



International Civil Aviation Organization

**THIRTEENTH MEETING OF THE
COMMUNICATIONS/NAVIGATION/SURVEILLANCE AND
METEOROLOGY SUB-GROUP OF APANPIRG (CNS/MET SG/13)**

Bangkok, Thailand, 20 – 24 July 2009

Agenda Item 8: Implementation of the World Area Forecast System (WAFS)

3) Review the status of implementation and utilization of the WAFS products

VISUALIZATION OF WAFS TRIAL GRIDDED FORECASTS

(Presented by Hong Kong, China)

SUMMARY

This paper presents results of a study of various visualization schemes for the WAFS trial gridded forecasts on cumulonimbus clouds, icing and turbulence.

This paper relates to

Strategic Objectives:

A: Safety – Enhance global civil aviation safety

D: Efficiency – Enhance the efficiency of aviation operations

Global Plan Initiatives:

GPI-18 Aeronautical information

GPI-19 Meteorological Systems

1. INTRODUCTION

1.1 The trial gridded forecasts on cumulonimbus clouds, icing and turbulence have been made available by the WAFC London and WAFC Washington in 2006 and 2007 respectively for evaluation. To facilitate comparison of these trial products, the Hong Kong Observatory (HKO) has made available selected products on its dedicated aviation weather website (<http://wafs-grid-fc.weather.gov.hk/>) for evaluation by aviation users.

1.2 Apart from the issue with the quality and interpretation of the SIGWX gridded forecasts, the development of suitable visualization schemes to present the large amount of forecast information from each model run (37 forecast parameters for icing, turbulence and CB are provided for each valid time at T+6 h, T+12 h, ... up to T+36 h) relevant to the flight/route in a clear and concise format similar to that of the existing SIGWX forecast chart remains a great challenge.

1.3 A working paper on the findings of an ad hoc group of the ICAO WAFS Operations Group (WAFSOPSG) regarding a study of concatenating, interpolating and visualizing WAFS

gridded forecasts of icing, turbulence and cumulonimbus clouds has been submitted for presentation at the WAFSOPSG/5 meeting to be held in September 2009 (<http://www.icao.int/anb/wafsopsg/meetings/wafsopsg5/wp/wp16.pdf>). A copy of this paper is given in the Appendix to this paper for information of the CNS/MET SG. This paper presents additional information supplementing the WAFSOPSG/5 working paper.

2. DISCUSSION

2.1 One technical point which needs to be considered in developing the visualization schemes for the WAFS gridded forecasts is the presentation of the strip charts (see examples in Figure 3 in the Appendix) and high “at-a-glance” cross-sectional charts (see examples in Figures 4, 5, 7 and 8 in the Appendix) in colour. In these examples, the colour schemes used basically follows those adopted by the WAFCs (see Appendices B and C of WAFSOPG/5-WP/15), except for a minor adjustment to avoid direct conflict (same colour (light blue) used for CAT and icing). If monochrome presentation is required, especially for the printed flight documents, it should be feasible to replace the colour schemes (e.g. by using dotted/continuous/thick lines, grey shades or hatched areas), especially that the number of different levels could be reduced to a small number (e.g. two levels, as in using MOD/SEV in quantifying turbulence intensities). A monochrome presentation suitable for black and white printing is illustrated in Figure 1 in this paper.

2.2 Figure 1 may be further simplified considering that a forecast of CB would already imply the presence of in-cloud turbulence and icing and thus separate forecasts of in-cloud turbulence and icing may be seen as redundant. Figure 2 shows a simplification of the monochrome presentation in Figure 1, with the in-cloud-turbulence and icing potential forecasts within CB removed.

2.3 It is also suggested that the strip chart concept may also be extended to visualize upper-air wind and temperature forecasts. An example of this is shown in Figure 3. Together with the high “at-a-glance” route-specific vertical cross-sectional chart and a selection of route-specific horizontal strip charts for the SIGWX elements concerned, the users could get a comprehensive picture of the en-route SIGWX relevant to the flight from just a few pages of flight documentation.

2.4 While the above may suggest a model set for visualization of the WAFS gridded forecasts, the depiction of safety-related information including tropical cyclone and volcanic eruption, which are currently available from the SIGWX forecast, has yet to be addressed. The users will need to be consulted on whether or not such safety-related information should be included in the future visualization models for the WAFS gridded forecasts, e.g. whenever such SIGWX features are present within a certain distance of the flight route.

3. ACTION BY THE MEETING

3.1 The meeting is invited to note and exchange views on the information provided in this paper.

Figure 1 - High “at-a-glance” vertical cross-sectional SIGWX chart generated from temporal interpolation for hypothetical flight route from west to east in monochrome presentation (based on 00 UTC 18 May 2009)

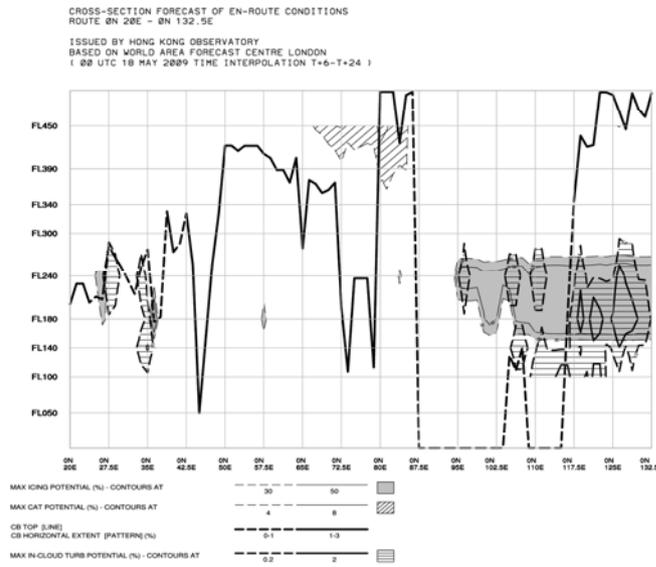


Figure 2 – Simplified version of Figure 1, with in-cloud-turbulence and icing potential forecasts within CB removed (based on 00 UTC 18 May 2009)

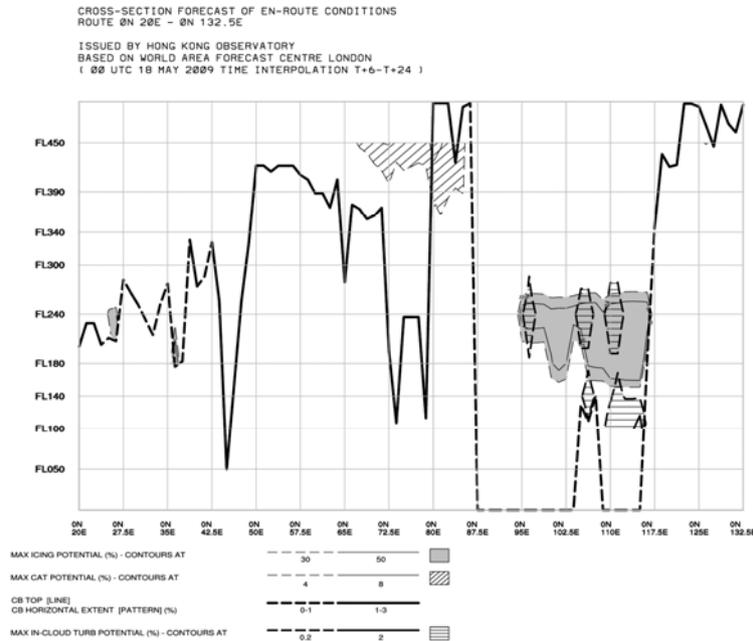
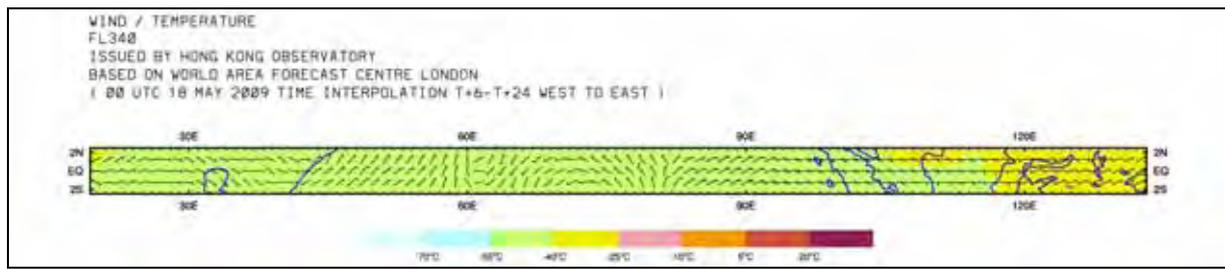


Figure 3 – Horizontal strip chart generated from temporal interpolation of wind and temperature forecasts at FL 340 (based on 00 UTC 18 May 2009)





International Civil Aviation Organization

WAFSOPSG/5-WP/16
19/6/09

WORKING PAPER

WORLD AREA FORECAST SYSTEM OPERATIONS GROUP (WAFSOPSG)

FIFTH MEETING

Paris, France, 16 to 18 September 2009

Agenda Item 6: Development of the WAFS

6.2: Visualization of WAFS forecasts

USE OF CONCATENATED WAFS FORECASTS

(Presented by China, on behalf of the Ad Hoc Group)

SUMMARY

This paper presents the results of a study of concatenating, interpolating and visualizing WAFS gridded forecasts of icing, turbulence and cumulonimbus clouds.

1. INTRODUCTION

1.1 At the WAFSOPSG/3 Meeting, a proposal was made on the concatenation of several consecutive fixed-time WAFS forecasts (of the same product and level) for use by long-haul flights. An ad hoc group was formed to study this proposal. Based on the findings of the ad hoc group, the WAFSOPSG/4 Meeting agreed that, for long-haul flights, spatial and temporal linear interpolation could be used for generating a route-specific wind/temperature chart from data from consecutive forecast hours, where required by users. However, for SIGWX charts, it was apparent that insufficient data was available for interpolating the SIGWX features from the different forecasts and that this procedure should not therefore be applied thereto.

1.2 Recognizing that the situation might change in the future as the gridded forecasts of icing, turbulence and CB clouds would be introduced, the WAFSOPSG/4 Meeting also agreed that the ad hoc group, in coordination with the WAFC Provider States, should undertake a follow-up study on the applicability of interpolation to facilitate the use of concatenated visualization as far as the new gridded forecasts of icing, turbulence and CB clouds were concerned.

2. DISCUSSIONS

2.1 As an illustration of the use of concatenated visualization for the new gridded forecasts of icing, turbulence and CB clouds, the ad hoc group first consider the consecutive gridded forecasts of maximum icing potential at FL180 for T+6 h, T+12 h, T+18 h and T+24 h from WAFS London based on the same model run (Figures 1(a) to 1(d)). Figure 1(e) shows the chart generated by simply joining the consecutive maximum icing potential forecast charts (T+12 h, T+18 h and T+24 h from west to east) of the same level. For this concatenated maximum icing potential chart, discontinuities are still observed at the grid points where two charts join, but such discontinuities are less obvious as compared to the concatenated SIGWX chart previously considered by the ad hoc group due to the digital presentation versus the distinct SIGWX features shown on the SIGWX chart.

2.2 Next the ad hoc group consider temporal linear interpolation of the above maximum icing potential gridded forecasts for a hypothetical flight route along the Equator from 0°N 20°E to 0°N 132.5°E (Figure 2). Strip charts with latitudinal width of ± 3 degrees of the flight route (note: this width could be fine-tuned subject to user's feedback) showing the maximum icing potential forecasts at T+6 h, T+12 h, T+18 h and T+24 h are shown in Figures 3(a) to 3(d). Applying the interpolation procedure in Appendix, the strip charts showing the time-interpolated forecasts for the flight route are given in Figure 3(e) and 3(f) respectively for a flight flying from west to east and a flight flying from west to east, both departing at the time T+9 h. While the two interpolated charts appear to show reasonable quality after the interpolation, e.g. the main SIGWX features could be reproduced in the interpolated charts, it is observed that the interpolation could smooth out some smaller scale features, and result in reduced "magnitude" (e.g. icing potential near 30°E in Figure 3(e)). Nevertheless, this issue is expected to be mitigated when the temporal resolution of the WAFS gridded forecasts are increased from 6 hours to 3 hours in the future. Of course, there is also an issue with the quality of the SIGWX gridded forecasts in general and interpretation of those SIGWX gridded forecasts given in "potential" in particular, e.g. what an increase/decrease of the potential would mean to the pilots. However, these issues are beyond the scope of this paper.

2.3 With the above discussion on the possible use of interpolation, we take a step forward to look at generating a high "at-a-glance" concatenated vertical cross-sectional SIGWX forecast chart for the pilots by applying the simple-joining method (para. 2.1) and the temporal interpolation method (para. 2.2) to the gridded SIGWX forecasts. Figures 4(a) to 4(d) show the vertical cross-sections for four consecutive forecast hours (T+6 h, T+12 h, T+18 h and T+24 h) depicting five of the space-interpolated gridded forecast products, viz. maximum turbulence potential, maximum in-cloud turbulence potential, maximum icing potential, CB horizontal extent and height of CB top, for the same hypothetical flight route (for a flight flying from west to east departing at the time T+9 h) considered above. Figure 4(e) shows the concatenated vertical cross-sectional SIGWX chart generated by simply joining the charts for T+12 h, T+18 h and T+24 h. Again, some discontinuities could be present at the chart boundaries (marked in red). On the other hand, Figure 5, obtained using the temporal interpolation method (Appendix), manages to capture all SIGWX features depicted in Figures 4(a) to 4(d) and smooth out the discontinuities. For example, as compared to Figure 4(e), Figure 5 is able to reflect the icing features west of 40°E depicted at T+6 h (which are not considered in generating Figure 4(e) by the simple-joining method), albeit with reduced "magnitudes" of the icing potential and in-cloud turbulence (c.f. T+6 h forecast), as well as lower heights of CB top (c.f. T+12 h forecast).

2.4 The high "at-a-glance" concatenated vertical cross-sectional SIGWX forecast charts generated above have been presented to an IFALPA representative and such presentation is generally welcomed. It is noted that such vertical cross-section visualization is in line with Flight Documentation Model CR "Cross-section forecast of en-route conditions" recommended by WMO CAeM-VI back in

1976 (Figure 6). Technological advancement and availability of the new gridded forecasts once again enable preparation of these high “at-a-glance” route-specific forecast charts for the end users, now achievable using automatic means. One suggestion from the IFALPA representative is to explore the use of median/maximum value of all grid points within a certain distance of each grid point on the flight route (instead of just using the value of the grid point on the route) so as to reflect the probable weather conditions taking into account forecast uncertainties and the potential need for diversions around SIGWX weather on the flight route. As an initial attempt, the median/maximum values within 3x3 grid points of the same flight level are considered and Figures 7 and 8 show the resulting charts. It is apparent that the median-value chart tends to smooth out the SIGWX features whereas the maximum-value chart tends to provide a conservative view taking into account all the SIGWX features within 2.5 degrees of the flight route. The adoption of these approaches for generating the high “at-a-glance” vertical cross-sectional SIGWX charts from the gridded forecasts should be a matter of choice of the pilots and airlines, depending on their operational decision models and risk management procedures.

2.5 Even though the above proof-of-concept results are demonstrated based on a hypothetical flight route along the Equator (which is a great circle itself), technically the results could be extended to cover other flight routes on great circles. For more complicated flight routes that ‘dog-leg’ through en-route stopover points / way points, some fine-tuning of the strip charts presentation (e.g. straightening the route with clear labelling of the turning points) will be required. The availability of information on the turning points in the flight plan will however be necessary for the meteorological offices to provide this type of strip charts.

2.6 Another technical point which needs to be considered by the group is the presentation of the strip charts and cross-sectional charts in colour. In the examples presented in this paper, the colour schemes used basically follows those adopted by the WAFs (see Appendices B and C of WP/15), except for a minor adjustment to avoid direct conflict (same colour (light blue) used for CAT and icing). If monochrome presentation is required, especially for the printed flight documents, it should be feasible to replace the colour schemes (e.g. by using dotted/continuous/thick lines, grey shades or hatched areas), especially that the number of different levels could be reduced to a small number (e.g. two levels, as in using MOD/SEV in quantifying turbulence intensities).

3. CONCLUSION

3.1 Based on the above discussions and the positive user’s feedback on the use of concatenated charts of gridded SIGWX forecasts for flight planning, in particular, the high “at-a-glance” route-specific vertical cross-sectional SIGWX forecast charts, possibly supplemented with a combination of strip charts of route-specific SIGWX forecasts for selected forecast parameters and flight levels, the WAFSOPG may wish to support formulating the following conclusion:

Conclusion 5/ — Use of concatenated WAFS gridded forecasts of cumulonimbus clouds, icing and turbulence in particular for long-haul flights

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That, the Secretariat, in coordination with the WMO Member of the WAFSOPSG, develop Annex 3 provisions to enable the provision of concatenated route-specific gridded forecast charts of cumulonimbus clouds, icing and turbulence, generated preferably from interpolating data from consecutive forecast times.

Note. — The concatenated forecast charts may be a high “at-a-glance” route-specific vertical cross-sectional SIGWX forecast chart, possibly supplemented with a combination of strip charts of route-specific SIGWX forecasts for selected forecast parameters and flight levels.

4. ACTION BY THE WAFSOPSG

4.1 The WAFSOPSG is invited to:

- a) note the information provided in this paper; and
- b) decide on the draft conclusion proposed for the group’s consideration.

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APPENDIX

PROCEDURE OF LINEAR TIME INTERPOLATION OF DATA FROM CONSECUTIVE FORECAST HOURS FOR GENERATING ROUTE-SPECIFIC GRIDDED SIGWX FORECASTS

- 1) A hypothetical flight route along the Equator from 0°N 20°E to 0°N 132.5°E, covering 112.5 degrees longitude (Figure 2) is considered. The flight time is around 15 hours assuming a typical ground speed.
- 2) Assuming that the departure time of the aircraft is 09 UTC, the arrival time will be around 00 UTC the next day. The flight document should be dispatched at or before 07 UTC based on the latest model run at 00 UTC (time T).
- 3) Time interpolation for the 15 hourly time steps along the flight route is computed using the following method:

Forecast hour (UTC)	Interpolated value
09	$(\text{value at T+6 h}) * 3/6 + (\text{value at T+12 h}) * 3/6$
10	$(\text{value at T+6 h}) * 2/6 + (\text{value at T+12 h}) * 4/6$
11	$(\text{value at T+6 h}) * 1/6 + (\text{value at T+12 h}) * 5/6$
12	(value at T+12 h) – no interpolation
13	$(\text{value at T+12 h}) * 5/6 + (\text{value at T+18 h}) * 1/6$
14	$(\text{value at T+12 h}) * 4/6 + (\text{value at T+18 h}) * 2/6$
15	$(\text{value at T+12 h}) * 3/6 + (\text{value at T+18 h}) * 3/6$
16	$(\text{value at T+12 h}) * 2/6 + (\text{value at T+18 h}) * 4/6$
17	$(\text{value at T+12 h}) * 1/6 + (\text{value at T+18 h}) * 5/6$
18	(value at T+18 h) – no interpolation
19	$(\text{value at T+18 h}) * 5/6 + (\text{value at T+24 h}) * 1/6$
20	$(\text{value at T+18 h}) * 4/6 + (\text{value at T+24 h}) * 2/6$
21	$(\text{value at T+18 h}) * 3/6 + (\text{value at T+24 h}) * 3/6$
22	$(\text{value at T+18 h}) * 2/6 + (\text{value at T+24 h}) * 4/6$
23	$(\text{value at T+18 h}) * 1/6 + (\text{value at T+24 h}) * 5/6$
00 (next day)	(value at T+24 h) – no interpolation

Figure 1(a) - WAFc London T+6 h forecast of maximum icing potential at FL 180
(based on 00 UTC 18 May 2009)

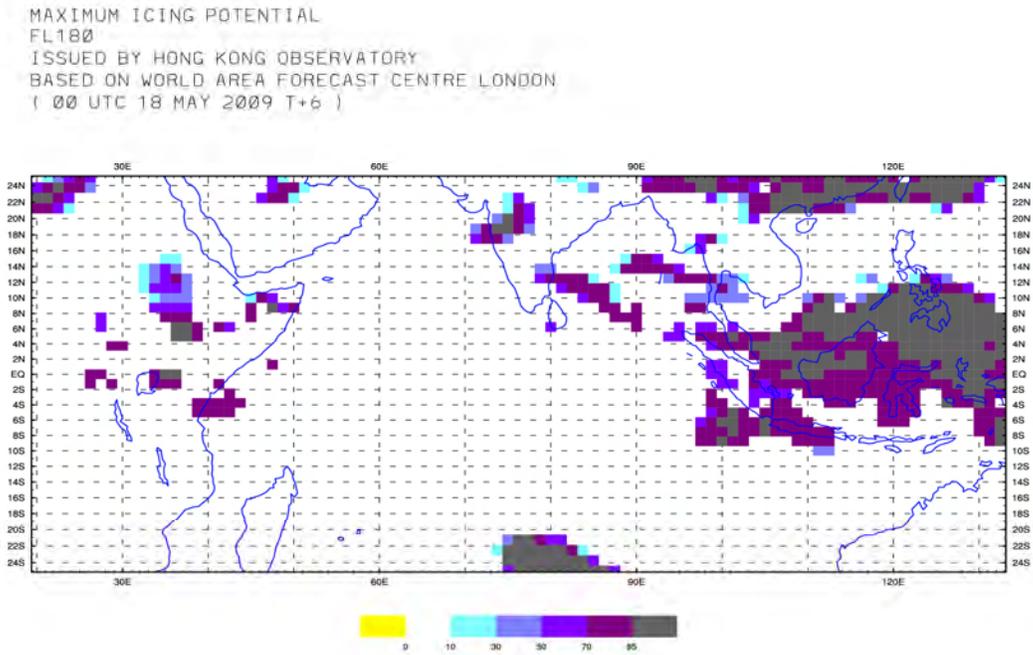


Figure 1(b) - WAFc London T+12 h forecast of maximum icing potential at FL 180
(based on 00 UTC 18 May 2009)

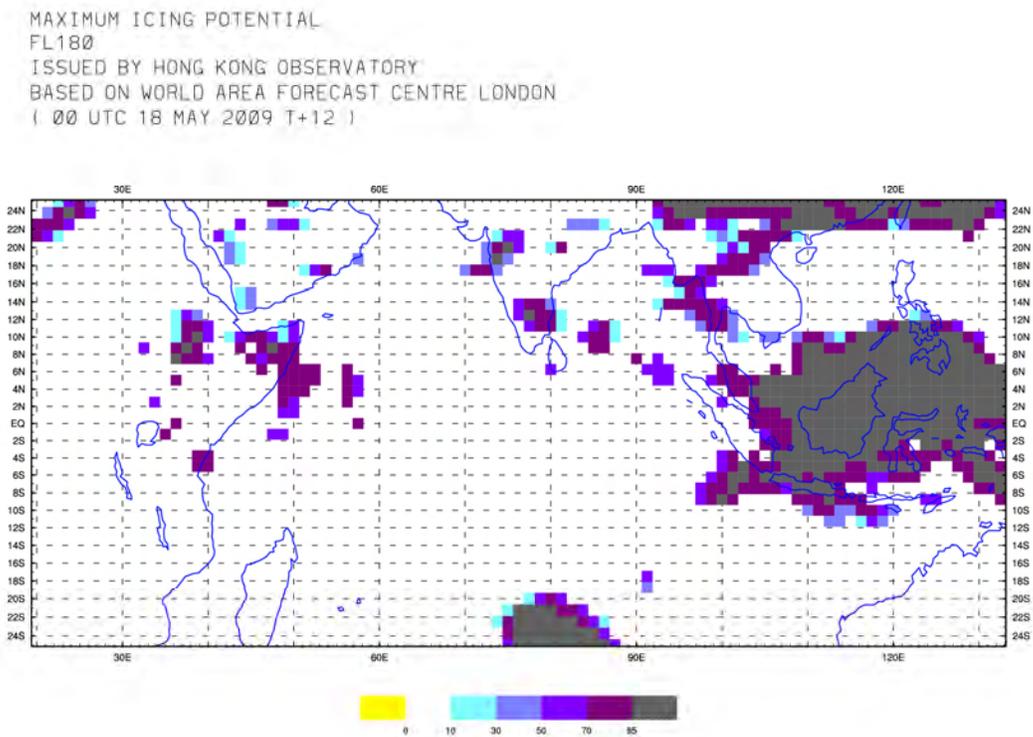


Figure 1(c) - WAFC London T+18 h forecast of maximum icing potential at FL 180
(based on 00 UTC 18 May 2009)

MAXIMUM ICING POTENTIAL
FL180
ISSUED BY HONG KONG OBSERVATORY
BASED ON WORLD AREA FORECAST CENTRE LONDON
(00 UTC 18 MAY 2009 T+18)

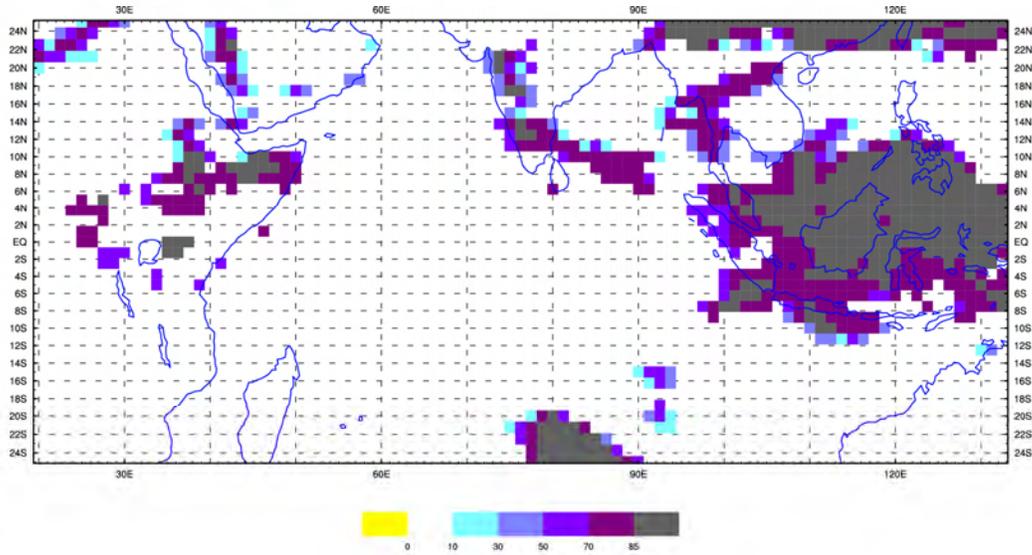


Figure 1(d) - WAFC London T+24 h forecast of maximum icing potential at FL 180
(based on 00 UTC 18 May 2009)

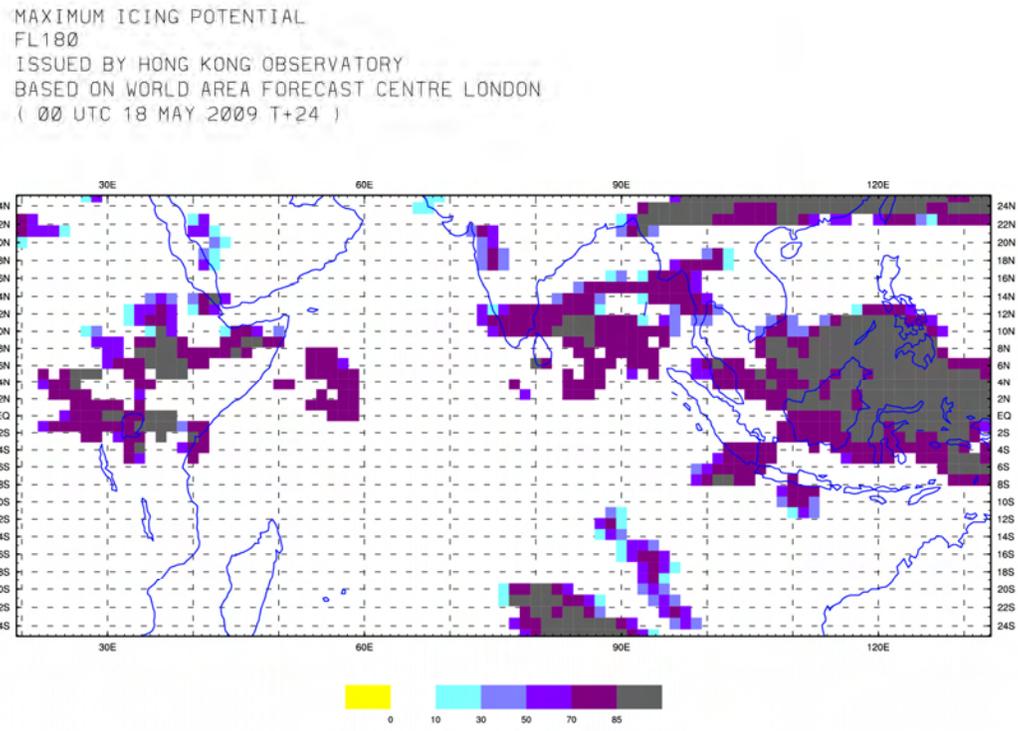


Figure 1(e) - Concatenated visualization of WAFC London forecast of maximum icing potential at FL180 using T+12 h, T+18 h and T+24 h forecasts from west to east (based on 00 UTC 18 May 2009)

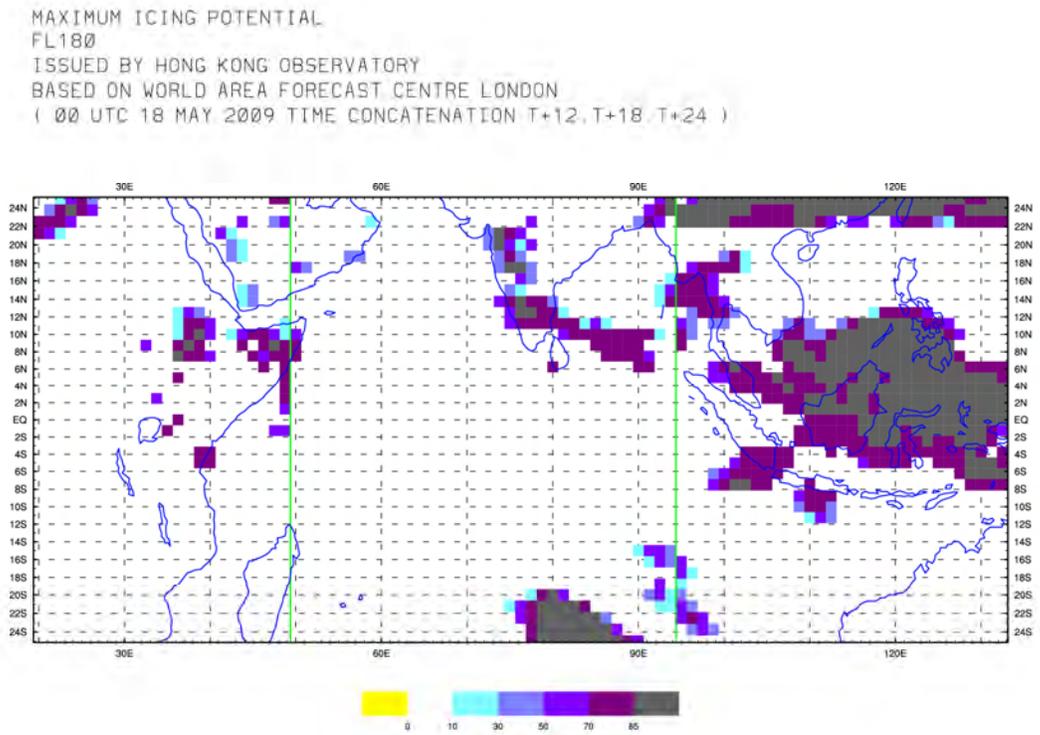


Figure 2 - A hypothetical flight route (red line) along the Equator from 0°N 20°E to 0°N 132.5°E

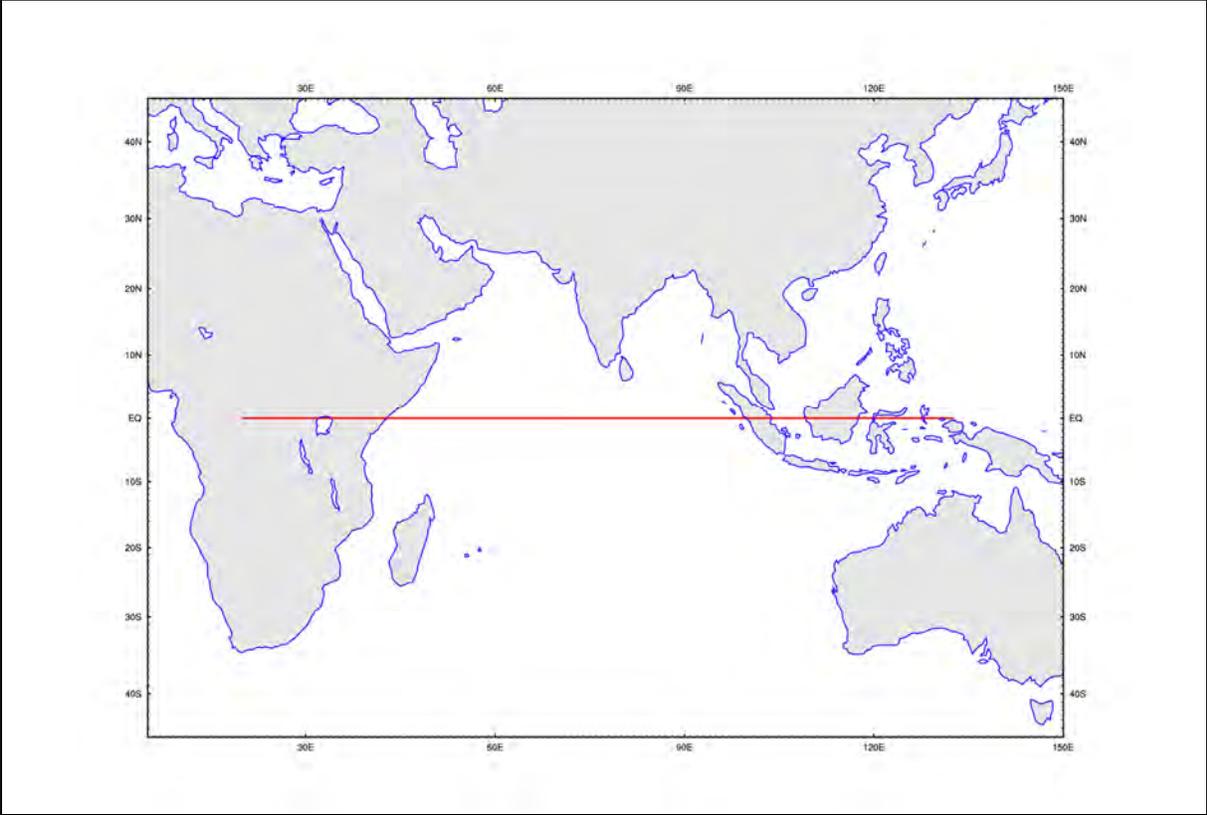


Figure 3(a) - WAFC London T+6 h forecast of maximum icing potential at FL180 for hypothetical flight route (based on 00 UTC 18 May 2009)

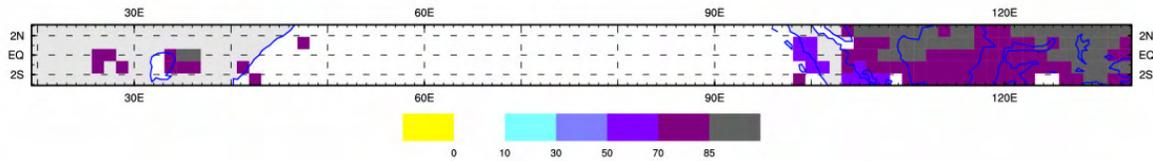


Figure 3(b) - WAFC London T+12 h forecast of maximum icing potential at FL180 for hypothetical flight route (based on 00 UTC 18 May 2009)

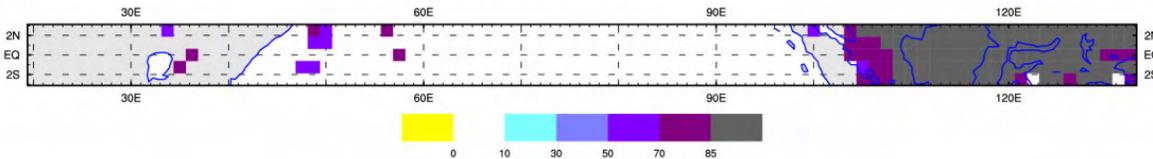


Figure 3(c) - WAFC London T+18 h forecast of maximum icing potential at FL180 for hypothetical flight route (based on 00 UTC 18 May 2009)

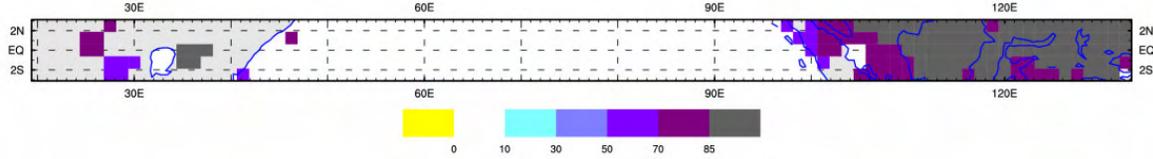


Figure 3(d) - WAFC London T+24 h forecast of maximum icing potential at FL180 for hypothetical flight route (based on 00 UTC 18 May 2009)

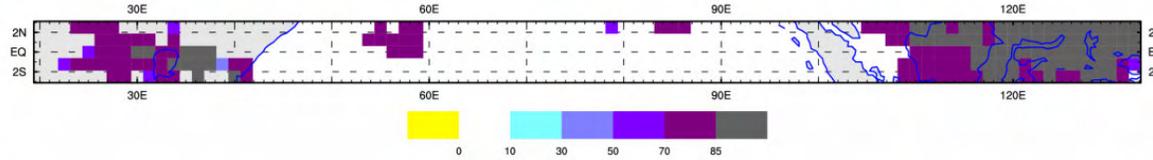


Figure 3(e) - Time interpolated forecast chart of maximum icing potential from WAFC London T+6 h, T+12 h, T+18 h and T+24 h forecasts for hypothetical flight route (flying from west to east) (based on 00 UTC 18 May 2009)

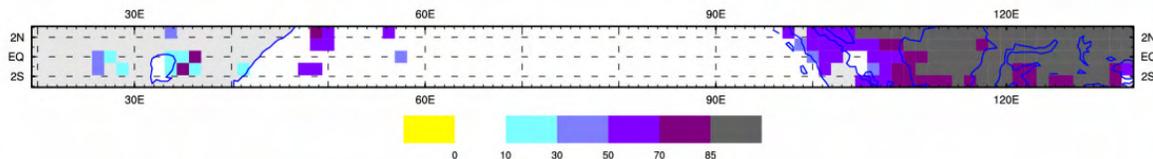


Figure 3(f) - Time interpolated forecast chart of maximum icing potential from WAFC London T+6 h, T+12 h, T+18 h and T+24 h forecasts for hypothetical flight route (flying from east to west) (based on 00 UTC 18 May 2009)

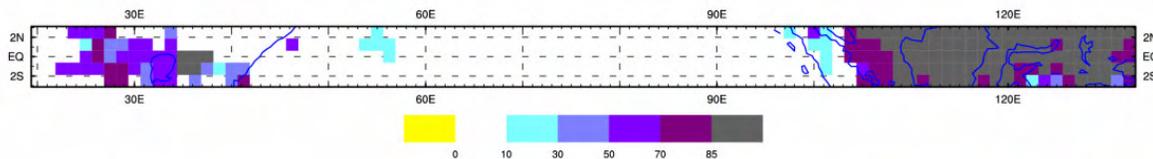


Figure 4(a) - High “at-a-glance” vertical cross-sectional SIGWX chart generated by spatial interpolation from WAFC London T+6 h gridded forecasts for hypothetical flight route (based on 00 UTC 18 May 2009)

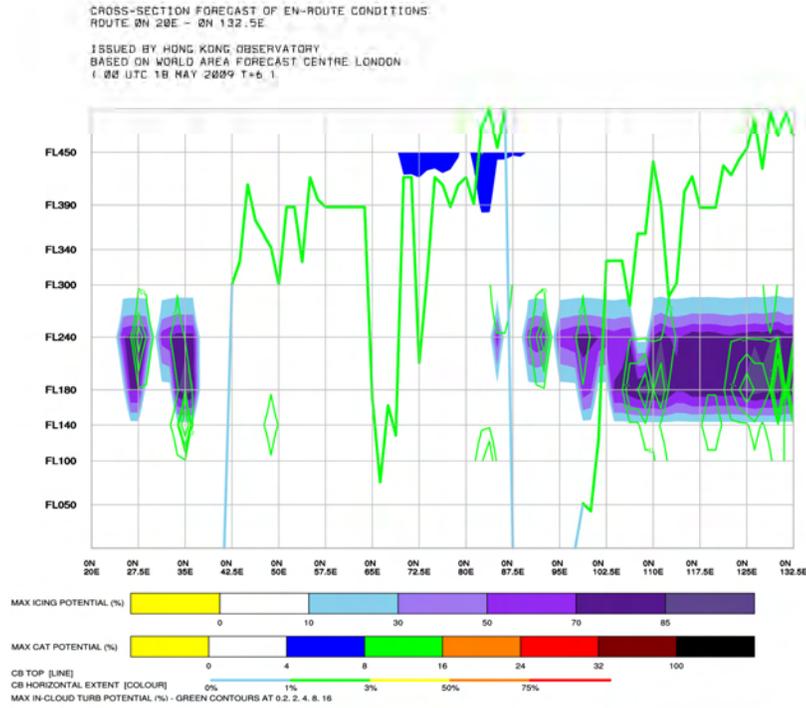


Figure 4(b) - High “at-a-glance” vertical cross-sectional SIGWX chart generated by spatial interpolation from WAFC London T+12 h gridded forecasts for hypothetical flight route (based on 00 UTC 18 May 2009)

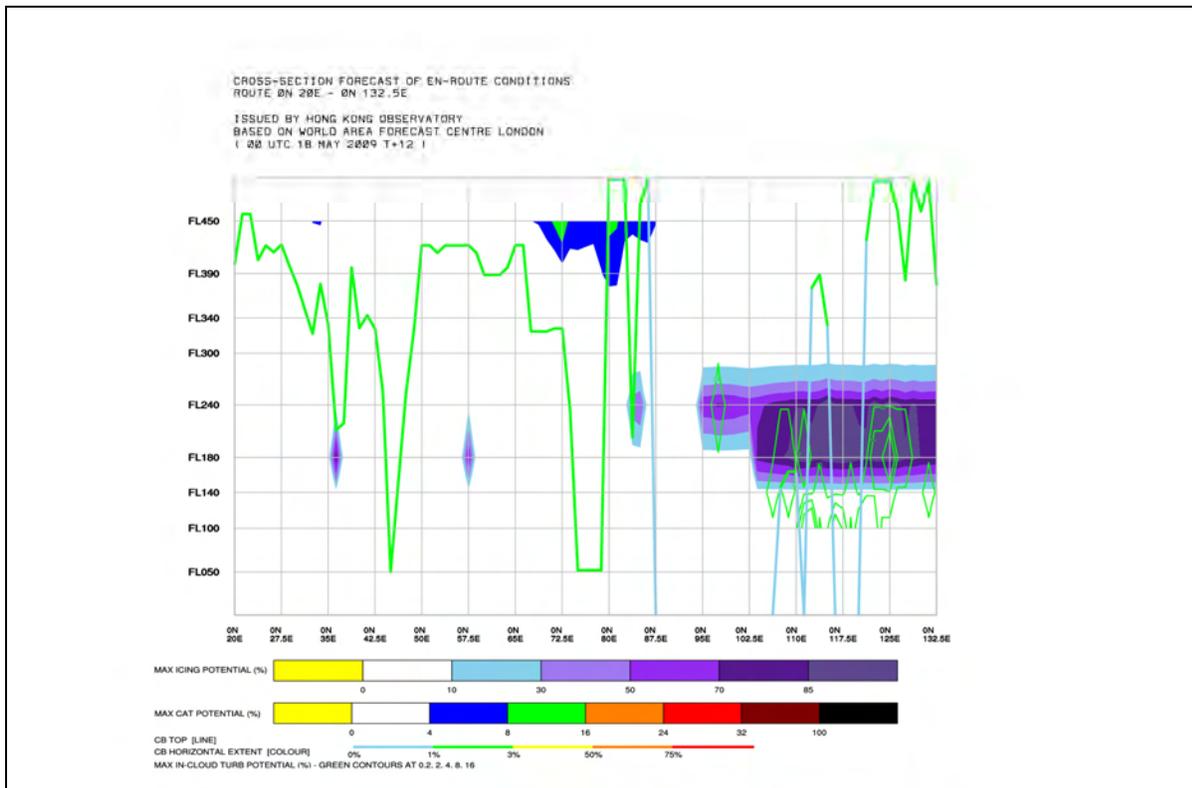


Figure 4(c) - High “at-a-glance” vertical cross-sectional SIGWX chart generated by spatial interpolation from WAFC London T+18 h gridded forecasts for hypothetical flight route (based on 00 UTC 18 May 2009)

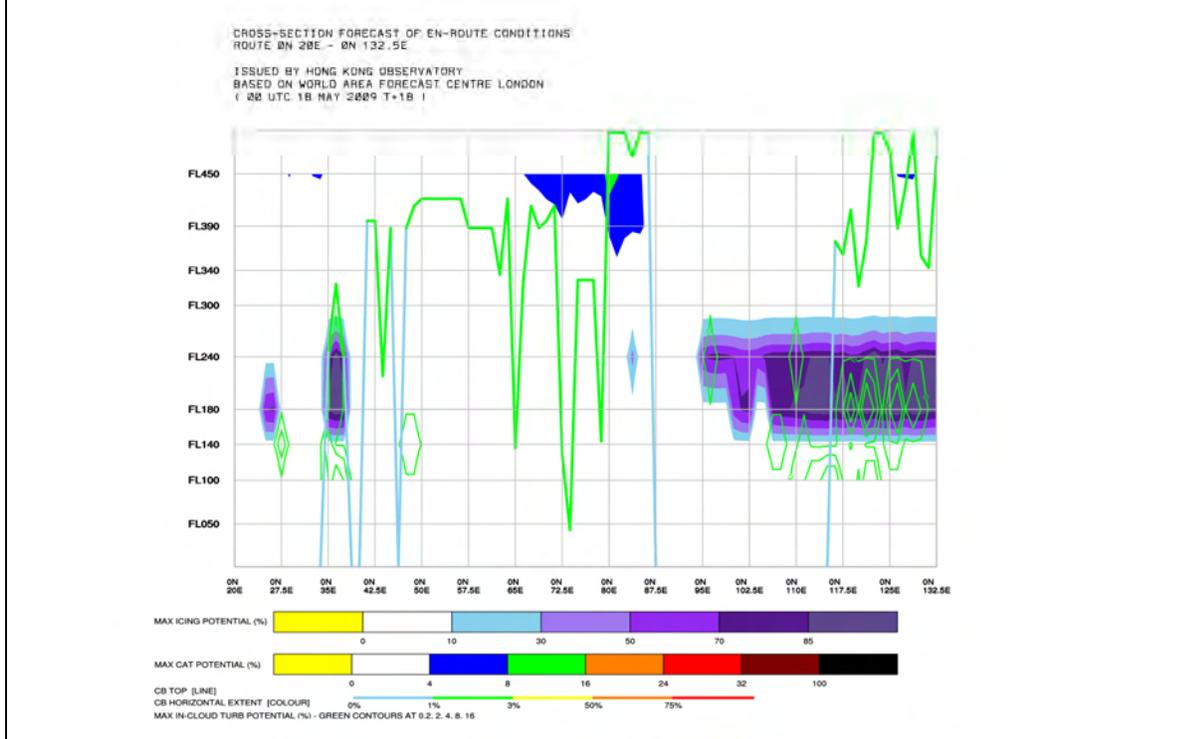


Figure 4(d) - High “at-a-glance” vertical cross-sectional SIGWX chart generated by spatial interpolation from WAFC London T+24 h gridded forecasts for hypothetical flight route (based on 00 UTC 18 May 2009)

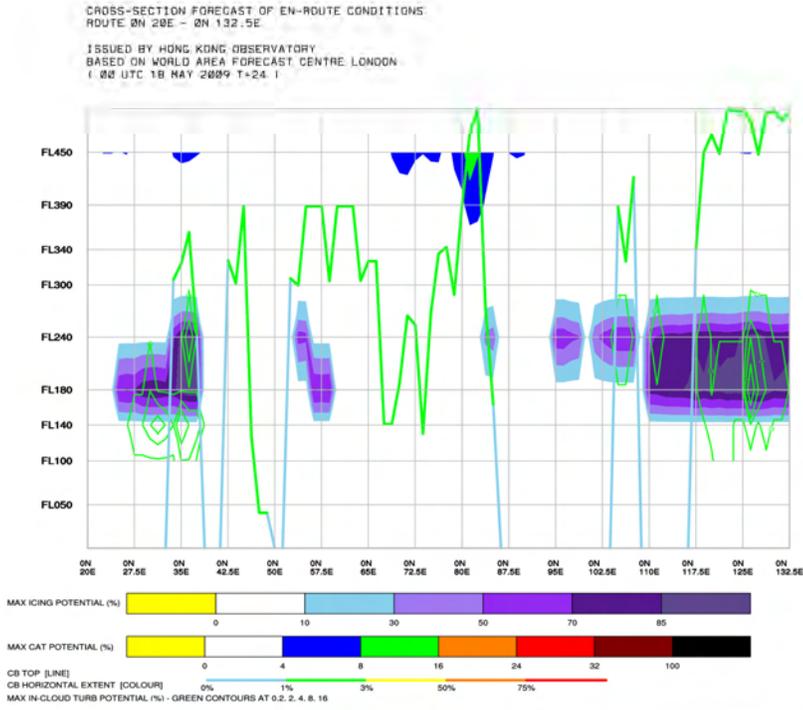


Figure 4(e) - High “at-a-glance” vertical cross-sectional SIGWX chart generated from simply joining Figures 4(b) – 4(d) for hypothetical flight route from west to east (based on 00 UTC 18 May 2009)

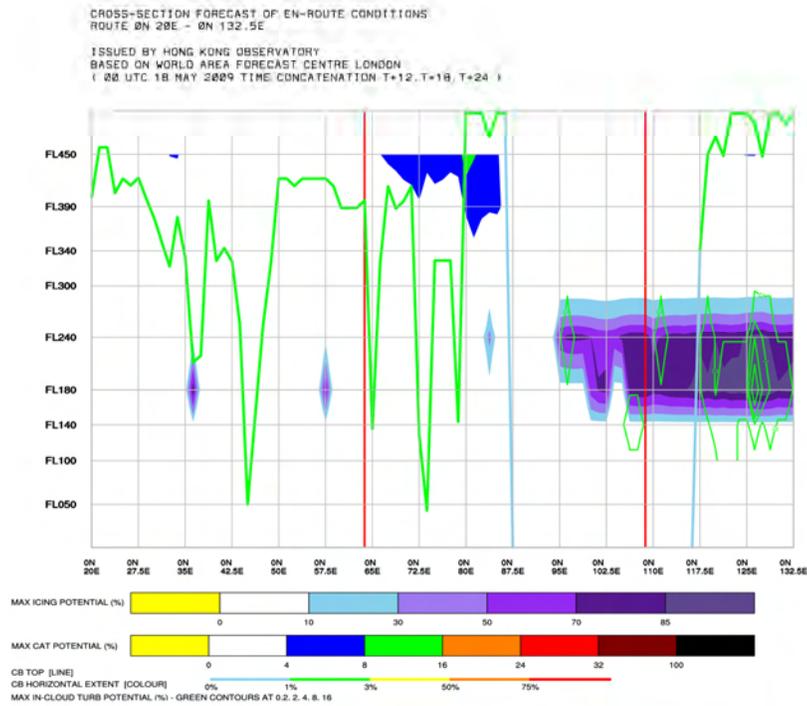


Figure 5 - High “at-a-glance” vertical cross-sectional SIGWX chart generated from temporal interpolation of Figures 4(a) – 4(d) for hypothetical flight route from west to east (based on 00 UTC 18 May 2009)

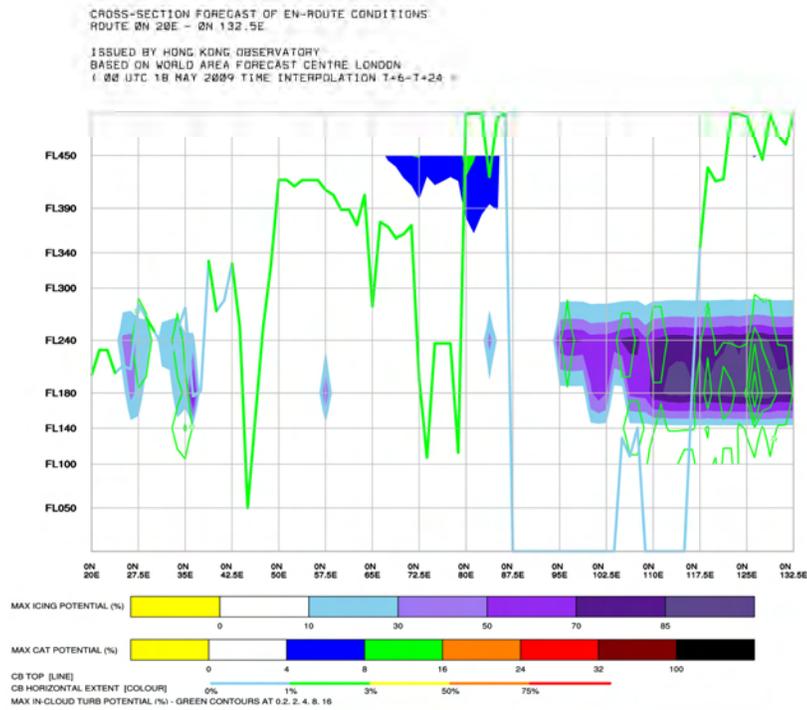


Figure 6 - Flight Documentation Model CR "Cross-section forecast of en-route conditions" recommended by WMO CAEm-VI back in 1976

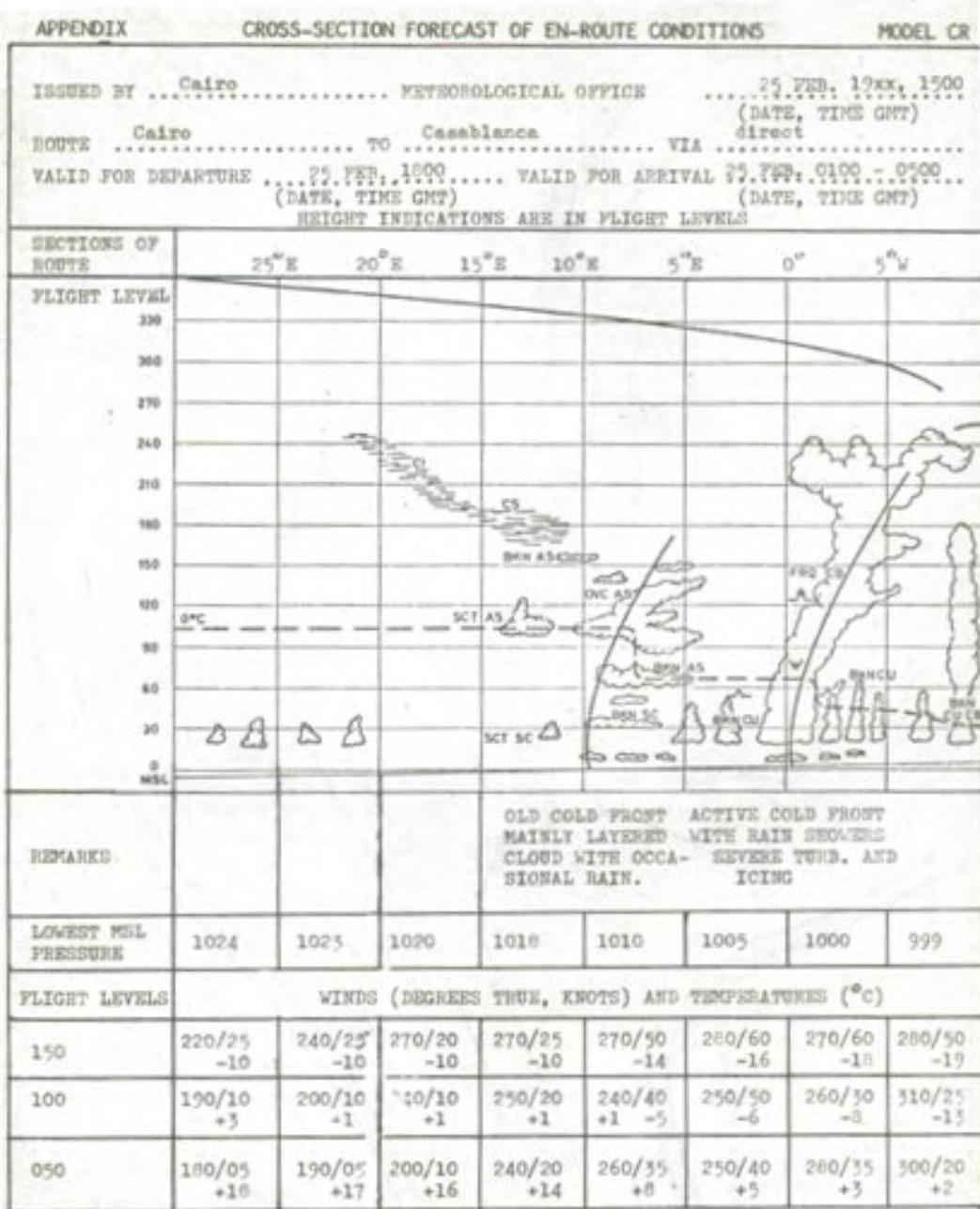


Figure 7 - High “at-a-glance” vertical cross-sectional SIGWX chart generated from temporal interpolation of median value within 3x3 grid points for hypothetical flight route from west to east (based on 00 UTC 18 May 2009)

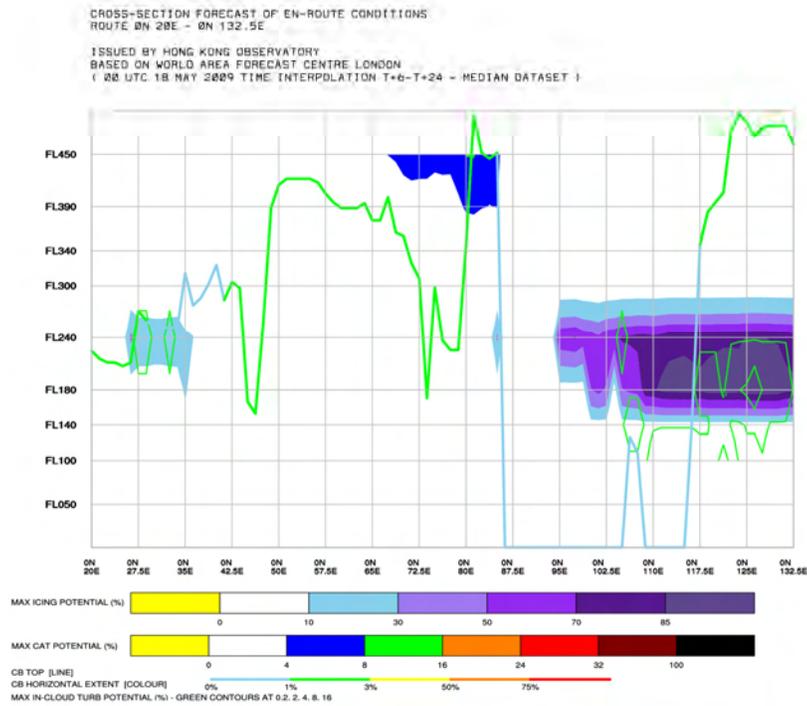
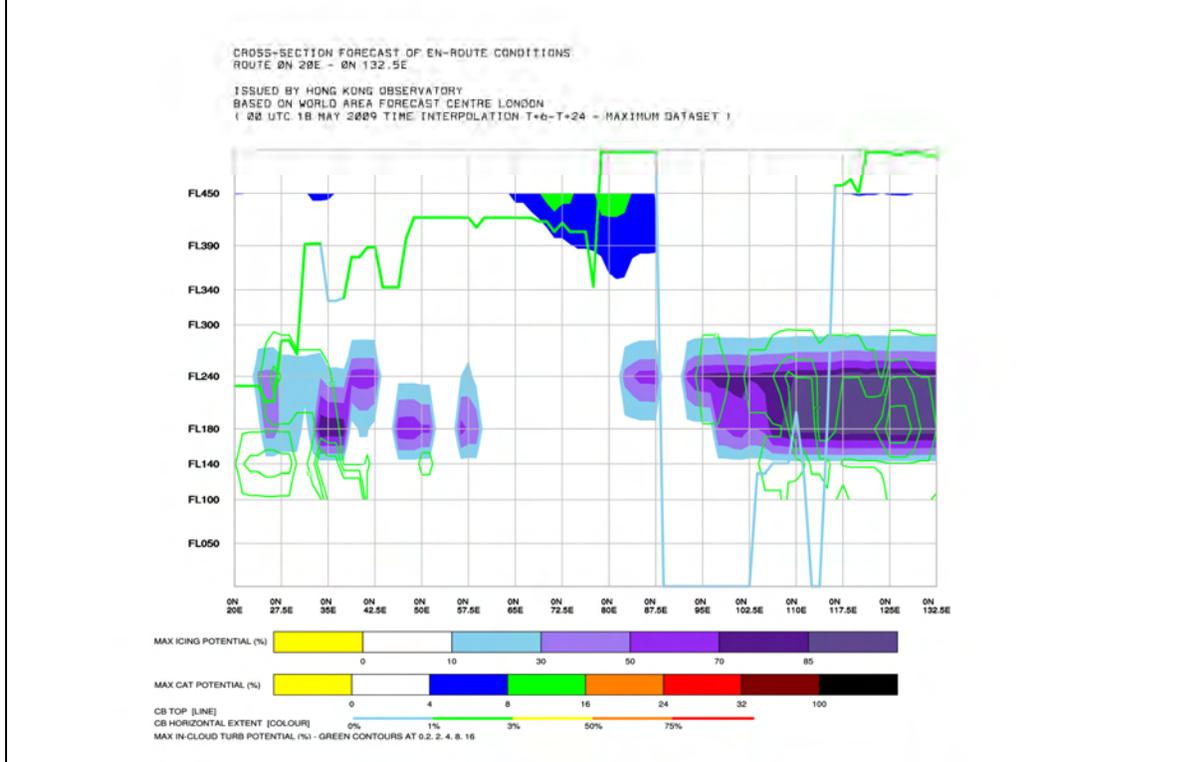


Figure 8 - High “at-a-glance” vertical cross-sectional SIGWX chart generated from temporal interpolation of maximum value within 3x3 grid points for hypothetical flight route from west to east (based on 00 UTC 18 May 2009)



— END —