Limits to the Predictability of Tidal Current Energy

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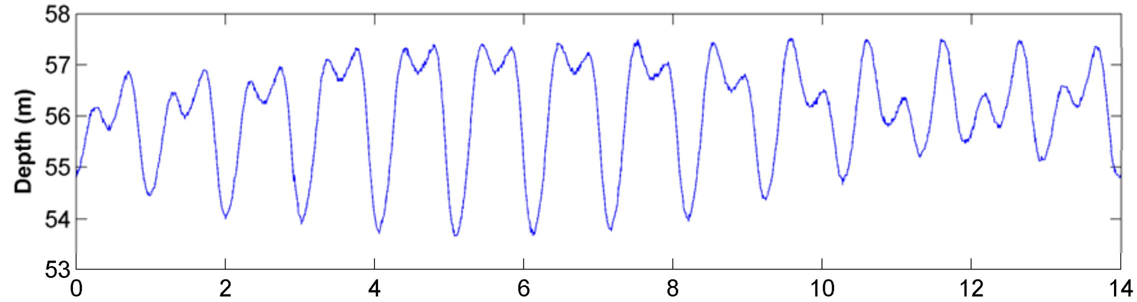
Motivation

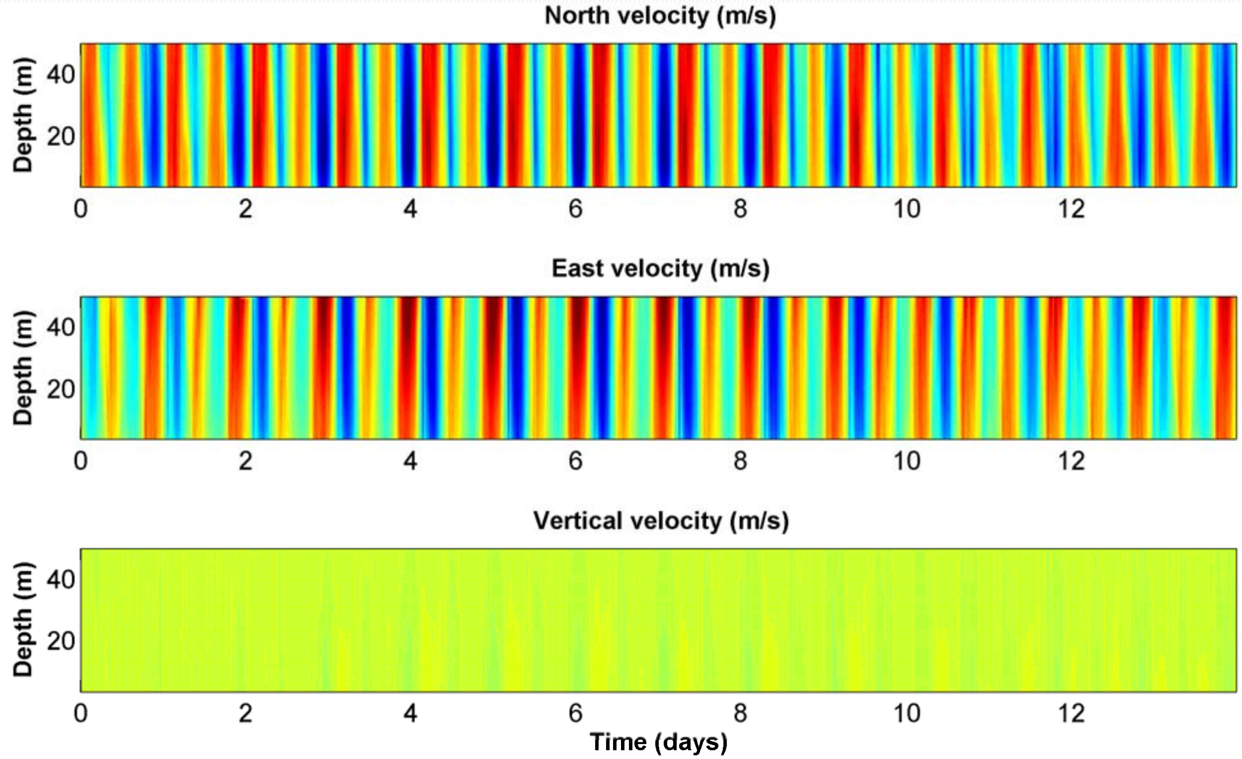
- **Resource predictability is beneficial**
  - — More accurate economic assessments
  - — Easier for grid operators to integrate with other generation options
  - — No extreme loading cases for device design
- **A presumed benefit to tidal hydrokinetic power generation is resource predictability**
  - — Predictability of tidal heights is well-established

Tide and Current Comparison

Tides



Currents



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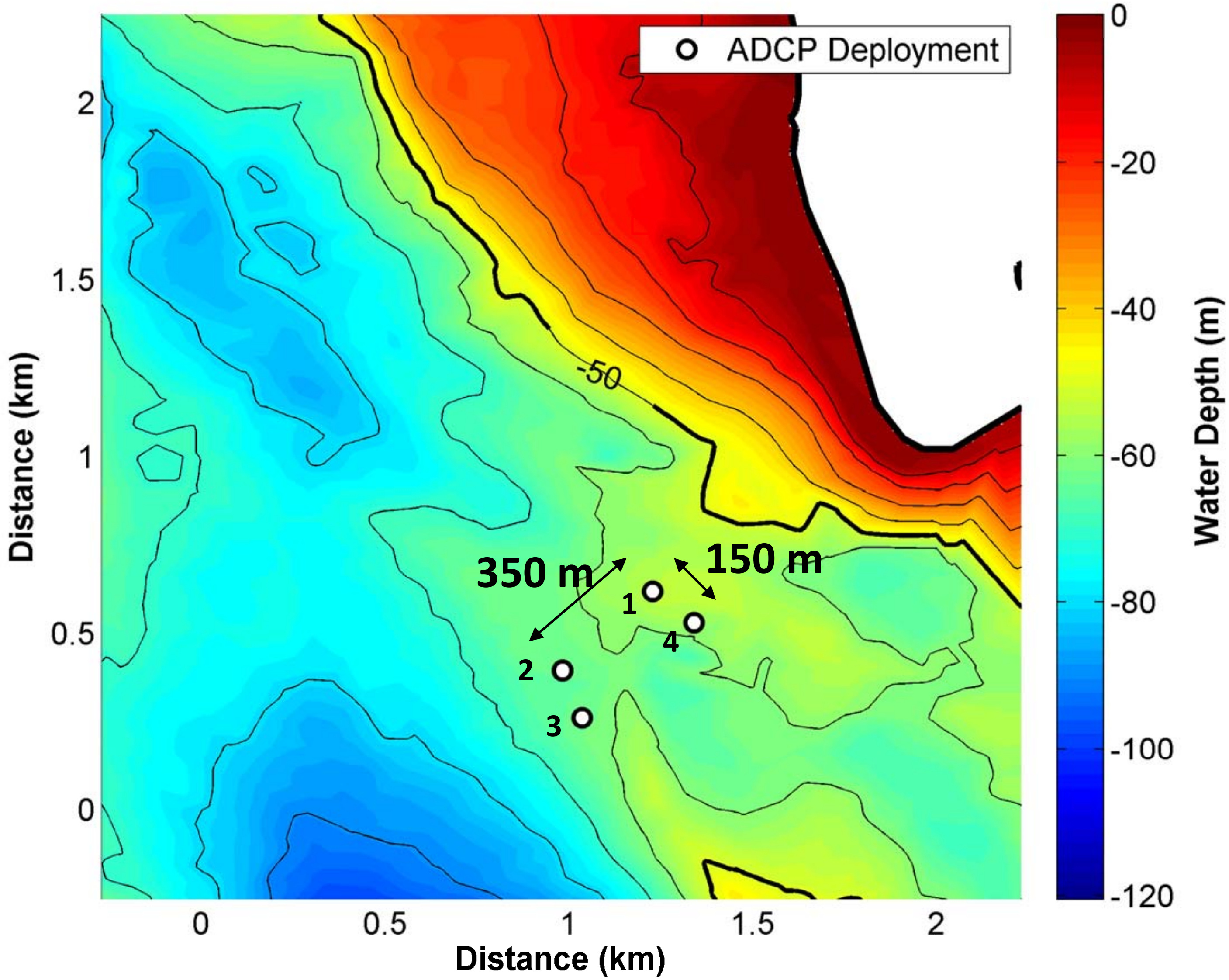
Study Area



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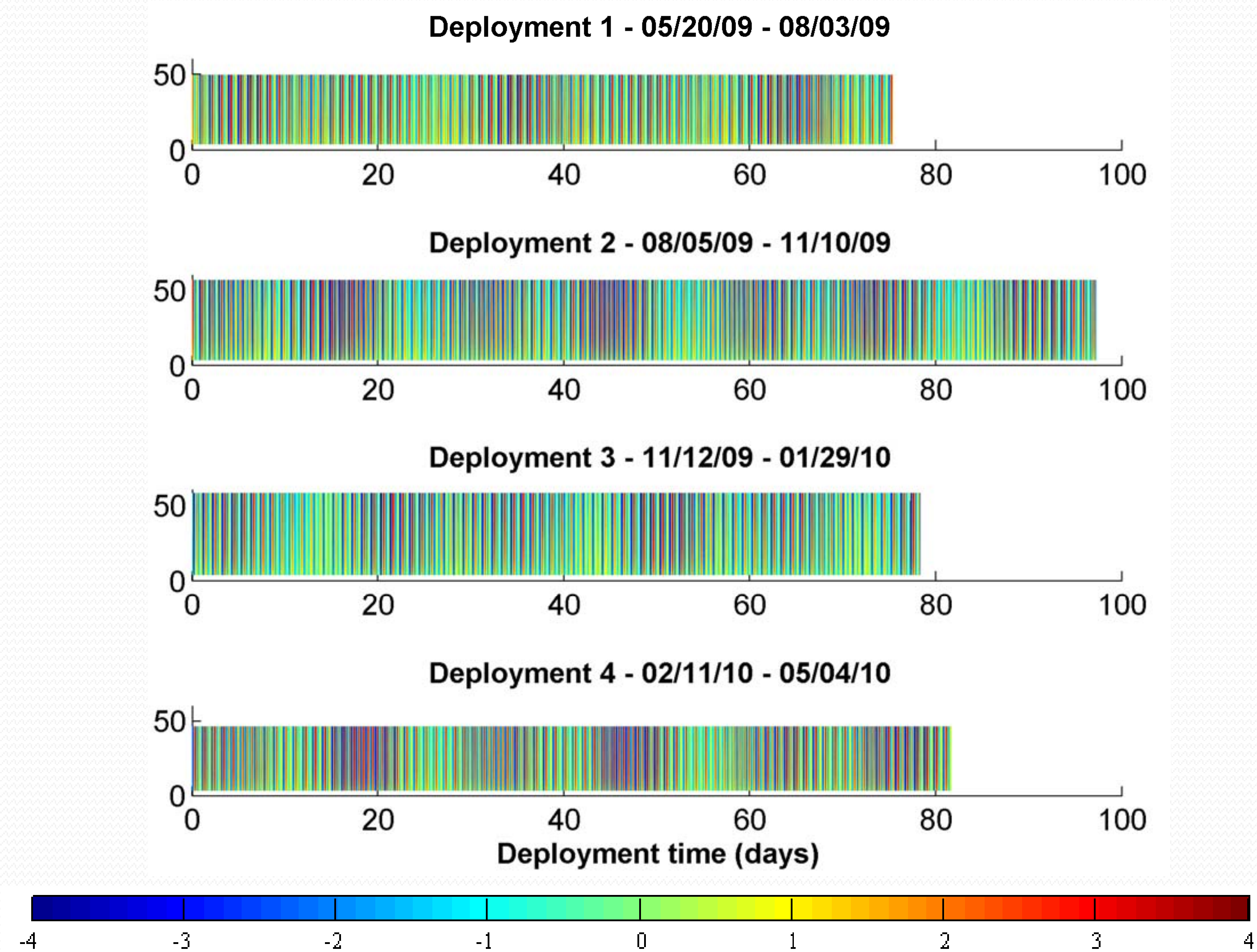
Data Collected



Current Velocity (m/s)

Current Predictions for Hydrokinetics

Classical Problem
Predict horizontal current speed and direction throughout water column

Complications

- Predict kinetic power density (varies as u^3)

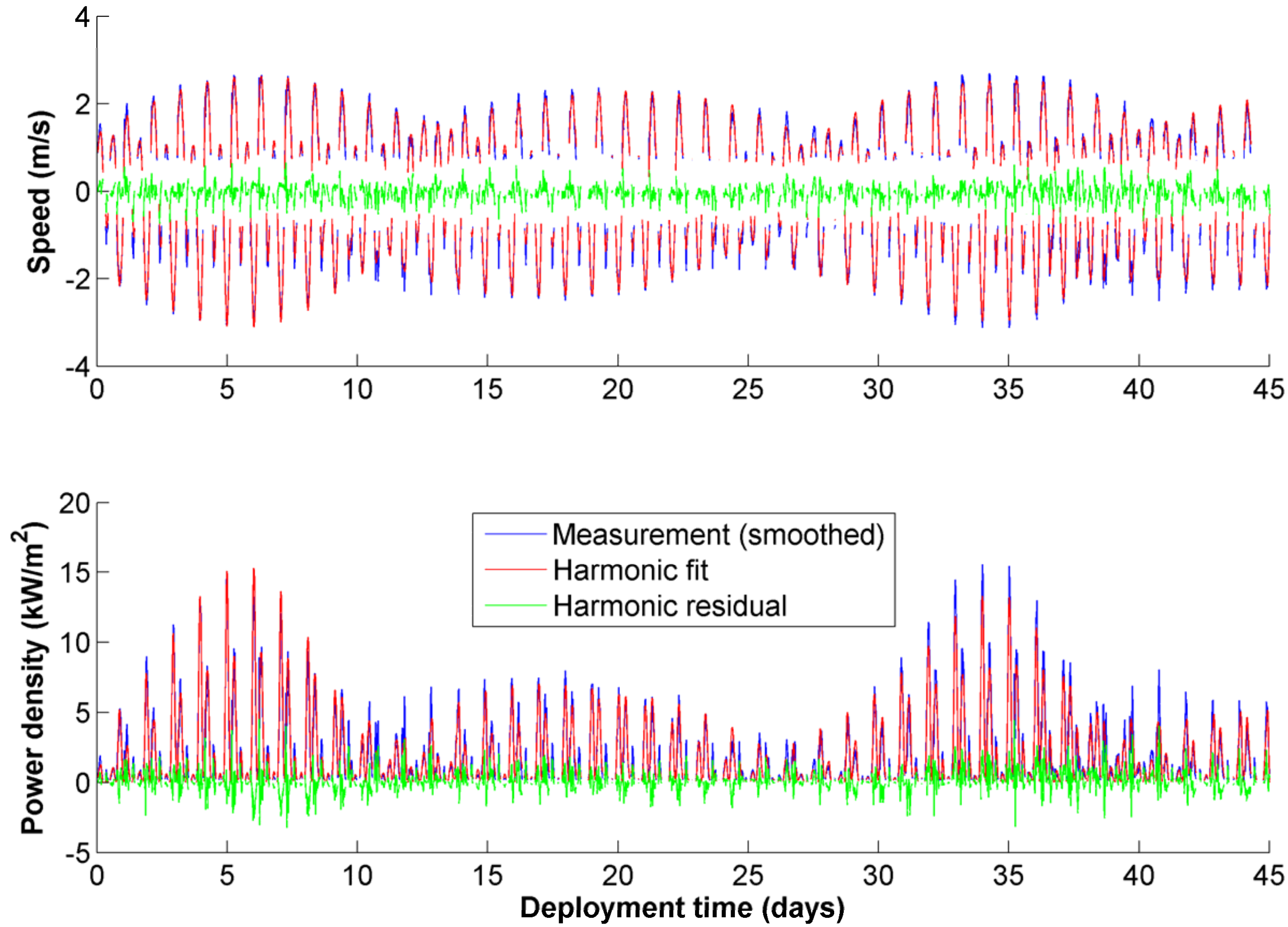
Simplifications

- Neglect direction
- Neglect velocities below device cut-in (0.7 m/s)
- Prediction for device hub height only

Approach

- **Harmonic constituent analysis of horizontal velocity**
  - $u(t) = \sum_{i=1}^{N} u_i \sin(\omega_i t + \phi_i)$
  - 15 minute ensemble average at 10m hub height
- **Rayleigh criteria defines number of included constituents**
  - $(\omega_i - \omega_j)T > R$
  - With 45 days of data and *R*=1, 35 constituents can be included
- **Signal to noise ratio defines number of resolved constituent**
  - Signal to noise ratio of 3, 29 constituents can be included
- **Test ability to fit measurement with harmonic constituents**
- **Test ability to predict currents with harmonic constituents**
  - At same location: 30 days at Deployment 1
  - At other locations: Deployments 2-4

Harmonic Fit of Measurements



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Accuracy of Harmonic Fit

Metric	Value	Definition
$\mathrm{var}(K_{\mathrm{fit}})/\mathrm{var}(K_{\mathrm{measured}})$	0.99	Ratio of variance in fit compared to variance in measurement
RMS error (kW/m^2)	0.5	RMS error between fit and measurement
Coefficient of determination (R^2)	0.96	Goodness of fit
$K_{\mathrm{max,fit}}/K_{\mathrm{max,measured}}$	0.98	Ratio of maximum kinetic power density in fit compared to measurement
$\langle K_{\mathrm{fit}}\rangle/\langle K_{\mathrm{measured}}\rangle$	0.98	Ratio of mean kinetic power density of fit compared to measurement

Evaluating Predictive Accuracy

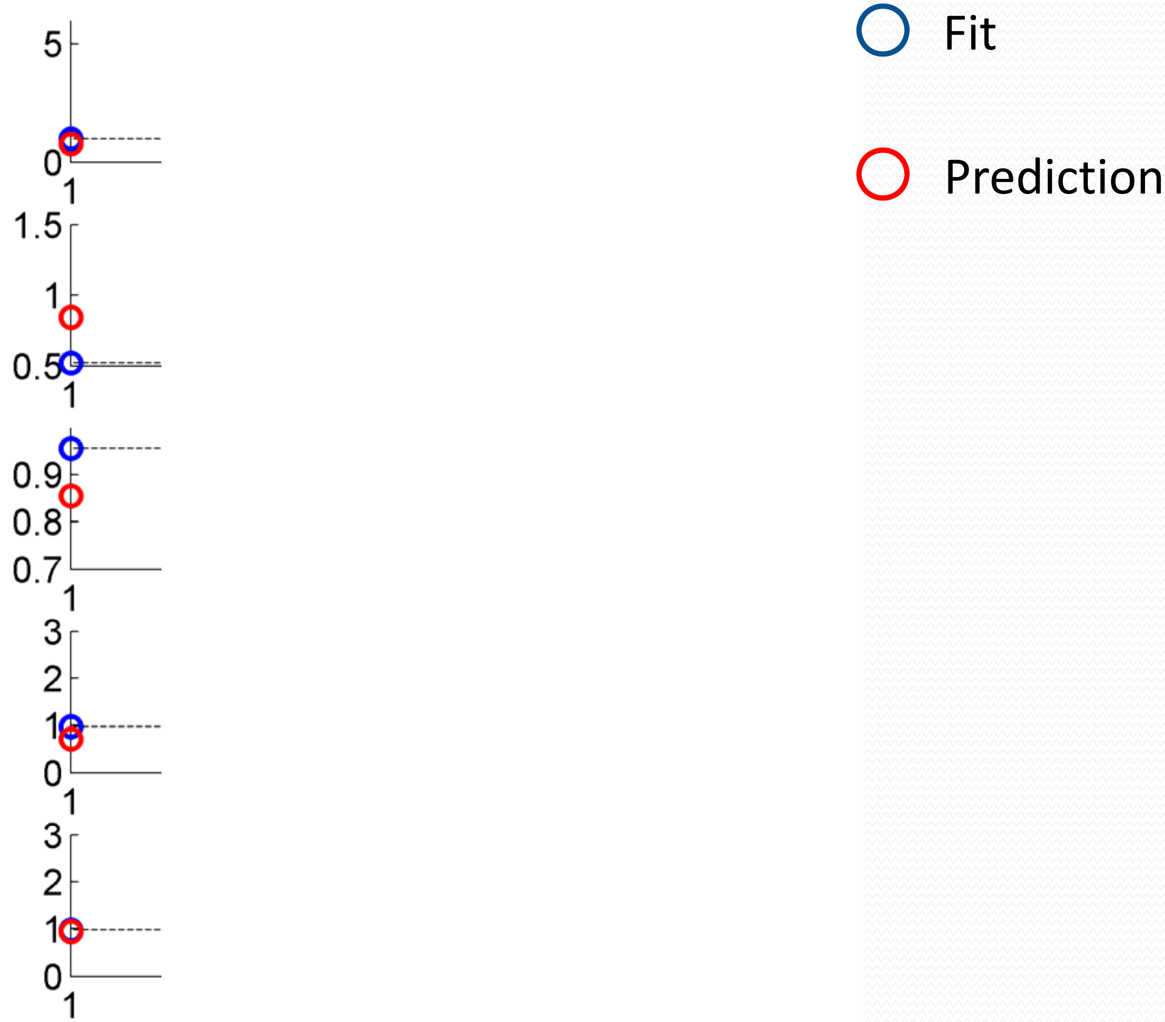
$\mathrm{var}(K_{\mathrm{fit}})/\mathrm{var}(K_{\mathrm{measured}})$

RMS error (kW/m^2)

Coefficient of determination (R^2)

$K_{max,fit}/K_{max,measured}$

$\langle K_{\mathrm{fit}} \rangle / \langle K_{\mathrm{measured}} \rangle$



Deployment

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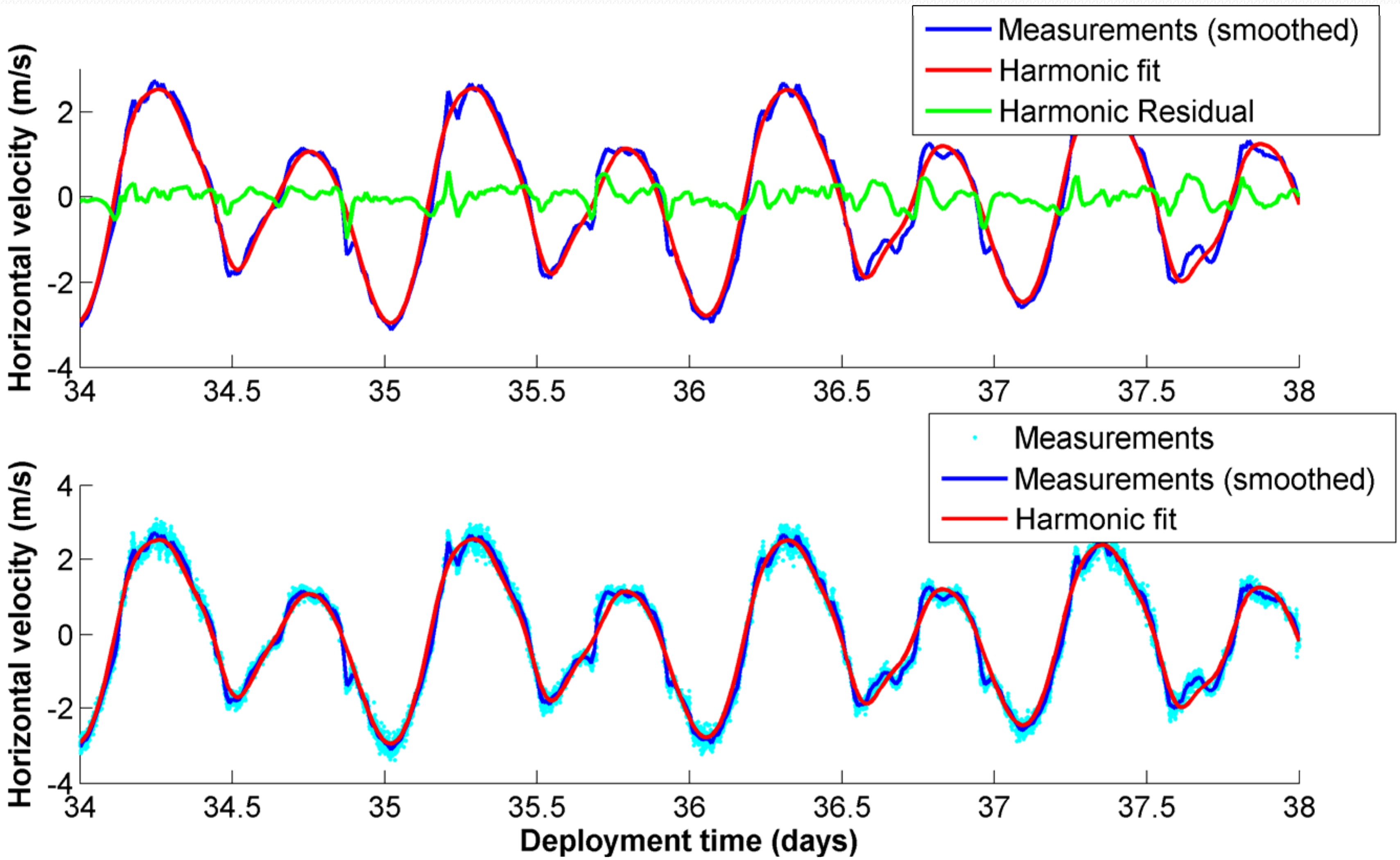
Sources of Error in Harmonic Fit



Conclusions

- **Predictions of mean flow conditions are possible**
  - — Requires long time series to resolve constituents
  - — Requires empirical relations to predict topographic currents
- **Predictions of mean flow are only valid over short spatial scales *O*(100m)**
- **Turbulent fluctuations cannot be predicted and may be operationally significant**

Questions?

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