The chain of weather events that led to unusual rainfall over the Gulf

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Last week, the heaviest rainfall in over a decade left many residents of the UAE and other Gulf countries soggy. While some played in puddles, or broke out umbrellas, we at NYU Abu Dhabi’s Center for Prototype Climate Modeling tried to determine just what caused this unusual weather event.

Weather and climate enthusiasts often ask if a particular whether event is due to climate change. This question can not be answered with certainty. It is too early attribute last week's rains — or any recent isolated weather event — to climate change. That kind of determination must come from a detailed comparison of the present climate to the past and future (projected) climates.

Scientists at our center are in the process of such an investigation. In our recent work we have found that 2013 is marked by many global weather anomalies, such as unusual jet stream patterns, strong monsoons, heat waves, intense snowfall over US and Europe — and last week's rains here in the UAE.

The national weather bureau (NCMS) correctly forecasted and attributed the cause of last pattern to an atmospheric low pressure system that moved across the Middle East countries. But we wanted to learn more about the origins of this weather event.

In mid-November, Cyclone Hilde formed off the southern coast of Greenland and brought high winds and rain to Norway, Sweden, and Finland. Around the same time, another cyclone, Cleopatra, formed over the Mediterranean and brought destructive rain and flooding to the Italian island of Sardinia. Cyclones occurs rarely over the Mediterranean Sea.

A wave-like atmospheric flow controls the winter weather of mid-latitudes. These are basically a chain of cyclone-anticyclone circulation patterns propagating from west to east (see schematic below). An anticyclone, which is characterized by a high pressure center around 55°N and clockwise rotating winds, followed Cleopatra. Over the next few days, when the rain over the Middle East occurred, this high pressure system moved south eastwards and was positioned close to the Middle East (see Figure below). Eventually, the cold dry air of the anticyclone met the warm moist air from the Arabian Sea and Africa.

When dry cold air meets warm moist air, a phenomenon called "occlusion" occurs. This results in the formation of a low pressure area (low), followed by clouds, and, finally, rain. The amount of rain is determined by the amount of moisture carried by the warm air. This year, the unusually strong Indian monsoon left a great deal of moisture over the Arabian Sea. (The level of moisture over Arabian Sea in October and November has been 15 – 20% higher than normal.) Last week, the meeting of the dry cold air from the anticyclone and the warm moist air from the tropics triggered a low over the upper Arabian Gulf, which moved south-east down the Gulf after dumping rain on Kuwait, Bahrain, Eastern Saudi Arabia, Qatar, the UAE and Oman (see animated image in the web; http://goo.gl/ByrJSq).
Scientists at our center conducted several "hindcasts" with the Weather Research and Forecasting (WRF) models using the assimilated data obtained from various weather agencies like NCEP GFS (National Center for Environmental Prediction Global Forecast System). With these hindcasts, we were able to simulate the extreme rainfall events over the Middle East (see web page), which is an example of the ability of the contemporary weather and climate models in simulating extreme weather events. Note that these simulations are made with out in-situ data from the local weather stations from the Gulf region. Some of the mismatch with the simulated and observed rainfall patterns like relatively weak amplitude and the 3hour time lag in the simulations are due to this. We believe that model skill can be considerably improved, if more in-situ data is used for the assimilation.

We hope that work like this will help improve our understanding of the vagaries of weather and ability to predict future weather events like this.
Schematic representation of midlatitude waves and associated weather systems. Anti-cyclonic (clockwise) patterns represent high pressure systems while cyclonic (anticlockwise) patterns represent low pressure systems. When the cold dry air pushed by the high pressure system meets the warm moist air from the tropics, a phenomenon called occlusion occurs, resulting in the formation of a low, followed by rain. In this incidence, the high pressure system is positioned close to the Gulf (see Figure below).
Weather patterns during the extreme rainfall events over Middle East. Arrows represent movement of low-level (~1.5 Km from surface) winds and shaded patterns represent accumulated rainfall in the previous 24 hours as measured from TRMM satellites. Anti-cyclonic (clock-wise) pattern represent high pressure systems while cyclonic (anticlockwise) patterns represent low pressure systems.