Marine Climatology from Satellite Remote Sensing

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Overview

- Satellites and Sensors
- Satellite data for Climatology?
- Case Studies
  - Wind Speed
  - Significant Wave Height
  - Atmospheric Moisture and Precipitation

Satellites and Sensors

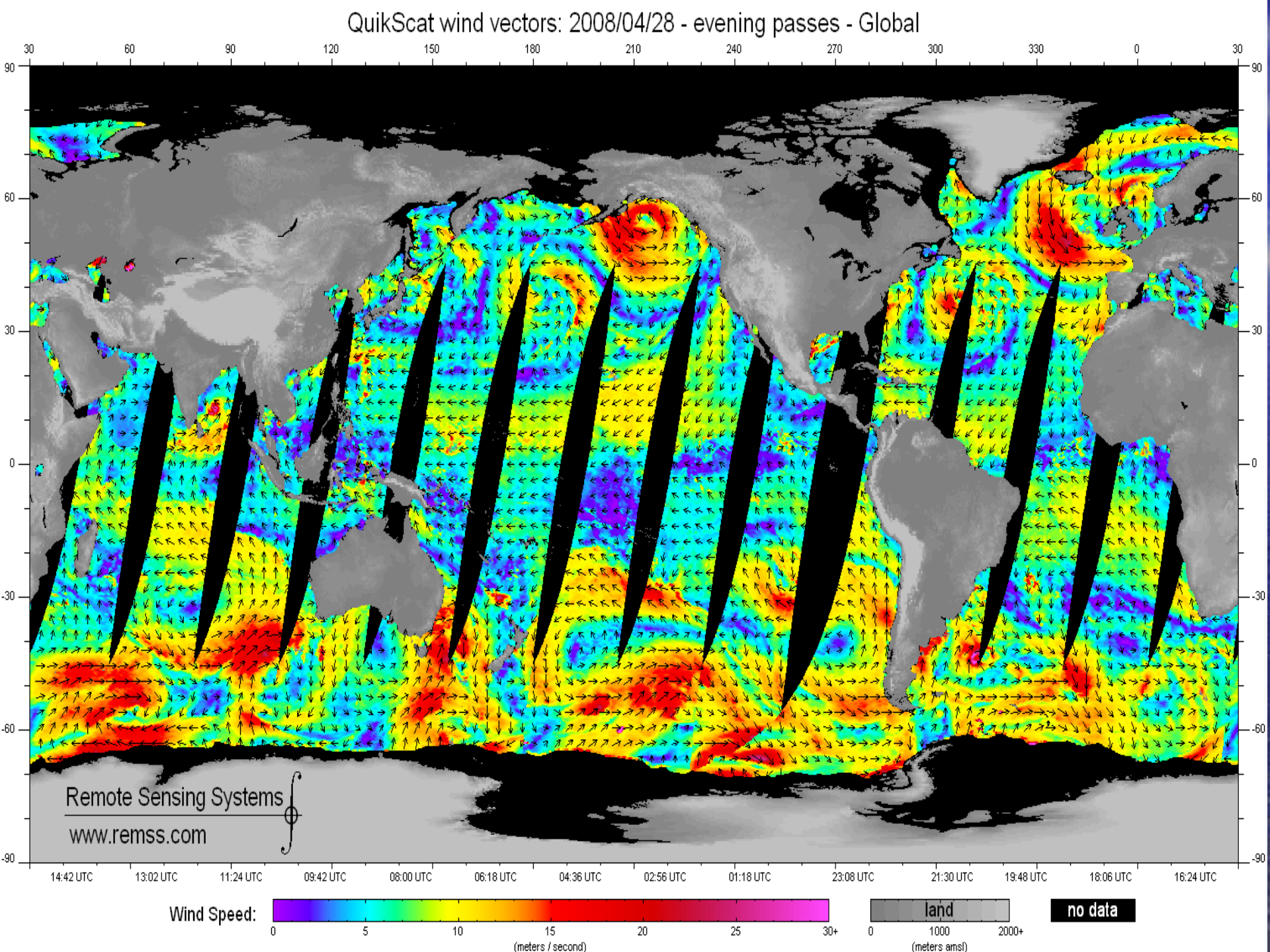
- Active Microwave
  - Transmit 'ping' from space, measure returning signal
- Passive Microwave
  - Measure microwave energy emitted from earth
- Passive Visible/Near IR Imaging
  - Measure visible light and heat reflected off earth
- Passive Thermal Imaging
  - Measure 'black body' temperature emitted from earth
- Passive Multi-spectral Imaging
  - Measure across microwave, visible/NIR and thermal bands

Satellites and Sensors

- Active Microwave – Radar Imaging
  - Sensors: SAR, ASAR
  - Returns: image at radar wavelengths
  - Flown on: Radarsat, Envisat
  - Resolution: down to 10 m
  - Parameters: Ice, waves, swell, internal waves

Satellites and Sensors

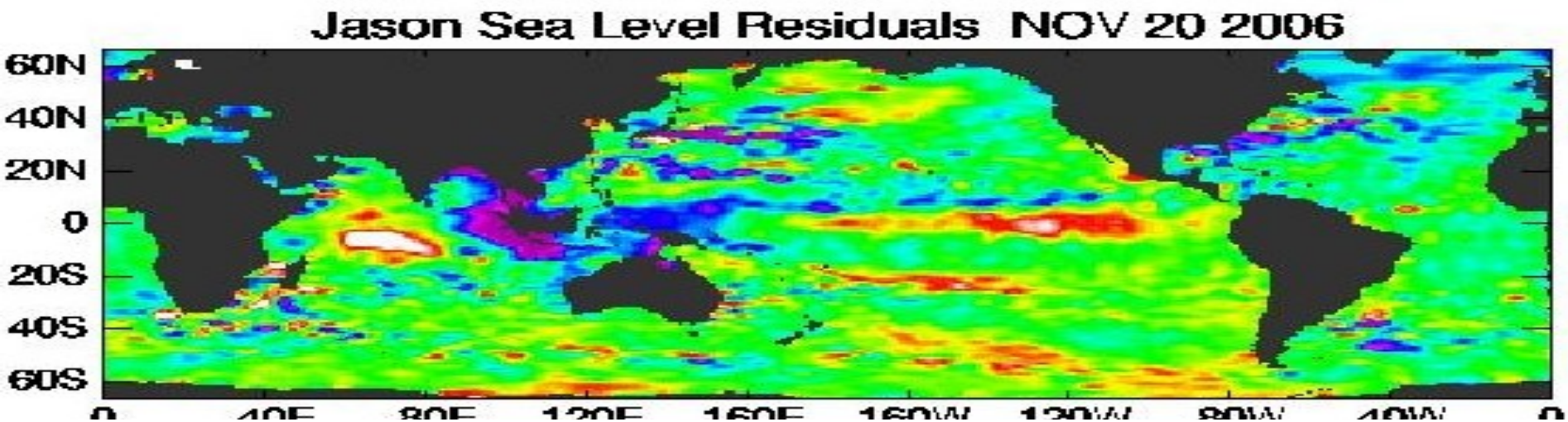
- Active Microwave - Scatterometer
  - Sensors: SeaWinds/Quikscat, ASCAT, (NSCAT)
  - Measures: Backscatter ~ surface roughness ~ wind speed
  - Flown on: QuikBird, Metop, ERS-2 (ADEOS, ERS-1)
  - Resolution: 25km
  - Parameters: Ice, Wind vectors

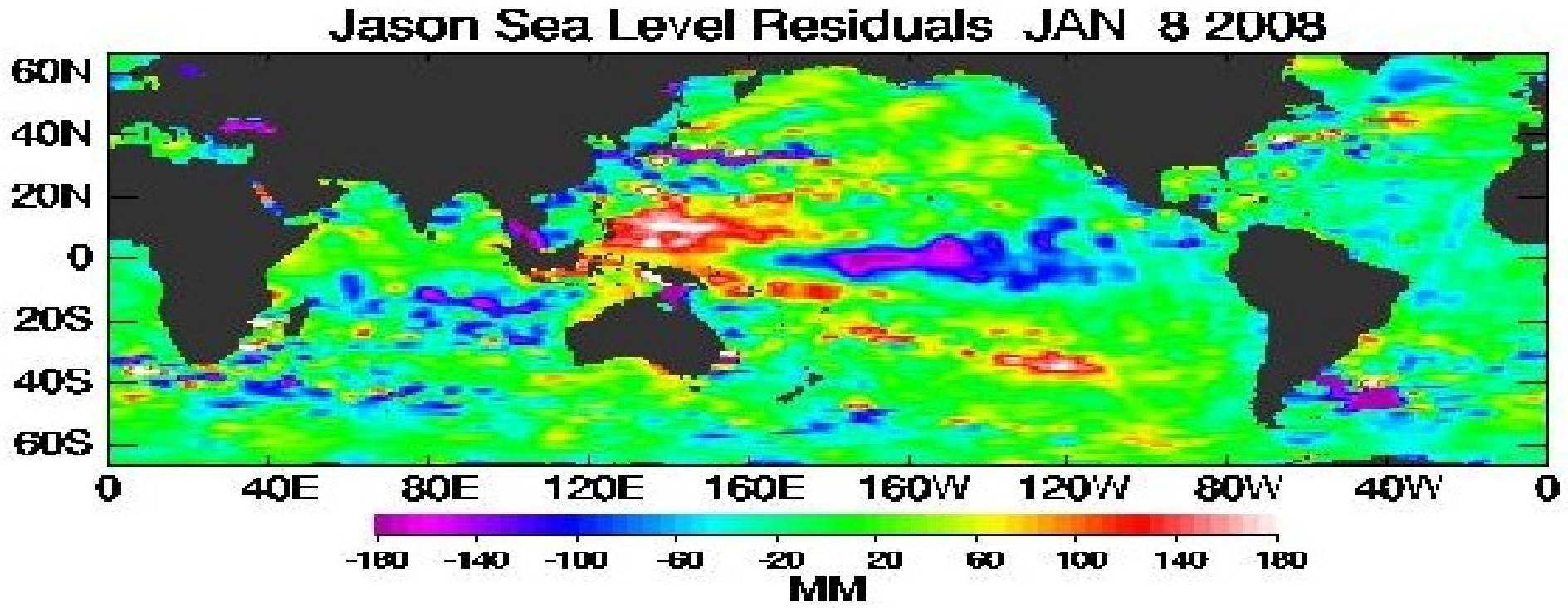

QuikScat wind vectors: 2008/04/28 - evening passes - Global
30 60 90 120 150 180 210 240 270 300 330 0 30
90 60 30 0 -30 -60 -90
Remote Sensing Systems
www.remss.com
14:42 UTC 13:02 UTC 11:24 UTC 09:42 UTC 08:00 UTC 06:18 UTC 04:36 UTC 02:56 UTC 01:18 UTC 23:08 UTC 21:30 UTC 19:48 UTC 18:06 UTC 16:24 UTC
Wind Speed:
0 5 10 15 20 25 30+
(meters / second)
land
0 1000 2000+
(meters amsl)
no data

Satellites and Sensors

- Active Microwave - Altimeter
  - Sensors: SSALT, NRA-2, RA-2, GFO RA
  - Measures: time ~ altitude; signal shape ~ wave height; signal scatter ~ wind speed
  - Flown on: Jason, Envisat, GFO (ERS-1, ERS-2, Topex/Poseidon)
  - Resolution: 5 km along track. No swath
  - Parameters: Significant Wave Height, Wind Speed, Ocean Surface Topography, Mesoscale Ocean Features, Derived Geostrophic Currents

Altimeter (Jason) Sea Level Anomaly: El Nino (Top) & La Nina (Bottom)





Satellites and Sensors

- Passive Microwave
  - Sensors: TMI, SSM/I, AMSR, AMSU
  - Measures: Brightness temperatures from surface and atmospheric radiation at multiple wavelengths in microwave spectrum
  - Flown on: TRMM, DMSP, AQUA, MetOp
  - Resolution: 25 km in 1400 km wide swath
  - Parameters: ocean surface wind speed, ice cover and age, integrated columnar water vapor, cloud liquid water, precipitation rate, and sea surface temperature

F13 SSM/I 28 April 2008 Evening Pass

Remote Sensing Systems
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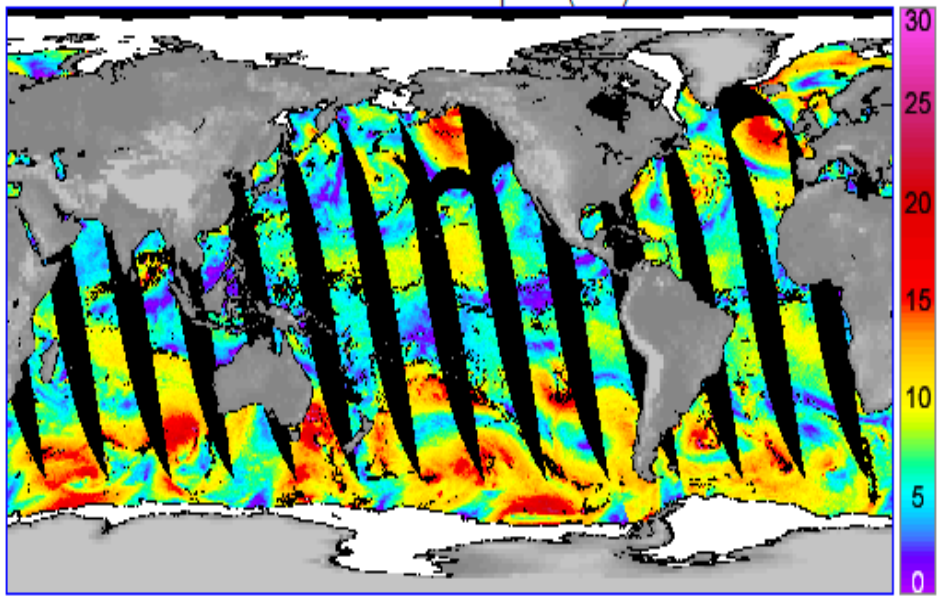
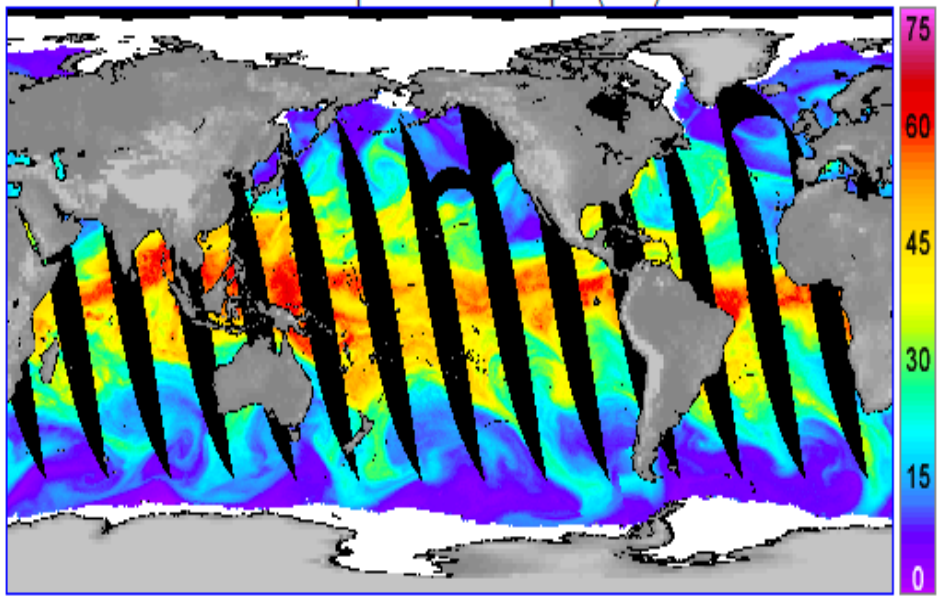
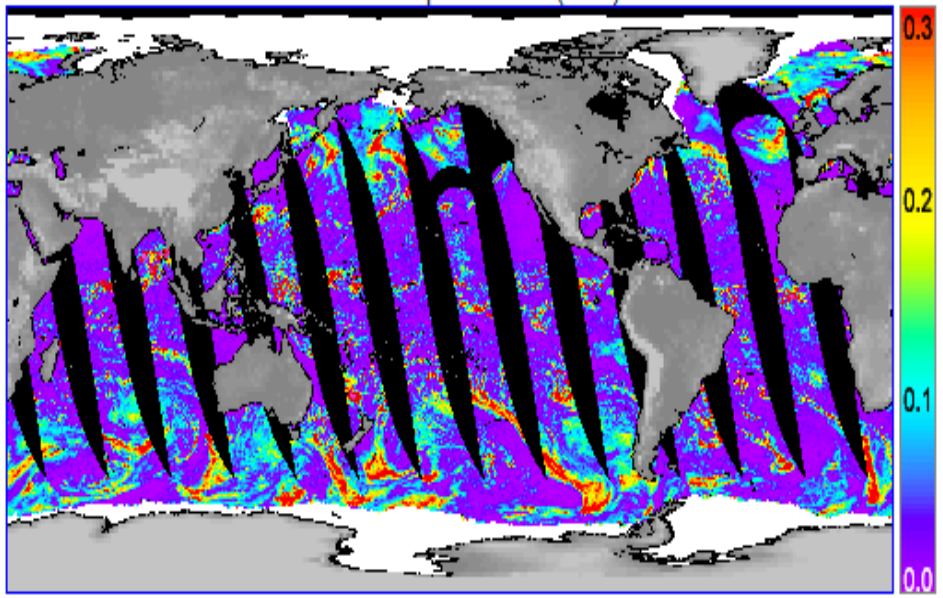
Surface Wind Speed (m/s)



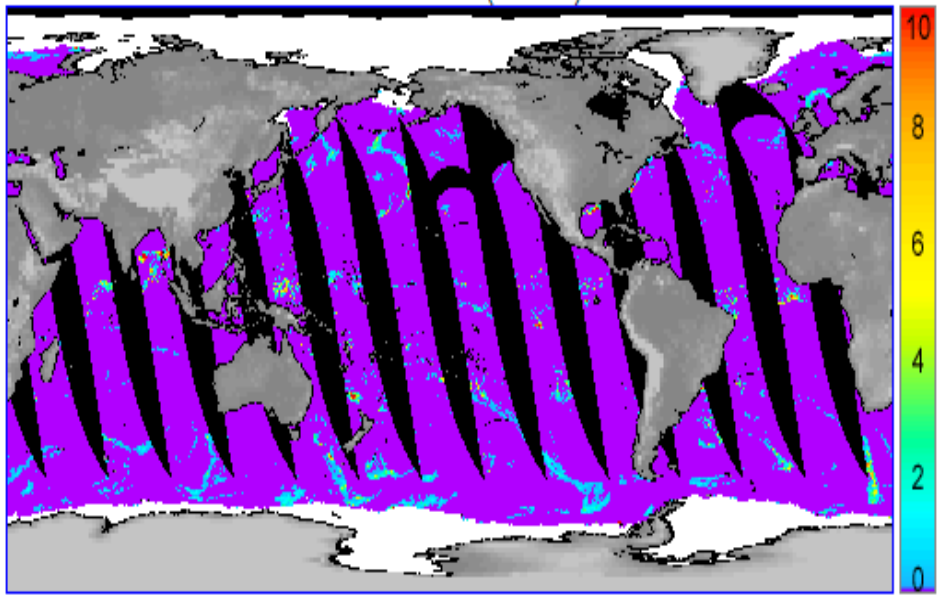
Atmospheric Water Vapor (mm)



Cloud Liquid Water (mm)

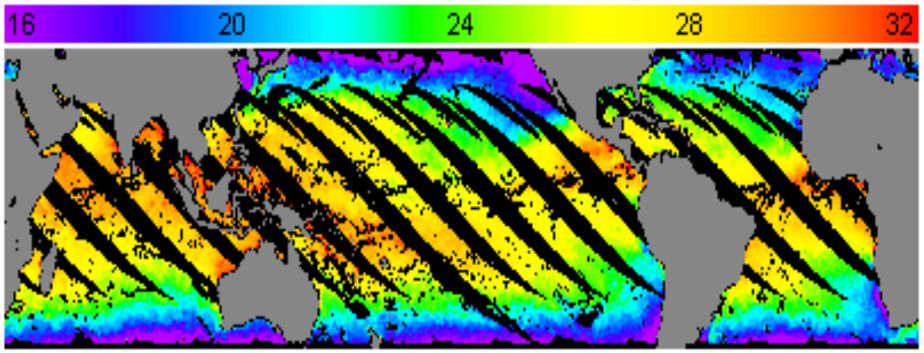


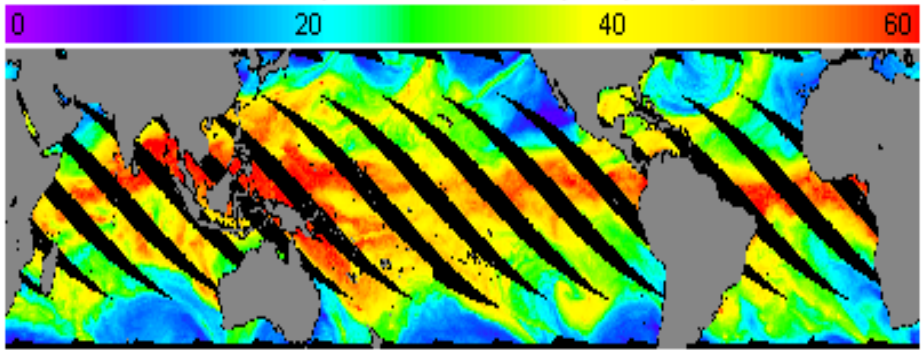
Rain Rate (mm/hr)

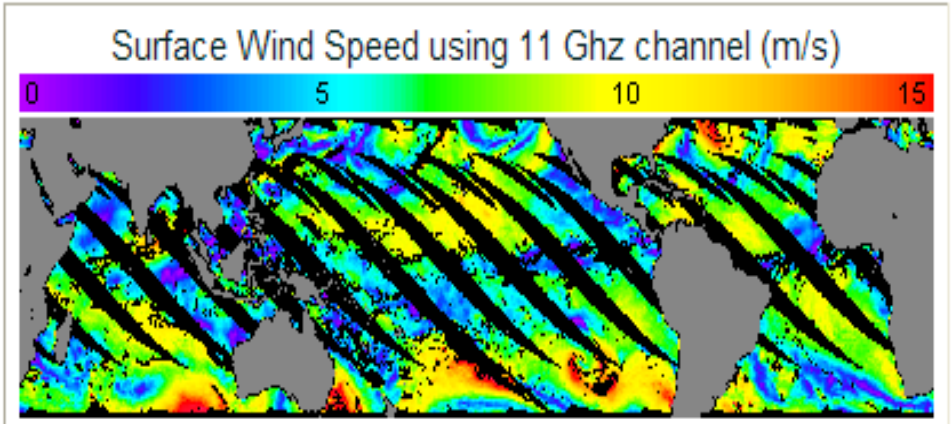


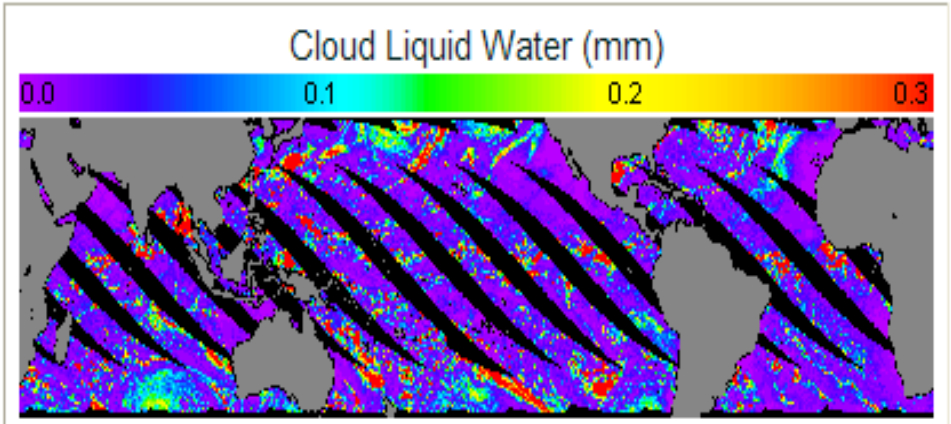
TRMM TMI 28 April 2008 Evening Pass

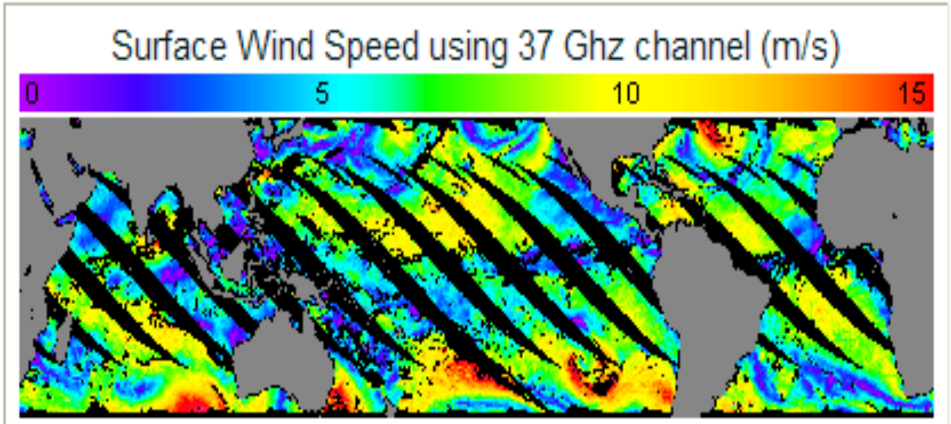
Remote Sensing Systems
www.remss.com

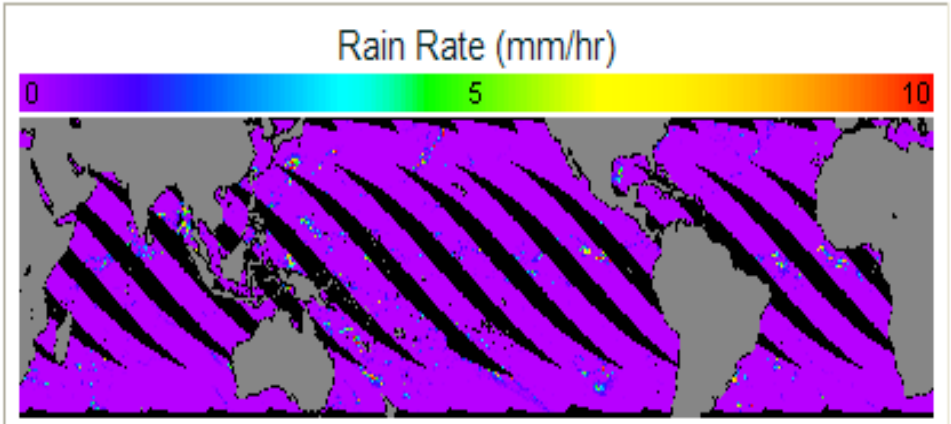








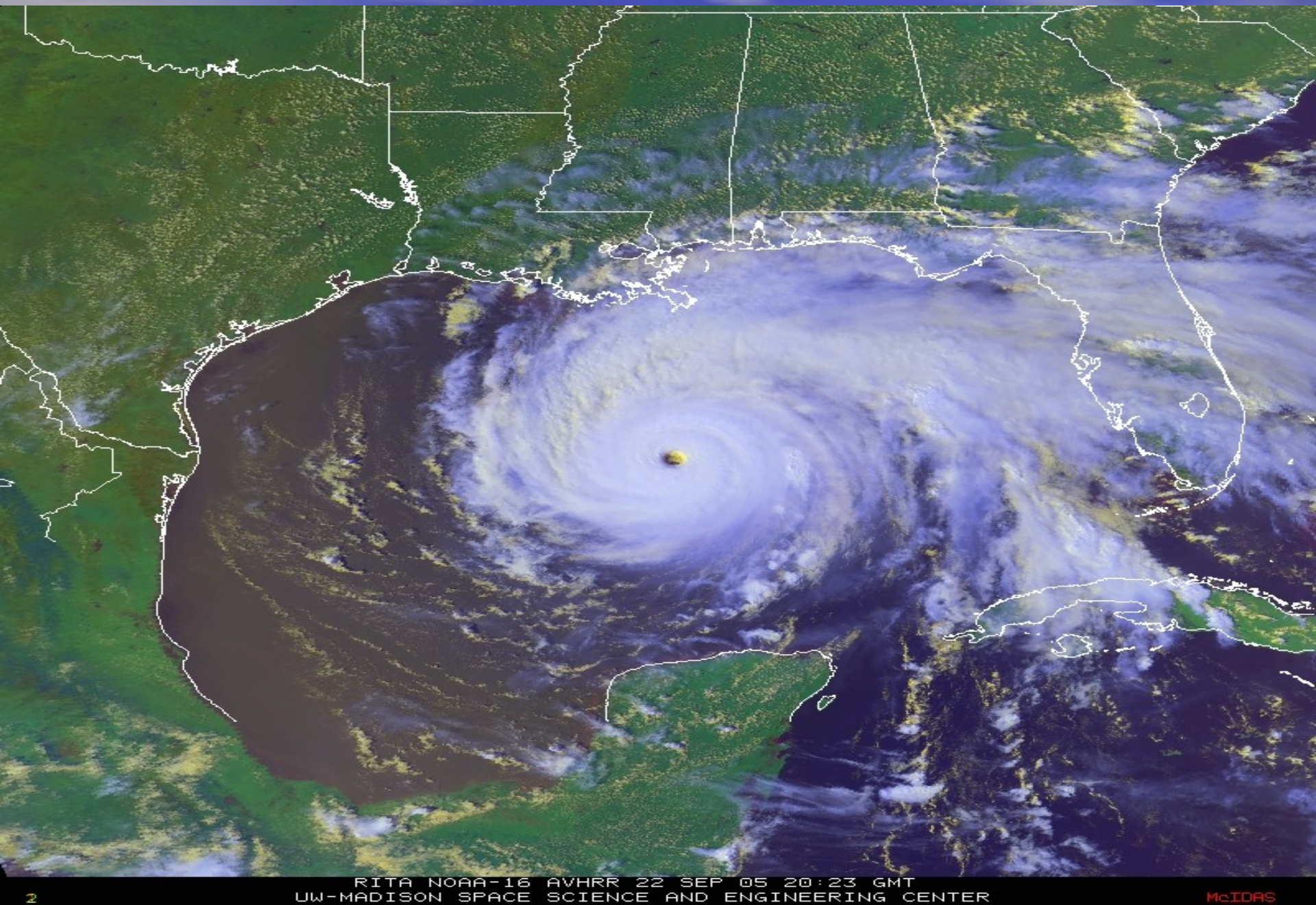




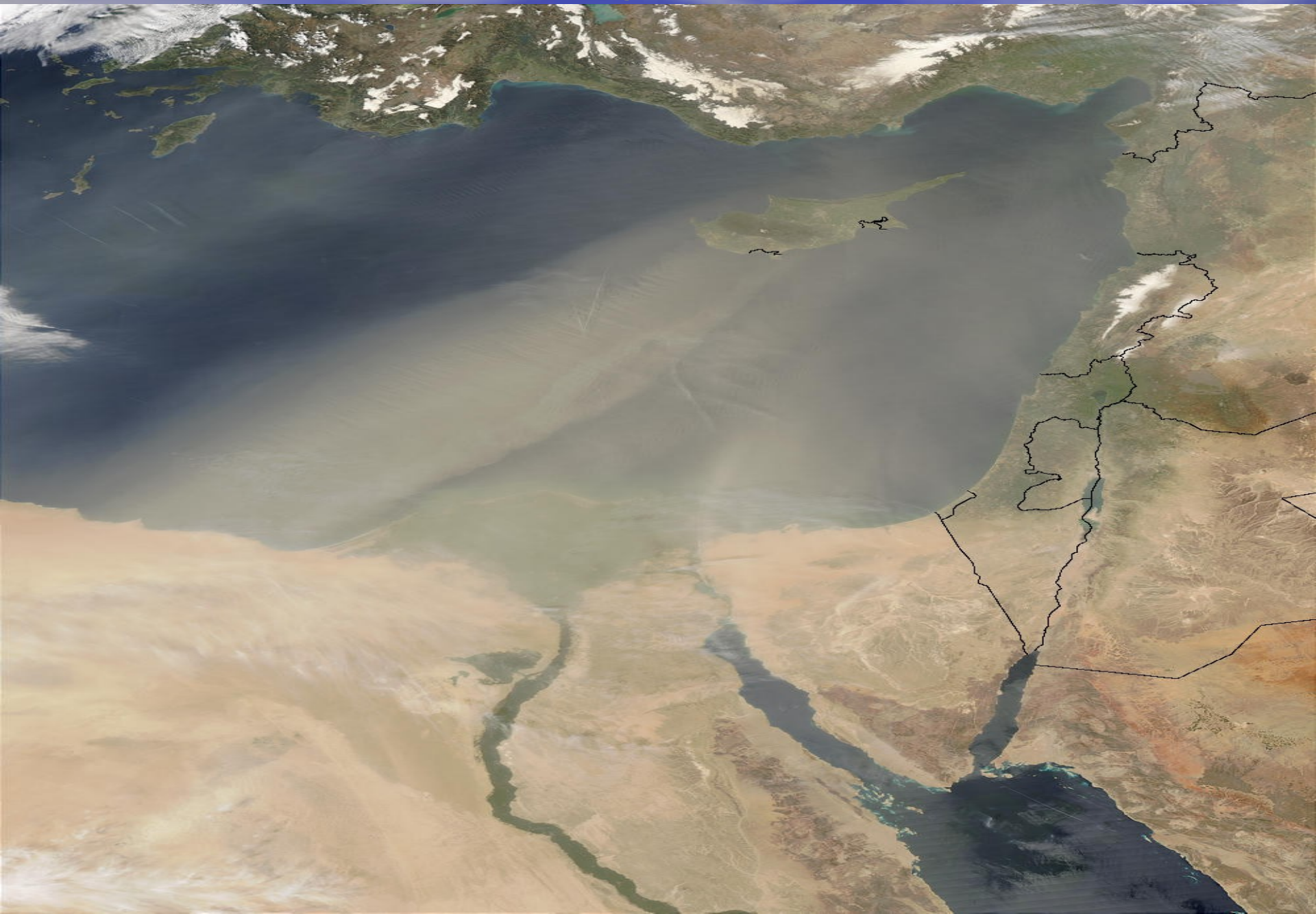
Satellites and Sensors

- Passive Visible/NIR/IR Imaging
  - Sensors: VISSR, MVISR, AVHRR, MODIS, MERIS, ATSR, SEAWIFS ….
  - Returns: Brightness at multiple wavelengths
  - Flown on: Multiple platforms
  - Resolution: From 100s of metres
  - Parameters: cloud incl low cloud/fog, ocean colour, turbidity, dust, aerosols

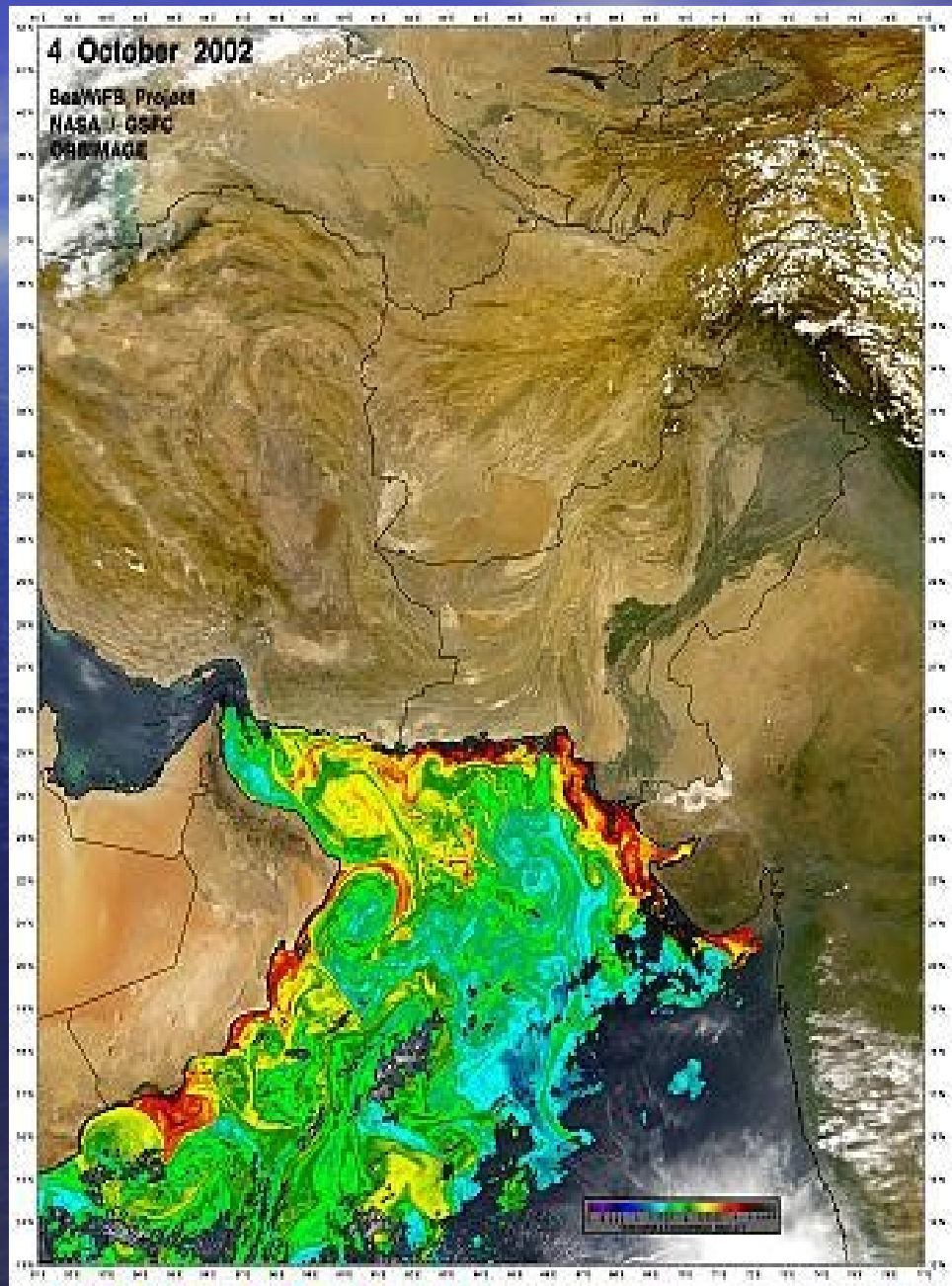
AVHRR Image (NOAA-16) 22 Sep 2005 – Hurricane Rita



MODIS Image - 04 Apr 2003



SEAWIFS (OrbView-2) Images: 04 Oct 2002 – Chrorophyll



The Case for Satellite Climatology

- Global coverage (not just shipping routes)
- Don’t avoid severe weather conditions
- Volume of observations
- Well calibrated against in situ measurements
- Bulk re-processing for new algorithms
- Minimal subjective human interpretation

Limitations and Challenges

- 'Incomplete' weather observation
- Affected by severe weather
- Unable to capture some extreme events
- Limited diurnal coverage from sun synchronous satellites
- Limited coastal coverage
- Short observational history unsuitable for long time series, climate change trends etc

Case Studies

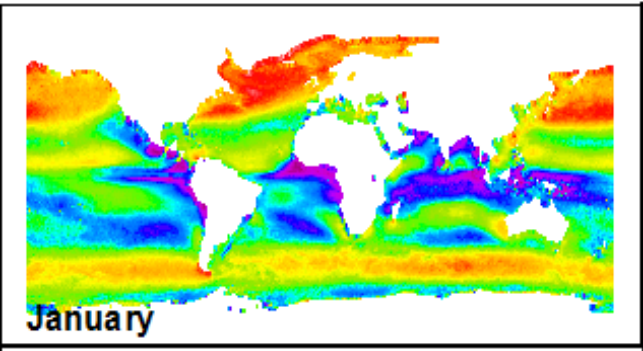
- Wind Speed (Quikscat)
- Significant Wave Height (Multiple altimeters)
- Atmospheric Moisture and Precipitation (SSM/I)

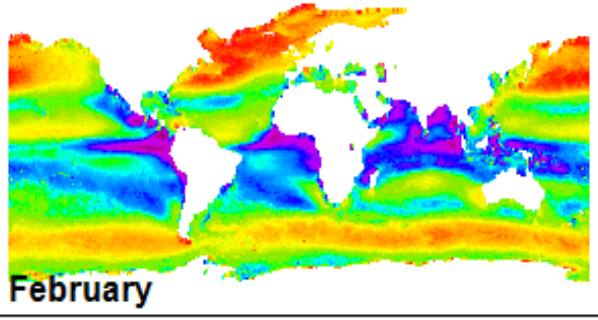
- Sea Surface Temperature
- Cloud
- Sea Ice
- Ocean Colour

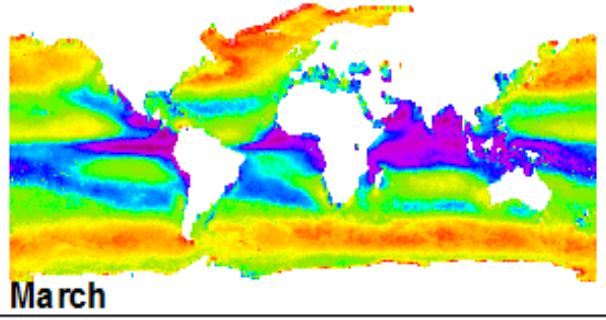
Wind Speed and Direction

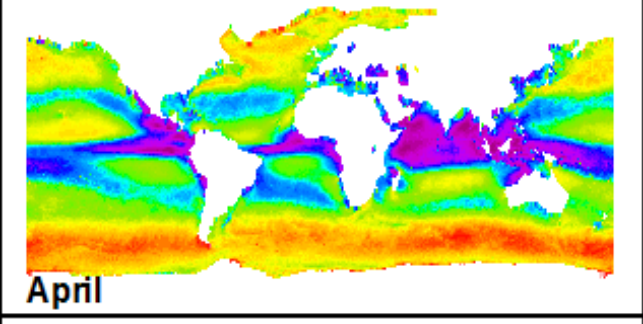
- Sensor: SeaWinds scatterometer on Quikscat
- Data Source: Remote Sensing Systems
- Resolution: 25 km
- Swath Width: 1800 km
- Time Series: ~ 9 years
- Observations: ~ 2.2 billion
- Parameter: Wind speed vectors at 10 m (~ 10 minute averaged)
- Processing: Already QC'd and flagged. Bin on regular grid and calculate statistics

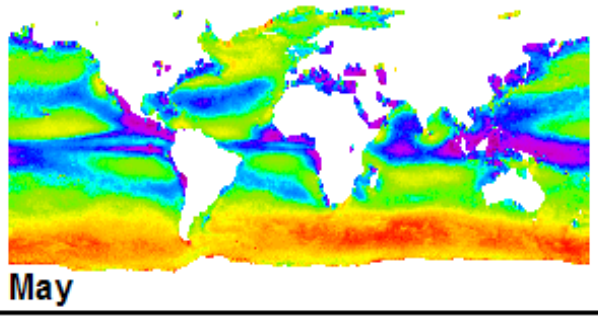
Mean Wind Speed (0.25 degree)

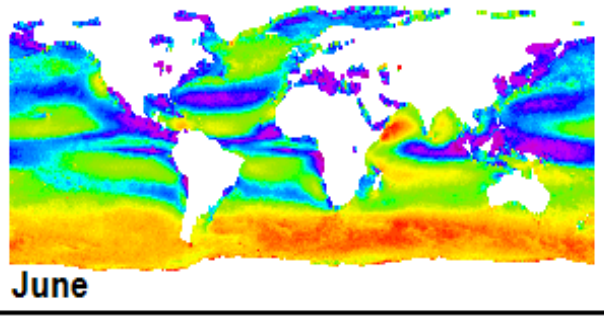


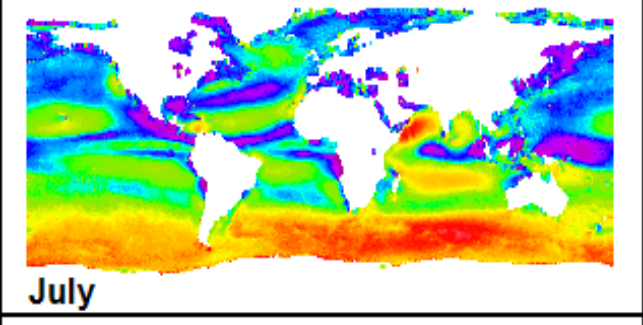


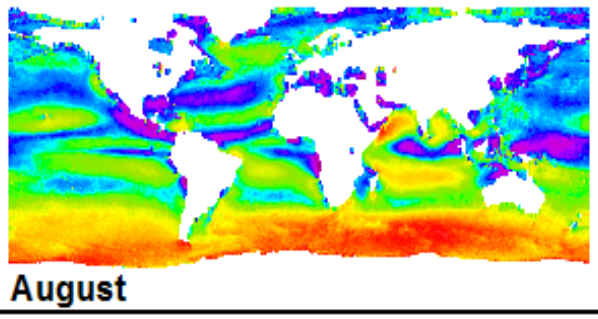


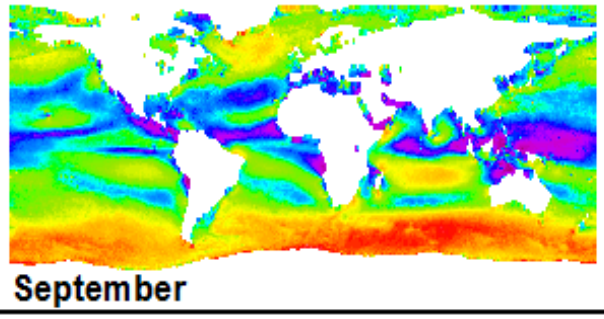


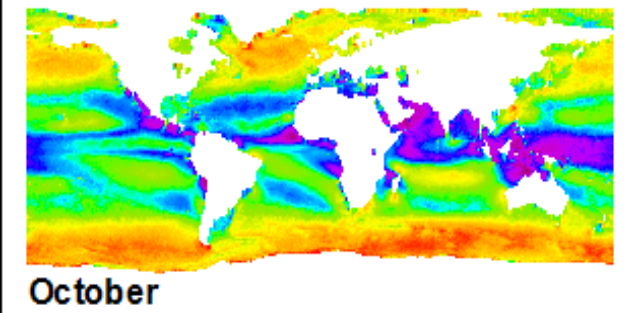


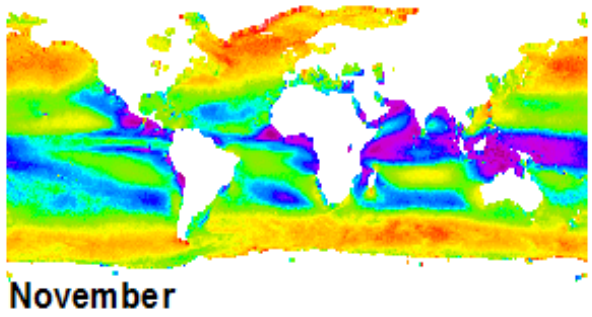


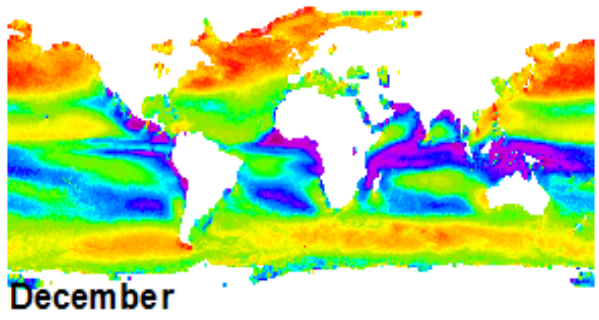




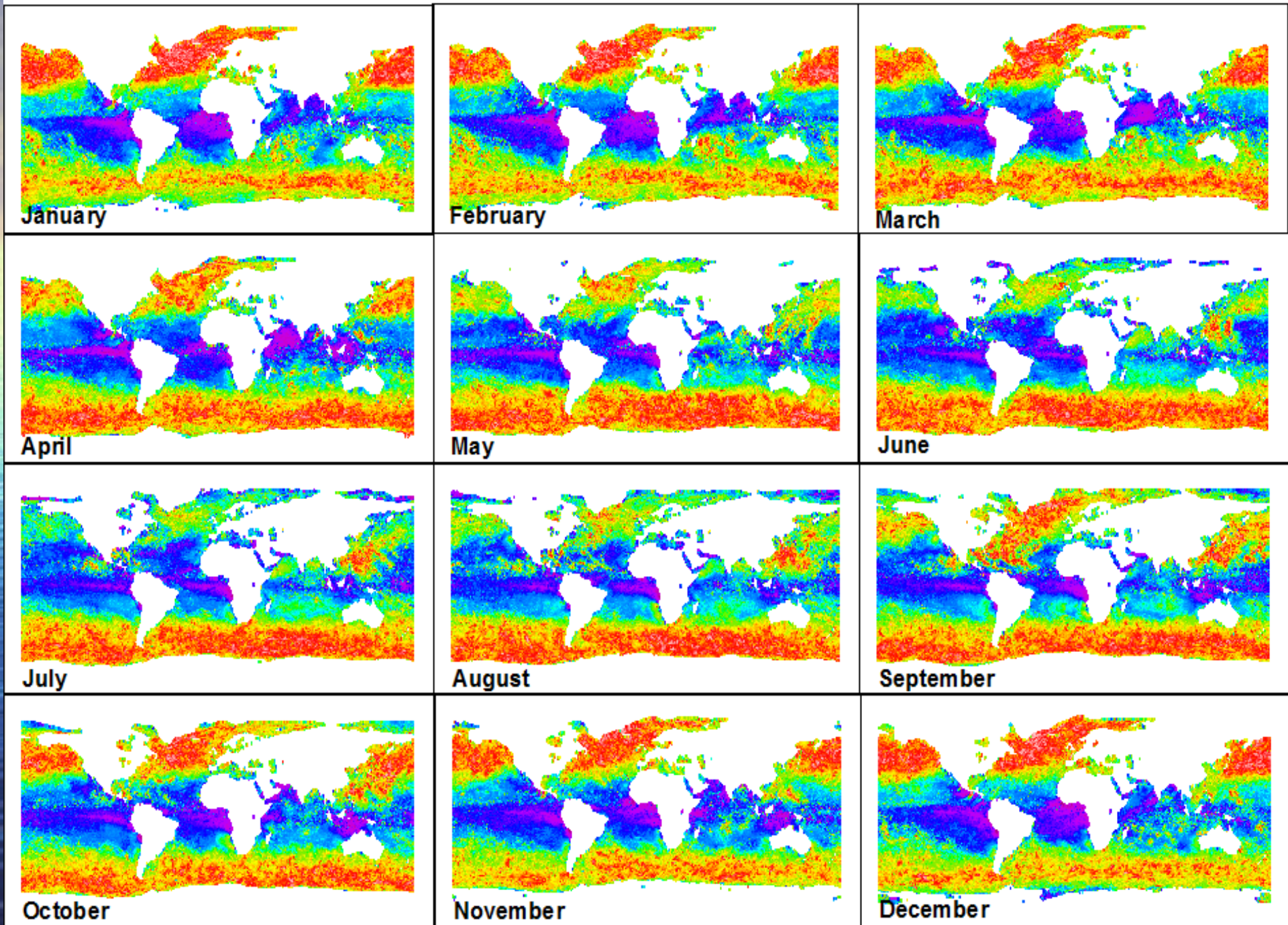




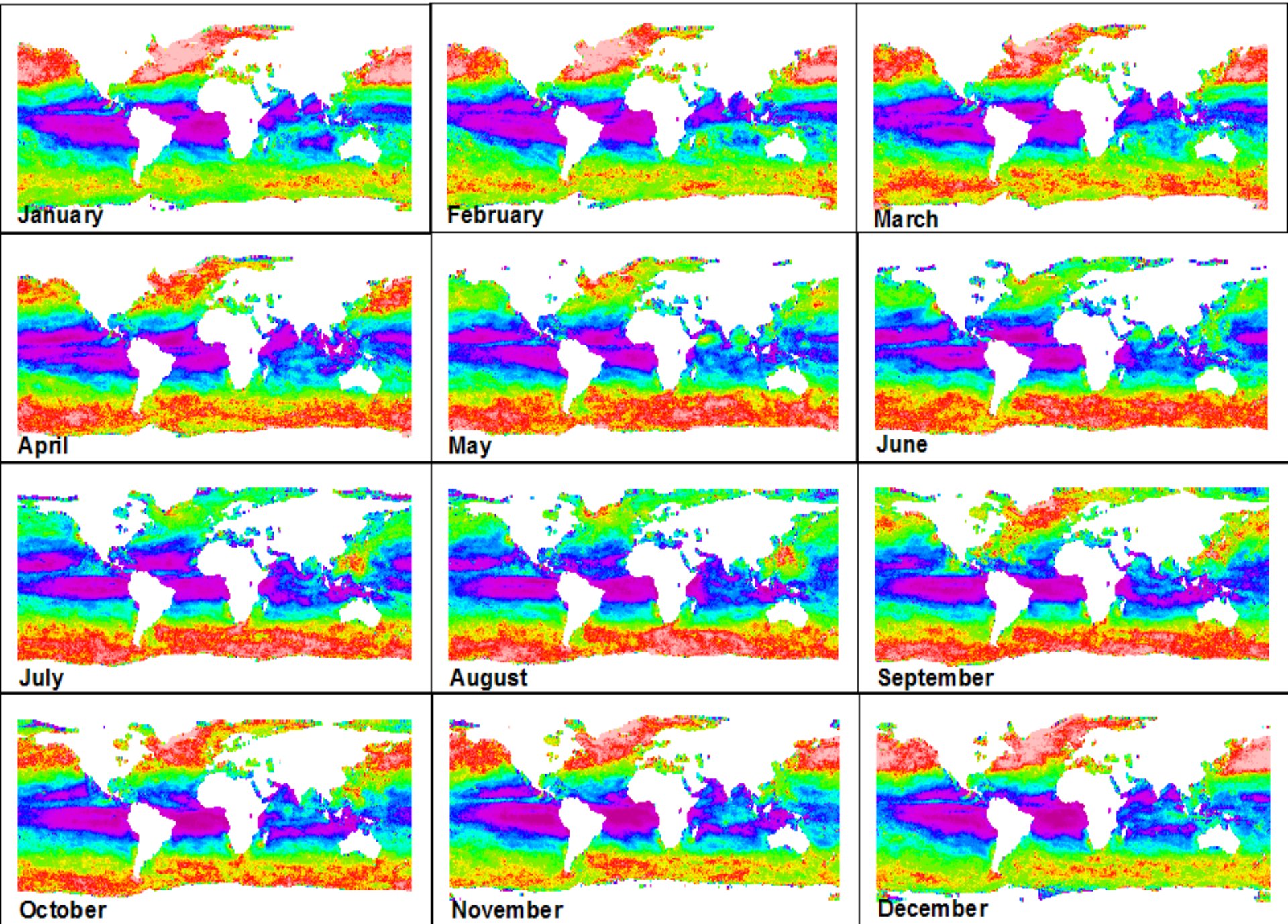




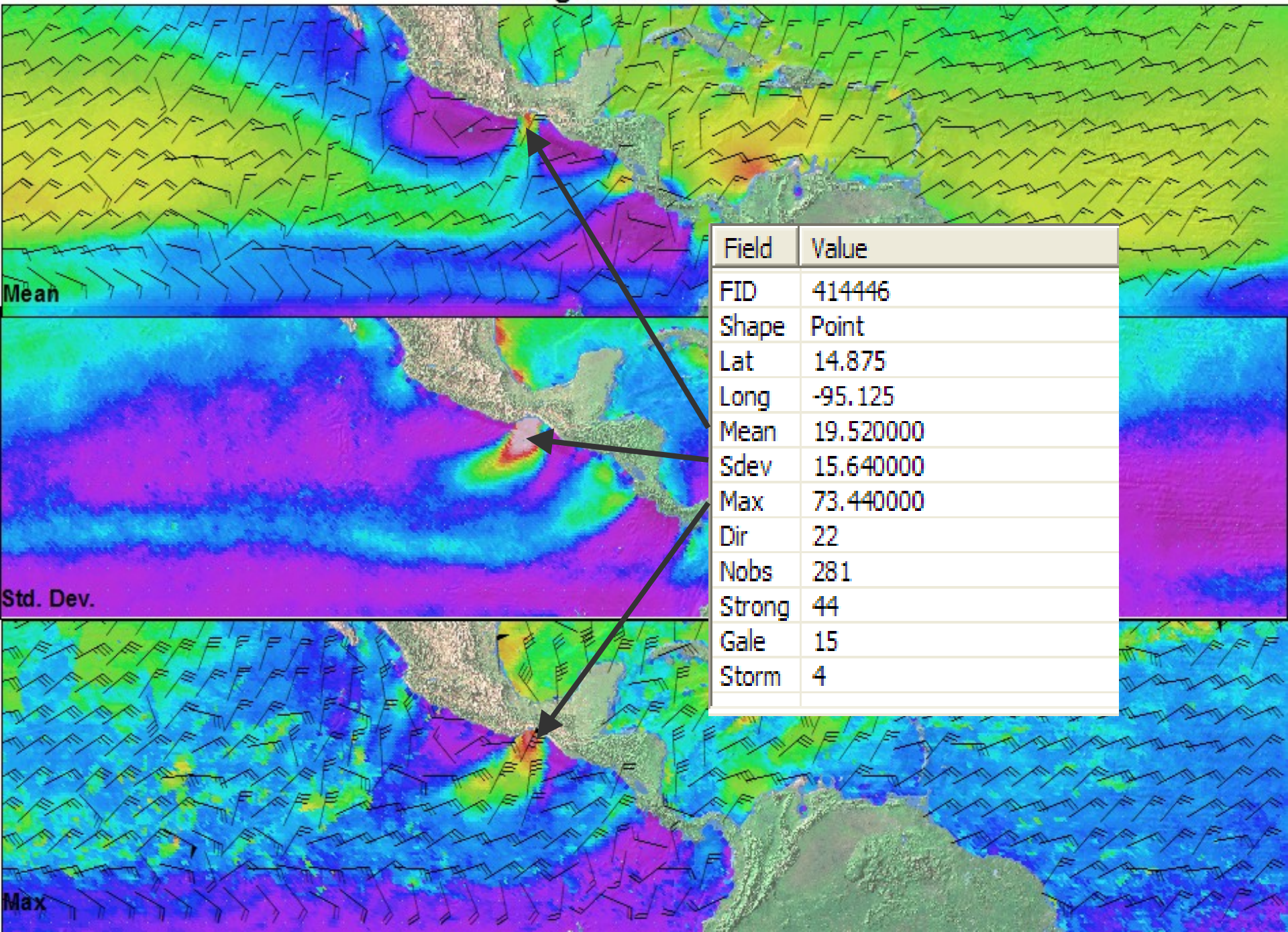
Max Wind Speed (0.25 degree)



Std. Dev. of Wind Speed (0.25 degree)

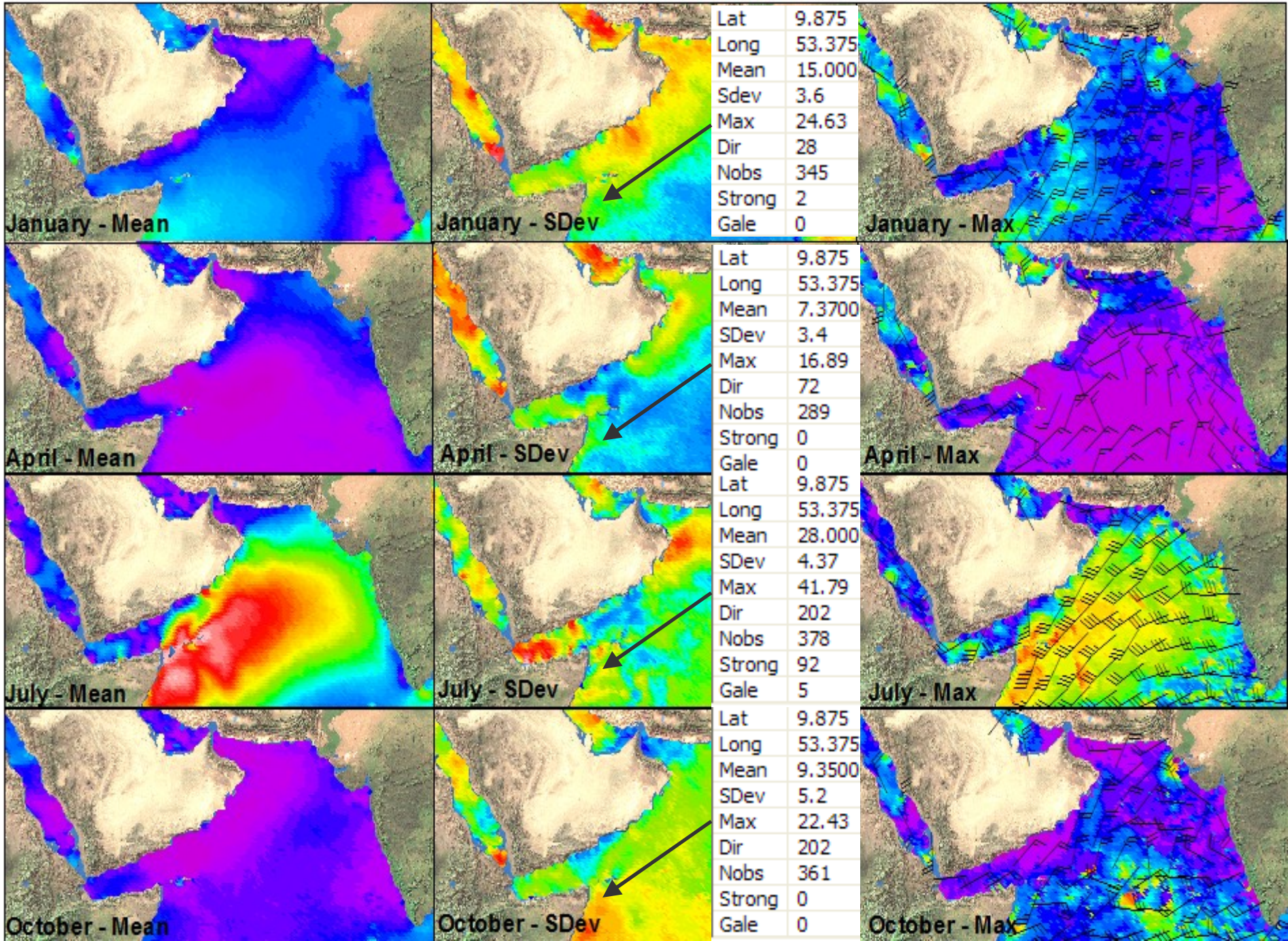


Regional Studies



Field	Value
FID	414446
Shape	Point
Lat	14.875
Long	-95.125
Mean	19.520000
Sdev	15.640000
Max	73.440000
Dir	22
Nobs	281
Strong	44
Gale	15
Storm	4

Quikscat Wind Speed



Lat	9.875
Long	53.375
Mean	15.000
Sdev	3.6
Max	24.63
Dir	28
Nobs	345
Strong	2
Gale	0

Lat	9.875
Long	53.375
Mean	7.3700
SDev	3.4
Max	16.89
Dir	72
Nobs	289
Strong	0
Gale	0

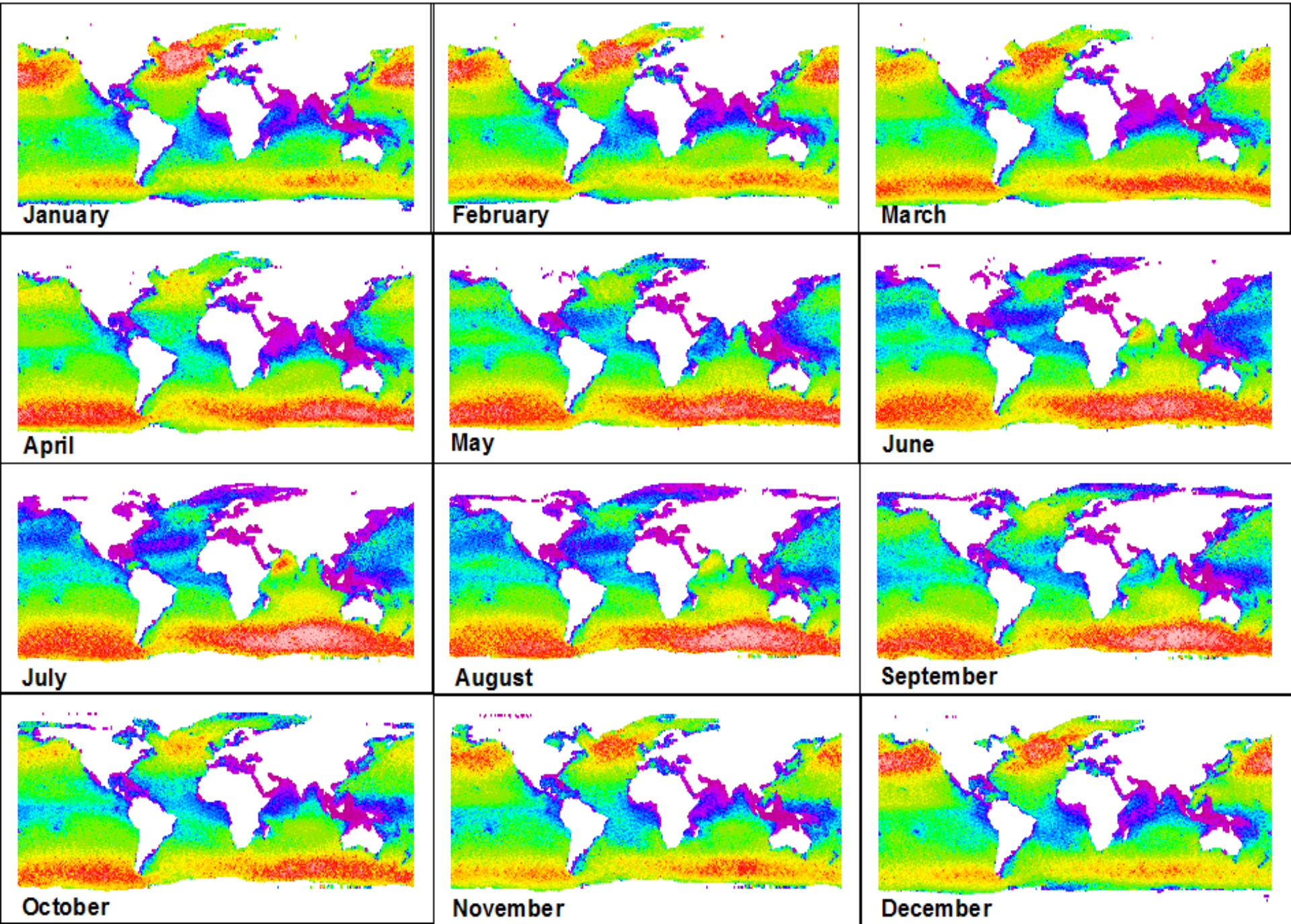
Lat	9.875
Long	53.375
Mean	28.000
SDev	4.37
Max	41.79
Dir	202
Nobs	378
Strong	92
Gale	5

Lat	9.875
Long	53.375
Mean	9.3500
SDev	5.2
Max	22.43
Dir	202
Nobs	361
Strong	0
Gale	0

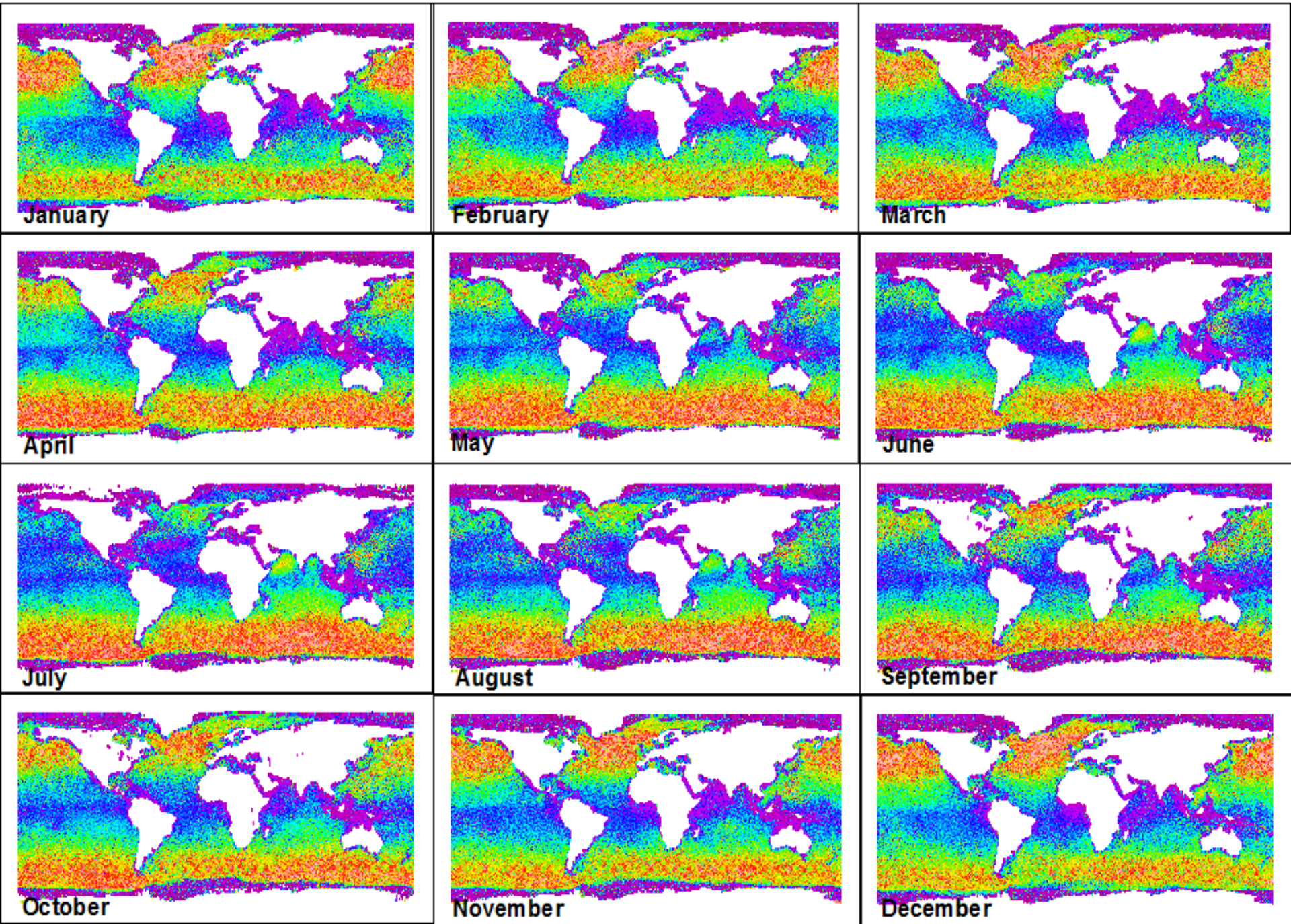
Significant Wave Height

- Sensors: GFO, Envisat, Topex/Poseidon, Jason, ERS-2
- Data Source: JPL PODAAC, ESA, USN
- Resolution: 5 km
- Swath Width: Nil
- Time Series: ~ 36 satellite years
- Observations: ~ 600 million
- Parameter: Significant Wave Height
- Processing: Extract from geophysical data records, QC, bin on ¼ degree grid, calculate statistics

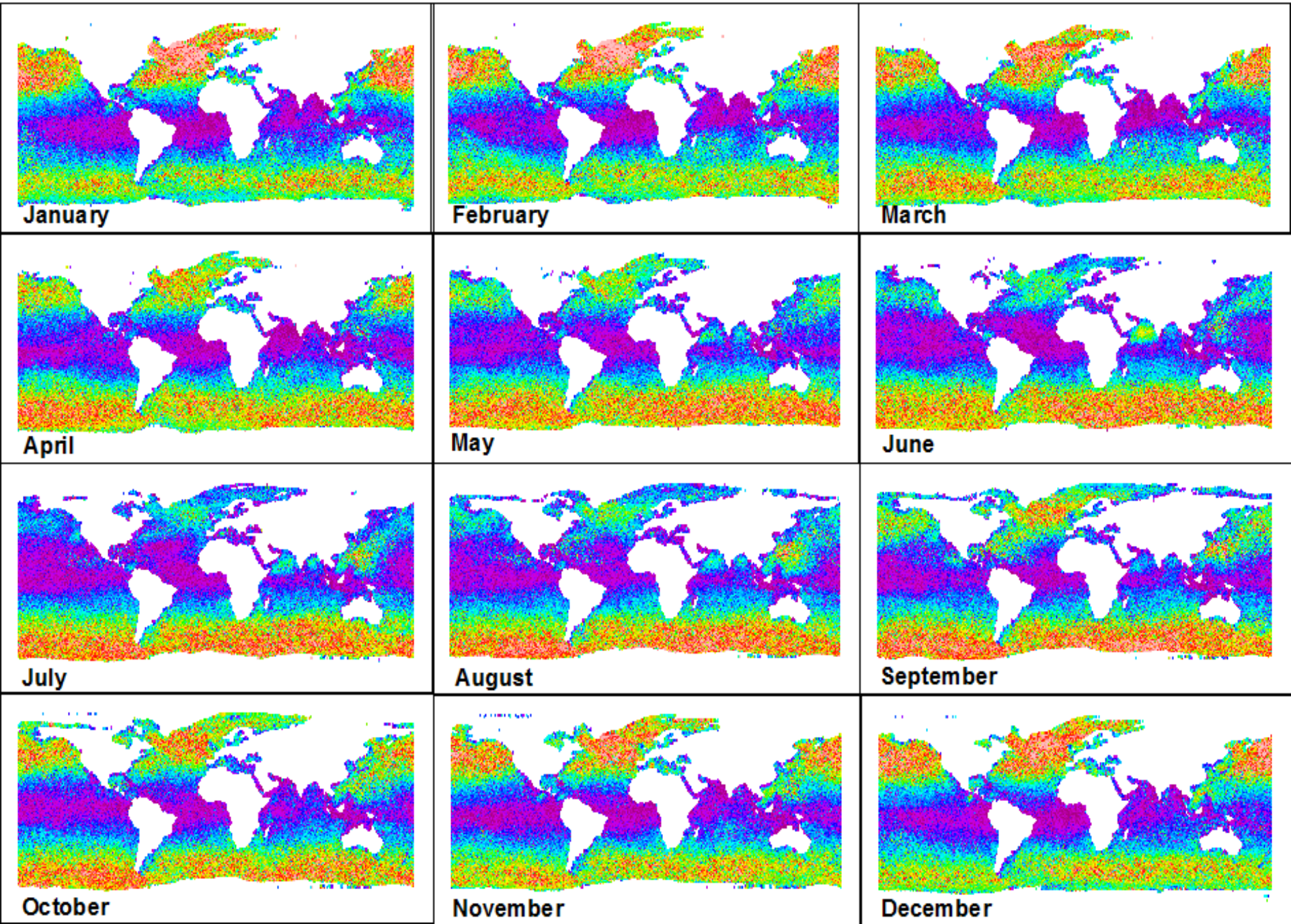
Mean Significant Wave Height (0.25 degree)



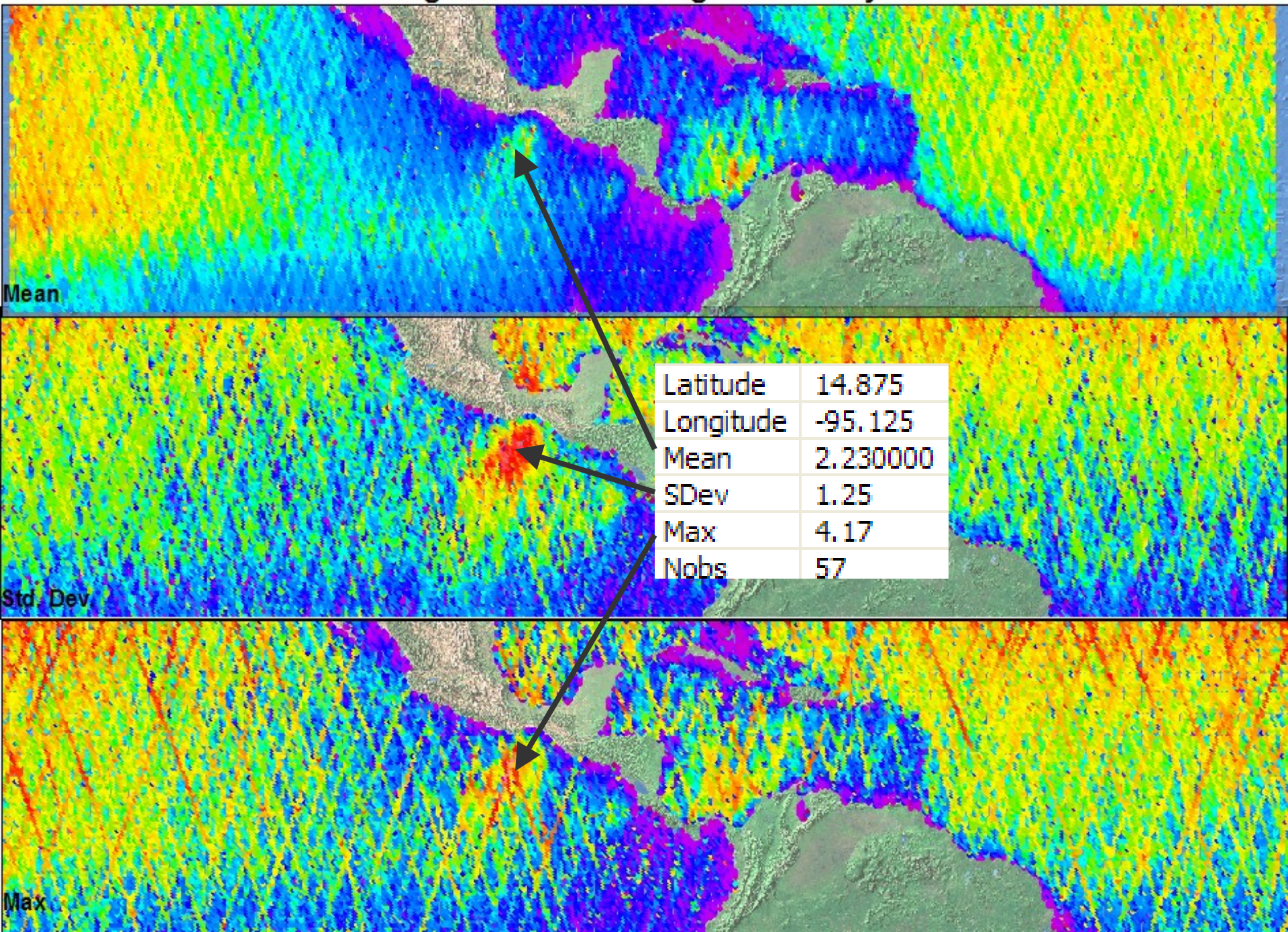
Max. Significant Wave Height (0.25 degree)



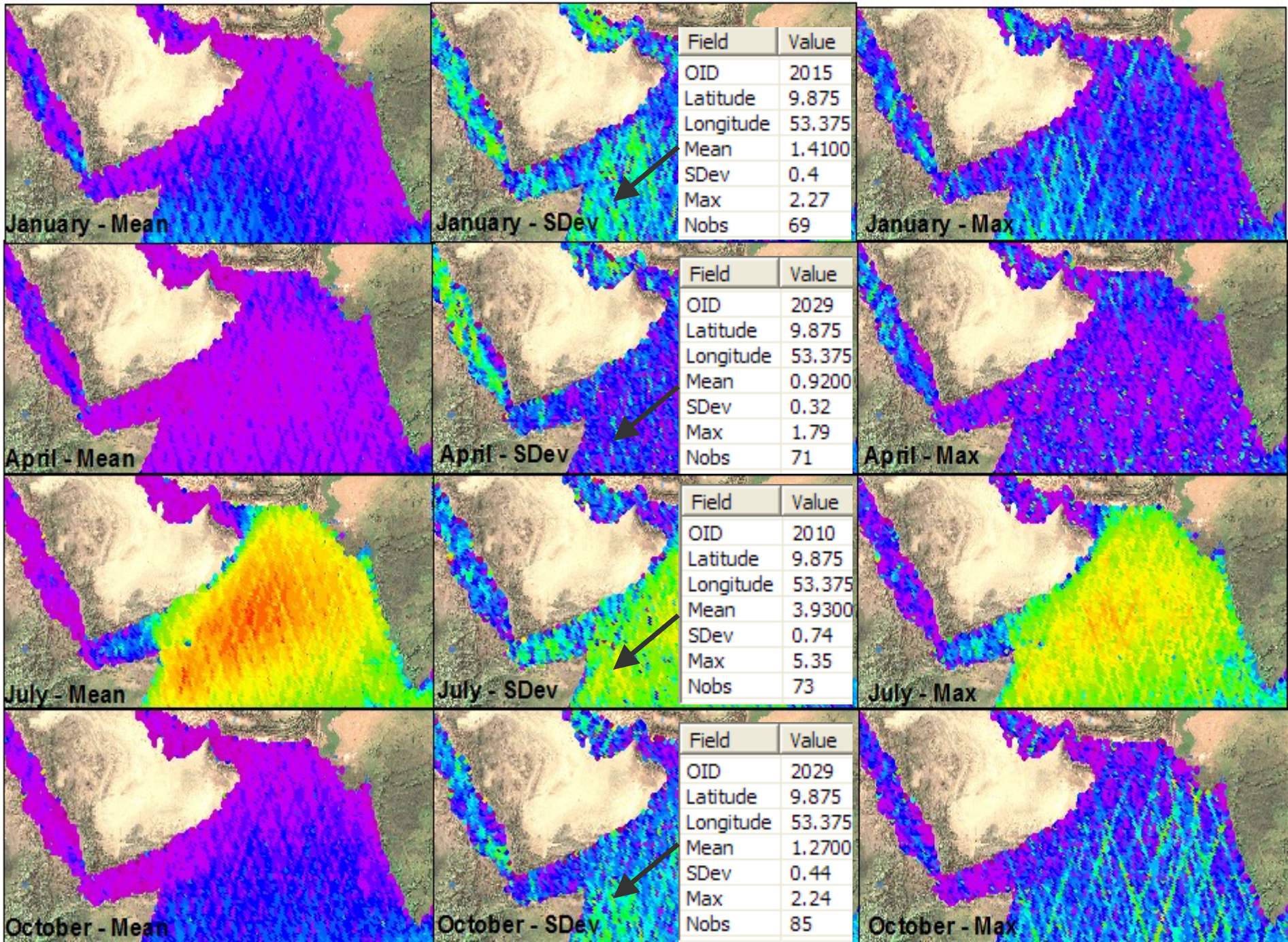
Standard Deviation of Significant Wave Height (0.25 degree)



Significant Wave Height - January



Significant Wave Height



Field	Value
OID	2015
Latitude	9.875
Longitude	53.375
Mean	1.4100
SDev	0.4
Max	2.27
Nobs	69

Field	Value
OID	2029
Latitude	9.875
Longitude	53.375
Mean	0.9200
SDev	0.32
Max	1.79
Nobs	71

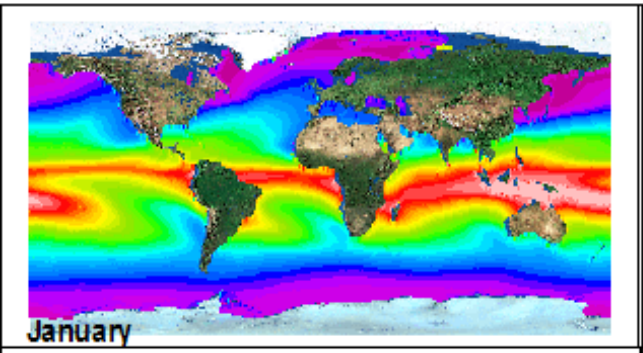
Field	Value
OID	2010
Latitude	9.875
Longitude	53.375
Mean	3.9300
SDev	0.74
Max	5.35
Nobs	73

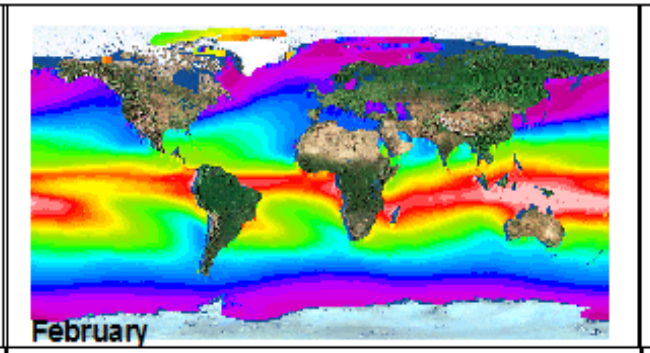
Field	Value
OID	2029
Latitude	9.875
Longitude	53.375
Mean	1.2700
SDev	0.44
Max	2.24
Nobs	85

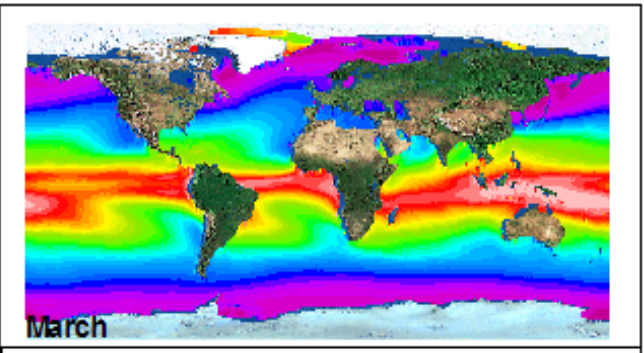
Atmospheric Moisture and Precipitation

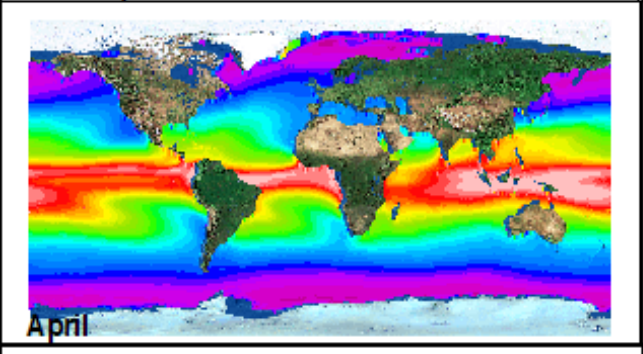
- Sensor: SSM/I on DMSP and TMI on TRMM
- Data Source: Remote Sensing Systems
- Resolution: 25 km
- Swath Width: ~ 1400 km
- Time Series: ~ 51 satellite years
- Observations: ~ 41 billion
- Processing: Already QC'd and flagged. Bin in regular grid and calculate statistics

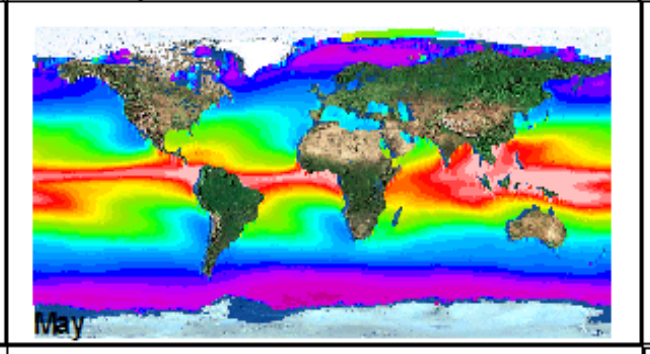
SSMI Mean Atmospheric Water Vapour

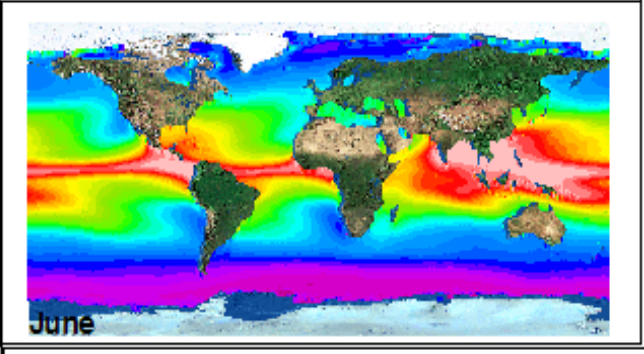


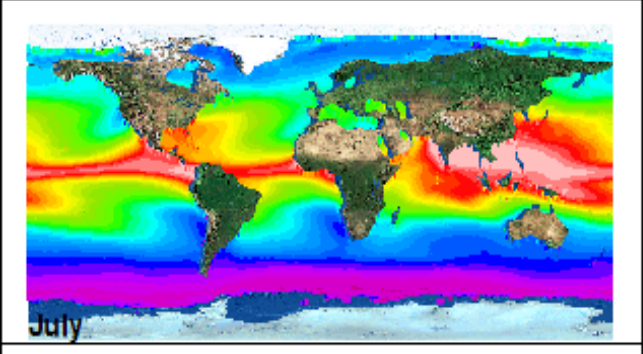


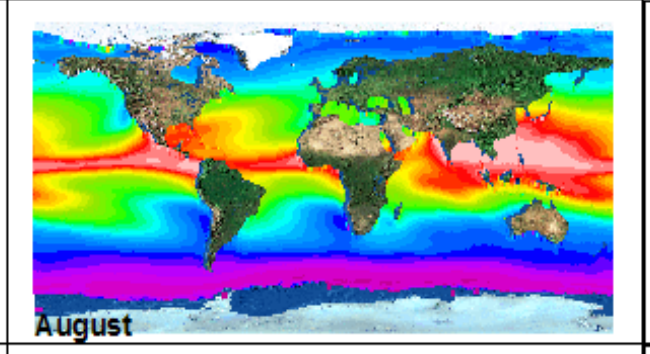


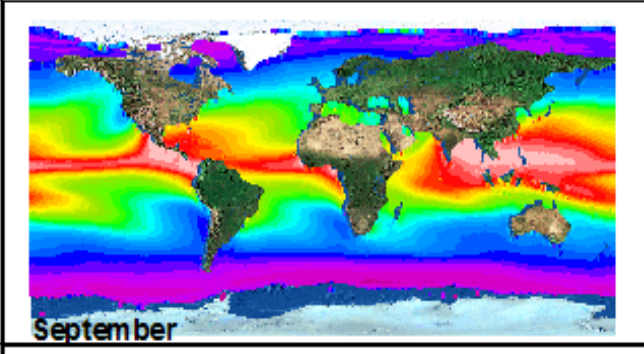


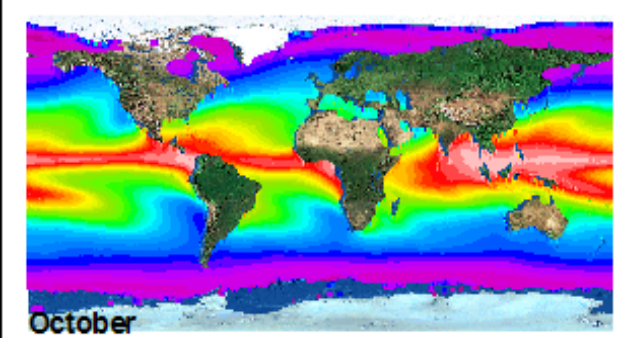


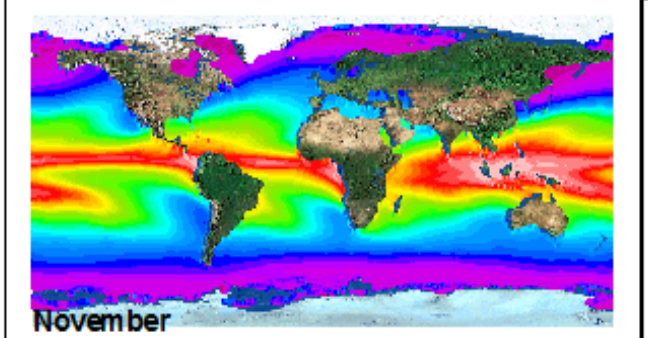


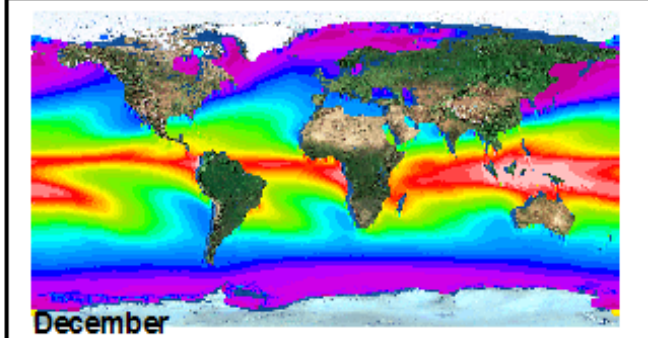




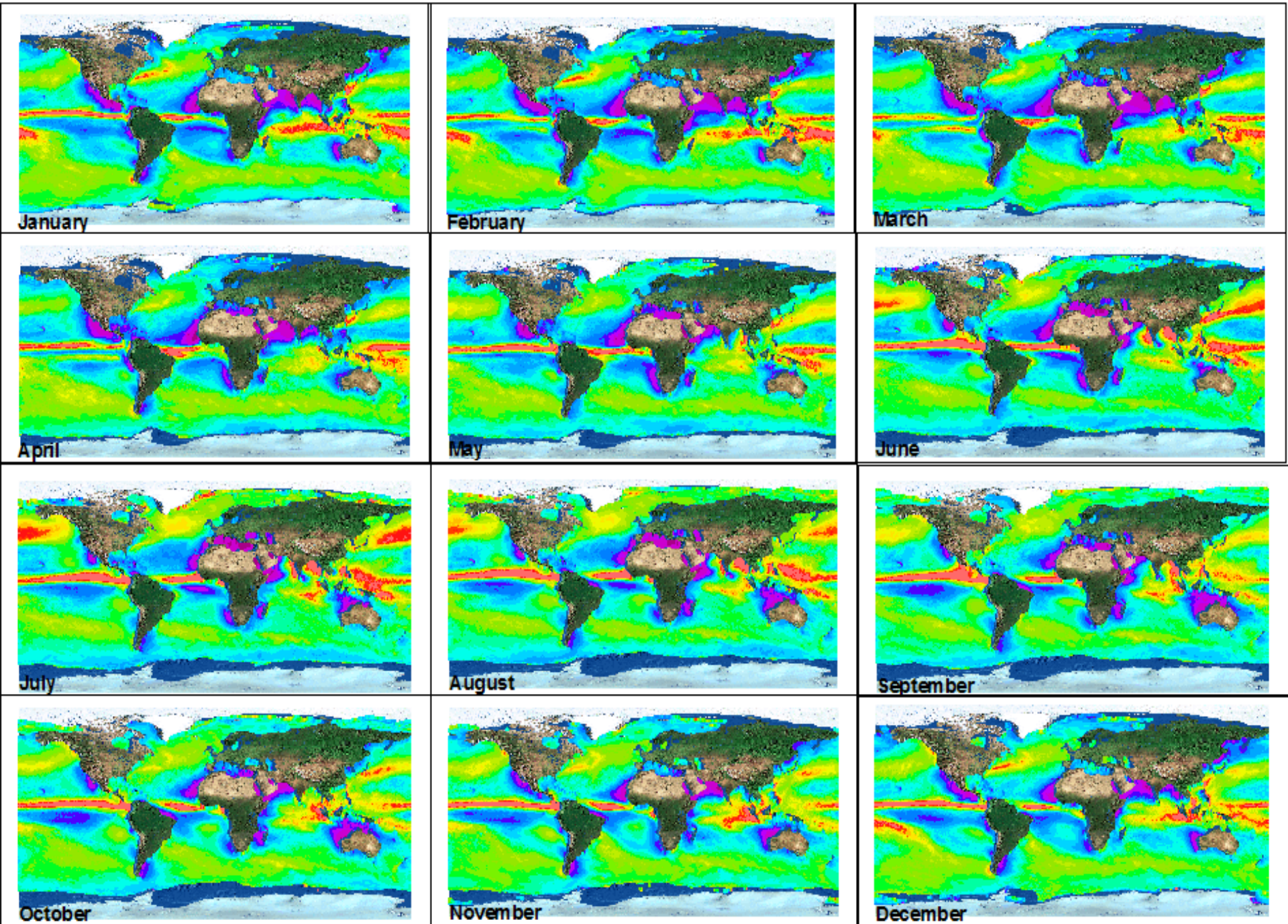




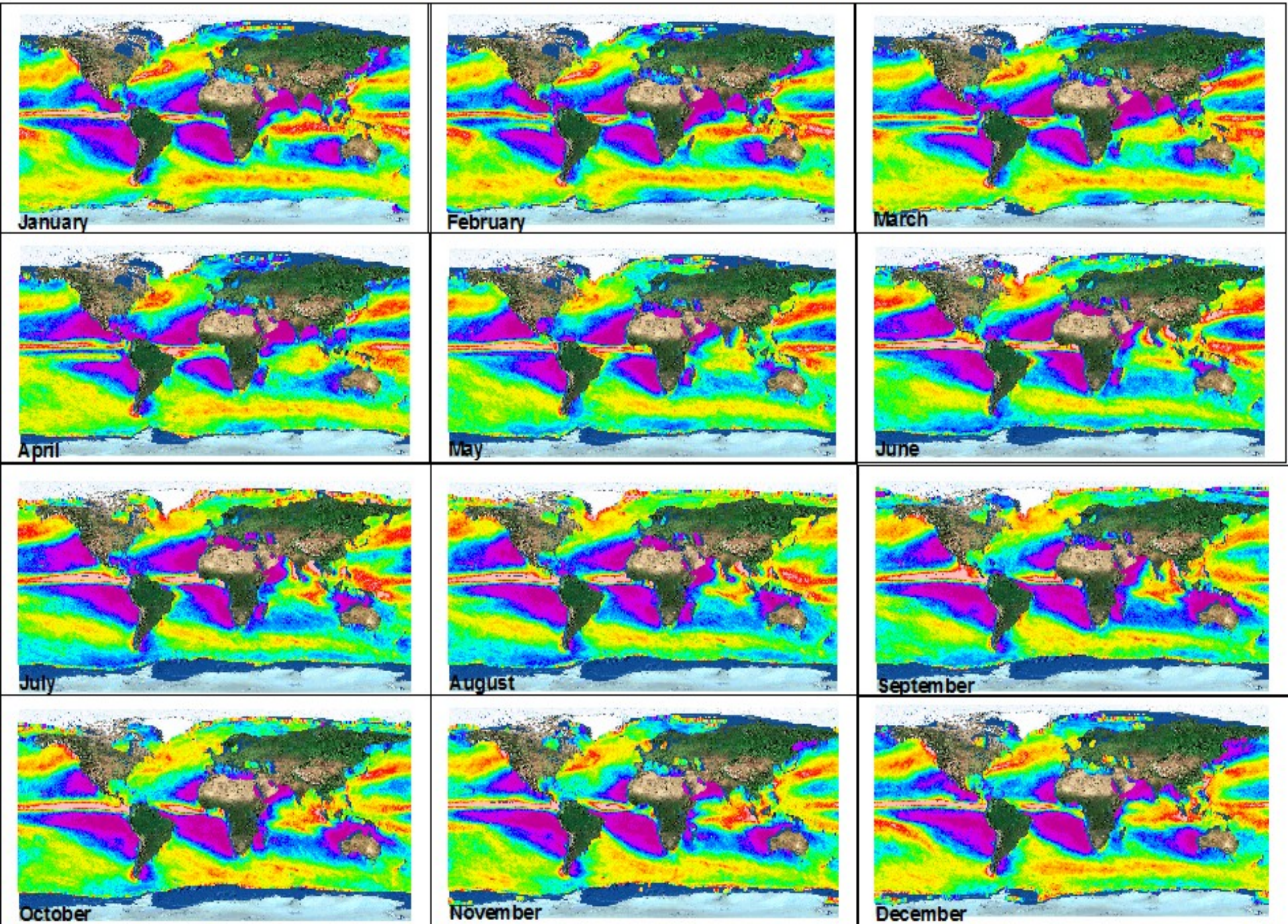




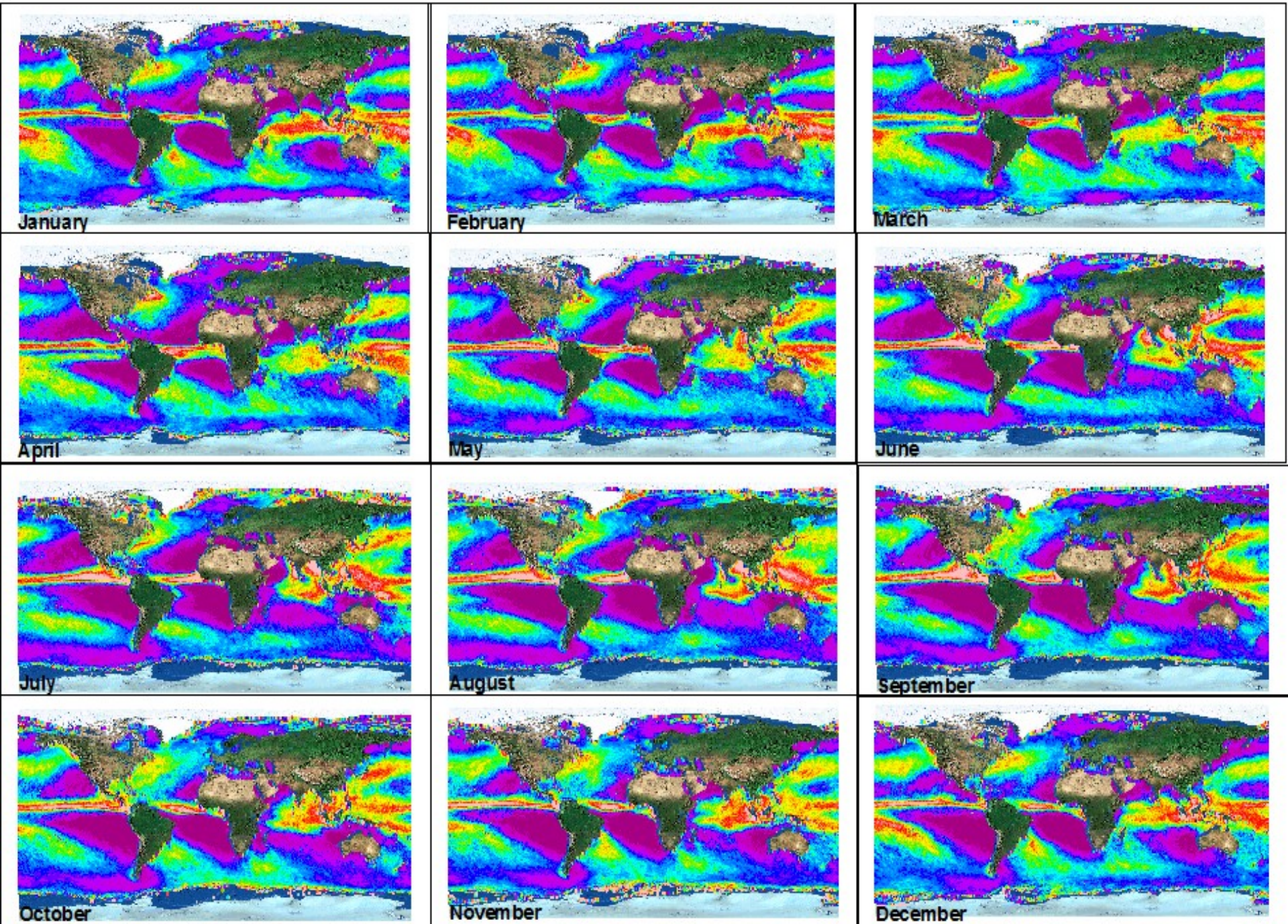
SSMI Mean Cloud Liquid Water



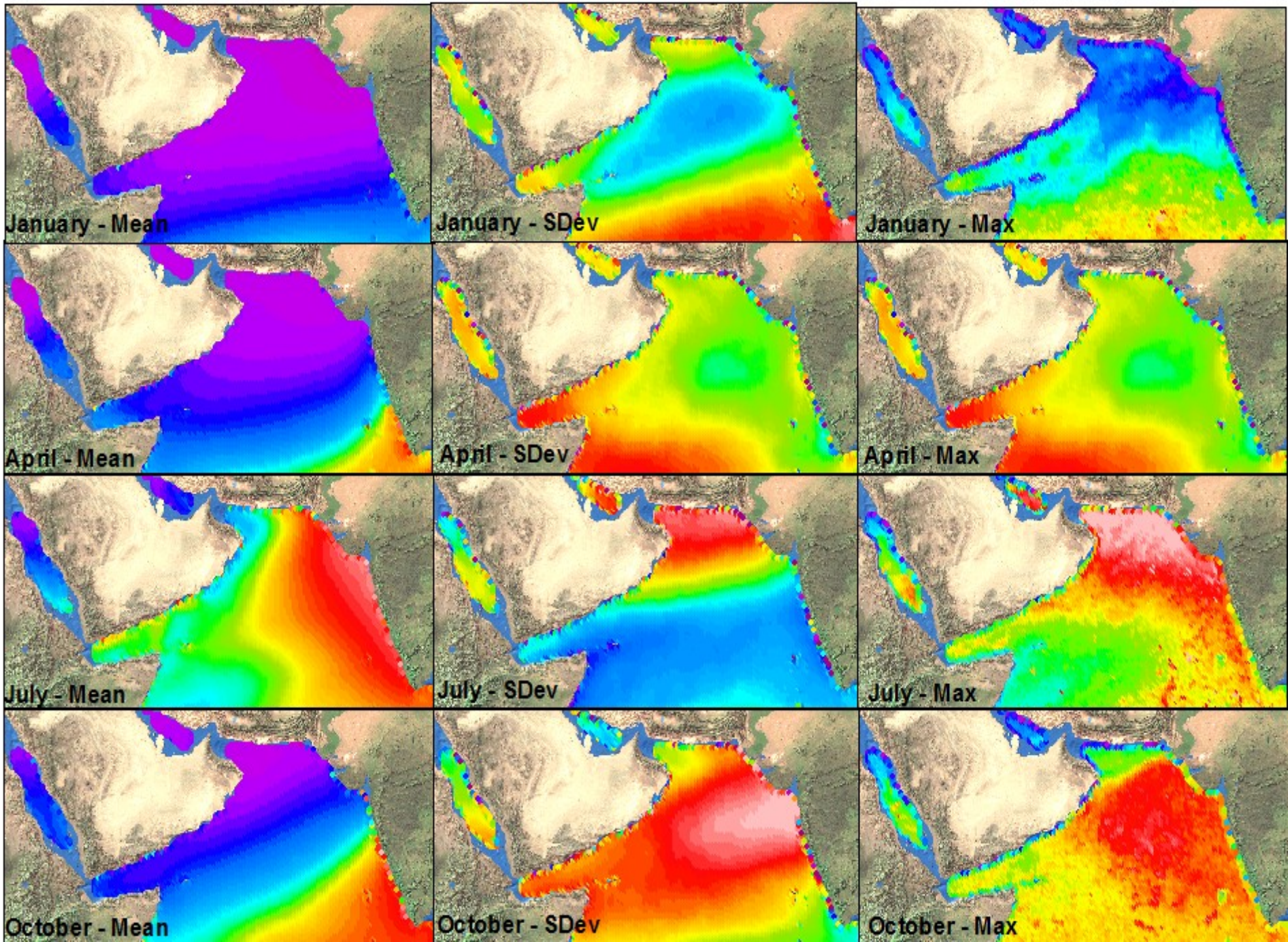
SSMI Percentage Occurrence Precipitation



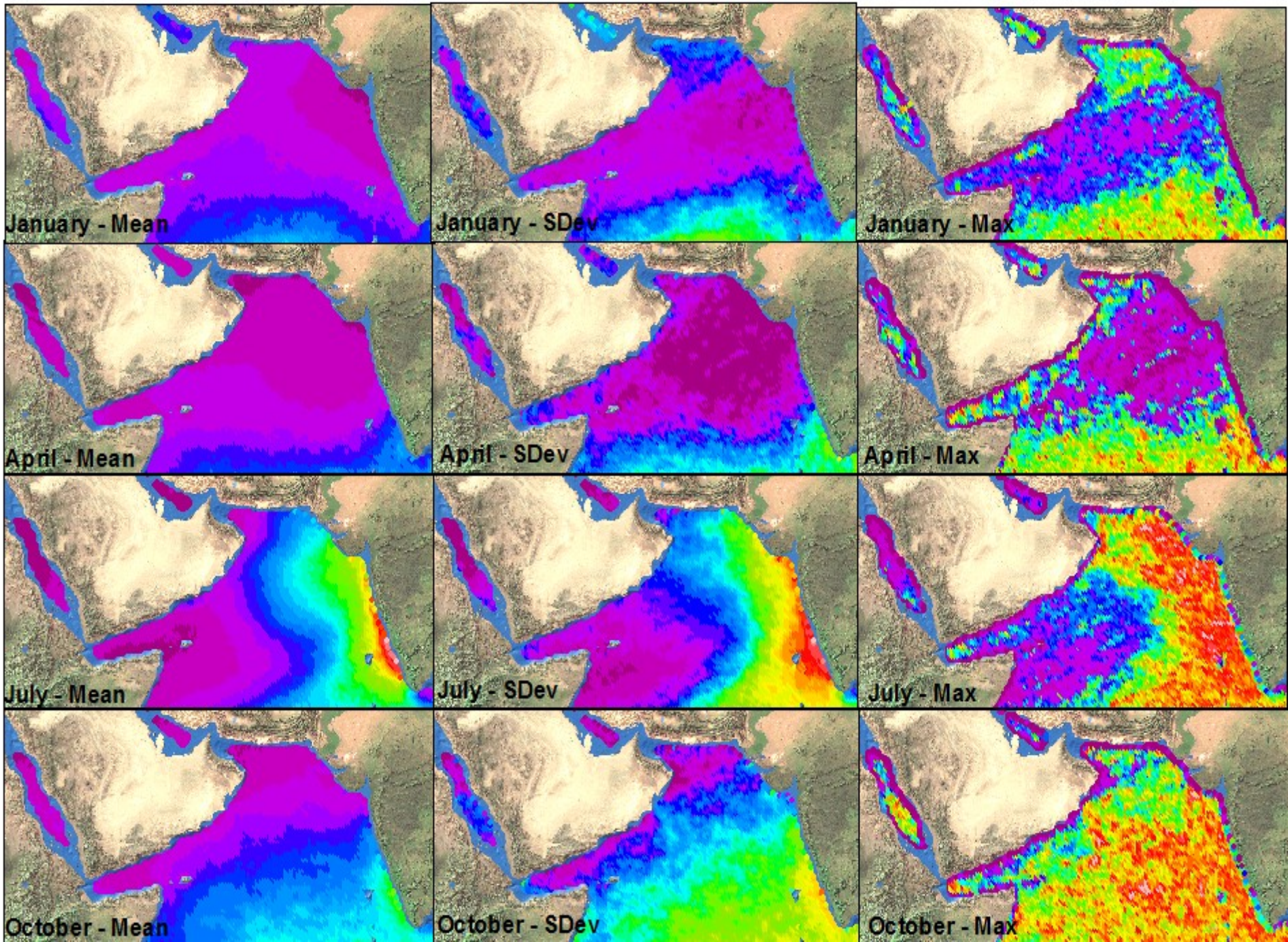
SSMI Mean Precipitation Rate



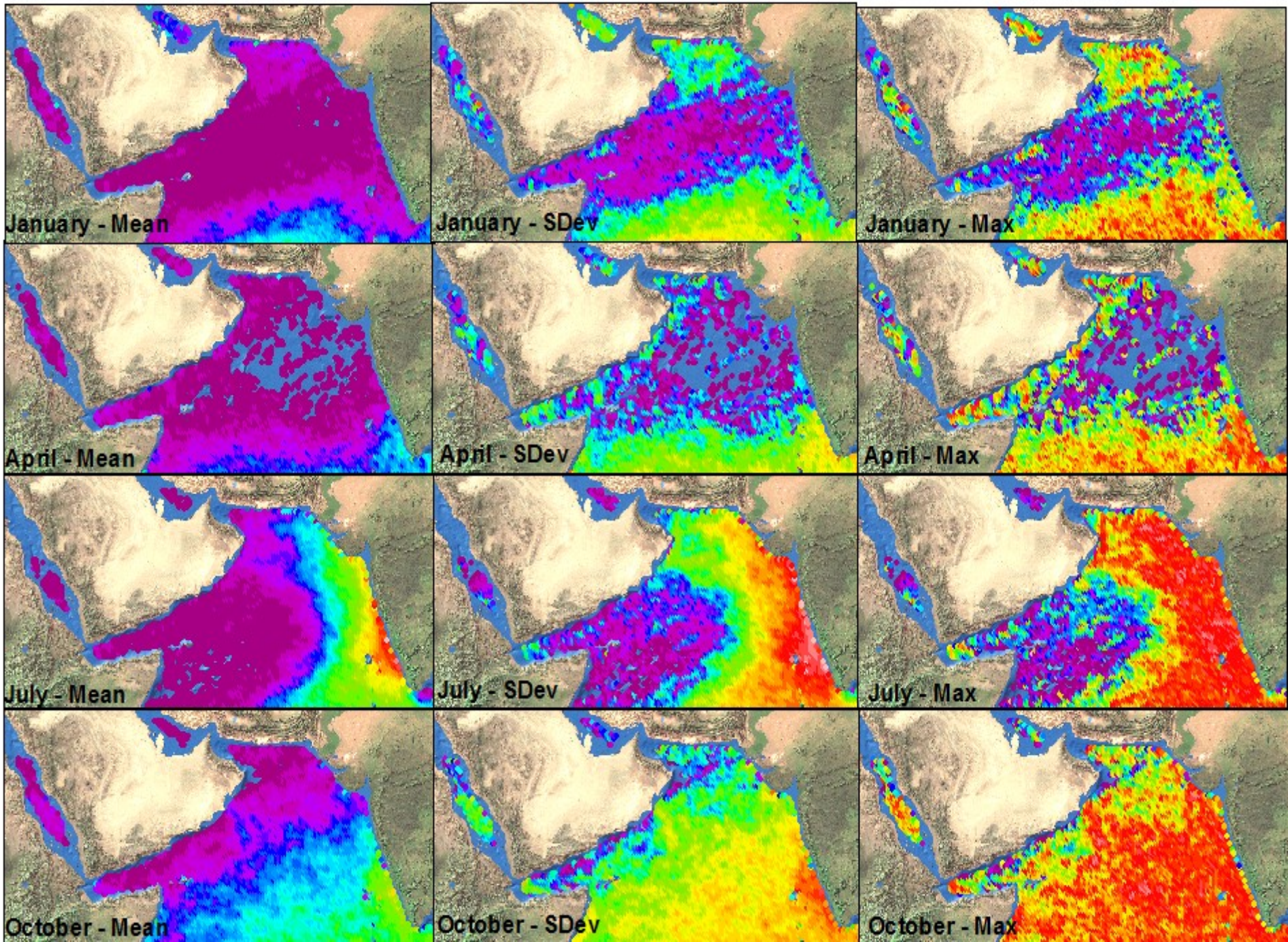
Atmospheric Water Vapour



Cloud Liquid Water



Precipitation Rate



What is GPCP?

The Global Precipitation Climatology Project (GPCP) is an element of the Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programme (WCRP). It was established by the WCRP in 1986 with the initial goal of providing monthly mean precipitation data on a 2.5°×2.5°latitude -longitude grid. Monthly mean precipitation estimates are being produced beginning in 1979 and planned to go through 2005.....

more about this.....

The GPCP Quarterly/Semi-Annual Reports

The GPCP citation list

How to access the data?

These data are available from the WDCA.

How is the GPCP organized?

The GPCP is organized as follows.

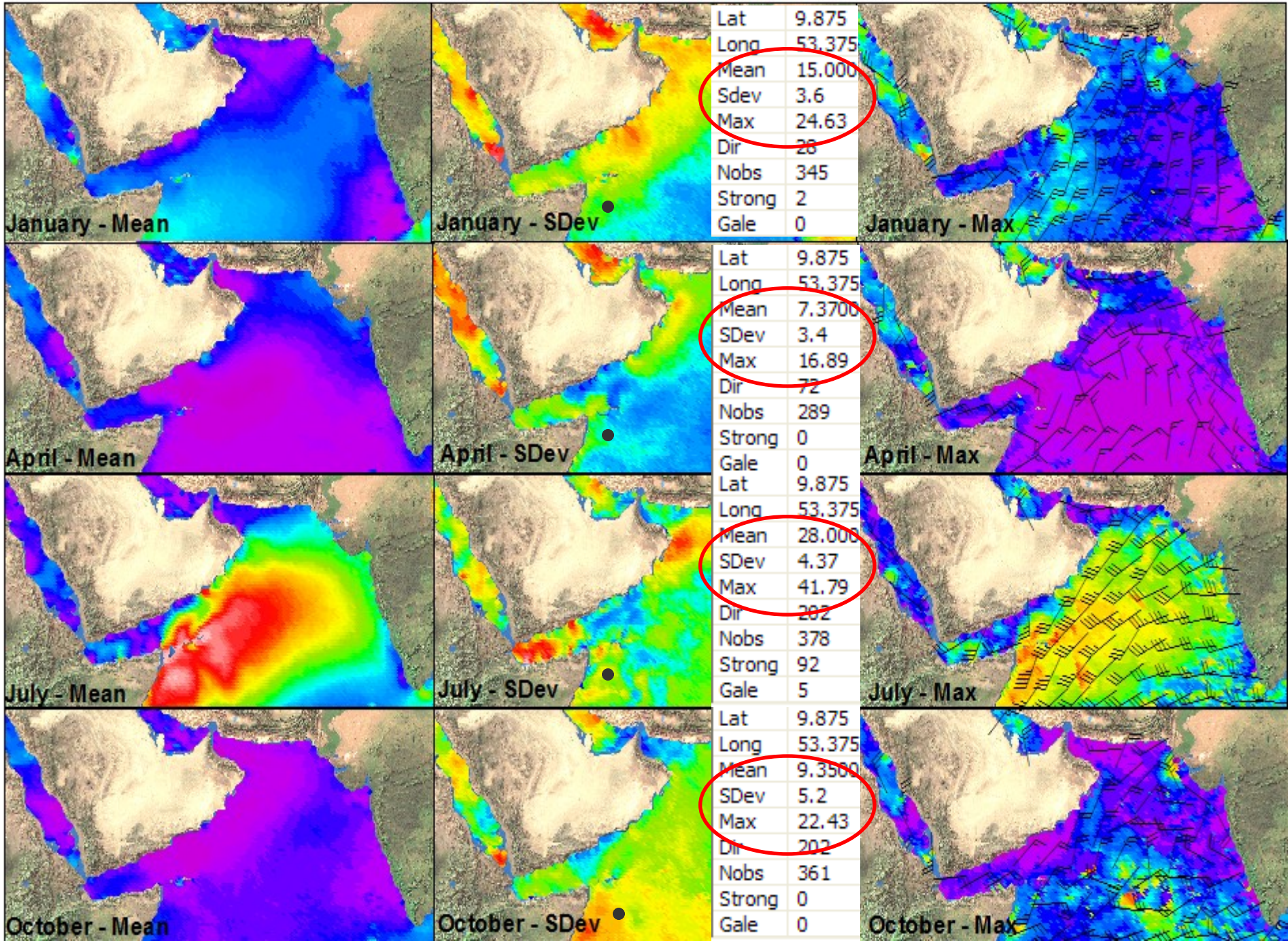
- IR Component
- Microwave Component
- In Situ Component
- Merge satellite and Gauge Data

ANNOUNCEMENT

NEW!
Aug 23, 2006

Assessment of Global Precipitation
The Assessment of Global Precipitation is completed!
more.....

Quikscat Wind Speed



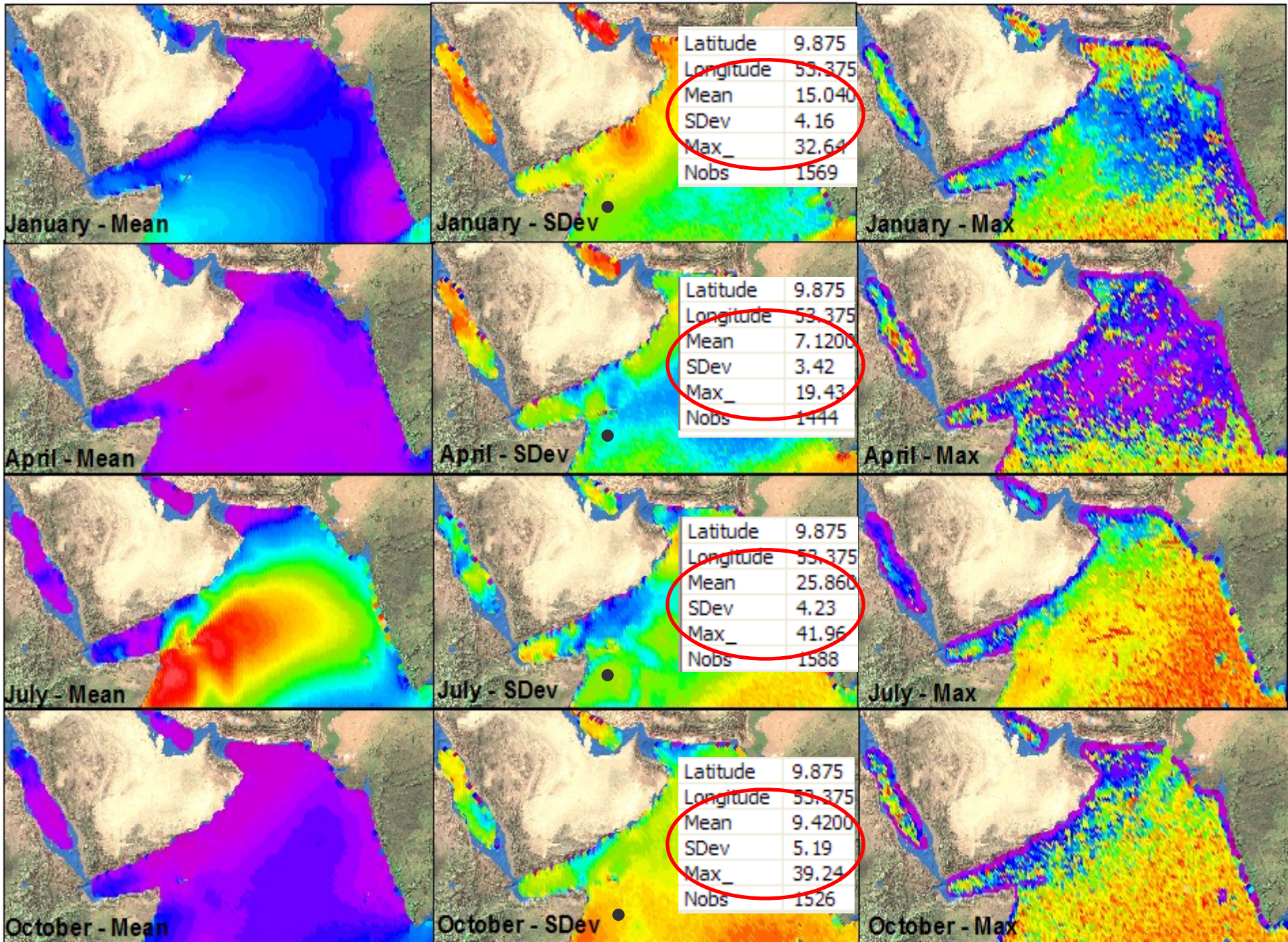
Lat	9.875
Long	53.375
Mean	15.000
Sdev	3.6
Max	24.63
Dir	28
Nobs	345
Strong	2
Gale	0

Lat	9.875
Long	53.375
Mean	7.3700
SDev	3.4
Max	16.89
Dir	72
Nobs	289
Strong	0
Gale	0

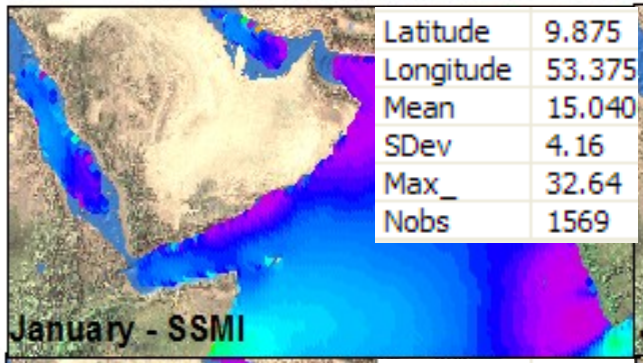
Lat	9.875
Long	53.375
Mean	28.000
SDev	4.37
Max	41.79
Dir	202
Nobs	378
Strong	92
Gale	5

Lat	9.875
Long	53.375
Mean	9.3500
SDev	5.2
Max	22.43
Dir	202
Nobs	361
Strong	0
Gale	0

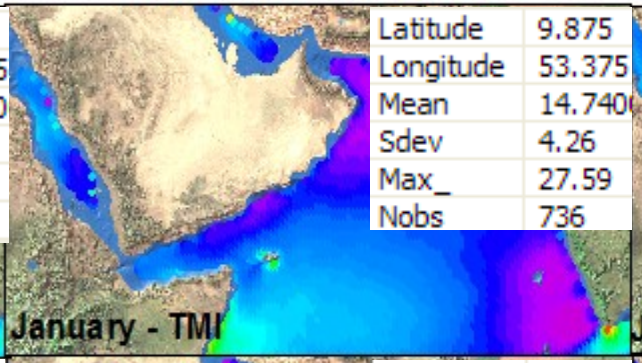
SSM/I Wind Speed



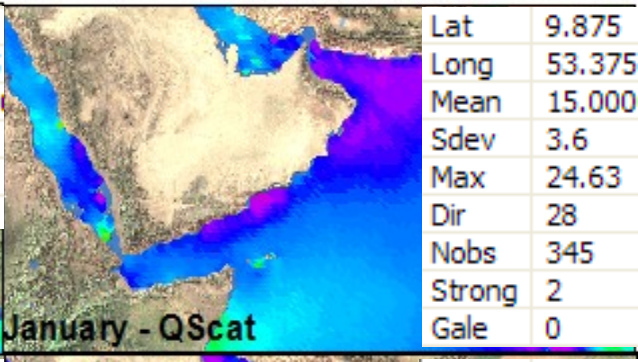
Mean Wind Speed



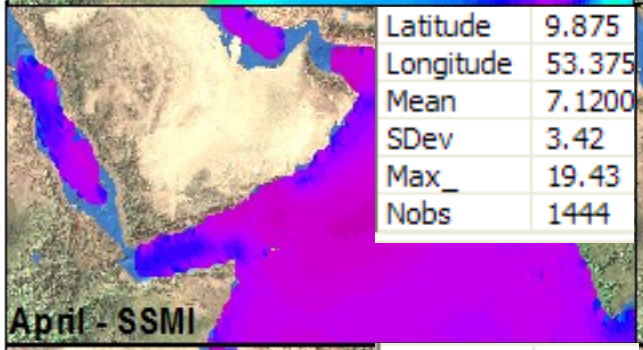
Latitude	9.875
Longitude	53.375
Mean	15.040
SDev	4.16
Max_	32.64
Nobs	1569



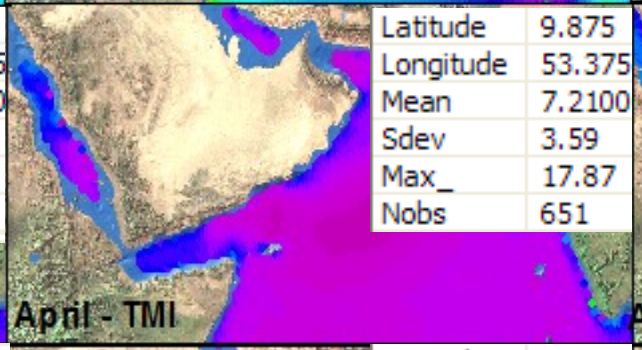
Latitude	9.875
Longitude	53.375
Mean	14.740
Sdev	4.26
Max_	27.59
Nobs	736



Lat	9.875
Long	53.375
Mean	15.000
Sdev	3.6
Max	24.63
Dir	28
Nobs	345
Strong	2
Gale	0



Latitude	9.875
Longitude	53.375
Mean	7.1200
SDev	3.42
Max_	19.43
Nobs	1444



Latitude	9.875
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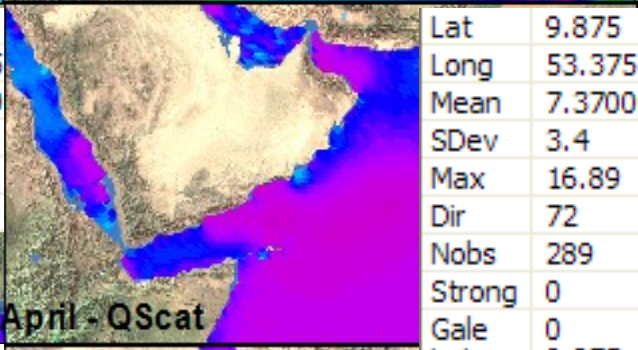
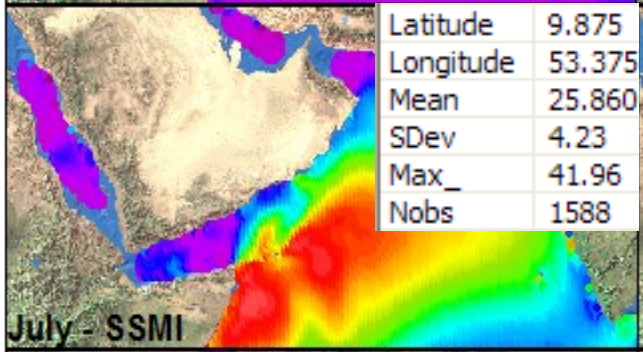
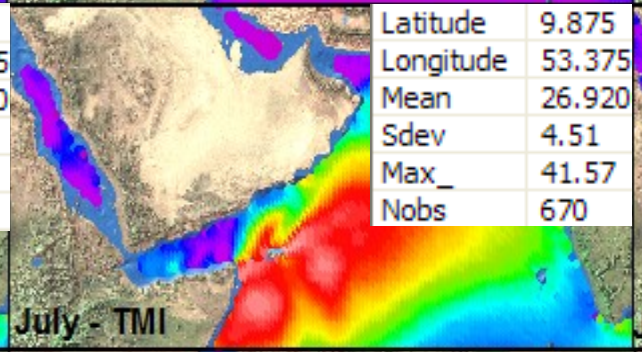
Mean	7.2100
Sdev	3.59
Max_	17.87
Nobs	651



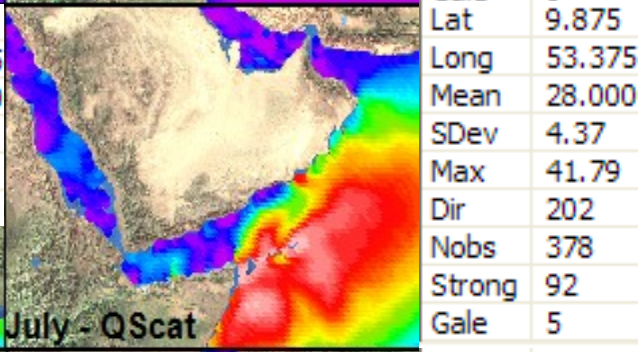
Lat	9.875
Long	53.375
Mean	7.3700
SDev	3.4
Max	16.89
Dir	72
Nobs	289
Strong	0
Gale	0



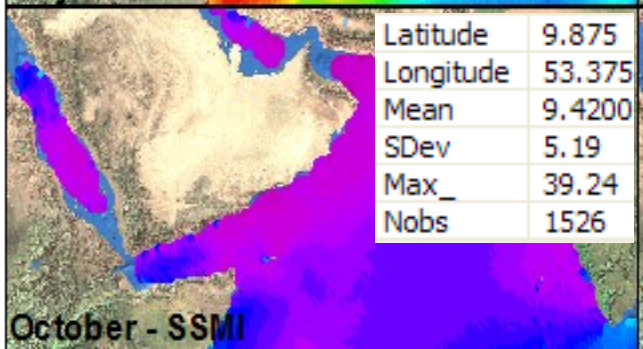
Latitude	9.875
Longitude	53.375
Mean	25.860
SDev	4.23
Max_	41.96
Nobs	1588



Latitude	9.875
Longitude	53.375
Mean	26.920
Sdev	4.51
Max_	41.57
Nobs	670



Lat	9.875
Long	53.375
Mean	28.000
SDev	4.37
Max	41.79
Dir	202
Nobs	378
Strong	92
Gale	5



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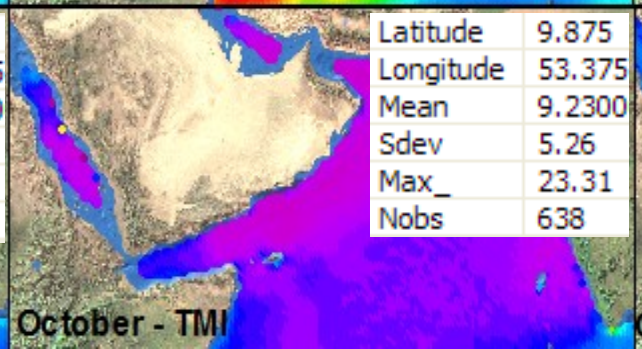
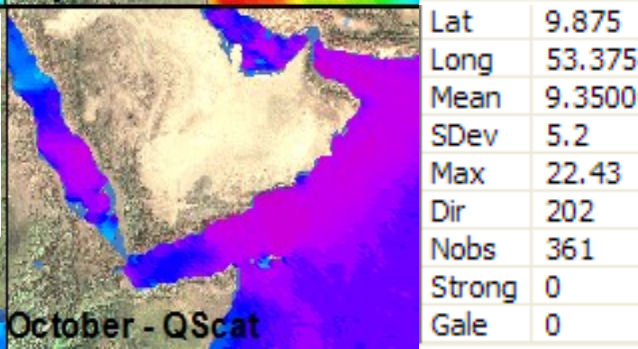
SDev	5.19
Max_	39.24
Nobs	1526



Latitude	9.875
Longitude	53.375
Mean	9.2300
Sdev	5.26
Max_	23.31
Nobs	638



Lat	9.875
Long	53.375
Mean	9.3500
SDev	5.2
Max	22.43
Dir	202
Nobs	361
Strong	0
Gale	0

Blended Sea Winds

Summary

The Blended Sea Winds contain globally gridded, high resolution ocean surface vector winds and wind stresses on a global 0.25° grid, and multiple time resolutions of 6-hourly, daily, monthly, and 11-year (1995-2005) climatological monthlies. The period of record is 9 July 1987 - present. The wind speeds were generated by blending observations from multiple satellites (up to six satellites since June 2002; Figure 2). The wind directions came from two sources depending on the products: for the research products the source is the NCEP Reanalysis 2 (NRA-2) and for near-real-time products the source is the ECMWF NWP. The wind directions were interpolated onto the blended speed grids.

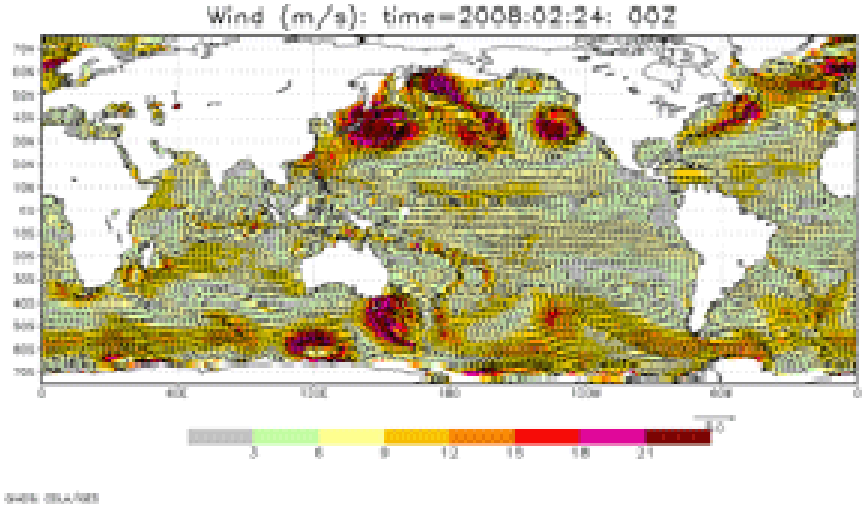
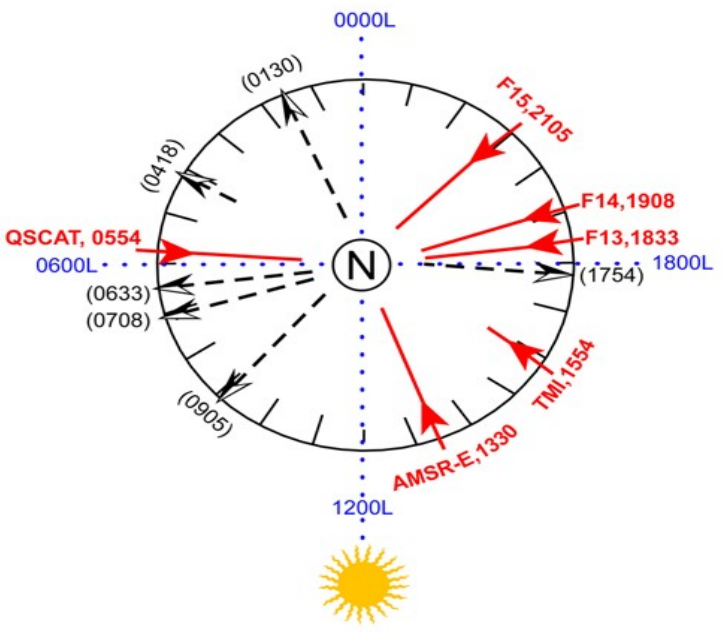


Figure 1 - Click on image to see latest animation (3mb)
Please read disclaimer for the near-real-time products

Blended SeaWinds

- NCDC Project
  - Sensors: SSM/I F13, F14, F15; AMSR-E; TMI; Quikscat
  - 21 year, 6 hourly, 0.25º dataset (6 satellites since 2002)
  - http://www.ncdc.noaa.gov/oa/rsad/seawinds.html
  - Local diurnal variability?



Other Satellite Climatology Resources

- GHRSST
- ISCCP
- Sea Ice
- Ocean Colour

GHRSST-PP

GODAE High Resolution Sea Surface Temperature Pilot Project

- Home
- Latest SST map
- What is GHRSST PP?
- Site Map
- Data Access
- Applications
- Data Products
- Product Validation
- Science Team & Groups
- GHRSST articles
- Operational Announcements
- Contact us
- GHRSST-PP Metrics Dashboard
- What's New
- Calendar
- Documents

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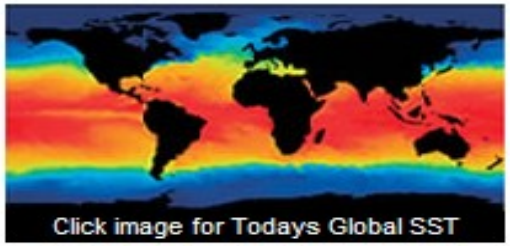
Integrated SST Data Products.

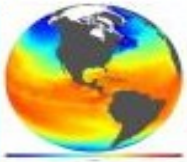
The Global High-Resolution Sea Surface Temperature (SST) Pilot Project (GHRSST-PP) provides a new generation of global high-resolution (<10km) SST products to the operational oceanographic, meteorological, climate and general scientific community.

Every day, GHRSST-PP global processing systems combine several complementary satellite and in situ SST data streams together and deliver integrated SST products with supporting data in a common netCDF format.

More>


Click image for Todays Global SST

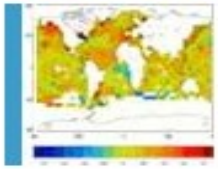
Data Access



GHRSST PP data products are freely available in real time every day through various delivery services

more >

Applications



A variety of applications are now using GHRSST-PP products and services

more >

Documents

Project reference documents provide a detailed description of the plans and activities

Calendar

Meetings, workshops and key dates for the GHRSST-PP Regional/Global

What's New RSS

► Added: 21-04-2008
GMPE median ensemble includes Canadian Met. Service 1–3degree SST...
Read More

► Added: 16-04-2008
JPL GDAC filling L2P files with ancillary data
Read More

► Added: 10-04-2008
NAVOCEANO 10km Analysis now available in L4 netcdf
Read More

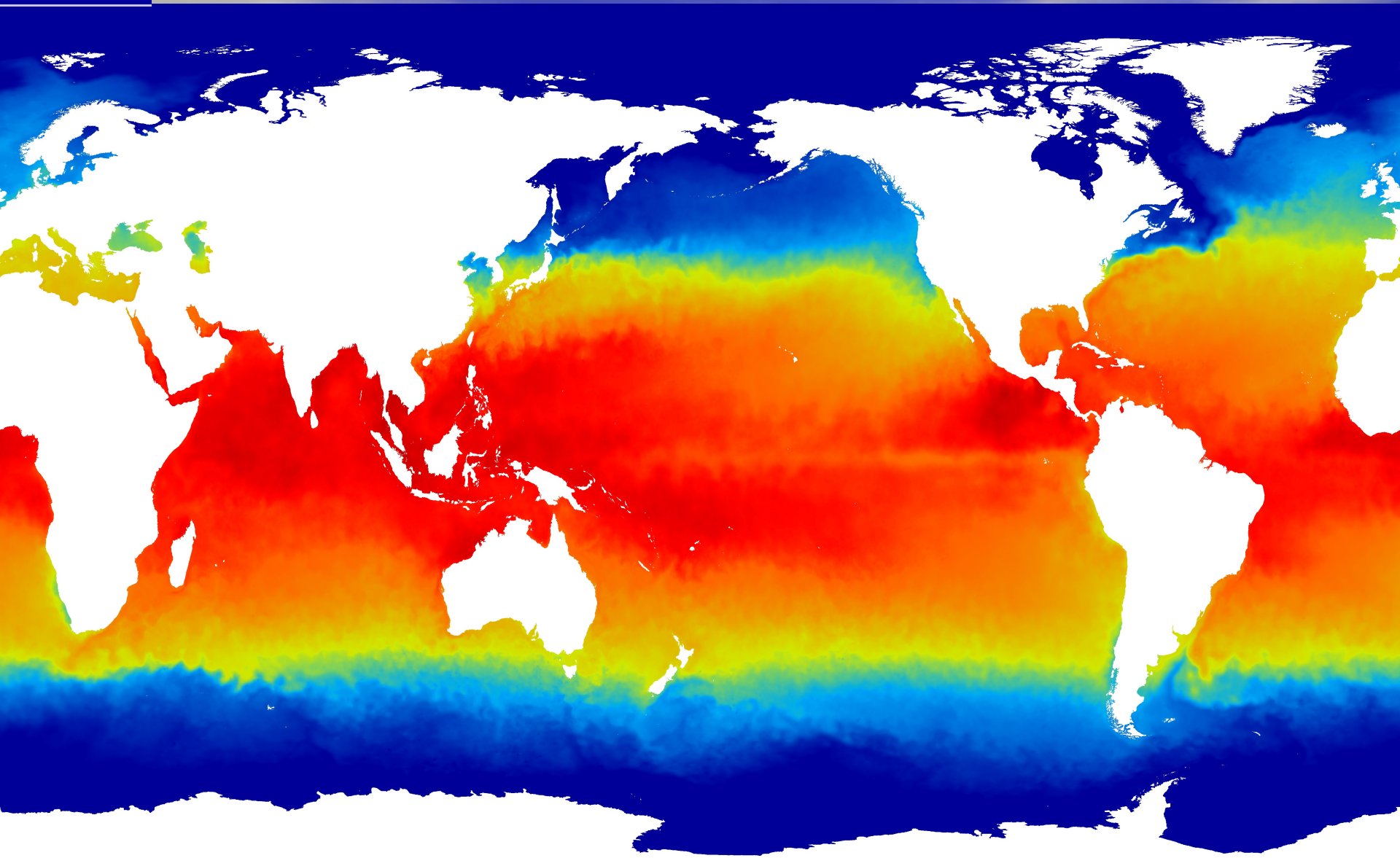
► Added: 02-04-2008
GHRSST–PP–IX ST Meeting Registration open
Read More

► Added: 19-03-2008
GHRSST–PP datacasting now up and running!
Read More

GHRSST-PP

- Multi-sensor, multi-platform foundation SST
- Geostationary and sun-synchronous platforms
- Microwave and thermal imaging sensors
- Near real-time swath (L2P) products
- Re-mapped (L3) products
- Optimally interpolated gridded regional and global (L4) analyses to 5 km and 6 hourly resolution
- Best copy re-analysis datasets for climate studies

OSTIA L4 Global SST Analysis – 04 May 2008



PROJECT DESCRIPTION
Participants & Status

CLOUD DATA
Maps & Plots
Available On-Line

OTHER RELATED DATA
Maps & Plots
Available On-Line

DATA ANALYSIS
To Understand Climate

WHAT'S NEW

DATA PRODUCT
DOCUMENTATION
& Software Available
On-Line

RELATED PROJECTS
Web Sites & Data Centers

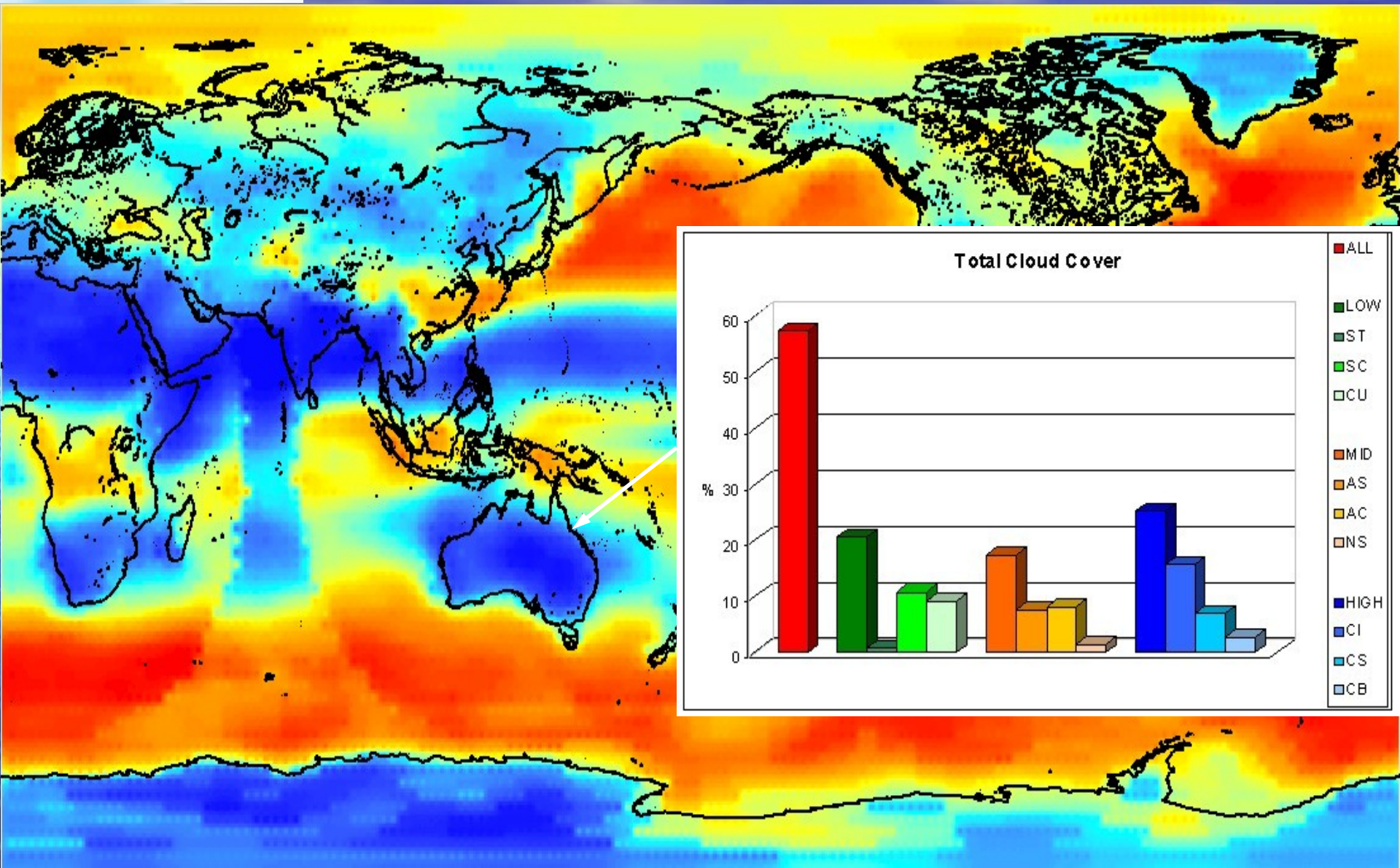
FURTHER INFORMATION

ISCCP ANALYSIS
SOFTWARE

ISCCP

- 8 km, 3 hourly geostationary satellite brightness temperature in all channels
- Covers 28 satellites since 1978
- Cloud type determined by reflectance and temperature from pairs of IR and VIS/NIR images

ISCCP Cloud Climatology



National Snow and Ice Data Center

Distributed Active Archive Center

The NSIDC DAAC archives and distributes brightness temperature data, polar atmosphere data, satellite imagery, sea ice data, snow cover data, and ice sheet data.

Visible Infrared: NSIDC distributes visible and infrared data from the TIROS Operational Vertical Sounder (TOVS) suite of instruments, the MODIS instruments, and the AVHRR instrument.

LIDAR: NSIDC distributes laser data from the GLAS instrument.

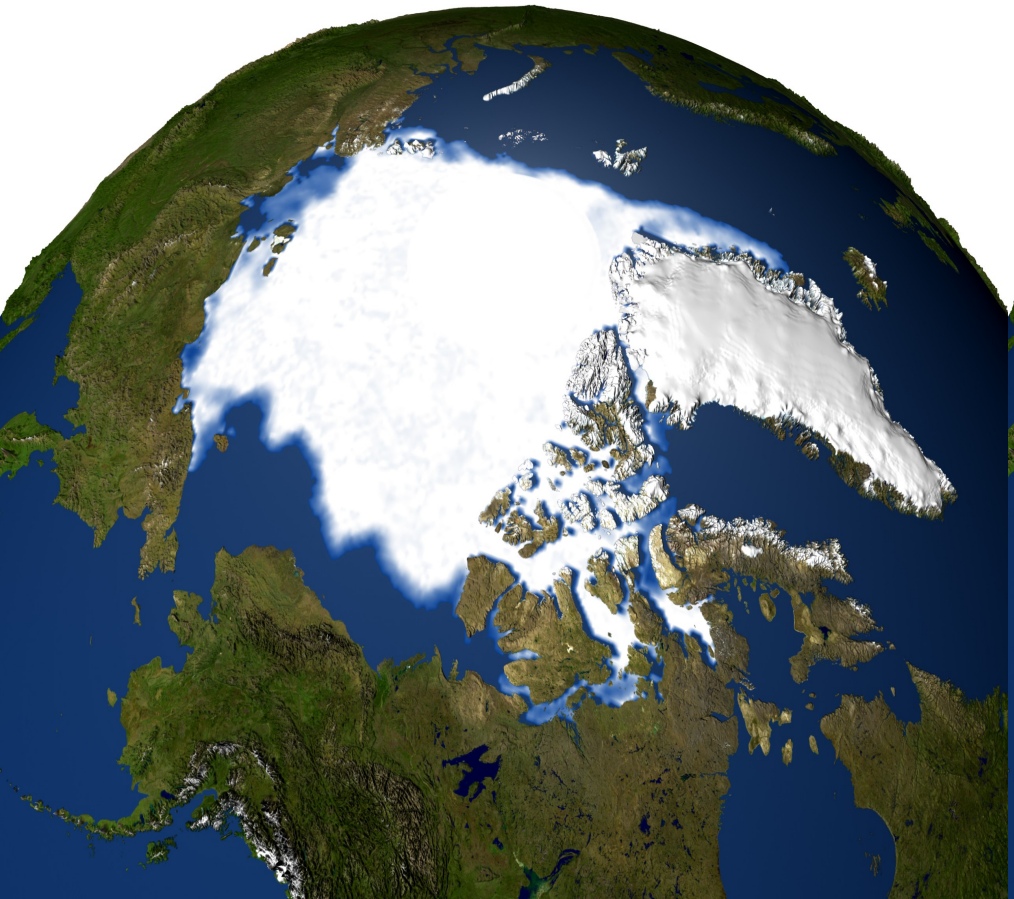
Passive Microwave: NSIDC distributes passive microwave data from the AMSR-E instrument, the AMSR instrument, the SSMR instrument, and the SSM/I instrument.

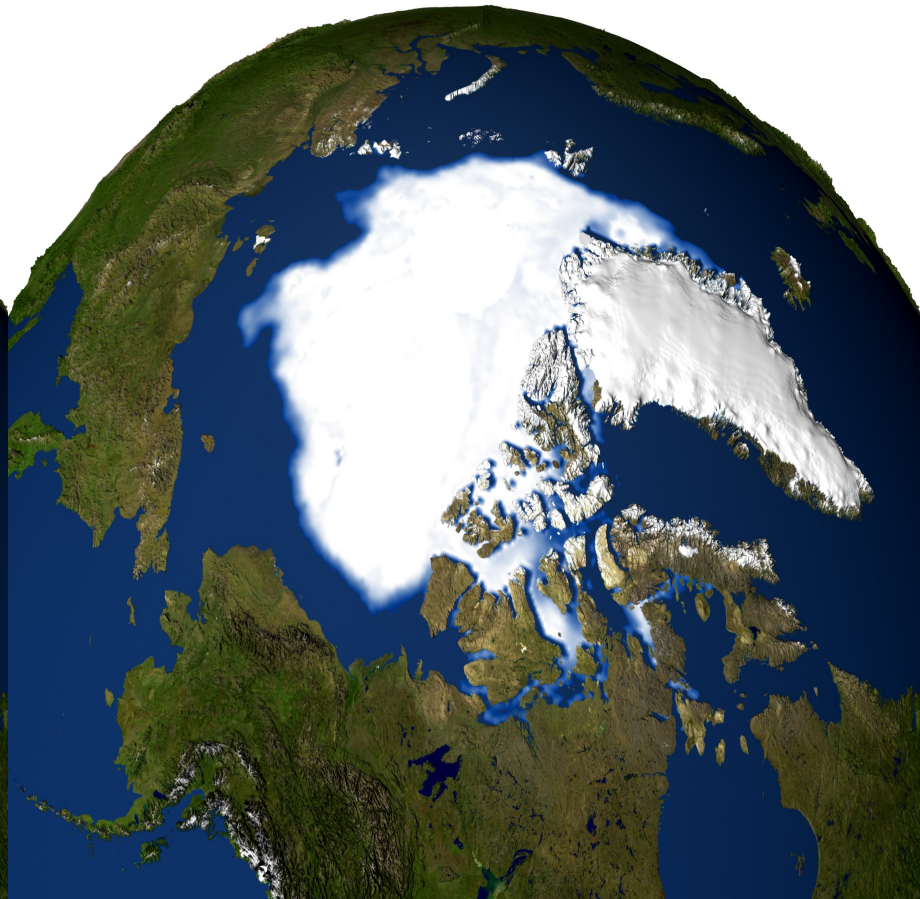
Active Microwave: NSIDC distributes active microwave data from the RADARSAT instrument, scatterometer instruments, and radar altimeters.

NSIDC Minimum Arctic Sea Ice Extent

NScat - 1979

Quikscat - 2005

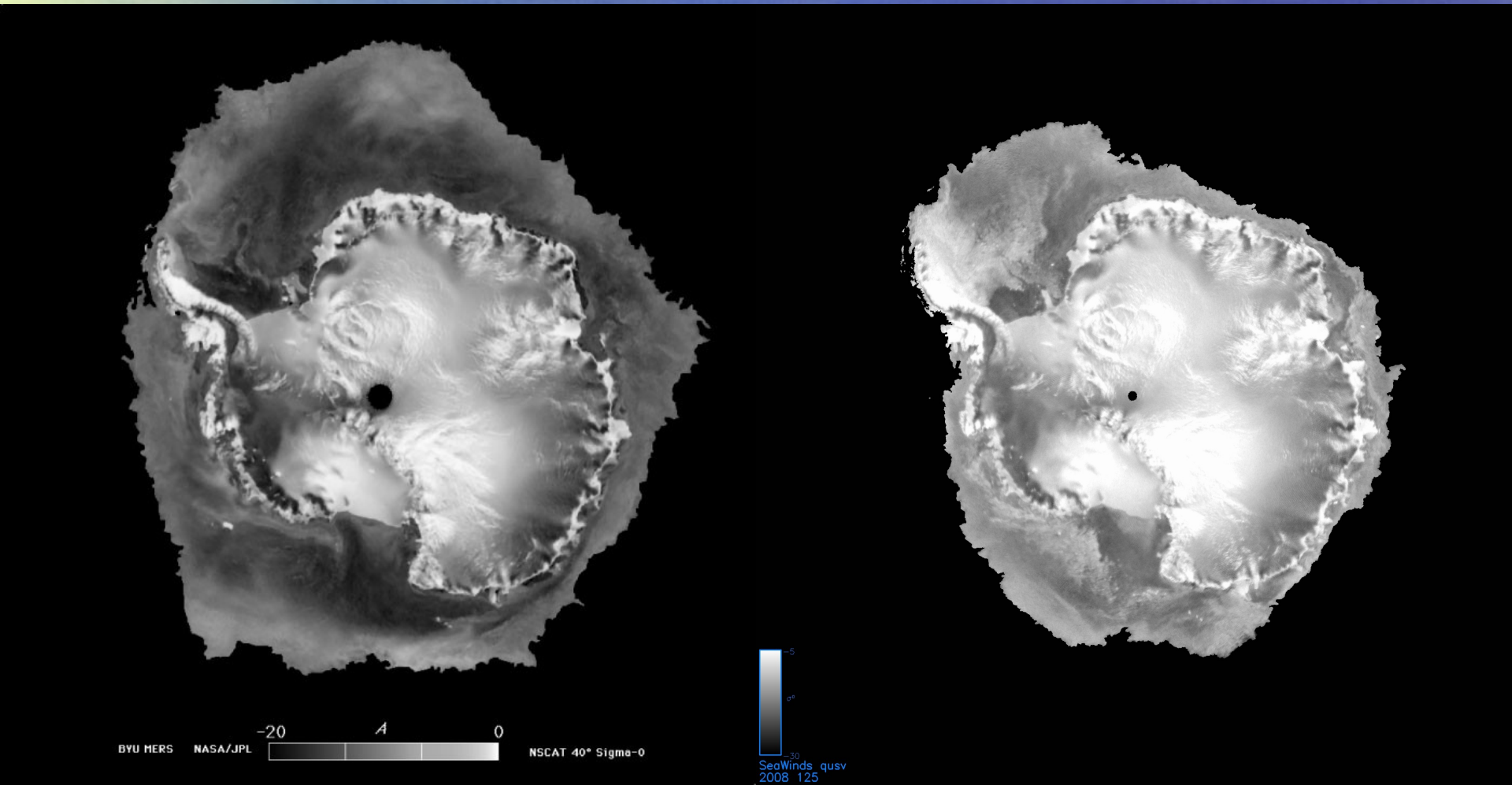




Antarctic Sea Ice Extent (Quikscat)

Jul 99

May 08



Ocean Color Time-Series Online Visualization and Analysis

Welcome to the Ocean Color Time-Series Online Visualization and Analysis System! This system is based on the GES-DISC Interactive Online Visualization and ANalysis Infrastructure (Giovanni) which was developed by the GES DISC DAAC to provide users with an easy-to-use, Web-based interface for the visualization and analysis of the Earth Science data.

The Ocean Color Time-Series Project (REASoN CAN, Dr. Watson Gregg, PI) currently employs Giovanni for the visualization and analysis of SeaWiFS ocean color data, and MODIS Aqua ocean-color and SST data processed by the Ocean Biology Processing Group (OBPG). In the future, merged (multiple mission) data products will be added.

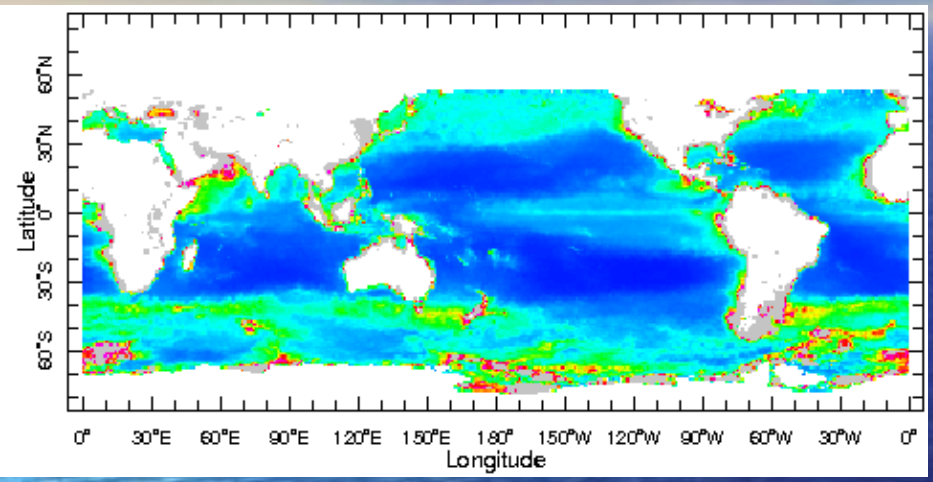
Ocean Color Time-Series Online Visualization and Analysis

Product Description	Java Link	Non-Java Link
OBPG MODIS-Aqua Monthly Global 9-km Products	JAVA Version	Non JAVA Version
OBPG SeaWiFS Monthly Global 9-km Products	JAVA Version	Non JAVA Version
OBPG SeaWiFS 8-Day Global 9-km Products	JAVA Version	Non JAVA Version
GSM Merged Monthly Global 9-km Products	JAVA Version	Non JAVA Version
GSM SeaWiFS Optical Monthly Global 9-km Products	JAVA Version	Non JAVA Version
GSM Modis-Aqua Optical Monthly Global 9-km Products	JAVA Version	Non JAVA Version
NOBM Assimilated Monthly Global Products	JAVA Version	Non JAVA Version
NOBM Assimilated Daily Global Products	JAVA Version	Non JAVA Version

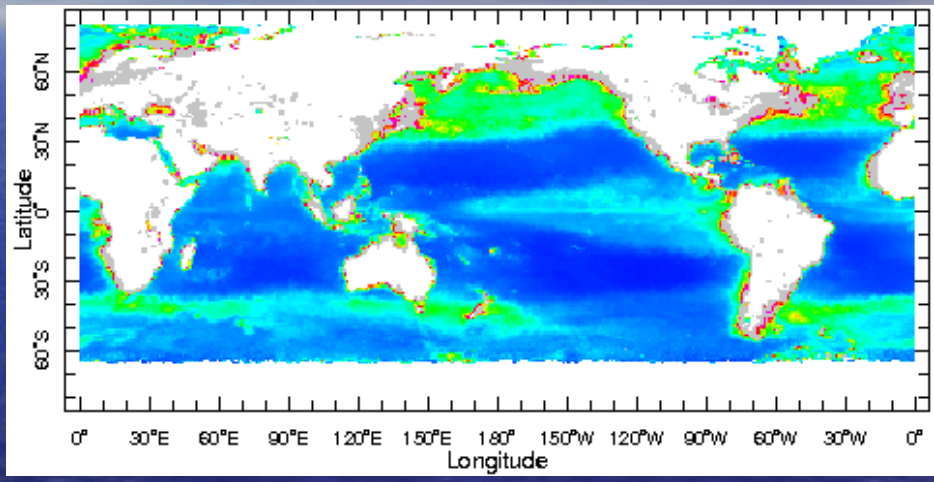
The International Research Institute for Climate and Society

Mean Chrorophyll 2003 – 2006 (MODIS and SEAWIFS)

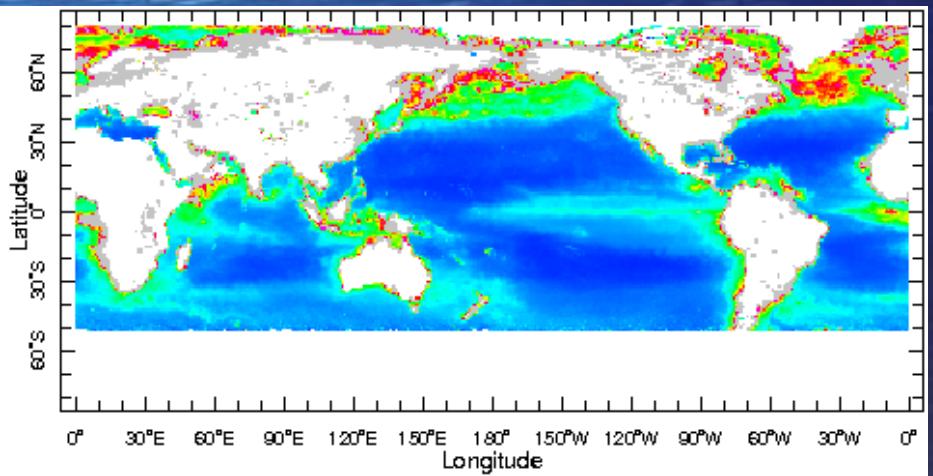
January



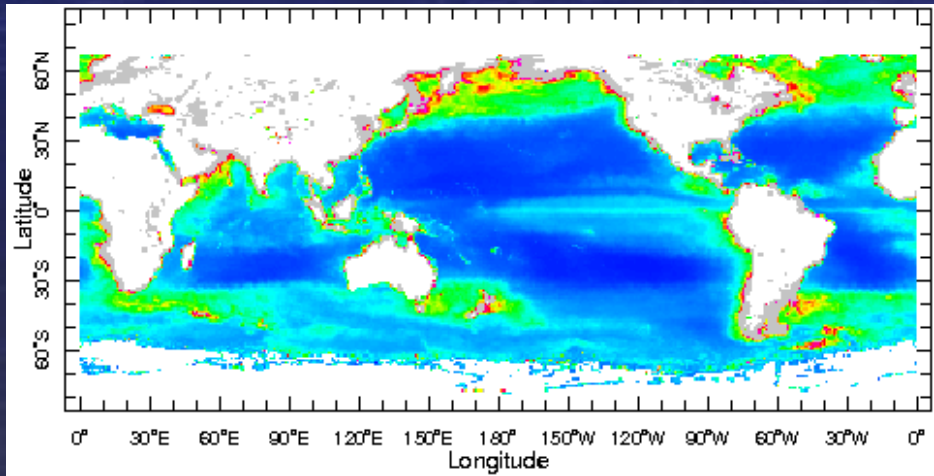
April



July



October



Summary

- Satellite sensors provide a massive volume of quality data that can be used to develop climatologies of some variables also measured by in-situ observations.
- These data are already in the public domain (USA) or available to researchers (Europe)
- We cannot ignore them, but
- Which is the right JCOMM group to exploit them?
- What products should be developed?

Questions