Dust Transport over the Arabian Peninsula and Kuwait

Carly Baumann[1*] Olga Kalashnikova[2] Michael Garay[2] Jun Wang[1]
[1] University of Nebraska – Lincoln [2] Jet Propulsion Lab, Pasadena, CA

I. Introduction and Background

Satellite images, particularly those showing significant amounts of dust in the atmosphere, are examined to find the source of dust events, determine meteorological parameters for a severe versus insignificant dust event, and determine velocity, direction, and height of dust storms to see what other regions are affected. Linkages between dust plume information at the source and dust properties in downwind transport regions were evaluated using the MINX software application. Images from the MISR instrument aboard NASA's Terra satellite were brought into MINX and height and velocity measurements were obtained. In order to verify the data retrieved by MINX, other satellites and surface observations were checked for consistency.

The Arabian Peninsula is home to many severe dust storms. Its warm and dry climate contributes to the vast landscape of deserts. Across the peninsula strong northwesterly winds called "Shamal," meaning "north" in Arabic, bring in dust storms across the country of Kuwait. As the severity of dust storms has increased over time due to these effects, the people of Kuwait are also being affected by health and transportation hazards the dust brings. The presence of atmospheric dust can also affect the climate of Kuwait. As the aerosol optical depth (AOD) increases during dust events, variations in temperature occur since solar radiation cannot pass through such deep layers of aerosols to reach and warm the surface.

II. Methods

MODIS

Moderate Resolution Imaging Spectroradiometer, Images on Terra and Aqua are used to spot and follow dust events over the area. Events were found for four case studies, case 1: March 2012, case 2: September 2008, case 3: February 2010, and case 4: August 2007.

MISR/MINX

The analysis of the MISR images is done through the use of MISR Interactive eXplorer (MINX) software, which yields higher resolution results than provided by the standard, operational MISR product. MINX output includes digitizations of the height and speed of the traveling aerosols during dust storms moving into Kuwait.

Meteosat and PM_{10} models

Paticulate Matter with a diameter of less than 10 μm. The models showed a density map of PM_{10} at certain time intervals, used to determine the speed of dust, and verify the severity of the storm.

METAR

Surface observations from ground-based weather stations. The station observed was OKBK, Kuwait City. Parameters (Visibility, wind diretion, wind speed, and temperature) were graphed out over the duration of the dust event in order to note key changes.

Soundings/Radiosondes

PDF files of skew-T charts used from the selected stations OKBK of Kuwait City and nearby locations. The soundings show the vertical temperature and dew point of the atmosphere.

HYSPLIT Trajectories

Hybrid Single-Particle Lagrangian Integrated Trajectory analysis through NOAA indicate a path of a parcel of air based on a forecast model, used to determine direction and height of dust.

CALIPSO

Vertical structures of attenuated backscatter from satellite images used to determine height and location of dust.

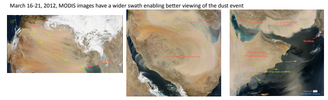
Inidan Ocean Wind Vectors

Seasonal variations in the area create different wind patterns. Monsoonal winds over the Indian Ocean would have an effect on the dust transport based on the season a dust storm may occur.

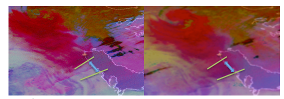
Case 1: March 2012

MODIS

March 16-21, 2012, MODIS images have a wider swath enabling better viewing of the dust event

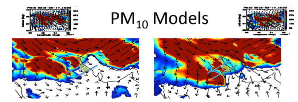


Meteosat



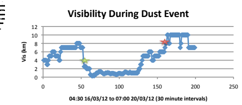
March 17, 2012
Distance between both points = 222,719 m (Google Earth) over 6.5 hours
Dust traveling at 9.5 ms^{-1}

PM_{10} Models



March 17, 2012
Using the same method as on Meteosat the distance was 220,206 m over 6 hours
Dust traveling at 10.1 ms^{-1}

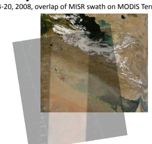
Surface and METAR data



START: March 17, 2012 06:30Z END: March 19, 2012 15:00Z

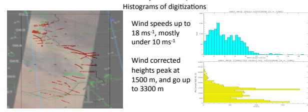
Case 2: September 2008

September 14-20, 2008, overlap of MISR swath on MODIS Terra



MISR/MINX

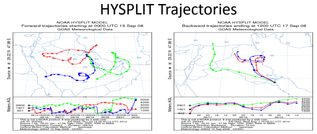
MISR September 15, 2008
Histograms of digitizations



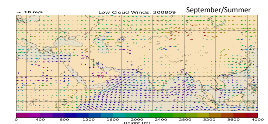
Wind speeds up to 18 ms^{-1}, mostly under 10 ms^{-1}

Wind corrected heights peak at 1500 m, and go up to 3300 m

HYSPLIT Trajectories



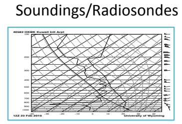
Indian Ocean Wind Vectors



Case 3: February 2010

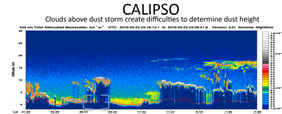
Soundings/Radiosondes

Clouds above dust storm do not show a large dry pocket of air above the dust event



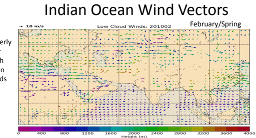
CALIPSO

Clouds above dust storm create difficulties to determine dust height



Indian Ocean Wind Vectors

Northwesterly winds over Kuwait with weak Indian Ocean winds

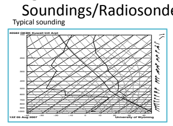


Case 4: August 2007

Soundings/Radiosondes

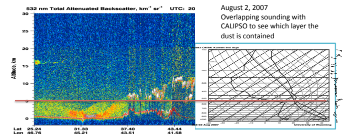
Typical sounding

Very dry air near the surface with an inversion and large dry air pocket above



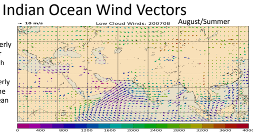
CALIPSO

August 2, 2007
Overlapping sounding with CALIPSO to see which layer the dust is contained



Indian Ocean Wind Vectors

Weak northwesterly winds over Kuwait with stronger southeasterly winds in the Indian Ocean



III. Results

CASES I, II, III, IV	CASE I March 16-21, 2012	CASE II September 14-20, 2008	CASE III February 20-28, 2010	CASE IV August 2-6, 2007
Season	Spring	Summer	Spring	Summer
Speed (avg) MINX	10ms^{-1}	10 ms^{-1}	9 ms^{-1}	8 ms^{-1}
Dust Height CALIPSO MINX soundings	2.5 km 1.5 km 2 km	5 km 2 km 5 decreasing to 3.5 km	2-3 km 1.5 km .7 – 3 km (clouds)	3-4 km Not enough pts 2 inc. to 4 km
Dust Origins HYSPLIT	Syria	Syria	Syria	Iraq/Iran
Path HYSPLIT MODIS	Across Arabian Peninsula over Arabian Sea	Within the Arabian Peninsula	Eastward into Gulfs and Iran	South into Arabian Peninsula

IV. Preliminary Conclusion and Future Work

Future work done for the case focusing more on health would be distinguishing the transport of different sized dust particles. The mechanical transfer of dust includes suspension, saltation, and creep. Suspension is observed in finer particles once lifted into the air remain in the atmosphere for long periods of time. Saltation describes more coarse particles being lifted primarily in stronger winds for some time then hitting the surface and repeating the cycle in a bouncing fashion. Creep describes much larger particles, like sand, which usually roll along the surface because the wind is unable to lift them. Particle transport models depend on wind speed and particle size more so than the parameters for air parcels to transfer. So, finer particles can still travel within air parcels, but may detour from some of the trajectories and become injected over the boundary layer, like the Saharan Air Layer (SAL), or not travel as far as the trajectories depict.

This data may be interrelated to the size distribution of particles, and how far these particles may travel based on wind speed and direction. Dust storms originating in Syria already affecting the health in Kuwait may have effects in other countries further East like India. Dust particle size ranges from 0.001 – 1000 μm. Dust particles under 100 μm diameters are inhalable. Thoracic (PM_{10}) is that portion of the inhalable particles that pass the larynx and penetrate into the conducting airways and the bronchial region of the lung. Respirable ($PM_{2.5}$) is the portion of inhalable particles that enter the deepest part of the lung. Once the tracks of different sized particles are known different locations may be able to forecast the severity of hazardous particles sooner in order for people to prepare.

Combining satellite images and meteorological parameters are useful in making better forecasts for the severity of a dust event and where the dust will be traveling. Dust travelling up to 10 ms^{-1} (22 mph, 36 kmh) and maintaining speed over 5ms^{-1} is a good sign for a severe dust event and cause low visibility.

Depending on the season the heights of dust would fluctuate with the warm air inversion in the atmosphere, from 2 km in winter and early spring up to 5 km in the summer based on the case studies. Dust origins were typically seen from Syria moving in from the northwest (Shamal). The path of the dust also varied based on the monsoonal season, but typically moved southeast over the Arabian Peninsula.

Acknowledgments

Kalashnikova, Olga, for METAR report and Meteosat images
Garay, Michael, and Nelson, David for usage with MINX
Wang, Jun for PM_{10} models
This project was funded by JPLSIP (summer 2012) and Space Grant at the Jet Propulsion Lab and California Institute of Technology in Pasadena, CA.

*Contact information: baumann.carly@gmail.com