Report

This brief report summarizes the work carried out as part of the exchange ECOS-CONYCIT project during the period November 18-December 16 (2005) at LOA (Laboratoire d'Optique Atmosphérique) in the Université des Sciences et Technologies de Lille.

Basically the work consisted:

- Detection of dust in the North of Chile using infrared difference dust index. Work guided by Jean François Léon.
- POLDER products and the potential use in Chile. Work guided by Isabelle Chiapello.

I. Infrared difference dust index

The data for this work was provided by GOES satellite data (http://www.class.noaa.gov/). It was used the channel 4, which corresponds to wavelength range among 10.2 to 11.2 um. The study period encompasses August 2001 to June 2002.

The technique used corresponds to the infrared difference dust index (IDDI, Legrand et al. 2001).

Following Legrand et al. (2001), they were processed the Reference Images (RI) and Difference Images (DI). The RI was obtained for each day using 7 days before and 7 days after of such a day (k). For these two weeks, it was computed a matrix defined as follows.

$$P^{RI}{}_{ij} = Max\left(P_{ij}^{\ k-7},..,P_{ij}^{\ k},....P_{ij}^{\ k+7}\right) \qquad (1)$$

The DI was obtained as the difference between RI and the original image(OI) , DI= RI-OI.

The figure 1.a shows the annual cycle for the RI using two average areas. This cycle represents the annual isolation. The minimum variability in the DI signal is associated with the period December-January (350-365, 1-30 julian day).

IDDI shows the DI image with the cloudy pixels removed. Figure 1.2 illustrates an example of OI, RI, DI and IDDI images.

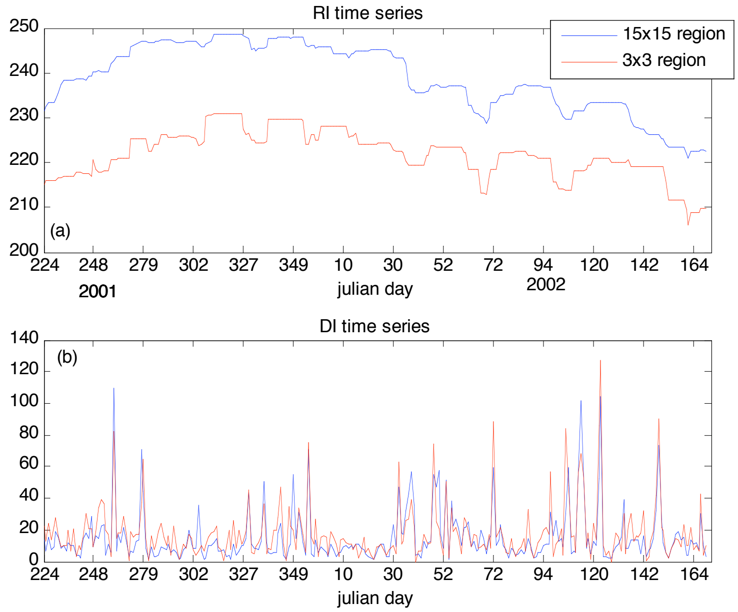


Figure 1.1: Times series for a) RI, b) DI. It was selected two different average areas, 3x3 pixels and 15x15 pixels. The area was centered approximately in 20.2S, 70W.

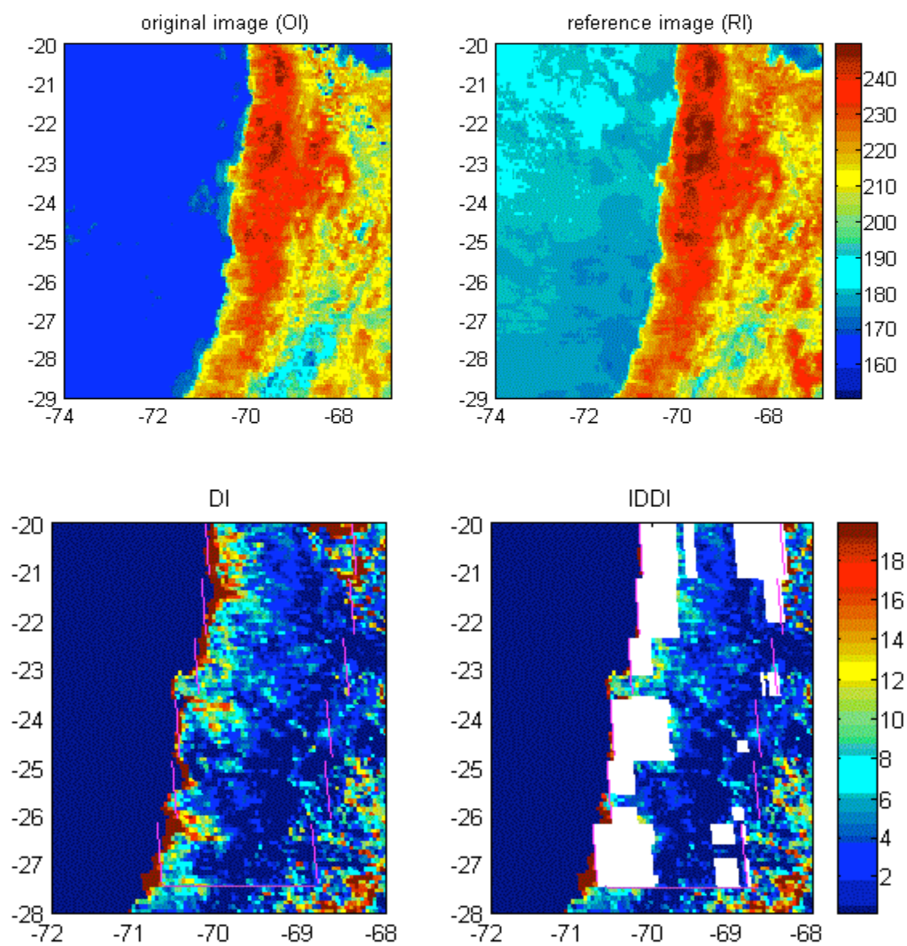


Figure 1.2: An example of the technique. Using the reference image and original image, it was obtained the DI matrix. The IDDI shows the DI which the cloudy pixels have been removed. The magenta lines

correspond to the border line of the analysis area. The day corresponds to April 5 (2002). The color bar is GOES units.

The information content of DI includes both, the cloud and the dust radiative effect. In order to discriminate the cloud and dust contribution it was used a straightforward technique which implies calculations of the standard deviation and the mean using a 3x3 pixel area.

$$\sigma_{ij} = std(DI_{kl})_{\substack{k=i-1,i,i+1 \\ l=j-1,j,j+1}} \qquad mean_{ij} = mean(DI_{kl})_{\substack{k=i-1,i,i+1 \\ l=j-1,j,j+1}}$$

For these new matrixes, it was taken a 15x15 pixel area. This area showed an arch shape, as observed in a spatial scatter-plot. The method consists in separating the clear (hot) foot of the arch, located near of the origin. Considering the use of a standard deviation threshold of 4, it was computed the number of the means values associated with the standard deviation below 4, using intervals of three (number of means between 0 and 2, between 3 and 5, etc.).

The interval where the count of means was zero, can be considered as a threshold for the mean value. The decision rule implies that the pixel in which standard deviation and mean are lower than the thresholds (mean or standard deviation), they are considered as clear, in other case is cloudy.

I.1 IDDI Monthly Average:

The IDDI monthly average was calculated as the monthly average for each pixel. When the number of cloudy pixels exceed the number of 20 (monthly), this pixel was considered as cloudy and the monthly average was not calculated.

The results (figure 1.4) show an almost permanent cloud cover along the coast (represented by white areas). It is not clear the observation of potential areas with dust. However, August and September (2001) present a small region with higher values located near of 24.5S and 70W. The question is if it is feasible to consider this area with dust or if it is only noise effect. The monthly time series for this region present a weak cycle with maximum values in august and September as well (figure 1.5).

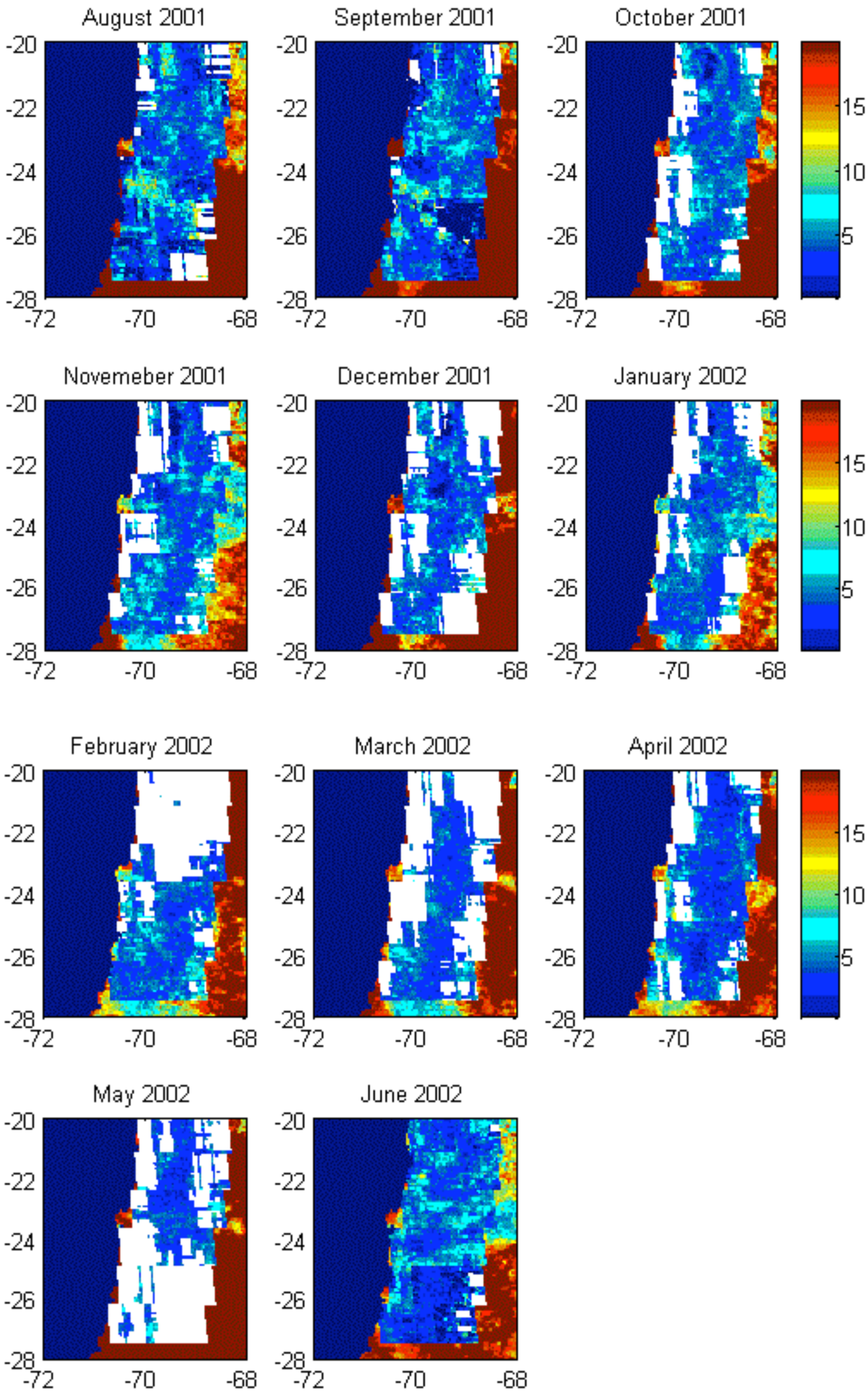


Figure 1.3: Monthly average IDDI. The dark blue color corresponds to ocean mask. The white areas indicate cloudy regions. August 2001 to January 2002.

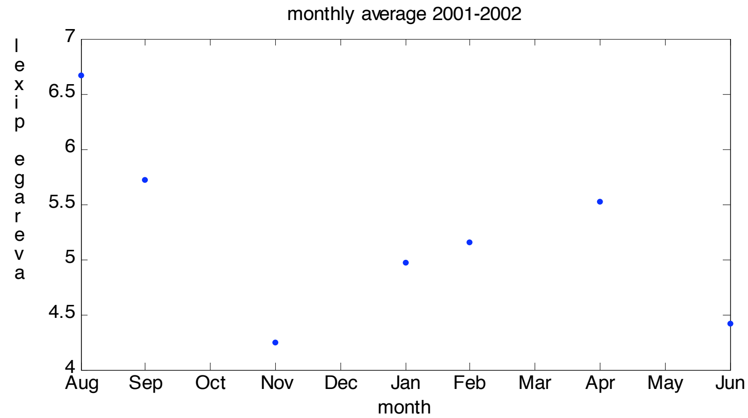


Figure 1.4: Monthly average obtained for a 15x 15 pixel area centered in 24.5S and 70W. The months with no information are associated with periods considered cloudy.

II. POLDER

1. Introduction

POLDER (Polarization and Directionality of the Earth's Reflectances) is a multispectral imaging radiometer providing unique measurements of the anisotropy and polarization of the solar radiation reflected by the Earth-atmosphere system. POLDER was developed by the Centre National d'Etudes Spatiales (Toulouse, France) and was flown on board NASDA's ADEOS-1 platform between August 1996 and June 1997. POLDER II was flown on board ADEOS-2 platform between December 2002 and October 2003.

POLDER is a multidisciplinary programme addressing four aspects of earth observation: (i) aerosols, (ii) clouds and water vapor, (iii) ocean color, and (iv) land surfaces. With only three bands dedicated to ocean color (443, 490, and 565 nm, and 670, 765 and 865 nm for atmospheric correction) and a 6 x 7 km resolution, POLDER is often seen as an outsider for ocean color compared to other sensors such as OCTS (also on ADEOS) or SeaWiFS. Clearly, coastal and real-time applications are outside the scope of POLDER.

2. POLDER instrumental concept

The POLDER instrument concept is based on a wide-field-of-view telecentric optics, a rotating wheel carrying spectral and polarizing filters and a charged coupled device (CCD) detector array.
The POLDER instrument presents original features since it is not only multispectral but also multidirectional (owing to its bidimensional wide field of view, POLDER has the ability of looking at the same point

on the ground from different viewing angles during a single orbit) and multipolarization. Algorithms dedicated to "Earth Radiation Budget, Water Vapor, and Clouds" (hereafter noted "ERB, WV & Clouds") were developed, taking into account these capabilities more particularly:

- **multi-polarization** allows to determine the cloud thermodynamic phase and the cloud top pressure.
- the **multi-directionality** improves the derivation of the cloud optical thickness and the estimate of the reflected flux.
- **multi-spectrality** allows to derive the cloud middle pressure and the clear-sky water vapor content.

POLDER has 15 spectral bands which range from 443 nm to 910 nm. Two of these spectral bands are centered on molecular absorption bands : 763 (O2) and 910 (H2O).

POLDER band	**443P**	**443NP**	**490NP**	**565NP**	**670P**	**763NP**	**765NP**	**910NP**	**865P**
Central Wavelength	444.5	444.9	492.2	564.5	670.2	763.3	763.1	907.7	860.8
Approximate Band Width	20	20	20	20	20	10	40	20	40
Polarization	Yes	No	No	No	Yes	No	No	No	Yes

Table 2.1: POLDER bands.

The level 2 (orbital swath) products contain about thirty non-directional parameters and ten directional parameters (for each of the 14 viewing directions). The level 3 (monthly) products contain about forty parameters

The information available corresponds to:

- Level 1: Radiances
- Level 2: Products: Ocean colors and marine aerosols, land surfaces & aerosols over land, water vapor & clouds
- Level 3: Temporal synthesis (computed every month or ten days) of the level 2 geophysical parameters.

Comparison with MODIS TERRA

Both algorithms use bimodal aerosol size distributions; the ratio between small and large particles is deduced from the spectral measurement behavior, while the signal level is related to the optical thickness. In specific geometries and using directional and polarized measurements, POLDER is able to detect non spherical aerosols (dust), which are not distinguished by MODIS that considers such particles as large spherical ones.

	MODIS	**PARASOL-POLDER**
Spectral band	0.4 µm to 14.4 µm	0.443µm to 0.91 µm
Spatial Resolution	250 m (bands 1-2) 500 m (bands 3-7) 1000 m (bands 8-36)	6 km x 7 km

Swath	2330 km (cross track) by 10 km (along track at nadir)	2400 km

Table 2.2: Characteristics MODIS-POLDER.

Polder products available in HDF format:

Cloud parameters:

Ident	Parameter Description	Synthesis		Over Ocean/Over Land (O/L)
		Daily	monthly	
UT	Universal time			
MASK	Coastline			
CC	Cloud Cover	X	X	O/ L
QCC	Cloud Cover Confidence Index	X		O/ L
WV	Total precipitable Water Vapor	X	X	O/ L
SDWV	Standard Deviation of Water Vapor	X		O/ L
PHASE	Cloud thermodynamic Phase	X		O/ L
TAU	Cloud optical Thickness	X		O/ L
PRAY	Cloud Rayleigh Pressure	X	X	O/ L
POXY	Cloud Oxygen Pressure	X	X	O/ L
AVIS	Albedo at 670/865 nm	X	X	O/ L
QAVIS	Albedo Quality index	X		O/ L
AVISCL	Clear-sky Albedo at 670/865 nm		X	O/ L
ASW	Shortwave Albedo	X	X	O/ L
ASWCL	Clear-sky Shortwave Albedo		X	O/ L
TOTFRE	Percentaje of successful Phase retrievals		X	O/ L
LIQFRE	Liquid Phase Frequency		X	O/ L
ICEFRE	Ice Phase Frequency		X	O/ L
MIXFRE	Mixed Phase Frequency		X	O/ L
LIQTAU	Liquid Water Cloud Optical Thickness		X	O/ L
ICETAU	Ice Cloud Optical Thickness		X	O/ L
MIXTAU	Mixed-phase Cloud Optical Thickness		X	O/ L
FINC	Shortwave Incident flux		X	O/ L
FREFL	Shortwave Reflected flux		X	O/ L
FCLEAR	Clear-sky Shortwave Reflected Flux		X	O/L

Table 2.3: cloud parameters available in HDF format.

Aerosol parameters

Ident	Parameter Description	Synthesis		Over Ocean/Over Land (O/L)
		Daily	monthly	
TAUA	Aerosol Optical Thickness at 865 nm	X	X	O
TAUAFM	Aerosol Optical Thickness (865nm Fine Mode)	X	X	O/L
ANG	Angstrom Coefficients	X	X	O
ANGFM	Angstrom Coefficients for Fine Mode	X	X	O/L
IQAI	Aerosol Inversion Quality Index	X		O/L
REF	Aerosol Effective Radius	X		O

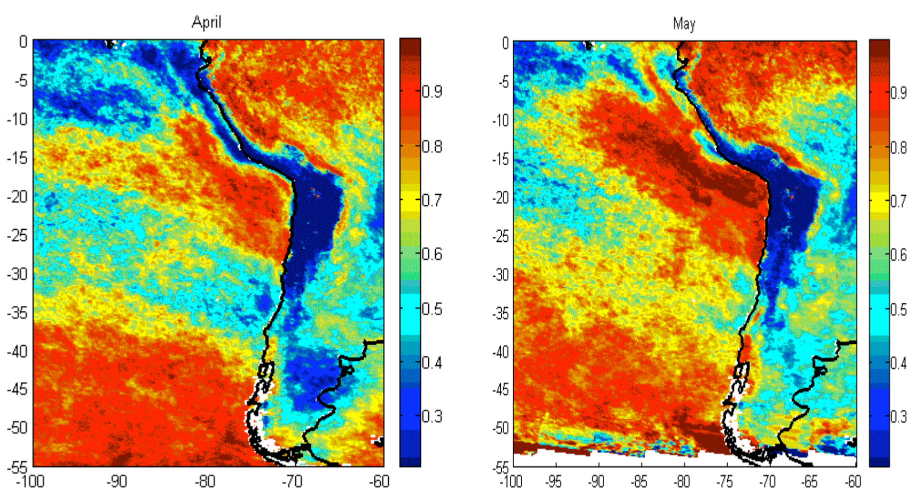
REFFM	Fine Mode Aerosol Effective Radius	X		O
TAUACNM	Aerosol Optical Thickness of the Coarse Non-Spherical Mode at 865 nm	X		O
TAUACSM	Aerosol Optical Thickness of the Coarse Spherical Mode at 865 nm	X	X	O
NSICM	Non-Sphericity index of coarse mode		X	O
F1REF	Aerosol Frequency of Effective Radius=< 0.7 micron		X	O
F2REF	Aerosol Frequency of Effective Radius in]0.7;1.1] micron		X	O
F3REF	Aerosol Frequency of Effective Radius in]1.1;1.75] micron		X	O
F4REF	Aerosol Frequency of Effective Radius> 1.75 micron		X	O
F1REFM	Aerosol Frequency of Fine Mode Effective Radius =<0.1 micron		X	O
F2REFM	Aerosol Frequency of Fine Mode Effective Radius in]0.1;0.15] micron		X	O
F3REFM	Aerosol Frequency of Fine Mode Effective Radius in]0.15;0.2] micron		X	O
F4REFM	Aerosol Frequency of Fine Mode Effective Radius >0.2 micron		X	O

Table 2.4: Aerosols parameters available in HDF format.

Examples of POLDER products:

Cloud Parameters:

- Cloud Cover:



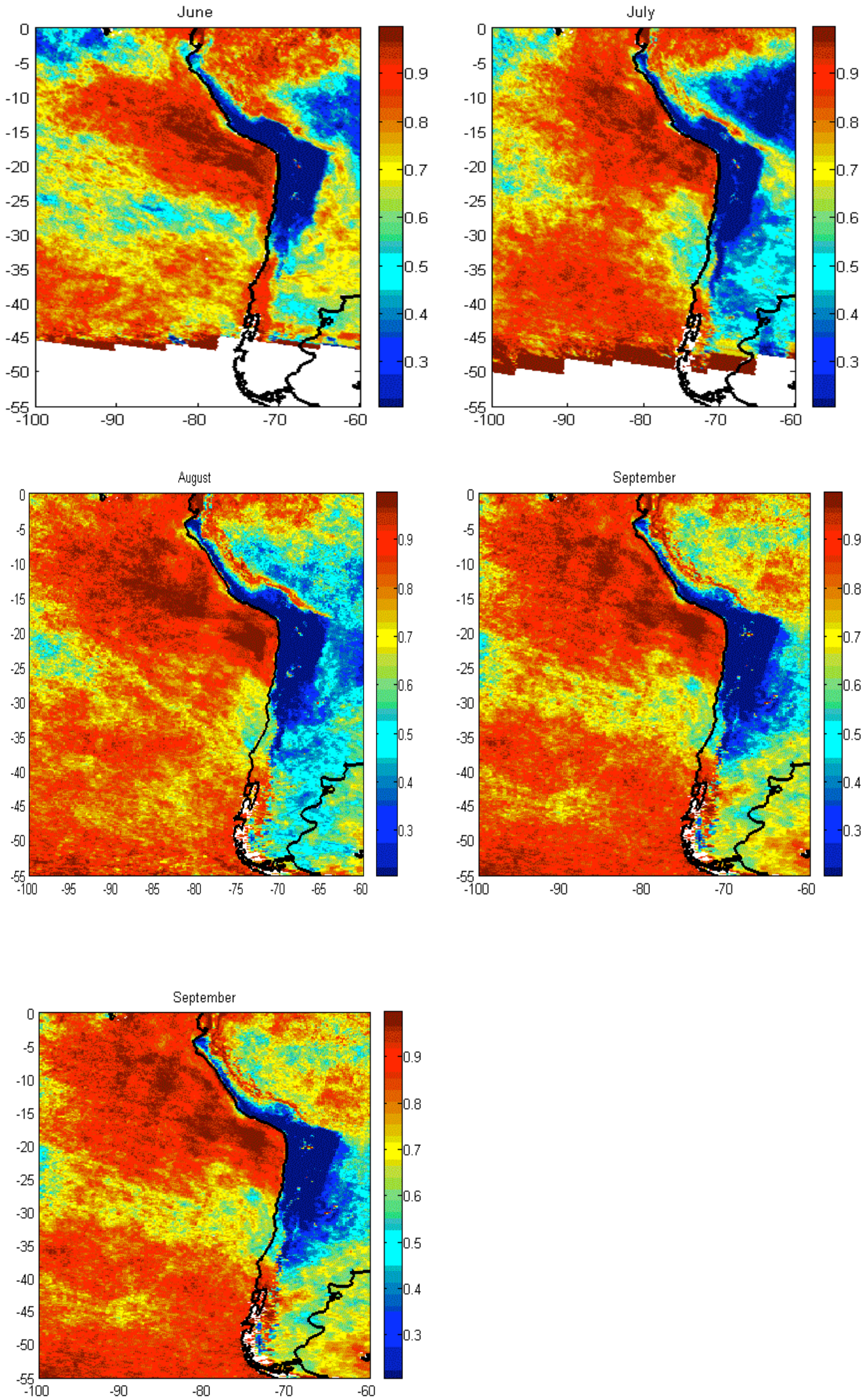
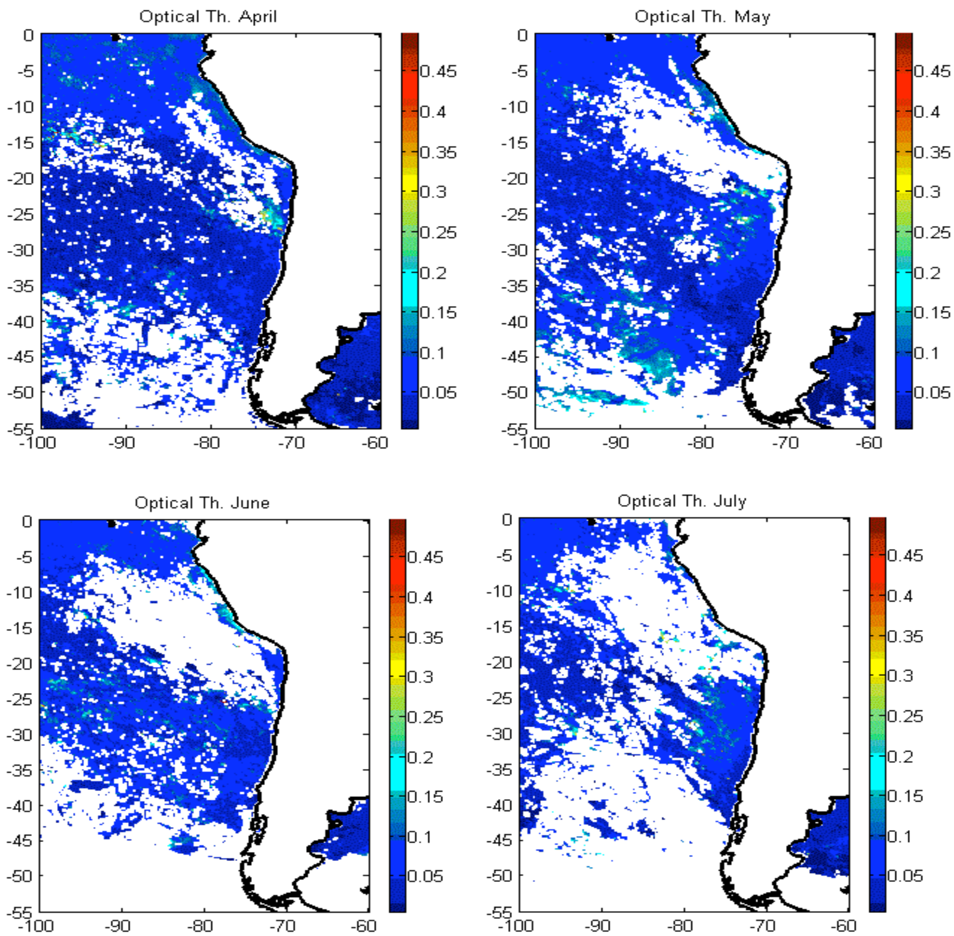


Figure 2.1: Monthly mean Cloud cover obtained from POLDER-2

Aerosol parameters:

<u>Over Ocean:</u>

Aerosol Optical Thickness at 865nm:



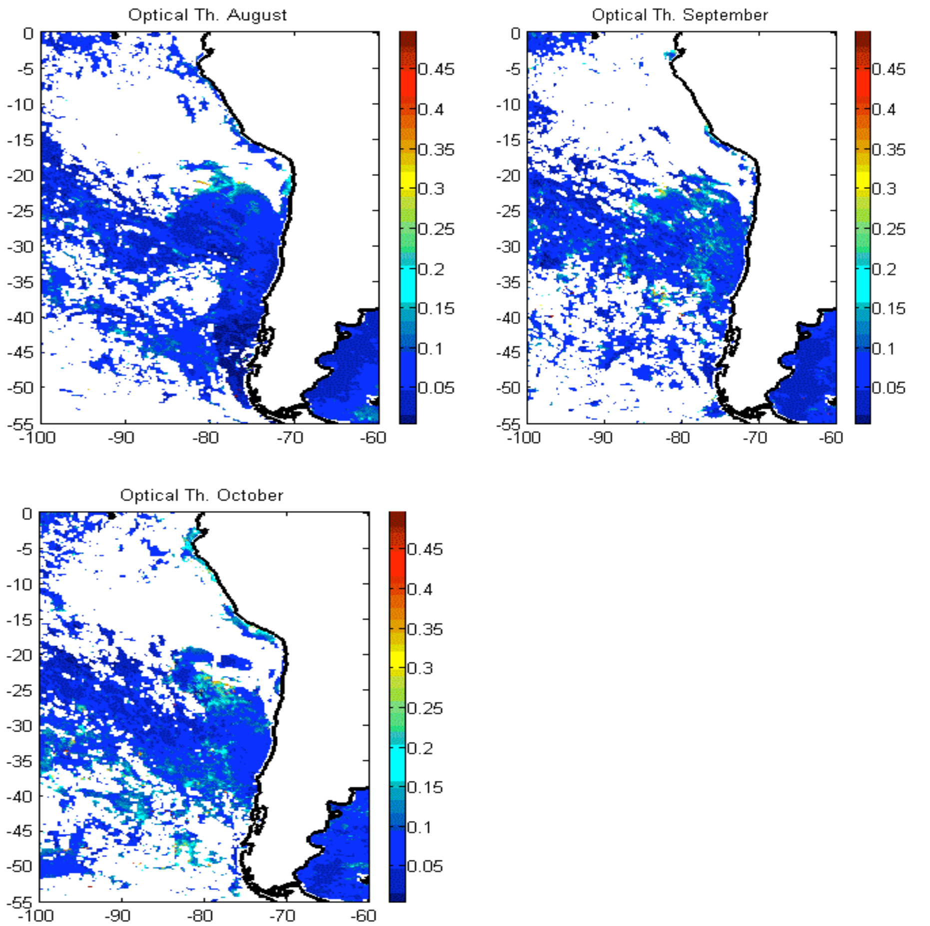
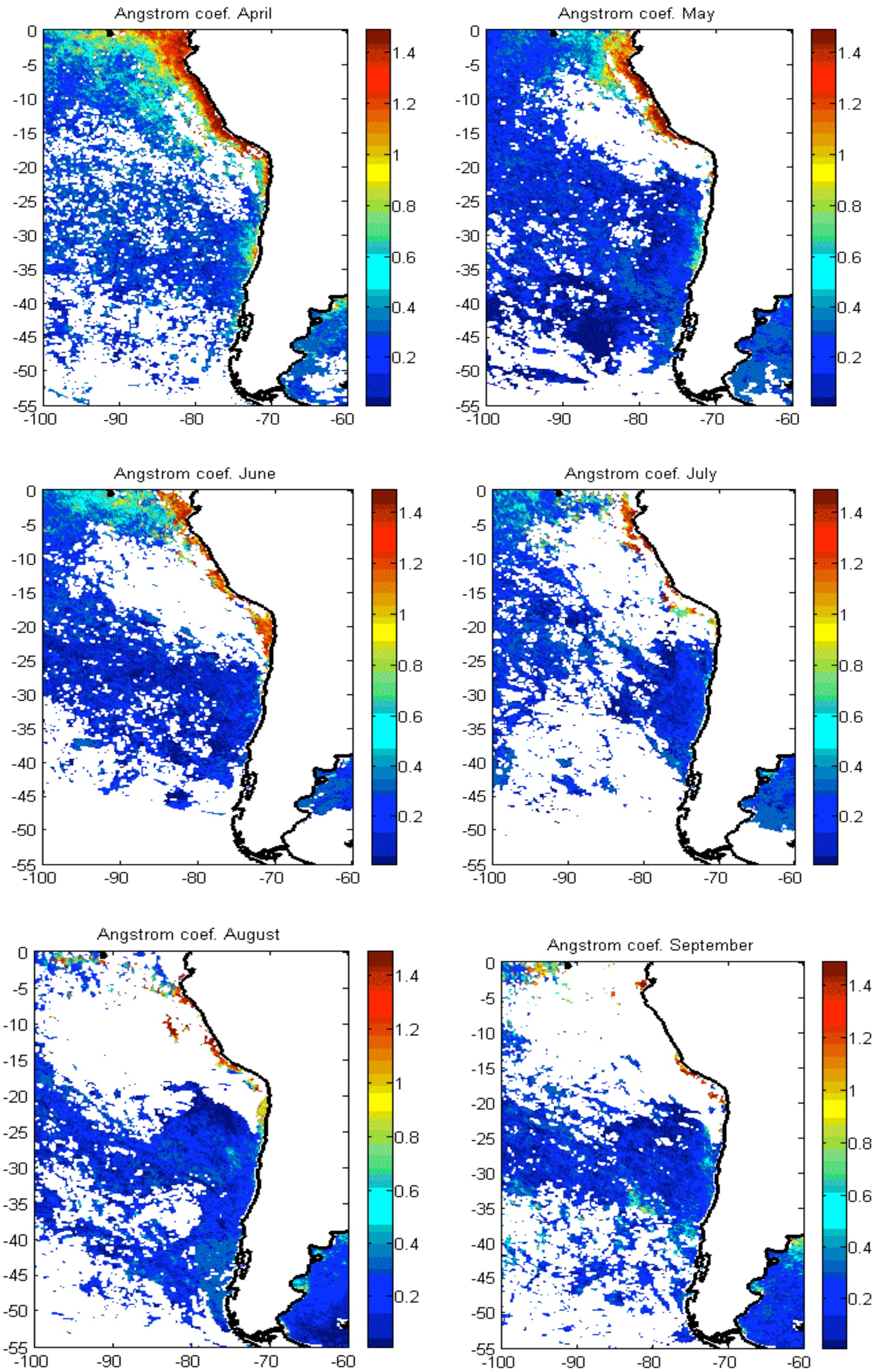


Figure 2.2: Monthly mean aerosol optical depth at 865nm obtained from POLDER-2 (year 2003).

Angstrom Coefficients



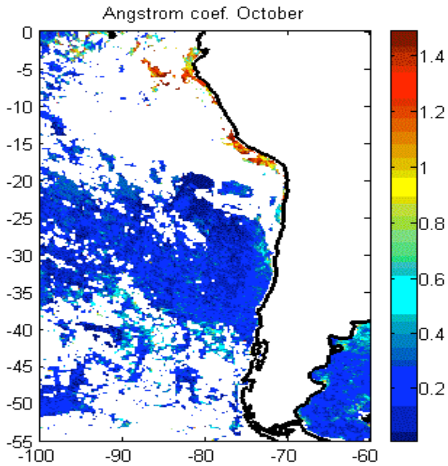
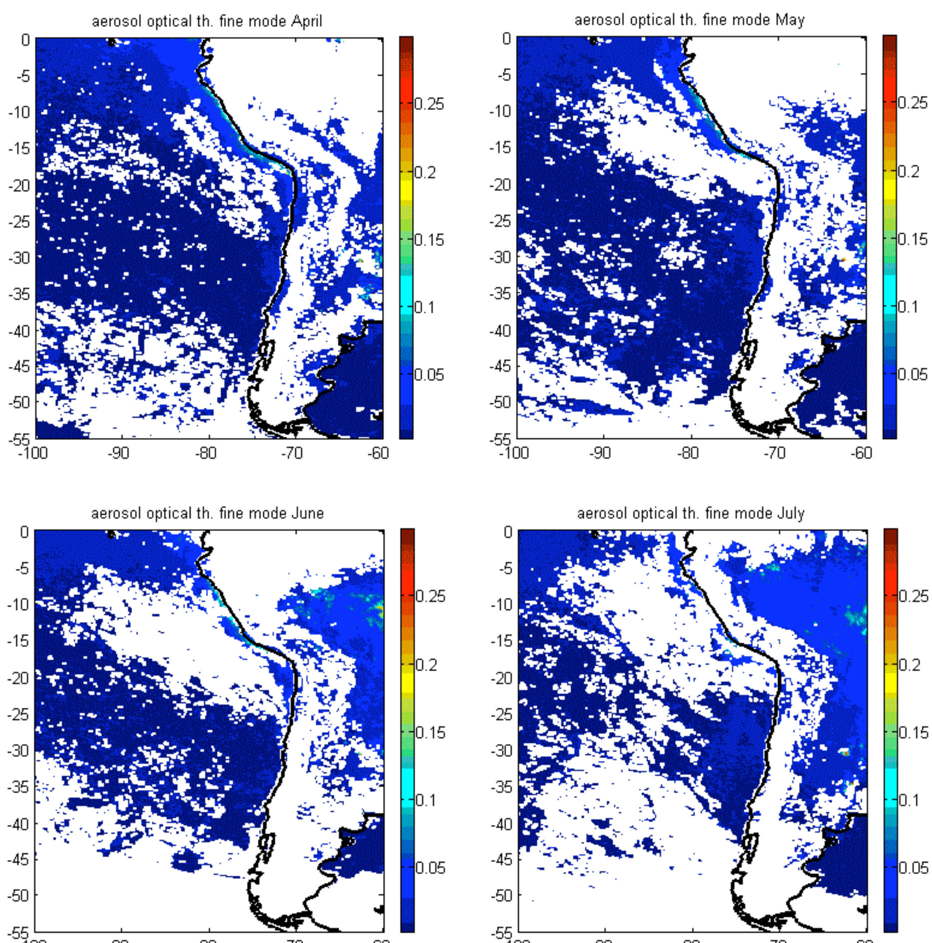


Figure 2.3: Monthly mean Angstrom coefficient at 865nm obtained from POLDER-2 (year 2003).

Over Land and Ocean:

<u>Aerosol optical thickness (865nm Fine Mode)</u>



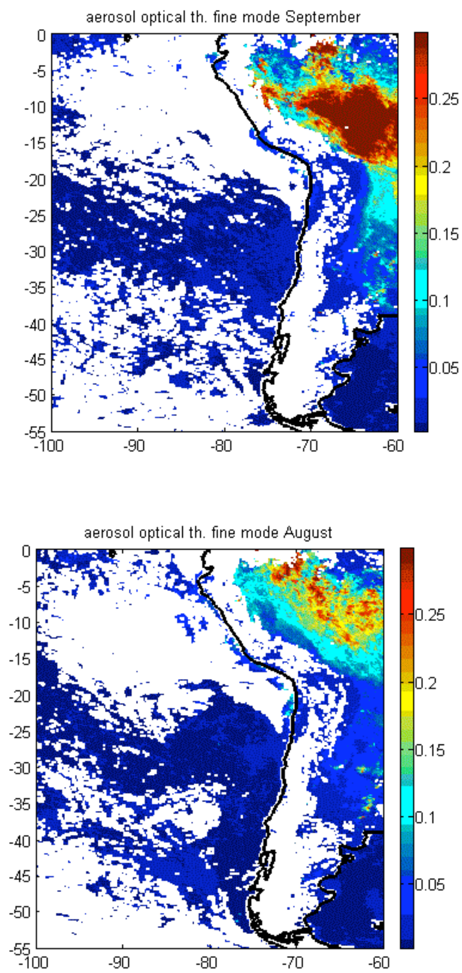


Figure 2.4: Monthly mean aerosol optical depth fine mode at 865nm obtained from POLDER-2 (year 2003).

Aerosol optical thickness over Santiago

The time series was obtained using the “fine mode aerosol optical thickness at 865nm” product from POLDER-II. The period encompasses April 1 (2003) to October 31 (2003). The time series was calculated as the area approximately of 75kmx75km centered in 33.5S and 70.5W, averaged. The main problem for the region is the permanent lost of data, possibly owed to the cloud cover over Santiago. However, this problem is less important in the north of Chile (figure not shown).

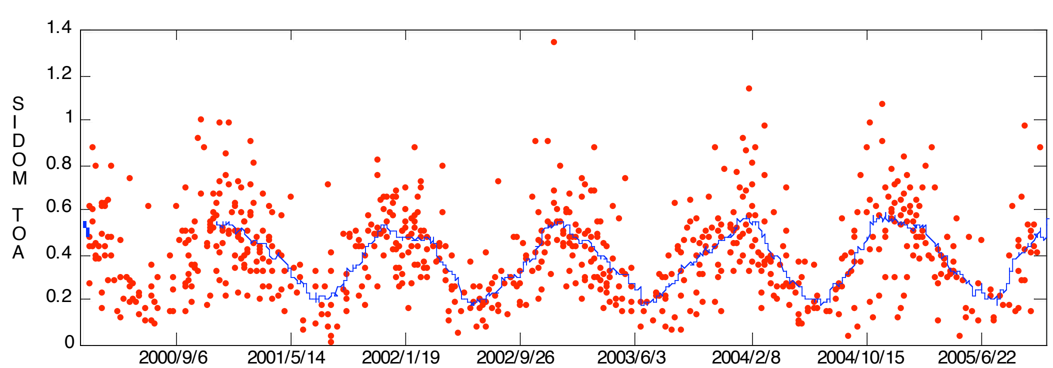


Figure 2.5: MODIS AOT over Santiago. Blue line corresponds to mobile mean of 50 days

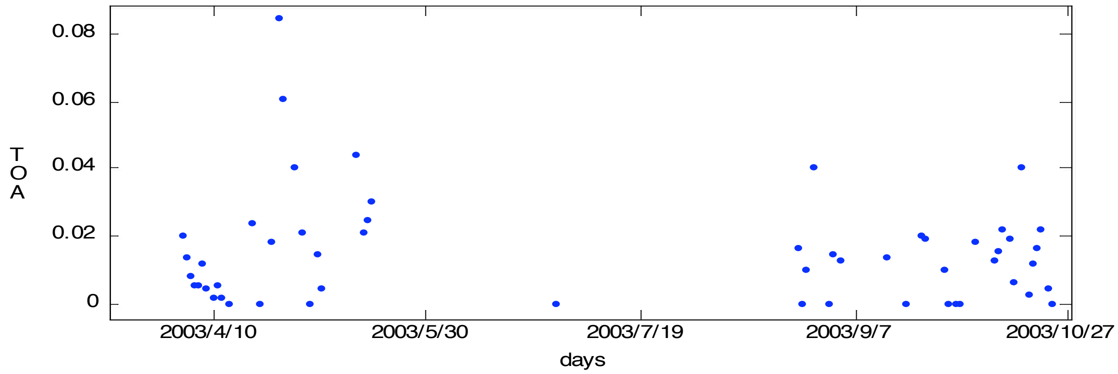


Figure 2.6: POLDER AOT-FM over Santiago