distribution function. From this list, likelihood functions for the 500-yr and 2500-yr losses can be obtained, yielding most likely values of about 300 million dollars and 600 million, respectively, with ranges of uncertainty (10th to 90th percentile) of about 10 and 20 percent. The ordered list of non-zero losses is nearly exponentially distributed. This simple structure permits estimation, through the employment of bootstrapping with variance-reduction techniques, of the average conditional loss around several tens of times more precise than the average of the simulated losses. The model for earthquake magnitude, locations, and occurrence frequency has been taken from the US Geological Survey sources used for national hazard mapping in the central United States.

U22C-08 1745h

A Probabilistic Benefit Cost Analysis of Seismic Retrofitting of Apartment Houses in Turkey

George Deodatis[1] (+1 212-854-9728; deodatis@civil.columbia.edu); Guillermo E Franco[1] (+1 212-854-3143; franco@civil.columbia.edu); Howard Kunreuther[3] (215 898-4589; Kunreuther@wharton.upenn.edu); Hilmi Lus[2] (+90 (212) 358 15 40; hilmilus@boun.edu.tr); Nano Seeber[4] (845-365-8385; nano@ldeo.columbia.edu); Andrew W Smyth[1] (+1 212-854-3369; smyth@civil.columbia.edu)

[1]Columbia University, 500W 120th St. SW Mudd Bldg. Rm 610 MC 4709, New York, NY 10027, United States

[2]Bogazici University, School of Engineering Dept. of Civil Engineering, Istanbul 34342, Turkey

[3]University of Pennsylvania, The Wharton School 3730 Walnut St. 500 Jon M. Huntsman Hall, Philadelphia, PA 19104, United States

[4]Columbia University, Lamont-Doherty Earth Observatory, Palisades, NY 10964, United States

Three different seismic retrofitting measures for a common and vulnerable type of apartment building in Istanbul are studied in this paper. A probabilistic cost benefit analysis is carried out by means of obtaining the fragility curves of the structure in its retrofitted configurations. These curves are calculated using a Monte Carlo simulation, that is subjecting the three dimensional nonlinear model of the structure to 400 ground motion acceleration time histories compatible with the site specific elastic response spectrum. Considering a time independent probabilistic distribution of the peak ground accelerations for the region and a given discount rate, the expected losses can be estimated in present value terms for the desired time horizon. Even considering only direct losses, mitigation is shown to be cost effective for all but the very short time-horizons provided that the cost of life is far higher than the material costs. The methodology presented here is attractive for application at a regional level incorporating different types of soils and different types of structures and it may be of use to support urgent decisions on retrofitting strategies. A time dependent probability distribution of accelerations can be readily implemented in the methodology.

U31A MCC: 3016 Wednesday 0800h

Health, Air Pollution, and Climate I

Presiding: **T Holloway,** Gaylord Nelson Institute for Environmental Studies, University of Wisconsin-Madison**; G McKinley,** Princeton University

U31A-01 0800h

Overview of Issues in Health, Air Pollution, and Climate

Tracey Holloway[1] (608 262 5356; taholloway@wisc.edu)

Galen McKinley[2] (galen@alum.mit.edu)

[1]University of Wisconsin-Madison, Gaylord Nelson Institute for Environmental Studies/SAGE 1710 University Ave., Rm 201A, Madison, WI 53726, United States

[2]Princeton University, Atmospheric and Oceanic Sciences Program, Princeton, NJ 08540, United States

Air pollution contributes to mortality and respiratory disease worldwide, with developing countries at highest risk. The World Health Organization estimates that between 1.4 and 6 million people die each year from air pollution, and in some populations up to 30 % of all respiratory disease may be linked to air pollution. As the climate changes, increasing temperatures and changing precipitation patterns are expected to yield new health challenges and may worsen existing risks. This talk provides an overview of issues linking health impacts of air pollution and climate change, as an introduction for the session. Increasingly, health-driven projects are employing state-of-the-art modeling and measurement methodologies. We discuss how quantitative assessment methodologies have been used to understand the connections between health, air pollution and climate.

U31A-02 0820h INVITED

Health Impacts of Air Pollution Under a Changing Climate

Patrick L Kinney[1] (212-305-3663; plk3@columbia.edu); Kim Knowlton[1]; Joyce Rosenthal[1]; Christian Hogrefe[2]; Cynthia Rosenzweig[3]; William Solecki[4]

[1]Columbia University, Mailman School of Public Health, Department of Environ Health Sci,60 Haven Ave., B-1, New York, NY 10032, United States

[2]Atmospheric Sciences Research Center, State University of NY, 625 Broadway, Albany, NY 12233-3259

[3]NASA-Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025

[4]Hunter College, 695 Park Avenue, New York, NY 10021

Outdoor air pollution remains a serious public health problem in cities throughout the world. In the US, despite considerable progress in reducing emissions over the past 30 years, as many as 50,000 premature deaths each year have been attributed to airborne particulate matter alone. Tropospheric ozone has been associated with increased daily mortality and hospitalization rates, and with a variety of related respiratory problems. Weather plays an important role in the transport and transformation of air pollution. In particular, a warming climate is likely to promote the atmospheric reactions that are responsible for ozone and secondary aerosol production, as well as increasing emissions of many of their volatile precursors. Increasingly, efforts to address urban air pollution problems throughout the world will be complicated by trends and variability in climate. The New York Climate and Health Project (NYCHP) is developing and applying tools for integrated assessment of health impacts from air pollution and heat associated with climate and land-use changes in the New York City metropolitan region. Global climate change is modeled over the 21st century based on the Intergovernmental Panel on Climate Change (IPCC) A2 greenhouse gas emissions scenario using the Goddard Institute for Space Studies (GISS) Global Atmosphere-Ocean Model (GCM). Meteorological fields are downscaled to a 36 km grid over the eastern US using the Penn State/NCAR MM5 mesoscale meteorological model. MM5 results are then used as input to the Community Multiscale Air Quality (CMAQ) model for simulating air quality, with emissions based on the Sparse Matrix Operator Kernel Emissions Modeling System (SMOKE). To date, simulations have been performed for five summer seasons each during the 1990s and the 2050s. An evaluation of the present-day climate and air quality predictions indicates that the modeling system largely captures the observed climate-ozone system. Analysis of future-year predictions shows an increase in temperature and humidity as well as mean and extreme ozone concentrations under the IPCC A2 emission scenario. To address public health impacts, a risk assessment framework is used to estimate ozone-related mortality in the region, with a focus on comparing health impact estimates for the 1990s versus the 2050s. This endpoint represents a potentially appreciable public health impact resulting from climate change-induced alterations in regional air quality profiles. Concentration-response functions from the epidemiological literature describing ozone-mortality relationships are used to estimate numbers of regional deaths in a typical 1990s summer and a typical 2050s summer. Preliminary analysis of future-year ozone-related mortality suggests a subtle increase in the number of summer ozone-related deaths in the New York region in the 2050s as compared to the 1990s. A parallel evaluation of heat-related mortality in a typical summer of the 2050s suggests a greater relative increase as compared to the 1990s, with a doubling to tripling of regional summer heat deaths possible by the 2050s.

U31A-03 0845h INVITED

Greenhouse Gas and Particulate Emissions and Impacts from Cooking Technologies in Africa

Daniel M. Kammen[1,2] (510-642-1139; kammen@socrates.berkeley.edu)

Robert Bailis[1] (510-642-1640; rbailis@socrates.berkeley.edu)

Evans Kituyi[3] ((254-2) 524000; e.kituyi@cgiar.org)

Majid Ezzati[4] (617-432-5722; mezzati@hsph.harvard.edu)

[1]Energy and Resources Group, University of California, Berkeley, CA 94720-3050, United States

[2]Goldman School of Public Policy, University of California, Berkeley, CA 94720-3050, United States

[3]African Center for Technology Studies & University of Nairobi, P.O. Box 45917, Nairobi 45917, Kenya

[4]Harvard School of Public Health, 677 Huntington Avenue, Boston, MA 02115, United States

In much of Africa, the largest fraction of energy consumption occurs within the residential sector and is derived primarily from woodfuels burned in simple stoves with poor combustion characteristics. Many of the products of incomplete combustion (PICs) are damaging to human health, particularly when they are concentrated in poorly ventilated indoor environments. Incomplete combustion also has potentially harmful impacts on the climate. Prevalent PICs include methane, a potent greenhouse gas (GHG) that is among the pollutants subject to controls under the Kyoto Protocol as well as carbon monoxide (CO), non-methane hydrocarbons (NMHCs) and particulate matter (PM), which can all have an effect on climate, but are not subject to controls under Kyoto. In addition, when woodfuels are used at a rate that reduces standing stocks of trees over the medium or long term, the CO2 released by combustion also has an impact. The choice of stove and fuel technology can have a significant impact on the emission of GHGs as well as on human exposure to health damaging pollutants. In this paper we analyze the emissions of different household energy technologies on a life-cycle basis. We use emission factors to estimate the emissions associated with production, distribution and end-use of common household fuels and assess the likely impacts of these emissions on public health and the global environment. We focus largely on charcoal, a popular fuel in many sub-Saharan African countries. Charcoal is produced by heating wood in the absence of sufficient air for complete combustion to occur. This process removes moisture and most of the volatile compounds. The compounds driven off in the process consist of condensable tars as well as many gaseous hydrocarbons, including 40 g CH4 per kg of charcoal produced. Combining upstream and end-use emissions, every meal cooked with charcoal has 2-10 times the global warming effect of cooking the same meal with firewood and 5-12 times the effect of cooking the same meal with LPG or kerosene. When charcoal is produced in large quantities, as it is in Africa, the net warming effect can exceed the impact from the "modern energy sector" (transportation and industry) by 50-100 percent, even if charcoal is produced on a sustainable cycle so that all of the wood harvested for charcoal production is allowed to regenerate. However, while charcoal may be worse than firewood with respect to greenhouse gas emissions, it is an improvement with respect to exposure to health damaging pollutants, particularly particulate matter (PM). Levels of PM in households using charcoal are over 90 percent lower than households using open wood fires (316 -(159) mg/m3 for households using charcoal in a common improved stove compared to 3764 (360) mg/m3) for households using wood in open fires: mean (standard error)). These differences in exposure are consistent with 30 and 50 percent reductions in the incidence of acute respiratory infection (ARI) in adults and children under 5 respectively. Reconciling the costs and benefits of different household energy technologies creates a difficult policy challenge, particularly with the severe budgetary and resource constraints that household consumers and government agencies face in sub-Saharan Africa.

URL: http://socrates.berkeley.edu/~rael

U31A-04 0910h

Climate Change, Air Pollution, and the Economics of Health Impacts

John Reilly[1] (jreilly@mit.edu); Trent Yang[1] (ttyang@mit.edu); Sergey Paltsev[1] (paltsev@mit.edu); Chien Wang[1] (wangc@mit.edu); Ronald Prinn[1] (rprinn@mit.edu); Marcus Sarofim[1] (msarofim@mit.edu)

[1]Massachusetts Institute of Technology, 77 Massachusetts Ave E40-433, Cambridge, MA 02466, United States

Climate change and air pollution are intricately linked. The distinction between greenhouse substances and other air pollutants is resolved at least for the time being in the context of international negotiations on climate policy through the identification of CO2, CH4, N2O, SF6 and the per- and hydro- fluorocarbons as substances targeted for control. Many of the traditional air pollutant emissions including for example

CO, NMVOCs, NOx, SO2, aerosols, and NH3 also directly or indirectly affect the radiative balance of the atmosphere. Among both sets of gases are precursors of and contributors to pollutants such as tropopospheric ozone, itself a strong greenhouse gas, particulate matter, and other pollutants that affect human health. Fossil fuel combustion, production, or transportation is a significant source for many of these substances. Climate policy can thus affect traditional air pollution or air pollution policy can affect climate. Health effects of acute or chronic exposure to air pollution include increased asthma, lung cancer, heart disease and bronchitis among others. These, in turn, redirect resources in the economy toward medical expenditures or result in lost labor or non-labor time with consequent effects on economic activity, itself producing a potential feedback on emissions levels. Study of these effects ultimately requires a fully coupled earth system model. Toward that end we develop an approach for introducing air pollution health impacts into the Emissions Prediction and Policy Analysis (EPPA) model, a component of the MIT Integrated Global Systems Model (IGSM) a coupled economics-chemistry-atmosphere-ocean-terrestrial biosphere model of earth systems including an air pollution model resolving the urban scale. This preliminary examination allows us to consider how climate policy affects air pollution and consequent health effects, and to study the potential impacts of air pollution policy on climate. The novel contribution is the effort to endogenize air pollution impacts within the EPPA model, allowing us to study potential economic effects and feedbacks. We find strong interaction between air pollution and economies, although precise estimates of the effects require further investigation and refined resolution of the urban scale chemistry model.

U31A-05 0925h

Local benefits of greenhouse gas mitigation in Mexico City

Galen McKinley[1] (609 258 6571; galen@alum.mit.edu); Miriam Zuk[1] (5255 5524 5402; mzuk@alum.mit.edu); Morten Hojer[1] (mhoejer@hotmail.com); Monserrat Avalos[1]; Isabel Gonzalez[1]; Rodolfo Iniestra[1]; Israel Laguna[1]; Miguel Angel Martinez[1]; Patricia Osnaya[1]; Luz Miriam Reynales[2]; Raydel Valdes[2]; Julia Martinez[1] (jmartine@ine.gob.mx)

[1]Instituto Nacional de Ecologia, Periferico 5000, piso 4, Mexico, DF 04530, Mexico

[2]Instituto Nacional de Salud Publica, Ave. Universidad #655, Cuernavaca, MOR 62508, Mexico

For Mexico City, we estimate public health improvements due to air pollution reductions that could occur simultaneously with greenhouse gas emission mitigation, and we compare the costs and benefits of 5 specific policy measures. Reduced-form air quality models are used to calculate the impacts of changed emissions on exposure. Dose-response methodology is applied to estimate public health improvements, and several valuation metrics are applied to determine the monetized health benefits to society of the control measures. Implementation of these 5 measures in Mexico City could reduce annualized exposure to particulate air pollution by 1% and to maximum daily ozone by 3%, and also reduce greenhouse gas emissions by 2% (more than 300,000 tons C equivalent per year). We estimate that over 4400 quality-adjusted life-years (QALYs) per year could be saved, with monetized health benefits on the order of $200 million USD per year. In contrast, total costs are under $70 million USD per year. The mean cost per QALY is under $40,000. Of the measures considered, those that improve transportation efficiency are most promising for the simultaneous reduction of local and global pollution in the region.

URL: http://www.ine.gob.mx/dgicurg/cclimatico/benlg.html

U31A-06 0945h

A Synoptic Climatological Approach to Assess Possible Impacts of Climate Change on Human Mortality in South Central Canada

Chad Shouquan Cheng[1] ((416) 739-4642; shouquan.cheng@ec.gc.ca); Joan Klaassen[1]; Heather Auld[1]; Guilong Li[2]; Qian Li[2]; Monica Campbell[2]; Nancy Day[2]; David Pengelly[3]

[1]Meteorological Service of Canada - Ontario Region Environment Canada, 4905 Dufferin Street, Downsview, ON M3H 5T4, Canada

[2]Public Health Department City of Toronto, 277 Victoria Street 7th Floor, Toronto, ON M5B 1W2, Canada

[3]Department of Medicine McMaster University, 99 Turnbull Road, Dundas, ON L9H 5R9, Canada

Synoptic climatological approaches were used in this study to determine the synergistic impacts of severe weather and air pollution on excess mortality risks in south-central Canada. The derived relationships based on the past and current conditions were then used to determine the potential impacts of climate change on human mortality risks. This study used principal components analysis, an average linkage clustering procedure, and discriminant function analysis to automatically classify distinctive synoptic categories based on the differentiations and similarities of meteorological characteristics between and within weather types. Meteorological data for 1953-2001 were used in the analyses. The data included hourly surface observations of air temperature, dew point temperature, sea-level air pressure, total cloud cover, wind speed and direction. Three atmospheric levels of 6-hourly NCEP-NCAR upper-air reanalysis weather variables (air and dew point temperatures, wind speed and direction) were used for the period 1958-2000. Air pollution data, including O3, SO2, NO2, CO and COH, was retrieved from the National Air Pollution Surveillance (NAPS) network for the period 1974-2000. Mortality data from Statistics Canada included the daily total non-traumatic mortality (e.g., ICD-9: 001-799) for the period 1950-1998. The study area included 3 cities in Ontario (Toronto, Ottawa and Windsor) and 1 city in Quebec (Montreal). Using the above procedures, 14-20 major synoptic types were identified for the selected weather stations during both warm (Apr.-Sep.) and cold seasons (Oct.-Mar.). The statistical procedure was able to successfully identify 8-12 weather types (depending upon location), that were associated with high mortality rates. Excess mortality within the identified synoptic weather types were shown to be associated with temperature extremes (heat and cold) and air pollution. Using GCM outputs and statistical downscaling methods, discriminant function analysis was then used to estimate the projected frequencies of excess mortality-related weather types for future climate scenarios. Climate change scenarios from the Canadian GCMs (CGCM1 and CGCM2) and the U.S. GCM (GFDL R30 Coupled Climate Model) for the periods 2040-2059 and 2070-89 were used in the analysis. For estimation of the future air pollution conditions, there are two methods: 1) discriminant function analysis is able to assess the projected frequencies of weather types associated with high air pollution concentrations for the future climate change scenarios; 2) the downscaled climate change scenarios were applied to the historical regression models to estimate the future projected concentrations. The expected mortality rates due to modeled global warming and pollutant effects for both warm and cold seasons can then be estimated for the selected cities.

U31B MCC: Level 1 Wednesday 0830h

Recent Infrasound Studies, Phenomena, and Development I Posters

Presiding: **C Wilson,** Geophysical Institute, University of Alaska, Fairbanks**; L Liszka,** Swedish Institute of Space Physics

U31B-0001 0830h POSTER

Infrasound Signals from the Space Shuttle Columbia

Eugene T Herrin[1] (herrin@passion.isem.smu.edu)

Petru T Negraru[1] (negraru@passion.isem.smu.edu)

Mihan Mckenna[1] (smckenna@mail.smu.edu)

[1]Southern Methodist University, PO Box 7503975, Dallas, TX 75275

Infrasound signals from the shuttle Columbia were observed at the TXAR infrasound array on 1 February 2003. TXAR is in far Southwest Texas about 6oo km south of the shuttle's track across the panhandle of Texas. The signals were compared with those from STS 78 (7 July 1996) which had on almost identical track to Columbia (STS 107). Whereas the STS 78 signals had the characteristics of acoustic arrivals from a decaying N-Wave, the signals from STS 107 showed a number of sharp peaks superimposed on a background similar to the STS 78 data. Using a cross-correlation method, we estimated the back azimuths for eight of the peaks, and they agreed within $\pm$1 degree. We thus concluded that the peaks were multiple arrivals from a single explosive source. By crossing the mean back azimuth with the well known track of STS 107 we were able to determine the following parameters for the explosion. Location : 33.85 N, 101.92 W $\pm$20 km Time: 13 56.65 Z $\pm$ 0.1 min Height: 63.3 km Speed: Mach 16. Z Having the source location and time we were able to simulate the signals expected at TXAR using the InfraMAP program from BBN. This simulation showed arrivals that agreed with several of the observed impulsive signals to within a few seconds out of a total travel time of about 2000 seconds. The yield of the explosion was estimated using on AFTAC empirical formula based upon the dominant period of the signals, corrected for the elevation of 63.3 km. The estimated yield is 2 lbs. (0.9 kgm) HE (TNT). Because the signal to noise ratios for the observed arrivals at TXAR were large, we conclude that rocket experiments at White Sands involving explosions with yields of the order of 10 lbs at a height of 60 km should provide controlled infrasound sources that could be observed at a number of infrasound arrays.

U31B-0002 0830h POSTER

Seismo-acoustics, VLP and ULP signals, and other comparisons of surface broadband and CALIPSO borehole data at Soufriere Hills Volcano, Montserrat, B.W.I.

Dannie Hidayat[1] ((814) 865-6720; hidayat@geosc.psu.edu); B Voight[1] (voight@ems.psu.edu); G Mattioli[2]; S R Young[1]; A T Linde[3]; I S Sacks[3]; P E Malin[4]; E Shalev[4]; D Elsworth[1]; C Widiwijayanti[1]; R Herd[5]; G Thompson[5]; V Bass[5]

[1]Dept. of Geosciences, Penn State University, 542 Deike Bldg, University Park, PA 16802, United States

[2]Dept. of Geosciences, University of Arkansas, 113 Ozark Hall, Fayatteville, AR 72701, United States

[3]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington, DC 20015, United States

[4]Division Earth/Ocean Sciences, Duke University, 109A Old Chemistry, Durham, NC 27708, United States

[5]Montserrat Volcano Observatory, Fleming, Montserrat 1600, Montserrat

Project CALIPSO (Caribbean Andesite Lava Island-volcano Precision Seismo-geodetic Observatory) investigates with borehole and surface instruments the magmatic system at the very active Soufriere Hills Volcano (SHV), Montserrat, supplementing surface monitoring systems of the Montserrat Volcano Observatory, and those of other institutions including PSU and U Ark. Many aspects of andesitic magmatic system dynamics remain little understood despite significant monitoring and research efforts, and CALIPSO is expected to improve our understanding of SHV and of andesitic magmatic systems generally. As an example of such studies, we examine data from the 12-13 July 2003 major lava dome collapse and eruption of SHV. The analyses illustrate the opportunity to evaluate seismic and volumetric strain signals in very-long period (VLP, $\sim$10 s) and ultra-long period (ULP, $\sim$100 s) ranges, as well as the long period (LP, $\sim$1 s) and short period ($\sim$0.1 s) ranges typically considered. The strainmeters act as very-broad-band instruments, and not only detect quasi-static strain changes, but also dynamic strains equivalent to the response of a volumetric seismometer from high frequencies to ULP. Waveforms from several broadband seismometers and three strainmeters installed around the volcano indicate VLP and ULP signals in association with the explosive events. Additional information is derived from infrasonic microphones installed at two PSU surface broadband stations prior to the July 2003 events. Combining information from infrasonic pressure waves in the air with broadband seismicity and dynamic strain aids understanding of eruption dynamics and the physical eruptive processes.

U31B-0003 0830h POSTER

Observed dispersion curves of long period atmospheric acoustic waves

Kiwamu Nishida[1] (knishida@eri.u-tokyo.ac.jp); Yoshio Fukao[1]; Shingo Watada[1]; Naoki Kobayashi[2]; Makoto Tahira[3]; Naoki Suda[4]; Kazanari Nawa[5]

[1]ERI, Univ. of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan

[2]EPS, Tokyo Inst. of Tech., 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551, Japan

[3]Aichi Univ. of Edu., 1 Hirosawa, Igaya-cho, Kariya 448-8545, Japan

[4]Hiroshima Univ., 1-3-1 Kagami-yama, Higashi-Hiroshima 739-8526, Japan

[5]AIST, Tsukuba Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan

Recently some groups reported Earth's background free oscillations even on seismically quiet days [e.g.