# Relationships Between Snow Cover Ablation, Global-Scale Atmospheric Forcings and Winter Season Chesapeake Bay Hydrology


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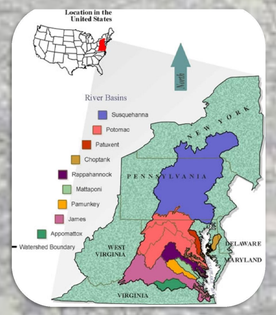
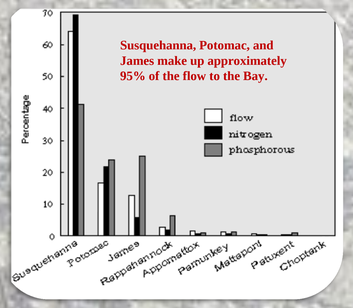
## Research Questions

1)How important is snow cover ablation to the flood hydroclimatology of the Chesapeake Bay?

2)What are the global and synoptic scale forcings that are related to Chesapeake Bay flooding events?

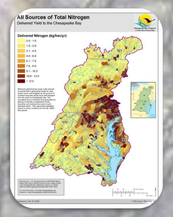
3) What are the "pathways" for these relationships.

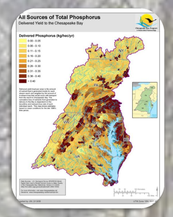


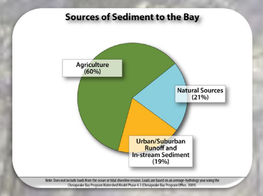

February 12, 2010 MODIS Image

The Chesapeake Bay watershed covers an area of approximately 166,000 km² in the Mid-Atlantic Region of the United States. It is the United States largest estuary and the watershed is home to nearly 17 million inhabitants. The basin frequently experiences significant ephemeral snow cover during the winter season, resulting in large runoff events to the Bay.



Fluxes of nutrients and sediments from the watershed during snow cover ablation events greatly effect Bay health. The excess nutrients and large sediment fluxes to the Bay can result in algae blooms and damaging sediment loads.




## Methodology

1) Examine the record of major flooding events in the Chesapeake Bay Basin to ascertain the role of snow cover ablation on the flood hydroclimatology (using gridded snow cover data).

2) Explore relationships between global-scale forcing mechanisms and ablation associated flooding events (using NCEP reanalysis data).

3) Examine connections between global-scale forcings and synoptic types (using TSI).

1° X 1° gridded daily snow depth data set developed at the University of Georgia and Rutgers University.

Utilizes U.S. COOP and Canadian daily surface observations.

Extensive quality control routines.

Ablation values calculated using 3-day total. Critical ablation of 5 cm used in this study.

A 5 cm basin-wide ablation (0.2" of water equivalent) results in a flow of 2.2 X $10^{11}$ gallons of water into the system! This is approximately seven times the January mean daily flow into the Chesapeake Bay!

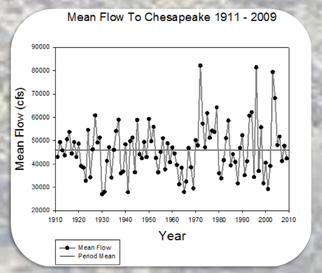
### Temporal Synoptic Index (TSI)

Daily Synoptic Weather Data
1950 - 2000, Philadelphia, PA

(Temperature, Dewpoint Temperature, Cloud Cover, Vector Wind Speed, Atmospheric Pressure)

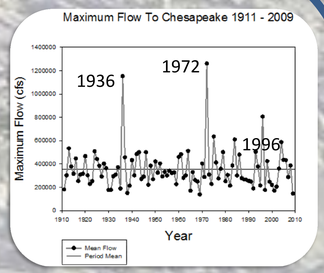
Kalkstein and Corrigan, Annals, 1986
Winter 13 synoptic types.
Spring 13 synoptic types.

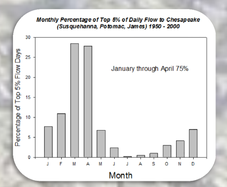
## Results

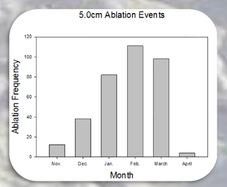



Mean flow to the Chesapeake is quite variable on an interannual basis. Since the long-term drought conditions of the 1960s, interannual variability has increased, with several very large mean flow years.

The variability of the annual maximum flow to the Bay has also increased since the 1960s. Extreme events are apparent during three years, two related to snow cover ablation.



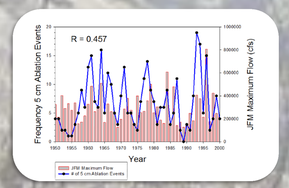



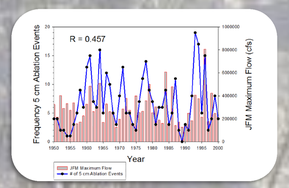




| Year | Month | Associated with.. |
|---|---|---|
| 1972 | June | Agnes |
| 1996 | January | snow |
| 1975 | September | Eloise |
| 1984 | February | snow |
| 1964 | March | snow |
| 1993 | April | snow |
| 1979 | March | snow |
| 1961 | February | snow |
| 1986 | March | snow |
| 1960 | April | snow |

| | Jan-March Mean Depth | Jan-March Max Depth | Mean Flow (jan-march) | Max Flow (jan-march) | 5 cm Ablations (annual) |
|---|---|---|---|---|---|
| Jan-March Mean Depth | 1 | .798 | .264 | .314 | .776 |
| | | .000 | .072 | .025 | .000 |
| | 51 | 51 | 51 | 51 | 51 |
| Jan-March Max Depth | .798 | 1 | .264 | .479 | .844 |
| | .000 | | .061 | .000 | .000 |
| | 51 | 51 | 51 | 51 | 51 |
| Mean Flow (jan-march) | .264 | .264 | 1 | .673 | .266 |
| | .072 | .061 | | .000 | .071 |
| | 51 | 51 | 51 | 51 | 51 |
| Max Flow (jan-march) | .314 | .479 | .673 | 1 | .457 |
| | .025 | .000 | .000 | | .001 |
| | 51 | 51 | 51 | 51 | 51 |
| 5 cm Ablations (annual) | .776 | .844 | .266 | .457 | 1 |
| | .000 | .000 | .071 | .001 | |
| | 51 | 51 | 51 | 51 | 51 |

Results indicate that more than 50% of the top 5% of mean daily flows are associated with snow cover ablation. Moreover, basin-wide January through March maximum snow depth, mean snow depth and the number of 5 cm ablation events are significantly related to January through March maximum flow to the Chesapeake.

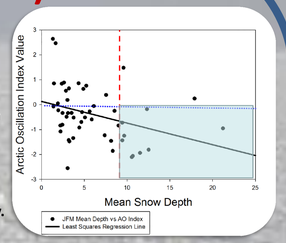


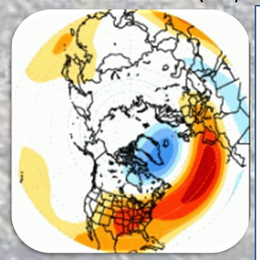

## Results (cont.)

| | SOI | PNA | NAO | AO | Nino_3.4 |
|---|---|---|---|---|---|
| Jan-March Mean Depth | -.094 | .244 | -.270 | -.337 | .044 |
| | .510 | .085 | .056 | .015 | .759 |
| | 51 | 51 | 51 | 51 | 51 |
| Jan-March Max Depth | -.224 | .261 | -.214 | -.281 | .165 |
| | .115 | .064 | .132 | .046 | .246 |
| | 51 | 51 | 51 | 51 | 51 |
| Mean Flow (jan-march) | .045 | -.161 | .000 | -.028 | -.079 |
| | .754 | .260 | .999 | .845 | .582 |
| | 51 | 51 | 51 | 51 | 51 |
| Max Flow (jan-march) | .030 | .058 | -.044 | -.091 | -.110 |
| | .836 | .687 | .760 | .526 | .444 |
| | 51 | 51 | 51 | 51 | 51 |
| 5 cm Ablations (annual) | -.151 | .264 | -.157 | -.147 | .152 |
| | .290 | .061 | .270 | .303 | .288 |
| | 51 | 51 | 51 | 51 | 51 |

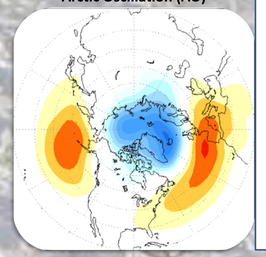
Although correlations between the Arctic Oscillation and snow depth are not large, nearly all large basin-wide mean snow depth seasons are associated with a negative phase of this major mode of low-frequency atmospheric variability.

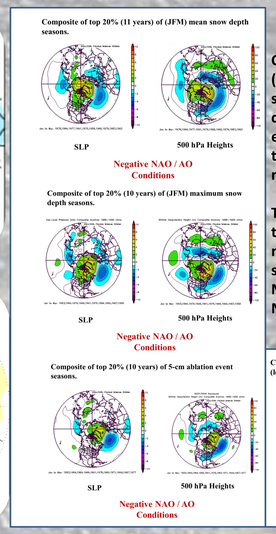



North Atlantic Oscillation (NAO)



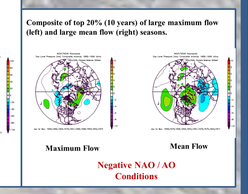
Arctic Oscillation (AO)






Compositing of the top 20% (10 or 11 years) of mean snow depth, maximum snow depth and 5 cm ablation event seasons (left) indicate that all show strongly negative NAO/AO patterns.

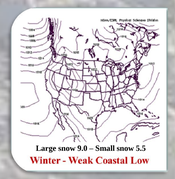
The same analysis applied to the top 20% of maximum and mean flow seasons (below) shows a weaker, but clear NAO/AO pattern across the Northern Hemisphere.



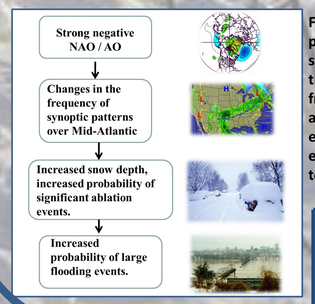

By what "pathway" does the NAO effect snow cover, frequency of ablation events and large flows into the Chesapeake? Are there changes in the frequency of synoptic types between large and small mean snow depth seasons?

| Type | SOI | Nino 3.4 | PNA | NAO | AO |
|---|---|---|---|---|---|
| Atlantic High | .178 | -.303 | -.074 | .559 | .545 |
| Weak NW Flow | .074 | .033 | .138 | -.436 | -.415 |
| Strong NW Flow | -.127 | .088 | .263 | -.268 | -.323 |
| Coastal Low | -.189 | .343 | .159 | -.485 | -.510 |
| NW Flow (March) | -.101 | .152 | .013 | -.466 | -.456 |

Correlation between large-scale teleconnection patterns and synoptic types.



Example synoptic types affected by NAO/AO patterns.




Final results suggest that mid-winter negative NAO/AO patterns cause a change in the frequency of specific synoptic weather types over the Mid-Atlantic region of the United States. The modified synoptic type frequencies lead to an increased basin-wide snow depth and an increased probability of significant ablation events. These increase the probability of large flooding events and damaging fluxes of nutrients and sediments to the Bay.

### References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USGS - http://water.usgs.gov/wid/html/chesbay.html
USGS - http://water.usgs.gov/wid/FS_140-96/
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