SPECIAL
Cold Land Processes Experiment
COLLECTION

NASA Cold Land Processes Experiment (CLPX 2002/03): Atmospheric Analyses Datasets

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ABSTRACT

This paper describes the Local Analysis and Prediction System (LAPS) and the 20-km horizontal grid version of the Rapid Update Cycle (RUC20) atmospheric analyses datasets, which are available as part of the Cold Land Processes Field Experiment (CLPX) data archive. The LAPS dataset contains spatially and temporally continuous atmospheric and surface variables over Colorado, Wyoming, and parts of the surrounding states. The analysis used a 10-km horizontal grid with 21 vertical levels and an hourly temporal resolution. The LAPS archive includes forty-six 1D surface fields and nine 3D upper-air fields, spanning the period 1 September 2001 through 31 August 2003. The RUC20 dataset includes hourly 3D atmospheric analyses over the contiguous United States and parts of southern Canada and northern Mexico, with 50 vertical levels. The RUC20 archive contains forty-six 1D surface fields and fourteen 3D upper-air fields, spanning the period 1 October 2002 through 31 September 2003. The datasets are archived at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado.

1. Introduction

For many applications, earth system scientists can benefit from continuous (in space and time) representations of state variables, such as air temperature, precipitation, and snow depth. Unfortunately, most field observations are both spatially and temporally irregular. In the atmospheric sciences, a data assimilation procedure is commonly used to produce a continuous (in x, y, z, and t) and physically consistent representation of the atmosphere from a collection of irregular observations. The data assimilation procedure applies filters to extract the signal from the generally noisy observations, perform interpolation in space and time, and use atmospheric models to construct state variables that were not sampled by the observational network and to ensure the analyzed data are physically consistent. The models are based on general fluid mechanics equations applied to the earth's atmosphere. These equations are the conservation laws applied to individual air parcels: conservation of momentum (equations of motion), con-

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servation of energy (first law of thermodynamics), and conservation of mass for dry air and moisture (continuity equations). The resulting analysis is an optimal combination of the available observations and model representation. Thus, the analysis dataset contains the advantage of spatial and temporal continuity but also includes the possible disadvantage of being removed from the original observations. In this paper, we summarize the atmospheric analysis–related data available within the Cold Land Processes Field Experiment (CLPX; Elder et al. 2008) archive. The datasets are archived at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado (available online at http://nsidc.org/data/clpx/).

2. Atmospheric analysis models and data descriptions

a. LAPS analyses

The Local Analysis and Prediction System (LAPS; McGinley et al. 1991; Albers 1995; Albers et al. 1996; Birkenheuer 1999; Hiemstra et al. 2006), developed and operated by the National Oceanic and Atmospheric Administration's (NOAA) Earth System Research Laboratory (ESRL), combines numerous observed meteorological datasets into a unified atmospheric analysis, typically with a time interval of an hour or less. An analysis contains both spatially and temporally continuous atmospheric state variables, in addition to special atmospheric- and land-based fields over Colorado, Wyoming, and parts of the surrounding states (Fig. 1). The quasi-operational analysis used for development at ESRL utilizes a 10-km horizontal grid (125 × 105) with 21 isobaric vertical levels and an hourly temporal resolution. The purpose of a system such as LAPS is to not only provide an up-to-date atmospheric state representation for nowcasting and assessment but also serve as a mechanism to initialize local-scale mesoscale weather forecast models.

LAPS makes use of a wide range of observational datasets as part of its analyses, including 1) surface observations from regional surface networks every 5 min to 3 h; 2) hourly surface aviation observations; 3) Doppler radar volume scans every 6–10 min; 4) wind and temperature radio acoustic sounding system (RASS) profiles from the NOAA Demonstration Profiler Network every 6–60 min; 5) satellite visible data every 15–30 min; 6) multispectral image and sounding radiance data every 60 min; 7) global positioning system (GPS) total precipitable water vapor determined from signal delay; and 8) automated aircraft observations.

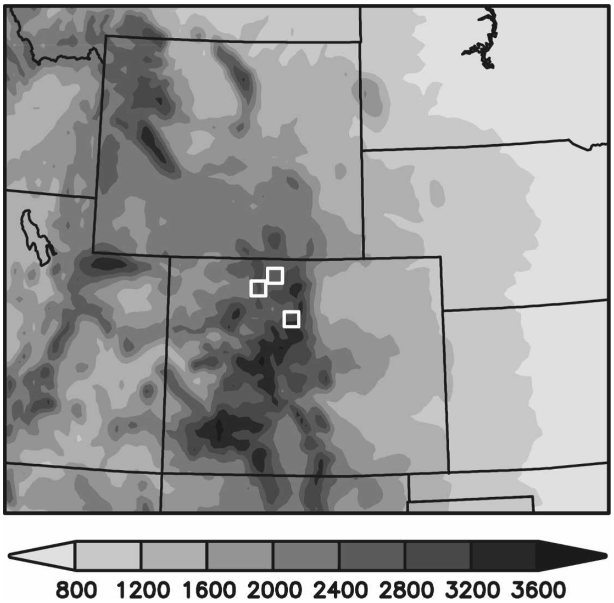

FIG. 1. The LAPS analyses domain and topography (gray shades; m) with outlines of the three 25 × 25 km^2 CLPX MSAs.

LAPS, like many analysis systems, begins with a first guess or a background field interpolated to a finer grid from a coarser large-scale forecast model output. The source for LAPS background fields is generally Rapid Update Cycle (RUC) forecasts (described below), but it is also configured to use Medium-Range Forecasts (MRFs), the National Centers for Environmental Prediction (NCEP) Eta Model, and Navy Operational Global Atmospheric Prediction System (NOGAPS) forecasts [high-resolution backgrounds from the fifth-generation Pennsylvania State University–National Center for Atmospheric Research Mesoscale Model (MM5) or the Weather Research and Forecasting (WRF) Model can also be used for a 4D variational application if lateral boundary conditions are not critical]. The LAPS analysis is a series of routines that then takes the local observations with other nationally disseminated data and modifies the background field to match those observations. In addition, quality control measures (buddy checking and weighting by measurement error) are used to assess the observations and reject those that are deemed unsuitable. Different analysis methods are currently used in the set of analysis routines consisting of Kalman, traditional Barnes, and variational minimization techniques, depending on the dataset (e.g., Daley 1991).

A recent and valuable addition to the LAPS system is termed the "hot start" method for model initialization. Conventional numerical weather models take a few hours to "spin up" convective activity—precipitation processes that are vital to weather forecasting. The hot start method developed at ESRL uses the

TABLE 1. Summary of LAPS variables available within the CLPX data archive.

1D surface fields
U surface wind component (m s^{-1})
V surface wind component (m s^{-1})
1500-m pressure (Pa)
Surface temperature (K)
Surface dew point temperature (K)
Vertical velocity (m s^{-1})
Relative humidity (%)
MSL pressure (Pa)
Temperature advection (K s^{-1})
Potential temperature (K)
Equivalent potential temperature (K)
Surface pressure (Pa)
Vorticity (s^{-1})
Mixing ratio (g kg^{-1})
Moisture convergence (g kg^{-1} s^{-1})
Divergence (s^{-1})
Potential temperature advection (kg s^{-1})
Moisture advection (g kg^{-1} s^{-1})
Surface wind speed (m s^{-1})
Colorado severe storm index (−)
Surface visibility (m)
Fire danger (−)
Heat index (−)
Ground temperature (K)
60-min snow accumulation (m)
Storm-tot snow accumulation (m)
60-min liquid precipitation accumulation (m)
Storm-tot liquid precipitation accumulation (m)
Integrated tot precipitable water vapor (m)
Cloud base (m)
Cloud top (m)
Cloud ceiling (m)
Cloud cover (0–1)
Cloud analysis implied snow cover (0–1)
Clear sky water temperature (K)
IR channel 4 (11.2 μm) blackbody temperature: averaged (K)
IR channel 2 (3.9 μm) blackbody temperature: averaged (K)
LAPS-derived albedo (0–1)
Soil moisture, 3 levels (m m^{-1})
Cumulative infiltration volume (m)
Depth to wetting front (m)
Wet/dry grid point (-)
Evaporation data (m s^{-1})
Snow cover (0–1)
Snowmelt (m^3 m^{-3})
Wetting front soil moist content (m^3 m^{-3})
3D upper-air fields
Geopotential height (m)
Temperature (K)
Specific humidity (kg kg^{-1})
Relative humidity (%)
Relative humidity with respect to liquid (%)
U wind component (m s^{-1})
V wind component (m s^{-1})
Wind omega (Pa s^{-1})
Fractional cloud cover (0–1)

cloud field that is analyzed from satellite, radar, surface, and aircraft data and imposes a balanced vertical motion field in regions of the "observed" analyzed clouds with constraints based on stability and cloud type. Because this balanced field is dynamically consistent, when the 3D winds and temperatures are inserted into a forecast model, the model accepts them directly; thus, precipitation spinup time is either greatly reduced or, in most cases, completely eliminated.

The CLPX LAPS analyses archive spans the period 1 September 2001 through 31 August 2003 (roughly the 2002/03 water years) at an hourly time increment. It includes the three-dimensional and surface variables listed in Table 1 and covers the entire LAPS Regional Operational Cooperative domain (Fig. 1). For reference, Fig. 1 also outlines the CLPX Mesoscale Study Areas (MSAs). Hiemstra et al. (2006) compared LAPS analyses outputs (air temperature, relative humidity, wind speed, and precipitation) for the archived period with CLPX meteorological station observations (Elder et al. 2008) and other independent datasets. They found that LAPS assimilations accurately depicted temperature and relative humidity values. The ability of LAPS to represent wind speed was satisfactory overall, but accuracy declined with increasing elevation. Precipitation estimates performed by LAPS were irregular and reflected inherent difficulties in measuring and estimating precipitation.

An example application using the archived LAPS datasets can be found in Liston and Elder (2006a), in which LAPS meteorological outputs (air temperature, relative humidity, wind speed and direction, and precipitation) were used to drive micrometeorological model (MicroMet) simulations over the CLPX Rabbit Ears MSA. An additional LAPS data application can be found in Liston et al. (2008), where LAPS data were used to drive snow-evolution modeling system (SnowModel; Liston and Elder 2006b) simulations over all three CLPX MSAs shown in Fig. 1.

b. *RUC20 analyses*

NOAA's ESRL also operates a 20-km version of the Rapid Update Cycle (RUC20) atmospheric analysis and forecast system (Benjamin et al. 1998, 2002). The system produces high-frequency (every 1 h) 3D objec-

TABLE 2. Summary of RUC20 variables available within the CLPX data archive.

1D surface fields

Mesoscale Analysis and Prediction System (MAPS) mean sea level pressure (Pa)
Soil temperature at surface (K)
Sensible heat flux (W m^{-2})
Latent heat flux (W m^{-2})
Net longwave radiation at surface (W m^{-2})
Precipitation rate (kg m^{-2} s^{-1})
Resolvable (large) scale precipitation (kg m^{-2})
Subgrid (convective) scale precipitation (kg m^{-2})
Precipitable water (kg m^{-2})
Pressure at tropopause (Pa)
Potential temperature at tropopause (K)
U component of wind at tropopause (m s^{-1})
V component of wind at tropopause (m s^{-1})
Convective available potential energy (J kg^{-1})
Convective inhibition (J kg^{-1})
Soil temperature, 5 cm below surface (K)
Soil temperature, 20 cm below surface (K)
Soil temperature, 40 cm below surface (K)
Soil temperature, 160 cm below surface (K)
Soil temperature, 300 cm below surface (K)
Soil vol. moisture at surface (wfv)
Soil vol. moisture, 5 cm below surface (wfv)
Soil vol. moisture, 20 cm below surface (wfv)
Soil vol. moisture, 40 cm below surface [water fraction by volume (wfv)]
Soil vol. moisture, 160 cm below surface (wfv)
Soil vol. moisture, 300 cm below surface (wfv)
Soil type [0 . . 9 (Zobler)]
Vegetation type (SiB Model; 0 . . 13, as in SiB)
Icing potential SIGMET/AIRMET (-)
Lightning (-)
Rate of water dropping canopy to ground (-)
Net shortwave radiation at surface (W m^{-2})
Snow accumulation (m depth, 100 kg m^{-2})
Snow depth (m)
Surface runoff (kg m^{-2})
Subsurface runoff (kg m^{-2})
Canopy water (kg m^{-2})
Snow temperature, 5 cm below surface or top soil (K)
Snow temperature, 10 cm below surface or top soil (K)
Water vapor mixing ratio at surface (kg kg^{-1})
Snow accumulation (m depth, 100 kg m^{-2})
Snow density, 5 cm below snow surface (kg m^{-3})
Air temperature, 2 m above ground (K)
Water vapor mixing ratio, 2 m (kg kg^{-1})
U component of wind, 10 m (m s^{-1})
V component of wind, 10 m (m s^{-1})

3D upper-air fields

Pressure (Pa)
Height (gpm)
Virtual potential temperature (K)
Water vapor mixing ratio (kg kg^{-1})
U component of wind (m s^{-1})
V component of wind (m s^{-1})
Vertical velocity (Pa s^{-1})
Cloud water mixing ratio (kg kg^{-1})
Rain water mixing ratio (kg kg^{-1})
Ice mixing ratio (kg kg^{-1})
Snow mixing ratio (kg kg^{-1})
Graupel mixing ratio (kg kg^{-1})
Cloud ice number concentration (m^{-3})
Turbulence kinetic energy (J kg^{-1})

tive atmospheric analyses over the contiguous United States and parts of southern Canada and northern Mexico on a 20-km horizontal grid, with 50 vertical levels. The system assimilates the following observations: commercial aircraft [relayed through Aircraft Communication, Addressing, and Reporting System (ACARS)]; NOAA 405-MHz wind profilers; 915-MHz boundary layer profilers; rawinsondes and special dropwinsondes; surface stations, aviation routine weather reports (METARs), and buoys; RASS virtual temperatures; velocity–azimuth display (VAD) winds from National Weather Service (NWS) Weather Surveillance Radar-1988 Doppler (WSR-88D) radars; Geostationary Operational Environmental Satellite (GOES) total precipitable water estimates; GOES cloud-top pressure; GOES high-density visible and IR cloud drift winds; Special Sensor Microwave Imager (SSM/I) total precipitable water estimates; and GPS total precipitable water.

When the source for the LAPS background fields are provided by RUC outputs, the RUC data are treated as a LAPS data source in the first guess, which are then refined by the addition of information from other data sources. If there are no other data, any coincident initial LAPS grid points will be very close to the RUC value, but this is generally the exception. The RUC outputs are not sufficient to provide a hot start capability (mentioned above) to LAPS. RUC lacks the cloud scale information that is inserted by LAPS through the cloud analysis and subsequent balance constraints to support a local-scale vertical motion field suitable for a mesoscale model hot start. Without imposing a horizontal thermal and wind structure to support the imposed vertical motions, any vertical motion field would typically be destroyed by the model in the first one or two time steps.

The CLPX RUC20 analyses archive spans the period 1 October 2002 through 31 September 2003 at an hourly time increment. The archive includes the three-dimensional and surface variables listed in Table 2. Like the LAPS data, the RUC20 data are available for a wide range of applications, including studies of large-scale weather patterns and timing, as well as surface energy- and moisture-flux analyses.

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