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An evaluation of the FY-3A sounding radiance observations

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1.0	4.10.10	W. Bell	Summary report with link to ECMWF Tech. Memo. 631 as Annex A

Introduction

The first of a series of eight polar-orbiting Chinese meteorological satellites, FY-3A, was launched successfully on 28th May 2008. FY-3A carries a payload of eleven sensors, including a suite of three infrared/microwave temperature and humidity sounders (IRAS, MWTS and MWHS similar in specification to HIRS, MSU and AMSU-B/MHS respectively) as well as a microwave imager (MWRI, similar in specification to AMSR-E). Given the operational importance of these data it is timely to establish a real-time radiance monitoring system and study the potential for NWP exploitation.

The aims of the NWPSAF visiting scientist mission were to establish a real-time radiance monitoring system and study the potential for NWP exploitation of observations from the FY-3A microwave and infrared sounding instruments

The specific deliverables of the mission were:

1) A report on the outcome of the investigations, covering an analysis of departures as well as observing system experiments.

2) Real-time monitoring of FY-3 data made available on the external web.

Summary of progress

The detailed results of the study are documented in **Appendix A**: a copy of ECMWF Technical Memorandum No. 631, which describes initial investigations of the four FY-3A instruments of interest for NWP users.

This Technical Memorandum is also available at the following link:

http://www.ecmwf.int/publications/library/do/references/show?id=89899

Two additional manuscripts have been prepared which cover, respectively, an overview of the impacts of the FY-3A data on NWP forecast quality as well as a detailed characterisation of the microwave temperature sounder.

Manuscript 1: (to be submitted to the Quarterly Journal of the Royal Meteorological Society (QJRMS)), on an assessment of the FY-3A data through a series of observing system experiments.

Manuscript 2: (to be submitted to the AMS Journal of Atmospheric and Oceanic Technology), on more detailed work carried out during the VS mission on the characterisation of the FY-3A Microwave Temperature Sounder.

Real time monitoring of the FY-3A data has been established and can be found here:

http://www.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/fy/

As an *executive summary* of the work carried out, the conclusions of the initial assessment and the more detailed assessment of the MWTS instrument are given below.

Conclusions from the initial assessment of the FY-3A instruments

Data from the FY-3A VASS instruments as well as the microwave imager (MWRI), obtained during the July-November 2008 Calibration-Validation phase of this preparatory mission, have been introduced into the ECMWF Integrated Forecasting System. This has permitted an assessment of data quality through an analysis of first guess departure statistics, a comparison with equivalent ATOVS instruments, as well as through observing system experiments. The use of NWP model fields for the calibration and validation of satellite missions is becoming standard practice as the global coverage and high accuracy provided by NWP models have been proven to be a powerful tool in the diagnosis of systematic biases in the data, and this has again been the case with the assessment presented here. The assessment of the data through OSEs provides, in addition, valuable information on the impact of the data on NWP analysis and forecast quality.

In the OSEs presented here the individual VASS instruments (MWTS, MWHS and IRAS) were able to show significant positive impact, equivalent to a significant fraction of the impact from the equivalent MetOp-A ATOVS instruments when assimilated in a *like-for-like* configuration. As a *package* the VASS instruments show impact equivalent to a significant fraction (e.g. 30% at day 5 in SH 500hPa geopotential height anomaly correlation) of that obtained from the MetOp-A ATOVS suite, even when added on top of a control experiment with one AMSU-A. When added to a full observing system OSE the impact of the FY-3A data is neutral to slightly positive, a result which is encouraging and indicates that there are no major problems with the data from FY-3A from an NWP perspective. Overall the results from these OSEs, using data from the Cal/Val phase of this preparatory mission, are a very promising start to the FY-3 program.

Perhaps more importantly, this assessment has highlighted several issues where further work needs to be done to refine the instrument design and pre-launch testing as well as the ground processing systems, in order to further improve the quality of FY-3 data for FY-3A and subsequent missions. In order of significance these are:

Uncertainties in MWTS passbands. This initial assessment has presented evidence that the passband for channel 4 of the MWTS instrument is shifted by ~100 MHz relative to that for the pre-launch design specification, and ~50 MHz relative to pre-launch measurements. This uncertainty leads to an airmass dependent bias which is only partially compensated for by VarBC. Further work is needed to establish the in-orbit passband centre frequencies and bandwidths for all MWTS channels and determine if there is any temporal or orbital evolution of the shift. Independent studies have recently shown that uncertainties of 1.5 MHz or less are required in the specification of band centres in order to render the effects negligible on NWP forecast accuracy.

Orbitally dependent biases in the IRAS observations. Channels 1-3 show orbitally dependent biases that are probably correlated with the solar induced thermal cycling of the instrument. For channel 1 the effect is locally as large as 10 Kelvin. There is some indication that these biases affect other channels as well. Further work should establish the cause of these biases, in order that improvements can be made in future FY-3 instruments, if appropriate. A more detailed study on the impact for channels 4-7 would be worthwhile.

Scan biases for MWHS. The water vapour sounding channels exhibit complex cross scan biases which are difficult to correct in the present ECMWF VarBC scheme. These biases, in the short term, would be best dealt with in a pre-processing step or by a modification of the VarBC predictor scheme to include field of view dependent offsets. In the longer term, perhaps for future instruments, it would be beneficial to eliminate the cause of the cross scan bias problems.

Biases in sections of the IRAS orbit. Sections of IRAS orbit were found to exhibit biases different from those of adjacent orbits and of other parts of the same orbit. This is distinct from the orbital

biases described above. This particular type of error is not handled well using VarBC and therefore more work is required to identify the cause of these biases and to develop methods for screening these data.

Offsets in the brightness temperatures for all VASS instruments and the MWRI instrument. Although these types of errors can generally be dealt with effectively using VarBC, there are some climate related applications of the data that would benefit from smaller absolute uncertainties in the measured brightness temperatures. For MWRI, for example, the biases in some channels are in the range 5-10K. This may be a result of uncertainties in the antenna to brightness temperature corrections applied to date, which may require further tuning. For future missions, improved characterisation pre-launch would be a better solution.

Data Outages. The regular data outages at the end of each calendar month do not present a serious problem for the use of the data in NWP and are doubtless the consequence of early Cal/Val phase tuning of the ground segment, however it would be beneficial to eliminate these for future data streams before further OSE's are performed.

Conclusions from the detailed characterisation of the FY-3A Microwave Temperature Sounding Instrument

This part of the VS Mission study reports an assessment of the MWTS instrument using the ECMWF NWP model, radiative transfer modelling and comparisons with equivalent observations from the Advanced Microwave Sounding Unit-A (AMSU-A). The study suggests the MWTS instrument is affected by biases related to large shifts in the frequency of the channel passbands as well as radiometer non-linearity. The passband shifts, relative to pre-launch measurements, are 55 MHz, 39 MHz and 33 MHz for channels 2-4 respectively. Relative to the design specification the shifts are 60 MHz, 80 MHz and 83 MHz with uncertainties of ±2.5 MHz. The radiometer non-linearity results in a positive bias in measured brightness temperatures and is manifested as a quadratic function of measured scene temperatures. By correcting for both of these effects the quality of the MWTS data is improved significantly, with the standard deviations of (observed minus simulated) differences based on short range forecast fields reduced by 30-50 % relative to simulations using pre-launch measurements of the passband, to values close to those observed for AMSU-A equivalent channels. The mean first guess departures, before bias correction, are reduced to -0.31K, -0.035K and 0.003K for MWTS channels 2-4. The new methodology could be applied to other microwave temperature sounding instruments and illustrates the value of NWP fields for the on-orbit characterisation of satellite sensors.

Appendix A:

ECMWF Technical Memorandum 631: An Initial Assessment of FY-3A Satellite Data.

http://www.ecmwf.int/publications/library/do/references/show?id=89899