Prospective tracking and modeling of the impact of hydroclimatic factors on the ongoing COVID-19 pandemic

A supplement to the NASA GEO-Health project *Environmental Determinants of Enteric Infectious Disease: a GEO platform for analysis and risk assessment*

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Motivation

The ongoing COVID-19 pandemic has already caused widespread illness, loss of life and societal upheaval across the globe and has still not reached its peak. As the public health crisis unfolds, there is both an urgent need and a unique opportunity to track and characterize the sensitivity of disease transmission to background climate conditions and to seasonal factors. The questions of whether the disease will exhibit seasonal variability and what the relative transmission risk is across climate zones are already much debated and are highly uncertain. This is in part because so little is known about the SARS-CoV2 virus, and in part because climate and seasonal sensitivities are not well understood even for established diseases like influenza. This lack of understanding stems from the fact that climate sensitivities, including "seasonality," comprise a host of behavioral, biophysical, and structural factors, usually set on a background of complex host immunity patterns, all of which make it difficult to disentangle the drivers of differences in disease risk in a quantitative manner.

The COVID-19 pandemic, in contrast to other known seasonal illnesses, has global reach, is hitting a human population with no immunity due to prior infection, has led to the use of common tests for a common disease across countries, and has triggered a range of policy responses across diverse geographies and cultures. For these reasons, COVID-19 may allow us to understand geographic differences and seasonality as functions of climate and hydrologic variability in the context of the host, the health system and policies that restrict human interaction and movement. Doing so could be critical for informing appropriate response measures. For example, should disease transmission peak in early summer in the United States and major European countries--as is currently predicted by many models--then there will be a reduction in transmission rates later in summer. We need to be prepared to interpret this anticipated slowing of transmission rates as a function of environmental stability and transmissibility of the virus, policy measures, and climatic factors in order to prepare properly for potential reemergence of the disease as policy measures are relaxed or temperatures cool going into the fall.

Earth Observations (EO) play a critical role in this effort. As we have found in our active GEO-Health project *Environmental Determinants of Enteric Infectious Disease: a GEO platform for analysis and risk assessment*, EO have the power to reveal relationships between hydroclimatic variability and disease in a way that standard weather observations cannot. This is because of the spatially and temporally complete nature of EO estimates of precipitation, temperature, and other meteorological fields, and also because EO in the form of satellite-derived observations and data assimilation systems allow us to estimate variables like soil moisture and flood potential in a manner that is not possible when depending on conventional monitoring techniques. For example, we have found significant and meaningful associations between rotavirus infection risk and soil moisture (Colston et al., 2019) that are directly relevant to targeted vaccination campaigns and other interventions. While the environmental sensitivities of COVID-19 transmission are unknown, there is potential to detect sensitivities using EO and advanced analysis methods even when those associations are not obvious in conventional studies. This is important, because even seemingly subtle changes in transmission parameters can have a significant impact on case counts and on the expected effectiveness of control policies.

Goal and Tasks

In this context, *the goal of this proposed project is to quantify the role that climatic and hydrometeorological factors play in temporal and spatial variability in COVID-19 transmission.* To do this, we will bring together highly spatiotemporally disaggregated data relating to incident COVID-19 cases, Earth Observations of climate and land surface hydrology, and reported policies on screening and control strategies to understand their relative contributions to the trajectory of the pandemic at a global scale. This approach builds directly on the work we have done to analyze data from multiple multi-site cohort studies in our *GEO-Health* project.

Project tasks are:

1. Apply geospatial databasing techniques used in our *GEO-Health* project to structure COVID-19 case and health burden data in a manner appropriate for EO-informed analysis. This effort will benefit from our involvement in the JHU COVID-19 Dashboard [Investigator Gardner leads that effort], which provides time series of COVID-19 testing rates, case numbers, and relevant demographic information at the finest available spatiotemporal resolution, with global coverage.
2. Further leveraging work our team has performed in the *GEO-Health* project, align the COVID-19 inventory with Earth Observations of near-surface meteorology, hydrology, and land cover, including: (1) satellite-derived estimates of precipitation (GPM) and daily minimum and maximum temperature (CHIRTS daily intermediate product; available to us via collaborations with the Climate Hazards Center); (2) near-surface meteorology obtained both through WMO-reporting weather stations (*in situ*, synoptic scale) and global meteorological analyses (data assimilation-based, gridded); for humidity, and as a check on satellite estimates of temperature and precipitation; (3) surface soil moisture obtained from operational land data assimilation systems (LDAS) and, for evaluation and comparison, satellite-derived estimates (SMAP); (4) vegetation-based land cover and ecosystem classification. We note that humidity and temperature have both been associated with influenza risk, while information on soil moisture, precipitation, and land

cover have proved to be important in our ongoing studies of viral enteric infectious disease.

3. Centralize data on policies which restrict social behavior of human populations (policies restricting meetings over different population thresholds), stay at home policies, and policies that restrict human movement within and between countries.

4. Derive parameter estimates for comorbid conditions derived from the regional estimates from the Global Burden of Disease estimates, which will be input into all models with deaths or severe disease as an outcome.

5. Applying our team's experience with advanced machine learning techniques, applied to enteric diseases in the *GEO-Health* project, build statistical models of COVID-19 transmission, incidence, and mortality rates that account for climate and hydrology in the presence of other proposed predictors (demographics, policy, hospital capacity, testing rate, etc.).

6. Input the results of our statistical models for transmission rate, incidence, and mortality (Task 5) to infectious disease dynamics models [Investigator Lessler] that apply the environmentally-informed transmission rate estimates to reconstruction of disease burden and projection of future spread under various policy scenarios.