

## **A Comparison of IASI and SSMIS Impacts on NWP Analyses and Forecasts**

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### **Abstract**

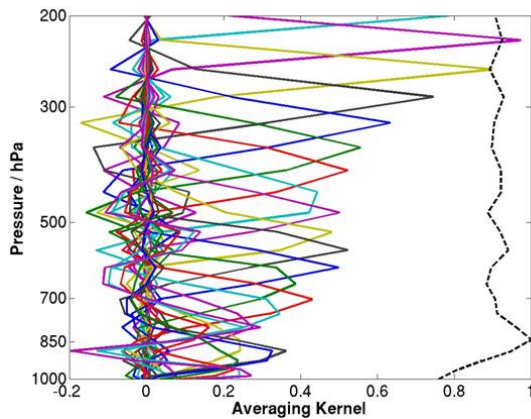
Moisture increments produced by SSMIS and IASI in the Met Office 4D-Var assimilation system are compared in a study using co-locations from MetOp-A and F-16. Statistically the 4D-Var increments show similar structure in the vertical, however a direct comparison shows surprisingly weak correlation between the two sensors. The impact of SSMIS window channels (12-16) and IASI water vapour channels shows disappointingly small impacts on forecast accuracy with impacts around 1-2% or less on PMSL, geopotential height and wind scores. Impacts on forecast humidity fields are weaker still at 0.5% or less for forecast ranges 1-3 days.

### **Introduction**

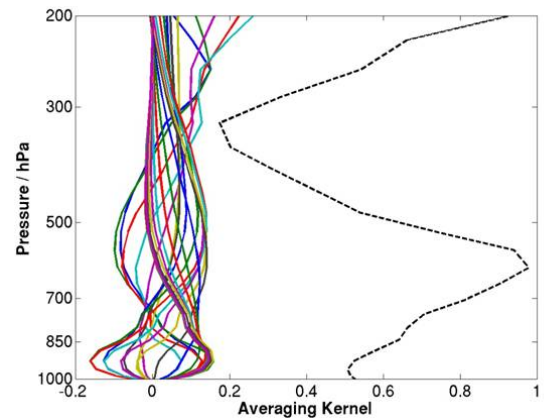
SSMI radiances, which contain information on atmospheric water vapour, are assimilated at many NWP Centres. Andersson *et al* [1] note that SSMI has the largest influence on lower tropospheric humidity analyses over oceans of all satellite data types currently used in the ECMWF model. Assimilation tests using the Met Office 3D-Var, and more recently 4D-Var, assimilation and forecasting system have never produced consistent positive impacts in both the tropics and extra-tropics. Occasional benefits in the tropics are offset by degradations in the southern hemisphere, or *vice-versa*. The aim of this study is to gain a better understanding of the impact of SSMI / SSMIS window channel radiances on moisture fields through comparisons with the impacts from IASI radiances on analyses and forecasts.

The existing SSMI series of sensors will be replaced by the SSMIS series of instruments, the first of which (F-16) was launched in 2003. The SSMIS series (F-16 - F-20) will provide operational continuity for this type of observation until 2020, at least, and therefore the continued investigation and optimisation of the impact of SSMI / SSMIS radiances on NWP moisture fields is worthwhile.

The launch of the IASI instrument on the MetOp-A platform, in a similar orbit plane to F-16 SSMIS offers the possibility of simultaneously comparing the analysis influence of moisture sensitive radiances from a high spectral resolution advanced IR sounder (associated with high vertical resolution) and a microwave imager (low resolution in the vertical). Figure 1 shows the averaging kernels derived from the 31 moisture sensitive channels of IASI used at the Met Office [see Hilton *et al*, these proceedings] and Figure 2 shows the averaging kernels corresponding to SSMIS channels 12-16 at 19 GHz (H&V polarisation), 22 GHz (V polarisation) and 37 GHz (V&H polarisation).



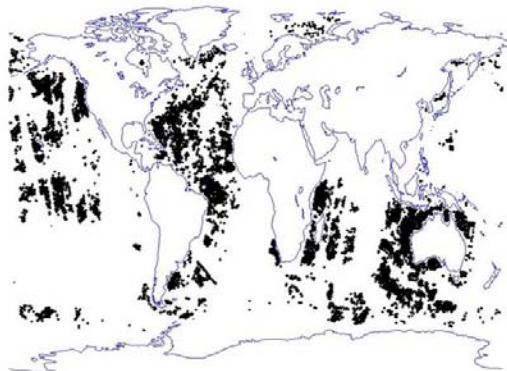
**Fig.1:** IASI Averaging Kernels



**Fig. 2:** SSMIS Averaging Kernels

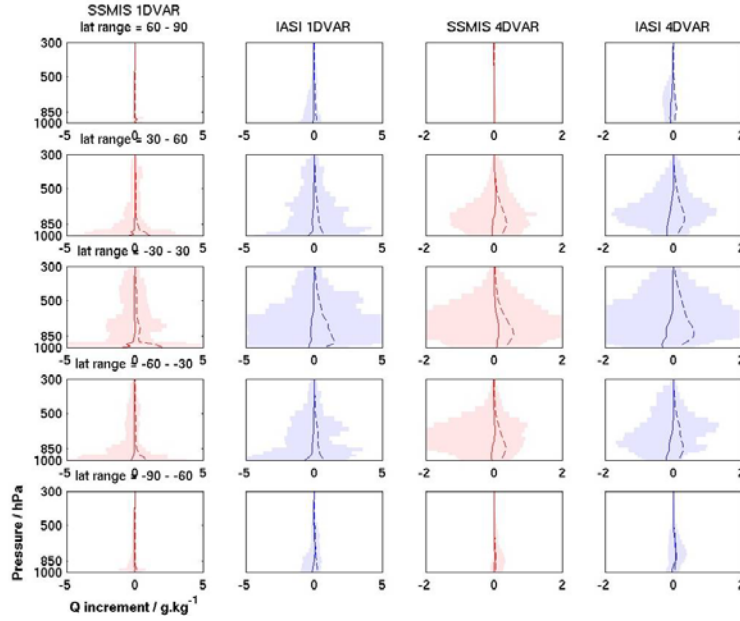
### F-16 SSMIS / MetOp-A IASI Co-locations

The similar orbital planes of F-16 SSMIS (LTAN 20:03) and MetOp-A (LTAN 09:30) make it possible to generate a co-location data set. During the period 24<sup>th</sup> - 27<sup>th</sup> October 2007 9,718 co-locations were generated, with a spatial co-location criteria of 20 km. The difference in orbit planes makes the temporal displacement nearly constant at 95 minutes. The co-locations are shown in Figure 3 below. Although not global in coverage, the dataset represents a wide range of tropical and extra-tropical meteorological situations.



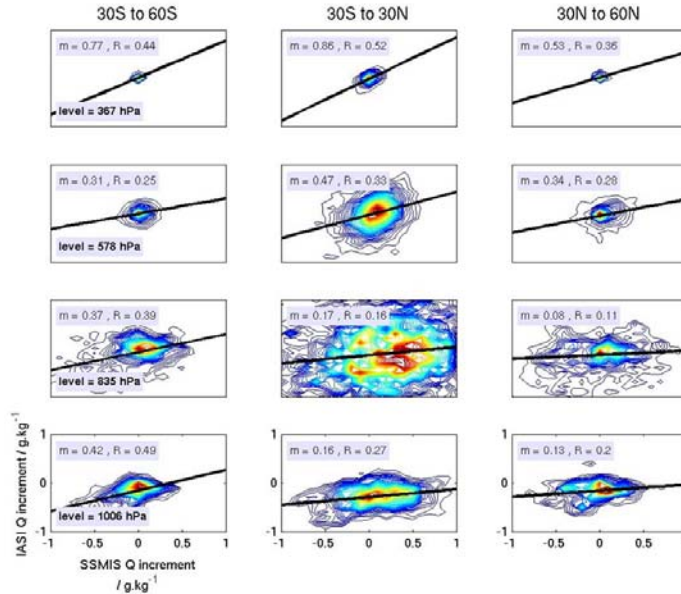
**Fig. 3:** F-16 SSMIS / MetOp-A IASI co-locations obtained during the period 24 - 27<sup>th</sup> October 2007. The collocation criteria are  $\Delta x < 20\text{km}$ ,  $\Delta t < 95\text{ mins}$ .

The form of the increments in specific humidity from IASI and SSMIS at the co-location positions for both 1D-Var and 4D-Var analyses are shown in Figure 4 below. The largest increments appear in the tropics, as expected. For the 1D-Var increments, IASI and SSMIS appear to complement each other in that SSMIS increments peak close to the surface, whereas



**Fig. 4:** Moisture increments for SSMIS and IASI for both 1D-Var and 4D-Var. Solid lines represent the mean analysis increments, dotted lines show the standard deviation of the increments, and the shaded areas represent the envelope for all increments.

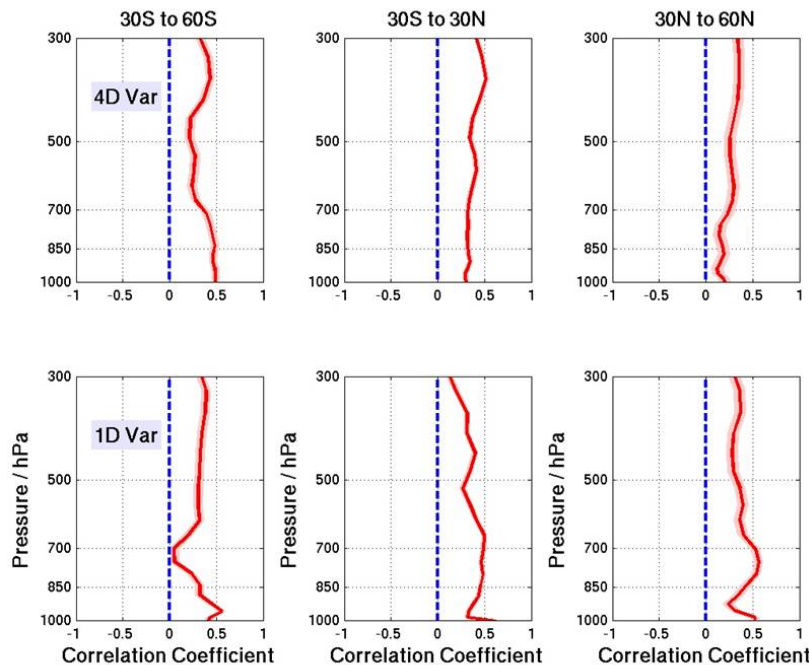
IASI increments span the troposphere, with slightly decreased sensitivity close to the surface. The 4D-Var increments show a much more similar form between sensors with a peak around 850 hPa for both SSMIS and IASI. For each pressure level, a direct comparison can be made of SSMIS and IASI driven moisture increments. This is shown for a subset of pressure levels in Figure 5 below. There is generally positive correlation for IASI and SSMIS driven increments.



**Fig. 5:** The correlation of IASI and SSMIS driven moisture increments at 367, 578, 835 and 1006 hPa for SH mid-latitudes, NH mid-latitudes and tropics. The gradients and correlation coefficients are also shown.

This is shown in a more compact form in Figure 6 below. Correlations are positive at all levels, but surprisingly weak, usually around 0.2-0.5. There are several possible causes of this weak correlation. Firstly, it can be hypothesised that both instruments are observing the same moisture

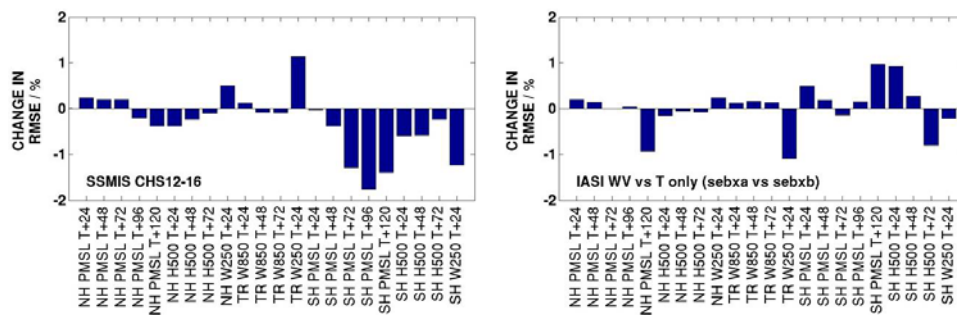
errors, but the different information content of the IR vs MW measurements (expressed via the averaging kernels presented earlier) results in a weak correlation. i.e. IASI and SSMIS smear the moisture errors in very different ways, and this weakens the correlation. Secondly, it may be a consequence of the temporal displacement of the observation. 95 minutes may be too long an interval over which it can be assumed the moisture structures remain constant.



**Fig. 6:** The correlation coefficient of IASI vs SSMIS driven moisture increments in the pressure range 300 - 1000 hPa. The shaded area represents 95% confidence limits.

## Assimilation experiments

The impact of SSMIS window channels and IASI water vapour channels was compared through two assimilation experiments. The experiments covered the period 24<sup>th</sup> May - 24<sup>th</sup> June 2007. The impact on a range of verification measures is shown in Figure 7 below.

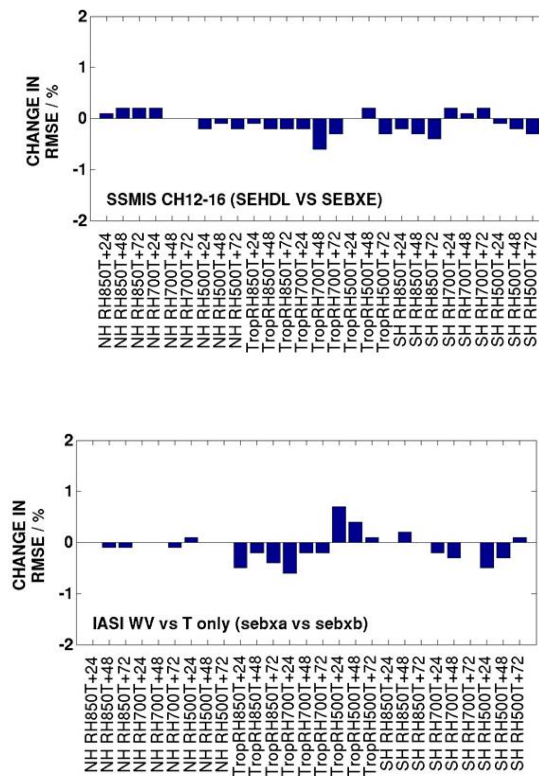


**Fig. 7:** Verification for assimilation experiments in which SSMIS window channels 12-16 (top plot) and 31 IASI water vapour channels (bottom plot) were added to a full operational system.

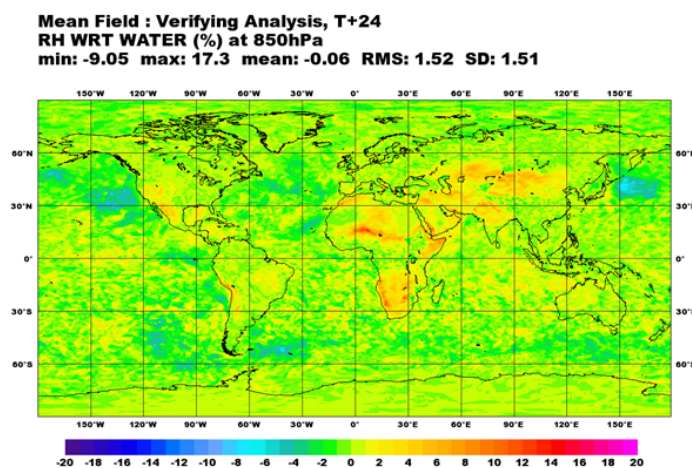
For SSMIS positive impacts in the southern hemisphere are offset by degradations in tropical winds. For IASI, neglecting verification statistics at long range (T+120 hours) impacts are fairly neutral in the extra-tropics and positive for tropical winds at 250 hPa. The contrasting performance

of IASI and SSMIS in the tropics could be the result of biases in both sets of observations. As can be seen in Figure 4, IASI observations appear dry in the tropical lower troposphere (mean moisture increments negative) whereas SSMIS exhibits a smaller, moist bias. Previous OSEs have shown that drying the tropics reduces convective activity and tends to improve wind scores.

Figure 8 shows the impacts on relative humidity forecasts for both IASI and SSMIS. Impacts are generally weak, with forecast humidity errors changed by less than 1% for both observation types.



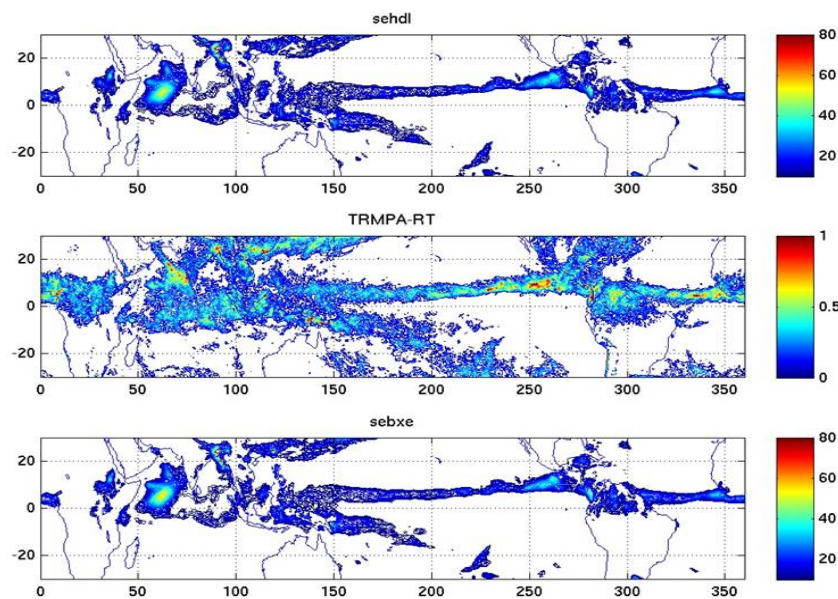
**Fig. 8:** Verification for relative humidity for assimilation experiments in which SSMIS window channels 12-16 (left plot) and 31 IASI water vapour channels (right plot) were added to a full operational system.



**Fig. 9:** Mean analysis difference field relative to control experiment without SSMIS data, for the 850 hPa pressure level.

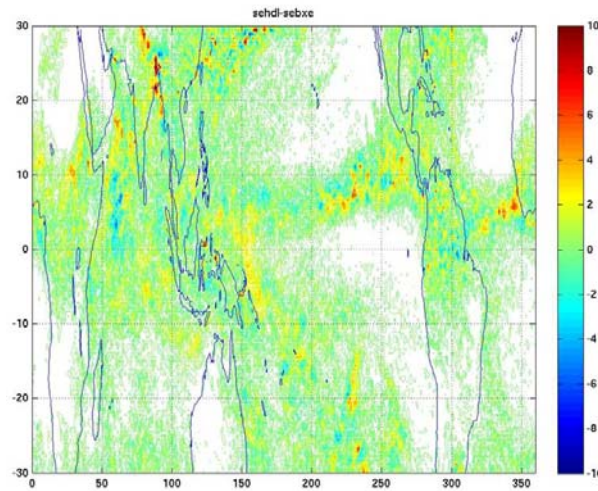
The impact of the addition of the SSMIS observations on the global analysed humidity field, averaged over the 30 days of the trial period, is indicated in Figure 9, for the 850 hPa pressure level. The largest differences, of around 5%, are seen in the sub-tropical subsidence regions, although smaller impacts are seen in the northern and southern Pacific.

Precipitation estimates from the TRMM satellite were used to verify precipitation fields from both trial and control. The measured 24-hour forecast fields averaged over the trial period are shown in Figure 10.



**Fig. 10:** Averaged precipitation fields for trial (top) in which SSMIS window channel radiances are added to a full observing system, TRMM observations (middle) and control experiment (bottom)

Differences between observations and the forecast model (both trial and control experiment) are large in relation to differences between trial and control. One significant difference here is in the placement of the precipitation field associated with the Asian Monsoon, for which TRMM observations places the maximum close to the SW coast of India, whereas forecast fields place the maximum much further south, in the equatorial Indian Ocean. As shown in Figure 11, the trial experiment appears to be shifting this maximum in the correct direction.



**Fig. 11:** Differences between trial and control precipitation fields.

equatorial Indian Ocean. As shown in Figure 11, the trial experiment appears to be shifting this maximum in the correct direction.

## Summary and conclusions

Co-locations between MetOp-A IASI and F-16 SSMIS have been used to study the consistency of analysed moisture profiles. At all levels, there is positive correlation between IASI and SSMIS driven moisture increments, but the correlation is surprisingly weak (-0.2 - 0.5). The reasons for this are not clear, but may be due the differing information content of the IR and microwave data.

In assimilation experiments the impact of SSMIS is small but positive in the SH, but negative in the tropics. For IASI *water vapour channels*, impacts are generally neutral in the extra-tropics and positive in the tropics. This may be due to a bias between forecast model and IASI observations which results in IASI drying the tropics. Impacts of both observation types on forecast humidity fields are surprisingly weak, with forecast accuracy changing by less than 1% across all forecast ranges, and in all regions, upon the introduction of both data types. TRMM data has been used to assess the precipitation fields and there is some evidence that the inclusion of SSMIS data improves the positioning of the Asian monsoon.

## References

- [1] E. Andersson, E. Hólm, P. Bauer, A. Beljaars, G. A. Kelly, A. P. McNally, A. J. Simmons, J.-N. Thépaut, A. M. Tompkins, Analysis and forecast impact of the main humidity observing systems, Quarterly Journal of the Royal Meteorological Society, Volume 133, Issue 627, Date: July 2007 Part B, Pages: 1473-1485.

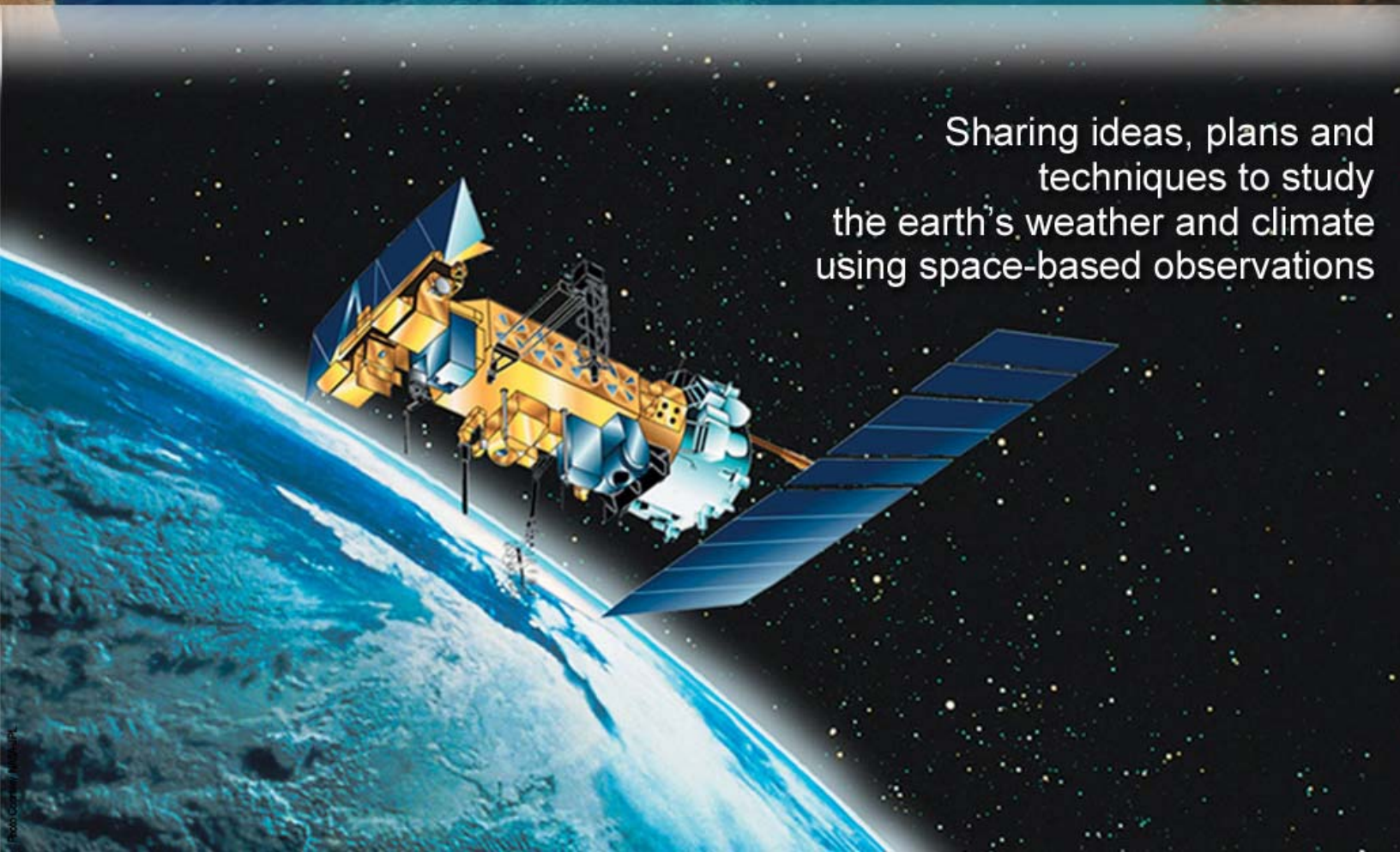


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