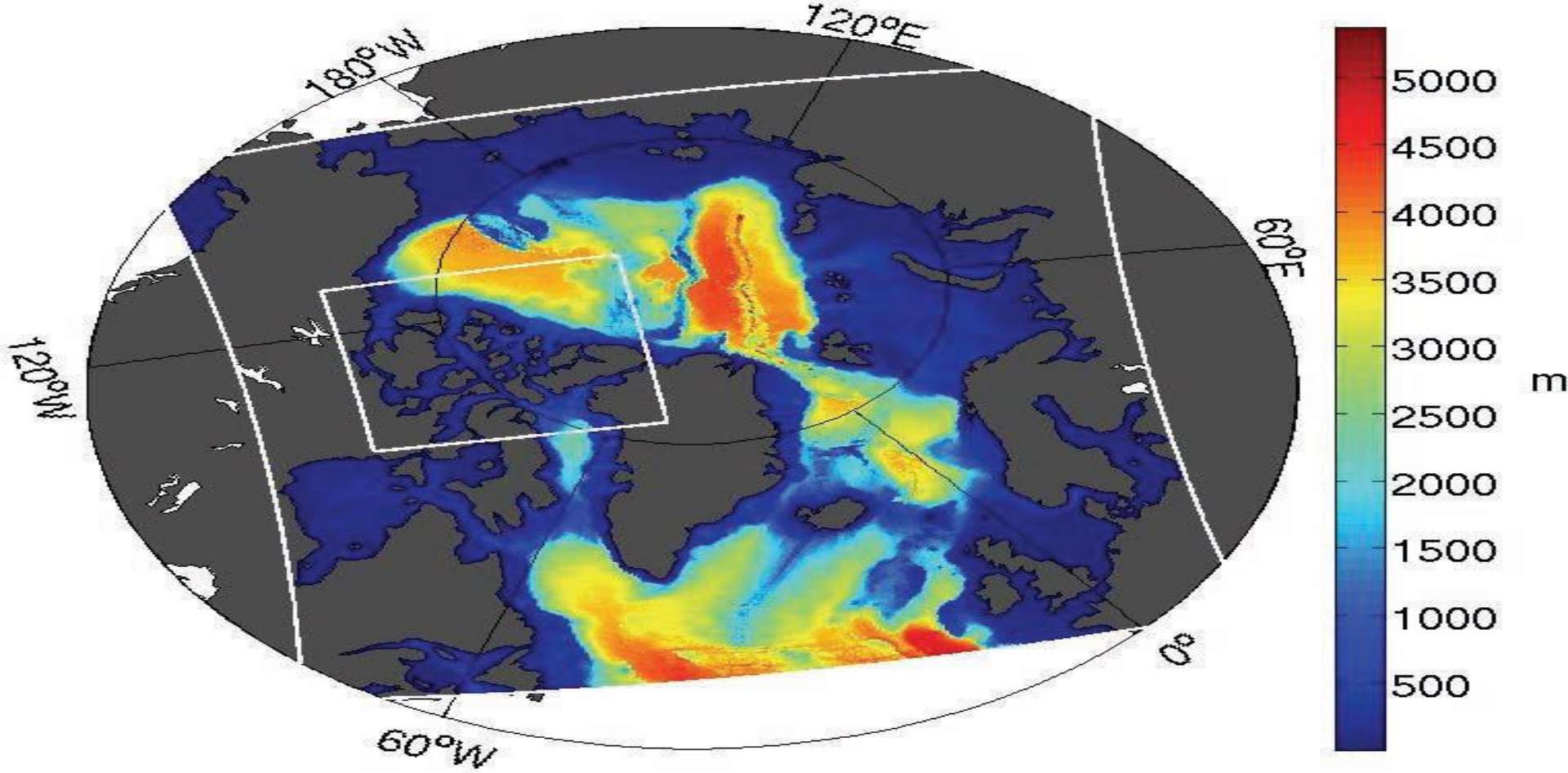
NUMERICAL MODELS
PRINCIPLES OF OCEANOGRAPHY



What is Oceanography?

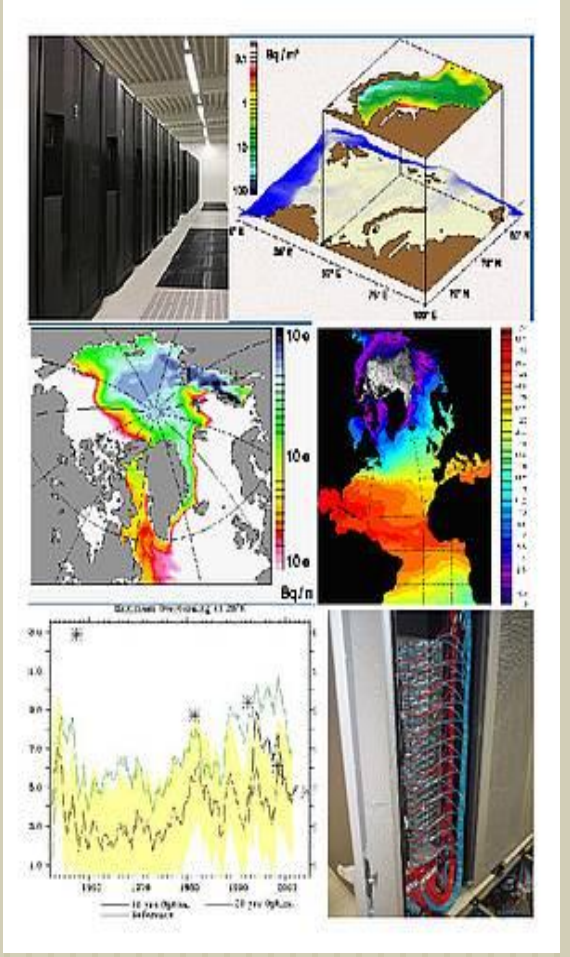
- The term "oceanography" is used exclusively for physical marine science, i.e. the physics of the ocean.

- The aim of oceanography is to provide a systematic understanding and quantitative description of the ocean by means of the relevant physical parameters (i.e. temperature, salinity, density, pressure).

Numerical Modeling

- In numerical models, the relevant system of equations describing the ocean are numerically discretized and approximated.

- We have to be able to understand and possibly predict some of changes is to use numerical models to investigate the dynamics of atmosphere-ocean.



Numerical Modeling

Numerical models of ocean currents have many advantages.

- They simulate flows in realistic ocean basins with a realistic sea floor.
- They include the influence of viscosity and non-linear dynamics.
- They can calculate possible future flows in the ocean. Perhaps, most important, they interpolate between sparse observations of the ocean produced by ships, drifters, and satellites

Numerical Models in Oceanography

Two main types of numerical models:

- ***Mechanistic models** – simplified models that examine the mathematics behind physical processes*
- ***Simulation models** – complex models that can be used to calculate the realistic flow in the ocean*

- *Mechanistic models are easier to interpret and help to advance our understanding of particular aspects of ocean circulation dynamics.*
- *On the other hand, simulation models allow direct comparison with nature which is essential to prove that ocean models really do represent nature*

Numerical Models in Oceanography

What are some of the advantages and disadvantages of using numerical models?

- *Advantage:*
  - *The models can be used to simulate realistic flow and predict future flow in the ocean*
- *Disadvantage:*
  - *The models cannot give completely accurate descriptions of the flow in the ocean*

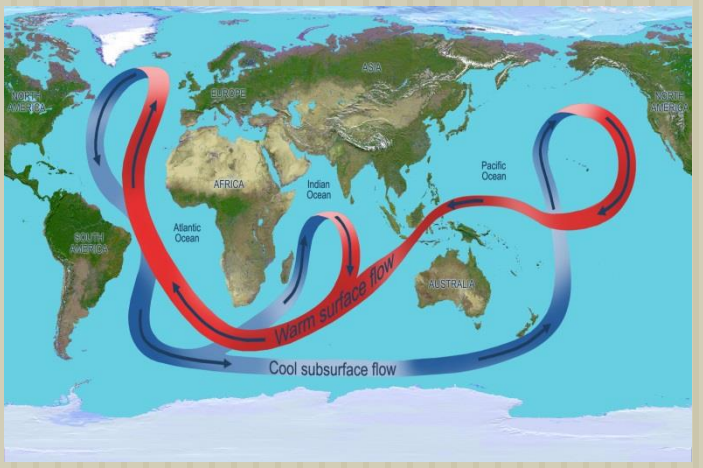
Global Ocean Model

Several types of global models are widely used in oceanography which are providing impressive views of the global ocean circulation.

- *Geophysical Fluid Dynamics Laboratory Modular Ocean Model*
- *Parallel Ocean Program Model*
- *Hybrid Coordinate Ocean Model HYCOM*
- *Regional Oceanic Modelling System ROMS*
- *Climate Models*

Global ocean models include:

1) *Realistic coasts and bottom features*
2) *Heat and water fluxes through the surface*
3) *Eddy dynamics*
4) *Meridional- overturning circulation*



Global Ocean Model

- *Geophysical Fluid Dynamics Laboratory Modular Ocean Model*

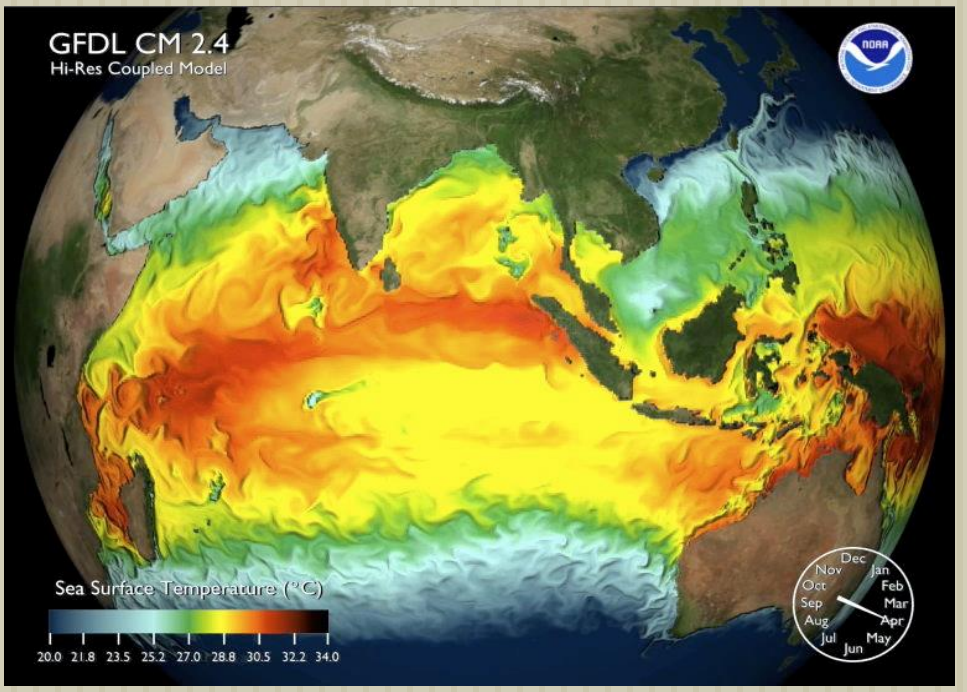
The model is widely use

- *For climate studies*
- *For studying the ocean's circulation*

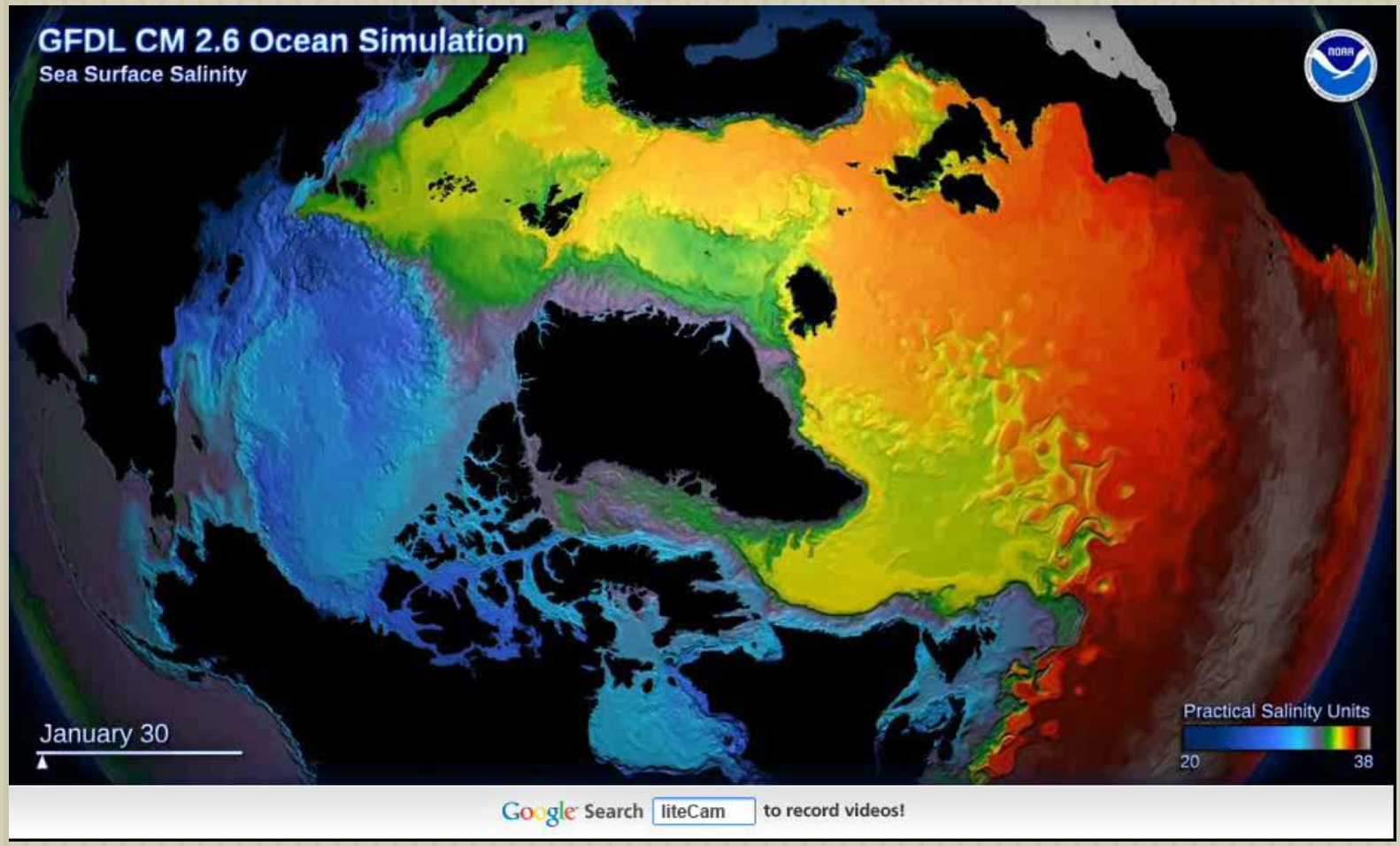
The model uses

- *Momentum equations*
- *Equation of state*
- *Hydrostatic and Boussinesq*

Approximations



Global Ocean Model- Geophysical Fluid Dynamics Laboratory Modular Ocean Model

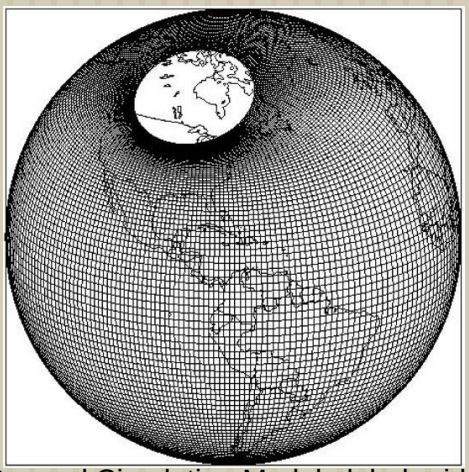


Global Ocean Model

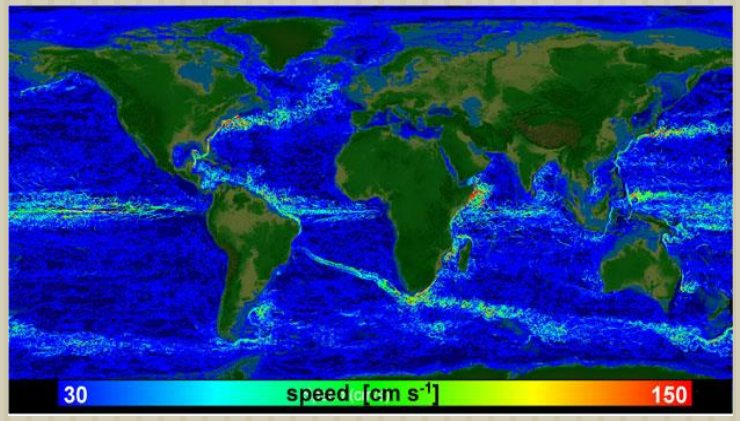
- *Parallel Ocean Program Model Produced by Smith and colleagues at Los Alamos National Laboratory*

The model includes

- *Improved numerical algorithms*
- *Realistic coasts, islands*
- *Unsmoothed bottom features*



General Circulation Model global grid

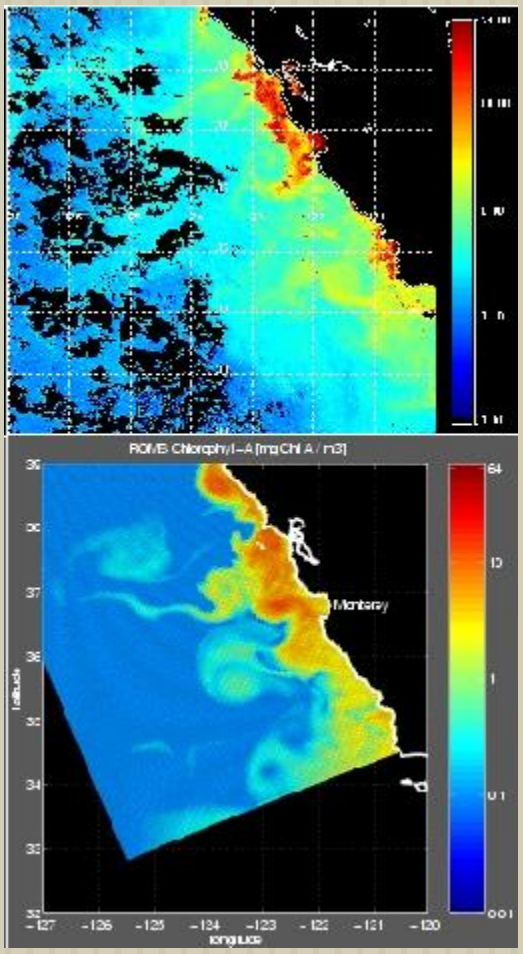


Parallel Ocean Program General Circulation Model surface currents (speed of the water) in cm/sec

Global Ocean Model

- *Regional Oceanic Modeling System*

  A major aspect of ROMS current focus along these lines is the investigation of biogeochemical cycling and ecosystem population dynamics along the U.S. West Coast



***Top**: SeaWIFS Ocean Color satellite image of Monterey Bay.*

***Bottom**: Results of a ROMS simulation with the US West Coast model. Shown are chlorophyll-a concentrations in spring.*

- *Climate Models*

It is used for studies

- *Large-scale hydrographic structure*
- *Climate dynamics*
- *Water mass formation*

Coastal Models

Many different numerical models for describing coastal currents, tides and storm surges. Coastal models can include

- *A free surface*
- *Realistic coasts and bottom features*
- *River runoff*
- *Atmospheric forcing*

Examples of different coastal models,

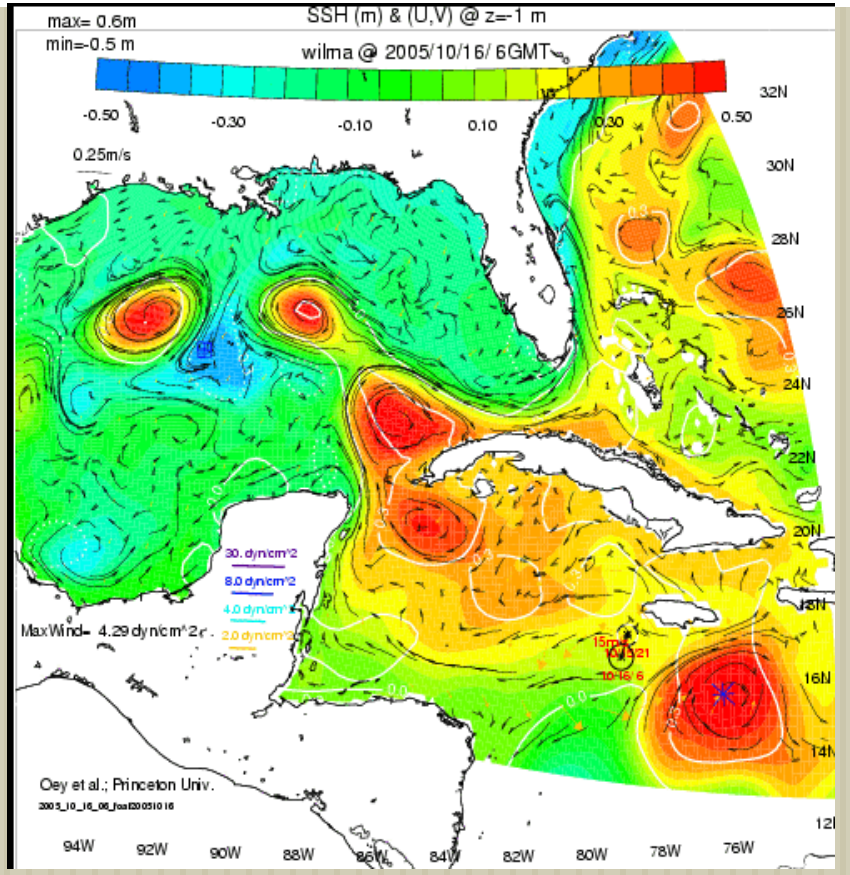
- *Princeton Ocean Model*
- *Dartmouth Gulf of Maine Model*

Coastal Models

- Princeton Ocean Model

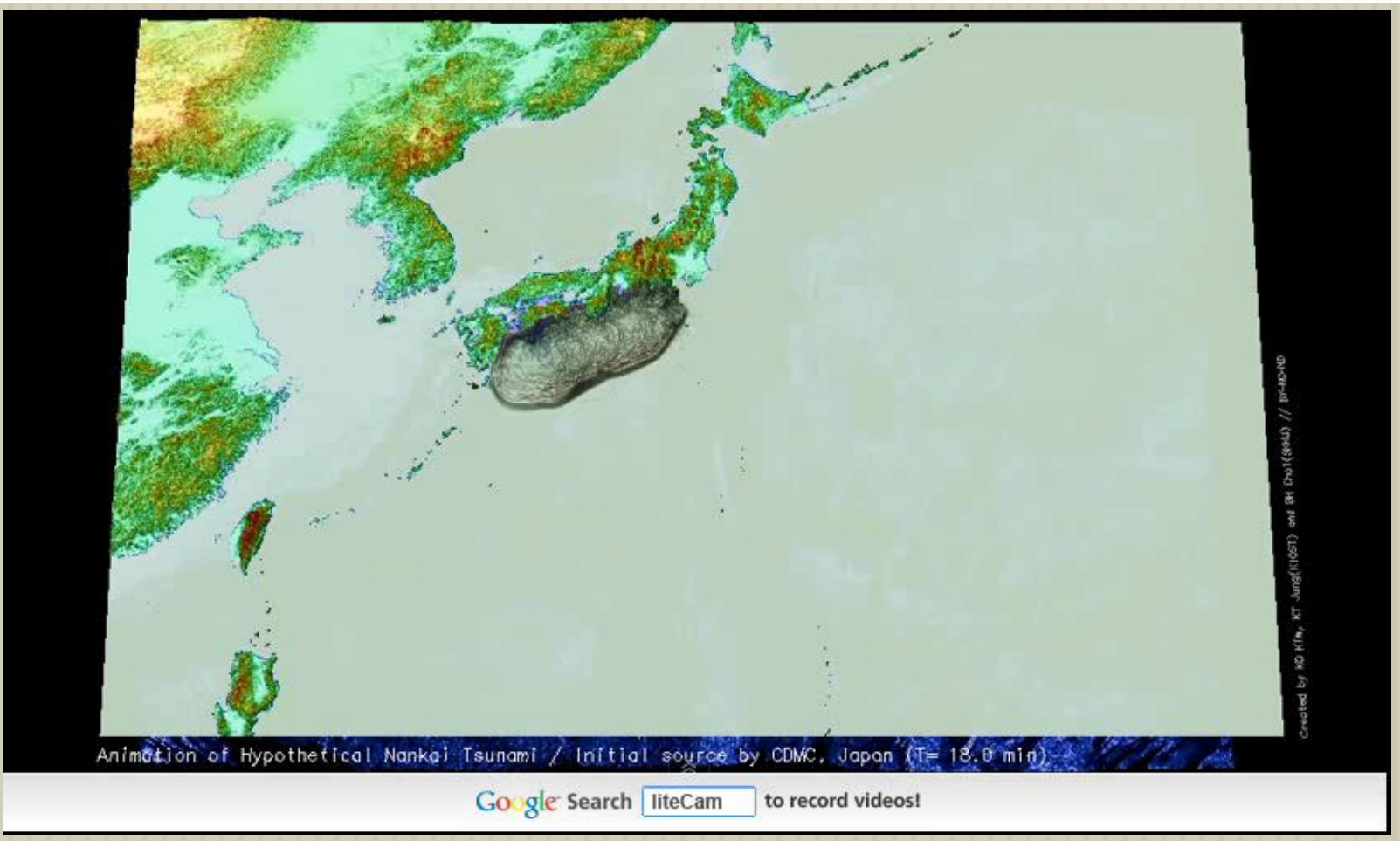
The model has been used to calculate the three-dimansional distrbution of

- *Velocity*
- *Salinity*
- *Sea level*
- *Turbulance*



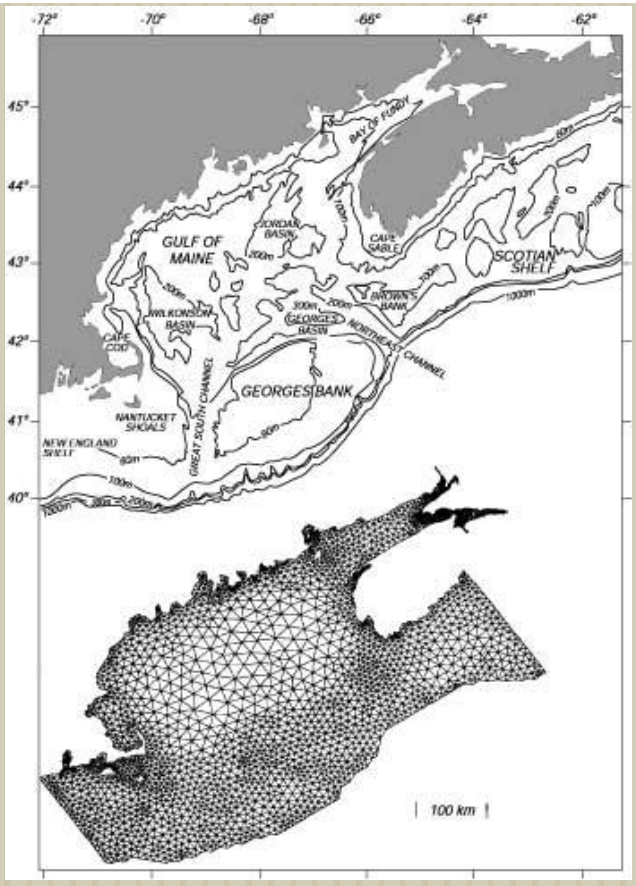
Surface height of hurricane Wilma

Coastal Models – Princeton Ocean Model



Coastal Models

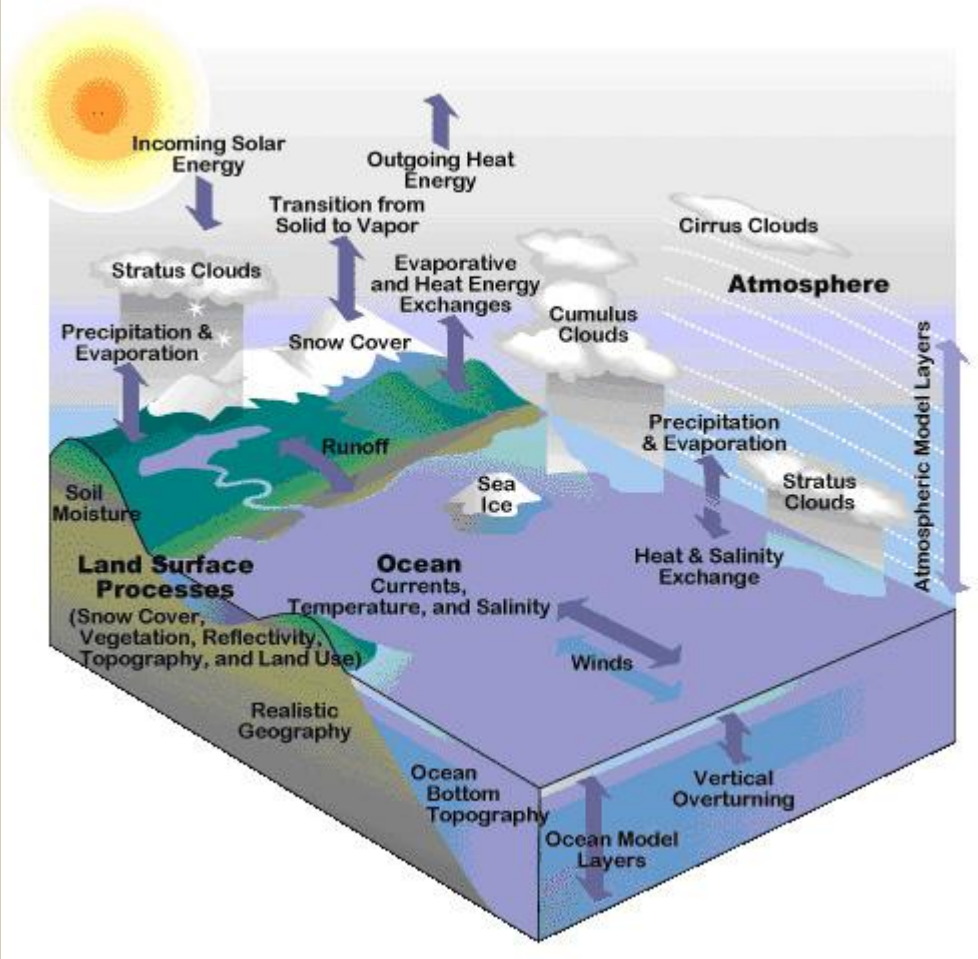
- *Dartmouth Gulf of Maine Model*
  - *The model uses roughly 13.000 triangles to cover the Gulf of Maine and nearby waters of the north Atlantic*
  - *The model has a simplified equation of state and it uses the hydrostatic and Boussinesq assumptions.*



Top: Topographic map of the Gulf of Maine showing important features. **Inset:** Triangular grid used to compute flow in the gulf.

Coupled Ocean and Atmosphere Models

*A **coupled** model is different. Changes in the atmosphere do cause changes in the ocean. Changes in the ocean part of the model can cause changes in the atmosphere part. So if lots of carbon dioxide moved from the atmosphere to the ocean, the ocean might get "full" of CO_2. It might not be able to hold any more. Or it might take in more CO_2 very slowly.*



Coupled Ocean and Atmosphere Models

The most important use of the models has been to study

- *How earth's climate might respond to a doubling of carbondioxide in the atmosphere*
- *El Nino and the meridional overturning circulation*

Many coupled ocean and atmosphere models have been developed

- *Climate System Model*
- *Princeton Coupled Model*
- *Hadley Center Model*

Some include only physical processes in the ocean, atmosphere and the ice-covered polar seas

Others add the influence of land and biological activity in the ocean

Result

- *Why don’t scientist always use coupled models instead of uncoupled model?*

Coupled models are very very complicated. It takes a lot of work to make sure the answers from them are right. It takes a long time to run, even on fast computers.

- *Numerical models is very important to recognize that a model is an approximation of the real world. Good understanding and prediction of the real world.*