OC 3570

Final Report

"SST retrieved by AVHRR and IR sensors versus *in situ* SAIL, BOOM and CTD instruments"

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Introduction

The main goal of this project is to compare the results of SST - Sea Surface Temperature - measurements between in situ instruments and remote sensors.

In situ data were acquired by SAIL -Serial ASCII Interface Loop-, BOOM probe and CTD - Seabird model SBE 9 - instruments. The remote sensors were AVHRR/2- Advanced Very High Resolution Radiometer/2 - aboard of NOAA-14 satellite and Everest Interscience Infrared SST reader - model 4000.4GL.

All in situ instruments and the IR SST sensor are part of the R/V Point Sur acquisition data system and were collected during the OC3570 cruises from 5 to12 of February 2001. The R/V did two cruises. The best NOAA-14 AVHRR/2 images were acquired during fifth and eighth of February of 2001 (day 5 and day 8 from now on for simplicity) in the first cruise (Figure 1) due to favorable cloud cover conditions.

Some limitation and differences in data acquisition should be mentioned. Depths on SST measurement of all instruments are different and they can impact SST values. AVHRR and IR sensors work with the first millimeter of sea surface layer being strongly affected by sea state, turbulence and meteorological conditions (clouds, fog and etc.). BOOM floats close to sea surface but under the first millimeter and it can be affected by sea state too. SAIL works at 1.5 m depth and it should show temperatures closer to the first CTD temperature (between 1.5 m and 2m) than other sensors. Later in this report, the correlations and differences among all instruments will be quantified.

The BOOM/SAIL SST looks to go whacko around 1400 UTC on Feb 10th The SST returns to "normal" again around 1300 UTC on Feb 12th but as the NOAA images were acquired on 5th and 8th this fact does not affect directly the report conclusions.

Data Acquisition

All data from ship instruments were placed on an ASCII table format, on the Internet by the ship technical crew. This suitable form allowed an easy export for Microsoft EXCEL or MATLAB native data format. These two tools were used to manipulate the data and generate the plots and graphs.

AVHRR/2

AVHRR/2 is a sensor that takes images in five channels from visible, channel 1 (0.58-0.68 µm), to the thermal infrared, channels 4 (10.3-11.3 µm) and 5 (11.5-12.5 µm). This last two were used in an algorithm that corrects effects of reflection, scattering and atmospheric absorption and retrieve SST. All images are calibrated for radiation and navigation allowing position and temperature retrieving. The ground resolution on Nadir is 1.1 Km IFOV - instantaneous field of view. Positions used to retrieve SST are close to nadir so a value around 1.1 Km can be assumed for the pixel size, or, each SST measured by AVHRR/2 correspond to 1.1 Km^2 on the sea. The IFOV SST accuracy will impact all correlations between instruments and the conclusions about AVHRR for SST measurements.

NOAA-16 is not calibrated yet; so SST algorithm constants are not available leaving NOAA-14 passes as the only source of satellite SST data retrievable by an algorithm using channels 3, 4 and 5
After a cloud cover condition analysis of all NOAA-14 AVHRR images, only day 5 and day8 were able to retrieve SST.

The Software used to apply the algorithm and retrieve the temperature was Teravison Version 3.0 that is the new graphic interface of Terascan, software responsible for the image acquisition.

SAIL

The 1.5 m below the surface sensor of serial ASCII interface loop instrument collected data in a rate 30s averaged and recorded on R/V Point Sur lab. The data was placed in the same format previous mentioned.

BOOM probe

The thermistor protected by a plastic hose, towed few meters away from the stern, floats very close to the surface due to the ship movement. Collected every 30s SST was averaged and stored in R/V Point Sur Lab. The result was placed in the same files and format as SAIL data.

CTD

During the two days that cloud conditions allowed SST measurements only five CTD stations were made, three of them on day 5 and two on day 8. The model SEABIRD 9 did a good job during these stations. Again, the technical crew place all data in a very suitable format, being an easy job to retrieve it with the tools already mentioned.

IR ship sensor

The sensor used is an Everest Interscience, Inc. model 000.4GL.with the following specifications: Accuracy - +/- 0.5 deg C; Spectral pass band - 8 to 14 micrometers, field of view - 4 degrees, Optical lens - germanium. The sensor was pointed off the starboard bow for the cruise. Deployment angle was roughly 45 degrees below horizontal. No corrections have been made for sky reflection. Surface emittance for the sensor was set at 1.0.The sensor samples the uppermost few micrometers of the surface, as water is considered nearly radiative “black”, moisture between the sensor height and the surface may bias the values. The sampling is done in the "water vapor window," which is essentially transparent to water vapor.

Unfortunately, the data collected in both days was not good enough to be used showing large fluctuation compared with BOOM/SAIL temperature probably due to moisture contamination or malfunction.

Data processing

All BOOM, SAIL, CTD and AVHRR data were placed as a table in the same ASCII file (master file).

The position and time for the first three instruments were considered the same due to the small differences in time and position from Furuno and Ashtech systems. CTD position was retrieved manually from the ship repeater in the lab and recorded by the automatic system. AVHRR data were collected manually matching visually some preset positions retrieved from ship system.

This file arrangement made easy statistical computation and plotting with minor errors in time (+/-30") and position (+/- 0'.5)

AVHRR

AVHRR temperatures should be retrieved manually by a preset SST algorithm stored in TERASCAN but due to problems with image server it was not possible to retrieve the temperatures from the same image provided by Bob Creasey on Internet (Figures 2 and 3).

To retrieved SST from a different raw format (Terascan format) all the steps imposed by the methodology must be crossed. This was done for both days with good qualitative and quantitative results on day 5 but with only good qualitative results on day 8 (Figures 4 and 5).

The reason for this bad quantitative result on day 8 was not detected. Problems in navigation showed on day 8 image or differences between the parameters from the raw image format and Terascan format are some of the reasons listed by Prof Phill Durkee to explain the results.

Values on image color scale are matching but the colours are not.

The methodology used to retrieve SST from NOAA-14 satellites is now summarized.

Steps:

1. Exclusion of Data at Large Zenith Angles
2. Cloud Clearing (Measurements over cloud area are not used).
3. IR uniformity test.
4. Maximum Value in the Channel 2 Albedo.
5. Difference in Channel 3,4 and 5.
6. Test for daytime/nighttime
7. Minimum Channel 4 Temperature
8. Use of Day and Night time algorithms
9. Choice of SST Algorithms type

NOAA-14 Daytime Algorithm

MCSST Day Split Window Algorithm

$SST = (1.017342 * T_4) + 2.139588 * (T_4 - T_5) + 0.779706 + (T_4 - T_5) *(\sec(ZA) - 1) -278.43 + 273.16$

Where: SST - computed SST value in degrees C, T_4 - channel 4 scene temperature, T_5 - channel 5 scene temperature, ZA - solar zenith angle

NOAA-14 Night time Algorithms

MCSST Night Dual Channel Algorithm
SST1 = (1.008751 * T_4) + 1.409936 * (T_3 - T_4) + 1.975581 * (sec (ZA) - 1) - 273.914 + 273.16
MCSST Night Split Window Algorithm
SST2 = (1.029088 * T_4) + 2.275385 * (T_4 - T_5) + 0.752567 * (T_4 - T_5) * (sec (ZA) - 1) - 282.24 + 273.16
MCSST Night Triple Channel Algorithm
SST3 = (1.010037 * T_4) + 0.920822 * (T_3 - T_5) + 0.067026 * (sec (ZA) - 1) - 275.364 + 273.16
Where: SST n - computed SST value in degrees C., T3 - channel 3-scene temperature, T_4 - channel 4-scene temperature, T_5 - channel 5 scene temperature. ZA - solar zenith angle
Computed SST rejected if differs from climatology by more than 10º

SAIL

Direct plotted from the master file and the results are showed in Figure 6.

BOOM probe

Direct plotted from the master file and the results are showed in Figure 7.

CTD

The first row of temperature was retrieved from the data files and considered as surface temperature despite the fact that CTD temperatures come from 1.5 to 2m depths.

The only process made with CTD data files was the manual retrieve of the first temperature collect to used as a cross check for SAIL, BOOM and AVHRR data.

CTD Station	TimeJ	Latitude	Longitude	T 90(ºC)	Sal ($^0/_{00}$)
CTD1	37.72818	36.79688	121.84959	12.2649	33.4905
CTD2	37.82309	36.73270	122.02631	12.1152	33.4674
CTD3	37.96685	36.67937	122.19909	12.1209	33.4117
CDT8	39.64538	36.73448	122.01926	10.9780	33.6147
CTD9	39.73291	36.79623	121.84624	11.3972	33.5046

IR Sensor

IR sensor did not work well those days and it was disregarded. No data processing was made.

Statistics Results

The parameters mean, standard deviation and variance were calculated for each instrument and summarized in the table below

Day 5	**AVG (ºC)**	**STD**	**VAR**
Boom	12.1920	0.1012	0.0102
Sail	12.1115	0.0801	0.0064
AVHRR	12.4400	0.1178	0.0139
Day 8			
Boom	10.7103	0.7747	0.6001
Sail	10.7040	0.7629	0.5820
AVHRR*	8.5073*	0.6768	0.4580

*Low valued due to bad quantitative results retrieved from AVHRR image

The correlation and the linear regression among instruments are summarized in the table below and graphically showed by the Figures 8 and 9

Correlation Table	**DAY5**	**DAY 8**
Boomtemp X sailtemp	0.9320	0.9894
Boomtemp X avhrrtemp	0.0*	0.8320
Sailtemp X avhrrtemp	0.0*	0.8363

* Zero due to only one AVHRR temperature over all leg

Conclusions

The instruments BOOM and SAIL shown an excellent performance during the two days as the three individual statistics parameters (close means with almost the same variance and standard deviation), the correlation index (near one) and linear regression (well fitted) testify.

AVHRR performance was not so good but showed that for mesoscale phenomenas or large temperature variations could be a good tool to avoid the costs of *in situ* measurement or maybe double-checking it. AVHRR should be used in small areas as a secondary tool.

Use good in situ measurements as control points to AVHRR images. The opposite way will not work.

Be sure, when you are retrieving temperatures from AVHRR, that you have a clean image with all parameters in a native format, the methodology and the right algorithm to avoid bad quantitative results.

Figure 1

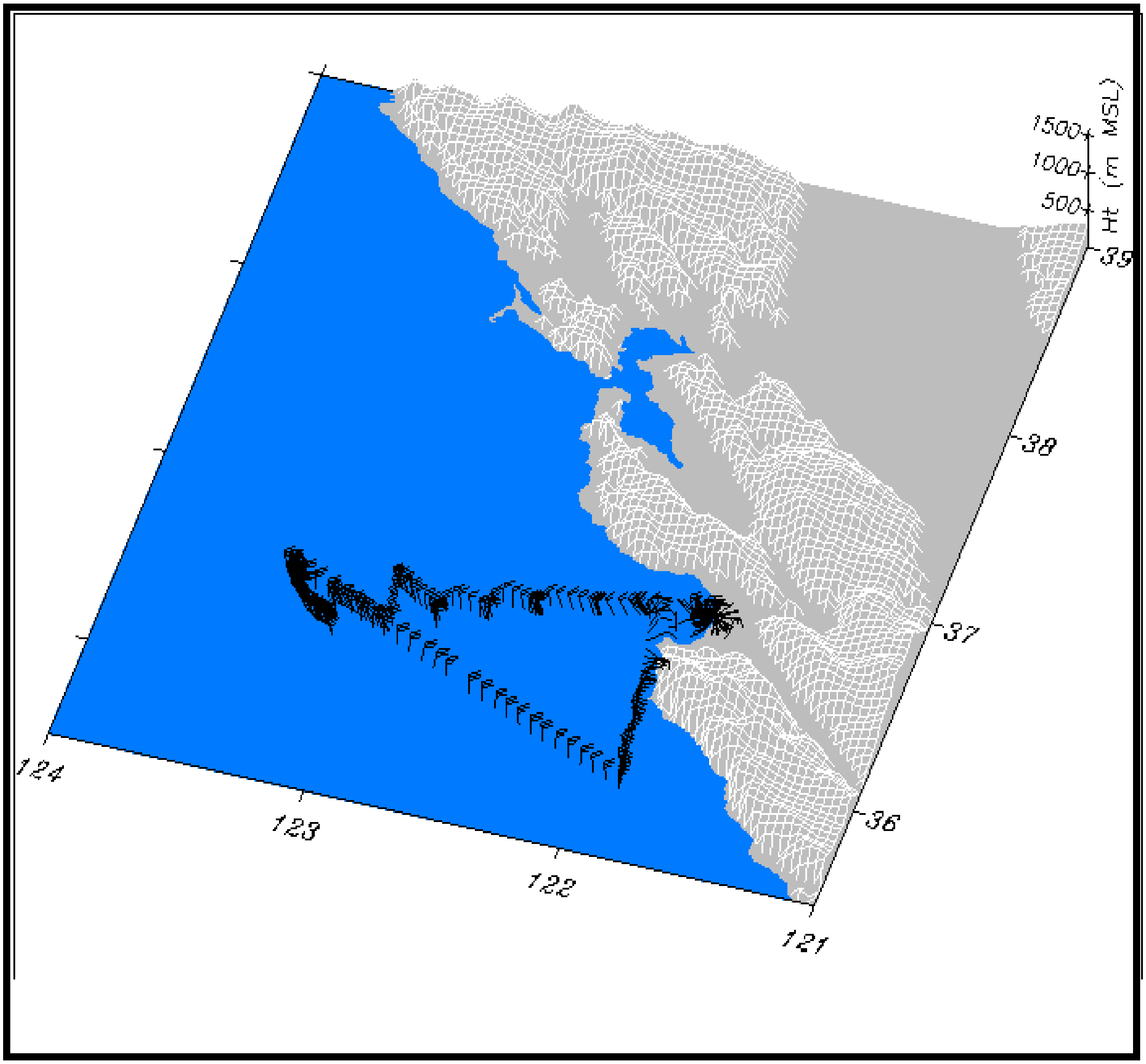


Figure 2

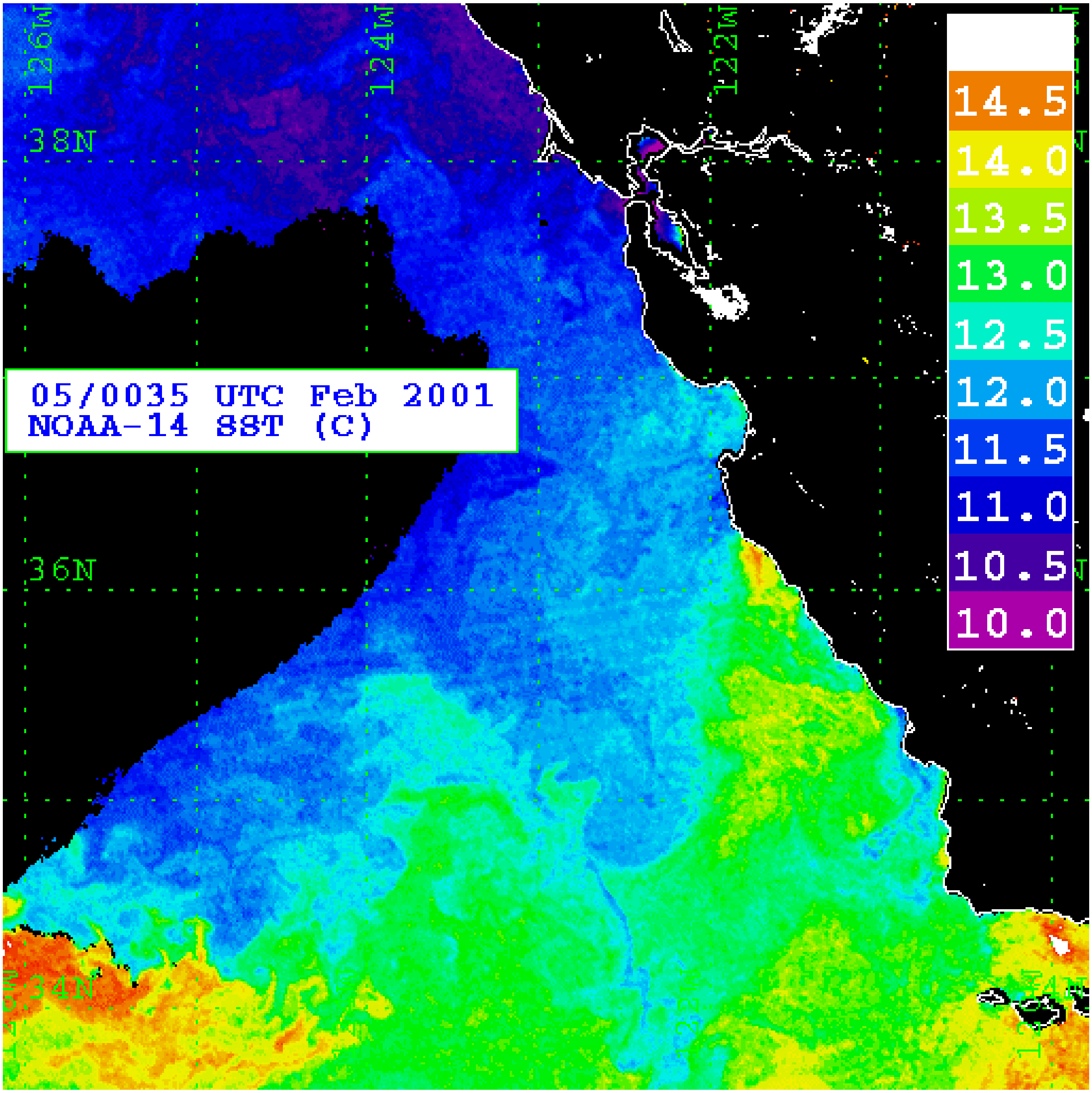

05/0035 UTC Feb 2001
NOAA-14 SST (C)
126W
124W
122W
38N
36N
34N
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0

Figure 3

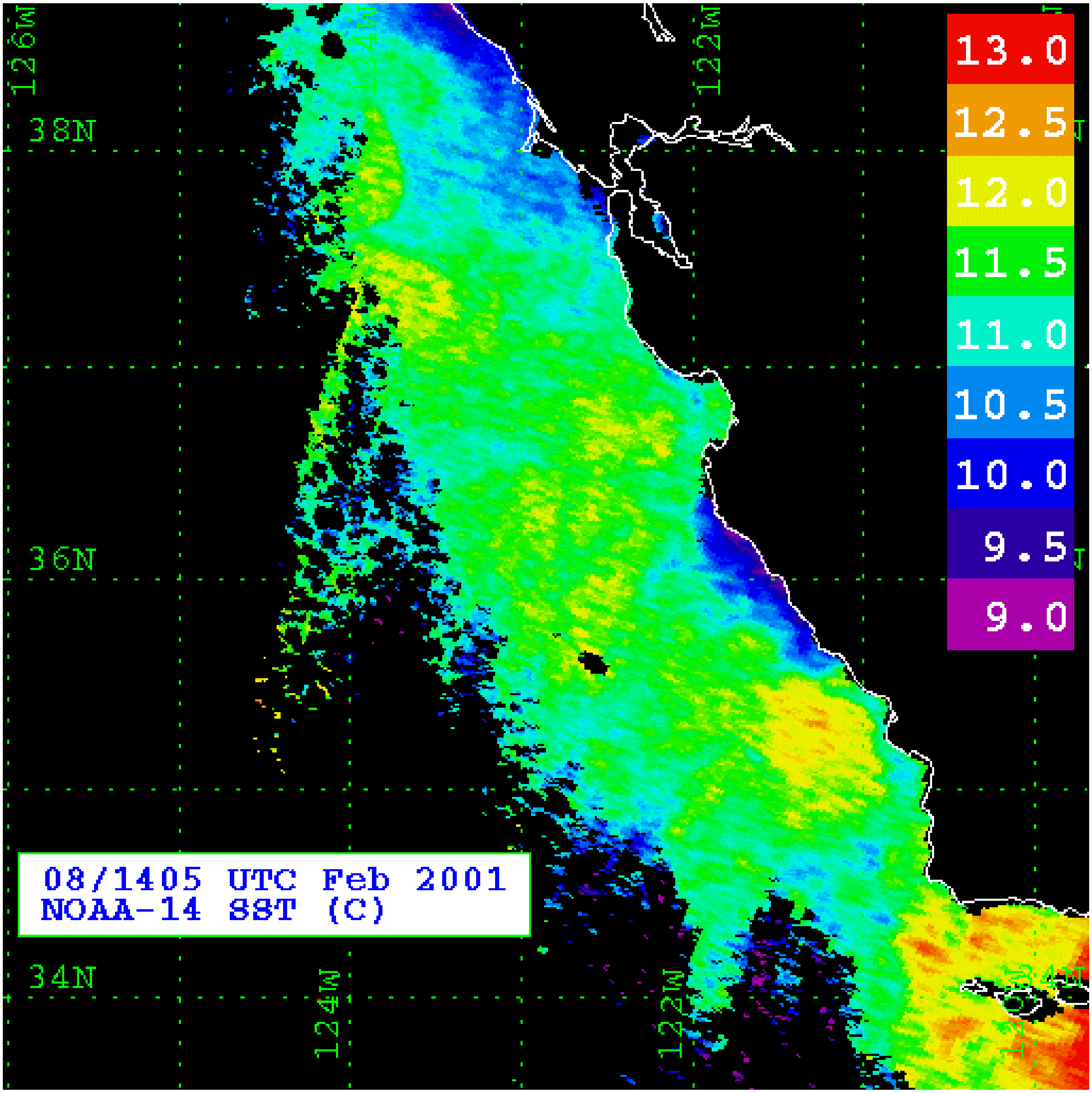
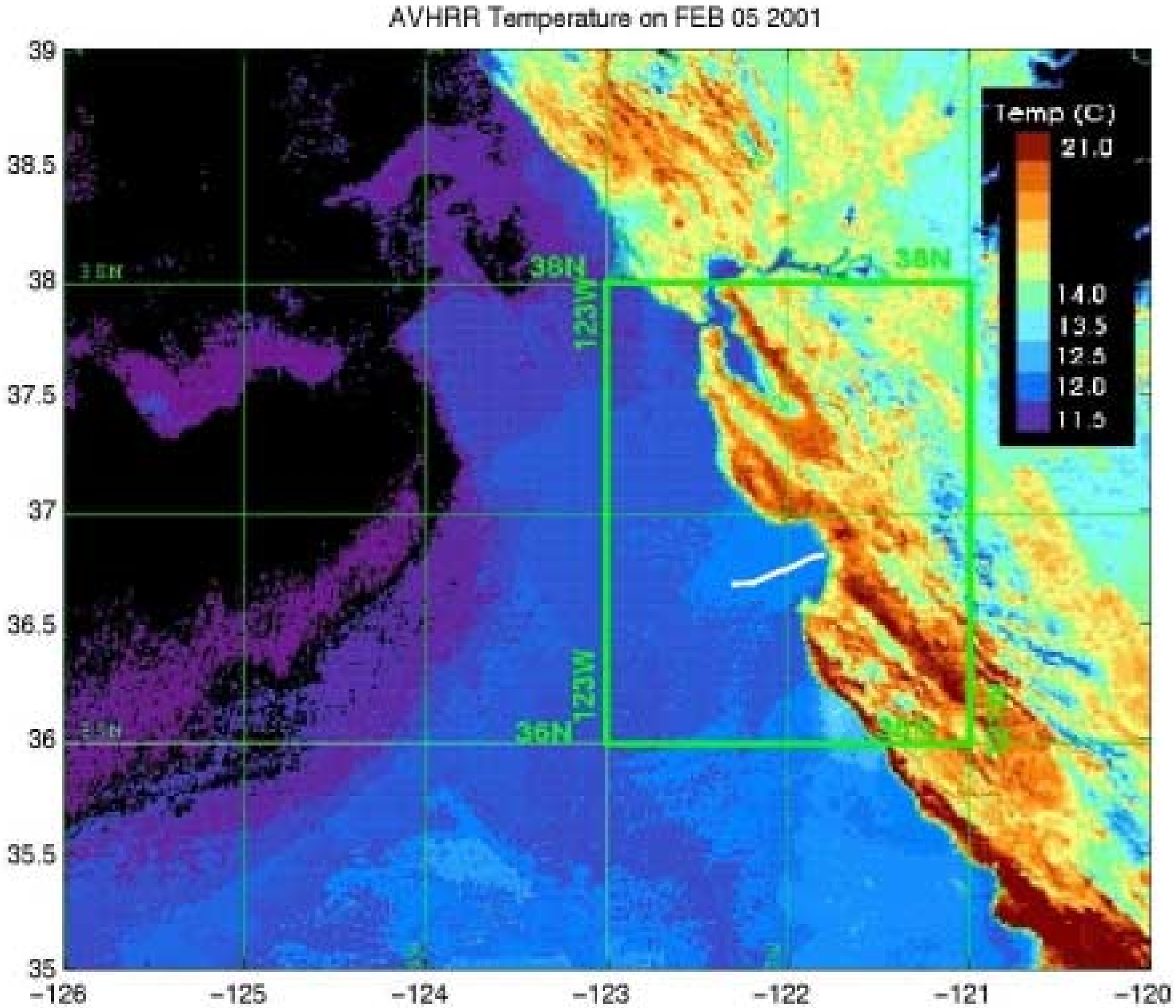
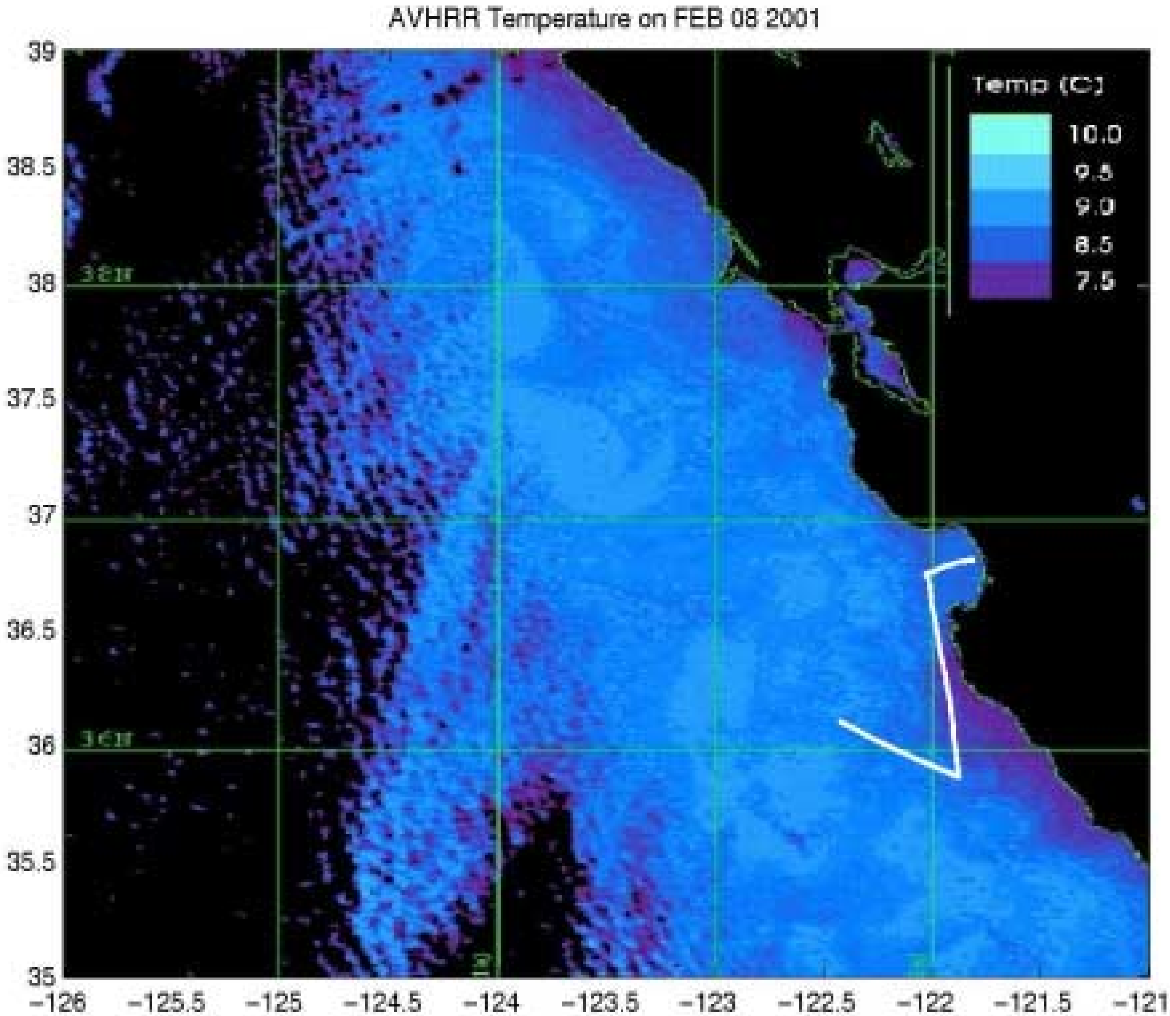

126W
124W
122W
38N
36N
34N
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
08/1405 UTC Feb 2001
NOAA-14 SST (C)

Figure 4



AVHRR Temperature on FEB 05 2001
Temp (C)
21.0
14.0
13.5
12.5
12.0
11.5
38N
36N
123W
39
38.5
38
37.5
37
36.5
36
35.5
35
−126
−125
−124
−123
−122
−121
−120

Figure 5



AVHRR Temperature on FEB 08 2001
Temp (C)
10.0
9.5
9.0
8.5
7.5
39
38.5
38
37.5
37
36.5
36
35.5
35
−126
−125.5
−125
−124.5
−124
−123.5
−123
−122.5
−122
−121.5
−121

Figure 6

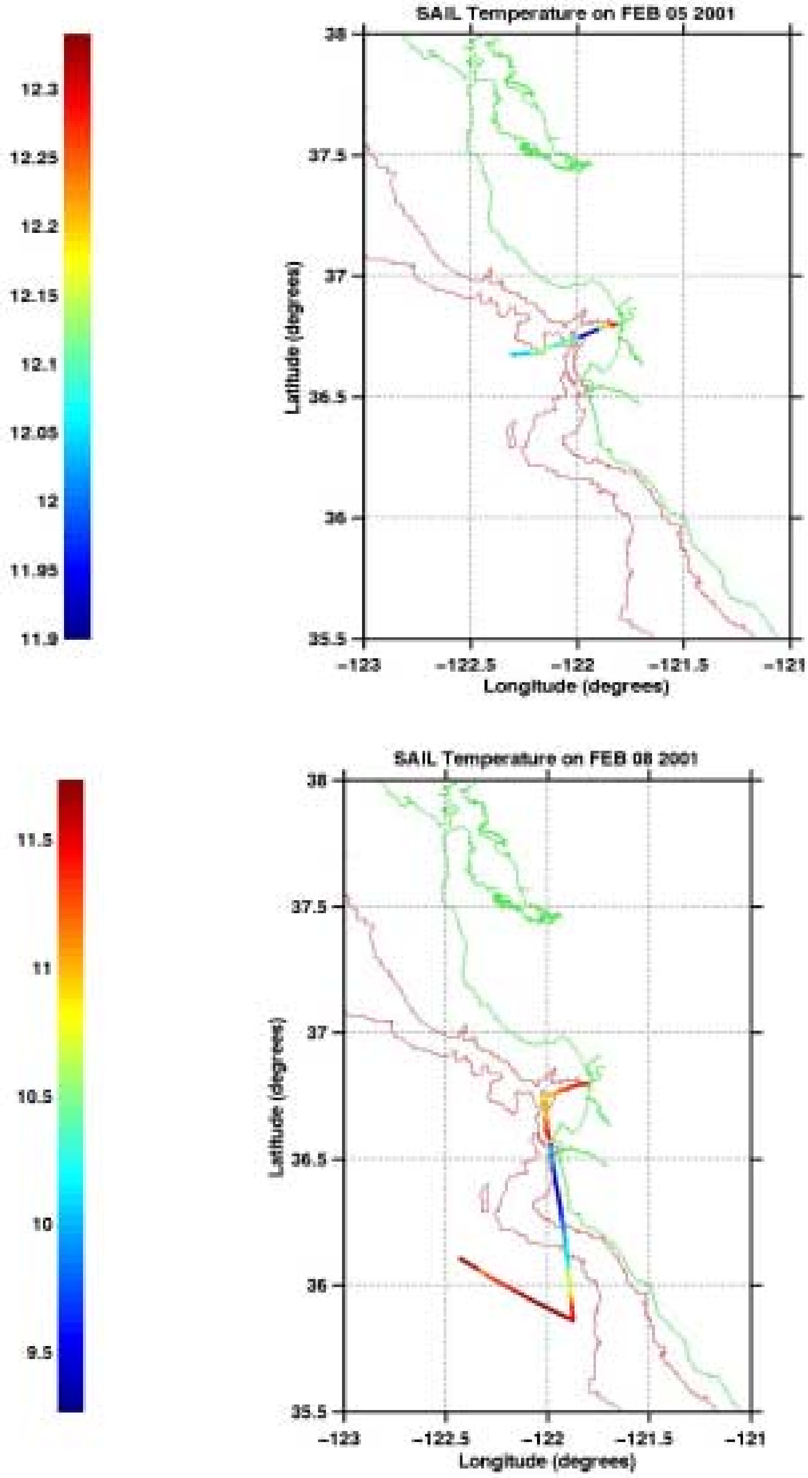

SAIL Temperature on FEB 05 2001
Latitude (degrees)
Longitude (degrees)
38
37.5
37
36.5
36
35.5
−123
−122.5
−122
−121.5
−121
12.3
12.25
12.2
12.15
12.1
12.05
12
11.95
11.9
SAIL Temperature on FEB 08 2001
Latitude (degrees)
Longitude (degrees)
38
37.5
37
36.5
36
35.5
−123
−122.5
−122
−121.5
−121
11.5
11
10.5
10
9.5

Figure 7

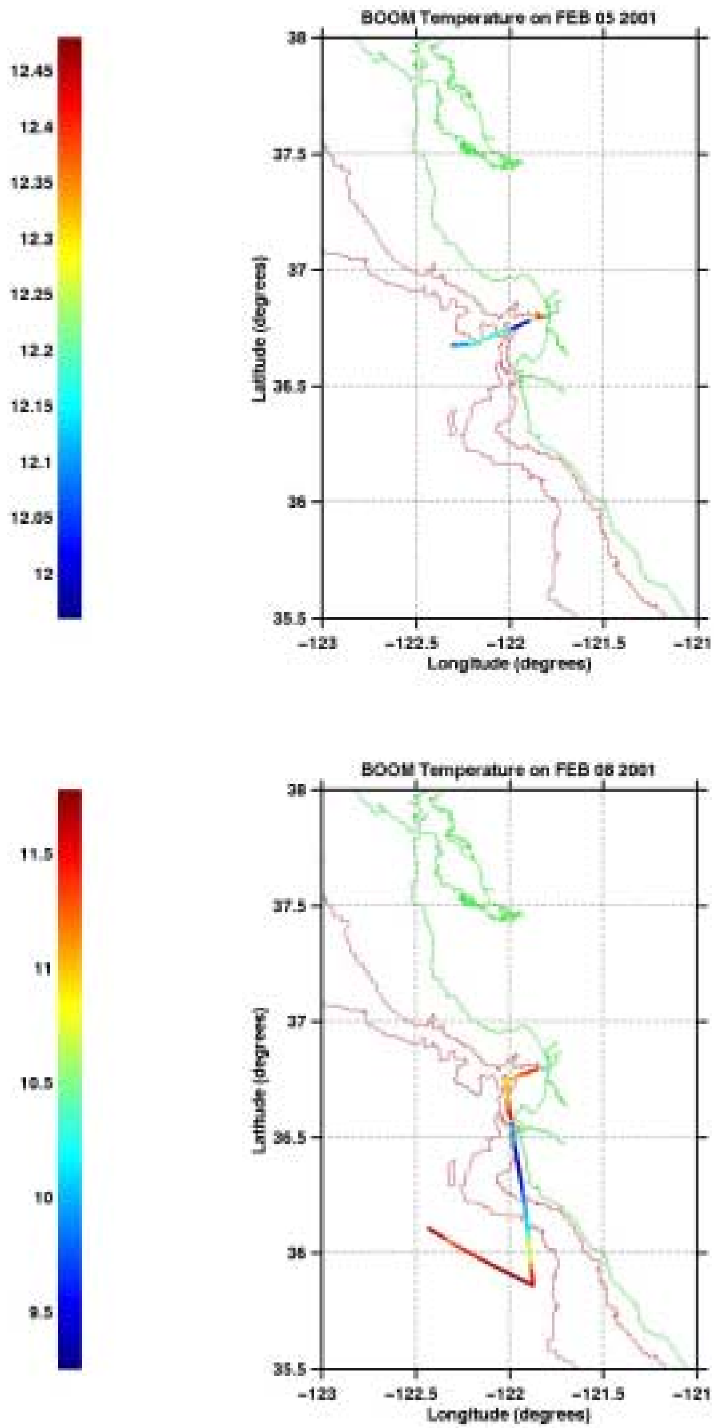
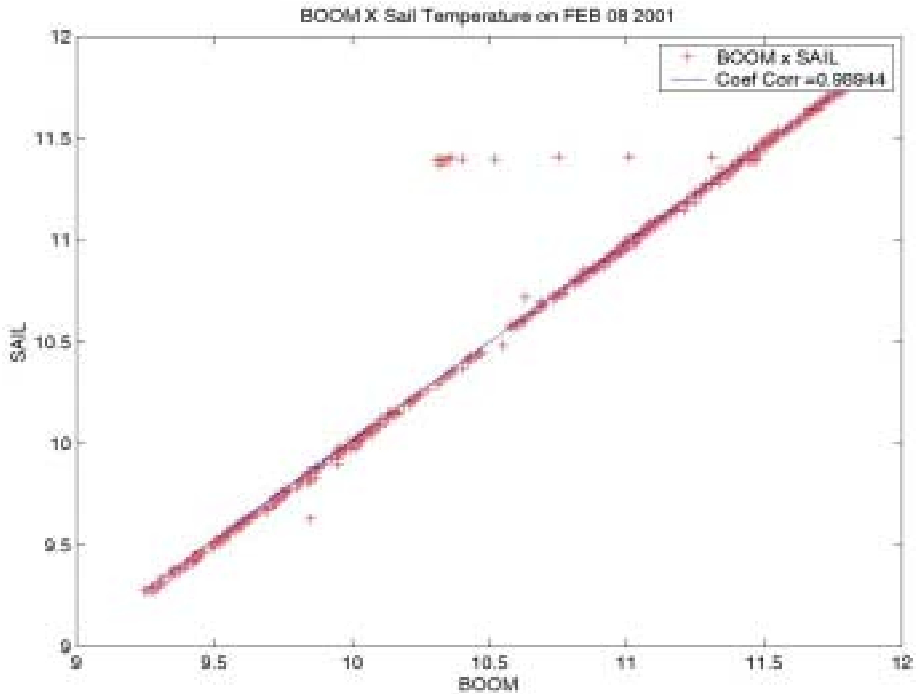

BOOM Temperature on FEB 05 2001
Latitude (degrees)
Longitude (degrees)
12.45
12.4
12.35
12.3
12.25
12.2
12.15
12.1
12.05
12
38
37.5
37
36.5
36
35.5
−123
−122.5
−122
−121.5
−121
BOOM Temperature on FEB 08 2001
Latitude (degrees)
Longitude (degrees)
11.5
11
10.5
10
9.5
38
37.5
37
36.5
36
35.5
−123
−122.5
−122
−121.5
−121

Figure 8


BOOM X Sail Temperature on FEB 08 2001
BOOM x SAIL
Coef Corr =0.98944
SAIL
12
11.5
11
10.5
10
9.5
9
9
9.5
10
10.5
11
11.5
12
BOOM

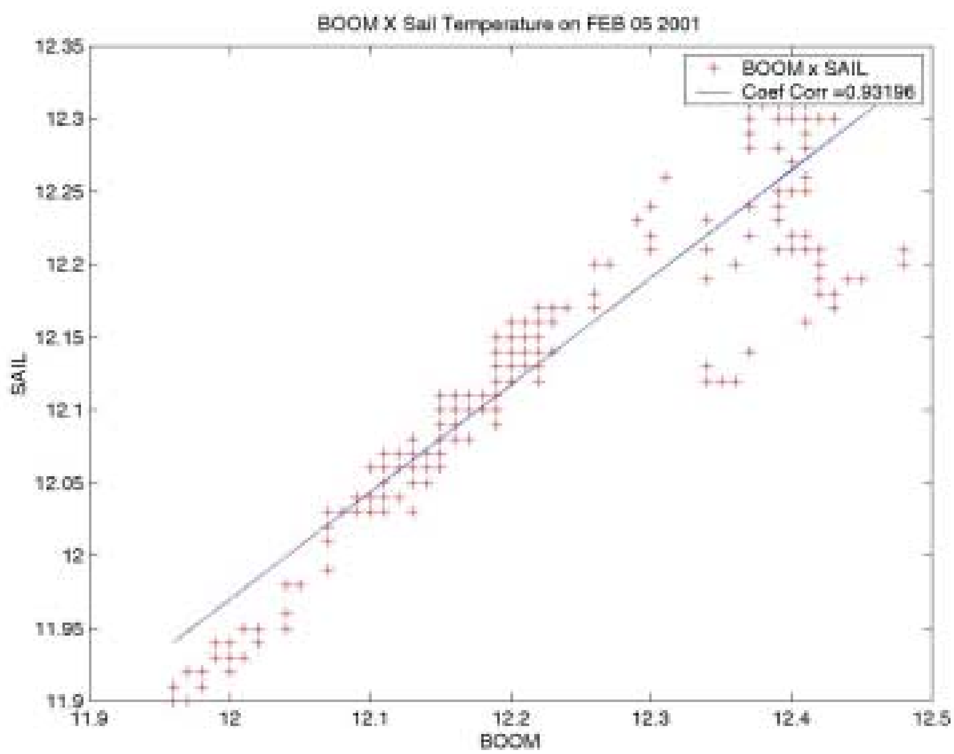
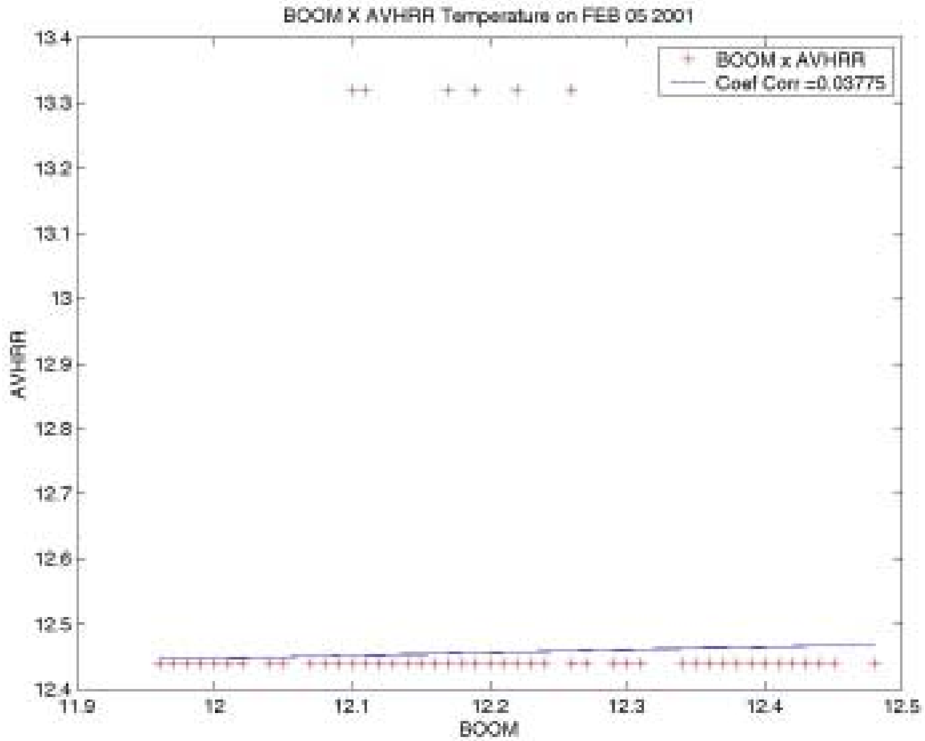
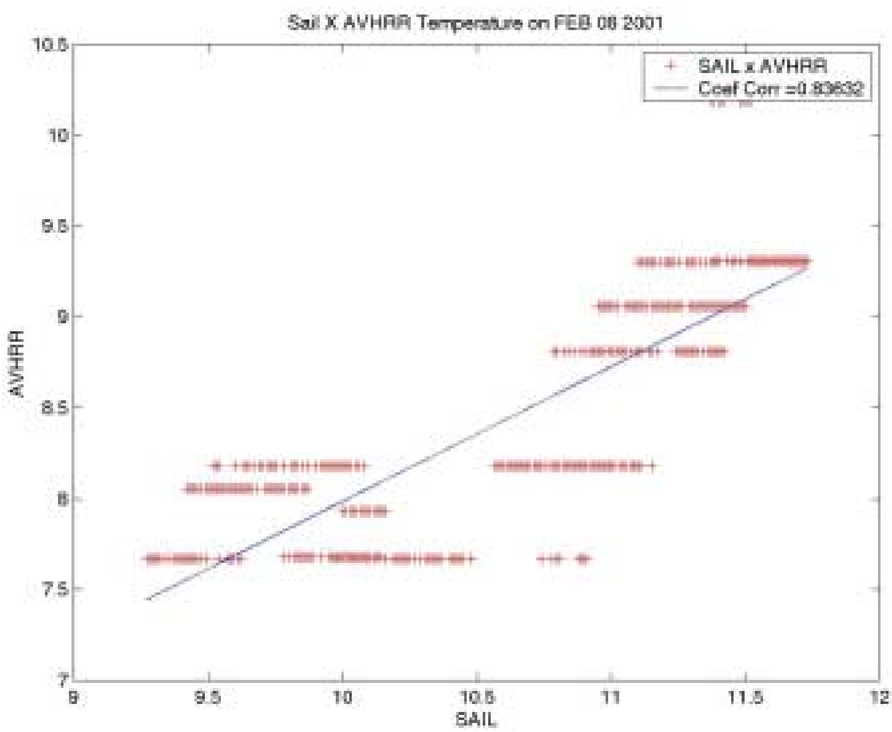

BOOM X Sail Temperature on FEB 05 2001
BOOM x SAIL
Coef Corr =0.93196
SAIL
12.35
12.3
12.25
12.2
12.15
12.1
12.05
12
11.95
11.9
11.9
12
12.1
12.2
12.3
12.4
12.5
BOOM

Figure 9


BOOM X AVHRR Temperature on FEB 05 2001
BOOM x AVHRR
Coef Corr =0.03775
AVHRR
BOOM
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
12.6
12.5
12.4
11.9
12
12.1
12.2
12.3
12.4
12.5


Sail X AVHRR Temperature on FEB 08 2001
SAIL x AVHRR
Coef Corr =0.83632
AVHRR
SAIL
10.5
10
9.5
9
8.5
8
7.5
7
9
9.5
10
10.5
11
11.5
12