Establishment of the South African baseline surface radiation network station at De Aar

by

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Dedicated to my dearest mother, who never had the opportunity to realise her intense love for nature in formal scientific training. Mom, this one is for you, out of gratefulness for this opportunity granted to me.

Opgedra aan my dierbare moeder, wat nooit self die geleentheid gehad het om haar intense liefde vir die natuur te kon realiseer in formele wetenskaplike opleiding nie. Mamma, hierdie een is vir u, uit dankbaarheid vir die geleentheid wat aan my gebied is.

ABSTRACT

Establishment of the South African baseline surface radiation network station at De Aar

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Summary

The South African Weather Service (SAWS) was offered a unique opportunity to become involved in the prestigious global Baseline Surface Radiation Network (BSRN) project in 1995. This study is an academical and technical document describing and elucidating aspects regarding the eventual establishment of the BSRN measurement facility at De Aar that embodies South Africa's involvement.

The dissertation opens with an introductory chapter offering background information and an explanation of circumstances leading to South Africa's involvement in this project, including reasons exactly why De Aar was chosen to be the South African BSRN site. This is followed by details on a scientific measurement plan including necessary information on radiation processes in the atmosphere, measurement techniques and associated instrumentation. The next chapter is devoted to the design of a radiometric measurement system answering to the scientific plan, with more details on instrumentation, peripherals, calibration and data management strategies.

Three years of real measured data since station establishment, is used as a basis to apply and evaluate the various quality assurance techniques of the central BSRN data-archive. Special reference is made in a separate chapter to the two partial solar eclipses that traversed Southern Africa in 2001 and 2002, in the form of case studies.

This dissertation is illustrated by several photos, and rounded off by details of the station-to-archive file format as laid down by the international BSRN data-archive, a useful table reflecting sunrise, sunset, solar transit, day length and Top Of Atmosphere (TOA) radiation, an explanation on climate zone classification, as well as a useful technical guide on setting up a pyrgeometer.

Apart from the academic content this document also intends to serve as a guideline for station operation and future development of whatever form, for both the station scientist and the station manager. Such developments can include the establishment of other BSRN stations, or in general the enhancement of the quality of solar radiation measurements over the entire Southern Africa Developing Community (SADC) region.

The author wishes to state that in presenting this document in English, he does not wish to promote English as scientific language at the expense of Afrikaans. The choice of language was taken purely on the basis of broader international involvement and a wider local usefulness of this document.

EKSERP

Totstandkoming van die Suid-Afrikaanse grondvlak-stralingsnetwerkstasie by De Aar

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Samevatting

Die Suid-Afrikaanse Weerdiens het in 1995 ‘n unieke geleentheid ontvang om deel te wees van die hoogs aangeskrewe grondvlak-stralingsnetwerk “(BSRN)” projek. In hierdie studiestuk wat akademies sowel as tegnies van aard is, word ‘n uiteensetting gelewer en toeligting gegee van aspekte rakende die uiteindelike instrumentele opstelling by De Aar wat Suid-Afrika se betrokkenheid in hierdie projek beliggaam.

Die verhandeling open met ‘n inleidende hoofstuk wat agtergrondinligting lewer sowel as ‘n uiteensetting gee van die redes presies waarom juis op De Aar as die Suid-Afrikaanse BSRN stasie besluit is. Dit word opgevolg deur besonderhede van die wetenskaplike metingsplan, wat nodige inligting oor stralingsprosesse in die aarde se atmosfeer, metingstegnieke, sowel as bybehorende instrumentasie insluit. ‘n Volgende hoofstuk word gewy aan die ontwerp van ‘n stralingsmetingstelsel wat aan die wetenskaplike plan kan verantwoord, en dit sluit die volgende in: meer besonderhede rakende instrumentasie, bykomstighede, kalibrasie en data-versorging.

Drie jaar van werklike waargenome data sedert die totstandkoming van die stasie, word as vertrekpunt geneem om die verskeie kwaliteitskontroletegnieke wat die sentrale BSRN data-argief gebruik, te evalueer in ‘n volgende hoofstuk. In die vorm van gedetailleerde gevallestudies word in ‘n afsonderlike hoofstuk spesiale melding gemaak van die twee gedeeltelike sonsverduisterings wat beide oor Suidelike Afrika beweeg het in 2001 en 2002.

Die verhandeling word geïllustreer deur verskeie fotos, en word afgerond deur besonderhede van die stasie-tot-argief formaat vir ‘n datalêer soos vasgestel deur die internasionale BSRN-argief, ‘n nuttige tabel wat sonop-en sonondertye, sonmiddaguur-tyd en daglengte, sowel as Top Van Atmosfeer straling bevat, ‘n verduideliking rakende klimaatsone-klassifisering, en ‘n nuttige tegniese gids om ‘n pyrgeometer op te stel.

Benewens die akademiese inhoud, is die dokument ook bedoel om as riglyn te dien vir die stasie-bestuurder en -wetenskaplike rakende die werking van die stasie en toekomstige ontwikkeling in watter vorm ookal. Sodanige ontwikkelings kan uitbreidings wees aan die bestaande stasie of moontlike ontwikkeling van ‘n ander nabygeleë BSRN stasie in ‘n buur-land, tot voordeel van stralingsmeting in die Suider- Afrikaanse Ontwikkelingsgemeenskap.

Die outeur wil hiermee onomwonde verklaar dat hy nie poog om met hierdie verhandeling Engels as wetenskapstaal ten koste van Afrikaans te bevorder nie. Die besluit om dit in Engels aan te bied, was suiwer geneem op grond van wyer internasionale betrokkenheid sowel as wyer plaaslike bruikbaarheid van die dokument.

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for his sheer inspiration and encouragement in a mentorship role to me as a young scientist in this field for the first five years of my employment at the SAWS ;

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for their dedication in maintaining the day-to-day chores and operation of the station. Guys, without your sustained effort this would not have been possible.

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CHAPTER 3 SYSTEM DESIGN

LIST OF SYMBOLS

UPPER CASE LETTERS

A Area (m^2)

AU Astronomical unit (1.5×10^{11}m)

A_0 Radius vector of solar distance (dimensionless)

C_1 Thermopile long-wave sensitivity constant (ca. 4 $mV.kW^{-1}.m^{-2}$)

E Radiant energy flux density (from a non-specific source per unit area) ($W.m^{-2}$)

E_{LW} Long-wave energy flux density ($W.m^{-2}$)

E_{OLR} Energy flux of outgoing Long-wave Radiation density ($W.m^{-2}$)

E_{SW} Short-wave energy flux density ($W.m^{-2}$)

E_{TOA} Energy flux density at the top of the atmosphere ($W.m^{-2}$)

E_v Excitation voltage used in pyrgeometer operation (mV)

F Radiometer reading (nominal units)

H (solar) Hour Angle (radians)

I Electric current (Ampere)

P Electric power (Watt)

Q Radiation flux density leaving the surface of the sun ($W.m^{-2}$)

R_c (calculated) Resistance of the pyrgeometer case thermistor (Ohm)

R_d (calculated) Resistance of the pyrgeometer dome thermistor (Ohm)

R_E Mean radius of the Earth (6.37×10^6 m)

R_v Resistance of the pyrgeometer precision resistor (Ohm)

S_0 Total radiant energy flux of the sun (3.9×10^{26} W)

S (annual mean) Solar constant, (1371 $W.m^{-2}$)

T Absolute temperature (K)

T_b Instrument body (case) temperature (K)

T_d Instrument dome temperature (K)

V_c Pyrgeometer case thermistor potential difference (mV)

V_d Pyrgeometer dome thermistor potential difference (mV)

W Power, energy flux ($Joules.s^{-1}$; Watts)

Z Solar zenith angle (degrees)

$Z(t)$ Solar zenith angle at time instant t , or a short time interval

LOWER CASE LETTERS

c Speed of light in vacuum (3 x 10^{8} m.s^{-1})

e Surface vapour pressure (hPa)

g Gravity acceleration on the Earth's surface (9.8 m.s^{-2})

h Planck's constant (6.62 x 10^{-34} J.s^{-1})

k_1 Pyrgeometer calibration constant 1 (dimensionless)

k_2 Pyrgeometer calibration constant 2 (dimensionless)

k_3 Pyrgeometer calibration constant 3 (dimensionless)

m Kasten optical air mass (dimensionless)

p Thermopile voltage (mV)

t Time (seconds)

GREEK LETTERS

α Planetary albedo, estimated at 0.3

δ Solar declination (radians)

ε Atmospheric emmissivity (dimensionless)

φ Site latitude (radians)

λ Wavelength (m)

κ Stefan-Bolzmann's constant in specific corresponding units (1.38 x 10^{-23} J.m^{-2}.K^{-1})

σ Stefan-Bolzmann's constant in specific corresponding units (5.67 x 10^{-8} W.m^{-2}.K^{-4})

θ Solar azimuth angle (radians)

ξ Equation of time (radians)

DATE FORMAT

The author is aware of the standard ISO- 8601 format for writing dates, i.e. **CCYY-MM-DD**, for example, 1964-02-10 meaning "The 10th of February 1964 AD". However, to omit any ambiguousity and also make dates equally well presentable in text, headings, figures and captions, it was decided to use alternatively the formats **DD Mmm CCYY** (written as "10 Feb 1964" with regards to the said example) in tables and figures, as well as **DD Month CCYY** (written as "10 February 1964) where most appropriate.

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LIST OF ACRONYMS AND ABBREVIATIONS

AMS	American Meteorological Society
AOD	Aerosol Optical Depth
ARM	(American) Atmosphere Radiation Monitoring
AVG	(Mathematical) Average
AWS	Automatic Weather Station
BOM	(Australian) Bureau of Meteorology
BSRN	Baseline Surface Radiation Network
CD	Compact Disk
CMDL	(American) Climate Monitoring and Diagnostics Laboratory
COSPAR	Committee on Space Research
CSI	Campbell Scientific Incorporated
DJF	December-January-February (average of summer data) – see also MAM, JJA and SON
DL	One-minute average value of downwelling longwave radiation – see also LWD
DSDFS	One-minute average value of diffuse radiation.
DSDIR	One-minute average value of direct radiation.
DSGL1	One-minute average value of calculated global radiation using the relationship between direct, diffuse and the solar zenith angle.
DSGL2	One-minute average value of global radiation using an unshaded pyranometer.
DSTM	(A complex definition involving DSGL2 and TOA radiation, in section 4.3.2.1.)
ECMWF	European Centre for Medium-Term Weather Forecasts
EMPA	*"Eidgenössische Materialprüfungs- und Forschungsanstalt"* (Swiss Federal Laboratory for Materials Research and Testing)
EPLAB	Eppley Laboratories
ERBE	Earth Radiation Budget Experiment
ETHZ	*"Eidgenössische Technische Hochschule Zürich"* (Swiss Federal Institute of Technology)
FTP	File Transfer Protocol
GAW	Global Atmosphere Watch
GBSRN	Global Baseline Surface Radiation Network
GEWEX	Global Energy and Water Cycle Experiment
GPS	Global Positioning System (by satellites)
GSFC	Goddard Space Flight Centre (the combination NASA-GSFC is often used).

HTTP	Hyper-text Transfer Protocol
ICSU	International Council of Scientific Unions
INFM	"*L'Istituto Nazionale per la Fisica della Materia*" (The (Italian) National Institute for the Physics of Matter)
IPC	International Pyrheliometric Comparisons (such as IPC VIII, IPC IX, etc.)
IPCC	Intergovernmental Panel on Climate Change
IPS	International Pyrheliometric Scale
IR	Infrared (radiation)
ITCZ	Inter-tropical Convergence Zone
IUCC	Information Unit on Climate Change
JJA	June-July-August (average of winter data) – see also DJF, MAM and SON.
KNMI	"*Koninklijk Nederlands Meteorolgisch Instituut*" (Royal Dutch Meteorological Institute).
LAN	Local Area Network
LW	Longwave (Radiation)
LWD	Longwave Downwelling (Radiation)
MAM	March-April-May (average of autumn data) – see also DJF, JJA and SON
NASA	(American) National Aeronautic Space Agency. See also GSFC.
NEPAD	New Plan for African Development
NH	Northern Hemisphere
NIP	Normal Incidence Pyrheliometer
NOAA	National Oceanic Atmospheric Administration
NREL	(American) National Renewable Energy Laboratory. See also SERI.
OLR	Outgoing Longwave Radiation
OSD	One-minute standard deviations (of BSRN measurements)
PAR	Photosynthetically Active Radiation
PC	Personal Computer
PDF	Portable Document File (computer format)
PIR	Precision Infrared Radiometer
PMOD	*"Physikalisch-Meteorologisches Observatorium Davos"* (World Radiation Centre) – also see WRC
PSP	Precision Spectral Pyranometer
PWV	Precipitable Water Vapour
RTM	Radiative Transfer Model(s)
SADC	Southern African Development Community
SAST	South African Standard Time
SAWB	South African Weather Bureau
SAWS	South African Weather Service

SERI	Solar Energy Research Institute (now known as NREL).
SGP	(American) Southern Great Plains
SH	Southern Hemisphere
SON	September-October-November (average of spring data) – see also DJF, MAM and JJA
SRB	Surface (Solar) Radiation Budget
STD	Standard Deviation
SURFRAD	(American) Surface Radiation Project
SW	Shortwave (Radiation)
TOA	Top Of (the) Atmosphere
UL	One-minute average value of upwelling longwave (radiation)
UNEP	United Nation's Environmental Programme
UPS	Uninterruped Power Supply
USSR	Union of Socialistic Soviet Republics
UT	Universal Time
UV	Ultraviolet (Radiation)
WAN	Wide Area (computer) Network
WCRP	World Climate Research Programme
WRDC	World Radiation Data Centre (St. Petersburg, Russia)
WRMC	World Radiation Monitoring Centre (Zürich, Switzerland)
WMO	World Meteorological Organization
WRC	World Radiation Centre (also see PMOD: the combination PMOD-WRC is often used)
WRR	World Radiometric Reference