# Earth Symulation System: General Considerations

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Dr Louis Uccellini, the director of the National Centers for Environmental Prediction, could not come.  He sends his greetings and best wishes for the success of the meeting.

# Basics

- Earth simulation system as a tool for
  - Regional climate studies
  - Downscaling
  - Seasonal forecasting
- Requirements
- Outstanding issues

# Basics

- Earth simulation system
  - Driving atmospheric model
  - Modeling subsystems
- Sufficient computing power
- Validation data and procedures
- Sufficient person-power
- Stable long term funding

# Driving Atmospheric Model

- Spatial scales?
- How regional is regional climate?
  - Mountain – valley contrasts
  - Urban – rural area contrasts
  - Maritime – continental area contrasts
  - …
- Multiple scales, from meso to global

# Driving Atmospheric Model

- Dynamics
  - Nonhydrostatic (on the small scale end)
  - Global (on the large scale end)
  - Suitable for extended integrations
    - Quadratic conservative
    - Sufficiently accurate conservative, positive definite and monotone tracer transport
    - Minimum non-physical dissipation
  - Computationally efficient, scalable

# Communication between scales

- Communication between large scale and regional models for driving nested models and downscaling
    - Can all the necessary information be passed through lateral boundary conditions?
    - Scale dependant nudging?
    - Impact of the size of nested domain?

# Driving atmospheric model

- Physics
  - Converging with resolution
  - Radiation formulation capable of interacting with particulate and gaseous aerosols
  - Processes at the lower boundary
  - Turbulence
  - Moist processes (grid scale and convection) capable of interacting with aerosols and radiation
  - Computationally efficient, scalable

# Driving Atmospheric Model

- Example of convergence problem with mass flux moist convection schemes (Arakawa et al. 2011)
  - Small fractional grid box cloudiness coverage assumed
  - At high resolutions entire grid box covered by clouds
  - No “environment” left
  - Conventional mass flux scheme concepts (plume, updrafts, downdrafts, entrainment, detrainment etc.) do not work any more
  - No convergence of large scale mass flux schemes!

# Driving Atmospheric Model

- Arakawa et al. 2011:

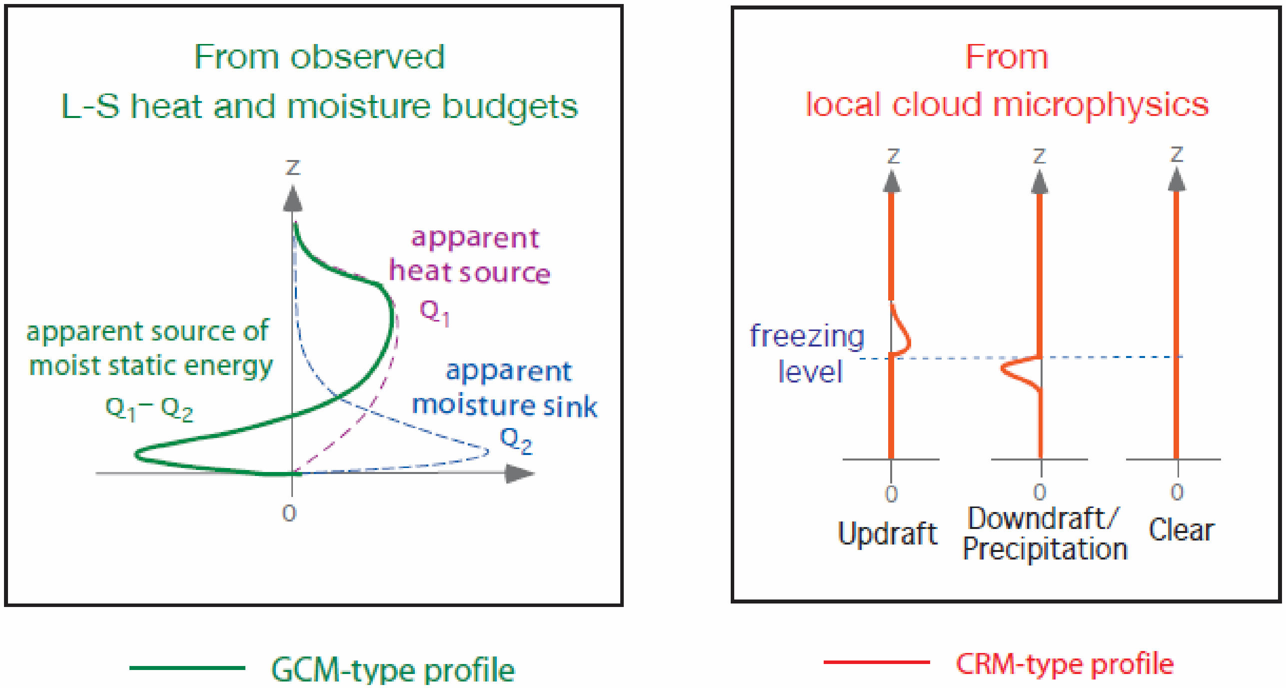



**Fig. 3.** Schematic illustration of typical vertical profiles of moist static energy source under disturbed tropical conditions.

# Driving atmospheric model

- Example of convergence problem with "nonlocal" PBL schemes
  - Adjustment schemes for convective BLs based on observations and LES, very popular
  - Attempt to take into account vertical transports by large eddies
  - At high resolutions model dynamics start resolving large eddies
  - Fundamental assumption not valid any more!

# Modeling subsystems

- Aerosols
- Atmospheric chemistry
- Land surface and soil
- Land hydrology
  - Surface
  - Subsurface
- Ocean

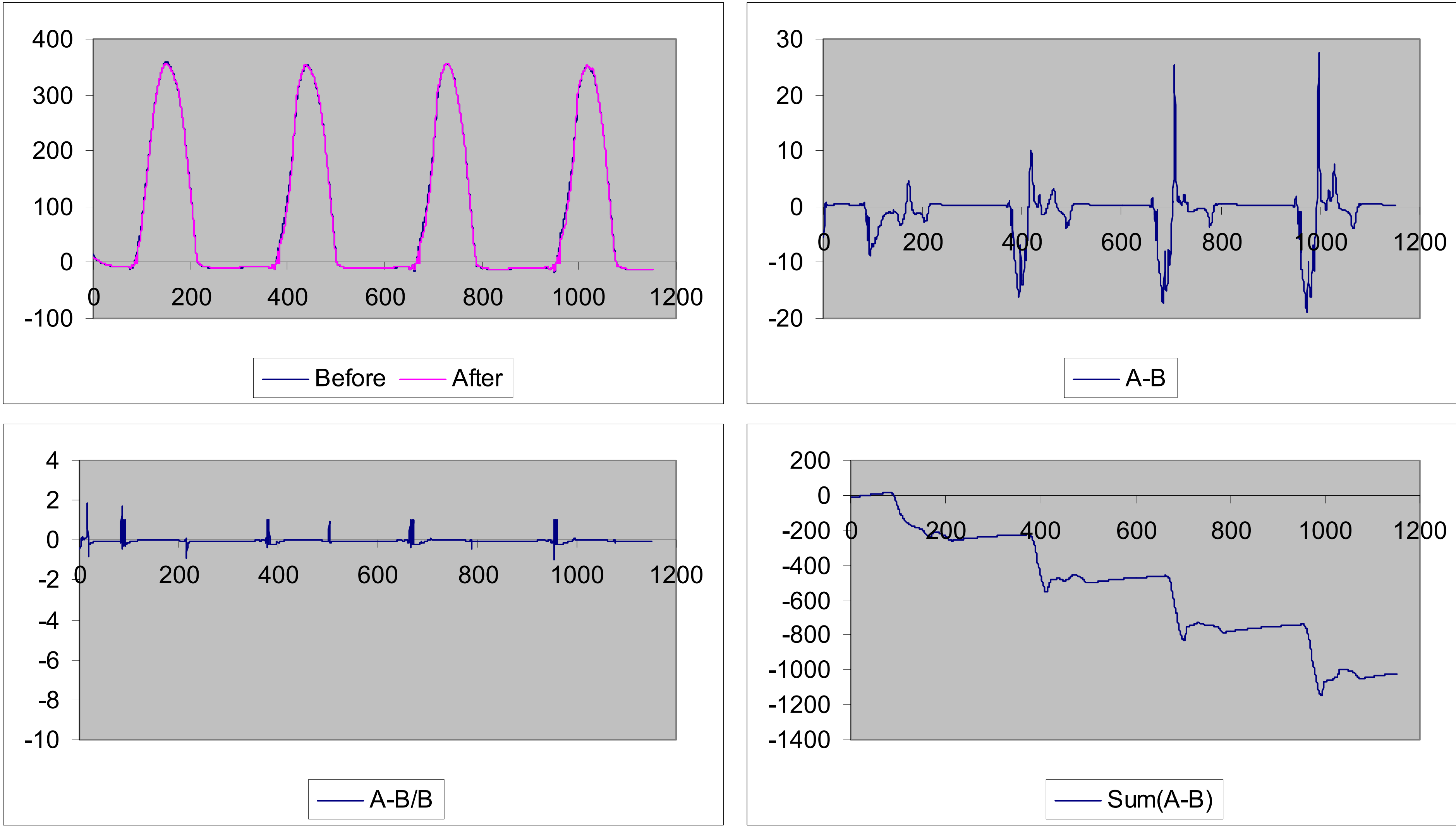
# Modeling subsystems: Aerosols

- Sources
- Uptake mechanisms
- Atmospheric transport
- Interactions
  - Radiation
  - Microphysics
- Deposition
  - Dry, gravity, turbulence
  - Wet, grid scale precipitation, convection

# Modeling subsystems: Land surface and soil

- Atmosphere exchanges energy through surface
- Are SVAT models with “sandwich” canopy adequate?
- Snow, age, density, heat conduction
- Urban canopy representation?
- Numerical methods for non-stationary, transitional regimes

```
      qflxbfr=-akhs*(q(lmhk)-qz0)*elwv
      call vdifh
     &(lmhk,dtphys,thz0,qz0,akhs,ct,the,q,c,akh,z)
          do l=1,lmhk
      cl=c(l)
      t(l)=elocp*cl+(the(l)/ape(l))
          enddo
      qflxaft=-akhs*(q(lmhk)-qz0)*elwv
      dqflx=qflxaft-qflxbfr
      sumdq=dqflx+sumdq
      if(abs(qflxbfr).gt.1.e-2) then
        rel=dqflx/qflxbfr
      else
        rel=dqflx/qflxaft
      endif
      write(10,2000) kt,qflxbfr,qflxaft,dqflx,rel,sumdq
 2000 format(' ',i4,5e14.5)
```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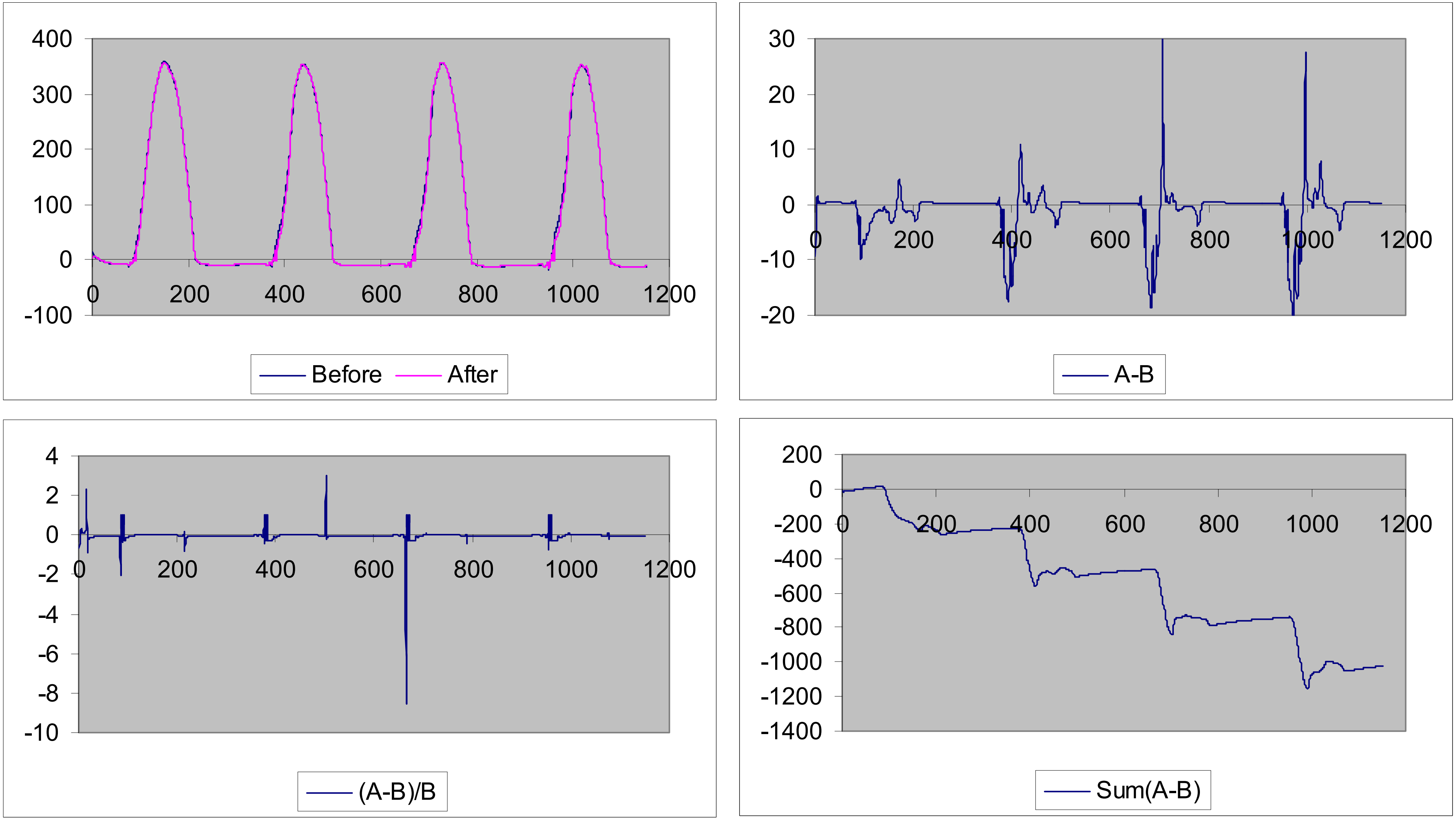
Qsfc BC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Sum(A-B)

# LH flux BC

# Modeling subsystems: Land Hydrology

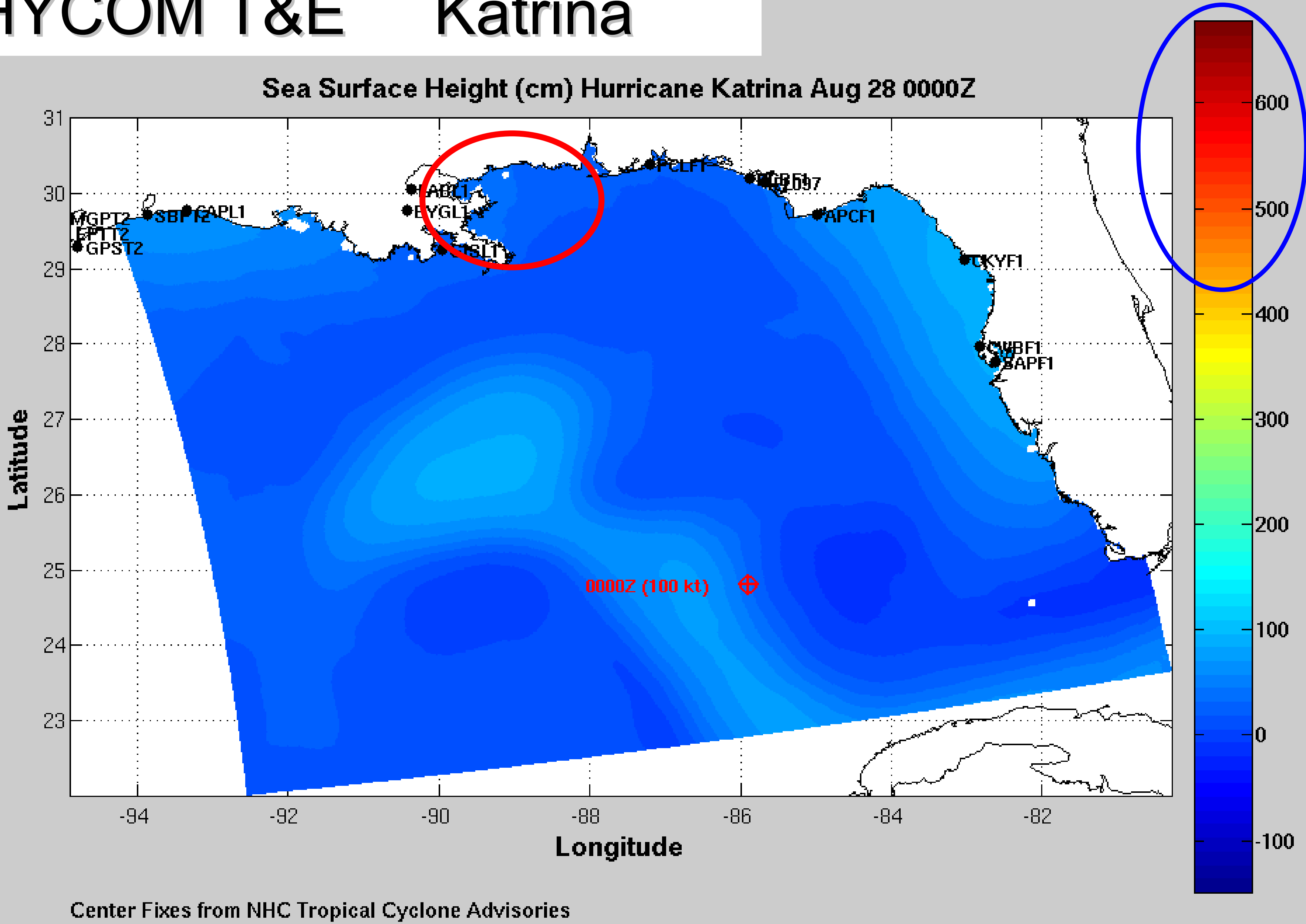
- Horizontal movement of subsurface water often ignored
  - Do we know enough about it?
  - Scale dependancy? Can it be ignored on some scales and not on others
- High resolution surface hydrology
  - Statistical models
  - Dynamical models, SEVCC already pioneering (Nickovic et al. 2010; Pejanovic et al. 2011)
  - Ignore surface runoff?

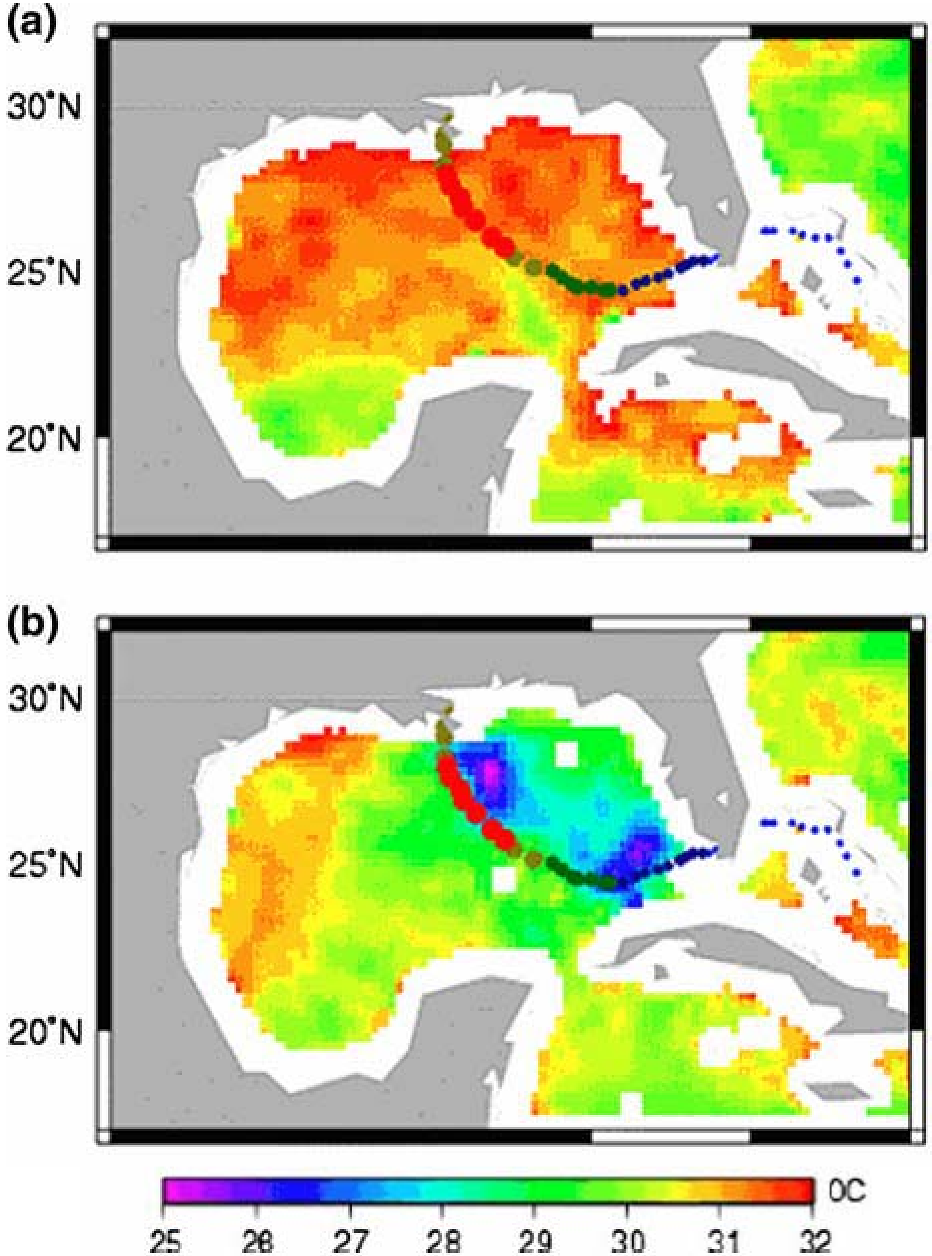
# Modeling subsystems: Ocean

- Significant feedback between atmosphere and ocean
  - Is ocean climatology sufficient?
  - Is a surface water slab sufficient?
  - Full ocean model?
    - Is a coupled full ocean model affordable?
    - Is a data assimilation system needed to prevent the ocean model from drifting away from climatology?

# HYCOM T&E Katrina

Courtesy: Naomi Surgi






SST (a) before and (b) after Katrina (Sun et al. 2006)

# Modeling subsystems: Ocean

- Ocean Ice (not much sea ice in SE Europe)
  - Climatology, prescribed properties?
  - Fully interacting ocean ice model?

# Modeling subsystems: Atmospheric Chemistry

- Very expensive
- Chemically inert strongly interacting species ($CO_2$)
- Minimum # of chemically active strongly interacting species (ozone)

# Computing resources

- No upper limit!
- Lower limit, to start with
  - Based on time scales, $10^{-2}$ to $10^{-1}$ of what is available at major climate centers

# Conclusions

- Good start
- Wide range of issues to be addressed, lot of work to be done
- Good luck!