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Karl Rawer's life and the history of IRI

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Abstract

This laudation is given in honor of the 90th birthday of Prof. Karl Rawer that coincides with the 35th anniversary of the International Reference Ionosphere (IRI). The ionosphere was discovered during Karl Rawer's life, and he has dedicated his life to the exploration of this part of Earth's environment. The horrible events of world wars I and II shaped his early life, but they also launched his career as one of the eminent geophysical scientists of the twentieth century. The paper looks back at Karl's life and the 35 years of research and development in the framework of the IRI project. K. Rawer initiated this international modeling effort and was the first chairman of the IRI Working Group. IRI is a joint project of the Committee on Space Research (COSPAR) and the International Union of Radio science (URSI) that has the goal to establish an international standard model of the ionospheric densities temperatures, and drifts.

Keywords: Karl Rawer; International Reference Ionosphere; Ionosphere

1. Introduction – Karl Rawer's early years

"Actually, it was chance and circumstances that gave me the opportunity to participate in the shaping of the research development in ionospheric and space science during the 20th century" so reminisces Karl Rawer, looking back on his life's achievements. From 1913 to 2003, i.e., from WW I to the current terrible war in Iraq, Karl has seen the world change. He was fortunate to learn from eminent physicists and mathematicians during his university years in the 1930s, Gustav Mie and Gustav Dötsch in Freiburg, and Arnold Sommerfeld and Jonathan Zenneck in München. Zenneck had started ionospheric echo sounding experiments in Bavaria and asked Rawer to develop the theory for the reflection of vertically incident radio waves from the ionosphere as his doctoral thesis. Being allowed to use the jewel of the mathematics institute, an electrically driven mechanical calculator, Karl was able to solve this problem in little more than a year. And from here on he was hooked in one way or other to ionospheric research and the computer, as an analysis tool, for the next 60 years. During WW II, he became responsible for ionospheric radio predictions, working with Johannes Plendl and Walter Dieminger, and also Ewald Harnischmacher and Klaus Bibl. When in 1945, after the end of the war, Roy Piggott escorted Dieminger's Radiowave Research Team from its operational base in Austria to Lindau near Göttingen (Niedersachsen) in the British Occupation Zone, Rawer's group followed the invitation by Yves Rocard to establish an ionospheric prediction service in Germany's "French Zone". A new ionospheric institute came to life first in Neuershausen, then in Breisach (Baden–Württemberg), i.e., close to Karl's academic origins in Freiburg and to his native Saarland. One of the author (BWR) first met Prof. Rawer in

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1960 when he accepted him as a graduate student at the "Ionosphären Institut Breisach". Other graduate students at the time included Rolf Kraft, Jürgen Büchau Fritz Fischer, Frank Ade, Gerhard Schmitdke, Christian Miinter, and Hans Böhnel. A life Iong friendship connected all of us until today, most of us now retired. Sadly Fritz and Hans died early and Jürgen, who together with BWR emigrated from Germany to the USA, died 10 years ago. Rawer's institute gave us a first opportunity to see real scientists and researchers in action: Ewald Harnischmacher Klaus Bibl, Rudolf Eyfrig, Hannes Hesse, Adolf Paul, Klaus Jacobs. Karl Rawer was born to lead and he did so by inspiring his coworkers and students, and by training young scientists from around the world.

On his way from Austria to Baden–Württemberg at the end of WW II, Karl and his family had stayed for a short while in Bayern, the native state of his wife, Waltraut. Of the seven children, their son Bernhard is here today to witness the ceremony in honor of his father. An unfortunate accident has hospitalized Mrs. Rawer preventing her from accompanying Karl to Miltenberg, as planned. Waltraut Rawer has made it possible for Karl to achieve a successful balance between a happy family life and an extraordinary career.

2. International outreach

Building international "research bridges" out of Germany was one of Karl's important objectives in the post-war years, and international cooperation became the leitmotiv in his career. For many years he made weekly trips from Breisach to Paris to lecture at the Sorbonne University as a Professeur Associé, in collaboration with his friend Prof. Etienne Vassy. International travel in the early 1960s was not as convenient as it is today and we students had great respect for Professor Rawer's strenuous schedule and of course his international recognition. We might have been even more impressed would we have known about another Associé lecturing at the Sorbonne at the same time, Robert Oppenheimer. Rawer's URSI activities began in 1954, and he represented the German ionospheric research in the preparation of the International Geophysical Year, 1957/58. By that time, ionospheric sounding was done in many countries around the world, but there were no common rules for the scaling and interpretation of the ionograms, making global studies difficult. Eight ionospheric experts joined and formed the Worldwide Sounding Committee under the leadership of Allen Shapley, Rawer among them, Piggott and Rawer (1961) published the results of the committee's work as a Handbook for the Scaling of Ionograms. At the URSI General Assembly in Munich in 1966, Rawer was elected international Vice-Chair of what is today commission G of URSI, and served as Vice-Chair and then Chair until 1972.

Starting in the early 1950s, his institute developed scientific payloads for the newly developed French rocket "Veronique" for a first successful launch in 1954 in the French Sahara. His space experience and the connections to international research groups made Prof. Rawer the natural choice to take a leading role in the West-German National Committee of COSPAR. After the death of Julius Bartels in 1964, Rawer became its chairman. He vigorously exploited the opportunity that COSPAR offered to establish long lasting relationships between scientists from west and east across the cold war borders, but also with researchers in India and in hitherto neglected countries in the far East and Africa.

Better writers than we are required to fully describe the impact of Karl's visionary activity on ionosphere and space research in the 20th century. As his former students and early beneficiaries of his leadership, we merely list a few highpoints that have impressed many in our generation. In 1953, he published the first book on the ionosphere, appropriately called *Die Ionosphäre*, which was later translated into English. Although by inclination an experimentalist, he was a master of describing and documenting new results and in sorting existing knowledge, as he did in a series of handbooks. Jointly with Kurt Suchy he wrote *Radio Observations of the Ionosphere*, published in 1967 as Volume III/II in the Geophysics Series of the Handbuch der Physik. After Bartels's death in 1964, Karl Rawer became the editor of the series and issued the next five volumes of the series, III/III to III/VII. We leave it to the historians to count the huge number of his scientific and science policy papers, there must be several hundred.

In the late 1960s, the Space Science Committee in COSPAR decided to develop a "Standard Ionosphere Model". Again the choice was clear who should lead this effort. Karl Rawer took on the challenge, mandated by COSPAR and later URSI, and so in 1968 began the odyssey of the International Reference Ionosphere, IRI, described in some detail below.

3. Rawer's institutes

Under most difficult post-war conditions an ionospheric vertical incidence sounding station came to life in 1946 at Schloss Neuershausen, near Freiburg, under the auspices of the French Sendee Prévision Ionosphérique de la Marine (SPIM). This was the beginning of a long cooperation between French and German ionospheric prediction studies. Rawer then managed to establish the "Ionosphären Institut" in Breisach under the administrative control of the German postal service. This institute gained international reputation in the field of ionospheric radio wave propagation and forecasting,

and instrumentation through its cooperation with research organizations in the USA and France, and joint measurement campaigns in Italy, Greece, and Norway.

To complement the remote ground-based sensing with radio waves by observations with space borne instrumentation, the Fraunhofer Society authorized Rawer to found a separate institute on Kronenstrasse in Freiburg, the Arbeitsgruppe für Weltraumforschung, with project funding from the Deutsche Forschungsgemeinschaft, NASA, and the European Space Agency ESRO. The launch of two successful satellite missions with instrumentation from the Arbeitsgruppe, AEROS in 1972 and AEROS-B in 1974, led to temperature and ion composition data that became an important input to the IRI. Soon the building on Kronenstrasse became too small to house the expanding space research activities, and the Fraunhofer Society built an expansive institute in Freiburg-West, Karl Rawer was appointed the director of this Institute for Space Research (later renamed Institute for Measuring Techniques), leading it until his retirement in the late 1970s.

4. A brief history of the IRI

In the mid-1960s it became clear that an international standard model for the ionosphere was needed, similar to the successfully established COSPAR International Reference Atmosphere (CIRA) for the thermosphere parameters (CIRA, 1961). Such models are required for the specifications of environmental parameters in the thermosphere and ionosphere for the design of space-based instruments, for satellite orbit determination and control, for analysis of radioastronomy data, satellite altimetry data, and many more applications. Foreseeing the need for such a model, COSPAR in 1968 initiated the IRI project and asked Karl Rawer to become its first chairman. Since that time until today, Karl Rawer has been closely involved with the IRI effort and has been the main reason for the great success and broad application of this international standard representation of the ionosphere. It is therefore quite appropriate that we are celebrating Karl Rawer's 90th birthday together with IRIs 35th anniversary. Table 1 lists the major IRI milestones throughout these past 35 years and highlights Karl Rawer's involvement. It also shows that the IRI group, under the guidance of Karl Rawer, has always tried to keep up with the rapidly changing computer and network environment in an effort to provide the user community with fast and easy access to the IRI model and its parameter.

It is interesting to note that the original IRI charter had only asked "... to provide vertical profiles of the main ionospheric parameters for suitably chosen locations, hours, seasons, and levels of solar activity; representing monthly median conditions based on experimental evidence". The IRI group, of course, quickly moved past the limitations in time and space, and its first major release [Rawer et al., 1978] already included global coverage for the electron density. COSPARs Terms of Reference for the IRI project now state: "the task group was established to develop and improve a standard model of the ionospheric plasma parameters. The model should be primarily based on experimental evidence using all available ground and space data sources; theoretical considerations can be helpful in bridging data gaps and for internal consistency checks. Where discrepancies exist between different data sources the IRI team should promote critical discussion to establish the reliability of the different databases. IRI should be updated as new data become available and as old data sources are fully evaluated and exploited. IRI is a joint working group of COSPAR and URSI. COSPARs prime interest is in a general description of the ionosphere as part of the terrestrial environment for the evaluation of environmental effects on spacecraft and experiments in space. URSIs prime interest is in the electron density part of IRI for defining the background ionosphere for radiowave propagation studies and applications".

5. IRI members, meetings and applications

Karl Rawer used four very important ingredients in establishing the IRI success story:

(1) Selection of working group members who provide a good, balanced cross-section in terms of the representation of different countries and continents (see Fig. 1) as well as in terms of the representation of different measurement techniques. This turned out to be a great asset in getting access to all essential ground and space data sets for ionospheric parameters.
(2) Annual IRI workshops (see Table 2) as the main venue for discussing improvements and enhancements of the model. These workshops quickly became the catalyst for a multitude of international collaborations whose goal it was to improve specific aspects of the model. A trademark of these quite informal meetings was (and is) the "Final discussion" session where the IRI team decides on the improvements and additions to be included in the next version of the model, and where "volunteers" are enlisted to investigate new data sources and specific modeling questions for future model updates.
(3) Publication of the workshop papers initially in Space Research, and later in Advances in Space Research (Table 2), resulting in an excellent record of the IRI activities. A unique series of publications now documents the international efforts in

Table 1
IRI milestones

Year	Event	Description	Media
1968	COSPAR establishes IRI WG	K. Rawer, Chair	
1969	URSI joins in		
1972	Prelimenary set of tables (Rawer and Ramakrishnan)	IRI parameters at selected locations	Report
1973	COSPAR Symposium, Konstanz, Germany (K. Rawer, Organizer) (Rawer, 1974)	Guidelines established for data that should be used for D-region modeling	
1978	URSI special report: IRI-79 (Rawer et al., 1978)	Global coverage for densities, CCIR maps for f_0E, f_0Fl, f_0F2, and M(3000)F2	Report, ALGOL and FORTRAN code on punched tape/cards
1981	World data center A for Solar-Terrestrial Physics Report: IRI-79 (Rawer et al., 1981)		Graphs and tables of IRI parameters
1986	IRI-86 on floppy disk for use on Personal Computers (PCs)	Global coverage for temperatures based on AE-C,-D,-E and AEROS-A,-B data	Floppy disk with DOS interactive program
1990	National Space Science Data Center (NSSDC) Report (Bilitza, 1990)	URSI maps for f_0F2	Retrievable from NSSDCs archive via anonymous ftp and available for online computation as part of NSSDCs Online Data and Infromation Service (NODIS)
1995	IRI-95 online (IRI web)	Improvements at low magnetic latitudes	IRI web: compute and plot IRI parameters on the Internet
1999	URSI resolution	IRI recognized as the international standard for the ionosphere	
2001	IRI -2001 with many improvements and new parameters (Bilitza, 2001; Reinisch and Huang, 1998, 1999)	Improvements: D-Fl-region, STORM, and Intercosmos Te model. New paramters: Fl probability, equatorial vertical ion drift	

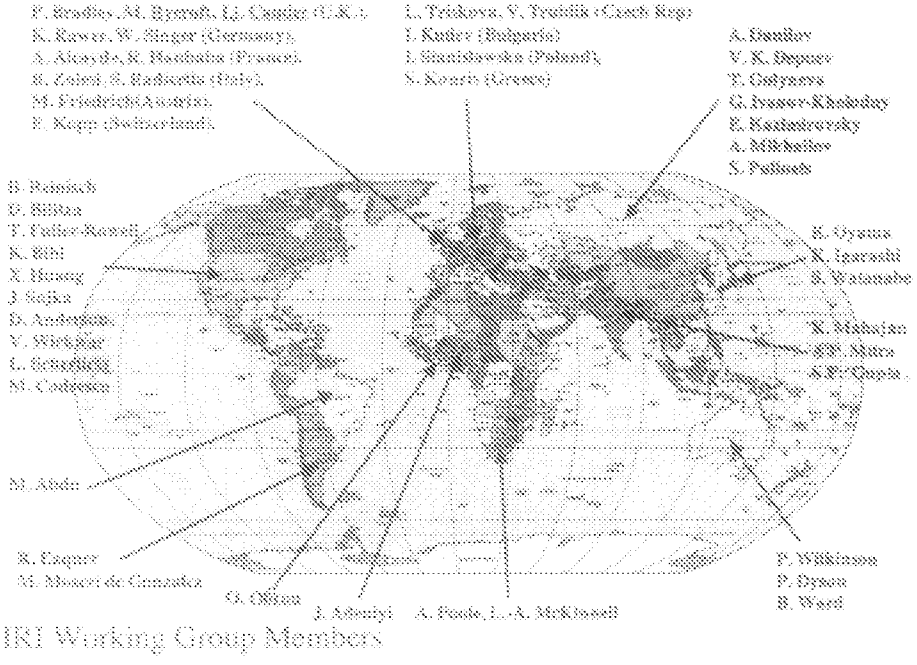

Fig. 1. Members of the IRI working group come from many countries and continents.

ionospheric modeling. As the main editor of these publications Karl Rawer has helped countless non-English speaking colleagues to correct their language and grammar and to publish their important results sometimes for the first time in an English-language journal.

(4) Newest technology to make the IRI model quickly and easily accessible to its wide user community and its broad spectrum of applications. IRI was one of the first international efforts to distribute its model in the form of computer codes in a number of different computer languages. In step with

Table 2
IRI workshops and publications

Year	Location	Topic	Publication
1971[a]	Seattle, USA		Space Res. XII, 1229–1335, 1972
1973	Konstanz, FRG	Measurements and results of lower ionosphere	Akademie-Verlag, Berlin, 1974
1974[a]	Sao Paulo, Brazil		Space Res. XV, 295–334, 1975
1980[a]	Budapest, Hungary	International Reference Ionosphere – IRI-79	WDC-A-STP, UAG-90, 1984
1982[a]	Ottawa, Canada	The upper atmosphere of the earth and planets	Adv. Space Res. (ASR) 2(10) 1982
1983	Stara Zagora, Bulgaria	Towards an improved IRI	ASR 4 (1), 1984
1984[a]	Graz, Austria	Models of the atmosphere and ionosphere	ASR 5 (7), 1985
1985	Louvain, Belgium	IRI – status 1985/1986	ASR 5 (10), 1985
1986[a]	Toulouse, France	IRI – status 1986/1987	ASR 7 (6), 1987
1987	Novgorod, Russia	Ionospheric informatics	ASR 8 (4), 1988
1988[a]	Espoo, Finland	Ionospheric informatics and empirical modelling	ASR 10 (8), 1990
1989	Abingdon, UK	Development of IRI-90	ASR 10 (11), 1990
1990[a]	The Hague, Netherlands	Enlarged space and ground data base for	ASR 11 (10), 1991
1991	Athens, Greece	Adv. in global/reg. descript. of ionospheric parameter	ASR 12 (7), 1992
1992[a]	Washington, DC, USA	Ionospheric models	ASR 13 (3), 1993
1993	Trieste, Italy	Off median phenomena and IRI	ASR 14 (12), 1994
1994[a]	Hamburg, FRG	The high latitudes in the IRI	ASR 16 (1), 1995
1995	New Dehli, India	Low and equat. latitudes in IRI	ASR 18 (6), 1996
1996[a]	Birmingham, UK	Description of ionospheric storm effects and irregularities	ASR 20 (9), 1997
1997	Kühlungsborn, Germany	New develops, in ionospheric modelling and prediction	ASR 22 (6), 1998
1998[a]	Nagoya, Japan	Lower ionosphere: measurements and models	ASR 25 (1), 2000
1999	Lowell, MA, USA	IRI – workshop 1999	ASR 27 (1), 2001
2000[a]	Warsaw, Poland	Modelling the topside ionosphere and plasmasphere	ASR 29 (6), 2002
2001	Sao Jose dos Campos, Brazil	Description of the low latitude ionosphere in the IRI	ASR 31 (3), 2003
2002[a]	Houston, Texas, USA	Improved ionosphere specification and forecast	ASR 33 (6), 2004
2003	Grahamstown, South Africa	Quantifying ionospheric variability	ASR, this issue

[a] IRI session during the General Assembly of the Committee on Space Research.

Table 3
Applications of the IRI model

Standard for engineering applications	IRI is used as the standard in "natural orbital environment definition guidelines for use in aerospace vehicle development" (NASA, 1994) IRI is the standard ionosphere model in the System Engineering Handbook of the European Cooperation for Space Standardization (ECSS, 1997) · IRI is under consideration to become the ISO standard for the ionospheric parameters (Bilitza et al., 2004) IRI is the ionosphere model used in ESA/ESTECs Space Environment Information System (SPENVIS) http:http://www.spenvis.oma.be/spenvis/, in NASA/MSFCs Space Environment Effects (SEE) web interface http:http://see.msfc.nasa.gov/pf/models.html, and NASA Glenn Research center's photovoltaic and space environments pages http:http://powerweb.grc.nasa.gov/pvsee/info/movies/iri90.html
Visualization tool for educational applications	IRI Total Electron Content (TEC) world maps (U. Leicester, UK) http:http://ion.le.ac.uli/remote sensing/models/tec.html 3-d electron density visualization using AVS (CRL, Tokyo, Japan) [Watari et al., 2003]
Ionospheric correction for single-frequency satellite altimeters	Longtime data record of sea surface heights (Pathfinder Project); updating IRI with ionosonde data [Bilitza et al., 1997; Lillibridge and Cheney, 1997] Processing of ERS-1 and ERS-2 data products [CERSAT, 1996] Work with Geosat Follow On (GFO) data [Navy-IGDR, 2000; Zhao et al., 2002]
Background ionosphere for evaluation of data mapping techniques	Testing algorithms that convert GPS measurements into global TEC maps [Hernandez-Pajares et al., 2002] TEC from NNSS Doppler measurements [Ciraolo and Spalla, 2002] Testing algorithms that convert GPS measurements into global TEC maps [Hernandez-Pajares et al., 2002]

the computer revolution of the 1980s and 1990s, the programs were first provided on nine-track tapes, then on punched tapes and cards, then on floppy disks, then online (ftp://nssdcftp.gsfc.nasa.gov/models/), then as a PC windows code (http://uml-car.uml.edu/downloads.html) [Huang et al., 2001],

and the latest incarnation is the IRI Web, an interface that lets the user compute and plot IRI parameters online (http://nssdc.gsfc.nasa.gov/space/models/iri.html).

The great legacy of Karl Rawer's push for an International Reference Ionosphere is best documented by the many applications that depend on this model. Table 3 summarizes the most important applications.

6. Conclusions

Karl, we take this opportunity to thank you for what you have done for geoscience, and for your leadership that affected so many of us assembled here today. The large international audience attending this special session bears witness to your high standing as a scientist and as a human being. We all wish you a happy 90th birthday and good health for the years to come.

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