Combat Outpost Tangi in the Tangi Valley, Afghanistan, Aug. 31, 2009. (Staff Sgt. Teddy Wade/DoD)

Source-Differentiated Air Quality System to Safeguard the Respiratory Health of US Military Personnel Deployed in Southwest Asia, Djibouti, and Afghanistan

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Team

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Airborne Exposures During Deployment

- Desert dust and sand:
  - Afghanistan, Iraq, Kuwait include desert regions
  - Dust storms 50-100 days/year in Iraq, spring and summer
  - Sand carries fungal spores, plant/grass pollens [allergens]
- Combustion sources:
  - Poorly controlled emissions from motor vehicles (old diesel), unregulated industrial sources
  - Burn Pits:
    - Open-air waste burning was the primary means of solid-waste management
    - At large bases ran continually - visible smoke

Camp Bastion, Afghanistan, 2014

Logistics Support Area, Balad, Iraq

Images: Army Times http://www.blogs.va.gov/VAntage/16192/ten-things-veterans-should-know-about-burn-pits
http://www.coasttocoastam.com/photo/view/sand_dust_storm_at_iraq_airbase/46040/

Burn Pits

- Trash includes batteries, equipment, plastics, medical and human waste. Jet fuel is typically used as an accelerant.
- The largest burn pits were located in Iraq and Afghanistan
- The practice started during post-9/11 invasion of Iraq
- Action was not taken until 2011 to provide guidance to move pits away from areas where troops are located.
- Many burn pits replaced with proper incinerators after 2011.

http://www.blogs.va.gov/VAntage/16192/ten-things-veterans-should-know-about-burn-pits

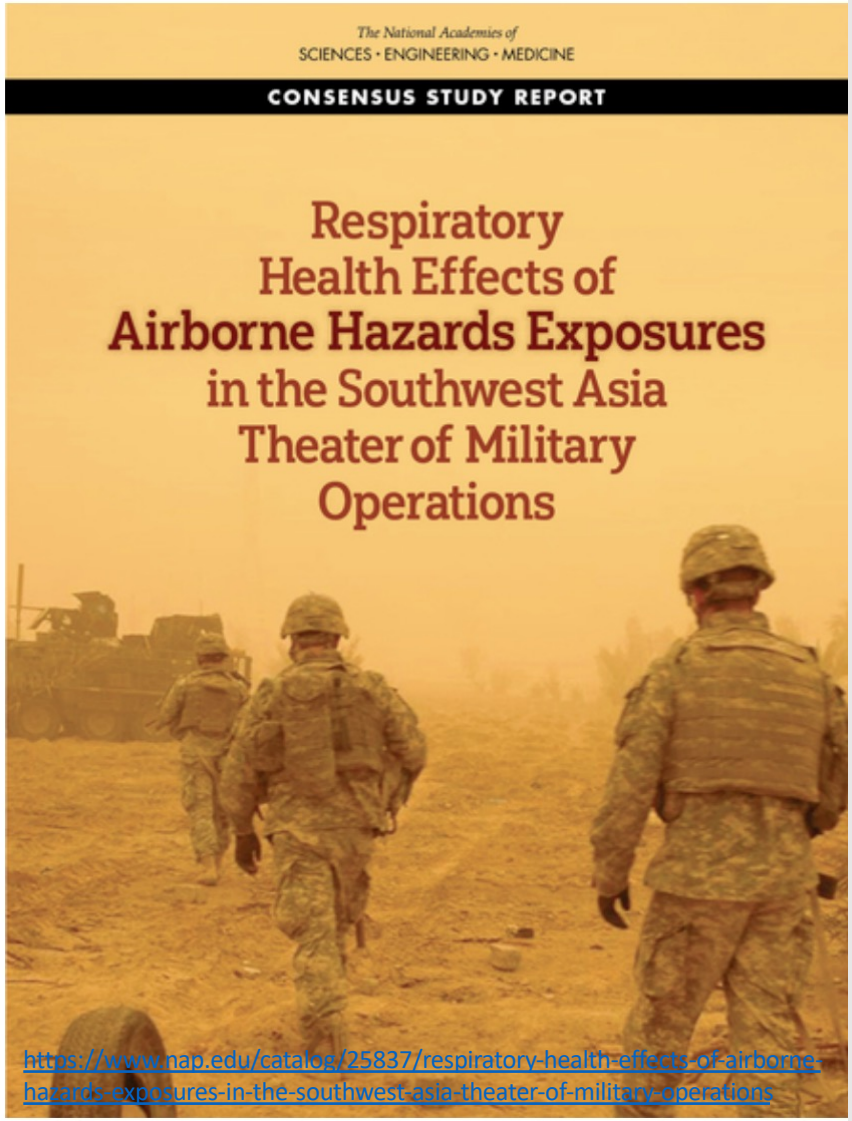
At Balad Air Base ~150 tons of waste burned per day 2003-2008, continued to 2011 Afghanistan's bases were burning up to 400 tons per day at their peak

Air Quality

- Chemicals and byproducts emitted from burn pits include volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and PM with varying compositions including those heavy metals.
- Very few ground-level sampling campaigns conducted during burn pit activity
  - Report by US Army, Screening Health Risk Assessment, Burn Pit Exposure, Balad Air Base, Iraq – Taylor, Rush, & Deck, 2008
  - Report by DOD, Enhanced Particulate Matter Surveillance Program – Engelbrecht et al., 2008

Health Effects

- Military personnel show higher rates of common respiratory illnesses like asthma and emphysema, as well as rare lung disorders.
  - Occupational and base-related exposures in addition to regional and off-base industrial source exposures
- Dust storms are an issue for respiratory illnesses, affecting both military and local residents.

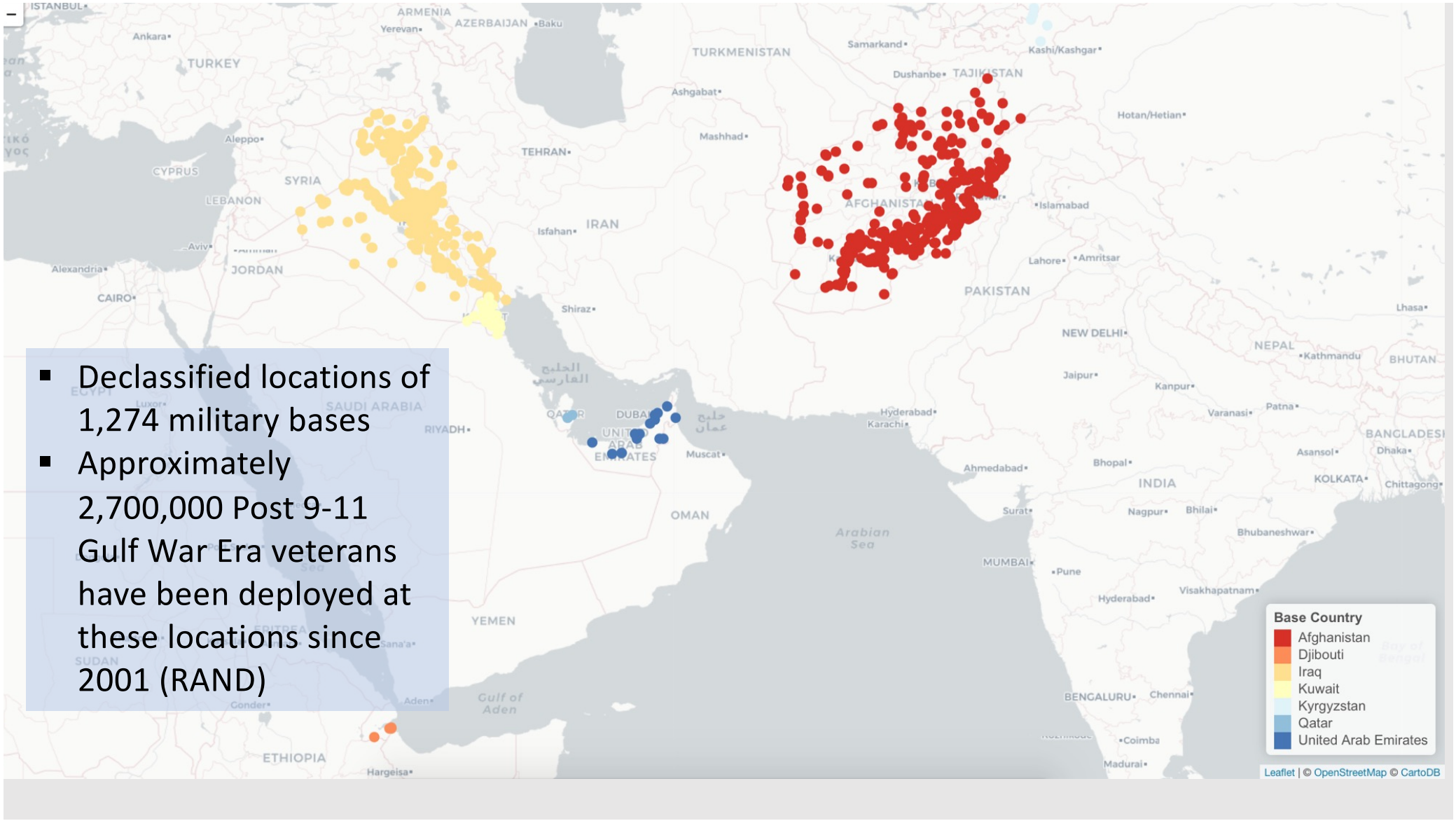


https://www.nap.edu/catalog/25837/respiratory-health-effects-of-airborne-hazards-exposures-in-the-southwest-asia-theater-of-military-operations

A recently released NASEM report indicated there are vast knowledge gaps in airborne exposure characterization in the southwest Asia region.

Recommend use of remote sensing to fill in these gaps.

Jon Stewart bringing additional press to the issue – demanding justice for veterans exposed to burn pits



- Declassified locations of 1,274 military bases
- Approximately 2,700,000 Post 9-11 Gulf War Era veterans have been deployed at these locations since 2001 (RAND)

Study Objectives

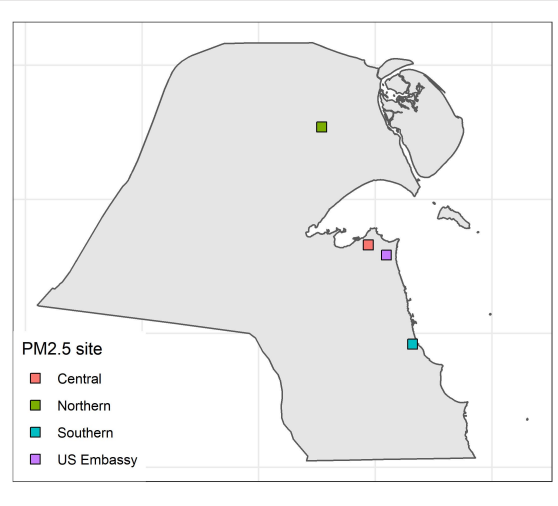
- Primary objectives
  - To develop exposures to fine particulate matter ($PM_{2.5}$) during deployments to the U.S. bases and other locations in Central Asia (Afghanistan and Kyrgyzstan), Southwest Asia (Iraq, Kuwait, Qatar, and United Arab Emirates) and Africa (Djibouti)
    - MAIAC 1x1 km coupled with meteorology (including visibility), MERRA2, land use, and available $PM_{2.5}$ mass concentrations in region
  - To develop source-specific exposures of $PM_{2.5}$ speciation (sulfate, nitrate, EC, OC, dust)
    - MISR 4.4x4.4 km coupled with meteorology, MERRA2, land use and available $PM_{2.5}$ speciation concentrations in Kuwait (Qatar being sited)
  - To develop and implement a software tool for deployment-related exposure assessment
    - To be used in clinical and research settings by the VA and DoD

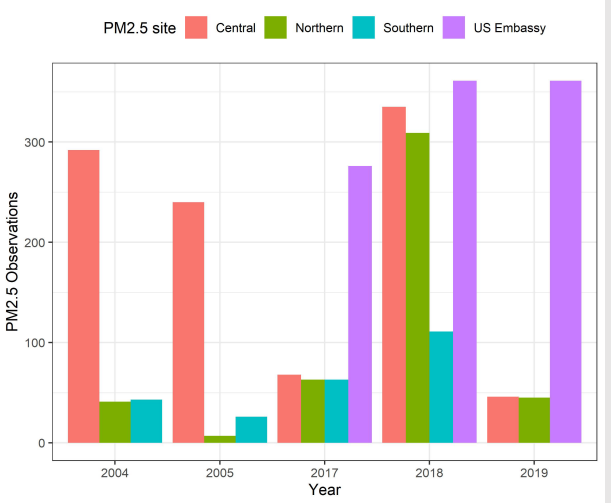
Study Objectives

- Secondary/exploratory objectives
  - To identify locations of and assess duration of burn pit exposures
    - Examine MODIS fire and VIIRS active fire in proximity to base locations with burn pits
    - Apply density based clustering to identify persistent sources of burning, minimizing distance between base and identified fires (Franklin et al ES&T 2019)
  - To conduct epidemiological assessment with VA partners (CSP#595) and Kuwait hospital admissions and mortality records
  - To forge partnership with State Dept and provide exposures for embassies in SADA region
  - To provide use-case for MAIA mission (Kuwait a proposed MAIA secondary target area)

Air Quality Monitoring in Kuwait and Qatar

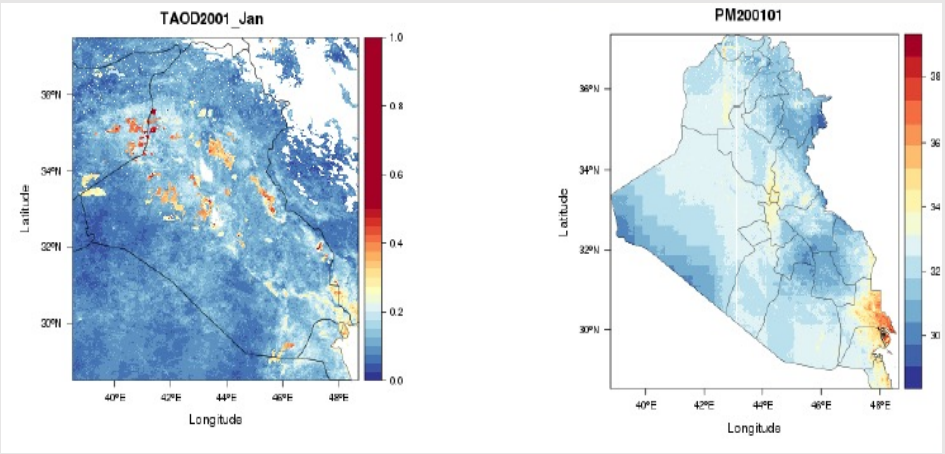
- Characterization of Particulate Matter (PM_{10} and $PM_{2.5}$ 2004-2006) for three Sites in Kuwait
  - PM_{10} ranged from 65.8 to 92.8 µg/m^3, $PM_{2.5}$ ranging from 30.8 µg/m^3 to 37.6 µg/m^3
- Since 2018 $PM_{2.5}$ and PM_{10} at two sites by co-I Petros Koutrakis' group (daily mass and XRF, ions, ICPMS).
  - One co-located at AERONET site (Kuwait U), other south of Kuwait city.
- Since 2020 monitoring at Doha Qatar (delayed due to covid)



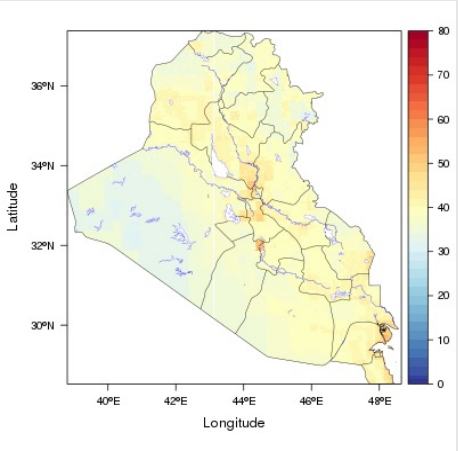


$PM_{2.5}$ estimates from MAIAC AOD

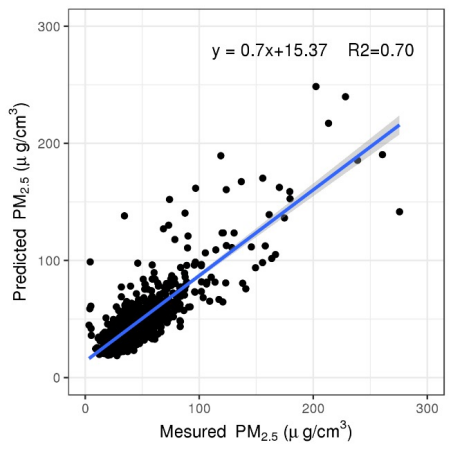
- Weekly $PM_{2.5}$ concentrations for Iraq and Kuwait at 1 km^2 resolution during 2001-2018



MAIAC AOD and mean $PM_{2.5}$ concentrations ($\mu g/m^3$) in each $1km^2$ grid for January 2001 over Kuwait and Iraq



$PM_{2.5}$ concentrations ($\mu g/m^3$) in each $1km^2$ grid averaged 2001-2018 over Kuwait and Iraq



Observed vs Predicted PM2.5 concentrations over Kuwait and Iraq

Li, J et al (2020) A novel approach to estimate $PM_{2.5}$ exposures with high spatial resolution for countries without air quality monitoring networks, In revision with ES&T

MAIAC model updates

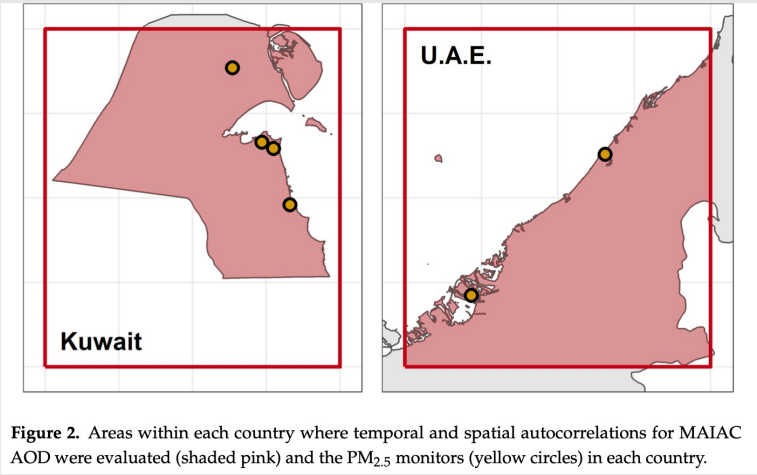
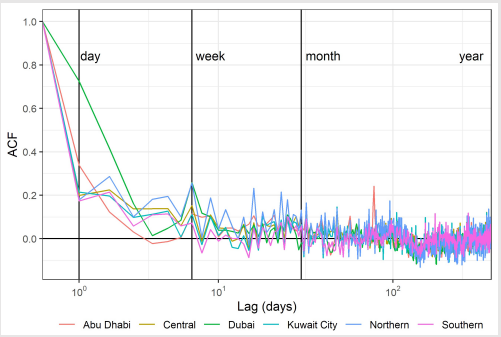
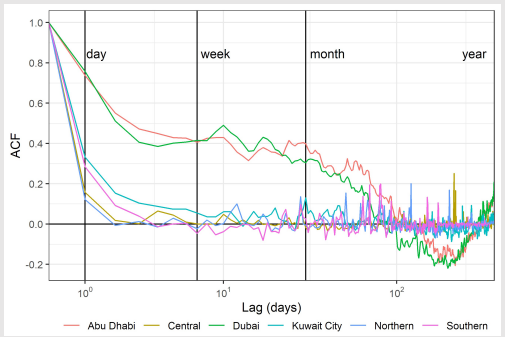


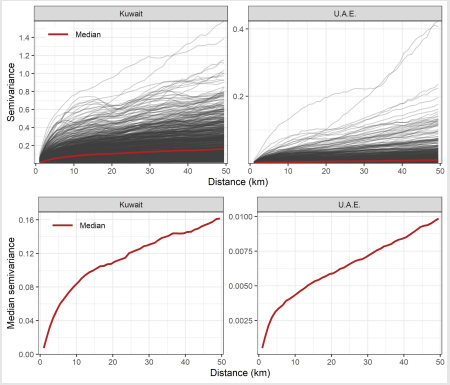
Figure 2. Areas within each country where temporal and spatial autocorrelations for MAIAC AOD were evaluated (shaded pink) and the $PM_{2.5}$ monitors (yellow circles) in each country.

Instrument	Model	N	R^2
MISR	Overall	542	0.48
	Kuwait	271	0.51
	U.A.E	138	**0.66**
MAIAC	Overall	3334	0.53
	Kuwait	1863	0.48
	U.A.E	642	**0.65**





Addressing spatial -> and <-temporal autocorrelation important

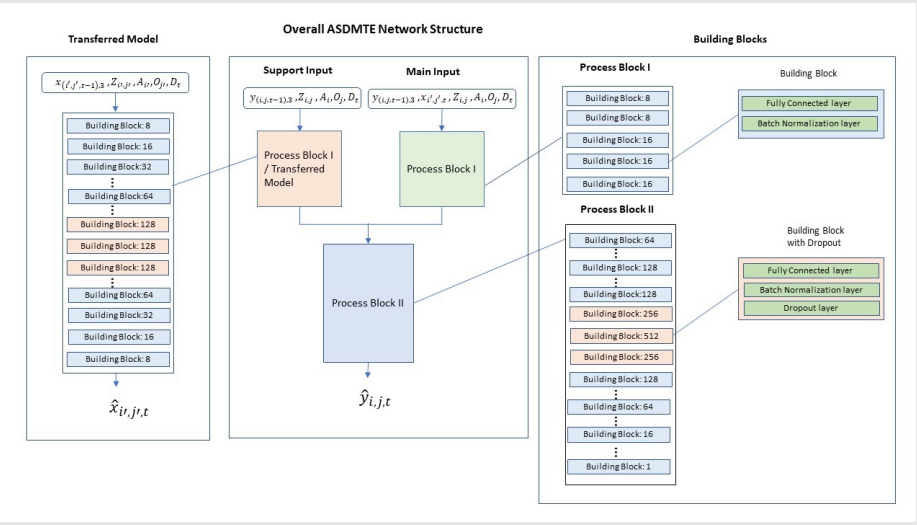


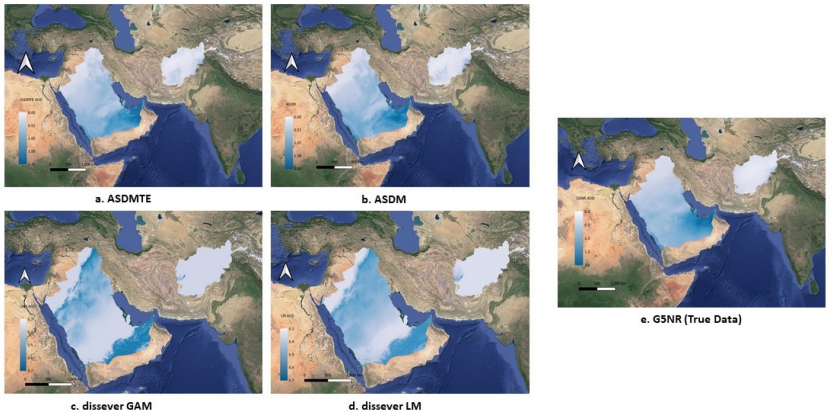
Source-differentiated $PM_{2.5}$ from GEOS-5 and MERRA-2

- The Goddard Earth Observing System Model, Version 5 (GEOS-5) Nature Run (G5NR) is a satellite-based two-year simulation which provide high-resolution (7km) aerosol data
- The fine scale of G5NR make it a spatially informative data source but the limited temporal range (2005-2007) of G5NR restricts its application on other studies.
- Modern-Era Retrospective analysis for Research and Applications, Version 2(MERRA-2), a reanalysis produced by NASA's Global Modeling and Assimilation Office(GMAO), can provide longer period of data (2000-2018), but in much lower resolution (50 km)
- *Both G5NR and MERRA-2 provide data on PM dust, sulfates, carbons*

Downscaling

- Artificial Neural Network Sequentially Downscaling Method (ASDM) with Transfer Learning Enhancement (ASDMTE) which make use of both between-scale association and within-scale inherent spatiotemporal association.
- Compared to other statistical downscaling methods (GAM, LM)



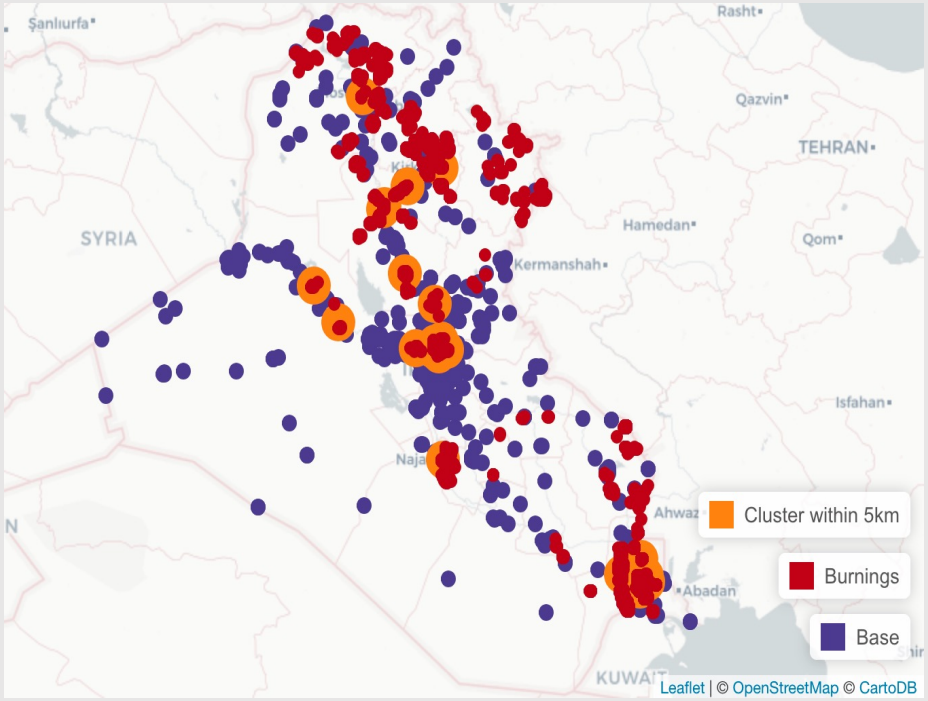


Exposure Assessment Tool

- https://airquality.ryanlue.com/
- https://github.com/rlue/sdaqs-sada

Burn Pit Detection – Hierarchical Density Based Clustering

- Records of the locations and durations of burn pits were not routinely taken.
- MODIS active fire with hierarchical density-based clustering to detect persistent thermal sources annually
- Identified persistent sources within 5 km of known base locations



Burn Pit Detection

- Validated with imagery where possible (much of the imagery in the region is blurred)
- Identified bases with most thermal detections 2002-2012
  - Chindit, Steelback, Camp Hutch, Al Saad appear frequently

TOP: Camp Al Saad, Iraq; BOTTOM: Steelback, Iraq

ARL and Spending

- Started at 3, we are at 7-8 as we wrap up this year
- Published 3 papers since last performance period
- Student engagement at USC and JPL internship
- Subcontracts to VA and Harvard up-to-date
- Next steps:
  - update exposure assessment tool with 7km MERRA-2 exposures
  - finalize deployment of exposure tool with VA and DoD groups
  - Follow-on grant from VA submitted

Entry Level	Exit Level	Success Criteria for ARL Transition	Completed by
3	4	Integration of application components: a) deployment of monitors and sensors in Kuwait, Qatar, Djibouti; b) integration of monitors and sensors with Terra satellite overpass c) processing of all historical MISR data over SADA.	Halfway through year 1
4	5	Validation of MISR source-specific PM estimation in the relevant decision-making environment (SADA).	Halfway through year 2
5	6	Prototype of PM exposure software tool for VA and DoD decision-making activities.	End of year 2
6	7	Integration and application of prototype PM exposure software tool on VA and DoD systems. Decision-making activity functionality tested.	Part way through year 3
7	8	Functionality proven: final implementation of PM exposure tool at VA and DoD, documentation and training of tool usage complete and disseminated.	End of year 3