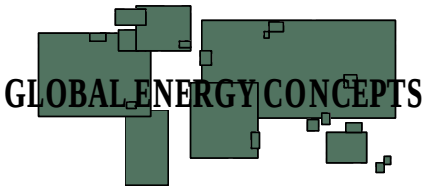

Aerodynamic forces on a yawed wind turbine rotor

presented at the
Furling Workshop
held at NWTC, July 14, 2000

by

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GLOBAL ENERGY CONCEPTS

Background/objectives

- This work has grown out of studies by Kamzin Technology (now GEC) on behalf of Windlite.
- It was also influenced by studies of the mechanics of teetering rotors.
- The forces from the tail vane and from the eccentricity of the thrust are not the only forces affecting the yawed equilibrium.
- the subsequent slides discuss the relevant aerodynamic forces on the yawed rotor.

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The model

- An ADAMS model was used, similar to the Windlite 8 kW rotor.
- Output included an integral of the translational and the moment effects on the rotor.
- the rotor was fixed in yaw but the wind direction was changed.
- The rotor speed was kept constant and the wind speed increased stepwise.

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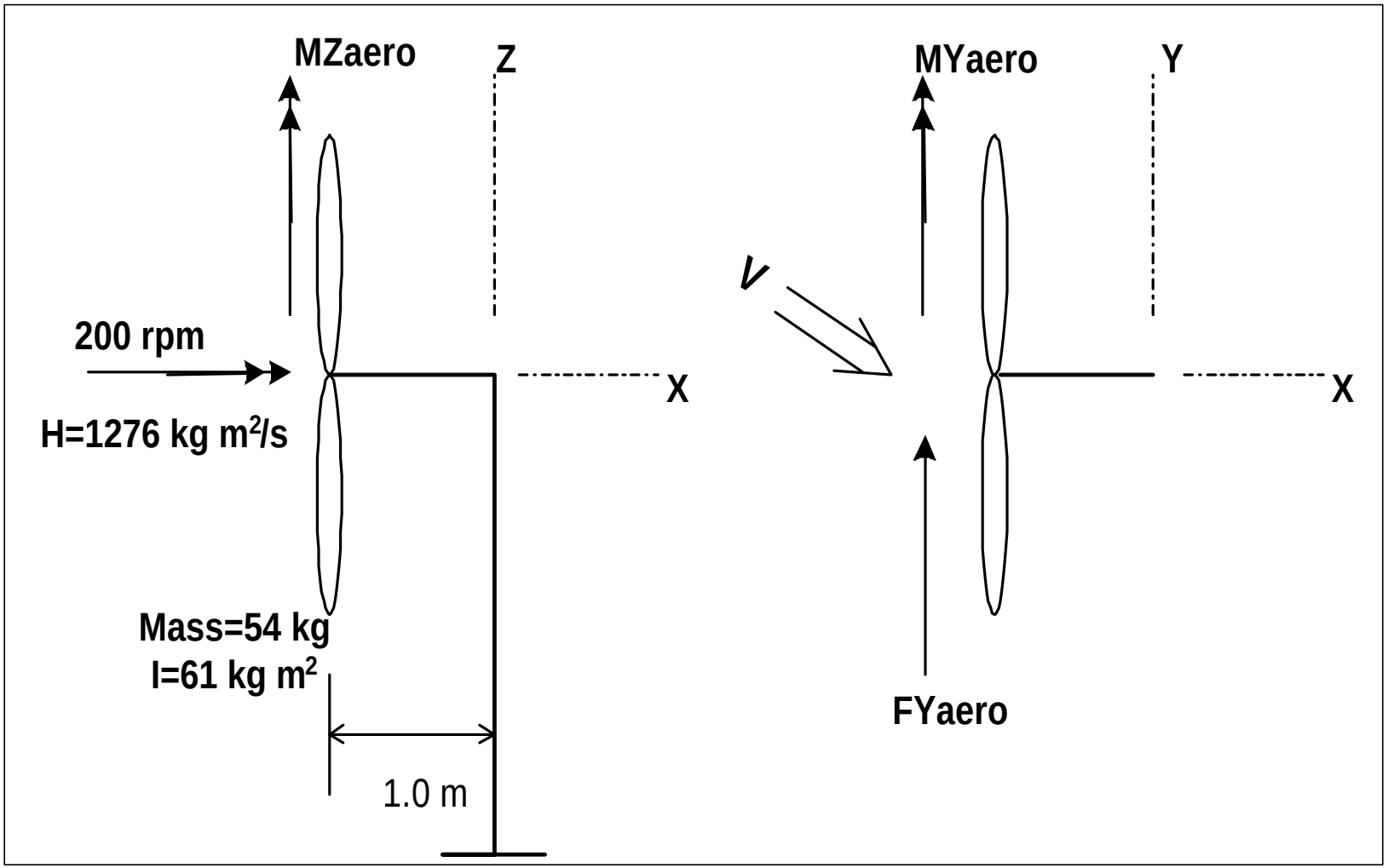
Terminology, coordinates



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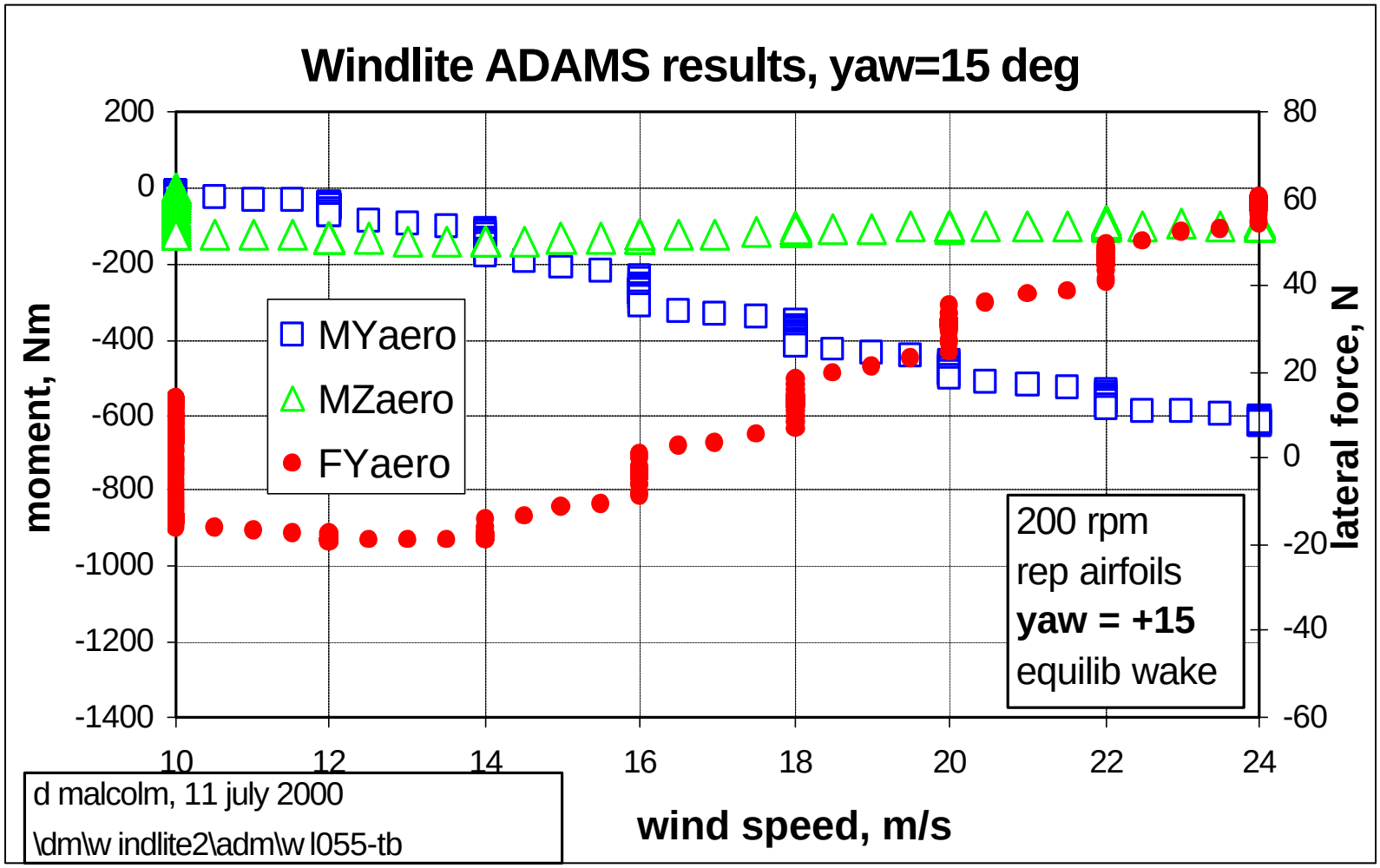
Aerodynamic forces, yaw angle=15 deg



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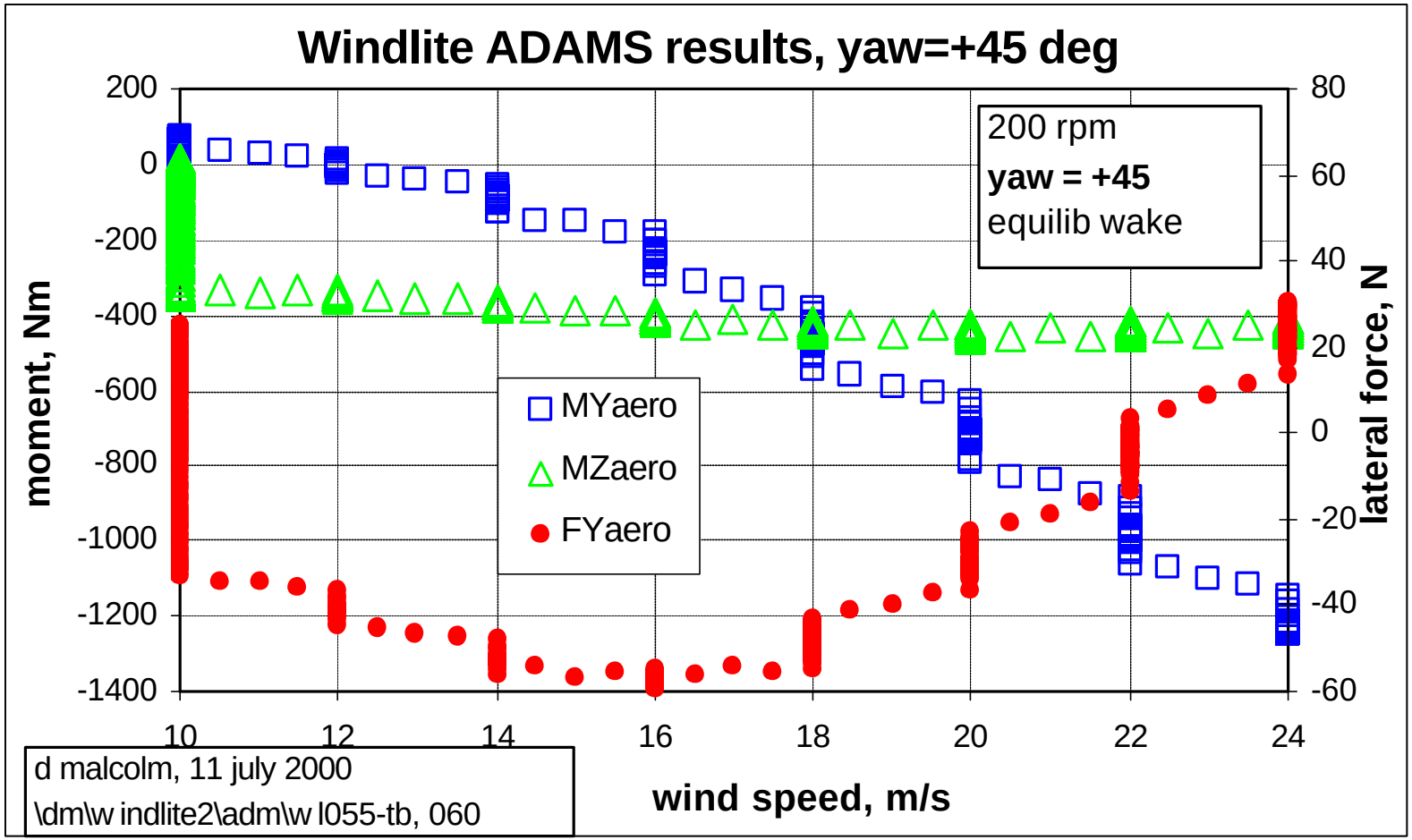
Aerodynamic forces, yaw=45 deg



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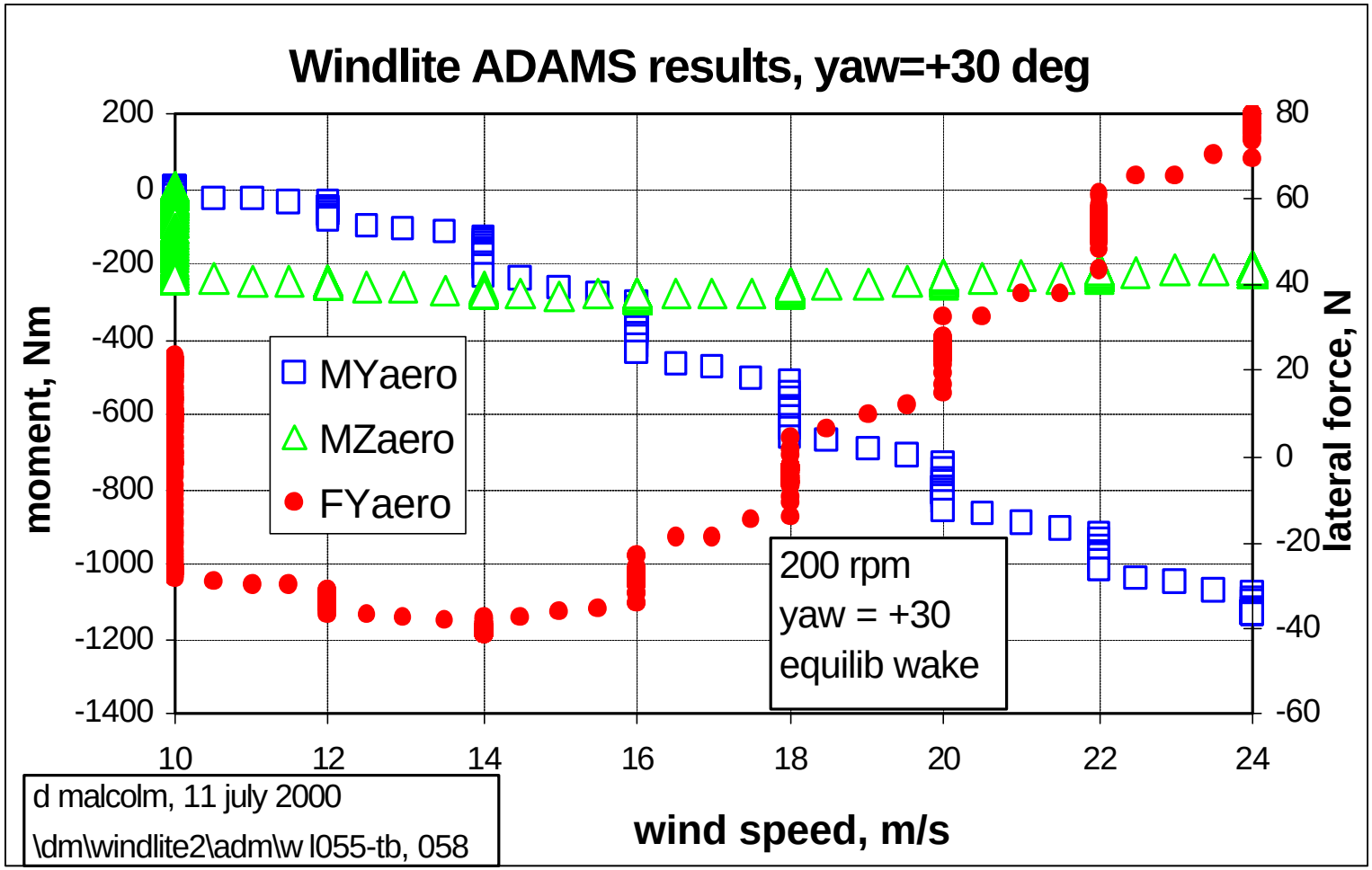
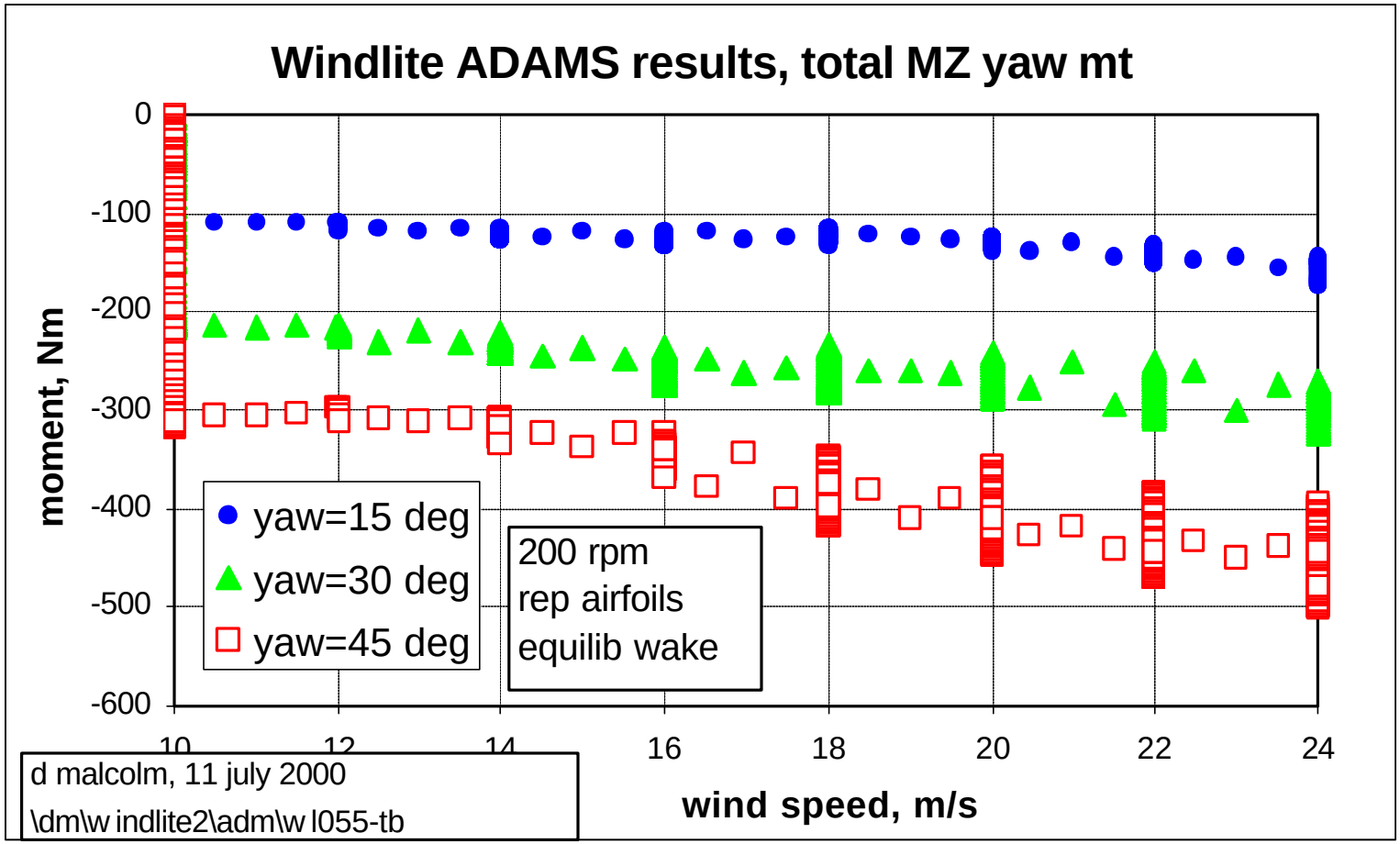
Aerodynamic forces, yaw=30 deg



Total yawing moments

- mt about yaw axis = MZaero + FYaero x **l**



Motion and gyroscopic effects

- total mt of inertia about yaw axis =114 kg m^2
- suppose total yaw mt = -200 N m, and MYaero=-400 Nm;
  then, yaw_acceleration = -200/114 = -1.75 rad/s2
- If ω_z = -1.0 rad/s

  then MYtotal = $\mathbf{H} \times \omega_z$ = -1276 N m
- Then moment from bearings is

  MYbearing = MYtotal – MYaero
  = -1276 + 400
  = -876 N m

GLOBAL ENERGY CONCEPTS

Some conclusions

- FYaero can change sign and tend to yaw rotor in undesired direction.
- MZaero effect is usually greater than that of Fyaero.
- High yaw rates can lead to high bearing reactions.
- These yawing influences must be added to those from furling mechanisms
- Can the aerodyn routines be believed at high yaw angles?