US EPA ARCHIVE DOCUMENT

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

OFFICE OF CHEMICAL SAFETY AND POLLUTION PREVENTION

March 3, 2011

MEMORANDUM

SUBJECT: Transmittal of Meeting Minutes of the FIFRA Scientific Advisory Panel Meeting held December 7, 2010 on Pesticide Exposure Modeling and Climate Change

TO: Steven Bradbury, Ph.D.
Director
Office of Pesticide Programs

FROM: Fred Jenkins, Jr., Ph.D.
Designated Federal Official
FIFRA Scientific Advisory Panel
Office of Science Coordination and Policy

THRU: Laura Bailey, M.S.
Executive Secretary
FIFRA Scientific Advisory Panel
Office of Science Coordination and Policy

Frank Sanders
Director
Office of Science Coordination and Policy

Attached, please find the meeting minutes of the FIFRA Scientific Advisory Panel open meeting held in Arlington, VA on December 7, 2010. This report addresses a set of scientific issues associated with Pesticide Exposure Modeling and Climate Change.

Enclosure

cc:

Stephen Owens
James J. Jones
William Diamond
William Jordan
Vicki Dellarco
Margie Fehrenbach
Keith Matthews
Donald Brady
Jack Housenger
Tina Levine
Joan Harrigan-Farrelly
Lois Rossi

Richard Keigwin
Richard Dumas
Joel Scheraga
Christine Olinger
Kelly O'Rourke
Faruque Khan
Enesta Jones
Douglas Parsons
Vanessa Vu
OPP Docket

FIFRA Scientific Advisory Panel Members

Steven Heeringa, Ph.D. (FIFRA SAP Chair)
Kenneth Portier, Ph.D. (Session Chair)
Janice Chambers, Ph.D., DABT, Fellow ATS
Daniel Schlenk, Ph.D.

FQPA Science Review Board Members

Alistair Boxall, Ph.D.
Jeffrey P. Fisher, Ph.D.
Karen Garrett, Ph.D.
Chensheng Lu, Ph.D.
Robert Peart, Ph.D.
Thomas Peterson, Ph.D.
Thomas L. Potter, Ph.D.
James C. Randolph, Ph.D.
Geoffrey Scott, Ph.D.

SAP Minutes No. 2011-01

A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding:

Pesticide Exposure Modeling and Climate Change

December 7, 2010
FIFRA Scientific Advisory Panel Meeting
Held at the
Hyatt Regency Crystal City at Reagan National Airport
Tidewater Room
2799 Jefferson Davis Highway
Arlington, VA 22202, USA

NOTICE

These meeting minutes have been written as part of the activities of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Scientific Advisory Panel (SAP). The meeting minutes represent the views and recommendations of the FIFRA SAP, not the United States Environmental Protection Agency (Agency). The content of the meeting minutes does not represent information approved or disseminated by the Agency. The meeting minutes have not been reviewed for approval by the Agency and, hence, the contents of these meeting minutes do not necessarily represent the views and policies of the Agency, nor of other agencies in the Executive Branch of the Federal Government, nor does mention of trade names or commercial products constitute a recommendation for use.

The FIFRA SAP is a Federal advisory committee operating in accordance with the Federal Advisory Committee Act and established under the provisions of FIFRA as amended by the Food Quality Protection Act (FQPA) of 1996. The FIFRA SAP provides advice, information, and recommendations to the Agency Administrator on pesticides and pesticide-related issues regarding the impact of regulatory actions on health and the environment. The Panel serves as the primary scientific peer review mechanism of the Environmental Protection Agency, Office of Pesticide Programs (OPP), and is structured to provide balanced expert assessment of pesticide and pesticide-related matters facing the Agency. FQPA Science Review Board members serve the FIFRA SAP on an ad hoc basis to assist in reviews conducted by the FIFRA SAP. Further information about FIFRA SAP reports and activities can be obtained from its website at http://www.epa.gov/scipoly/sap/ or the OPP Docket at (703) 305-5805. Interested persons are invited to contact Fred Jenkins, Jr., Ph.D., SAP Designated Federal Official, via e-mail at jenkins.fred@epa.gov.

In preparing these meeting minutes, the Panel carefully considered all information provided and presented by EPA, as well as information presented by public commenters.

TABLE OF CONTENTS

SAP Minutes No. 2011-01

A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding:

Pesticide Exposure Models and Climate Change

December 7, 2010
FIFRA Scientific Advisory Panel Meeting
Held at the
Hyatt Regency Crystal City at Reagan National Airport in
Arlington, VA

Kenneth M. Portier, Ph.D.	**Fred Jenkins Jr., Ph.D.**
FIFRA SAP Session Chair	**Designated Federal Official**
FIFRA Scientific Advisory Panel	**FIFRA Scientific Advisory Panel**
Date: MAR 03 2011	**Date:** MAR 03 2011

Federal Insecticide Fungicide and Rodenticide Act
Scientific Advisory Panel Meeting
December 7, 2010

PARTICIPANTS

FIFRA SAP Chair

Steven G. Heeringa, Ph.D., Research Scientist & Director for Statistical Design, University of Michigan, Institute for Social Research, Ann Arbor, MI

FIFRA SAP Session Chair

Kenneth M. Portier, Ph.D., Program Director, Statistics, American Cancer Society, National Home Office, Atlanta, GA

Designated Federal Official

Fred Jenkins, Jr., Ph.D., FIFRA Scientific Advisory Panel, Office of Science Coordination and Policy, EPA

FIFRA Scientific Advisory Panel Members

Janice Chambers, Ph.D., DABT, Fellow ATS, Director, Center for Environmental Health Sciences, College of Veterinary Medicine, Mississippi State University, Mississippi State, MS

Daniel Schlenk, Ph.D., Professor of Aquatic Ecotoxicology and Environmental Toxicology, Department of Environmental Sciences, University of California, Riverside, CA

FIFRA Science Advisory Board Members

Alistair Boxall, Ph.D.
Reader, Environment Department, University of York Heslington
York, UK

Jeffrey P. Fisher, Ph.D.
Principal, ENVIRON, Seattle, WA

Karen Garrett, Ph.D.
Professor, Department of Plant Pathology, Kansas State University, Manhattan, KS

Chensheng Lu, Ph.D.
Assistant Professor, Department of Environmental Health Exposure, Epidemiology, and Risk Program, Harvard School of Public Health, Harvard University, Boston, MA

Robert Peart, Ph.D.
Graduate Research Professor Emeritus, Department of Agricultural Engineering, University of Florida, Gainesville, FL

Thomas Peterson, Ph.D.
Chief Scientist, NOAA's National Climatic Data Center, Asheville, NC

Thomas L. Potter, Ph.D.
Research Chemist, USDA-Agricultural Research Service, Southeast Watershed Research Laboratory, Tifton, GA

James C. Randolph, Ph.D.
Professor and Director, School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana

Geoffrey Scott, Ph.D.
Director of NOAA, National Ocean Service, Center for Coastal Environmental Health & Biomolecular Research, Charleston, SC

INTRODUCTION

The Federal Insecticide, Fungicide and Rodenticide Act Scientific Advisory Panel (FIFRA SAP) has completed its review of a set of scientific issues associated with Pesticide Exposure Modeling and Climate Change. Advance notice of the meeting was published in the *Federal Register* on September 29, 2010. The review was conducted in an open Panel meeting held in Arlington, VA on December 7, 2010. Dr. Kenneth M. Portier chaired the meeting and Dr. Fred Jenkins, Jr. served as the Designated Federal Official.

EPA assesses pesticide exposure to people from the food and water they consume and from the pesticides they use or otherwise come in contact with in and around the home, public areas and occupational settings. EPA also assesses environmental exposure to terrestrial and aquatic species. In assessing exposures to pesticides, EPA uses many peer reviewed models and methodologies.

The Agency recognizes that climate change will affect parts of its core mission. To achieve its core mission, the Office of Pesticide Programs' (OPP) assessment methodologies must continue to provide high quality science-based predictions of the risks from exposure to pesticides. OPP is in the early stages of examining how well existing assessment tools may perform in light of climate change and if any modifications are needed to respond to changes in climate. OPP's initial effort was to examine its exposure models.

OPP reviewed most of its human and ecological exposure assessment models for conventional pesticides to evaluate which inputs and parameters may be affected by changing climatic conditions. To illustrate the approach used for considering the potential effects of climate change on the modeling exposure estimates, OPP selected two of its models that address human exposures and one model that addresses ecological exposures as case studies. OPP reached some preliminary conclusions based on their review of these case studies.

The purpose of this consultation was to seek the SAP's advice on OPP's: 1) approach used to examine exposure model performance in light of climate change, 2) preliminary conclusions resulting from the Agency's review of the models, and 3) sources of information that may inform identified knowledge gaps.

Opening remarks at the meeting were provided by Steven Bradbury, Ph.D., OPP Director. United States Environmental Protection Agency (EPA) presentations were given by Richard Dumas of the OPP Pesticide Re-Evaluation Division, Joel Scheraga, Ph.D., Senior Advisor for Climate Adaptation of the Office of Policy, Christine Olinger and Kelly O'Rourke of the OPP Health Effects Division, and Faruque Khan, Ph. D. of the OPP Environmental Fate and Effects Division. Presentations were also given by Margaret Walsh, Ph.D. of the Climate Change Program Office in the United States Department of Agriculture (USDA), and C. Ben Beard, Ph.D., Associate Director for

Climate Change National Center for Emerging and Zoonotic Infectious Diseases in the Center for Disease Control (CDC).

PUBLIC COMMENTS

Oral Statements were presented as follows:

Craig Segall on behalf of the Sierra Club

Stuart Z. Cohen, Ph.D. on behalf of Environmental and Turf Services, Inc.

Michael Fry, Ph.D. on behalf of the American Bird Conservancy

Written Statements were provided by:

Craig Segall on behalf of the Sierra Club

Stuart Z. Cohen, Ph.D. on behalf of Environmental and Turf Services, Inc.

Summary of Panel Discussion and Recommendations

Charge Issue 1. OPP's approach

The Panel concurred that OPP's approach was a reasonable first step to initiate the evaluation of the potential impact of climate change on pesticide exposure modeling. However, several recommendations were provided for the Agency to consider. For human dietary exposure modeling, the panel recommended that OPP evaluate the performance of the Dietary Exposure Evaluation Model (DEEM™) using residue data from recent years to examine whether the model outputs coincide with pesticide use patterns that may have changed as a result of climate change. For human exposure in occupational settings, the panel advised OPP to reconsider its conclusion that handler exposure is unaffected by climate particularly considering that handler usage of Personal Protective Equipment (PPE) may be impacted by climate change as a result of either increasing frequency of pesticide applications, decreasing intervals between applications within a short period of time, and worker discomfort during periods of high heat stress.

Concerning the ecological exposure modeling, the Panel noted the Agency's focus on how existing ecological exposure models may be impacted by climate change assumes that key environmental exposure pathways and processes will remain the same in the future. The Panel explained that this assumption may not be true and recommended that the Agency expand its focus to consider two questions: 1) 'How could ecological and human exposure pathways change under climate change?', and 2) 'Do the current models adequately address exposure routes and fate and transport processes likely to be affected?'

The Panel provided several recommendations for the Agency to consider in addressing the aforestated questions. They especially highlighted a conceptual model framework that was developed by the National Oceanic and Atmospheric Administration (NOAA) which entailed a four tiered strategy for assessing how climatic changes may impact ecological risks posed by environmental contaminants associated with urbanization.

Charge Issue 2. Temporal and Spatial Considerations

For temporal considerations associated with climate change, the Panel concluded that evaluating climate change projections over a 15 year timeframe would add little value. This conclusion was based upon the premise that a projected 15 year time period in climate change modeling is regarded as a "short term" time span. Such short term climate change projections typically contain a high degree of uncertainty. Uncertainty decreases with increasing time projections, and the accuracy of climate change projections become more reliable as a 100 year time period is approached. As explained by the Panel, if pesticide exposure assessments incorporate climate change projections which entail 15 year incrementally progressive periods (e.g., 15 years, 30 years, 45 years, 60 years, 75 years, 90 years, 105 years, etc...), the accuracy of the climate change projections is expected to increase with each progressive 15 year time interval.

In regards to spatial and geographical climate change considerations, the Panel concluded that over the next (at a minimum) 20 years temperature change will occur fairly uniformly for all regions of the U.S. However, for anticipated geographic changes in precipitation, the Panel concluded that the 20 year projection for future precipitation (which is considered to be a short term projection) is highly uncertain due to the relative importance of variations in the climate system such as the North Atlantic Oscillation over such short periods. The Panel reiterated that uncertainty decreases for longer term projections. However, it was noted that there is an ongoing nationwide precipitation trend of increased heavy precipitation events. This nationwide trend is certainly expected to continue over the short and long term.

The Panel also recommended that the Agency explore the use and development of geographically and spatially based crop models that could predict the effects of climate change on when and where pests and diseases occur and whether a pesticide will be applied. A panel member recommended consideration of probabilistic (stochastic) models rather than only deterministic models, so that the likelihood of different scenarios can be evaluated.

Charge Issue 3. Agency's Use of Historic Data

It is the recommendation of the Panel that the Agency systematically enhance utilization of data produced by USDA's Pesticide Data Program (PDP) to determine whether pesticide residues on agricultural commodities in the U.S. food supply are impacted by climate change (e.g., increases in temperature and precipitation events). This recommendation was provided on the premise that pesticide residues on agricultural commodities may increase because of an increase in pesticide application rates and/or application frequency in certain crops due to climate change.

When historic data are used to evaluate the potential influence of climate change on ecological exposure model outputs, the Panel concluded that existing models may not incorporate algorithms that account for changes in processes that are likely to occur. The Panel elaborated that it is possible that set variables (e.g., crop and soil parameters) used in existing exposure models may no longer be appropriate in the future or that climate driven changes in agricultural systems will fall outside the prediction space of embedded equations. For example, kinetic equations used to describe pesticide dissipation rates in soil, on plant tissues, and various other surfaces, are typically based on pseudo-first-order kinetics with kinetic rate data reported as the half-life of the active ingredient. Because changes in temperature and rainfall patterns may increase dissipation rates, the Panel suggested that alternate kinetic models may be required to more accurately predict dissipation processes, and they suggested that adjustments to kinetic rate constants may be needed. The Panel also recommended that the Agency evaluate the significance of climate change on the reliability of the model parameters by performing a sensitivity analysis on all relevant parameters in the environmental exposure models utilized by OPP.

Regarding historical weather data use in pesticide exposure modeling, the Panel concluded that the 1960-1990 weather data currently used by the Agency is less reliable than using the most recent data available. Additionally, the Panel advised the Agency that using an aggregation of 1960-2010 weather data to predict future weather would be less accurate than using a "Normal" of a more recent aggregate weather data such as 1980-2010. A "Normal" is defined as a set of the averages of climatological data computed for any period of at least ten years starting on 1 January of a year ending with the digit 1 (The World Meteorological Organization, 2007). The Panel recommended a methodology called "Optimal Climate Numbers" (OCN) as a means of developing normal data sets to be utilized in support of the Agency's consideration of how climate change impacts pesticide exposure modeling.

Charge Issue 4. Agency's Priority Setting

The Panel identified two main areas that the Agency should explore in setting priorities for evaluating how pesticide dietary exposure may be impacted by climate change. They include: 1) using USDA PDP data to determine pesticide residues on food commodities that are commonly consumed and likely to be affected by climate change, and 2) incorporating into pesticide risk assessments consideration of new agricultural technologies designed to combat the increased pest pressures caused by climate change.

In reference to the ecological exposure models, the Panel recommended that the Agency explore the following questions: 1) Are key exposure routes which are likely to occur in the future covered by existing frameworks?; 2) What are the key input parameters that will be affected, and how will they vary spatially across regions where significant climate change is likely?, and 3) Are process algorithms inadequate for addressing anticipated changes in climate?

PANEL DELIBERATIONS AND RESPONSE TO CHARGE

Question 1. OPP is seeking guidance on its approach to climate change to date and suggestions for how to approach future work.

a. Comment on the approach that OPP used to evaluate the models in light of the expected likely effects and impacts of climate change to determine whether climate change would influence the inputs and parameters.

Panel Response to the Human Dietary and Occupational Exposure Case Studies

The Panel concluded that OPP's approach to evaluate the influence of climate change on pesticide exposure modeling estimates is a reasonable first step. They further elaborated that an important underlying issue is whether or not OPP's human pesticide exposure models, such as DEEM™, are adequate and sensitive enough to capture the fluctuations of pesticide residues in foods and in occupational settings, as a result of climate change.

The Panel suggested that regardless of which dietary model is used by OPP, pesticide residues in or on foods are likely to be the most important model input affected by climate change. They also suggested that OPP re-evaluate the characteristics of available pesticide residue data, which should take into account temporal and spatial variations of pesticide use patterns nationwide as a result of climate changes. For instance, as crop hardiness zones move northward (apparently as a result of climate changes), more pesticides, both the types and amounts needed for crop production in northern states, are likely to change. If this scenario holds true, OPP should evaluate the performance of DEEM™ using residue data from recent years to examine whether the model outputs coincide with actual pesticide use patterns.

The Panel also explained that another uncertainty associated with the dietary exposure modeling is the food consumption input parameter. A concern was raised in prior SAP meetings (October 2009 and July 2010) with respect to the current consumption database used by EPA. The database collected by Continuing Survey of Food Intakes by Individuals (CFSII) or National Health and Nutrition Examination Survey (NHANES), is cross-sectional in design with repeat sampling separated by 7-10 days. A recent publication highlighted a significant difference in the consumption frequency of fresh fruits and vegetables determined in a longitudinal dietary intervention study (Riederer, Pearson, and Lu, 2010). The seasonality in the availability of these commodities indicates that a cross-sectional study design like NHANES would not be able to capture the representative consumption patterns. Those seasonal food commodities are also likely to contain pesticide residues, as indicated by the annual USDA PDP databases. Whether or not climate change would further modify food consumption patterns is unknown; however, food consumption itself should be treated as a dependent model input variable when performing the dietary exposure estimation.

One Panel member pointed out that there are parameters either embedded directly or as assumptions in the current models that are likely to change under projected climate change. These include: (1) the distribution of the amount of water consumed in a day and/or the timing of consumptions; (2) personal interactions with the external environment through changes in exercise patterns; and, (3) the seasonal availability of various food types. Climate change may result in earlier crop planting, faster development, and earlier harvest which may overlap with dryer or wetter conditions than current conditions resulting in changes in food residues. Other issues such as the effects of climate change on genetically modified crops in terms of selection of conventional crop buffer size needed to minimize gene flow may need to be addressed.

The Panel also commented that although OPP has the opinion that handler exposure is unaffected by climate change, pesticide handlers' exposure is likely to be influenced by climate changes. It is the Panel's opinion that handler exposure will be affected as a result of either increasing frequency of pesticide applications, or decreasing the interval between applications within a short period of time, and/or changes in the use of personal protective equipment (PPE). PPE use patterns are likely to change as heat indices increase in a changing climate. A key issue is how to monitor those scenarios in the field, and subsequently respond to the changes of pesticide application patterns.

As suggested by the Panel although it is intuitive for OPP to adapt peer-reviewed models to assess the impact of climate change, cautious notes should be made based on the nature of DEEM™, handler exposure, and post-application exposure models in assessing acute dietary or occupational pesticide exposures. One Panel member identified a missing aspect that was not discussed in OPP's model evaluation. It is the assessment of the extent to which embedded model parameters describe conditions expected under climate change. In particular, data used to establish values for the embedded parameters may not be representative of future climate conditions. Embedded parameters, which are actually functions, may be assessed under future climate at the extremes of the driving factor ranges, where uncertainty in the functional form and value is highest. The current and past use of this same function is likely to have occurred for values in the middle of the range, a place where uncertainty is smallest.

Panel Response to the Ecological Case Study

OPP's review included: (1) an examination of selected exposure models to identify those variables that are likely to be affected by climate change, directly or indirectly; (2) assessment of how critical the results of climate change might be in terms of model outputs; and (3) a determination of how best to address OPP's priority needs.

The Panel concurred that EPA has developed an effective approach for evaluating existing environmental exposure models and frameworks in light of expected effects and impacts of climate change. The focus on exposure assessment, rather than effects assessment, seemed to be appropriate to the Panel as many of the exposure assessment models are unique to pesticides, whereas questions of ecological sensitivity are not.

The Panel explained that by focusing on existing models used in environmental risk assessment assumes that the current key environmental exposure pathways and processes will remain the same in the future. The Panel noted that this may not be the case and recommended that the Agency consider the following questions: 1) ' In what ways could ecological and human exposure pathways be altered because of climate change?' and 2) 'Do the current models cover the exposure routes and fate and transport processes likely to be affected?'.

The Panel observed that present models have been relatively reliable for estimating exposure concentrations in environmental media, but do not necessarily predict non-target ecological receptor exposure accurately across the range of landscapes where pesticides are applied. They explained that a number of studies have addressed this question for other contaminant sources and geographic areas. NOAA used a conceptual model framework to help define research gaps and needs in formulating ecological risks associated with urbanization (Scott et al., 2006). This model was based upon a four tiered strategy including: (1) defining stressors associated with climate change (temperature, altered precipitation, pH, acidification, and sea level rise) and pesticide usage; (2) increased exposure to stressors; (3) ecological responses to stressors and (4) human health and well being. In a similar exercise that focused on agrichemical risks in the United Kingdom (UK), dust transport and flooding were identified as becoming more important exposure routes (Boxall *et al.*, 2009), yet these are not currently considered in regulatory pesticide exposure modeling in Europe. In addition, pesticide volatilization, atmospheric transport, and wet and dry deposition are likely to become much more important exposure pathways. This may result in increased bystander exposure and more global trans-boundary pollution, including transport and deposition in Arctic regions.

The Panel agreed that the variables considered in the OPP review were logical. However, the Panel recommended that the effects of climate change on other parameters that could affect pesticide fate should also be identified. For example: intuitively, one would expect that pesticides would degrade more rapidly in warmer climates; however, recent studies (Daam and Van den Brink, 2010) show this may not be the case since the characteristics (e.g., turbidity) of receiving streams may offset the effects of changes in temperature; and bioaccumulation might be affected by shifts in temperature, salinity/hardness and pH. Existing bioaccumulation models do not account for these effects. In coastal areas, where sea level rise is expected, exposure models must factor in increased soil saturation conditions and effects of salt water intrusion on groundwater interactions, which may enhance runoff conditions and result in greater pesticide exposure. Other variables, such as antecedent dry period and rainfall intensity are expected to be altered significantly in some regions, likely leading to differences in crop selection and pesticide use patterns, dissipation and runoff. Changes in these factors may result in differences in environmental media through which ecological and human exposure occur. Climate change effects on these and other variables may have differential effects on the modeling of ecological versus human health risks (e.g., increased runoff may reduce plant residue concentrations decreasing potential human health risks, but increase ecological receptor risk through elevated water or sediment concentrations).

To effectively address these issues the Panel recommended that a systematic review of the literature be performed to identify potential effects of climate change on processes affecting the environmental fate and transport of pesticides in air, soil, fugitive dust, sediments, and surface and ground water. Several existing reviews were identified (e.g., Bloomfield, Williams, Gooddy, Cape, and Guha, 2007; Boxall et al., 2009; Daam and Van den Brink, 2010) that can be used as a starting point for this work. In the review, careful attention should be paid to how changes in temperature and precipitation may impact soil and landscape scale processes that govern predicted pesticide and other exposure pathway conditions at the eco-regional scale. These factors, in turn, may affect environmental exposure concentrations in forage, water and sediment, and key exposure parameters used for non-target species in ecological risk modeling such as site use, and food and water ingestion rates.

Lastly, the Panel elaborated on EPA's current use of label directions to dictate pesticide application rates, number of applications, and application intervals, and how increased temperature and precipitation may result in alterations in label requirements (increased number of applications/year). Panel members suggested that model predictions that forecast worse case scenarios (e.g., maximum number of applications with the minimum application interval throughout the entire growing season or year) may be an effective way to estimate the magnitude of climate change effects on exposure. They also commented that this approach allows for a comparative risk approach to be used (e.g., increased amount of pesticide exposure in terms of both concentration and duration of exposure) in which worse case climate responses can be compared to baseline climate condition predictions.

Question 2. OPP reviews chemicals and assesses risks as needed at least every 15 years. Over a 15 year time period, pesticide use and crop residues from monitoring data could change as a result of climate change.

Question 2A.. Based on current projections, will the pace of climate change significantly increase the uncertainty in our exposure assessments?

Panel Response

The Panel concluded that incorporating a modeled 15 year climate change projection into a pesticide exposure assessment would add little value. Decadal scale projections are both initial value problems and climate change problems. As the magnitude of the anthropogenic influence will increase over the next century, these factors become the dominant forcing factor for century scale models. On a decadal scale the anthropogenic influences are fairly modest so the most important influences can be internal variability of the climate system such as El Niño/Southern Oscillation, the Pacific Decadal Oscillation and the North Atlantic Oscillation. These climatic factors influence the uncertainty of 10 to 15 year model projections of temperature and precipitation patterns. Although there is high uncertainty associated with shorter term climate change projections this uncertainty relative to the magnitude of the projected changes decreases with successively progressive time projections. The accuracy of a climate change projection becomes increasingly more reliable as it progressively approaches a 100 year time period (U.S. Global Change Research Program, 2009).

Thus, as explained by the Panel, if a pesticide exposure assessment incorporated climate change projections which entail 15 year incrementally progressive periods (including time intervals of 15 years, 30 years, 45 years, 60 years, 75 years, 90 years, 105 years, etc...), the accuracy of the climate change projections would be expected to increase with each progressive 15 year time interval. Such a methodology would provide a means of acquiring more accurate estimates of future temperature and precipitation increases with time.

Question 2B.: If yes, which inputs are likely to change in such a manner that the uncertainty in the exposure assessment would significantly increase? Comment on how OPP might explore this issue.

Panel Response

As discussed by the Panel, the primary modeling components that would not be expected to decrease the inherent uncertainty of the exposure assessment include the predicted future precipitation and temperature patterns. Although both inputs necessitate uncertainty, future precipitation patterns are expected to entail more uncertainty than temperature. To explore these issues, the Panel made the following two recommendations:

Recommendation 1: *The Agency should develop a pesticide exposure simulation model which incorporates climate change projections and which addresses the uncertainties of model outputs.*

As a means of addressing the uncertainty associated with projected precipitation and temperature patterns associated with climate change, the Panel suggested that the Agency develop a pesticide exposure modeling simulation assessment that incorporates climate change projections over an incrementally progressive 15 year time period. Thus, presumably the certainty/accuracy of the climate change projections within the pesticide exposure assessment would increase with each progressive 15 year time interval. The Panel suggested that this simulation model also contain the following mechanisms/elements:

1. A tool that could provide combined probabilistic estimates of cropping patterns, pest and disease patterns and pesticide application patterns in conjunction with projected precipitation events: The Panel suggested that this tool could possibly be supported via the use of a meteorological model called a stochastic "Weather Generator." A stochastic weather generator creates an artificial time sequence of weather data of limitless length for a site based on the statistical characteristics of observed weather at that site. The model should also include evaluation of potential new invasive pests and diseases; especially since, the rate of arrival of new invasive species is likely to increase because of global change factors.

2. A mechanism for estimating the probability of extreme weather events that would induce large crop impacts from pests and diseases as well as increased runoff associated with more severe precipitation events: Accounting for such impacts would consequently provide estimates of when there could be increased pesticide applications and exposures. It was also suggested that the simulation be updated as climate change (and annual weather) predictions are incrementally improved.

3. A sensitivity analysis: Some Panel members suggested that simulations include a sensitivity analysis to determine impacts of changes in inputs on 'bottom line' outputs of the model.

***Recommendation** 2: The Agency should increase use of pesticide field trials data*

One panel member suggested that the current methodology for conducting field studies to collect pesticide residue data could be amended to incorporate a strategy that would entail adjusting the locations of field trials annually to focus on regions that yield greater uncertainty in estimates.

Another panel member recommended that the Agency further utilize USDA's Pesticide Data Program (PDP) to determine whether data are influenced by extreme weather events for example frequent heavy rainfalls events within a given time period. The recommendation was qualified by a comment that PDP data has uncertainty and that systematic efforts are needed to quantify it.

Question 3. Over time, the environment will change due to climate change and these changes will manifest differently in different regions of the country. Irrespective of climate change, there already exists a wide variety of climatic conditions across the country. Because climatic conditions vary greatly across the country, often data collected for exposure assessments are from studies performed at multiple locations chosen to be geographically representative of the entire country.

a. Please comment on the geographic changes anticipated due to climate change relative to the existing climate diversity within the U.S. Over what time period might climate change significantly affect the range of diversity in weather conditions in the U.S in such a way as to significantly increase our uncertainty in pesticide exposure assessments?

Panel Response

The Panel acknowledged that climatic conditions, particularly temperature and precipitation, vary nationwide and climatic conditions are on an anticipated trajectory of future change. The Panel concluded that at a minimum over the next 20 years temperature change will occur fairly uniformly for all regions of the U.S. This conclusion was based upon a presented modeled projection which demonstrated that the average projected change in temperature across the U.S. from 1970 to 2020 is 2 to 3 degrees Fahrenheit (U.S. Global Climate Research Program, 2009).

In the case of geographic changes in precipitation, the Panel concluded that the 20 year projection for future precipitation (which is considered to be a short term projection) is highly uncertain due the relative importance of variations in the climate system components (currently not able to be forecasted with 5 year lead times) such as the North Atlantic Oscillation over such short periods. The Panel reiterated this uncertainty decreases for longer term projections (especially as the projections approach 100 years). Additionally the Panel explained that despite the uncertainty associated with short term projections of future precipitation across the entire U.S., there is an ongoing nationwide precipitation trend of increased heavy precipitation events. This nationwide trend is certainly expected to continue over the short and long term (NOAA Climatic Data Center, 2002); United States Global Change Research Program (2009).

Finally, the Panel recommended that the Agency explore the development of a geographically and spatially based cropping system model. The purpose of the model would be to predict based on climatic variables when a pesticide should be applied to a crop. The Panel recommended that the model have a mechanism for providing geographical estimates of when specific types of crop pest and diseases may occur based on anticipated changes in climatic conditions. Such a mechanism may assist in providing realistic projections of pesticide usage. One Panel member suggested that the crop model also account for the anticipated rises in CO_2 levels, They further explained that the anticipated rises in CO_2 are expected to impact what types of crops may be planted in a given region or area and may also increase the occurrence of weeds and other pests. A panel member suggested that sensitivity analyses of this proposed model could inform these evaluations, as well.

Question 4. All exposure assessments rely in some degree on historical data – weather, residues on food, cultural practices, pesticide use practices, etc. In many situations data that are directly used as inputs into an exposure assessment can readily be updated with each successive assessment. For example, a dietary exposure assessment today would rely on recent monitoring data, while an assessment in 5, 10, or 15 years from now would rely on more up-to-date monitoring data than an assessment conducted today. In other situations, data are used to develop a parameter in a model, such as the runoff curve discussed in section III.B.1.e. of the background paper. Please comment on the significance of climate change on the reliability of embedded model parameters. How might OPP systematically approach an evaluation of the significance of such model parameters?

Panel Response to Human Exposure Case Study

The Panel concluded that the use of historical data in assessing climate change impact on human pesticide exposure assessment may be valuable in identifying past trends associated with patterns in meteorological data (such as increasing temperature, precipitation patterns, etc.). Use of the USDA PDP data for this purpose is recommended. If pesticide application rates increase or application intervals in certain crops decrease due to increasing stress from climate, then residues measured in those crops by the USDA PDP would likely indicate an upward trend. Thus, the Panel recommended that OPP use these data to systematically evaluate the significance of climate change on pesticide residues in the dietary exposure model.

Panel Response to Ecological Case Study

As noted in responses to Question 1, the Panel concluded that existing exposure models may not incorporate algorithms that account for changes in processes or symptoms that are likely to occur under climate change. This would include changes in environmental exposure concentrations in select media such as sediment from increased runoff; bioaccumulation due to increases in temperature and changes in pH, changes in species prevalence and changes in specific areas where pesticides would be applied.

The Panel further elaborated that it is possible that set variables (such as crop and soil parameters) used in existing exposure models may not be appropriate in the future. Furthermore, climate driven changes in agricultural systems will fall outside the predictions obtained when using embedded equations in existing models. For example, the kinetic equations used to describe pesticide dissipation rates in soil, on plant tissues, and various other surfaces, are typically based on pseudo-first-order kinetics where kinetic rate data are reported as the half-life of the active ingredient. Because changes in temperature and rainfall patterns may increase dissipation rates, alternative kinetic models may need to be used. Kinetic rate constants may also need to be adjusted as climate changes. For soil dissipation, there are well established computational approaches for modifying first-order rate equation half-lives measured at "standard" temperature and soil water conditions. Both equations require compound specific constants to make adjustments to soil half-lives. The values of these "constants" are not readily available for many pesticide active ingredients, therefore, "default" values are often used. A systematic effort is needed to compile available data and identify data gaps. For other transport/fate process equations (e.g., spray drift) the Panel commented that it is difficult to establish whether they will be able to model the influence of future climate conditions.

In order to evaluate the significance of climate change on the reliability of the model parameters, the Panel recommended that in the first instance a sensitivity analysis be performed on all environmental exposure models used by OPP. They further recommended that particular attention be focused on the curve number approach used in

PRZM/EXAMS as well as hydrological conditions that may result from altered precipitation patterns, including extended periods of drought and excessive precipitation associated with climate change. Panel members elaborated that this is a necessary first step in identifying model input parameters that will likely be impacted by climate change and the extent to which outputs may impact exposure assessments. Analyses should not only take into account expected changes in input parameters associated with anticipated changes in temperature, precipitation, pesticide use patterns, soil properties, but these analyses should also examine the likelihood and degree to which these input parameters could be altered over the 15 year period considered under the registration renewal regime. There are many published studies that could be consulted and used as a basis for this work.

Concurrent with the sensitivity analysis, the Panel recommended that underlying model algorithms be reviewed in light of climate change to determine whether the algorithms are able to predict climate driven changes in the future. The Panel commented that algorithms t requiring particular attention include mechanisms for estimating spray drift and relationships between cropping, infiltration and runoff and application timing and runoff. They further explained that this work will require multidisplinary collaboration from a range of experts including soil physist, climatologist, hydrologist and microbiologist. Better use of existing data (e.g., data on effects of soil moisture and temperature) on pesticide fate would be beneficial. In instances where large knowledge gaps exist, experimental studies should be performed to fill the gaps.

Question 5. Currently, OPP uses weather data from 1960-90 in its ecological assessments, giving equal weight to every year. OPP intends to acquire more recent data. Please comment about the effects of using these data in light of climate change. If this is viewed as an important factor, will aggregating the data from 1960-2010 be appropriate in light of climate change? For example, would the use of data from the last 10 years be a more appropriate indicator of future weather patterns or should OPP consider adding a predictive component to weather data? If the use of predictive models is appropriate, provide any sources of ongoing research or relevant models that might be explored.

Panel Response

The Panel concluded that the current practice of using 1960-1990 weather data to predict future weather is less reliable than using currently available data. Additionally the Panel advised the Agency that using an aggregation of 1960-2010 weather data to predict future weather would be less accurate than using a "Normal" of a more recent aggregate weather data, such as 1980-2010. Thus, the relevance to future weather is significantly enhanced with the use of the most recent "Normal" weather data set. A "Normal" is defined as a set of the averages for climatological data computed for any period of at least ten years starting on 1 January of a year ending with the digit 1 (The World Meteorological Organization, 2007). NOAA is currently in the process of updating its technique for utilizing "Normal" weather data. The Panel provided a brief explanation of several different technique choices being explored in support of this updating process. Among the several different techniques presented, the Panel suggested that a technique called "Optimal Climate Numbers" (OCN) appeared to be the most suitable one to support the Agency's pesticide exposure assessment.

One panel member recommended that EPA consider modifying the evaluation to emphasize the probability distribution of different weather combinations. The panel member further explained that this would support a fuller evaluation of meteorological effects and make it easier to adjust analyses to new scenarios in the future. The panel member also explained that the biology of pests and diseases is often driven by extreme events rather than mean conditions, and a sensitivity analysis can be used to determine how sensitive predicted pesticide exposure is to extreme weather conditions.

Question 6. Please consider a systematic approach for OPP to prioritize future work on Climate Change. Priority areas to help guide OPP to inputs/models that would be most important to help assure that our assessments do not underestimate exposure and risks (include magnitude and uncertainty).

Panel Response to Human Exposure Case Study

The Panel concurred that a systematic approach is needed to prioritize future regulatory activities so that the impact of climate change on pesticide exposure modeling can be measured by OPP. Thus, the Panel recommended that OPP explore the following areas related to dietary pesticide exposure while considering new agricultural technology that may be adopted due to climate change.

1. **Dietary Pesticide Exposure:** *Further examine the USDA PDP monitoring program of pesticide residues in food commodities that are commonly consumed and likely to be affected by climate change.*

   The annual USDA PDP provides an excellent platform to further expand the pesticide residue monitoring program in food commodities that could enable OPP to assess how climate change (temperature, precipitation, etc.) affects pesticide use in the field and subsequently residues in food commodities. A key issue discussed during the SAP meeting is at what speed climate change would alter pest and disease pressure compared to how frequently PDP monitoring data are updated. Although PDP monitoring data are collected annually, individual commodities may be sampled less frequently. One Panel member also noted that selection of commodities for PDP may not be reflective of the program's original mandate. For example, it was observed that commodities such as "kale" have been included in the PDP monitoring program; however, it is questionable how pesticide residues in this vegetable consumed by few in relatively low quantities would pose the so called "greatest potential to contribute to dietary exposure in children," Children's kale consumption is likely small when compared to other foods.

   Several Panel members suggested that "index food commodities", such as strawberries, spinach, and peach/nectarine, should be used as indicators by OPP to monitor pesticide residues over a period of years at different locations throughout

U.S. The criteria of selecting those index commodities should reflect the possible adverse effects of climate change, such as high temperature, increased or decreased precipitation and/or precipitation intensity, increasing insect pressure, or excessive ambient carbon dioxide levels of climate change to the crops. One Panel member mentioned the current study in Florida being conducted by Dr. Clyde Fraisse on a production model for strawberries with a concurrent model under development on the growth of molds. The goal is to develop a decision support system to advise growers when fungicide use is needed. Additional information regarding this study may be found at the following web sites:
www.abe.ufl.edu/people/directory/fraisse-clyde.shtml
http://agroclimate.org/tools/strawberry/

Most U.S. land grant universities have faculty working to develop and improve such disease and pest forecasting systems to support short-term decision making by growers. One active and new area of research is the adaptation of small-scale tactical models for individual growers into large-scale models useful for forming strategies under climate change scenarios (Garrett et al. 2011), such as modifying pesticide risk models. One approach mentioned by the Panel is the utilization of metamodels to adapt small-scale models for larger-scale applications, often by streamlining the input variables needed for analysis and determining the resulting uncertainty (Sparks et al., in review; preprint available on request from kgarrett@ksu.edu).

2. **New technology**: *New technologies designed for delivering pesticides systematically to plants should be incorporated into OPP's dietary pesticide exposure and risk assessments.*

As new technologies are developed to deliver pesticides at pre-determined dosages to crops to combat increasing insect pressure due to climate change, conventional tolerance or field crop studies may not be relevant to both dietary and handler exposure and risk assessments. Newly introduced seed treatment and other technologies may add additional residues to the dietary exposure.
This needs to be taken into account in the design of monitoring programs like the USDA-PDP.

Panel Response to Ecological Case Study

Generally, the Panel concurred that the OPP review and approach was useful and logical. However, Panel members commented that focusing on exposure models in use today could result in omission of important exposure pathways and processes that could occur in the future. The Panel advocated a further review of models and frameworks to identify: a) whether key exposure routes that are likely in the future are covered by existing frameworks; b) the key input parameters that will be affected and how they may vary spatially across regions where significant climate change is likely, and c) whether process algorithms are inadequate for addressing anticipated changes in climate.

The Panel suggested that the results be used to direct research and development efforts. This approach was used by Scott, Holland, and Sandifer (2006) to identify knowledge gaps and research needs for effects of urbanization on coastal systems. As explained by the Panel, it may be a useful model for the proposed work. Sensitivity analysis of current models and a thorough evaluation of model algorithms and parameters taking into account predicted changes in temperature, rainfall, soil characteristics were also recommended. Based on the findings, the Panel concluded that the current exposure assessment approaches should be reviewed and, if necessary, refined. They also recommended that consideration be given to strengthening programs focused on long-term monitoring of pesticides across the U.S. agricultural landscape. This will provide data to help assess pesticide occurrences in environmental media that may be associated with climate change.

While the Panel agreed with the decision by OPP to only address the exposure component of the risk assessments within its review, they noted that it is important that the effects of climate change on ecosystem sensitivity (e.g., due to changes in structure of ecological communities) to pesticides are considered. The Panel strongly encouraged a two-way exchange of information across different parts of EPA (and other Agencies) that are looking at the interactions of climate change on terrestrial and aquatic systems.

The Panel elaborated that one of the greatest uncertainties in assessing how climate change will impact pesticide exposure is estimating impacts on land use and cropping patterns and how such impacts may affect pesticide use. They explained that if spatial and temporal variability in use patterns of pesticides can be reliably predicted under climate change scenarios at regional scales, it may be possible to reflect the changes in predicted use patterns and embedded model parameters in label specifications. Thus, the Panel recommended that the Agency make national scale assessments so that magnitudes of change can be evaluated. They suggested use of the following tools may provide useful insights: (a) economic, market-driven models that guide crop selection decisions, and (b) pest and disease models for strategic analysis of climate scenarios, often developed from grower decision-support tools that specify pest and disease management practices as a function of weather variables. A companion effort involving development of a national pesticide use database was recommended by the Panel. The Panel commented that the current practice of using USDA-NASS crop profiles to estimate pesticide use provides estimates that may be highly uncertain and that a systematic effort is needed to evaluate uncertainty in these estimates.

The Panel advised that the combined effects of pesticides and other ecological stressors (e.g. temperature, pH, salinity) are likely to become more important in the future. For example, Scott et al. (1994) showed that changes in salinity and temperature increased the toxicity of pesticides to invertebrates. Also, the effects of increased chronic pesticide exposure on thermal tolerance of aquatic organisms may be important. Patra, Chapman, Lim, and Gehrke (2007) reported that chronic low level pesticide exposure may lower upper thermal tolerances of freshwater fish by 2.5-5.9°C for three classes of pesticides (organochlorines, organophosphates and pyrethroids). This effect in some (e.g., polar) ecosystems would be catastrophic as many species are stenothermal, with very little ability to survive alterations in temperature. There is a significant concern for rising temperatures that will cause certain pesticides to volatilize and travel to Polar regions. This may result in increased pesticide exposure in transboundary regions away from the initial pesticide application (due to altered Henry's Law Constants and other significantly influential variables). The Panel proposed that OPP determine whether 'multiple stressor' effects should be considered in the risk assessment process for pesticides and if so, develop mechanisms to incorporate these interactive effects.

As described by the Panel, the current discussion is focused on product risk assessment; however, the Panel asserted that the Agency should be more proactive in anticipating how risks in general could change in the future. They explained that this will mean that negative impacts be identified at an early stage so that adaptation and mitigation responses may be introduced before problems occur. They elaborated that the development of models that permit systematic assessment of mitigation practices on pesticide exposures via food intake, drinking water, etc. should be considered to help guide specification of practices that can reduce and minimize impacts.

Finally, the Panel concluded that it is important to recognize that climate change is just one driver. They commented that there will be many other environmental changes occurring, some of which may be more important than climate change when it comes to pesticide risk.

References

Bloomfield J.P., Williams R.J., Gooddy D.C., Cape J.N., Guha P. (2006). Impacts of climate change on the fate and behavior of pesticides in surface and groundwater—a UK perspective. *Science of the Total Environment* 369, 163-177.

Boxall A., Hardy A., Beulke S., Boucard T, Burgin L, Falloon P.D., Haygarth PM, Hutchinson T, Kovats R.S., Leonardi G., Levy L.S., Nichols G., Parsons S.A., Potts L., Stone D., Topp E., Turley D.B., Walsh K., Wellington E.M.H., & Williams R.J. (2009). Impacts of Climate Change on Indirect Human Exposure to Pathogens and Chemicals from Agriculture. *Environmental Health Perspectives* 117(4), 508-514.

Daam M.A., & Van den Brink P.J. (2010) Implications of differences between temperate and tropical freshwater ecosystems for the ecological risk assessment of pesticides. *Ecotoxicology* 19(1), 24-37.

Garrett K.A., Forbes G.A., Savary S., Skelsey P., Sparks A.H., Valdivia C., van Bruggen A.H.C., Willocquet L., Djurle A., Duveiller E., Eckersten H., Pande S., Vera Cruz C., & Yuen J. (2011). Complexity in climate change impacts: An analytical framework for effects mediated by plant disease. *Plant Pathology* 60:15-30.

Patra R.W., Chapman J.C., Lim R.P., and Gehrke P.C., (2007).The effects of three organic chemicals on the upper thermal tolerances of four freshwater fishes. *Env. Toxicol.* And Chem. 26:1454-59

Riederer A.M., Pearson M.A., Lu C. (2010). Comparison of food consumption frequencies among HANES and CPES children :Implication for dietary pesticide exposure and risk assessment. *J Exp Sci Environ Epidemiol.* 20(7):602-14. PMID: 9738638.

Scott, GI, Fulton MH , Crosby MC, Key PB, Daugomah JW, Waldren JT,Strozier ED, Louden CJ, Chandler GT, Biddleman TF, Jackson KL, Hampton TW, Huffman T, Schulz A and Bradford M.(1994) *Agricultural pesticide runoff effects on estuarine organisms: Correlating laboratory and field toxicity testing, ecophysiology bioassays, and ecotoxicological biomonitoring.* EPA Office of Research and Development, Washington DC; Report # EPA 600/R-94/004:288pp.

Scott, G.I ., Holland A.F., and Sandifer P.A. (2006) Managing Coastal Urbanization and Development in the 21st Century: *The Need for a New Paradigm.* In "Changing Land Use Patterns in the Coastal Zone: Managing Environmental Quality in Rapidly Developing Regions", (G. Kleppel et al., Eds.); Van Norstam press, NYC, NY: pp. 285 – 299.

NOAA National Climate Data Center (2002) *Climate Atlas of the United States*

Retrieved from:http://www.ncdc.noaa.gov/oa/about/cdrom/climatls2/info/atlasad.html

U.S. Global Change Research Program (2009) *Global Climate Change Impacts in the United States* Retrieved from:www.globalchange.gov/usimpacts

The World Meteorological Organization (2007) The *Role of Climate Normal in a Changing Climate*. Retrieved at: http://www.wmo.int/pages/prog/wcp/wcdmp/documents/WCDMPNo61.pdf