JRA-25: Japanese 25-year re-analysis project—progress and status

By KAZUTOSHI ONOGI[1]*, HIROSHI KOIDE[1], MASAMI SAKAMOTO[1], SHINYA KOBAYASHI[1], JUNICHI TSUTSUI[2], HIROAKI HATSUSHIKA[2], TAKANORI MATSUMOTO[1], NOBUO YAMAZAKI[3], HIROTAKA KAMAHORI[3], KIYOTOSHI TAKAHASHI[3], KOJI KATO[4], RYO OYAMA[4], TOMOAKI OSE[1], SHINJI KADOKURA[2] and KOJI WADA[2]

[1]*Japan Meteorological Agency, Japan*
[2]*Central Research Institute of Electric Power Industry, Japan*
[3]*Meteorological Research Institute/Japan Meteorological Agency, Japan*
[4]*Meteorological Satellite Center/Japan Meteorological Agency, Japan*

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SUMMARY

The progress and status of a new atmospheric re-analysis, JRA-25 the Japanese 25-year Re-analysis which covers the 26 years from 1979 to 2004, are introduced. Observational data include some newly produced for JRA-25 and advantages and drawbacks of performance are briefly described. JRA-25 has many advantages such as its handling of precipitation amounts, tropical cyclone analysis, and the extent of low-level cloud along western continents that are among the best compared to other re-analyses. The snow analysis is also good and stable. JRA-25 outputs analysis products every 6 hours.

KEYWORDS: Data assimilation Observations Precipitation

1. INTRODUCTION

The Japan Meteorological Agency (JMA) and the Central Research Institute of Electric Power Industry are conducting the Japanese 25-year re-analysis (JRA-25) which is a joint research project to make a long-term and high-quality, global atmospheric re-analysis dataset. The dataset is intended to benefit various climate information services and researchers, and also to complement other re-analyses completed by the European Centre for Medium-Range Weather Forecasts (ECMWF; ERA-15, Gibson *et al.* (1997); and ERA-40, Uppala *et al.* (2005)) and the National Centers for Environmental Prediction (NCEP; R1, Kalnay *et al.* (1996); and R2, Kanamitsu *et al.* (2002)).

The re-analysis period of JRA-25 is the 26 years from 1979 to 2004 inclusive. After acquisition and preparation of observational data and various kinds of preliminary experiments, production of JRA-25 was started in April 2004 and about 90% of the period had been completed as of November 2005. The entire period will be completed around the spring of 2006.

JRA-25 outputs a global analysis and a 6-hour forecast field every 6 hours, four times a day throughout 26 years. The output contains over 200 meteorological and physical parameters.

2. ASSIMILATION SYSTEM AND OBSERVATIONAL DATA

The global forecast model used in JRA-25 has a spectral resolution of T106 (equivalent to a horizontal grid size of around 120 km) and 40 vertical layers with the top level at 0.4 hPa. A three-dimensional variational (3D-Var) data assimilation system is adopted for assimilating various kinds of satellite data effectively. The global model used in JRA-25 is a low-resolution version of the JMA operational model reported in JMA (2002), but many advances made since then were adopted in the JRA-25 system.

* Corresponding author: Japan Meteorological Agency, 1-3-4, Ote-machi, Chiyoda-ku, Tokyo, 100-8122, Japan. e-mail: konogi@met.kishou.go.jp

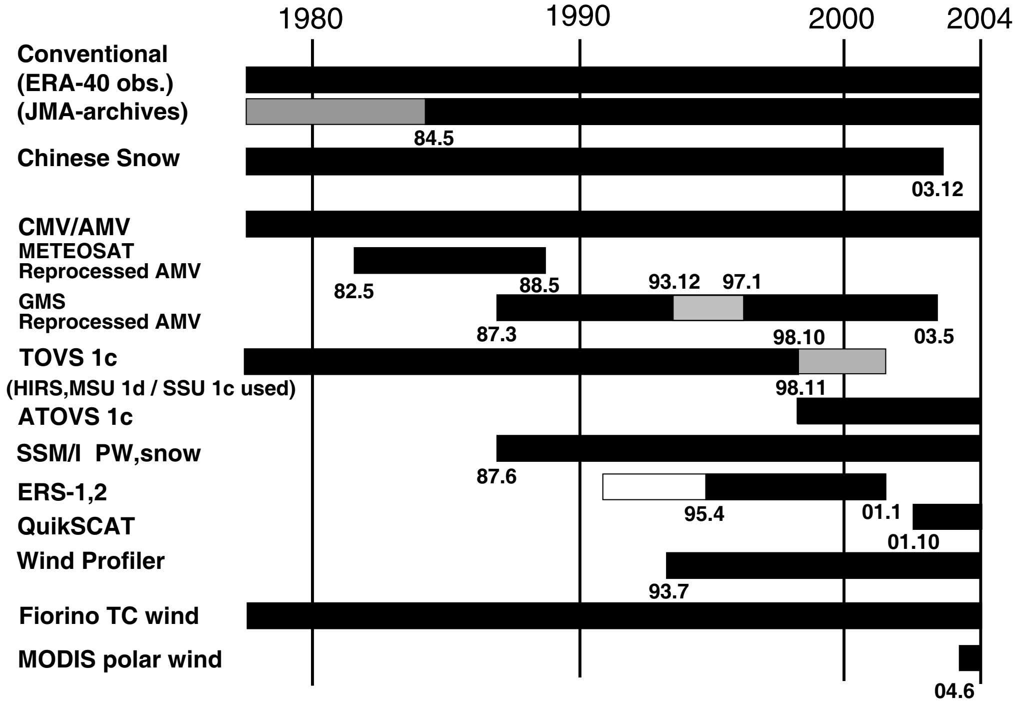

Figure 1. Observational data used in JRA-25; each category is shown with its period of availability. Grey zones denote data that are in house but not used; the white zone (ERS-1,2 only) indicates data that are available but not in house. ERS is European Remote Sensing Satellite; MSU is Microwave Sounding Unit; SSU is Stratosphere Sounding Unit; CMV is Cloud Motion Vector; QuikSCAT is a US satellite; and MODIS is Moderate resolution Imaging Spectroradiometer. See text for other definitions.

Observational data used in JRA-25 are shown in Fig. 1, including periods of availability. Most of the observational data were supplied by ECMWF as used in their ERA-40 project. These data consist of a merging of conventional data from both the ECMWF and NCEP/NCAR (NCEP/National Center for Atmospheric Research) archives; also from the TIROS Operational Vertical Sounder (TOVS) and Advanced TOVS (ATOVS) level 1c vertical sounding brightness temperatures; and from atmospheric motion vector (AMV) wind data from METEOSAT-2 in the 1980s that were reprocessed by EUMETSAT.

In addition to the ERA-40 observations, JRA-25 introduced some new historical observational data which had not been used previously. Wind profile retrievals surrounding tropical cyclones (TCs) were supplied by Dr M. Fiorino (of the Program for Climate Model Diagnosis and Intercomparison/Lawrence Livermore National Laboratory; Fiorino (2002)). The Meteorological Satellite Center of JMA reprocessed AMV wind data with a quality indicator (QI) for the period from March 1987 onward. Only AMV data which have high QI values assigned to them are selected, and these are assimilated after appropriate thinning. Meteorological Research Institute (MRI/JMA) digitized Chinese daily snow depth data are used for most of the JRA-25 re-analysis years until 2003, taken from 'Monthly Surface Meteorological Data in China'. The digitized data are assimilated to improve the snow analysis over China where few snow depth data were reported via the Global Telecommunications System. Precipitable water (PW) retrieved

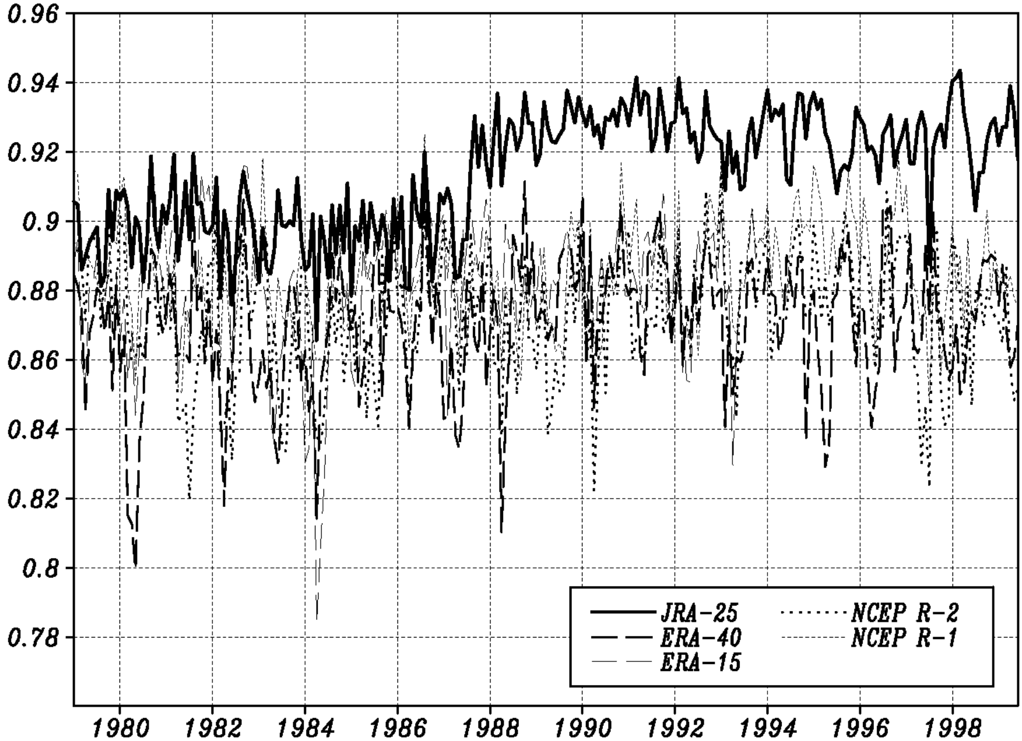

Figure 2. Spatial correlation of monthly mean JRA-25 precipitation with values from CMAP (the Climate Prediction Centre Merged Analysis of Precipitation (Xie *et al.* 1997)). JRA-25 is seen to have the best correlation, especially for the period with the assimilation of precipitable water retrieved from the Special Sensor Microwave Imager.

from Special Sensor Microwave Imager (SSM/I) brightness temperatures are assimilated from July 1987 onward, which appears to produce more accurate precipitation over the ocean. The distribution of snow coverage is also retrieved from the SSM/I data and used in snow depth analysis. The CPC/NCEP (Climate Prediction Center/NCEP) weekly snow coverage analysis is also used before the SSM/I data period (June 1987).

A new daily sea surface temperature (SST) and sea-ice dataset named COBE (Ishii *et al.* 2005) produced by JMA is used as a lower boundary condition. The global forecast model uses 3D daily ozone concentrations produced by JMA.

3. Performance of JRA-25

(*a*) *Advantages*

Many improvements have been found in the JRA-25 re-analysis and some show superior performance vis-à-vis other re-analyses.

(i) *Forecast 6-hour total precipitation* in JRA-25 compares well to observations and shows little bias, especially in the Tropics. The correlation of JRA-25 global total precipitation with both the Climate Prediction Centre Merged Analysis of Precipitation (CMAP, Xie and Arkin 1997) and Global Precipitation Climatology Project version 2 (GPCP, Adler *et al.* 2003) observational precipitation datasets is excellent, especially for the period including assimilated SSM/I PW as shown in Fig. 2. Correlation of PW with the National Aeronautics and Space Administration Water Vapour Project (NVAP,

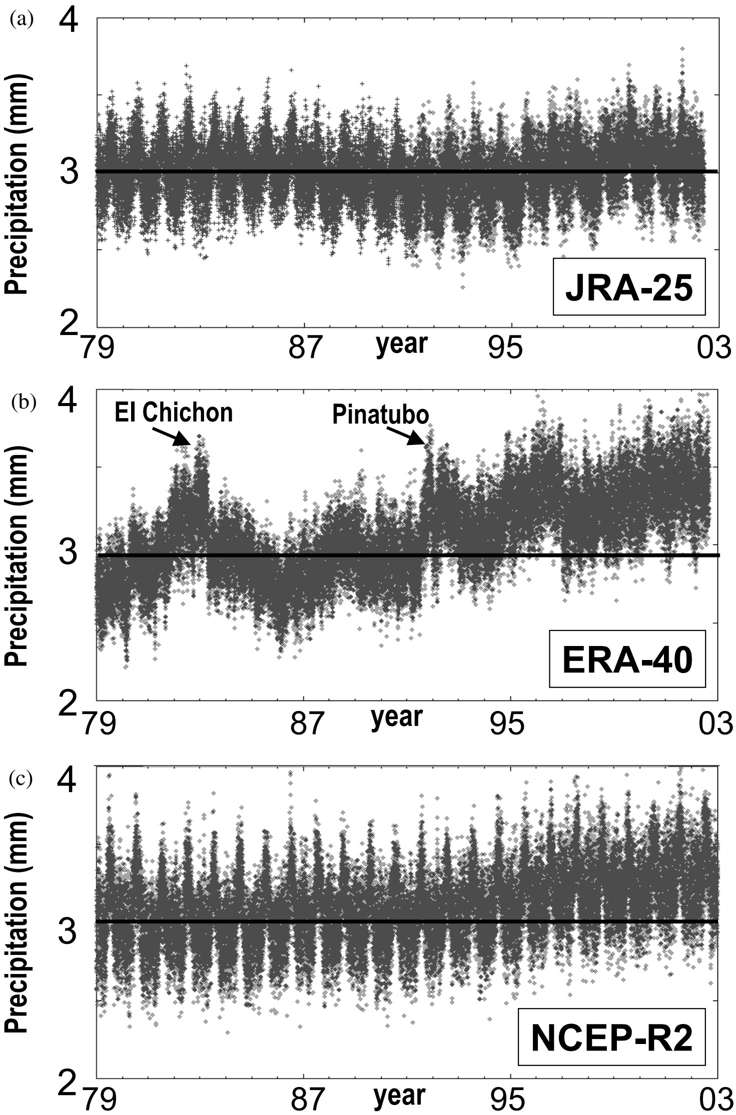

Figure 3. Comparison of time series of global mean 6 h precipitation for three re-analyses: (a) JRA-25, (b) European Centre for Medium-Range Weather Forecasts 45-year ERA-40, and (c) National Centers for Environmental Prediction (NCEP) RII.

Randel *et al.* 1996) observational dataset is also good. The time series of global-average precipitation in JRA-25 is rather stable throughout the period, without being greatly affected by volcanic eruptions, as shown in Fig. 3. In contrast ERA-40 is more variable and sensitive to volcanic eruptions such as those of Mt El Chichon in 1982 and Mt Pinatubo in 1991. In JRA-25, TOVS radiance data for which quality control could not be performed correctly were excluded. The retrieval method for SSM/I PW data and its assimilation in the 3D-Var system (Tauchi *et al.* 2004) performs very well with little bias. Quality control for the original SSM/I data is strict so as to remove erroneous data, such as wrongly located and mis-calibrated observations. This careful handling

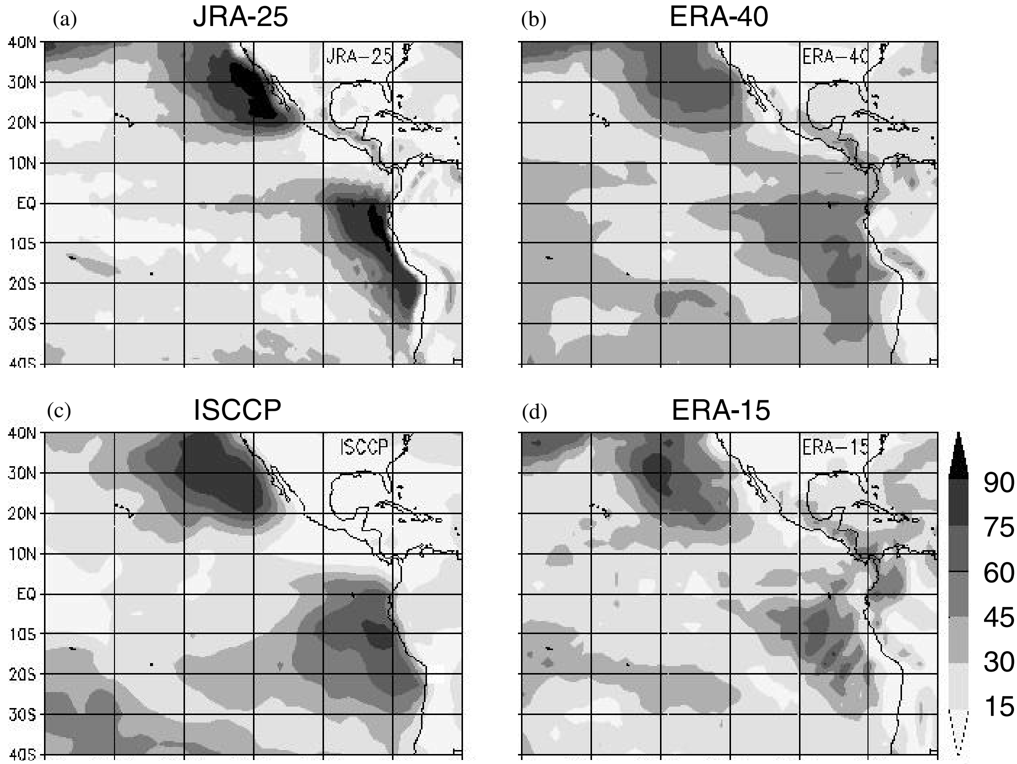

Figure 4. Monthly mean low-level cloud amounts (percent) along the subtropical western coasts of America for July 1993 from: (a) the Japanese 26-year re-analysis (JRA-25); (b) the European Centre for Medium-Range Weather Forecasts (ECMWF) 45-year re-analysis (ERA-40); (c) the International Satellite Cloud Climatology Project (ISCCP) observations; and (d) the ECMWF 15-year re-analysis (ERA-15).

of satellite data and a superior assimilation scheme contributed to the good analysis of precipitation .

(ii) *Low-level cloud along the subtropical western coast of continents* is forecast very well. A new cloud scheme (Kawai and Inoue 2006) implemented in the JMA operational system in 2004 contributed largely to the good low-level cloud analysis. The low-level cloud in the JRA-25 analyses has good consistency compared to the International Satellite Cloud Climatology Project (ISCCP) observed cloud (visible and infrared imagery of low-level cloud) as shown in Fig. 4. There is no open space between the coast and the eastern edge of the low cloud over the ocean, whilst in the other re-analyses some open spaces were found or cloud amount was not sufficient; the cloud amount of JRA-25 is more than the ISCCP amount in some areas.

(iii) *TCs are analysed precisely* owing to the assimilation of wind profile retrievals around TCs (hereafter TCR data) provided by Dr M. Fiorino, which were generated using TC best-track information such as positions and maximum surface winds. Figure 5 shows frequencies of TCs in the western and the eastern North Pacific Ocean (WNP and ENP) with the same criterion. JRA-25 has very good detection rates in both of the regions; ERA-40, and a control experiment of JRA-25 without the TCR data, perform well in WNP, but in ENP, with much sparser observational data coverage, their detection

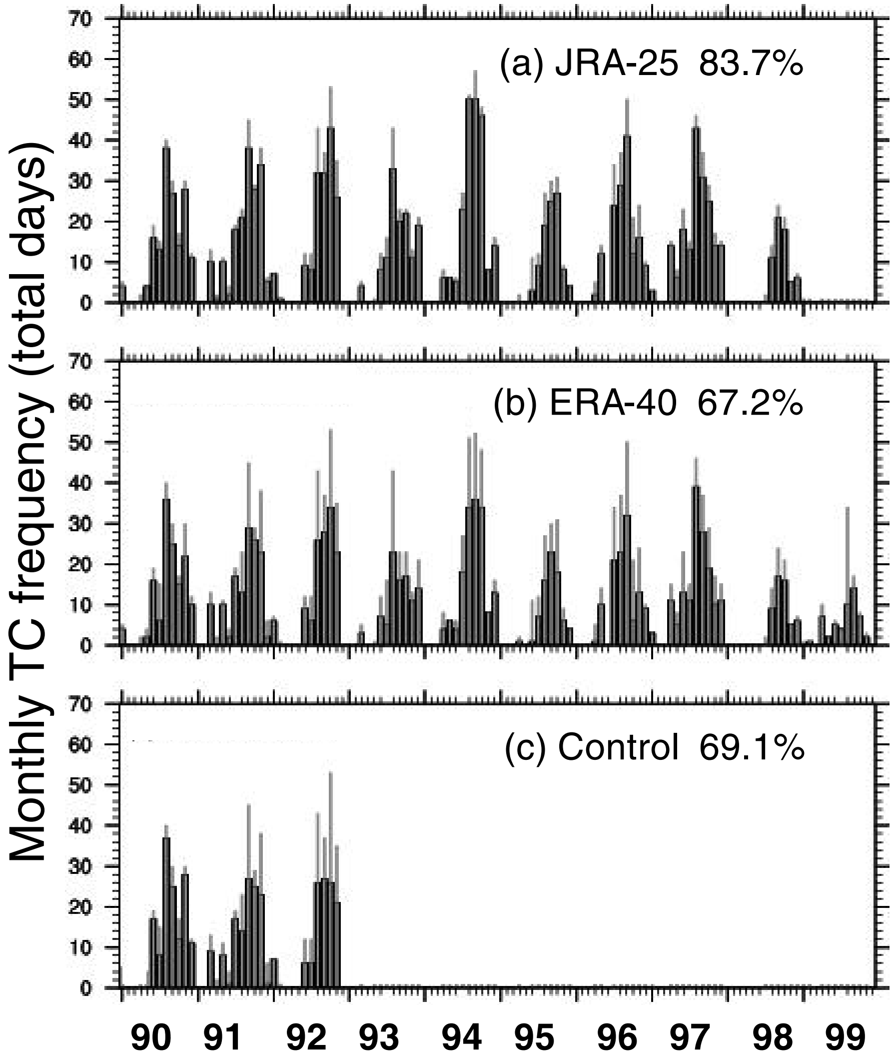

Figure 5. Tropical cyclone (TC) frequencies and detection rates in the western North Pacific for: (a) the Japanese 26-year re-analysis (JRA-25); (b) the European Centre for Medium-Range Weather Forecasts (ECMWF) 45-year re-analysis (ERA-40); (c) JRA-25 control; (d), (e) and (f) are as (a), (b) and (c), respectively, but for the eastern North Pacific. Thin grey bars and thick bars outlined in black are monthly TC frequencies of best track and re-analyses, respectively.

rates are poor. In contrast, JRA-25 has very good TC detection even in data-sparse regions. Fiorino's TCR data are quite effective in improving the analyses of TCs both in position and intensity.

(iv) *The digitized Chinese SYNOP snow depth data are effective* for snow analysis; they prevent the spread of snow covered areas in the analysis into actual no-snow areas as shown in Fig. 6. The retrieved snow depth from SSM/I contributed to a more consistent analysis of snow coverage. Since the number and distributions of SYNOP snow data are quite variable year-to-year, the snow coverage data are essential to prevent large, erroneous interannual variations.

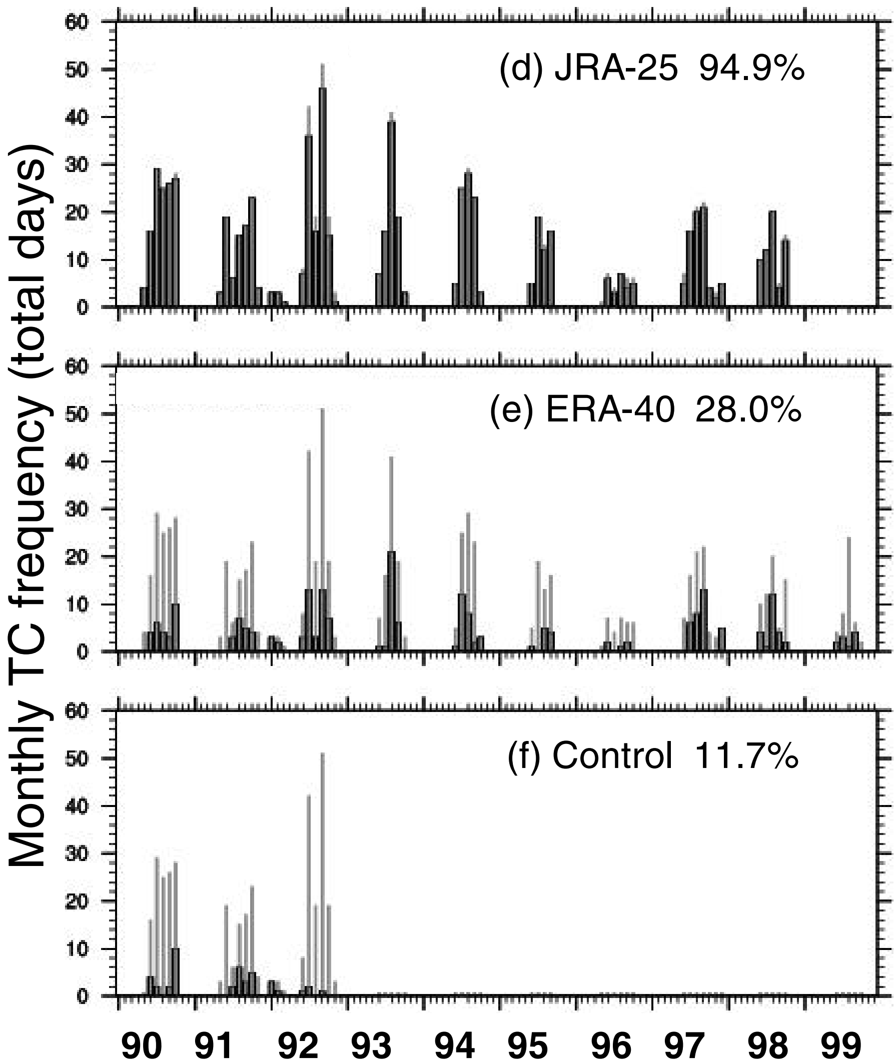

Figure 5. Continued.

(*b*) *Deficiencies*

As with all re-analysis a number of problems have been found.

(i) In the Amazonian area of JRA-25, the soil is relatively drier and the amount of precipitation less than in the other re-analyses. This problem may be due to the assimilation of a few positively biased SYNOP surface pressure observations. Since the biases were not large enough to be rejected by the quality control, in most of cases the data were assimilated and gave positive analysis increments. Consequently local high pressure was continuously generated and water vapour advected away from the Amazonian river basin. These problematic data were recently blacklisted and the excessive drying situation is thereby improved. Since soil moisture and surface air humidity do not interact directly in JRA-25, probably the advection caused the excessive drying in the region.

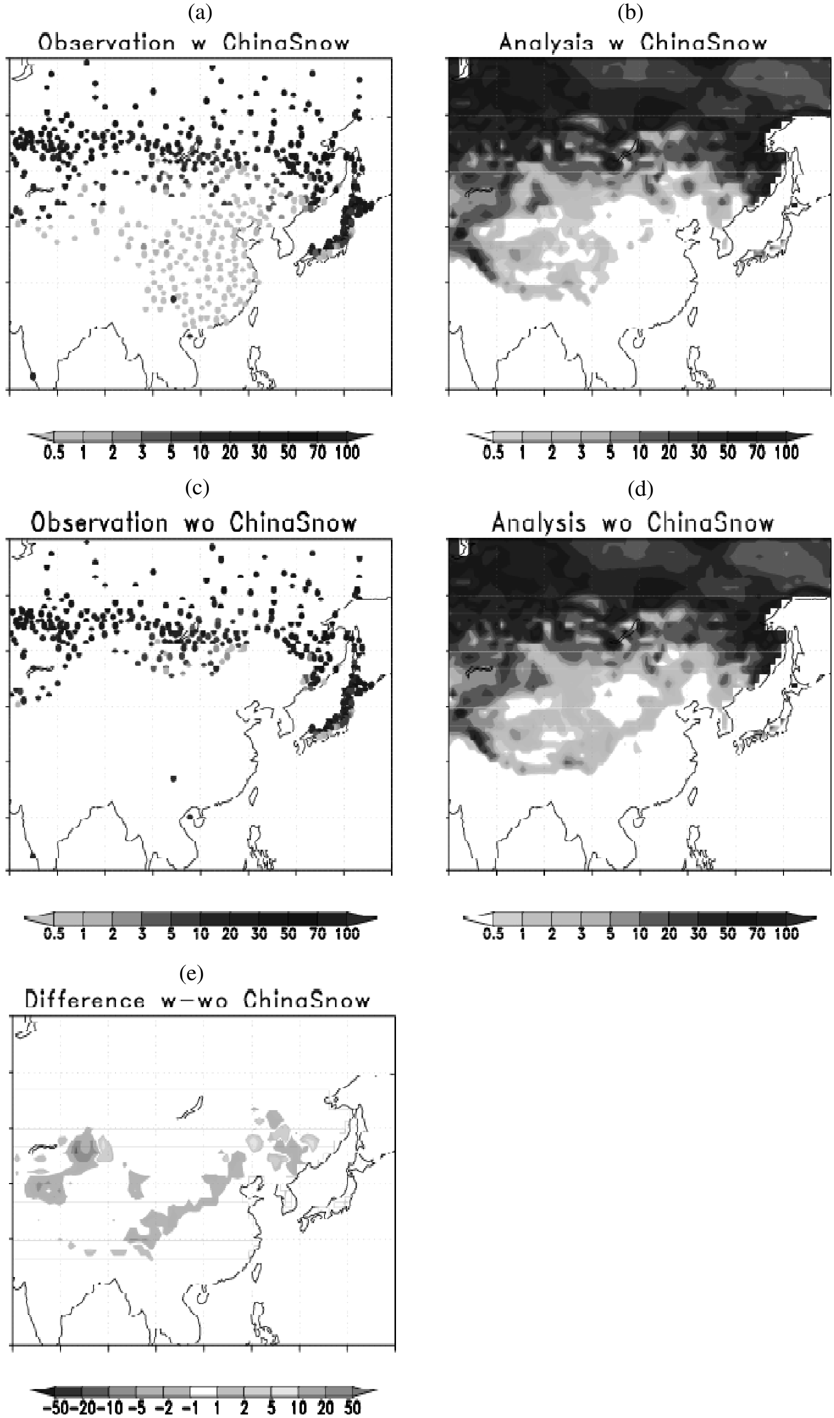

Figure 6. An example of the impact of assimilating digitized Chinese SYNOP snow data: (a) snow depth observation sites used in the Japanese 26-year re-analysis (JRA-25) showing Chinese SYNOP stations in grey; (b) the JRA-25 snow depth analysis (cm) on 31 January 1995 including Chinese observations from stations in (a); (c) observations sites in the control experiment, i.e. without Chinese snow data; (d) the control experiment analysis of snow depth on 31 January 1995; and (e) the difference between (b) and (d). Significant differences are seen around the boundary of the snow covered area and the area with no snow.

(ii) There are jumps in the time series of global mean temperature around the tropopause and in the stratosphere. Mainly these are due to biases of the background field forecast by the model. The model has significant temperature biases in the stratosphere. Since the forecast field and observed values are not consistent, the jumps are triggered by the absence of, or sudden changes in the quality of, TOVS brightness temperature observations.

4. JRA-25 AVAILABILITY

JRA-25 output a global analysis and a 6-hour forecast field every 6 hours, throughout 26 years. Every 5 days, 8-day forecasts were carried out. JMA is willing to supply JRA-25 re-analysis products for research use via the internet (from http://www.jreap.org/indexe.html). We expect that JRA-25 products will be used widely as a comprehensive climate database. Evaluation of the products and feedback are also desired for improving the numerical models.

5. FUTURE PLANS

After the completion of the production, the JRA-25 system will be incorporated into the JMA operational Climate Data Assimilation System (JCDAS). A more comprehensive report of the JRA-25 re-analysis will be written after the completion of the production. A second-generation re-analysis is planned using 4D-Var assimilation, improved physics and higher resolution.

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