# Fire and glint in AVHRR's channel 3: a possible reason for the non-saturation mystery

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Abstract. Evidence from a very strong and rare case of sunglint in a NOAA-11 AVHRR image is used to show that a problem exists in the on-board signal processing of channel 3. This problem, associated only with targets of high reflectivity and/or temperature, causes erroneous indication of digital counts (DN) and calculated brightness temperatures for near-saturation ranges in channel 3 images. The explanation proposed, a spurious conversion of the sensor signal to DNs, fits observations of sunglint and fire detection data in AVHRR images of the NOAA-series satellites which could not otherwise be explained.

#### 1. Introduction

Channel 3 (3.55-3.93 µm) of the Advanced Very High Resolution Radiometer (AVHRR) on-board the NOAA-series satellites is sensitive to emitted as well as reflected energy in the optical spectrum. It supposedly saturates for Earth targets at about 47°C, or 320K (Kidwell 1991), and also with light from sunglint in water bodies (Khattak et al. 1991) or sun light reflected from some types of exposed soils (Grégoire et al. 1993). Snow, ice, and ice clouds, however, reflect relatively little in the channel 3 spectral region; most other clouds also reflect less than sunglint (Scorer 1989). According to Wien's displacement law, the thermal emission of vegetation fires in the range 400-700°C peaks in the 3-4 µm range and calculations predict (e.g., Matson and Dozier 1981; Robinson 1991) that a fire of about 30 m × 30 m in extent and near the centre of a channel 3 pixel should saturate it. This expectation is not supported by available measurements, however. For instance, large fires in forests and grasslands, sometimes occupying areas many times the size of an AVHRR pixel  $(1 \cdot 1 \times 1 \cdot 1 \text{ km})$  at nadir) have been associated repeatedly with nonsaturated values of channel 3 (Belward et al. 1993, Pereira and Setzer 1993, Setzer and Malingreau 1993 a, Setzer et al. 1993). For sunglint no actual data are apparently found in the literaure. Brush (1993) showed an NOAA-12 AVHRR scene where the signal 'may' reach saturation; he also pointed to a 'transient' effect just entering the sunglint area, which will be easily explained with the new finding presented below. This transient signal, which appears in the channel 3 images like an atmospheric halo/corona effect around the sunglint area, whatever its size, as well as the non-saturation by very large fires may be the result of the on-board signal processing problem we believe to have found. This letter presents the evidence for our hypothesis.

# 2. Case description and discussion

Figure 1 shows the NOAA-11 AVHRR image used, where Indo-China is on the west side and the Philippines on the east. Its contrast has been enhanced artifically just for illustration purposes and the data analysis was performed using the raw uncorrected data with full 1-1 km (nominal) and 10-but maximum resolutions. The sunglint area in the South China Sea is shown in red. This image was recorded during orbit number 07698, with an ascending equatorial crossing of approximately 06:03 hours GMT and 121° W, and downloaded at Wallops Island, VA, USA. The sunglint in the image occurred at a scan angle of about 23°. Such specular reflection is commonly observed when the Sun is near the AVHRR's scanning plane. Uncommon in the image is the small sunglint region in the north Borneo coastline. Figure 2 shows an enlargement of the relevant area, in the centre of Brunei Bay, at 5° N and 115° W. The unusual characteristic of this small spot of sunglint is its

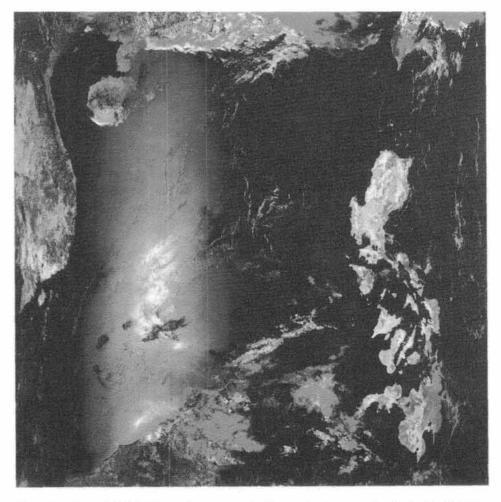


Figure 1. Raw AVHRR false-colour composite image showing sunglint in the South China Sea. Indo-China and the Gulf of Tonkin with Hai-Nan island are seen in the upper left corner; the Philippines are in the right side and Borneo in the lower side.

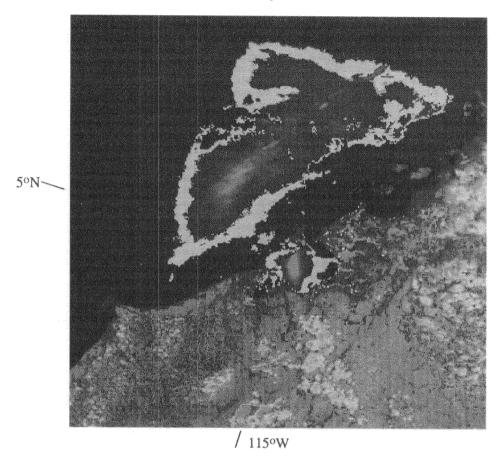


Figure 2. Very strong sunglint in the Brunei Bay at 5° N and 115° W, in the north coast of Borneo. Note 'halo' effect in red colour surrounding also the larger and less intensive sunglint further north.

intensity, which can be analyzed from figure 3. This figure shows the digital counts (DN) of individual raw pixels in the original 0–1023 (10-bit) scale, for channels 1 to 4, for an area of  $15 \times 15$  pixels with the sunglint at its centre. A saturated pixel with DN 1023 is found in channel 1 (0·55–0·68  $\mu$ m)—see figure 3 (a), and another with DN 1001, i.e., close to saturation, is found in channel 2 (0·75–1·1  $\mu$ m)—see figure 3 (b). In these two channels most pixels at the core of the sunglint, in the shaded area, have DNs above 700 and this is what makes the case unusual: normally, sunglint is associated with DNs in the 200–400 range, only rarely reaching the 600's or higher. Unquestionably, this is a case of 'metallic reflection from a water surface', using Scorer's (1989) terminology. The explanation for such high reflectance is likely to be the absence of waves (Khattak et al. 1991) in the wind protected waters of a closed bay.

An extreme case of sunglint such as this one should have saturated channel 3 also, but this is not observed. Channel 3 DNs in figure 3(c) are shown in their natural inverted scale, where saturation corresponds to 0 and very low temperature/reflectivity to 1023. We observe that the core of the sunglint is represented by pixels

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V   X   S77   S78   S79   S80   S81   S82   S83   S84   S85   S86   S87   S88   S89   S80   S81   S82   S83   S84   S85   S86   S87   S88   S89   S80   S81   S82   S83   S84   S85   S86   S87   S88   S89   S80   S81   S82   S84   S85   S86   S87   S88   S89   S80   S81   S81   S80   S81   S81   S80   S81   S81   S80   S81   S8	Chann y   x 2945 2946 2947 2948 2949 2950 2951 2952 2953 2954 2955 2956	et 03 577 22 28 35 37 38 37 38 39 38 38 36 32 28	578 25 29 35 38 39 40 40 40 40 40 37 36 36	579 30 34 37 39 40 41 41 41 42 41 40 40 39	580 33 37 39 41 42 42 42 42 43 41 41	581 36 39 41 42 42 43 43 43 43 43 43 42 42	582 38 42 43 43 44 44 44 43 43 43 43	583 42 43 43 45 45 45 45 45 45 46 44 44 43	584 43 43 44 45 45 45 45 45 45 44 44 44	585 43 44 44 45 44 43 44 44 44 44 44 44	586 43 43 43 43 43 43 43 43 44 44 44	587 43 43 43 43 43 43 43 43 43 43 43 43 43	588 42 42 43 43 43 43 43 43 43 43 43 43	589 41 42 42 42 42 42 42 42 42 42 42 43	590 40 41 41 40 41 41 41 41 42 42 42 42	591 39 39 40 39 39 40 40 40 40 41 41 41
Y   x   577   578   579   580   581   582   583   584   585   586   587   588   589   590   591     2945   385   385   383   382   382   382   381   380   379   379   379   379   379   380   381     2946   383   381   380   381   380   378   378   378   378   379   379   380   381   382     2948   380   380   380   379   377   376   376   377   379   380   381   381   381   381     2948   380   380   380   379   377   376   376   377   379   380   381   381   381   381     2949   380   380   379   378   377   376   376   377   379   380   380   380   380   380   380     2950   379   379   378   377   376   377   379   380   380   380   380   380   380     2951   379   378   378   378   378   378   378   379   380   380   381   381   381     2952   379   379   379   379   379   379   379   379   380     2953   378   378   377   376   376   376   377   379   380   381   381   381   381     2954   377   376   374   375   376   376   376   377   379   380   381   381   381   381     2953   378   378   378   378   378   378   379   379   380   381   381   381   381     2954   377   376   374   375   376   376   376   376   377   378   378   378   378   379   380     2955   378   377   376   376   376   376   376   377   378   378   378   378   379   380     2955   378   377   376   378   378   378   378   378   378   379   379   379   379   379     2958   379   379   378   378   378   378   378   379   381   381   381   379   379   379     2958   379   379   378   378   378   378   378   378   378   379   37	Chann y   x 2945 2946 2947 2948 2949 2950 2951 2952 2953 2954 2955 2956 2957 2958	et 03 577 22 28 35 37 38 37 38 39 38 39 38 36 32 28 21	578 25 29 35 38 39 40 40 40 40 37 36 36 36	579 30 34 37 39 40 41 41 41 42 41 40 40 39 40	580 33 37 39 41 42 42 42 42 43 41 41 41	581 36 39 41 42 42 43 43 43 43 43 43 42 42 42	582 38 42 43 43 44 44 44 43 43 43 43 43	583 42 43 43 45 45 45 45 45 45 44 44 43 43 43	584 43 43 44 45 45 45 45 45 45 45 44 44 44 43 43	585 43 44 44 45 44 43 44 44 44 44 44 43 44	586 43 43 43 43 43 43 43 43 44 44 44 44	587 43 43 43 43 43 43 43 43 43 43 43 43 43	588 42 42 43 43 43 43 43 43 43 43 43 43	589 41 42 42 42 42 42 42 42 42 42 42 42 42 42	590 40 41 41 40 41 41 41 41 42 42 42 42 42 42	591 39 39 40 39 39 40 40 40 41 41 41 41
2945         385         385         383         382         382         382         381         380         379         379         379         379         379         380         381         380         381         380         381         380         381         380         381         380         381         380         381         380         381         380         381         380         381         380         381         380         381         380         380         381         381         380         380         380         380         380         380         380         380         380         380         381 <td>Chann   y   x   2945   2946   2947   2948   2950   2951   2952   2953   2954   2955   2956   2957   2958   2959</td> <td>et 03 577 22 28 35 37 38 37 38 39 38 39 38 36 32 28 21 26</td> <td>578 25 29 35 38 39 40 40 40 40 37 36 36 36</td> <td>579 30 34 37 39 40 41 41 41 42 41 40 40 39 40</td> <td>580 33 37 39 41 42 42 42 42 43 41 41 41</td> <td>581 36 39 41 42 42 43 43 43 43 43 43 42 42 42</td> <td>582 38 42 43 43 44 44 44 43 43 43 43 43</td> <td>583 42 43 43 45 45 45 45 45 45 44 44 43 43 43</td> <td>584 43 43 44 45 45 45 45 45 45 45 44 44 44 43 43</td> <td>585 43 44 44 45 44 43 44 44 44 44 44 43 44</td> <td>586 43 43 43 43 43 43 43 43 44 44 44 44</td> <td>587 43 43 43 43 43 43 43 43 43 43 43 43 43</td> <td>588 42 42 43 43 43 43 43 43 43 43 43 43</td> <td>589 41 42 42 42 42 42 42 42 42 42 42 42 42 42</td> <td>590 40 41 41 40 41 41 41 41 42 42 42 42 42 42</td> <td>591 39 39 40 39 39 40 40 40 41 41 41 41</td>	Chann   y   x   2945   2946   2947   2948   2950   2951   2952   2953   2954   2955   2956   2957   2958   2959	et 03 577 22 28 35 37 38 37 38 39 38 39 38 36 32 28 21 26	578 25 29 35 38 39 40 40 40 40 37 36 36 36	579 30 34 37 39 40 41 41 41 42 41 40 40 39 40	580 33 37 39 41 42 42 42 42 43 41 41 41	581 36 39 41 42 42 43 43 43 43 43 43 42 42 42	582 38 42 43 43 44 44 44 43 43 43 43 43	583 42 43 43 45 45 45 45 45 45 44 44 43 43 43	584 43 43 44 45 45 45 45 45 45 45 44 44 44 43 43	585 43 44 44 45 44 43 44 44 44 44 44 43 44	586 43 43 43 43 43 43 43 43 44 44 44 44	587 43 43 43 43 43 43 43 43 43 43 43 43 43	588 42 42 43 43 43 43 43 43 43 43 43 43	589 41 42 42 42 42 42 42 42 42 42 42 42 42 42	590 40 41 41 40 41 41 41 41 42 42 42 42 42 42	591 39 39 40 39 39 40 40 40 41 41 41 41
2946         383         383         381         380         381         380         378         378         378         379         379         380         381         380         380         379         378         378         378         379         379         380         381         381         381         381         381         380         380         380         379         377         376         376         377         379         380         381         380 <td>Chann y   x 2945 2946 2947 2948 2949 2950 2951 2952 2953 2954 2955 2956 2957 2958 2959 Chann</td> <td>9 03 577 22 28 35 37 38 39 38 38 39 28 21 26</td> <td>578 25 29 35 38 39 40 40 40 40 40 37 36 36 35 35</td> <td>579 30 34 37 39 40 41 41 41 42 41 40 40 39 40</td> <td>580 33 37 39 41 42 42 42 42 41 41 41 41 41</td> <td>581 36 39 41 42 42 43 43 43 43 43 42 42 42 42</td> <td>582 38 42 43 43 44 44 44 43 43 43 43 43</td> <td>583 42 43 43 45 45 45 45 45 44 44 43 43 43 43 43</td> <td>584 43 44 45 45 45 45 45 45 44 44 44 43 43 43</td> <td>585 43 44 44 43 44 44 44 44 44 43 44 43 44 43</td> <td>586 43 43 43 43 43 43 43 44 44 44 44 44</td> <td>587 43 43 43 43 43 43 43 43 43 43 43 43 43</td> <td>588 42 42 43 43 43 43 43 43 43 43 43 43</td> <td>589 41 42 42 42 42 42 42 42 42 42 42 42 42 42</td> <td>590 40 41 41 40 41 41 41 41 42 42 42 42 42 42</td> <td>591 39 39 40 39 40 40 40 41 41 41 41 41</td>	Chann y   x 2945 2946 2947 2948 2949 2950 2951 2952 2953 2954 2955 2956 2957 2958 2959 Chann	9 03 577 22 28 35 37 38 39 38 38 39 28 21 26	578 25 29 35 38 39 40 40 40 40 40 37 36 36 35 35	579 30 34 37 39 40 41 41 41 42 41 40 40 39 40	580 33 37 39 41 42 42 42 42 41 41 41 41 41	581 36 39 41 42 42 43 43 43 43 43 42 42 42 42	582 38 42 43 43 44 44 44 43 43 43 43 43	583 42 43 43 45 45 45 45 45 44 44 43 43 43 43 43	584 43 44 45 45 45 45 45 45 44 44 44 43 43 43	585 43 44 44 43 44 44 44 44 44 43 44 43 44 43	586 43 43 43 43 43 43 43 44 44 44 44 44	587 43 43 43 43 43 43 43 43 43 43 43 43 43	588 42 42 43 43 43 43 43 43 43 43 43 43	589 41 42 42 42 42 42 42 42 42 42 42 42 42 42	590 40 41 41 40 41 41 41 41 42 42 42 42 42 42	591 39 39 40 39 40 40 40 41 41 41 41 41
2947   381   381   380   380   379   378   377   378   378   379   380   380   381   381   381   2948   380   380   380   379   377   376   376   377   379   380   380   380   380   380   380   380   380   380   380   380   380   380   380   380   2950   379   378   377   376   378   378   379   379   379   378   379   380   380   381   381   381   381   381   2952   379   379   379   379   379   379   379   379   380   381   381   381   381   381   2953   378   378   378   378   378   376   376   376   376   376   378	Chann y   x 2945 2946 2947 2948 2949 2950 2951 2952 2953 2954 2955 2956 2957 2958 2959 Chann y   x	el 03 577 22 28 35 37 38 39 38 39 38 39 38 22 28 21 26 el 04	578 25 29 35 38 39 40 40 40 40 40 37 36 36 35 35	579 30 34 37 39 40 41 41 42 41 40 40 39 40 40	580 33 37 39 41 42 42 42 42 43 41 41 41 41 41	581 36 39 41 42 43 43 43 43 43 42 42 42 42 42	582 38 42 43 43 44 44 44 43 43 43 43 43	583 42 43 43 45 45 45 45 45 44 44 44 43 43 43 43	584 43 43 44 45 45 45 45 45 44 44 44 43 43 43	585 43 44 44 45 44 43 44 44 44 44 44 43 44 43 44 43	586 43 43 43 43 43 43 43 44 44 44 44 44 45 86	587 43 43 43 43 43 43 43 43 43 43 43 43 43	588 42 42 43 43 43 43 43 43 43 43 43 43 43	589 41 42 42 42 42 42 42 42 42 42 42 42 42 42	590 40 41 41 40 41 41 41 42 42 42 42 42 42 42	591 39 39 40 39 40 40 40 41 41 41 41 41 41
2948         380         380         380         379         377         376         376         377         379         380         381         381         381         381         380         381         381         381         381         381         381         381         381 <td>Chann   y   x     2945   2946   2947   2948   2949   2950   2951   2952   2953   2954   2955   2956   2957   2958   2959   Chann   y   x     2945</td> <td>el 03 577 22 28 35 37 38 37 38 39 38 36 32 28 21 26 el 04 577 385</td> <td>578 25 29 35 38 39 40 40 40 40 37 36 36 35 35 35</td> <td>579 30 34 37 40 41 41 41 42 41 40 40 40 40 579 383</td> <td>580 33 37 39 41 42 42 42 42 43 41 41 41 41 41 41 580 382</td> <td>581 36 39 41 42 42 43 43 43 43 43 43 42 42 42 42 42 382</td> <td>582 38 42 43 43 44 44 44 43 43 43 43 43</td> <td>583 42 43 43 45 45 45 45 45 44 44 44 43 43 43 43 43 83 81</td> <td>584 43 43 44 45 45 45 45 45 44 44 44 43 43 43 43</td> <td>585 43 44 44 45 44 44 44 44 44 44 43 44 43 44 43 44 43 78 78 78 79</td> <td>586 43 43 43 43 43 43 43 44 44 44 44 44 43 44</td> <td>587 43 43 43 43 43 43 43 43 43 43 43 43 43</td> <td>588 42 42 43 43 43 43 43 43 43 43 43 43 43 43 43</td> <td>589 41 42 42 42 42 42 42 42 42 42 42 43 42 43 47 42 43</td> <td>590 40 41 41 40 41 41 41 42 42 42 42 42 42 42 42 380</td> <td>591 39 40 39 39 40 40 40 41 41 41 41 41 41 41 41 41 41</td>	Chann   y   x     2945   2946   2947   2948   2949   2950   2951   2952   2953   2954   2955   2956   2957   2958   2959   Chann   y   x     2945	el 03 577 22 28 35 37 38 37 38 39 38 36 32 28 21 26 el 04 577 385	578 25 29 35 38 39 40 40 40 40 37 36 36 35 35 35	579 30 34 37 40 41 41 41 42 41 40 40 40 40 579 383	580 33 37 39 41 42 42 42 42 43 41 41 41 41 41 41 580 382	581 36 39 41 42 42 43 43 43 43 43 43 42 42 42 42 42 382	582 38 42 43 43 44 44 44 43 43 43 43 43	583 42 43 43 45 45 45 45 45 44 44 44 43 43 43 43 43 83 81	584 43 43 44 45 45 45 45 45 44 44 44 43 43 43 43	585 43 44 44 45 44 44 44 44 44 44 43 44 43 44 43 44 43 78 78 78 79	586 43 43 43 43 43 43 43 44 44 44 44 44 43 44	587 43 43 43 43 43 43 43 43 43 43 43 43 43	588 42 42 43 43 43 43 43 43 43 43 43 43 43 43 43	589 41 42 42 42 42 42 42 42 42 42 42 43 42 43 47 42 43	590 40 41 41 40 41 41 41 42 42 42 42 42 42 42 42 380	591 39 40 39 39 40 40 40 41 41 41 41 41 41 41 41 41 41
2949         380         380         379         378         377         375         376         378         380         381 <td>Chann y   x 2945 2946 2947 2948 2949 2950 2951 2952 2953 2954 2955 2956 2957 2958 2959 Chann y   x</td> <td>el 03 577 22 28 35 37 38 37 38 39 38 39 28 21 28 21 28 21 28 37 38 38 39 38 39 38 39 38 39 38 39 38 38 39 38 39 38 38 38 38 38 38 38 38 38 38</td> <td>578 25 29 35 38 39 40 40 40 40 37 36 35 35 35 37 38 38 38</td> <td>579 30 34 37 39 40 41 41 42 41 40 40 40 40 579 383 381</td> <td>580 33 37 39 41 42 42 42 42 43 41 41 41 41 41 41 580 382 380</td> <td>581 36 39 41 42 43 43 43 43 43 42 42 42 42 381</td> <td>582 38 42 43 43 44 44 44 43 43 43 43 43</td> <td>583 42 43 43 45 45 45 45 46 44 43 43 43 43 43 43 43 43 43</td> <td>584 43 43 44 45 45 45 45 45 44 44 43 43 43 43 380 378</td> <td>585 43 44 44 43 44 44 44 44 43 44 43 44 43 44 43 78 78 79 378</td> <td>586 43 43 43 43 43 43 43 44 44 44 44 45 379 378</td> <td>587 43 43 43 43 43 43 43 43 43 43 43 43 43</td> <td>588 42 42 43 43 43 43 43 43 43 43 43 43 43 43 43</td> <td>589 41 42 42 42 42 42 42 42 42 42 42 43 42 43 40 42 43 40 41 41 42 42 43 43 40 41 41 42 42 42 43 43 44 44 44 45 45 46 47 48 48 48 48 48 48 48 48 48 48 48 48 48</td> <td>590 40 41 41 41 41 41 41 41 42 42 42 42 42 42 380 381</td> <td>591 39 40 39 40 40 40 41 41 41 41 41 41 41 381 382</td>	Chann y   x 2945 2946 2947 2948 2949 2950 2951 2952 2953 2954 2955 2956 2957 2958 2959 Chann y   x	el 03 577 22 28 35 37 38 37 38 39 38 39 28 21 28 21 28 21 28 37 38 38 39 38 39 38 39 38 39 38 39 38 38 39 38 39 38 38 38 38 38 38 38 38 38 38	578 25 29 35 38 39 40 40 40 40 37 36 35 35 35 37 38 38 38	579 30 34 37 39 40 41 41 42 41 40 40 40 40 579 383 381	580 33 37 39 41 42 42 42 42 43 41 41 41 41 41 41 580 382 380	581 36 39 41 42 43 43 43 43 43 42 42 42 42 381	582 38 42 43 43 44 44 44 43 43 43 43 43	583 42 43 43 45 45 45 45 46 44 43 43 43 43 43 43 43 43 43	584 43 43 44 45 45 45 45 45 44 44 43 43 43 43 380 378	585 43 44 44 43 44 44 44 44 43 44 43 44 43 44 43 78 78 79 378	586 43 43 43 43 43 43 43 44 44 44 44 45 379 378	587 43 43 43 43 43 43 43 43 43 43 43 43 43	588 42 42 43 43 43 43 43 43 43 43 43 43 43 43 43	589 41 42 42 42 42 42 42 42 42 42 42 43 42 43 40 42 43 40 41 41 42 42 43 43 40 41 41 42 42 42 43 43 44 44 44 45 45 46 47 48 48 48 48 48 48 48 48 48 48 48 48 48	590 40 41 41 41 41 41 41 41 42 42 42 42 42 42 380 381	591 39 40 39 40 40 40 41 41 41 41 41 41 41 381 382
2950         379         379         378         377         377         376         377         379         380         379         379         380         380         381         381         381         380         381         381         381         380         381         381         381         380         381 <td>Chann   y   x  2945 2946 2947 2948 2949 2950 2951 2952 2953 2956 2957 2958 2959 Chann   y   x  2946 2947</td> <td>el O3 577 22 28 35 37 38 37 38 39 38 38 36 32 28 21 26 el O4 577 385 383 383</td> <td>578 25 29 35 38 39 40 40 40 40 40 37 36 35 35 35 35 37 38 38 33 38 38 38 38 38 38 38 38 38 38</td> <td>579 30 34 37 39 40 41 41 42 41 40 40 39 40 40 579 383 381 380</td> <td>580 33 37 39 41 42 42 42 42 43 41 41 41 41 41 41 580 380 380</td> <td>581 36 39 41 42 42 43 43 43 43 43 43 43 44 42 42 42 42 42 381 379</td> <td>582 38 42 42 43 43 44 44 44 43 43 43 43 43</td> <td>583 42] 43 43 45 45 45 45 45 45 43 43 43 43 43 43 73 838 378</td> <td>584 43 43 44 45 45 45 45 45 45 44 44 43 43 43 43 584 378</td> <td>585 43 44 44 45 44 44 44 44 44 43 44 43 44 43 379 378 378</td> <td>586 43 43 43 43 43 43 43 44 44 44 43 44 47 48 49 49 49 49 49 49 49 49 49 49 49 49 49</td> <td>587 43 43 43 43 43 43 43 43 43 43 43 43 43</td> <td>588 42 42 43 43 43 43 43 43 43 43 43 43 43 43 43</td> <td>589 41 42 42 42 42 42 42 42 42 42 43 42 43 42 43 380 381</td> <td>590 40 41 41 41 41 41 41 42 42 42 42 42 42 380 381 381</td> <td>591 39 40 39 40 40 40 40 41 41 41 41 41 41 381 382 381</td>	Chann   y   x  2945 2946 2947 2948 2949 2950 2951 2952 2953 2956 2957 2958 2959 Chann   y   x  2946 2947	el O3 577 22 28 35 37 38 37 38 39 38 38 36 32 28 21 26 el O4 577 385 383 383	578 25 29 35 38 39 40 40 40 40 40 37 36 35 35 35 35 37 38 38 33 38 38 38 38 38 38 38 38 38 38	579 30 34 37 39 40 41 41 42 41 40 40 39 40 40 579 383 381 380	580 33 37 39 41 42 42 42 42 43 41 41 41 41 41 41 580 380 380	581 36 39 41 42 42 43 43 43 43 43 43 43 44 42 42 42 42 42 381 379	582 38 42 42 43 43 44 44 44 43 43 43 43 43	583 42] 43 43 45 45 45 45 45 45 43 43 43 43 43 43 73 838 378	584 43 43 44 45 45 45 45 45 45 44 44 43 43 43 43 584 378	585 43 44 44 45 44 44 44 44 44 43 44 43 44 43 379 378 378	586 43 43 43 43 43 43 43 44 44 44 43 44 47 48 49 49 49 49 49 49 49 49 49 49 49 49 49	587 43 43 43 43 43 43 43 43 43 43 43 43 43	588 42 42 43 43 43 43 43 43 43 43 43 43 43 43 43	589 41 42 42 42 42 42 42 42 42 42 43 42 43 42 43 380 381	590 40 41 41 41 41 41 41 42 42 42 42 42 42 380 381 381	591 39 40 39 40 40 40 40 41 41 41 41 41 41 381 382 381
2951   379   378   378   378   378   378   378   378   378   379   380   380   381   381   381   380   381   2952   379   379   379   379   379   379   379   379   379   380   381   382   382   381   381   2953   378   378   377   376   376   376   376   376   376   376   376   378   379   380   381   381   381   381   2954   377   378   377   378   378   379   380   2955   378   377   376   377   378   379   380   379	Chann   y   x     2945     2946     2947     2948     2950     2951     2952     2953     2955     2956     2957     2958     Chann     y   x     2945     2946     2947     2948	el 03 577 22 28 35 37 38 37 38 39 38 36 32 28 21 26 el 04 577 383 383 383 383 383 383 384 385 386 387 388 388 388 388 388 388 388	578 25 29 35 38 39 40 40 40 40 37 36 35 35 578 383 381 380	579 30 34 40 41 41 42 41 40 40 579 383 380 380	580 33 37 39 41 42 42 42 43 41 41 41 41 41 41 580 382 382 380 379	581 36 39 41 42 42 43 43 43 43 42 42 42 42 42 382 381 379 377	582 38 42 42 43 43 44 44 44 43 43 43 43 43	583 42] 43 43 45 45 45 46 44 44 43 43 381 381 377 376	584 43 43 44 45 45 45 45 45 44 44 43 43 380 378 378	585 43 44 44 43 44 44 44 44 43 585 379 378 379	586 43 43 43 43 43 43 43 44 44 44 44 43 44 586 379 378 379 380	587 43 43 43 43 43 43 43 43 43 43 43 43 43	588 42 42 43 43 43 43 43 43 43 43 43 43 43 43 43	589 41 42 42 42 42 42 42 42 42 42 43 379 378 381	590 40 41 41 41 41 41 42 42 42 42 42 42 42 380 381 381	591 39 40 40 40 41 41 41 41 41 381 382 381 380
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Figure 3. AVHRR digital counts (DNs) for pixels in the centre of intense sunglint. See table 1 for the limits of classes used for channels 1 to 3.

with a DN 45 instead of the expected value of zero. We further observe from figure 3 that the signal in channel 3 is positively correlated to the signals of channels 1 and 2. Therefore, surprisingly, the reflectance/temperature signal in channel 3 increases (lower DNs on the inverted scale) outwards from the sunglint while the reflectance decreases in the visible and near IR channels. The DN ranges for channels 1 and 2, associated with DN values of 45-41 in channel 3 for the data subset shown in figure 3, are listed in table 1. DNs of channels 1 and 2 for the corresponding channel 3 DNs of 46 to 49 found outside the intense sunglint inverted this trend and were in the following ranges, respectively: 195 to 200, and 168 to 170.

Figure 4 shows the profiles of pixel values for all 5 channels for a segment of an AVHRR scan line (2952 in figure 3) passing through the core of the sunglint. The peaks of channels 1 and 2 coincide and indicate unambiguously the core of the sunglint where they reach values at or close to saturation. Channels 4 and 5, on the other hand are not sensitive to reflected sun light and show no noticeable variation in the core of the sunglint area. This implies that the sea surface temperature must have been essentially constant throughout the area. Using calibration coefficients provided with the data, the nominal temperature for the area of figure 3 was close to 23° C and the variation was only a few tenths of one degree C. The interesting finding is that the curve for channel 3 reaches saturation at two other places, away from the core of the sunglint, at totally unexpected places.

This finding could however be explained by a faulty on-board conversion of the analogue signal from the channel 3 sensor into DNs. This conversion should in principle take place monotonically, i.e., associate progressively lower DNs to increasing radiance measurements. Instead, we postulate that beyond a specific threshold radiance, increasing radiances are transformed into increasing DNs. In this type of curve, schematically shown in figure 5, a signal level higher than the level corresponding to a null DN results in DNs previously allocated to lower signal levels. Therefore, in figure 4 we believe that the correct curve for channel 3 should be a kind of mirror image with respect to the x axis for those pixels situated in the interval between the pixels where saturation is first reached.

The areas with a DN of zero are shown with a red tone in figure 2 and can be found surrounding the sunglint regions following the pattern of the graph in figure 4. In addition to the Brunei Bay, another and larger sunglint to the north can be seen in the same figure, but presenting DNs in channels 1 and 2 in the common ranges below 400. This edge effect with pixels of zero DN, which gives the impression of a corona/halo/transient effect, is easily explained as resulting from a signal conversion curve like the one in figure 5. We also want to emphasize that this edge effect of

Channel 3	Channel 12	Channel 2		
45	> 878			
44	622-877	533-758		
43	347-621	304-532		
42	302-346	260-303		
41	285-301	243-259		
40	272-284	233-242		

Table 1. Class ranges in the core of the intense sunglint.

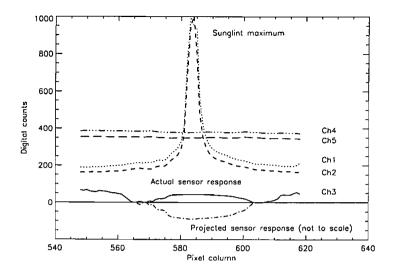


Figure 4. Line transect through an intense sunglint in an AVHRR image. Actual pixel values for the central part are found in figure 3, line 2952.

channel 3 was found not only in the two cases shown in figure 2, but also in all other cases of sunglint in dozens of NOAA-11 AVHRR channel 3 images we have examined.

This interpretation of anomalous data can be confirmed independently by analyzing data from an entirely different process, namely fire detection over continents in AVHRR channel 3 images. Vegetation fires, no matter their temperature or size, provided the fire front is larger than ~50 m, do not saturate channel 3 (Belward et al. 1993, Pereira and Setzer 1993, Setzer and Malingreau 1993 a, Setzer et al. 1993), contrary to calculations based on the emitted energy (e.g.,

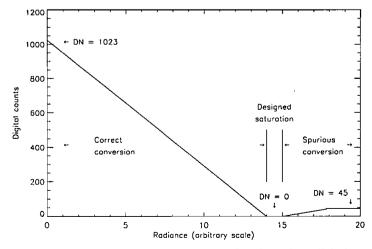


Figure 5. Hypothetical channel 3 conversion of radiance into digital counts.

Matson and Dozier 1981; Robinson 1991). Furthermore, actively burning fires were consistently associated with a DN of 45 in channel 3 during March, 1990 (Setzer and Malingreau 1993 a, b, precisely the same value found in the core of our exceptional sunglint. When examining histograms of channel 3 images containing many fires or sunglint a very steep change in their profiles was regularly found at DN 45 indicating a discontinuity at this point. We conclude that our postulated engineering problem would also explain why hot fires over continents do not saturate channel 3 pixels. This could further imply that AVHRR channel 3 may actually be observing much higher temperatures than currently estimated on the basis of existing data, calibration coefficients and established calibration procedures given by Kidwell (1991). Finally, the fact that at least NOAA-9 AVHRR exhibited the same pattern of nonsaturation of channel 3 over active fires (Pereira and Setzer 1993, Setzer and Pereira 1991) suggests that the same problem may affect multiple AVHRR instruments; histogram discontinuities for fire pixels in NOAA-9 AVHRR similar to what we found for NOAA-11 AVHRR can be seen in Brustet et al. (1991) and Pereira and Setzer (1993).

## 3. Conclusion

Our observation of particular DN values associated with targets which should, but do not saturate AVHRR's channel 3 is corroborated with analyses of a large number of AVHRR scenes both over oceans (sunglint) and continents (sunglint and fires). Our claim concerning a possible design flaw in the instrument circuitry could be confirmed by a thorough evaluation of the instrument. As far as channel 3 users are concerned, estimates of fire temperatures and sunglint energy becomes now a valid exercise combining a proposition along the pattern of figure 5 with the multispectral information of AVHRR from existing fire and sunglint data—an attractive possibility to extend the channel 3 range to 500°C or more. Unfortunately, highly reflective exposed soils in some cases will also have the same DN signal as fires in the defective AVHRR images, precluding a general application of AVHRR's image in fire monitoring. As for the future AVHRRs, if our hypothesis is correct, two possibilities exist; either leave the sensor in its current condition and alert users of the problem, or make the 0-1023 digital range match the sensor output. A third option, the elimination of the signal after the currently designed saturation limit of  $\sim 47^{\circ}$  C, would limit even more its use in such an important application as fire detection.

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