Mapping of Topographic Effects on Maximum Sustained Surface wind Speeds in Landfalling Hurricanes

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A Question of Scale

- Large-scale topography
  - elevations greater than 3000 m (Hispaniola)
  - affects overall structure and intensity of hurricanes interacting with such topography
- Small-scale topography
  - topography whose height is less than the depth of the boundary layer
  - marked increases in wind speed near the crest when compared to the wind speed measured at the same height above flat terrain

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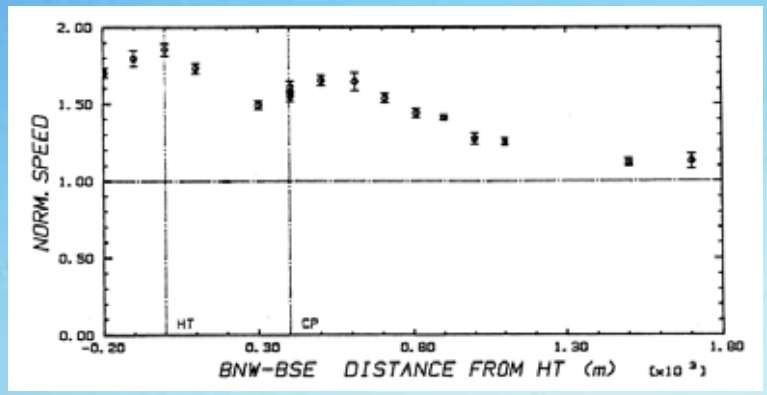
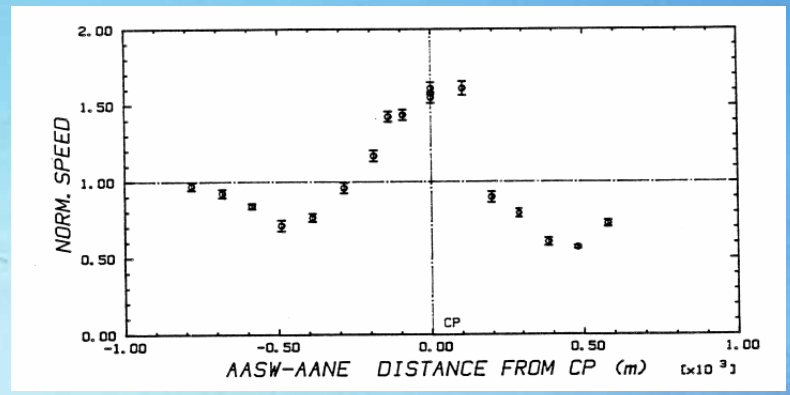
Askervein Hill, Outer Hebrides





- Rises 116 m above surrounding terrain
- Observed increases of up to 85% in wind speed at crest relative to reference wind speed above flat terrain

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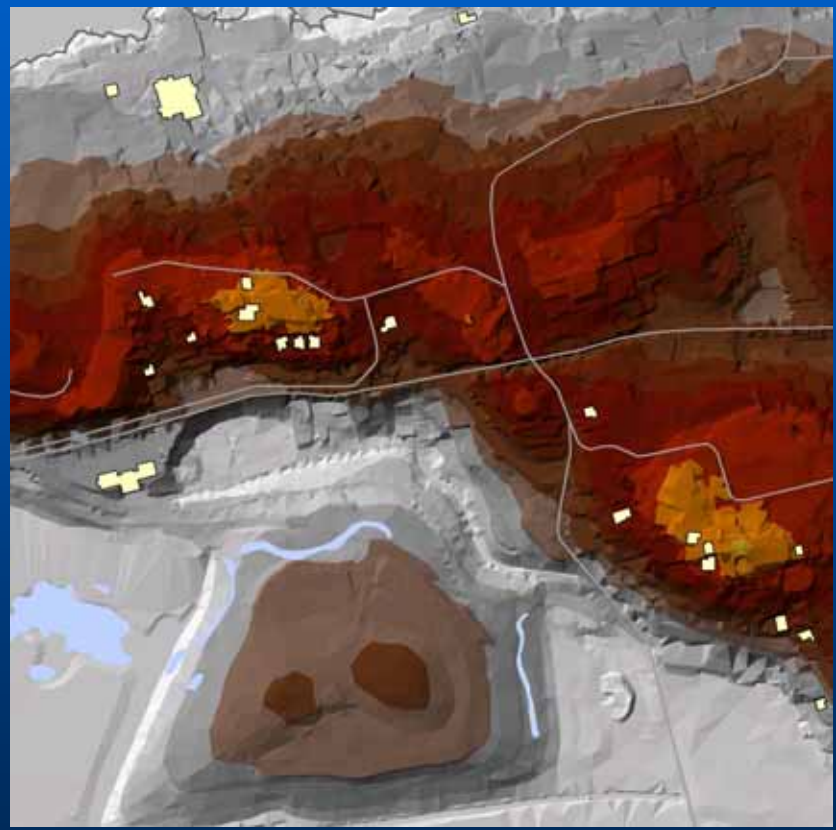
Observed Damage Due to Topographic Effects on Surface Wind Speeds

Largely qualitative observations from

- Cyclone Winifred (1986)
- Hurricane Iniki (1992)
- Hurricane Marilyn (1995)
- Super-Typhoon Paka (1997)



Observed roof damage from satellite imagery following Hurricane Fabian (2003) in Bermuda

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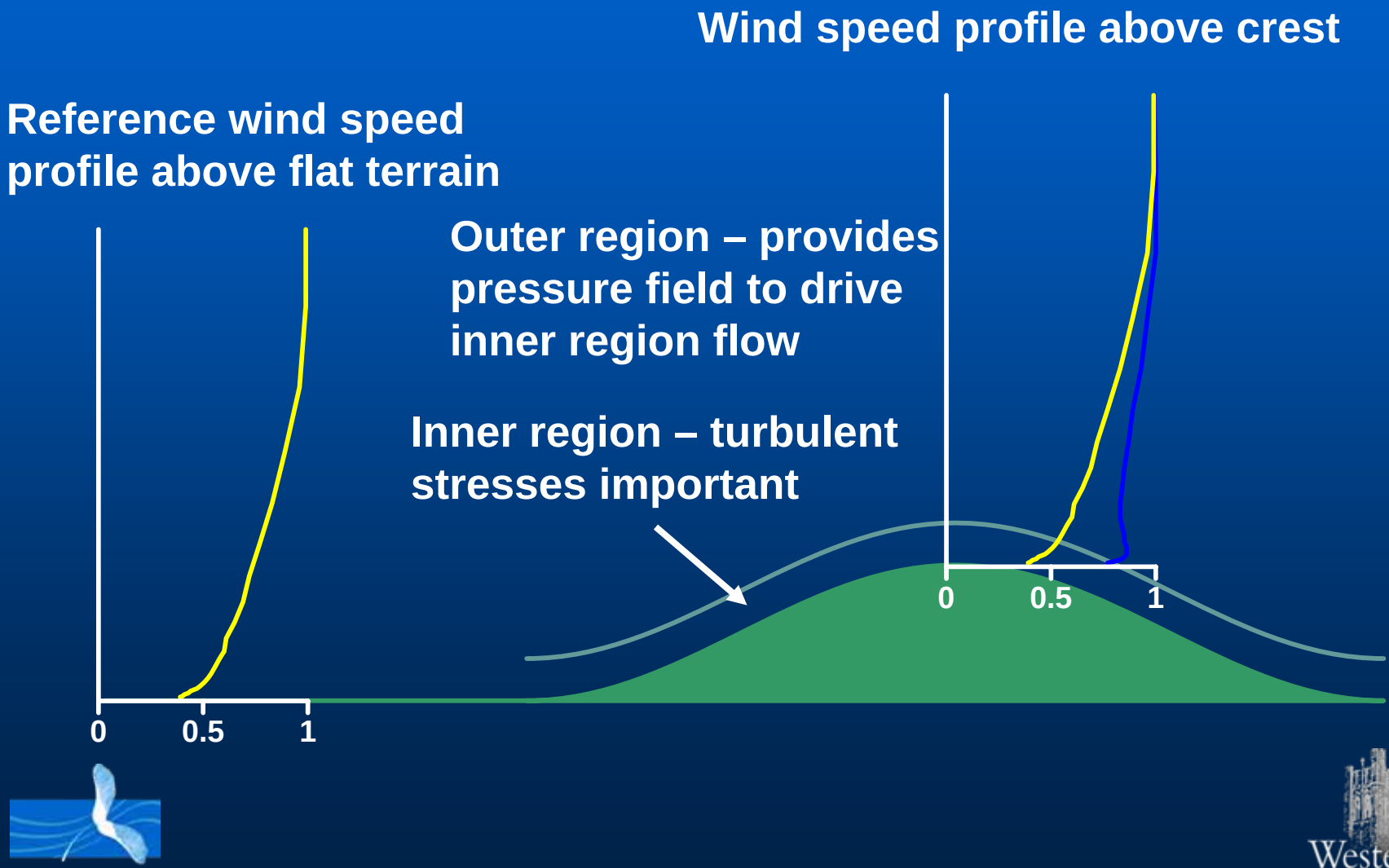
A Framework for Discussing Boundary Layer Flow Over Topography



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Factors That Influence Topographic Speed-up Effects On Surface Wind Speeds

- Slope of topography in direction wind is blowing
- Surface roughness
  - increasing surface roughness leads to larger speed-ups
- Whether topography is 2-D (ridge) or 3-D (hill)
  - speed-up is reduced if topography is 3-D
- Onset of flow separation places an upper limit on the maximum speed-up
  - depends on both slope and surface roughness

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MS-Micro

- Velocities are expressed in terms of an undisturbed logarithmic profile and a perturbation induced by the underlying topography
- Boundary layer equations are then linearized by splitting the flow into two regions and performing a scale analysis of all terms in both regions
- Flow in outer region provides pressure field that drives flow in inner region where turbulent stresses are important
- Horizontal derivatives transformed into the Fourier domain for solution

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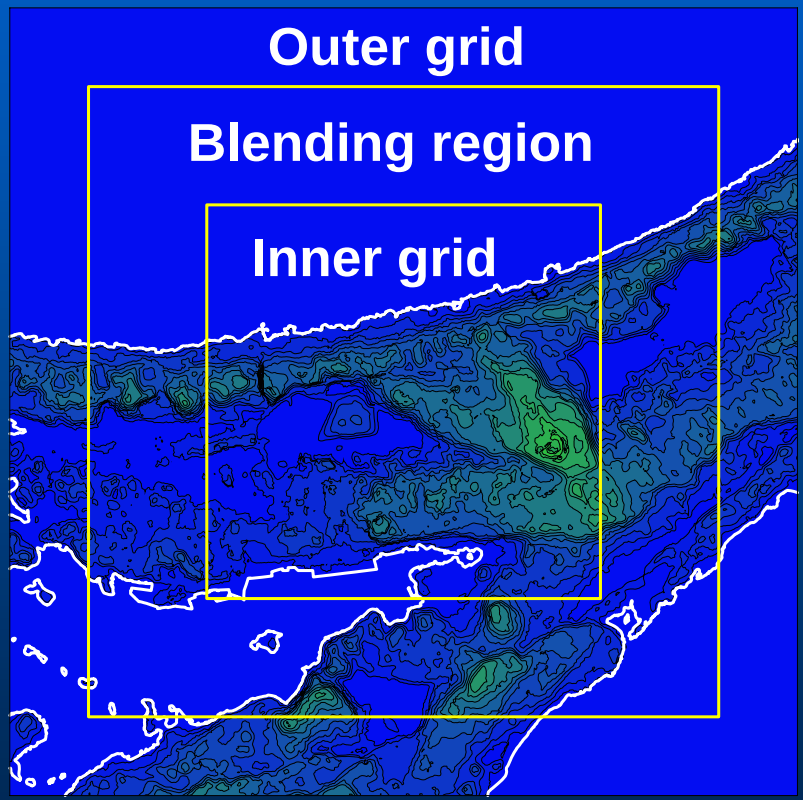
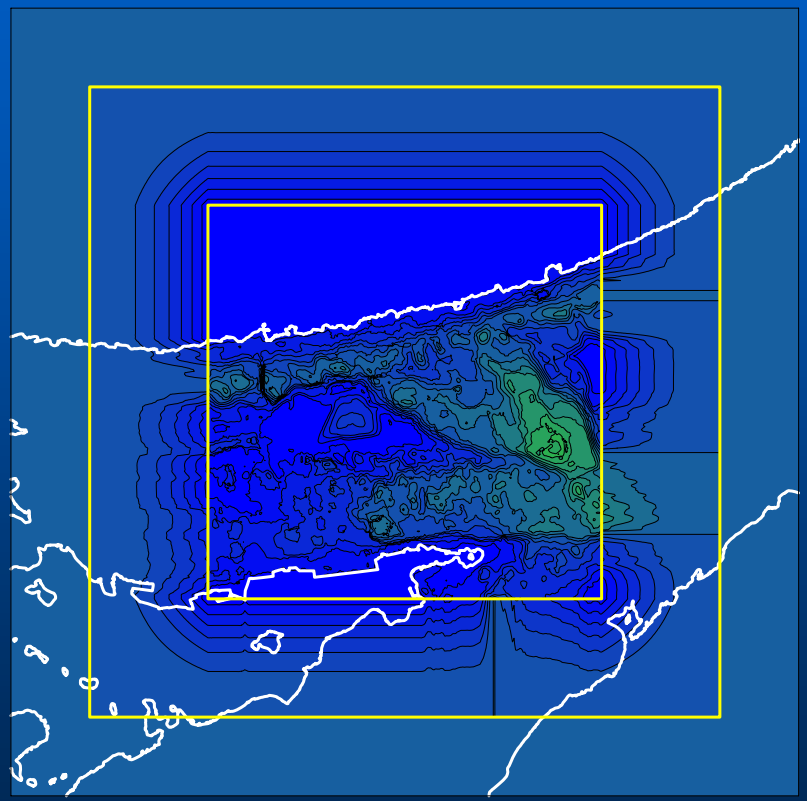
Horizontal Boundary Conditions

Use of Fourier transforms in horizontal domain requires consideration of horizontal boundary conditions for topography



Initial grid



Solution grid

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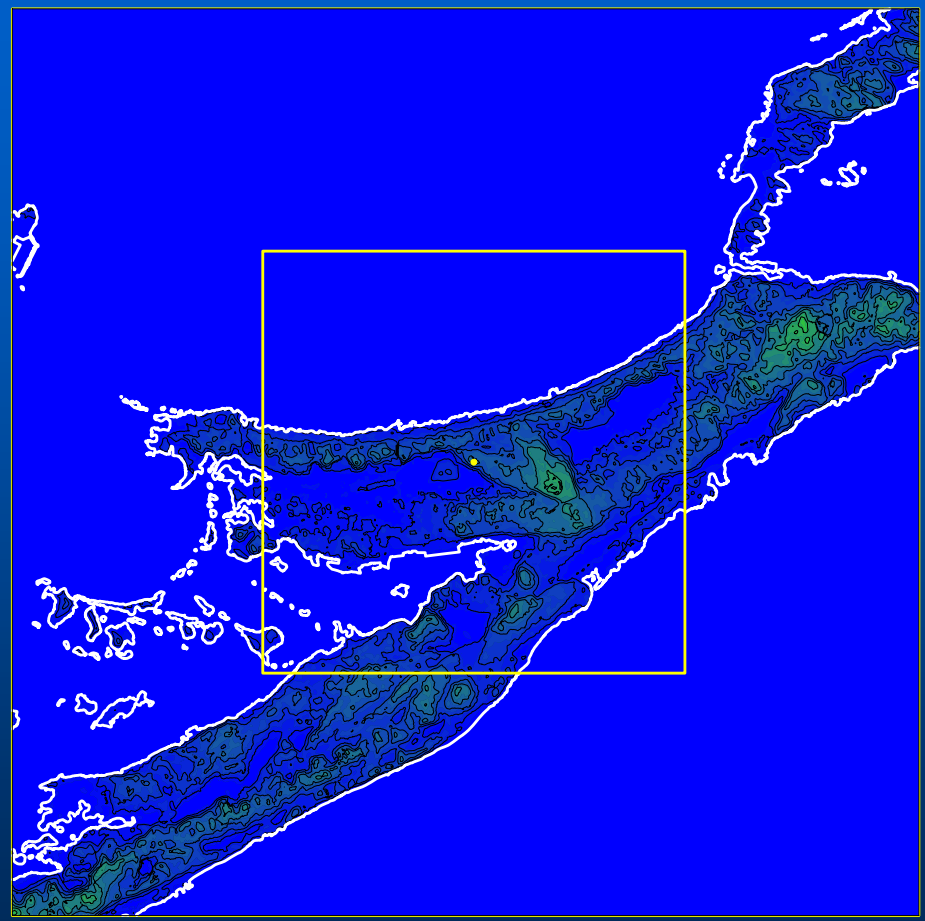
Calculating Speed-up Factors

- Create a regular mesh of grid points covering the region of interest
- For each grid point extract topography grid of required dimensions centred on the grid point
- Run MS-Micro for each required wind direction
- Extract speed-up factors from output files at centre of solution grid for post-processing



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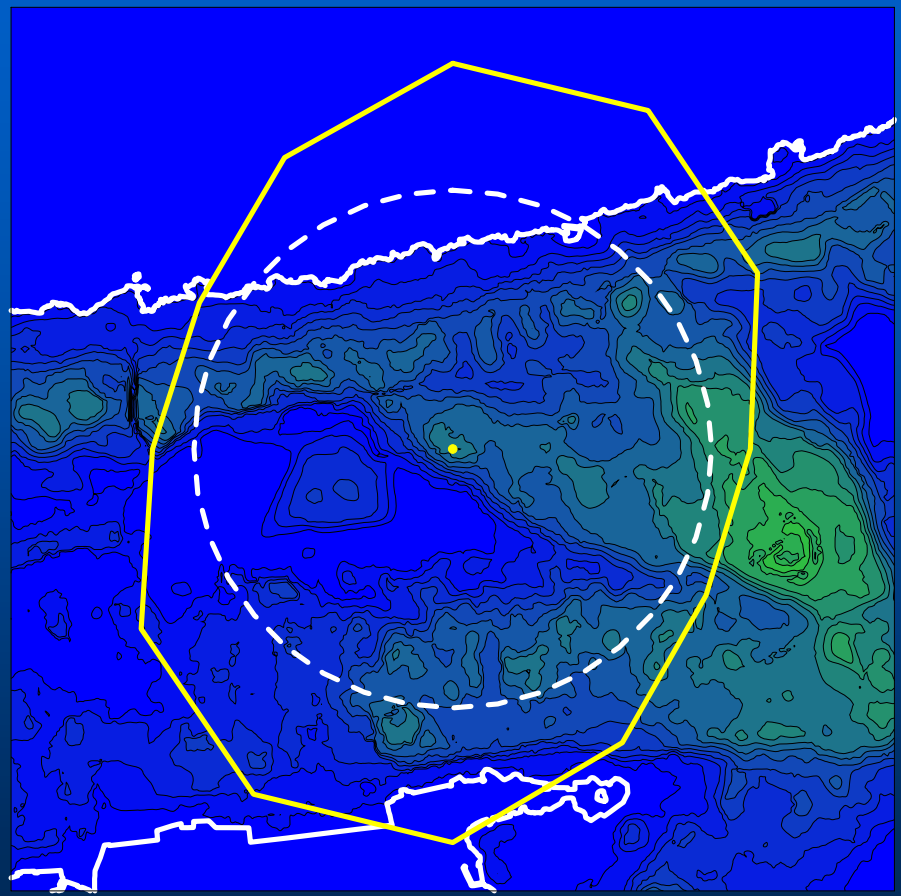
Radar Plot of Directional Speed-up Factors

- Dashed circle represents speed-up factor of 1
- Speed-up is directionally dependent
- Largest speed-ups occur when wind is blowing perpendicular to the ridge



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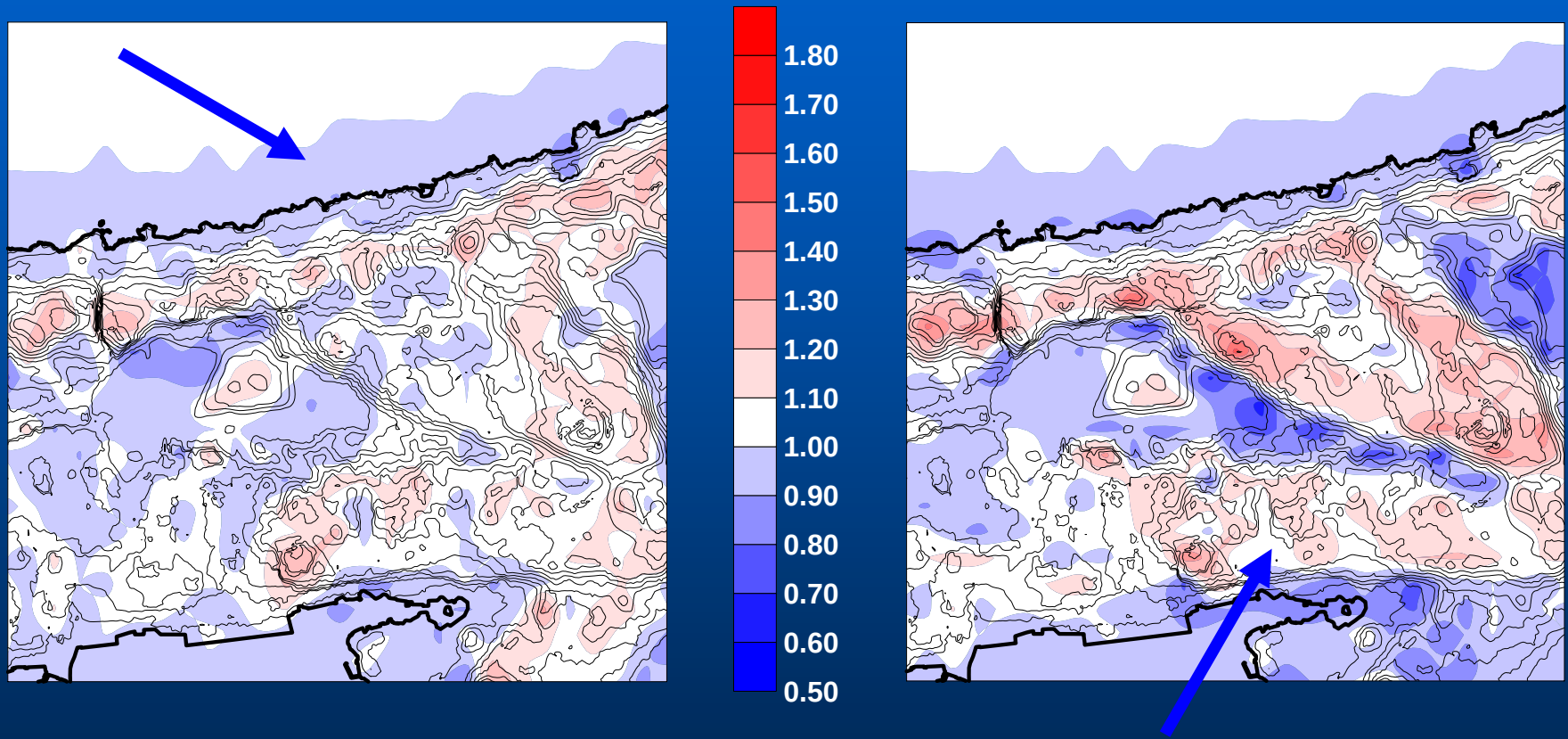
Directional Speed-up Maps

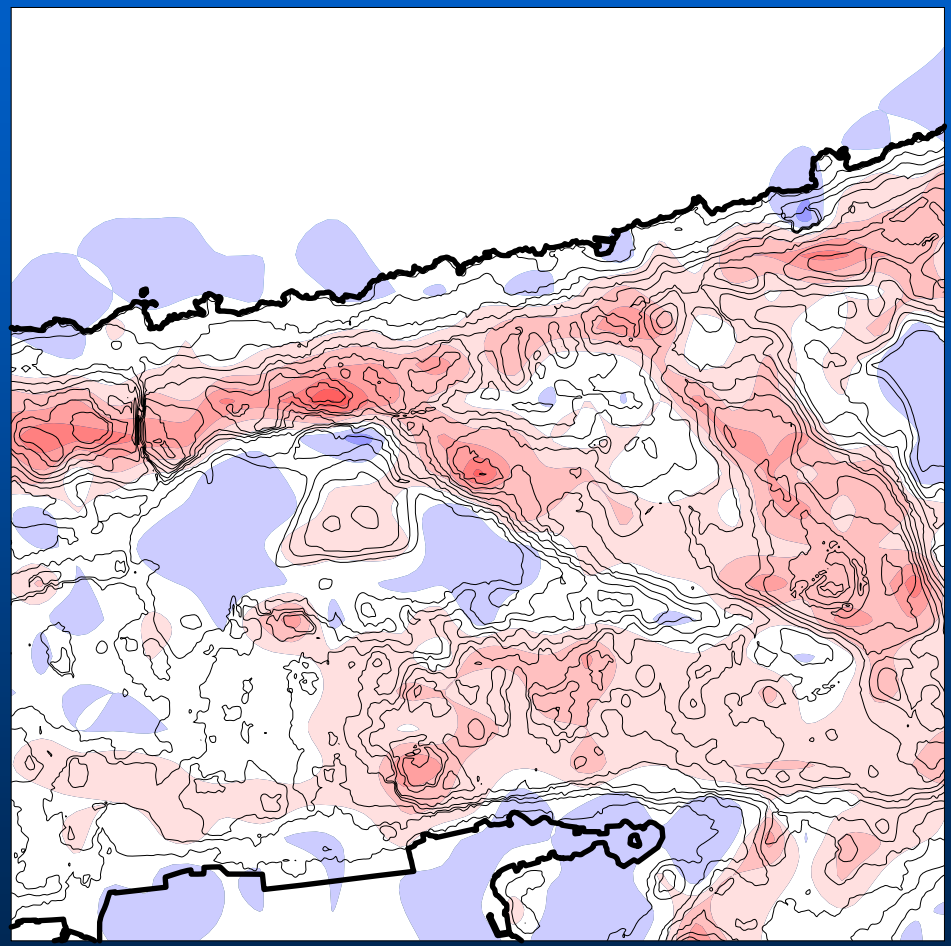
Wind direction 300º



Wind direction 210º

Map of Maximum Speed-up Irrespective of Direction

Largest speed-up value over all wind directions considered for every grid point



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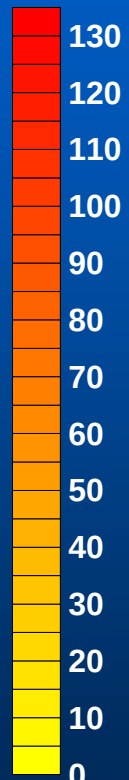
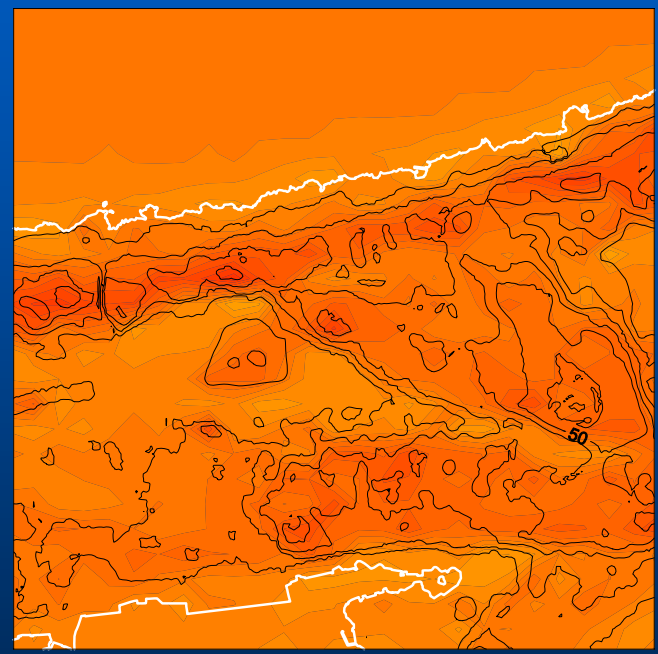
Speed-up Factors Combined With Base Over-Water Surface Wind Field

H*WIND wind field for 1930Z on 5 September, 2003



Including effects of topography



Maximum wind speed = 83 kts

Maximum wind speed = 128 kts

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Summary

- Topographic speed-up effects can have a significant effect on surface wind speeds in landfalling hurricanes
- Linear model of boundary layer flow over topography used to map topographic speed-up factors by both direction and irrespective of direction
- Speed-up factors can be applied to a base over-water surface wind field to predict likely surface wind speeds over land

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