Prospectus

Scenarios for future regional impacts of climate change:

A data-driven, climate dynamics approach

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SYNOPSIS

The impacts of climate change are occurring around the world in different ways and at different rates. CFAN works with clients to evaluate and assess risks from climate change impacts for their organization and/or region. CFAN provides a range of possible climate scenarios to enable decisions that are robust across a range of possible outcomes, and allows for focus on scenarios in the vicinity of vulnerability thresholds.

CFAN's climate impact assessments include historical analyses and decadal scale scenarios of future climate change that can be used to drive risk assessment models. Our scenarios of future climate change integrate projections of human-caused global warming with natural modes of climate variability. Extreme event scenarios consist of frequency distribution of regional extreme events over the target time interval, as well as worst-case scenarios of individual events.

CFAN has expertise and experience in developing regional climate variability/change scenarios for the following target variables:

- coastal sea level rise
- near surface weather variables such as 100 m wind speed and rainfall
- tropical cyclones (hurricanes)
- fire weather threat

Traditional approaches using global climate model simulations are not skillful on regional and decadal time scales. Further, climate models do not include future scenarios of solar variability, volcanic eruptions and large-scale oscillations in ocean circulation patterns. On time scales of up to 30 years, natural climate variability is expected to dominate in most regions over manmade global warming in terms of regional extreme weather events. For local sea level rise, in many regions local sinking (from land use and geological processes) and ocean circulation patterns dominate over the trend from global warming -- regional sea-level rise is characterized by decadal acceleration and deceleration periods that typically stem from oceanic climate variability.

CFAN's unique data-driven approach to developing regional climate variability/change scenarios includes the following elements:

i. Assembly of relevant historical data and paleoclimatic analyses of target variables.
ii. Assembly of a historical data base of atmospheric and ocean circulation data; assembly of paleoclimate circulation index data for interpreting current climate regimes and bounding 21st century projections.
iii. Interpretation of historical target variable data in context of the weather and climate regimes and the secular trend of manmade global warming.
iv. Generation of future scenarios using multiple scenarios of manmade climate change, solar variability, volcanic eruptions and ocean climate variations
vi. Generation of seasonal, regional scenarios for the target variable based on iii and iv.

21st Century Scenarios

CFAN's 21st century climate change scenarios are based on the latest scenario information from CMIP6 (for the forthcoming IPCC 6th Assessment Report), including emissions scenarios and solar scenarios. Scenarios of 21st century volcanic eruptions are derived from reconstructed

volcanic activity over the past 2,500 years. Developing scenarios of multi-decadal oceanic climate variations, including climate 'shifts', is an active area of CFAN's research. Plausible bounds for each of the relevant ocean climate regime indices are established, and direction and timing probabilities for regime shifts are assessed for the decadal-scale circulation indices.

Future scenarios of statistics of regional near surface weather and extreme weather events are reconstructed based on historical analyses of ocean climate and weather regimes and accounting for any secular trends from global warming. CFAN has developed a cluster analysis approach to identify the dominant weather regimes for the target location/region. Reconstruction of the target variables at the specified locations using reduced/combined decadal indices, populated by statistics of interannual climate variability and weather regimes, plus any secular trend related to global warming.

Types of Deliverables

Examples of the products CFAN can provide to clients as part of the assessment, tailored to a client's need include:

Data sets:

- Historical data sets
- Time series of individual climate inputs used in the 21st century scenarios
- Seasonal (3 monthly) time series of target variable for each location, for each scenario
- Integral statistics (e.g. 10, 30 years) (for each season, or annual) of average anomalies, coefficient of variation, periods of high/low anomalies.

Reports with the following elements:

- Literature survey of previous historical assessments of the target weather variables and 21st century projected outcomes specific to the client's objectives
- Detailed description of data and analysis methods
- Analysis of the key drivers and source of weather variability for each location of interest
- Description of key results with graphics
- Interpretation of new analysis in context of previous historical analyses and previously published 21st century scenarios of relevance to the region and target variables

CFAN OVERVIEW

Climate Forecast Applications Network (CFAN) is a weather and climate services company that develops innovative forecast tools to support decision-oriented solutions for our clients. CFAN was founded in 2006 by Judith Curry and Peter Webster and launched under Georgia Tech's Enterprise Innovation Institute VentureLab program. CFAN is a Woman-Owned Small Business (WOSB).

CFAN's weather and climate forecast products provide daily, weekly, and seasonal probabilistic forecasts http://www.cfanclimate.net/products. CFAN provides forecasts for surface meteorological variables and upper air components. CFAN has developed advanced forecast modules for:

- Tropical cyclones: formation, tracks, wind speeds, landfall impacts
- Regional wind power: hub height winds, % of rated power, power ramps
- Hydrological modeling system: streamflow, flooding and inundation
- Extreme weather: severe convection, wind gusts, lightning, hail, fire risk
- Teleconnection patterns and circulation regimes.

CFAN develops regional scenarios of future climate variability that integrate projections of externally forced century-scale climate change with natural modes of climate variability. In addition to climate model simulations, CFAN uses a network-based dynamic climatology based on multidecadal teleconnection indices. http://www.cfanclimate.net/climate-scenarios

CFAN's core competencies and sustainable competitive advantages include:

- Extensive research and operational experience using the world's best weather forecast and climate models
- Strong scientific reputation of CFAN's owners, who excel in advancing the scientific understanding of weather and climate dynamics and its predictability and prediction
- Superior weather prediction expertise with respect to extreme weather events: floods, droughts, tropical cyclones, heat waves and cold outbreaks, severe convection
- Substantial expertise utilizing ensemble-based probabilistic and scenario forecast methods in developing enhanced forecasting solutions and in assessing forecast uncertainty and confidence

CFAN's research staff includes 7 scientists holding a Ph.D. Summary qualifications of key personnel are provided below.

Judith Curry, PhD 1982 U. Chicago (Geophysical Sciences). Dr. Curry is President and majority owner of CFAN. Curry's research areas are climate dynamics, probabilistic prediction of extreme weather events, and the socioeconomic impacts of weather and climate variability. Curry recently retired from her position as Professor and Chair of the School of Earth and Atmospheric Sciences at Georgia Tech. Dr. Curry is Fellow of the American Association for the Advancement of Science, American Meteorological Society and American Geophysical Union.

Peter Webster, PhD 1972 MIT (Meteorology). Dr. Webster is co-owner and Chief Scientist of CFAN. Webster's area of research is tropical climate dynamics and applications to prediction of rainfall, floods and droughts in monsoon regions. Webster is Professor Emeritus in Earth and Atmospheric Sciences at Georgia Tech. Dr. Webster is Fellow of the American Geophysical Union, American Meteorological Society, and American Association for the Advancement of Science and an Honorary Fellow of the Royal Meteorological Society. Research Awards include the Charney Award and the Rossby Research Medal from the American Meteorological Society and the Adrian Gill Award and Mason Gold Medal from the Royal Meteorological Society.

Violeta Toma, PhD 2008 Georgia Tech (Atmospheric Science). Dr. Toma is CFAN's Vice President for Forecast Product Development. She leads the overall effort for CFAN's temperature and wind forecasts for the energy sector. Her research expertise includes tropical atmospheric dynamics, ensemble forecast methods, statistical analysis and energy meteorology. n.

James LeMunyon, MS 1987 U. Wisconsin-Madison (Meteorology). Jim LeMunyon is CFAN's Business Development Manager. He was co-founder and president of Sterling Semiconductor, which was acquired by Dow Corning in 2003. LeMunyon's professional experience includes working as the Chief of Staff for Congressman Ed Zschau and Deputy Assistant Secretary -- U.S. Department of Commerce. He recently served four terms in the Virginia House of Delegates.

James Johnstone**,** PhD 2010 U. California-Berkeley (Geography). Dr. Johnstone is a Senior Scientist and CFAN's lead scientist on long-range projections. Dr. Johnstone joined CFAN in 2016, following a postdoc at the University of Washington. Dr. Johnstone's research expertise includes climate dynamics, statistical/dynamical modeling and applied interpretation of large weather and climate datasets.

RELEVANT PRIOR RESEARCH PROJECTS

A. Small Business Innovation Research grants

CFAN has received three Small Business Innovation Research (SBIR) grants:

III. Department of Defense: **Predicting Extreme Events Associated with Climate Variability/ Change Having Implications for Regional Stability in Asia**
https://www.sbir.gov/sbirsearch/detail/13021 Two reports are publicly available:

Impact of extreme weather/climate events on regional stability of Asia. The Office of the Secretary of Defense funded CFAN to assess natural disaster and climate change impact threats in South Asia - Pakistan, Afghanistan, Bangladesh and India. The project related CFAN's regional weather and climate predictive capability to a comprehensive regional analysis of weather hazards and climate impacts as security threat accelerants, and to address how effective use of this predictive capability could proactively reduce the threat acceleration associated with these events.
http://media.wix.com/ugd/867d28_089850cf3dff497c88182f07e814b923.pdf

Integrated Assessment of the 2010 Pakistan floods. CFAN prepared a comprehensive analysis for the U.S. Office of the Secretary of Defense of the flooding of the Indus River system in Pakistan during the summer and autumn of 2010. Our analysis examined the causes and impacts of the floods, including how the floods have acted as a threat accelerant to an already unstable nation. The report illustrated how a probabilistic forecasting scheme can help reduce the threat accelerant components of natural disasters.
http://media.wix.com/ugd/867d28_c9d8e672555f4eeab0f4172e3dc18735.pdf

II. Department of Energy: **Application of Global Weather and Climate Model Output to the Design and Operation of Wind Energy Systems.** This project addressed the challenge of providing weather and climate information to support the operation, management and planning for wind-energy systems. CFAN developed a hybrid statistical/dynamical forecasting scheme for delivering probabilistic forecasts on time scales from one day to seven months. The project also developed a framework to assess future wind power through developing scenarios of interannual to decadal climate variability and change. https://www.sbir.gov/sbirsearch/detail/410156

III. National Oceanic and Atmospheric Administration: **Probabilistic subseasonal weather forecasts for the energy & agricultural sectors.** This project developed and implemented a strategy to provide improved subseasonal forecasts for the energy and agricultural sectors, including applications to renewable energy. https://www.sbir.gov/sbirsearch/detail/1240933

B. World Bank and USAID Projects

Projected Economic Impacts of Hurricanes in Latin America 2020-2025. As part of a World Bank project (2009), CFAN conducted an assessment of the potential economic impacts of hurricanes during the period 2020-2025. CFAN developed scenarios for the statistics of landfalling tropical cyclones for different regions in Latin America, accounting for the impacts of both natural variability and global warming on tropical cyclone frequency, intensity, and the cyclone tracks. The hurricane projections were combined with projections of population and GNP and damage estimates from past hurricanes to estimate the future risk of hurricane damage in each of the regions.
http://siteresources.worldbank.org/INTLAC/Resources/Assessing_Potential_Consequences_CC_in_LAC_3.pdf

Climate Forecast Applications in Bangladesh (CFAB) Every few years, major floods engorge the Brahmaputra and Ganges Rivers for periods ranging from a few days to a month or more, often displacing tens of millions of people and devastating agricultural production. With funding from USAID and CARE, CFAN developed an extended-range probabilistic flood forecasting system for the Ganges and Brahmaputra (time scales from days to 6 months) to predict the probability that river water level heights will exceed critical levels. The CFAB project began in 1999, and the flood forecast system became operational in 2003 for the Ganges and Brahmaputra Rivers. In 2007, a new experimental dissemination program brought warnings directly via a cell phone network to more than 100,000 residents in five rural provinces in Bangladesh.
http://media.wix.com/ugd/867d28_f7f3852a70f04417b3909fcc0ee10b35.pdf

Extended-range water management and flood prediction system for the Indus River basin. Pakistan has the highest percent irrigation usage on the planet. Flooding during the summer monsoon period is a constant threat and water managers have to contend with the delicate balance between withholding water for drought periods and leaving sufficient storage capacity to contain flood pulses while maintaining sufficient discharge for power generation. CFAN developed a new coupled hydrological model for the entire Indus River basin, including a new flood plain module to determine the degree and duration of inundation when over-bank flow occurs in the delta. Specific recommendations were made about how extended streamflow forecasts could be developed for use in country-wide commerce, power and agriculture optimization and hazard mitigation. http://webster.eas.gatech.edu/Papers/PAKISTAN_FLOOD_WB_RPT.pdf

Building resilience for sustainable development of the Sunderbans. The Sunderbans are a highly susceptible coastal region occupying the Indian and Bangladeshi coastlines at the head of the Bay of Bengal. The cost of environmental damage and health effects in this region is as high as 10% of Sunderban's gross domestic product each year. Working with a team from the World Bank, CFAN contributed to an assessment report to support socioeconomic development and improve overall social and ecosystem resilience of the Sunderbans under future uncertain conditions.
https://openknowledge.worldbank.org/bitstream/handle/10986/20116/880610REVISED00ns000Strategy0Report.pdf?sequence=1

Scenarios of Climate Variability for the Hindu-Kush-Himalaya Region out to 2050. As part of a current (in progress) World Bank project on *Climate Impacts on the Himalayas: Aerosol-Precipitation Interaction Senstivity Analysis,* CFAN developed scenarios of climate variability for the HKH region out to 2050 that account for both natural and human caused climate change. Variability of decision relevant variables (e.g. glacier mass balance, streamflow) was determined using statistical relationships developed from large-scale circulation indices and high-resolution reanalyses. The possibility of extreme drought/monsoon failure during the period is assessed.

C. Other client-funded assessment reports

- Climate dynamics of West Pacific Typhoons and Japan Landfalls (in progress)
- Climate Change: What's the Worst Case? https://judithcurry.com/2019/08/22/climate-change-whats-the-worst-case/
- Hurricanes and Climate Change
  https://docs.wixstatic.com/ugd/867d28_32f52bbef6d24cbfb018540b6b8d60bd.pdf
- Sea Level and Climate Change
  https://docs.wixstatic.com/ugd/867d28_b238a31cc22c4d398b4a6cec0159f78d.pdf
- Projections of future U.S. landfalling hurricanes
  https://docs.wixstatic.com/ugd/867d28_8dcbe3b4b5a045c4a78a87c2d1b98891.pdf