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SeaWiFS Science Algorithm Flow Chart

Michael Darzi

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

January 1998

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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:

Geophysical Parameter	Alternate Value
nLw_412	Level-1A radiance counts of band 1
nLw_443	Level-1A radiance counts of band 2
nLw_490	Level-1A radiance counts of band 3
nLw_510	Level-1A radiance counts of band 4
nLw_555	Level-1A radiance counts of band 5
La_670	Level-1A radiance counts of band 6
La_865	Level-1A radiance counts of band 8
CZCS_pigment	0
chlor_a	0
K_490	0
eps_78	0
tau_865	0

e. 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:

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

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 $MEAN_{b,j} = SUMX_{b,j} / W_b$ for bin b and parameter j. The standard deviation is equal to $\{[(SUMXX_{b,j}/W_b)-MEAN_{b,j}^2]W_b^2/(W_b^2-S_b)\}^{0.5}$ 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 $MEAN_{b,j} = SUMX_{b,j} / W_b$ for bin b and parameter j. The standard deviation is equal to $\{[(SUMXX_{b,j}/W_b)-MEAN_{b,j}^2]W_b^2/(W_b^2-S_b)\}^{0.5}$ for bin b and parameter j.

Standard Mapped Image Generation (28):

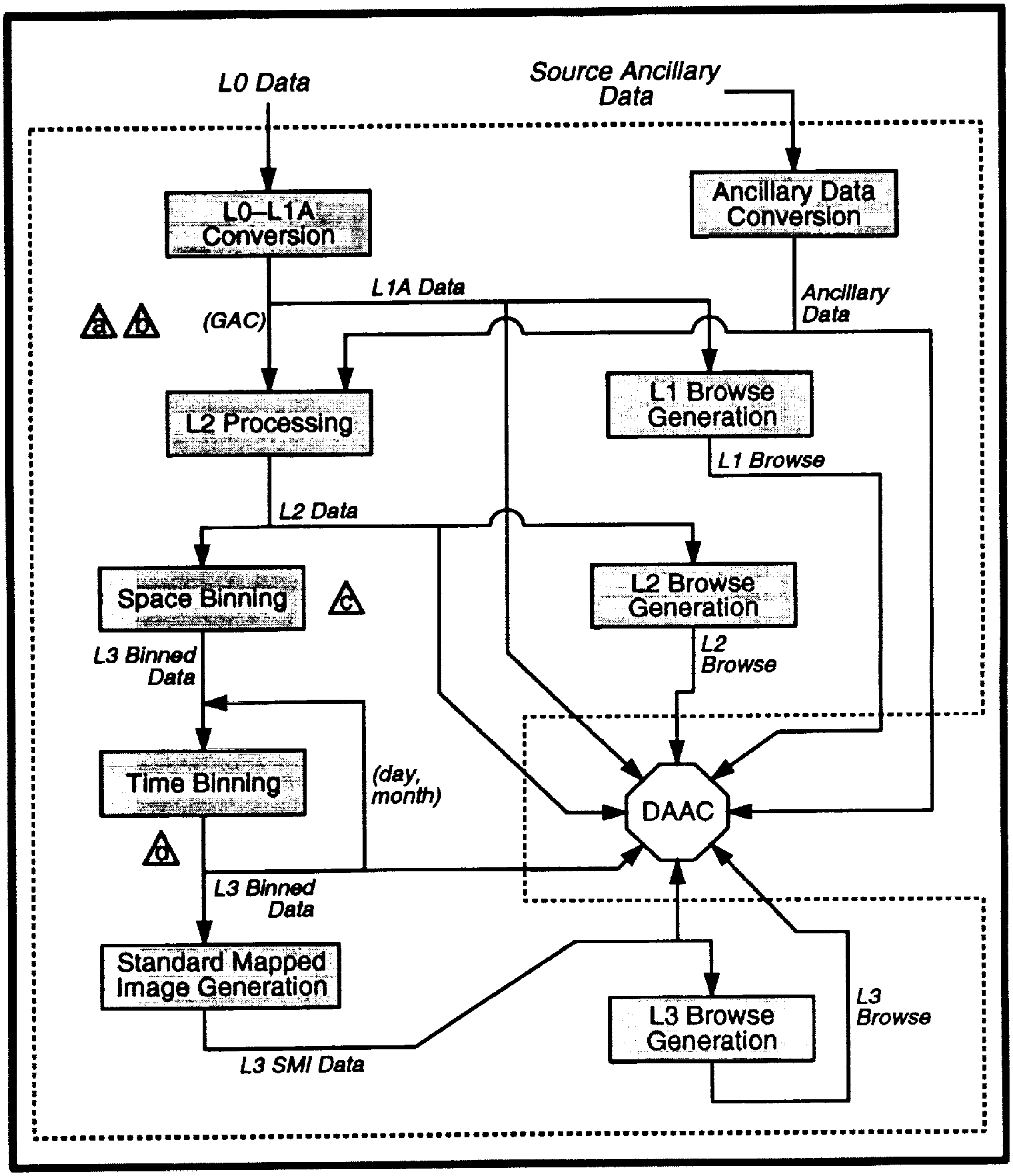
a. A different standard mapped image product is generated for each of five geophysical parameters, chlor_a, CZCS_pigment, nLw_555, tau_865, and K_490, from each time-binned product.

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.

Outline of Pages

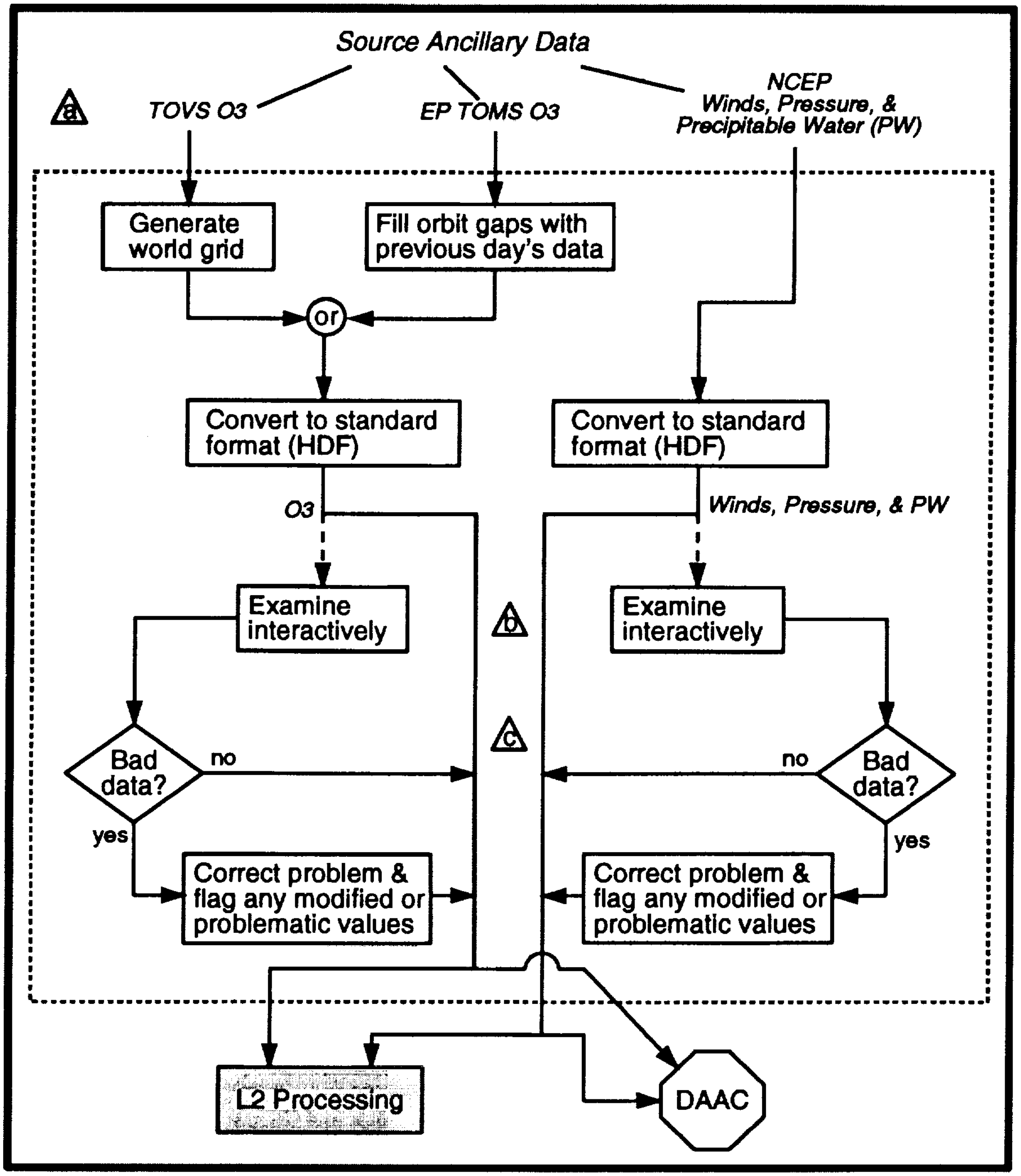
SeaWiFS Data Processing



SeaWiFS Science Algorithm Flow Chart

Science information flow	Control path	Functional limit of topic

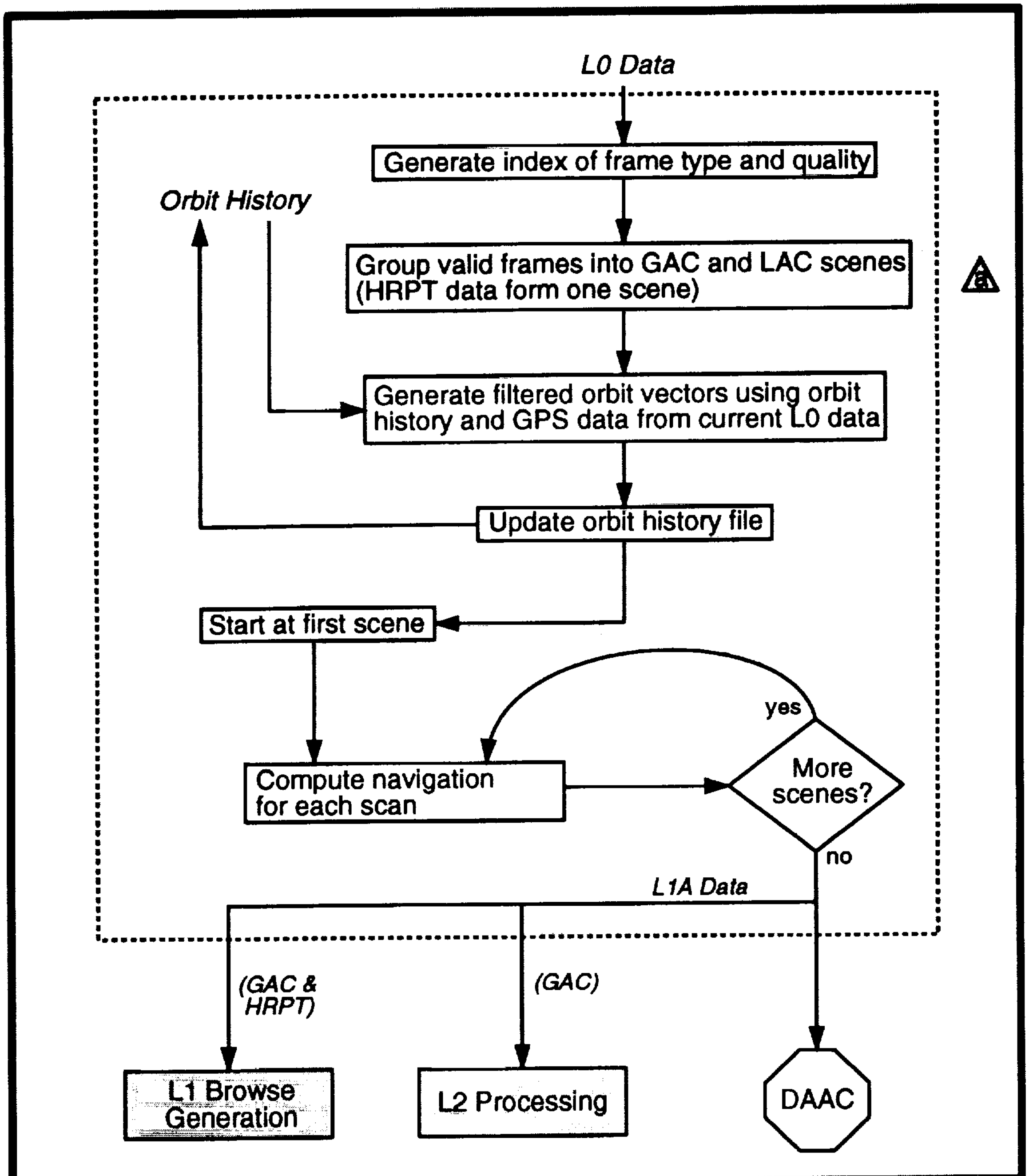
Ancillary Data Conversion



SeaWiFS Science Algorithm Flow Chart

Science information flow	Control path	Functional limit of topic

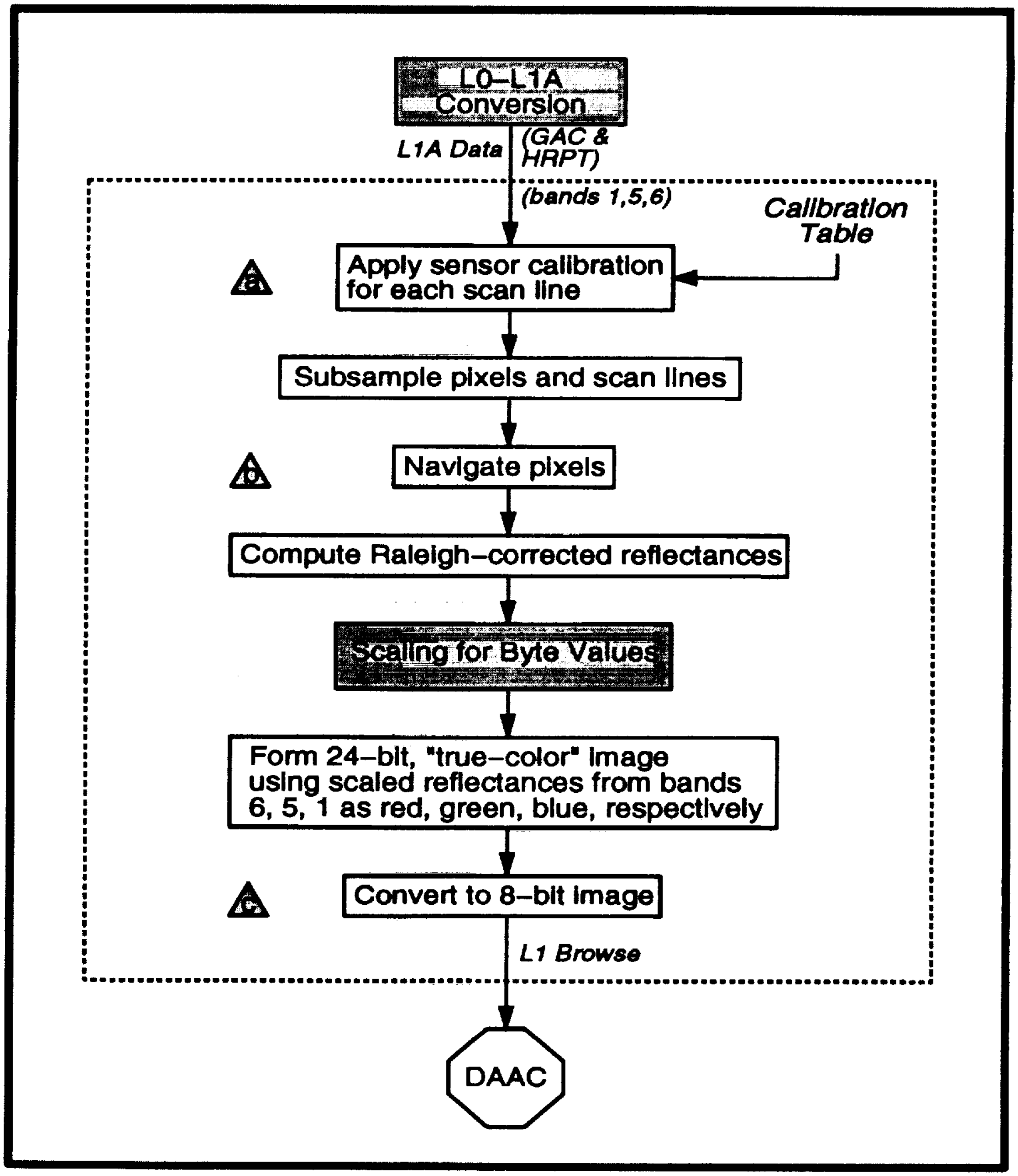
L0–L1A Conversion



SeaWiFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

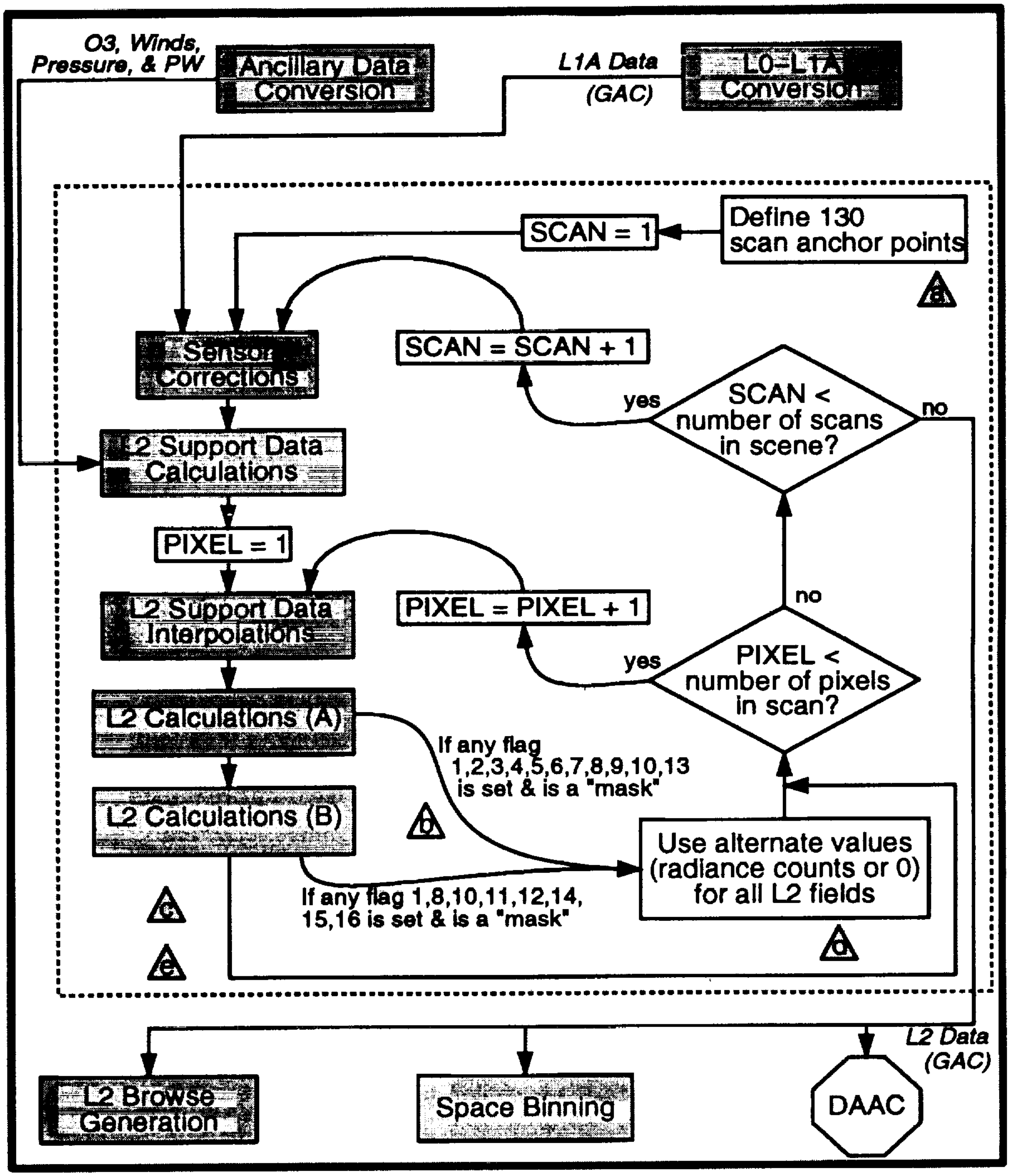
L1 Browse Generation



SeaWIFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

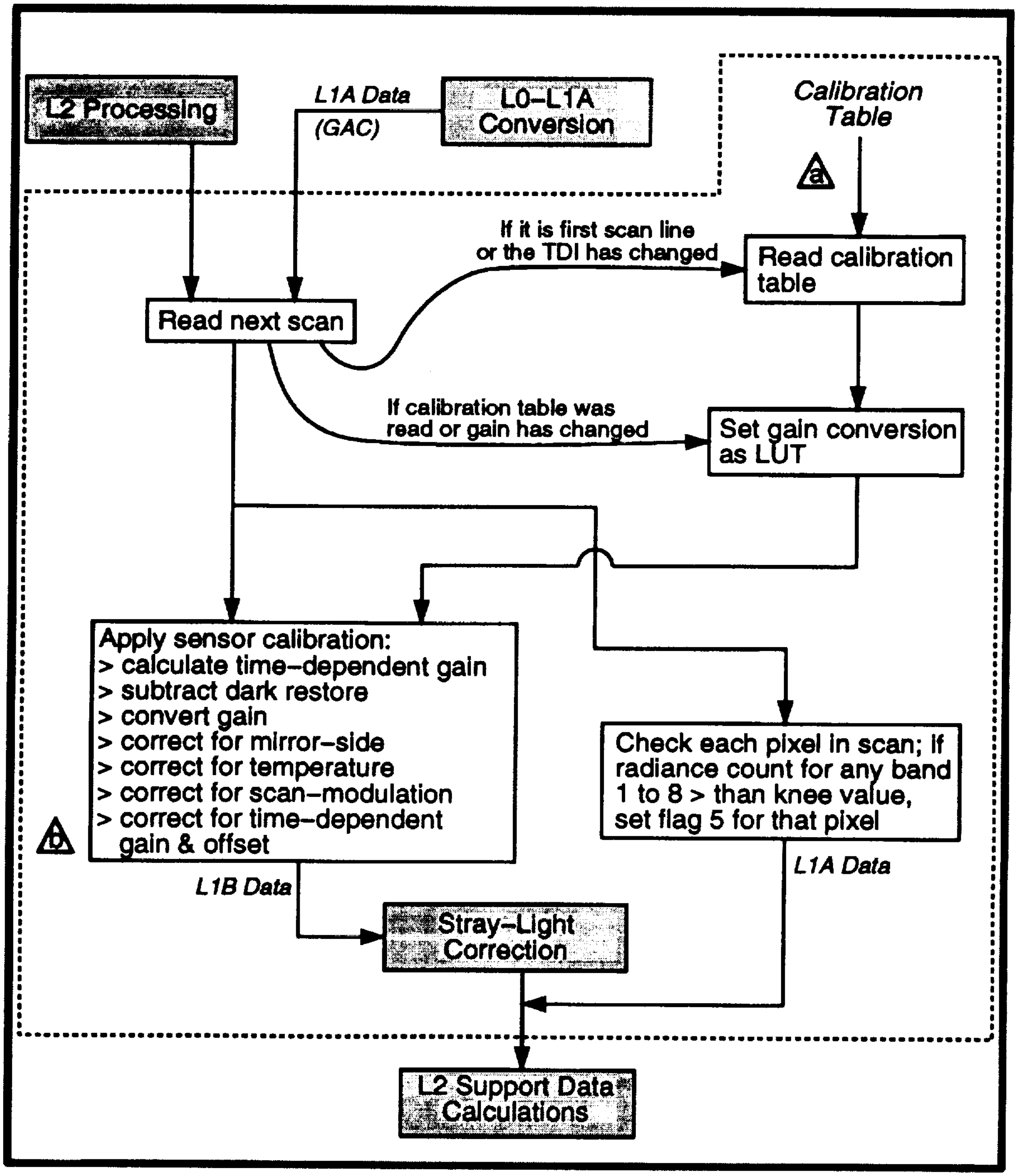
L2 Processing



SeaWIFS Science Algorithm Flow Chart

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

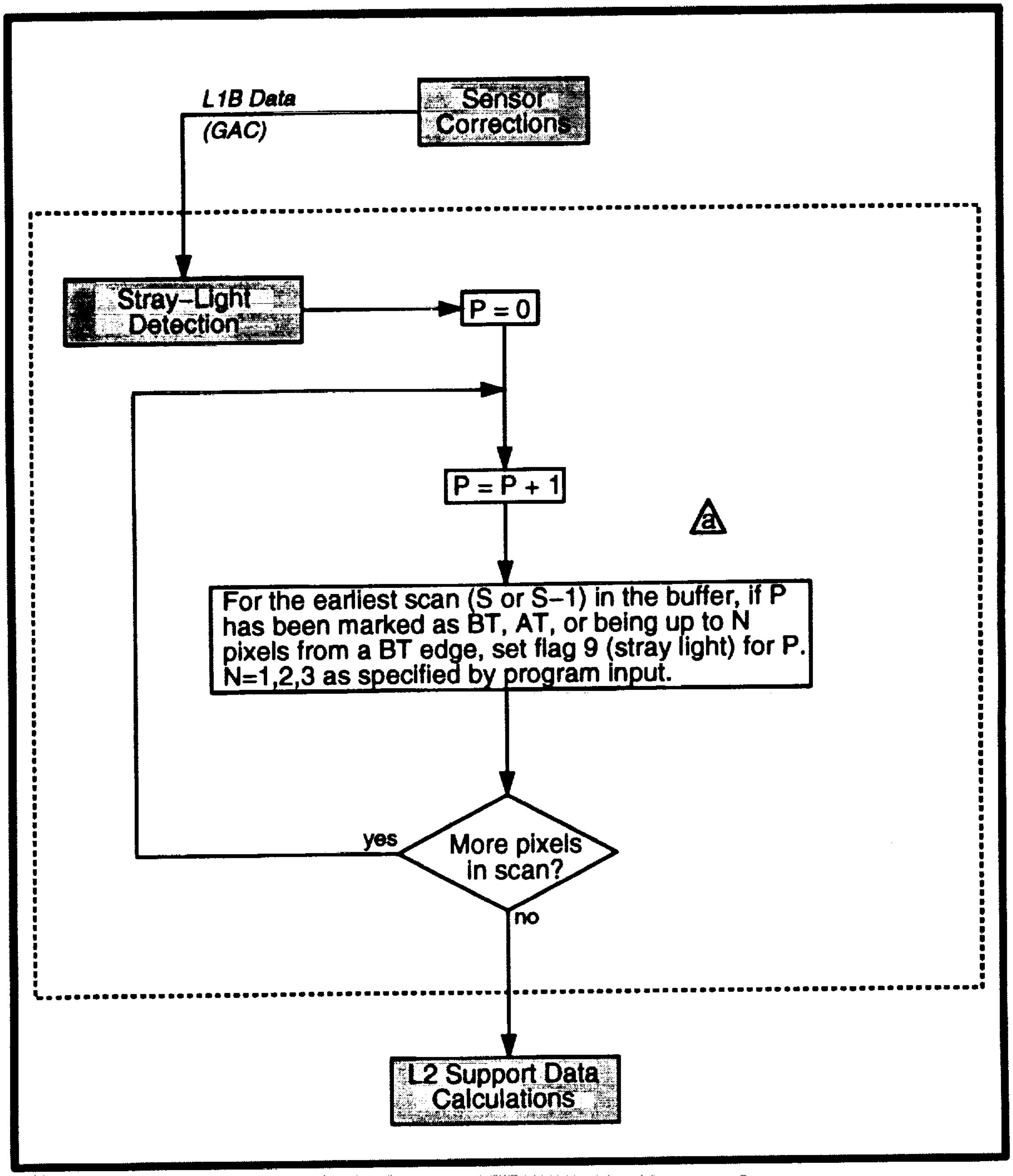
Sensor Corrections



SeaWIFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

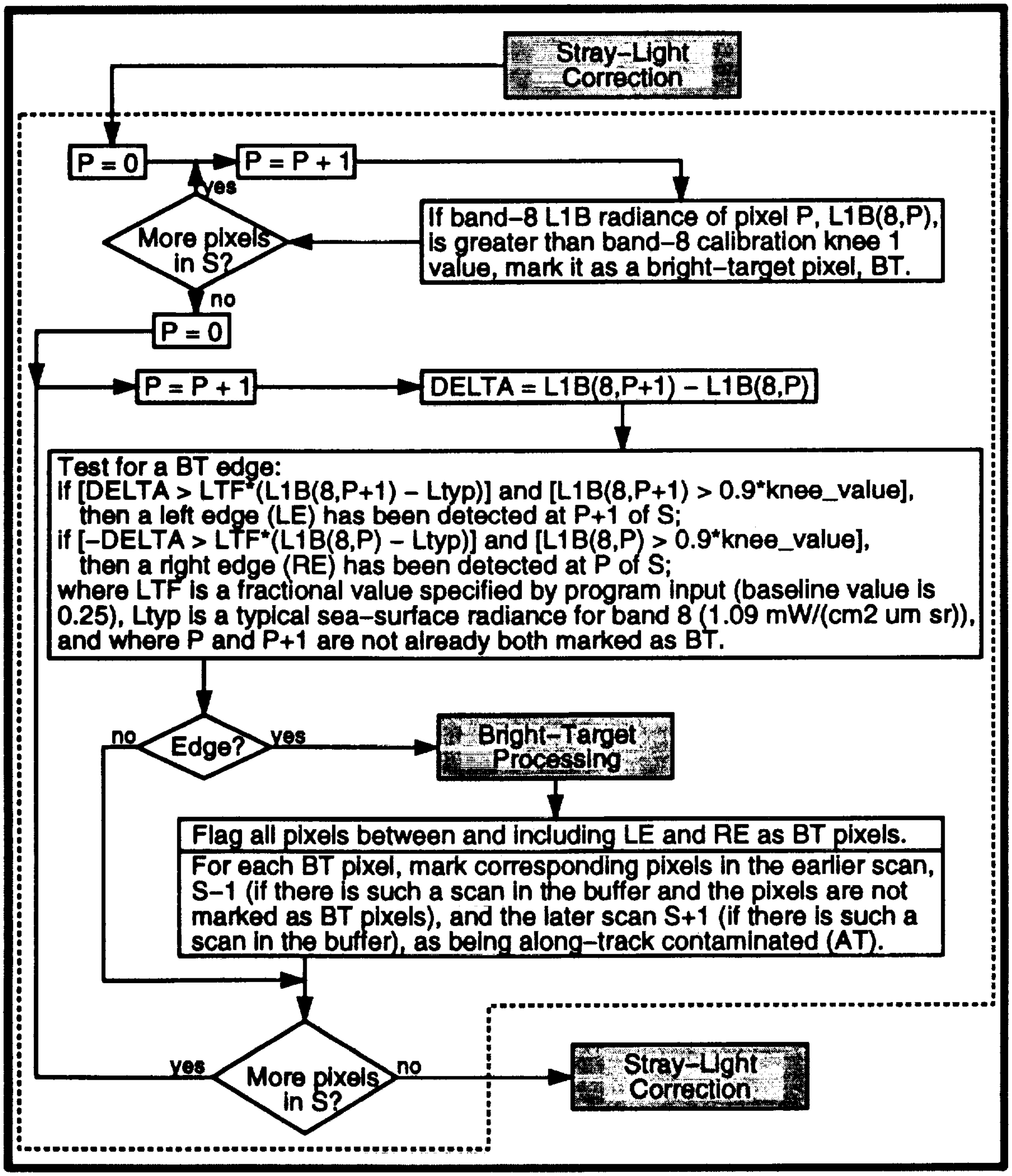
Stray-Light Correction



SeaWiFS Science Algorithm Flow Chart

Science information flow	Control path	Functional limit of topic

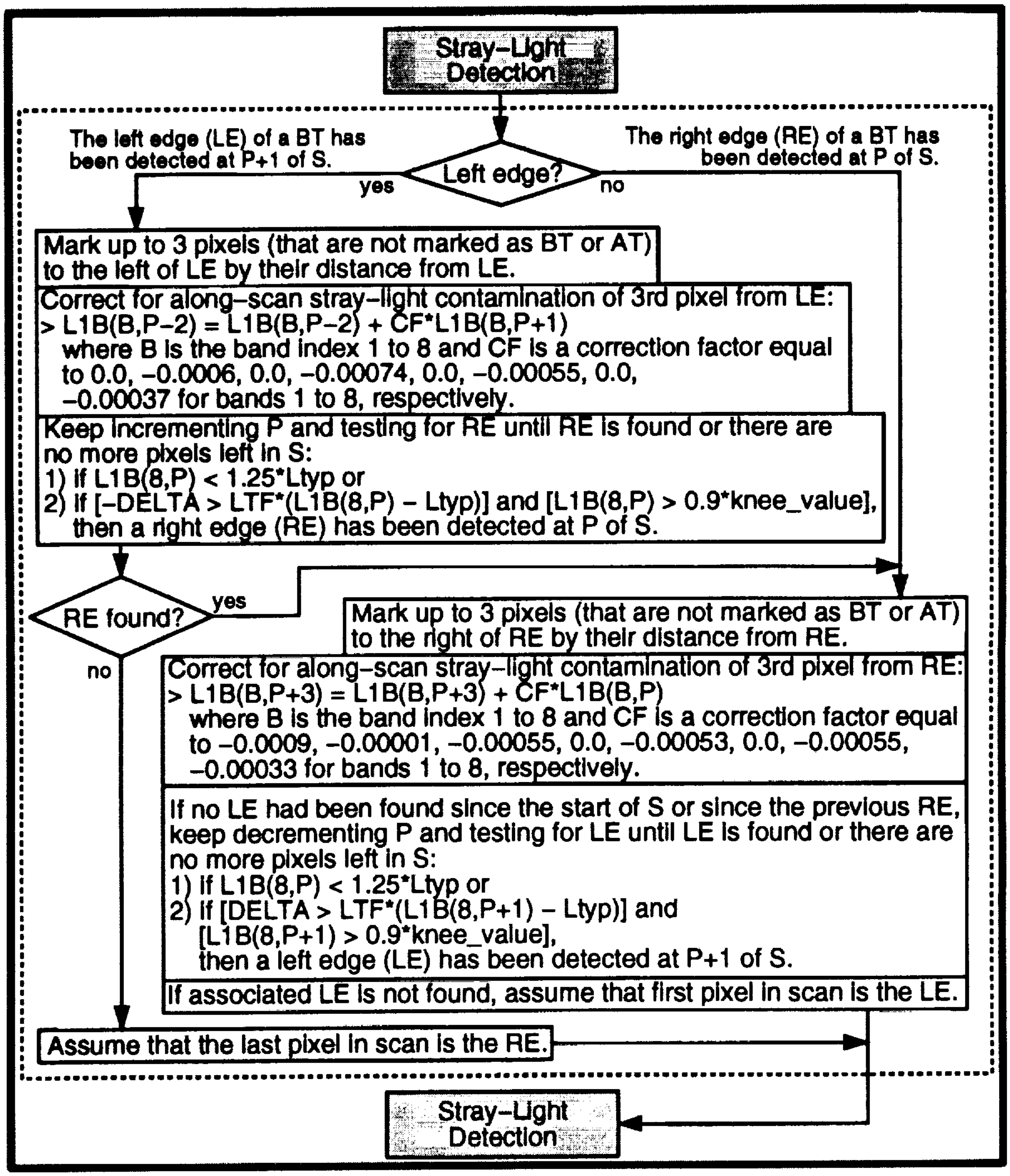
Stray-Light Detection



SeaWIFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

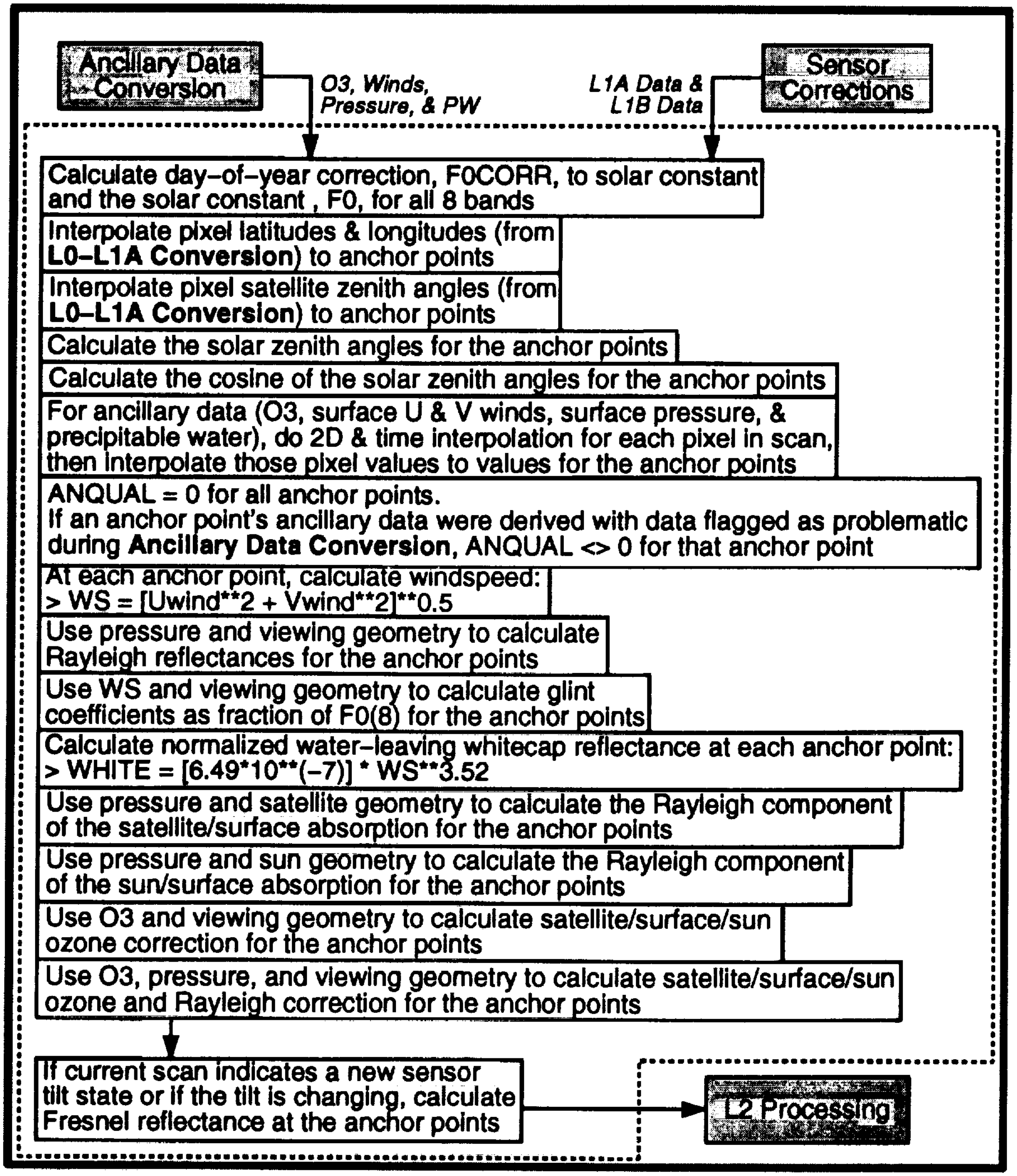
Bright-Target Processing



SeaWIFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

L2 Support Data Calculations



SeaWIFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

L2 Support Data Interpolations

L2 Processing

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

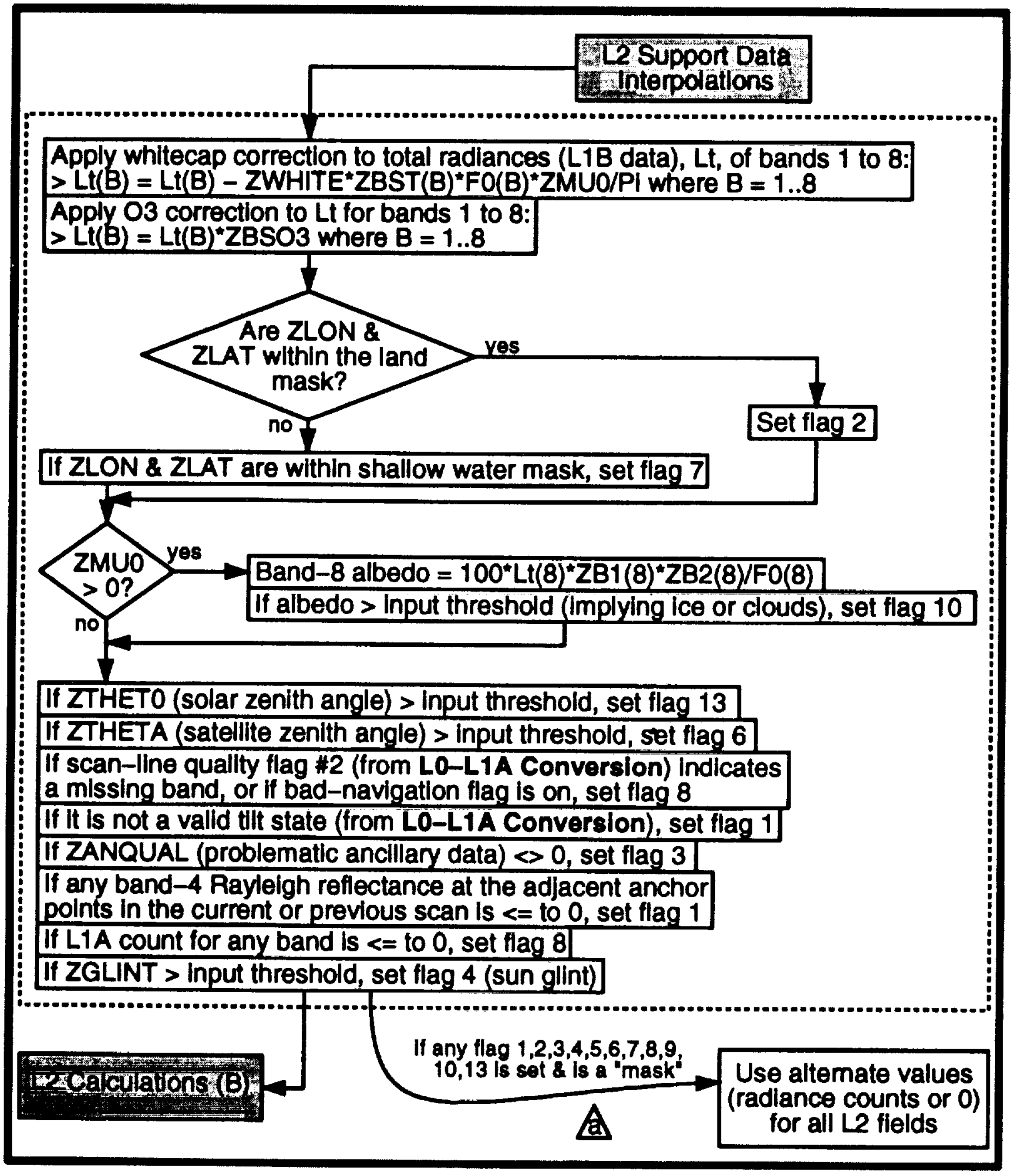
a

L2 Calculations (A)

SeaWIFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

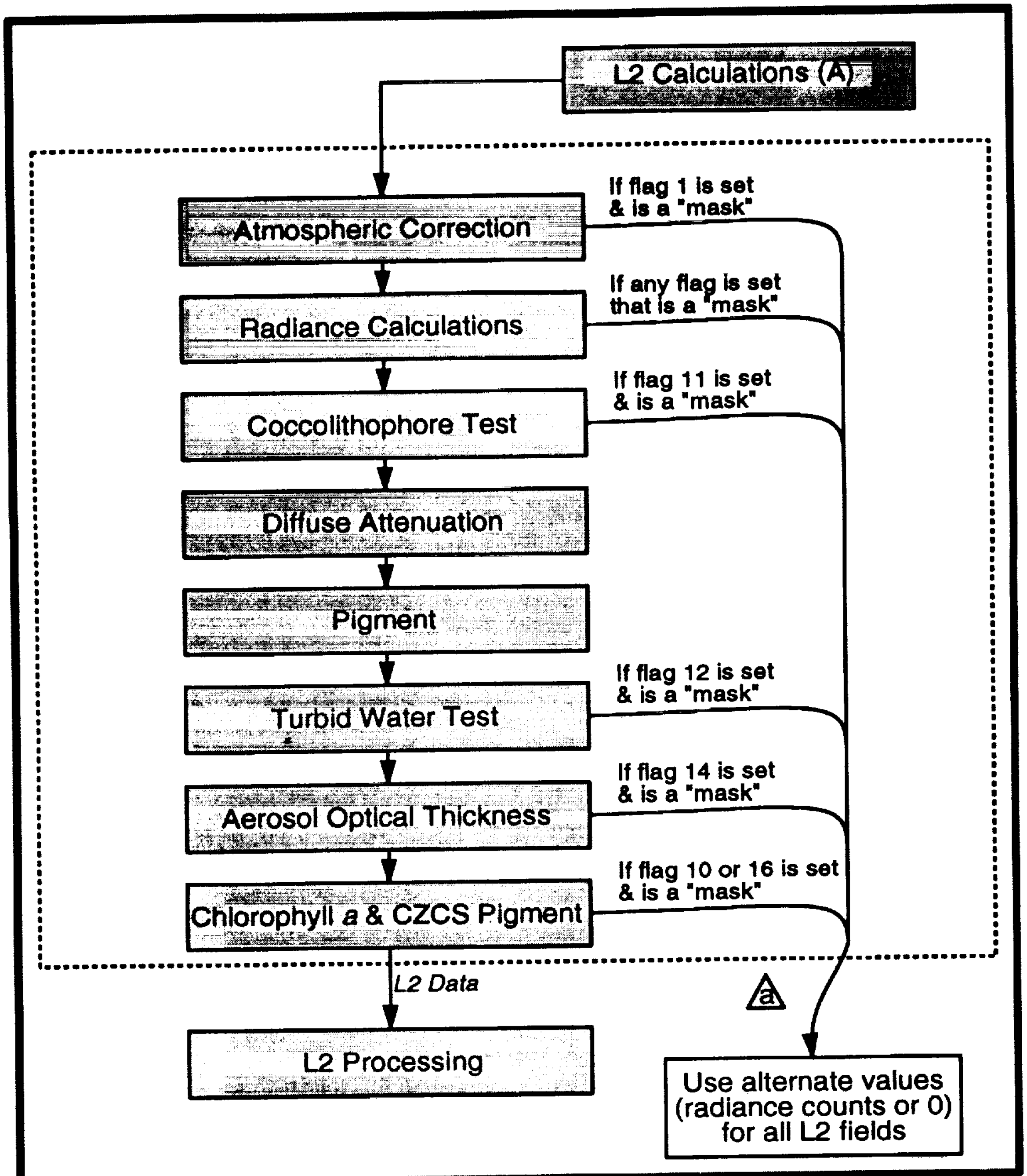
L2 Calculations (A)



SeaWIFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

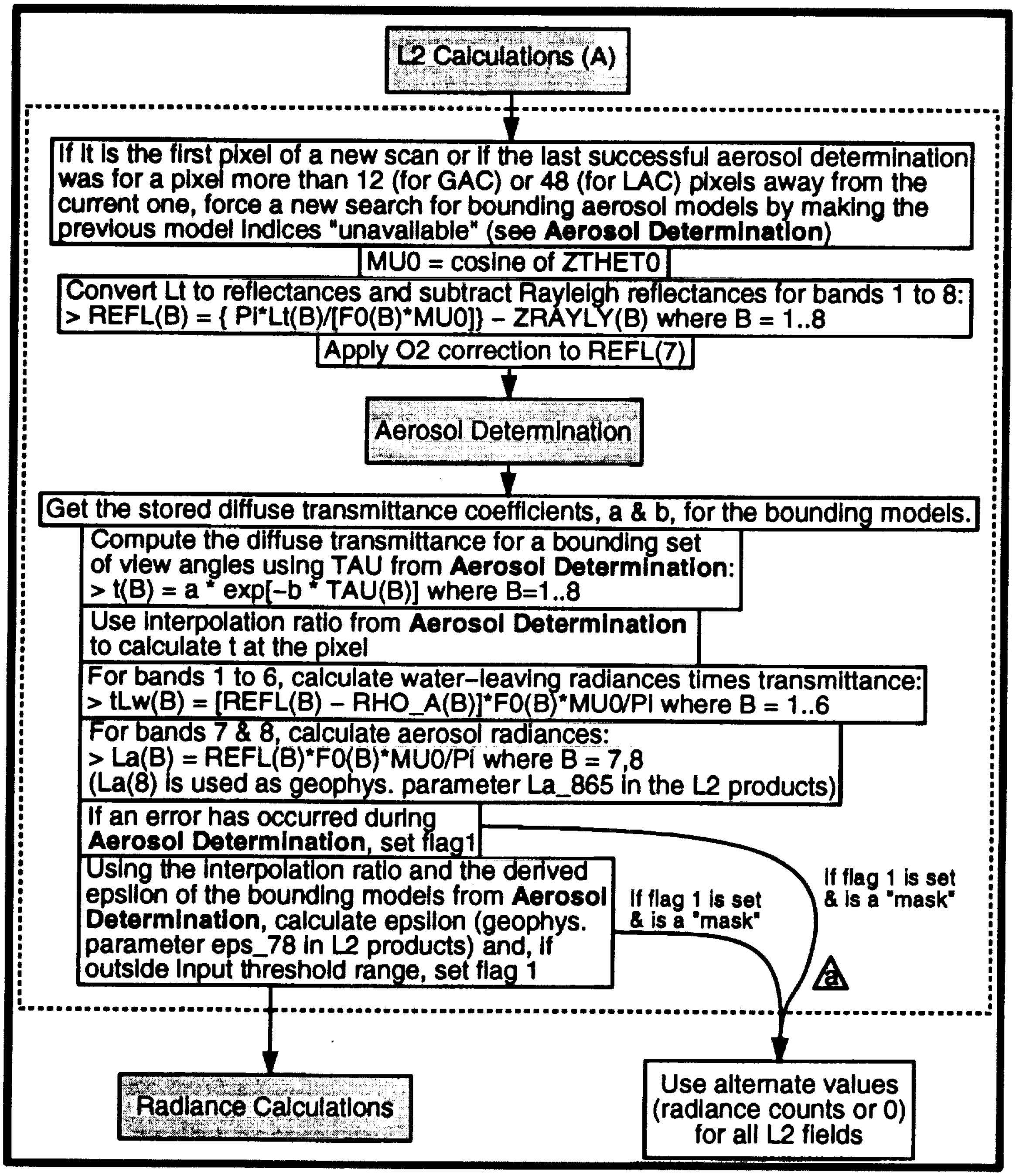
L2 Calculations (B)



SeaWiFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

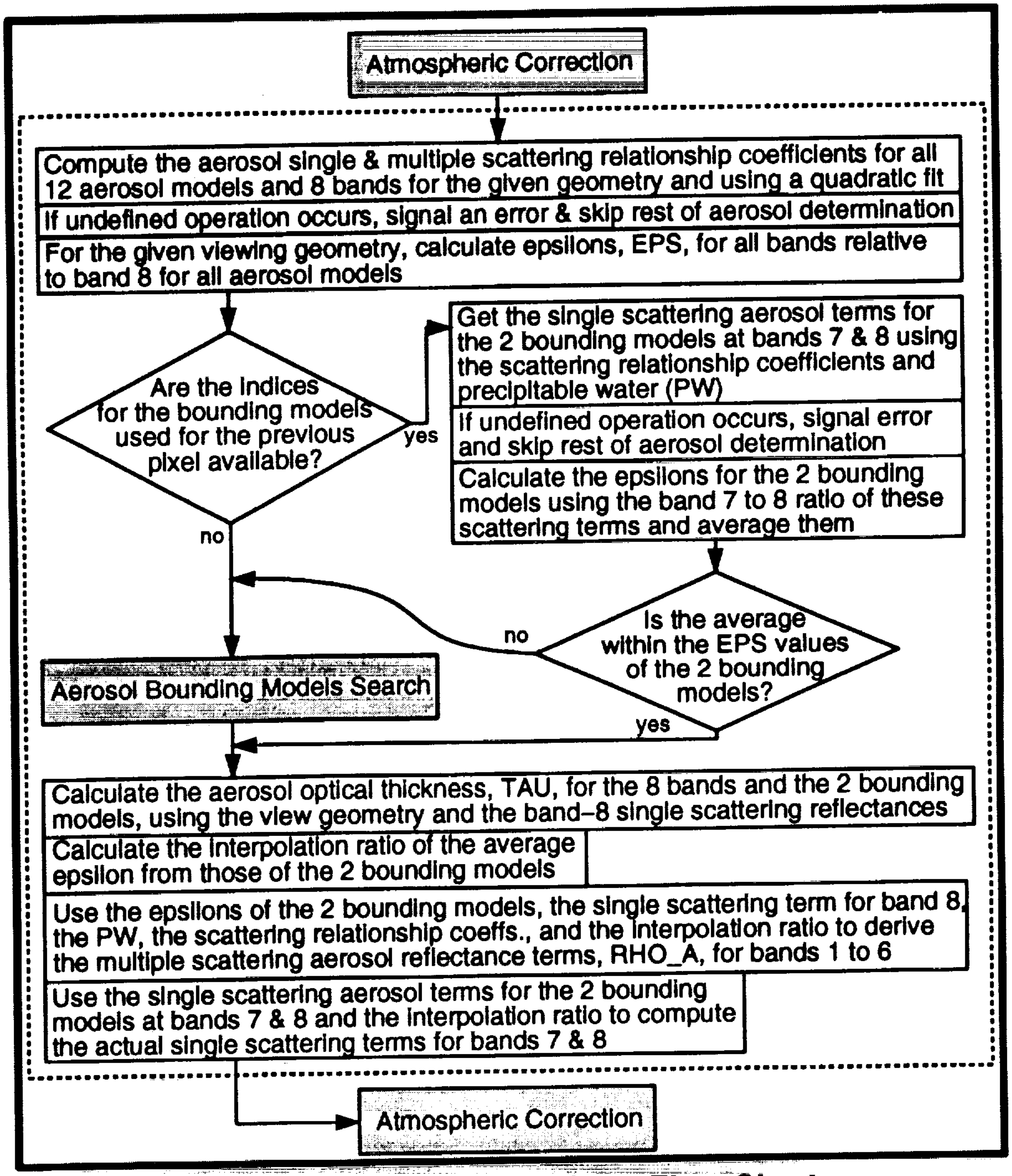
Atmospheric Correction



SeaWIFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

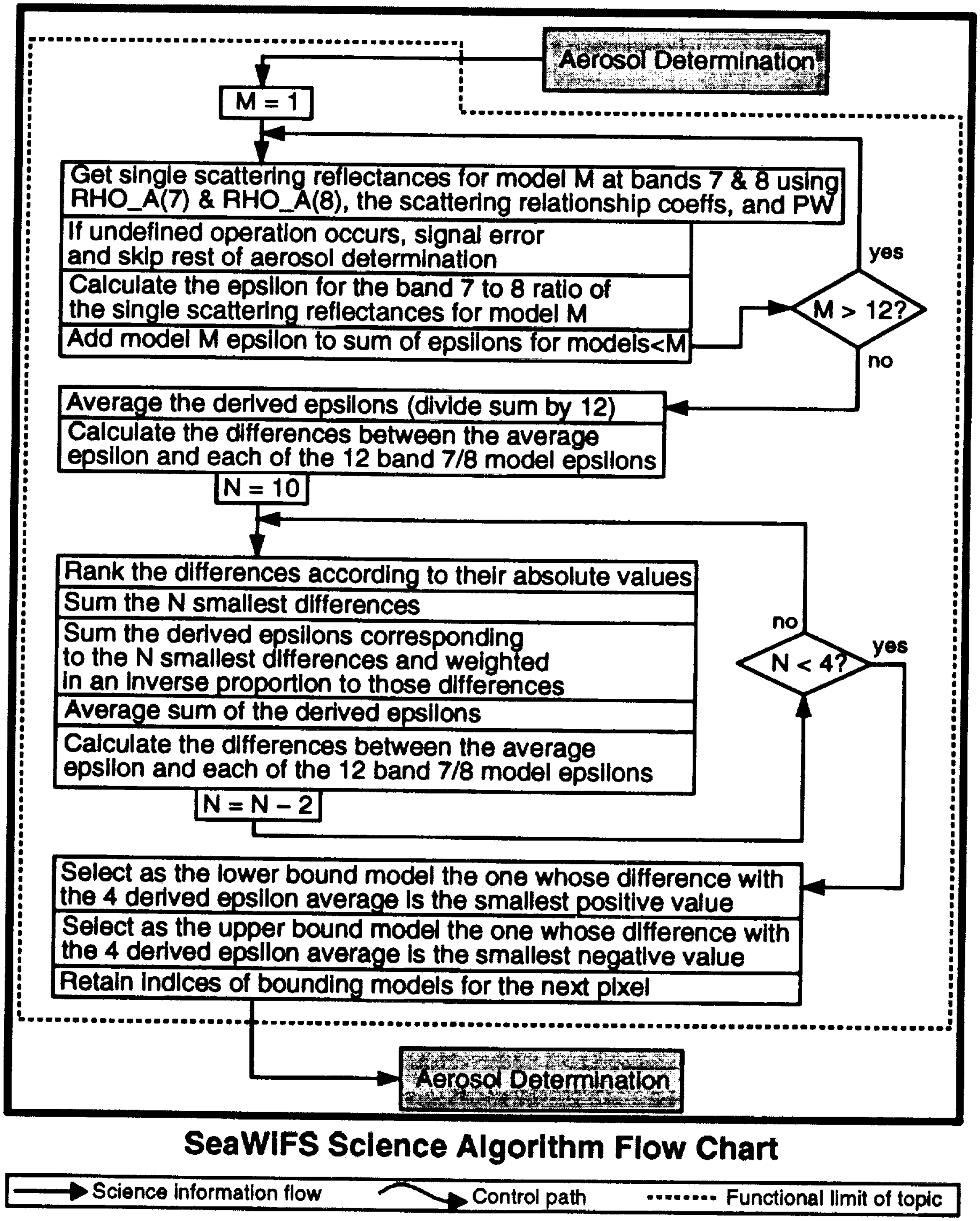
Aerosol Determination



SeaWIFS Science Algorithm Flow Chart

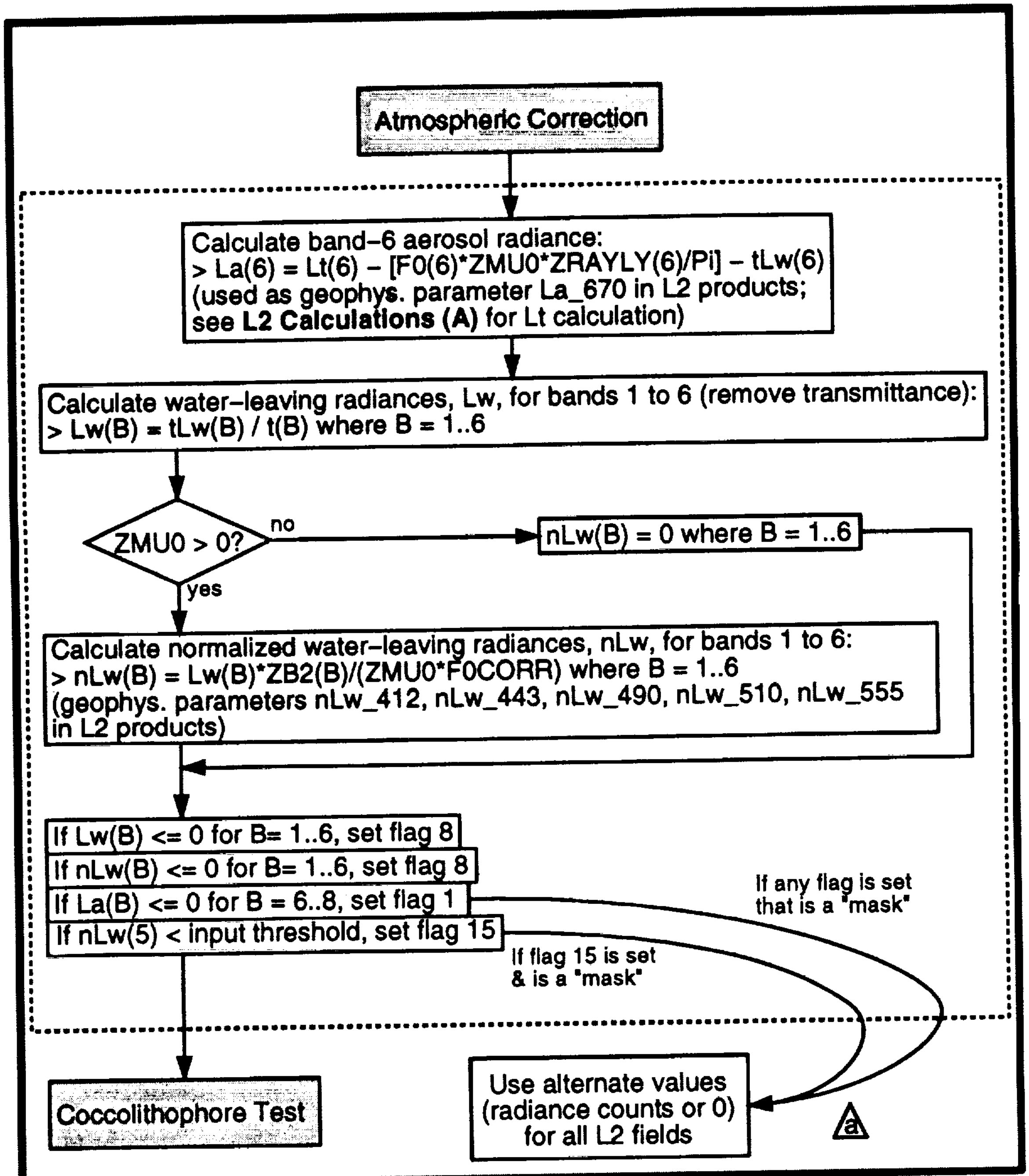
Science information flow — Control path — Functional limit of topic

Aerosol Bounding Models Search



SeaWiFS Science Algorithm Flow Chart

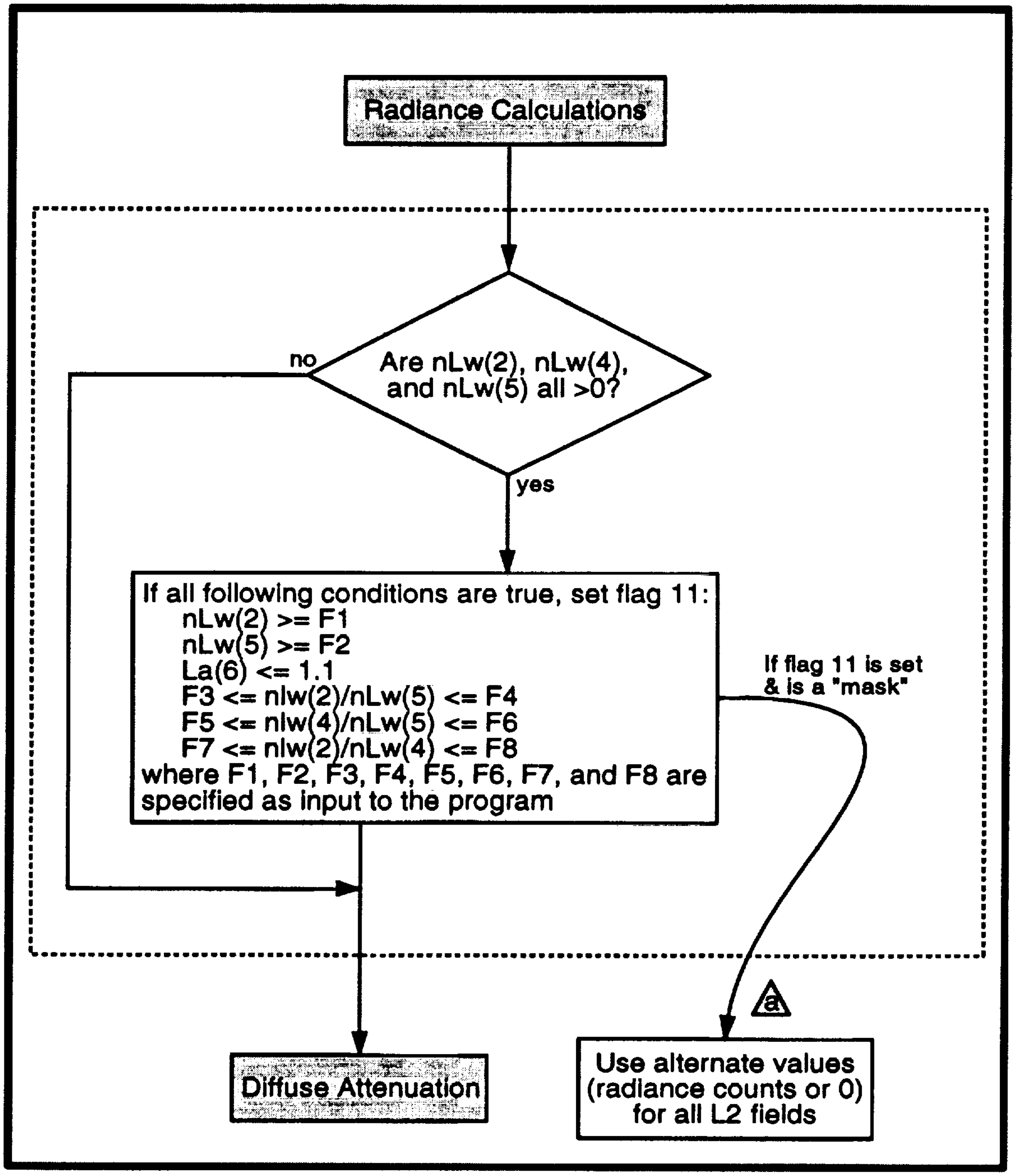
Radiance Calculations



SeaWiFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

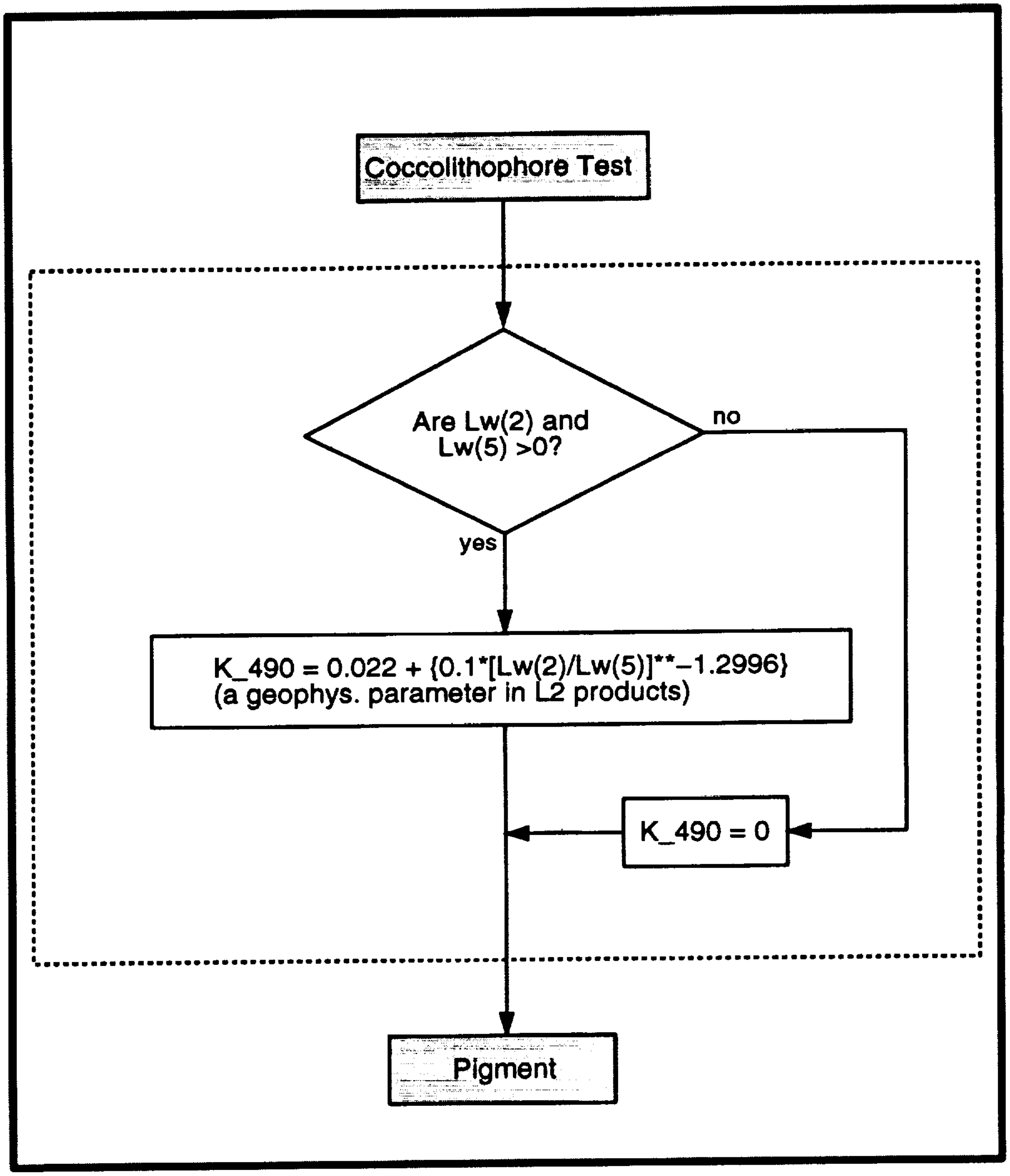
Coccolithophore Test



SeaWIFS Science Algorithm Flow Chart

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

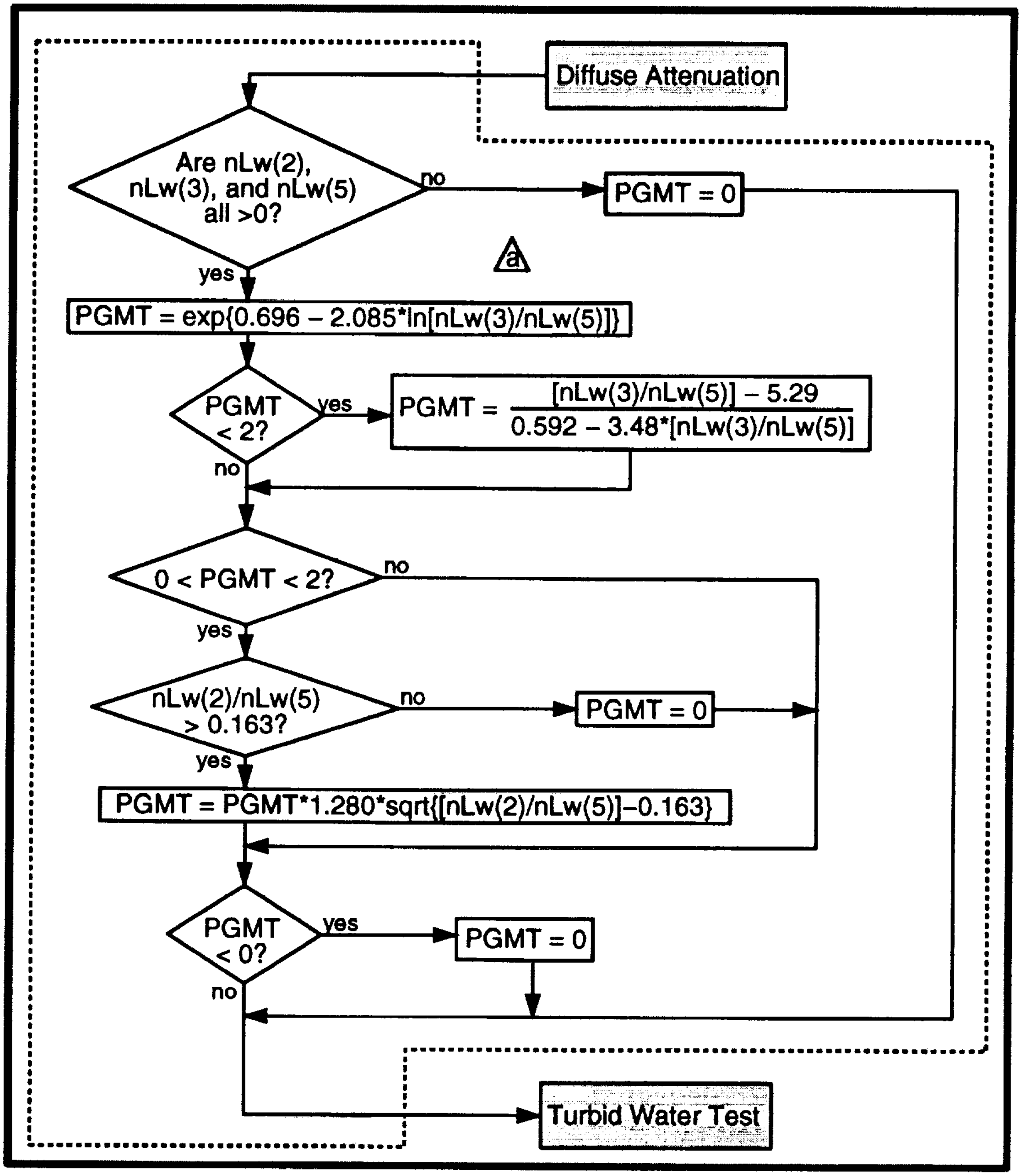
Diffuse Attenuation



SeaWiFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

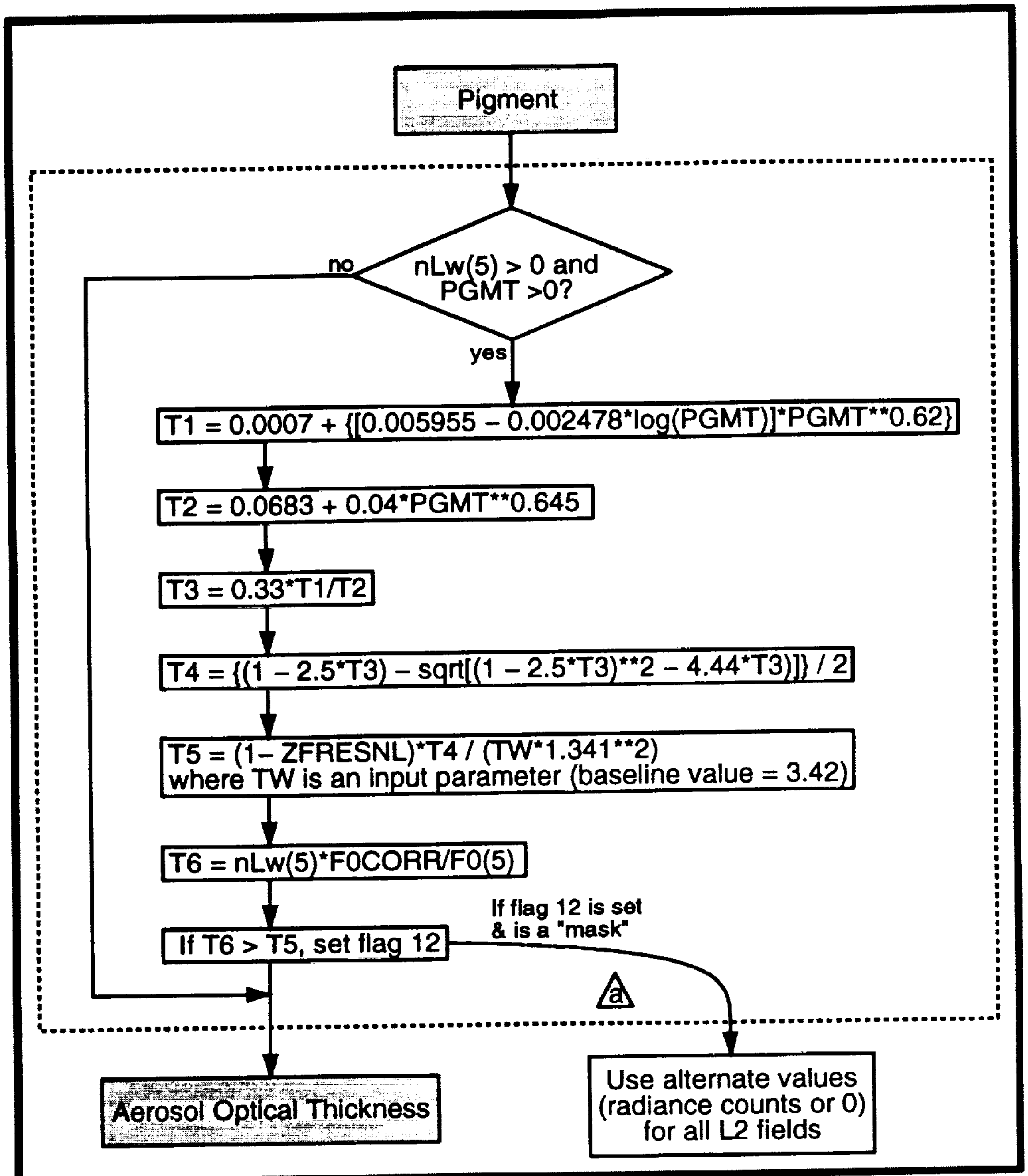
Pigment



SeaWiFS Science Algorithm Flow Chart

Science information flow | Control path | Functional limit of topic

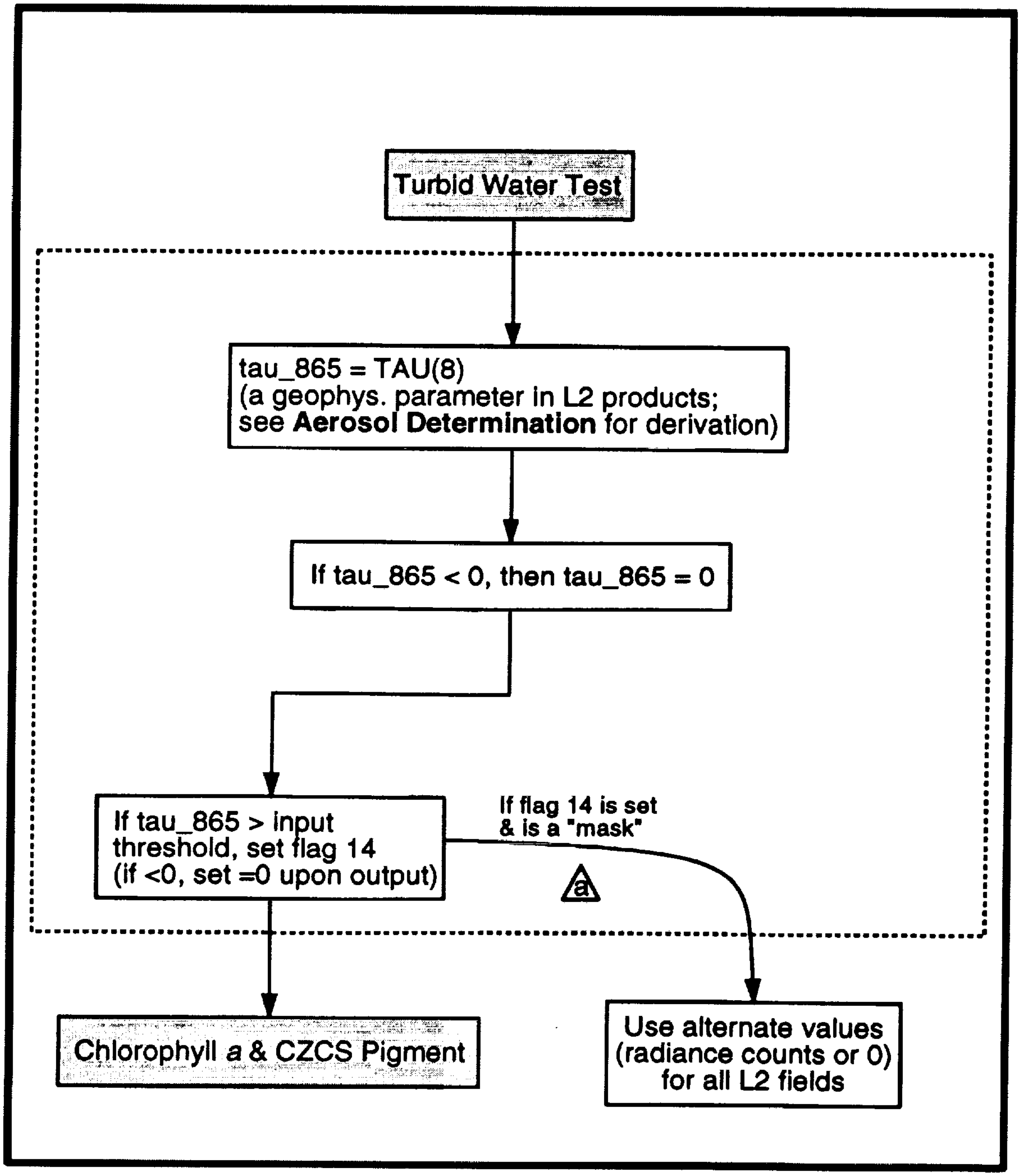
Turbid Water Test



SeaWiFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

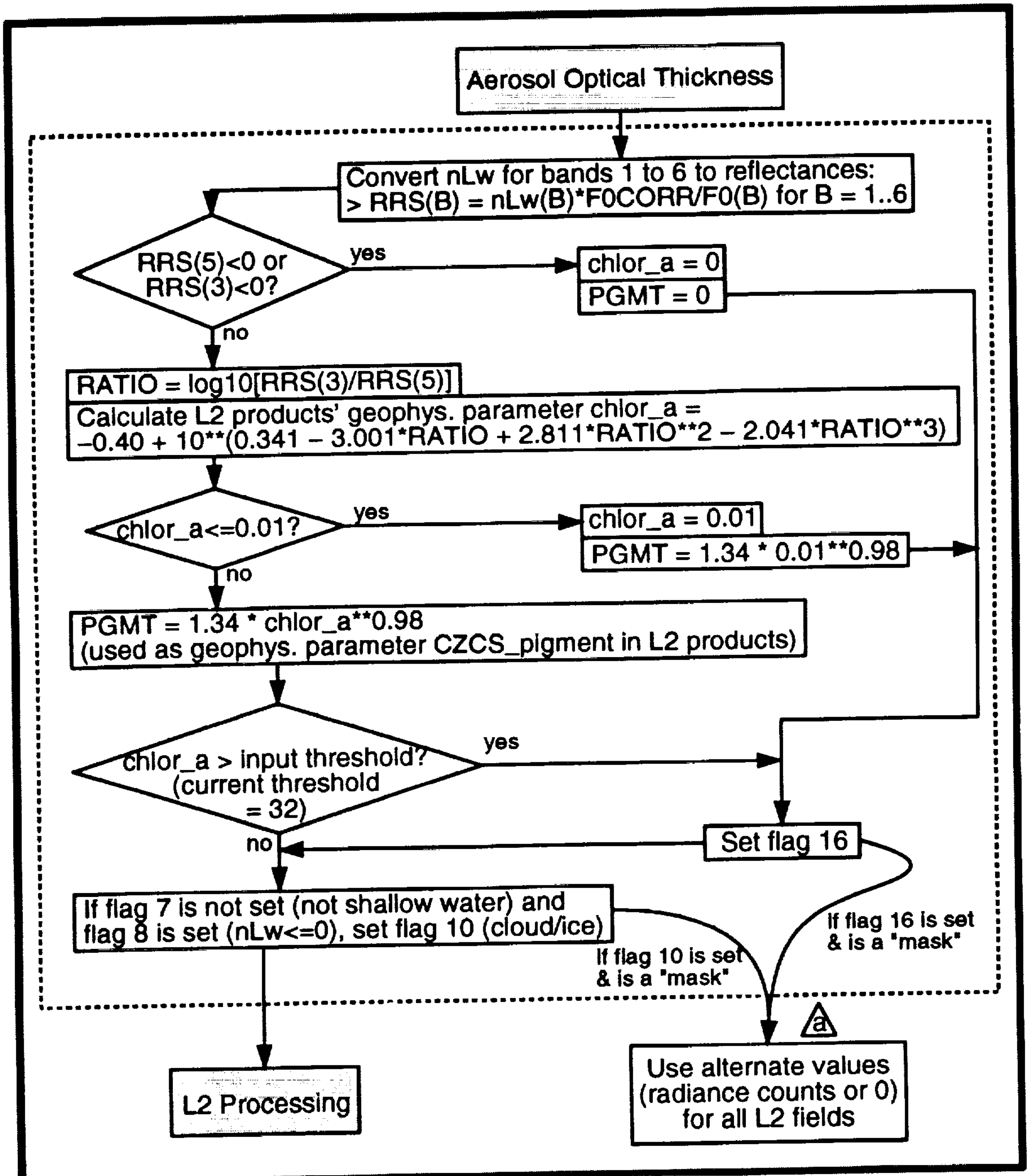
Aerosol Optical Thickness



SeaWiFS Science Algorithm Flow Chart

Science information flow — Control path ········ Functional limit of topic

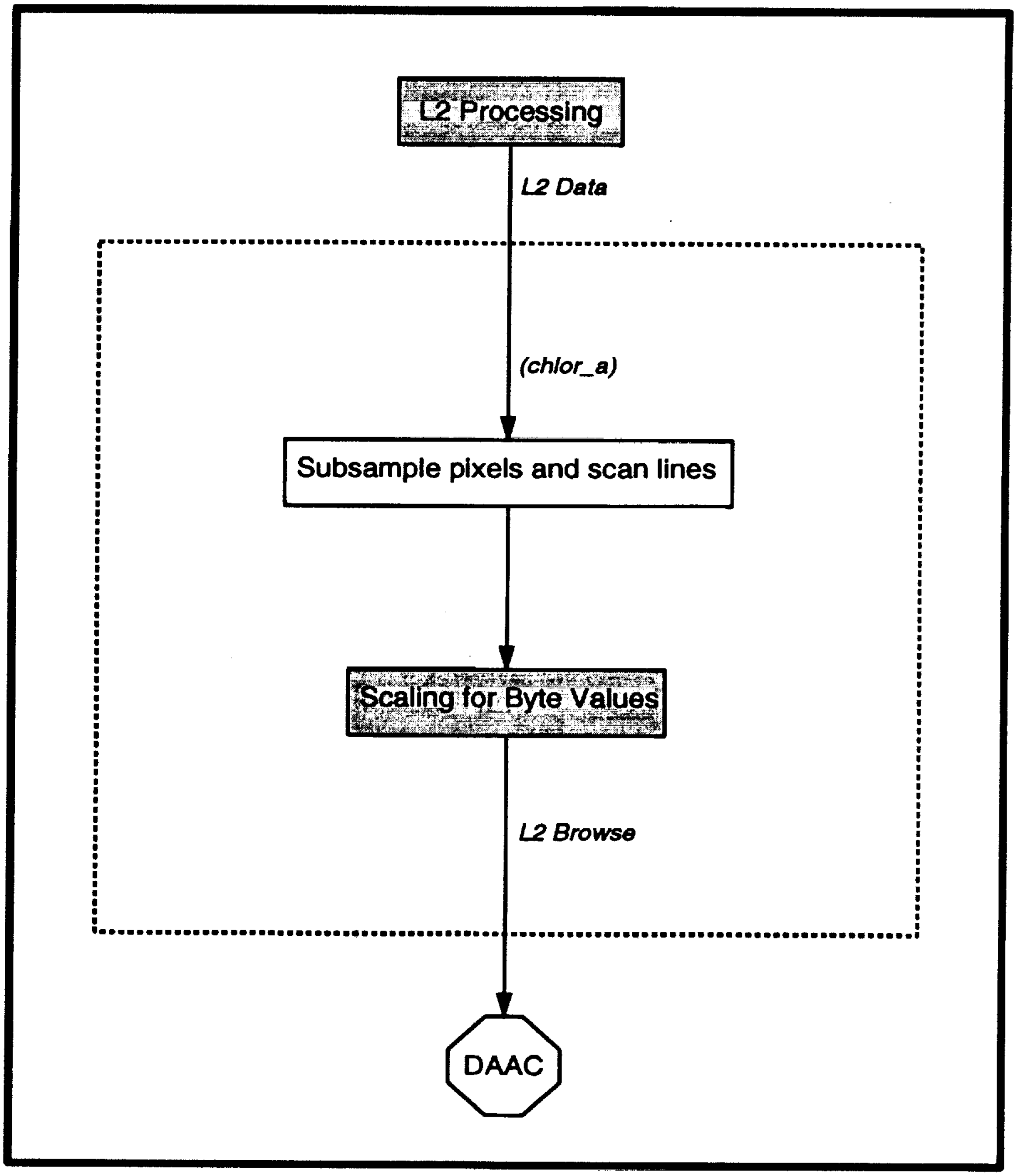
Chlorophyll *a* & CZCS Pigment



SeaWiFS Science Algorithm Flow Chart

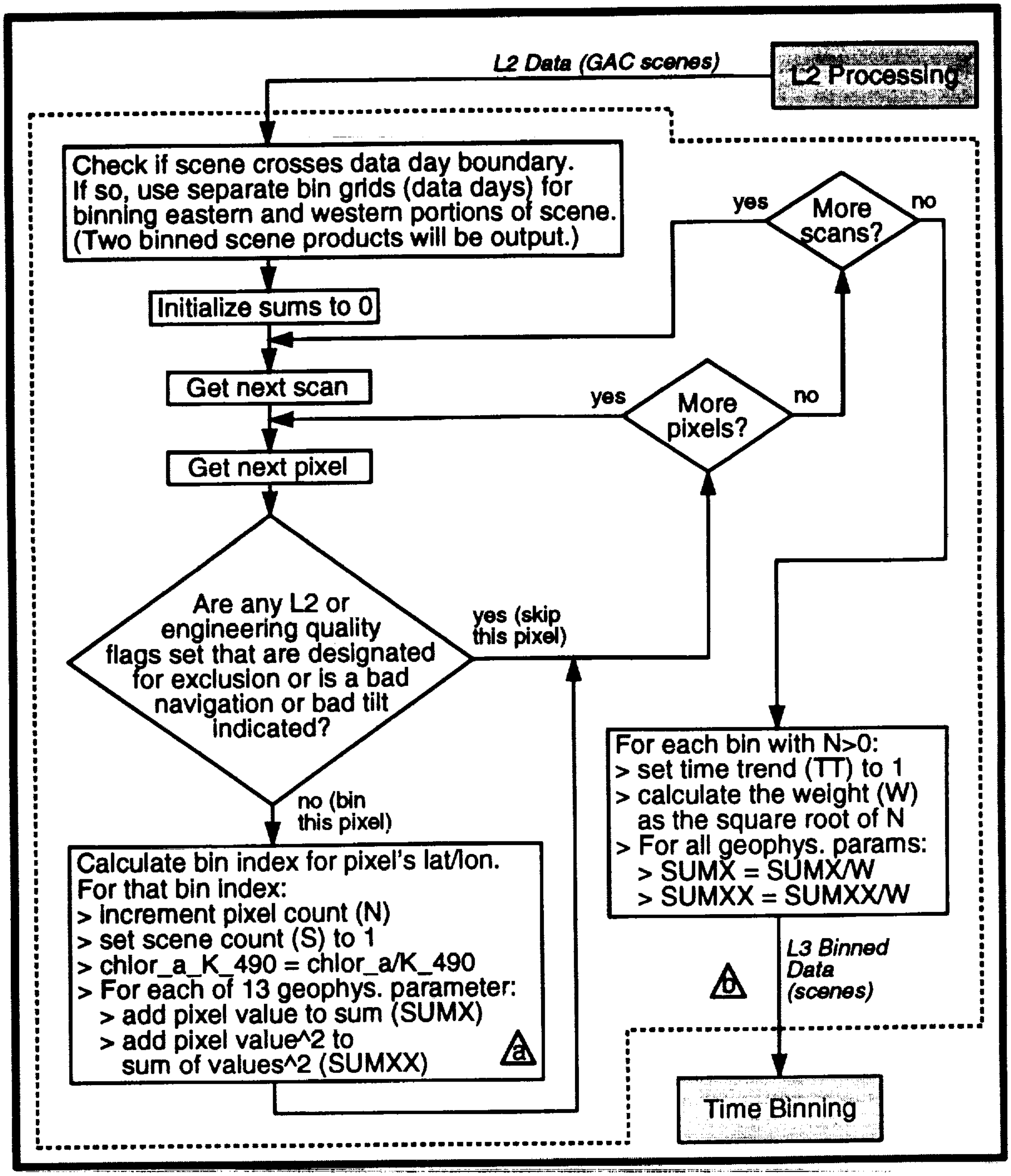
Science information flow — Control path — Functional limit of topic

L2 Browse Generation



SeaWIFS Science Algorithm Flow Chart

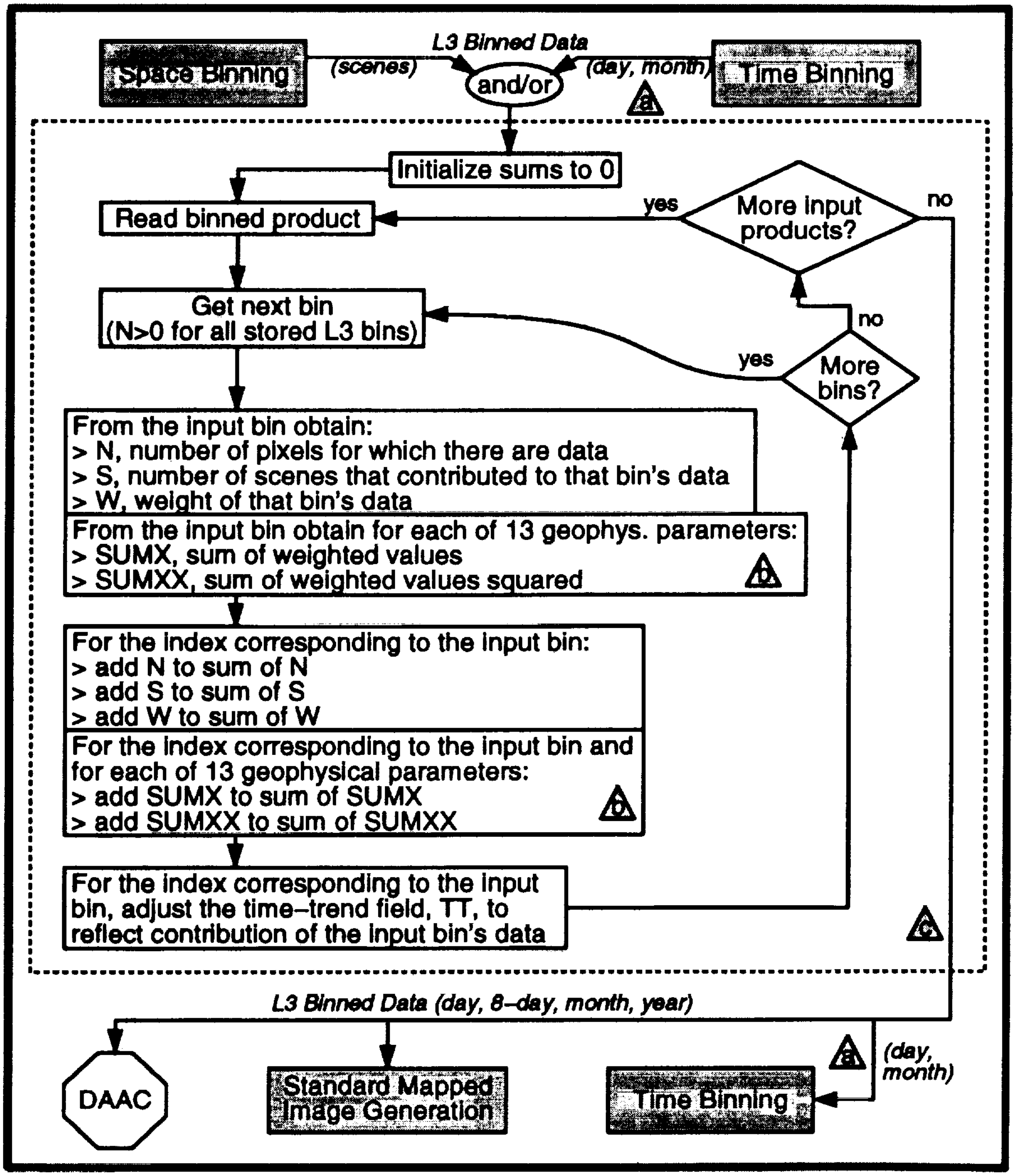
Space Binning



SeaWiFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

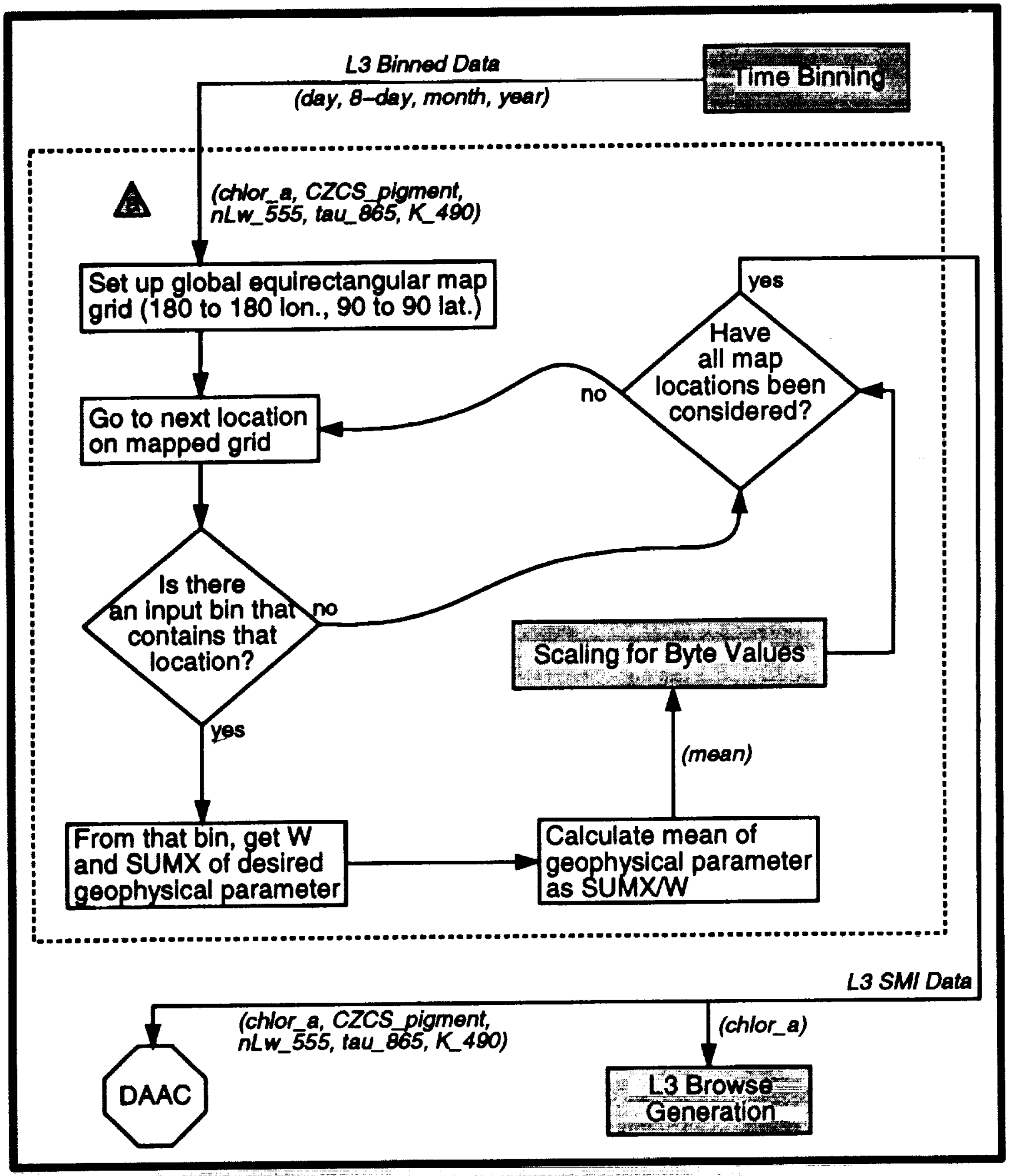
Time Binning



SeaWIFS Science Algorithm Flow Chart

Science information flow — Control path — Functional limit of topic

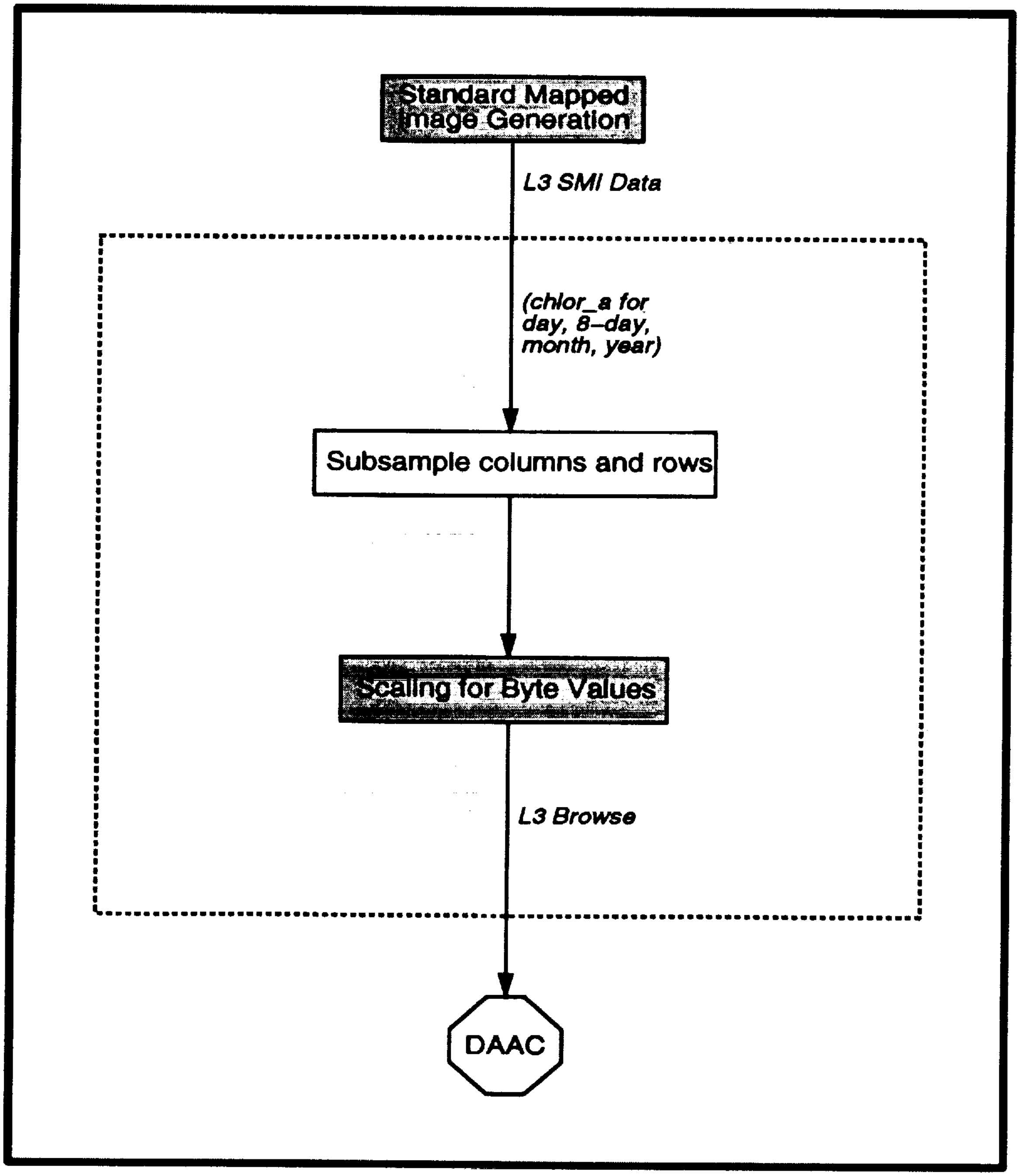
Standard Mapped Image Generation



SeaWiFS Science Algorithm Flow Chart

Science information flow — Control path ········ Functional limit of topic

L3 Browse Generation



SeaWiFS Science Algorithm Flow Chart

Scaling for Byte Values

B = byte value to form true-color image (L1) or to write into product (L2 & L3)
D = Rayleigh-corrected reflectances (L1) or geophysical value (L2 & L3)

L1 Browse Generation

B = [log(D)+2] / (2/255)
B = 0 <==> D = 0.01
B = 255 <==> D = 1.0

L2 Browse Generation

B = [log(D)+2] / 0.015 for chlor_a, and if B>250, B=250
B = 0 <==> D = 0.01 mg m^-3
B = 250 <==> D = 56.234133 mg m^-3

Standard Mapped Image (SMI) Generation

B = [log(D)+2] / 0.015 for chlor_a & CZCS_pigment, and if B>254, B=254
B = 0 <==> D = 0.01 mg m^-3
B = 254 <==> D = 64.565423 mg m^-3

B = D / 0.063 for nLw_255, and if B>254, B=254
B = 0 <==> D = 0.01 mW cm^-2 um^-1 sr^-1
B = 254 <==> D = 16.002 mW cm^-2 um^-1 sr^-1

B = D / 0.005 for tau_865, and if B>254, B=254
B = 0 <==> D = 0.01
B = 254 <==> D = 1.270

B = D / 0.025 for K_490, and if B>254, B=254
B = 0 <==> D = 0.01 m^-1
B = 254 <==> D = 6.350 m^-1

L3 Browse Generation

B = SMI chlor_a byte value and if 250<B<255, B=250
B = 0 <==> D = 0.01 mg m^-3
B = 250 <==> D = 56.234133 mg m^-3

Summary of Reserved Byte Values

Byte	L1 brs	L2 brs	SMI	L3 brs
0–250	data	data	data	data
251	data	not used	data	caption (1)*
252	data	flag 4 (3)	data	geocoordinate grid (3)*
253	data	flag 2 (1)	data	land (4)*
254	data	flags 1, 5, or 10 (2)	data	political boundaries (2)*
255	data	not used	no data	no data (5)

() 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

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13. ABSTRACT *(Maximum 200 words)*

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 gephysical 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.

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