Developing Obstruction grids

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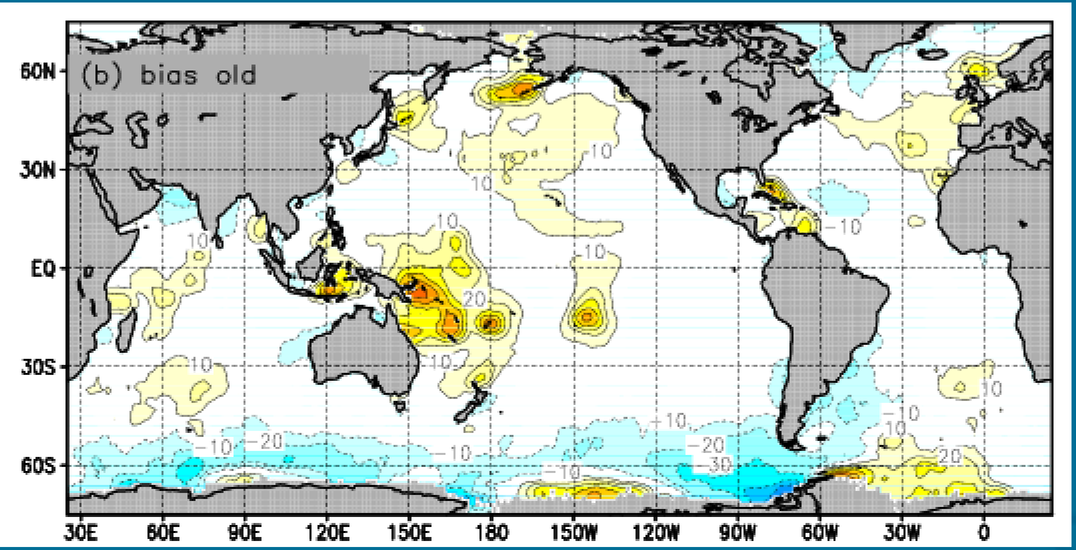
Covered in this lecture:

- The concept of having obstruction grids to mimic the blocking effect of unresolved islands on wave energy propagation
- The ideas behind building an automated obstruction grid algorithm
- Numerical tests of this algorithm in wave propagation

Why Obstruction grids ?

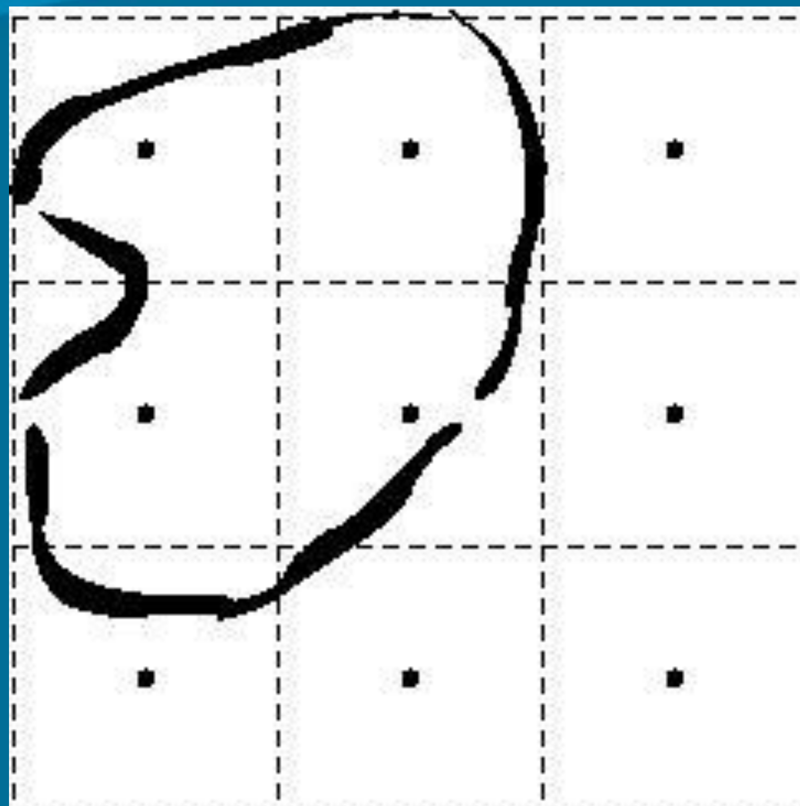
Motivation

To account for energy reduction due to blocking effects of unresolved land masses (small islands, atolls etc.)



Bias maps (Model – Data) show Bulls eye patterns behind unresolved islands in grid

Why Obstruction grids ?



Atolls / Barrier Islands cover very little surface area but provide effective barriers to wave propagation (e.g. Tuomotu)

Obstruction grid – Proof of concept

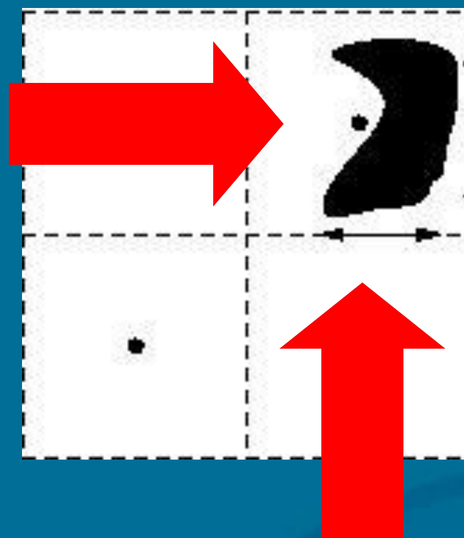
Tolman (2003) showed that sub-grid islands can be modeled in WAVEWATCHIII by physically reducing the energy fluxes between the cells

1D Spatial propagation in WAVEWATCHIII

$$F_i^{n+1} = F_i^n + \frac{\Delta t}{\Delta x}\left(\alpha_{i,-}G_{i,-} - \alpha_{i,+}G_{i,+}\right)$$

Spectral density

Density flux and transparencies at cell boundaries



Reduction of energy dependent upon the proportion of cell being obstructed

Obstruction grid ranges from 0 (no obstruction) to 1 (full obstruction)

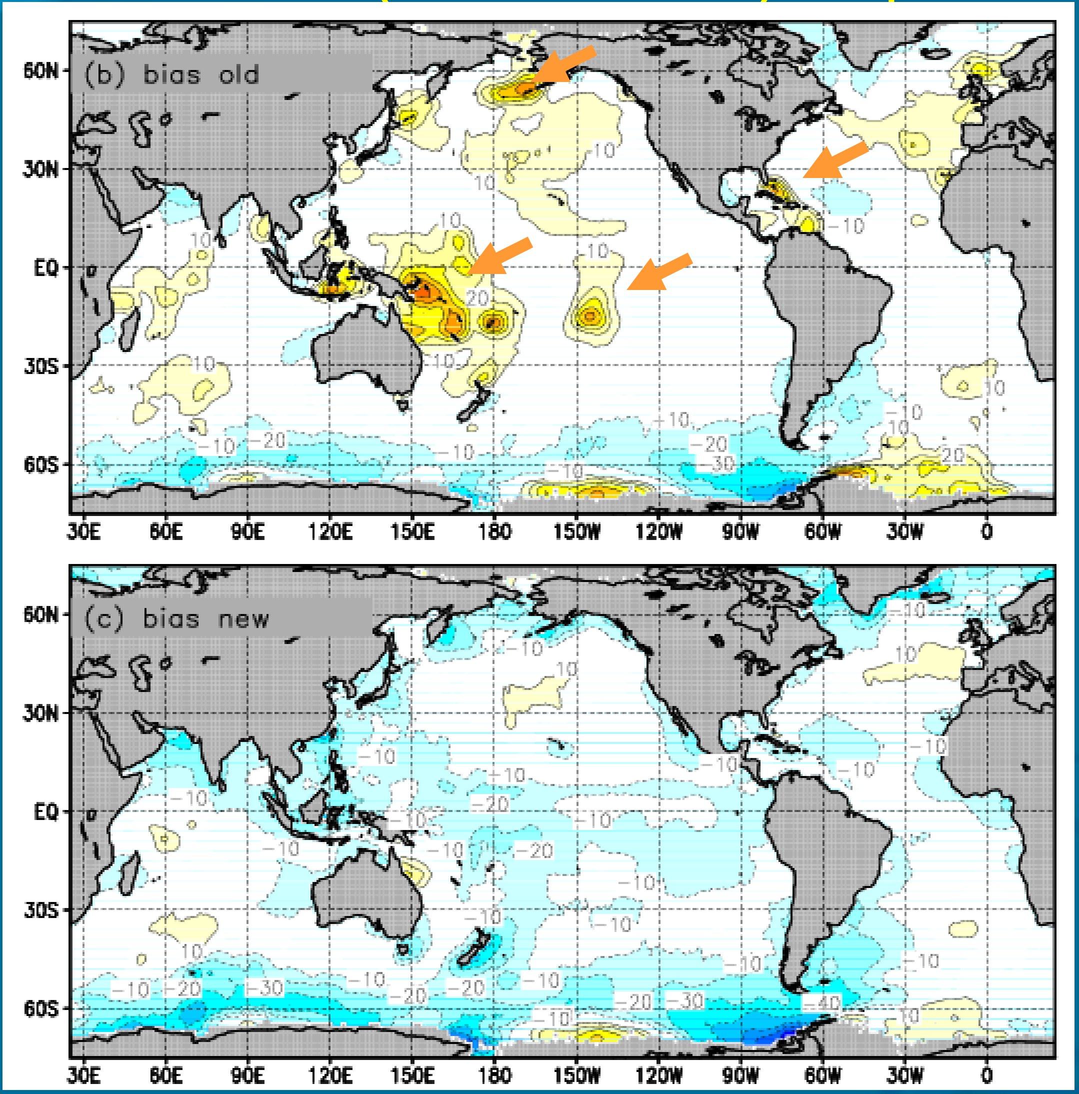
Two obstruction grids (for the 2 directions of motion) used in WAVEWATCHIII

Obstruction grids in action

Bias (Model –Data) map

No obstruction grid

Obstruction grid



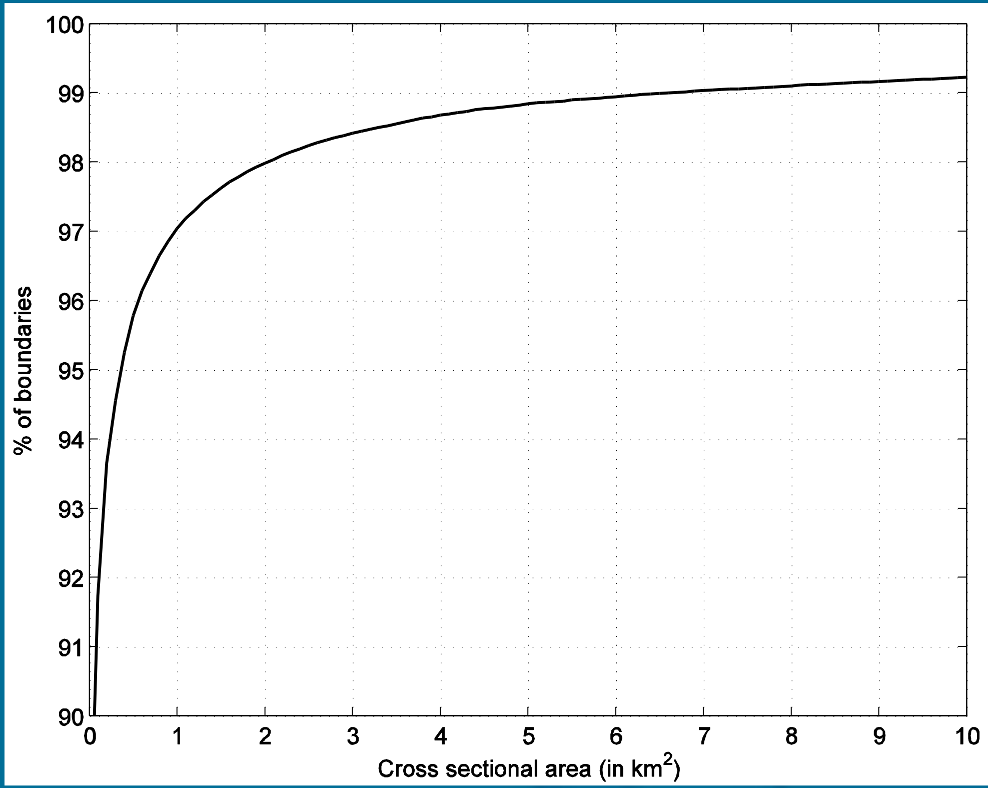
Obstruction grids remove the bulls – eye patterns behind islands

Building an Obstruction Grid

- Initial development of Obstruction grids was done manually using high resolution grids.
  - Time consuming
  - Lead to inconsistencies across overlapping grids
- Aim is to build an automated algorithm
- Reference Data ?
  - A base high resolution bathymetric data set that resolves most coastal features (e.g. ETOPO1)
  - A database of coastal polygons (e.g. Global Self Consistent Hierarchical High resolution Shoreline – GSHHS)
- Our choice is the GSHHS database.

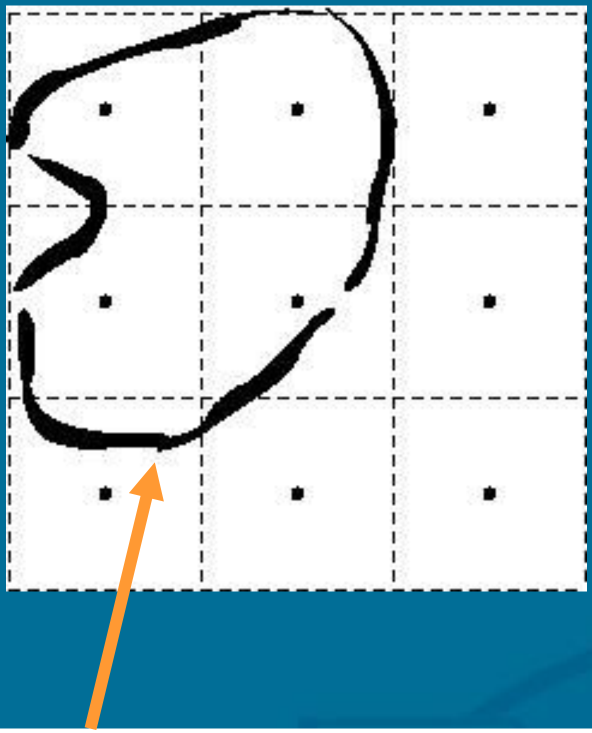
Why Shoreline Polygons?

- There are 188,606 shoreline polygons (180,509 coastal) in the data base
- Over 99 % of these have a cross sectional area < 6 km2 (cross sectional area of a 2’ grid square ~ 14 km2)
- Convenient to treat land bodies as closed polygons
  - Precludes need for representation in high resolution grid
  - Trivial to compute extent of coastal bodies along the grid axes



Why Shoreline Polygons (contd.)?

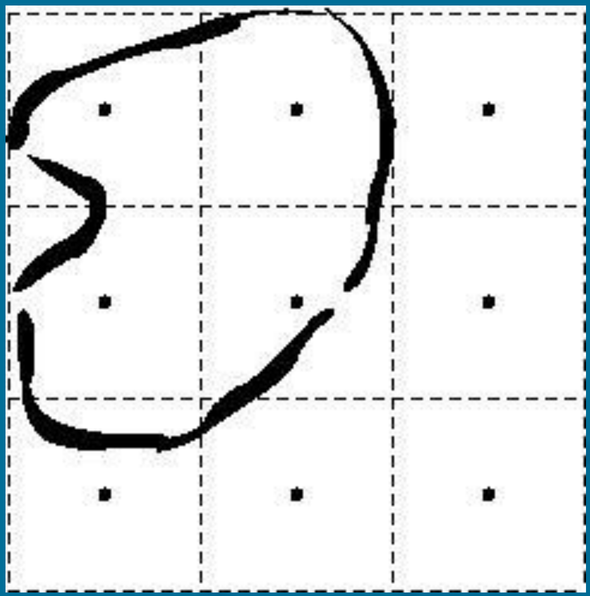
- Atolls are very well represented
- Additional obstructions (e.g. breakwaters) easily added
- Trivial to mask out selected bodies of water (e.g. Hudson Bay) or reefs (e.g. Great Barrier Reef)



Atolls cover very little surface area but provide effective barriers to wave propagation

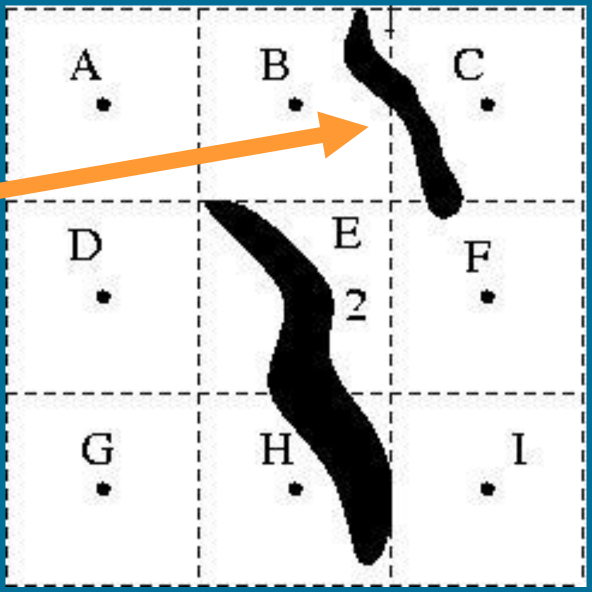
Obstruction grid algorithm

- Obstruction computed as *proportion* of cell length obstructed by boundary (ies)
- Obstruction data for cells next to dry cells set to 0 (to avoid spurious energy decay)
- Sx = obstruction along x = obstruction height/cell height
- Sy = obstruction along y = obstruction width/cell width



(a) Boundaries crossing cells in the same path

Energy flux from B to C should be fully obstructed



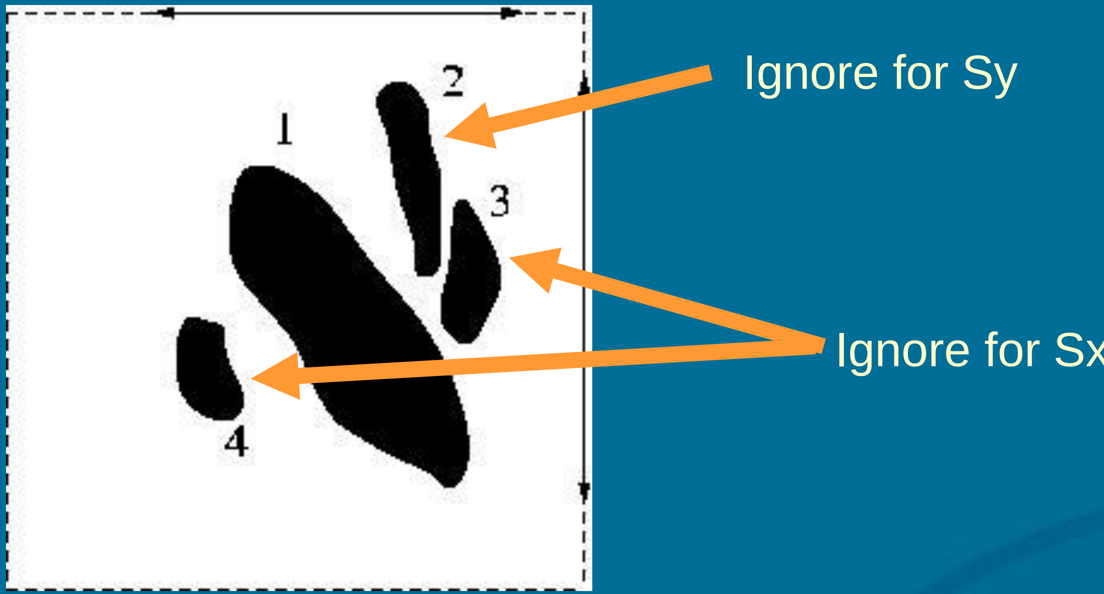
Option1: Account for obstruction path in neighboring cells

Option2: Move boundary segments from common boundary in neighboring cells to the same cell

Using option 2 prevents over counting

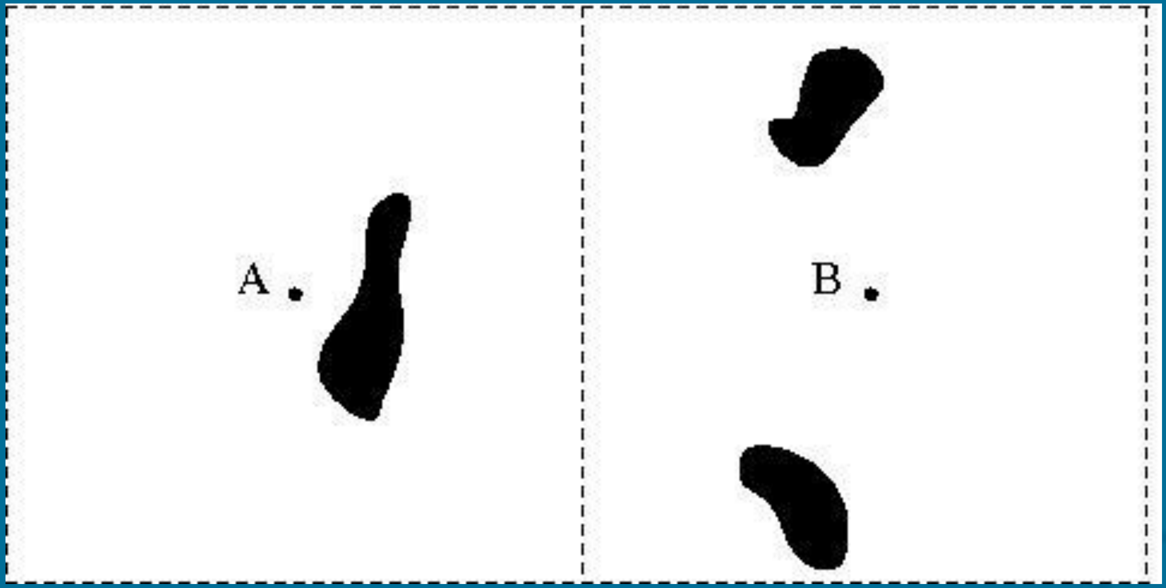
Points to consider while building an obstruction grid (contd.)

(b) Multiple boundaries within a cell



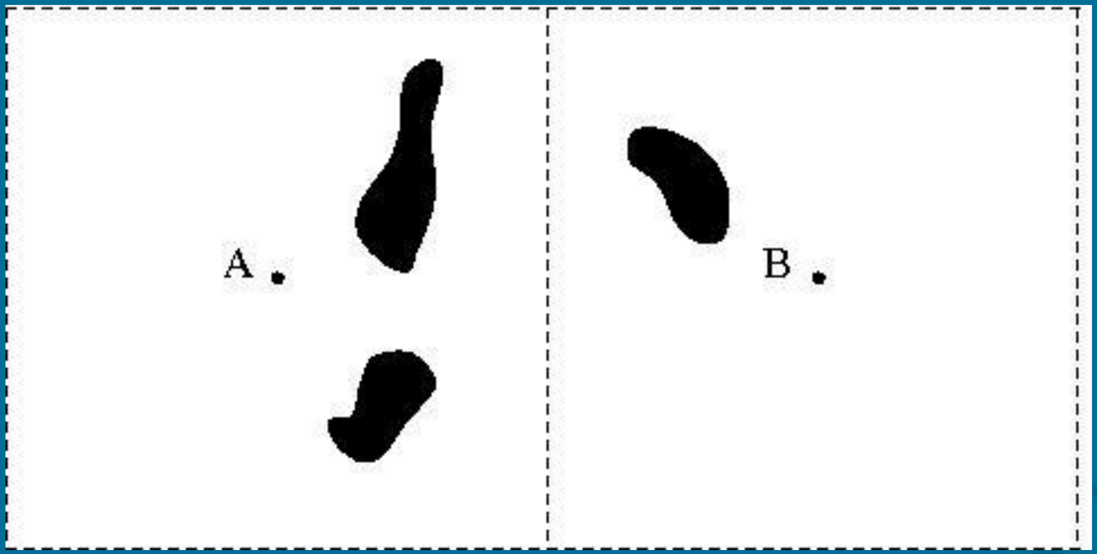
Obstruction should not be determined from the sum of all lengths but the ***net length***

(c) Neighboring cell information



Orientation of boundaries in neighboring cell can lead to greater obstruction than from using boundary information in individual cells only

(d) Discount overlapping boundaries from neighboring cells



*Non – zero Sx,Sy values for any particular cell should be computed **if** obstructions in the cell contribute to the obstruction process*

Points to consider while building an Obstruction grid (contd.)

(e) How do you account for neighboring cells ?

<u>Option1</u>: Consider neighbors on both sides

Cell B Sx values would include information from cell C

Cell C Sx values would include information from cell B

Wave propagation from left to right (or right to left) will lead to over attenuation

(e) How do you account for neighboring cells (contd.)?

Option2: Consider neighbors on one side alone

Cell B Sx values would include information from cell C (neighbor to right)

Cell C Sx values would include information from cell B (neighbor to left)

Use right neighbor for wave propagation from right to left

Use left neighbor for wave propagation from left to right

Numerical Tests to validate obstruction algorithm

- 3 different regions
  - Caribbean Islands
  - Hawaii
  - French Polynesian Islands
- For each region
  - 5 grid resolutions (2’, 4’, 8’, 15’ and 30’)
  - 4 different scenarios
    - No obstruction
    - Obstruction grids based on individual cell info only
    - Obstruction grids based on cell info from one neighbor
    - Obstruction grids based on cell info from both neighbors

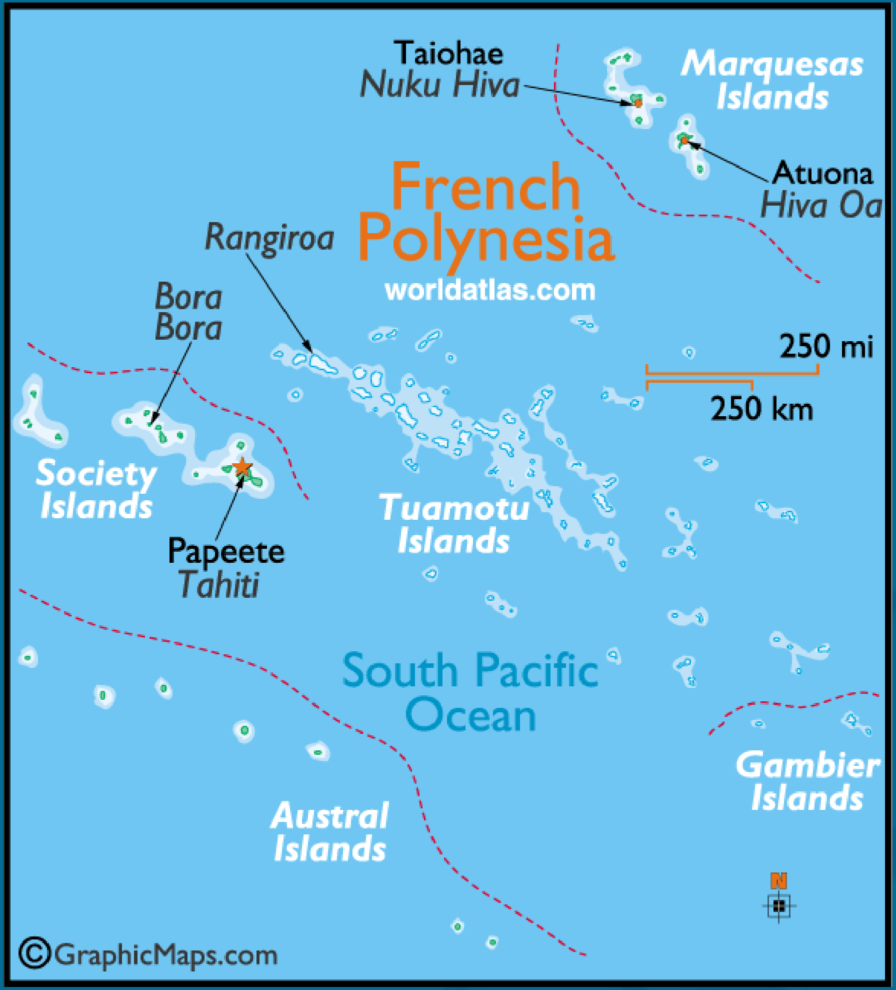
Numerical Tests (contd.)

- Constant swell applied along Northern and Eastern boundaries
  - Hs = 4m, Tp = 10 sec
  - Swell direction = 45º from the North East
  - Directional spread = 20º
  - Monochromatic frequency component
  - 72 directional components (to minimize Garden Sprinkler Effects)
- Tests limited to swell propagation
  - No refraction
  - Source terms switched off

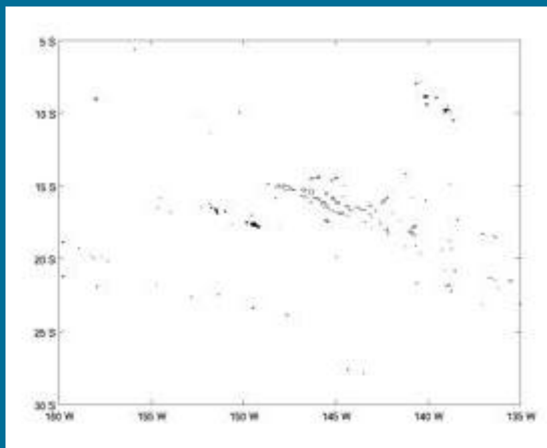
Test Case – French Polynesia

Total # of boundary polygons for this region = 1640
Max projected area ~ 2400 km^2
Min projected area ~ 0.0092 km^2

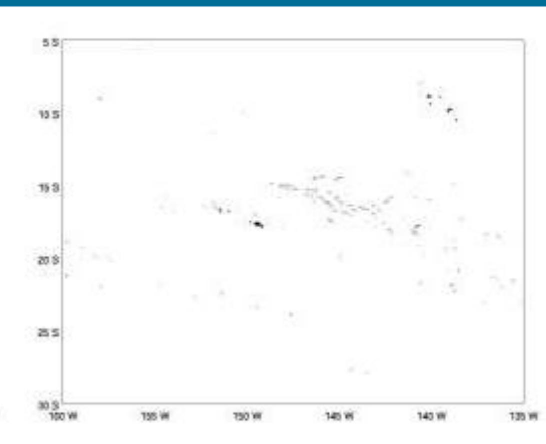
Projected area = length*width



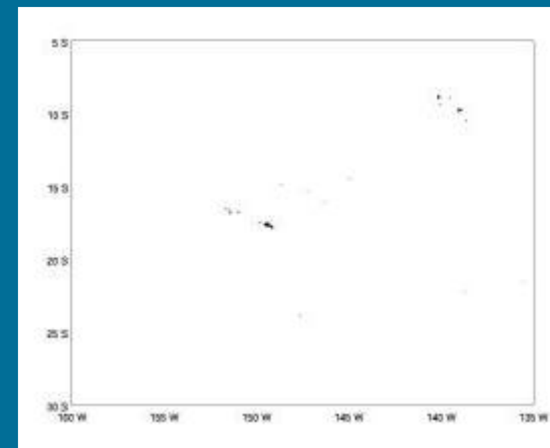
Grids (land – sea masks)



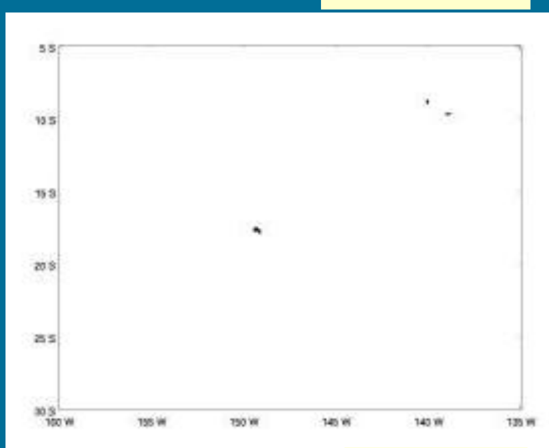
GSHHS



2’ grid



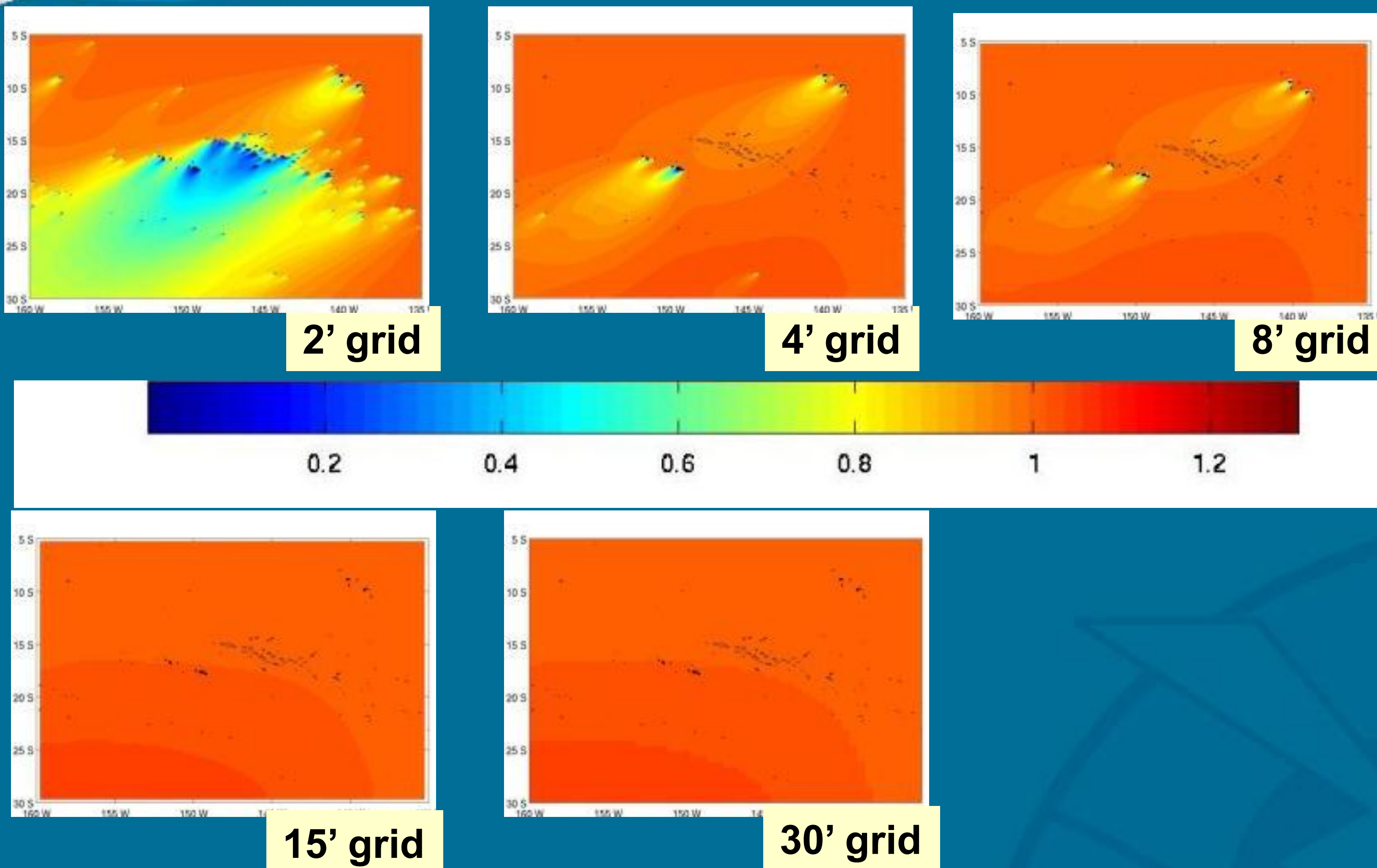
4’ grid



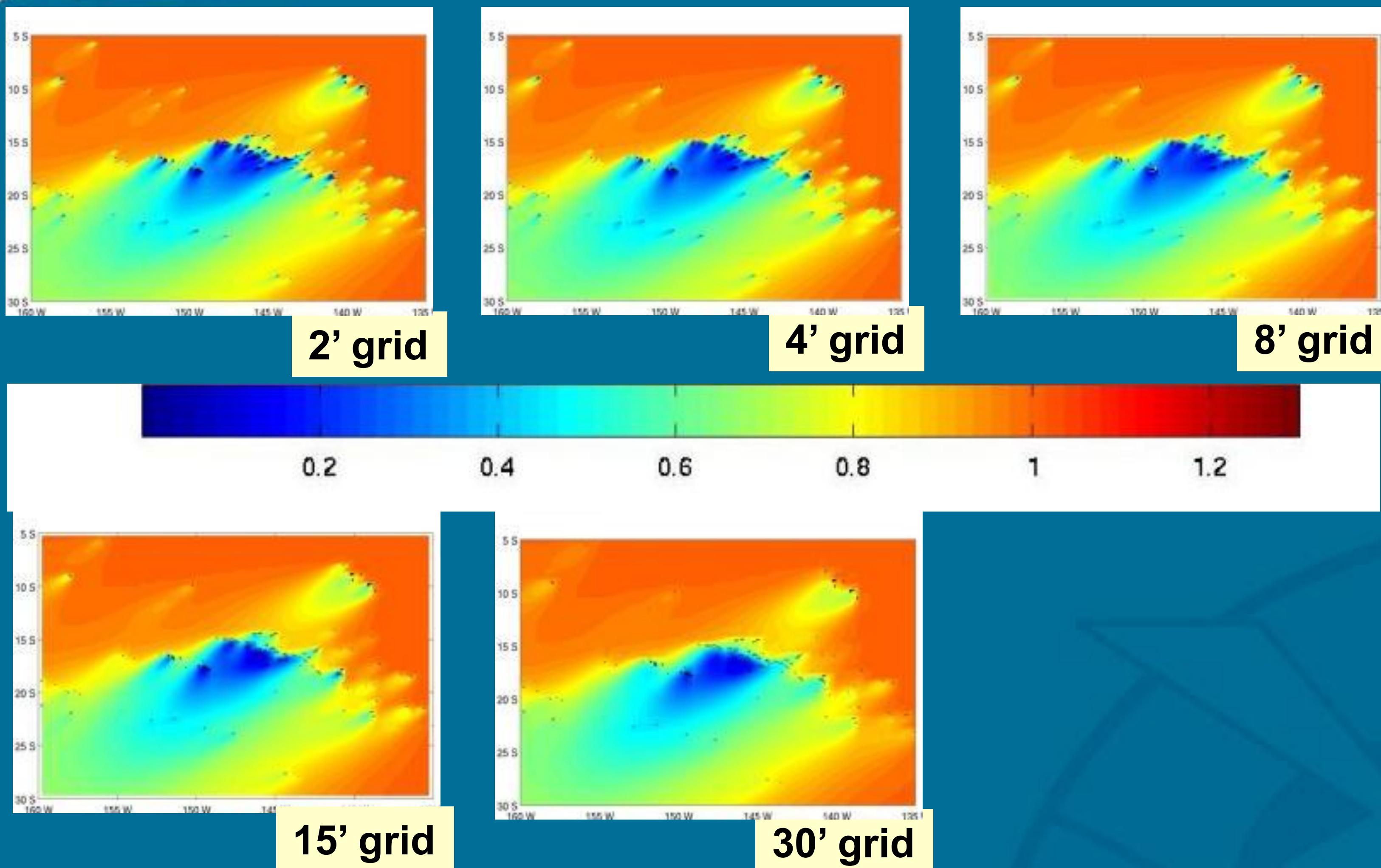
8’ grid

Coarser grids had no land boundaries

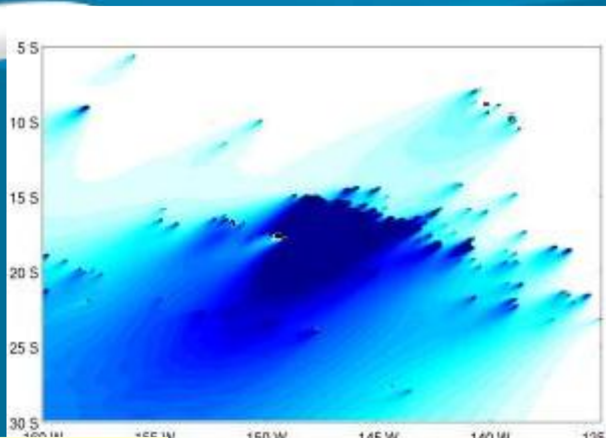
Swell propagation without obstruction grids



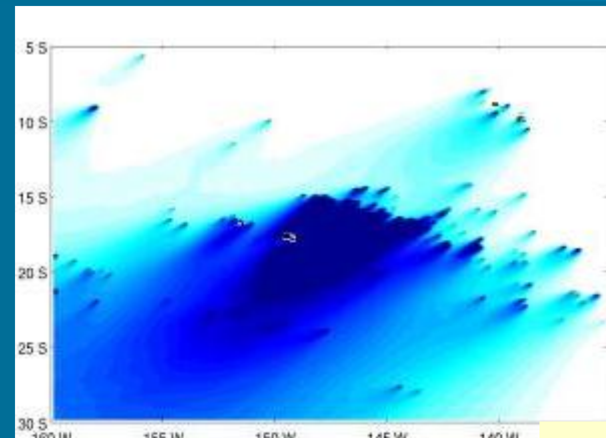
Swell propagation with obstruction grids



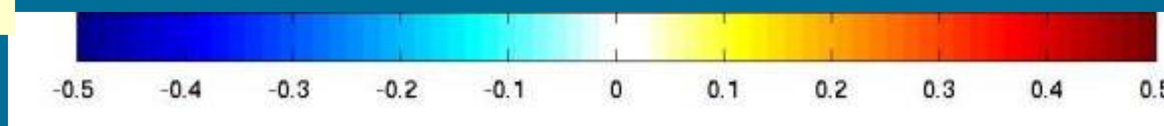
Difference plots (no obstruction)

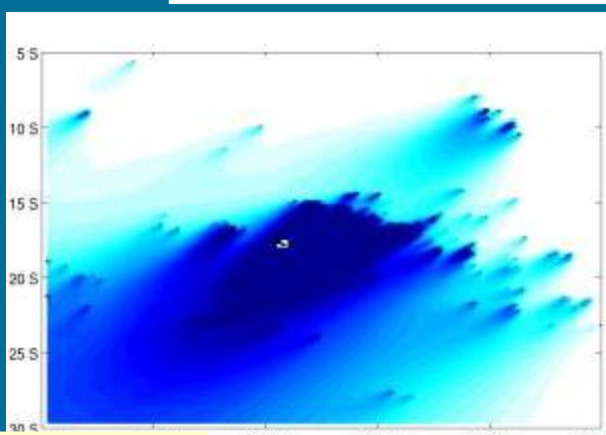


(a) 2' – 4'

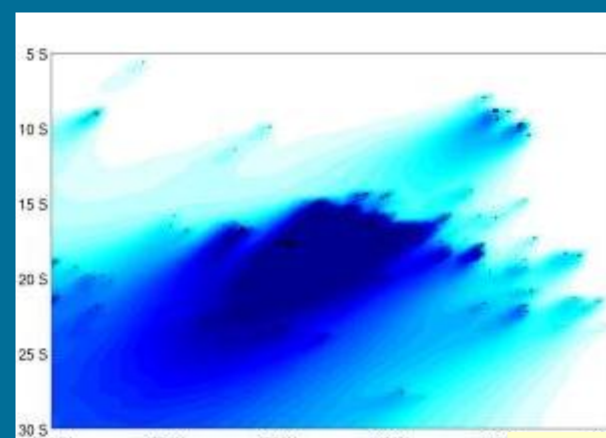


(b) 2' – 8'



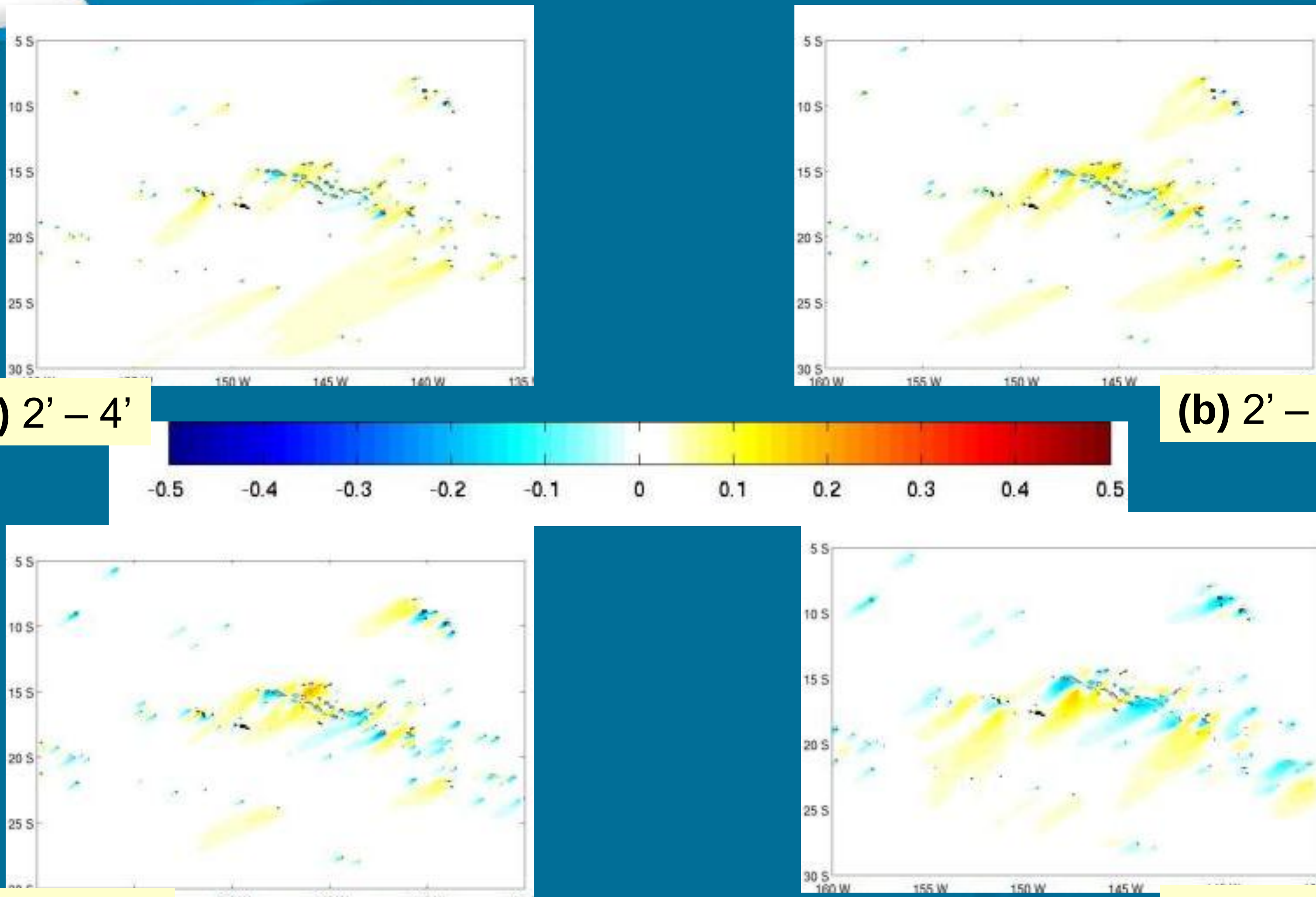


(c) 2' – 15'



(d) 2' – 30'

Difference plots (with obstruction)



(a) 2’ – 4’

(b) 2’ – 8’

(c) 2’ – 15’

(d) 2’ – 30’

Conclusion

- An obstruction grid algorithm has been developed
- Algorithm works in Matlab and uses the GSHHS polygons with the land – sea mask and is part of the grid generation package (to be covered next)
- The obstruction grid algorithm is designed to work downstream of unresolved islands
  - For accurate solutions close to islands, they have to be resolved using high resolution grids
- Obstruction grids work by reducing the energy over the unresolved grid cell, and thus are limited by the resolution of the grid in question

The end

End of lecture