Evidence suggests that spatial skills are highly malleable and that training in spatial thinking is effective, durable, and transferrable. Understanding how meteorologists employ spatial skills in the forecasting process has implications for operational weather forecasting and meteorology education. This study began with exploratory research that identified mental animation and disembedding as key spatial skills used in weather forecasting. A follow-on pilot study tested the instruments, collected think-aloud data and found a correlation between spatial skills and forecasting. The complete study, in progress, is investigating the effect of spatial thinking, working memory and expertise on forecast task performance.

**Exploratory Study**

Research questions:

1. What are the primary spatial skills used by meteorologists?
2. How do experts and novices use spatial skills differently?

**Methods**

Sample: 25 undergraduate meteorology students, 12 graduate meteorology students and 50 professional meteorologists. N = 93.

Data collection: Survey data were collected at the annual meeting of the American Meteorological Society, January 2016, followed by online administration Spring 2016.

Participants were introduced to 6 spatial skills and practiced with the surface analysis of a weather event in 2015. Examples:

- **Mental animation**
- Developing a plausible scenario of a sequence of events based on static information (e.g., which direction will the last gear turn when the string is pulled?)

Mark the low pressure center with an "L". Draw in the warm front and cold front. "Yes" or "No" to "Did you use this type of mental animation?" after interpreting each weather image. Participants responded yes or no to "Did you use this type of mental animation?" after interpreting each weather image, producing a total of 54 data points for each participant.

**Results**

<table>
<thead>
<tr>
<th>Spatial Thinking</th>
<th>Undergraduate</th>
<th>Graduate</th>
<th>Professional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental animation</td>
<td>48.0%</td>
<td>40.0%</td>
<td>46.8%</td>
</tr>
<tr>
<td>Mental Disembedding</td>
<td>63.9%</td>
<td>79.6%</td>
<td>76.9%</td>
</tr>
<tr>
<td>Mental Rotation</td>
<td>37.8%</td>
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<td>65.7%</td>
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<tr>
<td>Mental Rotation*</td>
<td>52.0%</td>
<td>43.9%</td>
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<td>Mental Rotation**</td>
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<td>70.4%</td>
</tr>
<tr>
<td>Mental Rotation***</td>
<td>89.8%</td>
<td>86.7%</td>
<td>88.8%</td>
</tr>
<tr>
<td>Mental Rotation****</td>
<td>88.8%</td>
<td>86.7%</td>
<td>88.8%</td>
</tr>
</tbody>
</table>

**Pilot Study**

Research question:

What is the correlation between spatial thinking and weather forecasting?

**Methods**

Sample: 2 atmospheric science faculty, 8 undergraduate meteorology students and 4 graduate meteorology students. N = 14.

Data collection: Data were collected at 2 Midwestern universities during Fall 2016.

Participants completed the Vandenberg and Kuse Test of Mental Rotation, the ETS Hidden Figures test and an expertise survey prior to completing a five-part forecasting task. Examples:

- **Hidden Figures Test**
- Choose the figures on the right that contain figure (x)
- **Test of Mental Rotation**
- Mark the low pressure center with an "L". Draw in the warm front and cold front.

**Results**

- Analysis of verbal think-aloud data align with findings from the exploratory study: novice meteorologists made superficial interpretations of the plots without attempting to conceptualize spatial representations. Initial process models:
  - Novices: surface plot
  - Experts: 300 mb chart, 500 mb chart, 850 mb chart

**Potential Implications**

The purpose of this research is to understand the cognitive underpinnings of weather forecasting. This is motivated by a desire to improve atmospheric science education broadly and weather forecaster training specifically, including multiple operational meteorology forums and training pipelines. The overall goal is to improve student learning and the ongoing training of the current and future weather forecasting workforce.

**Current Work**

Research questions:

1. What effects do working memory, domain knowledge, spatial relations, and expertise have on weather forecasting?
2. What processes do individuals use in conjunction with working memory, domain knowledge, spatial relations, and expertise during weather forecasting?

**Methods**

Sample: Anticipated 60 total comprised of students and faculty in university meteorology programs along with operational meteorologists at National Weather Service offices.

Data collection: Ongoing through Fall 2017.

In addition to spatial thinking tests, participants are completing a matrix span test of working memory, expertise survey and meteorology concept inventory. Scores will be used in regression analysis to evaluate their effect on forecasting skill and to test for interactions. A process model developed from verbal protocol data will describe processes used by novice and expert forecasters. Example:

**Diagram**

- Graph of forecast vs spatial thinking score
- Table of regression analysis
- Bar chart of expertise scores

We gratefully acknowledge our participants’ contribution to this research.