

## 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

[Link back to DTU Orbit](#)

*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)]. The science of Making Torque from Wind 2012, Oldenburg, Germany, 09/10/2012, <http://www.forwind.de/makingtorque>

## DTU Library

Technical Information Center of Denmark

---

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

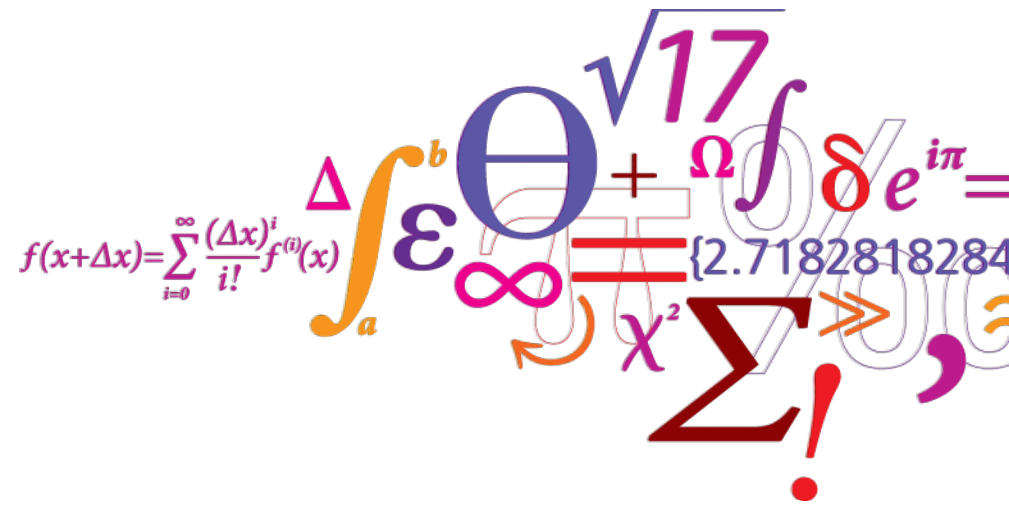
- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

# Atmospheric stability and complex terrain

Comparing measurements and CFD

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



# Atmospheric stability

Chimney plume under stable and unstable conditions

**stable**

**unstable**

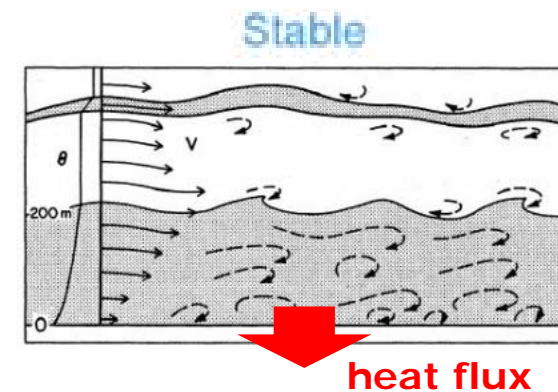
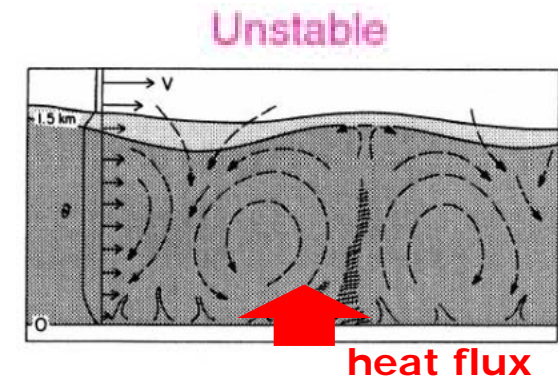
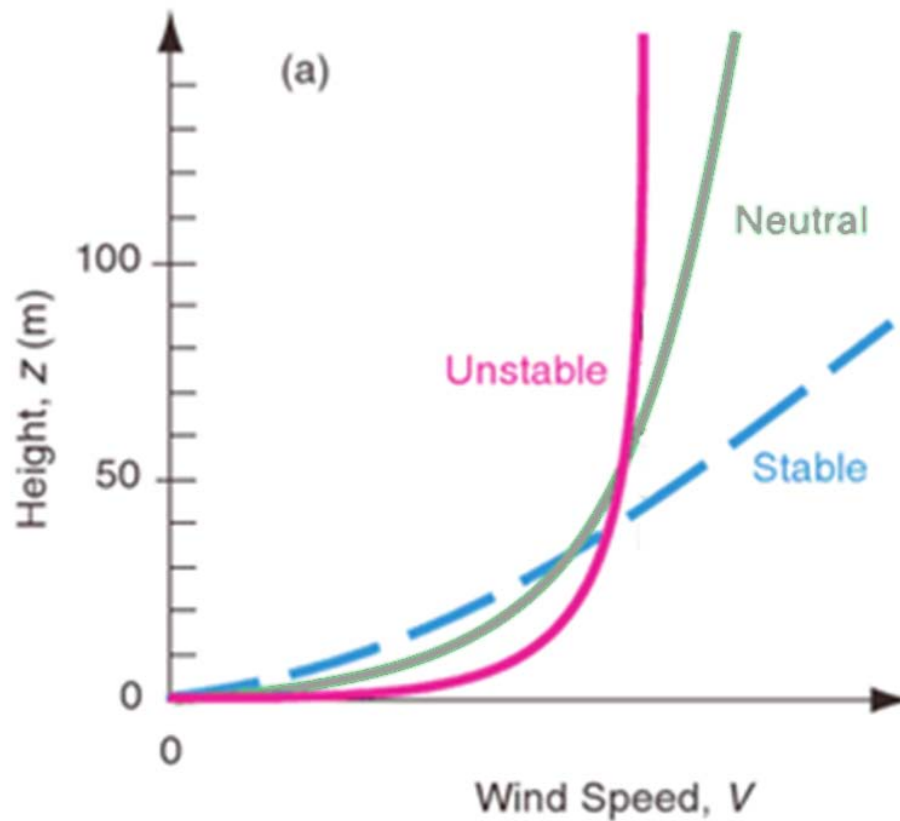


*Source: kindly been provided by  
Dr. Torben Mikkelsen, Risø DTU and  
Dr. Thomas Ellermann,  
National Environmental Research Institute*

# Atmospheric stability

Why: Influence on the wind field

Flat terrain

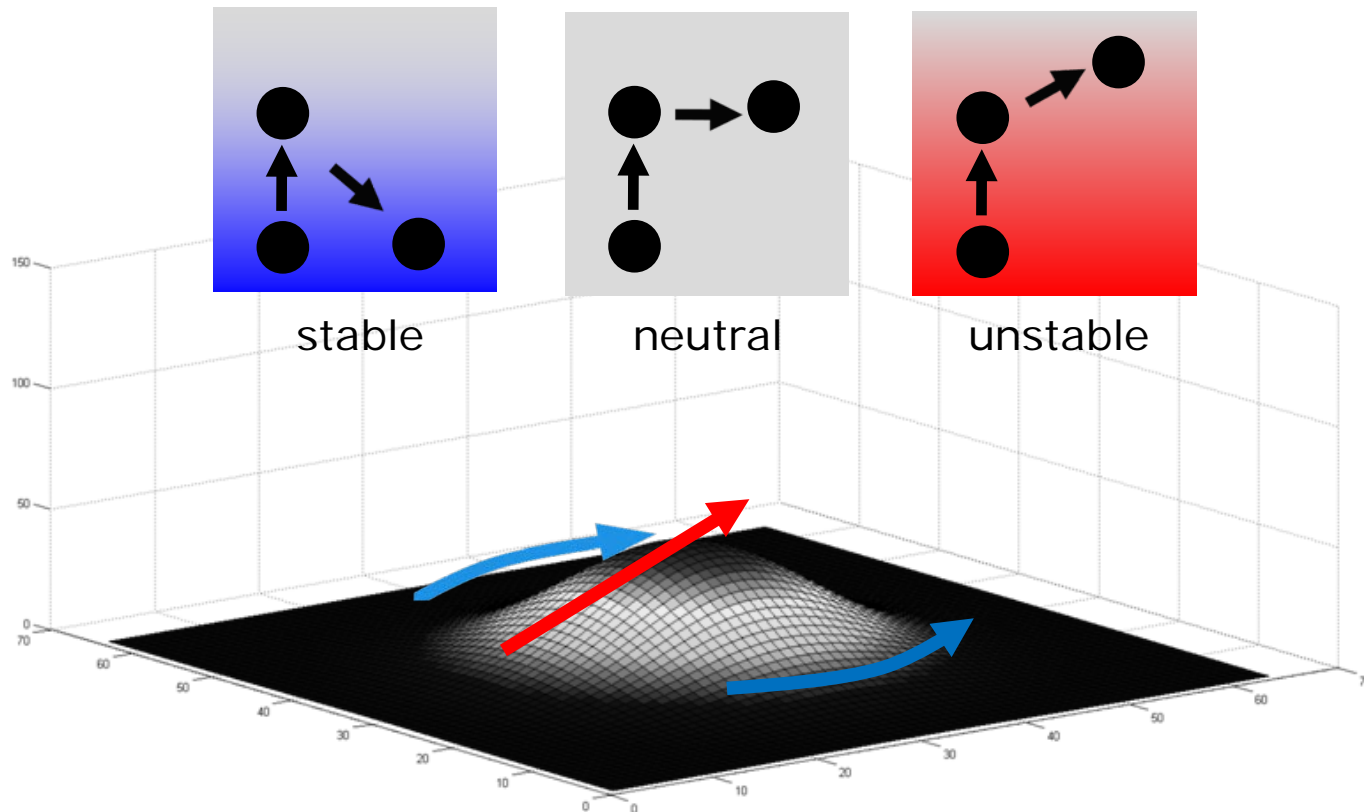


Source: Kaimal and Finnigan 1994, Wallace and Hobbs 2006

# Atmospheric stability

Why: Influence on the wind field

## Complex terrain



# The Benakanahalli experiment

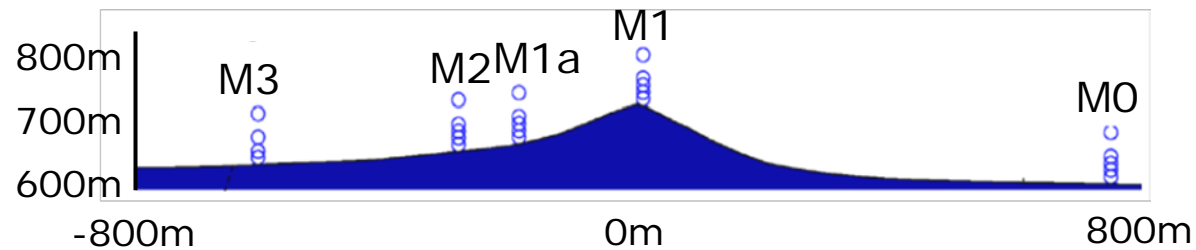
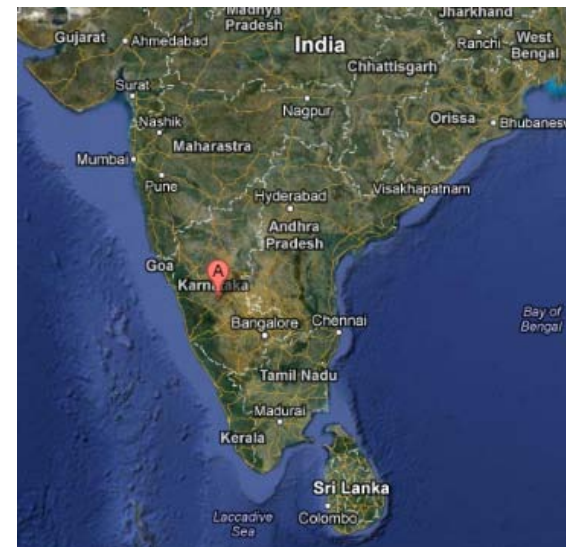
Stratification and Complex Terrain





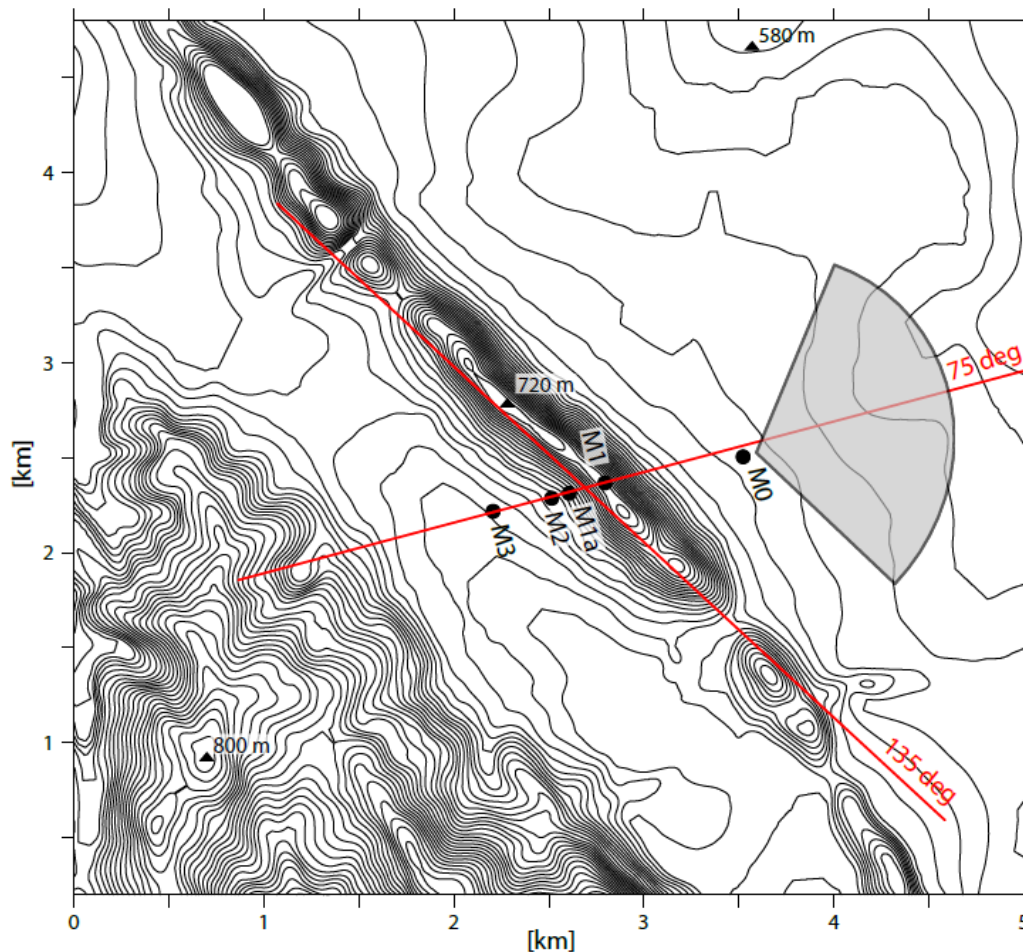
# The Benakanahalli experiment

Location and instrumentation



# The Benakanahalli experiment

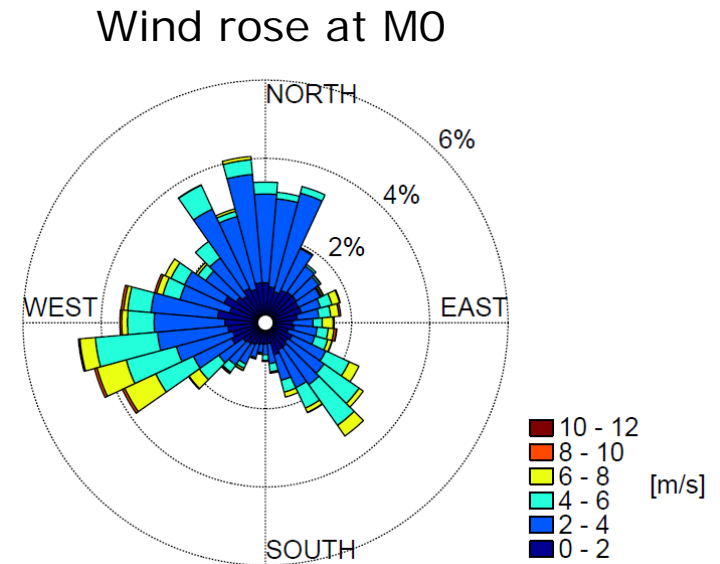
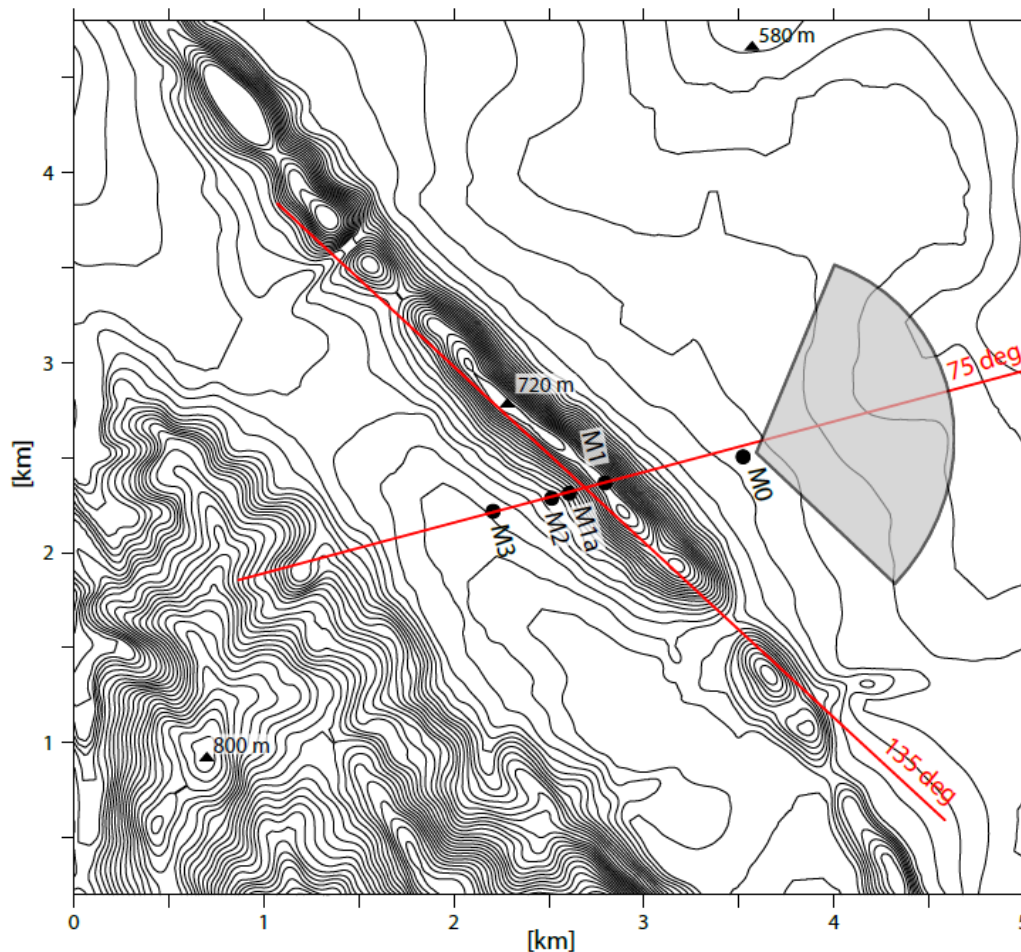
## Location and instrumentation





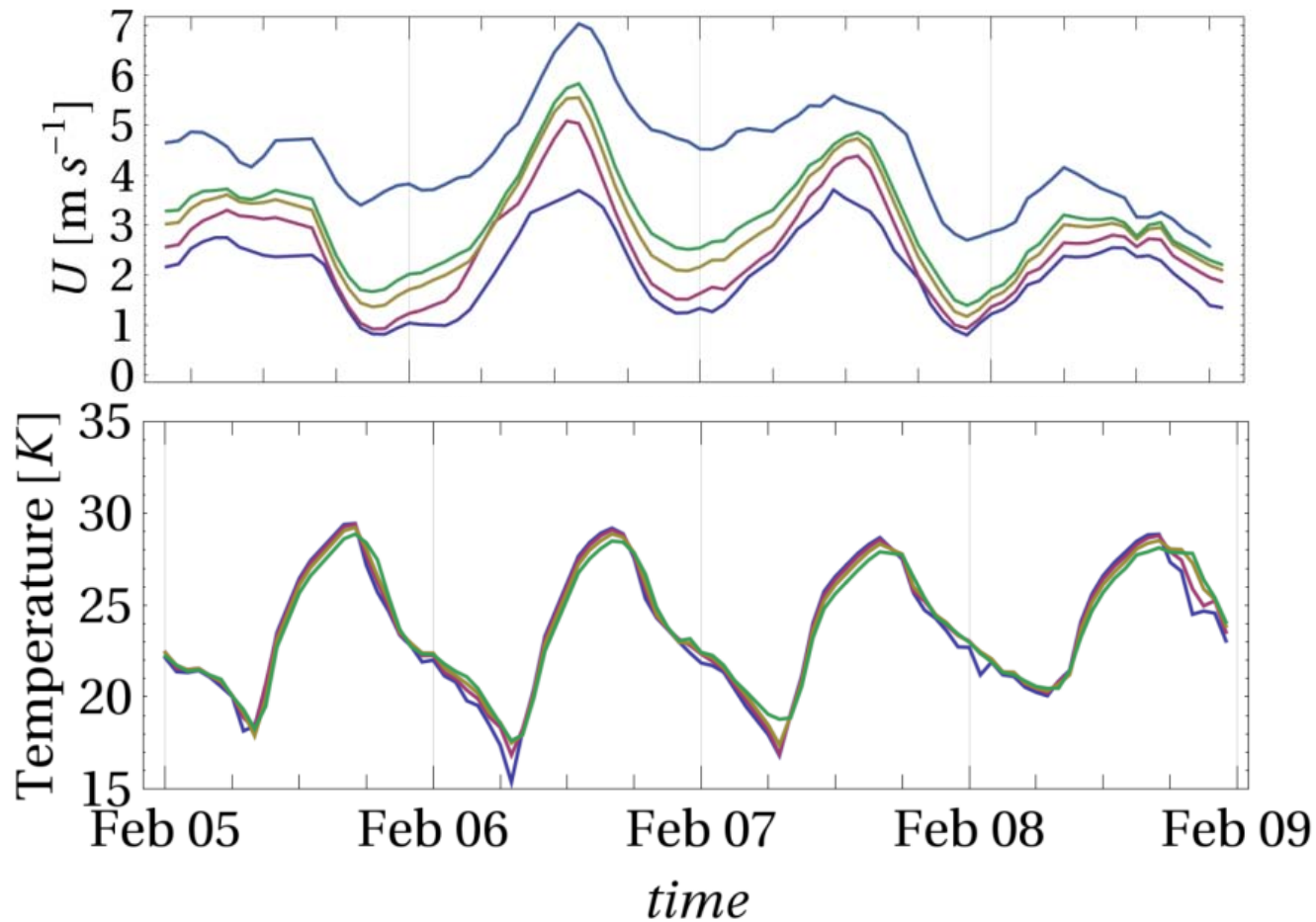
# The Benakanahalli experiment

## Wind climate



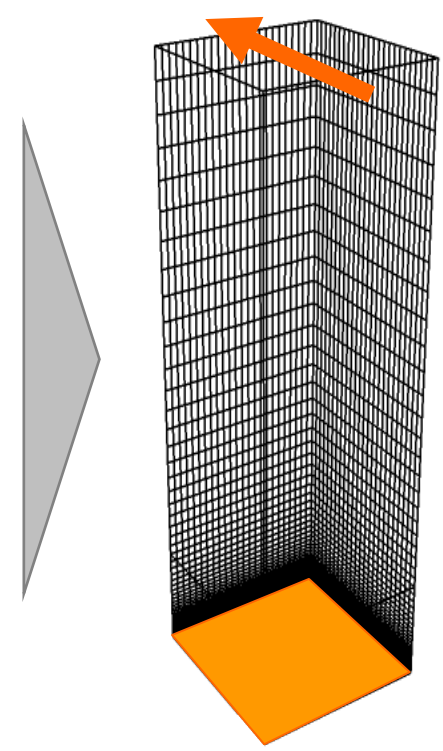
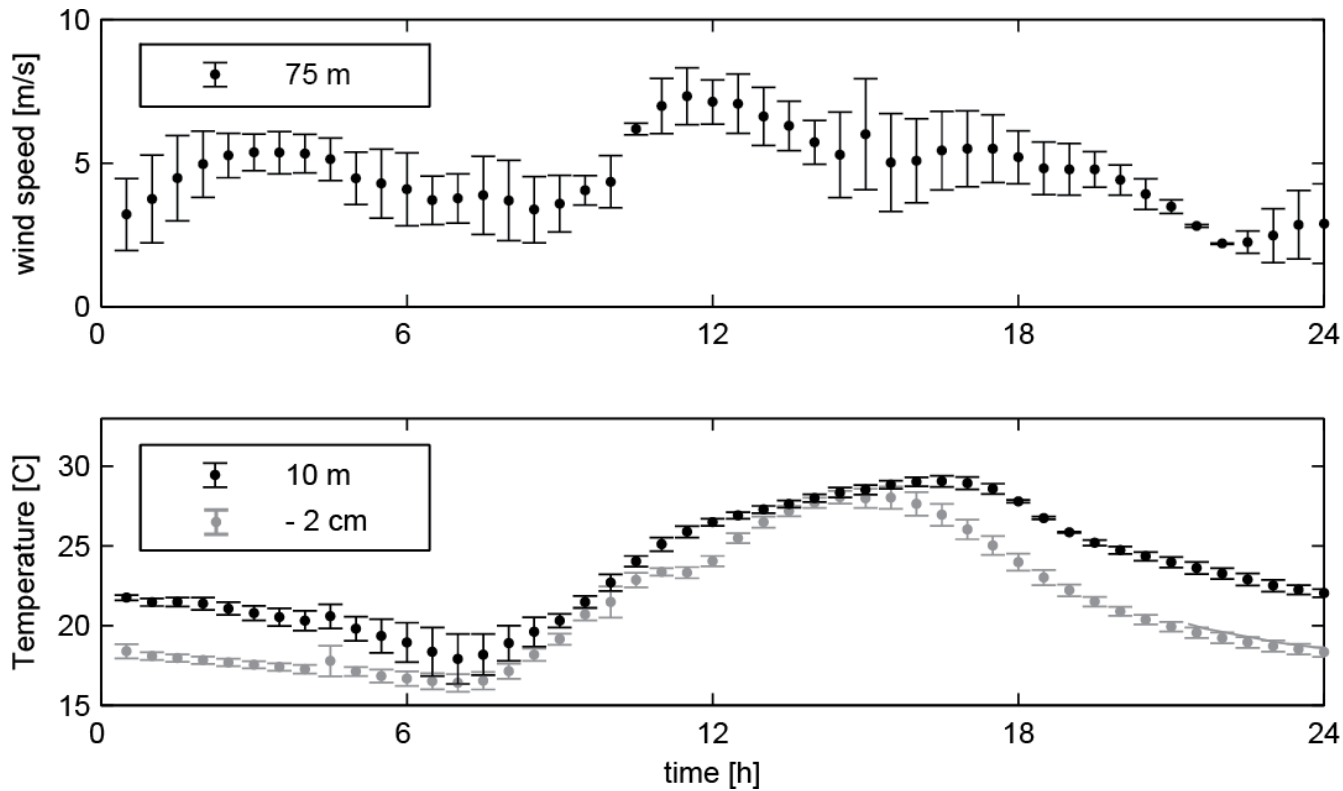
# Benchmark dataset

Selected data: 3 days in February 2010



# Benchmark dataset

Averaged data and model forcing



# Simulating Benakanahalli

Modeling atmospheric stability in CFD

**k-e turbulence model:**

RANS equations

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

$$\frac{\delta}{\delta t}(\rho \varepsilon) + \frac{\delta}{\delta x_j}(\rho U_j \varepsilon) = \frac{\delta}{\delta x_j} \left[ \left( \mu + \frac{\mu_T}{\sigma_\varepsilon} \right) \frac{\delta \varepsilon}{\delta x_j} \right] + C_{\varepsilon 1} \frac{\varepsilon}{k} P - C_{\varepsilon 2} \rho \frac{\varepsilon^2}{k} + C_{\varepsilon 3} \frac{\varepsilon}{k} G$$

Energy equation

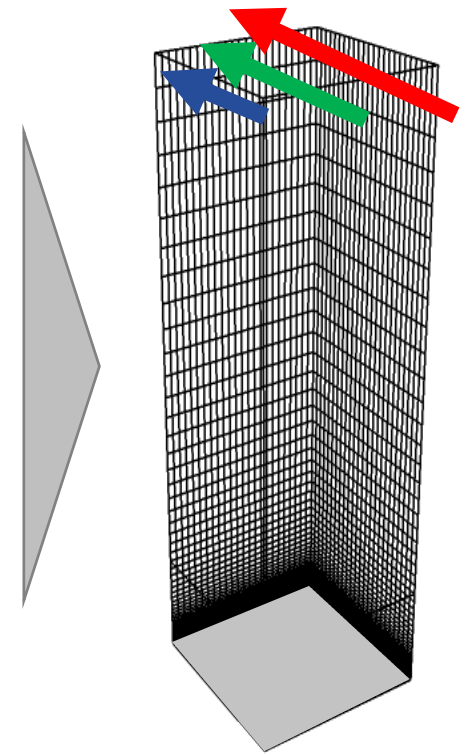
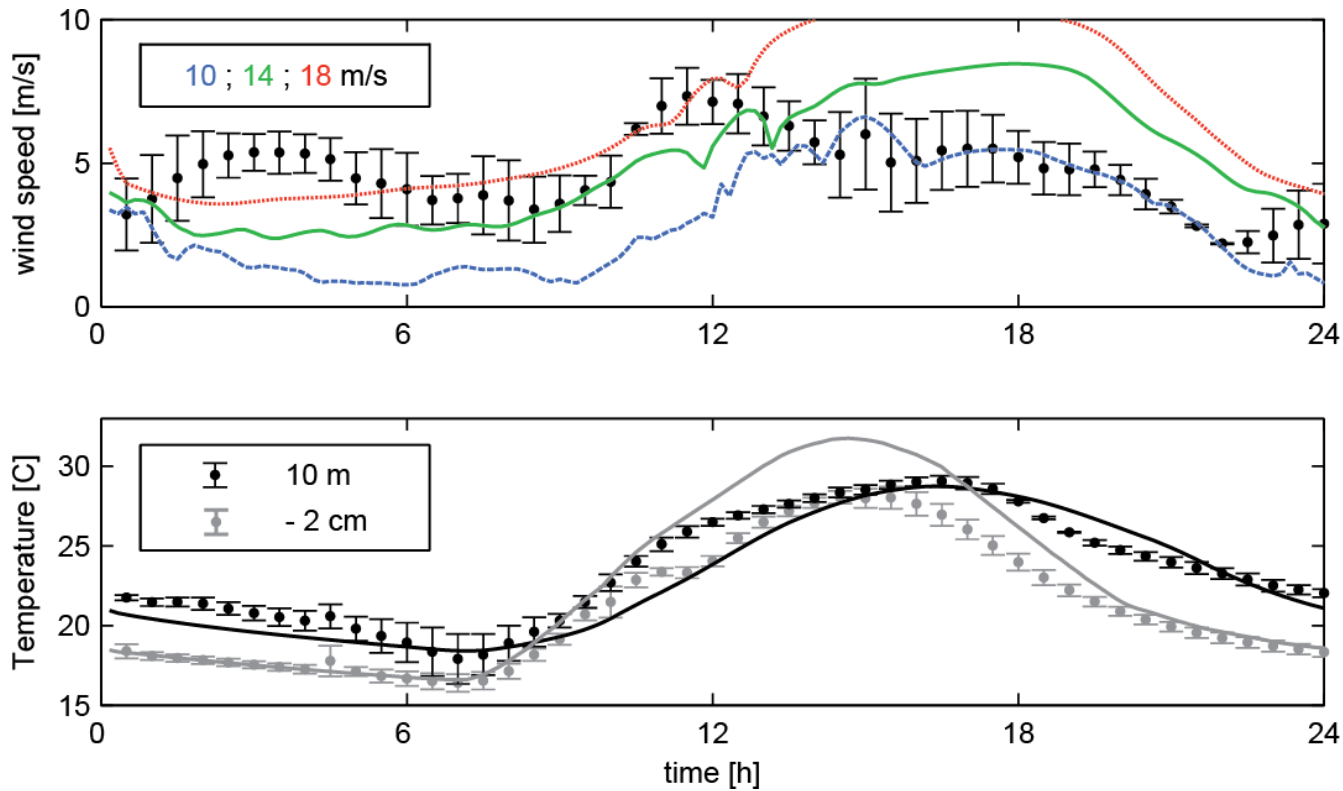
$$\frac{\delta}{\delta t}(\rho \theta) + \frac{\delta}{\delta x_j}(\rho U_j \theta) = \frac{\delta}{\delta x_j} \left[ \left( \frac{\lambda}{C_p} + \frac{\mu_T}{\sigma_\theta} \right) \frac{\delta \theta}{\delta x_j} \right]$$

Coriolis forcing

$$F_{C,i} = f_c u_j m, f_c = 2\Omega \sin \lambda$$

# Simulating Benakanahalli

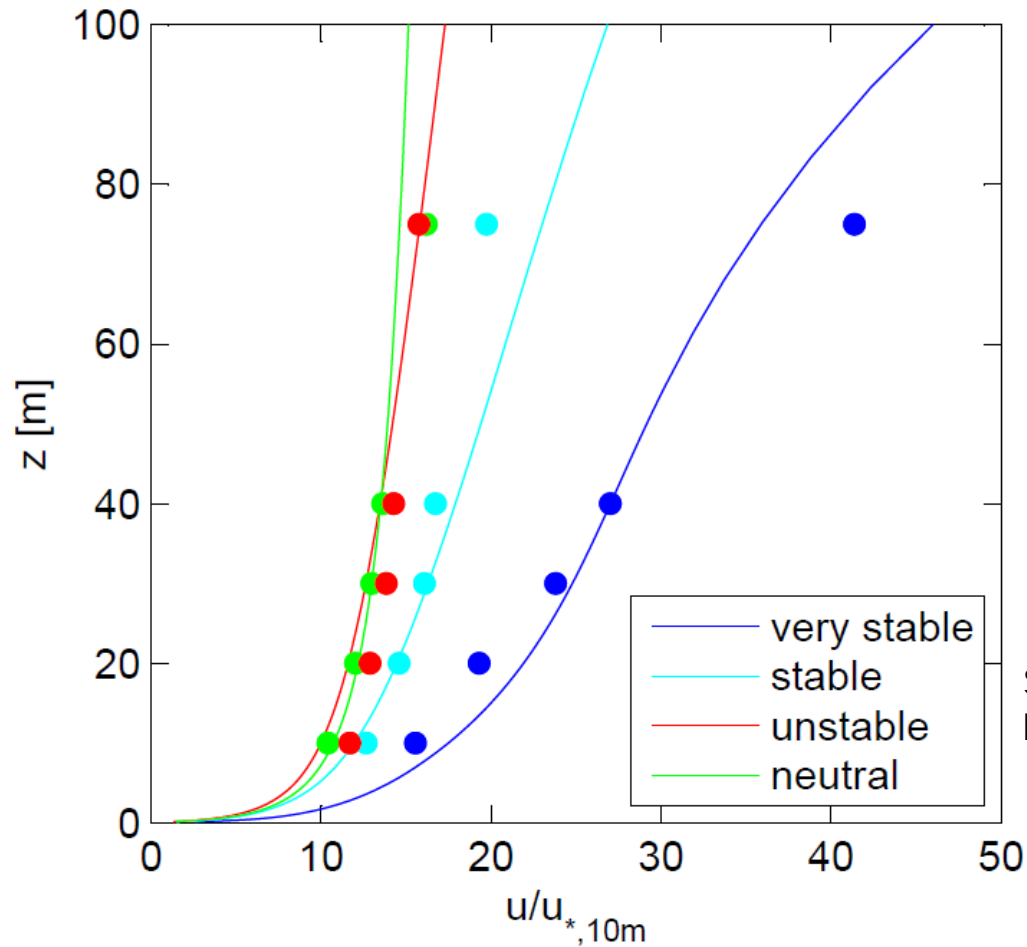
Precursor simulation vs. Measurements at M0





# Simulating Benakanahalli

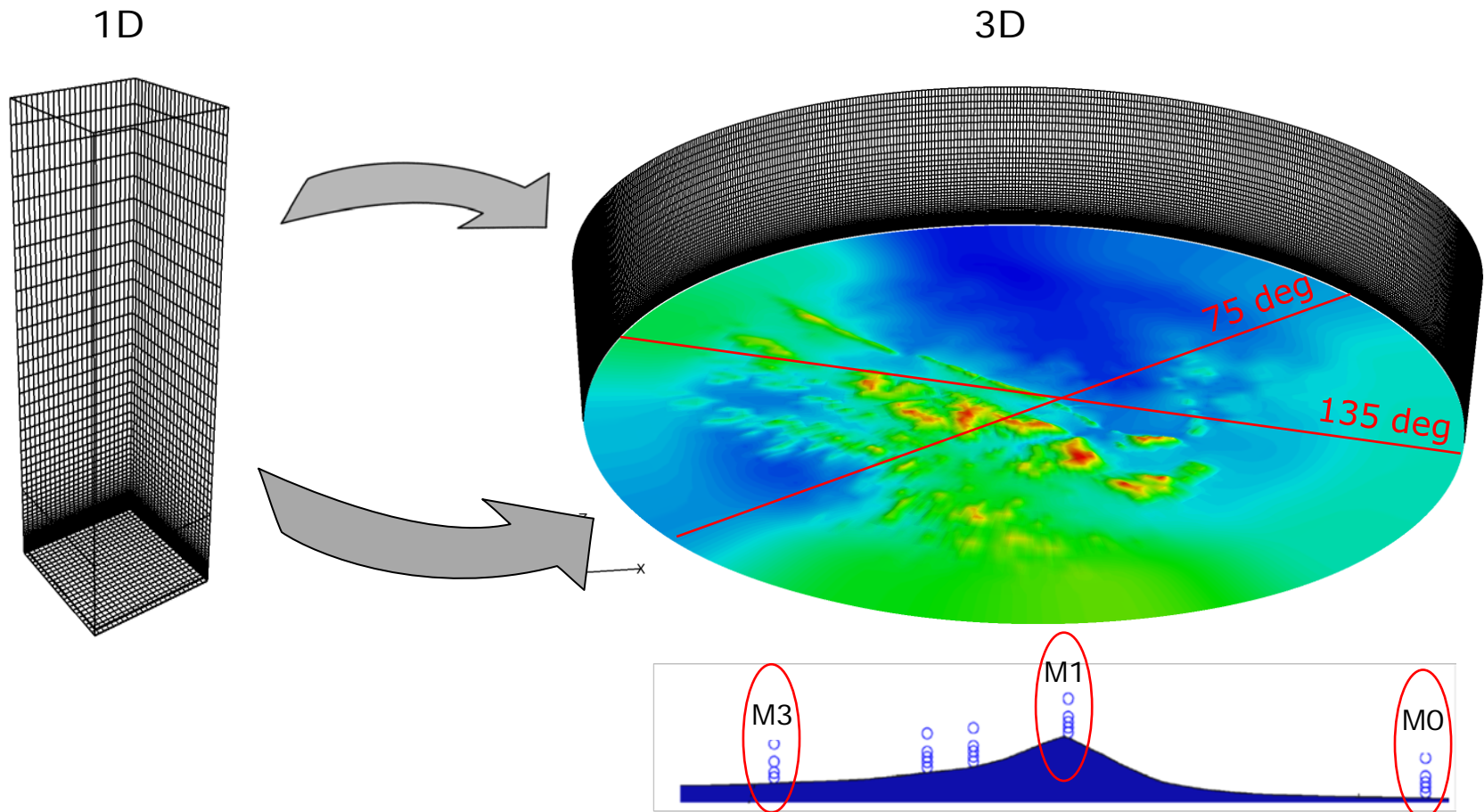
Precursor simulation vs. Measurements at M0



Stability classes based on Monin-Obukhov length

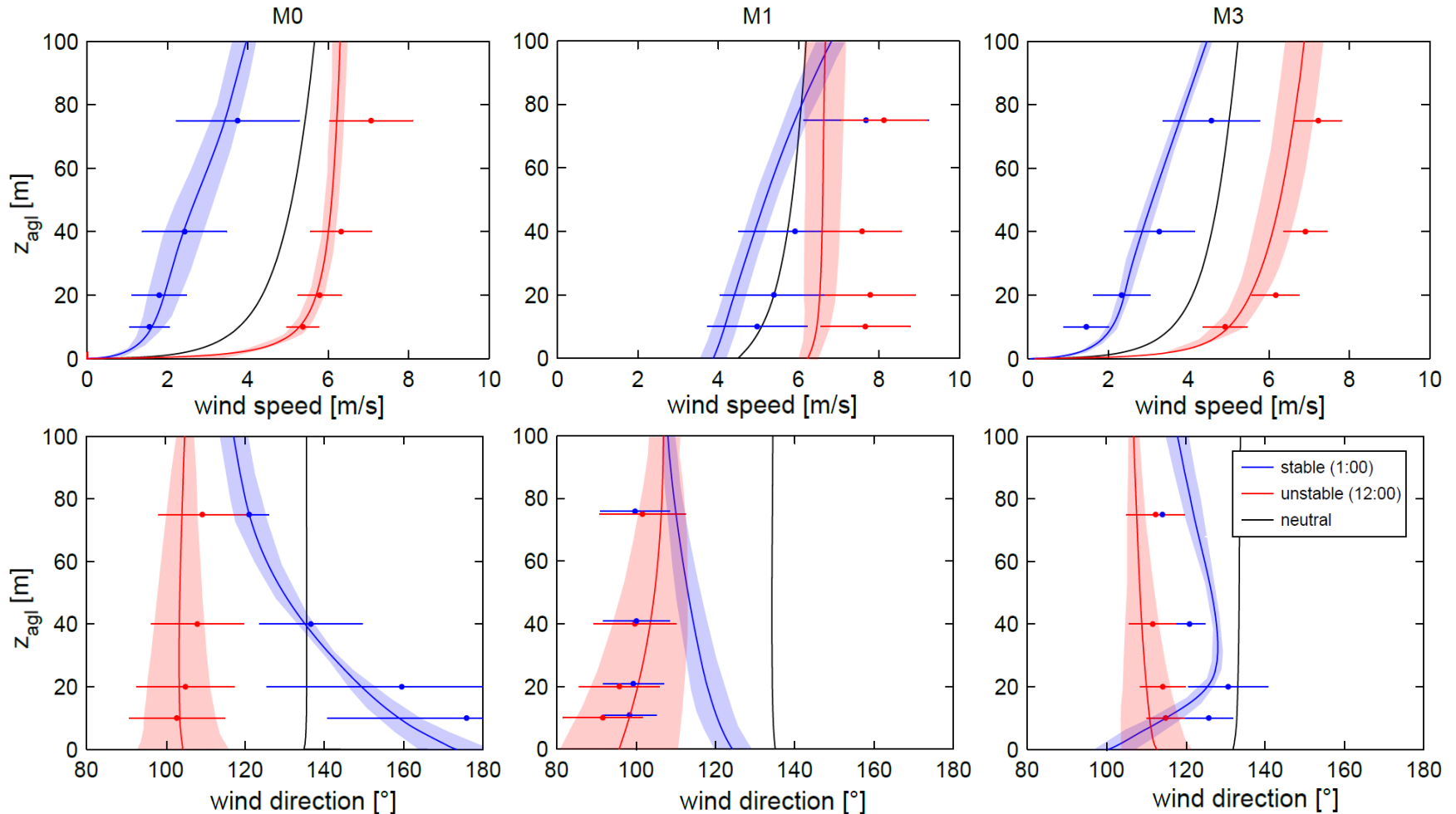
# Simulating Benakanahalli

Computational mesh and boundary conditions



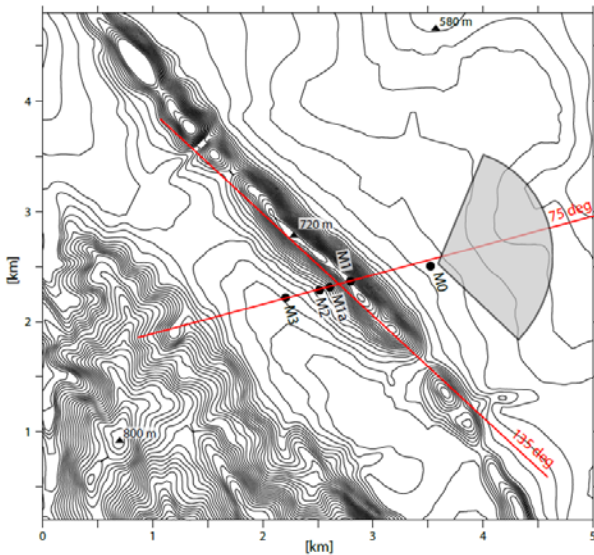
# Simulating Benakanahalli

Wind speed and direction: comparison of modeled and observed data

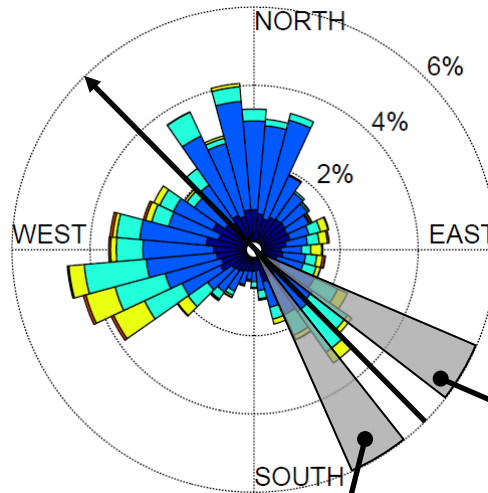


# Simulating Benakanahalli

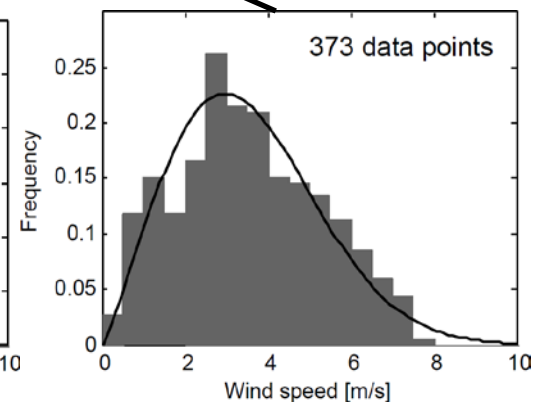
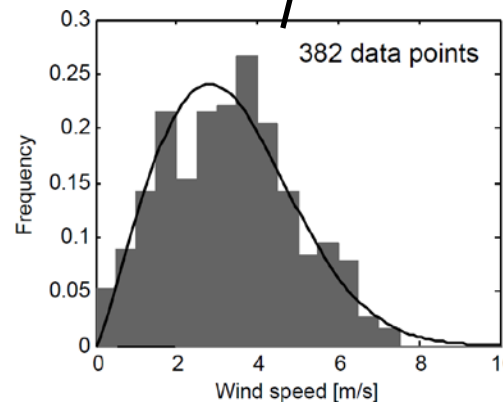
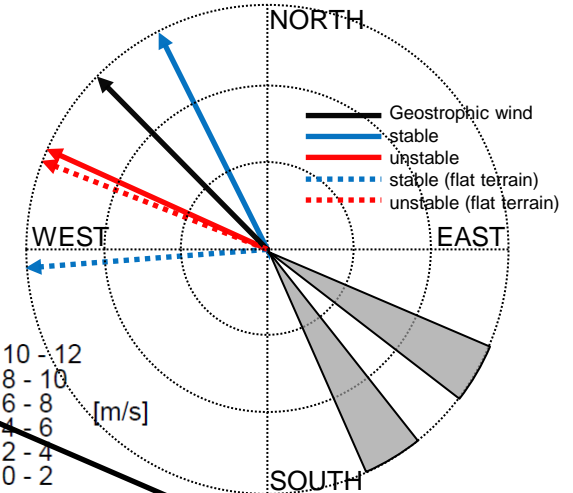
Contour map of terrain



Wind rose

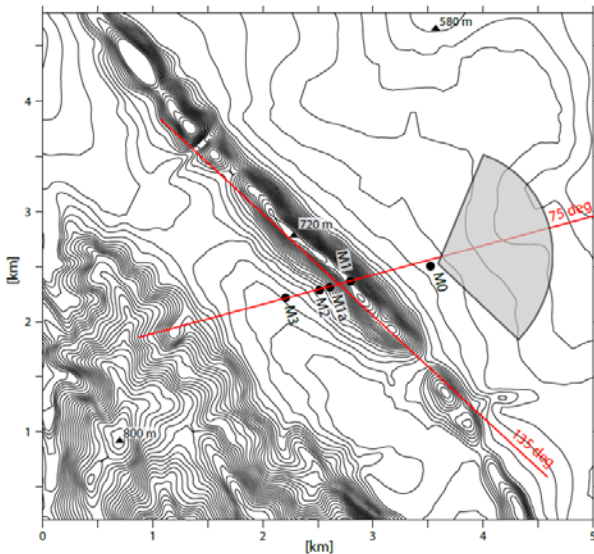


Wind direction in 20m

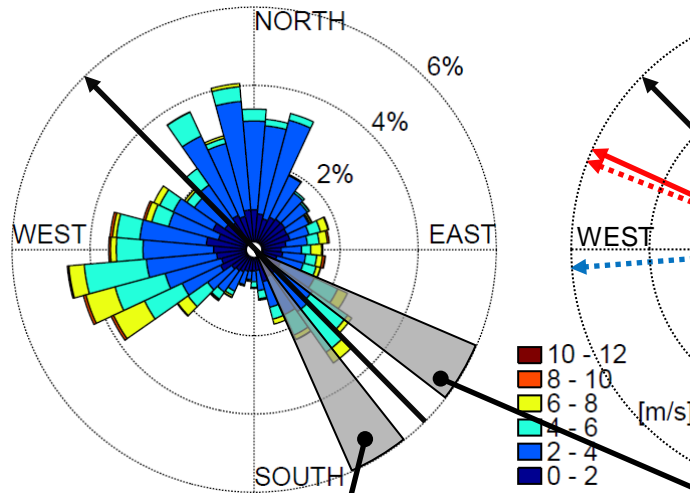


# Simulating Benakanahalli

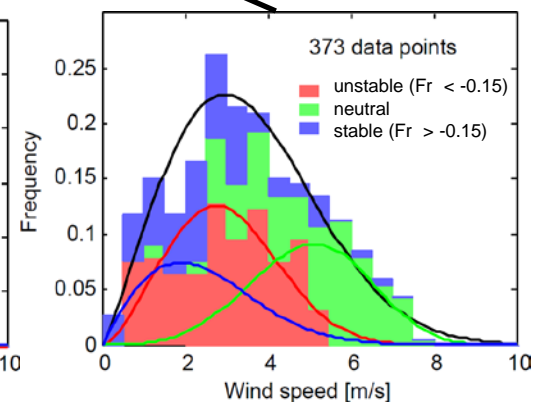
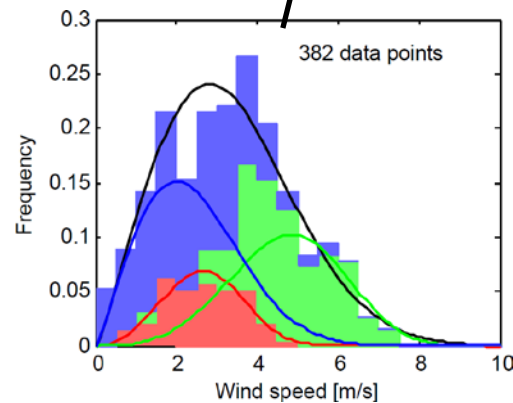
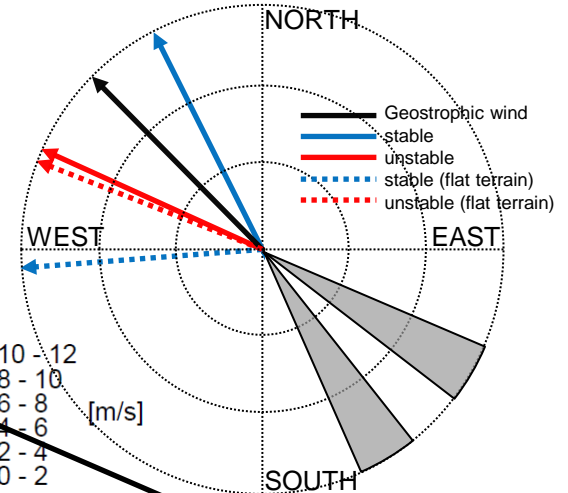
Contour map of terrain



Wind rose



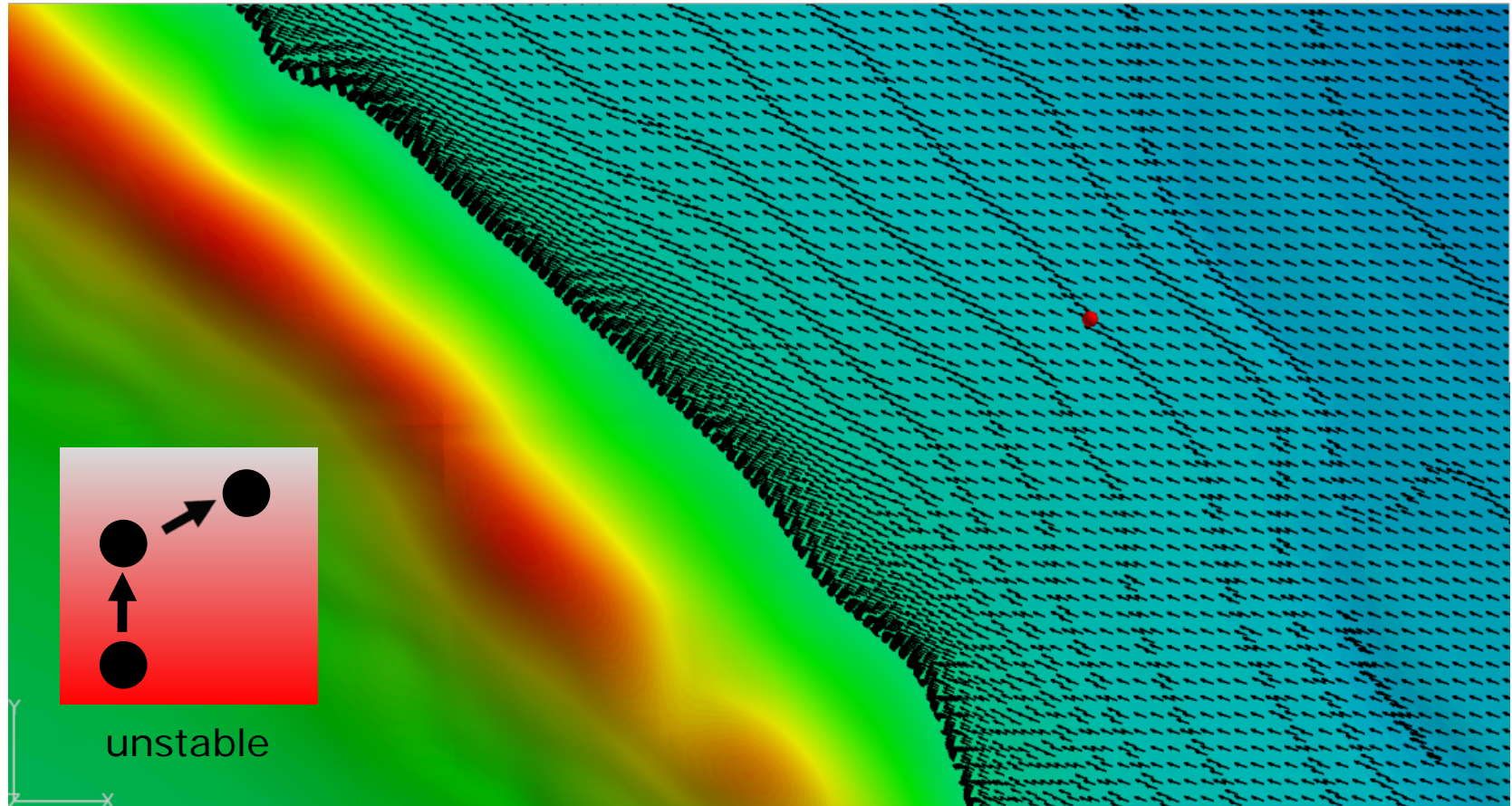
Wind direction in 20m





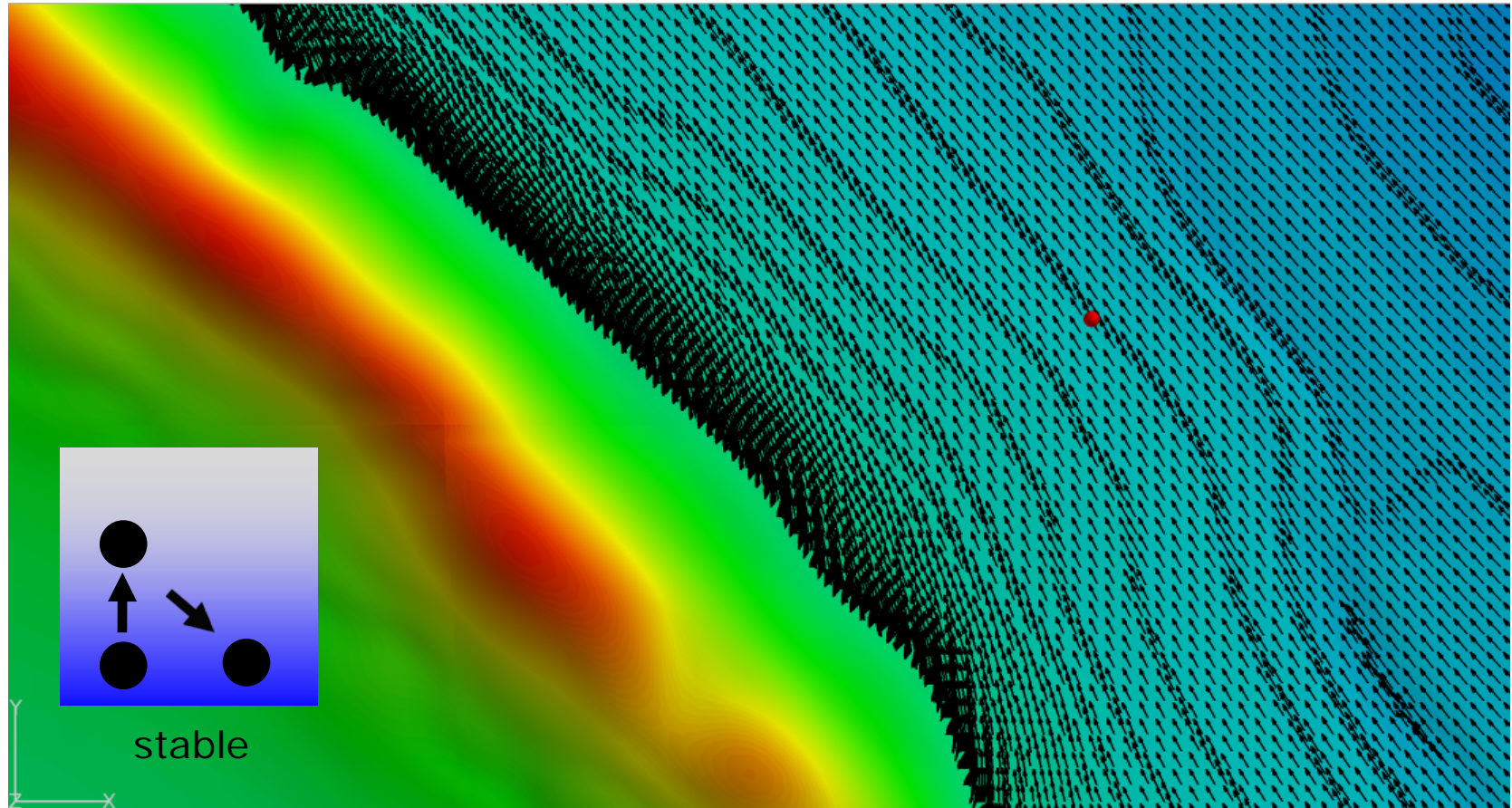
# Simulating Benakanahalli

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

