Office of Satellite and Product Operations
Environmental Satellite Processing Center

NOAA Geostationary Operational Environmental Satellite-R Fog and Low Stratus External Users' Manual

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Prepared by: Earth Resources Technologies, Inc.

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Office of Satellite and Product Operations

Approval Page

Office of Satellite and Product Operations
Environmental Satellite Processing Center
NOAA Geostationary Operational Environmental Satellite-R
Fog and Low Stratus
External Users' Manual

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Changes/Revisions Record

This external users' manual is changed as required to reflect system, operational, or organizational changes. Modifications made to this document are recorded in the Changes/Revisions Record below. This record will be maintained throughout the life of the document.

Version Number	Date	Description of Change/Revision	Section/Pages Affected	Changes Made by Name/Title/ Organization
1.0	08/15/2018	Created by John Lindeman – similar to GOES FLS manuals, but for GOES-R satellite series. Includes some information about the related offline snow mask and ASOS products.	All	John Lindeman, Emily Doss
1.0a	3/22/2019	**ASOS:** output filename update; ASOS inputs Cloud Mask/Height now obtained from Clouds unit; support for Mode6; minor script updates for NDE; ASOS fall-back option **FLS:** FW2.0 implementation; parallel processing; improved latency; full disk processing (not truncated full disk); Clouds/Fog algorithms now run with buffering; FLS unit separated to Clouds and Fog processing units **NOTE:** this version of the EUM (and SMM) is a **rough draft**. Finalized versions will be available for the final DAP in April 2019		
1.0b	5/24/2019	EPSx Mode6 patch to final DAP processing architecture updates. Version number updated to v1r1.		
1.1	10/5/2019	OISST patch update; product version number updated to v1r2		
1.2a	1/31/2020	**ASOS:** Clouds unit (height, mask) from previous DAPs have been merged with the ASOS unit. **FLS:** No update with this DAP		

Version Number	Date	Description of Change/Revision	Section/Pages Affected	Changes Made by Name/Title/ Organization
1.2b	2/28/2020	**ASOS:** No update **FLS:** Update to correspond with previous ASOS update (1) Cloud phase calculated for FLS, (2) output file now compatible with AWIPS software		
3.0	2/19/2021	FLS has been decoupled from ASOS, and this document only describes the FLS product system. FLS now works on GOES-17.		
3.1	11/1//2021	Technical Edits; conformed to OSPO template, inserted Appendix A- Acronyms	All	Chris Edwards, ERT Technical Writer
3.1	2/22/2022	Quality Assurance	All	Clint Sherwood, Quality Manager, ERT Inc.

Preface

This document comprises the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS), Office of Satellite and Product Operations (OSPO), publication of this Geostationary Operational Environmental Satellite-R Fog and Low Stratus External Users' Manual. This document reflects current operations for the DOC/NOAA/NESDIS/ESPC information technology systems. This document describes the NESDIS Fog and Low Stratus Program in accordance with Federal, DOC, NOAA, NESDIS and OSPO/ESPC requirements.

NOAA/NESDIS/OSPO/ESPC acknowledges the efforts of ERT Inc. personnel for their preparation of this document. Future updates and revisions to this document will be produced and controlled by DOC/NOAA/NESDIS/ESPC.

The published version of this document can be found at the OSPO Products SharePoint site.

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1. PRODUCTS

This is an external users' manual (EUM) document describing the GOES-R satellite series Fog and Low Stratus (FLS) products and output files. The Enterprise Processing System (EPS) GOES-R Fog product system was developed at the Center for Satellite Applications and Research (STAR) and will be implemented into operations at the NOAA NPOESS Data Exploitation (NDE).

The intended users of the EUM are end users of the output products and files, and the product verification and validation (V&V) teams. The purpose of the EUM is to provide product users and product testers with information that will enable them to acquire the product, understand its features, and use the data. External users are defined as those users who do not have direct access to the processing system.

Note that the terms "Fog" and "FLS" are used interchangeably in this document. Both terms refer to the suite of FLS products. FLS products are processed after the intermediate cloud phase product.

1.1. Product Overview

The NOAA Fog product system produces the fog mask and fog depth products. The products are generated from raw GOES-R GRB (GOES Rebroadcast) L1b data and ancillary data from external sources. The output products are intended for operational and scientific users.

This document contains some information about the offline ice mapping system (IMS)/special sensor microwave imager (SSMI) snow mask and the intermediate clouds products. These products are used as input for FLS. For more detailed information about these products, please refer to the GOES-R FLS System Maintenance Manual (SMM).

1.1.1. Product Requirements

The requirements are to develop a production system to demonstrate that common algorithm approach for new EPS products. It is expected to demonstrate a cost-effective algorithm development, implementation, transition to operations, and maintenance process for NOAA products on future GOES satellites. Please see the requirements section of the FLS ARR (Algorithm Readiness Review) presentation for details on specific FLS requirements.

1.1.2. Product Team

The GOES EPS Development product team consists of members from STAR, OSPO, and NDE. The roles and contact information for the different product team members is identified in Table 1-1.

Table 1-1 - Product Team Members

Team Member	Organization	Role	Contact Information
Mike Pavolonis	STAR	Science Team Lead	michael.pavolonis@noaa.gov
Corey Calvert	CIMSS	Science Team	ccalvert@ssec.wisc.edu
Hongming Qi	OSPO	FLS PAL	hongming.qi@noaa.gov

Team Member	Organization	Role	Contact Information
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Zhaohui Cheng	OSPO	OSPO QA PAL	zhaohui.cheng@noaa.gov
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Team Member	Organization	Role	Contact Information
		Integration Team Lead	
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Claire McCaskill	STAR	PLAIT QA Specialist	claire.mccaskill@noaa.gov
Valeria Guadalupe-Cruz	STAR	T4 R2O & Processing	valeria.guadalupe-cruz@noaa.gov
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Hongming Qi

Point of Contact:
Feedbacks, comments, criticisms, suggestions, are welcome and should be sent to:

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1.1.3. Product Description

The NOAA GOES-R EPS Fog products will be used as a risk reduction assessment for the implementation of common NESDIS algorithms of the GOES-R system. The system was designed to run within the Enterprise Processing System environment. Fog products include the fog depth, Marginal Visual Flight Rule (MVFR) probability, Instrument Flight Rule (IFR) (infrared) fog probability, Low Instrument Flight Rule (LIFR) probability, fog mask, and quality flags. The output files are in NetCDF format.

1.1.4. Product History

The algorithms in the GOES-R Fog products are upgraded versions of the original GOES-R algorithms developed for STAR. The result of this implementation is to have just one set of algorithm software that will need to be maintained for generating products from the GOES-R Advanced Baseline. It is expected that instruments onboard future GOES-R series satellites will also use these algorithms. This EPS Fog project supports the common algorithm approach for new satellite products.

This version of GOES-R Fog is configured for NDE operations. The previous version (April 2017) was delivered to the consolidated high-throughput operational products system (CHOPS) operational system. In the current version, the coding language data access protocol (DAP) scripts have been changed from Perl to Python 3.7.3. Other changes involve Framework version 2.0 implementation, faster processing, full-disk processing, and scripting updates (most of these updates are outside the scope of this document).

1.2. Product Characteristics

The Fog products are dependent on other products derived from GOES-R L1b data including the cloud mask, cloud phase, cloud height, and the radiative transfer model (RTM). The Clouds products are generated internally and are called intermediate products. Other products obtained from elsewhere (static and dynamic ancillary) include snow mask (combined IMS and SSMI), land mask, coast mask, desert mask, Numerical Weather Prediction (NWP) global forecast system (GFS) data, NWP restricted access processor (RAP) data, sea surface temperature, surface elevation, surface type, surface emissivity, pseudo emissivity, and surface albedo.

1.3. Product Access

All Fog output data files will be made available by the NDE data handling subsystem (DHS) on the NDE data distribution server at ESPC in a near real time manner. For access to this server, information about data files, and associated documentation, the EPS Fog Product Area Lead (PAL) should be contacted (see Table 1-1).

The NESDIS' Policy on Access and Distribution of Environmental Data and Products is provided at: http://www.ospo.noaa.gov/Organization/About/access.html.

Users need to fill out the Data Access Request Form located on this site and submit to the PAL with a copy to nesdis.data.access@noaa.gov. This address provides the OSPO Data Access Team a copy of the correspondence. The process is defined in the following diagram. Once the request is approved by the OSPO management the data will be delivered by the Product Distribution and Access (PDA) system. The ESPC Data Distribution Manager, Donna McNamara (donna.mcnamara@noaa.gov) should be contacted for any data accessibility and data distribution problems.

Table 1-2 lists the Fog output file name and format. Note that the Fog output files have NetCDF level2 compression applied (saves space and meets time requirements). The FLS NetCDF output files are now compatible with the advanced weather interactive processing system (AWIPS) software for National Weather Service (NWS) AWIPS users (February 2020).

Table 1-2 - EPS Fog Output File Names (NetCDF4 format)

EPS FLS Product Algorithm Names	***Approx. File Size (CONUS/FD)***	***NetCDF4 EPS FLS product filenames***
Fog	325 MB / 1.8 GB	ABI-L2-GFLS<C|F>-<M6>_v3r0_<g16|g17_sYYYYMMDDhhmmsss_eYYYYMMDDhhmmsss_cYYYYMMDDhhmmsss.nc
Reformatted Fog for AWIPS	3 MB / 24 MB	ABI-L2-GFLS<C|F>-AWIPS-<M6>_v3r0_<g16|g17>_sYYYYMMDDhhmmsss_eYYYYMMDDhhmmsss_cYYYYMMDDhhmmsss.nc

Where,
ABI – Advanced Baseline Imager satellite instrument
GFLS – GOES Fog/Low Stratus
<C|F> – ABI FD or CONUS scan
<M6> - ABI Scan Mode
v1r2 – version 3.0, release 0
<g16|g17> – Satellite identifier- GOES-16 or GOES-17
s – image start time
e – image end time
c – image creation time
YYYY – 4 digit year
MM – 2 digit month
DD – 2 digit day
hh – 2 digit hour
mm – 2 digit minute
sss – 3 digit second

For the current operational GOES-R satellites (GOES East and GOES West), the full disk scans are produced once every 10 minutes, and the other sectors are generated every 5 minutes. Note that the sectors are static - the latitude and longitude coordinates do not change. The EPSx FLS products are processed for GOES-R CONUS and full disk (FD).

The FLS file contents are shown in Table 1-3.

Table 1-3 - FLS Output File product description

Variable	Type	Description	Dim	Units	Range
Latitude	Float	Pixel latitude in field latitude	2	Degrees north	-90, 90
Longitude	Float	Pixel longitude in field longitude	2	Degrees east	-180, 180
BT_Chn14_StdDev	Float	Standard deviation of the brightness temperature for ABI channel 14	2	K	?

Variable	Type	Description	Dim	Units	Range
Emiss_Chn7_Atm_Correc	Float	Emissions ABI channel 7 atmospheric correction	2	1	?
Emiss_Chn7_Composite	Float	Composite ABI channel 7 emissions	2	1	?
FLSperct	Float	Fraction of pixels in scene detected as fog/low cloud	0	Percent	0, 100
Fog_Depth	Float	Fog Depth	2	M	0, 1000
Fog_Lrc_Mask	Byte	Fog Mask	2	Percent	0, 100
Fog_Qf	Short	Fog Quality Flag	3	None	?
Fog_Qpi	Short	Fog quality pixels	3	None	?
FractionClear	Float	Fraction of FLS pixels retrieved that are classified as clear	0	1	0.0,1.0
FractionFLS	Float	Fraction of FLS eligible pixels to total number of pixels	0	1	0.0,1.0
FractionIce	Float	Fraction of FLS pixels retrieved that are classified as ice	0	1	0.0,1.0
FractionMixed	Float	Fraction of FLS pixels retrieved that are classified as mixed phase	0	1	0.0,1.0
FractionNotClear	Float	Fraction of FLS pixels retrieved that are classified as not clear	0	1	0.0,1.0
FractionSuperCooled	Float	Fraction of FLS pixels retrieved that are classified a supercooled	0	1	0.0,1.0
FractionWater	Float	Fraction of FLS pixels retrieved that are classified as liquid water	0	1	0.0,1.0

Variable	Type	Description	Dim	Units	Range
granule_level_quality_flag	Long	Fog Low Level Stratus Granule Level Degradation Quality Flag	2	1	?
IFR_Fog_Prob	Float	Infrared fog probability	2	Percent	0, 100
IFR_RHonly_Fog_Prob	Float	Infrared relative humidity fog probability	2	Percent	0, 100
LIFR_Fog_Prob	Float	LIFR fog probability	2	Percent	0, 100
MVFR_Fog_Prob	Float	MVFR fog probability	2	Percent	0, 100
MaxFLSdepth	Float	Maximum fog/low stratus depth from pixels detected as containing fog/low cloud	0	M	?
MaxIFRprob	Float	Maximum probably of pixels containing valid IFR probabilities	0	Percent	0,100
MaxLIFRprob	Float	Maximum probabilities of pixels containing LIFR probabilities	0	Percent	0,100
MaxMVFRprob	Float	Maximum probability of pixels containing valid MVFR probabilities	0	Percent	0,100
Max_RH_1000ft_9X9	Float	Maximum relative humidity at 1000 feet	2	1	?
Max_RH_1000ft_Lay	Float	Maximum relative humidity layer 1000 ft above ground level	2	1	?

Variable	Type	Description	Dim	Units	Range
Max_RH_1000ft_Lay_Above	Float	Maximum relative humidity layer above 1000 ft above ground level	2	1	?
Max_RH_1000ft_Lay_Above_Global	Float	Maximum relative humidity layer above 1000 ft above ground level global	2	1	?
Max_RH_1000ft_Lay_Global	Float	Maximum relative humidity layer 1000 ft global	2	1	?
Max_RH_3000ft_9X9	Float	Maximum relative humidity at 3000 feet	2	1	?
Max_RH_3000ft_Lay	Float	Maximum relative humidity layer 3000 ft above ground level	2	1	?
Max_RH_3000ft_Lay_Above	Float	Maximum relative humidity layer above 3000 ft above ground level	2	1	?
Max_RH_3000ft_Lay_Above_Global	Float	Maximum relative humidity layer above 3000 ft above ground level global	2	1	?
Max_RH_3000ft_Lay_Global	Float	Maximum relative humidity layer 3000 ft global	2	1	?
Max_RH_500ft_9X9	Float	Maximum relative humidity at 500 feet	2	1	?
Max_RH_500ft_Lay	Float	Maximum relative humidity layer 500 ft above ground	2	1	?

Variable	Type	Description	Dim	Units	Range
		level			
Max_RH_500ft_Lay_Above	Float	Maximum relative humidity layer above 500 ft above ground level	2	1	?
Max_RH_500ft_Lay_Above_Global	Float	Maximum relative humidity layer above 500 ft above ground level global	2	1	?
Max_RH_500ft_Lay_Global	Float	Maximum relative humidity layer 500 ft global	2	1	?
Max_RH_Hgt_1000ft_Lay_Above	Float	Maximum relative humidity height layer above 1000 ft above ground level	2	1	?
Max_RH_Hgt_1000ft_Lay_Above_Global	Float	Maximum relative humidity height layer above 1000 ft above ground level global	2	1	?
Max_RH_Hgt_3000ft_Lay_Above	Float	Maximum relative humidity height layer above 3000 ft above ground level	2	1	?
Max_RH_Hgt_3000ft_Lay_Above_Global	Float	Maximum relative humidity height layer above 3000 ft above ground level global	2	1	?
Max_RH_Hgt_500ft_Lay_Above	Float	Maximum relative humidity height layer above 500 ft	2	1	?

Variable	Type	Description	Dim	Units	Range
		above ground level			
Max_RH_Hgt_500ft_Lay_Above_Global	Float	Maximum relative humidity height layer above 500 ft above ground level global	2	1	?
Max_RH_Hgt_Sfc_Elev_Diff	Float	Maximum relative humidity height surface elevation difference	2	M	?
MeanFLSdepth	Float	Mean fog/low stratus depth from pixels detected as containing fog/low cloud	0	M	?
MeanIFRprob	Float	Mean probability of pixels containing valid IFR probabilities	0	Percent	0,100
MeanLIFRprob	Float	Mean probability of pixels containing valid LIFR probabilities	0	Percent	0,100
MeanMVFRprob	Float	Mean probability of pixels containing valid MVFR probabilities	0	Percent	0,100
Meso_Nwp_Valid	Byte	Validity of mesoscale NWP model at given pixel location	2	1	0,1
MinFLSdepth	Float	Minimum fog/low stratus depth from pixels detected as containing fog/low cloud	0	M	?

Variable	Type	Description	Dim	Units	Range
MinIFRprob	Float	Minimum probability of pixels containing valid IFR probabilities	0	Percent	0,100
MinLIFRprob	Float	Minimum probability of pixels containing valid LIFR probabilities	0	Percent	0,100
MinMVFRprob	Float	Minimum probability of pixels containing MVFR probabilities	0	Percent	0,100
NumFLSpix	Long	Number of FLS eligible pixels	0	1	?
NumPixClear	Long	Number of FLS pixels retrieved that are classified as clear	0	1	?
NumPixIce	Long	Number of FLS pixels retrieved that are classified as ice	0	1	?
NumPixMixed	Long	Number of FLS pixels retrieved that are classified as mixed phase	0	1	?
NumPixNotClear	Long	Number of FLS pixels retrieved that are classified as not clear	0	1	?
NumPixSuperCooled	Long	Number of FLS pixels retrieved that are classified as super cooled	0	1	?
NumPixWater	Long	Number of FLS pixels retrieved that are classified as liquid water	0	1	?
NumTotPixAtpt	Long	Number of pixels where retrieval	0	1	?

Variable	Type	Description	Dim	Units	Range
		was attempted			
NumTotalPix	Long	Total number of pixels (including space)	0	1	Columns x rows
Refl_Chn2_StdDev	Float	ABI Channel 2 reflectance standard deviation	2	Percent	0, 100
Refl_Chn2_StdDev_Lrc	Float	ABI Channel 2 reflectance standard deviation Lrc	2	Percent	0, 100
Refl_Chn2_StdDev_Composite	Float	Composite ABI Channel 2 reflectance standard deviation	2	1	?
Refl_Chn7_Composite	Float	Composite ABI Channel 7 reflectance	2	Percent	0, 100
Sfc_Elevation	Float	Surface Elevation	2	M	?
Sfc_RH	Float	Surface relative humidity	2	1	?
Sfc_RH_Global	Float	Surface relative humidity global	2	1	?
Sfc_Temp_Bias	Float	Surface temperature bias	2	K	?
Sfc_Temp_Bias_Global	Float	Surface temperature bias global	2	K	?
StdDevFLSdepth	Float	Standard deviation of fog/low stratus depth from pixels detected as containing fog/low cloud	0	M	?
StdDevIFRprob	Float	Std dev of probabilities of pixels containing IFR probabilities	0	Percent	0,100
StdDevLIFRprob	Float	Std dev of probabilities of	0	Percent	0,100

Variable	Type	Description	Dim	Units	Range
		pixels containing LIFR probabilities			
StdDevLIFRprob	Float	Std dev of probabilities of pixels containing MVFR probabilities	0	Percent	0,100
Xgrad_Idx	Log	Xgrad Index	2	1	?
Ygrad_Idx	Log	Ygrad Index	2	1	?

Product-monitoring metadata is now included with the NetCDF output files for FLS. The metadata was added in compliance with CHOPS requirements (April 2017 CHOPS delivery) of having both collection level metadata and geographic metadata. The metadata can be found in Table 1-4.

Table 1-4 - NDE Level Metadata

Attribute Name	Data Type	Description / Value
Collection Level Metadata		
Conventions	string	CF-1.6
Metadata_Conventions	string	CF-1.6, Unidata Dataset Discovery v1.0
standard_name_vocabulary	string	CF Standard Name Table v76
project	string	Enterprise Processing System Extension: GOES-R Fog/ Low Stratus Cloud Product
institution	string	DOC/NOAA/NESDIS/NDE > S-NPP Data Exploitation, NESDIS, NOAA, U.S. Department of Commerce
naming_authority	string	gov.noaa.nesdis.nde
satellite_name	string	GOES-<16|17>
instrument_name	string	GOES-R Series Advanced Baseline Imager
orbital_slot	string	GOES-<East|West>
Timeline_id	string	ABI scan mode. Eg., ABI Mode<3|4|6>
title	string	Set to the NUP product short name E.g., ABI-L2-GFLS<C|F>-M<3|4|6>

Attribute Name	Data Type	Description / Value
summary	string	Brief description of the product. Ex. Fog Depth and Flight Rule Probabilities
history	string	Provides the science algorithm version used to product the NUP. v2.3.1
history_package	string	Provides the delivery package version used to produce the NUP. v3r0
Attribute Name	Data Type	Value/Description
processing_level	string	NOAA Level 2
references	string	Optional. Published or web-based references describing the data or methods used to produce the product
production_site	string	[NSOF | CBU] (NSOF = Suitland, CBU = Wallops backup site)
production_environment	string	[DE | ITE | OE] (Dev, Integration & Test, Ops)
id	string	Each product team can implement a unique identifier, so long as it is approved by their NEDSIS data center representative. If the team chooses to use the recommended UUID version 4 for this, then the identifier will rely only on random numbers. Version 4 UUIDs have the form xxxxxxxx-xxxx-4xxx-yxxx-xxxxxxxxxxxx where x is any hexadecimal digit and y is one of 8, 9, A, or B., creating an identifier like: f47ac10b-58cc-4372-a567-0e02b2c3d479
Metadata_link	string	This attribute lists the unique NUP product file name
time_coverage_start	string	This attribute should be set to the UTC start time of an observation as "YYYY-MM-DDThh:mm:ssZ", where YYYY is the four digit year, MM is the two digit month, DD is the two digit day, hh is the UTC hour, mm is the UTC minute, and ss is the UTC second
time_coverage_end	string	Optional for Geostationary. This attribute should be set to the UTC end time of an observation as "YYYY-MM-DDThh:mm:ssZ", where YYYY is the four digit year,

Attribute Name	Data Type	Description / Value
		MM is the two digit month, DD is the two digit day, hh is the UTC hour, mm is the UTC minute, and ss is the UTC second
date_created	string	This attribute should be set to the UTC time the NUP file was created as "YYYY-MM-DDThh:mm:ssZ", where YYYY is the four digit year, MM is the two digit month, DD is the two digit day, hh is the UTC hour, mm is the UTC minute, and ss is the UTC second
sensor_band_identifier	string	This attribute should be set to the instrument channels used to generate the product. If more than one channel, comma used to separate them; "2, 7, 14"
sensor_band_center_wavelength	string	This attribute should be set to the center wavelength of those channels used to generate the product. "0.64um, 3.9um, 11.2um"
resolution	string	The resolution at which the product is generated. 2km at nadir
Geographic Metadata		
Attribute Name	**Data Type**	**Description**
cdm_data_type	string	This attribute describes the geographic coverage category the NUP data represents. "Image"
scene_id	string	CONUS | FD
geospatial_lat_units	string	This attribute should be "degrees_north"
geospatial_lon_units	string	This attribute should be "degrees_east"
geospatial_bounds	string	This attribute describes a closed polygon of N (N>3) latitude and longitude vertices. The last latitude/longitude pair must be identical to the first pair. Latitudes values include -90 (south) to 90 (north) degrees and Longitude values include -180 (west) to 180 (east). This should be "POLYGON((lon1 lat1, lon2 lat2,…,lonN latN, lon1 lat1)) Below is an example for CONUS:

Attribute Name	Data Type	Description / Value
		geospatial_bounds = POLYGON((-152.109 56.7615, -52.9469 56.7615, -52.9469 14.5713, -152.109 14.5713)) geospatial_lat_units = degrees_north geospatial_lon_units = degrees_east

2. ALGORITHM

2.1. Algorithm Overview

The Fog products are generated from the Enterprise Processing System fog and low stratus algorithms located within the framework. The Fog algorithms include fog depth, IFR probability, LIFR probability, and MVFR probabilities.

These algorithms run inside a system of supporting software. This is the AIT-Framework system or the GOES-R Algorithm Working Group (AWG) Product Processing System Framework. The Framework has been developed to be plug-and-play system for GOES-R scientific algorithms enabling the development and testing of the Level 2 GOES products within a single system. Many of the Fog products originated as GOES-R products but have been adapted for other satellites. The system has been created to run products and store them in memory to be used as inputs for other products: i.e. product precedence. Common ancillary data has been used by the algorithms and the ancillary data is also stored in memory and treated as precedence for the products. Within the Framework system, the Fog algorithms have flexible interface designs though is currently designed to work only on data from GOES-R satellites.

2.1.1 Pre-Processing Steps

For Fog, there is one preprocessing step. The preprocessing step, or the Snow Mask ancillary preparation unit, is to prepare by combining the ancillary daily-produced IMS / SSMI snow mask data files, which are then converted into NetCDF4 format.

The output snow mask file name is recorded onto a PSF file for use in the main processing step. Although this is technically an ancillary product, the amount of computation involved with this product requires that it be processed separately. For detailed information about the preprocessing step, please refer to the EPS FLS System Maintenance Manual.

2.2. Input Data Files

This section describes the input data files required by the EPS Fog system, including the satellite data, the ancillary data required by the AIT-framework to generate the products, as well as the algorithm-specified coefficient files, etc.

2.2.1. Satellite Data Files

To generate EPS Fog products, GOES-R satellite pixel L1b files in NetCDF4 format are required.

The GOES sectors, which use the Fog algorithms include GOES-R CONUS and FD. These files include the calibrated and navigated radiance data and brightness temperature. The satellite data is also temporal, meaning that up to two prior L1b satellite data files are required. All of these files are in NetCDF4 format and are generated by the interface data processing segment (IDPS) system at NDE.

2.3. Ancillary Data Files Required by AIT-framework

The ancillary files are in NetCDF format, except for the community radiative transfer model (CRTM) coefficient files (binary format) and NWP GFS and RAP data (GRIB2 format). Each of the three product categories requires some ancillary files. The Fog products require NWP GFS data, NWP RAP data, interpolated NWP GFS data (onto the satellite pixels), 1km National Aeronautics and Space Administration (NASA) Land Mask, 1km NASA Coast Mask, Desert Mask, Visible Infrared Imager Radiometer Suite (VIIRS) Surface Type, 1km Surface Elevation, Seebor Surface Emissivity, Surface Albedo, Pseudo Emissivity, Canadian Meteorological Center Global Foundation Sea Surface Temperature (CMCSST), and CRTM.

Note that the ancillary products are either static (unchanging) or dynamic (changing). The static products such as land mask will typically take the least amount of time to calculate and are often dependent on a dataset or lookup table, while the dynamic products such as NWP GFS and RAP require an external data source which is updated on a daily or weekly basis. Note that if no NWP RAP data can be found, NWP GFS will be used in its place.

The Fog products also require an offline product called the combined daily snow mask. This product is technically ancillary, but is more complicated than the other products as it is calculated offline and is dependent on the SSMI and IMS daily snow mask products. The GOES-R framework cloud products calculated upstream of Fog also require ancillary data. These ancillary products are described below.

2.3.1. Land Mask (static)

The land mask is derived from the NASA EOS project supplied static dataset as well as World Vector Shoreline data and digital terrain elevation data (DTED) digital elevation model (DEM) data provided by NIMA (then DMA) and bathymetric data provided by the oceanographic community. The original global binary file, version 3, produced in 2003 by Robert Wolfe, was converted to NetCDF and HDF for usage in the framework.

Resolution: The land/ocean mask is stored in a 1 km geographic (geodetic) projection.

Filename: lw_geo_2001001_v03m.nc

Origin: Created by SSEC/CIMSS based on NASA Moderate Resolution Imaging Spectroradiometer (MODIS) collection 5

Size: 890 MB.

Static/Dynamic: Static

Values:

0 = Shallow ocean
1 = Land (Nothing else but land)
2 = Ocean coastlines and lake shorelines
3 = Shallow inland water
4 = Ephemeral water
5 = Deep inland water
6 = Moderate or continental ocean
7 = Deep ocean

2.3.2. Coast Mask (static)

The coast mask is created from the land/water mask and differentiates coast at resolutions ranging from 1 – 10 km. It is produced by searching for heterogeneity in concentric boxes 3x3 (1 km) up to 21x21 (10 km) of pixels centered on any given pixel.

Resolution: The coast mask is stored in a 1 km geographic (geodetic) equal area projection.

Filename: coast_mask_1km.nc

Origin: Created by SSEC/CIMSS based upon NASA MODIS collection 5.

Size: 890 MB.

Static/Dynamic: Static

Values: A value of 1 means that the pixel 1km away is a water/land transition or is a water/land transition. 0 is considered the fill value of the coast mask.

2.3.3. Calculated Desert Mask (static)

The Calculated Desert Mask uses two ancillary products to generate the desert mask: Land Mask (section 2.3.1), and VIIRS Surface Type (section 2.3.6). A value of 0 means no desert, 1 is wooden grass, closed shrubs, open shrubs, grasses, or cropland, and 2 is bare surface.

2.3.4. Surface Elevation Mask (static)

The digital surface elevation is Global Land One-km Base Elevation (GLOBE) Project 1km database global file converted into a file format readable by the framework.

Resolution**:** The surface elevation is stored as meters in a Plate Carrée projection at 30 arc-second (1km) resolution.

Filename: GLOBE_1km_digelev.nc

Origin: NGDC

Size: 1843.2 MB

Static/Dynamic: Static

2.3.5. Surface Emissivity SEEBOR (static)

The surface IR emissivity for advanced baseline imager (ABI) bands comes from UW-Madison baseline fit database. This is a global database of monthly (001-031, 032-059, etc.) IR land surface emissivity derived from the MODIS operational land surface emissivity product (MOD11). Emissivity is available globally at ten wavelengths (3.6, 4.3, 5.0, 5.8, 7.6, 8.3, 9.3, 10.8, 12.1, and 14.3 μm). Monthly emissivities have been integrated into the ABI spectral response functions to match the ABI bands. The SEEBOR emissivity training set was interpolated over the spectral response function for a given channel at each data point. These are then output to a static file for usage in the framework. For the production of the test dataset, the ABI SRFs, provided by the Imagery AWG, were used to produce the static emissivity dataset.

Resolution: 0.05 degree (5km) spatial resolution

Filename: global_emiss_intABI_YYYYDDD.nc where**,** YYYYDDD = year plus Julian day

Origin: UW Baseline Fit, Seeman and Borbas (2006).

Size: 693 MB x 12

Static/Dynamic: Dynamic

Values: The emissivities are fractional values scaled with a scale factor of 0.001 and have fill value of -9999. Generally, the data points that are the fill value are ocean or water pixels.

Surface emissivity at 5km resolution (climatologically monthly), required by AIT Framework is listed in Table 2-1.

Table 2-1 – Surface Emissivity Data

File Name	Description	Size (MB)
global_emiss_intABI_2005001.nc	SEEBOR data for January	693
global_emiss_intABI_2005032.nc	SEEBOR data for February	693
global_emiss_intABI_2005060.nc	SEEBOR data for March	693
global_emiss_intABI_2005091.nc	SEEBOR data for April	693
global_emiss_intABI_2005121.nc	SEEBOR data for May	693
global_emiss_intABI_2005152.nc	SEEBOR data for June	693
global_emiss_intABI_2005182.nc	SEEBOR data for July	693
global_emiss_intABI_2005213.nc	SEEBOR data for August	693
global_emiss_intABI_2005244.nc	SEEBOR data for September	693
global_emiss_intABI_2005274.nc	SEEBOR data for October	693
global_emiss_intABI_2005305.nc	SEEBOR data for November	693
global_emiss_intABI_2005335.nc	SEEBOR data for December	693

2.3.6. VIIRS Surface Type

A global gridded surface type map to label surface type of the pixels within each granule. The

horizontal resolution is 1km, and 17 different surface types are listed:

1. Evergreen Needleleaf Forests
2. Evergreen Broadleaf Forests
3. Deciduous Needleleaf Forests
4. Deciduous Broadleaf Forests
5. Mixed Forests
6. Closed Shrublands
7. Open Shrublands
8. Woody Savannas
9. Savannas
10. Grasslands
11. Permanent Wetlands
12. Croplands
13. Urban and Built-Up Lands
14. Cropland/Natural Vegetation Mosaics
15. Snow and Ice
16. Barren
17. Water Bodies

2.3.7. CRTM Coefficients (static)

CRTM coefficient files for GOES-R data, required by AIT Framework, are shown in Table 2-2.

Table 2-2 - CRTM Coefficient Data

File Name	Size of a Single File
CloudCoeff.bin	1.6 MB
AerosolCoeff.bin	5.5 MB
VIS Land EmisCoeff.bin	1.9 MB
IR Land EmisCoeff.bin	8 KB
IR Water EmisCoeff.bin	16 KB
SpcCoeff.bin	4 KB
TauCoeff.bin	184 KB

2.3.8. NWP Data - GFS GRIB2 Forecast Files (dynamic)

These are GFS 6-hour global forecast data files at 0.5 degree resolution in GRIB2 format from the National Centers for Environmental Prediction (NCEP).

File Name: *gfs.t${Hour}z.pgrbf${Forecast}.YYYYMMDD*
Size: 51~52 MB

2.3.9. NWP – RAP GRIB2 Forecast Files (dynamic)

These are RAP 1-hour mesoscale forecast data files at resolutions of 13 km for the CONUS domain, 11.25 km for the Alaska domain, and 32 km for the North American domain. Note that if any RAP data sets are missing, then GFS data will be used in its place.

File Name: rap.t${Hour}z.pgrbf${Forecast}

Size: 14~15 MB

There are static ancillary files for the domains:

File Name:
rap_alaska_lat_lon.nc
Size: 2 MB
rap_conus_lat_lon.nc
Size: 1.3 MB
rap_na_lat_lon.nc
Size 0.8 MB

There are static ancillary files containing meta-data about the domains:
File Name:
rap_alaska_metadata.nc
Size: 1 KB
rap_conus_metadata.nc
Size: 1 KB
rap_na_metadata.nc
Size: 1 KB

2.3.10. Desert Mask (static)

The desert mask uses the NASA 1km land mask and 1km surface type ancillary algorithms to calculate the desert mask. A value of '0' denotes no desert, '1' refers to wooden grass, closed shrubs, open shrubs, grasses, or croplands, and '2' is desert. There are no external files associated specifically with this algorithm.

2.3.11. Surface Albedo (static)

The surface albedo provides a global estimate of the cloud-clear white sky reflectance from 2004 MODIS data. The albedo is an averaged value over a seventeen-day period. There are three wavelengths, 0.659 um, 1.64 um, and 2.13 um.

Filenames:
AlbMap.WS.c004.v2.0.2004.DDD.0.659_x4.nc
AlbMap.WS.c004.v2.0.2004.DDD.1.64_x4.nc
AlbMap.WS.c004.v2.0.2004.DDD.2.13_x4.nc

Where DDD is the Julian day of the year, which ranges from 001 to 353 in increments of 17. There are a total of 66 files. Each file is 28 MB in size.

2.3.12. Pseudo Emissivity (dynamic)

The pseudo emissivity uses the Plank function to calculate the channel 7 emissivity. There are no external files associated with this algorithm.

2.3.13. CMCSST Daily Data (dynamic)

The file naming convention for the CMCSST daily data can be seen below.

File Name (example): 20200920120000-CMC-L4_GHRSST-SSTfnd-CMC0.1deg-GLOB-v02.0-fv03.0.nc

Size: 6.8 MB

2.3.14. Combined Daily Snow Mask (dynamic)

This product is a combination of two other dynamic ancillary products produced daily, SSMI snow mask and IMS snow mask. These two products are combined offline (outside of the framework) and the resulting output file is in NetCDF format and has the naming convention:

File Name: snow_map_4km_YYMMDD.nc

Size: 39 MB

3. PERFORMANCE

3.1. Product Testing

3.1.1. Test Data

Test cases are provided with each DAP to NDE and OSPO for product verification before transition to operations. The test cases provide input and static and dynamic ancillary data, and the resulting product datasets for verification. Requirements as specified in the RAD (Requirements Allocation Document) must be met in testing, and only after NDE and OSPO are satisfied that requirements are met will the FLS products will be transitioned into operations.

Test data includes FD L1b data for an ideal case (input data closest to top of the hour) and dynamic data necessary to execute the Framework successfully. The provided data provides an example of how those data are utilized and the output you can expect to generate using the data.

3.1.2. Test Plans

FLS products (and all products) are tested regularly with each update. The science teams, which develop these products, test them for accuracy and validation. The STAR group tests the algorithms and scripts to ensure that RAD requirements are met, and then operations must test these products to make sure that they run successfully on their systems. If there are problems in any one of these testing procedures, then the relevant groups must work together to "iron-out" any issues.

3.2. Product Accuracy

3.2.1. Test Results

Algorithm validation test results from the science team can be found in the Algorithm Theoretical Basis Document (ATBD) and Algorithm Readiness Review presentation (ARR).

3.2.2. Product Accuracy

EPS Fog products have been validated against observations. The accuracy and precision of the EPS Fog products fall well within the accuracy and precision specifications. The detailed validations are available in the Algorithm Readiness Review obtained by contacting the EPS Fog PAL at OSPO.

3.3. Product Quality

Each failure is associated with a unique "flag" value that is saved in the EPS GOES-R Fog output files. These values are shown in Table 3-1. FLS Product Quality Information is shown in Table 3-2. The granule level quality flag can be found in Table 3-1. Additional information about AWIPS output and quality flags can be found in Table 3-4 and Table 3-5 respectively.

Table 3-1 - FLS Quality Control Flags

Bit(s)	QF Description	Bit Interpretation
1-2	**Fog/low cloud MVFR probability quality flag** – the product quality will be dependent on the MVFR probability assigned to each pixel. Four levels of quality, with 0 being the highest and 3 being the lowest will be designated.	0 = 75% - 100% (high) 1 = 50% - 75% 2 = 25% - 50% 3 = 0% - 25% (low)
3-4	**Fog/low cloud IFR probability quality flag** – the product quality will be dependent on the IFR probability assigned to each pixel. Four levels of quality, with 0 being the highest and 3 being the lowest will be designated.	0 = 75% - 100% (high) 1 = 50% - 75% 2 = 25% - 50% 3 = 0% - 25% (low)
5	**Multi-layered cloud quality flag** – this will be set to "low quality" if multi-layered clouds are detected by the GOES-R cloud phase algorithm as FLS may be present but may not be detected	0 = multi-layered clouds not detected 1 = multi-layered clouds are detected
6	**Cloud phase quality flag** – this will bet set to "low quality" if ice clouds are detected by the GOES-R cloud phase algorithm because the fog/low cloud algorithm will not be run	0 = ice clouds not detected 1 = ice clouds are detected
7	**Freezing FLS flag** – this flag will represent whether each pixel containing fog/low cloud has a temperature below freezing (0 K) indicating the possibility of freezing fog	0 = temperature of fog/low cloud pixel is at or below 0 K 1 = temperature of fog/low cloud pixel is above 0 K
8	**FLS Depth quality flag** – this flag will indicate which pixels have solar zenith angles between 70° – 90°, where FLS depth is not possible due to the lack of lwp or ems(3.9 μm) information	0 = pixel has solar zenith angle either < 70° or > 90° (FLS depth available) 1 = pixel has solar zenith angle between 70° - 90° (FLS depth NOT available)

Table 3-2 - FLS Product Quality Information

Bit(s)	PQI Description	Bit Interpretation
1	Pixel is geolocated and has valid spectral data	0 = FALSE 1 = TRUE
2	Pixel is considered a daylight pixel (solar zenith angle > 90°)	0 = FALSE 1 = TRUE
3	Pixel is located over land	0 = FALSE 1 = TRUE

Table 3-3 - Granule Level Quality Flag

Bit(s)	Description	Bit Interpretation
0	Missing Channel Degradation	0 = False 1 = True
1	Missing Ancillary SST Degradation	0 = False 1 = True
60	Low impact: (82K-90K) LHP anomaly has a low impact of increased striping/noise	0 = False 1 = True
61	Moderate impact: (90K-100K) LHP anomaly has a moderate impact of increased striping/noise	0 = False 1 = True
62	High impact: (> 100K) LHP anomaly has a high impact of increased striping/noise	0 = False 1 = True
63	Complete IR Failure	0 = False 1 = True

Table 3-4 - FLS AWIPS Output

Name	Type	Description	Dimension
Fog-depth	Product	Fog Depth Output expressed in meters	Grid (xsize, ysize)
MVFR	Product	Marginal Visual Flight Rule probability	Grid (xsize, ysize)
IFR	Product	Instrument Flight Rule probability	Grid (xsize, ysize)
LIFR	Product	Low Instrument Flight Rule probability	Grid (xsize, ysize)

Table 3-5 - FLS AWIPS LHP Quality Flag

QC Value	Description
0	No mitigation
1	Low impact: (82K-90K) LHP anomaly has a low impact of increased striping/noise
2	Moderate impact: (90K-100K) LHP anomaly has a moderate impact of increased striping/noise

QC Value	Description
3	High impact: (>100K) LHP anomaly has a high impact of increased striping/noise

3.4. External Product Tools

The EPS FLS output files are NetCDF4 files. External users can choose their own tools to display and analyze these output files. Software in the form of FLS AWIPS plug-ins is being developed by the science team, and installation instructions are provided below. This software package is NOT meant to be implemented by NDE, and OSPO will make these data available to end users.

AIT Fog/Low Stratus Product (FLS) AWIPS Installation

Files needed for processing and visualization of GOES-16/17 FLS products:

- goesrDistributionAdditions.xml
- AIT-FLS.xml
- satellitePurgeRulesAIT-FLS.xml
- AIT-FLSImageryStyleRules.xml
- IFR_PROB.cmap
- LIFR_PROB.cmap
- MVFR_PROB.cmap
- AIT-FLSBundle.xml
- AIT-FLSImagery.xml
- satelliteMenuAdditions.xml

All files can be acquired from ftp://ftp.ssec.wisc.edu/pub/leec/FLS/AIT-FLSConfig.tar.

Directories used herein should be created, if they do not already exist. 'LLL' in directory paths should be replaced with your respective site identifier. All directories referenced are located on your processing servers.

EDEX Processing Configuration for AIT-sourced FLS products:

- Append the contents of the *goesrDistributionAdditions.xml* file into the file */awips2/edex/data/utility/common_static/site/LLL/distribution/goesr.xml.* If this file does not exist, copy the file *goesr.xml* from */awips2/edex/data/utility/common_static/base/distribution/* into the site location listed above, and then append the information as stated above.
- Place the *AIT-FLS.xml* file into the directory */awips2/edex/data/utility/common_static/site/LLL/satellite/goesr/descriptions/Level2/*.
- Place the *satellitePurgeRulesAIT-FLS.xml* file into the directory */awips2/edex/data/utility/common_static/site/LLL/purge/*.
- Once all files are in place, your EDEX servers will need to be restarted.

CAVE Visualization Configuration:

- Place the *AIT-FLSImageryStyleRules.xml* file into the directory */awips2/edex/data/utility/common_static/site/LLL/styleRules/*.

- All colormap files, ending in '*.cmap*,' need to be placed in the directory */awips2/edex/data/utility/common_static/site/LLL/colormaps/*.
- If a menu option is preferred, the *satelliteMenuAdditions.xml* information can be appended to anywhere you prefer the menu to show up (the satellite drop-down menu probably makes most sense under */awips2/edex/data/utility/cave_static/site/LLL/menus/*). The *AIT-FLSImagery.xml* menu file will need to be placed in that same directory.
- Last, the *AIT-FLSBundle.xml* file needs to be placed into the directory */awips2/edex/data/utility/cave_static/site/LLL/bundles/*.
- Once all files are in place, if you have an active CAVE client, you will need to close and restart CAVE.

4. PRODUCT STATUS

4.1. Operations Documentation

NESDIS/STAR (2018), Enterprise Processing System Extension: GOES-R Low Cloud / Fog and ASOS Algorithm Readiness Review (ARR) Presentation

NESDIS/STAR (2018), Enterprise Processing System Extension: GOES-R Low Cloud / Fog and ASOS Requirements Allocation Document (RAD)

NESDIS/STAR (2016), EPS FLS Software Architecture and Detailed Design

NESDIS/STAR (2018), The NOAA GOES-R Fog and Low Stratus (FLS) System Maintenance Manual

NESDIS/STAR (2017) The ASOS External Users' Manual

NESDIS/STAR (2020), The NOAA GOES-R Fog and Low Stratus (FLS) ASOS System Maintenance Manual

NESDIS/STAR (2020), The NOAA GOES-R Fog) and ASOS External Users' Manual

NESDIS/STAR (2020), GOES-17 UTRR

NESDIS/STAR (2019), GOES-17 CDR

NESDIS/STAR (2021), Enterprise Processing System Extension: GOES-R Low Cloud / Fog Algorithm Readiness Review (ARR) Presentation

NESDIS/STAR (2021), FLS DAP Documents including the Readme file, Delivery Memo, PCF_PSF file, and Production Rules

4.2. Maintenance History

August 2020: FLS v1r3 released into operation on ESPDS NDE system for GOES-16 products

October 2021: FLS v3r0 released into operation on ESPDS NDE system for GOES-17 products

APPENDIX A – ACRONYMS

Acronym	Definition
ABI	Advanced Baseline Imager
AIT	Algorithm Integration Team
ARR	Algorithm Readiness Review
ATBD	Algorithm Theoretical Basis Document
AWG	Algorithm Working Group
AWIPS	Advanced Weather Interactive Processing System
CHOPS	Consolidated High-throughput Operational Products System
CMCSST	Canadian Meteorological Center Global Foundation Sea Surface Temperature
CONUS	contiguous United States
CRTM	Community Radiative Transfer Model
DAP	Data Access Protocol
DDS	Data Distribution System
DEM	Digital Elevation Model
DHS	Data Handling Subsystem
DOC	Department of Commerce
DTED	Digital Terrain Elevation Data
EPS	Enterprise Processing System
ESPC	Environmental Satellite Processing Center
EUM	External Users' Manual
FD	Full Disk
FLS	Fog and Low Stratus

Acronym	Definition
GFS	Global Forecast System
GLOBE	Global Land One-km Base Elevation
GOES	Geostationary Operational Environmental Satellite
IDPS	Interface Data Processing Segment
IFR	Instrument Flight Rules
IMS	Ice Mapping System
LIFR	Low Instrument Flight Rule
MODIS	Moderate Resolution Imaging Spectroradiometer
MVFR	Marginal Visual Flight Rule
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NDE	NPOESS Data Exploitation
NetCDF	Network Common Data Form
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NSOF	NOAA Satellite Operations Facility (NOAA/NESDIS Suitland, MD)
NWS	National Weather Service
NWP	Numerical Weather Prediction
OSPO	Office of Satellite Product Operations
PAL	Product Area Lead
PDA	Product Distribution and Access
RAD	Requirements Allocation Document

Acronym	Definition
RAP	Restricted Access Processor
RTM	Radiative Transfer Model
SE	System Engineer
SMM	System Maintenance Manual
SSMI	Special Sensor Microwave Imager
VIIRS	Visible Infrared Imager Radiometer Suite
V&V	Verification and Validation