WORLD CLIMATE PROGRAMME

RESEARCH

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WORLD METEOROLOGICAL ORGANIZATION

RADIATION AND CLIMATE

WORKSHOP ON IMPLEMENTATION OF THE

BASELINE SURFACE RADIATION NETWORK

(WASHINGTON, DC, U.S.A., 3-5 December 1990)

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The World Climate Programme launched by the World Meteorological Organization (WMO) includes four components:

- The World Climate Data Programme
- The World Climate Applications Programme
- The World Climate Impact Studies Programme
- The World Climate Research Programme

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1. Objectives of the workshop

1.1 The workshop on the implementation of the WCRP Baseline Surface Radiation Network (BSRN) opened at 0830 hours on 3 December 1990 at the Omni Shoreham Hotel, Washington, DC. Participants in the session are listed in Appendix A.

1.2 The objectives of the workshop were to consider the planning of the overall policy in developing the BSRN and the detailed procedures to be followed in network operation. Progress in selection of sites would be reviewed as would the adequacy of instruments and measurements to meet the stated BSRN requirements. The basic scientific plan for the BSRN is attached (Appendix B).

1.3 It was recalled that the BSRN is primarily designed to address the needs of climate research i.e. providing the highest possible quality, high sampling rate observations of short and longwave surface radiative fluxes at a small number of selected sites in contrasting climatic zones together with co-located surface and upper-air meteorological data and other supporting observations (such as cloud distribution). The aim is to collect uniform and consistent measurements throughout the network. The BSRN will also provide a basis for monitoring regional trends in surface radiation fluxes. The BSRN will not comprise a sufficient number of stations nor have adequate spatial distribution to permit comprehensive measurements of surface radiation flux over the whole global domain and, for this reason, it has been suggested that the word "global" be omitted from the original title of the project.

1.4 It was noted that the BSRN project will contribute to the overall WMO Global Atmosphere Watch (see paragraphs 7.7, 7.8) and will supplement other surface radiation monitoring programmes carried out by WMO's Commission for Atmospheric Sciences (CAS).

2. Review of potential BSRN sites

2.1 Participants in the workshop presented brief reviews of the sites proposed for inclusion in the BSRN, covering topics such as site characteristics, instrumentation, existing measurement programmes and future plans. The list of sites proposed is given in Appendix C (which also indicates other sites which may form part of the network).

2.2 The workshop agreed that all the sites on which information had been provided had characteristics rendering them suitable for inclusion in the BSRN and could be expected to provide valuable data for the project. Some stations appeared particularly suitable for providing data for satellite calibration because of the homogeneity of the site and surrounding landscape, others were more suitable for monitoring trends in radiative fluxes. Participants responsible for planning and developing sites were strongly encouraged to proceed with implementation.

3. Measurements and instrumentation

3.1 The workshop assessed the level of accuracy for radiative flux measurements that could be achieved by using currently available instrumentation, assuming constant instrument attendance and the most careful attention and maintenance. The workshop assessments are shown in Table I, which also presents estimates of accuracies that may be achievable in a few years time taking into account possible instrument refinement, improved observing procedures and understanding of instrument error and measurement uncertainty. Of interest in this regard was a presentation on measurement uncertainty analysis illustrating methods of identifying and estimating random and systematic errors and the effects of these errors on final results from Dr. C. Wells of the Solar Energy Research Institute.

Table I. Estimated accuracy achievable in surface radiation flux measurements (W/m^2) with existing field instruments assuming careful operation

	Current Estimate	Anticipated (in 5 years)
Incoming short-wave radiation (I)	15	5
Diffuse short-wave radiation (D)	10	5
Reflected short-wave radiation (R)	15	5
Downwelling long-wave radiation (A)	30	10
Upwelling longwave radiation (E)	30	5

3.2 Present attainable accuracies therefore hardly reach BSRN requirements, although expected to do so within a few years. However, the estimates in Table I were based on individual participants' subjective experience. Unfortunately, there have been few organized intercomparisons. There are also a number of uncertainties outstanding concerning characteristics of various instruments in different conditions and errors that can arise as a result of operating techniques.

3.3 Participants in the workshop agreed to undertake a number of specific studies to elucidate some of the outstanding uncertainties:

(i) Comparison of normal incidence pyrheliometers to assess random errors (B. Forgan, J. DeLuisi)

(ii) Assessment of calibration uncertainty of pyranometers used in measuring diffuse and reflected shortwave radiation (A. Ohmura)

(iii) Operation of instruments for measuring downwelling longwave radiation (K. Dehne, J. Olivieri)

(iv) Influence of instrument domes and observation height on infrared measurements (F. Miskolschi).

3.4 Notwithstanding the uncertainties in various instrumental characteristics and even though BSRN standard operational procedures remain to be finalised, a further step of major importance agreed was that participants already having suitable established sites and instrumentation should begin to collect on a trial basis in 1991 whatever BSRN measurements they were able to. For this pilot phase, a maximum sampling interval of six minutes (i.e. the longest allowed) should be employed. Efforts would be made to measure direct, diffuse and global solar irradiance, downwelling and upwelling longwave radiation (this last quantity only if a suitable tower were available when readings should also be taken at several different heights). Procedures followed would be carefully documented. The set of measurements collected would provide a valuable basis for an objective assessment of instrumental characteristics and the experience of procedures would be used in establishing standard network operational procedures. This early effort would also test out the logistics of local station operation and data acquisition, as well as giving momentum to the BSRN project and facilitating the transition to full network operation. Candidate sites for the pilot phase are Payerne, Switzerland (A. Ohmura); Cape Grim, Australia (B. Forgan); Boulder, Colorado (J. DeLuisi); Schleswig, Germany (K. Dehne); Canadian station (B. McArthur); a USSR station (A. Tsvetkov).

3.5 The results from the pilot phase would be thoroughly reviewed at a further BSRN workshop in 1991 (see paragraphs 8.1, 8.2) which would also consider the findings from the studies listed in paragraph 3.3 as well as considering more generally the behaviour and use of infrared broadband instruments.

3.6 The workshop discussed, in a preliminary way, the instrument calibration scheme that would be necessary. To ensure maintenance of satisfactory standards (e.g. to show the required consistency with the World Radiometric Reference) would need major efforts. Advantage would be taken of existing radiation instrument calibration facilities as far as possible. A detailed proposal (to be prepared by Dr. C. Fröhlich) will be considered at the workshop in mid-1991.

4. Site characterization, operations and training for the BSRN

4.1 The workshop discussed the issues of desirable and undesirable features of BSRN sites and of preparing a detailed operations manual. Among the topics covered were the requirement to be close to a radiosonde station, the need for on-site staffing for attending to instruments and the possibility of a satellite survey of sites to evaluate their suitability in providing data for calibrating satellite-based estimates of the surface radiation budget.

4.2 In regard to this last aspect, Dr. D. Tarpley presented the plan by NESDIS to collect high resolution specialized satellite data sets over a number of target areas:

(i) GOES I-M: 50 selectable targets for each spacecraft, 3-hourly frequency, all VISSR channels;

(ii) NOAA polar orbiters: 50-100 selectable targets for each spacecraft, 2-4 times daily, all AVHRR and HIRS channels.

The workshop recognized that such special data sets obtained over BSRN sites would permit a good validation of satellite measurements and be extremely valuable in deriving global surface radiation fields. The workshop suggested that WCRP write to NESDIS to request that BSRN sites whose locations were already known be included among target areas for which the special satellite data sets will be collected. The European Space Agency and Japan's National Space Development Agency should also be approached to ask whether they would be able to provide similar data sets for given target locations.

4.3 As to the preparation of the required BSRN operations manual, Dr. B. McArthur agreed to prepare a first draft including sections on instrumentation and installation of a station as well as maintenance and intercalibration of instrumentation. However, it would only be possible to finalise the manual following the review of the results of the test phase (see paragraph 3.4) and the outcome of the specific studies listed in paragraph 3.3. In the meantime, Dr. McArthur would draw extensively on existing documentation and manuals on radiation instrumentation (e.g. WCRP Publication Series No. 7 - Revised Instruction Manual on Radiation Instruments and Measurements) and other manuals that have been prepared for national use, which several participants agreed to forward to Dr. McArthur. Additionally, contributions on specific areas may be solicited from workshop participants. The draft manual will be reviewed at the further BSRN workshop in 1991 (see paragraphs 8.1, 8.2) and will be distributed to BSRN participants at least one month in advance of the workshop for prior study.

4.4 The recommendation was made that personnel concerned with the calibration of BSRN instruments should have the opportunity of visiting other sites in order to speed up the dissemination of technical developments and know-how. Progress in surface-based radiation measurements has been considerably slower than in many other areas of atmospheric science in recent years. Rapid advances in the technology of radiation measurements are now needed to meet the challenge of global climate change research.

4.5 The workshop recognised clearly that it will be necessary to give support to developing countries for the implementation of some essential BSRN stations and in training personnel to operate and maintain instruments. The workshop strongly encouraged bilateral arrangements to meet this requirement. WMO should also be ready to help both through the Technical Co-operation and Education and Training Programmes.

4.6 The workshop stressed strongly the need to ensure complete and free exchange of all data from all BSRN stations.

5. Data transmission and archival

5.1 Dr. C. Whitlock introduced a discussion on the data management transmission and archival schemes for the BSRN. He recalled that there will be a minimum of four levels of quality control in the data flow from instrument sensor to the BSRN archival centre, namely routine station checks, station director review, checks at the archival centre, final evaluation of data quality by a review panel (composed of representatives of network participants, the World Radiation Centre at Davos, the WCRP Working Group on Data Management for Radiation Projects, the Satellite Data Analysis Centre (see paragraph 6.3) and the archival centre).

5.2 Dr. Whitlock suggested a basic transmission and archival format for BSRN data comprising static header records containing information on the BSRN site, instrument types, calibration information and variable data records including the required set of radiance measurements and corresponding surface and upper air meteorological data. A proposal for the basic data flow was also put forward.

5.3 The workshop requested that, building on the principals outlined, a specific data management plan now be drawn up. Dr. Whitlock and Professor Ohmura will work together on the preparation of the plan which, like the draft operations manual, should be reviewed at the BSRN workshop in 1991 and will also be distributed at least one month in advance of the workshop.

6. Progress in the implementation of the WCRP Surface Radiation Budget Climatology Project

6.1 Drs. T. Charlock and C. Whitlock reported on progress in the implementation of the WCRP Surface Radiation Budget Climatology (SRB) Project. Results for longwave algorithms are not in good agreement with ground-truth data gathered in the course of a pilot experiment over Wisconsin during October 1986 (in conjunction with FIRE field observations). Studies of the causes of the discrepancies have been undertaken, examining the effects of likely errors in TOVS-derived surface temperature, retrieved moisture profiles and cloud height estimates as well as the accuracy of the ground-truth data itself. On the other hand, several shortwave algorithms using ISCCP data as input and on the basis of validation against the Wisconsin experiment ground truth, appeared to be acceptable (monthly average within $10W/m^2$ for a vegetated, mid-latitude plain area provided that satellite calibration accuracy is within 5%). However, when applied globally (again using ISCCP radiances as input), significant algorithm-to-algorithm differences have been found, particularly in locations with high clouds and/or areas of overlap between different satellites.

6.2 As well as uncertainties in the input data being used, further refinement of algorithms is also required, e.g. use of additional satellite data to infer downwelling longwave fluxes, improved models of complex three-dimensional cloud systems. More realistic treatment of bi-directional reflectance could be introduced in shortwave algorithms. Pending the routine availability of BSRN measurements, two additional test data sets will be used. The first is a time series of measurements of incident and reflected shortwave, upwelling and downwelling longwave radiances from the Boulder tower in July 1987 with concurrent ISCCP, ERBE and spatially continuous GOES data. The second includes longwave flux data collected in Bermuda with concurrent satellite information, lidar and radiosonde measurements.

6.3 Despite the outstanding difficulties, the NASA Langley Research Center (designated as the SRB Satellite Data Analysis Centre) has begun experimental production of a global shortwave dataset for a one year period, using the algorithm of F. Staylor. This experimental phase will enable solution of operational problems so that routine processing can begin rapidly once algorithms are finally selected, as well as providing experience in handling and compositing the various data streams required. The SRB Satellite Data Analysis Centre plans to use 3-4 different shortwave algorithms in the experimental phase.

7. Linkages with related programmes

7.1 In this section of the workshop, a number of existing and planned national and international activities that could contribute to or benefit from the BSRN project were reviewed. The establishment of a suitable liaison or co-ordinating mechanism was considered in the cases where this might be necessary.

U.S. Department of Energy Atmospheric Radiation Measurement (ARM) programme

7.2 Professor R. Ellingson described progress in planning the Atmospheric Radiation Measurement (ARM) programme being conducted by the U.S. Department of Energy as part of the U.S. Global Change Research Programme. The overall objective of the ARM programme is the improvement of the representation of clouds and radiation in climate models (corresponding to the stated scientific priorities of the WCRP). As a means to this end, the ARM initiative includes the development of new radiation instruments of greater accuracy than currently available, a prospect of great interest for BSRN implementation. Furthermore, the surface-based radiation measurement component of ARM would contribute to and complement the BSRN.

7.3 Informal co-ordination between ARM and the BSRN is assured by the part played by Dr. J. DeLuisi (BSRN Project Manager) in both programmes. It is hoped that collaboration between the Department of Energy and NOAA will lead to upgrading selected U.S.A. surface radiation stations to meet the requirements of the BSRN. The need for more formal arrangements between the ARM programme and the WCRP in regard to the BSRN as well as other radiation activities should perhaps be considered.

Solar radiation networks

7.4 Dr. J. DeLuisi (U.S.A.), Dr. K. Dehne (Federal Republic of Germany) and Dr. A. Tsvetkov (U.S.S.R.) described the status of their respective countries' solar radiation networks. The BSRN will incorporate some solar radiation sites that meet the minimal BSRN measurements requirements and which include infrared measurements. Other than this, the workshop was concerned that no specific role for a solar radiation network in climate research studies appeared to have been defined and, indeed, that in both U.S.A. and U.S.S.R. there was uncertainty regarding support to maintain and/or improve the solar radiation network.

7.5 The workshop expressed the view that solar radiation measurements make an important contribution to climate change studies in several areas (e.g., detection of trends in cloudiness, assessment of large-scale solar radiation surface heating). However, the question of the role and future of such networks goes beyond the scope of the BSRN project, although BSRN developments could certainly have a beneficial spin-off for the standardization and accuracy of solar radiation measurements. It was pointed out that the Global Atmosphere Watch (see paragraph 7.7) included a radiation monitoring component. Although planning for this was much less advanced than for the measurements of atmospheric composition, the Workshop suggested that it was appropriate that the organization and support to a comprehensive global solar radiation network be taken up within the framework of the Global Atmosphere Watch.

Commission for Instruments and Methods of Observation (CIMO)

7.6 Dr. B. Forgan described the main recommendations of the CIMO Working Group on Radiation and Atmospheric Turbidity measurements at its session in Davos, Switzerland, October 1990. Close collaboration will be maintained with this working group which is responsible for setting the international standardization, calibration and maintenance of a high level of performance of radiation instruments, including the definition of the World Radiometric Reference as well as organization of international and regional instrumentation comparisons. The BSRN would obviously need to co-operate with the CIMO Working Group in developing its instrument calibration and characterization procedures and measurement practices. The required liaison will be facilitated by the fact that several members of the CIMO Working Group on Radiation and Atmospheric Turbidity Measurements are participating directly in the BSRN. The workshop was pleased to hear of the interest expressed by the CIMO Working Group in the development of the BSRN.

Global Atmosphere Watch

7.7 Dr. D. Whelpdale, Chairman of the EC Panel/CAS Working Group on Environmental Pollution and Atmospheric Chemistry gave a presentation on the Global Atmosphere Watch (GAW), with the mission of monitoring the physical characteristics and chemical composition of the global atmosphere and the relationship of their variation with climate change. He noted the contribution to GAW that would be made by the BSRN in supplementing the surface radiation monitoring component of GAW, the scientific input which could be provided by BSRN participants in planning GAW radiation monitoring and the stimulus that BSRN would give to obtaining radiation measurements of increased accuracy. He pointed to the possibility that, for implementation at the national level, GAW sites could in some cases also take on the role of a BSRN station and, conversely, a BSRN station could be suitably placed to undertake additional measurements that could contribute to GAW. In short, there were significant mutual advantages in co-operation in building up the two activities.

7.8 The workshop agreed that BSRN international data exchange and archival procedures should be planned taking into account proposed GAW procedures to the extent possible. It was noted that required liaison and co-operation with GAW would be secured by the participation of a CAS-nominated expert on the WCRP Working Group for Radiative Fluxes which has responsibility for scientific oversight of the BSRN.

First ISCCP Regional Experiment (FIRE)

7.9 The second phase of FIRE will focus on detailed questions concerning the formation, maintenance and dissipation of cirrus and marine stratocumulus cloud systems. Of interest to BSRN is the spectral field radiance component (SPECTRE) of the FIRE Phase II Cirrus Experiment in Kansas in November 1991, in which it is planned to measure and model the full spectral detail of radiances, together with profiles of temperature, humidity and cloud for a range of meteorological conditions. Also as part of FIRE Phase II, a number of BSRN participants will be involved in a field intercomparison of different types of longwave instruments, which will provide an assessment of how well broadband measurements relate to spectral measurements.

8. Future plans

8.1 The participants agreed that a further workshop on the implementation of the BSRN was essential to review the outcome of the actions agreed at this workshop (i.e. the specific studies of instrumental uncertainties (paragraph 3.3), conclusions from the test phase at pilot stations (paragraph 3.4), the proposed calibration and instrument traceability procedures (paragraph 3.6), the draft operations manual (paragraph 4.3), the draft data management plan (paragraph 5.3)). At the next workshop, it would be essential to finalize the calibration procedures, operations manual and data management plan, taking into account the results of the specific studies and experience gained in the pilot phase. It was hoped that selected BSRN stations could begin formal operation and collecting measurements shortly after the workshop.

8.2 It was proposed that the next workshop take place at the World Radiation Centre at Davos, hosted by Dr. Frölich, 5-9 August 1991 (i.e. the week immediately preceding the IUGG Assembly in Vienna). BSRN participants will be advised of detailed arrangements for the workshop and formally invited to attend as soon as possible.

8.3 It was also agreed that the concept and implementation of the BSRN should be advertized as widely as possible in order to attract essential scientific support and the resources required to establish and maintain the network. To this end, an article on the BSRN will be prepared for submission to the Bulletin of the American Meteorological Society and a suitably edited version for the WMO Bulletin.

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APPENDIX B

PLAN FOR THE

BASELINE SURFACE RADIATION NETWORK (BSRN)

1. INTRODUCTION

The WMO/ICSU Joint Scientific Committee (JSC) for the World Climate Research Programme (WCRP) is proposing the establishment of an international Baseline Surface Radiation Network (BSRN) to support studies of global climate change. The goal of this project is to:

* provide data for calibrating satellite-based estimates of the surface radiation budget (SRB) and radiation transfer through the atmosphere

* monitor regional trends in radiation fluxes at the surface.

The network should consist of 10 to 20 strategically located stations, and could take advantage of existing national sites that meet the criteria laid out below. The establishment of new advanced research stations with more ambitious instrumentation is also proposed.

The implementation of the network and its international co-ordination involves the following tasks:

* organization and management of the stations at which operations will be carried out

* meeting observational requirements and implementation of observational procedures

* data collection and quality control followed by permanent archival.

To guarantee data homogeneity among the stations, instrument calibration and performance standards will be routinely checked. More advanced stations may require a special calibration facility. To qualify as a BSRN station, a minimal set of measurements will be required.

2. OBJECTIVES OF THE BSRN

The BSRN will be part of a wider integrated scientific programme with the common purpose of observing and developing the physical basis of understanding, determining and ultimately predicting changes in the earth's radiation budget elements and, especially, radiation fluxes at the surface of the earth. The specific objectives of the BSRN are:

* to measure the surface radiation components at strategic locations with a demonstrated accuracy and precision sufficient for revealing long-term trends

* To obtain concurrent measurements of atmospheric constituents such as clouds, water vapour, ozone, and aerosols that affect the radiation at the surface and at the top of the atmosphere

* to assure uniform adherence to the highest achievable standards of procedure, accuracy, and calibration throughout the entire network.

To meet these objectives, a detailed set of implementation standards will be laid out. These standards will be subject to modification as experience is acquired in the course of network operation.

3. MEASUREMENTS REQUIRED

The measurements of radiances by the BSRN must meet the highest possible standards of precision. The accuracies required are at the edge of what is currently feasible technically. The goal is to obtain measurements superior to those from present networks. Another unique requirement is adherence to a fairly short sampling interval to facilitate co-location with concurrent space-based measurements and to sample properly rapidly changing radiation fields.

Basic measurement programme and minimum accuracy requirements

* global irradiance (2%, 5 W/m^2)

* direct irradiance (1%, 2 W/m^2)

* diffuse irradiance (4%, 5 W/m^2)

* long-wave downward irradiance (5%, 20 W/m^2)

* standard meteorological observations (including co-located or adjacent radio-sonde observations)

Accuracies are expressed as the acceptable maximum deviation from the true value in SI units. The percentages and irradiance units are based on the fraction of the measured solar or terrestrial irradiance.

Expanded measurement programme

Stations with an expanded measurement programme will provide additional information for satellite algorithm improvement, and data interpretation. As well as the above quantities, these stations may measure one or more of the following quantities:

* direct spectral solar irradiance at WMO specified wavelengths and bandwidths (368, 500, 778 nm, and with an accuracy of 1 percent of the extraterrestrial value)

* cloud amount (by whole sky video imaging)

* cloud base height, aerosol, and water vapour vertical distributions (lidar measurements)

* water vapour (microwave radiometers) and ozone

Other measurements for atmospheric radiation research

BSRN stations will also be invited to undertake additional measurements in research mode in order to advance various aspects of atmospheric radiation research. As well as their significance for the WCRP radiation programme, these observations are important in the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) initiative which has the objective of providing detailed measurements of radiative effects in the atmosphere and to provide parameterizations of these effects for use in atmospheric models. The type of measurements required include:

* upward components of solar and long-wave irradiance from a tall tower when available

* low resolution thermal spectral infrared radiance (for example, in the "window" region)

* low resolution hemispheric solar spectral irradiance (including UV)

* other quantities for improvement of the capability to determine the surface radiation budget

4. INSTRUMENTATION AND CALIBRATION

The basic radiation instrumentation required includes pyranometers, pyrgeometers and tracking pyrheliometers. More advanced stations will also have a lidar (for cloud base height), pyrheliometer and pyranometer with (RG-89/RG-705) filter, sun photometer with three wavelengths (368, 500, 778nm) as well as instrumentation to permit measurement of upward and downward components of solar and longwave infra-red radiation, low-resolution thermal infra-red on both sides of the 9.6 μm ozone band and spectral ultra-violet at appropriate sites. At a few special locations, use of a tall tower would be envisaged to measure upward fluxes for research applications. The instrumental suite and facilities for a station carrying out the basic measurement programme are:

Pyranometers (ideal 4, minimum 2)
Pyrheliometers (ideal 2, minimum 1)
Pyrgeometers (ideal 3, minimum 1)
Filter sun photometer
Automated solar tracker
Data acquisition system
and micro-processor
Meteorological sensors and tower

The instrumental suite for the expanded measurement programme is as above but also includes a spectral UV radiometer and calibrator, lidar and electronic test equipment.

Various versions of instruments, usually commercially available are currently being used in different regions around the globe. In general, the different solar radiation sensing instruments will all respond in a similar way to incident radiation to perhaps within a few percent. Below this level, the instrumental characteristics such as azimuth and elevation response (especially for pyranometers) and temperature response will vary among the different instruments and differences will arise even among instruments produced in "identical" fashion. To assure measurement homogeneity among the network measurements, all instruments should be characterized following a standardized procedure. It is now quite feasible to characterize a pyranometric and pyrheliométric instrumentation at qualified laboratories by use of an active cavity radiometer that has been occasionally compared and referenced to the World Radiation Reference instruments kept at the World Radiation Centre, Davos, Switzerland. Well maintained cavity radiometers are usually stable to within 0.3% which is a significant advantage for maintaining standards at a calibration facility.

Corrections to radiation measurements according to the characterization results will assure uniformity among the data reported by the international network. As an initial step, in order to implement network operations as soon as possible, it makes sense to use instrumentation on hand. However, an ongoing effort to develop and deploy new instruments that require less or no characterization will be part of the development of the network. In this way, corrections can be minimized or eliminated completely, thus, reducing the noise in the network data stream. Retrofitting old instrument casings with new sensors is a possible approach for reducing costs.

5. DATA ACQUISITION AND MANAGEMENT

The planned data acquisition schedule for all radiation measurement is 1 recording per minute, each recording being the average of 60 readings taken at the basic sampling rate of one measurement per second.

Records from all stations in the network will be collected by a special BSRN Archival Centre which will be responsible for final evaluation of the data arriving from the BSRN. Questionable data will be returned to the originating site for a re-check. A copy of data finalized at the centre for archival will be sent to the observing site. A brief annual report will be prepared by the archival centre representative.

The final data sets will also be forwarded to the Asheville National Climate Data Centre and the Leningrad World Radiation Centre as appropriate.

6. ASSOCIATED BSRN RESEARCH GOALS

As well as the practical implementation of the network, research will be promoted to improve observational capabilities and to use the data collected in refinement of algorithms for retrieval of SRB components from satellite measurements. Specific research topics for consideration during the first few years of operation in order of preference are:

* Site characterization - acquisition of quantitative information on features such as nature of the surface, average cloud cover and type, aerosols, etc., that characterize the site for satellite applications

* Infrared irradiance measurements - advancing the state-of-the-art for accurate measurement of downwelling radiance and irradiance measurements to meet SRB measurement standards

* Extended-surface reflectance and in situ measurements - development of methods for measuring surface reflectance over a larger area (e.g. 20 x 20 km) by using a tower or small aircraft; special aircraft and balloon experiments to collect in situ information to validate the remote sensing measurements

* Atmospheric inhomogeneities - studies aimed at improving the understanding and measurement of the radiative features of inhomogeneous and broken clouds

* Special measurements - development of cost-effective instrumentation and methods for measurement of spectral ultraviolet and infrared SRB that will aid the improvement of satellite algorithm design and validation of satellite SRB determinations

* Improvement of instrumentation - investigations to improve the design and performance of "standardized" instrumentation such as sunphotometers and pyranometers, and development of more sophisticated remote sensing instrumentation to enhance the cloud-observing capabilities of the BSRN.

Close collaboration will be maintained between BSRN scientists and those working on satellite measurements of SRB in order to ensure the overall success of the project.

7. SITE SELECTION

To achieve the necessary accuracy, it is foreseen that stations will have to be manned. As well as undertaking the required radiation measurements, stations will have to follow a minimum routine of meteorological observations at a frequency compatible with BSRN requirements. Stations should be located within a distance of no more than 50 km from a radio-sonde site.

BSRN stations are required in a variety of contrasting climatic zones, providing information on the variability of radiation fluxes on both synoptic and seasonal timescales, range of cloud types experienced, and occurrence of significant aerosol loadings or unusually low atmospheric humidity. Other considerations include potentially high sensitivity of a region to global climate change, various surface types (e.g. snow, sea ice, vegetation coverings or desert) as well as locations with uniform and high surface reflectance suitable for satellite calibration. Finally, locations should be selected which allow a variety of viewing conditions from operational satellites and/or overlap of satellite coverages.

8. RADIATION INSTRUMENTATION LABORATORY

At least one laboratory will be identified for the purpose of providing facilities for characterization, improvement, development and calibration of instruments in support of the BSRN needs. The existence of such a laboratory will greatly enhance quality assurance of the network data products that are referenced to a common standard and will stimulate the development of the new instruments required. The possibility of one or more existing national laboratories providing the required facilities is being explored.

9. NETWORK IMPLEMENTATION ACTION

It is planned that the GBSRN should begin operation as soon as possible with existing stations, even though further effort is required to complete the planning work on site selection, data transmittal and archival procedures, data quality control, instrument evaluation and station operations. The following steps will be taken in the near future:

(i) An instrumentation evaluation workshop to determine the present status of infrared radiometer instruments (including calibration) and to make recommendations for new instrument design, as required (in collaboration with the WMO Commission for Instruments and Methods of Observation)

(ii) A meeting of BSRN participants to finalize a Station Operations Manual and to review training procedures

(iii) A one-month test of the network data quality control and archival system.

EXPECTED BASELINE SURFACE RADIATION NETWORK SITES

Operating country/ institution/ contact point	Station	Location (lat/long)	Altitude (m)
Australia			
Bureau of Meteorology Dr. B. Forgan (1)	Alice Springs	23.82S, 133.90E	544
	Cape Grim (test site only)	40.68S, 144.69E	93
Brazil			
Federal University of Santa Catarina Prof. S. Colle (1)	Manaus (2)	3.10S, 60.00W	
	Florianopolis	27.53S, 48.50W	
Canada			
Atmospheric Environment Service Dr. B. McArthur (1)	Eureka	80.05N, 86.42W	
	Saskatoon	52.23N, 107.12W	
China			
Lanzhou Institute of Plateau Atmospheric Physics Prof. Zhibao Shen (1)	Ping Chuan (2)	39.35N, 100.17E	1378
	Wudaoliang	35.28N, 93.10E	4612
Egypt			
Meteorological Authority Dr. D.M. Ahmed	Aswan	23.97N, 32.78E	
France			
Météorologie Nationale Dr. J. Olivieri (1)	Carpentras	44.08N, 5.04E	
Germany			
Deutscher Wetterdienst/ Alfred-Wegener Institute for Polar and Marine Research Dr. K. Dehne (1)	Ny Alesund, Spitzbergen (in conjunction with Norway)	To be advised	
	Schleswig	54.53N, 9.55E	59
	Georg von Neumeyer, Antarctica	70.62S, 8.37W	

Operating country/ institution/ contact point	Station	Location (lat/long)	Altitude (m)
Hungary			
Institute for Atmospheric Physics Dr. F. Miskolczi (1)	Budapest-Lorinc	47.43N, 19.18E	138
Israel			
Desert Research Institute (in collaboration with Israel Meteorological Service) Dr. A. Zangvil	Sede Boqer (2)	30.85N, 34.78E	
Japan			
Japan Meteorological Agency/	Tateno	36.05N, 140.13E	25
National Institute of Polar Research T. Yamanouchi	Syowa, Antarctica	69.00S, 39.58E	20
New Zealand			
University of Auckland/ New Zealand Meteorological Service Dr. J. Hay (3)	Tarawa, Kiribati (2)	1.35N, 172.92E	
	Pukekohe (2)	37.04S, 174.98E	
Saudi Arabia			
Meteorological and Environmental Protection Agency Dr. A.M. Heneidi	Al Soodah	18.25N, 42.40E	
Switzerland			
Meteorological Institute Dr. A. Heimo (4)	Payerne	46.82N, 6.95E	491
U.S.A.			
National Oceanic and Atmospheric Administration, Environmental Research Laboratories Dr. J. DeLuisi (1)	Barrow, Alaska	71.32N, 156.61W	10
	Boulder, Colorado	46.05N, 105.01W	
	Bermuda	32.33N, 64.75W	10
	Kwajalein, Marshall Island	8.71N, 167.73W	10
	South Pole	90.00S, 0.00E	2800

Operating country/ institution/ contact point	Station	Location (lat/long)	Altitude (m)
U.S.S.R.			
Main Geophysical Observatory, Leningrad Dr. A. Tsvetkov (1)	Franz Josef Land (2)	To be advised	
Institute of Astrophysics and Atmospheric Physics, Toravere, Estonia Dr. V. Russak (1)	Toravere, Estonia	58.27N, 26.47E	

Notes

(1) Participant in workshop and spoke for stations shown

(2) Proposal only at present time: firm confirmation awaited

(3) Represented at workshop by Dr. M. Uddstrom, New Zealand Meteorological Service

(4) Represented at workshop by Professor A. Ohmura, ETH, Zurich

LIST OF REPORTS

WCRP-1	VALIDATION OF SATELLITE PRECIPITATION MEASUREMENTS FOR THE GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (Report of an International Workshop, Washington, D.C., 17-21 November 1986) (WMO/TD-No. 203)
WCRP-2	WOCE CORE PROJECT 1 PLANNING MEETING ON THE GLOBAL DESCRIPTION (Washington, D.C., USA, 10-14 November 1986) (WMO/TD-No. 205)
WCRP-3	INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP) WORKING GROUP ON DATA MANAGEMENT (Report of the Sixth Session, Fort Collins, USA, 16-18 June 1987) (WMO/TD-No. 210)
WCRP-4	JSC/CCCO TOGA NUMERICAL EXPERIMENTATION GROUP (Report of the First Session, Unesco, Paris, France, 25-26 June 1987) (WMO/TD No. 204)
WCRP-5	CONCEPT OF THE GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Report of the JSC Study Group on GEWEX, Montreal, Canada, 8-12 June 1987 and Pasadena, USA, 5-9 January 1988) (WMO/TD-No. 215) (out of print)
WCRP-6	INTERNATIONAL WORKING GROUP ON DATA MANAGEMENT FOR THE GLOBAL PRECIPITATION CLIMATOLOGY PROJECT, (Report of the Second Session, Madison, USA, 9-11 September 1988) (WMO/TD-No. 221) (out of print)
WCRP-7	CAS GROUP OF RAPPORTEURS ON CLIMATE, (Leningrad, USSR, 28 October-1 November 1985) (WMO/TD-No. 226)
WCRP-8	JSC WORKING GROUP ON LAND SURFACE PROCESSES AND CLIMATE, (Report of the Third Session, Manhattan, USA, 29 June-3 July 1987) (WMO/TD-No. 232)
WCRP-9	AEROSOLS, CLOUDS AND OTHER CLIMATICALLY IMPORTANT PARAMETERS: LIDAR APPLICATIONS AND NETWORKS, (Report of a Meeting of Experts, Geneva, Switzerland, 10-12 December 1985) (WMO/TD-No. 233)
WCRP-10	RADIATION AND CLIMATE: (Report of the First Session, JSC Working Group on Radiative Fluxes, Greenbelt, USA, 14-17 December 1987) (WMO/TD-No. 235)
WCRP-11	WORLD OCEAN CIRCULATION EXPERIMENT - IMPLEMENTATION PLAN - DETAILED REQUIREMENTS (Volume I) (WMO/TD-No. 242)
WCRP-12	WORLD OCEAN CIRCULATION EXPERIMENT - IMPLEMENTATION PLAN - SCIENTIFIC BACKGROUND (Volume II) (WMO/TD-No. 243)
WCRP-13	RADIATION AND CLIMATE (Report of the Seventh Session of the International Satellite Cloud Climatology Project (ISCCP) Working Group on Data Management, Banff, Canada, 6-8 July 1988) (WMO/TD-No. 252)
WCRP-14	AN EXPERIMENTAL CLOUD LIDAR PILOT STUDY (ECLIPS) (Report of the WCRP/CSIRO Workshop on Cloud Base Measurement, CSIRO, Mordialloc, Victoria, Australia, 29 February-3 March 1988) (WMO/TD-No. 251)
WCRP-15	MODELLING THE SENSITIVITY AND VARIATIONS OF THE OCEAN-ATMOSPHERE SYSTEM (Report of a Workshop at the European Centre for Medium Range Weather Forecasts, 11-13 May 1988) (WMO/TD-No. 254)

WCRP-16 GLOBAL DATA ASSIMILATION PROGRAMME FOR AIR-SEA FLUXES (Report of the JSC/CCCO Working Group on Air-Sea Fluxes, October 1988) (WMO/TD-No. 257)

WCRP-17 JSC/CCCO TOGA SCIENTIFIC STEERING GROUP (Report of the Seventh Session, Cairns, Queensland, Australia, 11-15 July 1988) (WMO/TD-No. 259)

WCRP-18 SEA ICE AND CLIMATE (Report of the Third Session of the Working Group on Sea Ice and Climate, Oslo, 31 May-3 June 1988) (WMO/TD-No. 272)

WCRP-19 THE GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (Report of the Third Session of the International Working Group on Data Management, Darmstadt, FRG, 13-15 July 1988) (WMO/TD-No. 274)

WCRP-20 RADIATION AND CLIMATE (Report of the Second Session of the WCRP Working Group on Radiative Fluxes, Geneva, Switzerland, 19-21 October 1988) (WMO/TD No. 291)

WCRP-21 INTERNATIONAL WOCE SCIENTIFIC CONFERENCE (Report of the International WOCE Scientific Conference, Unesco, Paris, 28 November to 2 December 1988) (WMO/TD No. 295)

WCRP-22 THE GLOBAL WATER RUNOFF DATA PROJECT (Workshop on the Global Runoff Data Set and Grid estimation, Koblenz, FRG, 10-15 November 1988) (WMO/TD No. 302)

WCRP-23 WOCE SURFACE FLUX DETERMINATIONS - A STRATEGY FOR IN SITU MEASUREMENTS (Report of the Working Group on In Situ Measurements for Fluxes, La Jolla, California, USA, 27 February-3 March 1989) (WMO/TD No. 304)

WCRP-24 JSC/CCCO TOGA NUMERICAL EXPERIMENTATION GROUP (Report of the Second Session, Royal Society, London, UK, 15-16 December 1988) (WMO/TD-No. 307)

WCRP-25 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (GEWEX) (Report of the First Session of the JSC Scientific Steering Group for GEWEX, Pasadena, USA, 7-10 February 1989) (WMO/TD-No. 321) (out of print)

WCRP-26 WOCE GLOBAL SURFACE VELOCITY PROGRAMME (SVP) (Workshop Report of WOCE/SVP Planning Committee and TOGA Pan-Pacific Surface Current Study, Miami, Florida, USA, 25-26 April 1988) (WMO/TD-No. 323)

WCRP-27 DIAGNOSTICS OF THE GLOBAL ATMOSPHERIC CIRCULATION (Based on ECMWF analyses 1979-1989, Department of Meteorology, University of Reading, Compiled as part of the U.K. Universities Global Atmospheric Modelling Project) (WMO/TD-No. 326)

WCRP-28 INVERSION OF OCEAN GENERAL CIRCULATION MODELS (Report of the CCCO/WOCE Workshop, London, 10-12 July 1989) (WMO/TD-No. 331)

WCRP-29 CAS WORKING GROUP ON CLIMATE RESEARCH (Report of Session, Geneva, 22-26 May 1989) (WMO/TD-No. 333)

WCRP-30 WOCE - FLOW STATISTICS FROM LONG-TERM CURRENT METER MOORINGS: THE GLOBAL DATA SET IN JANUARY 1989 (Report prepared by Robert R. Dickinson, Eddy Statistics Scientific Panel) (WMO/TD-No. 337)

WCRP-31 JSC/CCCO TOGA SCIENTIFIC STEERING GROUP (Report of the Eighth Session, Hamburg, FRG, 18-22 September 1989) (WMO/TD-No. 338)

WCRP-32 JSC/CCCO TOGA NUMERICAL EXPERIMENTATION GROUP (Report of the Third Session, Hamburg, FRG, 18-20 September 1989) (WMO/TD-No. 339)

WCRP-33 TOGA MONSOON CLIMATE RESEARCH (Report of the First Session of the Monsoon Numerical Experimentation Group, Hamburg, FRG, 21-22 September 1989) (WMO/TD-No. 349)

WCRP-34 THE GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (Report of the Fourth Session of the International Working Group on Data Management, Bristol, UK, 26-28 July 1989) (WMO/TD-No. 356)

WCRP-35 RADIATION AND CLIMATE (Report of the Third Session of the WCRP Working Group on Radiative Fluxes, Fort Lauderdale, USA, 12-15 December 1989) (WMO/TD-No. 364)

WCRP-36 LAND-SURFACE PHYSICAL AND BIOLOGICAL PROCESSES (Report of an ad-hoc Joint Meeting of the IGBP Co-ordinating Panel No.3 and WCRP Experts, Paris, France, 24-26 October 1989) (WMO/TD-No. 368)

WCRP-37 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Report of the Workshop to Evaluate the Need for a Rain Radar in Polar Orbit for GEWEX, Greenbelt, USA, 25-26 October 1989) (WMO/TD-No. 369)

WCRP-38 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Report of the First Session of the WCRP-GEWEX/IGBP-CP3 Joint Working Group on Land-Surface Experiments, Wallingford, UK, 25-26 January 1990) (WMO/TD No. 370)

WCRP-39 RADIATION AND CLIMATE (Intercomparison of Radiation Codes in Climate Models, Report of Workshop, Paris, France, 15-17 August 1988) (WMO/TD No. 371)

WCRP-40 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Scientific Plan), August 1990 (WMO/TD-No. 376)

WCRP-41 SEA-ICE AND CLIMATE (Report of the fourth session of the Working Group, Rome, Italy, 20-23 November, 1989) (WMO/TD-No. 377)

WCRP-42 PLANETARY BOUNDARY LAYER (Model Evaluation Workshop, Reading, U.K., 14-15 August 1989) (WMO/TD-No. 378)

WCRP-43 INTERNATIONAL TOGA SCIENTIFIC CONFERENCE PROCEEDINGS (Honolulu, USA, 16-20 July 1990) (WMO/TD-No. 379)

WCRP-44 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Report of the 2nd Session of the JSC Scientific Steering Group, Paris, France, 15-19 January 1990) (WMO/TD-No. 383)

WCRP-45 SEA ICE NUMERICAL EXPERIMENTATION GROUP (SINEG) (Report of the First Session, Washington, D.C., 23-25 May 1989) (WMO/TD-No. 384)

WCRP-46 EARTH OBSERVING SYSTEM FOR CLIMATE RESEARCH (Report of a WCRP Planning Meeting, Reading, U.K., 2-3 July 1990) (WMO/TD-No. 388)

WCRP-47 JSC/CCCO TOGA SCIENTIFIC STEERING GROUP (Report of the Ninth Session, Kona, Hawaii, USA, 23-25 July 1990) (WMO/TD-No. 387)

WCRP-48 SPACE OBSERVATIONS OF TROPOSPHERIC AEROSOLS AND COMPLEMENTARY MEASUREMENTS (Report of experts meeting at Science and Technology Corporation, Hampton, Virginia, U.S.A., 15-18 November 1989) (WMO/TD-No. 389)

WCRP-49 TOGA MONSOON CLIMATE RESEARCH (Report of the 2nd session of the Monsoon Numerical Experimention Group, Kona, Hawaii, U.S.A., 26-27 July 1990) (WMO/TD-No. 392)

WCRP-50 TOGA NUMERICAL EXPERIMENTATION GROUP (Report of the 4th Session, Palisades, New York, U.S.A., 13-14 June 1990) (WMO/TD-No. 393)

WCRP-51 RADIATION AND CLIMATE (Report of the 1st Session, International Working Group on Data Management for WCRP Radiation Projects, New York City, U.S.A., 21-23 May 1990) (WMO/TD-No. 398)

WCRP-52 THE RADIATIVE EFFECTS OF CLOUDS AND THEIR IMPACT ON CLIMATE (Review prepared by Dr. A. Arking at request of IAMAP Radiation Commission) (WMO/TD-No. 399)

WCRP-53 CAS/JSC WORKING GROUP ON NUMERICAL EXPERIMENTATION (Report of the sixth session, Melbourne, Australia, 24-28 September 1990) (WMO/TD-No. 405)

WCRP-54 RADIATION AND CLIMATE (Workshop on Implementation of the Baseline Surface Radiation Network, Washington, DC, U.S.A., 3-5 December 1990) (WMO/TD-No. 406)

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