Short-range Forecasting Research

Short - Range Forecasting Research Division

Technical Report No. 7

More satellite sounding data - can we make good use of it?

by

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January 1992

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1. Introduction

Recently NESDIS satellite soundings have become available at a higher density as a result of data compaction by means of the BUFR format. Now all the retrievals processed by NESDIS are available, giving a typical spacing between observations of 120kms. Previously only a subset of this was received at Bracknell, known in-house as compressed satems with a spacing of 250km which have now been discontinued. Data transmitted in SATEM code at a resolution of 500km is still available as backup. In this paper, we will refer to the lower resolution data streams as SAT250 and SAT500.

There are several questions to be answered by this study:

Firstly, is the SAT120 data of comparable quality to that which we are accustomed? NESDIS policy may well have been to select 'best' for inclusion in the SAT250/SAT500 data streams, rather some arbitrary choice, so additional quality control measures might be required. In section 2, we examine SAT120 quality, using (observation-background) statistics from the quality control stage, data rejection rates, and also comparison of colocated SAT120 and SAT500 reports. We also review quality control options in the light of the increased data volume.

Secondly, how do we cope with the 400% increase in data volume (cf. SAT250)? There are two aspects to this issue. The change in data density of satellite soundings is likely to have an impact on the assimilation of other observations, particularly in the oceanic regions. Algorithm changes might be required to avoid the sounding data 'swamping' other data types. There are also cost implications associated with any increase in data volumes. Is there a worthwhile improvement in quality to merit the extra processing cost? If not, do we minimise the cost increase by amending the assimilation to thin or average the data or perhaps reduce its horizontal influence on the grounds that the observation density is high? In section 3, we describe the results of a short data assimilation experiment which benchmarks the various options for assimilating the SAT120 data. We also discuss results of several additional runs involving modifications to the observation processing and quality control, to assess changes to the layer thickness processing and the permanent reject strategy.

In section 4, we present the results of a longer experiment comparing the optimal SAT120 assimilation, as identified by the experiments discussed in section 3, with the current operational system.

2. SAT120 quality and qc strategy

2.1 Colocations

An examination of SAT120 and SAT500 data files for the same time revealed that, where colocated (in space and time), the observations were approximately the same, but it was not possible to find exact matches. Exact colocation were not possible because the precision with which the position of the SAT500 data is given (nearest degree/hour) is less than for the SAT120 data.

On one case (00z 15/9/91) where 118 colocations (within 0.5° and ½hour) were found from 674 SAT500 reports and 7480 SAT120 reports, the mean and rms difference between SAT120 and SAT500 was:

lvls	1000	850	700	500	400	300	200	100	70	50	30	10
mn dif	-.17	.10	-.04	-.04	.06	-.01	.03	-.16	-.12	.03	.03	
rms dif	.62	.62	.43	.68	.57	.38	.20	.92	.88	.51	.54	

Table 1

The differences in table 1 suggests that different retrieval algorithms are being used for the two products. The differences between 100mb and 50mb are particularly pronounced.

2.2 QC changes

Two measures have been considered to tighten quality control and reduce data volume for the assimilation.

Firstly the data which fail stability check (some 20% of the total) are now rejected completely, instead of just being flagged in the troposphere. This implies a 20% reduction in cost for the assimilation of soundings. It was felt that there was sufficient stratospheric reports without resorting to data which had been flagged in the troposphere.

Secondly, a reassessment of the relative quality of soundings generated via different retrieval routes seems appropriate. This is being done because we now have all the retrievals rather than just those selected by NESDIS as being 'best'. The current position is that cloudy soundings have a 15% higher observation error than clear or partly cloudy at all levels and all latitudes, but the information on which this was based is some years old. All soundings are assigned the same initial PGE. This work is being undertaken in CF. Preliminary results (Smith, pers. comm.) suggest that a larger scaling might be more appropriate for cloudy data at least below 100mb and that errors for partly cloudy should also be larger. Similar scalings should also be adopted for PGEs.

2.3 QC results

We present here the QC statistics for a 24 hour period (26/11/91), for a control run with only SAT500 compared with a run including SAT120. Operational background fields are used for both runs, so this favours the control run.

	SAT500	SAT120
No of reports (excl perm rejects)	2289	38519
% failing stability check	22.6	22.6
No of levels (excl perm rejects)	24411	425864
% failing BG & Final check	0.6	2.1
% failing Final check only	13.2	24.2

Table 2

The following points arise from Table 2. The characteristic error in the troposphere which results in a QC flag from the stability check is the same in both data sets. The increase in final flags for the SAT120 run is explained by the change in the impact of the stability check, which results in a complete sounding being flagged for SAT120 (12 levels), where as only the bottom 7 levels are flagged for SAT500. The difference in background flags (0.6% cf 2.1%) is less easy to understand. The following table gives the rms differences from background by level and the % flagged at each level by the background check alone.

lvls	1000	850	700	500	400	300	200	100	70	50	30	10
rms diff												
SAT500	1.80		1.50	1.30	1.32	1.32	1.40	1.25	1.35	1.25	1.27	1.32
SAT120	1.80		1.31	1.14	1.16	1.15	1.30	1.14	1.42	1.27	1.29	1.40
% flagged												
SAT500	0.6		1.8	0.6	1.0	0.7	0.1	0.1	0.2	0.2	0.0	0.0
SAT120	0.2		2.3	0.6	0.7	0.5	0.2	0.1	3.8	3.1	2.6	2.2

Table 3

We see SAT120 fits background better below 100mb and worse above 100mb. The poorer fit to background above 100mb accounts for the difference in background flags. The backgrounds were based on analyses using SAT500, so more flagging of SAT120 and a higher rms difference does not necessarily imply poorer observations. Equally, we cannot assume that the lower rms difference for SAT120 in the troposphere indicates better data, because the two datasets may not have the same geographical coverage. It is an encouraging feature, but a larger sample is required to be sure of this point.

3. Assimilation tuning for SAT120

All the experiments in this section consist of 4 six hour assimilations followed by a 12 hour forecast. The verification results are mostly presented for the 12 hour forecast, but where significant differences in fit to the analysis were noted these are also given. In all cases, the observations other than soundings are identical. The SAT120 runs include LASS data over the North Atlantic if it was available, and SAT500 data in regions where SAT120 data was not received. The NO-SAT120 control also includes LASS data and a fuller 'global' set of SAT500 data covering also those regions where SAT120 data might have been located.

3.1. Impact of thinning

The first set of runs is a straightforward SAT120.v.SAT500 comparison, with additional runs to determine if an alternative cheaper formulation can be run. Three SAT120 runs are compared with the NO-SAT120 control

Run 1: NO-SAT120 control
Run 2: SAT120 at full resolution
Run 3: SAT120 1/3 thinned
Run 4: SAT120 1/3 thinned and iterate sounding data separately

In runs 3 and 4, the thinning strategy adopted reduces cost whilst still allowing all observations to influence the analysis without the full smoothing effect of superobbing the data. The full set of observations is presented to the assimilation and any one observation is only used each Nth timestep. Thus with N=3, the 1st,4th,7th... observations are used on the 1st,4th,7th... timestep, the 2nd,5th,8th... observations on the 2nd,5th,8th timesteps and the 3rd,6th,9th... observations on the 3rd,6th,9th timestep. Each observation is used fewer times to nudge the analysis, but the observation-model differences are likely to be strongly correlated horizontally so the model should be moving towards an observation even if it were not being used on that particular timestep.

The thinning by 1/3 was chosen because the cost would be approximately the same as runs using the now defunct SAT250 data. A basic data volume increase of 400% reduced by additional quality control measures to about 300% which would cost three times as much in the unthinned case.

The logic behind run 4 is that by partitioning the radiosonde and sounding temperature iterations we eliminate the problem of sounding data swamping the less dense radiosonde data.

Table 4 gives mean square fit of observations to model analysis after 4 cycles. For multilevel reports the result is combined for all levels. The variables are as assimilated (namely pressure,potential temperature,wind (m/s) and relative humidity). The data time is 00z 16/9/91. Results are presented for 3 latitude bands (nh=90°N-22°N, tr=22°N-22°S, sh=22°S-90°S)

Table 5, gives the 12 hour forecast verification for Runs 1-4. These results are expressed in terms of rms difference, temperature is given rather than potential temperature, and the fit to SAT500s is shown, otherwise the format follows Table 4.

	P_*	θsonde	θairep	Vsonde	Vairep/ satob	Vship	RHsonde
<u>Run 1 - control</u>							
nh	1.14	2.24	8.24	6.52	42.4	11.5	131.
tr	1.76	2.37	5.95	8.11	10.5	7.28	127.
sh	2.33	3.12	5.81	16.4	11.6	15.0	120.
<u>Run 2 - SAT120 at full res</u>							
nh	1.13	2.48	8.35	6.54	43.1	11.6	131.
tr	1.79	3.02	6.73	7.97	10.7	7.21	128.
sh	2.23	5.35	5.97	16.8	11.6	15.2	125.
<u>Run 3 - SAT120 1/3 thin</u>							
nh	1.13	2.34	8.31	6.53	43.2	11.6	131.
tr	1.78	2.68	6.47	7.96	10.6	7.25	126.
sh	2.23	4.41	5.92	16.6	11.7	15.3	123.
<u>Run 4 - SAT120 1/3 thin and separate iteration for soundings</u>							
nh	1.14	2.26	8.42	6.51	43.6	11.7	131.
tr	1.79	2.34	6.20	8.12	10.7	7.24	124.
sh	2.30	2.78	5.69	16.6	11.9	15.3	120.

<u>Table 4- T+0 scores</u>

	P_*	Tsonde	Tairep	Tsatem	Vsonde	Vairep/ satob	Vship	RHsonde
<u>Run 1- control</u>								
nh	1.60	1.47	2.06	1.19	4.60	7.73	4.82	17.9
tr	1.70	1.43	1.75	1.20	5.80	6.48	4.74	19.3
sh	2.57	1.78	2.01	1.72	7.47	6.08	5.18	20.7
<u>Run 2 - SAT120 at full res</u>								
nh	1.54✓	1.47	2.17×	1.14✓	4.64×	7.91×	4.87×	17.8✓
tr	1.73×	1.44×	1.74✓	1.06✓	5.91×	6.54×	4.78×	19.0✓
sh	2.55✓	1.79×	1.96✓	1.67✓	7.49×	5.97✓	5.24×	21.0×
<u>Run 3 - SAT120 1/3 thin</u>								
nh	1.55✓	1.47	2.13×	1.15✓	4.61×	7.86×	4.85×	17.8✓
tr	1.73×	1.44×	1.73✓	1.07✓	5.87×	6.53×	4.78×	19.1✓
sh	2.56✓	1.78	1.96✓	1.68✓	7.49×	5.98✓	5.26×	20.9×
<u>Run 4 - SAT120 1/3 thin and separate iteration for soundings</u>								
nh	1.53✓	1.47	2.17×	1.17✓	4.63×	7.92×	4.84×	18.0×
tr	1.72×	1.42✓	1.73✓	1.09✓	5.89×	6.51×	4.79×	19.2✓
sh	2.57	1.77✓	1.98✓	1.69✓	7.54×	6.03✓	5.27×	20.8×

<u>Table 5 - T+12 scores</u>

The most significant point to be made about Table 4 is that the inclusion of SAT120 data (particularly at full resolution) increases the mean square temperature differences for sondes and aireps. This suggests that the sounding data density is sufficiently high to diminish the impact of the less dense radiosonde network, where the two coincide. The thinning option reduces this tendency (run 3). The partitioning of the temperature iteration into a satellite sounding and a conventional component (run 4), was an attempt to reduce this tendency further and as far as the analysis is concerned it seems to be successful for temperature data but not perhaps for surface pressure and wind data.

The T+12 verification in Table 5 shows that the apparently poorer fit to radiosondes at T+0 does not diminish the quality of the forecast. However, on the basis of this short test, it does not seem that the availability of sounding data at a higher resolution is giving any significant benefit. There are at least as many crosses (Run 1 best) as ticks (Run 1 worse). Run 3 where the thinning option has been used appears to be marginally better than Run 2. There is a clear tendency in all the SAT120 runs for the winds to verify marginally worse and the temperatures to verify marginally better compared with the control. There is no benefit to partitioning the temperature iteration (run 4) despite a closer fit at T+0. Overall the difference between the runs is quite small.

3.2. Impact of assimilating virtual temperature

One feature that has recently been adopted for BOGUS thickness data is its direct assimilation as layer mean virtual temperature (Bell et al 1991a,b). This could also be appropriate for sounding data since it avoids the problem of estimating a layer mean specific humidity to use in the conversion of observed virtual temperature and greatly simplifies the observation preprocessing stage. The assimilation forward model is modified to provide a model field of mean layer virtual temperature from which a virtual temperature increment can be determined.

The current procedure for the assimilation of satellite sounding data was devised by Swinbank and Wilson (1990). The procedure correctly treats the data as layer means but still requires as input a layer mean dry bulb temperature. The observations are received as layer thicknesses and the conversion of the layer mean virtual temperature to a layer mean temperature is by no means straightforward. Half of the retreivals contain a precipitable water content report, but this is difficult to use because it is reported in thicker layers (1000-700,700-500 and 500-300mb) and we require estimates between standard layers. For those retrievals with PWC missing, an arbitrary estimate of relative humidity must be made. An alternative is to make use of the model background moisture fields, but their reliability in oceanic area is questionable.

A simple revision of the forward process, evaluating observed variables from model variables, allows us to process the sounding data more effectively as thickness without concerning ourselves with the virtual temperature calculation in the observation preprocessing stage.

The model virtual potential temperature θ_v is calculated from θ and q using the standard definition

$$\theta_v = \theta \, (1 + (\varepsilon^{-1} - 1) \, q)$$

where ε is the ratio of molecular weights of water and dry air

With model layers denoted by ,k, bounded by $k\pm\frac{1}{2}$ and observation layers denoted by ,i, bounded by $i\pm\frac{1}{2}$. The calculation of model mean layer virtual temperature $(\acute{T}_v)_i$ for observation layer ,i, proceeds as before, thus for the example where an observation layer straddles two model layers

$$(\acute{T}_v)_i = \frac{((\theta_v)_{k+½} + (\theta_v)_{i+½})\ (\Pi_{k+½} - \Pi_{i+½}) + ((\theta_v)_{i-½} + (\theta_v)_{k+½})\ (\Pi_{i-½} - \Pi_{k+½})}{2 \times \log\ (p_{i-½}/p_{i+½})}$$

And the virtual temperature increment for observation layer i is

$$\delta(T_v)_i = (T_v)_i - (\acute{T}_v)_i$$

we now assume that the temperature increment can be approximated by the virtual temperature increment. The calculation of the potential temperature increment for model level k proceeds as before.

A 5th run is to be compared with Run 3 from section 3.1

Run 3: SAT120 1/3 thinned
Run 5: SAT120 1/3 thinned with soundings treated as virtual temperatures

	P_*	Tsonde	Tairep	Tsatem	Vsonde	Vairep/ satob	Vship	RHsonde
Run 3 - SAT120 1/3 thin								
nh	1.55	1.47	2.13	1.15	4.61	7.86	4.85	17.8
tr	1.73	1.44	1.73	1.07	5.87	6.53	4.78	19.1
sh	2.56	1.78	1.96	1.68	7.49	5.98	5.26	20.9
Run 5 - SAT120 1/3 thin and Tvirt								
nh	1.55	1.47	2.14×	1.16×	4.62×	7.86	4.85	17.8
tr	1.76×	1.45×	1.73	1.08×	5.84✓	6.50✓	4.74✓	19.1
sh	2.54✓	1.77✓	1.96	1.68	7.50×	5.95✓	5.25✓	20.9

Table 6

Run 5 seems to verify marginally better in the southern hemisphere and for the tropical wind field. Results are worse for the northern hemisphere and for the mass field in the tropics. The lack of impact in the northern hemisphere is not surprising since there is a permanent reject on the lowest sounding layer (1000-850) where the moisture content is greatest. On balance this 'nul' result does not seem worth following up, with any urgency.

3.3 Permanent reject strategy

Another option to consider is our strategy with regard permanent intervention . We currently reject all soundings over land and also in the northern latitudes those in the 1000-850 layer. Recently data was included operationally over Antarctica above 100mb to alleviate a model problem there. This will be assessed as will the lowest layer reject. The larger issue of land satems generally will not be addressed. In support of the OPD studies we also examine the separate impact of clear and cloudy soundings.

3.3.1 Impact of antarctic stratospheric reports

	P*	Tsonde	Tairep	Tsatem	Vsonde	Vairep/ satob	Vship	RHsonde
Run 2 - SAT120 at full res								
nh	1.54	1.47	2.17	1.14	4.64	7.91	4.87	17.8
tr	1.73	1.44	1.74	1.06	5.91	6.54	4.78	19.0
sh	2.55	1.79	1.96	1.67	7.49	5.97	5.24	21.0
Run 6 - SAT120 at full res inc stratopheric data over Antarctic								
nh	1.54	1.47	2.17	1.14	4.63✓	7.91	4.87	17.8
tr	1.72✓	1.44	1.74	1.06	5.91	6.53✓	4.77✓	19.0
sh	2.54✓	1.79	1.95✓	1.66✓	7.49	5.97	5.24	21.0

Table 7

We see a marginal improvement in verification scores at T+12 from use of the stratospheric data over the Antarctic land mass. This provides support for the operational change which has already been implemented and provides a spur for studies of use of stratospheric land soundings over other areas.

3.3.2 Impact of 1000-850 layer

	P*	Tsonde	Tairep	Tsatem	Vsonde	Vairep/ satob	Vship	RHsonde
Run 2 - SAT120 at full res								
nh	1.54	1.47	2.17	1.14	4.64	7.91	4.87	17.8
tr	1.73	1.44	1.74	1.06	5.91	6.54	4.78	19.0
sh	2.55	1.79	1.96	1.67	7.49	5.97	5.24	21.0
Run 7 - SAT120 at full res inc 1000-850 layer								
nh	1.55×	1.48×	2.15✓	1.15×	4.62✓	7.99×	4.81✓	17.9×
tr	1.72✓	1.47×	1.76×	1.05✓	5.87✓	6.52✓	4.70✓	19.1×
sh	2.55	1.79	1.96	1.67	7.50×	6.00×	5.38×	20.9✓

Table 8

More × than ✓ in Table 8 give little encouragement to remove the current permanent reject on the lowest layer. Should we follow ECMWF and extend the northern hemisphere reject criteria further, encompassing all non-clear reports or even all reports? The next sub-section begins to address this.

3.3.3 Impact of cloudy/clear

	P*	Tsonde	Tairep	Tsatem	Vsonde	Vairep/ satob	Vship	RHsonde
Run 8 - rpt run 7 with relaxed strato qc and 1/3 thinning								
nh	1.54	1.49	2.13	1.16	4.55	7.83	4.86	17.8
tr	1.69	1.44	1.74	1.01	5.88	6.51	4.78	19.2
sh	2.55	1.77	1.94	1.68	7.51	5.97	5.25	20.8
Run 9 - as run 8 with only clear soundings								
nh	1.57×	1.46✓	2.05✓	1.18×	4.56×	7.80✓	4.84✓	17.9×
tr	1.70×	1.44	1.75×	1.06×	5.81✓	6.44✓	4.74✓	19.2
sh	2.55	1.79×	2.04×	1.72×	7.42✓	5.97	5.26×	20.6✓
Run 10 - as run 8 with only clear and part cloudy soundings								
nh	1.55×	1.46✓	2.12✓	1.20×	4.54✓	7.80✓	4.84✓	17.9×
tr	1.68✓	1.45×	1.74	1.04×	5.87✓	6.54×	4.75✓	19.3×
sh	2.62×	1.80×	1.96×	1.75×	7.61×	6.08	5.31×	21.1×
Run 11 - as run 8 with only cloudy soundings								
nh	1.55×	1.46✓	2.07✓	1.17×	4.55	7.80✓	4.84✓	17.8
tr	1.71×	1.45×	1.74	1.04×	5.80✓	6.43✓	4.76✓	19.2
sh	2.53✓	1.77	2.02×	1.70×	7.42✓	5.96✓	5.24✓	20.8
Run 12 - no soundings								
nh	1.52✓	1.47✓	1.91✓	1.37×	4.55	7.83	4.84✓	18.2×
tr	1.66✓	1.49×	1.76×	1.59×	5.78✓	6.45✓	4.74✓	19.5×
sh	2.77×	1.86×	2.31×	2.22×	7.56×	6.20×	5.37×	21.5×

Table 9

Run 8 is a repeat of Run 3 as far as the assimilation is concerned, but with a slightly different set of data since it was run after the experiment described in 3.3.1. It is given as the control for Runs 9-12 which use only a subset of the total number of soundings

Removing some or all of the sounding data gives worse verification against soundings.
For other verifying observations, we see that :
Run 9 scores 8×,9✓; Run 10 scores 11×,8✓; Run 11 scores 4×,11✓.
We conclude that there is something amiss with the cloud clearing such that the inclusion of partly cloudy data gives a worse result. We also conclude that cloudy soundings are more valuable than the full set of soundings. ie using clear in preference to cloudy is not a reasonable choice.
The no sounding Run (12) is clearly worse in the southern hemisphere, but outscores the Run 9 by 4:1 in the NH and 4:3 in TR. This is clearly something to be concerned about. The no sounding run has no LASS data as well as no NESDIS data. Further studies are required to see if this apparent improvement results from removing LASS data from the N.Atlantic or NESDIS data from the N.Pacific.

4. A fuller trial of the 'optimal' configuration

For the present, the 'optimal' run consists of:
-SAT120 data in place of SAT500 data where it is available
-LASS data still having preference to both SAT120 and SAT500
-The same permanent reject strategy
-Data thinning by a factor of 3 on any given timestep as described above

As indicated above, it is clearly worth considering the following points in a follow up study.
-linking permanent reject/quality control to retrieval route. This should be done after revising observation errors.
-extension of northern hemisphere permanent rejects. This should also consider the worth of LASS data

The 'optimal' configuration was tested over a 4 day period starting 24/11/91. Table 12 gives the data volumes during that period (after qc)

Date	CONTROL	TRIAL				
	SAT500	SAT500		SAT120		
			Clear	P.Cldy	Cldy	Total
18z 24th	658	193	3077	771	3895	7743
00z 25th	678	221	3163	914	0	4077
06z 25th	477	182	2253	526	0	2779
12z 25th	278	167	2784	766	1993	5543
18z 25th	464	125	2842	687	3269	6798
00z 26th	514	150	2977	648	3164	6789
06z 26th	444	50	2734	583	3420	6734
12z 26th	685	141	3112	911	4343	8366
18z 26th	640	199	2843	793	3120	6756
00z 27th	645	431	1612	467	0	2079
06z 27th	496	158	2568	638	0	3256
12z 27th	635	484	1263	288	538	2089
18z 27th	719	409	1679	480	2965	5124
00z 28th	686	257	3038	778	3289	7105
06z 28th	474	256	1473	404	957	2834
12z 28th	649	504	1198	372	1119	2689

Table 12

It is clear from table 12 that receipt of SAT120 data is not as reliable as SAT500 data. The data extractions were all rerun, several days late so cutoff time is not an issue. On 7/16 periods, the data volume was less than 50% of peak, for SAT120, whereas this only happened on 1/16 periods for SAT500.
It is also interesting to see that non-cloudy reports are more likely to arrive than cloudy reports, which were missing on 4/16 occasions.
It should be noted that ≈20% of the SAT500 reports are stratosphere only because the troposphere has been flagged due to stability checks. A similar check on SAT120 data results in the whole report being flagged and thus not being presented to the assimilation. The reasoning behind this was given in section 2.

When SAT120 data are being used, SAT500 data are only presented to the assimilation if there are no SAT120 data covering the same geographical area. Even the periods which had a large volume of SAT120 data made use of as much as a third of the SAT500 data, which again points to problems with receipt of data.

Aside from the use of SAT120 data in place of SAT500 data where the two data sources colocated, the observation files for the control and test runs were identical. The results were assessed by running short forecasts (12 hour) from each 00z and 12z analysis. Thus 8 verifying times are available. The verification results for each observation type are given in the following 8 tables.

P*

	......NH.....		.....TR.....		.....SH....	
	cntl	trial	cntl	trial	cntl	trial
VT 12z 25/11	1.88	1.88	1.92	1.84✓	2.62	2.61✓
VT 00z 26/11	1.88	1.88	1.71	1.66✓	2.58	2.43✓
VT 12z 26/11	1.98	1.97✓	1.72	1.65✓	3.03	2.94✓
VT 00z 27/11	1.76	1.75✓	1.63	1.69×	3.69	3.57✓
VT 12z 27/11	1.80	1.75✓	2.11	2.03✓	2.40	2.42×
VT 00z 28/11	2.04	2.05×	1.67	1.67	2.00	2.07×
VT 12z 28/11	1.98	2.01×	2.03	1.98✓	4.91	4.75✓
VT 00z 29/11	2.31	2.29✓	1.69	1.66✓	2.78	2.84×
Mean	1.954	1.947	1.810	1.773	3.001	2.954

Table 13

Trial wins NH 4✓:2×, TR 6✓:1×, SH 5✓:3×
mean rms improvements NH 0.4%, TR 2.0%, SH 1.6%

sonde temperatures

	......NH.....		.....TR.....		.....SH....	
	cntl	trial	cntl	trial	cntl	trial
VT 12z 25/11	1.63	1.63	1.44	1.43✓	2.00	2.01×
VT 00z 26/11	1.55	1.54✓	1.41	1.41	1.81	1.89×
VT 12z 26/11	1.60	1.58✓	1.42	1.41✓	2.00	1.97✓
VT 00z 27/11	1.54	1.53✓	1.34	1.33✓	1.97	2.06×
VT 12z 27/11	1.54	1.53✓	1.55	1.54✓	2.08	2.07✓
VT 00z 28/11	1.61	1.61	1.51	1.48✓	1.78	1.76✓
VT 12z 28/11	1.64	1.65×	1.51	1.49✓	1.76	1.73✓
VT 00z 29/11	1.68	1.69×	1.51	1.49✓	1.68	1.71×
Mean	1.599	1.594	1.461	1.446	1.885	1.890

Table 14

Trial wins NH 4✓:2×, TR 7✓:0×, SH 4✓:4×
mean rms improvements NH 0.3%, TR 1.0%, SH -0.8%

airep temperatures

	......NH.....		.....TR.....		.....SH....	
	cntl	trial	cntl	trial	cntl	trial
VT 12z 25/11	2.13	2.12✓	2.04	2.13×	2.55	2.76×
VT 00z 26/11	1.91	1.92×	1.82	1.82	2.61	2.64×
VT 12z 26/11	2.34	2.36×	2.10	2.17×	1.91	1.89✓
VT 00z 27/11	1.75	1.79×	1.88	2.01×	1.99	1.96✓
VT 12z 27/11	1.83	1.86×	1.85	1.92×	2.02	2.03×
VT 00z 28/11	2.10	2.14×	2.15	2.09✓	2.07	2.11×
VT 12z 28/11	2.10	2.16×	1.80	1.77✓	2.29	2.42×
VT 00z 29/11	2.29	2.31×	2.04	2.02✓	2.12	2.31×
Mean	2.076	2.103	1.960	1.991	2.195	2.265

Table 15

Trial loses NH 1✓:7×, TR 3✓:4×, SH 2✓:6×
mean rms improvements NH -1.3%, TR -1.6%, SH -3.2%

satem temperatures

	......NH.....		.....TR.....		.....SH....	
	cntl	trial	cntl	trial	cntl	trial
VT 12z 25/11	1.42	1.40✓	1.13	1.08✓	1.45	1.42✓
VT 00z 26/11	1.65	1.52✓	1.16	1.05✓	1.53	1.43✓
VT 12z 26/11	1.47	1.36✓	1.21	1.13✓	1.56	1.47✓
VT 00z 27/11	1.75	1.59✓	1.18	1.07✓	1.42	1.32✓
VT 12z 27/11	1.57	1.51✓	1.21	1.08✓	1.44	1.38✓
VT 00z 28/11	1.74	1.64✓	1.17	1.10✓	1.44	1.40✓
VT 12z 28/11	1.59	1.52✓	1.19	1.09✓	1.52	1.45✓
VT 00z 29/11	1.91	1.76✓	1.11	1.05✓	1.51	1.45✓
Mean	1.637	1.534	1.170	1.082	1.484	1.416

Table 16

Trial wins NH 8✓:0×, TR 8✓:0×, SH 8✓:0×
mean rms improvements NH 6.1%, TR 7.5%, SH 4.6%

sonde winds

	......NH.....		.....TR.....		.....SH....	
	cntl	trial	cntl	trial	cntl	trial
VT 12z 25/11	5.23	5.21✓	6.07	6.04✓	6.66	6.66
VT 00z 26/11	5.25	5.23✓	5.97	5.91✓	6.64	6.57✓
VT 12z 26/11	5.38	5.31✓	6.03	5.98✓	6.91	6.76✓
VT 00z 27/11	5.41	5.34✓	6.03	5.94✓	5.70	5.80×
VT 12z 27/11	5.05	5.06×	6.20	6.31×	6.31	6.33×
VT 00z 28/11	5.50	5.47✓	5.97	6.04×	5.93	5.90✓
VT 12z 28/11	5.65	5.62✓	5.92	5.92	5.90	5.62✓
VT 00z 29/11	5.77	5.74✓	5.69	5.62✓	5.63	5.60✓
Mean	5.405	5.372	5.985	5.967	6.210	6.154

Table 17

Trial wins NH 7✓:1×, TR 5✓:2×, SH 5✓:2×
mean rms improvements NH 0.6%, TR 0.3%, SH 0.9%

airep/satob winds

	......NH.....		.....TR.....		.....SH....	
	cntl	trial	cntl	trial	cntl	trial
VT 12z 25/11	8.25	8.08✓	6.69	6.74×	5.69	5.68✓
VT 00z 26/11	7.66	7.53✓	6.37	6.37	7.23	7.31×
VT 12z 26/11	8.60	8.27✓	6.50	6.52×	6.11	5.80✓
VT 00z 27/11	7.29	7.19✓	6.43	6.42✓	7.99	7.68✓
VT 12z 27/11	7.85	7.76✓	6.05	5.97✓	7.47	7.47
VT 00z 28/11	8.71	8.55✓	7.86	8.13×	7.04	7.15×
VT 12z 28/11	9.61	9.67×	6.66	6.65✓	6.64	6.71×
VT 00z 29/11	10.57	10.40✓	7.49	7.53×	5.21	5.40×
Mean	8.567	8.430	6.756	6.790	6.672	6.652

Table 18

Trial wins NH 7✓:1×, TR 3✓:4×, SH 3✓:4×
(except in tropics) mean rms improvements NH 1.6%, TR -0.5%, SH 0.3%

ship surface winds

	......NH.....		.....TR.....		.....SH....	
	cntl	trial	cntl	trial	cntl	trial
VT 12z 25/11	5.32	5.31✓	4.31	4.33×	5.22	5.26×
VT 00z 26/11	5.56	5.47✓	4.51	4.47✓	3.99	3.99
VT 12z 26/11	5.25	5.18✓	4.24	4.22✓	5.56	5.51✓
VT 00z 27/11	4.83	4.82✓	4.49	4.47✓	11.3	10.6✓
VT 12z 27/11	4.88	4.86✓	4.47	4.47	4.18	4.28×
VT 00z 28/11	5.02	5.03×	4.46	4.54×	4.66	4.65✓
VT 12z 28/11	5.24	5.25×	4.40	4.36✓	10.6	10.5✓
VT 00z 29/11	5.40	5.43×	4.43	4.42✓	10.1	9.67✓
Mean	5.187	5.166	4.414	4.410	6.951	6.805

Table 19

Trial wins NH 5✓:3×, TR 5✓:2×, SH 5✓:2×
mean rms improvements NH 0.4%, TR 0.1%, SH 2.1%

sonde RH

	......NH.....		.....TR.....		.....SH....	
	cntl	trial	cntl	trial	cntl	trial
VT 12z 25/11	16.9	16.9	17.6	17.5✓	23.0	22.8✓
VT 00z 26/11	17.7	17.7	18.5	18.6×	19.9	20.4×
VT 12z 26/11	17.9	17.8✓	19.8	19.7✓	22.6	22.7×
VT 00z 27/11	17.7	17.7	20.1	19.8✓	18.2	18.3×
VT 12z 27/11	17.1	17.1	19.4	19.1✓	21.3	21.6×
VT 00z 28/11	17.4	17.5×	19.5	18.9✓	20.8	20.8
VT 12z 28/11	17.6	17.7×	18.8	18.8	21.0	20.7✓
VT 00z 29/11	18.1	18.1	19.7	19.3✓	20.2	20.1✓
Mean	17.55	17.57	19.17	18.96	20.87	20.91

Table 20

Trial wins NH 1✓:2×, TR 6✓:1×, SH 3✓:4×
(in tropics) mean rms improvements NH -0.1%, TR 1.1%, SH -0.2%

Summarising tables 13-20, we can say that the runs are very close. The only significant loss is in the fit to verifying airep temperatures. The largest 'improvement' is in the fit to verifying satems. Given that aireps and satems are both oceanic observing systems, we must conclude that the reduced variance (model-satem) in part reflects an increased correlation between model error and satem error, and that some of the detail available from the airep data around the tropopause is being lost when more of the 'smoother' sounding data is being used. A more clear cut measure of the impact over the oceans is the 1.6% improvement in fit to NH airep winds. The marginal improvements in fit to verifying radiosondes and synops is also encouraging. Since the bulk of the radiosonde network is far removed from the areas where satems are being used, we should expect the biggest change immediately downstream of oceanic areas and a minimal change elsewhere. We might presume that improvements would be larger for longer forecast periods (measured against the radiosonde network) as the differences begin to show in continental areas. To determine the medium range impact, the forecasts were continued for a further 36 hours. The T+48 forecasts were compared in a similar way to the T+12 forecasts. The results are summarised below:

	No. of trial wins/losses			mean rms improvement		
	NH	TR	SH	NH	TR	SH
P*	4✓:4×	5✓:2×	2✓:6×	-0.5%	2.0%	-2.3%
sonde temperatures	4✓:3×	6✓:0×	2✓:5×	0.4%	1.2%	-0.8%
airep temperatures	5✓:2×	2✓:6×	2✓:5×	0.3%	-2.1%	-0.8%
satem temperatures	8✓:0×	8✓:0×	7✓:0×	3.9%	6.7%	1.4%
sonde winds	7✓:1×	4✓:3×	4✓:4×	0.9%	0.6%	0.2%
airep/satob winds	7✓:1×	2✓:6×	2✓:6×	1.9%	-0.6%	-2.0%
ship surface winds	4✓:3×	5✓:3×	5✓:2×	0.2%	0.2%	4.0%
sonde RH	3✓:4×	3✓:5×	4✓:1×	-0.4%	0.0%	0.8%

Table 21

The global trend at T+48, is still for the trial to be marginally better than the control, but there is no clear indication that the margin of difference between control and trial has widened. In fact there is some suggestion that the trial southern hemisphere compares less well at T+48 than it did at T+12. This difference between the trend in different hemispheres could be due to the different correlation scales used. With the higher data densities it may no longer be appropriate to use a large correlation scale in the southern hemisphere.

The maps at Figures 1-3, show the impact at T+0 for pmsl,500mb height and 250mb winds for the last assimilation cycle, comparing the control run with the trial. We see small differences which are probably not verifyable subjectively. The biggest differences being in the southern oceans, one feature in the Pacific and in the tropical wind field. Note the nul change on the North Atlantic where LASS data was used in both trial and control in preference to NESDIS data.

5.Conclusion

The quality control statistics of both SAT120 and SAT500 were compared and it was determined that the two data sources were comparable. Where differences existed, SAT120 fitted the background better in the troposphere and worse in the stratosphere, but it could not be determined that these differences indicated differences in data quality.

Several short runs were performed in a search for the 'optimal' configuration for the assimilation of high resolution global sounding data. That is 'optimal' both from an impact and a cost viewpoint.

This 'optimal' run which essentially consisted of SAT120 replacing SAT250 and being thinned within the assimilation by a factor of 3. The thinning strategy still left all the data in place but each report was used on fewer timesteps. A further period of 4 days assimilation was run, with verification based on 8 short forecasts from 00 and 12z analyses.

The overall picture is a modest (≃1%) reduction in rms fit to verifying observations (radiosonde t&v /synop p&v /airep v) at T+12 and at T+48. The cost increase has been minimised via additional qc and thinning such that the run time is no longer than it was when compressed satems (SAT250) were used operationally prior to there withdrawal in Sept 1991.

It seems reasonable to implement SAT120 operationally on the basis of these tests. It is rather disappointing not to see a bigger impact from what is a large increase in data. (What would we give for a sixteenfold increase in the radiosonde network!).

This study also suggested the need for further work to examine the impact of changing the correlation scales and influence areas in an attempt to analyse smaller scales, particularly in the southern hemisphere, which might be evident in the higher resolution data and are now supportable by the higher resolution model.

The following points also arose and seem worth considering in a follow up study. The permanent reject/quality control strategy should be linked to the retrieval route. This should be done after revising observation errors. The extension of northern hemisphere permanent rejects should be considered, encompassing LASS data as well as NESDIS data. There also seems to be some value in the stratospheric reports over land and consideration should be given to extending their use.

The implementation of SAT120 before GLOSS trials will allow a more sensible comparison to be made since GLOSS and NESDIS data densities will be the same. It is disturbing to see that some 25% of NESDIS sounding data flagged by a stability check. This gives one less confidence in the remaining 75% of data some of which will only marginally pass the qc stability check and perhaps explains the miniscule impact of the data. This is clearly an area where GLOSS might provide an advantage.

Acknowledgement

Thanks are due to Dave Robinson for providing all the observation files for these experiments

References

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Bell R.S.,Macpherson B. and Robinson D.	1991b	Technical details of the Unified model data assimilation scheme SRFR UMDP P3
Swinbank R. and Wilson C.A	1990	Vertical Interpolation of temperature observations and model data SRFR TN 48

Figures

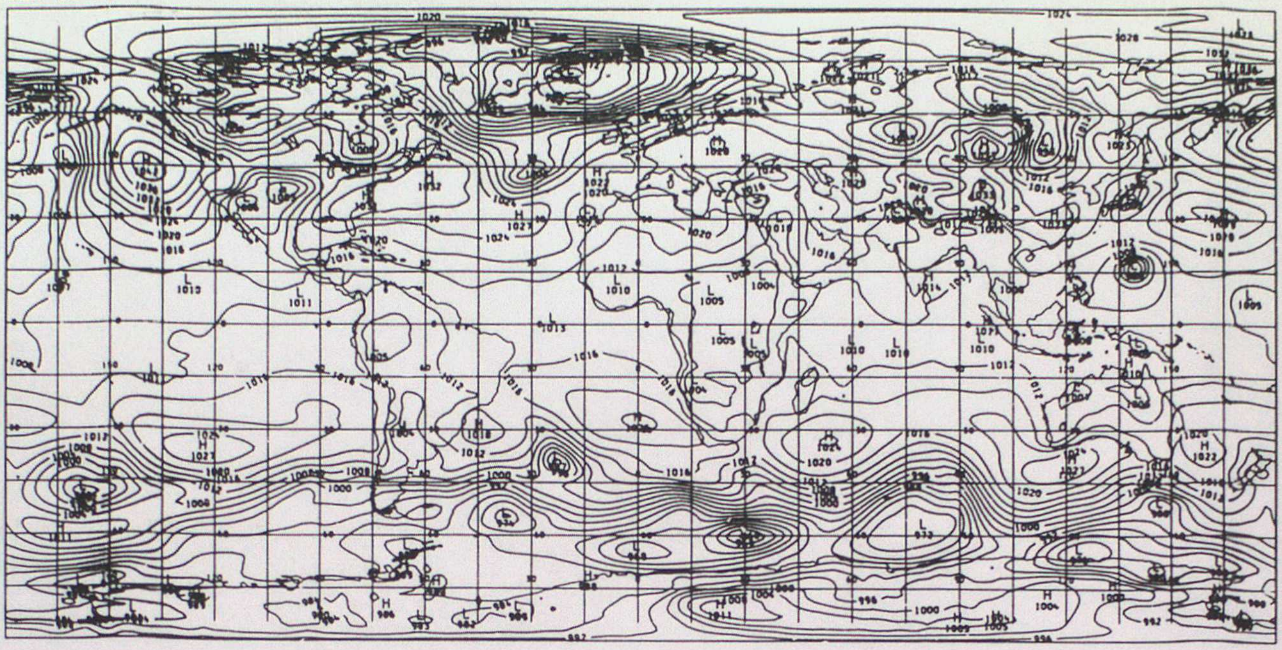
Figure 1. Control pmsl analysis at end of 4 day experiment. and pmsl difference from trial (SAT120) analysis

Figure 2. Control 500mb height analysis at end of 4 day experiment. and height difference from trial (SAT120) analysis

Figure 3. Control 250mb wind analysis at end of 4 day experiment. and speed difference from trial (SAT120) analysis

CONTROL

VALID AT 12Z ON 28/11/1991 DAY 332 DATA TIME 12Z ON 28/11/1991 DAY 332
SEA LEVEL



CONTROL- SAT120

VALID AT 12Z ON 28/11/1991 DAY 332 DATA TIME 12Z ON 26/11/1991 DAY 332
SEA LEVEL

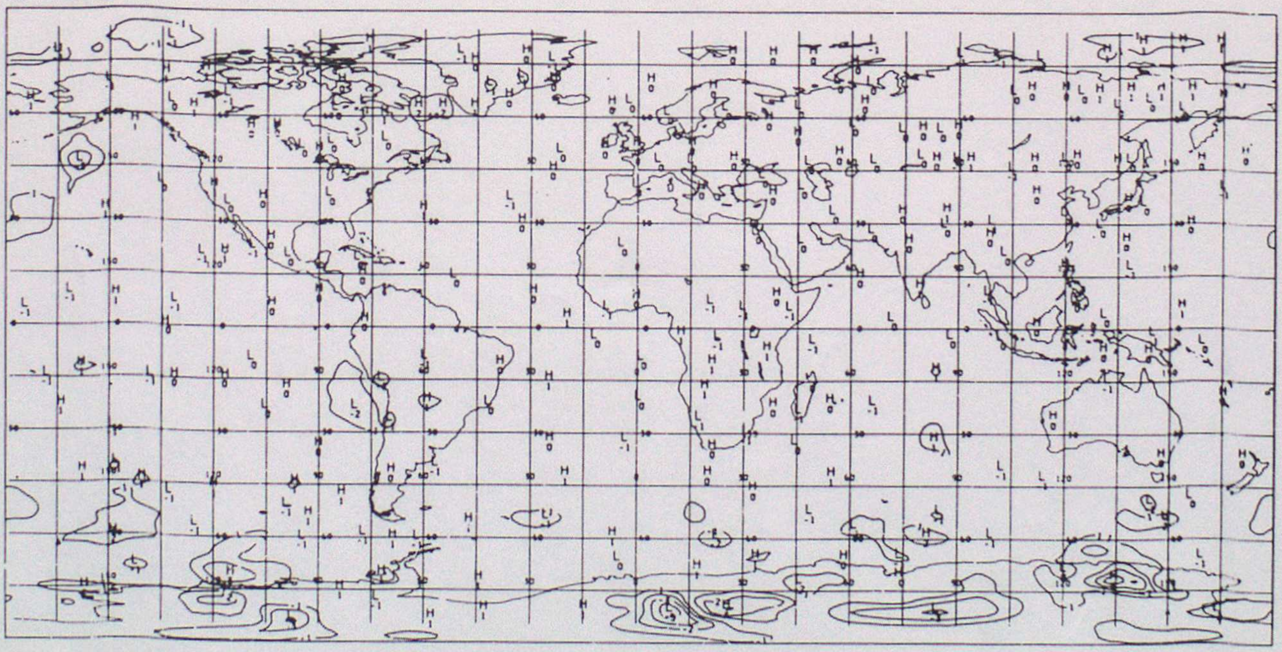
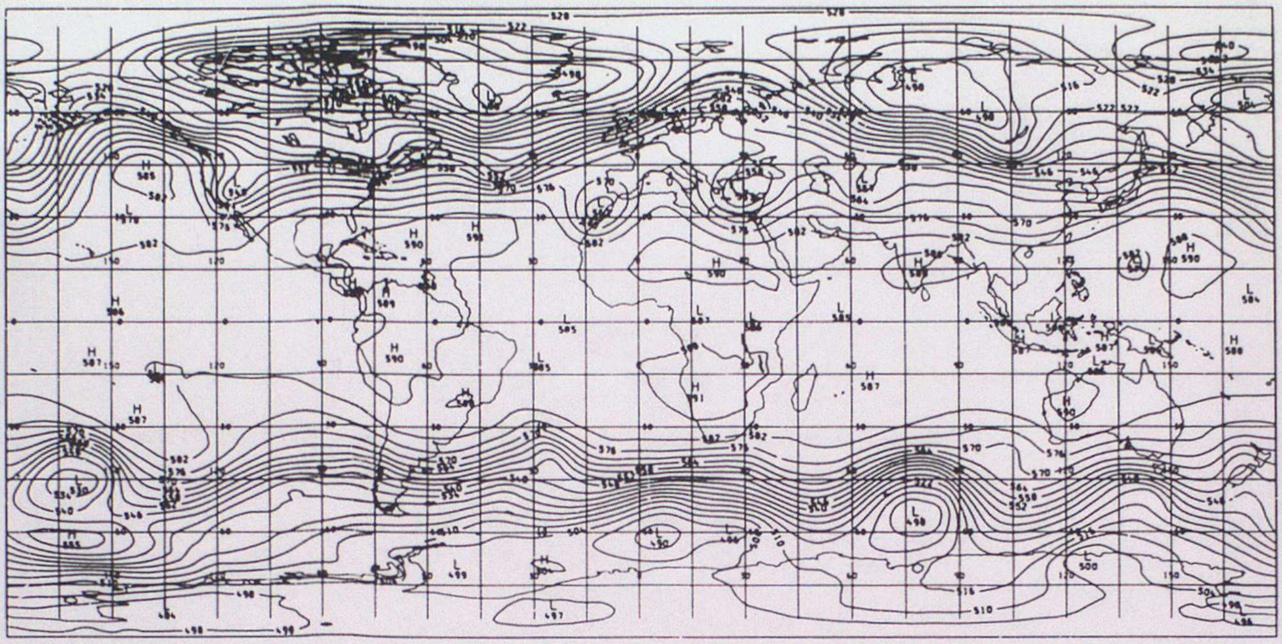


FIGURE 1

CONTROL

VALID AT 12Z ON 28/11/1991 DAY 332 DATA TIME 12Z ON 28/11/1991 DAY 332
LEVEL: 500 MB



CONTROL- SAT120

VALID AT 12Z ON 28/11/1991 DAY 332 DATA TIME 12Z ON 28/11/1991 DAY 332
LEVEL: 500 MB

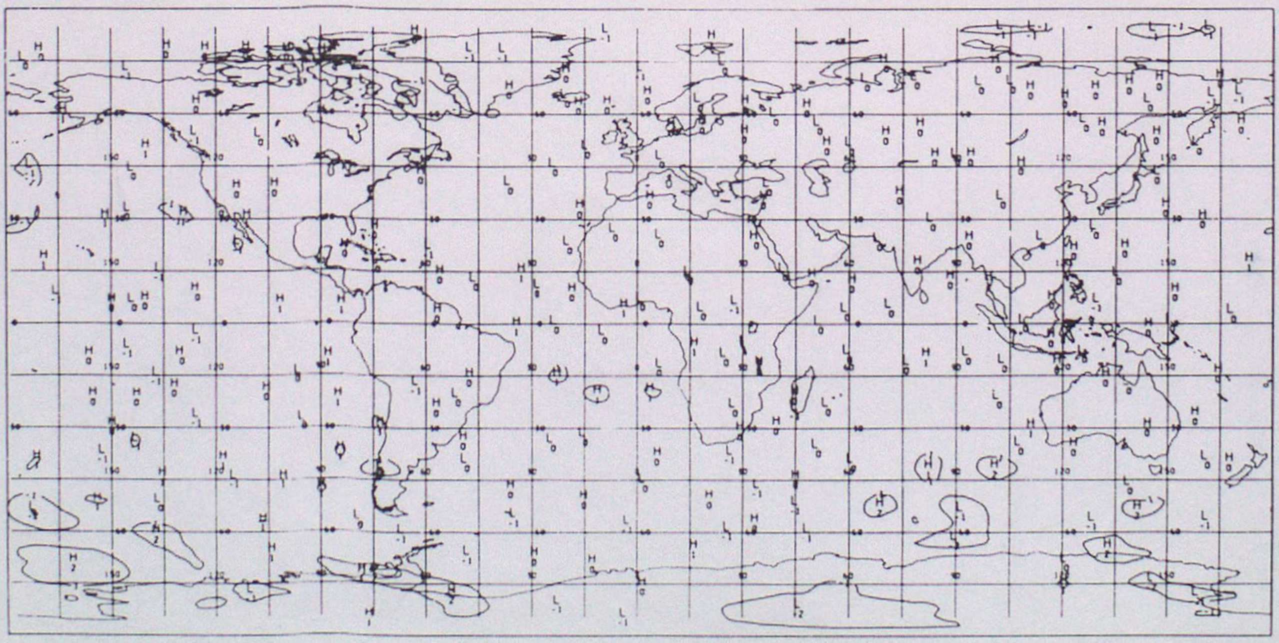
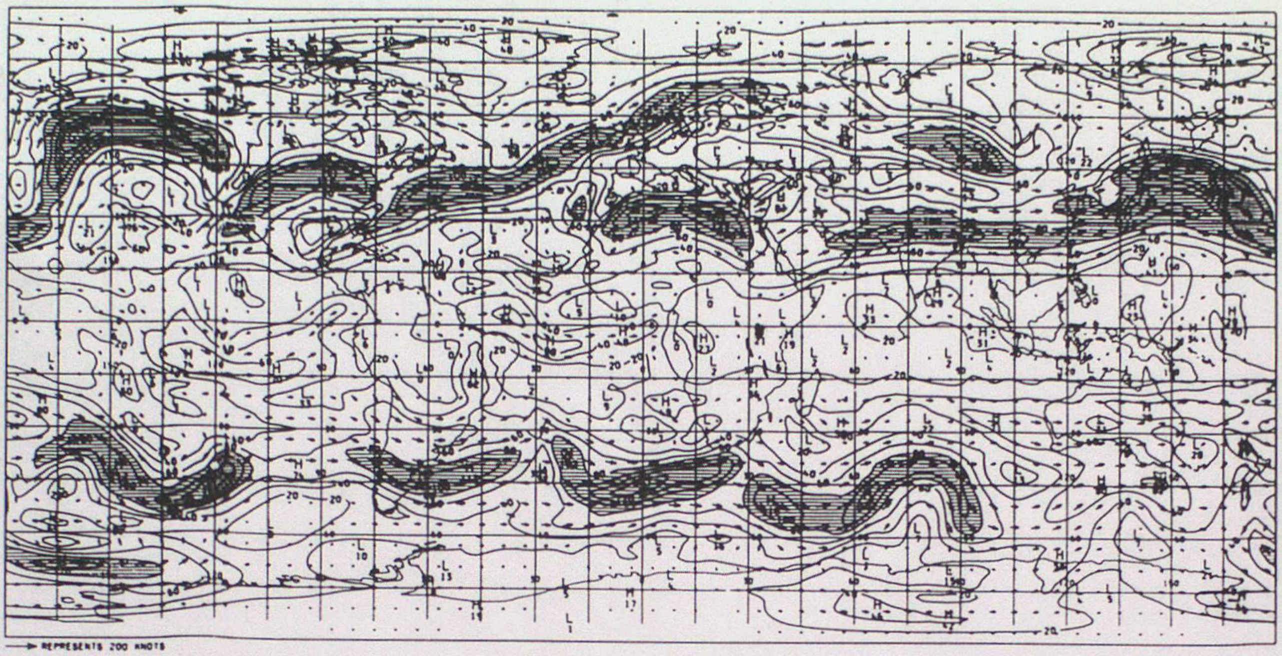


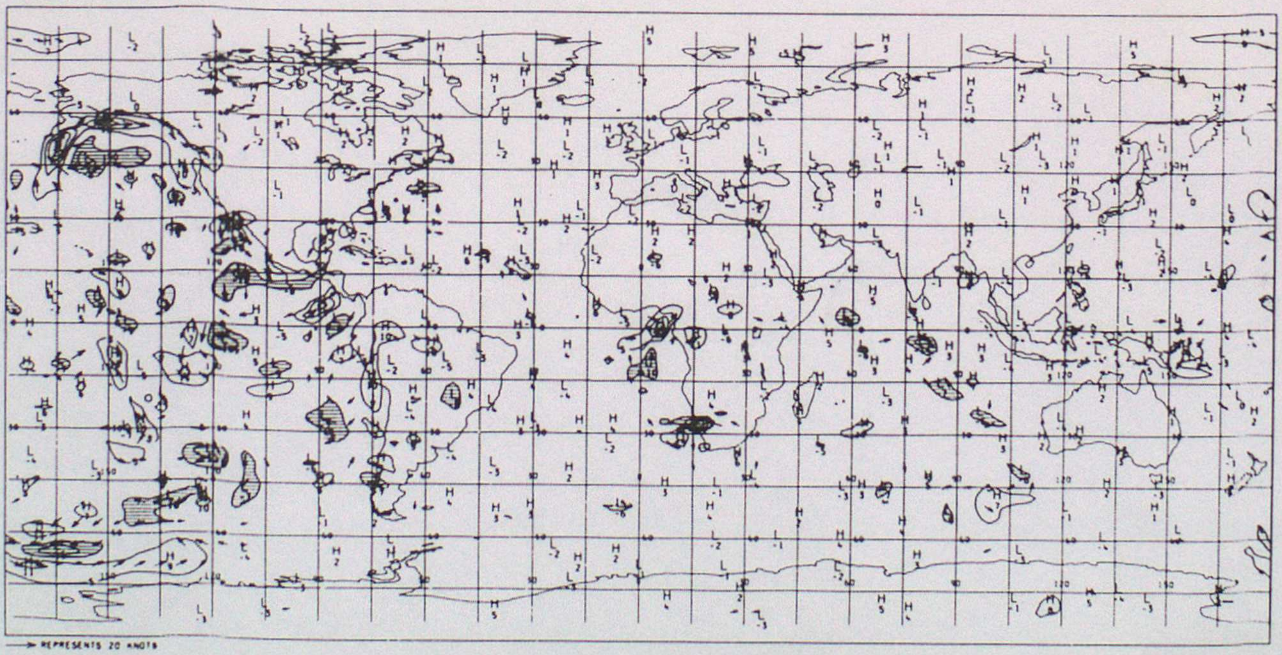
FIGURE 2

CONTROL
FIELD= 0
VALID AT 12Z ON 28/11/1991 DAY 332 DATA TIME 12Z ON 28/11/1991 DAY 332
LEVEL: 250 MB



→ REPRESENTS 200 KNOTS

CONTROL-SAT120
FIELD= 0
VALID AT 12Z ON 28/11/1991 DAY 332 DATA TIME 12Z ON 28/11/1991 DAY 332
LEVEL: 250 MB



→ REPRESENTS 20 KNOTS

FIGURE 3