Environmental Satellite Processing Center (ESPC)

Advanced Clear Sky Processor for Oceans Visible Infrared Imaging Radiometer Suite (ACSPO-VIIRS) Version 2.31 External User's Manual (EUM)

Version 2.0, January 26, 2015

Version 1.0 Contributors: John Stroup (STAR and SGT, Inc.), John Sapper (OSPO), Dr. Boris Petrenko (STAR and GST, Inc.), Yury Kihai (STAR and GST, Inc.), ACSPO Integrated Product Team (IPT), NPP Data Exploitation Project (NDE)

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite, Data, and Information Service (NESDIS)
Office of Satellite and Product Operations (OSPO)
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Prepared by: John Sapper, OSPO, John Stroup, STAR/SGT
for the:
U.S. Department of Commerce
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ACSPO-VIIRS Version 2.31

External User's Manual

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GROUP: ESPC Date: 1/30/2015 NAME: Robert Potash, Contract Manager	GROUP: ESPC Date

DOCUMENT HISTORY

The Document History identifies the document origination and the series of revisions to the document that may occur at any point after the baseline release. This page will become a permanent part of this document.

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1 PRODUCTS

1.1 Product Overview

1.1.1 Product Requirements

The ACSPO-VIIRS SST requirements, as taken from the Joint Polar Satellite System (JPSS) Level 1 Requirements Document (L1RD), are shown in Table 1-1.

Table 1-1 – Requirements for ACSPO-VIIRS SST

Attribute	Threshold	Objective
Horizontal cell size	1.6 km[1]	0.25 km
Mapping Uncertainty, 3 sigma	2 km[1]	0.1 km
Measurement Range	271 K to 313 K	271 K to 318 K
Measurement Accuracy[2]	0.2 K	0.05 K
Measurement Precision[2]	0.6 K	0.2 K (<55° View Zenith Angle)
Refresh Rate	12 hrs	3 hrs
Geographic Coverage	Global cloud- and ice-free ocean, excluding lakes and rivers	Global cloud- and ice-free ocean, including large lakes and wide rivers

Notes:

1. Worst case scenarios corresponding to swath edge; both numbers are ~1 km at nadir.
2. Represent global mean bias and standard deviation validation statistics against quality-controlled drifting buoys (for day and night, and in full VIIRS swath and range of atmospheric conditions). Better performance is expected against ship radiometers.

1.1.2 Product Team

<u>NDE-ACSPO Product Team Members</u>

Alexander Ignatov – STAR Project Lead

John Sapper – OSPO Product Area Lead and NDE SST Project Co-Lead

John Stroup – STAR/OSPO Developer – Software Engineer

Yury Kihai – STAR Developer – High Performance Computing

Boris Petrenko –STAR Algorithm Scientist, Developer

XingMing Liang – STAR Developer - Monitoring IR Clear-sky Radiances over Oceans for SST (MICROS)

Prasanjit Dash – STAR Developer – SST Quality Monitor (SQUAM)

Xinjia Zhou – STAR QC Systems and Reprocessing

Karlis Mikelsons – STAR Developer – De-Striping and Noise Analysis and Mitigation

Kai He – STAR Developer

Dylan Powell – OSD NDE Algorithm and Application Integration

See NOAA Staff Directory for contact information: https://nsd.rdc.noaa.gov/nsd/search

1.1.3 Product Description

SST in ACSPO is produced for all clear-sky ocean pixels observed by the VIIRS sensor within full VIIRS swath. Accuracy, precision, computational efficiency, and robustness are priorities of the ACSPO SST development.

The general features of the ACSPO SST product are determined by the physics of the transfer of infrared (IR) radiation in the ocean surface-atmosphere system. Since clouds are not transparent for IR radiation, accurate SST retrieval is possible under clear-sky conditions only. SST estimates in pixels fully or partially filled with clouds usually include large negative SST biases. Consequently, the overall quality of the global SST product largely depends on the performance of the product's cloud mask. In addition to the SST estimates, produced for all VIIRS pixels over ocean, the ACSPO SST product includes quality flags which allow selection of clear-sky pixels.

In the absence of clouds, the IR radiation emitted by the sea surface is attenuated by atmospheric water vapor, other atmospheric gases, and aerosol. To minimize atmospheric effects on SST, the SST algorithms use observations in IR bands within the atmospheric transparency windows 8-12 μm (Long Wave Infrared Range - LWIR) and 3.4-4.2 μm (Midwave Infrared Range - MWIR). Furthermore, since the atmospheric absorption varies in different window bands, multichannel retrieval algorithms allow more comprehensive accounting for the atmospheric effects (McMillin et al., 1975). The outgoing radiation in the MWIR transparency window is more sensitive to SST and less affected by the atmospheric absorption than in LWIR bands. However, the MWIR bands cannot be used for SST in the daytime due to contamination with reflected solar radiation. Currently, ACSPO uses regression SST retrieval algorithms (e.g., Petrenko et al., 2010), consistent with all other operational SST systems. These algorithms are modifications of two approaches developed earlier for AVHRR. The nighttime "Multichannel" SST (MCSST) approach (McClain et al., 1983) exploits both LWIR and MWIR bands. In the case of VIIRS, these bands are M12, M15 and M16 centered at 3.70 μm, 10.76 μm and 12.01 μm respectively. During daytime, the ACSPO exploits the "Nonlinear" SST (NLSST) approach (Walton et al., 1998) using only LWIR split-window bands M15 and M16 and *a priori* SST T_S^0 which is used as a proxy for atmospheric humidity. The coefficients for the ACSPO SST algorithms are produced from matchups of a satellite's brightness temperatures (BTs) with *in situ* SST.

A common problem of regression algorithms is that SST accuracy and precision are sensitive to atmospheric attenuation and significantly vary in space (Petrenko et al., 2013a). As alternatives to regression, several SST algorithms based on a radiative transfer model (RTM) have been recently developed (Merchant et al., 2009; Le Borgne et al., 2011; Petrenko et al., 2011). These algorithms have been shown to be capable of providing more uniform SST accuracy and precision than is possible with pure regression. Currently, one such algorithm - Incremental Regression - is being tested within an experimental version of ACSPO and will likely become a baseline SST algorithm in future operational ACSPO versions.

A frequently asked question about satellite SST is: to what ocean layer - “skin” or “bulk” - should it be attributed? On one hand, satellite SST is derived from observed BTs, which are sensitive to temperature variations in the upper ~10 µm “skin” ocean layer (e.g., Sounders, 1967; Donlon et al., 2002; Minnett, 2003). On the other hand, the regression coefficients are derived from matchups with *in situ* SST measured at ~ 1 m depth (“bulk” SST). The “bulk” SST can differ from “skin” SST due to the skin effect (cold skin layer, due to heat exchange at the surface), and diurnal thermocline (Gentemann et al., 2003; Horrocs et al., 2003; Gentemann and Minnett, 2008). We suggest that satellite SST reflects spatial and temporal variations in “skin” SST, but its absolute value is anchored to “bulk” SST.

1.2 Product History

Significant milestones of the ACSPO project are shown in Table 1-2.

Table 1-2 – Significant ACSPO Milestones

Date	Milestone
September 2007	Critical Design Review (CDR)
May 2008	ACSPO-AVHRR v1.00 (GAC only) made operational in OSPO
March 2009	ACSPO-AVHRR v1.10 (GAC only) made operational in OSPO
April 2009	ACSPO-AVHRR v1.10 (GAC & FRAC) made operational in OSPO
August 2009	ACSPO-AVHRR v1.20 made operational in OSPO
March 2010	ACSPO-AVHRR v1.30 made operational in OSPO
December 2010	ACSPO-AVHRR v1.40 made operational in OSPO
October 2011	Original delivery of DAP v0.1, containing ACSPO-VIIRS v2.00, to NDE
May 2012	ACSPO-AVHRR v2.00 made operational in OSPO
May 2012	ACSPO-MODIS (v2.10) implemented in STAR
August 2012	Original delivery of DAP v0.2, containing ACSPO-VIIRS v2.11, to NDE
April 2013	ACSPO-AVHRR v2.20 made operational in OSPO
May 2013	Original delivery of DAP v0.3, containing ACSPO-VIIRS v2.20, to NDE
November 2013	ACSPO-AVHRR v2.21 made operational in OSPO
November 2013	Original delivery of DAP v0.4, containing ACSPO-VIIRS v2.30, to NDE
February 2014	ACSPO-VIIRS (v2.30) approved by the SPSRB for operational implementation in NDE
March 2014	ACSPO-AVHRR v2.30 made operational in OSPO
October 2014	Original delivery of DAP v0.5, containing ACSPO-VIIRS v2.31, to NDE

Product Access

To obtain near-real-time ACSPO-VIIRS products, contact the Product Area Lead (PAL) for Sea Surface Temperature in the Office of Satellite and Products Operations (OSPO), Satellite Products and Services Division, Satellite Products Branch. Currently that position is held by John Sapper, Room 3625, in the NOAA Center for Weather and Climate Prediction (NCWCP), 5830 University Research Court, College Park, MD, 26740, phone 301-683-3234, email: john.sapper@noaa.gov. The PAL will provide the user a data access request form and assist the user in filling out the form. The form will then be submitted to the data access managers for approval. Near-real-time data is generally available to users who have an operational NOAA mission or possibly an operational mission that supports another government entity. The near-real-time ACSPO-VIIRS products are available on the NPP Data Exploitation (NDE) distribution servers.

OSPO and NDE personnel as well as STAR developers and scientists are the team responsible for ensuring maintenance and access.

Currently the key personnel are:

- SST PAL (above)
- ACSPO-VIIRS Principal Investigator and Project Lead – Alexander Ignatov, STAR
- Maintenance Lead - TBD
- Development Lead – John Stroup, STAR
- Algorithm Lead – Boris Petrenko, STAR
- Data Access Lead – Donna McNamara, OSPO

Upon approval for data access, near-real-time users will be provided with a user account on the NDE distribution server and instructions for downloading the data. Currently, the protocol required for transferring all NDE data (ACSPO-VIIRS included) is ftp-s. This is a secure version of ftp that encrypts only the user ID and password and not the data and is faster than sftp or scp.

Non-operational users (non-near-real-time users) and near-real-time users with relaxed latency requirements can access the ACSPO-VIIRS data from the Group for High-Resolution SST (GHRSST) 30-day repository at NASA's Jet Propulsion Laboratory (JPL) (http://podaac.jpl.nasa.gov/). Data older than 30 days can be accessed at the GHRSST Long Term Stewardship and Reanalysis Facility (LTSRF) at the National Oceanographic Data Center (NODC). See http://www.nodc.noaa.gov/sog/ghrsst/accessdata.html.

ACSPO generates two netCDF4 files during its execution, one in a legacy format and one in GHRSST Data Specification 2.0 (GDS2) format. The legacy format is the same basic style and structure that ACSPO has been generating from its inception. The GDS2 format follows a set of conventions specified by the Group for High Resolution Sea Surface Temperature (GHRSST). Both formats are available for distribution from NDE. However, the legacy format is an internal format, and not archived. The GDS2 format is archived in the National Oceanographic Data Center (NODC) via the Jet Propulsion Laboratory (JPL) Physical Oceanography Distributed Active Archive Center (PO.DAAC).

The GDS2 ACSPO format is presented first, in Section 1.3.1, followed by the legacy ACSPO format, in Section 1.3.2. Each format is primarily described in two tables, one listing the metadata header or global attributes information and one listing the layer (aka, variable or dataset) information. In these tables, the "Data Type" column contains:

- CHAR -- a character string
- INT*n* -- an *n*-byte integer
- UINT*n* -- an *n*-byte unsigned integer
- Scaled INT*n* -- a floating-point number stored (scaled) in an *n*-byte integer
- REAL*n* -- an *n*-byte floating-point number
- REAL4 (*n*) -- an *n*-element array of floating-point numbers

In the "Dimension" column of the layers tables,

- 'nx' is the number of pixels in a detector row
- 'nr' is the number of detector rows in a file. (NOTE: A moderate resolution VIIRS scan line is composed of 16 detector rows. Thus, nr = 16 * number of scans in the file.)
- 't' indicates a third, "time", dimension only used for certain GDS2 data sets. It is always 1.

1.2.1 GDS2 Format

The name of a GDS2 ACSPO output file follows the GDS2 naming convention as defined in the GHRSST Data Specification 2.0. An example ACSPO-VIIRS file name is

20120117125001-OSPO-L2P_GHRSST-SST1m-VIIRS_NPP-v02.0-fv01.0.nc

Table 1-4 lists the global attributes in a GDS2 ACSPO output file. The source of these attributes (as identified in the Source column of this table) is the NetCDF Climate and Forecast (CF) Metadata Convention, NetCDF Attribute Convention for Dataset Discovery (ACDD), GHRSST Data Specification (GDS), and NPP Data Exploitation (NDE). For details of the GDS attributes, see The Recommended GHRSST Data Specification (GDS) document, version 2.0, revision 5. For details of the NDE attributes, see the NDE document, "Standards for Algorithm Delivery and Integration Using Delivered Algorithm Packages (DAPs)".

In addition to the global attributes, each layer, or data set, will have one or more of their own (local) attributes. These are shown, below, in Table 1-3. The data type of each local attribute is

- a string (CHAR),
- the same as the layer's data type (<layer_type>), or
- the same as the layer's unpacked data type (<unpacked_type>) – for scaled data only

Table 1-3 – GDS2 ACSPO Local Attributes

Attribute Name	Source	Data Type
add_offset	CF	<unpacked_type>
axis	CF	CHAR
comment	CF	CHAR
coordinates	CF	CHAR
depth	GDS	CHAR
_FillValue	CF	<layer_type>
flag_masks	CF	<layer_type>
flag_meanings	CF	CHAR
flag_values	CF	<layer_type>
height	GDS	CHAR
long_name	CF, ACDD	CHAR
reference	CF	CHAR
scale_factor	CF	<unpacked_type>
source	CF	CHAR
standard_name	CF, ACDD	CHAR
units	CF, ACDD	CHAR
valid_max	CF	<layer_type>
valid_min	CF	<layer_type>

Table 1-5 lists the data sets, or layers, contained within the GDS2 ACSPO output file.

Table 1-4 – GDS2 ACSPO Global Attributes

Attribute Name	Source	Data Type	Sample Content
acknowledgment	ACDD	CHAR	Please acknowledge the use of these data with the following statement: These data were provided by Group for High Resolution Sea Surface Temperature (GHRSST) and the National Oceanic and Atmospheric Administration (NOAA).
cdm_data_type	ACDD	CHAR	swath
comment	CF, ACDD	CHAR	none
Conventions	CF	CHAR	CF-1.6, Unidata Observation Dataset v1.0
creator_email	ACDD	CHAR	Alex.Ignatov@noaa.gov
creator_name	ACDD	CHAR	Alex Ignatov
creator_url	ACDD	CHAR	http://www.star.nesdis.noaa.gov
date_created	ACDD	CHAR	20131108T162120Z
easternmost_longitude	GDS	REAL4	-8.441172
file_quality_level	GDS	INT2	3
gds_version_id	GDS	CHAR	02.0
geospatial_bounds	ACDD, NDE	CHAR	POLYGON((-10.803 -28.924, -9.681 -31.234, -8.441 -33.644, -25.101 -37.452, -42.817 -38.849, -42.978 -36.278, -43.180 -33.827, -26.586 -32.491, -10.803 -28.924))
geospatial_first_scanline_first_fov_lat	NDE	REAL4	-33.6435f
geospatial_first_scanline_first_fov_lon	NDE	REAL4	-8.441172f
geospatial_first_scanline_last_fov_lat	NDE	REAL4	-38.84898f
geospatial_first_scanline_last_fov_lon	NDE	REAL4	-42.81652f
geospatial_last_scanline_first_fov_lat	NDE	REAL4	-28.92354f
geospatial_last_scanline_first_fov_lon	NDE	REAL4	-10.80283f
geospatial_last_scanline_last_fov_lat	NDE	REAL4	-33.82688f
geospatial_last_scanline_last_fov_lon	NDE	REAL4	-43.17992f
geospatial_lat_resolution	ACDD	REAL4	0.0067
geospatial_lat_units	ACDD	CHAR	degrees_north
geospatial_lon_resolution	ACDD	REAL4	0.0067
geospatial_lon_units	ACDD	CHAR	degrees_east
history	CF, ACDD	CHAR	Created by Advanced Clear-Sky Processor for Oceans (ACSPO)-VIIRS at NOAA/NESDIS/STAR.
id	ACDD	CHAR	VIIRS_NPP-STAR-L2P-v2.0
institution	CF, ACDD	CHAR	NOAA/NESDIS/STAR
keywords	ACDD	CHAR	Ocean > Ocean Temperature > Sea Surface Temperature
keywords_vocabulary	ACDD	CHAR	NASA Global Change Master Directory (GCMD) Science Keywords

Attribute Name	Source	Data Type	Sample Content
license	ACDD	CHAR	GHRSST protocol describes data use as free and open
Metadata_Conventions	ACDD	CHAR	Unidata Dataset Discovery v1.0
metadata_link	ACDD	CHAR	http://podaac.jpl.nasa.gov/ws/metadata/dataset/?format=iso&shortName=VIIRS_NPP-STAR-L2P-v2.0
naming_authority	ACDD	CHAR	org.ghrsst
netcdf_version_id	GDS	CHAR	4.3.0 of Oct 30 2013 15:14:50 $
northernmost_latitude	GDS	REAL4	-28.92354
platform	GDS	CHAR	NPP
processing_level	ACDD, GDS	CHAR	L2P
product_version	GDS	CHAR	2.30
project	ACDD	CHAR	Group for High Resolution Sea Surface Temperature
publisher_email	ACDD	CHAR	ghrsst-po@nceo.ac.uk
publisher_name	ACDD	CHAR	The GHRSST Project Office
publisher_url	ACDD	CHAR	http://www.ghrsst.org
references	CF	CHAR	Data convention: GHRSST Data Specification (GDS) v2.0. Algorithms: ACSPO-VIIRS ATBD (NOAA/NESDIS/STAR)
sensor	GDS	CHAR	VIIRS
source	CF	CHAR	VIIRS-MOD-GEO,VIIRS-M5-SDR,VIIRS-M7-SDR,VIIRS-M10-SDR,VIIRS-M12-SDR,VIIRS-M15-SDR,VIIRS-M16-SDR,CMC0.2deg-CMC-L4-GLOB-v2.0,NOAA-NCEP-GFS
southernmost_latitude	GDS	REAL4	-38.84898
spatial_resolution	GDS	CHAR	742 m at nadir
standard_name_vocabulary	ACDD	CHAR	NetCDF Climate and Forecast (CF) Metadata Convention
start_time	GDS	CHAR	20120911T153023Z
stop_time	GDS	CHAR	20120911T153148Z
summary	ACDD	CHAR	Sea surface temperature retrievals produced by NOAA/NESDIS/STAR office from VIIRS sensor
time_coverage_end	ACDD	CHAR	20120911T153148Z
time_coverage_start	ACDD	CHAR	20120911T153023Z
title	CF, ACDD	CHAR	VIIRS L2P SST
uuid	GDS	CHAR	cd9535ee-4891-11e3-a935-d4ae52e5526d
westernmost_longitude	GDS	REAL4	-43.17992

Table 1-5 – GDS2 ACSPO Layers

Layer (Dataset) Name	Description	Dimension	Data Type	Units	Range of Expected Values
brightness_temperature_11um	Channel M15 brightness temperature	t,nx,nr	Scaled INT2	K	180 to 335
brightness_temperature_12um	Channel M16 brightness temperature	t,nx,nr	Scaled INT2	K	180 to 335
brightness_temperature_4um	Channel M12 brightness temperature	t,nx,nr	Scaled INT2	K	180 to 335
dt_analysis	Deviation from reference SST	t,nx,nr	Scaled INT1	K	-12.7 to 12.7
l2p_flags	L2P flags	t,nx,nr	UINT2	n/a	0 to 65,536
lat	Latitude	nx,nr	REAL4	degrees	-90 to 90
lon	Longitude	nx,nr	REAL4	degrees	-180 to 180
quality_level	Quality level	t,nx,nr	INT1	n/a	0 to 5
satellite_zenith_angle	Satellite zenith angle	t,nx,nr	Scaled INT1	degrees	-70 to 70
sea_ice_fraction	Sea ice concentration	t,nx,nr	Scaled INT1	%	0 to 100
sea_surface_temperature	Retrieved sea surface temperature from regression	t,nx,nr	Scaled INT2	K	100 to 309
sses_bias	Sensor Specific Error Statistic (SSES) bias estimate	t,nx,nr	Scaled INT1	K	-1 to 1
sses_standard_deviation	Sensor Specific Error Statistic (SSES) standard deviation	t,nx,nr	Scaled INT1	K	0 to 2
sst_dtime	Time difference from reference (or start) time	t,nx,nr	Scaled INT2	seconds	-8192 to 8192
wind_speed	NCEP wind velocity	t,nx,nr	Scaled INT1	m/sec	0 to 20

1.2.2 Legacy Format

The name of a legacy ACSPO output file follows the NDE product file name convention as defined in the "Standards for Algorithm Delivery and Integration Using Delivered Algorithm Packages (DAPs)". An example of an ACSPO file name is:

ACSPO-VIIRS_v2-20_npp_s201104280100008_e201104280109594_c201104291826493.nc

Table 1-6 lists the global attributes of a legacy ACSPO output file.

Table 1-7 lists the data sets, or layers, contained within the legacy ACSPO output files.

Table 1-6 – Legacy ACSPO Global Attributes

Attribute Name	Description	Data Type	Sample Content
ACSPO_VERSION	ACSPO version	CHAR	v2-30
C1	C1	REAL4	0.000012
C2	C2	REAL4	1.438786
CREATED	Time of file creation	CHAR	2012-07-11T11:15:01-04:00
CRTM_VERSION	Version of CRTM	CHAR	REL-2.1
DATA_TYPE	Data type	CHAR	PIXEL
EASTERNMOST_LONGITUDE	Easternmost longitude value in the file. This is not necessarily the longitude of the file's easternmost point.	REAL4	179.99995
END_DAY	End day-of-year of data	INT2	192
END_TIME	End time, in hours, of data	REAL8	10.001994
END_YEAR	End year of data	INT2	2012
FILENAME	Name of output file	CHAR	ACSPO-VIIRS_v2.30_npp_s201209111530230_e201209111531480_c201401311338003.nc
G-RING_LATITUDE	8 latitude points of the file's bounding polygon (G-ring). They are taken from the latitudes reported for the file's 4 corner points and the mid points of each of the file's 4 sides. The points are ordered beginning with the lower left (last row, first FOV) and proceeding clockwise around the file.	REAL4(8)	39.920048,-24.937986,18.849018,17.2613,14.75189,-29.755205,34.971855,38.61308
G-RING_LONGITUDE	8 longitude points of the file's bounding polygon (G-ring). They are taken from the longitudes reported for the file's 4 corner points and the mid points of each of the file's 4 sides. The points are ordered the same as G-RING_LATITUDE.	REAL4(8)	-148.5101,15.191488,-120.39517,-134.19879,-147.70927,45.863785,178.51384,-165.55215
INSTRUMENT_DATA	Type of instrument (sensor) data	CHAR	VIIRS
L1B	Name of input L1B file	CHAR	GMODO_npp_d20131003_t1029598_e1040017_b10017_c20131206145756962567_star_dev.h5

Attribute Name	Description	Data Type	Sample Content
L1B_VERSION	Version of input L1B file	INT2	0
LAUNCH_DATE	Satellite launch date	REAL4	2011.823
MISSING_VALUE_INT1	Missing value code for INT1 data	INT1	-128
MISSING_VALUE_INT2	Missing value code for INT2 data	INT2	-32768
MISSING_VALUE_INT4	Missing value code for INT4 data	INT4	-999
MISSING_VALUE_REAL4	Missing value code for REAL4 data	REAL4	NaN ("not a number")
netcdf_version_id	netCDF library version	CHAR	4.3.0 of Sep 26 2013 12:18:50 $
NORTHERNMOST_LATITUDE	Northernmost latitude value in the file.	REAL4	89.785995
NWP_FILE_AFTER	Name of NWP (e.g., GFS) file that temporally follows the L1B input file	CHAR	gblav.12071000_F012.hdf
NWP_FILE_BEFORE	Name of NWP (e.g., GFS) file that temporally precedes the L1B input file	CHAR	gblav.12070918_F012.hdf
PROCESSOR	Name of ACSPO processor	CHAR	ACSPO-V_v2.30
PROGLANG	Programming language of software that created the output file	CHAR	F2003 (i.e., Fortran 2003)
REFERENCE_SST	Name of reference SST file	CHAR	20131003-CMC-L4_GHRSST-SSTfnd-CMC0.2deg-v02.0-fv01.nc
SATELLITE	Satellite name	CHAR	NPP
SENSOR	Sensor name	CHAR	VIIRS
SOUTHERNMOST_LATITUDE	Southernmost latitude value in the file.	REAL4	-89.91255
START_DAY	Start day-of-year of data	INT2	192
START_TIME	Start time, in hours, of data	REAL8	8.997966
START_YEAR	Start year of data	INT2	2012
SUN_EARTH_DISTANCE	Sun-Earth distance in AU	REAL4	1.016658
TIME_COVERAGE_END	End time of data in "yyyy-mm-ddThh:mm:ssZ" format.	CHAR	2012-07-11T01:36:09Z
TIME_COVERAGE_START	Start time of data in "yyyy-mm-ddThh:mm:ssZ" format.	CHAR	2012-07-10T23:54:29Z
USE_SST_ANALYSIS_FLAG	SST analysis flag	CHAR	T
WESTERNMOST_LONGITUDE	Westernmost longitude value in the file. This is not necessarily the longitude of the file's westernmost point.	REAL4	-179.99976

Table 1-7 – Legacy ACSPO Layers

Layer (Dataset) Name	Description	Dimension	Data Type	Units	Range of Expected Values
acspo_mask	ACSPO clear-sky mask and other flags	nx,nr	UINT1	n/a	0 to 255
air_temp_gfs	NCEP air temperature	nx, nr	REAL4	K	270 to 310
albedo_chM5	Channel M5 albedo	nx,nr	REAL4	%	0 to 100
albedo_chM7	Channel M7 albedo	nx,nr	REAL4	%	0 to 100
albedo_chM10	Channel M10 albedo	nx,nr	REAL4	%	0 to 100
ascending_descending_flag	0=descending, 1=ascending	nr	INT1	n/a	0,1
bathymetry_elevation	Ocean bathymetry and land elevation	nx, nr	INT2	m	~-11,000 to ~9,000
brightness_temp_chM12	Channel M12 brightness temperature	nx,nr	REAL4	K	180 to 335
brightness_temp_chM15	Channel M15 brightness temperature	nx,nr	REAL4	K	180 to 335
brightness_temp_chM16	Channel M16 brightness temperature	nx,nr	REAL4	K	180 to 335
brightness_temp_crtm_chM12	Simulated channel M12 brightness temperature	nx,nr	REAL4	K	180 to 335
brightness_temp_crtm_chM15	Simulated channel M15 brightness temperature	nx,nr	REAL4	K	180 to 335
brightness_temp_crtm_chM16	Simulated channel M16 brightness temperature	nx,nr	REAL4	K	180 to 335
extra_byte_clear_sky_tests_results	Additional clear-sky test results (i.e., an extension of individual_clear_sky_tests_results)	nx,nr	UINT1	n/a	0-7 (only least-significant 3 bits used; rest are zero)
individual_clear_sky_tests_results	Individual clear-sky tests results	nx,nr	UINT1	n/a	0 to 255
inland_water_to_land_dist	Distance from inland water pixels to the land	nx, nr	REAL4	km	0-50
land_to_water_dist	Distance from land pixels to any water	nx, nr	REAL4	km	0-20
latitude	Latitude	nx,nr	REAL4	degrees	-90 to 90
longitude	Longitude	nx,nr	REAL4	degrees	-180 to 180
ocean_to_land_dist	Distance from ocean water pixels to the land	nx, nr	REAL4	km	0-50
relative_azimuth_angle	Relative azimuth angle	nx,nr	REAL4	degrees	0 to 180
satellite_zenith_angle	Satellite zenith angle	nx,nr	REAL4	degrees	-70 to 70
pixel_line_number	Number of pixel line, i.e., detector row	nr	INT4	n/a	1 to 5408
pixel_line_time	Start time of pixel line	nr	REAL8	hours	0 to 24
solar_zenith_angle	Solar zenith angle	nx,nr	REAL4	degrees	0 to 180
sst_regression	Retrieved sea surface temperature from regression	nx, nr	REAL4	K	100 to 309
sst_reynolds	Reference (first-guess) SST from daily Reynolds	nx, nr	REAL4	K	270 to 310
tpw_acspo	Total precipitable water derived from relative humidity	nx, nr	REAL4	g/cm^2	0 to 6
u_wind_gfs	NCEP zonal wind velocity	nx, nr	REAL4	m/sec	0 to 20
v_wind_gfs	NCEP meridional wind velocity	nx, nr	REAL4	m/sec	0 to 20

Each output file from NDE ACSPO-VIIRS processing to be sent to the archive (JPL for 30 days, then NODC as described above) is a 10-minute granule of data in netCDF format. Each granule contains the attributes and layers described above in the GHRSST GDS 2.0 netCDF granule content description. Each granule varies in size because of variations in compression but is generally in the range between 120 -150 MBytes. Archived output files (granules) have the following naming convention:

YYYYMMDDhhmmss-OSPO-L2P_GHRSST-SST1m-VIIRS_NPP-v02.0-fv01.0.nc

where YYYY, MM, DD, hh, mm, ss are the normal date and time information (in UTC) and indicate the start time of the data in the file.

Both types of ACSPO netCDF4 files (legacy and GDS2) produced in the NDE environment contain a metadata header based on the NDE-STAR metadata template. In addition the ACSPO GDS2 files, archived at NODC, adhere to the GHRSST Data Specification, version 2 (GDS2), which follows some of the recommendations of the Unidata Attribute Convention for Dataset Discovery (ACDD), complies with the Climate and Forecast (CF) metadata conventions, and follows the ISO 19115-2 metadata standards. The metadata headers for these files have already been described. Table 1-4 describes the header of the GDS2 file. Table 1-6 describes the header of the legacy file.

2 ALGORITHM

2.1 Algorithm Overview

ACSPO is a processing system developed at NOAA NESDIS STAR with the initial objective to process data of the Advanced Very High Resolution Radiometer (AVHRR) on NOAA satellites for SST, aerosol and clear-sky radiances. Since May 2008, ACSPO has been used for operational processing of the AVHRR data at the NOAA Office of Satellite and Product Operations (OSPO). Since then, ACSPO has been continuously developed, and the scope of ACSPO applications extended to include processing Full Resolution Area Coverage (FRAC) AVHRR data from MetOp, Moderate Resolution Imaging Spectroradiometer (MODIS) data from Terra and Aqua, and Visible Infrared Imaging Radiometer Suite (VIIRS) data from Suomi-National Polar-orbiting Partnership (S-NPP).

ACSPO has a number of features which make it different from the majority of existing operational SST retrieval systems. These features are as follows:

- ACSPO incorporates the Community Radiative Transfer Model (CRTM), which performs on-line clear-sky radiative transfer simulations. The inputs for CRTM are an L4 SST analysis and the atmospheric profiles of temperature and humidity from the National Center for Environmental Prediction (NCEP) Global Forecast System (GFS).
- ACSPO can use a variety of L4 SST products, including:
    - Weekly Optimal Interpolation Reynolds SST
    - AVHRR-based NOAA Optimum Interpolation 0.25° Daily SST Analysis
    - Operational SST and Sea Ice Analysis (OSTIA)
    - Canadian Meteorological Centre (CMC) SST
- The quality of the ACSPO SST product is controlled with a special ACSPO module, ACSPO Clear-Sky Mask (ACSM). The ACSM performs downstream of the SST algorithm and detects cloud manifestations directly in the retrieved SST and in deviations of observed brightness temperatures (BT) from ones simulated with CRTM.
- Prior to cloud filtering, the ACSM evaluates global biases in retrieved SST with respect to L4 analysis and in observed BTs with respect to CRTM BTs. Accounting for these biases in the ACSM cloud filters reduces sensitivity of the ACSM to calibration trends and potential biases in retrieved SST.
- Similar to many other existing operational processing systems, ACSPO exploits regression SST algorithms. These algorithms will be periodically upgraded as new and more effective algorithms are developed. In fact, beginning with version 2.3, ACSPO incorporates the regression algorithms developed at the EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF), which were shown to be more efficient than the prior ACSPO algorithms. In addition, the availability of CRTM simulations within ACSPO allows using algorithms based on radiative transfer simulations. One such algorithm, the Hybrid or Incremental Regression, is currently being tested within the experimental version of ACSPO.

The flow chart of processing VIIRS Sensor Data Records (SDRs) with ACSPO is shown in Figure 2-1. ACSPO processes VIIRS SDRs sequentially in time. The sequence of SDRs is important for accumulation of histograms of deviations of SST from the reference L4 SST and VIIRS BTs from CRTM BTs. The histograms are used in ACSM to estimate global biases in the corresponding variables. If the histogram files are not available at the beginning of processing of a given series of SDRs, they are initially calculated from the first processed SDR. The processing of each SDR begins with reading the input data, including the L4 SST analysis field and GFS atmospheric profiles which are used as input for CRTM. L4 SST is also used as reference (first guess) SST in SST retrieval. The reference SST field is interpolated from the native grid to the sensor's pixels. The simulated clear-sky BTs are also interpolated to all ocean pixels. SST retrievals are performed for all ocean pixels, using two LWIR split-window bands during day and three bands (2 LWIR and 1 MWIR) during night. The Single Sensor Error Statistics (SSES), i.e. the estimates of bias and SD of clear-sky SST estimates, are produced at every pixel by interpolation of pre-calculated look-up tables (LUT). The previously accumulated histograms of deviations of retrieved SST from reference SST and observed BTs from CRTM BTs are read from the histogram files and updated using the information from the current SDR. The updated histograms are written in the histogram files, and used to estimate the global biases of the corresponding variables. Finally, the ACSM separates clear-sky and cloudy pixels.

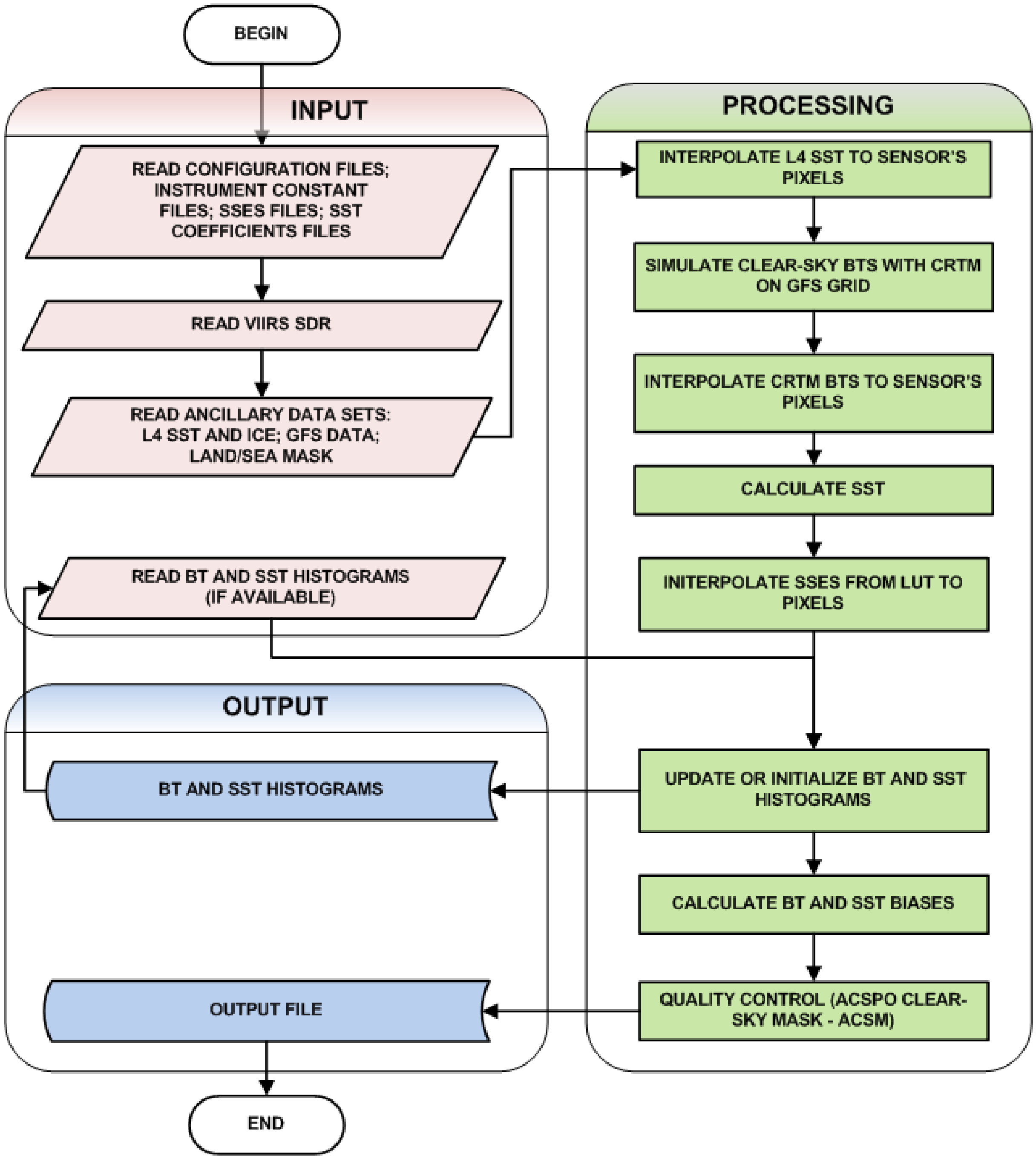

Figure 2-1 – Flow Chart of ACSPO Data Processing

2.2 Input Satellite Data

2.2.1 Satellite Instrument Overview

The ACSPO products described in this document are being produced from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument aboard the Suomi National Polar-orbiting Partnership (NPP) satellite launched on October 28, 2011, and aboard subsequent Joint Polar Satellite System (JPSS) satellites. The VIIRS instrument offers a new generation of operational moderate resolution-imaging capabilities following the legacy of the AVHRR on NOAA and MODIS on Terra and Aqua satellites. VIIRS is a whiskbroom scanning radiometer with a field of regard of 112.56 degrees in the cross-track direction. At a nominal altitude of 829km, the swath width is 3060 km, providing full daily coverage both in the day and night side of the Earth. VIIRS has 22 spectral bands covering the spectrum between 0.412 μm and 12.01μm, including 16 moderate resolution bands (M-bands) with a spatial resolution of 750 m at nadir. ACSPO currently uses one mid-wave infrared band (M12 – 3.7 micron) and two thermal infrared bands (M15 and M16, 10.763 microns and 12.013 microns respectively) to retrieve sea surface temperature. Some details of the VIIRS instrument on NPP can be found in the table below.

Table 2-1 – VIIRS Bands

Band	Driving EDR(s)	Center Wavelength (μm)	Equiv. Width (μm)	Horizontal Sample Interval (km) (track × scan)		Band Gain	Ltyp or Ttyp (Spec)	Lmin or Tmin	Lmax or Tmax	Spec SNR or NEdT (K)	On Orbit SNR or NEdT (K)	MODIS equiv. band
				Nadir	End of Scan							
VisNIR												
M1	Ocean Color Aerosol	0.411	0.0198	0.75×0.75	1.60x1.58	H	44.9	30	135	352	588	B8
						L	155		615	316	1045	
M2	Ocean Color Aerosol	0.444	0.0143	0.75×0.75	1.60x1.58	H	40	26	127	380	572	B9
						L	146		687	409	1010	
M3	Ocean Color Aerosol	0.486	0.0190	0.75×0.75	1.60x1.58	H	32	22	107	416	628	B10
						L	123		702	414	988	
M4	Ocean Color Aerosol	0.551	0.0209	0.75×0.75	1.60x1.58	H	21	12	78	362	534	B4/B12
						L	90		667	315	856	
I1	Imagery EDR	0.639	0.0775	0.375x0.375	0.80x0.79	S	22	5	718	119	214	B1
M5	Ocean Color Aerosol	0.672	0.02	0.75×0.75	1.60x1.58	H	10	9	59	242	336	B13/B1
						L	68		651	360	631	
M6	Atmosph. Correct.	0.745	0.0146	0.75×0.75	1.60x1.58	S	9.6	5.3	41	199	368	B15
I2	NDVI	0.862	0.0394	0.375x0.375	0.80x0.79	S	25	10.3	349	150	264	B2
M7	Ocean Color Aerosol	0.862	0.0387	0.75×0.75	1.60x1.58	H	6.4	3.4	29	215	457	B16/B2
						L	33.4		349	340	631	
DNB	NCC Imagery	0.700	0.200	0.75×0.75	0.75×0.75	LG/MG/HG	3E-9	3E-9	0.02	6	>9	-
S/MWIR												
M8	Cloud Particle Size	1.238	0.0271	0.75×0.75	1.60x1.58	S	5.4	3.5	165	74	221	B5
M9	Cirrus/Cloud Cover	1.375	0.0150	0.75×0.75	1.60x1.58	S	6	0.6	77.1	83	227	B26
I3	Binary Snow Map	1.602	0.0572	0.375x0.375	0.80x0.79	S	7.3	1.2	72.5	6	149	B6
M10	Snow Fraction	1.602	0.0587	0.75×0.75	1.60x1.58	S	7.3	1.2	71.2	342	586	B6
M11	Clouds	2.257	0.0467	0.75×0.75	1.60x1.58	S	0.12	0.12	31.8	10	22	B7
I4	Imagery Clouds	3.753	0.360	0.375x0.375	0.80x0.79	S	270	210	353	2.5	0.4	B20
M12	SST	3.697	0.192	0.75×0.75	1.60x1.58	S	270	230	353	0.396	0.12	B20
M13	SST/Fires	4.067	0.165	0.75×0.75	1.60x1.58	H	300	230	343	0.107	0.04	B23
						L	380		634	0.423		
LWIR												
M14	Cloud Top Properties	8.578	0.324	0.75×0.75	1.60x1.58	S	270	190	336	0.091	0.06	B29
M15	SST	10.729	0.990	0.75×0.75	1.60x1.58	S	300	190	343	0.07	0.03	B31
I5	Cloud Imagery	11.469	1.75	0.375x0.375	0.80x0.79	S	210	190	340	1.5	0.4	B31
M16	SST	11.845	0.866	0.75×0.75	1.60x1.58	S	300	190	340	0.072	0.03	B32

Other VIIRS resources can be found here: https://cs.star.nesdis.noaa.gov/NCC/VIIRS

2.2.2 Satellite Data Preprocessing Overview

ACSPO receives input sensor data (level 1b, for VIIRS also referred to as Sensor Data Records, SDRs), and processes them into a level 2 SST product (referred to as Environmental Data Records, EDRs). SDR data contain swath (pixel-level) geo-located and radiometrically calibrated radiances.

Navigation refers to the process which uses an orbital model along with ephemeris data or spacecraft position data and known characteristics of the instrument scanning geometry, to determine the earth footprint and location of every earth field-of- view recorded by the instrument detectors.

Calibration of the VIIRS instrument is performed on a line-by-line basis, using space view and warm calibration target (black body) measurements, recorded for each individual scan. A non-linearity correction is applied using data derived from pre-launch measurements on the ground.

The calibration and navigation steps are performed by the Interface Data Processing Segment (IDPS) software developed by the NPOESS and later JPSS programs. An algorithm overview can be found in the Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Geolocation (GEO) Sensor Data Record (SDR) and Calibration (CAL) SDR Software (section 2.0, page 28): http://npp.gsfc.nasa.gov/sciencedocuments/2013-11/474-00090_OAD-VIIRS-CAL-GEO-SDR_E.pdf. This document is a good reference for all details of the navigation and calibration steps for the VIIRS instrument. More detailed information is also available on the calibration and navigation theoretical basis in the following documents:
http://npp.gsfc.nasa.gov/sciencedocuments/474-00027_ATBD-VIIRS-RadiometricCal_B_20120411.pdf
http://npp.gsfc.nasa.gov/sciencedocuments/ATBD_122011/474-00053_Geolocation_ATBD_Rev-_20110422.pdf

Brightness temperatures in the following VIIRS bands are used for SST retrievals: M12 (3.7 µm), M15 (11 µm), and M16 (12 µm). Reflectance bands M5 (0.67 µm), M7 (0.86 µm), and M10 (1.6 µm) are also used for clear-scene identification. Work is underway to include M13 (4.05 µm) and M14 (8.6 µm) in SST retrievals.

Note also that VIIRS takes measurements using two mirror sides and 16 detectors, each of which is calibrated independently thus leading to striping in L1b radiances and derived SSTs. Work is currently underway to perform de-striping of the input brightness temperatures.

2.2.3 Input Satellite Data Description

The satellite data input to ACSPO-VIIRS processing are currently 6 separate VIIRS moderate resolution sensor data records (SDRs) and the corresponding earth location SDR from S-NPP and follow-on JPSS satellites. The SDRs are created in the JPSS Interface Data Processing Segment (IDPS) and are transferred to the NDE processing machines. SDRs are in the form of 86-second granules, one granule per band, and contain calibrated brightness temperatures and reflectances (level 1c or 1b+, i.e. calibration has been applied). The SDRs are in HDF5 format upon input to the ACSPO processing. The specific bands used by the ACSPO VIIRS processing are cited above in Section 2.2.1.

Details of the VIIRS SDR formats for the moderate resolution bands can be found in Section 2.16 titled "*Visible/Infrared Imaging Radiometer Suite Moderate Resolution Band Sensor Data Records"* of the document "Joint Polar Satellite System (JPSS) Common Data Format Control Book - External (CDFCB-X) Volume III - SDR/TDR Formats" at http://npp.gsfc.nasa.gov/documents.html.

2.3 Input Ancillary Data

ACSPO reads the following ancillary data sets:

- Level 4 (L4) reference SST and sea ice data
- Forecast model (i.e., GFS) data

Each of these ancillary data sets is described in the following sections.

2.3.1 Reference SST and Sea Ice Maps

ACSPO is setup to handle a variety of L4 reference SST files, including NOAA Optimum Interpolation (OI SST), Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA), and Canadian Meteorological Centre (CMC) products. Currently, the CMC SST data is used. Sea ice information is available in all of these products.

The OI SST data includes both the weekly OI SST (v2) data and either the AVHRR or AVHRR & AMSR daily OI SST (v1 or v2) data. The weekly OI v2 SST and sea ice maps are generated by NCEP on a weekly basis and have grid spacing of 1° both in latitude and longitude. The dimensions of the maps are 360 in longitude (from 0.5° to 359.5°) and 180 in latitude (from -89.5° to 89.5°). The SST and sea ice maps are stored in a binary form as arrays of 4-byte floats in the files called oisst.yyyymmdd, where yyyy is a 4-digit year, mm is 2-digit month and dd is 2-digit day. The description of weekly OI v2 SST data can be found in, and data are available from, ftp://ftp.emc.ncep.noaa.gov/cmb/sst/oisst_v2 (Reynolds, R.W., N.A.Rayner, T.M.Smith, D.C.Stokes, and W. Wang, 2002: An improved in situ and satellite SST analysis for climate, J. Climate, 15, 929-948).

The AVHRR or AVHRR & AMSR daily OI SST and sea ice maps are generated by NCDC on a daily basis and have grid spacing of 0.25° both in latitude and longitude. The dimensions of the maps are 1440 in longitude (from 0.125° to 359.875°) and 720 in latitude (from -89.875° to 89.875°). The data archive is netCDF format and the names for the different versions are defined as follows,

AVHRR daily OI v1 SST:	sst4-navy-eot.yyyymmdd.nc
AVHRR & AMSR daily OI v1 SST:	sst4-navy-amsr-eot.yyyymmdd.nc
AVHRR daily OI v2 SST:	avhrr-only-v2.yyyymmdd_preliminary.nc (real-time interim version) or avhrr-only-v2.yyyymmdd.nc (14-day latency, final version)
AVHRR & AMSR daily OI v2 SST:	amsr-avhrr-v2.yyyymmdd.nc

The description of daily OI SST data can be found in, and data are available from, ftp://eclipse.ncdc.noaa.gov/pub/oisst/NetCDF/, and http://www.ncdc.noaa.gov/thredds/catalog/oisst/NetCDF/AVHRR/catalog.html (Reynolds, R.W., T. M. Smith, C. Liu, D. B. Chelton, K. S. Casey, and M. G. Schlax (2007). Daily high-resolution blended analyses for sea surface temperature. J. Clim., 20, 5473–5496).

OSTIA SST and sea ice fraction maps are generated by the UK Met Office on a daily basis at a 0.05° resolution. The dimensions of the data are 7200 in longitude (from -179.975° to 179.975°) and 3600 in latitude (from -89.975° to 89.975°). The data archive is netCDF format and the names of the files are as follows,

yyyymmdd-UKMO-L4HRfnd-GLOB-v01-fv02-OSTIA.nc

Information about OSTIA data can be found in, and data are available from, http://ghrsst-pp.metoffice.com/pages/latest_analysis/ostia.html.

CMC SST and sea ice mask maps are generated by the Canadian Meteorological Centre on a daily basis at 0.2° resolution in either GHRSST Data Specification (GDS) 1 or GDS2 format. The dimensions of the data are 1800 in longitude (from -180° to 179.8°) and 901 in latitude (from -90° to 90°). The data archive is netCDF format and the names of the CMC files are as follows,

yyyymmdd-CMC-L4_GHRSST-SSTfnd-CMC0.2deg-v02.0-fv01.nc (GDS1)
yyyymmddhhMMss-CMC-L4_GHRSST-SSTfnd-CMC0.2deg-GLOB-v02.0-fv02.0.nc (GDS2)

Information about CMC data can be found in, and data are available from, ftp://podaac-ftp.jpl.nasa.gov/OceanTemperature/ghrsst/data/GDS2/L4/GLOB/CMC/CMC0.2deg/v2/. In the operational setting, the CMC data is pushed to the OSPO DDS and then to the NDE servers for use in the ACSPO processing.

2.3.2 Forecast Model Data

The Global Forecasting System (GFS) files (http://nomad3.ncep.noaa.gov/pub/gfs/rotating/) contain the meteorological fields that are used for simulation of clear-sky radiances using the Community Radiative Transfer Model (CRTM). A separate tool is used to convert GFS files from their native Gridded Binary (GRIB2) format (http://www.nws.noaa.gov/tdl/iwt/grib2) to HDF4 format. The resulting HDF files are read by ACSPO and used to generate clear-sky BTs in conjunction with the reference SST. The dimensions of the GFS data are 360 in longitude (from 0.5° to 359.5°) and 181 in latitude (from 90° to -90°), thus, a resolution of 1°. In the operational setting, the GFS files are pushed to the OSPO DDS from NCEP and then transferred to the NDE servers for use in ACSPO and other application processing.

3 PERFORMANCE

3.1 Product Testing

3.1.1 Test Data Description

Several primary VIIRS SDR granules (data sets) are used during development and testing within the STAR environment. Most of these granules are aggregated, 10-minute files, but some select 86-second granules are also used. From them, a baseline set of ACSPO data sets are created, typically, from the current operational version of ACSPO. This baseline set of data sets are then used extensively for comparison with new data sets created with an updated version of ACSPO under development. Comparisons between these two sets of ACSPO files can be done relatively quickly to identify various differences, which can be verified as expected or not, based on the code changes that were made.

In addition, a number of other VIIRS SDR granules (both 10-minute and 86-second) have been saved for use in testing and verification. They include ones covering larger time ranges (i.e., a time series) as well as ones containing interesting conditions. Finally, via the STAR Collaborative Data Repository (SCDR), any VIIRS SDR 86-second granule from the most recent 3-4 months is easily available for use in testing. Generally, these granules are first aggregated into larger 10-minute granules before they are used in ACSPO testing.

For NDE, one set of 86-second granules, covering a 10-minute period, was selected as the sample test data and is included in the ACSPO DAP. This set of granules was selected based on a timing test performed against a full day of data. This set was one of the longest to process and resulted in one of the largest files for that day. The long processing time and large file indicates a complex input scene (i.e., a lot of clear-sky pixels over water), well-suited for testing.

3.1.2 Unit Test Plans

N/A

3.2 Product Accuracy

3.2.1 Test Results

Several types of manual and automated testing are performed by multiple personnel and on multiple platforms.

- The CoastWatch Data Analysis Tool (CDAT) and IDL are used to generate images from select ACSPO granules for visual examination. Generally, SST and cloud mask data are analyzed with these tools, which help in identifying anomalous areas within the data.
- Using various Unix and HDF command-line tools (e.g., h5diff, h5dump), ACSPO granules are compared against their equivalent baseline set to identify differences. All differences are analyzed and must be explainable by a specific code modification that was made. See Section 3.1.1. Along these same lines, ACSPO granules

generated in the NDE environment are compared against the same granules generated in the STAR environment. Given identical input, identical output—to machine precision—is expected.

- Following successful completion of the various testing as described above, a DAP is generated and made available for subsequent automated testing in Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS). During this phase of testing, a much longer time series (typically, a week or more) of data is processed. The results get automatically displayed on the MICROS web pages where maps and statistics can be viewed and analyzed to determine if the results of the new version of ACSPO are acceptable and as expected.

3.2.2 Product Accuracy

Figure 3-1 demonstrates daytime and nighttime histograms of VIIRS ACSPO SST – *in situ* SST accumulated during May 2013. Both histograms have a quasi-Gaussian shape. The statistics are shown on the left-hand side of each plot. The retrieval accuracy (Mean) and the precision (Stdv) are well within the threshold requirements as defined in Table 1-1, above. Figure 3-2 and Figure 3-3 plot the time series of monthly averaged bias and standard deviation of ACSPO SST minus *in situ* SST for several satellite sensors and processing systems. The retrieval statistics of ACSPO-VIIRS SST are stable in time and consistent with or better than for other satellite SST products. The daytime and nighttime composite maps of ACSPO-VIIRS SST – OSTIA produced from VIIRS data for 20 May 2013 and shown in Figure 3-4 and Figure 3-5 demonstrate good consistency of ACSPO-VIIRS SST with L4 SST analyses field. The daytime and nighttime histograms and statistics of ACSPO-VIIRS SST – OSTIA for the same day are shown in Figure 3-6 and Figure 3-7. (NOTE: The images in the figures below are from http://www.star.nesdis.noaa.gov/sod/sst/squam/HR/index.html.)

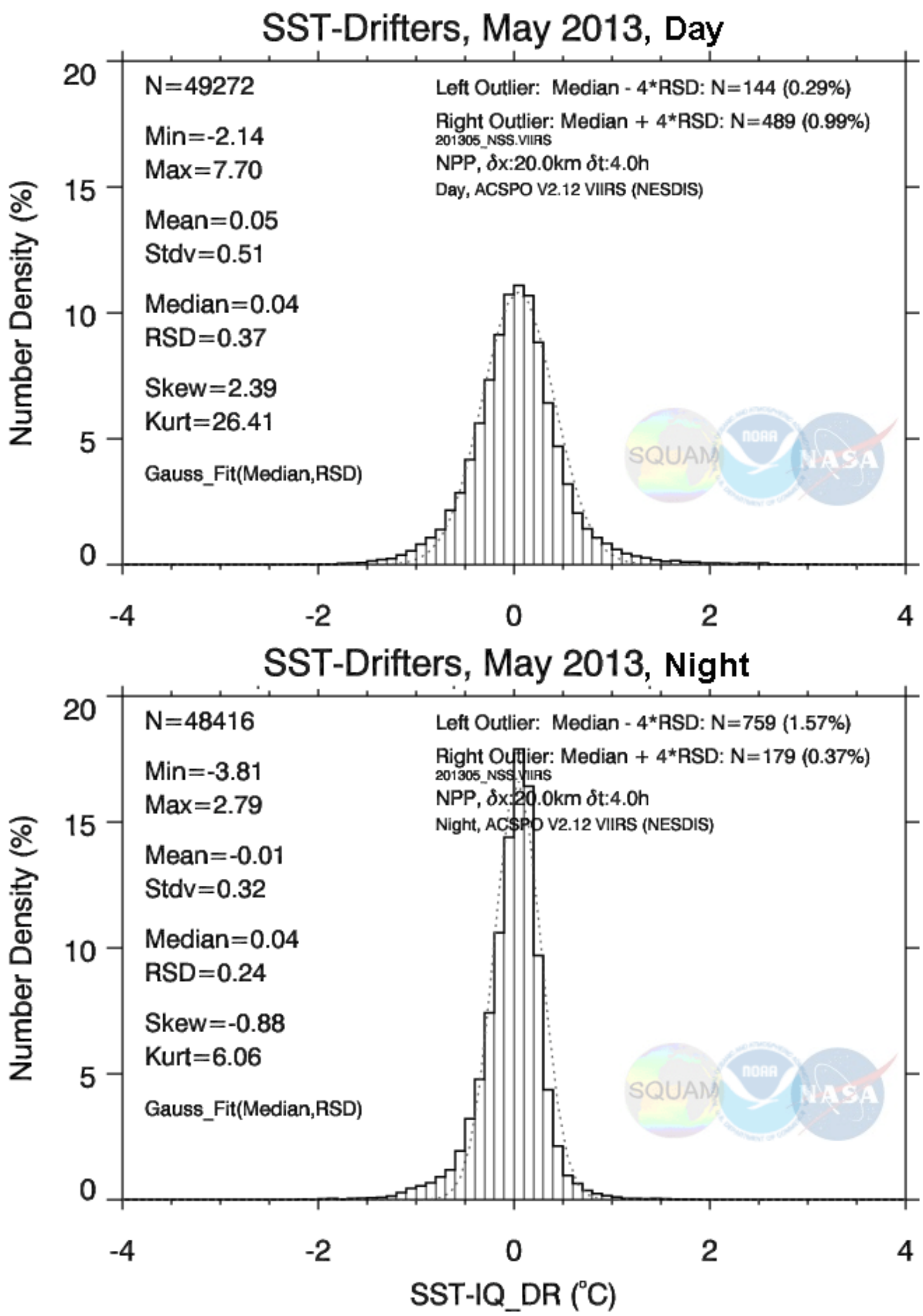

Figure 3-1 – Daytime and nighttime histograms of ACSPO VIIRS SST minus in situ SST accumulated during May 2013

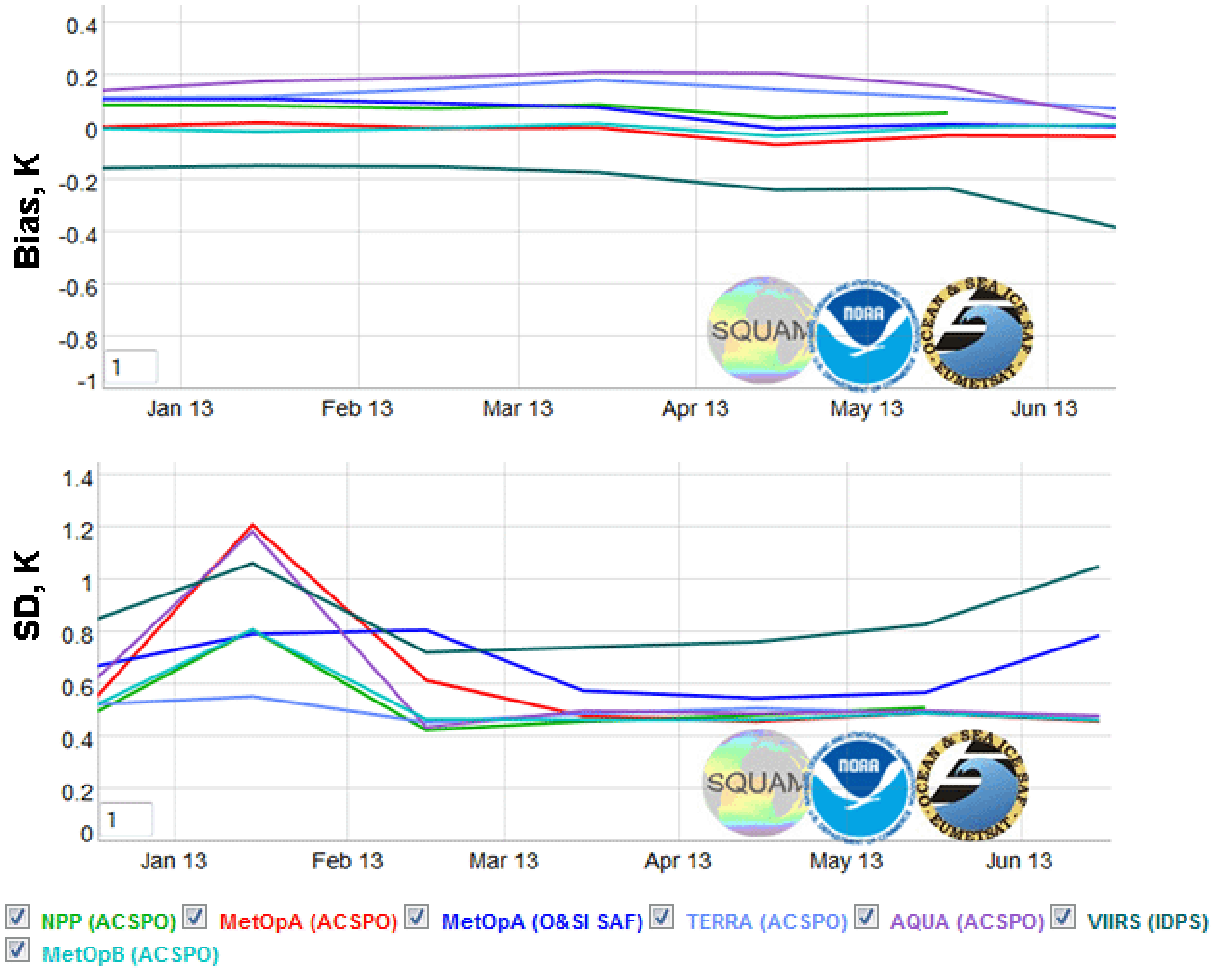

Figure 3-2 – Time series of daytime monthly bias and SD of retrieved SST minus in situ SST for several satellite sensors and processing systems

NOTE: **NPP(ACSPO)** is VIIRS SST produced with ACSPO; **MetOpA(ACSPO)** and **MetOpB(ACSPO)** are the ACSPO products from the MetOp-A and MetOp-B AVHRRs; **MetOpA(O&SI SAF)** is SST produced from the MetOp-A AVHRR at OSI-SAF; **TERRA(ACSPO)** and **AQUA(ACSPO)** are the ACSPO products from Aqua and Terra MODIS; and **VIIRS(IDPS)** is SST produced from VIIRS with the Interface Data Processing System.

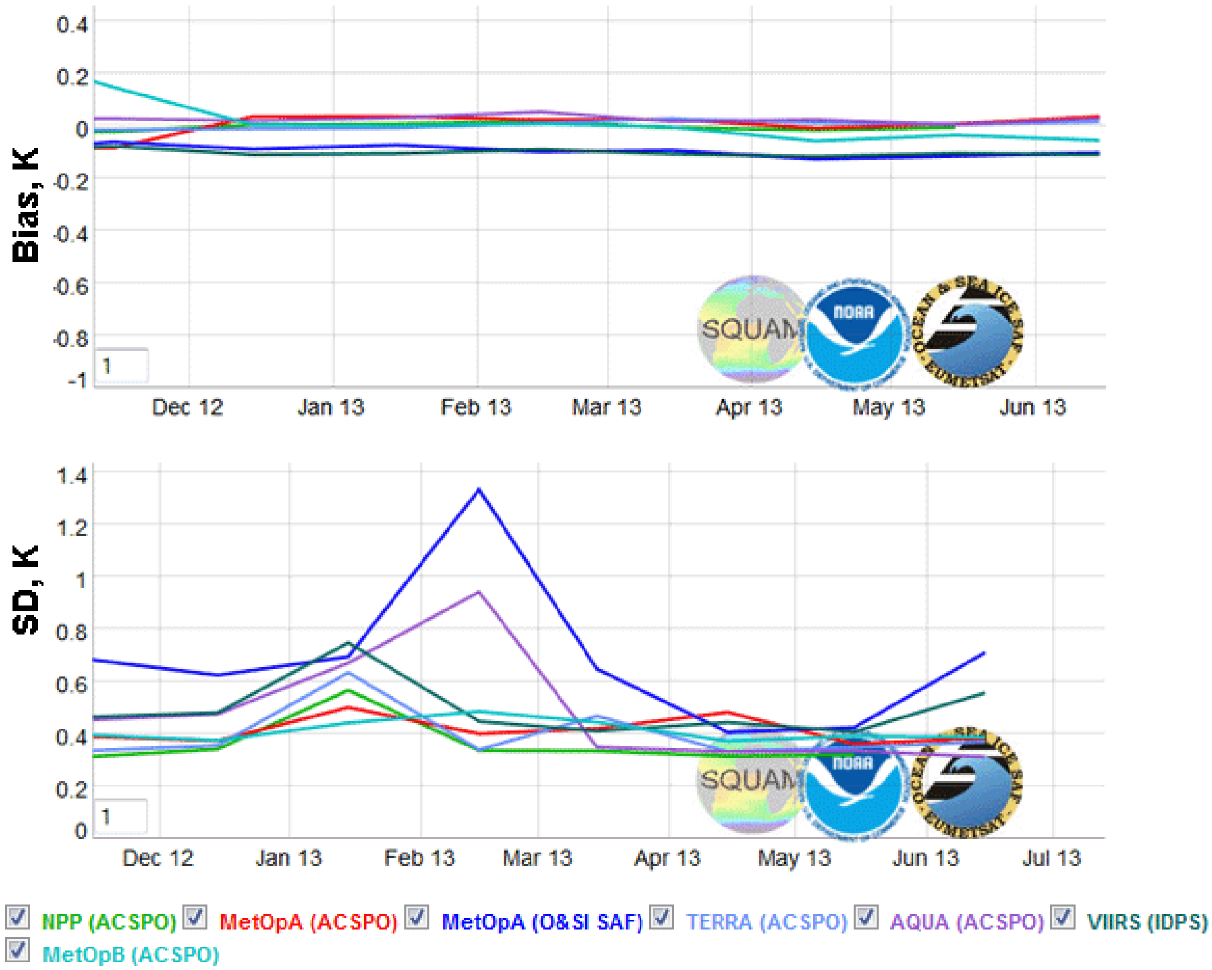

Figure 3-3 – Time series of nighttime monthly bias and SD of retrieved SST minus in situ SST for the same satellite sensors and processing systems as listed in Figure 3-2

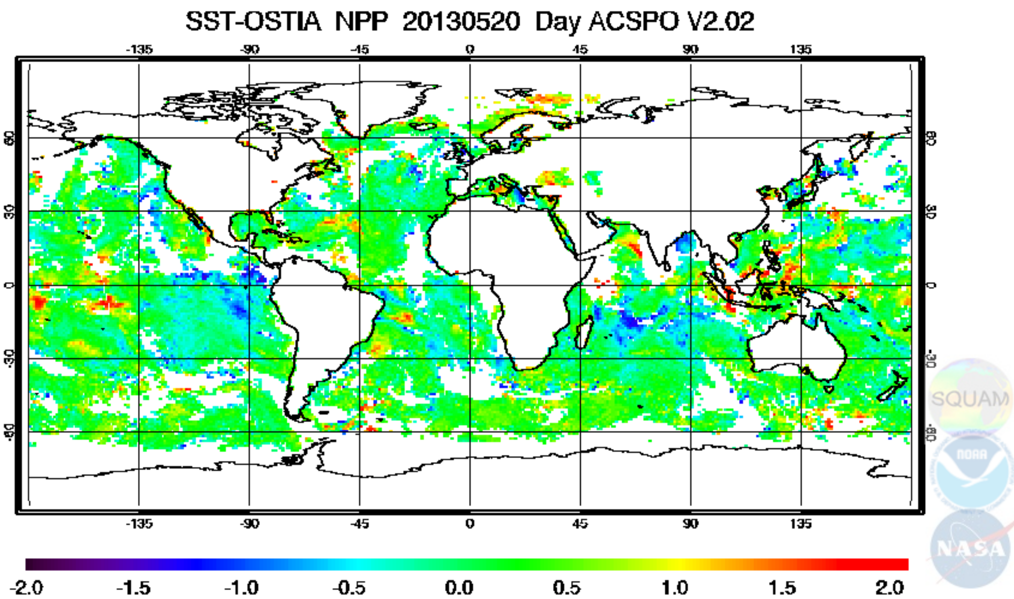

Figure 3-4 – Daytime global composite map of ACSPO VIIRS SST – OSTIA for 20 May 2013

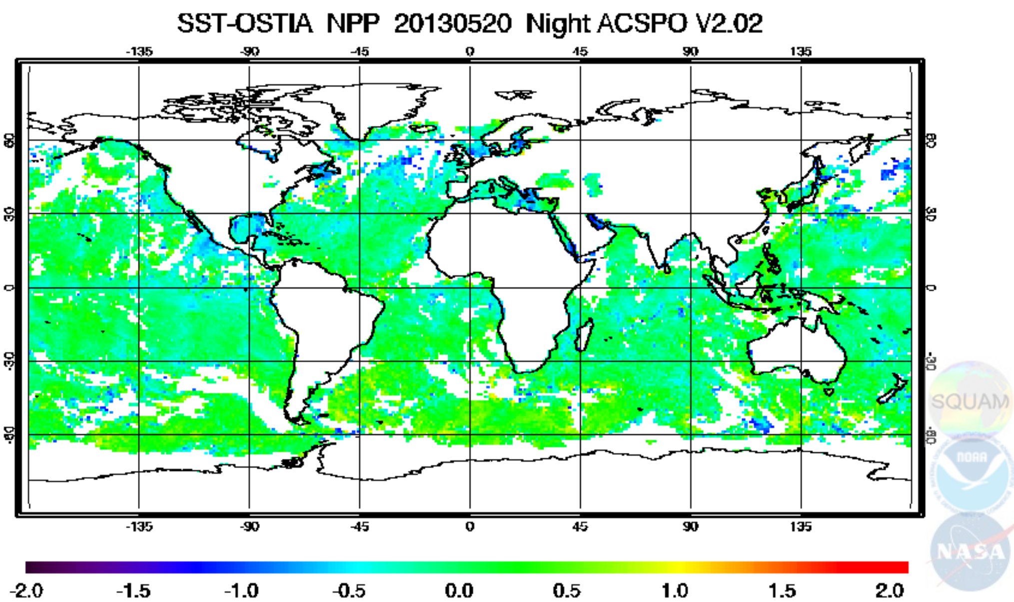

Figure 3-5 – Nighttime global composite map of ACSPO VIIRS SST – OSTIA for 20 May 2013

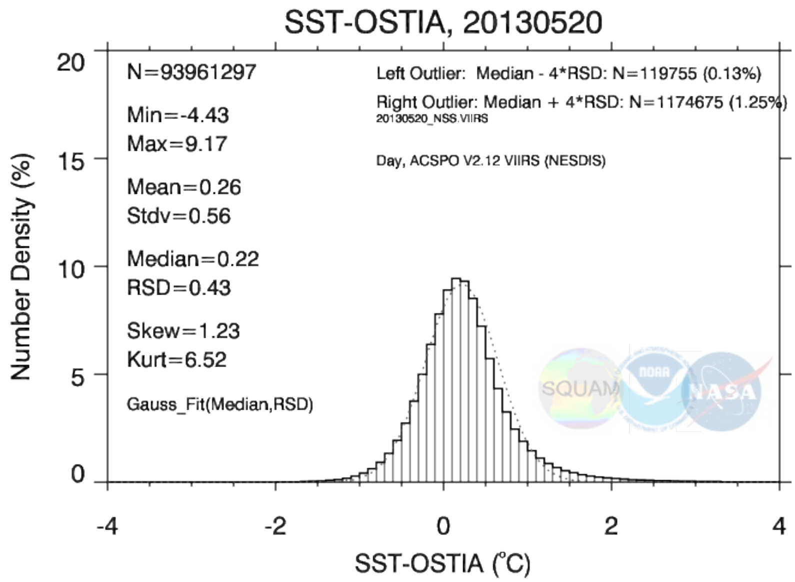

Figure 3-6 – Daytime histogram of ACSPO VIIRS SST – OSTIA for 20 May 2013

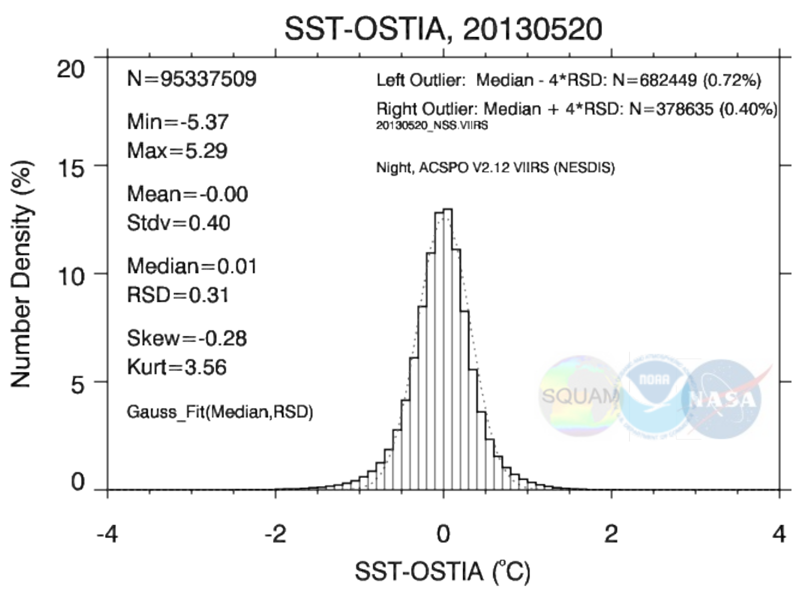

Figure 3-7 – Nighttime histogram of ACSPO VIIRS SST – OSTIA for 20 May 2013

3.3 Product Quality Output

The ACSPO output files contain several pixel-level layers containing quality information:

- acspo_mask in the legacy format. (In addition, a pair of other layers--individual_clear_sky_tests_results and extra_byte_clear_sky_tests_results--may be used alongside the acspo_mask layer for help in interpreting the layer's clear-sky mask field.)
- l2p_flags and quality_level in the GDS2 format

The quality information in the legacy format is described first, in Section 3.3.1, as it provides a basis for the subsequent description, in Section 3.3.2, of the quality information in the GDS2 format.

3.3.1 Legacy Format

The acspo_mask layer (1 byte per pixel) contains a set of bit flags, which characterize some important quality and observation conditions. Table 3-1 describes the meaning of each flag in acspo_mask (convention is bit 1 is the least significant).

Table 3-1 – acspo_mask

it	Description
1	0 – valid pixel, 1 – invalid pixel
2	0 – night, 1 – day
3	0 – sea, 1 - land
4	1 – "twilight" region (degraded quality data)
5	1 – glint
6	1 – snow / ice
7, 8	ACSPO clear-sky mask (ACSM): 0 – clear, 1 – probably clear, 2 – cloudy, 3 – undefined

The values of the ACSM (bits 7-8 of acspo_mask layer) are produced from the outputs of individual ACSM cloud filters. These outputs are represented in two additional layers, individual_clear_sky_tests_results and extra_byte_clear_sky_tests_results (1 byte per pixel each). Each pixel of these layers is composed of a set of 1-bit flags showing the results of individual clear-sky filters. The individual_clear_sky_tests_results layer contains 8 flags, while the extra_byte_clear_sky_tests_results layer contains 3 flags (the other 5 bits are reserved for future use and set to zero). (Refer to "Petrenko, B., A.Heidinger, A.Ignatov, Y.Kihai: Clear-Sky Mask for the AVHRR Clear-Sky Processor for Oceans. AGU Ocean Sciences Meeting, Orlando, FL, 2-7 March 2008 http://www.star.nesdis.noaa.gov/smcd/emb/aerosol/ignatov/conf/2008-AGU-OSM-PetrenkoEtAl_ACSPO_CSM_Poster.pdf" for more detail.) Table 3-2 lists each clear-sky filter and its associated bit and layer location. If filters 2-11 show "clear" (i.e. all the corresponding bits are 0), the value of the ACSM is 0 ("clear"); if at least one of the filters 2-6 or 9-11 shows "cloudy," (i.e., at least one the corresponding bits is 1) the value of the ACSM is 2 ("cloudy"); if all the filters except 7-8 show "clear," and at least one of the filters 7 - 8 show "cloudy", then the value of the ACSM is 1 ("probably clear").

Table 3-2 – Clear-Sky Filters

Filter	Bit	Layer	Clear-Sky Filter
1	1	individual_clear_sky_tests_results	Radiance Filter for Brightness Temperatures
2	2	individual_clear_sky_tests_results	Radiance Filter for SST
3	3	individual_clear_sky_tests_results	Static SST Filter
4	4	individual_clear_sky_tests_results	Adaptive SST Filter
5	5	individual_clear_sky_tests_results	Reflectance Gross Contrast Filter (RGCT)
6	6	individual_clear_sky_tests_results	Reflectance Ratio Contrast Filter (RRCT)
7	7	individual_clear_sky_tests_results	SST Uniformity Filter (USST)
8	8	individual_clear_sky_tests_results	SST / Reflectance Cross-Correlation Filter
9	1	extra_byte_clear_sky_tests_results	Warm Static SST Filter
10	2	extra_byte_clear_sky_tests_results	Warm Adaptive SST Filter
11	3	extra_byte_clear_sky_tests_results	Low Stratus Filter

An ACSM value of 3 identifies pixels for which the mask has not been defined for such reasons as invalid pixels, pixels over land, coast, snow, ice and saturated pixels. The values 0 – 2 correspond to valid pixel over ocean. To select clear-sky pixels over oceans for SST analysis, it is sufficient to select ones with the only condition being ACSM = 0. If a user is interested in the extended set of both "clear" and "probably clear" pixels, the condition ACSM < 2 should be used. To select the clear-sky pixels for brightness temperature (BT) analysis, a user should combine the conditions ACSM = 0 and bit 1 of the individual_clear_sky_tests_results layer = 0 (Radiance Filter for Brightness Temperatures shows "clear"). This will filter out the abnormal BT values, which are handled well by the SST algorithm, but deteriorate the statistics of BT anomalies with respect to simulated BTs.

3.3.2 GDS2 Format

In the GDS2 format, acspo_mask is stored in the 2-byte layer "l2p_flags". The least significant 6 bits of l2p_flags are generic flags that are common to all GDS2 Level-2 Pre-processed (L2P) data files. The most significant 10 bits are product specific, and contain acspo_mask in the most significant 8 bits (the other 2 bits are spare). Table 3-3 describes the content of l2p_flags.

Table 3-3 – l2p_flags

Bit	Description
1	0 – infrared data
2	0 – ocean, 1 – land (same as bit 11)
3	1 – ice (same as bit 14)
4	1 – lake (if known)
5	1 – river (if known)
6	Reserved for future use
7, 8	Spare
9	0 – valid pixel, 1 – invalid pixel
10	0 – night, 1 – day
11	0 – sea, 1 - land
12	1 – "twilight" region (degraded quality data)
13	1 – glint
14	1 – snow / ice
15, 16	ACSPO clear-sky mask (ACSM): 0 – clear, 1 – probably clear, 2 – cloudy, 3 – undefined

In addition to the l2p_flags, each pixel contains a "quality_level" indicator. It's an integer value that ranges from 0 to 5. This quality_level layer is primarily derived from the setting of the ACSM in the l2p_flags layer, as follows:

- If the ACSM is 0 (clear), then quality_level is 5.
- If the ACSM is 1 (probably clear), then quality_level is 4.
- If the ACSM is 2 (cloudy), then quality_level is 3.
- If the ACSM is 3 (undefined), then quality_level is 0.

A quality_level of 1 or 2 is not used.

3.4 External Product Tools

No tools are delivered with ACSPO as part of its DAP. However, there are a variety of tools, both "off-the-shelf" (OTS) and internally (i.e., STAR) developed, that are freely available for users to display, monitor, and analyze ACSPO data. Below is a list of the OTS tools and where to download them. Each tool has its own documentation describing its use.

Tool: HDFView
Description: "[A] visual tool for browsing and editing HDF4 and HDF5 files"
URL: http://www.hdfgroup.org/hdf-java-html/hdfview/

Tool: Panoply
Description: "[C]ross-platform application which plots geo-gridded arrays from netCDF, HDF and GRIB datasets"
URL: http://www.giss.nasa.gov/tools/panoply/

Tool: CoastWatch Software Library and Utilities

Description: "[P]ackage of software tools for working with earth data sets distributed by the NOAA/NESDIS CoastWatch program" (including ACSPO data)
URL: http://coastwatch.noaa.gov/cwn/cw_software.html

Below is a list of the web-based tools developed by the SST team.

Tool: Monitoring of IR Clear-Sky Radiances over Oceans for SST (MICROS)
Description: Near real-time monitoring and analysis of (1) "Model (i.e., CRTM) minus Observation" biases in top of the atmosphere (TOA) brightness temperatures (BTs) and (2) "Retrieval minus Reference" SST biases.
URL: http://www.star.nesdis.noaa.gov/sod/sst/micros/

Tool: SST Quality Monitor (SQUAM)
Description: Near real-time monitoring of major global SST products
URL: http://www.star.nesdis.noaa.gov/sod/sst/squam/

Tool: *in situ* SST Quality Monitor (iQUAM)
Description: Quality monitoring system for *in situ* data
URL: http://www.star.nesdis.noaa.gov/sod/sst/iquam/

Tool: Aerosol Quality Monitor (AQUAM)
Description: Near real-time monitoring of aerosol retrievals from various products. For the ACSPO products, only ACSPO-AVHRR is monitored since no aerosol retrievals are generated in ACSPO-MODIS and ACSPO-VIIRS.
URL: http://www.star.nesdis.noaa.gov/sod/sst/aquam/

4 PRODUCT STATUS

4.1 Operations Documentation

There is an NDE Data Consumer Portal available for users to monitor product subscription and system status:
https://nppportal.espc.nesdis.noaa.gov:8443/dhsDataConsumerPortal/#Login.

Users should use the same account name as the account name used to get data. A password should be provided by the NDE data access team for the portal. The portal is fully described in the NDE User's Manual. Contact DDS_Administrator@noaa.gov to request a copy of this manual.

For operational emergencies, please contact ESPCOperations@noaa.gov.
When reporting problems, ESPC/NDE can serve you better if you provide user ID and filename information.

For administrative assistance, it is good practice to send the email to, or at least copy, DDS_Administrator@noaa.gov. That box is monitored by someone on the distribution team several times a day (8x5).

The ACSPO SST group plans to have an events log of significant events or changes to the ACSPO algorithm or processing. We are planning to publish that events log onto the web. There is no events log yet as the product is just now becoming operational for VIIRS. When the events log is published on the web, this document will be updated with the URL of the log.

Some ACSPO algorithm history is available at:
ftp://www.star.nesdis.noaa.gov/pub/sod/osb/aignatov/ACSPO/, including information on the latest version of ACSPO.

4.2 Maintenance History

The operations maintenance history of ACSPO for VIIRS is as follows:

- 02/19/2014 – ACSPO V2.30 installed
- 03/12/2014 – patch to ACSPO V2.30 (fix error in seconds field of GDS2 file name)
- 05/27/2014 – patch to ACSPO V2.30 (correct values of 2 GDS2 metadata fields)

5 ACRONYMS

ACSM	ACSPO Clear-Sky Mask
ACSPO	Advanced Clear-Sky Processor for Oceans
AMSR	Advanced Microwave Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BT	Brightness Temperature
CMC	Canadian Meteorological Centre
CRTM	Community Radiative Transfer Model
DAP	Delivered Algorithm Package
FRAC	Full Resolution Area Coverage
GAC	Global Area Coverage
GDS	GHRSST Data Specification
GFS	Global Forecast System
GHRSST	Group for High-Resolution SST
HDF	Hierarchical Data Format
IDPS	Interface Data Processing Segment
IR	InfraRed
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
L2P	Level-2 Pre-processed
L4	Level 4
LWIR	Long Wave Infrared Range
MICROS	Monitoring of IR Clear-sky Radiances over Oceans for SST
MODIS	Moderate Resolution Imaging Spectroradiometer
MWIR	Midwave Infrared Range
NCEP	National Center for Environmental Prediction
NDE	NPP Data Exploitation
netCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NCDC	National Climatic Data Center
NODC	National Oceanographic Data Center
OSPO	Office of Satellite and Product Operations
OSTIA	Operational SST and Sea Ice Analysis
PO.DAAC	Physical Oceanography Distributed Active Archive Center
S-NPP	Suomi National Polar-orbiting Partnership
SD	Standard Deviation
SDR	Sensor Data Record
SPSRB	Satellite Products and Services Review Board
SQUAM	SST Quality Monitor
SST	Sea Surface Temperature
STAR	Center for Satellite Applications and Research
URL	Uniform Resource Locator
VIIRS	Visible Infrared Imaging Radiometer Suite

END OF DOCUMENT