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# Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Net Heat Flux (NHF) Environmental Data Record (EDR) and Ocean Surface Albedo (OSA) Intermediate Product (IP) Software

## For Public Release



**Goddard Space Flight Center**
**Greenbelt, Maryland**

National Aeronautics and Space Administration

# Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Net Heat Flux (NHF) Environmental Data Record (EDR) and Ocean Surface Albedo (OSA) Intermediate Product (IP) Software

# JPSS Electronic Signature Page

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# Preface

This document is under JPSS Ground Algorithm ERB configuration control. Once this document is approved, JPSS approved changes are handled in accordance with Class I and Class II change control requirements as described in the JPSS Configuration Management Procedures, and changes to this document shall be made by complete revision.

Any questions should be addressed to:

JPSS Configuration Management Office
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# Change History Log

| Revision | Effective Date | Description of Changes (Reference the CCR & CCB/ERB Approve Date) |
|---|---|---|
| Original | 06/03/2011 | **474-CCR-11-0096:** This version baselines D39552, Operational Algorithm Description (OAD) VIIRS Net Heat Flux (NHF) EDR and Ocean Surface Albedo (OSA) IP, Rev B dated 07/16/2010 as a JPSS document, version Rev –. This is the version that was approved for NPP launch. Per NPOESS CDFCB - External, Volume V – Metadata, doc number D34862-05, this has been approved for Public Release into CLASS. This CCR was approved by the JPSS Algorithm ERB on June 3. 2011. |
| Revision A | 01/27/2012 | **474-CCR-11-0264:** This version baselines 474-00082, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Net Heat Flux (NHF) Environmental Data Record (EDR) and Ocean Surface Albedo (OSA) Intermediate Product (IP) Software, for the Mx 6 IDPS release. This CCR was approved by the JPSS Algorithm ERB on January 18, 2012. |
| Revision B | 10/09/2012 | **474-CCR-11-0627:** This version authorizes 474-00082, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Net Heat Flux (NHF) Environmental Data Record (EDR) and Ocean Surface Albedo (OSA) Intermediate Product (IP) Software, for the Mx 6.1 – 6.3 IDPS releases. Includes **ECR-ALG-0035** which contains Raytheon PCR031117, OAD: Implement 474-CCR-12-0402 (Add Mirror Side Information to VIIRS NHF OAD) (ADR 4703), updated Table 4, Section 2.1.1.2, references, and various typos. |
| Revision C | 05/14/2013 | **474-CCR-13-0948:** This version authorizes 474-00082, JPSS OAD Document for VIIRS NHF EDR and OSA IP Software, for the Mx 7.0 IDPS release. Includes Raytheon PCR032720; 474-CCR-13-0916/ECR-ALG-0037: Update applicable OAD filenames/template/Rev/etc. for Mx7 Release. |
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# NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

# OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS NET HEAT FLUX (NHF) EDR AND OCEAN SURFACE ALBEDO (OSA) IP SOFTWARE

## SDRL No. S141
## SYSTEM SPECIFICATION SS22-0096

**RAYTHEON COMPANY**
**INTELLIGENCE AND INFORMATION SYSTEMS (IIS)**
**NPOESS PROGRAM**
**OMAHA, NEBRASKA**

IAW DFAR 252.227-7036, Raytheon hereby declares that, to the best of its knowledge and belief, the technical data delivered under Subcontract No. 7600002744 is complete, accurate, and complies with all requirements of the Subcontract.

TITLE: NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS NET HEAT FLUX (NHF) EDR AND OCEAN SURFACE ALBEDO (OSA) IP

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**Engineering & Manufacturing Development (EMD) Phase**
**Acquisition & Operations Contract**

**CAGE NO. 11982**

# Operational Algorithm Description
# VIIRS Net Heat Flux (NHF) EDR and Ocean Surface Albedo (OSA) IP

**Document Number: D39552**

**Document Date: Jun 30, 2011** **Revision: C6**

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Under
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This document has been identified per the NPOESS Common Data Format Control Book – External Volume 5 Metadata, D34862-05, Appendix B as a document to be provided to the NOAA Comprehensive Large Array-data Stewardship System (CLASS) via the delivery of NPOESS Document Release Packages to CLASS.

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## Revision/Change Record

**Document Number** **D39552**

| Revision | Document Date | Revision/Change Description | Pages Affected |
|---|---|---|---|
| --- | 9-30-04 | Initial Release. | All |
| A1 | 5-5-05 | Updates for Version 1.3 of the NHF and Ocean Albedo software. | All |
| A2 | 6-24-08 | Updated Input/Output tables for Sci-Ops conversion. Also, modified references to input data files that have been removed during the Sci-Ops conversion. Implemented Tech memos NP-EMD-2008.510.0026 and NP-EMD.2008.510.0013_RevA. | All |
| A3 | 7-2-08 | Reformatted in accordance to new OAD template. Delivered to NGST. | All |
| A4 | 9-5-08 | Updated Graceful Degradation. | 19, 20 |
| A5 | 10-29-08 | Prepare for TIM/ACCB. | All |
| A | 12-17-08 | Updated Table 15 quality flag descriptions. Addressed TIM/ACCB comments. ECR A-180 Rev. A. | All |
| B1 | 3-30-08 | Updated legends for Suspended Matter and Ice Age inputs(PCR019230) | Tables 3, & 6 |
| B2 | 4-27-09 | Updated for PCR 20193 (Table 16) | 23 |
| B3 | 7-13-09 | Updated table 16 for Tech Memo NP-EMD.2008.510.0072_ NPP_OceanAlbedo_DegradQFUpdate for PCR 19258. | 23 |
| B4 | 11-04-09 | Incorporated RFAs 322 & 323 and updated for SDRL. | All |
| B5 | 11-06-09 | Changed output windspeed source flag bits 00 from not used to MIS. PCR 020506 | 29,30 |
| B6 | 11-11-09 | Update quality flags as described in tech memo NP-EMD-2009.510.0063 Rev A VIIRS Albedo input quality flags specification | Table 9 &16 |
| B7 | 2-16-10 | Updated 2.1.1.3.1 based on NG comments from the 11-04-09 SDRL | 15 |
| B8 | 2-24-10 | Updated for TIM | All |
| B9 | 5-24-10 | Updated for PCR022759 | 14 |
| B | 7-07-10 | Updated and resubmitted for TIM/ARB/ACCB | All |
| C1 | 8-17-10 | Incorporated TM 2010.510.0058 | All |
| C2 | 10-18-10 | Updated due to document convergence to include tech memos: 2010.510.0011, 2010.510.0013 & 2010.510.0015 | All |
| C3 | 10-22-10 | PCR024908 Updated OSA IP quality flag table | Table 17 |
| C4 | 12-08-10 | PCR025299 NHF qf4 offset 5 changed to match CDFCB | Table16 |

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| **Revision** | **Document Date** | **Revision/Change Description** | **Pages Affected** |
|---|---|---|---|
| C5 | 12-16-10 | PCR024754 Updated ancillary granulation information | All |
| C6 | 06-30-11 | Updated for PCR026125 | All |

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# 1.0 INTRODUCTION

## 1.1 Objective

The purpose of the Operational Algorithm Description (OAD) document is to express, in computer-science terms, the remote sensing algorithms that produce the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) end-user data products. These products are individually known as Raw Data Records (RDRs), Temperature Data Records (TDRs), Sensor Data Records (SDRs) and Environmental Data Records (EDRs). In addition, any Intermediate Products (IPs) produced in the process are also described in the OAD.

The science basis of an algorithm is described in a corresponding Algorithm Theoretical Basis Document (ATBD). The OAD provides a software description of that science as implemented in the operational ground system -- the Data Processing Element (DPE).

The purpose of an OAD is two-fold:

1. Provide initial implementation design guidance to the operational software developer.
2. Capture the "as-built" operational implementation of the algorithm reflecting any changes needed to meet operational performance/design requirements.

An individual OAD document describes one or more algorithms used in the production of one or more data products. There is a general, but not strict, one-to-one correspondence between OAD and ATBD documents.

## 1.2 Scope

The scope of this document is limited to the description of the core operational algorithm(s) required to create the Net Heat Flux (NHF) EDR and Ocean Surface Albedo (OSA) IP. The theoretical bases for these algorithms are described Section in the VIIRS Net Heat Flux (NHF) Environmental Data Record (EDR) and Ocean Surface Albedo Intermediate Product (IP) ATBD, 474-00036.

## 1.3 References

### 1.3.1 Document References

The science and system engineering documents relevant to the algorithms described in this OAD are listed in Table 1.

**Table 1. Reference Documents**

| Document Title | Document Number/Revision | Revision Date |
|---|---|---|
| VIIRS Net Heat Flux (NHF) Environmental Data Record (EDR) and Ocean Surface Albedo Intermediate Product (IP) ATBD | 474-00036 | Latest |
| JPSS Environmental Data Record (EDR) Production Report (PR) for NPP | 474-00012 | Latest |
| JPSS Environmental Data Record (EDR) Interdependency Report (IR) for NPP | 474-00007 | Latest |
| NPP Mission Data Format Control Book and App A (MDFCB) | 429-05-02-42_MDFCB | Latest |
| JPSS Common Data Format Control Book - External - –Block | 474-00001-01-B0122 CDFCB-X | Latest |

| Document Title | Document Number/Revision | Revision Date |
|---|---|---|
| 1.2.2 (All Volumes) | Vol I<br>474-00001-02-B0122 CDFCB-X Vol II<br>474-00001-03-B0122 CDFCB-X Vol III<br>474-00001-04-01-B0122 CDFCB-X Vol IV Part 1<br>474-00001-04-02-B0122 CDFCB-X Vol IV Part 2<br>474-00001-04-03-B0122 CDFCB-X Vol IV Part 3<br>474-00001-04-04-B0122 CDFCB-X Vol IV Part 4<br>474-00001-05-B0122 CDFCB-X Vol V<br>474-00001-06-B0122 CDFCB-X Vol VI<br>474-00001-08-B0122 CDFCB-X Vol VIII | |
| JPSS Common Data Format Control Book - External - Block 1.2.3 (All Volumes) | 474-00001-01-B0123 CDFCB-X Vol I<br>474-00001-02-B0123 CDFCB-X Vol II<br>474-00001-03-B0123 CDFCB-X Vol III<br>474-00001-04-01-B0123 CDFCB-X Vol IV Part 1<br>474-00001-04-02-B0123 CDFCB-X Vol IV Part 2<br>474-00001-04-03-B0123 CDFCB-X Vol IV Part 3<br>474-00001-04-04-B0123 CDFCB-X Vol IV Part 4<br>474-00001-05-B0123 CDFCB-X Vol V<br>474-00001-06-B0123 CDFCB-X Vol VI<br>474-00001-08-B0123 CDFCB-X Vol VIII | Latest |
| NPP Command and Telemetry (C&T) Handbook | D568423 Rev. C | 30 Sep 2008 |
| JPSS Program Lexicon | 474-00175 | Latest |
| Operational Algorithm Description Document for VIIRS Cloud Mask Intermediate Product (VCM IP) | 474-00062 | Latest |
| Operational Algorithm Description Document for VIIRS Sea Surface Temperature (SST) Environmental Data Records (EDR) | 474-00061 | Latest |
| Operational Algorithm Description Document for VIIRS Ice Surface Temperature (IST) Environmental Data Records (EDR) Software | 474-00072 | Latest |
| Operational Algorithm Description Document for VIIRS Aerosol Products (AOT, APSP & SM) Intermediate Product (IP)/Environmental Data Records (EDR) | 474-00073 | Latest |
| Operational Algorithm Description Document for Atmospheric Correction Over Ocean / Ocean Color Chlorophyll (ACO/OCC) | 474-00057 | Latest |
| VIIRS Sea Ice Age Unit Level Detailed Design Document | Y3231 Ver. 5 Rev. 5 | 21 Mar 2005 |
| Operational Algorithm Description Document for VIIRS Sea Ice Age Environmental Data Record (EDR) | 474-00087 | Latest |

| Document Title | Document Number/Revision | Revision Date |
|---|---|---|
| VIIRS Net Heat Flux EDR Software Documentation | AER: P1187-SW-I-003 Ver. 1.3 | 05 May 2005 |
| Fairall, C. W., E. F. Bradley, D. P. Rogers, J. B. Edson, and G. S. Young, 1996: Bulk parameterization of air-sea fluxes for Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment. *Journal of Geophysical Research-Oceans*, 101, 3747-3764 | | 1996 |
| Charnock, H., 1955: Wind stress on a water surface, *Q.J.R. Meteorolo. Soc.*, **81**, 639 | | 1995 |
| Liu, W. T., K. B. Katsaros and J. A. Businger, 1979: Bulk parameterization of air-sea exchange of heat and water vapor including the molecular constraints at the interface. *J. Atmos. Sci*, **36**, 1722-1735 | | 1979 |
| NGST/SE technical memo – NPP_NHF_OzoneClimatology | NP-EMD-2008.510.0026 Rev. --- | 12 May 2008 |
| NGST/SE technical memo – NPP_VIIRS_NHF_OSA_QFs_Instruction | NP-EMD-2006.510.0052 Rev. --- | 07 Jul 2006 |
| NGST/SE technical memo – RevA_NPP_NHF_Sci2Ops | NP-EMD.2008.510.0013 Rev. A | 12 May 2008 |
| Operational Algorithm Description Document for the Granulate Ancillary Software | 474-00089 | Latest |
| NGST/SE technical memo – Calculation of NHF Retrieval Quality | NP-EMD-2010.510.0058 | 26 Jul 2010 |
| NGST/SE technical memo – Granule-Level Summary Exclusion Flag Definition Rev. C.doc | NP.EMD.2010.510.0005.Rev-C | 02 Mar 2010 |
| NGST/SE technical memo – NHF Bug Fix on Initialization of the COARE Ice Model | NP-EMD.2010.510.0060 | 10 Sep 2010 |
| NGST/SE technical memos:<br>LUT_OAD_Drop History_Corrections<br>PC_OAD_Last_Drop_Corrections<br>SAD_OAD_Last_Drop_Corrections | <br>NPOESS GJM-2010.510.0011<br>NPOESS GJM-2010.510.0013<br>NPOESS GJM-2010.510.0015 | <br>21 Sep 2010<br>22 Sep 2010<br>22 Sep 2010 |
| Operational Algorithm Description Document for VIIRS Geolocation (GEO) Sensor Data Record (SDR) and Calibration (CAL) SDR Software | 474-00090 | Latest |

### 1.3.2 Source Code References

The science and operational code and associated documentation relevant to the algorithms described in this OAD are listed in Table 2.

**Table 2. Source Code References**

| Reference Title | Reference Tag/Revision | Revision Date |
|---|---|---|
| VIIRS Net Heat Flux EDR Science Software | ISTN_VIIRS_NGST_2.9 | 30 Sep 2004 |
| VIIRS Net Heat Flux EDR Science Software | ISTN_VIIRS_NGST_4.3 (OAD Rev A) | 21 Jun 2006 |
| VIIRS Net Heat Flux EDR Operational Software includes implementation of TMs 2008.510 0013.Rev-A (PCR17170) & 2008.510.0026 (PCR17703) | B1.5.x.1<br>(OAD Rev-A2) | 02 Jul 2008 |
| Implemented TM 2008.510.0052 (PCR14269) | B1.5.x.1 (E-build) not reflected in OAD | 18 Jul 2008 |
| VIIRS Net Heat Flux EDR Operational Software includes (PCR 019230) | Build Post-X-C<br>(OAD Rev-B1) | 30 Mar 2009 |
| VIIRS Net Heat Flux EDR Operational Software includes (PCRs 019258 & 020193) | Build Sensor Characterization (SC)-2 (OAD Revs-B2 & B3) | 18 Sep 2009 |
| SDRL | (OAD Rev B4) | 04 Nov 2009 |
| PCR 22882 [TM 2010.510.0005.Rev-C ] (No OAD update | Build Sensor Characterization SC-09 | 18 Mar 2010 |

| Reference Title | Reference Tag/Revision | Revision Date |
|---|---|---|
| required) | | |
| PCR022759 | Build Sensor Characterization (SC)-10 (OAD Rev-B9) | 24 May 2010 |
| ACCB | OAD Rev B | 07 Jul 2010 |
| PCR024382 (TM 2010.510.0058), PCR023804 (TM 2010.510.0060) | Build Sensor Characterization (SC)-13 (OAD Rev-C1) | 17 Aug 2010 |
| Convergence Updates (No code updates) | (OAD Rev C2) | 18 Oct 2010 |
| PCR024908 | Maintenance Build 1.5.04.C (OAD Rev C3) | 04 Nov 2010 |
| PCR025299 | Maintenance Build 1.5.05.A (OAD Rev C4) | 08 Dec 2010 |
| PCR024754 | Maintenance Build 1.5.05.C (OAD Rev C5) | 02 Feb 2011 |
| PCR026125 (OAD only) | Maintenance Build 1.5.05.E (OAD Rev C6) | 30 Jun 2011 |
| OAD transitioned to JPSS Program – this table is no longer updated. | | |

## 2.0 ALGORITHM OVERVIEW

The purpose of the NHF module is to determine the net heat flux from the ocean surface based on EDR inputs from VIIRS, and from numerical weather prediction models (NWP). The NHF product is computed as the sum of four components. In addition, the ocean surface albedo is determined as a by-product of the calculations. The NHF module is built around two community standard models for computing individual components of the heat flux. The Rapid Radiative Transfer Model (RRTM) is used to model long-wave and short-wave radiative fluxes. The Coupled Ocean-Atmosphere Response Experiment (COARE) bulk flux algorithm is used to model the two turbulent flux components of latent and sensible heat. In addition, the module uses the Coupled Ocean and Atmosphere Radiative Transfer (COART) LUT code to determine the ocean surface albedo. Figure 1 illustrates the algorithm processing chain, identifying all inputs including internal data bases and EDR outputs.

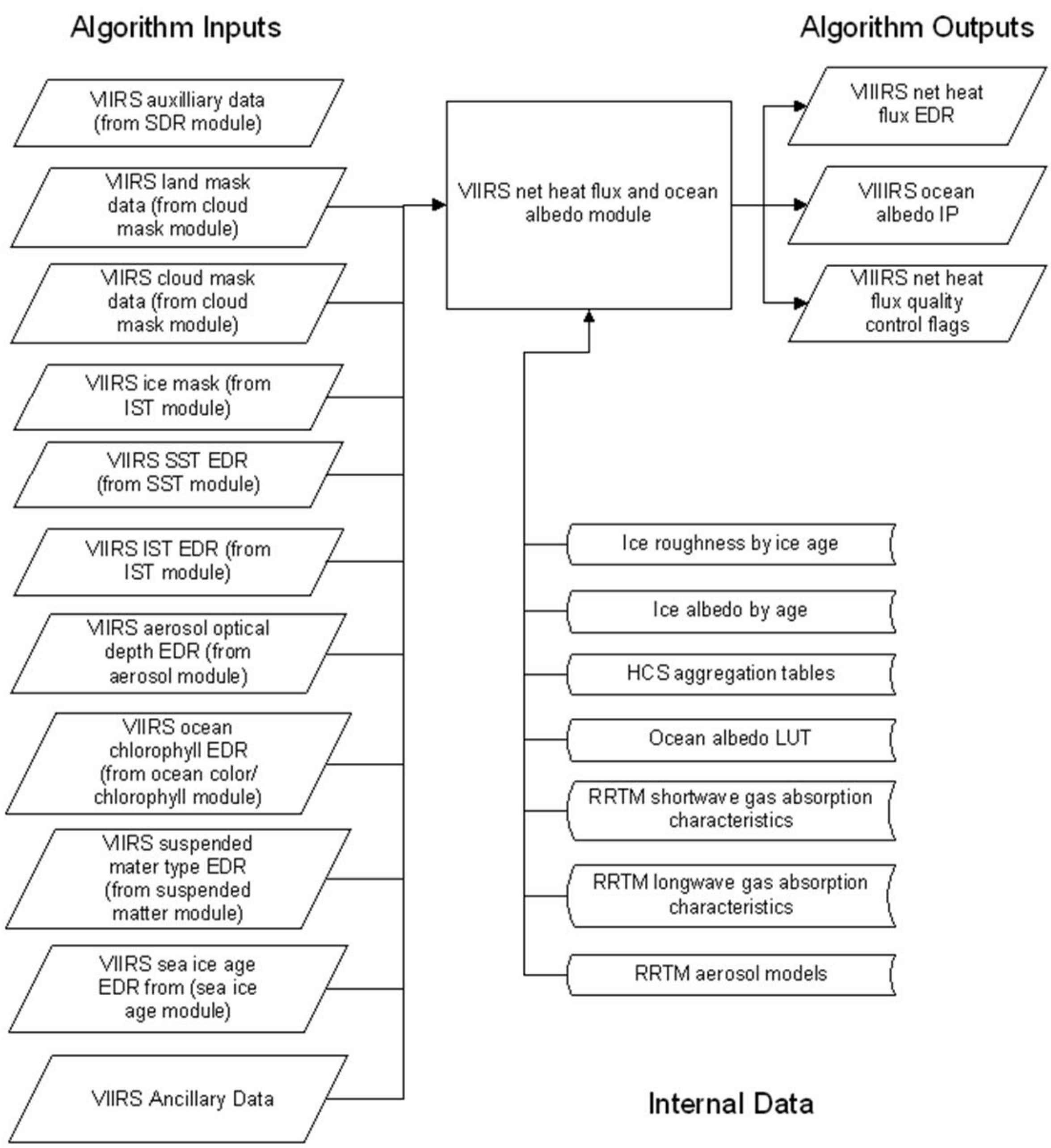



**Figure 1. NHF Processing Chain**

## 2.1 Net Heat Flux Description

The NHF retrieval algorithm and the theoretical basis are described in detail in the VIIRS Net Heat Flux (NHF) Environmental Data Record (EDR) and Ocean Surface Albedo Intermediate Product (IP) ATBD, 474-00036.

All features described in the NHF and OSA ATBDs have been implemented in the NHF and OSA module.

The NHF algorithm uses community standard models to compute the individual components of the heat flux and ocean albedo:

- The Rapid Radiative Transfer Model (RRTM) model, developed at AER, is used to compute the long-wave and short-wave radiative fluxes.
- The Coupled Ocean-Atmosphere Response Experiment (COARE) module is used to model the turbulent components of latent and sensible heat.
- The Coupled Ocean and Atmospheric Radiative Transfer (COART) LUT code is used to calculate the ocean surface albedo.

NHF is designed to process VIIRS data, producing VIIRS-sized outputs in a raw structure (a 'C' language construct) format. The file formats used by the NHF and Ocean Albedo code are defined by the data structures used to store and retrieve data via the Data Management System (DMS).

Please note that in order to maintain compatibility with future releases of these utilities (RRTM, COARE, COART), minimal optimization and re-structuring of the provided code is recommended.

### 2.1.1 Interfaces

#### 2.1.1.1 Inputs

The inputs to the NHF and Ocean Albedo module, summarized in Table 3, are retrieved from DMS operational inputs. The inputs consist of the

- Main Data Inputs, Table 3
- Geolocation Inputs, Table 4 (see also 474-00090, Table 10)
- Ancillary Inputs, Table 5
- Processing Coefficients, Table 6 (see Section 2.1.1.1.1)
- Look-up Tables, Table 7 (see Section 2.1.1.1.2)

The range values specified in the tables list the values assumed by the code and, where relevant, the recommended range of values for each variable (in square brackets).

**Table 3. NHF Main Inputs**

| Input | Type | Description/Source | Units | Valid Range |
|---|---|---|---|---|
| CLOUDMASK_IP<br>vcm0 | Uint8 x<br>[nLines x nSamples | Cloud bit mask from VIIRS 750 m resolution cloud mask EDR | Bit 0-1: Poor; 1=Low; 2=Medium; 3=High<br>Bit 2-3: 0=Confidently Clear; 1=Probably Clear; 2=Probably Cloudy; 3=Confidently Cloudy<br>Bit 4: Day/Night Flag<br>0=Night, 1=Day<br>Bit 5: Snow/Ice Flag<br>0=no Snow/Ice<br>1=Snow/Ice<br>Bit 6-7: Sun-Glint: 0=None; 1=Geometry Based; 2=Wind Speed Based; 3=Geometry and Wind Based | |
| CLOUDMASK_IP<br>vcm1 | Uint8 x<br>[nLines x nSamples] | Cloud bit mask from VIIRS 750 m resolution cloud mask EDR | Bit 0-2: 0=Land and Desert; 1=Land No Desert; 2=Inland Water; 3=Sea Water; 5=Coastal | |
| SST_EDR<br>(SST) | Float32 x<br>[nLines x nSamples] | Sea Surface (skin) Temperature from VIIRS 750 m resolution EDR | K | ≥ 271<br>[ 271 to 313] |
| VIIRS_IST_EDR<br>(IST) | Float32 x<br>[nLines x nSamples] | Ice Surface (skin) Temperature/ from VIIRS 750 m resolution EDR | K | ≤ 275<br>[213 to 275 ] |

| Input | Type | Description/Source | Units | Valid Range |
|---|---|---|---|---|
| VIIRS_AOT_IP (OD) | Float32 x [nLines x nSamples] | Aerosol Optical Thickness/Depth at 550nm from VIIRS 750 m resolution EDR | unitless | ≥ 0<br>[0 to 1]<br>maxfloat |
| OCC_EDR (CHL) | Float32 x [nLines x nSamples] | Surface Ocean Chlorophyll Concentration from VIIRS 750 m resolution EDR | $mg/m^3$ | ≥ 0.001 |
| VIIRS_SUSMAT_EDR (SM) | Float32 x [nLines x nSamples] | Index for Suspended Matter Type associated with aerosol models from VIIRS 750 m resolution EDR | Ash 0<br>Dust 1<br>Smoke 2<br>Sea Salt 3<br>Unknown 4<br>None 5 | |
| VIIRS_ICE_AGE_FEDR (IA) | Float32 x [nLines x nSamples] | Index for Ice Age associate with Ice Roughness length from VIIRS 750 m resolution EDR | Unclassified 0<br>Ice Free 1<br>New or Young Ice 2<br>All Other Ice 4<br>Land Fill 10<br>Cloud Fill 12 | |

**Table 4. NHF GEOLOCATION Inputs (Moderate Resolution)**

| Input | Type/Dimensions | Description | Units/Valid Range | Fill Value |
|---|---|---|---|---|
| Scan Start Time | Int64[VIIRS_RDR_SCANS] | Scan start time, defined at the leading edge of the first Earth View frame in IET | Microseconds 0 <= scanStartTime <= 1.00E+38 | -999 |
| Scan Mid Time | Int64[VIIRS_RDR_SCANS] | Mid Time of Scan in IET | Microseconds 0 <= scanStartTime <= 1.00E+38 | -999 |
| Latitude | Float32[MOD_VIIRS_SDR_ROWS] [MOD_VIIRS_SDR_COLS] | Geodetic latitude of the VIIRS pixels | Degrees -90° <= Latitude <= 90° (positive to the North) | -999.9 |
| Longitude | Float32[MOD_VIIRS_SDR_ROWS] [MOD_VIIRS_SDR_COLS] | Geodetic longitude of the VIIRS pixels | Degrees -180° <= Longitude <= 180° (positive to the East of Greenwich) | -999.9 |
| SolarZenith | Float32[MOD_VIIRS_SDR_ROWS] [MOD_VIIRS_SDR_COLS] | Solar zenith angle relative to the VIIRS pixels measured from the local vertical | Degrees 0 <= SolarZenith <= 180 | -999.9 |
| SolarAzimuth | Float32[MOD_VIIRS_SDR_ROWS] [MOD_VIIRS_SDR_COLS] | solar azimuth angle relative to the VIIRS pixels and measured from the local North towards East | Degrees -180 <= SolarAzimuth <= 180 | -999.9 |
| satZen | Float32[MOD_VIIRS_SDR_ROWS] [MOD_VIIRS_SDR_COLS] | S/C zenith angle relative to the VIIRS pixels measured from the local vertical | Degrees 0° <= satZen <= 180° | -999.9 |
| satAzm | Float32[MOD_VIIRS_SDR_ROWS] [MOD_VIIRS_SDR_COLS] | S/C azimuth angle relative to the VIIRS pixels and measured from the local North towards East | Degrees -180 <= satAzm <= 180 | -999.9 |

| Input | Type/Dimensions | Description | Units/Valid Range | Fill Value |
|---|---|---|---|---|
| Height | Float32[MOD_VIIRS_SDR_ROWS] [MOD_VIIRS_SDR_COLS] | Ellipsoid-geoid separation for non-terrain corrected Geo, and the height is the terrain height above the MSL for terrain corrected Geo | Meters -150 <= Height <= 150 | -999.9 |
| Range | Float32[MOD_VIIRS_SDR_ROWS] [MOD_VIIRS_SDR_COLS] | The distance from the ground position represented by the pixel to the S/C | Meters 800000<= Range <=2000000 | -999.9 |
| S/C Position | Float32[VIIRS_RDR_SCANS][3] | S/C Position in ECR coordinates at mid-scan time | Meters -7.46E+06 <= Position <=7.46E+06 | -999.9 |
| S/C Velocity | Float32[VIIRS_RDR_SCANS][3] | S/C Velocity in ECR coordinates at mid-scan time | Meters/sec -6600<= Velocity <=6600 | -999.9 |
| S/C Attitude | Float32[VIIRS_RDR_SCANS][3] | S/C Attitude (roll, pitch, yaw) computed at mid-scan time. The roll, pitch, and yaw angles can be used to create a direction cosine matrix that rotates the S/C coordinates to the Orbit Frame coordinates | Arcseconds -648000 <= Attitude <= 648000 | -999.9 |
| S/C Solar Zenith | Float32[VIIRS_RDR_SCANS] | Solar zenith angle with respect to the solar diffuser reference frame z-axis, where the SD z-axis is normal to the SD surface. | Degrees 0 <= scSunZen <= 180 | -999.9 |
| S/C Solar Azimuth | Float32[VIIRS_RDR_SCANS] | Solar azimuth angle measured counterclockwise about the solar diffuser reference frame z-axis with respect to the solar diffuser x-axis (with positive z-axis towards the observer) | Degrees -180 <= scSunZen <= 180 | -999.9 |
| Scan_Quality | Uint8[VIIRS_RDR_SCANS] | Scan-level quality flags | See 474-00090, Table 13, QF1 | None |
| pixelQuality | Int8[MOD_VIIRS_SDR_ROWS] [MOD_VIIRS_SDR_COLS] | Pixel-level quality flags | See 474-00090, Table 14 | none |

**Table 5. NHF Ancillary Data Inputs**

| Input | Resolution | Description | Units |
|---|---|---|---|
| VIIRS_GRAN_WINDSPD | Moderate | Ocean wind velocity | m/s |
| VIIRS_GRAN_NHFSURFTEMP | NHF EDR Aggregation [48x254] | Surface air temperature | K |
| VIIRS_GRAN_NHFSPECSURFHUMIDITY | NHF EDR Aggregation [48x254] | Used to estimate Surface humidity | $kg/m^3$ |
| VIIRS_GRAN_NHFPRESLEVELTEMP | NHF EDR Aggregation [48x254] | Atmospheric temperature profile | K |
| VIIRS_GRAN_NHFWATERVAPORMIXRATIO | NHF EDR Aggregation [48x254] | Atmospheric moisture profile | kg/kg |

| Input | Resolution | Description | Units |
|---|---|---|---|
| VIIRS_GRAN_NHFOZONE | NHF EDR Aggregation [48x254] | TC-Ozone used to estimate ozone profile | Atm-cm |
| VIIRS_GRAN_NHFSURFPRES | NHF EDR Aggregation [48x254] | Surface Pressure (spatial interpolation of Surface Pressure is performed in ln(p) to the target location) | hPa |

#### 2.1.1.1.1 Configuration

The algorithm is configured via Processing Coefficients defined in the source header, IngMsdCoefficients_ViirsNHFStruct.h. This structure defines the data stored in the DMS and retrieved for algorithm execution. Table 6 lists these configurable parameters.

**Table 6. Configurable Processing Coefficients**

| Input | Type | Description/Source | Value |
|---|---|---|---|
| minClear | float | threshold for determining clear pixels (fraction) | 0.8 |
| minIceWater | float | threshold for determining water or ice pixels (fraction) | 0.1 |
| minSSTp | int | minimum input data points needed to make cell-aggregated value | 5 |
| minISTp | int | same for ice skin temperature data | 5 |
| minODp | int | for aerosol optical depth (aot at 550nm) data | 0 |
| minSMp | int | same for suspended matter index data | 1 |
| minCHLp | int | same for chlorophyll data | 5 |
| minIAp | int | Minimum for ice age index data | 1 |
| minALBp | int | Minimum for albedo data | 1 |
| defaultIA | int | data source flag (1=default, 0=retrieve if available) for ice age index | 0 |
| defaultCHL | int | data source flag for chlorophyll | 0 |
| defaultSM | int | data source flag for suspended matter model | 0 |
| iaBase | int | index to ice age model for ice roughness length | 2 |
| chloro | float | default value of chlorophyll concentration (mg/m3) | 0.1 |
| smBase | int | default index to suspended matter model for optical depth distribution | 1 |
| aotBase | float | base aerosol optical depth at 0.55 microns | 0.1 |
| nAotModels | int | number of AOT models as defined in RRTM SW | 6 |
| bmAOT | float | default value of base maritime optical depth | 0.05 |
| bbsAOT | float | default value of base stratospheric optical depth | 0.004 |
| newice | float | default value of roughness length over new ice (m) | 0.0001 |
| firstyr | float | default value of roughness length over first year ice (m) | 0.0005 |
| multiyr | float | default value of roughness length over multi year ice (m) | 0.001 |
| co2mmr | float | default value for gaseous species $CO_2$ (kg/kg) | 5.38301e-4 |
| ch4mmr | float | default value for gaseous species $CH_4$ (kg/kg | 9.10876e-7 |
| n2ommr | float | default value for gaseous species $N_2O$ (kg/kg) | 4.65468e-7 |
| cfc11mmr | float | default value for gaseous species CFC-11 (kg/kg) | 1.28052e-9 |
| cfc12mmr | float | default value for gaseous species CFC-12 (kg/kg) | 2.00379e-09 |
| emislwW | float | default value for LW emissivity over water | 0.95 |
| emislwI | float | default value for LW emissivity over ice | 0.99 |

| Input | Type | Description/Source | Value |
|---|---|---|---|
| levels[26] | float | NWP atmospheric data levels (pressure in hPa) | 10.0, 20.0, 30.0, 50.0, 70.0, 100.0, 150.0, 200.0, 250.0, 300.0, 350.0, 400.0, 450.0, 500.0, 550.0, 600.0, 650.0, 700.0, 750.0, 800.0, 850.0, 900.0, 925.0, 950.0, 975.0, 1000.0 |
| surfaceD[14] | float | default value of surface albedo over water (diffuse) | .05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.0 |
| surfaceP[14] | float | default value of surface albedo over water (parallel) | 0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.0 |
| surfaceIceD[14] | float | default value of surface albedo over ice (diffuse) | 0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.0 |
| surfaceIceP[14] | float | default value of surface albedo over ice (parallel) | 0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.0 |
| bands[16] | float | spectral channels for RRTM SW (bounding values in microns) | 3.846,3.077,2.500,2.150,1.942,1.626,1.299,1.242,0.7782,0.6250,0.4415,0.3448,0.2632,0.2000,12.195,3.846 |
| aotExclThreshold | float | exclusion set if AOT 550nm value is greater than the threshold | 1 |
| windExclThreshold | float | exclusion set if wind speed is greater than the threshold | 25 |
| minFlux | float | exclusion set if flux is less than the minimum | -2000 |
| maxFlux | float | exclusion set if flux is greater than the maximum | +2000 |

#### 2.1.1.1.2 Internal Data (Look-Up Tables)

A variety of look-up tables and algorithm coefficients are used by the NHF and Ocean Albedo algorithms. These include:

- correlated-k absorption coefficients
- aerosol model optical depth and phase function tables
- parameters related to the turbulent fluxes
- look-up tables relating ocean albedo to chlorophyll, wind speed, etc.

These tables are subject to revision based on scientific advances in the underlying community algorithms or NPOESS testing and validation. They should be reviewed prior to launch and periodically during operations to determine if updated tables should be incorporated. Table 7 describes the key internal data used by the various algorithm components.

**Table 7. Summary of Key Internal Data (Static) Used by the NHF Algorithm**

| Data | Used by | Descriptions |
|---|---|---|
| Ice roughness by ice age | Driver for COARE | Standard Data Input |

| | | |
|---|---|---|
| Ice albedo by ice age | Driver for RRTM-SW | Standard Data Input |
| Horizontal cell aggregation tables | HC construction function | External binary lookup table |
| Ocean albedo look up tables | Ocean albedo interpolation code | External binary lookup table |
| RRTM shortwave gas absorption characteristics | RRTM-SW | External binary lookup table |
| RRTM longwave gas absorption characteristics | RRTM-LW | External binary lookup table |
| RRTM aerosol models | RRTM-SW | External binary lookup table |
| Ozone Climatology Data | RRTM-SW and RRTM-LW | External binary lookup table (see TM NP-EMD-2008.510.0026) |
| Processing Coefficients | NHF in general | Configurable Parameters |

#### 2.1.1.2 Outputs

The NHF EDR and Ocean Surface Albedo IP writes output products to the DMS: the Net Heat Flux EDR and corresponding quality and diagnostic data and the other containing the Ocean Surface Albedo IP and corresponding quality and diagnostic data. The output products are described in Table 8 and Table 9. See the relevant CDFCB-X, 474-00001, for details. For the Scan level Geolocation Quality output that contains Interpolation Stage, HAM impulse flag, SAA, Solar Eclipse, Lunar Eclipse flags and HAM side which is passed through from the VIIRS SDR GEO, see 474-00090_OAD.

**Table 8. Output NHF EDR Content**

| Output | Data Type/size | Description | Units | Valid Range |
|---|---|---|---|---|
| netHeatFluxTotal | Float32 x [48 x 254] | Total net heat flux over water and/or ice | W/m$^2$ | -2000 to 2000 |
| netHeatFluxWater | Float32 x [48 x 254] | Total net heat flux over water | W/m$^2$ | -2000 to 2000 |
| netHeatFluxIce | Float32 x [48 x 254] | Total net heat flux over ice | W/m$^2$ | -2000 to 2000 |
| latentHeatFluxWater | Float32 x [48 x 254] | Latent net heat flux over water | W/m$^2$ | -2000 to 2000 |
| latentHeatFluxIce | Float32 x [48 x 254] | Latent net heat flux over ice | W/m$^2$ | -2000 to 2000 |
| sensibleHeatFluxWater | Float32 x [48 x 254] | Sensible net heat flux over water | W/m$^2$ | -2000 to 2000 |
| sensibleHeatFluxIce | Float32 x [48 x 254] | Sensible net heat flux over ice | W/m$^2$ | -2000 to 2000 |
| longWaveFluxWater | Float32 x [48 x 254] | Long wave flux over Water | W/m$^2$ | -2000 to 2000 |
| longWaveFluxIce | Float32 x [48 x 254] | Long wave flux over ice | W/m$^2$ | -2000 to 2000 |
| shortWaveFluxWater | Float32 x [48 x 254] | Short wave flux over Water | W/m$^2$ | -2000 to 2000 |
| shortWaveFluxIce | Float32 x [48 x 254] | Short wave flux over ice | W/m$^2$ | -2000 to 2000 |
| nTotal | Int16 x [48 x 254] | Total pixels in aggregation | unitless | ≥ 0 |
| nClear | Int16 x [48 x 254] | Number of clear pixels in aggregation | unitless | ≥ 0 |
| nWater | Int16 x [48 x 254] | Number of pixels in aggregation over water | unitless | ≥ 0 |
| nIce | Int16 x [48 x 254] | Number of pixels in aggregation over ice | unitless | ≥ 0 |
| nhfQualityByte (0 – 4) | Uint8 x [5x48x254] | NHF Quality flags (see Table 16 for details) | unitless | N/A |

**Table 9. Output Ocean Surface Albedo IP Content**

| Output | Data Type/size | Description | Units | Range |
|---|---|---|---|---|
| OceanAlbedoFlux Corrected | Float32 x [nLines x nSamples] | Flux Corrected Ocean surface albedo | unitless | 0 to 1 |
| OceanAlbedoRaw | Float32 x [nLines x nSamples] | Raw Corrected Ocean surface albedo | unitless | 0 to 1 |
| osaIPQualityByte (0 – 2) Pixel level quality flags | Uint8 x [3 x nLines x nSamples] | OSA quality flags (see Table 17 for details) | unitless | N/A |

#### 2.1.1.3 I/O Timeliness Requirements

##### 2.1.1.3.1 Requirements for Input

The VIIRS EDR and IP input data are listed in Tables 3 and 4. The NHF EDR must be processed after these are produced as governed by EDR precedence. All the products in Tables 3 and 4 are processed on the same moderate resolution VIIRS grid. All products are from the most current pass and no historical, time-averaged or gridded EDRs are required.

NHF is processed one 16-pixel scan swath at a time. The other VIIRS inputs must be available in these same 16 along-track pixel scans.

The NHF process can be initiated when the required VIIRS (EDRs, IPs and auxiliary) and ancillary data inputs are available. A minimum of one VIIRS scan (16 pixels along-track) is required to be run. The code assumes each input dataset contains an integral number of scans. Only data from the current sensor/pass are required.

The ancillary data from National Centers for Environmental Prediction (NCEP) are provided via the granulated ancillary data inputs. NCEP time-interpolated values are used for the granulation. All NCEP data is granulated to the NHF EDR aggregation size (48x254) with the exception of ocean wind velocity, which is granulated at moderate resolution. Spatial interpolation of Surface Pressure is performed in ln(p). It is assumed forecasts for a time period valid prior to and after the observation are available. See Operational Algorithm Description Document for the Granulate Ancillary Software, 474-00089, section 2.1.1.1.2, for guidance.

##### 2.1.1.3.2 Requirements for Applicable Auxiliary/Ancillary and/or Optional Input Data

Auxiliary data are listed in Table 10. This is for the VIIRS sensor. No special requirements are imposed by these data. Ancillary data are listed in Table 5 and is provided by upstream algorithms. Note that NCEP data (excluding ocean wind velocity) is granulated to the NHF EDR aggregation size (48x254) and the name includes NHF to differentiate the ancillary inputs from the moderate resolution version.

**Table 10. Required and Fall-back Inputs**

| Input | Primary | Secondary | Comments |
|---|---|---|---|
| Cloud Mask | VIIRS CM IP | none | None |
| SST | VIIRS SST EDR | none | None |
| IST | VIIRS IST EDR | none | None |
| Aerosol optical depth | VIIRS AOT IP | internal default value | future upgrade may use a climatological model |
| Chlorophyll | VIIRS Ocean Color/Chlorophyll EDR | internal default value | future upgrade may use a climatological model |

| Input | Primary | Secondary | Comments |
|---|---|---|---|
| Ice age | VIIRS Sea Ice Characteristics EDR | internal default value | None |
| Wind speed | Ancillary Input | none | Data interpolated between three hour forecasts. |

### 2.1.2 Algorithm Processing

The objective of the NHF algorithm is to calculate the total contributions to heat flux over the ocean under clear conditions for a horizontal cell that meets the 20 km (worst case) size requirements.  The detailed flow diagram for the NHF and OSA algorithms is illustrated in Figure 2.

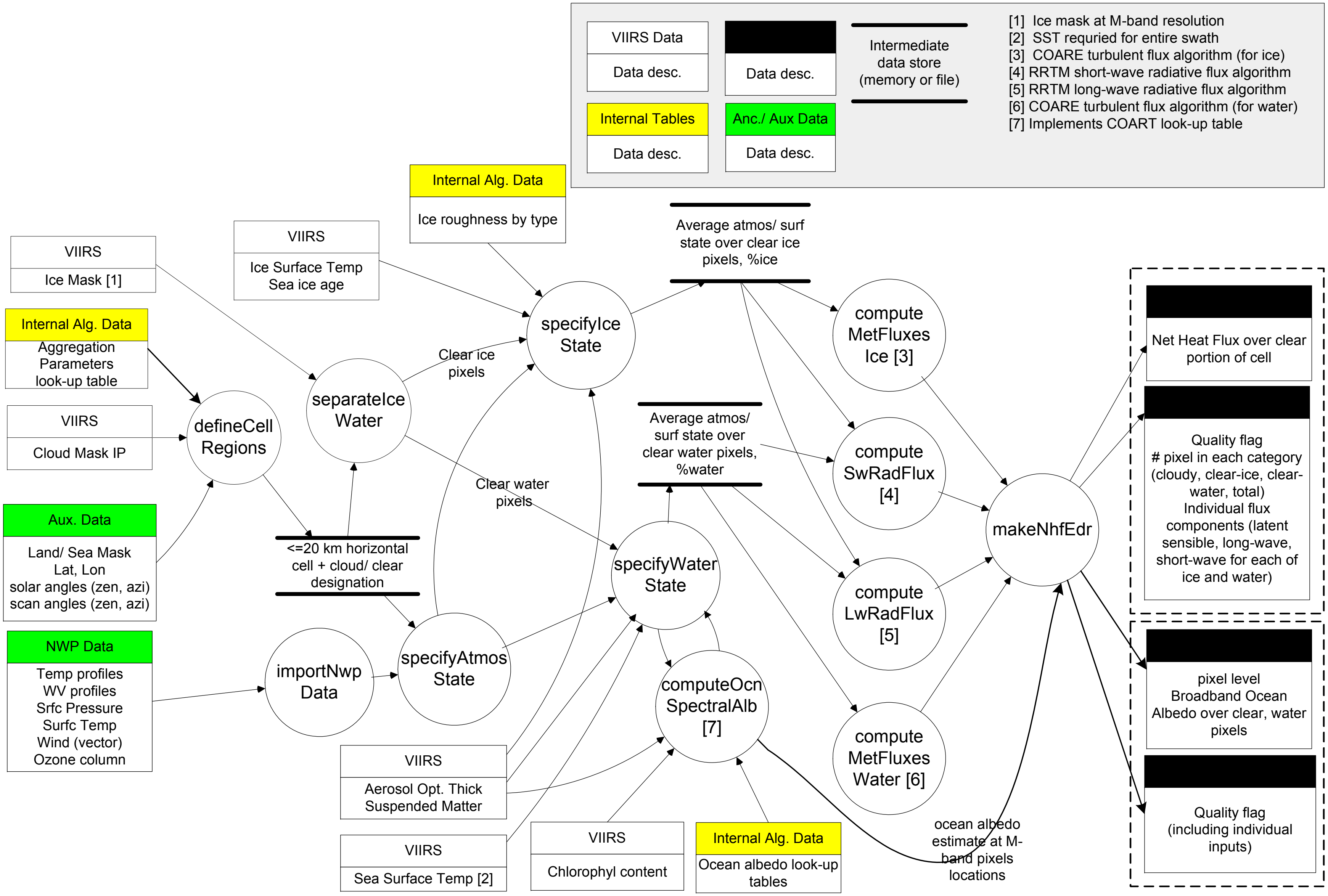



**Figure 2. VIIRS NHF and OSA Algorithms Data Flow Diagram**

#### 2.1.2.1 Main Module - NHF Retrieval

The NHF EDR and OSA IP Retrieval Logic flow diagram is shown in Figure 3. The NHF module reads in data one scan at a time for processing. These scans are divided up into aggregation cells that meet the HCS requirements across the scan. The baseline algorithm maintains cells that are approximately square across the scan. The logic for defining the aggregation geometry is described in Section 2.1.2.2.

The logic flow for the processing of pixels within an aggregation cell is provided in Figure 4.

The retrieval proceeds only if the number of pixels in the cell meets the requirements for clear sky and meets the requirements for water or ice. The availability of valid SST or IST inputs is also a prerequisite for the retrieval algorithm. If these tests fail, the output EDR is assigned fill values and the QC flag is set to indicate that results for the cell are invalid.

The day/night flag is assigned based on the solar zenith angle at the center of the cell. For daytime conditions, the Aerosol Optical Thickness EDR is obtained and used in the calculation of the surface albedo. Over water, the surface albedo is computed using the look-up tables produced by the Couple Ocean Atmosphere Radiative Transfer (COART) Model (see Section 2.1.2.3). Over ice, albedo is determined as a temporary measure until an external ice albedo product is made available. For nighttime conditions, the parameters describing the water, ice, and ocean albedo are set to zero. Ice roughness is computed based on the ice age index.

If the water fraction in the cell meets minimum criteria and SST inputs are valid, then the flux components over water are computed. The long wave radiative flux is computed with RRTMlw (see Section 2.1.2.5). Under daytime conditions, the shortwave radiative flux is computed using RRTMsw (see Section 2.1.2.6) and the ocean albedo is computed from the ratio of upward and downward fluxes. The latent and sensible heat flux components are computed from the COARE-water module (see Section 2.1.2.7). Finally all components are summed to give the net heat flux over water.

If the ice fraction in the cell meets minimum criteria and IST inputs are valid, then the flux components over ice are computed. The long wave radiative flux is computed with RRTMlw (see Section 2.1.2.5). Under daytime conditions, the shortwave radiative flux is computed using RRTMsw (see Section 2.1.2.6). The latent and sensible heat flux components are computed from the COARE ice module (see Section 2.1.2.8). Finally all components are summed to give the net heat flux over ice.

The total net heat flux is computed from the component over water and over ice, weighted by the fraction of the cell containing water or ice.

Quality control bit flags are set for the net heat flux EDR and ocean albedo IP which identify the results as valid, invalid, out of range, or excluded. QC flags for interim products are also assigned. The EDRs with QC flags are output to the DMS.

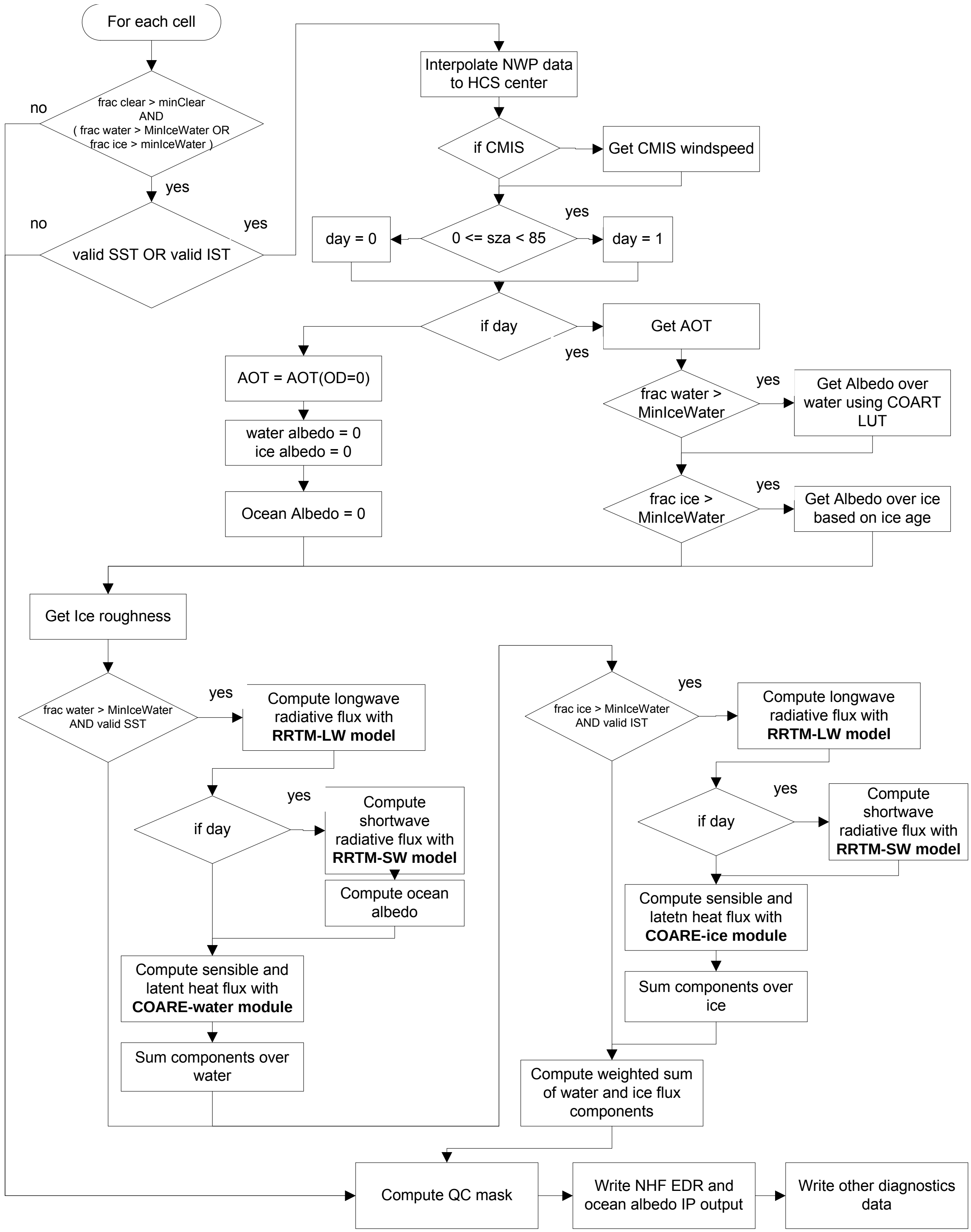



**Figure 3. NHF EDR and Ocean Surface Albedo IP Retrieval Logic Flow Diagram**

#### 2.1.2.2 Defining the Aggregation Geometry

The construction of the horizontal cells (how pixels are grouped together to form the NHF EDR horizontal cells) is determined from an input aggregation table retrieved from the DMS.

Aggregation tables are read in and processed using routines found in the library file, aggFunctions.cpp. A helper method, `viirsNHF::validateAggregation()`, is used to validate user-input configuration parameters defining the aggregation for consistency and correctness. The validation method results in an abnormal algorithm termination if the aggregation parameters are not correct.

This method is called once per execution and so aggregation settings are fixed for each execution of the NHF main program.

The method works in conjunction with the swath-oriented, overlapping-scan geometry of VIIRS and accommodates the on-board bow-tie deletion.

The code assumes the data are processed one swath at a time. The input data is assumed to contain 16 VIIRS scans.

The possibility of a memory leak noted in the comments should not occur if the code is used as delivered as this routine is called only once. If the member function is to be called more than once per execution, then either the creation of a new aggregation map (`aggMap`) could be bypassed if the aggregation map is unchanged or a destructor could be called for the old aggregation map first.

As an option, the original code could use aggregation-map parameters from a configuration file to test the algorithm with MODIS data. These have been removed from the operational algorithm, but are listed here for the explanation that follows. Values specific for VIIRS could have been created, however, only an aggregation table is used for the operational application.

Table 11 lists the aggregation parameters originally used for testing with the MODIS test data.

**Table 11. Aggregation Configuration Parameters for MODIS Testing and Recommended Operational Values**

| Configuration Variable (.cfg file) | Type | MODIS Testing | VIIRS Operational Values |
|---|---|---|---|
| mapyLow | int[nMap] | 2,1,0,1,2 | none |
| mapyHi | int[nMap] | 7,8,9,8,7 | none |
| mapx | int[nMap+1] | 2, 142, 352, 1012, 1212, 1352 | none |
| mapxAgg | int[nMap] | 10, 10, 10, 10, 10 | none |
| nmap is not input in the configuration file, but is deduced from the sizes of the input arrays | | | |

An illustration of how the aggregation works with a hypothetical set of configuration parameters (Table 12) is shown in Figure 4. This example does not correspond to any real sensor, but is used to indicate how the aggregation configuration parameters are used to specify a particular aggregation and how aggregation works with bow-tie deletion. The hypothetical sensor scan characteristics are given in Table 13. The figure shows selected portions of the scan for a single scan swath. It shows how the cells are aggregated for the settings in the following table. The figure is not to scale and is not designed to accurately represent geometric distortions.

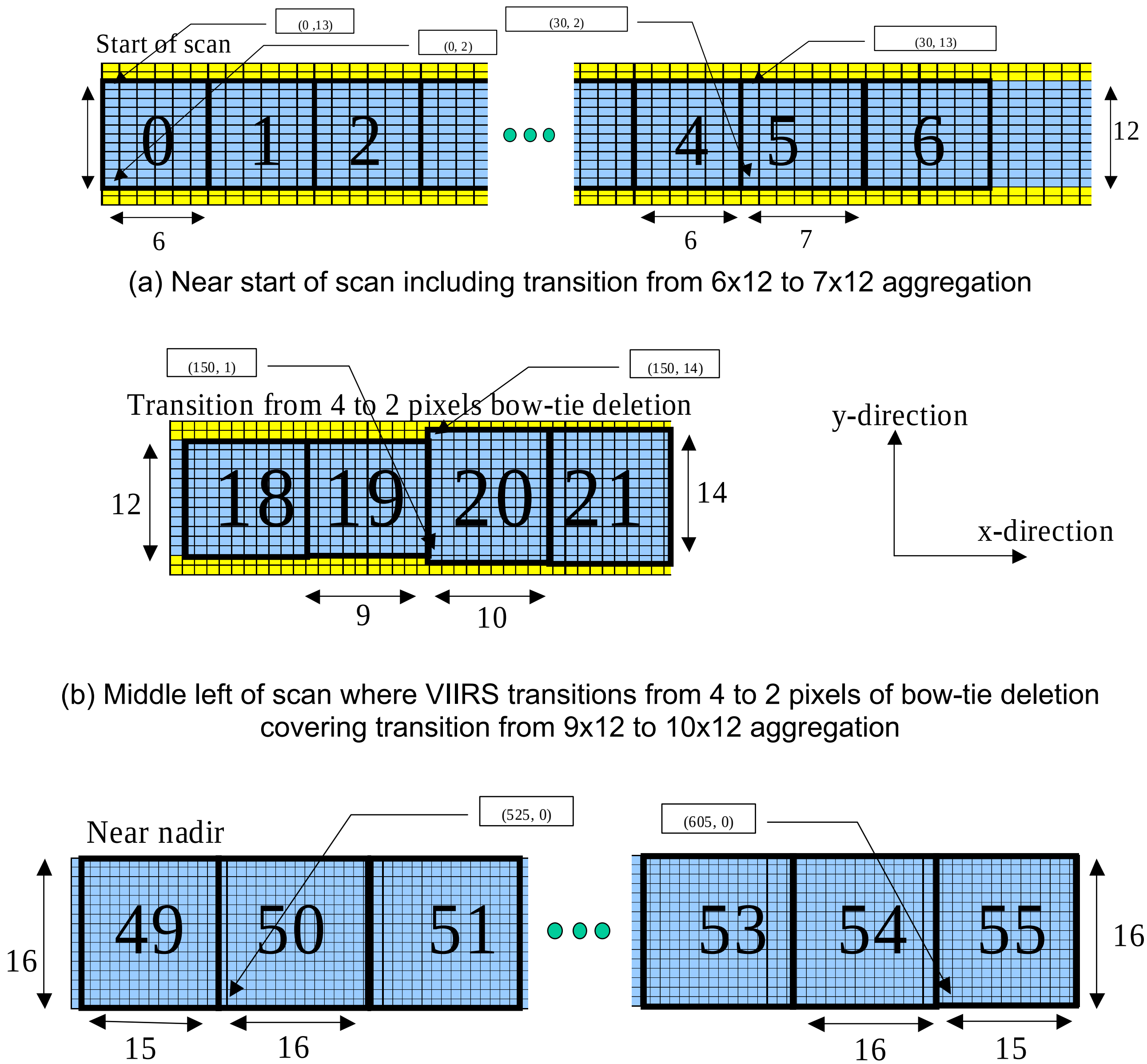
Three portions of the scan are shown: (a) at the start of the scan; (b) intermediate scan where bow-tie deletion changes from 4 deleted pixels to 2; and (c) just past nadir.

**Table 12. Aggregation Related Configuration Parameters for the Example in Figure 4**

| Variable | Parameters |
|---|---|
| mapyLow | 2, 2, 2, 2, 1, 1, 1, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 2, 2, 2, 2 |
| mapyHi | 13,13,13,13,14,14,14,14,15,15,15,15,15,14,14,14,14,13,13,13,13 |
| mapx | 0,30,65,105,150,200,255,315,380,450,525,605,680,750,815,875,930, 980,1025,1065,1100,1111,1117,1123,1130 |
| mapxAgg | 6, 7, 8, 9,10,11,12,13,14,15,16,15,14,13,12,11,10, 9, 8, 7, 6 |

**Table 13. Sensor Scan Characteristics**

| Item | Value |
|---|---|
| number of pixels along scan | 1129 |
| along-track swath width (pixels) | 16 |
| position along-scan (pixel number) where bow-tie deletion changes: | - |
| from 4 deleted to 2 deleted | from pixel 149 to 150 |
| from 2 deleted to none deleted | from pixel 379 to 380 |
| from none deleted to 2 deleted | from pixel 749 to 750 |
| from 2 deleted to four deleted | from pixel 979 to 980 |
| Number of cells after aggregation | 104 |




(a) Near start of scan including transition from 6x12 to 7x12 aggregation

(b) Middle left of scan where VIIRS transitions from 4 to 2 pixels of bow-tie deletion covering transition from 9x12 to 10x12 aggregation

(c) near nadir where16 x 16 pixels are aggregated

**Figure 4. Illustration of Aggregation for a Hypothetical Sensor With Swath Width Equal to 16 Pixels**

Yellow cells indicate on-board bow-tie deleted pixels that have replaced with fill values in the SDR.  Pixel coordinates are (along-scan or x, along-track or y).

### 2.1.2.3 Ocean Albedo Retrieval Logic

The NHF module reads in data one scan at a time for processing.  These scans are divided up into aggregation cells that meet the HCS requirements across the scan.  The baseline algorithm maintains cells that are approximately square across the scan.  The logic for defining the aggregation geometry is described in Section 2.1.2.2. The aggregation map is used by the ocean albedo to determine baseline valid pixels (i.e. not bow tie deleted).

Sensor pixel level input data relevant for input into the COART LUT code is retrieved. Ocean albedo is determined for each pixel in the scan. Checks are made for clear, over water/no ice and for valid inputs. The ocean albedo product stored until all radiative fluxes have been computed for a scan. Although the albedo product is primarily COART LUT-based, this ocean albedo is aggregated onto the horizontal cell for comparison with the aggregated albedo from the ratio of the up-welling to down-welling shortwave fluxes as output by RRTM.

For the final output pixel level Ocean Albedo product, a correction factor between the flux-based and the COART LUT aggregated albedo is computed and this correction is applied to the initial COART LUT pixel level albedo.

This approach ensures consistency between the ocean albedo product and the shortwave radiative fluxes computed by RRTM.

### 2.1.2.4 COART Retrieval Logic

For specifying the ocean-water albedo, we used a set of pre-computed look-up tables produced by the Couple Ocean Atmosphere Radiative Transfer (COART) Model. The LUT have dependencies on solar zenith angle, (SZA), aerosol optical thickness (AOT), wind speed (U), and chlorophyll concentration (CHL). For a given input of SZA, AOT, U, and CHL n-dimensional linear interpolation (with n = 4) is used to compute the ocean surface reflectivity at several wavelengths in the visible. This reflectivity is input to the RRTM shortwave model. As described above, the pixel level ocean albedo is computed directly from using the COART LUT and corrected using the aggregated flux-derived albedo computed from the ratio of the up-welling to down-welling shortwave fluxes computed by RRTM. The flow diagram for the COART module is shown in Figure 5.

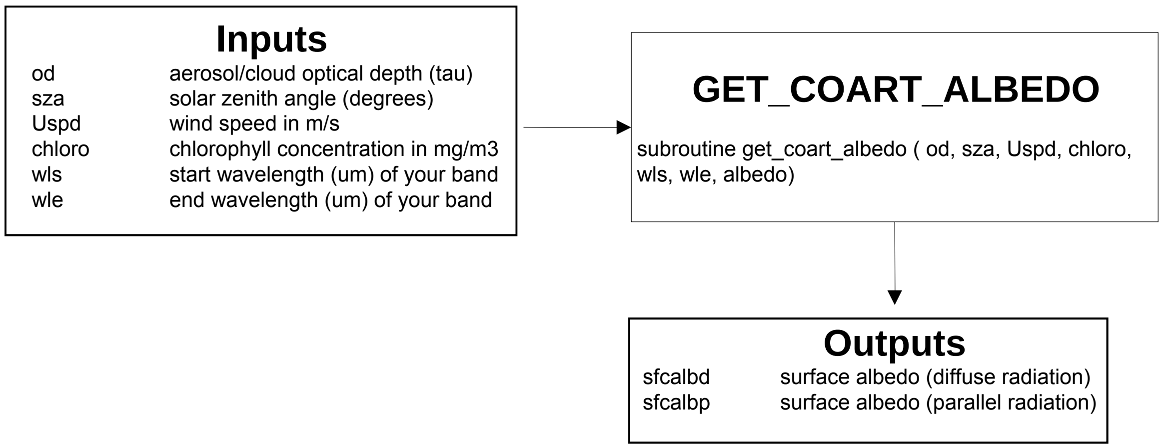



**Figure 5. Flow Diagram for COART Module**

### 2.1.2.5 RRTM-LW Retrieval Logic

RRTM is a rapid radiative transfer model that uses the correlated-k approach to calculate fluxes and heating rates. The k-correlated method for calculating fluxes is an approximate technique with accuracy comparable to line-by-line methods, but which offers an extreme reduction (by a factor of 10,000) in the number of Radiative Transfer operations, and thus in processing time. The RRTM version chosen uses a two-stream scattering model, offering substantial speed improvements over n-stream versions coupled to DISORT. The flow diagram for the RRTM long-wave module is shown in Figure 6.

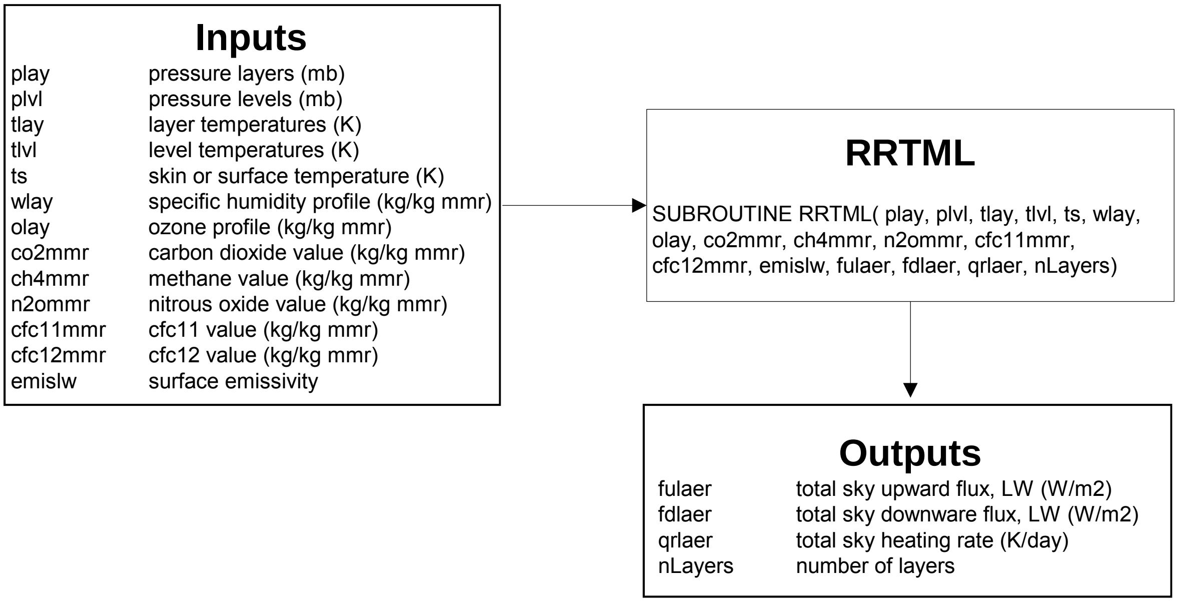



**Figure 6. Flow Diagram for RRTM Long-Wave Module**

#### 2.1.2.6 RRTM-SW Retrieval Logic

RRTM is a rapid radiative transfer model that uses the correlated-k approach to calculate fluxes and heating rates efficiently and accurately. Aerosol scattering is crucial for accurate short-wave flux calculations. For the shortwave portion of the spectrum, a version RRTM is employed which calculates the optical depths and scattering coefficients then passes this information into a two-stream multiple scattering model to perform the radiative transfer calculations with scattering. The flow diagram for the RRTM short-wave module is shown in Figure 7.

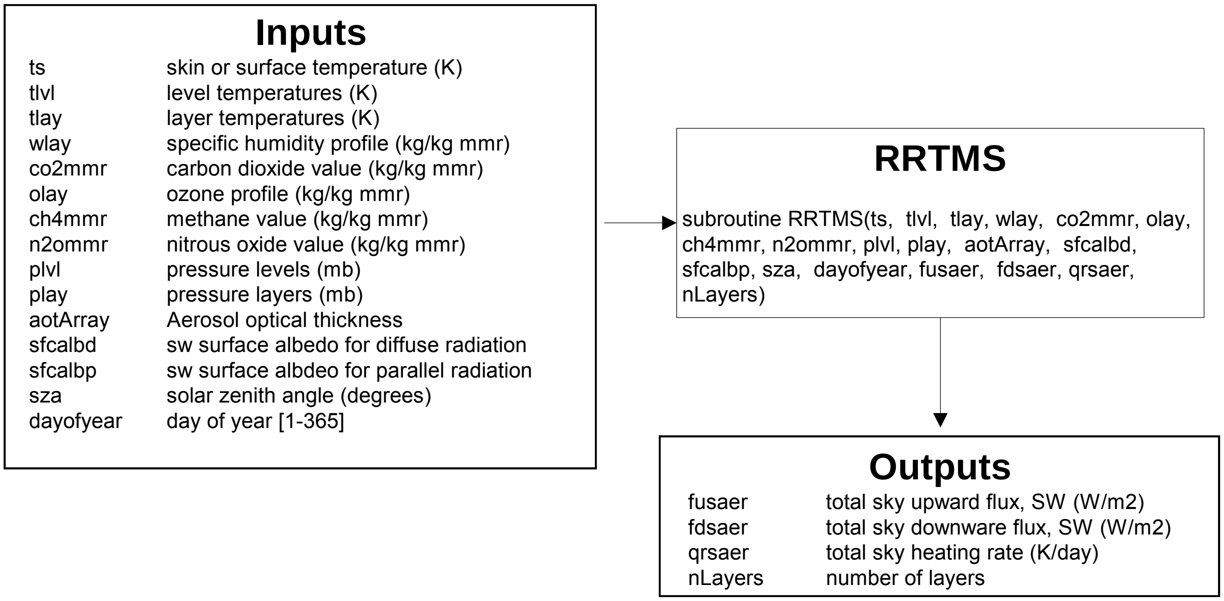



**Figure 7. Flow Diagram for RRTM Short-Wave Module**

### 2.1.2.7 COARE-water Retrieval Logic

The turbulent flux model selected for VIIRS is the flux code written for the TOGA COARE (Fairall et al, 1996) (Tropical Ocean – Global Atmosphere Coupled Ocean-Atmosphere Response Experiment). This code incorporates Monin-Obukhov stability theory, with modifications for the convective limit, surface roughness/stress formulations based on the work of Charnock (1955) and the LKB (Liu, Katsaros and Businger, 1979) model for scalar roughness. The flow diagram for the COARE-water module is shown in Figure 8.

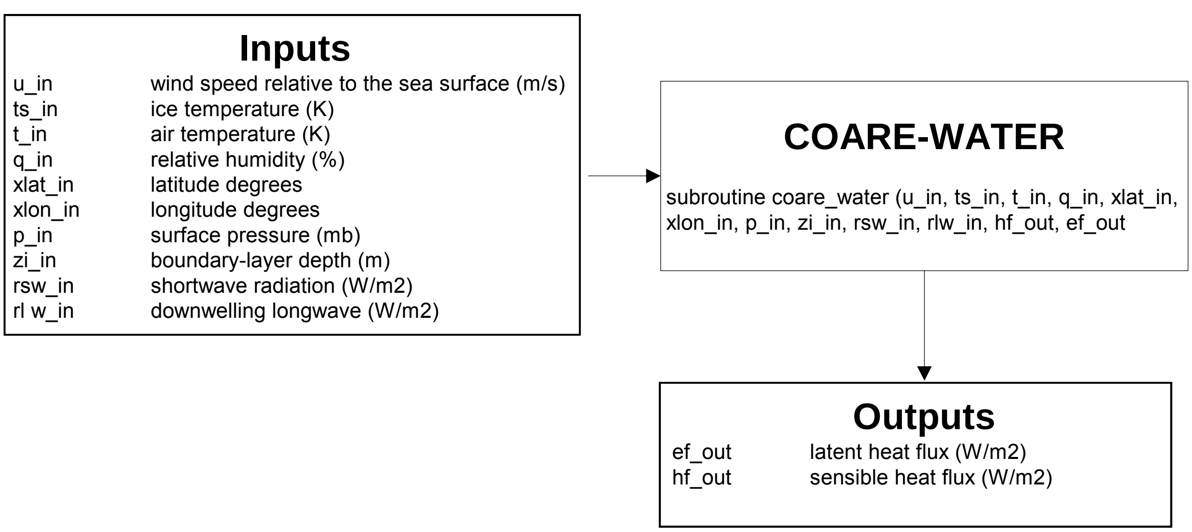



**Figure 8. Flow Diagram for COARE-water Module**

#### 2.1.2.8 COARE-ice Retrieval Logic

The COARE-ice retrieval algorithm was derived from the COARE-water algorithm. The only difference between the ice algorithm and the water code is that water turbulence model was replaced with an ice roughness base bulk turbulence model. The calling arguments were also modified to provide access to the necessary inputs for the ice specific changes. The flow diagram for the COARE-ice module is shown in Figure 9.

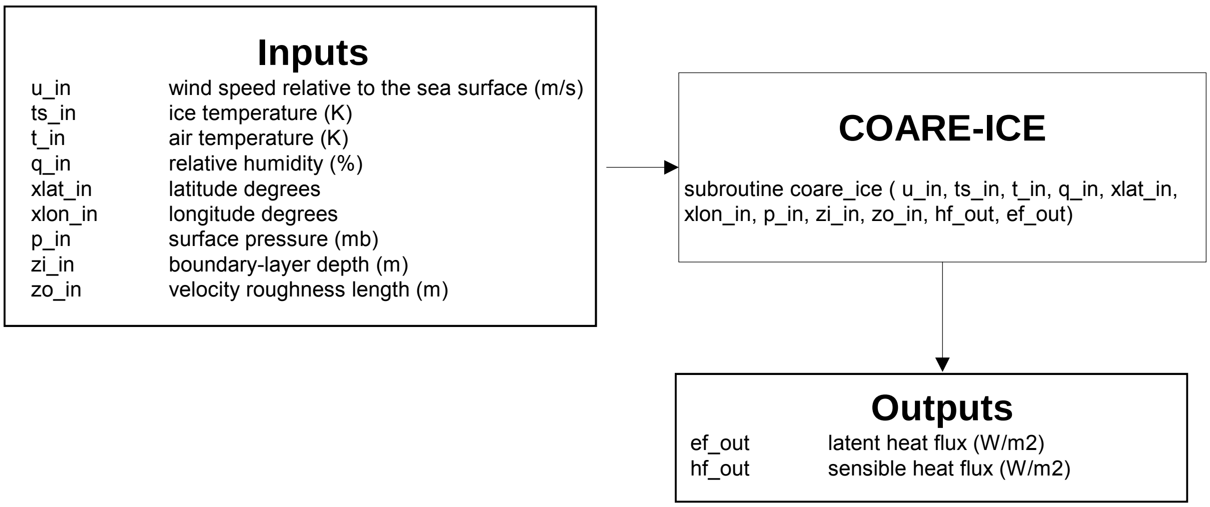



**Figure 9. Flow Diagram for COARE-ice Module**

#### 2.1.2.9 Error Handling Logic

The current algorithm has limited error-handling logic based primarily on input and output range checking. The algorithm checks the state of each pixel prior to processing. This logic tests the number of valid and cloud-free VIIRS medium resolution pixels per aggregated processing cells. The number of valid pixels must meet or exceed a user defined threshold. Valid pixels are defined as cloud-free with SST or IST values that fall within some defined range. The state of the input cell is denoted in the QC flags and controls the processing flow. This range checking logic should be augmented in future versions.

The output state is also checked based on the state of intermediate product and the final EDR results. The product status is reflected in the QC flags. See Section 2.1.5.

#### 2.1.2.10 NHF Quality Flag Logic

The NHF quality flag consists of 40 bits describing the quality of the total net heat flux product, plus diagnostic products and inputs. The bit assignments are described in Table 16 and Table 17. Assignment of the EDR quality is performed by the `viirsEDR::setQC()` module. If the EDR value is invalid, then the QC flag bits for that variable are set equal to binary value 01. If the EDR value is retrieved under exclusion conditions, then the QC flag is set to binary value 11. Finally the EDR value is compared against the minimum and maximum values. If the min/max is not equal and the EDR value is either larger than the maximum or smaller than the minimum, then the QC flag is set to the binary value 10. Otherwise the EDR value is determined to be good and the QC flag has a binary value of 00. QC flag bits associated with the input variables CM, AOT, Wind Speed, glint, SST, IST, SM, CHL, and IA are assigned by the `viirsEDR::appendQC()` method which append the source QC bits to the NHF QC flag. See Table 14 for the details on how the EDR quality is computed.

**Table 14. EDR Quality**

| Flag | Values | Definition |
|---|---|---|
| Longwave Heat Flux over Water Quality | Good | SST = Valid AND ("Confidently Clear" ≥ 80% AND NWATER ≥ 10%) |
| | Invalid | SST = Invalid AND ("Confidently Clear" ≥ 80% AND NWATER ≥ 10%) |
| | Out of range | Retrieved value > 2 kW/m2 OR < -2 kW/m2 |
| | Exclusion | "Confidently Clear" < 80% OR NWATER < 10% |
| Longwave Heat Flux over Ice Quality | Good | IST = Valid AND ("Confidently Clear" ≥ 80% AND NICE ≥ 10%) |
| | Invalid | IST = Invalid AND ("Confidently Clear" ≥ 80% AND NICE ≥ 10%) |
| | Out of range | Retrieved value > 2 kW/m2 OR < -2 kW/m2 |
| | Exclusion | "Confidently Clear" < 80% OR NICE < 10% |
| Shortwave Heat Flux over Water Quality | Good | (SST = Valid AND SM = Valid AND Chlorophyll = Valid) AND ("Confidently Clear" ≥ 80% AND NWATER ≥ 10% AND NOT (Sun Glint < 36 deg.) AND NOT (Wind Speed > 25 m/s) AND NOT (AOT>1) ) |
| | Invalid | (SST = Invalid OR SM = Invalid OR Chlorophyll = Invalid) AND ("Confidently Clear" ≥ 80% AND NWATER ≥ 10% AND NOT (Sun Glint < 36 deg.) AND NOT (Wind Speed > 25 m/s) AND NOT (AOT>1) ) |
| | Out of range | Retrieved value > 2 kW/m^2 OR < -2 kW/m^2 |
| | Exclusion | "Confidently Clear" < 80% OR NWATER < 10% OR Sun Glint < 36 deg. OR Wind Speed > 25m/s OR AOT>1 |
| Shortwave Heat Flux over Ice Quality | Good | (IST = Valid AND SM = Valid AND Ice Age = Valid) AND ("Confidently Clear" ≥ 80% AND NICE ≥ 10% AND NOT (Sun Glint < 36 deg.) AND NOT (AOT>1) ) |
| | Invalid | (IST = Invalid OR SM = Invalid OR Ice Age = Invalid) AND ("Confidently Clear" ≥ 80% AND NICE ≥ 10% AND NOT (Sun Glint < 36 deg.) AND NOT (AOT>1) ) |
| | Out of range | Retrieved value > 2 kW/m^2 OR < -2 kW/m^2 |
| | Exclusion | "Confidently Clear" < 80% OR NICE < 10% OR Sun Glint < 36 deg. OR AOT>1 |
| Sensible Heat Flux over Water Quality | Good | (SST = Valid AND SW over Water = Good AND LW over Water = Good) AND ("Confidently Clear" ≥ 80% AND NWATER ≥ 10% AND NOT (Wind Speed > 25 m/s) ) |
| | Invalid | (SST = Invalid OR SW over Water = Invalid or Exclusion OR LW over Water = Invalid or Exclusion) AND ("Confidently Clear" ≥ 80% AND NWATER ≥ 10% AND NOT (Wind Speed > 25 m/s) ) |
| | Out of range | Retrieved value > 2 kW/m2 OR < -2 kW/m2 |
| | Exclusion | ("Confidently Clear" < 80% OR NWATER < 10% OR Wind Speed > 25 m/s) |
| Sensible Heat Flux over Ice Quality | Good | (IST = Valid AND SW over Ice = Good AND LW over Ice = Good AND Ice Age = Valid) AND ("Confidently Clear" ≥ 80% AND NICE ≥ 10% AND NOT (Wind Speed > 25 m/s) ) |
| | Invalid | (IST = Invalid OR SW over Ice = Invalid or Exclusion OR LW over Ice = Invalid or Exclusion OR Ice Age = Invalid) AND ("Confidently Clear" ≥ 80% AND NICE ≥ 10% AND NOT (Wind Speed > 25 m/s) ) |
| | Out of range | Retrieved value > 2 kW/m^2 OR < -2 kW/m^2 |
| | Exclusion | ("Confidently Clear" < 80% OR NICE < 10% OR Wind Speed > 25 m/s) |

| Flag | Values | Definition |
|---|---|---|
| Latent Heat Flux over Water Quality | Good | (SST = Valid AND SW over Water = Good AND LW over Water = Good) AND ("Confidently Clear" ≥ 80% AND NWATER ≥ 10% AND NOT (Wind Speed > 25 m/s) ) |
| | Invalid | (SST = Invalid OR SW over Water = Invalid or Exclusion OR LW over Water = Invalid or Exclusion) AND ("Confidently Clear" ≥ 80% AND NWATER ≥ 10% AND NOT (Wind Speed > 25 m/s) ) |
| | Out of range | Retrieved value > 2 kW/m2 OR < -2 kW/m2 |
| | Exclusion | ("Confidently Clear" < 80% OR NWATER < 10% OR Wind Speed > 25 m/s) |
| Latent Heat Flux over Ice Quality | Good | (IST = Valid AND SW over Ice = Good AND LW over Ice = Good AND Ice Age = Valid) AND ("Confidently Clear" ≥ 80% AND NICE ≥ 10% AND NOT (Wind Speed > 25 m/s) ) |
| | Invalid | (IST = Invalid OR SW over Ice = Invalid or Exclusion OR LW over Ice = Invalid or Exclusion OR Ice Age = Invalid) AND ("Confidently Clear" ≥ 80% AND NICE ≥ 10% AND NOT (Wind Speed > 25 m/s) ) |
| | Out of range | Retrieved value > 2 kW/m2 OR < -2 kW/m2 |
| | Exclusion | ("Confidently Clear" < 80% OR NICE < 10% OR Wind Speed > 25 m/s) |
| Net Heat Flux over Water Quality | Good | LW over Water, SW over Water, Sensible Heat over Water, AND Latent Heat over Water all = Good |
| | Invalid | LW over Water, SW over Water, Sensible Heat over Water, OR Latent Heat over Water = Invalid AND None Excluded |
| | Out of range | Retrieved value > 2 kW/m2 OR < -2 kW/m2 |
| | Exclusion | LW over Water, SW over Water, Sensible Heat over Water, OR Latent Heat over Water = Excluded |
| Net Heat Flux over Ice Quality | Good | LW over Ice, SW over Ice, Sensible Heat over Ice, AND Latent Heat over Ice all = Good |
| | Invalid | LW over Ice, SW over Ice, Sensible Heat over Ice, OR Latent Heat over Ice = Invalid AND None Excluded |
| | Out of range | Retrieved value > 2 kW/m2 OR < -2 kW/m2 |
| | Exclusion | LW over Ice, SW over Ice, Sensible Heat over Ice, OR Latent Heat over Ice = Excluded |
| Net Heat Flux Pixel Quality | Good | (NHF over Water = Good AND NHF over Ice = Good) OR (NHF over Water = Good AND NICE < 10%) OR (NHF over Ice = Good AND NWATER < 10%) |
| | Invalid | (NHF over Water = Invalid AND NHF over Ice = Invalid) OR (NHF over Water = Invalid AND NWATER ≥ 10%) OR (NHF over Ice = Invalid AND NICE ≥ 10%) |
| | Out of range | Retrieved value > 2 kW/m2 OR < -2 kW/m2 |
| | Exclusion | "Confidently Clear" < 80% OR Sun Glint < 36 deg. OR Wind Speed > 25 m/s OR AOT>1 OR (NWATER < 10% AND NICE < 10%) |
| Total Net Heat Flux Product Quality | 0-100% | (Number of Cells with NHF Pixel Quality = good) / (Total number of cells in granule) |
| Exclusion Summary | 0-100% | (Number of Cells with NHF Pixel Quality = Exclusion) / (Total number of cells in granule) |

### 2.1.3 Graceful Degradation

#### 2.1.3.1 Graceful Degradation Inputs

There are two cases where input graceful degradation is indicated in the NHF:

1. A primary input denoted in the algorithm configuration guide cannot be successfully retrieved but an alternate input can be retrieved.
2. An input that is retrieved for an algorithm has the N_Graceful_Degradation metadata field set (propagation).

Table 15 details the instances of these cases. Note that the shaded cells indicate that the graceful degradation was done upstream at product production.

**Table 15. Graceful Degradation**

| Input Data Description | Baseline Data Source | Primary Backup Data Source | Secondary Backup Data Source | Tertiary Backup Data Source | Graceful Degradation Done Upstream |
|---|---|---|---|---|---|
| Water Vapor Mixing Ratio at Pressure Levels | ALL_GD_01.4.4 NCEP | ALL_GD_01.4.4 NCEP (Extended Forecast) | N/A | N/A | Yes |
| Isobaric Level Temperature | ALL_GD_01.4.7 NCEP | ALL_GD_01.4.7 NCEP (Extended Forecast) | N/A | N/A | Yes |
| Total Column Ozone | ALL_GD_01.4.1 NCEP | ALL_GD_01.4.1 NCEP (Extended Forecast) | N/A | N/A | Yes |
| Sea Surface Wind Speed and Direction | ALL_GD_01.4.2 NCEP | ALL_GD_01.4.2 NCEP (Extended Forecast) | N/A | N/A | Yes |
| Surface Air Temperature | ALL_GD_01.4. NCEP | ALL_GD_01.4. NCEP (Extended Forecast) | N/A | N/A | Yes |
| Specific Humidity at Surface | ALL_GD_01.4.11 NCEP | ALL_GD_01.4.11 NCEP (Extended Forecast) | N/A | N/A | Yes |
| Chlorophyll Climatology | X47 Climatology | N/A | N/A | N/A | N/A |
| Aerosol Optical Thickness | VIIRS_GD_15.4.1 VIIRS AOT IP | VIIRS_GD_25.4.1 NAAPS | VIIRS_GD_15.4.1 Climatology | N/A | Yes, backup only |

#### 2.1.3.2 Graceful Degradation Processing

None.

#### 2.1.3.3 Graceful Degradation Outputs

None.

### 2.1.4 Exception Handling

The algorithm tests and flags for missing or bad input data. Bad input data are flagged based on range checking. Tests for input data meeting exclusion conditions also exist and the QC flag is adjusted accordingly. Range checking is also performed on the output data. Provided valid data for all required inputs are provided and the output passes the range checking tests, a valid output EDR is produced, otherwise a flag is set and a fill value is inserted into the output.

The logic that tests the validity of input produced should be augmented in the future version of the NHF and Ocean Albedo algorithm. This should include range and QC flag checks for each of the required inputs. Currently there are stub methods, e.g. `isValidAOT()` and `isValidSM()`, that were designed as place holders for subsequent development efforts. These methods should be augmented to check that each medium resolution input IP or EDR fall within a specified range and that its associated quality flags indicate that the product is of sufficient quality to include it in the aggregation process.

### 2.1.5 Data Quality Monitoring

Quality control and diagnostic information output includes:

- flags denoting source and quality of input data.
- number of pixels within each cell that are: cloudy, cloud free & water covered, cloud free and ice covered.
- individual flux contributors separately for the ice and water portions: short-wave, long-wave, sensible heat and latent heat fluxes.

For the NHF EDR, five 1-byte quality flags are output at each aggregated cell. The descriptions and values of the quality flags are listed in Table 16.

**Table 16. Net Heat Flux EDR, 40-Bit Quality Control Flags**

| Byte | Bit | Flag Description Key | Result |
|---|---|---|---|
| 0 | 0-1 | Total net heat flux product | 00=good<br>01=invalid<br>10=out of range<br>11=exclusion |
| | 2-3 | Net heat flux over water | 00=good<br>01=invalid<br>10=out of range<br>11=exclusion |
| | 4-5 | Net heat flux over ice | 00=good<br>01=invalid<br>10=out of range<br>11=exclusion |
| | 6-7 | Latent heat flux over water | 00=good<br>01=invalid<br>10=out of range<br>11= exclusion |
| 1 | 0-1 | Latent heat flux over ice | 00=good<br>01=invalid<br>10=out of range<br>11= exclusion |

| Byte | Bit | Flag Description Key | Result |
|---|---|---|---|
| | 2-3 | Sensible heat flux over water | 00=good<br>01=invalid<br>10=out of range<br>11= exclusion |
| | 4-5 | Sensible heat flux over ice | 00=good<br>01=invalid<br>10=out of range<br>11= exclusion |
| | 6-7 | Shortwave heat flux over water | 00=good<br>01=invalid<br>10=out of range<br>11= exclusion |
| 2 | 0-1 | Shortwave heat flux over ice | 00=good<br>01=invalid<br>10=out of range<br>11= exclusion |
| | 2-3 | Longwave heat flux over water | 00=good<br>01=invalid<br>10=out of range<br>11= exclusion |
| | 4-5 | Longwave heat flux over ice | 00=good<br>01=invalid<br>10=out of range<br>11= exclusion |
| | 6 | Sea Surface Temperature Input is of poor quality | 0=false<br>1=true |
| | 7 | Ice Surface Temperature Input is of poor quality | 0=false<br>1=true |
| 3 | 0-1 | Aerosol optical depth | 00=available<br>01=climatology<br>10=exclusion |
| | 2 | Suspended Matter Index Input is of poor quality | 0=false<br>1=true |
| | 3 | Chlorophyll Input is of poor quality | 0=false<br>1=true |
| | 4 | Sea Ice Age Input is of poor quality | 0=false<br>1=true |
| | 5-6 | Exclusion - Cloud Present (80% or more of the moderate resolution pixels in the horizontal cell are not assigned "Confidently Clear" by the VIIRS Cloud Mask (VCM)) | Clear Ocean (Water or Ice)Fraction >= 0.8=00<br>0.8 > Clear Ocean Fraction > 0.1=01<br>Clear Ocean Fraction <= 0.1 or Land=10<br>Not Used=11 |
| | 7 | Sun Glint detected in horizontal cell (Average sun glint in horizontal cell < 36 degrees – AOT and APSP cannot be determined) | 0=false<br>1=true |
| 4 | 0-1 | Wind Speed Source/Exclusion (Indicates the source of wind speed if less than exclusion condition or indicates that the average wind speed in horizontal cell exceeds 25 m/s) | Not Used =00<br>NWP=01<br>Exclusion (> 25 m/s)=10<br>MIS =11 |

| Byte | Bit | Flag Description Key | Result |
|---|---|---|---|
| | 2 | Exclusion: AOT > 1.0 (AOT in horizontal cell > 1.0 on the slant path (AOT @550nm)) | 0=false<br>1=true |
| | 3-7 | Spare | |

For the Ocean Surface Albedo IP, three 1-byte quality flags are output at each VIIRS moderate resolution pixel. The descriptions and values of the pixel level quality flags are listed in Table 17. In addition, the descriptions and values of the granule level quality flags are listed in Table 18.

**Table 17. Ocean Surface Albedo IP, 24-Bit Pixel Level Quality Control Flag**

| Byte | Bit | Flag Description Key | Bit Value |
|---|---|---|---|
| 0 | 0-1 | Albedo retrieval quality | 00 = Good<br>01 = Poor (retrieved under exclusion)<br>10 = No retrieval |
| | 2 | Retrieved albedo out of expected reporting range | 0 = Within range (0<=Albedo<=1)<br>1 = Out of range |
| | 3 | AOT slant exclusion (AOT @ 550nm) | 0 = No Exclusion (AOT <= 1.0)<br>1= Exclusion (AOT > 1.0) |
| | 4 | Input chlorophyll concentration | 0 = Available<br>1 = Climatology |
| | 5-6 | Input wind speed | 00 = Not used<br>01 = NWP<br>10 = Exclusion (> 25 m/s)<br>11 = MIS |
| | 7 | Spare | NA |
| 1 | 0-1 | Cloud indicator | 00 = Clear<br>11 = Coudy |
| | 2 | Cloud shadow detected | 0 = No<br>1 = Yes |
| | 3-5 | Land/water mask | 000 = Land with desert<br>001 = Land without desert<br>010 = Inland water<br>011 = Sea water<br>101 = Coastal |
| | 6-7 | Solar zenith angle for degradation and exclusion | 00 = None (SZA<65$^o$)<br>01 = Degraded (65$^o$ $\leq$ SZA $\leq$ 85$^o$)<br>10 = Exclusion (SZA > 85$^o$) |
| 2 | 0-1 | Aerosol optical depth @ 555nm quality | 00 = None<br>01 = Interpolation only<br>10 = Interpolation & Climatology/NAAPS<br>11 = Climatology/NAAPS only |
| | 2 | AOT vertical exclusion (AOT @ 555nm) | 0 = No exclusion (AOT <= 1.0)<br>1 = Exclusion (AOT > 1.0) |
| | 3 | Coccolithophore degradation with calcite concentration due to coccolithophores $\geq$0.3 mg/m$^3$ | 0 = No degradation<br>1 = Degradation |
| | 4 | Input Data Quality | 0 = Good<br>1 = Degraded. |
| | 5 | Spare | NA |
| | 6-7 | Cloud Confidence | 0 0= Confidently clear<br>01 = Probably clear<br>10 = Probably cloudy<br>11 = Confidently cloudy |

**Table 18. Ocean Surface Albedo IP, Granule Level Quality Control Flags**

| Input | Type | Description/Source | Units/Valid Range |
|---|---|---|---|
| Ocean Albedo Quality | int | Percent of retrieved pixels with high quality retrieval | 0 % to 100 % |
| No Ocean Coverage | int | Granule No Ocean flag / VIIRS Cloud Mask IP | 0 = ocean<br>1 = no ocean |
| No Land Coverage | int | Granule All Ocean flag / VIIRS Cloud Mask IP | 0 = land<br>1 = no land |
| Range Check Summary | int | Percent of retrieved pixels with Albedo outside reporting range / Ocean Albedo retrieval | 0 % to 100 % |
| Performance Exclusion Summary | int | Percent of retrieved pixels with at least one exclusion condition / Albedo quality flags | 0 % to 100 % |

### 2.1.6 Computational Precision Requirements

The main algorithm used single precision for all calculations. The COART and RRTM shortwave/longwave modules also use single precision. Double precision is used for calculations performed in the coare_water and coare_ice modules. Input variables are converted to double precision in the main wrapper for these modules.

The physical model calculations are performed in FORTRAN-90 codes primarily using 32-bit single precision computations. The code has been tested on both 32-bit and 64-bit architectures. Testing of the algorithm has not revealed any numerical instability in the underlying algorithms over the range of conditions evaluated.

### 2.1.7 Algorithm Support Considerations

Over the course of the mission it may prove necessary to modify the software configurable parameters. Most of the Configurable Parameters are set in the Configuration file described in Section 2.1.1.1. Three additional Configurable Parameters are listed in Table 19.

**Table 19. Configurable Parameters for NHF EDR and Ocean Surface Albedo IP**

| Configurable Parameter | Description | Parameter Location | Assigned Value |
|---|---|---|---|
| minClear | Minimum fraction of clear pixels in an aggregated cell | Processing Coefficients LUT | □□1 |
| minIceWater | Minimum Ice fraction in an aggregated cell | Processing Coefficients LUT | □□□ |
| maxModels | Maximum number of aerosol models | Processing Coefficients LUT | 6 |
| pblConstant | Planetary boundary layer constant | Processing Coefficients LUT | 400 |

### 2.1.8 Assumptions and Limitations

#### 2.1.8.1 Assumptions

a) The VIIRS inputs data products SST and aerosols are assumed provided on the medium resolution sensor grid.
b) The code assumes that auxiliary data (i.e., latitude, longitude, and zenith angle) exists for all pixels that are included in the aggregation map. No testing for filled values or valid data in included for these data.

c) Alternative data inputs (Graceful Degradation) are handled by upstream algorithms.

#### 2.1.8.2 Limitations

None

# 3.0 GLOSSARY/ACRONYM LIST

## 3.1 Glossary

Table 20 contains terms most applicable for this OAD.

**Table 20. Glossary**

| Term | Description |
|---|---|
| Algorithm | A formula or set of steps for solving a particular problem. Algorithms can be expressed in any language, from natural languages like English to mathematical expressions to programming languages like FORTRAN. On NPOESS, an algorithm consists of:<br>1. A theoretical description (i.e., science/mathematical basis)<br>2. A computer implementation description (i.e., method of solution)<br>3. A computer implementation (i.e., code) |
| Algorithm Configuration Control Board (ACCB) | Interdisciplinary team of scientific and engineering personnel responsible for the approval and disposition of algorithm acceptance, verification, development and testing transitions. Chaired by the Algorithm Implementation Process Lead, members include representatives from IWPTB, Systems Engineering & Integration IPT, System Test IPT, and IDPS IPT. |
| Algorithm Verification | Science-grade software delivered by an algorithm provider is verified for compliance with data quality and timeliness requirements by Algorithm Team science personnel. This activity is nominally performed at the IWPTB facility. Delivered code is executed on compatible IWPTB computing platforms. Minor hosting modifications may be made to allow code execution. Optionally, verification may be performed at the Algorithm Provider's facility if warranted due to technical, schedule or cost considerations. |
| Ancillary Data | Any data which is not produced by the NPOESS System, but which is acquired from external providers and used by the NPOESS system in the production of NPOESS data products. |
| Auxiliary Data | Auxiliary Data is defined as data, other than data included in the sensor application packets, which is produced internally by the NPOESS system, and used to produce the NPOESS deliverable data products. |
| EDR Algorithm | Scientific description and corresponding software and test data necessary to produce one or more environmental data records. The scientific computational basis for the production of each data record is described in an ATBD. At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance. |
| Environmental Data Record (EDR) | *[IORD Definition]*<br>Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to geophysical parameters (including ancillary parameters, e.g., cloud clear radiation, etc.).<br>*[Supplementary Definition]*<br>An Environmental Data Record (EDR) represents the state of the environment, and the related information needed to access and understand the record. Specifically, it is a set of related data items that describe one or more related estimated environmental parameters over a limited time-space range. The parameters are located by time and Earth coordinates. EDRs may have been resampled if they are created from multiple data sources with different sampling patterns. An EDR is created from one or more NPOESS SDRs or EDRs, plus ancillary environmental data provided by others. EDR metadata contains references to its processing history, spatial and temporal coverage, and quality. |
| Model Validation | The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management] |
| Model Verification | The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management] |
| Operational Code | Verified science-grade software, delivered by an algorithm provider and verified by IWPTB, is developed into operational-grade code by the IDPS IPT. |
| Operational-Grade Software | Code that produces data records compliant with the System Specification requirements for data quality and IDPS timeliness and operational infrastructure. The software is modular relative to the IDPS infrastructure and compliant with IDPS application programming interfaces (APIs) as specified for TDR/SDR or EDR code. |

| Term | Description |
|---|---|
| Raw Data Record (RDR) | *[IORD Definition]*<br>Full resolution digital sensor data, time referenced and earth located, with absolute radiometric and geometric calibration coefficients appended, but not applied, to the data. Aggregates (sums or weighted averages) of detector samples are considered to be full resolution data if the aggregation is normally performed to meet resolution and other requirements. Sensor data shall be unprocessed with the following exceptions: time delay and integration (TDI), detector array non-uniformity correction (i.e., offset and responsivity equalization), and data compression are allowed. Lossy data compression is allowed only if the total measurement error is dominated by error sources other than the data compression algorithm. All calibration data will be retained and communicated to the ground without lossy compression.<br>*[Supplementary Definition]*<br>A Raw Data Record (RDR) is a logical grouping of raw data output by a sensor, and related information needed to process the record into an SDR or TDR. Specifically, it is a set of unmodified raw data (mission and housekeeping) produced by a sensor suite, one sensor, or a reasonable subset of a sensor (e.g., channel or channel group), over a specified, limited time range. Along with the sensor data, the RDR includes auxiliary data from other portions of NPOESS (space or ground) needed to recreate the sensor measurement, to correct the measurement for known distortions, and to locate the measurement in time and space, through subsequent processing. Metadata is associated with the sensor and auxiliary data to permit its effective use. |
| Retrieval Algorithm | A science-based algorithm used to 'retrieve' a set of environmental/geophysical parameters (EDR) from calibrated and geolocated sensor data (SDR). Synonym for EDR processing. |
| Science Algorithm | The theoretical description and a corresponding software implementation needed to produce an NPP/NPOESS data product (TDR, SDR or EDR). The former is described in an ATBD. The latter is typically developed for a research setting and characterized as "science-grade". |
| Science Algorithm Provider | Organization responsible for development and/or delivery of TDR/SDR or EDR algorithms associated with a given sensor. |
| Science-Grade Software | Code that produces data records in accordance with the science algorithm data quality requirements. This code, typically, has no software requirements for implementation language, targeted operating system, modularity, input and output data format or any other design discipline or assumed infrastructure. |
| SDR/TDR Algorithm | Scientific description and corresponding software and test data necessary to produce a Temperature Data Record and/or Sensor Data Record given a sensor's Raw Data Record. The scientific computational basis for the production of each data record is described in an Algorithm Theoretical Basis Document (ATBD). At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance. |
| Sensor Data Record (SDR) | *[IORD Definition]*<br>Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to calibrated brightness temperatures with associated ephemeris data. The existence of the SDRs provides reversible data tracking back from the EDRs to the Raw data.<br>*[Supplementary Definition]*<br>A Sensor Data Record (SDR) is the recreated input to a sensor, and the related information needed to access and understand the record. Specifically, it is a set of incident flux estimates made by a sensor, over a limited time interval, with annotations that permit its effective use. The environmental flux estimates at the sensor aperture are corrected for sensor effects. The estimates are reported in physically meaningful units, usually in terms of an angular or spatial and temporal distribution at the sensor location, as a function of spectrum, polarization, or delay, and always at full resolution. When meaningful, the flux is also associated with the point on the Earth geoid from which it apparently originated. Also, when meaningful, the sensor flux is converted to an equivalent top-of-atmosphere (TOA) brightness. The associated metadata includes a record of the processing and sources from which the SDR was created, and other information needed to understand the data. |

| Term | Description |
|---|---|
| Temperature Data Record (TDR) | *[IORD Definition]*<br>Temperature Data Records (TDRs) are geolocated, antenna temperatures with all relevant calibration data counts and ephemeris data to revert from T-sub-a into counts.<br>*[Supplementary Definition]*<br>A Temperature Data Record (TDR) is the brightness temperature value measured by a microwave sensor, and the related information needed to access and understand the record. Specifically, it is a set of the corrected radiometric measurements made by an imaging microwave sensor, over a limited time range, with annotation that permits its effective use. A TDR is a partially-processed variant of an SDR. Instead of reporting the estimated microwave flux from a specified direction, it reports the observed antenna brightness temperature in that direction. |

## 3.2 Acronyms

Table 21 contains acronyms most applicable for this OAD.

**Table 21. Acronyms**

| Term | Expansion |
|---|---|
| ACO | Atmospheric Correction over Ocean |
| API | Application Programming Interfaces |
| ARP | Application Related Product |
| CI | Configured Item |
| COARE | Coupled Ocean – Atmosphere Response Experiment |
| COART | Coupled Ocean and Atmosphere Radiative Transfer |
| DES | Digital Encryption System |
| DMS | Data Management Subsystem |
| DPIS ICD | Data Processor Inter-subsystem Interface Control Document |
| EDR | Environmental Data Record |
| GPS | Global Positioning System |
| IIS | Intelligence and Information Systems |
| INF | Infrastructure |
| ING | Ingest |
| IP | Intermediate Product |
| LUT | Look-Up Table or Local User Terminal |
| NCEP | National Centers for Environmental Prediction |
| OC/C | Ocean Color/Chlorophyll |
| OSA | Ocean Surface Albedo |
| PRO | Processing |
| QF | Quality Flag |
| RRTM | Rapid Radiative Transfer Model |
| SDR | Sensor Data Records |
| SOC | Satellite Operations Center |
| SS | Space Segment |
| SST | Sea Surface Temperature |
| TOA | Top of the Atmosphere |

# 4.0 OPEN ISSUES

**Table 22. TBXs**

| TBX ID | Title/Description | Resolution Date |
|---|---|---|
| None | | |
| | | |