*Document for consideration at 15th N. America/Europe Meeting*

# Identification of satellite data anomalies using NWP monitoring

## 1. Background

Over the past decade global NWP centres have significantly increased their exploitation of satellite data products within their operational NWP models to an extent that the forecast quality even in the N. Hemisphere is degraded if satellite data are not available. Even more serious degradations in forecast quality are seen if corrupted satellite data is allowed to enter the NWP systems, which may not be trapped by the q/c checks. The economic implications of degraded forecasts are significant and so it is important that satellite operators and NWP centres between them set up an alert mechanism to make the 24hr/7day operational staff at these centres aware when there is a potential problem. NWP centres themselves should not issue alerts but make available their monitoring results in real time to the satellite agencies.

**Table 1 Satellite products used for NWP and monitoring web sites**

| Sensor | Product | NWP Centres Use | Monitoring sites |
|---|---|---|---|
| HIRS | 1b Radiance | NCEP, METO, ECMWF, MF | http://sgi62.wwb.noaa.gov:8080/RTPUB/radiance/opr/index.html<br>http://www.ecmwf.int/products/forecasts/d/charts/monitoring/radiances/<br>http://www.metoffice.com/research/interproj/nwpsaf/monitoring.html<br>http://www.cmc.ec.gc.ca/~cmcdev/data_monitoring/ |
| AMSU-A | 1b Radiance | NCEP, METO, MSC, ECMWF, MF, HIRLAM | |
| AMSU-B | 1b Radiance | NCEP, METO | |
| ATOVS | Retrieval (T, q) , 1d radiance | DWD,MF (longer term will use 1b radiance) | http://orbit36i.nesdis.noaa.gov/graphics/vstats/ but only weekly radiosonde not NWP |
| SATEMS | Retrieval (T, q) | DWD (longer term will use 1b radiance) | http://orbit36i.nesdis.noaa.gov/graphics/vstats/ but only weekly radiosonde not NWP |
| SBUV/GOME | Retrieval ($O_3$) | NCEP(SBUV), ECMWF(SBUV & GOME) | http://psbsgi1.nesdis.noaa.gov:8080/PSB/OZONE/OZONE.html#SBUV and http://www.knmi.nl/gome_fd/ no NWP stats available ECMWF have plans |
| SeaWinds | $\sigma_o$, surface wind | NCEP, ECMWF, METO | http://www.ecmwf.int/products/forecasts/d/charts/monitoring/radiances/ |
| SSM/I | Radiance | ECMWF, METO, MF | http://www.ecmwf.int/products/forecasts/d/charts/monitoring/radiances/ |
| GOES | Atmospheric motion winds | NCEP, ECMWF, MSC, METO, MF, DWD | http://www.metoffice.com/research/interproj/nwpsaf/satwind_report/index.html<br>http://www.cmc.ec.gc.ca/~cmcdev/data_monitoring/ |
| METEOSAT | Atmospheric motion winds | NCEP, ECMWF, MSC, METO, MF, DWD | http://www.metoffice.com/research/interproj/nwpsaf/satwind_report/index.html<br>http://www.cmc.ec.gc.ca/~cmcdev/data_monitoring/ |
| AVHRR | SSTs | METO | http://www.osdpd.noaa.gov/PSB/EPS/SST/sst_anal_fields.html |
| METEOSAT | Radiances | ECMWF | http://www.ecmwf.int/products/forecasts/d/charts/monitoring/radiances/ |
| GOES | Radiances | NCEP | http://sgi62.wwb.noaa.gov:8080/RTPUB/radiance/opr/index.html |

This document attempts to define what constitutes a situation when satellite data products are judged to be sufficiently anomalous, as perceived by the NWP centres (the key customers), so that the satellite data provider should issue an alert to all operational NWP centres that assimilate their data.

## 2. Satellite Products considered

The type and number of satellite products assimilated into NWP models is continually expanding but Table 1 attempts to summarise the main products in use in mid 2002 for which alerts should be considered if anomalies arise. The Table is based on the European requirements list and NCEP, MSC's known use of satellite data. The Table should be reviewed periodically as new instruments begin to be used, instrument usage changes and older instruments are retired. The links to monitoring sites in Table 1 are listed in order of priority, so the NCEP site is the most important for ATOVS radiance monitoring.

## 3. Criteria for raising an alert

There needs to be objective criteria for satellite operators to judge whether to issue an alert or not. One approach is to include automated software to check the monitoring statistics and raise an alert when an anomaly occurs. NWP centres do not have this capability at present but it is recommended that such warning mechanisms be put in place in the future. For the short term Table 2 attempts to define roughly what these criteria are for each data type but the eye is the best judge of an anomaly occurring so operators will have to apply some subjective judgement. Note that the links in Table 1 do not always provide enough information yet but an indication of what could be done now and what can be done with improved monitoring sites is given. The criteria are mainly based on observation (i.e. satellite product) minus equivalent NWP simulation of that observation referred to as O-B in Table 2. NWP centres have updated O-B statistics daily or even 6 hourly in some cases on their web sites.

**Table 2 Objective criteria for raising an alert**

| Sensor | Product | Criteria for alert | Information available? |
|---|---|---|---|
| HIRS | Radiance | A sudden change in global mean O-B bias or sdev in less than 24 hours. Changes > 0.5K is a rough guide but for some channels the criteria should be more/less. | Yes see links in Table 1 |
| AMSU-A | Radiance | | |
| AMSU-B | Radiance | | |
| ATOVS | Retrieval | DWD to add? | ? |
| SATEMS | Retrieval | DWD to add? | ? |
| SBUV/GOME | Retrieval | A change >30% of the observed values for all layers | Planned at ECMWF |
| SeaWinds | $\sigma_o$, surface wind | A 50% increase of distance to cone or 50% increase in O-B windspeed bias/sdev. | Yes but only at ECMWF |
| SSM/I | Radiance | A sudden change in mean or sdev O-B > 1K in less than 24 hours. | Yes but only at ECMWF |
| GOES | Atmospheric motion winds | Numbers failing O-B check increases by more than 5% in 24 hours. | Yes but only at MSC. |
| METEOSAT | Atmospheric motion winds | | |
| AVHRR | SSTs | 10% of satellite SSTs > 3K from analysis | No time series only anomaly map available |
| METEOSAT | Radiances | A change in mean or sdev O-B > 1K in less than 24 hours. | Yes but only at ECMWF (MET) and NCEP (GOES) |
| GOES | Radiances | | |

These O-B stats give a global view of the performance of the satellite sensor and sudden changes in the mean or standard deviation are not expected unless there is a change in the satellite data or change in the NWP model. Some examples are shown for different satellite data types in Figures 1-4. Figure 1 shows a case where the moon entered the AMSU-A space view contaminating the calibration (which assumes the radiance is of cold space). This corrupted the Earth view radiances causing a difference in the O-B AMSU-A channel 8 radiance statistics as shown in the plot. These corrupted radiances would have damaged the NWP analyses if they had entered the NWP system. Figure 2 shows the ECMWF monitoring of NOAA-15 AMSU-A during the failure of channel 11 in April 2002. Evidence of the problem can be seen a few days before the actual failure although in this case it is not obvious an early alert should have been issued given the criteria in Table 2. Figure 3 shows the ECMWF monitoring of the SeaWinds wind product which in this case shows a problem due to the attitude of the Quikscat spacecraft being far from nominal which can produce bad data. Note that for the scatterometer the distance to the `cone plots' (not shown) are independent of the NWP model and so this can be used by the agencies as check on the scatterometer data consistency. Finally Figure 4 shows a plot of the number of low level GOES-10 cloud track wind observations rejected by the O-B check during a period when there was a problem with the height assignment of the GOES-10 winds.

To eliminate the possibility of `false alarms' from NWP model changes or anomalies it is recommended that monitoring statistics from *at least* 2 NWP centres should be studied and to only issue an alert if the O-B stats show the anomaly at all the centres at the same time. The satellite data provider is also recommended to try and correlate any changes seen in the NWP monitoring stats with those from the detailed instrument housekeeping. This can give confidence the anomaly is an instrument problem and not an artefact of the NWP monitoring.

## 4. Practical implementation

It is proposed the mechanism by which an alert is issued would be by email from the satellite providers to the designated points of contact in the NWP centres that are available 24hrs/7 days a week. The satellite experts at each NWP centre should also be made aware of the anomaly by email. If the problem is severe and affects all the data the data provider should consider stopping the flow of data to the NWP centres.

Monitoring staff are already in place by the satellite agencies to monitor the instrument health. An initial (minimal cost) proposal is for these staff to additionally review the NWP monitoring web pages given in Table 1 at least on a 6 hourly basis as another piece of information for them to decide when and if to issue an alert. It is not always immediately clear where in the processing chain the problem lies (e.g. instrument hardware, calibration, pre-processing or product generation) and for this reason it would be best for space agencies to monitor their products at the final output of their product to the users. It is also desirable (and planned by EUMETSAT) for the satellite agencies themselves to monitor their products against simulated NWP products. However it should be recognised that the satellite agency will usually only have access to older forecasts than the NWP centres.

The NWP centres look at their (and other centre's plots) during working hours and can give alerts but they do not always have mechanisms in place outside working hours. It is clear not all the necessary monitoring tools are in place on open web sites and the NWP centres should move to facilitate easier open monitoring of their O-B stats for all data types.

Finally it is important that the pertinent information is included in an alert to the NWP centres to allow them to respond accordingly. Table 3 attempts to define this for the various data types.

**Table 3 Information to include with an alert**

| Sensor | Product | Information required |
|---|---|---|
| HIRS | Radiance | Time, satellite platform, sensor, channels affected, bias or sdev change. |
| AMSU-A | Radiance | |
| AMSU-B | Radiance | |
| ATOVS | Retrieval | Time, satellite platform, bias or sdev change. |
| SATEMS | Retrieval | Time, satellite platform, bias or sdev change. |
| SBUV/GOME | Retrieval | Time, satellite platform, total column or profile , bias or sdev change. |
| SeaWinds | $\sigma_o$, surface wind | Time, satellite platform, bias or sdev change. |
| SSM/I | Radiance | Time, satellite platform, channels affected, bias or sdev change. |
| GOES | Atmospheric motion winds | Time, satellite platform, wind types affected (e.g. IR, WV, VIS etc). Areas affected or all. |
| METEOSAT | Atmospheric motion winds | |
| AVHRR | SSTs | Time, satellite platform, , bias or sdev change. |
| METEOSAT | Radiances | Time, satellite platform, channels affected. Areas/times affected or all, bias or sdev change. |
| GOES | Radiances | |

## 5. Recommendations

The following list of recommendations can be made:

- Space agencies should monitor the final output product sent to the users and improve their automated systems to prevent bad data from going out to the users.

- The space agencies should put into place an improved alert mechanism by including NWP monitoring of their products as one of their tools.

- Statistics from at least two NWP centres should be monitored for each product.

- NWP centres need to enhance their monitoring for some products on web pages accessible to space agencies.

- In the longer term NWP centre should provide automated monitoring tools to raise alerts when anomalies in the satellite data occur.

- Alerts should be sent out by email to designated points of contact at NWP centres.

- If the problem is severe, and affects all the data, space agencies should stop the flow of data to the NWP centres.

## 6. Acknowledgements

I thank ECMWF for providing 2 of the Figures and the many people who provided constructive comments on an earlier draft of this document.

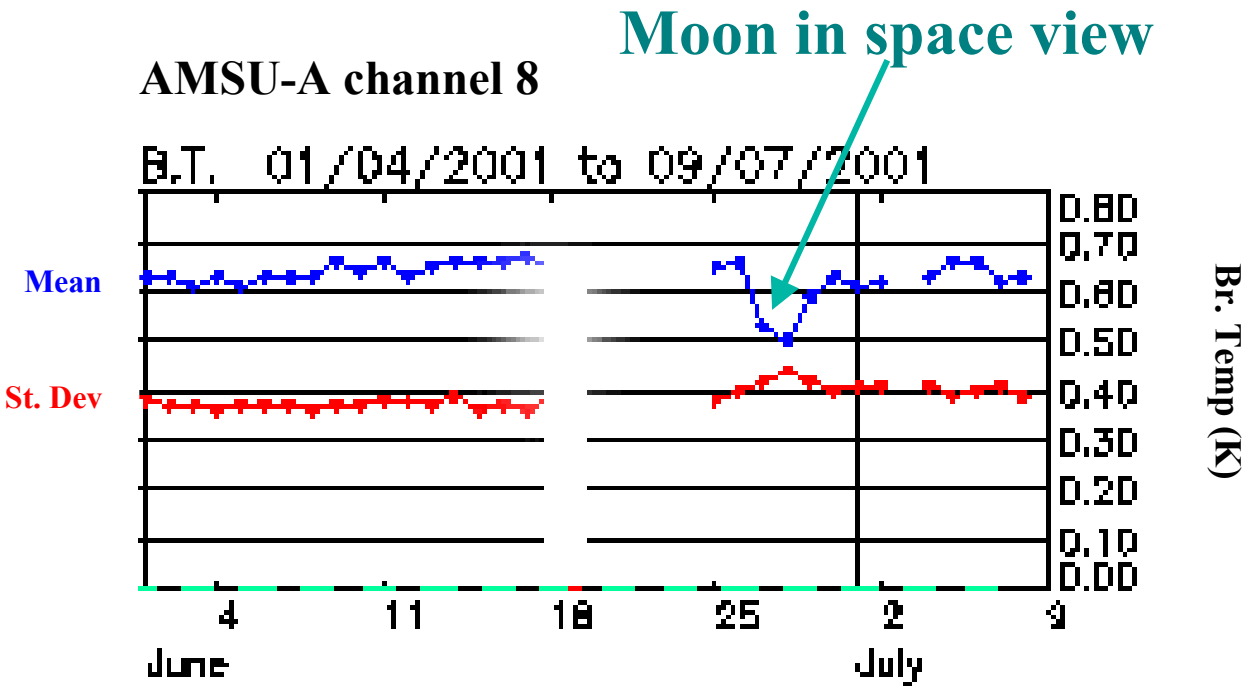


Figure 1. Time series plot of global mean difference of observed minus NWP simulated AMSU-A channel 8 brightness temperature (blue line) and standard deviation (red line) during June/July 2001. This plot was taken from the Met Office monitoring site.

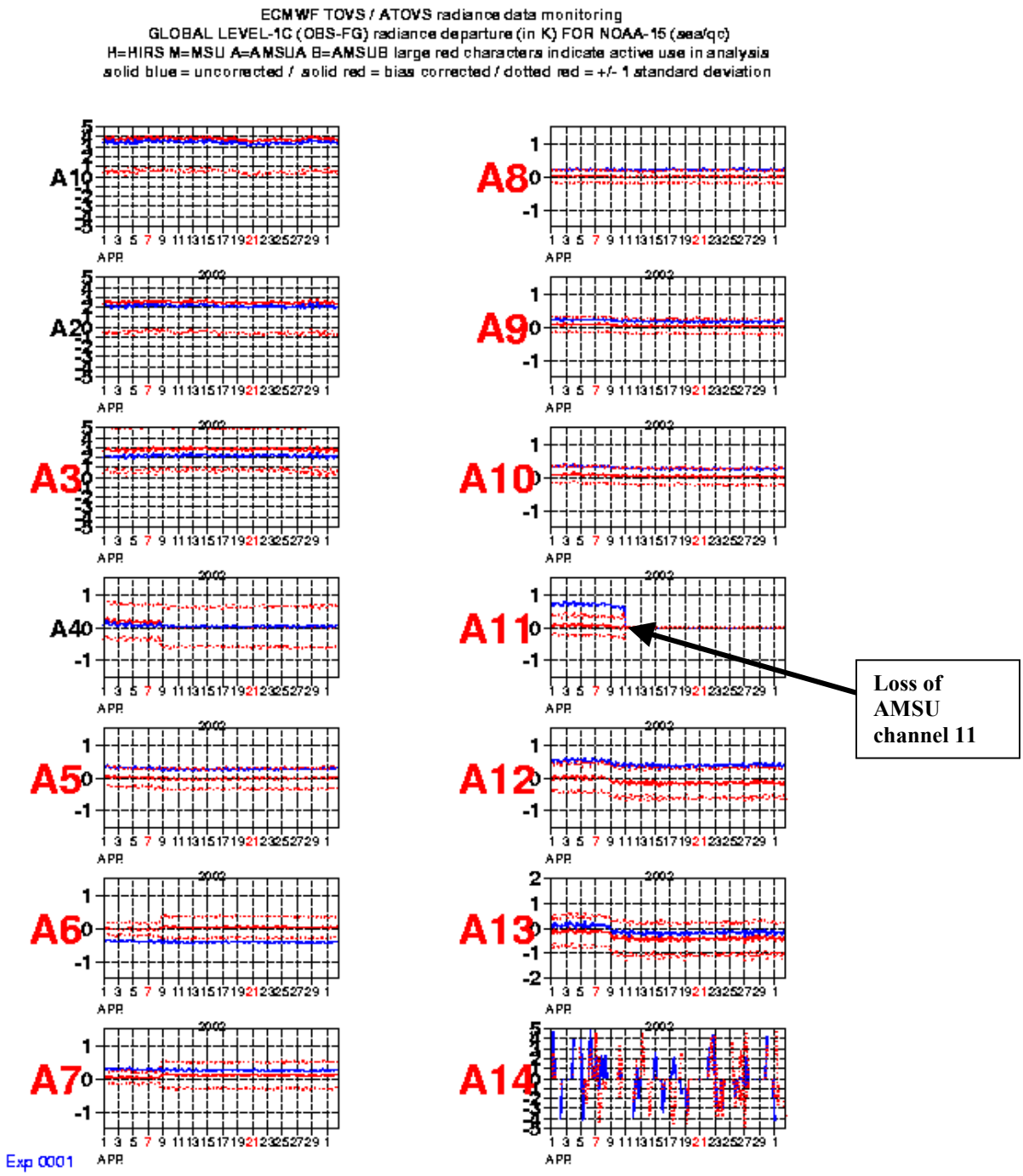


Figure 2. Time series plots of global mean difference of observed minus NWP simulated NOAA-15 AMSU channel brightness temperature (blue line) and standard deviation (red dotted line) during April 2002. This plot was taken from the ECMWF monitoring site. Note the changes seen when AMSU-A channel 11 failed.

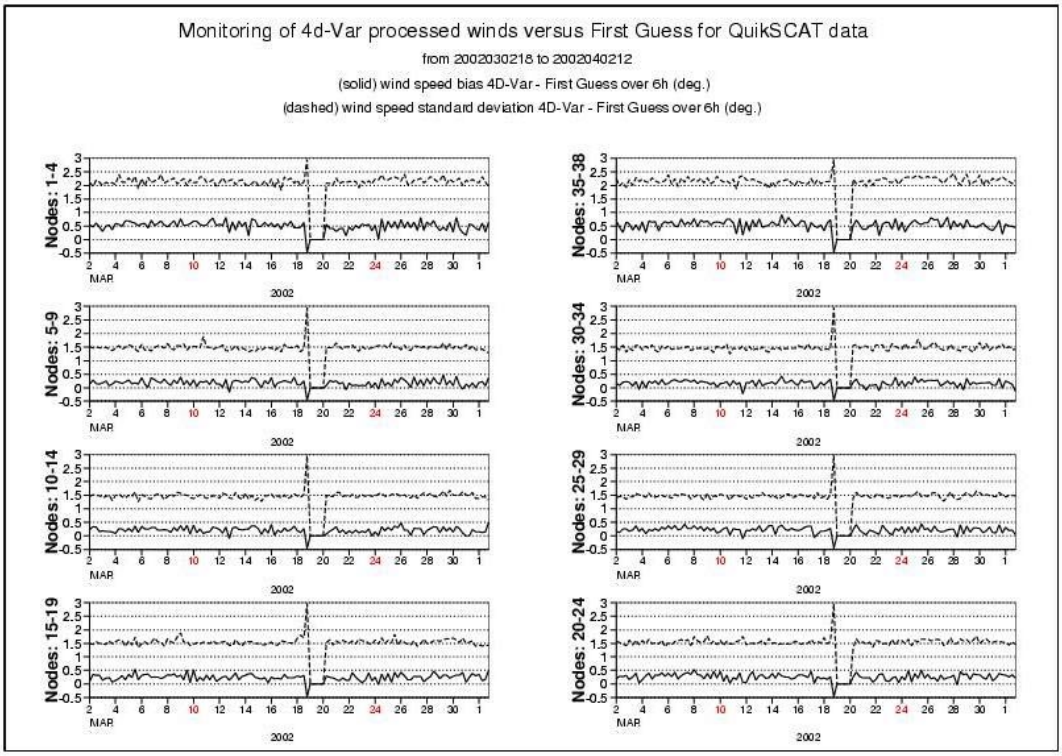


Figure 3. Time series plots of global mean difference of observed minus NWP simulated SeaWinds wind speeds. This plot was taken from the ECMWF monitoring site. The anomaly on 19 March was initially due to the spacecraft attitude being outside limits followed by the instrument being switched off for 38 hours.

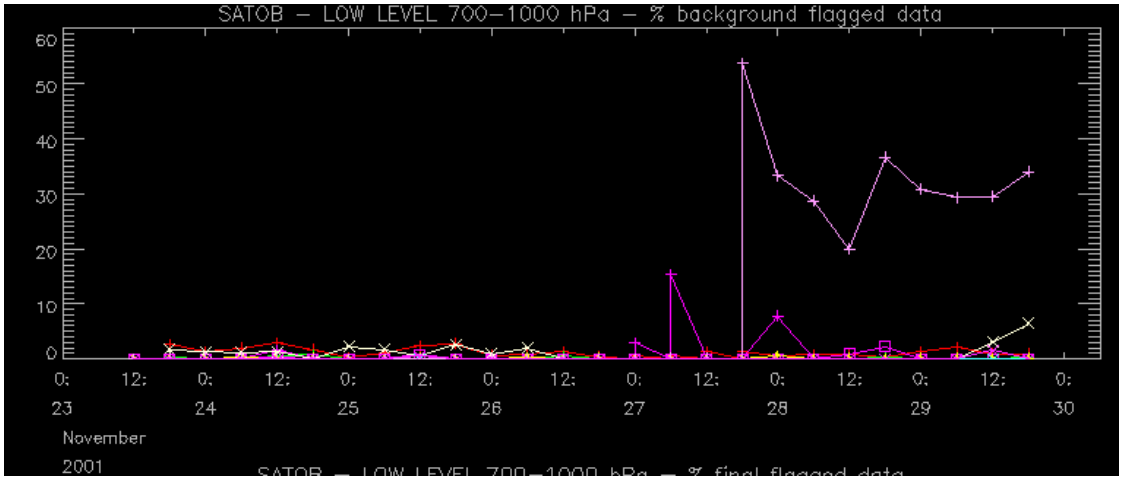


Figure 4. Time series plot of percentage of rejected low-level cloud track winds for the various geostationary satellites in Nov 2001. The purple line shows the increase in GOES-10 winds rejected. This plot is from an internal Met Office site.