

*Atmospheric Explorations II*

Science Museum of Minnesota  
The Center for Atmospheric and  
Space Sciences at Augsburg College



Front-End Evaluation  
Phase II

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## EXECUTIVE SUMMARY

*Atmospheric Explorations II* is an exhibit currently being developed at the Science Museum of Minnesota in collaboration with the Center for Atmospheric and Space Sciences at Augsburg College. Selinda Research Associates conducted a front-end evaluation for this project.

The purpose of front-end evaluation is to identify visitors' needs, interests, and understandings about the exhibition topic in order to inform the exhibit development team throughout the planning and development process. We conducted this evaluation in two phases. The first phase was intended to provide the exhibit team with some preliminary data to help them make decisions about which three of four possible topics to select. The second phase occurred once topics were selected and goals and objectives for each exhibit cluster were defined. These topics were: *Mid-Latitude Cyclones*, *Physical Climate*, and *Cycle of the Ice Ages*. In phase two, we explored the three selected topics in detail and more thoroughly assessed visitors' understandings and connections to the topics. In this report, we present findings from phase two of this evaluation.

We collected data in May and June, 1999 at the Museum of Science and Industry in Chicago. Using naturalistic methodology, we conducted depth interviews with 24 visitor groups (comprised of 59 individuals). Interviews ranged in length from 15 to 45 minutes. We also used a weather map and a U.S. map where visitors could physically move certain landforms. These maps helped to focus conversations and helped us assess how visitors thought about certain weather processes.

## RESULTS

Below is a summary of our major findings. Specific recommendations are included in the full report.

Visitors thought about weather primarily in relation to how it affected their daily lives. We identified four primary ways visitors connected to this topic:

1. **Recreational Activities** - Visitors talked about how weather affects their ability to enjoy outdoor activities;
2. **Work** - Another connection was the effect of weather on respondents' commutes to and from work or on their working conditions;
3. **Play** - Younger respondents related to weather primarily as an opportunity to play (e.g., playing in the snow);
4. **Sensory Experience** - Many respondents connected with the sensory experience of weather. They saw weather as something to feel, hear, or touch.

The exhibit team can use the connections identified as entry points to the exhibition. Doing so can strengthen visitors' experiences at the exhibition. Research indicates that helping visitors make these connections is essential because it facilitates learning and they are more likely to

continue learning if they can take what they learned at the exhibit and apply it to their lives (Gyllenhaal & Perry, 1998).

### Ways of Thinking About Weather and Climate

While visitors were very familiar with the topic of weather, they were more concerned with the *effects* of weather on their daily lives rather than weather *processes*. Many respondents had not thought very much, if at all, about weather in a scientific way. The exhibition will be asking visitors to think about this topic in very different ways than they normally do. However, this is not an impossible task. Visitors' connections to this topic can facilitate that process.

### Weather as a Global System

One way of representing the range of visitor understandings about a topic is through the knowledge hierarchy. We developed a hierarchy to describe the range of visitor understandings about weather as a global system. Following is a range of visitors' understandings about how their weather is part of large-scale global processes:

- 0 "Don't know, don't care." These visitors haven't thought very much about weather as a system and aren't interested in finding out about the topic.
- 1 "Don't know but was wondering." These visitors aren't sure that there are large, global weather processes but they are curious about it. These visitors have formed the question in their minds.
- 2 Most visitors at this level think of weather as a local phenomena that is not tied to larger weather patterns. They think about weather only in terms of their specific location. Some visitors at Level Two do understand that the weather in their area is tied to larger weather patterns, but they tend to think of these patterns as relatively local, usually relating it to weather from "further west" in the U.S. from where they are located.
- 3 Visitors at this level are aware that weather has larger patterns than just in the U.S. They have begun to make some connections between weather in nearby parts of the world such as Mexico and Canada with that in the U.S. However, their understanding is incomplete.
- 4 These visitors have a rudimentary understanding that weather is a global system and that local weather can be affected by patterns elsewhere.
- 5 Visitors at Level Five have a sophisticated understanding of weather as a global system.

Most visitors were at Level Two of the hierarchy, making limited connections to larger weather patterns. Usually, respondents tied their local weather to weather that "traveled" from "further west" in the U.S. from where they lived. While most respondents were at Level Two, the fact that they saw weather as something that travels or moves indicates that it could help introduce the concept of large-scale weather processes. Our findings suggest that a primary goal of the

exhibit—one that might be achieved for many visitors—should be to change people’s focus on weather towards more global ways of thinking about the topic.

### Mid-Latitude Cyclones

Most visitors had never really thought about why we have weather and told us that they didn’t know the reasons for it. Some visitors were willing to guess, however, and there were three factors which respondents identified: air movement, the sun, and the earth’s rotation. Respondent’s understandings, however, were incomplete and they were not able to explain these factors in detail or how they interacted to create weather.

We also spoke with visitors to find out to what extent and in what ways they understood weather symbols. We used a weather map as a springboard for these conversations. Most visitors were familiar with the weather symbols we presented and they seemed to have a basic understanding of what they meant. Most respondents understood that fronts and pressure systems affect the kinds of weather in a given area. Visitors, however, could not explain these in great detail and were not sure how they fit together to create specific kinds of weather. Since visitors do have some understanding of factors involved in weather systems, one of the goals of *Mid-Latitude Cyclones* should be to help visitors better organize what they already know about fronts and pressure systems.

### Physical Climate

Using a map of the U.S., we talked with visitors about how they thought the climate in the Midwest would be affected if we moved the Rocky Mountains and the Gulf of Mexico around to other parts of the country or removed them altogether.

Most visitors understood that mountains and oceans affect climate. They saw mountains as barriers that “block” weather from moving. Therefore, their hypotheses about climate changes in the Midwest revolved around what type of weather they assumed was being blocked or released to move further west. Respondents primarily thought of oceans as increasing the moisture in the atmosphere and, consequently, contributing to the amount of precipitation in an area.

Overall, respondents drew from their personal experiences to figure out how oceans and mountains affect climate. Visitors seemed to have very accurate (although sometimes incomplete) “gut level” understandings of what might happen when oceans or mountains are added or removed in an area. This suggests that visitors could easily draw on their personal experiences to form specific hypotheses when using the *Physical Climate* simulation. This exhibit cluster can serve as a building block for furthering visitors’ understandings about landforms.

### Ice Ages

This topic may be the most challenging of the *Atmospheric Explorations II* exhibit clusters. Most visitors had not thought about ice ages and, in fact, many did not realize that there was more than one ice age. When respondents thought about “the” ice age, they were usually referring to the last ice age.

Respondents usually attributed “the” ice age to a decrease in the earth’s temperature (although they could not explain how the temperature could fluctuate) or to catastrophic events such as volcanic eruptions which blocked out sunlight. Given respondents’ mental models about the causes of an ice age, many were confused when we told them they were cyclical and they had difficulty explaining how this phenomenon occurred.

Nonetheless, respondents did have some understandings about glaciers which can serve as entry points in helping visitors gain a better sense of ice ages. Respondents seemed to understand: 1) that the intensity of solar radiation is a factor in glaciation; 2) that an increased level of moisture and snow could account for glacial formation; and 3) some of the effects of advancing and receding glaciers (e.g., the formation of the Great Lakes and physical traits such as moraines). It is important to recognize, however, that what we expect visitors to take away from this exhibit cluster may be at a more basic level.

We also found that visitors had difficulty conceptualizing the time scale involved when thinking about the ice ages. There was a wide range of years given by visitors for when the last ice age occurred (from “thousands” to “one million”). This may be due to primarily to the fact that visitors tend to relate time to the human life span. Research by Stehr and von Storch (1995) suggests that this “human scale” is why most people relate to weather in terms of daily changes and over a period of a few decades. A timeline that provides visitors with concrete, historical markers they can relate to may help.

## INTRODUCTION

The Science Museum of Minnesota (SMM), in collaboration with the Center for Atmospheric and Space Sciences (CASS) at Augsburg College, is currently developing *Atmospheric Explorations II*. The goal of the exhibit is to help visitors understand the large-scale processes that affect the climates we live in and the weather around us.

It will consist of three exhibit clusters on weather and climate systems:

1. **Mid-latitude cyclones:** In this cluster SMM will show how weather changes result from very large spiral weather systems that move across the U.S. from west to east.
2. **Physical Climate:** This exhibit will be about the physical features that affect local climate, such as mountains and oceans.
3. **Cycle of the Ice Ages:** In this exhibit the development team hopes to show visitors that glaciation is a cyclical process and will introduce visitors to some of the factors that cause ice ages.

Each exhibit cluster will contain a computer-based exhibit that runs a program of a weather system; a 3-D “meteorological diorama” that illustrates key concepts of the exhibit; a physical interactive that illustrates related physical phenomena; and appropriate illustrations and photographs of the system. One cluster will be designed to encourage social interaction among members of a visitor group.

## OVERVIEW OF EVALUATION

The Science Museum of Minnesota contracted with Selinda Research Associates to conduct front-end evaluation for the project. Front-end evaluation identifies visitors’ needs, interests, and understandings about the topic of the exhibition. This helps inform decisions the exhibit development team makes throughout the planning and development process.

We conducted this evaluation two phases. The goal of the first phase of evaluation, which occurred in November and December, 1998, was to assist the exhibit development team in deciding which of four possible topics to include in the exhibition: *mid-latitude cyclones*, *physical climate*, *cycle of the ice ages*, and *global warming*. This phase was a broad, exploratory study to provide the exhibit development team with some of the primary ways visitors thought about each of these topics. We wrote a summary report of our findings and also presented the results at the Advisory Committee meeting held in April, 1999. At this meeting, the team decided which of the three topics to include (those mentioned at the beginning of this report).

Phase two of this evaluation took place after the topics were selected by the exhibit development team and goals and objectives for each exhibit cluster were defined (see Appendix A for exhibit goals). It explored the three chosen topics in more detail, more thoroughly assessing visitors’ connections to and understandings of the topics. It also assessed how the goals and objectives

might work, given the range of ways visitors think about these topics. In this report, we present findings from phase two of this evaluation. Where appropriate, we have included results from the first phase of this study. However, the first report contains detailed findings that may only be alluded to in this report. Therefore, it is important to remember that these reports should be read together.

## **RESEARCH QUESTIONS**

During phase two of the evaluation we focused on three primary goals: 1) identify the range of visitors' understandings about the three proposed topics, particularly in relation to the goals and objectives presented at the Advisory Committee meeting; 2) continue to investigate the way visitors think about the concept of weather and the ways they connect it to their lives; 3) further identify appropriate entry points for the exhibition.

## **METHODOLOGY AND METHODS**

This evaluation used naturalistic methodology to collect and analyze the data (Lincoln & Guba, 1985). Naturalistic inquiry is a primarily qualitative approach of conducting research and evaluation in natural non-laboratory settings.

Naturalistic inquiry is grounded in the belief that the best way to study a particular research question is to look at as many different aspects as possible, in as much detail as possible, in the context in which it naturally occurs.

A qualitative approach to visitor research is particularly useful in museums because these institutions have different types of visitors with varying degrees of knowledge, experiences, and interests. Therefore, naturalistic inquiry aims to describe the range of visitor experiences and understandings, rather than an "average" experience. As such, it is a powerful tool for museums, especially those institutions concerned with reaching multiple audiences.

At the beginning of the evaluation study, we developed a topical framework in collaboration with the exhibit development team (see Appendix B). This framework served as a guide for focusing our research. We collected data in May and June, 1999 at the Museum of Science and Industry in Chicago. Because this was a large science museum, the exhibit and evaluation teams felt it would attract visitors similar to those at the Science Museum of Minnesota and would make the results more transferable to the visitor population at SMM.

We used depth interviews as the primary data collection method for this study. Depth interviews are open-ended and rely on building rapport with visitors. The strength of depth interviews is that they yield rich, detailed narrative data in respondents' own words. They also allow the evaluators to pursue different threads with visitors in order to illuminate different respondents' ways of thinking and talking about the issues at hand. As such, they give us a deeper understanding of visitors' knowledge and experiences.

We interviewed a total of 24 visitor groups (comprised of 59 individuals). Most interviews lasted from 15 to 45 minutes. Visitors ranged in age from 11 to the mid 50s. We spoke with visitors in various configurations, including families, adults, groups of kids, and single visitors. In selecting respondents for this study, we used purposive sampling methods (Lincoln & Guba, 1985). Purposive sampling (as opposed to random sampling) is a deliberate selection of the next respondent based on the results of the data collection to date. In this study, we selected respondents to include a wide range of perspectives and experiences including age, gender, race, ethnicity, social and economic background, and configuration of the social group with whom they were visiting. By employing purposive sampling, we obtained a broad visitor sample.

## RESULTS

The following section describes the themes and information that emerged from this study. When appropriate, we have included comments from the interviews to illustrate various points.

In naturalistic evaluation, we describe the *range* of visitor experiences rather than the percentage of people that acted in or thought a certain way. Because respondents were purposively selected (as described above), it would be inappropriate to report the percentages of respondents who felt a particular way. Instead, by using depth interviews, we are able to identify which views are more commonly held and which are more idiosyncratic. We represent this range of responses using the words: *all, most, many, some, few, and none*.

### Personal Connections to Weather

One of our assumptions during this evaluation was that learning about visitors' connections to weather would help us identify possible entry points for *Atmospheric Explorations II*. While these results were described in detail in phase one of this evaluation, they nonetheless merit some discussion here because they are important in understanding how visitors relate to weather and climate.

Understanding and incorporating visitors' personal connections into an exhibit is essential because: 1) visitors are more likely to engage with the exhibit; 2) research indicates that when visitors can personally connect with the information, it is easier for them to understand and remember; 3) visitors are more likely to continue their learning if they can apply what they see to their lives (Gyllenhaal & Perry, 1998).

In order to establish rapport with visitors and get a sense of what their "top of mind" images about weather were, we often asked respondents what went through their head when they thought about weather. We identified four primary connections to weather and climate.

### Recreational Activities

Many respondents talked about weather as affecting their recreational activities. Most visitors placed a value on types of weather. They talked about "good" or "nice" weather versus "bad" weather. When we probed further, we found that their associations had to do with how weather

affected their activities. Respondents associated "good" weather with the ability to enjoy outdoor activities.

*We need snow...You know, [for] skiers, snow mobilers, that kind of stuff. I like the snow [for skiing]. (112901)*

By contrast, visitors equated "bad" weather with weather that prohibited them from engaging in fun activities.

*If it's going to rain that evening, or early evening, and I'm going to cook out, well, I got a problem. Well, I don't have a covered patio. And I guess I could cook in the garage. (112803)*

## **Work**

Many visitors also talked about weather in relation to how it affected their commutes to and from work or their working conditions.

*It affects commuting conditions. I have a longer drive, although not longer time than most people. I drive from Waukegan to Chicago. So the driving conditions or my ability to anticipate what they're going to be like is very critical. (112803)*

*[I look at weather] mostly just [for the] road [conditions] and if there's [going to be] difficulty getting around. I usually check the night before on the weather channel to find out...[how] it's going to be...[the next] day. (121701)*

*He [my son is] a life-guard. He's going to be concerned [with the weather] in the summer. If it's going to be 60 degrees, or rain, then they won't have many patrons at the water park. (112801)*

## **Play**

Younger respondents primarily connected to weather as an opportunity to play.

*[When I think of weather I think of] having fun [in the summer]. Playing in water. Having a snowball fight [in the winter]. Playing in the mud after it rains. (120503)*

*I remember this really tall mound of snow and I got a chance to slide on it. It was fun! (121801)*

## **A Sensory Experience**

Many respondents expressed sensory connections to weather, often talking about it as something that is felt, seen and heard. Visitors often described this aspect of weather in detail:

*That's the part of the weather that I like the best, because it's dramatic and you can feel it, you know, it's this sensual kind of experience.... You use your other senses besides just your sight. It's hearing the sound, and the feel of the rain, and the wind. All the different [senses]. (120502)*

In addition to the connections we identified, the first phase of this evaluation also revealed that many respondents do their own short-range “forecasting” based on their observations. Visitors, for example, said they watched animals, paid attention to pain in bones and joints, or looked at the color of the morning sky to predict the weather.

Overall, there were many indications that while weather is something visitors are familiar with, they don't often think about the *concept* of weather. Most respondents were more interested in the results than in the causes of weather and how it affects their day-to-day lives. Getting them to change their focus to weather processes/causes may be a bit of a leap, but not an impossible one.

In order to engage visitors, the exhibit will need to help them connect the processes presented in the exhibition with their daily lives. Doing so will also help visitors apply what they see in the exhibit to their lives, thereby increasing the likelihood that they will continue their learning. The exhibit will also be more powerful for visitors if they can connect with it on a sensory level. This can be accomplished through the physical displays such as dioramas or even through some design elements which are visually appealing and which bring in sound.

### **Weather as a Global System**

One of the goals of this exhibition is to help visitors gain an understanding that their local weather is part of a global pattern. That is, that large-scale processes affect visitors' local climates and weather. We wondered whether, in fact, visitors thought of their local weather as connected to a larger system. As we explored this concept, we identified a range of understandings about weather as a system.

#### The Knowledge Hierarchy

One useful way to represent the range of how visitors understand a topic is the knowledge hierarchy. It emerges from the data and the conceptual information that the exhibit development team wishes to communicate.

*The knowledge hierarchy assessment technique is based on the assumption that inherent in each exhibit is an internal knowledge structure. This knowledge structure is at the intersection of the exhibit developer's and the visitors' organization and understanding of the topic. A knowledge hierarchy is simply a description of the range of understanding. It is not the range of knowledge visitors have about a topic, but the range of knowledge within the context of the exhibit. (Perry, 1998, p. 73)*

A knowledge hierarchy describes five to seven levels of understanding which depict the range of visitors' knowledge about a specific concept, usually organized by increasing levels of sophistication.

The hierarchy as defined here, does not identify the number of visitors in each category. Instead, it represents virtually all visitors' understandings. The knowledge hierarchy enables museums to recognize that they have at least some visitors at all levels and to understand what those levels are. The following hierarchy describes visitors' understandings about weather as part of a global system.

- 0 "Don't know, don't care." These visitors haven't thought very much about weather as a system and aren't interested in finding out about the topic.
- 1 "Don't know but was wondering." These visitors aren't sure that there are large, global weather processes but they are curious about it. These visitors have formed the question in their minds.
- 2 Most visitors at this level think of weather as a local phenomena that is not tied to larger weather patterns. They think about weather only in terms of their specific location. Some visitors at Level Two do understand that the weather in their area is tied to larger weather patterns, but they tend to think of these patterns as relatively local, usually relating it to weather from "further west" in the U.S. from where they are located.
- 3 Visitors at this level are aware that weather has larger patterns than just in the U.S. They have begun to make some connections between weather in nearby parts of the world such as Mexico and Canada with that in the U.S. However, their understanding is incomplete.
- 4 These visitors have a rudimentary understanding that weather is a global system and that local weather can be affected by patterns elsewhere.
- 5 Visitors at Level Five have a sophisticated understanding of weather as a global system.

#### Level Zero

Because weather seems to be something even children are aware of to some degree, we did not speak with any visitor at this level. However, it represents one end of the learning hierarchy.

#### Level One

We spoke with a few respondents that weren't sure about the large scale processes of weather but they had begun to wonder how weather worked.

### Level Two

Most visitors we spoke with were at this level of understanding and thought of weather in relatively local terms. A few visitors, mostly younger children, thought of weather as a local event that had little connection to weather elsewhere. Their understandings were mostly rooted in how the weather that day affected what they did outside.

Other visitors understood that weather in their area was connected to weather elsewhere, but the distance they related it to was very limited. Most often, respondents explained that the weather in their area traveled from “further west” in the United States.

*We get our weather a couple of days before they do in Chicago, so, you know, it comes from west to east. So what you have, we had a couple of days earlier.*  
(112902)

*They always say if it's raining in Chicago one day, and then I call New York, they'll say, "We're getting it tomorrow." (121701)*

### Level Three

Some respondents recognized that their local weather is affected by larger patterns. These visitors seemed to think about weather in slightly larger distances than visitors at Level Two. Most respondents at this level talked about weather from Mexico and Canada affecting weather in the United States.

*I know fronts come in across Mexico and on up through Texas and Arizona. [On the] news you hear that Canada affects your weather, especially in the northern states. And then, Mexico affects the south too.(052006)*

### Level Four

We spoke with a few respondents who recognized that weather has large global patterns. However, their understanding was rudimentary and visitors could not explain in detail how these patterns worked.

### Level Five

We did not speak with any visitors at Level Five of the knowledge hierarchy. People at this level would most likely be those with an extensive science background.

Overall, most respondents in this study tended to look at weather on a local scale. One of the challenges of this exhibition will be to help visitors recognize that weather patterns are much larger. However, since most visitors thought of weather as moving, this concept should be a good entry point in helping visitors understand that their local weather is a result of larger, dynamic processes.

Our findings suggest that a primary goal of the exhibit—one that might be achieved for many visitors—should be to change people’s focus on weather towards more global ways of thinking about the topic. Even if they don’t understand specific mechanisms very well when they leave the exhibit, visitors should still have a better understanding of the global nature of weather. Or, even if visitors started out thinking just locally about weather, getting them to think about it nationally would be an achievement.

### **Mid-Latitude Cyclones**

One of the exhibit clusters for *Atmospheric Explorations II* will focus on mid-latitude cyclones and the fact that most of the weather visitors experience are the results of large spiral systems that move across the country from West to East. Our conversations with visitors explored a variety of issues on how they thought about weather processes.

### **Why Do We Have Weather?**

One of the questions we explored with visitors during this evaluation was what they thought were the reasons we have weather. Our intent was to assess how visitors visualized weather and to identify visitors’ range of understandings and conceptions about weather systems.

Most visitors had not thought very much about this question and often looked at us with blank stares when we asked them. Some visitors simply told us that they just had “no idea” or that they had never stopped to think about it. Others ventured some guesses about several factors that might contribute to weather formation. We identified three common explanatory models of why we have weather.

#### *Air Movement*

Many visitors explained they thought we have weather as a result of air movement. Respondents explained that weather moved from west to east and therefore reasoned that winds “out of the west” pushed weather further east. As mentioned in the phase one report, respondents’ understandings about weather movement were primarily based on their personal experiences. Visitors in Chicago, for example, explained that storms came from the west or that relatives in the east coast got Chicago’s weather a few days later. Most visitors, however, could not describe why they thought currents traveled in specific directions.

We were encouraged to find that many visitors described “winds” moving as *air currents* and likened them to water currents. This comparison may help visitors understand that there are wind patterns that are factors in creating weather systems.

*It’s just lots of wind up there. It’s like currents in water. It’s the same with air.  
(042406)*

As we talked with respondents further about the movement of weather, we found that they visualized specific types of weather when they talked about it moving. Visitors visualized air moving and bringing with it weather such as: snow, storms, tornadoes, and cold or hot temperatures.

### Sun

Some visitors explained that the sun was the main reason we have weather. These respondents seemed to think about weather more like seasons than the day-to-day changes. They understood that temperatures on earth depended on energy from the sun.

*The sun mainly [is why we have weather] the sun and its path. (052006)*

These visitors also seemed to think of the sun as a constant that is always present (although depending on the time of year the intensity of the sun might be different), but which is occasionally blocked by clouds or “hidden” when storms moved in. In other words, these respondents seemed to think that were it not for rainstorms or winds blowing through, it would always be sunny.

### The Rotation of the Earth

There were some visitors who reasoned that the earth’s rotation also determined weather patterns although they were not sure of the details.

*It think it has to do with [the] rotation [of the earth] and the air currents coming off the water....And then, the currents moving. (042407)*

While visitors had some notion of the factors that contribute to weather formation, their understandings were incomplete in three ways: a) most respondents did not mention one or more of the key factors of weather formation; b) most visitors described an incomplete understanding of the factors they did mention; and c) respondents were not able to piece these concepts together to create a larger picture of weather systems. However, some visitors’ conceptions may be good entry points. Many visitors seemed to realize that air movement (which some visitors equated to wind) is a key aspect of weather and some respondents realized the importance of the sun and the earth’s rotation.

As we talked with respondents, it also became clear to us that weather is not a topic most visitors think about in scientific ways. The topic is familiar to them because they watch the news and because they are concerned about how weather affects their daily life, but they do not think about what causes weather or how it is formed.

## **Weather Symbols**

Not surprisingly, during phase one of this evaluation we found that many visitors paid attention to their local weather on a daily basis. Many respondents indicated that they often watched the local news or the Weather Channel and were familiar with weather maps. The exhibit development team wondered, however, whether visitors understood what the weather symbols on the maps

really meant or if they were simply "empty symbols." During phase two of this study, we further explored visitors' understandings of weather symbols. When we spoke with respondents we often showed them a weather map, which included some common weather symbols.

### Warm and Cold Fronts

Most respondents readily identified that two of the symbols on the map were warm and cold fronts. Visitors' explanations about what warm and cold fronts meant were rudimentary.

*It's like the movement of body of air, I guess. (052903)*

*It means a big blast of cold or warm air coming into the area. (042402)*

*It's like an air mass. Like there's cold fronts and warm fronts. So let's say there's like a warm air mass or a cold air mass here, and this warm air mass comes along that's where they meet. That's the front. (042406)*

Most visitors understood that weather changes when fronts move through an area.

*It's the leading edge of a cold zone that's moving toward -- Well, the temperature would be dropping along that area. (042407)*

*The temperature changes when a front moves through, usually. (042403)*

*On a warm front you're going to have more turbulent air, more thunderstorms. Tornadoes possibly. (052902)*

Most respondents, however, had more difficulty explaining how the interactions of warm and cold air masses works. When visitors thought further about what happens when two air masses meet, we found that they usually associated it with storms.

*The air that's moving down this way, it's actually colliding. There's two different types of air that are colliding at this point, a hot and a cool temperature that mix together...when they collide together they produce a storm. (050203)*

*If the warm front comes through and hits some cold air...it's going to rain all day. But if like a cold front comes into a warm front, it's really strong and violent and there could be thunderstorms. (042406)*

*And I guess you'd also have some kind of turbulence, possible wind or something, just because of the two different fronts coming together. I guess it's friction between two different air groups. (042407)*

Only a few respondents explained in some detail what happened when two air masses meet.

*I guess the way precipitation forms is that because the warmer air is lighter...it rises. The cold air is heavier so it goes down. And friction kind of stuff [happens]. I think it causes the formations of clouds and...rising of the air and the falling of the air. (042406)*

We were intrigued to find that many visitors' conceptions about what happens when two air masses meet evoked very powerful images for respondents. There was a visceral quality to the way respondents thought about this idea. Often, visitors used words such as "colliding," "running into," and "crashing" to describe two air masses meeting.

We also found that few respondents associated cold or warm fronts with pressure systems. That is, most visitors did not connect the movement of cold or warm fronts with the movement of low pressure systems across the country. Helping visitors make this link could be one of the objectives of the exhibit.

### Stationary Fronts

Fewer respondents were able to identify the stationary front on the weather map. Visitors that did recognize what the symbol was, explained that it meant that neither a cold nor warm front was predominant.

*That's [a] stationary [front]. It's where it stalls out. (052904)*

When we explained to visitors what a stationary front was, most indicated that they weren't sure why stationary fronts occurred and what they meant in terms of the kind of weather they brought.

### High and Low Pressure

Two symbols visitors readily identified on the map we showed visitors were the "H" and "L." Almost all respondents said that they indicated high and low air pressure.

*That's pressure in the atmosphere....The flow of weather kind of goes with [air] pressures, I guess...How it travels, how the weather systems travel. They usually travel with like fronts and stuff like that, or behind fronts, I guess. (042403)*

Most visitors associated pressure systems with either "good," "cold," "warm," or "rainy" weather. There were indications, however, that some visitors had misperceptions about what type of weather was associated with a high or low pressure system. We found a wide range of understanding about weather and pressure systems. Below is a sample of the range of visitors' associations between pressure systems and weather.

*It's moving hot air when it's a high pressure and cold air when it's low pressure. (042404)*

*High pressure is generally clear, warm weather. Low pressure is when you get precipitation. (052904)*

*High pressure always bring the bitter cold that we get all the time in the winter. (052903)*

*I think the high pressure...brings the moisture with it and it rains. (052901)*

*I think the high pressure would mean more thunderstorms, tornadoes. (042404)*

*Low pressure would be a cold point. And the high pressure has to be warmer, more stable air.*

*I think low pressure systems are more volatile. They'll cause more unstable weather. Whereas high pressure systems [are] more stable. (042406)*

While some visitors had some misperceptions about what type of weather was associated with the different pressure systems, they did understand that air pressure played a role in determining weather. However, most visitors were not able to explain this system further. They could not explain, for example, what caused different air pressure systems or that air moves from high pressure areas to low pressure areas.

Overall, our conversations with visitors revealed that respondents seemed to have some general understanding of what the weather symbols meant. Most visitors understood that fronts and pressure systems affect the kind of weather they get. However, they were not able to explain these in great detail.

There were also indications that respondents had some difficulty understanding how these different concepts tied together. Most visitors, for example, did not associate fronts and pressure systems as interacting to create a particular weather system. While they knew they played a role in determining weather, they were not sure how they intersected. One visitor, for example, explained that he have a general idea of some factors affecting weather, but that he still didn't really know what caused it.

*I really don't know where [weather] comes from, you know? It's just there. And I'm sure it has something to do with like the heaviness of the air and the heat of the air and things like that. But what causes it?(042406)*

The exhibit developers should try to use the mid-latitude cyclone concept to help visitors organize what they *already* know about weather fronts and pressure systems. The exhibit could help visitors realize that mid-latitude cyclones are one of the weather phenomena that link our local weather to changes on a global scale.

## Clouds

The exhibit development team was also interested in finding out visitors' understandings about cloud formation and their relationship to weather (particularly to the concept of warm and cold fronts). They wondered whether visitors associated specific types of clouds with certain kinds of weather.

Most visitors thought clouds were formed when water from oceans or large lakes evaporates into the atmosphere. Most respondents distinguished between two types of clouds: large, dark clouds, which they associated with storms, and "puffy, white" clouds which they said accompanied sunny weather. When we asked visitors why there was such a difference, they attributed it to moisture. Respondents explained that the dark clouds had a lot of water in them while the white clouds associated with good weather had less moisture.

*The big, puffy clouds [mean] it is a pretty sunny, blue sky day. And the dark gray, black, ominous clouds [mean]...it's going to storm. [They're dark] because they're heavy with the moisture. (052901)*

*Dark clouds mean stormy weather. The white, billowy clouds mean nice...it's going to be a nice day. It's those big puffy clouds. The dark ones are full of rain (042404)*

Not surprisingly, grade school kids who had learned about weather in school named different types of clouds such as cumulonimbus, cirrus, and cumulus. However, most could not remember which was which.

While visitors were certainly familiar with clouds, there were indications that they did not think very often about how they form. Most respondents realized that there were more than two kinds of clouds (i.e., "puffy" or "dark" clouds), but their only associations were with clouds on sunny days or during storms. Nonetheless, the fact that they made connections between moisture and clouds may be a possible entry point in helping visitors understand why clouds form and how that connects to mid-latitude cyclones.

### The Word "Cyclone"

During the first phase of this evaluation, we found that respondents attributed a very specific meaning to the word "cyclone." Almost everyone we spoke with equated "cyclone" with "tornado." Visitors explained that the words had the same meaning and that the variation in terms had to do with what part of the country someone was from. While this was not an area we focused on during the second phase of this evaluation, it is important to keep this in mind as the exhibit development team moves forward with this exhibit cluster. Using the term "mid-latitude cyclone" as the name of the exhibit will probably confuse visitors and they will most likely expect to see an exhibit about tornadoes.

## Physical Climate

One of the exhibit clusters for *Atmospheric Explorations II* is intended to show visitors how local climate depends on physical features, such as mountains and oceans. We thought giving visitors the opportunity to move some land forms might be a good springboard to assess how they thought physical features affect climate. In conjunction with the exhibit development team, we decided to have visitors move either the Rockies or the Gulf of Mexico. We came up with several scenarios to present visitors with and get their reactions.

We gave visitors a map of the United States in which they could physically move both of these landforms and asked them about the following scenarios. For the Rocky Mountains, we asked visitors what they thought might happen to the climate in the Midwest if: 1) we removed them altogether; 2) we placed them where the Appalachian Mountains are; and 3) we placed them between the border of Canada and the U.S. For the Gulf of Mexico, we asked visitors what might happen to the climate in the Midwest if: 1) we removed the Gulf of Mexico and instead that area was just land and; 2) we placed the Gulf of Mexico in the Ohio Valley. We found remarkable continuity between visitors' responses

### Mountains

Most respondents thought of mountains as barriers that kept weather from moving. Visitors explained that clouds and storms can't get over the mountains because they are too high and therefore weather "gets stuck" on one side of the mountain.

Almost all visitors talked about weather in the western part of the United States as coming from the Pacific Ocean and that, therefore, the west side of the Rockies gets a lot more rain. The east side, on the other hand, is much drier.

*At the Rockies, the weather is coming this way [from the west]. The [west] side is going to get a lot of rain...where the east side will not. It'll be drier. It has something to do with air masses moving up and causing the rain to fall on...[the west] side of the mountain and then all the moisture's out of the air. (042406)*

*If you've got a weather system coming across and it hits a mountain, obviously, it's going to have to go up and over that mountain. So you'd get, depending on the shape of the mountains, on one side of the mountain....you might have less precipitation on one side. (042407)*

Visitors said that removing the Rockies, would permit certain types of weather to move further east. Most visitors reasoned that the Midwest would get more wind, rain and snow because the mountains would no longer be there to block incoming weather.

*I think [there would be more] rain. Nothing's stopping it. It would rain more. (052904)*

*I think it would be cooler....Probably the moisture out over the ocean helps to cool the air temperature. It might snow. (052901)*

Some respondents thought it would be warmer because they reasoned that the warmer weather from the west would move further east.

*It might not be as cold. There's more passage of air and just clouds and moisture. (05903)*

*Maybe possibly warmer....The Rockies kind of block the warm weather and keep it isolated in that one area. So you get the warmer air blowing over through here...the summers would be warmer. (052902)*

When visitors placed the Rockies between Canada and the U.S., many respondents said that it would probably be much warmer in Chicago. They explained that the mountains would block the cold air coming from Canada.

*It would be warmer [in Chicago] because the mountains would be blocking the wind coming from Canada. (052905)*

*Less snow...a lot of cold air comes down from Canada in the winter and it catches the moisture. [The mountain] blocks some of the air. (052904)*

*It may be warmer in the Midwest because usually the cold air comes down from Canada, so that might block some of the cold air coming down. (052903)*

*I just know that's where the arctic cold fronts come from. They could stay up there, and we would have much milder weather...I don't think we would get much snow....Maybe our precipitation would be more rain than snow. (052901)*

Replacing the Appalachian Mountains with the Rockies was probably the most difficult scenario for visitors to predict. Visitors were not sure how climate in the Midwest would be affected (either because they didn't know the Rockies were much taller or because they thought weather only moved west to east). Most were not sure if such a change would affect the Midwest at all. Some visitors reasoned that the climate would be the same as the scenario where the Rockies were removed.

*It'd be more wet probably...just like we said when [the Rockies were gone]. So it would have the same effect. (052904)*

Some thought it might increase precipitation.

*You're going to get more rain because you're going to get the moisture from the Gulf coming up. And it's just going to hang out and it's going to be spread down by the mountains. (052901)*

Some respondents also ventured to guess what the climate of the east coast would be like. Most thought that perhaps weather coming off of the Atlantic Ocean might get trapped on the east side of the mountain. They reasoned that this would mean the east coast would get more rain and that it would be cooler, while it might be drier directly west of the mountain range.

*It might be cooler along the beach side because of the wind coming [from the ocean]. Because the wind would...be blocked by the mountains. It might make...[the west side] a little warmer. (052905)*

*[There would] probably [be] more snow east of the mountain. (052006)*

Most respondents saw mountains as barriers that prevented weather from moving. This was true of both kids and adults. Thus, their hypotheses about how the climate might change if the Rockies weren't there or if they were in a different spot, revolved around what type of weather was being blocked or released to move further west.

Interestingly, almost no one mentioned how the jet stream might be affected by the scenarios we proposed. Nonetheless, many respondents often had relatively accurate "gut level" understandings, particularly in the second scenario in which they moved the Rockies at the U.S./Canada border.

## **Oceans**

While respondents initially had some difficulty envisioning the role oceans play in creating weather systems, their personal experiences with the climate near the coasts and the Gulf of Mexico appeared to help them reason out our proposed scenarios.

Most visitors associated large bodies of water with rain or snow. Respondents indicated that oceans and large lakes emit moisture into the atmosphere which evaporates and rises to the clouds. Thus, they are the major contributors to rain and snow.

*[Oceans] that's where storms will build up. Storms will build out on the ocean and come ashore....I guess it has something to do with evaporation...It helps make clouds. Clouds collect rain. For some reason I don't know, it tends to move to shore....[Probably] if there's wind [the storm will move]. Which way the wind is blowing is going to obviously build a storm that way. (052902)*

Some respondents also thought that land near the large bodies of water is much cooler because of the breeze off the water.

*The wind off the bodies of water makes things cooler...because of the wind [coming] off the water. (052905)*

*My daughter lives on the lake and it's really windy....I'll go out [to the ocean] and you can see your breath...the temperature is a lot chillier. (042402)*

When we asked visitors what would happen if the Gulf of Mexico weren't there, most were not sure what might happen to the weather in Chicago. They had a much easier time thinking through possible scenarios for how the climate in Florida or states surrounding the Gulf might change.

*I know they get that warm Gulf air. So I think you would probably take some of that away. There would probably be no monsoon season. You may get a tail end of the summer that's very humid and warm. It would probably just do away with that. (052006)*

*For those people that live in Texas...they would heat up because there'd be no more [cool air] from the Gulf. (052007)*

*Texas...might turn into a desert region because it's not right off near a body of water...I think Mississippi and Alabama would become drier and more desert-like climate. Not completely desert, but drier. (052002)*

When visitors ventured a guess at how the climate in the Midwest might change without the Gulf, they reasoned that the Midwest would be drier because there would be less moisture moving up from the Gulf of Mexico.

*You would get less rain probably...because [the Gulf] is where a lot of the rain might be picked up. And by the time it makes it up to Illinois, it'll probably rain [less]. (052002)*

*It would be drier. (052005)*

When we asked visitors what might happen if we moved the Gulf of Mexico to the Ohio Valley, most reasoned the weather would be much like the states surrounding the Gulf. This was based largely on their personal experiences.

*It makes it very warm and also very moist....[We] may get some tropical storms. That would be weird. (052903)*

*I think we'd get more rain...It rains often [near the Gulf of Mexico]. It's the evaporation of the water. And that brings more moisture into the air. And it causes...rain. (052901)*

A few visitors explained that the Gulf would moderate the temperature in the Midwest.

*Just being close to that much of a body of water, the water's going to hold the temperature more, so you're going to have less extreme temperatures throughout the year.(042407)*

Some respondents reasoned that the large body of water would make the Midwest cooler, largely because, as previously mentioned, they thought of large bodies of water as bringing cool air.

*It'd be cooler. You'd get the breeze coming off the water. The water helps cool down the air. (052902)*

Visitors drew largely on their personal experiences with large bodies of water and the climate near the Gulf to reason out how water affects climate. As with mountains, we found that many visitors' responses were relatively accurate (if sometimes incomplete). They understood that large bodies of water affect climate largely by emitting moisture into the atmosphere. We also found that visitors had some conception that wind somehow "carried" this moisture to other places. This may be a good entry point to introduce visitors to the role surface currents play in weather systems.

Overall, what we found most promising from our conversations with visitors about landforms was the degree to which respondents seemed to have a "gut level" understanding about these concepts. They formed some very specific hypotheses by using their personal experiences with areas of the country near mountains or oceans.

Visitors seemed to have enough of an understanding about mountains and oceans that: 1) they can probably develop a stake in the results (by making their own predictions); and 2) the exhibit can serve as a building block for furthering visitors' understandings about landforms.

Visitors also seemed to enjoy using the map of the U.S. and moving physical landforms around. It suggests that visitors could do some really fun and dramatic things in the simulation (paralleling the very successful *Winds* model in *Atmospheric Explorations I*).

### **Cycle of the Ice Ages**

Another exhibit cluster for *Atmospheric Explorations II* will be on the ice ages. The exhibit team hopes to introduce visitors to the concept that ice ages are cyclical and to help them learn about some of the factors that cause ice ages. In particular, the exhibition team hopes to show that: 1) glaciers build-up or recede due to a decrease or increase in solar radiation and quantity of atmospheric CO<sub>2</sub>; 2) these ice sheets cause positive and negative feedback effects (e.g., increase the amount of solar radiation that's reflected from the land and sea); and 3) oceans have a moderating effect on the swing of the earth's temperatures.

From phase one of evaluation, we know that that few respondents realized that glaciation is a cyclical process. Most visitors thought that there had been only one ice age and usually associated it with the last glaciation period. Respondents that did know there was more than one ice age were usually younger visitors who had learned about it in school (although their understandings were largely incomplete).

During phase two of the evaluation we hoped to gain a better understanding of what visitors thought caused an ice age, the ways they thought about glaciation processes, and what time frames respondents associated with the last ice age.

### **What Causes an Ice Age?**

While most visitors had heard the term “ice age,” it wasn’t something most respondents thought about very often. When we asked respondents what might cause glaciers to form, most said they had “no idea.” However, most visitors were willing to venture a guess at factors that might cause glaciation.

Many respondents assumed that the earth’s temperature dropped, and that snow or moisture formed the glaciers.

*[Glaciers formed from an] accumulation of moisture...[the more moisture there was] then the glaciers would become bigger. (042404)*

*I guess I'd say [it] was dropping temperatures, so you've got more precipitation turning into solid ice. So more of the water became -- more of the actual bodies of water [became] ice. I guess I don't know how you actually get more. I don't know how you'd actually come up with more of the moisture. Well, because I know that there's moisture in our air. I mean, we've got -- and I'm trying to think of all the sources of water that there [are] -- so there's bodies of water that could freeze. There's moisture in the air, so that could freeze and fall down as snow, I suppose, and then, add to that. (042407)*

Conversely, visitors reasoned that glaciers melted when the earth’s temperatures got warmer.

*The sun melted them and the ice ages [are] over now. (052905)*

*It was warmer. The sun melted them. (052005)*

Visitors had significant difficulty explaining why in the past, the earth’s temperatures fluctuated so drastically as to cause glaciation. Many respondents reasoned that the earth must have gotten much less sun that it does currently. They guessed that the earth’s orbit must have been different than it is now, which would explain why it was colder (and later, when the orbit changed, why glaciers receded).

*Maybe the earth was farther away from the sun then....Because the farther away you get [the] colder [it is]. (052905)*

*Just different weather patterns, colder weather patterns. And I'm not sure why. It may have to do with earth's axis or something like that. I don't know. If it's like tilted away --...that's my guess. It would be like further away from the sun. Like in*

*the winter, the reason it's so cold is because the tilt is further away from the sun. In the summer, it's closer. (042406)*

*Maybe the earth was spinning differently from the sun. Something happened to the sun. (052005)*

Some respondents thought that perhaps a catastrophic event had taken place such as volcanic eruptions which blocked out sunlight.

*There might have been a giant volcano or something. And it caused dust all over the earth. And then, the sun wasn't able to shine down. And so, it got colder. (050202)*

A few visitors guessed that meteors might have caused a decrease in sunlight.

*Does it have anything to do with the meteor impact?....It's kind of like a nuclear winter effect from a meteorite or asteroid or whatever. The first thing [that's] going to happen is it's going to cool off. (052904)*

As we spoke with visitors, we sometimes explained that there had actually been more than one ice age to see if this would color their explanations. We found, however, that visitors were at a loss for explaining the cyclical nature of glaciation.

There were also indications that visitors did not realize how long it takes for glaciers to recede and what causes their retreat. Most visitors seemed to think that glaciers melted very, very quickly and that the sun alone was totally responsible for their retreat. For example, when visitors talked about the formation of the Great Lakes, they imagined the glaciers melting all at once in a very short time frame and “turning into” large bodies of water.

Overall, we found that respondents were largely unfamiliar with the causes of glaciation and it will be a difficult concept for visitors. Nonetheless, we were encouraged that many visitors seemed to understand: 1) that the intensity of solar radiation is a factor in glaciation; 2) that an increased level of moisture and snow could account for glacial formation; and 3) some of the effects of advancing and receding glaciers (e.g., formation of lakes and physical landforms--see the “effects of glaciation on the landscape” section). These may be possible entry points for visitors.

## **Time Scale**

As indicated in the first phase of this evaluation, most respondents were not sure when the last ice age was. Guesses ranged all the way from thousands of years to 1 million years ago. It seems that visitors have difficulty conceiving of such large time scales. During this phase of evaluation we asked visitors what plants and animals might have lived during the last ice age. We hoped that it would illuminate visitors' associations of time scale for the last ice age. Visitors associated a wide range of living things with the last ice age.

Many respondents associated woolly mammoths and mastodons with the ice ages. Visitors indicated that they figured these animals lived “back then” because of their thick fur and size.

*The animals were significantly different. They were bushier. [Like] the woolly mammoths. (052005)*

As respondents brainstormed with each other about what lived during the last ice age, some said that humans were around because they remembered learning about the Bering Strait. They explained that Native Americans were supposed to have crossed it during the last ice.

*I almost want to say [the Ice Age was] almost a million years ago, before the Native Americans arrived. Or during, I guess. They supposedly walked over the strait thing. So the theory goes. (052903)*

Some respondents also thought that cave men lived during the last ice age.

*[There would be] like Neanderthals and cavemen. (052901)*

A few visitor thought that perhaps dinosaurs lived during the ice age.

Overall, most visitors had difficulty relating specific plants or animals with the last ice age. Even when they did come up with some guesses, it was clear that these associations were not particularly strong. While this information was helpful, we do not feel that visitors have concrete understandings of time scale for the last ice age. They had a difficult time conceptualizing such large time scales, perhaps because most people find it easier to relate time to the human life span. Research by Stehr and von Storch (1995), in fact, suggest that most people relate weather according to this “human scale” (i.e., in terms of daily changes and/or changes over a period of a few decades). As a result, people find it difficult to conceptualize and respond to long-term changes. Visitors will need some concrete types of time frames they can refer to if they are to gain a more solid understanding of when the last ice age occurred.

## **Oceans**

Our conversations with visitors about landforms also gave us some insight into how their understandings relate to the ice ages exhibit cluster. Because visitors are aware that oceans play a role in the weather or local climate, it may be a good entry point in helping visitors understand that oceans have a moderating effect on the swing of the earth’s temperatures.

## **Effects of Glaciation on the Landscape**

During the advisory meeting some our discussion revolved around possible entry points for the ice age exhibit cluster. Because glaciers leave geologic evidence behind, we thought this might be a good way to help visitors connect the last ice age more directly to where they live. We wondered what sorts of associations visitors made between glaciers and their homes. Since our

interviews took place in Chicago, it was not surprising that many visitors talked about glaciers and the Midwest.

Many respondents knew that glaciers had a significant role in shaping the land. Respondents often mentioned that the glaciers formed large bodies of water.

*[Glaciers] shaped the land. They made the Great Lakes. (052904)*

*Glaciers are the reasons why we have so many lakes in Wisconsin and Minnesota. It cuts into the ground, swallows into the ground, the glaciers, the very huge masses. (042406)*

Many visitors also explained that the glaciers were responsible for changing and forming the land where they live.

*[Glaciers formed] a lot of landscapes in Wisconsin...it's like a big, slow moving river that [takes] deposits along but very slowly. Then when it receded, it just kind of dropped everything. They have a lot of hills and limestone [in Wisconsin]. (052903)*

Overall, many of the visitors we spoke with had some knowledge that glaciers had shaped the landscape where they live. Visitors connected with this concept primarily because they had been to places where they could see the “physical evidence” that glaciers had once been there, such as the Great Lakes or moraines in Wisconsin. This was the one concept about glaciation with which many respondents readily connected. Not surprisingly, we often noticed that when we talked with respondents about glaciers, this portion of the conversation was when they were the most animated. Clearly, connecting ice ages to “place” will be important in this.

## SOCIAL INTERACTIONS

The exhibit development team plans to design one simulation to provide opportunities for collaborative experiences among visitor groups. Increasingly research indicates that learning in museums occurs as a result of meaningful social interactions (Diamond, 1986; McManus, 1987; Perry, 1989). As Paulette McManus notes:

*Groups of visitors which had good social relationships and moved around the museum in closed units were more likely to engage in behaviors which would allow them to process information from exhibits satisfactorily (McManus, 1991, p. 39).*

Because social interaction is so important in museum learning, we suggest that a major goal of the exhibit should be to encourage social interaction throughout the exhibit, including at *all three* simulations. The topics for these simulations lend themselves to some interesting possibilities for collaborative activities.

In addition to creating collaborative experiences at the simulations, however, there are other ways to encourage social interaction that can be incorporated throughout the exhibition. According to the research, successful exhibitions promote and encourage conversation (Diamond, 1986; McManus, 1987; Silverman, 1997; Borun, 1997; Perry, 1992). Learning in a sense, is a group experience. When visitors are stimulated to have conversations about an exhibit, it is more likely that learning will take place. This research indicates that meaning making in museums occurs not as a result of a message conveyed from an exhibit to an individual, but as a result of conversations that occur in the context of the exhibit. McManus also found that when members of social groups were in close proximity, they tended to engage in more meaningful conversations and learn more. In other words, exhibit areas should be designed to encourage members to stay together rather than to separate. Some elements the exhibition could incorporate to encourage social interaction include:

- Design “read-at-a-glance” labels in the physical exhibits that visitors can quickly interpret for other members of their group. This promotes conversations about what visitors are seeing and doing.
- Physical exhibits should allow visitors to gather around them comfortably.
- At the computer simulations, create areas where several visitors can comfortably sit together and all view the screen.

Minda Borun has also developed a model for designing exhibits conducive to family learning (Borun, 1997) which we believe is applicable for many types of social groups. She has identified seven characteristics that appear to enhance learning at an exhibition. The exhibition team may want to incorporate these in their design for *Atmospheric Explorations II*. These components are:

- Multi-sided—An exhibit should allow for a visitor group to cluster around it.
- Multi-user—The exhibit allows for more than one user at a time.
- Accessible—It can comfortably be used by both adults and kids.
- Multi-outcome—Interactions foster possible outcomes.
- Multi-modal—Allows for different learning styles and knowledge levels.
- Readable—Text is easy to comprehend.
- Relevant—Provides links to visitors’ existing knowledge/experience.

## DISCUSSION AND CONCLUSIONS

The topic of weather is certainly a familiar one to visitors. There were many indications throughout this evaluation that visitors pay close attention to day-to-day weather and most watch local forecasts on a regular basis. This study indicated, however, that visitors think of *how* weather affects their daily activities and recreation. They do not often think about the *processes* involved in weather formation. While this exhibition will be asking visitors to think about concepts they don't think about very often, it is not an impossible task.

Because weather affects everyone, the exhibit development team has the opportunity to help visitors connect with this topic to their day-to-day activities. The summative evaluation of *Atmospheric Explorations I* indicated that visitors seemed to “be thinking somewhat abstractly about the phenomena in the simulations” (Gyllenhaal & Perry, 1998). If one of the goals of this exhibition is to help visitors translate their experiences at the simulations to their own lives, it will need to help visitors directly connect with what they are seeing and doing.

Of the three topics selected, *Mid-Latitude Cyclones* will probably be the easiest for visitors to connect with their day-to-day activities. First, visitors were familiar with weather maps and are used to seeing forecasts on television. Second, visitors had some basic understandings of weather symbols and that certain factors such as pressure systems and fronts affect their weather. However, they did not understand how these relate to each other. This exhibit cluster can help visitors tie these ideas together and help them organize what they already know about these concepts. In a sense, what we want is to give visitors a better or more dynamic picture to take away from the exhibit and to relate it to their lives. Next time visitors see a “well organized” low pressure system on a weather map, for example, they should think about the ways they were able to manipulate this computer model.

The *Physical Climate* cluster is also very promising. First, visitors seemed to have some “gut level” knowledge about how mountains and oceans affect weather systems. Their understandings were relatively accurate (if sometimes incomplete). This is encouraging because it indicates that visitors might easily draw upon their personal experiences to make predictions about what might happen if they moved around landforms. Because respondents seemed to have a visceral understanding of the effects mountains and oceans have on climate, it is also possible that the exhibit can help visitors build on their already existing “gut level” understandings. One challenge for this exhibit will be to make sure visitors can readily see how landforms affect the climate of a specific area. Naturally, visitors will be most familiar with the climate in the area where they live. They may be less familiar however, with the climate in other places. Therefore, it will be important that visitors can see what the “real” climate is like and then how it would change.

Of the three exhibit clusters, the *Cycle of Ice Ages* appears to be the most challenging, largely because visitors seemed to have more difficulty relating to the topic. First, it is not something they think about very often. Second, many visitors did not understand the cyclical nature of ice ages and were confused about why and how this could happen. Third, research indicates that large time scales are difficult for most people to grasp.

However, visitors did seem to have some basic understandings about glaciers that might serve as entry points for this exhibit. Many respondents were familiar with some of the effects the advancing and retreating glaciers had on the landscape. Also, visitors understood that the intensity of solar radiation is a factor in glaciation. However, how this process works and other factors that hasten or slow glaciation will be new for most visitors. Perhaps this is the one exhibit cluster where we need to recognize that what visitors will take away must start from a very basic level.

Finally, this study indicated that most visitors saw weather as relatively local, connecting their weather only in limited ways to other locations (usually to places “further west” in the U.S.). An important goal of *Atmospheric Explorations II* should be help visitors think about weather more globally. Each of these exhibit clusters—both in the simulations and physical components—can reinforce the “meta-message” that local weather is tied to large-scale processes. Repeating a message in this way, known in the field of instructional design as the “redundancy principle,” is an important technique for reinforcing a message (Fleming & Levie, 1978). Presenting this concept to visitors at each cluster can enhance learning and help visitors better understand the global nature of weather. Even if visitors leave the exhibit without understanding a specific weather process, they should still have a better understanding that weather is a result of global, large-scale processes.

## RECOMMENDATIONS

### Mid-Latitude Cyclones

- **Use a weather map as the main screen for the simulation:** Because visitors were familiar with weather maps from seeing them on television, this is an ideal way to help them connect with what they are seeing and doing. Using an “animated weather map” that visitors can manipulate may also help them get a visceral understanding of how some of these weather systems work. By using a weather map, visitors may be able to connect it more directly to what they see on TV and their daily lives.
- **Avoid calling this exhibit cluster “mid-latitude cyclones.”** Phase one of the evaluation revealed that visitors associate cyclones with tornadoes. Therefore, this name will confuse visitors. Some suggestions for names include “weather maker” or “storm systems”

### Physical Climate

- **Tie outcomes to concrete ideas to which visitors can relate.** One suggestion at the advisory meeting was to show visitors what an area’s climate might be like once they moved around some land forms. The suggestion to show what the main recreational attractions might be and what food might grow there are an excellent way to help visitors connect with this simulation.
- **Link the appearance of this screen to *Mid-Latitude Cyclones*.** Using a weather map will be familiar to visitors and will add continuity to what they see.

### Cycle of Ice Ages

- **Set reasonable goals related to clearly stated concepts (or images).** The concept of ice ages will be a very complex idea for visitors. The exhibit development team may want to think about dealing with only a few (basic) concepts in this cluster. Perhaps these could include:
  1. Showing the basics of how to grow an ice sheet by manipulating seasonal temperatures and precipitation. This could be one simulation, perhaps of an idealized landscape. This could be conceived of as a game which might involve trying to destroy (or preserve) a city in the path of a major ice sheet.
  2. The natural forces that drive cyclical changes in seasonal temperatures such as precipitation. This could be a second simulation of a larger scale than the first (e.g. continent). This could also reinforce the “meta-message” that local weather is part of large scale processes.
  3. The historical results of these cyclical changes such as multiple ice ages in Minnesota. This could be linked to the second simulation outlined above.
  4. Making future predictions such as if and when the ice sheets will return to Minnesota. Again, this could be linked to the second simulation.

- **Use a timeline for ice ages that incorporates key historical moments familiar to many visitors.** If the exhibit development team wants visitors to have a better concept of the last ice age, a timeline can help. It could include visual images or events that lived before, during, and after the last ice age (e.g., dinosaurs, humans, certain animals). Formative testing may help determine which markers have some meaning for visitors beyond what we have identified to date.
- **Provide visuals that tie what visitors are seeing to “place.”** For example, the ice age section can include pictures of places throughout Minnesota that were shaped by glaciers or samples of rock that show evidence of striation.

### **Overall**

- **Include visitor “talk back” areas.** During the advisory meeting in April, advisory members recommended including areas that encouraged the visitor voice. One suggestion was to incorporate a section where visitors could record their favorite weather stories. In addition, simple ideas such as a “talk back” wall where visitors can write down and post something about the weather could be fun.
- **Include sensory experiences for visitors throughout the exhibit.** This includes ways they can hear, feel, and see weather. These can easily be incorporated through simple design elements and in the physical exhibit components.

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# Weather & Climate Systems

## Provisional Goals by Topic

4/2/99  
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### Overall Goal

To give museum visitors a visceral, cognitive, and verbal understanding of large-scale processes that affect the climates we live in and the weather changes we experience.

### Mid Latitude Cyclones

Visitors will understand that most of the weather changes they experience are the results of very large spiral weather systems that move across the country from West to East.

- These systems are very large low pressure areas that often form on the lee sides of mountain ranges.
- These systems form along the boundary between warm and cold air masses known as fronts. Warm fronts move generally northward ahead of the low pressure areas and cold fronts move southward behind them. Warm fronts often bring lingering rain and snow. Cold fronts often bring showers, thunderstorms, and sometimes hail.
- Jet Streams in the upper atmosphere influence the path these systems take.
- These systems evolve over time and eventually disappear into the large-scale flow of the atmosphere.

A **warm front** is a boundary between a cold air mass and a warm air mass in which the warm air mass is displacing the cold air mass.

A **cold front** is a boundary between a cold air mass and a warm air mass in which the cold air mass is displacing the warm air mass.

A **stationary front** is a boundary between a cold air mass and a warm air mass in which neither air mass is displacing the other.

### Cycle of Ice Ages

To introduce visitors to the cyclical buildup and decay of major continental ice sheets called glaciers—and to the factors that may cause them.

The build-up of these sheets seem to respond to:

- a decrease in the intensity or change in the distribution of incoming solar radiation.
- a decrease in the quantity of atmospheric CO<sub>2</sub>.

These sheets cause positive and negative feedback effects:

- they increase the amount of solar radiation reflected from the land and from the sea, thus cooling the earth (positive).
- they decrease the amount of CO<sub>2</sub> trapped in the ocean by small animals (negative).
- the weight of the ice sheets depresses the surface of the earth; lower surfaces are typically warmer (negative).

The retreat of these sheets seem to respond to:

- an increase in the intensity or change in the distribution of incoming solar radiation.

- an increase in the quantity of atmospheric CO<sub>2</sub>.

The earth's oceans have a large moderating effect on the swing of the earth's temperature.

- They have a large heat capacity so they are slow both to heat up and to cool down.
- Ocean currents tend to redistribute heat from the tropics to polar regions.
- When the surface of the oceans freeze over, heat is trapped, tending to warm up the oceans and melt the ice.

## **Physical Climate**

To show museum visitors how their local climate depends on physical features such as mountains, oceans, ocean currents, and high plains.

- wet side/dry side of mountains
- orientation of mountain chains
- warm and cold ocean currents
- high plateaus (monsoon rains)

## APPENDIX B

### Topical Framework Phase Two Evaluation Atmospheric Explorations April 20, 1999

#### 1. Mid-Latitude Cyclones

- a) Given a weather map, how do visitors interpret it? To what extent and in what ways do they feel confident in their ability to interpret a weather map?
- b) To what extent and in what ways do visitors understand symbols on a weather map, including highs, low, and fronts?
- c) To what extent and in what ways do visitors understand the jet stream? What relationship do they see between the jet stream and weather?
- d) To what extent and in what ways do visitors understand daily weather changes?
- e) What is the range of understanding about what causes weather?
- f) To what extent and in what ways do visitors understand clouds? What relationship do they see between certain kinds of weather and certain clouds?
- g) To what extent and in what ways do visitors understand thunderstorms?
- h) What is the range of ways visitors tend to get weather information?

#### 2. Ice Ages

- a) To what extent and in what ways do visitors think about ice ages?
- b) What is the range of understanding about what causes ice ages?
- c) To what extent and in what ways do visitors see relationships between the current landscape and ice ages?
- d) To what extent and in what ways do visitors understand the role of oceans on the earth's temperature?
- e) In what ways do visitors think about time scales of the last ice age? What markers do they use?

#### 3. Physical Climate

- a) To what extent and in what ways do visitors think about land forms as affecting climate?
- b) To what extent and in what ways do visitors understand of how mountains affect climate?
- c) To what extent and in what ways do visitors understand of how large bodies of water (e.g., oceans) affect climate?
- d) To what extent and in what ways do visitors understand how high plateaus affect climate?

## APPENDIX C

### Respondents

<b>Interview #</b>	<b>Number of Respondents</b>	<b>Age</b>	<b>Sex</b>	<b>Social Group</b>	<b>Home Town</b>
042401	3	high school	female	3 friends in town for a school trip	Iowa
042402	1	mid 40s	male	visiting the museum with wife and child	
042403	2	juniors in college	male	students in town for a band concert	Wisconsin
042404	1	50s	female	visiting daughter in Chicago	Maryland
042405	1	mid 20s	female	visiting with her family	S. Illinois
042406	2	college students	1 female; 1 male	boyfriend/girl-friend visiting for the day	
042407	1	early 30s	female	in town for a conference; came to museum with boyfriend	Toronto
042408	2	21, 13	females	mentor/student relationship	Champaign, IL
050201	2	20s	female	couple on vacation	Louisville, KY
050202	2	50s	1 female; 1 male	married couple	Chicago
050203	4	12, 14, 16, 30s	3 females (teens); 1 male	Family of teen girls and the museum with their dad.	Evanston, IL
050304	1	30s	female	Woman who said she was in town for a wedding.	Tokyo
052001	3	12 year olds	female	Group of 7th graders who said they were on a school field trip.	Danville, IL
052002	3	15; 16	1 female; 2 males	Group of friends. They were accompanied by one of child's parent.	North Chicago suburbs
052003	3	12/13	2 females; 1 male	Three 8th graders who were on a school field trip to the museum.	Michigan
052004	2	late teens	1 female, 1 male	Brother and sister visiting the museum with their class.	Chicago
<b>Interview #</b>	<b>Number of</b>	<b>Age</b>	<b>Sex</b>	<b>Social Group</b>	<b>Home</b>

	<b>Respondents</b>				<b>Town</b>
052005	2	20s	2 males	College sophomores who were on vacation.	Iowa
052006	2	30s	1 male; 1 female	Married couple.	Arizona
052007	2	30s/ 14	1 male; 1 female	Father at the museum with his daughter. He was in town on vacation.	L.A./ Chicago
052901	1	24	male	just finished boot camp in the Navy; visiting with his family	Arizona
052902	1	30s	female	housewife and mother; visiting with her family of 6	S. Illinois
052903	1	22	female	came to museum with two friends	Wisconsin
052904	15	junior and seniors in high school; with 3 teachers in their early 40s	approx. half females and half males, females	a group of teachers and students	Ohio
052905	2	16	females	friends	Chicago

**APPENDIX D**

**Maps Used in Interviews for Mid-Latitude Cyclones  
and Physical Climate**

**See Next Page**

## APPENDIX E

### Literature Review on the Public's Understandings of Global Warming

As part of the front-end evaluation, we conducted a literature review of previous research on laypeople's (i.e., non-experts) perceptions and understandings of weather and climate. Most of the articles we located dealt with people's understandings of global warming. (We found little research on public literacy about weather systems in general, and on ice ages.)

While global climate change was not one of the topics selected for *Atmospheric Explorations II*, we know that SMM believes this is an important topic. Based on our research during phase one of this evaluation, we also know that this topic interests visitors and is a concern for many of them. The topic, however, is so complex, that it may require a larger exhibition in order to give it the kind of treatment it requires. Below we have briefly summarized the results of our literature review and have provided a list of publications which we hope will be of use to the exhibit development team should this topic be selected for a future exhibition.

#### Previous Research on Global Warming

Researchers have been concerned with the public's understandings of global warming and climate change primarily to find out how to most effectively communicate the potential risks of global warming—how people's understandings can be translated into effective messages about the risk of such issues as global warming.

#### Climate Change as a Cultural Construct

Research indicates that climate and climate change are perceived within a cultural context. This cultural context influences how a person understands the processes of climate change and whether or not they perceive it as a risk. In other words, climate change is a cultural construct, in addition to being a (contested) empirical reality. As one researcher explained

*[N]either the manufacture nor the communication of research on climate and climate change occurs in a social vacuum.... [This has a bearing on] the ways in which scientific conjectures can be communicated to the public without encountering disinterest or disbelief. (Stehr & von Storch, 1995)*

In our research with museum visitors, we discovered that people hold diverse opinions about global climate change, based on their experiences and attitudes toward the scientific establishment, the media, religion, etc.

## Time Scale

People perceive changes in the weather and climate according to a human scale, i.e. in terms of daily changes and/or changes over a period of decades. Most people can conceive of time in relation to their own life. Longer time periods are difficult for most people to understand. Therefore, they find it difficult to conceptualize and respond to long-term changes in climate, such as those changes which produce global warming (see Stehr & von Storch 1995). Many of the visitors we interviewed, in fact, found it difficult to conceive of very large time periods relevant to global climate change.

## Misperceptions About Climate Change

Two very thorough studies (Bostrom et al, 1994 and Read et al, 1994) documented a number of misperceptions about global warming—many of which we found as well during Phase One of this study.

A common mistake made by “non-experts” is that global warming is caused by the depletion of the ozone layer. Many people also conflate the greenhouse effect and stratospheric ozone depletion. For example, both Bostrom et al (1994) and front-end research for *Atmospheric Explorations II* found that people believe that the hole in the ozone layer lets in more heat from the sun which gets trapped in the atmosphere, heating the earth. Bostrom found that confusion about climate change and the ozone layer is related to media reports which often conflate the issues (Bostrom, et al 1994).

Bostrom et al. (1994) also found that non-experts tend not to make a distinction between weather and climate, a finding which was replicated to some degree in our research. However, in our research, we found that many respondents distinguished between the two, describing weather as short term changes in temperature and precipitation, and climate as longer term, regional variations in precipitation and temperature.

One common “mental model” described by Bostrom et al. (1994) about global warming which we replicated in our research indicated that many people assert that air pollution causes global warming. Airborne emissions from factories, power plants, cars, etcetera are thought to cause global warming. When pressed further about what respondents meant by air pollution, respondents tended to attribute air pollution to the release of CFCs from aerosol cans, car emissions, and factory emissions.

## Incomplete Understandings about Climate Change

In addition to documenting misperceptions about climate change, Bostrom et al (1994) found that the general public has an incomplete understanding about climate change. More specifically, few of the people interviewed in the 1994 study mentioned greenhouse gases other than CFCs, few mentioned the role of destruction of “carbon sinks” in global warming, and only a few “made a connection between energy use and global warming” (Bostrom et al 1994).

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