Validation of AATSR SSTs with the SISTeR

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Introduction

- ATSR SSTs are derived from measurements in thermal infrared channels at 3.7μm, 10.8μm and 12.0μm.
- As the penetration depth of infrared radiation in water is rather small (80μm at 3.7μm, falling to 4μm at 12.0μm) infrared radiometers only sample the brightness temperature of the extreme surface of the sea, commonly called the skin SST.
- This measurement can differ significantly from the bulk SST which is recorded by buoys, typically at depths of 1m and more, especially during the day and at low wind speeds.
- As a result, buoy measurements are not a suitable validation source for satellite radiometers, such as the ATSR series of instruments, for a significant range of sea conditions.
- In-situ radiometers can record validation skin SSTs in all conditions (when it is safe to operate).
The sea surface is not completely black, so the reflected component of the upwelling radiance must be corrected with a direct measurement of the downwelling sky radiance.

For a narrow band filter radiometer, SST can be calculated to a very good approximation from

\[ R_{up} = \varepsilon B(SST) + (1 - \varepsilon) R_{down} \]

where \( \varepsilon \) is the emissivity of the sea surface and \( B(SST) \) is the black body radiance at the sea surface temperature, each integrated over the instrumental filter function and field of view, and \( R_{up} \) and \( R_{down} \) are the upwelling and complementary downwelling sea and sky radiances measured by the radiometer.
SISTeR is a chopped, self-calibrating filter radiometer with infrared filters matching those in ATSR series of satellite radiometers.

- Near to ambient temperature and with the 10.8µm or 12.0µm filter, radiometric noise is approximately 30mK for a 0.8s sample and radiometric accuracy is of order 20mK.
- SISTeR measures sea and sky radiances.
SISTeR black bodies

- Calculated emissivity > 0.999
- Embedded 4-wire 27Ω RhFe thermometer
- Constant power heater at cavity mounting point, near aperture
- Outer fibreglass shell with small air gap to inhibit convection
- Black body cavities calibrated complete in a specialised facility at Oxford University, against a secondary standard traceable to NPL.
SISTeR filters

- Foreoptics window: 3µm to 15µm
- Channels at 3.7µm, 10.8µm and 12.0µm
SISTeR electronics

- On-board x86 XT-bus PC running DOS.
- All signal-processing and driver electronics are XT-compatible peripherals.
- **ALL** configurable features (scan mirror position, PSD phase, *etc.*) and data values (signal, thermometry counts *etc.*) accessible at I/O addresses.
- C library “SISTeR.h” allows **ALL** instrument parameters to be set or interrogated within a simple C program.
- Data packet containing **ALL** instrument data points delivered to ground station every measurement cycle.
- Ground station logs **ALL** instrument data and allows direct manipulation of the instrument at a command line prompt.
#include "SISTeR.h"

void move (WORD position, WORD settle, WORD sample)
{
    scan_d = position;
    byte[1] = FALSE; wait (settle);
    byte[1] = TRUE;  wait (sample);
}

int main (void)
{
    htren_d = 2;       // Enable BB2 heater
    BB2_d = 220;      // Set BB2 heater power (~ +10K)

    while (TRUE) {
        byte[0] = 2;   move (BB2, 4, 8);
        byte[0] = 1;   move (BB1, 4, 8);
        byte[0] = 48;  move (NADIR + degrees (48), 4, 76);
        byte[0] = 120; move (NADIR + degrees (120), 4, 4);
        byte[0] = 132; move (NADIR + degrees (132), 4, 4);
        byte[0] = 172; move (NADIR + degrees (172), 4, 4);
    }
}

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SISTeR self-calibration

- The instrument’s two reference black bodies are positioned at the end of its optical chain, so external scene radiances can be calculated with the calibration equation:

\[
x = \frac{(S_{\text{scene}} - S_{BB1})}{(S_{BB2} - S_{BB1})}
\]

\[
R_{\text{scene}} = (1 - x) B(T_{BB1}) + x B(T_{BB2})
\]

- \(B(T_{BB1})\) and \(B(T_{BB2})\) are the black body radiances, calculated from the black body thermometers and integrated over the instrumental filter response, and \(S_{\text{scene}}, S_{BB1}\) and \(S_{BB2}\) are the signal counts recorded for views to the external scene and to each of the black bodies.

- Note that the radiometer optics are open to the elements – the radiometer can’t be sealed with a window as the window would not be included in the calibration measurements.
SISTeR weather door (mark 1)
SISTeR calibrations

Calibration of SISTeR against a CASOTS black body at RAL on the 8th May 2002, just prior to shipping. The SISTeR ambient black body, BB1, was operated at approximately 26°C during these measurements.

Calibration of SISTeR against a CASOTS black body on board the RRS Charles Darwin on the 10th July 2002, just prior to return. The ambient black body, BB1, was operated at approximately 27°C during these measurements.

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SISTeR autonomy (introduction)

- SISTeR has always had limited autonomy – given a control program, it generated data continuously without intervention, however, it could not
  - protect itself against the elements,
  - recover after a power failure,
  - recover after a software crash (never happened to date!),
  - operate in a low power environment (needs a PC to log data).
- As a result, SISTeR has always had to be accompanied on deployments. This restricts the range of deployment opportunities, particularly on non-traditional platforms such as ferries and static towers, where instrument support and sometimes available power can be very limited.
- SISTeR has now been updated to address these issues.
SISTeR autonomy (hardware)

- SISTeR now has:
  - an electrically powered weather door with an opto-isolated 5V logic interface,
  - a rain sensor (Optical Scientific Inc. ORG-815),
  - a new electronics card to interface the door and rain gauge to the on-board PC,
  - a GPS receiver (Garmin GPS-25) and waterproof survey aerial,
  - a serial data logger (Acumen Instruments DataBridge).
SISTeR weather door (after)
OSI ORG-815 rain gauge
SISTeR GPS

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SISTeR autonomy (software)

- SISTeR software library completely rewritten. New software addresses three issues:
  - Weather protection:
    - software drivers to integrate door and rain gauge with SISTeR code,
    - software to interpret rain gauge data and operate door as required.
  - Tolerance of “upsets” (power failures and system crashes):
    - watchdog timer integrated into code,
    - Instrument can boot from cold into scanning program.
  - Time stamping and location:
    - software driver to interpret GPS NMEA strings,
    - all data frame times extrapolated from GPS 1s reference pulses.
SISTeR autonomy (power and data)

- Acumen Instruments DataBridge inserted in series with serial data stream from SISTeR.
- All data logged to a solid state disk – laptop can be disconnected once system is set up.
SISTeR measurements

- Best position for SISTeR is high and well forward. A foremost platform is ideal.
- View to undisturbed sea ahead of bow wave.
- Instrument is above any spray that breaks over the bow.
- Clear view to the sky for complementary downwelling radiance measurement.

SISTeR installation on the foremost platform of the RRS Charles Darwin.
Ships of opportunity systems operated in Norwegian Waters

- **Color Festival: Oslo – Hirtshals**
  - Operative since August 2001
  - EU-project FerryBox and DISMAR
  - Data used in REVAMP project
  - Used for algal monitoring, satellite validation and phytoplankton studies

- **Fjord Norway: Bergen – Hanstholm**
  - In operation since May 2005
  - Used for algal monitoring

- **Fjord Norway: Bergen – Newcastle**
  - Started November 2005

- **Hurtigruten: Bergen – Kirkenes**
  - MS Trollfjord operated by NIVA
    - InteReg project NorSEN
    - Algal monitoring

www.ferrybox.no
The FerryBox system

- Flow through ferrybox system for temperature, salinity, chlorophyll-a fluorescence and turbidity
- Sensors for above water radiance measuring the marine reflectance

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SISTeR installation (starboard bridge wing)
SISTeR deployment

- SISTeR will be deployed in the next few weeks on the Color Festival ferry, running between Oslo and Hirtshals, in collaboration with Kai Sørensen of NIVA (Norwegian Institute for Water Research).
- SISTeR will accompany a FerryBox instrument set – valuable context (from an SST point of view) for the SST data.
- Expect to deploy for a short time (2 – 3 weeks) to assess the new systems, and then for a more extended period.
- May also transfer to the Bergen – Newcastle ferry at some point (more open water and easier to support from the UK).
Conclusions

- SISTeR capabilities have been extended significantly.
- SISTeR is now ready for autonomous operations.
- The upcoming Color Festival measurements should provide a useful extension to the set of AATSR cold water SST validation points.

- Development and upcoming deployments supported by ESA contract 18324/04/NL/AR.
- Thanks to Paul Snoeij (for being patient) and to Kai Sørensen and NIVA for hosting SISTeR on the Color Line Color Festival ferry.
AATSR overpass (5th June 2002)

CD141 SiSTeR Temperatures (RRS Charles Darwin, 5th June 2002)

CD141 – SCIPIO (18:13:18 UTC, 5th June 2002)

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