Water & Ice

New Mexico
Super Computing Challenge
Final Report
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Executive Summary:

Our team is trying to find out how density of water affects currents in the ocean and measure how the heat input affects velocity of the currents. Ocean currents profoundly affect the weather and climates of continents, marine transportation, and the cycling of nutrients. Our team decided to concentrate and research the deep water current known as the global conveyor belt that is driven by density and salinity differences in the water. The ocean's water density is controlled by temperature which means that the cold water is denser than warm water, and the salinity of the water which mean that the salt water is denser than fresh water.

Deep-ocean currents are initiated in Earth's Polar Regions. Water flowing into the Polar Regions becomes colder, which increases its density. When the water freezes the freshwater is turned into ice which is removed from the ocean causing the ocean water to become saltier. The cold water becomes denser because of the added salts, causing it to sink toward the bottom of the ocean. Surface water begins to move in to replacing the cold salty sinking water, which creates a circular motion called a current. This is a very slow process and can sometimes take over 1,000 years for a current of water to circulate from one point to another, but when the current moves it moves a lot of water around the globe.

My scientists fear that global warming could affect the global conveyor belt. Increased rain and melting ice adds fresh water which decreases salinity levels in the ocean making it warmer at the poles. The warmer the water become the less dense it becomes. If this happens the water will not be dense enough to sink and create a current, this could cause the global conveyor belt to stop. The global conveyor belt is crucial to the world's food chain as it transports water around the world.

Problem:

The ocean water is not uniform due to the climatic processes creating differences in ocean water temperature and salinity. Salinity is dissolved salt concentration. In the deep ocean, huge masses of water circulate around the globe, driven by differences in temperature and salinity. Differences in temperature and salinity cause differences in ocean water density. When water warms, it expands, decreasing density. As salt concentration rises, density increases, because the salt molecules can occupy spaces between the water molecules. Denser water sinks beneath water that is less dense. As denser water sinks, water must raise somewhere to replace it.

The computer program will model ocean density currents (temperature & salinity) using Net Logo Tng. This density computer model will be validated against data gathered from a real world experimental model. The end goal is to use this program in a subroutine for a larger computer model.

Plan:

All data used for this computer program will be collected by conducting science experiments on density and salinity of water. Also we will measure how the heat input affects the velocity of the currents in the ocean. We will use the following formula and equation for calculating the density of water.

Formula:

Density (ρ), as shown below in Equation 1, is the mass (m) of a material per unit volume (v). For example, the density of freshwater under standard conditions is approximately 1 gram (g) per cubic centimeter (cm3). In other words, if you filled a 1-cm x 1-cm x 1-cm box with freshwater, the water inside the box would have a mass of 1 g. Adding salt to the water increases the density of the water, because the salt increases the mass without changing the volume very much.

Equation 1:

ρ = m

v

- ρ = Density in whatever units are used for mass and volume.
- m = Mass in grams (g), kilograms (kg), or any other unit of weight.
- v = Volume in centimeters cubed (cm3), meters cubed (m3), or any other unit of volume.

Computer Program:

Our present program as been constructed by using Net Logo Tng to simulate the temperature of water as rays of sunlight interacts with water molecules. The sunlight appears at the top of y coordinate. As the sunlight hits the molecules, they change their color. This program is quite simple at this time, but we hope it will be more complex as time goes by.

The way we started our creation of this program was to research environmental issues affecting the Earth. One environmental issue is excessive heat which is causing global warming and melting the Ice Burgs near the Polar Regions of the Earth. We created a simulation of sunlight creating heat rays that penetrate water molecules. In this program the sunlight is simulated by small yellow colored arrows we call rays. The rays can be viewed from pushing a button on the side. When you watch a ray, it is circled in a small gray area fixed to a single random ray. You may also adjust the heat and speed of each ray this will cause the rays to increase or decrease in size. The rays or sunlight are only able to penetrate the first two layers deep into the ocean module.

The water molecules are simulated by small blue circles. The small blue circles contain small red arrows inside. The red arrows simulate the direction the water molecule is moving. When the sunlight or rays hits, the water molecules will move faster and larger. The reason they grow larger is because when a liquid is heated, the molecules rebound off of each other and the liquid expands.

When creating this computer program by using Net Logo Tng we hope to show how heat affects the velocity of water currents, density, and the salinity of the oceans. We expect to model how temperature and salinity affects density of ocean currents. We intend to accurately model the effects of ice burgs melting in the Antarctic due to climate change and global warming.

Procedures:

```
globals
[
  sky-top      ;; y coordinate of top row of sky
  water-top    ;; y coordinate of top row of water
  temperature  ;; overall temperature
]

breed [water a-water] ;;what is created
breed [rays ray] ;;what is created with globals

water-own [density temp salinity] ;;water own these traits

to setup
  clear-all
  set-default-shape rays "ray"
  set-default-shape water "circle-arrow"
  setup-world
  make-water
end;;all written is made when you hit setup
```

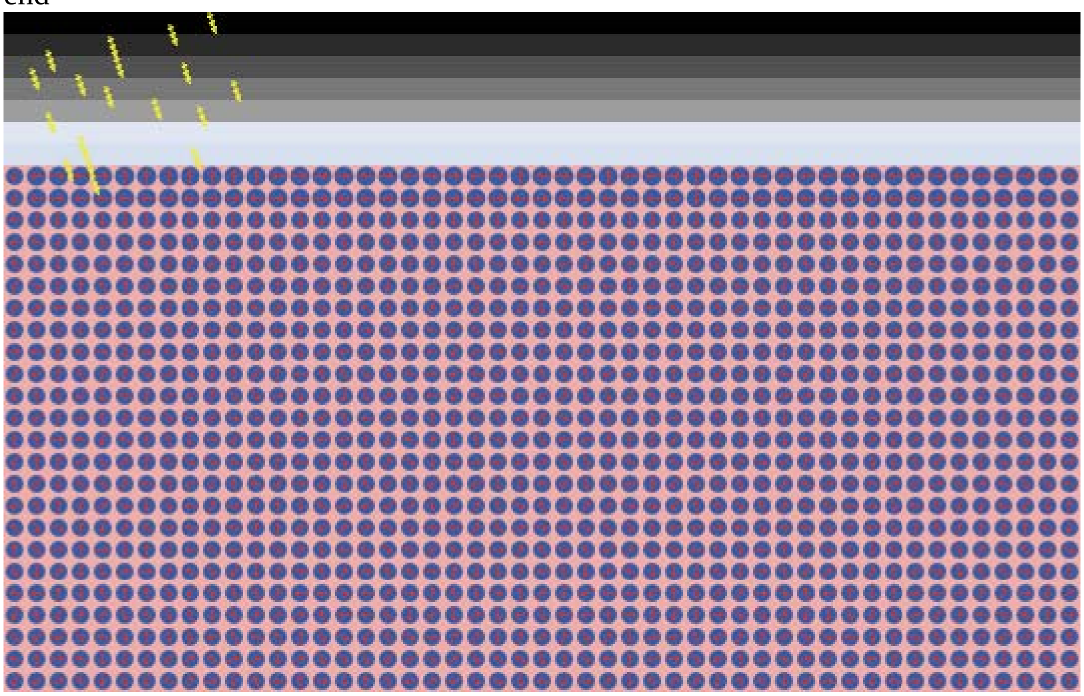
```
to make-water
  ask patches
  [
    if pcolor = red + 3
    [
      sprout-water 1;;if patch is red then sprout water
      [
        set color 105
        set size .8  ;;water traits when sprouted
      ]
    ]
  ]
  set temperature 12;;water temp.
  plot temperature;;graphs temp. on plot line
end

to setup-world
  set sky-top max-pycor - 5;;the lowest the sky ends in patches
  set water-top 15;;highest poit of water
  ask patches
  [
    if pycor > sky-top
    [
      set pcolor scale-color white pycor 22 15;;if pycor is greater than sky top,then turn white
    ]
    if pycor <= sky-top and pycor > water-top
    [
      set pcolor scale-color blue pycor -20 20;;if pycor is less than sky but greater than watr top,
turn blue
    ]
    if pycor <= water-top
    [
      set pcolor red + 3 ;;set pcolor red if greter or = to water top
    ]
  ]
end;;whats written is the setup of the virtual world

to go
  run-sunshine ;;as going, runs all procedures written
  encounter-water
  move-warm-water-up-and-down
  move-warm-water-left-and-right

  tick;;to keep track of each loop
  plot temperature;;plots temp. while on "go"
```

```
end

to run-sunshine
  ask rays
  [
    if not can-move? 0.3;;if the rays can't move forward 0.3, then they die
    [
      die
    ]
    fd 0.3;;how much the ray moves
  ]
  create-sunshine ;;procedure after sunshine
  encounter-water ;;procedure water follows
end

to create-sunshine
  if 10 * sun-brightness > random 50;;if sun-brightness is greater than 10*,make a random # of
rays between 50
  [
    create-rays 1 ;;1 ray at a time
    [
      set heading 160;;heading of ray 160
      set color yellow;;color of ray
      setxy (random 10) + min-pxcor max-pycor;;set rays at xycor arond 10 added by sky & water
top
    ]
  ]
end

to encounter-water
  ask rays
  [
    if any? water in-radius .25;;any water in radius of.25 than heat water
    [
       if water-here != nobody
       [
         ask water-here
         [
           heat-water
         ]
       ]
       die;;rays die when finished prcedures
    ]
  ]
end
```

```
to heat-water
  ask water-here
  [
    set size size + .001;;add .1 size to water for each size
  ]
end

to move-warm-water-up-and-down
  ask water
  [
    if pycor < 15
    [
      let test0 one-of water-here
      let test1 one-of water-at 0 1
      if test0 != nobody and test1 != nobody
      [
        if [size] of test0 > [size] of test1
        [
          ask test0
            [
              set heading 0
              forward 1
              stop
            ]
            ask test1
            [
              set heading 180
              forward 1
              stop
            ]
         ]

        if [size] of test0 < [size] of test1
        [
          ask test0
            [
              set heading 180
              stop
            ]
            ask test1
            [
              set heading 0
              stop
```

```
          ]
        ]
      ]
    ]
  ]
end

to move-warm-water-left-and-right
 ask water
  [
  let test-center one-of water-here
  let test-right one-of water-at 1 0
  let test-left one-of water-at -1 0
  if test-center != nobody
    [
      if test-right != nobody and test-left != nobody
      [
         if [size] of test-right > [size] of test-left
         [
           ask test-right
             [
               set heading 270
               forward 1
               stop
             ]
             ask test-center
             [
               set heading 90
               forward 1
               stop
             ]
           ]


         if [size] of test-right < [size] of test-left
         [
           ask test-center
           [
             set heading 270
             forward 1
             stop
            ]
            ask test-left
            [
              set heading 90
```

```
              forward 1
              stop

             ]
         ]
      ]
    ]
  ]
end

to mix-temp
 let mixer one-of water-here
 ask mixer
 [
  let total-water [count turtles-here] of neighbors
 ]
end
```



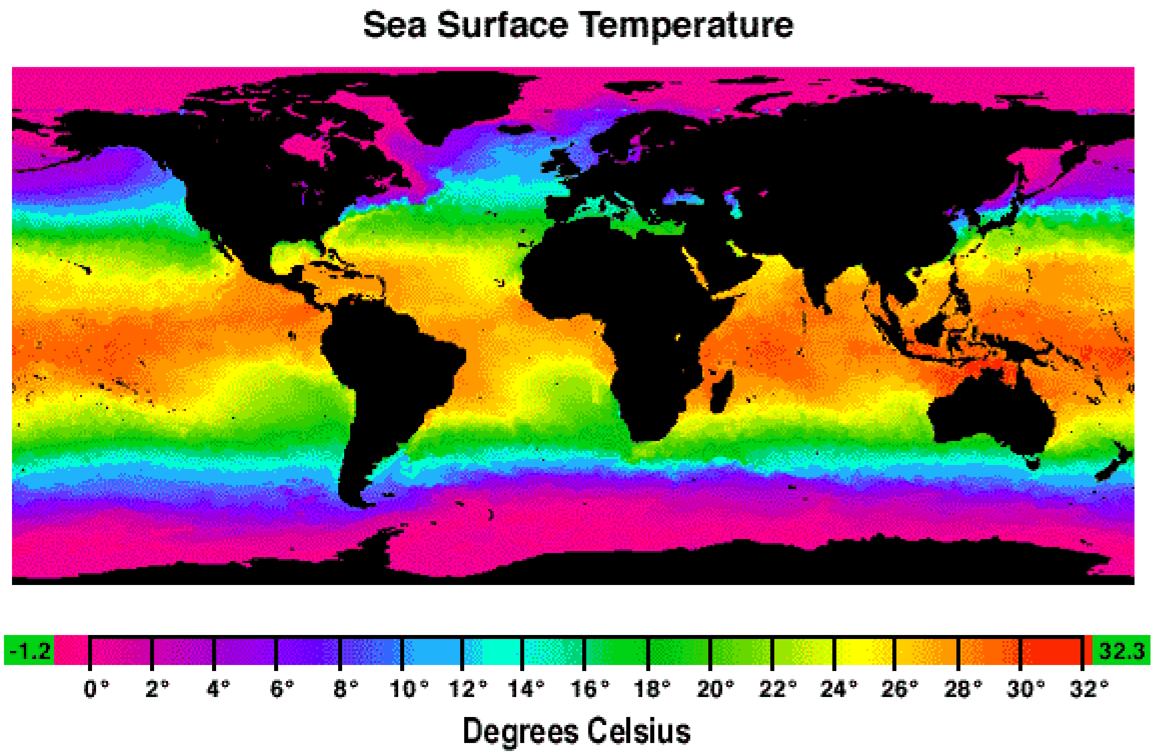
Results:

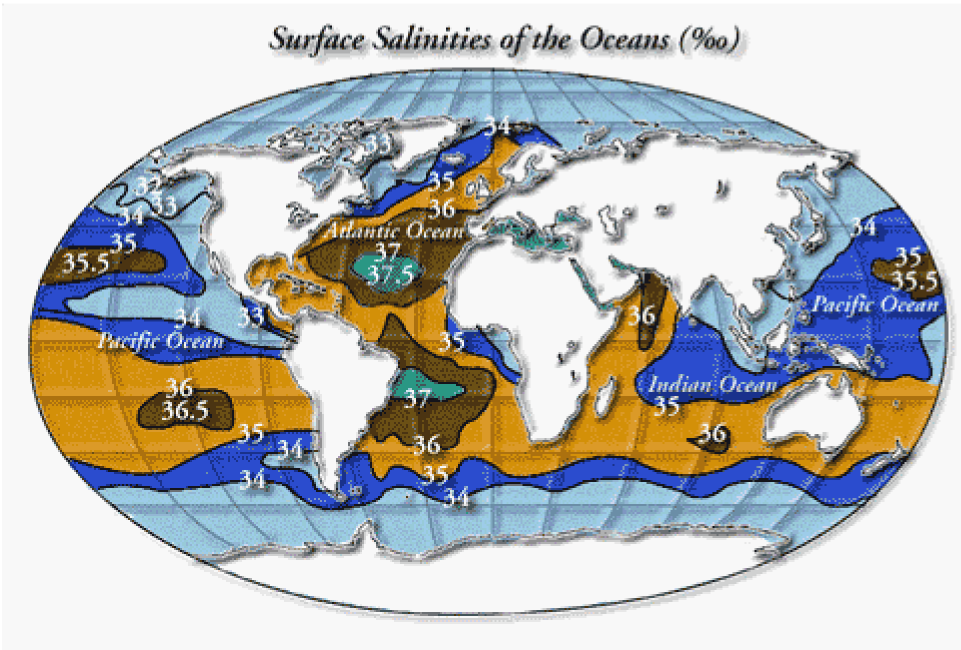
In the future we hope to improve our computer program by including simulations that can control and show the changes of salinity and density of the ocean water. We hope to include underwater hills inside the simulation, and show the actual deep water current or global "conveyor belt".

Conclusion:

The global conveyor belt moves water slowly, 10 centimeters per second at the most, but it transports a lot of water in a huge, slow circulation pattern. This type of energy movement is called thermal convection, because added heat causes the water flow to circulate by lowering the density of the water. The goal of this project is to model ocean currents, with a particular focus on the role of heat in the current's velocity.

Appendix Page: Diagrams Illustrating Temperature & Salinity of Ocean Water





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2. Horton, J. (2008). *How Ocean Currents Work.* Retrieved October 15, 2010, from http://science.howstuffworks.com/ocean-current.htm/printable

3. Swenson, H. (n.d.). Why Is the Ocean Salty? U.S. Geological Survey Publication. Retrieved October 10, 2010,fromhttp://www.palomar.edu/oceanography/salty_ocean.htm Ophardt, C. E. (2003).

4. Density – a Physical Property. Virtual Chembook, Elmhurst College. Retrieved October 10,2010.http://www.elmhurst.edu/~chm/vchembook/120Adensity.html

5. Resources: Experiments—Saltwater vs. Freshwater, which is Denser? Retrieved October 10, 2010, from http://www.onr.navy.mil/Focus/ocean/resources/water2.htm

6. The NASA Aquarius project will measure sea surface salinity from space. Launch is planned for 2009. These pages provide an overview of sea surface salinity and its importance for ocean currents and their effects on climate:
   o NASA, date unknown b. "Overview: Sea Surface Salinity," http://aquarius.gsfc.nasa.gov/overview.php.
   o NASA, date unknown a. "Science: Ocean Circulation and Climate,” http://aquarius.gsfc.nasa.gov/science.php.

Acknowledgements:

Mr. Edington- Designing the computer program & programming the code

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