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METEOROLOGY

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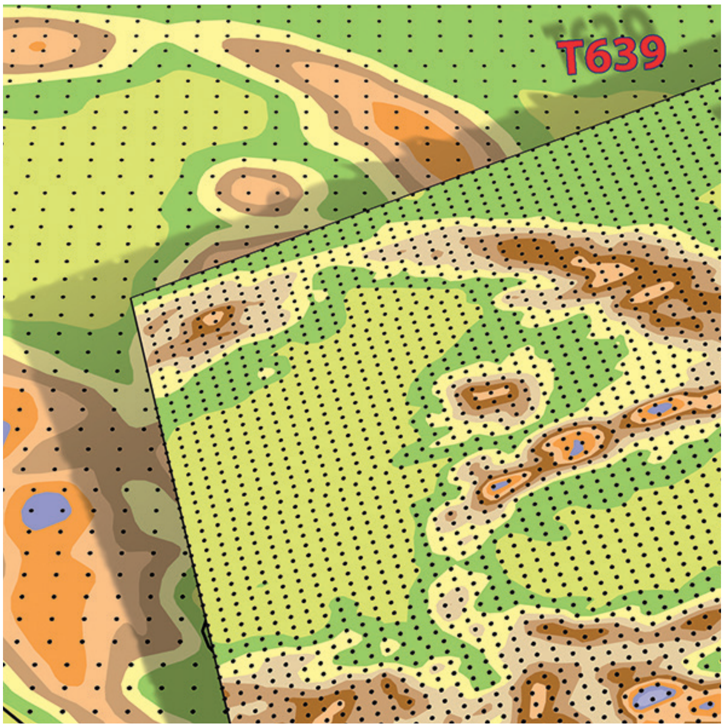

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Quantifying the benefit of the advanced infrared sounders AIRS and IASI

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The AIRS INSTRUMENT onboard the NASA-AQUA satellite and the IASI instrument onboard the EUMETSAT-MetOp satellite are arguably the two most sophisticated atmospheric sounders ever flown. Due to their very high-resolution sampling of the infrared spectrum they have the potential to provide more detailed and accurate information about atmospheric temperature and composition than has been possible with previous satellite sensors.

ECMWF, together with other NWP centres, assigned a very high priority (and devoted significant resources) to the successful exploitation of data from AIRS and IASI. Results quickly emerged that clearly demonstrated that the new information brought by these instruments was beneficial to NWP systems and improved forecast skill. On the basis of these results, first AIRS (in 2003) and subsequently IASI (in 2007) became important elements of the operational observing system.

The results of pre-operational trials of AIRS and IASI from a number of NWP centres have been published in the open literature, but more recent evaluations of their impact have been rather limited. In view of the prominent position occupied by these instruments and the fact that the planning process for the next generation infrared sounders is now under way, it was considered timely to perform an extensive and consolidated review of the NWP impact of advanced infrared sounders.

Experiments

The latest experiments have been run with version Cy35r2 of the ECMWF Integrated Forecasting System (IFS), run at T511 horizontal resolution (typically 40 km grid spacing) with 91 levels in the vertical. While this is not the most recent version of the analysis system, it was operational at the time the study began. In respect of the handling of data from AIRS and IASI this version is also rather similar to the current operational scheme – the only difference being that the latter additionally exploits overcast (cloudy) observations from AIRS and IASI. The test period considered is 7 August 2008 to 6 August 2009 and thus covers an unprecedented full continuous calendar year.

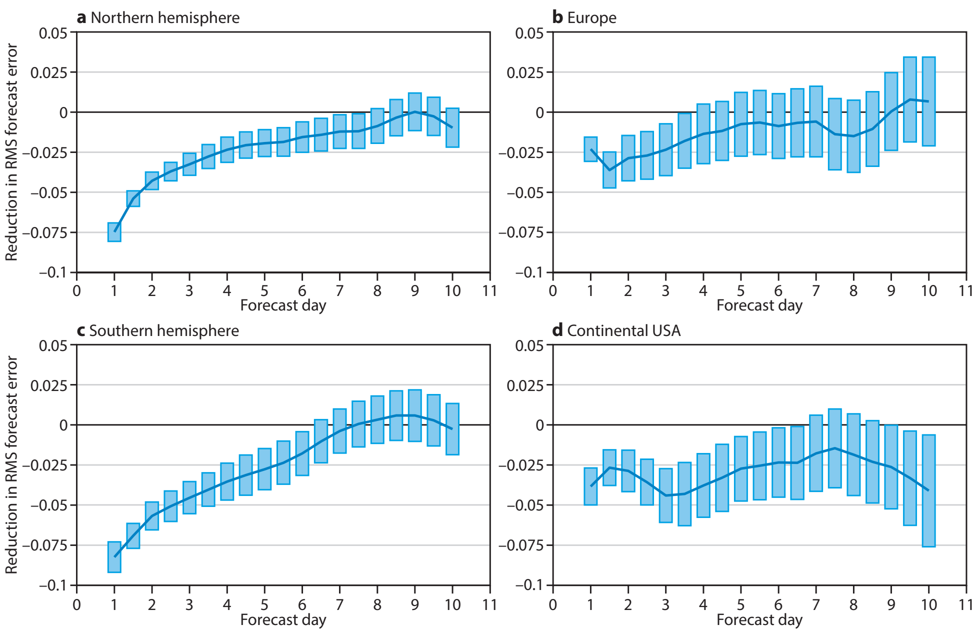

Figure 1 Reduction in the one-year average RMS forecast error for 500 hPa geopotential height when AIRS and IASI are added to a baseline system for the (a) northern hemisphere, (b) Europe, (c) southern hemisphere and (d) continental United States of America. The vertical grey bars indicate 95% confidence intervals on the normalized mean change.

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Two different types of impact experiment have been run:

- *Addition experiments.* AIRS and IASI data are added separately and in tandem to a baseline that contains no advanced infrared sounder data (but does contain all other satellite and conventional observations). The primary aim of this is to quantify the benefits brought by the additional availability of these data.
- *Denial experiments.* AIRS and IASI data are removed individually and together from a control system that otherwise exploits the full global observing system. The primary aim of this is to quantify the cost of losing data from one or both sounders. All forecasts have been verified against ECMWF operational analyses.

Results of adding AIRS and IASI to a baseline system

It has been found that the addition of either AIRS or IASI to the baseline both have a clear positive impact upon reducing root mean square (RMS) forecast error for geopotential and humidity. The large-scale hemispheric impact of AIRS is very similar to that of IASI. Both instruments show the largest reduction in the short-range, but there is a clear and statistically significant improvement signal out as far as day 6.

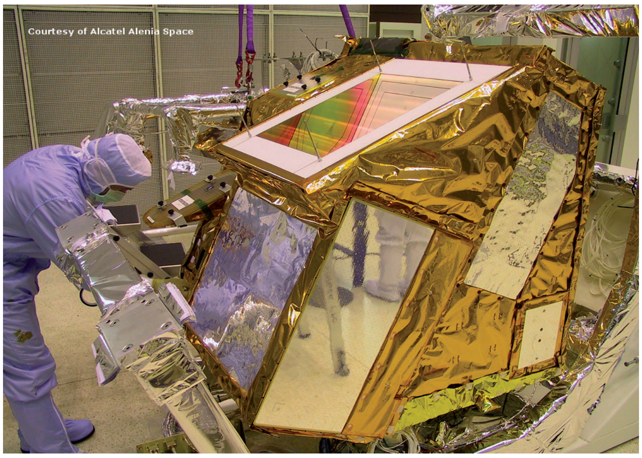
In the United States (US) and European regions the short-range forecast error impact from AIRS and IASI is smaller, but this is because conventional observations determine the local initial conditions very strongly in these data-dense areas and the influence of satellites is less. For the medium-range forecast errors for the US and European areas (where the initial conditions from satellite dominated remote ocean areas are important) there is again a statistically significant benefit when adding either instrument. One possible exception to this is the unexpected result that the addition of IASI appears to have a much weaker medium-range impact over the European region than that of AIRS.

In Figure 1 we see the effect on 500 hPa geopotential forecast scores of adding both AIRS and IASI in tandem to the baseline. In each case the quantity plotted is the reduction in RMS error, normalized by the RMS error of the baseline system. Together the two instruments generally produce a larger impact than that seen when either is used alone. This is an important result for future satellite planning as it suggests that there is a measurable benefit to forecast skill from flying two advanced infrared sounders compared to one.

Results of denying AIRS and IASI from a control system

Experiments where AIRS and IASI are denied from a control system (that contains all available observations) generally support the results of the addition experiments.

For the hemispheric scores it has been found that the individual removal of either AIRS or IASI degrades the forecast skill and results in larger RMS errors. However, the increase in error from removing a single instrument is much smaller than the corresponding reduction in forecast error when the same single instrument is added to the baseline system (previous section). This indicates that the presence of one advanced infrared sounder is able to partially compensate for the loss of the other. The compensation is such that only the simultaneous removal of both instruments produces a measurable loss of skill in the medium-range for the European and US regions.



The Infrared Atmospheric Sounding Interferometer (IASI) instrument during construction. (Photograph © 2006 Alcatel Alenia Space)

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Overview of the impact of AIRS and IASI

The impact of AIRS and IASI used either separately or together is very clear over this extended one-year test period. Forecast accuracy improves when these data are added and degraded forecasts result when the instruments are withheld. Results also demonstrate that there is a measurable extra benefit of having two instruments in orbit compared to just one and that a single AIRS or IASI is partially able to compensate for a loss of the other.

Investigations to understand why IASI appears to have little medium-range impact over the local European region are ongoing – this result was unexpected in view of previous studies (*ECMWF Newsletter No. 120*) that have showed IASI producing a clearly positive impact on forecasts over Europe.

Although not discussed here, key diagnostics from the analysis system also highlight the importance of AIRS and IASI. Adding the instruments (separately and together) have been found to improve the fit of analyses to radiosonde observations of temperature, humidity and wind.

These studies generally confirm and consolidate other impact experiments (performed at ECMWF and other centres) which collectively demonstrate that the information brought by advanced infrared sounders is significant.

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