Detecting Anomalies in Time and Frequency Data

Judah Levine

NIST, Time and Frequency Division

Boulder, Colorado

Judah.Levine@nist.gov

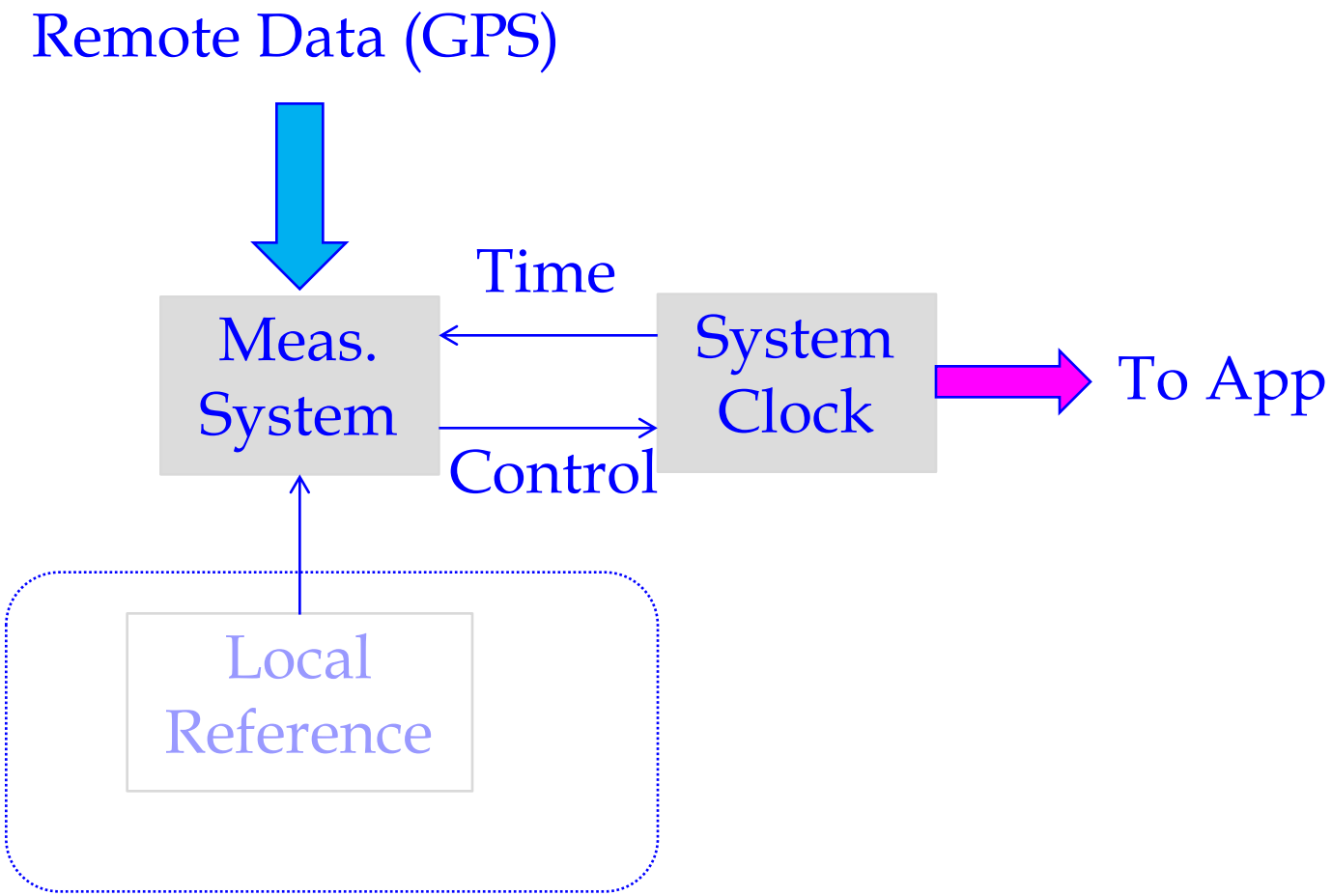
Outline

- Types of Anomalies
- Measurement configurations
- Analysis methods
- Examples
- Summary

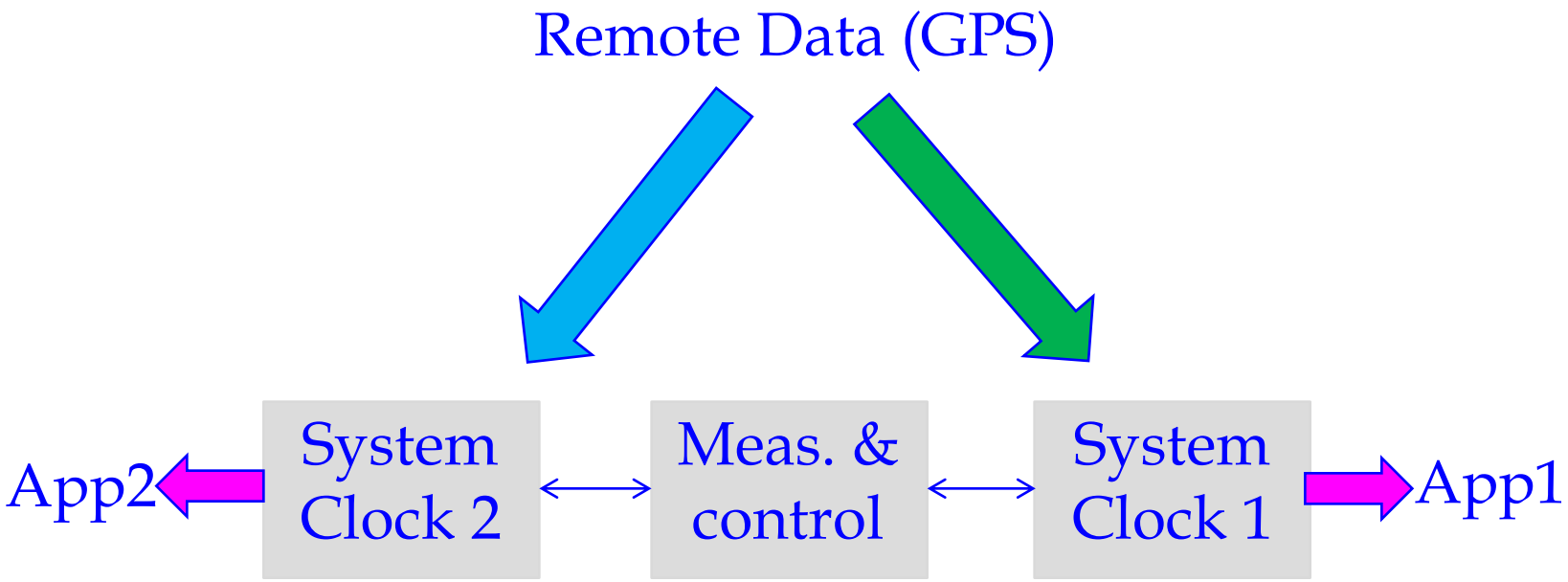
Types of anomalies

- Time Step
- Frequency Step
- Missing Data

Measurement Configuration - 1



Measurement Configuration - 2



The Common-View Method

Data Analysis - 1

Recursive model for measurement channel j:

$$\hat{x}_j(t_k) = x_j(t_{k-1}) + y_j(t_{k-1})\tau$$

$$\varepsilon_j(t_k) = X_j(t_k) - \hat{x}_j(t_k)$$

X_j is measured time difference
x, y are model time and frequency
τ is time interval between measurements

Parameters are constant between measurements

Data Analysis - 2

Time variance for each measurement: ξ_j and $\eta_j\tau^s$

Choice of τ important!

Case 1: The good news:

$\varepsilon_j(t_k)$ << All noise terms

Error Models - 1

Time Step:

For all channels:

$\varepsilon_j(t_k)$ > noise terms

$\varepsilon_j(t_{k-1})$ < noise terms

Magnitude = $\langle \varepsilon_j(t_k) \rangle$

Frequency Step:

For all channels:

$\varepsilon_j(t_k)$ > noise terms

$\varepsilon_j(t_{k-1})$ > noise terms

Magnitude = $\langle \varepsilon_j(t_k)/\tau \rangle$

Error Models - 2

Local clock broken:

For all channels:

$\varepsilon_j(t_k)$ >> noise terms

$\varepsilon_j(t_{k-1})$ >> noise terms

$\varepsilon_j(t_{k-2})$ >> noise terms

Reference Channel *m* is broken:

For channel *m*:

$\varepsilon_m(t_k)$ > noise terms

For other channels:

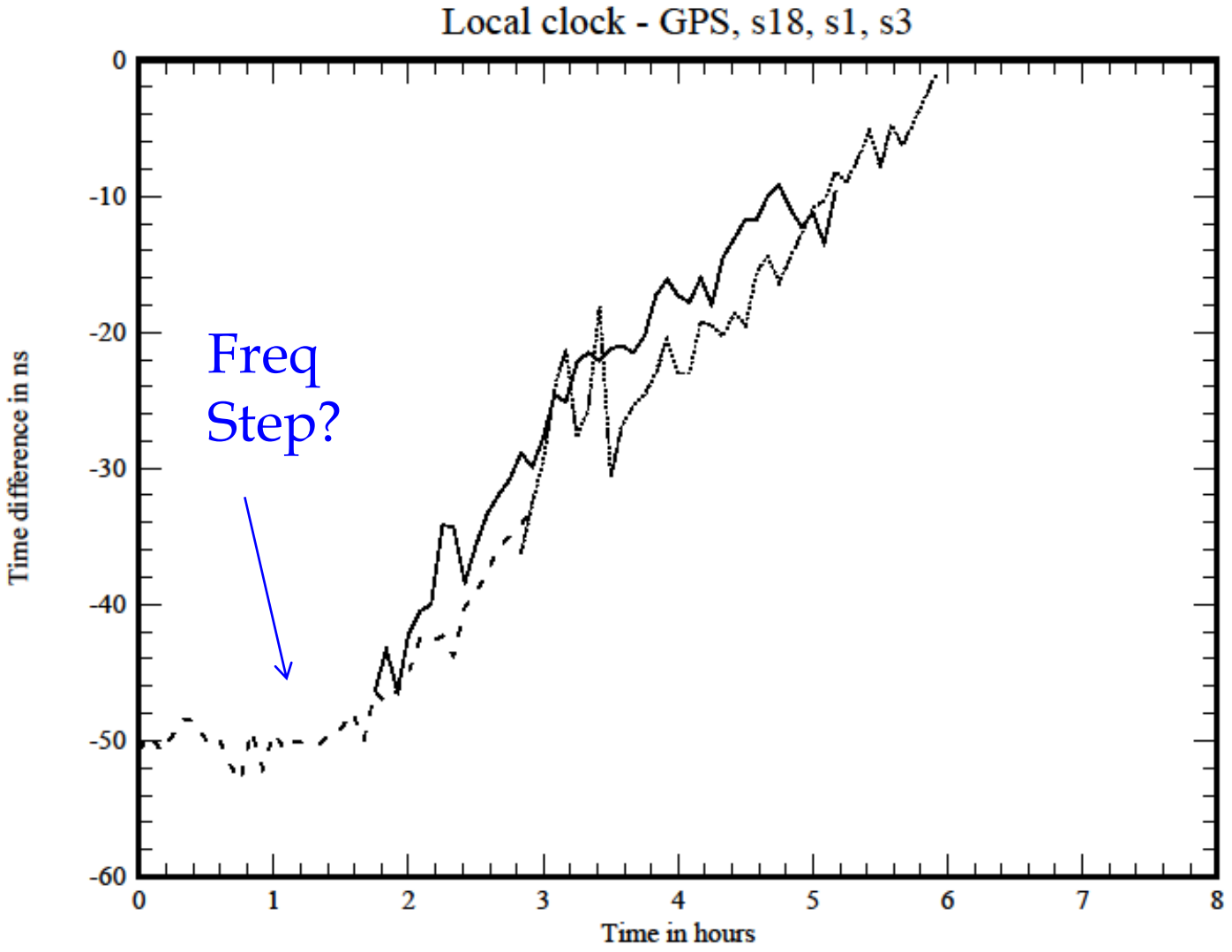
$\varepsilon_n(t_k)$ < noise terms

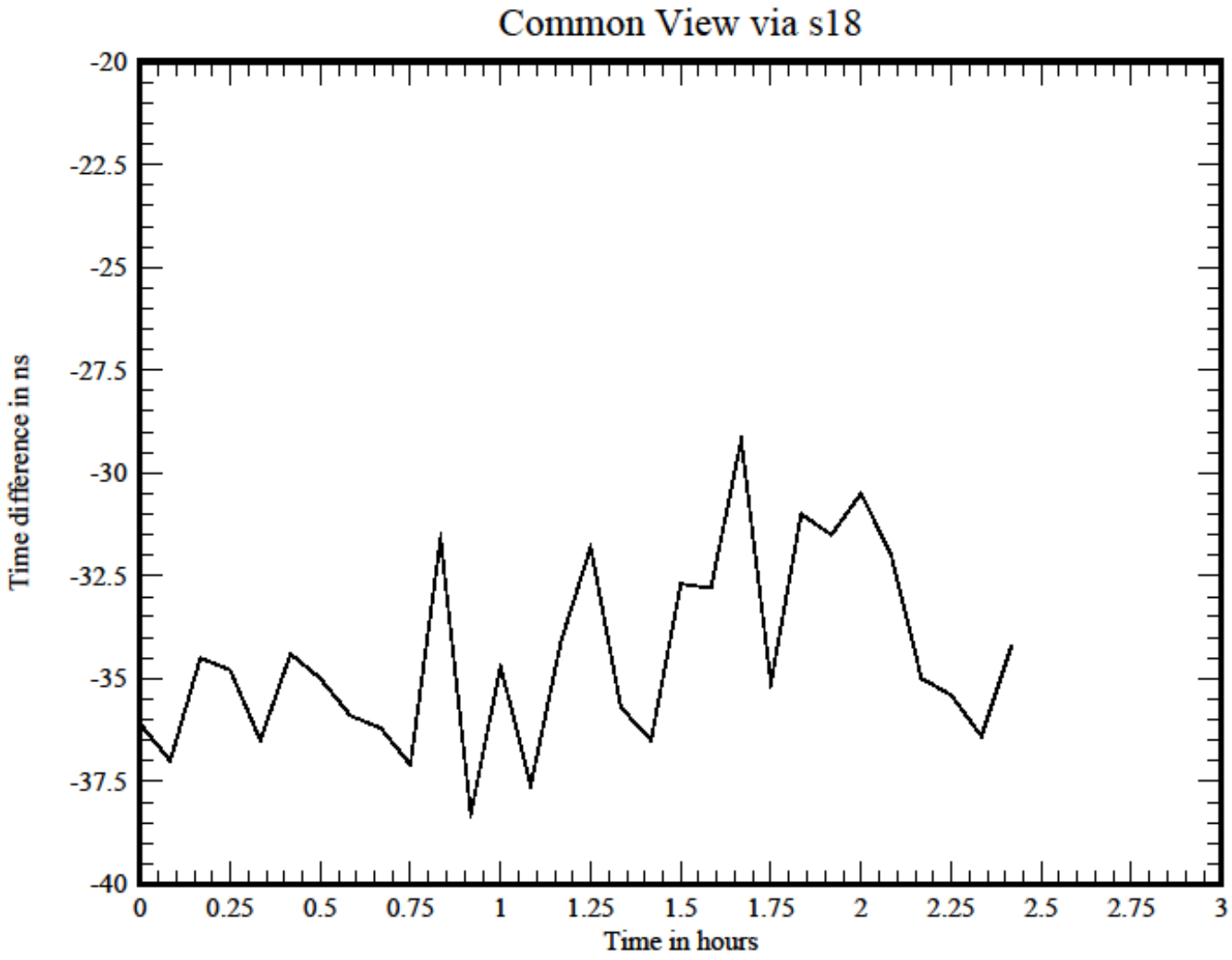
Error Model - 3

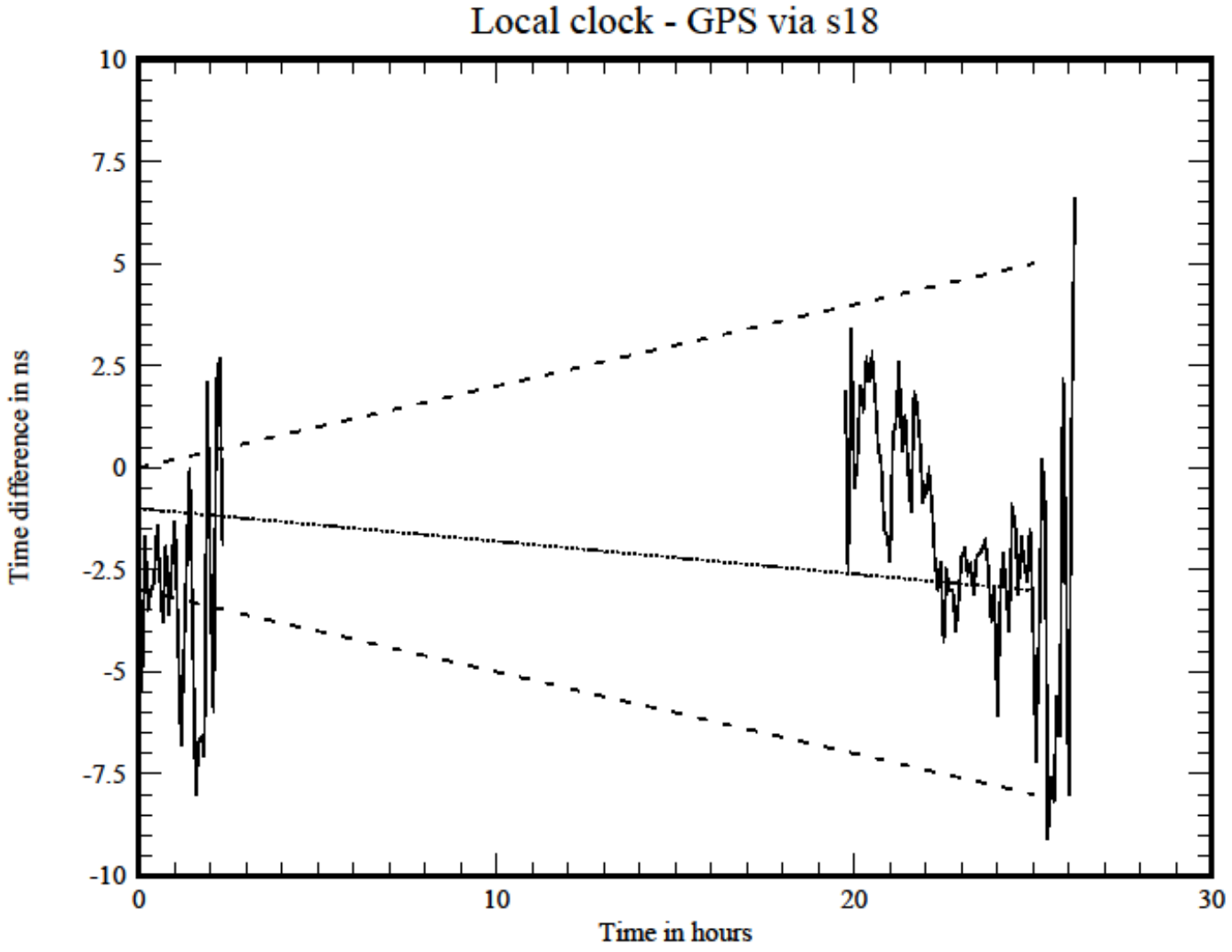
- No data at time t_k:
  - Extrapolate by using model equation

$$x_j(t_k) = x_j(t_{k-1}) + y_j(t_{k-1})\tau$$

  - Extrapolation error: $\sqrt{\xi^2 + (\eta\tau)^2}$


Local clock - GPS, s18, s1, s3
Time difference in ns
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
6
7
8
Time in hours
Freq
Step?


Common View via s18
Time difference in ns
-20
-22.5
-25
-27.5
-30
-32.5
-35
-37.5
-40
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
Time in hours


Local clock - GPS via s18
Time difference in ns
10
7.5
5
2.5
0
-2.5
-5
-7.5
-10
0
10
20
30
Time in hours

Summary

- Anomaly Detection compares data with model of measurement channel(s)
  - Optimum strategy based on redundant measurements
    - Multiple satellite GPS common application
    - Local reference clock can be very useful
- Missing data holdover uses model for extrapolation
- Performance depends on statistical parameters