

# WindSim Forest Model

A pragmatic search for useful parameter values

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# Background

# Project Description

Use flat plate CFD Model to find plausible parameters for Forest Model

# Forest Model Parameters

- Forest Height
- Z-Cells
- P- Porosity
- C1 – resistance proportional to wind speed
- C2 – resistance proportional to square of wind speed

# The Model

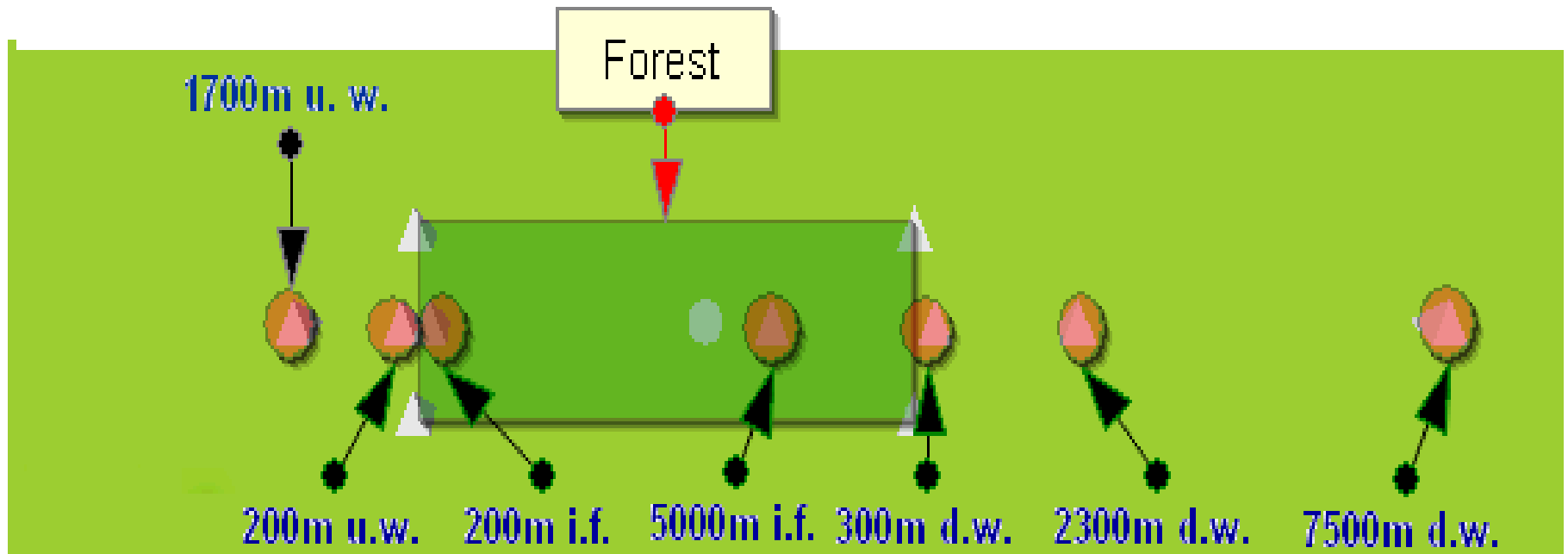


Fig 1. Digital terrain model with objects ▲ Wind turbine ● Climatology station

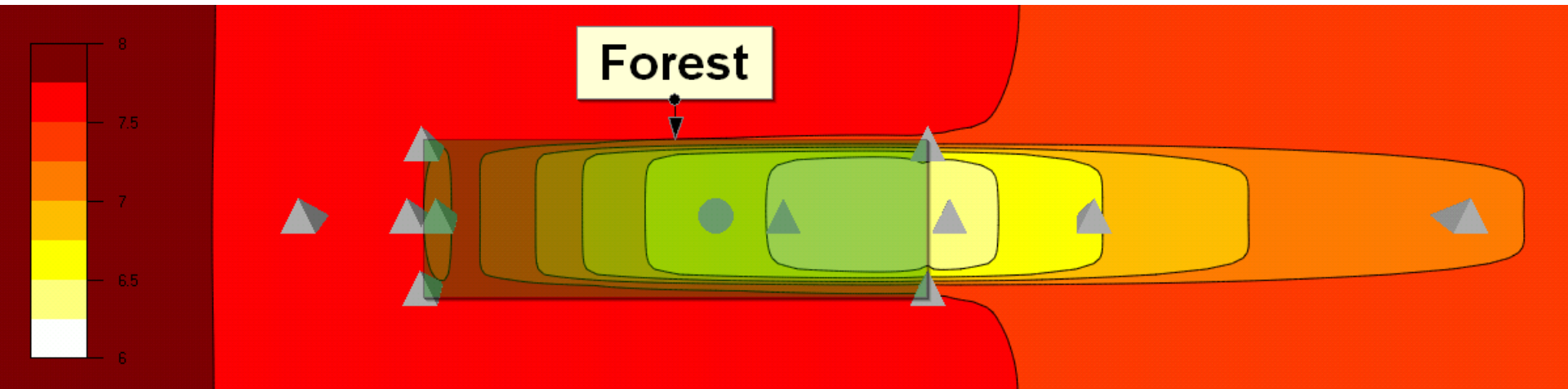
# Initial setup

- Artificial Terrain Model (flat plate)
  - 24 km x 6 km
  - Height: 1 km
- Forest Model
  - 7 km x 2 km
  - Height: Typically 10 or 25 m
- Seven fixed analysis points

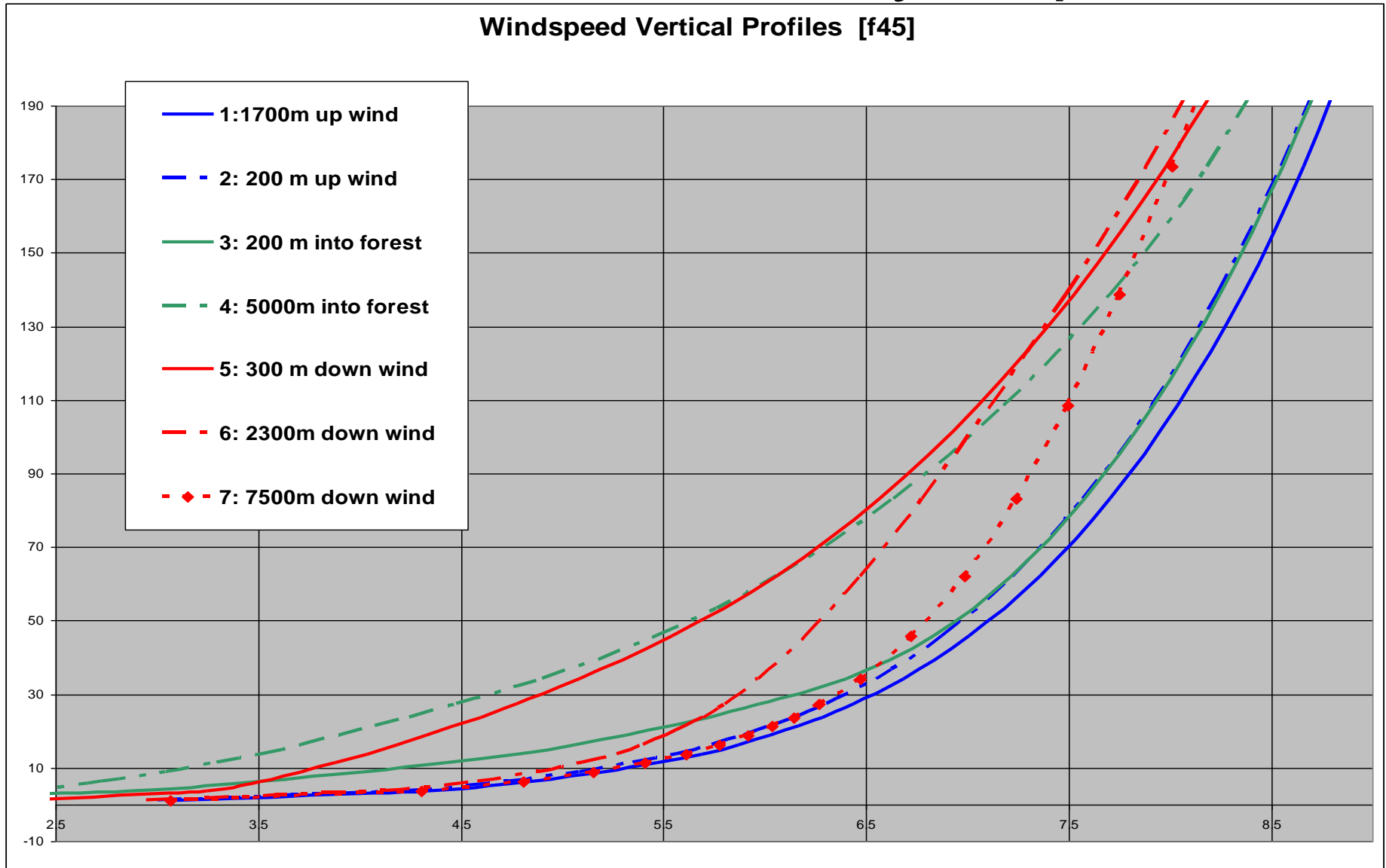
# Initial Setup continued...

- Total cells: 700,000
- 30 cells in z-direction
- Resolution:
  - Horizontal: 80 m
  - Vertical: 1.2 m at base (Height distribution factor 0.05)
- Forest: 10 cells in z-direction
- Top Boundary Condition: frictionless wall
- One sector 270 at 10 m/s

# Wind speed (f80) Height: 80 Meters



# Wind Profile at 7 analysis points



# Pre-Tests

- Solver/Convergence
  - Coupled: ca 500 iterations
  - Segregated: ca 6000 iterations
  - Similar results from Segregated and Coupled Solver
  - Similar time required
    - Segregated takes about 5 times more iterations than coupled, but every iteration is 5 times faster
  - Crashes in particular cases

Used coupled solver with 1000 iterations (ca 4.5hrs)
- Upper BC
  - wall or pressure?

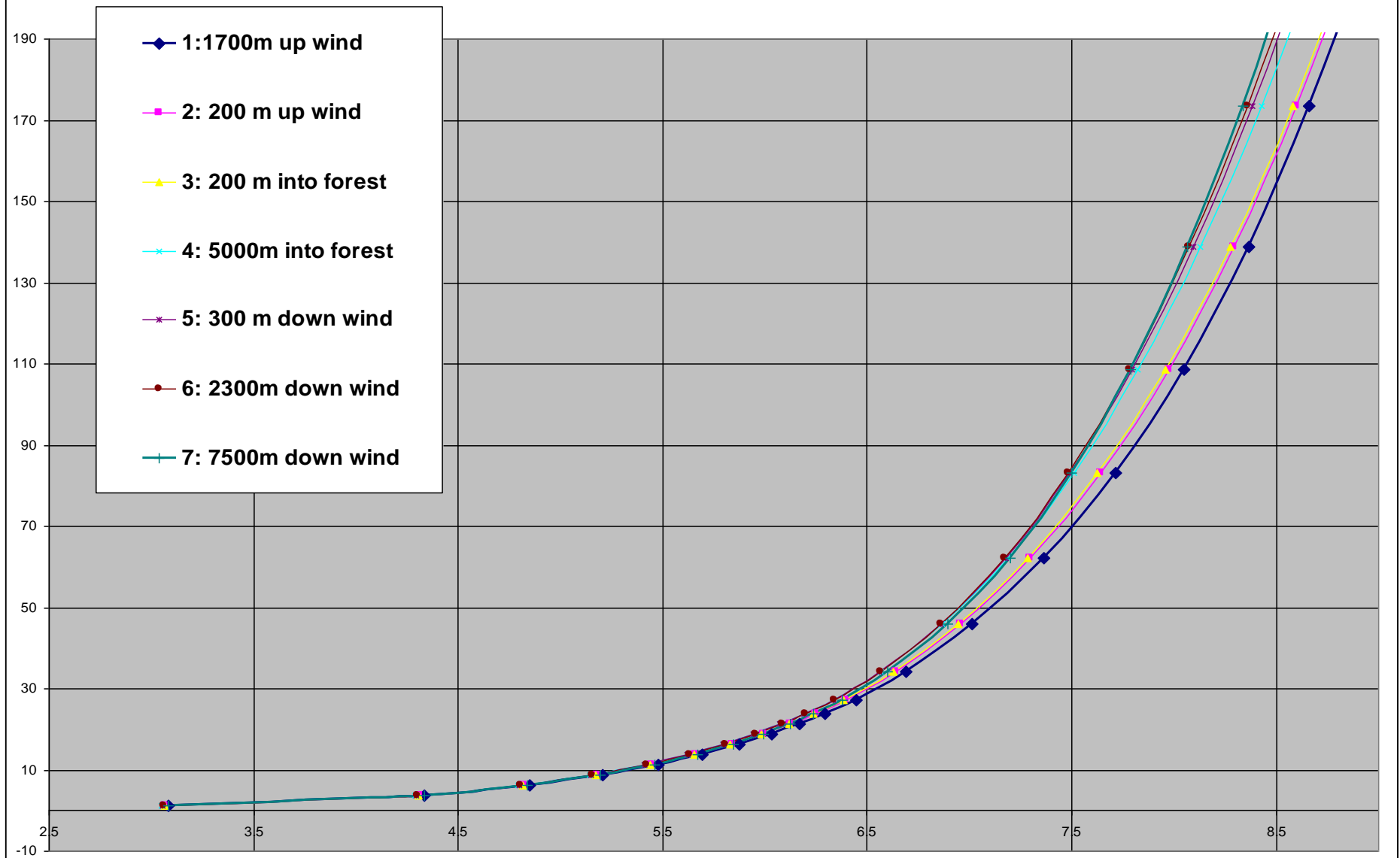
used wall to avoid “leakage”

# Encountered Problems

- Profile changes throughout the empty model (standard inlet profile needs to adapt itself)
- Diverging profiles (~3% deviation)
- Convergence problems with very long model
- **Some WindSim crashes** (apparently linked to forest height cell Heights or low Z-cell Numbers etc) Forest models appears to promote divergence – reduces stability)
- Are real world measurements comparable

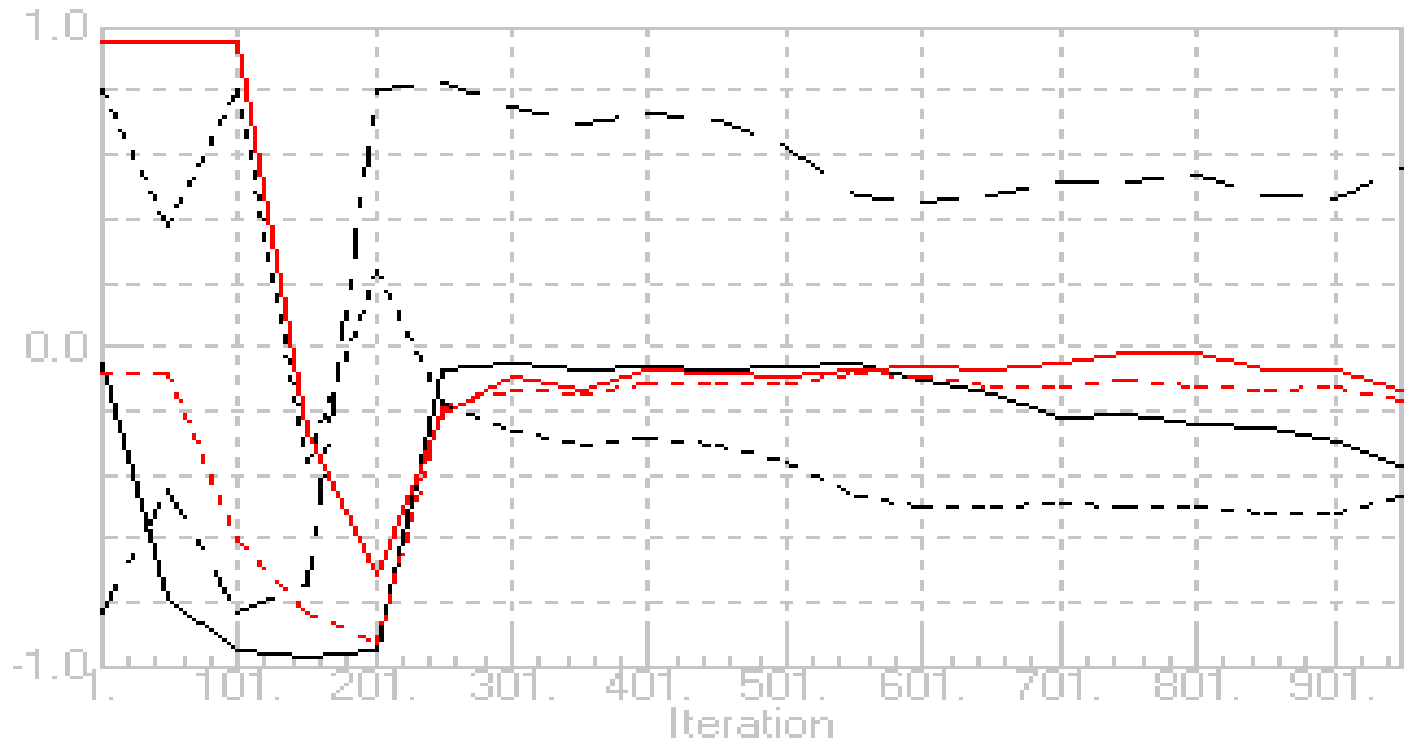
# Profile changes without forest

Windspeed over flat plate [f06a]

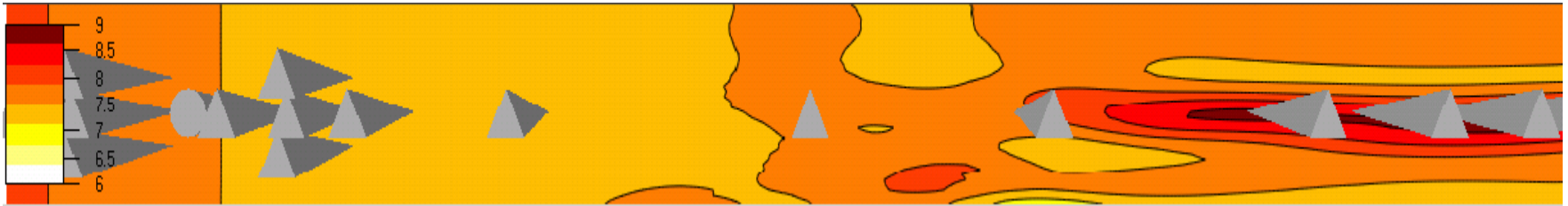


# Poor Convergence of long Model after 1000 iterations (f66)

**Residuals**



# Artefacts in Plain Terrain of a Long Model (f66)





# Questions

- Reason for diverging profiles
- Options for adjusting inflow conditions

Until these questions are answered  
uncertainties in model performance remain,  
limiting our potential for accurate results.

# Revised Aims

- Understand parameters
- Find plausible ranges

# Study Results

# The Model

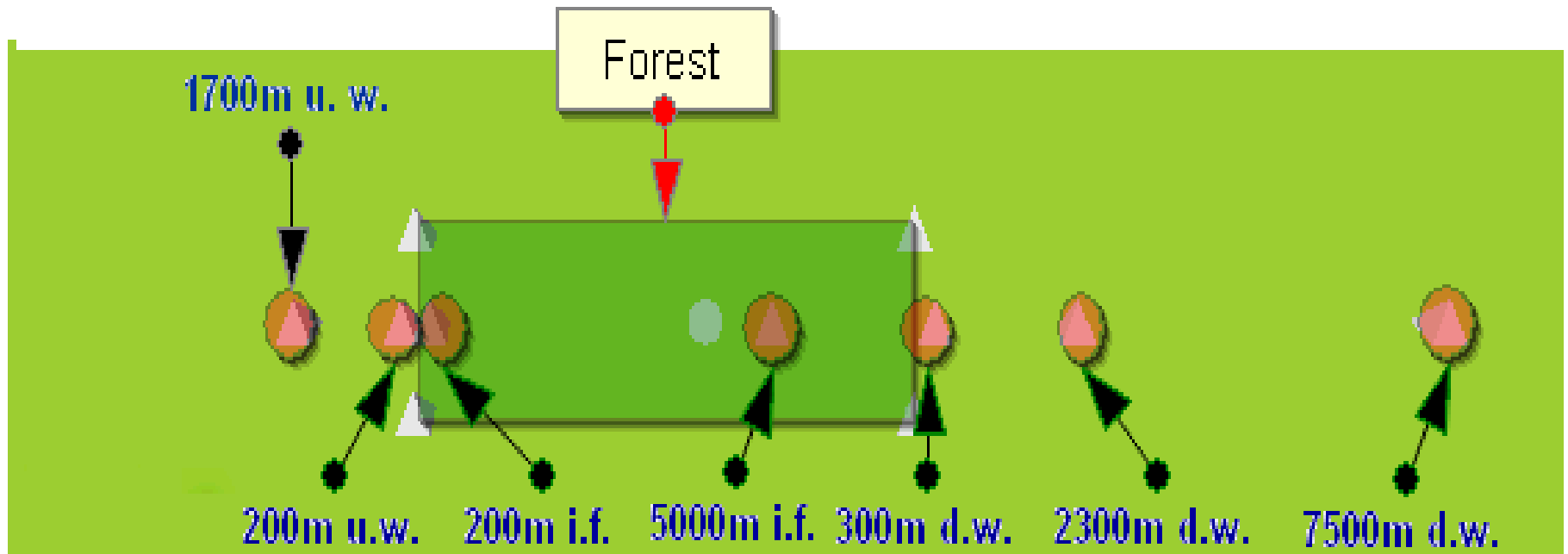
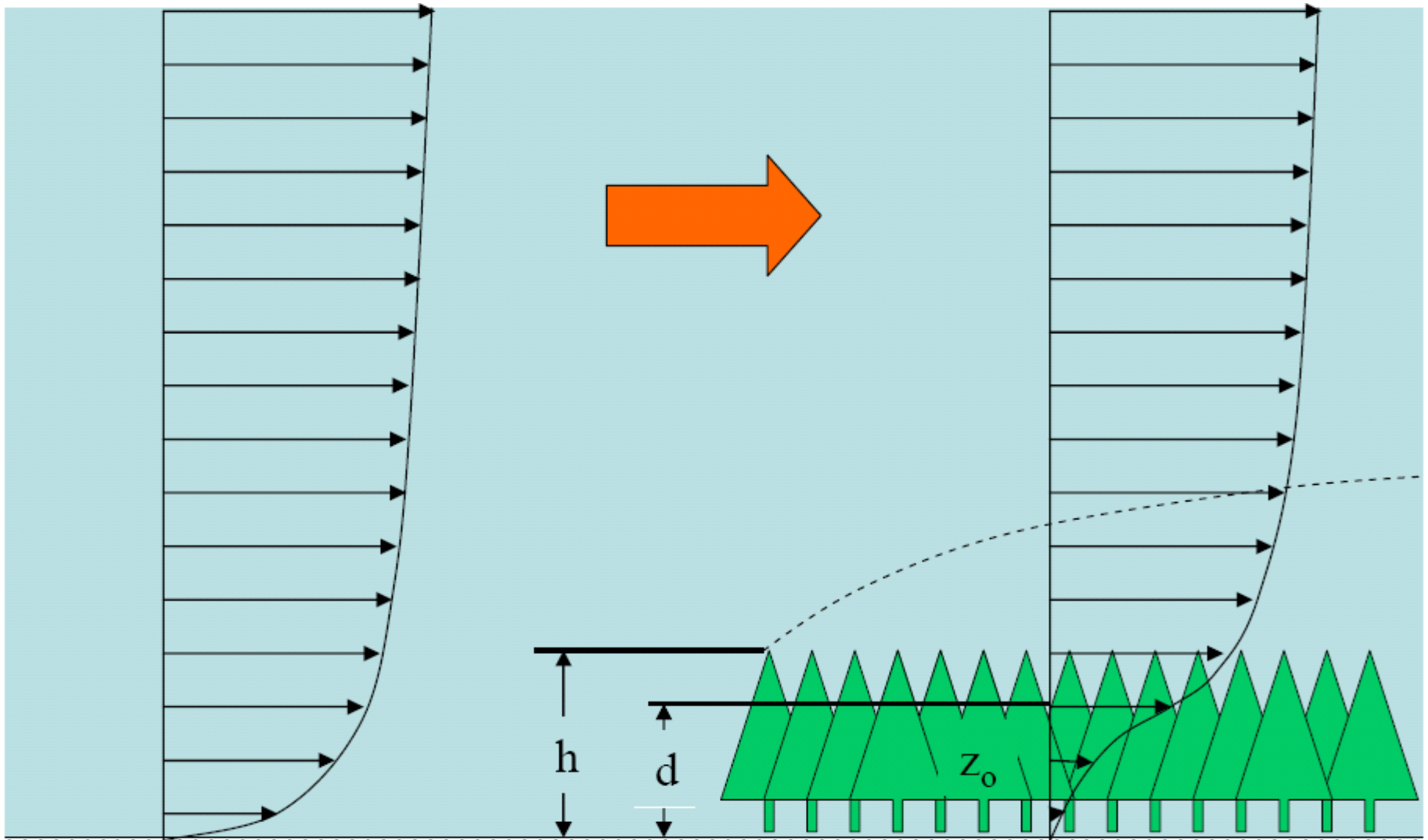


Fig 1. Digital terrain model with objects ▲ Wind turbine ● Climatology station

# What should it look like



from: "WASP Validation Study of Forestry Effects" by Peter Raftery, Marc LeBlanc and Joel Manning of Garrad Hassan

# What should profile look like?

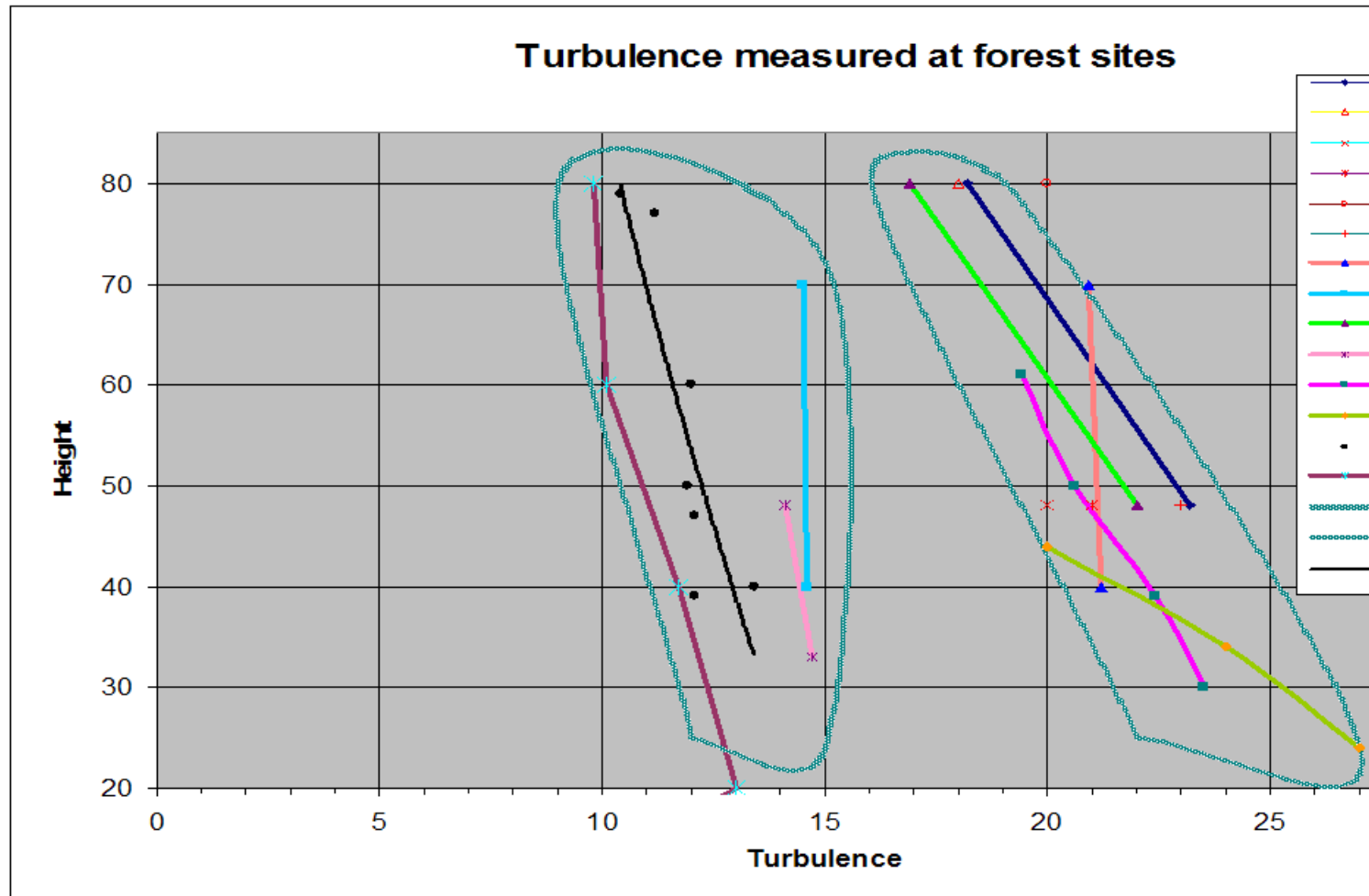
## WIND SPEED

- available real measurements
- change of profile in forest
- similar to roughness profile far behind forest

## TURBULENCE

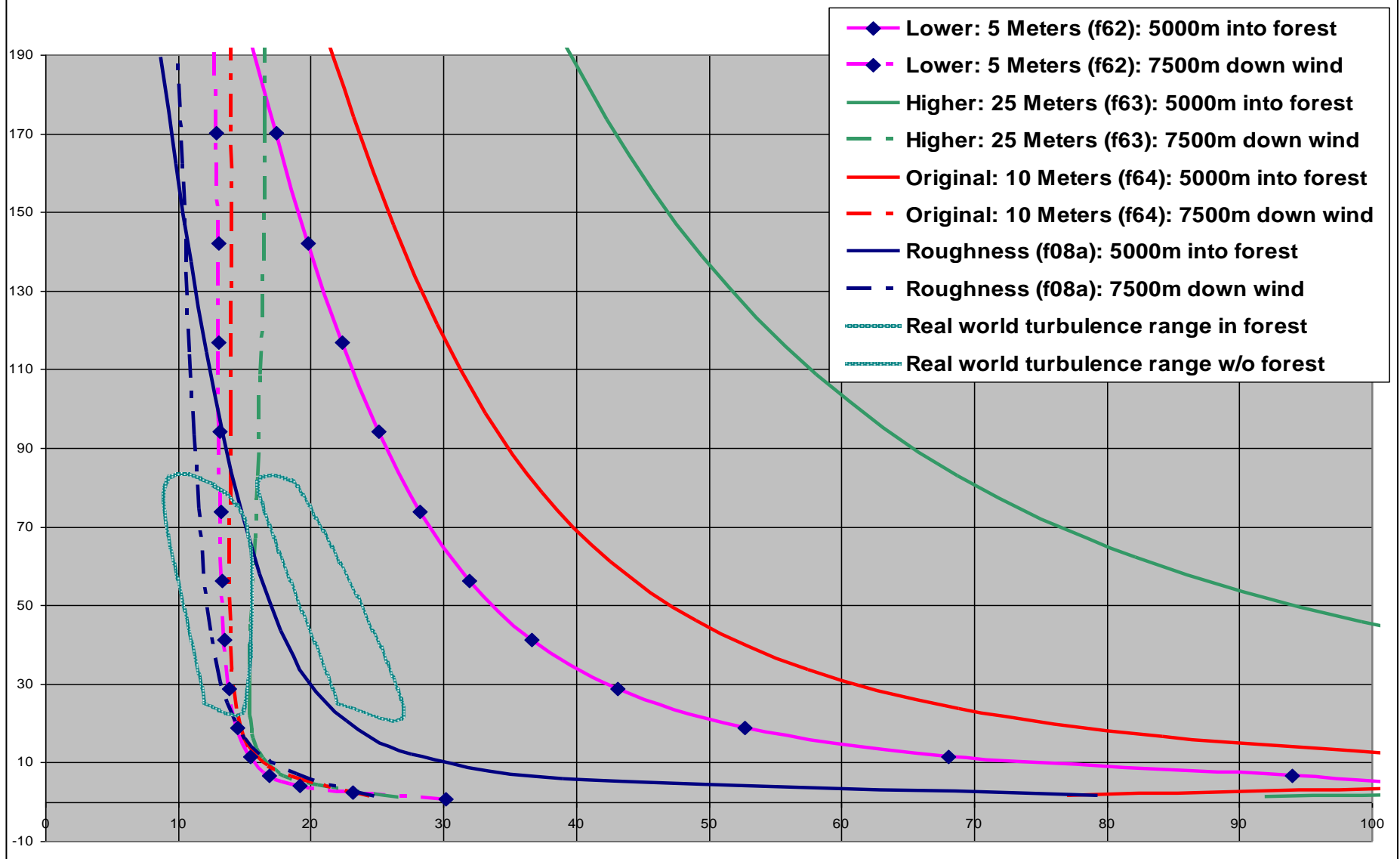
- real world measurements for (turbulence profiles)
- real measurements – typically don't go into canopy

# Turbulence assessment



# Default values: turbulence

Turbulence: Default Values (P=0.5 C1&C2=0.01 Z-Cells 3 to 10)



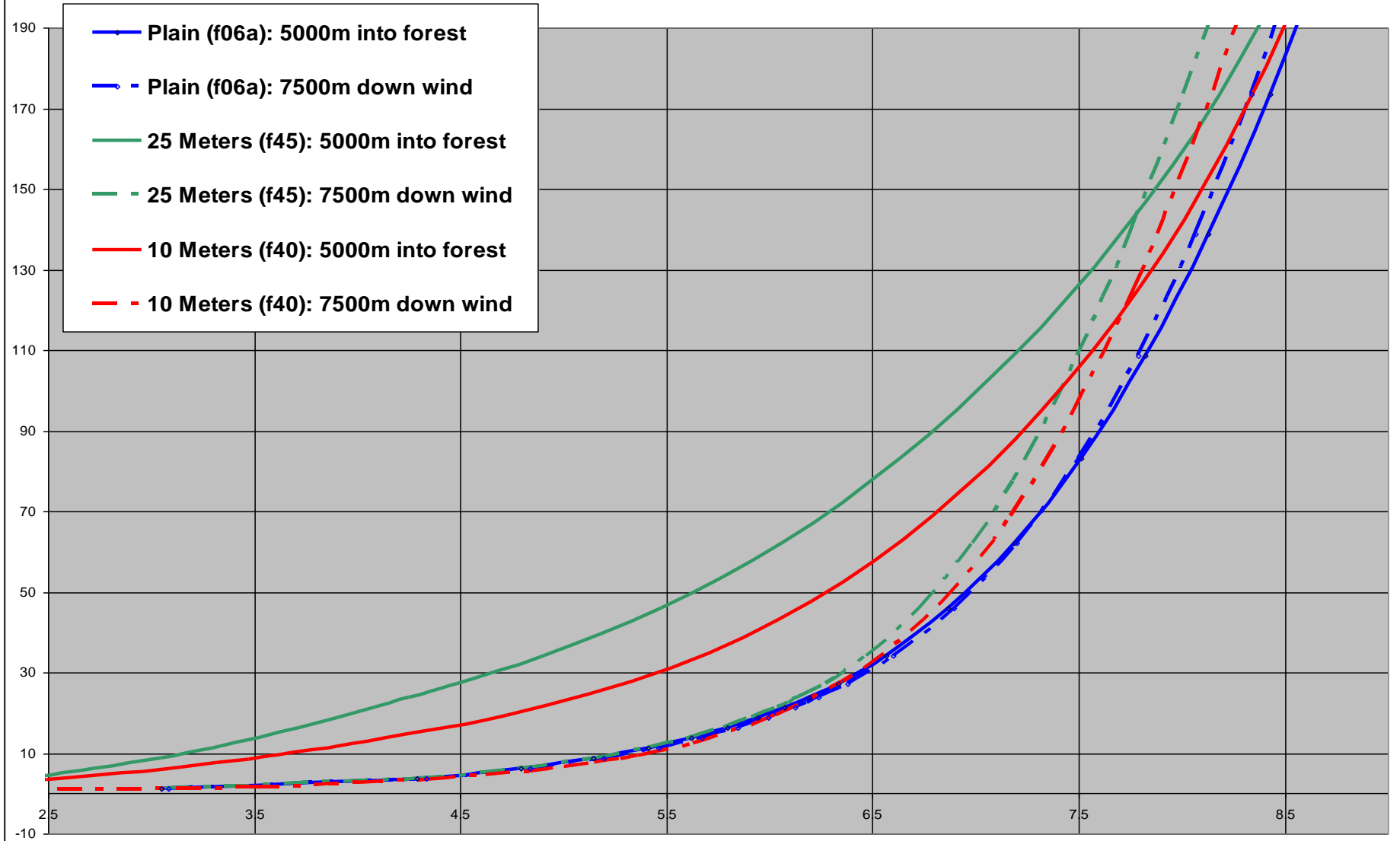
# Comparison Graphs

- Height (10m 25m)  $P=0.5$   $C2 = 0.0001$ 
  - Turbulence
  - Speed
- Porosity (0.25 0.5)  $H=25m$   $C2 = 0.0001$ 
  - Turbulence
  - Speed
- $C2$  (0.0001, 0.00025, 0.0005)  $P= 0.25$   $H=25m$ 
  - Turbulence
  - Speed
- $C2$  (0.0001, 0.00025, 0.0005)  $P= 0.5$   $H=25m$ 
  - Turbulence
  - Speed

$C1$  always 0.0001

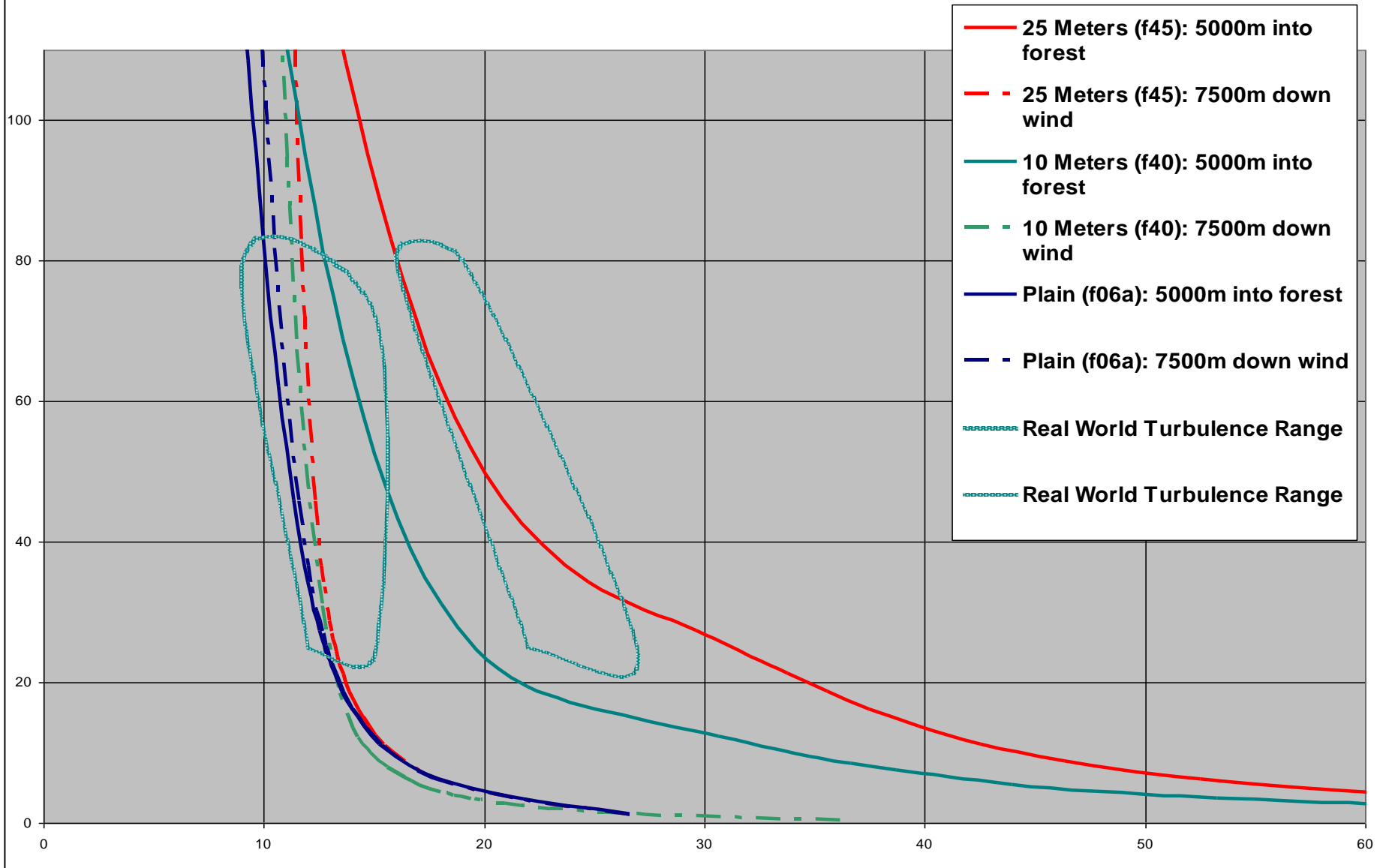
# Forest height change

Windspeed: 10 vs 25 Meters (  $p=0.5$   $C1\&c2=0.0001$  )



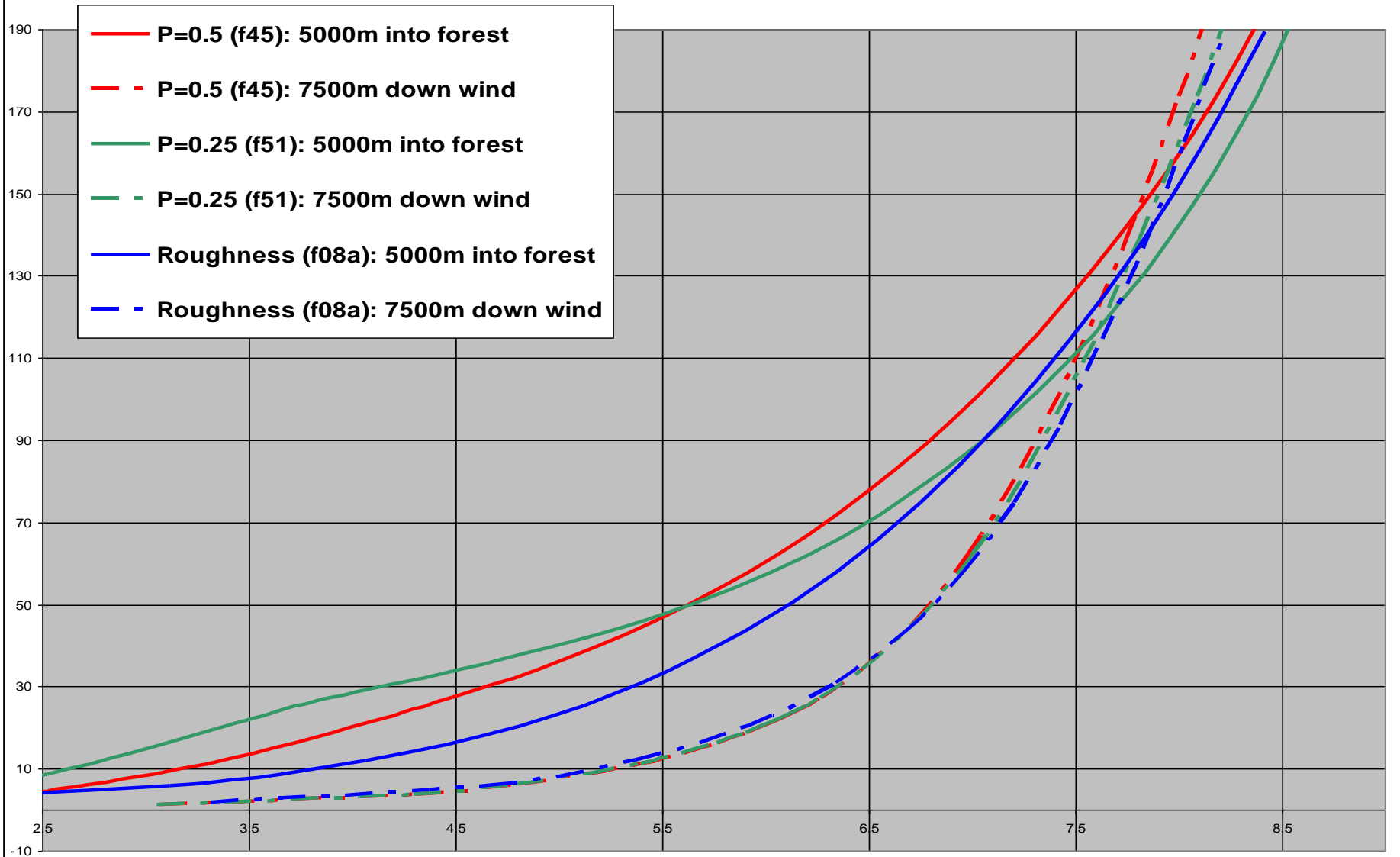
# Forest height change

Turbulence: 10 vs 25 Meters (  $p=0.5$   $C1\&c2=0.0001$  )



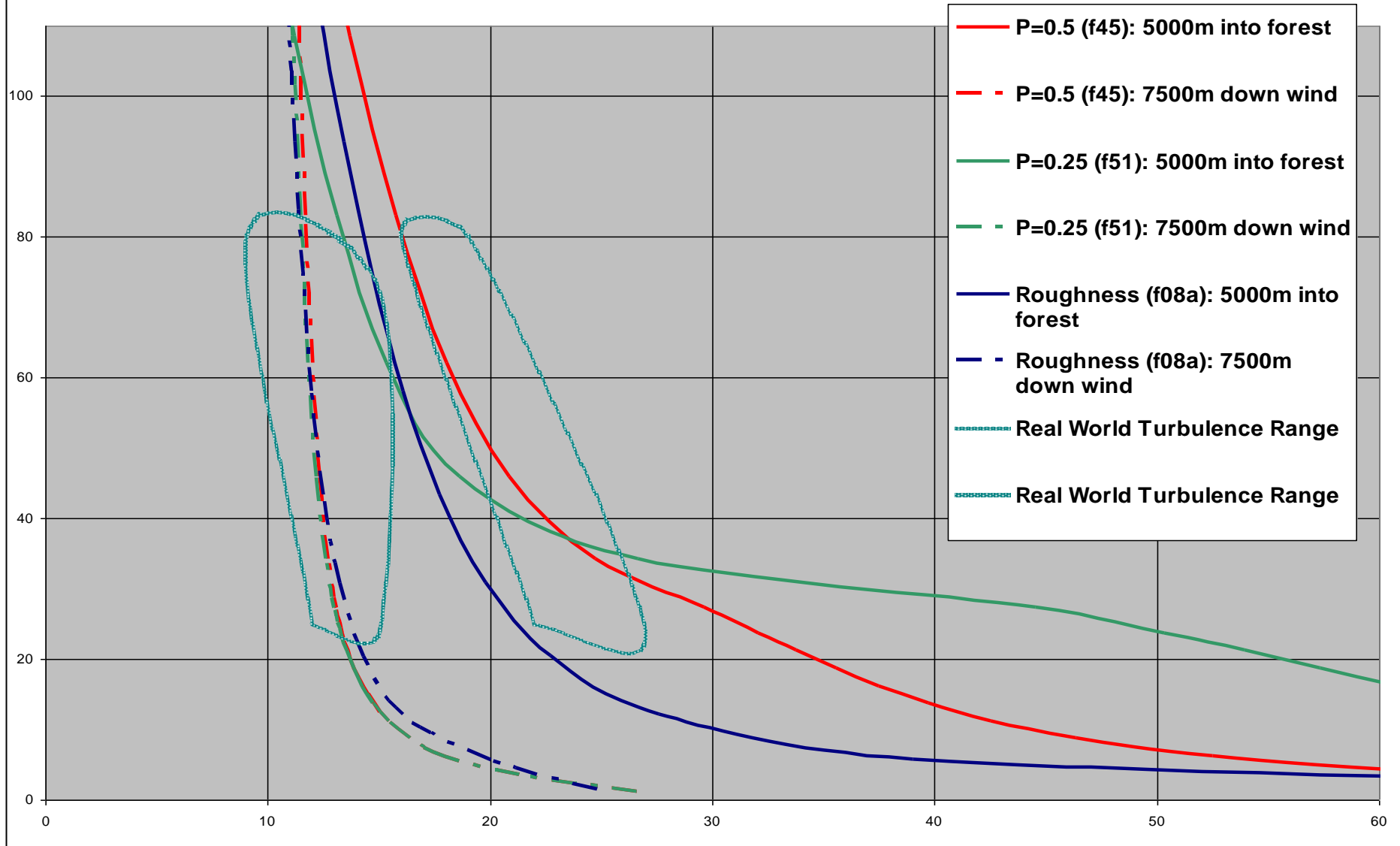
# Porosity changes

Windspeed: P=0.5 vs P=0.25 (25 Meters, c1&c2=0.0001 )



# Porosity changes

Turbulence: P=0.5 vs P=0.25 (25 Meters, c1&c2=0.0001 )

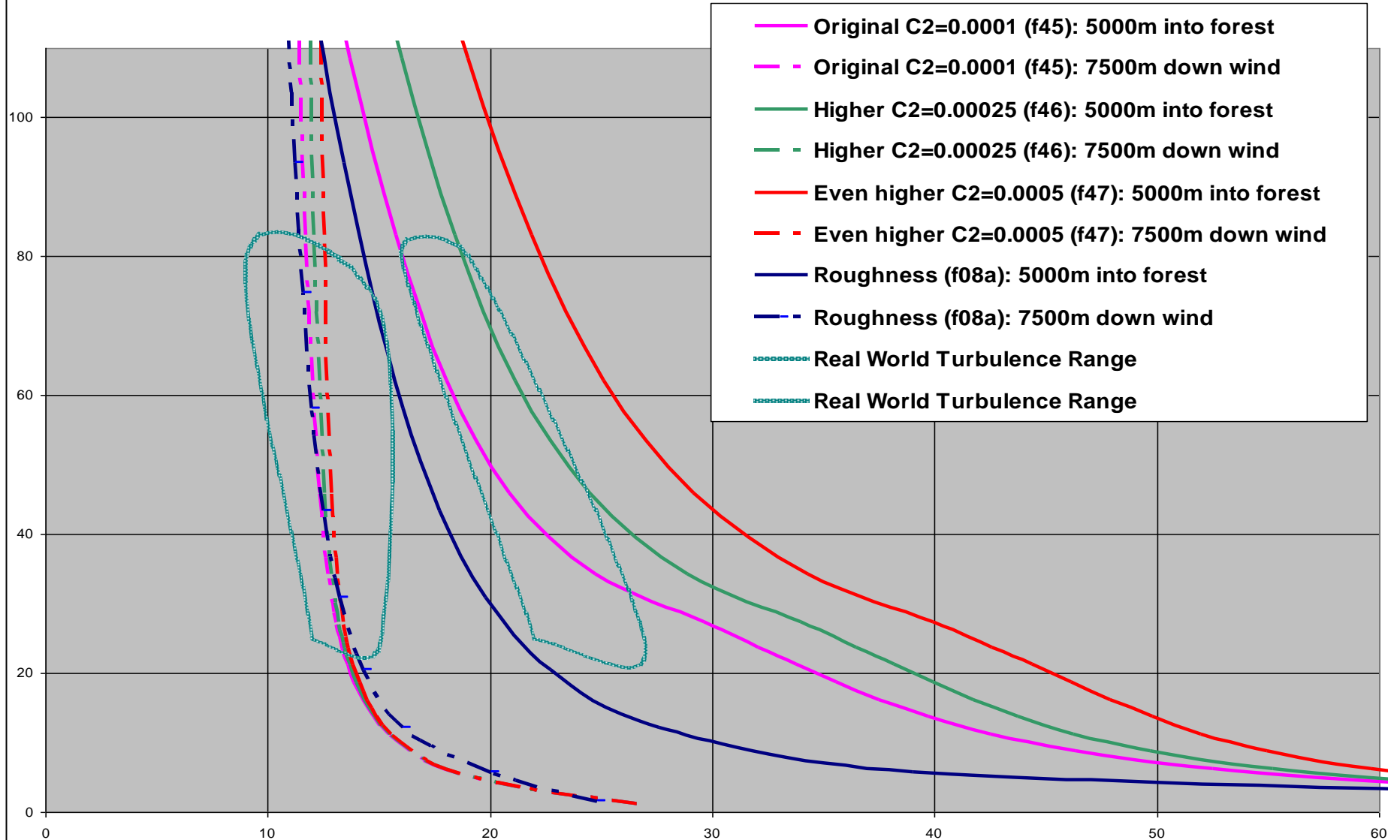






# C2 Changes at high porosity $P=0.5$

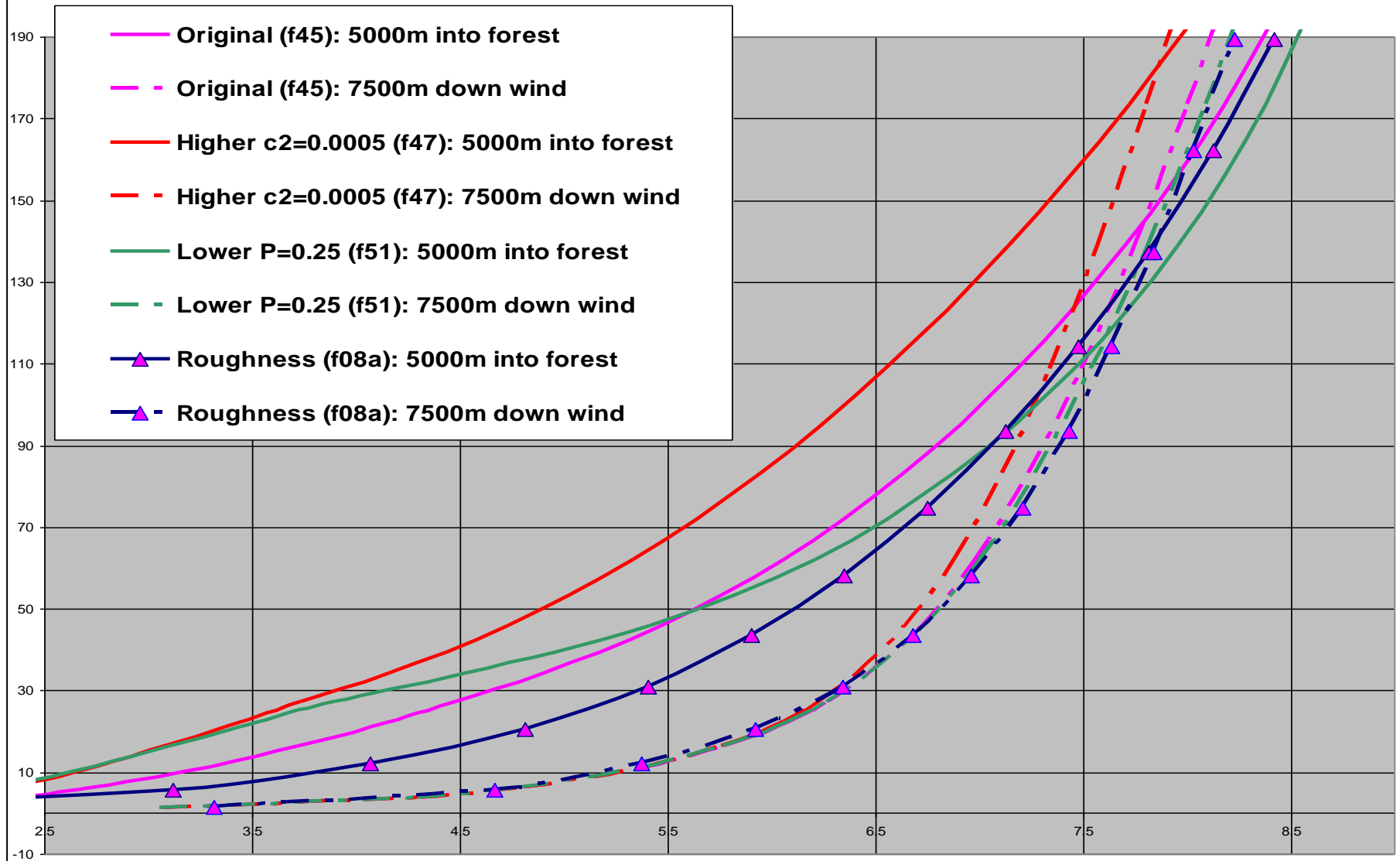
Turbulence:  $P=0.5$  ( $C1=0.0001$  Height: 25 Meters)





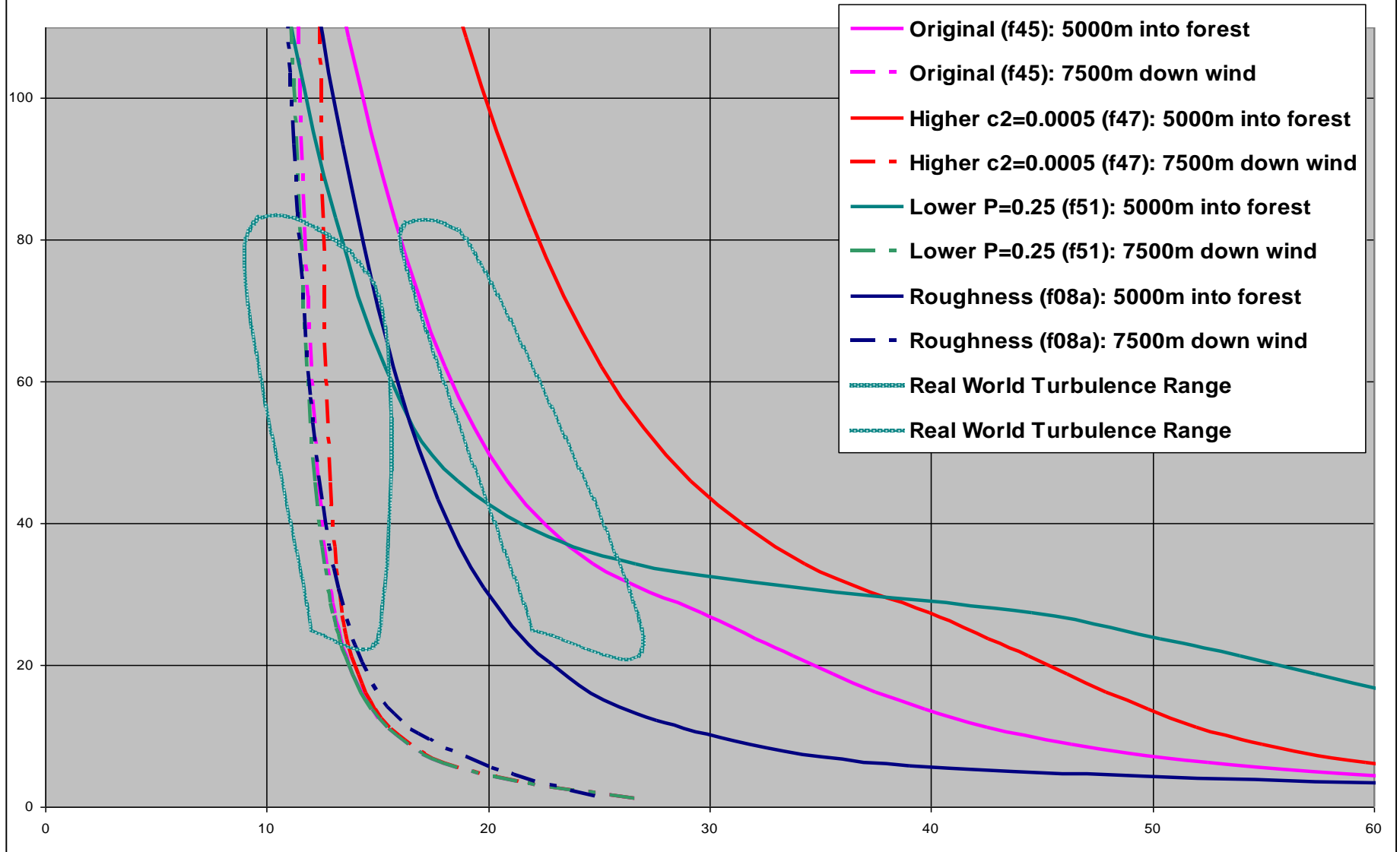
# Summary Porosity vs. C2 Changes

Wind speed: ( $p=0.5$ ,  $c_1$  &  $c_2=0.0001$  height: 25 Meters)



# Summary Porosity vs. C2 Changes

Turbulence: ( $p=0.5$ ,  $c_1$  &  $c_2=0.0001$  height: 25 Meters)



# Summary: Parameter Ranges

- C1 and C2 have similar effects
- C2 ~ 0.0001 to 0.001
- P ~ 0.25 to 0.5

for 25m forest and C1= 0.0001

# Next Steps

# Next steps

- Answer flow model questions...
- Further refinement of parameters...
  - Comparison to normalised wind speeds
  - Just behind forest (100m to 3 km)
  - Simple real forest cases in simple terrain
  - Extend forest database
  - Refine forest database for different conditions
  - ... study forest in complex terrain
- Additional measurements

Thank You

# Suggestions

Increase flexibility: allow vertical profiles based on any number of available sector results

Allow yield calculation based on combinations of sector sizes eg 10° and 30°

Terrain: Rectangle Selections with the mouse (Extension/Refinement/etc) show coordinates on Mouseover

Option of showing Objects or their coordinates in Terrain view eg for extension area selection

Better support for parallel Windsim calculations (conflicting angle lists)

# General Questions

- Reason for diverging profiles
- Options for adjusting inflow conditions
- Coupled solver crashes with large models  
~6mio cells
- How to use residuals or spot values as convergence criteria
- Nearest vs best modelled mast....