EOP Prediction Improvements

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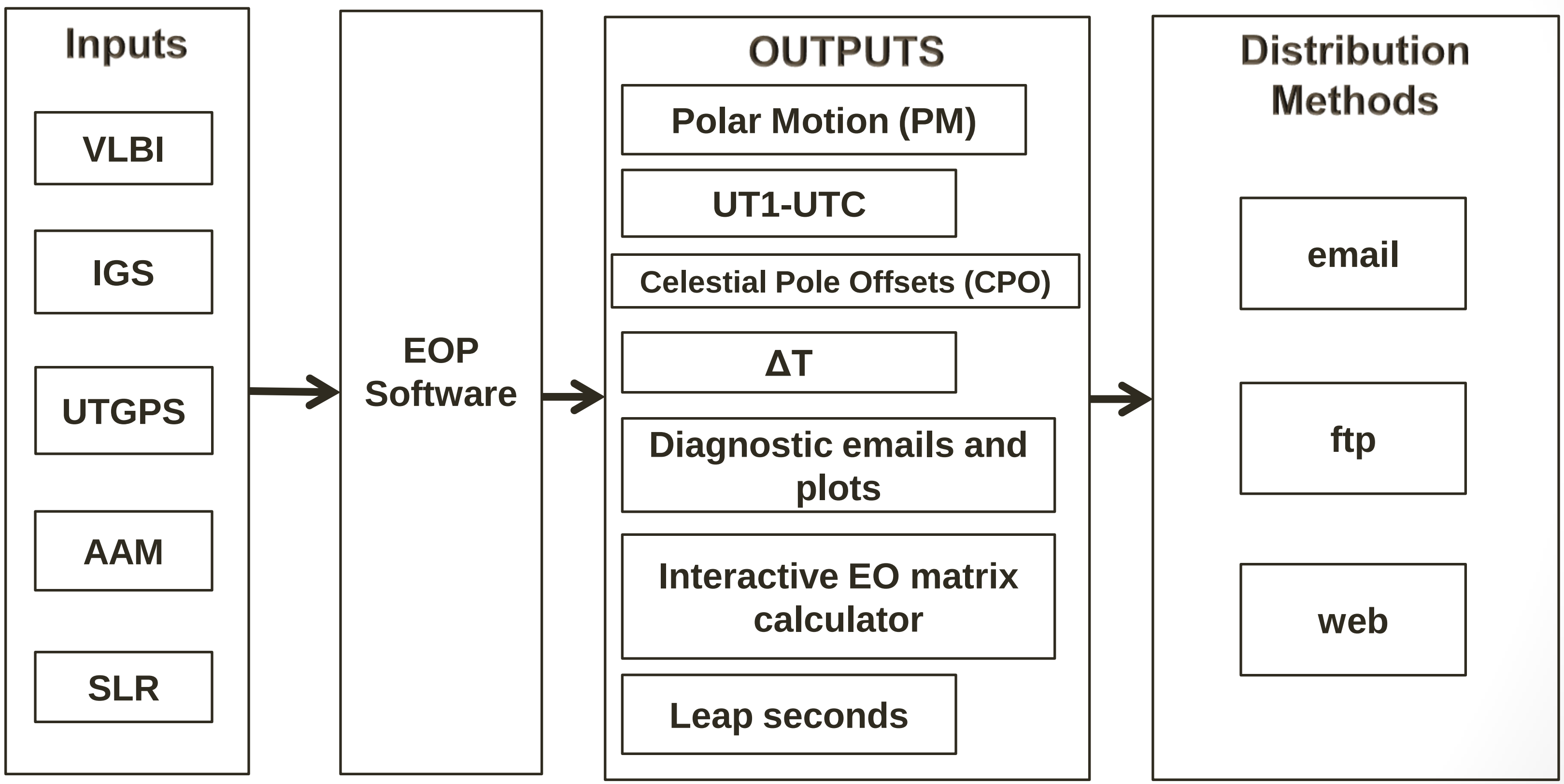
Outline

- Identify prediction needs and applications
- Identify appropriate outputs
- Improvement in input EOP data
- Improvement in processing
- Improved EOP modeling
- Improved geophysical analysis and forecasts

EOP Information Flow



From N. Stamatakos

Identify prediction needs and applications

- Long-term predictions (several months to years — how long is needed?)
  - Ephemerides (including almanacs)
  - Leap seconds
- Medium-term predictions (few weeks to several months)
- Short-term predictions (day to few weeks)
  - Pointing
  - Navigation
  - Real-time and predicted orbits
  - EOP determination
- Ultra-short-term predictions? (minutes/hours to day)
  - Pointing

Recommendation: Survey users regarding needs

Recommendation: Identify other ways to get feedback from users

Improved short-term predictions

- Not all EOPs are created equal
  - UT1−UTC is the largest error source
  - Polar motion is the second largest source
  - Celestial pole offset errors are small, but not negligible
- Reducing latency of EOP products decreases errors of the predictions for users
  - How short can the latency be?
    - Already measured in hours through quick turnaround data and 4 EOP solutions per day
    - Minutes?

Recommendation: Investigate real-time EOP combining and prediction

Recommendation: Investigate real-time EOP transfer protocol

Improved long-term predictions

- Long-term predictions may become more important depending on the status of the leap second
  - It is important to understand long-term prediction capability
- Ensemble predictions offer another way of improving long-term predictions
  - Better rms error
  - More robust

Recommendation: Investigate improved long-term predictions

Identify appropriate outputs

- Data files
  - Formats
    - Need to be machine-friendly
  - Metadata
    - Extensible Markup Language (XML)?
  - Authentication?
- EOP/UT1 transfer protocol?
  - Associated with ultra-short-term predictions
  - Simple Object Access Protocol (SOAP)?
  - Representational State Transfer (REST)?

Recommendation: Establish data file formats to meet modern needs

Improvement in input EOP data

- Reduced latency
- Improved accuracy

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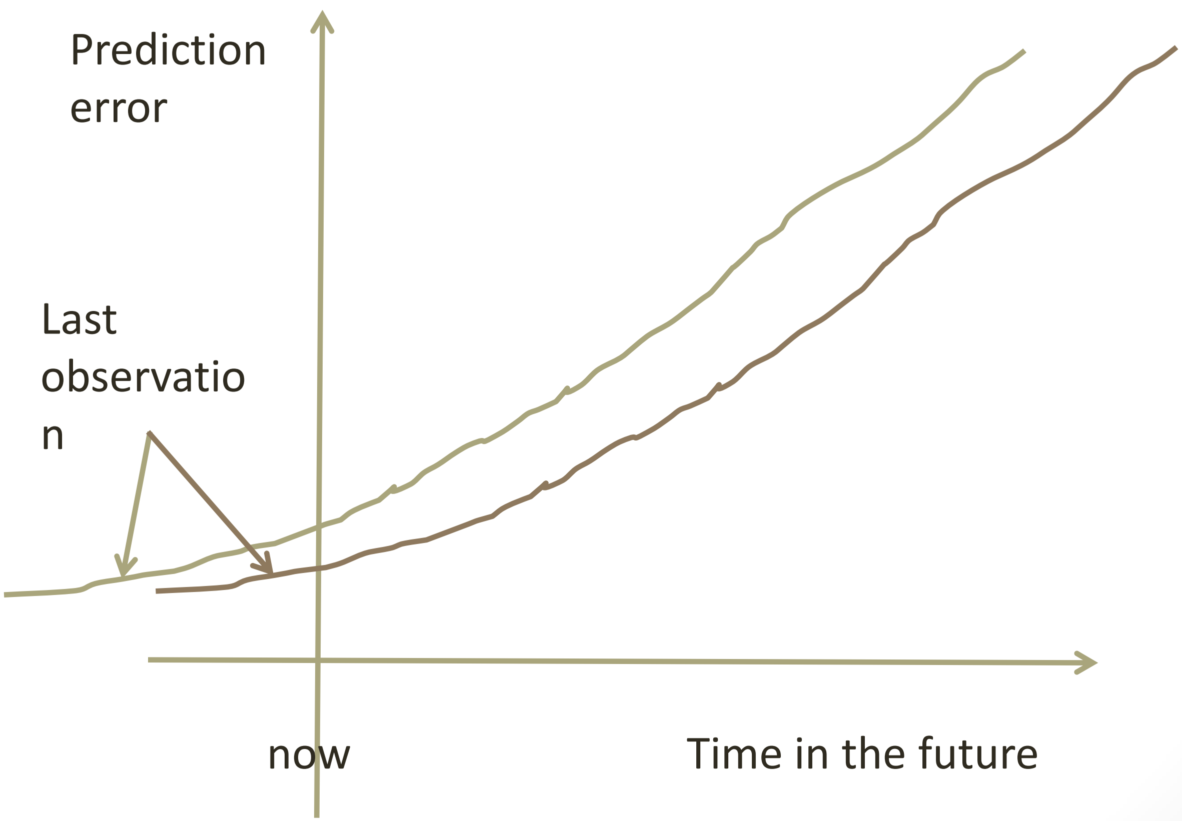

Improvement in input EOP data

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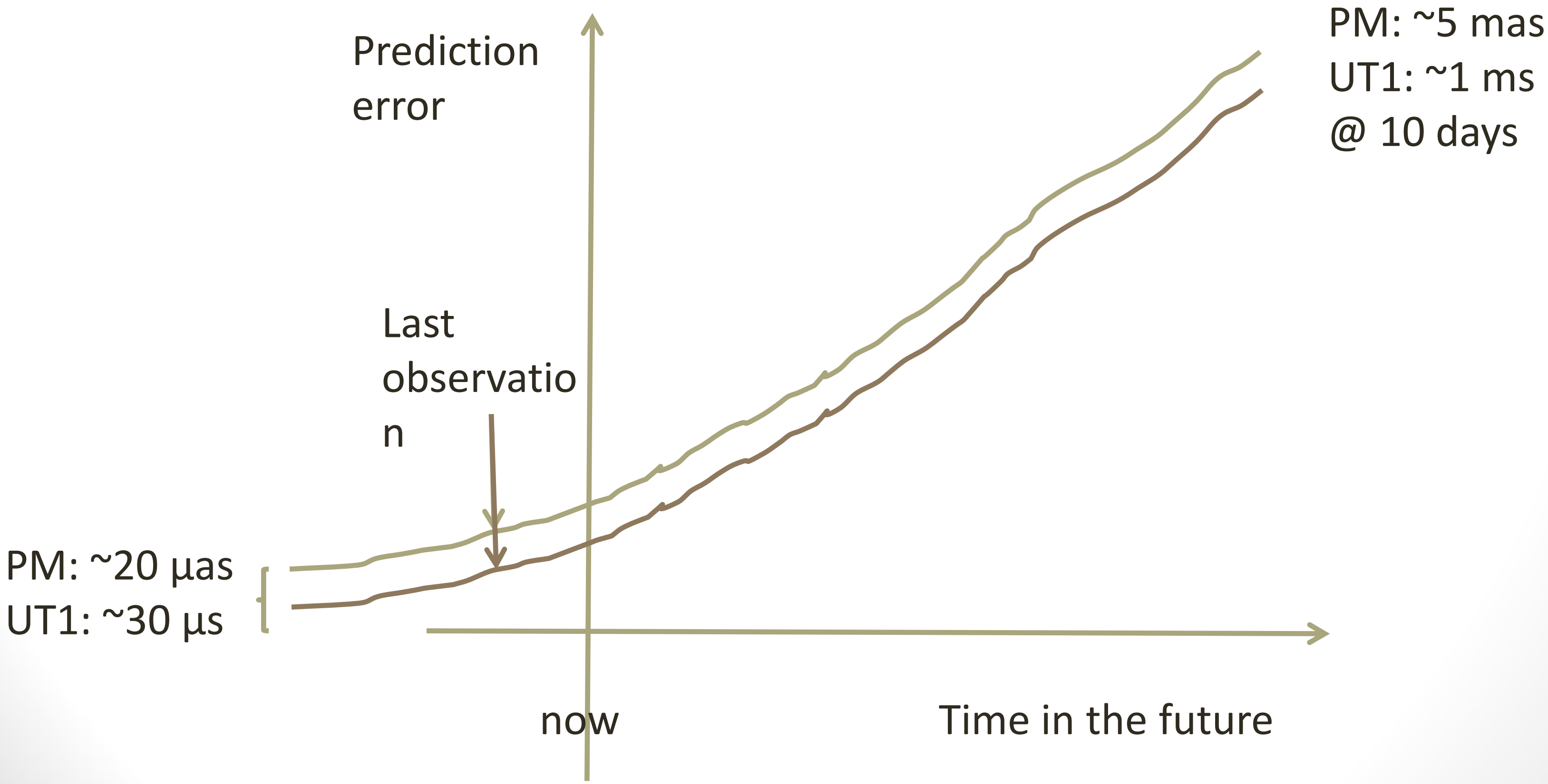
- Improved accuracy



Improvement in processing

- Better error detection/elimination
- Better algorithms

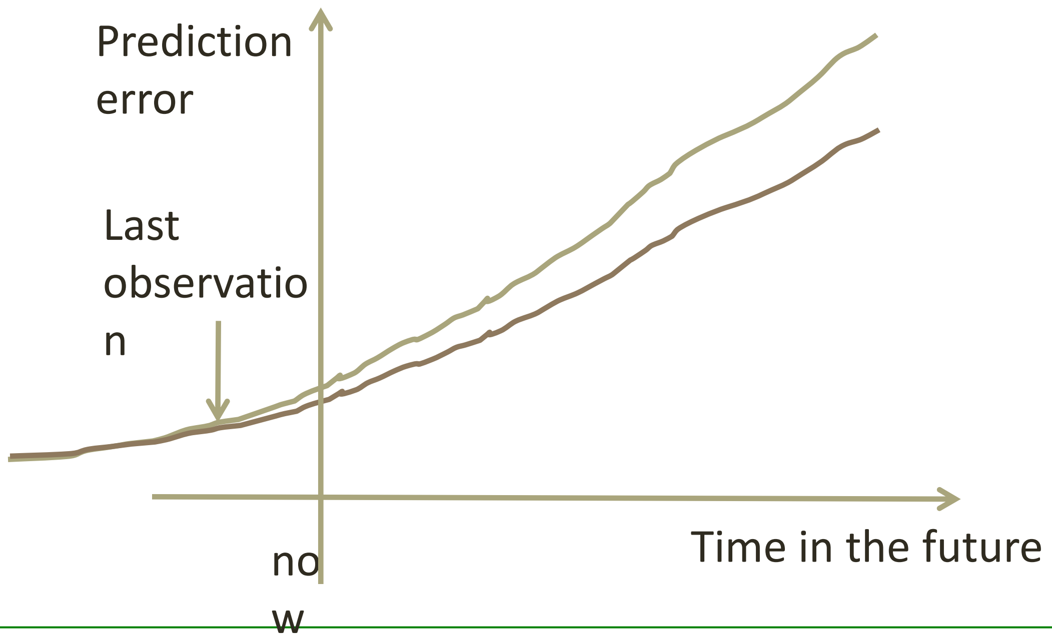
Improvement in processing

- Better error detection/elimination
  - Ingesting problematic data for near-real-time, automated processes tends to lead to problems
  - Works best if implemented throughout the data chain
  - Goal: processes that are more robust, more resilient
- Better algorithms

Recommendation: Implement better automated error detection and notification

Improvement in processing

- Better error detection/elimination
- Better algorithms
  - Research continues into improved prediction algorithms



Recommendation: Adopt ensemble predictions operationally

Improved EOP modeling

- Diurnal/semidiurnal effects
  - Amplitude = 0.5 mas
- Long-period tesseral tidal effect on polar motion
  - Amplitude = 0.2 mas
- Long-period zonal tide effect on LOD/UT1

Improved geophysical analysis and forecasts

- General needs
  - Internal errors provided by models
  - External errors provided by comparisons between analysis and forecasts
  - External errors provided by comparisons between centers
  - Provided by service?
  - More frequent updates
    - Currently updated once per day

Recommendation: Request formal errors on data from AAM sources

Recommendation: Investigate operational AAM inter-comparisons

Recommendation: Request more frequent AAM updates

Improved geophysical analysis and forecasts

- Available AAM forecasts and results
  - NCEP, NAVGEM, ECMWF, JMA, UKMO
- Available OAM forecasts and results
  - Operational OAM forecasts not available in real-time
  - Prediction by French model NEMO:project of N. Ferry, MERCATOR OCEAN)
  - Will it reach the required precision?

- HAM?
  - In light of current model, hydrological effects on EOP are not significant at weekly scales (the effect of HAM is at seasonal and multi-year scales)
- Consistent AAM+OAM+HAM

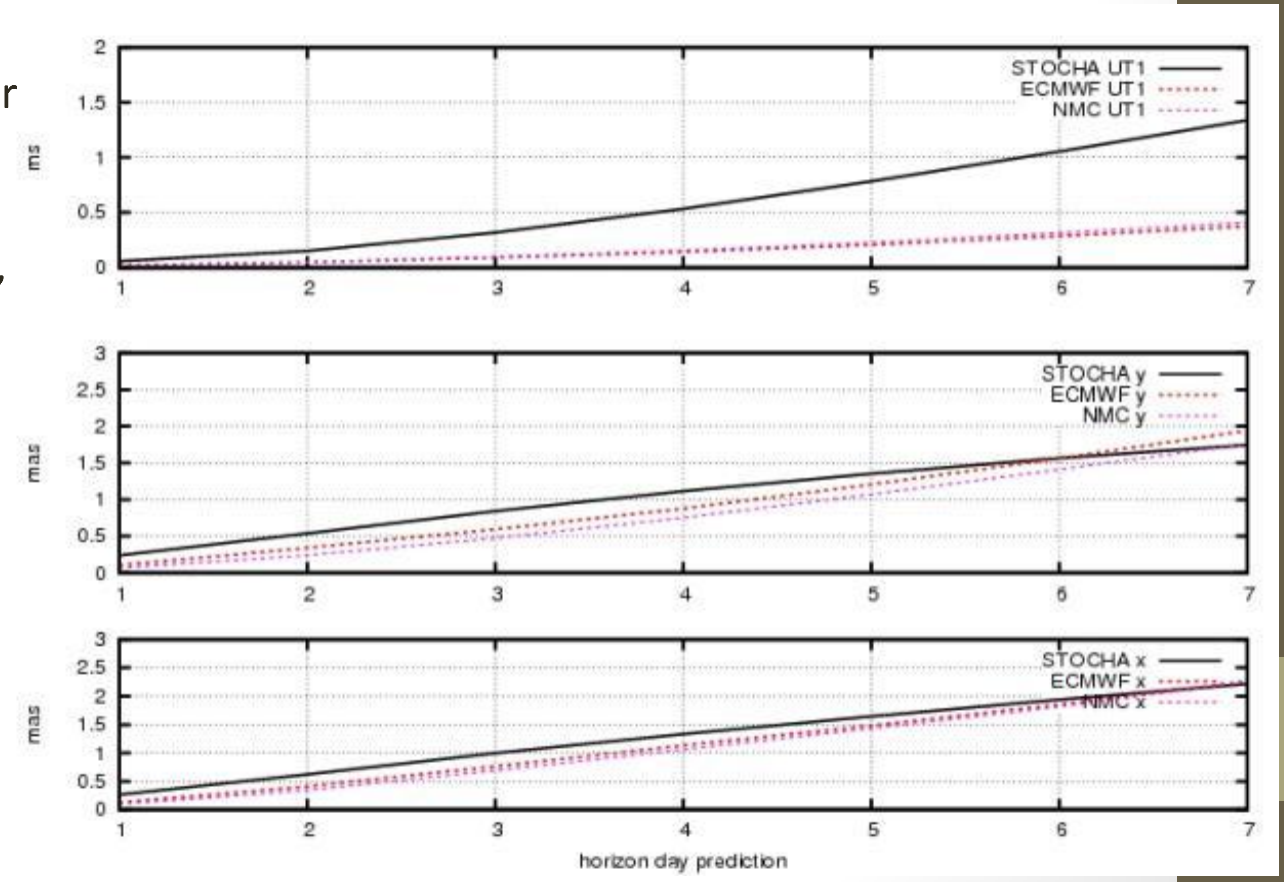
Recommendation: Request availability of real-time OAM analysis and forecasts

Non operational weekly predictions based on AAM forecast s

Statistics over the period January 2013 -May 2013 and comparison with stochastic prediction

Weekly EOP prediction based upon integration of AAM forecast is better than a pure stochastic extrapolation (see also table of slide 21 for x/y), especially for UT1.

Consideration of OAM forecast should improve the present skill for x and y by a factor 2.



Recommendations

- Survey users regarding needs
- Identify other ways to get feedback from users
- Investigate real-time EOP combining and prediction
- Investigate real-time EOP transfer protocol
- Investigate improved long-term predictions
- Establish data file formats to meet modern needs
- Implement better automated error detection and notification
- Adopt ensemble predictions operationally
- Request formal errors on data from AAM sources
- Investigate operational AAM inter-comparisons
- Request more frequent AAM updates
- Request availability of real-time OAM analysis and forecasts

Backups

Current Data Latency/Accuracy

Input	Latency	Refresh rate	PM Accuracy	UT1/LOD Accuracy
AAM	~18-42 hours	1/day		~60 μs/day
GPS (Ultras)	~15 hours	4/day	~20 μas	~15 μs/day
SLR	48-72 hours	1/day	~200 μas	
VLBI Intensives	~8-32 hours	1-2/day		~20 μs
VLBI 24-hour	10-17 days	2/week	~200 μas	~5 μs

Future Data Latency/Accuracy?

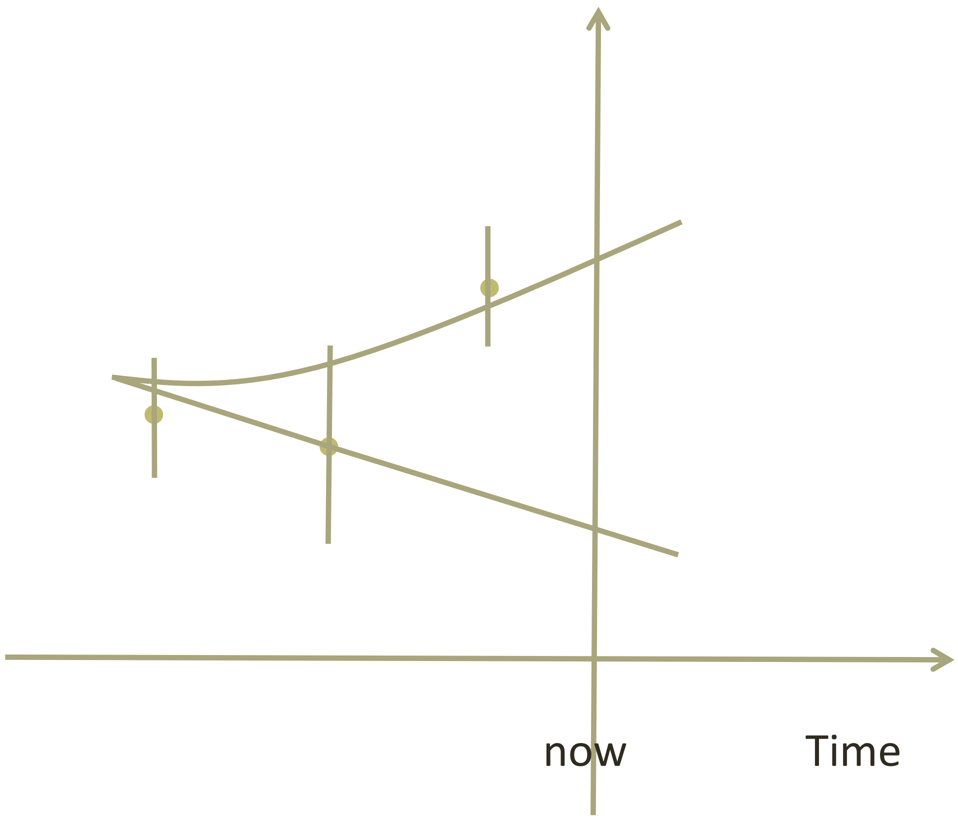
Input	Latency	Refresh rate	PM Accuracy	UT1/LOD Accuracy
AAM	<15 hours	4/day		<50 µs/d
OAM	<24 hours	1/day	<200 µas/d	
DORIS	<24 hours	1/day	~100 µas	
GPS (Ultras)	~15 hours	4/day	~20 µas	~10 µs/day
LLR	<1 hour	1-6/day§		~50 µs
Ring Laser	~1 hour	several/day	<200 µas/d	<50 µs/d
SLR	24 hours	2/day	~100 µas	
VLBI Intensives	<2 hours	2+/day		~10 µs
VLBI 24-hour	2 days	1/day	~100 µas	~5 µs

§ will likely have a phase of moon dependence

Why ensembles work

	PMy 1–day predictions		PMy 90-day predictions	
Contributor	Mean (mas)	St. Dev. (mas)	Mean (mas)	St. Dev. (mas)
JPL	0.055	0.409		
Paris Obs.	0.033	0.325	7.640	21.447
Pulkovo	0.027	0.280	-9.523	28.586
Shanghai	-0.073	0.957	-10.336	33.647
Siberian	0.053	0.268	-3.511	16.929
SRC (WK)	0.184	0.559	-1.874	21.666
SRC (MK)	0.014	0.252	-20.309	13.495
Sternberg	-0.098	0.534	-5.616	16.994
Sternberg/SAO	-0.092	0.837	-17.708	25.313
USNO	0.033	0.273	-1.694	21.238
Ensemble	-0.011	0.504	-9.104	10.871

Uncertainty in the last point



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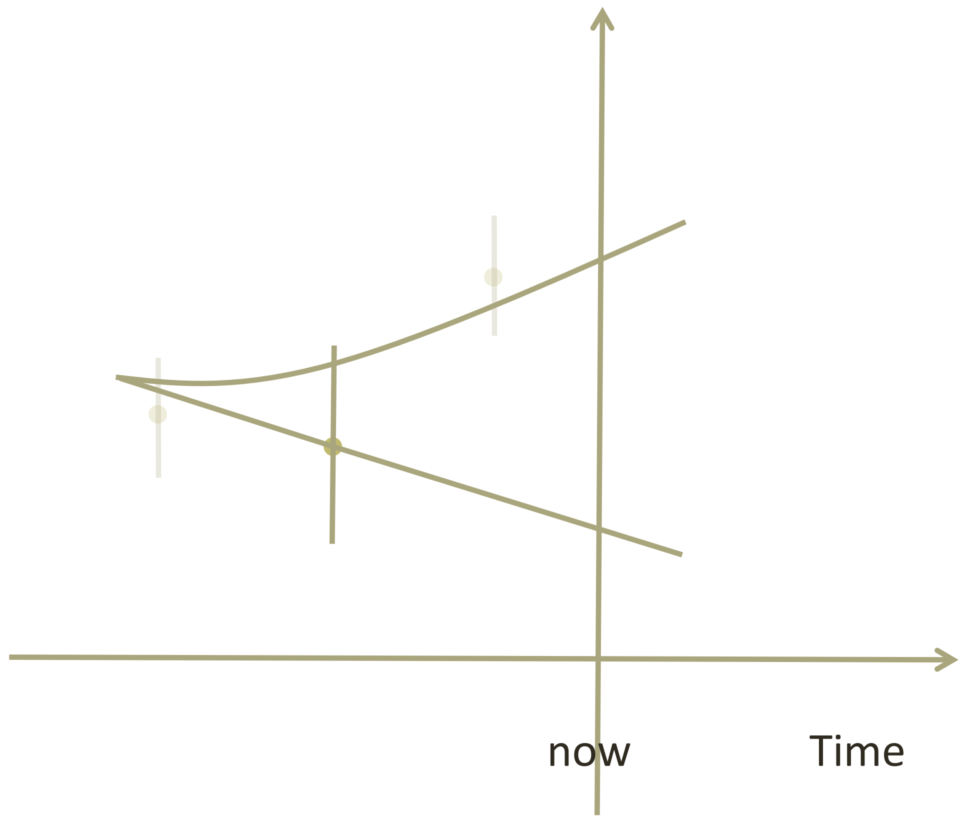
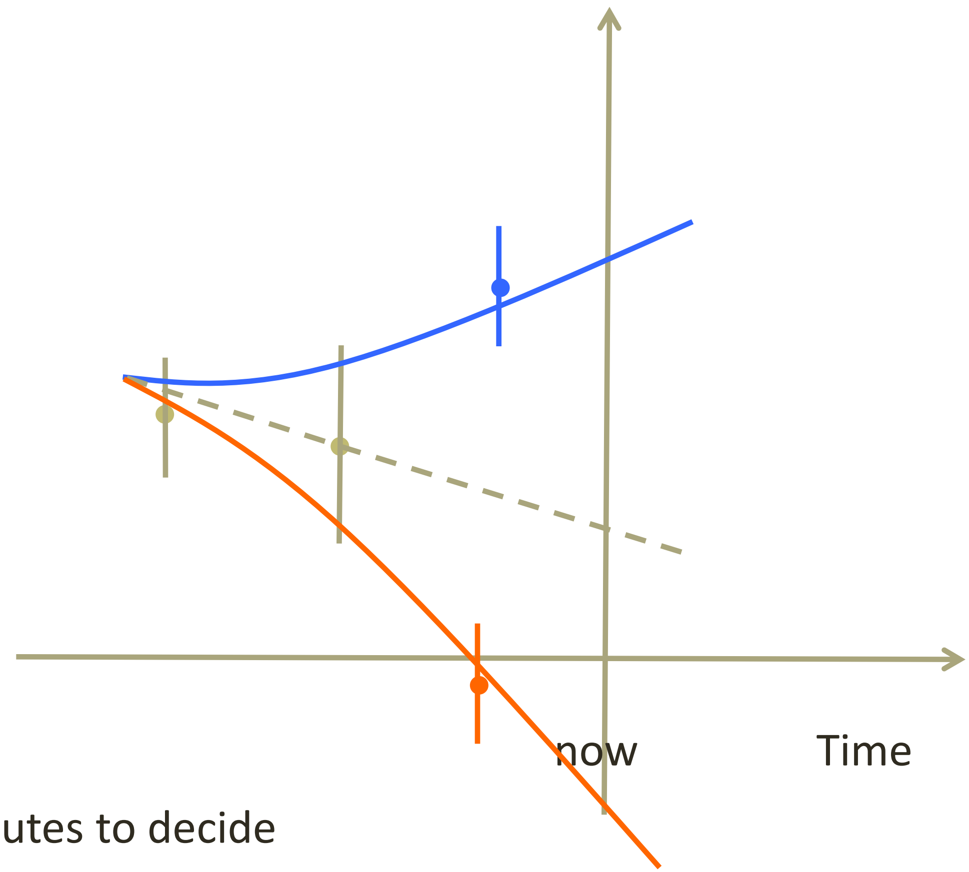


Nightmare scenario



Think fast: < 30 minutes to decide

Input Data Latency/Accuracy

Input	Latency	PM Accuracy	UT1/LOD Accuracy
GPS (Ultras)	~15 hours	~20 μas	
SLR	48 hours	~200 μas	
VLBI Intensives	~8 hours		~20 μs
VLBI 24-hour	10 days	~200 μas	~5 μs

A few references 2010-2013

AAM/OAM/HAM forecasts:

- Dill R., Dobslaw H., Thomas M. (2013): Combination of modeled short-term angular momentum function forecasts from atmosphere, ocean, and hydrology with 90-day EOP predictions. *J. Geodesy*.
- Dill R., Dobslaw H. (2010): Short-term Polar Motion Forecasts from Earth System Modeling Data. *J. Geodesy* 84, 9

Stochastic prediction:

- Kosek W. (2012): **Future Improvements in EOP Prediction,** IAG Symposium 136
- Kalarus et al. (2010): Achievments of the earth orientation parameters prediction comparison campaign. *J. Geodesy* 84
- Z. Malkin (2010): **Employing Combination Procedures to Short-Time Eop Prediction,** Artificial Satellites. 45 Issue 2