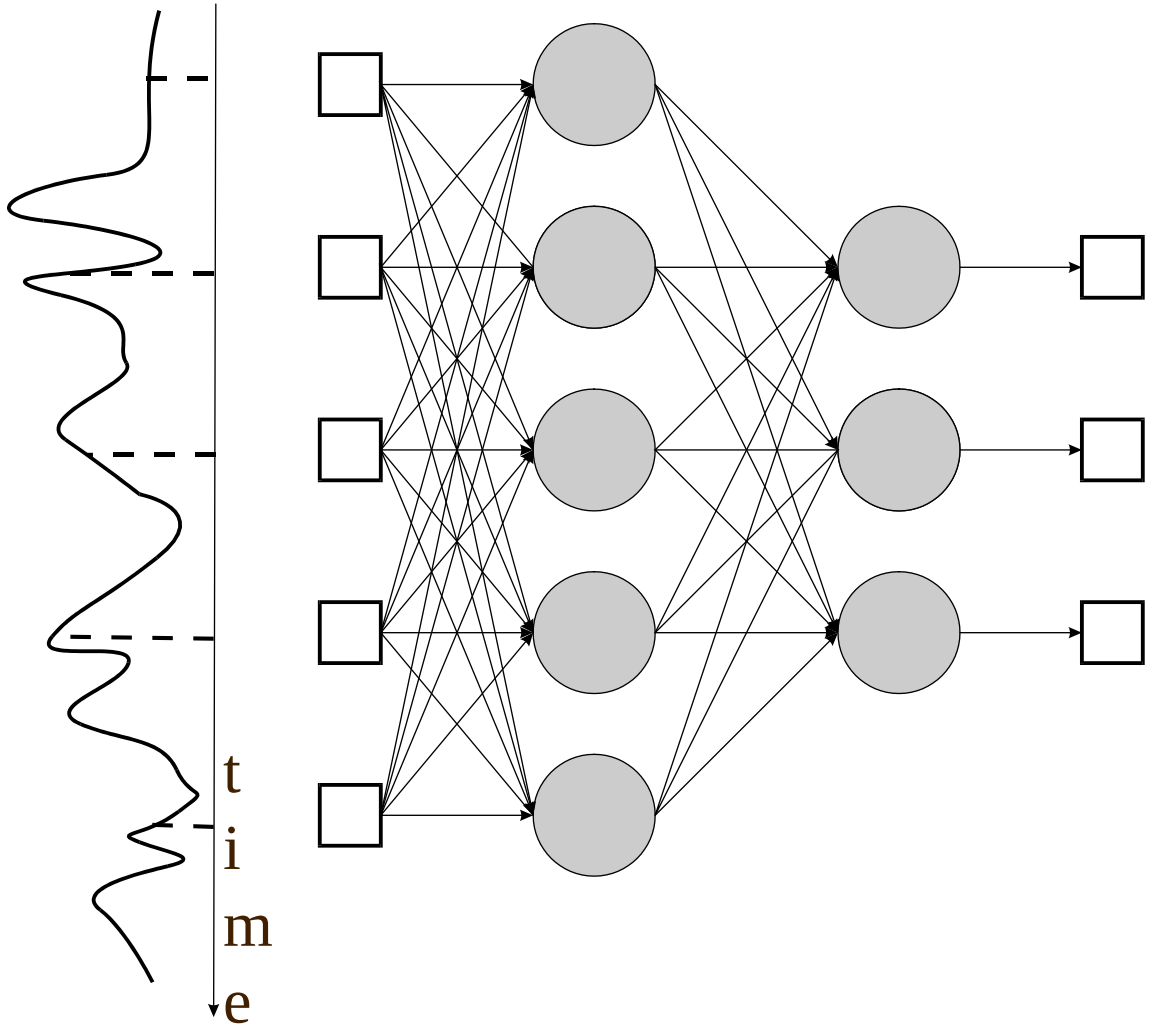
Application of ANN to forecasting

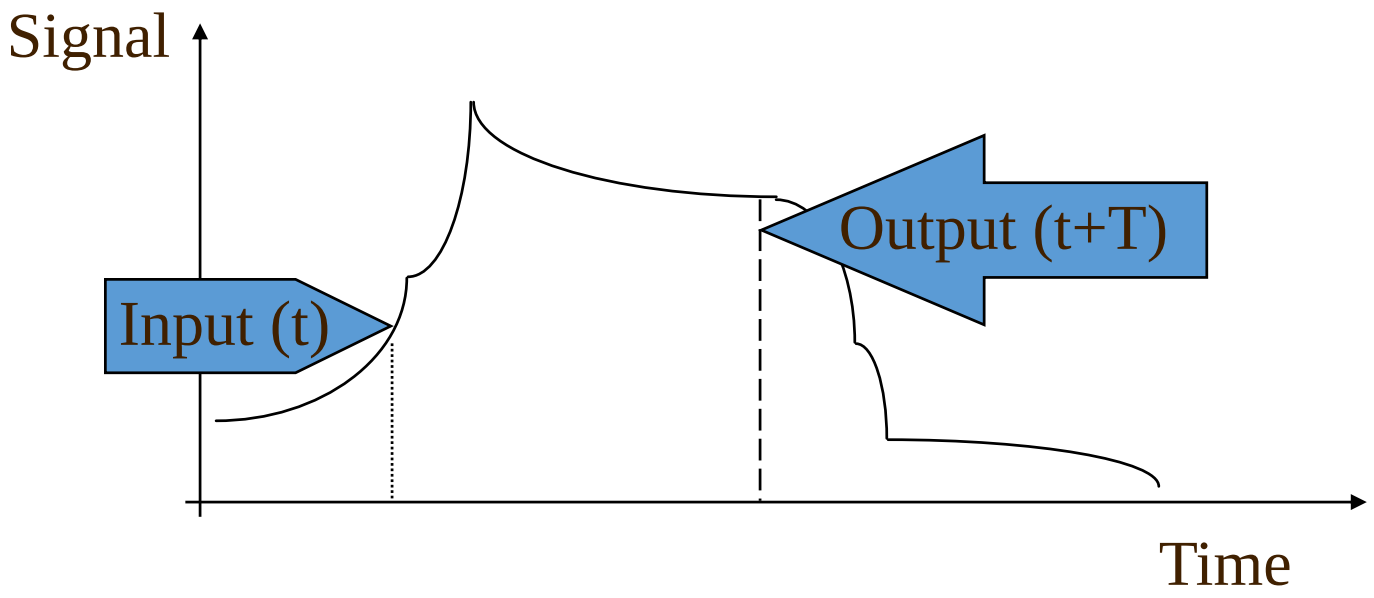
Agenda

- Problems in applying ANN in time-domain
- Case-study: Current speed forecast in Oresund
- Drawbacks

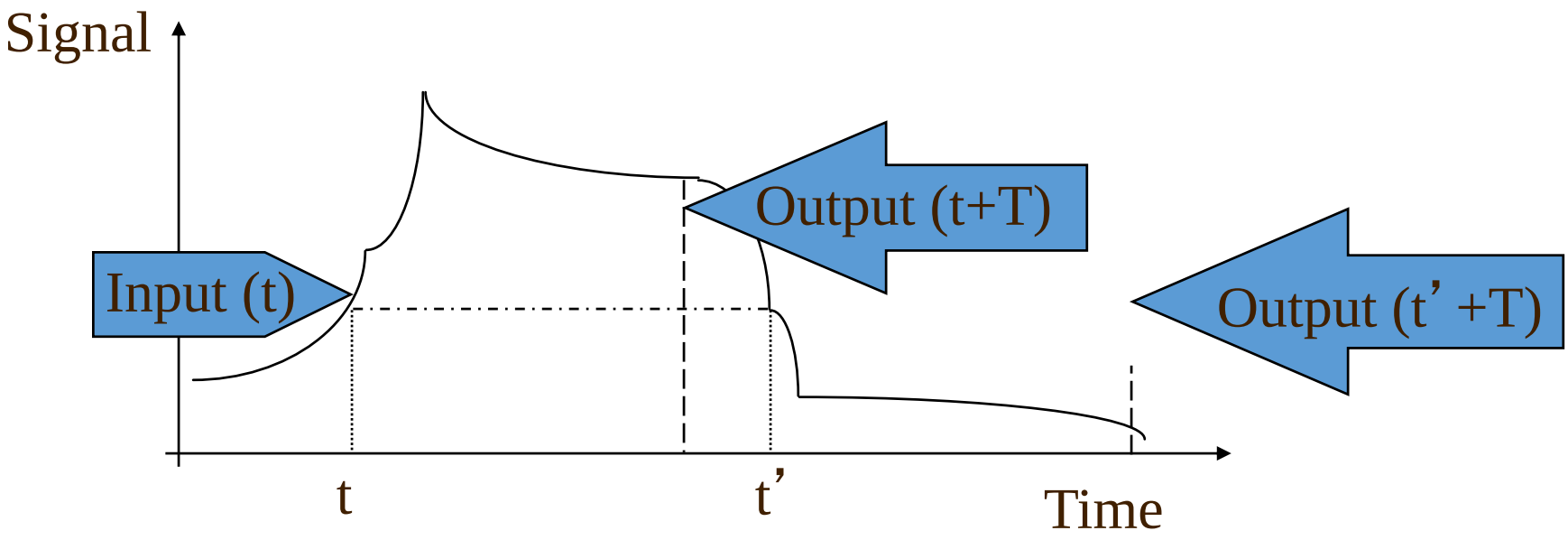
Feedforward Network in Time



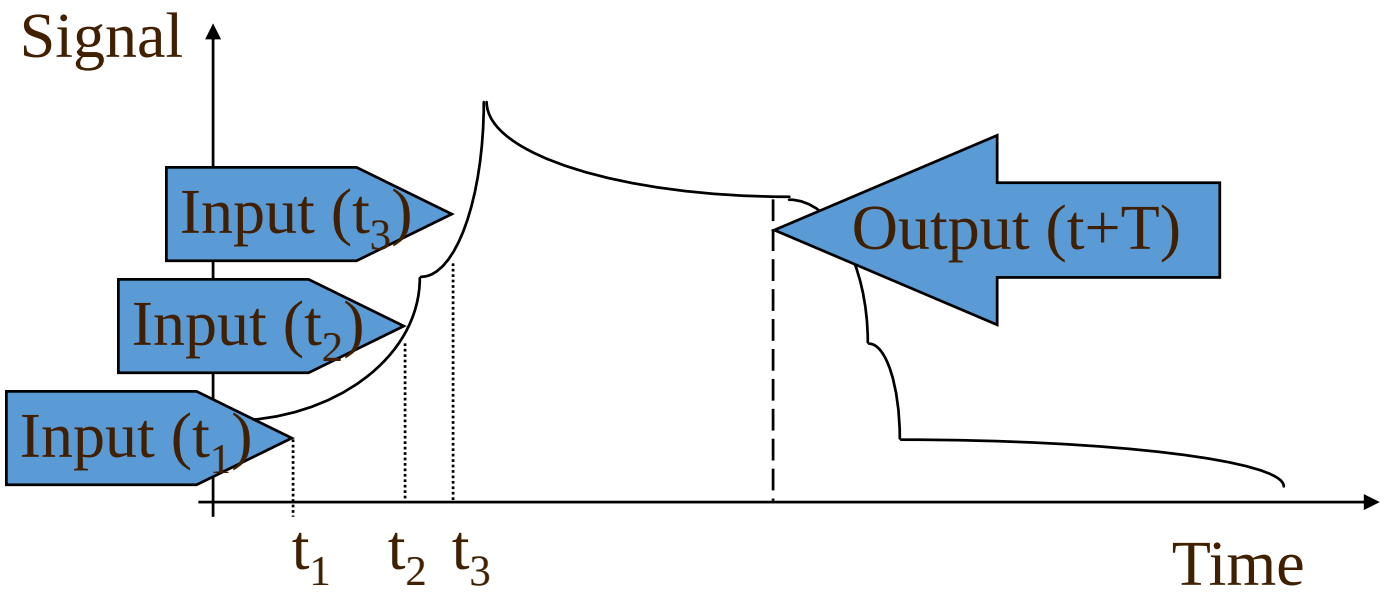
Neural Network in Time



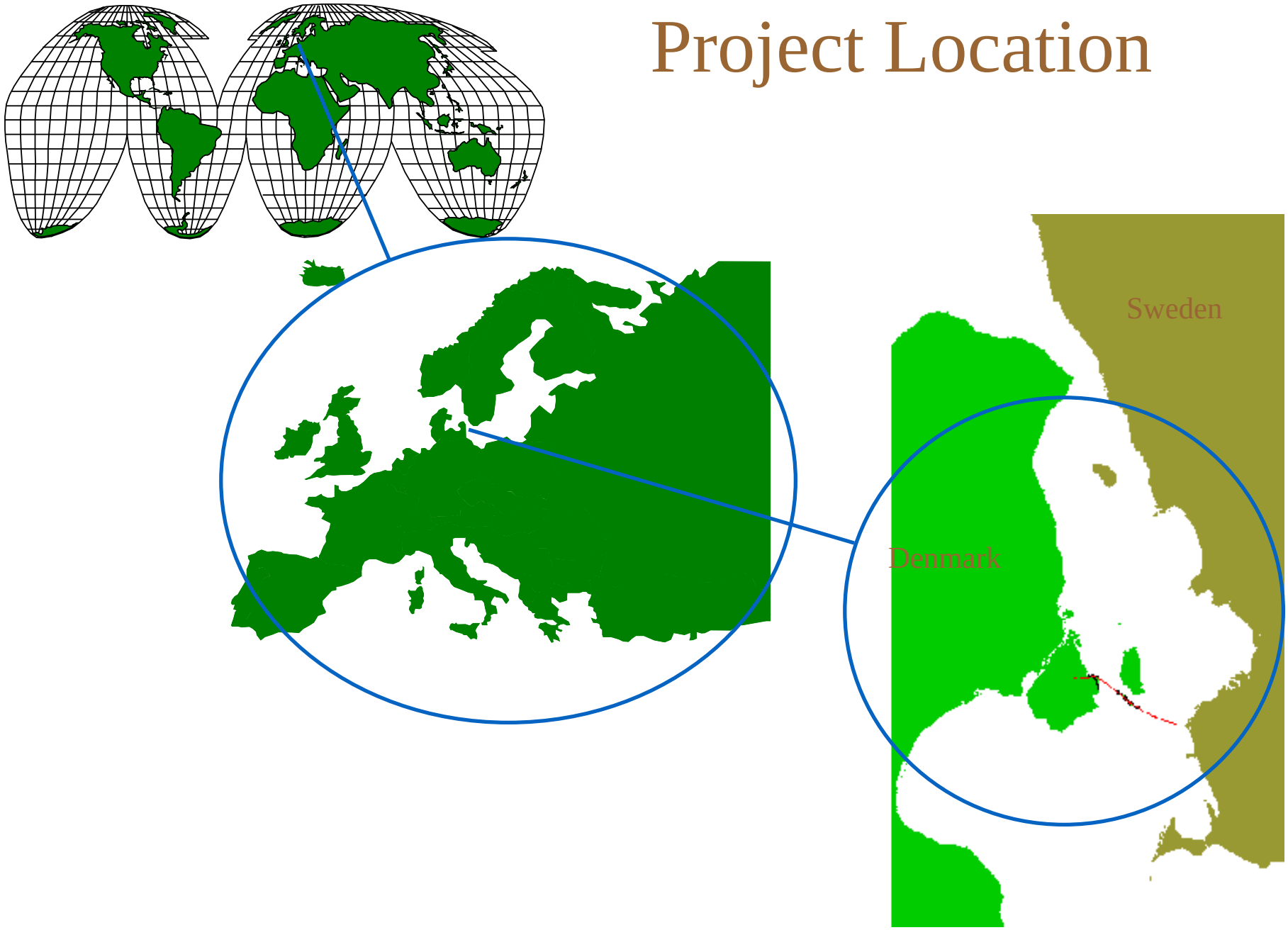
Neural Network in Time



Neural Network in Time



Project Location

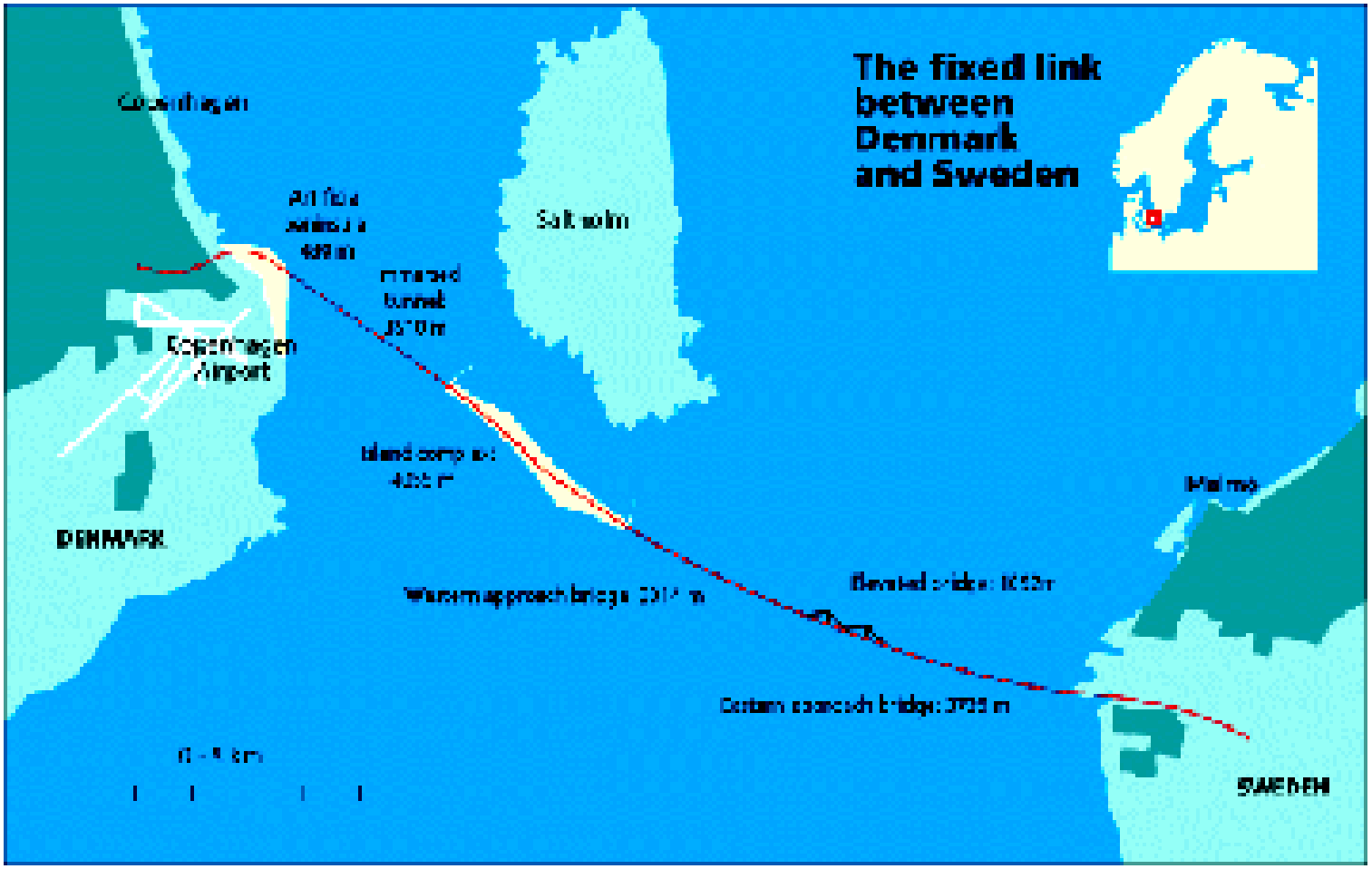


The Project

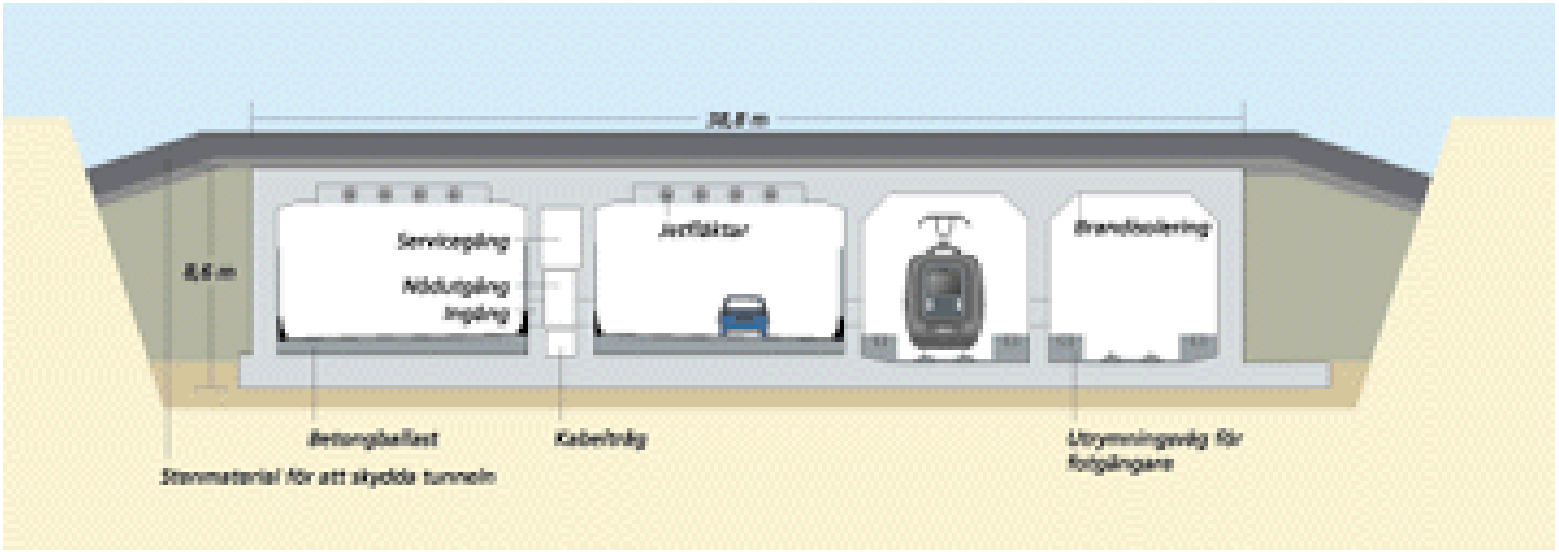
Total Span: 15.9 km

Total Cost: 3.7 billion US$

The Project



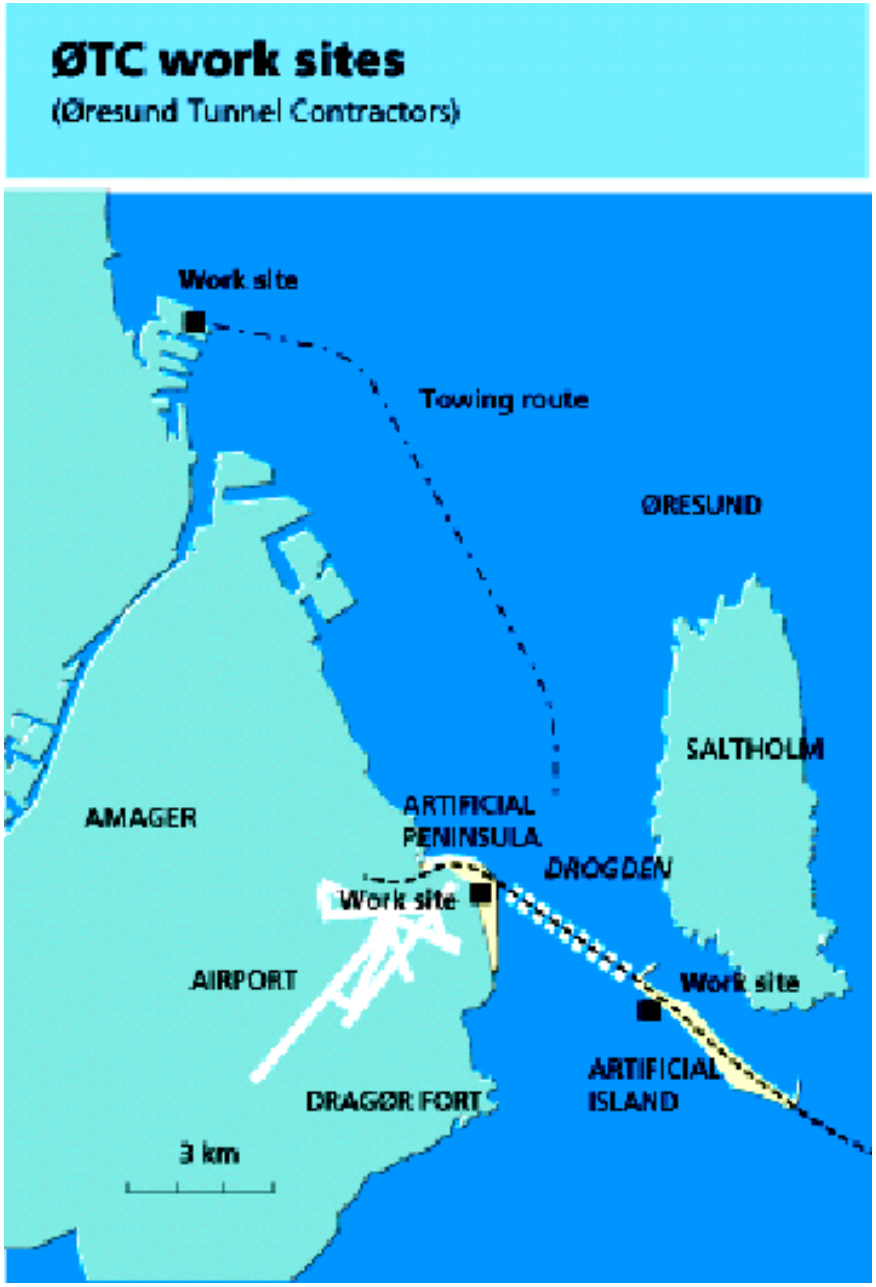
Tunnel


Servicegång
Nödutgång
Ingång
Jetfläktar
Brandisolering
Betongballast
Kabelhylla
Utrymningsväg för fotgängare

Bridge

Tunnel Element Towing

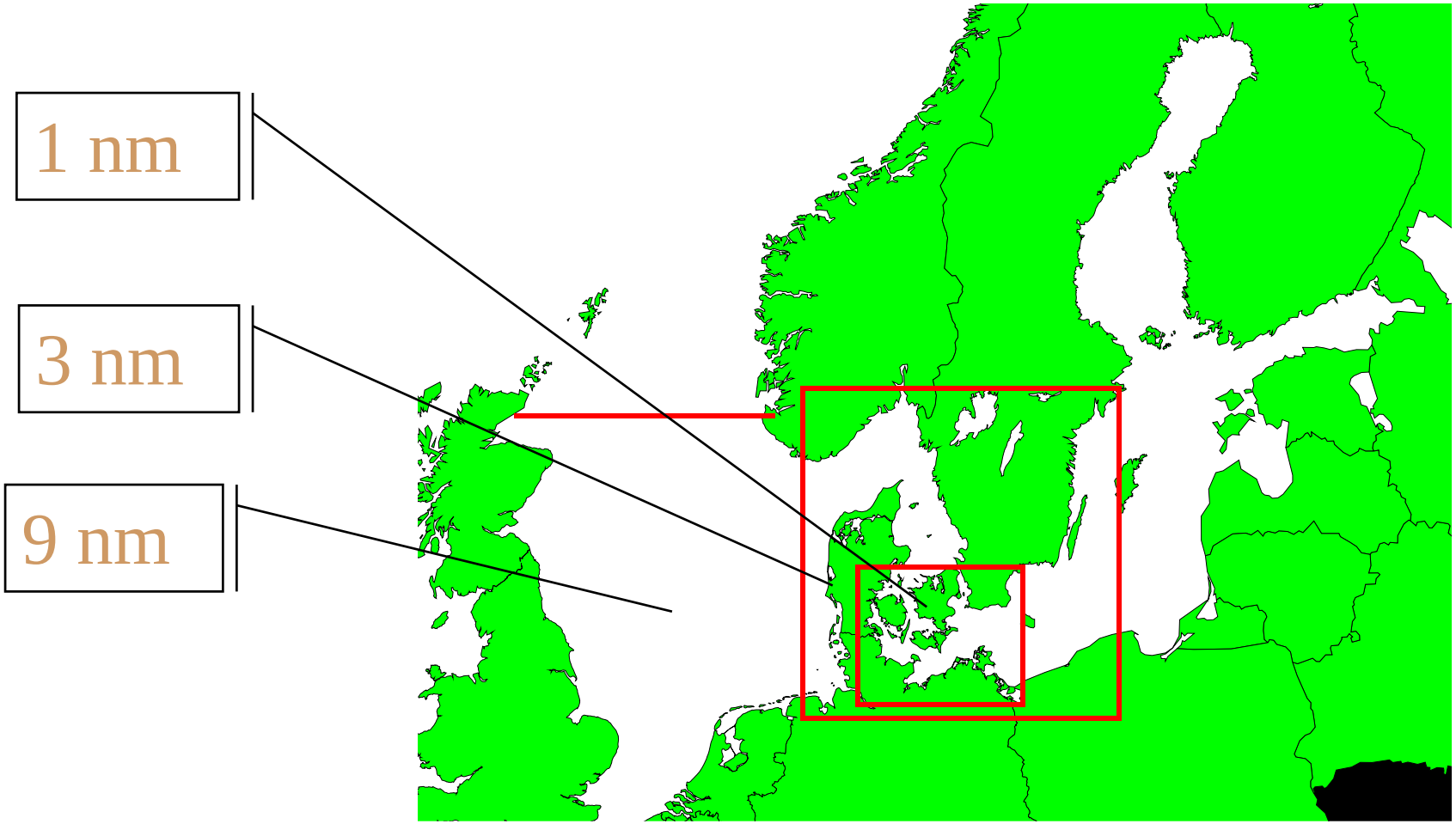
- 0.75 m/s (operational limit)
- 1.0 m/s (survival limit)
- 1.2 m/s (critical limit)



24 hour Weather Windows

	0.75 m/s	1.0 m/s	1.25 m/s	1.5 m/s
February	18.90%	49.90%	77.40%	93.70%
August	50.70%	86.40%	96.80%	99.00%
October	38.10%	68.00%	90.50%	98.30%

Nested Deterministic Models



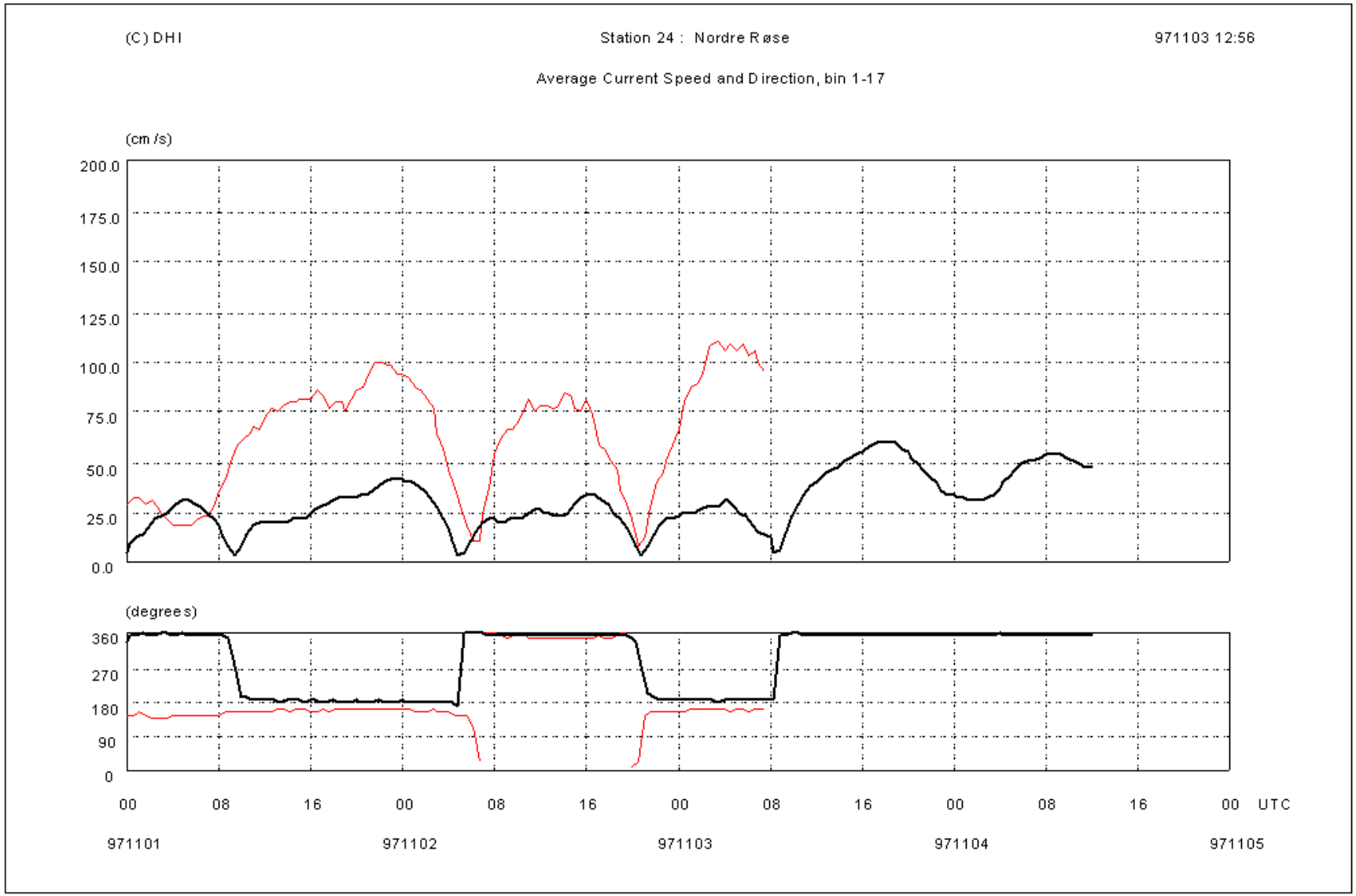
ArcView

File Edit View Theme Graphics Window Help

Scale 1:

469.28
297.51

DMI Depth average (bins 1-17) Current - latest forecast - t0plot.odb



The Idea

- Use (local) observations (water levels, wind speed, current speed and direction)
- Use global information through models (pressure fields)
- Use ANNs as a data assimilation system

ArcXDisp ver 1.0

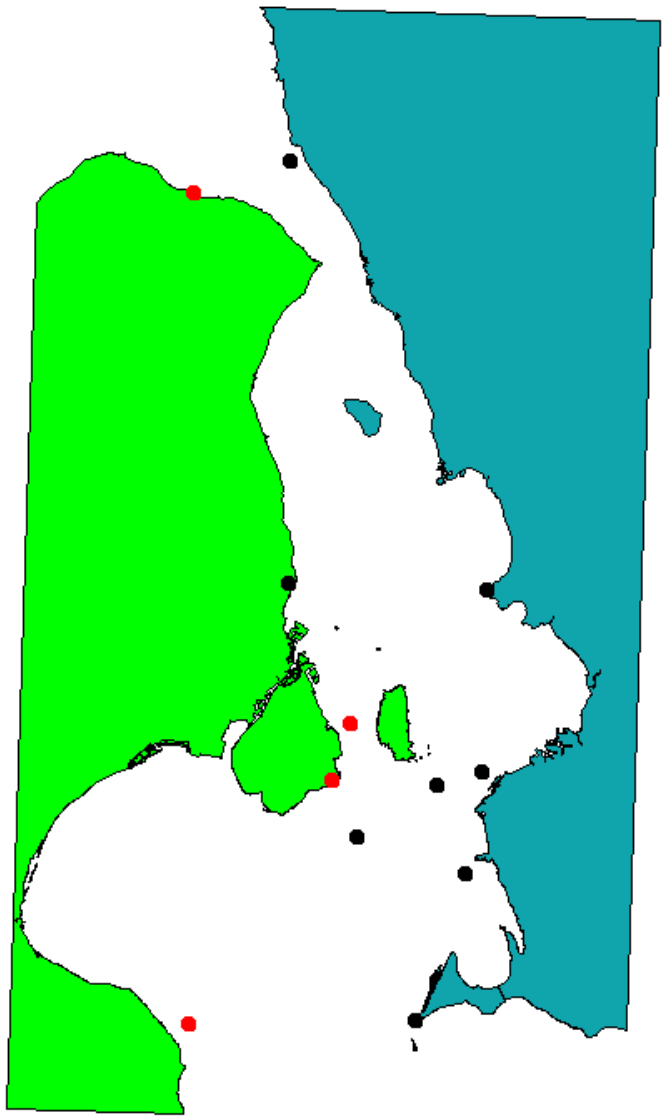
File Edit View Theme Graphics Water level Waterlevel forecast Window Help

Scale 1: 616,086

421,817.35
6,215,919.45

X-Disp

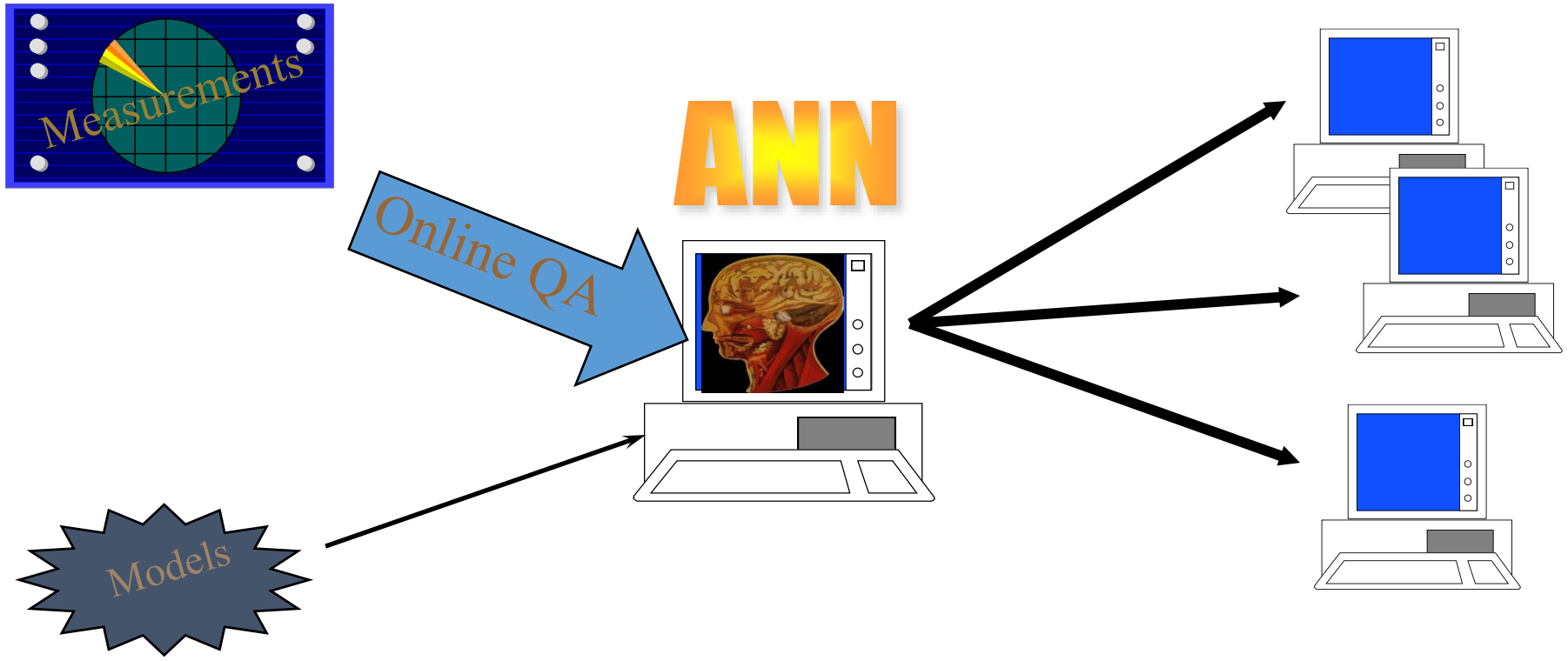
- ADCP
  - Acoustic Doppler Current Profiler
- Current forecast
  - Current forecast
- Meteorology
  - Meteorological Data - 10 Meter Wi
  - Meteorological data - Wind
- Temperature and Conductivity
  - TC(OT) Chain
- Water level
  - Acoustic Water Level Recorder
  - GMI Water Level Recorder
  - Mechanical Water Level Recorder
- Waterlevel forecast
  - Waterlevel forecast
- Wave recordings
  - Acoustic Wave Recorder
  - Wave Recorder
- Øresund



Real-Time Current Forecast

- On-line observations
- Operational deterministic forecast (MIKE 21, HIRLAM)
- Artificial Neural Networks
- Forecast Window +36 hours
- Confidence limits (90%)

System Architecture



ArcXDisp ver 1.0

File Edit View Theme Graphics Current forecast Window Help

Scale 1:

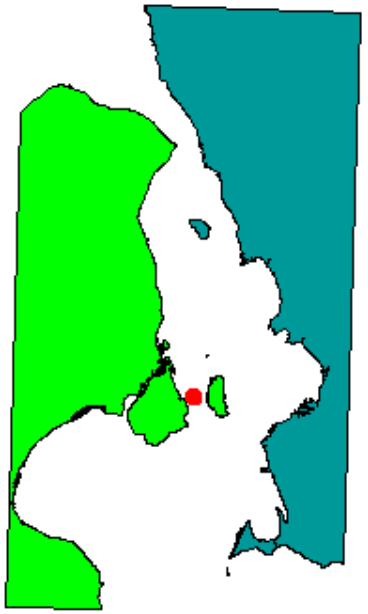
351,606.67
6,127,541.88

Active sensors - 1 of 23 (1 selected)

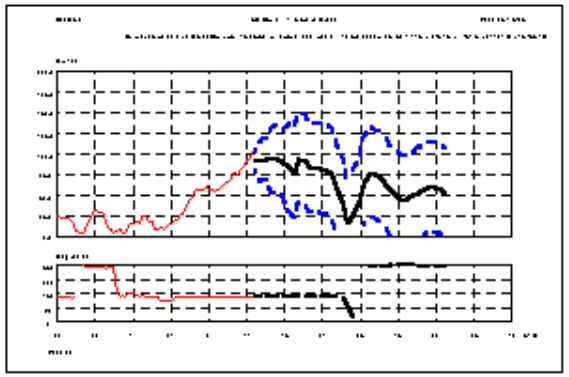
Station	Sensor Type
Nordre Røse - DHI-24	Current forecast

X-Disp

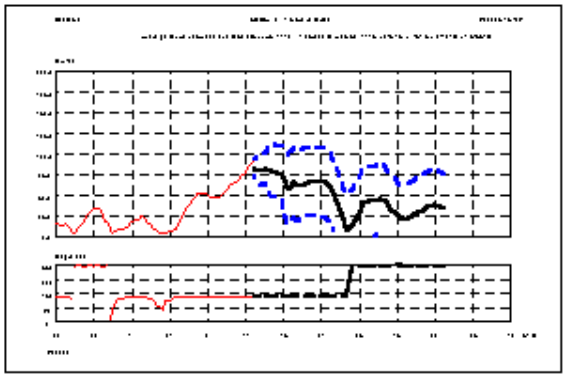
- ☐ ADCP
  - Acoustic Doppler Current Profiler
- ☑ Current forecast
  - Current forecast
- ☐ Meteorology
  - Meteorological Data - 10 Meter Wind
  - Meteorological data - Wind
- ☐ Temperature and Conductivity
  - TC(OT) Chain
- ☐ Water level
  - Acoustic Water Level Recorder
  - GMI Water Level Recorder
  - Mechanical Water Level Recorder
- ☐ Waterlevel forecast
  - Waterlevel forecast
- ☐ Wave recordings
  - Acoustic Wave Recorder
  - Wave Recorder
- ☑ Country



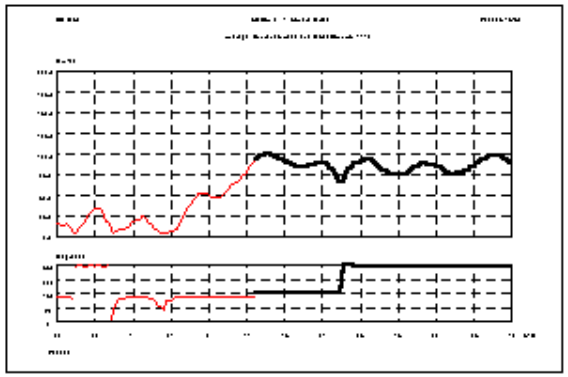
Nordre Røse - DHI-24 : Current forecast



Nordre Røse - DHI-24 : Current forecast - 2



Nordre Røse - DHI-24 : Current forecast - 3

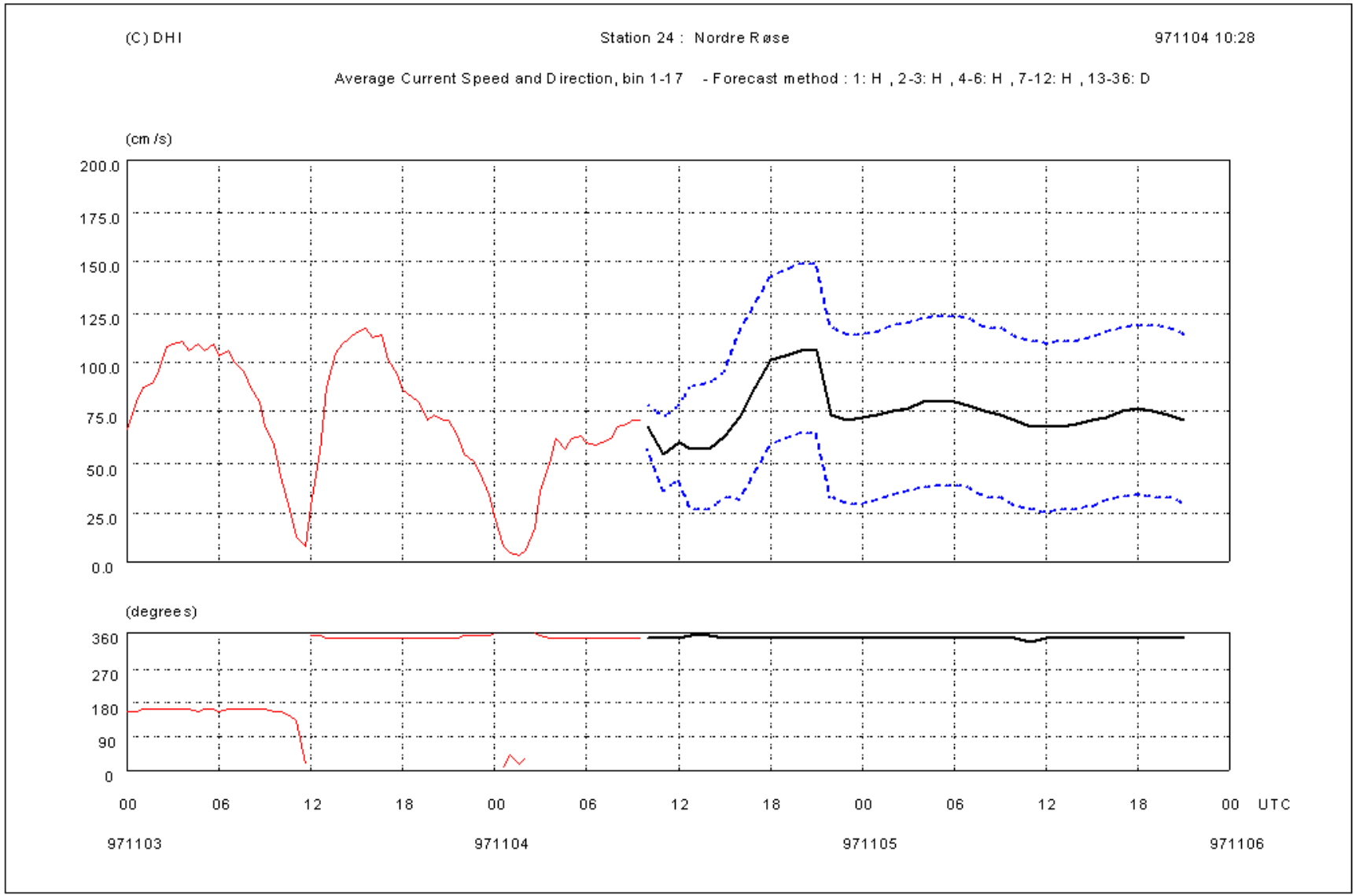


ArcXDisp ver 1.0

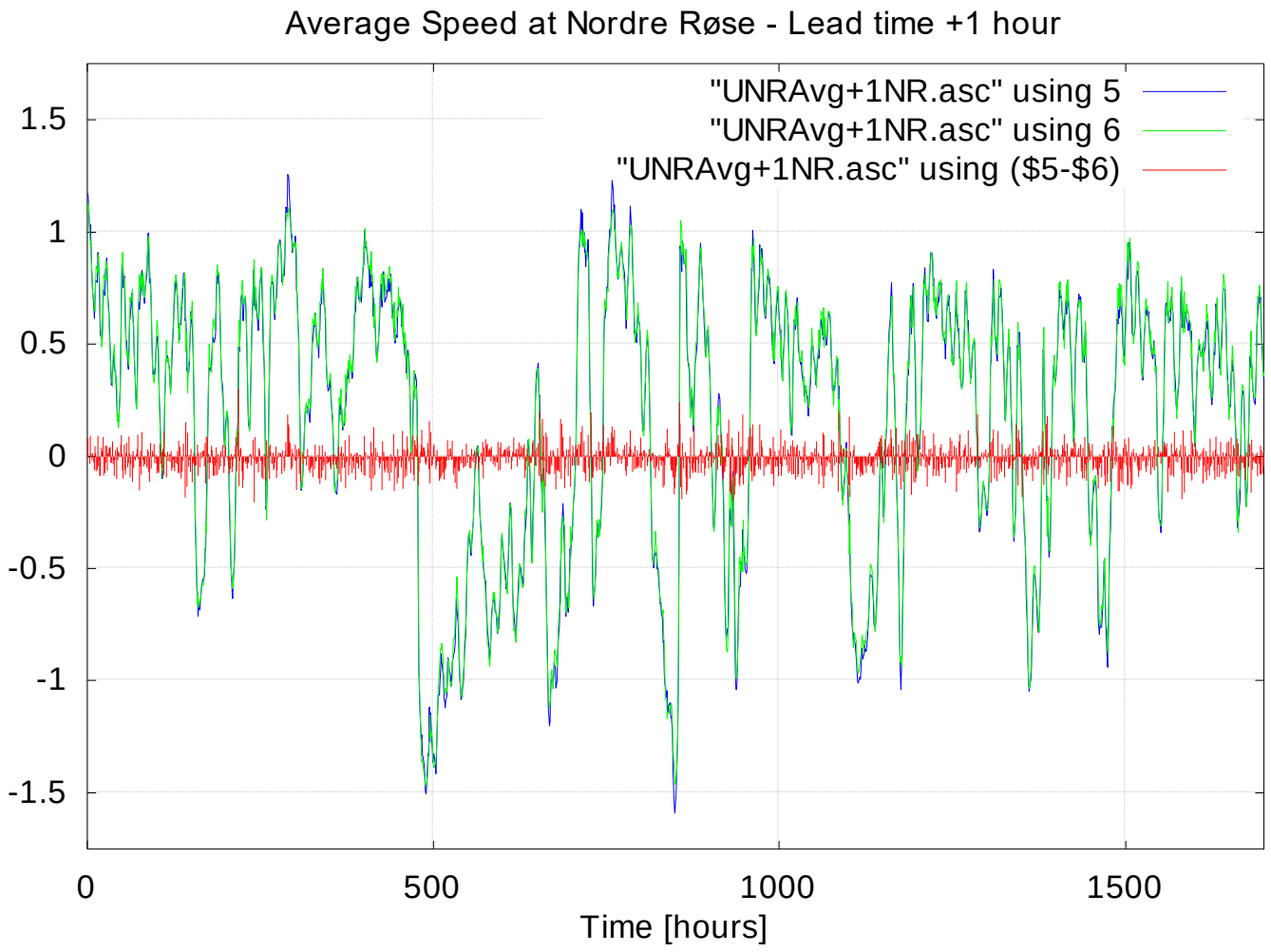
File Edit View Theme Graphics Window Help

Scale 1: 469.71 306.50

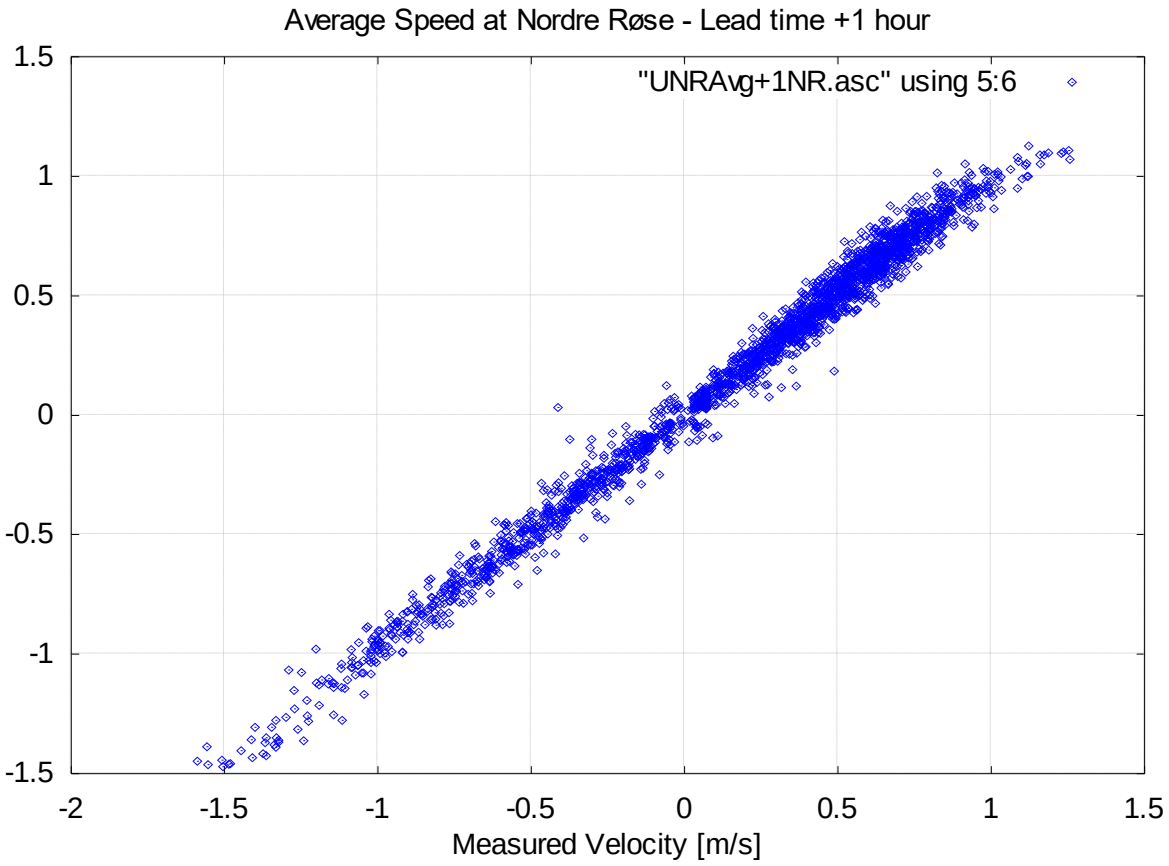
Nordre Røse - DHI-24 : Current forecast - 2



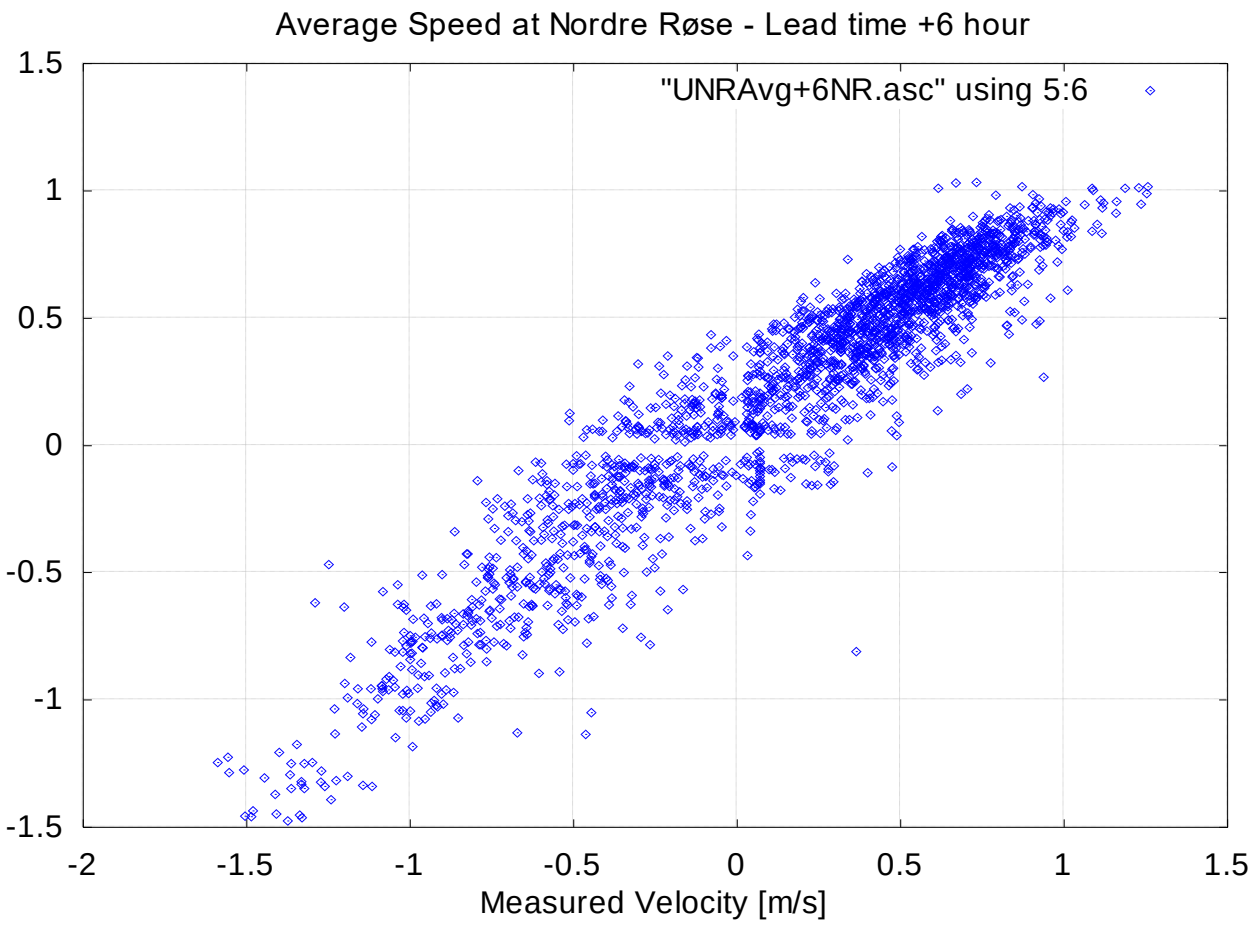
Results +1 hour



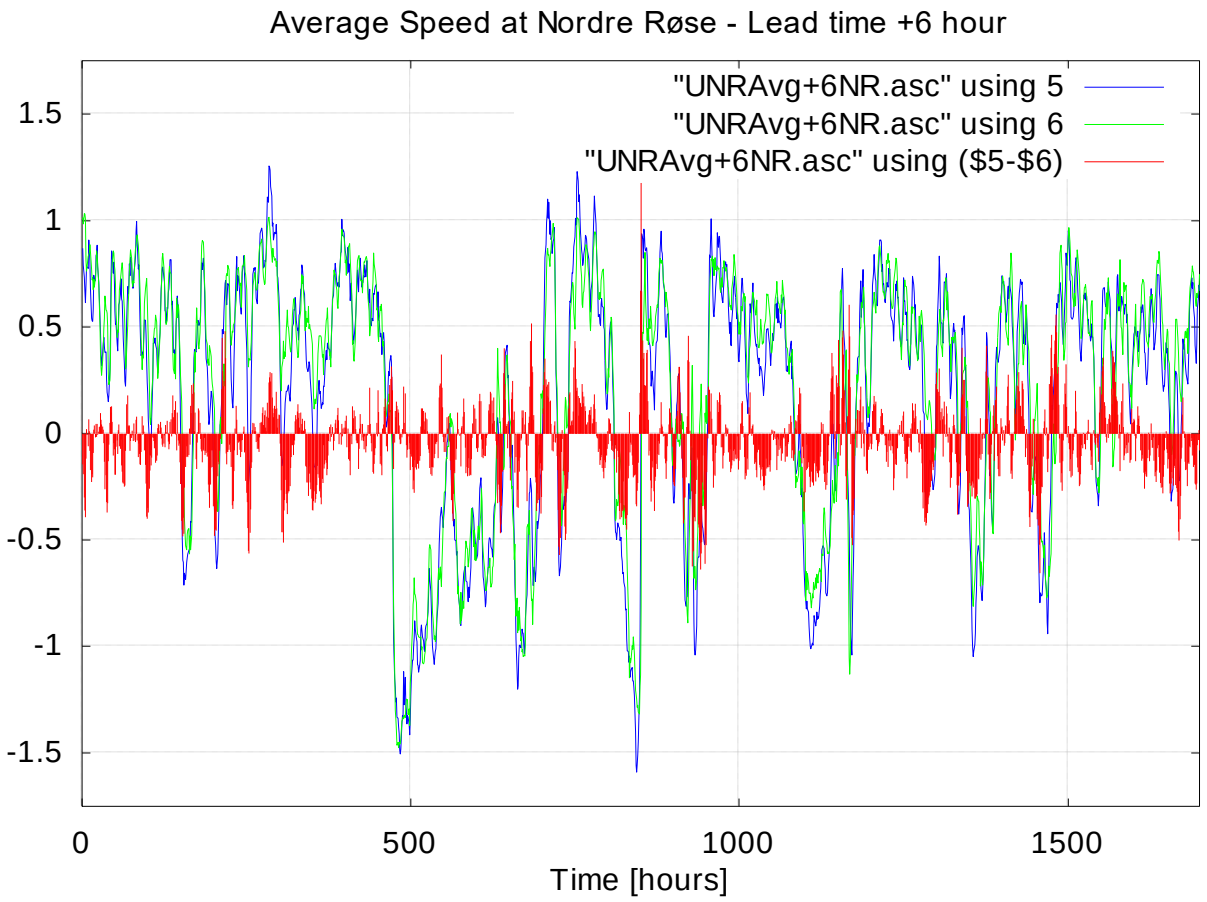
Results +1 hour



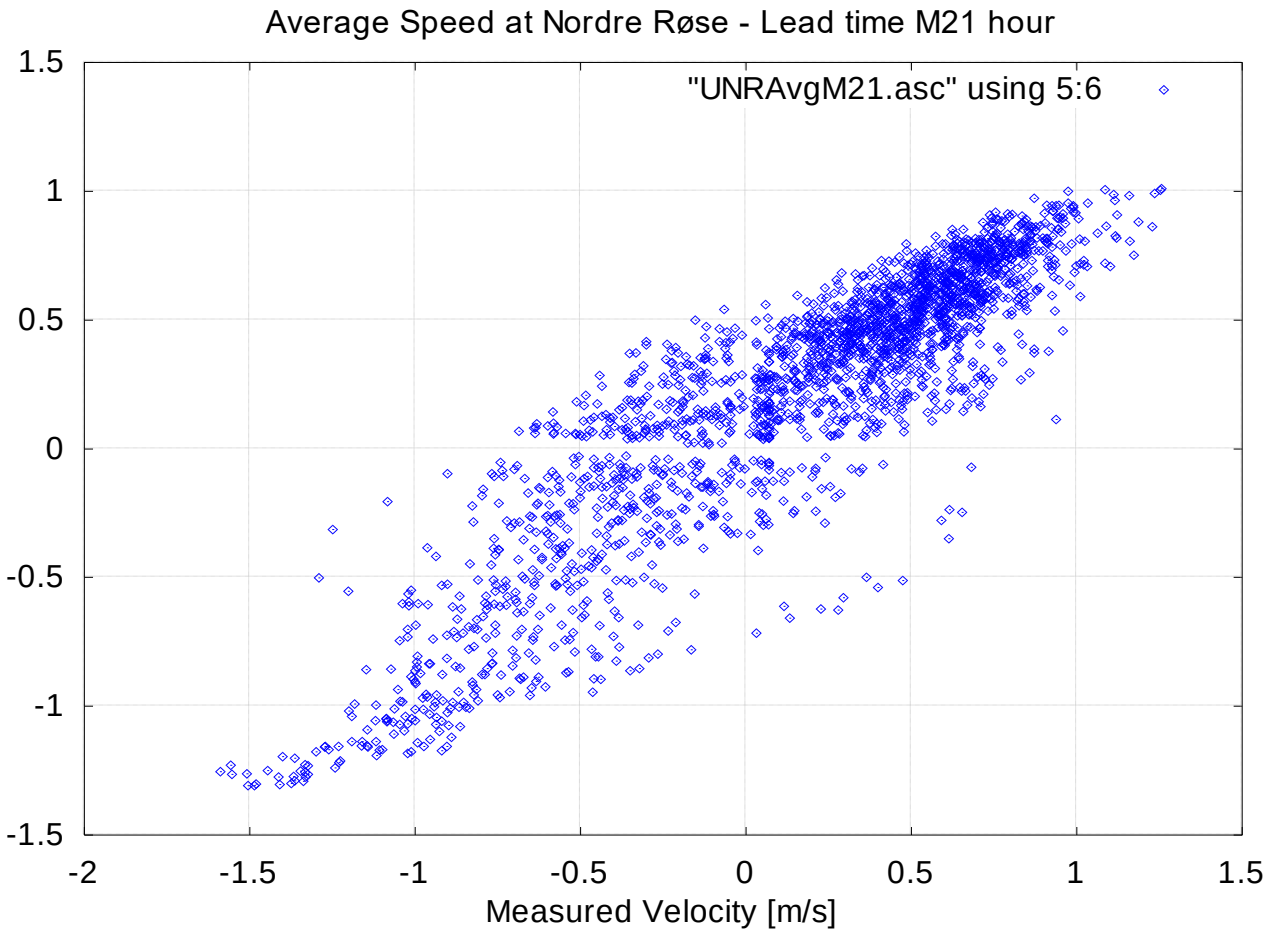
Results +6 hours



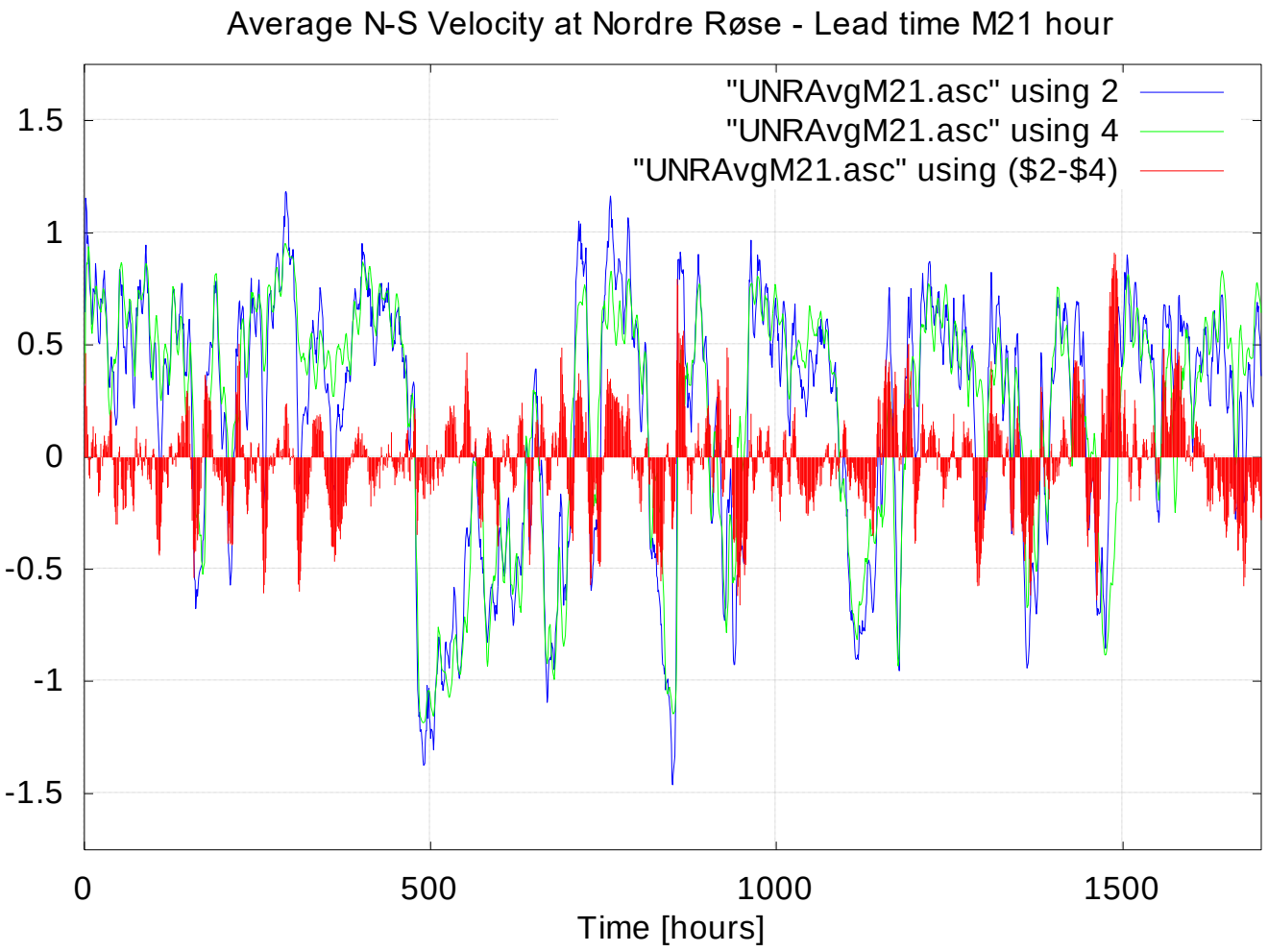
Results +6 hours



Results - up to 48 hours



Results - up to 48 hours



Results - Summary

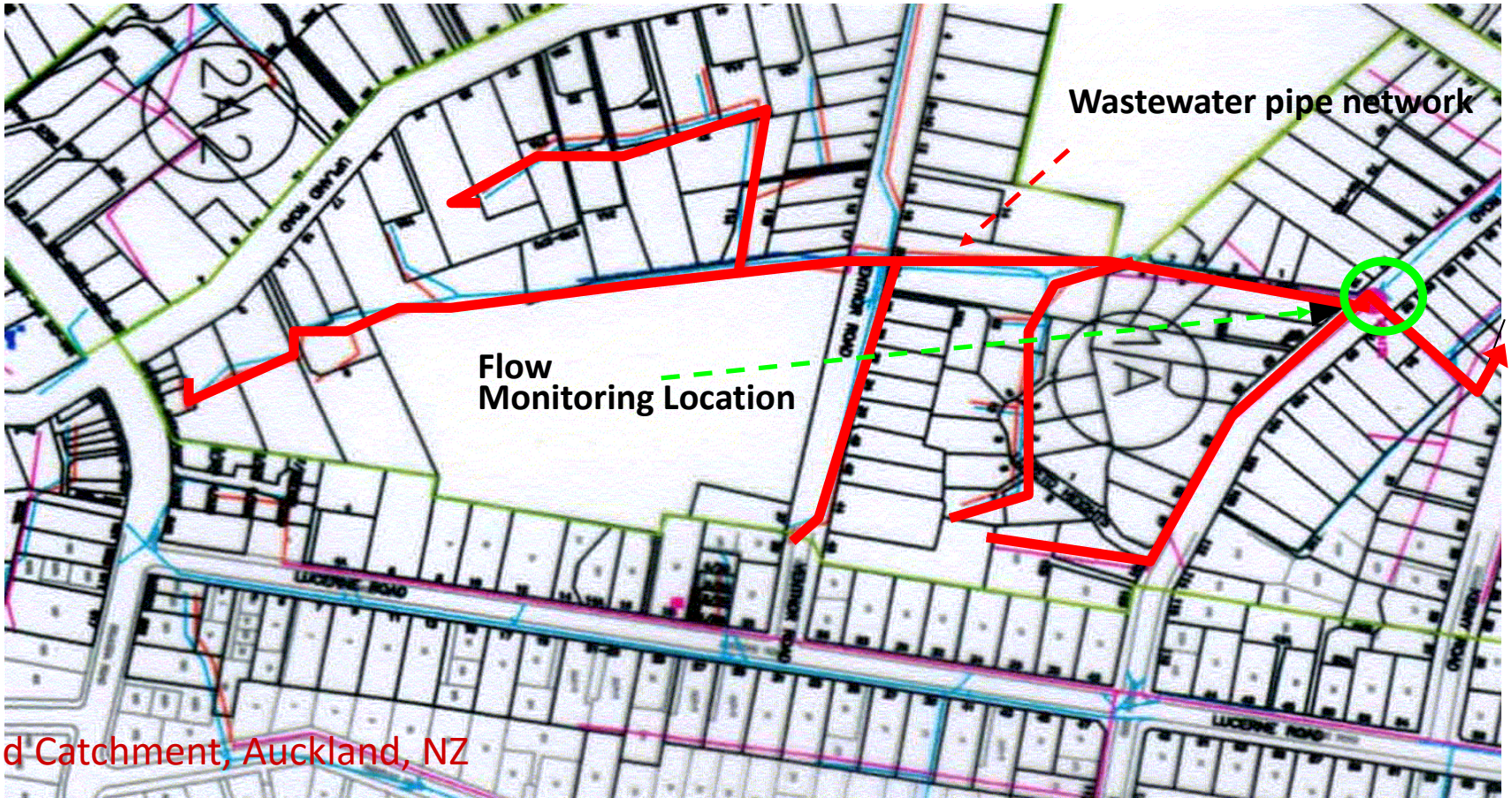
Performance	1	6	48
MSE (m/s)	0.0034	0.0311	0.0526
NMSE	0.0125	0.116	0.1955
MAE (m/s)	0.0439	0.1355	0.1718
r	0.994	0.9466	0.9026
R2	0.988	0.9002	0.8147

One more example from civil engineering field:

Hybrid Approach for Modeling Wet Weather Response in Wastewater Systems

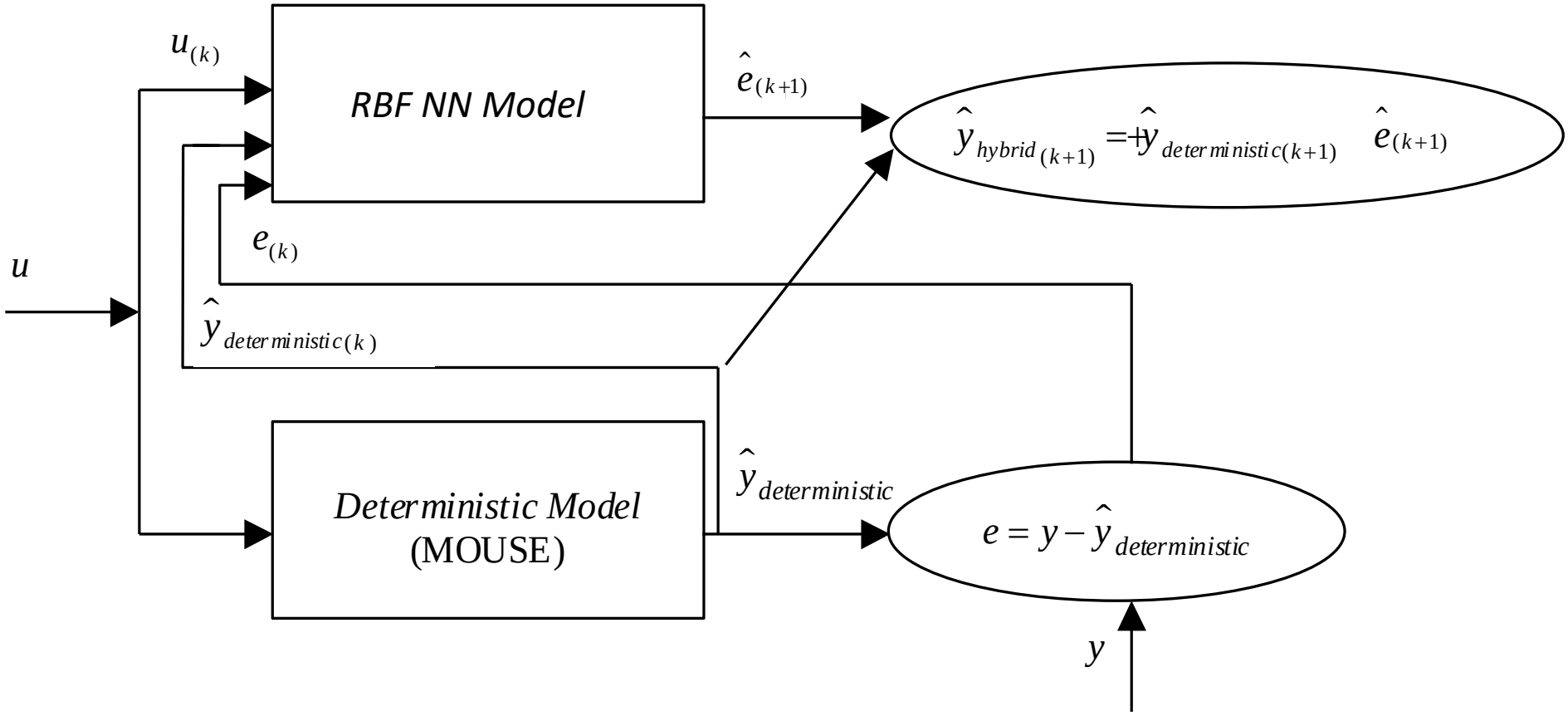
(Vojinovic, Kecman, Babovic, ASCE, J. OF WATER RESOURCES PLANNING AND MANAGEMENT, NOV/DEC 2003, 511-521)

Modeling by deterministic (first principle) models takes account of what we know, Modeling data (statistical models) takes account of uncertainty, or random phenomena.



Upland Catchment, Auckland, NZ

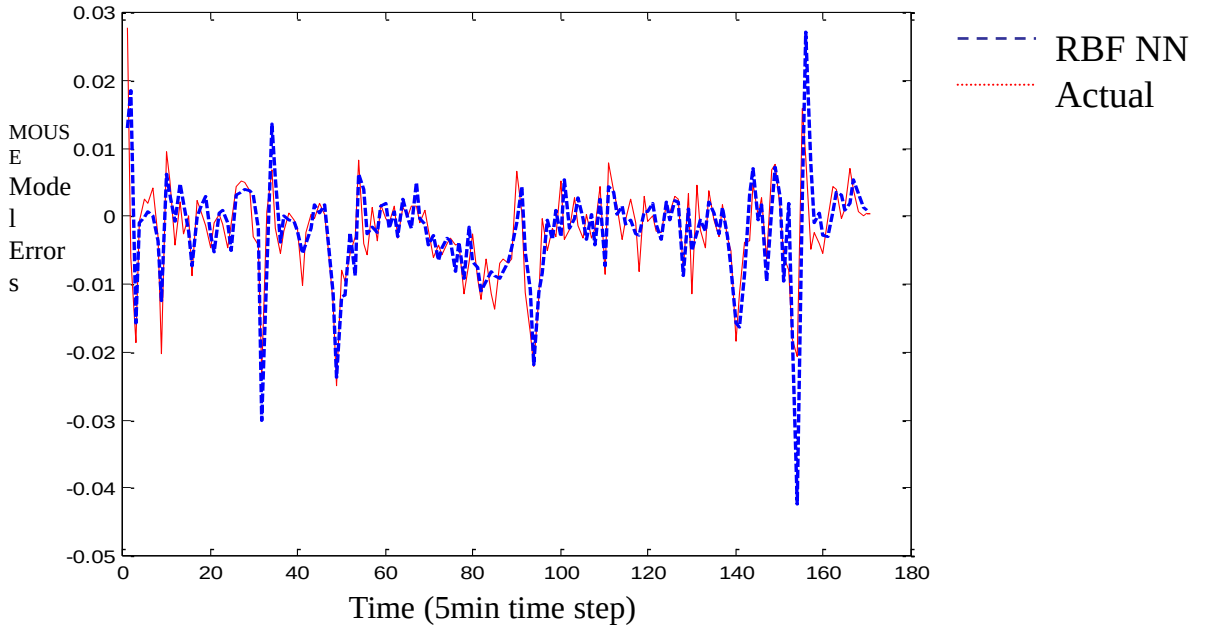
Hybrid Model

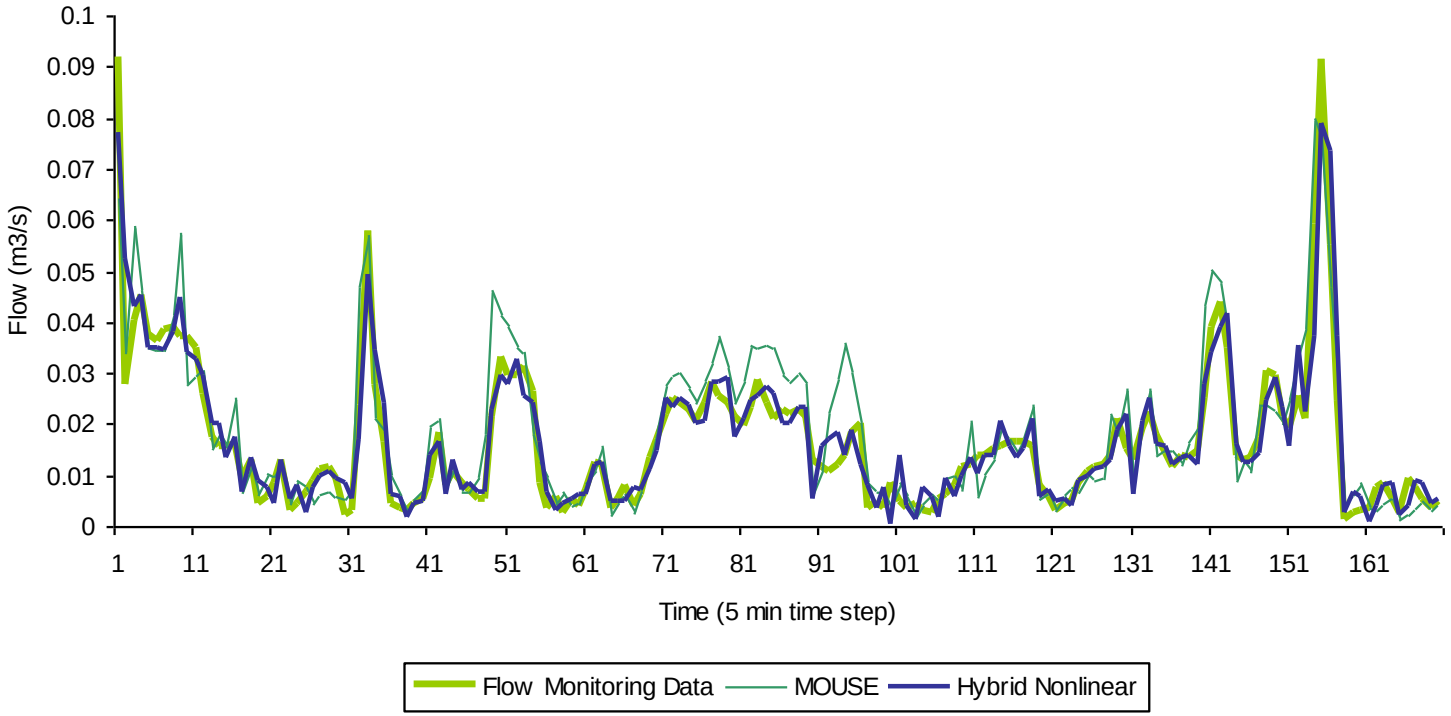


u - rainfall

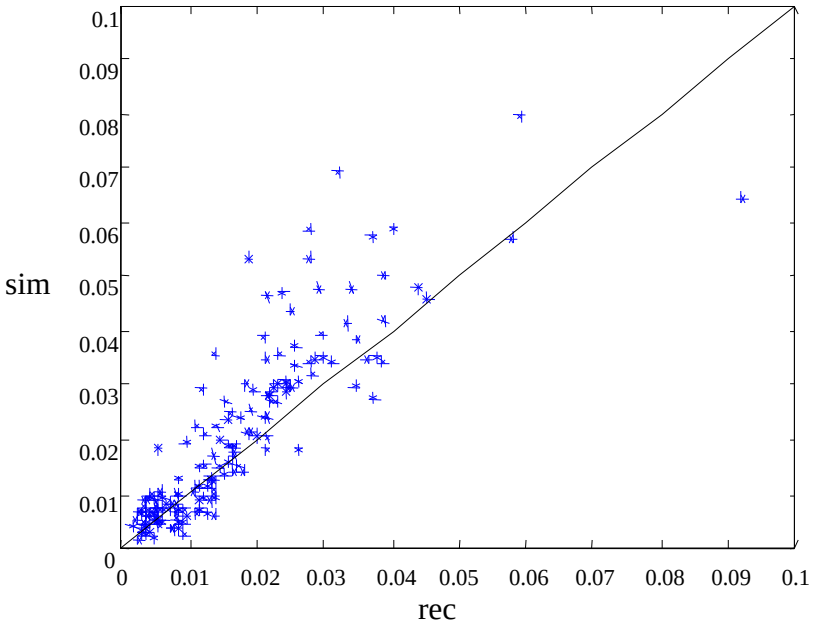
$\hat{e}$ - deterministic model error

$\hat{y}_{deterministic}$ - deterministic model output

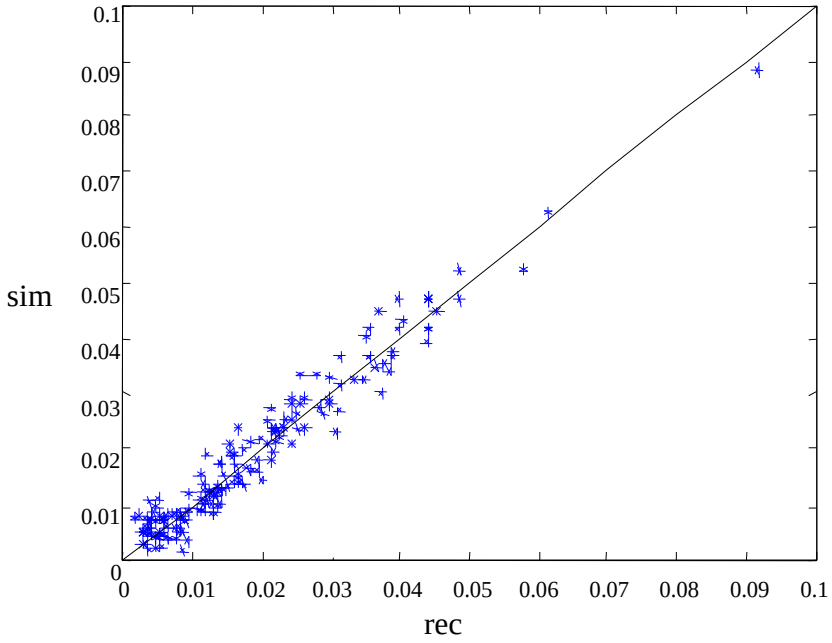

RBF NN
Actual
MOUSE Model Errors
Time (5min time step)


Flow (m3/s)
Time (5 min time step)
Flow Monitoring Data
MOUSE
Hybrid Nonlinear

MOUSE



HYBRID



FORECAST HORIZON	PERFORMANCE			
	$E_{(exp\,d\sigma)}$	*R2*	*r*	*MAE*
1	0.147 (28%)	0.910 (12%)	0.955 (4%)	0.003 (40%)
2	0.174 (15%)	0.869 (6%)	0.935 (2%)	0.004 (20%)
3	0.175 (15%)	0.866 (6%)	0.936 (2%)	0.004 (20%)
4	0.173 (16%)	0.868 (6%)	0.936 (2%)	0.004 (20%)
5	0.175 (15%)	0.864 (6%)	0.934 (2%)	0.004 (20%)

Results: Improvements in respect to the deterministic model results