

South Asian Regional Reanalysis (SARR)

A Collaborative Project between
Ministry of Earth Sciences
Government of India



सत्यमेव जयते

and

**National Oceanic and Atmospheric
Administration**
Department of Commerce
United States of America



SARR SCOPING WORKSHOP REPORT
February 10-11, 2010 New Delhi

South Asian Regional Reanalysis Scoping Workshop

**February 10-11, 2010
New Delhi, India**

Background

The South Asian Regional Reanalysis (SARR) project is being implemented at National Centre for Medium Range Weather Forecasting (NCMRWF) as a part of Memorandum of Understanding between the Ministry of Earth Sciences (MoES) and National Oceanic and Atmospheric Administration (NOAA) on Technical Cooperation in Earth Observations and Earth Sciences. Main purpose of the SARR is to advance understanding, modeling and prediction of monsoon hydroclimate variability and change over the south Asian region. The Principal Investigators and points of contact from USA and India are given in Annexure-I. It was envisaged in the project proposal to hold a two-day Scoping Workshop on "South Asian Regional Reanalysis" in which key data assimilation experts and monsoon scientists would participate and make recommendations on the project scope, including model choice, reanalysis domain, etc.

The two-day Scoping Workshop on "South Asian Regional Reanalysis" was organized during February 10-11, 2010, at India Habitat Centre, New Delhi. Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences, Government of India formally opened the Workshop. The list of participants is at Annexure-II. The participants presented scientific talks and participated in the discussion. The Agenda of the Workshop is at Annexure-III. Valuable recommendations were made to make the South Asian Regional Reanalysis. In this report, the presentations and recommendations in the Workshop are described briefly.

The SARR Project

Due to the direct societal impacts, interest in regional hydroclimate (precipitation, surface temperature, soil moisture, stream flow, drought indices, etc.) over South Asia is intense and growing. Global reanalysis datasets, for various reasons, do not represent the hydroclimate over the South Asian region adequately. Through the SARR project, a retrospective analysis (reanalysis) of circulation and thermodynamic fields will be developed to advance characterization, understanding, modeling and prediction of monsoon climate variability and change over this subcontinent. The SARR project will generate refined description of the regional hydroclimate state; a description unattainable from canonical assimilation of circulation and temperature data as model forecasts of precipitation remain inaccurate. It is proposed to overcome this deficiency through assimilation of precipitation, radiance, additional meteorological data that may be collected from various sources/agencies and aerosol observations in numerical weather prediction models. The SARR project will thus provide an atmosphere-land-

surface state description where consistency between circulation and hydroclimate components is assured.

The SARR project will exploit the high spatio-temporal resolution of satellite observations; generate unique synthesis of conventional and remotely sensed data using state-of-the-art atmosphere/land-surface models while being mindful of regional water and energy budgets; provide a framework for diagnosing the influence of regional anthropogenic aerosols/pollutants on circulation and hydroclimate; permit a more rigorous analysis of water resource management and agricultural practices and above all, forge stronger links between climate programs of South Asian countries. The goals of the SARR project are:

- Refine methods for assimilation of precipitation and radiances with the goal of reducing the water and energy budget imbalances during the assimilation procedure.
- Conduct a 5-year pilot-phase reanalysis for the period 1998-2002, to test and optimize data stream organization and the geographic domain and assimilating model choices. The short period reanalysis will be evaluated from intercomparisons with satellite observations (e.g., TRMM) and state-of-the-art global reanalysis and the assimilation technique refined as necessary.
- Develop high-resolution SST analysis for the Indian ocean from satellite and in-situ observations, including moorings, drifters and Argo floats.
- Design techniques for assimilation of aerosols.
- Improve state estimation of the Northern Indian Ocean from refined surface circulation and heat-flux estimates produced by the regional atmospheric reanalysis.
- Generate a dynamics-thermodynamics consistent, high spatio-temporal resolution (≤ 30 Km, ≤ 3 hours) climate data set from retrospective analysis of in-situ and remotely sensed ocean-atmosphere observations for the 1979-2006 period over the South Asian Monsoon land-ocean region.

Opening Session:

At the outset, Dr. A.K. Bohra, Head NCMRWF and Principal Investigator of the project from India welcomed all the delegates to the Workshop and presented the agenda. Dr. Shailesh Nayak, Secretary, MoES, Government of India formally opened the Workshop at 2.30pm on February 10, 2010, at India Habitat Centre, New Delhi.

In his opening address, Dr. Nayak highlighted the importance and priority the Ministry gives to this MoES-NOAA project. Organization of atmospheric,

oceanic, satellite and hydrological datasets are not only important for assimilating them into numerical models for weather forecasting, these datasets can play a very important role to enhance our understanding of climate variability and climate change. He set the tone by expressing hope that SARR will be as successful as RAMA, the MoES-NOAA flagship collaborative project in the Indian Ocean.

Prof. J. Shukla, George Mason University, USA presented the opening talk of the Workshop on "Retrospective Atmospheric Analysis". He expressed interest and support for the project, noting its potential contributions to capacity building, prediction research, and forecast system improvements. He mentioned the importance of increasing scientific manpower in data acquisition, management and assimilation efforts. Dr. S.C. Kar, Project Manger of SARR at NCMRWF proposed the vote of thanks.

Scientific Session-I

Prof. Sumant Nigam, University of Maryland, USA and Principal Investigator of the project from USA talked about "The South Asian Regional Reanalysis Project: Motivation, Objectives and Challenges". He showed the century-long declining precipitation trend over the northern Gangetic Plain and eastern India – a concerning trend manifest also in the 1958-onward sub period. He argued that understanding the causes of the trend is presently challenging as both NCEP and ERA40 reanalyses grossly misrepresent this feature, getting even the sign wrong. The surface air temperature trend was shown to fare better, indirectly, indicating the large degree of freedom in unconstrained variables in the global reanalyses. Such freedom and the substantial imbalance in the atmospheric water budget over the Gangetic Plain was used to motivate the need for the precipitation-assimilating South Asian Regional Reanalysis. He suggested that assimilation strategies that reduce long-term imbalances in regional water and energy budgets in addition to minimizing short-term circulation forecast errors will have to be developed. Regional, precipitation-assimilating atmospheric reanalysis can provide a high value data set for advancing understanding, modeling and prediction of regional hydroclimate variability and change.

Dr. A.K. Bohra, NCMRWF, Noida, and Principal Investigator of the project from India talked about "The South Asian Regional Reanalysis Project: Motivation and Plans at NCMRWF:". He informed that the SARR project is being implemented at NCMRWF and for SARR Pilot phase, WRF-VAR and WRF model (version 3.1) is being used. Background error statistics has been computed. Regional Assimilation Experiments have been carried out using NCMRWF Archived GTS data for 1999. Additional Experiments have been carried out using Satellite data. Modeling Experiments have been carried out using different physics options in the model. He informed that efforts re being made to get observed data from other countries in the region and letters of request have been sent to Met Departments of these countries for their participation in the project. It is envisaged that SARR

shall be an ongoing activity & after Phase-I, several reanalysis experiments shall be carried out with improved assimilation scheme and regional models.

Prof. T. N. Krishnamurti Florida State University, USA, talked on "Regional Re-Analysis using Physical Initialization". He described the benefits of precipitation assimilation in regional reanalysis. Rain rate initialization is very important since most models place the position of rain areas and their amplitudes incorrectly as compared to those suggested by observational estimates. This is true for monsoon depressions, orographic rains, ITCZ and meridional propagations. He further remarked that the assimilation of brightness temperatures from the microwave instrument of the SSMI/DMSP and the TRMM satellites does not assure that the model will provide a sufficiently high skill for precipitation initialization. He mentioned that both 3D and 4D-VAR generate low skills in precipitation. Retrospective assimilation of precipitation from the high-resolution land precipitation analysis (Yatagai 2009) and TRMM 3B22 ocean precipitation was discussed as a possibility for the SARR project. He suggested one option is to use the FSU physical initialization.

Dr. V. Ramaswamy, NOAA-GFDL, USA talked about the "Aerosol Influences on Monsoon Hydroclimate: Guidance for Aerosol Modeling and Assimilation". He noted the importance of aerosol effects on monsoon hydroclimate and the contrasting responses of different aerosol types. Improving modeling of aerosol-circulation-convection interaction should be high priority, in his opinion. He recommended that aerosol assimilation be pursued in two steps: a near-term focus on direct effects, followed by improved representation of the 'semi-direct' effects (e.g., cloud evaporation) in models. Ramaswamy raised the possibility of assimilating surface fluxes in the SARR effort.

Dr. A. Tyagi, DGM, India Meteorological Department (IMD) talked about "Indian Observations for SARR". He informed that IMD has vast resource of various type of meteorological datasets for many past years which can be made available for the SARR project. He especially emphasized on the upper air data, surface data and rainfall data which should be utilized in the SARR project to improve the quality of the reanalysis over the region..

Prof. U. C. Mohanty, IIT Delhi talked about "Mesoscale Data Assimilation for Extreme Weather Events". He said that SARR is an excellent program as it will generate a high-resolution analysis from retrospective in-situ and remotely sensed observations. He expected that SARR shall provide mesoscale data assimilation for longer period (1979-2008); provide a frame work to diagnosis the genesis and development of Meso convective activities; thunderstorms; tropical cyclones and heavy rainfall events. He proposed to contribute to SARR project through sensitivity studies on optimum combination of parameterization schemes; data assimilation schemes; and data impact studies for extreme weather events etc.

Dr. R. Leung, DOE PNL, USA talked about "Hydrometeorological Modeling over Complex Terrain: Lessons for SARR". She highlighted about the challenges in developing regional reanalyses over complex terrain, such as the Himalayan-Tibetan complex and pointed out that large uncertainties and insufficient spatial/temporal coverage of data in mountainous regions add difficulties for data assimilation; characterization of the spatial scales relevant to data assimilation and model validation is lacking; assimilating near surface data is challenging over the complex terrain because the dynamical and thermodynamical balance is not well understood. These challenges have implications to SARR. Ruby described a poor man's reanalysis generated from a 15-Km WRF with spectral nudging from GFS circulation. She suggested that aerosol effects are amplified in mountain regions (e.g., soot deposition on snow/ice) and must be considered in an effective regional assimilation effort, such as SARR.

Dr. Arun Kumr, Climate Prediction Center, NCEP, USA talked about "The NCEP Climate Forecast System Reanalysis". He described the operational NCEP Global Data Assimilation System: GADAS (the atmospheric component of GDAS) uses GSI (Global Statistical Interpolation scheme), while the ocean component of GDAS uses MOMA (GFDL Modular Ocean Model implementation for Array processing). The land component of the assimilation system is GLDAS but with observed precipitation driving the NOAH land surface model. He also talked about the new global coupled reanalysis uses an atmosphere model at high horizontal resolution (spectral T382, ~38 km) and high vertical resolution (64 sigma-pressure hybrid levels). The reanalysis has an interactive ocean with 40 levels in the vertical. An interactive sea-ice model and an interactive land model with four soil levels are also used. He informed us of the imminent release of NOAA's latest reanalysis product, the CFSRR.

Scientific Session-II

Dr. S.C. Kar, NCMRWF talked about the "Pilot-phase Regional Reanalysis– Preliminary Results and Future Strategy". He dealt with the SARR observation data Issues in detail. NCMRWF has archived GTS data since June 1994. For test runs, the year 1999 was chosen in order to test the utilization of archived GTS data at the Centre for the SARR project. He gave the statistics of observations available over India and the SARR domain. He emphasized that we need to utilize other Indian data (not going in GTS) from IMD archive. We also need to get archived data at NCEP from 1979 onwards. We also shall have to utilize satellite radiance data, TOVS/ATOVS data etc in the SARR project. He presented experimental runs with model domain choice etc with different parameterization schemes.

Dr. A. Routray, NCMRWF talked about "South Asian Regional Reanalysis-Preliminary results". He discussed about the SARR assimilation methods being followed for pilot phase and informed that model background error statistics have been computed. Comparative assimilation experiments have been carried out

using two sets of observations from NCMRWF Archived data and NCEP PrepBuf data. He showed that assimilation of data improves the various mandatory statistics that are required in any analysis.

Dr. P. Mali, NCMRWF talked about the "Impact of Physics Schemes in WRF for SARR". He informed that several sensitivity experiments (with different combinations of convection, planetary boundary layer, and land surface schemes) are being carried out to choose the optimum combination of physics parameterization schemes in WRF model which can be used in SARR.

Dr. K. G. Rao, ISRO-HQ Bangalore talked about the "Satellite Data and Assimilation for SARR". She informed about major satellite missions and science projects of ISRO. She talked in detail about the PRWONAM project which is a science Project of ISRO in mission mode with Multi-institutional participation. She informed that all necessary data for SARR can be provided which are available at ISRO.

Dr. P. Goswami, CMMACS, Bangalore talked about the "High-resolution Regional Atmospheric Analysis: Modeling Issues". He informed about a similar CSIR Initiative on the High-resolution Regional Atmospheric Analysis (HiRRAA). The objectives include configuration, calibration and validation of a GCM and a Limited Area Model; data assimilation for both GCM and Limited Area Model; downscaling; algorithm for calibration and validation, objective debiasing for application multi-scale validation with multi-source data generation of meso-scale observations.

D. Ganguly, NOAA GFDL talked about the "Constraining atmospheric GCMs by ground-based, satellite and reanalysis data for improved estimation of the aerosol impact on South-Asian monsoon South Asian Regional Reanalysis". He discussed about the development of a technique to derive the concentration of aerosols from optical measurements in places where direct measurements of aerosol composition are not available and use this information to constrain the GCM. He presented results of such studies over the South Asian region which are being carried out at GFDL to investigate the climate response to the direct as well as indirect effects of anthropogenic versus natural aerosols from South Asia on monsoon dynamics.

Dr. W. Ebisuzaki, NOAA, NCEP talked about "The North American Regional Reanalysis (NARR) System: Lessons for SARR". He told that in operational systems, the model precipitation forces the land surface model. Errors in the model precipitation adversely affect the soil moisture. For NARR, two precipitation assimilation methods were attempted. In the first method, humidity and temperature were nudged to reproduce observed hourly precipitation. In the second method, observed precipitation was directly assimilated using 3d Var scheme. It was found that the first method was more practical while the second method is theoretically nicer and works better. However, this method needs hourly

precipitation data for assimilation scheme. He recommended preparation of the output file variables/fields should be user oriented and should be decided as a part of pre-production. Redundant and less useful fields should be removed.

Dr. V.K. Dadhwal, IIRS, Dehradun talked about "Land Surface Processes- Studies with Remote sensed (RS) Data at IIRS". He informed that IIRS has prepared remote-sensed land cover/ land use and vegetation classification datasets which can be inputs to regional models. He showed results of field studies on land surface processes/ parameters and RS studies on geospatial modeling of land properties/activities and long-term land transformation.

Scientific Session-III

This session was dedicated for discussion on implementation strategy of the SARR project. Discussions were held on the domain of reanalysis, the choice of regional model and parameterization schemes. Further, discussions were held on assimilation techniques, observational data availability, archival issues and format of output to be stored and disseminated. The salient points of the discussions are as follows:

Pilot-phase experiment has been conducted with WRF3.1 at 25 Km resolution for the January-July 1999 period; current domain is 40-120E, 15S-45N, and 38 vertical levels. The 1994-onward GTS data is available at NCMRWF. For reference, the North American Regional Reanalysis was generated using the Eta model with 3D-VAR.

Western boundary effects on SARR: Potentially troubling given the poor observational network over the African and Arabian deserts, etc. Ruby used spectral nudging on the large-scale in a WRF-based poor man's reanalysis.

Forecast and Reanalysis models: Strong sentiment to keep them the same. NCMRWF currently runs WRF 2.2 operationally. NCMRWF plans to upgrade to WRF3.1 after this monsoon season.

WRF model domain: It was suggested that the resolution be fixed first and the domain choice be then guided by the availability of computational resources. The domain should include the Somali jet to the west and the Maritime Continent to the east.

SARR Validation: It was suggested that the validation must include terrestrial hydroclimate metrics. Soil moisture data sets from ISRO, IIRS, Dehradun and other sources must be acquired and formatted for model vetting. In-line land surface model in SARR could be made to see observed rather than model precipitation during the assimilation cycle.

High resolution SST analysis: It was suggested to use TMI SST. MoES-INCOIS has agreed to provide enhanced products for the Indian Ocean basin.

Aerosol assimilation: Ruby and Ramaswamy's advice was to begin with Aerosol Optical Depth (AOD) assimilation (not in WRF-CHEM yet, but will be soon); assimilation of Single Scattering Albedo (SSA) is not yet an option in WRF-CHEM; SSA data comes from Aeronet, while AOD comes from MODIS.

Regarding precipitation assimilation: Two options were discussed: (i) Implement TNK's physical initialization; (ii) Implement NARR's precipitation assimilation.

The experts participating in discussion noted the interesting intersections with CSIR's ongoing HiRRAA (High Resolution Regional Atmospheric Analysis, at least in terms of mesoscale observations for SARR validation and IAF WRF modeling effort, where the model is run at 6 and 12Km resolution. Based on the discussions, the experts made the following recommendations.

Recommendations

Model Choice for SARR: The Pilot phase reanalysis shall be carried out using the WRF-ARW version 3.1 and WRF-VAR.

Model Domain: The Pilot phase reanalysis shall be carried out over the domain covering Lon: 40⁰E -120⁰E and Lat:15⁰S-45⁰N. This domain is such that the lateral boundaries of the model are far from the interest domain of SARR.

Model Resolution: The Pilot phase reanalysis shall be carried out at 25 km horizontal resolution and 38 vertical sigma levels. It was also suggested that if computing power permits, reanalysis may also be carried out at further high resolution such as at 18km or 9km.

Observational Data: It was recommended to carry out pilot phase assimilation with as much observational data that can be available. Observations that have been used during CFS reanalysis over the SARR computational domain shall be used in SARR pilot phase in addition to other observational data that can be collected for the pilot phase. For this purpose, NCEP shall provide PREPBUFR data for one year to start with (April-1999 and March 2000). Subsequently, PREPBUFR data for other years shall be made available by NCEP for the SARR project.

Indian Satellite Data: The SARR project shall aim to utilize as much as Indian satellite data. ISRO and IMD shall provide all relevant datasets needed.

Data from Special Experiments: It was recommended to utilize available data from special experiments carried out by different agencies in India from time to time, such as BOBMEX, ARMEX, etc.

Inventory of Observation Data: It was recommended to prepare a list of all the observation data available with different agencies in India and other countries in the SARR region. Daily statistics of data used in the reanalysis shall be prepared.

Physics Scheme: Assimilation experiments shall be carried out with different physical parameterization schemes to evaluate the performance of the model at least for one year period.

Experiments with Surface data: Data of soil moisture, vegetable fractions etc from ISRO shall be used in the SARR. It was also recommended to use available SST for the period without collecting SST from different sources. A SST analysis for the Indian Ocean region shall be carried out at the later stage of the project.

Rainfall Assimilation: Assimilation of precipitation is a critical component of the SARR project. The schemes developed at FSU can be used. As a first step, the scheme used in the NARR project shall be implemented. NCEP shall provide relevant portion of the codes to be implemented at NCMRWF for the project.

Aerosol Assimilation: NOAA GFDL shall provide all necessary know-how for assimilating aerosol in the SARR. However, this part of the project shall be implemented at a later stage.

Verification Packages: It was recommended to start developing verification packages for different parameters that will demonstrate utility of SARR datasets to some other agencies. These packages shall also help in finalizing physics options of the model.

Scripts for SARR: An unified script should be developed during the pilot phase SARR so that routine production runs can be easily carried out and monitored. It was suggested that for quick testing of the scripts, lower resolution experiments should be carried out.

SARR product: Final reanalysis data shall be in GRIB2 format and shall be made available to all participating agencies.

Technical Committee: It was recommended that a technical committee with members from organization who shall contribute to the project shall be constituted for the implementation of the SARR project.

Manpower: NCMRWF and MoES shall expedite the recruitment of project scientists committed for the SARR project.

Computing Power: NCMRWF shall provide necessary computing power and storage for the implementation of the project.

South Asian Regional Reanalysis

PIs & Points of Contact of the Project

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<p>Core Team Members for SARR at NCMRWF</p> <p>Dr. S.C. Kar Dr. P. Mali Dr. A. Routray</p>	<p>Associated members of the SARR Team at NCMRWF</p> <p>Dr. V.S. Prasad Dr. P. Devrajan</p>

**South Asian Regional Reanalysis
Scoping Workshop**

**February 10-11, 2010
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South Asian Regional Reanalysis Scoping Workshop

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INDIA HABITAT CENTRE
Lodi Road, New Delhi, India
(AGENDA)

WEDNESDAY, February 10, 2010		
OPENING SESSION (2.00-2.30pm)		
Welcome:	A.K. Bohra, NCMRWF	
Opening Address:	S. Nayak, Secretary, MoES	
Talk:	J. Shukla, George Mason University, USA	
Scientific Session-I (2:30-6.30pm)		
Time	Name	Title
2:30 – 3:00pm	S. Nigam University of Maryland	The South Asian Regional Reanalysis Project: Motivation, Objectives, and Challenges
3:00 – 3:20pm	A.K. Bohra NCMRWF, Noida	The South Asian Regional Reanalysis Project: Motivation and Plans at NCMRWF
3:20 – 4:00pm	T. N. Krishnamurti FSU, Tallahassee	Regional Re-Analysis using Physical Initialization (SARR)
<i>TEA</i>		
4:10 – 4:40pm	V. Ramaswamy NOAA, GFDL	Aerosol Influences on Monsoon Hydroclimate: Guidance for Aerosol Modeling and Assimilation
4:40 – 5:00pm	A. Tyagi IMD, New Delhi	Indian Observations for SARR
5:00-5:20am	U. C. Mohanty IIT Delhi	Meso Scale Data Assimilation for Extreme Weather Events
5:20-5:50	R. Leung DOE, PNL	Hydrometeorological Modeling Over Complex Terrain: Lessons for SARR
5:50 – 6:20pm	Arun Kumar NOAA, NCEP	The NCEP Climate Forecast System Reanalysis
SARR DINNER at 7.00pm (Mapple, India Habitat Centre)		

FRIDAY, February 11		
Scientific Session-II (9.30am-1.00pm)		
9:30 – 9:45am	S.C. Kar NCMRWF, Noida	Pilot-phase Regional Reanalysis – Preliminary Results and Future Strategy
9:45 – 10:00am	A. Routray NCMRWF, Noida	South Asian Regional Reanalysis-Preliminary results
10:00-10:15am	P. Mali NCMRWF, Noida	Impact of Physics Schemes in WRF for SARR
10:15-10:35am	K. G. Rao ISRO-HQ Bangalore	Satellite Data and Assimilation for SARR
10:35-11:00am	P. Goswami, CMMACS, Bangalore	High-resolution Regional Atmospheric Analysis: Modeling Issues
<i>TEA</i>		
11:15 – 11:45	D. Ganguly NOAA, GFDL	Constraining atmospheric GCMs by ground-based, satellite and reanalysis data for improved estimation of the aerosol impact on South-Asian monsoon
11:45 – 12:15 pm	W. Ebisuzaki NOAA, NCEP	The North American Regional Reanalysis System: Lessons for SARR
12:15 – 12:35pm	V.K. Dadhwal IIRS, Dehradun	Land Surface Processes- Studies with RS Data at IIRS
12:35 – 1:00pm	S. C. Kar and Others	Discussion on Implementation strategy
<i>LUNCH</i>		

FRIDAY, February 11		
Scientific Session-III (1:45pm-3.00pm)		
1:45 – 2:45 pm	All	Implementation Strategy: Discussion of Domain, Regional Model, and Parameterization Choices and Assimilation Techniques
2:45 – 3:00pm	A. Kumar (NOAA) S. Nigam (UMD) A.K. Bohra (NCMRWF)	Concluding Remarks
<i>TEA</i>		