Oceansat-2 Scatterometer algorithms for sigma-0, processing and products format (April-2010) (Version 1.1)

by

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CONTENT

Introduction:

Oceansat-2 carries a pencil beam scatterometer, which scans the earth surface conically, with a swath of 1800 km. It has two beams with outer beam having VV polarization and inner beam has HH polarization. It covers entire globe in two days. This document describes details on specifications of Oceansat-2 Scatterometer System and Data products, followed by mathematical formulation for computation of sigma-0 from on-board compressed data. It also describes definition of various levels of products, formats of products and approach for data products generation.

2.0 Oceansat-2 Mission Specifications:

The OCEANSAT-2 mission is envisaged as the continuity service provider to IRS-P4 data users. The satellite is planned to be operated in 720 km altitude, sun-synchronous orbit with a local time of 12:00 Noon at descending nodal crossing. The spacecraft contains three payloads, viz. OCM, Scatterometer and ROSA (Radio Occultation Sounder for Atomosphere). The spacecraft has two SPS units to provide instantaneous GPS-navigational solution for the spacecraft. For the onboard orbit requirement three orbit sources are provided viz. GOODS, FPS (Fourier Power Series) and NI (Numerical Integrator), of which GOODS is the primary mode of operation. For FPS and NI orbit coefficients and orbital elements are uplinked on day to day basis from ground. S-band data from the tracking station network is going to be used for regular orbit determination along with SPS Playback based orbit determination on ground.

2.1 Characteristics of Orbit:

Mean Altitude	: 720 km
Inclination	: 98.28 deg
Eccentricity	: 0.00113
Arg. Of perigee	: 90 deg
Nodal Period	: 99.31 min (5958.60 seconds)
Repeat cycle	: 29 orbits in 2 days
Distance Between Adjacent Paths	: 1382 Km (At equator)
Distance between Adjacent Ground Track	: 2764 Km (At equator)
Avg. Ground Track Velocity	: 6.7818 km/sec

The orbit determination accuracy is 80 meters and velocity accuracy is 8 cms/sec.

2.2 Attitude Specifications:

Two pairs of CSES are mounted on the spacecraft in Pitch-Yaw plane. It measures roll and pitch of the spacecraft. Primarily both the sensors will be operated and normal output (dual head) is derived and used for attitude purpose. The pointing accuracy is ±0.15 deg on all axes. The drift rate is better than 3×10^{-4} deg/sec.

3. Scatterometer System Specifications:

The basic system parameters of Oceansat-2 scatterometer are shown in Table 3.1 below.

Table 3.1: Scatterometer system parameters

Parameter	Inner Beam	Outer Beam
Satellite Altitude	720 kms	
Frequency	13.515 GHz	
Wavelength	0.0221 meters	
Swath	1400 Kms	
Polarisation	HH	VV
One Way 3dB Foot Print (Az x El)	26.82 X 45.14 kms	29.68 X 68.49 kms
Scan Rate	20.5 rpm	
Antenna Diameter	1 meter	
Parameter	**Inner Beam**	**Outer Beam**
Beam width (Az X El)	1.47^0 X 1.62^0	1.39^0 X 1.72^0
Slant Range	1031 kms	1208 kms
$NE\sigma_0$	-29 dB	-27 dB
Transmit Power	100 W	
Transmit PRF for each beam (nominal)	96.5 Hz	
Transmit Pulse width	1.35 ms	
Transmit Modulation	LFM	
Transmit Chirp Bandwidth	400 kHz (negative Chirp)	
Receive Window	2.097 ms (4096 sample points)	
Window start time	6.675 ms	7.896 to 8.185 ms
Quantization	8 bits I + 8 bits Q (including sign bit)	
Sampling Frequency	1.953 MHz	
Elevation pointing (Inclusive of attitude error)	$\pm0.25^0$	
Attitude accuracy	0.1^0	
Altitude resilience with PRF of 200 Hz	702 Km to 725 Km without changing PRF	
Noise bandwidth	1245 KHz	
Processing bandwidth	305.175 KHz	
Measurement bandwidth	1.9073, 7.6292, 9.5365(nom.), 15.258 KHz	

4.0 Oceansat-II Scatterometer Data Products Specifications:

The basic product parameters of Oceansat-2 scatterometer are shown in Table (4.1) below.

Table 4.1: Scatterometer product parameters

Product	Level-2A	Level-2B	Level-3S (Sigma-0)	Level-3W (Wind)
Swath	1800 km	1800 km	Global	Global
Product definition	One revolution	One revolution	Full globe	Full globe
Cell size	50 X 50 km	50 X 50 km	0.5 X 0.5 deg	0.5 X 0.5 deg
Parameter	Sigma-0	Wind	Sigma-0	Wind
Accuracy				
NEσ_0	-29 dB inner -27 dB outer		-29 dB inner -27 dB outer	
Location	1 Cell	1 Cell	1 Cell	1 Cell
Wind speed		2 m/s		2 m/s
Wind Dir.		20^0		20^0

Figure (4.1) display the viewing geometry of Oceansat-2 scatterometer with an inner beam of HH polarization and outer beam of VV polarization.

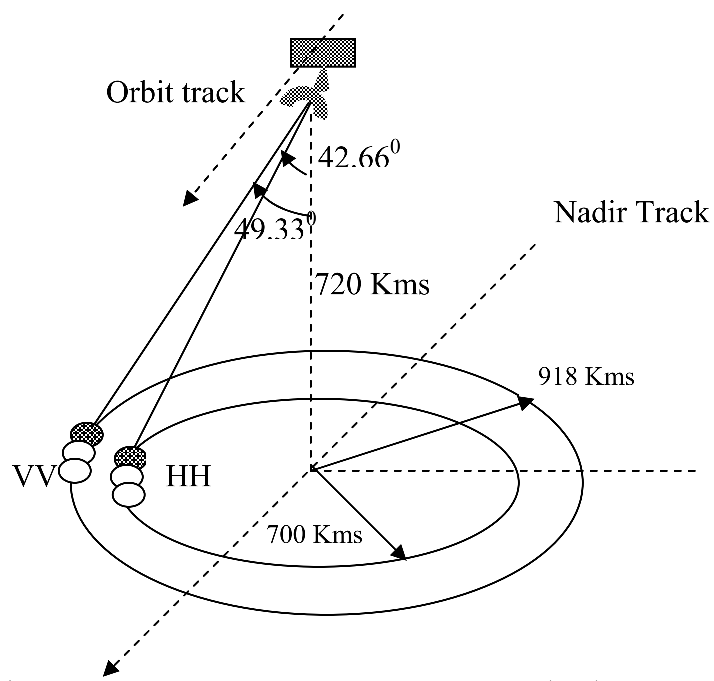

Figure 4.1: Oceansat-II Scatterometer Viewing Geometry

5.0 Algorithms Description :

5.1 Estimation of Sigma-0:

The total power received (P_r) by the scatterometer system consists of backscattered radiation P_b by target and additional noise introduced by the instrument electronics.

$$P_r = P_b + P_n \qquad \ldots(5.1)$$

The relation between normalized radar backscatter, σ_0 of an extended target and power transmitted and backscattered by the radar is written as

$$P_b = \frac{\lambda^2}{(4\pi)^3} \int_{area} \frac{P_t G^2 \sigma_0}{R^4} dA \qquad \ldots(5.2)$$

where the area is the illuminated area. Assuming σ_0 is constant over the footprint, we can relate the normalized radar backscatter to P_b in terms of a radar calibration parameter, X,

$$\sigma_0 = \frac{P_b}{X} \qquad \ldots(5.3)$$

where X is defined as

$$X = \frac{\lambda^2}{(4\pi)^3} \int_{area} \frac{P_t G^2}{R^4} dA \qquad \ldots(5.4)$$

For discrete case (which must be used for numerical integration), the integral form of radar equation mentioned above can be written as

$$P_b = \frac{\lambda^2}{(4\pi)^3} \sum_{i \in F} \frac{P_{ti} G_i^2 \sigma_0 \delta A_i}{R_i^4} \qquad \ldots(5.5)$$

where P_b is averaged received power, λ is wavelength, F is the illuminated area, P_{ti} is the power illuminating each incremental area δA_i, G_i is gain over each incremental area and R_i is slant range from satellite to each area.

Due to the instrument thermal noise and radar signal fading effects, the estimates of σ_0 will be noisy. A parameter commonly used to indicate the magnitude of the noise is K_p, which is defined as the normalized standard deviation of the echo return energy

$$K_p = \{Var[P_s]\}^{1/2} / \overline{P_s} \qquad \ldots(5.6)$$

K_p is a function of instrument signal processing parameters and the return signal-only to noise-only energy ratio (SNR). K_p for slice can be written as (Ref. 2):

$$K_p^2 = A + (B/SNR) + (C/SNR^2)$$
$$A = 1/B_sT_p$$
$$B = 2/B_sT_g$$
$$C = \frac{1}{B_sT_g}\sqrt{\left(1+\frac{B_s}{B_n}\right)}$$
$$SNR_s = X_s\sigma_{0s}/(T_gB_sN_0) \qquad \ldots(5.7)$$

where ,

B_s is bandwidth of the individual slices
B_n is bandwidth of the noise filter
T_p is Transmit pulse width
T_g is Range gate width
N_0 is Noise power spectral density

And for 3 dB footprint

$$A = 1/B_{3dB}T_p$$
$$B = 2/B_{egg}T_g$$
$$C = \frac{1}{B_{egg}T_g}\sqrt{\left(1+\frac{B_{egg}}{B_n}\right)} \qquad \ldots(5.8)$$

where,
B_{3dB} is 3 dB bandwidth of the egg
B_{egg} is sum of individual slice bandwidths comprising an egg

5.2 Geo-location algorithm:

The scatterometer antenna mounted on Oceansat-2 satellite rotates about yaw axis of satellite and scans the Earth with inner beam at a look angle of 42.66 deg and outer beam at a look angle of 49.33 deg with a radius of inner circle equal to 700 kms. and radius of outer circle equal to 918 kms. In order to geo-locate a footprint on the earth, it is required to know where the satellite look vector intersects the earth. In order to achieve this the basic co-ordinate system assumed is earth centered Cartesian coordinate system in which X-Y-Z axes coincide with the principle diameters of a spheroid which is used to model the body surface. The X and Y axes coincide with the two principle diameters of equal length while the Z axis will coincide with the third principle diameter. The equation of body surface (the Earth) is

$$\frac{X^2 + Y^2}{a^2} + \frac{Z^2}{b^2} = 1 \qquad \ldots(5.9)$$

where *a* is equatorial radius and *b* is polar radius of the earth. Knowing the satellite position vector **S**, the velocity vector **V**, satellite attitude in yaw, pitch and roll; the pointing direction **W** of antenna measured relative to the satellite axis and description of Earth surface, the location of footprint on the Earth can be computed.

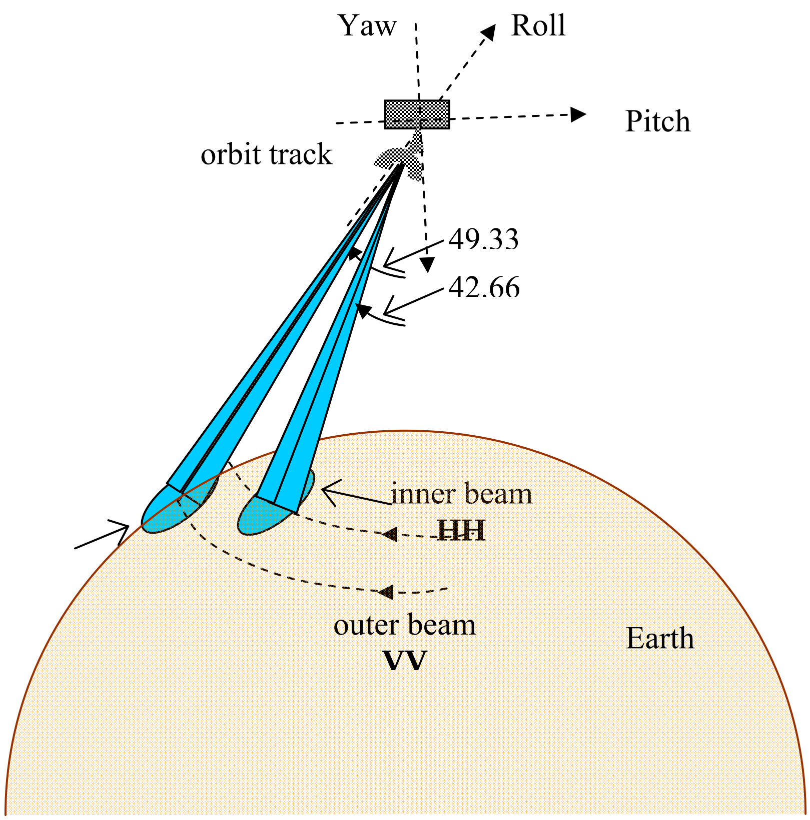

Figure 5.1: Relation between Earth , Satellite and footprint

Using the satellite position vector **S** and velocity vector **V**, we can define satellite coordinate system which is related to the basic coordinate system. The satellite coordinate system about which yaw, pitch and roll are measured is defined such that (Fig. 5.1) roll axis is taken to be coincident with the velocity vectory **V,** the pitch axis is taken to be **V** X **S**, which is normal to orbital plane and the roll axis, and the yaw axis is taken to be **V** X (**VXS**). Let the orientation of satellite axes relative to the Earth coordinate system is given by a orthogonal matrix D(c1,c2,c3) and let M represents the rotation matrix of the spacecraft axis due to yaw, pitch and roll, then the column vectors of the orthogonal matrix

$$\mathbf{F} = \mathbf{DM} \qquad \ldots(5.10)$$

are the directions of the spacecraft axis in the Earth coordinate system after a change in spacecraft attitude. If we define the rotations describing the scanner viewing direction in the spacecraft coordinate system similar to **M** and described it by **M'**, then the orthogonal matrix

$$\mathbf{G} = \mathbf{F}\,\mathbf{M'} \qquad \text{...(5.11)}$$

is a matrix of which third column is the unit vector describing the antenna viewing direction in the Earth coordinate system. Let **m'** be the third column of **M'**, i.e.,

$$\mathbf{m}' = \begin{pmatrix} \cos\psi\sin\phi\cos\theta + \sin\psi\sin\theta \\ \sin\psi\sin\phi\cos\theta - \cos\psi\sin\theta \\ \cos\phi\cos\theta \end{pmatrix} \qquad \text{...(5.12)}$$

where ψ,ϕ and θ are rotations about yaw, pitch and roll axis respectively.
Then, **g**, where

$$\mathbf{g} = \mathbf{F}\,\mathbf{m'} \qquad \text{...(5.13)}$$

is the unit vector representing the scanner line of sight in the Earth coordinate system. The intersection of **g** with the Earth surface is given by the vector **e**, where

$$\mathbf{e} = \mathbf{S} + u\mathbf{g} \qquad \text{...(5.14)}$$

The parameter u represents the distance from sensor to the intersect point and is given by

$$u = \frac{-B - \sqrt{B^2 - AC}}{A} \qquad \text{...(5.15)}$$

where

$$\begin{aligned} A &= b^2(g_x^2 + g_y^2) + a^2 g_z^2 \\ B &= b^2(p_x g_x + p_y g_y) + a^2 p_z g_z \\ C &= b^2(p_x^2 + p_y^2) + a^2(p_z^2 - b^2) \end{aligned} \qquad \text{...(5.16)}$$

The resulting location vector **e** (e_x,e_y,e_z) can be converted to geocentric latitude ϕ_c and longitude λ by

$$\varphi_c = \tan^{-1}\left(\frac{e_z}{\sqrt{e_x^2 + e_y^2}}\right) \qquad \text{...(5.17)}$$

$$\lambda = \tan^{-1}\frac{e_y}{e_z} \qquad \text{...(5.18)}$$

and the geodetic map latitude is given by

$$\varphi = \tan^{-1}(\frac{a^2}{b^2})\tan\varphi_c \qquad \text{...(5.19)}$$

5.3 Footprint and Slices :

The scatterometer system transmits a modulated chirp signal for inner and outer beam at specified interval of time depending on PRF. Due to the motion of spacecraft the returned signal experiences a Doppler shift. The doppler shift experienced by the signal consists of shift due to azimuth position of antenna, earth rotation and attitude. During on board processing the doppler compensation due to azimuth position will be corrected, however there will be no correction for earth rotation and attitude but sufficient receiver bandwidth is provided to receive the returned signal.

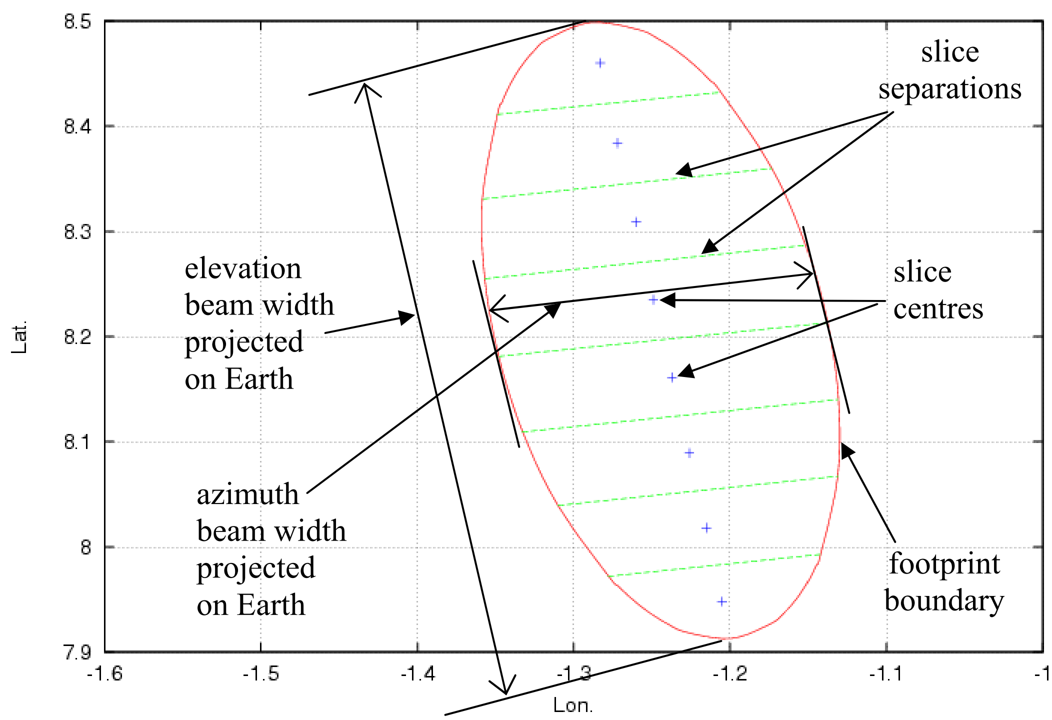

Figure 5.2:A typical footprint and slices with slice centers

Fig. (5.2) displays a typical footprint and slices on earth surface with azimuth and elevation beam widths. The received signal will be de-chirped and range compressed. The post de-ramped bandwidth for inner and outer beam footprints is about 68 KHz and 110 KHz respectively. Considering margin for earth doppler and other errors, total processing bandwidth of 250 KHz is kept. The range compressed sliced power data is sent to ground for further processing. The no. of data samples corresponding to the footprint will vary depending on bandwidth of slice chosen. Due to earth and attitude doppler, the data corresponding to a particular footprint will shift left or right from nominal position within total bandwidth range.

On ground using orbit and attitude information; doppler centroid and bandwidth of footprint is computed. The formulation to compute doppler frequency is given by

$$f_d = -\frac{2}{\lambda R}(\mathbf{R_s} - \mathbf{R_e})(\mathbf{V_s} - \mathbf{V_t}) \qquad \ldots(5.20)$$

where R_s ,R_e and V_s, V_t are spacecraft and target position and velocity vectors respectively. The spectral peak of slice data which corresponds to the doppler centroid is found out from the data and around this no. of slices corresponding to the bandwidth of footprint are extracted. For each slice, extreme points of slice and slice center, slice area are computed and also footprint center as well as footprint area is worked out. Each slice is divided into number of cells and then X factor (eq. 5.4) and sigma-0 is computed over slice by using on-board calibration information, range for each cell and antenna gain information. Sigma-0 and K_p for footprint is computed using sigma-0 information at slice level.

5.4 Land-Sea Flagging:

The scatterometer measures radar back scatter σ_0 over total earth surface. A Geophysical Model Function derives wind velocity from back scatter observations. The model requires the observations to be in pure sea region only. Hence, we need a mechanism to classify location of observation to be as sea or land area. Global land-sea Information is available on internet in form of polygons at *0.2 kms* resolution. A global database having Land-Sea marking at *5 kms* resolution is generated using this information. The scatterometer footprint and slice orientation changes with orbit and scan position. Each slice is identified with its corners and slice center. Using global database, each slice of a footprint is marked for land sea information. If all the slices of a footprint fall in sea, the footprint is marked to be in sea. Thus, a slice or footprint is marked to be in sea area only if it totally falls in sea. This ensures reliable land sea marking.

5.5 Azimuth and Incidence angle :

For every slice and footprint as well as every element of grid data of Level-2A product, incidence angle and azimuth angle is computed. Following figure explains geometry for the same.

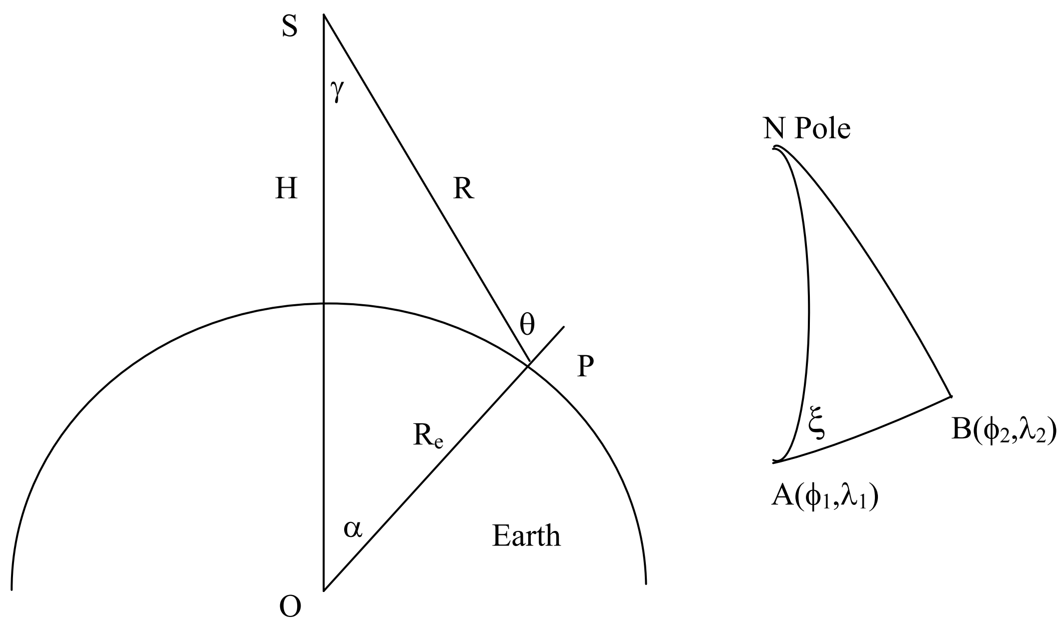

Figure 5.3: Computation of incidence angle and azimuth angle

From above figure we can write following expression to get incidence angle θ and azimuth angle ξ

$$\frac{Sin\gamma}{R_e} = \frac{Sin\alpha}{R} = \frac{Sin\theta}{H} \qquad \ldots(5.21)$$

$$R^2 = H^2 + R_e^2 - 2HR_e \cos\alpha \qquad \ldots(5.22)$$

$$\tan\xi = \frac{\cos\phi_2 \sin(\lambda_2 - \lambda_1)}{[\cos\phi_1 \sin\phi_2 - \sin\phi_1 \cos\phi_2 \cos(\lambda_2 - \lambda_1)]} \qquad \ldots(5.23)$$

5.5 Grid Generation :

Generation of wind vector information requires scatterometer sigma-0 information of a foot print of a sea region to be obtained at multiple azimuth angles. This is achieved by inner and outer beam scanning (Fig.5.1). These multiple acquisitions of the same area with different azimuth angles are used by Geophysical Model Function to derive wind vector information. To co-locate multiple observations over an orbit, a grid is generated at fixed interval over the swath acquired by Oceansat-2 scatterometer (Fig.5.4). To generate the grid, above mentioned geo-location algorithm, satellite position and velocity information are used to get sub-satellite point information at desired grid interval (50 kms.). Let $S_1(x_1, y_1, z_1)$ be a sub-satellite point at any instance of time on the earth surface as well as on the orbital plane. There is another plane which is perpendicular to the orbital plane and passing through origin *O* and sub-satellite point S_1(Fig.5.5). This plane is named as P and n_p is normal vector to the plane. There is intersection of this plane P and ellipsoidal earth which results in a *great circle*. All the grid points on plane P are computed on both sides from point S_1. These points are on the arc of the said great circle which is perpendicular to the orbital plane. Having obtained required *great circle plane P*, the next step is to find points on the earth surface which are on the same *great circle* with desired distance from point S_1. (Fig. 5.4).

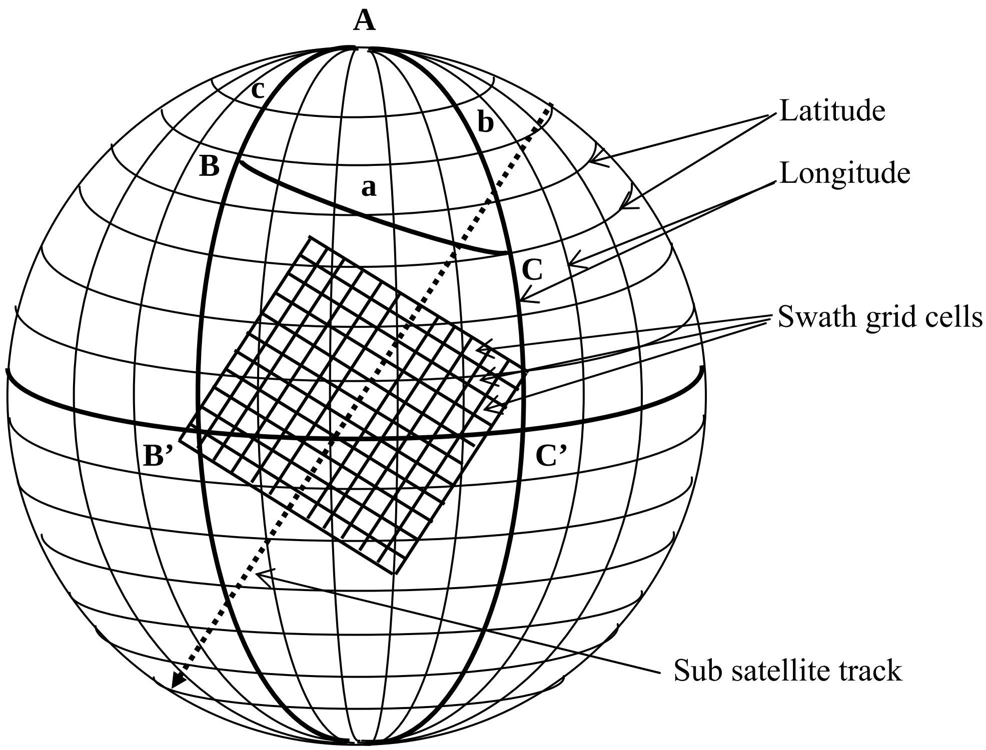

Figure 5.4: Earth spherical geometry & sub-satellite track grid

Using the latitude and longitude information derived for each footprint center for all fore and aft foot prints, they are assigned to respective grid cells along with incidence angle and azimuth angle information. Geophysical Model Function is used along with grid sigma-0 data to derive wind information at fixed grid interval over the swath.

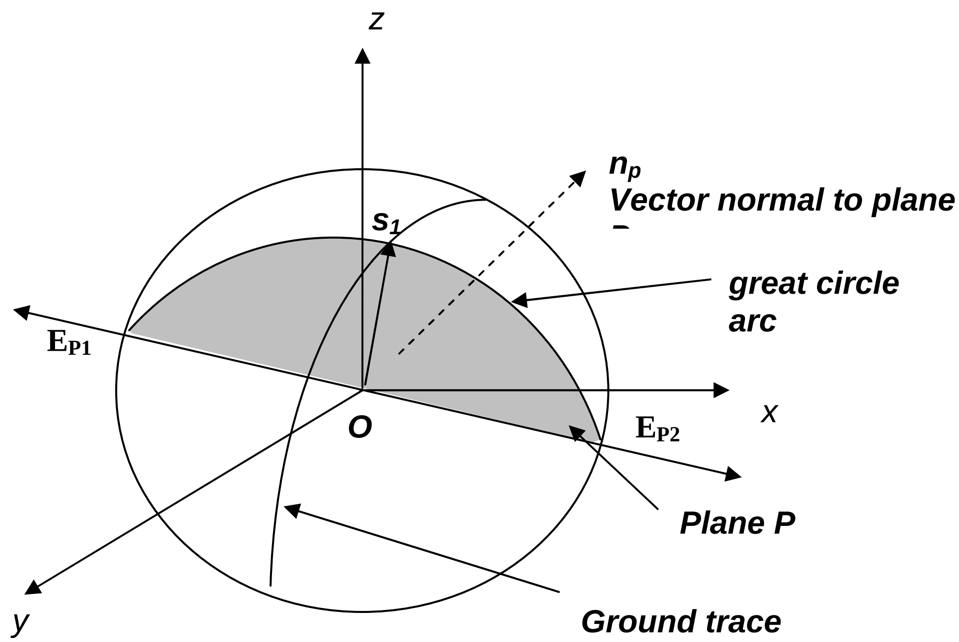

Figure 5.5: Ground trace and plane perpendicular to the ground trace

5.6 Brightness Temperature Estimation :

For Oceansat-2 Scatterometer, there was no provision to carry pre launch laboratory experiments to derive calibration parameters for converting noise data into brightness temperature data. Instrument measured cold and hot counts are not available as in traditional radiometers. The brightness temperature from QuikSCAT Level 1B product have been used to derive initial brightness temperature values by inter comparisons. The noise data derived from Oceansat-2 Scatterometer and the QuikSCAT brightness temperature data are analyzed. The statistical nature of noise and brightness temperature for ocean & land region have been studied and conversion factors are derived.

6.0 Levels of Data Products:

The data received by scatterometer is compressed onboard and sent to ground. After formatting of sensor data by NRSC software element and post facto orbit information generation by ISAC software element, sensor and orbit data is fed to Data Products Generation System. The data is separated revolution wise before processing for subsequent levels. The final products are wind and sigma-0 products at fixed grid interval over a revolution and global.

Level 1B:

The task of this level is to generate σ_0 at slice level (and then compositing it at footprint level) using sensor and OAT data. The two data sets (sensor and OAT) are first synchronized in time using derived time information. For each footprint, satellite position, velocity, attitude and other information is obtained from OAT data and footprint is located on the Earth's surface. Received power and noise data is available in sensor data format for all the slices of a footprint. Using these values, σ_0 , *SNR & Kp* are computed for each slice. Also, slices are marked for land-sea information. Using slice information; σ_0, *SNR* and *Kp* values at footprint level is also generated. Similarly, footprints are also marked for land-sea information based on marking of slices. Footprints are also marked for sea-ice information. Final scan mode output is written in binary format. This product is an internal product which will become input for Level-2A product. This product can also be used for DQE purpose.

Level 2A:

Input to this level processor is scan mode σ_0. The processor co-locates various fore and aft observations in swath grid cells and outputs σ_0 in swath grid. For each orbit, sub satellite points at fixed grid interval *(50 kms)* can be obtained using satellite ephemeris information. Using outer beam swath information, extreme points of swath corresponding to these sub satellite points are obtained. The intermediate points of swath grid are obtained using viewing geometry and earth ellipsoid information. Thus, swath grid for each orbit is formed.

Each σ_0 observation is classified (as outer fore, outer aft, inner fore or inner aft) and assigned to a grid cell based on its latitude and longitude information. The Level-2A output is written in HDF. This product is used as input for wind information generation. This product will be provided to selected users only. This product is also used as input for global σ_0 generation.

Level 2B:

This level takes σ_0 in swath grid as inputs along with other wind model related information and generates wind vectors in the same swath grid. Co-located σ_0 observations of Level-2A along with *Geophysical Model Function (GMF)* are used to generate wind vector information corresponding to each cell of swath grid. Wind vectors are marked for sea-ice and rain flags. The output generated for every orbit is provided in HDF format on internet and is freely available to users.

Level 3 (wind & sigma0):

A global grid is defined at *0.5°* interval. Data obtained from Level 2B swath grid is assigned to global grid based on nearest neighborhood criteria. If two or more observations from different swath grids are encountered for single grid cell, previous information is replaced by the latest one. If multiple wind vectors from same swath grid are encountered, wind vector closest to the grid cell centre is used. Ascending and descending vectors are stored in same file in different fields. Level 3 wind vector product is provided to users freely on internet in HDF. Similarly, Level 3 sigma-0 product at *0.5°* interval is obtained from Level 2A output. All sigma-0 measurements (forward and aft looking) for each polarization and falling within a grid cell are averaged. A separate product is generated for each polarization. This product also is available to users freely on internet in HDF.

6.1 Data Volumes:

Input sensor data volume will depend on slice mode chosen. The sensor data volume for nominal slice bandwidth of *9.54* KHz and at a PRF of *196 Hz* will be *240.0 MB*. With *451 bytes* per second, OAT data volume for one revolution will be *2.58 MB*. Payload data format and OAT data format are described elsewhere in the document. Size of Level 1B product varies depending on the slicing mode chosen. Sizes for different levels are mentioned in the table 6.1 below:

Table 6.1: Data Volumes for different level products

Level	1 rev.	12hr.	24hr.
Sensor data (BW=1.91 kHz)	526.91 MB	3.70 GB	7.41 GB
Sensor data (BW=9.54 kHz)	239.91 MB	1.69 GB	3.37 GB
Sensor data (BW=15.26 kHz)	213.00 MB	1.50 GB	3.00 GB
Sensor data (BW=7.62 kHz)	257.85 MB	1.81 GB	3.63 GB
1B (BW=1.91 kHz)	1871.15 MB	13.16 GB	26.31 GB
1B (BW=9.54 kHz)	418.22 MB	2.94 GB	5.88 GB
1B (BW=15.26 kHz)	274.72 MB	1.93 GB	3.86 GB
1B (BW=7.62 kHz)	507.9 MB	3.57 GB	7.14 GB
For 50 km grid			
2A	83.33 MB	0.59 GB	1.17GB
2B	1.64 MB	11.81 MB	23.62MB
3W	2. 97 MB	2. 97 MB	2. 97 MB
3S	3.96 MB	3.96 MB	3.96 MB

6.2 File naming conventions:

Filename conventions for various levels of data products are mentioned below:

- Sensor data file (revolution wise):
  S1SDFYYYYDDD_NNNNN_MMMMM .STN
- Orbit data file (revolution wise):
  S1OATYYYYDDD_NNNNN_MMMMM .STN
- Level 1B: S1L1BYYYYDDD_NNNNN_MMMMM.dat
- Level 2A: S1L2AYYYYDDD_NNNNN_MMMMM.dat
- Level 2B: S1L2BYYYYDDD_NNNNN_MMMMM.dat
- Level 3: S1L3PPYYYYDDD.dat

where:

- STN: Indicates Station identification where data is acquired
- L$: Indicates Level of product
- YYYY: The calendar year when data was acquired
- DDD: The day of the year when data was acquired
- NNNNN: satellite orbit no. at start of revolution
- MMMMM: satellite orbit no. at end of revolution
- PP: Indicator of wind(WW) or sigma0(SV or SH) product

The date *1st January 2007* corresponds to day number *1*, and *31st December 2007* corresponds to day number *365*. Using this convention, product names for *31st December 2007* and orbit no. *12345* will be as shown in Table 6.2. Level-1B, 2A and 2B products are defined revolution wise (north pole to north pole) while Level-3W and 3S are global grid (0.5 deg) products.

Table 6.2: File naming convention for Oceansat-2 Scatterometer

Product Level	Product File Name
Sensor data file (revolution wise)	S1SDF2007365_12345_12346.SAN
Orbit data file (revolution wise)	S1OAT2007365_12345_12346.SAN
Level 1B	S1L1B2007365_12345_12346.dat
Level 2A	S1L2A2007365_12345_12346.dat
Level 2B	S1L2B2007365_12345_12346.dat
Level 3 Wind	S1L3WW2007365.dat
Level 3 v-pol sigma0	S1L3SV2007365.dat
Level 3 h-pol sigma0	S1L3SH2007365.dat

6.3 Formats for data products:

6.3.1 Parameters list for Level-1B products in HDF-5

This section describes parameters list for various output products. Table 6.3.1 describes the structure for Level 1B header record.

Table 6.3.1: Level-1B header structure

No.	ElementName	Num Bytes	Storage Format	No.	ElementName	Num Bytes	Storage Format
1	ProductIdentification	129	string	17	EphemerisType	17	string
2	OrganizationName	17	string	18	ProductionDate	22	string
3	SatelliteName	17	string	19	SkipStartTime	5*22	string
4	SensorName	17	string	20	SkipStopTime	5*22	string
5	DataFormatType	17	string	21	SkipStartScan	5*5	4d
6	DataFormatVer	17	string	22	SkipStopScan	5*5	4d
7	ProcessorVer	17	string	23	PRF	5	4d
8	EquatorCrossingLongitude (Descending)	9	8.3f	24	L1bActualScans	5	4d
9	EquatorCrossingDate	22	string	25	SliceSize	9	8.3f
10	OrbitPeriod	9	8.3f	26	LatScale	9	8.6f
11	OrbitInclination	9	8.3f	27	LonScale	9	8.6f
12	OrbitSemiMajorAxis	9	8.3f	28	IncAngleScale	9	8.6f
13	OrbitEccentricity	9	8.6f	29	AziAngleScale	9	8.6f
14	RevNumber	12	string	30	Sigma0Scale	9	8.6f
15	RangeBeginningDate	22	string	31	SNRScale	9	8.6f
16	RangeEndingDate	22	string	32	xfactorScale	9	8.6f
				33	BrightnessTemperatureScale	9	8.6f

Table 6.3.2 describes the structure for output parameters of Scan Header.

Table 6.3.2: Output parameters : Scan header

Element Name	Storage Type	Num Bytes
ScanStartTime	char	22
ScanNumber	uint16	2
NumFootprints	uint16	2

Level 1B output parameters at footprint level are described in Table 6.3.3.

Table 6.3.3: Output parameters at footprint level for Level-1B product		
Element Name	Storage Type	Num Bytes
FootprintNumber	uint16	2
Latitude	int16	2
Longitude	uint16	2
IncidenceAngle	int16	2
AzimuthAngle	uint16	2
DopplerFreq	float32	4
Range	float32	4
Sigma0	int16	2
Kp	float32	4
SNR	int16	2
XFactor	int16	2
Kpa	float32	4
Sigma0Flag	uint16	2
NumEleSlices	uint8	1
Brightness Temperature	uint16	2

Table 6.3.4 describes Level 1B output parameters at slice level.

Table 6.3.4: Output parameters for Level-1B at slice level		
Element Name	Storage Type	Num Bytes
SliceNumber	uint16	2
Latitude	int16	2
Longitude	uint16	2
IncidenceAngle	int16	2
AzimuthAngle	uint16	2
DopplerFreq	float32	4
Range	float32	4
Sigma0	int16	2
Kp	float32	4
SNR	int16	2
XFactor	int16	2
Sigma0Flag	uint16	2
Brightness Temperature	uint16	2

6.3.2 Parameters list for Level-2A products in HDF-5

Table 6.3.5 describes Level 2A header record structure.

Table 6.3.5: Level-2A header record							
No.	ElementName	Num Bytes	Storage Format	No.	ElementName	Num Bytes	Storage Format
1	ProductIdentification	129	string	16	RangeEndingDate	22	string
2	OrganizationName	17	string	17	EphemerisType	17	string
3	SatelliteName	17	string	18	ProductionDate	22	string
4	SensorName	17	string	19	SkipStartTime	5*22	string
5	DataFormatType	17	string	20	SkipStopTime	5*22	string
6	DataFormatVer	17	string	21	*L2aActualWVCRows*	5	4d
7	ProcessorVer	17	string	22	*L2aActualWVCCells*	5	4d
8	EquatorCrossingLongitude (Descending)	9	8.3f	23	*WVCSize*	9	8.3f
9	EquatorCrossingDate	22	string	24	LatitudeScale	9	8.6f
10	OrbitPeriod	9	8.3f	25	LongitudeScale	9	8.6f
11	OrbitInclination	9	8.3f	26	IncAngleScale	9	8.6f
12	OrbitSemiMajorAxis	9	8.3f	27	AziAngleScale	9	8.6f
13	OrbitEccentricity	9	8.6f	28	Sigma0Scale	9	8.6f
14	RevNumber	12	string	29	SNRScale	9	8.6f
15	RangeBeginningDate	22	string	30	BrightnessTemperatureScale	9	8.6f

Level 2A output parameters are provided in Table 6.3.6.

Table 6.3.6: Output parameters for Lev-2A product		
Element Name	Storage Type	Num Bytes
WVCRowTime	char	22
RowIndex	uint16	2
NumSigma0PerRow	int16	2
NumSigma0PerCell	int16	2
LatitudeFootprint	int16	2

LongitudeFootprint	uint16	2
IncidenceAngle	int16	2
AzimuthAngle	uint16	2
Sigma0	int16	2
SNR	int16	2
KpA	float32	4
KpB	float32	4
KpC	float32	4
Sigma0QualFlag	uint16	2
CellIndex	uint8	1
Brightness Temperature	uint16	2

6.3.3 Parameters list for Level-2B products in HDF-5

Table 6.3.7 provides Level 2B header record structure.

Table 6.3.7: Lev-2B header structure

No.	ElementName	Num Bytes	Storage Format	No.	ElementName	Num Bytes	Storage Format
1	ProductIdentification	129	string	18	ProductionDate	22	string
2	OrganizationName	17	string	19	SkipStartTime	5*22	string
3	SatelliteName	17	string	20	SkipStopTime	5*22	string
4	SensorName	17	string	21	*L2bActualWVC Rows*	5	4d
5	DataFormatType	17	string	22	*L2bActualWVC Cells*	5	4d
6	DataFormatVer	17	string	23	*WVCSize*	9	8.3f
7	ProcessorVer	17	string	24	LatitudeScale	9	8.6f
8	EquatorCrossingLongitude (Descending)	9	8.3f	25	LongitudeScale	9	8.6f
9	EquatorCrossingDate	22	string	26	ModelSpeedScale	9	8.6f
10	OrbitPeriod	9	8.3f	27	ModelDirScale	9	8.6f
11	OrbitInclination	9	8.3f	28	WindSpeedScale	9	8.6f
12	OrbitSemiMajorAxis	9	8.3f	29	WindDirScale	9	8.6f
13	OrbitEccentricity	9	8.6f	30	CostFunctionScale	9	8.6f
14	RevNumber	12	string	31	WindSpeedSelScale	9	8.6f
15	RangeBeginningDate	22	string	32	WindDirSelScale	9	8.6f
16	RangeEndingDate	22	string				
17	EphemerisType	17	string				

Level 2B output parameters are provided in Table 6.3.8.

Table 6.3.8: Lev-2B product parameters		
Element Name	Storage Type	Num Bytes
WVCRowTime	char	22
RowIndex	uint16	2
Latitude	int16	2
Longitude	uint16	2
ModelSpeed	int16	2
ModelDir	uint16	2
NumAmbigs	int8	1
WindSpeed	int16	2
WindDir	uint16	2
CostFunction	uint16	2
WVCSelection	int8	1
WindSpeedSelection	int16	2
WindDirSelection	uint16	2
CostFunctionSelection	uint16	2
WVCQualFlag	uint16	2

6.3.4 Parameters list for Level-3 products in HDF-5

Table 6.3.9 describes Level 3 header record structure.

Table 6.3.9: Lev-3 Header Record							
No.	ElementName	Num Bytes	Storage Format	No.	ElementName	Num Bytes	Storage Format
1	ProductIdentification	129	string	13	ProductionDate	22	string
2	OrganizationName	17	string	14	*StartRevNumber*	12	string
3	SatelliteName	17	string	15	EndRevNumber	12	string
4	SensorName	17	string	16	StartRevTime	22	string
5	DataFormatType	17	string	17	EndRevTime	22	string
6	DataFormatVer	17	string	18	L3WVCRows	5	4d
7	ProcessorVer	17	string	19	L3WVCCells	5	4d
8	EquatorCrossingLongitude (Descending)	16*9	8.3f	20	*WVCSize*	9	8.3f
9	EquatorCrossingDate	16*22	string	21	ProdTypeIndicator	11	string
10	OrbitInclination	9	8.3f	22	WindSpeedScale	9	8.6f
11	OrbitSemiMajorAxis	9	8.3f	23	WindDirScale	9	8.6f

12	OrbitEccentricity	9	8.6f	24	Sigma0Scale	9	8.6f
				25	Sigma0stddevscale	9	8.5f

Level 3 output parameters for wind and sigma-0 products are described in Tables 6.3.10(a) and 6.3.10(b) respectively.

Table 6.3.10(a): Parameters for Wind product (Level-3W)

Element Name	Storage Type	Num Bytes
AscWindSpeed	int16	2
AscWindDir	uint16	2
AscWindQualFlag	uint16	2
DesWindSpeed	int16	2
DesWindDir	uint16	2
DesWindQualFlag	uint16	2

Table 6.3.10(b): Parameters for Sigma-0 product (Level-3S)

Element Name	Storage Type	Num Bytes
Sigma0	int16	2
Sigma0QualFlag	uint16	2
Std. dev. Sigma0	int16	2
No.points averaged	int16	2

Information provided by sigma-0 quality flag is provided in Table 6.3.11.

Table 6.3.11: Sigma-0 quality flag information (slice/footprint)

Bit position	Bit value=1 indicates	Bit value=0 indicates
0 (LSb)	Asc	Des
1	Outer	Inner
2	Fore	Aft
3	Land	Sea
4	σ_0 is poor	σ_0 is ok
5	kp is poor	kp is ok
6	Invalid footprint	Valid footprint
7	Footprint contains saturated slice	Footprint does not contain saturated slice
8	Mixed Data flag (Land, water & Ice- any combination)	No Mixed data
9	Negative Sigma-0	No negative sigma-0
10		
11		

12		
13	Ice as per climatology and ocean as per sigma0 data	No ice
14	Ice as per climatology and sigma0 data	No ice
15(MSb)	No sigma0 data and ice flag reproduced from climatology data	No ice

Table 6.3.12 provides information provided by wind quality flag.

Table 6.3.12: Wind Quality flag information			
Bit Number	Related Parameter	Bit Value	Significance
1(LSb)	Rain-Flag	0	Rain-flagging not attempted
		1	Rain-flagging attempted
2		0	Rain-free
		1	Rain present /doubtful
3	Ambiguity Filter	0	Model data available
		1	Model data not available
4		0	Amb filtered using model
		1	Amb filtered without model
5		0	Sufficient neighbors
		1	insufficient neighbors, ambiguity not filtered
6	Vector quality	0	Retrieval attempted
		1	Retrieval aborted due to poor quality or insufficient sigma0 data
7		0	Quality is good
		1	Winds out of range or no solutions
8		0	Quality good wrt to rain
		1	High winds, possibly rain contamination
9	surface	0	Pure ocean
		1	Other surfaces (retrieval aborted)
10	Atmospheric Correction	0	Correction data available
		1	Correction data not available
11-16(MSb)	Spares		

6.4 Meta data file format

A metadata file in parameter=value form as in Table 6.4.1 shall be provided along with each product. Also browse images shall be generated in suitable image format (i.e. jpg) for all levels of products.

Table 6.4.1: Meta data file format		
Parameter name	**Value**	**Example**
Satellite name	OS2	Satellite_name=OS2
Sensor	SCAT	Sensor=SCAT
Start_Revolution_Number	XXXXX_YYYYY	Start_Revolution_Number= 00013_00014
End_Revolution_Number	XXXXX_YYYYY	End_Revolution_Number= 00013_00014
Product_type	1B, 2A, 2B, 3SV, 3SH, 3WW	Product_type=1B
Year_day_number	YYYYDDD	Year_day_number=2009204
Date_of_pass	DDMMMYYYY	Date_of_pass=23JUL2009
Extension	meta	Extension=meta

6.5 Mapping of Grid cells of Level-3S & 3W to Latitude and Longitude on earth:

Figure 6.1 demonstrates the correspondence between physical latitude (-90 to +90) to row cells (0 to 360)and longitude (0 to 360) to column cells (0 to 720) for 50 km grid of Level-3 (Sigma-0 VV & HH and Wind) products. In the figure, product boundaries in terms of cell no. are shown in blue colour and corresponding latitude/ longitude are in red colour.

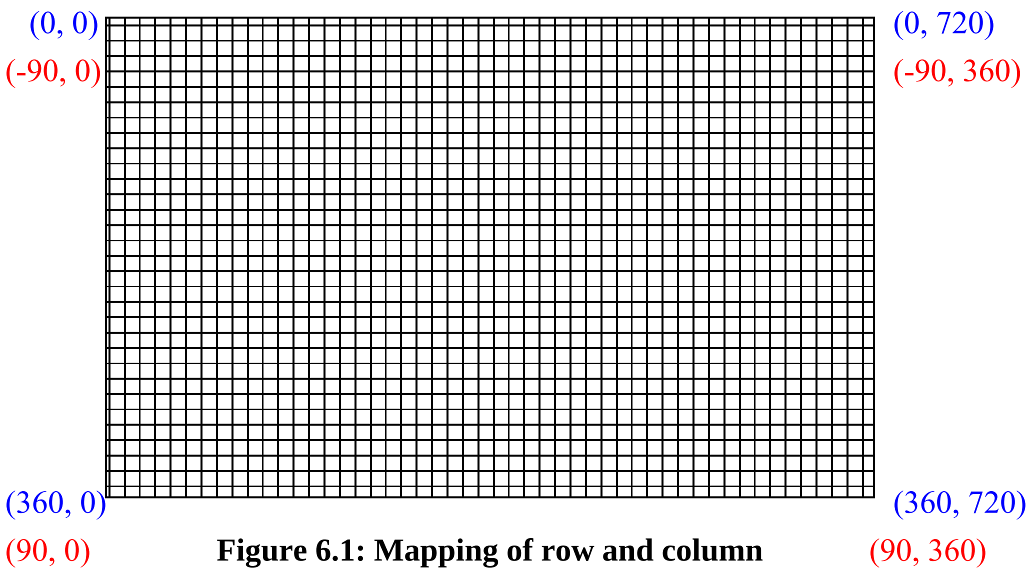

Figure 6.1: Mapping of row and column cell numbers to latitude and longitude

7.0 Data Processing Scenario:

The data processing software for scatterometer payload of Oceansat-2 has been operationlised at NRSC, Hyderabad. DP software needs to meet the operational requirements. For Scatterometer DP, the basic product definition is over a revolution and it being a global mission, all the acquired data will be processed routinely. Functions of DP software are listed below:

- Get data ingest information
- Perform systematic/emergency processing of ingested data
- Display various products/parameters
- Archive products on media/Internet upload
- Generate processing reports
- Generate log of errors/exceptions encountered during processing

Onboard compressed sensor data undergoes various levels of processing to finally generate global wind and sigma-0 products. Each level generates an output which is input for subsequent levels of processing. Various levels and output at each level are shown in Figure (7.1). Every Level-2B product will be put on Internet as a user product as soon as it is generated. Level-3 product is updated after every orbit is processed. All user products will be provided in HDF (Hierarchical Data Format). Level-2A product will be provided to selected users.

The onboard compressed and recorded data is downloaded twice in a day at Shadnagar. The output of NRSC Level-0 in a specified format, along with OAT + Derived time information is input for Scatterometer Data Products (SCAT-DP) software. OAT+ Derived time and SCAT Sensor data will be transferred to local disk of operational data products generation system at NRSC either through network or media.

In case of emergency data the processing chain is same as that of systematic processing except that data of emergency request is to be given priority by suspending/terminating systematic processing.

There is a provision to acquire raw mode data along with on-board compressed data. This mode of acquisition will be exercised for checking system performance and will be occasional.

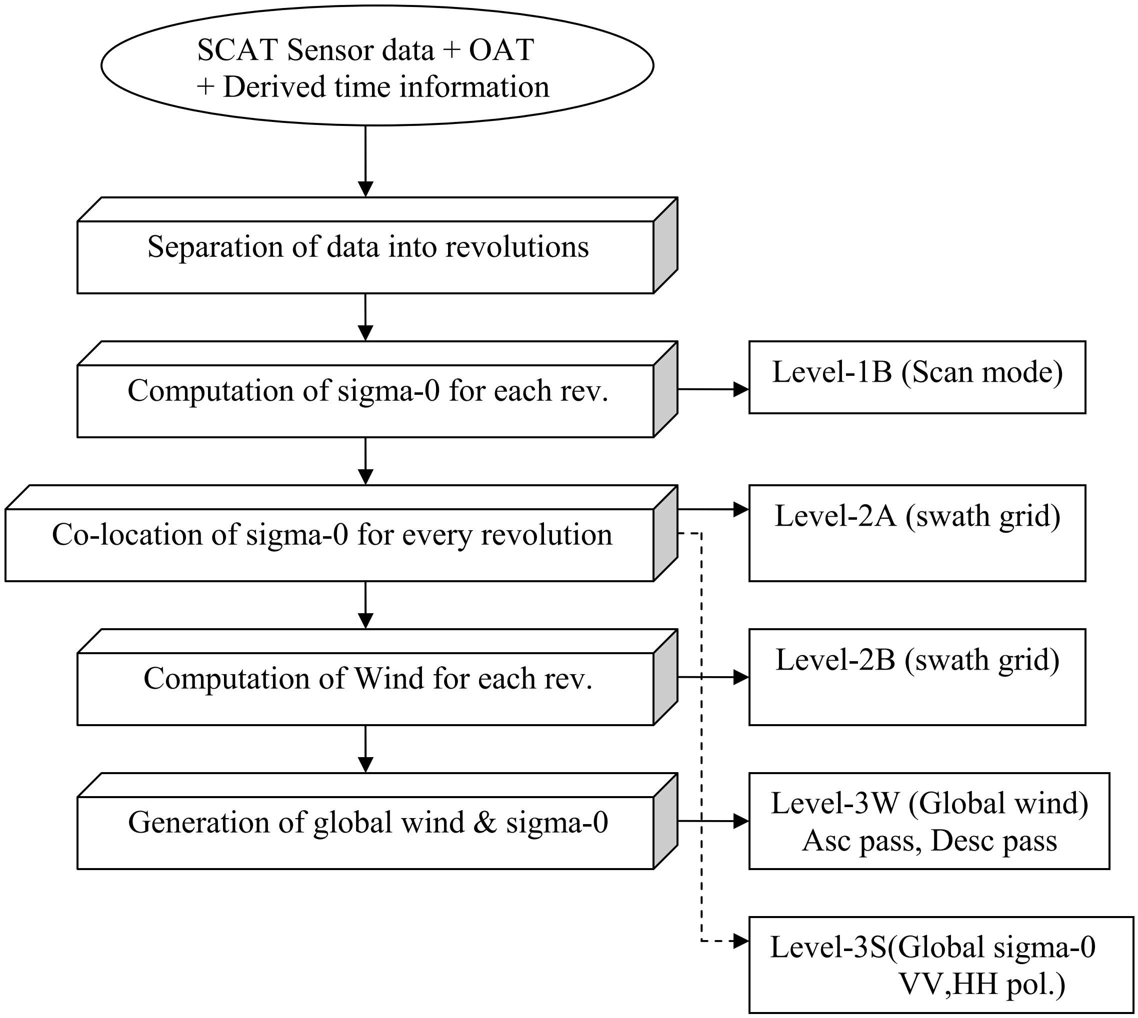

Figure 7.1: SCAT-DP: Different levels of processing

To improve turn around time, it is planned to download data at International Ground Station and transfer formatted data along with OAT information to NRSC through network. The processing scenario at NRSC and at other ground stations is shown in figure (7.2). For the same revolution, there can be multiple portions downloaded at multiple stations. These portions need to be stitched together to generate data products for the full revolution. This handling will be done by SAC DP software.

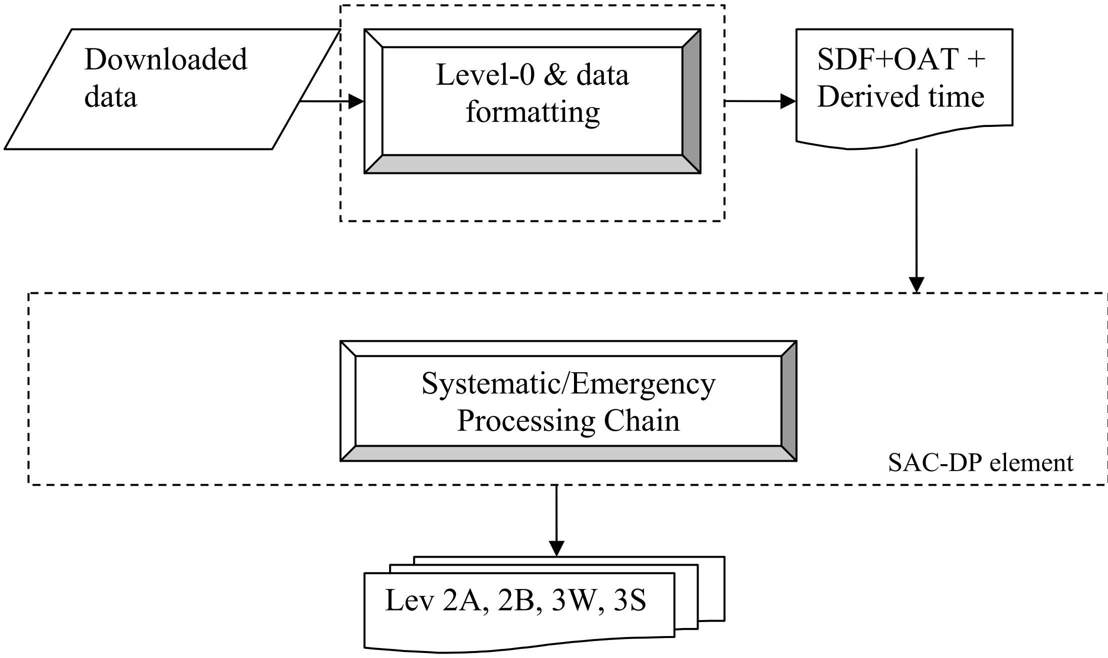

Fig 7.2(a) SCAT Data Processing at NRSC

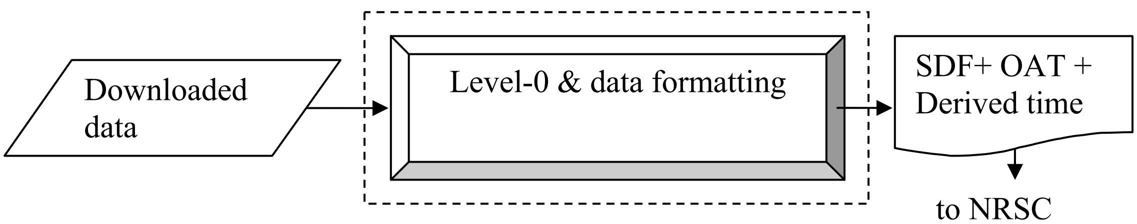

Fig 7.2(b) Data reception at IGS

SCAT-DP software at NRSC caters to the following requirements at a broad level

1) Systematic, Emergency processing
2) Generate various levels of data products (sigma-0 and wind) within a particular time duration and
3) Provide graphical interfaces to the operator to realize data processing.

For Scatterometer DP, the basic product definition is over a revolution and it being a global mission, all the acquired data will be processed routinely. DP generation will use, along with data, information acquired from Internet pertaining to similar mission or related parameters. Time estimate to process one orbit data from onboard compressed data to final sigma-0 and wind products is around 30 minutes. Total data volume per day is 14/15 orbits. It has been planned to process data using 4-CPU computer system. Multiple orbits will be simultaneously processed on this system and a Scheduler will control execution of various processes on multi-CPU machine along with a user-friendly operator interface.

7.1 Target system for operational DP generation:

Based on turn-around time requirements and data volumes, it becomes necessary to process multiple orbits simultaneously. Hence, a multi-CPU system has to be used. Table (7.1) highlights the salient features of the computer system finalized for operational Scatterometer DP generation.

Table (7.1): Target computer system for SCAT-DP

Processor	4-CPU System Intel Xeon E7310 Quad core processor (1.6 GHz)
OS	Red Hat Linux Enterprise Advanced Server Licensed Version (with media)
RAM	16 GB Main memory expandable to 128 GB
Ports	1 Serial , 1 Parallel and 2 USB ports
Graphics	Graphics card with 128 MB memory
HDD	1 TB hard disk space(10K RPM)
CD/DVD Writer	Slimline DVD writer
Monitor	LCD (24 ”)
Software/Compilers	JDK, C/C++, Fortran 90

8.0 References:

1. Scatterometer Data Products System preliminary design review document, August 2007.
2. Scatterometer Data Products System detailed design review document, February 2009.