1. TITLE

1.1 Data Set Title

ISLSCP II ECMWF Near-Surface Meteorology Parameters

1.2 Database Table Name(s)

Not applicable to this data set.

1.3 File Name(s)

There are 289 compressed data files with this data set. The files include data with fixed, monthly, monthly-6-hourly, and 3- hourly temporal resolutions. A complete listing of all parameters included in this data set is given in Section 8.2. When the compressed files are extrapolated, all files are named using the following general naming convention:

E40_XXXaabb_1d_YYYYMMDD_HH.asc

where

E40 Stands for ECMWF Re-Analysis (ERA-40).
XXX This is the code that identifies the parameter (See Section 8.2 for a full listing). Some codes have been assigned and/or modified by the ISLSCP II staff.
aa This indicates if the parameter is an average or mean value (“av”), “in” for instantaneous data, “d1" for the first day of the month, or "sd" for standard deviation. This can also be “_fixed” for time invariant fields.
bb This can be “fc” for forecast, or “an” for analysis.
1d This identifies the spatial resolution of the data: "1d" for 1-degree in both latitude and longitude.
YYYY 4-digit year from 1986 to 1995.
MM 2-digit month from 01 to 12.

DD 2-digit day. A value of 00 means that the file is a monthly average.

HH 2-digit hour (GMT) from 03 to 24. Depending on the parameter, this can be the end of the time period or the value AT the HH time (e.g. 06 means this is either an average from 03 to 06, or an instantaneous value at 06, denoted by "_av" or "_in" in the filename). **NOTE***:** A value of 24 is either an average from 21 to 24 or a value at 24 GMT, where 24 is the start of the next day, or hour 00. The hour 00 is not used here. Also note that the hourly time stamps are not provided for monthly data.

.asc This is the file extension, indicating that the file is in the ASCII, or text, format (See Section 8.4 for data format information).

1.3.1 Data File Descriptions

All data files are named by temporal frequency first (i.e. fixed, monthly, monthly diurnal, 6- or 3-hourly), then by parameter, and then by time stamp (e.g. year, month, day, and 6- or 3-hourly period).

<u>Fixed Fields and Boundary Conditions</u>

There are 10 files within the compressed file called **E40_fixed_1d.tar.gz**. The individual data files are named using the following naming convention:

E40_XX_fixed_1d_mZZ.asc

Where

XX is the parameter code (see the table in Section 8.2 for Fixed Fields)

ZZ is either 00 for time invariant fields or the month from 01 to 12 for the monthly varying fixed fields. Note that all the fixed field data are year-independent.

<u>Monthly Mean Fields (Analyses)</u>

There are 5,004 data files within the compressed file named **E40_monthly_analysis.tar.gz.** The data are for all 10 years. There are subdirectories named E40_variable_1d_monthly. When extrapolated, the files are named using the following naming convention:

E40_xxxan_1d_YYYYMM00.asc,

Where

XXX is the parameter code (see the table in Section 8.2 for Monthly Mean Fields (Analyses)

YYYY is the year from 1986 to 1995

an means these are analyses

MM is the month from 01 to 12, and

00 denotes a monthly value.

When a particular field contains “av”, “sd”, or “d1” files, these are all included in the same compressed file. Note that not all fields contain all three types of “av”, “sd” and “d1” files.

Example file names:

E40_SDsdan_1d_19860200.asc: standard deviation file
E40_SDavan_1d_19861200.asc: monthly average file
E40_SDd1an_1d_19861200.asc: 1st of month

Monthly Mean Fields of Precipitation (Forecasts)

The files for the monthly mean fields of precipitation are found in the compressed file named **E40_monthly_precip.tar.gz**. There are four subdirectories. When extrapolated, the files are named using the following naming convention:

E40_XXavfc4_1d_YYYYMMDD.asc

Where

XX is the parameter code

fc is for forecasts. These monthly fields contain monthly precipitation averaged over four different forecast ranges, named “fc1” through “fc4 (also see the table in Section 8.2 for the Monthly Mean Fields of Precipitation (Forecasts) parameter codes). This numbering system is related to the averaging of precipitation over different forecast ranges as seen below:

Forecast ranges:

1. fc1: Averaged over forecasts at 0, 6, 12, and 18 UTC with Step=0-6
2. fc2: Averaged over forecasts at 0 and 12 UTC with Step=0-12
3. fc3: Averaged over forecasts at 0 and 12 UTC with Step=0-12
4. fc4: Averaged over forecasts at 0, and 12 UTC with Step=0-12

Example file name:

E40_CPavfc1_1d_19860100.asc: Contains the average convective precipitation for the month of January 1986, averaged over forecasts at 0, 6, 12, and 18 UTC. There are no standard deviation or first day of the month files for the precipitation fields.

Monthly-6-Hourly (Mean 6-hour Diurnal Cycle) Fields (Analyses)

There are 14 compressed diurnal files and two monthly 6-hourly compressed data files.

6-hourly Diurnal Files:

1. **E40_10Sav_1d_diurnal6h.tar.gz…(note that this is an “average” file)**

2. **E40_10Uan_1d_diurnal6h.tar.gz**

3. **E40_10Van_1d_diurnal6h.tar.gz**

When extrapolated, the data files under files 1-3 above follow the naming convention:

E40_10xxx6an_1d_YYYYMMDD_ZZ.asc

Where

xxx is Sav, UXX or VXX (wind speed variables..see section 8.2)

YYYY is 1985-1995

MM is 01-12

DD is 00 in all cases

ZZ is 06, 12, 18, and 24 (every 6 hours)

4.E40_2Dan_1d_diurnal6h.tar.gz

When extrapolated, the data files for #4 are named

E40_2DXX6an_1d_YYYYMMDD_ZZ.asc

Where

2Dxx is a code for the dew point variable at 2 m (see section 8.2)

YYYY is 1985-1995

MM is 01-12

DD is 00 in all cases

ZZ is 06, 12, 18, and 24 (every 6 hours)

5. E40_2Tan_1d_diurnal6h.tar.gz

When extrapolated, the data files for #5 are named

E40_2TXX6an_1d_YYYYMMDD_ZZ.asc

Where

2Txx is a code for the temperature variable at 2 m. The xx is for av or sd files (average or standard deviation).

YYYY is 1985-1995

MM is 01-12

DD is 00 in all cases

ZZ is 06, 12, 18, and 24 (every 6 hours)

6. **E40_Q57an_1d_diurnal6h.tar.gz**

7. **E40_Q60an_1d_diurnal6h.tar.gz**

8. **E40_T57an_1d_diurnal6h.tar.gz**

9. **E40_T60an_1d_diurnal6h.tar.gz**

10. **E40_U57an_1d_diurnal6h.tar.gz**

11. **E40_V57an_1d_diurnal6h.tar.gz**

12. **E40_V60an_1d_diurnal6h.tar.gz**

When extrapolated, files within the compressed files 6-12 above follow the naming conventions:

E40_Q57xx6an_1d_YYYYMMDD_ZZ.asc

E40_Q60xx6an_1d_YYYYMMDD_ZZ.asc

E40_T57xx6an_1d_YYYYMMDD_ZZ.asc

E40_T60xx6an_1d_YYYYMMDD_ZZ.asc

E40_U57xx6an_1d_YYYYMMDD_ZZ.asc

E40_V57xx6an_1d_YYYYMMDD_ZZ.asc

E40_V60xx6an_1d_YYYYMMDD_ZZ.asc

Where

Q57xx is Specific humidity at level 57, Q60xx is specific humidity at level 60, T57xx is temperature at level 57, T60xx is temperature at level 60, U57xx is the U-component of wind speed at level 57, V60xx is the V-component of wind speed at level 60, and V57xx is the V-component of wind speed at level 57. The xx is for av or sd files (average or standard deviation).

YYYY is 1985-1995

MM is 01-12

DD is 00 in all cases

ZZ is 06, 12, 18, and 24 (every 6 hours)

13. E40_U60an_1d_diurnal6h.tar.gz

When extrapolated, files within the compressed file #13 above follow the naming convention:

E40_U60XX6an_1d_YYYYMMDD_ZZ.asc

Where

U60x" is the U-component of wind speed at level 60, and there are av and sd files (average or standard deviation..see section 8.2).

YYYY is 1985-1995

MM is the month from 01 to 12,

DD is 00

ZZ: Note that two types of variables (i.e. **ZZ6**) exist in the monthly-6-hourly data sets: **av6** indicates a monthly average for each 6-hour synoptic time and **sd6** indicates the standard deviation in the monthly mean for each 6-hour synoptic time. For all these analyses fields, all monthly averages are calculated from values EXACTLY AT the HH time stamp (i.e. instantaneous values).

14. **E40_LNPan_1d_diurnal6h.tar.gz**

When extrapolated, files within the compressed file #14 above follow the naming convention:

E40_LNPav6an_1d_YYYYMMDD_ZZ.asc

Where

LNP is the surface pressure variable, av files only—there are no standard deviation data files (see section 8.2).

YYYY is 1985-1995

MM is the month from 01 to 12

DD is 01-31

ZZ: Note that two types of variables (i.e. **ZZ6**) exist in the monthly-6-hourly data sets: **av6** indicates a monthly average for each 6-hour synoptic time and **sd6** indicates the standard deviation in the monthly mean for each 6-hour synoptic time. For all these analyses fields, all monthly averages are calculated from values EXACTLY AT the HH time stamp (i.e. instantaneous values).

6-hourly Files:

E40_2Dan_1d_6hourly.tar.gz

E40_2Tan_1d_6hourly.tar.gz

The individual monthly 6-hourly files are named:

E40_2X6hran_1d_YYYYMMDD_ZZ.asc

Where

2X6hran is either 2Dan or 2Tan

MM is the month from 01 to 12,

DD is 01-31

ZZ: Note that two types of variables (i.e. **ZZ6**) exist in the monthly-6-hourly data sets (see av6 and sd6 below):

av6 indicates a monthly average for each 6-hour synoptic time

sd6 indicates the standard deviation in the monthly mean for each 6-hour synoptic time. For all these analyses fields, all monthly averages are calculated from values EXACTLY AT the HH time stamp (i.e. instantaneous values).

Example file names:

E40_2Dav6an_1d_19930100_06.asc: monthly average at 06 UTC file

E40_2Dsd6an_1d_19930100_06.asc: standard deviation at 06 UTC file

E40_2Dav6an_1d_19931200_24.asc: monthly average at 24 UTC file*

E40_2Dsd6an_1d_19931200_24.asc: standard deviation at 24 UTC file*

*It is critical for users to understand that, using our ISLSCP II naming convention, the monthly 6-hourly data files at 24 UTC are monthly averages of analyses obtained at midnight of every day in the month and are equivalent to monthly averages of analyses at 00 UTC but for the very next day. This naming scheme was chosen to provide consistency amongst the forecast and analysis data sets in this ECWMF data set but also with other ISLSCP II near surface meteorology data sets. Using this naming logic there is a single file for 1985 that contains the 6-hourly monthly average for midnight (24 UTC) from December 31, 1985 through January 30, 1986. This file is archived in the archive for the year 1986 and is equivalent to a 6-hourly monthly average for 00 UTC from January 1, 1986 through January 31, 1986 **(***NOTE that 00 UTC is not used in the ISLSCP II collection***)**. Users may wish to unzip all years for a particular parameter to obtain a full listing of all files in the appropriate chronological sequence.

3-Hourly (Forecasts)

There are 270 compressed 3-hourly files **(27 variables for the years 1985-1995, for a total of 270 data files (27 variables x 10 years)).** When extrapolated, the files are named using the following naming convention:

E40_2D_in_1d_YYYYMMDD_hZZ.asc

All data (except for file #17), are for the years 1986-1995 (YYYY), January 1 (MMDD= 0101) through December 31 (MMDD=1231). File #17 data are for the years 1986-1993 (YYYY), April 1 (MMDD=0401) through December 31 (MMDD=1231).

ZZ for all files=03, 06 ,09, 12, 15, 18, 21, and 24 (times every 3 hours).

Notes:

Different variables exist in the 3- hourly data:

av means averaged -- the data are averaged over the 3-hour period.

av3 indicates a monthly average for each 3-hour synoptic time.

sd6 indicates the standard deviation in the monthly mean for each 6-hour synoptic time **(***NOTE: Standard deviations are only available at 6-hourly steps***)**. These are all forecast fields, with some parameters such as temperature and wind speed being averaged over forecasts valid AT a particular HH time stamp, and other fluxes such as precipitation or radiation being averages of *accumulated* fluxes over a 3-hour forecast period, then divided by the time period by the ISLSCP II staff (see Section 9.2.3).

in means instantaneous -- the data are valid exactly AT the given 3-hourly time stamp (i.e., 03, 06,...,24)

3-Hourly Files

1. **E40_CP_1d_3hourly.tar.gz**
2. **E40_2D_1d_3hourly.tar.gz**
3. **E40_Q57_1d_3hourly.tar.gz**
4. **E40_Q60_1d_3hourly.tar.gz**
5. **E40_T57_1d_3hourly.tar.gz**
6. **E40_U60_1d_3hourly.tar.gz**
7. **E40_T60_1d_3hourly.tar.gz**
8. **E40_V57_1d_3hourly.tar.gz**
9. **E40_2T_1d_3hourly.tar.gz**
10. **E40_SKT_1d_3hourly.tar.gz**

Example file names:

E40_Q57_in_1d_19860104_h18.asc

E40_SKT_in_1d_19860106_h12.asc

11. **E40_EWSS_1d_3hourly.tar.gz**

12. **E40_NSSS_1d_3hourly.tar.gz**

13. **E40_RO_1d_3hourly.tar.gz**

14**. E40_SLHF_1d_3hourly.tar.gz**

15. **E40_SSHF_1d_3hourly.tar.gz**

16. **E40_SSRD_1d_3hourly.tar.gz**

17. **E40_STRD_1d_3hourly.tar.gz**: Note..there are no data files for the years 1987,1989,1991,1994, or 1995. The earliest data are for 1986/04/01, and the latest data are for 1993/12/31.

18. **E40_LSP_1d_3hourly_YYYY.tar.gz**

19**. E40_SP_1d_3hourly_YYYY.tar.gz**

20. **E40_SSR_1d_3hourly_YYYY.tar.gz**

21. **E40_STR_1d_3hourly_YYYY.tar.gz**

22. **E40_SSRD_1d_3hourly_YYYY.tar.gz**

23. **E40_E_1d_3hourly_YYYY.tar.gz**

24. **E40_10U_1d_3hourly_YYYY.tar.gz**

25. **E40_10V_1d_3hourly_YYYY.tar.gz**

26. **E40_U57_1d_3hourly_YYYY.tar.gz**

27. **E40_SF_1d_YYYY_3hourly.tar.gz**

Example file names:

E40_10Sav3fc_1d_19860700_09.asc and **E40_ROav3fc_1d_19860700_21.asc** contain the monthly-3-hourly averages of forecasts for horizontal wind speed at 10-m level (10S) and runoff (RO) for July 1986, respectively. The 09 UTC wind speed monthly averages are computed from all the 3-hourly forecasts that are posted at 06 UTC.

E40_STRD_av_1d_19920210_h12.asc is the average of the forecast surface downward longwave flux from 09 to 12 UTC for February 10, 1992.

E40_2T_in_1d_19920210_h12.asc is the instantaneous forecast temperature at 2-m level at 12 GMT on February 10, 1992.

1.4 Revision Date of this Document

May 28, 2014

2. INVESTIGATOR(S)

2.1 Investigator(s) Name and Title

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2.2 Title of Investigation

ECMWF Contribution to ISLSCP Initiative II.

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2.4 Data Set Citation

Beljaars, A. C. M, A. K. Betts, and E. Brown de Colstoun. 2014. ISLSCP II ECMWF Near-Surface Meteorology Parameters. In Hall, Forrest G., G. Collatz, B. Meeson, S. Los, E. Brown de Colstoun, and D. Landis (eds.). ISLSCP Initiative II Collection. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, USA.

2.5 ISLSCP Initiative II Collection References

Users of the International Satellite Land Surface Climatology (ISLSCP) Initiative II data collection are requested to reference the following publications when these data are used:

Hall, F.G., E. Brown de Colstoun, G. J. Collatz, D. Landis, P. Dirmeyer, A. Betts, G. Huffman, L. Bounoua, and B. Meeson, The ISLSCP Initiative II Global Datasets: Surface Boundary Conditions and Atmospheric Forcings for Land-Atmosphere Studies, *J. Geophys. Res.*, 111, doi:10.1029/2006JD007366, 2006.

We acknowledge use of the ECMWF ISLSCP II data (Beljaars et al., 2002), a subset of the ERA-40 data set. Please cite the following data set when the data are used:

Beljaars, A.C.M., A. K. Betts, E. Brown, K. Fielding, P. Kallberg, S. Uppala [editors], 2004: *ECMWF ISLSCP-II near-surface dataset from ERA-40*, Available from ECMWF, Reading RG2 9AX, UK, and NASA-GSFC, Code 923, Greenbelt, MD 20771.

3. INTRODUCTION

3.1 Objective/Purpose

The ECMWF (European Centre for Medium-range Weather Forecasts) near-surface data set for the ISLSCP Initiative II data collection has been derived from the ECMWF 40-year re-analysis, or ERA-40 (Simmons and Gibson, 2000), covering the years 1957 to 2001. The purpose of ERA-40 is to produce an objective analysis of the atmosphere making optimal use of a wide range of observing systems. A recent version of the ECMWF Numerical Weather Prediction system (cycle 23r4) is used for the entire analysis period. The advantage of re-analysis over operational analysis is that no system changes occur that might affect the analysis products, although there are significant changes in the observations (see Section 3.3).

Two main elements can be distinguished in the ERA-40 system:

1. The analysis system that combined a background field in an optimal way with observations,
2. A forecast model that provides the background field by propagating the atmospheric state from one time level to the next.

The ERA-40 system works intermittently with 6-hour intervals and uses observations between 3 hours before and after the analysis time to correct the background field. The forecasts run out to 9 hours to allow comparison with observations at the right time, but the differences (increments) are used at the analysis time corresponding to the 6 hour forecast. The analysis times are the standard meteorological observing times of 0, 6, 12, and 18 UTC (Coordinated Universal Time).

The surface data set provided here has been extracted from the complete 1957-2001 archive and processed onto the ISLSCP II Earth grid.

3.2 Summary of Parameters

The fields that are supplied for ISLSCP II are near-surface meteorological fields (e.g. wind, humidity, temperature, pressure), fluxes (e.g. sensible and latent heat fluxes, radiative fluxes, stresses), and surface and sub-surface variables (e.g. sea surface temperatures, soil moisture, soil temperatures, snow variables). Some of these variables are constrained by observations (e.g. pressure, temperature, and moisture), others are the result of parameterization (e.g. fluxes). All variable in this dataset are provided on an Earth grid with a spatial resolution of 1 degree in both latitude and longitude and span the common ISLSCP II period from 1986 to 1995. Variables are provided with fixed, monthly, monthly-6-hourly and monthly-3-hourly (i.e. monthly mean diurnal cycle), 6-hourly, and 3-hourly temporal resolutions. See Section 8.2 for a complete listing of all the parameters provided here.

Some products in this data set come with 3-hour time intervals, i.e. with higher frequency than the analysis cycle. The in-between fields are part of the first guess forecast which is archived at forecast step 3 and 6. It is important to note that the difference between 6 hour forecast and analysis is always small; in other words the analysis increments are small. This means that for most applications it makes little difference whether short-range forecasts or analyses are used. We recommend using the 3 and 6-hour forecast fields, where 3-hourly time resolution is needed. A number of parameters do not even exist at analysis times as they are computed by the forecast model. The fluxes are an example of the latter: these are accumulated from the start of each forecast.

Exceptions are the 2-m temperature and 2-m moisture analyses. The 2-m level is not part of the model grid and therefore it is not really part of the atmospheric analysis (although 2-m moisture observations are used for the analysis of moisture in the lowest model levels). A completely separate analysis of 2-m temperature (T) and specific humidity (q) is done and archived as analysis. This 2-m analysis is not used as initial condition for the next first guess; it is only used to support the soil moisture and soil temperature analysis (Douville et al., 2000). Parameters T and q at the 2-m level from forecasts are post-processing products and are obtained by interpolation between the lowest model level and the surface (consistent with the model parameterization using Monin-Obukhov similarity).

3.3 Discussion

This near-surface meteorology data set from ERA-40 is one of two in this ISLSCP II data set that are derived from model analysis forecast systems (the other being the Center for Ocean-Land-Atmosphere Studies (COLA) version of the National Centers for Environmental Predictions (NCEP) Re-analysis II). The NCEP and ECMWF analysis-forecast systems differ in their model structure, physical parameterization and horizontal and vertical resolution, and in their methods of processing the input observations. Consequently there are differences between the model surface fields. Model products have biases, related to the specific model. Their advantage is that they are complete coverage and at 3-hourly time resolution. In contrast, surface observations are not uniformly distributed globally, and are sparse over many regions in the tropics, where monthly mean data or even just climatology may only be available. The ISLSCP II data set contains also a monthly mean near-surface product, based solely on observations.

4. THEORY OF ALGORITHM/MEASUREMENTS

Routine analyses were produced by operational meteorological centers in real time several times each day using the current version of the centers' global forecast model. These models are constantly being updated and improved, so that over time fundamental climatological properties of the model are also updated and improved. This makes a long time series of *operational* analyses useless for examining long-term trends or variations in climate. A reanalysis is a way to produce a global analysis of the state of the atmosphere at regular intervals over an extended period of time (many years or decades) with no gaps in space or time. This is done by using a "frozen" version of the analysis model, and performing a retrospective analysis using archives of observations going back throughout the period of record. A reanalysis also allows for the use of more observational data, as many high-quality observations are not available to the operational centers in real-time.

The ECMWF forecast system is called the Integrated Forecasting System (IFS) and has been developed in co-operation with Meteo-France. For ERA-40 it is used with 60 levels from the top of the model at 10 Pa to the lowest model at about 10 m above the surface. The spectral resolution is T159 (triangular truncation at wave number 159) with a corresponding resolution of about 110 km in grid point space. In grid point space a so-called Reduced Gaussian grid is used which has 320 points around the world at the equator, but the number reduces at higher latitudes to obtain a nearly constant grid spacing at all latitudes. This reduced Gaussian grid is also used for the land surface parameters. The ISLSCP Initiative II products have been interpolated from this grid to the 1 x 1-degree ISLSCP grid.

The analysis uses the 3-dimensional variational method (3DVAR), where a cost function is minimized that measures the difference of the model equivalent of observations to observations and the distance to the background field. The weighting of the different parts of the cost function is controlled by estimates of observation errors and background errors. The spreading of observations in the horizontal and the vertical is controlled by horizontal and vertical correlation of the background errors. Satellite observations are used by computing radiances from the model fields (forward model) and comparing them with the satellite radiances. The analysis system uses a wide range of observations, from conventional radiosonde and SYNOP observations, to ocean winds from satellite scatterometry.

The analysis of T and q at the 2-m level and the snow depth analysis are part of the so-called "surface analysis" and use a successive correction method. The model first guess is used as a background field. Because large areas over land do not have snow depth observations, a weak relaxation is applied to a specified snow depth climatology. The increments in 2-m T and q are subsequently used in the soil moisture and soil temperature analysis using and OI method (Douville et al., 2000).

There are several "epochs" with similarities in data sources and observation distribution. The satellite data has changed extensively. The main epochs are:

1. No satellite data, mid-1957-1971
2. VTPR 1972-1978
3. TOVS and Cloud Motion Winds 1979-
4. TOVS and Cloud Motion Winds and SSM/I 1987-
5. TOVS and Cloud Motion Winds and SSM/I and ERS 1991-
6. TOVS and Cloud Motion Winds and SSM/I and ERS and ATOVS 1998-

(TOVS= TIROS Operational Vertical Sounder; SSM/I= Special Sensor Microwave Imager; VTPR= Vertical Temperature Profile Radiometer). Thus the ISLSCP period of 1986-1995 spans the introduction of the satellite microwave data from SSM/I. The eruption of Mt. Pinatubo in 1992, which put volcanic aerosol into the stratosphere, impacts the TOVS radiances, which in turn impact the tropical circulation and rainfall, mainly over the tropical oceans. This adverse impact is present in ERA-40.

<u>Satellite Observations</u>

ERA-40 uses these data, in the form of the Level-1c radiances calibrated in house from Level-1b counts. A full TOVS-1b dataset, 1979-1998, was obtained from the National Center for Atmospheric Research (NCAR), NASA and LMD. The TOVS and ATOVS data from 1998 onwards is taken from the ECMWF archives. VTPR data (8-channel infrared instrument), 1972-1979, will be used for the first time in a data-assimilation as radiances. All earlier data-assimilations of VTPR data have been based on the old temperature and humidity retrievals. The direct use of radiances should reveal interesting potential of these older data. SSM/I data are used in ERA-40. The first satellite, F08, was launched in June 1987. The data, from one satellite at any time, originates from F. Wentz in the form of navigated antenna temperatures, which are then calibrated into brightness temperatures (Wentz, 1991). In contrast to the use of TOVS and VTPR radiances the use of SSM/I radiances involves a one dimensional variational analysis of the Total Column Water Content and surface wind speed. Scatterometer winds over oceans and altimeter wave height data from the European Space Agency (ESA) ERS satellites will be used from 1991 onwards in the wave analysis. Cloud Motion Wind processing techniques have been improved throughout the period, and EUMETSAT has initiated a task to reprocess the wind information from, at least, Meteosat-2. The ozone observations to be used in the ERA-40 are from the Total Ozone Mapping Spectrometer (TOMS) total ozone and from the Solar Backscatter Ultraviolet Instrument (SBUV) ozone layer measurements and TOVS High

Resolution Infrared Radiation Sounder (HIRS) channel 9 radiances. All these observations are available from 1978 to present time. The HIRS channel 9 radiance gives information on ozone in the upper troposphere and lower stratosphere, where ozone absorbs infrared radiation. The SBUV (and the SBUV/2) instrument measures solar backscattered radiation and gives information on ozone in 7-8 layers in the middle stratosphere and above. The TOMS instrument also measures solar backscattered radiation and gives accurate bounds on the total ozone content, which may possibly lead to more accurate estimates of lower tropospheric ozone.

<u>Conventional Observations</u>

Conventional data for ERA-40 came from a much wider selection of sources. The ERA-40 period begins with the International Geophysical Year of 1958 when the foundation for the current conventional network was established. Most of these data have been collected by NCAR and are used in ERA-40. The data sets used in ERA-15 such as ECMWF observation archive, FGGE, ALPEX and PAOBs are also included. A fully updated Comprehensive Ocean-Atmosphere Data Set (COADS) has been provided by NCAR. Separate additional datasets have been received from JMA and US Navy archives. In order to extract a unique stream of observations for the analysis, a Observation Data Base (ODB) software has been developed. Conventional observations from all sources are included in the database. A prior knowledge of the quality of each dataset has to be known in order to flag identified duplicates using information from the reports. Satellites allow for a more observation-driven stratospheric analysis during the second half of the ERA-40 period. The conventional network experienced large changes, e.g., disappearance of Ocean Weather Ships, improvement of the radiosonde network in the southern hemisphere and the gradually improving World Wide Web system found during the ERA-15 period (1979-93).

5. EQUIPMENT

This data set is derived from models, using a wide variety of surface and/or near-surface observations, and satellite measurements (see above). It is beyond the scope of this document to describe the various instruments and their calibration information.

5.1 Instrument Description

5.1.1 Platform (Satellite, Aircraft, Ground, Person)

See above.

5.1.2 Mission Objectives

See above.

5.1.3 Key Variables

Various.

5.1.4 Principles of Operation

See above.

5.1.5 Instrument Measurement Geometry

See above.

5.1.6 Manufacturer of Instrument

See above.

5.2 Calibration

5.2.1 Specifications

5.2.1.1 Tolerance

See above.

5.2.2 Frequency of Calibration

See above.

5.2.3 Other Calibration Information

None.

6. PROCEDURE

6.1 Data Acquisition Methods

All ERA-40 data were provided to the ISLSCP II project on digital tapes. All data were decoded from their original GRIB format to the ASCII format by the ISLSCP II staff.

6.2 Spatial Characteristics

6.2.1 Spatial Coverage

ERA-40 and this ECMWF ISLSCP II near-surface data set from ERA-40 have global coverage. Some parameters (e.g. radiation) are truly global in nature while others such as soil moisture, for example, are only defined over land. Sea ice is only defined over water.

6.2.2 Spatial Resolution

ERA-40 spatial resolution is T-159. For ISLSCP II, the data have been regridded from the model Gaussian grid to the ISLSCP II onto a uniform, equal-angle, global Earth grid with a spatial resolution of 1-degree in both latitude and longitude (see Section 9.1). Some of the atmospheric fields are at model level 57 and model level 60, which is roughly 125 m and 10 m above the surface. Their precise height above the surface depends on surface pressure and virtual temperature. Model levels are defined in terms of pressure with respect to surface pressure. First pressure at half levels are defined

$$P_{k+1/2} = A_{k+1/2} + B_{k+1/2}\, P_s \qquad 1)$$

where P_s is surface pressure. The constants A and B define the levels give below:

K	$A_{k+1/2}$	$B_{k+1/2}$
56	210.393890	0.97966272
57	65.889236	0.98827010
58	7.367743	0.99401945
59	0	0.99763012
60	0	1

The pressure at full level is given as

$$P_k = P_{k-1/2} + P_{k+1/2} \qquad 2)$$

The resulting pressure for levels 57 and 60 are given by:

$$P_{57} = 138.141563 + 0.98396641 \; P_s \qquad 3)$$
$$P_{60} = 0.9988151 \; P_s \qquad 4)$$

To compute the height above the surface it is necessary to use the hydrostatic equation.

6.3 Temporal Characteristics

6.3.1 Temporal Coverage

Data have been extracted from the ERA-40 archive for the ISLSCP II time span, January 1, 1986 to December 31, 1995.

6.3.2 Temporal Resolution

- Time invariant or fixed
- Climatological monthly fields or monthly varying fixed fields
- Monthly means and 1st of month fields
- Monthly averages of 6-hourly analysis fields
- 6-hourly analysis fields
- 3-hourly forecast fields

7. OBSERVATIONS

7.1 Field Notes

Not applicable to this data set.

8. DATA DESCRIPTION

8.1 Table Definition with Comments

Not applicable to this data set.

8.2 Type of Data

The following is extracted from the ECMWF documenter, slightly edited for clarity. The fields as supplied to the ISLSCP II project were put in different files according to their type. An original file may contain a large number of fields which are identified by:

PARAM= code that identifies the parameter (see Tables below). DATE = date representing the start of a forecast or analysis time.
TIME = time representing the start of a forecast or analysis time.
STEP = forecast step in hours (0 for analysis).
STREAM= 1025 for daily archive, i.e. normal analyses and forecasts,
1043 for monthly means at SYNOP times
1070 for monthly standard deviations at SYNOP times
1071 for monthly daily averages
1072 for monthly standard deviations over different times of the day

The ISLSCP II staff has used the information above for all processing and file naming decisions.

A) Fixed Fields

These fields are so-called 'climatological' or fixed fields and are constant during the project. The background albedo is a monthly field that is interpolated in time between the 15th of each month in order to obtain a smooth seasonal evolution.

8.2.1 Parameter (CODE)	**8.2.2 Parameter/ Variable Description**	**8.2.3 Data Range**	**8.2.4 Units/source**
SR (173)	Surface roughness length for momentum	0.001-99.999	m/ERA-40
LSRH (234)	Logarithm of surface roughness length for heat	-20.000 to -1.3892	Unitless
AL (174)	Albedo background (climatological monthly mean)	0.07 to 0.4918	Unitless
Z (129)	Geopotential of model surface (Orography * g)	0 to 51793	m^2/s^2
LSM (172)	Land/Water mask used to process data: 0 = Water 1 = Land	0-1	See 8.2.2
MASK_DIF	Differences between the ISLSCP II land/water mask and the original land/water mask above: 0 = Data sets agree over land or water 1 = ISLSCP II mask is water and original data is land (n=48) 2 = ISLSCP II mask is land and original data is water	0-2	See 8.2.2/ LSM and ISLSCP II land/water mask
CVL (027)	Low vegetation fraction	0-1	Unitless/ERA-40
CVH (028)	High vegetation fraction	0-1	Unitless
TVL (029)	Low vegetation dominant type. Types not available at this revision.	0-17	See 8.2.2
TVH (030)	High vegetation dominant type. Types not available at this revision.	0-19	See 8.2.2

B) Monthly Mean Fields (Analyses)

- Monthly averages for the following fields have been obtained by averaging over analyses for 0, 6, 12, and 18 UTC and all days of the month (GRIB headers DD=0). The stream is 1071 with step=0.
- 1st of the month data are for the analyses of 12 UTC. The stream is 1025 with step=0.
- Standard deviations have been obtained from fields of 0, 6, 12, 18 UTC and all days of the month (Step=0; Stream=1072).

8.2.1 Parameter (CODE)	8.2.2 Parameter/ Variable Description	8.2.3 Data Range #	8.2.4 Units/source
SD (141)	Snow Depth.	0 to 10 Ocean = -999	m of water/ERA-40
ASN (032)	Snow Albedo.	0.5 to 0.85 Ocean = -999	Unitless
RSN (033)	Snow Density	100-300 Ocean = -999	Kg/m^3
TSN (238)	Snow Temperature	218.93-273.16 Ocean = -999	degrees K
SWL1 (039)	Soil Moisture Layer 1	O to 0.4693 Ocean = -999	m^3/m^3
SWL2 (040)	Soil Moisture Layer 2	0 to 0.4676 Ocean = -999	m^3/m^3
SWL3 (041)	Soil Moisture Layer 3	0 to 0.4624 Ocean = -999	m^3/m^3
SWL4 (042)	Soil Moisture Layer 4	0 to 0.4692 Ocean = -999	m^3/m^3
STL1 (139)	Soil Temperature Layer 1 + Sea Surface Temperature (SST) over Ocean	222.51-313.65 Ocean = -999	degrees K
STL2 (170)	Soil Temperature Layer 2 + SST	225.36-313.4 Ocean = -999	degrees K
STL3 (183)	Soil Temperature Layer 3 + SST	222.97-311.78 Ocean = -999	degrees K
STL4 (236)	Soil Temperature Layer 4 + SST	217.58-309.67 Ocean = -999	degrees K
CI (031)	Sea Ice Fraction	Min = 0 Max = 1 Land = -888	Unitless
SMIR (022)*	Soil Moisture Availability Index (Root Zone)	0-1 Ocean = -999	Unitless
SMIB (023)*	Soil Moisture Availability Index (Bare Soil)	0-1 Ocean = -999	Unitless

Range values have been obtained for January 1989.
* These parameters did not have a GRIB ID. The ISLSCP II staff assigned the ID.
***NOTE: Standard deviations are not available for CI, SMIR and SMIB.

C) Monthly Mean Fields of Precipitation (Forecasts)

These monthly fields listed below contain monthly precipitation averaged over four different forecast ranges, named “fc1” through “fc4”:

- fc1: step: 0-6 (averaged over forecasts from 0,6,12, 18 UTC)
- fc2: step: 0-12 (averaged over forecasts from 0,12 UTC)

- fc3: step: 12-24 (averaged over forecasts from 0,12 UTC)
- fc4: step: 24-36 (averaged over forecasts from 0,12 UTC)

The data stream for these data is 1071. In the model precipitation is represented by the following 4 terms: large-scale rain (LSP), convective rain (CP), large-scale snowfall and convective snowfall. LSP is the sum of terms 1 + 3, CP is the sum of terms 2 + 4, and SF is the sum of terms 3 + 4. Total precipitation is the sum of LSP+CP. The ISLSCP II staff has produced fields for monthly averaged total precipitation (TOTP) using the appropriate LSP and CP fields over the different forecast ranges.

8.2.1 Parameter (CODE)	8.2.2 Parameter/ Variable Description	8.2.3 Data Range #	8.2.4 Units	8.2.5 Data Source
Monthly Mean Fields of Precipitation (Forecasts)				
LSP (142)	Large Scale Precipitation Rate	0-0.1153E-02	mm/s	ERA-40
CP (143)	Convective Precipitation Rate	0-0.7803E-03	mm/s	
SF (144)	Snow Fall Rate	0-0.1147E-03	mm/s	
TOTP *	Total Precipitation Rate, calculated as the sum of LSP and CP	0-0.1933E-02	mm/s	Computed

Range values have been obtained for September 1990 for “fc2”.
* The ISLSCP II staff assigned the ID.

D) Monthly 6-hourly (Mean 6-hour Diurnal Cycle) Fields (Analyses)
The monthly 6-hourly analysis fields listed below contain monthly averages and standard deviations of 6-hour fields averaged over different synoptic times (i.e. 06, 12, 18 and 24 UTC). The 10S and LNP fields do not contain standard deviation information. For the mean files Step=0 and Stream=1073 while for the standard deviations Stream=1070.

8.2.1 Parameter (CODE)	8.2.2 Parameter/ Variable Description	8.2.3 Data Range #	8.2.4 Units/source
2T (167)	Temperature at 2 m level	227.33 to 306.53	degrees K/ERA-40
2D (168)	Dew point at 2 m level	224.10 to 298.75	degrees K
10U (165)	U-component of wind speed at 10 m	-9.6303 to 10.187	m/s
10V (166)	V-component of wind speed at 10 m	-10.965 to 9.0245	m/s
10S (207)*	Horizontal wind speed at 10 m	0.56327 to 13.628	m/s
U57 (131)	U-component of wind speed at level 57	-11.956 to 12.937	m/s
V57 (132)	V-component of wind speed at level 57	-13.192 to 11.442	m/s
T57 (130)	Temperature at level 57	233.20 to 305.33	degrees K
Q57 (133)	Specific humidity at level 57	0.92408E-04 to 0.19091E-01	kg/kg
U60 (131)	U-component of wind speed at level 60	-9.6794 to 10.185	m/s
V60 (132)	V-component of wind speed at level 60	-11.021 to 9.0481	m/s
T60 (130)	Temperature at level 60	228.71 to 307.28	degrees K
Q60 (133)	Specific humidity at level 60	0.56757E-04 to 0.19558E-01	kg/kg
LNP (152)*	Surface Pressure	52444 to 103390	Pa/Computed

The data ranges were obtained from the 19851200_24.asc files (i.e. midnight of every day in the month).

*The ISLSCP II staff assigned the ID to these parameters. The original GRIB IDs were 10SI and LNSP. These two fields do not contain standard deviation files (i.e. only 48 files per year).

E) 6-hourly Fields (Analyses)

The 6-hourly fields are at Step=0 and Stream=1025 for 06, 12, 18 and 24 UTC.

8.2.1 Parameter (CODE)	8.2.2 Parameter/ Variable Description	8.2.3 Data Range #	8.2.4 Units/source
2T (167)	Temperature at 2 m level		degrees K/ERA-40
2D (168)	Dew point at 2 m level		degrees K/ERA-40

The data ranges are not available at this revision.

F) 3-hourly Fields (Forecasts)

The 3-hourly fields are at Step=3 and 6 and Stream=1025.

8.2.1 Parameter (CODE)	8.2.2 Parameter/ Variable Description	8.2.3 Data Range #	8.2.4 Units/Source
2T (167)	Temperature at 2 m level		degrees K/ERA-40
2D (168)	Dew point at 2 m level		degrees K
10U (165)	U-component of wind speed at 10 m		m/s
10V (166)	V-component of wind speed at 10 m		m/s
U57 (131)	U-component of wind speed at level 57		m/s
V57 (132)	V-component of wind speed at level 57		m/s
T57 (130)	Temperature at level 57		degrees K
Q57 (133)	Specific humidity at level 57		kg/kg
U60 (131)	U-component of wind speed at level 60		m/s
V60 (132)	V-component of wind speed at level 60		m/s
T60 (130)	Temperature at level 60		degrees K
Q60 (133)	Specific humidity at level 60		kg/kg
SP (152)*	Surface Pressure		Pa/ Computed from LNSP
SKT (235)	Skin Temperature		degrees K
EWSS (180)	U stress		N/m^2
NSSS (181)	V stress		N/m^2
SSR (176)	Surface net SW radiation		W/m^2
STR (177)	Surface net LW radiation		W/m^2
SSRD (169)	Surface SW downward		W/m^2
STRD (175)	Surface LW downward		W/m^2
SSHF (146)	Surface sensible heat flux		W/m^2
SLHF (147)	Surface latent heat flux		W/m^2
E (182)	Surface Evaporation Rate		m/s
LSP (142)	Large Scale Precipitation Rate		mm/s
CP (143)	Convective Precipitation Rate		mm/s
SF (144)	Snowfall Rate		mm/s
RO (205)	Runoff Rate		mm/s

The data ranges are not available at this revision.
*The ISLSCP II staff assigned the ID to this parameter. The original GRIB ID was LNSP.

8.3 Sample Data Record

Not applicable to this data set.

8.4 Data Format

All of the files in the ISLSCP Initiative II data collection are in text format. The file format for the ECMWF data files consists of numerical fields in scientific, or E- notation (e.g. "1.6343E+01") with a fixed 12-character length, which are delimited by one or two spaces and arranged in columns and rows. The files all contain 360 columns by 180 rows. Water data are encoded as "-9.9900E+02" for appropriate parameters. Land is coded as –8.8800E+02 in the sea ice fraction fields.

These files are gridded to a common 1-degree, equal-angle lat/long grid, where the coordinates of the upper left corner of the files are located at 180 degrees W, 90 degrees N and the lower right corner coordinates are located at 180 degrees E, 90 degrees S. Data in the files are ordered from North to South and from West to East beginning at 180 degrees West and 90 degrees North.

8.5 Related Data Sets

Related ISLSCP II data sets can be obtained at http://daac.ornl.gov/ISLSCP_II/islscpii.shtml.

9. DATA MANIPULATIONS

9.1 Formulas

9.1.1 Derivation Techniques/Algorithms

Interpolation Procedure

The ECMWF model grid has been interpolated to the ISLSCP 1-degree x 1-degree grid, as much as possible consistent with the land sea mask definitions. The ECMWF land sea mask (**E40_LSM_fixed_1d_m00.asc** file) and the ISLSCP II land/water masks are used to ensure that only land points are transformed into land points and only sea points are used for sea points. For every grid point on the target grid, the 4 surrounding points of the input grid are considered and only those points are selected that are of the same type as the target grid point (sea for sea and land for land). If all four points are of the same type bi-linear interpolation is used. If the four neighbors do not all have the same type, the nearest neighbor of matching type is used. If all four neighbors have different type from the new point, they are all used. The latter applies to locations where for instance the ISLSCP LSM has a lake, whereas the ERA-40 LSM has land points in the surroundings only. In this case the consistency between land sea masks is lost. The differences between the ISLSCP II and ECMWF land/water masks are shown on Figure 1 (p.23) and also provided in the file named **E40_MASK_DIF_fixed_1d_m00.asc**. Figures 2-6 (pp. 23-24) illustrate the effect of land/sea mask consistent interpolation in the Mediterranean area.

9.2 Data Processing Sequence

9.2.1 Processing Changes

Not available at this revision.

9.2.2 Processing by the ISLSCP II Staff

All ERA-40 data were provided by ECMWF in the GRIB format. Data were read from digital tapes and the GRIB files were decoded to the ASCII format using the GRIB decoder called "wgrib" created by Dr. Wesley Ebisuzaki at NCEP. A comparison was made between the ISLSCP II and the ECMWF land/water masks and the file **40_MASK_DIF_fixed_1d_m00.asc** was created that shows the differences between the two masks. For monthly parameters such as soil moisture that are only defined on land, the water cells in the ECMWF mask were imposed with a value of –999. For the monthly sea ice data, the land cells were imposed as –888 and all cells with a fill value of 9.999E+20 over water with no ice were set to zero. For monthly precipitation averages, total precipitation was calculated as the sum of large-scale precipitation and convective precipitation. All accumulated precipitation fields in units of m of water were re-calculated as precipitation rates in mm/s by multiplying the data by 1000/(6*3600) for the "fc1" fields, and by 1000/(12*3600) for the "fc2-fc4" fields. Very small spurious negative precipitation values (e.g. -0.1E-17) were set to zero before the calculation. For the monthly 6-hourly files the only changes were made to the surface pressure fields, which were originally provided as the logarithm of surface pressure in Pa (GRIB ID=LNSP). The surface pressure in Pa was retrieved as $LNP = e^{(LNSP)}$

The processing of the monthly 3-hourly data was complex because of the large number of files, the number of different types of parameters involved, the organization of the GRIB files and the methods used by ECWMF to calculate the monthly averages. Processing for monthly 3-hourly fields such as 2T, 2D, 10U, 10V and 10S was done directly by extracting the appropriate ASCII files directly from the GRIB files using 'wgrib' but without any calculations. Within the GRIB files, the files were organized such that, for any one parameter, a monthly *3-hourly* forecast file was followed by a monthly *6-hourly* forecast file and then by another monthly *3-hourly* forecast and so forth. The first four files for 1986, for example, were:

1. monthly 3-hourly average forecast posted at 00 UTC and valid at 03 UTC
2. monthly 6-hourly average forecast posted at 00 UTC and valid at 06 UTC
3. monthly 3-hourly average forecast posted at 06 UTC and valid at 09 UTC
4. monthly 6-hourly average forecast posted at 06 UTC and valid at 12 UTC

It is important to note that every eighth file for each parameter contained a monthly 6- hourly average forecast posted at 18 UTC and valid at 24 UTC (or 00 UTC) but with a date of minus one day with regards to the previous seven entries. In keeping with our 24 UTC naming convention, these files were assigned to 24 UTC of the previous month and/or year. For surface pressure the same calculation was done as shown above for the monthly 6-hourly data. Users wishing to examine the original GRIB headers are welcome to contact the ISLSCP II contact person for access.

All other fields besides the ones just described were monthly averages of *accumulated* fields, meaning that the values used for the monthly averages accumulated over the 3-hourly or 6-hourly forecast periods. In order to obtain 2, 3-hourly periods from the given 3-hourly and 6-hourly forecast periods in the GRIB files, we subtracted the first 3-hourly period from the 6-hourly period to obtain the second 3-hourly period. As an example, a 3-hourly forecast from 06 UTC to 09 UTC would give us the first accumulated period. A 6-hourly forecast from 06 UTC to 12 UTC is the next file in the GRIB file and would give us the next accumulated file, yet it overlaps the first 3-hourly period. However, we need to get the accumulated 3-hourly flux from **09 UTC to 12 UTC** so we have to subtract the first 3-hourly period from the 6-hourly forecast. We have done this to all accumulated fields for both monthly 3-hourly and 3-hourly forecasts fields. In addition, we have divided the values of each field by the number of seconds in each accumulation time period. For EWSS, NSSS, SSR, STR, SSRD, STRD, TSR, TTR, SSHF, SLHF all data were divided by 10800s (i.e. 3*3600s). LSP, CP and SF were processed to units of mm/s by dividing the original units of m of water by 10.8 but the data were also quality checked for any spurious negative values that were set to zero. Surface evaporation (E) was also processed into units of mm/s but the data had to be allowed to be negative. Water bodies in snow evaporation (ES), snow melt (SMLT), and runoff (RO) fields were set to –999 by using the water areas of the ECMWF land/water mask and units set to mm/s as well. Runoff and snowmelt fields with any negative values were set to zero as with the precipitation fields.

For the accumulated monthly 3-hourly averages from 21 to 24 UTC we used monthly 3-hourly average forecasts from 18 to 21 UTC and monthly 6-hourly average forecasts from 18 to 24 UTC. However, we encountered similar organizational problems in the GRIB files as we described above, in that the eighth file (6-hourly forecast from 18 to 24 UTC) in the file sequence was shifted to one day earlier than the seventh file (3-hourly forecast from 18 to 21 UTC). So the eighth file for 1988, for example, was the monthly 6-hourly average forecast for 18 to 24 UTC using values starting on 12/31/1987 and ending on 01/30/1988 (31 days). In contrast, the seventh file for 1988 was the monthly 3-hourly average forecast for 18 to 21 UTC using values starting on 01/01/1988 and ending on 01/31/1988 (also 31 days). While this mismatch was pointed out to ECWMF it was agreed that the error was probably quite small and that it was still reasonable to proceed with the creation of the 21 to 24 UTC monthly 3-hourly data from the subtraction of the monthly 3-hourly 18 to 21 UTC data from the monthly 6-hourly 18 to 24 UTC data as was done for all other accumulated fields. Division by the number of seconds in the time period and the same exact adjustments as described above were performed on these files as well. We also note that the very first accumulated file in the monthly 3-hourly files is actually a monthly **6-hourly** average from 18 to 24 UTC with a starting date of 12/31/1985. No monthly 3-hourly forecast from 18 to 21 UTC for 12/31/1985 file was provided so this file was processed as a 6-hourly file, as were all standard deviation files, meaning that all accumulated files were divided by 6*3600 seconds instead of 3*3600 as for the 3-hourly data. Otherwise, the units of all standard deviation files have been adjusted in the same way as those of the 3-hourly data.

The 6-hourly analyses and 3-hourly forecast fields were written directly from the GRIB files using the ‘wgrib’ decoder. Other than the very large number of files and data storage issues, no difficulties were encountered in GRIB file structure with these data. The data were processed in the same way as described above for both‘instantaneous’ and accumulated fields. The 3-hourly surface pressure was recalculated from the logarithm of surface of surface pressure. The water portion of the ECMWF land/water mask was applied as –999 to the 3-hourly runoff fields. The 6-hourly and 3- hourly data were processed and written directly from the GRIB data to binary files. Then these binary files were converted into ASCII files.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None given at this revision.

9.4 Graphs and Plots

See Figures 1 to 6 on the next two pages.

10. ERRORS

10.1 Sources of Error

Surface data from an analysis-forecast system depend largely on the physical parameterizations of the model constrained by the observations, where these are available. Douville et al. (2000) describes the surface and sub-surface data assimilation scheme.

The GRIB packing used to provide the data to the ISLSCP II staff and the way the ISLSCP II staff processed some fields such as precipitation can introduce some very small errors. The GRIB packing takes the minimum and maximum of a field and divides the range between min and max in 2**16 levels. The max and min are different for the 3 and 6 hour forecasts, so for example it is possible that the accumulation for 6 hours has a smaller number than the accumulation for 3, giving on subtraction a spurious small negative value. In some cases the 3-h accumulations were also negative. Note that this is simply related to the limited accuracy of the GRIB packing in the original archives. The user will notice this for fields like precipitation, because it has some points with very high values in the Tropics. The ISLSCP II staff eliminated any of these very small (on the order of –0.1E-17 m) and unphysical negative precipitation values from all precipitation and runoff fields. However, it is reasonable to assume that this very small error term is also positive but a satisfactory and robust method to address this problem could not be implemented at this revision. Users wishing to minimize this problem may request GRIB file headers with raw data min/max information for all fields.

Interpolated EHA40-LSM - originalISLSCP-LSM

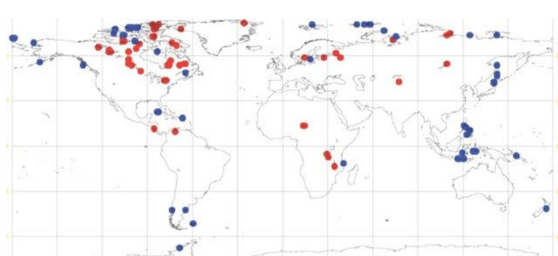

Figure 1. Points for which consistency between ERA-40 and ISLSCP land sea mask could not be obtained. Red: Land points in interpolated field where ISLSCP has sea points. Blue: Sea points in interpolated field where ISLSCP has land points.

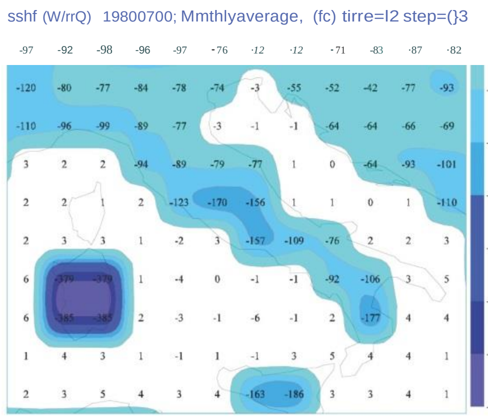

Figure 2. Example of monthly mean sensible heat flux in the Mediterranean area on the ISLSCP 1 x 1-degree grid. The printed values are the grid point values. Downward fluxes are positive (land sea masks were used for the interpolation).

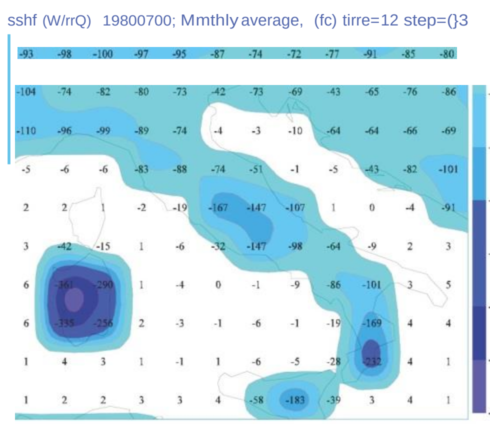

Figure 3. Example of monthly mean sensible heat flux in the Mediterranean area on the ISLSCP 1 x 1-degree grid. The printed values are the grid point values. Downward fluxes are positive (interpolation was done without land sea mask information).

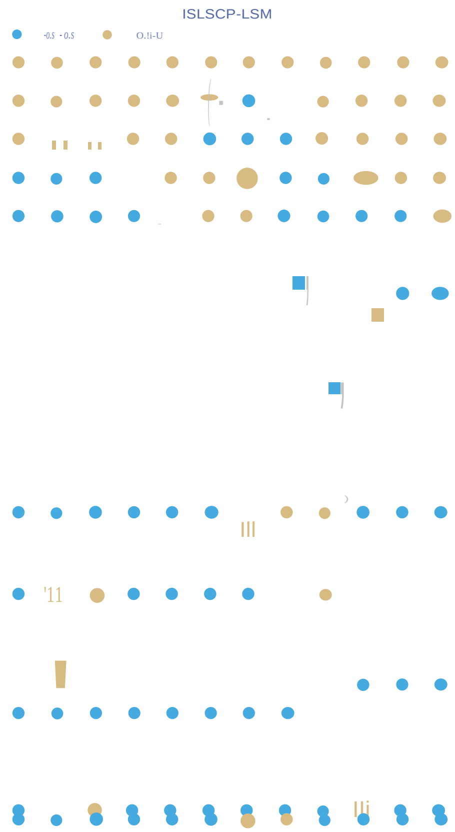

Figure 4. ISLSCP 1 degree x 1 degree land sea mask for the Mediterranean area.

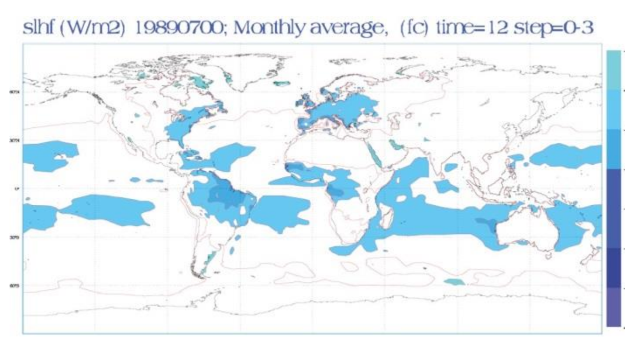

Figure 5. Example of monthly averaged latent heat flux for July 1989 between 12 and 15 UTC.

10.2 Quality Assessment

Model products have biases, related to the specific model. Their advantage is that they give complete coverage and at 3-hourly time resolution. In contrast, surface observations are not uniformly distributed globally, and are sparse over many regions in the tropics, where monthly mean data or even just climatology may only be available. The ISLSCP II data collection also contains several monthly mean near-surface products that are based solely on observations (e.g. Climate Research Unit (CRU) data sets).

Characteristics General

The temporal consistency of the ERA-40 analyses on synoptic timescales is better than that of the earlier ERA-15 analyses. This is most likely due to the 3-dimensional variational data-assimilation employed in ERA-40. Departures of the model atmosphere from observations are determined using model values at the time of observation rather than from the nearest synoptic hour.

Analysis quality inevitably changes over long timescales due to changes in observing systems. These systems evolved much more substantially during the more than 40 years covered by ERA-40 than during the shorter ERA-15 period. Sensitivity to observing system changes can be seen in particular in the quality of the tropical and southern hemispheric analyses. Throughout the period 1957-2001 there is a gradual tendency for observation accuracy and coverage to improve (radiosonde coverage being an exception), but there are a number of years during which analysis quality will improve stepwise in certain characteristics due to the introduction of satellite instruments: 1972 VTPR, 1979 TOVS (MSU/HIRS/SSU), Cloud Motion Vectors and TOMS & SBUV, 1987 SSM/ I, 1991 ERS Scatterometer and Altimeter, 1998 ATOVS (AMSU-A). Major additions to the in-situ observing system have been the deployment of drifting ocean buoys, first for FGGE in 1979 and then for the TOGA experiment in the mid-1980s, and the introduction and enhancements of observations from commercial aircraft from the 1970s onwards.

There are also changes in the observing systems that have short-term effects on analysis quality. These are due mainly to instrument failures or missing data, or to undetected poor-quality data entering the production analysis system. During the assimilation detailed information on how each observation is used in the analysis is archived in so called "feedback" files. A comprehensive diagnosis of this information, which will document the effect of changes to the observing system, will be carried out when production is complete.

Surface Parameters

The severe cold bias in the ERA-15 surface and near-surface temperatures during winter and spring over northern Eurasia and America was corrected in ERA-40. In some areas a smaller warm bias has however been noted in the ERA-40 analyses, especially during springtime. The ERA-40 analysis does not use unrepresentative surface wind observations, from isolated islands for example. This makes the surface wind analyses and the surface turbulent exchanges more realistic. A revised and more accurate surface orography description was used in ERA-40. This caused some quite large local differences in surface pressure and other near-surface parameters between ERA-40 and ERA-15, particularly over Antarctica.

Time series of global-mean snow mass from 1989 to 1997 exhibit low values from 1992 to 1994 due to a bug introduced into the snow analysis, and the analysis up to 1997 also suffers, though to a lesser extent, from a miscoding by ECMWF of Canadian snow-depth observations that moved some observation dates to later within the same month.

Forecast Performance

The accuracy of the forecasts run from the analyses provides a good indication of the general quality of the synoptic analyses. Forecasts to 36 hours ahead are run routinely as part of the production system. The forecasts of tropospheric and stratospheric winds and tropospheric temperatures from the ERA-40 analyses for 1989 have been shown to be much more consistent with corresponding verifying analyses than was the case for ERA-15 or for ECMWF operational forecasts in 1989. The ERA-40 forecasts also have the lowest temperature errors in the extra tropical stratosphere below 10hPa. In verifications of short-range forecasts against radiosonde data, the ERA-40 forecasts of stratospheric temperature stand out much more clearly as the best, in the tropics as well as the extra tropics.

Forecasts for five years, 1958, 1959, 1973, 1989 and 1996, have been completed. Results from 1989 and 1996 indicate similar performance in the two years, a little better than ECMWF operations in 1996 and substantially better than ECMWF operations in 1989. In the northern hemisphere there is a clear improvement in forecasts from 1958 to 1973 and from 1973 to 1989. The 1958 and 1959 forecasts are nevertheless quite good in the medium range, where they typically lose skill not much more than one day earlier than the 1989 forecasts.

Basin Hydrology

Ask Contact 2 in section 2.3 about the performance of ERA-40 over the Americas. Similar papers on earlier versions of the model include Betts et al. (1998, 1999); Betts and Viterbo (2000); and a comparison with an earlier NCEP reanalysis in Roads and Betts (2000). The land-surface scheme for ERA-40 is discussed in Van den Hurk et al (2000). Improvements at high latitudes are discussed further in Betts et al (2001). An evaluation over Amazonia is given in Betts and Jakob (2002).

10.2.1 Data Validation by Source

See above.

10.2.2 Confidence Level/Accuracy Judgment

None given at this revision.

10.2.3 Measurement Error for Parameters and Variables

None given at this revision.

10.2.4 Additional Quality Assessment Applied

The ISLSCP II staff thoroughly checked the data processing methods and processed data at multiple levels in the processing streams to further ensure data quality. The proper functioning of the ‘wgrib’ decoder was tested on multiple test files in both binary and ASCII formats. Computer code to process the data was tested on many random selected cells as well as random selected files both from raw GRIB dumps and fully processed data files. Final testing was performed on selected random suites of parameters. Logs of file numbers and file sizes for particular parameters were compiled for validation. Both original and processed data were compared visually on image processing software.

11. NOTES

11.1 Known Problems with the Data

Humidity Analysis and Rainfall over the Tropical Oceans

The most serious problem diagnosed in the ERA-40 analyses was excessive tropical oceanic precipitation in later years, particularly in stream 1 after 1991. The stream-1 analyses are moistened over tropical oceans by the assimilation of HIRS and SSM/I data. This moistening is rejected by the assimilating model in the subsequent background forecasts, leading to higher rainfall rates over the tropical oceans than produced by the model when run either in climate-simulation mode or in the stream-2 (pre-satellite) data assimilation. A substantial increase in rainfall rates from the second half of 1991 onwards was due in part to effects of volcanic aerosols on HIRS infrared radiances following the eruption of Mt. Pinatubo. These effects were not included directly in the forward radiative transfer model used in the variational analysis. Instead they had to be absorbed into the bias corrections applied to the radiance measurements. This was a problem especially for data from the NOAA-12 satellite that became operational just around the time Mt. Pinatubo erupted. Inadequately corrected infrared radiance biases tend to result in humidity changes in the tropical troposphere, since the relatively low background errors in temperature force analysis changes to be predominantly in humidity. A further complication came from poor bias correction of SSM/I data. This was corrected for ERA-40 analyses from January 1993. A revised thinning, channel-selection and quality control of HIRS radiances has been developed and tested, giving reduced (though still relatively high) tropical precipitation (and slightly improved short-range forecast verifications). It has been used for stream 1 from 1997 onwards, and will be used in stream 3 when it has progressed to the time that HIRS data first become available. Although this adverse impact is present in ERA-40 over the oceans after 1991, the impact is less obvious over say Amazonia.

Arctic Analyses since 1989

A problem of concern was cold bias in the lower troposphere (below about 500 hPa) over ice-covered oceans in both the Arctic and the Antarctic. A related problem in Arctic precipitation was also identified. These polar cold biases arise from the assimilation of HIRS radiances. Changes to the thinning, channel-selection and quality control of the infrared data that were introduced for analyses from 1997 onwards to reduce the tropical precipitation bias have also virtually eliminated the cold polar biases.

Issues Identified by the ISLSCP II Staff

- Errors with the calculation of monthly 3-hourly averages for 21-24 UTC.
- Issues with the calculation of monthly 3-hourly averages for 21-24 UTC for 12/31/1985 for all accumulated parameters (see Section 9.2.3).

- Monthly-3-hourly average record does not contain any files for 21 to 24 UTC for 1995 for any parameter.
- Small errors may be introduced by zeroing negative precipitation and/or runoff (GRIB packing errors).
- Some monthly 3-hourly and/or 3-hourly Surface SW downward radiation (SSRD) data may contain very small negative values related to the GRIB packing errors.
- At this revision monthly snow depth (SD) is in units of m of water and not m of snow water equivalent.
- Surface pressure is in Pa and not in mb. User needs to divide by 1,000.
- 3-hourly surface evaporation rate (E) is in units of m/s and not mm/s as are other hydrological units.

11.2 Usage Guidance

The ERA-40 system has significant spin-up at high latitudes of the precipitation field for 24-36 hours, associated with the spin-up of the dynamic fields. This is not so of the precipitation fields in the tropics. The extent of this spin-up can be assessed from the monthly mean precipitation fields which are given for four forecast intervals:

FX: 0-6 (averaged over forecasts from 0,6,12, 18 UTC)
0-12 (averaged over forecasts from 0,12 UTC)
12-24 (averaged over forecasts from 0,12 UTC)
24-36 (averaged over forecasts from 0,12 UTC)

The 3-hourly fields and fluxes including precipitation all come from the 0-6hour forecasts.

11.3 Other Relevant Information

None.

12. REFERENCES

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Simmons A.J. and J.K. Gibson, 2000. The ERA-40 Project Plan, ERA-40 Project Report Series No. 1, ECMWF, Reading RG2 9AX, UK., 63pp.

Van den Hurk, B.J.J.M., P. Viterbo, A.C.M. Beljaars and A. K. Betts, 2000: Offline validation of the ERA-40 surface scheme. *ECMWF Tech Memo, 295*, 43 pp., Eur. Cent. For Medium-Range Weather Forecasts, Shinfield Park, Reading RG2 9AX, England, UK.

13. DATA ACCESS

13.1 Data Access Information

The ISLSCP Initiative II data are archived and distributed through the Oak Ridge National Laboratory (ORNL) DAAC for Biogeochemical Dynamics at http://daac.ornl.gov.

13.2 Contacts for Archive

E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

13.3 Archive/Status/Plans

The ISLSCP Initiative II data are archived at the ORNL DAAC. There are no plans to update these data.

14. GLOSSARY OF ACRONYMS

3DVAR	3-dimensional variational method
ASCII	American Standard Code for Information Interchange
AMIP	Atmospheric Model Inter-comparison Project
COADS	Comprehensive Ocean-Atmosphere Data Set
COLA	Center for Ocean-Land-Atmosphere Studies
CRU	Climate Research Unit (Univ. of East Anglia)
DAAC	Distributed Active Archive Center
DOE	Department of Energy
ECMWF	European Centre for Medium-range Weather Forecasts
ERA	ECMWF Re-Analysis
ERA-40	ECMWF 40-year reanalysis
ESA	European Space Agency
HIRS	High Resolution Infrared Radiation Sounder
FS	Integrated Forecasting System
GCM	General Circulation Model
GRIB	Gridded Binary
GSFC	Goddard Space Flight Center
ISLSCP	International Satellite Land-Surface Climatology Project
LW	LongWave
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
ODB	Observational Data Base
NOAA	National Oceanic and Atmospheric Administration
ORNL	Oak Ridge National Laboratory
PAOBS	Australian Pressure Observations
SBUV	Solar Backscatter Ultraviolet Instrument
SSM/I	Special Sensor Microwave Imager
SST	Sea Surface Temperature
SW	ShortWave
TOA	Top Of Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TOVS	TIROS Operational Vertical Sounder
UTC	Coordinated Universal Time
VTPR	Vertical Temperature Profile Radiometer