Initial Assessment of the Climate of Guyana and the Region with a Focus on Iwokrama

Part A Appendices – Data Availability

A 4 month pilot study supported by the Commonwealth Secretariat in collaboration with the Iwokrama International Centre for Rainforest Conservation and Development

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The full report should be referenced as follows:

Bovolo C. I., Parkin G., Wagner T. (2009) *Initial Assessment of the Climate of Guyana and the Region with a Focus on Iwokrama.* Report produced for the Commonwealth Secretariat. School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, UK

The report has 4 sections. If referencing individual sections only, please reference these as follows (the current section is highlighted in bold):

Bovolo C. I., Parkin G., Wagner T. (2009) *Initial Assessment of the Climate of Guyana and the Region with a Focus on Iwokrama, Main Report.* Report produced for the Commonwealth Secretariat. School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, UK

Bovolo C. I., Parkin G., Wagner T. (2009) *Initial Assessment of the Climate of Guyana and the Region with a Focus on Iwokrama, Part A Appendices – Data Availability.* Report produced for the Commonwealth Secretariat. School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, UK

Bovolo C. I., Parkin G., Wagner T. (2009) *Initial Assessment of the Climate of Guyana and the Region with a Focus on Iwokrama, Part B Appendices – Climate Overview.* Report produced for the Commonwealth Secretariat. School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, UK

Parkin G., Bovolo C. I., Wagner T. (2009) *Initial Assessment of the Climate of Guyana and the Region with a Focus on Iwokrama – Hydrological Monitoring & Modelling Strategy.* Report produced for the Commonwealth Secretariat. School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, UK

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APPENDIX A1: Field visits

Two 'field-visits' enabled face-to-face contact to be made with key organisations and people and were instrumental in procuring data (which was not always in electronic formats) and in establishing good-will and rapport with contributors. Initial communications often revealed further potential data sources or contacts to be followed up.

Field-visit 1: 7th to 22nd March 2009.

The first field-visit involved an initial two days in Trinidad meeting various researchers at the University of the West Indies St. Augustine campus who have links with Guyana currently or through past projects. The visit was particularly useful in gaining an introduction to Guyana from the research perspective and in establishing known datasets and past projects.

Over a week was spent in Guyana which entailed meeting staff at the Iwokrama International Centre Georgetown Office and field-station (13-16th March), establishing face-to-face contact with regional and local organisations and following data-trails. In particular, several visits were made to HydroMet who were instrumental in providing climate data for Guyana. Additionally, contacts were made with South Florida University during a water quality field-visit at the Iwokrama Field station.

One day was also spent in Barbados visiting the University of the West Indies Cave Hill Campus plus the Caribbean Institute for Meteorology & Hydrology.

The following organisations and people were contacted during this visit:

TRINIDAD

University of the West Indies:

- David Rampersad (Director, Business Development Office) meeting
- Dr. Dave Chadee (Associate Professor Dept of Tropical Medicine) meeting
- Dr. Indira Omah-Maharaj (Lecturer in Ecology) meeting
- Mrs Yasmin Baksh-Comeau (Curator Herbarium) meeting
- Prof Paul Shaw (Lecturer in Geography) meeting
- Mr. Ramesh Pingal (Laboratory Manager, Chemistry Dept) meeting
- Dr. Matt Wilson (Lecturer Geography) meeting
- Prof. Nazeer Ahmad (Prof Emeritus Soil Scientist) meeting

GUYANA

Iwokrama International Centre:

- Dane Gobin (Chief Executive Officer) meeting
- Raquel Thomas (Director, Resource Management & Training) meeting
- Imole McDonald (Monitoring Manager) meeting
- Vanessa Benn (EU-ACP Forest Research Network Project) meeting
- Roxroy Bullers (GIS / IT coordinator) meeting
- Annalise Bayney (Public Communications & Outreach Coordinator) meeting
- Samantha James (Communities) meeting
- Richard Persaud (Guiana Shield Initiative) meeting

HydroMet, Guyana:

- Miss Bhaleka Seulall (Chief Hydrometeorological Officer email & meeting

National Climate Change Unit:

- Gita Chanderpal telephone

Office of the President (O.P.):

- Shyam Nokta (Chair for National Climate Change Commission) email

University of Guyana (U.G.):

- Dr Laurence Lewis (Lecturer Agriculture and Forestry) meeting
- Mr. Calvin Bernard (Lecturer Faculty of Natural Sciences) meeting
- Michelle Kalamandeen (Lecturer Biology & Guyana marine turtle conservation soc) telephone

Land and Surveys Commission:

- Naseem Nazeer meeting

National Agricultural Research Institute (N.A.R.I.):

- Mr. David Fredricks (Director) meeting

Guyana Sugar Corporation (GuySuCo):

- Dr. Harold Davies (Agricultural Research Director) email
- Mr. Dey (Manager Soil & Plant Nutrition) meeting
- Ashley Adams (Climate change research) meeting

Darwin Foundation:

- Graham Watkins (Director) meeting

BARBADOS

University of the West Indies:

- Prof. Wayne Hunte (PVC School of Graduate Studies & Research) meeting
- Prof. Sean Carrington (Dean of Science and Prof of plant biology) meeting
- Prof. Hazel Oxenford (Prof. Fisheries Biology & Management) meeting

Caribbean Institute for Meteorology and Hydrology (C.I.M.H.)

- Adrian Trotman meeting
- Sean Boyce meeting

OTHER

South Florida University, USA

- Maya Trotz (Lecturer) meeting

Field-visit 2: 25th April to 10th May 2009.

The second field-visit enabled follow up appointments to be made, in particular to organisations which had promised data during the fist visit. New contacts were also made with individuals who were unavailable during the first visit. Participation at the first Iwokrama Science Committee Meeting (28-29th April) enabled some initial findings to be presented to the group. A visit to Iwokrama field-station (1st to 4th May) enabled further discussions to take place with field-staff and potential sites for installing new climate and hydrological monitoring stations were identified with colleagues from Newcastle University (Geoff Parkin and Tom Wagner). The following organisations and people were contacted during this visit:

GUYANA

Iwokrama International Centre:

- Dane Gobin (Chief Executive Officer) meeting
- Raquel Thomas (Director, Resource Management & Training) meeting
- Imole McDonald (Monitoring Manager) meeting
- Vanessa Benn (EU-ACP Forest Research Network Project) meeting
- Roxroy Bullers (GIS / IT coordinator) meeting
- Richard Persaud (Guiana Shield Initiative) meeting

University of the West Indies:

- Prof. John Agard (Senior Lecturer, climate change) meeting
- Prof. Leonard Nurse (Senior Lecturer, climate change) meeting

Caribbean Community Climate Change Centre (C.C.C.C.C.)

- Dr. Ulric Trotz (Director) meeting

United Nations Development Program (UNDP)

- Patrick Chesney (Director GSI project) meeting

HydroMet, Guyana

- Kelvin Samaroo (Climate) meeting
- Zainool Rahaman (Hydrology) meeting
- Thaesh Pooran (Hydrology) email

Guyana Sugar Corporation (GuySuCo):

- Ashley Adams meeting

National Agricultural Research Institute (N.A.R.I.):

- David Fredricks (Director) telephone & email

University of Guyana (U.G.):

- Dr. Paulette Bynoe (Lecturer Earth and Environmental Sciences) meeting
- Dr. Denise Simmons (Lecturer Earth and Environmental Sciences) meeting

Guyana Forestry Commission

- Mr. Singh (Commissioner of Forests) letter

Project Fauna

- Han Overman telephone

Dadanawa Ranch, South Rupununi

- Duane Defritas email

Global Canopy

- Ms. Katherine Secoy (Project Manager) meeting

Shell International Ltd.

- Sachin Kapila (Group Biodiversity Adviser) meeting

APPENDIX A2: Full List of People and Organisations Contacted for Data

The following people and organisations have been contacted with respect to this work. Their help and assistance with this project is gratefully acknowledged.

Guyana:

Iwokrama International Centre http://www.iwokrama.org/
77 High Street, Kingston, Georgetown, Guyana. Tel (592) 225-1504

- Dane Gobin (Chief Executive Officer) meeting
- Raquel Thomas (Director, Resource Management & Training) meeting
- Imole McDonald (Monitoring Manager) meeting
- Vanessa Benn (EU-ACP Forest Research Network Project) meeting
- Roxroy Bullers (GIS / IT coordinator) meeting
- Annalise Bayney (Public Communications & Outreach Coordinator) meeting
- Samantha James (Communities) meeting
- Richard Persaud (Guiana Shield Initiative) meeting
- Angela Lewis (Field monitoring staff) meeting
- All other helpful Iwokrama staff meeting

HydroMet http://www.hydromet.gov.gy/
18 Brickdam, Stabroek, Georgetown, Guyana. Tel +592 225 9303

- Miss Bhaleka Seulall (Chief Hydrometeorological Officer email & meeting
- Kelvin Samaroo (Climate) meeting
- Zainool Rahaman (Hydrology) meeting
- Thaesh Pooran (Hydrology) email
- Reports web-access

University of Guyana (U.G.) http://www.uog.edu.gy/
Turkeyen Campus PO Box 10-1110 Greater Georgetown, Guyana. Tel +592 222 5402

- Dr. Paulette Bynoe (Lecturer Earth and Environmental Sciences) meeting
- Dr. Denise Simmons (Lecturer Earth and Environmental Sciences) meeting
- Dr Laurence Lewis (Lecturer Agriculture and Forestry) meeting
- Mr. Calvin Bernard (Lecturer Faculty of Natural Sciences) meeting
- Michelle Kalamandeen (Lecturer Biology & Guyana marine turtle conservation soc) telephone

Guyana Forestry Commission (G.F.C.) http://www.forestry.gov.gy/
1 Water Street, Kingston, Georgetown, Guyana. Tel +592 226-7271 to 4

- Mr. Singh (Commissioner of Forests) letter
- Bookshop & Library for publications visit

National Agricultural Research Institute (N.A.R.I.) http://www.agrinetguyana.org.gy/nari/index.htm
Guyana. Tel +592 220-2841 to 3

- Mr. David Fredricks (Director) meeting
- Soil data post

Guyana Sugar Corporation (GuySuCo) http://www.guysuco.com/
Guyana Tel +592 222-6030-41

- Dr. Harold Davies (Agricultural Research Director) email
- Mr. Dey (Manager Soil & Plant Nutrition) meeting
- Ashley Adams (Climate change research) meeting

Guyana Land & Surveys Commission http://www.lands.gov.gy/surveys.html
22 Upper Hadfield Street, Durban Backlands, Georgetown, Guyana,

- Naseem Nazeer — meeting

Office of the President (O.P) http://opnew.op.gov.gy/ and
National Climate Unit http://www.guyanaclimatechange.gov.gy/

- Shyam Nokta (Chair for National Climate Change Commission) — email
- Gita Chanderpal — telephone

United Nations Development Program (UNDP) http://www.undp.org.gy/

- Patrick Chesney (Director GSI project) — meeting

Darwin Foundation

- Graham Watkins (Director) — meeting

Gordon & Betty Moore Foundation http://www.moore.org/

- Jose MV Fragoso — email
- Kirsten Silvius — email

Project Fauna

- Dr. Han Overman (Field manager) — telephone
- Dr. Jeff Luzar (Field social aspects coordinator) — telephone
- Dr. Josie Demmer (Iwokrama liaison) — telephone

Dadanawa Ranch, South Rupununi

- Duane Defritas — email

Suriname:

Centre for Agricultural Research (CELOS) http://www.celos.sr.org/

- Rudi van Kanten — email

Anton de Kom University of Suriname, http://www.uvs.edu/English.html

- Dr. Sieuw Naipal (Lecturer in Hydrometeorology) — email

National Meteorology Institute

- Mr. Cornelius Becker — email
- Mr. Armand Amatali — email

French Guiana:

Météo-France, Direction Interrégionale Antilles-Guyane http://www.meteo.gp/

- Mr. Nicolas Beriod (Interregional Director) — email
- Mr. Philippe Hereil (Climatology) — email

Venezuela:

Servicio de Meteorologia de la Aviacion http://www.meteorologia.mil.ve/siafavm/frontend/

- Data — email request

Brazil:

Instituto National de Meteorologia, Brazil http://www.inmet.gov.br/

- Data — email request

Caribbean:

University of the West Indies
St Augustine (Trinidad) http://sta.uwi.edu/
Cave Hill (Barbados) http://www.cavehill.uwi.edu/
Mona (Jamaica) http://www.mona.uwi.edu/

- Prof. John Agard (Senior Lecturer, climate change) — meeting
- Prof. Leonard Nurse (Senior Lecturer, climate change) — meeting
- Prof. Wayne Hunte (PVC School of Graduate Studies & Research) — meeting
- Prof. Sean Carrington (Dean of Science and Prof of plant biology) — meeting

- Prof. Hazel Oxenford (Prof. Fisheries Biology & Management) meeting
- David Rampersad (Director, Business Development Office) meeting
- Dr. Dave Chadee (Associate Professor Dept of Tropical Medicine) meeting
- Dr. Indira Omah-Maharaj (Lecturer in Ecology) meeting
- Mrs Yasmin Baksh-Comeau (Curator Herbarium) meeting
- Prof Paul Shaw (Lecturer in Geography) meeting
- Mr. Ramesh Pingal (Laboratory Manager, Chemistry Dept) meeting
- Dr. Matt Wilson (Lecturer Geography) meeting
- Prof. Nazeer Ahmad (Prof Emeritus Soil Scientist) meeting
- Dr. Michael Taylor (Dept. Physics) email
- Ms. Tannecia Stephenson email

Caribbean Institute for Meteorology and Hydrology (C.I.M.H.) http://www.cimh.edu.bb/

- Dr. David Farrell email
- Adrian Trotman meeting
- Sean Boyce meeting
- Kailas Narayan (Chief Hydrologist) email
- Cherie Pounder email

Caribbean Meteorological Organisation, Trinidad http://www.cmo.org.tt/

- Dr. Tyrone Sutherland (Coordinating Director) email

Belize:

Caribbean Community Climate Change Centre (CCCCC)
http://www.caricom.org/jsp/community/ccccc.jsp?menu=community

- Dr. Ulric Trotz (Director) meeting

International:

Commonwealth Secretariat http://www.thecommonwealth.org/

- Tim Newman email/meeting
- Janet Strachen meeting

Commonwealth Foundation http://www.commonwealthfoundation.com/

- Dr. Mark Collins (Director) meeting

Newcastle University http://www.ncl.ac.uk/

- Access to on-line library databases web-access
- Dr. Hayley Fowler (Reader in Impacts of Climate Change) meeting
- Prof. Chris Kilsby (Professor of Hydrology & Climate Change) meeting
- Dr. Geoff Parkin (Senior Lecturer Hydrology) meeting
- Prof. Thomas Wagner (Professor Earth Systems Science) meeting
- Prof. Jim Hall (Professor Earth Systems Engineering) meeting
- Mr. Aidan Burton (Senior Research Associate) meeting
- Dr. Mark Wilkinson (Research Associate) meeting
- Dr. Meredith Williams (Lecturer Geodesy) meeting
- Mr. Gerard Corsane (Lecturer Museum, Heritage and Gallery Studies) meeting

NWFS Consultancy, Portland, OR

- Dr. David Hammond (Principal) email

Brock University, Department of Geography

- Prof. Antony Shaw email

University of South Florida, USA http://www.usf.edu/index.asp

- Maya Trotz (Lecturer) meeting

Mott MacDonald http://www.mottmac.com/

- Reports — email request

Organisation for Tropical Studies, Duke University http://www.ots.duke.edu/

- Dr. Elizabeth Losos (President, CEO) — meeting

Global Canopy Programme, UK http://www.globalcanopy.org/

- Dr. Andrew Mitchel (Executive Director) — meeting
- Ms. Katherine Secoy (Project Manager) — meeting
- Dr. Mandar Trivedi — meeting

Shell International Ltd.

- Sachin Kapila (Group Biodiversity Adviser) — meeting

Climatic Research Unit (UEA) http://www.cru.uea.ac.uk/

- Prof. Phil Jones (Director) — email
- Mr. David Lister (Researcher) — email

UK Meteorological Office http://www.metoffice.gov.uk/corporate/library/

- Library — web access

British Atmospheric Research Centre (BADC) http://badc.nerc.ac.uk/home/index.html

- Data — web access

USGS DEM Data http://seamless.usgs.gov/

- Data — web access

ERA 40 Data http://data-portal.ecmwf.int/data/d/era40_daily/

- Data — web access

NCEP/NCAR http://www.cdc.noaa.gov/data/reanalysis/reanalysis.shtml

- Data — web access

NCDC GHCN http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/index.php

- Data — web access

TRMM http://trmm.gsfc.nasa.gov/

- Data — web access

World Meteorological Organisation (WMO) http://www.wmo.int/pages/index_en.html

- Guidelines/Reports — web access

IPCC http://www.ipcc.ch/

- Reports / Data — web access

APPENDIX A3: Available Datasets

Identified datasets fall into three main sections. **Section 1** relates to climate data and is split into four parts. Section 1.1 relates to observed data for the wider region for (a) global and (b) regional datasets; section 1.2 relates to Guyana; and section 1.3 relates specifically to Iwokrama. Modelled climate change scenarios are also listed in section 1.4. Appendix 3 Table 1 details which climate datasets have been collated for this study and which have not.

Section 2 concerns Hydrology related data and relates only to Iwokrama and its surroundings. See Appendix 3 Table 2 for Hydrology related data.

Section 3 relates to physical environment data for Iwokrama. This section includes digital elevation maps and details of vegetation and soil distributions and properties for Iwokrama. Please also refer to Appendix 3 Table 3.

Each section contains a list of all identified sources of data identified by a number corresponding to the relevant table, a description of the datasets and a summary of the issues relating to the data.

An initial site resource survey was carried out in 1993 when Iwokrama was established. An executive summary [1] and report [2] detail several important site characteristics (access, climate, topography, geology, soils and forest) and should form an initial point of reference.

Table 1 – List of all Climate-related datasets

Dataset number	Acronym	Source Description	Web-Link	Dataset Description	Availability	Data collated?
	OBSERVED CLIMATE DATA					
	1.1 (a) Global datasets					
1	CRU	Climatic Research Unit, University of East Anglia (UEA), UK	http://www.cru.uea.ac.uk/cru/data/	Historical monthly datasets for precipitation and temperature	on request	Yes
1	CRU	Climatic Research Unit, University of East Anglia (UEA), UK	http://www.cru.uea.ac.uk/~mikeh/datasets/global/	Global historical monthly precipitation dataset for global land areas from 1900 to 1998 at two different resolutions (2.5deg latitude by 3.75 deg longitude and 5deg latitude/longitude)	downloadable for scientific research	x
1	CRU	Climatic Research Unit, University of East Anglia (UEA), UK	http://www.cru.uea.ac.uk/cru/data/temperature/	CRUTEM3 land air temperature anomalies dataset on 5 deg by 5 deg grid-box basis	freely downloadable for scientific research	x
				CRUTEM3v variance adjusted version of CRUTEM3		x
				HadCRUT3 combined land and marine (sea surface temperature SST) anomalies from HadSST2 temperature anomalies on 5deg by 5deg		x
				HadSST2 sea surface temperature anomalies		x
				Absolute temperatures for the 1961-1990		x
2	BADC	British Atmospheric Data Centre (BADC)	http://badc.nerc.ac.uk/home/index.html	UK Met Office MIDAS Land Surface Stations data (1853-current) for global weather data (including South America) for precipitation, temperature and other variables such as wind speed from 1974 to date	restricted use for UK-sourced academic research only	Yes
3	ERA 40	European Centre for Medium-Range Weather Forecasts (ECMWF)	http://data-portal.ecmwf.int/data/d/era40_daily/	Global reanalysis data of atmospheric, land and surface observations from mid-1957-2001.	freely downloadable for scientific research	x

Dataset number	Acronym	Source Description	Web-Link	Dataset Description	Availability	Data collated?
4	NCEP/NCAR	NOAA National Weather Service Climate Prediction Centre	http://www.cdc.noaa.gov/data/reanalysis/reanalysis.shtml	Global reanalysis data of atmospheric, land and surface observations from 1948-2009.	free for scientific research available on CD-ROMs or downloadable from 14/5/09	x
5	NCDC GHCN	National Climate Data Centre (NCDC) and NOAA Global Historical Climatology Network	http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/index.php	Monthly global historical temperature, precipitation and pressure data	freely available through NCDC's	Yes
6	TRMM	Tropical Rainfall Measuring Mission NASA & Japan Aerospace Exploration Agency	http://trmm.gsfc.nasa.gov/ and http://disc2.nascom.nasa.gov/Giovanni/tovas/ground.GPCC.shtml#description and http://disc.gsfc.nasa.gov/precipitation/documentation/TRMM_README	GPCC Monthly observed and gridded and orbital global datasets including rainfall	freely available to download	some
	1.1 (b) Regional datasets					
7	Suriname Met Office	National Meteorological Institute	http://www.meteosur.sr/english%20page.htm	National climate dataset	on request under licence agreement	some
8	French Guiana Met Office	Meteo France, Direction Interregionale Antilles-Guyane	http://www.meteo.fr/meteonet_en/index.htm	National climate dataset	on request under licence agreement	on request
9	Brazil Met Office	Instituto National de Meteorologia	http://www.inmet.gov.br/	National climate dataset	on request under licence agreement	on request
10	Venezuela Met Office	Servicio de Meteorologia de la Aviacion	http://www.meteorologia.mil.ve/siafavm/frontend/	National climate dataset	on request under licence agreement	on request

Dataset number	Acronym	Source Description	Web-Link	Dataset Description	Availability	Data collated?
	1.2 Guyana datasets					
11	HydroMet	HydroMeteorological Service (HydroMet), Guyana	http://www.hydromet.gov.gy/	Daily Precipitation Dataset Weather observations Station codes and locations for weather and precipitation stations	on request under licence agreement	Yes
11	HydroMet	HydroMeteorologial Service (HydroMet) Guyana	http://www.hydromet.gov.gy/	Hydrology Data	on request under agreement	x
12	GuySuCo	Guyana Sugar Corporation	http://www.guysuco.com/	Monthly Precipitation Datasets for GuySuCo plantations	on request under agreement	Yes
13	Dadanawa Ranch	Source dataset	Dadanawa Ranch	Monthly Precipitation Dataset for Dadanawa Ranch, South Rupununi	on request	Yes
14	Publications	Various	Various	Reports, publications	HydroMet, personal contacts, libraries	Yes
	1.3 Guyana datasets					
15	Iwokrama	Iwokrama field station	Iwokrama direct	Iwokrama daily weather observations	on request	Yes
16	Iwokrama	Local Amerindian community village school wildlife clubs	Iwokrama direct	Observed daily precipitation from schools	on request	x
	MODELLED CLIMATE DATA					
	1.4 Simulated climate datasets					
17	IPCC	Intergovernmental Panel on Climate Change (IPCC)	http://www.ipcc-data.org/ddc_climscen.html	Various General Circulation Models outputs used in the construction and application of climate change scenarios for climate change impacts assessments	freely available to download for research	x
18	UNDP	UNDP Climate change country profiles	http://country-profiles.geog.ox.ac.uk/	UNDP Climate change country profiles. Country level studies of climate observations and multi-model projections. Report contains a set of maps demonstrating the observed and projected climates as average time series. Dataset is available for download	freely available to download	Yes

Dataset number	Acronym	Source Description	Web-Link	Dataset Description	Availability	Data collated?
19	PRECIS	Instituto de Meteorologia de la Republica de Cuba (INSEMT), the University of the West Indies (UWI) and the Caribbean Community Climate Change centre (CCCCC)	http://precis.insmet.cu/eng/datos.html	PRECIS Regional Climate Model Future Climate Scenarios for the Caribbean Region for A2, B2, baseline and reanalysis simulations	on request	x
20	GuySuCo	Guyana Sugar Corporation data	DSSAT / WeatherMan Dataset from GuySuCo	Simulated climates from the Decision Support System for Agro-Technology Transfer (DSSAT) and WeatherMan models - Daily Max/Min T / Precipitation / solar radiation	on request	Yes
21	Publications	Various	http://ipcc-data.org/sres/scatter_plots/scatter_plot_report.pdf	Future Climate in world regions; an inter-comparison of model-based projections for the new IPCC emissions scenarios. Finnish Environment Institute 2003	freely available to download	Yes

Table 2 – List of all Hydrology-related datasets

Dataset number	Acronym	Source Description	Web-Link	Dataset Description	Availability	Data collated?
	Hydrology Data					
11		see Table 1				
15		see Table 1				
22	South Florida University	South Florida University	none	Water quality field visit to Iwokrama	on request	x
30		see Table 3				

Table 3 – List of all physical environment datasets

Dataset number	Acronym	Source Description	Web-Link	Dataset Description	Availability	Data collated?
	DEM Data					
23	Spot heights	Guiana Shield Initiative project	none	Spot heights for the Guianas and surrounding regions	Restricted use	Yes
24	SAREX-92	SAREX data from Guiana Shield Initiative project	none	Synthetic Aperture Radar (SAR) data from the SAREX-92 program. SarVision has/is processing the SAREX and new PALSAR-I band radar data. DEM data is currently available at ~100x100 m resolution for the Iwokrama area.	Restricted use	Yes
25	SRTM	Shuttle Radar Topography Mission	http://seamless.usgs.gov/	SRTM uses radar-C/X Band Synthetic Aperture Radar (SIR-C/X-SAR). Data has a global coverage of 3 Arc Seconds (about 90 m resolution) and has been downloaded for the Iwokrama area	Freely available to download	Yes
26	GLS 2005	Global Land Survey 2005	http://edcsns17.cr.usgs.gov/EarthExplorer/	Global Land Survey 2005 data created using Landsat Thematic Mapper and Enhanced Thematic Mapper Plus imagery in 2005, corrected using SRTM data. DEM is at 30 m resolution and has been downloaded for the Iwokrama area.	Freely available to download	Yes
27	JERS-1	Guiana Shield Initiative project	none	Japanese Earth Resources Satellite 1 mission (1992-1998) observed the Earth's surface using optical sensors and a Synthetic Aperture Radar (SAR) sensor. Good quality data is available from the Guiana Shield Initiative project	Restricted use	x
	River Network					
28	Various	Guiana Shield Initiative project and others	none	Various digital	Restricted use	Yes
29	SRTM-water bodies	Shuttle Radar Topography Mission	http://seamless.usgs.gov/	Water body data identified during the processing of SRTM data (dataset 24). Downloaded for Iwokrama area.	Freely available to download	Yes
	Land Forms / Geology					
30	Site Survey	Iwokrama Site Survey 1993	none	Land Form data from the Iwokrama site survey 1993 from reference [2].	Paper copy	Yes
	Land Forms / Geology / Vegetation					

Dataset number	Acronym	Source Description	Web-Link	Dataset Description	Availability	Data collated?
31	GFC	Guyana Forestry Commission	none	Detailed digital vegetation maps for Iwokrama.	Restricted use, on request	x
	Soil Data					
32	FAO	F.A.O. Soil survey project, British Guyana 1966	none	Soil survey for Guyana, 7 volumes. Volume III parts 1 and 2 are relevant to Iwokrama.	Books	x
33	N.A.R.I. CD		http://www.agrinetguyana.org.gy/nari/index.htm	CD 'Soil Resource Inventories of Guyana', 2003	For purchase	Yes

Table 4 – List of other data

Dataset number	Acronym	Source Description	Domain	Dataset Description	Availability	Data collated?
	Other Climate-related Data					
a1	HydroMet	HydroMet	Map	Persaud C 1982 Bright sunshine maps of Guyana. Hydrometeorological Service, Ministry of Works, Georgetown, Guyana		x
a2	HydroMet	HydroMet	Map	Persaud C and Persaud K 1995. The classification of the rainfall regions of Guyana. Caribbean Climate Centre, Barbados		x
a3	HydroMet	HydroMet	Map	Persaud G. and Persaud C., 1993 Preparation of pan evaporation maps of Guyana. Caribbean Climate Centre, Barbados		x
a4	HydroMet	HydroMet	Book	Guyana – Population, environment, economic activities. (Ed) Robert Ramraj 2003, Battleground Printing Publishing USA. Chapter IV - Climate p63-86 ISBN 0-9728295-0.4	Difficult to obtain	Yes
a5	HydroMet	HydroMet	Diagram	Pencil Colour Map of mean rainfall distribution in Guyana (part of Book chapter above)	Difficult to obtain	Yes
a6	Mott MacDonald	Mott MacDonald Consultancy	Report	Mott MacDonald Guyana Drainage and Irrigation Systems Rehabilitation Project Hydrology and Water Resources, Interim Report	Restricted Publication	Yes
a7	Mott MacDonald	Mott MacDonald Consultancy	Report	Mott MacDonald Guyana Drainage and Irrigation Systems Rehabilitation Project Hydrology and Water Resources Final Report, 2004	Restricted Publication	Yes
a8	WMO	World Meteorological Organisation	Web	Guide to Meteorological Instruments and Methods of Observation: Measurement of Meteorological Variables PART 1 and 2. WMO-No8	Free once registered	Yes
a9	WMO	World Meteorological Organisation	Web	Technical Regulations: Hydrology 2006 edition WMO-No. 49.	Free once registered	Yes
a10	WMO	World Meteorological Organisation	Web	Guide to Hydrological Practices: Data acquisition and processing, analysis, forecasting and other applications. WMO-No. 168	Free once registered	Yes
a11	WMO	World Meteorological Organisation	Web	Guidelines for the education and training of personnel in Meteorology and Operational Hydrology. Vol 1: Meteorology. Ed Draghici JF, Necco GV, Riddaway RW, Snow JT, Billard C, Ogallo LA. Fourth Edition. WMO-No.258.	Free once registered	Yes
a12	WMO	World Meteorological Organisation	Web	Guidelines for the education and training of personnel in Meteorology and Operational Hydrology. Vol 1: Hydrology Ed Arduino G, Draghici I, Hall MJ, Holly FM Jr, Van der Beken A. Fourth Edition. WMO-No.258.	Free once registered	Yes

Dataset number	Acronym	Source Description	Domain	Dataset Description	Availability	Data collated?
a13	WMO	World Meteorological Organisation	Web	Guide to the Global Observing System. Third Edition, 2007. WMO-No.488	Free once registered	Yes
a14	WMO	World Meteorological Organisation	Web	Manual on the Global Observing System. 2003 WMO-No.544	Free once registered	Yes
a15	UG	HydroMet	HydroMet Publication	Annual Climatological Data Summary, Guyana 1972	Out of print	Yes
a16	UG	HydroMet	HydroMet Publication	Annual Climatological Data Summary, Guyana 1973	Out of print	Yes
a17	UG	HydroMet	HydroMet Publication	Annual Climatological Data Summary, Guyana 1974	Out of print	Yes
a18	UG	HydroMet	HydroMet Publication	Annual Surface Water Data, Guyana 1966	Out of print	Yes
a19	UG	HydroMet	HydroMet Publication	Annual Surface Water Data, Guyana 1968	Out of print	Yes
a20	UG	HydroMet	HydroMet Publication	Annual Surface Water Data, Guyana 1969	Out of print	Yes
a21	UG	HydroMet	HydroMet Publication	Annual Surface Water Data, Guyana 1970	Out of print	Yes
a22	UG	HydroMet	HydroMet Publication	Annual Surface Water Data, Guyana 1971	Out of print	Yes
a23	UG	HydroMet	HydroMet Publication	Compilation of Surface Water Data to December 31 1965	Out of print	Yes
a24	UG	HydroMet	HydroMet Publication	Records of Surface Water Quality 1966-1972	Out of print	Yes
a25	UG	HydroMet	HydroMet Publication	Reference Index of rainfall stations for which daily data sets are available and years in which daily data are available to 1970	Out of print	Yes
a26	GuySuCo	GuySuCo	Thesis	An investigation into the Impact of El Nino-Southern Oscillation events on rainfall and sugarcane production in Guyana	Unpublished	Yes
a27	Iwokrama	Iwokrama	Report	McGill University Savanna Research Project (Savanna research Series No 1) The Savanna Ecosystem - Northern Rupununi, British Guyana by MJ Eden 1964	Unpublished	Yes
a28	Iwokrama	Iwokrama	Book	Hydrology of Moist Tropical Forests and effects of Conservation: A state of knowledge review 1990 by LA Bruijnzeel	Out of print	Yes
a29	GFC	Guyana Forestry Commission	Book	Tropenbos Series 6: Modelling the effects of logging on the water balance of a tropical rain forest. A study in Guyana.	For purchase	Yes
a30	IPCC	IPCC	Web report	Up in smoke? Latin America and the Caribbean. The threat from climate change to the environment and human development. The third report from the Working Group on Climate Change and Development.	for download from IPCC	Yes
a31	Web	Newcastle University on-line library by subscription	Journal Article	Carril A., Menedes CG., Nunez MN. 1997. Climate change scenarios over the South American Region: An inter-comparison of coupled general atmosphere-ocean circulation models. International Journal of Climatology, 17, 1613-1633	author or libraries	Yes

Dataset number	Acronym	Source Description	Domain	Dataset Description	Availability	Data collated?
a32	Web	Newcastle University on-line library by subscription	Journal Article	Haylock MR et al 2006 Trends in total and extreme South American Rainfall in 1960-2000 and Links with Sea Surface Temperature. Journal of Climate 19, 1490	author or libraries	Yes
a33	Web	Newcastle University on-line library by subscription	Journal Article	Nunez MN, Solman SA, Cabre MF. 2008 Regional climate change experiments over southern South America II: Climate change scenarios in the late twenty-first century. Clim. Dyn. DOI: 10.1007s00382-008-0449-8	author or libraries	Yes
a34	Web	request to author	Conference Article	Shaw AB. An analysis of rain-producing systems on coastal Guyana. 1986. Third International Conference on Statistical Climatology June 23-27, 1986, Vienna, Austria.	author request	Yes
a35	Web	request to author	Journal Article	Shaw AB. An analysis of the rainfall regimes on the coastal region of Guyana 1987 Journal of Climatology, 7, 291-302	author request	Yes
a36	Web	CCCCC	Report	Trotz 2002 Disaster Reduction and Adaptation to Climate change. A CARICOM Experience	free to download	Yes
	Other Data					
a37	Iwokrama	Iwokrama	Project and reports	Wetlands project and available reports	by request from Iwokrama	Yes
a38	GFC	Guyana Forestry Commission	Book	Tropenbos Series 1: Nutrient Cycling in Pristine and Logged Tropical Rain Forest. A study in Guyana by Leo Brouwer. 1996	For purchase	Yes
a39	GFC	Guyana Forestry Commission	Book	Tropenbos Series 14: Ecology and logging in a tropical rain forest in Guyana with recommendations for forest management by Hans ter Steege et al 1996	For purchase	Yes
a40	GFC	Guyana Forestry Commission	Book	Tropenbos - Guyana Series 3: Tree demography in the tropical rain forest of Guyana by Roderick Zagt 1997	For purchase	Yes
a41	GFC	Guyana Forestry Commission	Book	Tropenbos Series: Soils of the Rainforest in Central Guyana 1996	For purchase	Yes
a42	Web	Newcastle University on-line library by subscription	Journal Article	Propensity for Fire in Guianan Rainforests 1998 Conservation Biology Vol 12, 5, 944-947	author or libraries	Yes
a43	Smithsonian	Smithsonian, USA	Publication	Smithsonian Plant Collections, Guyana. 1989-1991 Lynn J Gillespie. by Tom Hollowell, Lynn Gillespie, VA Funk, Carol Kellof. Missouri NY, Smithsonian Institute.	author or libraries	x

1 Climate Data

1.1 Observed Climate Data for the Wider Region

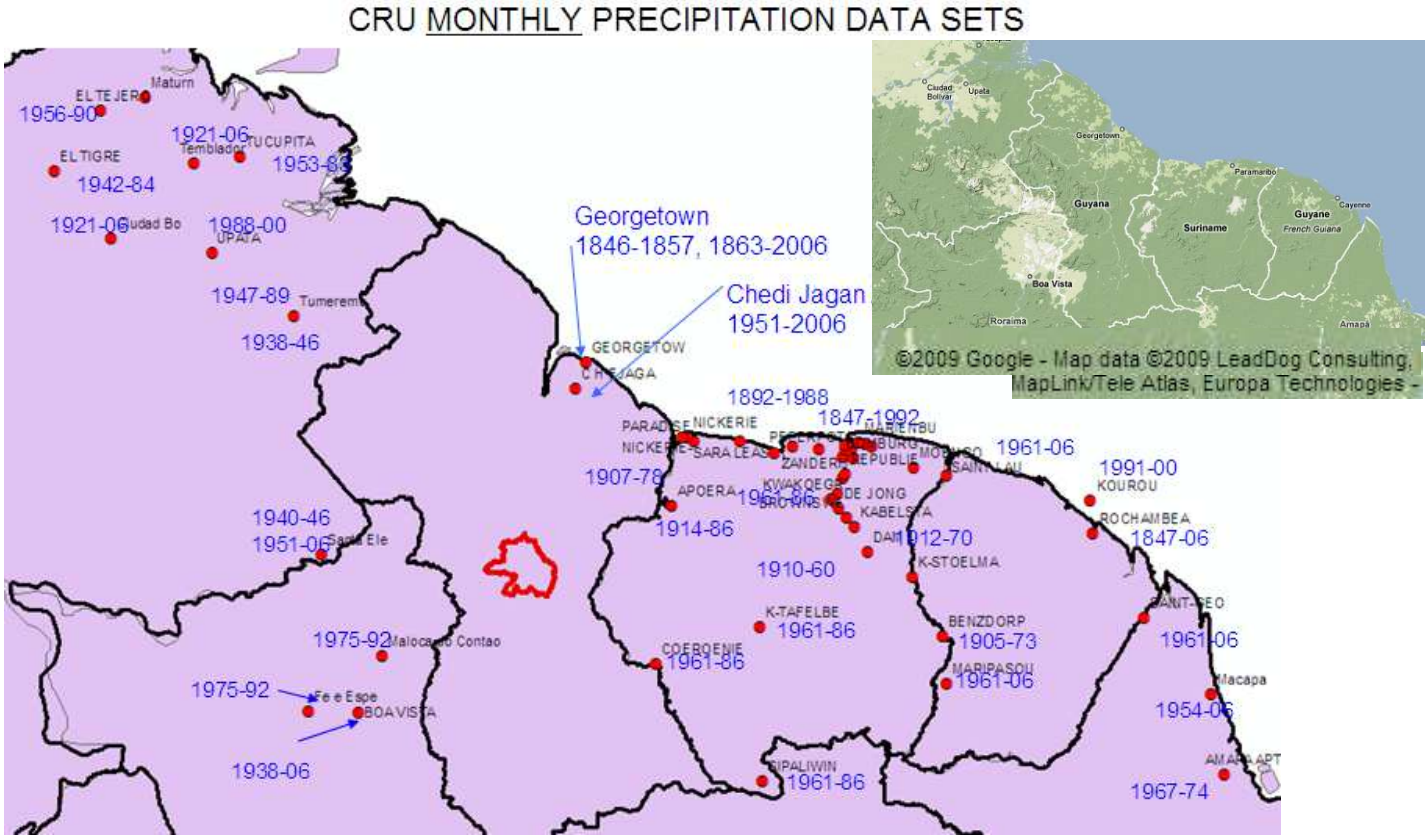


Figure 1- Summary of data and location of precipitation stations in Venezuela, Brazil, Guyana, Suriname and French Guiana, and map showing topography. [Data supplied by CRU database of monthly observed time-series, map from Google Maps]. Red outline is Iwokrama.

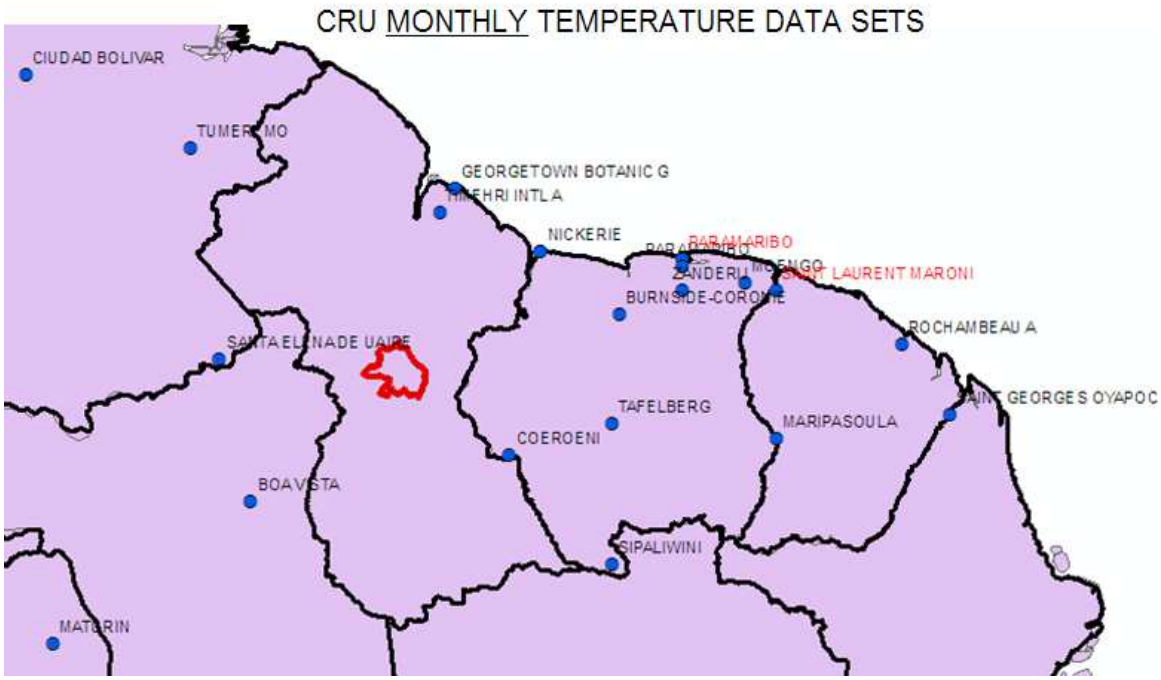


Figure 2- Summary of data and location of temperature stations in Venezuela, Brazil, Guyana, Suriname and French Guiana. [Data supplied by CRU database of monthly observed time-series]. Red outline is Iwokrama.

1.1.1 All sources of data

Please refer to Table 1 for acronym descriptions, dataset numbers and further information.

(a) GLOBAL DATASETS

1. Monthly archives of observed precipitation and temperature data from CRU (Figure 1 and Figure 2) and other CRU datasets such as the CRUTEM3 land air temperature anomalies dataset
2. BADC UK Met Office MIDAS Land Surface Station data
3. ERA 40 global reanalysis data
4. NCEP/NCAR global reanalysis data
5. NCDC GHCN monthly global datasets
6. Tropical Rainfall Measuring Mission (TRMM) data

(b) REGIONAL DATASETS

7. National Meteorology Institute of Suriname
8. Météo-France, Direction Interrégionale Antilles-Guyane, French Guiana
9. Instituto National de Meteorologia, Brazil
10. Servicio de Meterologia de la Aviacion, Venezuela

1.1.2 Description of data

(a) GLOBAL DATASETS

1. CRU observed precipitation and temperature dataset

- The Climatic Research Unit (CRU) at the University of East Anglia (UEA) maintains several observed and global climate datasets http://www.cru.uea.ac.uk/cru/data/. Records have been obtained by request.
- Two records exist in the CRU database for Guyana (see Figure 1 and Figure 2). These are a long-term data-set for Georgetown and a shorter data set for Chedi Jagan Airport.
- There are some long-term observed monthly datasets from surrounding countries: Boa Vista (Brazil) has a long record from 1938-2006; French Guiana records are mainly from 1961; Suriname has good records from 1847 to mid 1980s; Venezuela has good records from 1921 to present day.

2. BADC records

Figure 3 – Locations of BADC Midas surface stations. Current stations are shown with a green marker, closed stations with a red marker.

- The British Atmospheric Data Centre (BADC) records for precipitation and temperature from 1974 to 2009 from the UK MIDAS Land Surface Station dataset have been downloaded under licence agreement (http://badc.nerc.ac.uk/home/index.html). 3 stations exist in the database for Guyana (from 1974 at the international airport, from 1996 in Georgetown and from 1999 at New Amsterdam), 7 in Suriname (dating from 1983), 5 in French Guiana and others in Venezuela and Brazil (see Figure 3).

3. ERA 40 global reanalysis data
- The European Centre for Medium-range Weather Forecasts (ECMWF) ERA-40 project aims to produce and promote the use of a comprehensive set of global analyses describing the state of the atmosphere, land and ocean-wave conditions from mid-1957 to August 2002. The ERA-40 project applies a modern Variational Data Assimilation technique (used in daily operational numerical forecasting at ECMWF) to the past conventional and satellite observations. A 6-hourly reanalysis dataset at 2.5° resolution is available from the BADC but requires downloading and processing (http://badc.nerc.ac.uk/data/ecmwf-e40/). Monthly mean data is available for most parameters held in the full archive. Also an Atlas is available describing the climate during 1979-2001, the period with the best and most time-consistent product quality for the globe.

4. NCEP/NCAR global reanalysis data
- The reanalysis data is similar to the ERA 40 set. The NCEP/NCAR reanalysis 1 project (National Center for Environmental Prediction (NCEP) and the National Center for Atmosphiric Research (NCAR)) uses a state-of-the-art analysis/forecast system to perform data assimilation using past data from 1948 to present. The goal is to produce new atmospheric analyses on a horizontal resolution of about 210 km using historical data and to produce analyses of the current atmospheric state using the Climate Data Assimilation System (CDAS). Data is available to download from http://www.cdc.noaa.gov/data/gridded/.

5. NCDC GHCN
- The National Climatic Data Center (NCDC) Global Historical Climatology Network (GHCN-Monthly) is a monthly global observed dataset for precipitation and temperature. Data have been collated and adjusted for inhomogeneities (see Figure 4) by NCDC GHCN and have been downloaded (http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/index.php). Also available are lists of duplicate records containing different values, and data which have failed quality control tests.

Figure 4 – GHCN Monthly coverage maps for (a) precipitation, (b) mean temperature and (c) maximum / minimum temperature.

6. TRMM data
- The Tropical Rainfall Measuring Mission (TRMM) space mission by NASA and the Japan Aerospace Exploration Agency is designed to measure tropical precipitation and its variations. Its primary objective is to understand the role of latent heat in driving the circulation of the global atmosphere. The rainfall data is particularly important for studies of the global

hydrological cycle and for testing the realism of climate models to simulate and predict climate accurately on the seasonal time scale. 10 ground validation sites exist, the closest to Guyana being in Rondonia Brazil (a TRMM site associated with the Large Scale Biosphere-Atmosphere experiment (LBA)). Data such as gridded monthly 5° by 5° surface rain totals are available to download for free. Images of monthly rainfall climatology and monthly rainfall anomalies based on data from for 1998 to 2008 at 0.25 degree resolution are also available (see Figure 5).

- A visualisation system for data from the Global Precipitation Climatology Project (GPCP) providing a global merged rainfall analysis for research applications is available on-line from http://disc2.nascom.nasa.gov/Giovanni/tovas/ (see Figure 6).

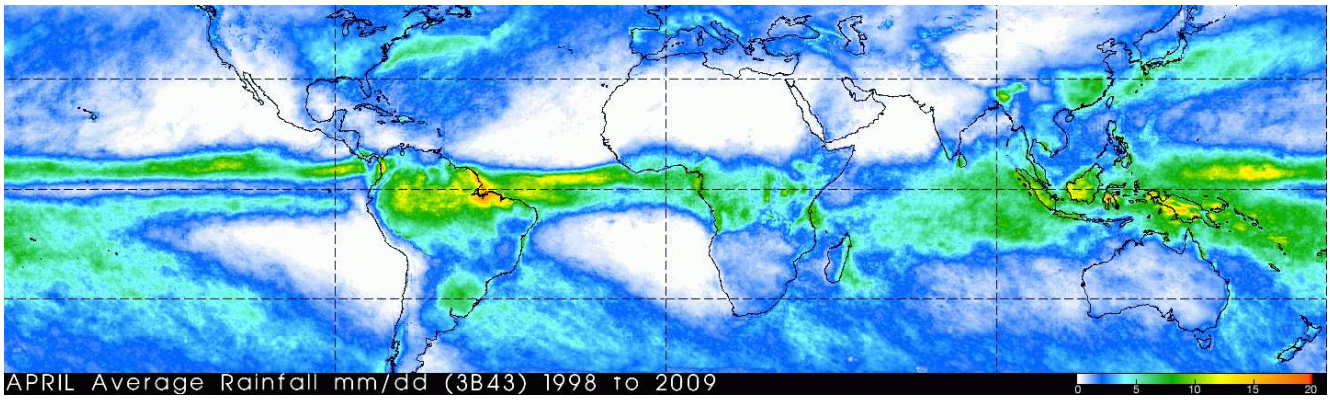


Figure 5 – TRMM average rainfall (mm/day) for April based on data from 1998 to 2009 at 0.25 degree resolution

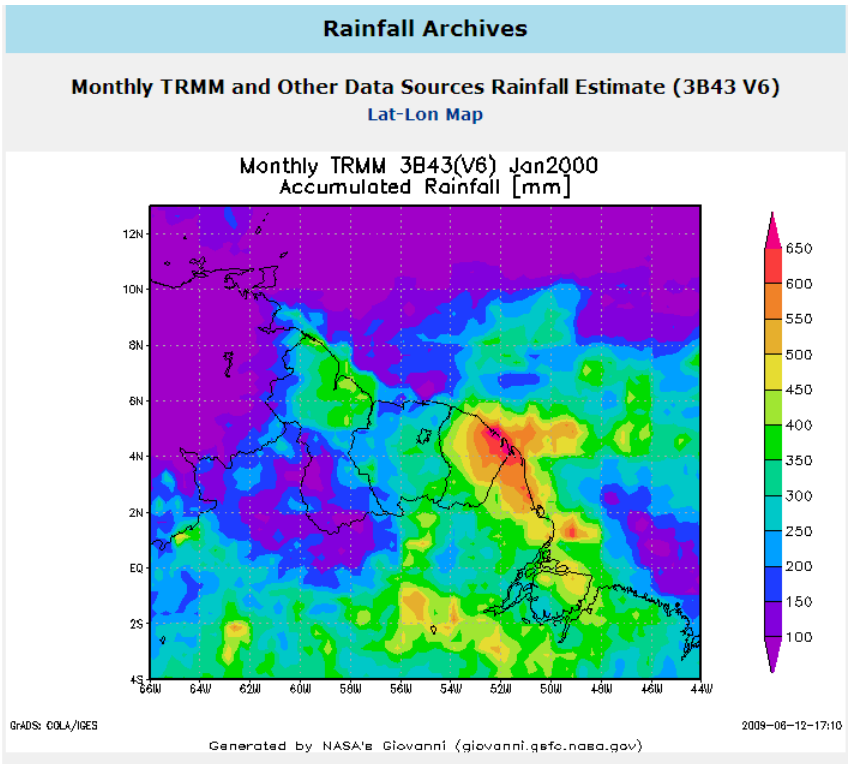


Figure 6 – Monthly TRMM accumulated rainfall estimate (mm) for January 2000.

Figure 7 – Manual and Automatic Weather stations present in Northern Brazil

(b) REGIONAL DATASETS

7. National Meteorological Institute, Suriname
   - Weather station data has been collated for Paramaribo Cultuurtuin (central Suriname coast) from 1900 to 2005, Nickerie (Suriname coast near Guyana) from 1960 to 2005 and Sipaliwini (south Suriname border) for 1961-2002. Additionally, rainfall data for Coeroeni and Apoera in the west and south-west of Suriname have been collated.

8. Météo-France, Direction Interrégionale Antilles-Guyane
   - Météo-France are composing a climate atlas of French Guiana to be available in 2010. They are willing to share their datasets for the Antilles-Guiana and plan to undertake a similar study to this one for French Guiana soon. This data is under request.

9. Instituto National de Meteorologia, Brazil
   - Data for the stations nearest Guyana are under request. Although a couple of stations exist near to the Guyana border, generally large gaps in the spatial coverage exist south of the Guianas. Available stations are shown in Figure 7.

10. Servicio de Meteorologia de la Aviacion, Venezuela
    - Data for stations near Guyana is under request.

1.1.3 Issues

1.1.3.1 Data sets

Global climate data sets are available in monthly formats only and are generally the best, most accessible or most long-term records available within each country. Records have the benefit of having been checked and standardised for quality, format and location information. Global climate dataset providers, however, do not always have access to all data within specific countries, and coverage of Guyana in the global datasets is poor and for neighbouring countries is adequate but not substantial.

Despite lack of adequate coverage, the available records do provide an overview of the climate in the region. Global datasets of observations are also used as the basis for driving and testing General Circulation Models (GCMs). They therefore give an indication of the quality, quantity and spatial distribution of the forcing data used within the models and provide a reference of the potential performance of the GCMs for the region.

Climate data originating from neighbouring countries provide otherwise unavailable data and are useful in establishing climate trends and zones across the Guyanan border and regionally.

1.1.3.2 Licensing issues

Several data providers exist, all with different licensing restrictions. Data is usually free for academic use but is not allowed to be distributed further without prior consent from the provider or without separate application by the interested party. Future research strategies therefore need to take licensing issues into account.

1.2 Observed Climate Data for Guyana

Please refer to Table 1 for acronym descriptions, dataset numbers and further information.

1.2.1 All sources of data

11. HydroMet
12. GuySuCo
13. Dadanawa Ranch, South Rupununi and others
14. Various Publications

1.2.2 Description of data

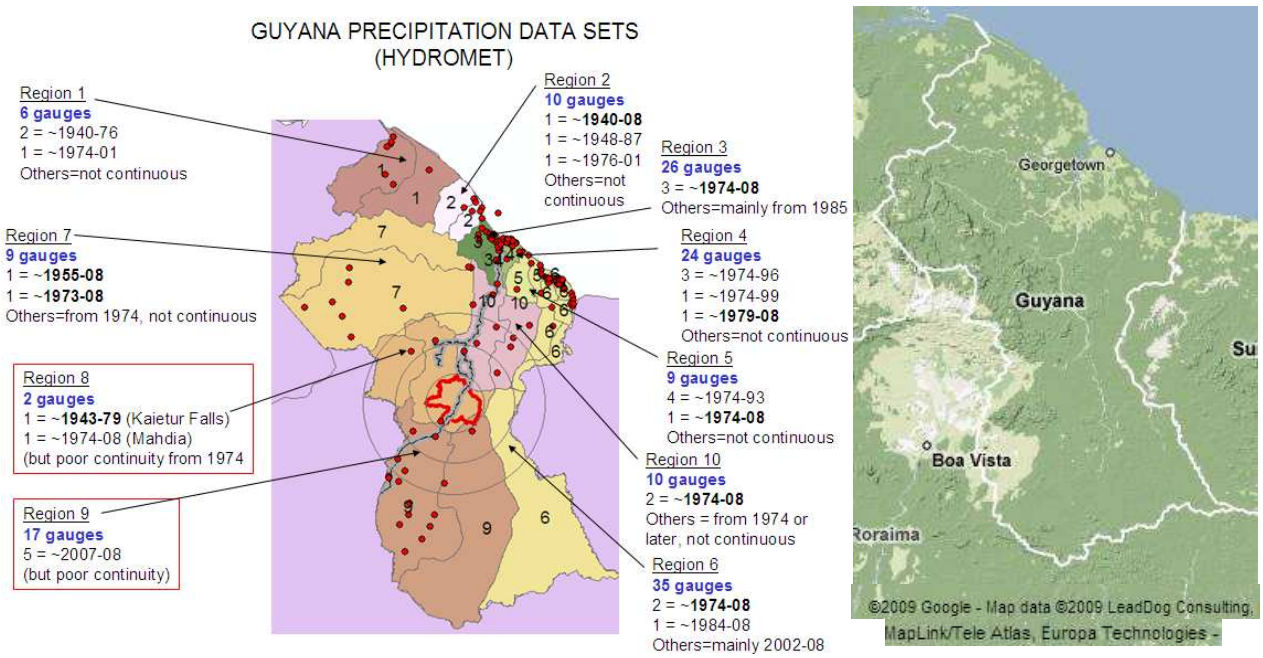


Figure 8 – Summary of data and location of precipitation stations in Guyana by region, and map showing topography. Circles show 50 and 100 km distance from the Iwokrama rainforest preserve. [Data supplied by HydroMet, map from Google Maps]

11. HydroMet

- HydroMet (Department of Agriculture, Guyana) is the main source of climate data for Guyana. It was created in 1965. It has the responsibility to monitor, collect, process and archive data and information on weather, climate, hydrology and oceanography. HydroMet receives data and information from a number of organisations (e.g. GuySuCo, who collect their own data) and depends on a network of volunteer gauge readers around the country. Potential data available include rainfall, temperature, stream flow, groundwater, evaporation, humidity, wind and sunshine [4] although not all data is available for all locations and for all years.
- HydroMet have been very helpful in providing the available digitised precipitation and climatological data. HydroMet data is available on application and is not intended for wider distribution.
- Daily rainfall data has been collated for 147 stations across Guyana for varying years (see Figure 8) and Appendix A4.
- Daily data for 5 weather stations (at Kaiteur Falls, Airport at Georgetown, New Amsterdam, Ebini and Lethem) consists of some or all of:
  - maximum and minimum temperature
  - rainfall

- mean relative humidity
- pan evaporation
- days with thunder
- grass or soil temperature
- sunshine hours
- wind speed

- Three of the five weather stations have automatic recording gauges and are located at Kaiteur Falls, Airport at Georgetown, New Amsterdam. Measurements are sent automatically to HydroMet using a 2.4 GHz transmitter radio. The Kaiteur Falls station sends data via New York, USA, by satellite.
- Actual digitised data available from HydroMet include:
  - Georgetown Promenade Gardens (1975-2001)
  - Georgetown Botanical Gardens (1892 – 2008)
- Most other digital data records begin in the 1970s. Five stations (two in region 1, two in region 2 and one in region 8) are relatively continuous from the early-late 1940s to the late 1970s (see Appendix A4).
- In 1970 there was an excellent network of approximately 35 operational recording rain gauges in Guyana, but several recording stations were closed in later years due to out-migration of skilled personnel and high maintenance costs, particularly in remote places. From the 1980s, data for the whole country becomes significantly more discontinuous.
- HydroMet are installing a new Doppler Weather Radar Tower at Hyde Park, Timehri, although coverage will not stretch as far as Iwokrama.
- Organisations within Guyana regularly submit data to HydroMet. As a member of CARICOM, HydroMet additionally submits meteorological data to the Caribbean Meteorological Institute (CMI) in Barbados. This ensures that the data is archived and backed-up regularly.

12. Data collated from GuySuCo:
    - Prior to 1965 when HydroMet was established, individual companies such as the sugar and bauxite industries (particularly Bookers, the sugar conglomerate and DEMBRA, the bauxite giant) and the Civil Aviation Department did their own monitoring of weather and water resources [4]. Since 1974 GuySuCo have been regularly submitting data to HydroMet consequently, data listed prior to 1974 below is not available directly from HydroMet. GuySuCo have been very helpful in providing data. As normal, data is not intended for wider distribution without prior consent.
    - GuySuCo have recorded rainfall data continuously from 1956 but mainly for the sugar plantations along the coastal regions. Continuous monthly data is available for the following coastal sugar plantations:
      - Skeldon 1956-1997
      - Albion 1956-1997
      - Rosehall **1907-1998**
      - Blairmont 1956-1997
      - Enmore 1956-1997
      - LBI 1956-1997
      - Diamond **1887-1930**
      - Wales 1956-1997
      - Uitvlugt 1956-2004
    - GuySuCo have just acquired 2 new automatic weather stations. These are of the Integrated Sensor Suite Vantage Pro2 Weather Station type from Davies in the USA. Tipping bucket rain gauges have a 0.2 mm bucket size.

13. Dadanawa Ranch, South Rupununi and others
    - Some data is available directly from the rainfall collecting sites, for example Dadanawa Ranch has provided monthly rainfall records for 1984-2009.

14. Various Publications
    - HydroMet has several useful publications such as the Annual Climatological Data Summary 1972-4 (a15 to a17, Table 4) and Maps of rainfall regions of Guyana, pan evaporation and sunshine (a1 to a3, Table 4)
    - The Gazetteer, a publication listing all coordinates of villages, is also known to exist but has not yet been located.

1.2.3 Issues

1.2.3.1 Spatial coverage

Station Density: HydroMet deal with a network of 147 current and/or historical rainfall gauges across Guyana plus 5 weather stations (Figure 8). The distribution of the existing rainfall stations is uneven however, mainly due to uneven population distribution and inaccessibility issues, especially in the interior of the country. There are several gauges in the coastal plain, where 90% of the population live [11] but there are large gaps in the spatial coverage in especially in the interior (region 8 and 9, and the southern part of region 6).

The World Meteorological Organisation (WMO) recommends that countries have at least a minimum hydrological/climatological network consisting of the minimum number of monitoring stations necessary to initiate planning for the economic development of water resources [10]. The density of stations for a minimum network depends on the type of climatic zone, areal and seasonal variation in rainfall and population density. The WMO have defined six types of physiographic regions and made recommendations for the minimum network density for non-recording gauges (i.e. standard gauges used for daily measurement), recording gauges (such as tipping-bucket rain gauges) and evaporation stations (or weather stations which measure precipitation, temperature, evaporation, relative humidity wind and sunshine hours) in each area (see Table 5 and Table 6). These should ideally be adjusted to reflect the actual socio-economic and physio-climatic conditions of the country [10].

Table 5 - WMO recommended Precipitation station density.

	Minimum densities per station (area in km2 per station)	
Physiographic Unit	Non-recording	Recording
|Coastal	900	9000
Mountainous	250	2500
Interior plains	575	5750
Hilly/undulating	575	5750
Small islands	25	250
Urban areas		10-20
Polar/arid	10 000	100 000

Table 6 – WMO recommended evaporation station density.

Physiographic Unit	Minimum densities per station (area in km2 per station)
|Coastal	50 000
Mountainous	50 000
Interior plains	50 000
Hilly/undulating	50 000
Small islands	50 000

Urban areas	50 000
Polar/arid	100 000

WMO recommends that precipitation stations be as uniformly distributed as is consistent with practical needs for data and the location of volunteer observers. In mountainous regions, attention should be given to vertical zonality. Stations should consist of standard gauges (for daily measurements) and recorders (for intense, short-duration rainfall which provide information on intensity, distribution and duration of precipitation, for example tipping bucket rain gauges). Priority should be given to urban areas where extensive drainage systems are likely to be constructed, river basins in which major river control systems are anticipated or in operation, large areas inadequately covered by the existing network and special research projects [10].

Guyana is approximately 211 996 km^2 in size. The coastal area (here counted as regions 1, 2, 3, 4, 5 and coastal areas of region 6) is approximately 37 444 km^2 and the interior or hilly/undulating area (i.e. the rest of the country) is approximately 174 551 km^2. Each non-recording rainfall gauge services an area of approximately 350 km^2 on the coast (so the density of the network is therefore well within WMO guidelines of 900 km^2 per gauge). Each non-recording gauge services an area of 4363 km^2 in the interior however (so the density of the network is well below WMO guidelines of 575 per gauge for interior plains or hilly/undulating areas). If considered by region alone, only regions 2, 3, 4 and 5 are have an adequate coverage of non-recording stations. Additionally, there is an inadequate coverage of recording rainfall stations (located with the five weather stations) as the minimum density for recording rain gauges at the coast is 9000 km^2 and 5750 km^2 for interior plains or hilly/undulating areas.

For weather stations, a minimum density of 50 000 km^2 is recommended for each coastal station or station in the interior plains or hilly/undulating areas. There are two automatic weather stations on the coast so evaporation stations are adequately represented whilst the one in the interior does not provide sufficient coverage.

One key outcome and recommendation of this survey is the urgent demand to bring the climatological network in Guyana up to minimum WMO recommendations. Several new rain gauges and weather stations need to be installed, particularly in the interior, and these should at least be a combination of standard and recording gauges.

1.2.3.2 Temporal coverage

1) Temporal Resolution: Rain gauges are usually of the standard type and require manual daily or monthly measurements. Very few gauges record measurements at the sub-daily level. Out of HydroMet's five existing weather stations, only three are automatic. GuySuCo, who maintain their own records, have also newly acquired two more weather stations in sugar plantations along the coast.

It is particularly important to have fine resolution measurements of rainfall and other variables across Guyana to assess and measure intense, short-duration rainfall which can provide information on the intensity, distribution and duration of precipitation. This type of data is particularly useful for assessing and quantifying extreme events. The data collated from HydroMet include only 5, 10, 15 and 30 minute precipitation and temperature maxima, and only for Georgetown since 1972. It is not currently known if HydroMet store finer resolution data for the other two weather stations.

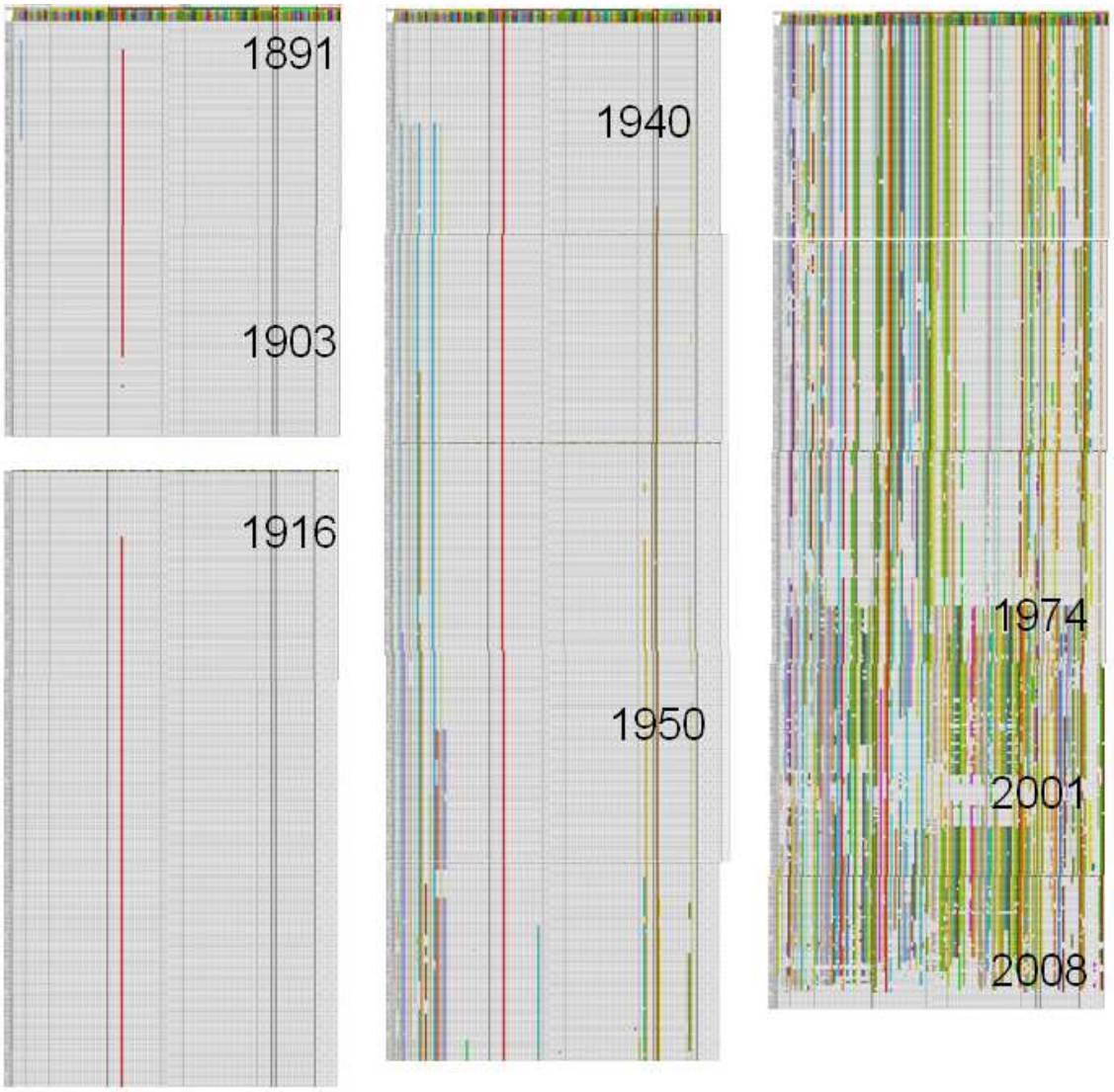


Figure 9 – Diagram showing overview of Appendix A4 - data continuity by month for HydroMet rainfall stations in different regions. A month is only listed if it is listed in HydroMet's database.

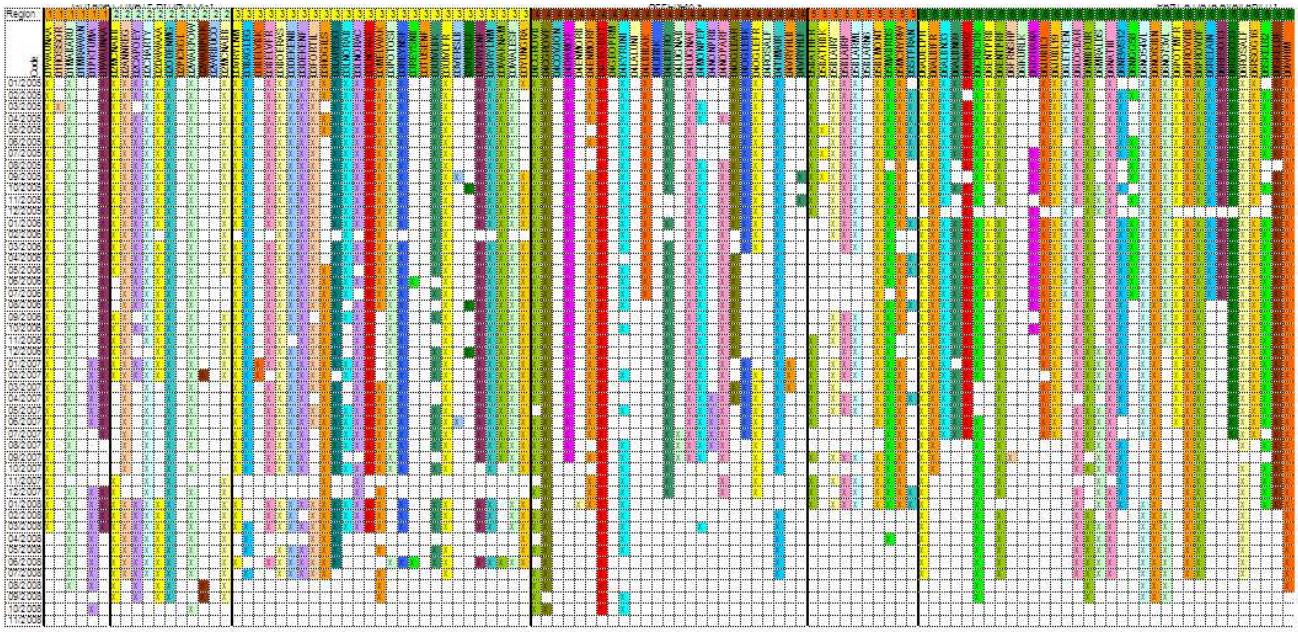


Figure 10 - Diagram showing data continuity by month for HydroMet rainfall stations in regions 1 to 6 for Jan 2005 to Oct 2008 (close up of Figure 9, see Appendix A4). A month is only listed if it is listed in HydroMet's database.

Table 7 – List of Station ID codes (with region number) and geographical coordinates in decimal degrees for daily precipitation stations in Guyana (from HydroMet). Also shown are the number of monthly records (aggregated from daily records) available at each location.

Station ID	LAT	LONG	Number of monthly records
01HOSSOR	8.17	-59.80	119
01MABARU	8.20	-59.78	576
01MRAWAN	8.27	-59.75	624
01PKTUMA	7.73	-59.87	454
01WAUNAA	8.13	-59.85	304
02ANNREG	7.25	-58.47	684
02CAPOEY	7.20	-58.48	129
02CHARTY	7.38	-58.58	705
02DAWAAA	7.20	-58.60	92
02MCNABB	7.33	-58.55	510
02ODENMG	7.10	-58.47	782
02PICKGL	7.25	-58.72	460
02WAKPOW	7.58	-59.75	220
02WARPOK	7.80	-59.23	192
02WRBUCO	7.18	-58.23	30
03BAGLEG	6.90	-58.40	774
03BELVBK	6.72	-58.22	405
03BELVFR	6.72	-58.20	270
03BOERAS	6.82	-58.35	744
03DEKENB	6.83	-58.32	512
03DEKENF	6.87	-58.33	498
03FORTIL	6.78	-58.50	137
03HOGILS	6.87	-58.52	139
03LARESO	6.72	-58.23	118
03LNORAB	6.78	-58.28	388
03LNORAC	6.78	-58.28	128
03LNORAF	6.87	-58.28	395
03MELWAK	6.95	-58.47	51
03POTOSI	6.67	-58.20	104
03REYNSF	6.63	-58.20	79
03REYSNB	6.63	-58.22	287
03TUSENF	6.88	-58.35	315
03UIVLBK	6.80	-58.32	400
03UIVLFR	6.87	-58.30	160
03VERSLB	6.78	-58.23	13
03VERSLF	6.78	-58.18	57
03VRYLNF	6.68	-58.20	130
03VRYLNM	6.68	-58.22	124
03WAKNAM	6.95	-58.47	141
03WALESF	6.70	-58.20	357
03YUNGRA	6.68	-58.23	103
04BLNDEB	6.23	-57.42	
04CGROVB	6.62	-57.88	307
04CGROVF	6.62	-57.92	400
04COVJON	6.75	-57.97	159
04DIAMOF	6.72	-58.18	116
04ENMORB	6.70	-58.02	230
04ENMORF	6.73	-57.98	376
04GEOBOT	6.80	-58.13	1250
04GEOPRM	6.82	-58.15	256
04KYRUNI	6.15	-58.23	376
04LALUNI	6.52	-58.10	219
04LBIBAK	6.75	-58.08	274
04LBIBK			171
04LBIFRO	6.80	-58.05	350
04LUGNAB	6.72	-58.05	46
04LUGNAF	6.80	-58.03	101
04MONPEP	6.78	-58.05	298
04NONPRB	6.70	-58.02	39
04NOPARF	6.77	-58.02	281
04OGLEAR	6.80	-58.10	34
04OGLEBK	6.75	-58.10	256
04OGLEFR	6.80	-58.10	362
04ROSALF			3
04TIMAIR	6.50	-58.25	472
04VRYHLB	6.75	-58.10	275
04VRYHLF	6.80	-58.08	269
05BATHBK	6.32	-57.62	267
05BATHFR	6.35	-57.60	358
05BLAIR7	6.27	-57.58	366
05BLAIRP			115
05BLARML	6.30	-57.60	119
05BLARN6			144
05BLMONT	6.25	-57.53	391
05MABRDS	6.45	-57.75	308
05MCHYRW	6.57	-57.78	352
05ONVFIC	6.42	-57.62	
05STFRAN	6.08	-57.95	24
06ADELPH	6.22	-57.47	126
06ALBIFR	6.25	-57.37	382
06ALBN33	6.23	-57.38	118
06ALBN69	6.20	-57.38	113
06ANKE82	6.15	-57.37	117
06CRBCRK	5.83	-57.15	352
06ENTPRB	6.20	-57.40	110
06ENTPRF	6.20	-57.45	113
06FRNSHP	5.82	-57.45	39
06IKURLK	5.55	-57.43	6
06JOHANA	6.07	-57.27	102
06JUBIL3	6.22	-57.38	116
06JUBL19	6.22	-57.30	105
06LESBEH	6.13	-57.30	
06LETKEN	6.20	-57.30	135
06LOCBAR	6.22	-57.48	124
06MIBKUR	6.10	-57.28	149
06MRALDS	6.02	-57.60	319
06NATIII	6.23	-57.52	376
06NEWS12	5.90	-57.17	102

Station ID	LAT	LONG	Number of monthly records
06NIGG58	6.20	-57.38	112
06NO54VL	6.02	-57.17	384
06NO63BN	5.97	-57.15	154
06NO73VL	5.92	-57.13	399
06POTMFR	6.23	-57.35	120
06PROVDB	6.17	-57.50	123
06PROVDF	6.22	-57.52	125
06RELAIN	6.25	-57.45	122
06RESO13	6.18	-57.35	116
06RESO33	6.15	-57.35	119
06ROSALF	6.23	-57.48	328
06RSOG16	6.22	-57.33	119
06SKEL82	5.87	-57.18	94
06SKELDF	5.87	-57.13	373
06WHIM	6.22	-57.30	139
07APAKWA	6.37	-60.38	398
07BARDEM	6.38	-58.62	245
07JAWLLA	5.68	-60.48	366
07KAMRNG	5.88	-60.62	539
07KURPNG	6.17	-60.38	11
07MAZPRS	6.40	-58.65	284
07PARIMA	5.80	-61.02	
07PIPLIP	5.38	-60.35	111
07TIBOKU	5.80	-59.60	
08KAIETF	5.17	-59.48	173
08MAHDIA	5.33	-59.13	469
09ACHWIB	2.28	-59.57	80
09ANNAII	3.95	-59.13	77
09APTERI	4.03	-58.60	85
09ASHTON	2.47	-59.32	394
09AWRANU	2.65	-59.20	61
09DADANA	2.82	-59.52	330
09KARSAB	4.02	-59.45	344
09KUMUUU	3.27	-59.00	70
09LETHEM	3.37	-59.80	270
09MOCOMO	3.30	-59.65	112
09PARSHA	3.45	-59.57	107
09PIRARA	3.62	-59.67	76
09SANCRK	2.98	-59.50	53
09SAWRAU	2.67	-59.63	195
09SHEAAA	2.82	-59.13	285
09STIGNA	3.35	-59.80	265
09SURAMA	4.17	-59.05	221
10AROIMA	5.37	-58.00	66
10EBINII	5.55	-57.77	343
10GREATF	5.30	-58.53	349
10ITABRU	4.87	-58.23	156
10ITUNII	5.53	-58.25	
10KWKWNI	5.25	-58.05	3
10MABHIL	5.18	-58.72	5
10MCKNZE	6.00	-58.30	308
10PLTILS	5.85	-58.58	108
10WISMAR	6.00	-58.30	130

2) Continuity of Data: HydroMet rain gauges are typically manual devices operated and maintained partially by a network of volunteers. Due to insufficient resources however, it is sometimes difficult for HydroMet to regularly collect data from remote sites. Where data has not been collected for several years, volunteers begin to lack interest in data collection which ultimately results in loss of record continuity (see Figure 9 and Figure 10). Reliance on human data collection also means that when an individual is unavailable and no replacement is available, then the data is not recorded. Gaps in the records are particularly noticeable around Christmas and other holiday periods for example.

It is known from old paper reports [3] that records prior to 1970 are usually of better continuity than the more recent ones which have significant discontinuities especially from the 1980s to the present day. However it is mainly records dating from 1974 that have been digitised and are available electronically. Some older records have also been digitised but of these longer-term rainfall records, none are fully continuous.

It is particularly important to have continuous records in order to be able to quantify the annual rainfall and evapotranspiration budgets; to compare rainfall properties such as amount and intensity, at one location with another; and to establish temporal and spatial trends. The WMO stresses that if only a minimum hydrological network is in place, due to the broad dependence on the stations in the basic network, it is important that records from all of the stations be continuous and of high quality [10].

The instalment of new automatic rain and weather gauges would reduce reliance on human data collection and would be less labour intensive, thereby ensuring adequate continuity of records. Automatic data-loggers would also be able to record continuous climate measurements.

Equipment to be installed under the new Iwokrama climate and hydrology monitoring program will address the urgent need to increase the temporal and spatial coverage. However, provisions need to be made for its long-term upkeep. WMO recommends that stations in the basic network should be operated for at least 10 years, to obtain satisfactory information on mean value of observed parameters and on their temporal variations [10].

1.2.3.3 Paper records

HydroMet have an archive which contains several older, and in most cases, hand-written records which require digitising. These paper records may be lost (by decay, fire or human error, as has happened previously) if not committed to digital form in the near future.

Reference [3] which lists data available up to 1970, suggests that the following data might be available in paper format [NOTE that this data has not yet been digitised or located and is therefore not currently available]:

- Monthly measurements for 1843-1857, daily measurements for 1846-1856 for Georgetown Observatory (now known as Republic Square, the open area south of the Promenade Gardens). These are the oldest known records.
- Monthly records from 1857 for Mon Repos
- Monthly records from 1865 for Albion
- Unbroken daily records from 1886 to 1970 for Farm Front
- Unbroken daily records from 1900 to 1970 for Blairmont Front
- Monthly records from 1880 for Georgetown Botanic Gardens
- Daily records from 1916 for Georgetown Botanic Gardens (the earliest available records from recording rainfall gauges started here in 1956).

As the above list of potentially available data shows, it is of great urgency that old paper records be digitised as soon as possible.

Long-term records are of obvious benefit in establishing long-term climatic trends, however HydroMet do not currently have the staff resources to digitise all of these records at present but this is clearly a priority.

1.2.3.4 Instrumentation

The HydroMet network consists mainly of non-recording standard rain gauges of the 'Snowdon' type with a 5 inch diameter rim [5] (similar to the type shown in Figure 16) and automatic recording rainfall gauges located with the weather stations.

Recording rainfall gauges do not require data to be digitised, whilst non recording standard gauges require manual measurement and record-keeping. Manual measurements are usually recorded in booklets of the type shown in Figure 11. Once HydroMet receive the booklets, they have to manually digitise the records.

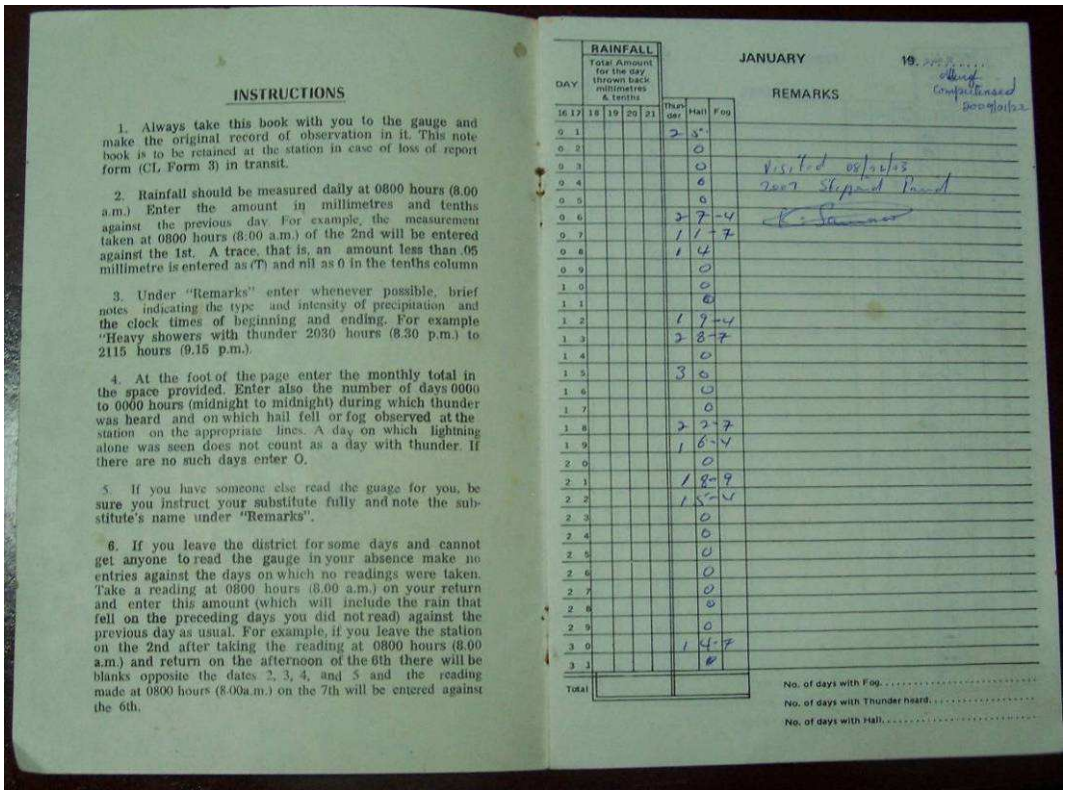


Figure 11 – Example of booklet for manually recording daily rainfall amounts.

HydroMet usually install rain gauges at 1 m above the ground surface following WMO international standards. These heights should be comparable to heights used in neighbouring countries if WMO standards are followed. On the other hand this may not be the case as WMO standards for rain gauge heights are usually 30 cm for areas with little chance of snow and where the surroundings are such that there is no risk of the ground being covered by puddles even in heavy rain [10]. Differences in instrumentation height need to be taken into account when comparing data across countries.

1.2.3.5 Data quality

There are some issues to consider with the quality of climate records. Firstly measurements may have been originally recorded wrongly (for example in the wrong units), either through human error, or through the use of incorrect or inaccurate measuring equipment, and secondly data may have been digitised from hand-written records incorrectly or in the wrong units. There is evidence of both forms

of errors. In particular, where different data sources are available for the same dataset, these can on occasion produce records which differ (see for example Figure 12).

(a) 09 Dadanawa (DAD)

	HM	DAD	HM	DAD	HM	DAD	HM	DAD	HM	DAD	HM	DAD	HM	DAD	HM	DAD	HM	DAD	HM	DAD	HM	DAD	HM	DAD
YEAR	J	J	F	F	M	M	A	A	M	M	J	J	J	J	A	A	S	S	O	O	N	N	D	D	TOTAL	TOTAL
84	M	16.1			0.0	1.6					335.4	309.0	333.0	338.9			104.1	85.5					21.8	8.6		
85			18.9	66.1					209.5	129.3	384.9	312.9	272.3	272.2	392.6	332.4	234.0	158.0								
86									233.6	212.3					18.5	185.5					25.0	23.3	88.0	8.8		
87	39.7	34.7	25.0	2.5	62.1	42.8	203.1	191.1	265.3	259.3			119.5	155.8							128.2	28.0	M	6.7		

(b) 04 Blairmont (GSC)

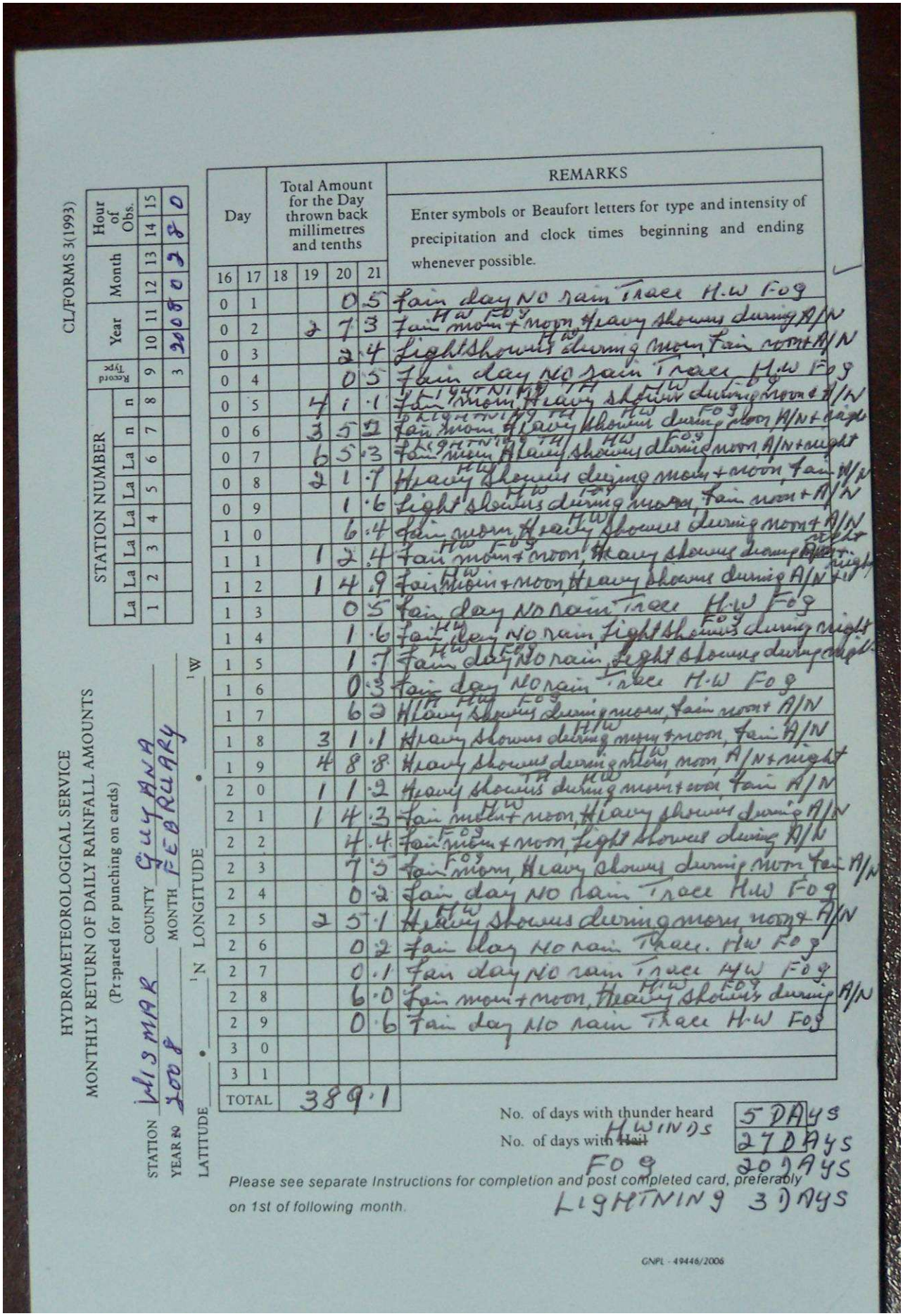
	GSC	HM	GSC	HM	GSC	HM	GSC	HM	GSC	HM	GSC	HM	GSC	HM	GSC	HM	GSC	HM	GSC	HM	GSC	HM	GSC	HM
YEAR	J	J	F	F	M	M	A	A	M	M	J	J	J	J	A	A	S	S	O	O	N	N	D	D
84	417	427	10	13	10	M	47	98	343	330	194	282	203	257	96	137			87	107	45	100		
85	31	47	11	15	95	145	29	59	104	157	242	269	189	283	146	236	62	100			157	144	144	168
86	30	51			11	22	12	23	164	234	406	369	324	380	120	128	18	51	68	101			162	229
87	53	68	10	16			255	315	236	275	322	266	171	215			49	56			39	28	27	35

Figure 12 – Comparison of monthly datasets from HydroMet (HM) with equivalent datasets from (a) Dadanawa Ranch (DAD) (region 9) and (b) GuySuCo (GSC) for Blairmont Estate (region 4). Green cells are where HM data are within 1 mm of DAD data (a) and within 5 mm of GSC data (b); M = Missing value.

Furthermore, rainfall gauge geographical locations, in the form of longitude and latitude, require quality controlling, as some are clearly incorrect (digitally plotting in the sea or wrong region, see for example Figure 8), and the height of the gauges above sea-level (the altitude) are also lacking, so no account can be taken of differences in the data due to the effects of elevation. HydroMet's database does not record the time of measurement, but records are ideally taken at 8 am local time.

1.2.3.6 HydroMet Capacity

HydroMet require trained professional staff to operate and maintain the network of rain gauges and weather stations and to digitise, manage, analyse and process the data produced. However they have both a shortage of staff resources and a shortage of qualified staff. Guyana as a whole has a lack of qualified meteorologists, climatologists and hydrologists as these courses are not offered at the University of Guyana or elsewhere in the country. There is, therefore, a demand for training and capacity building both in HydroMet and Guyana. This will be partly addressed by the establishment of the new Iwokrama hydrology and climate monitoring program however, longer-term provision for training and capacity building need to be considered.



CL/FORMS 3(1993)

HYDROMETEOROLOGICAL SERVICE

MONTHLY RETURN OF DAILY RAINFALL AMOUNTS

(Prepared for punching on cards)

STATION MAR COUNTY GUYANA

YEAR 2008 MONTH FEBRUARY

LATITUDE ____ ° ____ 'N LONGITUDE ____ ° ____ 'W

STATION NUMBER								Record Type	Year	Month	Hour of Obs.
La 1	La 2	La 3	La 4	La 5	La 6	n 7	n 8	9	10 11	12 13	14 15
								3	20 05	02	08 00

Day		Total Amount for the Day thrown back millimetres and tenths				REMARKS
						Enter symbols or Beaufort letters for type and intensity of precipitation and clock times beginning and ending whenever possible.
16	17	18	19	20	21	
0	1			0	5	Fair day NO rain Trace H.W F.O.G
0	2		2	7	3	Fair mom + noon, Heavy showers during A/N
0	3			2	4	Light showers during morn, Fair noon + A/N
0	4			0	5	Fair day NO rain Trace H.W F.O.G
0	5		4	1	1	Fair morn, Heavy showers during noon + A/N
0	6		3	5	2	Fair morn, Heavy showers during noon A/N + night
0	7		6	5	3	Fair morn, Heavy showers during noon A/N + night
0	8		2	1	7	Heavy showers during morn + noon, Fair A/N
0	9			1	6	Light showers during morn, Fair noon + A/N
1	0			6	4	Fair morn, Heavy showers during noon + A/N
1	1		1	2	4	Fair morn + noon, Heavy showers during A/N
1	2		1	4	9	Fair morn + noon, Heavy showers during A/N
1	3			0	5	Fair day NO rain Trace H.W F.O.G
1	4			1	6	Fair day NO rain, Light showers during night
1	5			1	7	Fair day NO rain, Light showers during night
1	6			0	3	Fair day NO rain Trace H.W F.O.G
1	7			6	2	Heavy showers during morn, Fair noon + A/N
1	8		3	1	1	Heavy showers during morn + noon, Fair A/N
1	9		4	8	8	Heavy showers during morn, noon A/N + night
2	0		1	1	2	Heavy showers during morn + noon, Fair A/N
2	1		1	4	3	Fair morn + noon, Heavy showers during A/N
2	2			4	4	Fair morn + noon, Light showers during A/N
2	3			7	5	Fair morn, Heavy showers during morn Fair A/N
2	4			0	2	Fair day NO rain Trace H.W F.O.G
2	5		2	5	1	Heavy showers during morn, noon + A/N
2	6			0	2	Fair day NO rain Trace. H.W F.O.G
2	7			0	1	Fair day NO rain Trace H.W F.O.G
2	8			6	0	Fair morn + noon, Heavy showers during A/N
2	9			0	6	Fair day NO rain Trace H.W F.O.G
3	0					
3	1					
TOTAL			389	1		

No. of days with thunder heard 5 DAYS

No. of days with ~~Hail~~ H WINDS 27 DAYS

F O G 20 DAYS

LIGHTNING 3 DAYS

Please see separate Instructions for completion and post completed card, preferably on 1st of following month.

GNPL - 49446/2006

Figure 13 – Example of high quality manual daily rainfall record sheet.

1.3 Observed Climate Data for Iwokrama

Refer to Table 1 for acronym descriptions, dataset numbers and further information.

1.3.1 All sources of data

11. HydroMet
15. Iwokrama field station
16. Local Amerindian community village school wildlife clubs

1.3.2 Description of data

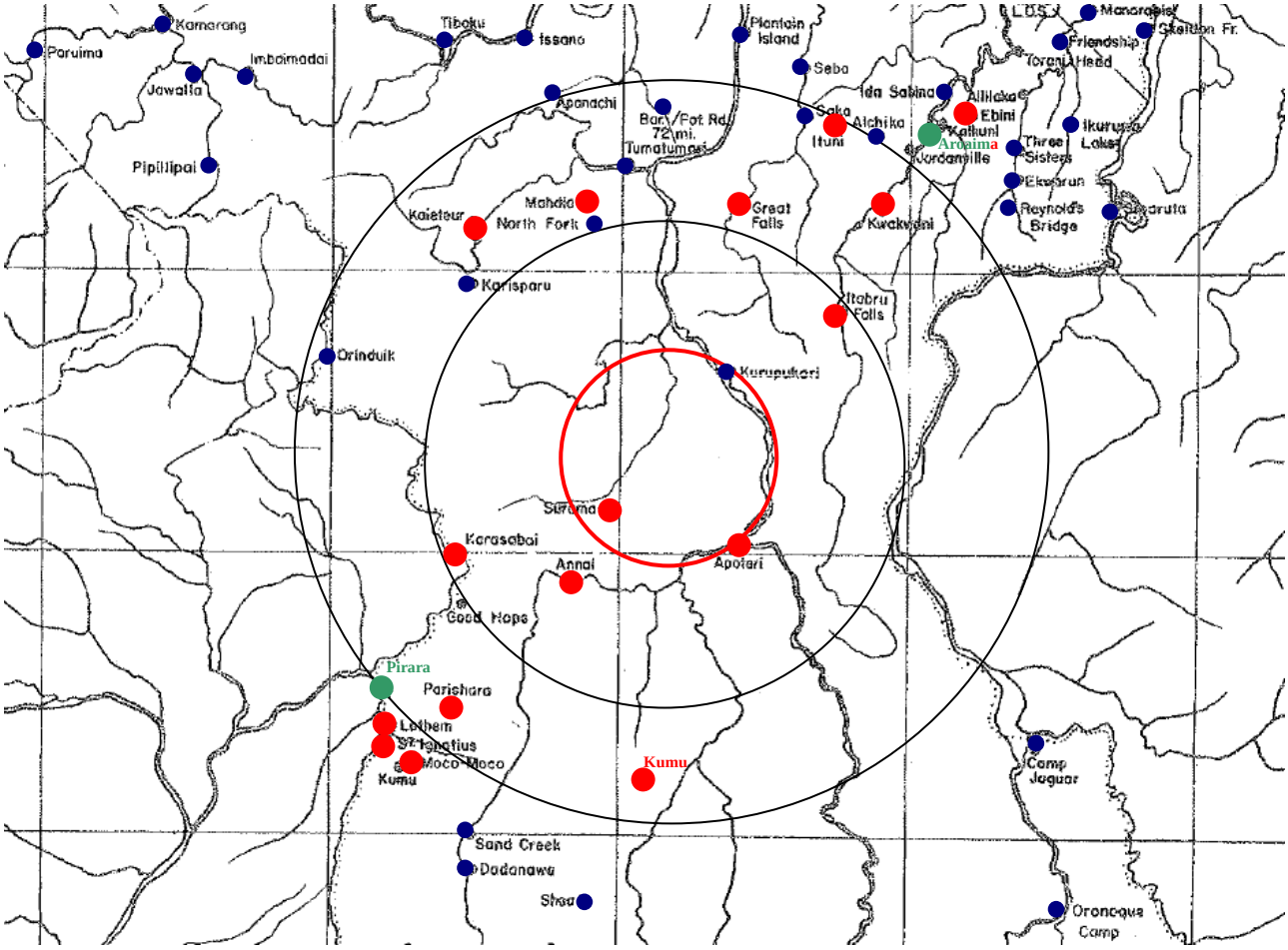


Figure 14 - Map of main rivers and weather/rainfall stations operational through or for part of 1973 (blue dots) and currently digitally available (red dots) at which precipitation, or precipitation and other elements were observed (from [5] and HydroMet). Green dots indicate stations installed since 1973 for which digital records are available. Inner circle denotes approximate location of Iwokrama; outer circles denote an area approximately 50 and 100 km around Iwokrama.

11. HydroMet

- Figure 14 shows the location of historical and existing weather and rainfall stations located approximately within 100 km distance of Iwokrama [5]. The figure shows that six rainfall stations (Kurupukari, Surama, Apoteri, Annai, and Karasabai) were/are approximately within 50 km of Iwokrama. However, of the four weather stations in existence in the area in 1973 (see Table 8), Itabru Falls is the only one located within 50 km of Iwokrama. It should be noted that although the existence of historical data has been noted in old documents, most of the data prior to 1973 has not been entered into HydroMet's database (see Table 8). It may be,

therefore, that the data exists in paper archives and requires digitising, or has been lost. Current datasets are significantly fewer, start predominantly in 1974 and non-continuous and on occasion doubtful in quality. Mahdia and Lethem$_2$ have longer datasets.

- It was acknowledged in the Iwokrama site survey report in 1993 [2] that climate data for Iwokrama was lacking and recommendations were made for rapid commencement of a climate monitoring program:
  "Existing climate data for the Reserve are almost non-existent. Even for the surrounding areas, the records are widely scattered and inadequate to build up a satisfactory picture of the climatic pattern… Many components of the research programme […] will depend on reliable and well-founded climatic descriptions of the Reserve. Instrumentation to achieve this should be commenced as soon as is practical."
  A weather station (for manually recording daily maximum and minimum temperature) and a manual rain gauge were therefore established at the Iwokrama Field Station in approximately May 2005 (see Figure 15 and Figure 16). A rain gauge was also established around this time at the Corkwood Ranger Station (southern entrance to Iwokrama), the Canopy Walkway and Surama Amerindian village. The Surama rain gauge fell into disrepair relatively quickly however, and was not repaired, whilst most of the other rain gauges were only in operation for a short time-frame.
- Daily precipitation data at the Iwokrama field station was collected from 03/05/02 and continued (with some intermittency) until 24/07/05 whilst maximum and minimum temperature was recorded from 01/06/03 to 22/08/03. Brief records also exist at the Canopy Walkway and Corkwood for 2004. After this time, data collection was suspended, until recent activities emphasised the importance of climate data collection, and climate monitoring was therefore incorporated into Iwokrama's overall monitoring strategy. Daily weather data (precipitation, max/min temperature and relative humidity) are now collected at least once a day at 08:00 following international world-meteorological organisation (WMO) standards and a record has built up (with intermittencies) since January 2009.
- Amerindian community school wildlife clubs have been collecting rainfall data from their various villages in and around Iwokrama. These records appear to be of reasonable quality however records are not maintained during school holidays. Data are available for a few communities, particularly Aranaputa from 2004-2005. These records will be available digitally in due course.

1.3.3 Issues

- Although several precipitation / weather stations exist within 100 km of Iwokrama, data has not yet been digitised within HydroMet and may have been lost. Currently available digitised data is mainly from 1974 for fewer stations.
- Manual data collection relies on human input, and there are consequently several gaps in recorded time series.
- Although climate data for Iwokrama has been collected sporadically, the establishment of new weather/rain gauges for Iwokrama as part of the new monitoring program will help the situation considerably.

Table 8 – Rainfall and weather stations in the vicinity of Iwokrama

	Daily data known to be available prior to and including 1970 from [3[1]]	Currently digitised daily data available from HydroMet
Rainfall stations (within 100 km of Iwokrama)		
Annai	1940-1970 (discontinuous)	1996-2003 (discontinuous)
Apanachi	1986-1970 (discontinuous)	no data
Apoteri	1926-1970 (discontinuous)	1974-1988 (discontinuous)
Good Hope	1965-1970 (discontinuous)	no data
Ituni	1948-1970 (discontinuous)	no data
Karasabai	1964-1970	1974-2008 (discontinuous)
Karisparu	1969-1970 (discontinuous)	no data
Kurupukari	1928-1970 (discontinuous)	no data
Kwakwani	1950-1970 (discontinuous)	2004 (discontinuous)
Mahdia	1943-1970 (discontinuous)	1943-1992 (discontinuous)
Pariahara	1967-1970 (discontinuous)	1995-2008 (discontinuous)
Saka	1960-1970	no data
Surama	no data	1974-2004 (discontinuous)
Tumatumari	1926-1970 (discontinuous)	no data
Weather stations		
Great Falls	1922-1970 (discontinuous)	1974-2008 (discontinuous, rainfall only)
Itabru Falls	1965-1970	1974-1989 (discontinuous, rainfall only)
Kaieteur Falls	1953-1964, 1965-1970	1974-2008 (discontinuous)
Lethem $_{\text{dataset1}}$	1953-1965 (discontinuous)	1974-2008 (discontinuous)
Lethem $_{\text{dataset2}}$		1939-2008

Note [2] reports that records were collected at Annai for 1922-35, 1938-42 and 1947-77; Apoteri for 1929-33 and 1954-73; and for Kurupukari 1930-53 and 1970-74 (source unknown).

[1] Reference [3] shows months for which complete daily data are available up to 1970. This publication is linked with publication HyM-No-TP.5 "Reference index of rainfall stations for which data are available, and years in which data are available, to 1979", issued by HydroMet in September 1972, but this publication has not been found.

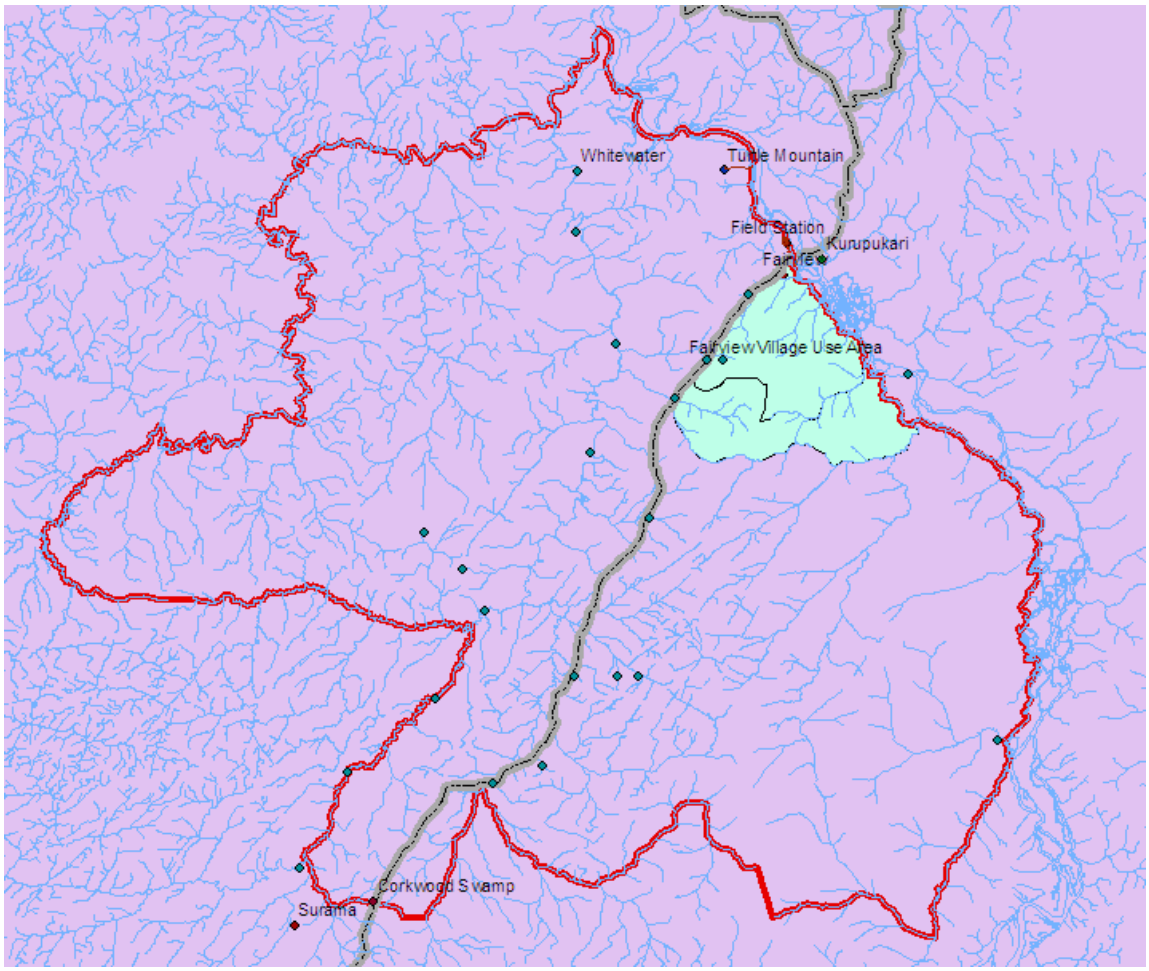


Figure 15 – Map of Iwokrama showing extent (red), river network (blue) and road (green). Also shown are the Iwokrama Field Station, the Kurupukari river crossing, Turtle Mountain, Fairview village, Corkwood Ranger Station and Surama Amerindian village. Other points highlight sites of camps. Of particular note is White-water camp which will be a new climate monitoring site under the new Iwokrama climate and hydrology monitoring program.

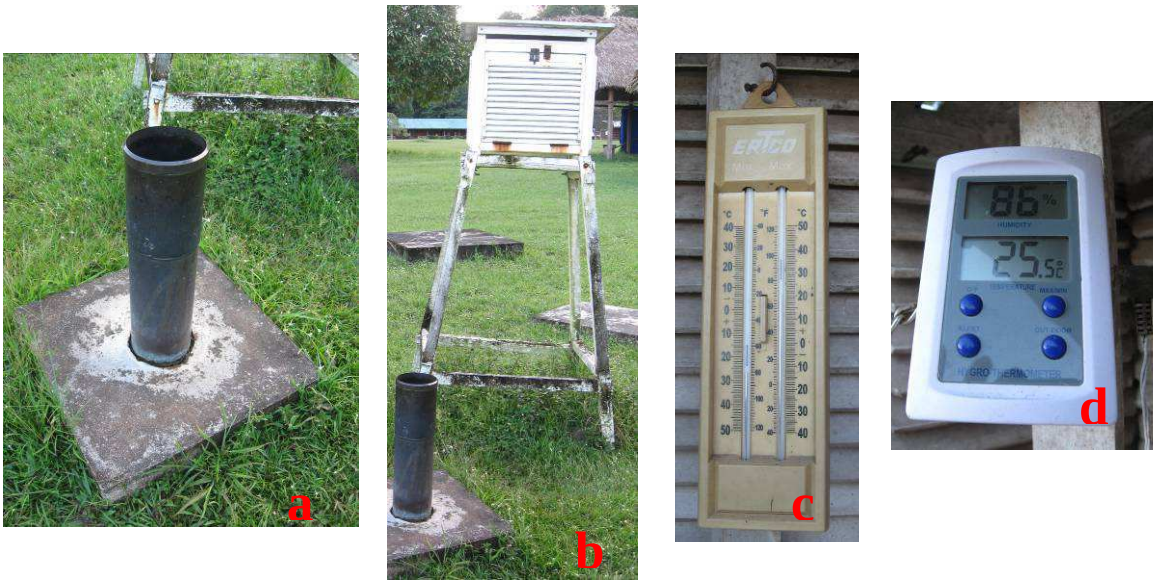


Figure 16 – (a) Weather station at Iwokrama, (b) rain gauge (has since been raised so that the opening is 1m above the ground in line with international WMO standards (as advised by HydroMet)), (c) maximum/minimum thermometer and (d) temperature / relative humidity recorder.

1.4 Modelled Future Climate Scenario Data

Please refer to Table 1 for acronym descriptions, dataset numbers and further information.

1.4.1 All sources of data

17. IPCC data distribution centre (22 GCMs)
18. UNDP Climate change country profiles (15 GCMs subset of IPCC models)
19. INSMET-UWI-CCCCC Regional Climate Model PRECIS data
20. GuySuCo data from DSSAT model
21. Various reports and journal articles

1.4.2 Description of data

17. IPCC models

- The Data Distribution Centre (DDC) of the Intergovernmental Panel on Climate Change (IPCC) distributes a number of datasets, derived from various climate modelling experiments using General Circulation Models (GCM), that are commonly used in the construction and application of climate change scenarios for climate change impacts assessments. 22 GCMs are used by the IPCC for the 4th Assessment Report. 30 year climatologies can be downloaded from http://www.ipcc-data.org/ddc_climscen.html.

18. UNDP Climate change country profiles

- The UNDP climate change country profiles were funded jointly by the UNDP National Communications Support Program (NCSP) and the UK Department for International Development (DfID) and are a sub-set of 15 of the IPCC GCMs with global data fields, re-gridded to a common 2.5 by 2.5 degree grid (Figure 17). They were assembled to address the climate change information gap in many developing countries by making use of existing climate data to generate country-level data plots from the most-up-to-date climate observations, and provide model-simulated current and future climate under three emissions scenarios. UNDP climate data exist for Guyana, Suriname and some Caribbean islands (but not French Guiana). Data and reports have been downloaded from http://country-profiles.geog.ox.ac.uk/.

19. INSMET-UWI-CCCCC Regional Climate Model PRECIS data

- The PRECIS Caribbean project focuses on how climate change could affect the countries within the Caribbean region. The freely available Hadley Centre Regional Climate Model (RCM) is called Providing REgional Climates for Impacts Studies (PRECIS) and is designed to run on a Linux based PC. Depending on the computer speed, simulations take about 3-6 months to run a 30 year simulation. PRECIS has been run at several institutions for various areas at resolutions of both 25 and 50 km. Institutions involved are the Instituto de Meteorologia de la Republica de Cuba (INSEMT), the University of the West Indies (UWI) and the Caribbean Community Climate Change centre (CCCCC). Specifically, the following simulations have been run:
  - INSEMET Cuba has run a 50 km domain for the A2, B2, baseline (1960-1990) and reanalysis cases
  - UWI Jamaica has run a 50 km domain for the A2, B2 and baseline cases
  - UWI Barbados has run a 25 km domain for the A2, B2 and baseline cases (for Eastern Caribbean)
- The INSMET Cuba results are available at: http://precis.insmet.cu/eng/datos.html (Figure 18). Examples of outputs are given in Figure 19. Guyana is not included in the INSMET Cuba outputs. It is apparently included in the 25 km runs by UWI Barbados.

20. Climate model data generated by WeatherMan component of Decision Support System for Agrotechnology Transfer (DSSAT) model (from GuySuCo)

- DSSAT is a software package integrating the effects of soil, crop phenotype, weather and management options that allow the user to ask 'what if' questions. It combines crop, soil and weather data bases into standard formats for access by crop models and application programs. The user can then simulate multi-year outcomes of crop management strategies for different crops at any world wide location. Daily simulated current and A2 and future scenarios for 2071-2100 and B2 for 2011-2100 has been provided by GuySuCo based on observed climate statistics (dataset 12).

21. Various reports, journal articles etc.

- The Finnish Environment Institute published, 'Future climate in world regions: an intercomparison of model-based projections for the new IPCC emissions scenarios' in 2003. Mean seasonal temperature and precipitation changes between 1961-1990 and three time periods in the future centred on the 2020s, 2050s and 2080s for several GCMs simulations for the IPCC emissions scenarios for the 32 world regions including the Caribbean are presented. http://ipcc-data.org/sres/scatter_plots/scatter_plot_report.pdf

1.4.3 Issues

- Several General Circulation Model (GCM) data sets exist (22 are used by the IPCC for the 4th Assessment Report) but there are few Regional Climate Model (RCM) data sets for the Caribbean area in general.
- Generally GCMs are not able to model precipitation in equatorial regions well, although simulations of temperature are generally better. (Note that RCMs take their boundary conditions from GCMs).
- Results available on the web indicate that RCM simulations undertaken by INSMET using PRECIS only cover the Caribbean and exclude Guyana. Simulations of climate change over Guyana should be available however through UWI Barbados.
- Further studies are needed to work out how good GCM and RCMs are in simulating the current climate for Guyana. Further studies are also required to work how climate change will affect Guyana and the region and the potential impacts.

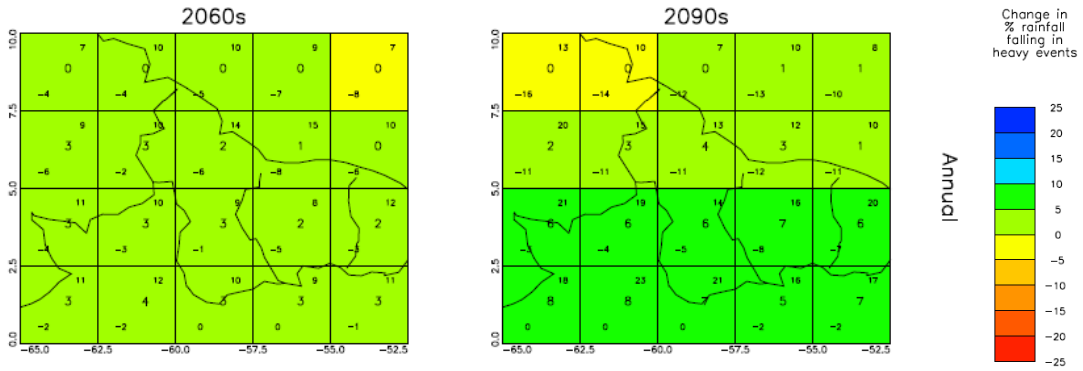


Figure 17 – UNPD Climate change country profiles. Spatial patterns of projected change in proportion of precipitation falling in 'heavy' events for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999.

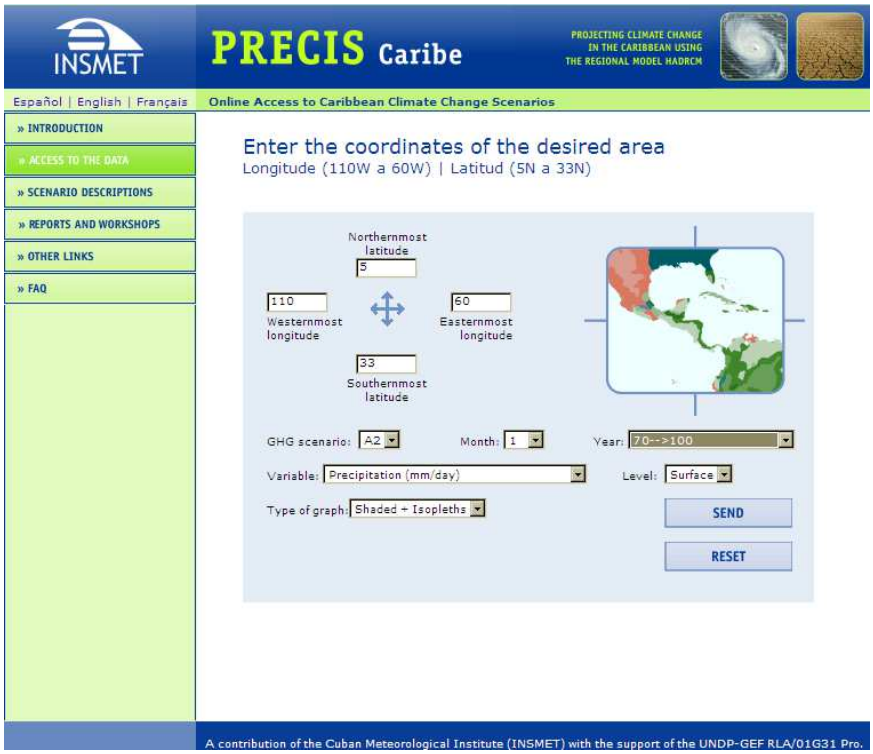


Figure 18 –PRECIS model simulations for the Caribbean as run by INSMET, Cuba, are available through a web-interface (http://precis.insmet.cu/eng/datos.html).

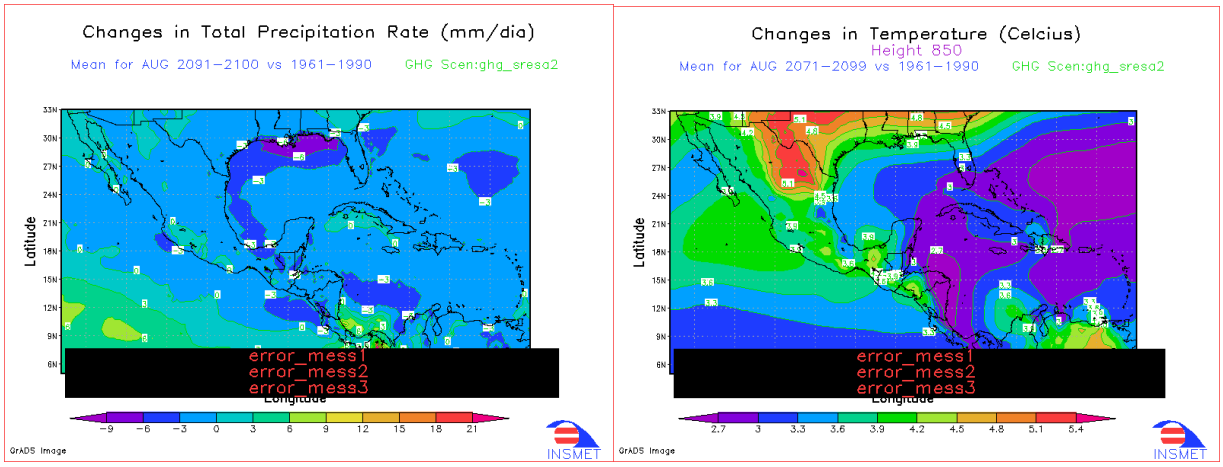


Figure 19 – PRECIS results showing changes in Total Precipitation (left) and Temperature (right) for August in the 2091-2100 and 2071-2099 respectively (A2 scenario) compared to 1961-1990 (control period).

2 Hydrology Data

Please refer to Table 2 for acronym descriptions, dataset numbers and further information.

2.1.1 All sources of data

11. HydroMet
15. Iwokrama
22. South Florida University
30. Iwokrama Site Survey Report

2.1.2 Description of data

11. HydroMet
    - In Guyana, HydroMet has the general responsibility for the inventory and evaluation of quantity and physical and chemical quality of the country's water resources. Hydrology data for Guyana's major rivers exist in the form of discharge data (for tidal and non-tidal sites) and gauge heights at gauging stations and miscellaneous sites (see Figure 20, Figure 21 and Figure 22), however very few other data exist for water quality or sediment discharge [12]. Furthermore, no small rivers or tributaries are currently monitored.
    - HydroMet have not identified and released data for in and around Iwokrama yet, although they are in the process of looking for this data in their database. This data is therefore currently unavailable. As Figure 20, Figure 21 and Figure 22 indicate, data may exist in and around Iwokrama, and also for the Siparuni and 'River Gauge' on the Essequibo, but it is uncertain at present whether this data is available electronically.

15. Iwokrama
    - Staff at the Iwokrama field station have recorded the water level height at the Essequibo river between April – August 2003, however records after this time are negligible.

22. South Florida University
    - Research students from South Florida University, USA have undertaken water quality field work in Iwokrama and the results of the study should be available soon.

30. Iwokrama Site Survey Report
    - The Iwokrama site survey report in 1993 stated the following [2]: "Whereas basic morphological characteristics of the river basin in the Reserve can be derived from map analysis, the automatic river-level recordings from the late 1960s-mid 1970s are insufficient to provide reliable seasonal flow characteristics. There are few water quality or sediment records. (…) The major rivers are not monitored." However, some basic hydrological information is given in [2], particularly for the Essequibo River, Siparuni and Burro Burro rivers.

2.1.3 Issues

- The WMO recommend a basic density of monitoring stations for hydrometric stations (stream flow, river stages, lake and reservoir stages, sediment discharge and sedimentation, water quality stations, water temperature) and groundwater observations however the density of the network for Guyana has not yet been established in this study due to the lack of data.
- HydroMet, in association with the WWF, will be installing two new hydrological gauges at Iwokrama (on the Burro-burro and Essequibo rivers) and one in the Conservation International (CI) concession. Additionally, new river monitoring instrumentation will be installed at various Iwokrama sites in September 2009 as part of a new hydrology and climate monitoring program.

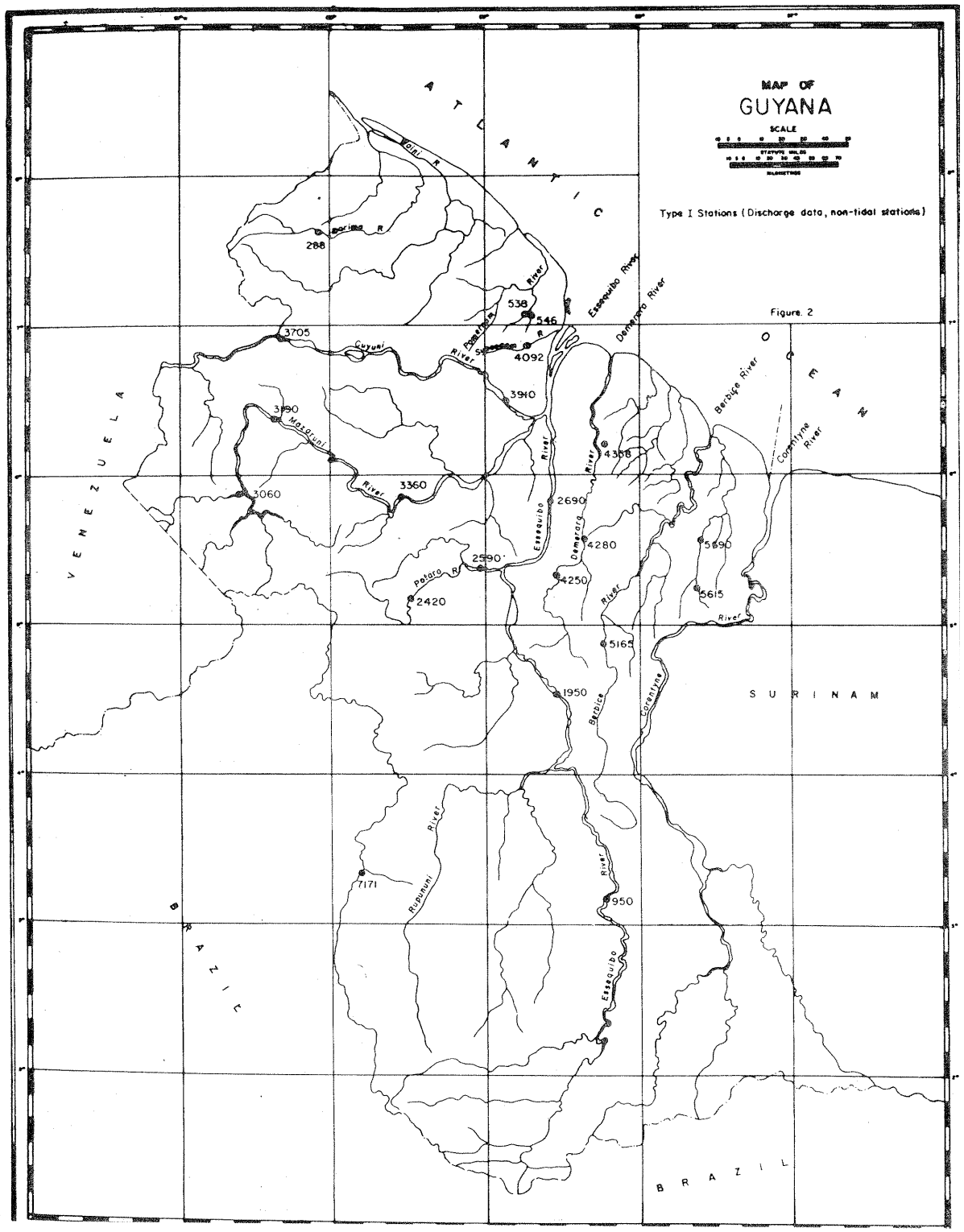


Figure 20 – Station locations for gauges recording discharge data for non-tidal stations in 1971.

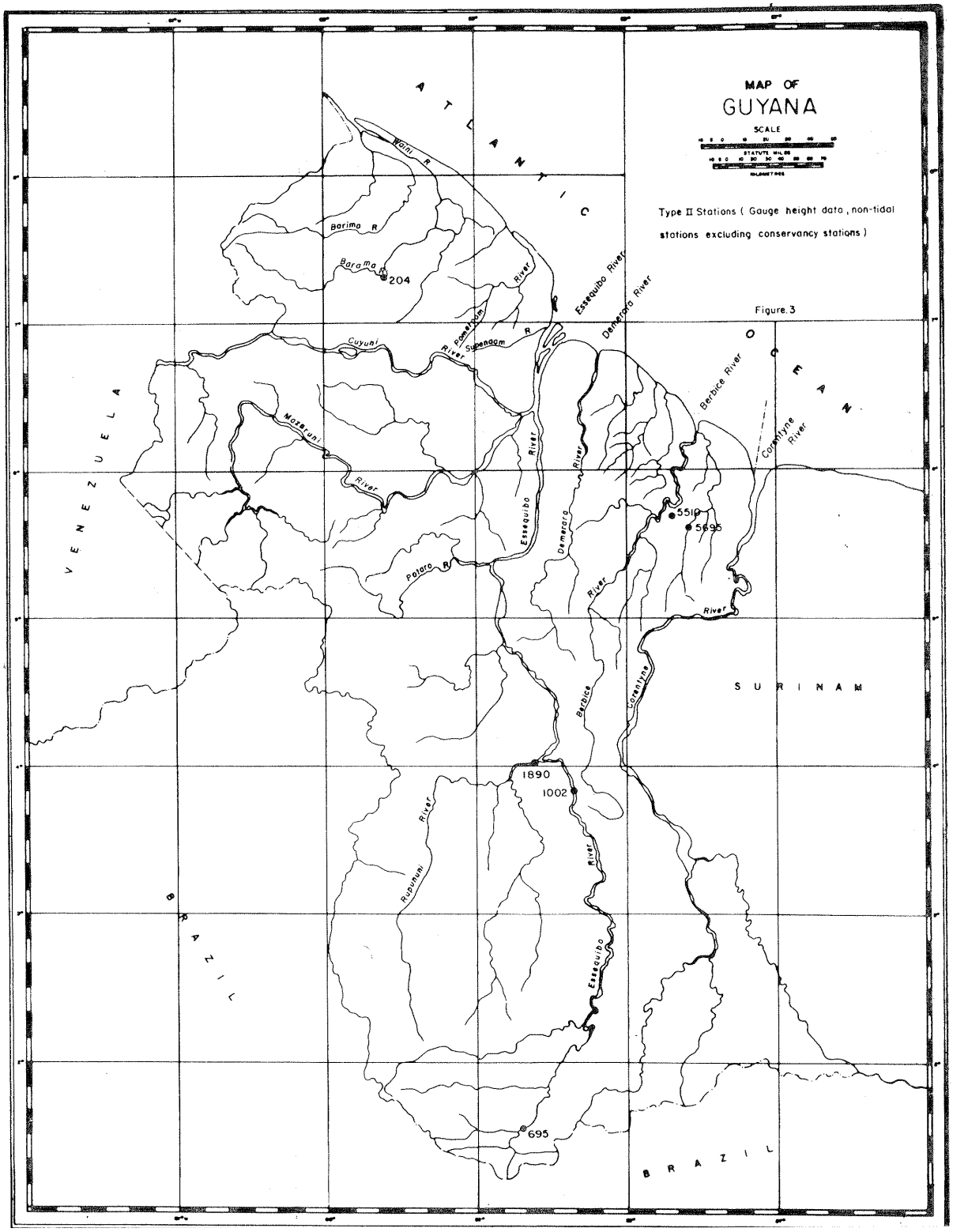


Figure 21 – Station locations for stations recording gauge heights for non-tidal stations (excluding conservancy stations) in 1971

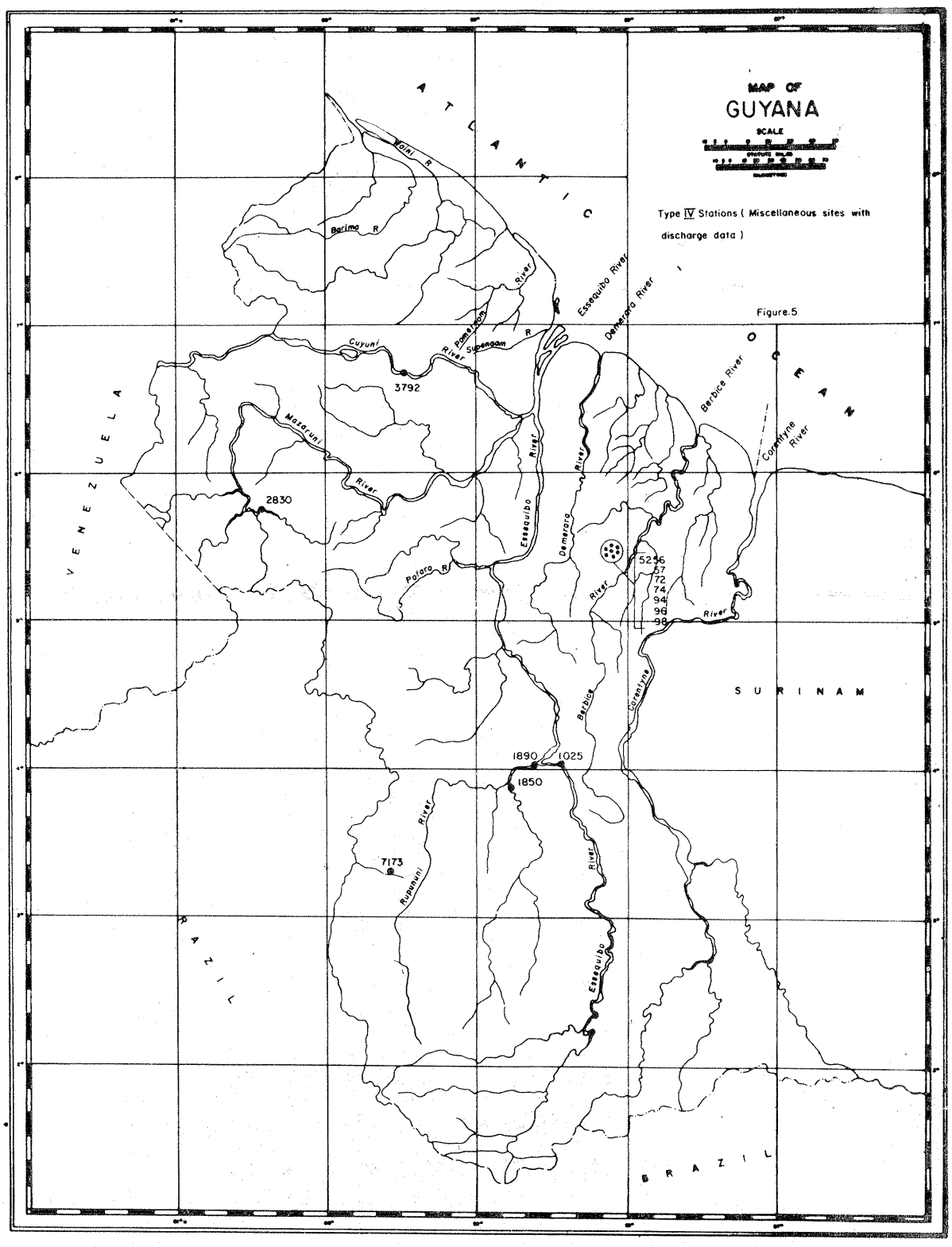


Figure 22 – Station location for gauges in miscellaneous sites with discharge data in 1971

3 Physical Environment Data

Please refer to Table 3 for acronym descriptions, dataset numbers and further information.

3.1 DEM

3.1.1 All sources of data

23. Spot heights for the Guianas and surrounding regions
24. SAREX-92 DEM data from GSI project
25. Shuttle Radar Topography Mission (SRTM) Elevation Raster dataset
26. Global Land Survey (GLS) 2005 images and DEM
27. JERS-1 data from GSI project

3.1.2 Description of data

23. Spot heights for Guianas and surrounding regions
    - Spot heights (possibly in feet and of unknown source) across the Guianas and surrounding areas are available from the Guiana Shield Initiative project. Two spot heights are available for the Iwokrama reserve area.

24. SAREX-92 DEM data from GSI project
    - Original Digital Elevation Model (DEM) data was obtained in April 1992 using Synthetic Aperture Radar (SAR) equipment developed by the Berch Group of Canada for the South American Radar Experiment program (SAREX-92), funded by the European Space Agency [1]. Resolution of the data is about 100 x 100 m. SAR imagery is of particular relevance in humid tropical areas as it able to penetrate cloud cover (see Figure 23) [2]. SarVision is still currently involved in the Guyana Shield Initiative project to process new ALOS PALSAR I-band radar data and this new data (mapping elevation, rivers, roads, canopy cover, natural features etc) should be available in September 2009. A new forest type classification based on the new data is also being developed.

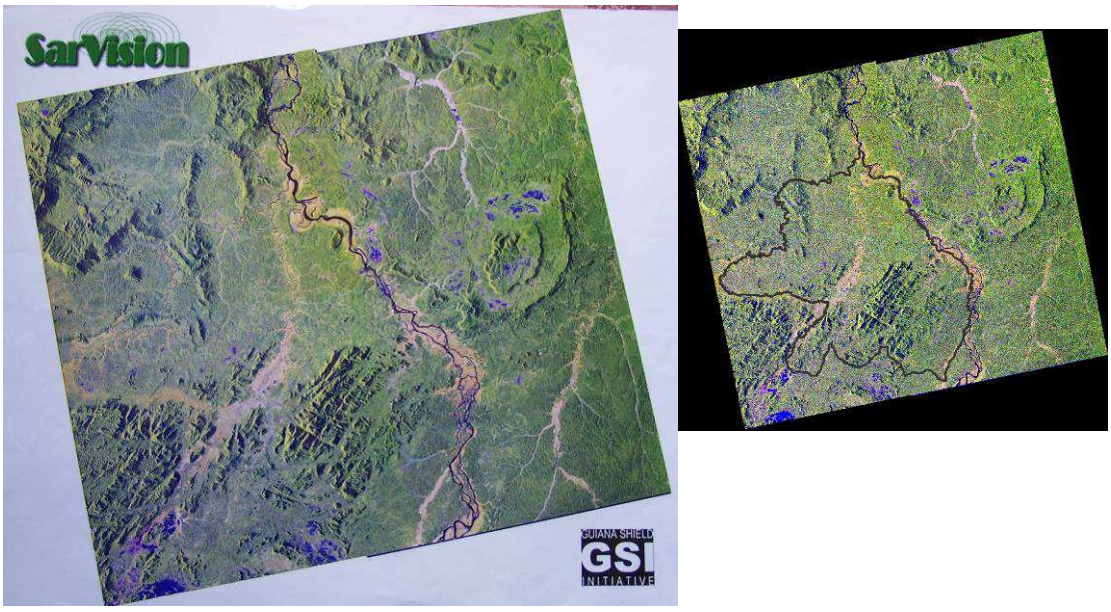


Figure 23 – SAREX-92 data processed by SarVision for the Guiana Shield Initiative project and used to derive DEM data at 100x100 m resolution. The right-hand diagram shows the Iwokrama outline.

25. Shuttle Radar Topography Mission (SRTM) Elevation Raster dataset
    - The Shuttle Radar Topography Mission (SRTM) Elevation dataset derives from the National Aeronautics and Space Administration (NASA), the National Geospatial-Intelligence Agency (NGA), the German Aerospace Centre (DLR) and the Italian Space Agency (ASI). It was collected in 2002, has a global coverage of 3 Arc Seconds (about 90 m) resolution and can be downloaded free of charge from http://seamless.usgs.gov/. The 'finished' version (version 2) of the data has been downloaded for the Iwokrama area in SDE raster digital format. SRTM uses Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR)

26. Global Land Survey (GLS) 2005 images and DEM
    - Global Land Survey (GLS) 2005 data has been downloaded for Iwokrama. These datasets were created using both Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) imagery in 2005. They have been corrected with SRTM data. This gives DEM with a resolution of 30 m. Data is also available for 2000 and can be downloaded from http://edcsns17.cr.usgs.gov/EarthExplorer/ (see Figure 24 and Figure 25). Various other Landsat Images are available from the same source.

Figure 24 – Data square available for Iwokrama site from GLS-2005 images.

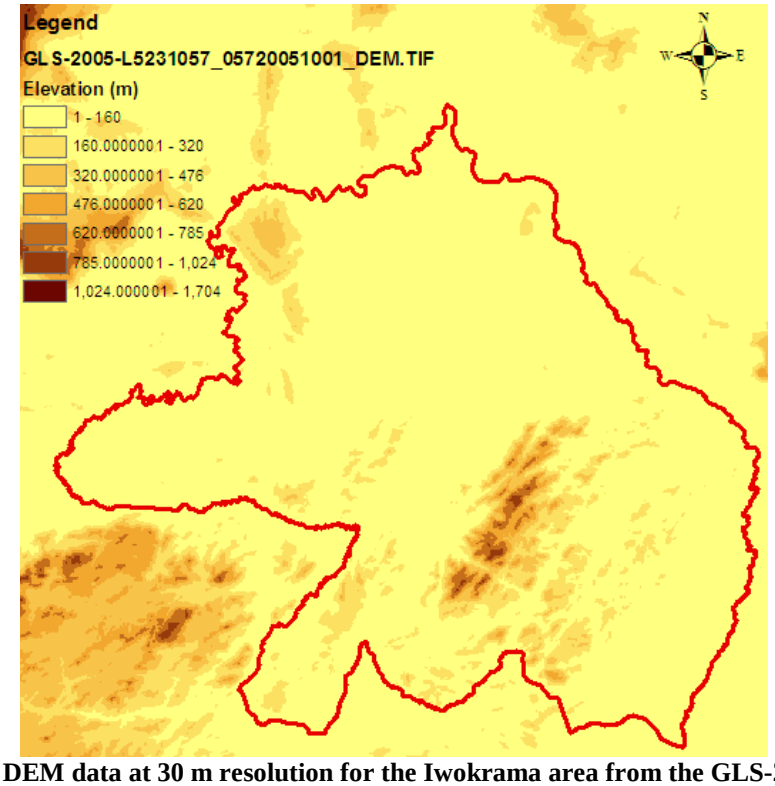


Figure 25 – DEM data at 30 m resolution for the Iwokrama area from the GLS-2005 dataset.

27. JERS-1 data from GSI project
    - The Japanese Earth Resources Satellite 1 (JERS-1) mission started in Feb 1992 and ended in 1998. The satellite observed the Earth's surface using optical sensors and a Synthetic Aperture Radar (SAR) sensor and was launched into a solar-synchronous sub-recurrent orbit with an altitude of 568 km and recurrent period of 44 days. Good quality JERS-1 data at 14 m resolution, which mapped water levels below the canopy, is available which mapped a particular seasonal inundation event in the Iwokrama forest (see Figure 26).

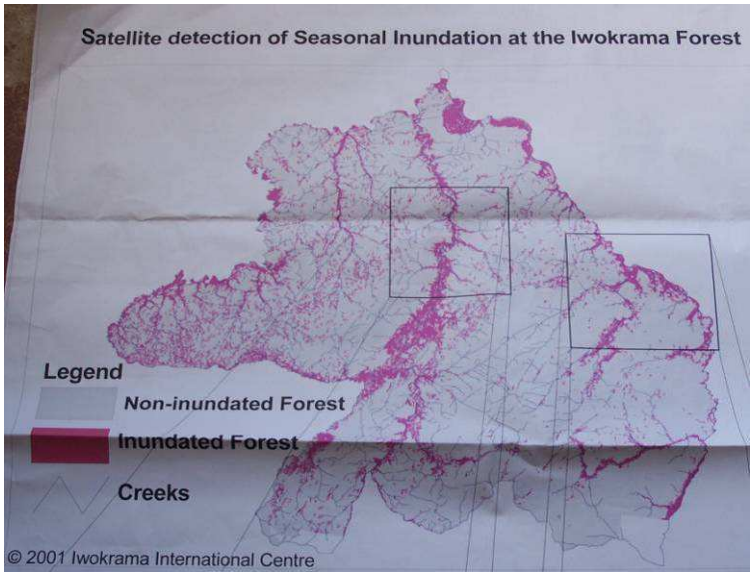


Figure 26 – Flooding detected below the forest canopy using 14 m resolution JERS-1 satellite radar imagery. Datadin, Chapman (NASA/JPL) and Helmer (USDA FS IITF). (Photograph of a Map available at Iwokrama.)

3.1.3 Issues

- Compared with JERS-1 data, TerraSar-X is a short wavelength radar (SAR-X-band is only 3.1 cm compared to 23.5 cm for JERS-1) so the radar is not able to penetrate totally through the forest canopy. Any DEM generated from it will, therefore, be mostly upper to mid canopy heights. This dataset is consequently very useful for tracking deforestation, but not suitable for applications such as hydrological modelling requiring ground surface elevations
- Relative heights in each DEM dataset should be relatively accurate, however actual elevation values require calibration with various known spot heights in Guyana and this has not yet been carried out. Each dataset therefore has a different elevation at a particular point (see Table 9)

	Site 1	Site 2
Spot height (23)	835	365
TerraSar-X (24)	692	116
STRM (25)	670	134
GLS (26)	651	115

Table 9 – Comparison of elevation (m) for two sites within Iwokrama given by four different datasets (listed with their dataset number). Note that spot-height values given here have been converted to meters assuming original dataset was in feet.

3.2 River network

3.2.1 All sources of data

28. Various sources
29. SRTM Water Body Data

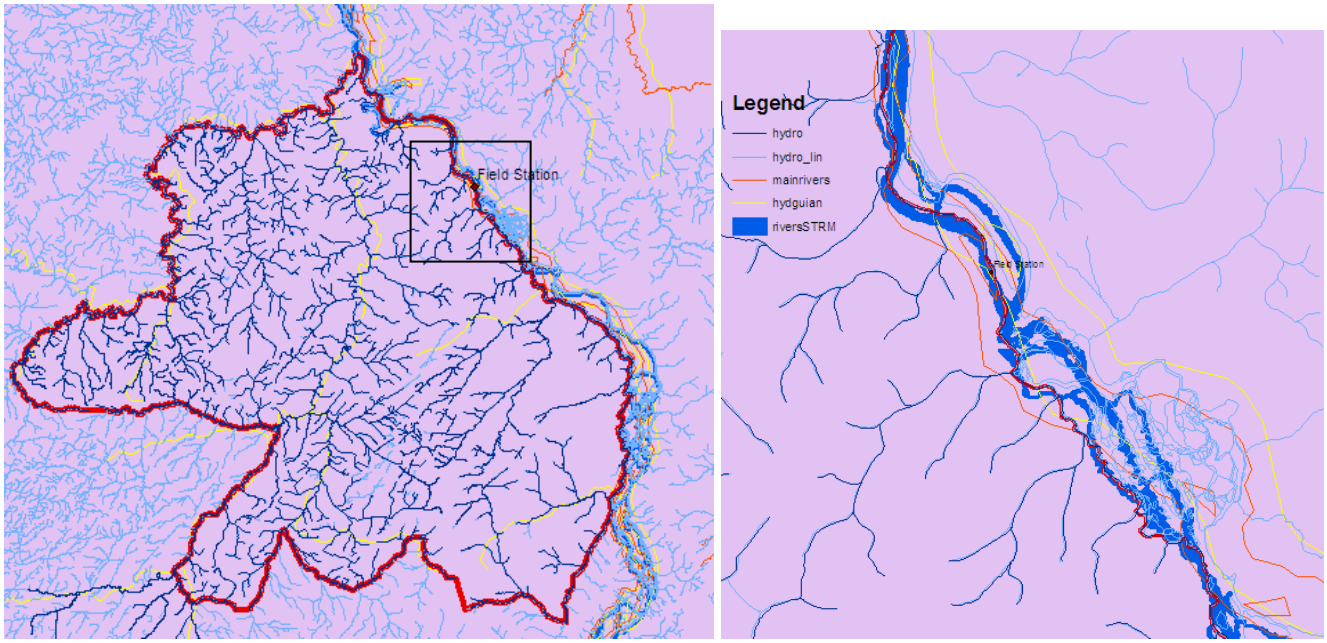


Figure 27 – Hydrological network in Iwokrama (left) as shown using various datasets. Boxed detail is shown on the right.

3.2.2 Description of data

28. Various sources
    - Various digital river network files are available at Iwokrama. Sources have not been identified, but obviously differ (see Figure 27).

29. SRTM Water Body Data
    - The Shuttle Radar Topography Mission Water Body Dataset (SRTM Water Body Data) was collected in Feb 2002 and is related to the finished SRTM Digital Terrain Data Level 2 (dataset 25). This data portrays water bodies that meet minimum capture criteria and as such, oceans, lakes and river shorelines were identified and delineated. Data has been downloaded from http://seamless.usgs.gov/ for Iwokrama in ESRI 3-D Shape file format and is labelled as 'Rivers-SRTM' in Figure 27.

3.2.3 Issues

- Datasets require validation.

3.3 Land Forms/Geology

3.3.1 All sources of data

30. Iwokrama Site Survey Report [2]

3.3.2 Description of data

30. Iwokrama Site Survey Report

- Data in the 1993 Iwokrama site survey report [2] is summarised below (see also Figure 28):
  "Landform maps based on aerial photograph interpretation provided the basis for identifying and mapping six major repeating landscape patterns (land systems) of the Reserve. They are in effect, ecosystems with distinctive combinations of physical conditions and dependent organisms.
  1. Kurupukari Sand Terraces (27% of reserve) – mixed forest
  2. Burro Burro Plains (31%) – mainly over granites, ill drained and swampy in places. Mixed alluvial land of the flood plains and clayey soils of hillocks have mixed forest with abundant timber species. Specialised woodland and palm marsh forest over poorly drained soils
  3. Moco Moco undulating plain (12%) – dolerite dykes capped with laterite. Rich mixed forest over red clay-rich soils and sandier soils.
  4. Iwokrama Mountains (8%) – granite massif, weakly developed soils. Mixed forest.
  5. Iwokrama Hills and Valleys (21%) – granitic hills separated by alluvium filled valleys. Poorly drained clayey soils dominant. Large trees, but open canopy, with palms dominating.
  6. Pakutau Hills (4%) – basic lavas capped with shallow soils. Mixed forest.
  Land systems were identified from air photography, field checked along selected cut lines and mapped in Phase 1 at 1:250 000 scale [2].

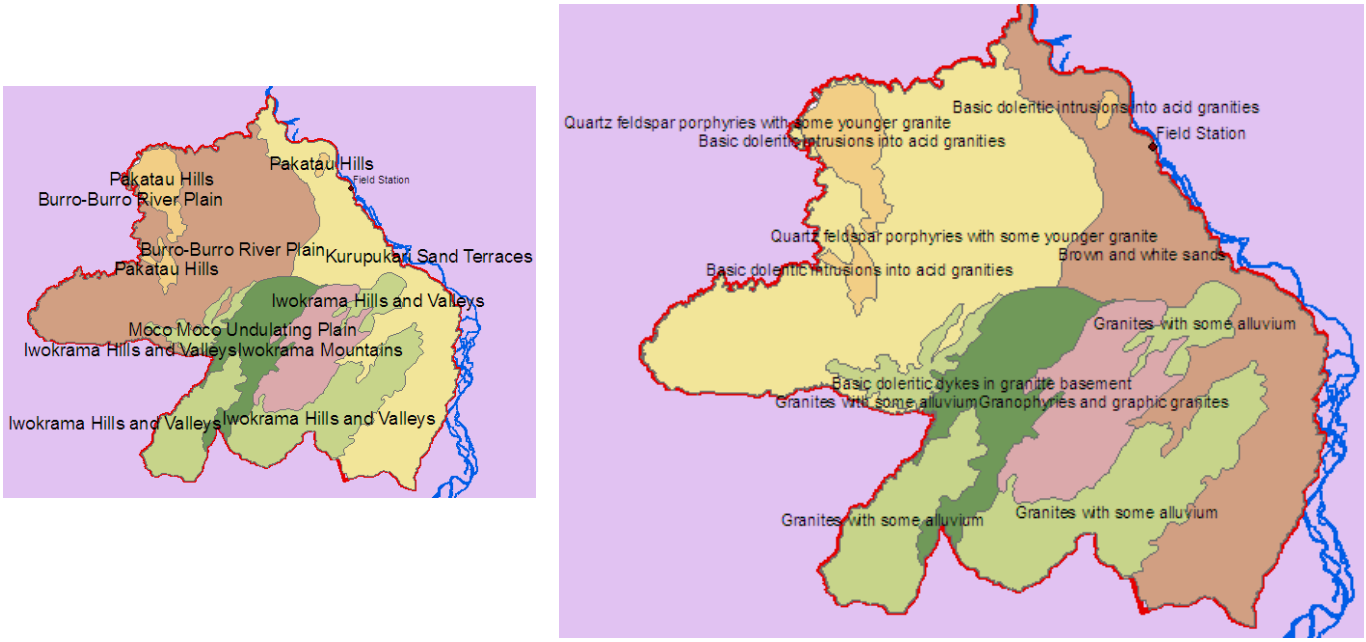


Figure 28 – Landforms (left) and geology (right) of Iwokrama

3.3.3 Issues

- Dataset require validation.

3.4 Vegetation

3.4.1 All sources of data

30. Iwokrama Site Survey Report [2]
31. Guyana Forestry Commission (GFC)

3.4.2 Description of data

30. Iwokrama Site Survey Report
    - Some data on vegetation distribution is given in [2].
31. Guyana Forestry Commission (GFC)
    - Vegetation maps are available on restricted use from the Forestry Commission. The Iwokrama centre have access to these, but their use in this project has been requested separately (by letter on 07/05/2000).

3.4.3 Issues

- Dataset require validation.

3.5 Soil

3.5.1 All sources of data

32. FAO Report on the soil survey project, British Guyana, 1966 (seven volumes)
33. N.A.R.I. Soil data CD

3.5.2 Description of data

30. FAO Report on the soil survey project, British Guyana, 1966 (seven volumes)
    - The 1993 Iwokrama site survey report [2] stated that the most comprehensive study on soils in Guyana was published by FAO in seven volumes in 1966 and was entitled Report on the soil survey project, British Guyana. Volumes III, parts 1 and 2 report the results of the reconnaissance survey, with maps at 1:500 000 scale. During the Iwokrama Phase I site survey, a senior soil scientist from N.A.R.I. (Prof. Nazeer Ahmad (Prof Emeritus Soil Scientist, UWI) was responsible for the collection of soil data.

31. N.A.R.I. Soil data CD
    - The National Agricultural Research Institute (NARI) in Guyana have produced a CD called 'Soil Resource Inventories of Guyana', 2003. The CD has a compilation of soil and land survey reports for Guyana. This has been purchased from N.A.R.I. The reports are mean to be a working supplement to the Soil and Land Capability map but the map has not been collated in this study.

3.5.3 Issues

- Limited soil analysis data is available in the original Iwokrama site survey reports [2].
- The CD of Guyanan soil properties from N.A.R.I. provides some basic soil properties information, however further detailed soil collection and analysis would need to be carried out for particular research projects for example involving hydrological modelling. For this purpose, full laboratory facilities are available both at GuySuCo and N.A.R.I. The University of Guyana also have limited equipment available.

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