Atmospheric stability and complex terrain - Comparing measurements and CFD

Koblitz, Tilman; Bechmann, Andreas; Berg, Jacob; Sogachev, Andrey; Sørensen, Niels N.; Réthoré, Pierre-Elouan

Publication date: 2012

Citation (APA):
Koblitz, T., Bechmann, A., Berg, J., Sogachev, A., Sørensen, N. N., & Réthoré, P.-E. (2012). Atmospheric stability and complex terrain - Comparing measurements and CFD. Sound/Visual production (digital) http://www.forwind.de/makingtorque
Atmospheric stability and complex terrain
Comparing measurements and CFD

T. Koblitz
A. Bechmann
J. Berg
A. Sogachev
N. N. Sørensen
P.-E. Réthoré

DTU Wind Energy
Department of Wind Energy
Atmospheric stability

Chimney plume under stable and unstable conditions

stable

unstable

Source: *kindly been provided by Dr. Torben Mikkelsen, Risø DTU and Dr. Thomas Ellermann, National Environmental Research Institute*
Atmospheric stability

Why: Influence on the wind field

Flat terrain

Source: Kaimal and Finnigan 1994, Wallace and Hobbs 2006
Atmospheric stability

Why: Influence on the wind field

Complex terrain

stable
neutral
unstable
The Benakanahalli experiment

Stratification and Complex Terrain
The Benakanahalli experiment

Location and instrumentation
The Benakanahalli experiment

Location and instrumentation
The Benakanahalli experiment

Wind climate

Wind rose at M0

8

10 October 2012
Benchmark dataset

Selected data: 3 days in February 2010
Benchmark dataset

Averaged data and model forcing

![Graph showing wind speed and temperature over time with markers and error bars.](image)
Simulating Benakanahalli
Modeling atmospheric stability in CFD

\[ \frac{\delta}{\delta t} (\rho k) + \frac{\delta}{\delta x_j} (\rho U_j k) = \frac{\delta}{\delta x_j} \left[ \left( \mu + \frac{\mu_T}{\sigma_k} \right) \frac{\delta k}{\delta x_j} \right] + P - \rho \varepsilon + G \]

\[ \frac{\delta}{\delta t} (\rho \varepsilon) + \frac{\delta}{\delta x_j} (\rho U_j \varepsilon) = \frac{\delta}{\delta x_j} \left[ \left( \mu + \frac{\mu_T}{\sigma_\varepsilon} \right) \frac{\delta \varepsilon}{\delta x_j} \right] + C_{\varepsilon 1} \frac{\varepsilon}{k} P - C_{\varepsilon 2} \frac{\varepsilon^2}{k} \]

\[ \frac{\delta}{\delta t} (\rho \theta) + \frac{\delta}{\delta x_j} (\rho U_j \theta) = \frac{\delta}{\delta x_j} \left[ \left( \frac{\lambda}{C_p} + \frac{\mu_T}{C\sigma_\theta} \right) \frac{\delta \theta}{\delta x_j} \right] \]

\[ F_{C,i} = f_c u_j m \quad f_c = 2\Omega \sin \lambda \]
Simulating Benakanahalli

Precursor simulation vs. Measurements at M0
Simulating Benakanahalli

Precursor simulation vs. Measurements at M0

Stability classes based on Monin-Obukhov length
Simulating Benakanahalli

Computational mesh and boundary conditions
Simulating Benakanahalli
Wind speed and direction: comparison of modeled and observed data

![Graphs comparing wind speed and direction](image-url)
Simulating Benakanahalli

Contour map of terrain

Wind rose

Wind direction in 20m

Geostrophic wind
stable
unstable
stable (flat terrain)
unstable (flat terrain)
Simulating Benakanahalli

Contour map of terrain

Wind rose

Wind direction in 20m

Geostrophic wind
stable
unstable
stable (flat terrain)
unstable (flat terrain)
unstable (Fr < -0.15)
neutral
stable (Fr > -0.15)
Simulating Benakanahalli
Unstable conditions: wind field at 12 p.m.
Simulating Benakanahalli

Stable conditions: wind field at 1 a.m.
Conclusions & Future work

Conclusions:

• Stability effects and Coriolis force implemented in EllipSys3D
• Methodology is generally applicable
• Improvement in predicting the airflow over Benakanahalli during non-neutral conditions

Future work:

• Get more information about boundary and initial conditions
• Mesoscale simulations to provide information on large scales
• Generate roughness map to replace uniform roughness
• Different parameterizations in turbulence model
Simulating Benakanahalli

Terrain effects on M0

Elevation profile upstream of M0