Technical Report Report No. : INCOIS-MOG-ARGO-TR-03-2008

# Indian Argo Trajectories and Surface Currents

submitted by

Anitha Gera and M Ravichandran

**Indian National Centre for Ocean Information Services**
**(Ministry of Earth Sciences, Govt. of India)**
**Hyderabad**

**March, 2008**

# DOCUMENT CONTROL SHEET

01. Report No & Date: **INCOIS-MOG-ARGO-TR-03-2008** Date:**13 March 2008**

02. Title & Sub Title: **Indian Argo Trajectories and Surface Currents**

03. Part No.: **-** 04. Vol. No.: **-**

05. Author(s): **Anitha.Gera and M.Ravichandran**

06. Originating agency (Group/Project/Entity): **MOG, INCOIS**

07. No. of Pages: **33** 08. No. of figures: **9**

09. No. of references: **6** 10. No. of enclosures/appendices: **-**

11. Abstract (Maximum 100 words):

An important objective of Argo is measurement of ocean circulation. As Argo floats collect salinity/temperature profiles, they also give information on the surface and subsurface currents. Indian National Centre for Ocean Information Services (INCOIS) being a Regional Data Assembly Centre for Indian Argo has so far launched 160 floats in the Indian Ocean to develop the global ocean observation system as a part of international cooperation project and is responsible for real time generation and dissemination of this data. This work is an attempt to extract information on sea surface in application to the Lagrangian part of the Argo floats. This report constitutes two sections. The first section documents the process of operational generation and dissemination of the Argo trajectory data. The second section describes the data product, Surface Currents and its comparison with Simple Ocean Data Assimilation & Drifting buoy currents.

12. Keywords: Argo, Ocean Surface Currents, Trajectory, Lagrangian

13. Security classification: **Unrestricted**

# Contents



# List of Figures

## List of Tables

## Abstract:

An important objective of Argo is measurement of ocean circulation. As Argo floats collect salinity/temperature profiles, they also give information on the surface and subsurface currents. Indian National Centre for Ocean Information Services (INCOIS) being a Regional Data Assembly Centre (RDAC) for Indian Argo has so far launched 160 floats in the Indian Ocean to develop the global ocean observation system as a part of international cooperation project and is responsible for real time generation and dissemination of this data. The Argo float sends data to the satellite while it drifts on the surface. It spends approximately 9 to 21 hours on the surface. During this time when the satellites pass the float overhead they fix the position and time. Using these positions fixed by the satellite, the surface current drift can be estimated. This work is an attempt to extract this information on sea surface in application to the Lagrangian part of the Argo floats. This report constitutes two sections. The first section documents the process of operational generation and dissemination of the Argo trajectory data. The second section describes the data product, Surface Currents and its comparison with Simple Ocean Data Assimilation (SODA) currents. Using the Argo surface trajectory data, climatology of the monthly surface currents is prepared. The climatology thus prepared shows all the important circulation patterns in the Indian Ocean quite clearly. The comparison with SODA currents U and V-components for January and July is matching well. A comparison of the U- and V- components of Surface currents obtained from a single Argo float with those obtained from one Drifting buoy showed good agreement.

# 1. Introduction

To monitor the world's oceans and understand the role of the oceans for climate change, an Array for Real-time Geostrophic Oceanography (ARGO) program has been carried out since year 2000. The concept Argo, a global array of autonomous profiling floats, grew out of "A Proposal for Global Ocean Observations for Climate: the Array for Real-time Geostrophic Oceanography" (ARGO) and another program for Global Salinity Monitoring. The floats used in this project feature the same design as ALACE (Davis et al., 1992).

One of the key themes of the ARGO is to compliment the JASON-1 altimeter and its successors. The practical outcome is that, integration of Argo float data will enhance the value of the the Jason altimeter for interpretation of altimetric sea surface height variability. The relationship of altimetric data to profiling float data is that the anomalies in altimetric height may be obtained from steric height (sea state f(T,S,P)) and from the float's drift velocity (Davis, 1998). Therefore, the role of profiling float data is to diagnose both the steric height and drift velocity. Hence to compute the drift velocities, surface trajectory information is required. And INCOIS being an Argo Regional Centre (ARC) has the responsibility to generate and disseminate this data on real-time. As of date a total of **140 trajectory** netcdf files were processed and uploaded to the Global data Assembly Centre (GDAC). The process of generation of trajectory netcdf files undergoes quality checks like position, time, cycle number, etc., and corresponding quality status is assigned to each parameter.

# 2. Section I: Argo Trajectory File Generation and Dissemination

## 2.1 Float Profiling Operation

Once the Argo float is deployed, it sinks to a programmed depth of about 1000m to 1500m (known as parking depth), and drifts for a few days as programmed (5 or 10 days cycle). After this period, the float sinks to a profiling pressure (2000m) (profiling depth), then rise collecting instantaneous profiles of pressure, temperature and salinity data on their way to the surface. Once at the surface, the float remains there for about 9-15 hrs, continuously transmitting the data collected and allowing the satellite system to determine the surface drift. As the satellites pass over the float while on surface, they collect the data sent by the transmitter overboard the float and deliver to the ground station. The float then sinks again repeating its profiling mission after 5/10 days. In most cases, a float is programmed to repeat the same cycle. However, in some instances parking pressure can be programmed to vary from cycle to cycle. The schematic of Argo profiling operation is shown in figure1.

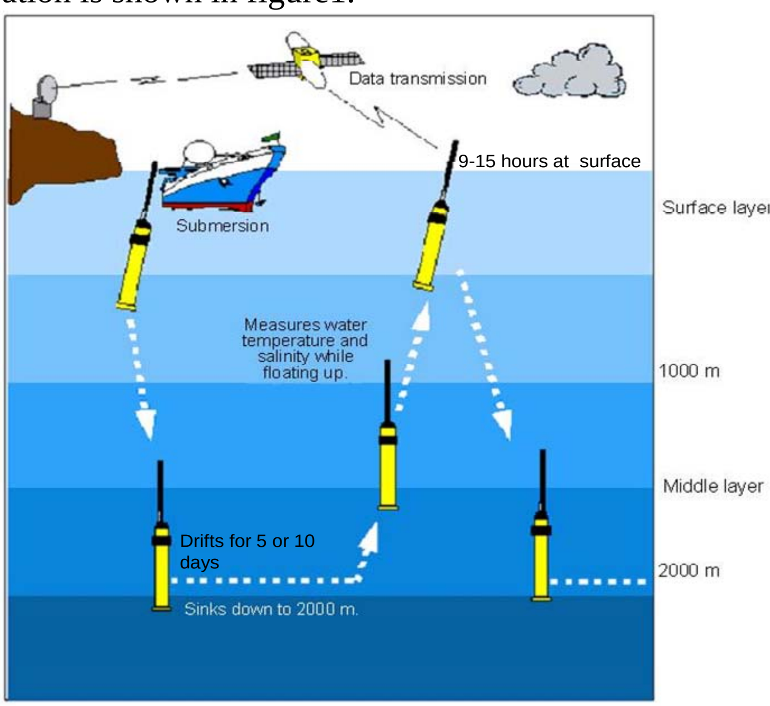


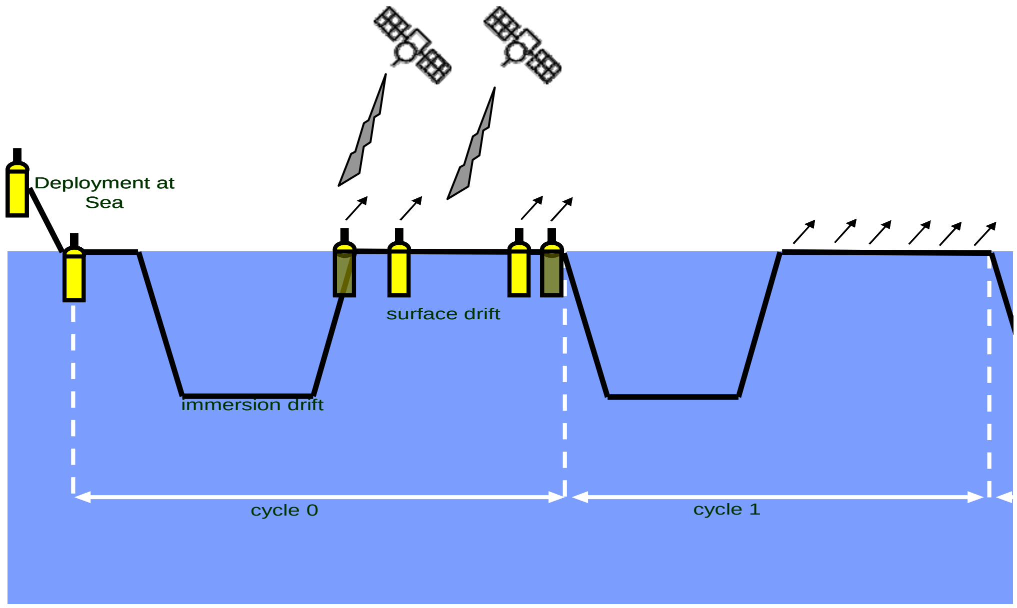

**Figure 1: Schematic of Profiling cycles of Argo Float in the Indian Ocean.**

## 2.2 Data Communication

The data measured by the Argo profiling floats is transmitted using the ARGOS **(Advanced Research and Global Observation Satellite)** satellite-based communications system which collects, processes and disseminates environmental data from fixed and mobile platforms worldwide (CLS/Service Argos Inc., 1996). Most of the floats use the Argos System of satellites to recover data, though lately a few are using the newer Iridium constellation of satellites. However, since Iridium floats spend very less time at the sea surface, the opportunity to observe surface currents by tracking the movements of the floats is lost.

The Argos system comprises six satellites, which follow polar orbits at an altitude of about 850km, 50 terrestrial receiving stations and two data processing centres. Unlike the Global Positioning System (GPS) that needs a minimum of three satellites to be in range to pinpoint an object's location, Argos requires just one satellite to "see" a transmitter to do this. As a (any of the six) satellite passes overhead, it picks up data from an ARGOS transmitter on board the Argo float, which is continuously sending out messages in short pulses. The floats transmit data while on surface. The transmitter on the float sends out data irrespective of the satellites' presence overhead as the data communication is only one way. However the duration of the satellite being in the range of the ARGOS transmitter onboard the float is very short. During the 10 minutes or so that the satellite is in range, it will measure the frequency of each message it receives. The satellite-system utilizes the Doppler shift effect to determine the location of the floats, allowing the satellite to determine their surface drift. The Doppler shift effect means that each frequency the satellite receives is slightly different - as it moves towards a transmitter, it records a higher frequency, and as it moves past the float, it records a lower frequency. Using these frequency changes, together with the satellite's speed, position and the original frequency that the transmitter beamed out, the transmitter's position can be determined.

Using the ARGOS system for data transmission, the maximum message size that can be transmitted at once is 32 bytes of binary data packet /string. The ARGOS transmitter can transmit these data packets every 90-200 seconds, depending on the transmission options selected. Due to the restrictions of the ARGOS system, the transmission repetition period of the ARGOS Platform Transmitter Terminal (PTT) onboard the floats that have been deployed thus far has been either 20, 44 or 90 seconds. The data volume of a single observation (full profile- float internal information and the pressure, temperature and salinity data measured for approximately 60 layers) by the ARGO float is approximately 400 bytes. Hence the data is divided into 12-14 message blocks and transmitted repeatedly, in message-number order. Approximately it takes (90 x 32 x 14) seconds ie., 672 minutes. It is therefore difficult to transmit all of the data during single satellite pass over the float. To ensure that the whole data is transmitted without fail, the profiling floats remain on the sea surface for 8-21 hours, depending on the latitude and satellite coverage. Most transmissions are repeated to ensure complete data transfer, as satellites are not always within range. There can be data gaps depending on location and the satellite pass. The communication between the satellites and the float is depicted schematically in figure 2.



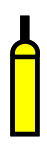

 Both position and time known  Only time known- computed.

**Figure2: A schematic representation of the float cycles and communication between the float and the satellite.**

The satellite communications system deliver the data to the either ARGOS data processing Centres (CLS- Collecte Localisation Satellites ) and then to Argo Regional Data Assembly Centres (RDAC) via email/ ftp or the RDACS access to the Service ARGOS host by ftp every 6 hours in order to retrieve data., or RDACs connect directly to the communications system provider to download data. This data transfer happens several times a day. INCOIS being a regional and national data centre for the Indian Ocean, is responsible for converting this data stream from each float to profile and drift information. INCOIS receives the data from CSL, France via ftp every 6hours. The data thus acquired is classified by CLS and the files of INCOIS Argo are made available to INCOIS for obtaining them.

## 2.3. Decoding and Trajectory File Generation

INCOIS has so far deployed 160 Argo floats and each has a PTT ID. All the PTTs deployed (and those to be deployed in future) by INCOIS are given a common program ID - “02602”. CLS receives the data from the ARGOS system and segregates the data by this program ID and makes available the data of Program ID 02602 to INCOIS by ftp. The decoding and trajectory file generation is performed on five modules which are described below.

**Module 1: Data Segregation & CRC**

Every six hours, CLS appends a new data file with all the Argo floats’ data belonging to Program ID -02602 which have surfaced and transmitted data in the last six hours. The data received from CLS is in Hexadecimal format. As mentioned earlier, the typical data set of a full profile contains 12-14 messages. All the information about the profiles is contained in the first message (message number 01). Message number 2 to 12/14 contains the parameter measurements. For each satellite transmission, ARGOS captures the data and attaches a station header (consisting of information like PTTID, location, date, time etc) to the transmission data. For preparing the trajectory files and computing the surface drifts, the station header and corresponding message number 01 packets are essential. The encoding for message “01” is given in table1. Hence, from each of the four (24/6) files received each day, the station header and all corresponding message number ‘01’ packets are retained and the profile information contained in the other message is discarded. However before discarding, the total number of message blocks is determined. The station data and packets of 01message are segregated based on PTT_ ID. Each PTT corresponds to unique WMO-ID i.e Each Argo float has a unique PTT and a unique WMO_ID.

The received data may contain errors occurred during transmission. Therefore, the first byte of the 32 bytes of transmission data is assigned to the 8-bits Cyclic Redundancy Check (CRC) code calculated from the remaining 31 bytes. The CRC effectively detects burst errors (successive bit errors) and has revealed that nearly 20% of the received data contains errors (Nakajima et al., 2001). Hence the message 01 is passed through the Cyclic Redundancy Check (CRC).

**Module 2: Real-time Quality Control**

After the data passes the CRC check it is then subjected to the following five real-time quality controls.

**1. Platform Identification:** Each time a new float is deployed a unique WMO ID is assigned to it and the metafile containing the metadata of that float should be available. Data from platforms (from PTTs) without WMOID should be discarded.

**2. Impossible Date Test:** The test requires that the observation date and time from the float be sensible.

- Year greater than 1997 (After Argo program launch)
- Month in range 1 to 12
- Day in range expected for month
- Hour in range 0 to 23
- Minute in range 0 to 59

If any one of the conditions is failed, the date should be flagged as wrong.

**3. Impossible Location Test:** The test requires that the observation latitude and longitude from the float be sensible.

- Latitude in range -90 to 90
- Longitude in range -180 to 180

If either latitude or longitude fails, the position should be flagged as wrong and none of the data from the float should go out on the GTS.

**4. Position on Land Test:** The test requires that the observation latitude and longitude from the float be located in an ocean. ETOPO5 is used to see if data are located on land. If the data are cannot be located in an ocean, the position should be flagged as wrong
and they should not be distributed on the GTS.

**5. Impossible Speed Test:** Drift speeds for floats can be generated given the positions and times of the floats when they are at the surface and between profiles. In all cases the drift speed should not exceed 3m/s. If it does, it means either a position or time is wrong, or a float is mislabeled. Using the multiple positions available for a float while at surface, the error position or time is isolated and flagged. As the real time quality controls are done quality status flags are assigned to each measurement.

**Module 3: Missing Cycle Introduction & Estimation of Surface time**

Sometimes the data of a cycle is not captured and the float is not reported on a day it has to report. Such a cycle is called a "Missing Cycle". For those cycles the cycle number and profile number are introduced and the position, time and all other parameters corresponding to the cycle are flagged. Other Parameters like computing Julian day from date and time, making the Julian day to be monotonic, etc are arrived at, using intermediate files and appropriate quality status flags are assigned to each measurement.

A majority of the present Argo fleet uses Argos satellites for data telemetry and position fixing, which means that several hours can elapse between a float reaching the surface and the first position being calculated. During this time the float can be carried several kilometers by the surface current. A corresponding unmeasured displacement can occur at the end of the float's surface time. If the surface arrival and departure times are known, a higher level product could be generated by extrapolating the surface trajectory from the end reported positions to estimated surfacing and diving positions. In an effort in this direction, as a first measure, the surface arrival times are estimated.

As the float surfaces at any (first surface position) position it starts sending out messages. But the satellite may or may not pass during the time the float just pops up. So the float waits on the surface for some time allowing the satellites to capture data during any part of this time. For the Indian INCOIS floats, a typical stay at the sea surface is between 9 and 15 hours. In other words, the floats once surfaced, continually transmit its profile data to satellites passing overhead until its next descent. As already mentioned, a particular profile data set can contain approximately 12 messages ( the number depending on the number of temperature measurements per profile as programmed at the time of launching the float) with the first message containing information about the profile. This set of 12 or so messages is called a block. Once sending the first block is over, the float PTT repeats sending the profile data as block 2. This is successively done until its next descent. The schematic representation of this communication of the float PTT with the satellite and the float cycle are shown in figure 2. Each time the satellite overhead determines the float's position and time as long as the latter drifts on the sea surface. Using these position and time measurements collected while on surface, the time of first surfacing can be estimated. This is one of the two main scientific challenges proposed at the second Argo Trajectory Workshop -1) Estimation of times at end of ascent and start of descent and 2) Estimation of position at those times by extrapolation of reported surface positions (the code for this module is under progress).

The surfacing time is estimated using,

$$SurfacingTime = t_m - (\tau \times n) \times (m - 1) \qquad (1)$$

Where,

$t_m$ is time at which message number “01” of message block number “m” was received

$\tau$ is repetition period of ARGOS transmission for that PTT

$n$ is the number of messages per message block

This information is encoded in the station header and message number “01”. The encoding of the message number “01” is given under in table1. Modules 1 to 3 are achieved using shell scripts and C-programming.

| Byte | Indication |
|---|---|
| 01 | CRC |
| 02 | Message Number (=1) |
| 03 | Message Block Number |
| 04 | Serial Number |
| 05 | |
| 06 | Profile Number |
| 07 | Profile Length |
| 08 | Profile termination flag byte |
| 09 | Piston position |
| 10 | Bottom temperature |
| 11 | |
| 12 | Bottom salinity |
| 13 | |
| 14 | Bottom pressure |
| 15 | |
| 16 | Battery voltage |
| 17 | Surface pressure |
| 18 | |
| 19 | Internal vaccum |
| 20 | Bottom piston position |
| 21 | Temperature of 2nd last measurement |
| 22 | |
| 23 | Salinty of 2nd last measurement |
| 24 | |
| 25 | Presure of 2nd last measurement |
| 26 | |
| 27 | Temperature of 3rd last measurement |
| 28 | |
| 29 | Salinty of of 3rd last measurement |
| 30 | |
| 31 | Presure of 3rd last measurement |
| 32 | |

Table1: Encoding for message number 01

**Module 4: Netcdf generation & Visual Quality control**

The Trajectory file contains information on three-dimensional movement of the float. It is one file containing the complete trajectory of the float as well as the measurements collected while drifting and the estimated times of first surfacing. Once the intermediate files with proper cycle numbers, computed monotonic Julian day, surfacing times, etc, are ready, ASCII- CDL files for each float are generated with the help of scripting and C programming. These CDL files are then converted to NETCDF format using NC utilities. Finally a visual check is performed to verify that there are no missing cycles without cycle numbers and to check the surface time intervals. For visually quality control, the "time of measurement – of the day" for each surface measurement is plotted against the "cycle number". By doing so, it is possible to know and check for the time duration spent by the float at the surface, and to check whether any missing cycles are overlooked. Also the cycles which are flagged can be known. Some examples of the visual check are shown in figures 3 and 4.

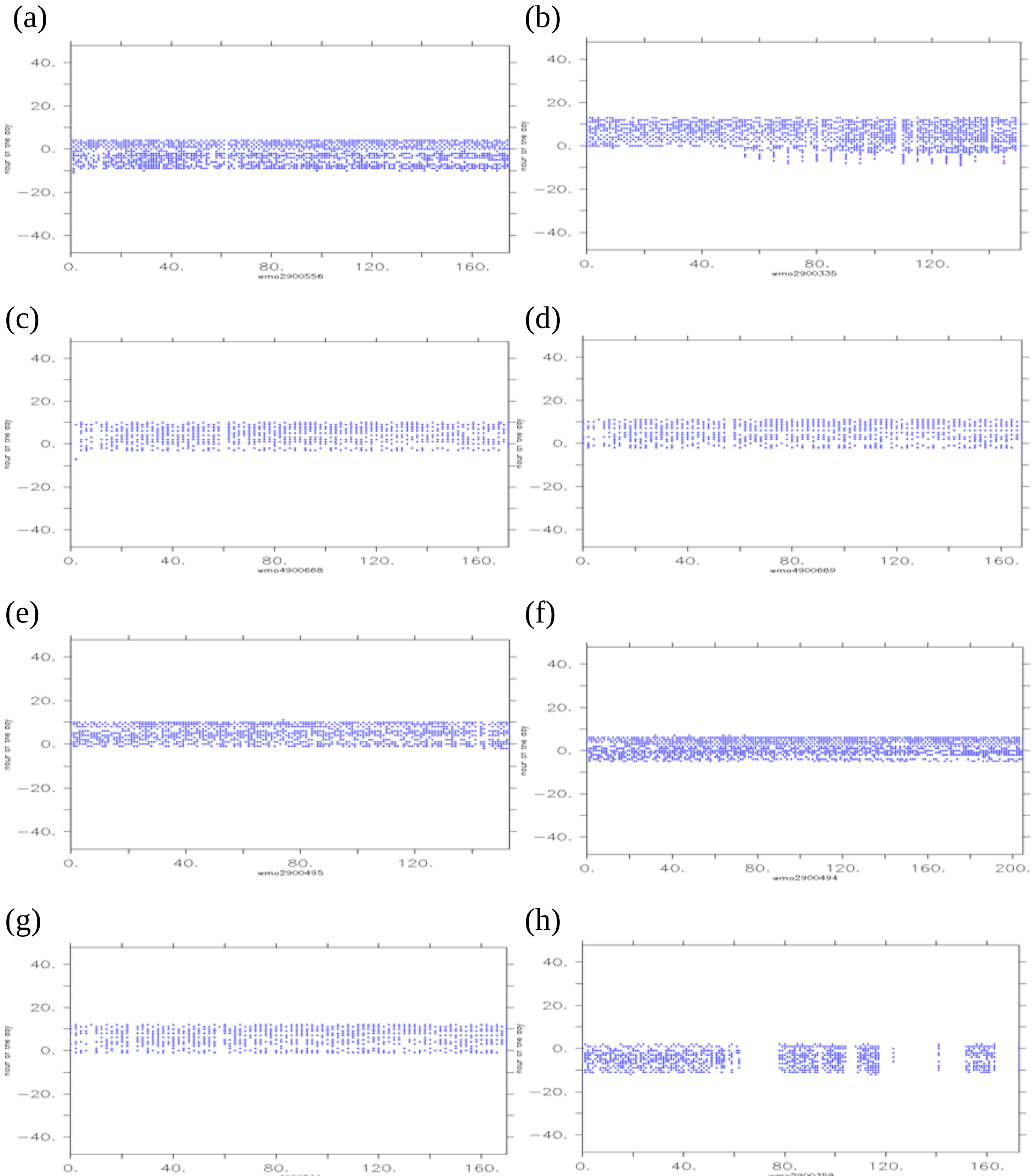



**Figure 3 Examples of visual quality control plots of floats which passed Quality control with hour of the day against cycle-number for WMO IDs (a) 2900556 (b) 2900335 (c) 4900668 (d) 4900669 (e) 2900495 (f) 2900494 (g) 4900511 (h) Passed but with data gap- Data missing for cycles 50 to 60 and data missing from 120 to 140 for float 2900358 ; (X-axis showing cycle number and Y-axis hour of the day)**

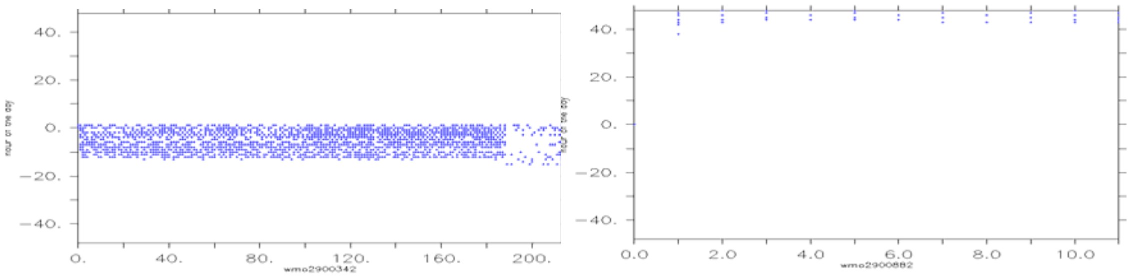



**Figure 4. Examples of visual quality control plots of floats which failed Quality control and reprocessed (a)For cycle numbers 180 to 200 reports of some satellites are missing for float 2900342 (b) Initial Land point when switched on before deployment to be eliminated float 2900883; (X-axis showing cycle number and Y-axis hour of the day)**

The trajectory files of floats that pass through the visual check are loaded in the database and uploaded to the GDAC (Global Data Assembly Centre). As of date a total of **140 trajectory** netcdf files were processed and uploaded to the GDAC. The trajectory summary of these floats like surfacing time period and surface residing time are listed in table2. The complete data flow from data transmission from the float to data reception at INCOIS to uploading output data( ie., decoded and Netcdf generated) to GDAC data is shown in Figure 5.

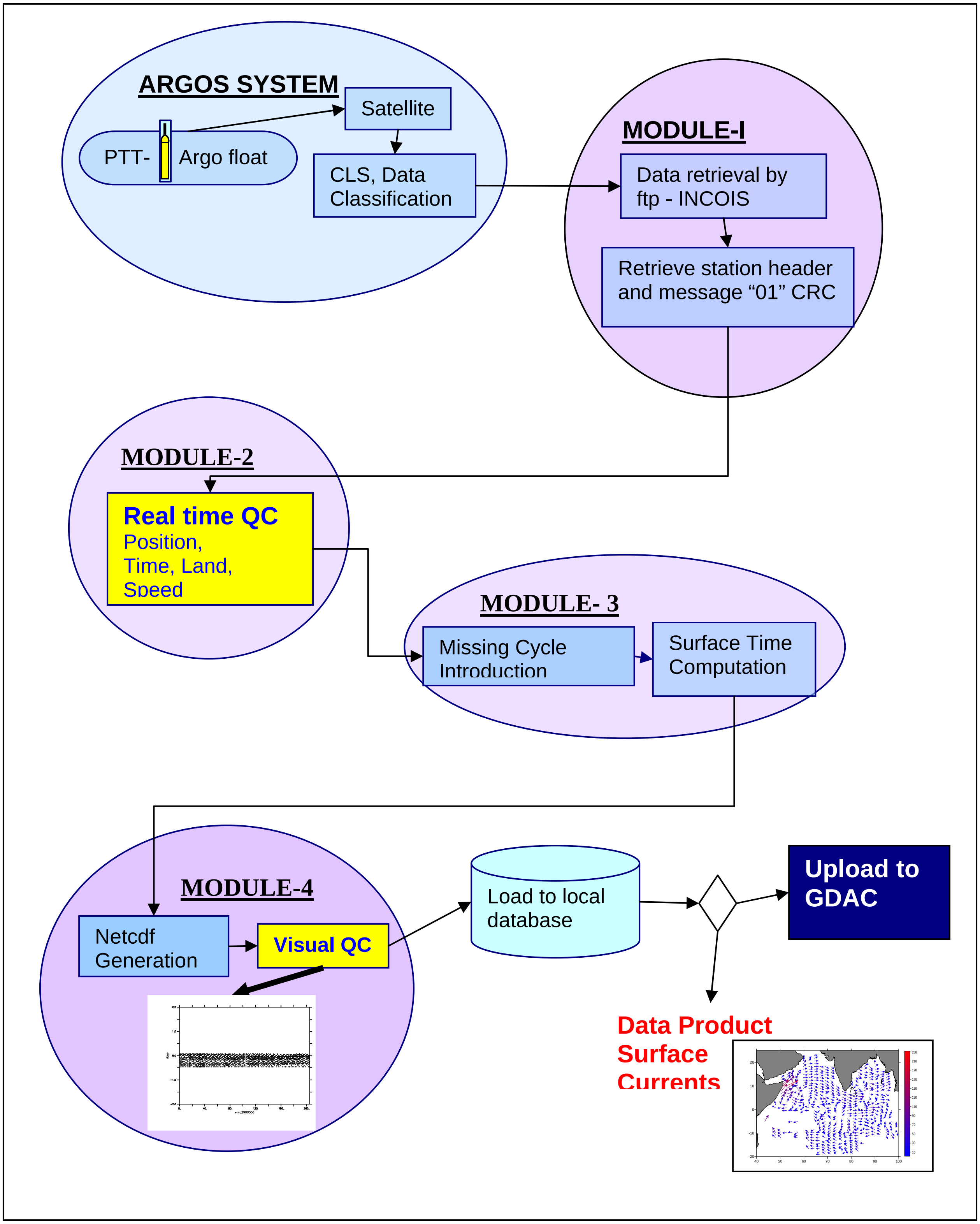



**Figure 5 Complete Data Flow from Float transmission to end products - data to GDAC & Surface Currents**

**Table2: Trajectory summary of INCOIS Argo floats listing PTT_ID, WMO_ID, deployment data, cycle of the float, surface residing time period and surface residing duration.**

| PTT ID | WMO_ID | Date of Deployment | Cycle (days) | Surface Residing Period | Max Surface Residing Time (hours) |
|---|---|---|---|---|---|
| 29990 | 1900121 | 2/11/2002 | 10 | 18h ~ 9h | 15 |
| 29779 | 2900228 | 22/10/2002 | 5 | 0h ~ 15h | 15 |
| 29806 | 2900229 | 25/10/2002 | 10 | 22h ~ 11h | 13 |
| 29989 | 2900230 | 27/10/2002 | 10 | 23h ~ 12h | 13 |
| 30589 | 2900258 | 2/6/2003 | 5 | 21h ~ 11h | 14 |
| 30596 | 2900259 | 30/05/2003 | 5 | 12h ~ 2h | 14 |
| 30604 | 2900260 | 30/05/2003 | 5 | 20h ~ 9h | 13 |
| 30609 | 2900261 | 10/6/2003 | 5 | 22h ~ 12h | 14 |
| 30615 | 2900262 | 10/6/2003 | 5 | 20h ~ 10h | 14 |
| 30634 | 2900265 | 2/9/2003 | 5 | 21h ~ 12h | 15 |
| 30635 | 2900266 | 22/06/2003 | 5 | 19h ~ 14h | 19 |
| 30641 | 2900267 | 23/06/2003 | 5 | 21h ~ 16h | 19 |
| 30670 | 2900269 | 21/06/2003 | 5 | 19h ~ 13h | 18 |
| 30734 | 2900271 | 20/06/2003 | 5 | 21h ~ 15h | 18 |
| 30735 | 2900272 | 19/06/2003 | 5 | 22h ~ 16h | 18 |
| 30736 | 2900273 | 18/06/2003 | 5 | 22h ~ 16h | 18 |
| 30764 | 2900274 | 18/06/2003 | 5 | 21h ~ 14h | 17 |
| 28657 | 2900336 | 27/04/2004 | 5 | 19h ~ 9h | 14 |
| 28651 | 2900337 | 28/04/2004 | 5 | 23h ~ 13h | 14 |
| 28653 | 2900338 | 29/04/2004 | 5 | 0h ~ 13h | 13 |
| 28652 | 2900339 | 4/5/2004 | 5 | 14h ~ 3h | 13 |
| 28658 | 2900340 | 1/5/2004 | 5 | 13h ~ 2h | 13 |
| 28659 | 2900341 | 1/5/2004 | 5 | 11h ~ 1h | 14 |
| 28696 | 2900342 | 2/5/2004 | 5 | 9h ~ 1h | 16 |
| 28697 | 2900343 | 3/5/2004 | 5 | 13h ~ 3h | 14 |
| 28699 | 2900345 | 4/5/2004 | 5 | 10h ~ 2h | 16 |
| 28656 | 2900346 | 5/5/2004 | 5 | 14h ~ 4h | 14 |
| 28700 | 2900347 | 5/5/2004 | 5 | 13h ~ 2h | 13 |
| 28701 | 2900348 | 6/5/2004 | 5 | 12h ~ 2h | 14 |
| 28702 | 2900349 | 7/5/2004 | 5 | 12h ~ 1h | 13 |
| 28703 | 2900350 | 8/5/2004 | 5 | 0h ~ 13h | 13 |
| 28270 | 2900351 | 19/05/2004 | 5 | 12h ~ 1h | 13 |
| 28269 | 2900352 | 20/05/2004 | 5 | 14h ~ 4h | 14 |
| 28707 | 2900353 | 21/05/2004 | 5 | 13h ~ 3h | 14 |
| 28706 | 2900354 | 21/05/2004 | 5 | 11h ~ 1h | 14 |
| 28704 | 2900355 | 22/05/2004 | 5 | 12h ~ 2h | 14 |
| 28705 | 2900356 | 23/05/2004 | 5 | 13h ~ 2h | 13 |
| 28268 | 2900357 | 24/05/2004 | 5 | 13h ~ 2h | 13 |
| 28271 | 2900358 | 25/05/2004 | 5 | 12h ~ 2h | 14 |
| 29749 | 2900459 | 29/09/2004 | 5 | 19h ~ 9h | 14 |
| 21858 | 2900461 | 6/12/2004 | 5 | 17h ~ 5h | 12 |

**Table2: Trajectory summary of INCOIS Argo floats (continued….)**

| PTT ID | WMO_ID | Date of Deployment | Cycle (days) | Surface Residing Period | Max Surface Residing Time (hours) |
|---|---|---|---|---|---|
| 21886 | 2900462 | 10/12/2004 | 5 | 17h ~ 5h | 12 |
| 21888 | 2900463 | 7/12/2004 | 5 | 14h ~ 5h | 15 |
| 21895 | 2900464 | 12/12/2004 | 5 | 15h ~ 3h | 12 |
| 21897 | 2900493 | 29/03/2005 | 5 | 0h ~ 12h | 12 |
| 21903 | 2900494 | 30/03/2005 | 5 | 19h ~ 7h | 12 |
| 21919 | 2900495 | 31/03/2005 | 5 | 22h ~ 11h | 13 |
| 21965 | 2900496 | 1/4/2005 | 5 | 22h ~ 10h | 12 |
| 21970 | 2900497 | 16/04/2005 | 5 | 22h ~ 11h | 13 |
| 21974 | 2900498 | 22/04/2005 | 5 | 20h ~ 11h | 15 |
| 22046 | 2900530 | 8/5/2005 | 5 | 12h ~ 2h | 14 |
| 22051 | 2900531 | 8/5/2005 | 5 | 14h ~ 2h | 12 |
| 22054 | 2900532 | 9/5/2005 | 5 | 16h ~ 3h | 11 |
| 22057 | 2900533 | 10/5/2005 | 5 | 16h ~ 3h | 11 |
| 21978 | 2900535 | 29/05/2005 | 5 | 23h ~ 14h | 15 |
| 21979 | 2900536 | 5/6/2005 | 5 | 22h ~ 13h | 15 |
| 21983 | 2900537 | 1/6/2005 | 5 | 23h ~ 14h | 15 |
| 21987 | 2900538 | 27/05/2005 | 5 | 13h ~ 1h | 12 |
| 22014 | 2900539 | 25/05/2005 | 5 | 15h ~ 3h | 12 |
| 25517 | 2900552 | 31/08/2005 | 5 | 14h ~ 4h | 14 |
| 25502 | 2900553 | 1/9/2005 | 10 | 13h ~ 4h | 15 |
| 25505 | 2900554 | 3/9/2005 | 5 | 11h ~ 2h | 15 |
| 25507 | 2900555 | 0309/2005 | 5 | 13h ~ 4h | 15 |
| 25512 | 2900556 | 4/9/2005 | 5 | 13h ~ 4h | 15 |
| 25477 | 2900557 | 5/9/2005 | 10 | 14h ~ 4h | 14 |
| 25463 | 2900558 | 5/9/2005 | 10 | 13h ~ 4h | 15 |
| 25378 | 2900559 | 6/9/2005 | 10 | 14h ~ 4h | 14 |
| 25295 | 2900560 | 7/9/2005 | 10 | 13h ~ 4h | 15 |
| 25191 | 2900561 | 8/9/2005 | 10 | 13h ~ 4h | 15 |
| 25190 | 2900562 | 8/9/2005 | 10 | 13h ~ 4h | 15 |
| 25451 | 2900563 | 9/9/2005 | 10 | 13h ~ 4h | 15 |
| 25452 | 2900564 | 10/9/2005 | 10 | 13h ~ 4h | 15 |
| 25059 | 2900565 | 11/9/2005 | 10 | 14h ~ 4h | 14 |
| 25188 | 2900566 | 11/9/2005 | 10 | 13h ~ 4h | 15 |
| 25292 | 2900567 | 12/9/2005 | 10 | 13h ~ 4h | 15 |
| 25286 | 2900568 | 12/9/2005 | 10 | 13h ~ 4h | 15 |
| 25246 | 2900569 | 13/09/2005 | 10 | 21h ~ 10h | 13 |
| 25252 | 2900570 | 15/09/2005 | 10 | 21h ~ 10h | 13 |
| 25270 | 2900571 | 15/09/2005 | 10 | 18h ~ 8h | 14 |
| 27423 | 2900754 | 23/05/2006 | 10 | 0h ~ 9h | 9 |
| 27419 | 2900755 | 24/07/2006 | 10 | 0h ~ 10h | 10 |
| 27417 | 2900756 | 24/07/2006 | 10 | 15h ~ 1h | 10 |
| 27435 | 2900757 | 3/8/2006 | 10 | 18h ~ 10h | 16 |
| 27436 | 2900758 | 6/8/2006 | 10 | 21h ~ 6h | 9 |
| 27446 | 2900759 | 11/8/2006 | 10 | 0h ~ 11h | 11 |

**Table2: Trajectory summary of INCOIS Argo floats (continued….)**

| PTT ID | WMO_ID | Date of Deployment | Cycle (days) | Surface Residing Period | | | Max Surface Residing Time (hours) |
|---|---|---|---|---|---|---|---|
| 27425 | 2900760 | 12/8/2006 | 10 | 22h | ~ | 8h | 10 |
| 27426 | 2900761 | 16/08/2006 | 10 | 18h | ~ | 4h | 10 |
| 27427 | 2900762 | 18/08/2006 | 10 | 18h | ~ | 4h | 10 |
| 23561 | 2900764 | 17/09/2006 | 10 | 0h | ~ | 10h | 10 |
| 23603 | 2900767 | 2/10/2006 | 10 | 11h | ~ | 1h | 14 |
| 23619 | 2900768 | 2/10/2006 | 5 | 11h | ~ | 3h | 16 |
| 27430 | 2900772 | 16/03/2007 | 10 | 17h | ~ | 3h | 10 |
| 27432 | 2900774 | 18/03/2007 | 10 | 15h | ~ | 5h | 14 |
| 27433 | 2900775 | 18/03/2007 | 10 | 15h | ~ | 5h | 14 |
| 27422 | 2900778 | 20/03/2007 | 10 | 11h | ~ | 2h | 15 |
| 27448 | 2900780 | 5/6/2007 | 10 | 23h | ~ | 9h | 10 |
| 23556 | 2900781 | 11/6/2007 | 10 | 13h | ~ | 3h | 14 |
| 27447 | 2900782 | 12/6/2007 | 10 | 0h | ~ | 12h | 12 |
| 27424 | 2900877 | 9/9/2007 | 10 | 15h | ~ | 6h | 15 |
| 23488 | 2900878 | 10/9/2007 | 10 | 13h | ~ | 4h | 15 |
| 27469 | 2900880 | 11/9/2007 | 10 | 15h | ~ | 6h | 15 |
| 27452 | 2900881 | 12/9/2007 | 10 | 13h | ~ | 1h | 12 |
| 78572 | 2900883 | 17/11/2007 | 5 | 15h | ~ | 5h | 14 |
| 78573 | 2900884 | 14/11/2007 | 5 | 17h | ~ | 8h | 15 |
| 78574 | 2900885 | 15/11/2007 | 5 | 17h | ~ | 3h | 10 |
| 78575 | 2900886 | 16/11/2007 | 5 | 0h | ~ | 13h | 13 |
| 78576 | 2900887 | 18/11/2007 | 5 | 14h | ~ | 4h | 14 |
| 78577 | 2900888 | 18/11/2007 | 5 | 0h | ~ | 10h | 10 |
| 78578 | 2901073 | 20/11/2007 | 5 | 0h | ~ | 15h | 15 |
| 78579 | 2901074 | 19/11/2007 | 5 | 0h | ~ | 15h | 15 |
| 78580 | 2901075 | 18/11/2007 | 5 | 21h | ~ | 6h | 9 |
| 25262 | 4900510 | 16/09/2005 | 10 | 21h | ~ | 10h | 13 |
| 25264 | 4900511 | 16/09/2005 | 10 | 23h | ~ | 12h | 13 |
| 25278 | 4900668 | 17/09/2005 | 10 | 17h | ~ | 10h | 17 |
| 25279 | 4900669 | 18/09/2005 | 10 | 22h | ~ | 11h | 13 |
| 25283 | 4900670 | 18/09/2005 | 10 | 0h | ~ | 15h | 15 |
| 25519 | 4900671 | 19/09/2005 | 5 | 15h | ~ | 5h | 14 |
| 25533 | 4900672 | 19/09/2005 | 5 | 13h | ~ | 2h | 13 |
| 25535 | 4900673 | 20/09/2005 | 5 | 0h | ~ | 15h | 15 |
| 25539 | 4900674 | 20/09/2005 | 5 | 23h | ~ | 13h | 14 |
| 25541 | 4900675 | 5/9/2005 | 5 | 13h | ~ | 3h | 14 |

## 3. Section II: Data Product- Monthly Climatology of Surface Velocities

An additional important objective of Argo is measurement of ocean circulation in order to determine the broad-scale fluctuations in advection of temperature and salinity. Argo should be capable of detecting not only anomalies in property distribution but also in the transport of these anomalies by the large-scale circulation. Neutrally buoyant satellite-tracked floats were developed in WOCE and deployed in all oceans to measure absolute velocity. The present generation of Argo floats is capable of approximately 100 cycles, each including a T/S profile to about 1500 m depth and a drift velocity measurement at any level between the sea surface and the profile base. The drift estimates from such an array would in addition provide useful estimates of deep pressure fields (reference level).

Surface Current velocities are estimated from the trajectory information of the Argo floats deployed by INCOIS. Surface velocities are obtained from float coordinates fixed by the ARGOS satellites.

The surface drifting velocity $V_s$ is estimated using,

$$V_s = \frac{P_2(x, y, z) - P_1(x, y, z)}{T_2 - T_1}$$

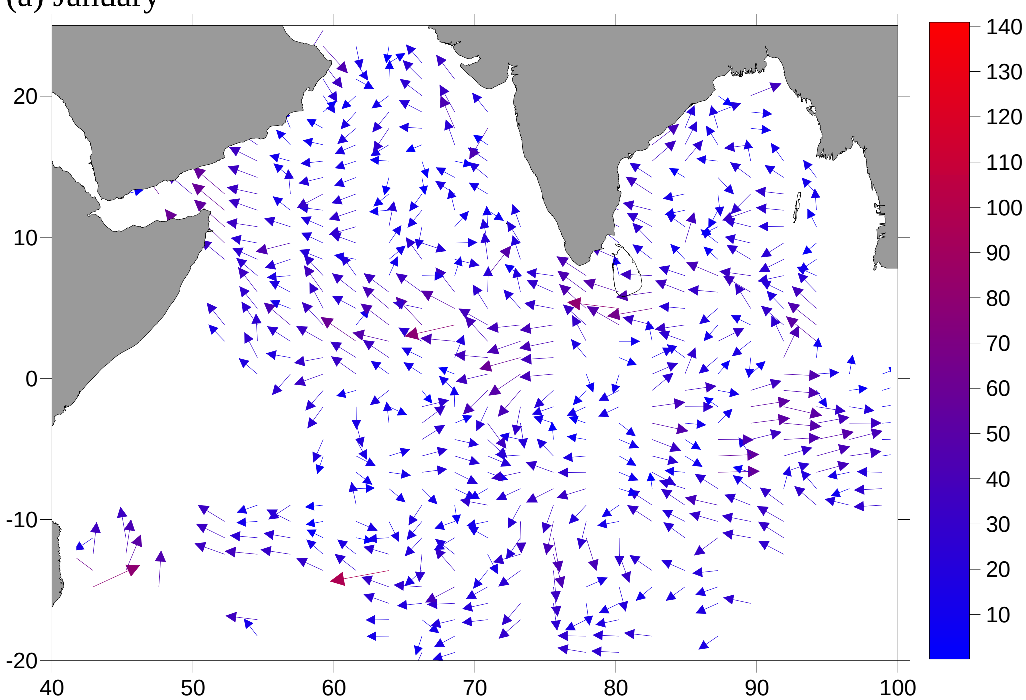
and the direction $\Theta$ using,

$$\Theta = a\tan\left(\frac{y_2 - y_1}{x_2 - x_1}\right)$$

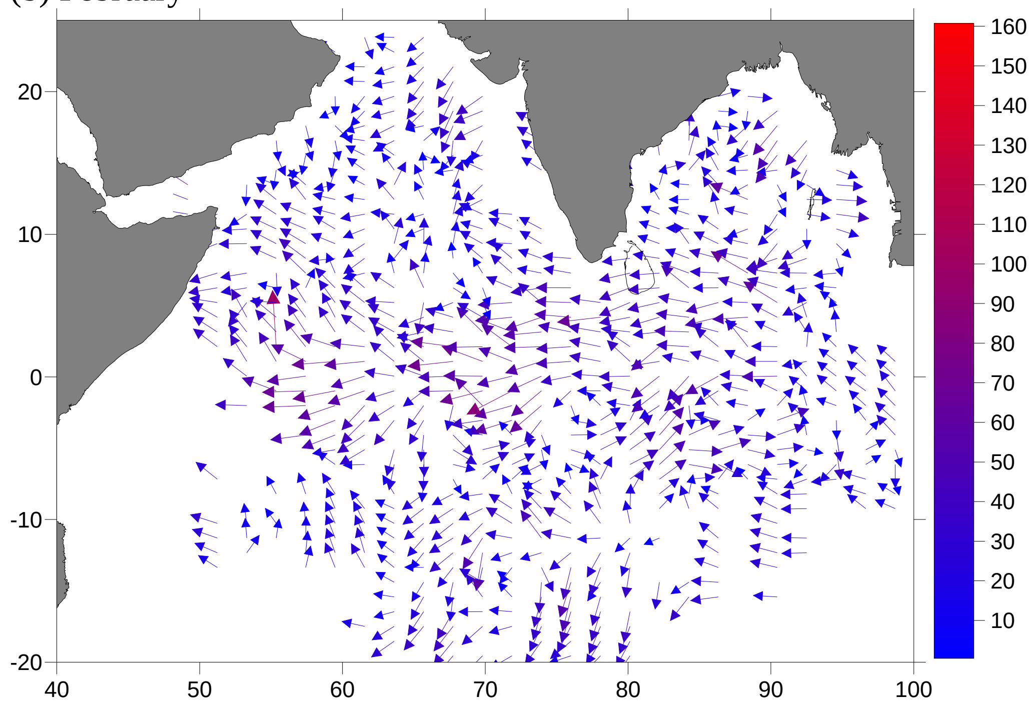
Using the surface drifting velocity and direction, the U and V-Components are computed. A gridded monthly climatology of these surface currents ie., Surface Current Magnitudes, the U- and V- Components of the Surface currents is prepared using objective analysis. The surface currents are derived using data from

140 floats and about 615, 66 values of velocity/Components. The data span the period from October 2002 to February 2008. Objective Analysis is done using Inverse square method adapted from Kessler and McCreary (1993) and modified. Figure 6 shows these climatological monthly fields of the surface current vectors. Figures 7 and 8 show comparison of these Argo generated zonal and meridional components of surface currents with those of SODA (Carton et al, 2000) monthly fields for January and July. In general the monthly fields exhibit the main features of the general circulation patterns of the Indian Ocean like the Somali Current, the Equatroial Jet. The South West Monsoon and East India coastal Currents are well reproduced in the Argo data set. However, because the time and space differences obtained from satellite fixes are very small these Argo Surface drifting patterns also shows mesoscale eddies. This Argo surface current climatology indicates promising products in the future.

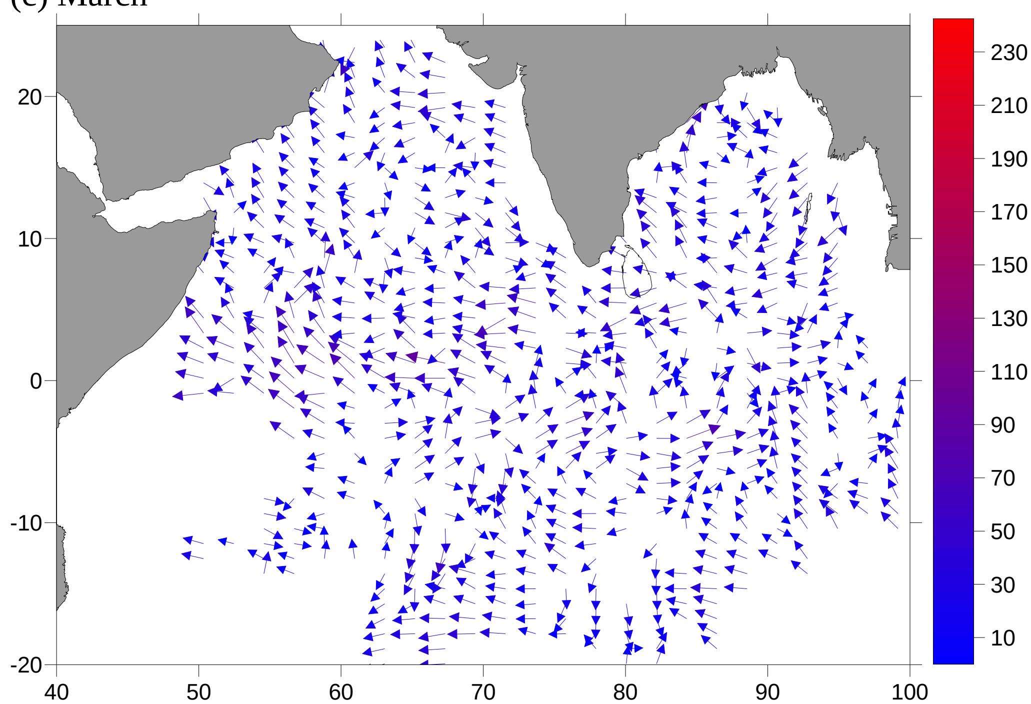
(a) January



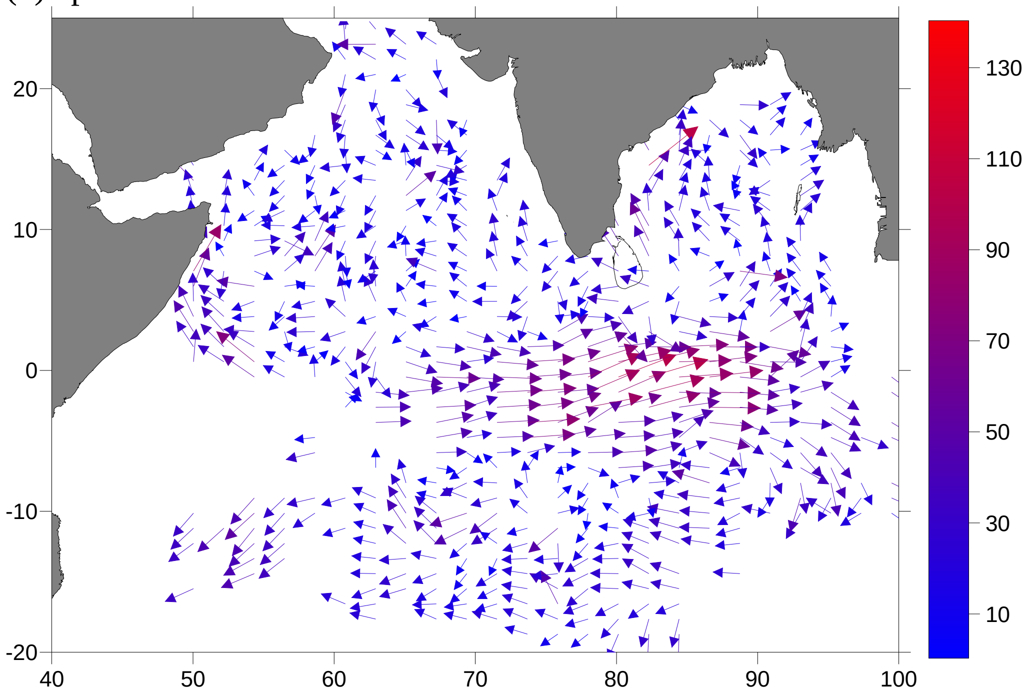
(b) February



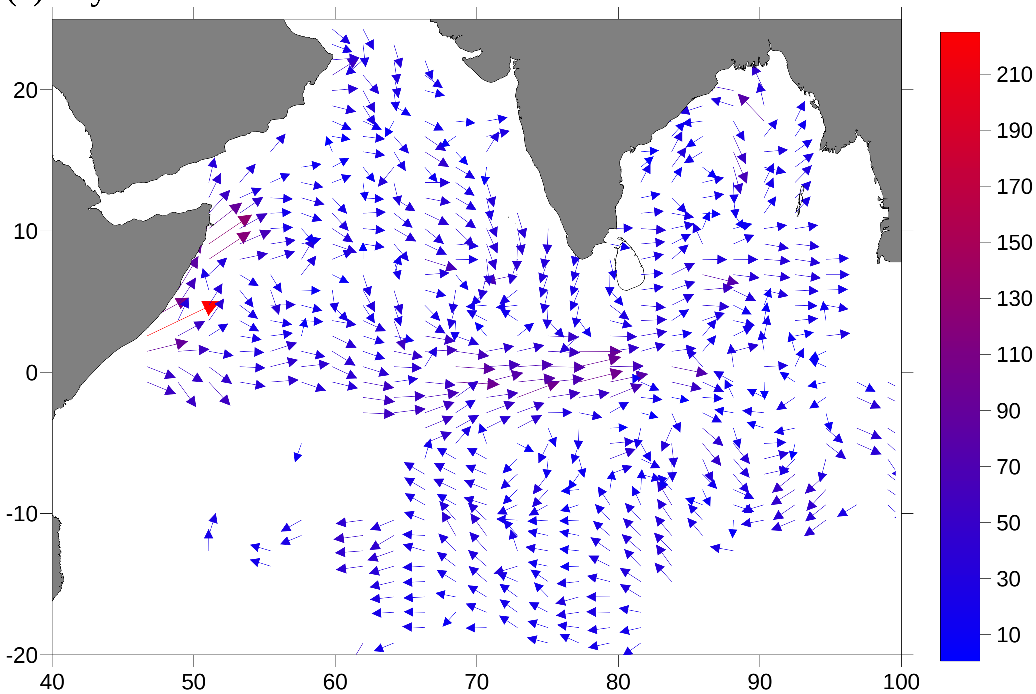

(c) March



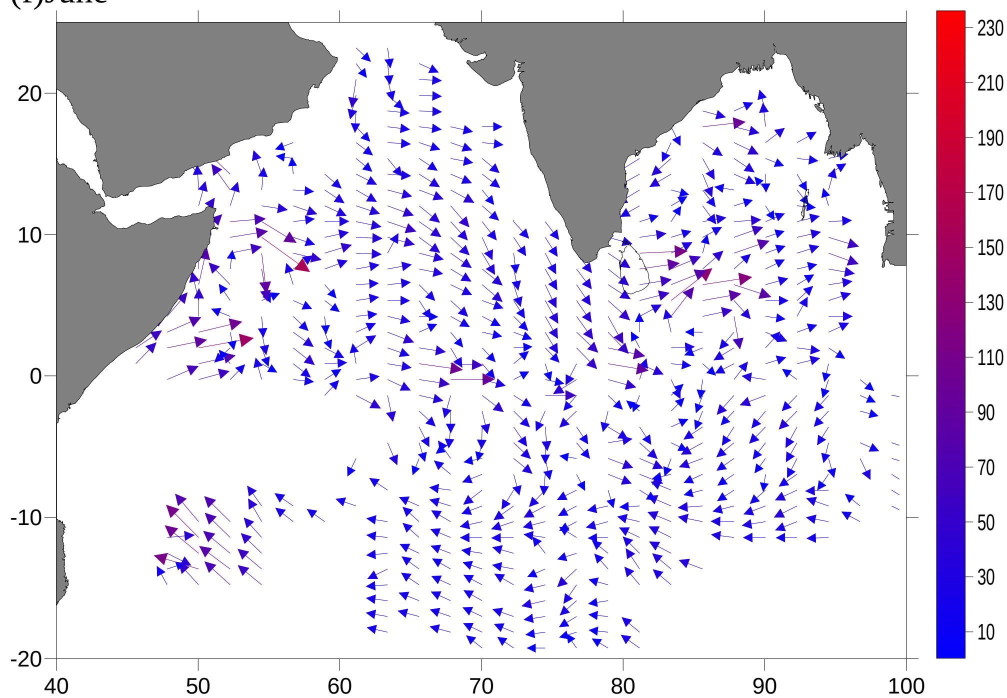
(d)April


20
10
0
-10
-20
40
50
60
70
80
90
100
130
110
90
70
50
30
10

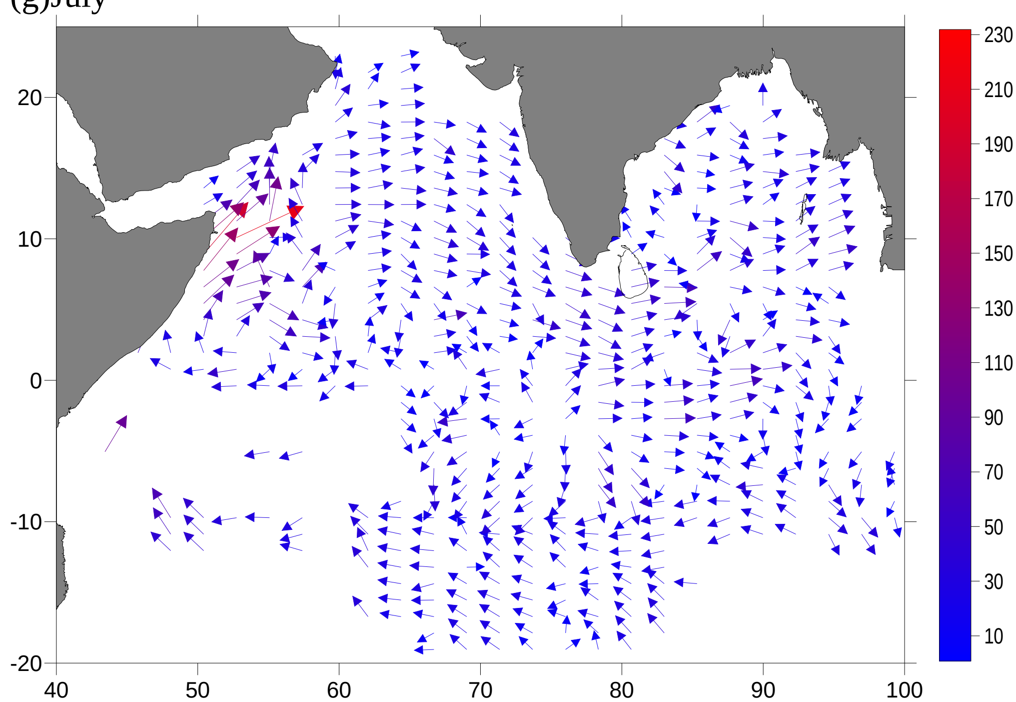
(e)May


20
10
0
-10
-20
40
50
60
70
80
90
100
210
190
170
150
130
110
90
70
50
30
10

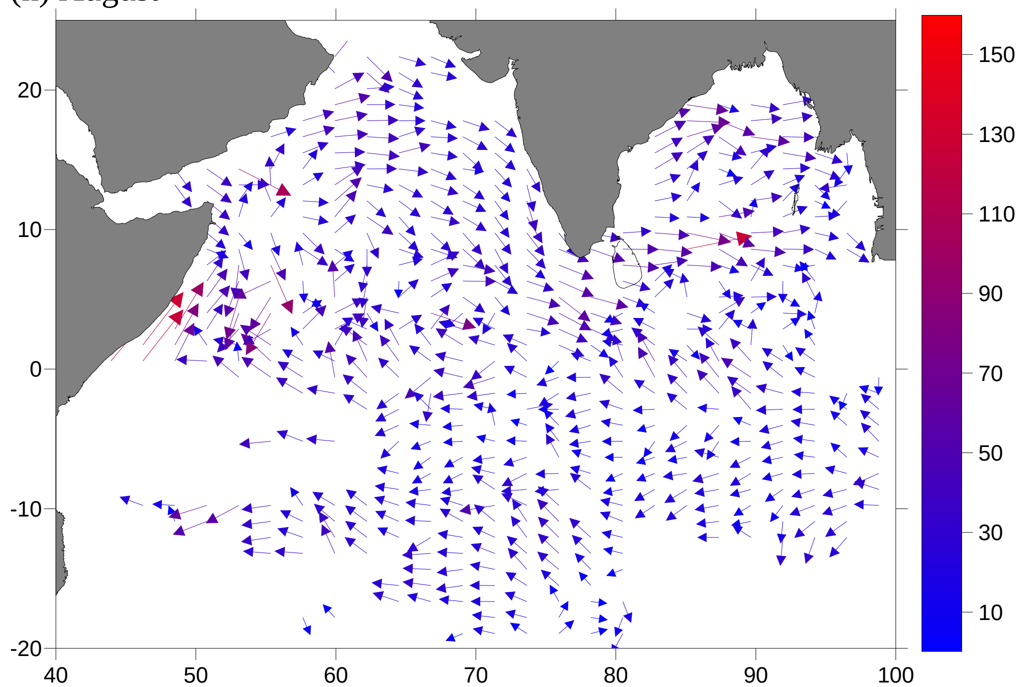
(f)June


20
10
0
-10
-20
40
50
60
70
80
90
100
230
210
190
170
150
130
110
90
70
50
30
10

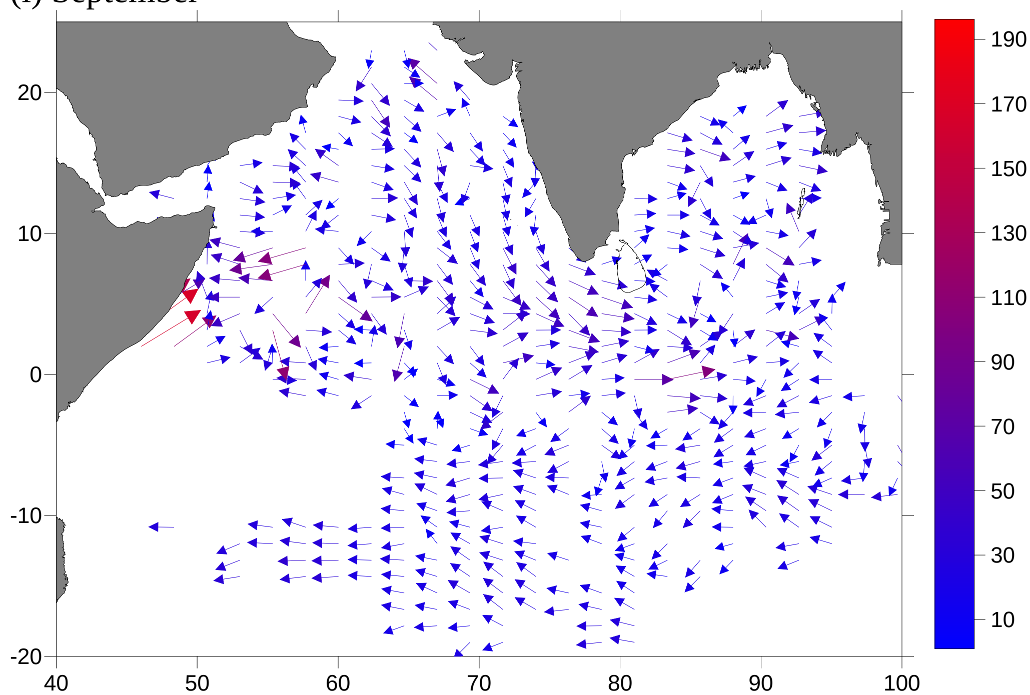
(g)July


20
10
0
-10
-20
40
50
60
70
80
90
100
230
210
190
170
150
130
110
90
70
50
30
10

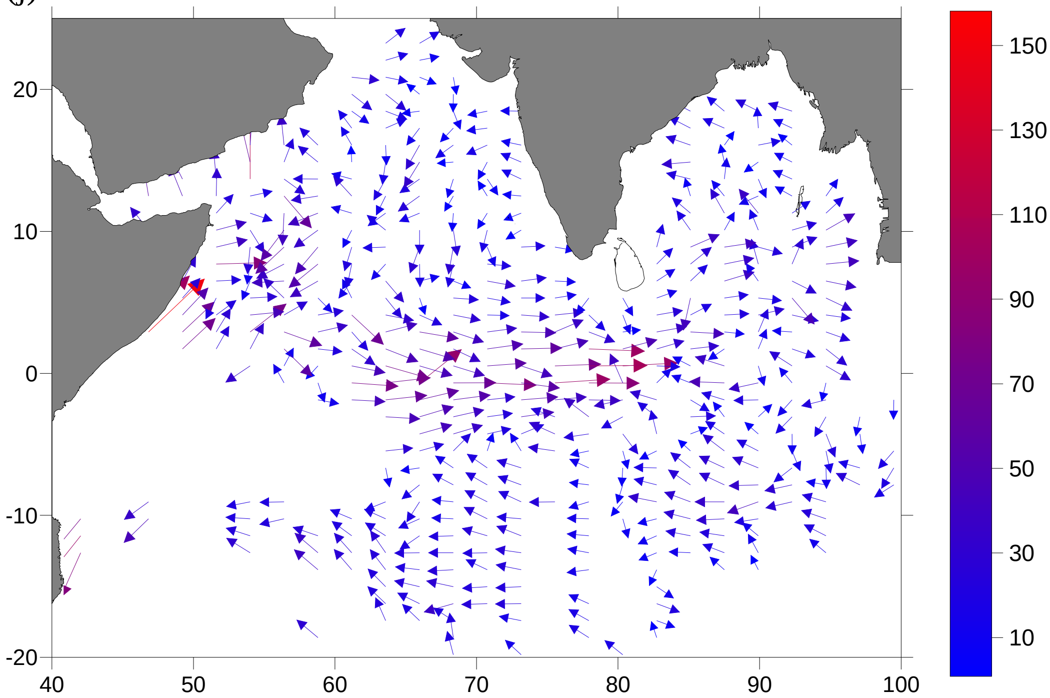
(h) August



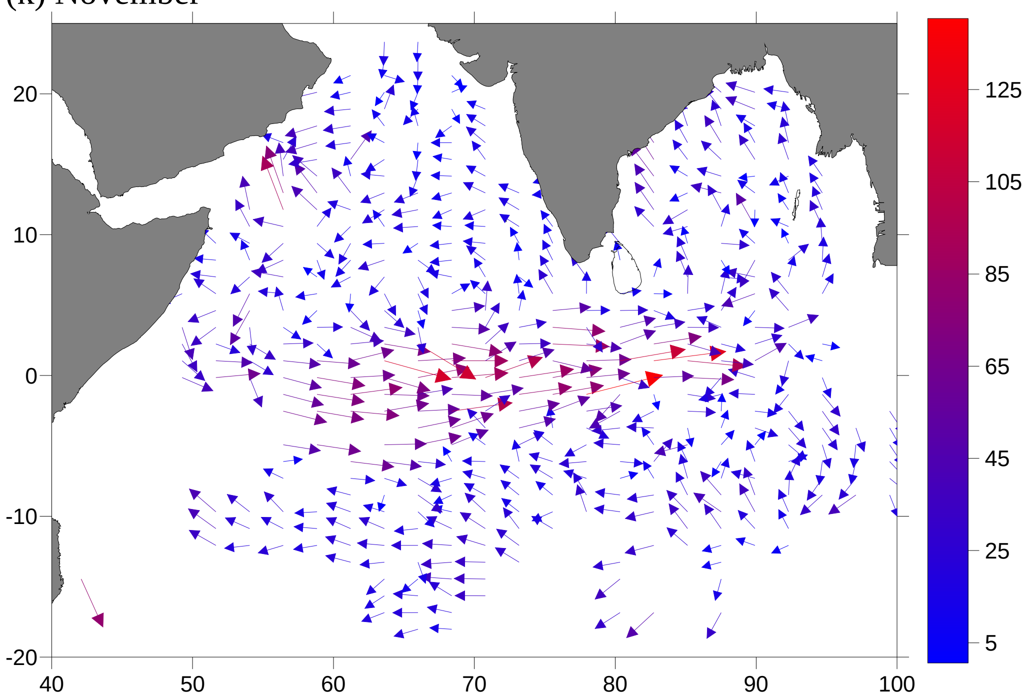

(i) September



(j) October




(k) November



(l) December

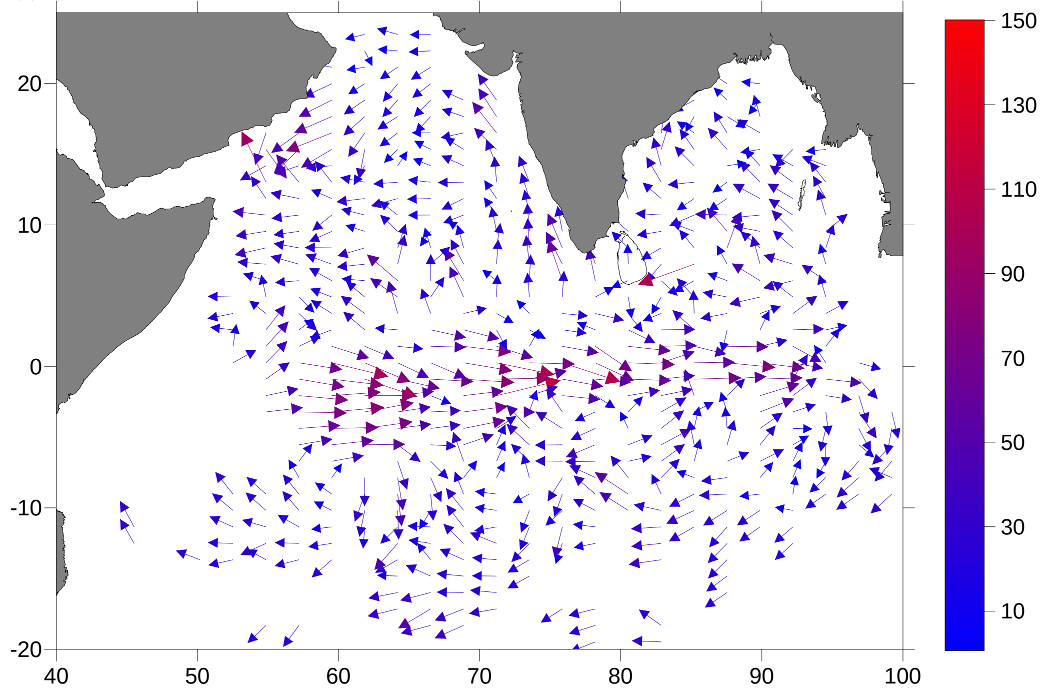
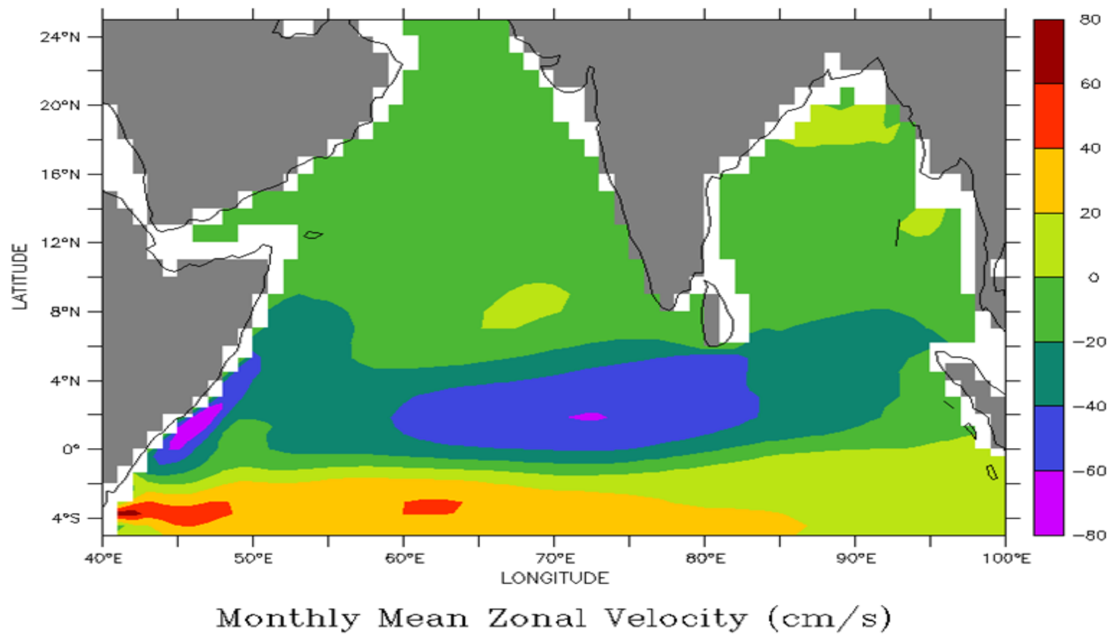



**Figure 6 Monthly Climatological Surface Currents estimated from Argo trajectory data**

(a)




(b)

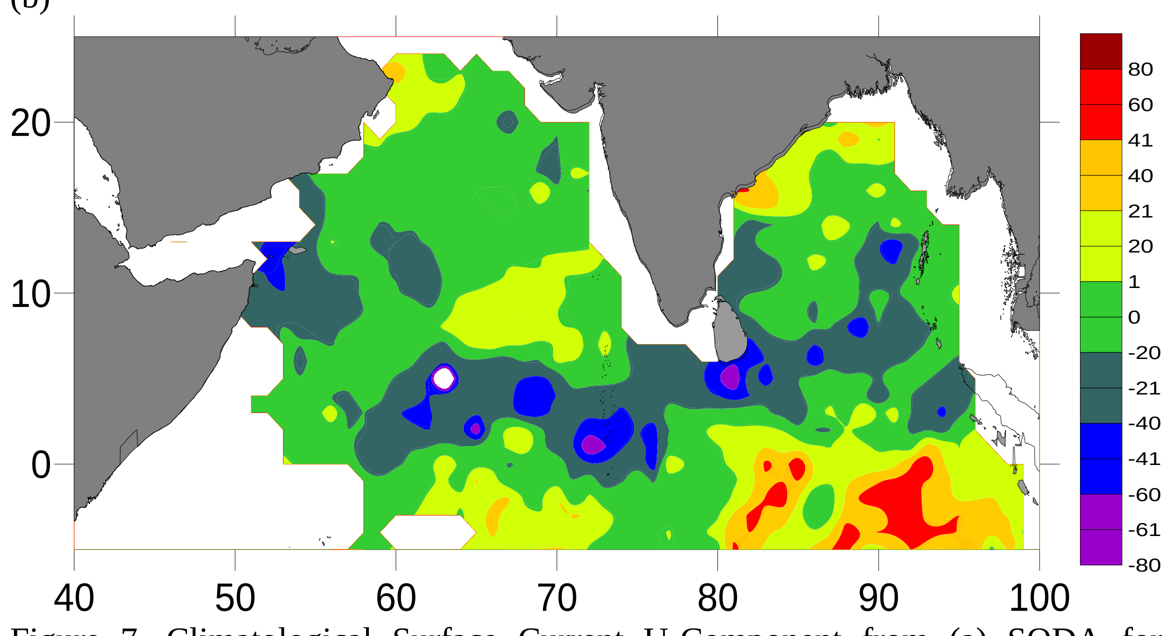
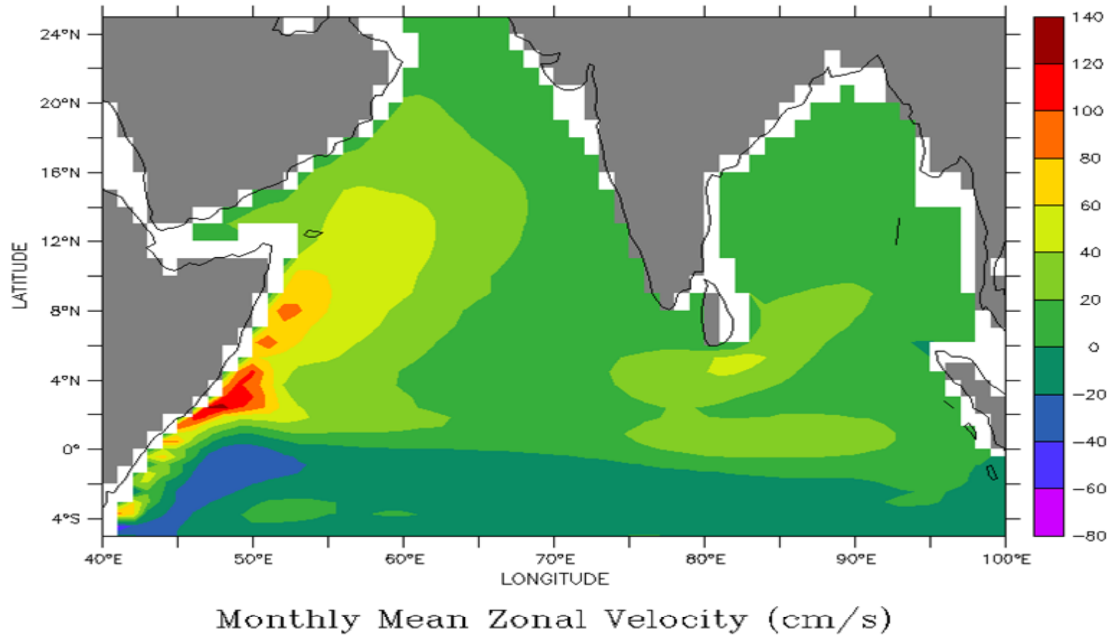



Figure 7. Climatological Surface Current U-Component from (a) SODA for January (b) Argo for January

(c)




(d)

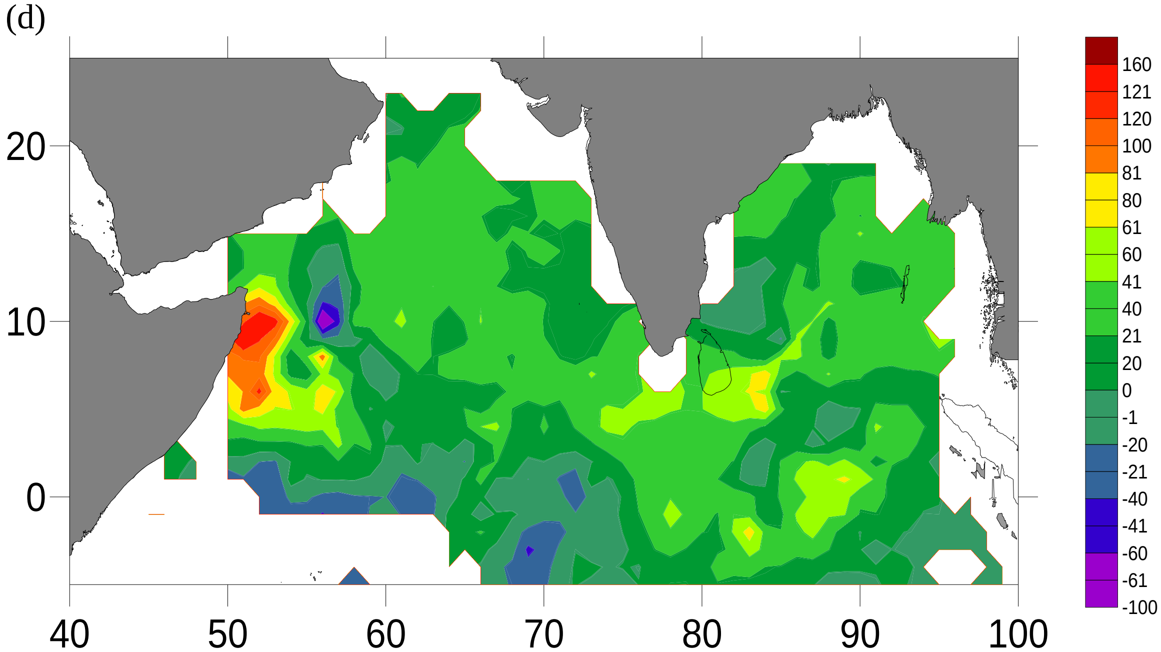
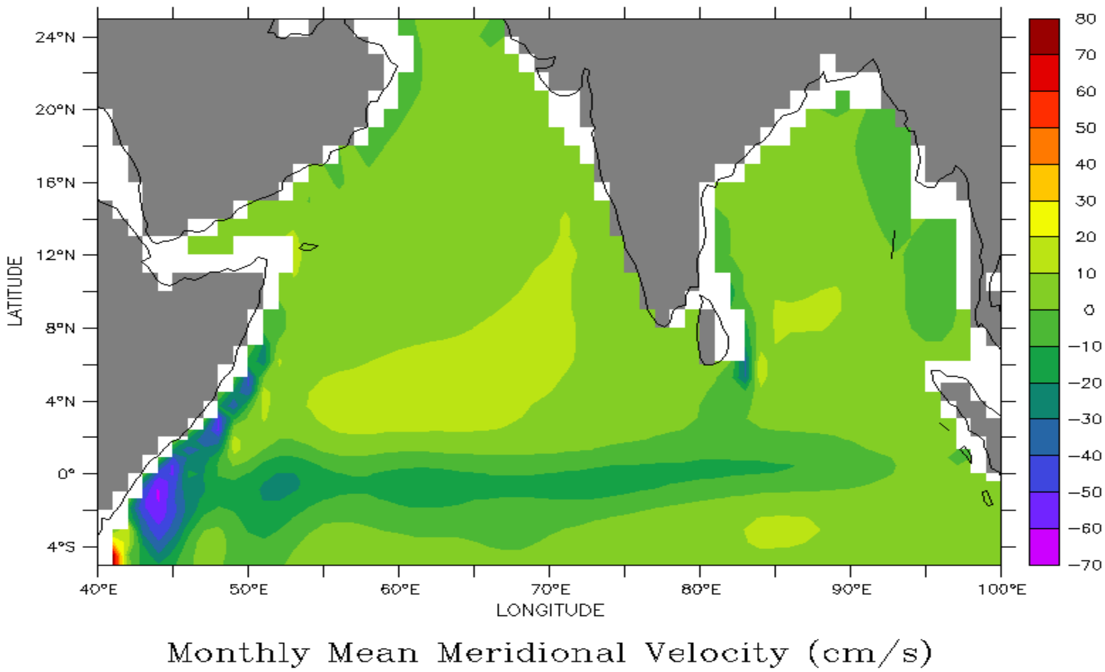



Figure 7. Climatological Surface Current U-Component from (c) SODA for July (d) Argo for July

(a)




(b)

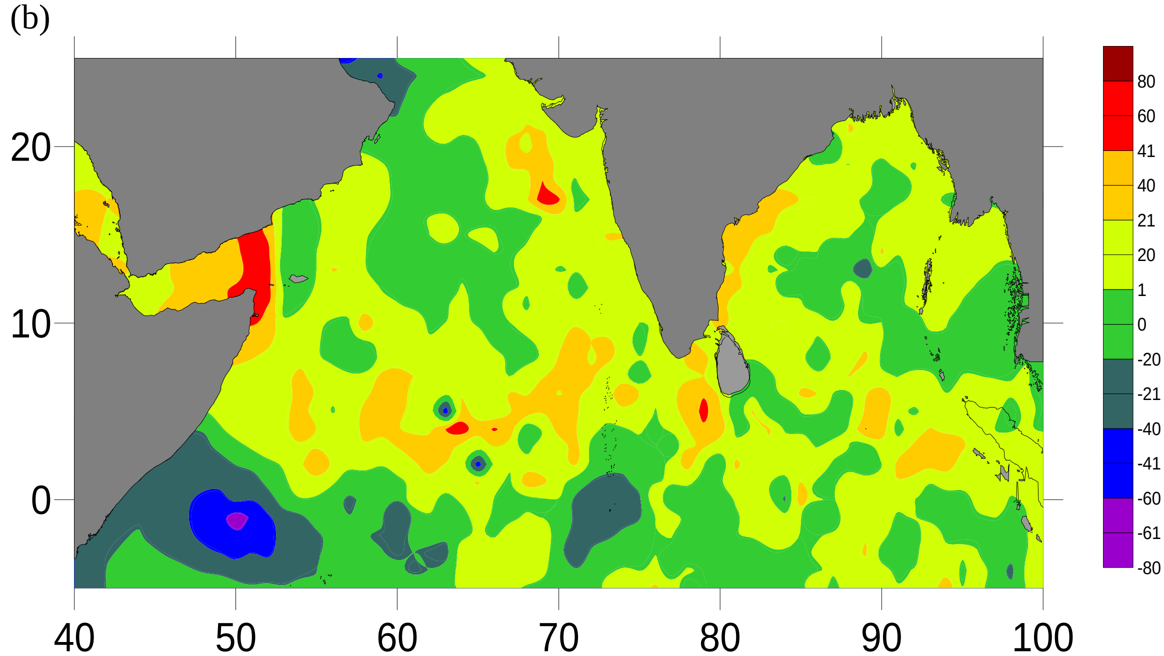
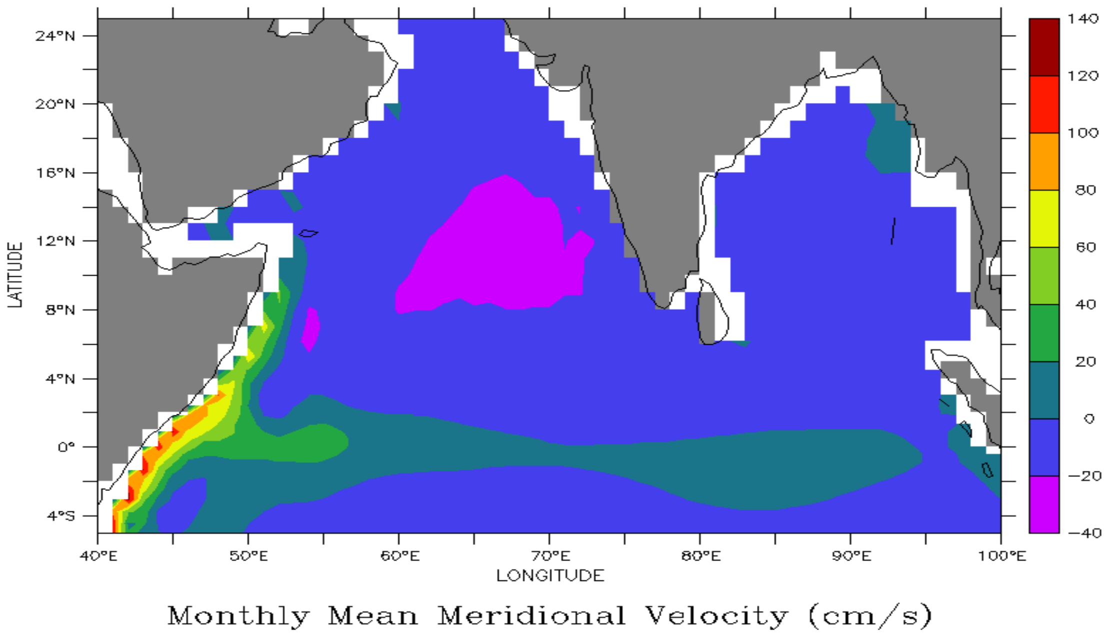



Figure 8. Climatological Surface Current V-components from (a) SODA for January (b) Argo for January

(c)




(d)

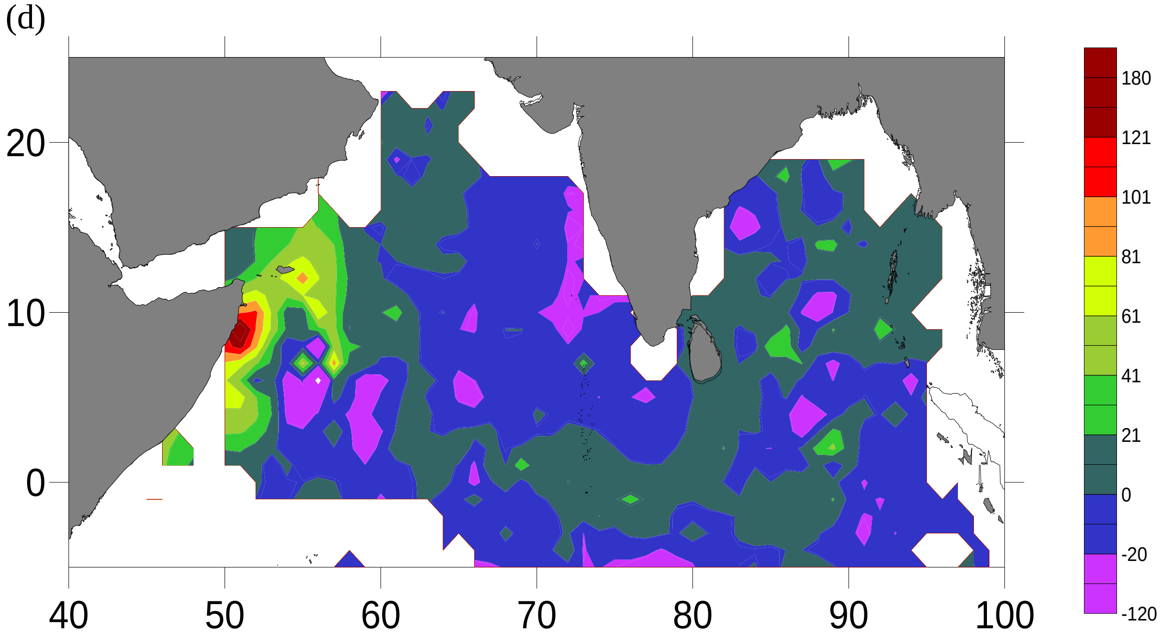
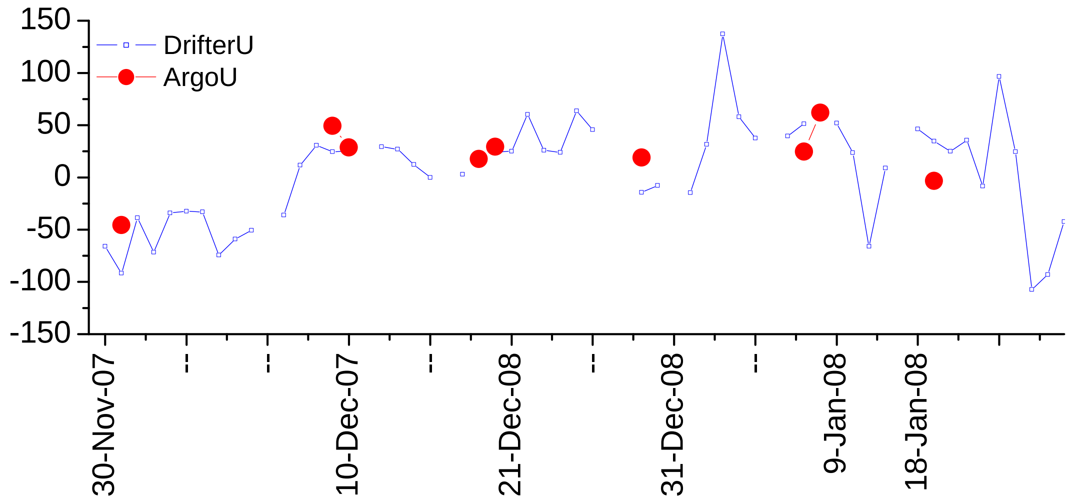


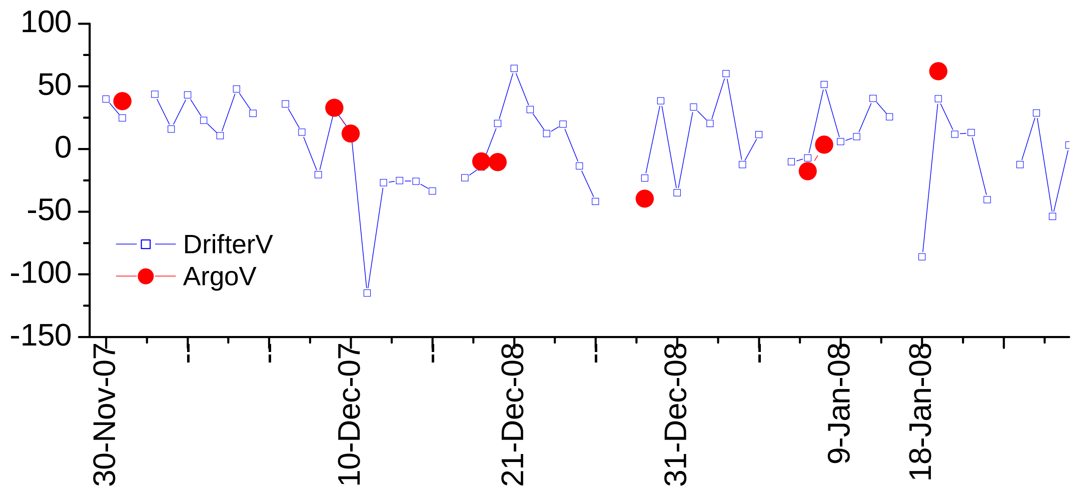

Figure 8. Climatological Surface Current V-components from (c) SODA for July (d) Argo for July.

The U- and V- components of Surface currents obtained from a single Argo float (WMO ID 2900754) are compared with those obtained from one Drifting buoy (ID 40273) during November 2007 to January 2008. The locations of these are shown in figure9c. Although the number of points is very less the comparison (shown in figure9a-b) seems to agree well.

**(a)**




**(b)**




**(c)**

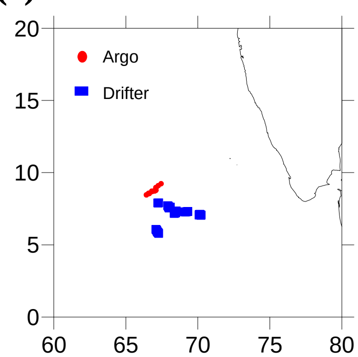



Figure 9. Comparison of Surface Current from Argo and Drifter buoy (a) U-components (b) V-components (c) Location of Argo and Drifter Buoy

## 4. Future Directions

The position of the first surfacing and first descent will be estimated by interpolation, followed by estimation of under water positions (first ascent). These interpolated positions of the float lead to estimation of currents at profiling and parking depths.

### Acknowledgements

The authors thank Dr.Shailesh Nayak, Director, INCOIS for his constant encouragement and suggestions in improving the document. The authors are thankful to APDRC for providing the SODA data set.

### Bibliography

ARGO Science Team, 1998, On the design and implementation of ARGO: An initial plan for a global array of profiling floats. International CLIVAR Project Office Report 21, GODAE Report 5. GODAE International Project Office, Melbourne, Australia, 32 pp.

Carton, J. A., Chepurin, G., Cao, X. H. and Giese, B. ,2000, A Simple Ocean Data Assimilation analysis of the global upper ocean 1950-95. Part I: Methodology. Journal of Physical Oceanography, 30(2), 294-309

CLS/Service Argos Users Manual 1.0. 1996, (CLS/Sercive Argos, Inc., January 1996).

Davis R.E., D. C. Webb, L. A. Reigier, and J. Dufour, 1992, The Autonomous Lagrangian Circulation Explorer (ALACE), J.Atm. and Oceanic Technol., 9(3), 264-285

Davis, 1998. Preliminary results from directly measuring mid-depth circulation in the tropical and South Pacific. Journal of Geophysical Research,103 (11), 24619-24639.

Kessler and McCreary, 1993, The Annual Wind-driven Rossby Wave in the Subthermocline Equatorial Pacific, Journal of Physical Oceanography 23, 1192 - 1207.