

Indian Ocean Surface Circulations and Their Connection To Indian Ocean Dipole, Identified From Ocean Surface Currents Analysis Realtime (OSCAR) Data

By

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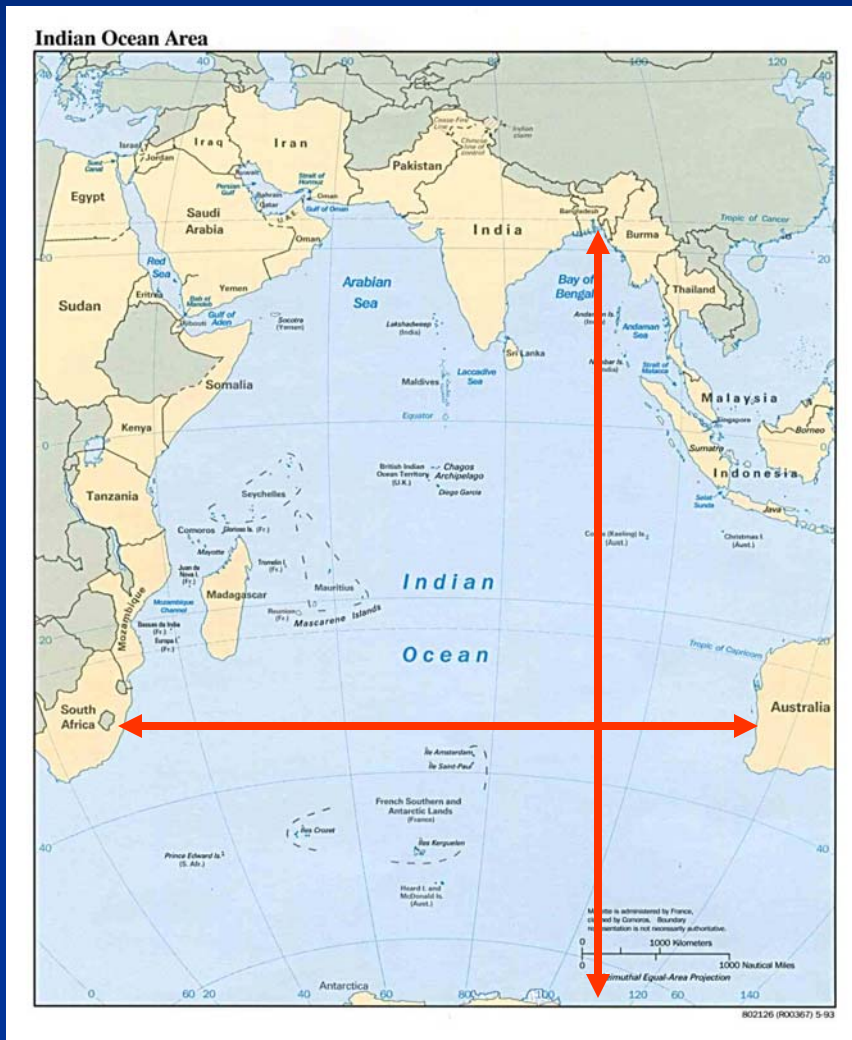
Outline

- Introduction
- Indian Ocean and its Importance
- OSCAR database
- Seasonal Variability
- Indian Ocean Dipole
- Operational and Scientific Applications
- Future Research

Introduction

- Seasonal variability derived from the satellite altimetry showed realistic Ocean Circulation patterns.
- Indian Ocean Dipole Events renders Adverse weather effects on Eastern and Western tropics of the Indian Ocean, one end have heavy rains/floods and the other side experience droughts/wild fires

Indian Ocean



- North South Extent 9600 Km
- East West Extent 7800 Km
- Total Area $74.1 \times 10^6 \text{ Km}^2$
- Sea trade can be traced to ancient times
- Until mid 1800 no nation dominated the region completely when British took control of most of surrounding parts
- In present mostly India and Australia dominate the region but after the fall of twin towers in US now in context to Global war against terror the US led coalition forces are also making a difference in overall dominance in the region

Economic Importance

Indian Ocean Houses some of the most busiest waterways in the world which include:

Persian Gulf and Strait of Hormuz



Red Sea and the Suez Canal



The Suez Canal

Strait of Bab el Mandeb

Strait of Malacca



Strait of Malacca

Economic Importance

- Indian Ocean Houses some of the most busiest waterways in the world (Strait of Hormuz, Strait of Bab el Mandeb, Strait of Malacca)
- Approx 40% world offshore oil production
- World's bigger economies Europe, Japan And US import approx 70%, 76% and 25% oil from the Gulf region
- World's growing Appetite for oil will make this region more and more important

Political and Operational Importance



- Peace and Stability in the Gulf region is essential for safer trade
- Continuous patrolling of Coalition Forces In the Region
- China's greater interest in Indian Ocean waters
- Iran's Ambitions to go Nuclear
- Afghanistan's Instability and disrupting Al-Qaida's network
- Iraq's Instability

Ocean Surface Currents Analysis – Realtime (OSCAR) Data Base

- Ocean Surface currents data available for whole world' oceans at www.oscar.noaa.gov
- Ocean Currents are computed from Sea Surface Height (SSH) data which is derived from satellite based altimeters JASON-1, GFO, Envisat and wind data which is derived from QUICKSCAT satellite
- Data continuously available after every 5 days
- Data can either be downloaded for subsequent analysis or can be instantly displayed
- The JavaScript-based user interface provides users great flexibility in extraction or display of the data

User Interfaces

Data Download
Lat-Lon Map
Lat-Time Section
Time Series Plot
Time-Lon Section

Data Display & Download

Latitude-Longitude Map for Ocean Surface Current [Non-Java Version](#)

Data Type: 5-day Interval Monthly Mean
 Mean over user selected time range
 Long Term Mean (1993-2006)
 Seasonal Mean (user select date range)

Plot Type: Vector overlay Speed
(plot type marked with * are not available for long term mean and seasonal mean data)

Location: (Enter Longitude and Latitude Range in boxes below, OR mouse-drag over map to select region.)

60 N
20 E 20 E
60 S
Reset Location Range

5-Day Interval Surface Current, May 8, 2008 → 1.0 meter/sec
 Mouse-Drag to select region.

Date: for 5-day or monthly mean: 2008 · May · 1 ·
(start from Oct 15, 1992)
 OR,
 for mean over user selected time range or seasonal mean:
 Month/Day Range: Jan · / all · to Mar · / all ·
 Year Range: 1993 · to 2007 ·

Options: Data to Plot: filtered unfiltered data
 Contour: color none

Data Download
Lat-Lon Map
Lat-Time Section
Time Series Plot
Time-Lon Section

Data Display & Download

Time Series for Ocean Surface Current [Non-Java Version](#)

Select a geographical range for averaged Time Series:

Location: (Enter Longitude and Latitude Range in boxes below, OR mouse-drag over map to select region.)

60 N
20 E 20 E
60 S
Reset Location Range

5-Day Interval Surface Current, May 2, 2008 → 1.0 meter/sec
 Mouse-Drag to select region.

Date Range: 1993 · Jan · 1 · to 2008 · May · 1 ·

Options: Data to Plot: filtered unfiltered
 Variables to Plot: u v u-anomaly v-anomaly

Generate Plot

User Interfaces

Data Download	
Lat-Lon Map	Lat-Time Section
Time Series Plot	Time-Lon Section

Data Display & Download

Latitude-Time Section for Ocean Surface Current [Non-Java Version](#)

Plot Type: Zonal and Meridional Currents

Longitude: 140 W

Lat/Time Range: (Enter Lat/Time range in boxes below, **OR** mouse-drag over Lat-Time section plot to select range.)

Ocean Surface Zonal Currents (meter/sec), at 140°W

60°N
50°N
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°S
50°S
60°S

1992 1995 1998 2001 2004 2007

0.8
0.4
0.0
-0.4
-0.8
-1.2

60 N
1992-10-15 2008-5-2
60 S
Reset Lat/Time Range

Options:

Data Type: 5-Day Mean Monthly Mean

Data to Plot: filtered unfiltered

Contour: color black/white

Generate Plot

Data Download	
Lat-Lon Map	Lat-Time Section
Time Series Plot	Time-Lon Section

Data Display & Download

Data Download for Ocean Surface Current [Non-Java Version](#)

Data Type: 5-day Mean Monthly Mean Long Term Mean (1993-2006)

Filter Type: unfiltered

Variable Type: U & V mean U & V anomaly

Location: (Enter Longitude and Latitude Range in boxes below, **OR** mouse-drag over map to select region.)

20°E 60°E 100°E 140°E 180° 140°W 100°W 80°W 20°W 20°E

60°N
40°N
20°N
0°
20°S
40°S
60°S

0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2

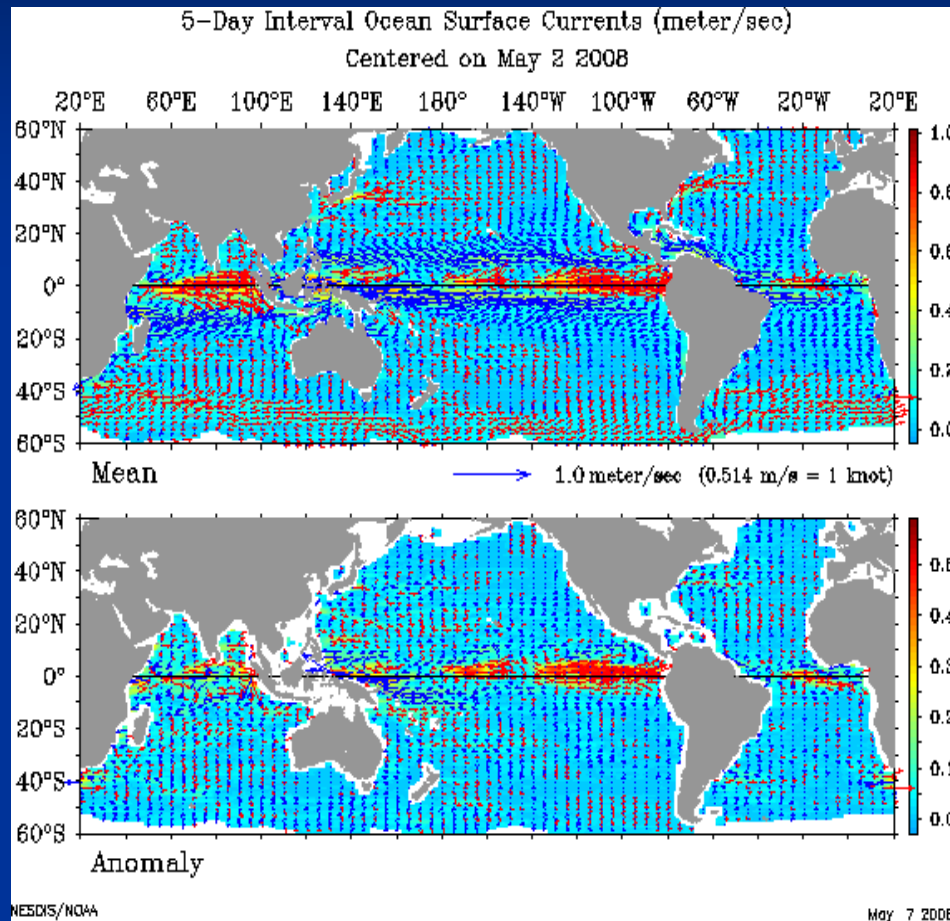
60 N
20 E 20 E
60 S
Reset Location Range

5-Day Interval Surface Current, May 2, 2008 → 1.0 meter/sec

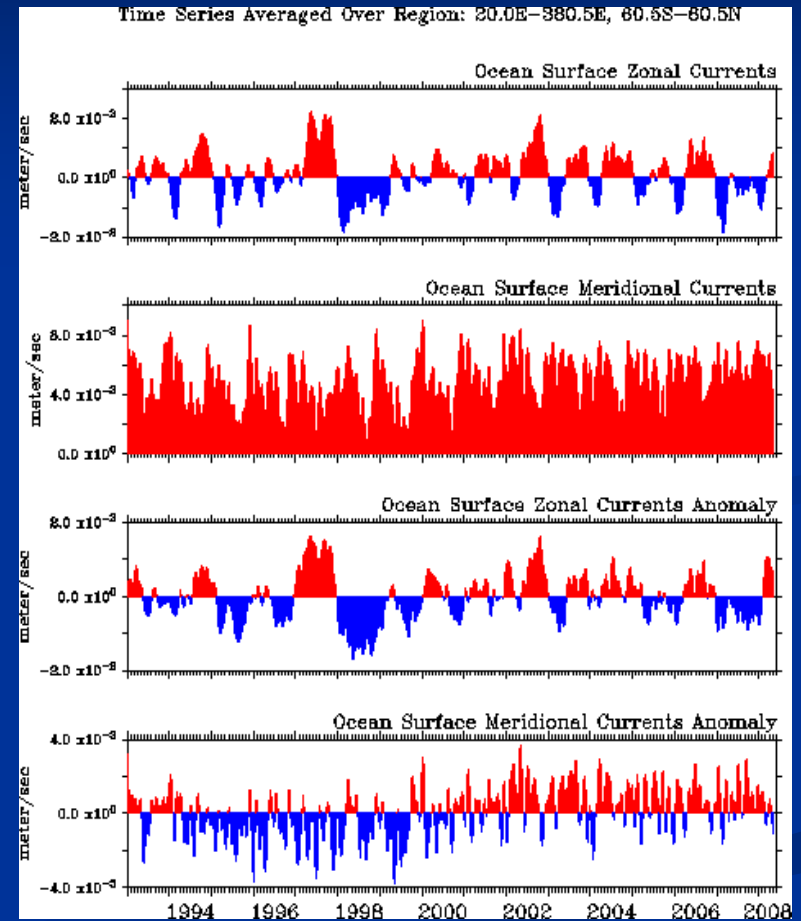
Date Range: 1992 · Oct · 15 · to 2008 · May · 5 ·

Mouse-Drag to select region.

Online Display



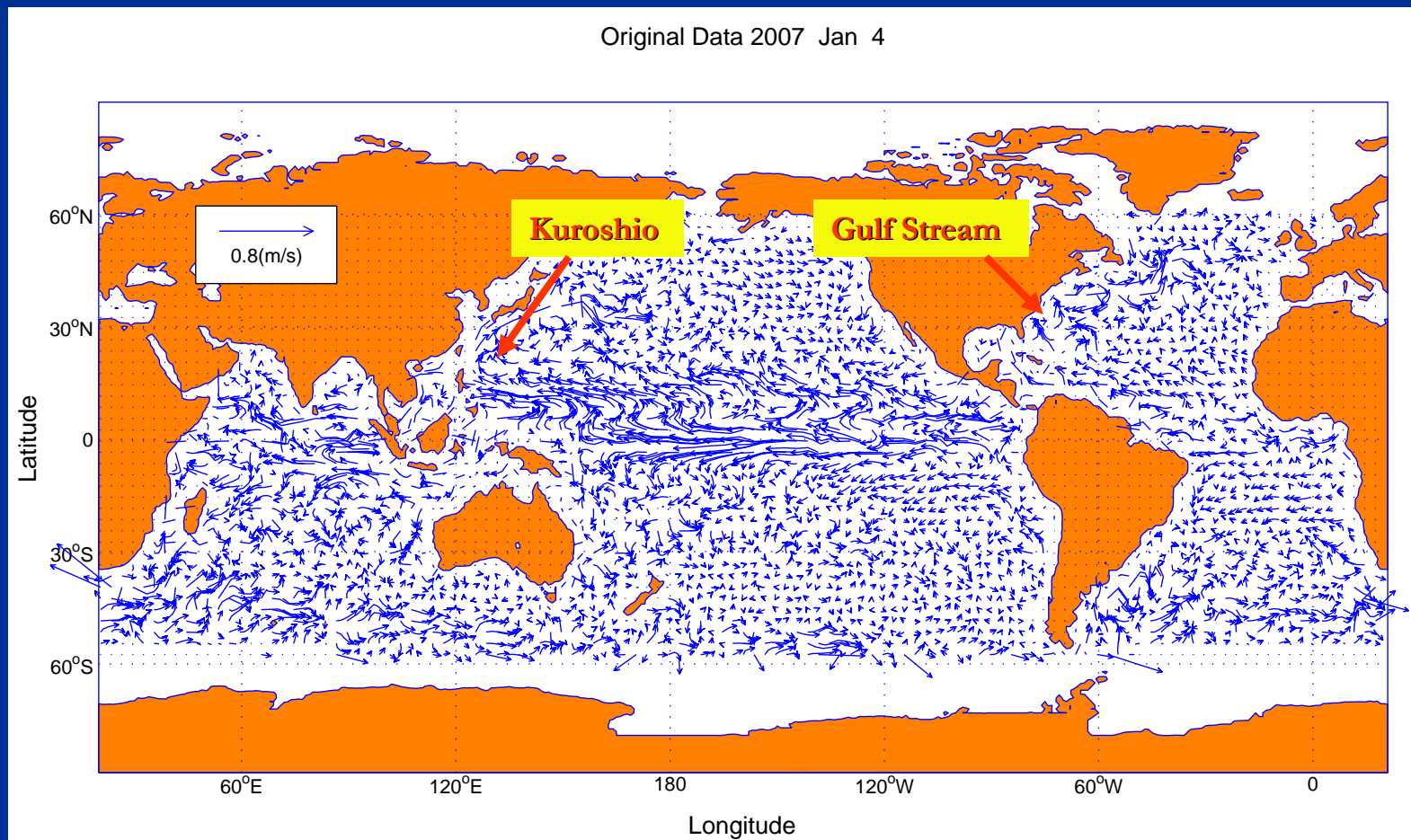
Lat-Long Map plot



Time Series plot

The Optimal Spectral Decomposition (OSD) Data Refinement Method

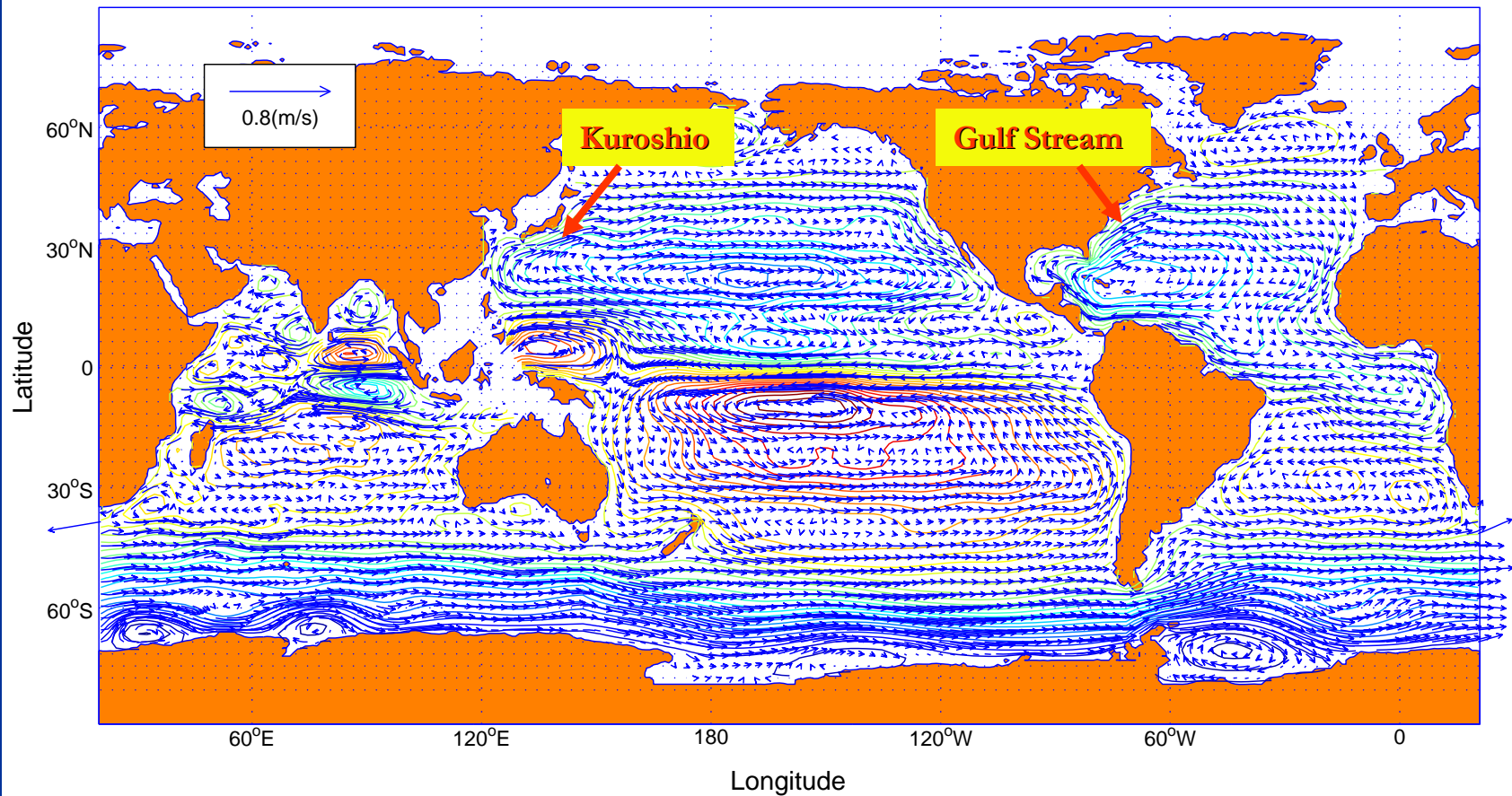
Besides all good Major weakness of OSCAR data is its inability to reveal realistic coastal boundary currents and also Data is quite Noisy



OSCAR Currents after applying OSD

The resultant Current field is much more realistic and adequately true depiction of lateral boundary current can be seen (Method Developed at NOAP in NPS headed by Professor Peter Chu)

OSD smooth data 2007 Jan 4



The Monsoon Winds

The Southwest or Summer Monsoon



- Deep low pressure develops over Northern Arabia and Pakistan and a zone of High Pressure over the Ocean
- Pressure gradient over the Ocean is large about 22 hPa
- Resultant winds are strong and humid
- Southwest Monsoon brings the well-known Monsoon rains and floods to the southern part of Asia

The Northeast or Winter Monsoon



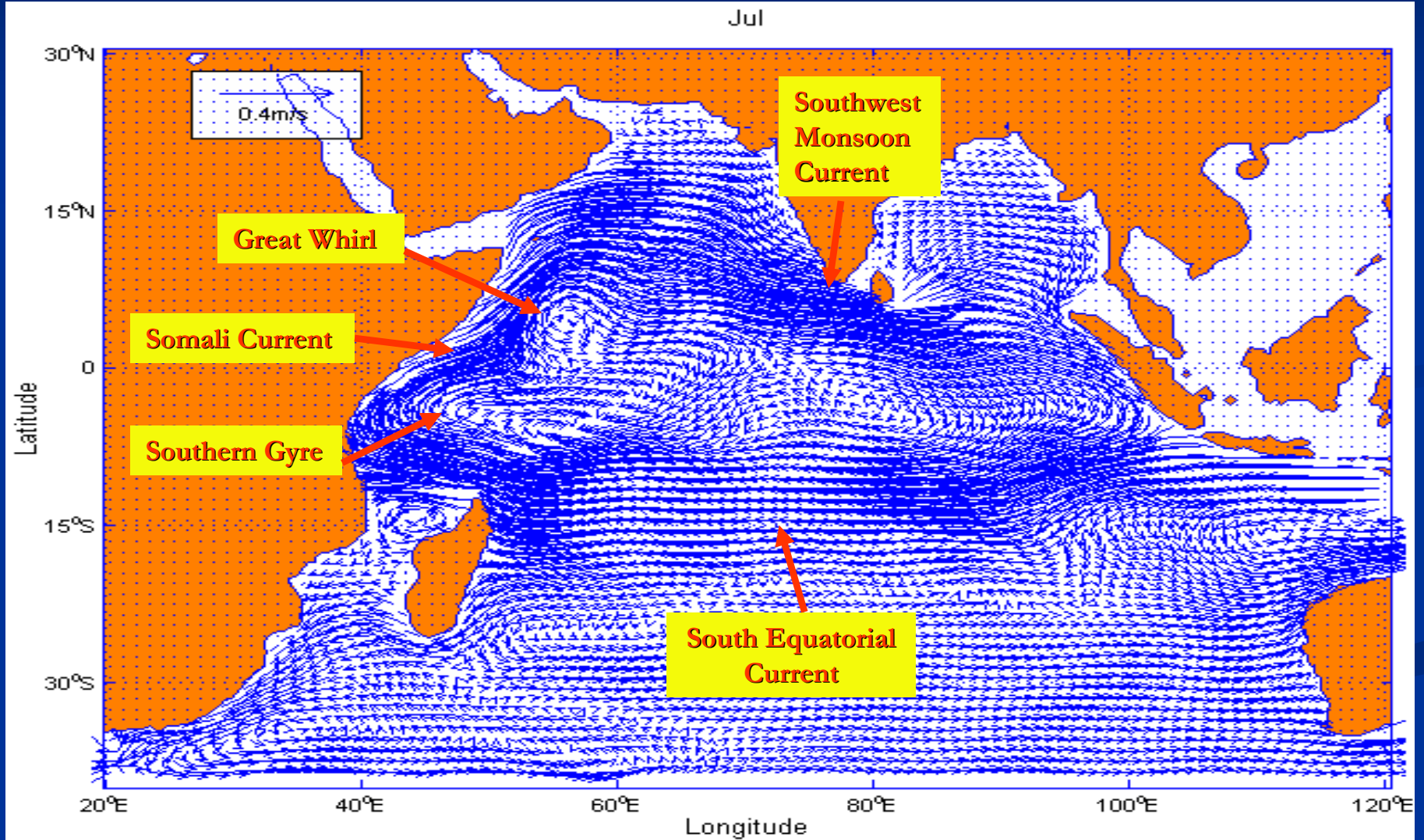
- High pressure develops over the Indian Land mass and a zone of low pressure over the ocean
- Air pressure gradient over the ocean is small as compared to Summer about 6 hPa
- Resultant winds are dry and have moderate force
- Winter season is dry over most of southern Asia

Seasonal Variability

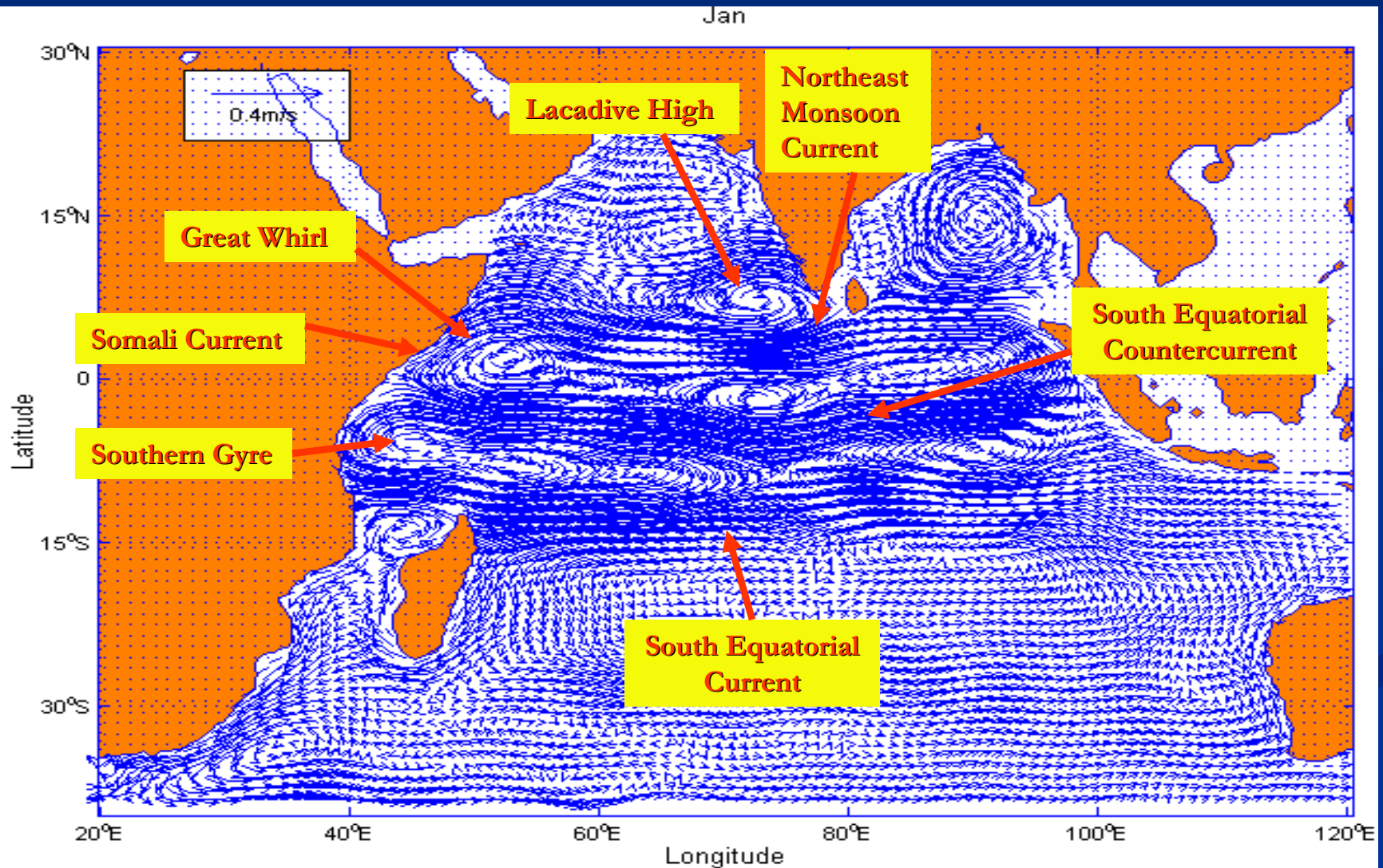
Data Processing

- Ocean Surface Currents Analysis (OSCAR) data was extracted from 1993 to 2006
- Monthly mean surface currents were calculated from the reconstructed OSCAR data
- Visuals for the whole Indian Ocean during the two Monsoon Regimes were Analyzed
- Ocean Surface currents variability as derived from the altimetry data in detail was analyzed for three most Dynamic regions of Somali Current, North Arabian Sea and the Bay of Bengal
- Side by side comparison with the previous studies showed that the data set produced true surface circulation patterns.

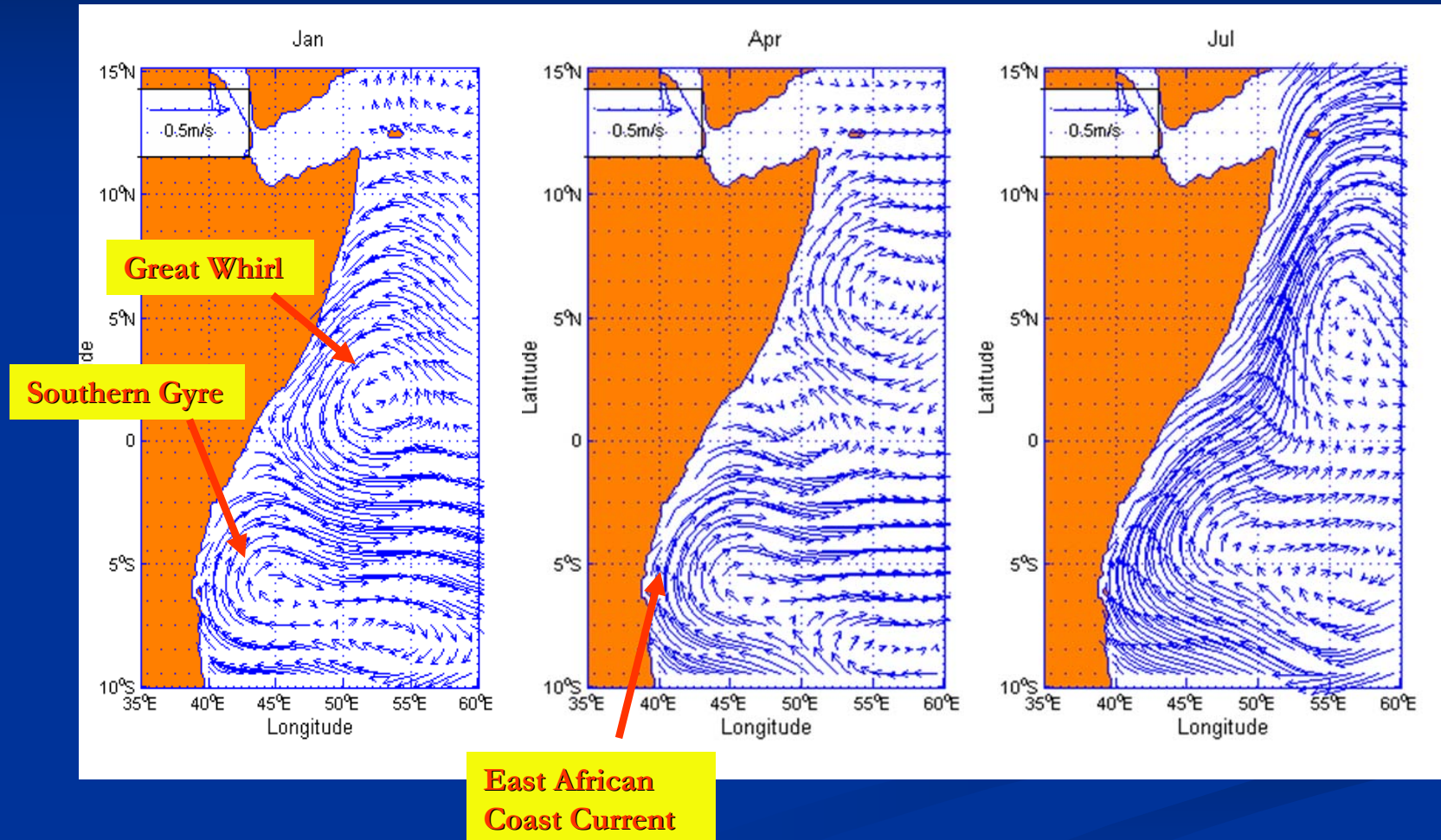
Indian Ocean During Summer



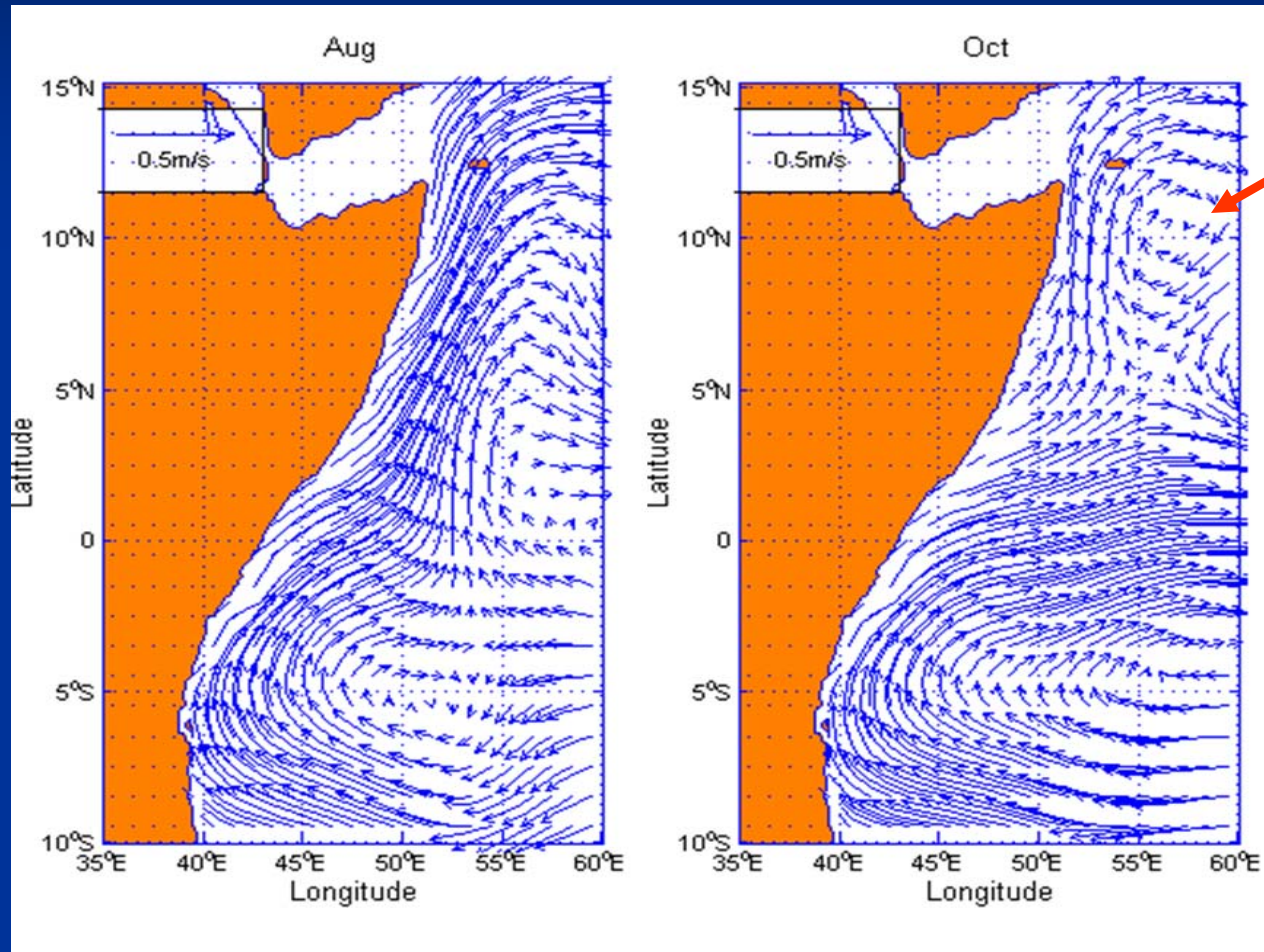
Indian Ocean During Winter



The Somali Current



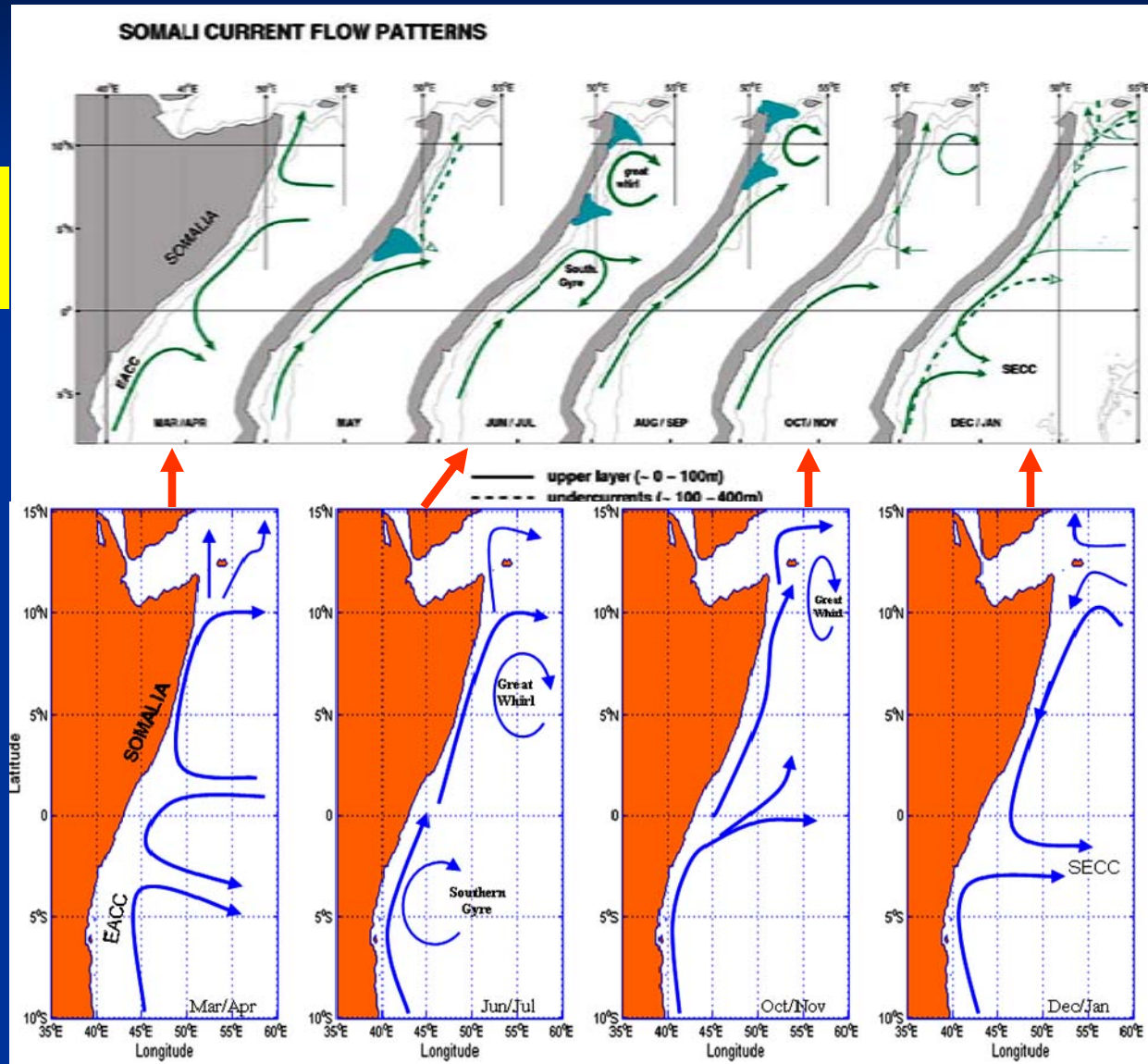
The Somali Current



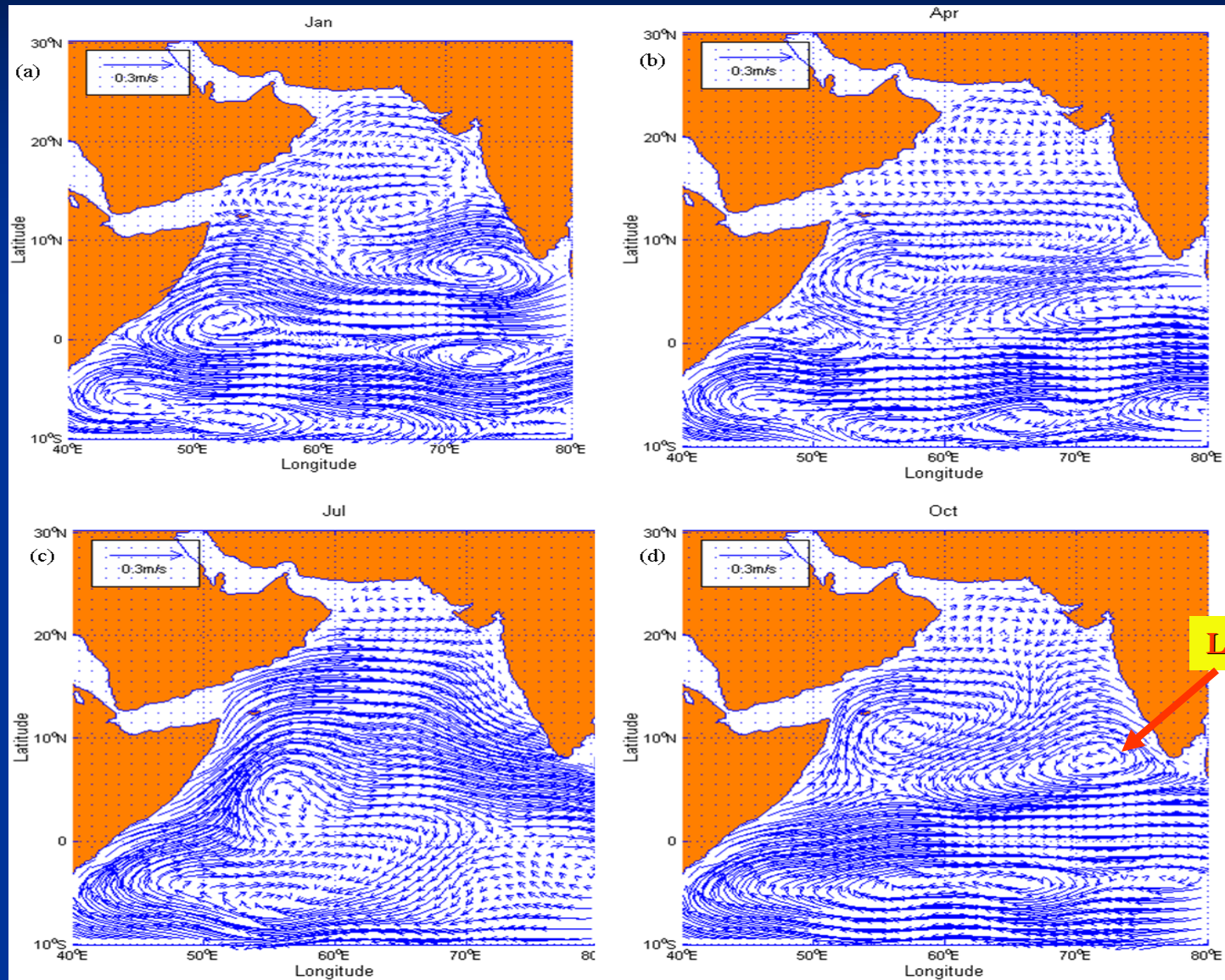
Great Whirl

Comparison With Previous Studies

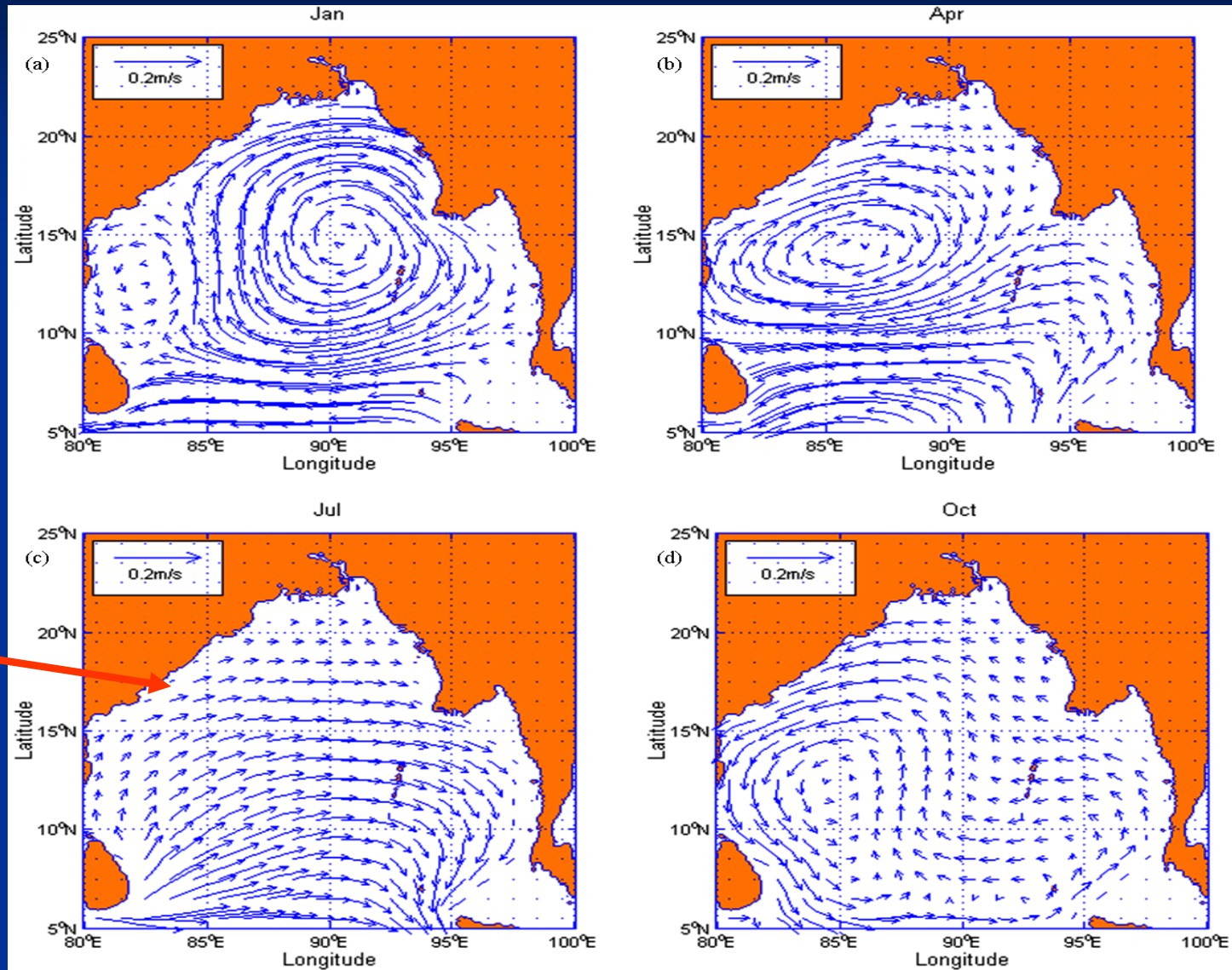
From: Schott
& McCreary,
2001



The North Arabian Sea



Bay of Bengal



East
Indian
Coast
Current

Indian Ocean Dipole and Eastward Equatorial Jets

Indian Ocean Dipole (IOD)

- Discovered in 1999, by Professor Yamagata and Dr. Saji
- An inter-annually occurring climate mode in the tropical parts of the Indian Ocean
- Typical to other climate oscillations the IOD climate mode also has a 'positive' and a 'negative' phase
- IOD events usually occur during the transition period between Monsoons

El Niño Mode Event

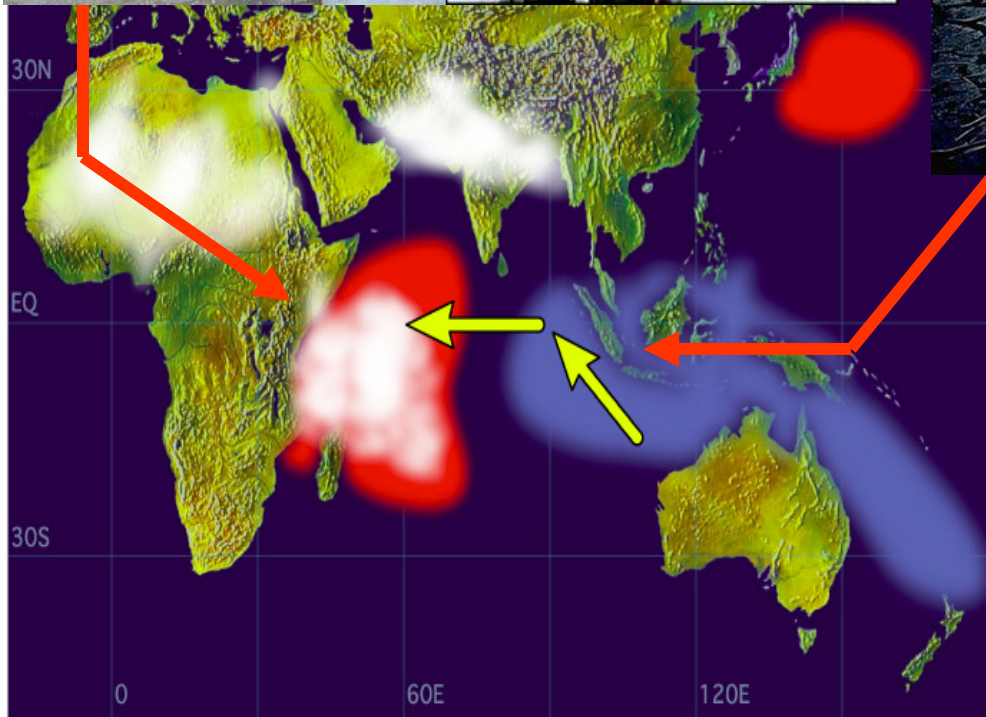


western
Indian Ocean and
Eastern Part

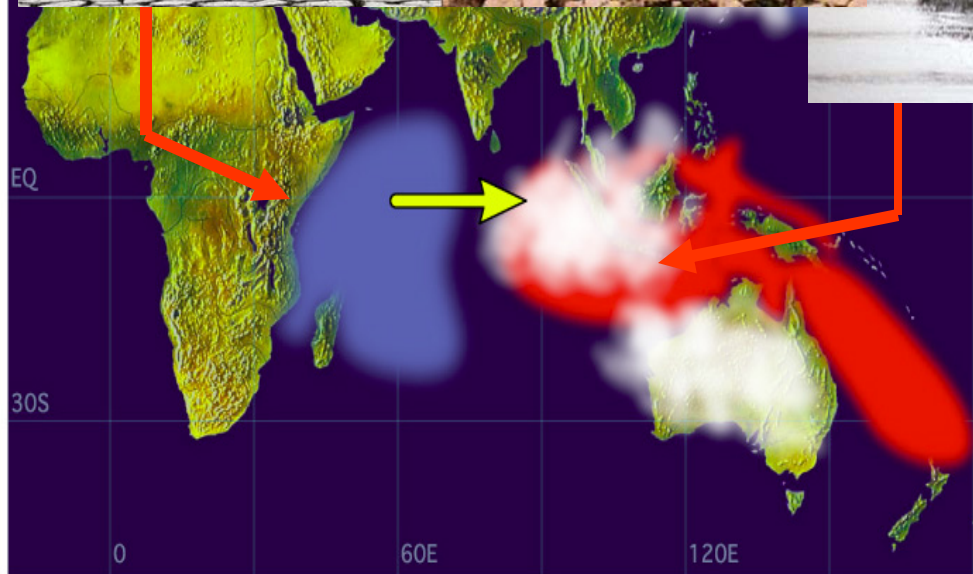
situated

over the eastern Indian Ocean
warm pool shifts to the west

- Heavy rainfall over eastern Africa and severe droughts/ Forest fires over the Indonesian region.

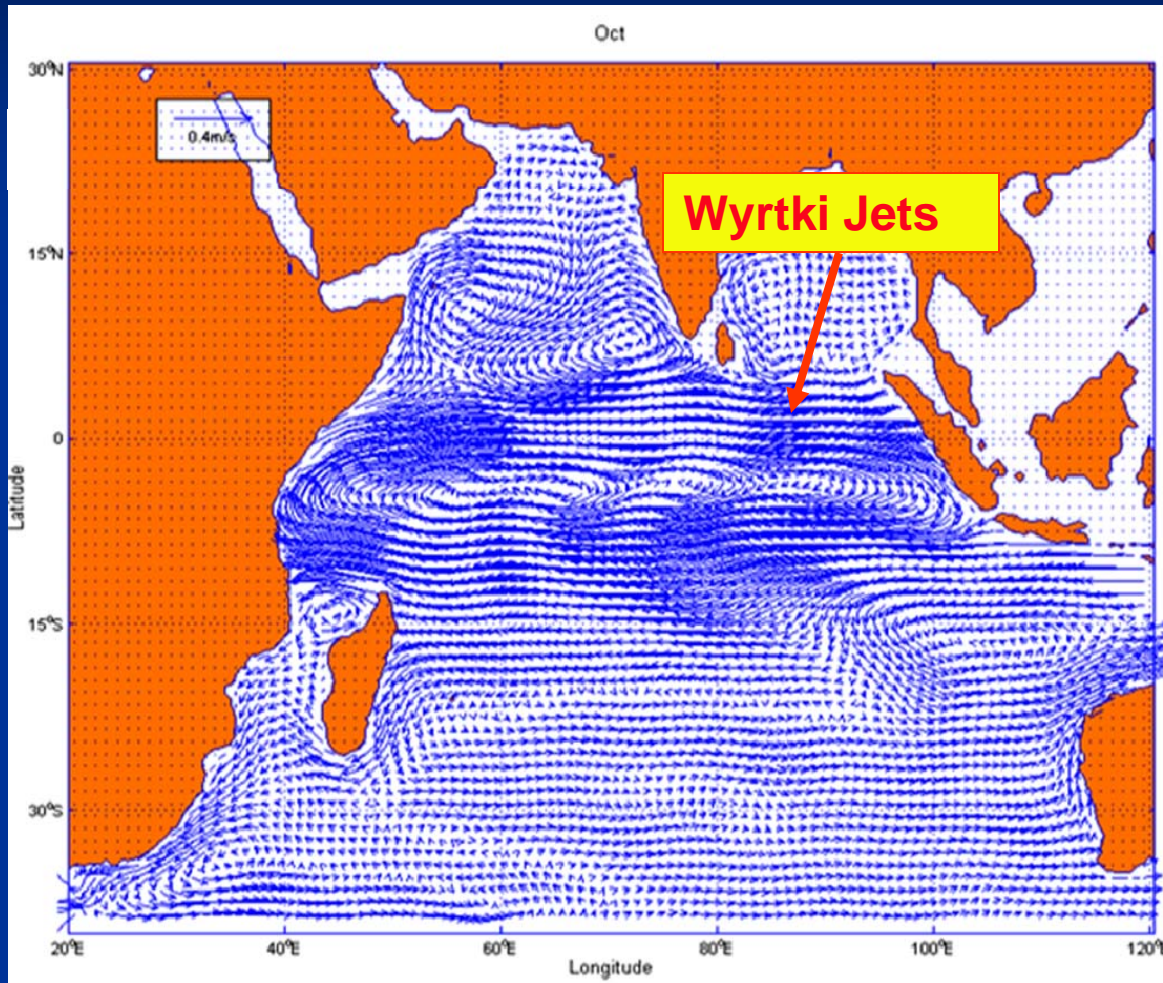


Negative Dipole Mode Event



ern
nd
of
ver
Indonesian Region and severe
droughts/ Forest fires over the
East African region.

The Eastward Equatorial Jet (Wyrтки Jet)

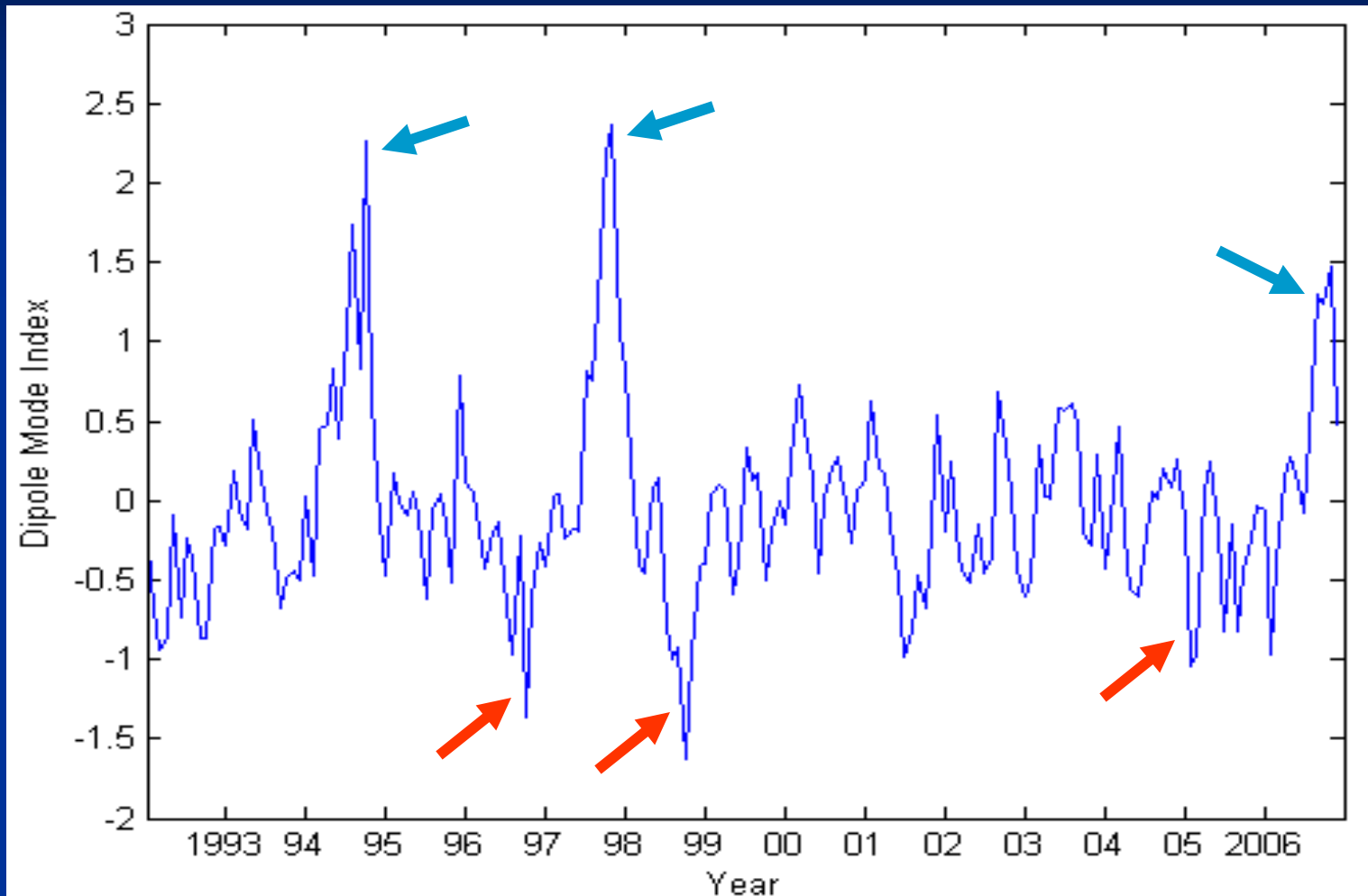


- Appear in Indian Ocean equatorial Region during transition period between Monsoons
- Several studies in past used Models to show that these jet **weakens** in a Positive IOD event and **strengthens** in a Negative IOD event
- In context to Surface circulations this is the most prominent feature which can be further analyzed to see its connection to Dipole Mode events

Dipole Mode Index

- Strength of IOD events are represented by the Dipole Mode Index (DMI)
- Defined as the zonal difference of sea surface temperature anomaly between the tropical western Indian Ocean (50°E - 70°E , 10°S - 10°N) and the southeastern Indian Ocean (90°E - 110°E , 10°s -Equator)

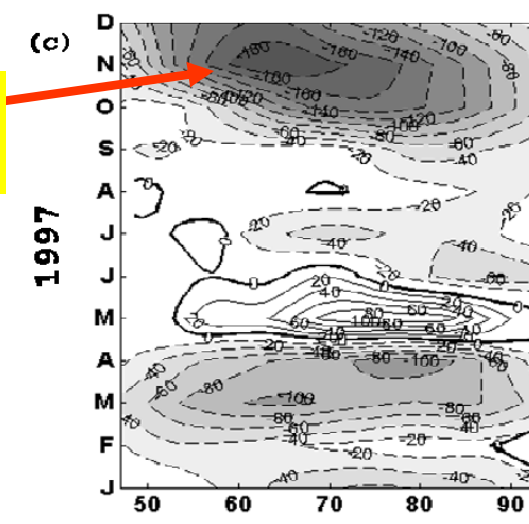
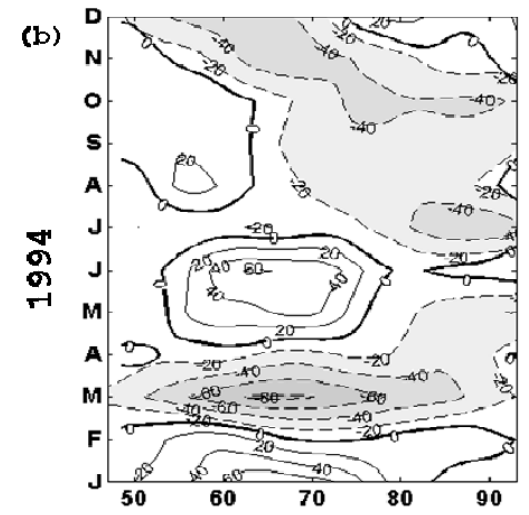
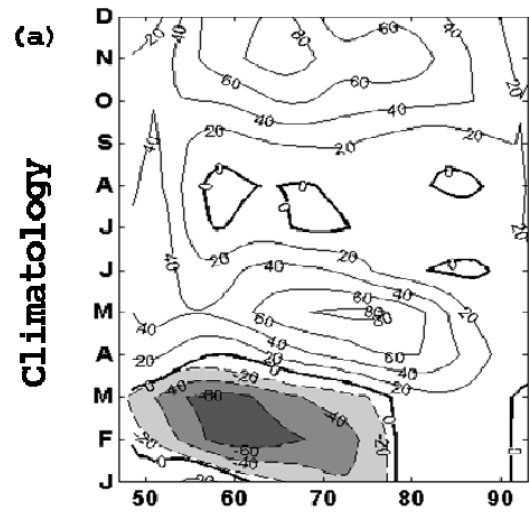
Time Series of DMI



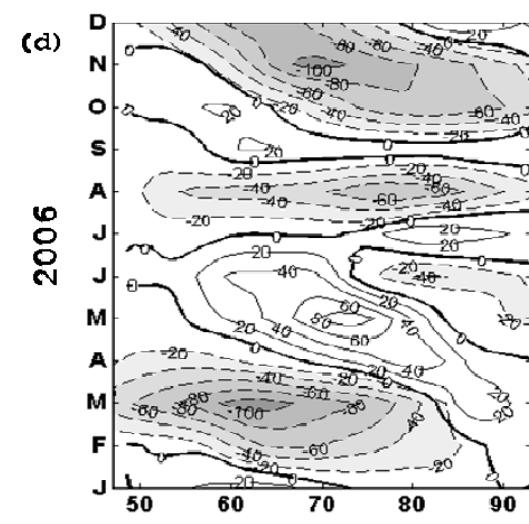
→ +ve → -ve

Anomalies During A Positive Dipole Mode Event

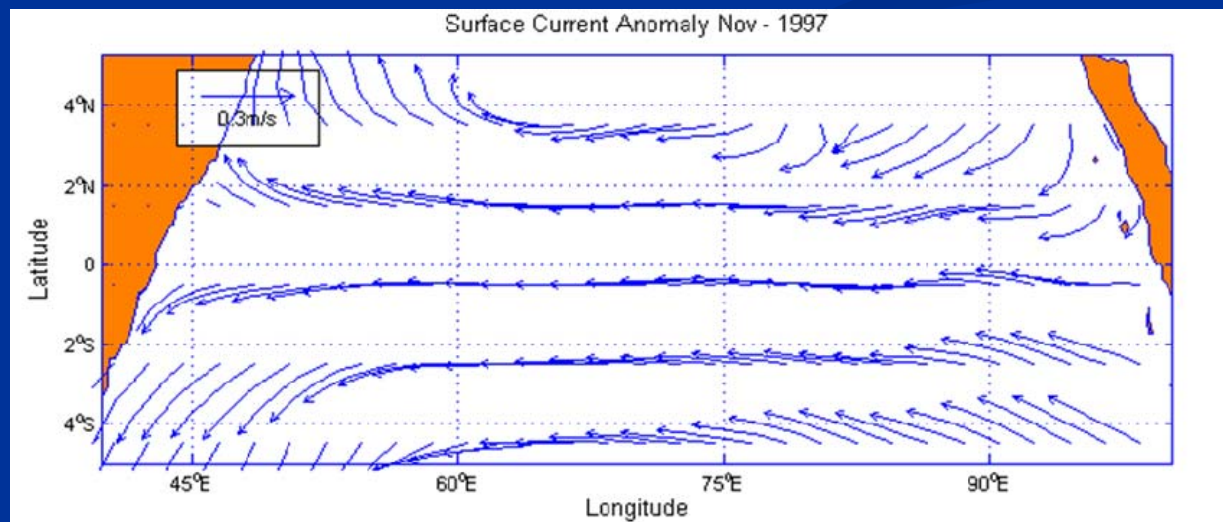
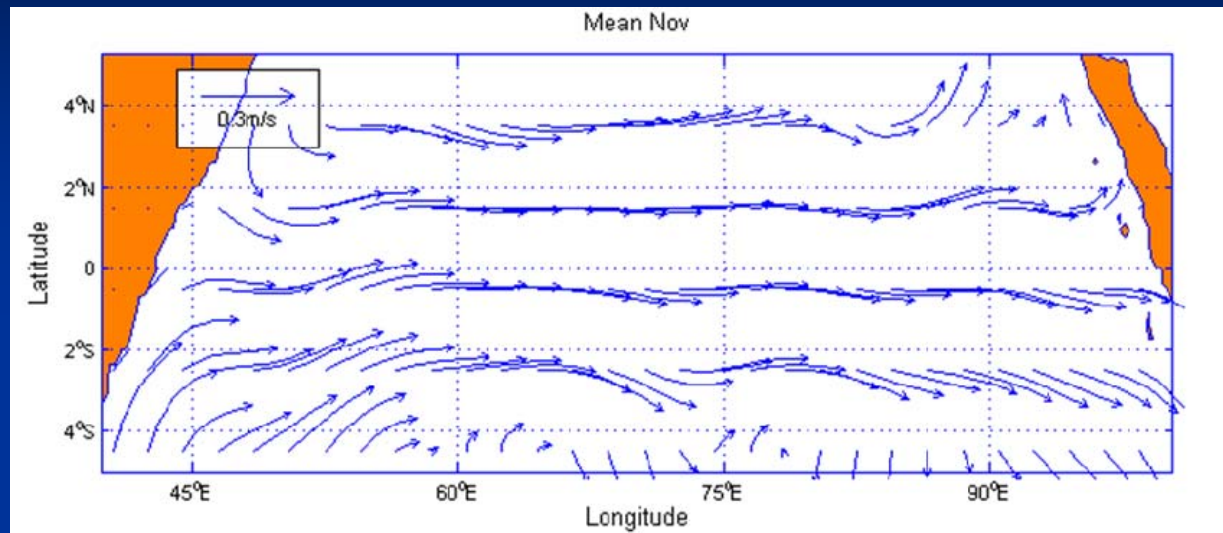
Zonal Currents Anomalies along the Equator During Positive IOD



Large Negative Anomalies

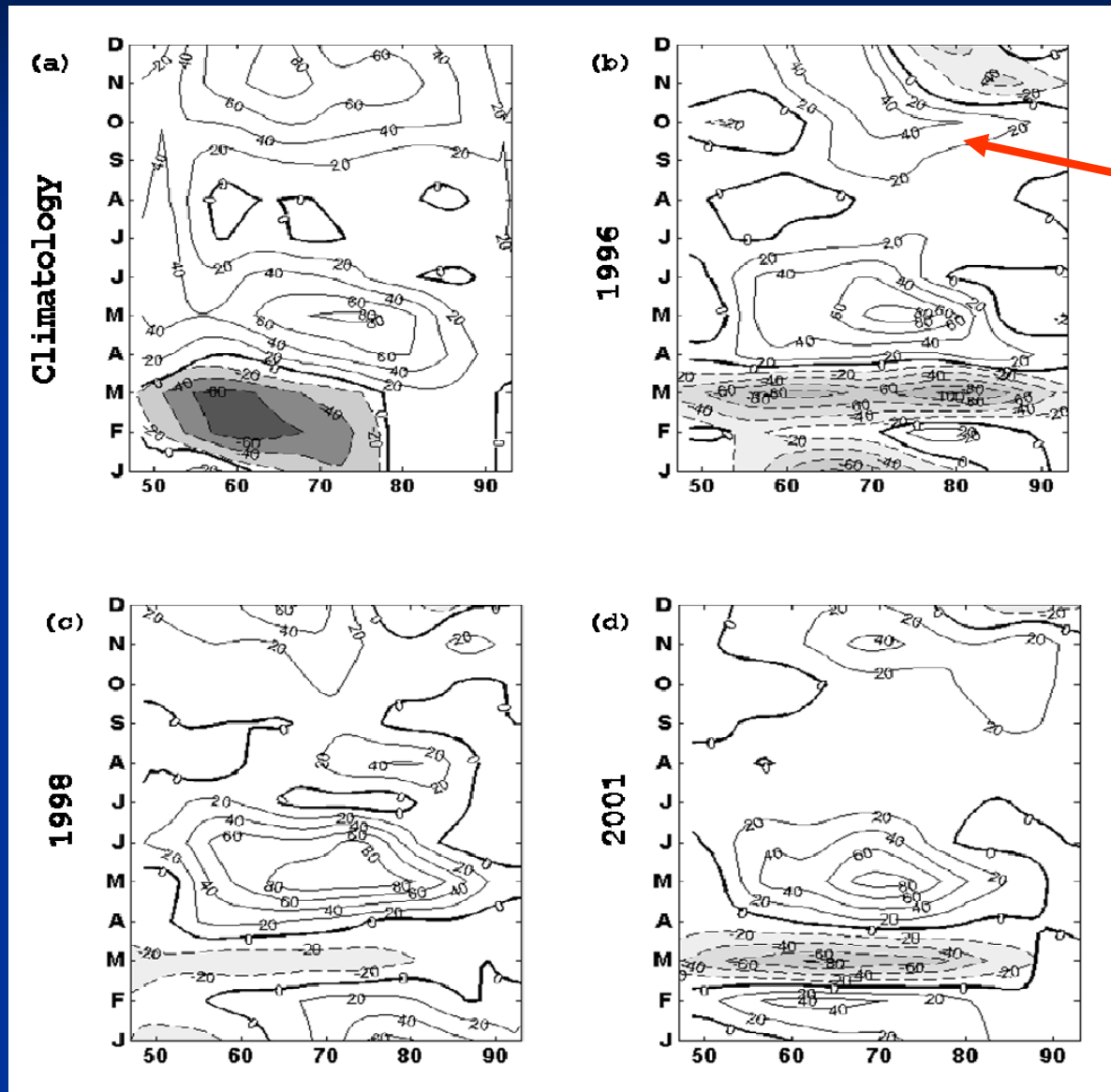


Vector Currents Anomalies During a Positive IOD



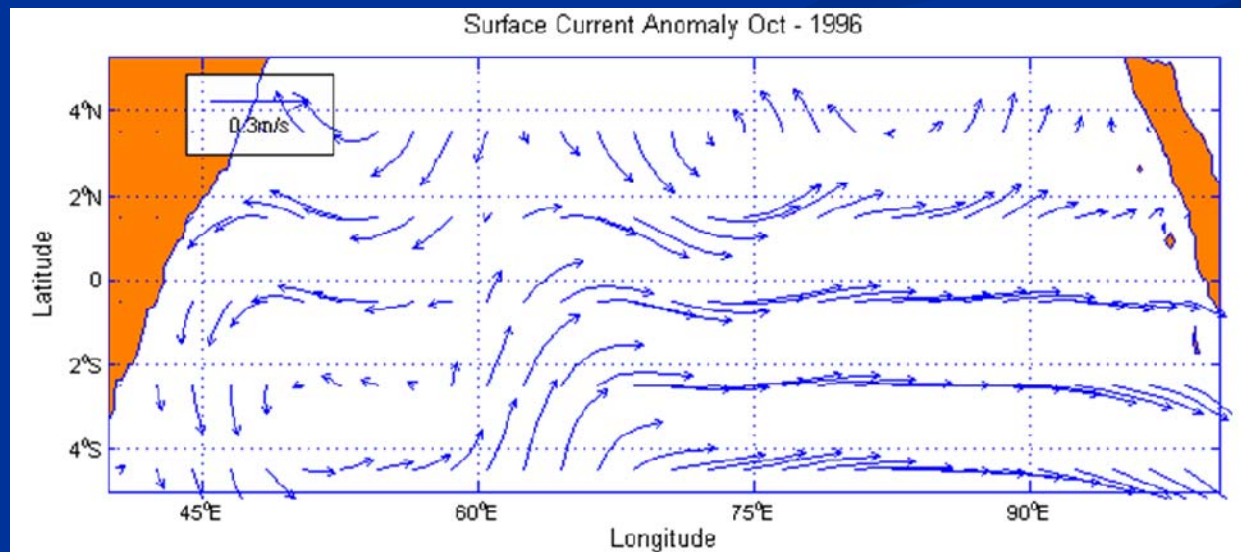
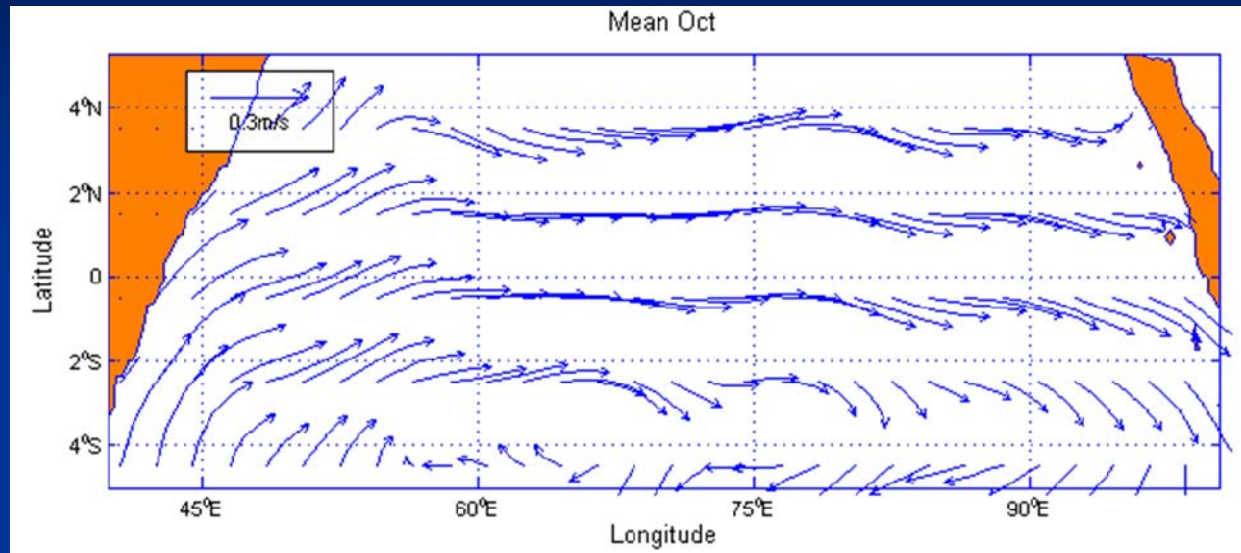
Anomalies During A Negative Dipole Mode Event

Zonal Currents Anomalies along the Equator During Negative IOD



Positive Anomalies

Vector Currents Anomalies During a Negative IOD



Results

- Positive Dipole Event ---- Equatorial Jets Weaken
- Negative Dipole Event ---- Equatorial Jets Strengthen

Operational Applications

Ocean Currents and Mine Warfare

- Integral Part of Naval warfare
- Most cost effective weapons as it is inexpensive, easy to conceal, easy to deploy, and almost requires no maintenance
- Mines can be used strategically and tactically for denying access and defense of vital facilities
- One of the important types of mine is the drifting mine, used to completely deny access of friend and foe to certain space
- Deploying locations of the mines could be decided by knowing the most recent surface circulation pattern

Search and Rescue at Sea

- In both peacetime and battle space environments, search and rescue operations require meticulous planning and careful execution
- ocean surface circulation is the most important factor to be kept in mind before planning a search and rescue operation
- Used to estimate the likely position of men and material to be rescued
- Rescue effort can concentrate in a smaller and more probable area of interception

Planning for an Economical Passage

- Ocean circulation patterns could be used to plan for a more economical passage
- without jeopardizing the shortest route, routes that are along the general flow of the ocean can be planned
- Save both fuel and time

Monitoring Chemical Pollutants and Oil Spills

- In an event of intentional or unintentional spills of chemical pollutants and oil, ocean surface currents could be used to determine how fast and far the spill could go
- Especially true in the coastal regions with very fast surface currents, such as the Gulf Stream, Kuroshio, and Somali Current.
- Good knowledge of surface currents will tell us how fast to act in terms of remedial measures

Scientific Applications

Ocean Currents as a Source of Energy

- In today's industrialized world, the importance of sustainable energy sources cannot be undermined
- Bigger economies of the world are always looking for newer ways to produce good amounts of energy
- If only 1/1000 of the energy in Gulf Stream is utilized, it will be about 21,000 times more energy than in the Niagara Falls
- Estimated world wide power in world's ocean is about 5,000 GW with the power densities of about 15 KW/m²
(Technology White paper 2006)

Large-Scale Climate and Synoptic Diagnostics

- OSCAR data is regularly available, with $1^\circ \times 1^\circ$ resolution therefore it can be used for large-scale synoptic diagnostics
- Different large-scale features in the ocean surface currents could be analyzed regularly to see the variability such as IOD events, Large Scale Eddiesetc
- Change in general surface circulation behavior can be analyzed or used for large-scale climate diagnostics

Future Research

- OSCAR Data can be used to Analyze Ocean Surface circulations in other parts of the world as well.
- With considerable refinement (OSD) and correct methodology this data can also be utilized to examine large scale phenomena such as El Nino, La Nino..... etc

Questions ?

Thank You !!