Research Projects in the SMART CENSAM IRG
(September 1, 2015)

1. **Regional Climate Modeling and Coupled Ocean-Atmosphere Modeling of the Maritime Continent**
   The capability of hindcasting the climate of a region and of reconstructing its evolution during the last decades leading to the present conditions is the necessary prerequisite for any future projection and prediction. The best reconstructions and future projections require the use of coupled ocean/atmosphere models. Regional, two-way coupled ocean/atmosphere models incorporating the representation of groundwater dynamics are still almost non-existent and will continue to be a major focus of our research. An integrated regional climate modeling system is being improved to better predict rainfall events and a coupled ocean-atmosphere model is being improved to predict future climate scenarios over the next 20 to 40 years. Downscaled climate projection using this modeling system is essential for assessing climate change impact due to global warming.

   MIT Principal Investigator(s):
   Elfatih ELTAHIR (Civil and Environmental Engineering)
   Paola RIZZOLI (Earth, Atmospheric, & Planetary Sciences)

   Singapore Co-Investigator(s):
   Shie Yui LIONG (NUS, Tropical Marine Science Institute)
   Jen Feng YEH (NUS, Civil and Environmental Engineering)

2. **Global Climate Modeling and Processes**
   Our team aims at improving our understanding of some of the largest uncertainties in climate projections, particularly those related to anthropogenic aerosols emitted from fossil fuel and biomass burnings. We use global climate system model, high-resolution process models, and various observational data to connect local air pollution events such as Southeast Asian fires and consequent haze to regional and global climate. We also study the impacts of aerosols on the monsoon systems. In addition, the projections of future climate change produced by our global climate system model are used in regional climate modeling.

   MIT Principal Investigator(s):
   Chien WANG (Center for Global Change Science)

   Singapore Co-Investigator(s):
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   Jason COHEN (NUS, Civil and Environmental Engineering)
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3. **Simulations of the Present Climate of the Circulation of the South China Sea and Indonesian Throughflow**
   Predicting sea level rise by studying the circulation of the Indonesian system connecting the Pacific to the Indian ocean through decadal simulations of its circulation and thermal structure on different space/time scales.

   MIT Principal Investigator(s):
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   Tieh Yong KOH (NTU, School of Physical & Mathematical Sciences/Physics & Applied Physics/Mathematical Sciences)

4. **Carbon, Water and Energy Fluxes from Forested and Deforested Tropical Environments**
Tropical peat swamp forests act as modern analogues for coal deposition but now emit large fluxes of CO2 as the peat is drained for agriculture. We have developed a framework for understanding the coupled hydrologic and ecological processes that shape tropical peatlands. We have explained the historical development of one of the last remaining primary tropical peat forests at our field site in Brunei by combining groundwater flow models with hydrologic, carbon-flux, and LIDAR data. We now focussing our work in five areas: 1) complete installation of all of the meteorological equipment at the field site; 2) complete our biometric survey at the field site; and 3) complete our modeling analysis of subsurface reactive transport; 4) characterize the methanisms of methanogenisis and the pathways of methane escape; 5) develop a quantitative understanding of the ecological processes of forest growth and gene dispersion.

MIT Principal Investigator(s):
Charles HARVEY (Civil and Environmental Engineering)

Singapore Co-Investigator(s):
Theo EVANS (NUS, Biological Sciences)
Shawn LUM (NTU, Natural Sciences & Science Education)

5. **Natural and Anthropogenic Trace Elements (Pb, Zn, Fe, Cd) & Regional Climate Change**
CENSAM's investigation of marine environmental metals has used the analysis of coral samples to provide a time history of lead deposition and other metals and is now being expanded to include 1) seawater sampling for additional heavy metals and their speciation; 2) altogether new types of samples, beginning with a time series of atmospheric aerosols supplemented with spatial samples near industrial sites; 3) analysis of samples of MacRitchie and Kranji reservoir sediment cores; 4) planned sampling of runoff and reservoir lead; and 5) regional open-ocean research cruises

MIT Principal Investigator(s):
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Kerry SIEH (NTU, Earth Sciences)
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6. **Measurement and Models of the Urban Atmosphere**
We study the interactions of the built environment and the urban atmosphere, as measured or modeled by near-surface air temperature, air quality, air movement, rainfall and fluxes of sensible and latent heat and CO_2. We have developed a high-resolution mesoscale meteorological simulation of Singapore's urban environment, with an emphasis of the urban heat island (UHI) effect and the impact of land use/land cover patterns and are coupling this model to regional climate models to study the effect of future climate projections on Singapore's urban environment. We are measuring and modeling the wind environment and heat and carbon fluxes in urban neighborhoods and developing a suite of simulation tools for architects and planners to support the environmentally responsible design of buildings at this scale. We are measuring, analyzing and modeling key urban air pollutants, notably particulate matter, with the goal of identifying means to reduce their concentration.

MIT Principal Investigator(s):
Leslie NORFORD (Architecture)
Steven BARRETT (Aviation)
Rex BRITTER (Senseable City Lab)

Singapore Co-Investigator(s):
Matthias ROTH (NUS, Geography)
Tieh Yong KOH (NTU, Physics & Applied Physics)
Jianmin MIAO (NTU, Engineering Mechanics)
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7. **Online Monitoring & Modeling of Urban Infrastructures**
The overall goal of this research is to demonstrate the benefits of wireless sensor networks in monitoring and controlling urban infrastructures. During the first phase of CENSAM, the main focus has been on applications for Water Distribution Systems (WDS), done in close collaboration with PUB. The second phase include a major focus on WDS water quality and new applications for monitoring the structural health of temporary excavation support systems for underground construction projects to be done in collaboration with LTA.

MIT Principal Investigator(s):
Andrew WHITTLE (Civil and Environmental Engineering)

Singapore Co-Investigator(s):
Karina GIN (NUS, Water Quality)
Stefan WUERTZ (NTU, Singapore Centre on Environmental Life Sciences Engineering and Microbiology)
Rohan WILLIAMS (NTU, Singapore Centre on Environmental Life Sciences Engineering and Microbiology)
Sing-Ping CHIEW (NTU, Structures and Mechanics)
Jian CHU (NTU, Geotechnical-Iowa State University)

8. **Non-point Source Water Quality in Singapore's Catchments**

We are sampling stormwater drains and analysing for bacteria to understand possible sources of contamination of Singapore's surface waters. We are also studying rain gardens, also known as bioretention basins, a best management practice now being used in Singapore. We are collecting data to elucidate the chemical processes that consume phosphorus and nitrogen in the rain garden.

MIT Principal Investigator(s):
Peter SHANAHAN (Civil and Environmental Engineering)
Janelle THOMPSON (Civil and Environmental Engineering)

Singapore Co-Investigator(s):
Lloyd CHUA (NTU, Environmental & Water Resources Engineering)
Karina GIN (NUS, Civil and Environmental Engineering)

9. **Ecological Genomic Indicators for Urban Water Quality**

The molecular ecology team seeks to understand how the microbial bacterioplankton in Kranji Reservoir interact as a complex system of heterotrophic and photosynthetic populations in order to control variables relevant to water quality management, including levels of toxins, taste and odor compounds, and total biomass. Advancements in genomic technology over the past decade enable us to observe the activity of these ubiquitous microbial communities. Metagenome and metatranscriptome profiles are thus a diagnostic feature or "metabolic fingerprint" of environmental conditions and can ultimately serve as an ecosystem sensor.

MIT Principal Investigator(s):
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10. **Wave-Current-Sediment Interaction Facility**

Experiments will be conducted in the WCS to obtain data on the hydrodynamics and sediment transport rates associated with turbulent boundary layers for sinusoidal, nonlinear, and spectral waves with or without a superimposed current over a horizontal or sloping bottom. The experimental results will be used to validate or modify existing theoretical models for the hydrodynamics, e.g. movable bottom roughness, and net sediment transport rates in combined wave-current flows, and incorporate these small-scale process models in a large scale numerical model for the prediction of circulation and sediment transport in the coastal environment.

MIT Principal Investigator(s):
Ole MADSEN (Civil and Environmental Engineering)

Singapore Co-Investigator(s):
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11. Dynamics of Sediment Clouds

Our goal is to better understand near-source sediment transport and eventually propose more effective land reclamation strategies and policies in support of Singapore's continued physical growth, which now includes 25% reclaimed land. We are performing detailed laboratory experiments using a range of sediment types, volumes and release methods, and a range of ambient conditions (waves, currents and turbulence). Results are being used to develop improved integral models of sediment cloud dynamics, LES models of particle-fluid interactions, and 3-D models of far field sediment transport and fate.

MIT Principal Investigator(s):
Eric ADAMS (Civil and Environmental Engineering)

Singapore Co-Investigator(s):
Adrian LAW (NTU, Environmental & Water Resources Engineering/Civil and Environmental Engineering)

12. Biomimetic Vehicles and Sensors

We develop biomimetic vehicles, emulating the function of fast aquatic animals, and sensors: pressure, velocity, chemical and biological sensors to detect objects, plumes, wakes and flow patterns underwater, and for underwater sensing and tracking. The biomimetic sensors are then mounted on autonomous surface and underwater robotic systems (WAVES Lab). We also use computational fluid dynamics simulations to accelerate the development of energy-efficient super-maneuverable marine vehicles. Finally, we study fleets of cooperating vehicles using concepts from fish schooling.

MIT Principal Investigator(s):
Michael TRIANTAFYLLOU (Mechanical Engineering)
George BARBASTATHIS (Mechanical Engineering)

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13. Water and Air Vehicles for Environmental Sensing (WAVES Lab)

Environmental phenomena in marine environments are dynamic and can span a wide range of scales in both space and time. Our group has developed path planning and navigation control methods along with new marine vehicles (soft robots, batoid robots) that can be used to augment the capabilities of an autonomous robotic fleet. The fleet consists of vehicles with different degrees of freedom and propulsion capabilities (underwater, surface, air) equipped with environmental (physical, optical, chemical, biological) sensors as well as acoustic modems and laser scanners. Communication-constrained control for multi-vehicle systems underwater also plays an important role in the project. This fleet is used for monitoring and inspection of Singapore's coastal zone. We plan to continue our algal bloom and industrial plume surveys and start a new project using our automated fleet to monitor the water properties in the coastal waters surrounding land reclamation areas, a topic of key national interest.

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14. Imaging Underwater in Occluded and Turbid Environments

Developing high-speed holographic particle image velocimetry (PIV) instruments to acquire 3D flow data and improve visibility for optical imaging in the turbulent waters of Singapore's port. Research has concentrated on the following inter-related topics: phase retrieval, compressive sensing, and turbulence compensation. A particular direction of interest is the experimental observation of particle trajectories during diffusion from oil slicks and derivation of strategies for more effective treatment, either by dispersants or by containment via booms.

MIT Principal Investigator(s):
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15. In-Situ Chemical Sensing for Urban, Marine, Climate Monitoring

This project focuses on miniaturised in-situ water quality sensors based primarily on optical sensing. The LEDIF (LED-induced fluorescence) technology has been successfully licensed to a local startup company for commercialization. Continuing work focuses on field deployments aboard the STARFISH autonomous underwater vehicle, intended to refine the instrumentation, assist in the development of adaptive sampling methods, and gain knowledge of water quality issues of interest to Singapore and to the scientific community generally. Other work focuses on long-term monitoring of water quality, both to help manage urban water systems and to understand the carbon cycle of tropical peatlands. A new initiative is aimed at the quantification of benthic fluxes of chemicals from contaminated sediments.

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Singapore Co-Investigator(s):
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Hongwei DUAN (NTU, Chemical & Biomedical Engineering)

16. Data-Driven Predictive Modeling of Passive Algal Blooms or Chemical Spills Dispersion and Advection

Our research team aim at designing and developing novel methodologies and systems for the effective and robust monitoring and tracking of algal blooms or chemical spills using a dynamic cooperative swarm of mobile sensors coupled to a computational fluid dynamics (CFD) based data-driven predictive model. The ultimate goal is to enable the deployment of large numbers of small, inexpensive, mobile sensors that may be dynamically deployed and cooperatively positioned, to perform dynamic monitoring and cooperative simultaneous localization and mapping in inland water bodies and the coastal and ocean environment. Practically, we are developing a floating supercomputer cluster with compute nodes onboard mobile buoys capable of sensing and collectively operating, i.e. swarming. To successfully achieve these goals, we are working on the following three components: 1) Distributed CFD predictive engine, 2) Smart sensory fleet of specially-designed buoys, and 3) Multifunctional and heterogeneous swarming system.

MIT Principal Investigator(s):
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Singapore Co-Investigator(s):
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