and P. Bourgeois. Both scientists were involved in astronomy clubs, of which Koeckelenbergh was a young member. Two years later, Koeckelenbergh got a permanent position of assistant for solar observations. Meanwhile, Coutrez studies and realizes at ROB an instrument of a new type: an automated solar equatorial table. This instrument was fully automated with solar and dome sensors, and motor driven photographic cameras.

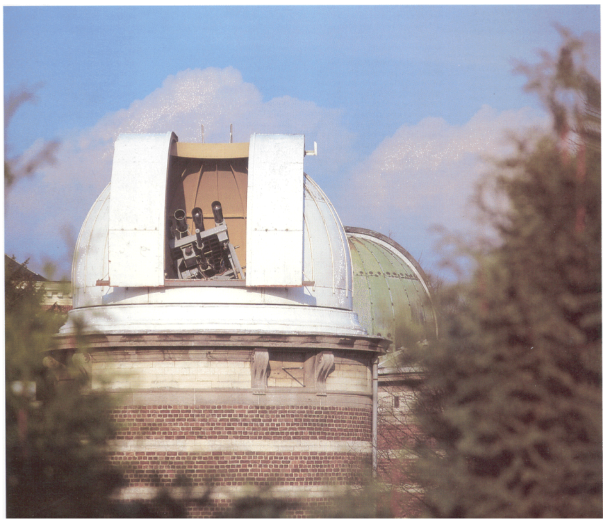
Fig. 1. The outside of the Uccle Solar dome today showing the equatorial table carrying 3 telescopes.

The solar equatorial table was designed to carry three telescopes. For chromospheric flare photographic monitoring, one of the three telescopes was equipped with an original Lyot filter built by Levallois-Perret (numbered 11, and still in use nowadays after several renovations, in particular in 1985 at the University of Nice). At the focus of the H-alpha optics was a home-made 35mm camera allowing a rhythm of one image in five minutes to thirty seconds. At the same time, time marks and photometric marks are printed on the film. The second telescope on the solar equatorial table was the Grubb refractor of 16cm aperture used since 1940 for sunspot observations.

This complete installation was put in place in 1953 in a renewed dome. This new system began on January 1st, 1954 and was used during the International Geophysical Year in 1957-1958. The analysis of the observations was forwarded to the World Data Centers. In 1961, a Zeiss heliograph of 13cm aperture was added on the Equatorial Table and equipped with a Camematic camera. Since 1964 this heliograph is daily used to obtain images of the sun. Up to today, this configuration of the *Uccle Solar Equatorial Table (USET)* has remained almost unchanged –which guarantees stability of the observations– except for the replacement of the photographic systems by CCDs. Coutrez leaves the observatory in 1966 when he becomes professor at the Université Libre de Bruxelles.

During that period, A. Koeckelenbergh was observing alone, while radio observations were being developed at the new Humain station (Marche-en-Famenne, S-E Belgium), by Raymond Coutrez. Soon it proved necessary to add better thermal protection to ensure the image sharpness. Thermal isolation (asbestos) was added on the inside of the solar dome and after a fierce controversy, the dome was painted white (Fig. 1), thus standing out compared to all other copper domes on the Uccle site, with their greenish oxidized copper. With this fully modernized solar telescope, the solar physics team of the ROB started a systematic collaboration with the Observatory of Paris-Meudon (Marie-Joseph Martres, Paul Simon), for chromospheric observations and with the Observatory of Zürich (Waldmeier) for photospheric sunspot observations. As we will see later, these systematic collaborations with both the Observatory of Paris and with the Observatory of Zürich are the basis on which the SIDC would be founded.

All the above activities took place in the 'Service de Physique Solaire et de Radioastronomie' of the ROB, which would later be renamed in the 'Department of Solar Physics'. Meanwhile advanced solar physics was also conducted in another research group of the Royal Observatory of Belgium (which would later be called the Department of Astrophysics). From about 1950 till the seventies, Lucien Neven carried out many investigations about spectroscopic solar physics: papers about the interpretation of high resolution solar line profiles, NLTE, line identifications and element abundance. This work was performed with Prof. Marcel Migeotte (Liège) and after with Prof. Luc Delbouille and Dr. Ginette Roland (Liège) for the observational parts at the Jungfraujoch Sphinx Observatory; a few solar spectrum atlases were published. Theoretical papers about the interpretation of solar and stellar lines were published mainly in collaboration with Prof. Kees de Jager, Utrecht. At that time, Prof. de Jager was also the only professor in astronomy/astrophysics at the new Vrije Universiteit Brussel (from 1962/63 onwards, one day per week).

At the date of June 1st, 1970, 9460 drawings of the sun had been made at Uccle since 1940; about 365000 filtergrams on the H-alpha line had been collected since 1954 during more than 6000 hours of effective survey (Koeckelenbergh 1971).

4. Transition from Zürich to Brussels

Towards the end of the seventies there were several evolutions that troubled the continued production of the Zürich Sunspot Number. One problem was that, as the Zürich Observatory was located inside the city, it suffered strong limitations in its observing abilities (bad seeing) as new tall buildings rose in its immediate vicinity. Two other stations had therefore already been established by Waldmeier in more pristine locations, one in Arosa, and one in Locarno.

It was also felt that the routine production of the sunspot number used up too much human resources at the observatory, which were thus not available for more original scientific investigations. Until his final retirement in 1980, Waldmeier produced the Zürich Sunspot Number in an essential manual method. At the end of the seventies, he asked A. Zelenka, an assistant who had joined the Zürich Observatory coming from Prague, to computerize the data processing. However, this work was never completed.

A third threat to the Zürich Sunspot Number was the availability of the 10.7cm radio flux (2800Mhz) measured in Ottawa (Canada) since the end of the Second World War [10]. Pioneering work by Arthur Covington (1959) had shown that the 10.7cm radio flux provided an index of solar activity comparable with the Zürich Sunspot Number. The clear advantage over the latter was that the radio measurements are completely objective, and can be made under almost any weather conditions.

On April 1, 1980, Jan Stenflo (Lund/Sweden) succeeded Waldmeier as Director of the Observatory and brought new views on the modernization of that institute. His most important decision (which was in fact already prepared before his formal nomination by the interim Director K. Dressler) was that Zürich must abandon the tradition, started by Rudolf Wolf more than a century before, of collating sunspot data from various observatories and issuing reports of relative sunspot numbers. The decision was inspired (Zelenka 1980, Eddy 1980) by a draft report of an IAU Working Group. The working group, involving prominent solar physicist such as A.H. Shapley (NOAA, Boulder) and J.A. Eddy (HAO, Boulder), found a linear correlation between the Zurich Sunspot Number R_Z and the American Sunspot Number R_A with a correlation coefficient of 0.99.

The decision by Stenflo of stopping the heritage of the first Director of the Observatory (Wolf) was not only unpopular in Switzerland but also in the astrophysical community. During the discussion in the years preceding the formal decision even international bodies had taken firm position against it. COSPAR adopted the resolution (COSPAR Information bulletin No.82, Aug 1978, p.25) that: "*COSPAR ... strongly recommends to the appropriate national organization the continuation of these long-term observations which are vital and irreplaceable for improvement of our understanding of solar-terrestrial relationship".* In addition, the International Union of Radio Sciences (URSI) pointed out that: *"We know two other more direct and less empirical indices (solar noise flux at 2800 MHz, i.e. F10, and IF2) which have smaller statistical fluctuations than the sunspot number. But, they are available only since 1947 and 1938 respectively. Hence only the sunspot number is available for a sufficiently long period to allow statistical studies of the solar cycle."* (Minnis, 1978).

Given this strong request from the scientific community, the Zürich Observatory looked for an institute that could take over the duty of the sunspot production. In a letter of February 18, 1980, the Zürich Observatory asked among its contributing stations who could take over the role of the World Data Center. During that transition period, A. Koeckelenbergh had visited Zürich and established personal contacts with the Zürich solar team. It turned out that the Royal Observatory of Belgium was the only institute which had the motivation and the resources to assume the responsibility.

In a meeting held in Zürich on June 3-6, 1980 of the ETH at Zürich (represented by O. Stenflo, K. Dressler and Waldmeier), the Specola Solare Ticinese at Locarno (represented by S. Cortesi) and the Royal Observatory of Belgium (represented by A. Koeckelenbergh) the formal decision was taken that:

- The "Sunspot Index Data Center, or SIDC" (a newly created structure under the responsibility of A. Koeckelenbergh) will start in January 1981 with the production of a sunspot index, called *International Sunspot Number* R_i.
- The continuity and coherence with the former index of Zürich is assured through the use of Locarno (one of the three main stations of the Zürich network) as reference station for the long term stability of the sunspot number.
- The main task of the new center was then to compute and broadcast the daily, monthly and yearly international sunspot numbers, with middle range predictions (up to 12 months).

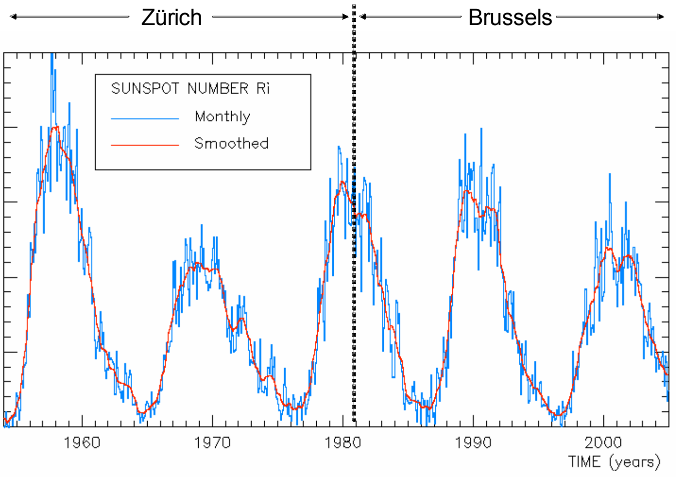

Fig. 2: The last 2.5 cycles of Zürich, and the first 2.5 cycles of Brussels. The continuity and coherence was assured during the transition by the fact that the SIDC (Brussels) used Locarno, one of the three main stations of the Zürich network, as reference station for the long term stability.

Soon after the transfer to Brussels in 1981, Koeckelenbergh made a presentation of the newly baptized Sunspot Index Data Center, at the August 1982 IAU Assembly in Patras, which marked the official start of the World Data Center (WDC) in Brussels [11]. Initially, the SIDC got only limited support (mailing costs) from its hosting institute and the ROB Director Prof. Velghe. When he retired in 1982, the new acting Director Prof. P. Melchior, who was then President of FAGS, fully understood the importance of this WDC, and he cared to provide some additional FAGS financial support to the SIDC. Since that time, the SIDC has become an integral part of the long term international services maintained at the ROB as a government-funded federal institute.

A key initial effort to develop the SIDC was the development of the processing software. Going beyond the Wolf number itself, a program was developed to derive the evolution and possible returns, after a solar rotation, of individual sunspot groups. As Koeckelenbergh was aware that the accuracy and stability of the international sunspot numbers could be significantly improved by increasing the number of contributing stations, he immediately started to contact many observatories and amateur astronomers around the world. In a few years time, he managed to double the number of contributing stations (Fig. 3).

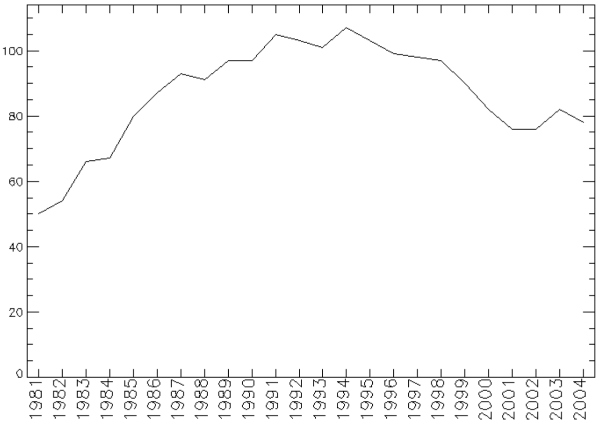

Fig. 3. The number of observing stations contributing to the International Sunspot Number Ri. 70% of these stations are European (including 10% Belgian).

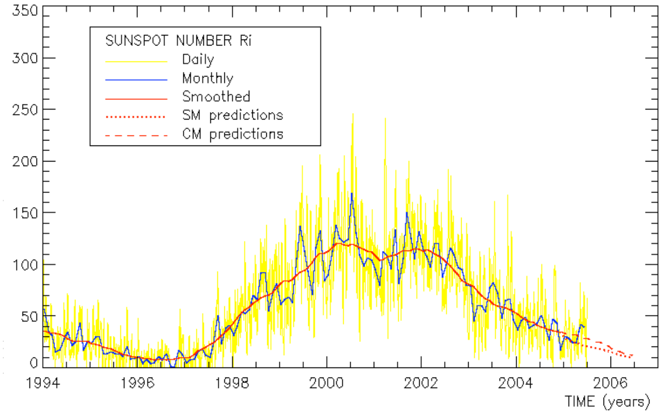

Fig. 4. The International Sunspot Number since the beginning of the Cugnon-Era.

5. Solar Cycle 22 and 23

In 1994, Koeckelenbergh retires and Pierre Cugnon becomes head of the ROB Solar Physics Department, as well as Director of the SIDC. Cugnon had joined the department already in 1968 and was thus involved in the SIDC from its creation in 1981. He worked first on photometric and chromospheric observations from the Uccle station; he then developed a program of coronal polarimetry that led him to participate personally to 4 total solar eclipse expeditions. He also introduced a quality control for the SIDC data products.

This control consists essentially in regular comparisons between the sunspot number R_i on one hand and an average of about 20 selected good stations (including the Locarno reference station) or the 10.7cm radio flux on the other hand. The purpose of these comparisons is to:

(1) detect possible long-term discrepancies (for example systematic drifts) in R_i,

(2) select additional reference stations, to minimise such effects in the future and ensure a good continuity in the computation of R_i.

Applied to the beginning of cycle 22, this control has detected systematic differences at the preceding minimum, and in the first part of the rising phase. Cugnon concluded there was a slight overestimation of the International Sunspot Number during this period (Cugnon 1997). Comparisons were also made occasionally with the sunspot number calculated by the American Association of Variable Stars Observers (AAVSO).

Since 1981, the SIDC proposes 12-month predictions based on Waldmeier's standard curves (SM predictions). A detailed analysis of various forecasting techniques due to K. Denkmayr (1993) showed that purely statistical methods tend to be inaccurate in the rising phase of the solar cycle. He proposed a precursor method that employs the geomagnetic aa index as a proxy of the "new" magnetic field that builds up in the polar regions of the sun while the old cycle is declining. This forecasting method, described in Denkmayr and Cugnon (1997), has been implemented in the SIDC software under the name 'Combined Method' (CM predictions) and provides an alternative set of predictions since 1997 (Fig. 4). Both forecasting methods, like many others, make use of the time of occurrence of the smoothed sunspot number minimum as an input parameter. However, the position of the "true" minimum of activity is subject to controversy due to different considerations, e.g. the separation between the "old" and the "new" cycles. A "corrected" latest minimum is used for instance by the SEC (NOAA – USA) for its predictions.

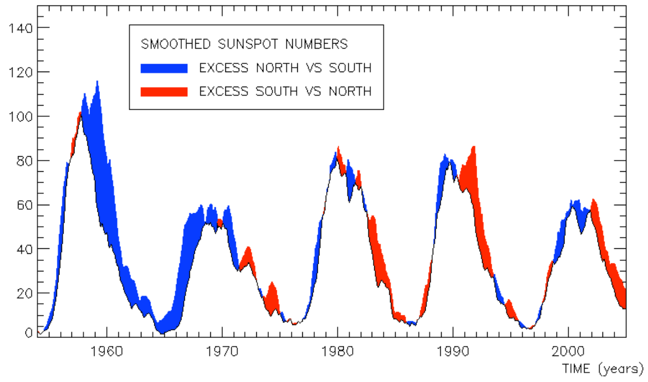

Fig. 5. The hemispheric sunspot numbers.

Since August 1992, the hemispheric sunspot numbers R_n (north) and R_s (south) are provided. They are calculated in the same way as the (total) International Sunspot Number, but separately for both hemispheres. The number of contributing stations is around 30 for the provisional values and 50 for the definitive ones. Locarno is also the reference station. The results are normalised to the International Sunspot Number, in order to satisfy the $R_n + R_s = R_i$.

In 1990, Cugnon played a key role in promoting the Belgian participation to the *Extreme Ultraviolet Imaging Telescope* (EIT) onboard the ESA/NASA mission SOHO. The original concept of EIT was that of a context imager for the SOHO spectrographs. Soon however, it was realized that movies of the EIT images provided space weather information that complemented the SOHO coronagraphs, LASCO, in an essential way. By observing flares, prominence eruptions and last but not least *EIT waves*, EIT images make it possible to determine if a LASCO *halo CME* is Earth-directed or not. The fact that the Royal Observatory of Belgium was involved in EIT, which turned out to be an excellent space weather monitor, has paved the way for the SIDC to grow in subsequent years from the World Data Center for the sunspot index to a full space weather monitoring center.

In January 2000, the SIDC makes a giant leap forward by taking over the responsibility of *Regional Warning Center (RWC) for Western Europe* from the Observatory of Paris (Meudon). A RWC is a space weather forecast and monitoring center of the *International Space Environment Service* (ISES, [12]). Via a network of Regional Warning Centres (RWCs), ISES provides rapid information to the world community on the Sun-Earth environment. A data exchange schedule operates with each centre providing and relaying data to the other centres. The centre in Boulder (US) plays a special role as "World Warning Agency", acting as a hub for data exchange and forecasts.

From 1965 onwards, the Observatory of Paris acted as the RWC for Western Europe. Since 1981, the SIDC was already a prominent partner of the RWC at the Observatory of Paris for the exchange of sunspot observations over the ISES network. In the fall of 1999, Pierre Lantos of the Observatory of Paris decided that the required human resources for the activities of the RWC could no longer be allocated. In a striking replay of history (cfr. the Zürich to Brussels transfer of the World Data Center), the SIDC was consulted if it could take over this activity. After an initial hesitation for this large load of work, Cugnon agreed and visited the Paris Observatory (Dec 7-10, 1999) for a technical study of the transfer. Note that other (non-RWC) forecasting services of the Observatory of Paris, including contractual obligations with the French space agency CNES, were not transferred to the SIDC, but remained in France.

From the beginning of 2000 onwards, the SIDC took over the RWC activities of the Observatory of Paris. After a few, difficult initial months it was soon decided to abandon the old forecasting software (PREVISOL) that was inherited from the Observatory of Paris and to switch to a web-based interactive system (PREVIWEB). This had the additional advantage that the forecast could easily be completed from the forecaster's home. This innovation opened the way for an increase of the RWC service to 7day/week instead of the previous office-hours only service. During Space Weather Week (May 2000) in Boulder (US), the ISES assembled and granted the SIDC the official status of "RWC for Western Europe" (Berghmans 2002). Later on, the ISES decided to change the naming convention of the RWCs according to host country and the SIDC became since then "RWC Belgium". Also to reflect the extended activities, the full name of the SIDC was changed to *"Solar Influences Data analysis Center"*, thus keeping the same acronym.

In April 2003, ESA started a two-year pilot project to extend the space weather community in Europe. The pilot project consisted of a federation ("SWENET") of existing space weather assets in Europe with the aim of demonstrating the potential and the need of space weather services in Europe. The SIDC participated as "Service Development activities" [13] through the development of new solar monitoring software and, in collaboration with the Geophysics Department of the ROB, through the development of GPS (global positioning system) services. The latter services deal with monitoring and forecasting space weather effects on the accuracy of global positioning systems (GPS).

6. Conclusions and Future Outlook

Almost 25 years after Zürich stopped the production of the sunspot number, it is still alive and kicking. The original time-series started at Zürich, has been continued till today at the SIDC under the name "International Sunspot Number R_i". Over the years, alternative sunspot number series have been produced by e.g. the AAVSO and by the Space Environment Center (Boulder, NOAA). These different implementations of the same idea are typically highly correlated, but detailed aspects such as time of minima and maxima can differ [8]. An e-mail update of the International Sunspot Number is requested every month by more than 300 registered users, and nearly another 500 users receive the same information in a monthly sunspot bulletin by regular mail. Moreover, these numbers show a slow rise over the years.

Meanwhile, the SIDC has grown much beyond the original World Data Center (WDC) for the Sunspot Index founded by A. Koeckelenbergh. Space weather is a new and flourishing interdisciplinary science with direct relevance for technological systems. Varying solar activity from cycle-to-cycle might have an important impact on the evolution of the earth's climate. Therefore, both on the short as well as on the long time scales, the study of 'Solar influences' is important for society as a whole. As a Regional Warning Center (RWC) of the ISES, the SIDC is now a solar monitoring center that follows up the space weather on this wide range of timescales. Both the functions of WDC and RWC of the SIDC are maintained by permanent staff members of the Royal Observatory of Belgium and will thus continue to be supported on the long term.

The involvement on a scientific level of SIDC members in space instruments like EIT and LASCO onboard SOHO has proven to lead to a productive cross-fertilization between space weather operations and solar physics as a science. In this respect, we expect a lot of our upcoming participation in the data analysis of the remote sensing package SECCHI onboard the NASA STEREO mission (expected launch mid 2006). This mission promises to bring important new insights in the 3D structure of coronal mass ejections (CMEs) and associated phenomena (EIT waves, prominence eruptions, flares). For the first time, STEREO will allow to image a CME all the way from the Sun to the Earth. It is clear that this will lift the forecast of CME induced geomagnetic storms from the quantitative to the qualitative level.

The highlight for the SIDC in the coming years will be the launch (Feb 2007) of PROBA2. This technology demonstration micro-satellite of ESA will carry two space weather instruments of the Royal Observatory of Belgium that will greatly enhance ESA's space weather capabilities. The Sun Watcher with APS Detector and Processing - SWAP - is a full disk imager that will monitor the Sun at high temporal cadence and spatial resolution in a single extreme UV passband (Berghmans 2005), while the Lyman-Alpha Radiometer - LYRA - will measure the solar flux in four carefully selected UV passbands (Hochedez 2005). SWAP can be viewed as ESA's replacement for the ageing EIT instrument onboard the joint ESA/NASA SOHO mission, while LYRA's higher-energy channels will complement the soft X-ray time series data observed by NOAA's GOES satellite series. Together they will provide real-time monitoring of solar output and eruptive events from the same platform.

Stay tuned during these exciting times: http://sidc.oma.be !

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