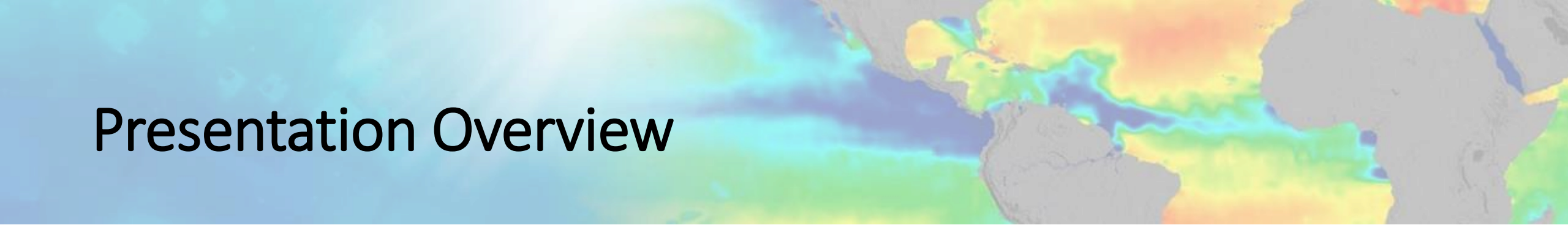


What's New on the “NASA Salinity” Website

Annette deCharon & Lisa Taylor (ODYSEA LLC)

Presentation Overview



- *Which Salinity Data Are Best For You?*
- *How Salty (or Fresh) Are You?*
- *Learn More*
- *Highlights – Research One-pagers*
- Publications Update
- What's Next?

Which Salinity Data Are Best For You?

• Overview

- Provides information and case studies for potential users of satellite sea surface salinity (SSS) data.
- Addresses the similarities and differences among SSS data products with a focus on SMAP.
- Users can navigate between pages.
 - Will have a “Table of Contents” at left.
- Developed with Alex Fore, Séverine Fournier, Wendy Tang, Vardis Tsonetos, and Jorge Vazquez (JPL) & Thomas Meissner (Remote Sensing Systems, RSS).

Which Salinity Data are Best for You?

SSS Retrieval – It's Complicated »

Overview

Salinity data have been used to understand not only oceanography but a broad range of topics. More than 500 publications have been amassed since satellites began measuring salinity over a decade ago.

There have been three spaceborne sensors that measure sea surface salinity (SSS), each with the same frequency (1.4 GHz, L-band) but with different technologies:

- Aquarius was primarily designed to measure sea surface salinity (SSS) but also measured soil moisture.
- SMAP is the opposite: Primarily designed for soil moisture but also detects SSS.
- SMOS was designed to measure both SSS and soil moisture.

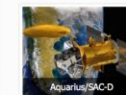
Accurately detecting SSS is an ongoing research activity. This has resulted in *continuous improvement in products* as new data versions are released.



View to learn how salinity might be right for you!



	SMOS	Aquarius	SMAP
Agency	European Space Agency	NASA	NASA
Antenna type	Microwave Imaging Radiometer using Aperture Synthesis (MIRAS)	Stationary; 3 beams; 100% reflective	Spinning; 99% reflective (1% emissive)
Global coverage / Repeat orbit	~4 days / 18 days (sub-cycle)	7 days / 7 days (exact)	3 days / 8 days (exact)
Spatial resolution	~50 km	~150 km	~40 km native
Comments	Strong land-sea emissivity contrasts have hampered SSS retrievals. Methodologies to mitigate systematic errors have improved data product quality over time (e.g., SMOS Debaised V4).	Onboard scatterometer provided internal wind correction. This helped achieve a high overall SSS accuracy (0.13 psu).	SMAP data are spatially averaged to reduce noise. Visit “SMAP Processing” section for more detailed information.



When determining which SSS data to use, here are some key questions to consider...

- + What is the time period of interest for my study?
- + Am I interested in open-ocean data away from high latitudes?
- + Am I interested in coastal regions and/or areas that may be affected by sea ice?
- + Is rainfall likely to affect SSS in my region of interest?
- + How might looking at multiple SSS products benefit my research (or beyond)?
- + Are in-water salinity data available to validate SSS retrievals in my region of interest?
- + Am I interested in anomaly data (i.e., variations from a long-term mean)?
- + Would I like to include wind data in my study? Does my area of interest include high winds?

Next »

RESEARCH INSIGHTS – PERSPECTIVES FROM SALINITY SCIENTISTS

Highlighted researchers have helped to characterize salinity variability in challenging environments. Not only that, their findings have benefited the research community by informing SSS processing algorithms. Their personal insights and other “tips” may help you to decide which salinity data to use in your own work.



Gulf of Mexico: A River-Influenced System [Jorge Vazquez] [VIEW »](#)



Arctic Ocean – Evaluation and Intercomparison of SMOS, Aquarius, and SMAP SSS Products [Séverine Fournier] [VIEW »](#)

SSS DATA SOURCES & DOCUMENTS

- [Aquarius PO.DAAC »](#)
- [SMAP PO.DAAC »](#)
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- [SMOS Debaised V4CATDS »](#)

KEY PAPERS ABOUT SSS RETRIEVALS

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Which Salinity Data Are Best For You?

- Beyond Oceanography
 - Short video (1 min 49 sec) with music.
 - Created for audiences in other disciplines who might consider using SSS data in their own work.

Next >

Correction for Aquarius SSS Retrieval (Tang et al., 2015) IEEE >

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2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

SMOS Aquarius SMAP

Beyond Oceanography

View to learn how salinity might be right for you!

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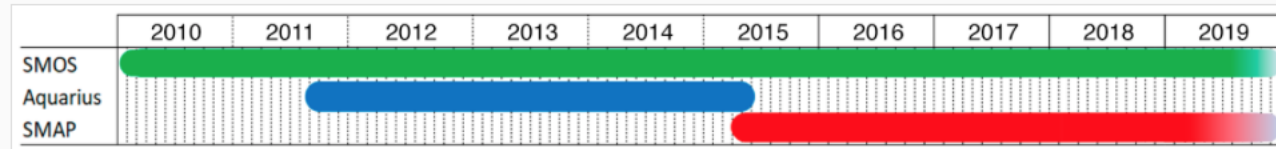
Gulf of Mexico: A River-Influenced System [Jorge Vazquez] VIEW >

Next >

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Which Salinity Data Are Best For You?

- Comparison Tables
 - Color coding is established at the outset to help users differentiate among SMOS, Aquarius, and SMAP.



	SMOS	Aquarius	SMAP
Agency	European Space Agency	NASA	NASA
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Which Salinity Data Are Best For You?

- Q&A Panels
 - Question & Answer (Q&A) panels are available throughout this feature.
 - This example addresses the types of information potential SSS users are likely to consider.

When determining which SSS data to use, here are some key questions to consider...

– What is the time period of interest for my study?

SMOS has the longest continuous coverage of these satellites as shown in the timeline. NASA's Aquarius and SMAP data have been acquired using similar technology and processed in similar ways. Both satellites operated simultaneously during mid 2015.

+ Am I interested in open-ocean data away from high latitudes?

+ Am I interested in coastal regions and/or areas that may be affected by sea ice?

+ Is rainfall likely to affect SSS in my region of interest?

+ How might looking at multiple SSS products benefit my research (or beyond)?

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Which Salinity Data Are Best for You?

- Research Insights

- Two studies – led by Jorge Vazquez and Séverine Fournier – are highlighted thus far.
- Both have similar formatting, including color-coded tables and Q&A panels.
- Some questions are geared towards personal perspectives.
- Each includes a time-series slideshow to show differences among data products.

Research Insights – Arctic Ocean: Evaluation and Intercomparison of SMOS, Aquarius, and SMAP SSS Products



Séverine Fournier, Ph.D.
Scientist: Ocean Circulation And Air-Sea Interaction
NASA Jet Propulsion Laboratory (JPL)

This publication includes the first systematic analysis of six commonly used, gridded (i.e., Level-3) SSS products from NASA (Aquarius and SMAP) and the European Space Agency (SMOS). The products are evaluated in terms of their consistency among one another and with in-water data.

The study is performed in areas where SSS retrievals are available for each product. Availability of SSS data – i.e., "ice-free" or non-masked ocean areas – varies considerably among products as shown in the following table.

	SMOS		Aquarius		SMAP	
Data product used in study	Debiased Version 3 (LOCEAN)	Version 2 – Barcelona Expert Center (BEC)	Version 5 – RSS (native)	Version 5 – JPL (smoothed)	Version 3 – RSS (smoothed)	Version 4.2 – JPL
Ancillary product	ECMWF sea surface temperature (SST)	EUMETSAT Ocean and Sea-ice Satellite Application Facility sea-ice concentration	1/12° sea-ice concentration data from NOAA NCEP is integrated over the Aquarius satellite footprint and weighted by the antenna gain to obtain an ice fraction		Daily AMSR-E/AMSR2 sea-ice concentration data are integrated over SMAP footprint and weighted by the antenna gain to give an ice fraction	1/12° NOAA NCEP sea-ice concentration (re-gridded to 0.5° x 0.5°). For each SMAP footprint, the nearest sea-ice concentration value is found
Ice mask or flag	Ice mask based on dielectric constant* and ancillary SST	Masks sea-ice concentrations higher than 15%	Flagged if ice fraction exceeds 0.1%	Flagged if ice fraction exceeds 3%	Pixels are flagged if ice fraction exceeds 0.1%	Pixels are flagged where sea-ice concentration exceeds 3%
Notes	*Uses Klein & Swift (1977) dielectric constant model. Others use Meissner & Wentz (2004).	BEC products are dedicated to high latitudes.	Official end-of-mission product from Remote Sensing Systems.	Investigator-led product (also known as "CAP").	40-km resolution mean product used for this study.	60-km resolution investigator-led product (also known as "CAP").

When averaged over the Arctic Ocean, the six products show excellent consistency in capturing seasonal and year-to-year variations (Fig. 1). The products also consistently identify regions with strong SSS variability over time.

Primary challenge for Arctic Ocean SSS: Cold seawater. This is because brightness temperature (T_b) has lower sensitivity in colder waters at the frequency employed by today's SSS satellites (L-band). As expected, root-mean square differences of satellite SSS with respect to in-water measurements improves with increasing seawater temperature.

In the Arctic Ocean, in-water data are sparse as illustrated in a map showing the number of observations from 2011 to 2017 (Fig. 2). So, the study team focused on comparing satellite SSS with in-situ salinity measurements along ship transects (red lines in the map). Based on these transects, the data suggest that satellite SSS captures salinity gradients away from regions with significant sea-ice concentration.

Questions and Answers

- + Were you surprised by any of the findings of your study?
- + Your research team seems to have made heroic efforts to find in-water data in the Arctic Ocean. And yet, there isn't much to be found. What are your thoughts (or dreams) on improving monitoring of the Arctic Ocean?
- + You mention the use of multi-satellite observations such as SSS and ocean color (chlorophyll) data to track river plumes, which are, at times, a big source of low-salinity water in the Arctic Ocean. Any thoughts (or plans) on pursuing this type of multi-satellite (or multi-sensor) research in the future?
- + You state that SSS may respond to "river discharge, sea-ice growth and melt, net precipitation, and ocean circulation." Any thoughts on how to investigate the overall system to discover how SSS is influenced by these processes?
- + Since publication, RSS released Version 4 (V4) of their SSS product. Have you had the opportunity to see if RSS V4 has increased coverage of the Arctic Ocean?
- + Any advice for other scientists whose data might be updated during or after their publication is submitted?
- + How might your findings help to improve future versions of SSS data from NASA or ESA?
- + Does contributing to improved algorithms bring you professional (or perhaps personal) satisfaction?
- + Anything else you'd like to share?

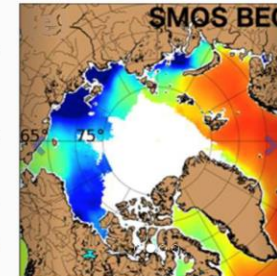


Figure 1. Slideshow of annual mean of SSS over 2015-2017 from 1) SMOS Laboratory of Oceanography and Climatology, 2) SMOS Barcelona Expert Center, 3) SMAP Remote Sensing Systems, and 4) SMAP JPL.

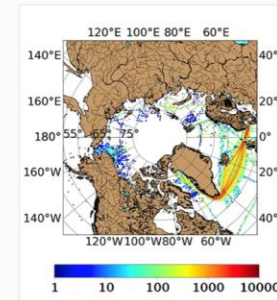


Figure 2. Number of in-situ observations from 2011 to 2017 available to collocate with satellite SSS observations within the upper 10 m per 36 km grid cell.

Which Salinity Data are Best for You?

SSS Retrieval – It's Complicated »



How salinity might be right for you!

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SMAP

NASA

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3 days / 8 days (exact)

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SMAP data are spatially averaged to larger footprints to reduce noise. Visit "SMAP Processing" section for more detailed information.

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Which Salinity Data Are Best For You?

- SSS Retrieval – It's Complicated
 - Recognizing that some users are unfamiliar with satellite data, this part addresses:
 - Processing levels
 - Ancillary Inputs
 - Corrections
 - Flags, Filters & Masks

SSS Retrieval – It's Complicated

Satellite salinity instruments measure natural microwave emission from the top 1 cm (or less) of ocean surface in terms of **brightness temperature** (T_b). These data are processed into SSS at various levels:

- **Level 1:** Radiometer observations at full resolution (1A) or processed to sensor units such as brightness temperature (1B);
- **Level 2:** Derived geophysical variables from Level 1 source data; and
- **Level 3:** Variables mapped on uniform space-time grid scales.

Many researchers use gridded (i.e., Level 3) data. It can be useful to "dive deeper" and be aware of the types of documents describing how the data are acquired, validated, calibrated, processed and distributed.

The complexity behind SSS data has been captured in the PO.DAAC's [Aquarius Documentation Roadmap](#). In addition to User Guides, there are Validation Analyses, Algorithm Descriptions, Calibration and other Technical Reports. The PO.DAAC also offers [similar documentation for SMAP SSS processing](#).



Aquarius documentation roadmap.

There are differences among the retrieval algorithms used to generate satellite SSS data. Not only that, the algorithms used to process various missions' data evolve over time. So, the information below is meant to provide an *overview of the types of variations* among data products.

The variation among SSS data products falls into these general categories:

- **Ancillary inputs**
 - Typical inputs include sea surface temperature (SST), wind speed and direction, galactic map, sea ice mask, dielectric constant model, and a reference salinity field (e.g., [HYCOM model](#)). Differences among these inputs can affect the consistency among SSS products.
- **Corrections**
 - A variety of corrections are applied to SSS data. Although the specific corrections differ from product-to-product, typical SSS corrections are summarized in the e-brochure, [Ocean Salinity From Space](#).
- **Flags, Filters & Masks**
 - **Flags** are employed when values exceed threshold values, thus indicating potentially degraded algorithm performance.
 - Each SSS data product employs its own type of flagging. For example, flags can affect data availability and/or quality *near coasts* (i.e., land contamination) and at *high latitudes* (i.e., sea ice contamination).
 - *"Research Insights"* show the affect of ice flagging and masking on retrievals of SSS data from the [Arctic Ocean](#).
 - Flags can also be used to filter values according to your specific needs.
 - For example, RSS provides rain-filtered SMAP SSS products.
 - **Masks** are used to omit data that do not meet established quality criteria
- **Error Sources and Uncertainty Estimation**
 - Approaches to estimating errors or uncertainties vary among SSS products.

The specific application of corrections, flags, filters, and masks – along with approaches to estimating errors or uncertainties – are described in each product's User Guide and other literature.

both RSS and the NASA Jet Propulsion Laboratory (JPL). In the next section, we focus on similarities and differences in how these SMAP data products are processed.

Did We Mention It's Complicated?

A potentially confusing aspect is that there can be overlap between items in these categories. For example, RSS uses an ancillary "land mask" as an input to its SSS processing. Land corrections are applied to ensure the quality of coastal SSS data. RSS products also include land-related quality flags ranging from "light contamination" (i.e., removed from averaging in smoothed products) to "strong contamination" (i.e., masked altogether). Finally, RSS includes systematic errors from land contamination in its empirical uncertainty estimates.

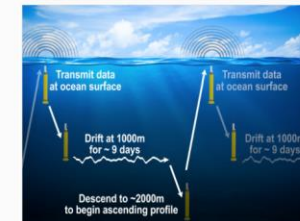


Figure 1. Argo floats drift at depth then rise to the surface while measuring temperature and salinity.



Figure 2. Saildrones – autonomous sailing drones – are used as a tool to provide high quality oceanic and atmospheric observations.

WHAT'S IN A VERSION?

It is not uncommon for months (or years) to pass between gathering data, analyzing it, writing a manuscript, and publishing your results. In parallel, the SSS data processing community is working to update algorithms and improve its products.

New releases of SSS data products are accompanied by changes in version numbers. This [timeline](#) shows major release dates of three examples of SSS data products (i.e., De-biased SMOS Level 3, Aquarius RSS, and SMAP RSS). Interestingly, two versions of Aquarius data (V4, V5) were released after the satellite stopped operating on 07-Jun-15.

It is important to know which data version number(s) you are working with and be cognizant of new data releases that may occur while your manuscript is being reviewed. Even though the new data product will be better in quality, it may affect your results. **Consider contacting the data providers (e.g., PO.DAAC for NASA SSS data) about the timing of data release updates.**



Timeline of major release dates for three examples of SSS data products. Click image to enlarge.

SSS VALIDATION & SAMPLING DIFFERENCES

The accuracy of satellite-derived SSS measurements is largely validated by data from in-water sensors. Nonetheless, comparing the two is challenging for many reasons.

Timing is a challenge: Satellite observations need to be "matched up" with in-water data that has been collected at or near the sea surface within a few days of the satellite retrieval.

Spatial mismatch is another challenge. Satellite footprints cover tens of kilometers. Thus, a single satellite footprint may sample an area with non-uniform salinity (e.g., region with discrete patches of low salinity caused by recent rainfall). In-water salinity instruments, on the other hand, provide discrete "pinpoints" of salinity data.

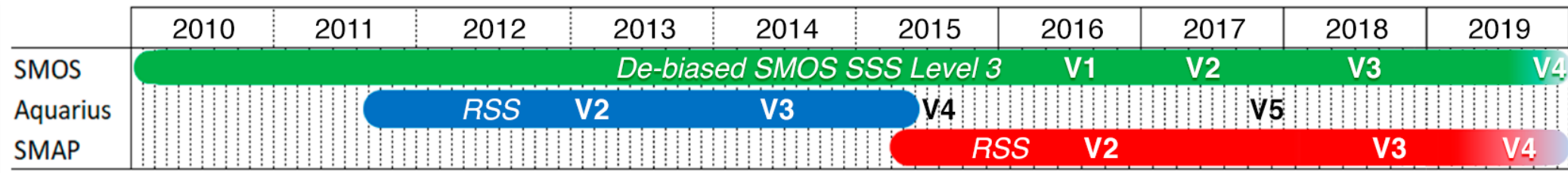
Horizontal mismatches are only one part of the story. There are also differences in the depths where salinity is being measured. Satellite sensors retrieve from the very top of the ocean while in-water instruments measure salinity at greater depths.

Systematic sampling differences between satellite and in-water SSS data are sometimes referred to as "biases." **However, these sampling differences do not necessarily equate to errors in satellite SSS.** There can be physical reasons for the differences; for example, thin layers of low-salinity water that "float" on the ocean surface. These conditions would be detected by satellites, which measure T_b in the top centimeter of the ocean, but missed by sensors such as [Argo profiling floats](#) (Fig. 1) that generally do not detect salinity shallower than 3 – 5 meters.

SSS validation is being aided by a relatively new technology, [Saildrones](#) (Fig. 2). This instrument acquires salinity at a depth of 0.6 m, closer to the sea surface and thus more indicative of conditions detected by satellites. Other novel SSS-measuring technologies have been employed in conjunction with the [SPURS campaigns](#). These instruments are key to understanding discrepancies between "sea truth" data and satellites' SSS retrievals, which are fed back into processing algorithms to improve SSS data products.

Which Salinity Data Are Best For You?

- SSS Retrieval – It's Complicated
 - The fact that our community continues to learn about SSS retrievals – and releases new versions of data products over time – is addressed.
 - The advice to be mindful of product version(s) is illustrated by this timeline showing three examples.



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The complexity behind SSS data has been captured in the PO.DAAC's [Aquarius Documentation Roadmap](#). In addition to User Guides, there are Validation Analyses, Algorithm Descriptions, Calibration and other Technical Reports. The PO.DAAC also offers [similar documentation for SMAP SSS processing](#).



Aquarius documentation roadmap.

There are differences among the retrieval algorithms used to generate satellite SSS data. Not only that, the algorithms used to process various missions' data evolve over time. So, the information below is meant to provide an overview of the types of variations among data products.

The variation among SSS data products falls into these general categories:

- **Ancillary inputs**
 - Typical inputs include sea surface temperature (SST), wind speed and direction, galactic map, sea ice mask, dielectric constant model, and a reference salinity field (e.g., [HYCOM model](#)). Differences among these inputs can affect the consistency among SSS products.
- **Corrections**
 - A variety of corrections are applied to SSS data. Although the specific corrections differ from product-to-product, typical SSS corrections are summarized in the e-brochure, [Ocean Salinity From Space](#).
- **Flags, Filters & Masks**
 - **Flags** are employed when values exceed threshold values, thus indicating potentially degraded algorithm performance.
 - Each SSS data product employs its own type of flagging. For example, flags can affect data availability and/or quality near coasts (i.e., land contamination) and at high latitudes (i.e., sea ice contamination).
 - "Research Insights" show the affect of ice flagging and masking on retrievals of SSS data from the [Arctic Ocean](#).
 - **Flags** can also be used to filter values according to your specific needs.
 - For example, RSS provides rain-filtered SMAP SSS products.
 - **Masks** are used to omit data that do not meet established quality criteria
- **Error Sources and Uncertainty Estimation**
 - Approaches to estimating errors or uncertainties vary among SSS products.

The specific application of corrections, flags, filters, and masks – along with approaches to estimating errors or uncertainties – are described in each product's User Guide and other literature.

Another consideration: Some data are processed by multiple institutions. SMAP SSS data, for example, are processed by both RSS and the NASA Jet Propulsion Laboratory (JPL). In the next section, we focus on similarities and differences in how these SMAP data products are processed.

Did We Mention It's Complicated?

A potentially confusing aspect is that there can be overlap between items in these categories. For example, RSS uses an ancillary "land mask" as an input to its SSS processing. Land corrections are applied to ensure the quality of coastal SSS data. RSS products also include land-related quality flags ranging from "light contamination" (i.e., removed from averaging in smoothed products) to "strong contamination" (i.e., masked altogether). Finally, RSS includes systematic errors from land contamination in its empirical uncertainty estimates.

WHAT'S IN A VERSION?

It is not uncommon for months (or years) to pass between gathering data, analyzing it, writing a manuscript, and publishing your results. In parallel, the SSS data processing community is working to update algorithms and improve its products.

New releases of SSS data products are accompanied by changes in version numbers. This [timeline](#) shows major release dates of three examples of SSS data products (i.e., De-biased SMOS Level 3, Aquarius RSS, and SMAP RSS). Interestingly, two versions of Aquarius data (V4, V5) were released after the satellite stopped operating on 07-Jun-15.

It is important to know which data version number(s) you are working with and be cognizant of new data releases that may occur while your manuscript is being reviewed. Even though the new data product will be better in quality, it may affect your results. **Consider contacting the data providers (e.g., PO.DAAC for NASA SSS data) about the timing of data release updates.**



Timeline of major release dates for three examples of SSS data products. Click image to enlarge.

SSS VALIDATION & SAMPLING DIFFERENCES

The accuracy of satellite-derived SSS measurements is largely validated by data from in-water sensors. Nonetheless, comparing the two is challenging for many reasons.

Timing is a challenge: Satellite observations need to be "matched up" with in-water data that has been collected at or near the sea surface within a few days of the satellite retrieval.

Spatial mismatch is another challenge. Satellite footprints cover tens of kilometers. Thus, a single satellite footprint may sample an area with non-uniform salinity (e.g., region with discrete patches of low salinity caused by recent rainfall). In-water salinity instruments, on the other hand, provide discrete "pinpoints" of salinity data.

Horizontal mismatches are only one part of the story. There are also differences in the depths where salinity is being measured. Satellite sensors retrieve from the very top of the ocean while in-water instruments measure salinity at greater depths.

Systematic sampling differences between satellite and in-water SSS data are sometimes referred to as "biases." **However, these sampling differences do not necessarily equate to errors in satellite**

retrievals. There can be physical reasons for the differences; for example, thin layers of low-salinity water, known as "floats" on the ocean surface. These "floats" would be detected by satellites, which measure salinity in the top centimeter of the ocean, but not by in-water sensors such as [Argo profiling floats](#) (Fig. 2). Profiling floats generally do not detect salinity shallower than 10 m.

Salinity retrieval is being aided by a relatively new type of in-water instrument, the [Salidrone](#) (Fig. 2). This instrument measures salinity at a depth of 0.6 m, closer to the sea surface and thus more indicative of conditions measured by satellites. Other novel SSS-measuring instruments have been employed in conjunction with satellite campaigns. These instruments are key to understanding discrepancies between "sea truth" data and satellites' SSS retrievals, which are fed back into processing algorithms to improve SSS data products.

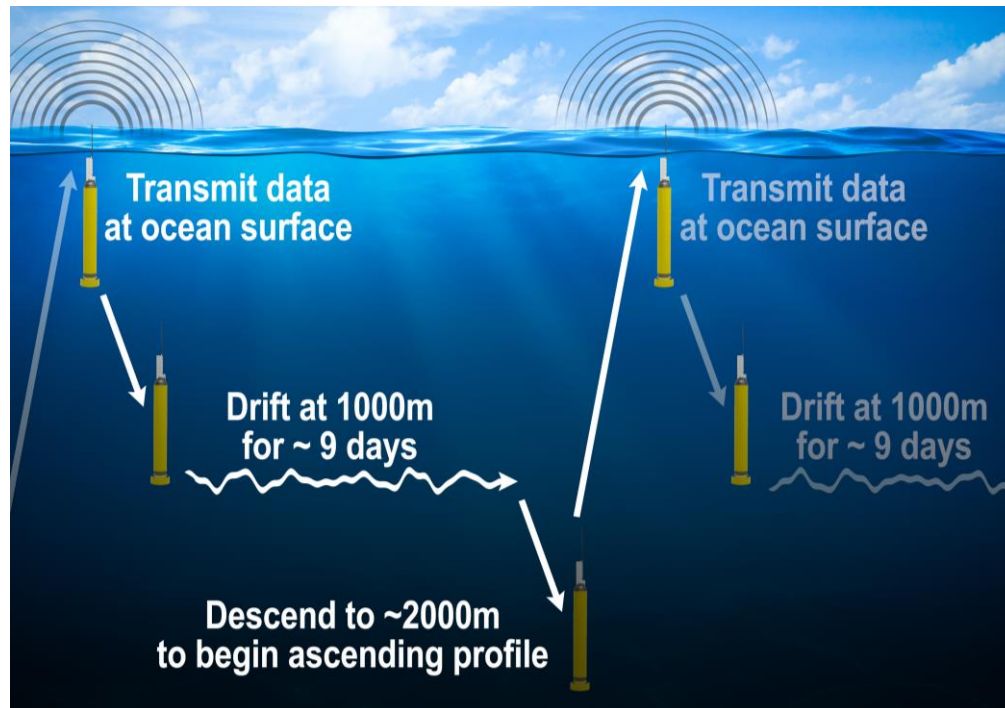
measuring temperature and salinity.

tool to provide high quality oceanic and atmospheric observations.

< Previous Next >

Which Salinity Data Are Best For You

- SSS Retrieval – It's Complicated
 - Sampling differences between in-water instruments and skin SSS from satellites is addressed, as is use of the term "bias."



SSS Retrieval – It's Complicated

Satellite salinity instruments measure natural microwave emission from the top 1 cm (or less) of ocean surface in terms of brightness temperature (T_b). These data are processed into SSS at various levels:

- **Level 1:** Radiometer observations at full resolution (1A) or processed to sensor units such as brightness temperature (1B);
- **Level 2:** Derived geophysical variables from Level 1 source data; and
- **Level 3:** Variables mapped on uniform space-time grid scales.

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Aquarius documentation roadmap.

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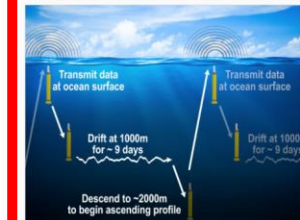


Figure 1. Argo floats drift at depth then rise to the surface while measuring temperature and salinity.



Figure 2. Saildrones – autonomous sailing drones – are used as a tool to provide high quality oceanic and atmospheric observations.

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Horizontal mismatches are only one part of the story. There are also differences in the depths where salinity is being measured. Satellite sensors retrieve from the very top of the ocean while in-water instruments measure salinity at greater depths.

Systematic sampling differences between satellite and in-water SSS data are sometimes referred to as "biases." **However, these sampling differences do not necessarily equate to errors in satellite SSS.** There can be physical reasons for the differences; for example, thin layers of low-salinity water that "float" on the ocean surface. These conditions would be detected by satellites, which measure T_b in the top centimeter of the ocean, but missed by sensors such as Argo profiling floats (Fig. 1) that generally do not detect salinity shallower than 3 – 5 meters.

SSS validation is being aided by a relatively new technology, [Saildrones](#) (Fig. 2). This instrument acquires salinity at a depth of 0.6 m, closer to the sea surface and thus more indicative of conditions detected by satellites. Other novel SSS-measuring technologies have been employed in conjunction with the [SPURS campaigns](#). These instruments are key to understanding discrepancies between "sea truth" data and satellites' SSS retrievals, which are fed back into processing algorithms to improve SSS data products.

Which Salinity Data Are Best For You?

- SMAP Data Processing by RSS and JPL
 - Similarities and differences between these processing streams are described (e.g., Q&A).
 - Detailed comparisons between RSS and JPL data products are available in the appendix.

Appendix B: SMAP SSS L2 Variables

[XXX] is ancillary data source; {Q#} is related quality flag

RSS (V4)		JPL (4.3)	
time	Seconds of observation since 2000-01-01 00:00:00 UTC	row_time	Approximate observation time for each SWC row as UTC seconds since 2015-01-01 0000 UTC
cellat	Geodetic latitude of grid cell	lat	Average latitude of all T_B observations for each SWC
cellon	Longitude of grid cell	lon	Average longitude of all T_B observations for each SWC
eia	Boresight Earth incidence angle	inc_aft, inc_fore	Average cell incidence angle of all aft and fore observations for each SWC, respectively {Q2}.
eea	Boresight Earth azimuth angle	azi_aft, azi_fore	Average cell azimuth angle (clockwise relative North) of all aft and fore observations included for each SWC, respectively.

salinity.oceansciences.org/data-salinity-appendix.htm

SMAP Processing Focus – RSS

The RSS processing approach is based on understanding – and correcting for – the antenna temperatures and variables in the geophysical environment that affect the salinity signal retrieval. The empirical calibration steps are outlined in the figure at right. Numbers correspond to Level 2 data fields, which are shown in detail in the Appendix. Visit the [SMAP SSS Products Overview and Ancillary Data Sources section](#) to learn more about how RSS and JPL process SMAP data.

Questions and Answers



Thomas Meissner, Ph.D.
Senior Research Scientist
Remote Sensing Systems (RSS)

- + What are the benefits of working closely with the salinity science community in terms of improving your products?
- + RSS and JPL have different approaches to processing data from the same instrument. What are the advantages of having data from both types of processing?
- + JPL has a 7-hour latency product. Is RSS considering adding near-real-time data to its future products?
- + What are some of the differences between RSS and JPL in terms of corrections (Galaxy Correction, high-latitude T_B Bias Adjustment, Reflector Emissivity Correction)?

SMAP Processing Focus – JPL

Salinity Wind Cells - JPL's SMAP salinity data product combines sea surface salinity (SSS) and wind speed. Time-ordered data are projected into swaths (Level 2A) whose along-track and cross-track coordinates are similar to longitude and latitude, respectively. These gridded data are, in turn, used to generate "Salinity Wind Cells" (SWCs).

Flavors - SMAP's spinning antenna results in some footprints acquired either to the fore or aft of the spacecraft. Also, the retrieved signals are horizontally and vertically polarized (H-pol and V-pol, respectively). JPL processing separately bookkeeps these four "flavors" of T_B for each SWC: Fore H-pol, Aft H-pol, Fore V-pol, and Aft V-pol. JPL's data fields are shown in detail in the Appendix.

JPL pre-processes collocations of HYCOM SSS, NOAA Optimum Interpolation SST, NOAA WaveWatch III Significant Wave Height, and SMAP Level 1 T_B data. For each SWC, land- and ice-contaminated data are flagged and removed before averaging. Averaged "four-flavor" composite T_B values with a small number of corrections (i.e., Galaxy Correction, high-latitude T_B Bias Adjustment, Reflector Emissivity Correction) are generated prior to Level 2B processing.

Both salinity and sea surface roughness affect sea surface emissivity and cannot be fully distinguished from one another. Thus, the two effects are combined during JPL processing but generated as two datasets (*smap_sss* for salinity and *smap_spd* for wind speed). SSS uncertainties are estimated from combined salinity and wind speed computations and include the effects of cold water, radio frequency interference (RFI), geophysical model function (GMF) errors, and measurement errors.

Data are provided in the case of "extreme winds" such as those associated with tropical storms. In these cases, salinity is fixed at the ancillary HYCOM value while the emissivity signal is attributed to winds. Users should be aware that errors in the ancillary salinity – e.g., areas with high salinity variability such as major river outflows - will map to erroneously high wind speed.

Visit the [SMAP SSS Products Overview and Ancillary Data Sources section](#) to learn more about how RSS and JPL process SMAP data.

Questions and Answers



Alexander Fore, Ph.D.
Signal Engineer
NASA Jet Propulsion Laboratory (JPL)

- + As can be inferred from Appendix A, JPL does not recalibrate the Level-2 brightness temperatures while RSS does a number of corrections related to the SMAP antenna. Any thoughts on the differences between your approaches?
- + As shown in Appendix B, JPL has fewer Level-2 variables than RSS. Why is that?
- + You put salinity and wind in the same data product (whereas RSS has a completely different wind product). Why did you decide to do it this way?

salinity.oceansciences.org/data-salinity-03.htm

salinity.oceansciences.org/data-salinity-04.htm

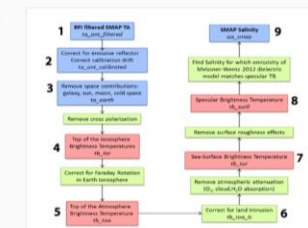
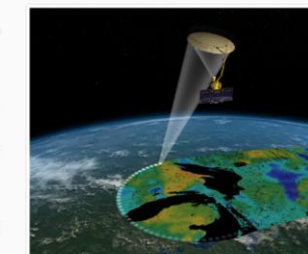


Figure 1. The empirical calibration steps in RSS processing.



Artist's rendering of the Soil Moisture Active Passive satellite. Credit: NASA/JPL-Caltech

Which Salinity Data Are Best For You?

- SMAP SSS Products Overview
 - Compares RSS and JPL products at a high level including ancillary data sources.
 - Data tools served by the Physical Oceanography Distributed Active Archive Center (PODAAC) are also featured here:
 - State of the Ocean
 - Live Access Server
 - Hi-level Tool for Interactive Data Extraction

SMAP SSS Products Overview

	SMAP	
	RSS (V4)	JPL* (4.3)
Antenna type	Spinning; 99% reflective (1% emissive)	
Global coverage / Repeat orbit	3 days / 8 days (exact)	
Data products available: <i>L2 is Level-2 swath L3 is Level-3 gridded</i>	L2C: Standard L3: 8-day Running Mean; Monthly	L2B: Standard; Near-real-time (6 hours) L3: 8-day Running Mean, Monthly
Gridding	0.25° x 0.25°	0.25° x 0.25°
Feature resolution	70 km**	~60 km**

* JPL's SMAP SSS data set is also referred to as the "Combined Active Passive (CAP)" product.
** SMAP's native 40-km variable is relatively noisy. As a result, SMAP products are spatially averaged to larger footprints (i.e., 70 km, 60 km) to reduce data noise, especially for open ocean applications.

SMAP Ancillary Data Sources

	RSS (V4)	JPL (4.3)
SST	GHRST Level 4 from Canadian Meteorological Center [CMC]	NOAA Optimum Interpolation [OI]
Atmospheric profile fields	NCEP GDAS 1-deg, 6-hour fields [GDAS]	N/A
Solar flux	Ancillary mean solar flux from NOAA Space Weather Prediction Center [SWPC]	N/A
Wind speed & direction	CCMP V2 [CCMP]	National Centers for Environmental Prediction Global Forecast System [GFS]
Land mask	ODPS static 1-km land/water mask from GSFC [ODPS]	US Geological Survey 30-second Land Use Data [USGS] integrated using SMAP antenna patterns
Rain	IMERG	Rain effect and rain roughness corrections are in development
Dielectric constant	Meissner and Wentz 2004, 2012	Meissner and Wentz 2004, 2012
Galactic map	Dinnat, E.; Le Vine, D.; Abraham, S.; Floury, N. Map of Sky Background Brightness Temperature at L-Band (2018)	Own derived galaxy correction (3.2.2 of User Guide)
Total electron content (TEC)	IGS IONEX TEC files [TEC]	N/A
Sea ice fraction	RSS Version 8 AMSR-2 ocean suite (Wentz et al., 2014) [RSS]	National Centers for Environmental Prediction [NCEP]
Argo salinity from Scripps Institution of Oceanography (SIO)	Included to facilitate comparison of rain-filtered SMAP SSS; not used in the actual salinity algorithm [SIO]	Used for comparison but not included in data files.
Reference salinity field	Hybrid Coordinate Ocean Model [HYCOM]	Hybrid Coordinate Ocean Model [HYCOM]
Significant wave height	N/A	NOAA WaveWatch III [WaveWatch III]

Level-3 Gridded Products

State of the Ocean (SOTO)

Live Access Server (LAS)

Level-2 Swath Products

HITIDE

SEARCH DATASETS GRANULE SELECTION DOWNLOADS

Search for datasets by date range, region, and parameter. Datasets selected in the results table will be available for submitting and pre-viewing in GRANULE SELECTION. Note: Dataset granules in GRANULE SELECTION will be constrained by the date range and region filters you apply below.

SELECT DATE RANGE SELECT REGION

Variable Sensor Provider

SEA SURFACE TEMPERATURE (S)

SURFACE WINDS (W)

SALINITY (S)

SEA SURFACE HEIGHT (S)

SIGNIFICANT WAVE HEIGHT (S)

Start Date End Date

Aug 24, 2011 Jun 7, 2015

Mar 31, 2015 Today

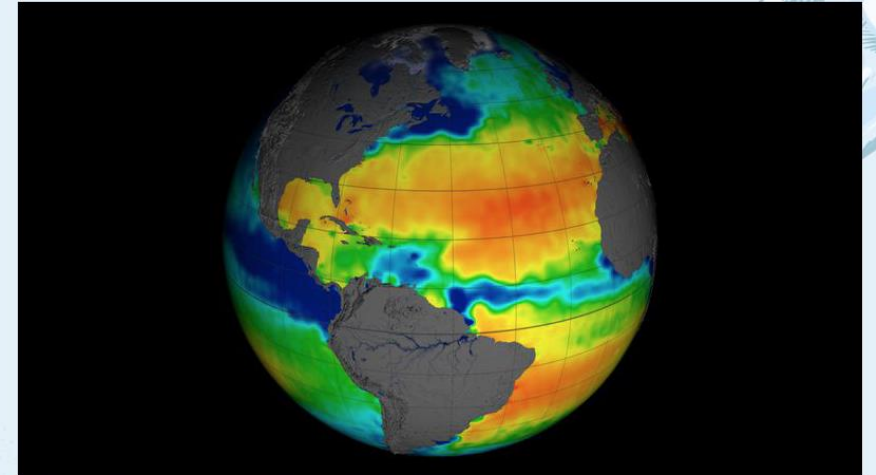
High-level Tool for Interactive Data Extraction

High-level Tool for Interactive Data Extraction (HITIDE)

« Previous Next »

How Salty (or Fresh) Are You?

- Quiz proposed during 2019 OSST meeting
 - Participants answer multiple-choice questions about their personal preferences:
 - Visibility at a party venue (light conditions, or depth within the water column)
 - Food choices (saltiness)
 - Thermostat settings (temperature)
 - Environmental change (levels of stability)



How Salty (or Fresh) Are You?

Find out by answering four questions.

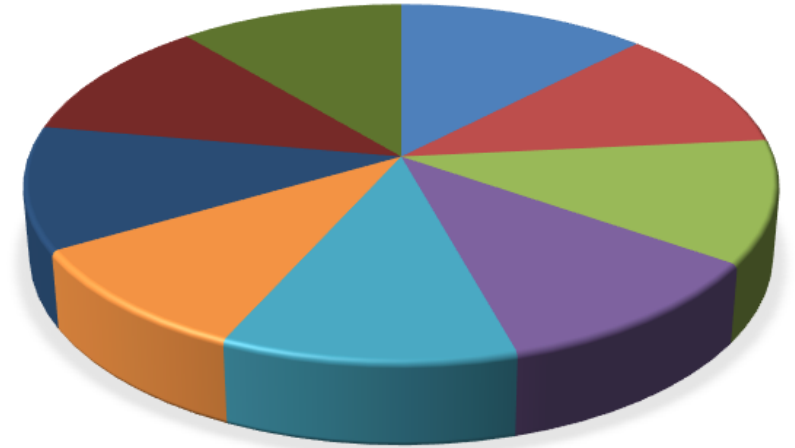
GET STARTED

press Enter ↵

How Salty (or Fresh) Are You?

- Quiz results match responders with one out of nine possible outcomes.
- Pie chart shows that the *possible outcomes** are evenly distributed among the nine outcomes.
 - **Probability of individuals receiving a specific outcome based on combination of answers to the four quiz questions.*

Possible Outcomes



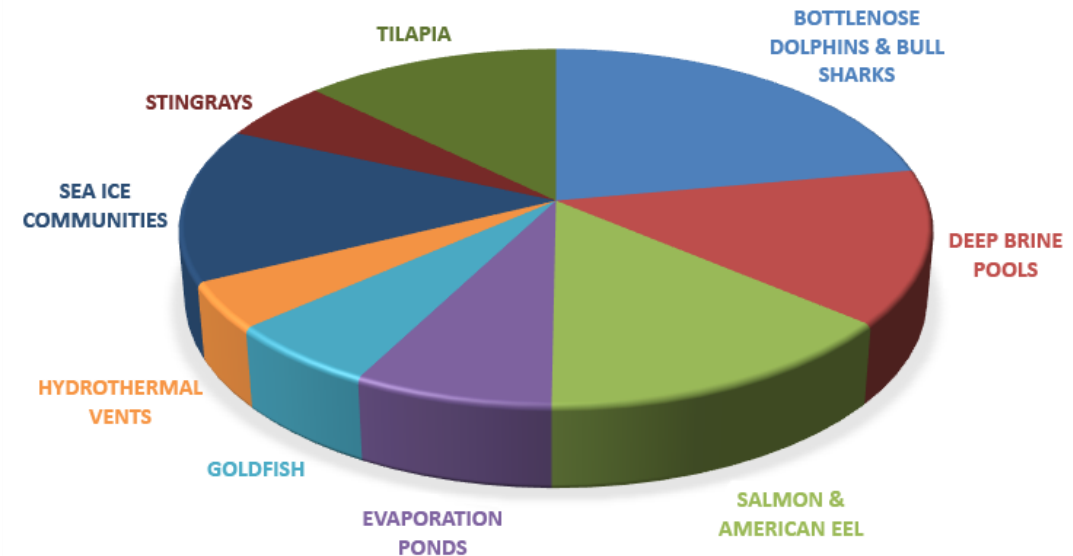
How Salty (or Fresh) Are You?

- People's preferences are not random!
- Responders tend to identify with:
 - *Bottlenose Dolphins & Bull Sharks*
 - *Deep Brine Pools*
 - *Salmon & American Eel*
 - *Sea Ice Communities*
- Less common outcomes:
 - *Goldfish*
 - *Hydrothermal Vents*
 - *Stingrays*

Possible Outcomes

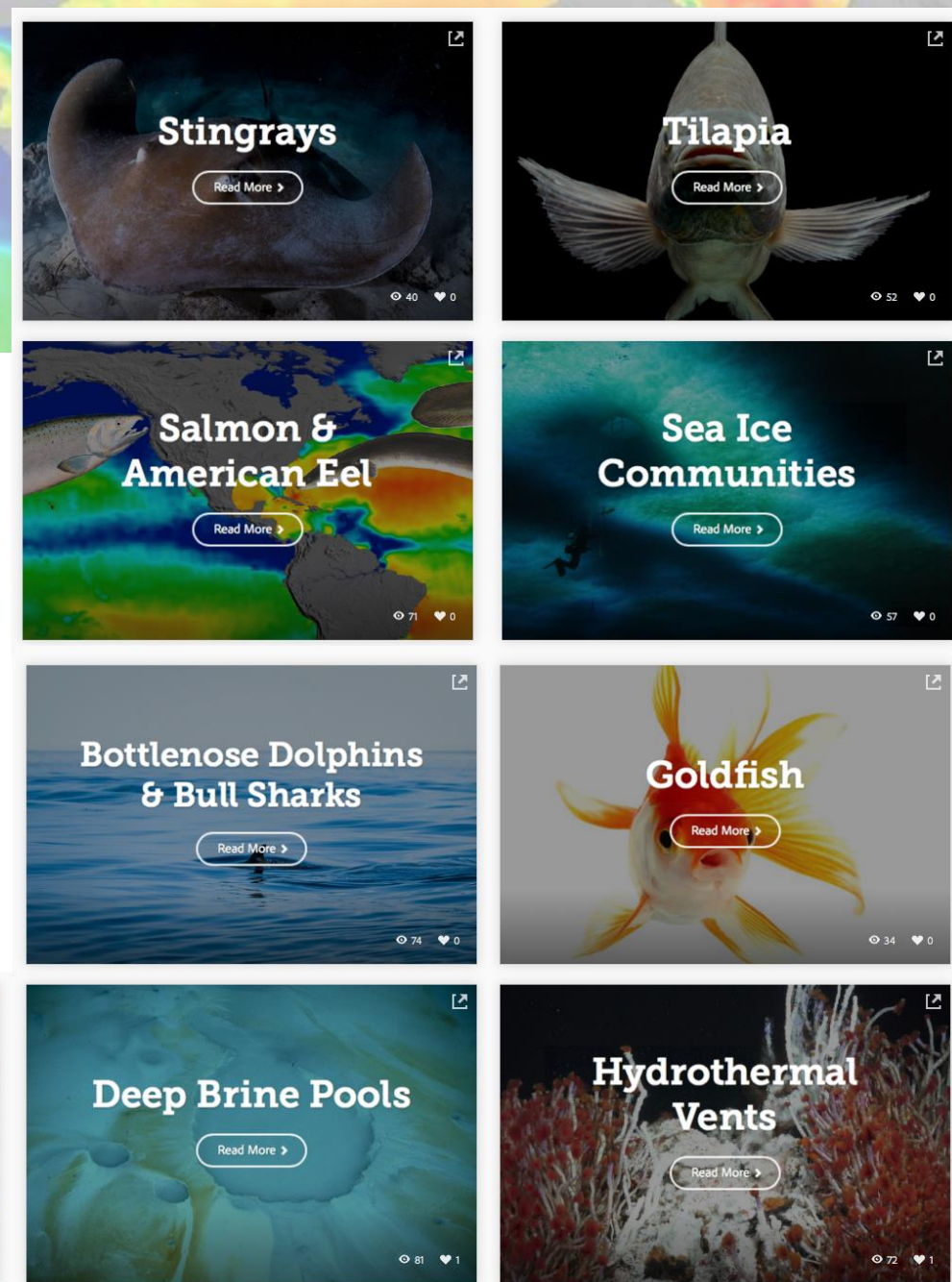


Survey Results



How Salty (or Fresh) Are You?

- Information about each organism or habitat is presented as an interactive multimedia e-brochure.
 - These stories weave in connections to salinity research and items of historical interest.
 - E-brochures have been viewed over 500 times.
- Maybe incorporate the quiz (or e-brochures' content) in your next talk?



Learn More

- New section of website with learning resources.
- Arranged by topic:
 - *The Role Of Salt*
 - *Following The Water Cycle*
 - Shown in detail on next slide
 - *Density And Ocean Circulation*
 - *Salinity's Connections To Climate*
 - *Measuring Salinity*

The Role Of Salt
More than just a seasoning

Following The Water Cycle
Vital to life - critical to understand

Density And Ocean Circulation
Salinity and temperature drive the ocean's motion

Salinity's Connections To Climate
Salinity - a driving force for weather and climate

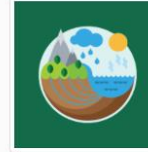
Measuring Salinity
The perspective from space

Learn More

- Variety of materials:
 - Hands-on activities
 - Online resources
 - Video clips from salinity webinars (*Hear from a scientist*)
 - Data images
 - FAQs
- If you have learning resources to share or recommend, please let me know!

Following the Water Cycle

The amount of dissolved salt in the ocean is relatively stable. However, the flux of freshwater into and out of the sea is always changing. Salinity patterns help to discern the water cycle over the ocean, where most of the world's evaporation and precipitation occurs.



Sea surface salinity is key to understanding how freshwater moves into and out of the ocean system. Using satellite data from Aquarius and SMAP, scientists are now able to relate salinity variations to evaporation and precipitation, providing insight into how the ocean responds to seasonal and annual changes in the water cycle. Use the resources on this page to learn more about how water circulates around the globe.

What's New

[12-Aug-18] **Earth's Water Cycle** - This animation uses Earth science data to describe Earth's water cycle. [View >](#)

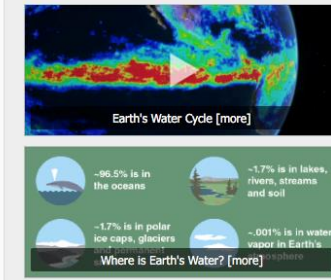
[15-July-18] **Where is Earth's Water?** - Learn about water on Earth. [View >](#)



The Water Cycle [more]

The Water Cycle

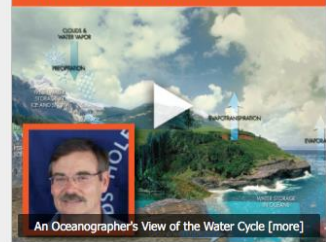
Introducing the water cycle.



Where is Earth's Water?

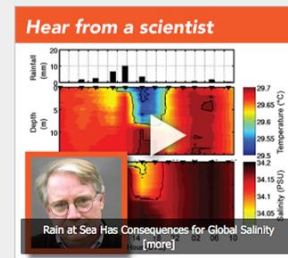
Water is practically everywhere on Earth.

Hear from a scientist



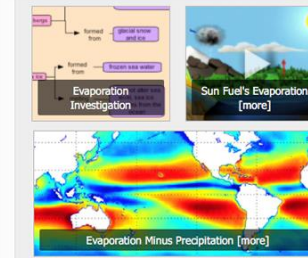
An Oceanographer's View of the Water Cycle

Dr. Raymond Schmitt walks us through water's journey around the globe.



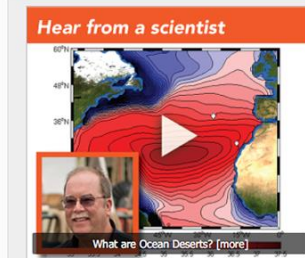
Rain's Impact

Dr. Stephen Riser discusses rain's impact on global salinity.



Evaporation

Evaporation in the ocean is driven by energy from the sun.



Ocean Deserts

Dr. Eric Lindstrom explains how the ocean can have a "desert."



Tracking Water by Satellite

Ocean-sensing satellites complement in-situ technology.

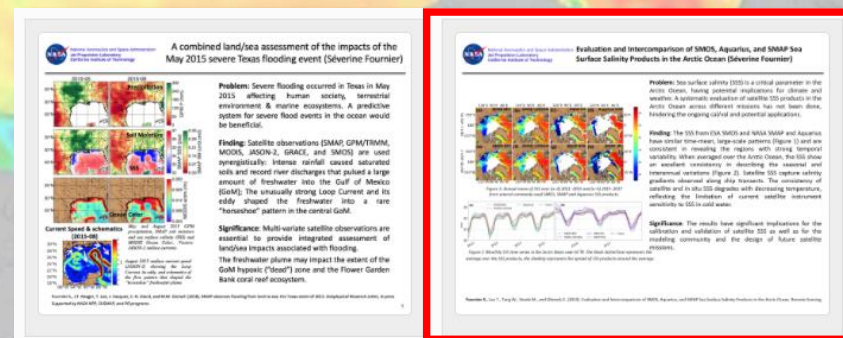
FAQs

- 🚩 In the global water cycle, is "salty" good?
- 📍 Why does the Atlantic Ocean have more evaporation?
- ⚡ What insights have been gained to better understand the Earth's water cycle and changing weather patterns?

salinity.oceansciences.org/learn-cycle.htm

Highlights – Research One-pagers

- Template includes:
 - Large graphic
 - Problem being addressed and motivation
 - Method
 - Key finding(s)
 - Broader significance or implications
 - Publication source
- NASA HQ would like to see more of these!
- Tony Lee or I can provide the template and feedback on draft versions, if desired.



Author Title Date SORT

Evaluation and Intercomparison of SMOS, Aquarius, and SMAP Sea Surface Salinity Products in the Arctic Ocean (Séverine Fournier)

Problem: Sea surface salinity (SSS) is a critical parameter in the Arctic Ocean, having potential implications for climate and weather. A systematic evaluation of satellite SSS products in the Arctic Ocean across different missions has not been done, hindering the ongoing cal/val and potential applications.

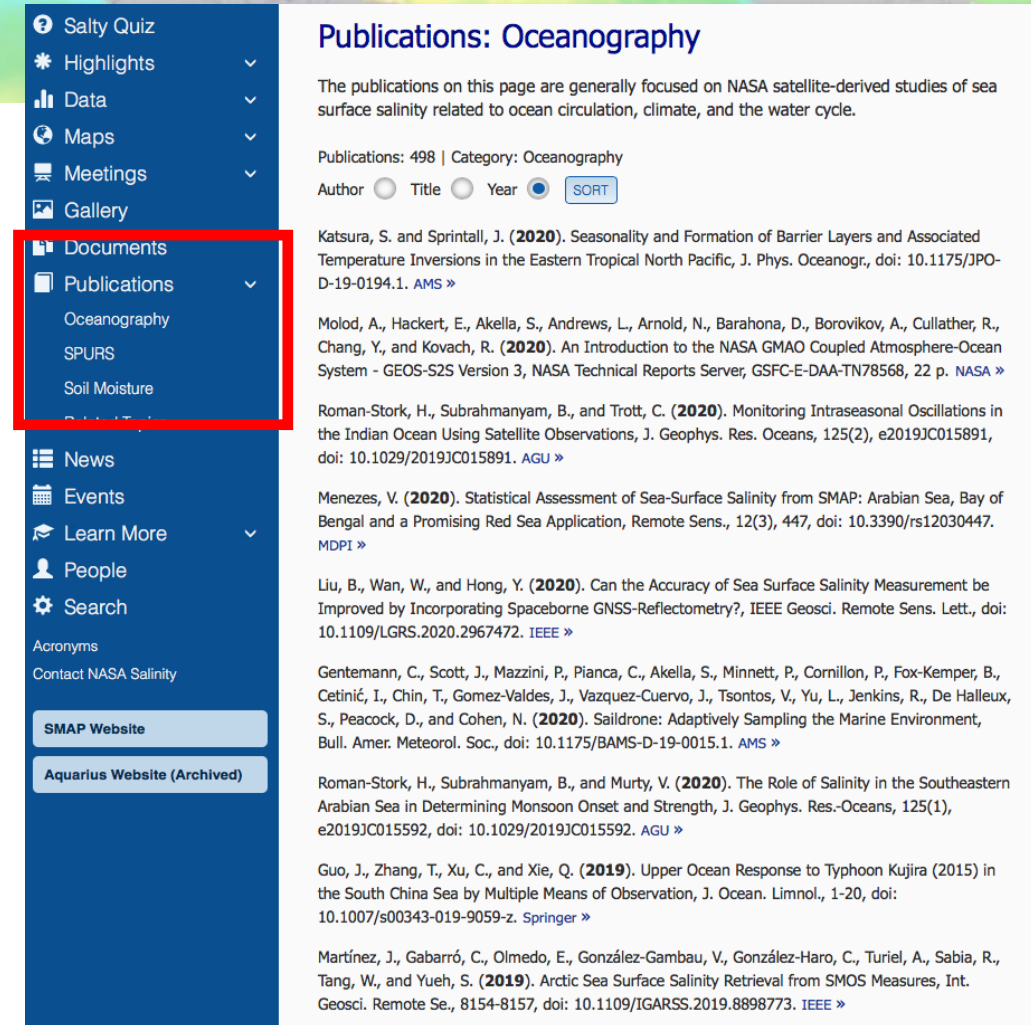
Finding: The SSS from ESA SMOS and NASA SMAP and Aquarius have similar time-mean, large-scale patterns (Figure 1) and are consistent in revealing the regions with strong temporal variability. When averaged over the Arctic Ocean, the SSS show an excellent consistency in describing the seasonal and interannual variations (Figure 2). Satellite SSS capture salinity gradients observed along ship transects. The consistency of satellite and in situ SSS degrades with decreasing temperature, reflecting the limitation of current satellite instrument sensitivity to SSS in cold water.

Significance: The results have significant implications for the calibration and validation of satellite SSS as well as for the modeling community and the design of future satellite missions.

Fournier S., Lee T., Tang W., Steele M., and Olmsted E. (2019). Evaluation and Intercomparison of SMOS, Aquarius, and SMAP Sea Surface Salinity Products in the Arctic Ocean. Remote Sensing, 17-Dec-19 | Fournier, S. Evaluation and Intercomparison of SMOS, Aquarius, and SMAP Sea Surface Salinity Products in the Arctic Ocean [PDF, 1.6 MB]

Publications Update

- New approach to finding and posting publications:
 - Receive “Google Scholar” alerts each week.
 - Review paper for relevancy.
 - Tag based on these topics:
 - *Oceanography*
 - *SPURS*
 - *Soil Moisture*
 - *Related Topics*
- We’re also looking for papers with societal implications to feature on the website!



Publications: Oceanography

The publications on this page are generally focused on NASA satellite-derived studies of sea surface salinity related to ocean circulation, climate, and the water cycle.

Publications: 498 | Category: Oceanography

Author Title Year

Katsura, S. and Sprintall, J. (2020). Seasonality and Formation of Barrier Layers and Associated Temperature Inversions in the Eastern Tropical North Pacific, *J. Phys. Oceanogr.*, doi: 10.1175/JPO-D-19-0194.1. [AMS »](#)

Molod, A., Hackert, E., Akella, S., Andrews, L., Arnold, N., Barahona, D., Borovikov, A., Cullather, R., Chang, Y., and Kovach, R. (2020). An Introduction to the NASA GMAO Coupled Atmosphere–Ocean System - GEOS-S2S Version 3, NASA Technical Reports Server, GSFC-E-DAA-TN78568, 22 p. [NASA »](#)

Roman-Stork, H., Subrahmanyam, B., and Trott, C. (2020). Monitoring Intraseasonal Oscillations in the Indian Ocean Using Satellite Observations, *J. Geophys. Res. Oceans*, 125(2), e2019JC015891, doi: 10.1029/2019JC015891. [AGU »](#)

Menezes, V. (2020). Statistical Assessment of Sea-Surface Salinity from SMAP: Arabian Sea, Bay of Bengal and a Promising Red Sea Application, *Remote Sens.*, 12(3), 447, doi: 10.3390/rs12030447. [MDPI »](#)

Liu, B., Wan, W., and Hong, Y. (2020). Can the Accuracy of Sea Surface Salinity Measurement be Improved by Incorporating Spaceborne GNSS-Reflectometry?, *IEEE Geosci. Remote Sens. Lett.*, doi: 10.1109/LGRS.2020.2967472. [IEEE »](#)

Gentemann, C., Scott, J., Mazzini, P., Pianca, C., Akella, S., Minnett, P., Cornillon, P., Fox-Kemper, B., Cetinić, I., Chin, T., Gomez-Valdes, J., Vazquez-Cuervo, J., Tsonos, V., Yu, L., Jenkins, R., De Halleux, S., Peacock, D., and Cohen, N. (2020). Saildrone: Adaptively Sampling the Marine Environment, *Bull. Amer. Meteorol. Soc.*, doi: 10.1175/BAMS-D-19-0015.1. [AMS »](#)

Roman-Stork, H., Subrahmanyam, B., and Murty, V. (2020). The Role of Salinity in the Southeastern Arabian Sea in Determining Monsoon Onset and Strength, *J. Geophys. Res.-Oceans*, 125(1), e2019JC015592, doi: 10.1029/2019JC015592. [AGU »](#)

Guo, J., Zhang, T., Xu, C., and Xie, Q. (2019). Upper Ocean Response to Typhoon Kujira (2015) in the South China Sea by Multiple Means of Observation, *J. Ocean. Limnol.*, 1-20, doi: 10.1007/s00343-019-9059-z. [Springer »](#)

Martínez, J., Gabarró, C., Olmedo, E., González-Gambau, V., González-Haro, C., Turiel, A., Sabia, R., Tang, W., and Yueh, S. (2019). Arctic Sea Surface Salinity Retrieval from SMOS Measures, *Int. Geosci. Remote Se.*, 8154-8157, doi: 10.1109/IGARSS.2019.8898773. [IEEE »](#)

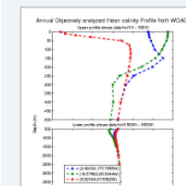
What's Next?

- *Which Salinity Are Best For You?*
 - Ready to go live now. Or send to team for a short review period?
 - Consider whether/how to add Pi-MEP.
- Find ways to broaden quiz participation.
- New website features in the works:
 - Interactive timeline about the history of SSS.
 - See format at pace.oceansciences.org/timeline.htm
 - Updating salinity tools developed for Aquarius.

www.salinity-pimep.org

Historical Ocean Data

We have developed a set of interactive tools to explore historical salinity, temperature, and density data sets (2005 NOAA World Ocean Atlas & Database for the "Flat Map Interface" and 2009 NOAA World Ocean Atlas & Database for the "GoogleEarth Interface"). These data are available as the following three distinct yet complementary tools:



Annual Mean Data

Maps of salinity, temperature, or density data averaged over a year can be clicked to create in-water profiles at up to six locations. Plotted data will also be displayed in a table (and downloadable as Excel files). Sources include interpolated atlas data (i.e., data gaps are filled in) or actual measurements from the database (i.e., data gaps are not filled in).

[FlatMap Interface](#)

[Tutorial](#)

Questions That Can Be Explored Using This Tool

- Does salinity vary with depth?
- For the three locations explored in the previous question, does temperature vary with depth?
- For the three locations explored in the previous question, does density vary with depth?
- Compare profiles salinity, temperature, and density with depth: which is the most consistent?
- What is the relationship between salinity, temperature, and density?

aquarius.oceansciences.org/cgi/ed_aq_datatool.htm

Questions?

- ✓ *Which Salinity Are Best For You?*
- ✓ *How Salty (or Fresh) Are You?*
- ✓ *Learn More*
- ✓ *Highlights – Research One-pagers*
- ✓ Publications Update
- ✓ What's Next?

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