Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Jeffrey A. Newcomer, Editors

Volume 120

BOREAS ECMWF 6-Hour Analysis and Forecast Data

Pedro Viterbo, ECMWF, Shinfield Park, Reading, United Kingdom
Alan Betts, Atmospheric Research, Pittsford, Vermont
Richard Strub, Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

September 2000
Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA’s scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA’s institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA’s counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.

- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA’s mission.

Specialized services that complement the STI Program Office’s diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results... even providing videos.

For more information about the NASA STI Program Office, see the following:

- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Jeffrey A. Newcomer, Editors

Volume 120

BOREAS ECMWF 6-Hour Analysis and Forecast Data

Pedro Viterbo, ECMWF, Shinfield Park, Reading, United Kingdom
Alan Betts, Atmospheric Research, Pittsford, Vermont
Richard Strub, Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

September 2000
BOREAS ECMWF 6-Hour Analysis and Forecast Data

Pedro Viterbo, Alan K. Betts, Richard Strub

Summary

In cooperation with BOREAS atmospheric research efforts, the ECMWF agreed to provide BOREAS with a customized subset of its 6-hourly forecast data. This data set contains parameters from three ECMWF data products in GRIB format: Surface and Diagnostic Fields, Supplemental Fields, and Extension Data. Sample software and information are provided to assist in reading the data files. Temporally, the atmospheric parameters are available for the four main synoptic hours of 00, 06, 12, and 18 UTC from 1994 to 1996. Spatially, the data are stored in a 0.5- by 0.5-degree latitude/longitude grid. To cover the entire BOREAS study area, the grid extends from 48 to 62 degrees latitude and -92 to -114 degrees longitude. The data are stored in binary data representation known as FM 92 GRIB. Due to the complexity of the content and format of this data set, users are advised to read Sections 6, 7, 8, and 14 before using data.

Based on agreements between BOREAS and ECMWF, users may legally obtain and use these data only by having a set of the BOREAS CD-ROMs that contain the data. Possession or use of these data under any other circumstance is prohibited. See Sections 11.3 and 20.4 for details.

Note that the data files on the BOREAS CD-ROMs have been compressed using the Gzip program. See Section 8.2 for details on the compression.

Table of Contents

1) Data Set Overview
2) Investigator(s)
3) Theory of Measurements
4) Equipment
5) Data Acquisition Methods
6) Observations
7) Data Description
8) Data Organization
9) Data Manipulations
10) Errors
11) Notes
12) Application of the Data Set
13) Future Modifications and Plans
14) Software
15) Data Access
16) Output Products and Availability
17) References
18) Glossary of Terms
19) List of Acronyms
20) Document Information
1. Data Set Overview

1.1 Data Set Identification
BOREAS ECMWF 6-Hour Analysis and Forecast Data

1.2 Data Set Introduction
In cooperation with BOREal Ecosystem-Atmosphere Study (BOREAS) atmospheric research efforts, the European Centre for Medium-Range Weather Forecasts (ECMWF) agreed to provide a customized subset of their 6-hourly forecast data. This data set contains parameters from three ECMWF data products: Surface and Diagnostic Fields, Supplemental Fields, and Extension Data. The data cover the four main synoptic hours of 00, 06, 12, and 18 Universal Time Code (UTC) from 1994 to 1996 and are stored in a 0.5- by 0.5-degree regular latitude/longitude grid. Before using these data, users are advised to carefully read Sections 6.1 and 11.3, which discuss model changes, known errors, and proper use and referencing of the data.

1.3 Objective/Purpose
The ECMWF data sets were obtained in order to compare these large-area modeled data with more localized data sets and to provide data for large-area models.

1.4 Summary of Parameters
This data set contains parameters from three ECMWF data products: Surface and Diagnostic Fields, Supplemental Fields, and Extension Data. The data are reported at time intervals ranging from 6 to 24 hours. See Sections 7.3.1 and 8 for details.

1.5 Discussion
These are the operational ECMWF analyses for the period 1994 to 1996, covering the entire large-scale BOREAS area at a 6-hour time resolution and a 0.5-degree lat/long resolution. Their advantage over point data is that they are gridded and continuous with no gaps for the whole domain for 3 years. However, they are subject to known and unknown model errors, and the ECMWF model had several significant changes made to the model physics during this time period.

Although the global analysis uses the upper air observations and some surface synoptic data, the diurnal cycle of temperature and humidity and the surface fluxes over land away from the analysis times are calculated from the model radiation, cloud, and land-surface parameterizations. Consequently, they are subject to any errors in the model parameterizations. In particular, the subsurface variables, for which there are no input data, can drift with time unless constrained.

Users are advised to carefully read Section 6.1, which discusses model changes and known errors, before using these data.

1.6 Related Data Sets
BOREAS AFM-05 Level-1 Upper Air Network Data
BOREAS AFM-05 Level-2 Upper Air Network Standard Pressure Level Data
BOREAS AFM-07 SRC Surface Meteorological Data
BOREAS AES Campbell Scientific Surface Meteorological Data
BOREAS AES MARSII Surface Meteorological Data
BOREAS AES READAC Surface Meteorological Data
2. Investigator(s)

2.1 Investigator(s) Name and Title
BOREAS Staff Science

2.2 Title of Investigation
BOREAS Staff Science Meteorological Data Acquisition Program

2.3 Contact Information

Contact 1:
Pedro Viterbo
ECMWF
Shinfield Park
Reading RG2 9AX
UK
011-44-1189-499734
011-44-1189-869450 (fax)
pedro.viterbo@ecmwf.int

Contact 2:
Keith Fielding
Data Services
ECMWF
Shinfield Park
Reading RG2 9AX
UK
(0118) 949-9453
(0118) 986-9450 (fax)
Data.Services@ecmwf.int

Contact 3:
Alan K. Betts
Atmospheric Research
58 Hendee Lane
Pittsford, VT 05763
(802) 483-2087
(802) 483-6167 (fax)
akbetts@aol.com

Contact 4:
Jeffrey A. Newcomer
Raytheon ITSS
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-7858
(301) 286-0239 (fax)
Jeffrey.Newcomer@gsfc.nasa.gov
3. Theory of Measurements

The theory behind the acquisition of a high-resolution gridded data set with several weather parameters is to provide data for large-area models after validation against localized data.

These model products are conveniently gridded, and extend for the 3 years of BOREAS. The land-surface scheme is discussed in Viterbo and Beljaars (1995). Some of the characteristics of the surface analyses and fluxes of the ECMWF model after April 1995 are discussed in Betts et al (1998a,b,c).

Users are advised to carefully read Section 6.1, which discusses model changes and known errors, before using these data.

4. Equipment

4.1 Sensor/Instrument Description

The ECMWF uses surface and upper air data from numerous sources and locations around Earth to create its 6-hour forecast product. The output data are created using multivariate optimal interpolation analysis, followed by nonlinear normal model initialization, before 960129 and 3D-VAR from 960130, and a high-resolution spectral model that produces a first-guess forecast for the subsequent analysis. Data were assimilated every 6 hours.

4.1.1 Collection Environment

The input data used in the ECMWF models are collected from a wide range of global stations that are operated in ambient atmospheric conditions.

4.1.2 Source/Platform

The platforms from which the input data are collected include human observers, fixed towers of various sorts, and tethered and free-flying balloons.

4.1.3 Source/Platform Mission Objectives

The objective is for the platforms to support the instrumentation that is being used to make the various measurements.

4.1.4 Key Variables

This data set contains parameters from three ECMWF data products: Surface and Diagnostic Fields, Supplemental Fields, and Extension Data. The data are reported at time intervals ranging from 6 to 24 hours. See Sections 7.3.1 and 8 for details.

4.1.5 Principles of Operation

Not applicable.

4.1.6 Sensor/Instrument Measurement Geometry

Not applicable.

4.1.7 Manufacturer of Sensor/Instrument

The ECMWF in Reading, England.

4.2 Calibration

4.2.1 Specifications

Not applicable.
4.2.1.1 Tolerance
Not applicable.

4.2.2 Frequency of Calibration
Not applicable.

4.2.3 Other Calibration Information
The land-surface scheme is discussed in Viterbo and Beljaars (1995). Some of the characteristics of the surface analysis of the ECMWF model after April 1995 are discussed in Betts et al. (1998a,b,c).

Users are advised to carefully read Section 6.1, which discusses model changes and known errors, before using these data.

5. Data Acquisition Methods

The current model resolution, introduced into operation on 17-September-1991, is T213 with 31 levels in the vertical.

ECMWF produces routine global analyses for the four main synoptic hours 00, 06, 12, and 18 UTC and global 10-day forecasts based on 12 UTC data. As a forecasting center with the emphasis on the medium range, ECMWF operates with long data collection times of between 18 hours for the 18 UTC analysis and 8 hours for the 12 UTC final analysis. This schedule ensures the most comprehensive global data coverage including the Southern Hemisphere surface data and global satellite sounding data.

6. Observations

6.1 Data Notes

Users are advised to carefully read this section, which discusses model changes and known errors, before using these data.

This is an operational analysis, so the user needs to be aware of heterogeneity's introduced when new model physics cycles were introduced to correct known model problems. (A reanalysis is planned for 1999 with a current model version.)

Key changes affecting the boreal forest land surface are:

- **04-Aug-1993**: 4-layer prognostic land surface scheme introduced (Viterbo and Beljaars, 1995).
- **04-Jul-1994**: Soil reservoirs refilled because they had partially dried out after model had run freely for one year. The impact of this is that the evaporation increases after 04-Jul-1994; probably too low before that date and too high after.
- **06-Dec-1994**: Nudging of soil water introduced to control long-term drifts of soil water (Viterbo and Courtier, 1995).
- **04-Apr-1995**: ERA-15 Reanalysis model introduced into operations. Including prognostic cloud scheme of Tiedtke (1993) and new subgrid orography scheme (Lott and Miller, 1997). The impact of this is that it improves radiative fluxes at surface, probably incoming solar is too high before this date. The summer surface evaporation in this model appears to be too high over the boreal forest (see Betts et al., 1998b), although in spring it is low because of an albedo error (see below).
- **30-Jan-1996**: The 3-dimensional variational data assimilation technique (3D-VAR) replaces the optimal interpolation (OI) method. For a description see Courtier et al. (1998) and Rabier et al. (1998); for a description of the impact on analysis and forecasts see Andersson et al. (1998).
- **19-Sep-1996**: Soil freezing plus new stable boundary layer parameterization and increased soil heat flux coupling introduced. The impact of this is that it reduces cold bias in winter caused by lack of latent heat of phase change and uncoupling of surface temperature from atmosphere under stable boundary layer (Viterbo et al., 1997). It also reduces cold temperature bias at night, caused by stable boundary layer uncoupling, and may affect daytime diurnal cycle of humidity (Betts et al., 1998a).

- **10-Dec-1996**: New boreal forest snow albedo introduced (Viterbo and Betts, 1997, 1998), which reduces maximum snow albedo of boreal forests from 0.8 to 0.2. The impact is that before this, the winter of 1996-97 net radiation is small until snow melts in spring and spring temperatures are too cold by 10 to 15 K. (Betts et al., 1998b).

Primary validation studies all deal with the model version after 04-Apr-1995 and are as follows:

- Betts et al., 1998a, dealing with comparison with the First International Satellite Land Surface Climatology Project (ISLSCP) Field Experiment (FIFE) data.
- Betts et al., 1998b, dealing with both a comparison with the FIFE data and the BOREAS TF#3 black spruce site west of Thompson, Manitoba.
- Betts et al., 1998c, dealing with basin scale studies of the Arkansas-Red River basin with the ERA-15 reanalysis model. This addresses the impact of nudging on the soil hydrology and the errors in the diurnal cycle of precipitation, which appears to affect the BOREAS region also. In brief, the model has a 25-30% spin-up of precipitation in the analysis cycle and the 12-24 hour forecast, which brackets the observed gridded precipitation from Higgins et al. (1996) over the United States. The model has a near local noon precipitation maximum which may be related to a morning peak of mixing ratio.

In this data set the model spin-up can be assessed by comparing the three fields:

<table>
<thead>
<tr>
<th>ECHWF Parameter Number</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>142</td>
<td>Large Scale Precipitation</td>
<td>(m)</td>
</tr>
<tr>
<td>143</td>
<td>Convective Precipitation</td>
<td>(m)</td>
</tr>
<tr>
<td>228</td>
<td>Total Precipitation</td>
<td>(m)</td>
</tr>
</tbody>
</table>

Fields 142 and 143 are from the analysis cycle, and field 228 is convective plus large-scale precipitation from a 12- to 36-hour forecast after the model has spun up. Field 228 is probably a better estimate of total precipitation, but 142+143 give a crude estimate of the diurnal cycle.

Evaporation (field 182) and latent heat flux (field 147) are inconsistent. There was a numeric problem in the computations related to the interception reservoir, which results in the surface latent heat flux being higher than the liquid evaporation in the subsurface hydrology, when converted to the same units. The ratio is variable, as it depends on the variable interception. For Mississippi basin averages it was on the order of 1.07 (see Betts et al., 1998c).

Beljaars et al., 1996, and Betts et al., 1996, deal with the improvements associated with the introduction of the 4-layer soil water model in 1993 (Viterbo and Beljaars, 1995)

**6.2 Field Notes**

Not applicable.
7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage
The BOREAS ECMWF data cover the area of 48° N to 62° N latitude and 114° to 92° W longitude. The North American Datum of 1983 (NAD83) corner coordinates of the BOREAS region are:

<table>
<thead>
<tr>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwest</td>
<td>111.000 W</td>
</tr>
<tr>
<td>Northeast</td>
<td>93.502 W</td>
</tr>
<tr>
<td>Southeast</td>
<td>96.970 W</td>
</tr>
<tr>
<td>Southwest</td>
<td>111.000 W</td>
</tr>
</tbody>
</table>

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
The BOREAS Information System (BORIS) ECMWF data were extracted in a 0.5-degree by 0.5-degree grid. The 0.5-degree grid was interpolated from the original model resolution of Gaussian N160 for the physics calculations. The points in the 0.5 x 0.5-degree grid are at whole degrees and half degrees in both latitude and longitude, and they represent the center of the 0.5 x 0.5 box surrounding them.

7.1.4 Projection
The coordinates for the BORIS ECMWF data are latitude and longitude.

7.1.5 Grid Description
The BORIS ECMWF data are stored in a systematic latitude/longitude grid.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
With the exception of parameters 236 and 237 (Soil Temperature and Soil Wetness level 4) for 1994, BORIS has all of the ECMWF parameters listed in Section 7.3.1 for every day of the years 1994 through 1996. Different parameters were modeled for different times (see Section 7.2.3).

7.2.2 Temporal Coverage Map
Not available.

7.2.3 Temporal Resolution
All the ECMWF parameters, except for Total Precipitation, are given once every 6 hours. All fluxes are accumulated for the forecast period. The Total Precipitation values are given once every 24-hour period, calculated from the 12-36 hour forecast from 1200 UTC the preceding day.

7.3 Data Characteristics

7.3.1 Parameter/Variable
The parameters that are included in each of the three ECMWF data products and their associated descriptions and units are:

Surface and Diagnostic Fields
Note that in 1994, data set parameters 236 and 237 (Soil Temperature and Soil Wetness level 4) are
missing. All of the ECMWF parameters are available for every day during 1995 and 1996. Different parameters were modeled for different time intervals (see Section 7.2.3).

<table>
<thead>
<tr>
<th>Parameter Number</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>129</td>
<td>Geopotential</td>
<td>(as gz in m²/s²)</td>
</tr>
<tr>
<td>134</td>
<td>Surface Pressure</td>
<td>(Pa)</td>
</tr>
<tr>
<td>139</td>
<td>Soil Temperature level 1</td>
<td>(K)</td>
</tr>
<tr>
<td>140</td>
<td>Soil wetness level 1</td>
<td>(see * below)</td>
</tr>
<tr>
<td>141</td>
<td>Snow Depth</td>
<td>(m)</td>
</tr>
<tr>
<td>151</td>
<td>Mean Sea Level Pressure</td>
<td>(Pa)</td>
</tr>
<tr>
<td>165</td>
<td>U-Wind Component at 10m</td>
<td>(m/s)</td>
</tr>
<tr>
<td>166</td>
<td>V-Wind Component At 10 m</td>
<td>(m/s)</td>
</tr>
<tr>
<td>167</td>
<td>Temperature At 2m</td>
<td>(K)</td>
</tr>
<tr>
<td>168</td>
<td>Dewpoint At 2m</td>
<td>(K)</td>
</tr>
<tr>
<td>170</td>
<td>Soil Temperature level 2</td>
<td>(K)</td>
</tr>
<tr>
<td>171</td>
<td>Soil Wetness level 2</td>
<td>(see * below)</td>
</tr>
<tr>
<td>172</td>
<td>Land/Sea Mask</td>
<td>(see ** below)</td>
</tr>
<tr>
<td>173</td>
<td>Surface Roughness</td>
<td>(m)</td>
</tr>
<tr>
<td>174</td>
<td>Albedo</td>
<td>(see *** below)</td>
</tr>
<tr>
<td>183</td>
<td>Soil Temperature level 3</td>
<td>(K)</td>
</tr>
<tr>
<td>184</td>
<td>Soil Wetness level 3</td>
<td>(see * below)</td>
</tr>
<tr>
<td>236</td>
<td>Soil Temperature level 4</td>
<td>(K)</td>
</tr>
<tr>
<td>237</td>
<td>Soil Wetness level 4</td>
<td>(see * below)</td>
</tr>
</tbody>
</table>

These are values every 6 hours at 00, 06, 12, and 18 UTC.

* The units of soil water in this archive are unusual. They are (m³ of water)/(0.07 m³ of soil) for all levels 1-4. That is, if the value in the ECMWF file is X, the value W (m³ of water)/(m³ of soil) will be W = X/0.07. The 4 soil levels represent depths of 0 to 7 cm, 7 to 28 cm, 28 to 100 cm and 100 to 289 cm.

** The land/sea mask contains values of 0 to indicate sea (or water) and 1 to indicate land areas.

*** The albedo values range from 0 to 1 indicating from 0 to 100% reflectance of the incoming radiation by the surface.

**Supplemental Fields**

These are 0- to 6-hour accumulated fluxes from short-term forecasts starting at 00, 06, 12, and 18 UTC. The units are peculiar in that they are accumulated in seconds of forecast time (6 hours x 3600 secs/hour). Heat and radiation fluxes are therefore in W/m², stresses in N/m²; while precipitation, snowfall and evaporation are in accumulated meters. Snowfall is the sum of convective and large-scale snowfall. Evaporation and latent heat flux are numerically inconsistent (see Section 6.1).

The 1994 supplemental field data were delivered to BOREAS in two pieces. As such, two files are required to make a complete set of supplemental variables for a given date. See Section 8 for more information.
### ECMWF Parameter

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>142</td>
<td>Large Scale Precipitation</td>
<td>(m)</td>
</tr>
<tr>
<td>143</td>
<td>Convective Precipitation</td>
<td>(m)</td>
</tr>
<tr>
<td>144</td>
<td>Snow Fall</td>
<td>(m)</td>
</tr>
<tr>
<td>146</td>
<td>Surface Sensible Heat Flux</td>
<td>((W * seconds)/m²)</td>
</tr>
<tr>
<td>147</td>
<td>Surface Latent Heat Flux</td>
<td>((W * seconds)/m²)</td>
</tr>
<tr>
<td>164</td>
<td>Total Cloud Cover</td>
<td>(see **** below)</td>
</tr>
<tr>
<td>176</td>
<td>Surface Solar Radiation</td>
<td>((W * seconds)/m²)</td>
</tr>
<tr>
<td>177</td>
<td>Surface Thermal Radiation</td>
<td>((W * seconds)/m²)</td>
</tr>
<tr>
<td>178</td>
<td>Top Solar Radiation</td>
<td>((W * seconds)/m²)</td>
</tr>
<tr>
<td>179</td>
<td>Top Thermal Radiation</td>
<td>((W * seconds)/m²)</td>
</tr>
<tr>
<td>180</td>
<td>East/West Surface Stress</td>
<td>((N * seconds)/m²)</td>
</tr>
<tr>
<td>181</td>
<td>North/South Surface Stress</td>
<td>((N * seconds)/m²)</td>
</tr>
<tr>
<td>182</td>
<td>Evaporation</td>
<td>(m)</td>
</tr>
</tbody>
</table>

**** The Total Cloud Cover values range from 0 to 1 indicating from 0 to 100% cloud cover.

### Extension Data

These are 24-hour accumulated precipitation from the 12- to 36-hour forecast starting from 12 UTC the previous day.

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>228</td>
<td>Total Precipitation</td>
<td>(m)</td>
</tr>
</tbody>
</table>

### 7.3.2 Variable Description/Definition

See Section 7.3.1.

### 7.3.3 Unit of Measurement

See Section 7.3.1.

### 7.3.4 Data Source

The data were provided to BOREAS by ECMWF personnel.

### 7.3.5 Data Range

None given.

### 7.4 Sample Data Record

Not applicable.
8. Data Organization

8.1 Data Granularity

The ECMWF data are stored in multi-date GRIB files. The smallest unit of data is a multi-date block containing several of the ECMWF parameters. Refer to section 7.3.1 for the organization of parameters.

8.2 Data Format(s)

8.2.1 Uncompressed Data Files

The BOREAS ECMWF data set consists of multi-date blocks of three ECMWF data products (Surface and Diagnostic Fields, Supplemental Fields, and Extension Data) and associated software files.

The data products contain data for multiple days, with the file names containing the start date of the multiple day period. The data in a file are stored in chronological order in a binary data representation known as FM 92 GRIB. GRIB is a common standard used by the operational meteorological centers for storage and exchange of gridded fields. The major advantages of the GRIB format are that files are typically 1/2 to 1/3 of the size of normal binary files, the fields are self-describing, and GRIB is an open, international standard.

On the BOREAS CD-ROM set, the format of the uncompressed file names is:

YY-MM-DD REGION FILETYPE

where YY MM DD is the starting date (YY - year, MM - month, DD - day of month) of the data contained in the file,
REGION is a constant field indicating that the spatial coverage of the data is the entire BOREAS region, and
FILETYPE is a three or four character string indicating the file type (EC1, EC2, EC2a, EC2b, or EC3), where:
EC1 files contain the Surface and Diagnostic Field data,
EC2* files contain the Supplemental Fields data. In 1994 the Supplemental Fields data were delivered in two components, EC2a and EC2b files. The EC2a files contain parameters 146, 147, 164, and 176 through 181 of the Supplemental Fields data. EC2b files contain parameter numbers 142, 143, 144, and 182 of the Supplemental Fields data. In 1995 and 1996, all of the Supplemental Fields data are stored in a single EC2 file.
EC3 files contain the Extension data.

Two American Standard Code for Information Interchange (ASCII) software files are provided with the data. The first one (SOFTWARE1) contains source code that when built and run, uses the second file (SOFTWARE2) as input and divides the SOFTWARE2 file into various components. See the associated gribex_readme.txt file for more information about these files, and section 14.1. The specification of the GRIB code is given in the World Meteorological Organization (WMO) Publication 306, Manual on Codes.

8.2.2 Compressed CD-ROM Files

On the BOREAS CD-ROMs, the ECMWF data and software files have been compressed with the GNU zip (Gzip) compression program (file name *.gz). These data have been compressed using gzip version 1.2.4 and the high compression (-9) option (Copyright (C) 1992-1993 Jean-loup Gailly). Gzip uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP programs. The compressed files may be uncompressed using gzip (-d option) or gunzip. Gzip is available from many Web sites (for example, ftp site prep.ai.mit.edu/pub/gnu/gzip-*.*) for a variety of operating systems in both
executable and source code form. Versions of the decompression software for various systems are included on the CD-ROMs.

9. Data Manipulations

9.1 Formulae

9.1.1 Derivation Techniques and Algorithms
For a detailed description of the ECMWF/WCRP Level III-A Global Atmospheric Data Archive, see ECMWF ECMWF/WCRP Level III-A Global Atmospheric Data Archive Technical Attachment.

9.2 Data Processing Sequence

9.2.1 Processing Steps
BORIS staff adapted the ECMWF software to extract metadata, verify the data set content, and inventory the data in the BORIS Oracle data base. BORIS staff compressed the binary files for release on CD-ROM.

9.2.2 Processing Changes
None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments
See Section 9.1.1.

9.3.2 Calculated Variables
See Section 9.1.1.

9.4 Graphs and Plots
None.

10. Errors

10.1 Sources of Error
Users are advised to carefully read Section 6.1, which discusses model changes and known errors, before using these data. The land-surface scheme is discussed in Viterbo and Beljaars (1995). Some of the characteristics of the surface analysis of the ECMWF model after April 1995 and its errors are discussed in Betts et al. (1998a,b,c).

10.2 Quality Assessment

10.2.1 Data Validation by Source
Users are advised to carefully read Section 6.1, which discusses model changes and known errors, before using these data. The land-surface scheme is discussed in Viterbo and Beljaars (1995). Some of the characteristics of the surface analysis of the ECMWF model after April 1995 and its errors are discussed in Betts et al. (1998a,b,c).
10.2.2 Confidence Level/Accuracy Judgment

Users are advised to carefully read Section 6.1, which discusses model changes and known errors, before using these data. The precipitation data have a known spin-up of 25 to 30% from the 6-hour analysis cycle to the 12- to 36-hour forecast that is in the extension data set. Use the latter to assess this and read the discussion in Betts et al. (1998c) for the Arkansas-Red River basin.

In this data set, the model spin-up can be assessed by comparing three fields.

142 Large Scale Precipitation
143 Convective Precipitation
228 Total Precipitation

Fields 142 and 143 are from the analysis cycle and field 228 accounts for convective and large-scale precipitation from a 12- to 36-hour forecast after the model has spun up. Field 228 is probably a better estimate of total precipitation, but 142 + 143 give a crude estimate of the diurnal cycle.

Model data sets will reflect model parameterizations and model problems. For example, in the ECMWF model, the 2-m surface temperature is not itself a model variable - it is derived from the lowest model level at ~ 30 m elevation above the surface and the skin temperature, using similarity theory. The surface 'skin' temperature is sensitive to radiation errors (particularly at night), which are themselves sensitive to model cloud amount. Thus, a variable like Tmin in a model must be used with caution. Values may have absolute biases because of model cloud biases even if horizontal gradients across the BOREAS domain are of interest. Comparison with data time series at key locations should show these biases.

10.2.3 Measurement Error for Parameters

Users are advised to carefully read Section 6.1, which discusses model changes and known errors, before using these data. The land-surface scheme is discussed in Viterbo and Beljaars (1995). Some of the characteristics of the surface analysis of the ECMWF model after April 1995 and its errors are discussed in Betts et al. (1998a,b,c).

10.2.4 Additional Quality Assessments

None.

10.2.5 Data Verification by Data Center

BORIS adapted the sample software supplied by ECMWF to extract information about the parameters contained in each data file and the spatial and temporal extent of the data. This information was then used to inventory the data files in the BORIS data base. The actual parameter values were not verified or reviewed.

11. Notes

11.1 Limitations of the Data

Users are advised to carefully read Section 6.1, which discusses model changes and known errors, before using these data. The land-surface scheme is discussed in Viterbo and Beljaars (1995). Some of the characteristics of the surface analysis of the ECMWF model after April 1995 and its errors are discussed in Betts et al. (1998a,b,c).

11.2 Known Problems with the Data

Users are advised to carefully read Section 6.1, which discusses model changes and known errors, before using these data. The refilling of the soil water reservoirs on 04-Jul-1994 will increase evaporation after that date. The winter temperatures are biased cold (by as much as 10-15 K in spring before the winter of 1996-97, because of a stable boundary layer error (corrected on 19-Sep-1996) and a forest snow albedo error (corrected on 10-Dec-1996) (see Viterbo et al., 1997; Viterbo and Betts, 1997).
11.3 Usage Guidance

Before uncompressing the Gzip files on the CD-ROM, be sure that you have enough disk space to hold the uncompressed data files. Then use the appropriate decompression program provided on the CD-ROM for your specific system.

The ECMWF data may be used while noting the following:
- The 0.5-degree grid was interpolated from the original model resolution of Gaussian N160
- The data sets are adapted to a specific model orography; the data sets have biases that are only partially documented
- No surface observations of T, q, precipitation, or surface wind observations over land were used in the analysis
- Model spin-up can seriously affect the 6-hour forecast data supplied from the supplementary fields (precipitation, fluxes, radiation, surface stress, total cloud cover, and evaporation). A check on precipitation can be made using the data supplied from the Extension data set, which represents a day (0000 UTC to 2400 UTC) of total precipitation. This is derived from the 36-hour forecast time step minus the 12-hour time step to reduce the effect of spin-up
- Several fields such as soil moisture and temperature (4-levels) and snow depth, although included in the analysis data set, are not analyzed but evolve during the assimilation cycle.

The ECMWF provided data for the BOREAS CD-ROM set from the ECMWF/WCRP Level III-A Global Atmospheric Data Archive. ECMWF data on the CD-ROM set are provided under the following conditions:
- Based on agreements between BOREAS and ECMWF, users may legally obtain and use these data only by having a set of the BOREAS CD-ROMs that contain the data. Possession or use of these data under any other circumstance is prohibited.
- The proprietary rights and copyright of the software remain with ECMWF. The software supplied is intended solely for use with ECMWF data and must not be used for any other purpose.
- The ECMWF data and software will not be supplied in whole or in part to any third party without the authorization of ECMWF.
- Data and software will not be used for commercial purposes.
- Articles, papers, or written scientific works of any form, based in whole or in part on data supplied by ECMWF, will contain an acknowledgment concerning the supplied data. The data may be cited as follows: ECMWF 1994. The Description of the ECMWF/WCRP Level III-A Global Atmospheric Data Archive.

Although every care has been taken in preparing and testing the data and software, ECMWF cannot guarantee that the data are correct in all circumstances, or that the software will work correctly in all circumstances; neither does ECMWF accept any liability whatsoever for any error or omission in the data or software, or for any loss or damage arising from its use.

11.4 Other Relevant Information

None.

12. Application of the Data Set

These are the operational ECMWF analyses for the period 1994 to 1996, covering the entire large-scale BOREAS area at a 6-hour time resolution and a 0.5-degree latitude/longitude resolution. Their advantage over point data is that they are gridded and continuous with no gaps for the whole domain for 3 years. However, they are subject to known and unknown model errors, and the ECMWF model had several significant changes made to the model physics during this time period. The ECMWF data sets were obtained in order to compare these large-area modeled data with more localized data sets and to provide data for large-area models.
13. Future Modifications and Plans

A reanalysis is planned in 1999 for the period of 1979 to 1998 with a 1998/99 version of the ECMWF model. This model will have several improvements over the operational model. In particular, the winter surface temperatures will be improved, and the boreal forest may be better represented.

During the BOREAS follow-on research period (1998 to 1999), a gridded data set will be produced from the various surface meteorological data sets that should be helpful in further analyzing the ECMWF results.

14. Software

14.1 Software Description

Two ASCII software files are provided with the data. The first one (SOFTWARE1) contains Fortran source code (data_split) that when built and run, uses the second file (SOFTWARE2 - a file of routines) as input and divides the SOFTWARE2 file into its several subroutine components. The file ecmwf_grib.pdf is also provided as an information source. This is a paper describing the GRIBEX subroutine for encoding and decoding GRIB data.

There are various sources of software on the WWW for reading GRIB format data. Two sites provided particularly useful utilities for reading and/or inventorying the GRIB files. These sites are mentioned below.

http://wesley.wwb.noaa.gov/reading_grib.html

This site is a great resource for users of data stored in GRIB, complete with syntax examples for different platforms. This site has a pointer to the c-program wgrib.c that is more user-friendly than that provided by ECMWF. The program wgrib.c processes one variable per time-step. Using the wgrib code one can extract desired variables and put them in one image per time-step per variable. A comment on this site states that "One's first impulse is to convert the GRIB file into some "understandable" format. It is better to extract the desired data and leave it in GRIB. This extraction can take as little as one command line using wgrib. Keep the data min GRIB until you need it immediately."

http://www.nerc-bas.ac.uk/public/icd/wmc/perl.html

There isn't much documentation and information here, but this site provides a handy perl script for decoding standard GRIB files.

14.2 Software Access

Gzip is available from many Web sites across the Internet (for example, FTP site prep.ai.mit.edu/pub/gnu/gzip-*.*) for a variety of operating systems in both executable and source code form. Versions of the decompression software for various systems are included on the CD-ROMs.

The GRIB software provided on the CDROM to convert the data from GRIB Binary Representation to ASCII is available from ECMWF. There are various additional sources on the World Wide Web (WWW), see section 14.1.

Please note the following regarding the ECMWF-provided software: The proprietary rights and copyright of the software remain with ECMWF. The software supplied is intended solely for use with ECMWF data and must not be used for any other purpose. The ECMWF data and software will not be supplied in whole or in part to any third party without the authorization of ECMWF. Data and software will not be used for commercial purposes. Although every care has been taken in preparing and testing the data and software, ECMWF cannot guarantee that the data are correct in all circumstances, or that
the software will work correctly in all circumstances; neither does ECMWF accept any liability whatsoever for any error or omission in the data or software, or for any loss or damage arising from its use.

15. Data Access

The ECMWF 6-hour analysis and forecast data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information
For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification
Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics

15.3 Procedures for Obtaining Data
Although the BOREAS ECMWF data are being held in a public archive, agreements between BOREAS and ECMWF limit the distribution and use of the data. The BOREAS CD-ROM series is publicly available, and the ECMWF data on the CD-ROMs are available for use by the owner of the CD-ROM set only. See Section 11.3 and please contact the ORNL DAAC User Services office to get the most recent information.

Users may obtain information on these data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans
The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products
None.

16.2 Film Products
None.

16.3 Other Products
These data are available on the BOREAS CD-ROM series.
17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

17.2 Journal Articles and Study Reports


ECMWF Physics and Its Validation (Key References):


ECMWF Initialization and Analysis System:


ECMWF Prediction Model:

ECMWF provides a comprehensive service from the Level II data archive, which is documented under ECMWF. 1996. The Description of the ECMWF/WRCP Level III-A Global Atmospheric Data Archive. ECMWF. Reading RG2 9AX, England. Interested users may write to The Director, ECMWF, Shinfield Park, Reading RG2 9AX, U.K., for further information.


17.3 Archive/DBMS Usage Documentation
None.

18. Glossary of Terms
None.
19. List of Acronyms

ASCII - American Standard Code for Information Interchange
BOREAS - BOReal Ecosystem-Atmosphere Study
BORIS - BOREAS Information System
CD-ROM - Compact Disk-Read-Only Memory
DAAC - Distributed Active Archive Center
ECMWF - European Centre for Medium Range Weather Forecasts
EOS - Earth Observing System
EOSDIS - EOS Data and Information System
FIFE - First ISLSCP Field Experiment
GIS - Geographic Information System
GSFC - Goddard Space Flight Center
HTML - HyperText Markup Language
ISLSCP - International Satellite Land Surface Climatology Project
MARS - Meteorological Archive and Retrieval System
NAD83 - North American Datum 1983
NASA - National Aeronautics and Space Administration
NSA - Northern Study Area
OI - Optimal Interpolation
ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park
PDF - Portable Document Format
SSA - Southern Study Area
URL - Uniform Resource Locator
UTC - Universal Time Code
WHO - World Meteorological Organization

20. Document Information

20.1 Document Revision Date
Written: 22-Jun-1998
Last Updated: 20-Dec-1999

20.2 Document Review Date(s)
BORIS Review: 04-Aug-1998
Science Review: 04-Aug-1998

20.3 Document ID

20.4 Citation
Articles, papers, or written scientific works of any form, based in whole or in part on the data supplied by ECMWF, must contain an acknowledgment concerning the supplied data. The data may be cited as follows:
ECMWF 1995. The Description of the ECMWF/WRCP Level III-A Global Atmospheric Data Archive. ECMWF. Reading RG2 9AX, England. Please include citations of relevant papers in Section 17.2.
If using data from the BOREAS CD-ROM series, also reference the data as:


Also, cite the BOREAS CD-ROM set as:


20.5 Document Curator

20.6 Document URL
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

BOREAS ECMWF 6-Hour Analysis and Forecast Data

Pedro Viterbo, Alan Betts, and Richard Strub
Forrest G. Hall and Jeffrey A. Newcomer, Editors

Goddard Space Flight Center
Greenbelt, Maryland 20771

National Aeronautics and Space Administration
Washington, DC 20546-0001

In cooperation with BOREAS atmospheric research efforts, the ECMWF agreed to provide BOREAS with a customized subset of its 6-hourly forecast data. This data set contains parameters from three ECMWF data products in GRIB format: Surface and Diagnostic Fields, Supplemental Fields, and Extension Data. Sample software and information are provided to assist in reading the data files. Temporally, the atmospheric parameters are available for the four main synoptic hours of 00, 06, 12, and 18 UTC from 1994 to 1996. Spatially, the data are stored in a 0.5- by 0.5-degree latitude/longitude grid. To cover the entire BOREAS study area, the grid extends from 48 to 62 degrees latitude and -92 to -114 degrees longitude. The data are stored in binary data representation known as FM 92 GRIB. Due to the complexity of the content and format of this data set, users are advised to read Sections 6, 7, 8, and 14 before using data. Based on agreements between BOREAS and ECMWF, users may legally obtain and use these data only by having a set of the BOREAS CD-ROMs that contain the data. Possession or use of these data under any other circumstance is prohibited. See Sections 11.3 and 20.4 for details.

Subject Terms:
- BOREAS, aircraft flux meteorology.

Security Classification of Report: Unclassified
Security Classification of This Page: Unclassified
Security Classification of Abstract: Unclassified
Limitation of Abstract: UL

Number of Pages: 21
Price Code: 298-102