Annual Report for Period: 03/2003 - 03/2004
Submitted on: 02/20/2004
Principal Investigator: Molders, Nicole
Award ID: 0232198
Organization: U of Alaska Fairbanks
Title:
WCR: Impact of Land-use Changes and/or Radiative Forcing on Water Availability and the Pathways and Interactions of the Global and Regional Water Cycles

Project Participants

Senior Personnel
Name: Molders, Nicole
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student
Name: Li, Zhao
Worked for more than 160 Hours: Yes
Contribution to Project:

Undergraduate Student

Technician, Programmer
Name: Newman, Gary
Worked for more than 160 Hours: No
Contribution to Project:
Name: Covey, Dave
Worked for more than 160 Hours: No
Contribution to Project:

Other Participant

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts
Gerhard Kramm

Activities and Findings

Research and Education Activities:
Major research activities
In the last year, the major achievements of our activities were to develop a theoretical concept that allows for including the atmospheric liquid and solid water substances as well as runoff in a precipitation-recycling model, to code and test the precipitation-recycling model, and to apply it to synthetic and 'real world' model data. The precipitation-recycling model developed here can be seen as an enlargement of the precipitation-recycling model originally introduced by Eltahir and Bras (1994).

Since in a hydrological sense, liquid and solid water substances reside in storage that rapidly changes with time, our modification to Eltahir and Bras’ (1994) precipitation-recycling model make it suitable to address variability of the water cycle at various scales, and to make efficient use of climate model data. Note that Eltahir and Bras (1994) designed their precipitation-recycling model for analysis data. Since analysis data provide no information on solid and liquid water substance except for precipitation that reached the ground, these authors had no need to consider other solid or liquid water substances or runoff.

Education activities

The graduate student Zhao Li took six courses during the last year (1) Weather Discussion Practicum, (2) Scientific Presentation Seminar, (3) Atmospheric Dynamics, (4) Atmospheric Chemistry, (5) Atmospheric Thermodynamics, and (6) Numerical Modeling and Parameterization methods. Furthermore, she attended the NCL workshop tutorial in April 2003 that IARC (International Arctic Research Center) jointly carried out with NCAR (National Center for Atmospheric Research). Zhao Li also learnt how to work with UNIX, shell scripts, IDL, CCSM, and to program in FORTRAN90.

The student went to two conferences, namely 'The Fifth Conference on Coastal Atmospheric and Oceanic Prediction and Processes' and the 'American Geophysical Union (AGU) fall meeting 2003'. An 'American Meteorological Society graduate student travel award' that she won sponsored her attending the first mentioned conference. At the AGU meeting, the student presented her first poster entitled 'Diagnosing the Influence of Radiative Forcing on Local Recycling of Precipitation Using a Three Dimensional Recycling Model'. She also attended the 'Eighth CCSM workshop' at Breckenridge to make contacts with scientists working in her field and to learn about recent results achieved with CCSM.

Unfortunately, this year NCAR did not offer a tutorial after the workshop. Attending a tutorial would have made it easier and quicker for the student to get started with the CCSM simulations.

The PI taught one 3-credit class (Numeric modeling and parameterization methods), and two 1-credit seminar classes (atmospheric sciences informal seminar). In addition, she supervised two other graduate students and two REU undergraduate students.

Findings:

Brief description of the theoretical concept to include liquid and solid water in a precipitation-recycling model

Generally, in an arbitrary volume of the atmosphere, the change in mass with time depends on the divergence of flow of water substances in gaseous, liquid, solid form through the surface area of the volume and the sources and sinks within the volume. Within the framework of our activities, we enlarged the precipitation-recycling model introduced by Eltahir and Bras (1994) by introducing terms for liquid and solid water substances as well as runoff. In doing so, we rely on the conservation of mass for each water phase, which provides us three conservation equations. Since a phase transition from one water phase (e.g. water vapor) to the other (e.g. water) is a sink for the phase depleted (in this example water vapor) and a source for the phase built (in this example water), we can combine these three conservation equations to one equation that includes all three water substances. Runoff is included as a water flow at the lower western, eastern, southern, and northern boundaries of the volume. Note that our enlarged precipitation-recycling model excludes ice sheets floating on rivers, as CCSM does not simulate them.

In the following, we distinguish between control volume, which corresponds to a grid column of CCSM, and the region, for instance, the area over Alaska. At the lateral boundaries of each control volume, CCSM data of wind, density, and water substances serve to calculate the flux divergence of water substances. We assume that no water substances leave or enter the model domain at the top of CCSM.

Eltahir and Bras (1994) assumed the change in water vapor mass is negligible on time scales of a month or longer. Since in a spatially limited region, as we want to consider in our activities, the change in total water mass may be non-zero, we examined the magnitude of the change in total mass of water substances exemplarily for a region over Alaska. We found that it is justified to neglect the change in total mass of water substances. Note that the change in total mass is zero in CCSM that is a global model as the model should not lose or gain total water.

In accord with Eltahir and Bras (1994), we divide precipitation fallen in a control volume into a fraction ‘r’ that stems from water vapor provided to the atmosphere by evapotranspiration from within the control volume itself and a fraction ‘1-r’ that results from advection of water substances into the control volume. They chose this value arbitrarily as a first guess to initialize the precipitation-recycling model. For the same reasons presented by these authors, we assume that the atmospheric water vapor stemming from within and outside the control volume is well mixed. Since cloud and precipitation particles as well as finally runoff result form this water vapor, we can assume these particles as well mixed too. Consequently, we can express our equation that considers all water substances once for the total water substances from within and once for those from without the control volume. This implies the definition for the recycling ratio as the ratio between the precipitation resulting from evapotranspiration within the control volume to the total precipitation in the control volume.

Eltahir and Bras (1994) approximated the recycling ratio by the ratio of the outflow of water vapor from within the control volume to the total outflow. They used the ratio of outflow from within to the total outflow of the control volume as an approximation of the recycling ratio, and as a closure for their equation system, and yielded a new equation to estimate the recycling ratio that only depends on inflow and
The activities of the project were presented to the public at the following outreach activities:

**Outreach Activities:**
- Introduce students in the exciting world of science.
- REU summer interns from other disciplines.
- Findings of the project contribute to promote interdisciplinary understanding, and to forcing, and/or land-use changes on water availability in various climatic areas to the PIs own students and REU-summer interns, but also to only provide insight into the problems and questions of water resources and the water cycle, its various scales, and the influence of radiative forcing.
- The PI presented findings of the project within the framework of the seminar series arranged for GI REU summer interns. Doing so did not curtail the curriculum of typical atmospheric science programs.
- The project provided the opportunity to Zhao Li to learn some basics of modeling, computational and analyzing techniques that are not on the curriculum of typical atmospheric science programs.
- Zhao Li was already able to contribute a poster at the AGU fall meeting, i.e. earlier than anticipated in the proposal. The presentation of her poster allowed her to collect some first experience in how to present and defend her own research in front of the scientific community, and to participate in the ongoing scientific discussion in her research field.

**References**


**Training and Development:**

The project provided first training opportunities (see above for details) for Zhao Li (graduate student) at the Geophysical Institute (GI) and College of Science, Engineering and Mathematics (CSEM), University Alaska Fairbanks (UAF). The project provided her with experience in the interdisciplinary world of climate system modeling, atmospheric science, and hydrology. The graduate student was already able to contribute a poster at the AGU fall meeting, i.e. earlier than anticipated in the proposal. The presentation of her poster allowed her to collect some first experience in how to present and defend her own research in front of the scientific community, and to participate in the ongoing scientific discussion in her research field.

The project provided the opportunity to Zhao Li to learn some basics of modeling, computational and analyzing techniques that are not on the curriculum of typical atmospheric science programs.

The PI presented findings of the project within the framework of the seminar series arranged for GI REU summer interns. Doing so did not only provide insight into the problems and questions of water resources and the water cycle, its various scales, and the influence of radiative forcing, and/or land-use changes on water availability in various climatic areas to the PIs own students and REU-summer interns, but also to REU summer interns from other disciplines. Thus, findings of the project contributed to promote interdisciplinary understanding, and to introduce students in the exciting world of science.

**Outreach Activities:**

The activities of the project were presented to the public at the following outreach activities:

Other outreach activities where activities of the project were presented are:


Activities of the project were presented at the following scientific meetings and/or workshops:


Mölders, N., 2003. Future goals of the Atmospheric Sciences group at the Geophysical Institute. GI Advisory Board meeting, Fairbanks, April 1 (oral presentation).


### Journal Publications

#### Books or Other One-time Publications

Zhao Li and Nicole Molders, "Diagnosing the influence of radiative forcing on local recycling of precipitation using a three-dimensional recycling model", (2003). CD of conference abstracts and related poster, Published Collection: AGU abstract CD of the AGU fall meeting 2003 Bibliography: AGU abstract CD and poster presented at the AGU (acknowledgement on poster as abstracts do not allow for acknowledgements)

### Web/Internet Site

**URL(s):**

http://www.gi.alaska.edu/~molders/nmlandus.htm,

http://www.gi.alaska.edu/~molders/CCSM.htm

**Description:**
The page http://www.gi.alaska.edu/~molders/nmlandus.htm serves to put the project in the framework of other related studies that the PI and her group make/made. The page http://www.gi.alaska.edu/~molders/CCSM.htm describes activities related to the grant.

### Other Specific Products

**Product Type:** Software (or netware)

**Product Description:**
The enlarged precipitation recycling was coded. Software to visualize results and for analyzing results was developed.

**Sharing Information:**
Contributions

Contributions within Discipline:
The activities provided an enlarged concept how to evaluate water recycling when liquid and solid water substances are taken into account. Now not only the atmospheric water vapor, but also the liquid and solid atmospheric water substances as well as runoff can be included in precipitation-recycling models. It has to be expected that analyzing precipitation-recycling with the enlarged precipitation-recycling model in conjunction with the other tools developed within the framework of our activities will allow for improving the knowledge on the natural fluctuations and anthropogenic factors as well as the feedback mechanism of the water cycle at its various spatial and temporal scales.

Contributions to Other Disciplines:
The concept developed within the framework of our activities and its realization in form of an enlarged precipitation-recycling model will help to improve the understanding of processes interacting on various scales of different disciplines (atmospheric science, hydrology).

Contributions to Human Resource Development:
The concept developed and its realization in form of a precipitation-recycling model may be a step forward for effective management of our recent and future water resources.

Contributions to Resources for Research and Education:
The project enhanced the relationship of UAF to NCAR (see e.g. NCL workshop at Fairbanks, discussion with NCAR scientists at the CCSM workshop, use of NCAR computers) and the International Arctic Research Center (see e.g. NCL workshop at Fairbanks, lectures at the IARC summer school by the PI). The project helped to further-develop the atmospheric science program in CSEM at UAF, where the PI teaches atmospheric science, by allowing her to supervise the student in research activities.

Contributions Beyond Science and Engineering:
The current state of climate modeling leaves us with many uncertainties on future climate, water cycle and water availability. However, this does not necessarily mean that there is no hope to formulate effective policies to meet the challenges of the future. Our activities will advance knowledge and understanding of the interaction between the water and land-based part of the water cycle, and the interaction between the global and regional/local pathways of the water cycle. Thus, they will improve the knowledge of the natural variability of the water cycle in comparison with the changes that anthropogenic factors may produce. Better knowledge of the scientific uncertainties in the water cycle itself or caused by unknown radiative forcing and/or land-use changes may help to avoid panic reactions, limits the costs of being wrong, and also give the possibility to formulate effective policies to meet the challenges of global change. In this way the activities helps to prepare for both short- and long-term changes of weather and climate, while investigations on ecological and societal effects of atmospheric fluctuations, both man and naturally caused are going on. Such preparations, for instance, can be the development of better water management strategies (e.g., by regulations similar to water management of rivers, subsidence policies), or guidelines for decision-making (e.g., basic for planning studies, need for approval for larger land-use). The identification of sensitive areas may provide hints where to install additional monitoring sites. The results on the time scales give hints at the question of the response time, and, hence, on how long a station at a given site must be operated to be able to detect a certain feedback mechanism.

Special Requirements

Special reporting requirements: None
Change in Objectives or Scope: None
Unobligated funds: less than 20 percent of current funds
Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:
Organizational Partners
Any Journal