Met Office

A study into the February 2008 Stratospheric sudden warming in the Northern Hemisphere

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Introduction

The conditions that led up to the Northern Hemisphere major warming in February 2008 are examined using Met Office assimilated analyses. It is largely accepted that stratospheric sudden warmings (SSW) are instigated by upward propagating planetary waves from the troposphere and thus are a clear demonstration of the stratosphere-troposphere coupled system. In light of this, diagnostics revealing planetary wave propagation are investigated over the development of this warming.

The predictability of the 2008 warming is also studied in detail by running forecasts from different initial conditions prior to the warming. The predictability of this warming is of particular interest due to the disturbed state of the stratosphere prior to the warming, a scenario which has been studied by Hirooka and Ichimaru (2007). Their study is used as a basis for comparison with the results obtained here.

Stratospheric Warming of February 2008

The criterion for a major warming was fulfilled in the northern hemisphere on 21 February 2008 as can be seen in Fig 2a. This warming was preceded by several minor warmings around the 5th and 15th, in which the zonal mean zonal winds at 60°N reversed but did not reach the 10hPa level.

Figure 1 shows the development of the warming from the relatively undisturbed stratosphere (pre-warming) where the cold polar vortex is strong and over the pole. However by the 23 February (during warming) the vortex has reduced in strength and has been displaced off the pole thus showing the typical characteristics of a wave 1 type warming. In addition the temperature over the pole has increased by approximately 60°K. Post-warming the polar vortex appears to be moving back up over the pole but it does not have the same magnitude as prior to the warming and did not re-establish its pre-warming values for this year.

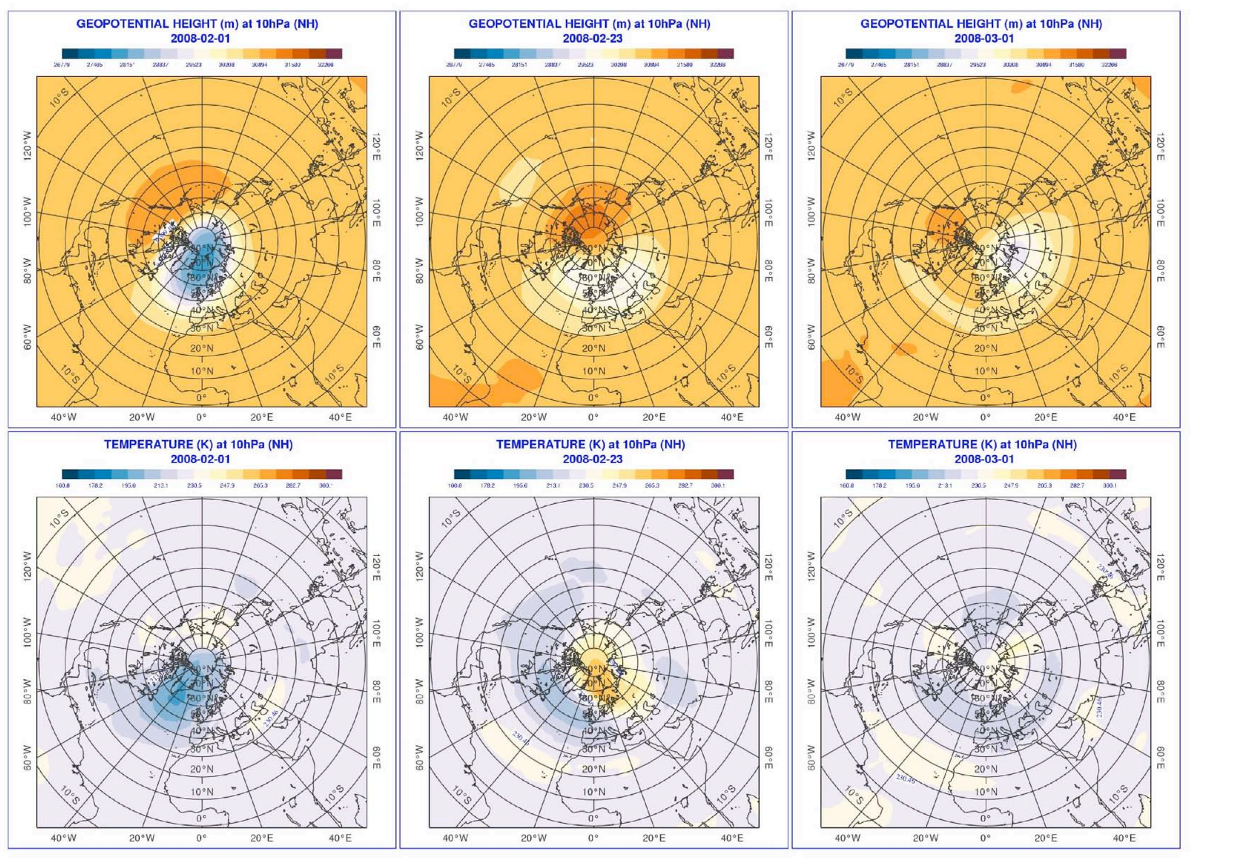

Figure1: Northern hemisphere geopotential height (top) and temperature (bottom) plots at the 10hPa level for pre-warming: 01-02-08 (left), during warming: 23-02-08 (centre) and post-warming: 01-03-08 (right).

Time series of the analyses (Figs 2a-5a) show the development of the warming and give an insight into the cause for the wind reversal. Foremost, the episodic changes in the zonal mean flow (Fig 2a) appear to be well correlated with wave driving of the mid-stratosphere. Each upper level wind reversal coincides with easterly forcing due to planetary waves (negative values in Fig 3a) which in turn appears to be onset by the upward propagation of planetary waves from the troposphere (Fig 4a).

(a)
(b)
(c)
(d)
(e)
(f)

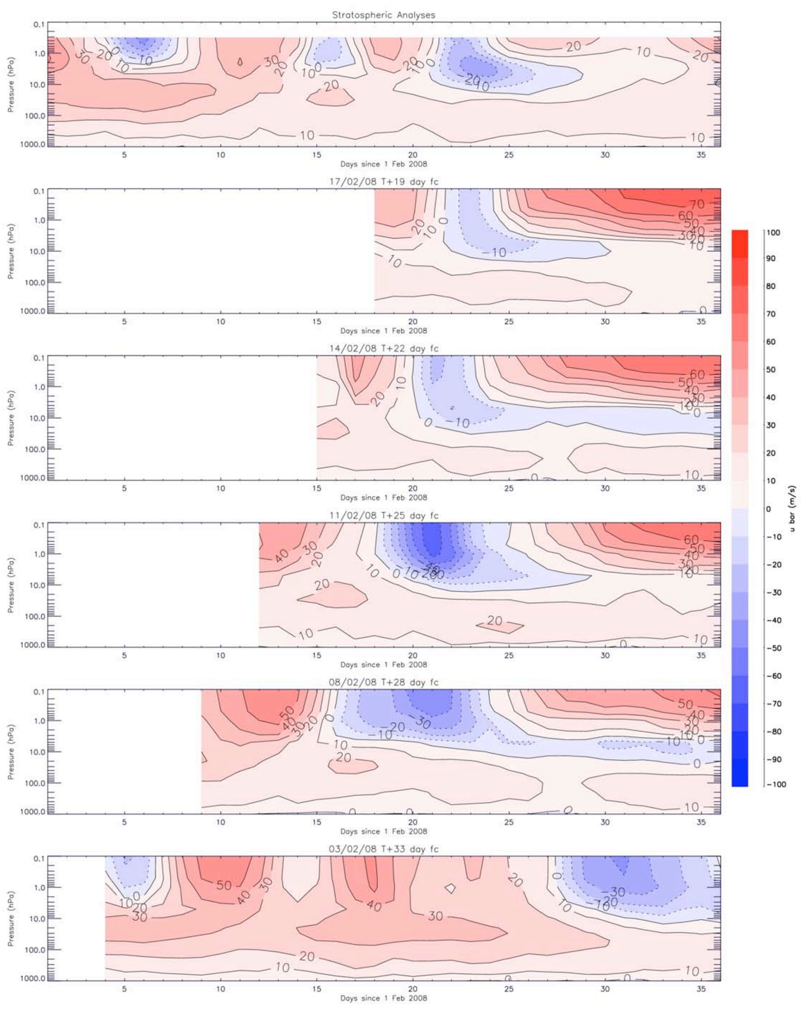

Figure 2: Zonal winds (ms^{-1}) at 60hPa (a) Stratospheric analyses from 1 Feb-6 Mar, (b) Run 1, (c) Run 2, (d) Run 3, (e) Run 4 and (f) Run 5.

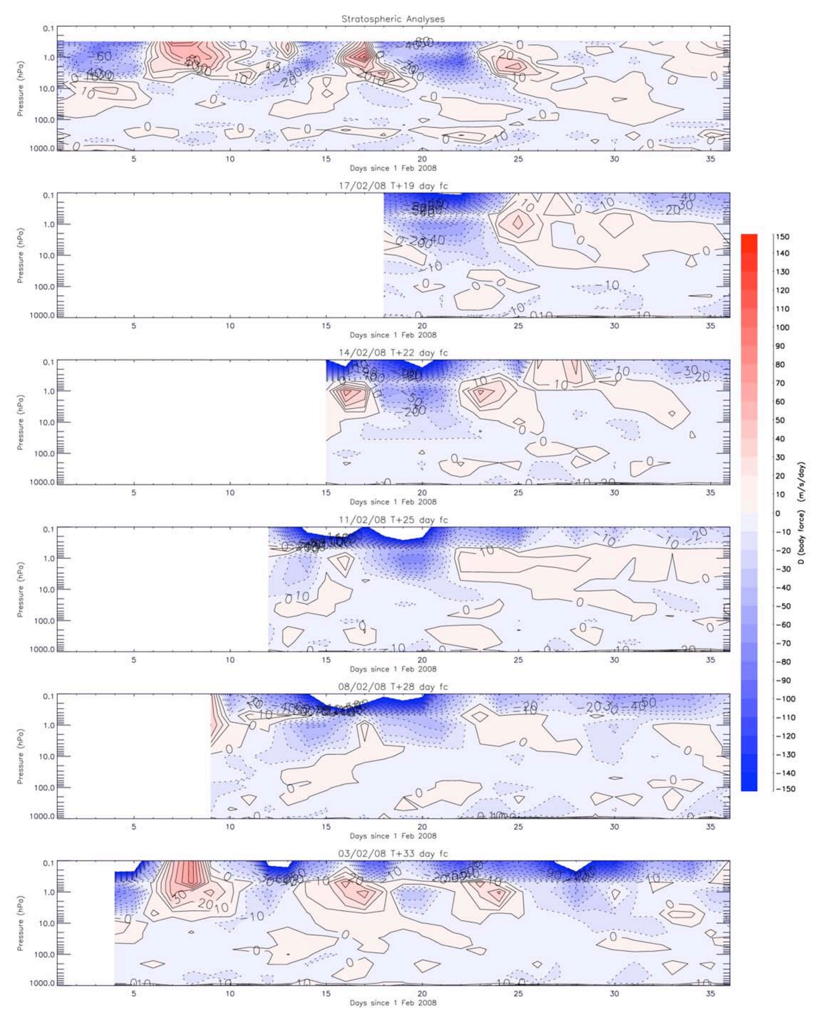

Figure 3: As in Figure 2 but for D - body force ($ms^{-1}day^{-1}$).

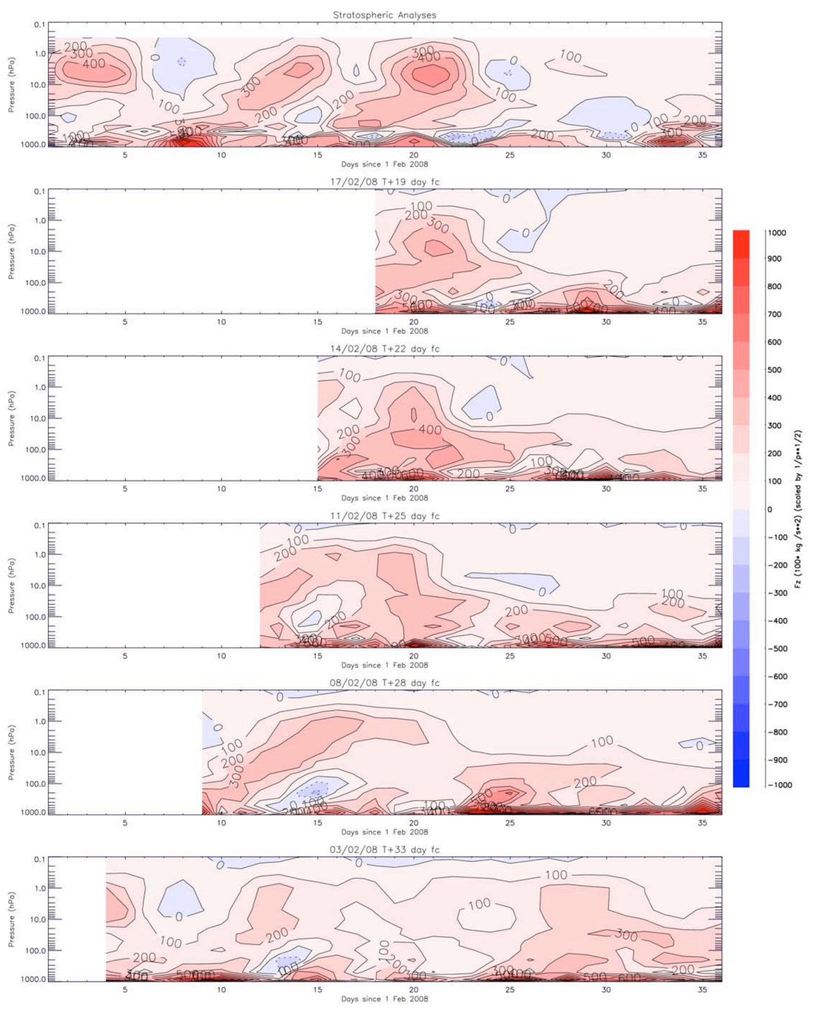

Figure 4: As in Figure 2 but for vertical component of EP-flux, Fz ($100{*}kg\ s^{-2}$ scaled by $1/p^{1/2}$). Upward focusing of waves are defined as the positive values of Fz.

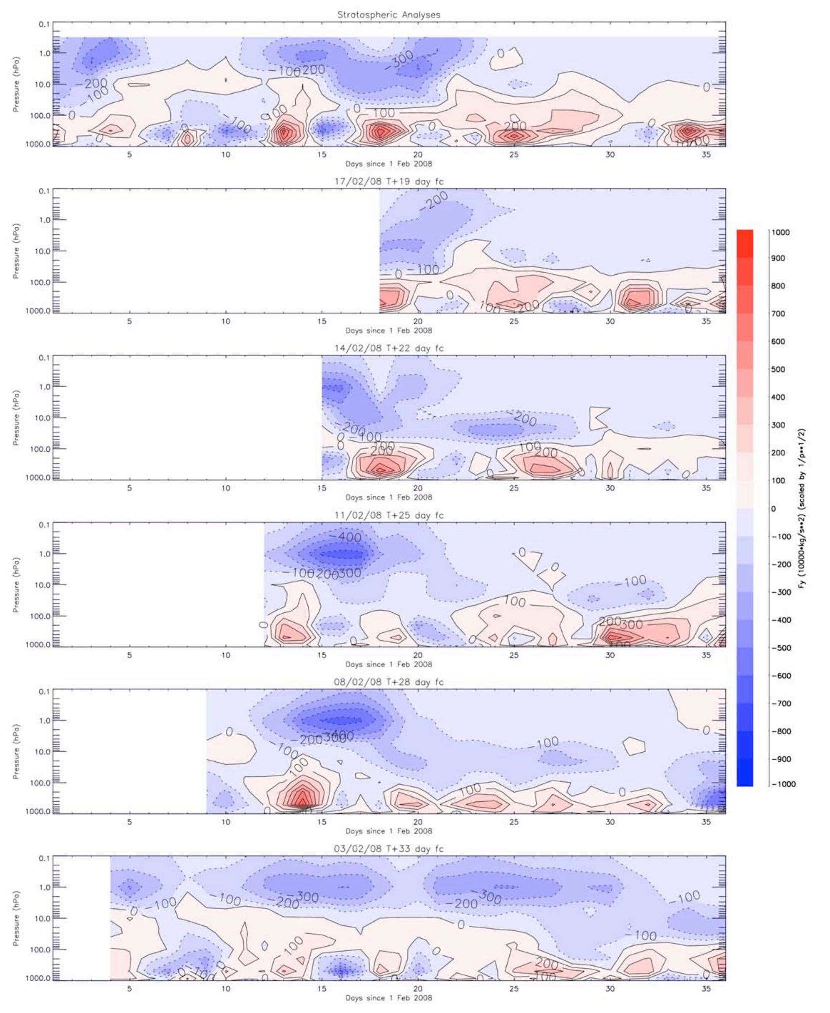

Figure 5: As in Figure 2 but for horizontal component of EP-flux, Fy ($10000{*}kg\ s^{-2}$ scaled by $1/p^{1/2}$). Poleward focusing of waves are defined as positive values of Fy.

Predictability Runs

Hirooka and Ichimaru (2007) compared the predictability of two major warmings, one with and the other without preceding minor warmings. They found that the predictable period reduced from 16 days in the event without preceding minor warmings to nine days in the event with them present. This reduction in predictability was attributed to the more complicated time evolution prior to the warming. This investigation hoped to emulate or disprove this result by running forecasts from different days prior to the warming to determine the predictability of the major event. The initial conditions for the forecast were the daily stratospheric analyses. The forecast start days were chosen to coincide with either the beginning or end of a minor warming. All the forecasts were run until the 6 March i.e. two weeks after the start of the warming.

Discussion

- The main feature of the zonal wind reversal at 60°N and 10hPa on the 21 February can be seen in all the runs and at roughly the same time for runs 1-4 (Figs 2b-2e). By contrast, the easterlies seen in the analysis on 15 February are not reproduced well in any of the forecast runs that begin before that date. The simulation of such easterlies is thus not key to the reproduction of the subsequent major warming on the 21 February. This contradicts Hirooka and Ichimaru's findings.

- Hirooka and Ichimaru showed that more predictable warmings are characterised by a gradual onset of easterly forcing (D) and less predictable warmings by a rapid appearance and disappearance of easterly forcing. Fig 3a shows such patterns in the forcing for the wind reversals at 21st and 15th February, respectively. This explains the predictability (lack of predictability) of the 21st (15th) event.

- Investigation of post-warming daily latitude versus pressure cross sections (not shown) revealed subtle differences in the location of the polar night jet between the analysis and forecast runs thus explaining the large differences in the upper level winds seen in Fig 2. In the case of the analysis, high latitude easterlies were present in the lower mesosphere and stratosphere and westerlies in the lower stratosphere and troposphere. This is explained by the descending westerly forcing (Fig 3a) allowing the recovery of the westerlies in the lower stratosphere and troposphere and pushing the jet to mid latitudes at upper levels. In contrast, forcing in the forecast runs remains easterly in the lower stratosphere and troposphere thus ensuring that the winds are easterly here and so the upper level jet is seen to be strong and westerly at mid latitudes in the cross sections.

- A further feature which reinforces the upper level wind differences between analysis and forecast runs is the presence of relatively high vertical EP-flux in the stratosphere around 28 February in the analysis (Fig 4a). This is probably the major contributing factor to the easterly forcing which is acting to decelerate the westerlies at upper levels at around this time.

- In conclusion, although this study has shown that the major warming event itself was predictable it has also highlighted that the atmospheric conditions post-warming are not well represented. Consequently, in investigations of the effects of stratospheric warmings on the troposphere on longer timescales (e.g. seasonal effects) a gross representation of the sudden warming (e.g. wind reversal at approximately the right location and time) may not be sufficient to represent these effects properly.

References

Hirooka, T. and Ichimaru, T., 2007: Predictability of Stratospheric Sudden Warmings as Inferred from Ensemble Forecast Data: Intercomparison of 2001/02 and 2003/04 Winters. *J. Meteor. Soc. Japan*, **85**, 919-925.

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