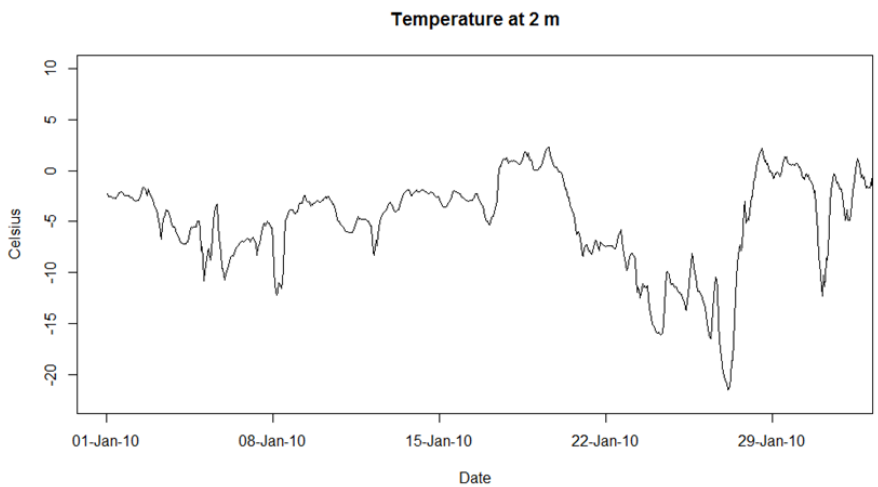
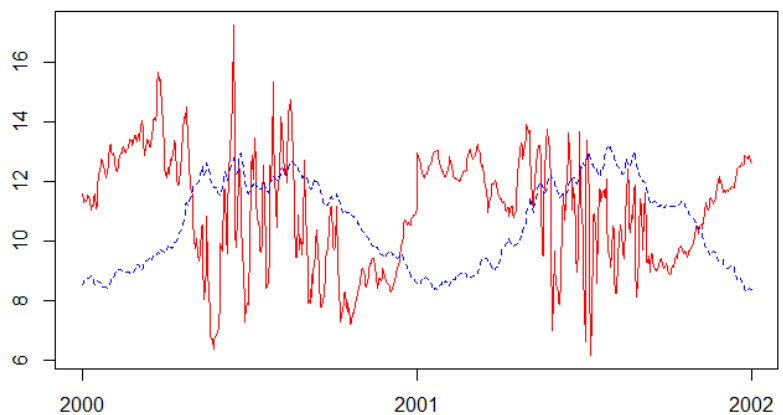
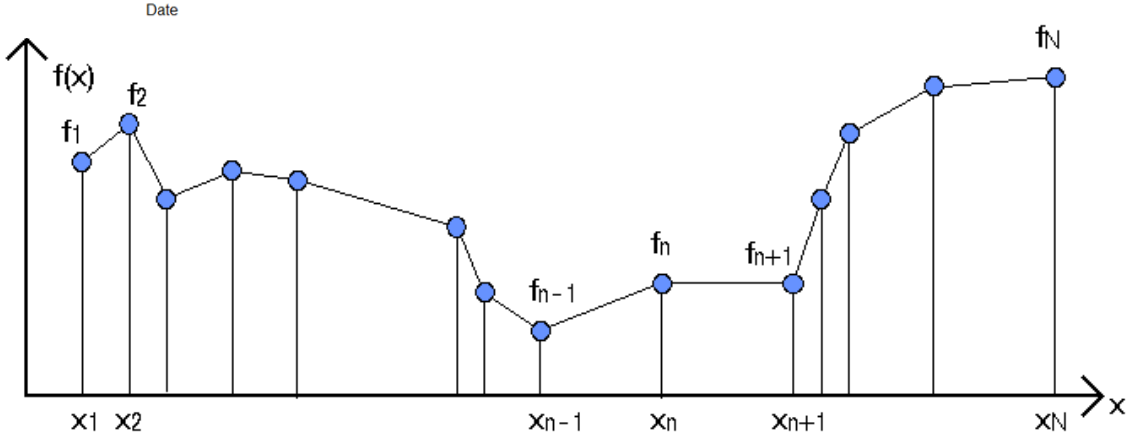
Modelling and Data Analysis with R

Introduction – Time Series







Hydroinformatics System

Modelling: Typical Working Steps for Simulation

- data pre-processing -> time series
- system simulation
  - scenario definition -> time series
  - calibration -> time series
  - validation -> time series
  - sensitivity analysis -> time series
  - uncertainty analysis -> time series
- data post-processing -> time series

Hydroinformatics System

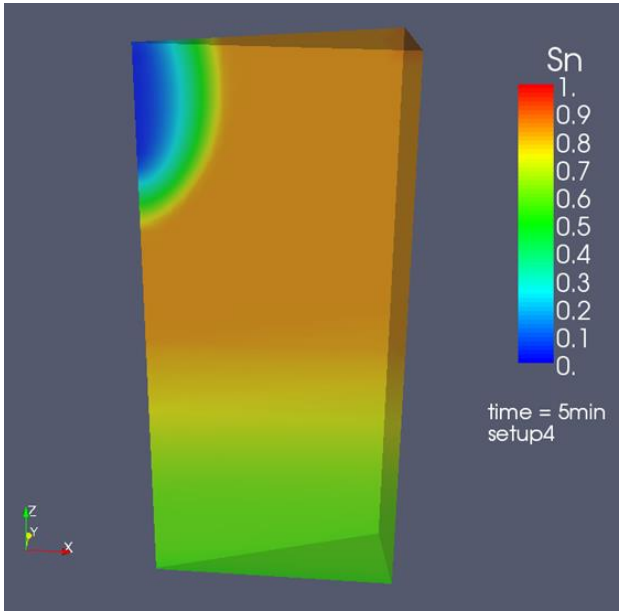
Modelling: Data Sources

- field measurements
- laboratory experiments
- simulation results

heterogeneity of data sources- > heterogeneity of time series

Field

Laboratory



Simulation

Time Series – Data Sources

Examples Field Measurement Data








Time Series – Data Sources

Sensor Specification -> MetaData

PTX 1835/1235 Series — **Druck**

Depth/Level Pressure Transmitter with Internal Lightning Protection

- Excellent stability
- ±0.1% FS or ±0.25% FS accuracy
- High integrity and reliability
- Fully welded titanium with 5 year corrosion warranty
- Output: 2-wire, 4-20mA
- Internal lightning protection (IEC 61000-4-5 Level 4)

The PTX 1835 and 1235 submersible depth/level pressure transmitters are specifically designed for depth/level measurements in groundwater, well water, canals, rivers and other similar applications where the possibility exists for lightning damage. These devices have the same high performance and excellent reliability as the PTX 1830 and 1230 with the additional benefit of internal lightning protection.

Internal lightning protection to IEC 61000-4-5, Level 4 is incorporated inside the device as a means of protecting against a possible water lightning strike. It is also recommended that a high-performance external lightning arrestor be used to provide extra protection to surrounding electronic devices.

As with Druck's PTX 1230 and 1830, the PTX 1235 and 1835 are constructed of all-welded titanium and are backed by a 5 year corrosion warranty. An advanced micromachined silicon piezoresistive pressure sensor provides excellent performance and resistance to shock and vibration. A tough, polyurethane cable is molded to the transmitter body providing a high-integrity waterproof assembly.

The fully titanium design ensures long term reliable measurements in water and wastewater management, industrial process and marine applications.

PTX 1835/1235 Series — **Druck**

Depth/Level Pressure Transmitter with Internal Lightning Protection

STANDARD SPECIFICATION

Operating Ranges
1 and 2.5 psig, and any range between 5 and 900 psig or psia
Other pressure units can be specified

Overpressure
1, 2.5 psig 8X
5 psig 6X
above 5 psi 4X
2000 psi max

Pressure Media
Fluids compatible with titanium, polyurethane and delrin

Transduction Principle
Piezoresistive micromachined silicon strain gauge

Combined Non-Linearity, Hysteresis and Repeatability
PTX 1835 ±0.1% FS BSL
PTX 1235 ±0.25% FS BSL
Improved accuracy available
Consult factory

Temperature Effects
PTX 1835
±0.3% FSTEB for ranges 5 psi and above
±0.6% FSTEB for ranges 1 and 2.5 psi

PTX 1235
±1.5% FSTEB for ranges 5 psi and above
±2% FSTEB for ranges 1 and 2.5 psi

Operating Temperature Range
-5 to 140°F

Compensated Temperature Range
30 to 86°F

Output
2-wire, 4-20mA

Excitation
9-30 Vdc

Sensor Body
All-welded titanium

Pressure Connection
Depth cone with radial inlet holes

Measurement Diaphragm
Titanium

Electrical Connection
Vented polyurethane cable molded to sensor (specify length)

Diameter
0.69 inches (17.5mm)

Weight
5 oz. nominal (excluding cable)

Safety

EMC & Surge Protection	
Electrostatic Discharge (per IEC 61000-4-2)	±4kV in contact w/ unit ±8kV in air
Radiated RF Immunity (per IEC 61000-4-3)	80 to 1000MHz@10V/m
Fast Transient (per IEC 61000-4-4)	±1kV@5/50 µS T_r/T_h
Surge Lines to Ground (per IEC 61000-4-5)	±1kV (42 Ohm Source) @ 1.2/50 µS T_r/T_h
Conducted RF Immunity (per IEC 61000-4-6)	0.15 to 80 MHz 10V/m
Lightning Surge Immunity (per IEC 61000-4-5 Level 4)	±4kV 8/20 µS T_r/T_h ±2kV 8/20 µS T_r/T_h

Ingress Protection
NEMA 6X (IP68) to 2300 ftH_2O

Insulation Resistance
Greater than 100 Megohms @ 500 Vdc

Compatible Fluids
Any fluid compatible with titanium, polyurethane and delrin

NOTE: Consult factory for FM/CSA/UL IS Class I, Div 1, Groups A, B, C, D and ATEX IS EEx ia IIC

OPTIONS

A) Sinkweight (P/N: DA2608-1-01)
B) Cable clamp (P/N: 192-373-01)

ASSOCIATED PRODUCTS

PTX 1885 - same as PTX 1835 with Tefzel cable
DPI 280 - Digital display
STE 110 - Sensor termination enclosure with desiccant
DPI 610 - Portable Pressure Calibrator
Lightning Arrestor - P/N: PT 1X2-24DC-ST with PT 1X2-BE

ORDERING INFORMATION

(1) Select model number
(2) State pressure range and units
(3) State output required
(4) State options (if required)

Continuing development sometimes necessitates specification changes without notice.

Druck is an ISO 9001 registered company

INSTALLATION DRAWINGS: Dimensions in inches

Druck Incorporated
4 Dunham Drive
New Fairfield , CT 06812
Tel: (203) 746-0400
Fax: (203) 746-2494
E-Mail: usa.sales@druck.com
www.druck.com
www.pressure.com

Representative

PDS-A148 5/02

Time Series – Data Files

Data Storage

- analogue -> paper based
- digital -> file based

  traditional (proprietary) text files
  files using standard formats
  data bases with proprietary data structure
  data bases with standard data formats/structures

Time Series – Data Files

File types

- ASCII files
  text files, readable in a text editor
  reading and writing requires transformation/parsing
  memory depends on data accuracy (number of digits)
  example -2.134562e05 -> 12 characters -> 12 bytes
- binary files
  machine data representation, not readable for humans
  reading and writing directly without transformation
  memory depends on number of vales and data type
  example -2.134562e05 -> 4 or 8 bytes (float or double)

Time Series – Data Files

File Formats

- defines the structure of a file:
  - order and number of data stored
  - special characters (e.g. comments)
  - key words for control and structure
- format specification is software independent
- proprietary, open and standard formats
- I/O interfaces implement the format specification
- can be used for data exchange

Time Series – Data Files

File Formats Examples

- general formats
  dxf files -> Autocad
  shape files -> ESRI
- formats used for time series
  xls(x) -> Microsoft excel spread sheets
  csv -> common separated values
  wml -> WaterML

-> no general, interdisciplinary format for time series

Time Series – Data Files

File Types

- raw data

  -> data as collected from the original source
  -> sensor values -> not always directly physical state variables
  -> including gaps, outlier, errors
  -> file size depends on data logger size and storage strategy
  -> proprietary file formats

- processed data

  -> data is pre-processed and validated
  -> raw data files are combined for time objects (e.g. day, year)
  -> outliers and errors might be filtered
  -> “standard” file formats

Time Series – Data Examples

Sensor Output – Data Logger Borehole Incliometer

```
"TimeInt";"TimeStr";"Batterie";"INKL01A";"INKL01B";"INKL02A";"INKL02B";"INKL03A";"INKL03B";"INKL04A";"INKL04B";"P
WDG1";"PWDG2";"PWDG3"
1240477442;"23/04/2009 09:04:02";14.081736;10.146138;-17.328259;63.360199;-36.680210;74.965454;-27.270308;-
1.068114;-15.539164;126.908859;94.769165;56.832054
1240477834;"23/04/2009 09:10:34";14.145227;10.134693;-17.313951;63.339214;-36.750778;74.957825;-27.267448;-
1.067161;-15.537257;126.937469;94.826385;56.927429
1240480800;"23/04/2009 10:00:00";13.981835;10.144230;-17.321583;63.357330;-36.743153;74.970215;-27.280798;-
1.070022;-15.531534;126.918396;94.816849;56.877834
1240484576;"23/04/2009 11:02:56";14.058204;10.141369;-17.327303;63.363056;-36.740292;74.974037;-27.270308;-
1.074790;-15.531534;126.947006;94.797775;56.847313
1240488176;"23/04/2009 12:02:56";13.907244;10.131833;-17.322536;63.370682;-36.752689;74.984520;-27.270308;-
1.073836;-15.545841;126.975624;94.788239;56.912170
1240491776;"23/04/2009 13:02:56";13.906356;10.134693;-17.334934;63.384033;-36.749828;74.992157;-27.273170;-
1.070022;-15.564913;126.947006;94.759628;56.908356
1240495376;"23/04/2009 14:02:56";13.894368;10.131833;-17.330164;63.389751;-36.758411;75.002647;-27.284615;-
1.068114;-15.550609;126.918396;94.845459;56.904541
1240498976;"23/04/2009 15:02:56";13.615980;10.139462;-17.320625;Undef;-36.751736;74.995018;-27.278893;-1.071929;-
15.567774;126.899323;94.778702;56.877834
1240502576;"23/04/2009 16:02:56";13.414404;10.130879;-17.327303;63.407879;-36.754597;75.002647;-27.285566;-
1.079559;-15.567774;126.842102;94.692871;56.851128
1240506176;"23/04/2009 17:02:56";13.376664;10.147092;-17.322536;63.413605;-36.751736;75.010269;-27.299873;-
1.076698;-15.562054;126.775345;94.702408;56.839684
1240509776;"23/04/2009 18:02:56";13.186188;10.147092;-17.319674;63.425049;-36.771759;75.022675;-27.293198;-
1.075744;-15.542979;126.832565;94.645195;56.843498
1240513376;"23/04/2009 19:02:56";13.026348;10.142323;-17.330164;63.425049;-36.756504;75.021721;-27.294149;-
1.073836;-15.555378;126.756271;94.645195;56.839684
1240516976;"23/04/2009 20:02:56";12.959304;10.144230;-17.320625;63.423134;-36.761272;75.033165;-27.297012;-
1.067161;-15.549655;126.803955;94.673798;56.839684
1240520576;"23/04/2009 21:02:56";12.916236;10.140416;-17.318720;63.444111;-36.764133;75.031258;-27.303688;-
1.077651;-15.548702;126.823029;94.664261;56.812981
1240524176;"23/04/2009 22:02:56";12.882492;10.129926;-17.326349;63.454609;-36.764133;75.050331;-27.300825;-
1.080512;-15.547747;126.823029;94.607048;56.839684
1240527776;"23/04/2009 23:02:56";12.854520;10.136602;-17.314905;63.461281;-36.760319;75.043655;-27.304640;-
1.079559;-15.539164;126.756271;94.597511;56.793903
1240531376;"24/04/2009 00:02:56";12.835428;10.129926;-17.323488;63.469868;-36.755550;75.066544;-27.302734;-
1.081466;-15.542025;126.775345;94.559364;56.820610
1240534976;"24/04/2009 01:02:56";12.819000;10.137555;-17.330164;63.480354;-36.769855;75.061775;-27.303688;-
1.070976;-15.527721;126.746735;94.597511;56.801533
```

Time Series – Data Examples

Sensor Output – Data Logger Water Discharge

```
QUELLE01 Datenlücke 07.01.2006 14:46: bis 07.01.2006 20:06 mit * gekennzeichnet
01.01.2006 00:06:51;1.001 ;6.17
01.01.2006 00:16:51;1.001 ;6.17
01.01.2006 00:26:51;1.001 ;6.17
01.01.2006 00:36:51;1.001 ;6.17
01.01.2006 00:46:51;1.001 ;6.17
01.01.2006 00:56:51;1.001 ;6.17
01.01.2006 01:06:51;1.001 ;6.17
01.01.2006 01:16:51;1.001 ;6.17
01.01.2006 01:26:51;1.001 ;6.17
01.01.2006 01:36:51;1.001 ;6.17
01.01.2006 01:46:51;1.001 ;6.17
01.01.2006 01:56:51;1.001 ;6.17
01.01.2006 02:06:51;1.001 ;6.17
01.01.2006 02:16:51;1.001 ;6.19
01.01.2006 02:26:51;1.001 ;6.17
01.01.2006 02:36:51;1.001 ;6.17
01.01.2006 02:46:51;1.001 ;6.19
01.01.2006 02:56:51;1.001 ;6.19
01.01.2006 03:06:51;1.001 ;6.19
01.01.2006 03:16:51;1.001 ;6.17
01.01.2006 03:26:51;1.001 ;6.19
01.01.2006 03:36:51;1.001 ;6.19
01.01.2006 05:06:51;1.001 ;6.19
01.01.2006 05:16:51;1.001 ;6.21
01.01.2006 05:26:51;1.001 ;6.21
01.01.2006 05:36:51;1.001 ;6.21
…
```

Time Series – Data Examples

Sensor Output – Data Logger Temperature

```
"Plot Title: 1133342 "
"#"          "Time, GMT+02:00"       "Temp, °C(LGR S/N: 1133342)"        "Batt, V(LGR S/N: 1133342)"
             "Ext. Line Event(LGR S/N: 1133342)" "Coupler Attached(LGR S/N: 1133342)"            "Host
Connected(LGR S/N: 1133342)"        "Stopped(LGR S/N: 1133342)"         "End Of File(LGR S/N: 1133342)"
1            21.09.07 16:00:00       12,883      3,05        0,0
2            21.09.07 16:20:00       12,690      3,05
3            21.09.07 16:40:00       12,980      3,05
4            21.09.07 17:00:00       12,690      3,05
5            21.09.07 17:20:00       12,690      3,05
6            21.09.07 17:40:00       12,883      3,05
7            21.09.07 18:00:00       12,787      3,05
8            21.09.07 18:20:00       12,401      3,05
9            21.09.07 18:40:00       12,401      3,05
10           21.09.07 19:00:00       12,497      3,05
11           21.09.07 19:20:00       11,819      3,05
12           21.09.07 19:40:00       11,722      3,05
13           21.09.07 20:00:00       12,013      3,05
14           21.09.07 20:20:00       12,497      3,05
15           21.09.07 20:40:00       12,013      3,05
16           21.09.07 21:00:00       12,304      3,05
17           21.09.07 21:20:00       12,304      3,05
18           21.09.07 21:40:00       12,497      3,05
19           21.09.07 22:00:00       12,110      3,05
20           21.09.07 22:20:00       12,304      3,05
21           21.09.07 22:40:00       11,819      3,05
22           21.09.07 23:00:00       12,401      3,05
23           21.09.07 23:20:00       12,304      3,05
24           21.09.07 23:40:00       12,690      3,05
25           22.09.07 00:00:00       12,304      3,05
26           22.09.07 00:20:00       12,207      3,05
…
```

Time Series – Data Examples

Sensor Output – Data Logger MultiSensor

```
SX80018002800180018000800280018500822284228001800180018001800080018002800199999999999999999999999999999999999999
999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999
CH57642968
GK00
GTMRSX
GV1206
…
KBPegel-SP
KEcm
KBRichtung
KEGrad
KBBoe
KEm/s
KBWindges.
KEm/s
KBLT-Dorf
KEøc
KBF-Dorf
KE%rF
KBNieders.
KEmm
…
IM0000000101060118 1185 0113 0060 0152 1266 0094 0345 0196 0038 0010 0953 0059 0203 0071 0008 1268
IM0010000101060118 1185 0114 0060 0150 1265 0094 0040 0078 0024 0010 0955 0061 0202 0070 0008 1268
IM0020000101060118 1185 0114 0060 0150 1265 0094 0054 0147 0045 0011 0950 0061 0202 0070 0007 1267
IM0030000101060117 1185 0113 0060 0148 1265 0094 0291 0186 0100 0011 0951 0062 0202 0070 0008 1267
IM0040000101060118 1185 0112 0060 0144 1264 0094 0284 0176 0023 0011 0949 0063 0202 0071 0007 1267
IM0050000101060117 1185 0112 0060 0144 1264 0094 0032 0176 0036 0010 0953 0063 0202 0070 0007 1267
IM0100000101060117 1185 0112 0060 0154 1264 0094 0279 0098 0061 0010 0952 0063 0201 0070 0007 1266
IM0110000101060117 1184 0113 0060 0151 1263 0095 0283 0078 0053 0009 0954 0063 0201 0070 0006 1266
…
```

Time Series – Data Examples

Sensor Output – Data Logger Thermistor Chain

```
100,2012,135,207,20,14.855,14.851,14.857,14.858,14.837,14.78,14.64,14.413,12.096,10.812,9.29,8.962,8.214,7.963
,7.722,7.554,7.417,7.385,7.302,6.964,6.639,6.268,5.869,5.546,5.307,4.812,4.397,4.187,4.137,4.121,4.096,4.086,4
.075,4.076
100,2012,135,207,34,14.854,14.854,14.86,14.857,14.843,14.808,14.649,14.364,12.407,10.852,9.267,8.953,8.198,7.9
57,7.705,7.543,7.419,7.385,7.3,6.964,6.638,6.264,5.869,5.538,5.303,4.814,4.399,4.189,4.138,4.121,4.102,4.086,4
.075,4.076
100,2012,135,208,20,14.847,14.848,14.856,14.851,14.828,14.801,14.61,14.181,12.007,10.844,9.266,8.94,8.192,7.95
5,7.708,7.544,7.42,7.385,7.305,6.963,6.638,6.26,5.868,5.54,5.306,4.813,4.399,4.19,4.138,4.121,4.102,4.085,4.07
6,4.076
100,2012,135,208,33.9,14.865,14.856,14.863,14.852,14.828,14.738,14.543,13.739,11.449,10.529,9.213,8.814,8.169,
7.952,7.691,7.533,7.419,7.383,7.302,6.964,6.638,6.252,5.868,5.531,5.31,4.817,4.403,4.192,4.137,4.121,4.103,4.0
86,4.075,4.075
100,2012,135,209,20,14.864,14.859,14.863,14.856,14.819,14.742,14.539,13.122,11.345,10.477,9.207,8.777,8.168,7.
952,7.69,7.529,7.42,7.384,7.307,6.963,6.64,6.253,5.869,5.528,5.309,4.818,4.405,4.193,4.139,4.121,4.102,4.086,4
.075,4.074
100,2012,135,209,33.9,14.837,14.84,14.858,14.841,14.774,14.728,14.42,12.44,11.062,10.152,9.187,8.759,8.171,7.9
49,7.669,7.515,7.42,7.384,7.304,6.962,6.643,6.245,5.868,5.52,5.31,4.815,4.405,4.199,4.139,4.121,4.104,4.086,4.
074,4.076
100,2012,135,210,19.9,14.85,14.841,14.859,14.851,14.79,14.721,14.463,12.187,11.052,10.121,9.186,8.764,8.173,7.
949,7.667,7.522,7.42,7.384,7.303,6.961,6.643,6.244,5.869,5.519,5.31,4.815,4.406,4.196,4.14,4.121,4.104,4.086,4
.075,4.077
100,2012,135,210,34,14.856,14.852,14.865,14.863,14.851,14.833,14.64,13.838,11.058,10.076,9.192,8.893,8.178,7.9
47,7.68,7.515,7.418,7.385,7.305,6.961,6.641,6.242,5.869,5.512,5.309,4.819,4.404,4.195,4.141,4.121,4.104,4.086,
4.074,4.076
100,2012,135,211,20,14.848,14.851,14.86,14.86,14.837,14.747,14.597,14.028,11.156,10.236,9.208,8.912,8.182,7.94
7,7.692,7.516,7.417,7.385,7.305,6.961,6.643,6.24,5.868,5.51,5.309,4.821,4.406,4.193,4.142,4.121,4.105,4.086,4.
074,4.076
100,2012,135,211,33.9,14.851,14.849,14.865,14.864,14.836,14.792,14.612,14.129,11.478,10.642,9.24,8.948,8.187,7
.949,7.687,7.516,7.415,7.383,7.301,6.959,6.643,6.234,5.867,5.509,5.31,4.821,4.41,4.193,4.143,4.121,4.105,4.085
,4.075,4.076
100,2012,135,212,20,14.842,14.852,14.859,14.855,14.832,14.79,14.63,14.17,11.603,10.684,9.268,8.951,8.187,7.949
,7.682,7.516,7.415,7.385,7.305,6.958,6.643,6.229,5.866,5.508,5.31,4.821,4.41,4.192,4.143,4.121,4.105,4.086,4.0
75,4.076
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948,7.671,7.51,7.411,7.383,7.302,6.955,6.638,6.221,5.865,5.512,5.311,4.823,4.412,4.19,4.145,4.123,4.106,4.087,
4.075,4.076
100,2012,135,213,20,14.844,14.845,14.855,14.853,14.842,14.838,14.703,14.448,12.099,11.006,9.253,8.924,8.173,7.
945,7.678,7.508,7.411,7.383,7.295,6.955,6.639,6.218,5.864,5.512,5.314,4.822,4.413,4.192,4.145,4.121,4.106,4.085
,4.073,4.077
100,2012,135,213,33.9,14.857,14.856,14.868,14.861,14.827,14.76,14.589,14.14,11.653,10.604,9.164,8.707,8.149,7.
```

Time Series – Data Examples

DWD WESTE-XL Files (German Meteorological Service)

```
Element;Messstation;Datum;Wert;Einheit;Geo-Breite (Grad);Geo-Länge (Grad);Höhe (m);Sensorhöhe (m);Erstellungsdatum;Copyright;
Temperatur 2 m;Cottbus;2010-01-01 00:00:00Z;-2,3;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 01:00:00Z;-2,5;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 02:00:00Z;-2,5;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 03:00:00Z;-2,5;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 04:00:00Z;-2,6;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 05:00:00Z;-2,7;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 06:00:00Z;-2,6;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 07:00:00Z;-2,7;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 08:00:00Z;-2,7;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 09:00:00Z;-2,5;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 10:00:00Z;-2,4;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 11:00:00Z;-2,2;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 12:00:00Z;-2,2;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 13:00:00Z;-2,1;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 14:00:00Z;-2,1;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 15:00:00Z;-2,2;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 16:00:00Z;-2,3;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 17:00:00Z;-2,4;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 18:00:00Z;-2,4;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 19:00:00Z;-2,4;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 20:00:00Z;-2,4;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 21:00:00Z;-2,4;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 22:00:00Z;-2,4;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-01 23:00:00Z;-2,6;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-02 00:00:00Z;-2,6;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-02 01:00:00Z;-2,7;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-02 02:00:00Z;-2,9;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-02 03:00:00Z;-2,9;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-02 04:00:00Z;-3,0;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-02 05:00:00Z;-2,9;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
Temperatur 2 m;Cottbus;2010-01-02 06:00:00Z;-2,9;Grad C;51,776;14,3168;69;keine Daten vorhanden;2014-10-16;© Deutscher Wetterdienst 2014;
…
```

Time Series – Data Examples

ELWIS – XML Files (German Waterways Administration)


```
<?xml version="1.0" encoding="iso-8859-1"?>
<RIS_Message xmlns="http://www.ris.eu/nts/3.0">
	<identification>
		<from>Elektronischer Wasserstraßen-Informationsservice (ELWIS)</from>
		<originator>Wasser- und Schifffahrtsverwaltung des Bundes</originator>
		<country_code>DE</country_code>
		<language_code>DE</language_code>
		<date_issue>2015-11-01+01:00</date_issue>
		<time_issue>18:01:01+01:00</time_issue>
	</identification>
	<wrm>
		<geo_object>
			<id>DEXXX00701G001500021</id>
			<name>SCHÖNA</name>
			<type_code>GAU</type_code>
			<coordinate>
				<lat>50 52.546 N</lat>
				<long>14 14.114 E</long>
			</coordinate>
		</geo_object>
		<reference_code>ZPG</reference_code>
		<measure>
			<predicted>false</predicted>
			<measure_code>WAL</measure_code>
			<value>94</value>
			<difference>-3</difference>
			<measuredate>2015-11-01+01:00</measuredate>
			<measuretime>06:00:00+01:00</measuretime>
		</measure>
	</wrm>
…
```

Time Series – Data Examples

HYMOG – Files (German Waterways Administration)

```
$Konvertiert aus Datei: H:\Hymog\Dateneingang\20100121_bfg_W60_Zentimetergenau\RUHRORT-W60.ZRX
$#ZRXPVERSION2206.235|*|ZRXPMODEStandard|*|ZRXPCREATORKisters ZRXP-Fileexporter|*|
$#TZMEZ|*|SANR2770010|*|SNAMERUHRORT/RHEIN|*|SWATERRhein|*|CNR10|*|CNAMEW|*|
$#CTYPEn-min-equi|*|CMW24|*|RTIMELVLhigh-resolution|*|CUNITcm|*|RINVAL-777|*|
$#RNR24|*|REXCHANGE27700105_RUHRORTRHEIN_W_W_60_P|*|RTYPEmean values|*|
$#RORPRProduktion|*|
$#LAYOUT(timestamp.value)|*|
$ib Funktion-Interpretation: Blockende
*Z
Wasserstand    cm            1900 2000
Ruhrort
8911 1 0 0 7103124 0
8911 1 0 0   -777.00
8911 1 1 0   250.000
8911 1 2 0   250.000
8911 1 3 0   250.000
8911 1 4 0   249.000
8911 1 5 0   250.000
8911 1 6 0   249.000
8911 1 7 0   250.000
8911 1 8 0   250.000
8911 1 9 0   251.000
8911 110 0   256.000
8911 111 0   255.000
8911 112 0   253.000
8911 113 0   254.000
8911 114 0   256.000
8911 115 0   257.000
8911 116 0   258.000
8911 117 0   260.000
8911 118 0   264.000
8911 119 0   266.000
…
```

Time Series – Data Examples

Mike11 – Export Files

```
M4220h
Time            M4220h
Unit            100000          1000            0
1990-08-01 00:00:00             0.39
1990-08-01 00:20:00             0.3
1990-08-01 00:40:00             0.2
1990-08-01 01:00:00             0.1
1990-08-01 01:20:00             -0.01
1990-08-01 01:40:00             -0.11
1990-08-01 02:00:00             -0.2
1990-08-01 02:20:00             -0.3
1990-08-01 02:40:00             -0.39
1990-08-01 03:00:00             -0.51
1990-08-01 03:20:00             -0.62
1990-08-01 03:40:00             -0.71
1990-08-01 04:00:00             -0.77
1990-08-01 04:40:00             -0.64
1990-08-01 05:00:00             -0.5
1990-08-01 05:20:00             -0.37
1990-08-01 05:40:00             -0.25
1990-08-01 06:00:00             -0.1
1990-08-01 06:20:00             0.06
1990-08-01 06:40:00             0.22
1990-08-01 07:00:00             0.35
1990-08-01 07:20:00             0.44
1990-08-01 07:40:00             0.54
1990-08-01 08:00:00             0.63
1990-08-01 08:20:00             0.7
1990-08-01 08:40:00             0.76
1990-08-01 09:00:00             0.81
1990-08-01 09:20:00             0.85
1990-08-01 09:40:00             0.86
1990-08-01 10:00:00             0.84
…
```

Hydroinformatics System

Handling of Time Series

- import to system environment (reading)
- time series pre-process (e.g. homogenization)
- time series analysis (e.g. extreme values, comparisons)
- time series documentation (reporting)
- export to components (writing)
- …

Hydroinformatics System

Time Series Pre-Processing

- delete outlier and out-of-range values
- filling gaps
- adjust scale (up- or downscaling)
- transformation (e.g. predefined units, formats)
- feature extraction (e.g. event identification)
- normalization (e.g. statistical distributions)
- simplification (e.g. regression)
- …

Hydroinformatics System

Time Series Analysis

- meta data (extreme values, min/max values, range, …)
- classification
- comparison (e.g. NSE, RMSE)
- regression (e.g. linear, non linear)
- correlation
- FFT: Fast Fourier Transformation (frequency analysis)
- differentiation, integration
- signal identification
- …

Hydroinformatics System

Type Series Types:

- temperature T(t) -> scalar -> tensor rank 0
- discharge **q**(t) -> vector -> tensor rank 1
- stress/strain **σ/ε** (t) -> matrix -> tensor rank 2

- single physical state variable
- multiple physical state variables

Hydroinformatics System

Time Series

Examples:

meteorological data:	DWD-WESTE-XL
hydrological data:	HYMOG-Data Rhein
ecological data:	Water-Quality Potsdam
simulation data:	HECRAS/Mike11 results

Hydroinformatics System

Modelling with R

Strategy for all examples:

- definition of a R data structure for time series
- R scripts for reading time series data files
- R scripts for pre-processing
- R scripts for analysis
- R script for system application

Hydroinformatics System

Modelling with R

R Script Structure

- option 1: all code in one file
- option 2: code structured in different files

  e.g.: Application.R
  InputOutput.R
  Management.R
  Analysis.R
  Plotting.R
- using source() command in R to integrate other scripts

Hydroinformatics System

Modelling with R

R Scripts DWD WESTE-XL:

- DWDFile_Input_Output.R
- DWDFile_ManagementFunctions.R
- DWDFile_AnalysisFunctions.R
- DWDFile_PlotFunctions.R
- DWDFile_Application.R

Hydroinformatics System

Modelling with R

R Scripts HYMOG:

- HYMOG_File_Input_Output.R
- HYMOG_File_MetaData.R
- HYMOG_File_Plot_Functions.R
- HYMOG_File_Application.R

Hydroinformatics System

Modelling with R

R Scripts Mike11/HEC-RAS:

- Mike11_File_Input_Output.R
- Mike11_File_PlotFunctions.R
- Mike11_Calibration_Application.R
- HecRas_File_Input_Output.R
- HecRas_File_PlotFunctions.R
- Model_Comparison_Application.R

Hydroinformatics System

Modelling with R

R Scripts Water Quality Data Potsdam:

- WQTSFile_Input_Output.R
- WQTSFile_Management.R
- WQTSFile_MetaData.R
- WQTSFile_Analysis.R
- WQTSFile_PlotFunctions.R
- WQTSFile_Application.R

Modelling Time Series with R

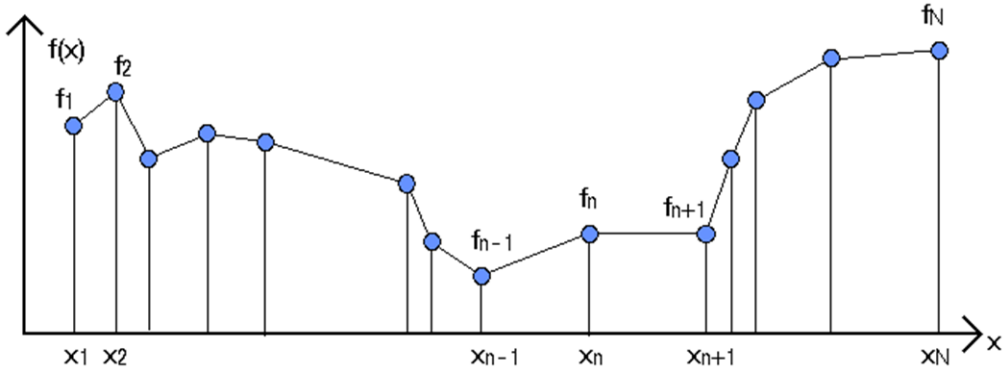
Working Steps:

- installation of R and RStudio
- specification of the problem
- data modelling for one time series
  -> to specify the data structure
- data analysis / visualization concept
  -> to specify analysis functions / results and plot types
- implementation in RStudio
  -> writing R scripts
- test, application and documentation

Modelling Time Series with R

Data Modelling:

- how to describe a time series
  -> analytic description
  -> discrete description
- first assumptions
  -> time scale
  -> time resolution
  -> regular or irregular discretization
  -> value range
  -> special values (NaN)



Modelling Time Series with R

Reading a simple ASCII data file

- file connections
- character by character
- format interpretation and text parsing

Reading a ASCII / CSV data file

- using readTable() and data.frame structure

Reading a Excel data file

- using zoo package and data.frame structure

Modelling Time Series with R

First Simple ASCII Data File

```
# This is a simple example of a ASCII time series file
10
1.    0.
2.    1.
3.    2.5
4.    3.5
5.5   3.0
6.    3.1
6.5   3.0
8.    2.2
9.    1.8
10.   1.7
```

Modelling Time Series with R

First Simple ASCII Data File -> Format

- 1st line is a line of comments marked with a #
- 2nd line contain the number of available data sets
- from 3rd line on: each line one data set
- each line two numbers:
  -> one for time, one for related value
- open questions:
  units ? gaps ? value range ? metadata ?
  data sets ordered by time ?
  EOF, EOL, tabulator characters ? additional comments ?

Modelling Time Series with R

Reading ASCII Data File

- reading character by character
  -> open file connection
  -> loop on all characters
  -> interpretation / parsing of characters
  -> closing connection
- improvement:
  -> reading line by line
  -> knowing format/structure of the file
  -> parsing words -> numbers

Modelling Time Series with R

R package

- set of functions combined in a library
- provides (validated) additional functionality
- reused for a specific application by the user
- installed in R Environment and linked to the application

Modelling Time Series with R

R packages - Examples

- stringr
  Simple, Consistent Wrappers for Common String Operations
- **zoo**
  S3 Infrastructure for Regular and Irregular Time Series
  (**Z**'s **O**rdered **O**bservations)
- openair
  Tools for the Analysis of Air Pollution Data
- see package list in RStudio and in the Web
  -> e.g. DBI; splines, timeseries, tseries, xts

Modelling Time Series with R

Time Series DWD Weste-XL Files

- source: Measurement Station nearby Cottbus
  DWD (German Meteorological Service): Weste-XL
  WEtterdaten und -**ST**atistiken **E**xpress
  https://www.dwd.de/DE/leistungen/weste/westexl/weste_xl.html
- files:
  `weste_product_2010_air_temperature.csv`
  `weste_product_2010_precipitation.csv`
  `weste_product_2010_soil_temperature.csv`
- format:
  spreadsheet table -> **C**omma-**s**eparated **v**alues (CSV)

Modelling Time Series with R

Reading DWD Weste-XL Files

- Weste-XL: Temperature Data File Format:

```
Element;Messstation;Datum;Wert;...
Temperatur 2 m;Cottbus;2010-01-01 00:00:00Z;-2,3;...
Temperatur 2 m;Cottbus;2010-01-01 01:00:00Z;-2,5;...
```

- several details to notice:

  -> How are columns separated? “;”

  -> What is the date/time format? “ISO 8601”

  -> Is any quotation mark outside quoting a string? “No”

  -> What is the decimal mark? “,”

Modelling Time Series with R

Reading DWD Weste-XL Files: using package

reading the raw data from the file with:

```
ts_temperature <-
read.csv("weste_product_2010_air_temperature.csv",
header = T, sep = ";", quote = "", dec = ",")
```

extracting relevant columns:

- `ts_temperature <- zoo(ts_temperature[, 3:4])`
- `ts_temperature <- read.zoo(ts_temperature[, 3:4], tz="UTC")`

-> see code examples

Modelling Time Series with R

Working Steps

- reading the data files
- pre-processing of the time series
- analysis (basic) of the time series
- reporting/plotting of the time series

Modelling Time Series with R

Working Step 1: Reading the data files

- analyzing the format:
  -> How are columns separated? ";"
  -> What is the date/time format? "ISO 8601"
  -> Is any quotation mark outside quoting a string? "No"
  -> What is the decimal mark? ","
- application of read functions, example:
  `read.csv(file, header, sep, quote, dec , …)`
- storage of spreadsheet table as `data.frame` object
- extracting relevant columns (time:3 and value:4)
- converting time string to time object (see POSIXct)

Modelling Time Series with R

Working Step 2: Pre-Processing of the time series

- identify gaps and irregularities
  -> 1 hour regular time step
  -> loop to check distance of time to 3600 secs
- report gaps and irregularities
  -> print() to time steps with distance != 3600 secs
- determine key information:
  min/max/mean of the three time series
  -> min(),max(), mean() for 2nd column value array

Modelling Time Series with R

Working Step 3: Analysis (basic) of the time series

- extract monthly sub time series
  -> find begin and end of month e.g. loop on all data sets
  -> subset operation
- monthly time series key properties
  -> min(),max(),mean() for extracted time series
- for precipitation: total amount of rainfall
  -> sum() for precipitation time series
- scaling to daily and weekly values
  -> create new time series with 1 day / 1 week time step
  -> value is mean value of hourly values for the new time window

Modelling Time Series with R

Working Step 4: Reporting/Plotting

- three plots of the full three time series
  -> plot() add plot properties in case of interest
- one plot with air and soil temperature in June 2010
  -> plot () first time series
  -> lines() second time series with time shift
- one plot with the hourly, daily and weekly time
  -> plot() as for 1st plot
  -> lines() for scaled daily time series and other color
  -> lines() for scaled weekly time series and other color