SeaWiFS Science Algorithm Flow Chart

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Introduction

This flow chart describes the baseline science algorithms for the SeaWiFS Data Processing System (SDPS). As such, it includes only processing steps used in the generation of the operational products that are archived by NASA’s Goddard Space Flight Center (GSFC) Distributed Active Archive Center (DAAC). It is meant to provide the reader with a basic understanding of the scientific algorithm steps applied to SeaWiFS data. It does not include non-science steps, such as format conversions, and places the greatest emphasis on the geophysical calculations of the Level-2 processing. Finally, the flow chart reflects the logic sequences and the conditional tests of the software so that it may be used to evaluate the fidelity of the implementation of the scientific algorithm. In many cases however, the chart may deviate from the details of the software implementation so as to simplify the presentation.

The flow chart was compiled as part of the SeaWiFS Project Calibration/Validation Element's effort to evaluate the scientific algorithms used for processing SeaWiFS data. The following people also contributed to the compilation of the flow chart: Wayne D. Robinson, Eueng-nan Yeh, Robert E. Eplee, Norman A. Kuring, and Bryan A. Franz.

A World Wide Web version of this chart is available as part of SeaWiFS’s main web site. The web version is updated whenever algorithm changes are implemented. The chart was designed for web use with hyperlinks connecting its pages.

Flow Chart Legend

A rectangular box represents a process, which, when shaded, indicates that an expanded chart of that process is depicted in another figure. A diamond shaped box indicates a binary decision and always has two exit paths representing "yes" and "no" results. A circle or oval represent a Boolean combination of paths. The DAAC is depicted by an octagon representing the repository for all operational products. Finally, a shaded triangular box with a lowercase letter indicates that a comment exists relevant to the processing or logic depicted in that area of a figure. The letter identifies the comment within the set of comments given for the figures of the flow chart.

A small dashed line represents the functional limit of each figure's topic. Straight lines indicate paths of science information, such as primary data. Dashed straight lines indicate optional or occasional science information paths. Curved lines indicate control paths, without science information transfers.

Italicized text describe data being transferred along the straight line paths or, in larger font, the starting source data. Normal, small font text is used to provide explanations of paths when needed.
Comments

The following comments accompany the figures of the flow chart. Each set of comments are labelled with the title of the figure to which they apply and the page number of that figure in the chart.

SeaWIFS Data Processing (2):
   a. Only global area coverage (GAC) data are processed operationally beyond Level-1.
   b. Each GAC scene is normally one swath of data taken on the sunny side (descending node) of an orbit.
   c. The space binning step converts each swath into binned products.
   d. The time binning step combines (i) all space-binned scenes of a day into a day-binned file; (ii) each 8-day set of consecutive day-binned files (starting each year from Julian day 1) into an 8-day binned product; (iii) all the day-binned products of each calendar month into a month-binned product; and (iv) all month-binned products of each calendar year into a year-binned product. Thus, day- and month-binned products are time binned again to generate the longer period time-binned products.

Ancillary Data Conversion (3):
   a. For each SeaWIFS scene, the ancillary data closest in time to before and after the scene, and during the scene, if any, are selected for processing with that scene. Each ancillary data parameter is interpolated to the location and time of each pixel in the scene. (See L2 Support Data Calculations, p.11.) If in the unusual situation where such near-real time ancillary data are not available, climatologies of the ancillary parameters are substituted.
   b. Interactive examination occurs as part of normal quality control procedures or when an automatic statistical check program, through which all ancillary data are run, indicates possibly problematic data.
   c. Bad data imply unrealistic or missing data. Correction of such data involves an analyst replacing the problematic areas with data from the climatologies or other averages, or using gridding or smoothing techniques.

L0-L1A Conversion (4):
   a. Recorded data consist of GAC and local area coverage (LAC) data. Each GAC scene is normally one swath of data taken on the sunny side (descending node) of an orbit. Each LAC scene, including calibration scenes, normally consists of one continuous recording of high-resolution data. For HRPT data, each Level-0 collection forms one scene.
L1 Browse Generation (5):

a. The calibration applied is the same as that shown under Sensor Corrections (p.7) without the stray-light correction.

b. The navigation of pixels is performed using data stored in the Level-1A product during L0-L1A Conversion (p.4).

c. The 8-bit image stored in a Level-1 browse file can be converted to a 24-bit (8 bits red, 8 bits green, 8 bits blue) image by application of a color look-up table. The 8-bit values stored in the browse file are no more than indices into that look-up table and should not be construed to bear any direct relationship to radiances measured by the sensor. Once the look-up table has been applied, the red, green, and blue components of a pixel will be close to--but probably not the same as--the scaled Rayleigh reflectances (for the 670, 555, and 412 nm bands, respectively) computed by the browse file generator before it quantized the 16,777,216 possible colors down to 256 or fewer.

L2 Processing (6):

a. For LAC resolution (not archived products for Levels-2 and -3), 194 anchor points are defined.

b. A flag may be designated as a "mask" by program input.

c. The final assignments of the 12 geophysical parameter values that are output in the Level-2 products are shown on the following pages:

- page 15: La_865 and eps_78;
- page 18: nLw_412, nLw_443, nLw_490, nLw_510, nLw_555, and La_670;
- page 20: K_490;
- page 23: tau_865;
- page 24: CZCS_pigment and chlor_a.

d. The alternate values for the 12 geophysical parameters are:

<table>
<thead>
<tr>
<th>Geophysical Parameter</th>
<th>Alternate Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>nLw_412</td>
<td>Level-1A radiance counts of band 1</td>
</tr>
<tr>
<td>nLw_443</td>
<td>Level-1A radiance counts of band 2</td>
</tr>
<tr>
<td>nLw_490</td>
<td>Level-1A radiance counts of band 3</td>
</tr>
<tr>
<td>nLw_510</td>
<td>Level-1A radiance counts of band 4</td>
</tr>
<tr>
<td>nLw_555</td>
<td>Level-1A radiance counts of band 5</td>
</tr>
<tr>
<td>La_670</td>
<td>Level-1A radiance counts of band 6</td>
</tr>
<tr>
<td>La_865</td>
<td>Level-1A radiance counts of band 8</td>
</tr>
<tr>
<td>CZCS_pigment</td>
<td>0</td>
</tr>
<tr>
<td>chlor_a</td>
<td>0</td>
</tr>
<tr>
<td>K_490</td>
<td>0</td>
</tr>
<tr>
<td>eps_78</td>
<td>0</td>
</tr>
<tr>
<td>tau_865</td>
<td>0</td>
</tr>
</tbody>
</table>
A summary of the conditions assigned to the various Level-2 flags, and the pages of the flow chart on which the assignments occur, is given in the following table:

<table>
<thead>
<tr>
<th>Flag</th>
<th>Page</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>invalid tilt state</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>band-4 Rayleigh less than or equal to 0</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>aerosol determination error</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>epsilon out of range</td>
</tr>
<tr>
<td>1</td>
<td>18</td>
<td>La(1..6) less than or equal to 0</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>land</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>problematic ancillary data</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>ZGLINT greater than threshold (glint)</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>L1A(1..8) greater than knee value</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>satellite zenith greater than threshold</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>shallow water</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>missing bands or bad navigation</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>L1A(1..8) less than or equal to 0</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
<td>Lw(1..6) less than or equal to 0</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
<td>nLw(1..6) less than or equal to 0</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>stray light</td>
</tr>
<tr>
<td>10</td>
<td>13</td>
<td>ice or cloud</td>
</tr>
<tr>
<td>10</td>
<td>24</td>
<td>not shallow water &amp; flag 8 is set</td>
</tr>
<tr>
<td>11</td>
<td>19</td>
<td>coccolithophores</td>
</tr>
<tr>
<td>12</td>
<td>22</td>
<td>T6 greater than T5 (turbid water)</td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td>solar zenith greater than threshold</td>
</tr>
<tr>
<td>14</td>
<td>23</td>
<td>tau_865 greater than threshold</td>
</tr>
<tr>
<td>15</td>
<td>18</td>
<td>nLw(5) less than threshold</td>
</tr>
<tr>
<td>16</td>
<td>24</td>
<td>chlorophyll algorithm error</td>
</tr>
</tbody>
</table>

Sensor Corrections (7):

a. The calibration table is occasionally updated to incorporate new information about the sensor's performance. The table always contains the calibration information for all data collected since the start of the mission.

b. A time-dependent gain and an offset may be specified as program input to override those read from the calibration table. This is normally done for testing purposes only.
Stray-Light Correction (8):
  a. If along-track stray-light correction is requested by program input (normal option),
     the GAC stray-light correction routine will work with a rotating buffer of 3 scans.
     Therefore, the routine must be fed 3 lines initially by calling it 3 times in a row. The
     buffer's center scan, S, will be processed for bright targets (BTs) and along-scan
     marking and corrections. S will be returned by the routine after it rotates it to the
     first (earliest) scan in the buffer where it can still be influenced by the center
     (succeeding) scan. If along-track processing is not requested, the routine will work
     with one scan, S, at a time. For LAC resolution (LAC scenes are not operational
     products), a similar process is used with a 5-scan line buffer.

L2 Support Data Interpolations (12):
  a. "Adjacent anchors" refers to the anchors (defined on p.6, L2 Processing) on both
     sides of, and on the same scan as, the current pixel.

L2 Calculations (A) (13):
  a. A flag may be designated as a "mask" by program input.

L2 Calculations (B) (14):
  a. A flag may be designated as a "mask" by program input.

Atmospheric Correction (15):
  a. A flag may be designated as a "mask" by program input.

Radiance Calculations (18):
  a. A flag may be designated as a "mask" by program input.

Coccolithophore Test (19):
  a. A flag may be designated as a "mask" by program input.

Pigment (21):
  a. Note that the PGMT value calculated here is only used for the turbid water test on
     the next page. The pigment value calculated on p.24, Chlorophyll a & CZCS
     Pigment, is the one used as a geophysical parameter output in the Level-2
     products.

Turbid Water Test (22):
  a. A flag may be designated as a "mask" by program input.

Aerosol Optical Thickness (23):
  a. A flag may be designated as a "mask" by program input.
Chlorophyll a & CZCS Pigment (24):
a. A flag may be designated as a "mask" by program input.

Space Binning (26):
a. The 13 geophysical parameters that are space binned are the 12 parameters of Level-2 products (see comment (c) under L2 Processing for a list) plus chlor_a_K_490, calculated during space binning.
b. The mean of any geophysical parameter in a space-binned product is equal to $\text{MEAN}_{b,j} = \frac{\text{SUMX}_{b,j}}{W_b}$ for bin b and parameter j. The standard deviation is equal to $\left\{\left[\text{SUMXX}_{b,j}/W_b^2 - \text{MEAN}_{b,j}^2\right]/(W_b^2-S_b)\right\}^{0.5}$ for bin b and parameter j. Note that space-binned products are not archived.

Time Binning (27):
a. The time binning step combines (i) all space-binned scenes of a day into a day-binned file; (ii) each 8-day set of consecutive day-binned files (starting each year from Julian day 1) into an 8-day binned product; (iii) all the day-binned products of each calendar month into a month-binned product; and (iv) all month-binned products of each calendar year into a year-binned product. Thus, day- and month-binned products are time binned again to generate the longer period time-binned products.
b. The 13 geophysical parameters that are time binned are those of the space-binned products (see comment (a) under Space Binning).
c. The mean of any geophysical parameter in a time-binned product is equal to $\text{MEAN}_{b,j} = \frac{\text{SUMX}_{t,j}}{W_b}$ for bin b and parameter j. The standard deviation is equal to $\left\{\left[\text{SUMXX}_{b,j}/W_b^2 - \text{MEAN}_{b,j}^2\right]/(W_b^2-S_b)\right\}^{0.5}$ for bin b and parameter j.

Standard Mapped Image Generation (28):
a. A different standard mapped image product is generated for each of five geophysical parameters, chlor_a, CZCS_pigment, nLw_555, tau_865, and K_490, from each time-binned product.

Scaling for Byte Values (30):
a. The 8-bit image stored in a Level-1 browse file can be converted to a 24-bit (8 bits red, 8 bits green, 8 bits blue) image by application of a color look-up table. The 8-bit values stored in the browse file are no more than indices into that look-up table and should not be construed to bear any direct relationship to radiances measured by the sensor. Once the look-up table has been applied, the red, green, and blue components of a pixel will be close to--but probably not the same as--the scaled Rayleigh reflectances (for the 670, 555, and 412 nm bands, respectively) computed by the browse file generator before it quantized the 16,777,216 possible colors down to 256 or fewer.
Ancillary Data Conversion

Source Ancillary Data

TOVS O3

EP TOMS O3

NCEP Winds, Pressure, & Precipitable Water (PW)

Generate world grid

Fill orbit gaps with previous day's data

Convert to standard format (HDF)

Convert to standard format (HDF)

Examine interactively

Examine interactively

Bad data?

Correct problem & flag any modified or problematic values

Correct problem & flag any modified or problematic values

L2 Processing

DAAC

SeaWiFS Science Algorithm Flow Chart

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L0–L1A Conversion

L0 Data

- Generate index of frame type and quality
- Group valid frames into GAC and LAC scenes (HRPT data form one scene)
- Generate filtered orbit vectors using orbit history and GPS data from current L0 data
- Update orbit history file

Orbit History

Start at first scene

- Compute navigation for each scan

More scenes?

yes

- (GAC & HRPT)
- L1 Browse Generation

L1A Data

no

- (GAC)
- L2 Processing

DAAC

SeaWiFS Science Algorithm Flow Chart

Science information flow → Control path ← Functional limit of topic

January 5, 1998
L1 Browse Generation

SeaWiFS Science Algorithm Flow Chart

- Science information flow
- Control path
- Functional limit of topic

January 5, 1996
L2 Processing

SeaWiFS Science Algorithm Flow Chart

- **O3, Winds, Pressure, & PW**
- **Ancillary Data Conversion**
- **L1A Data Conversion (GAC)**
- **L2 Support Data Calculations**
- **PIXEL = 1**
- **L2 Support Data Interpolations**
- **L2 Calculations (A)**
- **L2 Calculations (B)**
- **L2 Browse Generation**
- **Space Binning**
- **DAAC**

**Flow Chart Details:**
- **SCAN = 1**
- **SCAN = SCAN + 1**
- **PIXEL = PIXEL + 1**
- **If any flag 1, 8, 10, 11, 12, 14, 15, 16 is set & is a "mask"**
- **Use alternate values (radiance counts or 0) for all L2 fields**

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January 5, 1996
Sensor Corrections

If it is first scan line or the TDI has changed, read calibration table.

If calibration table was read or gain has changed, apply sensor calibration:
- calculate time-dependent gain
- subtract dark restore
- convert gain
- correct for mirror-side
- correct for temperature
- correct for scan-modulation
- correct for time-dependent gain & offset

Check each pixel in scan; if radiance count for any band 1 to 8 > than knee value, set flag 5 for that pixel.

SeaWIFS Science Algorithm Flow Chart
Stray-Light Correction

For the earliest scan (S or S−1) in the buffer, if P has been marked as BT, AT, or being up to N pixels from a BT edge, set flag 9 (stray light) for P.

N=1,2,3 as specified by program input.

SeaWiFS Science Algorithm Flow Chart

January 5, 1998
Stray-Light Detection

If band-8 L1B radiance of pixel P, \( L_{1B}(8,P) \), is greater than band-8 calibration knee value, mark it as a bright-target pixel, BT.

\[ \text{Test for a BT edge:} \]
\[ \left\{ \begin{array}{ll}
\text{If} & \left[ \text{DELTA} > L_{TF} \left( \text{L}_{1B}(8,P+1) - \text{L}_{typ} \right) \right] \text{ and } \left[ \text{L}_{1B}(8,P+1) > 0.9 \times \text{knee} \right], \\
\text{then a left edge (LE) has been detected at } P+1 \text{ of } S; \\
\text{If} & \left[ -\text{DELTA} > L_{TF} \left( \text{L}_{1B}(8,P) - \text{L}_{typ} \right) \right] \text{ and } \left[ \text{L}_{1B}(8,P) > 0.9 \times \text{knee} \right], \\
\text{then a right edge (RE) has been detected at } P \text{ of } S;
\end{array} \right. \]
where \( L_{TF} \) is a fractional value specified by program input (baseline value is 0.25), \( \text{L}_{typ} \) is a typical sea-surface radiance for band 8 (1.09 mW/(cm² um sr)), and where P and P+1 are not already both marked as BT.

Flag all pixels between and including LE and RE as BT pixels.

For each BT pixel, mark corresponding pixels in the earlier scan, S-1 (if there is such a scan in the buffer and the pixels are not marked as BT pixels), and the later scan S+1 (if there is such a scan in the buffer), as being along-track contaminated (AT).
Bright-Target Processing

The left edge (LE) of a BT has been detected at P-I of S.

The right edge (RE) of a BT has been detected at P of S.

Mark up to 3 pixels (that are not marked as BT or AT) to the left of LE by their distance from LE.

Correct for along-scan stray-light contamination of 3rd pixel from LE:

\[ L_{1B}(B,P-2) = L_{1B}(B,P-2) + CF \times L_{1B}(B,P+1) \]

where B is the band index 1 to 8 and CF is a correction factor equal to 0.0, -0.0006, 0.0, -0.00074, 0.0, -0.00055, 0.0, -0.00037 for bands 1 to 8, respectively.

Keep incrementing P and testing for RE until RE is found or there are no more pixels left in S:

1) If \( L_{1B}(B,P) < 1.25 \times L_{typ} \) or
2) If [\(-\Delta \text{DELT} > L_{TF} \times (L_{1B}(8,P) - L_{typ})\) and \( L_{1B}(8,P) > 0.9 \times \text{knee\_value}\)]
then a right edge (RE) has been detected at P of S.

Assume that the last pixel in scan is the RE.

Correct for along-scan stray-light contamination of 3rd pixel from RE:

\[ L_{1B}(B,P+3) = L_{1B}(B,P+3) + CF \times L_{1B}(B,P) \]

where B is the band index 1 to 8 and CF is a correction factor equal to -0.0009, -0.00001, -0.00055, 0.0, -0.00053, 0.0, -0.00055, -0.00033 for bands 1 to 8, respectively.

If no LE had been found since the start of S or since the previous RE, keep decrementing P and testing for LE until LE is found or there are no more pixels left in S:

1) If \( L_{1B}(B,P) < 1.25 \times L_{typ} \) or
2) If \([\Delta \text{DELT} > L_{TF} \times (L_{1B}(8,P+1) - L_{typ})\) and \( L_{1B}(8,P+1) > 0.9 \times \text{knee\_value}\)]
then a left edge (LE) has been detected at P+1 of S.

If associated LE is not found, assume that first pixel in scan is the LE.

SeaWiFS Science Algorithm Flow Chart

January 5, 1998
L2 Support Data Calculations

Calculate day-of-year correction, F0CORR, to solar constant and the solar constant, F0, for all 8 bands
Interpolate pixel latitudes & longitudes (from L0-L1A Conversion) to anchor points
Interpolate pixel satellite zenith angles (from L0-L1A Conversion) to anchor points
Calculate the solar zenith angles for the anchor points
Calculate the cosine of the solar zenith angles for the anchor points
For ancillary data (O3, surface U & V winds, surface pressure, & precipitable water), do 2D & time interpolation for each pixel in scan, then interpolate those pixel values to values for the anchor points
ANQUAL = 0 for all anchor points.
If an anchor point's ancillary data were derived with data flagged as problematic during Ancillary Data Conversion, ANQUAL <> 0 for that anchor point
At each anchor point, calculate windspeed:
> WS = [Uwind**2 + Vwind**2]**0.5
Use pressure and viewing geometry to calculate Rayleigh reflectances for the anchor points
Use WS and viewing geometry to calculate glint coefficients as fraction of F0(8) for the anchor points
Calculate normalized water-leaving whitecap reflectance at each anchor point:
> WHITE = [6.49*10**(-7)] * WS**3.52
Use pressure and satellite geometry to calculate the Rayleigh component of the satellite/surface absorption for the anchor points
Use pressure and sun geometry to calculate the Rayleigh component of the sun/surface absorption for the anchor points
Use O3 and viewing geometry to calculate satellite/surface/sun ozone correction for the anchor points
Use O3, pressure, and viewing geometry to calculate satellite/surface/sun ozone and Rayleigh correction for the anchor points
If current scan indicates a new sensor tilt state or if the tilt is changing, calculate Fresnel reflectance at the anchor points

SeaWiFS Science Algorithm Flow Chart
L2 Support Data Interpolations

ZLAT = pixel latitude interpolated from adjacent anchors
ZLON = pixel longitude interpolated from adjacent anchors
ZTHETA = pixel satellite zenith angle interpolated from adjacent anchors
ZTHET0 = pixel solar zenith angle interpolated from adjacent anchors
ZMU0 = pixel cosine of solar zenith angle interpolated from adjacent anchors
ZANQUAL = 0
If ANQUAL of either anchor adjacent to the pixel <> 0, ZANQUAL <> 0
ZRAYLY = pixel Rayleigh reflectance interpolated from adjacent anchors
ZGLINT = pixel glint coefficient interpolated from adjacent anchors
ZWHITE = WHITE of adjacent anchors interpolated to pixel

ZB1 = Rayleigh component of the satellite/surface absorption for pixel, interpolated from adjacent anchors
ZB2 = Rayleigh component of the sun/surface absorption for pixel, interpolated from adjacent anchors
ZBSO3 = satellite/surface/sun ozone correction for pixel, interpolated from adjacent anchors
ZBST = satellite/surface/sun ozone and Rayleigh correction for pixel, interpolated from adjacent anchors
ZFRESNL = pixel Fresnel reflectance interpolated from adjacent anchors

SeaWiFS Science Algorithm Flow Chart
L2 Calculations (A)

Apply whitecap correction to total radiances (L1B data), \( L_t \), of bands 1 to 8:
\[
L_t(B) = L_t(B) - Z\text{WHITE} * \text{ZB} * F_0(B) * Z\text{MU0/PI}
\]
where \( B = 1..8 \)

Apply O3 correction to \( L_t \) for bands 1 to 8:
\[
L_t(B) = L_t(B) * Z\text{BSO3}
\]
where \( B = 1..8 \)

Are ZLON & ZLAT within the land mask?

- yes
- no

If ZLON & ZLAT are within shallow water mask, set flag 7

- ZMUO > 0?
  - yes
  - no

Band-8 albedo = 100 * \( L_t(8) * \text{ZB1}(8) * \text{ZB2}(8) / F_0(8) \)

If albedo > input threshold (implying ice or clouds), set flag 10

If ZTHET0 (solar zenith angle) > input threshold, set flag 13

If ZTHETA (satellite zenith angle) > input threshold, set flag 6

If scan-line quality flag #2 (from L0-L1A Conversion) indicates a missing band, or if bad-navigation flag is on, set flag 8

If it is not a valid tilt state (from L0-L1A Conversion), set flag 1

If ZANQUAL (problematic ancillary data) \(<\) 0, set flag 3

If any band-4 Rayleigh reflectance at the adjacent anchor points in the current or previous scan is <= 0, set flag 1

If L1A count for any band is <= 0, set flag 8

If ZGLINT > input threshold, set flag 4 (sun glint)

Use alternate values (radiance counts or 0) for all L2 fields
If flag 1 is set & is a "mask"

If any flag is set that is a "mask"

If flag 11 is set & is a "mask"

If flag 12 is set & is a "mask"

If flag 14 is set & is a "mask"

If flag 10 or 16 is set & is a "mask"

Use alternate values (radiance counts or 0) for all L2 fields

SeaWiFS Science Algorithm Flow Chart
Atmospheric Correction

I2 Calculations (A)

If it is the first pixel of a new scan or if the last successful aerosol determination was for a pixel more than 12 (for GAC) or 48 (for LAC) pixels away from the current one, force a new search for bounding aerosol models by making the previous model indices "unavailable" (see Aerosol Determination).

相干 = cos(θ0)

Convert Lt to reflectances and subtract Rayleigh reflectances for bands 1 to 8:
> REFL(B) = (π*Lt(B)/(F0(B)*θ0)) - ZRAYL(B) where B = 1..8

Apply O2 correction to REFL(7)

Aerosol Determination

Get the stored diffuse transmittance coefficients, a & b, for the bounding models.

Compute the diffuse transmittance for a bounding set of view angles using TAU from Aerosol Determination:
> τ(B) = a * exp(-b * TAU(B)) where B = 1..8

Use interpolation ratio from Aerosol Determination to calculate τ at the pixel.

For bands 1 to 6, calculate water-leaving radiances times transmittance:
> τw(B) = [REFL(B) - RHO_A(B)*F0(B)*θ0]/π where B = 1..6

For bands 7 & 8, calculate aerosol radiances:
> τa(B) = REFL(B)*F0(B)*θ0/π where B = 7,8
(La(8) is used as geophys. parameter L865 in the L2 products)

If an error has occurred during Aerosol Determination, set flag 1.

Using the interpolation ratio and the derived epsilon of the bounding models from Aerosol Determination, calculate epsilon (geophys. parameter ε_78 in L2 products) and, if outside input threshold range, set flag 1.

Radiance Calculations

Use alternate values (radiance counts or 0) for all L2 fields.

SeaWiFS Science Algorithm Flow Chart

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January 5, 1998
Aerosol Determination

Compute the aerosol single & multiple scattering relationship coefficients for all 12 aerosol models and 8 bands for the given geometry and using a quadratic fit. If undefined operation occurs, signal an error & skip rest of aerosol determination.

For the given viewing geometry, calculate epsilons, EPS, for all bands relative to band 8 for all aerosol models.

If undefined operation occurs, signal an error & skip rest of aerosol determination.

Are the Indices for the bounding models used for the previous pixel available? 

Yes

Get the single scattering aerosol terms for the 2 bounding models at bands 7 & 8 using the scattering relationship coefficients and precipitable water (PW).

If undefined operation occurs, signal error and skip rest of aerosol determination.

Calculate the epsilons for the 2 bounding models using the band 7 to 8 ratio of these scattering terms and average them.

No

Is the average within the EPS values of the 2 bounding models?

Yes

Calculate the aerosol optical thickness, TAU, for the 8 bands and the 2 bounding models, using the view geometry and the band-8 single scattering reflectances.

Calculate the Interpolation ratio of the average epsilon from those of the 2 bounding models.

Use the epsilons of the 2 bounding models, the single scattering term for band 8, the PW, the scattering relationship coeffs., and the Interpolation ratio to derive the multiple scattering aerosol reflectance terms, RHO_A, for bands 1 to 6.

Use the single scattering aerosol terms for the 2 bounding models at bands 7 & 8 and the Interpolation ratio to compute the actual single scattering terms for bands 7 & 8.

Aerosol Bounding Models Search

SeaWIFS Science Algorithm Flow Chart
Aerosol Bounding Models Search

1. Get single scattering reflectances for model M at bands 7 & 8 using RHO_A(7) & RHO_A(8), the scattering relationship coeffs, and PW.

   If undefined operation occurs, signal error and skip rest of aerosol determination.

   Calculate the epsilon for the band 7 to 8 ratio of the single scattering reflectances for model M.

   Add model M epsilon to sum of epsilons for models < M.

2. Average the derived epsilons (divide sum by 12).

   Calculate the differences between the average epsilon and each of the 12 band 7/8 model epsilons.

   Rank the differences according to their absolute values.

   Sum the N smallest differences.

   Sum the derived epsilons corresponding to the N smallest differences and weighted in an inverse proportion to those differences.

   Average sum of the derived epsilons.

   Calculate the differences between the average epsilon and each of the 12 band 7/8 model epsilons.

   N = N - 2

3. Select as the lower bound model the one whose difference with the 4 derived epsilon average is the smallest positive value.

   Select as the upper bound model the one whose difference with the 4 derived epsilon average is the smallest negative value.

   Retain indices of bounding models for the next pixel.

---

SeaWiFS Science Algorithm Flow Chart

Science information flow

Control path

Functional limit of topic
Radiance Calculations

Atmospheric Correction

Calculate band-6 aerosol radiance:
\[ \text{La}(6) = \text{Lt}(6) - \left[ F0(6) \times ZMU0 \times ZRAYLY(6)/\pi \right] - tLw(6) \]
(used as geophys. parameter La_670 in L2 products; see L2 Calculations (A) for Lt calculation)

Calculate water-leaving radiance, Lw, for bands 1 to 6 (remove transmittance):
\[ Lw(B) = tLw(B)/t(B) \text{ where } B = 1 \ldots 6 \]

Calculate normalized water-leaving radiance, nLw, for bands 1 to 6:
\[ nLw(B) = Lw(B) \times ZB2(B)/(ZMU0 \times FCORR) \text{ where } B = 1 \ldots 6 \]
(geophys. parameters nLw_412, nLw_443, nLw_490, nLw_510, nLw_555 in L2 products)

If Lw(B) <= 0 for B = 1..6, set flag 8
If nLw(B) <= 0 for B = 1..6, set flag 8
If La(B) <= 0 for B = 6..8, set flag 1
If nLw(5) < input threshold, set flag 15

Coccolithophore Test

Use alternate values (radiance counts or 0) for all L2 fields

SeaWiFS Science Algorithm Flow Chart

January 5, 1998
Coccolithophore Test

Are nLw(2), nLw(4), and nLw(5) all > 0?

yes

If all following conditions are true, set flag 11:
- nLw(2) >= F1
- nLw(5) >= F2
- La(6) <= 1.1
- F3 <= nLw(2)/nLw(5) <= F4
- F5 <= nLw(4)/nLw(5) <= F6
- F7 <= nLw(2)/nLw(4) <= F8

where F1, F2, F3, F4, F5, F6, F7, and F8 are specified as input to the program.

If flag 11 is set & is a "mask"

Use alternate values (radiance counts or 0) for all L2 fields

SeaWiFS Science Algorithm Flow Chart
Diffuse Attenuation

\[
K_{490} = 0.022 + \left(0.1 \times \frac{L_w(2)}{L_w(5)}\right)^{-1.2996}
\]
(a geophys. parameter in L2 products)

SeaWiFS Science Algorithm Flow Chart

January 5, 1998
Pigment

\[ PGMT = \exp(0.696 - 2.085 \ln \left[ \frac{nLw(3)}{nLw(5)} \right]) \]

\[ PGMT = \frac{[nLw(3)/nLw(5)] - 5.29}{0.592 - 3.48*[nLw(3)/nLw(5)]} \]

SeaWiFS Science Algorithm Flow Chart
Turbid Water Test

\[ T_1 = 0.0007 + \left\{ 0.005955 - 0.002478 \log(PGMT) \right\} \times PGMT^{0.62} \]

\[ T_2 = 0.0683 + 0.04 \times PGMT^{0.645} \]

\[ T_3 = 0.33 \times T_1 / T_2 \]

\[ T_4 = \left( 1 - 2.5 \times T_3 \right) - \sqrt{\left( 1 - 2.5 \times T_3 \right)^2 - 4.44 \times T_3} \] / 2

\[ T_5 = (1 - ZFRESNL) \times T_4 / (TW^{1.341\times2}) \]

where \( TW \) is an input parameter (baseline value = 3.42)

\[ T_6 = nLw(5) \times F0CORR / F0(5) \]

If flag 12 is set

\& is a "mask"

If \( T_6 > T_5 \), set flag 12

Use alternate values (radiance counts or 0) for all L2 fields

SeaWiFS Science Algorithm Flow Chart

---

January 5, 1998
Aerosol Optical Thickness

\[
\text{tau}_{865} = \text{TAU(8)}
\]
(a geophys. parameter in L2 products; see Aerosol Determination for derivation)

If \(\text{tau}_{865} < 0\), then \(\text{tau}_{865} = 0\)

If \(\text{tau}_{865} > \) input threshold, set flag 14
(if <0, set =0 upon output)

Use alternate values (radiance counts or 0) for all L2 fields

SeaWiFS Science Algorithm Flow Chart

Science information flow

Control path

Functional limit of topic

January 5, 1998
Chlorophyll a & CZCS Pigment

Aerosol Optical Thickness

Convert nLw for bands 1 to 6 to reflectances:
> \( RRS(B) = nLw(B) \cdot F0CORR/F0(B) \) for \( B = 1..6 \)

\( \text{RRS(5)} < 0 \) or \( \text{RRS(3)} < 0 \)?

- yes: \( \text{chlor}_a = 0 \)
  \( \text{PGMT} = 0 \)

- no: \( \text{RATIO} = \log_{10}[\text{RRS(3)/RRS(5)}] \)

Calculate L2 products' geophys. parameter \( \text{chlor}_a = -0.40 + 10^{0.341 - 3.001 \cdot \text{RATIO} + 2.811 \cdot \text{RATIO}^2 - 2.041 \cdot \text{RATIO}^3} \)

\( \text{chlor}_a <= 0.01 \)?

- yes: \( \text{chlor}_a = 0.01 \)
  \( \text{PGMT} = 1.34 \cdot 0.01^0.98 \)

- no: \( \text{PGMT} = 1.34 \cdot \text{chlor}_a^{0.98} \)
  (used as geophys. parameter CZCS_pigment in L2 products)

\( \text{chlor}_a > \) input threshold?

- (current threshold = 32)
  - yes: Set flag 16
  - no: L2 Processing

If flag 7 is not set (not shallow water) and flag 8 is set (nLw<=0), set flag 10 (cloud/ice)

If flag 16 is set & is a "mask"*

Use alternate values (radiance counts or 0) for all L2 fields

SeaWiFS Science Algorithm Flow Chart

January 5, 1998
L2 Browse Generation

SeaWiFS Science Algorithm Flow Chart

- Science information flow
- Control path
- Functional limit of topic

January 5, 1998
Space Binning

Check if scene crosses data day boundary. If so, use separate bin grids (data days) for binning eastern and western portions of scene. (Two binned scene products will be output.)

Initialize sums to 0

Get next scan

Get next pixel

Are any L2 or engineering quality flags set that are designated for exclusion or is a bad navigation or bad tilt indicated?

Calculate bin index for pixel's IAT/IW.
For that bin index:
> increment pixel count (N)
> set scene count (S) to 1
> chlor_a/K_490 = chlor_a/K_490
> For each of 13 geophys. parameter:
  > add pixel value to sum (SUMX)
  > add pixel value^2 to sum of values^2 (SUMXX)

For each bin with N>0:
> set time trend (TT) to 1
> calculate the weight (W) as the square root of N
> For all geophys. params:
  > SUMX = SUMX/W
  > SUMXX = SUMXX/W

L3 Binned Data (scenes)

Time Binning

SeaWiFS Science Algorithm Flow Chart

January 5, 1998
Time Binning

Initialize sums to 0

Read binned product

Get next bin (N>0 for all stored L3 bins)

From the input bin obtain:
- N, number of pixels for which there are data
- S, number of scenes that contributed to that bin's data
- W, weight of that bin's data

From the input bin obtain for each of 13 geophys. parameters:
- SUMX, sum of weighted values
- SUMXX, sum of weighted values squared

For the index corresponding to the input bin:
- add N to sum of N
- add S to sum of S
- add W to sum of W

For the index corresponding to the input bin and for each of 13 geophysical parameters:
- add SUMX to sum of SUMX
- add SUMXX to sum of SUMXX

For the index corresponding to the input bin, adjust the time-trend field, TT, to reflect contribution of the input bin's data

SeaWIFS Science Algorithm Flow Chart

January 5, 1998
Standard Mapped Image Generation

L3 Binned Data
(day, 8-day, month, year)

(chlor_a, CZCS_pigment,
nLw_555, tau_865, K_490)

Set up global equirectangular map grid (180 to 180 lon., 90 to 90 lat.)

Go to next location on mapped grid

Is there an input bin that contains that location?

yes

From that bin, get W and SUMX of desired geophysical parameter

Calculate mean of geophysical parameter as SUMX/W

Have all map locations been considered?

no

Scaling for Byte Values
(mean)

L3 SMI Data

(chlor_a, CZCS_pigment,
nLw_555, tau_865, K_490)

DAAC

L3 Browse Generation

SeaWIFS Science Algorithm Flow Chart
Scaling for Byte Values

L1 Browse Generation

\[ B = \frac{\log(D)+2}{2/255} \]

- \( B = 0 \) \( \iff \) \( D = 0.01 \)
- \( B = 255 \) \( \iff \) \( D = 1.0 \)

L2 Browse Generation

- \( B = \frac{\log(D)+2}{0.015} \) for chlor_a, and if \( B > 250, B = 250 \)
  - \( B = 0 \) \( \iff \) \( D = 0.01 \text{ mg m}^{-3} \)
  - \( B = 254 \) \( \iff \) \( D = 64.565423 \text{ mg m}^{-3} \)
- \( B = D / 0.063 \) for nLw_255, and if \( B > 254, B = 254 \)
  - \( B = 0 \) \( \iff \) \( D = 0.01 \text{ mW cm}^{-2} \text{ um}^{-1} \text{ sr}^{-1} \)
  - \( B = 254 \) \( \iff \) \( D = 16.002 \text{ mW cm}^{-2} \text{ um}^{-1} \text{ sr}^{-1} \)
- \( B = D / 0.005 \) for tau_865, and if \( B > 254, B = 254 \)
  - \( B = 0 \) \( \iff \) \( D = 0.01 \text{ m}^{-1} \)
  - \( B = 254 \) \( \iff \) \( D = 6.350 \text{ m}^{-1} \)
- \( B = D / 0.025 \) for K_490, and if \( B > 254, B = 254 \)
  - \( B = 0 \) \( \iff \) \( D = 0.01 \text{ m}^{-1} \)
  - \( B = 254 \) \( \iff \) \( D = 6.350 \text{ m}^{-1} \)

L3 Browse Generation

- \( B = \text{SMI chlor}_a \) byte value and if 250 < \( B < 255, B = 250 \)
  - \( B = 0 \) \( \iff \) \( D = 0.01 \text{ mg m}^{-3} \)
  - \( B = 250 \) \( \iff \) \( D = 56.234133 \text{ mg m}^{-3} \)

Summary of Reserved Byte Values

<table>
<thead>
<tr>
<th>Byte</th>
<th>L1 brs</th>
<th>L2 brs</th>
<th>SMI</th>
<th>L3 brs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0−250</td>
<td>data</td>
<td>data</td>
<td>data</td>
<td>data</td>
</tr>
<tr>
<td>251</td>
<td>data</td>
<td>not used</td>
<td>data</td>
<td>caption (1)*</td>
</tr>
<tr>
<td>252</td>
<td>data</td>
<td>flag 4 (3)</td>
<td>data</td>
<td>geocoordinate grid (3)*</td>
</tr>
<tr>
<td>253</td>
<td>data</td>
<td>flag 2 (1)</td>
<td>data</td>
<td>land (4)*</td>
</tr>
<tr>
<td>254</td>
<td>data</td>
<td>flags 1, 5, or 10 (2)</td>
<td>data</td>
<td>political boundaries (2)*</td>
</tr>
<tr>
<td>255</td>
<td>data</td>
<td>not used</td>
<td>no data</td>
<td>no data (5)</td>
</tr>
</tbody>
</table>

(*) Numbers indicate priority of assignment: lowest value => highest priority
* indicates feature that is exercised only if requested by program input

SeaWIFS Science Algorithm Flow Chart
This flow chart describes the baseline science algorithms for the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Data Processing System (SDPS). As such, it includes only processing steps used in the generation of the operational products that are archived by NASA's Goddard Space Flight Center (GSFC) Distributed Active Archive Center (DAAC). It is meant to provide the reader with a basic understanding of the scientific algorithm steps applied to SeaWiFS data. It does not include non-science steps, such as format conversions, and places the greatest emphasis on the geophysical calculations of the level-2 processing. Finally, the flow chart reflects the logic sequences and the conditional tests of the software so that it may be used to evaluate the fidelity of the implementation of the scientific algorithm. In many cases however, the chart may deviate from the details of the software implementation so as to simplify the presentation.