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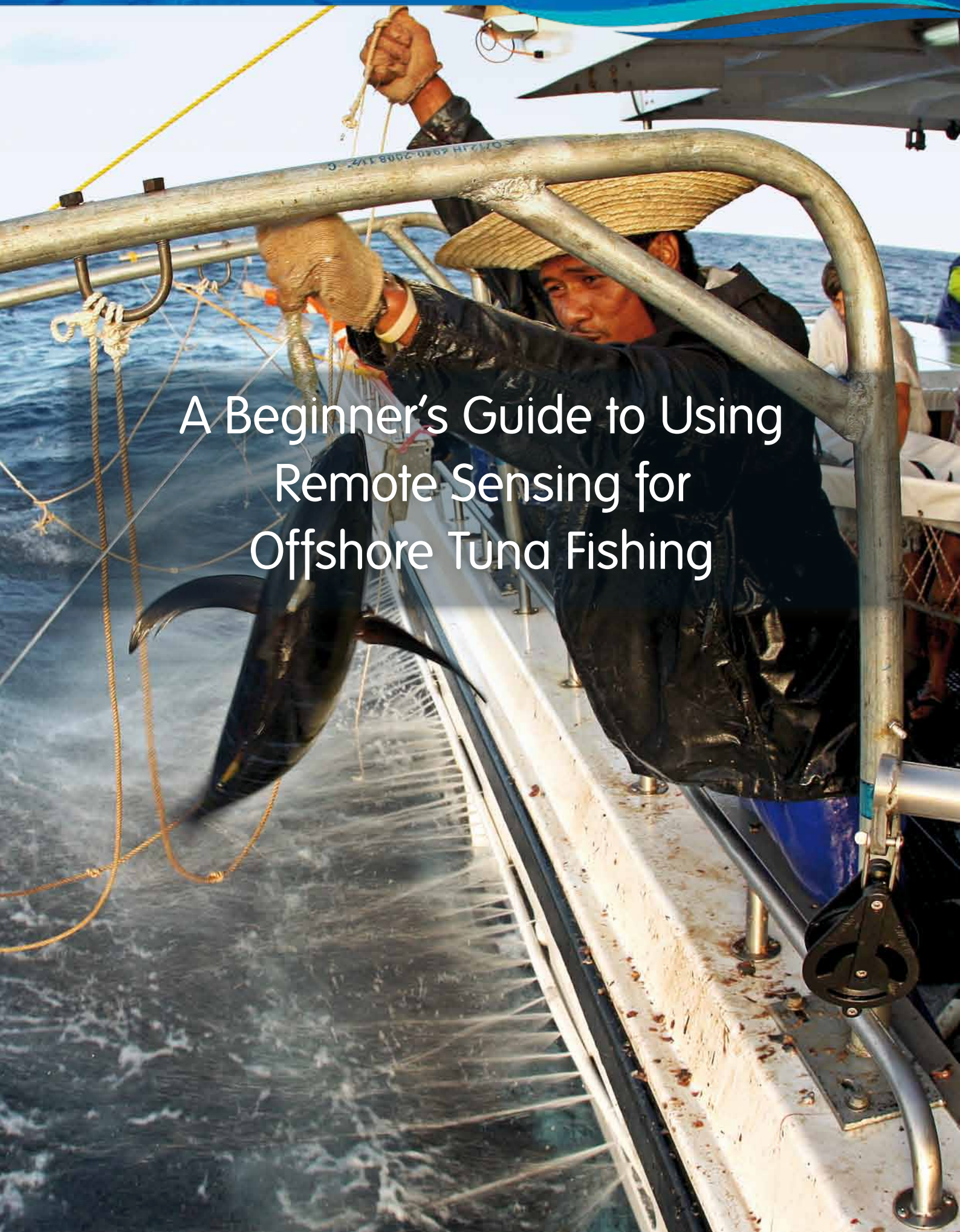

A Beginner's Guide to Using Remote Sensing for Offshore Tuna Fishing

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Produced by the
Secretariat of the Pacific Community Nearshore Fisheries Development Section

SPC
Secretariat
of the Pacific
Community

Secretariat of the Pacific Community
Noumea, New Caledonia, 2011

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A beginner's guide to using remote sensing for offshore tuna fishing / produced by the Secretariat of the Pacific Community Nearshore Fisheries Development Section

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What is remote sensing?

Remote sensing is a way of acquiring information about the surface of the earth without actually being in contact with it. Remote sensing is done by receiving and recording energy that is either emitted or reflected by the surface of the earth, so there must be a source of electromagnetic energy, a target, and a sensor. The source can be the sun or a satellite, depending on the type of energy being monitored. The target, in the case of remote sensing that may be useful to fishermen, is the sea surface.

Passive remote sensing depends on natural energy such as sunlight that is reflected off the surface of the earth or heat that is emitted from the surface of the earth. Active remote sensing uses energy emitted by satellites and reflected back to the satellites from the surface of the earth.

Sensors are usually installed on satellites (Figure 1) but can also be installed on airplanes. As energy passes through the atmosphere from the sun or a satellite it interacts with the atmosphere. It can be scattered or absorbed. This can happen twice if the energy travels from its source to the surface and then to a sensor on a satellite. The energy can also be affected by the target: it can be absorbed, reflected, or it can pass through the target. All of these things — scattering, absorption and reflection — can affect the quality of remote sensing data. After the sensor receives the energy, it is transmitted to a receiving and processing station where it is converted into digital data which are then converted into images (charts) using computer models. Finally, the images are interpreted to extract information about the target.

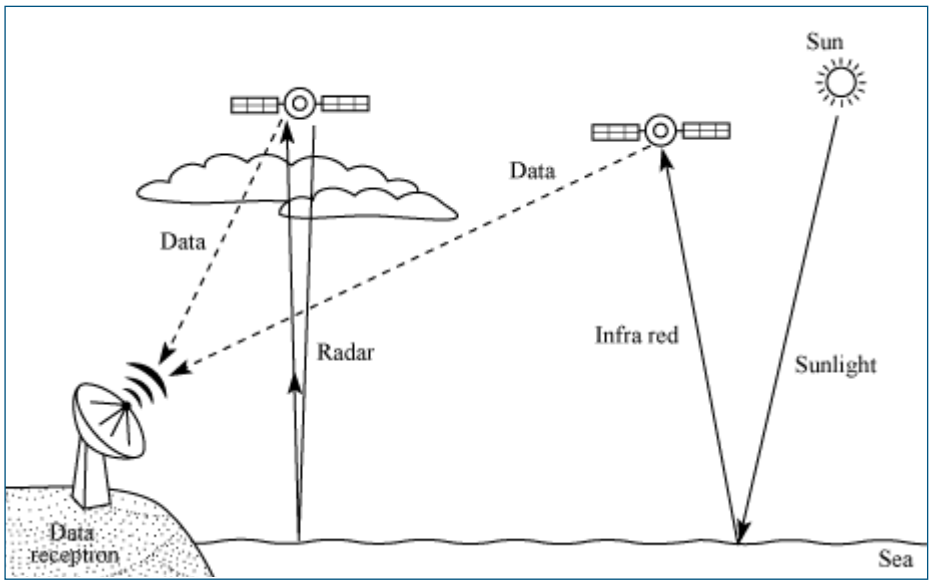


Figure 1. Remote sensing using satellites: active sensing on the left (radar) and passive sensing on the right (infra-red)

Reflected or emitted electromagnetic energy in the form of light waves or microwaves is the usual type of energy monitored by remote sensing for oceanographic purposes. There are three types of light in the electromagnetic spectrum: ultraviolet, visible and infra-red. All three can be used in remote sensing. Light is characterised as having shorter wave lengths and higher frequencies than microwave energy, another type of electromagnetic energy. Because of these properties, light does not penetrate heavy cloud cover, so remote sensing data from light sources are often incomplete. Also, when visible light is used in remote sensing, data from this energy source are limited to daylight hours. Infra-red light that is emitted from the surface, on the other hand, can be monitored day or night.

Microwaves are characterised as having longer wave lengths and lower frequencies than light waves. Because of these properties, microwave energy such as that emitted by radar[1] can penetrate heavy cloud cover, so data from this energy source are more complete, and radar can be used day or night.

Visible light is used to remotely sense sea surface colour, infra-red light is used to remotely sense sea surface temperature (SST), and radar is used to remotely sense sea surface height (SSH). All three of these phenomena — colour, temperature and sea surface height — can be used by oceanographers and fishermen to identify areas of potential productivity or areas where fish may be concentrated in the sea.

Ocean charts showing sea surface colour, sea surface temperature, sea surface height, currents and weather are available from a variety of sources on the Internet — some are by subscription and the user pays, while others are free to anyone with a computer and an internet connection. The user-pays websites are proprietary. In other words, either the data or the software that models the data are owned by a private company. The free websites are usually government owned so the data are in the public domain. The subscription websites and the free websites often use data from the same satellites. The advantage of the subscription sites is that the data are sometimes fresher — closer to real-time — and charts derived from the data are interpreted, either by software or by fisheries oceanographers, to show fishing areas that are likely to be good. The advantage of free websites, of course, is that they are free. However, it is up to the user to interpret the charts and choose good fishing spots. Below are some examples of pay per view, or subscription remote sensing websites, and some free remote sensing websites:

Pay per view websites[2]

- CATSAT: http://www.catsat.com/
- GeoEye: http://www.geoeye.com/CorpSite/products/solutions/seastar/
- Ocean Imaging: http://www.seaviewfishing.com/commercial/commercial.html
- OCENS.com: http://www.ocens.com/index.htm (Iridium phones)

Free websites

- NLOM 32 Degree Page: http://www7320.nrlssc.navy.mil/global_nlom32/pacific.html
- OceanWatch: http://oceanwatch.pifsc.noaa.gov/
- Oscar current plotter: http://www.oscar.noaa.gov/datadisplay/latlon-nj.htm

1 *Radar stands for RAdio Detection And Ranging*

2 *SPC does not endorse any commercial websites*

Remote sensing data from infra-red light to monitor SST are often incomplete because of cloud cover. Some SST charts will have blanked out areas where there are no data. Other charts will fill in the blank spaces using computer modeling. The point is that SST charts, while very useful, can be unreliable. SSH charts, on the other hand, are derived from radar which has the ability to penetrate cloud cover. Because of this, SSH charts are considered by some fishermen to be more useful than SST charts. SSH charts often show similar oceanographic features that SST charts show but with more reliable data, and they can be used as a proxy for SST. In Figure 2, for example, the SST chart on the left shows a cool spot (light blue-green colour) in the lower right hand corner that corresponds to a low spot (dark blue) on the SSH chart on the right. This is explained below.

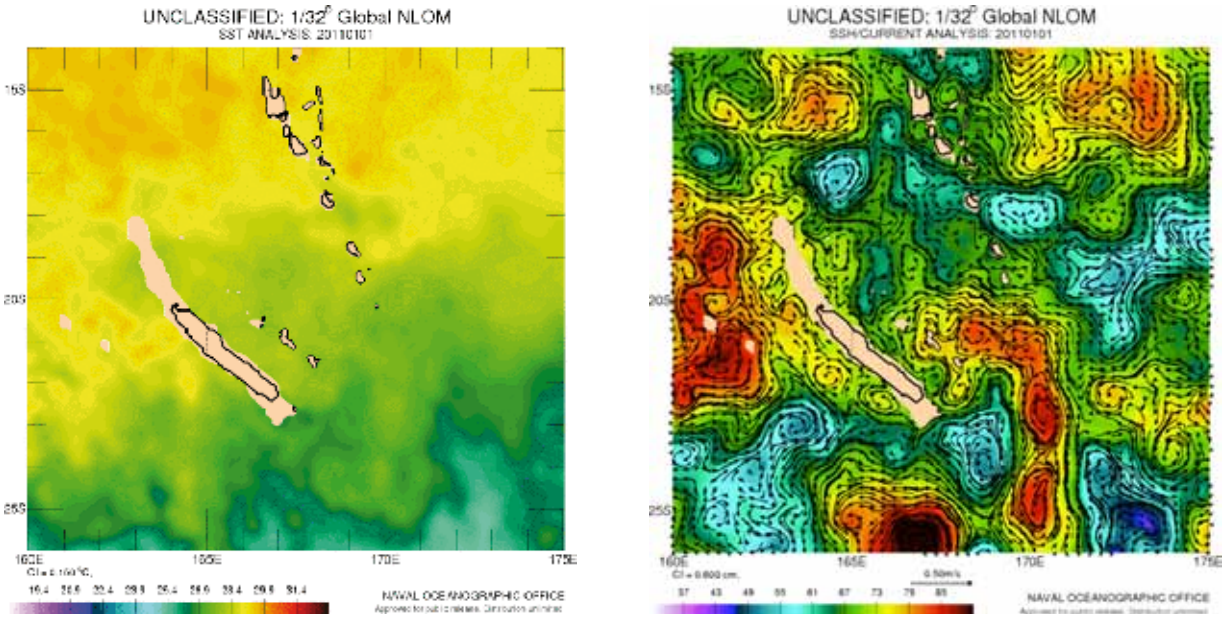


Figure 2. SST (left) and SSH (right) for the same day in New Caledonia[3]

3 *http://www7320.nrlssc.navy.mil/global_nlom32/nou.html*

Sea surface colour

Remotely sensed sea surface colour charts are produced from data acquired by the SeaWiFS[4] satellite (Figure 3). Sea surface colour reveals the abundance or not of chlorophyll-*a* (blue-green pigment), which is an indicator of the presence of phytoplankton. Phytoplankton is the main primary producer in the ocean. Planktonic algae use sunlight and nutrients, along with chlorophyll-*a*, for photosynthesis (food production for growth and reproduction). Most other living organisms in the sea depend on this growth either directly or indirectly for their own growth and reproduction. Large predator fish such as tuna and billfish, however, do not feed on planktonic algae. Large fish feed on small fish and invertebrates > that feed on planktonic animals > that feed on planktonic algae. This is the food chain, and there is a very large lag of time and distance between primary production and the appearance of large predators — sometimes many miles and many months — in the food chain.

The presence of chlorophyll *a* can also be an indicator of the presence of cyanobacteria such as *Trichodesmium*, which does not enter into the food chain in the ocean. Therefore, remote sensing data that show areas of high primary productivity may be of use to fishermen targeting small pelagic species but will be of little use to longline fishermen targeting tuna and billfish. Longline fishermen are more interested in SST and SSH anomalies.

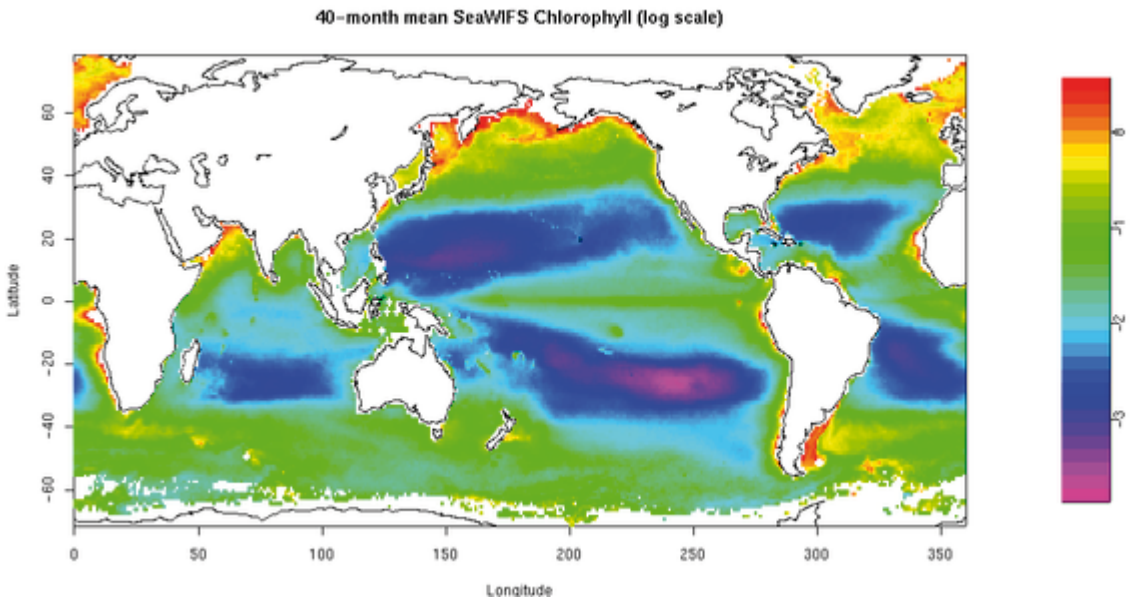


Figure 3. SeaWiFS colour chart showing average chlorophyll *a* in the world's oceans (http://oceancolor.gsfc.nasa.gov/SeaWiFS/)

4 *Sea-viewing Wide Field-of-view Sensor (http://oceancolor.gsfc.nasa.gov/SeaWiFS/)*

Sea surface temperature

SST is monitored by satellites regularly for all the world's oceans and global SST charts are produced for use by oceanographers and fisheries biologists (Figure 4). SST is one of the most important environmental parameters used by longline fishermen to locate good fishing areas. Pelagic fish such as albacore tuna (*Thunnus alulunga*), bigeye tuna (*Thunnus obesus*), skipjack tuna (*Katsuwonus pelamis*), striped marlin (*Tetrapturus audax*), swordfish (*Xiphias gladius*), and yellowfin tuna (*Thunnus albacores*) have preferences for waters with certain temperature ranges (Table 1). This is true for both horizontal and vertical temperature ranges, but longline fishermen are more interested in horizontal, or surface, temperatures when searching for fish. SST can be shown on an SST chart but it can also be inferred by looking at an SSH chart.

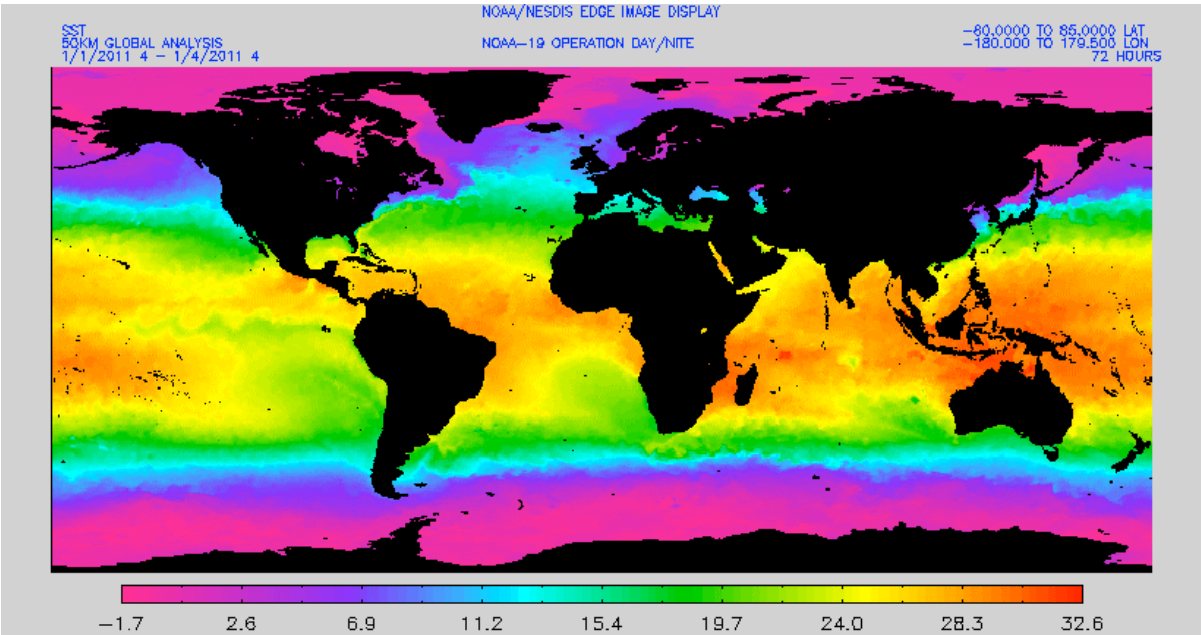


Figure 4. Global SST (°C) for a four-day period in 2011[5]

Table 1. Temperature preferences for some pelagic species

Species	Range of SST preferences °C
Albacore tuna	15 to 20
Bigeye tuna	17 to 22.5
Skipjack tuna	19 to 27
Striped marlin	22 to 24
Swordfish	15 to 23
Yellowfin tuna	21 to 27

5 *http://www.osdpd.noaa.gov/data/sst/fields/FS_km5000.gif*

Frontal zones

The two oceanographic features of the sea surface that are interesting to longline fishermen, and that show up on SST and SSH charts, are frontal zones and eddies. A frontal zone, also called a front or a break, is a rapid gradient in either SST or SSH. In other words, a frontal zone indicates an area where the temperature or sea surface height changes rapidly over a short geographical distance. SST is shown on a chart as lines connecting places with the same temperature. These lines are called isotherms. If the isotherms are far apart on a chart then the temperature gradient is gradual. If the isotherms are close together then the gradient is rapid, indicating the presence of a frontal zone (Figure 5). Frontal zones are interesting to fishermen because baitfish and predator fish often accumulate near them, often on the warm side of the frontal zone. Possibly cold water acts as a barrier, keeping baitfish on the warm side. Predator fish take advantage of this and search for bait on the warm side of a frontal zone. Fishermen can also take advantage of this by fishing on the warm side. The point is that the absolute temperature of the sea surface may not be as important as the presence of a frontal zone. A fisherman could search for water within the preferential range of yellowfin tuna (21°C to 27°C), for example, and not do well. However, if he finds a frontal zone where the SST changes rapidly from 25°C to 27°C over a short distance then he may also find fish. The presence of an SST frontal zone can be an indication of an abundance of both pelagic forage species and pelagic predator species.

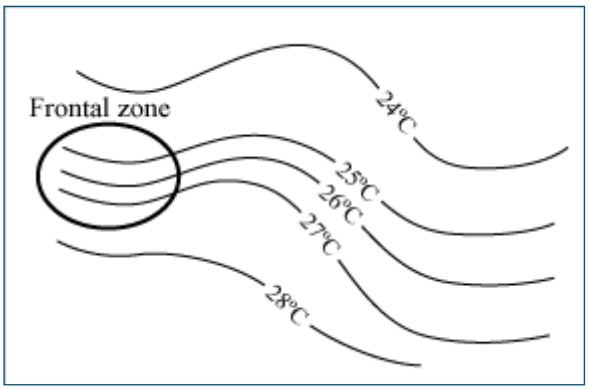


Figure 5. SST isotherms and an SST frontal zone

A special type of frontal zone is one that extends out from a typical frontal zone into a finger-like shape (Figure 6). In fact, fishermen sometimes call this type of front a *finger*. Sometimes a finger can break away from the main front and become a bubble-like area surrounded by water of a different temperature. Fingers can be good places to fish for pelagic species.

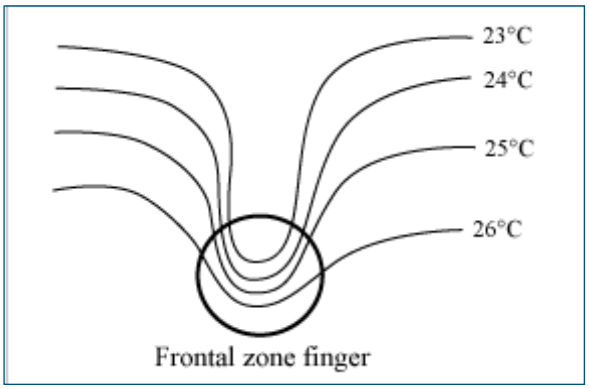


Figure 6. Frontal zone finger

Sea surface temperature can also be monitored from a fishing boat by using a sea surface temperature monitor (Figure 8). This device has a sensor, or probe, mounted somewhere on the hull below the waterline and a monitor mounted in the wheelhouse that displays the SST in either degrees centigrade (°C) or Fahrenheit (°F). Most SST monitors have a shear alarm that can alert the operator if the temperature goes up or down within a specified range of temperatures set by the operator. An SST monitor is not an example of remote sensing. It is on-site sensing. However, an SST monitor can be used to verify the SST derived from remote sensing data. There is a time lag between when remote sensing data were obtained and processed and when the user receives charts produced from that data. In the meantime, temperature boundaries may have shifted. An SST monitor enables fishermen to locate temperature boundaries with precision, so this device is a necessary tool to have on a boat to use in conjunction with remote sensing information. A good way to monitor SST is to keep a log in the wheelhouse and make entries recording position and SST every 15–30 minutes while the boat is traveling (looking for fish). This is also a good way of keeping the person on watch alert. SSTs can be entered on some GPS plotters as text. Good catches can also be entered on a GPS plotter. Later, catch results can be compared with temperature entries, giving the fisherman some useful information about where to fish the following day.

Figure 7. An SST monitor

Sea surface height anomalies and eddies

Sea surface height anomalies are areas in the ocean where the sea level, independent of normal tidal fluctuations, is either higher or lower than the mean sea level expected. The differences are caused by warming, cooling and circulation. The differences in sea level seem small (+ or -30 cm) but involve huge volumes of water. Water tends to flow away from a positive anomaly (+30 cm, for example), sometimes called a high spot, and towards a negative anomaly (-30 cm, for example), sometimes called a low spot. But water does not flow in a straight line from one place to the other. It turns and forms circular patterns called eddies.

Eddies are cyclonic movements of water caused by currents that are affected by the Coriolis force. The rotation of the earth causes air or water (or any object that is moving) to be deflected to the right in the northern hemisphere and to the left in the southern hemisphere. The result is that water moving away from a positive SSH anomaly in the southern hemisphere, for example, will turn to the left, forming an eddy that moves in a counter-clockwise direction (Figure 8). Conversely, water moving toward a negative SSH anomaly, while also turning to the left, will form an eddy that turns in a clockwise direction (Figure 8). Eddies in the ocean are very similar to anti-cyclones and cyclones in the atmosphere but they move much more slowly and are not often circular in shape.

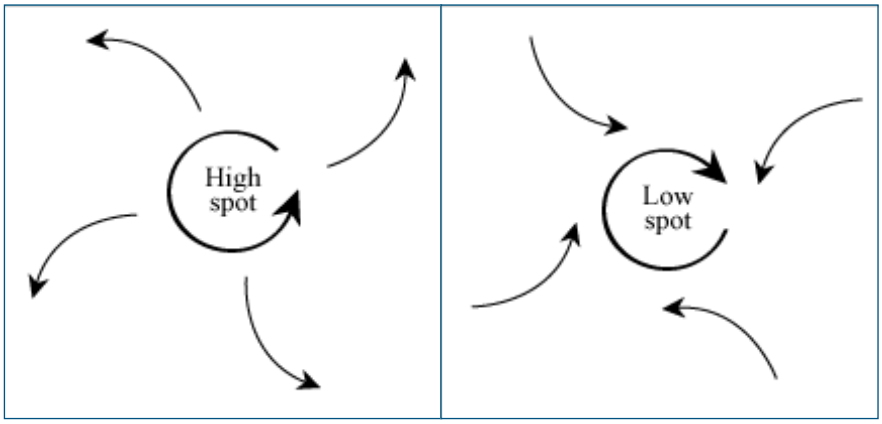


Figure 8. An eddy formed around a positive SSH anomaly, or high spot (left), and an eddy formed around a negative SSH anomaly, or low spot (right)

Generally, positive SSH anomalies are warmer than negative SSH anomalies. Because of this, water usually moves from warmer areas (high spots) to cooler areas (low spots). Eddies that form around a positive SSH anomaly are warmer in the centre and cooler at the edges. Eddies that form around a negative SSH anomaly are cooler in the centre and warmer at the edges. Because of this, an SSH chart can often be used as a proxy for an SST chart. In fact, SST charts and SSH charts often have similar features (Figure 2). The main difference between SST charts and SSH charts is that SSH charts are based on more reliable data because the data are generated by radar. Often, SST frontal zones can be found on the edges of both warm and cold eddies on an SSH chart. Therefore, the edges of an eddy can be good places to fish for pelagic species.

Many of the websites listed above also produce current charts. Sea surface currents on these charts are modeled on SSH data based on the fact that water travels from high spots to low spots and that movement is affected by the Coriolis force. Currents are usually indicated by arrows that show direction and relative velocity. Keep in mind, however, that currents on SSH remote sensing charts are not real — they are modeled, using SSH data.

Getting started

User-pays websites can be costly so fishermen, boat owners and fleet managers should weigh the benefits against the costs before getting started. A single owner-operator with a small or medium-scale longline boat, for example, may not be able to justify the cost of purchasing a subscription and maybe even hardware and software to look at SST and SSH charts for his area. On the other hand, a subscription to user-pays remote sensing for a company with a fleet of medium or large-scale longliners could easily be justified. In any case, it is wise to look at everything that is available before deciding what will work best in any given situation. Talking to other fishermen and boat owners who use remote sensing would be a good first step. Other than that, a good way to learn more about how to use remote sensing to find fish is to try out one of the free websites. Probably the most useful free remote sensing website is OceanWatch (http://oceanwatch.pifsc.noaa.gov/) that is operated by National Marine Fisheries Service's Pacific Island Fisheries Science Center in Honolulu, Hawaii.

Here is a guide for your first look at Ocean Watch. After opening the website, we click on **Live Access Server (LAS) for satellite imagery and data**. A list of 24 datasets will come up. For openers, we click on **15. Near Real-time (NRT) weekly sea surface height and geostrophic currents**.[6] Another page will come up with dataset variables. We select **2 (Sea surface height with no vectors)**. A page will come up with a world map and several options to choose from. The map can be shifted up or down, left or right, and can be enlarged or shrunk (zoom in/zoom out) but we will not bother with those. There are three choices above the world map: select **view**, select **output** and select **region**. For **view** we select **Longitude-Latitude Map (xy)**. For **output** we select **Color Plot**. For **region** we select **Full Region**. At the bottom of the map is a space to select beginning time. We select the most recent date: for example, **23-Dec-2010-00:00:00.**[7] To the right of the map there are four windows for selecting the area we want to look at. The top and bottom windows are for latitude and the left and right windows are for longitude. A conventional chart can be used to define the area of interest. For example, if the area of interest is Niue then the boundaries of the rectangle to be defined might be 18°–20° S and 169°–171° W. In the upper window we enter **18 S**, in the lower window we enter **20 S**, in the left-hand window we enter **171 W**, and in the right-hand window we enter **169 W** (the longitude entries must be in that order or the area selected will be a band all the way around the earth from 169° W going east to 171° W). This may take some practice to get right. Then we click on **Go** and the area selected will be highlighted in yellow on the world map. If it looks right, we click on **Next**. If everything has been done correctly an SSH chart will appear that looks similar to the one in Figure 9.

6 *A geostrophic current is an oceanic flow in which the pressure gradient force is balanced by the Coriolis force.*

7 *This date may not be available as Ocean Watch does not archive data for more than one month. Select the most recent date to get the most recent data. Your charts will, therefore, not be the same as in the figures.*

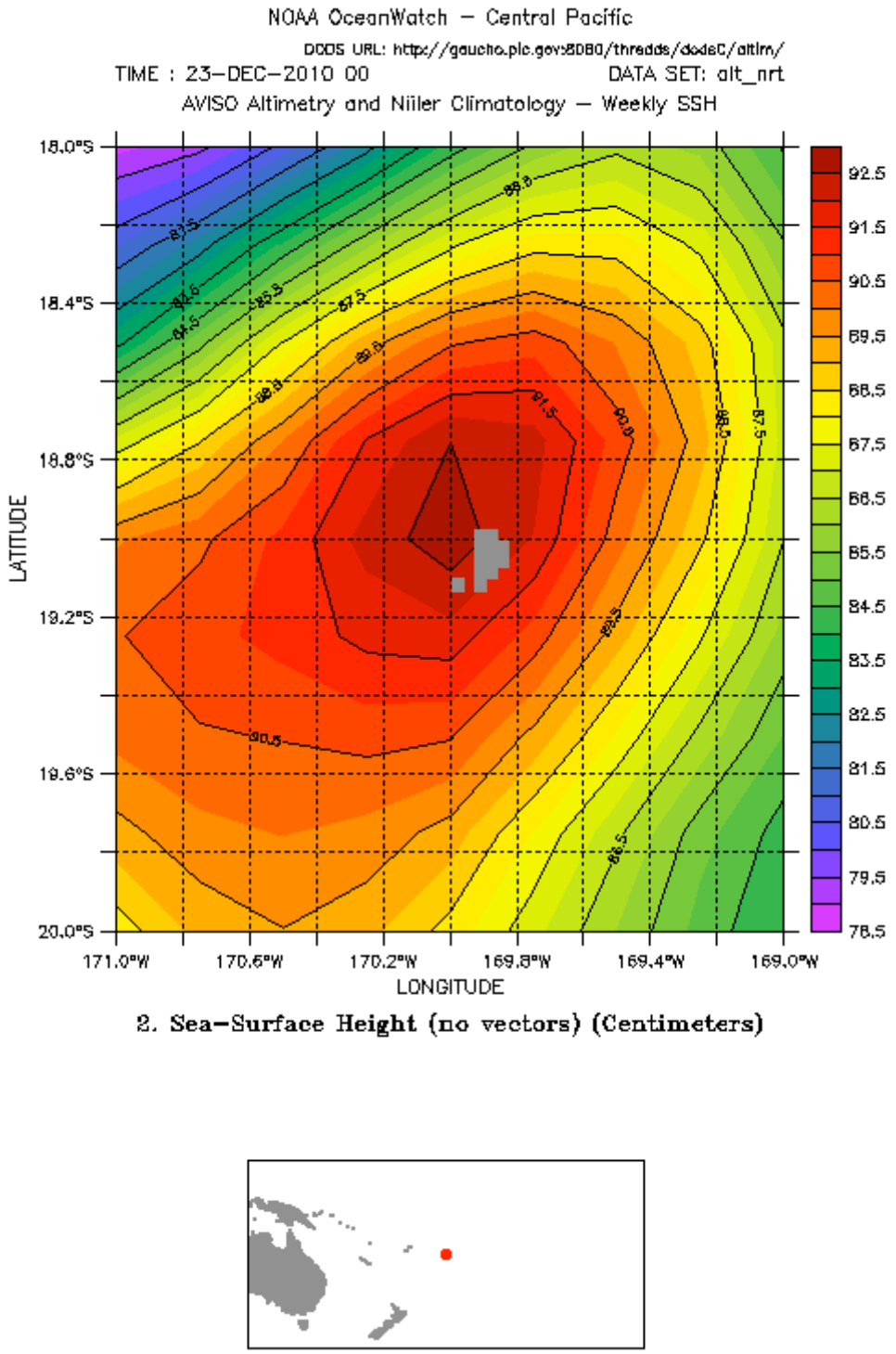
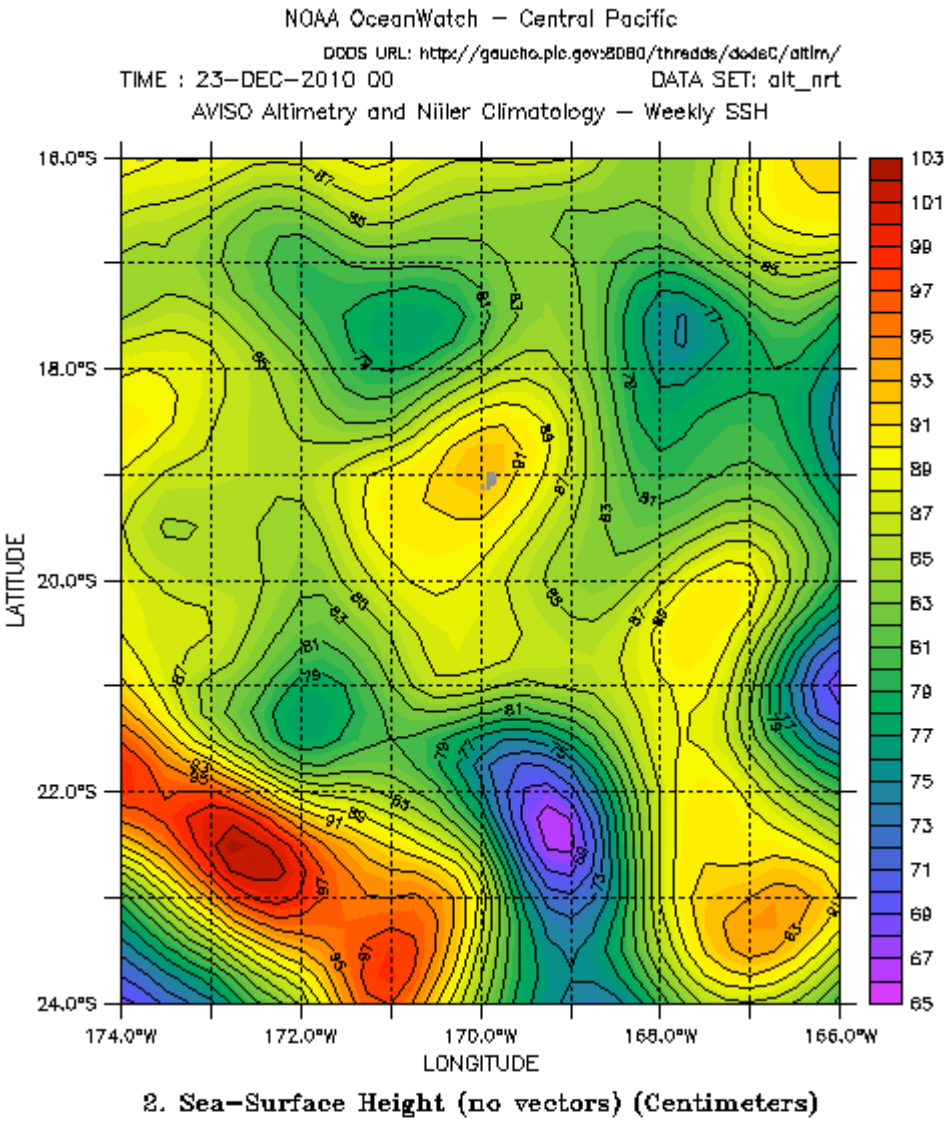


Figure 9. SSH chart for Niue for 23 Dec 2010. Niue appears roughly as the grey area in the centre of the chart

That was just for practice. Now the boundaries can be expanded to find a good fishing area near Niue. In the same window we expand the search by entering new boundaries: **16 S** and **24 S** in the latitude windows and **174 W** and **166 W** in the longitude windows. We click on **Go** again and then on **Next**. The larger chart that comes up (Figure 10) has some interesting features. Just south of the 22° S line there are two strong eddies. There is a high spot between 172° and 173° W and there is a low spot at 169° W. In between these two eddies is a frontal zone that may be a good place to fish. Figure 11 shows the same SSH anomalies but with geostrophic currents added. Note the current circling the high spot (orange-red) is running counter-clockwise while the current circling the low spot (blue-purple) is running clockwise. Based on the charts in Figures 10 and 11, a good place to start fishing would be around 23.0° S and 170.0° W, setting the longline east to west across the frontal zone.

A good feature of Ocean Watch is that the search can be expanded or narrowed. Figure 12 narrows in on the area that looked interesting in Figure 11. This was done by selecting new boundaries: 22° S–23° S and 170.5° W–169.5° W. On this higher resolution chart the frontal zone between the two eddies can be clearly seen (the green band running from the top left to the lower right of the chart). Figure 13 is an SST chart for the same area as that shown in Figure 12. An SST finger can be seen — the orange-red area that runs from the middle top to the centre of the chart. Based on this chart, a good strategy would be to set the longline across the frontal finger on the 22.40° S line in an easterly direction. SST charts are produced by selecting 17. 3-Day AVHRR-GAC[8] Sea Surface Temperature, from the list of datasets on the Ocean Watch website.

8. *AVHRR-GAC stands for Advanced Very High Resolution Radiometry-Global Area Coverage.*



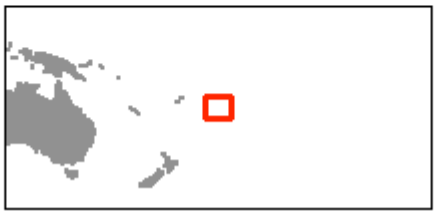


Figure 10. An expanded SSH chart for Niue for 23 Dec 2010 showing eddies to the south of Niue

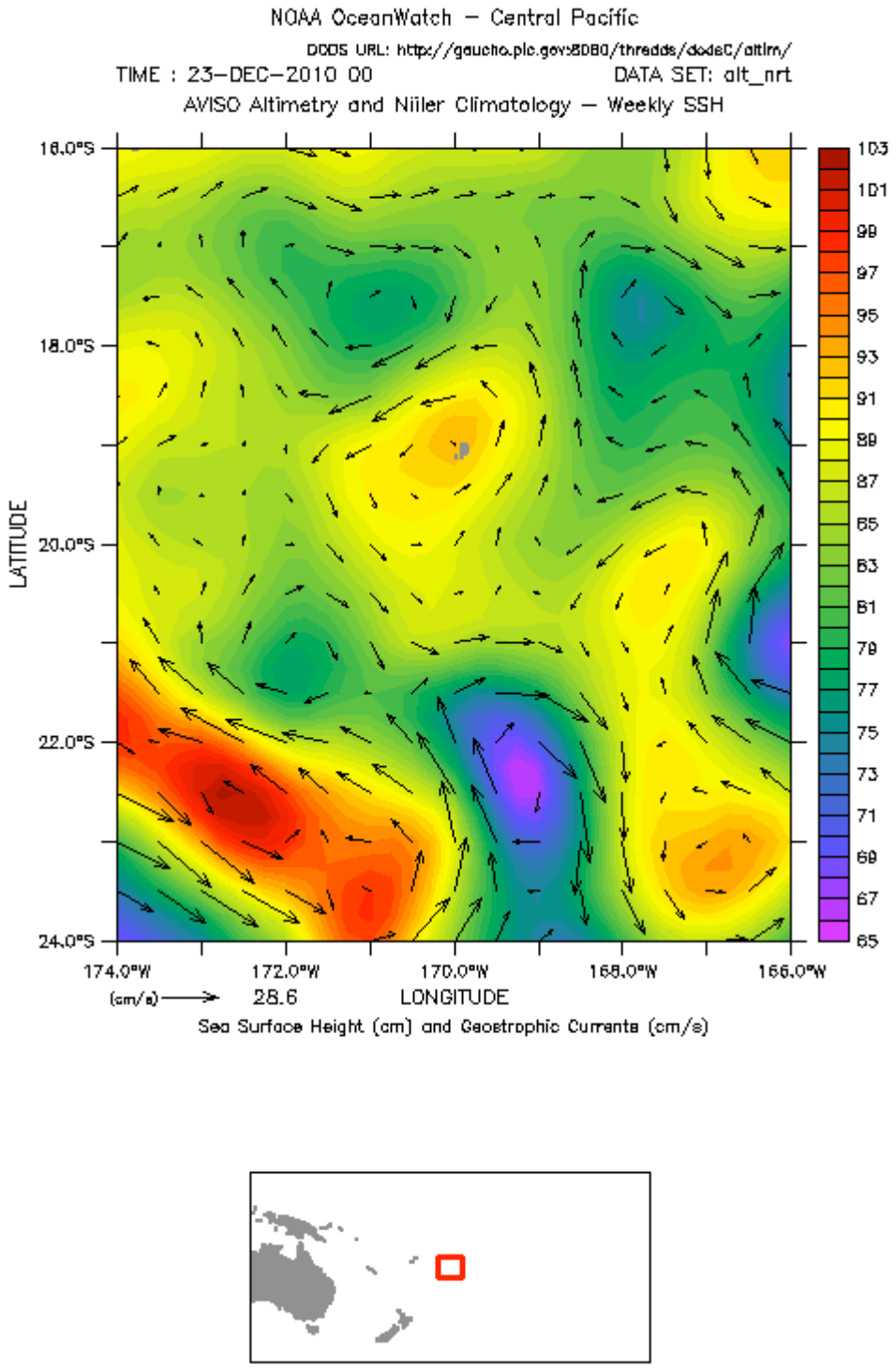


Figure 11. SSH for Niue for 23 Dec 2010 with geostrophic currents

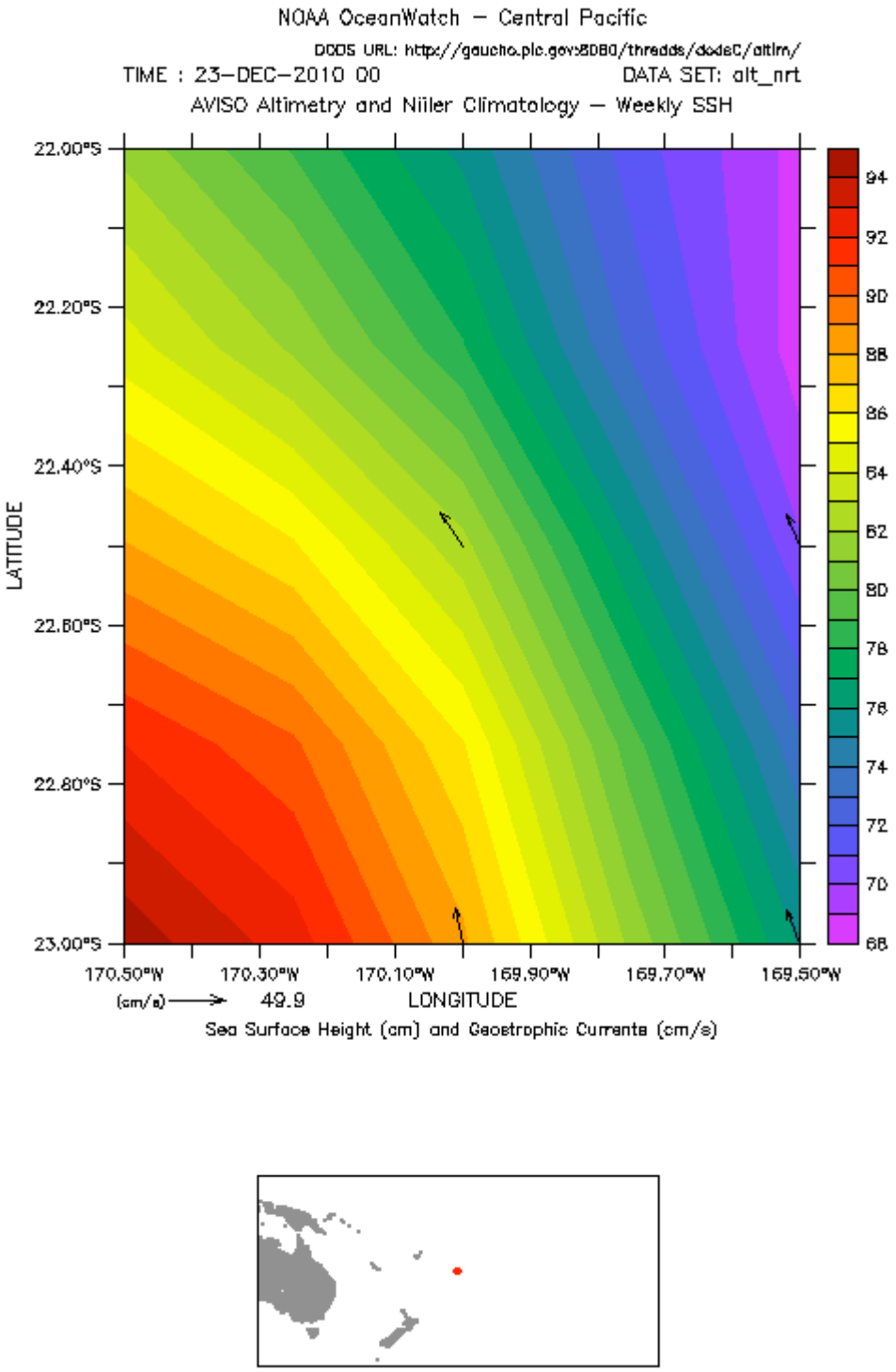
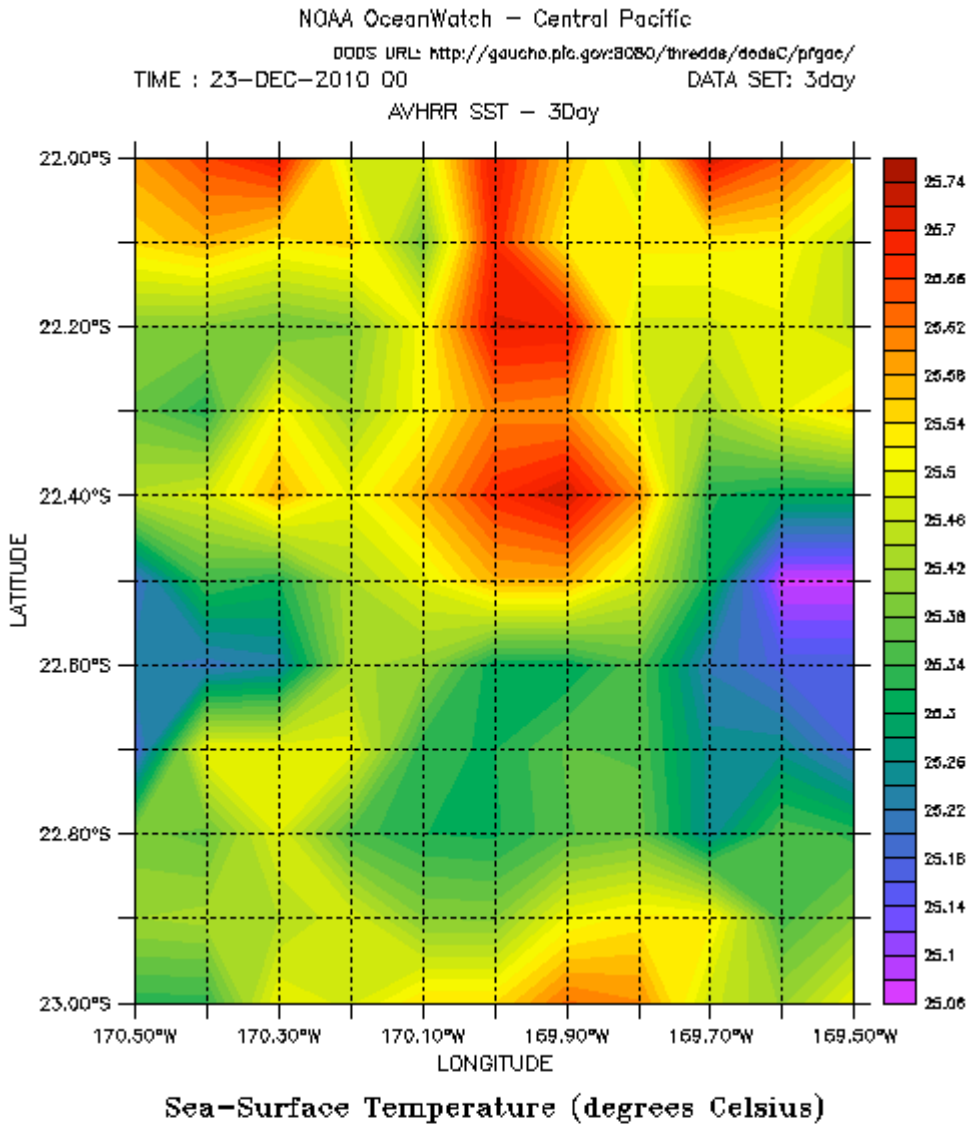


Figure 12. An SSH frontal zone shown on higher resolution chart as the green band between a high spot (orange-red) and a low spot (blue-purple)



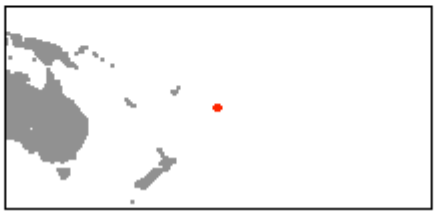


Figure 13. An SST chart of the same area as that shown in Figure 12. There is a very distinct SST frontal finger (the red-orange area extending from the top to the centre of the chart) that corresponds roughly with the SSH frontal zone from Figure 12.

Some useful hints

Many boats have the ability to access the internet while at sea using a computer and a satellite telephone. This is the ideal but may not be practical or affordable for many small or medium-scale longliners. However, if a boat cannot access remote sensing sites at sea, it can be very helpful to know where frontal zones and eddies are before the boat departs, whether the charts are downloaded from a commercial website or a free website. Frontal zones and eddies are relatively slow moving. Before leaving on a fishing trip a fisherman could download SST and SSH charts for several consecutive days. An examination of all of the charts side by side will give an indication of how any eddies or frontal zones are moving (Figure 14). This information can be used to predict, albeit roughly, where they will be on the day the boat starts fishing. Port captains or fleet managers can assist fishermen by downloading SST and SSH charts just before the boat departs for a fishing trip.

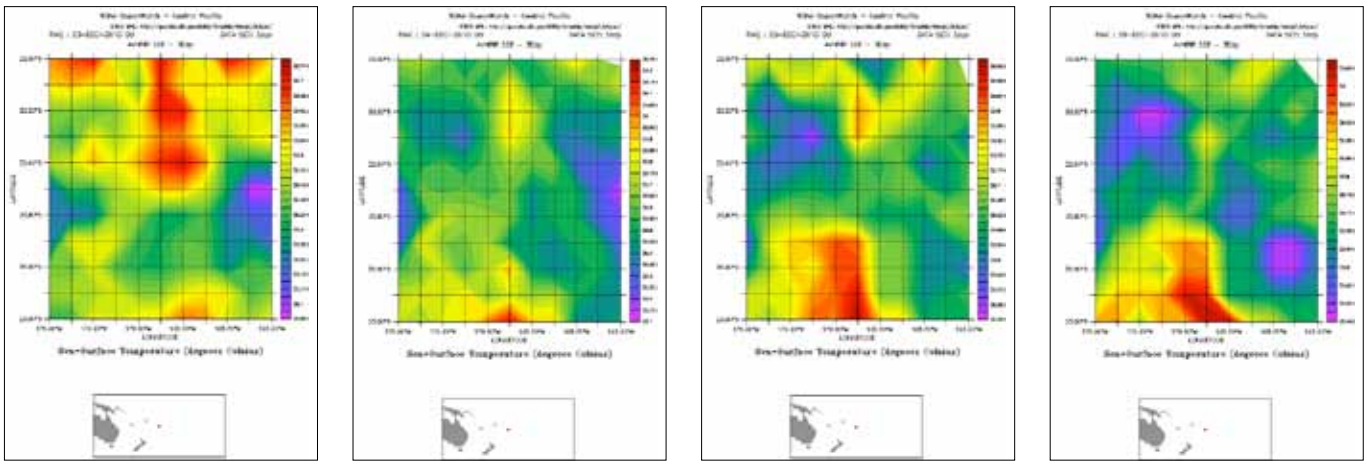


Figure 14. Four consecutive SST charts. The first is the same as in Figure 13 for 23 Dec 2010. The next three are for the same area but for 24, 25 and 26 Dec 2010. Note that the frontal finger identified in Figure 13 has diminished while a new frontal finger has developed just south of the first finger. The frontal zone is moving north, as was predicted by the geostrophic current pattern in Figure 11.

Another useful practice is to plot very good or very poor fishing days on remote sensing charts for those days. Set positions can be plotted on a chart after the boat returns from a fishing trip. This may give good information on what features to look for and what features to avoid. This is called hindcasting and is another way that port captains and fleet managers can assist fishermen. They can do hindcasting while the boat is at sea and provide the information to the captain on his return.

Keep in mind that using remote sensing charts does not guarantee a good catch. Remote sensing is just one of many tools in the longline fisherman's toolbox. Experience is probably the best tool but there are others, such as talking to other fishermen at sea and sharing information, keeping good records, using bathymetric information on charts such as location of the 1000 m isobath curve[9] and seamounts, looking for birds or bait in the water, and even eavesdropping on radio conversations of other boats. For more information refer to SPC's longline manual, *Horizontal longline fishing methods and techniques: A manual for fishermen.*[10]

9 *Isobath means same depth. The 1000 m isobath is considered by some fishermen to be a good place to start if nothing else is known.*

10 *http://www.spc.int/coastfish/Sections/Development/FDSPublications/FDSManuals/HLL/HLLIntros.pdf*

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