

SEASONAL OSCILLATIONS OF THE SUBTROPICAL CONVERGENCE BETWEEN  
THE BRAZIL AND MALVINAS CURRENTS, USING OCEANOGRAPHIC AND  
SMS-2 SATELLITE DATA

Sueli Susana de Godoi<sup>1</sup> and Merritt Raymond Stevenson<sup>2</sup>  
Instituto de Pesquisas Espaciais - INPE/CNPq  
12200 - São José dos Campos, SP., Caixa Postal 515 Brazil

ABSTRACT

A study of seasonal variations of the Subtropical Convergence (S.C.) between the Brazil Current and Malvinas (Falkland) Current, located in the study area between 25°S and 45°S and 45°W and 65°W, is presented. Oceanographic and SMS-2 data were utilized for this purpose. Maps of the surface distributions of temperature and salinity were made using oceanographic data. Thermal infrared images were received from the VISSR system aboard the SMS-2 satellite. These data were automatically interpreted on the computerized IMAGE 100 System at INPE. The satellite data were compared with a Gaussian Model in order to better evaluate thermal distributions. Where oceanographic data were available for comparison with SMS-2 data, the S.C. was located at or near the same position. The SMS-2 satellite data indicated, in the period of January 1980 to March 1981, the occurrence of zonal and latitudinal oscillations of the S.C. In this period, it was observed that the movement of the S.C. had a tendency to be dominated by its latitudinal fluctuations, in relation to its displacement in the zonal direction. Between autumn (April to June) and spring (October to December), the mean migratory velocity in the latitudinal direction was about 1.5 cm/s; while in the zonal direction, the velocity was about 0.7 cm/s. The thermal data obtained from the VISSR system, corresponded well with oceanographic data and showed that temperature data from the SMS-2 satellite may be effectively used to detect and monitor the Subtropical Convergence.

INTRODUCTION

Several techniques have been utilized for the study of the displacement of interfaces of oceanic currents. Experiments made with information obtained by remote sensors using visible (VIS) and thermal infrared (IR) channels, obtained from satellite as well as from analysis of conventional (shipboard) properties, have permitted the study of the detection and movement of boundaries of oceanic currents (Warnecke, et al., 1971; Stevenson and Miller, 1972; Stevenson and Miller, 1974; Tseng et al., 1977; Johnson and Norris, 1977; Leetma and Voorhis, 1978). Recent improvements made in the IR imaging systems aboard geostationary and polar orbiting satellites, now readily permit the detection of surface thermal interfaces, associated with oceanic fronts, with improved resolution (Legeckis, 1978; Harris et al., 1978; Legeckis and Gordon, 1982; Godoi, 1983).

---

<sup>1</sup> *Oceanographic Institute, University of São Paulo, São Paulo, SP.*

<sup>2</sup> *Department of Meteorology, Institute for Space Research, São José dos Campos, SP.*

The basic purpose of this work was to make a study of the seasonal oscillations of the Subtropical Convergence (S.C.), located between the Brazil and Malvinas (Falkland) Currents. Both oceanographic (conventional) data and data obtained from the SMS-2 satellite were used. Sea Surface Temperature (SST's) obtained via the SMS-2 satellite were referenced to the conventional SST's. This manuscript emphasizes the use of satellite data to study the S.C., because most previous studies were made using conventional data. The IR images, obtained from the VIS and IR Spin Scan Radiometer (VISSR) of the geostationary SMS-2 satellite, were utilized to extract information about the thermal structure of the sea surface, relative to the S.C.

## METHODOLOGY

### Study area

The study area (Figure 1) is located in the South Atlantic between 25°S and 45°S, and 45°W and 65°W, an oceanic area of  $2.5 \times 10^6$  km<sup>2</sup>. The area borders the State of Rio Grande do Sul (Brazil), Uruguay and part of Argentina. The presence of eddies in the water of the S.C. region attests to a complex area, with multiple sea surface temperature fronts extending southward to 50°S (Legeckis, 1978). Previous studies have demonstrated that vortex and meander components in the convergence zone are characteristically migratory (Legeckis and Gordon, 1982).

A sea surface temperature gradient on the order of 5.0°C in 2 km, and associated with the northern boundary of the Malvinas Current, has been verified by Legeckis and Gordon (1982). Godoi (1983) observed the thermal structure in this region with both oceanographic and SMS-2 satellite information. The greatest sea surface temperature variations occurred during autumn to spring. The seasons, as used in this report, occur in the opposite sense as for the northern hemisphere.

### Oceanographic and SMS-2 satellite data

The oceanographic data were provided by the National Bank of Oceanographic Data (Banco Nacional de Dados Oceanográficos) of the Hydrographic and Navigation Directory (Diretoria de Hidrografia e Navegação - DHN) in Rio de Janeiro, Brazil. Data for the period of July/August 1965, August/November 1977, April/June 1978 and January/April 1981 were analyzed. Only sea surface temperature and salinity were used in this study. Surface horizontal distributions of these parameters were constructed, using a seasonal time base. This data set was then utilized to locate the position of the S.C.

During this study, the Meteorology Department at INPE received and frequently recorded images from the SMS-2 satellite. From this INPE archive, a monthly collection of twelve IR images distributed over the period from April 1980 to March 1981, was selected. The IR images were automatically processed using a General Electric Interactive Multispectral Image Analysis System (IMAGE 100). The digital images were first processed utilizing a radiometric technique, that changed individual gray levels without considering neighbor pixels; and then, space processed by considering the relation between adjacent pixels (GE, 1975; Dutra et al., 1981).

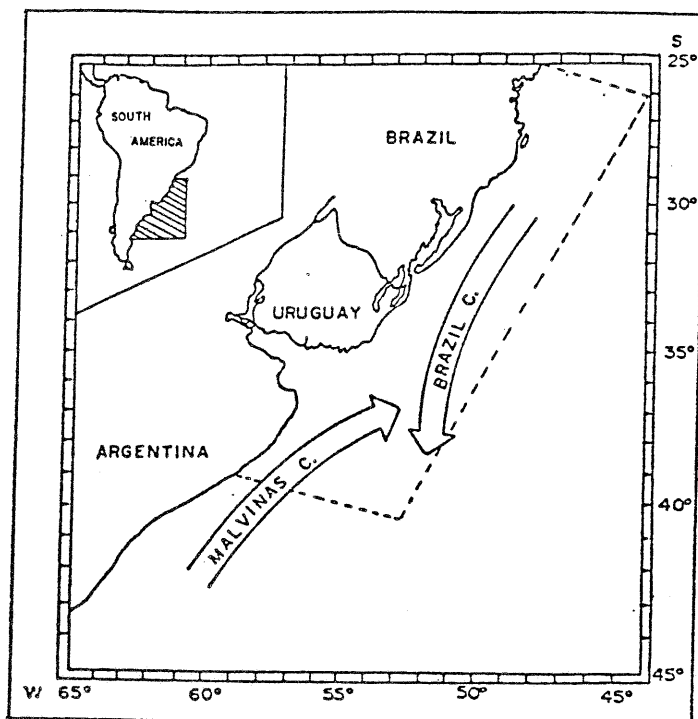


Fig. 1 - Study area and schematic representation of the Brazil and Malvinas Currents.

The rectangle indicates the limit of the oceanographic stations.

In order to better identify the occurrence of the S.C. and to verify its spatial variations, selected IR data sets were compared with a Gaussian model. In this evaluation we considered a population of digital values, representing a relatively homogeneous field of view (FOV), to closely approximate a Gaussian function. The details of the technique used to take the sample areas and the assumptions in the comparison and analysis of VISSR data and the Gaussian model can be found in Stevenson et al., 1977 and Godoi, 1983.

## RESULTS

### Spatial distribution of IR VISSR data

Figure 2 exemplifies the type of gray level image (24 Jul., 1980) classification that can be produced with the IMAGE 100 System. In this figure, the dark shading (offshore) is associated with warm temperatures of the Brazil Current; and the light shading is associated with cold temperatures of the Malvinas Current.

From an evaluation of statistical distributions of the cloud free areas sampled in the S.C. region, it is possible to quantitatively estimate whether or not thermal fronts are present. In this case, the procedure also facilitated identification of the S.C. frontal zone, principally in areas where the thermal structure was little defined by simple utilization of enhancement and digital filtering programs (Godoi, 1983).

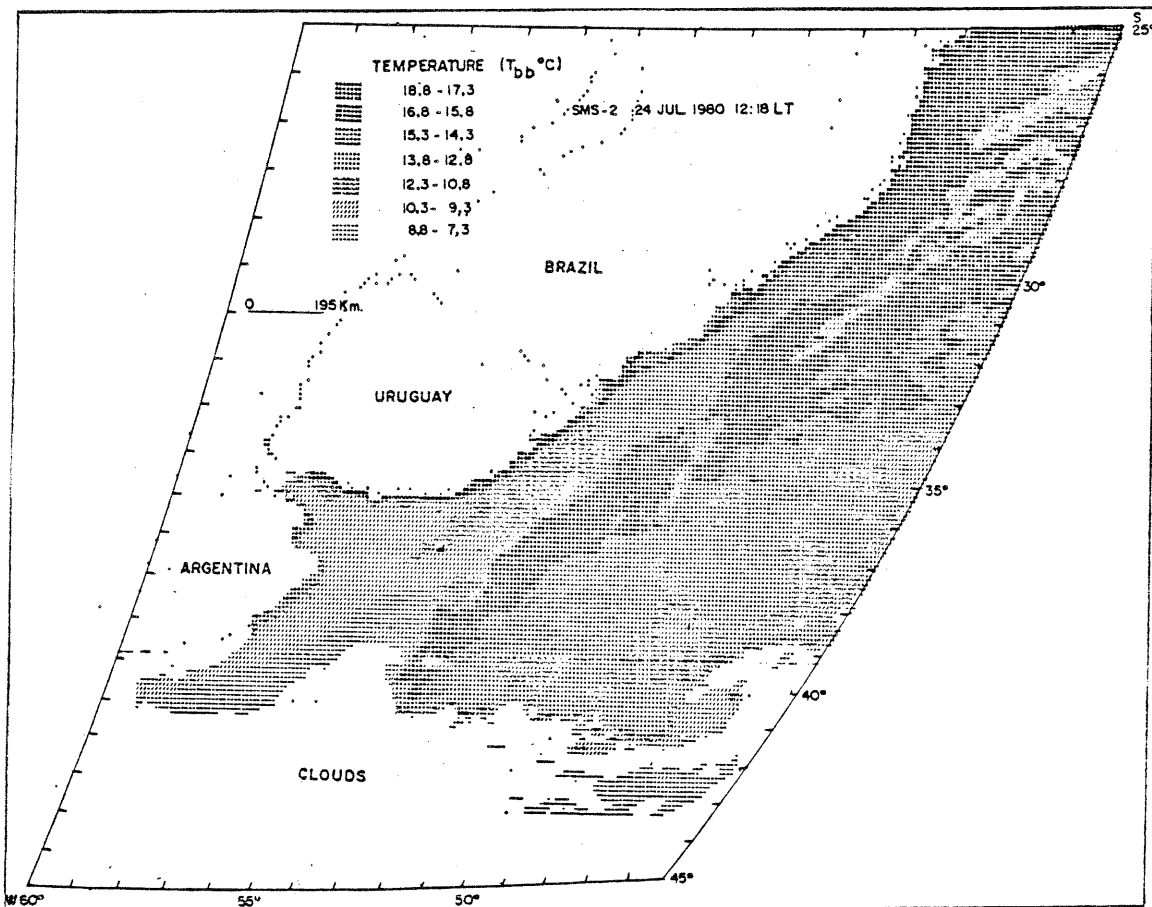


Fig. 2 - Gray level classification for 24 Jul., 1980 using IR VISSR data. This is the region of the Subtropical Convergence.

### Seasonal Oscillations of the Subtropical Convergence

In the study of seasonal variations of the S.C. with SMS-2 satellite data, the mean seasonal position of the sea surface temperature front was obtained using a monthly time base. A more detailed discussion of monthly variation of the S.C. is found in Godoi (1983). The mean velocity (migratory) of the S.C. was estimated by considering its displacement in both the latitudinal and longitudinal directions.

The seasonal oscillations of the S.C. may be seen in Figure 3. The extent, length and mean velocity, in both latitudinal and longitudinal directions, of this boundary are summarized in Table 1. Some comments are made in relation to Figure 3 and Table 1.

The northern extremity of the western boundary of the S.C. was observed in the winter and summer, near  $30^{\circ}\text{S}$  and  $35^{\circ}30'\text{S}$ , respectively. On the other hand, in autumn the boundary was only observed to  $36^{\circ}\text{S}$ , due to cloud cover in the images available for this study. In spring, it was observed at  $34^{\circ}30'\text{S}$ . In winter and summer, the southern extremity of this boundary was located near  $42^{\circ}\text{S}$ . During autumn, the southern limit was found at  $43^{\circ}\text{S}$ . In spring the boundary was located further north, near  $41^{\circ}\text{S}$ . For the overall region, the extent of the western boundary in the longitudinal direction was:  $53^{\circ}\text{W}$  to  $55^{\circ}\text{W}$  (autumn);  $48^{\circ}30'\text{W}$  to  $54^{\circ}30'\text{W}$  (winter);  $52^{\circ}\text{W}$  to  $54^{\circ}\text{W}$  (spring) and  $52^{\circ}30'\text{W}$  to  $54^{\circ}30'\text{W}$  (summer). The western boundary of the S.C. reached its maximum length in the winter, with 1900 km of extension, while in the summer, it was observed to extend over a distance of 1000 km. In autumn and spring, the latitudinal extent was approximately 900 km and 860 km, respectively.

The greatest mean zonal displacement and velocity was 100 km and 0.7 cm/s, respectively between the seasons of autumn and spring. The S.C. was also observed to undergo meridional movements during the study. The largest mean latitudinal displacement was during autumn and spring, about 210 km, corresponding to a mean velocity of 1.4 cm/s. For adjacent seasons, the most notable mean velocity, in the latitudinal and longitudinal directions, was observed between autumn and winter, with 2.0 cm/s and 1.2 cm/s, respectively. In general, the latitudinal oscillation was more intense than the longitudinal movement. In the summer months, the influence of the Brazil Current toward the south was greatest while during the winter months, the influence of the Malvinas Current has the opposite latitudinal effect.

Because the oceanographic data extended only to  $40^{\circ}\text{S}$ , with primary coverage restricted to the coastal region, the comparison was limited to the seasonal displacement of the western boundary of the S.C. In winter (Figure 4), the zonal displacement between the position of the S.C., obtained with oceanographic and SMS-2 satellite, is about 50 km in the region near  $30^{\circ}\text{S}$ ; and gradually comes into superposition between  $33^{\circ}\text{S}$  and  $39^{\circ}\text{S}$ . For the region between  $35^{\circ}\text{S}$  and  $40^{\circ}\text{S}$ , this displacement is 9 km. During summer (Figure 4), the mean difference in the position of the S.C., observed with oceanographic and satellite data, was about 50 km. The closest agreement in time between collection of oceanographic and satellite information occurred in this season. The most northern point of the western boundary of the S.C. in the winter and summer was near  $29^{\circ}$  and  $36^{\circ}\text{S}$ , with oceanographic observations, respectively.



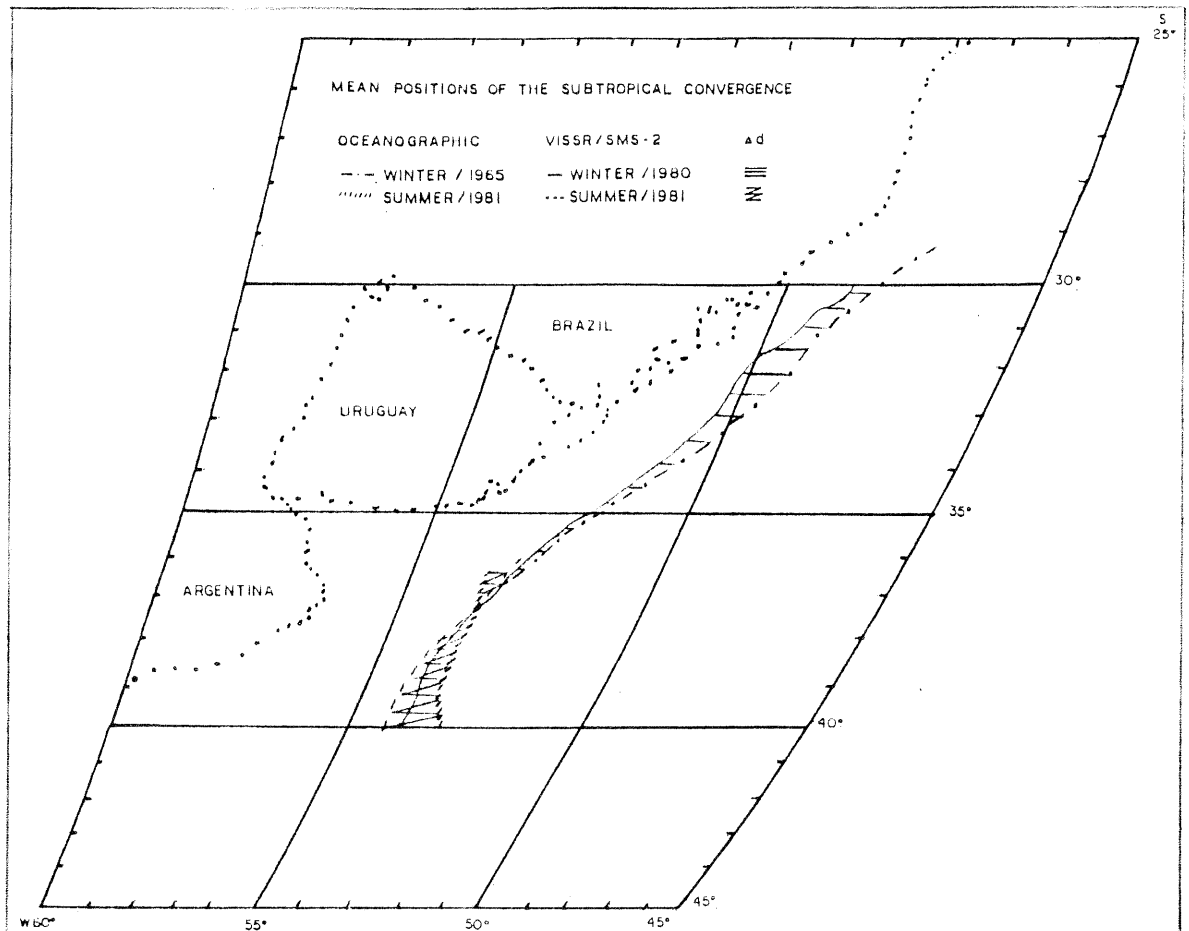


Fig. 4 - Displacement ( $\Delta d$ ) between mean positions of the S.C. observed with oceanographic and SMS-2 data.

From Figure 5 we note that in the spring, the difference between the two positions of the western boundary of the S.C., between 35°S and 40°S, was about 40 km. In this season, oceanographic data indicated that the S.C. reached its northern extreme at about 34°30'S. For autumn (Figure 5), the difference in position between 35°S and 40°S was about 25 km. With oceanographic information, the S.C. was observed from 29°S to 40°S. Most of the largest temperature gradients were observed below 34°S. Typical mean differences in position of the S.C. are found in Table 2.

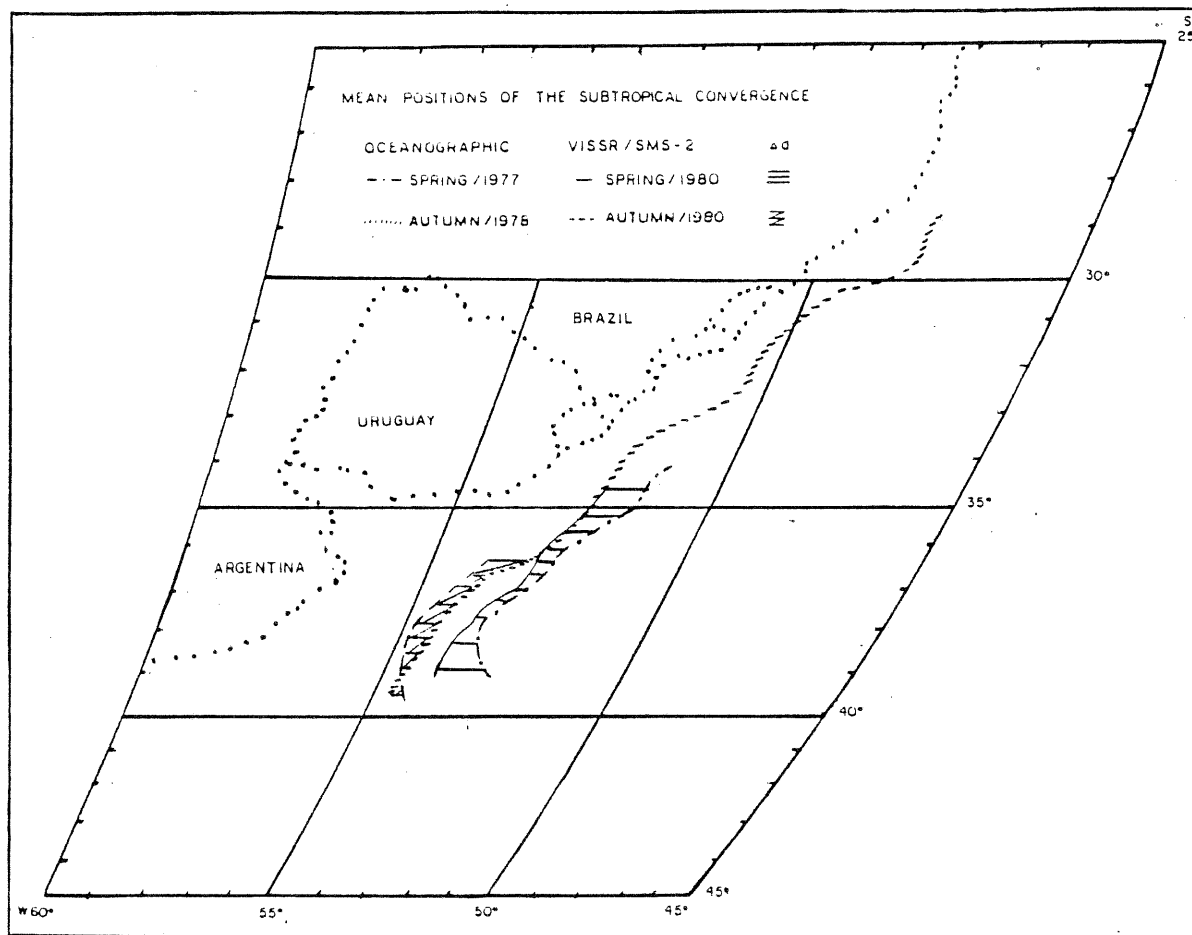


Fig. 5 - Displacement ( $\Delta d$ ) between mean positions of the S.C. observed with oceanographic and SMS-2 data.

Our results about the latitudinal extremities of the S.C. are similar to those of Boltovskoy (1965) and Pereira (1977). The seasonal oscillations of the S.C. can be influenced by various factors including the presence and passage of large scale meteorological fronts, that are common in the region of the S.C. As noted in the literature, the position of the S.C. can vary in response to fluctuations of the major wind system in this region (Balech, 1949).



TABLE 2

ZONAL DISPLACEMENT ( $\Delta d$ -km) IN THE MEAN POSITIONS OF THE SUBTROPICAL CONVERGENCE FROM OCEANOGRAPHIC AND SMS-2 DATA

LAT ( $^{\circ}$ S)	MEAN DISPLACEMENT ( $\Delta d$ -km)			
	WINTER 1965/1980	SUMMER 1981	SPRING 1977/1980	AUTUMN 1978/1980
30-35	50	-	30	-
35-40	9	50	40	25

CONCLUSIONS

- 1) By the information obtained from the SMS-2 satellite, during the period of the April 1980 to March 1981, it was observed that seasonal oscillations of the S.C. occurred in latitudinal and to a lesser extent longitudinal directions. In this period and between opposite seasons, both displacements from the mean positions of its western boundary were most notable between autumn (April - June) and spring (October - December). In the latitudinal direction, the western boundary of the S.C. extended between  $36^{\circ}$ S -  $43^{\circ}$ S (900 km) in autumn;  $30^{\circ}$ S -  $42^{\circ}$ S (1900 km) in winter;  $34^{\circ}30'$ S -  $41^{\circ}$ S (860 km) in spring;  $35^{\circ}30'$ S -  $42^{\circ}$ S (1000 km) in summer. In the region between  $30^{\circ}$ S -  $45^{\circ}$ S, the western boundary of the S.C. extended in the longitudinal direction,  $53^{\circ}$ W -  $55^{\circ}$ W (autumn);  $48^{\circ}30'$ W -  $54^{\circ}30'$ W (winter);  $52^{\circ}$ W -  $54^{\circ}$ W (spring) and  $52^{\circ}30'$ W -  $54^{\circ}30'$ W (summer).
- 2) The largest mean migratory velocity of the S.C., in the latitudinal direction was 1.5 cm/s, and for the longitudinal direction was 0.7 cm/s, between autumn and spring. For adjacent seasons, the largest velocities in the latitudinal and longitudinal directions were 2.0 cm/s and 1.2 cm/s (autumn/winter).

The study of the seasonal oscillations of the S.C. presented here, is not yet totally complete. The comparison of VISSR data with oceanographic measurements shows that the satellite data can yield very useful information on the location, extent and seasonal oscillations of the Subtropical Convergence.

REFERENCES

- Balech, E. Estudio critico de las corrientes marines del Litoral Argentina. *De Physics*, 20:159-164, 1949.
- Boltovskoy, E. Datos nuevos con respecto a la ubicación de la zona de convergencia subtropical/subantártica em base al estudio de los foraminíferos planctónicos. *Anais de Academia Brasileira de Ciências*,

- 37:146-155, 1965. Suplemento.
- Dutra, L.V.; Souza, R.C.M. de; Mitsuo Ii, F.A.; Moreira, J.C. *Análise automática de imagens multiespectrais*. São José dos Campos, INPE, ago. 1981. 40 p. (INPE-2212-MD/009)
- General Electric (GE). *IMAGE-100*; user manual. Daytona Beach, 1975.
- Godoi, S.S. *Estudo das variações sazonais da Frente Oceânica Subtropical entre a Corrente do Brasil e a Corrente das Malvinas, utilizando dados oceanográficos e do satélite SMS-2*. Dissertação de Mestrado em Sensoriamento Remoto. São José dos Campos, INPE, jun. 1983. 328 p. (INPE-2780-TDL/137)
- Harris, T.F.W.; Legeckis, R.; Forest, D.Van. Satellite infrared images in the Agulhas Current System. *Deep-Sea Research*, 25(5-8):543-548, 1978.
- Johnson, W.R.; Norris, D.R. A multispectral analysis of the interface between the Brazil and Falkland currents from Skylab. *Remote Sensing of Environment*, 6:271-278, 1977.
- Leetmaa, A.; Voorhis, A.D. Scales of motion in the subtropical convergence zone. *Journal of Geophysical Research*, 83(9):4589-4592, Sept. 1978.
- Legeckis, R. A survey of worldwide sea surface temperature fronts detected by environmental satellites. *Journal of Geophysical Research*, 83(NOG9):4501-4522, Sept. 1978.
- Legeckis, R.; Gordon, A.L. Satellite Observations of the Brazil and Falkland currents - 1975 to 1976 and 1978. *Deep Sea Research*, 29(3A):375-401, 1982.
- Pereira, C.S. *Correntes Costeiras: Estudo de um modelo estacionário aplicado ao litoral do Rio Grande do Sul (Latitude 29°S-35°S) e análise de um modelo transiente*. Dissertação de Mestrado em Oceanografia Física, São Paulo, IOUSP, 1977, 132p.
- Stevenson, M.R.; Miller, F.R. *Application of high resolution infrared and visual data to investigate changes in and the relationship between sea surface temperature and clouds patterns over the eastern Tropical Pacific; final report*. La Jolla, CA, Inter-American Tropical Tuna Commission, 1972. 84 p. (06-71-C-0120)
- *Application of satellite data to study oceanic fronts in the eastern Pacific*. La Jolla, CA, Inter-American Tropical Tuna Commission, 1974. 111 p.
- Stevenson, M.R.; Kirkham, R.G.; Madsen, B.J. *Development and testing of a cloud screening technique for use with satellite borne scanning radiometers*. La Jolla, CA, Inter-American Tropical Tuna Commission, c/o Scripps Institution of Oceanography, 1977. 95 p.
- Tseng, Y.C.; Inostroza, V.H.M.; Kumar, R. *Study of the Brazil and Falkland current using THIR images for NIMBUS V and Oceanographic data in 1972 to 1973*. São José dos Campos, INPE, Sept. 1977. 13p. (INPE-1123-PE/091).
- Warnecke, G.; Allison, L.J.; Mc Millin, L.M.; Szekiolda, K.H. Remote sensing of ocean currents and sea surface temperature changes derived from the NIMBUS II Satellite. *Journal of Physical Oceanography*, 1(1):45-60, 1971.