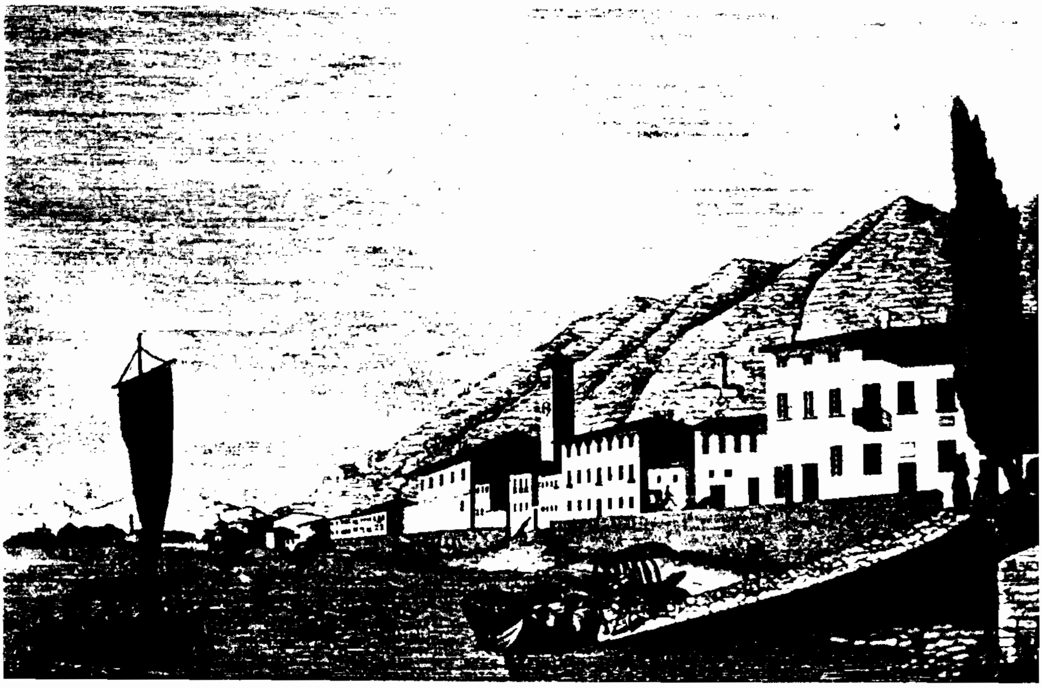
PROCEEDINGS

EUM P 12
ISSN 1015 9576

6TH AVHRR DATA USERS' MEETING



Belgirate, Italy
29th June – 2nd July 1993

EUMETSAT

Joint Research Centre
of the Commission of the European Communities

Local Organising Committee: Jean-Pierre Le Gorgeu
Manuel Florensa Molist

EUMETSAT Organising Committee: Michael Phillips
Madeleine Pooley
Karen Lasser

Published and distributed by

EUMETSAT
Am Elfengrund 45
64297 Darmstadt
Federal Republic of Germany

Tel. +49-6151-950-0
Fax. +49-6151-950-125

Printed by

Druckerei Drach
Alsbach
Federal Republic of Germany

Price

DM 50,-- (or equivalent)

ISBN No.

92-9110-012-9

The papers in this book comprise the proceedings of the meeting mentioned on the cover and title page. They reflect the authors' opinions and are published as presented and without change, in the interests of timely dissemination. Their inclusion in this publication does not necessarily constitute endorsement by EUMETSAT or the Joint Research Centre.

Cover page: Belgirate in the 1700's. Etching reproduced by kind permission of Sig. O. Mugnai, Villa Carlotta, Belgirate.

Software Displays

Commercial Display

TEMPORAL VARIATION IN THE DETECTION LIMIT OF FIRES IN AVHRR'S CH.3

A.W. Setzer (1,2) and J.P. Malingreau (1)

(1) JRC/IRSA - T.P. 440 - I 21020 - Ispra - Italy
(2) INPE - C.P.515 - 12201 - S.J.Campos, SP - Brazil

ABSTRACT

Comparison of the detection limit for active fires in NOAA-11 AVHRR's channel 3 (3.7um) afternoon images was done in different years and tropical regions of the world. In the analysis of digital counts for hundreds of fires a variation in the range of digital counts (DN) of fire pixels was observed. After the satellite launch in late 1988 fires had a maximum DN of 41 in the 0-1023 level scale, but in 1990 the limit went up to 45 and in 1992 up to 48. As in similar observations for channels 1 and 2 the variation can be the result of AVHRR's degradation with time. This effect has implications in fire detection algorithms since the detection limit will change in time and not remain constant as currently assumed.

INTRODUCTION

The possibility of fire detection in channel 3 (3.55-3.93um) thermal images of the Advanced Very High Resolution Radiometer (AVHRR) sensor on-board National Atmospheric and Oceanic Administration (NOAA) satellites is known for many years - see Pereira and Setzer (1993) for a recent update. An AVHRR operational program working on a daily basis to detect fires in the afternoon overpasses is already in use since 1987 in Brazil (Setzer, 1993) and AVHRR world-wide monitoring of fires (Malingreau, 1990; Malingreau, 1993) is currently being developed following recommendations by international programs investigating changes in the biosphere(IGBP, 1990).

However, no actual validations of channel 3 fire detection capabilities seem to be found in the international literature. Pereira and Setzer (1993) characterized spectral responses of AVHRR fire pixels in a region of tropical deforestation, but no field validation has been found. Belward et al. (1993) are reporting five cases in west Africa, and Setzer et al. (1993) are describing two other cases in Amazonia. An internal report quoted in Setzer et al.(1992) cites hundreds of fires detected by AVHRR's channel 3 being checked by field crews, just corroborating the effectiveness of the detection but without relating fires to pixel values in the images.

In this work we describe one of the findings of a validation effort (Setzer and Malingreau, 1993) of fire detection in AVHRR images of NOAA-11. In the following text we show that AVHRR's channel 3 is not stable in a scale of many years, a fact not yet reported which has to be considered in AVHRR-based fire detection algorithms.

METHODOLOGY: SELECTION OF ACTIVE FIRES

Any validation work of remote sensing detection of fires must be based on active fires at the time of image acquisition. When ground support is used to select or confirm fires during a satellite overpass only a few cases can usually be validated because of logistic difficulties. If many cases and images are needed the field effort and costs become prohibitive, particularly for continental or global-scale studies. To overcome this limitation the following simple technique was devised to validate active fires using supervised digital processing of raw AVHRR images.

Instances of vegetation fires were confirmed in the AVHRR images only when in an area of vegetation cover a smoke plume with a wedge/bending shape could be visually identified, clearly originating from a "hot" pixel in the channel 3 image. Plumes were visually detected by enhancing the channel 1 image (0.55-0.68 um), where they are more easily distinguished from other surfaces. The enhancement used for the plumes, linear stretching, varied very much among images and also for different sections of the same image due to differences in solar illumination, viewing geometry, atmospheric opacity and background reflectance. Hot pixels in channel 3 images were selected by thresholding its distribution histogram, using pixels below DN 50. In its original inverted scale of 1024 levels that results from 10-bit resolution, the 0-50 range corresponds to the hot extreme of the scale. Only cases of individual hot pixels (point fires) or of a few contiguous hot pixels were considered to avoid the problem in channel 3 known as "saturation" of large areas. The DNs of the "fire pixels" thus found, as well as those of all pixels in a square of 15 x 15 pixels centred around each fire detected were used in the present analysis. Almost all fire events with plumes in channel 1 and hot pixels in channel 3 showed a marked difference in channel 3 for their pixels in relation to surrounding pixels. As described by Pereira and Setzer (1993) fire pixels have DNs about one order of magnitude smaller than surrounding vegetation pixels, and this characteristic makes it simple to select them.

Hundreds of full resolution NOAA-11 AVHRR 10-bit digital images of the JRC/IRSA/MTV group archive were visually analyzed to select vegetation fire events. Twelve images of west Africa, twelve of south-east Asia, and ten of South America, each containing at least ten independent validated fire cases were used in the study. Other images showed no plumes clearly associated with hot pixels or had less than ten independent cases of fires. Thus, data for a total of 340 fire events in assorted tropical ecosystems ranging from dense rain forests to grassy savannas were analyzed. The dates of the images used in the study varied in time from early 1989, after the satellite launch (Nov/88) to late 1991, providing a diversified sample. Images for characterization of fire pixels were used in their raw format, i.e., without any kind of geometric and radiometric corrections. Geometric correction algorithms either sample or repeat values of individual raw pixels to transform uneven sizes of AVHRR's original pixels in a regular pattern. In the study of very localized phenomena such as fire this introduces significant errors with loss of information or wrong indication of the number of pixels detected by the satellite. Radiometric and atmospheric correction in areas of extensive biomass burning without any measurements of the heavy and variable aerosol loads is certainly very limited and was not attempted in this work. Concerning the conversion of pixel's DNs in channel 3 to brightness temperatures, the authors preferred the use of raw DNs. The great majority of fires, no matter their size or temperature, do not saturate channel 3 pixels, and the corresponding brightness temperature for fire pixels calculated using linear conversions and on-board real-time calibration data (Kidwell, 1991) results in temperatures around to 45^{o} C. Since no information is gained at all transforming DNs to temperature, we believe it is more reasonable to describe characteristics of fire pixels using digital count values than referring to unrealistic temperatures. The reason why large and hot fires do not saturate channel 3 pixels as expected in theory (Robinson, 1991) is still an open question and a possible explanation based on wrong on-board signal processing of AVHRR's channel 3 is being suggested by Setzer and Verstrate (1993).

ANALYSIS AND DISCUSSION OF RESULTS

To illustrate the variation of the detection limit of fires in AVHRR's channel 3 imagery we present data from eight of the 36 images analyzed. Each one contains ten independent cases of actual vegetation fires. Table 1 shows the image dates, the region they refer to, the maximum and minimum pixel values (DN) and the number of fire pixels in channel 3 found for every fire event. In all images, as well as in other ones not here presented, fire pixels were characterized by an upper limit in the DNs. DNs with zero count, i.e., saturation, represented just a minor percentage of fire pixels: of the 80 fire cases in Table 1, only three had pixels with zero DNs. For the total number of fire pixels in the eight images, 628, just the same three had zero DN. The table also indicates that for most of the fire events, the minimum DN of the fire pixels is significantly distant from the saturation limit. Even for very large fire events, like for example case no.8 in the image of 11/Aug/90 with 15 fire pixels, the lowest DN was just 38. However, the upper DN values of the fire cases in channel 3 were consistently close to a maximum value, in agreement with the findings of Pereira and Setzer (1993) in their NOAA-9 study. As seen in Table 1, this maximum value for the 4/Feb/89 image was 41, repeated in six of the ten cases; the other maxima were relatively close to this value, and not less than 36.

Also noticeable in Table 1 is that the DN maxima for the fire cases varied along the life time of NOAA-11's AVHRR. Summarizing that information, and not including the DN 48 of the Aug/90 image we have:

Date:	Feb/89	Aug/89	Mar/90	Aug/90	Dec/90	Mar/91	Aug/91	Dec/91
Maximum DN:	41	43-44	44-45	44-45	44-45	45-46	47	46-47

Unpublished data from the operational monitoring of fires in Brazil during 1992 and also from a fire validation experiment of Belward et al. (1993) in January, 93, in Africa, provide additional information to this sequence, showing that from mid-1992 onwards the detection DN limit for fires in channel 3 was already 48.

The variation in the channel 3 response to fires in day-time images can not be attributed to the change in equatorial crossing time that afternoon NOAA-series satellites present. This effect, with an yearly delay of about 20 minutes/year (Gutman, 1990), could affect the signal of channels 1 and 2 because they measure solar reflected light. If the image is acquired at a later solar time from year to year, changes in the sun-target-satellite angle will occur causing also a change in the image signal in the visible and near-infrared channels. But fires in channel 3 are detected because of their emitted thermal energy, which does not depend on the solar illumination angle, and therefore orbital changes should have no effect on the detection of fires.

Considerations about the fire temperature can not be made since the AVHRR thermal response is not adequate for this range of temperature. The temperature indication of fires in channel 3, of about 45 C that does not saturate the sensor, is obviously not real, and channels 4 and 5 show little or no response to active fires, regardless of their size and intensity (Setzer et al., 1993; Setzer and Malingreau, 1993).

Therefore, we suggest that the reduction in the DN limit of fire detection observed is the result of a degradation of channel 3 of the AVHRR sensor on-board NOAA-11. Actually, also for NOAA-9, launched in Dec/84, a very similar of channel 3 was observed in the operational monitoring of fires in Brazil. For 1985 the DN limit was 36 in the 0-1023 scale (Setzer and Pereira, 1993), progressively changing up to 48 in 1989. Degradation of AVHRR's channels 1 and 2 have been shown for NOAA-11 (Holben et al., 1990), as well as for NOAAs 7 and 9 (Kaufman and Holben, 1993) and we believe a similar type of phenomena could be occuring in channel 3 of the AVHRRs.

An important discussion point concerning the above results is related to the use of the calibration data which is transmitted in every scan line of AVHRR data for the thermal channels 3, 4 and 5. Two targets of known temperature, one hot and the other cold, provide on-board reference values for calibration (Kidwell, 1991) which in principle could compensate the sensor degradation. Nevertheless, if the evidence of wrong on-board processing of the signal from AVHRRs channel 3 exists as we believe (Setzer and Verstrate, 1993) the use of calibration information will tend to complicate the effect of the problem we have just presented in fire detection.

CONCLUSIONS

Detection of fires in NOAA-series satellites AVHRR rely mainly on thermal channel 3 thresholding. We have shown that as in the case of visible and near-infrared AVHRR channels, channel 3 is also subject to changes of signal with time, as a possible consequence of the sensor degradation. Fire algorithms currently under development or in use, either for local monitoring of fires or for global change studies, should consider this new evidence in their design.

ACKNOWLEDGMENTS

We acknowledge the support of the Brazilian Scientific Council (CNPq) which made the development of this work possible through grant no.200602/79-9 .

BIBLIOGRAPHY

Belward, A. S., Grégoire, J.M., D'Souza, G., Trigg, S., Hawkes, M., Brustet, J.M., Serca, D.,Tireford, J.L., Charlot, J.M., and Vuattoux, R., 1993. In-situ, real time fire detection using NOAA/AVHRR data. Proceedings, 6th European AVHRR Data Users' Meeting, Belgirate, Italy, 28/June-2/July, Italy, 7 pgs.

Gutman, G.G., 1990. Towards monitoring droughts from space. J.Climate, 3, 282-295.

Holben, B.N., Kaufman, Y.J., and Kendall, J.D., 1990. NOAA-11 AVHRR visible and near-IR inflight calibration. Int.J.Remote Sensing, 11,(8),1511-1519.

IGBP, 1990. Report No.13: Terrestrial Biosphere exchange with global atmospheric chemistry; Terrestrial biosphere perspective of the IGAC project. Stockholm, Sweden, 103 pp.
Kaufman, Y. and Holben, B.N., 1993. Calibration of the AVHRR visible and near-IR bands by atmospheric scattering, ocean glint and desert reflection. Int.J. Rem.Sensing 14(1)21-52.
Kidwell, K.B., 1991. NOAA polar orbiter data user's guide. NOAA/NESDIS, Wash. D.C.
Malingreau, J.P., 1990. The contribution of remote sensing to the global monitoring of fires in tropical and subtropical ecosystems. In Fire and the Tropical Biota, ed. J.G.Goldammer, chp.15, pp.337-370. Berlin, Springer-Verlag.
Malingreau, J.P., 1993. Group Report: Quantification of fire characteristics from local to global scales. In Fire in the Environment, ed.P.J.Crrutzen/J.G.Goldammer,pp.329-343.
Pereira, M.C. and Setzer, A.W., 1993. Spectral characteristics of deforestation fires in NOAA/AVHRR images. Int.J.Remote Sensing, 1993, 14 (3), 583-597.
Robinson, J.M., 1991. Fire from space: Global fire evaluation using infrared remote sensing. Int. J.Remote Sensing, 12, 3-24.
Setzer, A.W., 1993. Operational satellite monitoring of fires in Brazil. Int. Forest Fire News,9.
Setzer, A.W. and Malingreau, J.P., 1993. Fire detection validation in thetropics using AVHRR/NOAA-11. Manuscript in preparation for Remote Sensing of Environment.
Setzer, A.W. and Verstrate, M. M., 1993. Fire and glint in AVHRR's channel 3: a possible explanation for the non-saturation mystery. Submitted to Int. J. Remote Sensing.
Setzer, A.W., Pereira, M.C., and Pereira Jr., A.C., 1992. The use of NOAA satellites in the detection of fires in Brazil. Climanalise (INPE?Brazil) 7(8), 41-53 (in Portuguese).
Setzer, A.W., Pereira, M.C., and Pereira Jr., A.C., 1993. Satellite studies of biomass burning in Amazonia - some practical aspects. Submitted to Remote Sensing Reviews.

					Case Number									
Date	Region	Latit.	Long.	Case:	1	2	3	4	5	6	7	8	9	10
4-Feb-89	W-Africa	6.5-11 N	5.5-13.5 W	max.	41	41	41	36	39	41	36	41	41	37
				min.	1	5	39	28	39	36	36	10	12	0
				N.Pix	11	11	4	2	2	9	1	9	19	5
26-Aug-89	S-America	5-15.5 N	58-70 W	max.	43	43	41	43	43	44	43	43	43	42
				min.	25	6	38	3	1	5	4	3	7	11
				N.Pix	14	13	2	4	14	29	8	18	7	4
30-Mar-90	SE-Asia	10-19.5 N	97.5-102 E	max.	44	43	43	44	44	45	45	44	44	43
				min.	42	41	4	23	20	23	27	43	0	42
				N.Pix	6	4	11	10	6	12	8	2	4	2
11-Aug-90	S-America	11-23.5 S	49-57 W	max.	42	48	44	45	45	45	45	45	45	45
				min.	7	0	41	44	41	35	18	38	7	25
				N.Pix	4	20	3	3	5	7	7	15	10	10
31-Dec-90	W-Africa	9-11 N	1-3 E	max.	44	30	44	1	45	35	42	45	45	45
				min.	40	30	44	1	6	19	29	5	20	43
				N.Pix	2	1	2	1	4	2	2	7	5	2
28-Mar-91	SE-Asia	11.5-22 N	93.5-107 E	max.	45	26	46	42	45	46	46	46	46	46
				min.	44	19	42	22	44	45	15	43	43	45
				N.Pix	2	2	7	4	2	4	8	6	5	4
15-Aug-91	S-America	10-23.5 S	53-62.5 W	max.	47	47	47	47	47	47	47	47	47	47
				min.	37	2	11	33	33	12	2	3	30	22
				N.Pix	8	16	18	8	11	12	56	11	21	12
2-Dec-91	W-Africa	7-13 N	4-13.5 W	max.	45	47	45	37	45	46	46	47	45	46
				min.	27	17	45	26	42	25	4	41	42	37
				N.Pix	4	11	1	2	2	5	7	8	2	6

Table 1. Maximum and minimum digital counts of AVHRR/NOAA-11 channel 3 pixels in 80 cases of fire.