日欧の空域データにおける共通の傾向

Common Trends in Japanese – and European Airspace Data

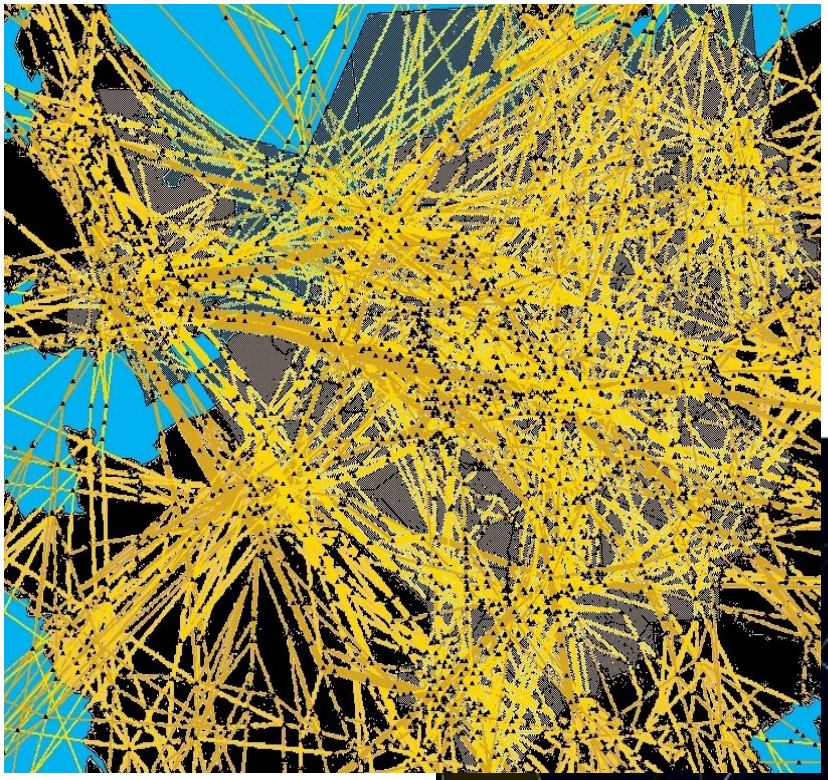
C. Gwiggner, 蔭山 康太 , 長岡 栄
ENRI, Tokyo
Happyo Kai 2008

ENRI Electronic Navigation Research Institute

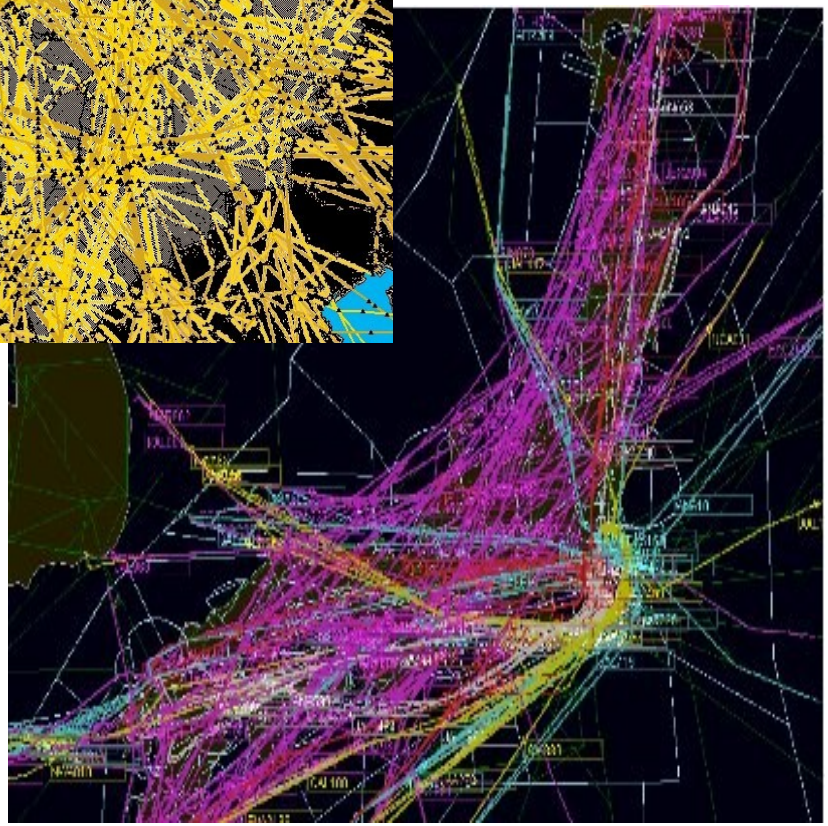
Outline

- Traffic Gaps
- Data Analysis
  - Trends
  - Propagation
- Comparison Japanese / European Data
- Future Work

Analysis of Traffic Flow



EUROPE

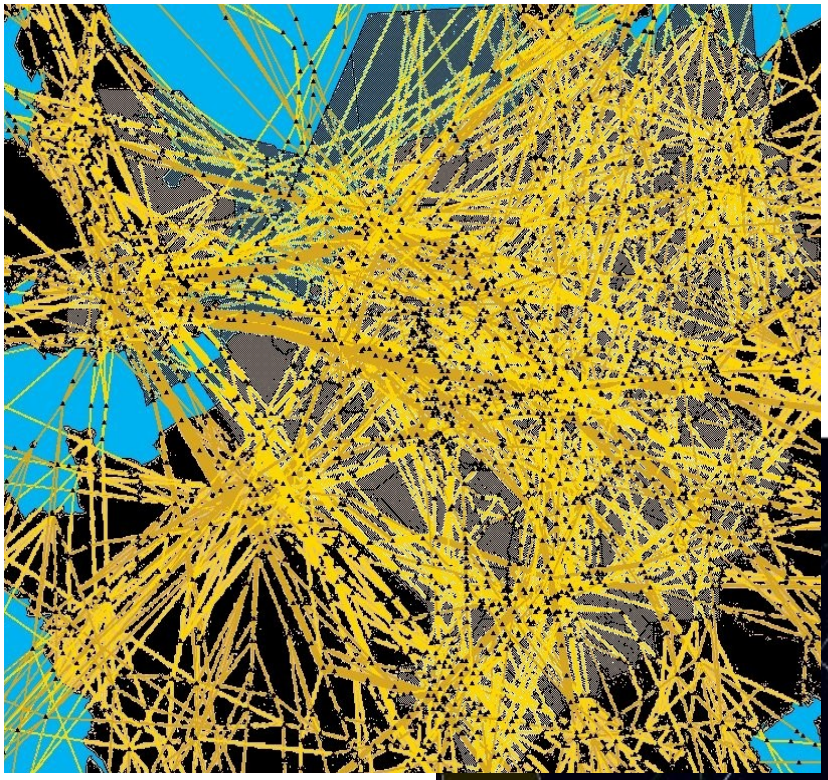


JAPAN

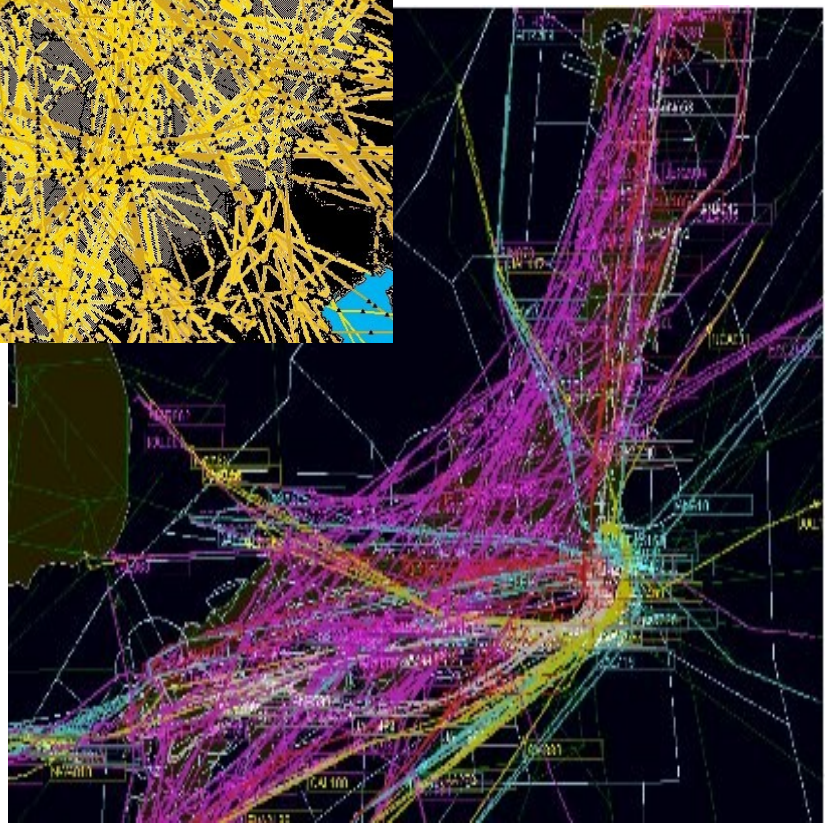
- Capacity/demand imbalances
- Congestion
- Delays

[PRR 2001-2007], [NextGen 2007]

Analysis of Traffic Flow



EUROPE



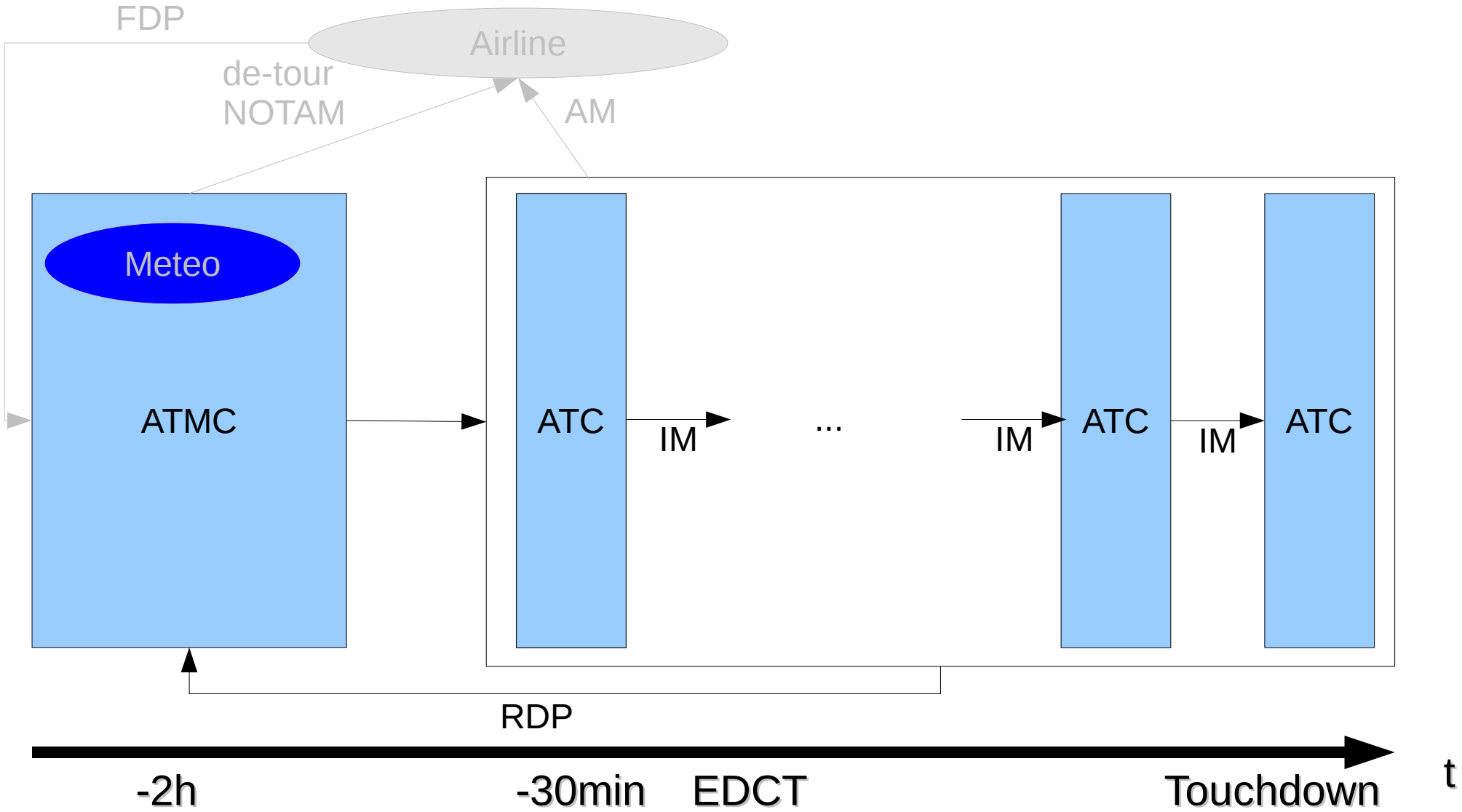
JAPAN

- Capacity/demand imbalances
- Congestion
- Delays

- ATM Performance
- Flow Management

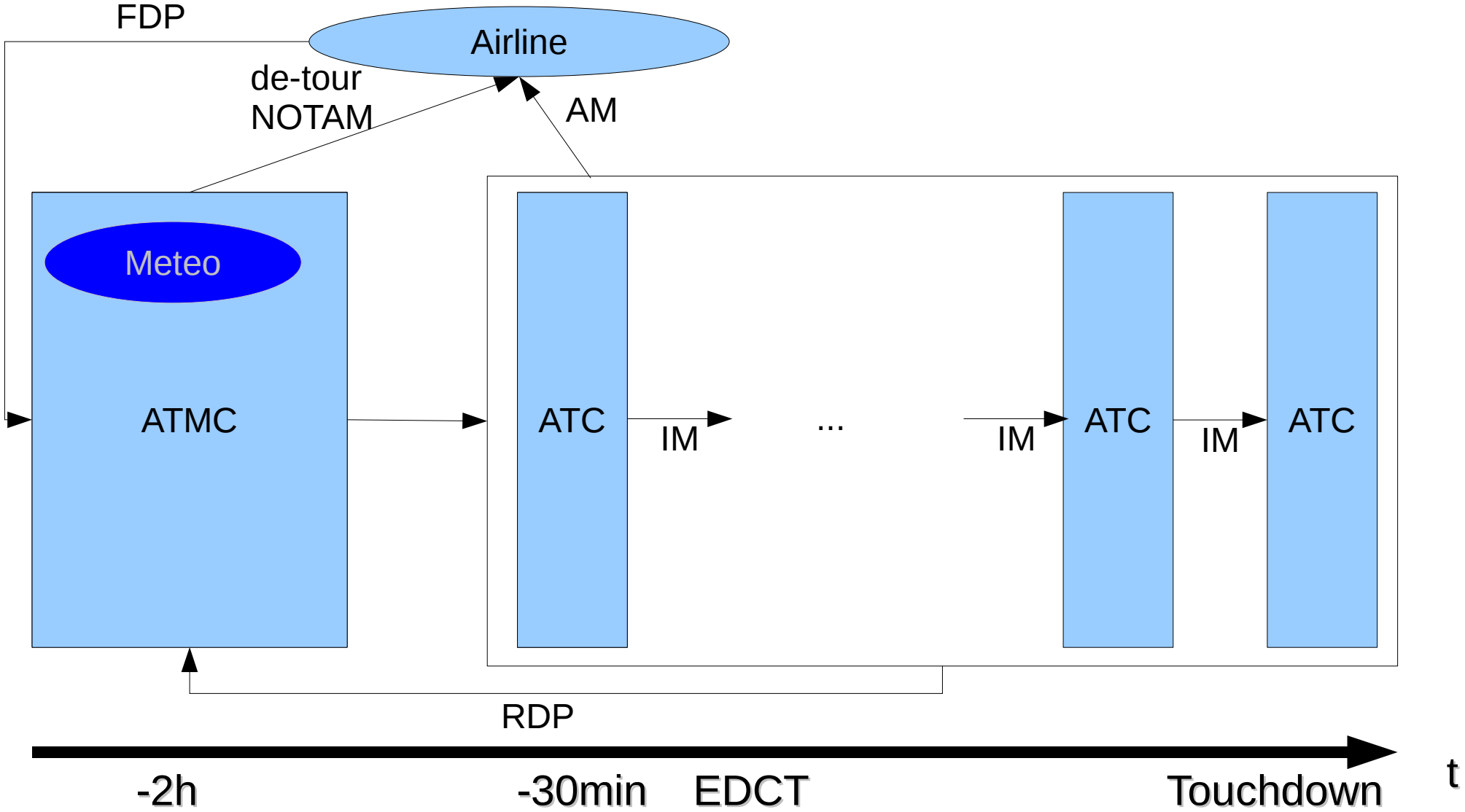
[PRR 2001-2007], [NextGen 2007]

Flight Plan Processes



[AIP 2008, AIMJ 2008]

Flight Plan Processes



[AIP 2008, AIMJ 2008]

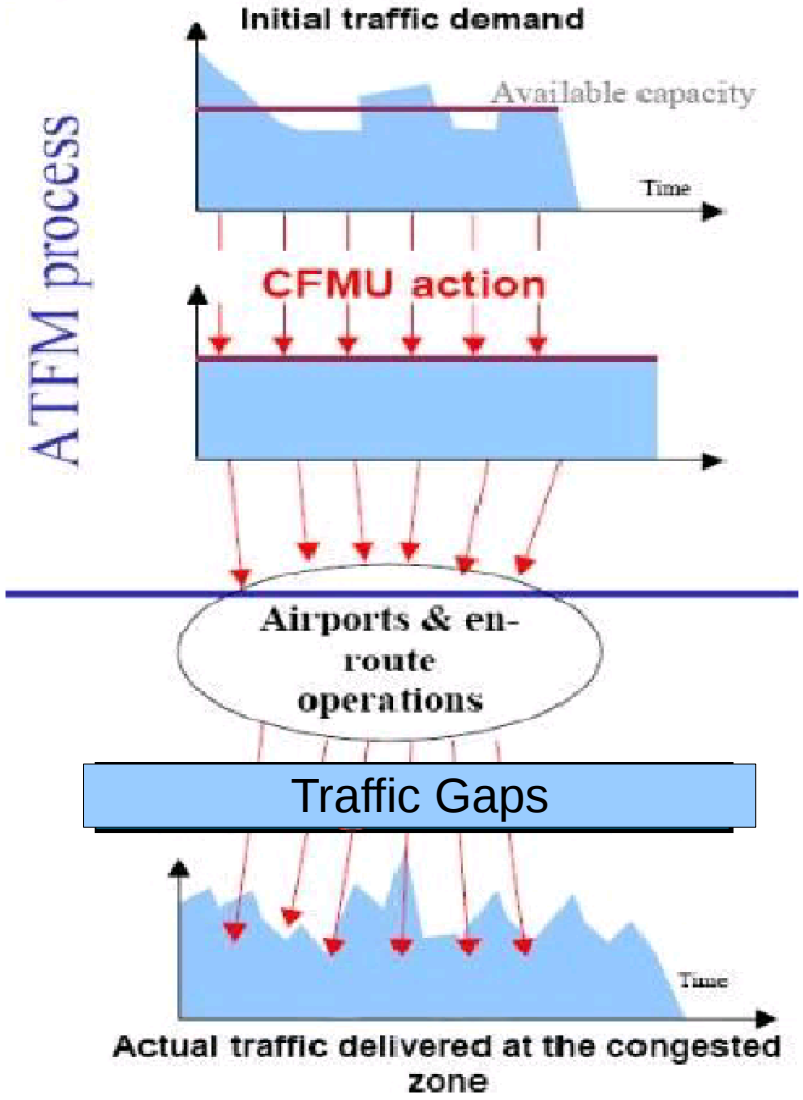
Definition: Traffic Gaps

known

- Uncertainty Factors
  - Demand Uncertainty
  - Capacity Uncertainty
  - Flow Control Uncertainty

unknown

- Traffic Gaps
  - Differences between planned and delivered traffic at sector entries



[Ball et al. 2005], [Eurocontrol 2002]

Definition: Traffic Gaps

known

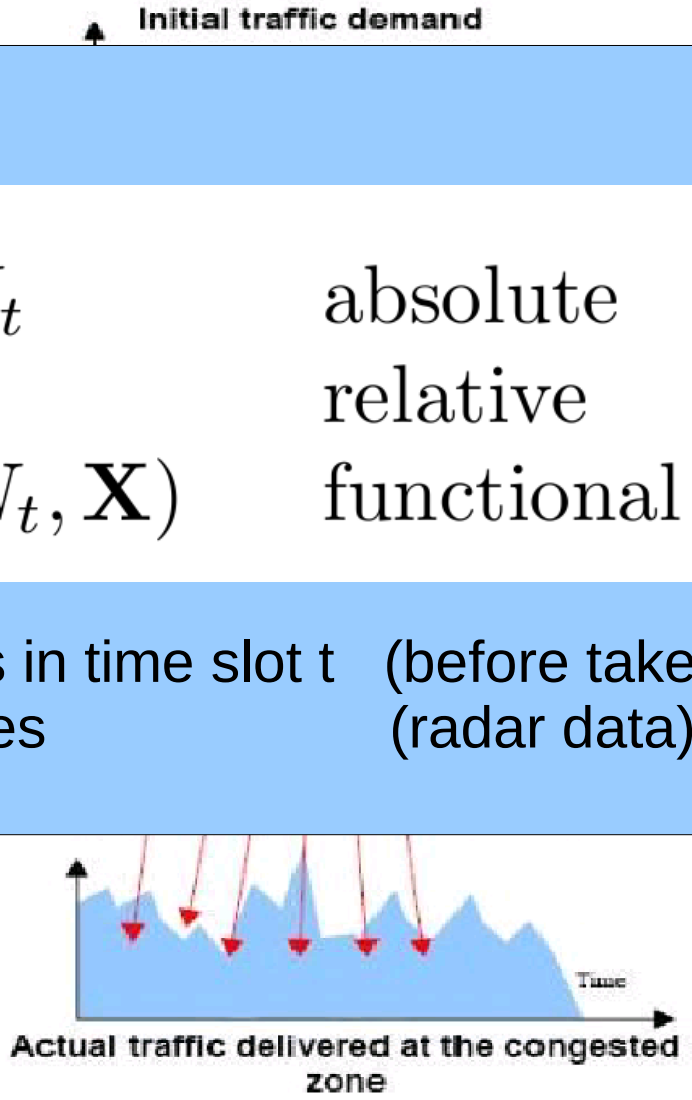
unknown

For an en-route sector:

$$GAP_t = \begin{cases} REAL_t - PLN_t & \text{absolute} \\ REAL_t / PLN_t & \text{relative} \\ f(REAL_t, PLN_t, \mathbf{X}) & \text{functional} \end{cases}$$

- PLN_t : number of planned entries in time slot t (before take-off)
- REAL_t : number of observed entries (radar data)

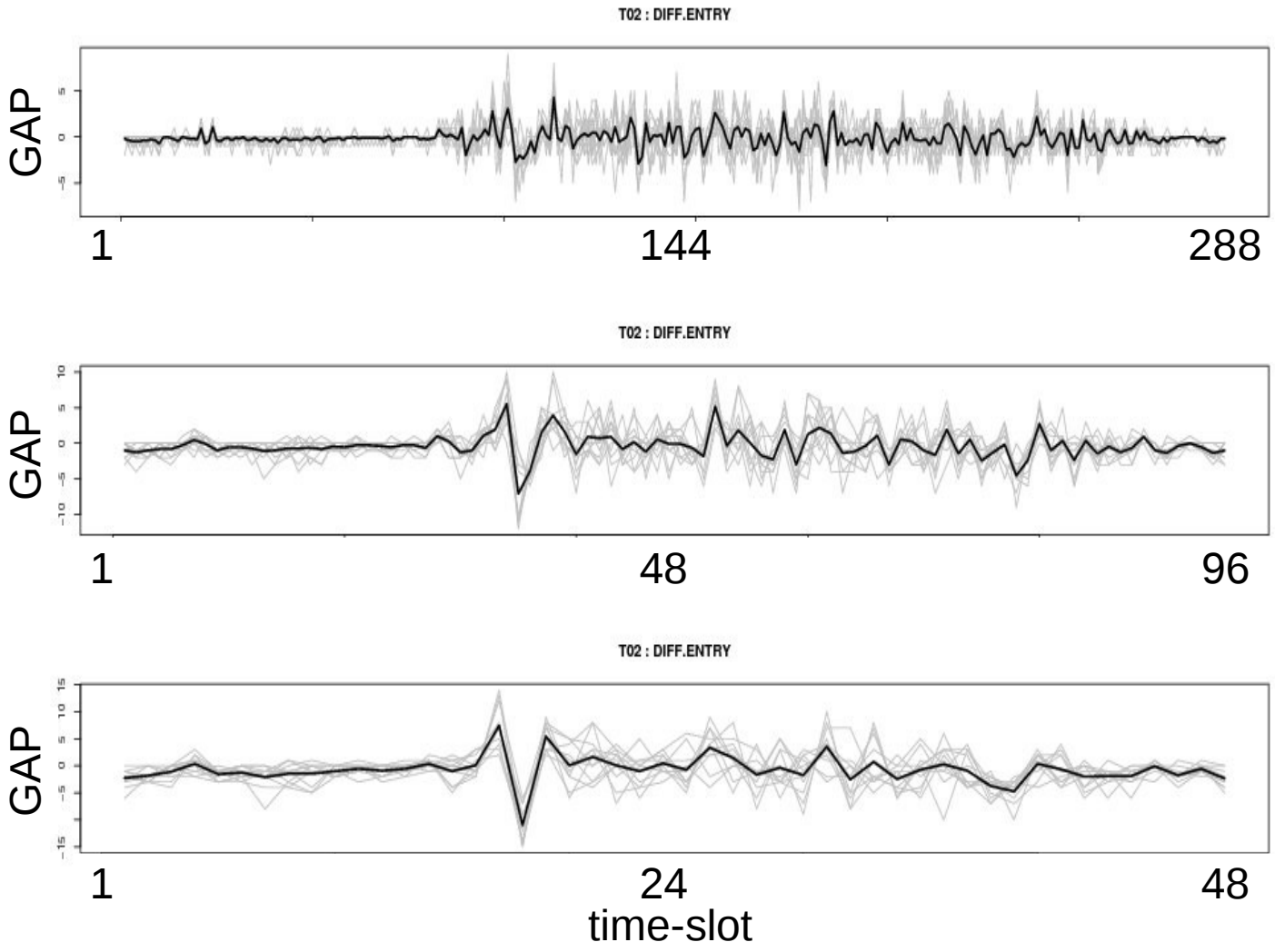
- Differences between planned and delivered traffic at sector entries



[Ball et al. 2005], [Eurocontrol 2002]

Trend Analysis

Trend Analysis



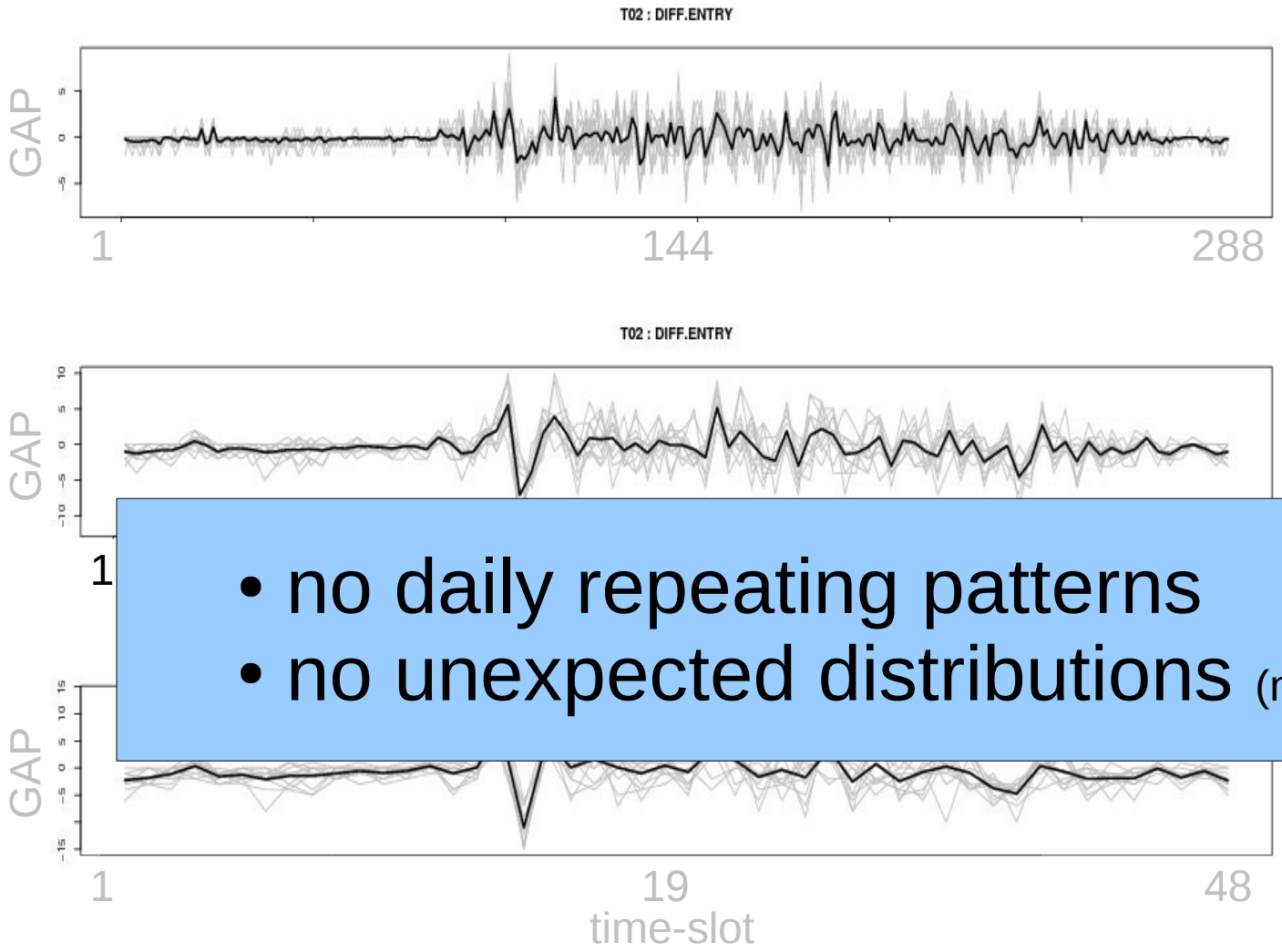
- Fluctuation ~ 0
- Night/Day variance
- A peak in the morning

X-axis: time slot (1 day)
Y-axis: gaps between planned and observed traffic

Top: 5 min, middle: 15 min, bottom: 30 min

[Gwi et al. 2007, 2006]
[Wanke et al. 2006, 2005]

Trend Analysis



- Fluctuation ~ 0
- Night/Day variance
- A peak in the ng

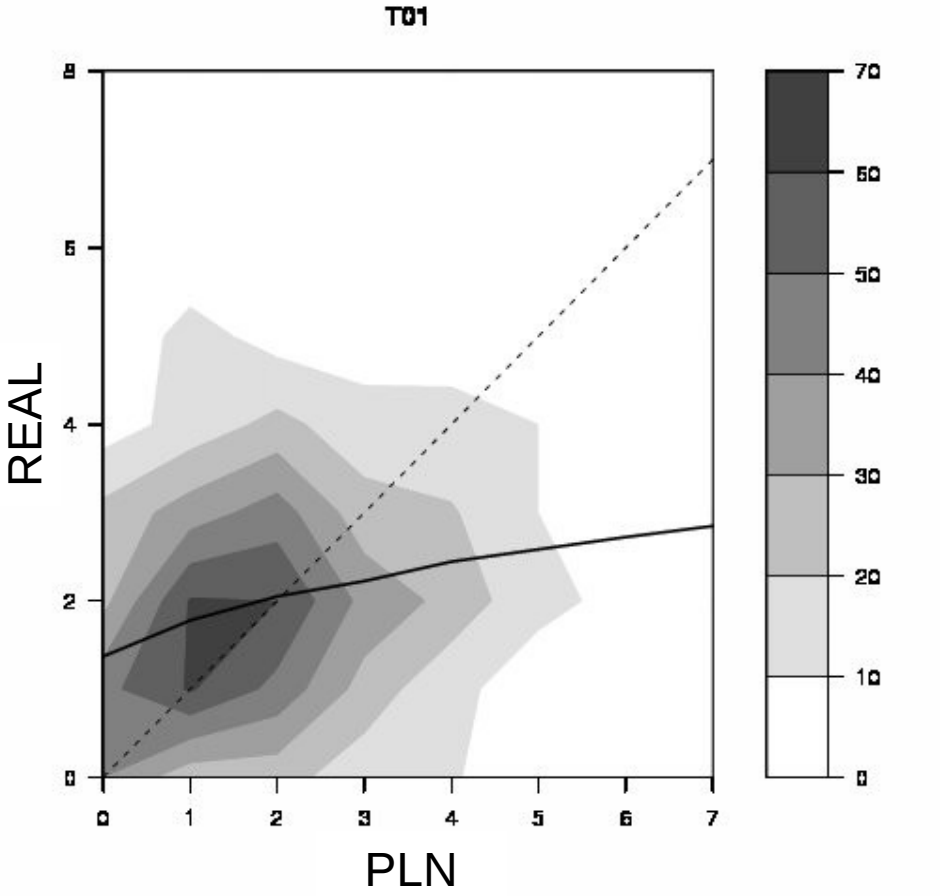
- no daily repeating patterns
- no unexpected distributions (not shown)

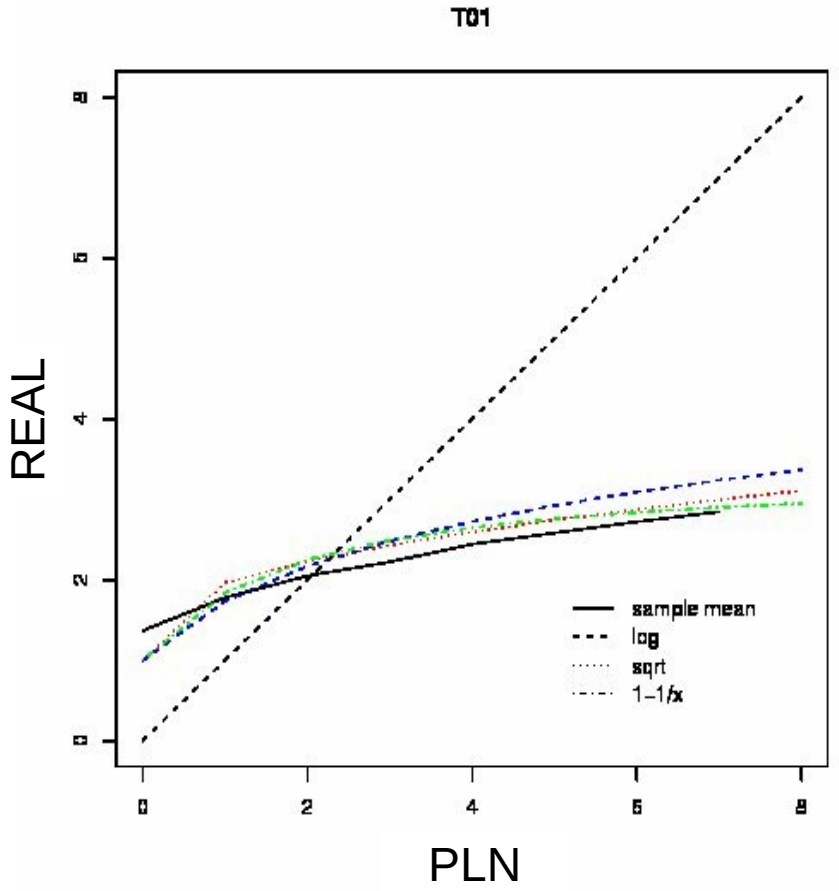
X-axis: time slot (1 day)
Y-axis: gaps between planned and observed traffic

Top: 5 min, middle: 15 min, bottom: 30 min

[Gwi et al. 2007, 2006]
[Wanke et al. 2006, 2005]

Trend Analysis

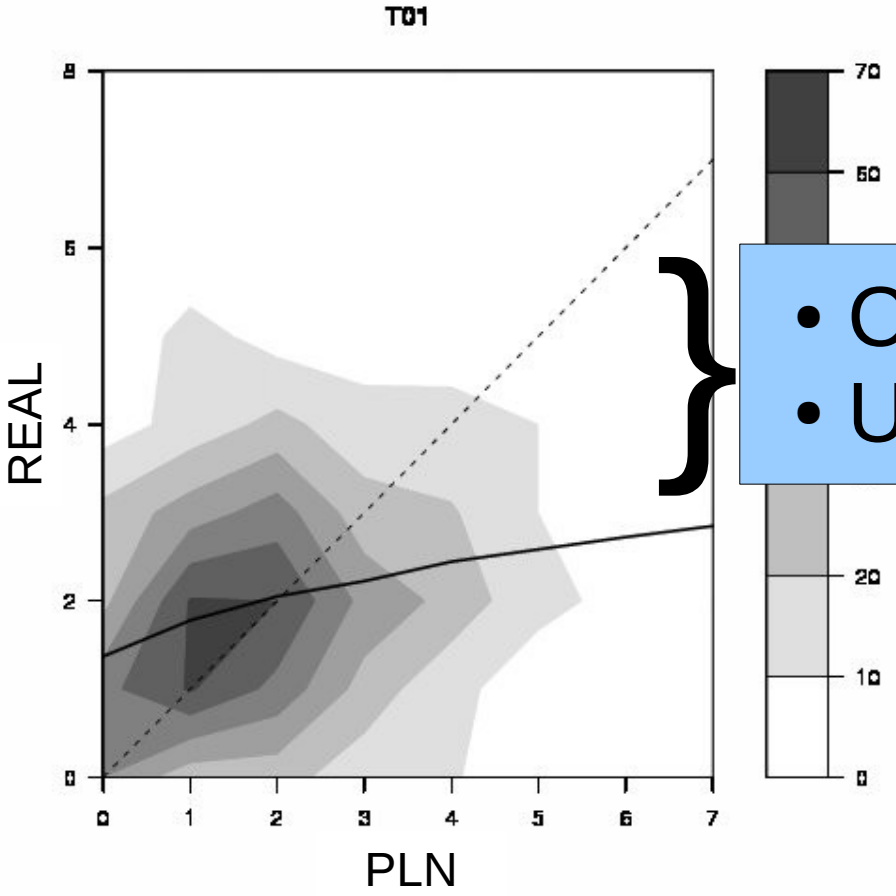




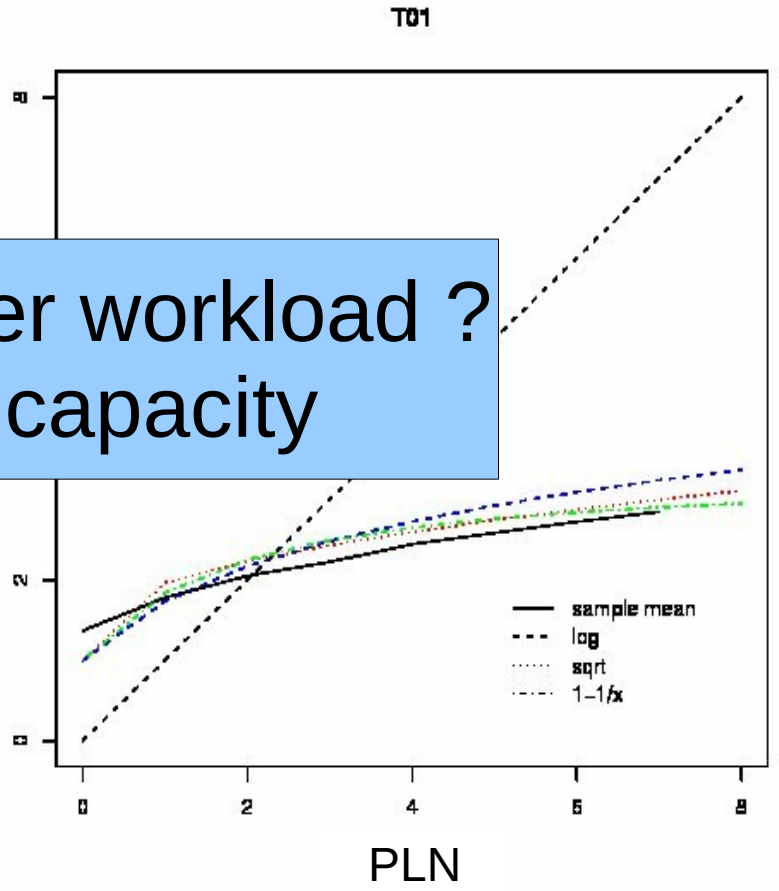
- Distribution
  - One single peak
  - Poisson (per column k)
- Average value
  - Systematic gaps
  - As a function of density

[GwiDuo 2006, GDN 2008]

Trend Analysis



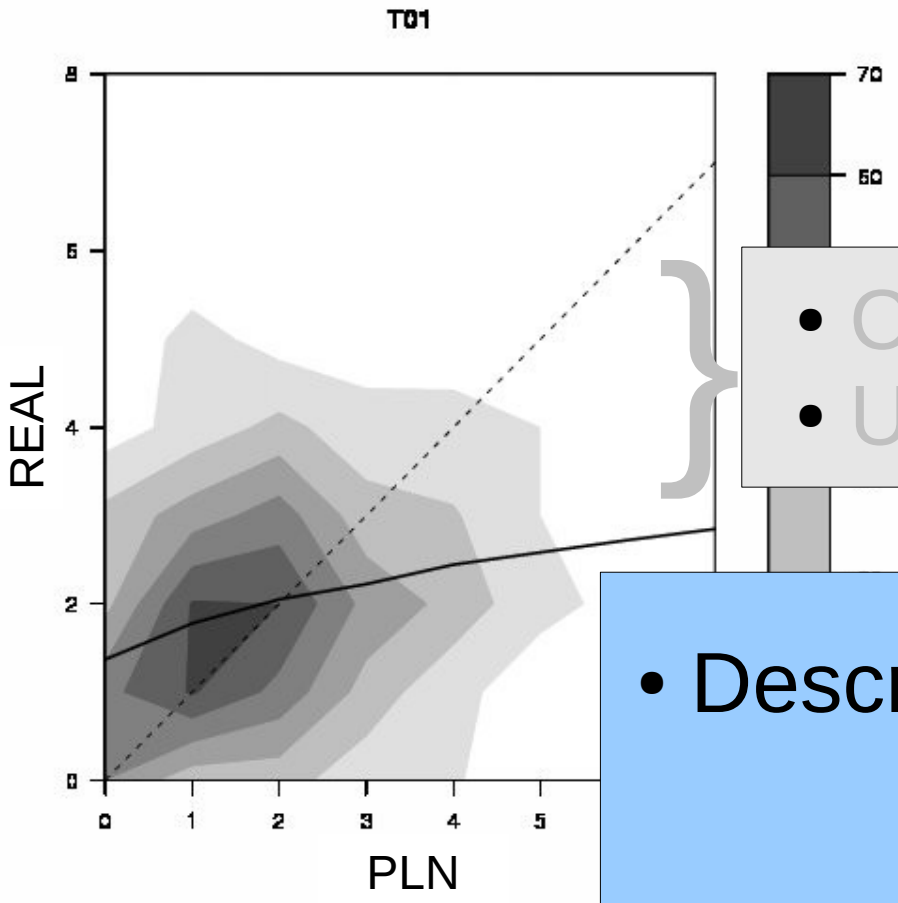
- Controller workload ?
- Unused capacity

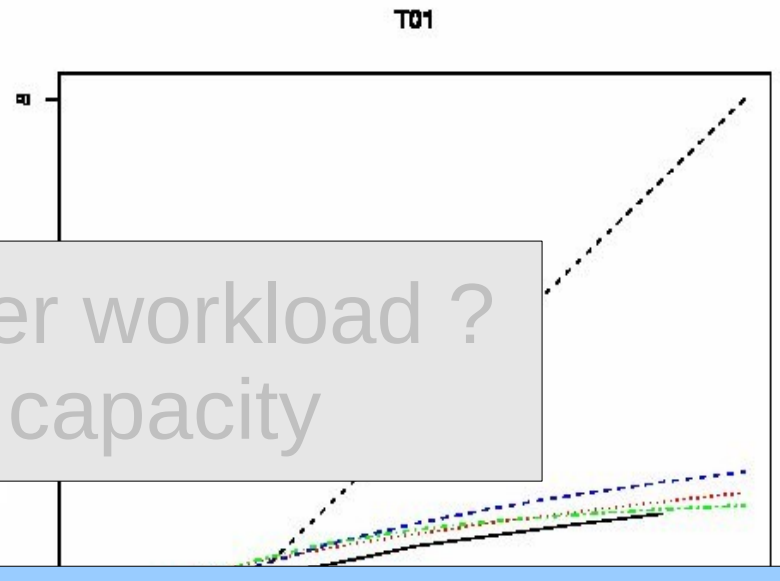


- Distribution
  - One single peak
  - Poisson (per column k)
- Average value
  - Systematic gaps
  - As a function of density

[GwiDuo 2006, GDN 2008]

Trend Analysis





- Controller workload ?
- Unused capacity

- Distribution
  - One single peak
  - Poisson (per column k)
  - Systematic gaps
  - As a function of density

- Descriptive model

$$P(REAL=n \mid PLN=k)=\frac{e^{-\mu_k}\mu_k^n}{n!}$$

$$\log(\mu_k)=\alpha k+\beta$$

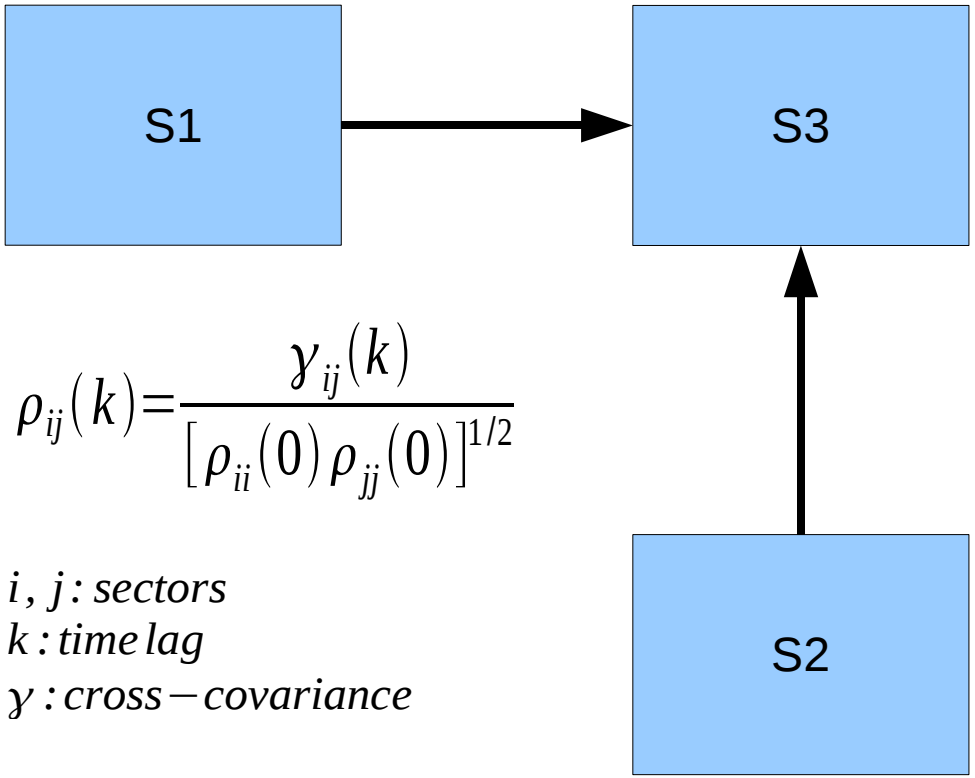
- Causal model

([Gwi 2007])

[GwiDuo 2006, GDN 2008]

Propagation of Gaps

Correlation Analysis



$$\rho_{ij}(k) = \frac{\gamma_{ij}(k)}{[\rho_{ii}(0)\rho_{jj}(0)]^{1/2}}$$

i, j : sectors
k : time lag
γ : cross−covariance

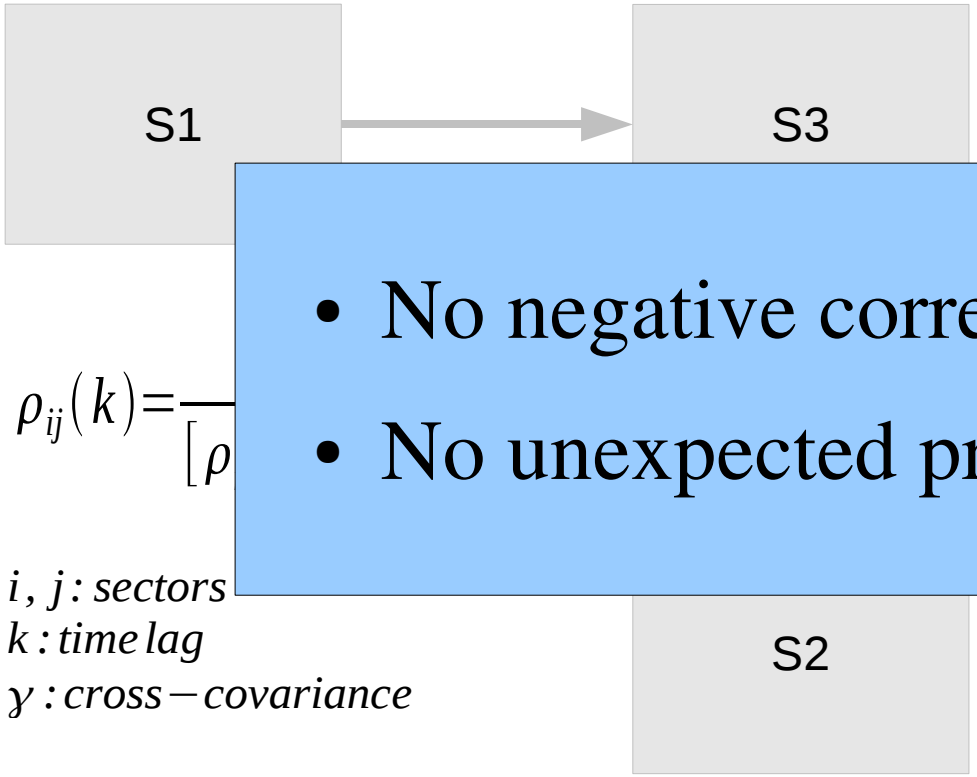
- Propagation: $\rho > 0$
- Compensation: $\rho < 0$

“ Traffic *gaps propagate naturally through the network, because aircraft cannot stand still.*”

“ *The question is whether controllers have strategies to compensate the gaps.*”

[Gwi, Kage, Naga 2008]

Correlation Analysis



- Propagation: $\rho > 0$
- ion: $\rho < 0$

- No negative correlation found
- No unexpected propagation found

$\rho_{ij}(k) = \frac{}{[\rho}$

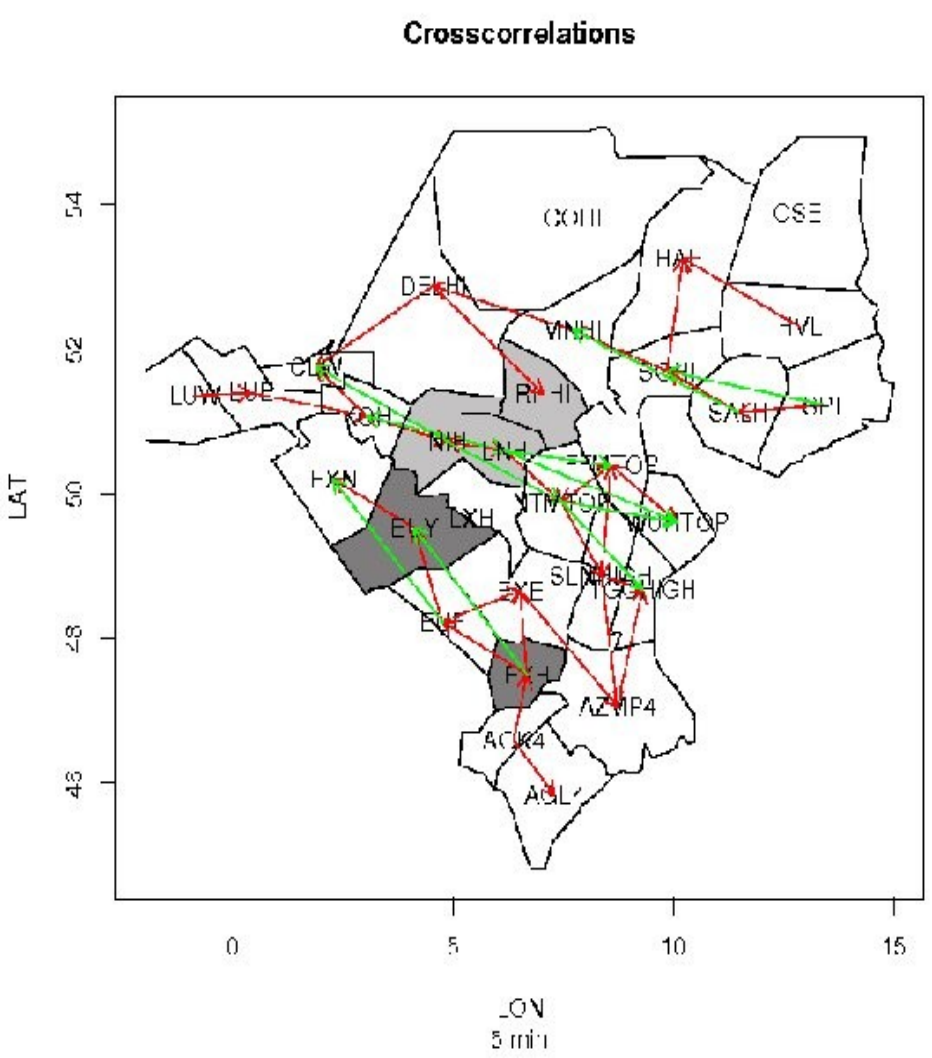
i, j : sectors
k : time lag
γ : cross − covariance

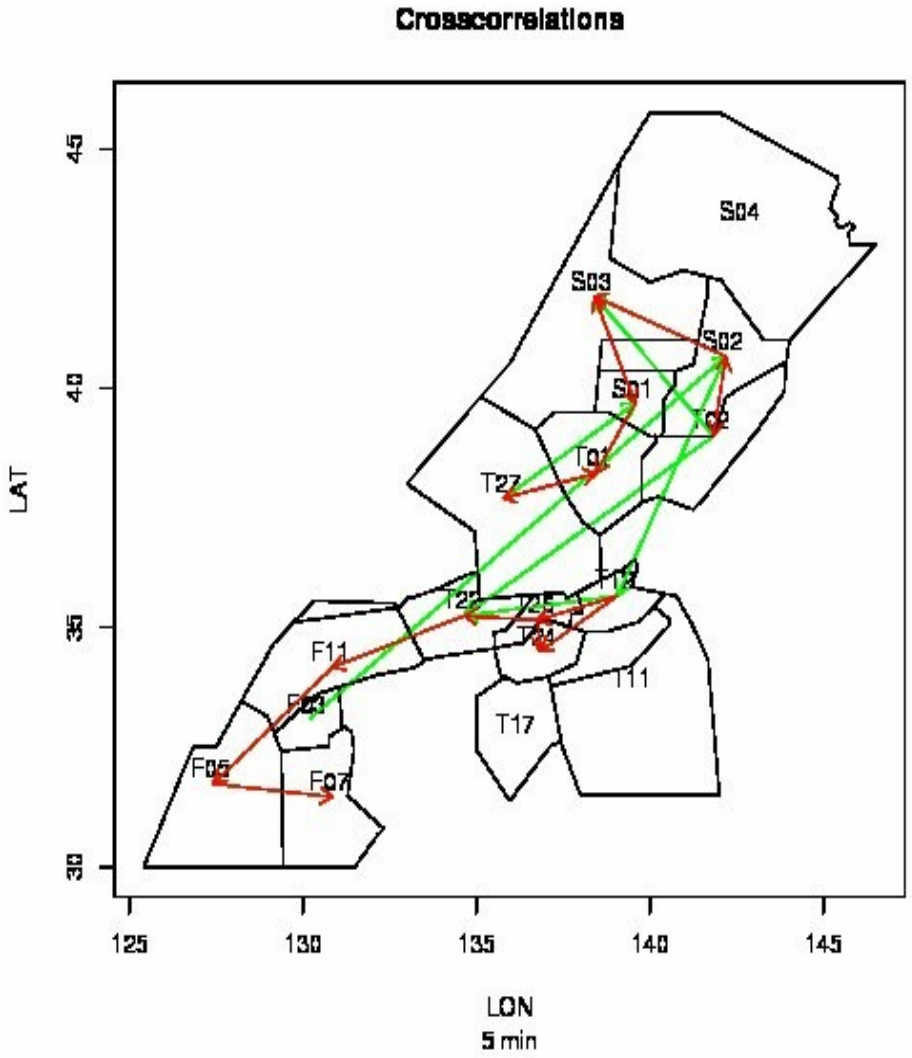
te naturally because aircraft cannot stand still."

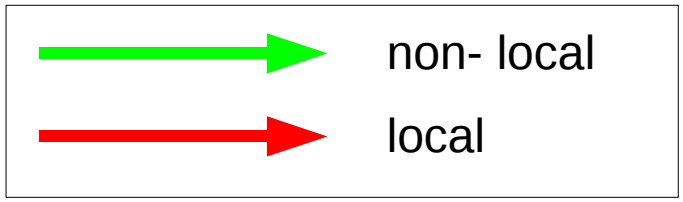
" The question is whether controllers have strategies to compensate the gaps."

[Gwi, Kage, Naga 2008]

Visualization

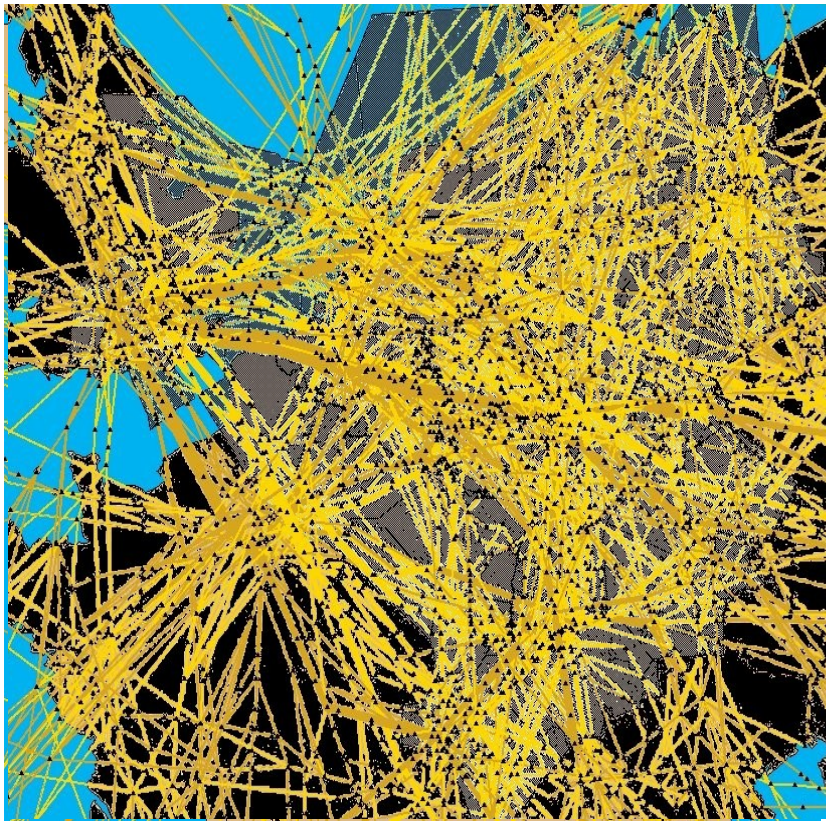




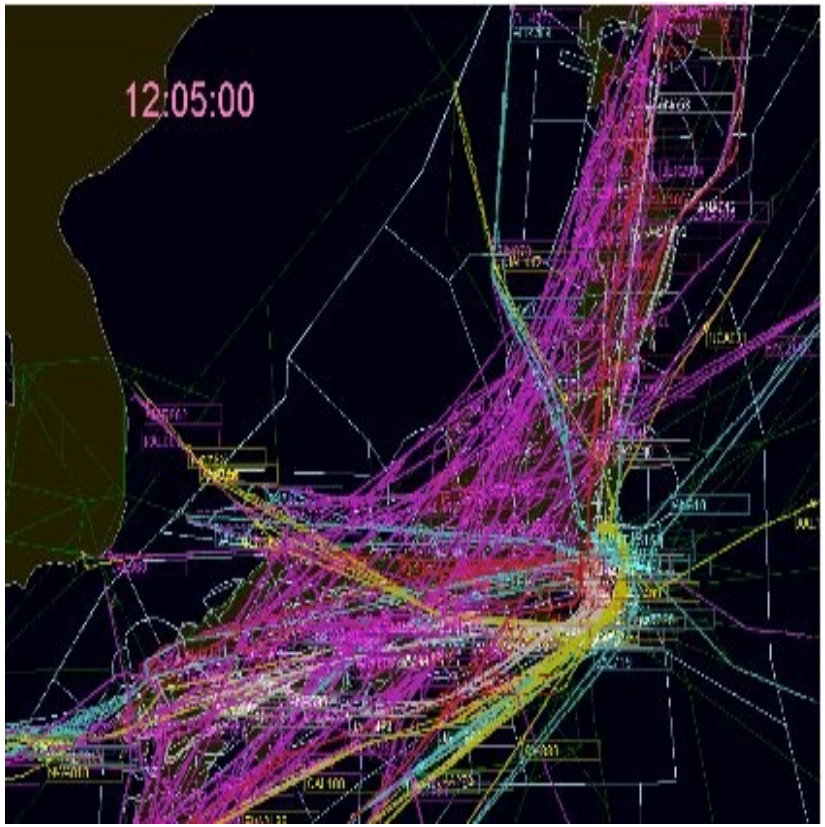


- Propagation along major routes
- No unexpected propagation

Visualization



EUROPE



JAPAN

Comparison JP / EU

Comparison JP/EU

Technique	Attribute	Data
Multi Time plot	Mean	similar
	Var (night/day)	similar
Distribution	Core	similar
(abs, rel)	Mean	similar
	Variances	differ
	Tails	differ
(cond)	Poisson	similar
Trend	Log-like	similar
Propagation	Time	similar
	Space	similar

Airspace

- Similarities
  - Procedures
  - Mechanisms
  - Equipment
- Differences
  - Flow patterns
  - ATFM
  - Culture

Comparison JP/EU

Technique	Attribute	Data
Multi Time plot	Mean	similar
	Var (night/day)	similar
	Variances	differ
	Tails	differ
(cond)	Poisson	similar
Trend	Log-like	similar
Propagation	Time	similar
	Space	similar

- All analyzed major trends are similar
- Tails of distributions show minor differences

Airspace

- Similarities
- Flow patterns
- ATFM
- Culture

Conclusions

- Data Analysis of Traffic Gaps
  - Systematic Gaps
    - the more planned, the less arrive
    - largely due to randomness
  - Propagation
    - only along major routes

Conclusions

- Data Analysis of Traffic Gaps
  - Systematic Gaps
    - the more planned, the less arrive
    - largely due to randomness
  - Propagation
    - only along major routes
- Comparison Japanese / European Data
  - All analyzed major trends are similar

Future Work

- Flow Analysis
  - density / delay relationship
  - model of air traffic flow
- Flow Optimization
  - trajectory based ATM
  - understandable decision support

[Bayen et al. 2005], [Helbing 2001]
[Menon et al. 2004]

Thank you for your attention.

Please ask your questions!