Mapping and modeling desertification and its impact on aeolian dust and human health in Central Asia

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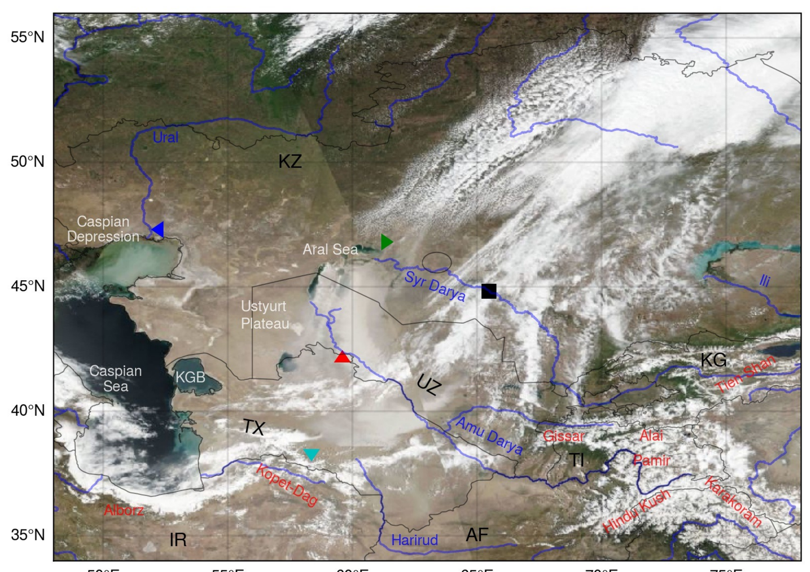
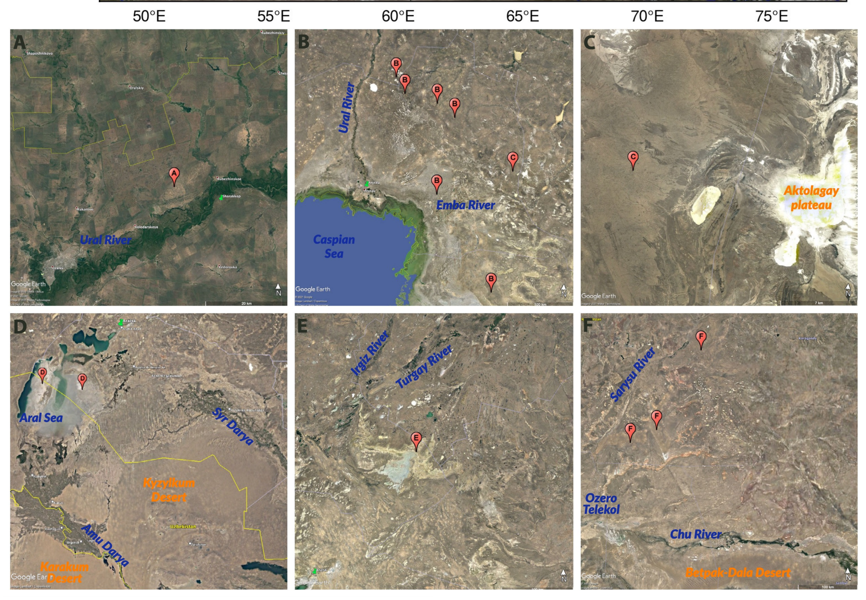
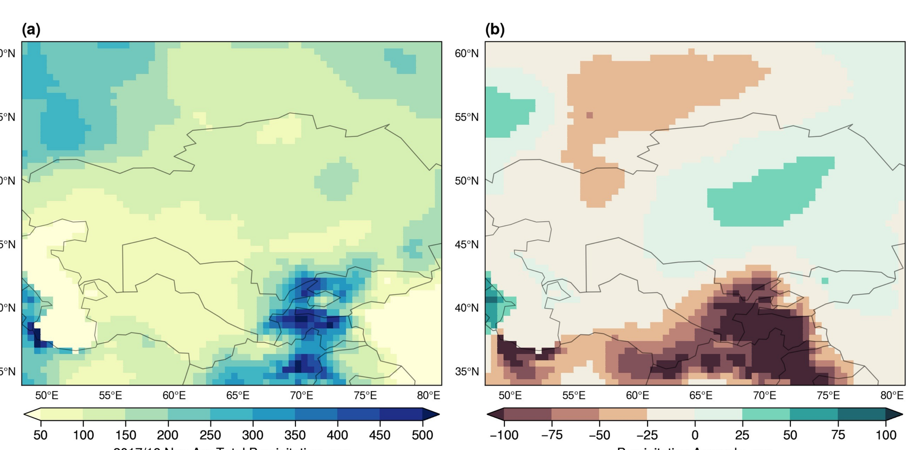
Study #1. Geomorphic & climate drivers of recent extreme dust storms

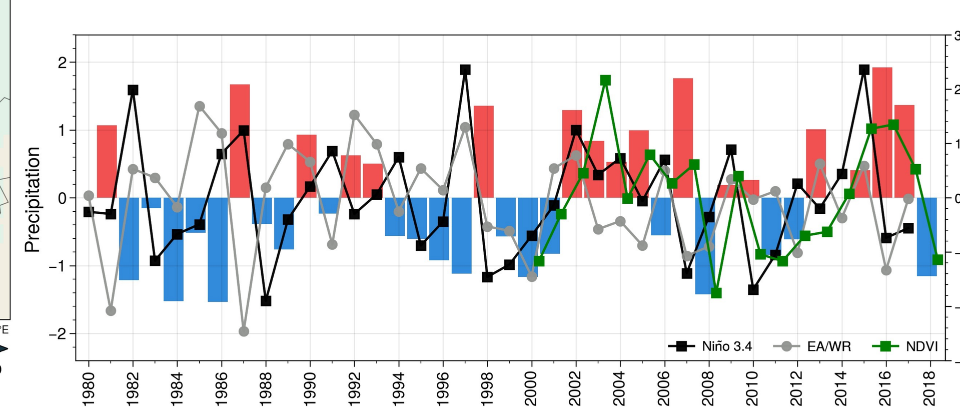
A sequence of dust outbreaks occurred in Central Asia in late May 2018, including an extreme salt dust storm (Fig. 1). Where are the dust sources? And what factors triggered the unusual dust activity in early summer 2018. This study highlights the vulnerability of Central Asia to climate extremes and compounding weather hazards. The key finding are:



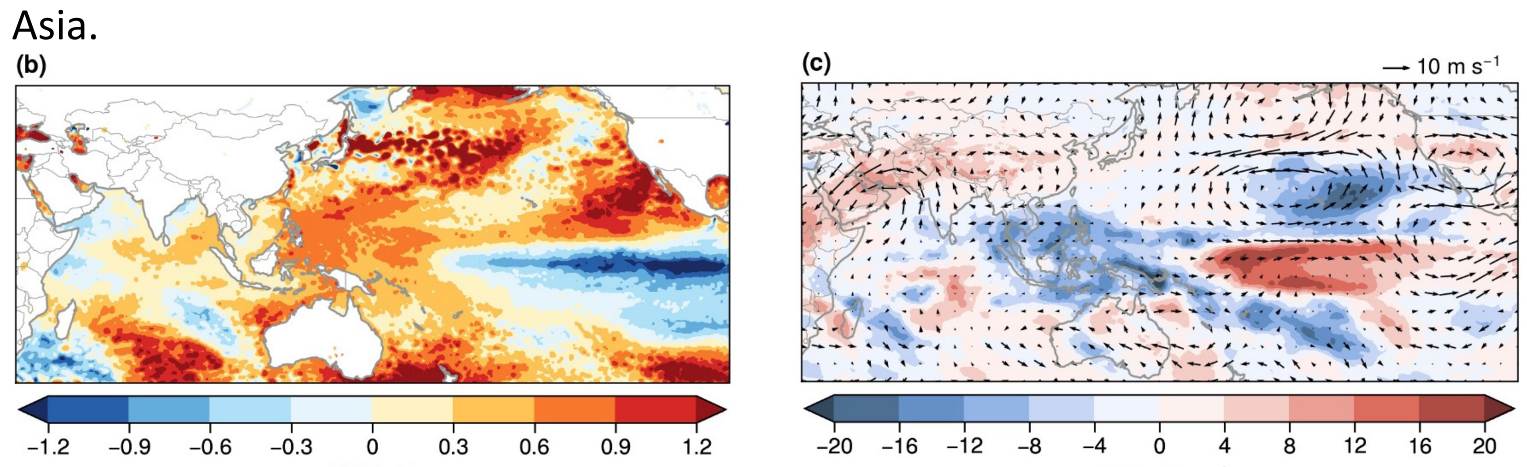


1. A number of active dust sources were detected over the lower drainage basin of major rivers, where alluvial deposits become progressively finer in size and thus have a larger potential for aeolian entrainment. In contrast, major sandy deserts showed minimal activity.
2. The sediment availability is enhanced by a growing-season drought, caused by reduced precipitation (esp. mountain snowfall) in the preceding winter season. The precipitation deficit has two possible climate drivers.

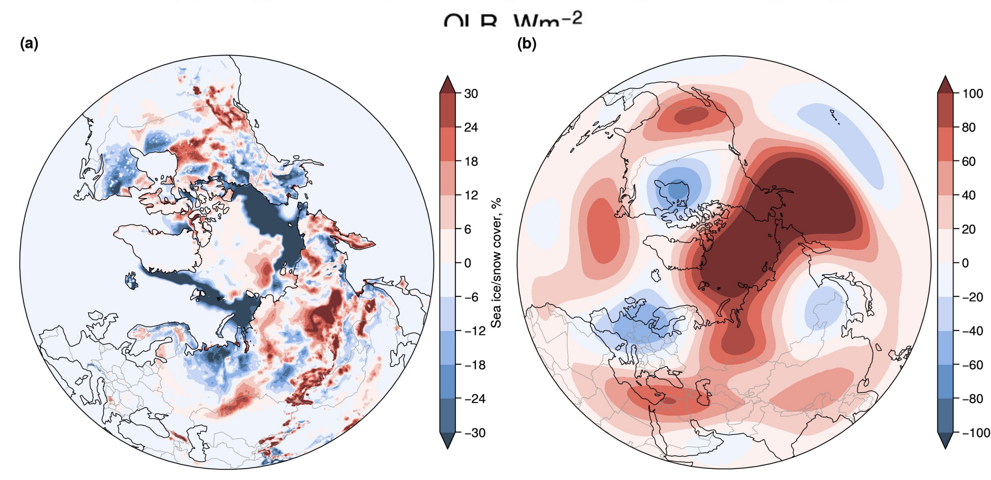




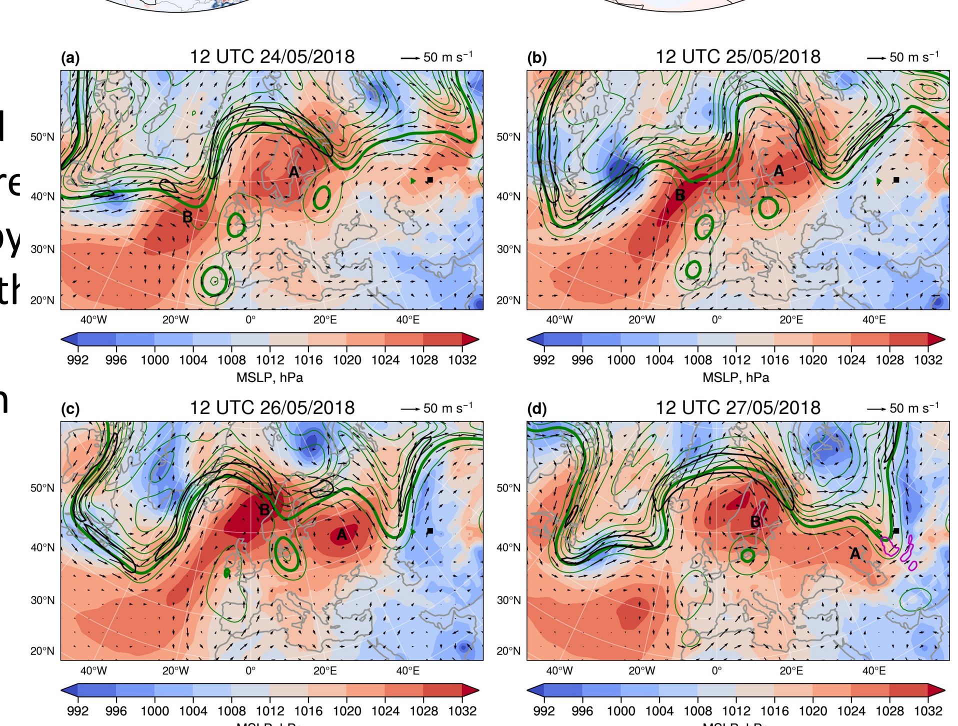
(a) A double-dip La Nina event in 2017/18 winter with an exceptional west Pacific warm pool and cold central Pacific triggered a precipitation-suppressing convergence anomaly over Arabian Sea and SW Asia.



(b) Above-average autumn (Oct 2017) Siberian snow cover intensifies the Siberian High and promoted the southern shift of midlatitude westerly jet. The SPV splitting pattern resembles negative EAWR pattern associated with below-average precipitation in Central Asia.



3. The salt dust storm was associated with pronounced cooling, pressure surge, and wind speed reaching 30 m/s. The intense winds were generated by amplified quasi-stationary Rossby waves and blocking anticyclones over the North Atlantic and Eurasia, forming a large surface pressure gradient with the thermal depression over Central Asia.

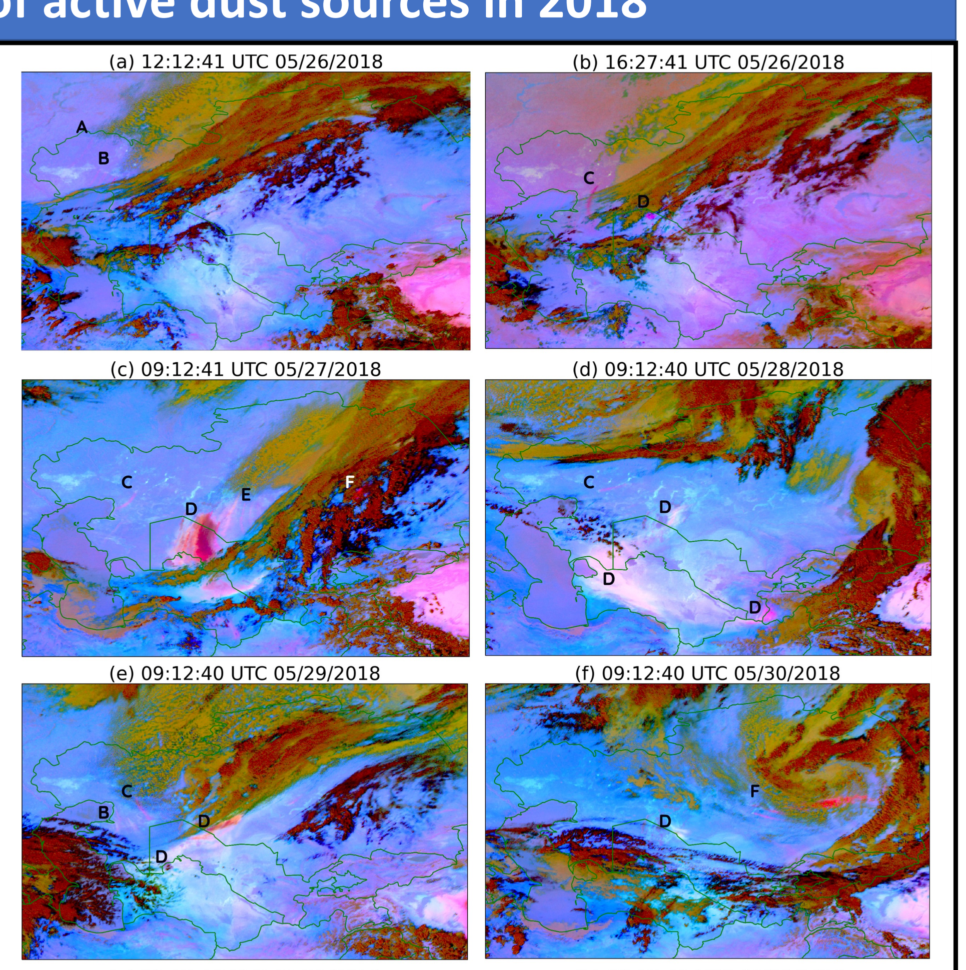


Implication: Synoptically-driven, extreme dust events in Central Asia are associated with compounding weather or climate extreme conditions, causing amplified societal impact.

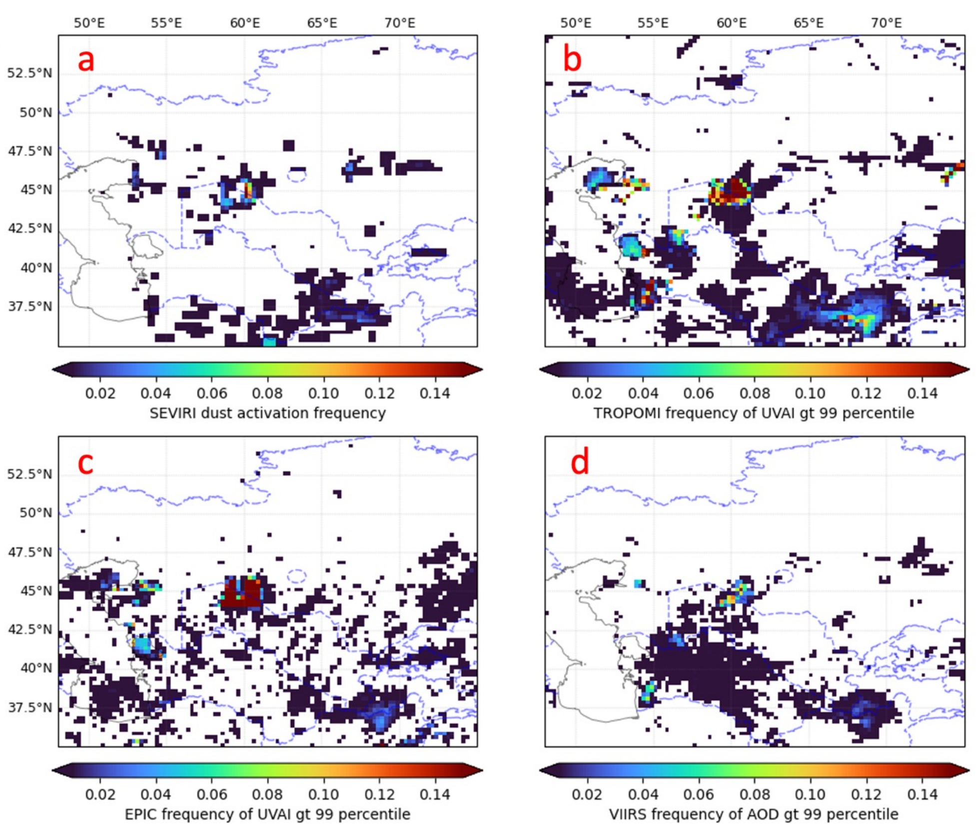
Study #2. Satellite mapping of active dust sources in 2018

The model prediction of dust emission and dispersion relies on the knowledge of the geographic locations of potential dust sources. We compared two different methods for detecting dust source locations using long-term satellite aerosol observations:

1. Back-tracking
   - The SEVIRI 15-min dust RGB composite images are used to visually back-track each dust plume to the ground origin.
   - Requires lots of man hours.
2. Frequency-of-occurrence
   - Assumes the regions with frequently high dust loading (UVAI, AOD) as dust sources.
   - Automatic, but depends on satellite product accuracy and empirical criteria.

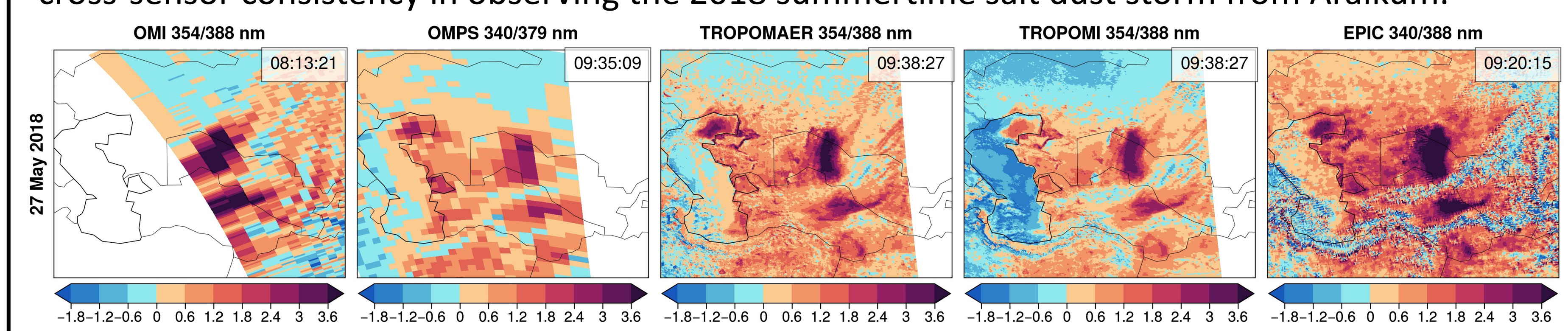


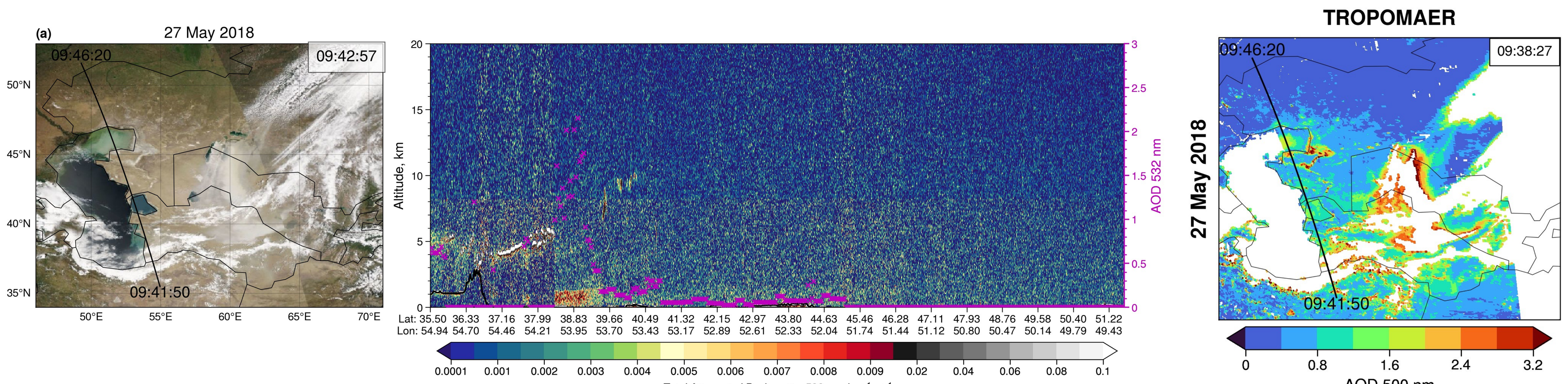
- SEVIRI (a) identifies four active dust source regions: Aralkum, Caspian Depression, lower Sarysu and Chu river basins, and upper Amu Darya basin.
- UVAI-based source map (b, c) overestimates the source extent & strength, due to the wind transport-related bias and non-dust-related positive UVAI over turbid water regions (e.g., northern Caspian, Kara-Bogaz-Gol)
- VIIRS AOD underestimates the source strength due to difficulty in retrieving AOD over bright deserts, esp. strong dust events which may be misclassified as clouds.



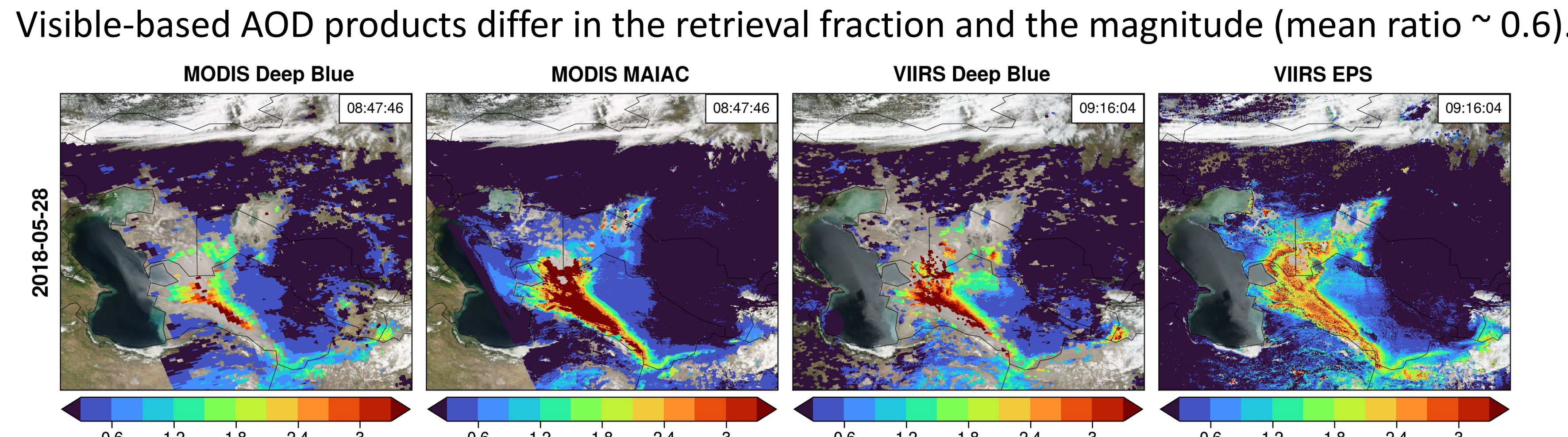
Study #3. Evaluation of cross-sensor consistency in dust observations

Satellite remote sensing has greatly improved the observation capability of large-scale dust emission and transport events on a daily basis. Due to the scarcity of ground-based validation data the performance of the passive aerosol sensors in Central Asia has not been carefully evaluated. Through an intercomparison of multi-sensor observations, this study evaluates the cross-sensor consistency in observing the 2018 summertime salt dust storm from Aralkum.





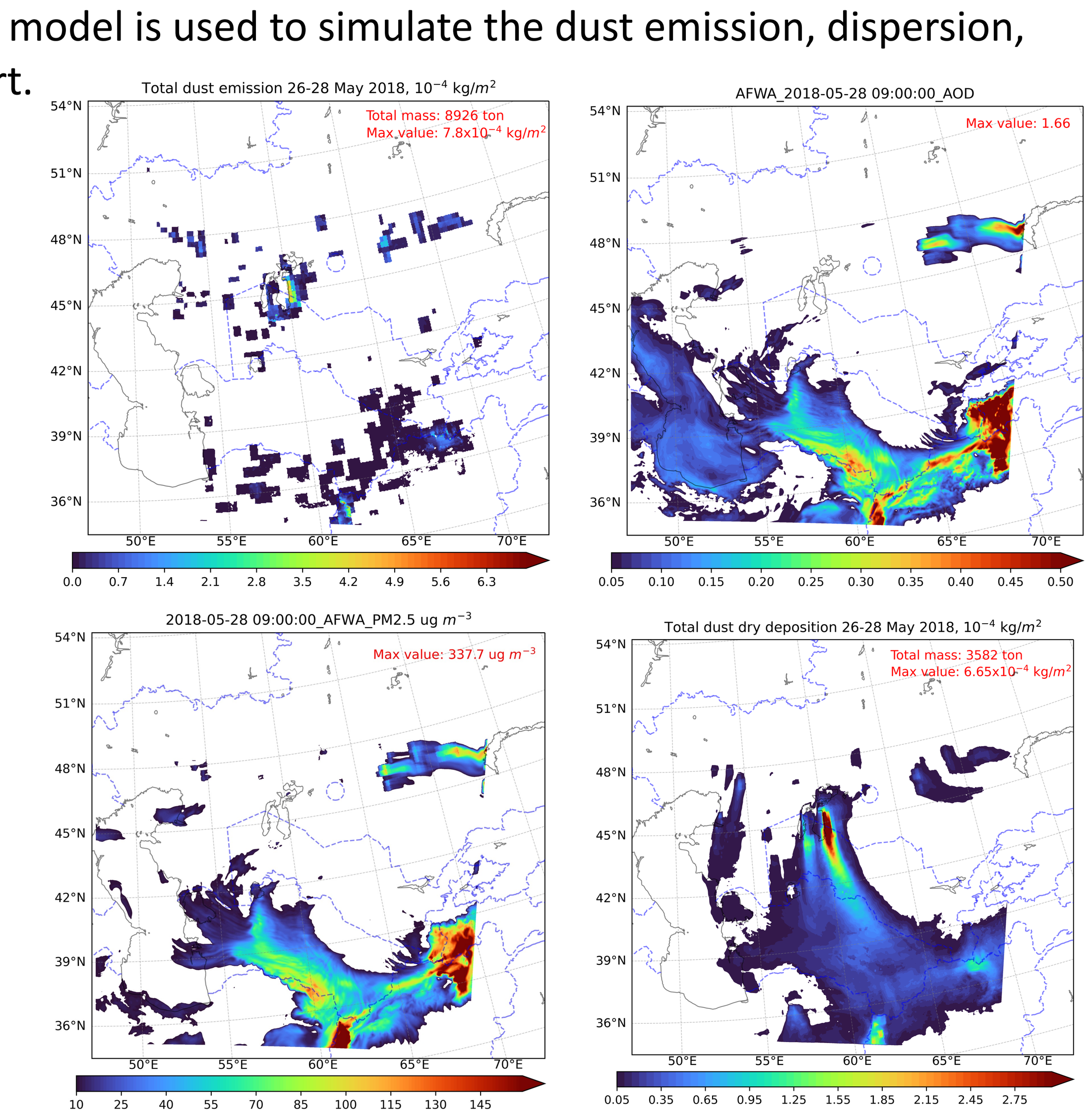
- All UVAI products captures the salt dust plume on 27 May 2018, but with different resolutions and sensitivity to clouds. All products are biased over turbid waters, based on CALIPSO.
- UV-based AOD products misclassified dust as clouds, due to erroneous cloud mask from VIIRS.
- Visible-based AOD products differ in the retrieval fraction and the magnitude (mean ratio ~ 0.6).



Study #4. Impact of the 2018 salt dust storm on air quality

The Aralkum salt dust storm caused persistently high dust concentrations and significant salt deposition in large parts of Uzbekistan and Turkmenistan. While the elevated PM level poses a risk for acute respiratory diseases, the salt accumulation in soil may have a long-lasting impact on the human welfare. The WRF-Chem model is used to simulate the dust emission, dispersion, and deposition from the Aralkum desert.

- Using the SEVIRI dust source map to constrain model simulations greatly improve the spatial pattern of dust emission.
- Model-simulated AOD is significantly lower than satellite retrieval, suggesting either the dust emission is too low or removal process is too efficient.
- Similarly, the PM concentration is likely also underestimated by the model.
- >3500 tons of dust was deposited during 3-day period. Combining with cropland distribution we will estimate how much salt was accumulated in the soil.



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