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ECOsysteM Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) Mission

Level 3 Product User Guide (Evapotranspiration - ALEXI)

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Note:

The users' guide is designed to be a living document that describes the ECOSTRESS DisALEXI evapotranspiration (ET) product. The document describes the current state of the art, and is revised as progress is made in the development and assessment of the ET product. The primary purpose of the document is to present an overview of the ECOSTRESS L3 DisALEXI data product to the potential user. For more detailed information on the physical basis and algorithm details please see the Algorithm Theoretical Basis Document (ATBD).

Change History Log

Revision	Effective Date	Prepared by	Description of Changes
Draft	6/4/2018	Martha Anderson	User Guide first draft
Preliminary	10/10/2018	Kerry Cawse-Nicholson	Updated references and formatting

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Contents

Figures	6
Tables	6
1 Introduction	7
1.1 File format for L3 products.....	7
1.2 DisALEXI ET Product.....	8
1.3 Product Availability	8
2 ECOSTRESS_L3_ET Product	8
2.1 Algorithm Description	8
2.2 Scientific Data Sets (SDS)	11
2.3 Attributes.....	11
2.4 Quality Flag	13
3 References	14

Figures

Figure 1. Example ECOSTRESS L2 Land Surface Temperature (LST) scene over the southwestern USA generated from simulated data.....	9
Figure 2. Schematic detailing the flow of the ECOSTRESS LST PGE within the JPL Science Data System.	10

Tables

Table 1: Summary of the ECOSTRESS LST&E product.....	8
Table 2: ECOSTRESS input products and ancillary data required to produce the L2 LST&E product.	10
Table 3. The Scientific Data Sets (SDS) in the ECOSTRESS L2 product.	11
Table 4. Standard product metadata included in all ECOSTRESS products.	11
Table 5. Product specific metadata for the ECOSTRESS L2 product.	13
Table 6. Bit flags defined in the QC SDS in the MxD21_L2 product. (Note: Bit 0 is the least significant bit).	14
Table 7. The SDSs in the ECOSTRESS L2 Cloud product.	Er
ror! Bookmark not defined.	
Table 8. The metadata definition in the ECOSTRESS L2 Cloud product.	Er
ror! Bookmark not defined.	

1 Introduction

This is the user guide for the ECOSTRESS Level-3 DisALEXI (evapotranspiration (ET) product. The L3 product uses a physics-based surface energy balance (SEB) algorithm to retrieve estimates of daily ET using the ECOSTRESS L-2 land-surface temperature and emissivity (LST&E) products, along with ancillary meteorological data and remotely sensed vegetation cover information. The output ET is generated on a grid consistent with the Landsat Worldwide Reference System (WRS-2) at a spatial resolution of $\sim 30 \times 30$ m. The algorithm is based on spatial disaggregation of regional-scale fluxes from the Atmosphere Land Exchange Inverse (ALEXI) SEB model. DisALEXI has been evaluated in comparison with micrometeorological flux tower observations over crop, forest, grassland, wetland and semiarid desert sites.

The ECOSTRESS DisALEXI L3 product will be produced on a grid in Universal Transverse Mercator (UTM) coordinates. The algorithms and data content of the ET product are briefly described in this guide, with the purpose of providing a user with sufficient information about the content and structure of the data files to enable the user to access and use the data, in addition to understanding the uncertainties involved with the product and how to interpret the mask information. Overviews of the file formats and provided first followed by descriptions of the algorithm and product contents including all metadata. Publications and documents related to the ECOSTRESS ET products are listed in the final section.

A description of the major components of the ECOSTRESS algorithm implemented in version 1 of the DisALEXI ET code provided in the ATBD available at <https://ecostress.jpl.nasa.gov/products>.

1.1 File format for L3 products

The ECOSTRESS ET products are distributed in HDF5 format and can be read in by HDF5 software. Information on Hierarchical Data Format 5 (HDF5) may be found at <https://www.hdfgroup.org/HDF5/>. The HDF format was developed by NCSA, and has been widely used in the scientific domain. HDF5 can store two primary types of objects: datasets and groups. A dataset is essentially a multidimensional array of data elements, and a group is a structure for organizing objects in an HDF5 file. HDF5 was designed to address some of the limitations of the HDF4. Using these two basic objects, one can create and store almost any kind of scientific data structure, such as images, arrays of vectors, and structured and unstructured grids. They can be mixed and matched in HDF5 files according to user needs. HDF5 does not limit the size of files or the size or number of objects in a file. The scientific data results are delivered as SDSs with local attributes including summary statistics and other information about the data. More detailed information on HDF5 data types may be found in the L3 Product Specification Document (PSD) available at <https://ecostress.jpl.nasa.gov/products>.

The ECOSTRESS ET data product files contain one set of Attributes (metadata) describing information relevant to production, archiving, user services, input products, geolocation and analysis of data, as well as provenance and Digital Object Identifier (DOI) of the product attached to the root group (the file). The attributes listed in Table 4 are not described further in this user guide.

1.2 DisALEXI ET Product

The ECOSTRESS DisALEXI ET data product is produced for ECOSTRESS overpass dates in gridded format, yielding estimates of daily integrated ET for pixels that were flagged as clear-sky in the input L2 LST&E product. The products are generated over target cropland sites within the continental U.S. (CONUS). The spatial resolution of each pixel is 30×30 m, with grid dimensions of approximately 3000x3000 pixels. Table 1 shows a summary of the L3 product characteristics.

Other data product levels briefly described: Level 1B (L1B) is a swath (scene) of measured radiance data geolocated to latitude and longitude centers of 70m resolution pixels. A Level 2 (L2) product is a geophysical product retrieved from the L1B data that remains in latitude and longitude orientation; it has not been temporally or spatially manipulated. The Level 3 and 4 (L3, L4) ECOSTRESS products consist of higher level geophysical variables output from models (evapotranspiration, evaporative stress index, water use efficiency) derived from the L2 and other ancillary data, and are reprojected to a 30m UTM grid.

Table 1: Summary of the ECOSTRESS DisALEXI ET product.

Earth Science Data Type (ESDT)	Product Level	Data Dimension	Spatial Resolution	Temporal Resolution	Map Projection
ECOSTRESS_L3_ET	L3	Approximately 3000 lines by 3000 samples	30 m	gridded	UTM

1.3 Product Availability

The ECOSTRESS L3 product will be made available at the NASA Land Processes Distribution Active Archive Center (LPDAAC),

<https://search.earthdata.nasa.gov/search?q=ecostress&ok=ecostress> and can be accessed via the Earthdata search engine (initially only available to early adopters; see <https://ecostress.jpl.nasa.gov/applications>).

2 ECOSTRESS_L3_ET Product

2.1 Algorithm Description

The basic processing steps involved in L3 ET product generation are outlined schematically in Fig. 2 - for a full detailed description of the DisALEXI processing scheme please see the ATBD at <https://ecostress.jpl.nasa.gov/products>. The energy balance model employed here is a multi-scale system designed to generate self-consistent flux assessments from field to regional/continental scales (Anderson, 2003). The regional Atmosphere-Land Exchange Inverse (ALEXI) model relates time-differential LST observations from geostationary satellites to the time-integrated energy balance within the surface-atmospheric boundary layer system (Anderson et al., 1997, 2007). ALEXI has minimal reliance on absolute (instantaneous) air or surface

temperature input data, and therefore provides a relatively robust flux determination at the coarse geostationary pixel scale. For finer scale ET applications, ALEXI flux fields can be spatially disaggregated using higher resolution LST information from ECOSTRESS, polar orbiting systems (e.g., Landsat or MODIS), or from aircraft using an algorithm referred to as DisALEXI (Norman et al., 2003; Anderson et al., 2004; Cammalleri et al., 2013, 2014; Anderson et al., 2018). Both ALEXI and DisALEXI use the two-source energy balance (TSEB; Norman, 1995; Kustas, 1999) land-surface representation to partition surface fluxes between the canopy and the soil.

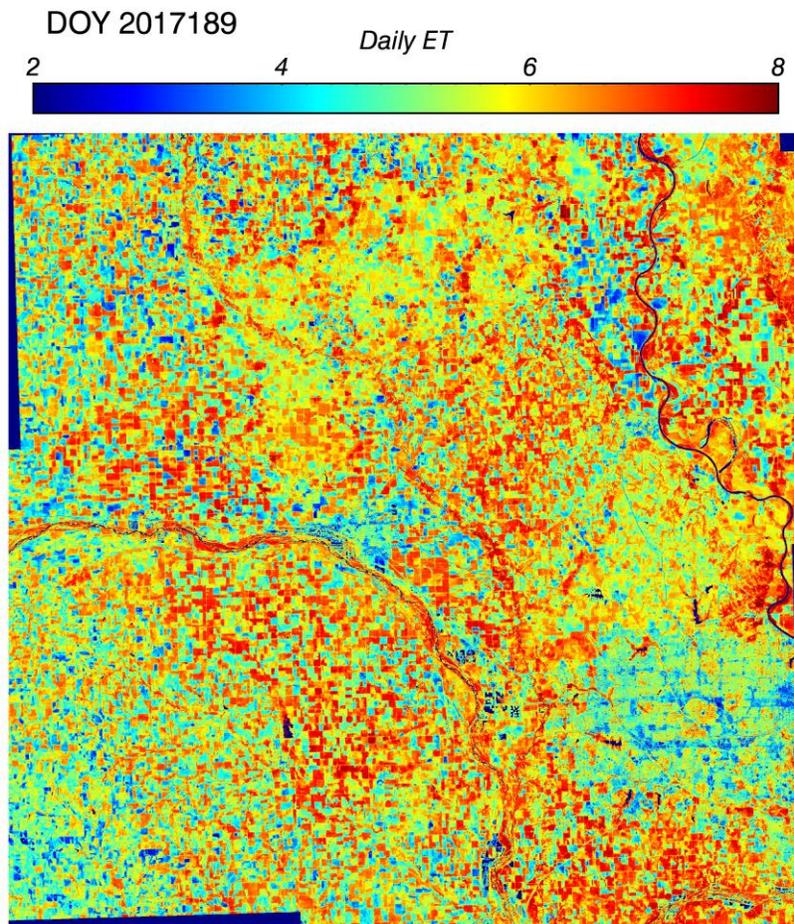


Figure 1. Example ECOSTRESS L3 Evapotranspiration (ET) scene over Mead, NE generated from Landsat data.

Data inputs to the ECOSTRESS L2 algorithm are listed in Table 2. Baseline ALEXI daily ET fluxes are produced at 4km resolution over CONUS using hourly morning LST retrievals from the East and West Geostationary Operational Environmental Satellites covering CONUS. Primary high resolution remote sensing inputs to DisALEXI are LST, leaf area index (LAI; used in the soil/canopy partitioning) and surface albedo (used to compute net radiation). For the L3 ET product, LST is obtained from the L2 LST&E product, while albedo is computed from Landsat spectral reflectance (SR) data. Landsat SR are also used to downscale MODIS LST to 30 m

resolution (Gao, 2012b). The ECOSTRESS LST data are sharpened to 30 m from the native 70 m resolution using Landsat SR data using a Data Mining Sharpener algorithm (Gao, 2012a). Gridded meteorological inputs (solar radiation, wind speed, vapor pressure, atmospheric pressure and air temperature) are obtained from the Climate Forecast System Reanalysis (CFRS) dataset at native resolution of 0.25 degrees (Saha, 2010).

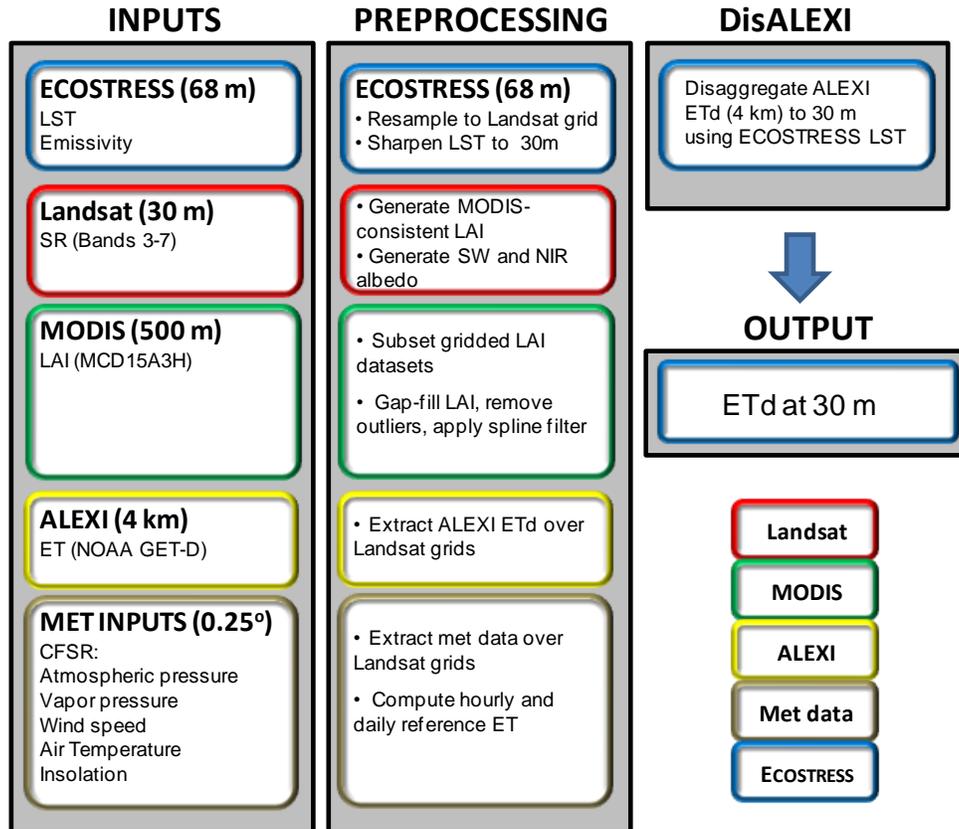


Figure 2. Conceptual diagram describing computation of L3(ALEXI_ET) evapotranspiration

Table 2: ECOSTRESS input products and ancillary data required to produce the L3 DisALEXI ET product.

Ancillary Data Set	Long Name	Data Used
ECOSTRESS_L2	ECOSTRESS Level-2 land-surface temperature and emissivity	Land-surface temperature
ECOSTRESS_L1B_GEO	Geolocation	Land/ocean mask Elevation Sensor and solar zenith angles Latitude, Longitude

Landsat Surface Reflectance product	Landsat Surface Reflectances, Collection 1 (EROS)	Multi-band surface reflectance
MCD15A3H	MODIS/Terra+Aqua Leaf Area Index/FPAR 4-Day L4 Global 500 m SIN Grid V006	Leaf Area Index
CFSR	Climate Forecast System Reanalysis	Air temperature, wind speed, mixing ratio, atmospheric pressure
NLCD	National Land Cover Dataset	Landcover classification

2.2 Scientific Data Sets (SDS)

The ECOSTRESS Level-3 DisALEXI ET product contains 3 scientific data sets (SDSs): ETdaily, ETdailyUncertainty, and QualityFlag. All SDS data are output on a 30 m x 30 m UTM grid. The ETdailyUncertainty data reflect the uncertainty ET associated with the error reported for the L2 ECOSTRESS LST inputs (LST_Err). Details of each SDS including data type and units are shown in Table 3.

Table 3. The Scientific Data Sets (SDS) in the ECOSTRESS L3 ET product.

Field Name	Type	Unit	Field Data
GROUP	EVAPOTRANSPIRATION ALEXI		
ETdaily	Float	mm/day	
ETdailyUncertainty	Float	mm/day	
QualityFlag	UInt8		

2.3 Attributes

Archived with the SDS are attributes (metadata) describing characteristics of the data. Contents of these attributes were determined and written during generation of the product at JPL by the Process Control System (PCS) and are used in archiving and populating the database at the LPDAAC to support user services. They are stored as very long character strings in parameter value language (PVL) format. Descriptions of the attributes are given here to assist the user in understanding them. ECOSTRESS products consist of a set of standard metadata (Table 4) and product-specific metadata (Table 5). The product specific metadata in Table 5 give details on ancillary data sets and average ET uncertainty values for the entire scene.

Table 4. Standard product metadata included in all ECOSTRESS products.

Name	Type	Size	Example
Group	StandardMetadata		
AncillaryInputPointer	String	variable	Group name of ancillary file list
AutomaticQualityFlag	String	variable	PASS/FAIL (of product data)
BuildId	String	variable	
CollectionLabel	String	variable	
DataFormatType	String	variable	NCSAHDF5
DayNightFlag	String	variable	
EastBoundingCoordinate	LongFloat	8	
HDFVersionId	String	variable	1.8.16
ImageLines	Int32	4	3000
ImageLineSpacing	Float32	4	30
ImagePixels	Int32	4	3000
ImagePixelSpacing	Float32	4	30
InputPointer	String	variable	
InstrumentShortName	String	variable	ECOSTRESS
LocalGranuleID	String	variable	
LongName	String	variable	ECOSTRESS
NorthBoundingCoordinate	LongFloat	8	
PGENAME	String	variable	L3_ET_ALEXI-USDA
PGEVersion	String	variable	
PlatformLongName	String	variable	ISS
PlatformShortName	String	variable	ISS
PlatformType	String	variable	Spacecraft
ProcessingLevelID	String	variable	1
ProcessingLevelDescription	String	variable	Level 3 evapotranspiration disALEXI from USDA
ProducerAgency	String	variable	USDA
ProducerInstitution	String	variable	USDA
ProductionDateTime	String	variable	
ProductionLocation	String	variable	
CampaignShortName	String	variable	Primary
RangeBeginningDate	String	variable	
RangeBeginningTime	String	variable	
RangeEndingDate	String	variable	
RangeEndingTime	String	variable	
SceneID	String	variable	
ShortName	String	variable	L3_ET_ALEXI-USDA
SISName	String	variable	
SISVersion	String	variable	
SouthBoundingCoordinate	LongFloat	8	
StartOrbitNumber	String	variable	

StopOrbitNumber	String	variable	
WestBoundingCoordinate	LongFloat	8	

Table 5. Product specific metadata for the ECOSTRESS L3 ET product.

Name	Type	Size	Example
Group			
L3_ET_ALEXI Metadata			
QualityBitFlag	String	255	01011011011
AvgETUncertainty	LongFloat	8	
AncillaryFiles	Int	4	100
AncillaryFileAirTemperature	String	255	CFSR_FILENAME_DATE
AncillaryFileALEXIETd	String	255	EDAY_V7NC_CFSRINSOL_2018200.dat
AncillaryFileBadMask	String	255	
AncillaryFileInsolation	String	255	CFSR_FILENAME_DATE
AncillaryFileLandcover	String	255	NLCD_FILENAME
AncillaryFileLST	String	255	LSTE_FILENAME
AncillaryFileMixingRatio	String	255	CFSR_FILENAME_DATE
AncillaryFilePressure	String	255	CFSR_FILENAME_DATE
AncillaryFileSurfaceReflectance	String	255	LANDSAT_TARFILE_NAME
AncillaryFileSurfReflectanceFill	String	255	
AncillaryFileWindSpeed	String	255	CFSR_FILENAME_DATE
Projection	String	255	(ECOSTRESS or UTM)
Geotransform	String	255	
OGC Well Known Text	String	variable	Blank if Projection=ECOSTRESS If Projection=UTM, EG: {PROJCS["UTM_Zone_11N",GEOGCS["GCS_WG S_1984",DATUM["D_WGS_1984",SPHEROID[" WGS_1984",6378137.0,298.257223563]],PRIM EM["Greenwich",0.0],UNIT["Degree",0.017453 2925199433]],PROJECTION["Transverse_Merca tor"],PARAMETER["False_Easting",500000.0],P ARAMETER["False_Northing",0.0],PARAMETER[" Central_Meridian",- 117.0],PARAMETER["Scale_Factor",0.9996],PAR AMETER["Latitude_Of_Origin",0.0],UNIT["Mete r",1.0]}

2.4 Quality Flag

Indicators of data quality are described in the quality flag SDS generated during production. The QualityFlag SDS provides information on regarding cause of missing data in the L3 DisALEXI ET product. A successful ET retrieval for a given pixel requires 1) good quality clear-sky L2 LST data are available, 2) good quality surface reflectance data are available from bracketing Landsat overpass date, 3) an ALEXI retrieval is available for the 4-km ALEXI grid cell encompassing the 30-m target pixel; and 4) the pixel is designated as land in the NLCD

(retrievals for open water bodies are not conducted). These conditions are tracked in the QualityFlag SDS at the pixel level. The QualityFlag SDS unsigned 8-bit data are stored as bit flags in the SDS. This QC information can be extracted by reading the bits in the 8-bit unsigned integer.

Table 6. Bit flags defined in the QC SDS in the L3 ALEXI ET product. (Note: Bit 0 is the least significant bit).

Bit Field	Long Name	Result
0	Pixel computed	0 = yes 1 = no
1	Good quality LSTE available	0 = yes 1 = no
2	Good quality Surface Reflectance data available	0 = yes 1 = no
3	ALEXI data available	0 = yes 1 = no
4	Other (land pixel, etc.)	0 = yes 1 = no

3 References

- Anderson, M.C., Norman, J.M., Diak, G.R., Kustas, W.P., & Mecikalski, J.R. (1997). A two-source time-integrated model for estimating surface fluxes using thermal infrared remote sensing. *Remote Sens. Environ.*, 60, 195-216
- Anderson, M.C., W. P. Kustas, and J. M. Norman, (2003). Upscaling and downscaling—A regional view of the soil–plant–atmosphere continuum. *Agron. J.*, 95, 1408–1423.
- Anderson, M.C., Norman, J.M., Mecikalski, J.R., Torn, R.D., Kustas, W.P., & Basara, J.B. (2004). A multi-scale remote sensing model for disaggregating regional fluxes to micrometeorological scales. *J. Hydrometeor.*, 5, 343-363
- Anderson, M.C., Norman, J.M., Mecikalski, J.R., Otkin, J.A., & Kustas, W.P. (2007). A climatological study of evapotranspiration and moisture stress across the continental U.S. based on thermal remote sensing: I. Model formulation. *J. Geophys. Res.*, 112, D10117, doi:10.1029/2006JD007506

-
- Anderson, M.C., Gao, F., Knipper, K., Hain, C., Dulaney, W., Baldocchi, D.D., Eichelmann, E., Hemes, K.S., Yang, Y., Medellín-Azuara, J., & Kustas, W.P. (2018). Field-scale assessment of land and water use change over the California Delta using remote sensing. *Remote Sens.*, *10*, 889
- Cammalleri, C., Anderson, M.C., Gao, F., Hain, C.R., & Kustas, W.P. (2013). A data fusion approach for mapping daily evapotranspiration at field scale. *Water Resources Res.*, *49*, 1-15, doi:10.1002/wrcr.20349
- Cammalleri, C., Anderson, M.C., Gao, F.H., C.R., & Kustas, W.P. (2014). Mapping daily evapotranspiration at field scales over rainfed and irrigated agricultural areas using remote sensing data fusion. *Agric. For. Meteorol.*, *186*, 1-11
- Gao, F., Kustas, W.P., Anderson, M.C., (2012a). A data mining approach for sharpening thermal satellite imagery over land. *Remote Sens.* *4*, 3287–3319. <http://dx.doi.org/10.3390/rs4113287>.
- Gao, F., Anderson, M.C., Kustas, W.P., Wang, Y., (2012b). Simple method for retrieving leaf area index from Landsat using MODIS leaf area index products as reference. *J. Appl. Remote. Sens.* *6*, 63554. <http://dx.doi.org/10.1117/1.JRS.6.063554>.
- Kustas, W. P., and J. M. Norman (1999), Evaluation of soil and vegetation heat flux predictions using a simple two-source model with radiometric temperatures for partial canopy cover, *Agric. For. Meteorol.*, *94*, 13– 25.
- Norman, J. M., Kustas, W. P., & Humes, K. S. (1995). A two-source approach for estimating soil and vegetation energy fluxes from observations of directional radiometric surface temperature. *Agricultural and Forest Meteorology*, *77*, 263-293.
- Norman, J.M., Anderson, M.C., Kustas, W.P., French, A.N., Mecikalski, J.R., Torn, R.D., Diak, G.R., Schmugge, T.J., & Tanner, B.C.W. (2003). Remote sensing of surface energy fluxes at 10¹-m pixel resolutions. *Water Resour. Res.*, *39*
- Saha, S., S. Moorthi, H. Pan, X. Wu, J. Wang, S. Nadiga, P. Tripp, R. Kistler, J. Woollen, D. Behringer, H. Liu, D. Stokes, R. Grumbine, G. Gayno, J. Wang, Y. Hou, H. Chuang, H.H. Juang, J. Sela, M. Iredell, R. Treadon, D. Kleist, P. Van Delst, D. Keyser, J. Derber, M. Ek, J. Meng, H. Wei, R. Yang, S. Lord, H. van den Dool, A. Kumar, W. Wang, C. Long, M. Chelliah, Y. Xue, B. Huang, J. Schemm, W. Ebisuzaki, R. Lin, P. Xie, M. Chen, S. Zhou, W. Higgins, C. Zou, Q. Liu, Y. Chen, Y. Han, L. Cucurull, R.W. Reynolds, G. Rutledge, and M. Goldberg, 2010: The NCEP Climate Forecast System Reanalysis. *Bull. Amer. Meteor. Soc.*, *91*, 1015–1058, <https://doi.org/10.1175/2010BAMS3001.1>