国际民用航空组织

世界气象组织

MET/14-WP/64
CAeM-15/Doc.64
18/1/14

气象（MET）专业会议
（2014年）

航空气象学委员会
第十五次届会

2014年7月7日至18日，蒙特利尔

议程项目 2 的报告

（所有议程项目均是与世界气象组织航空气象学委员会第十五次届会联合审议的）

本报告将由国际民航组织空中航行委员会和理事会以及世界气象组织执行理事会进行审查。这些机构就会议建议做出的决定将在及时发布的会议报告补篇中阐明。

议程项目2：通过加强气象服务的提供工作，提高国际空中航行的安全和效率

2.1：加强现行的气象服务提供工作，以支持目前的战略、战术前和战术运行决策（包括航空系统组块升级的 B0-AMET 模块）

2.1.1 会议审议了自 2002 年上次气象专业会议（MET/02）以来，关于加强现有的世界区域预报系统（WAFS），航空固定（电信）服务（AFS）的各个方面，以及在其它邻域中取得的进展情况的一些提案。此外，会议也注意到了与此议程分项目相关的九份信息文件。

机场和终端区的航空气象服务，包括飞行气象情报

2.1.2 会议高兴地注意到，自 2002 年的气象专业会议（MET/02）以来，尤其是在关于机场观测自动化，以及在一些选定的机场推行长达 30 小时的机场预报等方面，已取得了重大的进展。

世界区域预报系统（WAFS）、航空固定（电信）服务卫星发送系统和基于互联网的服务

2.1.3 会议赞赏地注意到，自 2002 年的气象专业会议以来，在世界区域预报系统方案中有了显著增强，已包括了提高世界区域预报系统高空网格全球预测时间和空间的分辨率，（包括从 6 小时的输出时间步长，过渡到 3 小时的输出时间步长；从 1.25 度稀疏水平网格，转变为 1.25 度常规（未稀疏）水平网格，特别是在巡航高度增加的垂直分辨率），以及为结冰、湍流和积雨云开发的并在运行上实施的世界区域预报系统的网格式全球预报。

2.1.4 会议同意认为，在2013年至2018年的时间段，向世界区域预报系统的转变，应注重于改进世界区域预报系统对结冰和紊流的网格式全球预报。在这方面，会议审查并商定了一些原则，将用（以可交付成果的形式）作为今后发展世界区域预报系统，支持航空系统组块升级（ASBU）方法的B0-AMET模块之基础。会议相应地制定了如下建议：

建议2/1 — 发展世界区域预报系统以支持至2018年的航空系统组块升级的方法

国际民航组织通过一个合适的专家组，用附录A中包含的各项可交付的成果所概述的原则，作为《全球空中航行计划（GANP）》（Doc 9750号文件）中所载的今后发展世界区域预报系统（WAFS），支持航空系统组块升级（ASBU）方法的B0-AMET模块之基础。

2.1.5 关于为空中航行的相关信息使用航空固定（电信）服务（AFS）卫星发送系统（SADIS），给各国和经授权的用户发送，或使其能够获得全球飞行气象情报和世界区域预报系统的预报这一方面，会议注意到了自 2002 年的气象专业会议以来的重大发展情况，它已经使得国际民航组织的欧洲（EUR）、中东(MID)、非洲印度洋(AFI)等地区、以及亚太（APAC）地区西部的几乎 110 个国家中，有 180 多个经授权的用户在运行方面，使用了卫星发送系统的第二代卫星广播（SADIS 2G）和（或）基于互联网的、安全的卫星发送系统之互联网文件传输协议（SADIS FTP）。会议同意认为，作为一种完全的成本可收回的服务，就需要确保卫星发送系统继续按照用户的期望运行，并进一步与不断演

进的全球空中航行计划，及其所载的航空系统组块升级方法相一致的方式发展。此外，会议还同意，此种发展，以及为（南北）美洲和亚洲、太平洋地区东部服务的世界区域预报系统互联网文件服务（WIFS）的发展，应与将来全系统信息管理（SWIM）的环境，以及国际民航组织其它负责全系统信息管理开发之专家组的工作保持一致。会议相应地制定了如下建议：

建议 2/2 — 航空固定（电信）服务卫星发送系统和基于互联网服务的运行和进一步发展

一个合适的国际民航组织专家小组负责，作为紧急事项，确保用于空中航行相关信息的航空固定（电信）服务（AFS）卫星发送系统（SADIS），以及安全的卫星发送系统互联网文件传输协议和世界区域预报系统互联网文件服务（WIFS）基于互联网的服务的运行继续满足用户的期望，并进一步按照与《全球空中航行计划》（Doc 9750 号文件）相一致的方式发展，其中包括：

a) 考虑卫星发送系统和世界区域预报系统互联网文件服务在支撑全球可互用的空中交通管理体系未来的全系统信息管理（SWIM）环境中的作用；和

b) 与国际民航组织今后在信息管理领域将要开展的活动保持一致。

2.1.6 关于卫星发送系统的第二代卫星广播在 2015 年之后的前景，会议同意卫星发送系统运行小组（SADISOPSG）发表的专家意见，卫星发送系统的第二代应延长到 2015 年之后，但只能到 2019 年 11 月，并得出结论认为，在此期间投资增强该系统是不可行的。会议相应地制定了如下建议：

建议 2/3 — 淘汰卫星发送系统的第二代卫星广播并正式测试在自动化电报处理系统上交换全球飞行气象情报和世界区域预报系统的预报

国际民航组织通过一个合适的专家小组将负责：

a) 采取必要措施，确保卫星发送系统的第二代卫星广播延长至 2015 年之后，但不得超过 2019 年 11 月；

b) 敦促尚未这样做的有关各国、用户，在上述 a）项所述期间迁移到在运行中使用安全的卫星发送系统之互联网文件传输协议（SADIS FTP）的服务；和

c) 作为紧急事项，着手正式测试在空中交通服务自动化电报处理系统（AMHS）上交换全球飞行气象情报和世

界区域预报系统的预报，以确定今后向各国、用户分发这些数据所需的能力和最低规范。

国际航路火山监视（IAVW）及放射性物质释放到大气和空间天气的相关事宜

2.1.7 会议注意到，自 2002 年的气象专业会议以来，在国际航路火山监视（IAVW）中有了显著增强，其中包括改进实时或近于实时的观察、探测和报告火山喷发、大气层中的火山灰，以及预测火山灰移动和在其中分散。会议还注意到，这些进步有些是由重大的火山喷发，特别是 2010 年和 2011 年冰岛的艾雅法拉火山和 Grimsvötn 火山喷发， 2011 年智利的 Puyehue-Cordón Caulle 火山喷发而得到了促进。会议注意到，国际民航组织与世界气象组织密切合作，建立了一个国际火山灰工作队（IVATF），在 2010 年和 2012 年期间，以相辅相成的能力与国际航路火山观测运行组（IAVWOPSG）合作，协助对这些喷发凸显出的一些科学、技术和运行方面的问题加快采取行动。此外，会议高兴地注意到，在艾雅法拉火山喷发前，于 2010 年 3 月就成立的世界气象组织（WMO）、国际大地测量和地球物理学联合会（IUGG）的火山灰科学咨询组（VASAG），帮助向国际火山灰工作队和国际航路火山观测运行组提供科学意见。

2.1.8 会议注意到，国际航路火山观测运行组已开始为国际航路火山监视编制路线图，以及有关放射性物质释放到大气和空间天气之信息的运行概念，目的都是帮助理解在未来若干年，在提供服务方面预期要如何发展，以支持新兴的全球空中交通管理体系。

危险气象条件，包括航路危险情况的信息

2.1.9 会议注意到，国际民航组织于 2007 年建立的气象预警研究小组（METWSG），其主要任务一直是审查附件 3、技术规则[C.3.1]中关于重要气象情报的内容及发布，以便满足飞行方面不断变化的需求，并解决许多国家长期遇到的重要气象情报落实方面的困难。在这方面，会议高兴地注意到，该气象预警研究小组已在 2011 年就做过一次尝试，在非洲印度洋地区和部分亚太地区提供重要气象情报的咨询信息。在该次试验期间，担任重要气象情报咨询中心的中国、法国和南非，都做出了重大贡献。鉴于这次试验的积极成果，会议注意到了一项关于建立地区危险天气咨询系统的提案（在议程项目 2.2 之下论及）。

2.1.10 此外，会议还注意到了其它一些来自气象预警研究小组的发展情况，包括对附件 3、技术规则[C.3.1]的拟议修订，尤其是打算改进关于危险气象条件，包括航路上的危险在内的重要气象情报和飞行员气象资料的编制（在议程项目 5.1 之下论及）。

议程项目2：通过加强气象服务的提供工作，提高国际空中航行的安全和效率

2.2：加强集成气象情报，以支持自2018年起的战略、战术前和战术运行决策（包括航空系统组块升级的B1-AMET模块）

2.2.1 从2018年开始，要加强航空气象服务，在这样一个背景下，会议审议了相关提案，涉及到加强世界区域预报系统（WAFS）和国际航路火山监视（IAVW）及提供空间天气、放射性物质和有毒化学物排放及其他危险天气现象方面的信息。此外，会议提到了与本子议程项目相关的第14号信息文件。

关于今后拟定航空气象情报要求的一般性考虑事项

2.2.2 会议原则上支持目前世界区域预报系统和国际航路火山监视的演变，并支持进一步制定关于空间天气、放射性物质和有毒化学物的排放及其他危险天气现象方面的规定。但会议认为，应额外考虑到在不断变化的航空运输环境下，提供航空气象服务方面的总体演变，以及为当地、次区域、区域、多区域和全球提供相关服务而制定一个服务提供框架。会议指出，基于这一框架，委员会指出，各项规定可支持这样一个概念，即在不同层面上建立用户群体，如单个空域用户、航空公司运行部门和各空中交通服务或职能部门等，同时确保以一种相对于其运行使用而言具有成本效益的、合适的和灵活的方式交换基于性能的气象情报并满足《全球空中航行计划》（Doc 9750号文件）中所载航空系统组块升级（ASBU）方法的组块1及其他相关目标。会议同意认为，必须对今后国际空中航行航空气象系统的管理与治理情况进行评估，并明确确定所需做出的变动。此外，还进一步指出，虽然技术开发是今后预期提供的各项服务的一个不可或缺的组成部分，但是使服务的提供始终具有协作性和全面性仍然十分重要。会议相应地制定了如下建议：

建议2/4 — 审查气象情报服务提供框架以反映全球空中航行计划中的目标

为了支持安全和效率方面的主要目标，敦促国际民航组织通过一个合适的专家组及与世界气象组织进行密切协调，以便：

a) 鉴于包括空中交通服务、空中交通管理在内各用户的新兴需求，审查目前附件3 —《国际空中航行气象服务》中所载的“气象情报服务提供框架”，以确保性能要求中规定的气象情报的一致性、统一性、精确性、权威性及与目标的相符性，从而支持《全球空中航行计划》（Doc 9750号文件）的整体目标；

b) 确保初步确定的应于2016年完成的审查工作优先事项与如下工作相互配合：

i) 今后建立世界区域预报系统（WAFS）、国际航路火山监视（IAVW）及制定关于空间天气和向大气中排放放射性物质的信息方面的规定；

ii) 针对在关于重要气象情报方面有缺陷的国家，拟定和实施一个针对所选航路危险气象条件的地区咨询系统；

iii) 向基于航迹线的整体运行及协作决策，包括在机场和网络一级进行的协作决策提供气象支持；和

iv) 就当地、次区域、区域、多区域和全球气象背景下，各国如何履行国际民航组织为其规定的义务拟定指导材料，包括对成本回收和监管方面做出考虑；

c) 确保在更新全球空中航行计划和相关的航空系统组块升级（ASBU）模块时，对上述审查的结果进行审议；和

d) 确保为各国拟定可同时符合国际民航组织和世界气象组织各项要求的指导原则，以便于按要求在当地、次区域、区域、多区域和全球提供全方位的气象服务，并确保当地、次区域、区域、多区域和全球用户群体可在其作业期间使用该信息。

2.2.3 除上文所述之外，会议还考虑到了全球空中航行计划中所设想的驾驶员需求，尤其是在向以电子形式提供航空气象情报进行过渡期间用户需求这一背景下的驾驶员需求。在此方面，会议指出，在对自动化和人的因素进行考虑时，将对许多问题，尤其是关于此类信息的可视化方面的问题做出考虑。

世界区域预报系统（WAFS）

2.2.4 会议提到了在拟定一张路线图以便确定世界区域预报系统的未来要求方面所开展的工作。会议指出，根据《全球空中航行计划》的未来演变，预计该路线图将在今后数年内进行演变，以确保服务水平可满足当前及未来需求。因此，会议同意认为，作为针对未来的服务提供采取一种全盘做法的一部分，世界区域预报系统应在进行适当管理的基础上，继续以一种有成本效益的方式按照《全球空中航行计划》进行演变，这一点至关重要。此外，会议还同意，将世界区域预报系统的框架内生成的信息纳入未来的全系统信息管理（SWIM）环境中，包括拟使用的以国际民航组织气象情报交换模型（IWXXM）为基础的可互用的数据格式。

2.2.5 会议同意，在组块1的2018年至2023年这一时间框架内对世界区域预报系统所做的变化以及在组块2的2023年至2028年这一时间框架内对该系统所做的其他变化应主要围绕附录B中所载的原则来进行。在此方面，会议审查了这些原则并同意将它们作为未来世界区域预报系统发展的依据。会议相应地制定了如下建议：

建议2/5 — 进一步开发世界区域预报系统

责成国际民航组织一个适当的专家组与世界气象组织进行密切协调，以便：

a) 进一步按照《全球空中航行计划》（Doc 9750号文件）为世界区域预报系统（WAFS）拟定相关要求，包括将世界区域预报系统所生成的信息纳入作为未来全球可互用空中交通管理系统基础的未来全系统信息管理（SWIM）环境中；和

b) 使用本报告附录A中所载各项目标所述的原则，据以在航空系统组块升级（ASBU）方法的组块1和组块2的时间框架内，开展世界区域预报系统的未来开发工作。

国际航路火山监视（IAVW）

2.2.6 委员会提到了自气象专业会议（2002年）MET/2以来在国际航路火山监视方面取得的重大进展，其中包括拟定了一张路线图，以便于今后拟定国际航路火山监视的相关要求。会议指出，根据《全球空中航行计划》的未来演变，预计国际航路火山监视路线图将在今后数年内进行演变，以确保服务水平可满足当前及未来需求。因此，会议同意认为，国际航路火山监视必须继续按照《全球空中航行计划》进行演变，且国际航路火山监视框架内所生成的信息应纳入到未来的全系统信息管理环境中。会议同意，今后应依照附录B中所载路线图来拟定国际航路火山监视的相关要求。会议相应地制定了如下建议：

建议2/6 — 进一步开发国际航路火山监视（IAVW）

责成国际民航组织一个适当的专家组与世界气象组织进行密切协调，按照《全球空中航行计划》（Doc 9750号文件），进一步为国际航路火山监视（IAVW）拟定相关要求，包括依据附录C中所载路线图将该系统所生成的信息纳入作为未来全球可互用空中交通管理系统基础的未来全系统信息管理（SWIM）环境中。

空间天气

2.2.7 会议提到了国际航路火山监视运行小组（IAVWOPSG）最近开展的工作。这些工作涉及到拟定初步规定草案，以纳入附件3、技术规范[C.3.1]，从而满足空间天气情报的要求；该工作还涉及建立空间天气中心。另外，会议还提到了为空间天气情报服务的运行补充拟定的一个概念。该运行概念是一份动态文件，预计将按照《全球空中航行计划》进行演变，并明确地将2012年国际民航组织第十二次空中航行会议（AN-Conf/12）上商定的空间天气纳入其中。会议还指出，空间天气情报应纳入未来全系统信息管理环境中。

2.2.8 在对世界气象组织，包括对世界气象组织空间天气方案间协调小组（ICTSW）及其他相关各方的建议进行考虑后，会议认为，应通过建立最佳数量的全球中心（针对太阳辐射风暴和太阳耀斑以及处于可预测阶段的地磁暴和电离层扰动）来组织为国际空中航行提供空间天气情报服务，这些全球中心再通过建立最佳数量的地区中心（针对处于可观测阶段的地磁暴和电离层扰动）得以壮大。会议同意，一直未对全球和地区中心的作用、要求和能力（以及中心的最佳数量）做充分说明。因此，会议同意，应该对上述内容做进一步考虑，包括制定一个过程，对全球和地区中心、其管理办法（包

括所提供服务的成本回收及胜任能力标准）以及任务的执行时间进行指定。此外，对于如何使用空间天气情报的整体理解，还需要做详细阐述并适当地反映在相应的空间天气的文件中。

2.2.9 鉴于上文所述，由于有必要确定进一步的服务要求和能力及拟定任何其他的相关指导材料，会议同意不将上文中提到的初步规定草案纳入附件3的第77次修订草案中（在议程项目5.1下进行讨论）。但是，会议一致认为，国际民航组织应努力通过拟定相关规定，在2018年纳入到附件3中（即：组块1）来支持对航空空间天气服务的提供。会议相应地制定了如下建议：

建议2/7 — 制定空间天气情报方面的规定

责成国际民航组织一个适当的专家组，与世界气象组织密切协调，拟定与《全球空中航行计划》（Doc 9750号文件）相符合的，关于供国际空中航行使用的空间天气情报方面的规定，包括将所生成信息纳入作为未来全球可互用空中交通管理系统基础的未来全系统信息管理（SWIM）环境中，特别应涉及：

a) 与空间天气情报服务的运行概念草案相一致的空间天气情报服务要求；

b) 指定全球和地区空间天气中心（包括确定这些中心的最佳数量）时所用的选择标准及相关的能力要求；

c) 为在全球和地区一级提供空间天气情报服务做出的适当管理和成本回收安排；和

d) 关于使用空间天气情报的考虑因素以及空间天气事件可能对国际空中航行产生的各种影响。

放射性物质排放

2.2.10 会议注意到了自2002年的气象专业会议以来，在将相关规定引入附件3、技术规范[C.3.1]方面取得的重大进展。这些规定涉及到放射性物质排放到大气中的相关情报的传播，并涉及到建立一个数据库，以便在出现放射性物质排放时协助与伦敦火山灰咨询中心（已指定为联络点）同处一处的世界气象组织区域专业气象中心（RSMC）直接通知受影响的区域管制中心。此外，会议还提到了针对放射性物质排放到大气中的相关情报拟定一个运行概念，该运行概念是一份动态文件，预计将按照《全球空中航行计划》进行演变；委员会还指出，应将此类情报纳入未来的全系统信息管理环境中。会议相应地制定了如下建议：

建议2/8 — 进一步制定关于向大气中排放放射性物质的信息方面的规定

责成国际民航组织一个适当的专家组，与世界气象组织密切协调，

根据不断演变的《全球空中航行计划》（Doc 9750号文件），进一步拟定关于向大气中排放放射性物质的信息方面的规定，包括将所生成情报纳入作为未来全球可互用空中交通管理系统基础的未来全系统信息管理（SWIM）环境中。

其他危险气象条件

2.2.11 会议高兴地注意到了自2002年的气象专业会议以来已取得了重大进展，尤其是气象警报研究组取得了重大进展，以期解决一些国家在提供重要气象情报方面所面临的未决实施问题，这阻碍着飞行运营的持续安全性和有效性。会议同意，应按照气象警报研究组的提议，积极致力于为所选危险气象条件实施一个地区咨询系统，以便对在此方面面临的困难提供一个长期的解决方案。

2.2.12 除了建立此种地区化咨询系统所涉及的技术挑战之外，会议还强调指出，在开展任何实施活动之前，需要对包括治理和公平成本回收安排在内的若干非技术问题做出处理。为此，会议审查了对地区危险天气咨询系统的实施模式所做的战略评估，以及对附录D和E中分别提出的相关治理和成本回收安排所做的评估。此外，会议还同意，在建立此类地区危险天气咨询系统时，应按照全球空中航行计划进行演进，且应将在此系统框架内生成的信息纳入到今后的全系统信息管理环境中。

2.2.13 会议注意到，在一些国家长期存在重要气象情报有缺陷的情况并且用户表示需要有协调一致的、基于现象的危险天气情报。在这方面，航空用户表示迫切需要建立地区危险天气咨询中心（RHWACs），以帮助气象监测台（MWOs）提供关于所选择的危险气象条件的重要气象情报，其中至少包括雷暴、结冰、湍流和地形波幅，但（考虑到现有的火山灰和热带气旋咨询系统）不包括火山灰和热带气旋。会议同意认为，向气象监测台发布咨询信息这一初始阶段，可作为所述的附录 D 中表示出的、进一步发展地区危险天气咨询信息之提供方式的后两个阶段的前奏。

2.2.14 考虑到这些用户的要求，会议完全同意应立即实施一个地区危险天气的框架，同时考虑制定一个治理和成本回收的框架。

2.2.15 会议同意认为，此种危险天气咨询系统的发展，应该得到如下适当指导材料的支持：

a) 给国际民航组织各地区规划和实施小组（PIRGs）提供的指导材料，它们是关于考虑到成本效益，如利用现有的能力，为有能力作为地区危险天气咨询中心的那些国家中的气象中心，提供技术背景及能力的指导材料；

b) 给用户国和服务提供国提供的指导材料，它们涉及到咨询信息的编制和传播过程、相互合作和现有气象基础设施的可持续性，以及对当地专门知识和技能的利用。

2.2.16 会议相应地拟定了如下建议：

建议2/9 — 实施一个针对所选航路危险气象条件的地区咨询系统

责成国际民航组织一个适当的专家小组，与世界气象组织密切协调，以便：

a) 考虑到用户长期以来的要求，特别是持续在重要气象情报方面有显著缺陷的那些国家的情况，酌情使用附录D和E中提供的战略、治理和成本回收等方面的评估结果，迅速拟定各项规定，以支持实施一个与不断演变的《全球空中航行计划》（Doc 9750号文件）相符合的、针对所选航路危险气象条件而基于现象的地区咨询系统；

b) 将上述系统所产生的信息，纳入到作为未来全球可互用空中交通管理体系之基础的未来全系统信息管理环境中；和

c) 拟定适当的指导材料，以支持地区危险天气咨询中心的选择标准，并考虑到如何确保成本效益，以及支持咨询信息的编制和传播过程、相互合作、现有气象基础设施的可持续性，以及当地专门知识和技能的利用。

注：在这一背景下的所选危险气象条件至少包括雷暴、结冰、湍流和地形波幅，但不包括火山灰和热带气旋。

终端区的气象服务信息

2.2.17 在一个相关的问题中，会议审查了关于将终端区气象服务纳入航空系统组块升级方法的组块1中的提案。会议还注意到一个国家在如下方面所做的工作：开发突出强调对空中交通流的潜在天气影响的空中交通管理定制气象信息，以及关于制定一个验证方法的指导意见，以持续改进供空中交通管理使用的气象信息的必要性。会议同意认为，必须具体提及气象要求，以支持航空系统组块升级方法组块B1（包括B1-AMET）中终端区的空中交通管理（ATM），并指出这种补充只能作为对整个全球空中航行计划进行的定期审查的一部分来进行。会议指出，世界气象组织的相关项目有可能就终端区气象服务的发展开展一项研究，该研究将包括天气对世界各地不同机场的影响。会议同意认为，从这种工作中取得的经验确实十分宝贵。此外，会议还指出，目前还在开展其他研究，以确定空中交通管理服务提供者和运营人对终端区气象服务信息的需求。会议注意到上述讨论内容，拟定了如下建议：

建议2/10 — 发展终端区的气象服务

责成国际民航组织与世界气象组织进行密切协调，以便：

a) 考虑到空中交通管制和空中交通管理（ATM），将终端区的气象服务及其他相关运行要求，纳入航空系统组块升级方法的组块1以及随后的各组块中，以凸显对空中交通流的潜在相关影响；

b) 针对终端区发展为空中交通管理定制的气象服务，以满足《全球空中航行计划》（Doc 9750号文件）确定的对未来空中交通管理的要求，并在相关的规定中体现适当的功能和绩效要求，同时注意到国际民航组织的气象、空中交通管理、飞行运行各专家组的成果；

c) 为持续改进供空中交通管理使用的气象信息，制定关于验证方法的指导意见；和

d) 将关于终端区的气象服务信息，纳入到作为未来全球可互用空中交通管理体系基础的未来全系统信息管理环境中。

2.2.18 会议高兴地指出，在日本气象机构内设立空中交通气象中心以支持空中交通管理方面取得了重大进展。会议特别指出，建立了一个新的系统，可提供定制的天气情报，用于表示天气给空中交通流产生影响的可能性。今后，该系统所提供的信息有可能被用作一个指数，衡量天气对空中交通流产生影响的可能性。

2.2.19 此外，会议还获悉进行了一项案例研究，以表明在东京国际机场进近区域内的积云团是如何给空中交通管制流量产生重大影响的，以及空中交通气象中心是如何帮助空中交通管理中心开展有效和高效的空中交通管理从而强调进近管制区内气象条件信息的重要性的。

议程项目 2：通过加强气象服务的提供工作，提高国际空中航行的安全和效率

2.3：加强集成气象情报，以支持自 2028 年起的战略、战术前和战术运行决策（包括航空系统组块升级的 B3-AMET 模块）

2.3.1 尽管，在全球空中航行计划（GANP）中所载的航空系统组块升级（ASBU）方法的模块 B3-AMET，定于从 2028 年实施，会议指出，所涉及的技术之复杂性，尤其是飞行管理系统和数据链通信，这意味着，需要尽早在模块 3 所设想的预计执行期（即：2028 年及之后）之前，对现有的和短期的系统和服务可能出现的显著改变，就要提前做好计划。

2.3.2 因此，会议一致认为，对航空系统组块升级模块 3，特别是模块 B3-AMET，以及与全系统信息管理（SWIM）有关的其它模块包含的技术要求和服务能力的考虑，需要在 2028 年实施之前留出多年的时间。会议相应地制定了如下建议：

建议 2/11— 航空系统组块升级模块 3 的航空气象组成部分的预先规划

一个合适的国际民航组织专家小组，与世界气象组织密切协调，负责在 2015 年至 2020 年期间，对支持 2028 年实施航空系统组块升级（ASBU）方法的模块 B3-AMET，以及与《全球空中航行计划》（Doc 9750 号文件）所载的全系统信息管理有关的、其它航空系统组块升级各模块之气象组成部分所需要的技术要求和航空气象服务能力进行预先规划。

2.3.3 会议审查了在组块 3 的时间范围内，对世界区域预报系统（WAFS）拟议的修改，它将以附录 F 中提出的原则为重点。在完成了审查并领会到，要充分设想到航空系统（和世界区域预报系统的组成部分）在 2028 年的时间范围内的未来状态，是特别具有挑战性的，会议商定了将用作今后发展世界区域预报系统，支持航空系统组块升级方法的模块 B3-AMET 之基础的一些原则。会议相应地制定了如下建议：

建议 2/12 — 发展世界区域预报系统以支持 2028 年之后的航空系统组块升级（ASBUs）

国际民航组织用附录 F 中包含的有关航路运行的可交付成果所概述的各项原则，作为今后发展世界区域预报系统（WAFS），支持航空系统组块升级方法的模块 B3-AMET 之基础。

议程项目 2：通过加强气象服务的提供工作，提高国际空中航行的安全和效率

2.4：协作决策及共同的状况意识 — 自动化和人的因素方面的考虑

2.4.1 会议注意到了在一个信息丰富的运行环境中，应用协作决策（CDM）将会产生的预期效益。在这方面，协作决策被视为是全球空中交通管理（ATM）体系将如何成熟的一个基本方面，确保所作出的决定是明智的，能为各方所理解，是以对基础信息的共享评价为基础的。也有人指出，由于航空气象是空中交通管理界，以协作方式作出运行决策的全部可用信息的一个组成部分，它遵循的是，航空气象对于共同的状态意识将是一个关键的促成因素。

2.4.2 会议强调，在这样一个协作环境中，非常需要有治理，包括质量管理和数据标准化在内，为此，要在全球空中交通管理领域未来的全系统信息管理（SWIM）环境中通用的所有信息领域内，有规定的数据格式。

2.4.3 会议注意到，预期的从以产品为导向转变为以提供信息或数据为导向的服务，由于自动化程度的提高，将不可避免地意味着与航空气象信息（在提供者和使用者方面）的互动会减少。此外，鉴于这样的自动化运行环境及认识到这是用户运行决策的独特性，会议同意，就常用的航空气象信息的可视化标准而言，不予以规范倒是可取的，因为每个用户将有自己的、往往是独特的运行需要与能力。

2.4.4 会议指出，为了最大限度地提高可互用性并简化实施过程，空中航行服务提供者（ANSP），作为空中交通管理界一个关键性成员，将在航空气象和空中交通管理界过渡到以信息为导向的环境方面，发挥不可或缺的作用。

2.4.5 会议同意，过渡到一个更具协作性的运行环境和提高的自动化程度，将需要改变如何向用户提供航空气象信息以及用户如何使用，而治理就是一个先决条件。此外，有必要确保在这种过渡期间并且在过渡时，人的因素之考虑仍然是提供航空气象服务的一个组成部分。委员会相应地制订了如下建议：

建议 2/13 — 制定在协作决策及共同的状况意识背景下的航空气象情报服务之规定

国际民航组织和世界气象组织确保及时制定航空气象情报服务的规定，促进空中交通管理（ATM）界中的协同决策（CDM）以及共同的状态意识。

建议 2/14 — 为制定航空气象服务的规定而对人的因素之考虑

国际民航组织和世界气象组织确保，人的因素之考虑是制定航空气象情报服务的核心。

2.5：中国代表团和俄罗斯联邦代表团的声明

世界区域预报系统（WAFS）

2.5.1 对于世界区域预报系统的发展，应当将其置于正确的历史角度来看待。人们知道在 1982 年世界区域预报系统是在当时不是所有国家都有数值天气预报（NWP）和卫星发送能力的情况之基础上建立的。然而，在过去三十年间，全球情况已发生了巨大的变化，许多国家现在都在运用具有高时空尺度达到一周或更长时间的各种数值天气预报模式。同时，与互联网相比，卫星发送技术已不具有成本效益。因此，除了世界区域预报系统模式的预报之外，还有许多不同的全球模式的预报，为航路飞行规划之目的可供使用，但它们必须达到所需的绩效水平并得到国际上的指定。

2.5.2 随着全世界空中交通的巨大增长，在亚洲太平洋地区尤其如此，用户对更好的预报，对重要天气信息有更及时的修改等等要求与日俱增，以应对天气的快速变化例如显著的对流等情况，而现有的全球各个中心对此都尚无预报。此外，在将来的全系统信息管理的环境中，将会更大地依赖网格式预报去支持空中交通管理和基于航迹的运行，现有的世界区域预报系统的结构是否在满足用户今后的各种需求尚不明了。为了支持空中交通不可避免的增长，各中心就有必要来处理用户不断增长的需求，而这可能无法由仅有的两个全球中心这样的现行安排来最好地办到。人们感到，要在全球空中航行计划和航空系统组块升级之办法的新背景下，来考虑世界区域预报系统的地点及作用是可行的。同样，在考虑全球各中心时就应顾及到在绩效、公平合理性、可持续性，包括各种备用安排等方面的考虑。应该由用户来选择最能满足其运行需要的全球模式。

2.5.3 此外，附件 3 和未来的《空中航行服务程序 — 气象》应该对提供气象服务进行规范，包括世界区域预报系统的预报在内，即：要设立每种服务而非提供该种服务的机构应达到的所需绩效标准。

2.6 巴林、科威特、卡塔尔和阿拉伯联合酋长国代表团的声明

致国际民航组织和世界气象组织的秘书长

2.6.1 谨提及支持“一个天空”之概念的 2014 年的国际民航组织气象专业会议，因为它涉及到了全球空中航行计划（GANP）和航空系统组块升级（ASBU）方法的气象组成部分。出席 2014 年国际民航组织气象专业会议的次地区（巴林、科威特、卡塔尔和阿拉伯联合酋长国）的代表，希望提出以下关切供你们考虑。

2.6.1.1 关于涉及为选择航路上的危险气象条件而实施一个地区咨询系统的 MET/14-WP/6|CAeM-15/Doc.6 号文件第 2.5.6 段的建议草案，并参考附录 B 和 C，我们谨提请你们注意，实施一个地区性的咨询系统来提供重要气象情报服务将会影响：

a) 作为服务提供者提供重要气象情报警告的次地区之作用，以及次地区国家气象和水文服务的组织机构之生存能力；

b) 作为次地区之有关准确程度都已完全合规，并自 1960 年以来，在提供重要气象情报警告方面完全是娴熟的；

c) 当前和正在进行的在人力资源及气象系统方面的投资；和

d) 关于 MET/14-WP/6|CAeM-15/Doc.6 号文件附录 C 的第 5.2.1.3 和 5.2.1.4 段提及的年度收费。

2.6.2 最后，上述各国要求国际民航组织和世界气象组织考虑由我们次地区提出的上述建议，因为它将对作为国际控制的体系之单一的地区化提供者的治理作用产生影响。所有上述成员国十余年来，一直都在早期天气警告方面，为航空界提供有价值的、高质量的、高效率的气象服务。我们次地区在各气象系统方面做了投资，通过我们指定的各飞行情报区提供重要气象情报服务，正在进行的投资计划有：复合的雷达覆盖区、在大气及海洋领域的高分辨率数值天气预报、卫星数据接收及次地区再次发送等。做了所有这些投资之后，由于新的地区化的全系统信息管理环境，我们在维护与保持这些基础设施方面处于危险状态，被迫落到我们在其它成员当中可能会失去我们的明显作用及来自政府支持的境地。

2.6.3 除了我们地区的情况之外，我们要求国际民航组织和世界气象组织，在指定相关的地区重要气象情报之提供时并在此之，要明确阐明将要制定的（关于双边协议方面的）规章与规则。

— — — — — — — —

附录 A

世界区域预报系统可交付的成果以支持航空系统组块升级的组块 0

— 实施经改进的紊流算法，包括用紊流强度（即涡流耗散率（EDR））代替紊流潜力

— 实施经改进的结冰算法，包括用结冰强度代替结冰潜力

— 利用各国和各用户组织提供的数据从全球和地区层面对世界区域预报系统的预报进行核查

————————

附录B

世界区域预报系统可交付的成果以支持航空系统组块升级的组块1和2

在 B1-AMET 模块 — 支持加强运行效率和安全的气象情报（2018 年至 2028 年）的时间框架内，预定的变化包括：

- 2018 年至 2023 年：
    - 实施基于预测系统的积云团
    - 采用涡流消散率（EDR）来实施紊流类型预报（例如对流、急流切变、地形）
    - 就世界区域预报系统的数据实施更精细的网格分辨率
    - 就结冰、紊流和积雨云实施经校准的概率预报
    - 提供适于纳入飞行规划、飞行管理和空中交通管理（ATM）决策支持系统的关于航路天气的部分气象情报数据集
    - 实施可扩展置标语言、地理置标语言格式的重要气象情报（SIGWX），替代 BUFR 格式的重要气象情报
    - 通过全系统信息管理（SWIM）提供世界区域预报系统的数据
- 2023 年至 2028 年：
    - 增加提供适于纳入飞行规划、飞行管理和空中交通管理决策支持系统的关于航路天气的气象情报数据集

改进算法

世界区域预报中心的改进措施包括但不局限于：

- 积雨云：
    - 与对流系统相关的改进，并使用基于云团的预报
    - 改变输出参数，以便提供更有用的校准数值
- 紊流：
    - 将紊流类型定性，例如对流型、高空风切变或地形引发的紊流

    - 使用涡流消散率（EDR）得出经校准的概率输出

- 结冰

    - 经校准的概率输出

— — — — — — — — —

APPENDIX C

Roadmap

for

International Airways Volcano Watch (IAVW)

in

Support of International Air Navigation

21 November 2013

Version 1.0

Revision	Date	Description
0.1	29 July 2013	Initial draft. Based on draft ConOps for the IAVW in response to IAVWOPSG Conclusion 7/17. Aligns with *Meteorological Information Supporting Enhanced Operational Efficiency and Safety* from ICAO's Aviation System Block Upgrades (ASBU).
0.2	27 September 2013	Revised draft based on comments from IAVWOPSG ad hoc group.
0.3	24 October 2013	Revised draft based on comments on version 0.2 from the IAVWOPSG ad hoc group.
0.4	10 November 2013	Revised draft based on comments on version 0.3 from the IAVWOPSG ad hoc group
1.0	19 November 2013	Submitted to IAVWOPSG Secretariat
1.0 rev	21 November 2013	Revised to include additional comments from WMO

Contents

Preface

At the first meeting of the International Volcanic Ash Task Force (IVATF/1), held at ICAO Headquarters in Montréal from 27 to 30 July 2010, it was recognized that there was a need to further promote and improve the services provided by Volcanic Ash Advisory Centres (VAAC) and Meteorological Watch Offices (MWO). It was agreed that a global Concept of Operations (ConOps) for volcanic ash should be developed that would cut across all service fields from a perspective of the providers of information to the users/operators of that information in support of both tactical and strategic decision making. This resulted in IVATF Task TF-VAA10, *Development of a Concept of Operations for the International Airways Volcano Watch (IAVW)*.

A draft version, and follow-on revisions, of the ConOps for volcanic ash were presented to the IVATF at their subsequent meetings. At the IVATF's fourth meeting the IAVW Operations Group (IAVWOPSG) was tasked with developing a version 1.0 of the ConOps, and this was subsequently presented to the seventh meeting of the IAVWOPSG (Bangkok, Thailand, 18-22 March 2013). At that meeting the group recognized the inherent value of the ConOps document and agreed to use the material included in the ConOps for the development of an IAVW roadmap to be consistent with the outcomes of ICAO's 12th Air Navigation Conference (Montreal, Canada, November 2012) and formulated Conclusion 7/17 which states:

Conclusion 7/17— Development of an IAVW roadmap

That an ad-hoc group consisting of Canada, China, France, Germany, New Zealand, United Kingdom, United States (Rapporteur), IATA, ICCAIA, and WMO to be tasked to:

a) develop an IAVW roadmap for the provision of information services in support of the aviation system block upgrade (ASBU) methodology to be included in ICAO's Global Air Navigation Plan, taking into consideration the draft concept of operations for the IAVW as presented in Appendix J to this report; and

b) provide a draft of the roadmap called for by a) above by 29 November 2013 for onward consideration at the IAVWOPSG/8 meeting and the proposed ICAO MET Divisional Meeting in July 2014.

This roadmap replaces the ConOps as originally proposed and is a living document that will evolve as the science and technology improves, and as operational requirements evolves.

1.0 Introduction/Scope

The roadmap for the International Airways Volcano Watch (IAVW) is based on the draft Concept of Operations (ConOps) for the IAVW which was presented at the seventh meeting of the IAVW Operations Group (IAVWOPSG/7). This roadmap replaces the ConOps.

The roadmap is not intended to provide detailed descriptions on all the areas presented in the document, rather it presents a high-level overview for the user.

1.1 Purpose

This document is intended to provide international air navigation users and providers of information under the IAVW with a roadmap that defines improved services including the integration of volcanic meteorological information into decision support systems for trajectory based operations (TBO).

This document provides a plan for the development and implementation of volcanic meteorological information for modules B*1-AMET* and B*3-AMET*, time frames 2018 and 2028 respectively[1].

Module B*0-AMET*[2] of ICAO's Aviation System Block Upgrades (ASBU), titled *Meteorological Information Supporting Enhanced Operational Efficiency and Safety*, describes the baseline of meteorological information provided in Block 0 of the ASBU which is defined as beginning in 2013. The IAVW element is included in module B*0-AMET* and describes the information services provided by State Volcano Observatories (VO), Meteorological Watch Offices (MWO) and Volcanic Ash Advisory Centers (VAAC).

1.2 Background

The Eyjafjallajökull volcanic eruption of April and May 2010 highlighted issues relating to all aspects of volcanic ash service provision including underpinning science and observational capabilities. Eyjafjallajökull brought direct attention to the need for a better understanding of volcanic ash information and the use of that information in Air Traffic Management (ATM) and flight operations. In addition it was recognized that there were no measureable certificated tolerances for volcanic ash for safe and permissible aircraft operations.

While the provision of contemporary volcanic ash information has served the international community well for many years, especially in areas where the airspace is not congested and operators have greater flexibility in avoiding airspace identified with ash, the application of this operational procedure did not work well in congested airspace. This was evident from the Eyjafjallajökull volcanic ash episode in April and May of 2010. During this time period, volcanic ash of mostly unknown concentrations, were detected visually and/or by satellite imagery at times over parts of Western Europe and parts of the North Atlantic. This was due to the

[1] Module B*1-AMET* encompasses the timeframes of Block 1 (2018) and Block 2 (2023).
[2] Advanced Meteorological Information (AMET).

prevailing meteorological conditions and the prolonged period of eruption. The busy and congested air routes over Europe were significantly impacted and issues also arose with the many Air Navigation Service Providers (ANSP) and MWOs serving a multitude of Flight Information Regions (FIRs). At one time during the Eyjafjallajökull eruption, more than 40 volcanic ash SIGMET messages were in effect.

The limited ability to identify observed areas of volcanic ash as well as forecast areas of volcanic ash concentrations hazardous to aircraft was another significant factor in the resultant closing of airspace, especially during the first few days after the initial eruption.

Aviation users (i.e. ANSP, operators and pilots) need to know the location, size and vertical extent of a given volcanic cloud, and where it will be located in the future. Ideally, the precise location and future location of the volcanic ash cloud would be known with great accuracy and confidence and over time scales ranging from minutes to days. However, the current science for observing and forecasting volcanic ash cannot provide that precision or accuracy.

Currently there are no requirements to observe and forecast volcanic gases, such as sulphur dioxide (SO_2), thus these observation and forecasts do not exist. However, Grímsvötn (2011) highlighted shortfalls in our understanding of and service provision for possible SO_2 impacts.

Aviation users need to know how much volcanic ash is in the atmosphere and if those amounts pose a threat to the aircraft's engine(s) and system(s). However, there are no agreed values of ash which constitute a hazard to an aircraft.

In addition, many volcanoes are not monitored despite continued efforts from the International Union of Geodesy and Geophysics (IUGG), ICAO and WMO. The lack of this monitoring contributes to uncertainty in the model output in that the source data from the eruption is based on an estimate.

1.3 Problem Statement

Explosive volcanic eruptions eject pulverized rock (volcanic ash) and corrosive/hazardous gases high into the atmosphere. Depending on the energy and duration of an eruption, there is potential for an ash cloud to cover a wide area for timescales ranging from hours to days.

Volcanic eruptions represent a direct threat to the safety of aircraft in flight and present major operational difficulties at aerodromes and in airspaces located proximal to volcanoes. Currently there are no agreed values of ash loading metrics (amount and rate of ash ingestion) that represent quantified hazard to aircraft or gas turbine engines. The exposure time of aircraft or engines to the ash, type of ash and the thrust settings at the time of the encounter, both have a direct bearing on the threshold value of ash loading that may constitute a hazard. Hence, the current globally recommended procedure is to avoid any volcanic ash, regardless of the level of ash contamination. Many years of service have demonstrated this to ensure safe operation.

In order to improve efficiencies in air transportation during volcanic events, quality, timely and consistent volcanic ash information (observations and forecasts) are essential to mitigate the safety risk of aircraft encountering volcanic ash. Education of all users (operators and ATM) is also needed to ensure proper use of volcanic ash information within the operator's risk assessment process.

If demonstrated to be beneficial and without compromising safety, it may be desirable to agree to standards on where and for how long aircraft can operate in specified concentrations. Until those standards are established, if indeed they can be, considerable effort is required to establish rigorous and well understood practices and products provided by the VAACs.

1.4 Identification

This roadmap is expected to provide the guidance on services tasked by the IVATF and the ICAO challenge team and identified in the ICAO's ASBUs. This document will be updated as required as procedures changes or as technology warrants a change to take advantage of new state of the art capabilities to detect, monitor, and forecast ash.

This document is intended to complement the ICAO *ATM Volcanic Ash Contingency Plan,* ICAO Doc 9974 *Flight Safety and Volcanic Ash*, ICAO Doc 9691 *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds*, and ICAO Doc 9766 *Handbook on the International Airways Volcano Watch*.

2.0 Current Operations and Capabilities

During a volcanic event the coordination and flow of information regarding the location and forecast position of the volcanic cloud is the primary concern. It involves cooperation among all information providers in support of operational decision makers. Providers of information primarily include MWO, VAACs, and VOs. Users of information are ANSPs that include Aeronautical Information Services (AIS), Air Traffic Control (ATC) and Air Traffic Flow Management (AFTM) units, flight crews, and airline operations centers (AOC). The cooperation between operators and civil aviation authorities (CAA) using the information provided by the providers is essential for the purpose of supporting the pre-flight process, and the in-flight and post-flight decision-making process, as part of the risk mitigation in accordance with ICAO Doc 9974 *Flight Safety and Volcanic Ash*.

2.1 Description of Current Operations

Services in support of the provision of meteorological information for volcanic events can be categorized in four areas: (1) monitoring the threat, onset, cessation, dimensions and characteristics of an eruption, (2) monitoring the volcanic ash in the atmosphere, (3) forecasting the expected trajectory and location of the ash cloud, and (4) communicating the information to the users.

2.1.1 Monitoring the threat, onset, cessation, dimensions and characteristics of an eruption

The ability to provide an advanced warning of an imminent eruption and the onset of the eruption rests with the VOs which are loosely organized under the banner of the World Organization of Volcano Observatories (WOVO) of the International Union of Geodesy and Geophysics (IUGG). These VOs provide guidance on the magnitude of the eruption, including dimensions and characteristics, which are then used in support of numerical dispersion and transport models.

Pre-eruptive activity may come from several sources, including, but not necessarily limited to: seismic monitors, physical observations of deformation, hydrologic activity, gaseous activity, steam explosions, or debris flow. The international aviation community has established a four-level color code chart for quick reference to indicate the general level of threat of an eruption for a given volcano. The color codes identify the state of the volcano (i.e. pre-eruptive vs. eruptive stage)[3] and not to ash in the atmosphere. While the international community has developed the color code chart, it should be noted that these codes are not assigned to all volcanoes for various reasons.

In 2008, the IAVWOPSG agreed to implement a message format to assist volcanologists in the provision of information on the state of a volcano in support of the issuance of volcanic ash advisories (VAA) by VAACs, and the issue of SIGMET information by MWOs, and the issuance of a Notice to Airmen (NOTAM) for volcanic ash by Air Traffic Services (ATS). The message, referred to as Volcano Observatory Notice for Aviation (VONA), was introduced into the ICAO *Handbook on the International Airways Volcano Watch*, Doc 9766. The VONA should be issued by an observatory when the aviation color code changes (up or down) or within a color code level when an ash producing event or other significant change in volcanic behavior occurs. The VONA allows the volcanologists to provide a succinct message on the state of volcano to MWO, VAAC, and ACC which as noted above assists in the issuance of SIGMET, VAA and NOTAM respectively.

For safety purposes, operators have stated the importance of having available pre-eruption activity for situational awareness. Some VOs and a VAAC[4] currently provide information the volcanic activity within their area of responsibility. This is expected to be extended so that all volcanic areas have improved activity reporting for aviation and is a task being looked at by the IAVWOPSG[5].

---

[3] In the aviation volcano color code; Green denotes a non-eruptive state; Yellow denotes a state of elevated unrest; Orange denotes a state of heightened unrest with the likelihood of eruption, or minor eruption underway; and Red denotes a forecast of imminent major eruption, or that major ash-producing eruption is underway.
[4] The Darwin VAAC provides a daily volcanic activity summary on the volcanoes in their area of responsibility.
[5] IAVWOPSG Conclusion 7/13 refers.

2.1.2 Volcanic ash-cloud monitoring

Depending on many variables, an ash cloud can be detected from the ground, air, or from satellite. A large number of different ground and air-based instruments are available to monitor volcanic ash clouds, including lidar, ceilometers, sun photometers, radar, imaging cameras and aerosol sondes. However, none of these are yet designed, networked or quality controlled for operational use and many are operated in ad-hoc research mode only[6]. Satellite-based sensors are used to locate ash cloud and aid in discerning the perimeter of ash clouds. Ash clouds can be detected on visible satellite imagery, but only during the day. Single and multi-spectral infrared imagery and applied techniques can be used both day and night, and can provide a means of estimating the top of the ash cloud and in the case of the multi-spectral Meteosat SEVERI sensor ash cloud composition characteristics including mean particle size and ash mass loading estimates. Both visible and infrared imagery have limitations when meteorological clouds (e.g., cirrus, etc.) are present depending on the thickness and height of the meteorological cloud cover. Infrared measurements can only detect volcanic ash if the ash is the highest cloud layer, regardless of the level of ash contamination.

Until recently, what was detected by satellite was assumed or interpreted by many to be the "visible ash cloud." This term was also used to refer to ash clouds seen by pilots in the air and people on the ground. To avoid further confusion and misuse of terms, the IAVWOPSG formulated Conclusion 7/16 which defined "visible ash" and "discernible ash". According to Conclusion 7/16:

- visible ash be defined as "volcanic ash observed by the human eye" and not be defined quantitatively by the observer
- discernible ash be defined as "volcanic ash detected by defined impacts on/in aircraft or by agreed in-situ and/or remote-sensing techniques"

It is noted that there is no single quantitative threshold value for 'visible ash'. Discernible ash agreed in-situ and/or remote-sensing techniques are based on the findings and recommendations of the IUGG/WMO Volcanic Ash Scientific Advisory Group.

2.1.3 Volcanic ash forecasts

Today's volcanic ash forecasts are basic textual and graphical products derived and produced using the output from dispersion and transport models validated and amended against available volcanic ash observations. Most of the numerical models utilized by VAACs depend on meteorological input (e.g. wind speed and direction) as well as input regarding the eruptive parameters at the volcanic source (Eruption Source Parameters - ESP). ESPs include (1) plume height, (2) eruption duration or start/stop time, (3) mass eruption rate, (4) fraction of fine ash particles, and (5) the vertical distribution of mass with height above the vent. Uncertainty or

[6] In 2012 WMO had established the GALION activity as a network (see also www.dwd.de/ceilomap) with a focus also on operational volcanic ash monitoring. This European network already now consists of several thousand systems, for which algorithms have been developed to get quantified volcanic ash information in a quality much better than (passive) satellite observation, although the location of systems is certainly restricted to continental (land-surface) stations.

inaccuracy in any of the various sources can result in large errors in the resultant volcanic ash forecasts.

Forecasters provide value added input to the model output as required before issuing a VAA and VAG. This work is dependent on real-time verification of the ash cloud model output against a range of observational resources, principally, remote sensing by satellite.

Today's two primary volcanic ash forecast products are the VAA and the SIGMET. The VAA is produced and issued by the VAAC, and the SIGMET is produced and issued by the MWO. The VAAC provides the VAA in a text and/or graphic-based format (the graphic version of the VAA is referred to as a VAG), that provides an analysis of the ash cloud and a 6, 12 and 18-hour forecast on the trajectory of the ash cloud and the associated flight levels that may be affected. The VAAs are produced and issued by nine VAACs across the world, each with a defined geographical area of responsibility, as shown in Figure 1. MWOs issue volcanic ash cloud SIGMETs based on the guidance provided by the associated VAAC. These SIGMETs are valid for up to six hours and describe the location and expected location of the ash cloud within the FIR or area of responsibility of the MWO.

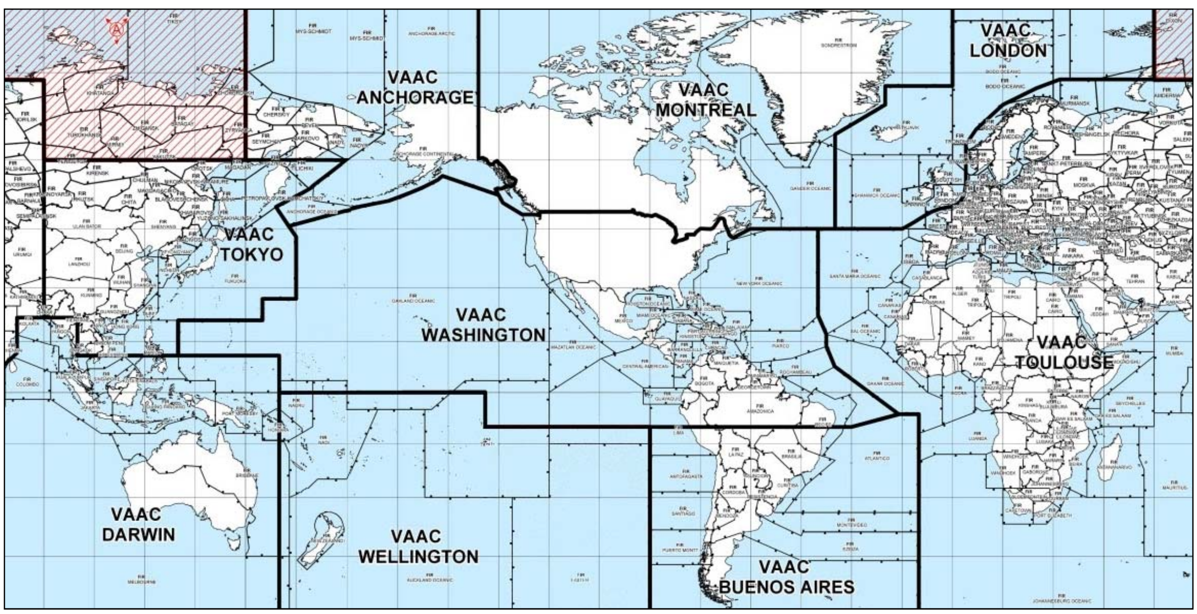


Figure 1. **Areas of responsibility for the nine VAACs.**

As a supplementary service, meteorological (MET) offices collocated with the EUR/NAT VAACs are required by regional documentation to issue forecast ash concentration charts. Such charts, depicting forecast ash concentration were first provided to users in April 2010 in response to the Eyjafjallajökull volcanic event. It is important to note that there are no globally agreed standards and procedures for the production and provision of such information. Despite lack of global requirement and large uncertainties the ICAO EUR/NAT Volcanic Ash Contingency Plan still includes the provision and use of such charts to underpin the current airlines volcanic ash safety risk assessments.

2.1.4 Communicate volcanic ash information to users

In the simplest terms, MET services are required to provide volcanic ash information to airline operators and ANSPs who then pass the information to aircraft and pilots. Figure 2 depicts an example of information flow following a volcanic eruption. The Figure identifies participants in the provision of contemporary volcanic ash cloud information. The lines between the providers in the diagram do not imply one-way communication, or communication relationships. The lines represent the distribution of information over aeronautical fixed services, with the exception of the VONA[7]. The box colors do not represent significance; rather they help distinguish the information products (e.g., observations and forecasts) (red) from the providers/users (shades of blue, purple and green).

The initial report of volcanic ash can result in many products being delivered to the end user. In most cases, information about a volcanic ash cloud will be provided to the pilot, either in-flight, or during pre-flight planning, in the form of a SIGMET, NOTAM or ASHTAM[8], Special AIREP, or VAA. Each of these products is unique in format and content, but all provide information regarding the location of the volcanic ash. It is critically evident that all of these products must be consistent in their overall message.

[7] VOs disseminate the VONA via facsimile or e-mail.
[8] ASHTAM is a special series NOTAM for a volcanic eruption and/or volcanic ash cloud.

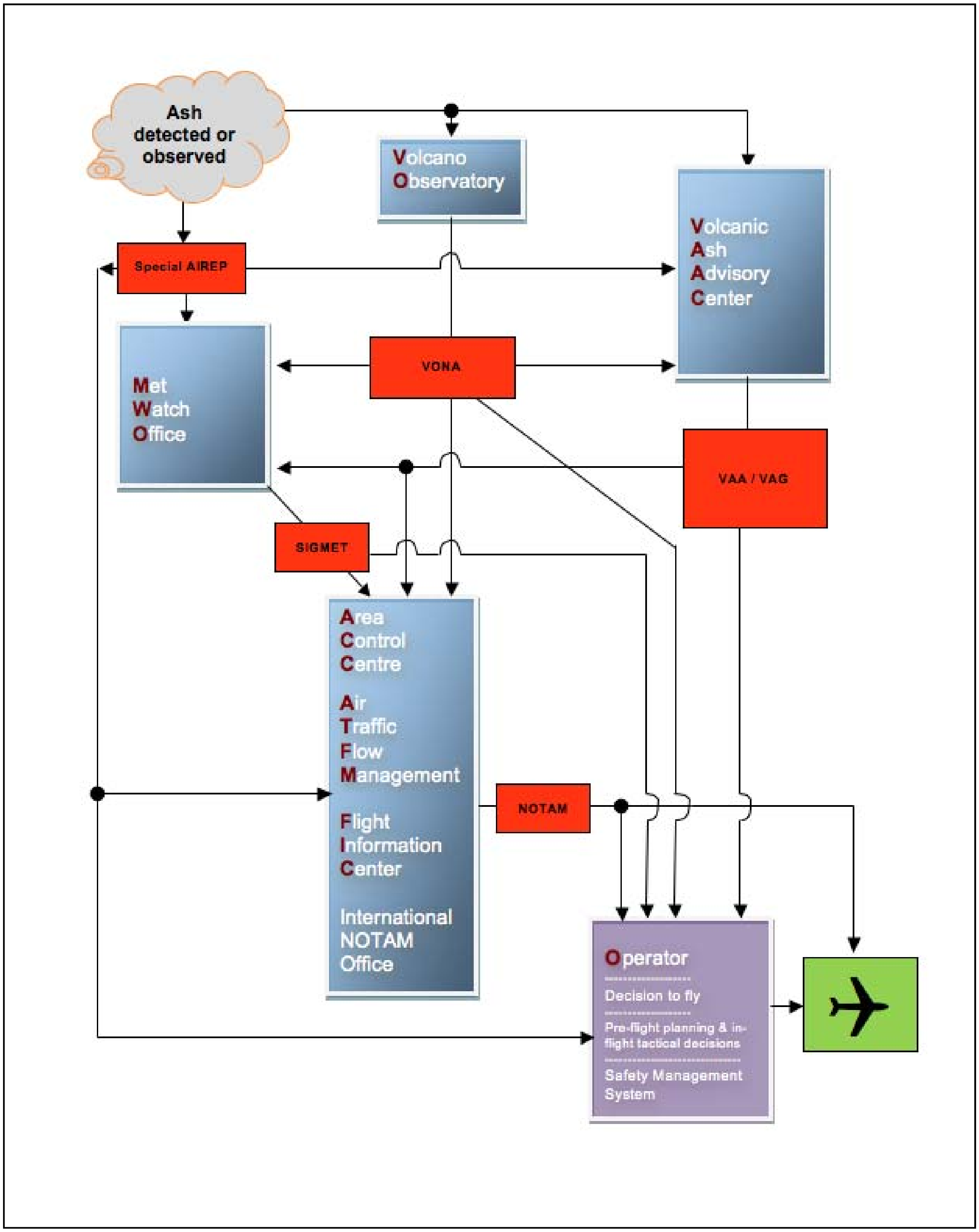


Figure 2. High-level information flow diagram between the users and providers of contemporary volcanic ash cloud information. The lines represent the distribution of information over aeronautical fixed services, with the exception of the VONA. The box colors do not represent significance; rather they help distinguish the information products (e.g., observations and forecasts) (red) from the providers/users (shades of blue, purple and green). It should be noted that there are other distribution networks and information sources that may be unique to different States which are not depicted in the diagram.

2.2 Current Supporting Infrastructure

Table 1 outlines service providers and their functions with respect to volcanic cloud information. The exact role of each provider depends on various circumstances that are not exhaustively described in the table.

<table>
<tr><th colspan="2">Current Services and Providers</th><th colspan="3">Functions for:</th><th colspan="2">Information</th></tr>
<tr><th colspan="2">Service Provider</th><th>Pre-Eruption</th><th>Eruption[9]</th><th>Volcanic Ash[10]</th><th>Information Received and Used</th><th>Information Provided (shared)</th></tr>
<tr><td colspan="2">Volcano Observatory (VO)</td><td>Monitor volcano, report changes in status.

Pre-eruption activity for situational awareness</td><td>Monitor eruption, report changes in status.</td><td>Monitor and report</td><td>Data from ground-based, air-based and satellite-based observing networks.</td><td>VONA</td></tr>
<tr><td rowspan="4">MET Service Provider</td><td>Met Watch Office (MWO)</td><td></td><td>Provide location and notice of eruption</td><td>Provide location and dimension of volcanic ash</td><td>AIREP, VONA (report from VO), VAA/VAG, METAR/SPECI, NOTAM.
Data from ground-based, air-based, satellite-based observing networks.
Input from VAACs and other research institutes.</td><td>SIGMET</td></tr>
<tr><td>Aerodrome Met Office and Stations</td><td>Report pre-eruption activity</td><td>Report</td><td>Report</td><td></td><td>METAR/SPECI.
Aerodrome Warning</td></tr>
<tr><td>Volcanic Ash Advisory Center (VAAC)</td><td>Pre-eruption activity for situational awareness.</td><td>Initial analysis including dispersion model initialization), forecast and coordination.</td><td>Determine and predict location and dimensions of airspace impacted by volcanic ash</td><td>VONA (report from VO).
Data from ground-based, air-based, satellite-based observing networks.
Input from other VAACs and other research institutes.</td><td>VAA and VAG</td></tr>
<tr><td>Other State, Research, University, Commercial Services (including research modeling centers)</td><td>Coordinate with VO and VAACs</td><td>Initialize dispersion model.
Operate aircraft and sondes for airborne sampling of ash.
LIDAR etc for ground based sampling.</td><td>Produce model derived predictions of volcanic ash.
Operate aircraft and sondes for airborne sampling of ash.
LIDAR etc for ground based sampling.</td><td>Data from ground-based, air-based, satellite-based observing networks.
ESP.</td><td>Deliver model derived predictions</td></tr>
</table>

[9] Known as the "Start of Eruption" cycle in Doc 9974 - ICAO Doc 9974 *Flight Safety and Volcanic Ash*.
[10] Same as the "Ongoing Eruption" cycle in Doc 9974 ICAO Doc 9974 *Flight Safety and Volcanic Ash*.

Current Services and Providers		Functions for:			Information	
Service Provider		Pre-Eruption	Eruption[9]	Volcanic Ash[10]	Information Received and Used	Information Provided (shared)
Air Navigation Service Provider (ANSP)	Air Traffic Control Units (Area, Approach, Aerodrome)	Identify appropriate areas[11] within airspace to outline hazard	Identify appropriate areas within airspace to outline hazard. Reroute traffic as necessary	Identify appropriate areas within airspace to outline hazard. Reroute traffic as necessary	SIGMET, NOTAM/ASHTAM, VAA/VAG, VONA or report from VO, VAR (Special AIREP)	IFR clearances. FIR's sector capacity. Affected aerodrome arrival and departure acceptance rate
	Air Traffic Management (ATM)	Maintain communications links and ATS monitoring systems	Implement contingency plans	Lead CDM process for adjusting traffic capacity and routes	SIGMET, NOTAM/ASHTAM, VAA/VAG, VONA (report from VO), VAR (Special AIREP, other[12]	FIR traffic capacity
	Flight Information Center (FIC)	Maintain communications links and ATS monitoring systems	Provide preflight and in-flight information about eruption	Provide preflight and in-flight information about volcanic cloud	SIGMET, NOTAM/ASHTAM, VAA/VAG, VONA (report from VO), Special AIREP	SIGMET, NOTAM/ASHTAM VAA/VAG, VONA (report from VO), Special AIREP
	International NOTAM Office (NOF)	Maintain communications links and ATS monitoring systems. Provide notice of pending hazard.	Provide notice of hazard	Provide notice of hazard	SIGMET, VONA (report from VO), Special AIREP	NOTAM/ASHTAM
Aerodrome		Maintain communications links and monitoring systems	Address ash contamination on runways, taxiways, ground equipment, planes	Address ash contamination on runways, taxiways, ground equipment, planes	Aerodrome Warning	Information for the NOTAM/ASHTAM
Operator	Airline Operations Center (AOC)	Maintain communications links and monitoring systems. Reroute aircraft around volcanoes identified in a pre-eruption state.	Reroute aircraft away from eruption.	Apply agreed SMS processes to adjust routes. Provide information to flight crew. Plan for reroute.	SIGMET, NOTAM/ASHTAM, VAA/VAG, VONA (report from VO), ash or SO2 report from flight crew, or ANSP (ATS, FIS, AIS).	Route/altitude selection, fuel, go/no-go decision, in-flight route/destination change.
	General Aviation Operators	Maintain communications links and monitoring systems	Appropriate decisions per SMS for operators of Large and Turbojet Aeroplanes.	Appropriate decisions per SMS for operators of Large and Turbojet Aeroplanes.	SIGMET, NOTAM/ASHTAM, VAR (Special AIREP), ash or SO2 report from ANSP (ATS, FIS, AIS)	Special AIREP, VAR

[11] In accordance with the *ATM Volcanic Ash Contingency Plan*
[12] Ash concentration forecast (if provided)

Current Services and Providers	Functions for:			Information	
Service Provider	Pre-Eruption	Eruption[9]	Volcanic Ash[10]	Information Received and Used	Information Provided (shared)
Pilot / Flight crew (Commercial and General Aviation)	Maintain communications links and monitoring systems	Report eruption	Report volcanic ash, sulphur	SIGMET, NOTAM/ASHTAM, VAR (Special AIREP), ash or SO2 report from AOC or ANSP (ATS, FIS, AIS)	Special AIREP, VAR
Original Equipment Manufacturers (OEM) or Type Certificate Holder (TCH)	Guidance and information to operators	Advice and information to operators	Advice and information to operators	Engineering and operations reports from operator.	Technical information about aircraft operation in volcanic ash, future/ongoing maintenance information requirements, details of inspection requirements

Table 1. Current service providers and their functions with respect to volcanic cloud information.

3.0 Description of Changes

Future services center on a number of changes that are intended to match the time frames of the Blocks of the ASBUs.

Module B*0-AMET* of the ASBUs is the baseline services for Block 0. The following is taken from ASBU module B*0-AMET*:

> *VAACs within the framework of the International Airways Volcano Watch (IAVW) respond to a notification that a volcano has erupted, or is expected to erupt or volcanic ash is reported in its area of responsibility. The VAACs monitor relevant satellite data to detect the existence and extent of volcanic ash in the atmosphere in the area concerned, and activate their volcanic ash numerical trajectory/dispersion model in order to forecast the movement of any ash cloud that has been detected or reported. In support, the VAACs also use surface-based observations and pilot reports to assist in the detection of volcanic ash. The VAACs issue advisory information (in plain language textual form and graphical form) concerning the extent and forecast movement of the volcanic ash cloud*[13]*, with fixed time validity T+0 to T+18 at 6-hour time-steps. The VAACs issue these forecasts at least every six hours until such time as the volcanic ash cloud is no longer identifiable from satellite data, no further reports of volcanic ash are received from the area, and no further eruptions of the volcano are reported. The VAACs maintain a 24-hour watch. Argentina, Australia, Canada, France, Japan, New Zealand, the United Kingdom and the United States are designated (by regional air navigation agreement) as the VAAC provider States. Accordingly, VAACs Buenos Aires, Darwin, Montreal, Toulouse,*

[13] There is no requirement in Annex 3 – *Meteorological Service for International Air Navigation* to monitor, observe and forecast volcanic gases.

Tokyo, Wellington, London, Anchorage and Washington make available the aforementioned advisories on the ICAO AFS.

This baseline describes the services as they are for the beginning of Block 0 with the timeframe of 2013. During Block 0, several improvements are proposed and they are described in subsequent sections of this roadmap.

Module B*1-AMET - Enhanced Operational Decisions through Integrated Meteorological Information* enables the identification of solutions when forecast or observed meteorological conditions impact aerodromes or airspace. Full ATM-MET integration is needed to ensure that: MET information is included in decision making process and the impact of the MET conditions (e.g., volcanic ash) are automatically taken into account. Module B*1-AMET* improves upon current operations where ATM decision makers manually determine the change in capacity associated with an observed or forecast MET condition (e.g., volcanic ash), manually compare the resultant capacity with the actual or projected demand for the airspace or aerodrome, and then manually devise ATM solutions when the demand exceeds the MET-constrained capacity value. Module B*1-AMET also* improves in-flight avoidance of hazardous MET conditions by providing more precise information on the location, extent, duration and severity of the hazard(s) affecting specific flights.

The aim of Module B*3-AMET - Enhanced Operational Decisions through Integrated Meteorological Information* is to enhance global ATM decision making in the face of hazardous MET conditions in the context of decisions that should have an immediate effect. Key points are a) tactical avoidance of hazardous MET conditions especially in the 0-20 minute timeframe; b) greater use of aircraft based capabilities to detect MET parameters (e.g. volcanic ash); and c) display of MET information to enhance situational awareness.

3.1 Changes intended through 2018:

Changes intended within the timeframe of 2013-2018 (i.e., Block 0 timeframe) to support Module B*0-AMET (Meteorological Information Supporting Enhanced Operational Efficiency and Safety)* are:

- Incorporate collaborative decisions and information sharing into volcanic ash cloud analyses and forecasts
- Increase the use of the aviation color-code alert system and provision of VONA by State VOs
- Develop confidence levels to aid decision makers as part of their safety risk assessment
- Improve ground-based, air-based and space-based observing networks to determine ESP and existing ash loading in the atmosphere
- Scientific research in support of reducing risks from volcanic ash hazards including understanding the impact of ash on aircraft and engines and the provision of enhanced guidance to operators

3.1.1 Collaborative decision analysis, forecasting and information sharing

The term Collaborative Decision Making (CDM) is a process used in ATM that allows all members of the ATM community, especially airspace users, to participate in the ATM decisions affecting all members. CDM means arriving at an acceptable solution that takes into account the needs of those involved. CDM for ATM is described in ICAO Document 9854 -*Global Air Traffic Management Operational Concept,* and Document 9982 – *Manual on Air Traffic Management System Requirements.*

A similar process has been proposed[14] for volcanic ash and is called Collaborative Decision Analysis and Forecasting (CDAF). From a high level perspective and for an example, collaboration on the perimeter of the volcanic ash could be done, at a minimum, for events that affect high density traffic areas, or several FIRs and extend beyond the area of responsibility of one or more VAACs. This collaboration could be undertaken between predetermined partners, based on the event and extent. Table 2 lists some of the volcanic ash information needed by airspace users. As part of this process, information sharing between the partners is essential, so that all possible outcomes can be considered. Table 3 lists the partners for collaboration and information sharing as well as the expected role of the partners. The final decision (i.e., the location of horizontal/vertical airspace volcanic ash contamination boundaries) will depend on agreed upon guidelines that may vary depending on the size and scope of the volcanic event, but efforts should be made to ensure that the authority for the final decision concerning volcanic ash information resides with the designated Primary VAAC, otherwise the final output (e.g., forecast) may lead to inconsistency and hamper effective decision making by ATM and airlines. Once the decision is finalized it can be integrated into ATM decision tools for a CDM process by ATM decision makers and airspace users.

One of the challenges for the IAVWOPSG is to establish agreed procedures to support CDAF which have not been defined.

Need to know	Information Sharing	Output from a Collaborative Decision
Location of volcanic ash contamination boundaries.	Share data from ground, air, and space observing platforms	Current horizontal and vertical extent (perimeter) of volcanic ash contamination to be used in decision support systems and forecast products.
How the volcanic ash boundaries are changing and where will they be in the future.	Share various outputs of dispersion models	Forecast horizontal and vertical extent of the volcanic ash contamination and produce seamless products
If provided and available, multiple contours of ash contamination	Share various outputs of dispersion models	Forecast horizontal and vertical extent of multiple contours of ash contamination

Table 2. Collaborative decisions for volcanic ash cloud information

[14] IVATF Recommendation 4/18, IAVWOPSG Conclusion 7/21 refers.

Partners	Role
Primary VAAC	Produces preliminary forecast and shares with rest of partners. Considers input and suggested changes from participating partners. Has the final decision on the forecast after considering information and input from partners.
Other VAAC(s)	Shares new information with participating partners. Reviews preliminary forecast and provides suggested changes.
VO(s)	
MWO(s)	
State's NMHS	
University or Research Centers (dispersion modeling)	
Others (TBD), e.g., operators	Share information.

Table 3. Partners for the collaboration and information sharing and expected roles

3.1.2 Increase the use of the aviation color-code alert system and provision of VONA by State VOs

Not all State VOs issue a VONA, which provides a concise statement describing the activity at the volcano, as well as the specific time of the onset and duration of the eruptive activity. VONAs also contain a color code (see 2.1.1). As a form of "best practice", this roadmap recommends that all State VOs use the VONA and its aviation color-code alert system for the provision of volcano information.

3.1.3 Develop confidence levels to aid decision makers as part of their safety risk assessment

In February 2012, the IATA met with the VAACs and discussed their need for levels of confidence in the volcanic analyses and forecasts (i.e., VAA/VAG). These confidence levels would be used or translated into the risk assessment conducted by operators to best determine the aircraft flight route or track.

The VAAC practices for presentation of 'confidence' must be consistent and be a well understood process to ensure a harmonized regional interoperability within the operator's risk assessment process. Development of guidance material should be conducted in parallel with the development of the presentation of confidence.

Development of confidence levels are considered to be a key factor in improving the quality of information provided which will aid in the decision making process as part of an operators safety risk management plan.

3.1.4 Improve ground-based, air-based and space-based observing networks to determine ESP

Observation and forecasts information on volcanic ash will require continued improvement of observational capabilities globally, including volcano-monitoring networks, ground-based aerosol networks, satellite platforms and sensors, and airborne sampling.

3.1.5 Scientific research in support of reducing risks from volcanic ash hazards including understanding the impact of ash on aircraft and engines and the provision of enhanced guidance to operators

Scientific research in support of reducing risks from volcanic ash hazards should aim for tangible improvements in the detection and measurement of volcanic plumes and ash clouds during eruptions and in the accuracy of model forecasts of ash transport and dispersion. Research topics (both new and on-going) pertinent to these goals include the following:

- Characterizing volcanic plumes at/near the source
- Understand the evolution of volcanic ash and gas clouds in time and space
- Verification of the model forecasts

In addition,

- Develop an understanding of the impact of ash on aircraft and engines and provide enhanced guidance to operators
- Scientific research to support service delivery for volcanic ash hazard risk reduction

Since 2010 manufacturers have continued work on developing their understanding of the impact of volcanic ash. This will continue through a number of initiatives including involvement of the major manufacturers in the National Aeronautics and Space Administration (NASA) and United States Air Force (USAF) Vehicle Integrated Propulsion Research (VIPRIII) test programme and coordination between manufacturers through the International Coordinating Council of Aerospace Industries Associations (ICCAIA) Volcanic Ash working group. As this knowledge and understanding increases enhanced guidance to operators will be provided where possible.

Further description and discussion regarding research is detailed in Working Paper 14 from the fourth meeting of the IVATF.

3.2 Changes intended within 2018-2023:

Changes intended within the timeframe of 2018-2023 (i.e., Block 1 timeframe) to support Module B*1-AMET (Enhanced Operational Decisions through Integrated Meteorological Information)* are:

- Enhance the provision of SIGMETs in support of operational decisions
- Transition to all digital format for all volcanic ash information

- Further develop ATM for operations in or close to areas of volcanic ash
- Increase the VAA/VAG issuance frequency and time steps
- Provide additional information which reflects the forecast of volcanic ash beyond 18 hours
- Continued improvement in ground-based, air-based and space-based observing networks to determine ESP
- Continued scientific research in support of reducing risks from volcanic ash hazards

3.2.1 Enhance the provision of SIGMETs in support of operational decisions

A large volcanic ash cloud over congested, multi-States areas such as Europe could result in multiple SIGMET information messages, all being in effect at the same time. Each of these SIGMETs becomes a part of a jigsaw puzzle for the user to assimilate, in order to obtain a good understanding of the entire area of the volcanic cloud. As a result the International Air Transport Association (IATA) has stated that they have strong preference for the VAA vs. the SIGMET, i.e., that is one message covering a large region.

Since SIGMETs are, in most cases, based on the first portion of a VAA, that portion of the VAA/VAG could technically be elevated in status to serve as a SIGMET. Making the VAA/VAG's first six-hour portion (i.e., T+0 and T+6 hour) equivalent to the SIGMET would reduce the information overload experienced by users (pilots, operators, etc) who must currently track dozens of SIGMETs for their particular flight in congested areas.

Under today's operations each MWO is responsible for the provision of a SIGMET for their FIR in support of defining the location and forecast position of the ash cloud. However, many MWOs do not have the skill to provide this service and are dependent on the VAAC for this information via the VAA. Some MWOs have more advanced skill levels to provide value input. In those cases the MWO should coordinate with the VAAC and advise the VAAC that the information provided in the VAA is not necessarily reflective of conditions in their FIR. With the proposal to support CDAF this divergence of information should be minimized where the information provided in the VAA is consistent with the SIGMET or vice versa. If achievable this then begs the issue on whether there is a need to retain both products but rather provide a single high quality product to the operator and ANSP in support of integration of MET information into air traffic flow management (ATFM) systems for the routing of aircraft away from a hazard.

Proposed SIGMET enhancements are:

- The first six-hour portion of the VAA (i.e., T+0 and T+6 hour) is equivalent to the SIGMET for a volcanic ash cloud (with validity for one or more FIRs)
- MWOs should participate in the CDAF process and share information with the VAAC to ensure the VAA reflects the conditions in their FIR

- SIGMET *Information* messages should only be issued by a MWO for those cases where the VAA is not yet available or the VAA does not reflect the conditions in the FIR even after the CDAF process.

It is noted that IATA has formulated a set of requirements which were presented to the VAAC Best Practices Seminar of 12-13 June 2012 and expanded upon at IAVWOPSG/7. Those requirements will be considered in this enhancement process taking into account the issues of sovereignty, cost recovery and collaborating procedures among related States.

3.2.2 Transition to all-digital format for all volcanic ash information

Today's volcanic cloud products are primarily text-based (e.g., SIGMET information message), with some supplementation of graphic-based products (e.g., VAG). Future volcanic cloud information must be provided in a digital format in order to better serve aviation users and decision makers. The visualization of volcanic information must be capable of being displayed on moving maps, cockpit displays, radar screens, etc.

The IAVWOPSG, recognizing the need for digital information, formulated Decision 7/25 which calls for the development of a digital format of the VAA/VAG in an XML/GML format for implementation with Amendment 77 to Annex 3 – *Meteorological Service for International Air Navigation.*

The transition from text and graphic-based products to all-digital formats will take time, as there will continue to be a need for legacy text-based products for several years, especially in certain regions of the world.

3.2.3 Further develop ATM for operations in or close to areas of volcanic ash

In an effort to increase information exchange between ATM and operators, make available to affected ANSP's the outcomes of the operators risk assessment for their consideration, especially where applicable to ATFM.

3.2.4 Increase VAA/VAG issuance frequency and time steps

Operators need frequent updates of volcanic ash information especially in congested airspace and around constrained airports. The current VAA/VAG with its 6-hourly issuance and 6-hour time steps does not meet those needs.

The VAA/VAG presenting levels of certainty should be developed to include three hourly time-step information. There is a need to have the capability to increase the frequency of VAA/VAG for pre-defined operational conditions. This would be when ash is present in congested airspace and around capacity constrained airports.

3.2.5 Provide additional information which reflects the forecast of volcanic ash beyond 18 hours

Operators at IAVWOPSG/7 expressed an interest in having volcanic ash information beyond the current practice of T+18 hours for long-haul flight planning and management of airline operations. While it is understood that today's numerical models provide information for various meteorological elements out to several days, providing volcanic ash information beyond T+18 hours introduces a number of uncertainties into the forecast as a result of unknown or uncertain source terms and meteorology as well as inaccuracies in the physics of the dispersion/transport models. With this understanding, the goal is to provide additional information which can realistically reflect the forecast of volcanic ash beyond 18 hours.

3.2.6 Continued improvements in ground-based, air-based and space-based observing networks to determine ESP

Improvements to volcano-monitoring networks, ground-based aerosol networks, satellite platforms and sensors, and airborne sampling will continue in Block 1, building on the accomplishments from Block 0.

3.2.7 Continued scientific research in support of reducing risks from volcanic ash hazards

Scientific research in support of reducing risks from volcanic ash hazards will need to continue in Block 1 and build upon the area and topics listed in section 3.1.5.

3.3 Changes intended within the time frame of 2023-2028

Changes intended within the time frame of 2023-2028 (i.e., Block 2 timeframe), which is an extension of ASBU Block 1, to support Module B*1-AMET (Enhanced Operational Decisions through Integrated Meteorological Information)* are:

- Develop volcanic ash nowcasts
- Develop volcanic ash forecasts that include the use of probability

3.3.1 Develop volcanic ash nowcasts

Users need to know the current location of the volcanic ash. The VAA/VAG and SIGMET provide information about the ash at T+0, but these products are issued every six hours, thus at two hours after T+0, users must do some kind of interpolation between T+0 and T+6 to obtain an estimate of where the ash contamination boundary lies. Providing VAA/VAG at three hour time-steps will help this issue, but more can be done with the transition to a digital information data base for meteorological information, as part of the ASBUs, including volcanic ash.

In the Block 2 timeframe, it is foreseen that a three-dimensional representation of the current or near-current volcanic ash contamination boundaries, known in this document as a "nowcast", could be made available and extracted by the user. Nowcasts would be updated at a high frequency and provide a more realistic assessment of the location and extent of the ash cloud.

3.3.2 Develop probabilistic volcanic ash forecasts

Current volcanic ash forecasts, such as the VAA/VAG, are deterministic forecasts. They are a yes/no forecast, with respect to the depiction of the airspace impacted by volcanic ash contamination. These forecasts are based on the definition of "discernible ash" as a fundamental criterion.

Volcanic ash transport and dispersion models can produce an array of solutions (e.g., forecasts) by varying the model input. Changes in meteorological parameters and ESP will result in different forecast outputs that affect the 4-dimensional shape (3-dimensional shape and change of shape with time) of the cloud. The purpose of a probabilistic forecast is to provide decision makers with an assessment of all the likelihoods of a weather parameter's risk of occurrence exceeding a defined magnitude. Probabilistic forecasts help multiple decision makers use the same weather information, applying their own operational constraints to determine risk to their operation. Section 5.2 identifies those functions that could be provided in deterministic and probabilistic terms.

From a high-level perspective, probability forecasts may be based on an ensemble approach. An ensemble is one way to account for some degree of uncertainty. For instance, the model can be run many times, each time with a realistic variant of one of the uncertain parameters (e.g. ash amount, ash column height, eruption start time and duration, input meteorology dataset, with and without wet deposition, etc.). Taken as a whole, the variability of the ensemble members' output gives an indication of the uncertainty associated with that particular ash forecast.

The application of probabilistic forecasts will best benefit high-density (congested) traffic areas, where decision makers can benefit from more than just a deterministic forecast. Also, decision support systems can use the probabilistic information to provide route and altitude selections based on user's acceptance thresholds.

For operators to effectively use 'probabilities' for specific time and space within the initial and ongoing risk assessments, a thorough understanding of the output from the VAAC is needed by operators and flight crew.

3.4 Changes intended by 2028 and beyond

Changes intended by 2028 (i.e., Block 3 timeframe) in support of Module B*3-AMET* (*Enhanced Operational Decisions through Integrated Meteorological Information)* are:

- Develop other volcanic derived contaminant forecasts, specifically SO_2
- Integrate volcanic ash forecasts into decision support systems for trajectory based operations

- Develop understanding of the impact of ash on aircraft and engines and provide enhanced guidance to operators
- Incorporate processes and procedures for the use of airborne detection equipment

3.4.1 Develop other volcanic derived contaminant forecasts, specifically sulphur dioxide

While the document has focused on volcanic ash there is strong evidence that there is a need to expand the services to other toxic elements that are typically associated with volcanic eruptions.

During volcanic eruptions, a number of toxic gases may be emitted in addition to ash; these include SO_2, hydrogen fluoride, and hydrogen sulphide amongst many others. Each of these gases has different atmospheric dispersion properties, and so gas clouds may be found coincident or separate from ash clouds. Of these gases, SO_2 is of particular importance as it may be emitted in large quantities and potentially has significant health effects. The documented experience to date of in-flight encounters with sulphurous gases suggests that SO_2 has never been a significant immediate safety hazard to an aircraft or health hazard to its occupants.

Through the work of the IVATF and IAVWOPSG[15], it was determined that ICAO, through an appropriate expert group or groups, should determine a clear meteorological/atmospheric chemistry requirement (such as a critical level of SO_2 in the atmosphere that would be observed or forecast) that, after passing through the aircrafts ventilation system, could pose a health risk to the aircraft's occupants.

3.4.2 Integrate volcanic ash forecasts into decision support systems for trajectory based operations

One of the key elements in Module B*3-AMET* of the ASBUs is the integration of meteorological information into decision support systems. Future ATM decision support systems need to directly incorporate volcanic ash nowcasts and forecasts, allowing decision makers to determine the best response to the potential operational effects and minimize the level of traffic restrictions. This integration of volcanic ash nowcasts and forecasts, combined with the use of probabilistic forecasts to address uncertainty, reduces the effects of volcanic ash on air traffic operations.

3.4.3 Development of index levels for ash tolerances

Different aircraft and engine designs may be affected differently by volcanic ash. For example, modern turbofan engines ingest large volumes of air and their turbines run hotter than the melting point for volcanic ash constituents. They typically utilize exotic turbine component coatings that can be affected by volcanic aerosols such as sulfates and chlorides. They also use turbine nozzle cooling and blade cooling with passages that are vulnerable to ash blockage. Older turboprop or turbofan engines typically do not have these same features and have

[15] IAVWOPSG Conclusion 7/34 and Decision 7/35 refers.

different vulnerabilities. These design and operational differences can significantly affect the engine's susceptibility to volcanic ash.

In the longer term the development of a volcanic ash index for ash tolerances of various types of engine/aircraft combinations may allow operators and ATM to take advantage of quantitative volcanic ash forecasts. It should be recognized that this may not be feasible due to the extensive testing and evaluation required to adequately cover the range of aircraft and engines in service.

3.4.4 Develop processes associated with airborne detection equipment

To allow operators to take advantage of tactical on-board volcanic ash detection equipment, ATM processes and procedures will need to be developed and incorporated into ATM Contingency Plans.

4.0 Proposed Roadmap

The proposed way forward will involve all the changes described in Section 3 above.
Specifically:

Through 2018:

- Incorporate collaborative decisions and information sharing into volcanic ash cloud analyses and forecasts
- Increase the use of the aviation color-code alert system and provision of VONA by State VOs
- Develop confidence levels to aid decision makers as part of their safety risk assessment
- Improve ground-based, air-based and space-based observing networks to determine ESP
- Scientific research in support of reducing risks from volcanic ash hazards including understanding the impact of ash on aircraft and engines and the provision of enhanced guidance to operators

2018-2023:

- Enhance the provision of SIGMETs in support of operational decisions
- Transition to all digital format for all volcanic ash information
- Further development of ATM for operations in or close to areas of volcanic ash
- Increase the VAA/VAG issuance frequency and time steps
- Provide additional information which reflects the forecast of volcanic ash beyond 18 hours
- Continued improvements in ground-based, air-based and space-based observing networks to determine ESP
- Continued scientific research in support of reducing risks from volcanic ash hazards

2023-2028:

- Develop volcanic ash forecasts that include the use of probability
- Develop volcanic ash nowcasts

2028 and beyond:

- Develop other volcanic derived contaminant forecasts, specifically SO_2
- Integrate volcanic ash forecasts into decision support systems for trajectory based operations
- Development of index levels for ash tolerances
- Incorporate processes and procedures for the use of airborne detection equipment

4.1 Assumptions and Constraints

The proposed concept is based on the following assumptions:

- IAVW retains global legal mandate for volcanic ash service delivery
- The first six-hour forecast from the VAA (i.e., T+0 and T+6 hour) can be used equivalent to a SIGMET
- Probabilistic forecasts can be utilized by aviation decision makers
- Probabilistic forecasts are best suited for users in congested airspace, but can also beneficial for users in uncongested airspace
- Before a probability can be derived from an ensemble, there Is a need to "calibrate" the ensemble, as the number of elements in a "cluster" is not necessarily a reliable measure of probability if the variations of the initial states and ESP's are not driven by a scientifically sound selection principle
- Index levels for volcanic ash tolerances can be developed
- Continuing user demand for phenomena based information rather than FIR based information

The following constraints may impede the implementation of the proposed concept:

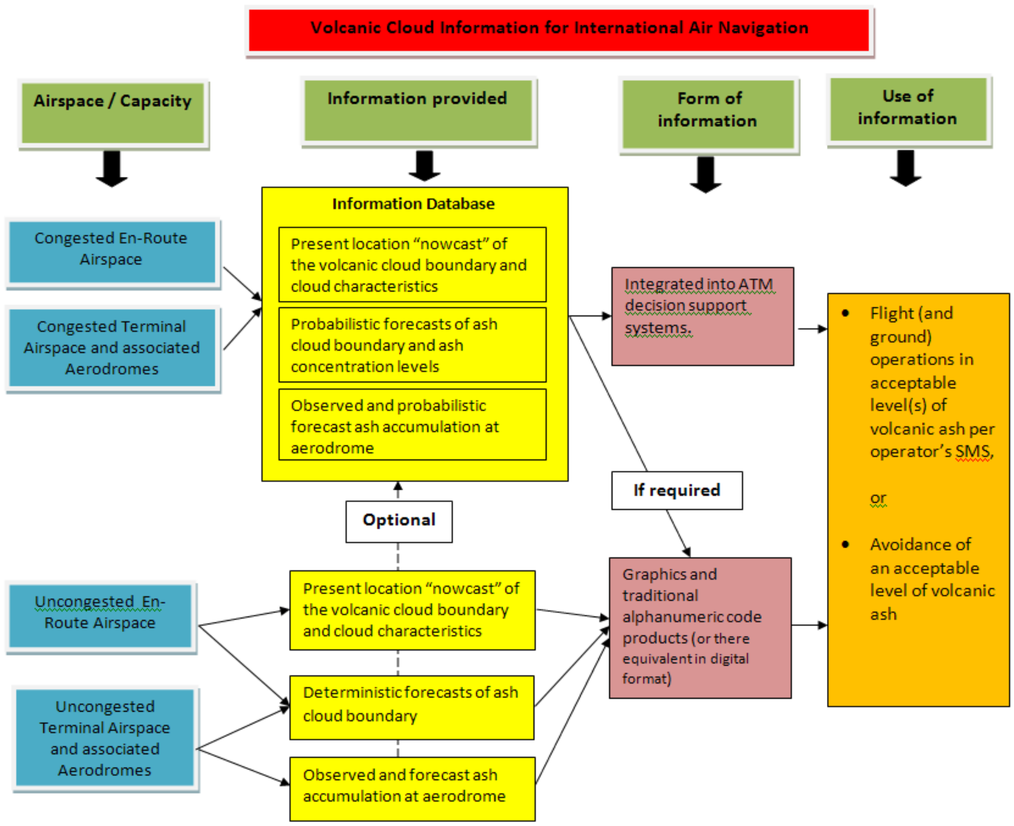
- The development of certifiable volcanic ash tolerances may take many years, or may not be feasible or beneficial to operators (if by 2028 the development is not possible then further work will be done to improve the avoidance of ash)
- Some States may not accept the VAA as equivalent to the SIGMET due to legal and political issues

4.2 Operational Environment

By 2028, volcanic cloud information will reside on a common information sharing platform and be part of the System Wide Information Management (SWIM) concept in support of global ATM.

4.3 Operations

Operations during a volcanic event depend on the information available as well as a function of



classification of airspace that being high density (congested) airspace versus low density (uncongested) airspace.

Nowcasts and deterministic forecasts may adequately serve the users of airspace that is not congested, and offers ample options for volcanic ash avoidance without great fuel penalties for the operator. But for congested airspace, the provision and use of probabilistic forecasts of the volcanic ash could be beneficial in order to achieve maximum efficiency of the air traffic system.

Figure **3** provides a high level schematic of meteorological service per airspace capacity. It should be noted that the provision and use of probabilistic forecasts is not restricted or limited to congested airspace, rather the "optional' block in Figure 3 denotes that operators in uncongested airspace, e.g., oceanic User Preferred Routes (UPR), can take full advantage of these forecasts.

Figure 3. Operations concept using volcanic cloud information per airspace capacity. Note that the "optional" box indicates that the Information Database and its probabilistic forecasts are available for users of uncongested airspace.

4.4 Supporting Infrastructure

In Blocks 0 through 2, the information on volcanic ash will continue to be product centric and be produced by humans in traditional alphanumeric text along with a graphical image. Production of these products will inevitably migrate from the MWOs to the VAACs.

In the Block 3, all relevant information on the volcanic clouds will reside on a common information sharing platform.

4.5 Benefits to be realized

The proposals for volcanic cloud information to be developed and implemented as noted in sections 3.1, 3.2, and 3.3 will provide users with volcanic ash information that has greater confidence and usability. Moving from a product centric environment to an information centric environment will meet the future operational needs of aviation decision-makers. Also, decision support systems can use the probabilistic information to provide route and altitude selections based on user's acceptance thresholds. The integration of volcanic cloud forecasts, combined with the use of probabilistic forecasts to address uncertainty, will lead to more effective and informed decision making and planning for air traffic operations. Finally, if feasible, the development of a volcanic ash index for ash tolerances for various types of engine/aircraft combinations may allow operators and ATM to take advantage of volcanic ash concentration forecasts.

5.0 Needs and Goals

5.1 Operational Needs

The following is a set of high-level operational needs[16] of aviation users for trajectory based operations in support of international air navigation:

- Determine the onset of a volcanic event (i.e., eruption)
- Determine if an eruption and any associated volcanic ash are a hazard to international air navigation based on any agreed threshold values of mass concentration
- Determine what aerodromes and airspace are affected by the eruption and associated cloud
- Determine when the eruption has ended
- Determine when the volcanic ash has dispersed below agreed threshold values
- Determine when the aerodrome/airspace affected by the eruption and/or cloud is safe to operate in or through
- Determine the cost of the event and stakeholder satisfaction

[16] As determined by the author based on information from users at ICAO's IVATF.

5.2 Functional Goals

Table 4 lists a set of functional goals for volcano eruption and volcanic cloud information based on different types of airspace and aerodrome densities (i.e., capacity or congestion). An “X” in the table’s cell indicates that this function is needed for this airspace and aerodrome. A “P” or “D” indicates whether the forecast function is Probabilistic or Deterministic. A “D, P” indicates that both are provided.

Future Functional Goals for Volcano Eruption and Volcanic Cloud Information		Route operations		Terminal control area (TMA) operations		Aerodrome	
		Congested (high density)	Un-congested (low density)	Congested (high density)	Un-congested (low density)	High density	Low density
Volcano Eruption							
Detect an Eruption in all kinds of meteorological and day/night conditions (i.e., including tropical regions where convective activity is common)		X	X	X	X	X	X
Determine the height of the eruption plume		X	X	X	X	X	X
Determine the duration of the eruption		X	X	X	X	X	X
Detect, determine and report the heightened volcanic activity (pre-eruption)		X	X	X	X		
Volcanic Cloud							
Determine the perimeter, top and base of the volcanic cloud in all kinds of meteorological and day/night conditions		X	X	X	X		
Determine when the “volcanic cloud” is a hazard due to:	Ash	X	X	X	X	X	X
	SO2	X	X	X	X	X	X
	Electro-magnetic risks to avionics	X	X	X	X	X	X
	Other (TBD)						
Determine the perimeter of the lowest acceptable ash contamination level (ash cloud)		X	X	X	X	X	X
Determine the perimeter of the gaseous cloud		X	X	X	X	X	X
Determine the eruption source parameters		X	X	X	X	X	X
Forecast the perimeter of the lowest acceptable ash contamination level (ash cloud)		D, P	D, P	D, P	D	P	D
Forecast the top and base height of the lowest acceptable ash contamination level (ash cloud)		D, P	D, P	D, P	D	P	D
Forecast the movement of the lowest acceptable ash		D	D	D	D		

Future Functional Goals for Volcano Eruption and Volcanic Cloud Information						
	Route operations		Terminal control area (TMA) operations		Aerodrome	
	Congested (high density)	Un-congested (low density)	Congested (high density)	Un-congested (low density)	High density	Low density
contamination level						
Forecast the growth and decay of the lowest acceptable ash contamination level (ash cloud)	D, P	D, P	D, P	D		
Forecast the location of the gaseous cloud	D, P	D, P	D, P	D	P	D
Forecast the top and base height of the gaseous cloud	D, P	D, P	D, P	D	P	D
Forecast the movement of the gaseous cloud	D, P	D, P	D, P	D		
Forecast the growth and decay of the gaseous cloud	P	D, P	P	D		
Determine when the volcanic cloud is no longer a hazard	X	X	X	X		
Determine when the volcanic cloud is hidden or mixed with clouds, especially cumulonimbus clouds and cirrus clouds	X	X	X	X		
Forecast when the volcanic cloud is hidden or mixed with meteorological clouds	P	D, P	P	D		
Volcanic Ash Accumulation						
Determine the ash accumulation at the aerodrome					X	X
Forecast the ash accumulation at the aerodrome					D, P	D

Table 4. Future functional goals for volcano eruption and volcanic cloud information

6.0 Operational Scenarios

Two kinds of operational scenarios are envisioned, avoidance of the volcanic cloud, and planned flight into a cloud. The information for both scenarios is in the form of nowcasts and forecasts that are integrated into decision support systems.

Nowcasts

The three-dimensional representation of the current or near-current volcanic ash cloud, including depiction of the perimeter of the lowest acceptable level of ash contamination, in a common exchange format that provides integration into decision making tools as well as offers a graphical depiction of the information. In the avoidance scenario, the nowcast provides users with the location of discernible volcanic ash. As the volcanic ash moves or changes, the nowcast is updated at a temporal frequency that meets user needs and service provider capabilities. For flight into acceptable levels of ash, volcano ESP, *in situ* measurements of the airborne volcanic ash (from ground-based, space-based, or airborne-based observing platforms) are required to provide a nowcast that has a high level of confidence of the ash concentration levels inside the cloud.

Forecasts

The four-dimensional representation of volcanic ash, including depiction of the perimeter of the lowest acceptable level of ash contamination, ash concentration levels and indices, in both deterministic and probabilistic terms, in a common exchange format that provides integration into decision making tools as well as offers a graphical depiction of the information. For both scenarios, the forecasts would be valid “X” hours and up to “Y” days, but would contain finer temporal resolution in the near time frame. Forecasts would also be provided in terms of uncertainty (use of probability). For flight into acceptable levels of ash contamination, volcano ESP, quantitative measurements of the airborne volcanic ash (from ground-based, space-based or airborne-based observing platforms), would be needed to enable accurate validation of ash contamination to support airline decision making.

The Collaboration Process

Aligned with the above forecast process is the collaborative decision and information sharing process. In this scenario, collaboration on the nowcasts and forecasts will occur on a regular basis such that all users are afforded the opportunity to contribute information. Information will be shared and could be made available on an information database or web portal that is jointly run by the VAACs.

Civil aviation operators will then apply these new nowcasts and forecasts to their operations specifications per their Safety Management System (SMS) and any specific Safety Risk Assessments (SRA) for any operations other in areas of a volcanic ash cloud.

— — — — — — — —

APPENDIX D

STRATEGY FOR THE FUTURE PROVISION OF INFORMATION ON HAZARDOUS METEOROLOGICAL CONDITIONS

Overall Objective

To develop a high-level strategic statement relating to the provision of information on hazardous meteorological conditions for international civil aviation, covering the period 2014 to 2025.

This strategic statement is expected to support recommended actions concerning aeronautical meteorological service provision arising from ICAO's 12th Air Navigation Conference (AN-Conf/12 held 19 to 30 November 2012), while recognizing that there is a need for shorter term action in some areas to rectify existing deficiencies in the provision of information on hazardous meteorological conditions to international civil aviation.

This strategic statement is intended to support and align with the programme and timing of the aviation system block upgrades (ASBUs)[17] methodology contained in the Fourth Edition (2013) of ICAO's Global Air Navigation Plan (GANP) (Doc 9750-AN/963). The ASBUs provide target availability timelines for a series of operational improvements – technological and procedural – that will eventually realize a fully-harmonized global air navigation system.

Refer: Agreed Action 5/1, Meteorological Warnings Study Group (METWSG), 5th Meeting, Montréal, 20 to 21 June 2013.

Problem Definition

There is a significant and long standing issue regarding deficiencies in some ICAO Regions concerning the provision of SIGMET information and harmonization of such information within the current State meteorological watch office (MWO) flight information region (FIR)-based system[18].

Deficiencies in SIGMET provision is a major concern, particularly given the programmed migration to performance-based air traffic management principles set out in the GANP. The need to provide better meteorological support for the safety and efficiency of international civil aviation is particularly important.

IATA and its member airlines continue to express concern over the safety and efficiency of operations in areas where SIGMETs are rarely, if ever, issued by MWOs.

Some States have a chronic lack of capacity[19] to fully meet their Annex 3 – *Meteorological Service for International Air Navigation* responsibilities. In particular, some smaller developing States have difficulty with SIGMET provision. Some developed States also have significant problems in this area[20]. These

[17] Refer Working document for the Aviation System Block Upgrades, 28 March 2013.

[18] Where a State has accepted the responsibility of providing air traffic services within an FIR (or control area), SIGMET information is to be issued by an MWO concerning the occurrence or expected occurrence of specified en-route weather phenomena which may affect the safety of aircraft operations. Such phenomena include severe turbulence, severe icing and others.

[19] Capacity includes people, expertise and underpinning infrastructure.

[20] The acute lack of capacity of some States to meet many Annex 3 responsibilities regarding SIGMET issuance was emphasised during a SIGMET trial conducted by the METWSG in April to July 2011. This trial was aimed at testing the feasibility of regional SIGMET advisory centres (RSAC) assisting MWOs to issue SIGMETs by providing them with SIGMET advisory information.

difficulties result in particular MWOs not being able to issue SIGMETs in a timely, reliable, or accurate manner.

The problem is not unique to any one State or any one ICAO Region. The issues range from State non-compliance in actually issuing SIGMET, non-functional or non-supportive MWO, through to providing SIGMET in incorrect formats. The problem is compounded with the current FIR-based system of SIGMET provision also presenting co-ordination challenges, particularly over areas with small and irregular FIR boundaries, as well as in those ICAO Regions with many small FIRs.

Furthermore, IATA has noted that inconsistent cessation or change of hazardous meteorological conditions information at FIR boundaries, due to differences in methods and working practices between MWOs, creates significant and expensive flight management issues.

Any remedial developments must therefore align meteorological inputs to the evolving technical capacity of modern airline and aircraft operations and the increasing globalization of the civil aviation industry.

Statement of Strategic Intent

Reflecting its strategic objectives, and in an increasingly competitive business and technically advancing environment, ICAO recognizes:

(a) the increasing demand from international civil aviation users for efficient and effective phenomena-based hazardous meteorological condition information, seamlessly covering the globe in a co-ordinated and harmonized way; and

(b) the limitations, inconsistencies and gaps in the current production of hazardous meteorological conditions information (in the form of SIGMET) required to be produced by each MWO for its associated FIR.

To meet international civil aviation user demands, and make best use of resources (including technology), this strategy proposes to transfer the issue of defined[21] regional hazardous meteorological condition information to appropriately resourced regional centres, supported by respective meteorological watch offices (MWOs) as may be determined, in a three phased approach and in support of the Aviation System Block Upgrades (ASBUs) methodology of ICAO's Global Air Navigation Plan (GANP), as follows:

1.1 **Phase One (2014-2017):** The first phase is the establishment of regional hazardous weather advisory centres (RHWACs) to assist MWOs with the existing provision of SIGMET information in those ICAO Regions in need of such support.

Explanatory note: *Formal planning and development will begin with a mandate from the ICAO Meteorology Divisional Meeting in July 2014. All planning and arrangements will be in place with formal ratification of the scheme expected in Amendment **77** to Annex 3 (with intended applicability in November 2016), and parallel documentation in Regional Air Navigation Plans. The allocated RHWACs will commence operations at a date to be agreed but no later than December 2017.*

1.2 **Phase Two (2016-2020):** The second phase (including the transition of the RHWACs) will cover the centralization of SIGMET-related responsibilities of MWOs to regional hazardous weather centres (RHWCs) supporting multiple FIRs. This may include the amalgamation of existing volcanic ash advisory

[21] Part of the first phase would be the identification of exactly what constitutes hazardous meteorological conditions, excluding the contemporary work of VAACs, TCACs and pending the expected future work of space weather centres.

centres (VAACs) and tropical cyclone advisory centres (TCACs)[22] into these RHWCs, and will include close liaison with users and detailed definition of all products to be supplied by the new centres.

Explanatory note: *Formal planning and development will begin in 2016 with the completion of planning for Phase 1. All planning and arrangements will be in place with formal ratification of the scheme expected in Amendment **78** to Annex 3 (with intended applicability in November 2019), and parallel documentation in Regional Air Navigation Plans. Planning will include the development of suitable RHWC performance metrics to support Phase 3. The allocated RHWCs will commence operations at a date to be agreed but no later than December 2020.*

1.3 **Phase Three (2020-2024):** This phase primarily covers the review of the performance of the regional hazardous weather centres, making any appropriate recommendations in this regard. The review will also include, inter alia, an evaluation of the efficacy, or otherwise[23], of consolidating, in a further phase (potentially a Phase Four), hazardous meteorological condition information issued from a few centres conjointly covering the globe[24], in or after 2025.

Explanatory note: *The review will be undertaken in 2023 using performance data compiled for the years 2020 – 2022 inclusive. The review will include evaluation of operations, modelling, logistics, communications and science capability. A final report and recommendations will be provided by the end of 2023. If recommended, a reduced number of regional centres, or a few centres conjointly covering the globe, could be operating in 2025 if mandated in Amendment **80** to Annex 3 (with intended applicability in November 2025). It is noted, however, that any highly significant recommendations from this review process may need to go an ICAO Meteorology Divisional meeting around 2025/2026 for ratification, delaying implementation of any significant changes until after about 2026.*

1.4 **Note**

Notwithstanding the strategic approach outlined above, and in accordance with Annex 3, Chapter 2, States can enter into bilateral arrangements at any time to obtain the support they may need to fulfil their MWO obligations with regard to SIGMET provision. As an interim arrangement, while Phase One of the strategy is implemented, such action is encouraged.

Supporting Considerations

This section references the areas of consideration taken into account in the derivation of the statement of strategic intent for the future provision of information on hazardous meteorological conditions.

1.5 ICAO Strategic Objectives

ICAO has established three strategic objectives for years 2011, 2012 and 2013:

(a) Safety: Enhance global civil aviation safety.

(b) Security: Enhance global civil aviation security.

(c) Environmental Protection and Sustainable Development of Air Transport: Foster harmonized and economically viable development of international civil aviation that does not unduly harm the environment.

In years 2014, 2015 and 2016 the number of strategic objectives of ICAO will increase to five. Ten key air navigation policy principles[25] are contained in the GANP, intended to guide global, regional and State air navigation planning consistent with ICAO's strategic objectives.

1.6 General Considerations

[22] VAACs and TCACs have been operating successfully in a regional capacity for the past several decades.

[23] It is accepted that the review may recommend slowing, delay, or postponement of further consolidation.

[24] There is a high level expectation of IATA for a better global hazardous weather scheme than exists today, consisting of only a few regional centres conjointly covering the globe, to be fully assessed and implemented in the mid-term.

[25] Refer Doc 9750-AN/963 — 2013-2028 Global Air Navigation Plan.

Those aspects contributing to the derivation of this document, not covered elsewhere, are:

(a) Identification of hazardous meteorological conditions best managed in a consolidated manner;

(b) Utilization of information within the envisaged data-centric environment[26] as part of the system wide information management (SWIM) concepts.

(c) Need for evaluation of cost recovery schemes to support regional centres.

(d) Need for evaluation of relevant airspace sovereignty, liability, and obligations of States - noting the range of political perceptions of regional and global change.

(e) Need to ensure robust implementation of quality management system (QMS) and safety management system (SMS) principles and requirements in any new system.

1.7 **Discussion**

Article 28 of the ICAO Convention on International Civil Aviation (Doc 7300) and Annex 3 to that Convention defines meteorological services in support of international air navigation. Over the past six decades, amendments of Annex 3 have been largely centred on meteorological observations and forecasts rather than the nature of the underlying global systems structures.

In the 1980s the international community recognized technological advances and user demand changes (for example, increasing long-haul flights) with the establishment of the world area forecast system (WAFS). The WAFS initially provided global wind and temperature data with planning for significant weather forecasts (as currently provided). In the final phase of WAFS implementation, the WAFS replaced regional area forecast centres (RAFC) which had provided regional forecasts within their defined area of responsibility, operating within the limits of technology and communication networks of the times. The development of the WAFS hinged on global modelling capabilities, the advent of satellite remote sensing techniques, and satellite broadcast of WAFS products to States/users across the globe.

Other changes reflected this on-going development of international civil aviation. An example is the removal of the two-hour rule that restricted dissemination of METAR/TAF reports within a two-hour flying distance from the aerodrome. Just as it was recognized that this two-hour rule was obsolete then, the international civil aviation community recognizes now that future systems and the nature of meteorological information will need to meet new and different requirements within new and different contexts.

Reflecting this perspective, the future vision for aeronautical meteorological service practices was covered at the AN-Conf/12.

The international civil aviation community understands that meteorological conditions are not restricted to the boundaries of a flight information region (FIR) and that there is a need to provide a harmonized assessment of meteorological conditions irrespective of FIR boundaries. This perspective became most apparent in recent years with the provision of volcanic ash information; where there was a lack of information on the location of the hazard in some areas compounded by occasional inconsistency of information from different providers, covering adjacent areas. Within the international airways volcano watch (IAVW) these deficiencies have been well documented, with a wide array of remedial system changes implemented or being implemented. However, the international community has not yet

[26] Including inter-alia the achievement of a robust global network based on the principles of Service Oriented Architecture (SOA).

implemented the necessary system and product changes needed for other hazardous meteorological conditions.

If States are to respond to user demands for the provision of better aeronautical meteorological services, there is a need to change how these services are provided in support of the vision provided at the AN-Conf/12. For example, if States fail to recognize these changes, operators may look to other sources to obtain the necessary information to support their performance based operations. While it is recognized that fundamental services must continue to be provided by States, there is a need to identify which services belong to the State to support operations within their FIR, and which services are required for situations where meteorological conditions are transparent to FIR boundaries

1.8 Working Relationships

To ensure the success of the strategic plan there is a need to develop a co-ordinated working relationship with various organizations, service providers and users of services that includes but not necessarily defines all the stakeholders, including:

- WMO — World Meteorological Organization.
- IATA — International Air Transport Association.
- CANSO — Civil Air Navigation Services Organisation.
- IFALPA — International Federation of Airline Pilots' Associations.
- IFATCA — International Federation of Air Traffic Controllers' Associations.
- ISO — International Organization for Standardization.
- States in general (States in need of assistance, States able to host RHWACs, States likely to be able to provide other assistance, VAAC and TCAC host States)
- ICAO Regional offices.
- Particular States with capability and capacity to serve as a regional centre.

Discussion on Implementation

Consideration will be needed as to the assignment of an expert group to manage the process. This group may need to have overall management responsibilities for the system, reporting on a regular basis to the Secretariat or to the Air Navigation Commission (ANC). Its work will need to include the implementation of appropriate funding systems.

It is recognized that States will continue to have an important role in support of the operation of the intended regional hazardous weather centre concept. States will need to:

(a) ensure that they provide, through their respective MWOs and requisite communications systems and protocols , local information[27] including special air-reports to the regional hazardous weather advisory centres, and eventually the regional hazardous weather centres, in a timely fashion;

(b) continue to provide so-called flight following services through their respective MWOs, including the relay as appropriate of hazardous meteorological conditions information, monitoring of the

[27] Local information includes data and information from any remote sensing and satellite reception capabilities not directly accessible by the Regional Centres.

regional hazardous weather advisory centres and eventually the regional hazardous weather centre products with formal routine and special feedback to the centres[28];

(c) where possible, provide routine evaluation of the hazardous weather information provided by the regional centres; and

(d) continue to undertake the specified tasks required in the volcanic ash advisory and tropical cyclone advisory schemes.

MWOs would continue with all other specified requirements as currently set out in Annex 3.

In implementing the strategy care needs to be taken to ensure the voice of all States is represented on the referred expert group. In this regard, it is suggested that there be particular representation from a State or several States in each ICAO Region, and service provider and user representative bodies to supplement the expertise required (including WMO experts). The experience and capabilities of States involved in the development and operation of TCAC, WAFC and VAAC responsibilities should also be represented on the expert group either through membership and/or defined relationships.

— — — — — — — —

[28] Routine feedback to the Regional Centre would include the routine provision of validation and complementary real-time information. Special feedback would include real-time quantitative and qualitative advice on specific quality matters with regard to the Regional Centre products.

APPENDIX E

PLAN FOR THE COST RECOVERY AND GOVERNANCE SUPPORTING REGIONAL HAZARDOUS WEATHER ADVISORY CENTRES

Overall Objective

To develop a plan for the future governance and equitable cost recovery of a regional SIGMET advisory system for hazardous meteorological conditions for international civil aviation.

This plan and associated discussion is expected to support recommended actions concerning aeronautical meteorological service provision arising from ICAO's 12th Air Navigation Conference (AN-Conf/12 held 19 to 30 November 2012), and, importantly, the strategic statement relating to the provision of information on hazardous meteorological conditions to international civil aviation from regional advisory centres.

This paper details some of the issues relating to the future governance and cost recovery arrangements of the regional hazardous weather advisory centres (RHWAC) and provides an initial plan for development to assist discussion at the forthcoming Meteorology (MET) Divisional Meeting in July 2014.

The plan is intended to support and align with the programme and timing of the aviation system block upgrades (ASBUs)[29].

Refer: Agreed Action 5/3, Meteorological Warnings Study Group (METWSG), 5th Meeting, Montréal, 20 to 21 June 2013.

Problem Definition

Strategy Linkage

The concurrent strategic paper on the Future Provision of Information on Hazardous Meteorological Conditions (deriving from the Agreed Action 5/1, METWSG, 5th Meeting) sets out that there is a significant and long standing issue regarding deficiencies in some ICAO Regions concerning SIGMET provision and harmonisation within the current State Meteorological Watch Office (MWO) flight information region (FIR)-based system.

Some States have a chronic lack of capacity[30] to fully meet their Annex 3 – *Meteorological Service for International Air Navigation* responsibilities. In particular, some smaller developing States have difficulty with SIGMET provision. Some developed States also have significant problems in this area[31]. These difficulties result in particular MWOs not being able to issue SIGMETs in a timely, reliable, or accurate manner.

A three phased remedial strategy is proposed in response to long voiced concerns from users (IATA and others) regarding the safety and efficiency of operations in areas where SIGMETs are rarely, if ever, issued for hazardous meteorological conditions.

Key Issue

---

[29] ASBUs methodology contained in the Fourth Edition (2013) of ICAO's Global Air Navigation Plan (GANP) (Doc 9750-AN/963). The ASBUs provide target availability timelines for a series of operational improvements – technological and procedural – that will eventually realize a fully-harmonized global air navigation system.

[30] Capacity includes people, funding, expertise and underpinning infrastructure.

[31] The acute lack of capacity of some States to meet many Annex 3 responsibilities regarding SIGMET issuance was emphasised during a SIGMET trial conducted by the METWSG in April to July 2011. This trial was aimed at testing the feasibility of regional SIGMET advisory centres (RSAC) assisting MWOs to issue SIGMETs by providing them with SIGMET advisory information.

There is currently no specific guidance or systems available through ICAO and WMO to assist in the funding or governance of regional centres providing advisory services on hazardous meteorological conditions.

The Plan

In direct relation to the *Statement of Strategic Intent* in the concurrent paper, *Future Provision of Information on Hazardous Meteorological Conditions*:

Assign an ICAO Expert Group by September 2014

The first objective will be to assign an ICAO expert group to have overall management responsibilities for developing the RHWAC scheme. The expert group would report on a regular basis to the Secretariat or directly to the Air Navigation Commission (ANC). Its work will need to include:

(a) the development and implementation of permanent governance arrangements by mid-2015; and

(b) the development and implementation of appropriate funding systems by mid- 2015.

The voice of key States should be represented on the expert group. In this regard, it is suggested that there be particular representation from a State or several States in each ICAO Region, and service provider and user representative bodies to supplement the expertise required (including WMO experts). The experience and capabilities of States involved in the development and operation of tropical cyclone advisory centre (TCAC), world area forecast centre (WAFC) and volcanic ash advisory centre (VAAC) responsibilities should also be represented on the expert group either through membership and/or defined relationships. The ICAO Secretariat will need to ensure that relevant ICAO financial and economic expertise is available (such as from within the Air Transport Bureau).

Develop and Implement Governance Arrangements by mid-2015

In developing robust governance arrangements, the expert group will need to consider, taking into account those matters considered in this paper:

(a) all technical management issues in establishing the RHWACs;
(b) establishment of formal governance processes within the ICAO framework, documentation and reporting;
(c) product validation/verification processes and routine assessment and reporting; and
(d) financial management relationships, accounting and reporting procedures.

Develop and Implement of Appropriate Funding Systems by mid-2015

In developing robust funding systems, the expert group will need to consider taking into account those matters considered in this paper:

(a) all possible alternatives, including those set out in this paper;
(b) current cost recovery systems and guidance from both ANSPs and NMHSs that cover FIRs outside respective State territories;
(c) extensive consultation and discussion with key stakeholders and possible third party assistance (for example, World Bank, Regional Development Banks);
(d) the most expeditious method for accounting, reviewing and reporting on revenue and allocation to the RHWACs; and
(e) the most expeditious method for RHWACs to report financial estimates, budgets and financial performance.

Complete all arrangements by the end of 2015
The target for ensuring good governance and funding systems are in place is the end of June 2015. It is expected that this will enable the first RHWACs to be established on a firm foundation within the time-scale set out in the *Statement of Strategic Intent* for regional centres – i.e. by the end of 2015.

As other regional centres are progressively developed they will have an already operating governance and financial system to engage, making the process straight forward and largely of a technical nature.

Background Considerations

This section sets out background information taken into account in the derivation of the plan for funding and governance of the future provision of advisory information on hazardous meteorological conditions.

ICAO Strategic Objectives

ICAO has established three Strategic Objectives for years 2011, 2012 and 2013:

(a) Safety: Enhance global civil aviation safety;
(b) Security: Enhance global civil aviation security; and
(c) Environmental Protection and Sustainable Development of Air Transport: Foster harmonized and economically viable development of international civil aviation that does not unduly harm the environment.

In years 2014, 2015 and 2016 the number of strategic objectives of ICAO will increase to five. Ten key air navigation policy principles[32] are contained in the GANP, intended to guide global, regional and State air navigation planning consistent with ICAO's strategic objectives.

Existing International Guidance

Extensive ICAO guidance on cost recovery is provided in *the Manual on Air Navigation Services Economics* (Doc 9161). This detailed manual sets out the ICAO policy on cost recovery and provides a robust array of perspectives that need to be taken into account in designing cost recovery systems. Appendix 3 of Doc 9161 details the guidance for determining the costs of aeronautical meteorological services. Additionally, ICAO's *Policies on Charges for Airports and Air Navigation Services* (Doc 9082) provides guidance on cost recovery.

WMO provides a *Guide to Aeronautical Meteorological Services Cost Recovery: Principles and Guidance* (WMO Publication No. 904). This publication contains additional information on the principles of cost allocations for National Meteorological Services and other providers of meteorological services to aviation, but currently does not provide guidance on multi-State/multi-FIR based cost recovery mechanisms.

Existing Regional Schemes

At present, within the ICAO framework there are:

(a) nine volcanic ash advisory centres (VAACs) (namely Anchorage, Buenos Aires, Darwin, London, Montreal, Tokyo, Toulouse, Washington and Wellington) as part of the international airways volcano watch (IAVW)
(b) seven tropical cyclone advisory centres (TCACs) (namely Darwin, Honolulu, La Réunion, Miami, Nadi, New Delhi and Tokyo), and

[32] Refer Doc 9750-AN/963 — 2013-2028 Global Air Navigation Plan.

(c) two world area forecast centres (WAFCs) (namely London and Washington) as part of the world area forecast system (WAFS)

In addition, there is the ICAO Satellite Distribution System (SADIS) that provides OPMET information and WAFS forecasts to States/users in the ICAO EUR, AFI, MID and western part of the ASIA/PAC Regions.

With the exception of the SADIS, which has a governance and cost recovery arrangement in place, there are no regional cost recovery arrangements in place for any of the other regional or global centres referred to above.

Currently the IAVW, WAFS and SADIS all have a governance structure in place by way of ICAO operations groups – namely the IAVWOPSG, WAFSOPSG and SADISOPSG – which report to the Air Navigation Commission and/or Planning and Implementation Regional Groups (PIRGs) of ICAO on a routine basis. These operations groups consist of, inter alia, the provider States, States who make use of the services provided, airline users represented by IATA, and flight crew users represented by IFALPA. ICAO provides the Secretariat support for these operations groups.

These operations groups currently meet on a 12- or 18-month cycle and each has a similar agenda that includes:

(a) review of associated regional and/or global ICAO provisions;
(b) operation of the centres or systems;
(c) development of the centres or systems; and
(d) long term development and implementation issues.

WMO arranges for the governance for the TCACs. A technical co-ordination meeting involving all of the TCAC provider States currently takes place once every three years, however a number of regional committees (within the construct of the WMO Regional Associations) take place during the intersession period. There are no airline or flight crew user representatives on these particular WMO groups, however the ICAO Secretariat attends where resources allow.

Known Issues

Each State is responsible for the provision or facilitation, and funding of its meteorological service. Some States contract out the work and rely on those contractors to recover costs through third party mechanisms. Others meanwhile fund service directly from taxes or through air traffic services (ATS) and airspace levies and charges. In many cases, airlines and operators have little input into how the State delivers the service and how it is funded, leading to a general lack of transparency.

Currently States that provide regional and global meteorological centres (such as the TCACs, WAFCs and VAACs alluded to above) have taken responsibility for funding and resourcing. Where cost-recovery takes place, airspace users receiving en-route air navigation services (ANS) within the particular State's FIR(s) may be charged directly by the ATS provider or indirectly through other charging mechanisms bearing on airline operations. There is no international or regionally common scheme for the collection of revenue to support regional and global meteorological centres.

The demands on providing more accurate regional or global forecasts require constant improvements to the provider State's capability. This includes increasingly expensive computing capability for numerical weather prediction (NWP), data post-processing, as well as more sophisticated production software development. In this regard, States providing regional and global meteorological centre operations have generally noted that that there is increasing scrutiny being applied to these costs by operators.

The additional costs of providing such services for aviation can no longer be considered marginal or just a bi-product of the routine activities. Staff resources and infrastructure costs to provide these often complex and demanding services are needed; in addition, they also have to be tested and exercised on a regular basis.

An important aspect for any regional centre is the need to share information with neighbouring States and other centres[33]. Operationally meeting this requirement, let alone the cost, may well be above and beyond what the provider State would be normally be required to undertake if it was not a regional centre.

Generally speaking, airlines/operators overflying the regional centres area of operation but not the provider State FIRs currently do not contribute to the cost of the provision of the particular service. In a regionalised scheme, this highlights that current cost State/FIR-based recovery methodologies would be materially inequitable.

Discussion

Management and Governance

It is considered that similar arrangements of governance to the existing regional and global centres alluded to above could be utilised for the RHWACs - a global group of experts advising ICAO on the operation of the service and its effectiveness in meeting user requirements.

Careful consideration is needed as to the makeup of the ICAO expert group(s) that would oversee the work of the RHWACs, noting the need for a variety of expertise not just in meteorology but airline operations, air traffic management (ATM) and cost recovery. The expert group would need to ensure best practices are developed and shared between the RHWACs.

More local discussions relating to the day-to-day operation of the RHWACs should take place at the ICAO regional MET sub-group meetings (or equivalent) of the PIRGs, since these meetings would also allow States and users within the ICAO Region to have the opportunity to influence the development of the service and to propose changes to the requirements to particular or all RHWACs.

Governance structures must be in place to manage the establishment of the RHWACs. These governance structures (expert group(s)) would need to;

- detail the specific regional requirements (based on global ICAO provisions);
- arrange appropriate user consultation, produce guidance and usability guides for the products being provided;
- set out the performance indicators as agreed with the users;
- detail the meteorological information required from States (for example, observations);
- ensure there is a transparent costing, budgeting and long term investment plan in place;
- assist in the running (or development) of a cost recovery scheme; and
- review of performance, based on the performance indicators.

During implementation, governance could reside with a more local group (for example, a PIRG) that assists the State providing the RHWAC by providing guidance on policy and strategy during its initial operation. However, recognising the need for harmonized practices it is suggested that during the implementation phase a number of best practices workshops are held for the RHWACs.

The alternative is for a global expert group to oversee the establishment of the RHWACs as currently defined and as may be requested by the PIRGs.

[33] Including, for example, pilot reports, satellite information and other observations.

It is noted that users have expressed a need for consistency between RHWACs, one aspect of the governance expert groups is to ensure that the advisory products are provided uniformly and in a similar manner and that change management principles are applied. Also critical to the work of the RHWACs will be the development and subsequent agreement of a common set of key performance indicators (KPIs) to ensure that the RHWACs meet the quality standards required by users.

It is considered that there are no additional liability issues for a State since all the information provided by the RHWAC is provided as guidance material only.

Funding

While in theory it can be relatively easy to determine what type of cost recovery system should be in place, practically this is not the case. There are complicated political considerations and administration arrangements that would need to be put in place and any such scheme also needs to be fair and enforceable.

The following excerpt from ICAO's *Policies on Charges for Airports and Air Navigation Services* (Doc 9082) provides details for the charges for air navigation services used by aircraft when not over the provider State. A similar policy could be developed for provision of meteorological services.

> "53. The Council observes that the providers of air navigation services for international use may require all users to pay their share of the cost of providing them regardless of whether or not the utilization takes place over the territory of the provider State. Accordingly, wherever a State has accepted the responsibility for providing route air navigation services over another State, over the high seas, or in an airspace of undetermined sovereignty (in accordance with the provisions of ICAO Annex 11 — *Air Traffic Services* to the *Convention on International Civil Aviation* and Regional Air Navigation Agreements approved by the Council), the State concerned may levy charges on all users for the services provided. A State may delegate to another State or to an organization the authority to levy such charges on its behalf.
>
> 54. The Council also notes that the collection of air navigation services charges in cases where the aircraft does not fly over the provider State poses difficult and complex problems. It is for the States to find the appropriate kind of machinery on a bilateral or regional basis for meetings between provider States and those of the users, aiming to reach as much agreement as possible concerning the facilities and services provided, the charges to be levied, and the methods of collecting these charges."

Whilst the direct costs of provision will be relatively straightforward to identify, the allocation of <u>additional</u> core costs (i.e. infrastructure and underpinning services) will be more difficult. It is likely that additional guidance on the subject would need to be provided to assist States in order that a standardised allocation of costs is undertaken by the RHWAC provider States. This guidance would need to ensure States undertaking the operation of an RHWAC understand the need for transparency in determining the associated core costs.

Conversely, it is recognised that if an RHWAC were to have multiple functions, for instance if they were responsible for tropical cyclone, volcanic ash and other hazardous phenomena, this would reduce costs for training/competencies, administration for recovering costs, staff costs, data transfer, etc.

5.2.1 Cost Recovery Options

Creating a cost recovery arrangement for the RHWACs will provide an opportunity for users to influence the development work and have knowledge of the quality of information being provided. This will also allow users to compare the output from the RHWACs and see which provide quality services in a cost effective manner whilst recognising that the costs of providing the RHWAC service will vary due to the cost of living and other factors.

While the prospect of no cost recovery mechanisms is not ideal, this does not mean that a State hosting (providing) an RHWAC must cost recover. An RHWAC provider State could elect to meet costs from its own internal budgetary process.

5.2.1.1 No Regional Cost Recovery

In the past, when the provision of regional based advisory services were considered part-and-parcel of the National Meteorological Service (NMS) it could be argued that the costs of provision were relatively low and therefore the costs were "*de minimis*" (i.e. the effort to collect the charges does not justify the means since its effect on the en-route rate was low). However, as noted above, the costs of provision of regional and global meteorological services are increasing. The other possible concern to consider is that while it might be perfectly feasible for a large or well-developed State to bear this cost, this might not be the case for smaller or developing States. This could result in discouraging important investment in capability.

5.2.1.2 Airspace Users / States contract directly with the State providing the regional service

Airline operators that conduct flights through a region being supplied with SIGMET advisories from a RHWAC would contract directly with the State providing the RHWAC service. In addition, there would be a facility for States within the region to make contractual arrangements with the RHWAC provider State in order that the NMS and other agencies (e.g. the ANSP) could receive the information.

This option is complex in that the role of contract Law between the RHWAC provider State and the airlines / users could be quite fraught, and expensive to administer. There is also the likelihood that either non-State based operators are denied access to the services or that a number of users do not pay but receive the information from other sources.

5.2.1.3 Regional Cost Recovery Scheme

The SADIS cost recovery scheme alluded to above is a good example of a regional cost recovery scheme, whereby each year the provider State establishes the costs of providing the service; this cost is then shared by the States that make use of the service according to usage information provided by ICAO. Such a model could be used for regional cost recovery of RHWAC. It is noted that countries designated by the United Nations as a Least Developed Country are not required to pay any share of the costs. A similar model is used in Europe for the central collection of en-route charges for regional institutions (i.e. Eurocontrol).

This option requires the support of all States in a given ICAO Region and would be open to argument as to the acceptance and/or proportionality of charges levied on each State.

5.2.1.4 Fee Collection

In the contemporary systems, the administration, record keeping and fee collection arrangements form a critical element for the success of such a scheme. In addition, any user - be it State or operator - that refuses to pay would almost certainly be able to receive the information from other sources. If substantial numbers of users do not pay then it is likely that the services provided from the RHWAC would be of lower quality since the resources and investment to maintain the service delivery at sustainable levels would not take place.

5.2.1.5 Third Party Alternative

From the discussion in this section it is clear that any State-based scheme to fund the RHWACs will be difficult to implement and manage due to complexity of relationships and State Law. An alternative to that approach is to use a method of third party funding. ICAO successfully administers the contributions from States (recovered from airlines) to fund the provision of certain international services through its joint financing program;

- Air Navigation Services in Greenland and Iceland (DEN/ICE),
- North Atlantic Height Monitoring System (HMS)

5.2.2 Summary

Any future cost recovery mechanism should ensure that there is:

- clear description of objectives and benefits;
- identification of facilities and services to be jointly financed;
- definition of the responsibilities of the different partners;
- simplicity and flexibility of the arrangements; and
- equitable recovery of costs through charges consistent with ICAO’s policies on charges
- alignment with the principles of *ICAO's Policies on Charges for Airports and Air Navigation Services* (Doc 9082)

5.3 Working Relationships

To ensure the success of the strategic plan there is a need to develop a co-ordinated working relationship with various organizations, service providers and users of services that includes but not necessarily defines all the stakeholders, including:

- ✈ WMO — World Meteorological Organization.
- ✈ IATA — International Air Transport Association.
- ✈ CANSO — Civil Air Navigation Services Organisation.
- ✈ IFALPA — International Federation of Airline Pilots’ Associations.
- ✈ IFATCA — International Federation of Air Traffic Controllers' Associations.
- ✈ ISO — International Organization for Standardization.
- ✈ States in general (States in need of assistance, States able to provide RHWACs, States likely to be able to provide other assistance, VAAC and TCAC provider States)
- ✈ ICAO Regional Offices.
- ✈ Particular States with capability and capacity to serve as a regional centre.

— — — — — — — —

附录 F

世界区域预报系统可交付的成果
以支持航空系统组块升级的模块 B3-AMET

- 完全一体化的多成员组合的危险预报
  - 实施世界区域预报系统数据库，载有来自合适模式的气象情报，以便制作全球气象情报的总体预报
- 实施空间和时间高分辨率的模式，生成经过改进的气象情报之表述
- 提供适于纳入为航路运行的飞行规划、飞行管理和空中交通管理（ATM）的决策支持系统一体化的涵盖航路天气的气象情报之完整数据集
- 完全自动化的网格式和重要气象预报（SIGWX）之产出
- 全面实施全系统信息管理（SWIM），以获得世界区域预报系统的数据
- 淘汰遗留的世界区域预报系统的产品和发送系统

— 完 —