Validation of Controller Workload Predictors at Conventional and Remote Towers

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Setup

Workload + Workload Rating

ATCO responsibility:

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➡ Results in individual workload (depending on different properties of the human operator)

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Assessing workload:

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- Adapted Cooper-Harper scale (CHS)

Rating	Evaluation	Question for Evaluation
1	No problems, desirable	Is the situation solvable without major Disturbance?
2	Simple, desirable	
3	Adequate, desirable	
4	Small, but disruptive "delays"	Is the situation solvable by capacity-reducing measures?
5	Medium loss of capacity, which can be improved	
6	Very disruptive, but tolerable difficulties	
7	Problems to predict development of traffic situation	Is the situation solvable if the ATCO works with a reduced situational awareness?
8	Problems in information processing	
9 9	Problems in information reception	
10	Impossible	

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- Instantaneous Self Assessment (ISA) scale

Rating	Workload	Spare Capacity	Description
1	Underutilized	Very much	Little or nothing to do. Rather boring.
2	Relaxed	Ample	More time than necessary to complete the tasks. Time passes slowly.
3	Comfortable	Some	The controller has enough work to keep him/her stimulated. All tasks under control.
4	High	Very little	Certain nonessential tasks are postponed. Could not work at this level very long. Controller is working at the limit. Time passes quickly.
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  → Approximate way of transferring ISA to CHS

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Neither of our studies was planned as a stress test at the boundaries of capabilities
→ Lower ratings present

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- Both might indicate an increase in workload:

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➡ Integrate length of communication related to AT types (as weights)

1. Average communication times for AT types
2. Percentage of the total communication time for AT types

- Both might indicate an increase in workload:
  1. Individual call related to AT1 takes up more time than those for AT2

Quantitative Measures Based on Communication Duration

- Counting ATs

➡ Treats all AT types equally

- But: some AT types may have higher impact on workload than others
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     - We assume sheer number of call leads to higher attention for these calls

SPAM Queries

- Probe questions during experimental studies: measure situational awareness

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- Situation Present Assessment Method (SPAM):
  - Measure ATCO reaction times to questions related to the current scenario
  - Proper SA: low latency + high accuracy
  - Possible question: ``What is the actual wind speed for Sundsvall/Örnsköldsvik (S/Ö)?''

Necessary and Sufficient Conditions

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- Goal: validate quantitative indicators on power to predict ATCO workload

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- IF: measure is sufficient condition for workload increases and decreases

➡ The measure would yield a perfect predictor for workload changes

Study Setup

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Two studies at two different occasions at two different locations:

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Field Study

- Conventional tower at Bromma airport

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- 3 ATCOs (2f, 1m)
- ATCO's mean age: 52

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- Mean years worked as ATCO: 23.3

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- Singular mode: 5 movements

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- Multiple mode: 6 movements

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- Each run: 75 mins

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- 3 video cameras towards ATCOs
- 3 ATCOs (2f, 1m)
- ATCO's mean age: 52
- Mean years worked as ATCO: 23.3
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- Singular mode: 5 movements
- Multiple mode: 6 movements
- Each run: 75 mins
- ISA scale used
- ATCO WL rating assessed every 3 mins

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- Mean years worked as ATCO: 23.3
- Mean years at RTC: 5.6 years
- Singular mode: 5 movements
- Multiple mode: 6 movements
- Each run: 75 mins
- ISA scale used
- ATCO WL rating assessed every 3 mins
- Sample size: 25 per ATCO

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- Also measured: length and purpose of communication

Simulation Study

- Simulated Remote Tower in single or multiple modes for airports in Örnsköldsvik and Sundsvall, simulation in Sundsvall
- May 6-17 2019
- 3 video cameras towards ATCOs
- 3 ATCOs (2f, 1m)
- ATCO's mean age: 52
- Mean years worked as ATCO: 23.3
- Mean years at RTC: 5.6 years
- Singular mode: 5 movements
- Multiple mode: 6 movements
- Each run: 75 mins
- ISA scale used
- ATCO WL rating assessed every 3 mins
- Sample size: 25 per ATCO
- Also measured: length and purpose of communication; reaction time to SPAM queries

Study Setup

Two studies at two different occasions at two different locations:

Field Study

- Conventional tower at Bromma airport
- March 4, 2019
- During actual operation
- 5 video cameras, 3 towards ATCOs, 2 towards opposite RWY ends
- Videos used to reconstruct ATs
- 2 ATCOs + 1 assistant
- 3 ATCOs observed for 4 hours (1f, 2m)
- ATCO's mean age: 43
- Mean years worked as ATCO: 19.6 years
- CHS used
- ATCO WL rating assessed every 5 mins (first 15 mins)
- Sample size: 45
- Also measured: length and purpose of communication

We observed:

- Snow sweeping with a convoy of 10-14 vehicles
- #Movements/h: 4, 5, 9, 27

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Results Field Study

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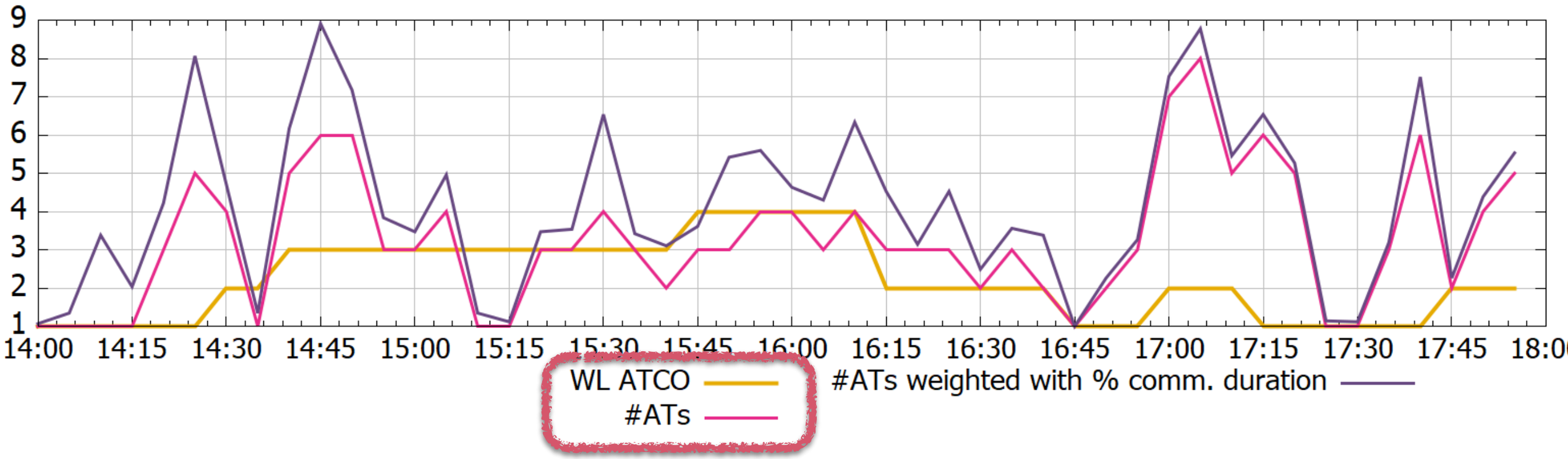

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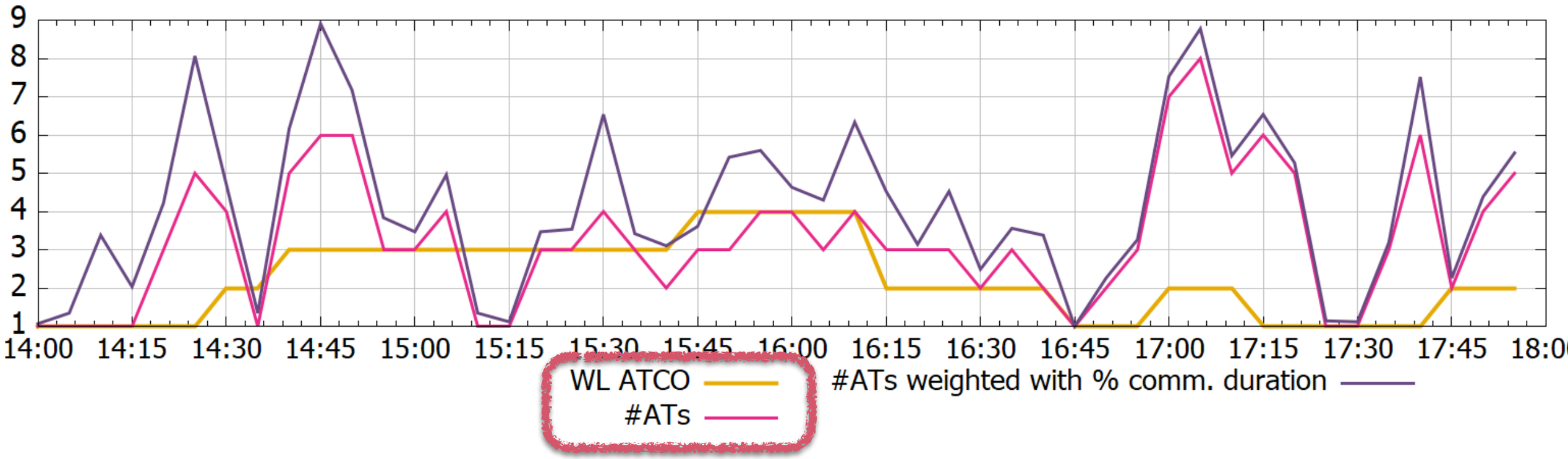

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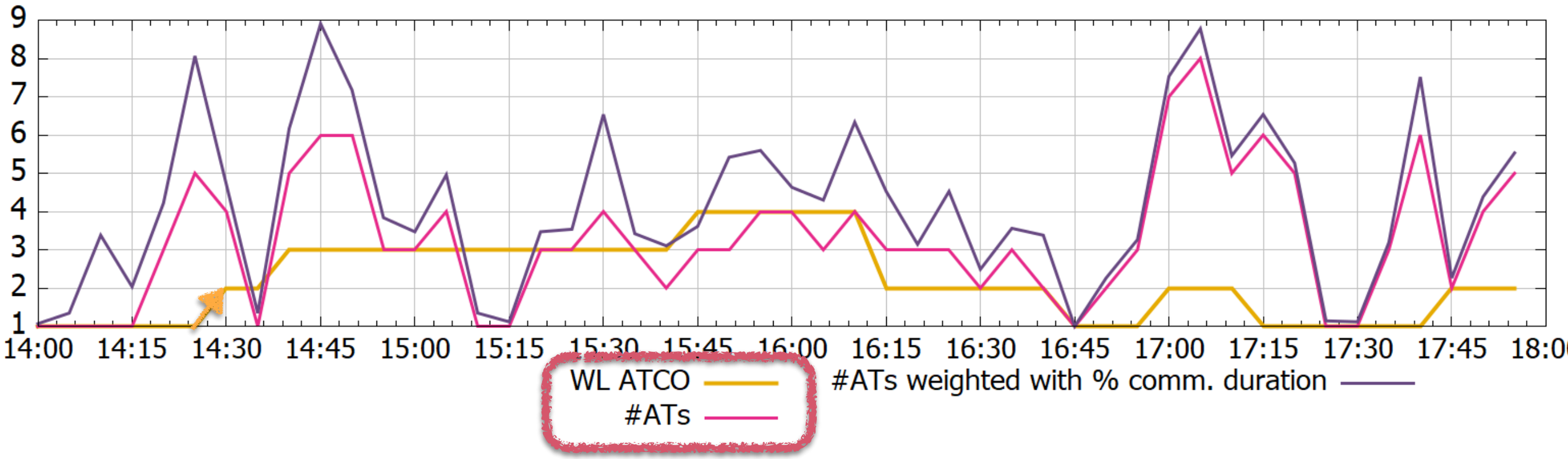

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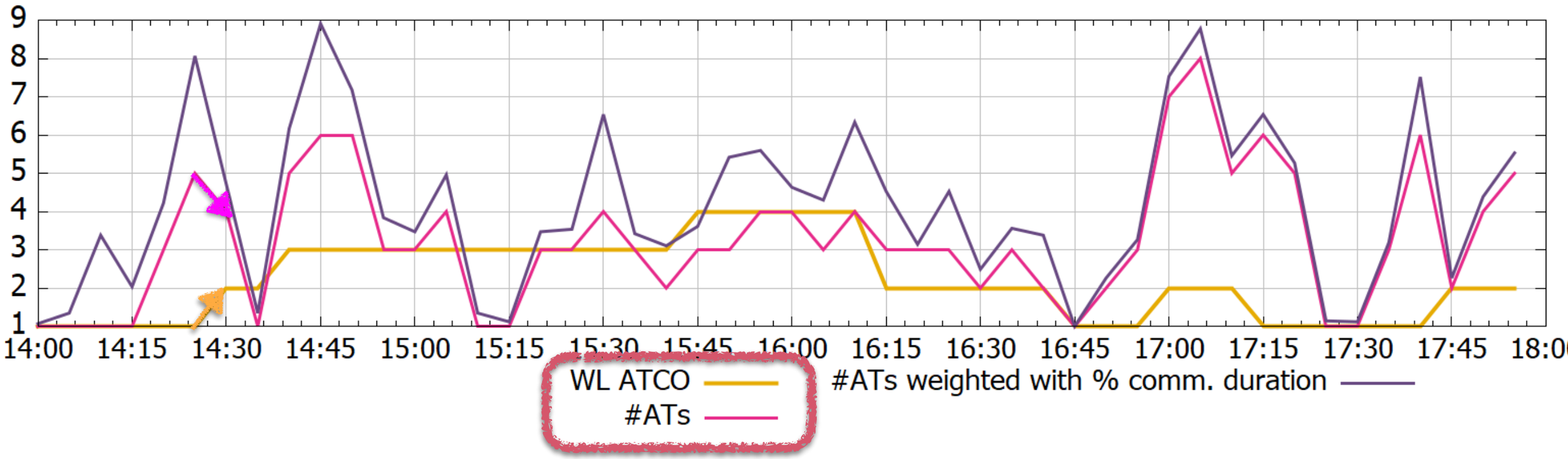

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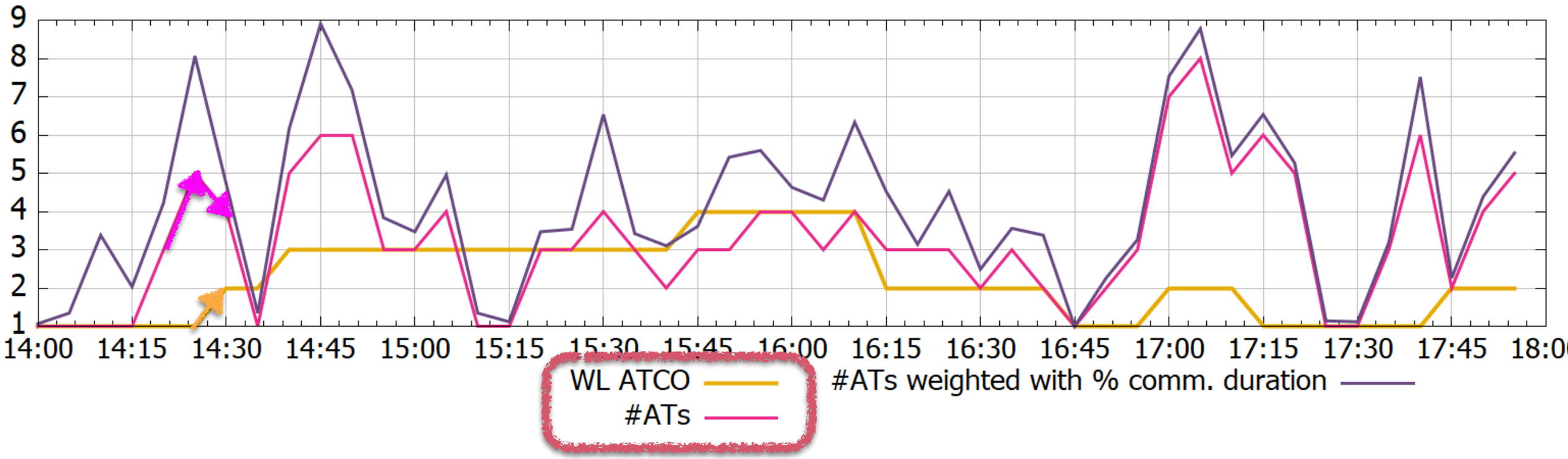

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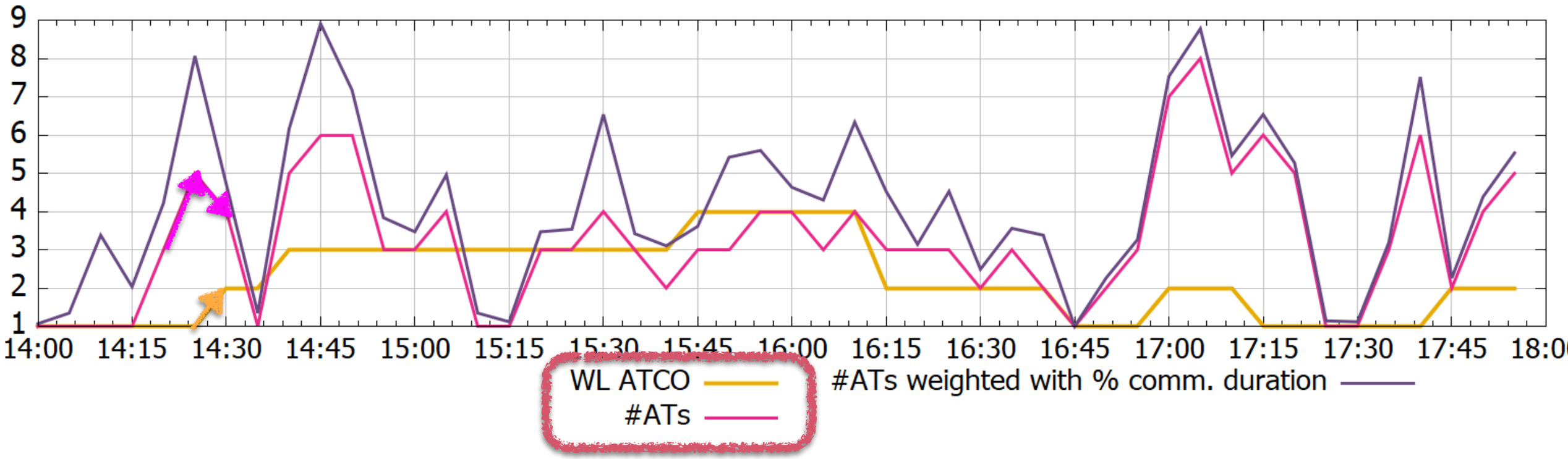

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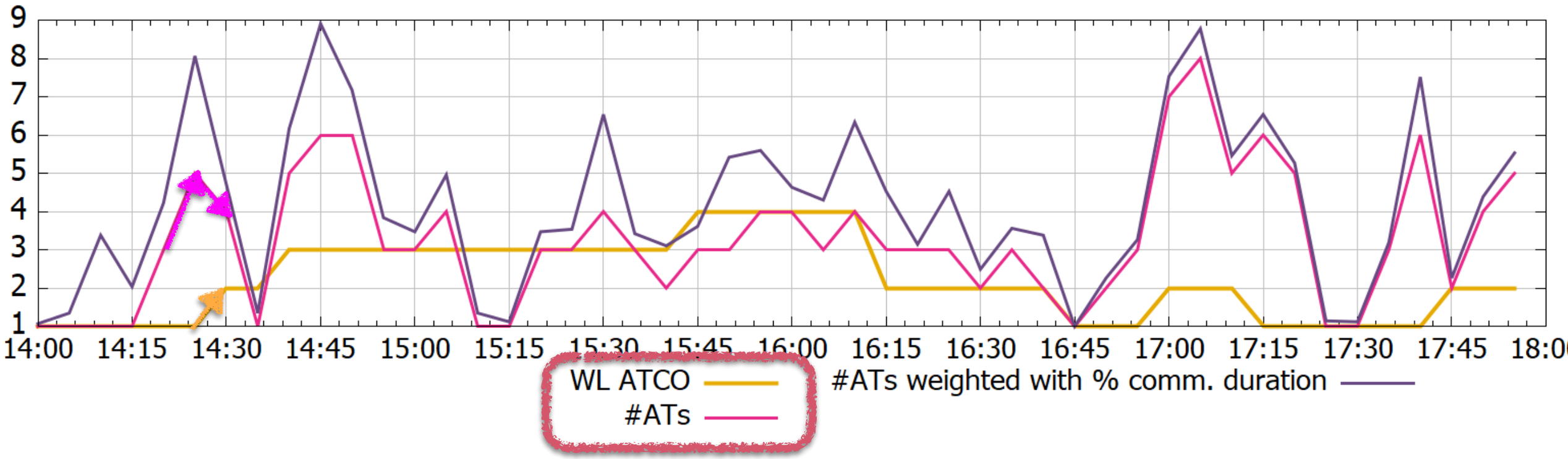

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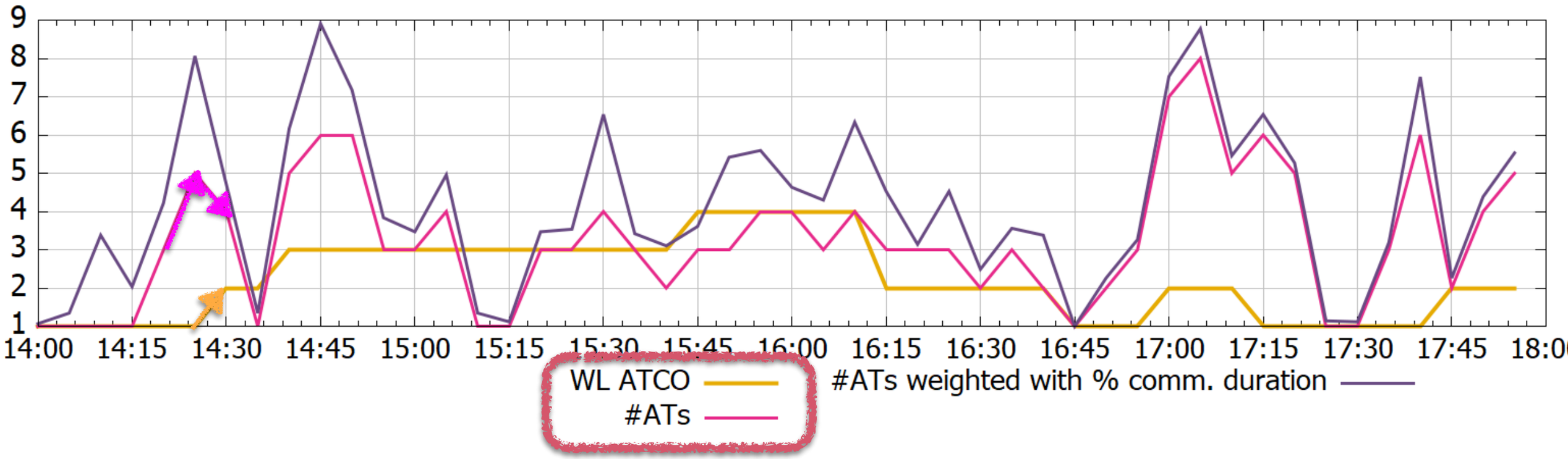

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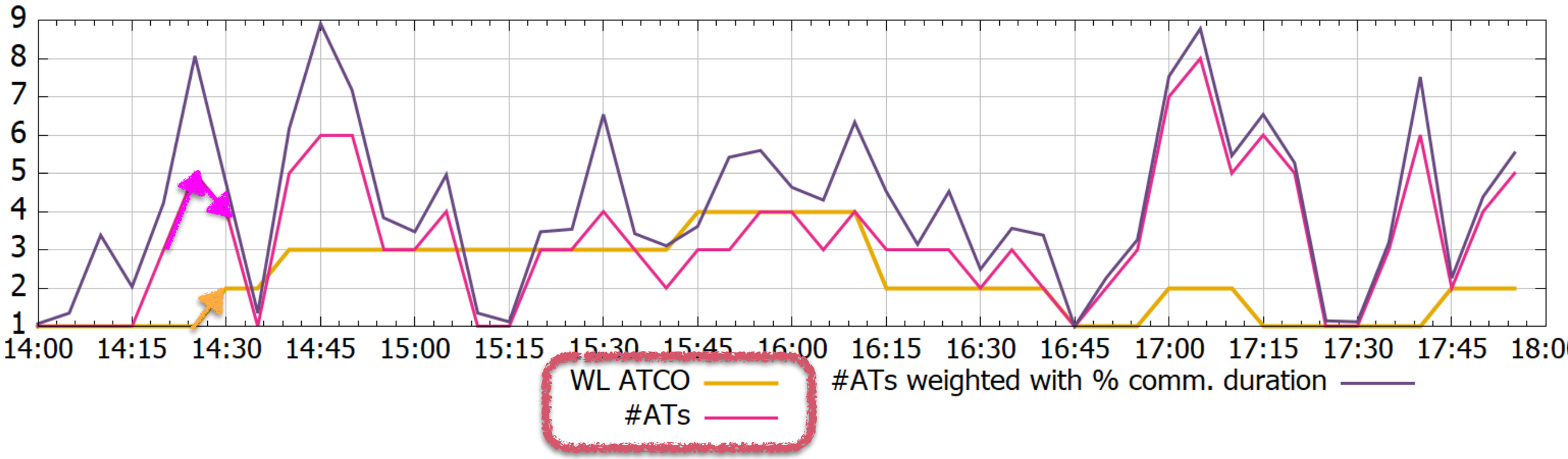

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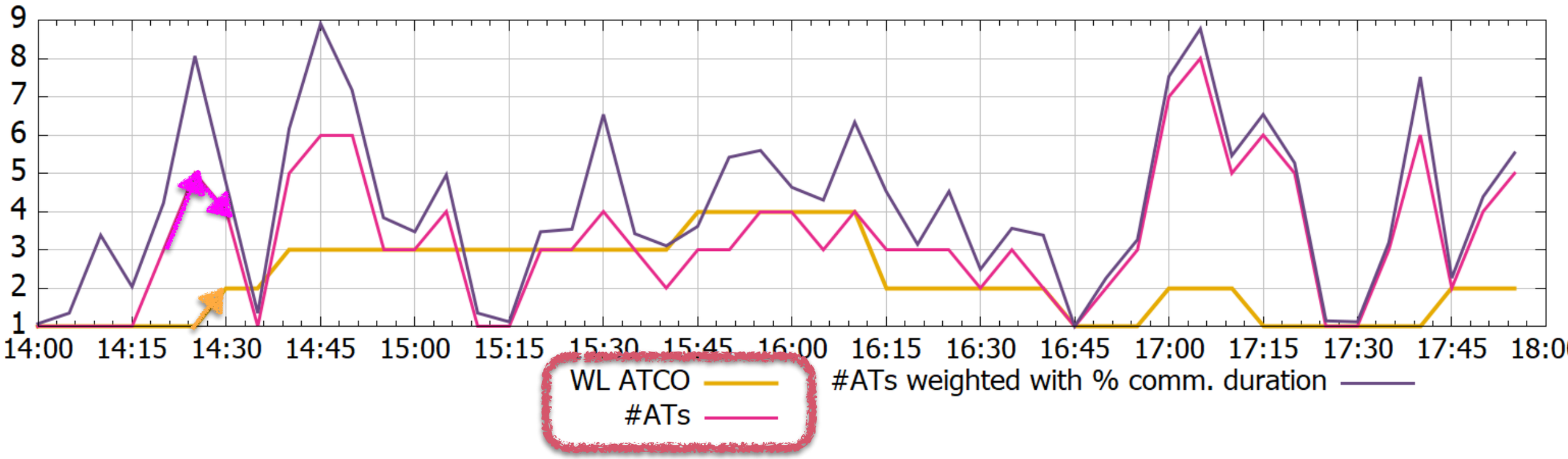

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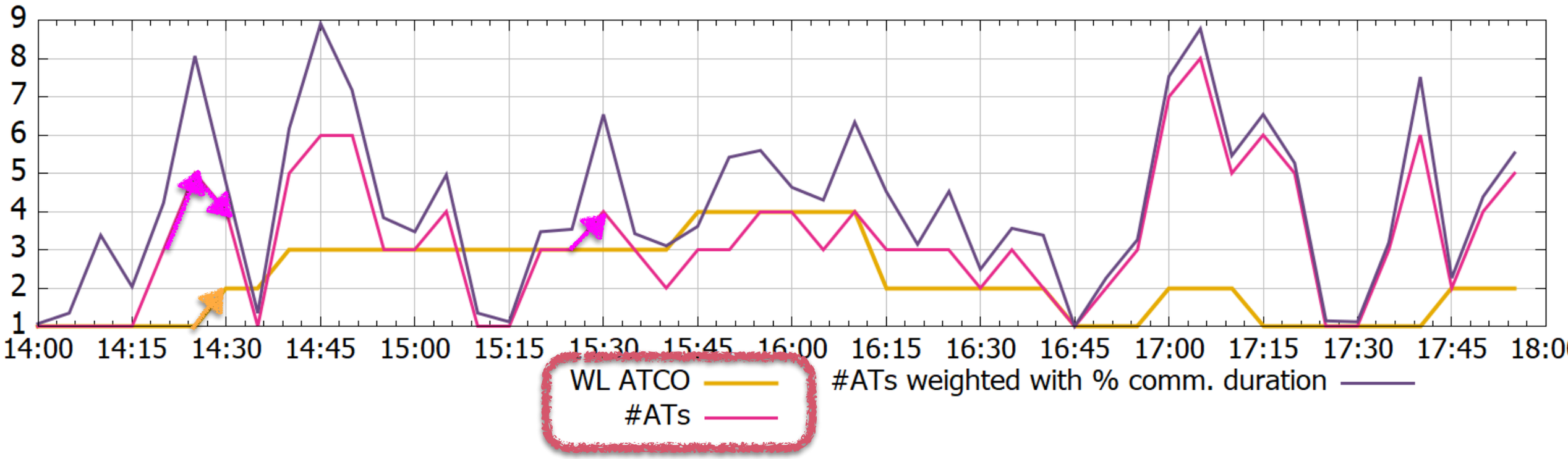

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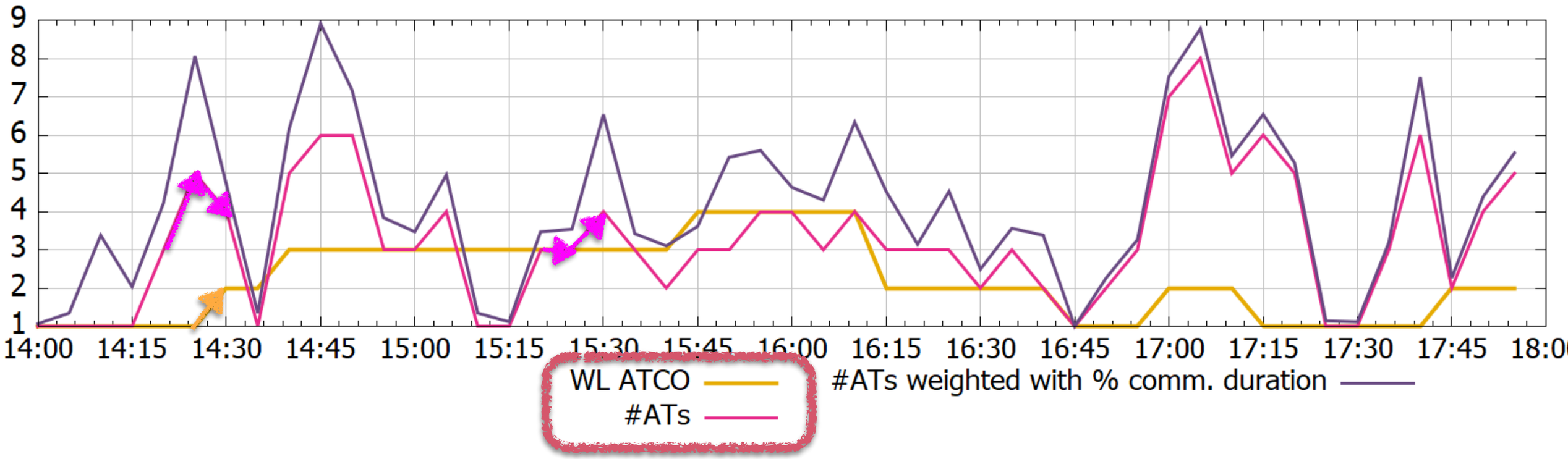

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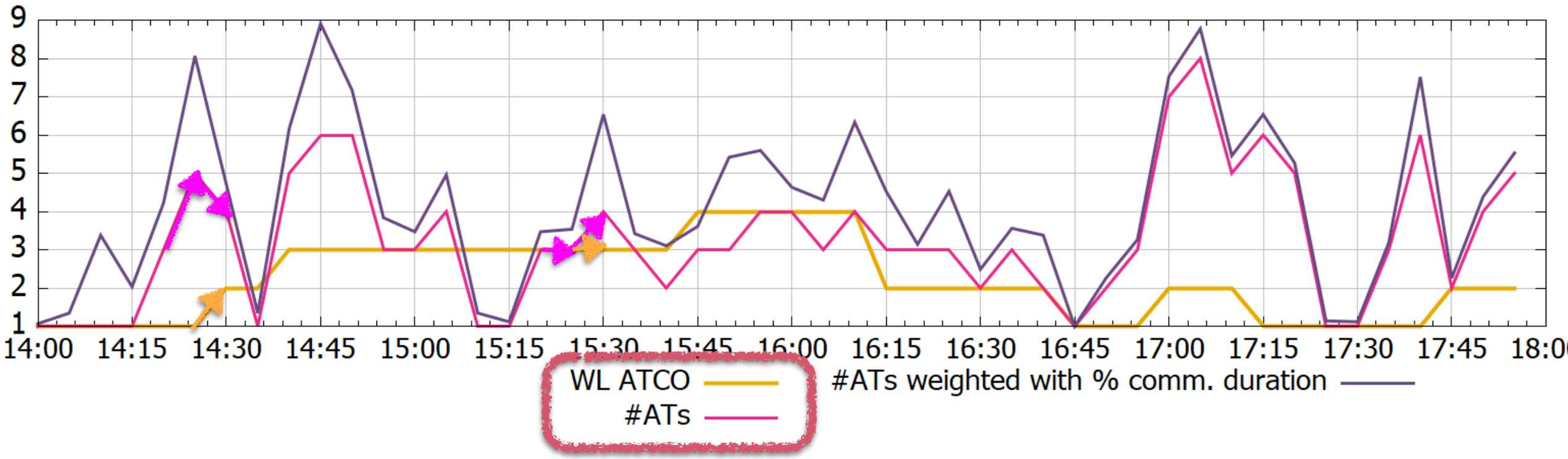

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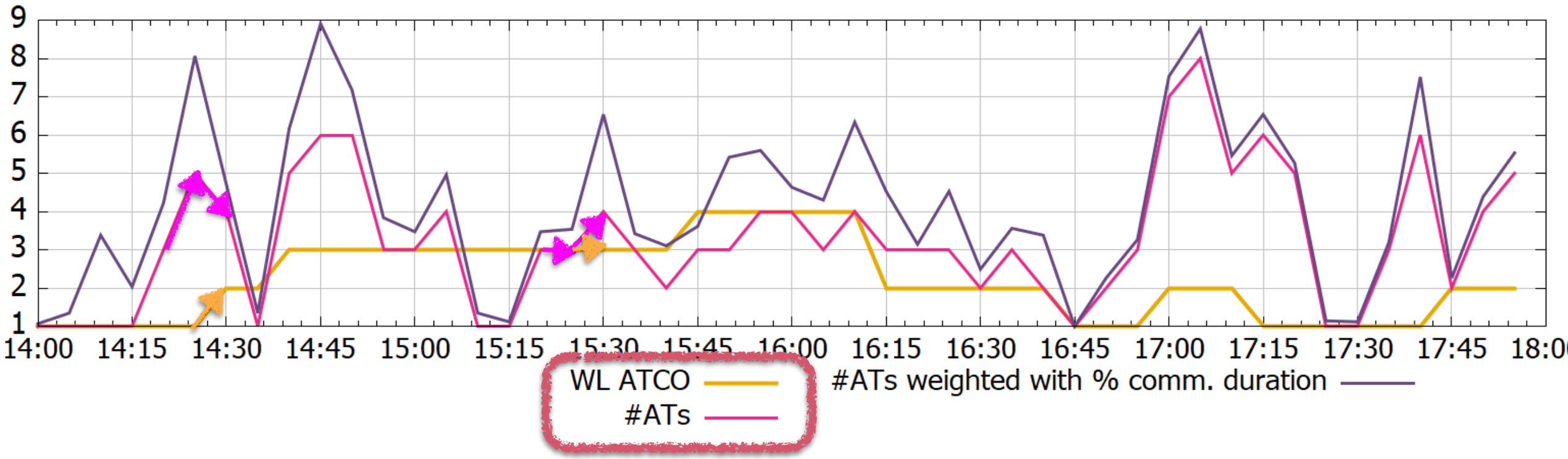

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➡Increase in the **number of ATs** can be a **necessary**, but **not a sufficient** indicator for increased **workload**

Communication Split: Weights for ATs

	Arrival	Clearance	Comm	Taxi	Departure	Ground	Total	
Average (in s)	10.04348	20.34783	11.2	10.7	11.44118	13.48	Ø	
Sum (in s)	231	468	448	321	389	674	2531	
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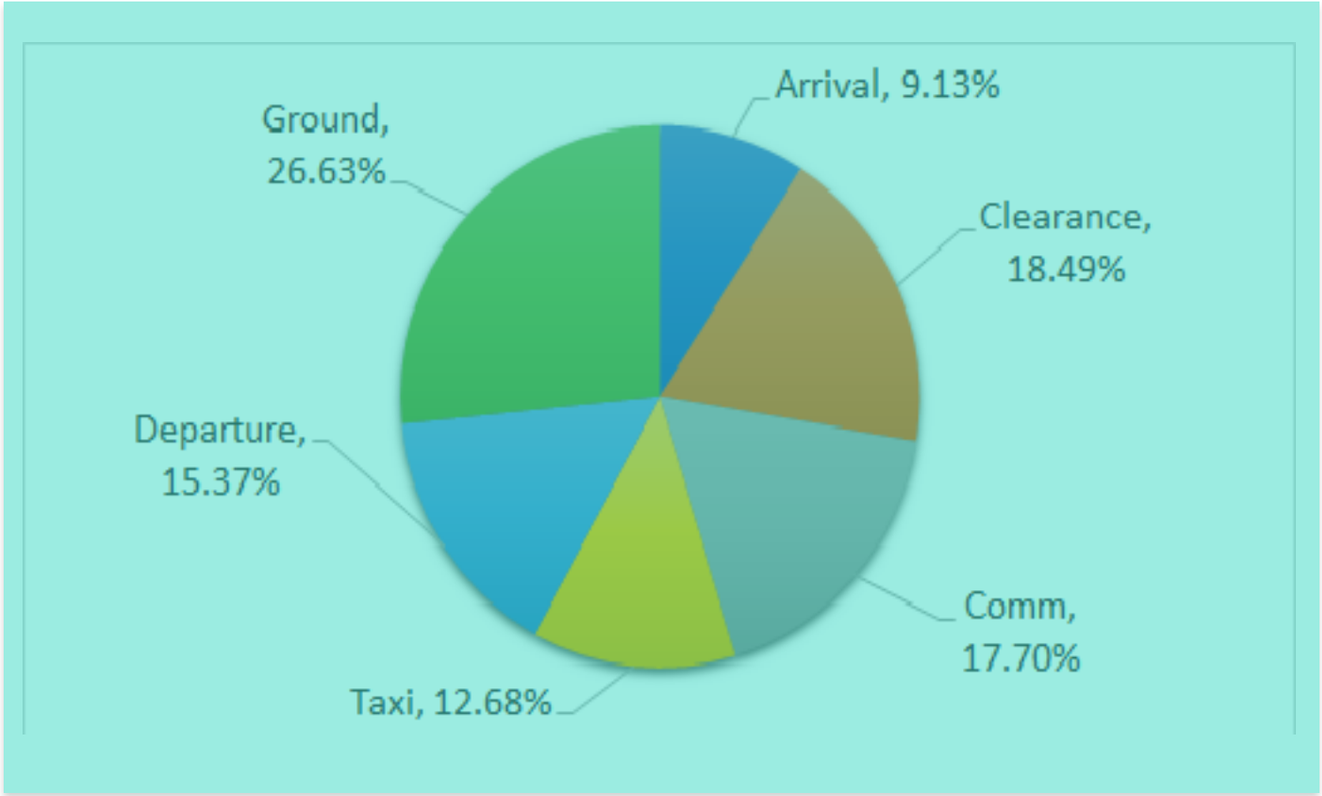

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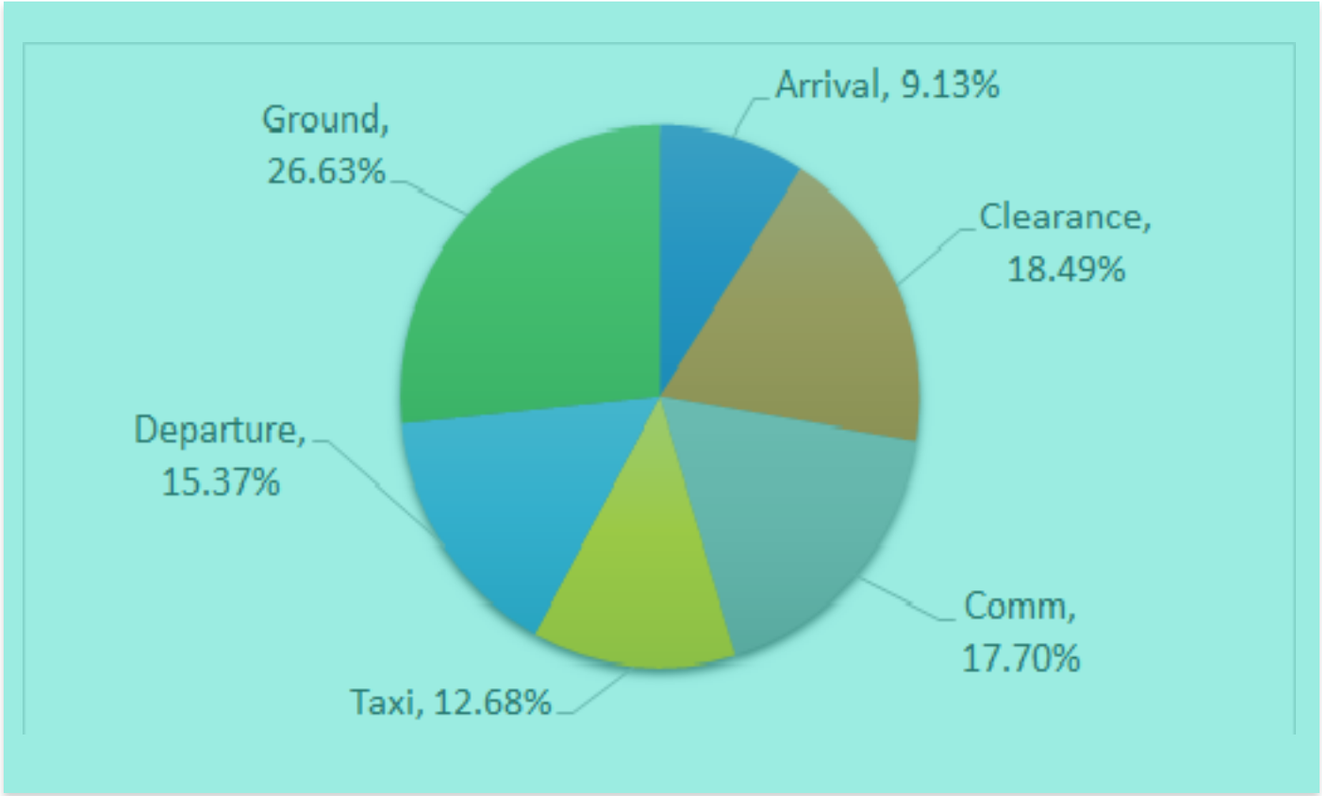

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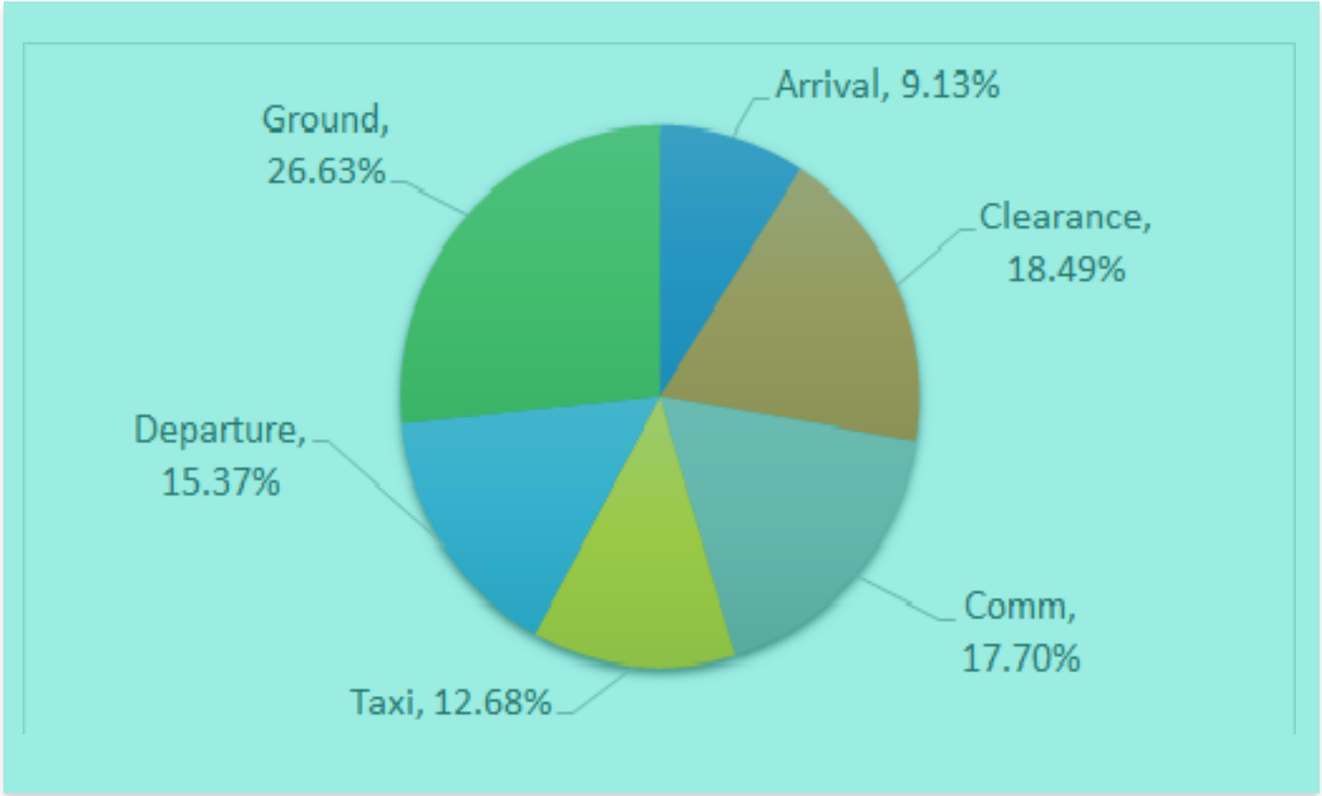

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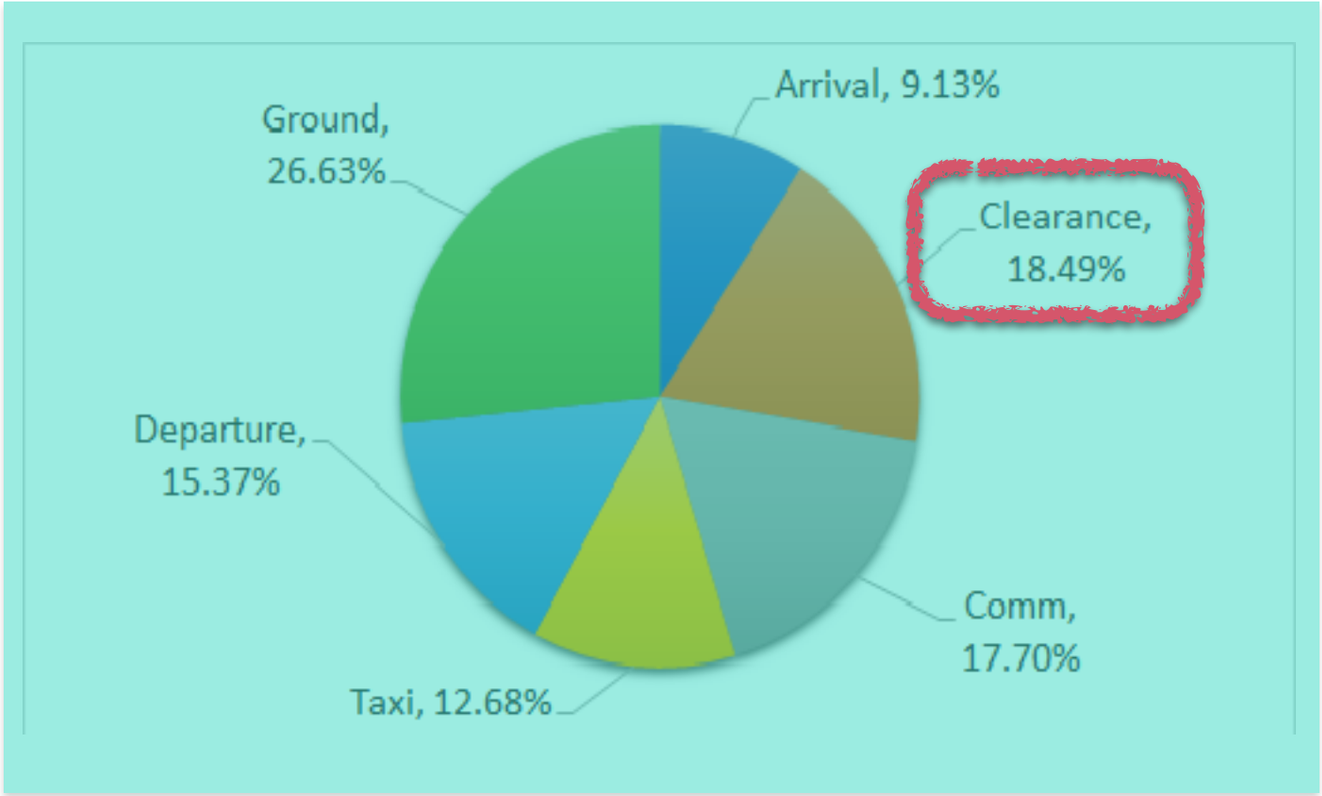

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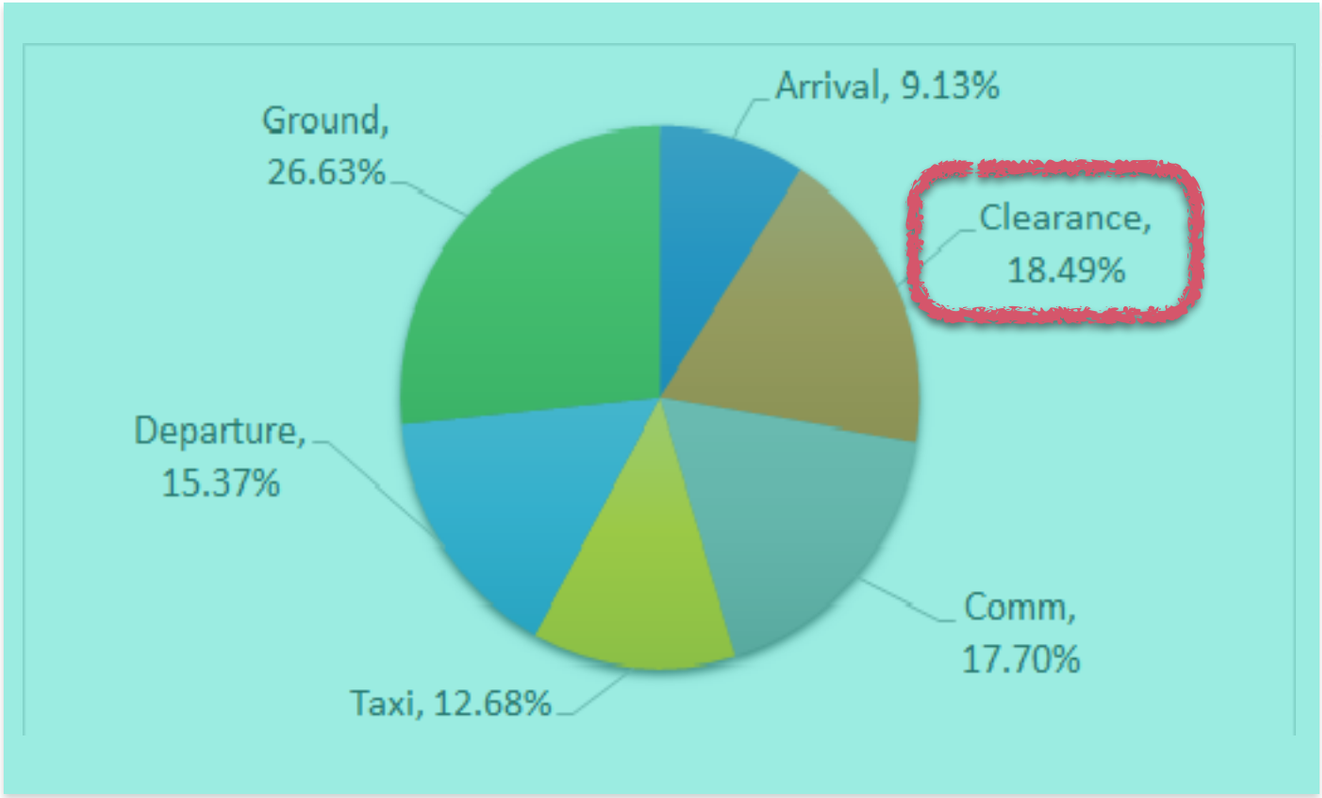

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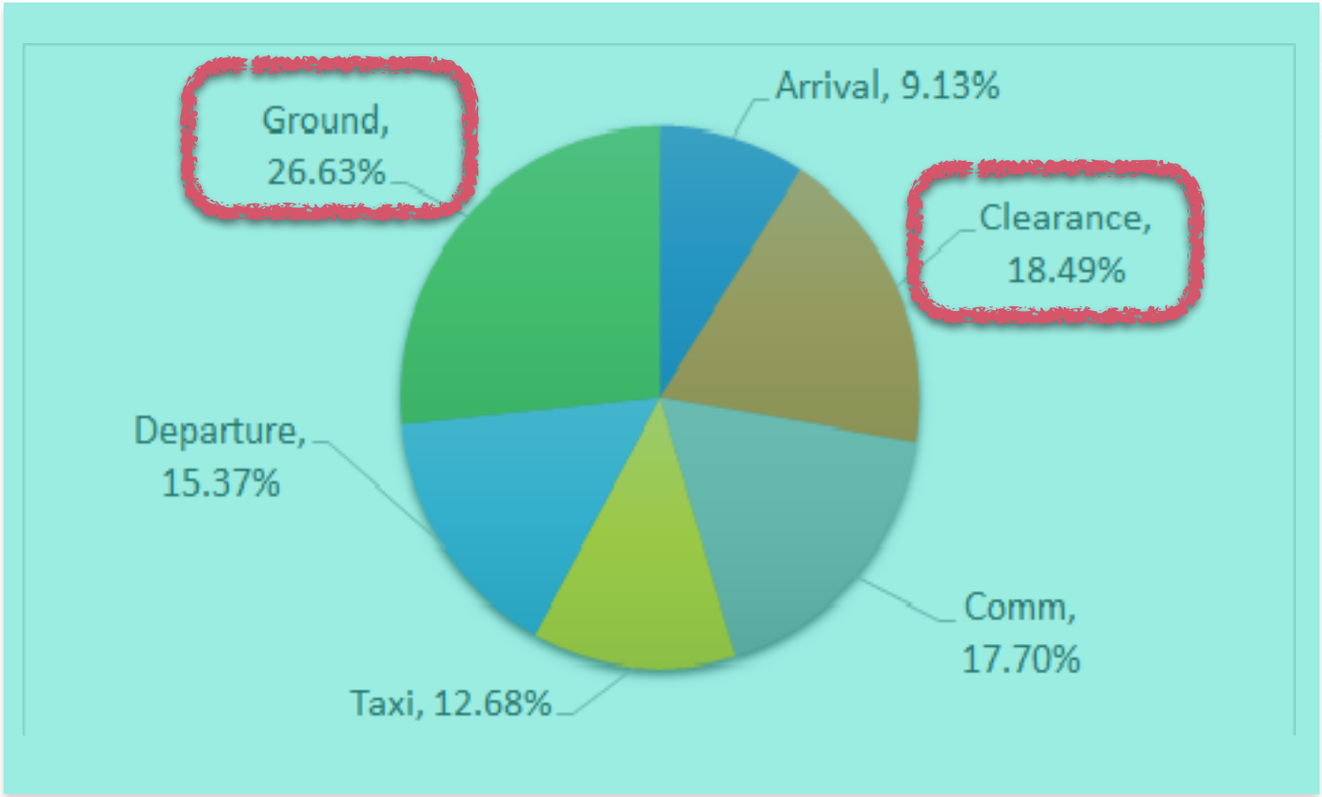

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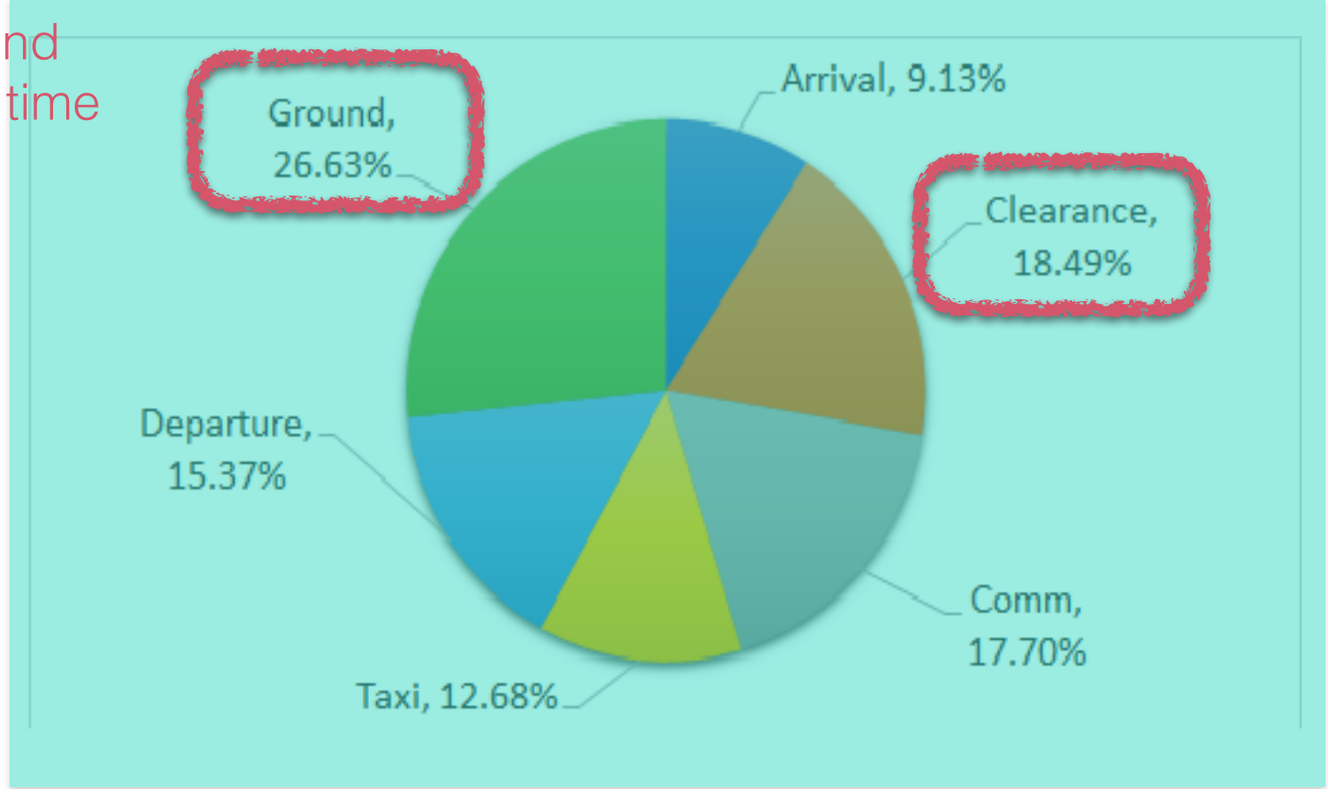
Communication to ground vehicles takes up most time (snow cleaning clearly represented here)



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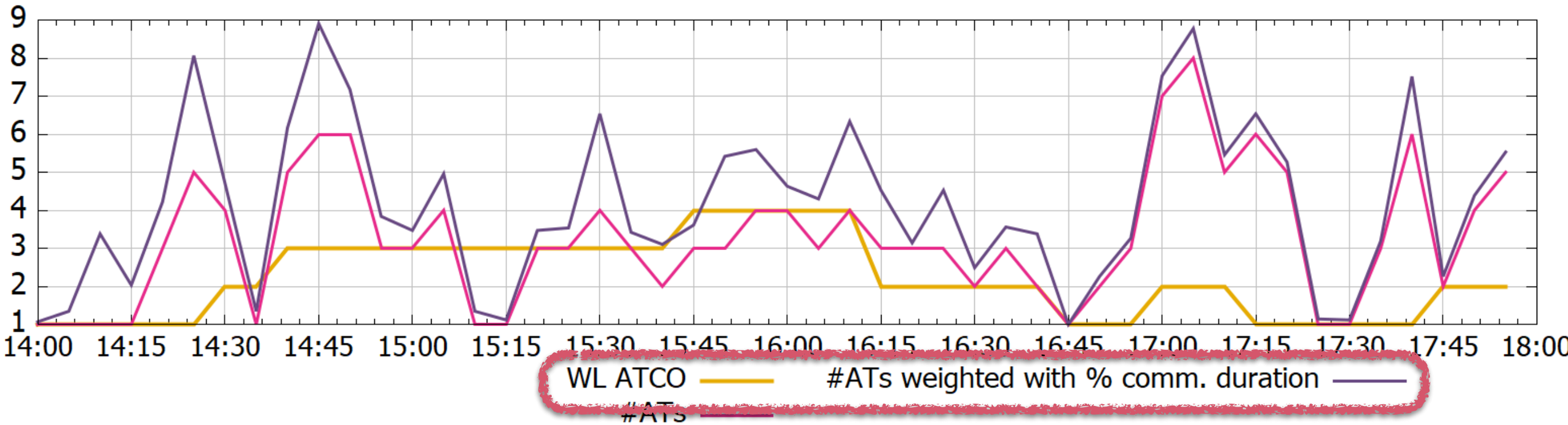

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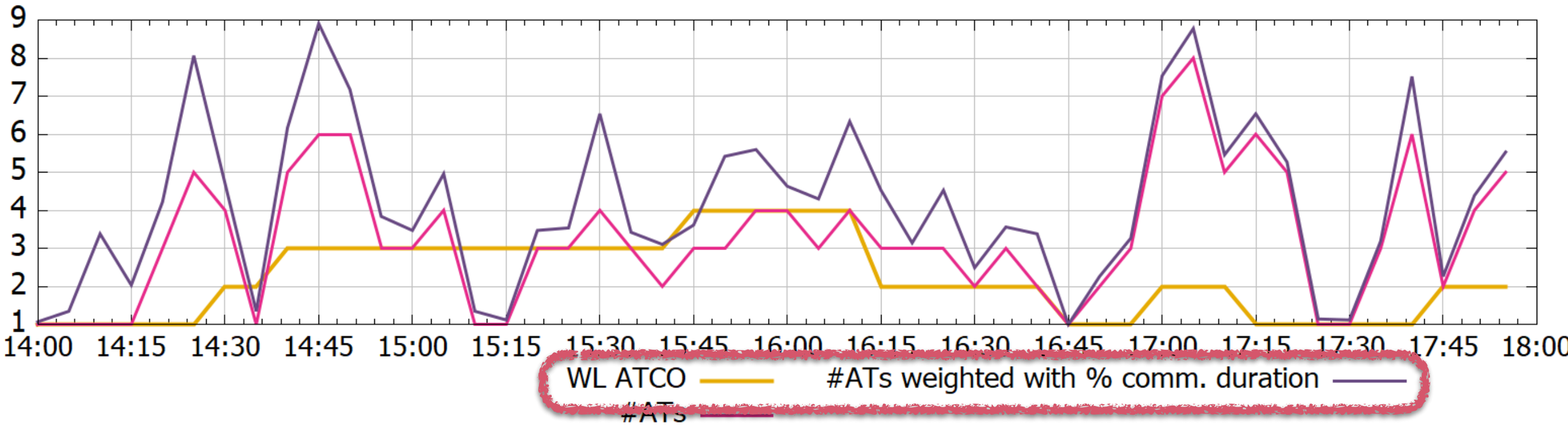

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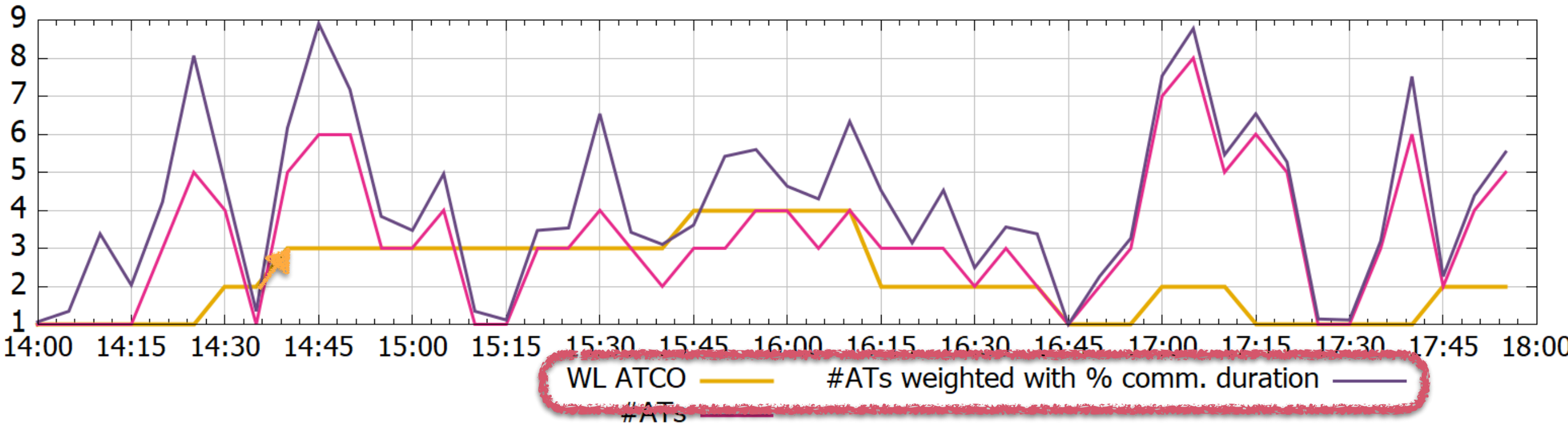

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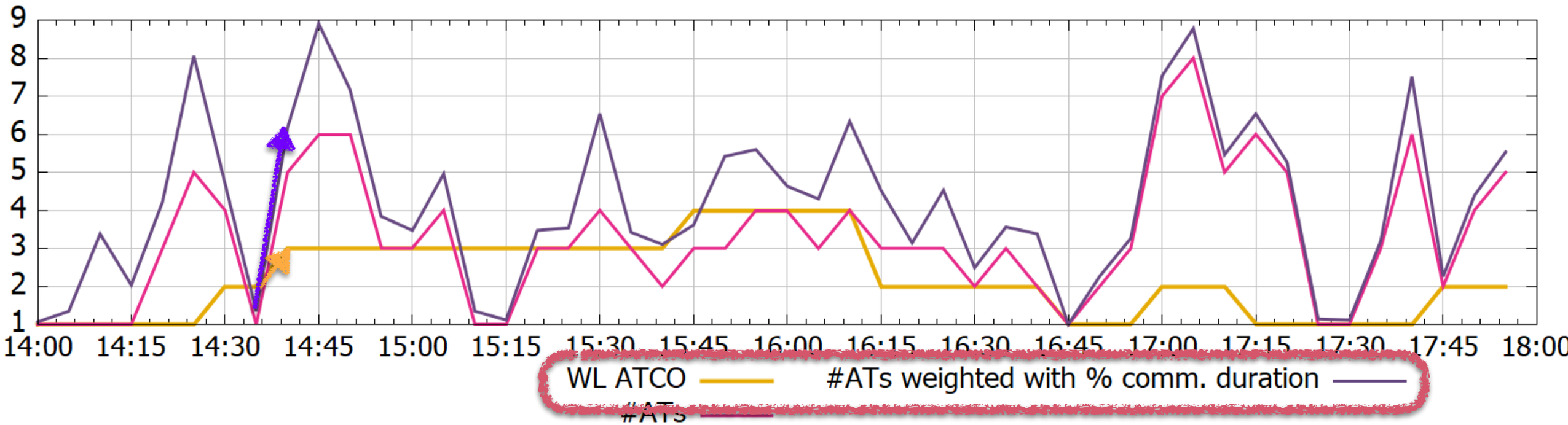

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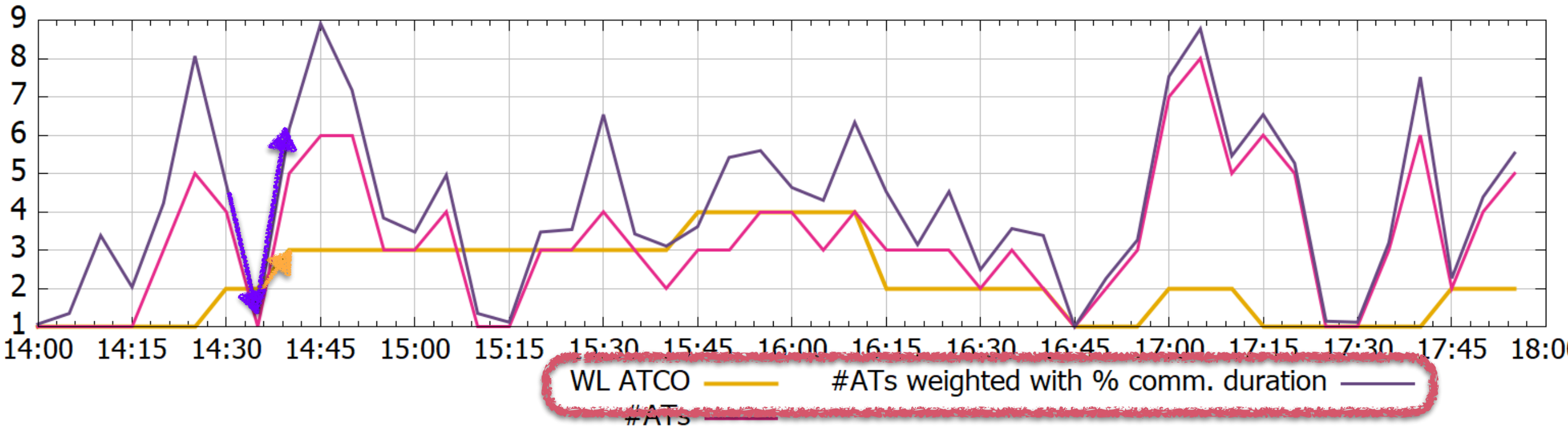

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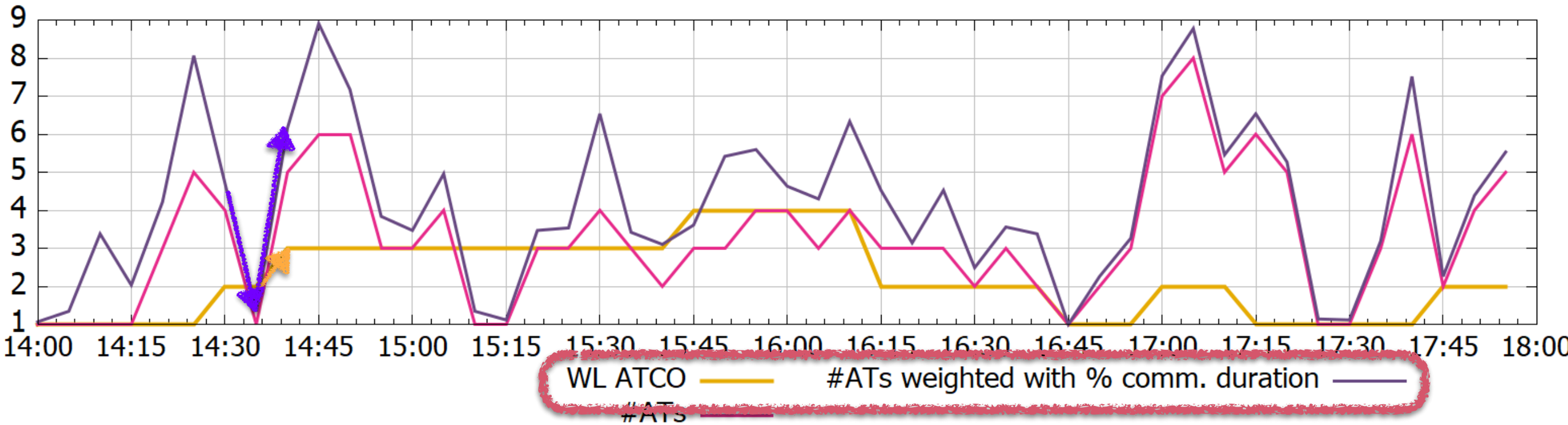

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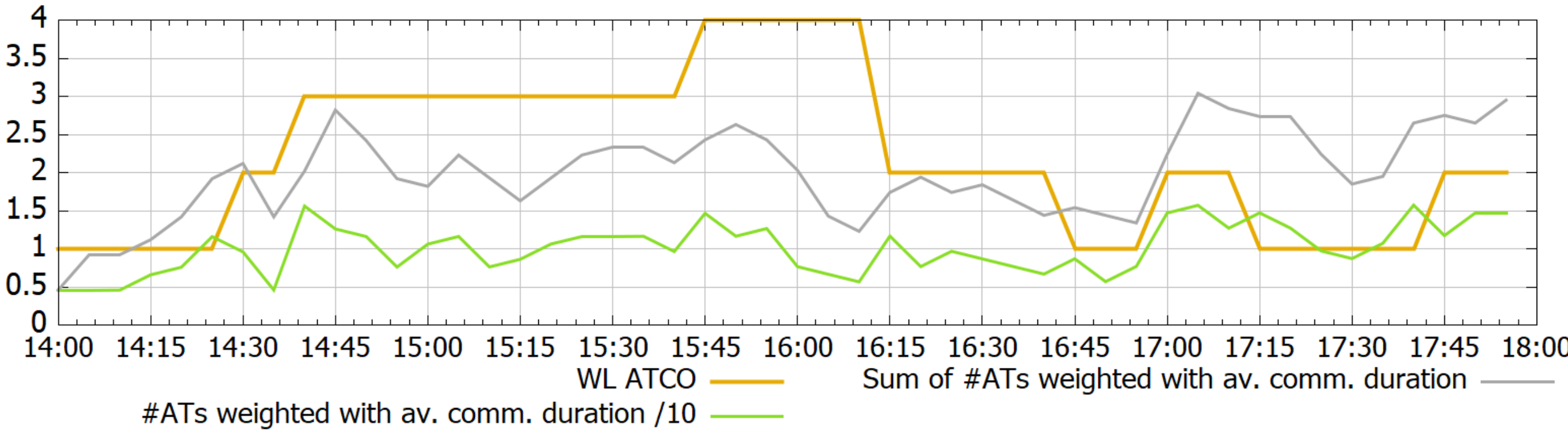

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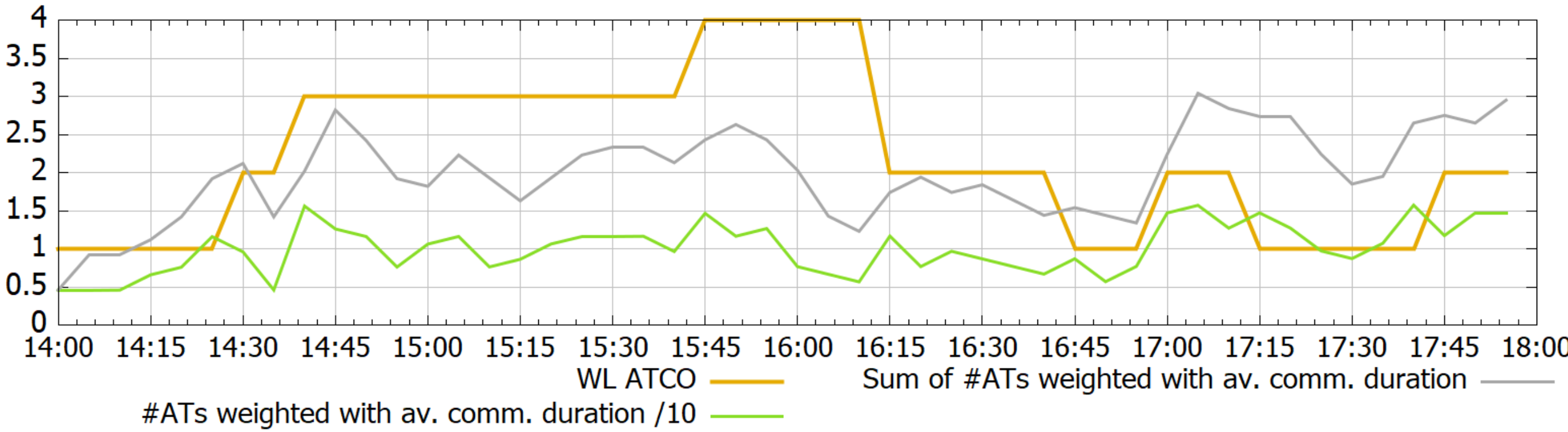

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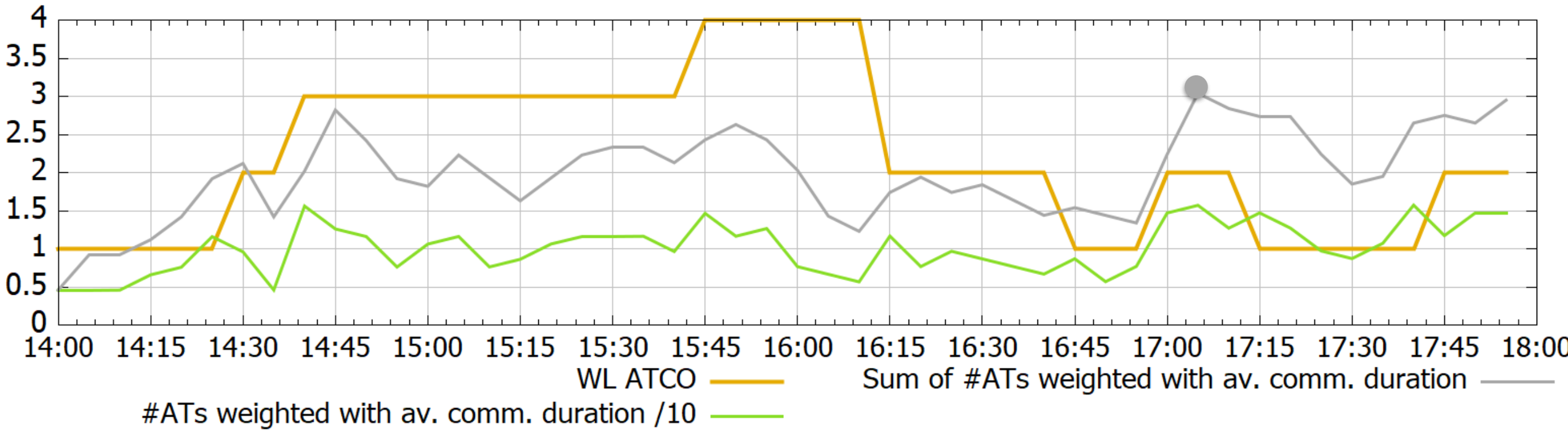

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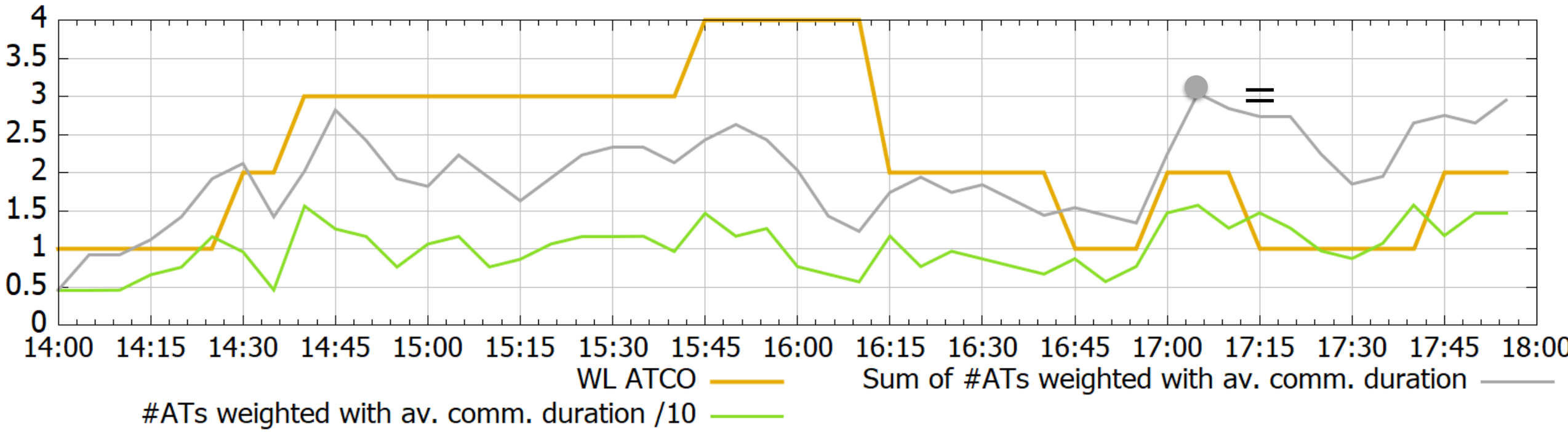

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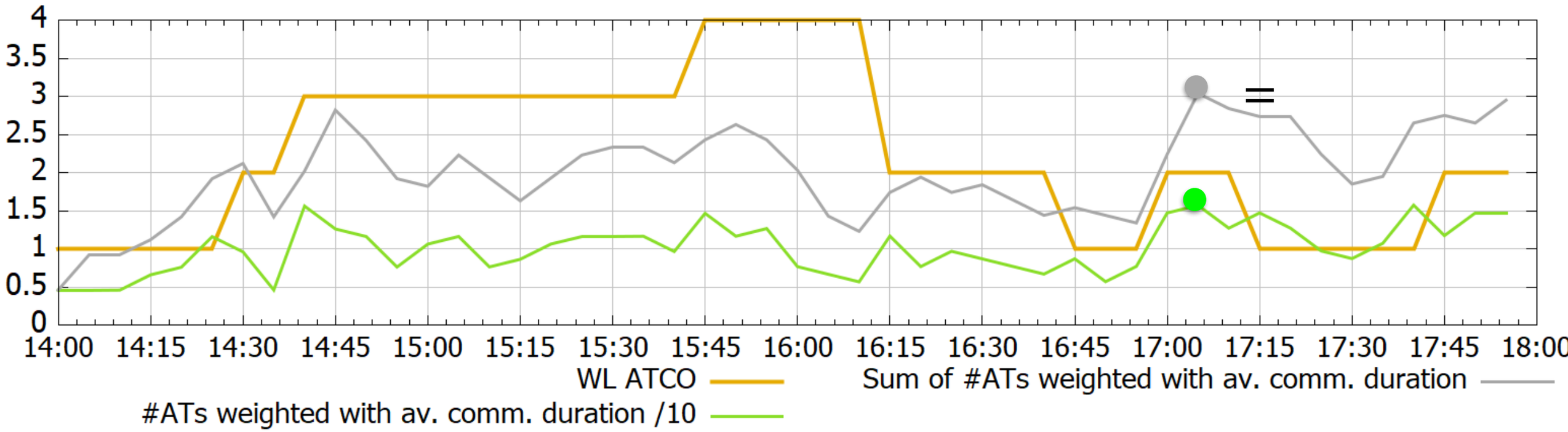

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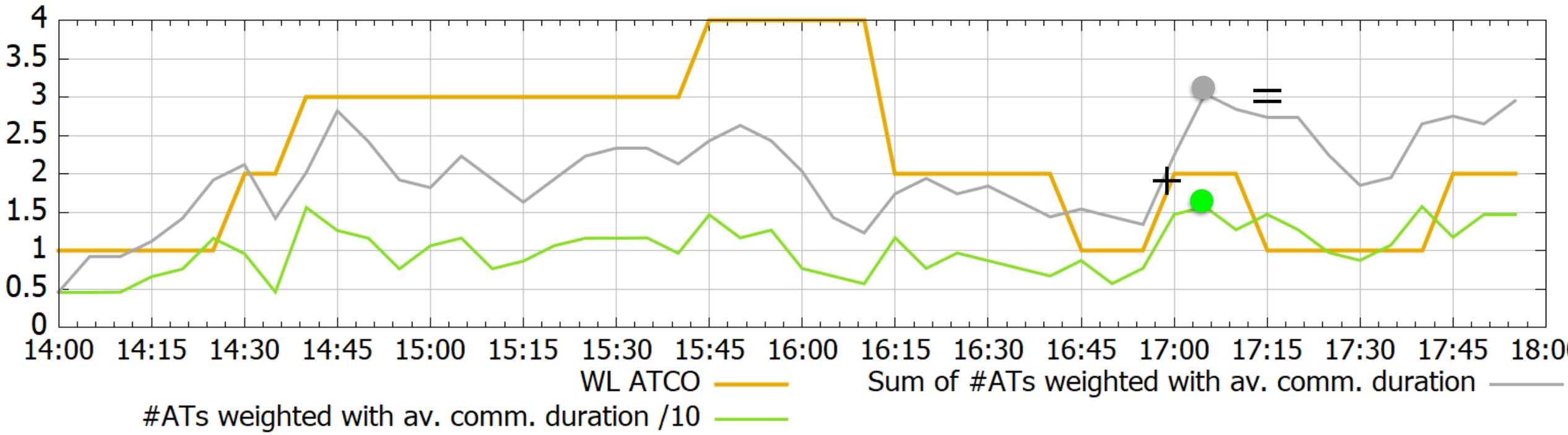

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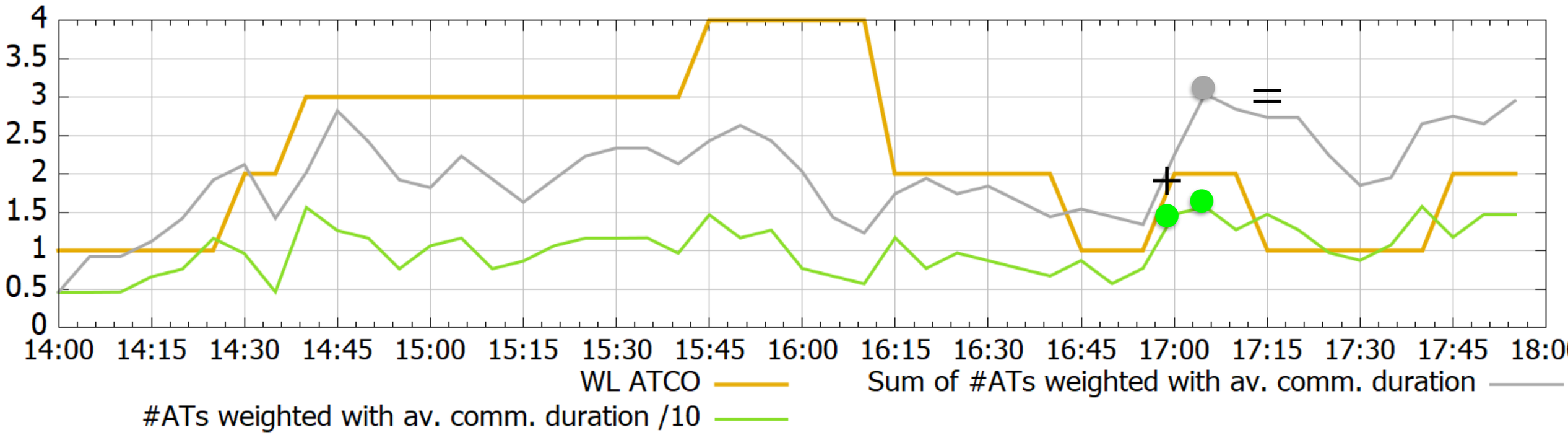

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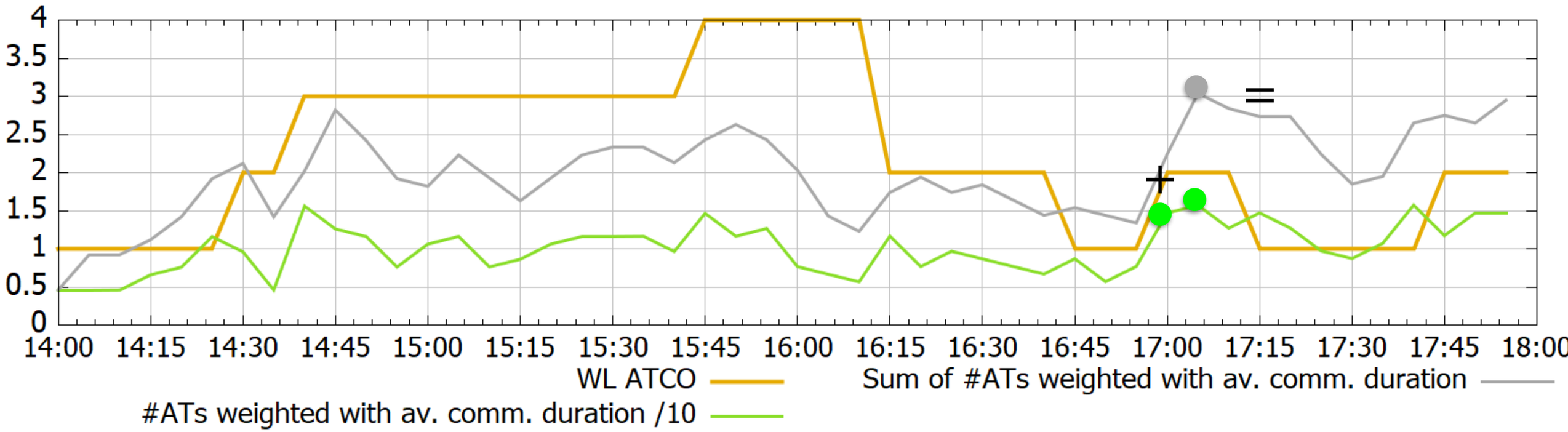

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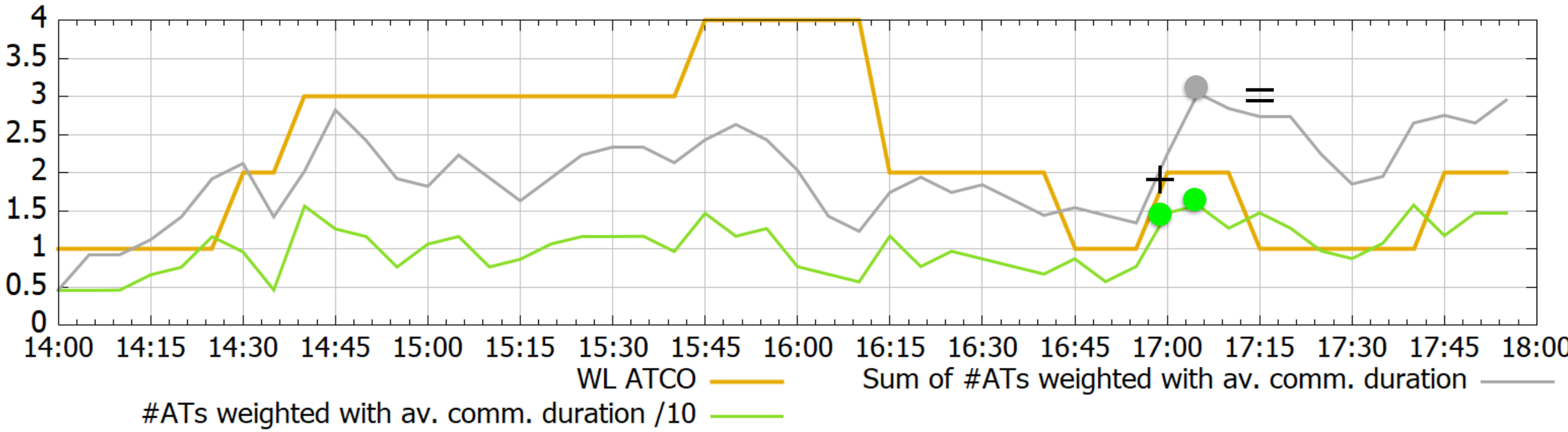

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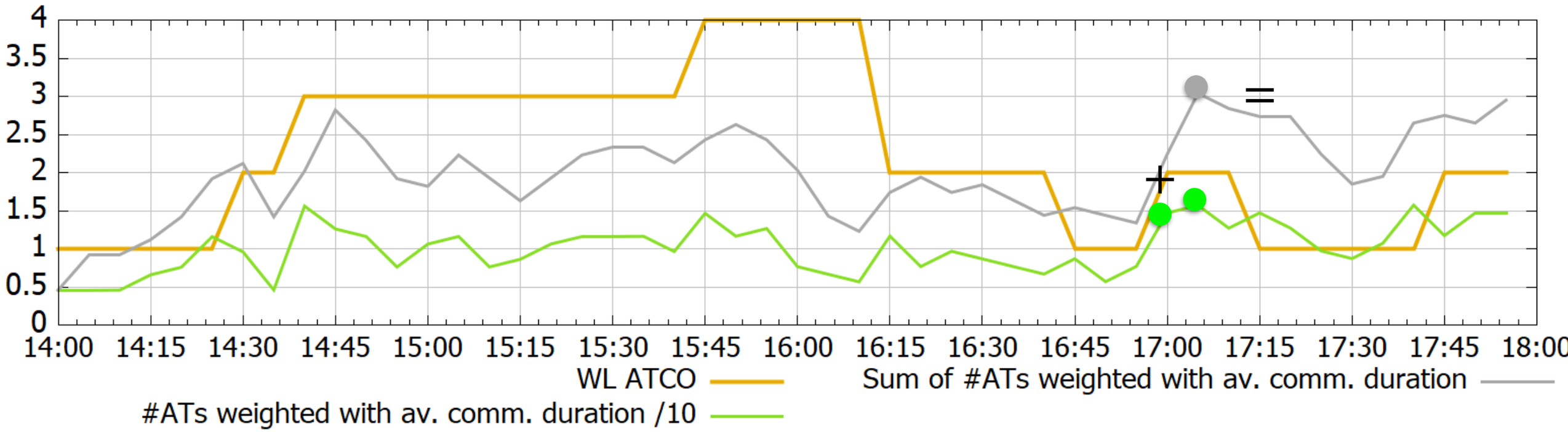

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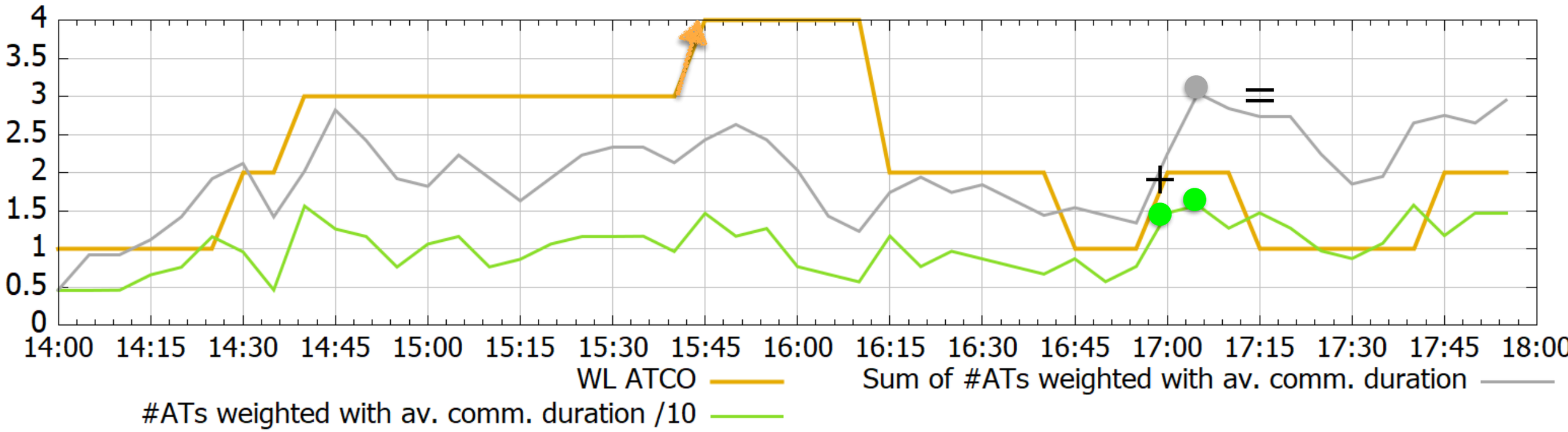

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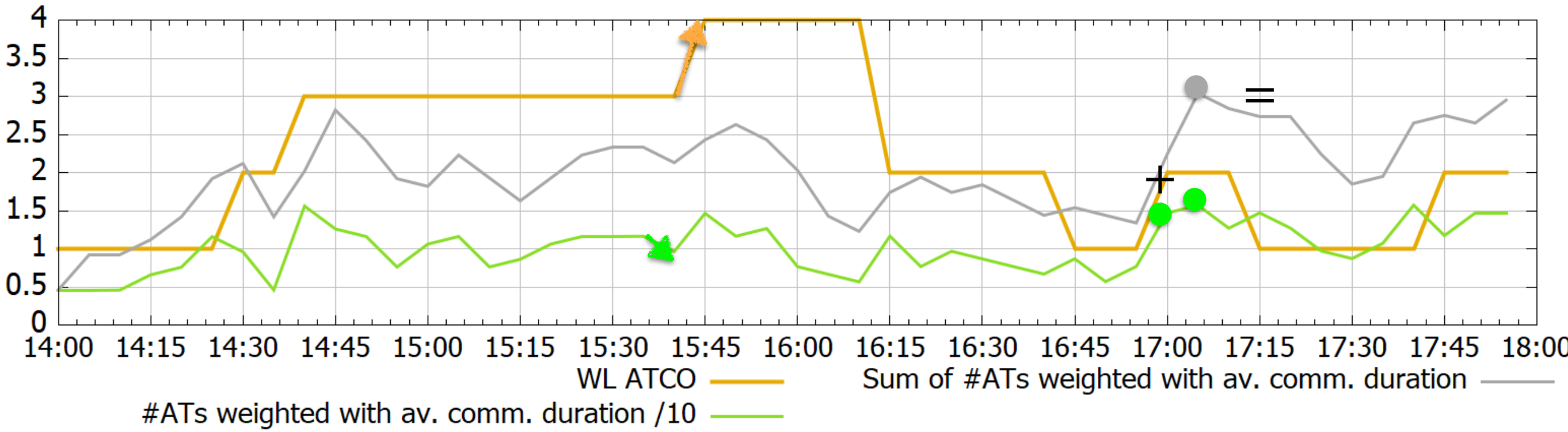

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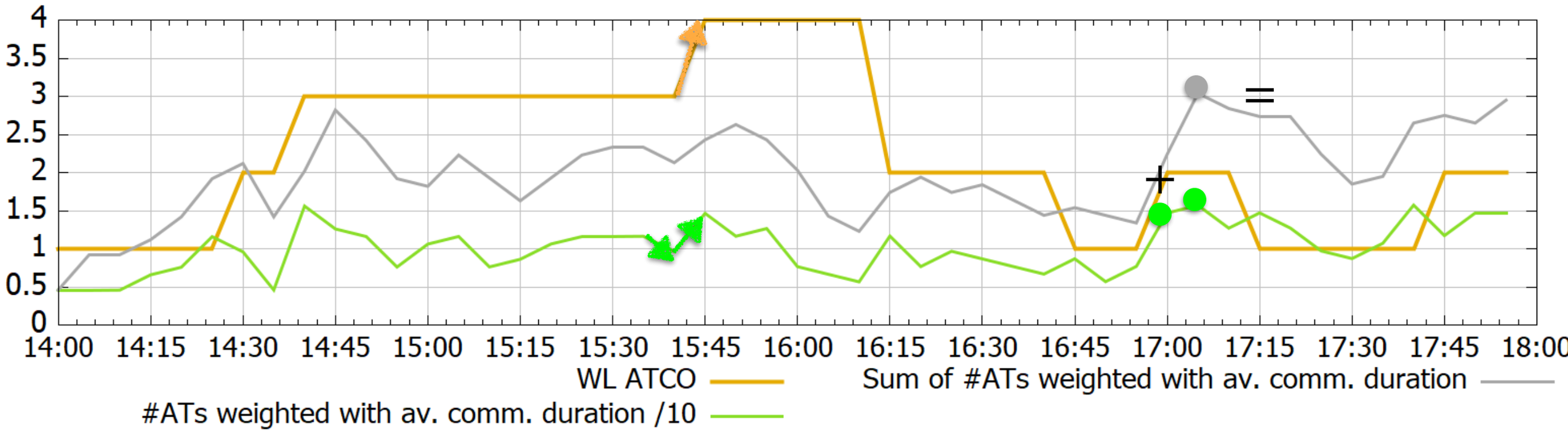

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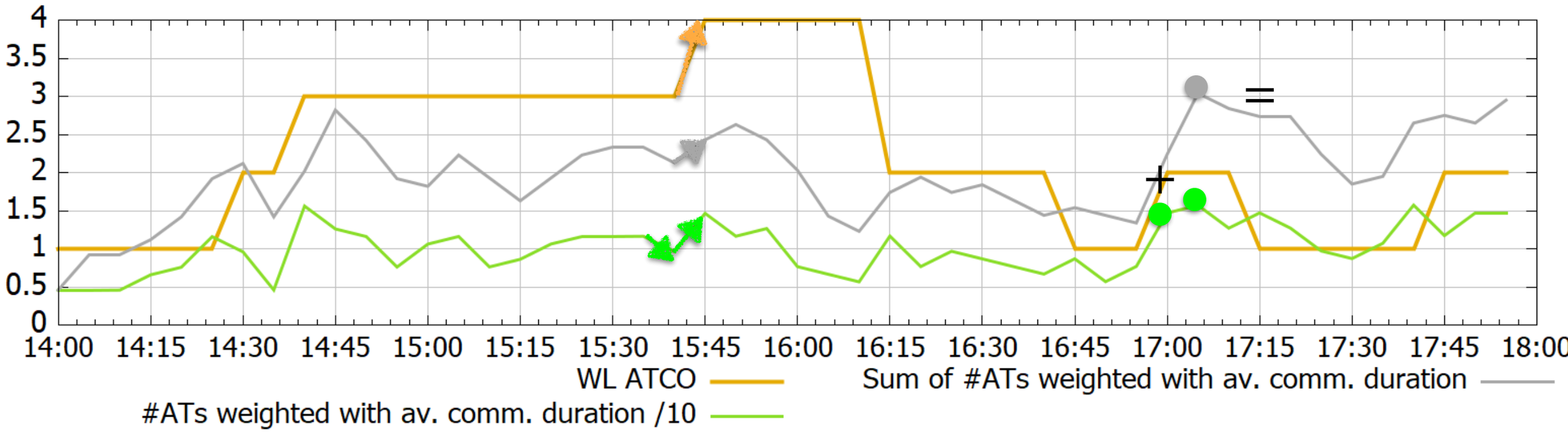

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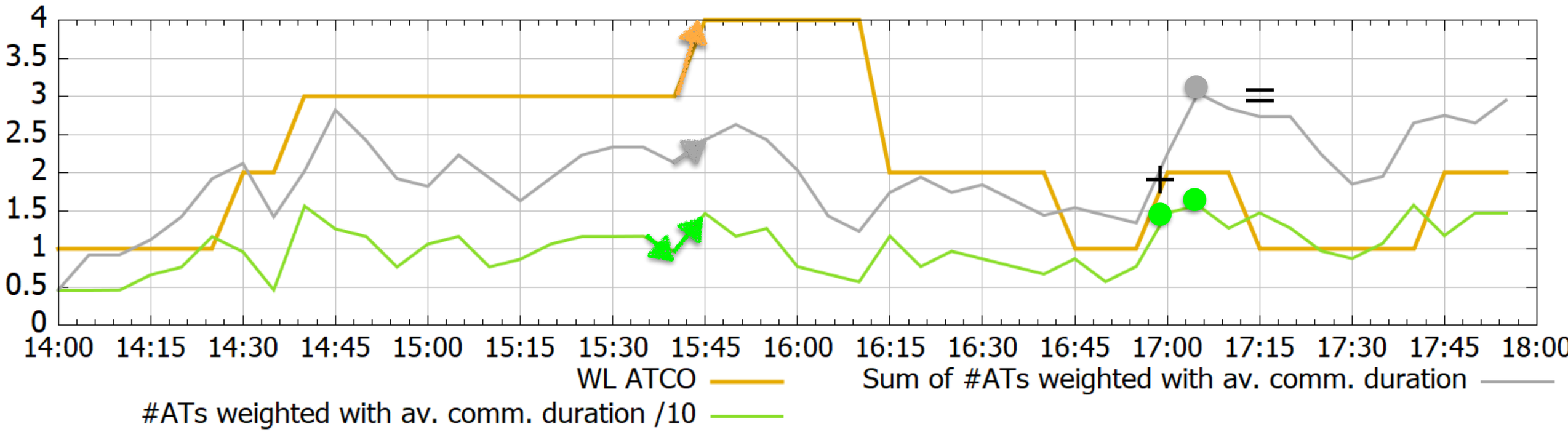

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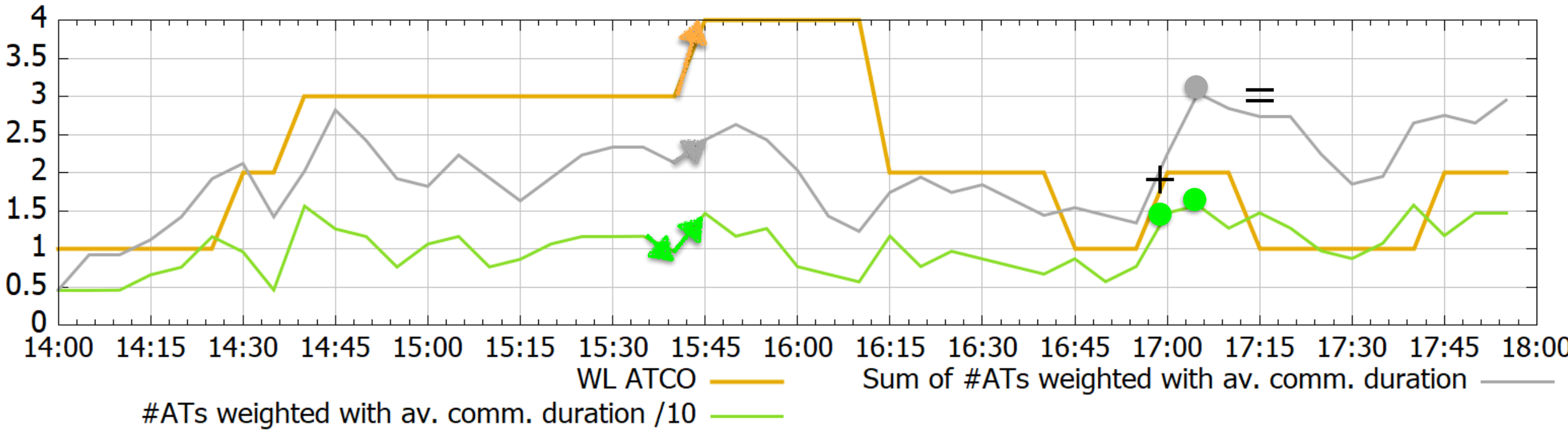

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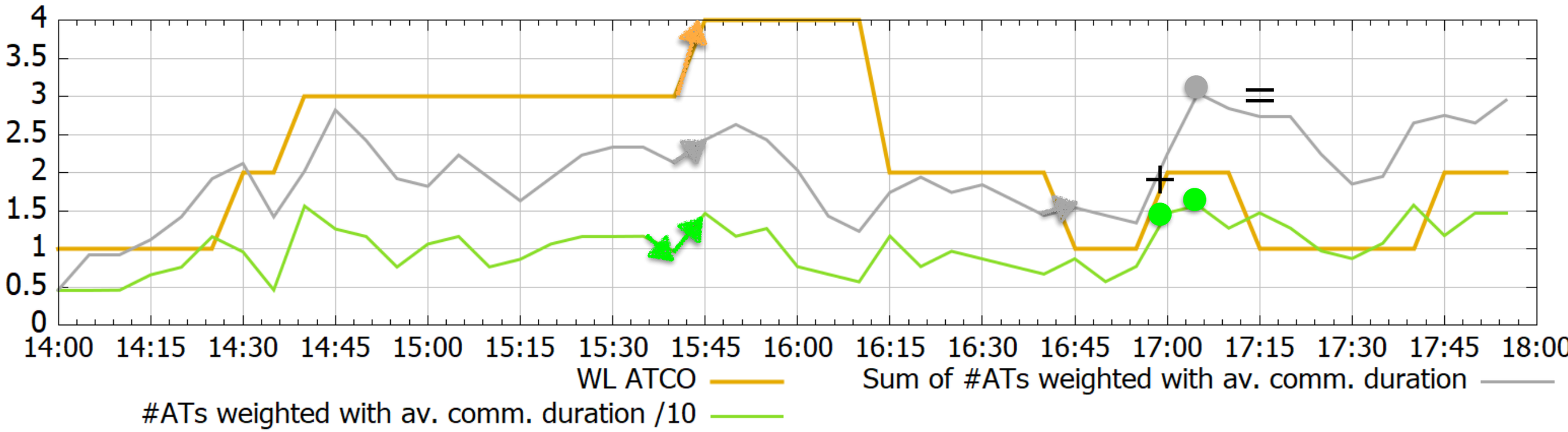

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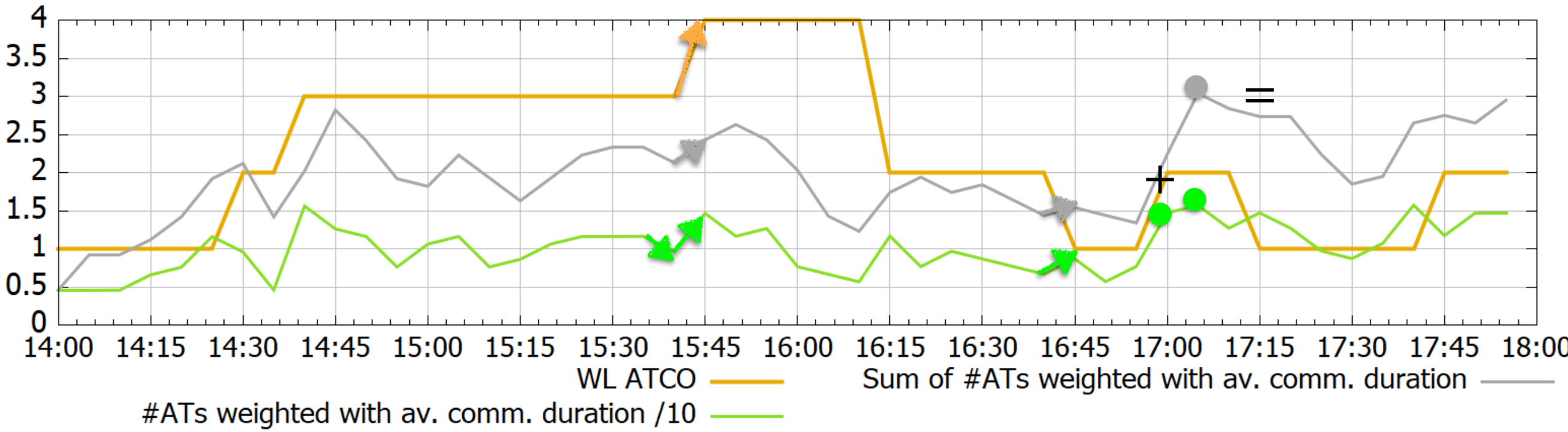

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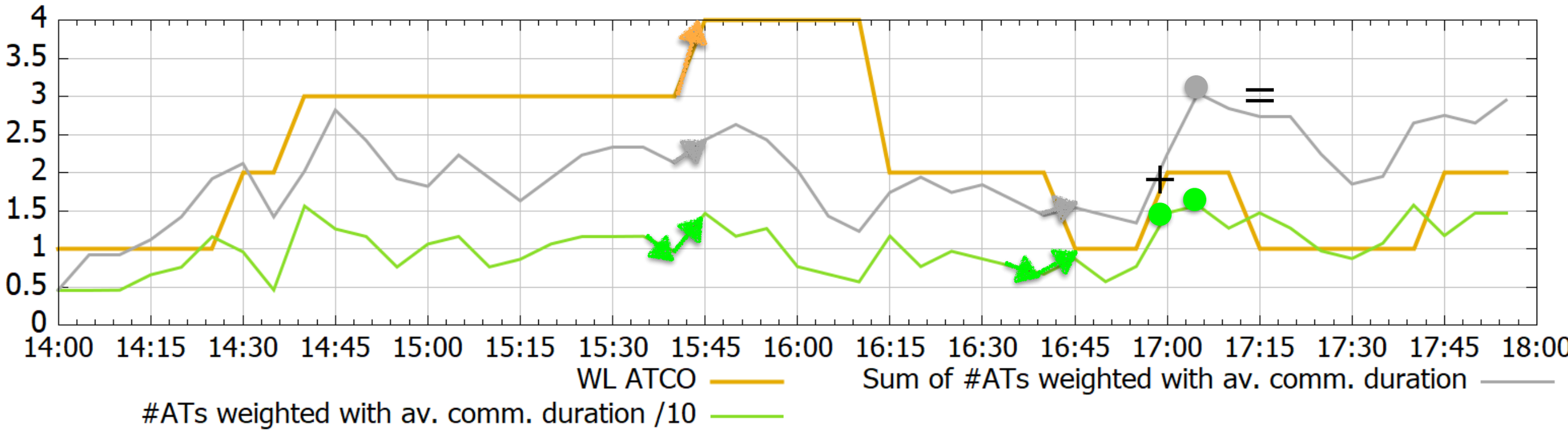

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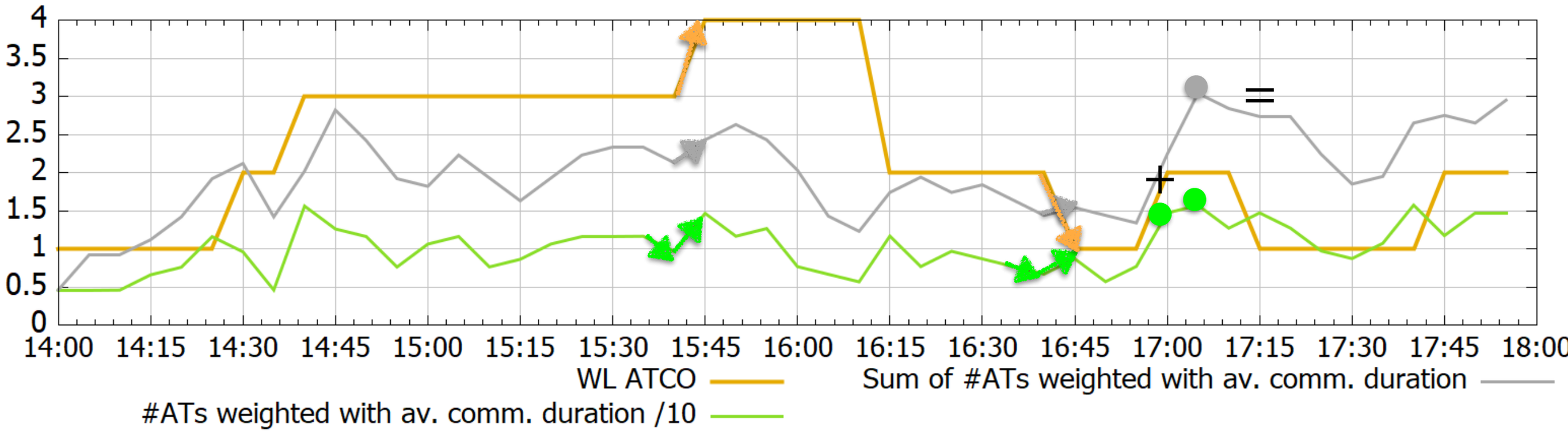

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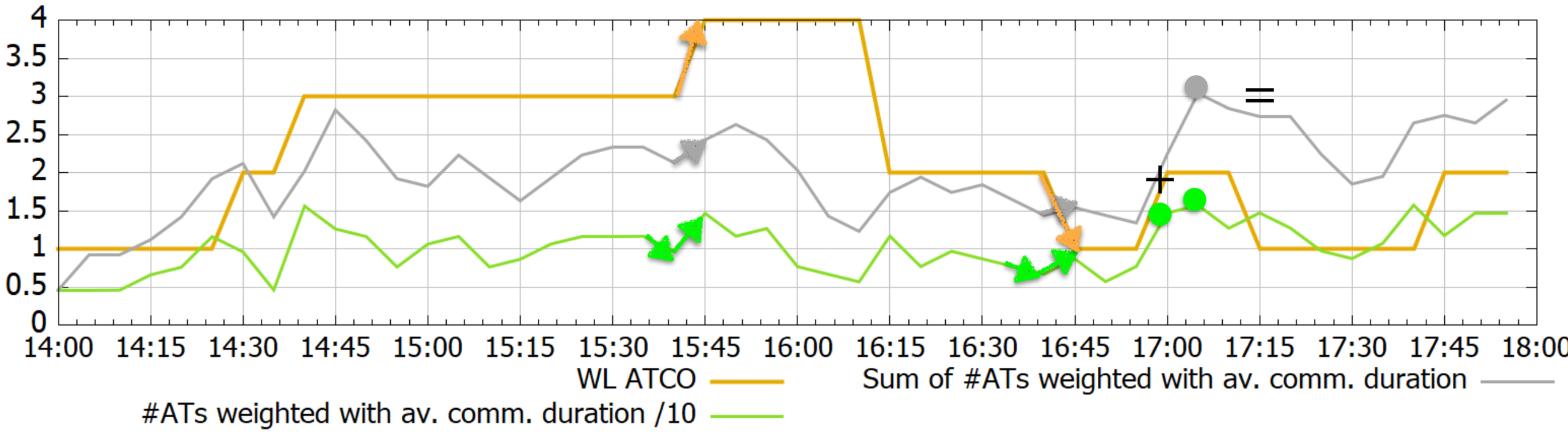

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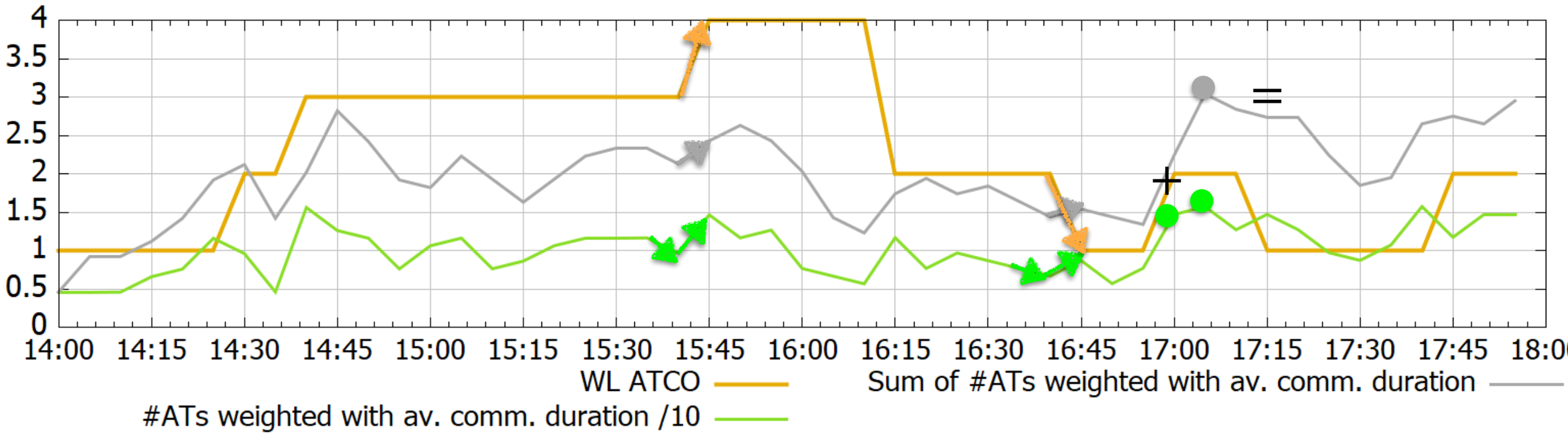

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More data is needed to study the influence of weather in detail.

Results Simulation Study

Communication Split: Weights for ATs

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- Used for single mode, for multiple mode

Single Mode

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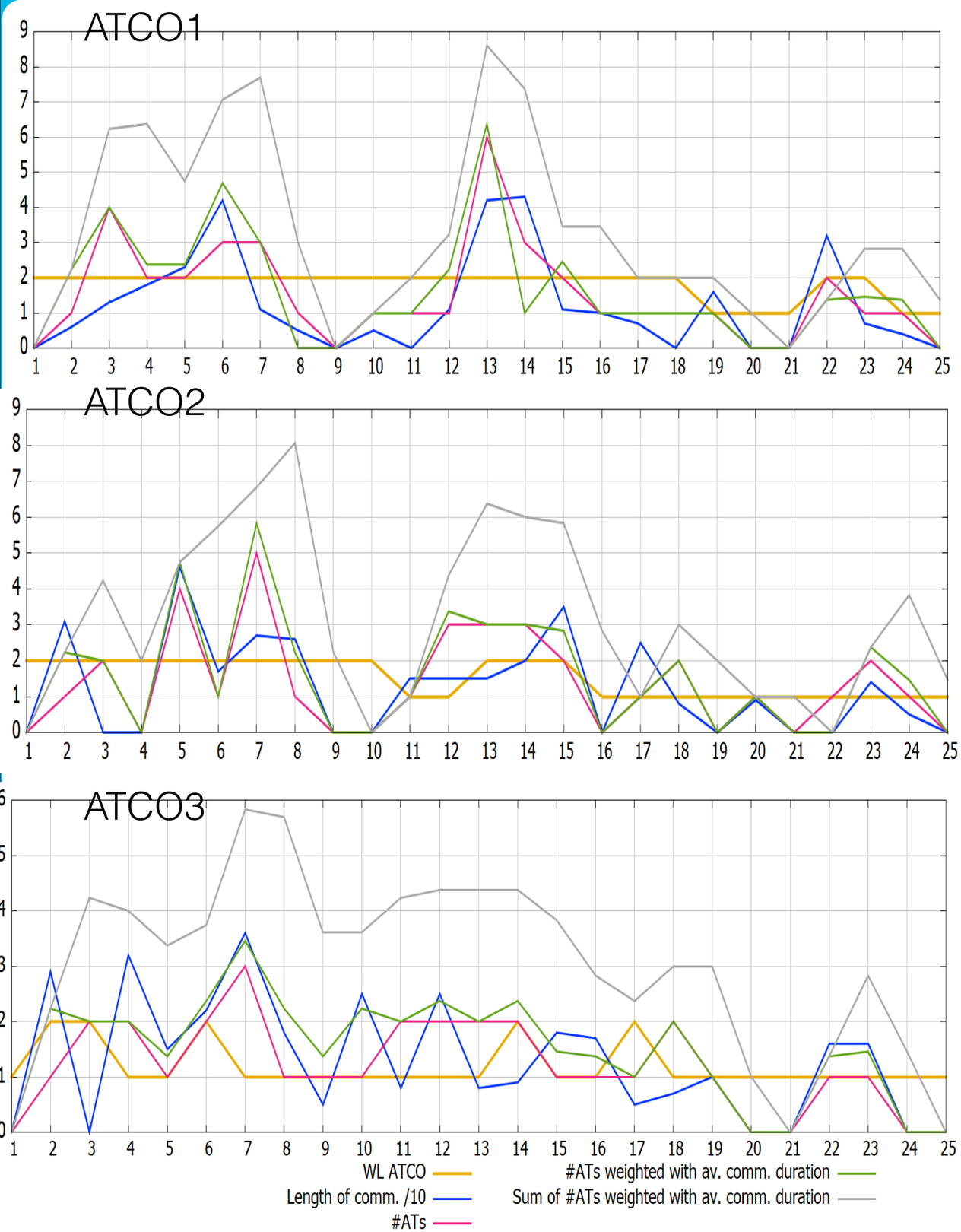

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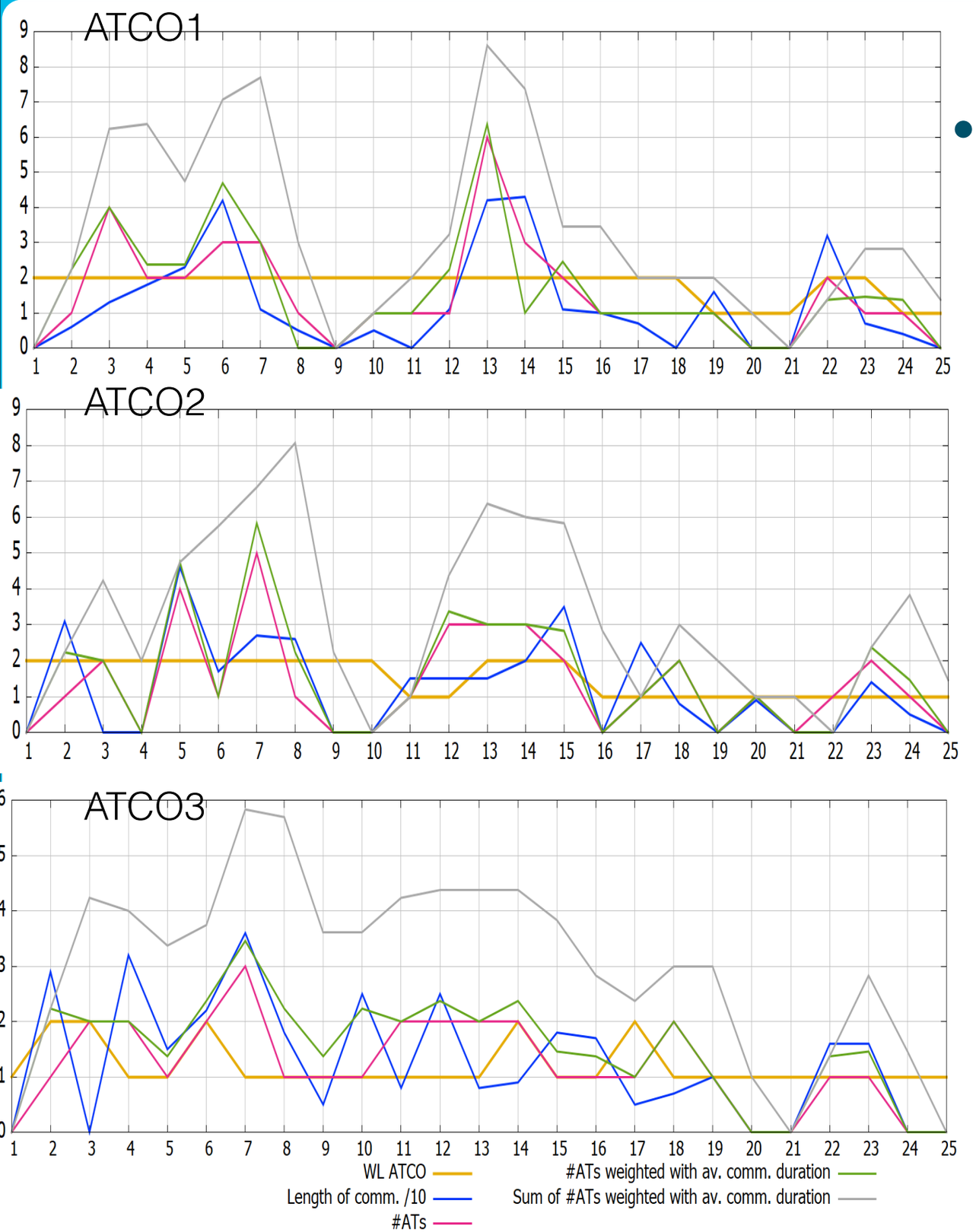

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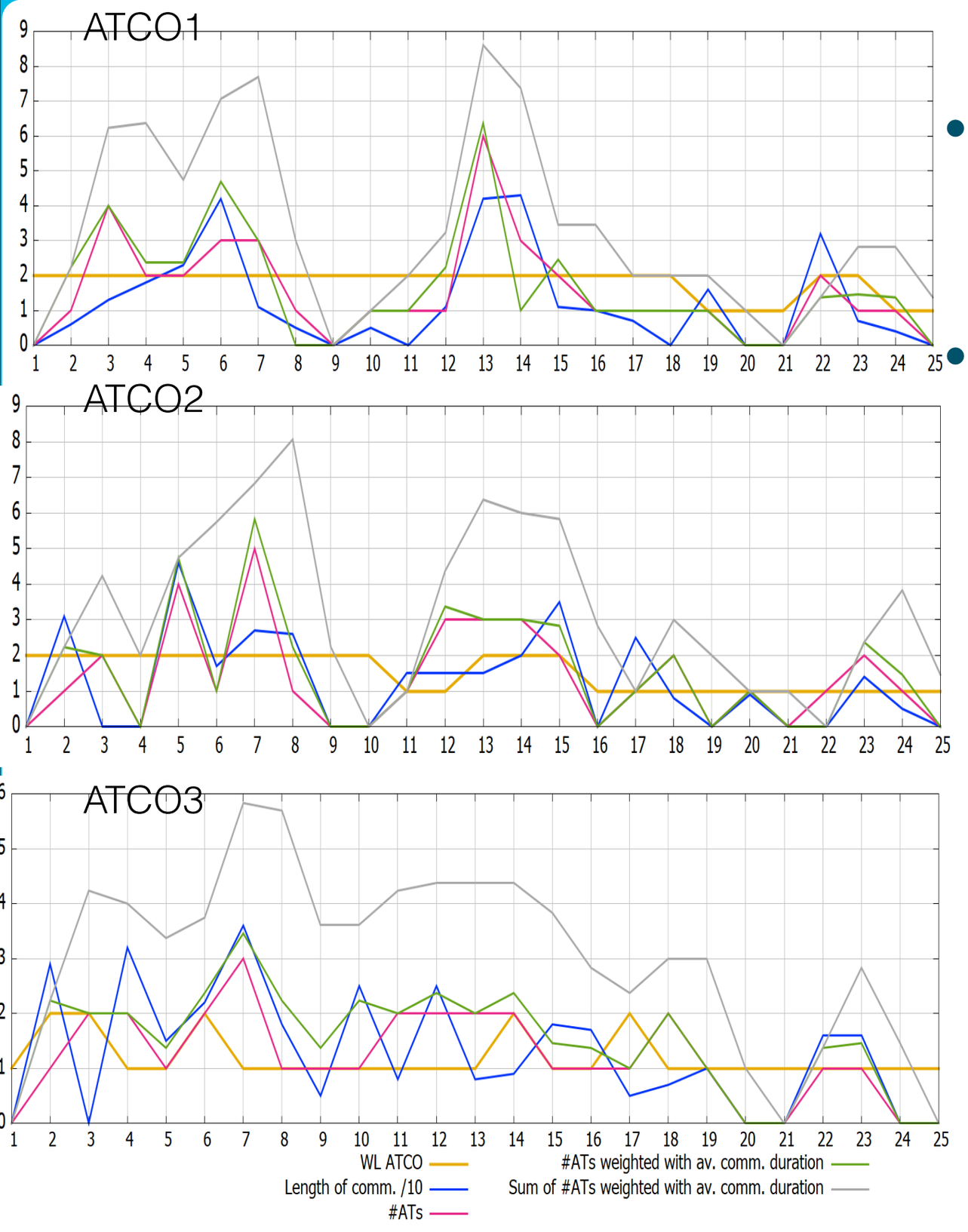

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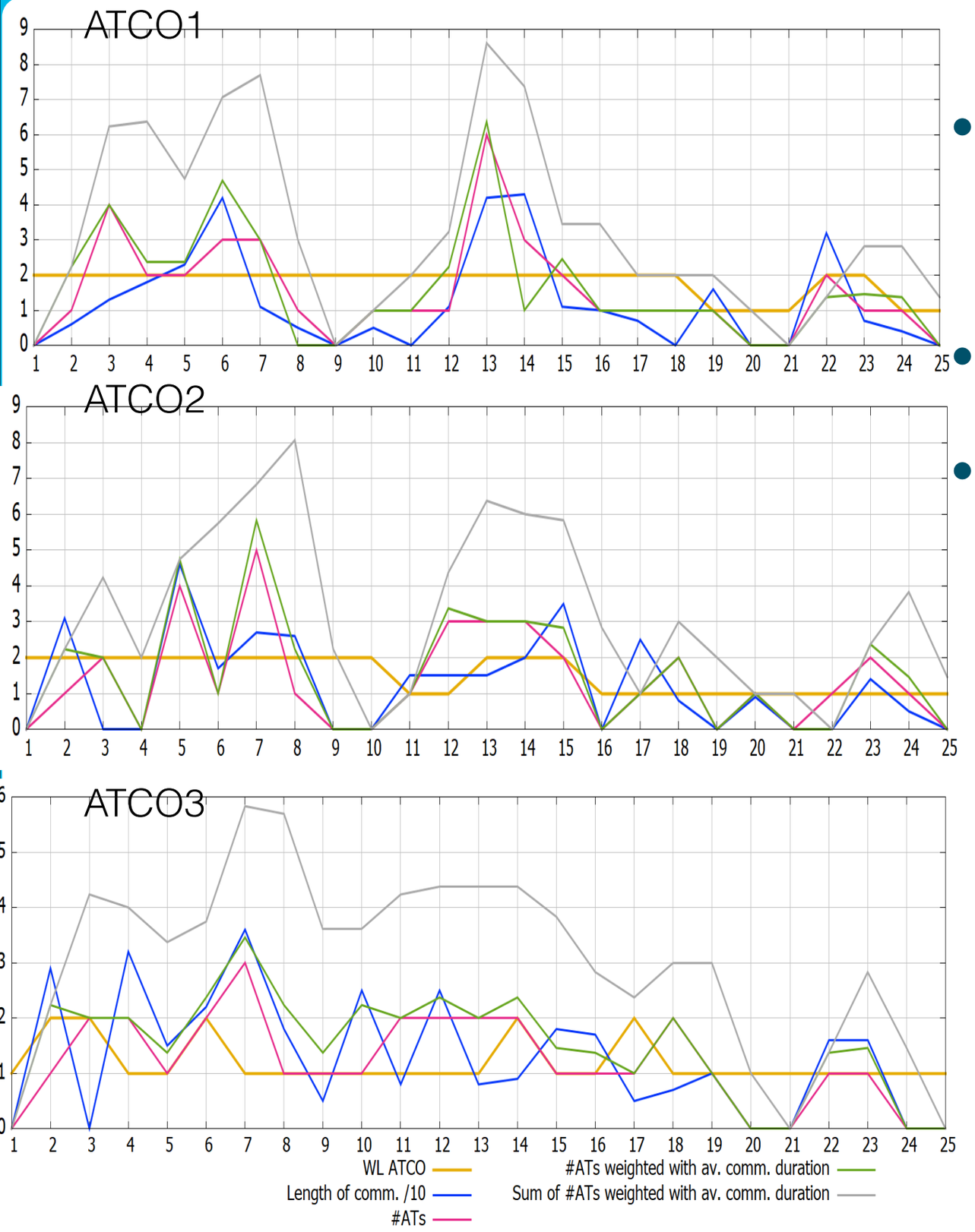

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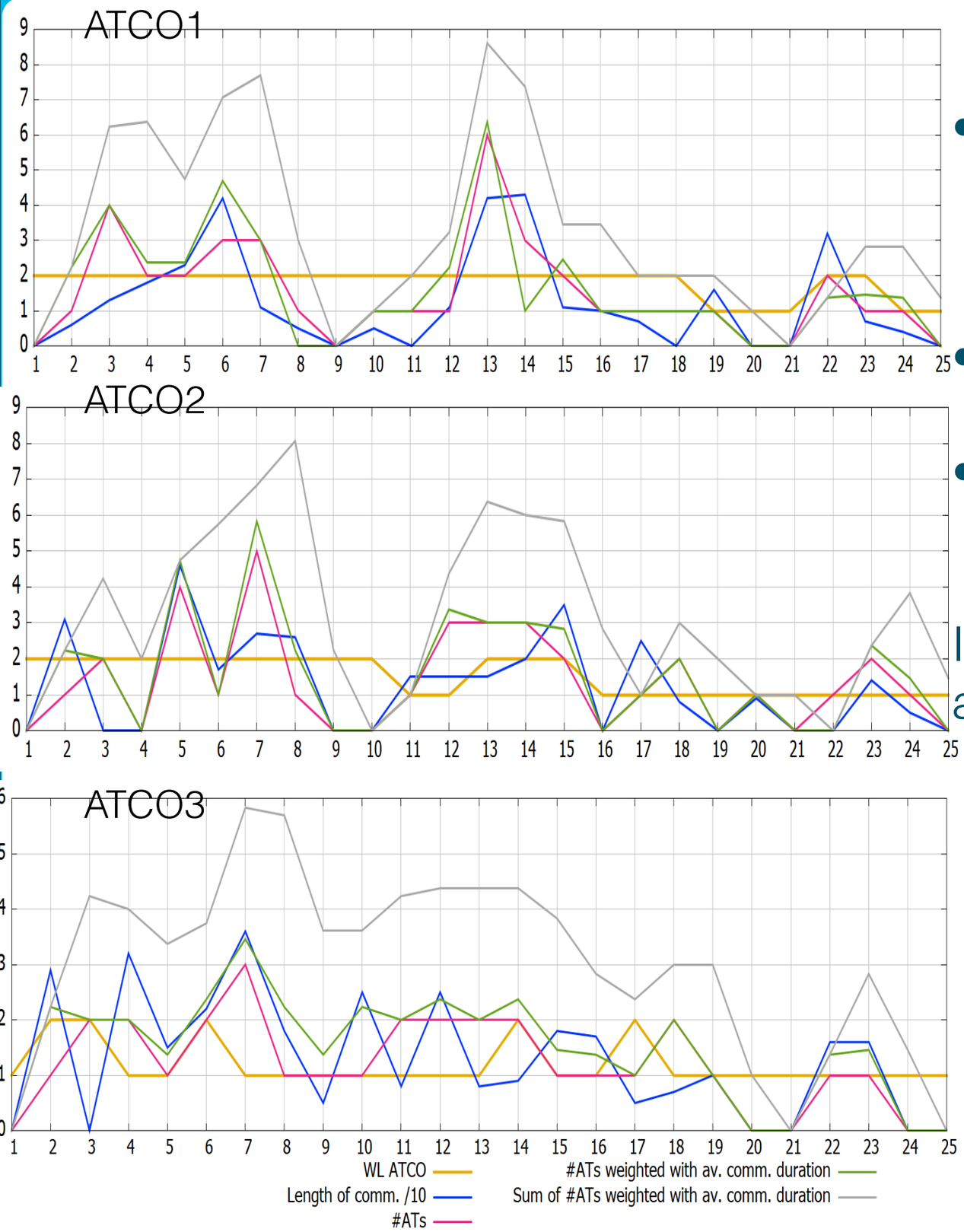

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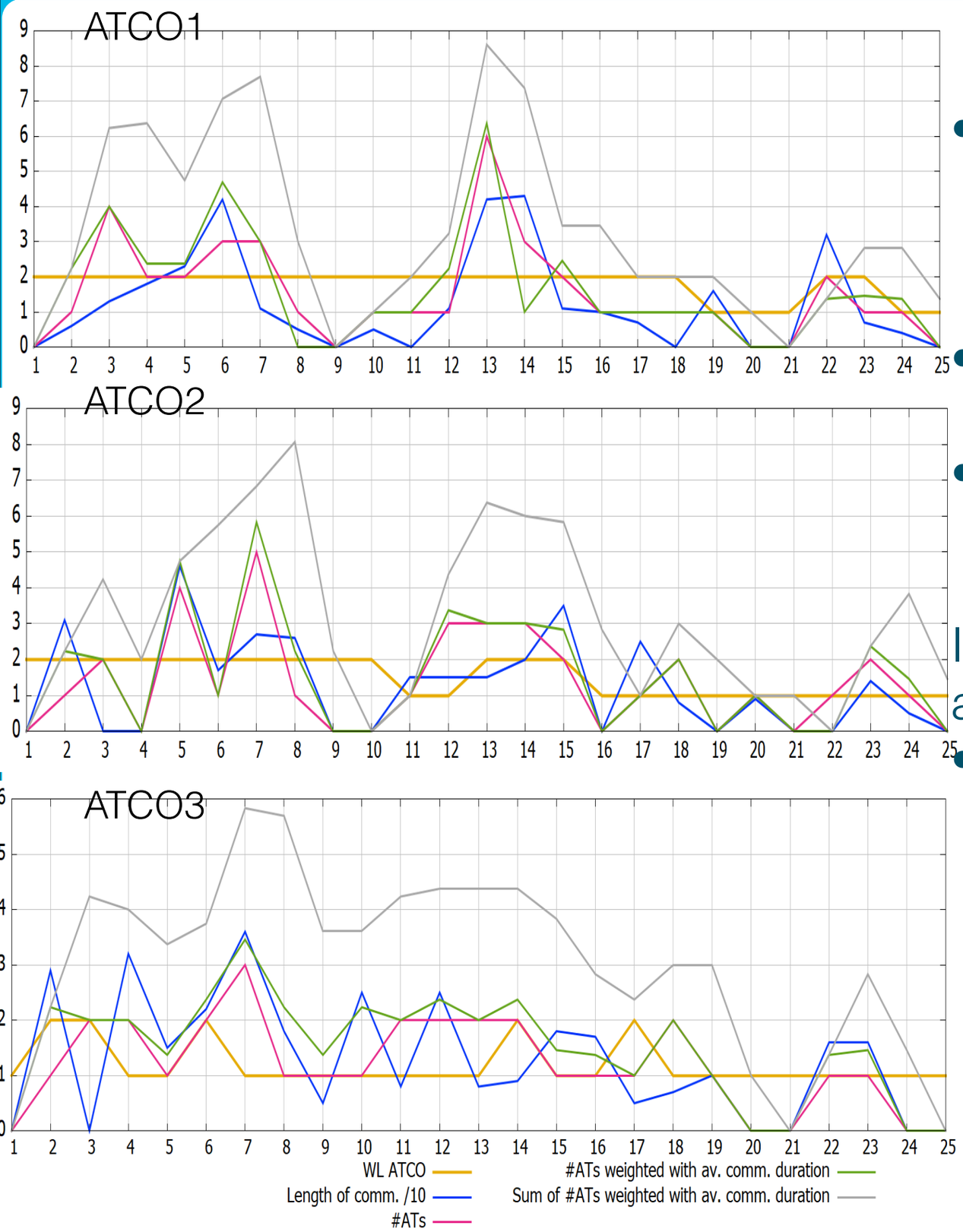

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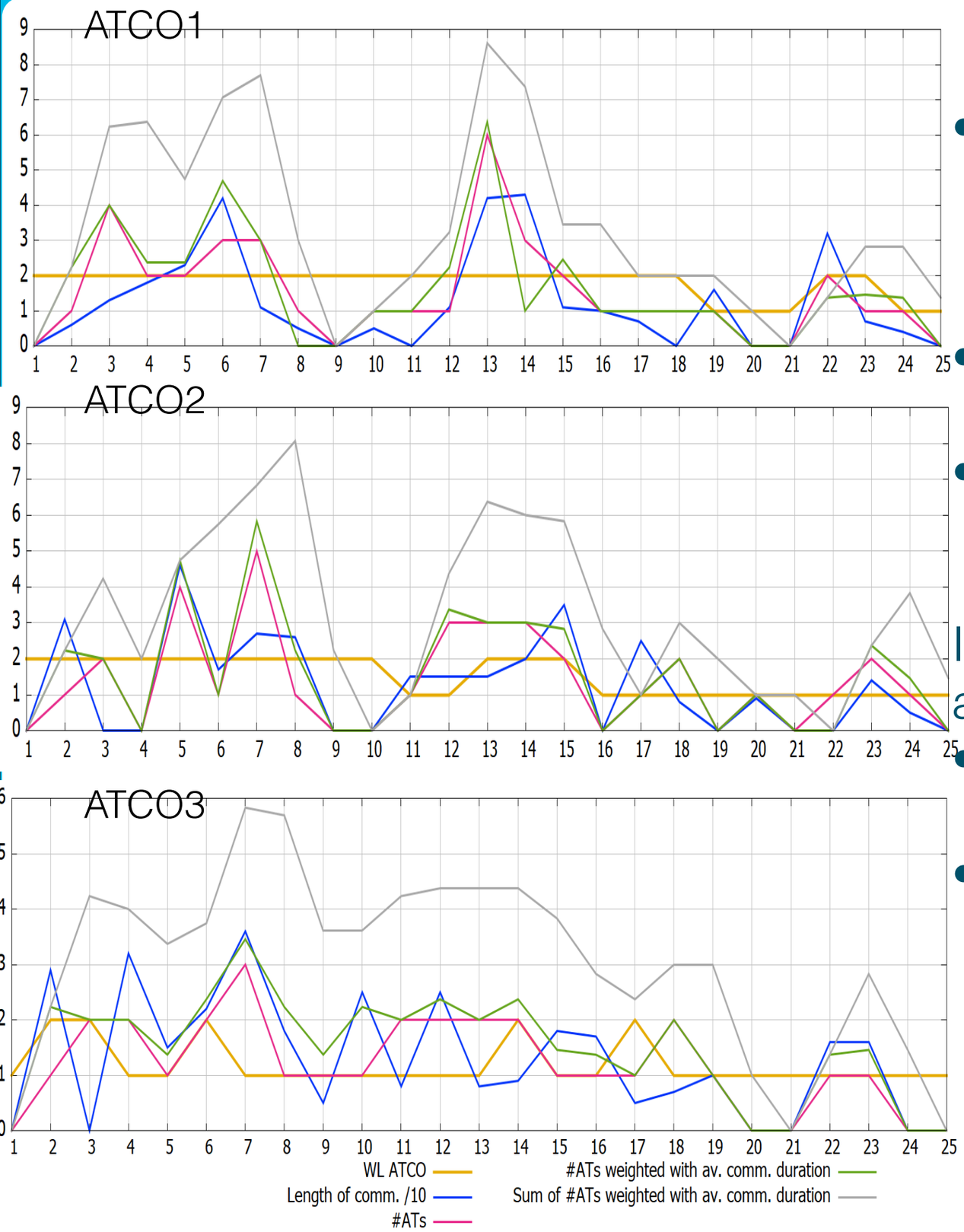

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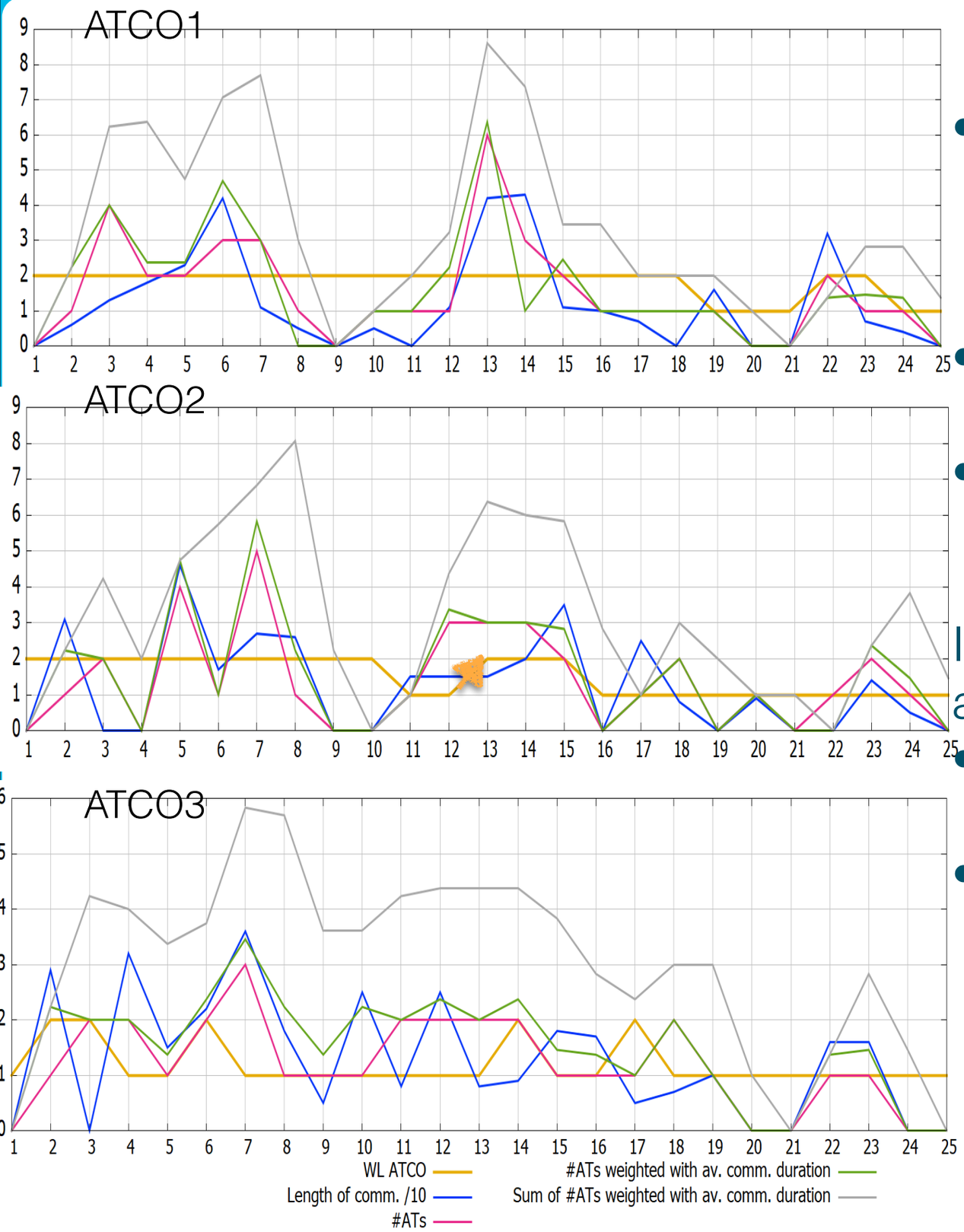

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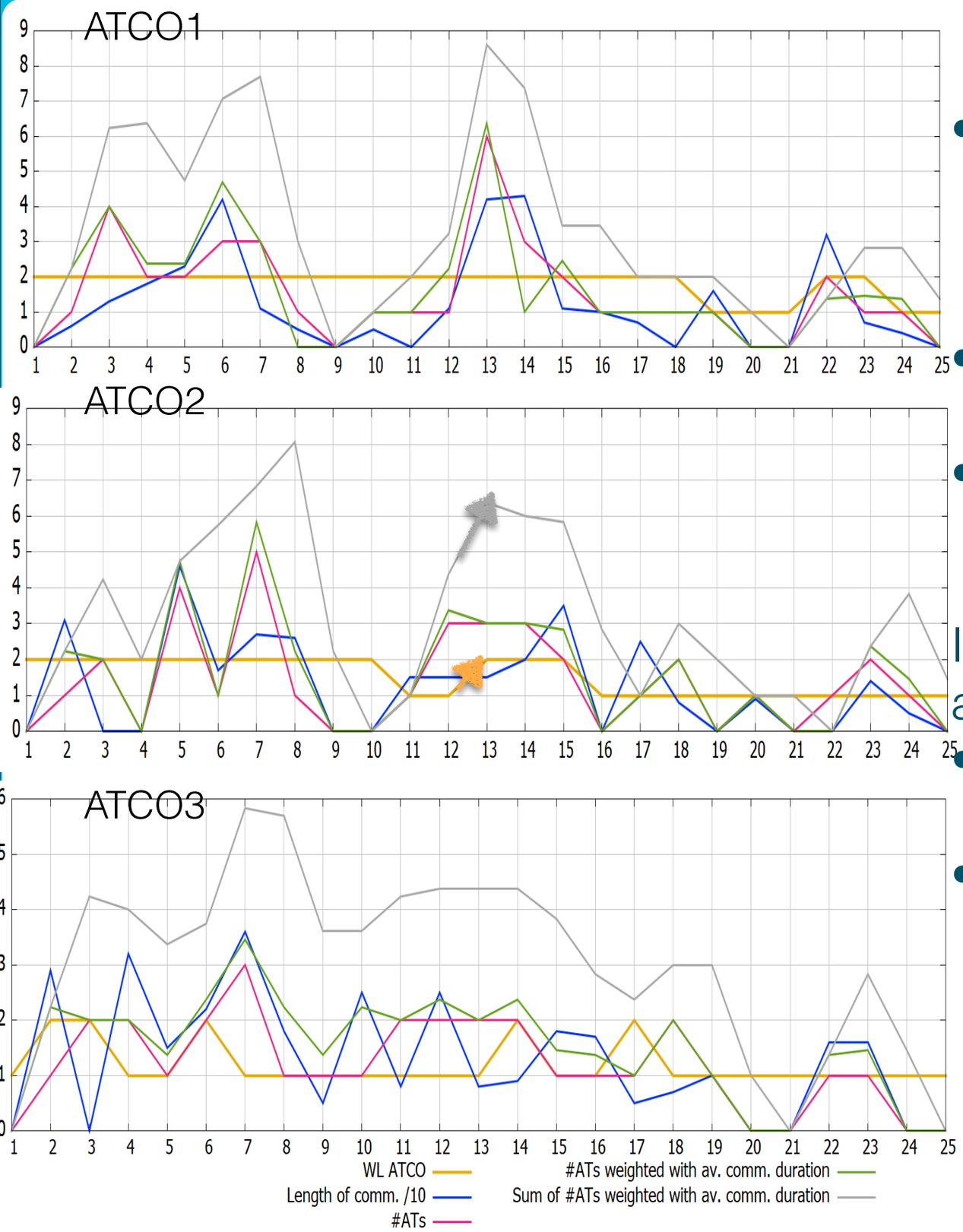

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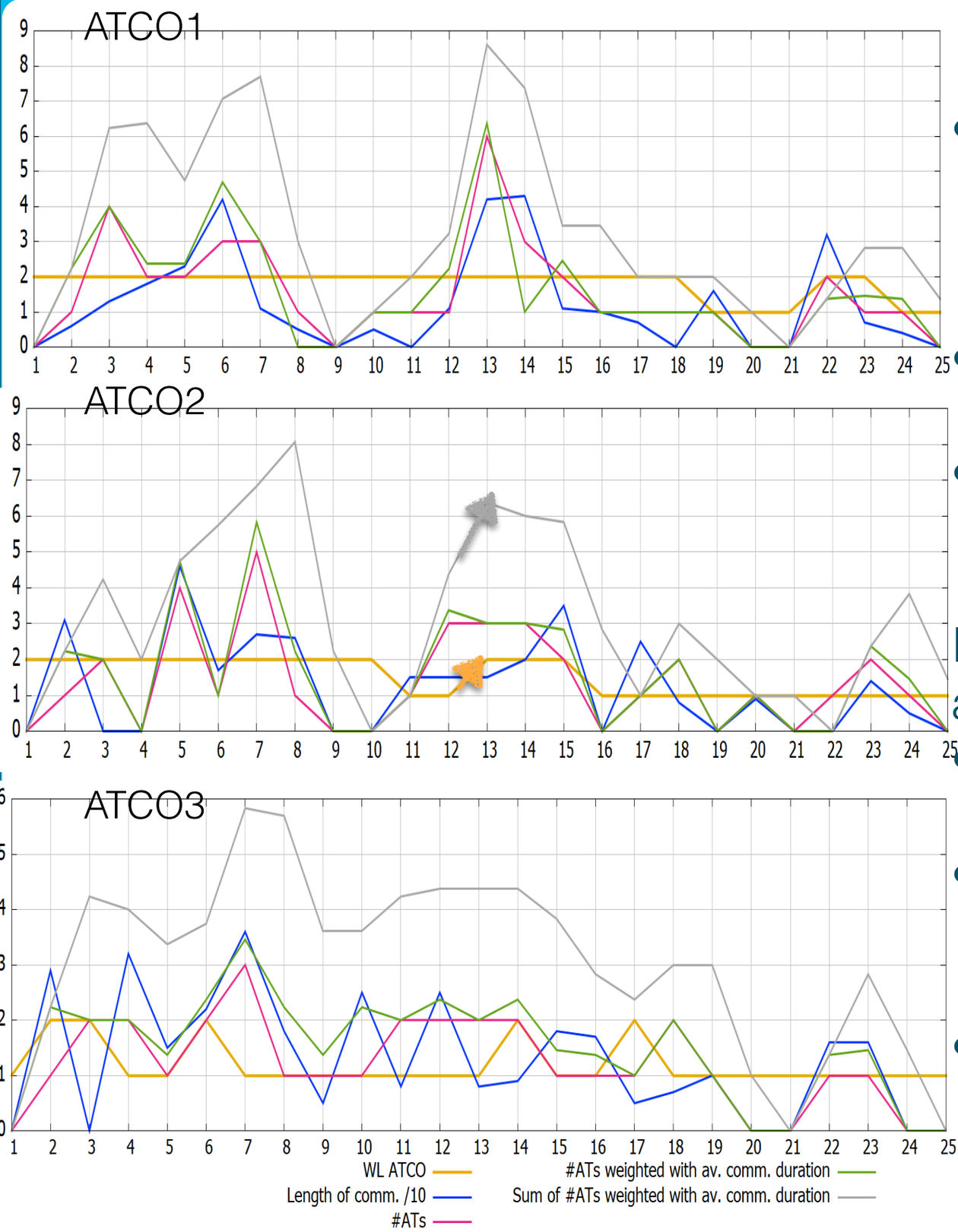
Workload vs. #ATs/Weighted ATs



- **Number of ATs not** a necessary condition for increase in **workload rating** (≤ 43% of **WL rating** increases accompanied by increase in **#of ATs**)
- Previous measures incl. communication length aren't for all ATCOs
- Considering length of communication, we also consider the following period—rationale: ATCO anticipates later tasks

Increase in **workload rating** always accompanied by an increase in:

- All measures that take the communication time into account (ATCO1)
- **Sum of the average-communication-duration weighted ATs for two consecutive time periods** (ATCO2)
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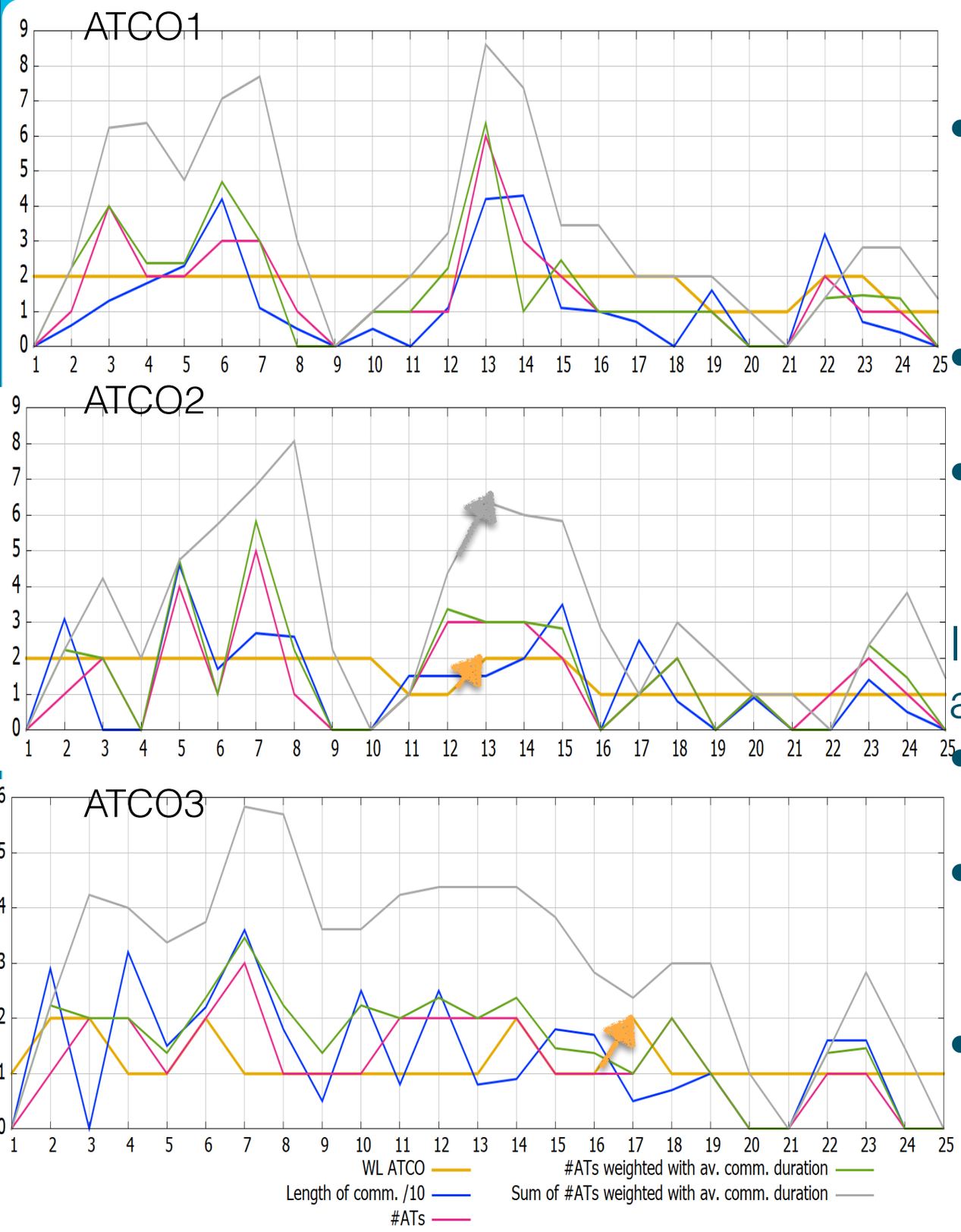
Workload vs. #ATs/Weighted ATs



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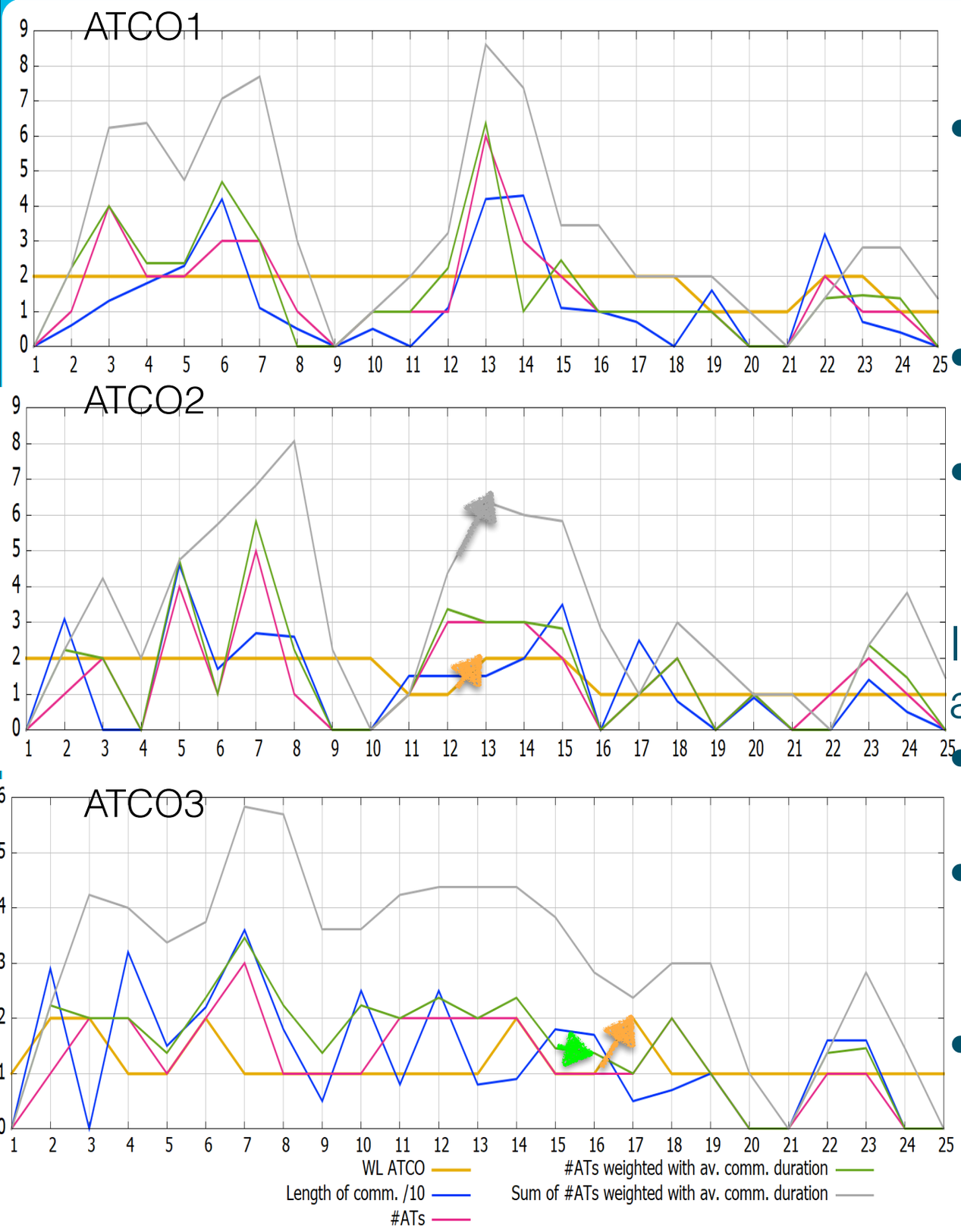
Workload vs. #ATs/Weighted ATs



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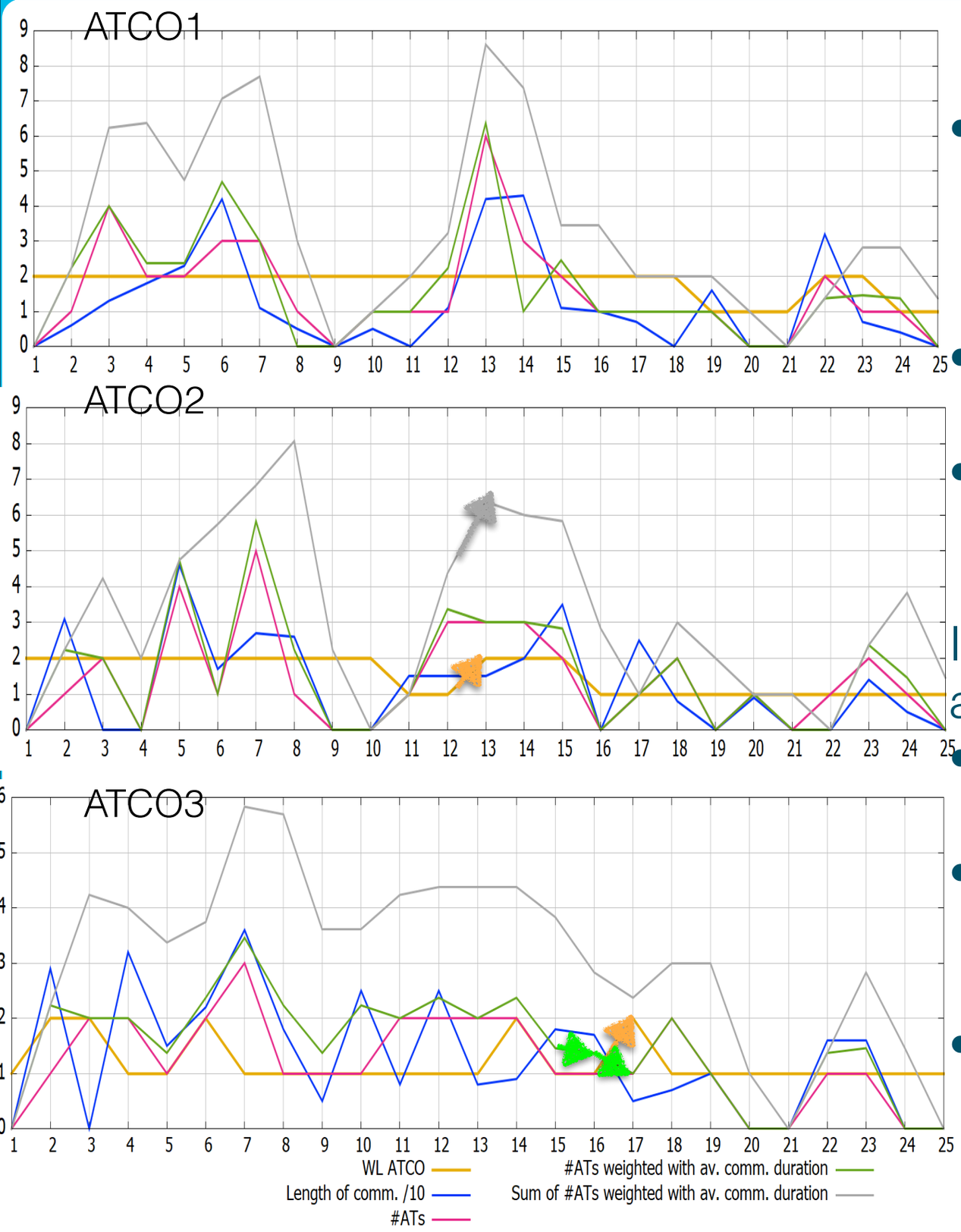

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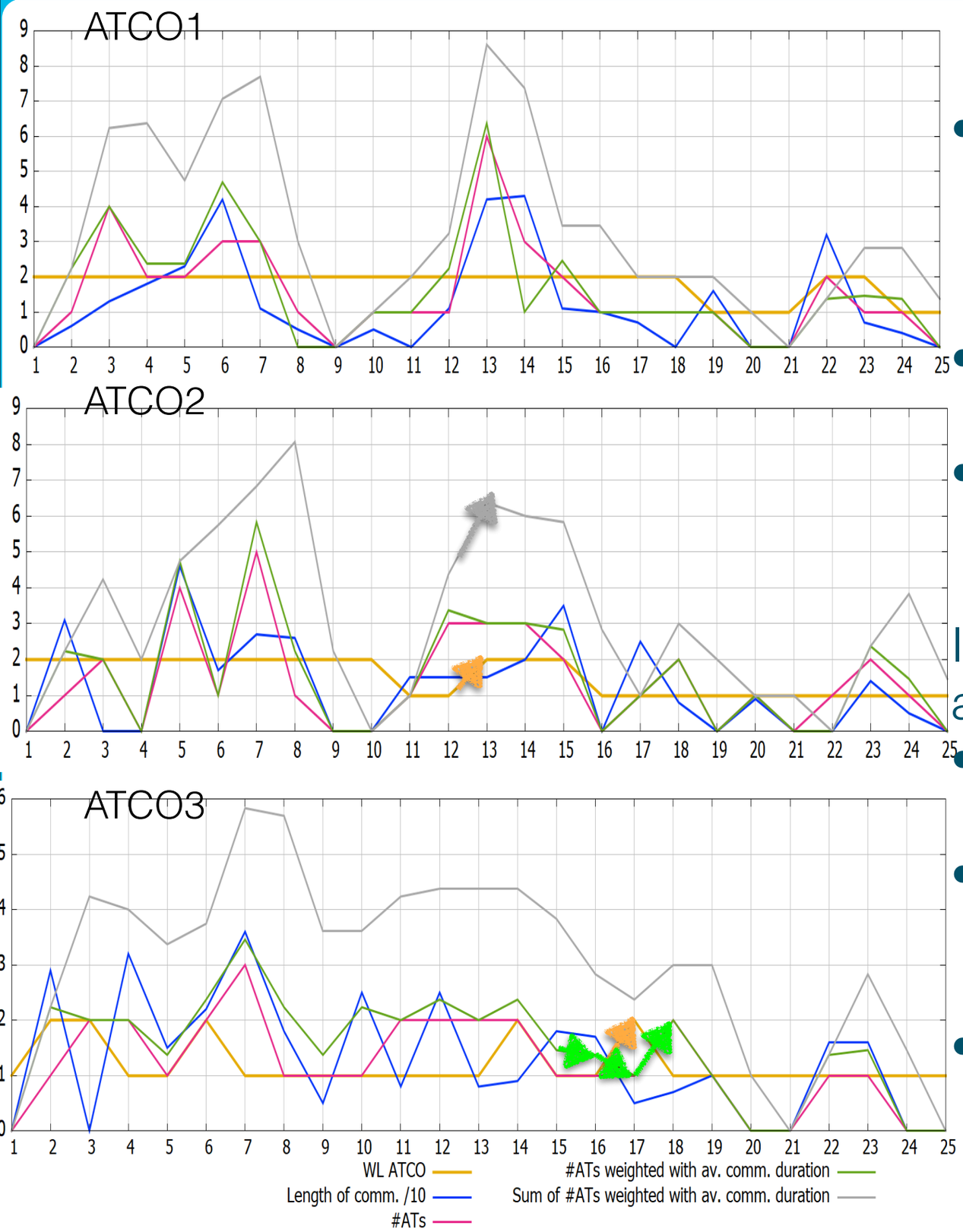

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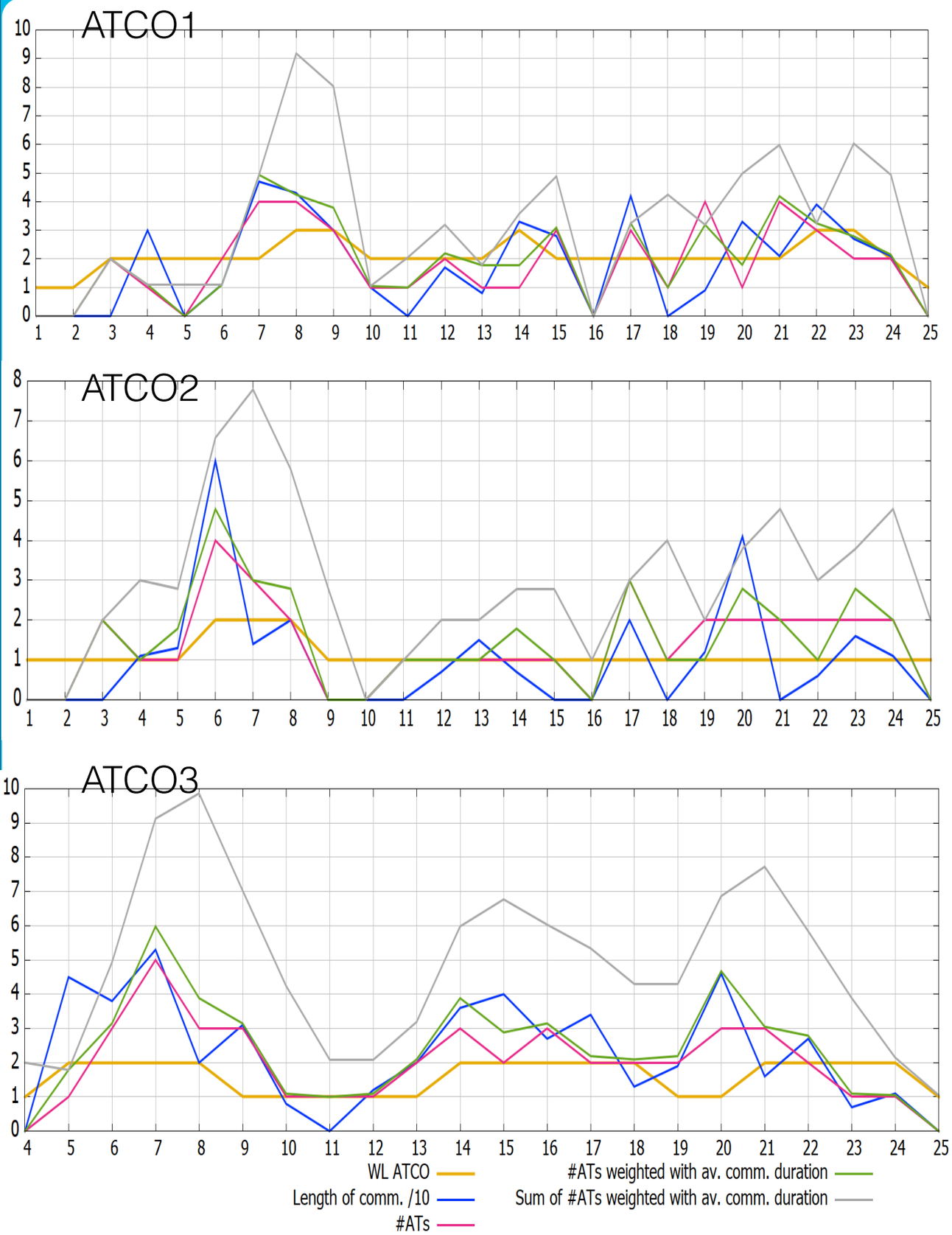
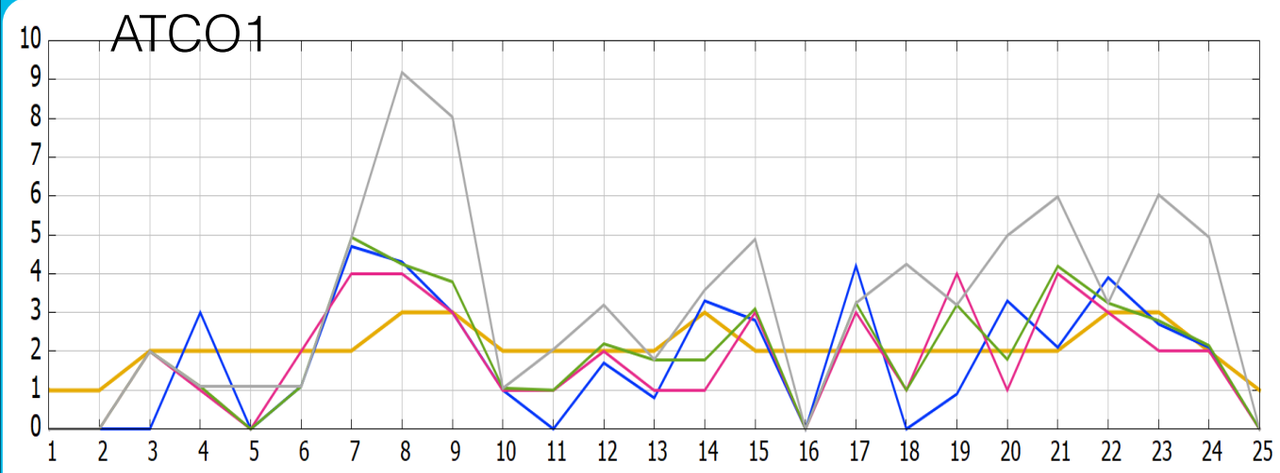
Multiple Mode

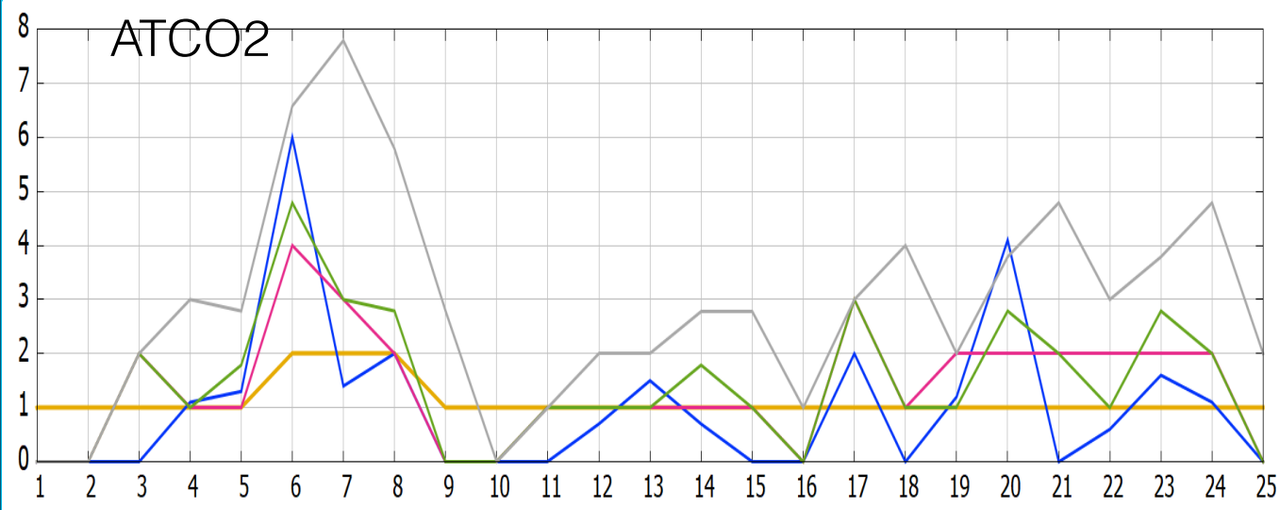
Workload vs. #ATs/Weighted ATs

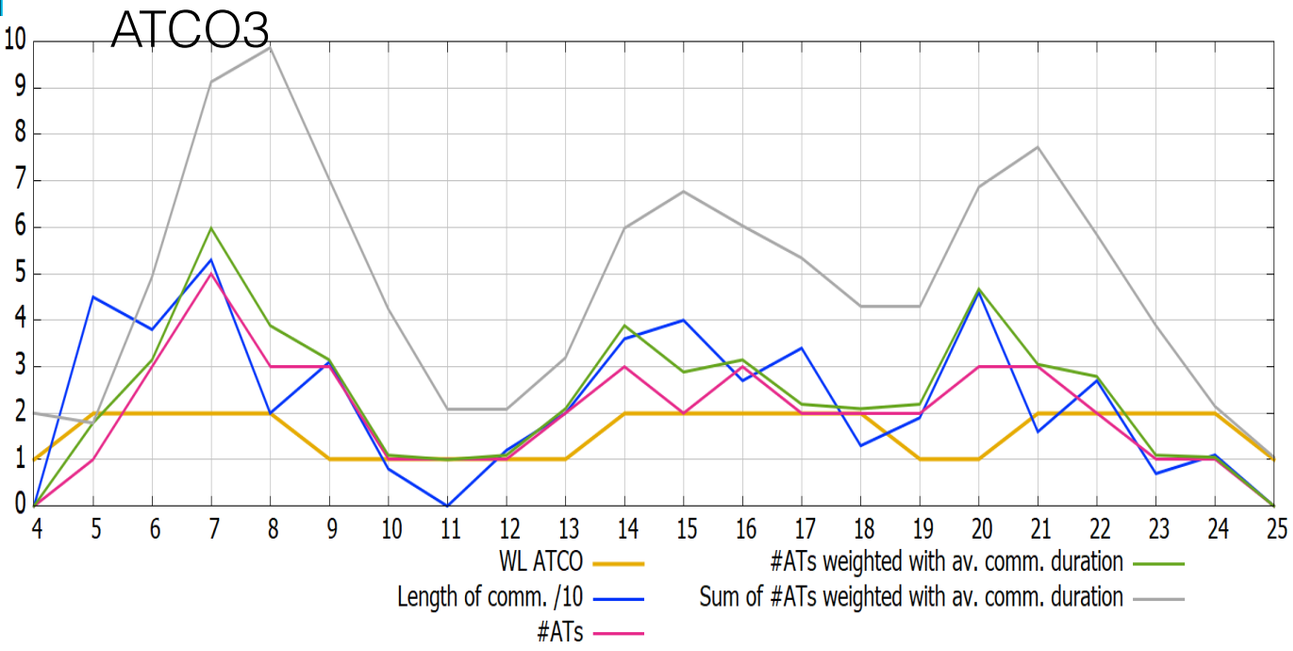


- ATCO3 stressed because of problems with simulation equipment → start at 9:09 (instead of 9:00)

Workload vs. #ATs/Weighted ATs







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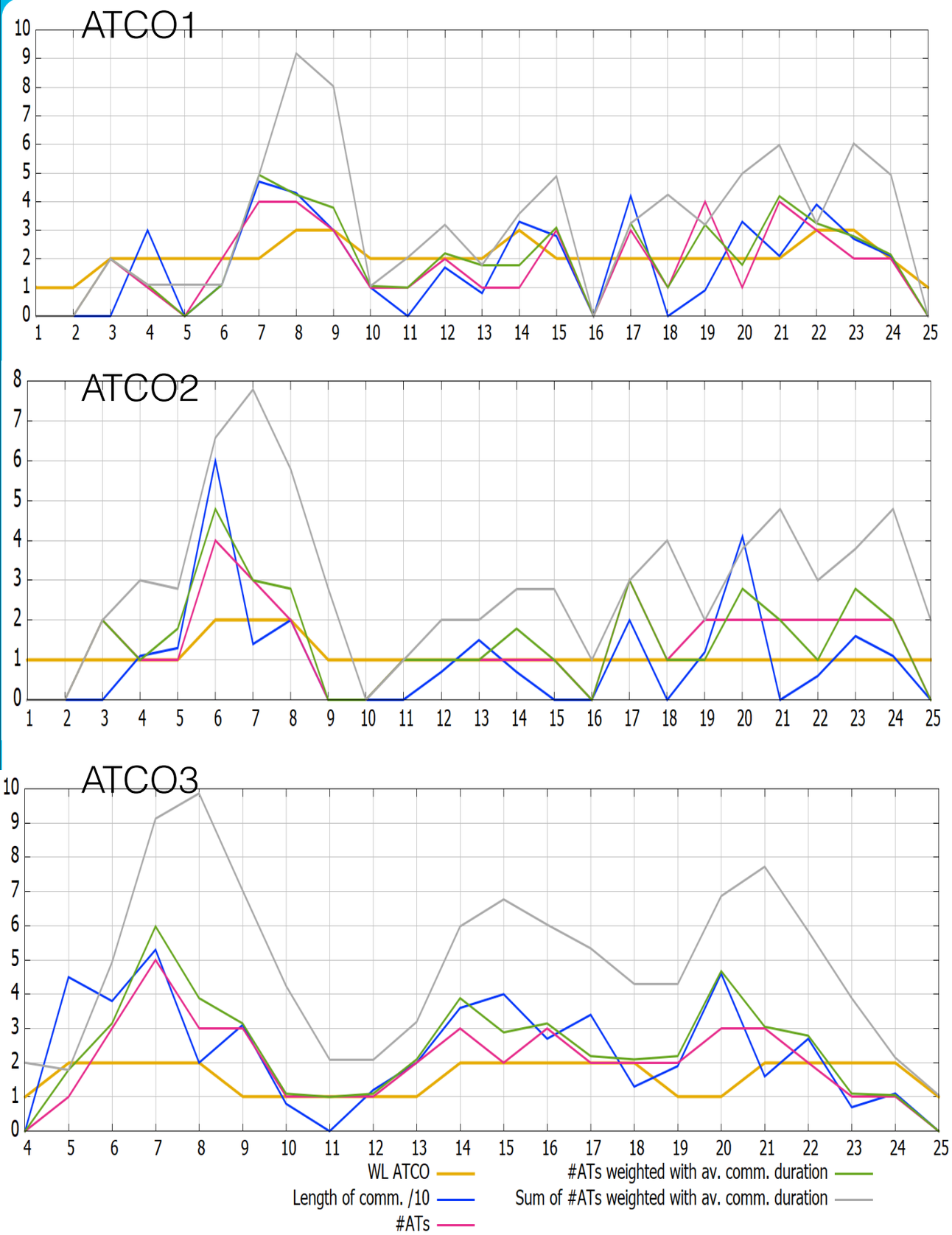
Workload vs. #ATs/Weighted ATs



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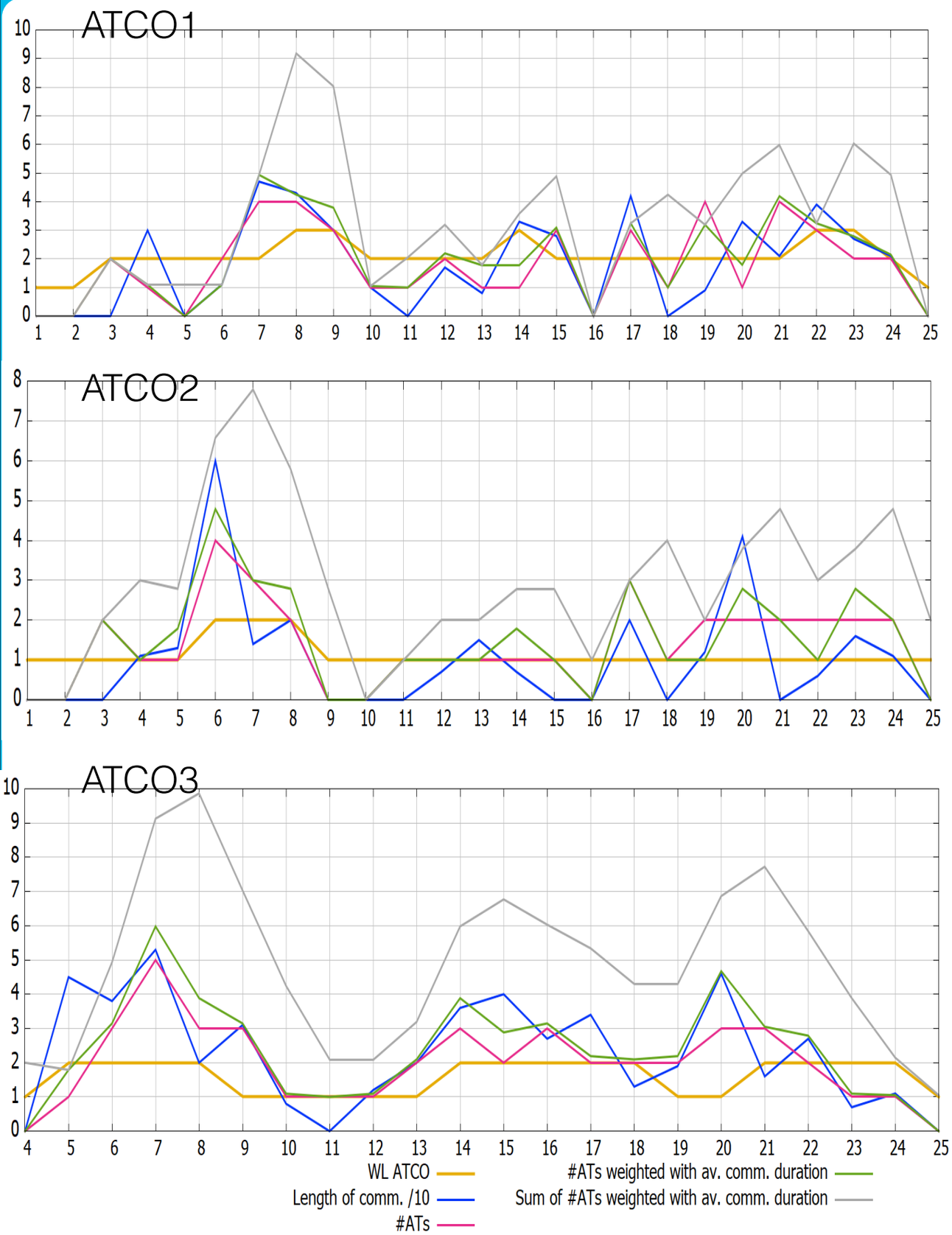
Workload vs. #ATs/Weighted ATs



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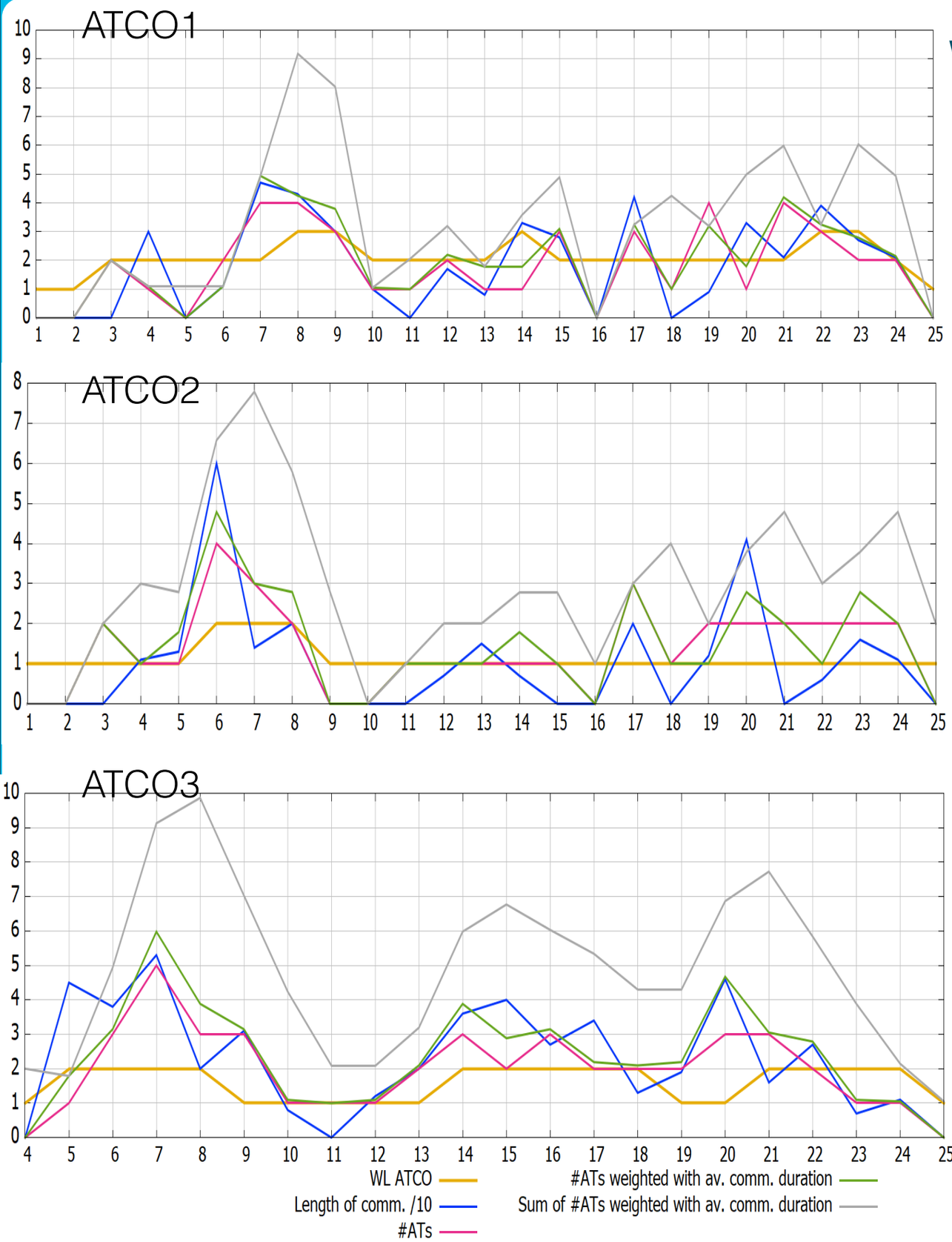
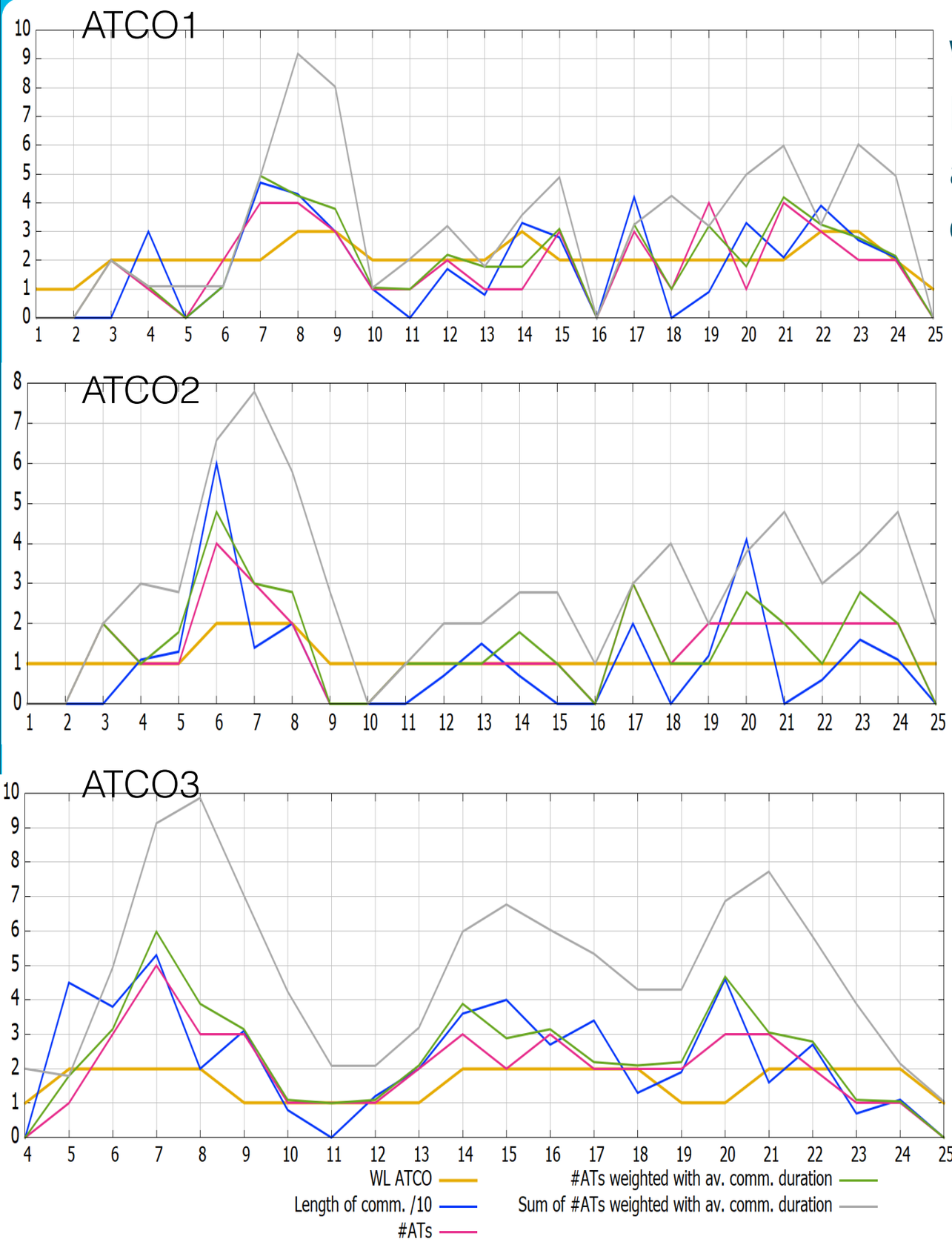
➡ Generally higher level and higher variations in **workload rating** for ATCO1

Workload vs. #ATs/Weighted ATs



We can observe a necessary condition:

Workload vs. #ATs/Weighted ATs



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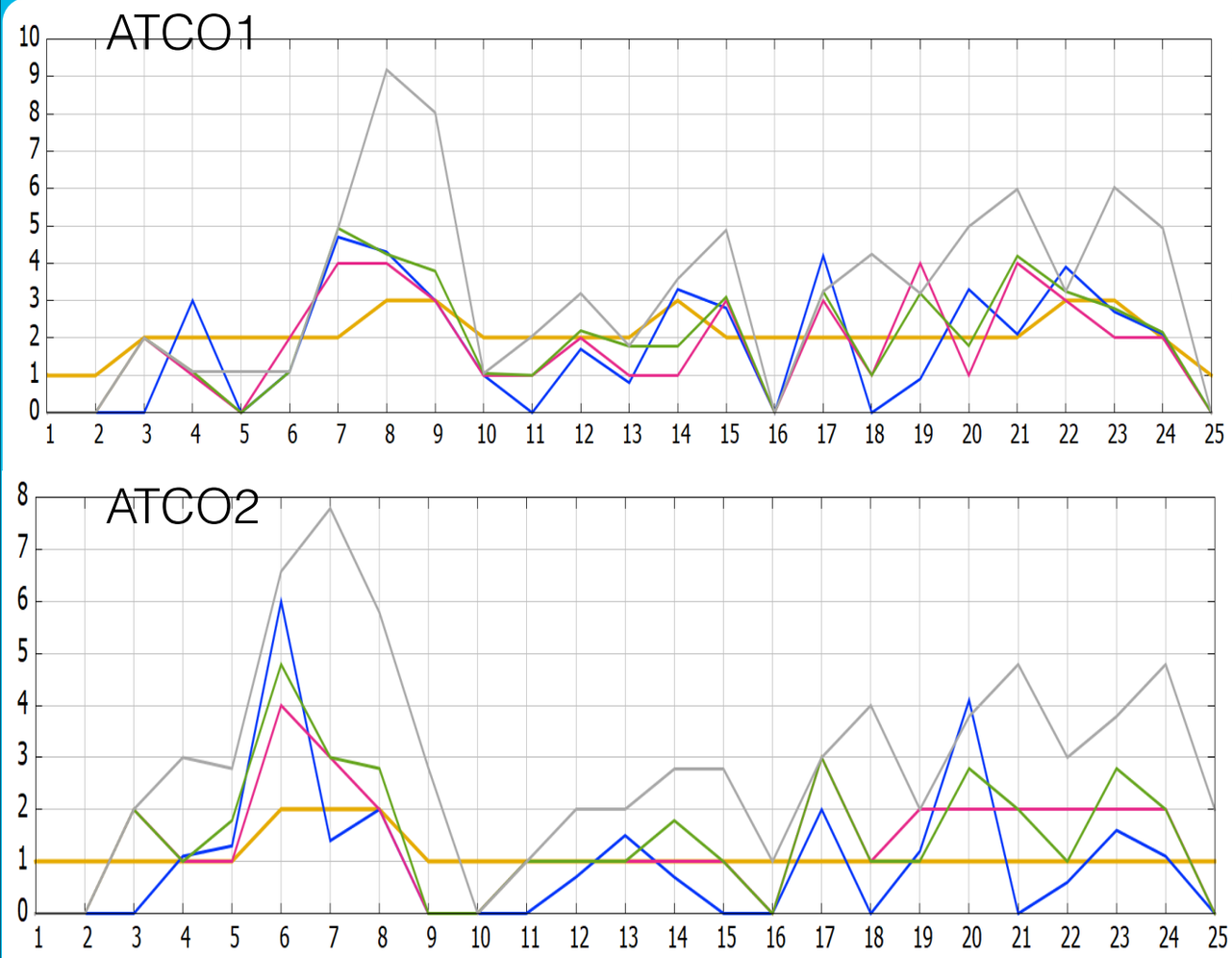
Workload vs. #ATs/Weighted ATs



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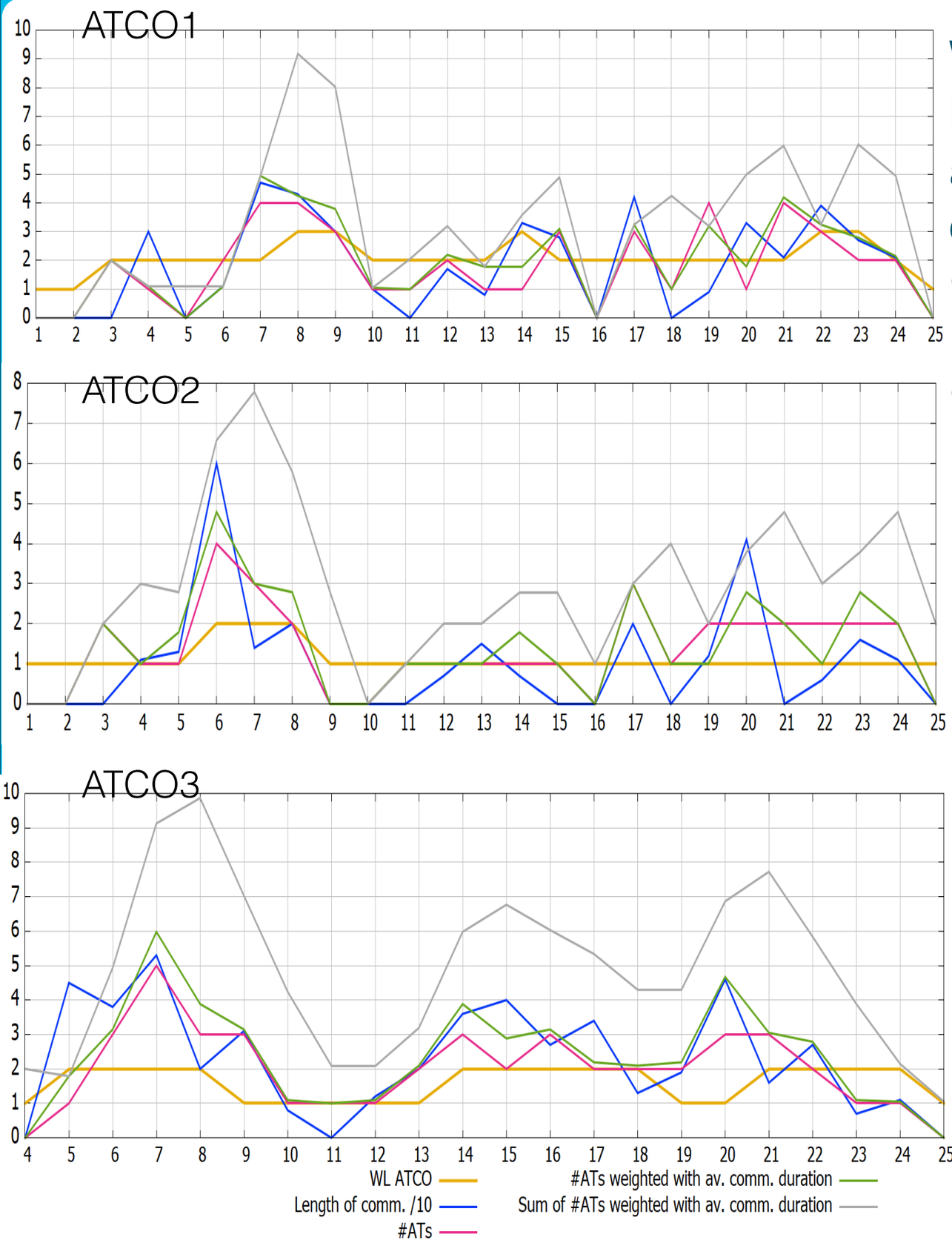
- **Duration of communication during that time interval**

Workload vs. #ATs/Weighted ATs



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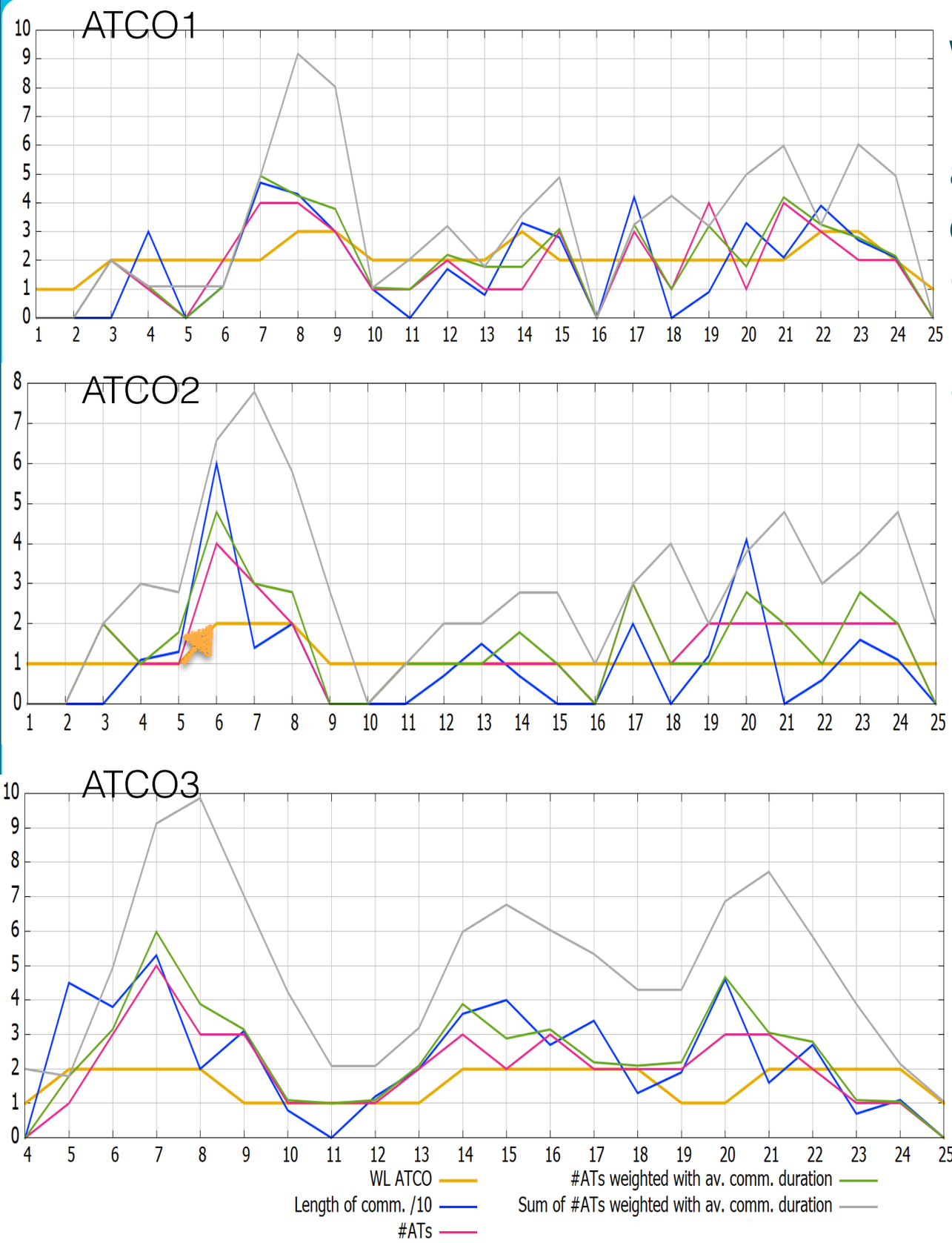
Workload vs. #ATs/Weighted ATs



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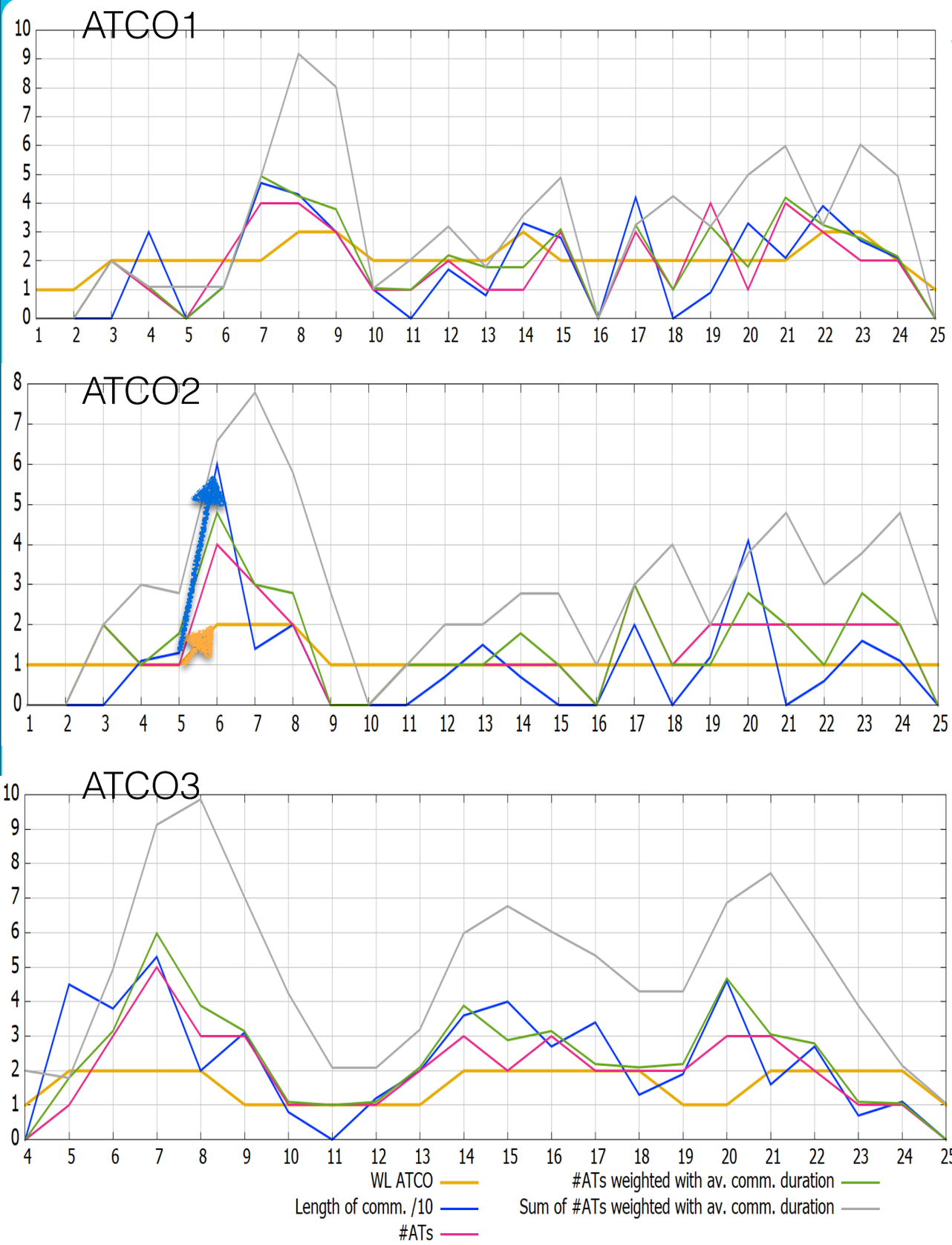

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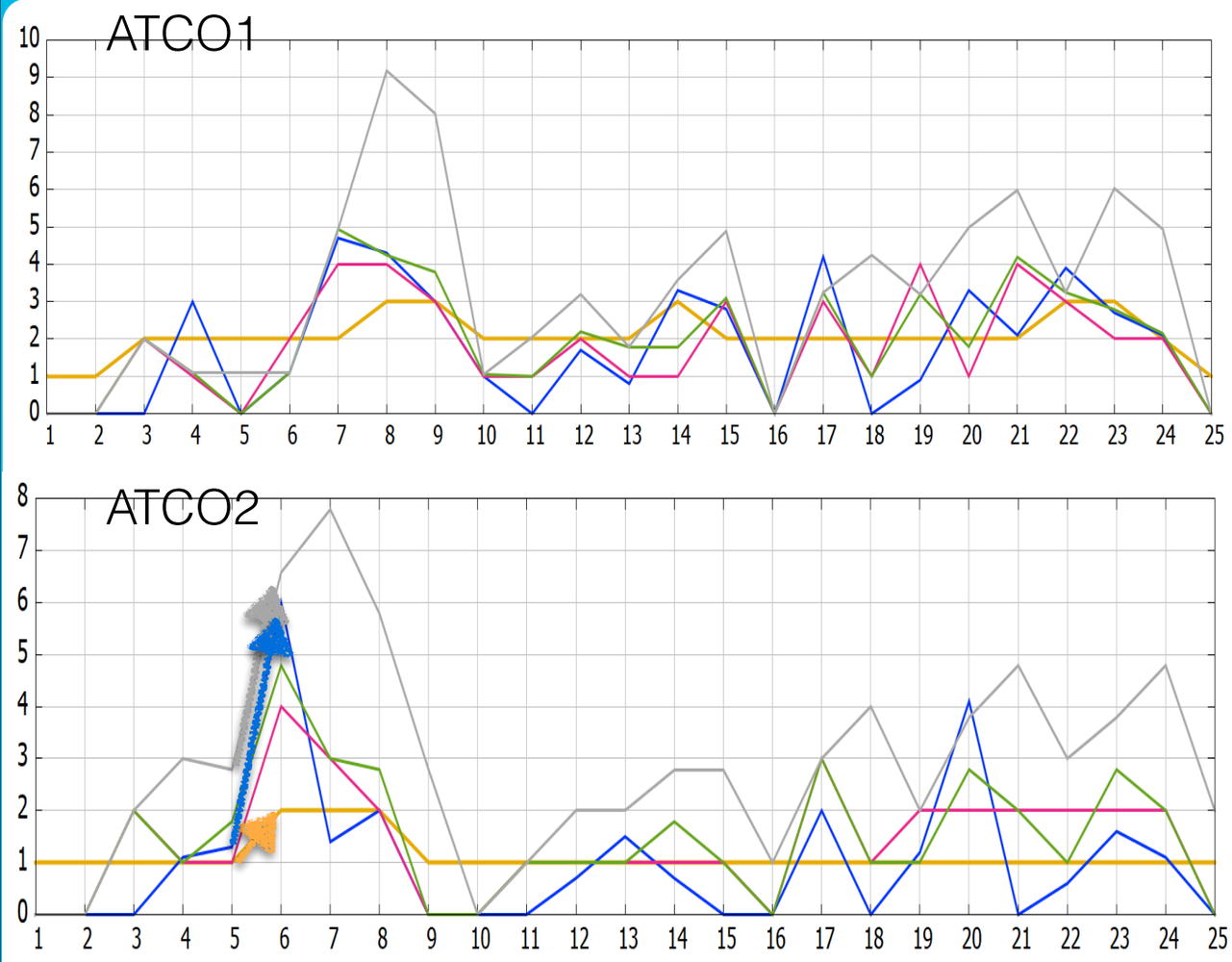

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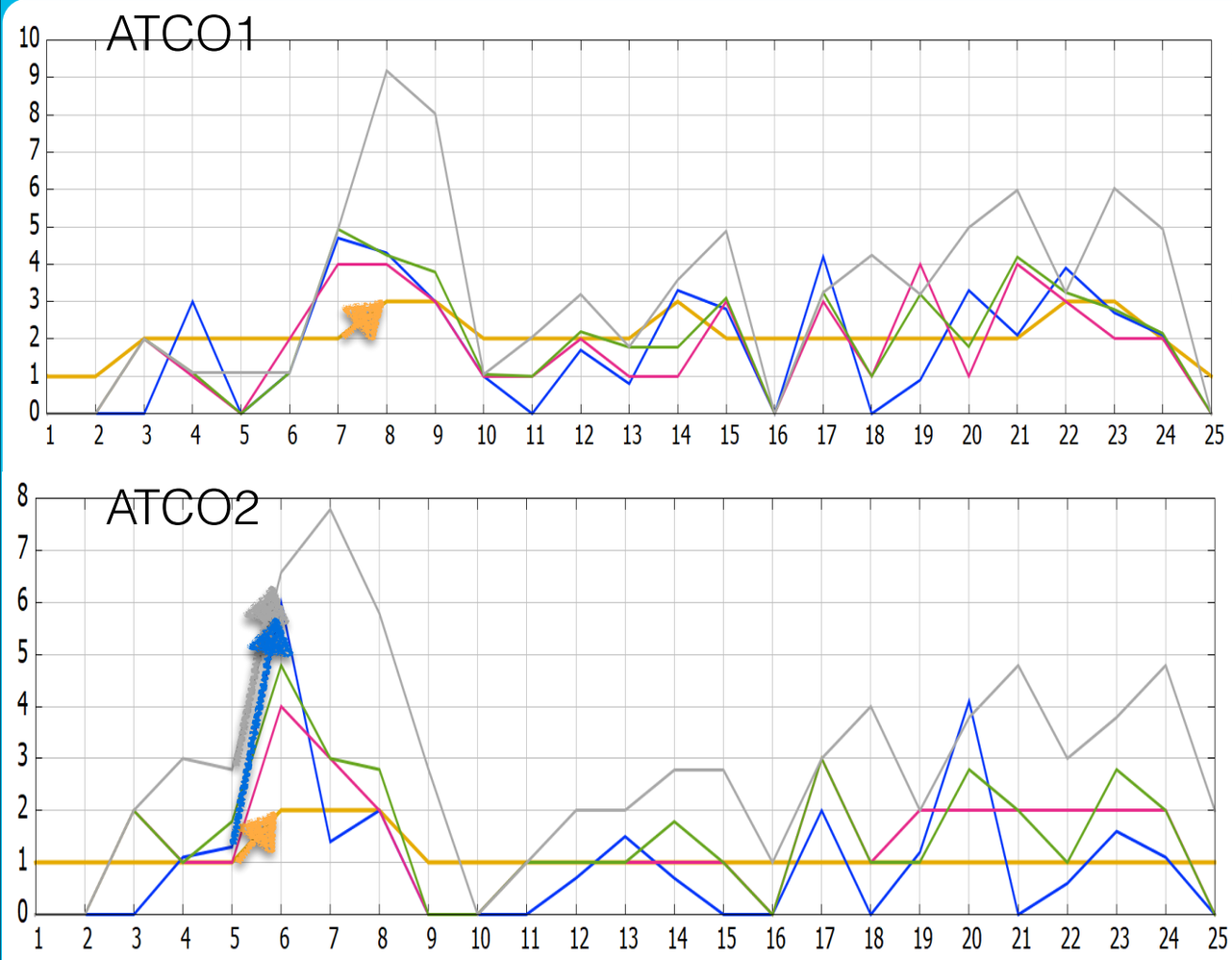

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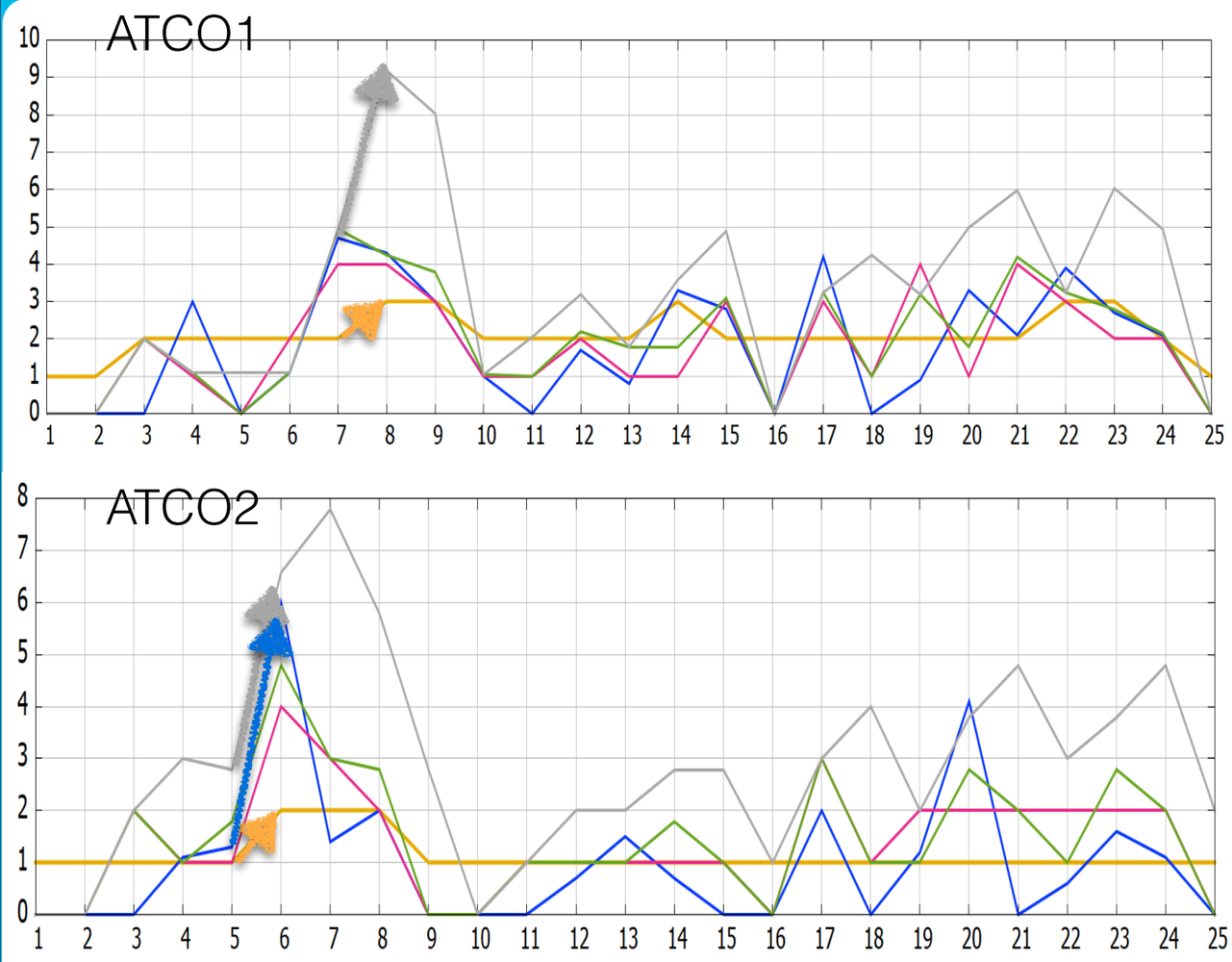
Workload vs. #ATs/Weighted ATs



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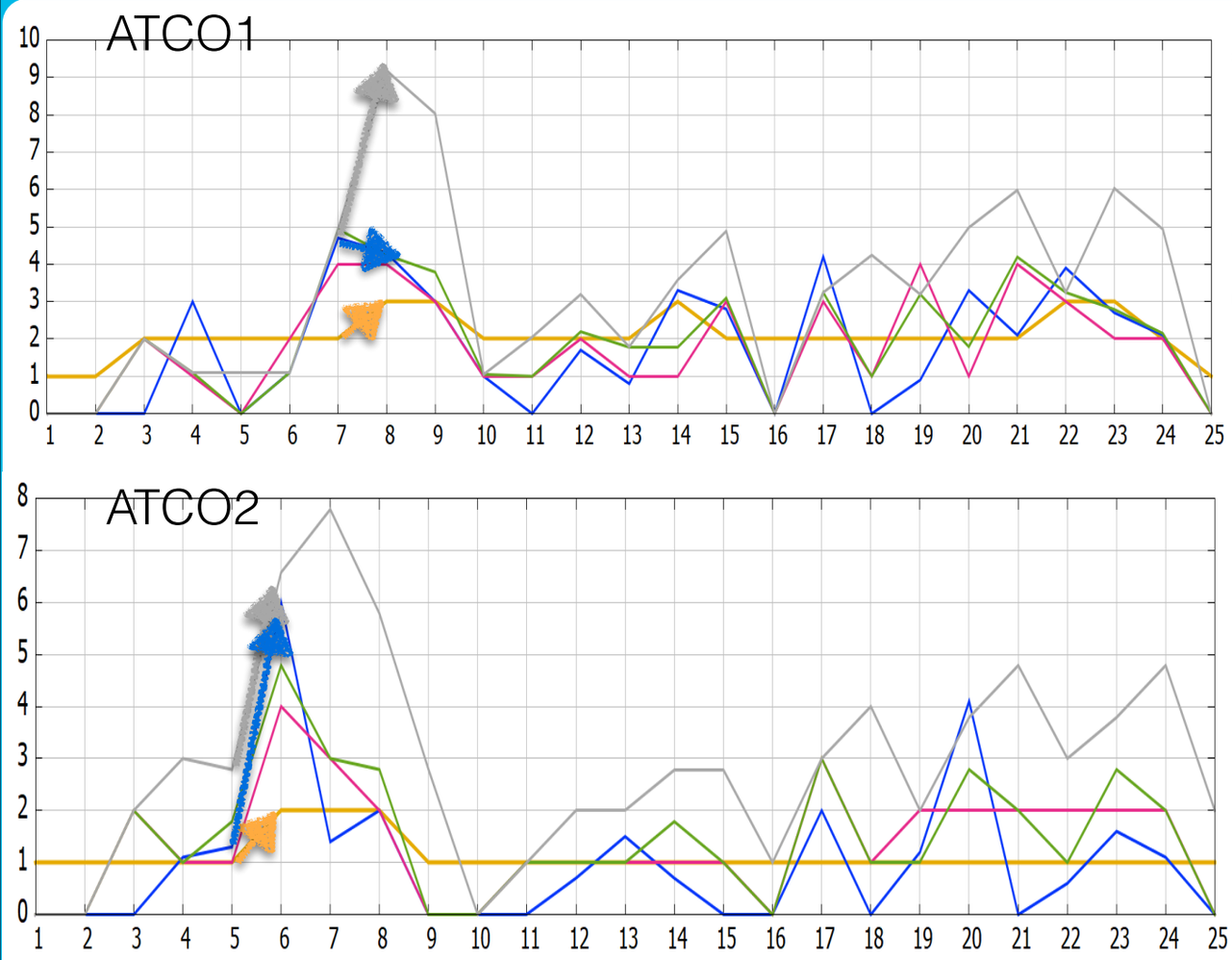

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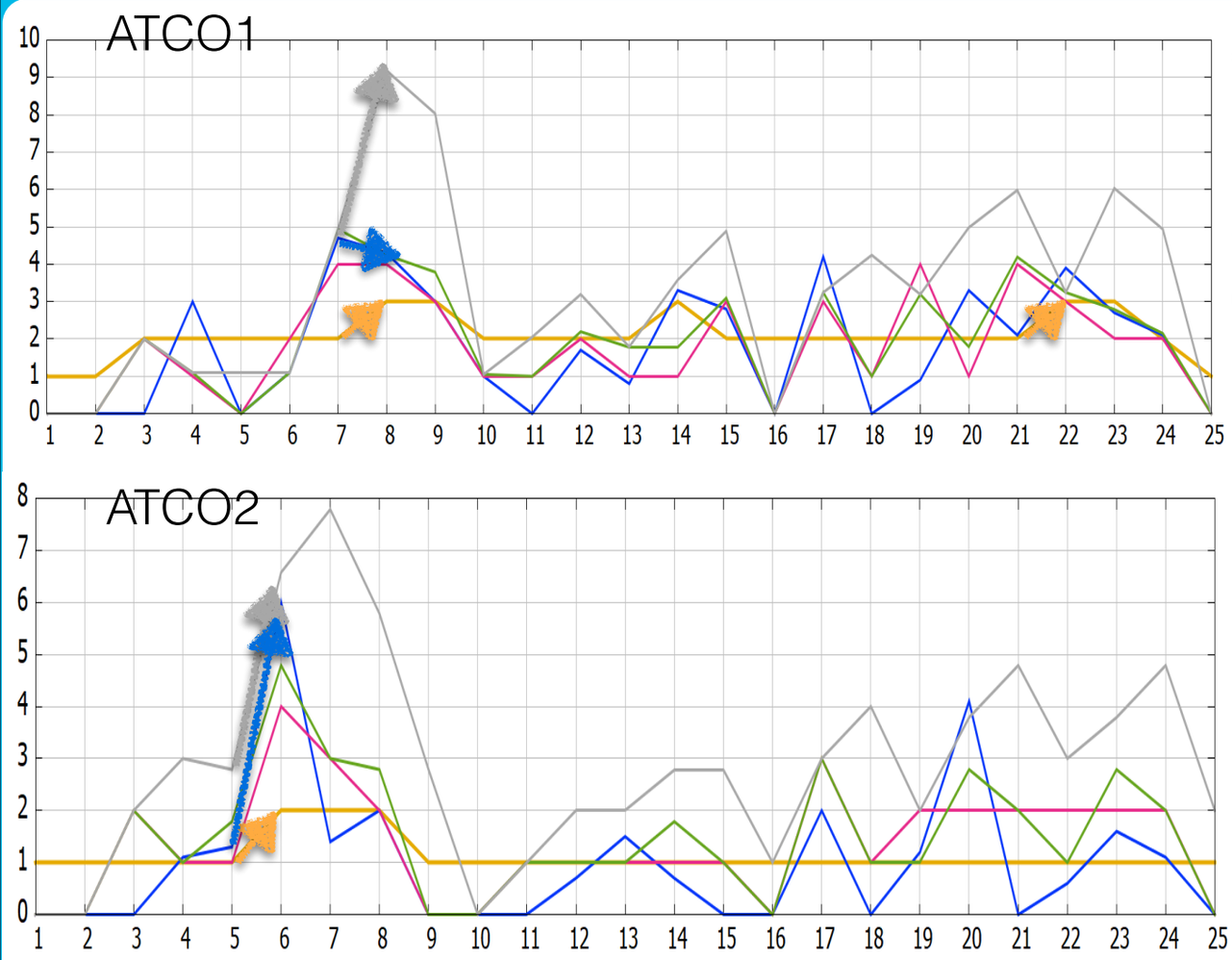

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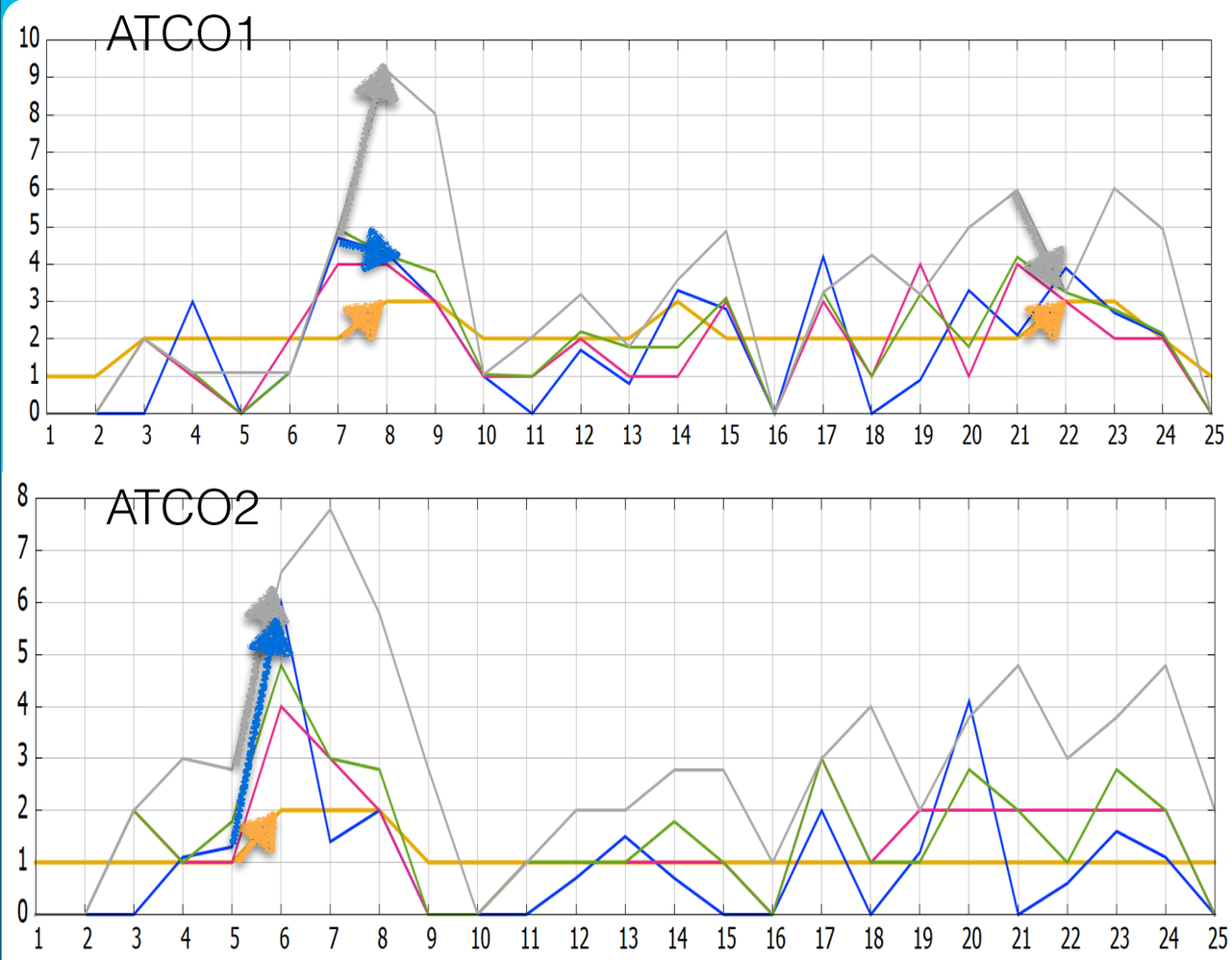

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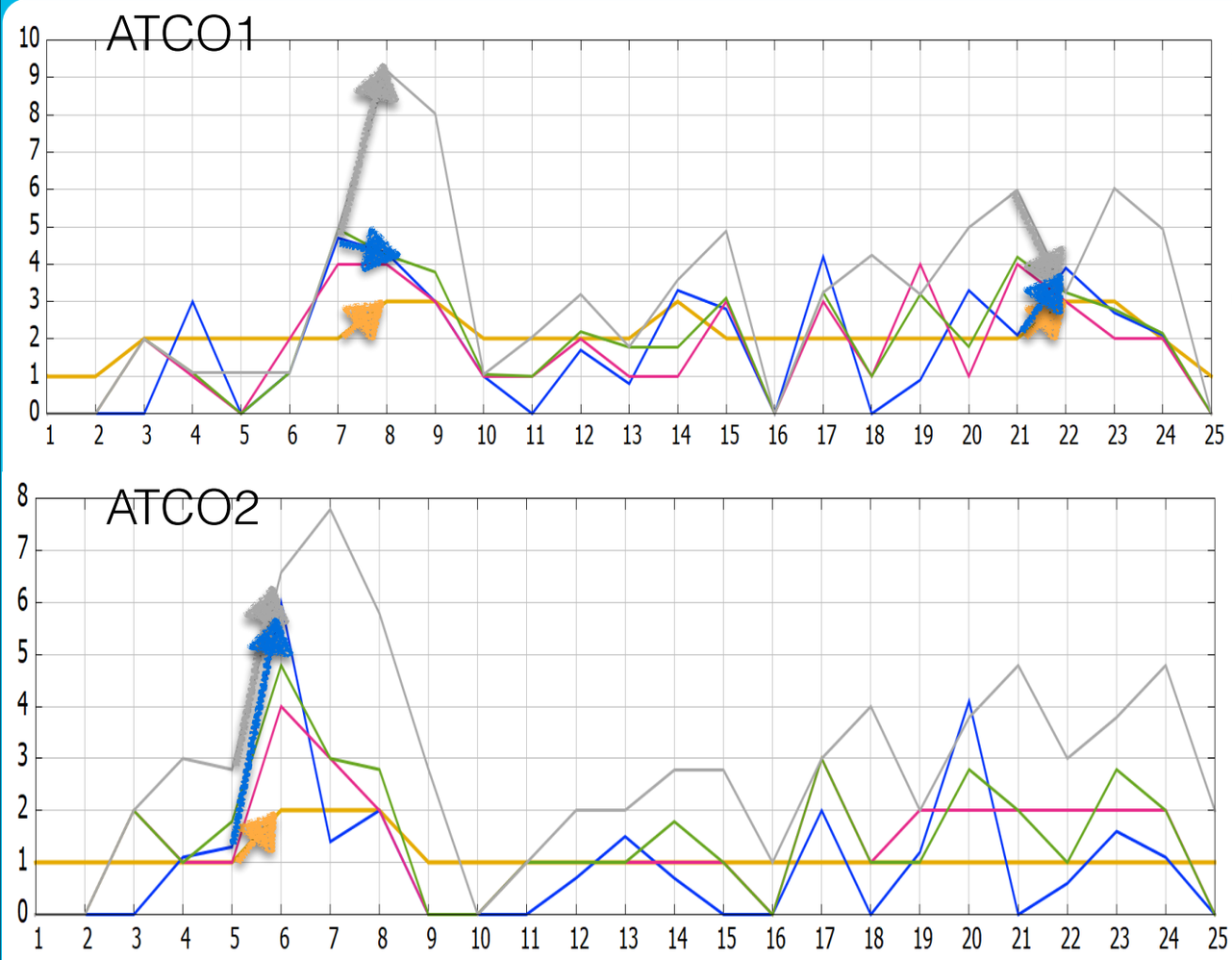

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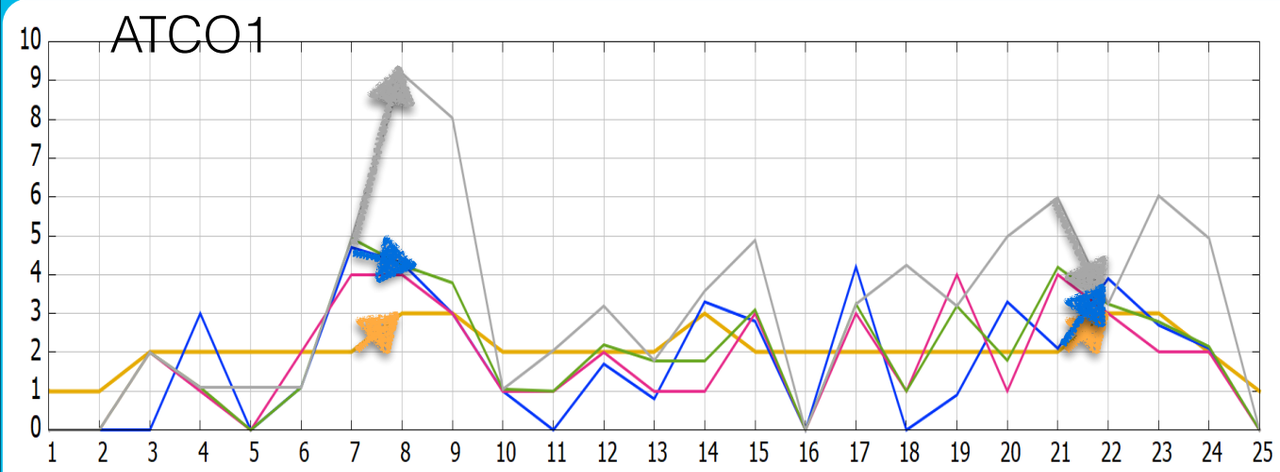

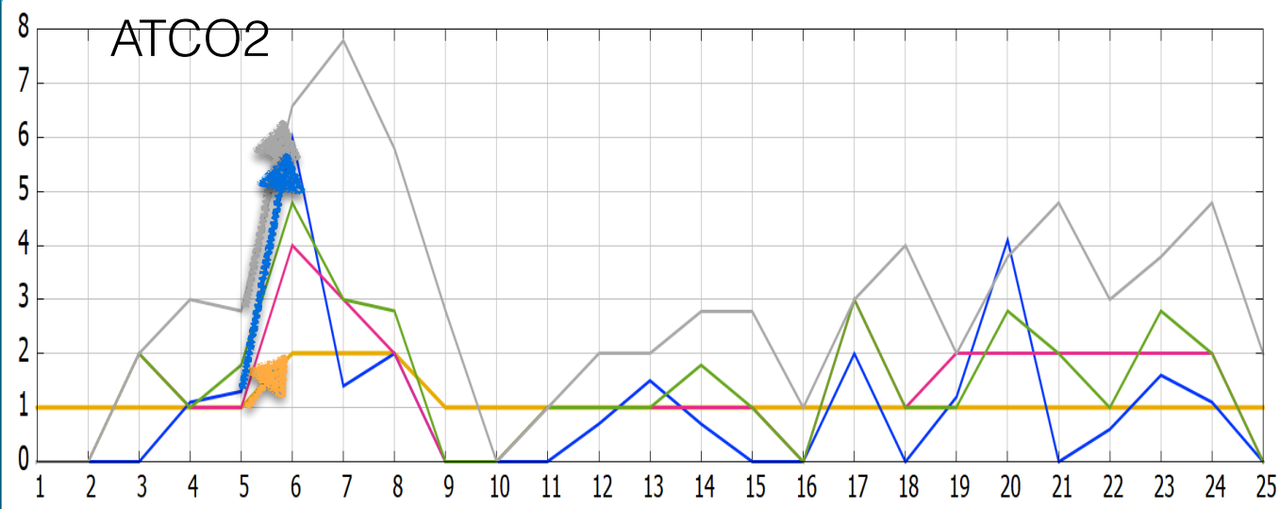

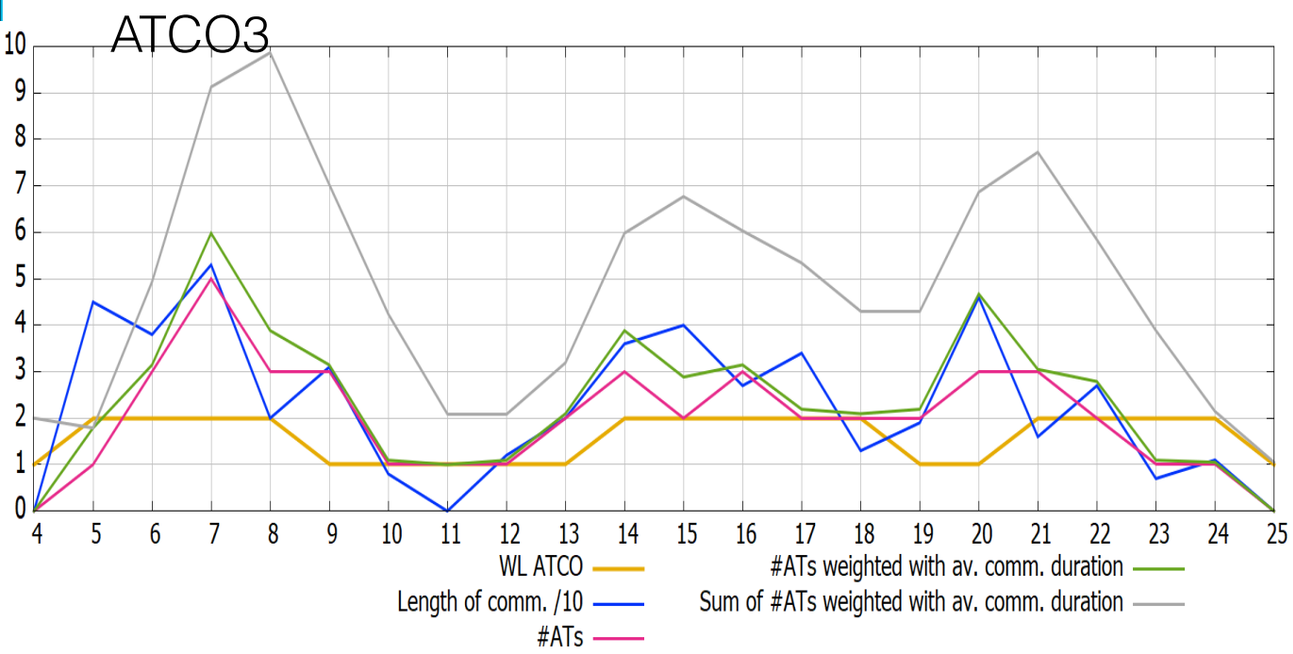

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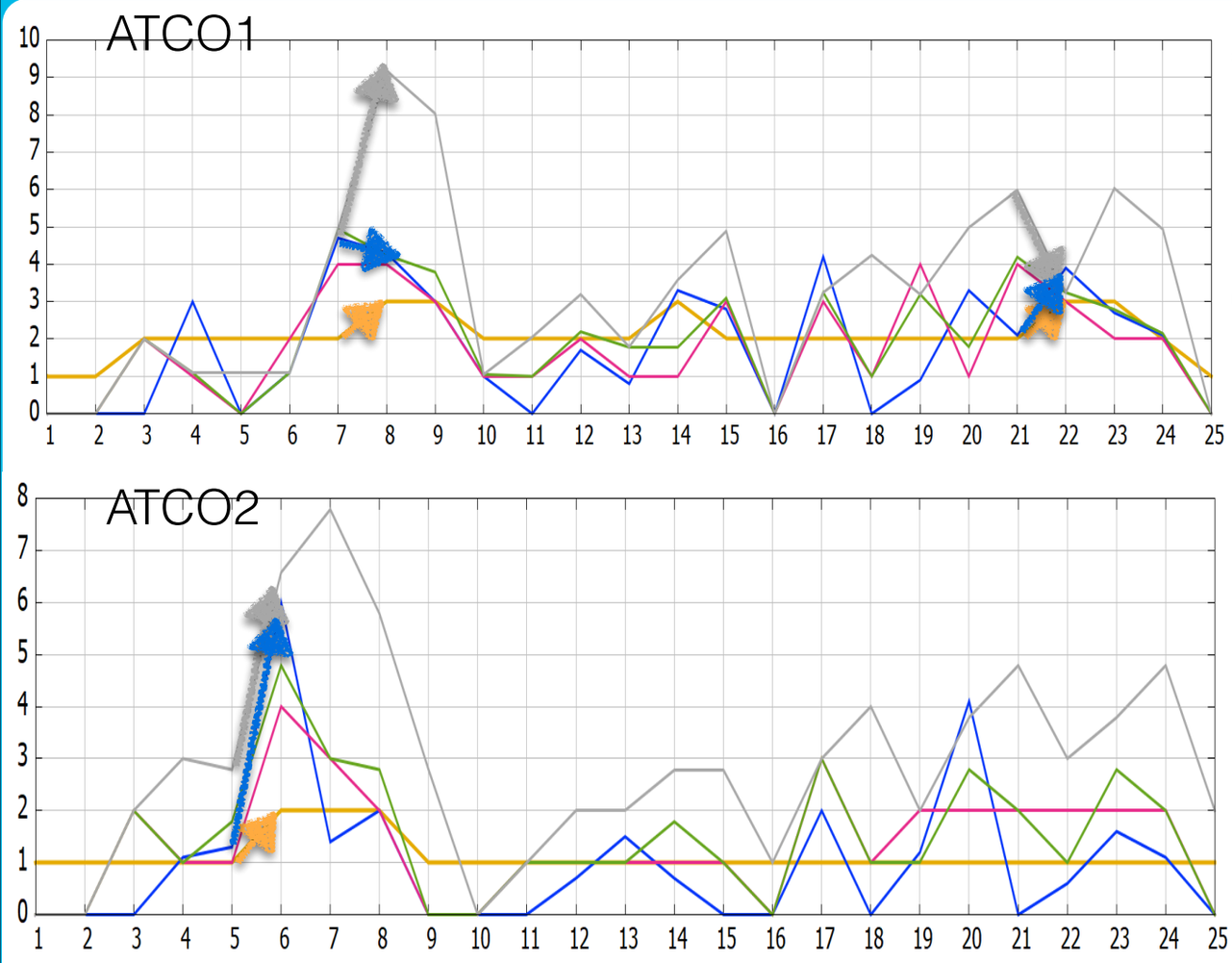

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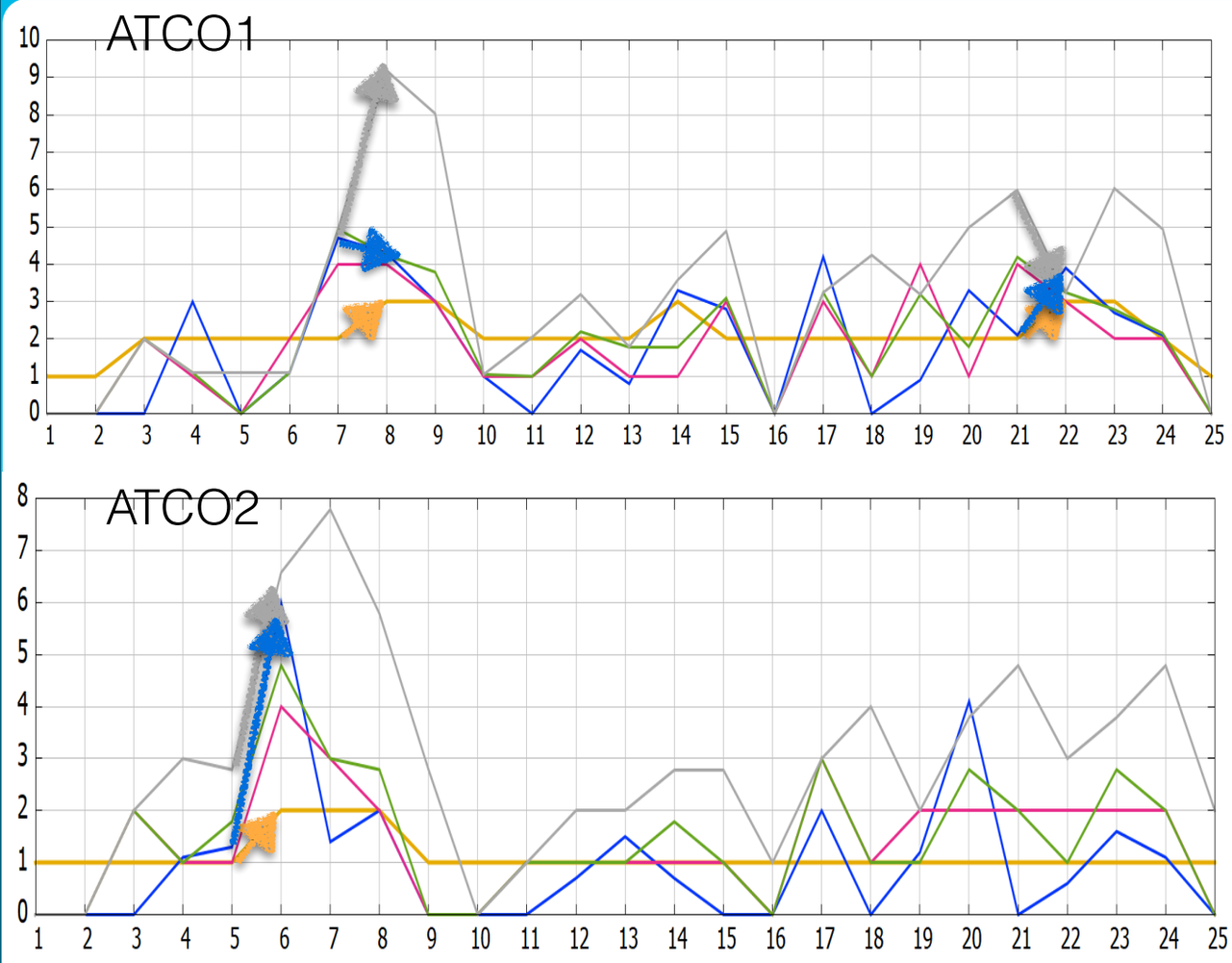

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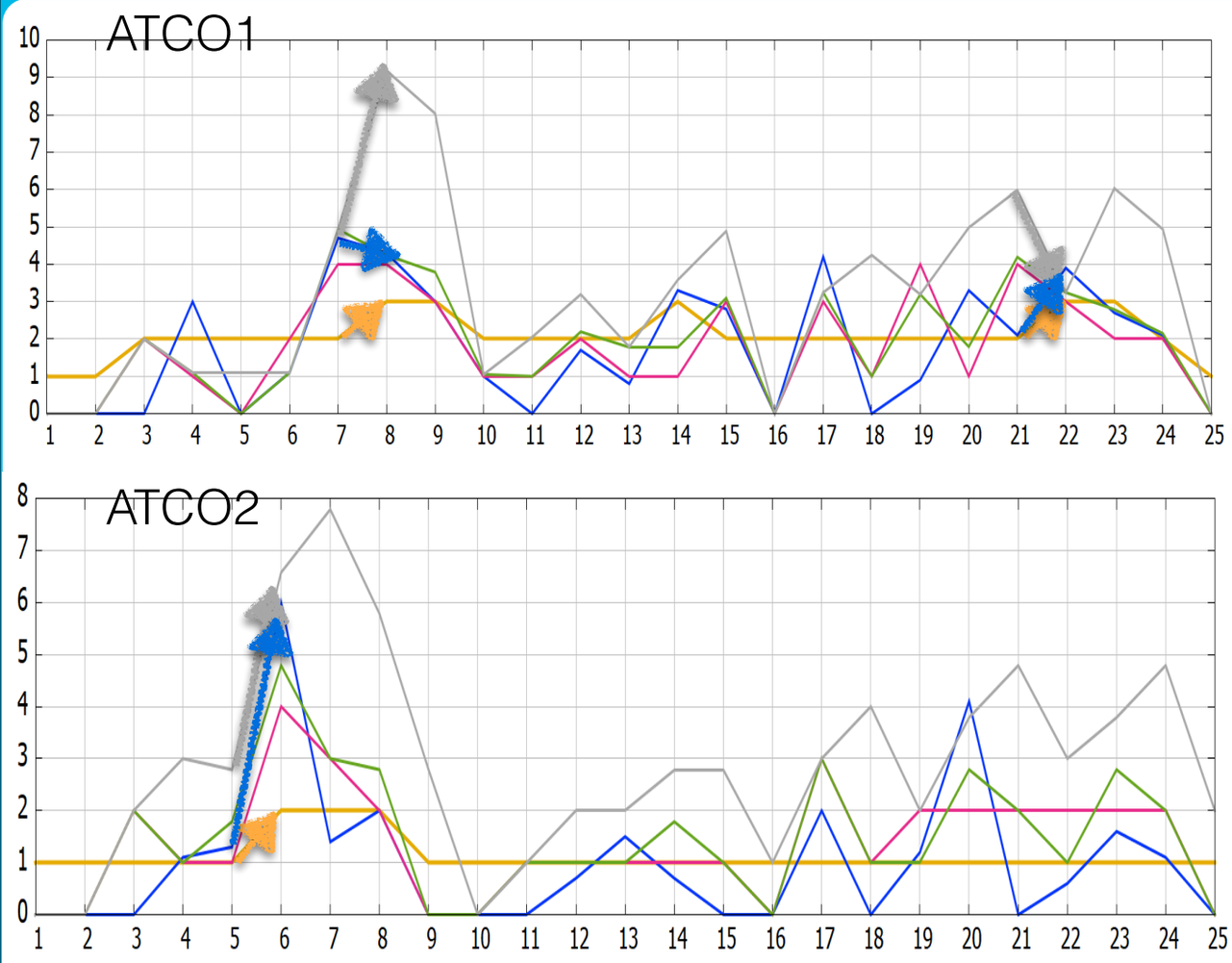
Workload vs. #ATs/Weighted ATs



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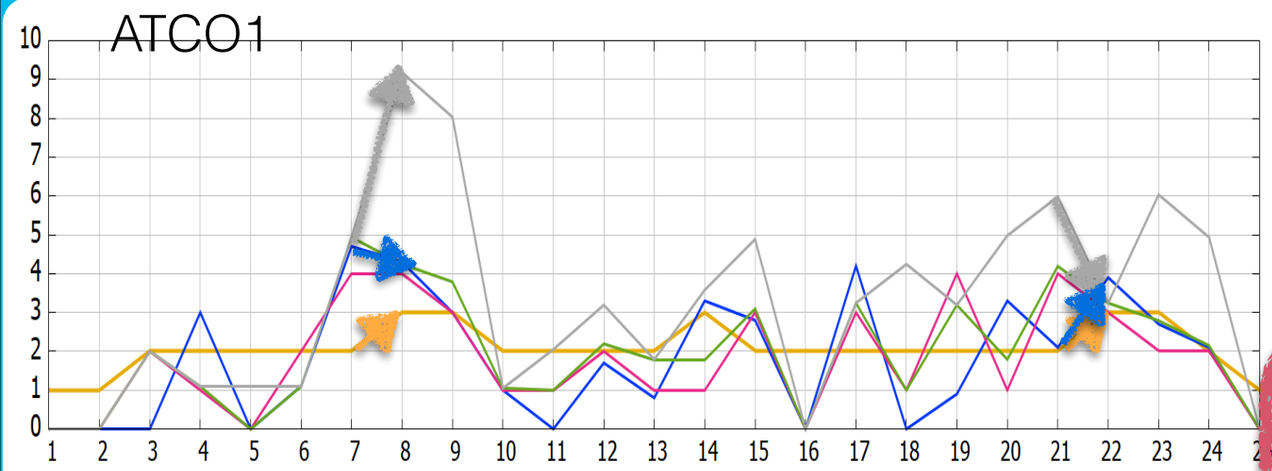
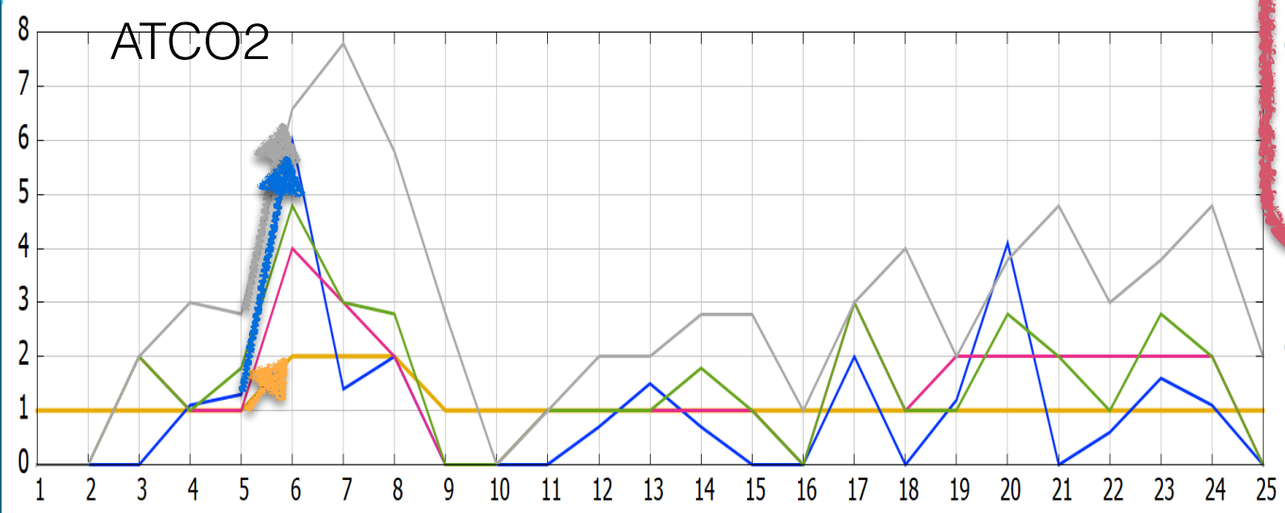
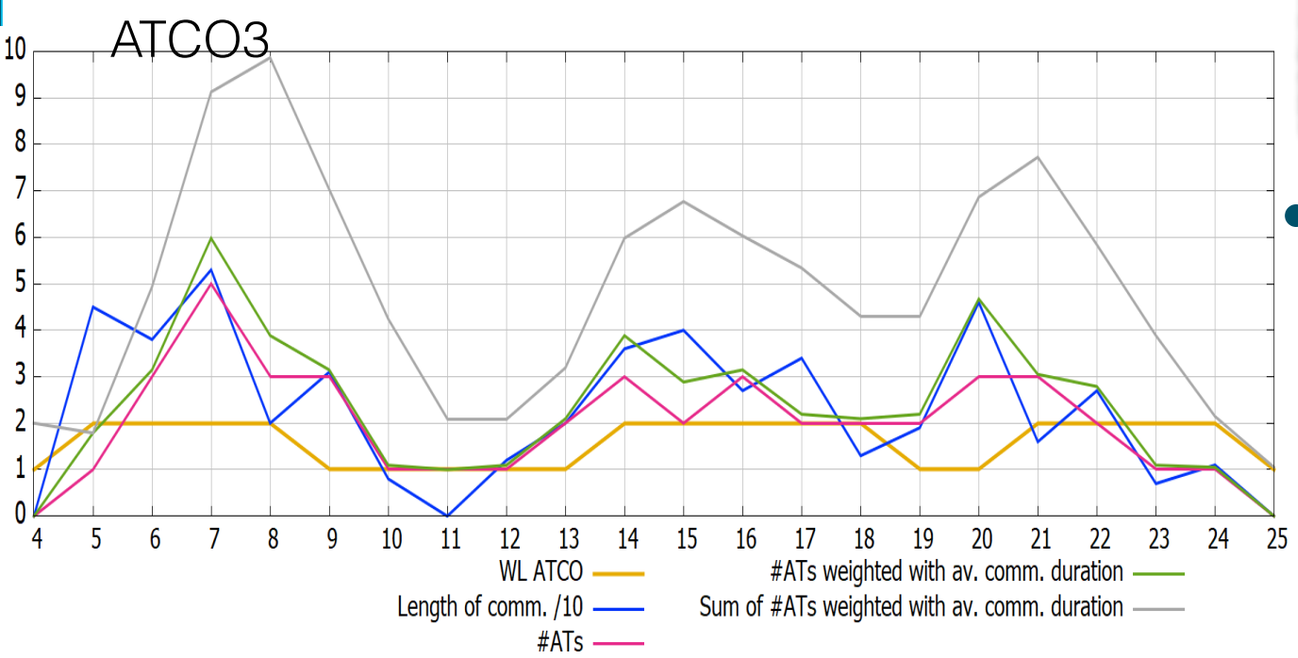
Workload vs. #ATs/Weighted ATs







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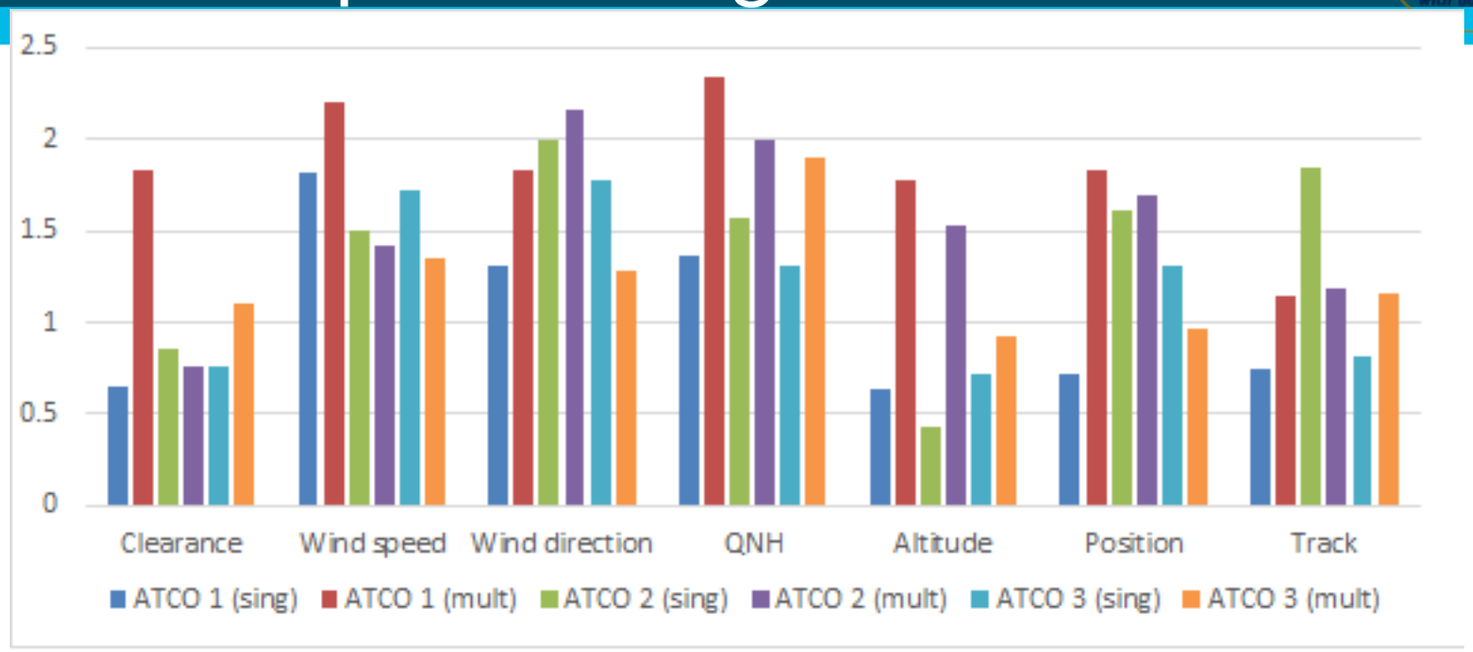
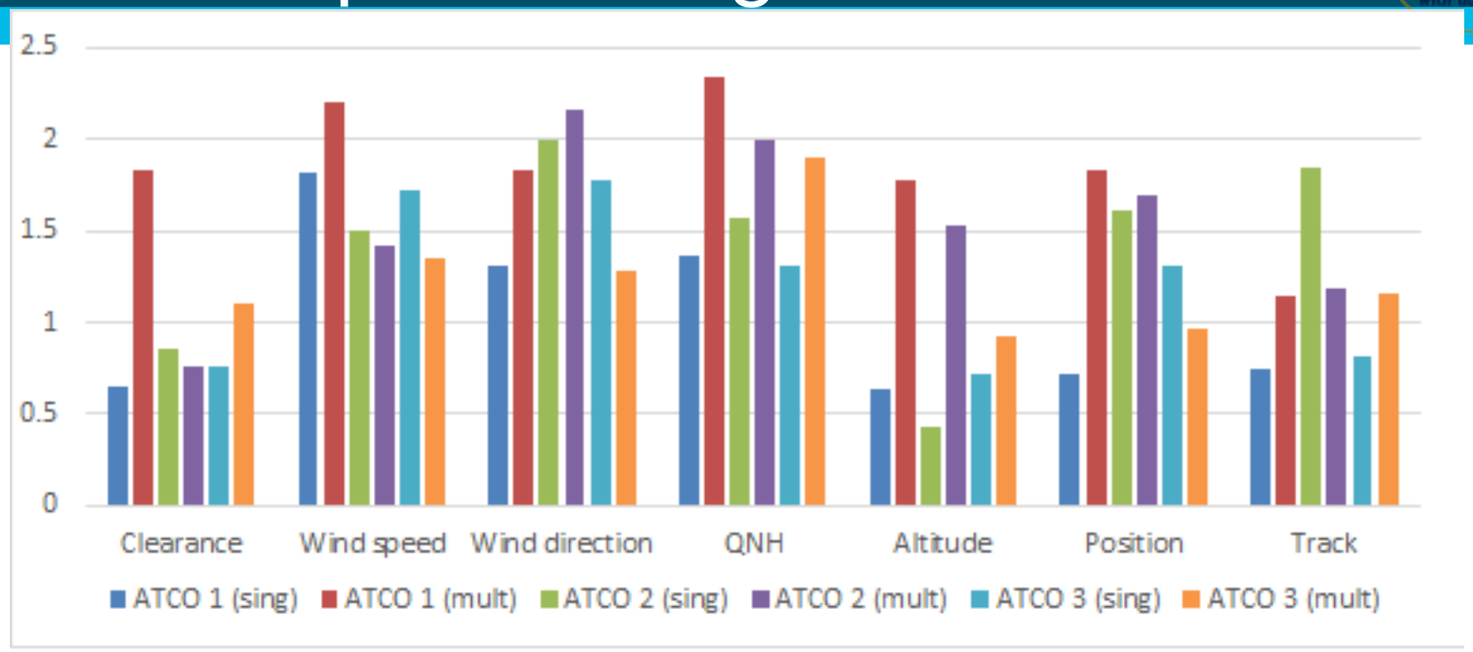
How exactly?
One of those or a combined measure?

Reaction Times: Multiple vs. Single



- For most queries: Reaction time by an ATCO in multiple mode increases vs. single mode

Reaction Times: Multiple vs. Single



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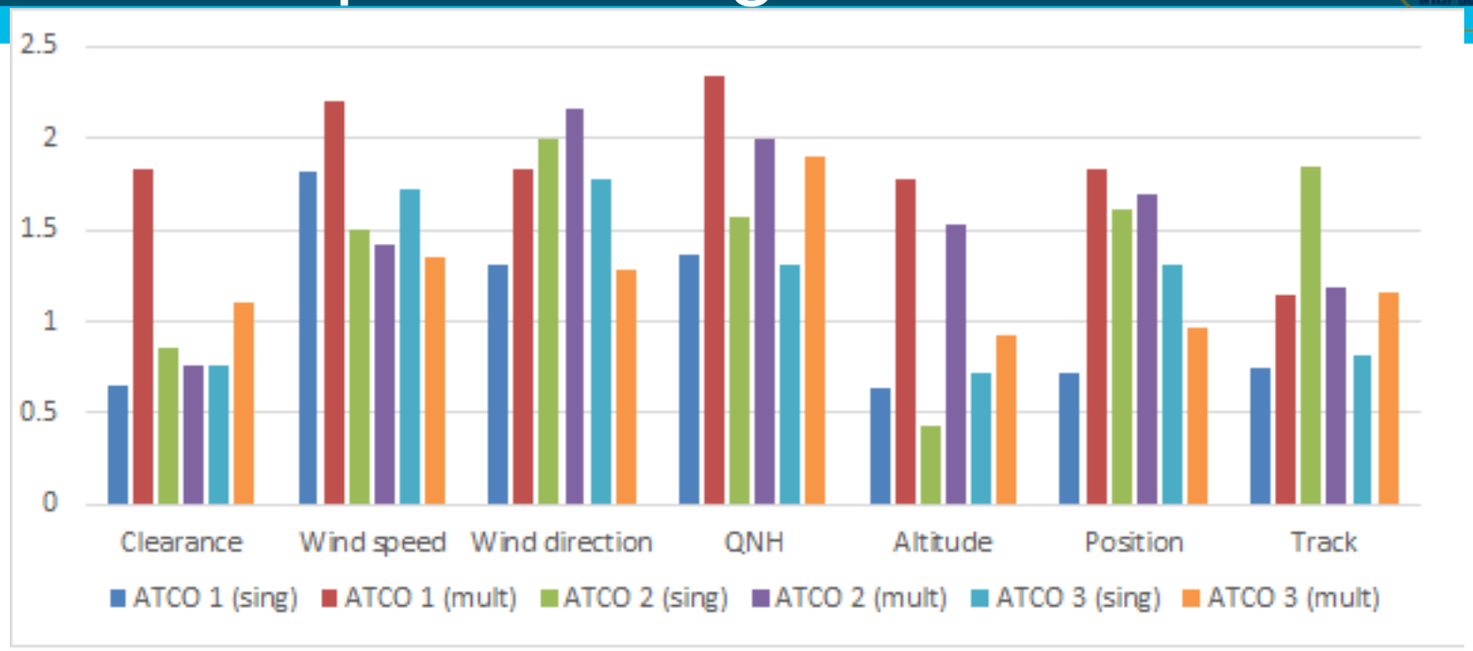
Reaction Times: Multiple vs. Single



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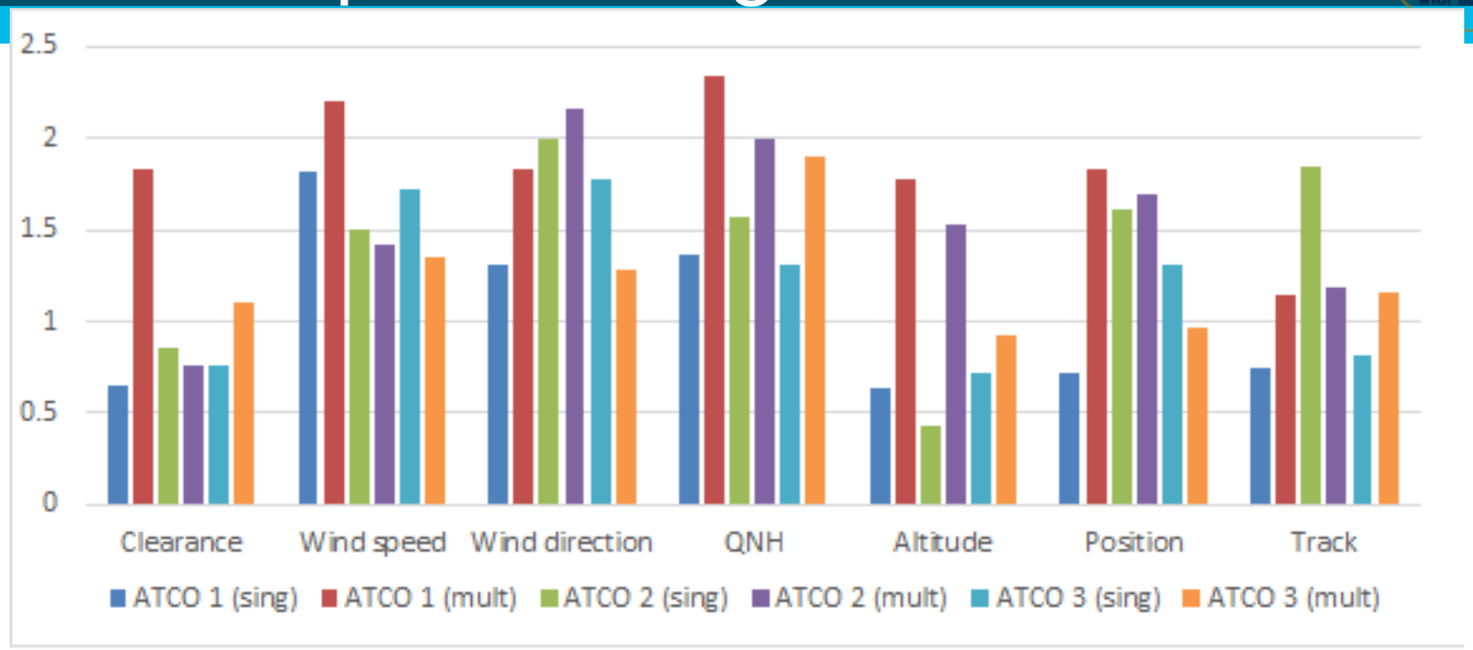
➡He/she might be less responsive—exhibit risk compensation behavior

Reaction Times: Multiple vs. Single



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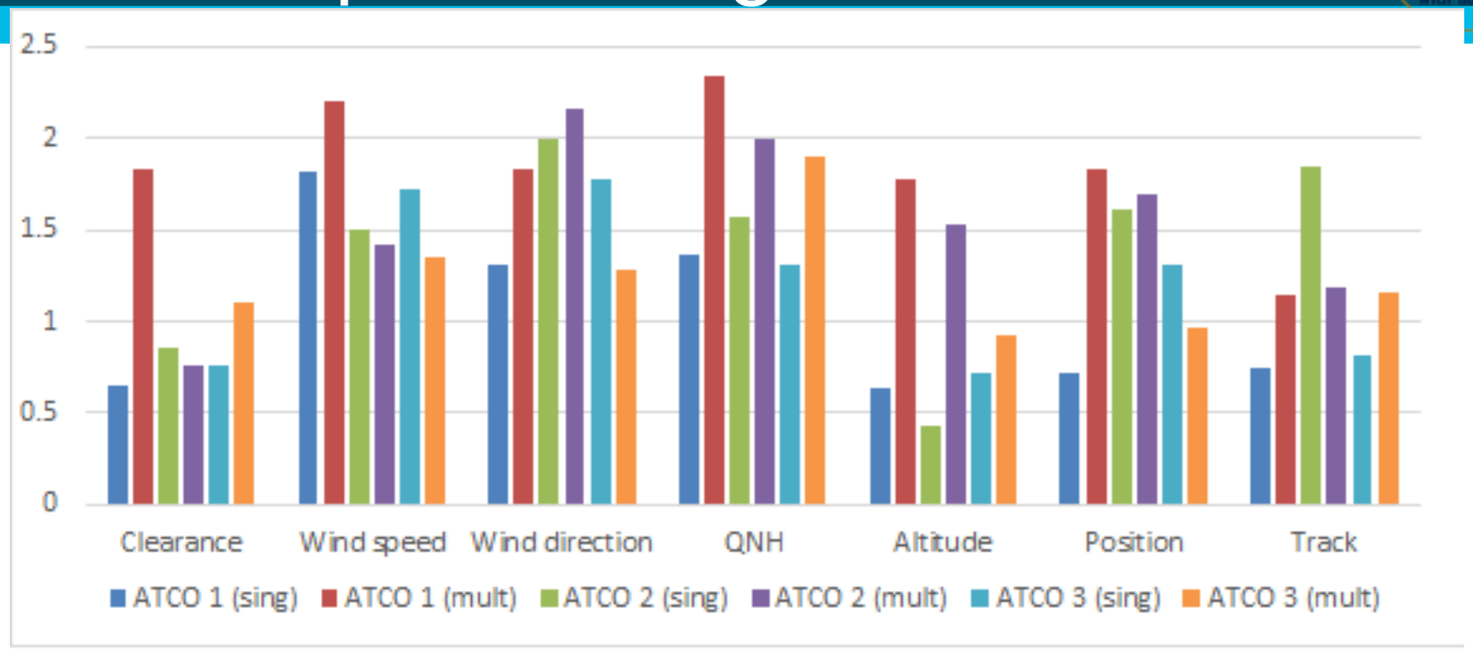
Reaction Times: Multiple vs. Single



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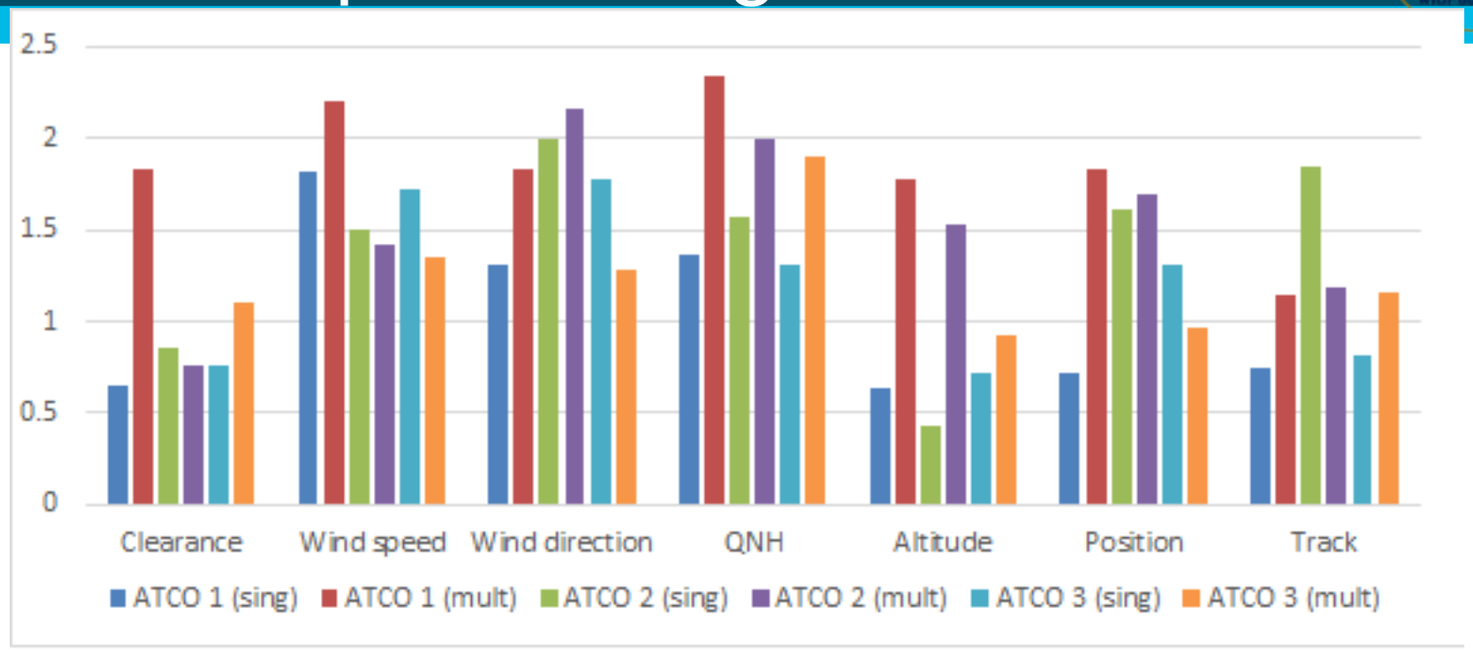
➡ ATCO double checks to avoid mistakes

Reaction Times: Multiple vs. Single



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➡Slowdown

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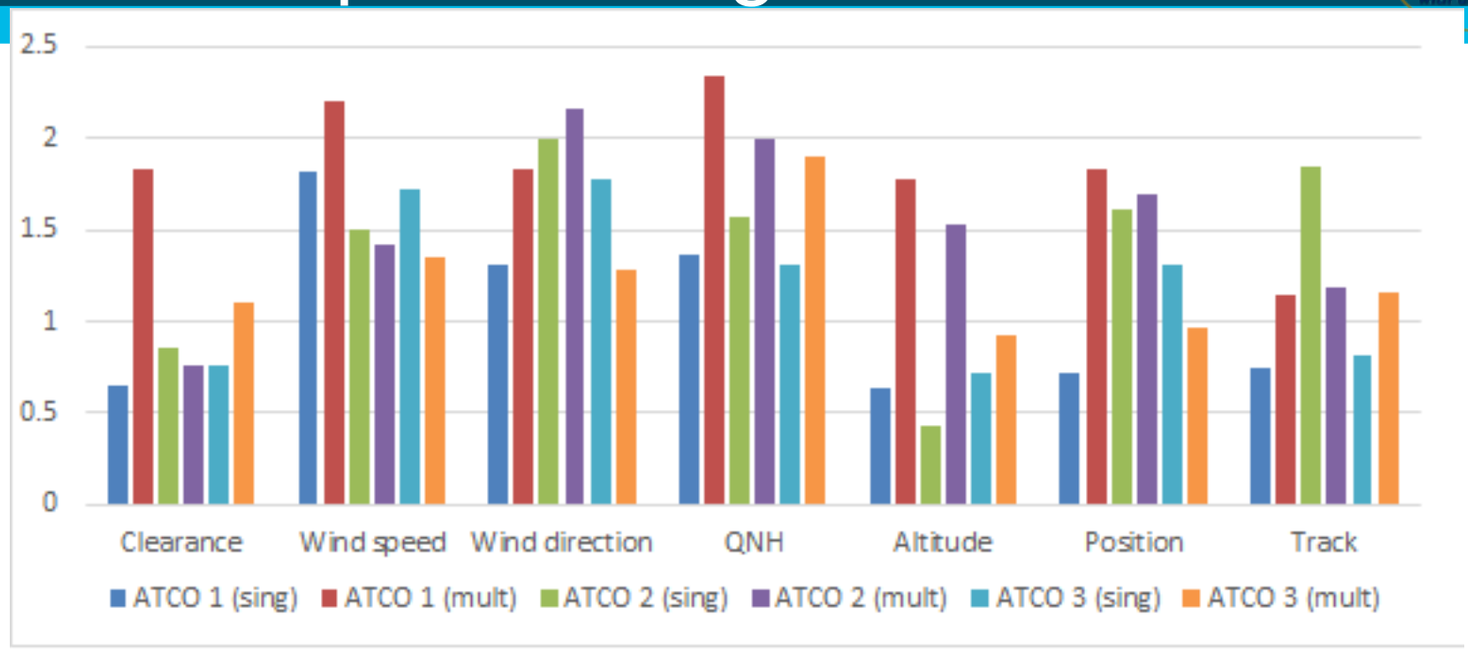

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➡Can be an indicator for uncertainty [2]

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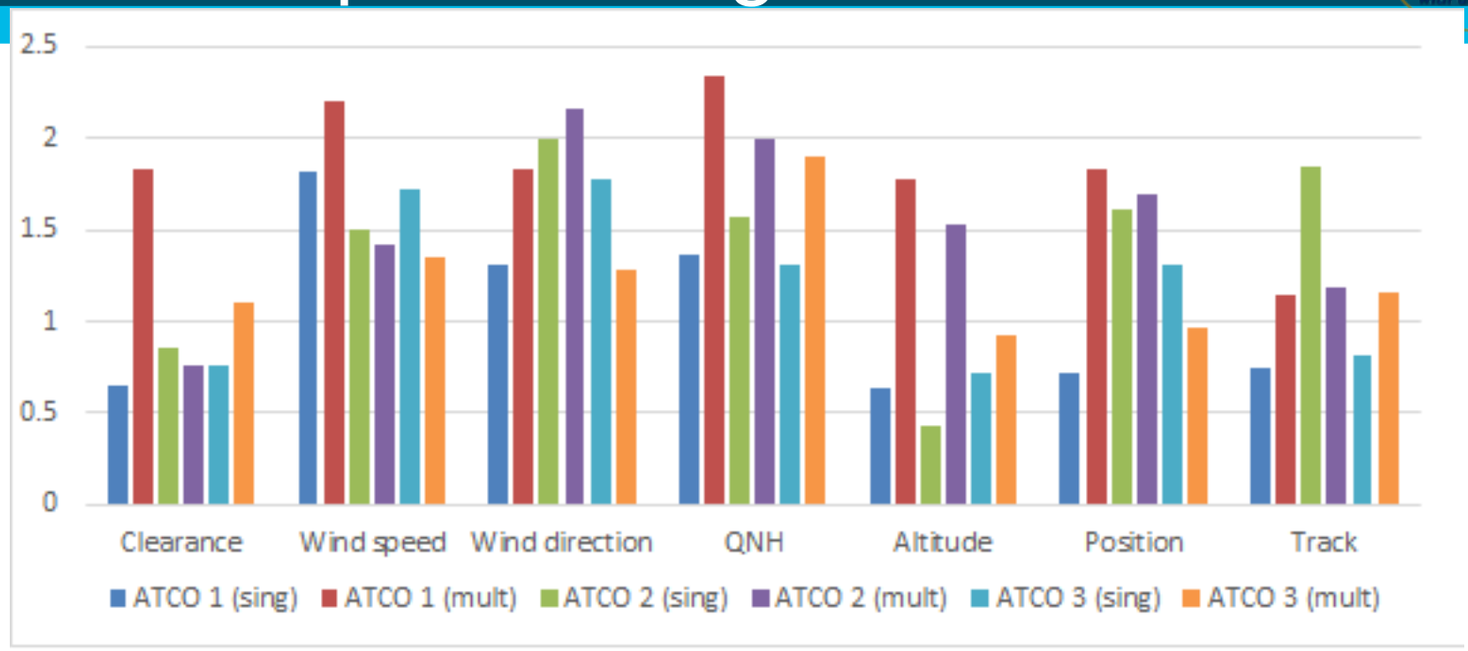

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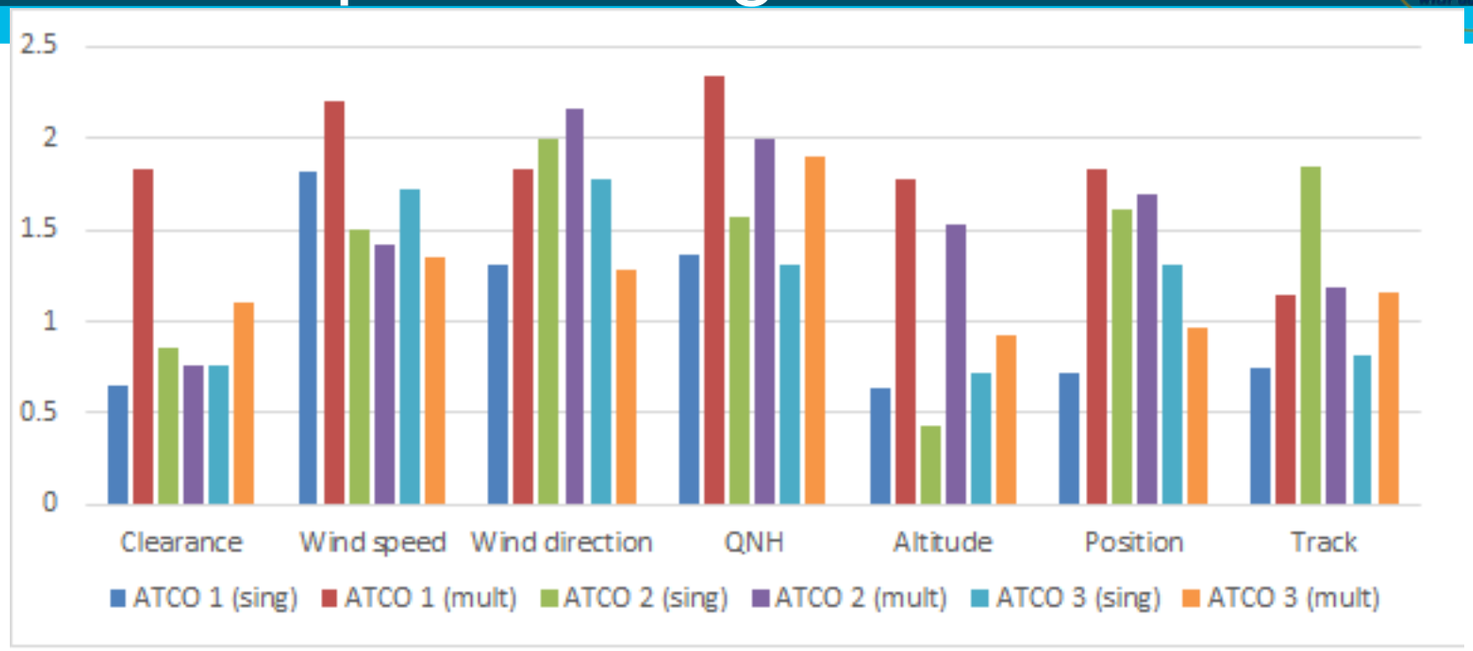

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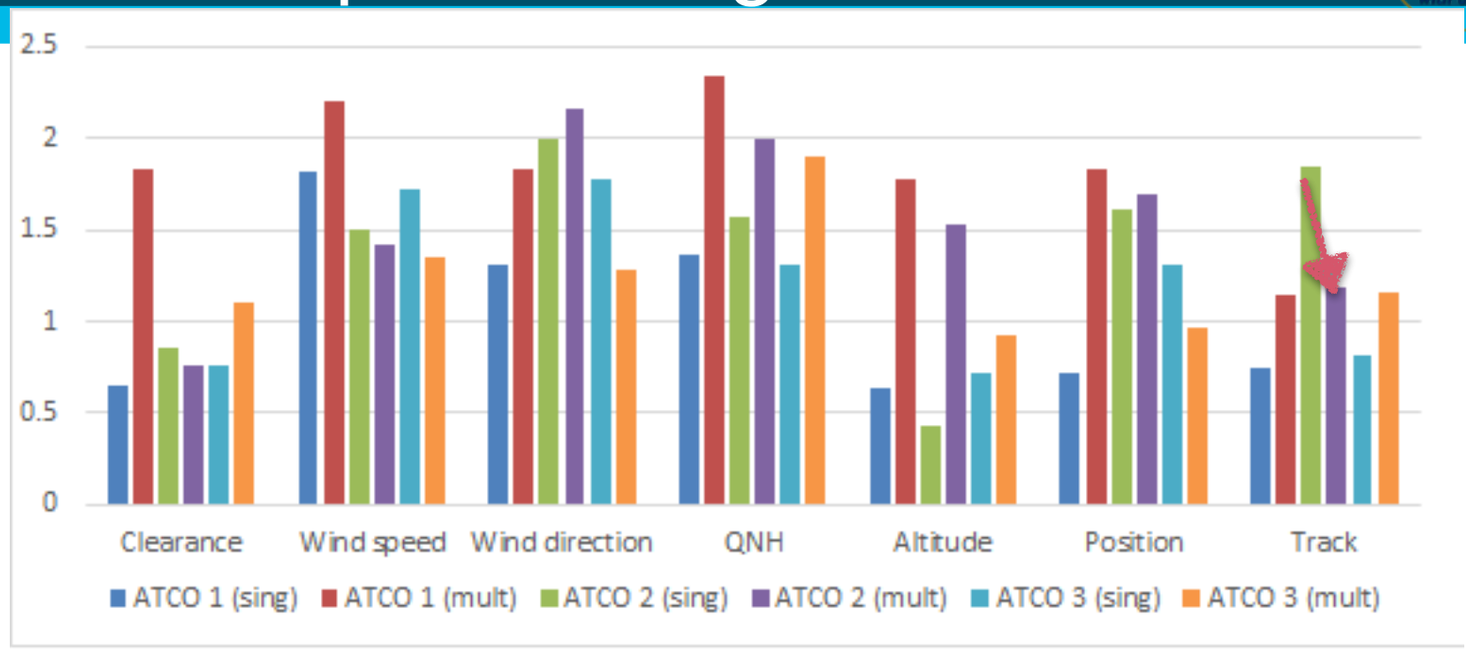

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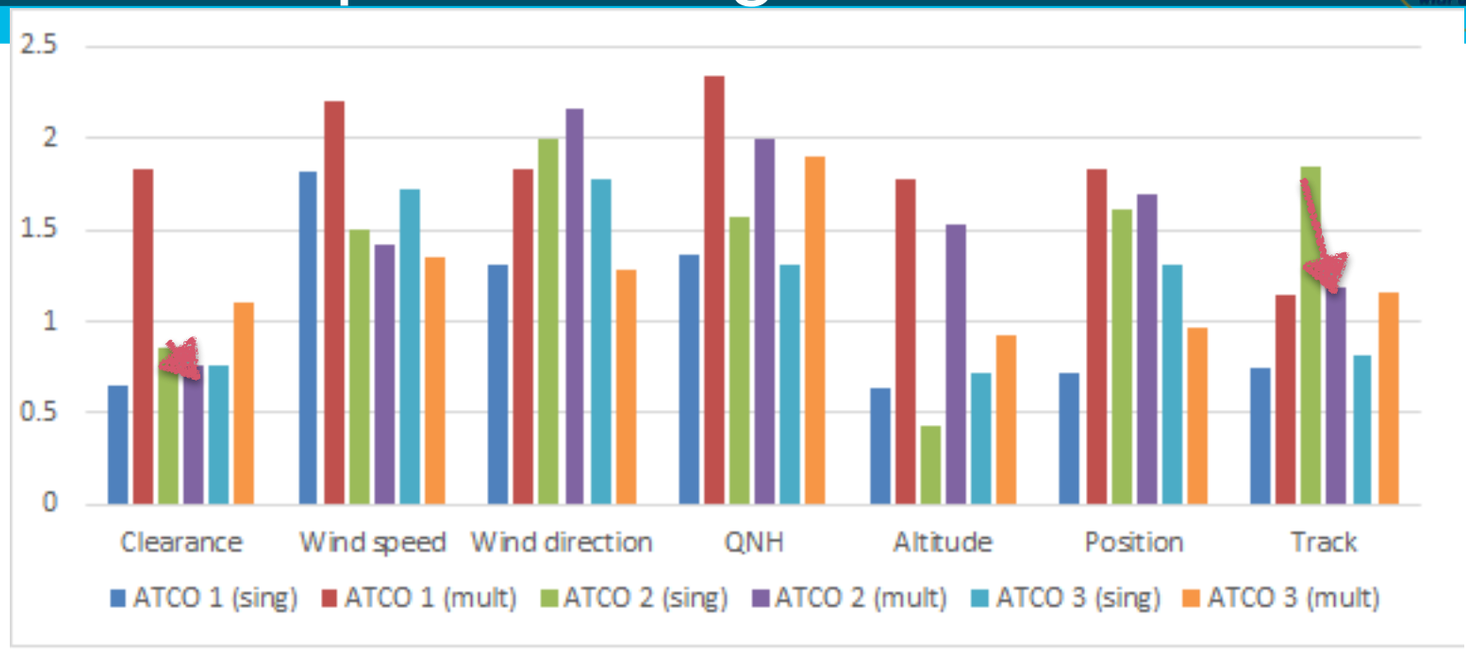

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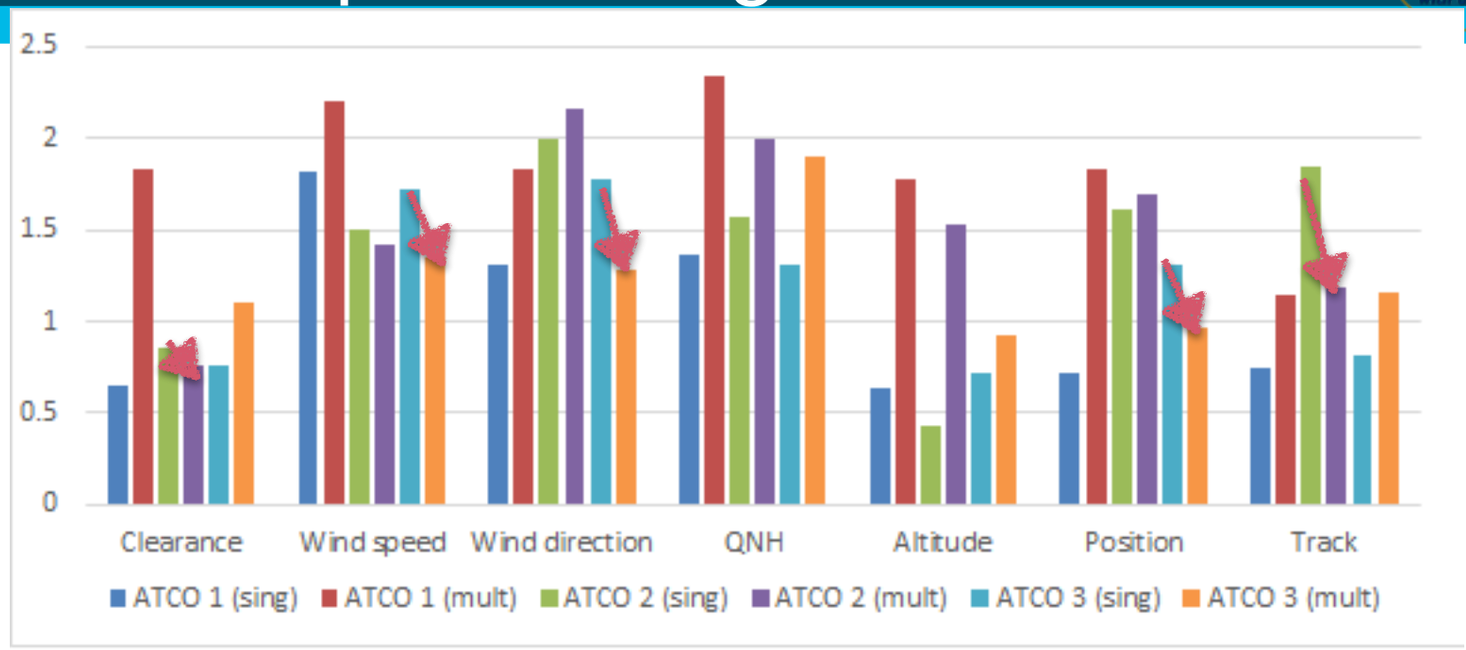

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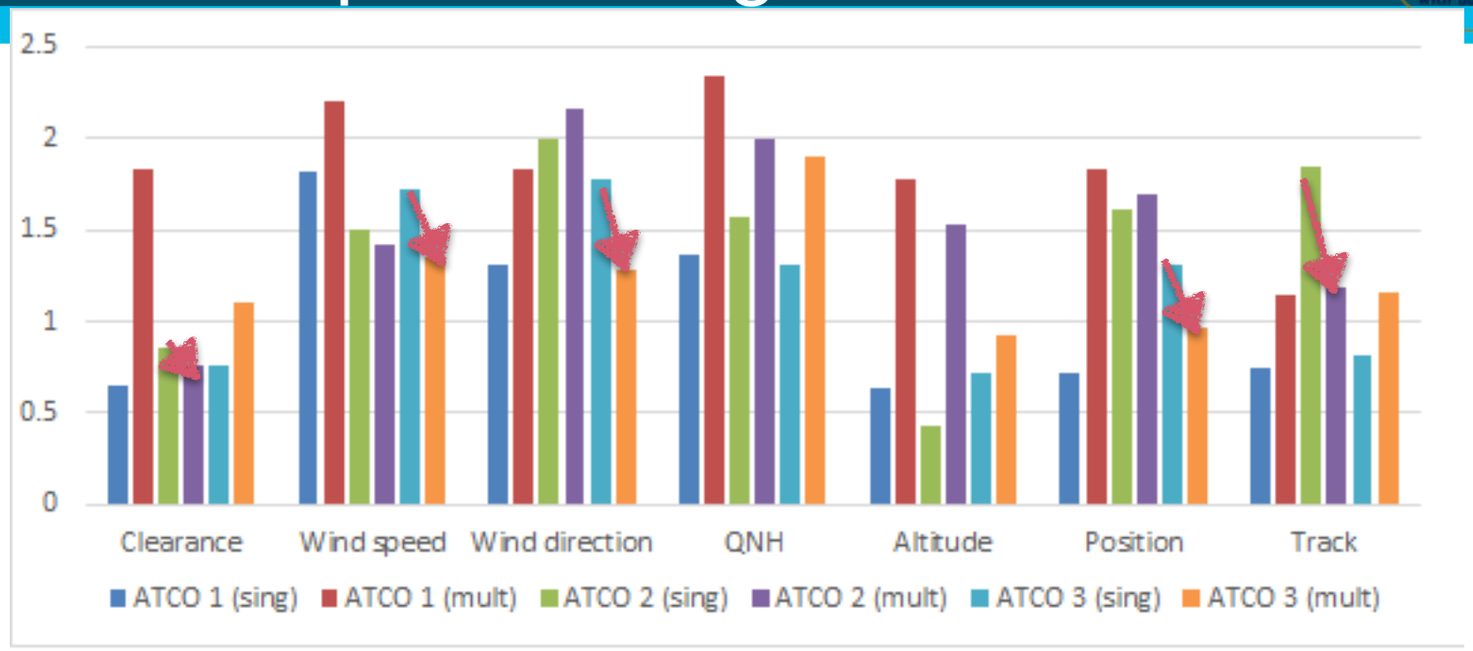

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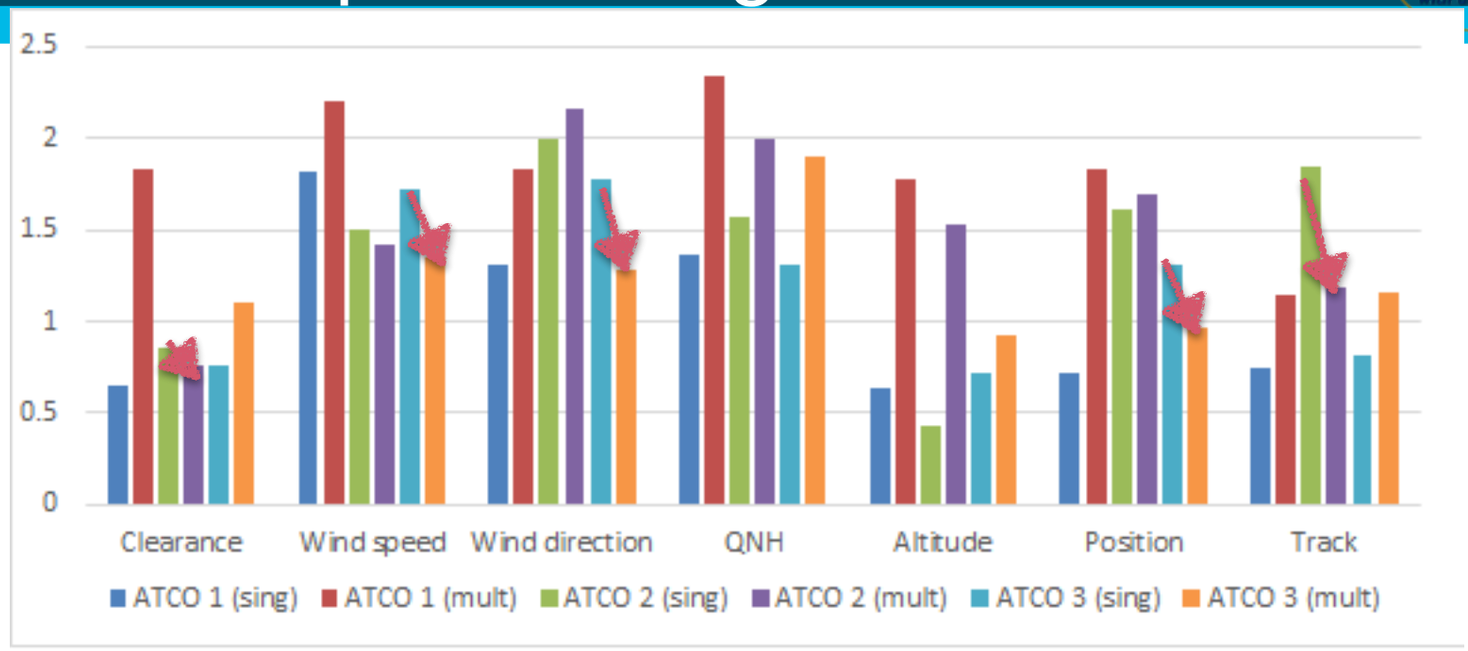

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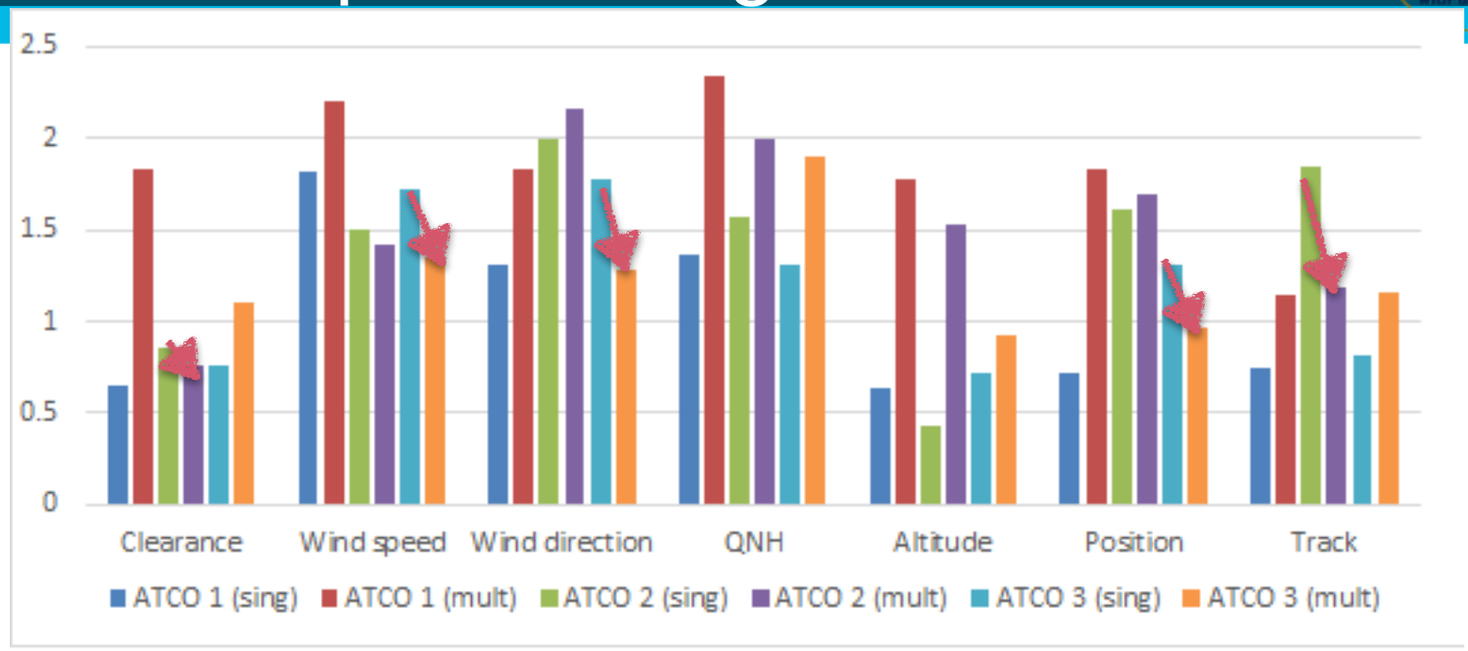

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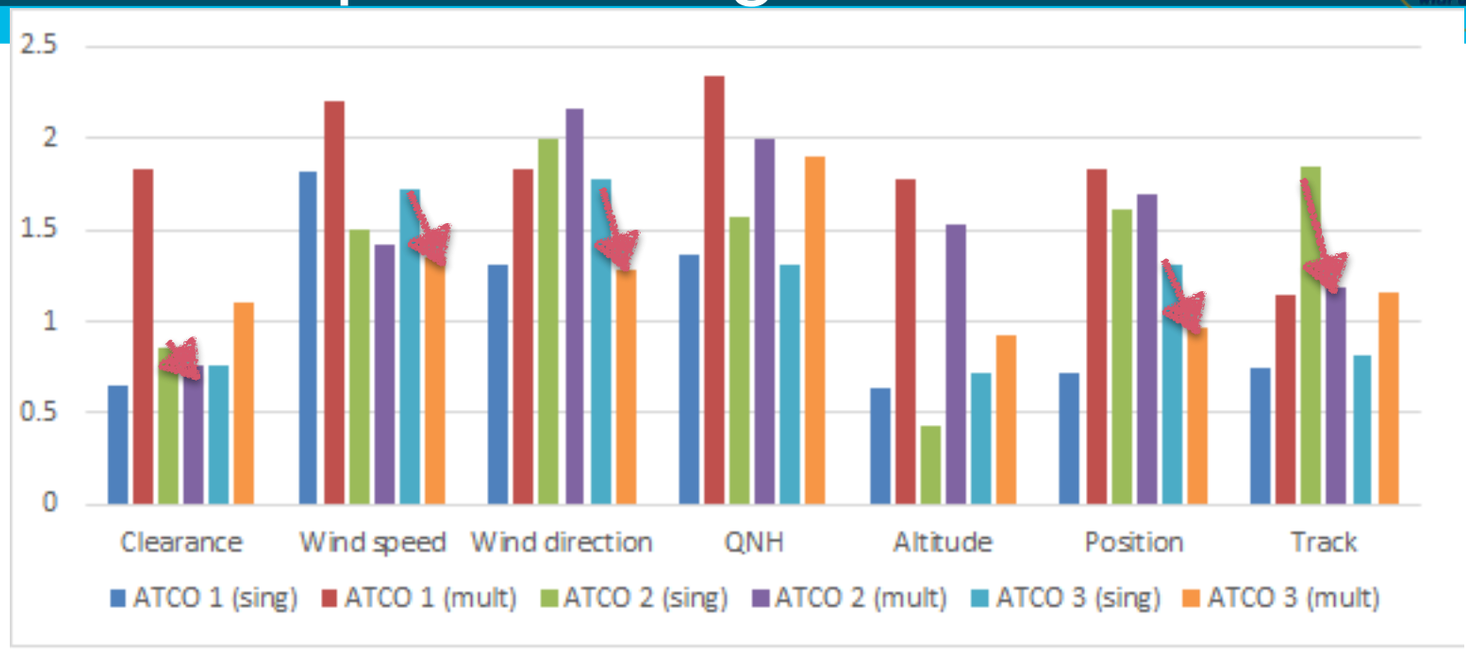

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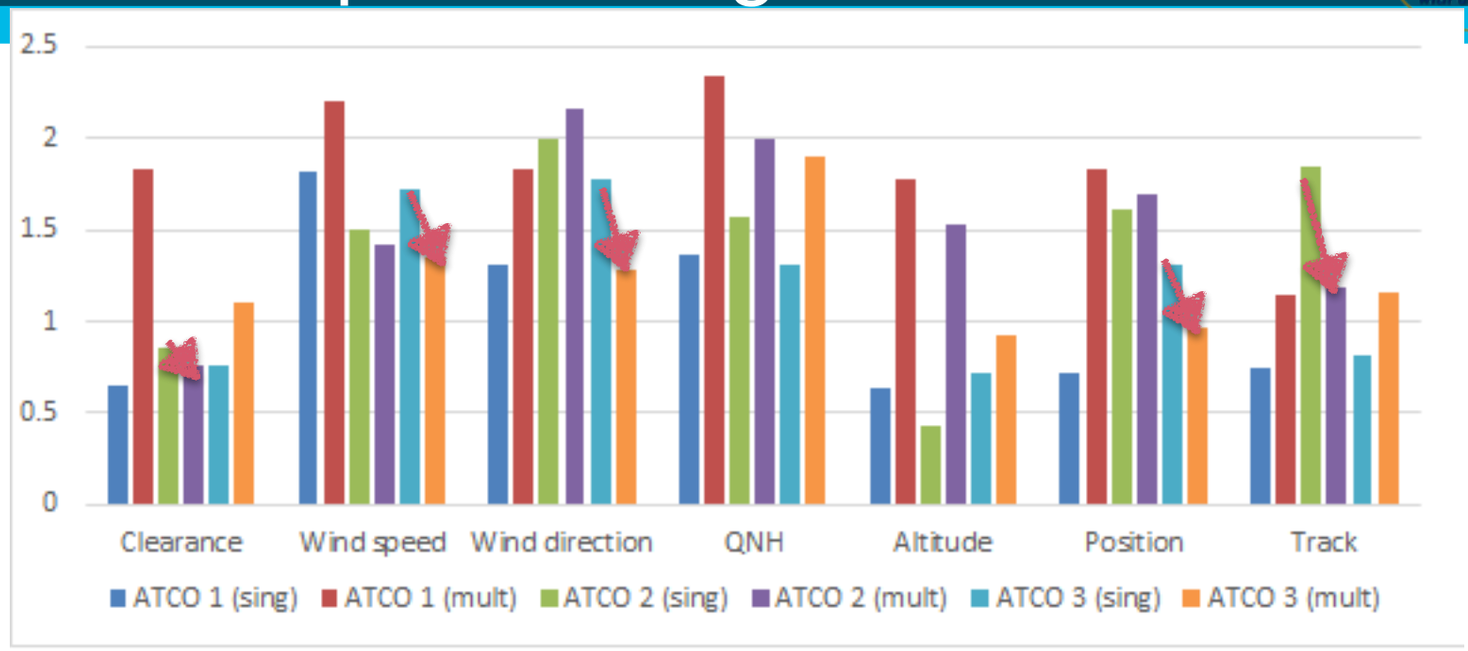

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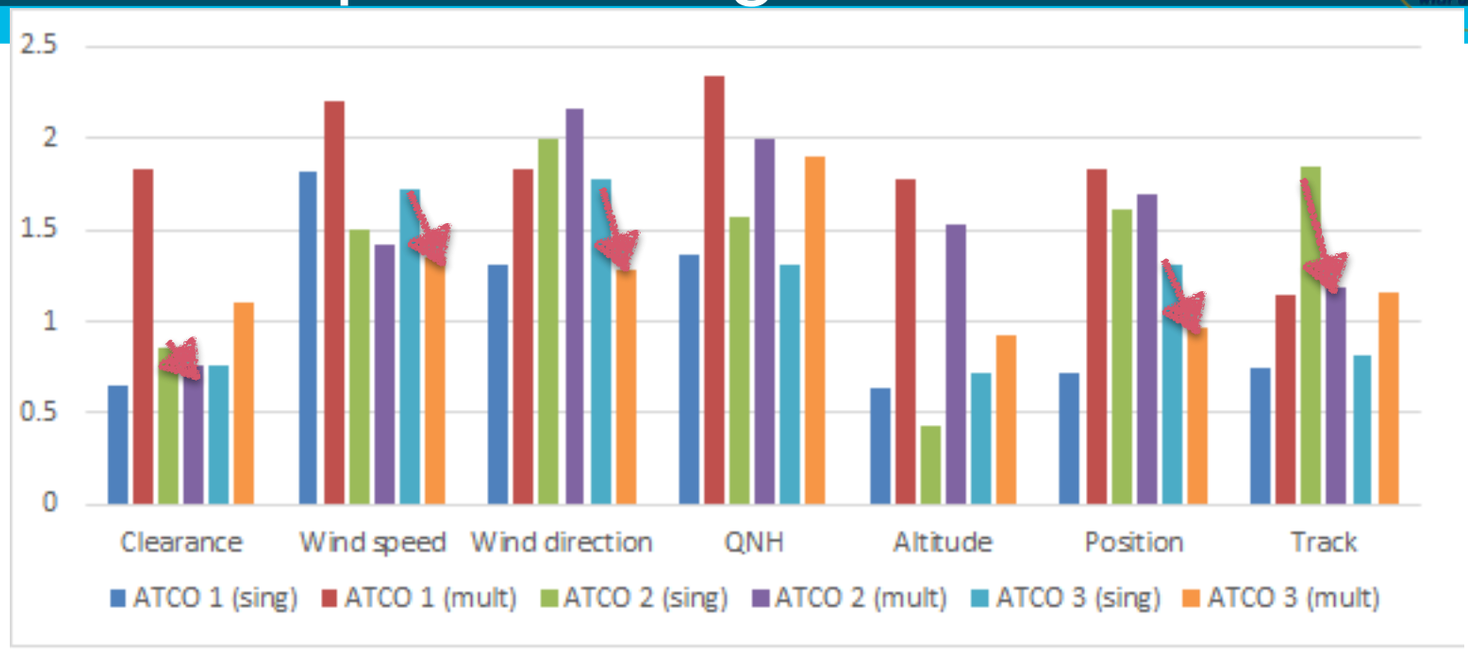

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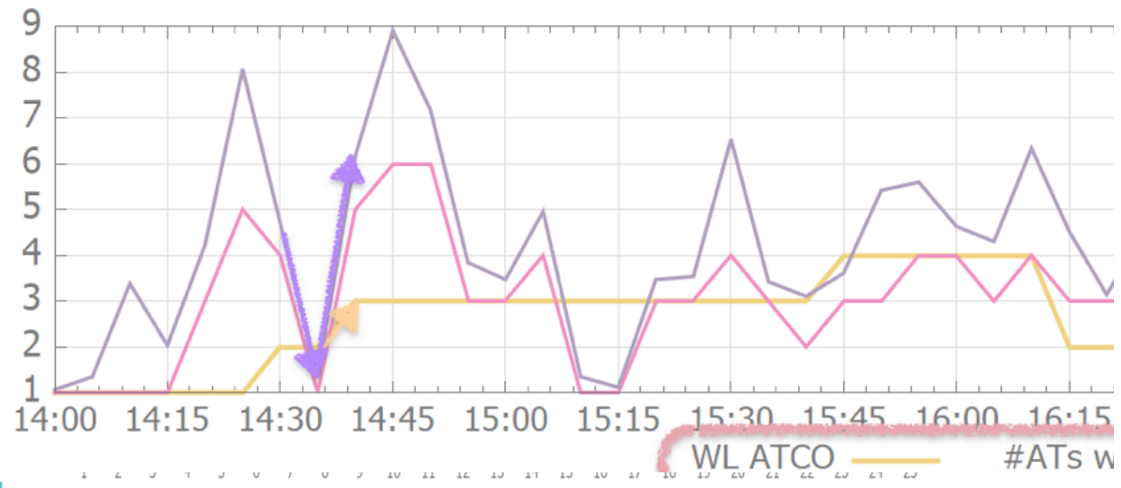
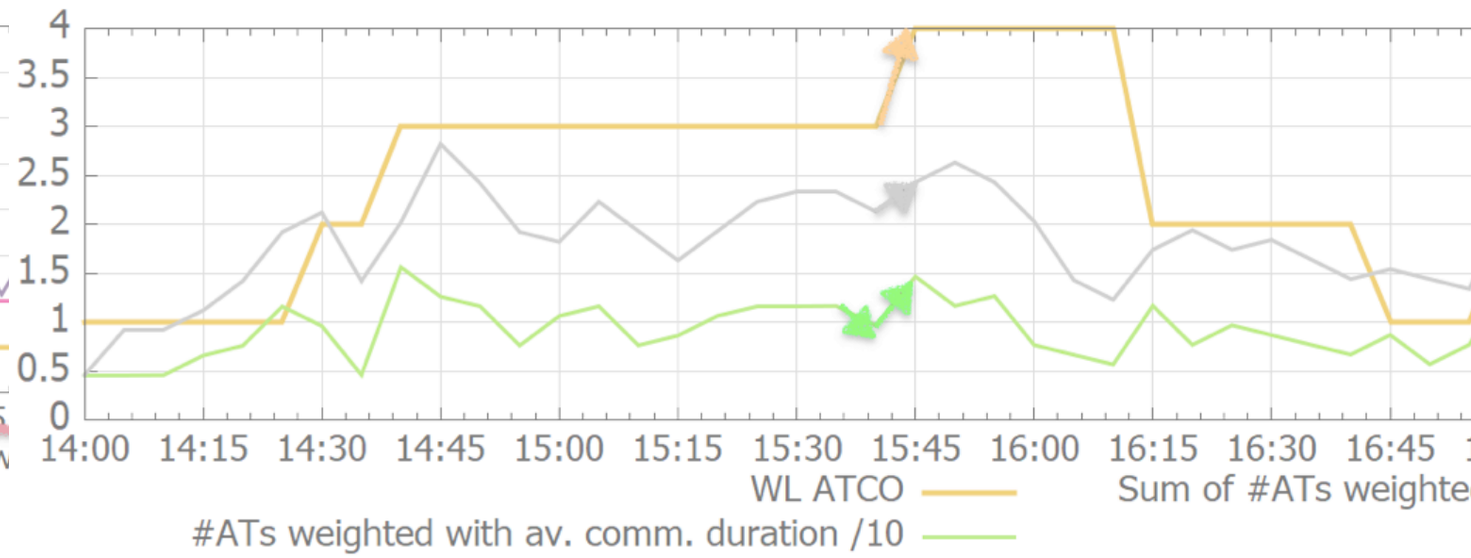
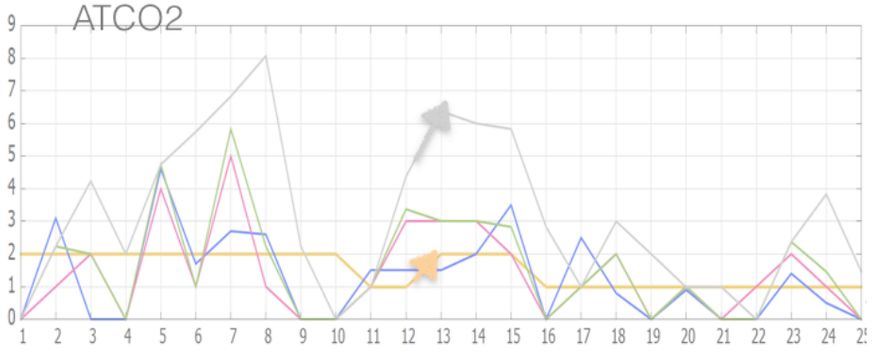
➡ Goal: Quantative empiric measurements with high power of predicting this physical measurement

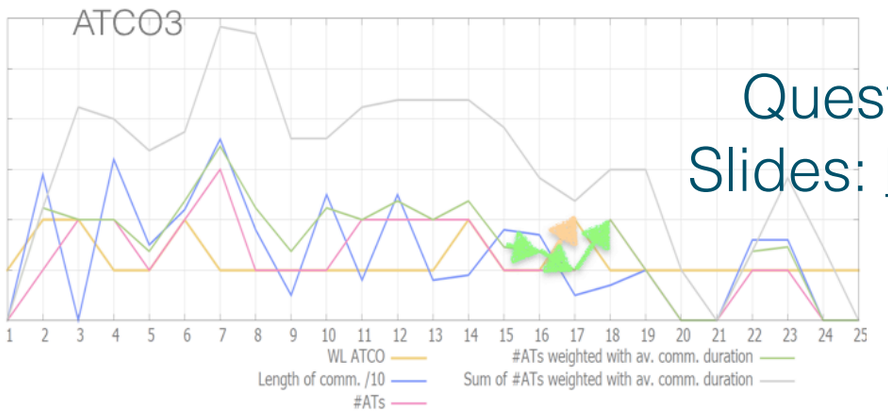
Each increase in the **ATCO workload rating** is accompanied by an increase in at least one of:

- **ATs weighted with the percentage of the total communication time**
- **Average-communication-duration weighted ATs in the previous, current or following time period**
- **Sum of the average-communication-duration weighted ATs for two consecutive time periods**
- **Duration of communication during that time interval**









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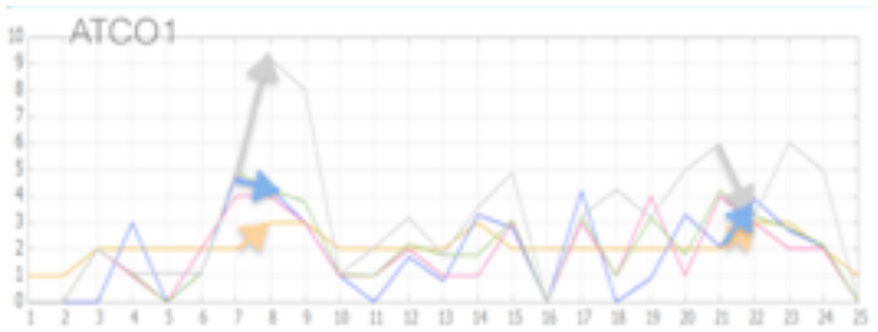

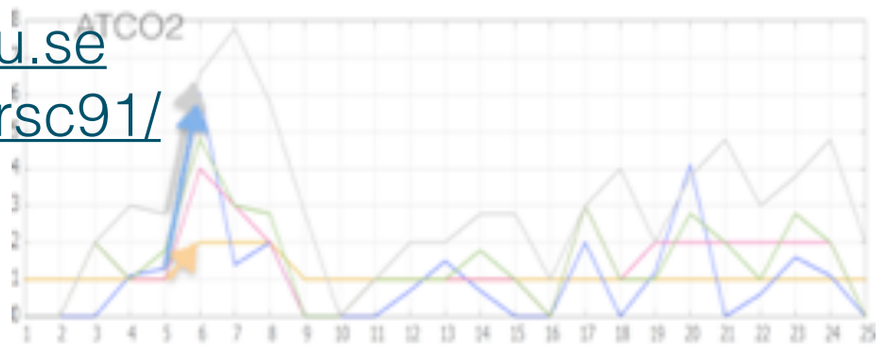

Questions? christiane.schmidt@liu.se
Slides: http://webstaff.itn.liu.se/~chrsc91/