出國報告(出國類別：其他)

出席「航空氣象現代化作業系統汰換及更新計畫協調會議」出國報告書

服務機關：交通部民用航空局飛航服務總臺
姓名職稱：余祖華 主任、楊川德 臺長
派赴國家/地區：美國，波德
出國期間：民國 **113** 年 **9** 月 **7** 日至 **9** 月 **13** 日
報告時間：民國 **113** 年 **10** 月 **14** 日

提要表

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<tr><td>系統識別號：</td><td>C11301731</td></tr>
<tr><td>視訊辦理：</td><td>否</td></tr>
<tr><td>相關專案：</td><td>無</td></tr>
<tr><td>計畫名稱：</td><td>航空氣象現代化作業系統汰換即更新計畫協調會議</td></tr>
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<tr><td>計畫主辦機關：</td><td>交通部民用航空局</td></tr>
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<tr><td>楊川德</td><td>交通部民用航空局飛航服務總臺</td><td>臺北航空氣象中心</td><td>臺長</td><td>薦任(派)</td><td>聯絡人：chuante@anws.gov.tw</td></tr>
<tr><td>余祖華</td><td>交通部民用航空局飛航服務總臺</td><td>臺北航空氣象中心</td><td>主任</td><td>簡任(派)</td><td></td></tr>
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<tr><td>前往地區：</td><td>美國</td></tr>
<tr><td>參訪機關：</td><td>美國國家大氣科學研究中心(NCAR)</td></tr>
<tr><td>出國類別：</td><td>其他</td></tr>
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<tr><td>報告日期：</td><td>民國 113 年 10 月 14 日</td></tr>
<tr><td>關鍵詞：</td><td>AOAWS-RU，演算法，航空氣象</td></tr>
<tr><td>報告書頁數：</td><td>13 頁</td></tr>
<tr><td>報告內容摘要：</td><td>飛航服務總臺基於提升飛航安全與服務品質，達成亞太地區飛航服務提供領先者之組織目標，自 110 年起至 113 年間推動「航空氣象現代化作業系統汰換及更新計畫(Advanced Operational Aviation Weather System Renewal and Update；AOAWS-RU)」，透過「駐美國臺北經濟文化代表處與美國在臺協會間航空氣象現代化作業系統發展技術合作協議」「航空氣象現代化作業系統汰換及更新計畫」「第十八(IA#18)及十九(IA#19)號執行辦法」，引進美國大氣研究大學聯盟之國家大氣科學研究中心(NCAR)所發展之最新航空氣象預報演算法，使我國之航空氣象預報品質得以持續精進。113 年為 IA#19 之最後一年，為確保年度工作順遂，本總臺特派員於 113 年 9 月 7 日至 13 日赴位於美國科羅拉多州波德市（Boulder）之 NCAR 進行業務協調，與美方針對未來可能之合作方向，及航空氣象預報演算法之後續維護及訓練等議題進行討論。</td></tr>
<tr><td>電子全文檔：</td><td>C11301731_01.pdf</td></tr>
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限閱與否：	否
專責人員姓名：	A15060000HA0
專責人員電話：	

目錄

壹、目的

交通部民用航空局(以下簡稱民航局)自 86 年 7 月起推動航空氣象現代化計畫，與美國大氣研究大學聯盟(The University Corporation for Atmospheric Research，UCAR)合作建置航空氣象現代化作業系統(Advanced Operational Aviation Weather System，AOAWS)，於 91 年 7 月完成建置。復自 95 年至 99 年及 100 年至 103 年間分別進行為期 5 及 4 年之「航空氣象現代化作業系統強化及支援計畫」(The Advanced Operational Aviation Weather System Enhancement and Support，AOAWS-ES)與「航空氣象現代化作業系統氣象技術增強計畫」(Technical Enhancement for the Advanced Operational Aviation Weather System，AOAWS-TE)，歷經三階段共 14 年之航空氣象現代化計畫，使臺北飛航情報區(下稱本區)之航空氣象服務水準得以與國際發展緊密接軌，並與歐美先進國家並駕齊驅。

另為因應科技之日新月異及精進飛航安全與服務品質，民航局自 110 年至 113 年推動「航空氣象現代化作業系統汰換及更新計畫(The Advanced Operational Aviation Weather System Renewal and Update，AOAWS-RU)」，透過「駐美國臺北經濟文化代表處與美國在臺協會間航空氣象現代化作業系統發展技術合作協議」「航空氣象現代化作業系統汰換及更新計畫」「第十八(IA#18)及十九(IA#19)號執行辦法」，引進美國大氣研究大學聯盟之國家大氣科學研究中心(NCAR)所發展之最新航空氣象預報演算法，使我國之航空氣象預報品質得以持續精進。

113 年為 IA#19 之最後一年，為確保年度工作順遂，本總臺特派員於 113 年 9 月 7 日至 13 日赴位於美國科羅拉多州波德市（Boulder）之 NCAR 進行業務協調，與美方針對未來可能之合作方向，及航空氣象預報演算法之後續維護及訓練等議題進行討論。

貳、過程

本次會議分別於 113 年 9 月 9 日至同年 9 月 11 日三天進行，由美方專案主持人許榮祥博士主持，分別就工作進度、協調議題及雙方未來可能合作項目進行介紹及討論，詳細行程如下表：

日期	時間	討論內容
9/9	0925-1015	Status updates from product development
	1030-1100	Advancement in aviation weather R&D and future Implementation Arrangements(Part I; Task leads, Julie Haggerty)
	1100-1200	Open discussion
	1330-1345	status update from NTDA product development team
	1345-1500	Advancement in aviation weather R&D and future Implementation Arrangements(Part II; Task leads, Larry Cornman)
	1500-1530	Status update from ASPIRE product development team
	1530-1700	Open discussion
9/10	0900-1100	Capacity building for the CAA in aviation weather science and technology – Exploring ways for NSF NCAR to host long-term visitors and/or students from Taiwan
	1115-1200	Open discussion
	1330-1600	Mesa Lab Tour
9/11	0900-1030	Post-IA #19 maintenance
	1045-1200	Open discussion

參、會議內容

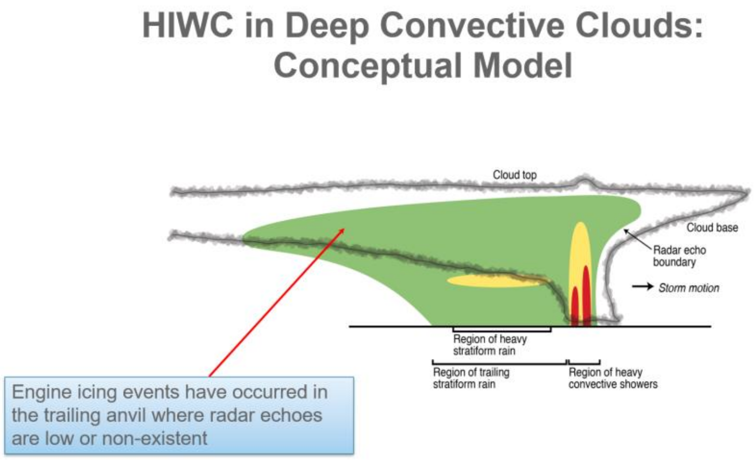
一、 氣象專題研究分享

(一) 講題：「Detection of High Ice Water Content (HIWC) Conditions: Recent Developments by NCAR and the FAA」。

(1) 報告人：Julie Haggerty(NCAR)。

(2) 重點摘要：

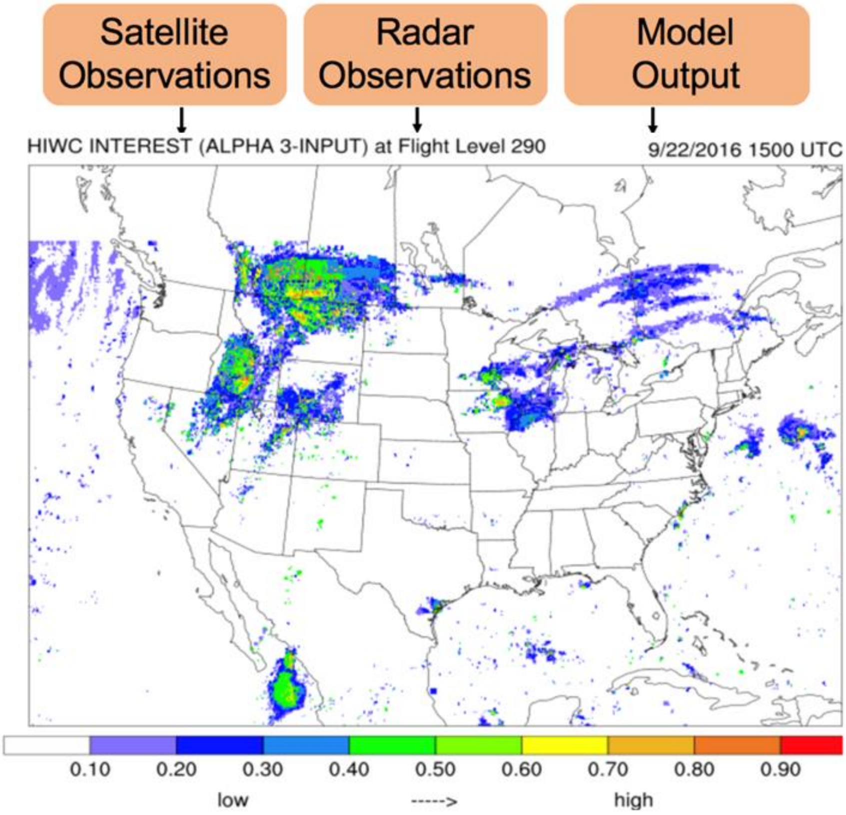
自 103 年起，FAA 贊助 NCAR 研究 Ice Crystal Icing (ICI)(或又稱 High Ice Water Content (HIWC))對航空器的影響。在深對流系統中（包括雲頂），可能存在高濃度的小顆粒冰晶，因粒徑較小，無法以機上雷達辨識。當航空器遇到小顆粒冰晶，可能對航空器發動機葉片造成損壞，也可能導致飛機數據系統失效。至於需要在多高的小顆粒冰晶濃度及停留時間內才會造成損傷，目前仍在研究中。根據官方通報統計，全球每年 HIWC 事件約 8-10 起，但航空公司並不需要報告 HIWC 事件，實際事件的數量可能超過官方記錄。



圖一：HIWC 概念圖

為了降低 ICI 事件對飛行器的影響，NCAR 開發出 ALPHA(Algorithm for Prediction of HIWC Areas)即時預報工具，ALPHA

最初是為支持 HIWC 飛行計畫而開發，但後來已被作為氣象即時預報工具以減少危害。



圖二：ALPHA(Algorithm for Prediction of HIWC Areas)即時預報頁面

ALPHA 採用模糊邏輯融合衛星、模式和雷達數據，以及使用大量的數據集供機器學習算法訓練。在 103 至 107 期間在美國四個地點以實地觀測取得大量數據，在 109 年 1 月至 7 月與澳洲航空公司合作進行 ALPHA 產品測試。111 年 6 月起在美國進行用戶評估，通過網站提供即時 ALPHA 產品，並取得用戶回饋及相關調查意見。從調查中顯示參與者對 HIWC 條件所帶來的危害理解有限。一些人混淆了由 HIWC 條件引起的冰晶結冰（影響發動機性能）和過冷液態水結冰（導致機身積冰並影響空氣動力學）。對 HIWC 事件的頻率和影響未能充分認識，這可能影響到對安全風險的評估和應對。可見在 HIWC 資訊的應用上仍有提升的空間，尤其是在安全決策方面。

主講者提到 ALPHA 有一個不依賴當地雷達運行的版本，因此若臺

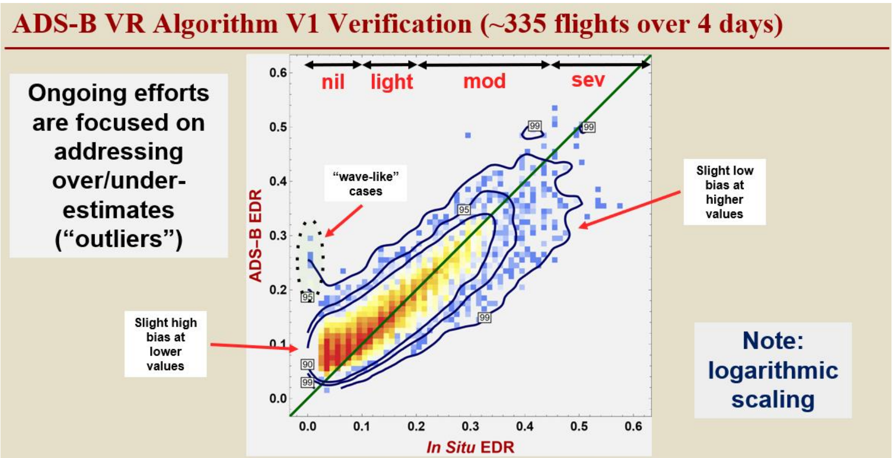
灣導入該產品應不存在困難。

(二) 講題「Turbulence Information Using ADS-B Vertical Rate Data」。

(1) 報告人：Larry Cornman (NCAR)。

(2) 重點摘要：

NCAR 持續發展以廣播式自動回報監視資料 (Automatic Dependent Surveillance Broadcast，ADS-B) 進行即時亂流觀測，並將其納入亂流圖形化指引即時預報（GTGN）作業中。在 113 年進行的實驗顯示在缺乏觀測 EDR 的情況下，ADS-B 數據具有填補亂流訊息的能力。此外 NCAR 也確認在 GTGN 中採用 ADS-B 的資料並不會顯著的增加系統 CPU 使用率。下一代 GTG4.5 正在開發中，將採用 AI 技術改善亂流預報，預計在兩年後完成。



圖三：ADS-B 計算之 EDR 與實際 EDR 之比對，兩者有相當良好線性關係

(三) 議題「Recent Advancements in CIP/FIP Research by NCAR and the FAA」。

(1) 報告人：Dan Adriaansen(NCAR)。

(2) 重點摘要：

有關 NCAR 目前在 CIP/FIP 演算法的進展說明如下:

A. 簡略演算法中氣壓座標轉換的步驟，可增進預報高度準確性。

B. 在美國地區針對凍雨產生機制部分架構了演算法的原型。

C. 可針對 CIP 引入雷達資料，意即使用雷達的垂直剖面來幫助引導積

冰演算法場景選擇。

D. 增加 CIP 的解析度及預報頻率(10 分鐘更新)，有助於使用者掌握每小時內的變化及更準確地觀察積冰系統的增長和消散。

二、工作進度報告

本次會議由美方各工作負責人員進行相關工作進度報告，並針對有關工作之後續配合事項進行確認。相關重要工作成果及未來發展說明如下：

(一) 工作項目 1 - 升級亂流圖形化指引至第 4 版(GTG4)，並建置亂流圖形化指引臨近預報(GTGN)：

(1) NCAR 已完成以 EDR 觀測資料驗證 GTG4 表現程序。

(2) NCAR 已基於 CWA WRF 3.8.1 版本對 D1 和 D2 區域進行了 GTG4 校準和評估。正在完成對 WRF 4.4.2 版本 GTG4 的進一步校準調整。

(3) GTG4 在 3 公里產品將包含對流、晴空及山岳波亂流；但 15km 產品因網格點解析度較粗(對流系統模擬需較高解析度)，因此不包含對流亂流。

(4) NCAR 使用臺灣當地觀測資料對 GTG4 進行調整後，比起利用美國觀測資料調整，GTG4 的表現有相當的進步。

(5) 預計收集民航局個案意見後將於 113 年 10 月完成 GTG4 相關調整。

(6) 目前 GTGN 已於本年度 7 月安裝在民航局測試主機，並以即時資料測試後，確認與美國測試主機產出資料一致。

(7) 已針對 GTGN 開發資料輸入處理程序，包括 IATA EDR 亂流數據及將合併的 METAR 數據轉換為 GTGN 系統所需的正確輸入格式。

(8) 源頭模式資料傳輸時間及資料同時大量抵達情況仍有改善空間。

(二) 工作項目 2- 更新 NCAR 亂流偵測演算法(NTDA)：

(1) NCAR 已收集使用者回饋意見並交付報告。

(2) 完成對使用 C 波段雷達資料所需修改的調整和測試，包括雜波抑制和處

理較小的奈奎斯特速度。

(3) 完成對 NTDA 的評估（例如個案研究）和調整。

(4) NTDA 軟體在民航局測試主機上已於 3 月更新至最新版本。

(5) 教育訓練材料已準備完畢，目前正在同步進行教育訓練。

(6) 雷達資料來源的可靠性已大幅改善，但來自部分雷達(空軍雷達)的資料中斷讓案例研究分析變得困難。

(7) 後續由FAA贊助的NTDA發展計畫正在進行中，如減少晴空干擾訊號(如鳥或蟲類)及減低風切干擾訊號。

(三) 工作項目 3 -更新雲頂高預測產品(CTH/CDO)：

(1) 已安裝在民航局測試主機上，正在使用即時資料傳送進行測試。

(2) CTH/CDO 產品驗證方面，在臺灣 FIR 內使用雷達產品驗證，在 FIR 外以低軌繞極軌道衛星(如 EarchCARE)相關產品驗證，此外效益評估正進行中。

(3) NCAR 未來的研發重點:

A. 利用 AI/ML 技術將不同衛星頻道整合到 CTH 產品的分窗閾值技術中，改進 CTH 及 CDOlite 相關產品。CDOlite 產品的潛在重點是用降水填補雷達盲區。從一些評估顯示，在沒有雷達資料的情況下存在 CDO，這可能是由於雷達視野被遮擋，即衛星可以看到，但雷達看不見。目前 CDO 像是以偵測對流為主，可以調整為偵測降水為主。

B. 利用 AI/ML 改進早期風暴發展的判斷和對流發展的檢測（至少是發展的機率）。

C. 增加外推的時間解析度是可行的；目前外推到未來 1 小時和 2 小時，可以進行小於 1 小時的外推。

(四) 工作項目 4 -更新機場雲幕與能見度預測產品(C&V)：

(1) NCAR 持續進行調整以協助校準、檢查系統性能及偏差修正參數。

(2) 效益評估正在進行中。

(3) 目前 WRF 模式有選項可直接輸出雲幕及能見度資料，後續可透過中央氣象署協助開啟該選項，以簡化目前需透過 UPP 程式才能產生雲幕及能見度資料的過程。

(五) 工作項目 5 - 發展 0-8 小時的風暴預報能力（ASPIRE）：

(1) 目前的測試版本已於 113 年 8 月 30 日安裝在民航局測試主機上；後續將收集足夠的輸出以便進行驗證統計，此外也將繼續收集民航局對產品的回饋意見。

(2) NCAR 建議當 RWRF 資料停機超過 6hr 時，系統僅顯示外延法結果，對未來 3-4 小時預測效果仍然很好。此外在上面情況回波多邊形標記仍然可用，因為它主要是由雷達觀測產生的 2 小時產品。

(3) RWRF 資料傳輸仍偶有不穩定情況，影響校準及權重分析，因此混合啟發式方法仍需持續進行優化。

(4) 未來發展建議使用機器學習方法改善目前混合權重的處理方式（之前對外推法以機器學習方式的成效尚未有結論）；目前是以經驗法則來處理。

(六) 工作項目 6 - 技術轉移及教育訓練：

(1) NCAR 於 113 年 9 月 2 日至同年 9 月 15 日辦理「研習航路及機場天氣預報產品演算法原理及發展技術」技術轉移訓練。

三、議題討論

(一) 演算法主機作業環境調整相關問題：

(1) NCAR 本(113)年度 3 月開始與臺灣資訊廠商合作檢視測試和營運主機的安裝流程，經檢視後已刪除了不必要流程。

(2) NCAR 正處理 OPS1 和 OPS2 之間有一臺主機停機時的應變方案，每臺

營運主機應能在另一營運主機進行更新時運行所有演算法。

(3) NCAR 正處理每晚將所需的校準數據（例如 C&V 和 ASPIRE）發送到遠端備援主機相關程序。

(4) 在緊急情況(如網路硬碟（NetApp）失效或 OPS1 和 OPS2 都離線（因停電或其他原因）時，將由臺灣資訊廠商手動切換輸入資料程序至遠端備援主機，此時遠端備援主機才會開始產出資料。

(5) 因資安相關議題，NCAR 將就演算法相關系統更新再次進行討論；目標為每季度更新一次。

(6) 有關管理 NetApp 和本地主機上的資料部分，GTG4 演算法使用主機 SSD 磁碟作為工作空間，輸出後再將資料傳送到 NetApp 儲存；所有其他演算法使用 NetApp 直接為工作空間。GTG4/GTGN 分開至 OPS2 上運行，與其他演算法分開，這使 GTG4 預測可延長至 48 小時（如果與其他算法在同一主機上運行則為 18 小時）。

(7) NCAR 將持續監控民航局端的系統，以識別任何錯誤和問題。

(8) 氣象署模式資料傳送到民航局主機仍有改善空間，主要為目前所有模式資料在運算完畢後同時從氣象署傳輸到民航局之作法，實非最佳的資料傳輸方式。這會造成大量資料在運算周期完成時搶用頻寬，而在運算期間頻寬大多處於閒置狀態。此外當這些資料同時進入系統時，會給系統計算資源帶來壓力，因為輸入及轉換過程必須同時處理所有這些資料。因此 NCAR 建議在 WRF 輸出資料當下，立即將每小時的資料發送給民航局。這在頻寬使用上更有效，並減少 WRF 資料的延遲。理想情況下，延遲不應超過一小時。解決延遲問題將使所有依賴 WRF 輸入資料的演算法受益。

(9) 未來可建立即時產品驗證系統以即時驗證產品之性能。

(二) 未來與 NCAR 在航空氣象科學與技術交流相關議題：

(1) NCAR 建議我方師法美國的作法，在單位內設立研發部門，或由臺灣的

國家科學基金會向主要大學提供資金，由學術單位派遣人員學習，以緩解目前民航局演算法學習人員於接受培訓後，可能因升職或其他因素離開原職位，導致知識和經驗未能傳承的問題。

(2) 若我方規劃持續派遣學習人員到 NCAR 進行更長的培訓，可專注於以下目標：

A. 培養深入調整和校準演算法的能力。

B. 發展離線產品驗證能力，以監控演算法性能；處理驗證資料格式變更和資料來源變更的能力。

C. 發展增強演算法的能力，但不改變演算法核心程式。

(3) 根據演算法/產品的不同，訓練時間應至少為一個月（簡單演算法）或 1.5 至 2 個月為目標（複雜演算法，如 ASPIRE）。

(三) IA#19 結束後 NCAR 演算法後續維護相關議題：

(1) 對於未來 AOAWS-RU 計畫的維護，NCAR 僅負責演算法及其產品及 SYSVIEW(演算法監控程序)，不負責資料輸入、網路及產品顯示架構。

(2) 未來演算法的維護仍將透過臺灣資訊廠商進行。

(3) AOAWS-RU 維護的第一年可能仍有較多之演算法效能調校及分析工作，需有較多的維護預算需求。

肆、心得與建議

本次會議除安排 113 年度工作成果報告外，亦就未來雙方可能合作之議題安排專題分享，此外雙方也針對演算法後續維運及未來相關人才之培訓進行討論。謹將參與本次會議之心得及建議臚列如下：

一、 持續關注美國 NCAR 各項預報技術發展狀況，為未來系統之精進預作準備

(一) 導入新型態天氣演算法：

在本次會議中，美方針對「High Ice Water Content」的危害進行相關報告，相關演算法 ALPHA(Algorithm for Prediction of HIWC Areas)已在美國進行驗證，我方可評估納入未來之合作計畫中。

(二) 強化及改良目前演算法：

由於近年來 AI 技術不斷進步，大多數演算法都規劃融入 AI 技術以強化其效能，爰建議我方亦應跟上此一潮流，加強關注 AI 技術於航空氣象領域之應用。此外，現有的演算法效能驗證主要以離線方式進行，NCAR 刻正規劃通過即時驗證進行演算法效能評估，我方亦可評估透過簽署後續合作計畫，導入此一即時驗證技術，以強化演算法效能之評估。

(三) 演算法人才培訓：

考慮到目前演算法的維護和驗證均由 NCAR 人員負責，預期計畫結束後，我方將需接手相關工作。因此我方需思考是否透過後續之合作或出國計畫，持續派員赴 NCAR 進行演算法培訓，以有效落實培養本土科技研發管理能力之計畫目標。

二、 評估是否依 NCAR 意見調整相關系統，以增進演算法效能

(一) 本次會議中，NCAR 就目前系統面提出三點建議：

(1) 將目前模式輸入傳檔形式由一次大量傳輸改為產出即傳方式，以善用頻寬及減少延遲時間。

(2) 協調氣象署開啟模式直接輸出雲及能見度相關參數，以簡化 C&V 演

算法流程。

(3) 確保 RWRF 模式輸入之資料質量，以優化 ASPIRE 演算法效能。

(二) 後續本總臺將評估依上述建議，於 AOAWS-RU 計畫剩餘期間，進行系統調校之可行性，以及各項建議對演算法效能提升之效益，如有必要，將於後續建議編列維護預算，進行相關演算法優化事宜。

三、 持續加強與國內氣象及學界的合作，拓展我國航空氣象實力

經過近 20 年來的努力，我國航空氣象的實力已可與各國並駕齊驅，惟相關成果之延續，仍需透過國內學界培養相關人才才能打下堅實之基礎。基於此一理念，本總臺特於本(113)年爭取於中央氣象署「天氣分析與預報研討會」增設航空氣象相關主題，透過本次研討會向各界介紹 AOAWS-RU 計畫，讓國內學界了解民航局之航空氣象發展方向及願景，因此建議持續鼓勵同仁參加國內氣象科研會議，並視需要辦理與國內學界共同研究計畫，實現民航局於航空氣象領域深耕發展之期望。

伍、附錄

一、會議簡報

Lastest Upgrade to ASPIRE V2.2

James Pinto

9 Sept 2024

Aviation Applications Program
Research Applications Laboratory

ASPIRE V1.5 vs ASPIRE 2.1

ASPIRE V1.5

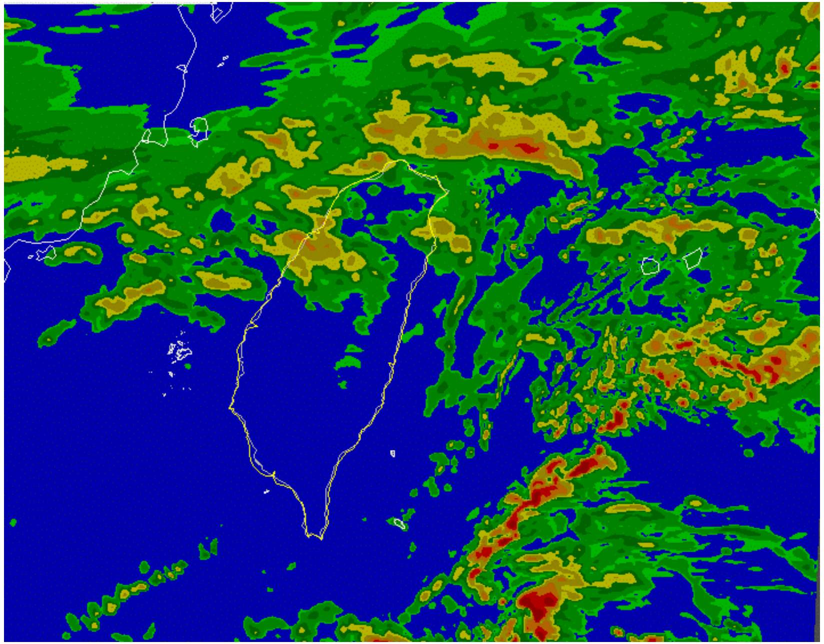
- 10 min update with 60 min leadtime resolution.
- Limited tuning of calibration and blending weight functions.
- Limited realtime evaluation and tuning.

ASPIRE V2.1

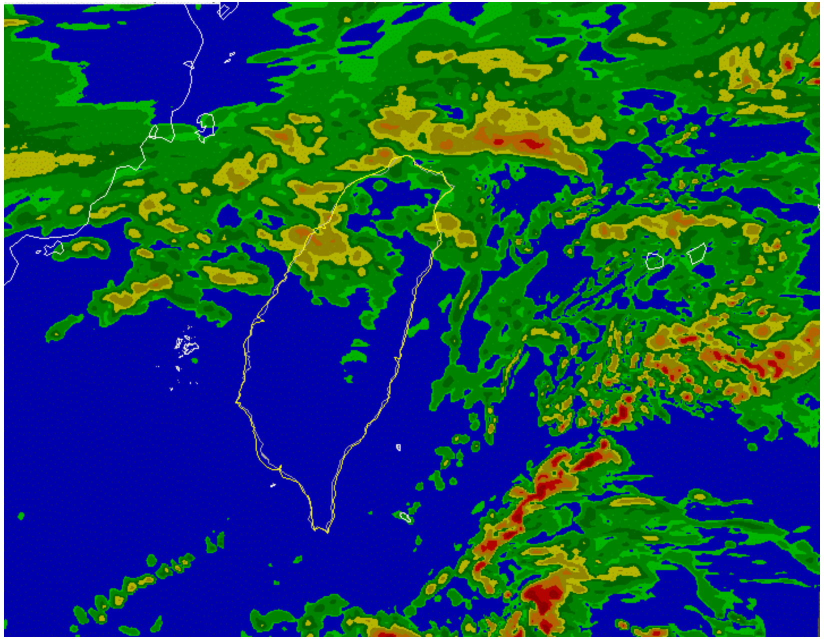
- Updates every 10 min with 10 min lead time resolution.
- Completed tuning of calibration and weighting functions for CREF and ECHOTOP.
- Numerous improvements to handle realtime timing issues
  - Sped up implementation of extrapolation code
  - Numerous adjustments to handle timing issues (e.g., delay in receiving QPESUMS data compared to dbz).
- Added TITAN processing to extract and add CTREC vectors to storm objects and output geoJSON.
- Other improvements
  - Improved ingest to handle missing data properly.
  - Added ability to handle variable lead times for a given forecast – to increase uptime of blended forecast when model latency is high.
  - Added app to handle out of sequence forecast lead times
  - Improved handling of background weights to force bgweight function to 1 for extrapolation to a lead time of 1 hour.
  - New code to allow for increased storm area if indicated by Calibration function.

ASPIRE V2.1 Improvements over V1.5

ASPIRE V1.5
(60 min lead time resolution)



ASPIRE V2.1
(10 min lead time resolution)



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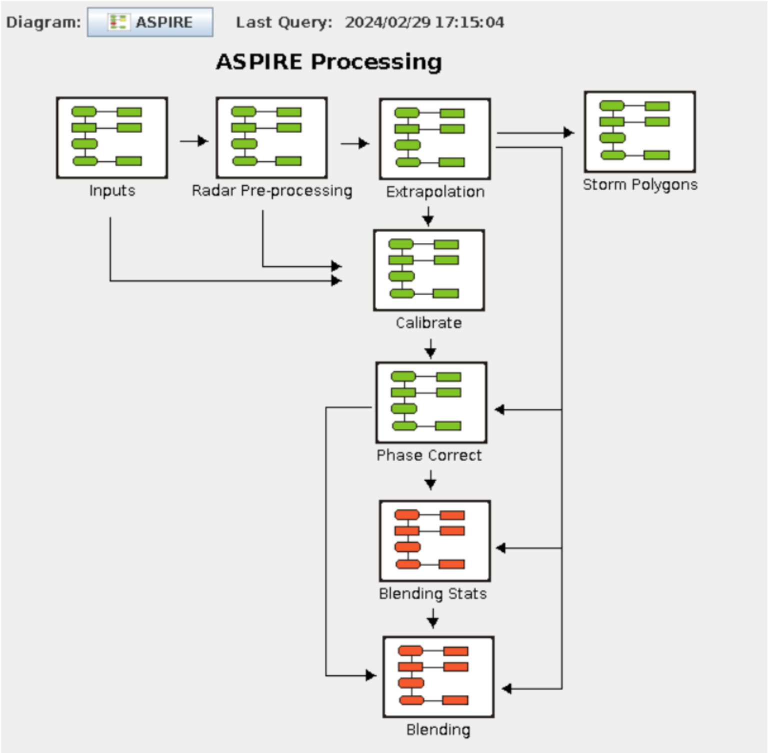
Installation Notes

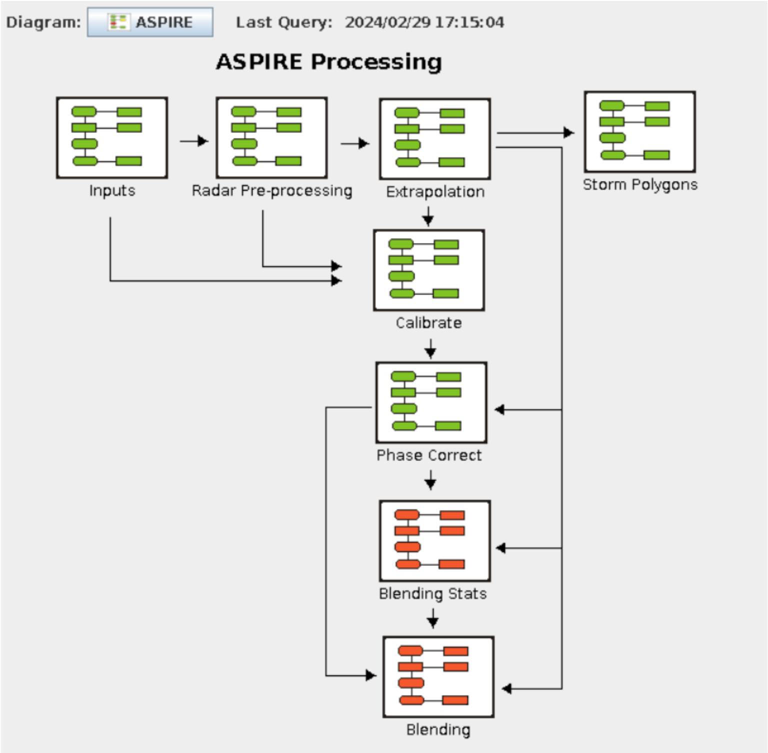
- Realtime testing of version 2.0 was moved from NCAR to CAA host on 10 May 2024.
  - This was done because RWRF feed to NCAR had become very unreliable.
  - Working on CAA host is less efficient than working on NCAR system resulting in increased costs.
  - In addition, data outages and latency issues on CAA host made it even more challenging for debugging and tuning system for realtime operations.
  - Despite these issues the system was improved and hardened with many upgrades to handle new RWRF model 10 min data out to 10 hours.
- **Version 2.1 was installed on 22 May 2024**
  - Major upgrade to handle both 10 min RWRF out to 10 hours and mixed forecast leadtimes (i.e., 10 min out to 10 hours and then hourly out to 12 hours.)
  - Added code to handle timing issues
- System was frozen for initial evaluation period.
  - Input data outages delayed evaluation period
  - Decided to move forward with eval despite continuing data outages.
- Used 8-17 June 2024 for verification report
- Some param files were updated on 18 June 2024 to fix precip rate calculation and calibration.
- System tuning ongoing.



Recent Updates: Version 2.2

- **Version 2.2 was installed on CAA Test Server on 30 Aug 2024**
  - Calibrate module code updates:
    - calibration tile now an exact match to smaller CTH and PRATE obs grids.
    - Calibration data not conditionally sampled to only include grid point where both model and obs are non-missing.
  - Minor bug fix to better handle situations when model experiences an extended outage

- Suggestion for downstream processing
  - When model outage exceeds 6 hours we suggest that users revert to viewing the extrapolation product.



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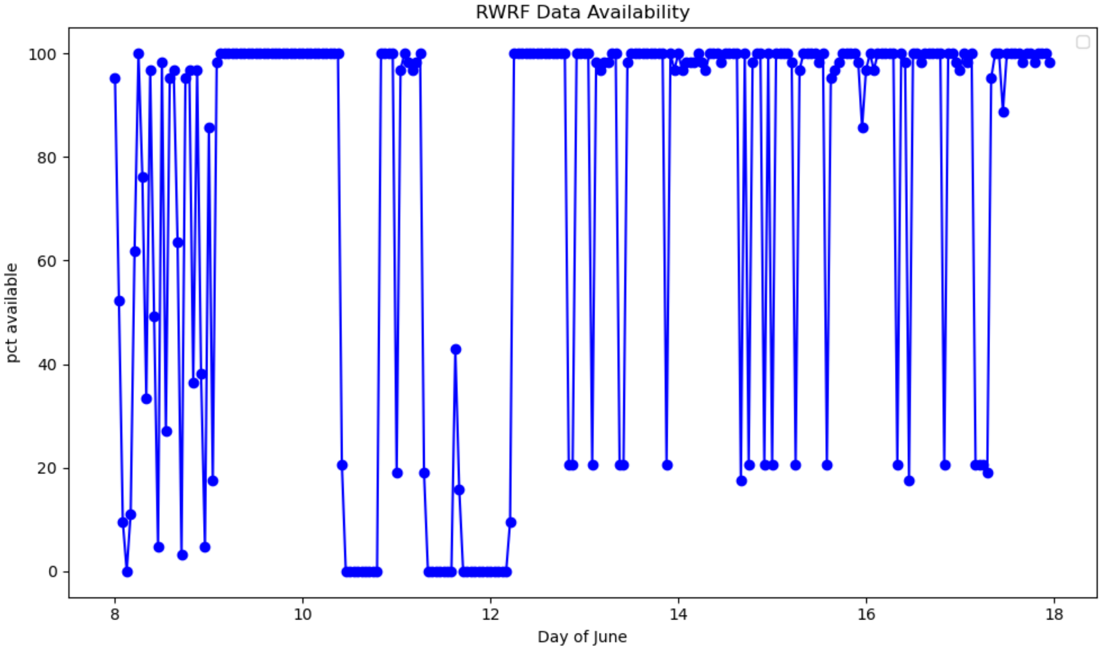
Model Availability



Over 10-day period in 08-17 June 2024:

- Only 33% of RWRF runs are complete and can be used by ASPIRE (see next slide).
- 49.75% of all model data is missing
- 10.42% missing only one leadtime

*Very challenging to test system & debug issues in realtime installation due to missing RWRF data files and high latency in radar mosaic data.

*This has resulted in an increased work load and cost for implementation.

*Lack of data affects the calibration and weighting, thus, the blending heuristics cannot be fully optimized.

ASPIRE V2.2 System Readiness Status

Instance	Subsystem[3,4]					
	Ingest[1]	Extrapolation	Model Calibration[2]	Model Phase Correction[2]	Dynamic Weights	Heuristic Blending
Composite Reflectivity	D	D	D	D	D	D
Storm Top Heights	D	D	D	NA	NA	D
Rain Rate	D	D	D	NA	NA	D

1. Need to implement pub fix to handle extended model data outages.
2. NCAR has been testing ASPIRE V2.2 Calibration updates on CAA Test host since 30 Aug 2024 – plan to perform some verification stats and get user feedback
3. Regression test modules have been developed and tested.
4. Draft of documentation is nearing completion.

Status Key	Subsystem Development Phase
C	Code Development
T1	Testing and Configuration
R	Realtime testing and tuning with new feed of 10 min RWRF out to 10 hours (V2.1)
D	Ready to Deliver

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Task 4. Update the Cloud Top Height (CTH) Prediction Products

Status Update 9 September 2024
Including Convection Diagnosis Oceanic (CDO) and CDO-Lite

Ken Stone, Dan Megenhardt, Josh Lave, Tom Blitz

Aviation Applications Program Research Applications Laboratory

Task 4 Deliverable Status

AOAWS-RU Task #	Deliverable	Due Date	Status
4	a) CTH/CDO testing report with evaluation	7/31/2024	Complete. Request for additional cases under review.
4	b) User feedback assessment documentation	8/15/2024	Complete.
4	c) CTH/CDO Confirmation report on algorithm changes	11/29/2024	On Schedule

CTH/CDO Task Update

- Continued to examine final output smoothing options to optimize information content.
- Installed on CAA test server; conducting testing with real-time data push
- Investigating options for verification and developing script for repeatable usage.
- Investigating benefits assessment and developing report.
- Developed test report containing information on regression tests and preliminary verification. Report in December 2023 contained evaluation of extrapolation (extrapolation performance can be quite good).

System Readiness Status

	Subsystem			
Instance [1]	CTH	CDO-Lite [2]	CTH 1 and 2 hr Extrapolation	CDO-Lite 1 and 2 hr Extrapolation
WRF D1	R	R	A	A
WRF D2	R	R	A	A

Notes
1. Intersection of WRF domain(s) with Himawari footprint using regular equal-angle grid.
2. CDO-Lite does not use Lightning data.

StatusKey	Subsystem Development Phase
C	Code Development
T1	Testing and Configuration
T2	Testing with CWB Sample Data
A	Assessing Performance and Fine Tuning
R	Ready to Deliver

System Readiness Status

	Subsystem			
Instance [1]	CTH	CDO [2]	CTH 1 and 2 hr Extrapolation	CDO 1 and 2 hr Extrapolation
DFIR	R	R	A	A

Notes
1. Intersection of FIR domain with Himawari footprint using regular equal-angle grid
2. CDO uses Lightning data.

StatusKey	Subsystem Development Phase
C	Code Development
T1	Testing and Configuration
T2	Testing with CWB Sample Data
A	Assessing Performance and Fine Tuning
R	Ready to Deliver

Plans

Deviverable Focus

- Benefits Assessment
- Technical Documentation
- Repeatable Script Development and Test (Script will be delivered later)
- Training Part 2
- Confirmation Report on Algorithm Changes

Possible R&D

- Improving CTH and CDOlite in D1 and D2 with additional IR channels (split window thresholds) using AI/ML techniques.
- Improve depiction of early storm development and detection of Convective Initiation using AI/ML.

Issues and Challenges

- No Current Issues.

Challenges:

- Using Lightning in UCAR test system (for CDO in the FIR) is limited to “simulated” realtime testing due to bundling of lightning into 1-hour blocks.

Turbulence Information Using ADS-B Vertical Rate Data

Larry Cornman

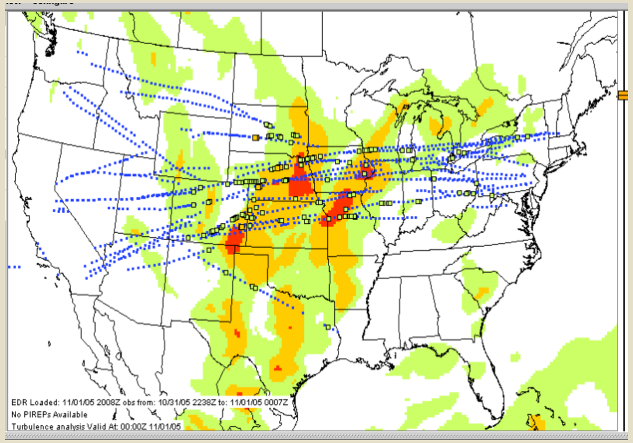
National Science Foundation

National Center for Atmospheric Research

Research Applications Laboratory

Background

- Turbulence encounters continue to be a significant operational problem.
- Given the spatial and temporal variability of turbulence, large numbers of observations are needed.
- **Automatic Dependent Surveillance-Broadcast (ADS-B) is an aircraft position/velocity reporting system that has the potential to augment existing turbulence observations.**



In situ EDR reports overlaid on GTG

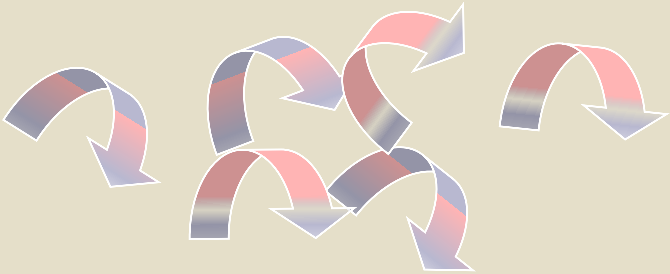
ADS-B Infrastructure

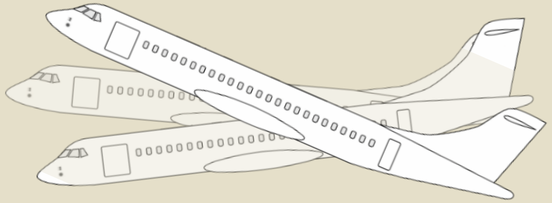
Research sponsored by the FAA’s WITC program considering the utility of ADS-B reports for turbulence detection

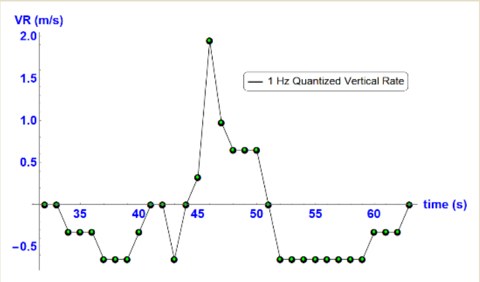
Potential Benefit of ADS-B Turbulence Reports is Significant

- **Large numbers of a/c**
  - Most a/c in US controlled airspace are now required to have ADS-B Out.
  - ***As of July 1, 2023 there are ~160K US a/c reporting, including ~105K fixed-wing GA a/c.***
  - Compare to ~1700 a/c reporting *in situ* EDR and ~1200 turbulence PIREPS/day (on an active day).
- **Good spatial and temporal accuracy**.
- ***No need to deal with aircraft side of implementation***.

Turbulence from ADS-B Reports: High-Level Concept







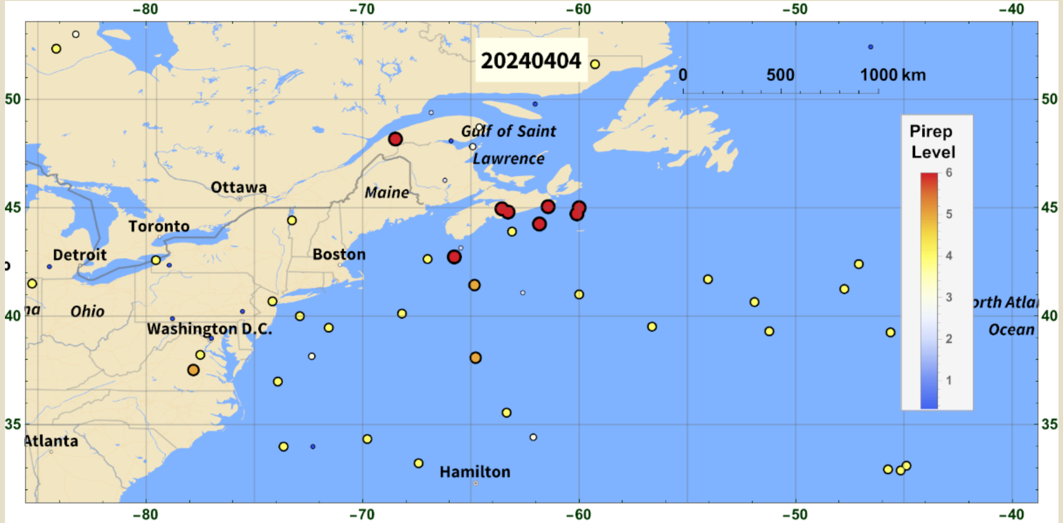
Input – Atmospheric turbulence

System – Aircraft + Controls Dynamics

Output – Sampled/ quantized Vertical Rate (VR)

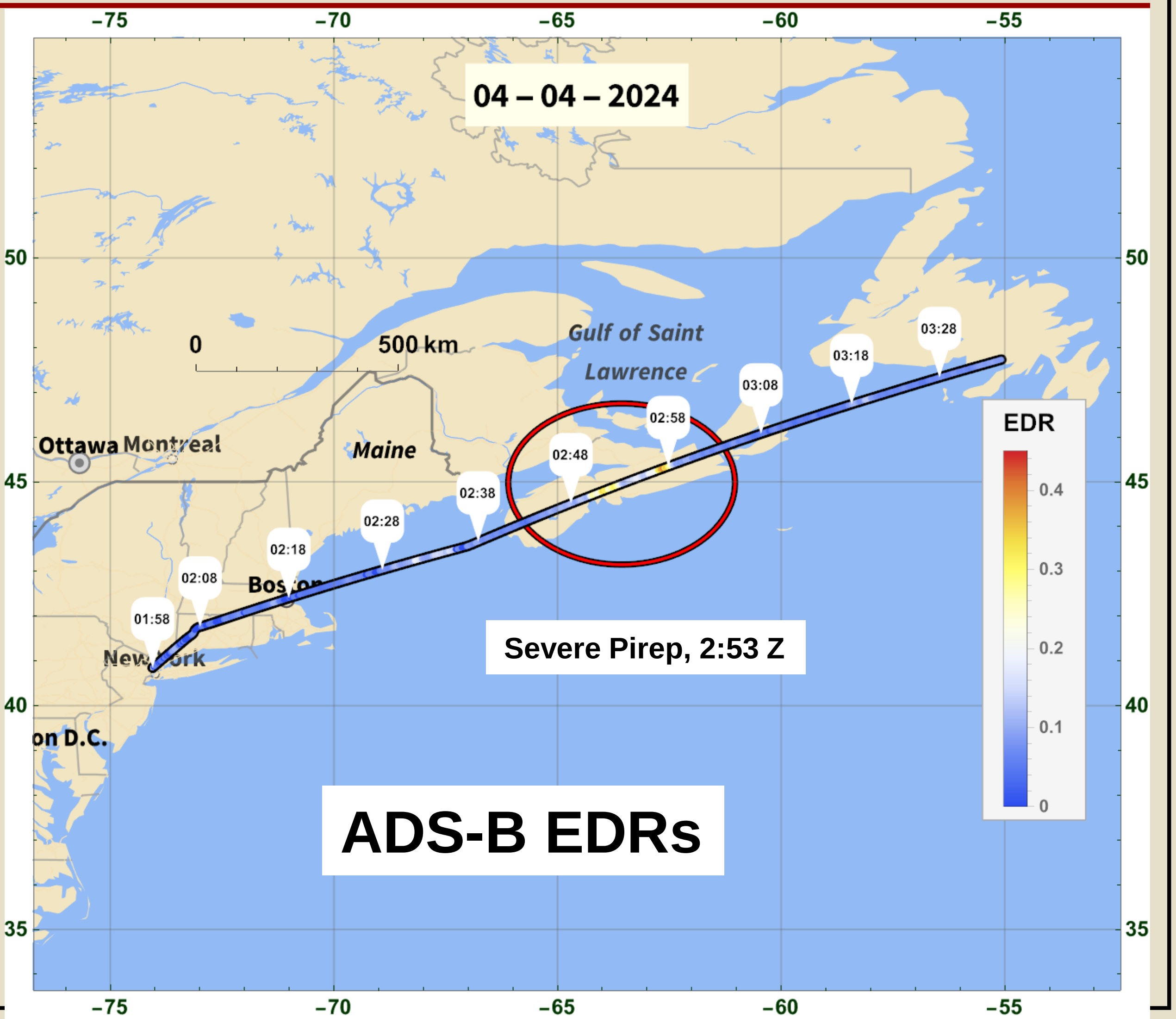
Desired algorithm goes <u>right to left</u> – meaning that we have to model each backwards step

April 4, 2024 Case Study



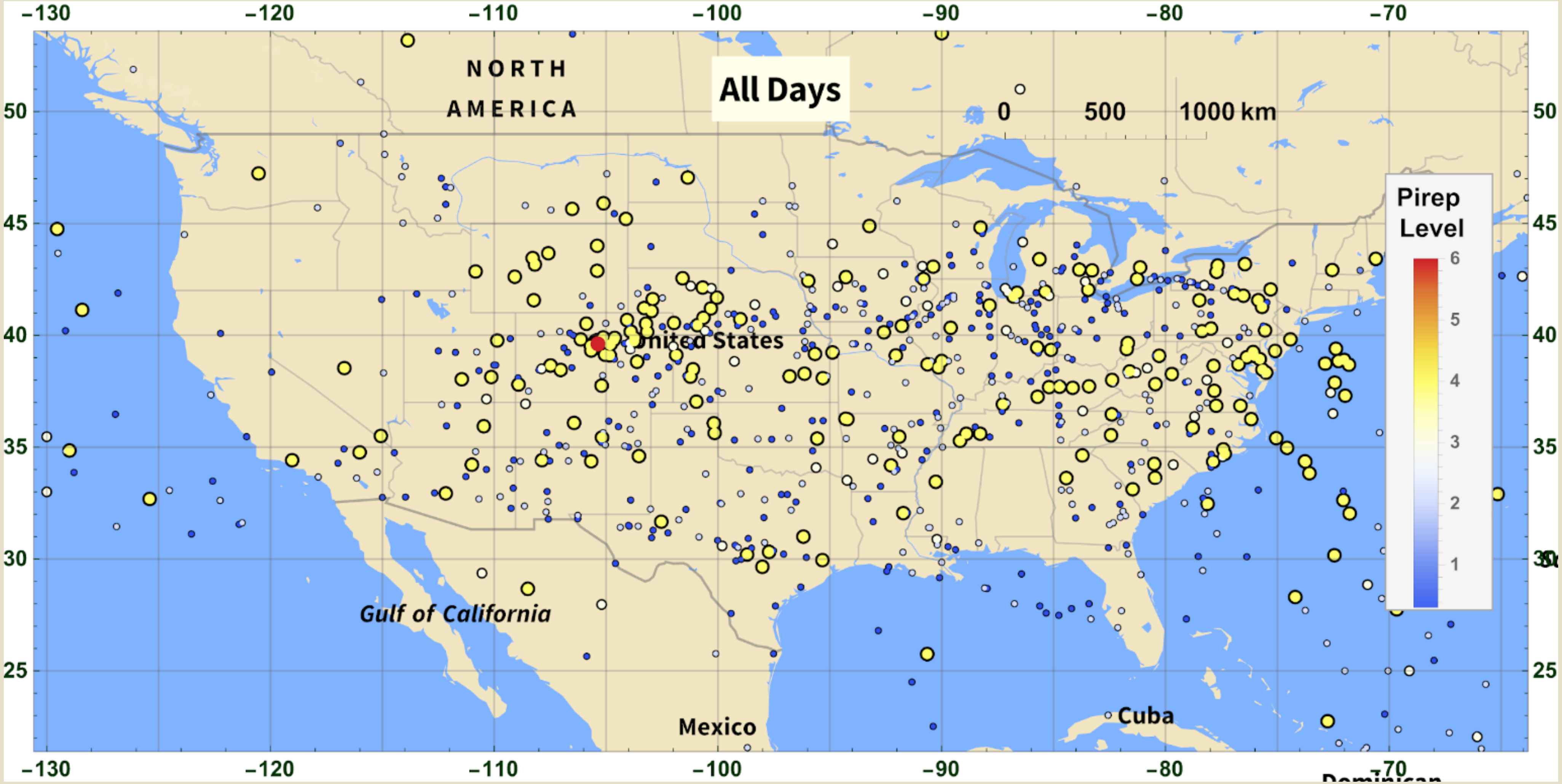
Active Turbulence Day

PIREPS



ADS-B EDRs

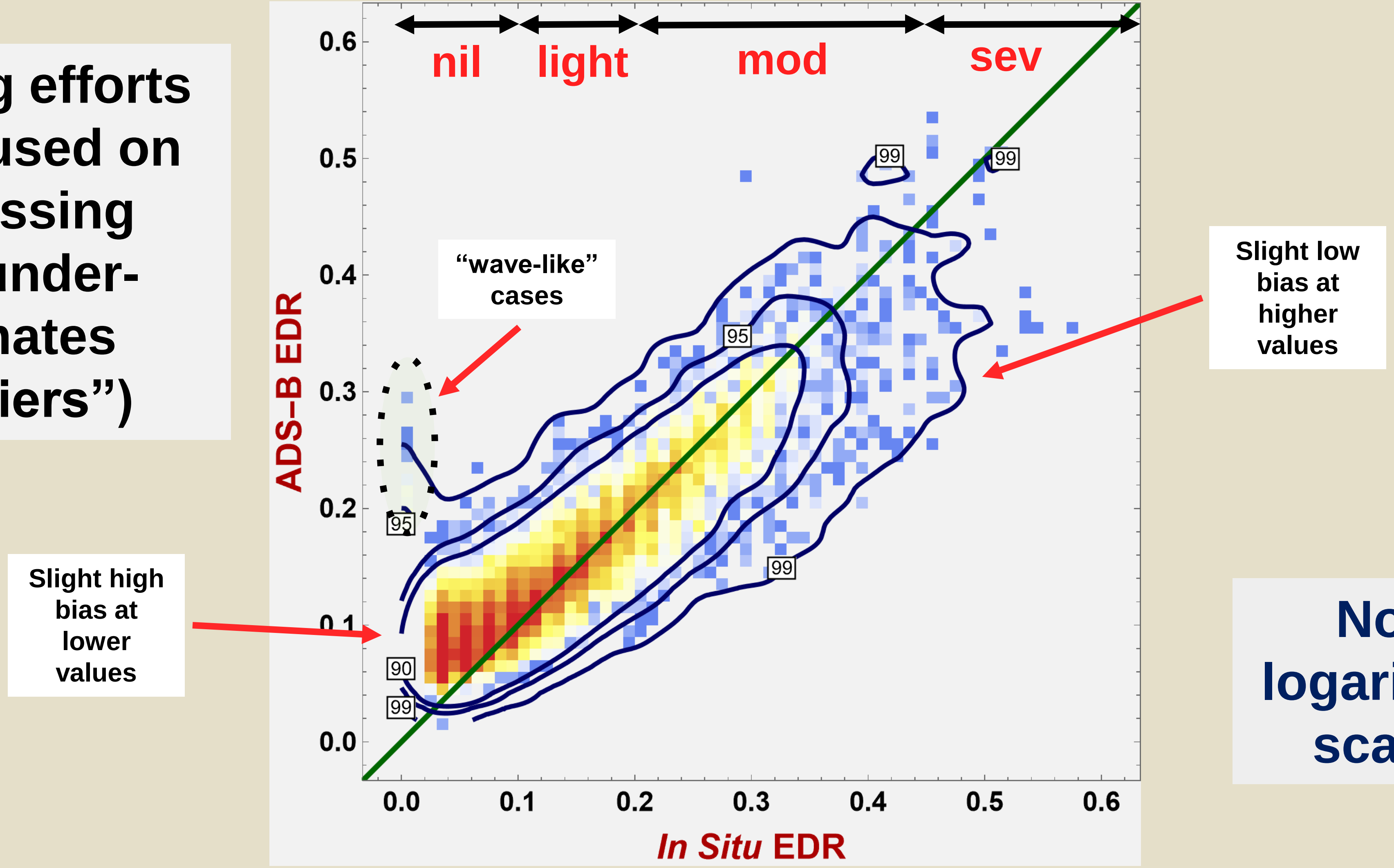
Pireps for Four Case Study Days



Very active turbulence days

ADS-B VR Algorithm V1 Verification (~335 flights over 4 days)

Ongoing efforts are focused on addressing over/under-estimates ("outliers")

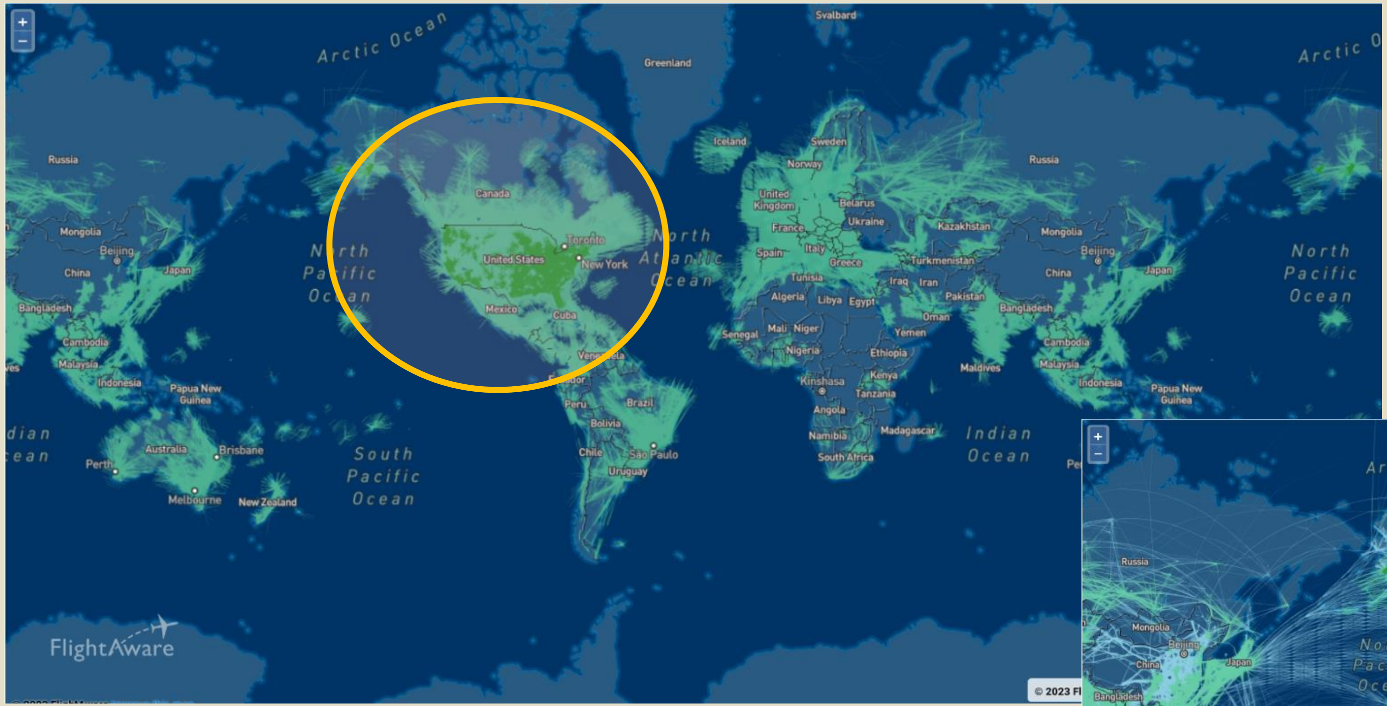


Note: logarithmic scaling

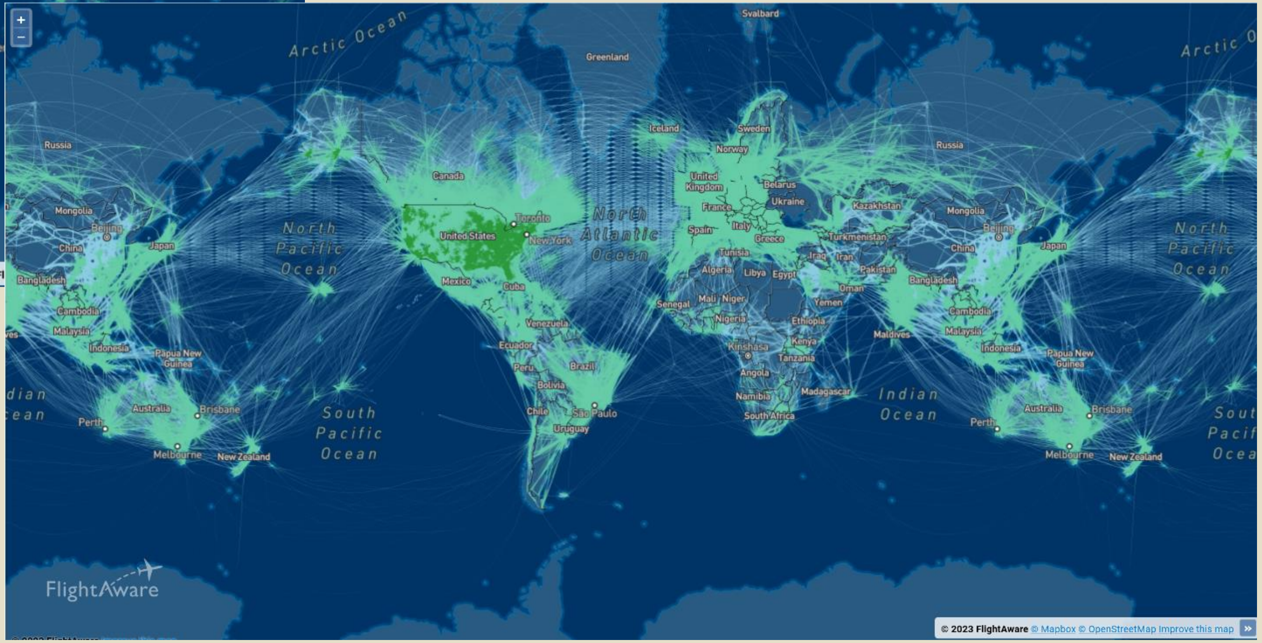
>95% of points are w/in +/- 0.1 of one-to-one line

ADS-B Coverage Map (1 week, source: FlightAware/Aireon)

Ground-based

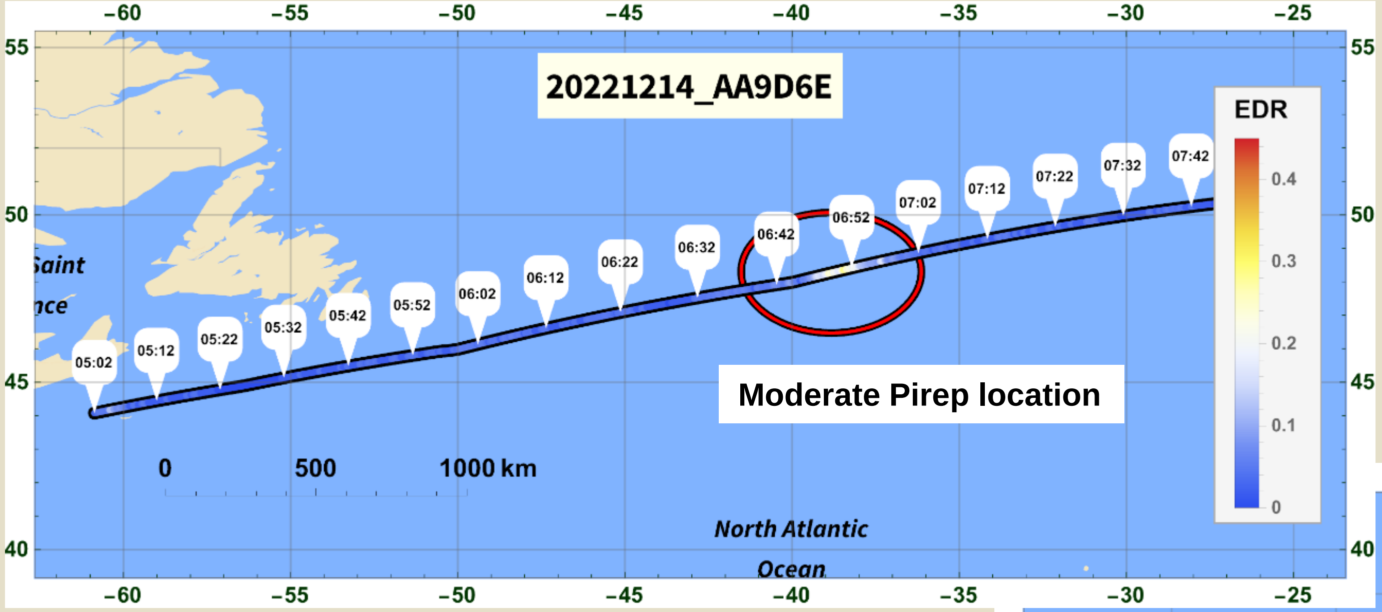


Ground-based + Satellite-based

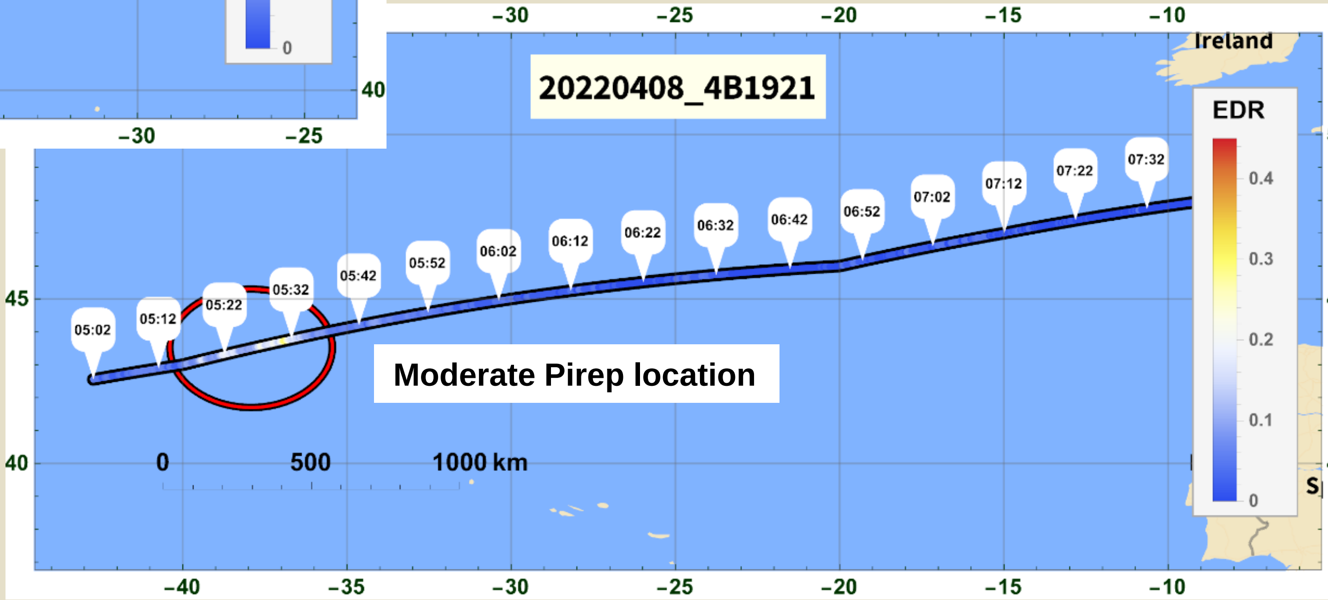


Ground-based + Spaced-based ADS-B provides broad global coverage

Application to Spaced-Based ADS-B (SBA) Data



Feasibility study is being funded by Aireon to investigate utility of SBA data for turbulence detection



ADS-B VR algorithm was modified to run on SBA VR data – results have been positive

SBA data allows for enhanced turbulence detection over remote regions

Detection of High Ice Water Content (HIWC) Conditions: Recent Developments by NCAR and the FAA

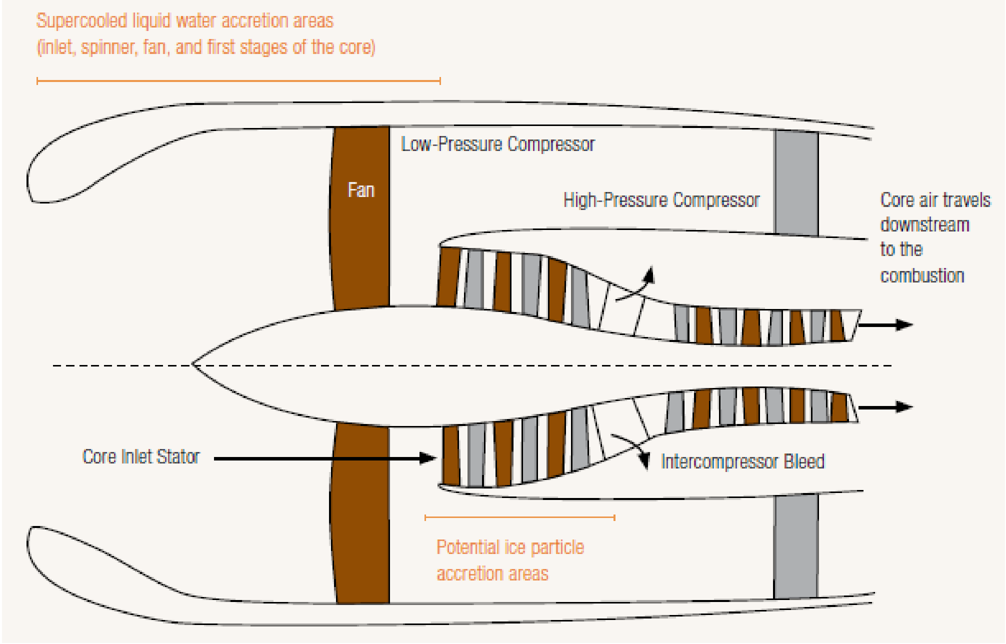
Julie Haggerty (NCAR)
Alex Rugg, George McCabe, Gary Cunning

NCAR | RESEARCH APPLICATIONS LABORATORY

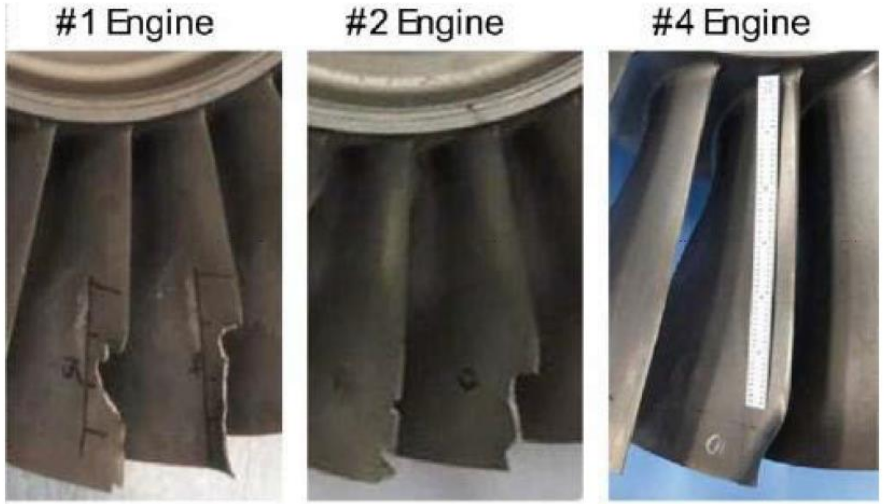
This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

What is Ice Crystal Icing (ICI)?

- **High concentrations of ice crystals**
  - High Ice Water Content may exist in apparently benign parts of convective clouds (e.g., anvil portion)
  - Low reflectivity on cockpit radar => small particle size
- **Ice crystals ingested into engine**
  - Heat transfer processes result in:
    - Cooling of warm surfaces through impact with crystals
    - Partial melting of ice crystals
    - Ice formation on surfaces
  - Additional ice accretes; accumulated ice can block flow into engine core or shed into compressor
  - Result may be power surge, power loss, engine damage
- **Aircraft data systems** may also be affected by ingest of ice crystals leading to errors in temperature, air speed, and angle of attack
- **IWC threshold and duration of exposure** needed to cause an event still under investigation

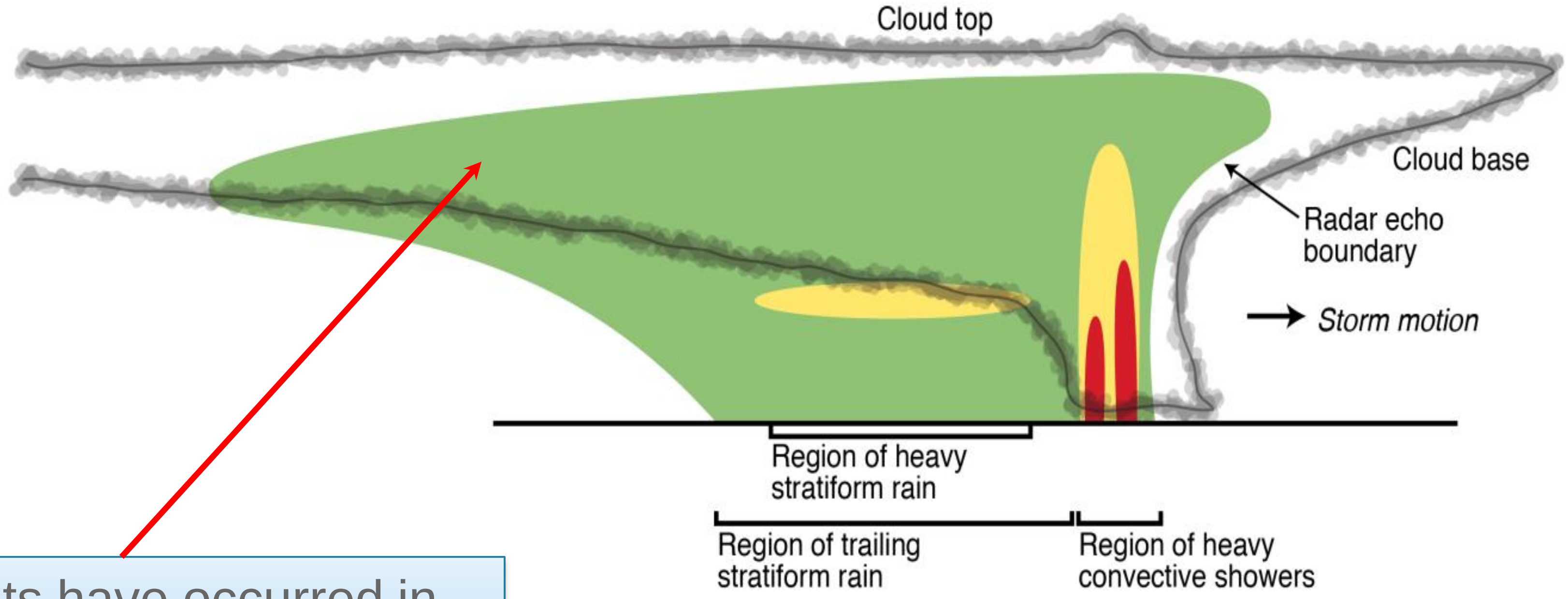


From Mason, 2006: "Engine Power Loss In Ice Crystal Conditions"



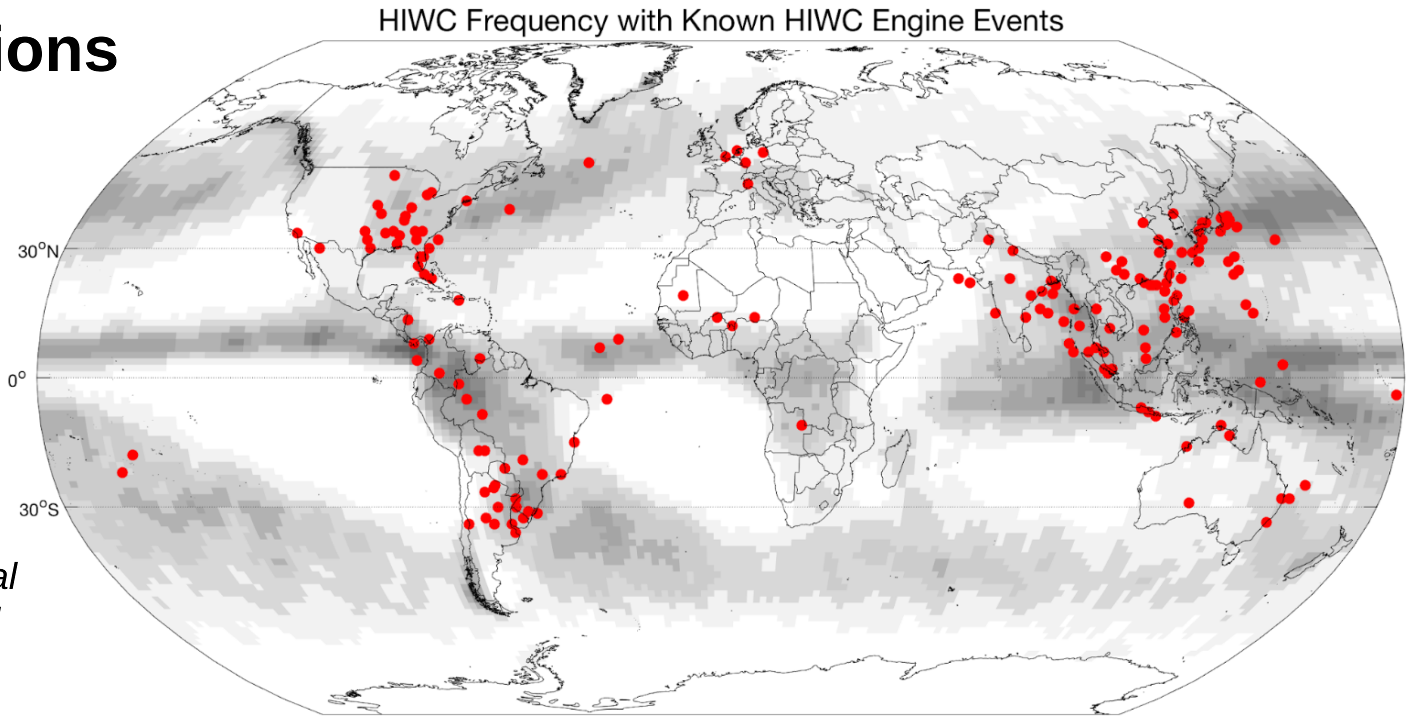
http://aviationweek.com/awin/core-engine-icing-strikes-russian-747-8f

HIWC in Deep Convective Clouds: Conceptual Model



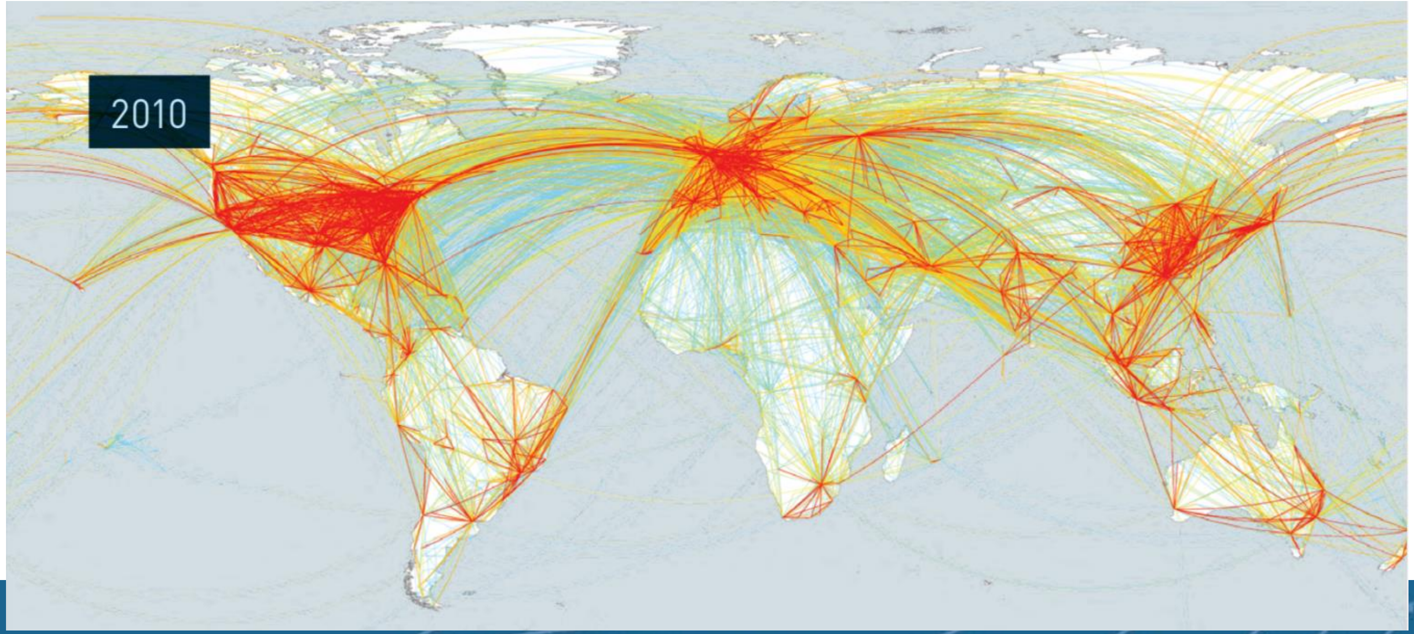
Engine icing events have occurred in the trailing anvil where radar echoes are low or non-existent

Global Frequency of HIWC Conditions



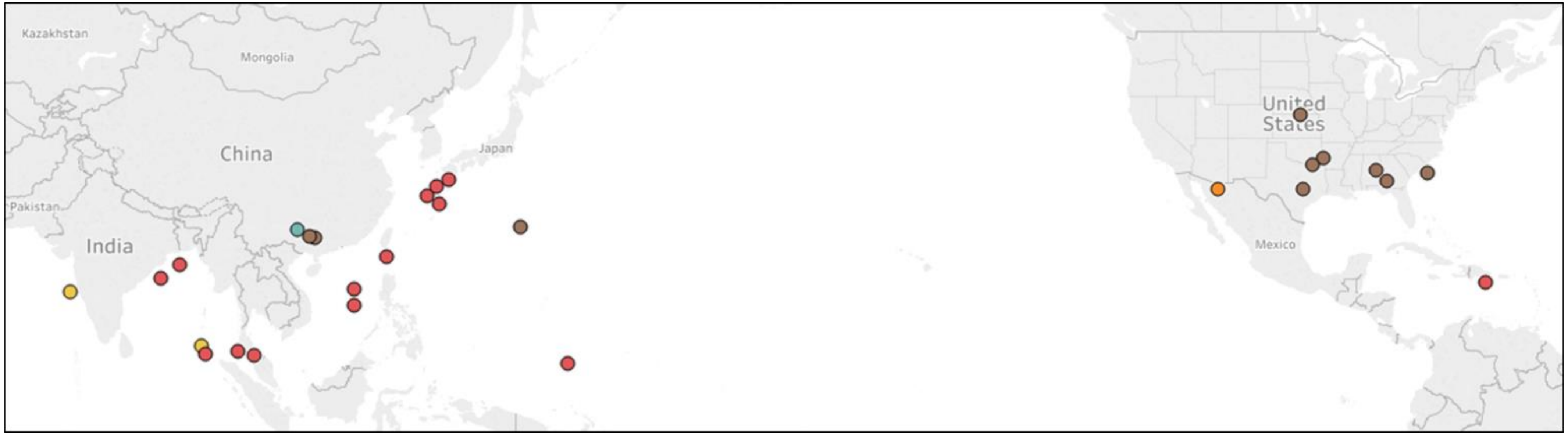
HIWC frequency with 174 ICI engine events (Bravin and Strapp, 2019)

Rugg, A., J. Haggerty, and A. Protat, 2021: Global and Regional Patterns in High Ice Water Content Conditions. J. Climatol. and Appl. Meteorol.



2010 Aircraft Movements (ICAO)

ICI Events Continue to Occur Worldwide



ICI engine events in US and Asia regions

All operators of **<u>Boeing</u>** Aircraft

8/1/2014 – 1/8/2020

Note: Colors indicate operator's base of operations (e.g. US-based operators = brown)

Three known engine events on large transport aircraft in 2021

Estimated to occur at a rate of 8-10 per year

FAA-Sponsored HIWC Efforts

Understand and address threat

- New Icing Regulations
  - FAA/EASA released new icing regulations effective January 2015
  - Defined new regulations for ICI conditions, environmental engineering standard (Appendix D/P), and guidance materials for new type design engines
  - Based on data collected in the 1950's
- Evaluation of ice crystal engineering standards
  - Data collected in a series of campaigns from 2014-2018
  - Development of simulation methods for ground testing and computational modeling
- **Mitigation strategies** for avoiding high altitude ice crystal environments

FAA Efforts – Mitigation Strategies

Airborne Weather Radar *(ongoing activity)*

→ **Weather Nowcasting Tool *(ongoing activity)***

- Algorithm for Prediction of HIWC Areas (ALPHA)
- ALPHA was originally developed to support the HIWC flight campaigns, but has since been explored as a weather nowcasting tool for hazard mitigation
- Note that other groups have also developed HIWC nowcasting tools *(Haggerty et al., BAMS, 2019)*

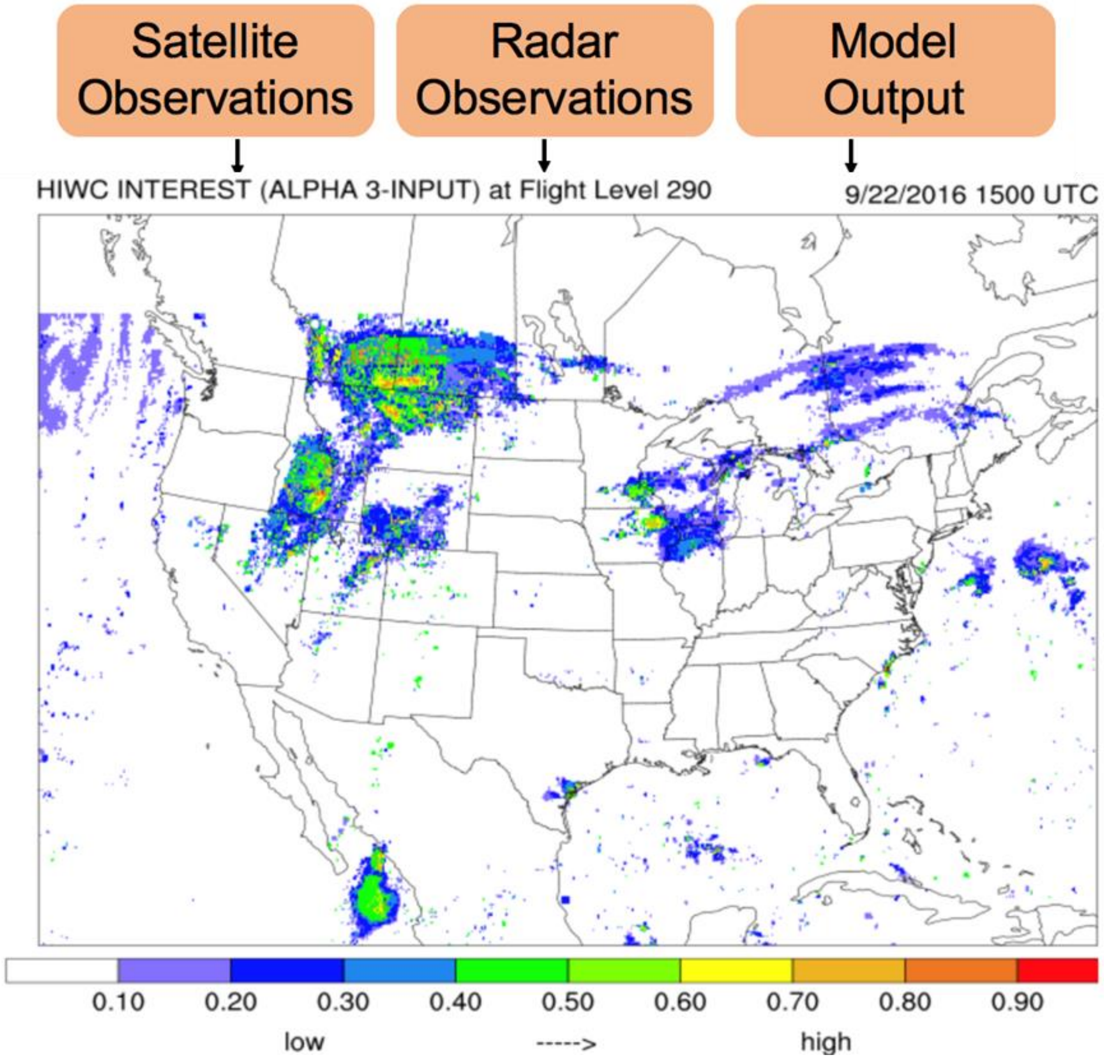
Development of an HIWC Nowcasting Product
The Algorithm for Prediction of HIWC Areas (ALPHA)

ALPHA blends routinely available meteorological data from:

- Geostationary Satellite
- Radar Mosaic
- NWP Models

Fuzzy Logic used to blend fields

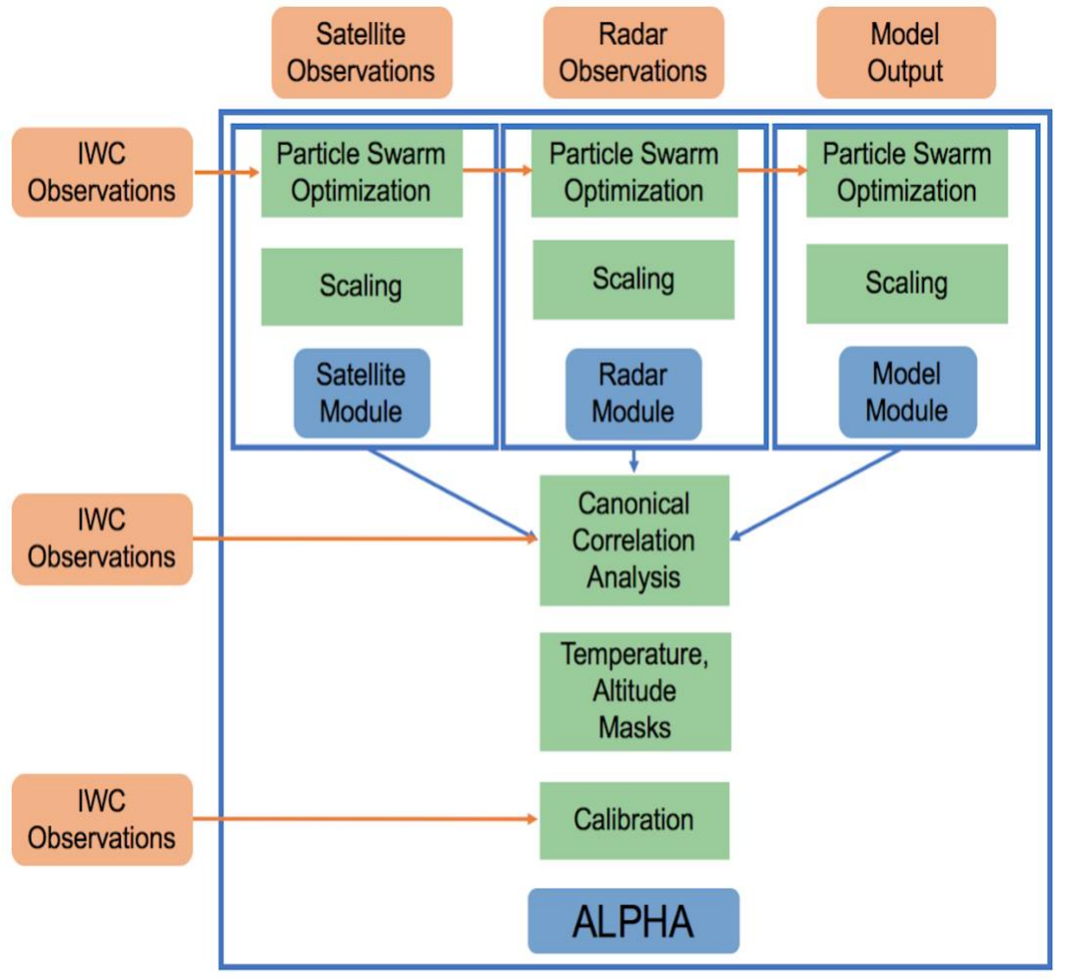
Machine Learning methods applied to train algorithms using in situ measurements from four field campaigns



Haggerty et al., JTech, 2020

Machine Learning Applied to Develop Membership Functions and Weights

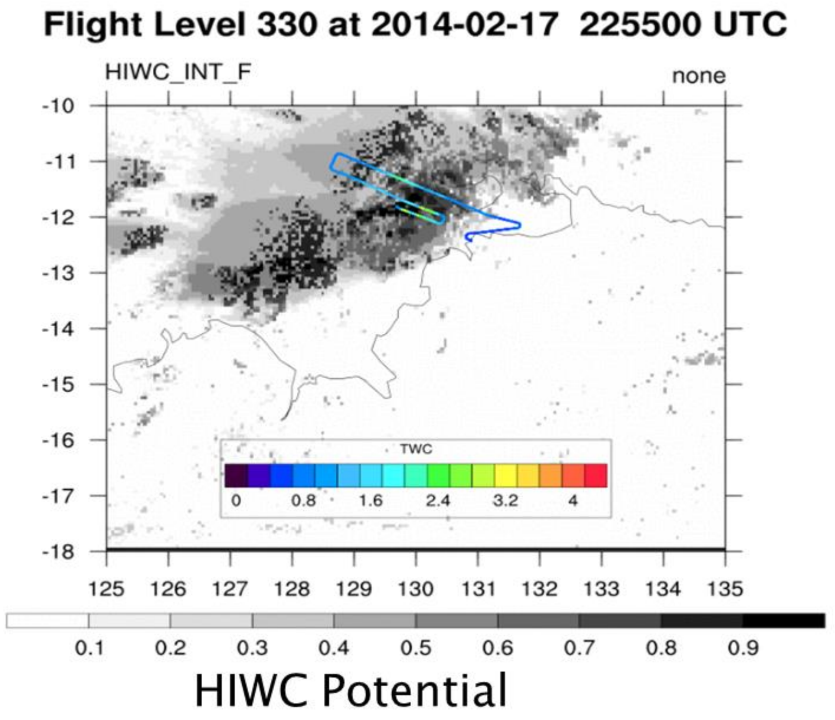
- Particle swarm optimization (PSO) finds optimal fuzzy logic membership functions and weights for each variable in each module
- Output scaled so *observed* range is from zero to one
- Canonical correlation analysis blends satellite, model, radar
- Temperature and cloud top/altitude masks applied
- HIWC Potential calibrated



ALPHA Implementation and Evaluation

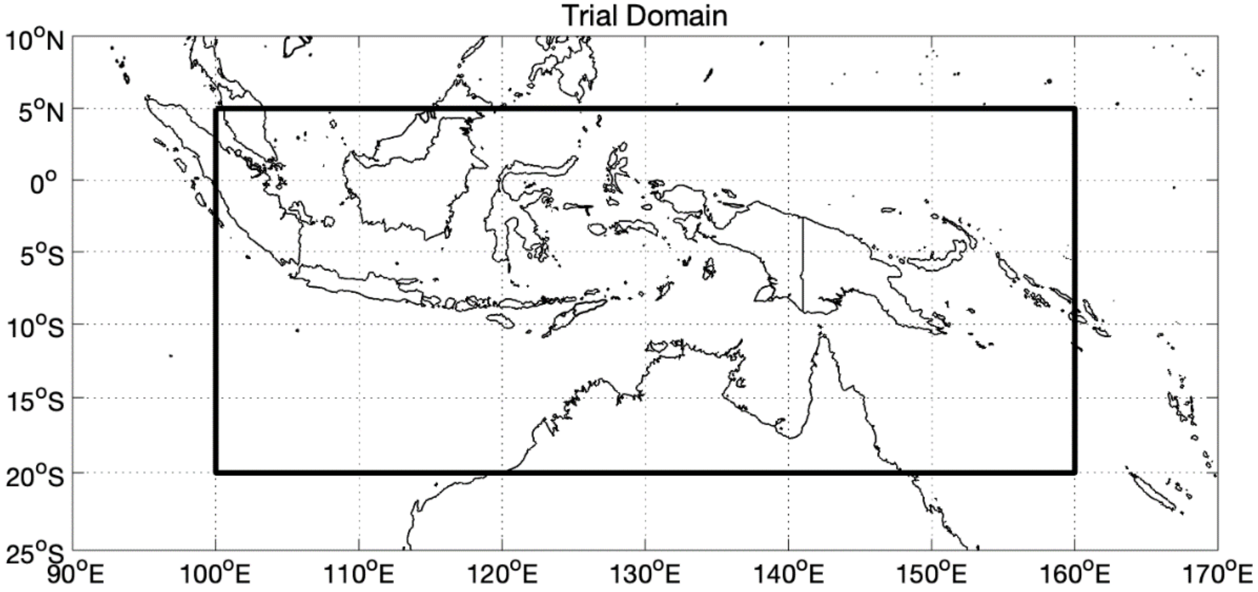
I. Field Experiment Support

- Darwin, Australia (2014)
- Cayenne, French Guiana (2015)
- Ft. Lauderdale, FL (2015)
- FL/CA/HI (2018)

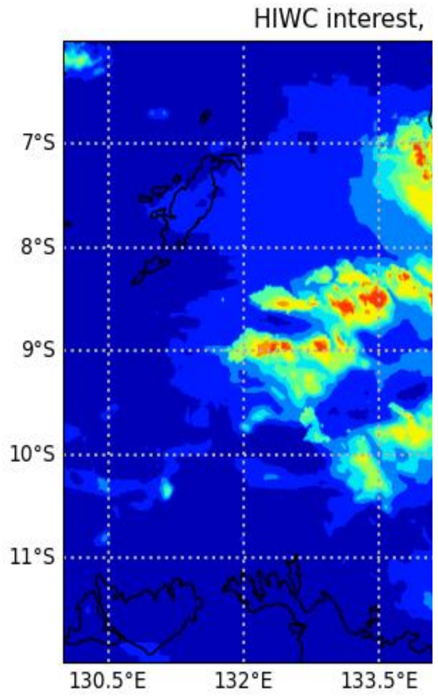


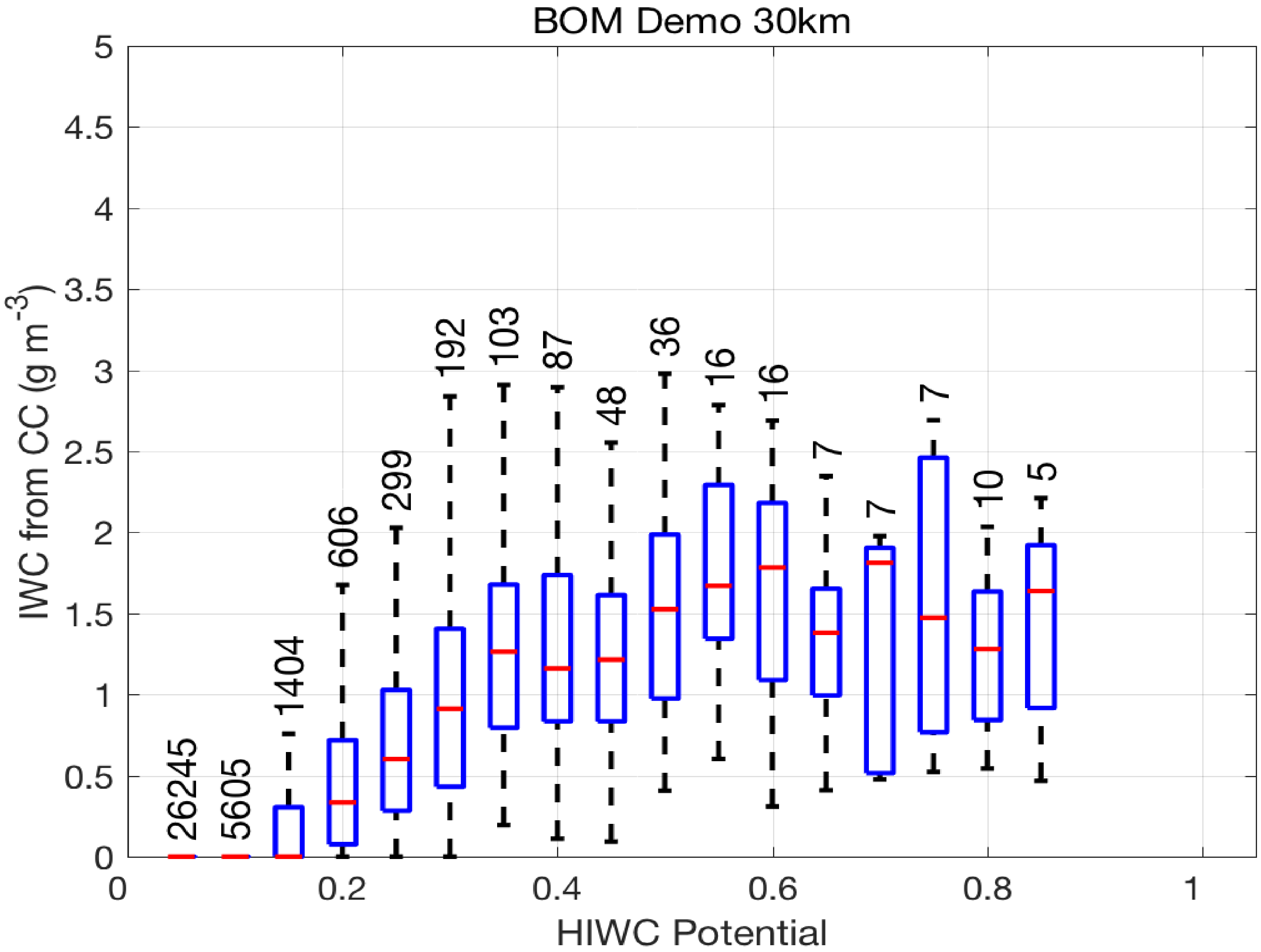
II. Operational Trial (Jan-Jun 2020)

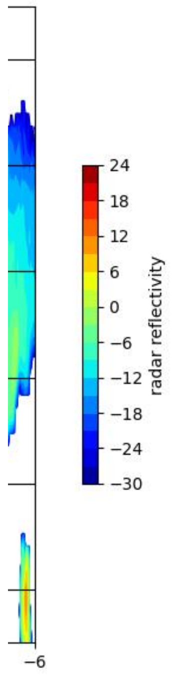
- FAA-NCAR-Australian Bureau of Meteorology
- Products provided to Australian-based airlines (Qantas and Virgin Australia)
  - Meteorologists, dispatchers, pilots
- Product delivered to airlines, but planned Intensive Operating Period derailed by COVID



ALPHA Verification with CloudSat-CALIPSO IWC







ugg, and A. Protat. 2023:
ting Service for High Ice
ditions. Atmosphere 14,
).3390/ atmos14050786

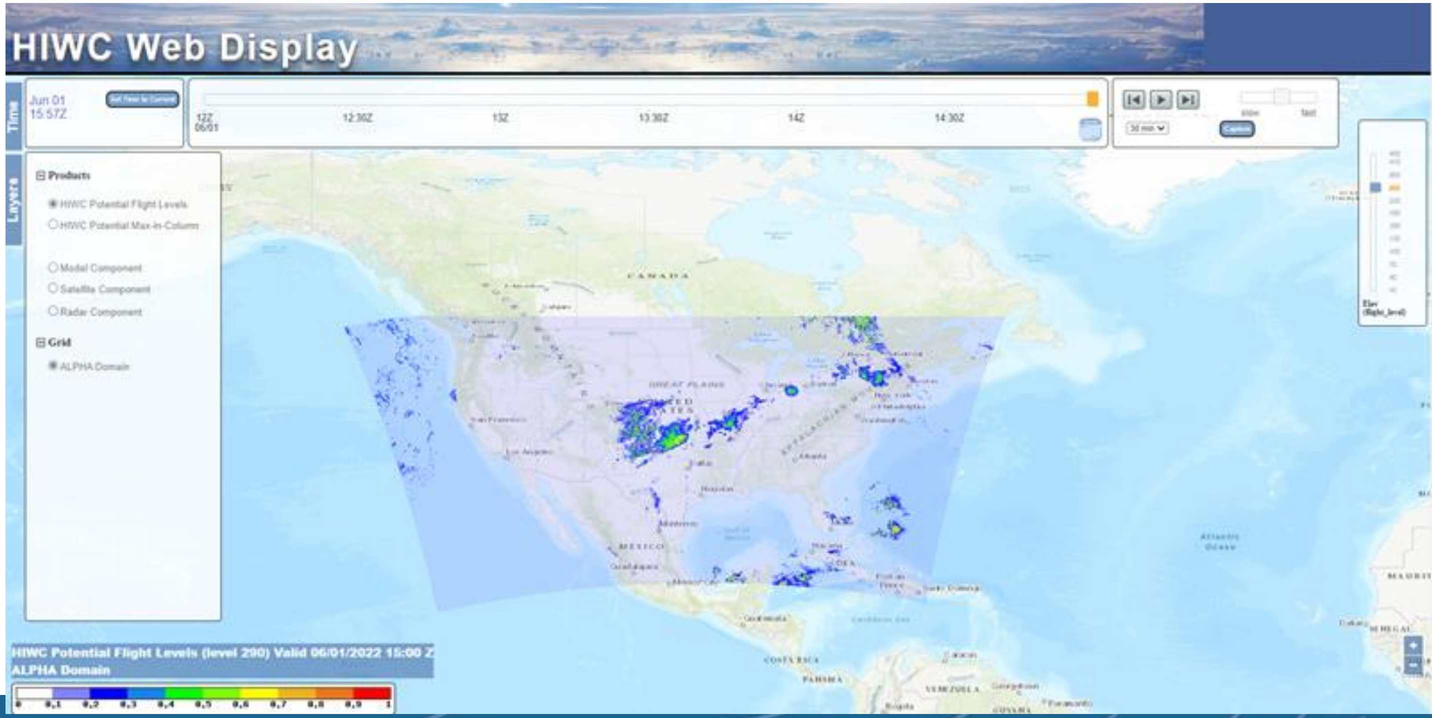
US-based Formal User Evaluation of ALPHA
June 2022

I. FAA Aviation Weather Demonstration and Evaluation (AWDE) Services Team

- Recruit and support participants
  - Meteorologists, pilots, dispatchers
- Gather feedback
  - Develop user surveys
  - Conduct virtual interviews with users

II. NCAR HIWC Product Development Team

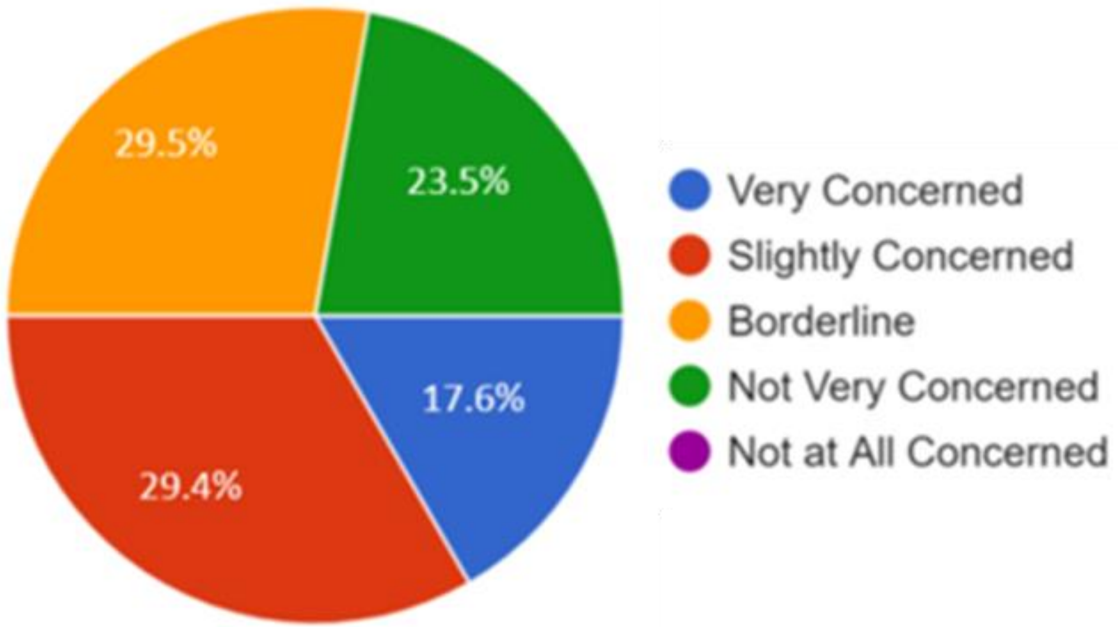
- Provide real-time ALPHA products via website
- Develop training materials for participants
- Support virtual interviews



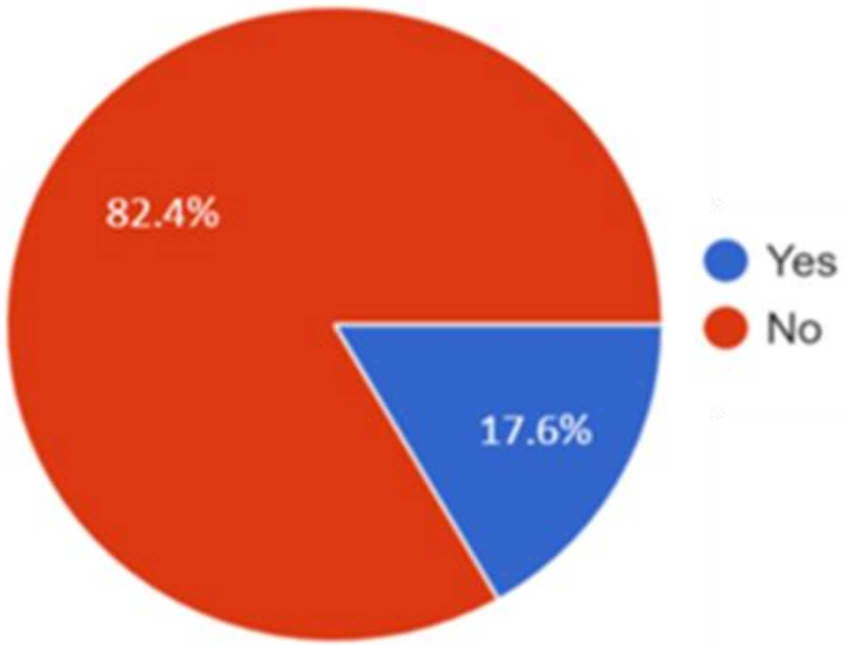
Feedback from Participants

Prior Familiarity with HIWC Conditions

How concerned are you about HIWC events?

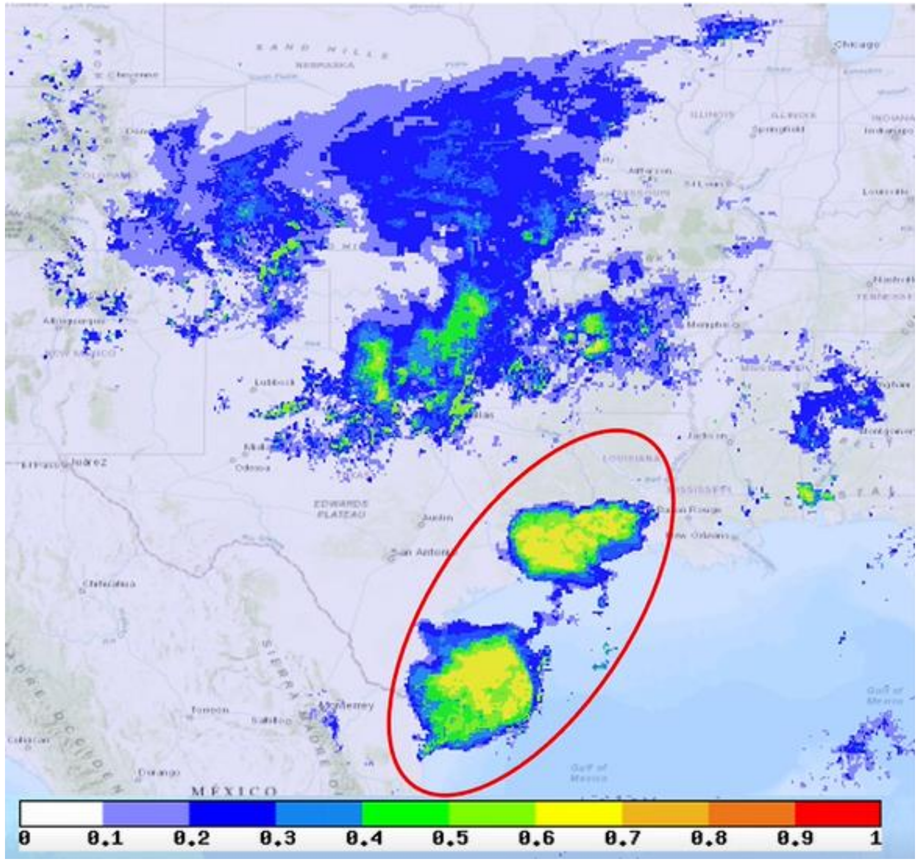


Have you ever experienced a HIWC event?



Summary of Significant Findings

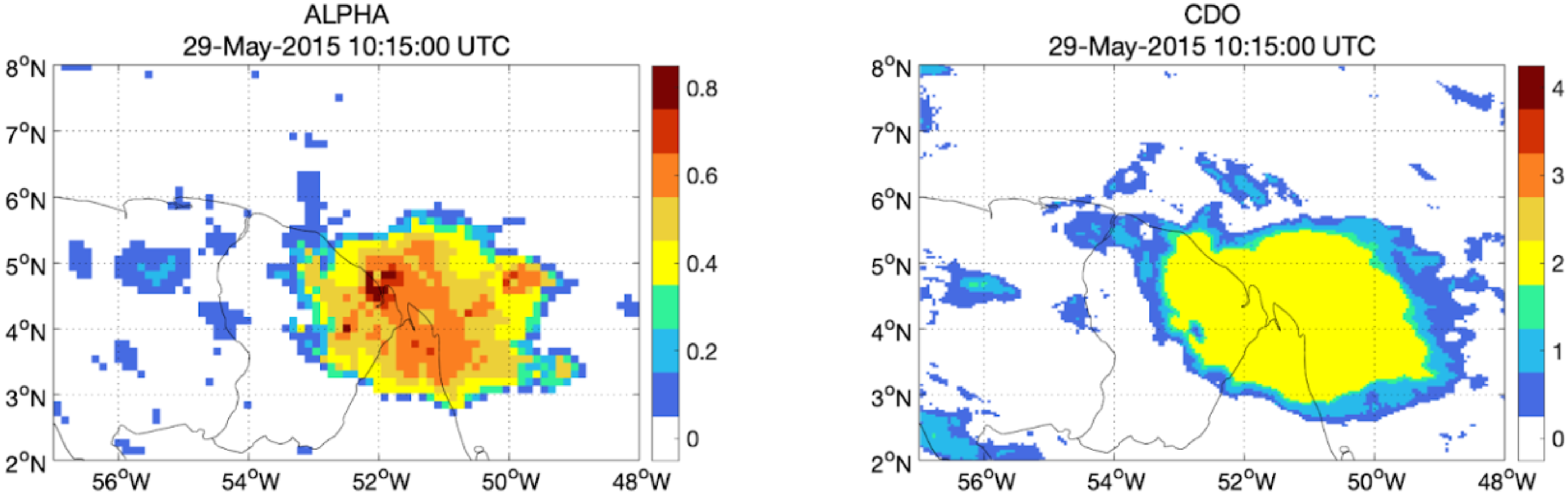
- Participants had limited understanding of the hazard presented by HIWC conditions
  - Some confused **Ice Crystal Icing** due to HIWC conditions (which impacts engine performance) with **Supercooled Liquid Water Icing** (which causes accretion on airframe and impacts aerodynamics)
  - Frequency and impact of ICI events not fully appreciated
- Most participants did not view HIWC information as necessary for decision-making, but might use it for situational awareness. Satisfied with other convective products.
- Participants stated that the absence of a **requirement to monitor HIWC** diminishes the need for a nowcasting product in operational settings



24 May 2022, 1630 UTC
HIWC Potential Column Maximum

ALPHA vs. Convective Diagnosis Oceanic (CDO)

- 5 case studies to compare ALPHA and CDO products
  - CDO product based on **lightning and turbulence**
  - ALPHA based on **high ice water content**
- Results show differences in intensity and location of hazard



Continuing Efforts

- Analysis of data from the HIWC-2022 field campaign
  - Minor revisions to ALPHA are ongoing
  - Add 2022 in situ airborne measurements to training and verification data sets
- Further education on the HIWC hazard with users
- Exploration of potential requirements from regulatory agencies
  - FAA
  - ICAO MetPanel

Questions?

This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.

Related Activities

- NASA LaRC satellite-based HIWC product
- DWD (Germany) model-based HIWC product; trained on Lufthansa TAT/Pitot tube anomaly events
- Boeing HIWC product
- TIE* machine learning project
- Ongoing research on mid-latitude and winter-time HIWC conditions (NCAR and ECCC)

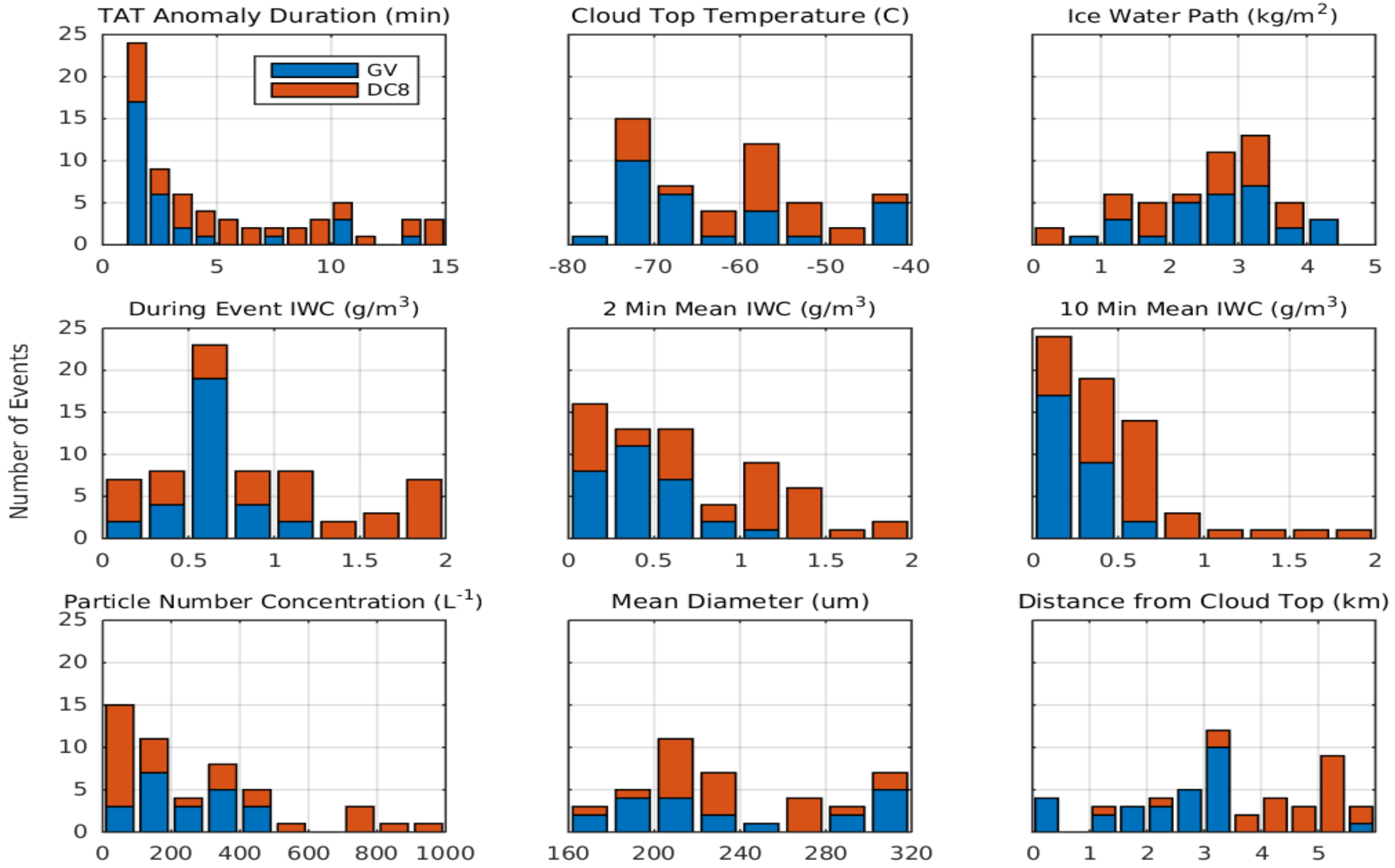
Rugg, A., B. C. Bernstein, J. A. Haggerty, A. Korolev, C. Nguyen, M. Wolde, I. Heckman, and S. DiVito, 2022: “High ice water content associated with wintertime elevated convection in the Midwest.” J. Appl. Meteor. Climatol., early online release, doi: 10.1175/JAMC-D-21-0189.1.

Variables Considered as Input to ALPHA

Satellite	Radar	WRF Model	ACCESS Model
Cloud Top Temperature	Composite Reflectivity	Ice Water Content	Ice Water Content
Cloud Top Height	Maximum Height with at least 10 dBZ	Relative Humidity	Relative humidity
Temperature Difference (6.8 µm – 10.8 µm)	Maximum Height with at least 30 dBz	Vertical Velocity	Vertical Velocity
Optical Depth	Echo Top (18 dBZ threshold)	One Hour Convective Precipitation	One Hour Convective Precipitation
Brightness Temperature (6.8 µm)	Cloud Depth (18 dBZ threshold)	One Hour Total Precipitation	One Hour Total Precipitation
Brightness Temperature (10.8 µm)	Ice Mass	Convective Available Potential Energy (CAPE)	High Cloud Cover
Tropopause Height – Cloud Top Height	Volume Averaged Height Integrated Radar Reflectivity (VAHIRR)	Convective Initiation (CIN)	Middle Cloud Cover
	Volume Integrated Liquid (VIL)	Temperature	Low Cloud Cover
			Temperature

Air Data System Anomalies

- According to Boeing analyses, TAT probe anomalies have occurred in many cases near the time of the engine powerloss events.
  - The airplane total air temperature probe (TAT) erroneously reporting 0^0C is known to be evidence of ice crystals in the atmosphere.
- TAT and TAS anomalies are common on research aircraft. Statistics on atmospheric conditions associated with the 68 events have been compiled.



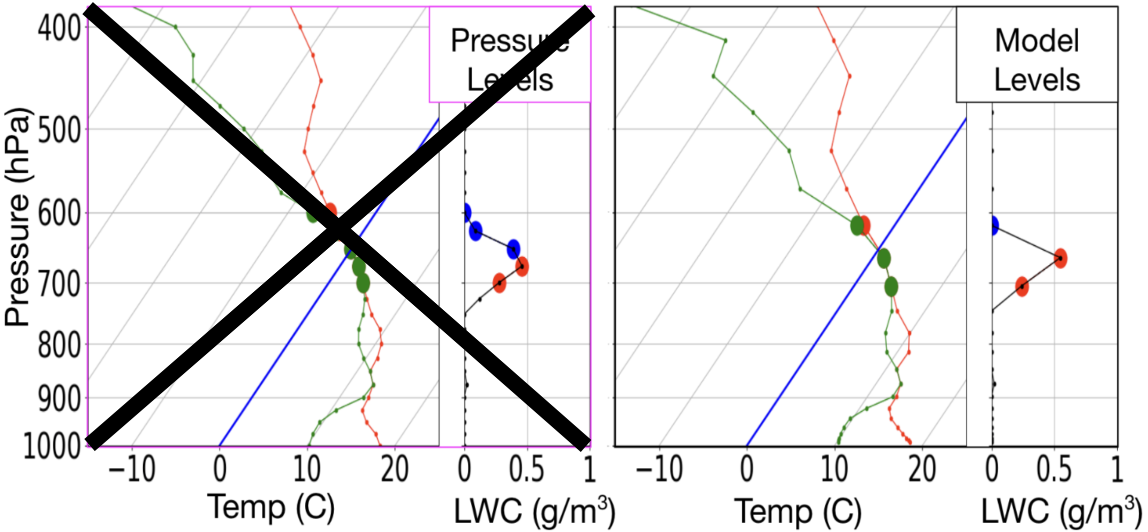
***Haggerty, J.,** A. Rugg, T. Ratvasky, J.W. Strapp, L. Lilie, K. Bedka, J. Jensen, and A. Bansemer, 2019: Characterization of high ice water content conditions that impact air data system performance. 19th Conference on Aviation, Range, and Aerospace Meteorology, American Meteorological Society, 9-12 January 2019, Phoenix, AZ.*

Recent Advancements in CIP/FIP Research by NCAR and the FAA

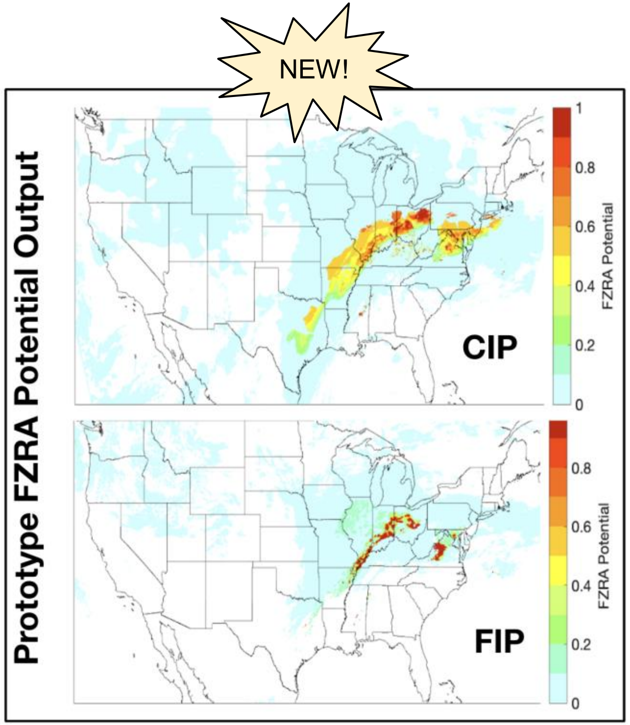
Mr. Dan Adriaansen
09 September 2024
Boulder, CO

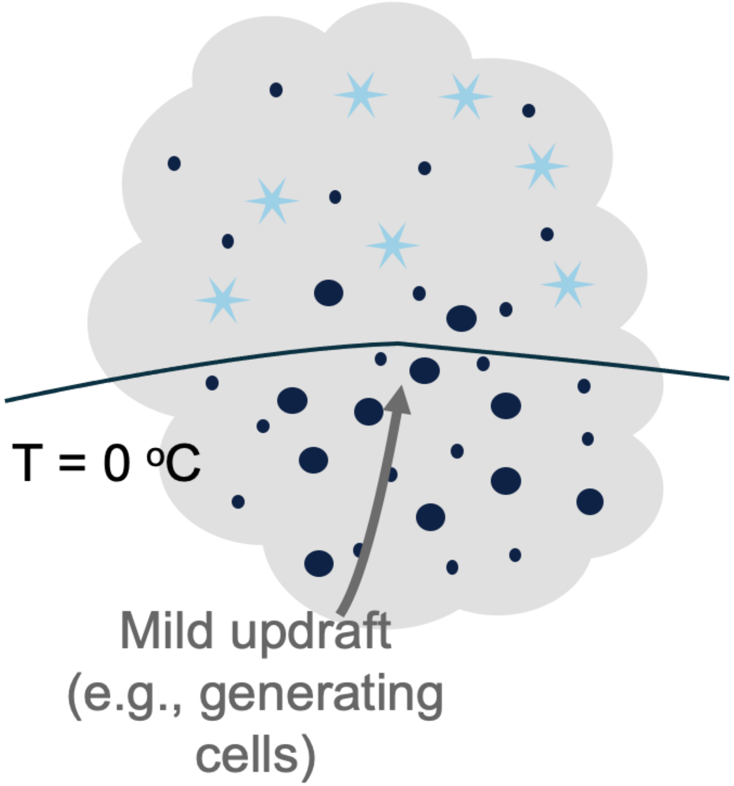
Aviation Applications Program
Research Applications Laboratory

CIP/FIP Enhancements



- No interpolation of model fields
- Retain information as long as possible
- Tighter coupling with model fields
- Vertical information tied to model
- Improved accuracy





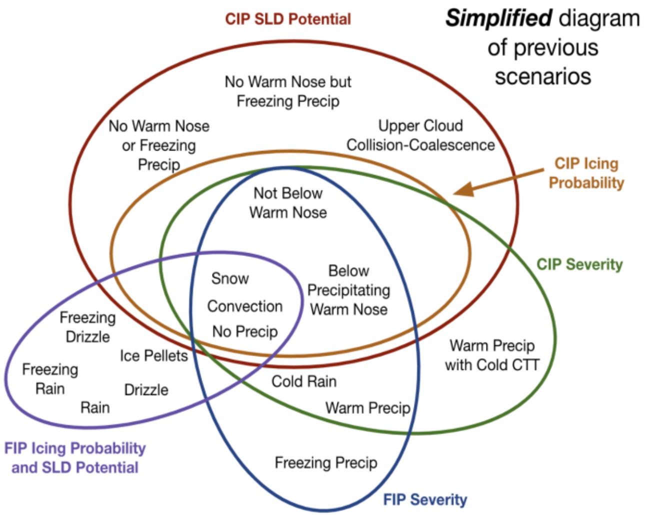
Recirculation

Falling snow/ice melt, then are lifted above the melting level in weak updrafts, often embedded in larger winter storms.

Small drop icing can be pervasive, but SLD is usually found in localized pockets within a few degrees of freezing.

This microphysical process was not well represented previously in any of the scenarios

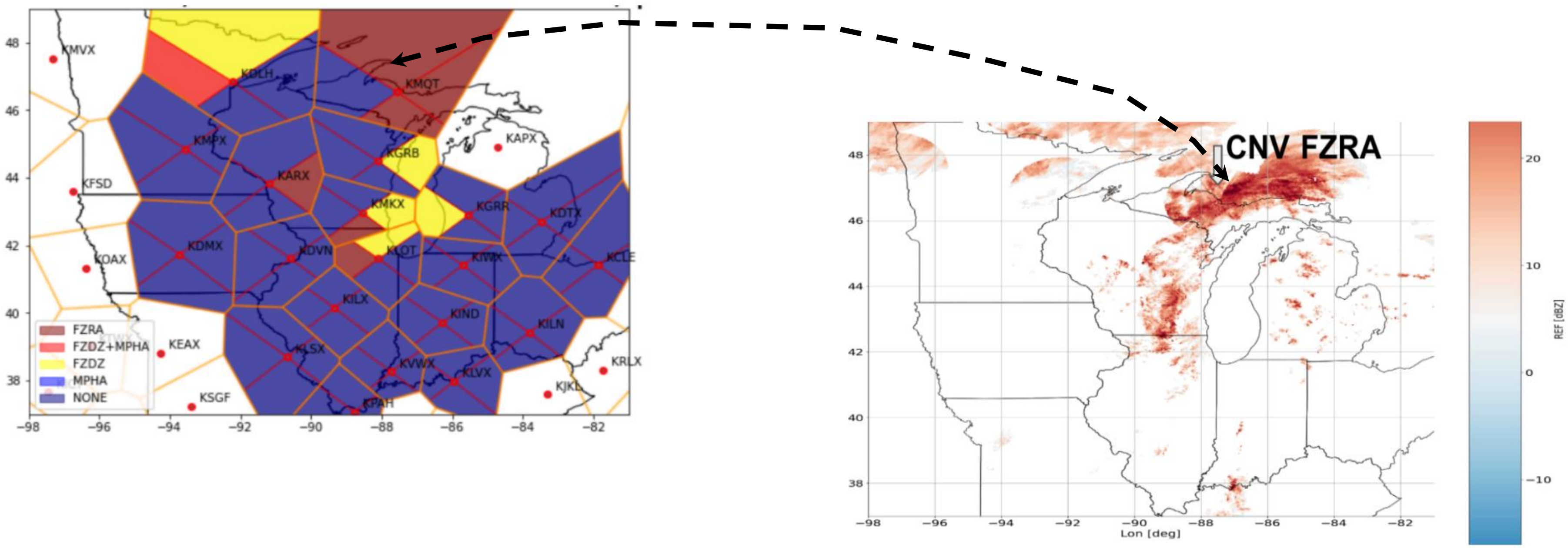
Shared CIP/FIP Scenarios



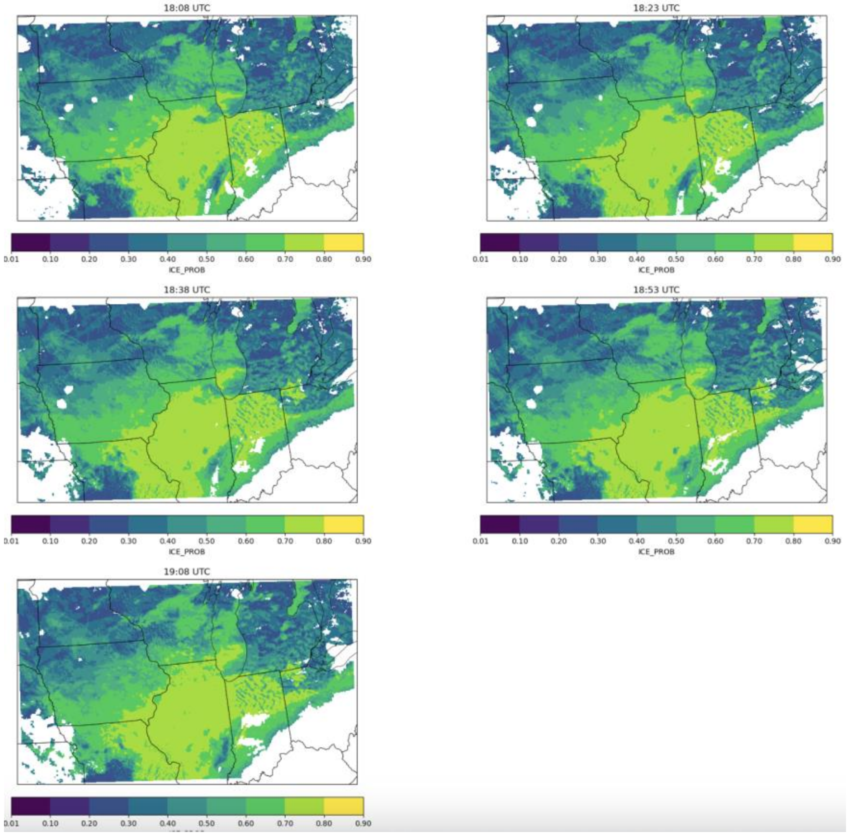
One set of scenarios for all CIP/FIP outputs based in modern knowledge of microphysical processes producing icing and SLD:

- Convection
- Below precipitating warm nose
- Recirculation
- Collision-coalescence
- Snow

Radar-derived vertical profile hazards to augment scenario selection



Tactical CIP



- 10-15 minute updates
- ABI scan mode “6”
- Intra-hour variability
- Feature evolution
- NWP forecast blend

Thank You!

dadriaan@ucar.edu

Task 3. NTDA

AOAWS **NCAR Turbulence Detection Algorithm**

Gregory Meymaris, Jason Craig, Scott Ellis, Wiebke Deierling

Aviation Applications Program
Research Applications Laboratory

Status Updates

- Collected user feedback and delivered report
- Finishing up debugging and testing of modifications needed to accommodate new C-band radars, including clutter mitigation and handling smaller Nyquist velocities
- Finishing evaluation (e.g. case studies) and tuning of NTDA
- The NTDA software on the CAA test and operational servers was updated to the latest version on the CAA test server in March.
- Training materials have been prepared and training is underway.

NTDA Deliverable Tracking

AOAWS-RU Task #	Deliverable	Due Date	Status
3a (2023)	Install NTDA software in CAA test environment	June 30, 2023	Completed.
3b (2023)	Report on NTDA case studies and evaluation as part of the quarterly report	Dec. 1 2023	Completed.
3c (2023)	NTDA status report on activities performed as part of quarterly report	Dec. 1 2023	Completed.
3a	User feedback assessment documentation	Feb. 15, 2024	Completed.
3b	NTDA status report on activities performed as part of quarterly report	Nov. 29 2024	In progress

NTDA Upgrade Readiness Status

Instance	Algorithm functionality
NEXRAD Ingester Component	R
Gematronik Ingester Component	A
NTDA Polar (Radar by Radar) Component	A
Mosaic component	R

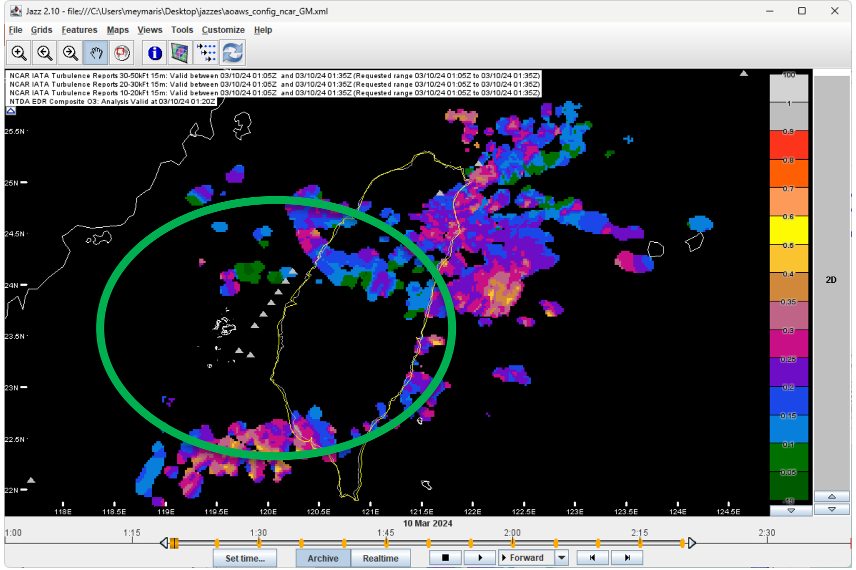
Notes
1. Debugging and testing continues

Status Key	Subsystem Development Phase
C	Code Development
T1	Testing and Configuration
T2	Testing with CWB Sample Data
A	Assessing Performance and Fine Tuning
R	Ready to Deliver

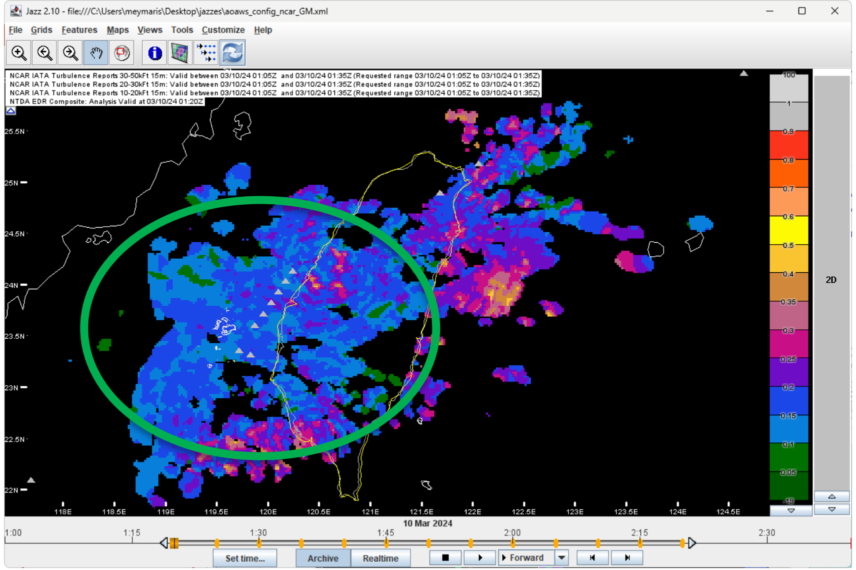
Coverage Increase

Case from:
3/10/2024 at 01:20Z, Composite (FL120-450)

Legacy NTDA (RCWF, RCKT, RCHD)



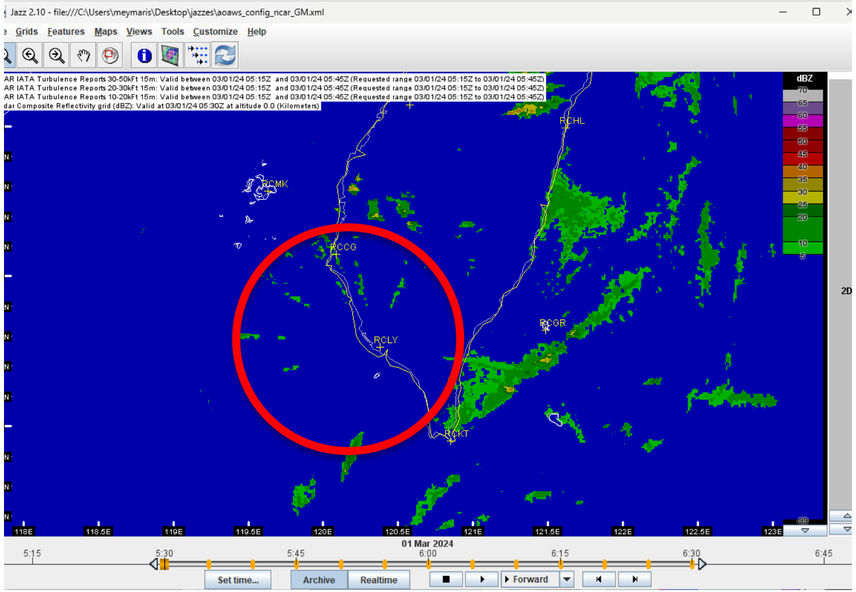
Updated NTDA including C-band radars



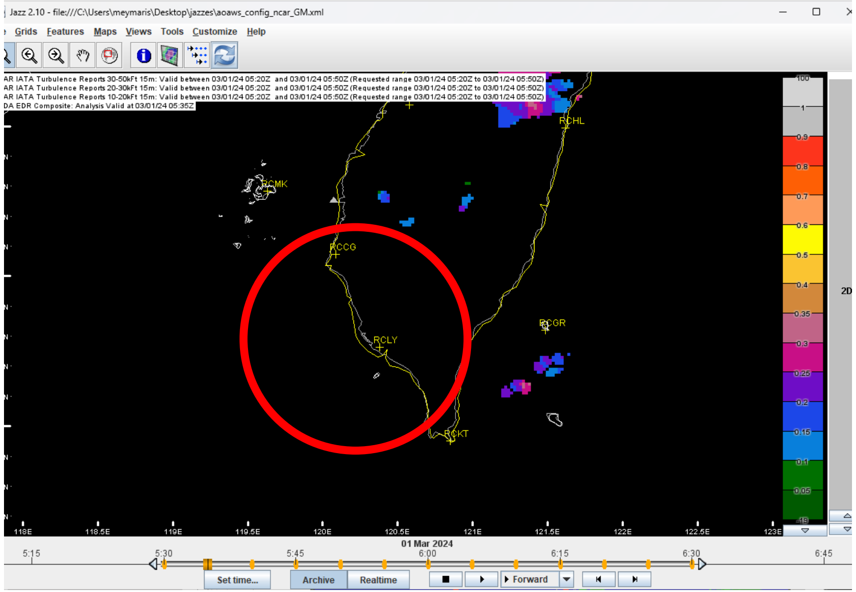
Improved RFI Mitigation

Case from:
3/1/2024 at 5:30Z

Taiwan Radar Composite Reflectivity

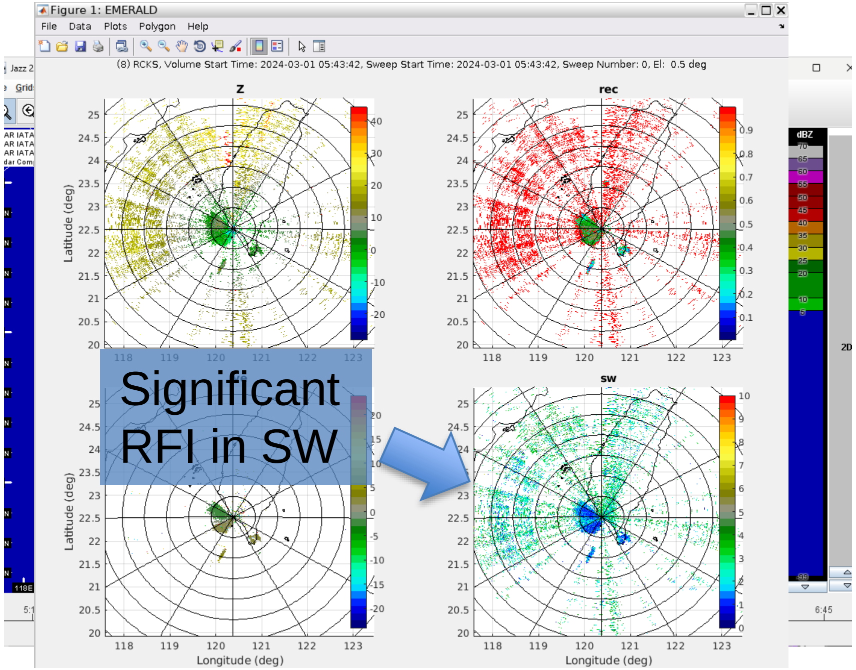


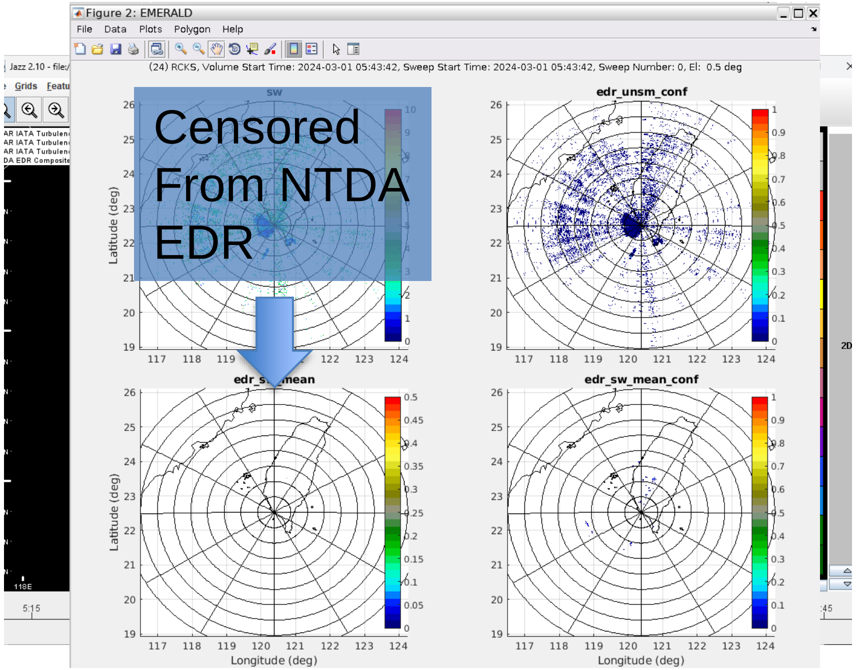
Updated NTDA including C-band radars



Improved RFI Mitigation

Case from:
3/1/2024 at 5:30Z





Plans

- Finalize all modifications needed to accommodate C-band radars, including clutter mitigation and smaller Nyquist velocity
- Finalize evaluation and tuning of NTDA.
- Complete regression test procedure
- Deliver final NTDA product
- Complete and deliver all remaining documentation and reports

Issues / Challenges

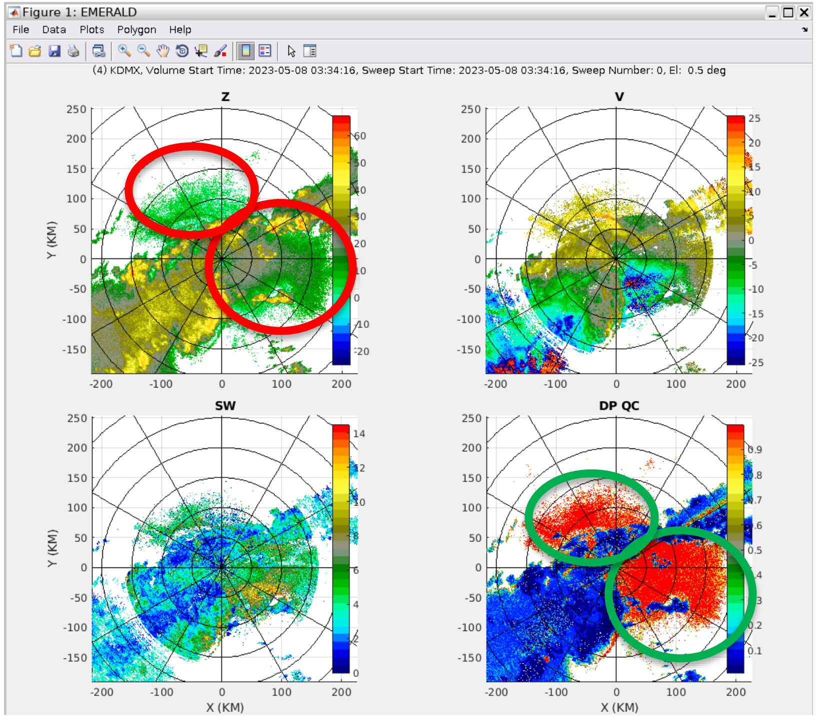
- Reliability of the data feed (time gaps, missing files, incomplete files) has greatly improved but outages from some radars (CAF C-band) have complicated case study analysis

FAA-sponsored development currently underway:

- Clear air echo mitigation
  - Use dual-pol moments to censor clear air (e.g. bugs) echoes
  - Potentially will allow for improved coverage near ground

Up next:

- Windshear mitigation



Task 2. GTG

Graphical Turbulence Guidance
and
Graphical Turbulence Guidance Nowcast

Wiebke Deierling, Hailey Shin, Jason Craig, Julia Pearson, Teddie Keller, Jeff Hancock, Greg Meymaris, Bob Sharman

Aviation Applications Program
Research Applications Laboratory

GTG4 Software Implementation and Updates

- Completed an initial installation of GTG4 software on the CAA test server
  - Documentation of the installation was provided at the end of June 2023.
  - Tested and evaluated the performance of the GTG4 system utilizing the real-time data on the CAA test server vs. the NCAR test server.

- Scripts to perform GTG4 output verification with in situ EDR observations have been developed

- Updated D1-GTG4 and D2-GTG4 calibration (mapping and selection of diagnostics). Performed statistical evaluation of updated GTG4 system based on ~2 years worth of in situ data and CWA WRFv3.8.1 model data.

- Finishing up case studies for further slight refinements of GTG4 calibration.

GTGN Task Updates

- Completed GTGN feasibility and implementation study and document recommending GTGN for Taiwan and specifying what input data should be included

- Developed Input data processing:
  - Developed an application for preparing IATA EDR turbulence data from Taiwan as input into GTGN
  - Developed a script for converting the combined METARS into the correct input format into the GTGN system.

- Developed code to identify and output an observation influence field (obsMask) that identifies areas of GTGN that can differ from the underlying GTG forecast

- Completed installation of GTGN prototype system on the CAA test server
  - Documentation of the installation was provided at the end of June 2024.
  - Tested and evaluated the performance of the GTGN system utilizing the real-time data on the CAA test server vs. the NCAR test server.

GTG Deliverable Tracking

AOAWS-RU Task #	Deliverable	Due Date	Status
2	Install GTG4 software in CAA test environment	June 30, 2023	Complete
2	GTG4 testing report	October 31, 2023	Complete
2	GTG4 user feedback assessment documentation	October 31, 2023	Complete
2	Report on one or more GTGN case studies as part of quarterly report	December 1, 2023	Complete
2	GTG4/GTGN status report on activities performed as part of quarterly report	December 1, 2023	Complete
2	Install GTGN software in CAA test environment	June 28, 2024	Complete
2	GTG4/GTGN status report on activities	November 29, 2024	In Progress

GTG4/GTGN System Readiness Status

Instance[1]	Algorithm Development	Initial Diagnostic Mapping to EDR and Diagnostic Selection (Calibration)	Updated Diagnostic Mapping to EDR and Diagnostic Selection (Calibration)	Verification
D1 - GTG4	Done	Done	Done based on CWA WRF version 3.8.1*	Done based on CWA WRF version 3.8.1*
D2 - GTG4	Done	Done	Done based on CWA WRF version 3.8.1*	Done based on CWA WRF version 3.8.1*

Notes:

- D1-GTG4 will not include CIT component because of its coarse grid spacing. CIT has been developed for higher grid resolution <= 3km

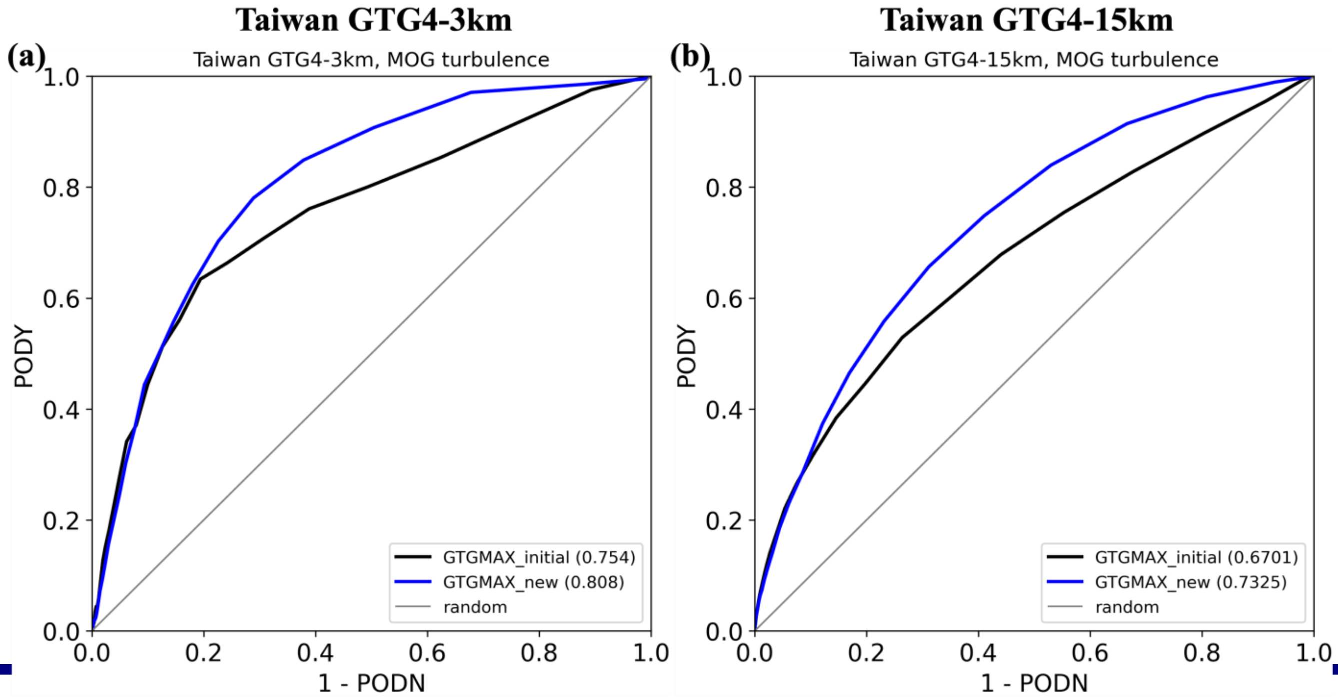
- *Calibration and Evaluation has been performed of D1- and D2-GTG4 based on CWA WRF version 3.8.1. Finishing further refinement of GTG4 calibration for WRF version 4.4.2.

Instance[1]	Algorithm Development	Configuration based on Case Studies
GTGN	Done	Done

Prototype GTG4 – Statistical Evaluation

- Verification of initial versus updated improved GTG4 calibration

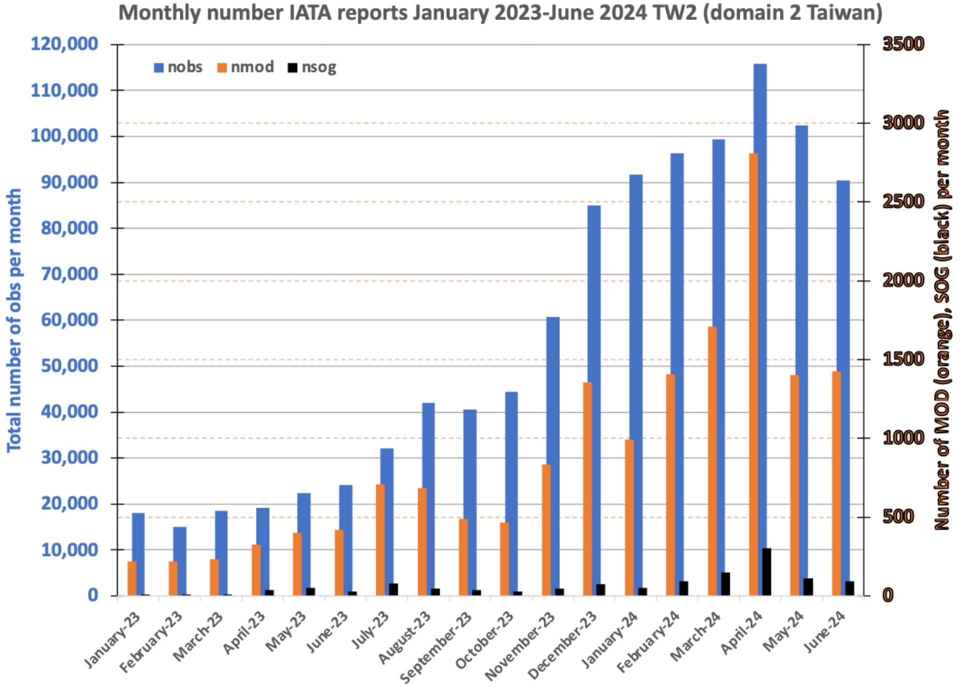
ROC curves for Moderate-or-greater (MOG) turbulence

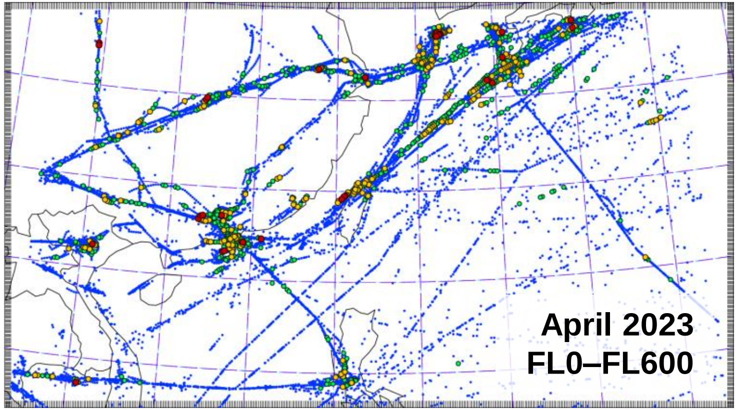


Issues and Challenges

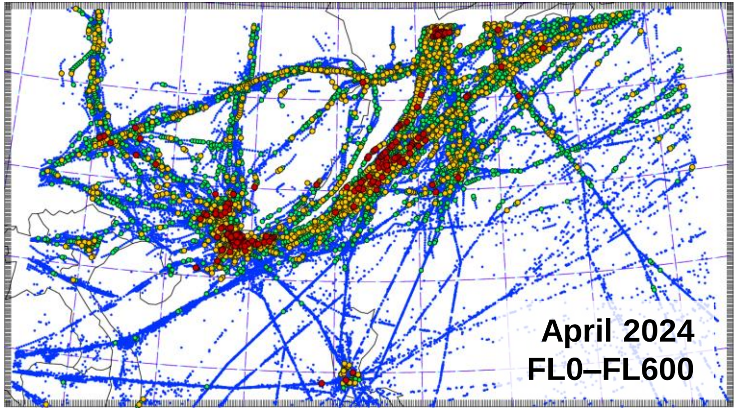
- Model data has data latencies.
- Can be challenging for GTGN

IATA EDR reports over Taiwan





LGT: 0.15 ≤ EDR < 0.22 | MOD 0.22 ≤ EDR < 0.34 | SOG EDR ≥ 0.34



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Plans

- Finishing final GTG4 tuning based on case studies.