行政院所屬各機關因公出國人員出國報告書

（出國類別：國際會議　　　　　　）

2014 年國際空氣品質會議

服務機關：行政院環境保護署
姓名職稱：張順欽副處長、游智淵技士
派赴國家：美國
出國期間：**103** 年 **2** 月 **8** 日至 **2** 月 **17** 日
報告日期：**103** 年 **5** 月

摘要

前往美國參加美國環保署（EPA）主辦 2014 年國際空氣品質會議，汲取美國空氣品質監測及預報技術及經驗，重點摘述如下：（1）美國也面臨到 $PM_{2.5}$ 手動及自動監測之差異問題，空氣品質指標(Air Quality Index, AQI)發布之小時數據，是先建立自動與手動監測之關係式，自動數據再換算成等似手動數據（FRM-like）後公布（2）美國空氣品質監測已納入衛星反衍之光學氣膠厚度（Aerosol Optical Depth, AOD）等技術，以了解未設監測站地區之空氣品質，預報模式已逐步納入實際監測及衛星反衍資料，可強化短期預報能力（3）美國空氣品質預報由美國海洋大氣總署(National Oceanic and Atmospheric Administration, NOAA)產出預報數據，提供各州參考，各州再依當地現況提供預報數據 AIRNOW 平台發布全國預報（4）AIRNOW 展示等濃度圖的全國空氣品質監測數據，是由監測站數據經由 Inverse Distance Weighted (IDW)法內插而產生。預報則是由模式之網格模擬資料繪製成預報展示圖（5）美國環保署正推行感測器技術（Sensor technology），並與環境空氣品質監測數據比對，提供個人暴露評估參考及環境教育之宣導。本次研習對本署空氣品質預報作業有三項助益，一是未來環資部可考慮由氣象預報單位，統籌辦理氣象及空氣品質預報；二是美國發布 AQI 之小時數據，是以自動數據經相關推估式（手動及自動監測之換算公式）換算後公布，擬參考美國監測數據發布之作法，提供未來 AQI 參考；三是擬參考美國預報及本署中國大陸沙塵預警經驗，納入衛星反衍資料，研擬境外污染物預警標準作業程序。

目錄

壹、 目的及背景說明

我國環保署目前每天公布空氣品質監測數據及發布 2 次空氣品質區及離島預報，全年無休公布預報資訊供民眾參考。為精進本署空氣品質監測及預報作業，需借鏡國外經驗及作法，以提升預報能力。美國環保署（EPA）召開 2014 年國際空氣品質會議並邀請我國分享及討論空氣品質監測及預報技術。

2014 年國際空氣品質會議內容包括空氣品質監測及預報，藉由 AIRNOW 平台彙整美國各州空氣品質監測數據及預報資料，公布即時空氣品質指標(Air Quality Index, AQI)及各區域預報資訊供民眾參考。

鑑於美國 EPA 在空氣品質監測及預報之經驗，本次研習目的及重點包括汲取美國空氣品質監測及預報技術，擴展及精進我國空氣品質監測及預報，提供民眾更適時監測及預報資訊。

貳、 研習過程

美國 EPA 於 103 年 2 月 10 日至 2 月 12 日，為期 3 天在美國北卡羅萊納州（North Carolina）德罕市（Durham），舉辦 2014 年國際空氣品質會議（議程如附錄一），三天的會議包含多項主題有（1）空氣品質監測（2）空氣品質預報（3）空氣品質與人體健康（4）衛星觀測應用在空氣品質監測及預報（5）感測器技術（Sensor technology）的發展及應用，會議中也介紹我國空氣品質監測及預報狀況，研習重點如下：

1. 空氣品質監測

美國以 AIRNOW 平台彙整美國各州空氣品質監測數據及預報資料，公布即時空氣品質指標(Air Quality Index, AQI)及各區域預報資訊供民眾參考，美國國土面積約 960 萬平方公里，約臺灣的 300 倍大，空氣品質測站數量約 4000 座，主要設置在人口較稠密地區，約有 25 %的區域無空氣品質測站（圖 1）。為讓前述區域能有相關空氣品質數據參考，美國環保署(EPA)提出，以 MODIS 等衛星觀測反衍的數據（圖 2）替代空氣品質測站數據，作為該地區空氣品質現況參考，如附錄二。

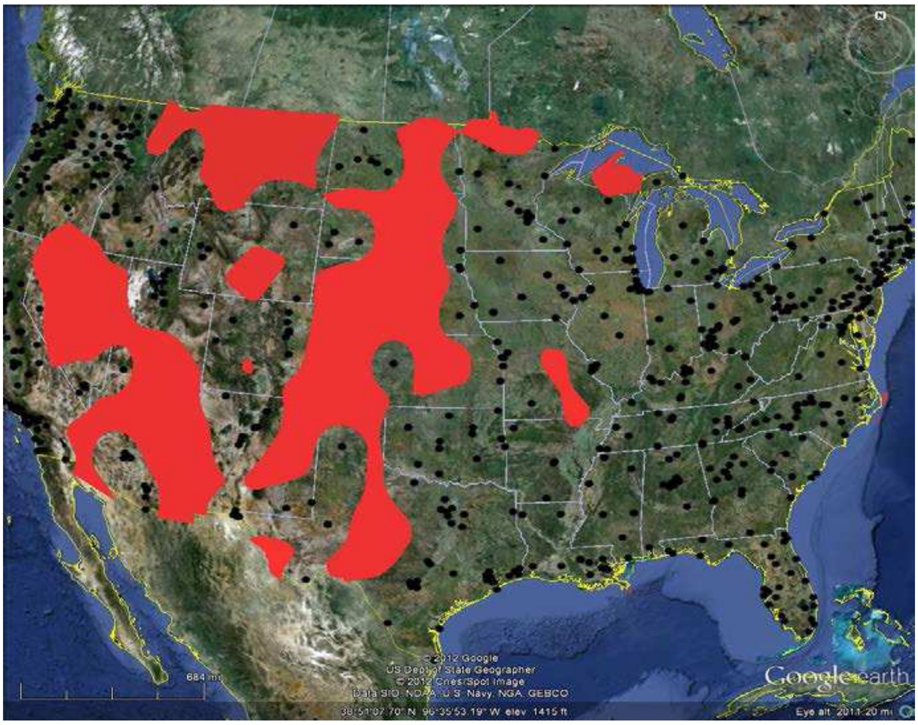

圖 1　美國空氣品質監測站分布圖(紅色部分為無氣品質測站區域)

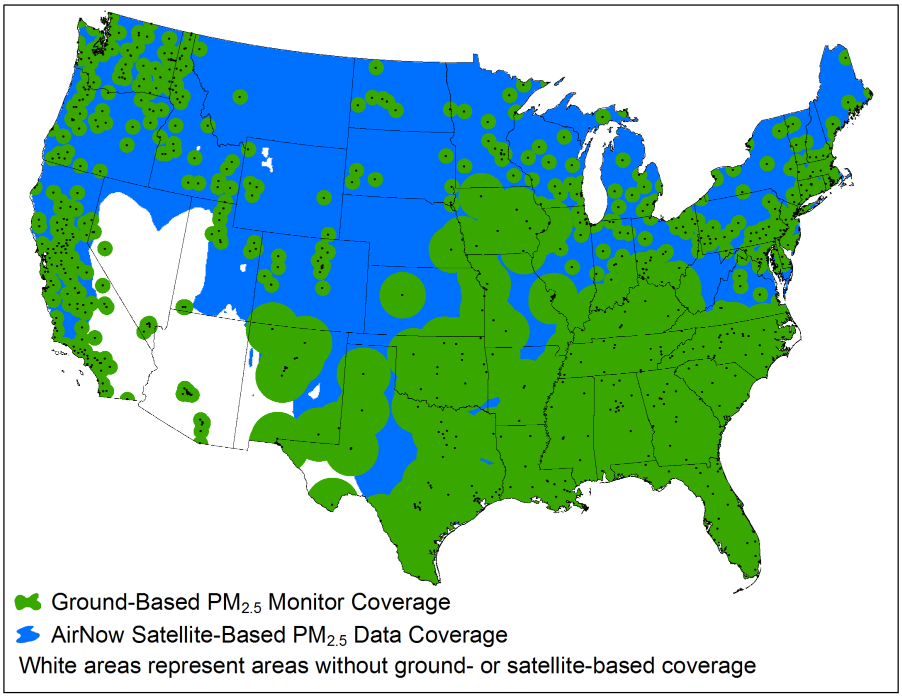

圖 2　MODIS 衛星反衍 $PM_{2.5}$ 的空間分布

在有限資源限制下，有效的監測空氣品質是非常重要的，因此，空氣品質測站設置的數量及位置就顯得相當重要，美國土地廣大，無法每個角落都有空氣品質測站，為了解現行空氣品質測站設置數量及位置是否足夠及恰當，美國使用 Aeroqual ozone sensors 分析監測網絡的代表性及評估測站新增之可行性。以臭氧為例，由於氣象條件及污染物排放對臭氧濃度及空間分布有顯著影響，以 Aeroqual ozone sensors 技術可評估臭氧空間梯度分布，了解區域臭氧濃度及分布狀況。

2. 空氣品質預報

這次的會議重點主要聚焦在空氣品質預報技術及經驗討論，包含空氣品質模式模擬結果改善及衛星觀測技術應用在預報之經驗等。

(1) 空氣品質模式

空氣品質模式是以一電腦程式為工具，以氣象及排放量資料作為輸入參數，將複雜的大氣物理及化學過程（擴散、傳輸、反應及沉降），藉由數值方程的計算，得到大氣污染物的預測數據，該程式需搭配較強運算能力之電腦資源完成模擬工作。各國使用的空氣品質模式大都類似上述作法，美國使用空氣品質模式已有多年經驗，發現已現行預報技術，氣象預報及污染源排放資料由時與實際監測及觀測結果有所出入，這也是模式模擬結果誤差的主要原因，為提升模式模擬準確度，以實際監測及衛星反衍資料輔助上述資料的不足，該技術稱為「資料同化」，可顯著改善模式模擬結果（圖 3），進而提升空氣品質預報能力，如附錄三。我國交通部中央氣象局以使用資料同化應用在氣象預報，惟氣象同化技術屬物理範疇，實際監測及衛星反衍資料的同化屬化學範疇且較為複雜，國內還尚在研發階段，因此，若要提高我國空氣品質模式模擬結果，須借鏡美國資料同化技術及經驗。

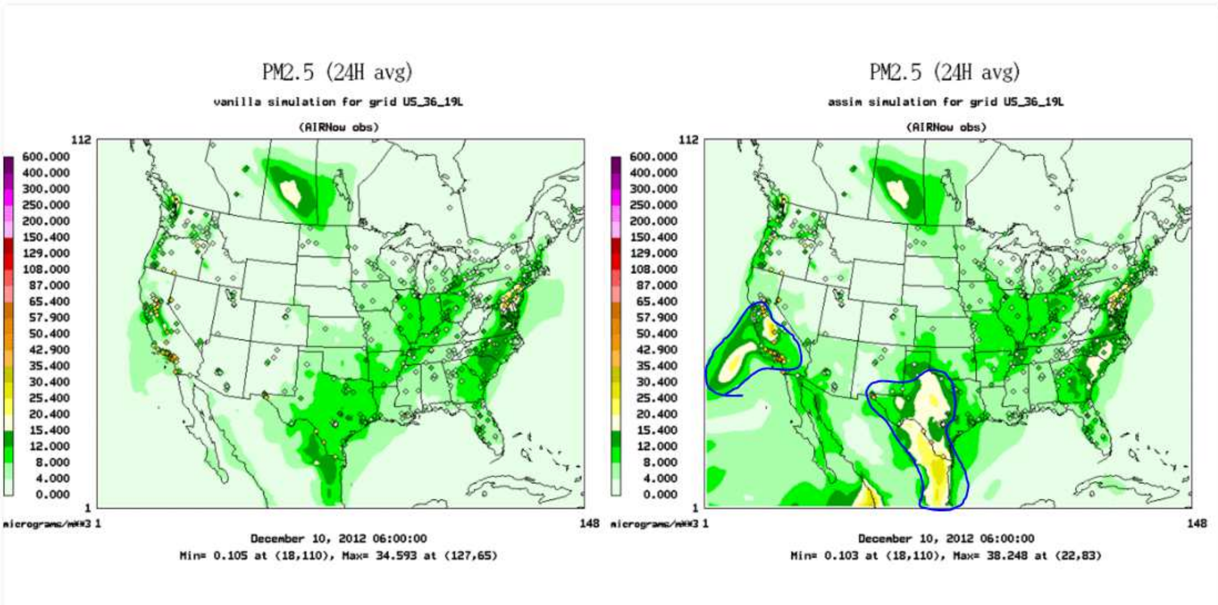

圖 3　資料同化前（左）及同化後（右）模式模擬比較圖

(2) 氣膠光學厚度

氣膠光學厚度(Aerosol Optical Depth, AOD)常被應用在觀測懸浮微粒(PM_{10})及細懸浮微粒($PM_{2.5}$)濃度（圖 4），氣膠光學厚度(Aerosol Optical Depth, AOD)為在特定波長（550 nm）下之衛星反衍數據，當 AOD 越大，代表空氣之垂直剖面中懸浮微粒顆粒較多，反之懸浮微粒顆粒較少，美國也常用此數據與監測數據比較及應用。由於衛星可反衍大範圍數據，使用 AOD 應用在中國大陸沙塵或霾害事件影響台灣空氣品質應有很好效果，可提前掌握該事件之發展及移動路徑，可助於研判預報或預警的發布的時機。

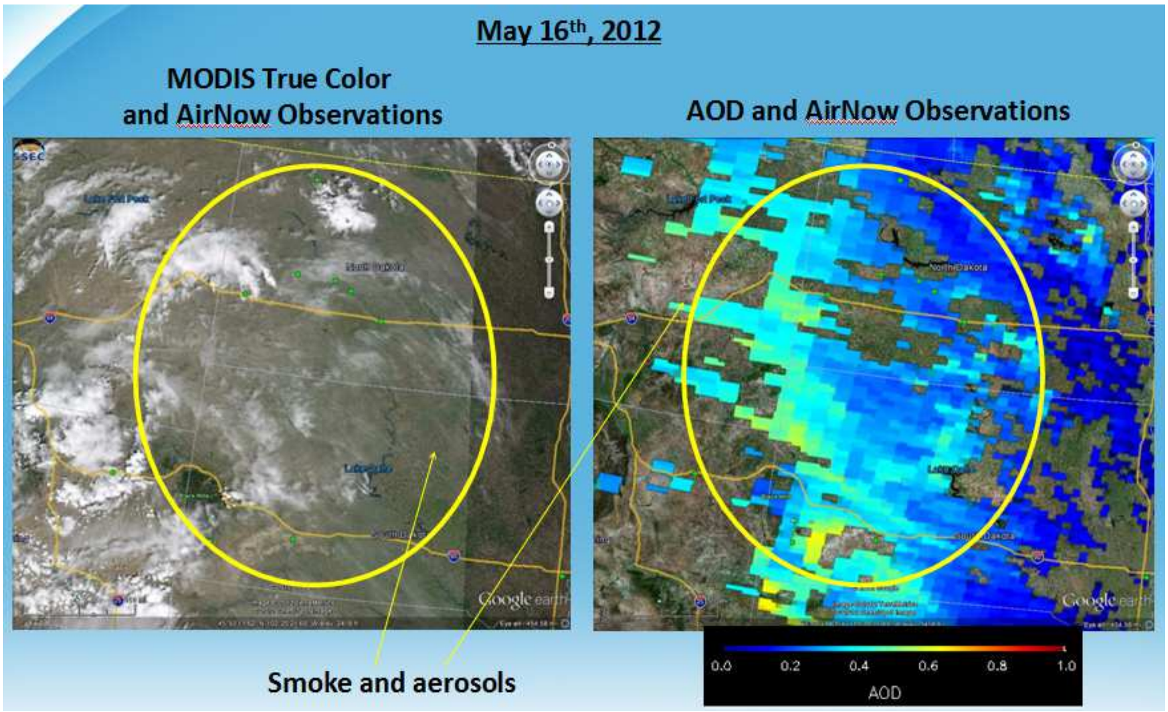

圖 4 氣膠光學厚度與空氣品質監測數據比較圖

(3) 衛星觀測與空氣品質預報

近幾年隨著衛星觀測技術的提升，關於氣候變遷及空氣污染等問題，逐漸可透過衛星反衍技術得到與實際監測相近之數據。美國環保署近幾年積極運用衛星反衍數據，補足監測及預報上的不足。無空氣品質監測站的區域，可使用該技術產出數據，以替代無空氣品質監測站的區域。由於結合監測及衛星觀測之時間、空間分布，有助於預報員掌握空氣品質現況，在將空氣品質現況，運用資料同化技術提高模式模擬準確度，進而運用在空氣品質預報。

3. 空氣品質與人體健康

本次會議主要著重在空氣污染對孩童健康之討論，不論氣態或粒狀污染物，須先考量濃度高低、暴露時間長短、劑量反應及個體差異等因素，才能評估對人體健康的影響，會議上著重在臭氧及細懸浮微粒($PM_{2.5}$)等光化學煙霧對健康影響討論。McConnel(2002)研究指出，長時間暴露在高臭氧的環境下（日平均值>75 ppb）可能導致有哮喘的孩童症狀加劇，高臭氧環境下孩童發生哮喘的風險是低臭氧環境下的 4 倍（附錄四）；$PM_{2.5}$ 的暴露與心血管發病率和死亡率有關。為了保護孩童暴露在空氣污染的環境中，美國部分州政府施行學校的空氣質量及戶外活動指引(Air Quality and Outdoor Activity Guidance for Schools)，學校以旗幟的方式呈現空氣品質現況（圖 5），若空氣品質不佳時，孩童須減少戶外活動，以減少暴露時間，保護孩童健康。

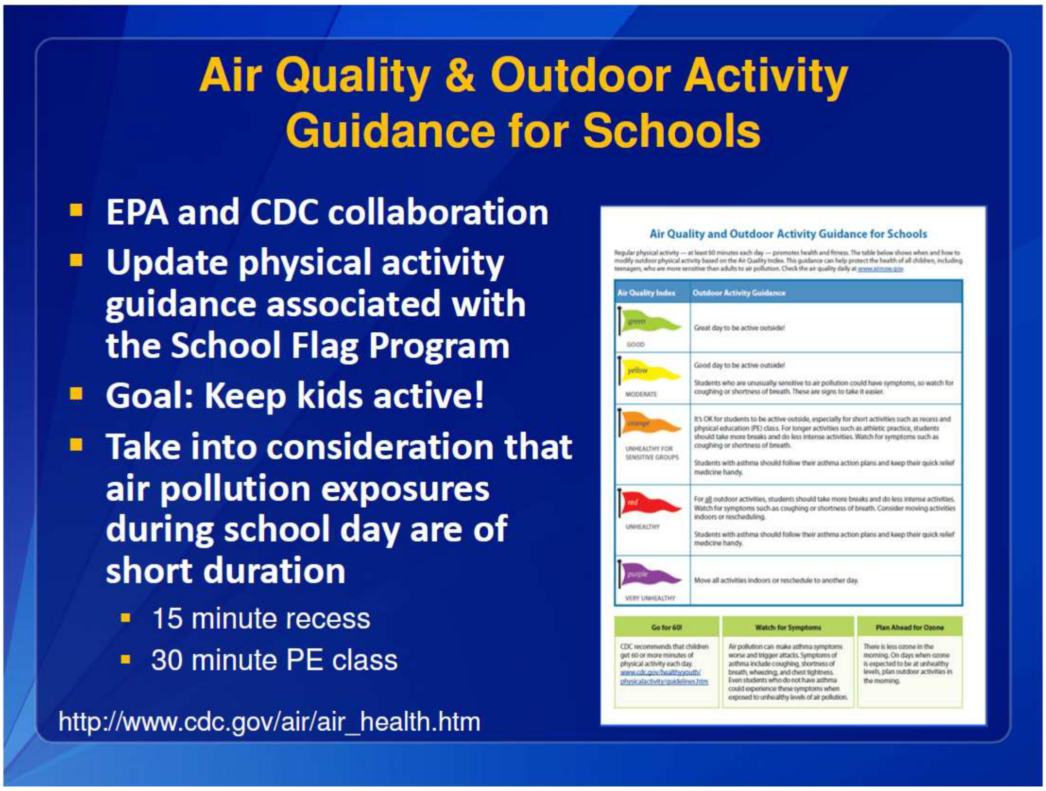

圖 5　美國施行學校的空氣質量及戶外活動指引

4. 衛星觀測應用在空氣品質監測及預報

前述已提到在空氣品質監測站不足條件下，美國使用衛星觀測數據替代空氣品質測站數據，作為無空氣品質監測站地區的空氣品質現況參考。衛星觀測也可協助空氣品質

預報的研判，衛星觀測反衍的數據以 AOD 應用最廣泛，2002 年 9 月 9 日~9 月 13 日 MODIS 反衍之 AOD 及細懸浮微粒($PM_{2.5}$)濃度，可以觀察到 $PM_{2.5}$ 移動路徑，由北往南移動（圖 6），有助於預報參考，如附錄五。在東亞區域，中國大陸沙塵或境外污染物易隨著東北季風南下而影響我國空氣品質，藉由衛星觀測垂直剖面的懸浮微粒(PM_{10})及 $PM_{2.5}$ 濃度，再利用其空間分布涵蓋較廣的優點，可協助掌握沙塵或境外污染物的移動路徑，再搭配氣象預報東北季風的移動路徑及時間，即可判斷影響我國空氣品質的時間點及程度。

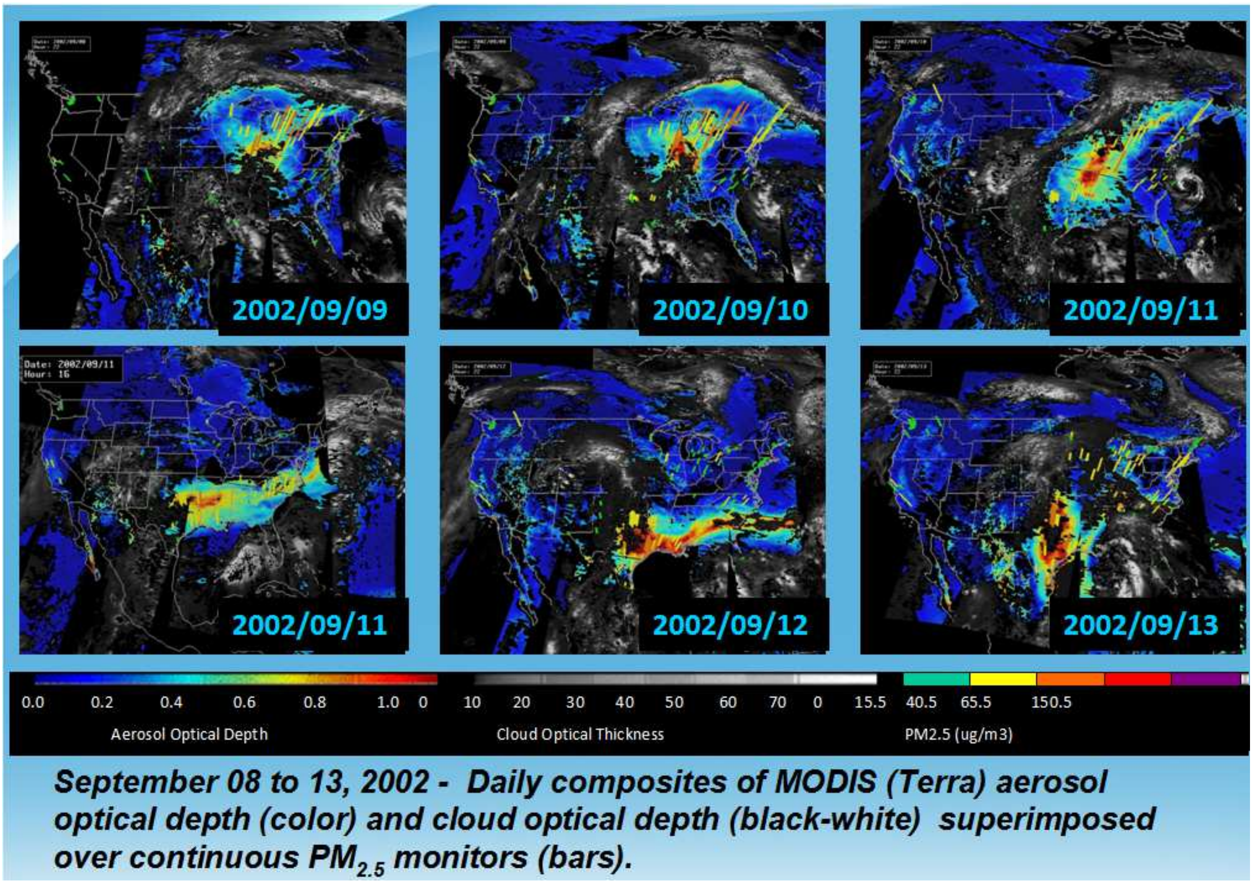

圖 6　2002 年 9 月 9 日~9 月 13 日 MODIS 反衍之 AOD 及 $PM_{2.5}$ 濃度圖

5. 感測器技術（Sensor technology）的發展及應用

為監測區域空氣品質以了解大氣中污染物濃度及分布，世界各國的環保單位大都以在 3~12 公尺左右的高度設置空氣品質監測站，以監測區域空氣品質現況。空氣品質監測站設置除了地點選擇外，需考量電源供應、維護人員及儀器的進出等因素。為了解人體暴露在環境中的污染物濃度及評估未來空氣品質監測站設置之參考，EPA 正推行感測

器技術（Sensor technology），如附錄六，並與環境空氣品質監測數據比對，提供個人暴露評估參考及環境教育之宣導（圖 7），該技術可使用太陽能供電方式，解決傳統需外接電源之限制，也可建構小型監測網絡，供社區或團體等監測環境中污染物現況，如附錄七。

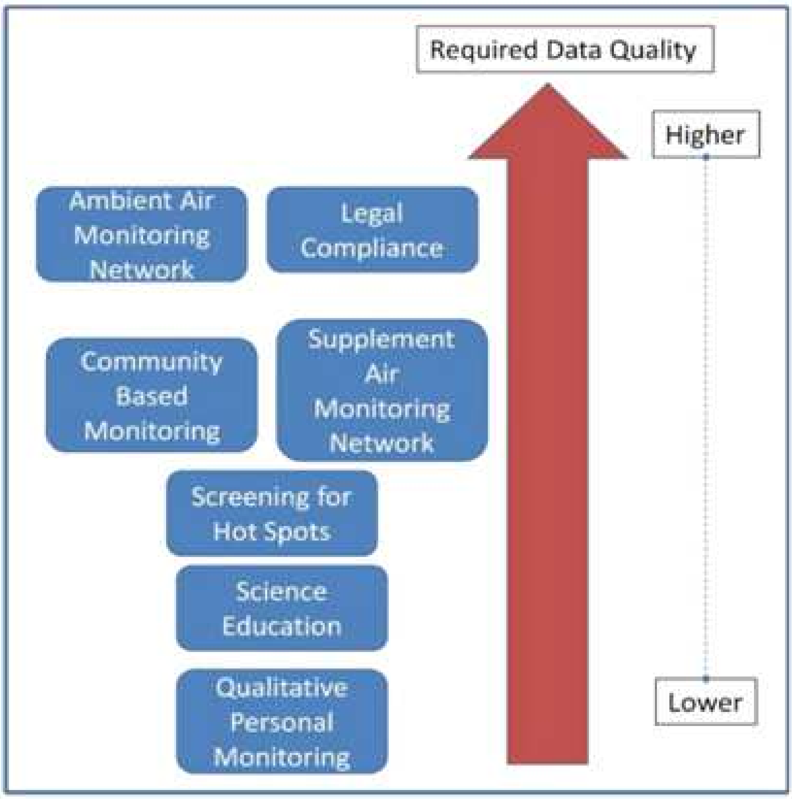

圖 7　不同需求之空氣品質監測技術

圖 8　感測器技術（Sensor technology）

參、 心得與建議事項

參加這次 2014 年國際空氣品質會議發現，美國經由 AIRNOW 平台公布即時空氣品質指標(Air Quality Index, AQI)及預報資訊已融入民眾的生活，如同我國的氣象預報一般。學校等團體也參考該指標作出適合學童活動等參考，氣象播報時也一同播報空氣品質現況及預報資訊。但也存在與我國面臨相同的問題，如即時 AQI 與健康之關係及 $PM_{2.5}$ 自動數據發布等問題。此次研習對我國空氣品質監測及預報之助益，歸納有下列幾點：

一、美國、日本等國家是由氣象單位主司氣象及空氣品質預報，未來環資部成立後可考慮由氣象預報單位，統籌辦理氣象及空氣品質預報。

二、美國局部地區無空氣品質監測站，EPA 結合空氣品質監測及衛星觀測資料，展示空氣品質監測現況。擬參考美國預報及本署中國大陸沙塵預警經驗，納入衛星反衍資料，研擬境外污染物預警標準作業程序。

三、根據美國預報經驗，空氣品質模式納入實際監測及衛星反衍資料之同化技術，可提升模式預報能力，惟國內目前並無相關技術之研究，且若能結合氣象單位，可加快預報技術之提升，本署在新世代空氣品質監測發展計畫中規劃可行之作法。

四、美國發布 AQI 之小時數據，是以自動數據經相關推估式（手動及自動監測之換算公式）換算後公布，擬參考美國監測數據發布之作法，提供未來 AQI 參考。

附錄一、2014 年國際空氣品質會議議程

❖ 2014 National Air Quality Conference ❖

AGENDA

MONDAY, FEBRUARY 10, 2014

8:00 a.m. – 12:30 p.m.	Exhibit and Poster Set-up
10:00 a.m. – 6:00 p.m.	Registration/Check-in
1:00 p.m. – 3:00 p.m.	**PLENARY SESSION** – *Imperial Ballroom 4-7*
1:00 p.m. – 1:30 p.m.	**OPENING REMARKS** – *Greg Green, Director, Outreach and Information Division U.S. EPA, Office of Air Quality Planning and Standards* – *Phillip Dickerson, AirNow Program Director, U.S. EPA* – *Anne Gobin, Bureau Chief, Connecticut DEEP Co-Chair NACAA Public Education and Communications Committee*
1:30 p.m. – 3:00 p.m.	Traffic-Related Air Pollution and Children's Health: The Cincinnati Childhood Allergy and Air Pollution Study (CCAAPS) – *Patrick H. Ryan, PhD, Cincinnati Children's Hospital Medical Center* CDC and State Health Department Activities Related to Children's Air Pollution Exposure – *Tegan Boehmer, PhD, Centers for Disease Control and Prevention (CDC), National Center for Environmental Health* National-Scale Activity Survey (N-SAS) Results – *Susan Stone, U.S. EPA*
3:00 p.m. – 3:30 p.m.	BREAK
3:30 p.m. – 5:00 p.m.	**PLENARY SESSION** (continued) AirNow International *Phillip Dickerson, U.S. EPA, Moderator* – *Mr. Lu Tao and Mr. Zhao Qianbiao, Shanghai Environmental Monitoring Center* – Monitoring and Forecast of Air Quality in Taiwan – *Mr. Jhih-Yuan Yu, Environmental Protection Administration, R.O.C. (Taiwan)* – Implementation of AirNow-International in Mexico – *Mr. Orlando Cabrera-Rivera, Commission for Environmental Cooperation* Secrets of San Lorenzo Valley's Atmosphere: Vertical Meteorological Measurements *Natalie Gallagher and Connor Lydon, San Lorenzo Valley High School (with Amy Clymo, Monterey Bay Unified APCD)*
5:30 p.m. – 7:00 p.m.	Cash Bar Reception/Exhibit and Poster Session

TUESDAY, FEBRUARY 11, 2014

7:00 a.m. – 5:30 p.m. Exhibits and Posters

7:00 a.m. – 8:00 a.m. Registration/Morning Refreshments

8:00 a.m. – 9:30 a.m. Breakout Sessions

Air Quality Forecasting, Mapping, and Monitoring Imperial Ballroom Forecasting Tools Moderator: Amy Huff, the Pennsylvania State University	**Communicating Air Quality** Empire Ballroom Communicating Air Quality and Public Health Moderator: Susan Stone, U.S. EPA
"Love is in the Air" (or is it?): Investigating Air Quality Using Handheld Monitoring Equipment – *Gary Olson, U.S. EPA* Improving EPA's AIRNow AQI Maps with MODIS Aerosol Products – *Jim Szykman, U.S. EPA* $PM_{2.5}$ Prediction & Analysis: Maryland's Toolbox – *Laura Warren, Maryland Department of the Environment*	The Impact of an Anti-Idling Campaign on Air Quality at Schools – *Dr. Patrick Ryan, Cincinnati Children's Hospital Medical Center* Health Effects of Smoke From Wildfires – *Dr. Wayne Cascio, U.S. EPA* Medical Advocates for Healthy Air – Harnessing a Medical Voice for Clean Air – *Rebecca Cheatham, Clean Air Carolina* Discussion of How to Include Socioeconomic Status in Upcoming AQI Materials for Particle Pollution – *Alison Davis, U.S. EPA*

9:30 a.m. – 10:00 a.m. BREAK

10:00 a.m. – 12:00 p.m. Breakout Sessions

Air Quality Forecasting, Mapping, and Monitoring Imperial Ballroom Air Quality Models Moderator: Cary Gentry, Forsyth County (NC) Office of Environmental Assistance and Protection	**Communicating Air Quality** Empire Ballroom Educational Programs Moderator: Laura DeGuire, Michigan Department of Environmental Quality
NOAA's AQ Predictions – *Ivanka Stajner, NOAA/NWS* North Carolina Real-time CMAQ Forecasting – *Nicholas Witcraft, North Carolina Department of Environment and Natural Resources* Improvement on PM Forecasting by Modulating Primary Dust Emissions – *Pius Lee, NOAA Air Resources Laboratory* Advancements in Operational CMAQ MODIS AOD data-assimilation at Baron Advanced Meteorological Systems during Forecast Year 2013 – *John McHenry, Baron Advanced Meteorological Systems*	Secrets of San Lorenzo Valley's Atmosphere: Vertical Meteorological Measurements – *Natalie Gallagher and Connor Lydon, San Lorenzo Valley High School (with Amy Clymo, Monterey Bay Unified Air Pollution Control District)* How to Do Your Own Teacher Workshop – *Donna Rogers, Melissa Payne, and Ellen Wildermann, U.S. EPA* Air Monitoring and Education at New Hampshire's Two NCore and IMPROVE Monitoring Sites – *Sherry Godlewski, New Hampshire Department of Environmental Services* GO3 Project: Enabling Student Scientists to Measure Air Pollutants and Promote AQ Awareness – *Dr. John Birks, Jessa Ellenburg, and Kali Basman, GO3 Foundation* Air Sensor Kits for Outreach – *Dana Buchbinder and Gayle Hagler, U.S. EPA*

Noon – 1:30 p.m. LUNCH (on your own)

1:30 p.m. – 3:00 p.m. Breakout Sessions

AIR QUALITY FORECASTING, MAPPING, AND MONITORING IMPERIAL BALLROOM Case Studies Moderator: Mike Goldstein, Shelby County (TN) Health Department	COMMUNICATING AIR QUALITY EMPIRE BALLROOM Reducing Greenhouse Gas Emissions Moderator: Jamie Arno, Sacramento (CA) Metropolitan Air Quality Management District
Predicting the Air Quality Health Index Without Aid of Observations: Results from the Northern New Brunswick Study – *Daniel Jubainville, Environment Canada* Ozone Update – *Ben Wells, U.S. EPA* Streamlining Exceptional Events Analysis and Reporting – *Daniel M. Alrick, Sonoma Technology, Inc.*	Two outreach initiatives that reduce greenhouse gases – a Home Energy Conservation Program and Farm to Fork to Fuel – *Christina Ragsdale, Sacramento (CA) Metropolitan AQMD* GHG Outreach and Mitigation Through Facility Energy Assessments – *Paula Hemmer, North Carolina DENR* Reducing Emissions from Marine Shipping: Local and Global Initiatives – *Mary Byrd and Brian Shafritz, Santa Barbara County (CA) APCD, and Lee Kindberg, Director, Environment, Maersk Line*

3:00 p.m. – 3:30 p.m. BREAK

3:30 p.m. – 5:30 p.m. Breakout Sessions

AIR QUALITY FORECASTING, MAPPING, AND MONITORING IMPERIAL BALLROOM Advanced Technology Moderator: Sam Rubens, Akron (OH) Regional Air Quality Management District	COMMUNICATING AIR QUALITY EMPIRE BALLROOM Innovative State and Local Outreach Initiatives Moderator: Dan Nelson, Olympic Region (WA) Clean Air Agency
WRF Model Boundary Layer Height Validation Using the Vaisala Ceilometer – *Scott Mackaro, Vaisala* Utilizing Nephelometers in Near Roadside Monitoring Environments – *John Carney, American Ecotech L.C.* VIIRS Satellite Products: New High-Resolution Aerosol Products for Air Quality Applications – *Amy Huff, The Pennsylvania State University* Measuring Spatial Variability in Ozone Concentrations Using a Small-Sensor Network – *Tim Dye, Sonoma Technology, Inc.*	Air Quality Real-time Release and Public Service in Shanghai – *Bill Zhao, Shanghai Environmental Monitoring Center* Keep It Clean – *Julie Hunter, Washoe County (NV) Health District Air Quality Management Division* Don't Be "Crabby", Turn Off Your Lights – *Megan Green, Mecklenburg County (NC) Air Quality* Embracing I.T.: Using iPhone, iMac, iMovie and previously unimagined online tools – *Pat Sullivan and Madison Stirland, Oklahoma DEQ* Implementing the Advance Program Statewide – Louisiana's Story – *Michael Vince, Louisiana DEQ*

WEDNESDAY, FEBRUARY 12, 2014

7:00 a.m. – 11:30 a.m.	Exhibits and Posters
7:00 a.m. – 8:00 a.m.	Registration/Morning Refreshments
8:00 a.m. – 11:30 a.m.	Breakout Sessions

AIR QUALITY FORECASTING, MAPPING, AND MONITORING IMPERIAL BALLROOM Monitoring News Moderator: John McHenry, Baron Advanced Meteorological Systems	COMMUNICATING AIR QUALITY EMPIRE BALLROOM Alternative Energy/Energy Efficiency Moderator: Larry Brockman, U.S. EPA
PM Designations Mapping Tool – *Doug Solomon, U.S. EPA* DOCS II, U.S. EPA Alternative Method 082, Moving Opacity Technology Forward – *Shawn Dolan, Virtual Technology LLC* Field Test Results for Continuous Beta Gauge Under High Dew Point Conditions – *Dr. David Gobeli and Thomas Pottberg, MetOne Instruments*	Southwest New Hampshire's Wood Smoke Outreach Initiative Partnership – *Sherry Godlewski, New Hampshire DES* Energy Efficiency (EE) & Renewable Energy (RE) in SIPs – EPA's Roadmap and a Tour of Several States – *Angie Shatas, U.S. EPA* EPA Burn Wise: Communicating the Health Effects of Residential Wood Smoke – *Leigh Herrington, U.S. EPA* EPA's Residential Wood Heater NSPS Proposal – *Gil Wood, U.S. EPA* Using Mobile Instruments to Monitor Residential Wood Smoke – *Timothy K. Dye, CCM, Sonoma Technology, Inc. and Leigh Herrington, U.S. EPA*

9:30 a.m. – 10:00 a.m.	BREAK
10:00 a.m. – 11:30 a.m.	Breakout Sessions

AIR QUALITY FORECASTING, MAPPING, AND MONITORING IMPERIAL BALLROOM Moderator: John White, U.S. EPA	COMMUNICATING AIR QUALITY EMPIRE BALLROOM Reducing Emissions from Mobile Sources Moderator: Jean Kelly, Louisiana Department of Environmental Protection
Roundtable Discussion of Regional Forecasting Challenges *Panel - To be announced* Apps and More with the AirNow API – *Steve Ludewig, Sonoma Technology, Inc.*	An Overview of GaDER Program – *Vicky Giles, Georgia EPD* Race to the Beach, a Clean Commute Challenge – *Kelly Smith, Charlotte Area NC Air Awareness* Constructing a Successful Corporate Partnership – *Elaine Loyack, Triangle Air Awareness (NC DENR and RTP)* Creating a Diesel/Black Carbon Emissions Calculator to Advance Clean Construction Practices – *Sean Flaherty, Centralina Council of Governments*

11:30 a.m.	What You Need to Know About the New AirNow-Tech: A Live Demonstration – *Natalie LaGuardia, Sonoma Technology, Inc.* –Imperial Ballroom
11:30 a.m. – 1:00 p.m.	LUNCH (on your own)
12:00 noon – 4:00 p.m.	Exhibit and Poster Tear Down
1:00 p.m. – 2:30 p.m.	**CLOSING PLENARY** – *Imperial Ballroom* Small Sensors and Citizen Science – *Richard Wayland, U.S.EPA, Moderator* – *Tim Dye, Sonoma Technology, Inc.* – *Tim Watkins, U.S. EPA* – *Donnie Redmond, NC DENR* – *Phillip Dickerson, U.S. EPA* Fracking: Air Pollution Issues – *Bruce Moore, U.S. EPA*
2:30 p.m. – 3:00 p.m.	**CLOSING REMARKS** – *Greg Green, Director, Outreach and Information Division U.S. EPA, Office of Air Quality Planning and Standards* – *Phillip Dickerson, AirNow Program Director, U.S. EPA*
3:00 p.m.	CONFERENCE ADJOURNS

附錄二、Improving EPA's AIRNow AQI Maps with MODIS Aerosol Products: The AirNow Satellite Data Processor (ASDP) Project

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Improving EPA's AIRNow AQI Maps with MODIS Aerosol Products: The AirNow Satellite Data Processor (ASDP) Project

Jim Szykman
National Exposure Research Laboratory
Office of Research and Development, US EPA

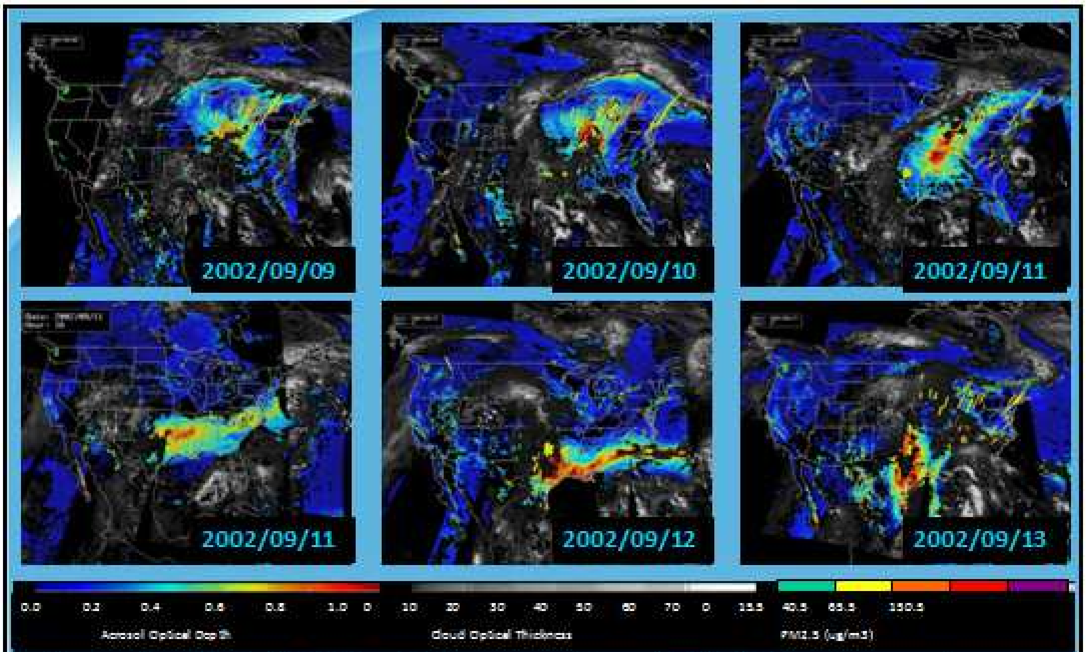
AIR QUALITY FORECASTING, MAPPING, AND MONITORING SESSION

2014 National Air Quality Conference
Research Triangle Park, NC 27711
February 10-12

EPA United States Environmental Protection Agency

Talk Outline

- **Project Team**
- **AirNow AQI Challenges & Project Objectives**
- **Approach (Satellite and Data Fusion)**
- **Results (Initial comparison to DISCOVER-AQ)**
- **Summary**



September 08 to 13, 2002 - Daily composites of MODIS (Terra) aerosol optical depth (color) and cloud optical depth (black-white) superimposed over continuous $PM_{2.5}$ monitors (bars).

EPA United States Environmental Protection Agency

ASDP Project Team and Partnerships

- *Philip Dickerson & John E. White, EPA/OAQPS, Research Triangle Park, NC*
- *Jim Szykman, EPA/ORD-NASA LaRC, Hampton, VA*
- *Randall Martin & Aaron van Donkelaar, Dalhousie University, Nova Scotia, Canada*
- *Allen Chu, UMBC, Baltimore, MD*
- *Shobha Kondragunta & Hai Zhang (IMSG) , NOAA/NESDIS, Washington D.C.*
- *Adam Pasch, Tim Dye, Patrick Zahn, Michael Haderman, & Jennifer L DeWinter, Sonoma Technology, Inc. (STI), EPA Contractor, Petaluma, CA*
- *Center for Technology and Government - University Albany (CTG), EPA Sub contractor, Albany, NY*

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AirNow

- The national framework for acquiring and distributing air quality information
- Gathers data provided by 130 federal, state, and local air quality agencies
- Presents near-real-time hourly AQI conditions and daily AQI forecasts, with maps of interpolated AQI levels on national, regional, and local spatial scales.

The Challenge for AirNow

- EPA, State, Local and Tribal agencies monitoring budgets are shrinking.
- The United States surface air quality monitoring network is too sparse in many areas to inform the public about adverse air quality conditions.
- More than 42 million people reside in populated places farther than 40 km from the nearest $PM_{2.5}$ monitor.
- From a public health perspective, there are substantial health benefits for people who take protective action to avoid exposure to high outdoor $PM_{2.5}$ concentrations.

Source: Socioeconomic Benefits of Adding NASA Satellite Data to AirNow, CTG University of Albany/SUNY & STI, October 2013

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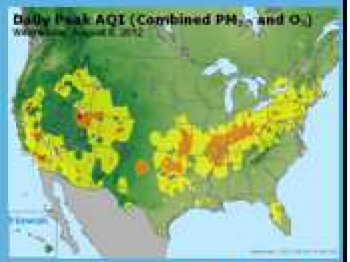

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AirNow Satellite Data Processor Project Objectives

AirNow Operational Map (airnow.gov)

Without satellite data, no contouring is possible in the hatched areas

- Developed a system for EPA to routinely estimate surface PM2.5 concentrations from satellite data and fuse these estimates with routine surface PM2.5 monitor observations in the AirNow system.
- Improve air quality maps currently in AirNow and make them available on a daily basis.
- Provide satellite data products in AirNow-Tech with tools to improve for Air Quality Index forecasts.

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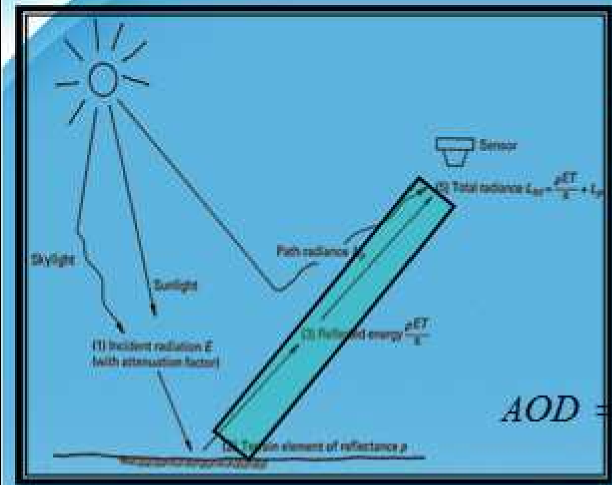
Project Approach

- Satellite data:
  - Focused on use of MODIS Terra/Aqua AOD using daily available from IDEA system.
  - Develop a robust approach to estimate 24-hour ground-level $PM_{2.5}$ concentrations with uncertainty estimates
  - Estimates are dependent on data availability (e.g., no satellite data are available in areas with significant cloud cover or bright surfaces)
- Ground observations:
  - Using hourly observations from AirNow to calculate $PM_{2.5}$ 24-hour averages
  - Point data are interpolated using kriging method
- Fused map product:
  - Ground observations are fused with satellite estimates
  - Fusion employs an algorithm that assigns relative weights to each observation and estimate according to the data's uncertainty at that point

Project Approach



- Need surface $PM_{2.5}$
- Have column AOD
- AOD is related to $PM_{2.5}$ but need ancillary information

$$AOD = PM_{2.5}\, H\, f(RH)\, \frac{3Q_{ext,dry}}{4\rho\, r_{eff}}$$

↑

SATELLITE MEASURED RADIANCES ARE CONVERTED TO COLUMNAR AEROSOL OPTICAL THICKNESS/DEPTH →

$$AOD = \int \beta_{ext}\, dz$$

Source: Sundar Christopher NSSTC/UAH

Begin by Inferring $PM_{2.5}$ from Satellite Aerosol Optical Depth (AOD) and Simulated η ($PM_{2.5}$/AOD)

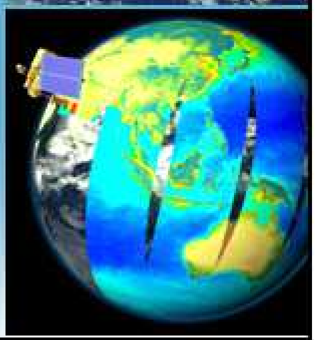
Excluded regions with biased AOD (>0.1 or 20%) as identified with AERONET

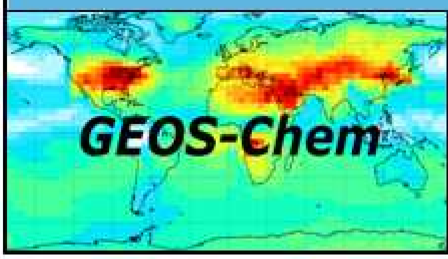
Estimated $PM_{2.5}$ = η · AOD

GEOS-Chem
Chemical Transport Model
- vertical structure
- aerosol properties
- meteorological effects

MISR
- -Multi-angle
- -4 bands
- -6-9 day coverage

MODIS
- -Single viewpoint
- -36 bands
- -daily coverage





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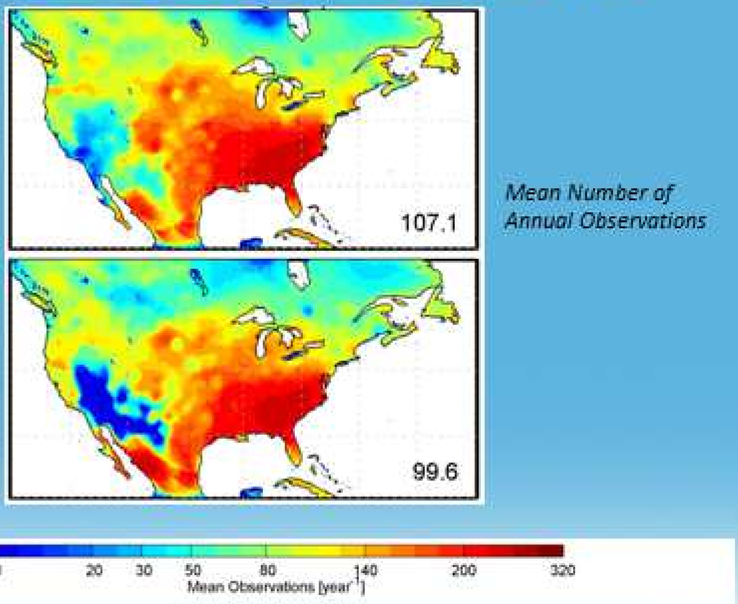
Near-real-time MISR AOD Would Improve Coverage in Southwest

MODIS&MISR

MODIS



van Donkelaar et al., ES&T, 2012

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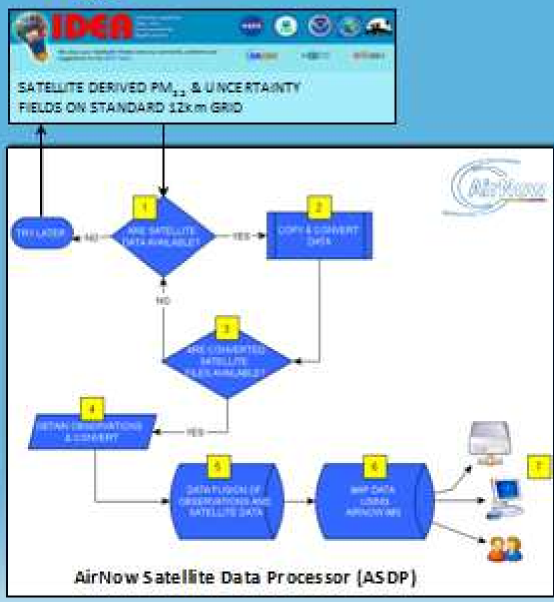
ASDP Satellite-AOD Approach for Derived $PM_{2.5}$ Concentrations

- Method documented in van Donkelaar et. al., 2012, ES&T (MODIS and MISR).
- GEOS-Chem used to create a daily Look-Up-Table (LUT) of the spatial varying relation of AOD and $PM_{2.5}$, η, and apply to MODIS (Terra and Aqua) daily AOD.
- Also included additional filters from Hyer et al. (2010), a climatological bias correction informed by in situ [$PM_{2.5}$], and spatial smoothing to increase coverage.
- Output - Daily [$PM_{2.5}$] and uncertainty fields pulled to ASDP and combined with Surface Monitor [$PM_{2.5}$] via a weighted average fusion approach.



ASDP Fusion Approach: Weighted Average

- Weighting assigned for each data type (indexed by grid cell) based on uncertainty

$$w_{obs} = \frac{1}{\sigma^2_{obs}} \qquad w_{sat} = \frac{1}{\sigma^2_{sat}}$$

- The final fused product is then

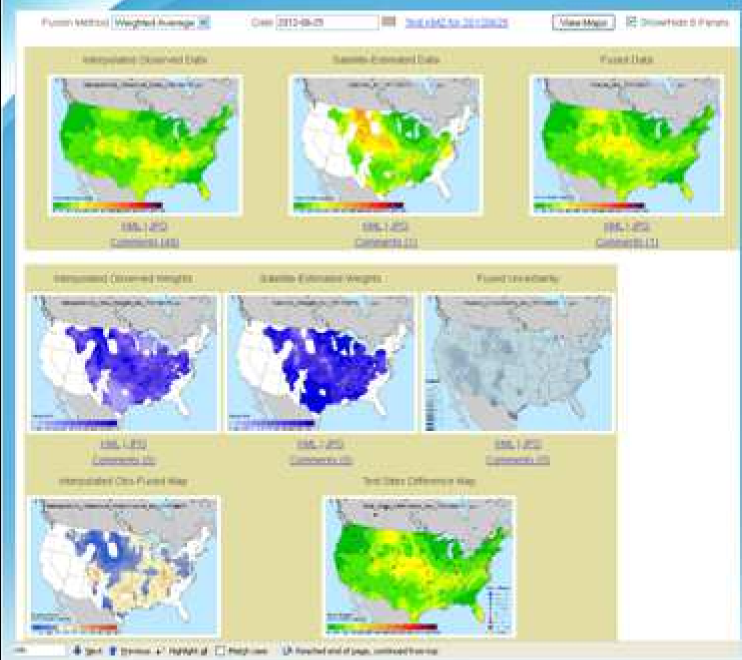
$$F_j = \frac{(w_j^{obs} \times O_j^{obs}) + (w_j^{sat} \times O_j^{sat})}{(w_j^{obs} + w_j^{sat})}$$

- Uncertainty of the final fused product is then

$$\sigma^2_F = \frac{\sigma^2_{obs} \times \sigma^2_{sat}}{\sigma^2_{obs} + \sigma^2_{sat}}$$

σ^2 = uncertainty
w = weight
j = index of grid cell
O = raw value
F = fused product

ASDP Provides Multiple Experimental Products to users via AirNow-Tech



ASDP Project website:

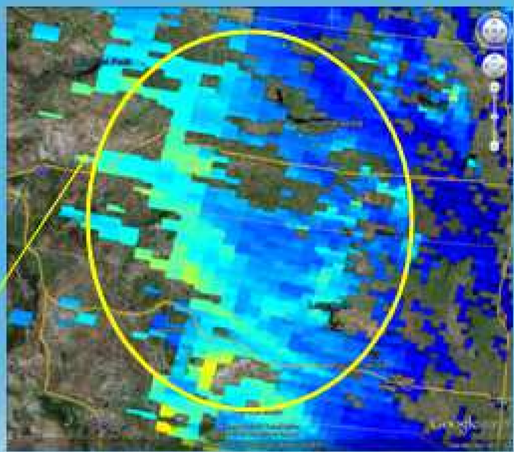
http://asdp.airnowtech.org

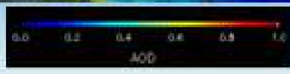
Smoke and No Monitors (Dakotas)

May 16th, 2012

MODIS True Color and AirNow Observations

AOD and AirNow Observations





Smoke and aerosols

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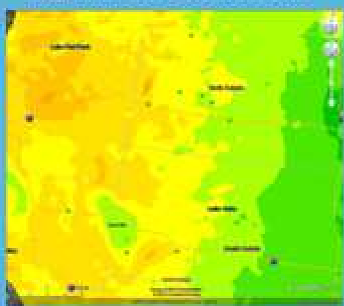
Smoke and No Monitors (Dakotas)

AirNow Observations

Satellite Estimates and AirNow Observations



Fused Product and AirNow Observations

PM$_{2.5}$ Concentration (μg/m^3)

- Smoke in Dakotas (MODIS and AOD)
- Limited Air Quality Monitors
- ASDP Product adds information (Moderate)
- On-going: How good is this information (from both a scientific, user and socio-economic perspective)

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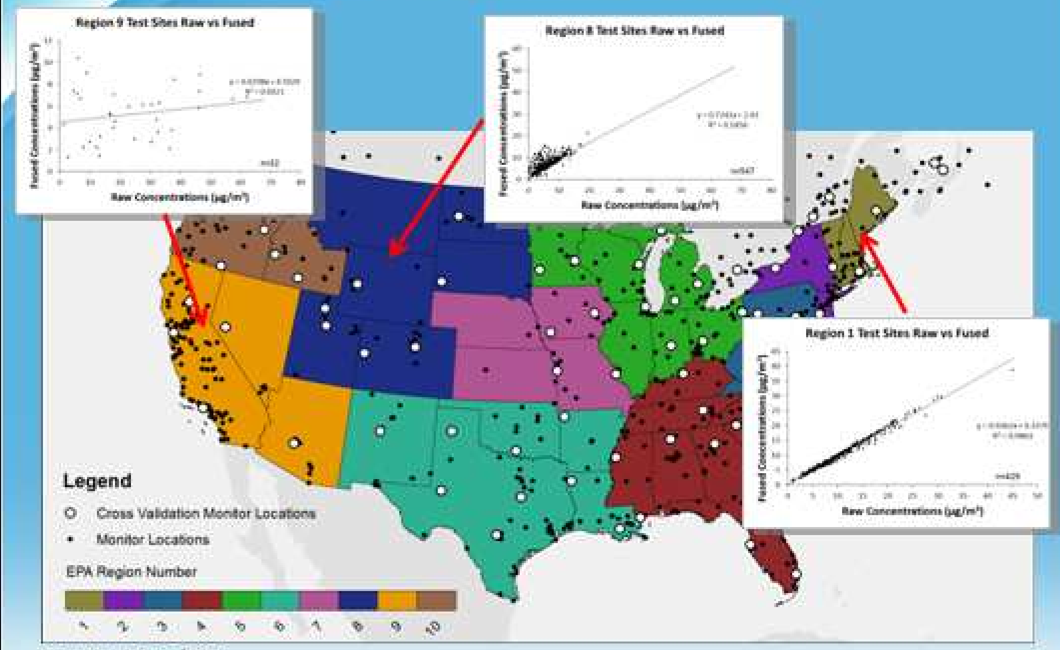
Testing: Scatter Plots



Source: A. Pasch STI

DISCOVER-AQ

What is DISCOVER-AQ?

DISCOVER-AQ (Deriving Information on Surface Conditions from Column and VERtically Resolved Observations Relevant to Air Quality)

- A NASA Earth Science Suborbital Venture Mission
- Primary Objective: *How can satellites be used to inform about AQ?*

1. Relate column observations to surface concentrations for aerosols and key trace gases

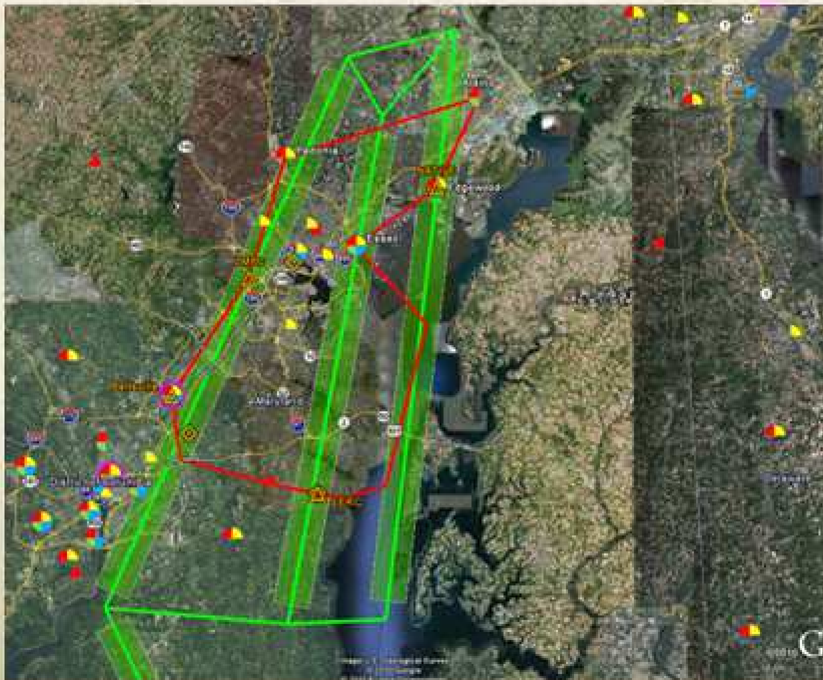
2. Characterize differences in diurnal variation of surface and column observations

3. Examine horizontal scales of variability affecting satellites and AQ modeling

DISCOVER-AQ Deployments and key collaborators
Maryland, July 2011 (EPA, MDE, UMd, UMBC, Howard U., PSU +)
SJV, California, January 2013 (EPA, CARB, UC-Davis&Irvine, PSU+)
Texas, September 2013 (EPA, TCEQ, U. of Houston, PSU+)
Denver, Summer 2014 (EPA, NSF, NOAA, CDPHE, PSU+)

DISCOVER-AQ

Observation Strategy Baltimore, MD
January-February 2013



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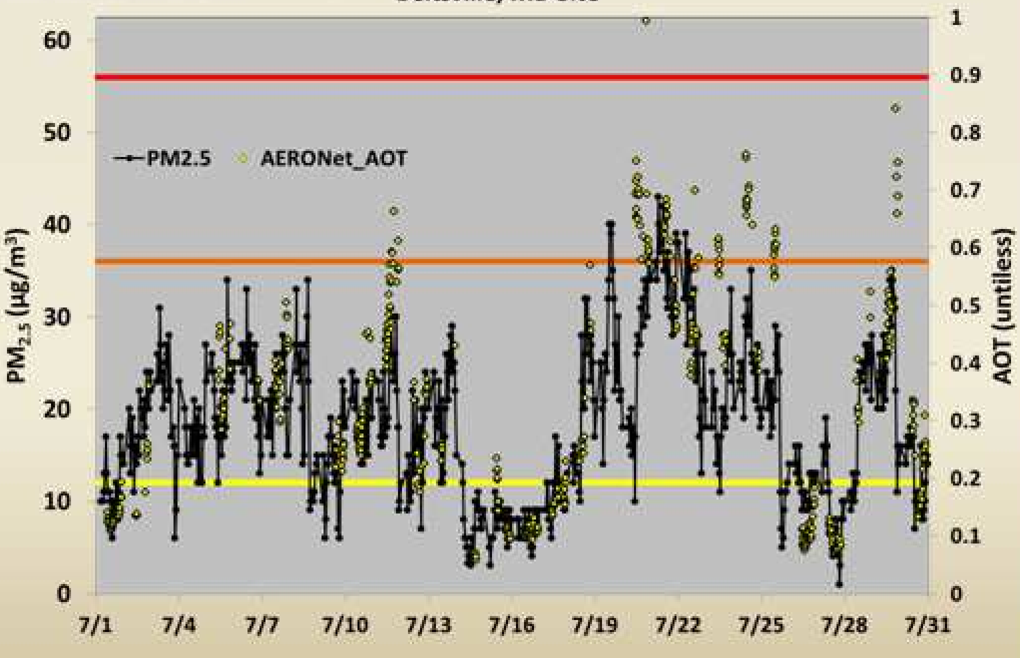
DISCOVER-AQ

DISCOVER-AQ July 2011
Beltsville, MD Site



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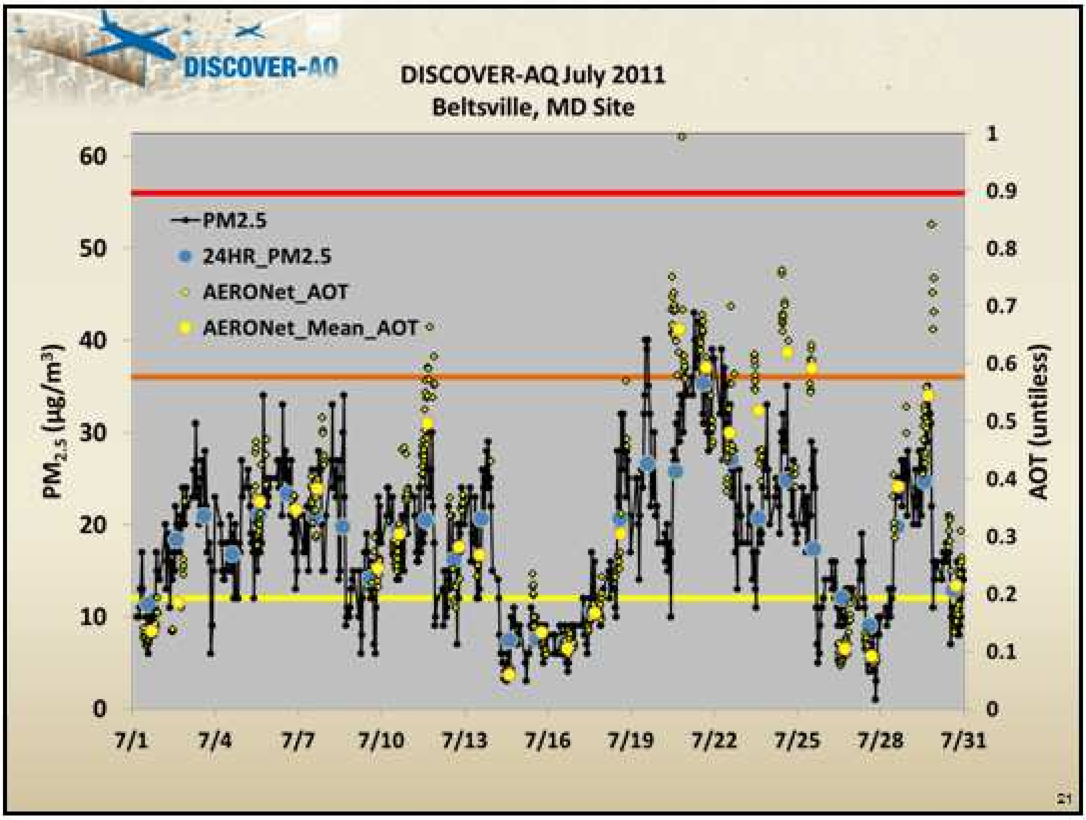
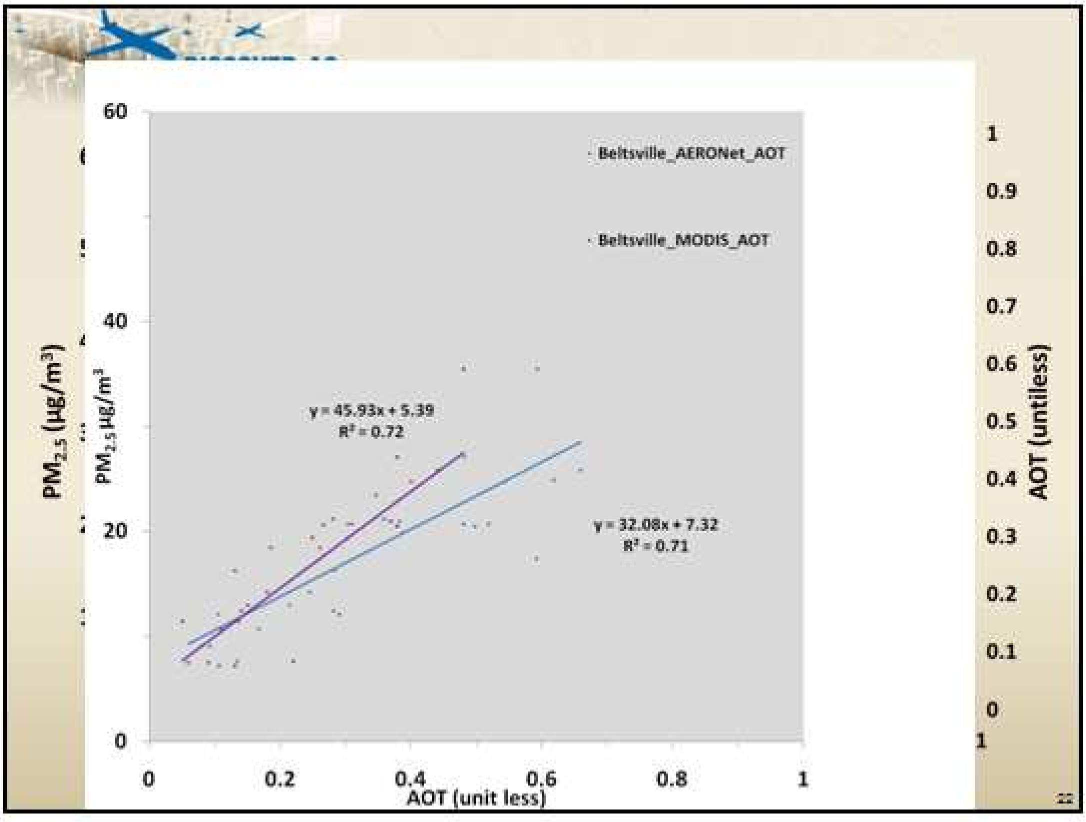
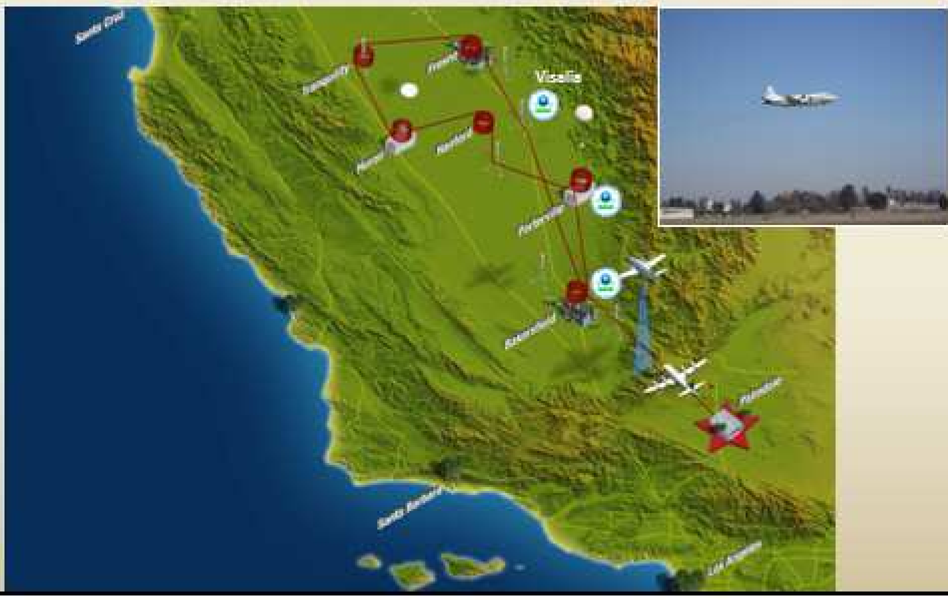

DISCOVER-AQ
DISCOVER-AQ July 2011
Beltsville, MD Site
PM2.5
24HR_PM2.5
AERONet_AOT
AERONet_Mean_AOT
PM2.5 (µg/m3)
AOT (untiless)
0
10
20
30
40
50
60
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
7/1
7/4
7/7
7/10
7/13
7/16
7/19
7/22
7/25
7/28
7/31
21


Beltsville_AERONet_AOT
Beltsville_MODIS_AOT
y = 45.93x + 5.39
R² = 0.72
y = 32.08x + 7.32
R² = 0.71
PM2.5 µg/m3
AOT (unit less)
0
20
40
60
0
0.2
0.4
0.6
0.8
1
PM2.5 (µg/m3)
AOT (untiless)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
22

Observation Strategy San Joaquin Valley, CA
January 2013

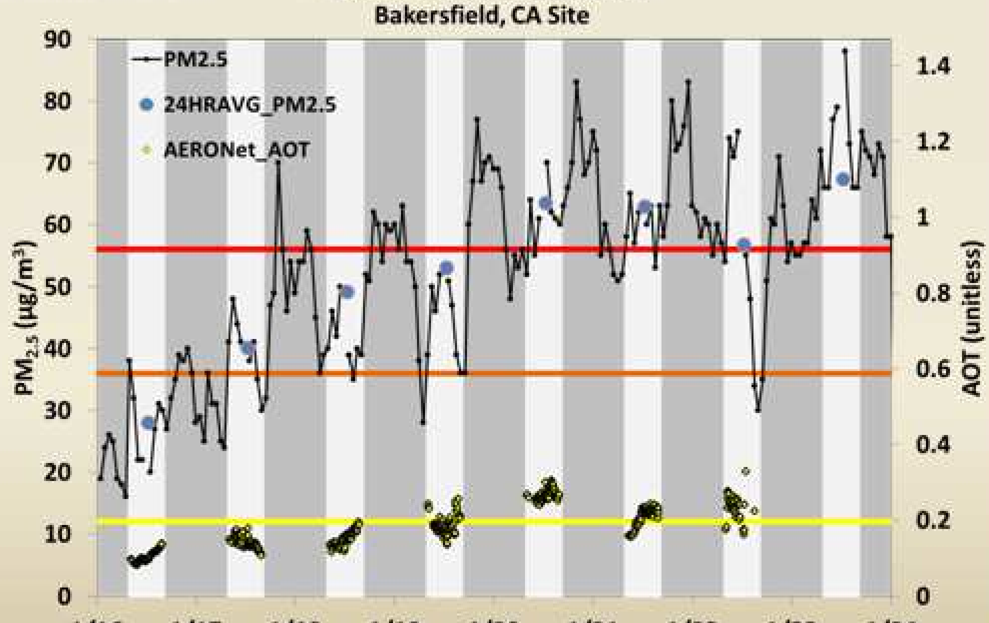
DISCOVER-AQ

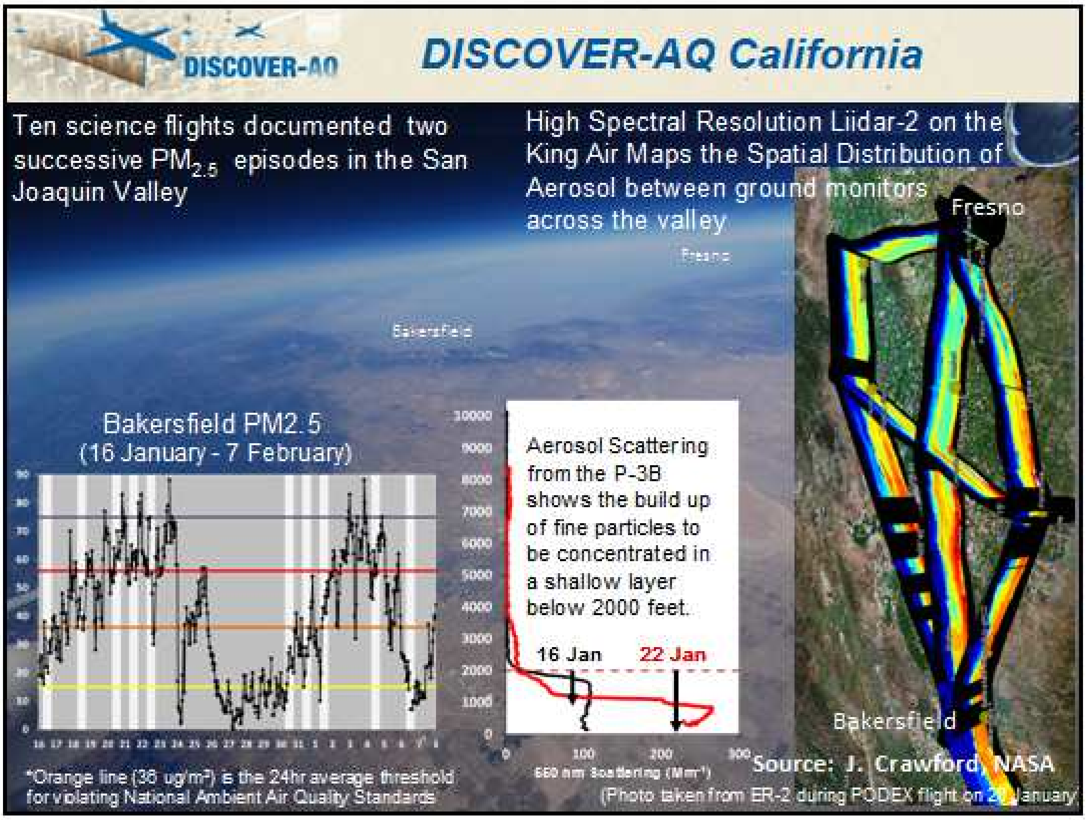
EPA field measurements were located at three sites (Visalia, Bakersfield, and Porterville). Visalia and Bakersfield included missed-approach routes with the NASA P-3B aircraft

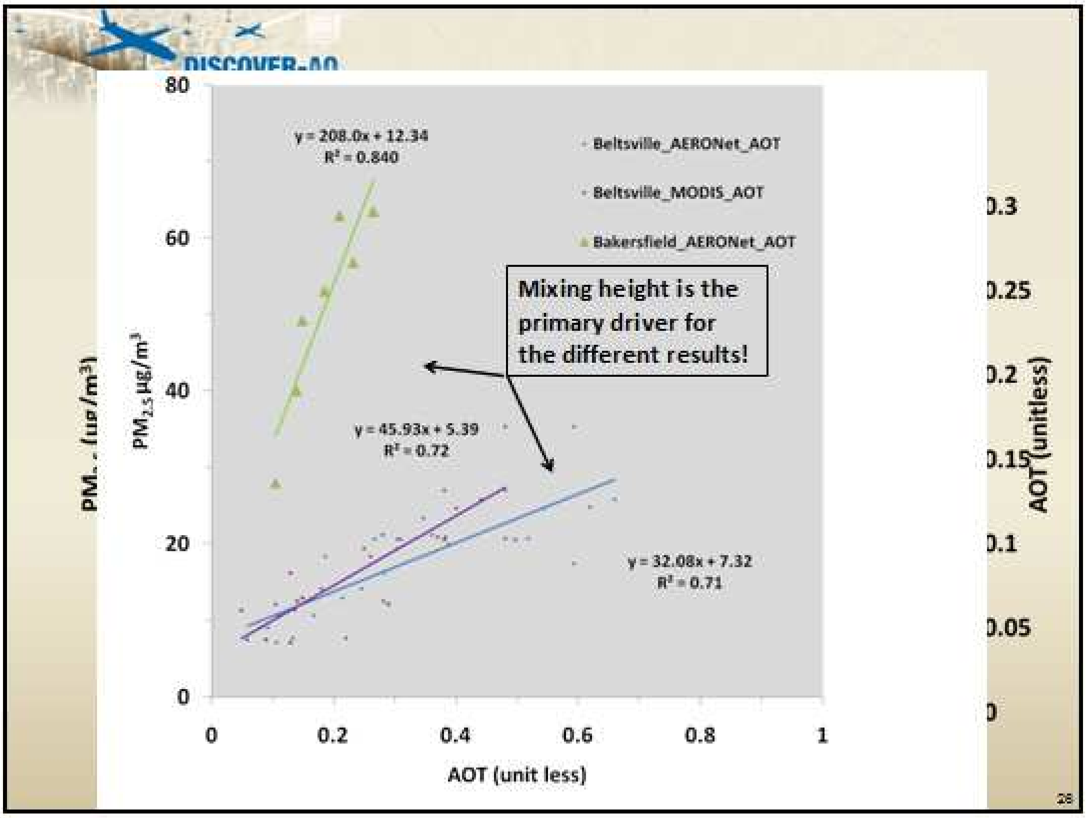


DISCOVER-AQ

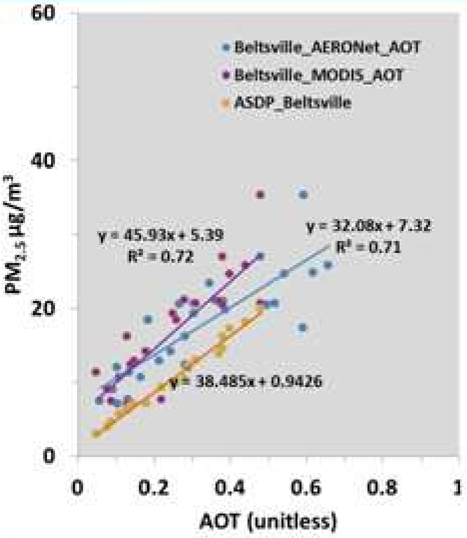
DISCOVER-AQ January 2013
Bakersfield, CA Site

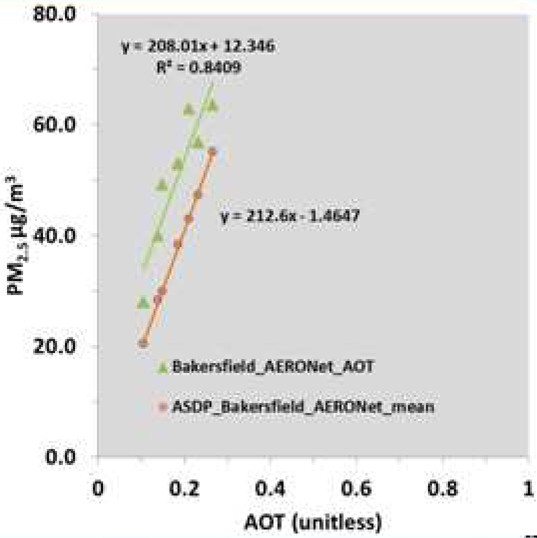



DISCOVER-AQ
DISCOVER-AQ California
Ten science flights documented two successive PM2.5 episodes in the San Joaquin Valley
High Spectral Resolution Liidar-2 on the King Air Maps the Spatial Distribution of Aerosol between ground monitors across the valley
Fresno
Bakersfield
Bakersfield PM2.5
(16 January - 7 February)
Aerosol Scattering from the P-3B shows the build up of fine particles to be concentrated in a shallow layer below 2000 feet.
16 Jan
22 Jan
660 nm Scattering (Mm⁻¹)
Fresno
Bakersfield
Source: J. Crawford, NASA
*Orange line (35 ug/m³) is the 24hr average threshold for violating National Ambient Air Quality Standards
(Photo taken from ER-2 during PODEX flight on 20 January)


DISCOVER-AQ
y = 208.0x + 12.34
R² = 0.840
Beltsville_AERONet_AOT
Beltsville_MODIS_AOT
Bakersfield_AERONet_AOT
Mixing height is the primary driver for the different results!
y = 45.93x + 5.39
R² = 0.72
y = 32.08x + 7.32
R² = 0.71
PM2.5 µg/m³
AOT (unit less)
AOT (unitless)
28

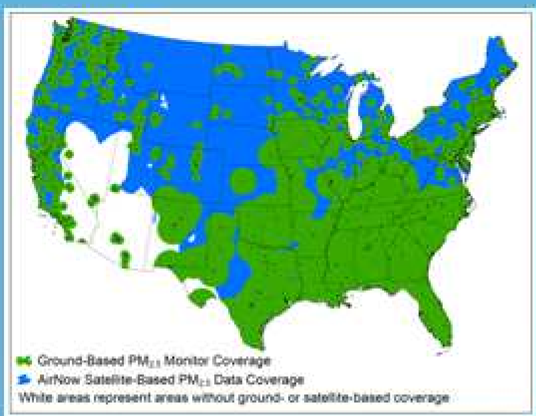
Preliminary Results: DISCOVER-AQ vs. ASDP





Summary

- Results:
  - Practical near-real-time technique to infer $PM_{2.5}$ from satellite AOD
  - For large episodic PM events (fires and dust storms) can fill data gaps in unmonitored areas, and can help refined AQI in monitored areas.
  - When there is data can provides additional AQ info (up to 92% of population) in unmonitored regions
  - ASDP can be extended for use with a variety of satellite products, including globally in developing countries with severe AQ problems.
  - Can help save tens of millions of dollars in ground monitoring costs to provide AQ info to currently underrepresented populations



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Satellite AQ Instrument Suite for Ground Validation Sites

Remote Sensing Column Measurements:
Pandora (**NO_2, O_2, SO_2, & HCHO**) and AERONet (**AOD**)

In-situ Measurements:
NO, NO_y, **NO_2** (photolytic or direct), **O_3**, **SO_2**, CO, **$PM_{2.5}$** (continuous and filter), **PM_{10}**, basic met. parameters

Profiling Measurements for Boundary Layer/Mixing Heights:
EPA-AIRS - Radar wind profiler (RWP)/Radio acoustic sounding system (RASS), **Ceilometers**, MPL, etc

EPA United States Environmental Protection Agency

Disclaimer: Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

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附錄三、National Air Quality Forecast Capability Nationwide Predication Furture Enhancements

National Air Quality Forecast Capability: Nationwide Prediction and Future Enhancements

Ivanka Stajner
NOAA NWS/OST

with contributions from the entire NAQFC Implementation Team

Outline:
- Background on NAQFC
- Recent progress and updates
  - -Ozone predictions
  - -Smoke predictions
  - -Dust predictions
  - -Prototype PM2.5 predictions
  - -Outreach and feedback
- Summary and plans

National Air Quality Conference, Durham, NC *February 11, 2014*

National Air Quality Forecast Capability
Capabilities as of 2/2014

- Improving the basis for air quality alerts
- Providing air quality information for people at risk

Prediction Capabilities:

- **Operations:**

  Ozone nationwide

  Smoke nationwide

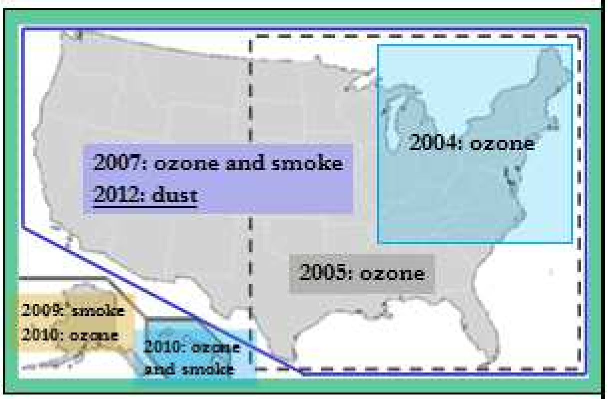
  Dust over CONUS

- **Experimental testing:**

  Ozone predictions

- **Developmental testing:**

  Components for particulate matter (PM) predictions



National Air Quality Forecast Capability
End-to-End Operational Capability

Model: Linked numerical prediction system

Operationally integrated on NCEP's supercomputer

- *NOAA NCEP mesoscale numerical weather prediction*
- *NOAA/EPA community model for air quality: CMAQ*
- *NOAA HYSPLIT model for smoke and dust prediction*

Observational Input:

- *NWS weather observations; NESDIS fire locations; climatology of regions with dust emission potential*
- *EPA emissions inventory*

Gridded forecast guidance products

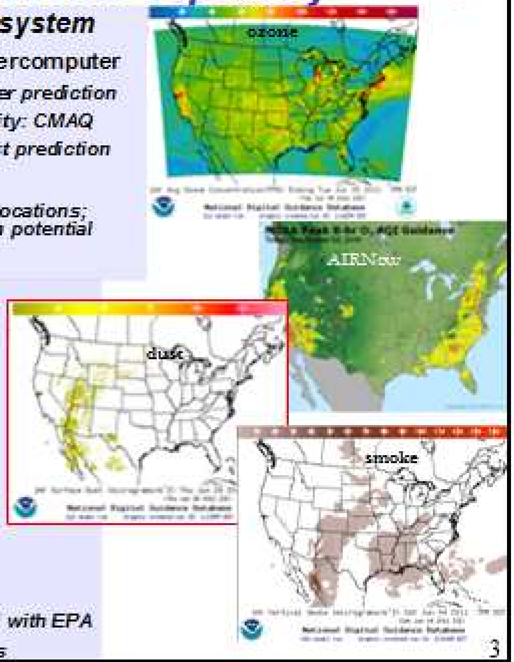
- *On NWS servers: airquality.weather.gov and ftp-servers (12km resolution, hourly for 48 hours)*
- *On EPA servers*
- *Updated 2x daily*

Verification basis, near-real time:

- *Ground-level AIRNow observations of surface ozone*
- *Satellite observations of smoke and dust*

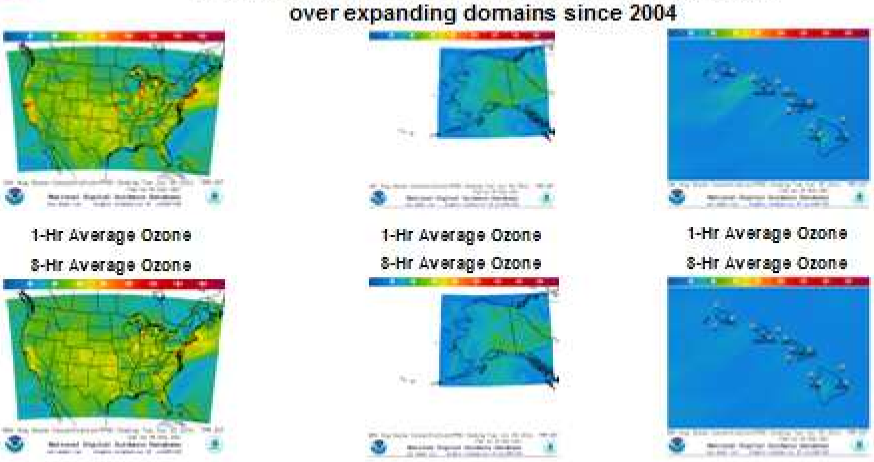
Customer outreach/feedback

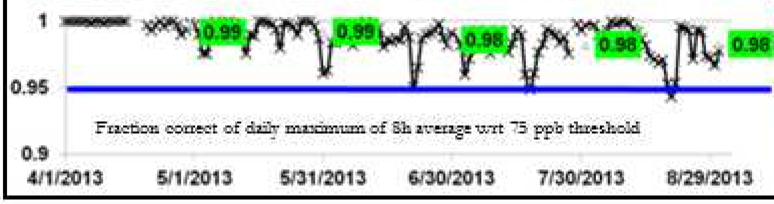
- *State & Local AQ forecasters coordinated with EPA*
- *Public and Private Sector AQ constituents*



Ozone predictions

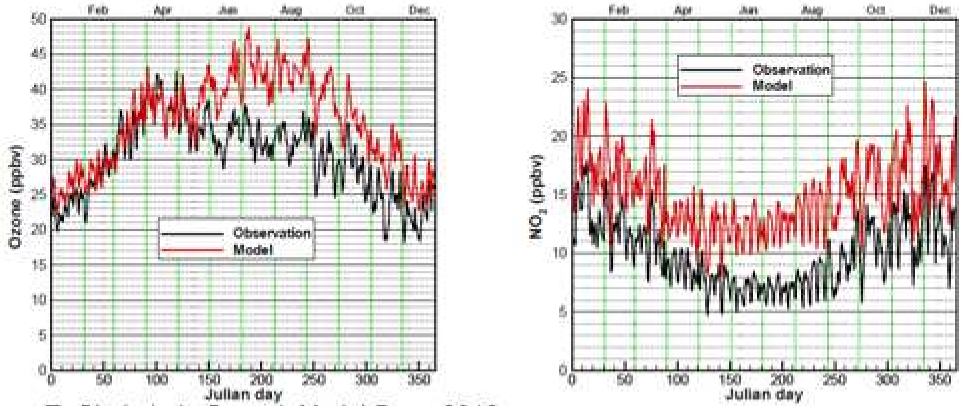
Operational predictions at http://airquality.weather.gov over expanding domains since 2004





Maintaining prediction accuracy as the warning threshold was lowered and emissions of pollutants are changing

Evaluation of experimental NAQFC ozone predictions for 2010, prior to emissions update

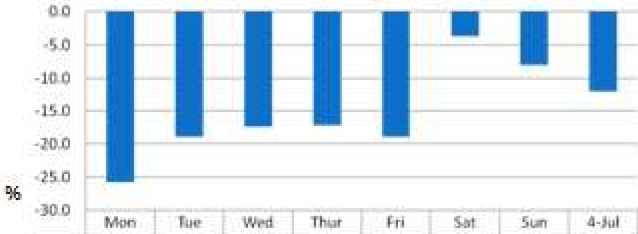


- *T. Chai et al., Geosci. Model Dev., 2013* (http://www.geosci-model-dev.net/6/1831/2013/gmd-6-1831-2013.html)
- *Ozone overestimation in August is larger in rural areas, during morning hours, and in the southeast US*
- *NO2 overestimation in August is larger at night time*
- *Ozone biases higher on weekends, but NO2 biases higher on weekdays*

Summary of Emission Data Sources

- Area Sources
  - US EPA Projected 2012 Nonroad + 2005 NEIs for other sectors;
  - Canada 2006 Emission Inventory;
  - Mexico 1996 EI for six border states;
- Mobile Sources (onroad)
  - 2005 NEI with Cross-State Air Pollution Rule (CSAPR) projection for US sources
  - Canada 2006 Emission Inventory;
- Point Sources (EGUs and non-EGUs)
  - NEI 2005 for base year;
  - Updated with 2011 Continuous Emission Monitoring (CEM) data for EGUs;
  - Projected into forecast year using DOE Annual Energy Outlook (2013) factors;
- Natural Sources
  - *Terrestrial biogenic emission:* BEIS model v3.14
  - *Sea-salt emission:* CMAQ online Sea-salt emission model;

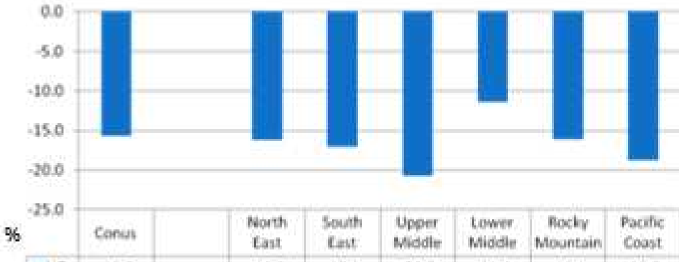
NOx emission change for 2012 and 2013



	Mon	Tue	Wed	Thur	Fri	Sat	Sun	4-Jul
NOx	-25.8	-18.9	-17.3	-17.1	-18.9	-3.7	-8.1	-12.0

NO_x emission change by day of week and holiday for July compared to those used in 2011

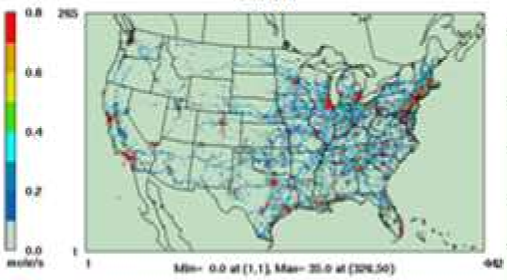
NO_x emission change by region for July compared to those used in 2011

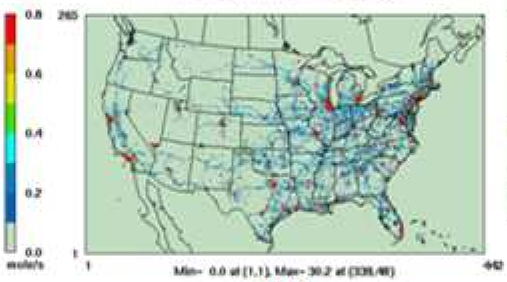


	Conus		North East	South East	Upper Middle	Lower Middle	Rocky Mountain	Pacific Coast
NOx	-15.7		-16.2	-17.1	-20.7	-11.4	-16.1	-18.8

Changes in Nitrogen Oxides Emissions

2011

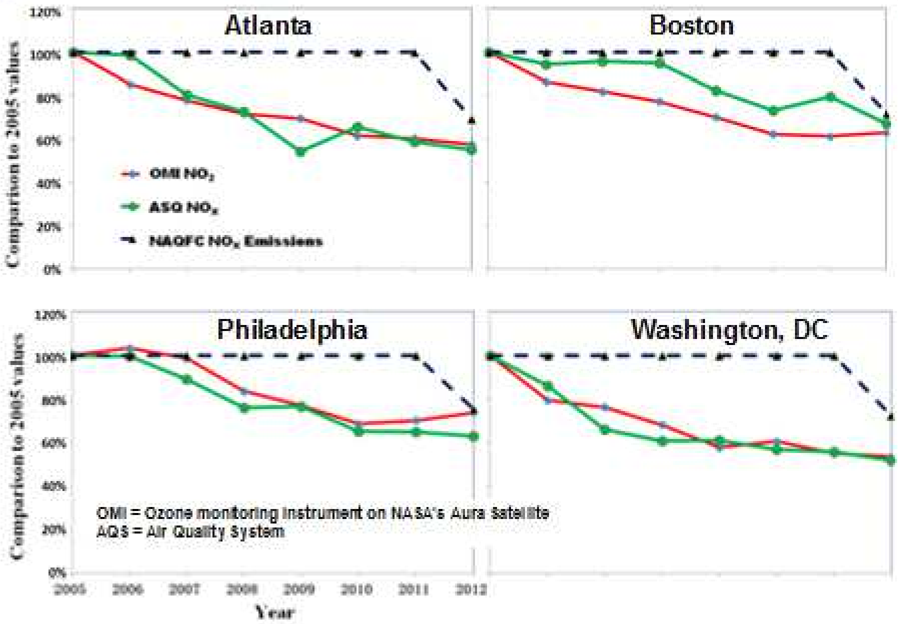




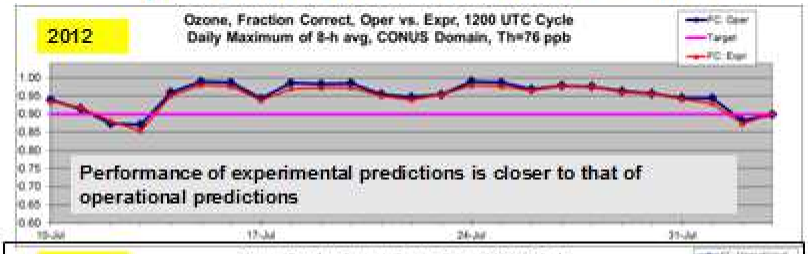
2013

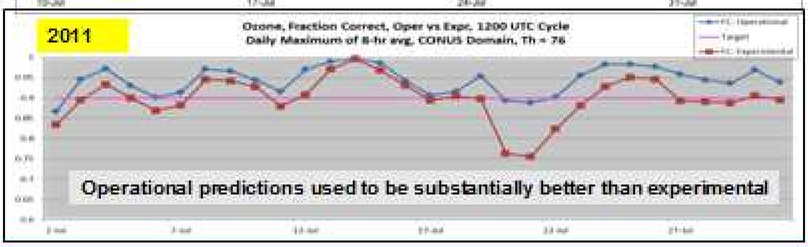
Difference

Observed change in NOx



Operational and experimental predictions: fraction correct

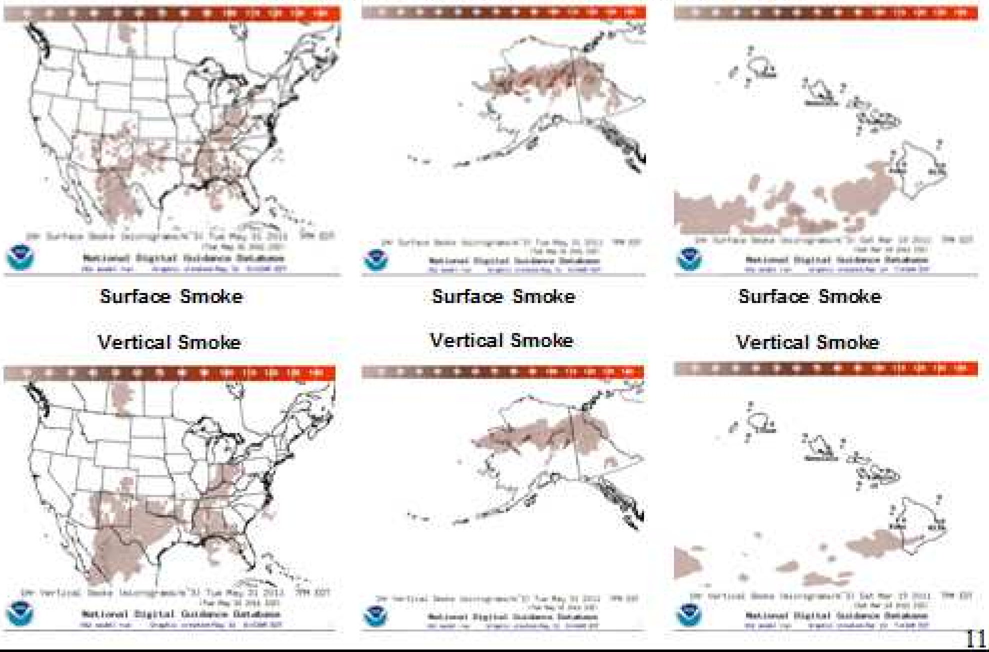




	2011	2012 changes		2013 changes
Operational CB-IV	WRF-NMM, 2005 NEI	NMM-B, 2012 emission projections		Reusing 2012 emissions
Experimental CB05	WRF-NMM, 2005 NEI	NMM-B, 2012 emission projections	LBC, dry deposition, minimum PBL height	Reusing 2012 emissions

Smoke predictions

Operational predictions at http://airquality.weather.gov



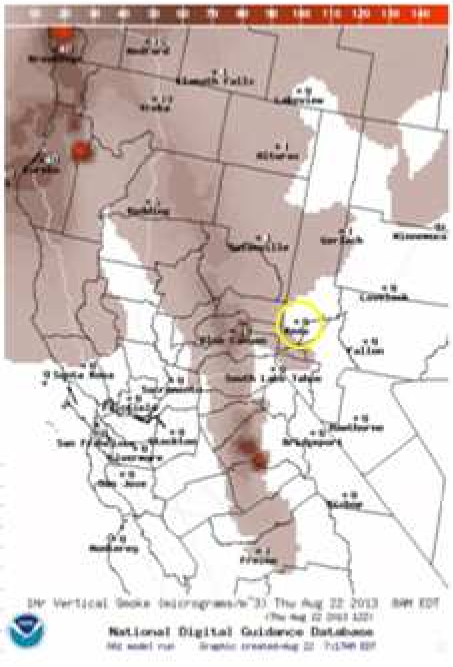
Rim Fire in California

The largest wildfire ever recorded in Yosemite National Park. Fire started on August 17.

Transport of smoke towards Reno, NV on 8/22 was confirmed by GOES-14 satellite imagery.

NWS office in Reno included smoke and haze in their forecast.

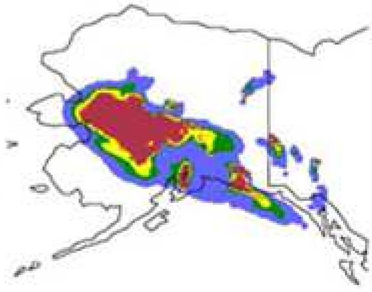
Observed PM2.5 concentrations peaked around 2 pm LST, predicted concentrations at the surface peaked at 1 pm, and the highest predicted concentration was lower than observed



http://airquality.weather.gov

Smoke Verification:
July 13, 2009

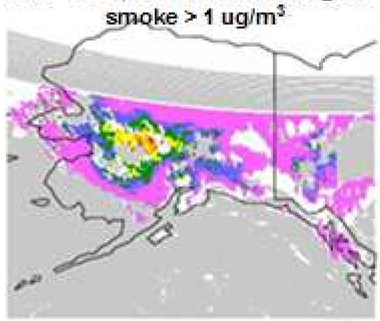
7/13/09, 17-18Z, Prediction:

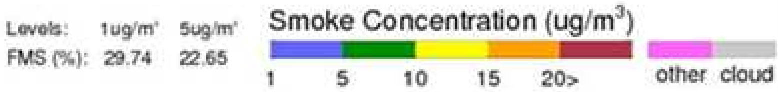


7/13/09, 17-18Z, Observation:

GOES smoke product: Confirms areal extent of peak concentrations

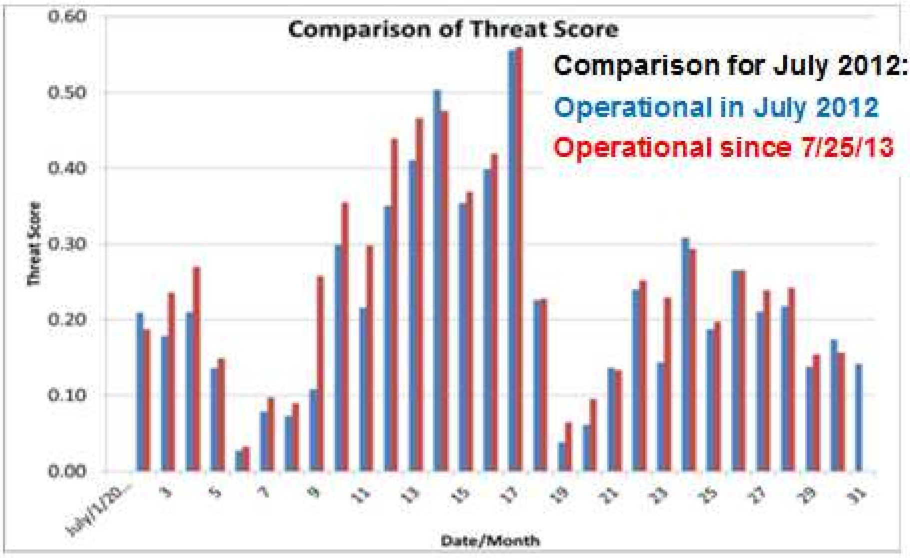
FMS = 30%, for column-averaged smoke > 1 ug/m^3





Manuscript about smoke verification product is in preparation

Verification of smoke predictions against GOES smoke retrievals



Updates: increased plume rise, decreased wet deposition, changes in daily emissions cycling

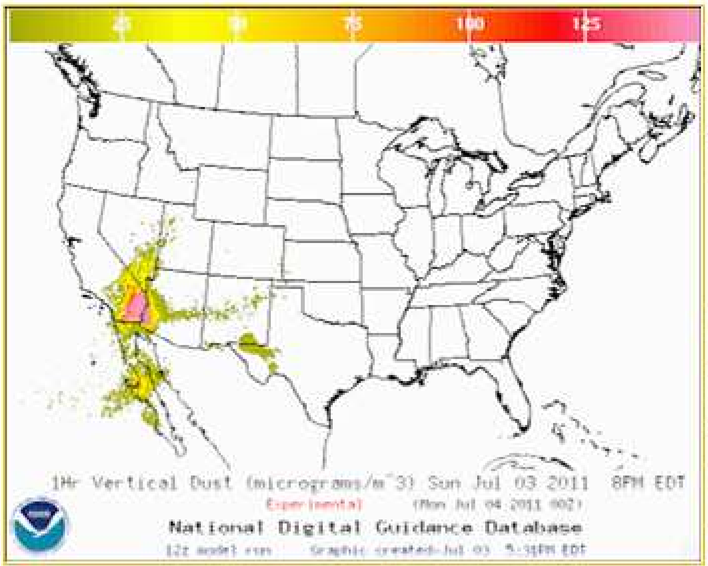
Verification of smoke predictions for CONUS

Daily time series of FMS for smoke concentrations larger than 1um/m3

- Figure of merit in space (FMS), which is a fraction of overlap between predicted and observed smoke plumes, threshold is 0.08 marked by red line
- NESDIS GOES Aerosol/Smoke Product is used for verification
- Since July 26, 2013, the model includes the following updates: increased plume rise, decreased deposition, changes in daily emissions cycling

CONUS Dust Predictions

Operational Predictions at http://airquality.weather.gov/



Standalone prediction of airborne dust from dust storms:

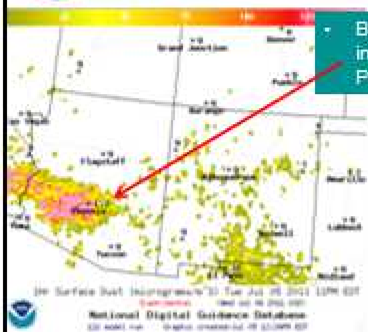
- Wind-driven dust emitted where surface winds exceed thresholds over source regions
- Source regions with emission potential estimated from MODIS deep blue climatology (2003-2006).
- Emissions modulated by real-time soil moisture.
- HYSPLIT model for transport, dispersion and deposition (Draxler et al., JGR, 2010)
- Wet deposition updates in July 2013
- Developed satellite product for verification (Zeng and Kondragunta)

Phoenix, AZ dust event on July 5, 2011

- Massive dust storm hit Phoenix, AZ in the evening on July 5, 2011
- Cloud was reported to be 5,000 feet when it hit, radar shows heights from 8,000-10,000 feet tall and 50 miles wide

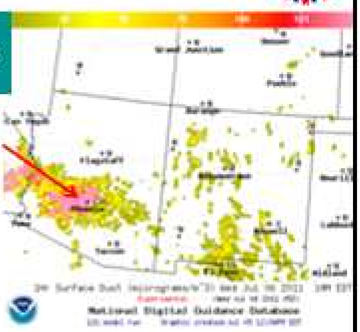
- Originated from convection near Tucson
- Stopped air traffic for over an hour
- Arizona DEQ reported a PM10 concentration of 6,348 ug/m^3 during peak of storm at site in downtown Phoenix
- Storm moved through Phoenix at 30-40 mph

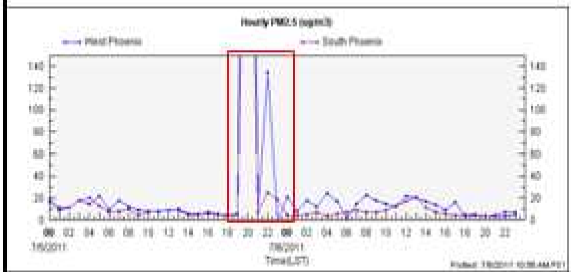
PM 2.5 observations in Phoenix



- Based on observations, height of impact on Phoenix was between 8 PM and 10 PM LST

Predicted surface dust concentrations:
- 8PM 158 ug/m^3
- 10PM 631 ug/m^3



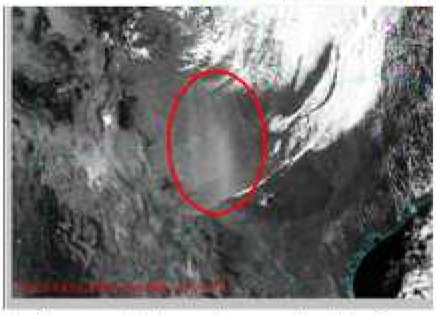


- Timing of storm based on comparing predictions to observations looks accurate (albeit perhaps early – 63 ug/m^3 predicted at 7 PM for Phoenix), however, the predictions keep the high levels seen at 10 PM LST for the next four to five hours, not seen in the observations

Dust prediction updates

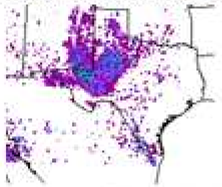
- Modulating dust emissions using real-time soil moisture information

Texas dust event on November 2, 2011

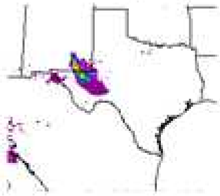


A widespread dust event occurred on Nov 2 beginning around 18Z in west central Texas. This event was the result of ~25kt synopticscale winds ahead of a cold front. Through 0Z (Nov 3) the dust blew south covering all of west Texas and parts of southeast New Mexico.

Predicted dust concentration (ug/m3) at the surface



Current model: emissions modulated by real time soil moisture using Bowen ratio (sensible heating / latent heating)



Previous model: emissions not modulated by soil moisture

- **Longer time step** (10 min vs. 6 min) provides comparable predictions, but 30% faster
- **Reduced wet deposition**

Quantitative PM performance

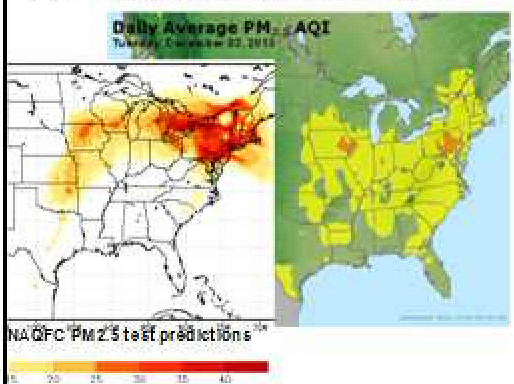
Focus group access only, real-time as resources permit

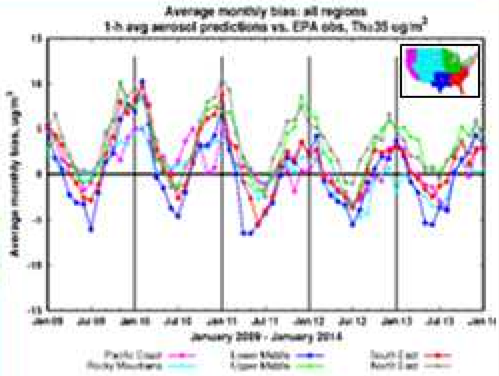
Aerosols over CONUS

From NEI sources only

- CMAQ:
  CB05 gases, AERO-4 aerosols
- Sea salt emissions

No wildfire smoke and dust storm emissions

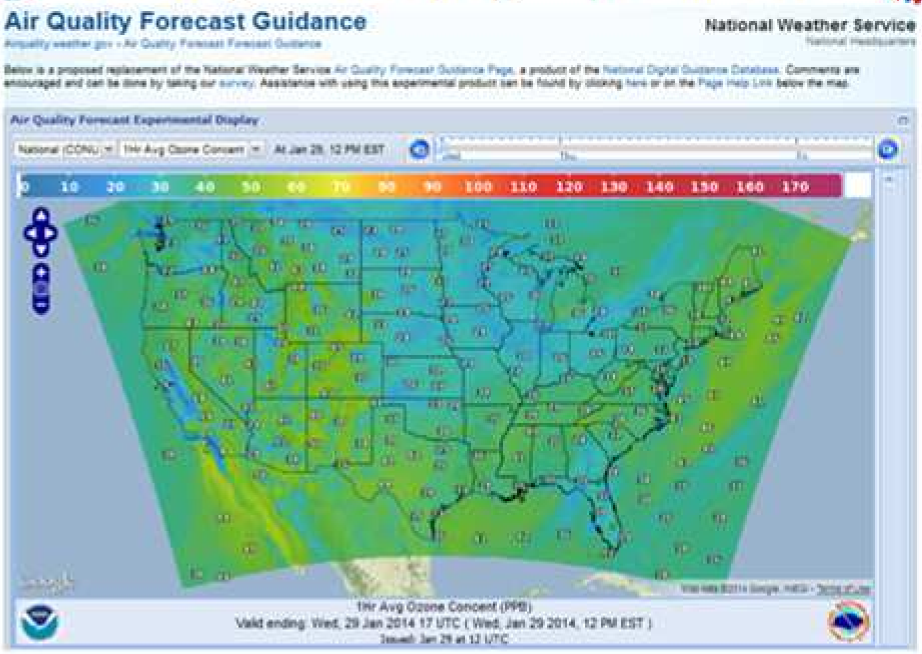




Forecast challenges

- *Aerosol simulation using emission inventories:*
  - Show seasonal bias– winter, overprediction; summer, underprediction
- *Intermittent sources*
- *Chemical boundary conditions/trans-boundary inputs*

Testing new display of predictions



Partnering with AQ Forecasters

Focus group, State/local AQ forecasters:

- Participate in real-time developmental testing of new capabilities, e.g. aerosol predictions
- Provide feedback on reliability, utility of test products
- Local episodes/case studies emphasis
- Regular meetings; working together with EPA's AIRNow and NOAA
- ***Feedback is essential for refining/improving coordination***

Examples of AQ forecaster feedback:

2013

•Local and state forecasters urged NOAA to continue to provide Air Quality Predictions

•Evaluation of ozone predictions in summer 2013 was hampered by unusually low number of high ozone events especially in southeast US.

2012

•In Connecticut, NOAA model outperformed [human] forecasts- 73% vs. 54%. The NOAA model past record of over-predicting during July-August didn't occur this year. *(Michael Geigert, Connecticut Dept.of Energy and Environmental Protection)*

•In Maryland, NOAA ozone predictions have improved since 2011: significant improvement in false alarm ratio (FAR) with some decrease in probability of detection (POD). *(Laura Landry, Maryland Department of the Environment)*

Summary and Future Plans

US national AQ forecasting capability and recent updates:

- Operational **ozone** prediction nationwide; substantial emission update in 2012
- Operational **smoke** prediction nationwide; recent plume rise update
- Operational **dust** prediction for CONUS sources; emissions moderated by soil moisture
- **Experimental ozone** predictions for CONUS; updated emissions, lateral boundary conditions, deposition
- Prototype CMAQ **aerosol** predictions with NEI sources

If/when resources allow we plan to:

- Maintain operational AQ predictions
- Improve and transition currently experimental ozone into operations
- Use lateral boundary conditions from global dust predictions in testing of PM2.5 predictions
- Testing of smoke predictions with 4 km meteorology and emission updates.

Acknowledgments:
AQF Implementation Team Members

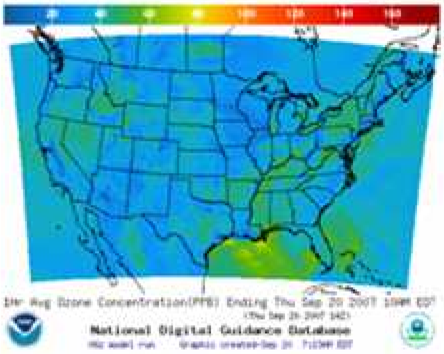
Special thanks to Paula Davidson, OST chief scientist and former NAQFC Manager and to Jim Meager former NOAA AQ Matrix Manager

NOAA/NWS/OST — *Ivanka Stajner* — *NAQFC Manager*
NWS/OCWWS — *Jannie Ferrell* — *Outreach, Feedback*
NWS/OPS/TOC — *Cynthia Jones* — *Data Communications*
NWS/OST/MDL — *Jerry Gorline, Marc Saccucci, Dave Ruth* — *Dev. Verification, NDGD Product Development*
NWS/OST — *Sikchya Upadhayay* — *Program Support*
NESDIS/NCDC *Alan Hall* — *Product Archiving*
NWS/NCEP
Jeff McQueen, Jianping Huang Perry Shafran — AQF model interface development, testing, & integration
*Sarah Lu — Global dust aerosol and feedback testing
*Brad Ferrier, *Eric Rogers, *Hui-Ya Chuang — NAM coordination
Geoff Manikin — Smoke and dust product testing and integration
Allan Darling, Chris Magee — NCO transition and systems testing
Mike Bodner, Andrew Orrison — HPC coordination and AQF web drawer
NOAA/OAR/ARL
Pius Lee, Daniel Tong, Tianfeng Chai — CMAQ development, adaptation of AQ simulations for AQF
Hyun-Cheol Kim
Roland Draxler, Glenn Rolph, Ariel Stein — HYSPLIT adaptations
NESDIS/STAR *Shobha Kondragunta* — *Smoke and dust verification product development*
NESDIS/OSDPD *Liqun Ma, Mark Ruminski* — *Production of smoke and dust verification products, HMS product integration with smoke forecast tool*
EPA/OAQPS partners:
Chet Wayland, Phil Dickerson, Brad Johns, John White — *AIRNow development, coordination with NAQFC*

* Guest Contributors

Operational AQ forecast guidance

airquality.weather.gov



Ozone products
Nationwide since 2010

Smoke Products
Nationwide since 2010
Dust Products
Implemented in 2012

Further information: www.nws.noaa.gov/ost/air_quality

Back up slides

Recent progress and updates

North American Meteorological model, currently Non-hydrostatic Multi-scale Model (NMMB) was updated and migrated to new supercomputers

- *These meteorological predictions are used for all air quality predictions (July 2013)*

Ozone - *Substantial emission updates for 2012; reuse these emissions in 2013:*

  - *Mobile6 used for mobile emissions, but with emissions scaled by growth/reduction rate from 2005 to 2012*
  - *Non-road area sources use Cross State Rule Inventory*
  - *Canadian emissions use 2006 inventory*

Dust predictions implemented operationally in March 2012:

- *Dust emissions are modulated by real-time soil moisture*
- *Longer time step to speed up dust predictions implemented in October 2012*

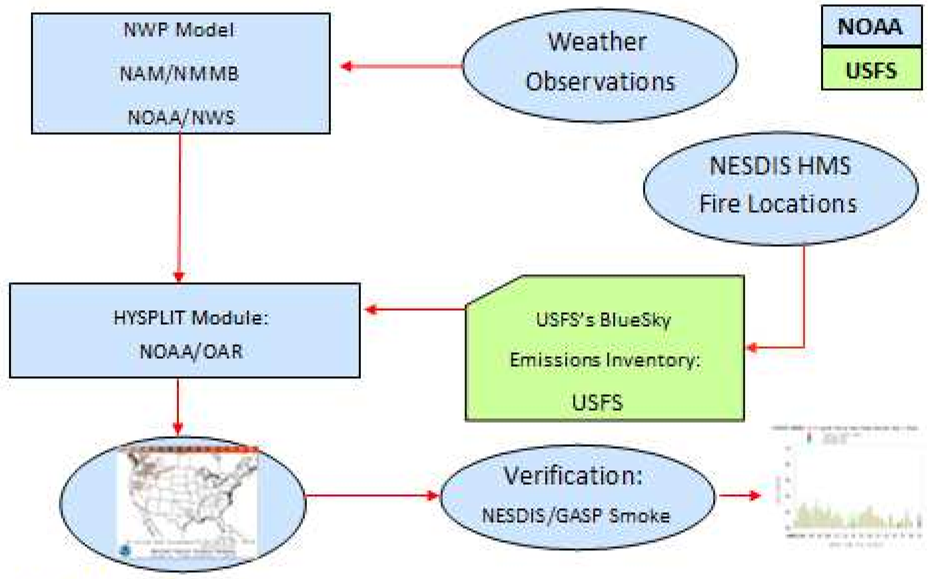
Smoke updates implemented in July 2013:

- *Increased maximum plume rise limit from 0.75 to 1.25 of the PBL depth; decreased wet removal, changed in daily emissions cycling; made horizontal puff dispersion rate more consistent with particle dispersion*

<u>All AQ predictions have migrated to new NCEP computers</u>

Smoke Forecast Tool

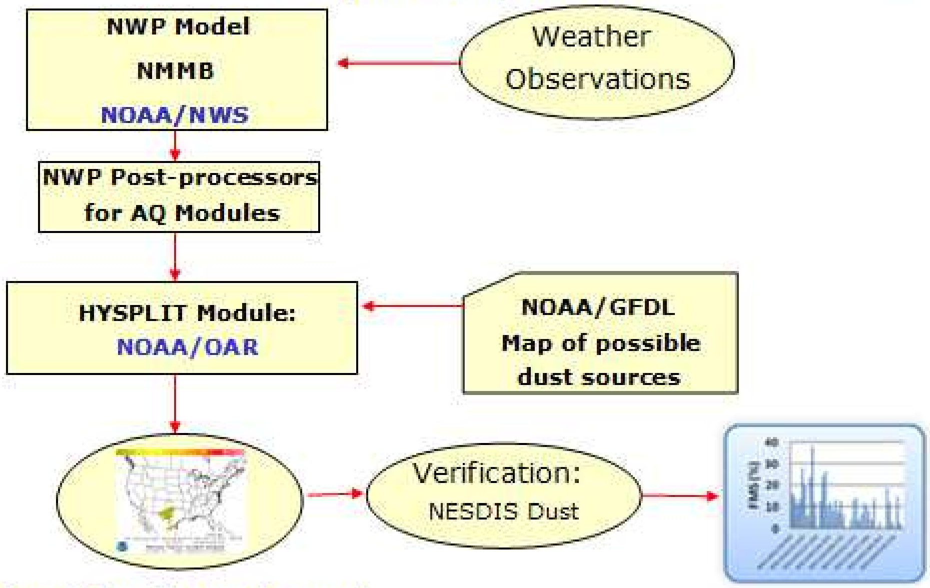
Major Components



http://airquality.weather.gov/

Dust Forecast Tool for CONUS

Major Components

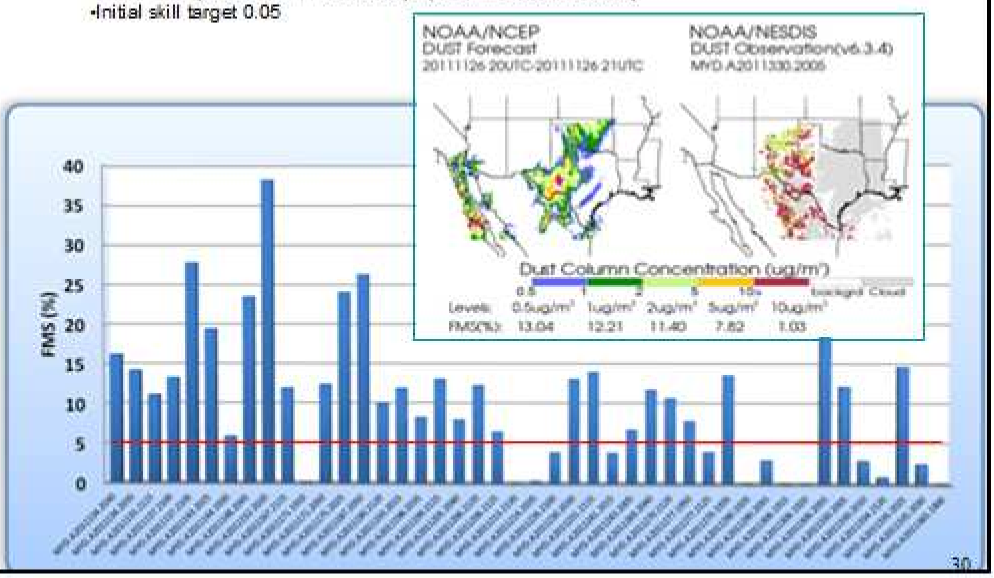


http://airquality.weather.gov/

Real time verification examples

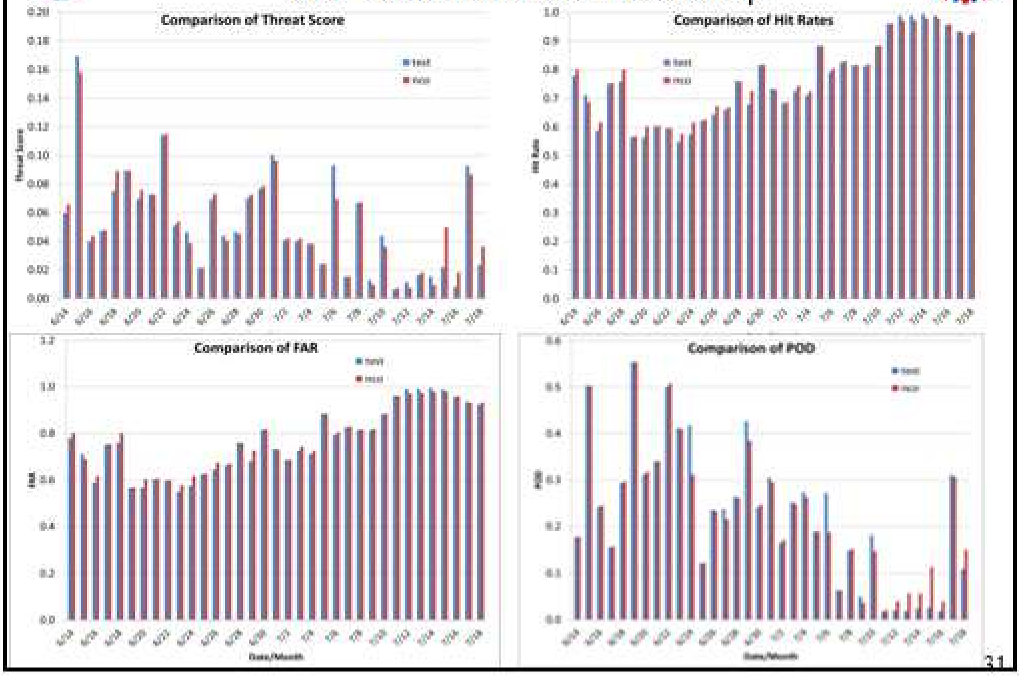
Using MODIS Dust Mask Algorithm from NOAA/NESDIS satellite imagery
"Footprint" comparison:

- Threshold concentration > 1 μg/m³, for average dust in the column
- Tracking threat scores, or figure-of-merit statistics:
  (Area Pred ∩ Area Obs) / (Area Pred U Area Obs)
- Initial skill target 0.05



Verification of dust predictions

with 10 min and 6 min time step



附錄四、Physical Activity and Air Pollution Exposure

Physical Activity and Air Pollution Exposure

Tegan K. Boehmer, PhD, MPH
Senior Research Scientist

National Air Quality Conference
Durham, NC
February 10, 2014

National Center for Environmental Health
Division of Environmental Hazards and Health Effects

CDC

Objectives

- Summarize health benefits of physical activity and public health recommendations
- Discuss public health significance of air pollution exposure while being physically active
- Provide an overview of CDC activities

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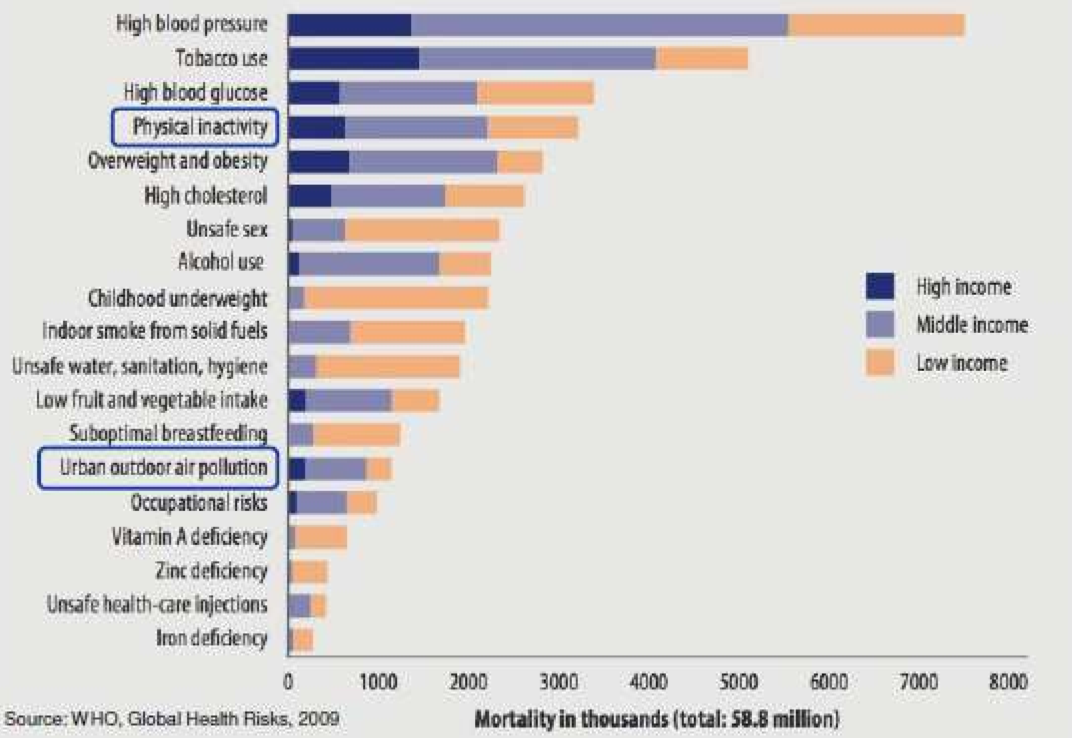
PHYSICAL ACTIVITY

PHYSICAL ACTIVITY

Figure 6: Deaths attributed to 19 leading risk factors, by country income level, 2004.



Source: WHO, Global Health Risks, 2009

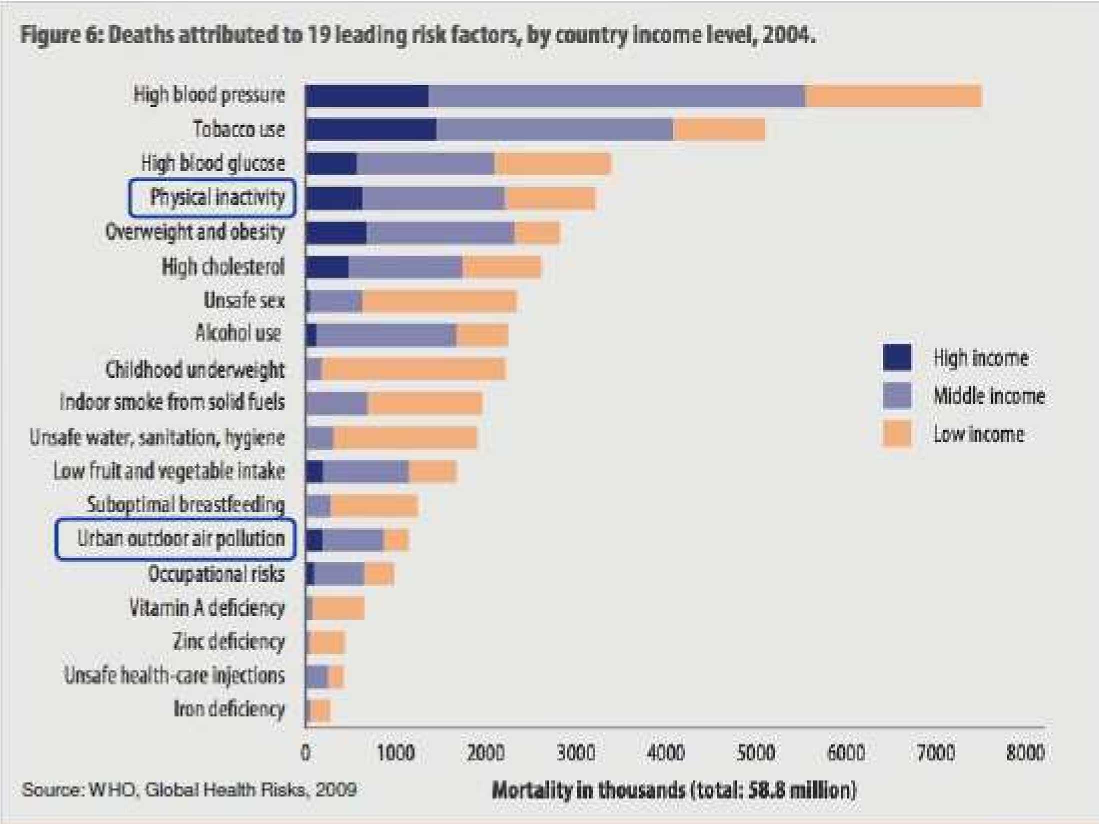


Figure 6: Deaths attributed to 19 leading risk factors, by country income level, 2004.

Source: WHO, Global Health Risks, 2009

Benefits of Physical Activity

- **In adults, physical activity lowers risk for:**
  - Premature death
  - Coronary heart disease
  - Stroke
  - Hypertension
  - Type 2 diabetes
  - Colon cancer
  - Breast cancer
  - Depression
  - Unhealthy weight gain
  - Injuries from falls
- **In children and adolescents, physical activity is associated with improved:**
  - Cardiorespiratory fitness
  - Bone health
  - Cardiovascular biomarkers
  - Metabolic health biomarkers
  - Academic achievement
  - Academic behaviors
  - Cognitive skills

1. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans. October 2008. http://www.health.gov/paguidelines/.
2. Centers for Disease Control and Prevention. The association between school-based physical activity, including physical education, and academic performance. 2010. http://www.cdc.gov/healthyyouth/health_and_academics/pdf/pa-pe_paper.pdf

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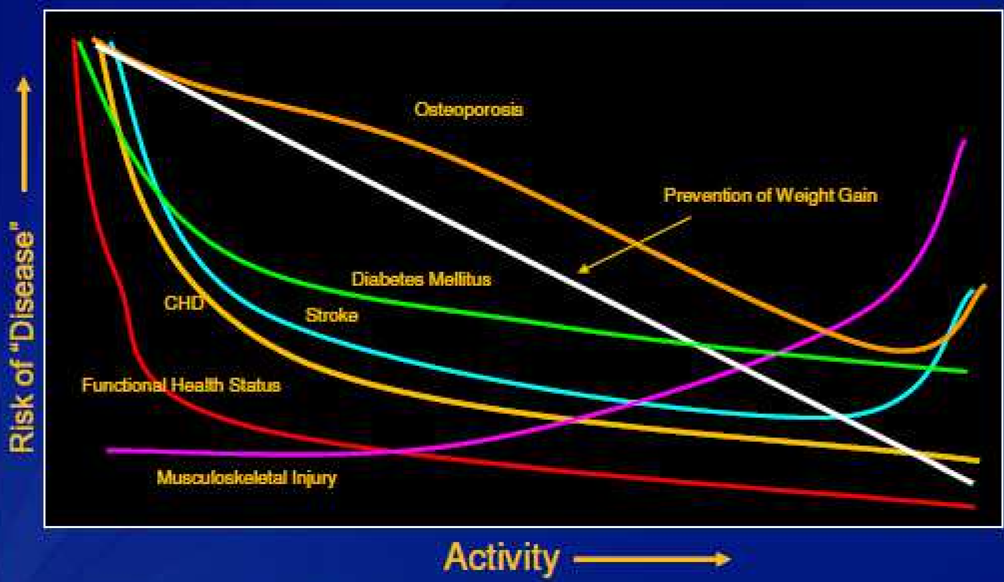
1. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans. October 2008. http://www.health.gov/paguidelines/.
2. Centers for Disease Control and Prevention. The association between school-based physical activity, including physical education, and academic performance. 2010. http://www.cdc.gov/healthyyouth/health_and_academics/pdf/pa-pe_paper.pdf

Benefits of Physical Activity



Source: HW Kohl, University of Texas School of Public Health

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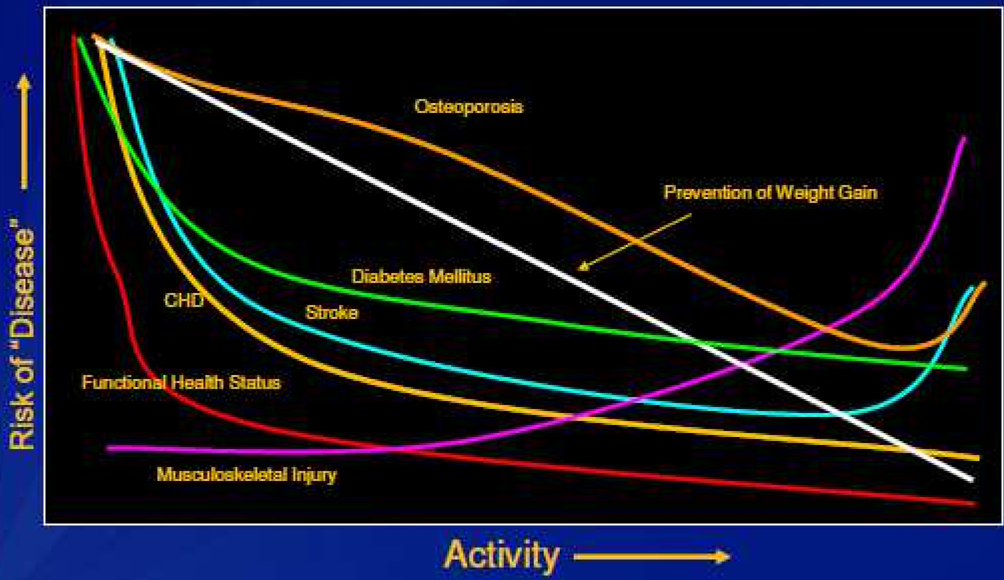

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Public Health Impacts of Physical Inactivity

- 36% of adults report no leisure-time physical activity
- 82% of adults and 88% of adolescents do not meet current federal guidelines for aerobic activity and muscle strengthening
- Estimated medical cost of physical inactivity =
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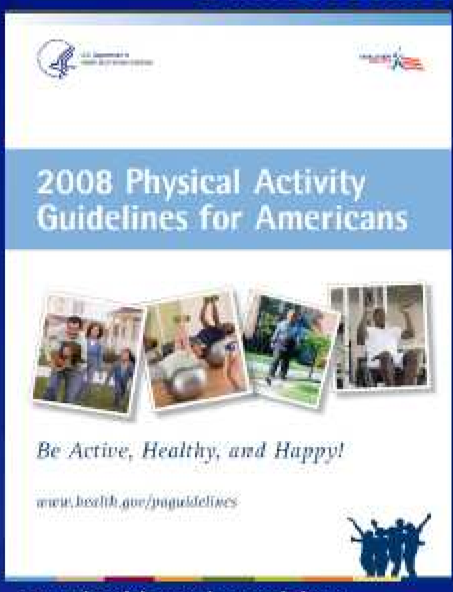

www.health.gov/paguidelines

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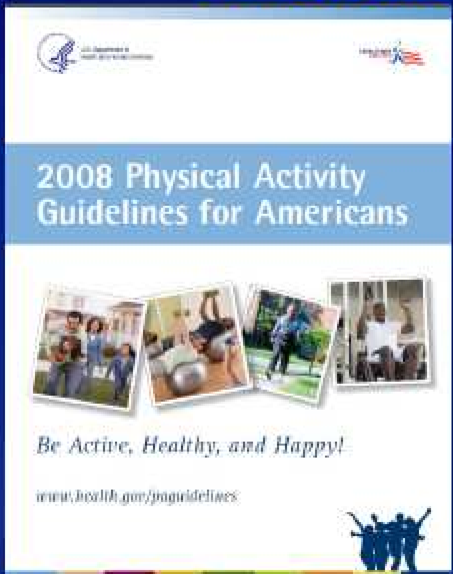

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Physical Activity Guidelines Children and Adolescents (6–17 yrs)

- **60+ minutes of physical activity every day**
  - Aerobic: Most of 60+ minutes should be moderate- or vigorous-intensity aerobic physical activity, with vigorous-intensity activity at least 3 days per week.
  - Muscle-strengthening: at least 3 days of the week
  - Bone-strengthening: at least 3 days of the week
- **Encourage participation in physical activities that are age appropriate, enjoyable, and offer variety**

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Physical Activity Guidelines
Adults (18–64 yrs)

- **Avoid inactivity. Health benefits are seen with any amount of physical activity.**
- **Substantial health benefits seen with:**
  - 150 min/week of moderate-intensity aerobic activity
  - 75 min/week of vigorous-intensity aerobic activity
  - Activity episodes for at least 10 minutes, throughout week
- **Additional health benefits seen with:**
  - 300 min/week of moderate-intensity aerobic activity
  - 150 min/week of vigorous-intensity aerobic activity
- **Muscle-strengthening activities at least 2 days/week provide additional benefits**

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Physical Activity Guidelines Older Adults (65+ yrs)

- **Same four principles on previous slide, but additional qualifying guidelines:**
  - Guidance for adults who cannot do 150 min/week
  - Use relative intensity to determine level of effort
  - Be aware of chronic conditions and injury risk
  - Recommend balance exercises for persons at risk of falling

Physical Activity Guidelines
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Physical Activity Guidelines
Chapter 6: Safe and Active

- Exposure to air pollution is associated with several adverse health outcomes, including asthma attacks and abnormal heart rhythms.
- People who can modify the location or time of exercise may wish to reduce these risks by exercising away from heavy traffic and industrial sites, especially during rush hour or times when pollution is known to be high.
- However, current evidence indicates that the benefits of being active, even in polluted air, outweigh the risk of being inactive.

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AIR POLLUTION EXPOSURE WHILE BEING ACTIVE

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How Physical Activity Affects Air Pollution Dose

- **Concentration varies across microenvironments**
  - When and where activity occurs
- **Time spent in microenvironment**
  - Duration of activity (e.g., active travel vs. driving)
- **Ventilation rate correlates with intensity of activity**
  - Increased ventilation rate: more breaths/minute
  - Increased velocity of breaths: forces air deeper into lungs and increases deposition fraction
  - More mouth breathing: bypasses nasal filtration
- **Dose is dependent on age, sex, and body size**

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Air Pollution & Physical Activity Joint Health Effects

- **Mortality risks vs. benefits**
  - Studies on increasing active travel consistently show that benefits (physical activity) > risks (air pollution and injury)
  - Modeled predictions of hypothetical scenarios using relative risk data from literature
- **Interaction effects are not well studied**
  - Short-term exposure and acute health effects
  - Long-term exposure and chronic health effects
- **Built environment plays an important role in determining air pollution and physical activity levels**

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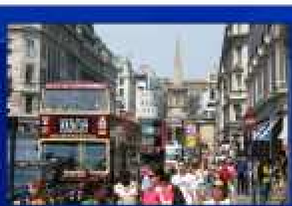
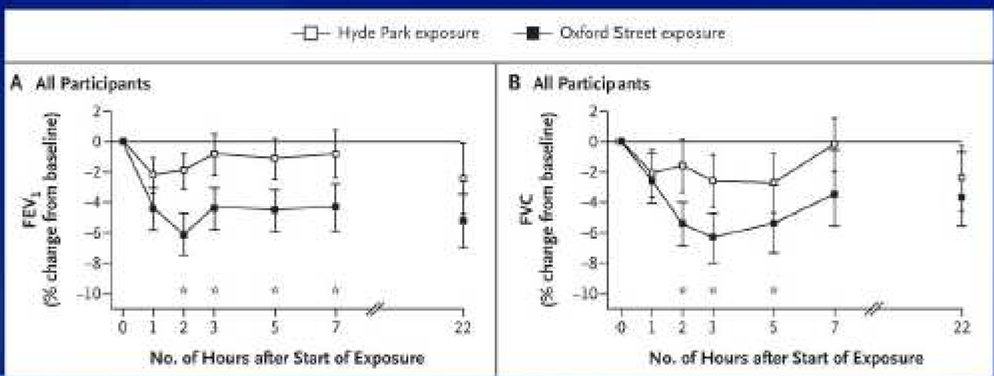
Short-term Exposure and Lung Function



- **60 adults with asthma walk for 2 hours along two different routes**
- **Larger decline in lung function after walking more polluted route**



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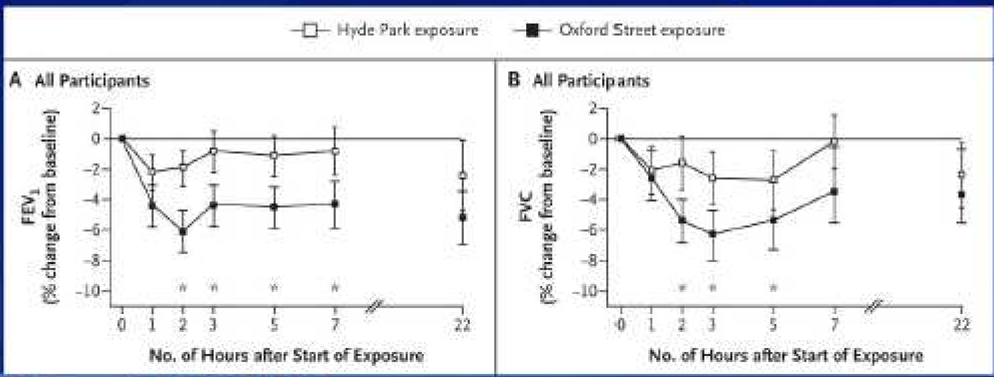

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Long-term Exposure and Asthma Incidence

- Cohort study of 3,535 children 9–16 yrs
- Southern California, 1993–1998
- Playing ≥3 sports increased risk of asthma in high ozone communities, but not in low ozone communities

Number of sports played	Low ozone communities		High ozone communities	
	N (incidence)*	RR (95% CI)	N (incidence)*	RR (95% CI)
0	58 (0·027)	1·0	46 (0·018)	1·0
1	50 (0·033)	1·3 (0·9–1·9)	40 (0·021)	1·3 (0·8–2·0)
2	20 (0·023)	0·8 (0·5–1·4)	16 (0·020)	1·3 (0·7–2·3)
≥3	9 (0·019)	0·8 (0·4–1·6)	20 (0·050)	3·3 (1·9–5·8)

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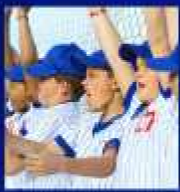

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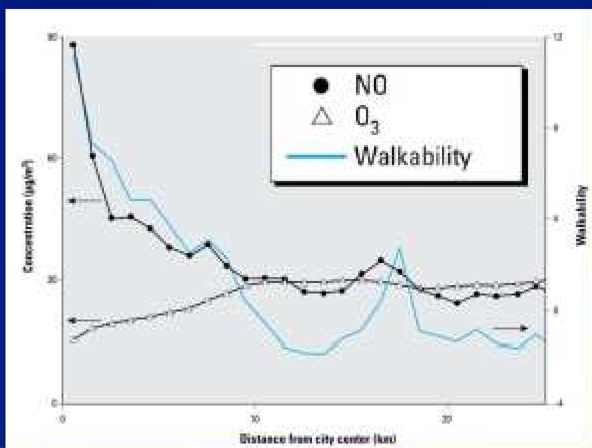
Role of the Built Environment

- Neighborhood walkability and air pollution concentrations correlated (Vancouver, Canada)
- Compare ischemic heart disease mortality in So. Cal neighborhoods
- High-walkable:
  - – 7 deaths from increased physical activity
  - + 6 more deaths from increased air pollution (+ 9 $PM_{2.5}$ – 3 O_3)



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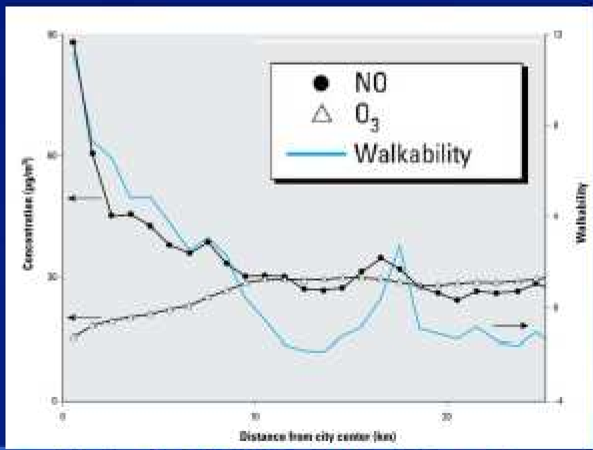

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CDC ACTIVITIES

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- Panel of 25 scientists from physical activity and air pollution disciplines
- Atlanta, April 2010
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  - Review state of the science
  - Provide recommendations to CDC on how to advise the general public and public health officials on physical activity in regard to outdoor air quality

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CDC Workshop Findings: Public Health Guidance

- **Promote physical activity while reducing risk from outdoor air pollution exposure**
- **Outline factors that impact risk:**
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  - Likelihood of exposure (when, where)
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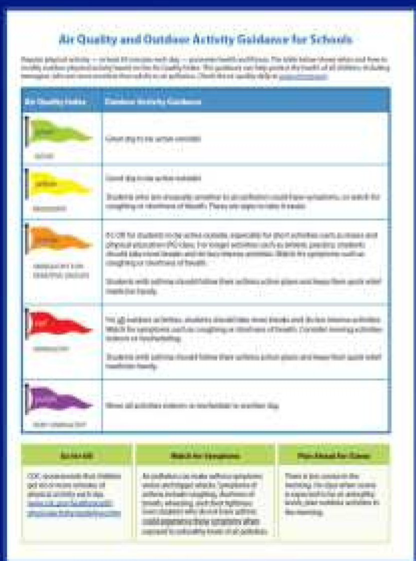
Air Quality & Outdoor Activity Guidance for Schools

- **EPA and CDC collaboration**
- **Update physical activity guidance associated with the School Flag Program**
- **Goal: Keep kids active!**
- **Take into consideration that air pollution exposures during school day are of short duration**
  - 15 minute recess
  - 30 minute PE class



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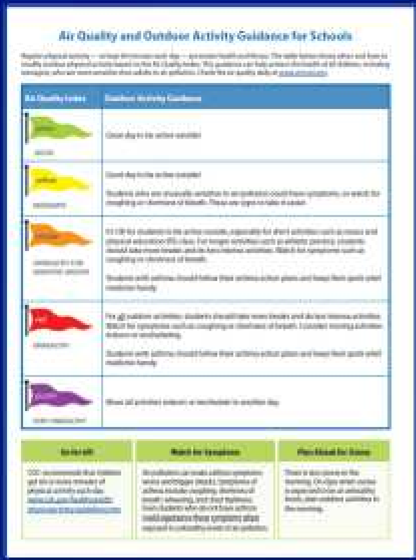
Air Quality and Outdoor Activity Guidance for Schools

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Regular physical activity — at least 60 minutes each day — promotes health and fitness. The table below shows when and how to modify outdoor physical activity based on the Air Quality Index. This guidance can help protect the health of all children, including teenagers, who are more sensitive than adults to air pollution. Check the air quality daily at www.airnow.gov.

Air Quality Index	Outdoor Activity Guidance
green GOOD	Great day to be active outside!
yellow MODERATE	Good day to be active outside! Students who are unusually sensitive to air pollution could have symptoms, so watch for coughing or shortness of breath. These are signs to take it easier.
orange UNHEALTHY FOR SENSITIVE GROUPS	It's OK for students to be active outside, especially for short activities such as recess and physical education (PE) class. For longer activities such as athletic practice, students should take more breaks and do less intense activities. Watch for symptoms such as coughing or shortness of breath. Students with asthma should follow their asthma action plans and keep their quick relief medicine handy.

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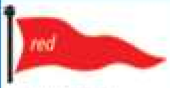
Go for 60!	Watch for Symptoms	Plan Ahead for Ozone
CDC recommends that children get 60 or more minutes of physical activity each day. www.cdc.gov/healthyyouth/physicalactivity/guidelines.htm	Air pollution can make asthma symptoms worse and trigger attacks. Symptoms of asthma include coughing, shortness of breath, wheezing, and chest tightness. Even students who do not have asthma could experience these symptoms when exposed to unhealthy levels of air pollution.	There is less ozone in the morning. On days when ozone is expected to be at unhealthy levels, plan outdoor activities in the morning.

Air Quality & Outdoor Activity Guidance for Schools

 UNHEALTHY	For all outdoor activities, students should take more breaks and do less intense activities. Watch for symptoms such as coughing or shortness of breath. Consider moving activities indoors or rescheduling. Students with asthma should follow their asthma action plans and keep their quick relief medicine handy.
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State Asthma Control Program Activities

- **Utah: developed "Recess Guidance for Schools" based on outdoor air quality**
  - Provide link to daily air quality and resources for keeping students with asthma healthy and safe
  - Developed three tutorials (available on website)
  - Email recess air quality alerts to 240 school personnel
  - 84% of principals/staff aware of and used guidance

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- **Indiana: promote "Fly a Flag for Clean Air" program**
  - Notify school and neighborhood about daily air quality
  - Also adopt no-idling and tobacco-free campus policies

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MOVING FORWARD

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Physical Activity and Air Pollution Guidance – Exposure Issues

- **Local air pollution levels needed to help inform individual's physical activity decisions**
  - Compare concentrations between different routes
  - Vancouver Cycling Route Planner http://www.cyclevancouver.ubc.ca/cv.aspx
- **Consider the proportion of total air pollution dose resulting from physical activity**

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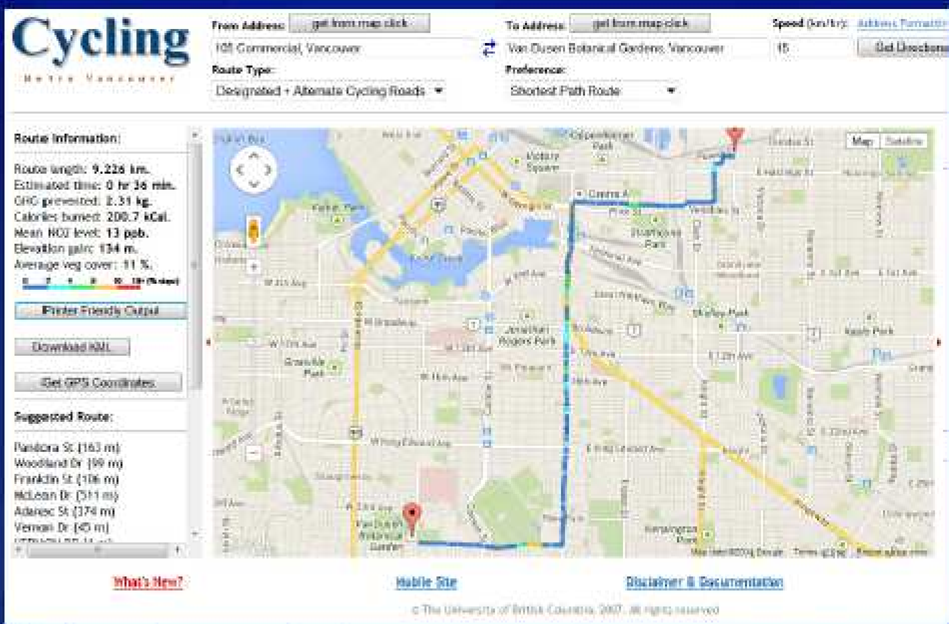
"Shortest path" route



http://www.cyclevancouver.ubc.ca/cv.aspx


"Shortest path" route
Cycling
From Address:
get from map click
105 Commercial, Vancouver
Route Type:
Designated + Alternate Cycling Roads
To Address:
get from map click
Van Dusen Botanical Gardens, Vancouver
Preference:
Shortest Path Route
Speed (km/hr):
15
Get Directions
Route Information:
Route length: 9.226 km.
Estimated time: 0 hr 36 min.
GHG prevented: 2.31 kg.
Calories burned: 200.7 kCal.
Mean NO2 level: 13 ppb.
Elevation gain: 134 m.
Average veg cover: 11 %.
Printer Friendly Output
Download KML
Get GPS Coordinates
Suggested Route:
Pandora St (163 m)
Woodland Dr (99 m)
Franklin St (106 m)
McLean Dr (511 m)
Adanac St (374 m)
Vernon Dr (45 m)
What's New?
Mobile Site
Disclaimer & Documentation
http://www.cyclevancouver.ubc.ca/cv.aspx


"Least traffic pollution" route
Cycling
From Address:
get from map click
105 Commercial, Vancouver
Route Type:
Designated + Alternate Cycling Roads
To Address:
get from map click
Van Dusen Botanical Gardens, Vancouver
Preference:
Least Traffic Pollution
Speed (km/hr):
15
Get Directions
Route Information:
Route length: 9.518 km.
Estimated time: 0 hr 38 min.
GHG prevented: 2.38 kg.
Calories burned: 207 kCal.
Mean NO2 level: 12 ppb.
Elevation gain: 160 m.
Average veg cover: 15 %.
Printer Friendly Output
Download KML
Get GPS Coordinates
Suggested Route:
Pandora St (163 m)
Woodland Dr (99 m)
Franklin St (106 m)
McLean Dr (717 m)
PARKER ST (3 m)
McLean Dr (202 m)
What's New?
Mobile Site
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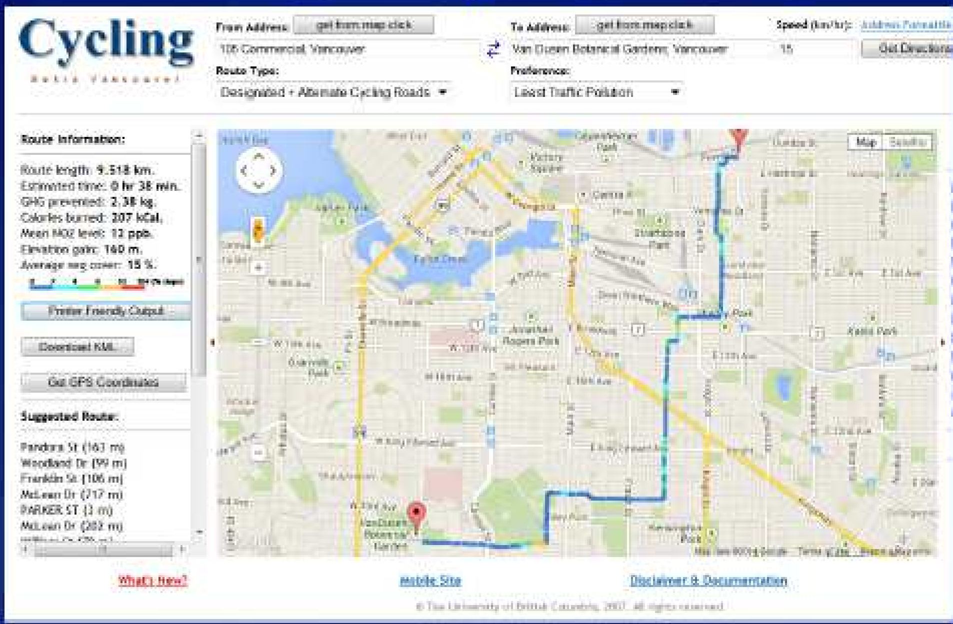
"Least traffic pollution" route



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Physical Activity and Air Pollution Guidance – Messaging Issues

- **Make it applicable to all types of physical activity, not just "exercise"**
  - Travel, household, occupational, and leisure-time
- **Address at-risk populations**
- **Address microenvironments**
  - Proximity to major roads, urban/rural settings
  - Time of day, seasonality
- **Encourage physical activity and time outdoors!**

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Change the Paradigm

Change the Paradigm

Thank You

Contact information:
Tegan Boehmer, PhD, MPH
tboehmer@cdc.gov

For more information please contact Centers for Disease Control and Prevention
1600 Clifton Road NE, Atlanta, GA 30333
Telephone, 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348
E-mail: cdcinfo@cdc.gov Web: www.cdc.gov

National Center for Environmental Health
Division of Environmental Hazards and Health Effects

附錄五、Advancements in Operational CMAQ MODIS AOD Data-Assimilation at Baron Advanced Meteorological Systems During Forecast Year 2013

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John N. McHenry,
Jeff Vukovich, Don Olerud, and W.T. Smith

Baron Advanced Meteorological Systems

Outline of the Talk

- Review of the MODIS-DA Modeling Component
- Review of Preliminary Real-Time Testing Results
- Improvements: Assimilating Surface PM2.5 Observations
- Initial Performance Analysis of Improved System
- Up-coming Enhancements

BAMS

Forecasting a Better Future

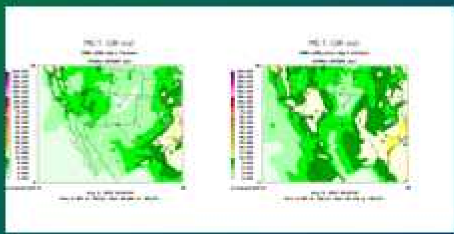
National Aeronautics and Space Administration

Review of the MODIS-DA Modeling Component

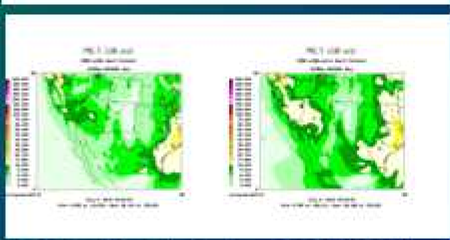
The promise of chemical data assimilation: An Example

No MODIS Assimilation | **MODIS Tau Assimilation**

Day 1 Forecast



Day 2 Forecast



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Review of the MODIS-DA Modeling Component

CMAQ-DA 2DVAR Algorithm Development

- **Partnering with the VISTA RPO, NCDENR and NASA, BAMS developed/tested/evaluated assimilation of MODIS AOD data into CMAQ V4.51 (soamods, CB4) using 2002 surface observations and annual run-results.**
- **The software implements a 2-D Variational Data-Assimilation system that produces an optimal AOD "analysis" through statistical blending between background CMAQ AOD and observed MODIS AOD.**
- **MODIS AOD is captured using both "Dark Target" and "Deep Blue" algorithms, the "Deep Blue" providing additional coverage over bright reflecting surfaces (Collection 5).**

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Review of the MODIS-DA Modeling Component

Data Assimilation Module: Observation Space Formulation for AOD

$$T_{b\lambda} = H_{mt}(C_m) + \varepsilon_{b\lambda} \quad (1)$$ Model Mass Concentration to AOD

$$T_{a\lambda} = T_{b\lambda} + P_b H^T [H P_b H^T + R_o]^{-1} [T_{o\lambda} - H(T_{b\lambda})] \quad (2)$$ Data Assimilation Step

$$C_m = H_{tm}(T_{a\lambda}) + \varepsilon_m \quad (3)$$ Analyzed AOD to Model Mass Concentration

(1) Is the "forward operator"
(2) Is the data-assimilation step (variational optimization)
(3) Is the inverse operator

AQ forecasting

Review of Initial Real-Time Experimental Implementation and Testing

Late-Fall; 19-day period after DA spin-up

- In November 2012, BAMS implemented a real-time version of the system, running on the "EPA-36km" CONUS grid w/ 19-layers (identical to the VISTAS configuration)
- The initial system was designed to produce real-time optimal AOD "*analyses*" using 2DVAR; but not forecasts.
- The objective was to evaluate whether or not the *analyses* improve against "none-assimilated" vanilla cycling, starting with evaluation of total surface PM2.5.

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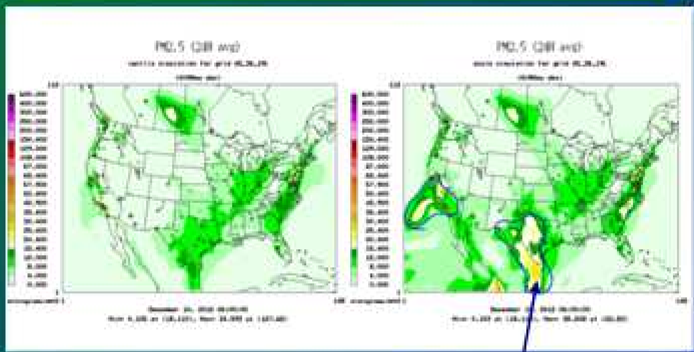
Initial Real-Time Experimental Implementation and Testing

Late-Fall; 19-day period after DA spin-up – December 10

- AirNow 24-hour average PM2.5 surface measurements as diamonds against CMAQ_DA 24-hr average (06z-06z)



- Improved areas circled blue
- Degraded areas circled red

- Mexican biomass burn event

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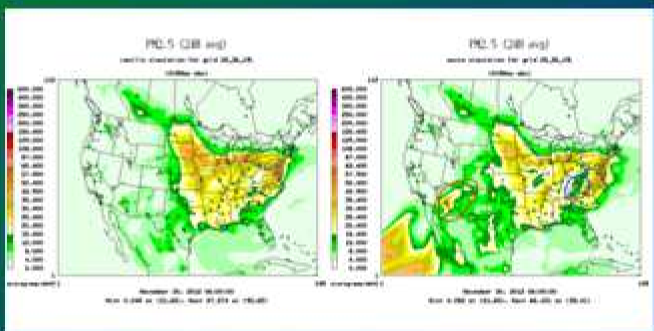
Initial Real-Time Experimental Implementation and Testing

Late-Fall; 19-day period after DA spin-up – November 30

- AirNow 24-hour average PM2.5 surface measurements as diamonds against CMAQ_DA 24-hr average (06z-06z)



- Improved areas circled blue
- Degraded areas circled red

Initial Real-Time Experimental Implementation and Testing

Late-Fall; 19-day period after DA spin-up

Representative improvements in California (dust components probable)

Glendora-Laurel site in LA county

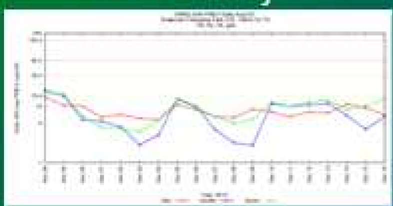
Anaheim

Initial Real-Time Experimental Implementation and Testing

Late-Fall; 19-day period after DA spin-up

Representative improvements in Texas/Desert SW (biomass burning in Mexico)

Harris County TX



Corpus Christi TX

Clark County Nevada

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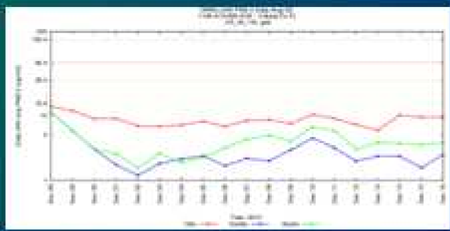
Initial Real-Time Experimental Implementation and Testing

Late-Fall; 19-day period after DA spin-up

Representative improvements in Florida (modest biomass burning)

Melbourne – Brevard County



Dunn Ave – Volusia County

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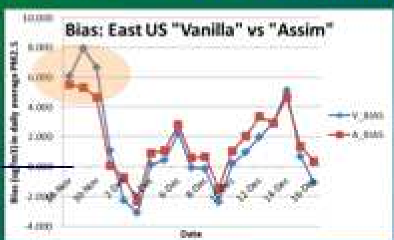
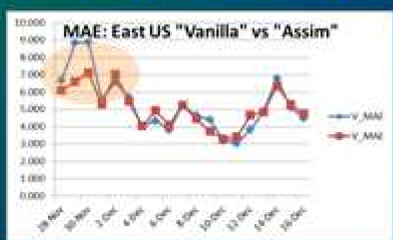
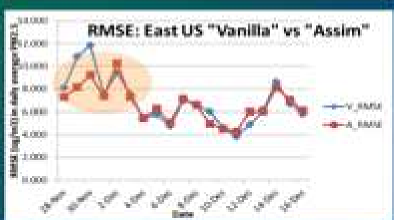
Initial Real-Time Experimental Implementation and Testing

Late-Fall; 19-day period after DA spin-up: Time-series of performance statistics in the East

0.00 Bias line







- Big improvement in skill first three days; little change in skill rest of period (clouds likely a big issue)

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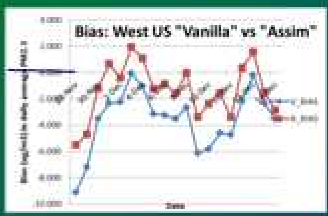
Initial Real-Time Experimental Implementation and Testing

Late-Fall; 19-day period after DA spin-up: Time series of performance statistics in the West

0.00 Bias line



- Major improvement in Bias throughout period
- Larger Errors days 2-6
- Smaller Errors days 10-14

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Initial Real-Time Experimental Implementation and Testing

- **Initial evaluation of 19-day late fall period against daily-average AirNow surface PM2.5 (TEOM) shows:**
  - Significant improvement in the East first three days and little change later (clouds)
  - Much improved bias in West over entire period
  - **Degraded error in the West days 2-6**
  - **Modest improved error in the West days 10-14**
- **On going work reported at that time:**
  - When it occurs, worsening of performance at the surface may result from *not distinguishing* aerosols aloft in MODIS: will be bringing in observed *surface* PM2.5 in upcoming scheme revision => **FOCUS of this talk: impacts**
  - Tuning of correlation length-scale in 2DVAR scheme may be needed **(DONE)**
  - A minor difference in AOD calculation between CMAQ and MODIS may be contributing some small unwanted bias in the final AOD "analysis." We are looking at this. **(UNNEEDED)**
  - Plan to migrate to operational status in the late spring/early summer time frame. **(DONE – Now running 1x daily 60-hour forecasts, 06Z Cycle)**

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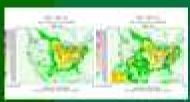
Improvements: Assimilating Surface PM2.5 Observations

Initial "Inverse Operator"
Had only linear-scaling in the vertical to match the assimilated AOD result

$$C_m = H_{tm}(T_{a\lambda}) + \varepsilon_m \qquad (3)$$ Analyzed AOD to Model Mass Concentration



Once the Tau increment is known in each CMAQ vertical column, the non-linear revised-IMPROVE equations are iterated to recover the newly analyzed aerosol optical depth by adjusting the aerosol constituents:

- For increasing Tau, all background accumulation or coarse mode aerosol species concentrations are adjusted upwards except:
  - Over the ocean: sulfates, nitrates, and chlorine
  - Near the coastline: sulfates
  - Inland: sulfates, sea-salts
- For decreasing Tau, all accumulation and coarse mode species may be adjusted downward
- Nothing is done to adjust modeled NO2, which is assumed "as good as can be" in the model due to its short life-time and relatively local nature
- Further species discrimination in the iterated-inverse adjustment is made based on "smoke" versus "dust" categorizations available from MODIS

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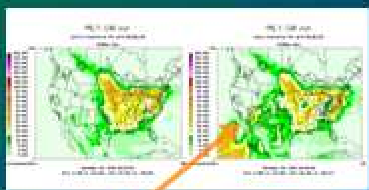
Improvements: Assimilating Surface PM2.5 Observations

Revised "Inverse Operator" preferentially nudges concentrations in the vertical with different weights to match both the assimilated (final analyzed) total column AOD result "and" to ensure the surface PM2.5 values do not exceed the observations – when TAU increases due to the assimilation. Further, over the ocean, TAU increases always result in nudged model concentrations above the PBL only



- Analysis showed that when MODIS detected a higher AOD than the initial CMAQ estimate, the inversion-step back to model concentrations sometimes resulted in CMAQ surface PM2.5 that was "too hot". This implied that relatively more of the increased concentration should be place above the PBL.

- The revised inversion step makes use of surface PM2.5 to mitigate the above: modeled PBL heights are used to preferentially nudge model concentrations above the PBL more heavily such that the resulting modeled surface PM2.5 does not exceed the "gridded-observed" PM2.5. This is a first improvement – with more to come (discussed later).

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Initial Performance Analysis of Improved System

- CMAQ is being run in both "vanilla" mode (non-DA cycling and forecast) and "MODIS-DA" mode (cycling and forecast) using the newly implemented surface PM2.5 data
- Runs began in late Spring and continued through Summer/Fall/Winter
- Due to occasional MODIS outages and network glitches, the dataset is not continuous but features about 170 total model days for comparison
- Preliminary analyses of both the final analysis (initial condition) and the day-1 and day-2 forecast results comparing "vanilla" and "MODIS-DA" were completed, with a focus on daily-average total surface PM2.5 observations as reported through the AIRNow "gateway"
- Performance in six CONUS sub-regions and "warm" (87 days) versus "cold" (84 days) season has been looked at to-date.

Defined as	minlat	maxlat	minlon	maxlon
Southeast	25	37	-90	-70
Northeast	37	50	-90	-65
SouthCentral	25	37	-105	-90
NorthCentral	37	50	-105	-90
SouthWest	25	37	-125	-105
NorthWest	37	50	-125	-105

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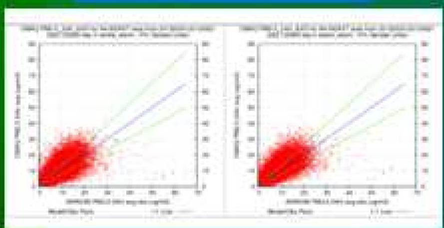
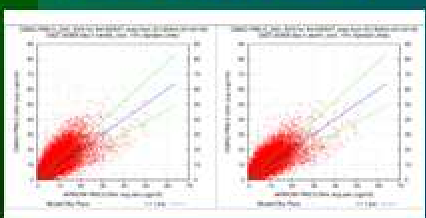
Initial Performance Analysis of Improved System

- NORTHEAST: Warm Season



- NORTHEAST: Cool Season



24-H PM2.5 for the "Initial Condition" Day	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	9.4892	9.4903	8.9299	8.9295
Model Average	11.3393	11.7308	11.6631	11.3698
Bias	1.8501	2.2405	2.7332	2.4403
Error	3.9706	4.0225	4.6090	4.2326
RMSE	5.3682	5.3158	6.2488	5.6503
Normalized Bias	-0.6187	-0.7013	-0.5975	-0.5905
GRS_ERR	0.7974	0.8415	0.7728	0.7476
Slope	0.6852	0.6457	0.8309	0.7623
R2	0.3639	0.3680	0.4316	0.4485
Indx_Agree	0.7458	0.7390	0.7581	0.7787

(blue circle) = MODIS assimilation improves

(red circle) = Vanilla Model Better

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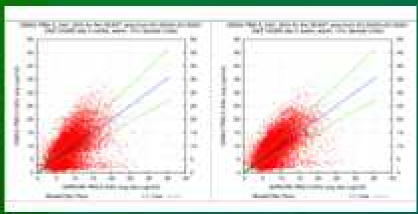
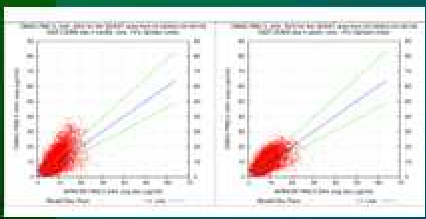
Initial Performance Analysis of Improved System

- SOUTHEAST: Warm Season



- SOUTHEAST: Cool Season



24-H PM2.5 for the "Initial Condition" Day	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	8.9794	8.9794	8.5046	8.5046
Model Average	9.4492	9.8256	10.8820	9.9118
Bias	0.4698	0.8462	2.3775	1.4073
Error	3.7810	3.5101	4.2870	3.3491
RMSE	4.9334	4.5689	5.6884	4.3162
Normalized Bias	-0.1338	-0.1961	-0.3577	-0.2745
GRS_ERR	0.4915	0.4786	0.5703	0.4819
Slope	0.7884	0.7842	0.9771	0.7245
R2	0.2774	0.3139	0.3456	0.3330
Indx_Agree	0.6918	0.7177	0.6681	0.7241

= MODIS assimilation improves

= Vanilla Model Better

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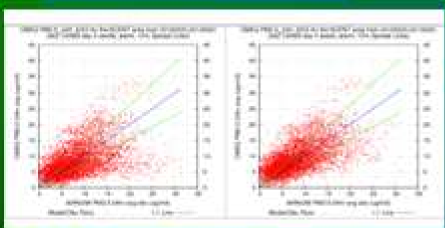
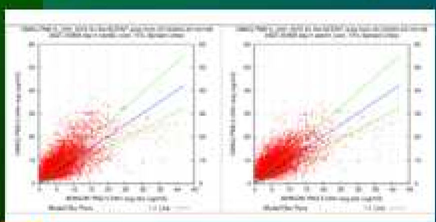
Initial Performance Analysis of Improved System

- NORTHCENTRAL: Warm Season



- NORTHCENTRAL: Cool Season



24-H PM2.5 for the "Initial Condition" Day	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	8.4975	8.4975	7.3967	7.3967
Model Average	8.5006	9.3410	9.8986	10.0487
Bias	0.0031	0.8435	2.5019	2.6520
Error	3.8677	3.5039	4.1232	4.0919
RMSE	5.1564	4.5714	5.4603	5.2517
Normalized Bias	-0.4563	-0.5863	-0.9653	-1.0584
GRS_ERR	0.7905	0.8151	1.1210	1.1852
Slope	0.4748	0.5858	0.7298	0.6446
R2	0.2362	0.3672	0.3899	0.3848
Indx_Agree	0.6929	0.7646	0.7405	0.7374

= MODIS assimilation improves

= Vanilla Model Better

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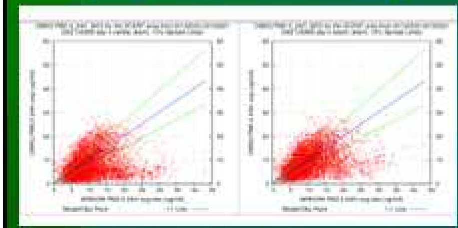
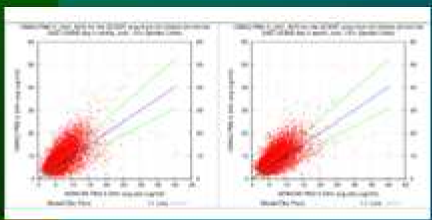
Initial Performance Analysis of Improved System

- SOUTHCENTRAL: Warm Season



- SOUTHCENTRAL: Cool Season



24-H PM2.5 for the "Initial Condition" Day	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	10.7651	10.7651	7.5871	7.5871
Model Average	8.0966	9.3495	10.0786	9.7353
Bias	-2.6685	-1.4156	2.4915	2.1482
Error	5.2390	4.3226	3.8805	3.4518
RMSE	7.1678	6.0735	5.0084	4.4572
Normalized Bias	0.1081	-0.0087	-0.4829	-0.4570
GRS_ERR	0.5054	0.4389	0.6321	0.5935
Slope	0.2143	0.3447	0.8278	0.7379
R2	0.0508	0.1394	0.3337	0.3392
Indx_Agree	0.5321	0.6209	0.6742	0.6981

= MODIS assimilation improves

= Vanilla Model Better

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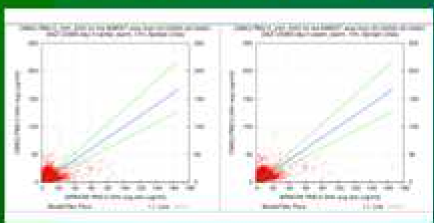
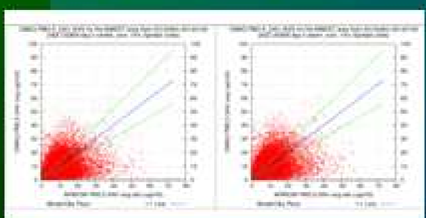
Initial Performance Analysis of Improved System

- NORTHWEST: Warm Season



- NORTHWEST: Cool Season



24-H PM2.5 for the "Initial Condition" Day	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	5.9655	5.9654	10.1270	10.1262
Model Average	7.3653	8.5235	9.1197	9.9441
Bias	1.3998	2.5580	-1.0073	-0.1821
Error	3.7657	4.1580	5.6625	5.6466
RMSE	5.8865	6.1070	8.3292	8.2278
Normalized Bias	-0.7261	-1.0032	-0.3036	-0.4143
GRS_ERR	0.9636	1.1435	0.7911	0.8273
Slope	0.3596	0.4126	0.3460	0.3830
R2	0.1433	0.1814	0.1314	0.1508
Indx_Agree	0.5858	0.6020	0.6100	0.6277

= MODIS assimilation improves

= Vanilla Model Better

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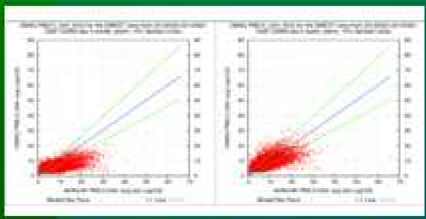
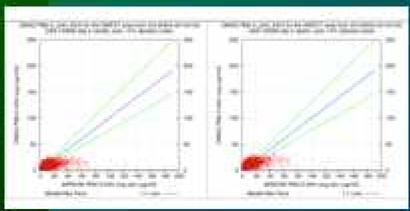
Initial Performance Analysis of Improved System

- SOUTHWEST: Warm Season



- SOUTHWEST: Cool Season



24-H PM2.5 for the "Initial Condition" Day	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	10.0840	10.0840	9.7894	9.7894
Model Average	6.6088	9.5934	7.9285	9.6457
Bias	-3.4752	-0.4907	-1.8609	-0.1437
Error	4.4826	3.8731	4.3985	4.2887
RMSE	6.0941	4.9921	7.7269	7.2445
Normalized Bias	0.1134	-0.2408	-0.2299	-0.4758
GRS_ERR	0.5091	0.5291	0.6513	0.7421
Slope	0.2826	0.4176	0.2295	0.2962
R2	0.2773	0.3188	0.2090	0.2641
Indx_Agree	0.6099	0.7276	0.5688	0.6417

= MODIS assimilation improves

= Vanilla Model Better

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Initial Performance Analysis of Improved System

Summary for 24-H Average "Initial Condition" Day

Region/ Season	Much Improves	Modest Improves	Wash	Modest Degrades	Much Degrades
NE - Warm			X		
NE - Cool		X			
SE- Warm		X			
SE- Cool		X			
NC - Warm		X			
NC - Cool			X		
SC - Warm		X			
SC - Cool		X			
NW - Warm			x	x	
NW - Cool		X			
SW - Warm	X				
SW - Cool	X				

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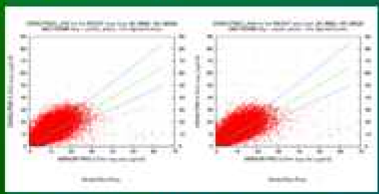
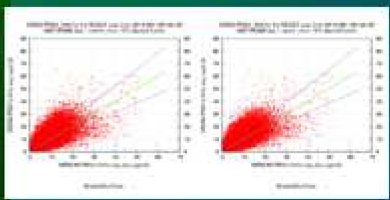
Initial Performance Analysis of Improved System (Forecast Day 1)

- NORTHEAST: Warm Season



- NORTHEAST: Cool Season



24-H PM2.5 for Forecast Day 1	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	9.6581	9.6581	9.0390	9.0390
Model Average	12.5987	12.830	10.7943	10.9560
Bias	2.9406	3.1721	1.7553	1.9170
Error	4.5326	4.6120	4.1786	4.2029
RMSE	5.9302	5.9293	5.8390	5.7761
Normalized Bias	-0.7848	-0.8636	-0.4396	-0.4798
GRS_ERR	0.9149	0.9733	0.6620	0.6848
Slope	0.7511	0.6858	0.7721	0.7442
R2	0.4060	0.3884	0.3981	0.3953
Indx_Agree	0.7420	0.7281	0.7625	0.7612

= MODIS assimilation improves

= Vanilla Model Better

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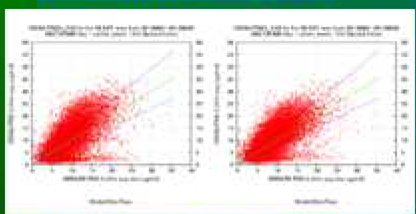
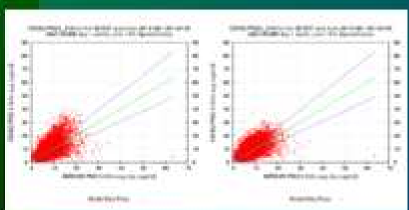
Initial Performance Analysis of Improved System (Forecast Day 1)

- SOUTHEAST: Warm Season



- SOUTHEAST: Cool Season



24-H PM2.5 for Forecast Day 1	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	9.6884	9.6884	8.3130	8.3130
Model Average	11.0597	11.116 8	10.1139	9.8767
Bias	1.3713	1.4284	1.8009	1.5638
Error	4.2794	3.9480	3.8600	3.4882
RMSE	5.5189	5.0876	5.3012	4.6218
Normalized Bias	-0.2086	-0.2406	-0.3168	-0.3153
GRS_ERR	0.5218	0.5041	0.5360	0.5150
Slope	0.9835	0.9050	0.8296	0.6756
R2	0.3902	0.3954	0.2933	0.2791
Indx_Agree	0.7334	0.7480	0.6663	0.6873

= MODIS assimilation improves

= Vanilla Model Better

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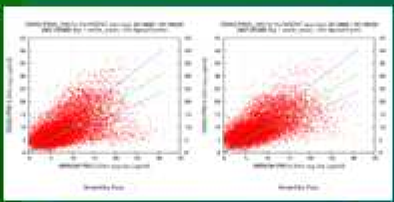
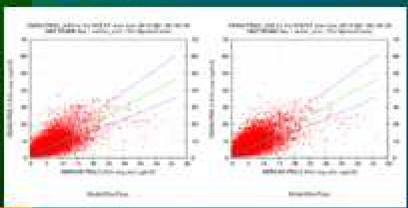
National Aeronautics and Space Administration

Initial Performance Analysis of Improved System (Forecast Day 1)

- NORTHCENTRAL: Warm Season



- NORTHCENTRAL: Cool Season



24-H PM2.6 for Forecast Day 1	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	8.7452	8.7452	7.1887	7.1887
Model Average	9.7957	10.1806	8.8249	9.3056
Bias	1.0505	1.4354	1.6363	2.1169
Error	4.0946	3.8036	3.7130	3.9892
RMSE	5.3778	4.9266	5.0187	5.2588
Normalized Bias	-0.5817	-0.6791	-0.7679	-0.8983
GRS_ERR	0.8424	0.8793	0.9800	1.0843
Slope	0.5890	0.6117	0.6963	0.6658
R2	0.2779	0.3471	0.3795	0.3567
Indx_Agree	0.7096	0.7446	0.7576	0.7372

= MODIS assimilation improves

= Vanilla Model Better

AQ orecasting

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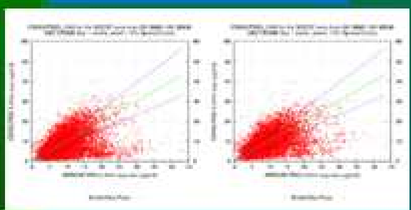
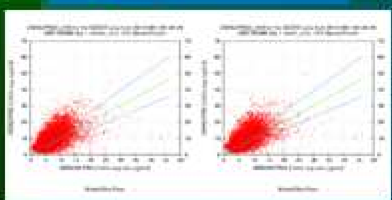
Initial Performance Analysis of Improved System (Forecast Day 1)

- SOUTHCENTRAL: Warm Season



- SOUTHCENTRAL: Cool Season



24-H PM2.6 for Forecast Day 1	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	10.6229	10.6229	7.4183	7.4183
Model Average	9.2387	9.8272	9.9363	10.1771
Bias	-1.3842	-0.7957	2.5181	2.7588
Error	4.7887	4.1853	3.8478	3.9387
RMSE	6.5350	5.7681	5.0821	5.1287
Normalized Bias	0.0019	-0.0555	-0.4931	-0.5511
GRS_ERR	0.4830	0.4412	0.6345	0.6734
Slope	0.3721	0.4423	0.7858	0.7490
R2	0.1172	0.1891	0.3164	0.3080
Indx_Agree	0.6118	0.6678	0.6855	0.6545

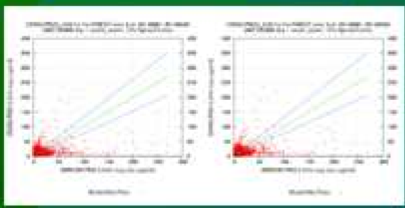
= MODIS assimilation improves

= Vanilla Model Better

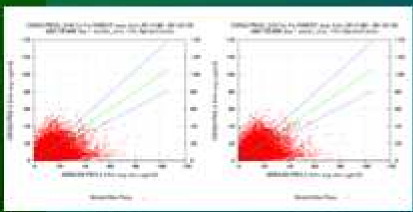
AQ orecasting

Initial Performance Analysis of Improved System (Forecast Day 1)

- NORTHWEST: Warm Season



- NORTHWEST: Cool Season



24-H PM2.5 for Forecast Day 1	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	6.7436	6.7436	11.1464	11.1464
Model Average	8.2023	9.3247	9.5097	10.2945
Bias	1.4587	2.5811	-1.6366	-0.8519
Error	4.4989	4.9322	6.4172	6.5298
RMSE	8.9164	9.0930	9.5400	9.5824
Normalized Bias	-0.7885	-1.0372	-0.2793	-0.3797
GRS_ERR	1.0331	1.2022	0.8077	0.8533
Slope	0.2797	0.2987	0.2883	0.3118
R2	0.1207	0.1338	0.1089	0.1148
Indx_Agree	0.5353	0.5451	0.5840	0.5923

= MODIS assimilation improves

= Vanilla Model Better

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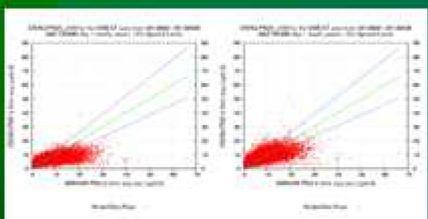
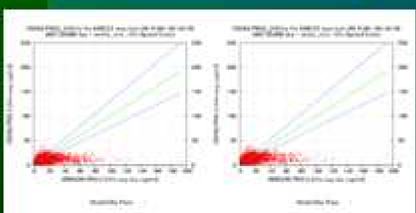
Initial Performance Analysis of Improved System (Forecast Day 1)

- SOUTHWEST: Warm Season



- SOUTHWEST: Cool Season



24-H PM2.5 for Forecast Day 1	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	9.1875	9.1875	10.7642	10.7642
Model Average	6.6119	8.6395	8.2219	9.6807
Bias	-2.5756	-0.5481	-2.5422	-1.0835
Error	3.8862	3.4981	5.2312	5.2071
RMSE	5.5024	4.8640	9.7225	9.4398
Normalized Bias	0.0183	-0.2531	-0.2369	-0.4473
GRS_ERR	0.4991	0.5475	0.6862	0.7729
Slope	0.2760	0.3700	0.1779	0.2007
R2	0.2682	0.2956	0.1604	0.1686
Indx_Agree	0.6200	0.7027	0.5017	0.5318

= MODIS assimilation improves

= Vanilla Model Better

AQ forecasting

Initial Performance Analysis of Improved System (Forecast Day 1)

Summary for 24-H Average Day 1 Forecast (06z – 06z)

Region/ Season	Much Improves	Modest Improves	Wash	Modest Degrades	Much Degrades
NE - Warm				x	
NE - Cool			x	x	
SE- Warm		X			
SE- Cool		X			
NC - Warm		X			
NC - Cool				X	
SC - Warm		X			
SC - Cool				X	
NW - Warm			x	x	
NW - Cool		X			
SW - Warm		X			
SW - Cool		X			

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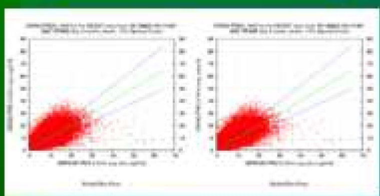
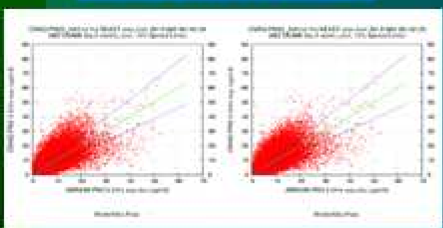
Initial Performance Analysis of Improved System (Forecast Day 2)

- NORTHEAST: Warm Season



- NORTHEAST: Cool Season



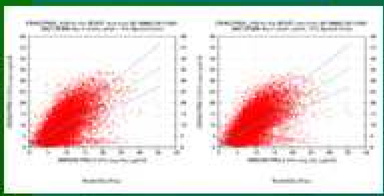
24-H PM2.5 for Forecast Day 2	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	9.6701	9.6701	9.0225	9.0225
Model Average	11.8277	12.2231	10.6047	10.8030
Bias	2.1577	2.5530	1.5822	1.7805
Error	4.4104	4.5648	4.2075	4.3063
RMSE	5.8506	5.9918	5.9172	5.9594
Normalized Bias	-0.6877	-0.7633	-0.4318	-0.4663
GRS_ERR	0.8692	0.9198	0.6873	0.6913
Slope	0.6686	0.6426	0.7249	0.7172
R2	0.3386	0.3252	0.3636	0.3610
Indx_Agree	0.7267	0.7121	0.7485	0.7452

= MODIS assimilation improves

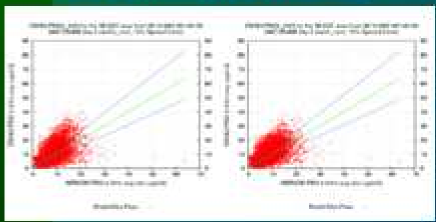
= Vanilla Model Better

Initial Performance Analysis of Improved System (Forecast Day 2)

- SOUTHEAST: Warm Season



- SOUTHEAST: Cool Season



24-H PM2.5 for Forecast Day 2	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	9.7129	9.7129	8.3013	8.3013
Model Average	10.6028	10.8593	9.9296	9.9459
Bias	0.8899	1.1464	1.6283	1.6446
Error	4.3487	4.2299	3.8362	3.6998
RMSE	5.6151	5.4595	5.3146	5.0049
Normalized Bias	-0.1521	-0.1934	-0.2988	-0.3162
GRS_ERR	0.5247	0.5233	0.5361	0.5340
Slope	0.9632	0.9314	0.8160	0.7407
R2	0.3828	0.3853	0.2818	0.2754
Indx_Agree	0.7237	0.7277	0.6625	0.6713

= MODIS assimilation improves

= Vanilla Model Better

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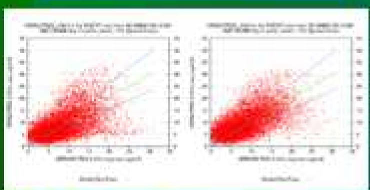
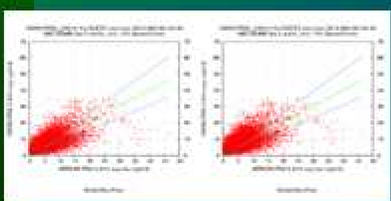
Initial Performance Analysis of Improved System (Forecast Day 2)

- NORTHCENTRAL: Warm Season



- NORTHCENTRAL: Cool Season



24-H PM2.5 for Forecast Day 2	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	8.7714	8.7714	7.1955	7.1955
Model Average	9.1849	9.8653	8.5960	8.9614
Bias	0.4134	1.0939	1.4005	1.7659
Error	3.9853	3.8155	3.6868	3.9190
RMSE	5.2985	5.0010	4.9846	5.2449
Normalized Bias	-0.4709	-0.5833	-0.7238	-0.8172
GRS_ERR	0.7876	0.8271	0.9505	1.0282
Slope	0.5755	0.6294	0.6484	0.6419
R2	0.2695	0.3361	0.3520	0.3322
Indx_Agree	0.7110	0.7439	0.7475	0.7294

= MODIS assimilation improves

= Vanilla Model Better

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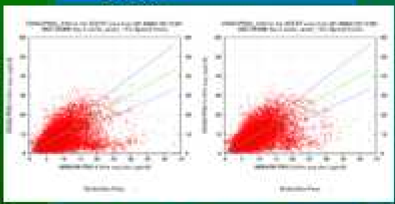
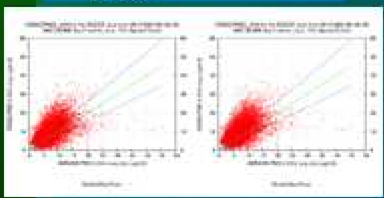
Initial Performance Analysis of Improved System (Forecast Day 2)

- SOUTHCENTRAL: Warm Season



- SOUTHCENTRAL: Cool Season



24-H PM2.5 for Forecast Day 2	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	10.6310	10.6310	7.4126	7.4126
Model Average	9.2952	10.0695	9.9050	10.2634
Bias	-1.3358	-0.5615	2.4924	2.8508
Error	4.9154	4.4921	3.8855	4.1135
RMSE	6.6775	6.1108	5.1227	5.3745
Normalized Bias	0.0009	-0.0742	-0.4953	-0.5590
GRS_ERR	0.4960	0.4726	0.6436	0.6916
Slope	0.3832	0.4623	0.7430	0.7438
R2	0.1151	0.1737	0.2899	0.2827
Indx_Agree	0.6082	0.6551	0.6530	0.6347

= MODIS assimilation improves

= Vanilla Model Better

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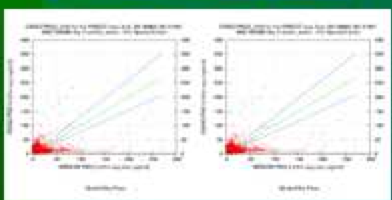
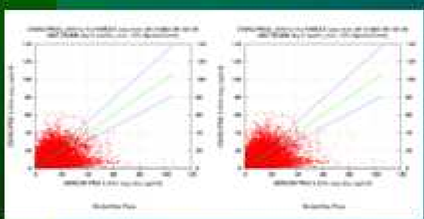
Initial Performance Analysis of Improved System (Forecast Day 2)

- NORTHWEST: Warm Season



- NORTHWEST: Cool Season



24-H PM2.5 for Forecast Day 2	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	6.7305	6.7305	11.1984	11.1984
Model Average	8.0950	8.8811	9.6964	10.2336
Bias	1.3645	2.1506	-1.5019	-0.9648
Error	4.4840	4.7930	6.6083	6.7406
RMSE	9.0250	9.1813	9.7324	9.8392
Normalized Bias	-0.7362	-0.8978	-0.2911	-0.3567
GRS_ERR	0.9990	1.1072	0.8314	0.8663
Slope	0.2827	0.2978	0.2993	0.3163
R2	0.1160	0.1231	0.1071	0.1092
Indx_Agree	0.5293	0.5358	0.5850	0.5884

= MODIS assimilation improves

= Vanilla Model Better

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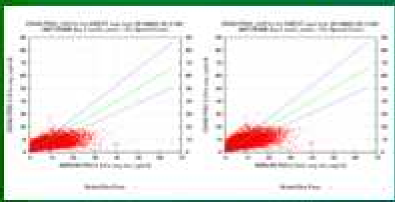
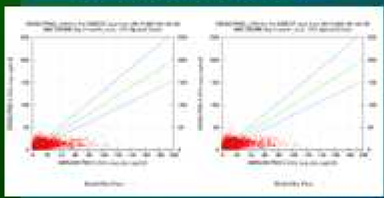
Initial Performance Analysis of Improved System (Forecast Day 2)

- SOUTHWEST: Warm Season



- SOUTHWEST: Cool Season



24-H PM2.5 for Forecast Day 2	Warm Season: Vanilla	Warm Season: Assim	Cool Season: Vanilla	Cool Season: Assim
Obs Average	9.1381	9.1381	10.7715	10.7715
Model Average	6.8056	8.2485	8.8409	9.7346
Bias	-2.3325	-0.8896	-1.9305	-1.0368
Error	3.8942	3.6348	5.4900	5.5367
RMSE	5.4889	5.0629	9.8228	9.7368
Normalized Bias	-0.0246	-0.2239	-0.3784	-0.5082
GRS_ERR	0.5198	0.5596	0.7973	0.8563
Slope	0.2596	0.3131	0.1740	0.1836
R2	0.2288	0.2431	0.1269	0.1262
Indx_Agree	0.6061	0.6577	0.4972	0.5095

= MODIS assimilation improves

= Vanilla Model Better

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Initial Performance Analysis of Improved System (Forecast Day 2)

Summary for 24-H Average Day 2 Forecast (06z – 06z)

Region/ Season	Much Improves	Modest Improves	Wash	Modest Degrades	Much Degrades
NE - Warm				X	
NE - Cool				x	
SE- Warm		x			
SE- Cool		x			
NC - Warm		X			
NC - Cool				X	
SC - Warm		X			
SC - Cool				X	
NW - Warm			x	x	
NW - Cool		x			
SW - Warm		X			
SW - Cool		x	x		

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Overview of Forecast Lead-Time Results by Region/Season

Legend:

- ⬆ = Much Improves
- ⬆ = Modest Improves
- ⬆ = Very slight improves
- ⟷ = Little Change
- ⬇ = Very slight degrade
- ⬇ = Modest Degrades
- ⬇ = Much Degrades

B: indicates the assimilated model worsened an already high bias

Region/ Season	Day 0 Forecast	Day 1 Forecast	Day 2 Forecast
NE - Warm	Little Change	Modest Degrades B	Modest Degrades B
NE - Cool	Modest Improves	Very slight degrade B	Very slight degrade B
SE- Warm	Modest Improves	Modest Improves	Modest Improves
SE- Cool	Modest Improves	Modest Improves	Modest Improves
NC - Warm	Modest Improves	Modest Improves	Modest Improves
NC - Cool	Little Change	Modest Degrades B	Modest Degrades B
SC - Warm	Modest Improves	Modest Improves	Modest Improves
SC - Cool	Modest Improves	Modest Degrades B	Modest Degrades B
NW - Warm	Very slight degrade B	Very slight degrade B	Very slight degrade B
NW - Cool	Modest Improves	Modest Improves	Very slight improves
SW - Warm	Much Improves	Modest Improves	Modest Improves
SW - Cool	Much Improves	Modest Improves	Very slight improves

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On the Horizon: Further improvements with the use of surface PM2.5 Observations

- Current Revised "Inverse Operator" only considers the situation when the final analyzed TAU increases and surface PM 2.5 is "too hot" as a result of linear concentration re-scaling in the vertical.
- *Three more improvements are planned in the near future, each of which will conserve the final analyzed TAU (after assimilation step):*

Revisions are planned to be implemented and running by May 1, 2014

1) *Tau Increases but surface PM2.5 is not high enough:* preferentially increase concentrations within PBL while not nudging as much above PBL in order to better match surface PM2.5

2) *Tau Decreases but surface PM2.5 is still too high:* preferentially decrease concentrations more within PBL than above so as to better match the observed surface PM2.5 (Focus Here First)

3) *Tau Decreases but surface PM2.5 is too low:* preferentially decrease concentrations more above the PBL than within so as to better match the observed surface PM2.5

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Conclusions

- Initial Performance Analysis of the BAMS CMAQ-MODIS-DA analysis and forecast model for Warm and Cool Seasons by Six Sub-regions shows:
  - Very encouraging overall improvements, extending out to at least the 2nd forecast day in many regions
    - More consistent improvements during the warm season, when cloudiness is not as much of an issue
    - Impressive improvements in the SW US (all seasons) and South Central during the warm season
  - Some areas of concern –
    - NE US where vanilla performance is already very good
    - The Pacific NW warm season (clouds?)
    - Cool season in the central US (clouds?)
- Analysis of regions/seasons that did degrade show that *increases* in an already high bias played a role in statistical degradation. Thus first order of business is to implement the additional vertically-sensitive improvements in the TAU-inversion step using real-time PM2.5 surface observations

AQ forecasting

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Contact Information

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Phone: 919-839-2344

AQ forecasting

EPA National Air Quality Conference, Feb.11, 2014, Durham, NC

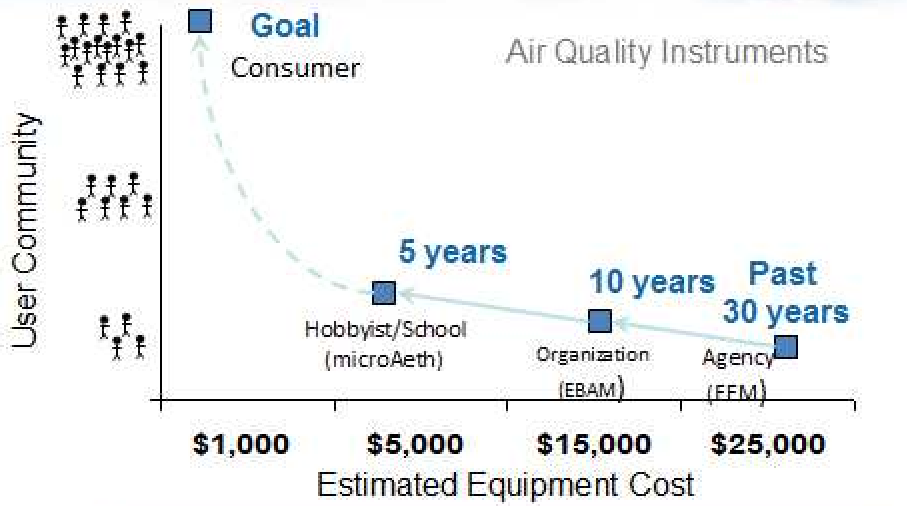
附錄六、Small Sensors and Citizen Science What is AirNow’s Role?

Small Sensors and Citizen Science
What is AirNow's Role?

Overview

- AIRNow Satellite Data Processor (ASDP)
  - Data fusion concept
- Global Ozone Initiative (GO3)
- ORD initiatives
  - Next Generation Air Monitoring (NGAM)
  - Village Green
- Other potential citizen science applications

Instruments versus Cost

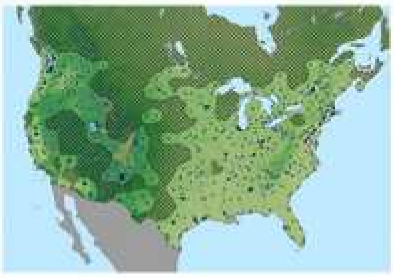


EBAM = Environmental beta attenuation monitor; FEM = Federal Equivalent Method; Aeth = Aethalometer

Global Ozone Initiative

- Schools buy a $600 kit to monitor ozone
- Worked with STI to allow that data to flow into a separate AirNow database
- STI has done analysis showing the GO3 data compares well with standard ozone instruments

ASDP: Project Objectives



Without satellite data, contouring would not be possible in the hatched areas.

- Improve operational air quality maps currently in AIRNow and make them available 24 hrs a day every day
- Provide satellite data products in AIRNow-Tech
  - Initially PM2.5, but limited only by available satellite instruments
- Improve tools for air quality forecasting

Preliminary Results: Smoke and No Monitors (Kansas)

MODIS & AIRNow Observations

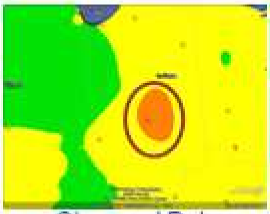
Observed Data Satellite Data

- Smoke in Nebraska (MODIS and AOD)
- No Monitors
- ASDP adds information (Moderate)
- Next Steps: How good is this information (scientific and socio-economic POV)

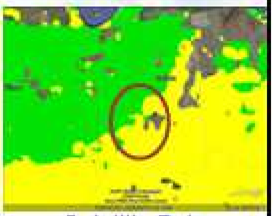
Fused Data

Preliminary Results: Isolated Unhealthy for Sensitive Groups

MODIS & AIRNow Observations

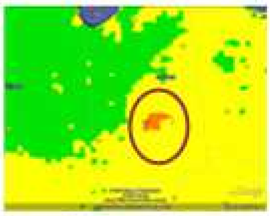


Observed Data



Satellite Data

- High AOD (smoke?) in central Indiana
- Large USG area due to interpolation
- ASDP constrains the monitor influences
- Next Steps: How good is this information? (scientific and socio-economic value)



Fused Data

US EPA ORD Initiatives

- Next Generation Air Monitoring (NGAM)
  - Workshops bring together sensor designers, state, local, tribal agencies, and EPA
  - Taking stock of the technology and its impact
  - Some work being done to move AirNow closer to being able to accept sub-hourly data
  - AirNow also being considered as a source of FRM and FEM data for small sensor evaluation

US EPA ORD Initiatives

- Village Green
  - A self-contained monitoring bench was installed at a public library in RTP
  - Delivers small sensor data to a server at EPA for display to the public
  - Talks underway to incorporate this dataflow in AirNowTech
    - Replication of the VG benches will be easier
    - Data will be more easily available to AirNow stakeholders

Other potential applications

- Environmental education
  - Small sensors are a great way to teach
- Granularity
  - Small sensors can provide data in many more locations than traditional monitors
- Field studies
- Your ideas?

附錄七、Air Sensor Kits for Outreach

EPA

www.epa.gov/airscience

AIR CLIMATE & ENERGY RESEARCH PROGRAM

BUILDING A SCIENTIFIC FOUNDATION FOR SOUND ENVIRONMENTAL DECISIONS

2014 National Air Quality Conference, Durham, NC

Air Sensor Kits for Outreach

Dana Buchbinder and Gayle Hagler
U.S. EPA Office of Research and Development

The EPA scientist role in Science, Technology, Engineering, and Math (STEM) outreach

Questions we ask ourselves:

- What can we do in our few spare hours to inspire students to learn about environmental science and engineering?
- What do we wish we had exposure to when we were growing up?
- How can we find low cost ways to bring hands-on activities and demonstrations to the classroom?
- How can we leave a lasting impact and avoid putting students (or ourselves!) to sleep?

The working EPA scientist role in Science, Technology, Engineering, and Math (STEM) outreach

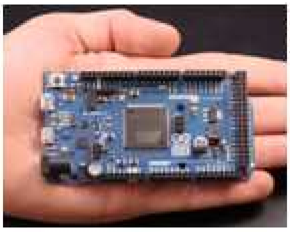
Many outreach activities at EPA-RTP

DISCOVER-AQ study

Image source: NASA

The emerging world of low cost sensors and electronics – an opportunity for STEM outreach and air science

A growing world of electronics supporting creative projects:



Arduino microprocessor – a simple computer

Lilypad Arduino – electronics meets home ec!

Image: http://web.media.mit.edu/

The emerging world of low cost sensors and electronics – an opportunity for STEM outreach and air science

Example air sensor components:

Nitrogen dioxide sensor
(images courtesy of Ron Williams)

Carbon dioxide sensor

Particle sensor

Particle sensor

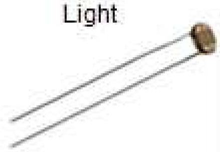
- Some are "raw" components that need additional electronics work (an opportunity to build and learn!)
- Some are ready to turn on and collect data (an opportunity to measure!)
- All are portable, data quality is variable

The emerging world of low cost sensors and electronics – an opportunity for STEM outreach and air science

Other sensors beyond air:

Noise

Light



Motion (accelerometer)

Relative Humidity

Temperature

Design of an air sampler: the basics

Learning how an air sampler is designed: the basic elements

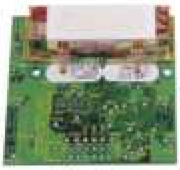
Air sensor → Computer ("data in, display out") → Data display

Design of an air sampler: the basics

Many examples emerging:

Air sensor → Computer ("data in, display out") → Data display

Carbon dioxide-sensing flower demo



CO_2 sensor

→

Arduino board

→

Light-up flowers displaying color based on concentration

Design of an air sampler: the basics

Many examples emerging:

Air sensor → Computer ("data in, display out") → Data display

Wearable particle sensor

Particle sensor

→

Lilypad board

→

Wearable sensor with light indicator of concentrations

Winner of DHHS/EPA's My Health/My Air contest: David Kuller, Gabrielle Dockterman, and Dot Kelly

Today's focus: Air sensor kit for outreach

Same general design strategy:

Air sensor → Computer ("data in, display out") → Data display

Goals:

1. Hands-on learning about multiple STEM topics: air measurement science, electronics, computer programming.

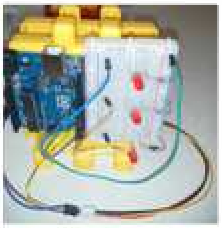
2. Real-time and interactive data collection on an air pollutant of interest.

3. A fun, memorable experience that fits within a classroom hour!

Air sensor kit for outreach

Air sensor → Computer ("data in, display out") → Data display

Arduino board



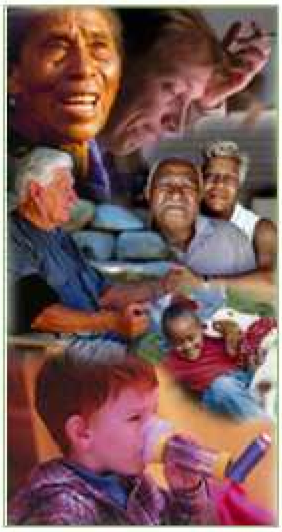
Portable "particle monitor" with LEDs lighting up to indicate concentration

Additional components:
- Resistors and wires
- Small battery
- 3 LEDs

Total kit cost: ~$65

Reuseable!

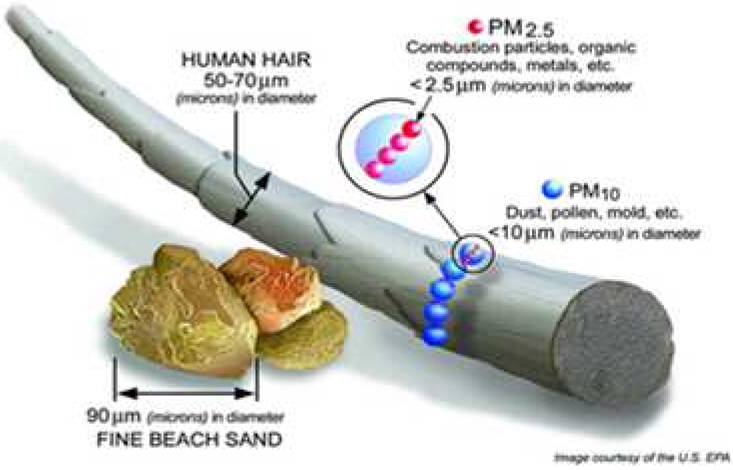
1. Give the big picture: EPA's goal for clean air



"The air in every American community will be safe and healthy to breathe. In particular, children, the elderly, and people with respiratory ailments will be protected from health risks of breathing polluted air."

1. Give the big picture: What is Particulate Matter?

Introduction to the basics of air quality, particulate matter, and health



1. Give the big picture: How do scientists measure the air?

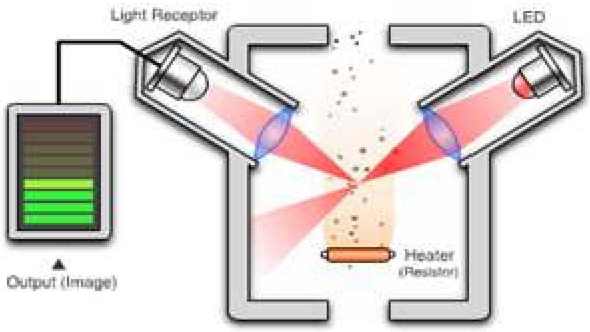
1. Give the big picture: Where would you choose to measure?

2. Primer on measuring particles

Introduction to measuring particles

The particle sensor works by measuring the light scattered by particles…have you ever seen something like this at the movies?

2. Primer on measuring particles



Works best oriented up ("hot air rises")

Air intake small white heater resistor visible in this opening

Image:

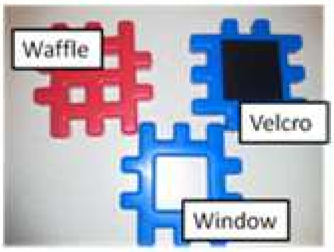
3. Explanation of the Arduino code

"These are the important pins! One will receive the PM signal, three will control the lights"

"Check the PM signal every 5 seconds"

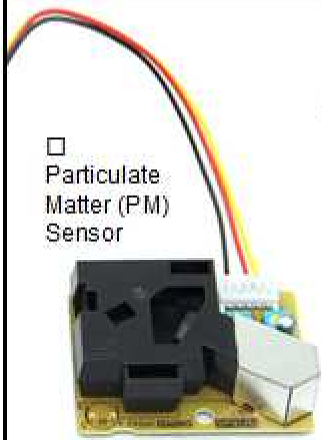
"Turn these lights on if PM level = ..."

4. Explain all the kit components



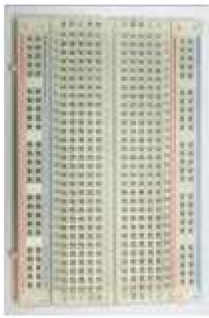
☐ ☐ ☐
3 Blocks for structure

☐ Particulate Matter (PM) Sensor



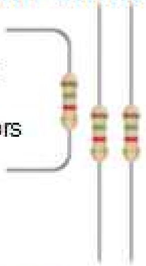
☐ Arduino computer

☐ Breadboard for wiring electronics

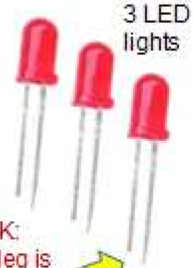


4. Explain all the kit components

☐ ☐ ☐
3 Resistors



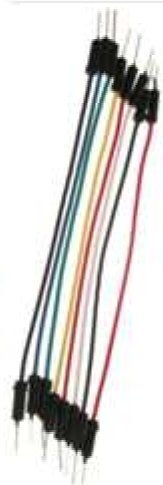
☐ ☐ ☐
3 LED lights



LOOK: one leg is longer!

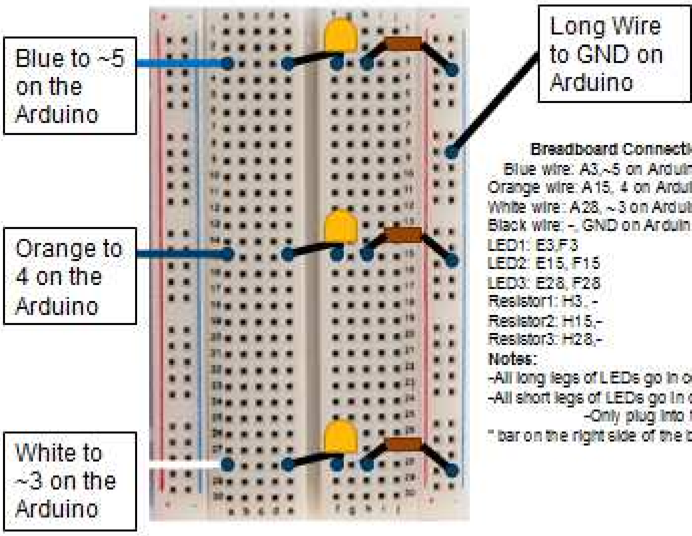
☐ ☐ ☐
☐ ☐ ☐
6 short wires
☐
1 longer wire

WIRE COLORS DON'T MATTER



☐ Battery and clip (you'll get this last)

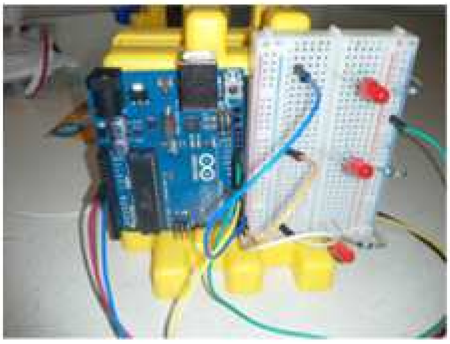
5. Build!



Breadboard Connections:
Blue wire: A3,~5 on Arduino
Orange wire: A15, 4 on Arduino
White wire: A28, ~3 on Arduino
Black wire: -, GND on Arduino
LED1: E3,F3
LED2: E15, F15
LED3: E28, F28
Resistor1: H3, -
Resistor2: H15,-
Resistor3: H28,-

Notes:
-All long legs of LEDs go in column E
-All short legs of LEDs go in column F
-Only plug into the Blue "–" bar on the right side of the breadboard

5. Build!

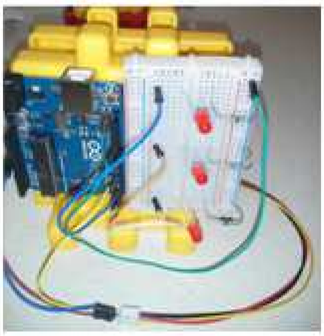


4. Build!

6. What can we do to make the lights turn on?

Air sensor kit for outreach

We've tried the kit with:
- EPA Air scientists and engineers
- EPA-RTP outreach volunteers
- Middle school students
- High school students
- Science teachers



Summary: Air sensor kit for outreach

Hands-on exploration of air quality science and electronics

Memorable and fun activity

Many ways to build out into a lesson plan series:
- Programming the Arduino board
- Trying to build other sensor systems
- Games to understand the basics of computer programming
- Designing new ways to show sensor readings

Questions are welcome!

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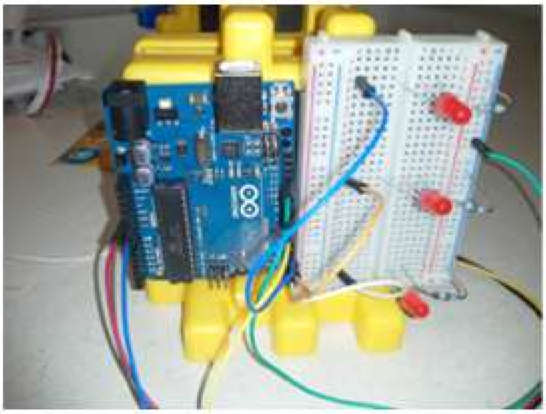
Gayle Hagler: hagler.gayle@epa.gov



Acknowledgements

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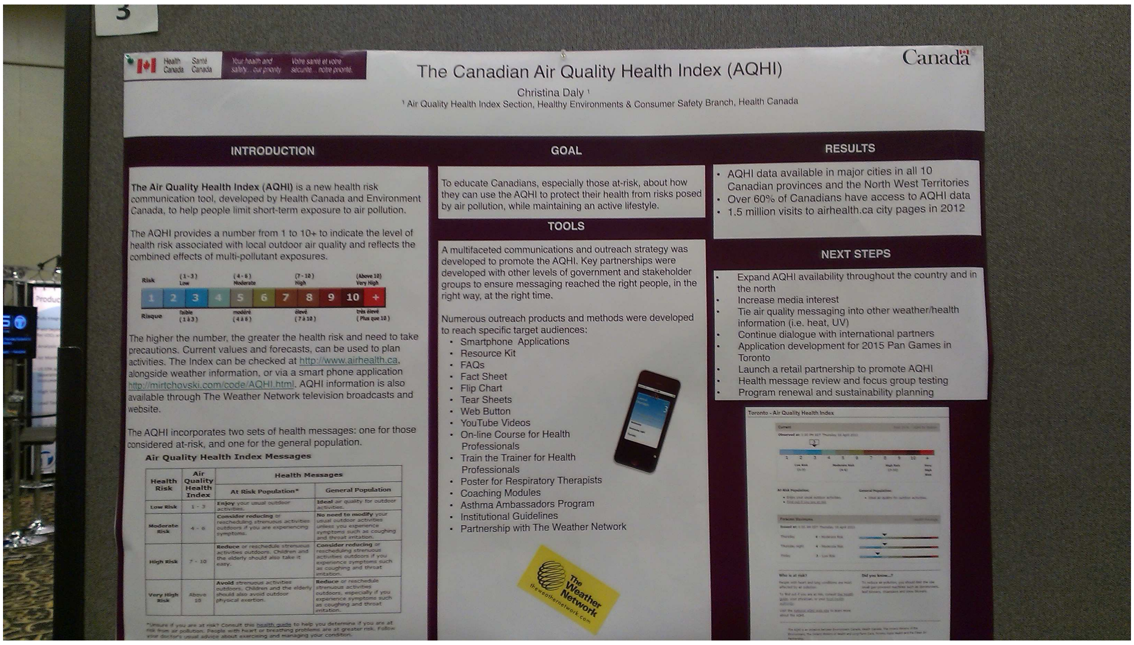
Citizen Schools apprenticeship program students

附錄八、參加會議相關照片

張順欽副處長(右)與美國環保署 AIRNOW 團隊主任及同仁合影

與美國環保署 AIRNOW 團隊主任及上海市監測總站人員合影

2014 年國際空氣品質會議場地



加拿大的 Air Quality Health Index(AQHI)海報展示