Enhancing the calculation of turbulence intensity in numerical weather prediction models.

Richard Foreman, Stefan Emeis

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Institute for Meteorology and Climate Research.
Karlsruhe Institute of Technology (KIT).
Garmisch-Partenkirchen, Germany

Overview

- Aim to enhance the prediction of turbulent quantities in the Marine Atmospheric Boundary Layer (MABL) by Numerical Weather Prediction (NWP) models.
    - Obvious applications for weather forecasters.
    - NWP models are used in part to help forecast expected wind energy converter yields.
    - Can be used to estimate expected turbulence levels at particular sites.
- We have made some updates to the Mellor-Yamada model in the Weather Research and Forecasting model.
    - Improvements of up to 20% in the calculation of turbulence intensity (Ti) will be shown here.

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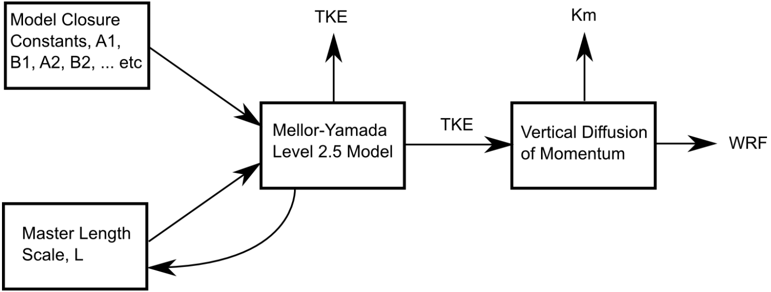
Mellor-Yamada-Janjic Model in WRF

- Weather Research and Forecasting (WRF) Model (Skamarock et al. 2008, http://www.mmm.ucar.edu/wrf/users/)



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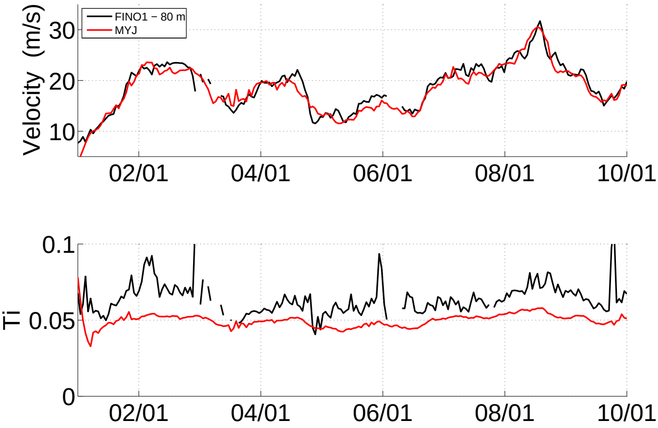
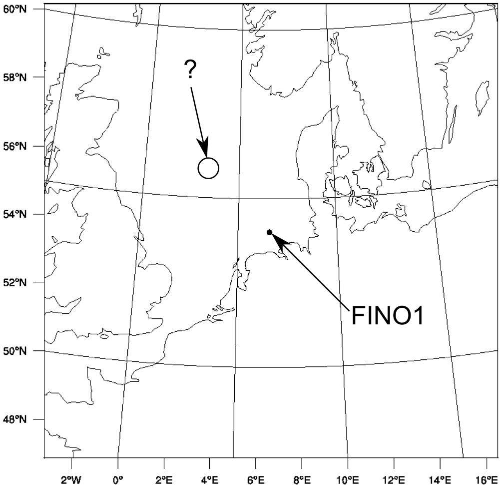
Initial WRF Model Results - FINO1 - Cyclone "Erwin" January 01-10, 2005.

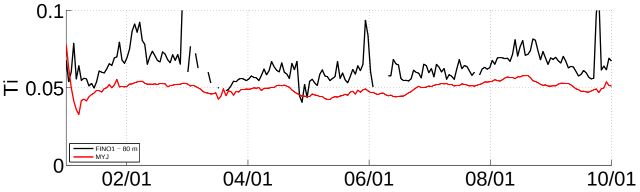


- Turbulence Intensity: $\mathrm{Ti} = \frac{\sqrt{\frac{1}{2}(\sigma_u^2+\sigma_v^2+\sigma_w^2)}}{U}$.

WRF Model Domain



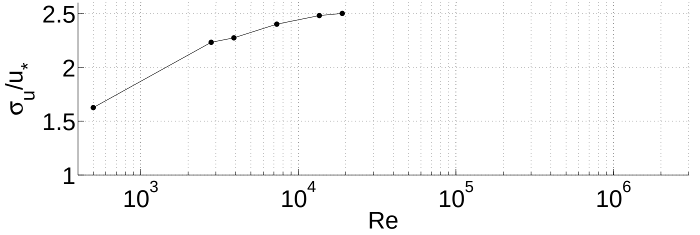
Turbulence intensity underpredicted by model

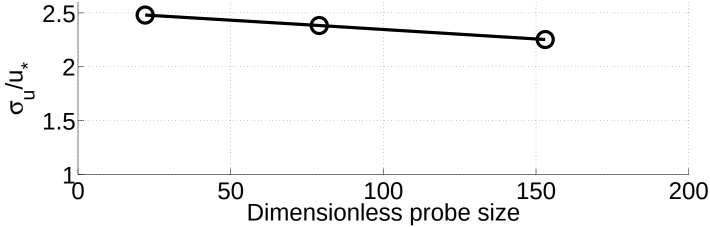


- Mellor-Yamada (1982) closure constants determined from laboratory data between 1950-1975.
- Closure constants determined from turbulent statistics in range where production = dissipation and Reynolds number independence.
    - Difficult to measure (close to the wall)
- **Have measurement techniques advanced sufficiently since then?**

Turbulent statistics at higher Reynolds number

(Hutchins et al. 2009. J. Fluid Mech. 635:103-136.)





- Dimensionless probe size $\propto$ Re

Recalibrated MYJ scheme in WRF

- B_1 = MY closure constant.
- $q = \sqrt{\sigma_u^2 + \sigma_v^2 + \sigma_w^2}$
- u_* = friction velocity.

Author	Re (x 10^4)	$\frac{q}{u_*}$	$B_1 = \left(\frac{q}{u_*}\right)^3$
Laboratory Data:			
Österlund (1999)	2.25	2.97	26.2
Carlier & Stanislas (2005)	2.06	2.96	25.9
Mellor-Yamada Models:			
Mellor & Yamada (1982)	-	2.55	16.6
Current WRF	-	2.28	11.9
Updated here	-	2.96	26.0

Recalibrated MYJ scheme in WRF

- Update MYJ coefficients based on $B_1 = 26.0$ (see Mellor & Yamada, 1982)
- Modify length scale, L based on Nakanishi (2001) (L is made an explicit function of stability).
- Obtain dimensionless wind and temperature gradients matching Businger (1971) (based on Monin-Obukhov similarity theory).

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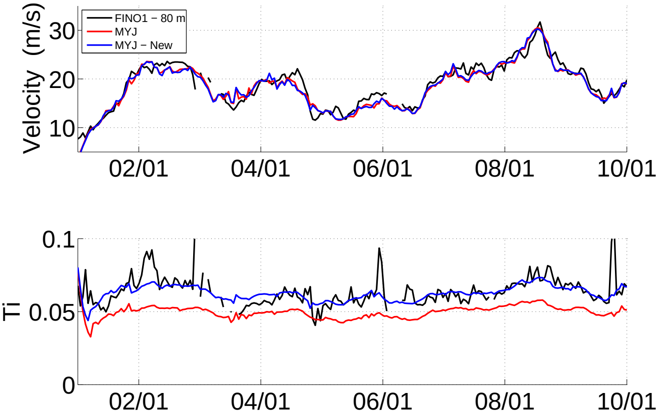
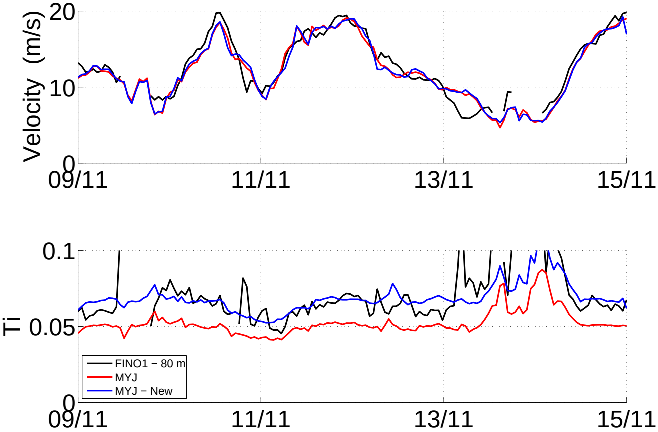
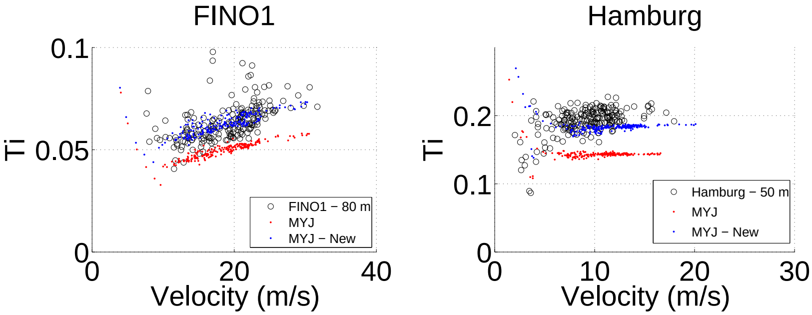
FINO1: January 1-10, 2005. Cyclone “Erwin”.



FINO1: November 09-15, 2005.



Janaury, 01-10, 2005. Turbulence Intensity: Offshore/Onshore



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Conclusions

- Updates to the Mellor-Yamada-Janjic model include:
  - New Model constants.
  - Extra specification for the master length scale.
- Updates improve calculation of turbulence intensity.
- Model more suitable for estimating turbulence levels at a particular site.

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