Proposal to the

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International Teams in Space Science

Generation of Climate Data Records of Sea-Surface Temperature from current and future satellite radiometers

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Abstract

We propose an ISSI study project on the Generation of Climate Data Records (CDRs) of Sea-Surface Temperature (SST) from current and future satellite radiometers, drawing on expertise of specialists from Europe, China and the USA.

Unlike many critical parameters in the earth's climate system the SST is a well-defined variable with a correspondence to an SI standard unit. It has been declared an Essential Climate Variable. Thus, the generation of Climate Data Records of SST is both of great importance and also tractable, at least in principle. In practice a pathway exists if the SST retrieval uncertainties are determined using accurate ship-based radiometers with calibration traceable to National Metrology Institute (NMI) standards, such those maintained by the National Physical Laboratory (NPL) in the UK and the National Institute of Standards and Technology (NIST) in the USA.

Time series of measurements intended for use in Climate Research are referred to as "Climate Data Records" (CDRs), which have been defined as "a data set designed to enable study and assessment of long-term climate change, with 'long-term' meaning year-to-year and decade-to-decade change. Climate research often involves the detection of small changes against a background of intense, short-term variations" (NRC 2000). It is important to continue validation efforts over the lifetimes of the spacecraft sensors to ensure that the effects of degradation of the instruments in orbit are not misinterpreted as being caused by environmental signals (NRC 2000). In generating time series of surface temperatures that span several satellite missions, the role of validation includes providing the necessary continuity in the derived fields.

The ISSI Study Project would build on a series of three infrared radiometers workshops held at the Rosenstiel School of Marine and Atmospheric Science (RSMAS), University of Miami, in collaboration with the US NIST to cross-calibrate ship-mounted, self-calibrating infrared radiometers used to validate the satellite SST. Another objective was to provide traceability of calibration to NMI SI standards. At these workshops, the radiometers were calibrated in the laboratory against black-body calibration devices that were in turn characterized by the NIST Transfer Radiometer (TXR). The measurements of the radiometers were then compared in the field, either from the RSMAS jetty, or, in the 2001 workshop, on the RSMAS research vessel. The most recent workshop was held in Miami in May 2009, in coordination with a laboratory blackbody calibration comparison held at the UK National Physical Laboratory.

The proposed ISSI Study Project will bring together scientists active in the field of satellite remote sensing of SST and ship-based radiometry with those from NMIs to establish the procedures for the consistent generation of CDRs of SSTs. We intend that the coordinated group activities will result in submissions to the peer-reviewed literature. This is a very timely effort given the imminent launch of new generations of satellite radiometers on NASA and ESA satellites, which have the potential of extending the time series of SST fields derived from Earth Observation Satellites into future decades.

Scientific Rationale

There are uncertainties associated with all measurements, and the magnitude of the uncertainties imposes restrictions on how the measurements should be applied or interpreted. The uncertainties can result from a variety of causes that relate to the nature of the variable being measured, and how the measurements are made. Furthermore, the techniques employed to assess the magnitude and characteristics of the uncertainties are also prone to error, and thus contribute to the overall uncertainty budget, which is conventionally attributed as a satellite SST retrieval error.

For sea-surface temperature (SST) derived from measurements taken by infrared radiometers on earth-observing satellites, the sources of uncertainties can be divided into those that result from the characteristics of the radiometer, and how well the measurements are calibrated, and those that arise from imperfections in the atmospheric correction algorithm that is applied to remove the effects of the intervening atmosphere, including identifying the effects of clouds and aerosols.

The application with the most demanding accuracy requirement is "climate research" where a multi-decadal time series of global SSTs is required to detect small changes that are expected to reveal the response of the climate to changing radiative forcing. Analysis of a time-series of SSTs to search for signatures of climate change will not lead to a convincing result if the uncertainties associated with the measurements are larger than the anticipated signal, which is likely to be <0.2K decade^{-1}. This requires 15-20 years of consistent and accurate SSTs with uncertainties <0.3K (Ohring et al. 2005).

The radiance measured in space by infrared radiometers has its origin in the skin layer of the ocean and not in the body of the water below, the "bulk temperature" of which is what is measured by in situ thermometers below the surface. The near-surface temperature gradients result from three distinct processes: the absorption of insolation, the heat exchange with the atmosphere and levels of subsurface turbulent mixing. In conditions of low wind speed, the heat generated in the upper ocean by the absorption of solar radiation is not well mixed through the surface layer, but causes thermal stratification with temperature differences between the uppermost layer of the ocean and the water below. There is a strong diurnal component to the magnitude of these temperature gradients, as well as a dependence on cloud cover, which modulates the insolation, and, importantly, wind speed which influences the turbulent mixing (e.g. Price et al. 1986; Fairall et al. 1996; Gentemann and Minnett 2008). The surface, skin layer of the ocean, much less than one millimeter thick (Hanafin 2002; Hanafin and Minnett 2001), is nearly always cooler than the underlying water because the heat flux is nearly always from the ocean to the atmosphere. The heat flow, supplying energy for both the turbulent and radiant heat loss to the atmosphere, is accomplished by molecular conduction through the aqueous side of the interface and this is associated with a temperature gradient in the surface skin layer. The relationship between skin and bulk SSTs just below the surface (at ~5cm) is reasonably well behaved (Minnett et al. 2011). The relationship with deeper bulk temperature, at depths of a few meters where many bulk SST measurements are taken, is the same on average during the night, and during the day for wind speed conditions of >~6ms^{-1} (Donlon et al. 2002). But under low winds the relationship is very variable - vertically, horizontally and temporally (Minnett 2003; Ward 2006). The difference between the skin temperature and that measured by a bulk, in situ thermometer is strongly dependent on the depth of the bulk measurement. Use of the bulk temperature for satellite-validation introduces these near-surface gradients into the error budget of the satellite retrieval and leads to an over-estimate of the uncertainties (Kearns et al., 2000). Physical models of the growth and decay of the diurnal thermocline (e.g. Woods and Barkmann, 1986; Price et al., 1986; Schiller and Godfrey, 2005; Gentemann et al. 2009) require high temporal resolution forcing fields to produce reliable predictions, and this is a limitation on their use in relating bulk to skin temperatures for the validation of satellite-derived SSTs.

Given that CDRs of SST span several satellite missions, ensuring that the validating measurements are themselves accurate over the CDR period is of prime importance. Without this assurance, systematic changes in the characteristics of the data sets used to validate the satellite SSTs could be misinterpreted as systematic changes in the upper ocean, and the climate. The only way of ensuring this stability in the calibration of the sensors used to provide the validation data is to have a traceable calibration chain to a national SI temperature standard.

The validation of SSTs with infrared radiometers can be done using instruments mounted on ships (e.g. Kearns et al. 2000; Noyes et al. 2006). For the highest quality data to be used in the validation of satellite SSTs, the ship-based radiometers must be mounted on the ships so they have a clear view of the sea surface ahead of the ship's bow wave. Otherwise they do not take measurements of the skin SST undisturbed by the presence of the ship. Because the emissivity of the sea surface is not unity, a small component of the signal measured by the radiometer when it is directed at the sea surface is reflected sky radiance. To correct for this a measurement of the downwelling atmospheric radiance is required and thus, the validating instrument must be able to view the sky at the same angle to zenith as the sea view is inclined to nadir. The radiometers on the ships must be calibrated throughout the field deployment using internal calibration targets; and the calibration procedure should be checked using laboratory facilities before and after each deployment. Consistency of practice by all groups taking such measurements is important to ensure the generation of accurate and compatible data.

The key to the generation of an SST CDRs lies in the calibration of the ship-based radiometers. The path to national temperature standards for satellite-derived SSTs, therefore, is through the calibration of the radiometers used to validate the satellite retrievals, and this requires, and provides, radiometric traceability to national standards. The national reference standards are maintained by the NPL in the UK and NIST in the USA.

As part of the pre-launch characterization of the satellite radiometers, they are carefully calibrated in thermal-vacuum chambers to replicate the conditions on orbit. The pre-launch calibration is traceable to national standards, but the satellite radiometers are never recovered at the end of the mission for recalibration and re-characterization. To ensure traceability to NIST standards, an infrared calibration facility has been set up at RSMAS at the University of Miami. Three international workshops have been held at which many of the ship-board radiometers used to validate satellite-derived SSTs were calibrated using a water-bath blackbody calibration target, built to a NIST design (Fowler 1995). The internal calibration of ship-board radiometers is assessed by pointing them into the cone of the water-bath blackbody calibration target. The radiation emerging from the cone depends not only on its temperature, as given by the thermometers in the water bath, but also on its emissivity. The emissivity was determined, and hence the calibration system characterized, by the NIST Transfer Radiometer (TXR; Rice and Johnson 1998), which is the infrared radiometric standard for the NASA Earth Observing System program (Rice and Johnson 1996). The TXR was also used to characterize the laboratory blackbody calibrators used elsewhere to check the internal calibration of the ship-deployed radiometers (Rice et al. 2004).

Goals and Outcomes of the ISSI Study Project

The goals of the ISSI Study Project are to bring experts together in a secluded environment to:

1. Review of the results of the three Miami infrared workshops and lay the groundwork for the next series of workshops to be held in the USA or Europe.
2. Review the current “state of the art” of satellite SST retrieval uncertainties, and identify the contributions to the satellite-derived uncertainty budget from the validating radiometers, and from the method of validation.
3. Revisit the specifications for future SST validation radiometers.
4. Establish and publish a Best Practices Handbook for validation of satellite-derived SSTs.
5. Ensure the steps to establishing SST CDRs are rigorous and well-understood by those involved in this activity.
6. Make longer term, coordinated plans to validate new satellite radiometers – VIIRS on NPP and JPSS, and SLSTR on Sentinel-3.
7. Coordinate the validation of the satellite-derived SSTs within the framework of the CEOS QA4EO.
8. Examine the initial validation results of the VIIRS on NPP.
9. Finalize publications arising from the Study Projects.

Much of the fundamental research and field programs that will provide the framework of the ISSI meetings are underway with funding from national sources. The research and the transition of results into the operational community is facilitated through the Group for High Resolution SST (GHRSST; Donlon et al. 2009) in which any of the participants in the proposed Study Project are active. A newly constituted SST Science Team, formed under aegis of the NASA Physical Oceanography Program, provides a loose framework and discussion forum for a large group of active researchers. The role of the proposed ISSI Study Project is to coordinate the effort and facilitate activities of a small subgroup of the satellite SST community concerned with the generation of CDRs of SST. The value of the ISSI involvement is to provide a forum for focused and dedicated discussions, analysis, and paper preparation.

The outcome will be a handbook of Best Practices and papers submitted to the peer-reviewed literature; potential titles of papers are:

> “Demonstrating traceability to SI in deriving climate data records: An example using sea-surface temperature”

> "Accuracy of satellite-derived sea-surface temperatures derived from multi-decadal time series from multiple satellite sensors"

Schedule

It is envisioned to hold three, three-five day workshops at ISSI, spanning an 18-24 month period beginning in the autumn of 2011, at about the launch of NPP (October 2011). Subsequent workshops would be at 8-12 month intervals. The main foci of each workshop will be the above topics in groups of three as listed, with overlap to review progress.

Participants

Dr Peter Minnett (Team Leader)	University of Miami, USA
Dr Gary Corlett (Co-leader)	University of Leicester, UK
Mr Werenfrid Wimmer	University of Southampton, UK
Dr Tim Nightingale	Rutherford Appleton Laboratory, UK
Dr Nigel Fox	National Physical Laboratory, UK
Dr Craig Donlon	ESA-ESTEC, NL
Dr Andrew Jessup	University of Washington, USA
Dr Gary Wick	NOAA Earth System Research Laboratory, USA
Dr Chelle Gentemann	Remote Sensing Systems, USA
Dr Sandra Castro	University of Colorado, USA
Dr Simon Hook	NASA Jet Propulsion Laboratory, USA
Dr Bob Evans	University of Miami, USA
Mrs Anne O'Carroll	EUMETSAT, DE
Dr Lei Guan	Ocean University of China, CN

Because of other commitments, it is not expected that all participants will be able to attend all ISSI meetings, and communications via email will ensure the group cohesion. It is expected that about six to eight of the participants would be able to attend each of the ISSI meetings.

Facilities required

It is anticipated each participant will bring their own computer, but internet access at ISSI would be needed. A meeting room with a white board and computer projector with a table large enough to accommodate discussions of the entire group would be required. Smaller, quiet offices where small subgroups could work would be advantageous.

Financial Support Requested

In accordance with the ISSI guidelines, requested financial support will be limited to travel costs of the Team Leader and hotel and per-diem expenses of the participants while in Bern for the ISSI meetings.

References cited

Donlon, C. J., P. J. Minnett, C. Gentemann, T. J. Nightingale, I. J. Barton, B. Ward, and J. Murray, 2002: Toward improved validation of satellite sea surface skin temperature measurements for climate research. *Journal of Climate*, **15,** 353-369.

Donlon, C. J., and Coauthors, 2009: The GODAE High-Resolution Sea Surface Temperature Pilot Project. *Oceanography*, **22,** 34-45.

Fairall, C., E. Bradley, J. Godfrey, G. Wick, J. Edson, and G. Young, 1996: Cool-skin and warm-layer effects on sea surface temperature. *Journal of Geophysical Research.*, **101,** 1295-1308.

Fowler, J. B., 1995: A third generation water bath based blackbody source. *Journal of Research of the National Institute of Standards and Technology*, **100,** 591-599.

Gentemann, C. L., and P. J. Minnett, 2008: Radiometric measurements of ocean surface thermal variability. *Journal of Geophysical Research*, **113,** C08017.

Gentemann, C. L., P. J. Minnett, and B. Ward, 2009: Profiles of Ocean Surface Heating (POSH): a new model of upper ocean diurnal thermal variability. *Journal of Geophysical Research*, **114,** C07017.

Hanafin, J. A., 2002: On sea surface properties and characteristics in the infrared. Ph.D., Meteorology and Physical Oceanography, University of Miami, 111 pp.

Hanafin, J. A., and P. J. Minnett, 2001: Profiling temperature in the sea surface skin layer using FTIR measurements. *Gas Transfer at Water Surfaces.*, M. A. Donelan, W. M. Drennan, E. S. Saltzmann, and R. Wanninkhof, Eds., American Geophysical Union Monograph, 161-166.

Kearns, E. J., J. A. Hanafin, R. H. Evans, P. J. Minnett, and O. B. Brown, 2000: An independent assessment of Pathfinder AVHRR sea surface temperature accuracy using the Marine-Atmosphere Emitted Radiance Interferometer (M-AERI). *Bulletin of the American Meteorological Society*, **81,** 1525-1536.

Minnett, P. J., 2003: Radiometric measurements of the sea-surface skin temperature - the competing roles of the diurnal thermocline and the cool skin. *International Journal of Remote Sensing*, **24,** 5033-5047.

Minnett, P. J., M. Smith, and B. Ward, 2011: Measurements of the oceanic thermal skin effect. *Deep Sea Research Part II: Topical Studies in Oceanography*, **58,** 861-868.

Noyes, E. J., P. J. Minnett, J. J. Remedios, G. K. Corlett, S. A. Good, and D. T. Llewellyn-Jones, 2006: The Accuracy of the AATSR Sea Surface Temperatures in the Caribbean. *Remote Sensing of Environment*, **101,** 38-51.

NRC, 2000: *Issues in the Integration of Research and Operational Satellite Systems for Climate Research: II. Implementation.* National Academy of Sciences, 82 pp.

Ohring, G., B. Wielicki, R. Spencer, B. Emery, and R. Datla, 2005: Satellite Instrument Calibration for Measuring Global Climate Change: Report of a Workshop. *Bulletin of the American Meteorological Society*, **86,** 1303-1313.

Price, J. F., R. A. Weller, and R. Pinkel, 1986: Diurnal cycling: observations and models of the upper ocean response to diurnal heating, cooling and wind mixing. *Journal of Geophysical Research*, **91,** 8411-8427.

Rice, J. P., and B. C. Johnson, 1996: A NIST Thermal Infrared Transfer Standard Radiometer for the EOS Program. *The Earth Observer*, **8,** 31.

Rice, J. P., and B. C. Johnson, 1998: The NIST EOS Thermal-Infrared Transfer Radiometer. *Metrologia*, **35,** 505-509.

Rice, J. P., and Coauthors, 2004: The Miami2001 Infrared Radiometer Calibration and Intercomparison: 1. Laboratory Characterization of Blackbody Targets. *Journal of Atmospheric and Oceanic Technology*, **21,** 258-267.

Ward, B., 2006: Near-Surface Ocean Temperature. *Journal of Geophysical Research*, **111,** C02005.

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Higher Education

Oxford University, UK, B.A. Physics, 1973
Southampton University, UK, M.Sc. Oceanography, 1975
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Experience

University of Miami	Professor	1999 to present
University of Miami	Research Professor	1995 to 1999
North Carolina State University	Adjunct Professor	1994 to 1999
State University of New York at Stony Brook	Adjunct Associate Professor	1994 to 1999
Brookhaven National Laboratory	Scientist	1990-1995
NATO Saclant Undersea Research Centre	Principal Scientist	1985-1990
Rutherford Appleton Laboratory, UK	Senior Scientific Officer	1981-1985
Christian-Albrechts University, Kiel, Germany	Scientist	1977-1981

Selected Relevant Reviewed Publications

Minnett, P. J. and I. J. Barton, 2010, Remote Sensing of the Earth's Surface Temperature. *Radiometric Temperature Measurements. II Applications*, Z. M. Zhang, B. K. Tsai, and G. Machin, Eds. Experimental Methods in the Physical Sciences, Vol 43. Academic Press (ISBN-13: 978-0-12-375091-4), pp 333-391.

Nalli, N.R., P. J. Minnett and P. van Delst, 2008, Emissivity and reflection model for calculating unpolarized isotropic water surface-leaving radiance in the infrared. 1: Theoretical development and calculations. *Applied Optics*, **47**, 3701-3721. doi:10.1364/AO.47.003701

Nalli, N.R., P.J. Minnett, E. Maddy, W. W. McMillan, C.D. Barnet and M. Goldberg, 2008, Emissivity and reflection model for calculating water surface leaving radiance in the infrared. 2: Field measurements. *Applied Optics*. **47**, 4649-4671. doi:10.1364/AO.47.004649

Szczodrak, M., P. J. Minnett, N. R. Nalli, and W. F. Feltz, 2007: Profiling the Lower Troposphere over the Ocean with Infrared Hyperspectral Measurements of the Marine-Atmosphere Emitted Radiance Interferometer. *Journal of Oceanic and Atmospheric Technology*, **24**, 390-402. doi: 10.1175/JTECH1961.1

Minnett, P. J., K. A. Maillet, J. A. Hanafin and B. J. Osborne, 2005, Infrared interferometric measurements of the near surface air temperature over the oceans. *Journal of Atmospheric and Oceanic Technology*. 22, 1016-1029.

Hanafin, J. A. and P. J. Minnett, 2005, Infrared-emissivity measurements of a wind-roughened sea surface. Applied Optics., 44, 398-411.

Nalli, N. R., P. Clemente-Colón, P. J. Minnett, M. Szczodrak, A. Jessup, R. Branch, V. Morris, M. D. Goldberg, C. Barnet, W. W. Wolf, E. Joseph, R. O. Knuteson, and W. F. Feltz, 2005. Ship-based measurements for infrared sensor validation during AEROSE 2004. *Journal of Geophysical Research*, **111,** D09S04. doi:10.1029/2005JD006385.

Vogelmann, A. M., P. J. Flatau, M.Szczodrak, K. Markowicz and P. J. Minnett, 2003. Observations of Large Aerosol Infrared Forcing at the Surface. *Geophys. Res. Let*. 30(12) 10.1029/2002GL016829. 1655.

Relevant Awards:

NASA Group Achievement Award - Moderate Resolution Imaging Spectroradiometer (MODIS) Support Team. August 2001.

NASA Outstanding Teamwork Award – NASA Earth Observing System *Aqua* satellite, June 2003.

NASA Group Achievement Award, Aqua Mission Team. August 2003.

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Education

2001 Ph.D., University of Colorado at Boulder (Aerospace Engineering Sciences)
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1992 B.S., Universidad Nacional de Colombia (Department of Civil Engineering)

Professional Experience

2002 – Date	Research Associate, Colorado Center for Astrodynamics Research, CCAR University of Colorado, Boulder, Colorado
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Awards

2008 NOPP Excellence in Partnering Award
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Relevant Activities

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Selected Publications

Castro, S. L., G. A. Wick, P. J. Minnett, A.T. Jessup, and W. J. Emery, The impact of measurement uncertainty and spatial variability on the accuracy of skin and subsurface regression-based sea surface temperature algorithms, *Rem. Sens. Env.*, 2010114, (11), doi:10.1016/j.rse.2010.06.003.

Castro, S. L., G. A. Wick, D. L. Jackson, and W. J. Emery, Error characterization of infrared and microwave satellite sea surface temperature products for merging and analysis, *J. Geophys.Res.*, 113, C03010, doi:10.1029/2006JC003829, 2008.

Castro, S. L., G. A. Wick, and W. J. Emery, Further refinements to models for the bulk-skin sea surface temperature difference, *J. Geophys. Res.*, 108 (C12), 3377, doi:10.1029/2002JC001641, 2003.

Emery, W. J., S. L. **Castro**, G. A. Wick, P. Schluessel, and C. J. Donlon, Estimating sea surface temperature from infrared satellite and in situ temperature data, *Bull. Amer. Meteor. Soc.*, 82, 2773-2785, 2001.

Donlon, C. J., S. L. **Castro**, and A. Kaye, Aircraft validation of ERS-1 ATSR and NOAA-14 AVHRR sea surface temperature measurements, *Int. J. Rem. Sensing.*, 20, 3503-3513, 1999.

Gupta, V. K., S. L. **Castro**, and T.Over, On scaling exponents of spatial peak flows from rainfall and river network geometry, *J. Hydrol.*, 187, 81-104, 1996.

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PUBLICATIONS

Casey, K.S., T.B. Brandon, P. Cornillon, and R. Evans. "The Past, Present and Future of the AVHRR Pathfinder SST Program", in Oceanography from Space: Revisited, eds. V. Barale, J.F.R. Gower, and L. Alberotanza, Springer, 2010.

Marullo, S., R. Santoleri, V. Banzon, R. Evans, M. Gaurracino. Validation and error analysis of O&SI SAF (SEVIRI) SST products over the tropical Atlantic: toward a bias-free diurnal-cycle resolving SST product combining microwave and infrared satellite data. *JGR*, In Press.

Donlon, C. J., K. S Casey, C. Gentemann, P. LeBorgne, I. S. Robinson, R. W Reynolds, C. Merchant, D. Llewellyn-Jones, P. J. Minnett, J. F. Piolle, P. Cornillon, N. Rayner, T. Brandon, J. Vazquez, E. Armstrong, H. Beggs, I. Barton, G. Wick, S. Castro, J. Hoeyer, D. May, O. Arino, D. J. Poulter, R. Evans, C. T. Mutlow, A. W. Bingham and A. Harris. Successes and Challenges for the Modern Sea Surface Temperature Observing System, *Oceanography* Vol. 22, No 3, 2009.

Vazquez-Cuervo, J., E.M. Armstrong, K.S. Casey, R. Evans, and K. Kilpatrick. A comparison between the Pathfinder Version 5.0 and Version 4.1 sea surface temperature data sets: A case study for high resolution. *JClim*, vol 23, no 5, pp 1047-1059, 2010.

Donlon, C.J., I. Robinson, K.S. Casey, et al. The Global Ocean Data Assimilation Project High Resolution SST Pilot Project, *BAMS*, vol 88, no 8, pp 1197-1213, 2007.

Kumar, A.P., P. Minnett, G. Podesta and R. Evans. Error characteristics of the Atmospheric Correction Algorithms used in Retrieval of Sea Surface Temperatures from Infrared Satellite Measurements: Global and Regional Aspects. *J. of the Atmos. Sci.*, 60(3), 2003: 575-585.

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1995 - 1998 ***Scripps Institute of Oceanography, Graduate Research Assistant.*** Investigation of baroclinic instabilities with Dr. Rick Salmon and Dr. Myrl Hendershott.

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Education:

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Awards: National Oceanographic Partnership Program 2008 Excellence in Partnering Award. NASA Group Achievement Award 2001 to the Satellite Ocean Atlas Team, for outstanding achievement in utilization of multiple observations from space for the study of the global oceans.

Publications (25 total peer reviewed):

Gentemann, C. L., F. J. Wentz, M. Brewer, K. A. Hilburn and D. K. Smith. “Passive microwave remote sensing of the ocean: an overview”, in Oceanography from Space, revisited (2010), edited by V. Barale, J. Gower and L. Alberotanza, Springer, Heidelberg.

Gentemann, C.L., T. Meissner, and F. J. Wentz, "Accuracy of satellite sea surface temperatures at 7 and 11 GHz" (2010), *Trans. Geosci. Rem. Sens.*, 48(3), 1009-1018, doi: 10.1109/TGRS.20092030322.

Donlon, C. J., K. S. Casey, I. S. Robinson, C. L. Gentemann, R. W. Reynolds, I. Barton, O. Arino, J. Stark, N. Rayner, P. LeBorgne, D. Poulter, J. Vazquez, H. Beggs, D. Llewellyn Jones, P. Minnett, “The GODAE High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP) (2009), *Oceanography*, 22(3), 34-45.

Donlon, C.J., K.S. Casey, C.L. Gentemann, et al., “Successes and Challenges for the Modern Sea Surface Temperature Observing System" (2009), *OceanObs 09 community white paper.*

Gentemann, C.L., P.J. Minnett, and B. Ward, “Profiles of Surface Heating (POSH): a new model of upper ocean diurnal warming” (2009), *J. Geophs. Res.*,114, C07017, doi:10.1029/2008JC004825.

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Education

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Experience

2007-Present:	Professor, Ocean University of China, China
2001-2007:	Associate Professor, Ocean University of China, China
1997-2001:	Assistant, Lecturer, Ocean University of Qingdao, China
Sept. 2000 – Sept. 2001:	Research Associate, Tohoku University, Japan
May – Dec. 1997:	Visiting research, NOAA / NESDIS, USA
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Simon Hook is a scientist in the Earth Surface Science Group, Climate, Oceans and Solid Earth Science Section at the Jet Propulsion Laboratory. His research is focused on improving our understanding of geologic and hydrodynamic processes. He is currently leading a study to look at large lakes as climate change indicators.

Simon is an expert on optical radiometry, in particular thermal infrared spectroscopy. He is a member of several instrument teams including ASTER, MODIS, NPP, Landsat and AATSR. He has developed validation sites at Lake Tahoe, CA/NV and Salton Sea CA for determining the absolute radiometry of airborne and spaceborne mid and thermal infrared radiometers and surface temperature retrieval algorithms. The measurements at the sites are unique and now used as an absolute reference standard for multiple instruments developed by both domestic and foreign research agencies.

EDUCATION:

Ph. D., University of Durham, England, 1989.

M. Sc., University of Edmonton, Canada, 1985.

B. Sc., University of Durham, England, 1982.

SELECTED PEER REVIEWED PAPERS FROMTHE WEB OF SCIENCE (54 total papers)

Schneider. P. and S. J. Hook, 2010. Space observations of inland water bodies show rapid surface warming since 1985. Geophysical research letters, vol. 37.

Schneider, P., S. J. Hook, R. G. Radocinski, G. K. Corlett, G. C. Hulley, S. G. Schladow and T. E. Steissberg, 2009. Satellite observations indicate rapid warming trend for lakes in California and Nevada. Geophysical Research Letters, vol. 36.

Coll, C., S. J. Hook and J. M. Galve, 2009.. Land Surface Temperature From The Advanced Along-Track Scanning Radiometer: Validation Over Inland Waters And Vegetated Surfaces. IEEE Geoscience and Remote Sensing, vol. 47, pp. 350-360.

Marti-Cardona, B., Steissberg, T. E., Schladow, S. G. and S. J. Hook, 2008. Relating Fish Kills to Upwellings and Wind Patterns in the Salton Sea. Hydrobiologica, vol. 604, pp. 85-95.

Barsi, J. A., S. J. Hook, J. R. Schott, N. G. Raqueno, B. L. Markham, 2007. Landsat-5 thematic mapper thermal band calibration update. IEEE Geoscience and Remote Sensing Letters, vol. 4 pp. 552-555.

Hook, S. J., R. G. Vaughan, H. Tonooka and S. G. Schladow, 2007. Absolute Radiometric In-Flight Validation of Mid Infrared and Thermal Infrared Data From ASTER and MODIS on the Terra Spacecraft Using the Lake Tahoe, CA/NV, USA, Automated Validation Site. IEEE Transactions Geoscience and Remote Sensing, vol. 45, pp. 1798-1807

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Present employment and activities

2009 – present: Oceanographic Scientist, EUMETSAT, Germany

Activities:
- Sea surface temperature support to EPS and GMES Sentinel-3 programmes.
- Calibration/validation activities of satellite-derived sea surface temperatures.
- Uncertainty estimation and Single Sensor Error Statistics for sea surface temperatures.
- Sea surface temperature and scatterometer air-sea interactions in level 1b data.
- Scientific interface to EUM Ocean & Sea-Ice Satellite Application Facility (SST, sea-ice, wind).
- Support to EUMETSAT ocean missions including future programs.

Previous career summary

2008 – 2009: Senior Research Scientist, Satellite Applications, Met Office, U.K.

1998 – 2008: Research Scientist, Satellite Applications, Met Office, U.K.

Met Office activities:
- Operational satellite sea surface temperature processing using (A)ATSR for climate.
- Research of (A)ATSR SSTs: skin effect; diurnal variations; biases; uncertainties.
- Calibration/validation activities of AATSR sea surface temperatures.
- Bias correction of AVHRR pathfinder sea surface temperature with respect to (A)ATSR.
- GMES Sentinel-3 optical level-2 algorithm definition project.

1996 – 1998: Research Scientist, Space Department, Defence Evaluation and Research Agency, U.K.

Qualifications

1993-1996: BSc(Hons) 2:1 Physics & Meteorology, University of Reading, U.K.

Professional activities

EUMETSAT Ocean & Sea-Ice Satellite Application Facility Steering Group Member Science Expert
Observer to GMES Sentinel-3 Mission Advisory Group
Member of the Group for High Resolution Sea Surface Temperature
Member of AATSR Science Advisory Group
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Publications in peer-reviewed journals

O'Carroll, A.G., T.A. Blackmore, K. Fennig, R.W. Saunders and S. Millington, 2011 (submitted): Towards a bias correction of the AVHRR Pathfinder SST data from 1985 to 1998 using ATSR *RSE*.

Blackmore, T.A., **A.G. O'Carroll**, K. Fennig and R.W. Saunders, 2011 (submitted): Correction of AVHRR Pathfinder SST data for volcanic aerosol effects using ATSR SSTs and TOMS aerosol optical depth. *RSE*.

O'Carroll, A.G., J.R. Eyre and R.W. Saunders, 2008: Three-way error analysis between AATSR, AMSR-E and in situ sea surface temperatures. *JAOT*, **25**, 1197-1207

Stark, J.D., C. Donlon, **A.G. O'Carroll** and G Corlett, 2008: Determination of AATSR biases using the OSTIA SST analysis system and a matchup-up database. *JAOT*, **25**, 1208-1217 , **25**, 1197-1207

Merchant C. J., D. Llewellyn-Jones, R.W. Saunders, N.A. Rayner, et al, 2008: Deriving a sea surface temperature record suitable for climate change research from the along-track scanning radiometers, *Adv. Sp. Res*, **41**, No. 1

O'Carroll, A.G., R.W. Saunders and J.G. Watts, 2006: The measurement of the sea surface temperature climatology by satellites from 1991 to 2005. *JAOT*, **23**, 1573-1582.

O'Carroll, A.G., J.G. Watts, L.A. Horrocks, R.W. Saunders and N.A. Rayner, 2006: Validation of the AATSR meteo product sea surface temperature, *JAOT*, **23**, 711-726

Corlett, G.K., I.J. Barton, et al., 2006: The accuracy of SST retrievals from AATSR: an initial assessment through geophysical validation against in situ radiometers, buoys and other SST datasets, *Adv. Space Research*, ***37***,*764-769*.

Merchant, C.J., Horrocks, L.A., Eyre, J.R., and **A.G. O'Carroll**, 2006. Retrievals of sea surface temperature from infrared imagery: origin and form of systematic errors *QJRMS, Vol.132, no.617, pp 1205-1223*.

Horrocks, L.A., B. Candy, T. Nightingale, R.W. Saunders, **A.G. O'Carroll** and A.R. Harris, 2003: Parameterisations of the skin effect and implications for satellite-based measurement of sea-surface temperature, *JGR*, **108**(C3), 3096.

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Education:

1995 Ph.D., University of Colorado at Boulder (Aerospace Engineering Sciences)
1990 M.S., University of Colorado at Boulder (Aerospace Engineering Sciences)
1988 B.S., with Special Honors, University of Colorado (Aerospace Engineering Sciences)

Employment:

2000-date Physicist, NOAA Earth System Research Laboratory / Environmental Technology Laboratory Boulder, Colorado
1997-2000 Research Scientist, Cooperative Institute for Research in Environmental Sciences University of Colorado, Boulder, Colorado
1995-1997 Postdoctoral Research Associate, Applied Physics Laboratory, University of Washington, Seattle, Washington.

Selected Relevant Publications:

Castro, S. L., G. A. **Wick**, P. J. Minnett, A. T. Jessup, and W. J. Emery, The impact of measurement uncertainty and spatial variability on the accuracy of skin and subsurface regression-based sea surface temperature algorithms, *Remote Sensing of Environment*, 114, 2666-2678, doi:10.1016/j.rse.2010.06.003, 2010.

Castro, S. L., G. A. **Wick**, D. L. Jackson, and W. J. Emery, Error characterization of infrared and microwave satellite sea surface temperature products for merging and analysis, *J. Geophys. Res*., 113, C03010, doi:10.1029/2006JC003829, 2008.

Donlon, C. J. et al., The Global Ocean Data Assimilation Project (GODAE) High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP), *Bull. Amer. Meteor. Soc*., 88, 1197-1213, 2007.

Wick, G. A., J. C. Ohlmann, C. W. Fairall, and A. T. Jessup, Improved oceanic cool skin corrections using a refined solar penetration model, *J. Phys. Oceanogr*., 35, 1986-1996, 2005.

Castro, S. L., G. A. **Wick**, and W. J. Emery, Further refinements to models for the bulk-skin sea surface temperature difference, *J. Geophys. Res*., 108(C12), 3377, doi:10.1029/2002JC001641, 2003.

Wick, G. A., J. J. Bates, and D. J. Scott, Satellite and Skin Layer Effects on the Accuracy of Sea Surface Temperature Measurements from the GOES Satellites, *J. Atm. Oceanic Technol*., 19, 1834-1848, 2002.

Wick, G. A., and A. T. Jessup, Simulation of ocean skin temperature modulation by swell waves, *J. Geophys. Res*., 103, 3149-3161, 1998.

Suarez, M. J., W. J. Emery, and G. A. **Wick**, The multi-channel infrared sea truth radiometric calibrator (MISTRC), *J. Atm. Oceanic Technol*., 14, 243, 1997.

Wick, G. A., W. J. Emery, L. H. Kantha, and P. Schlüssel, The behavior of the bulk-skin sea surface temperature difference under varying wind speed and heat flux, *J. Phys. Oceanogr*., 26, 1969-1988, 1996.

Fairall, C. W., E. F. Bradley, J. S. Godfrey, G. A. **Wick**, J. B. Edson, and G. S. Young, Cool-skin and warm-layer effects on sea surface temperature, *J. Geophys. Res*., 101, 1295-1308, 1996.

Relevant Activities:

Member – Group for High-Resolution Sea Surface Temperature (GHRSST) Science Team

Chair – GHRSST Diurnal Variability Working Group

Member – NASA Sea Surface Temperature Science Team

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