

Sensitivity of flight durations to uncertainties in numerical weather predictions

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The IMET Project (SESAR WP-E)



Investigation of the Optimal Approach for Future Trajectory Prediction Systems to Use **MET**eorological Uncertainty Information

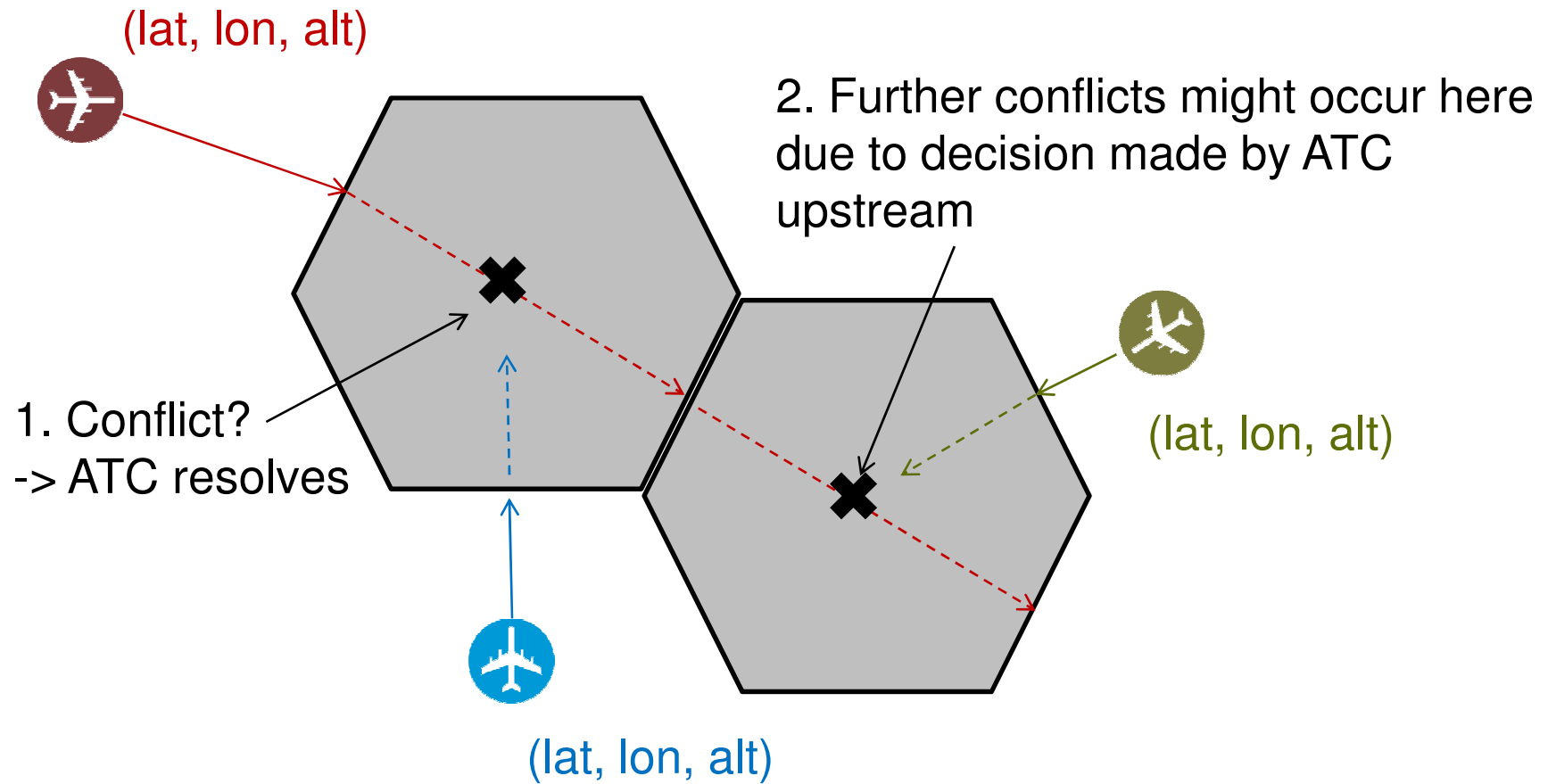
Aim - To design and demonstrate the benefits of a probabilistic/ensemble trajectory prediction system



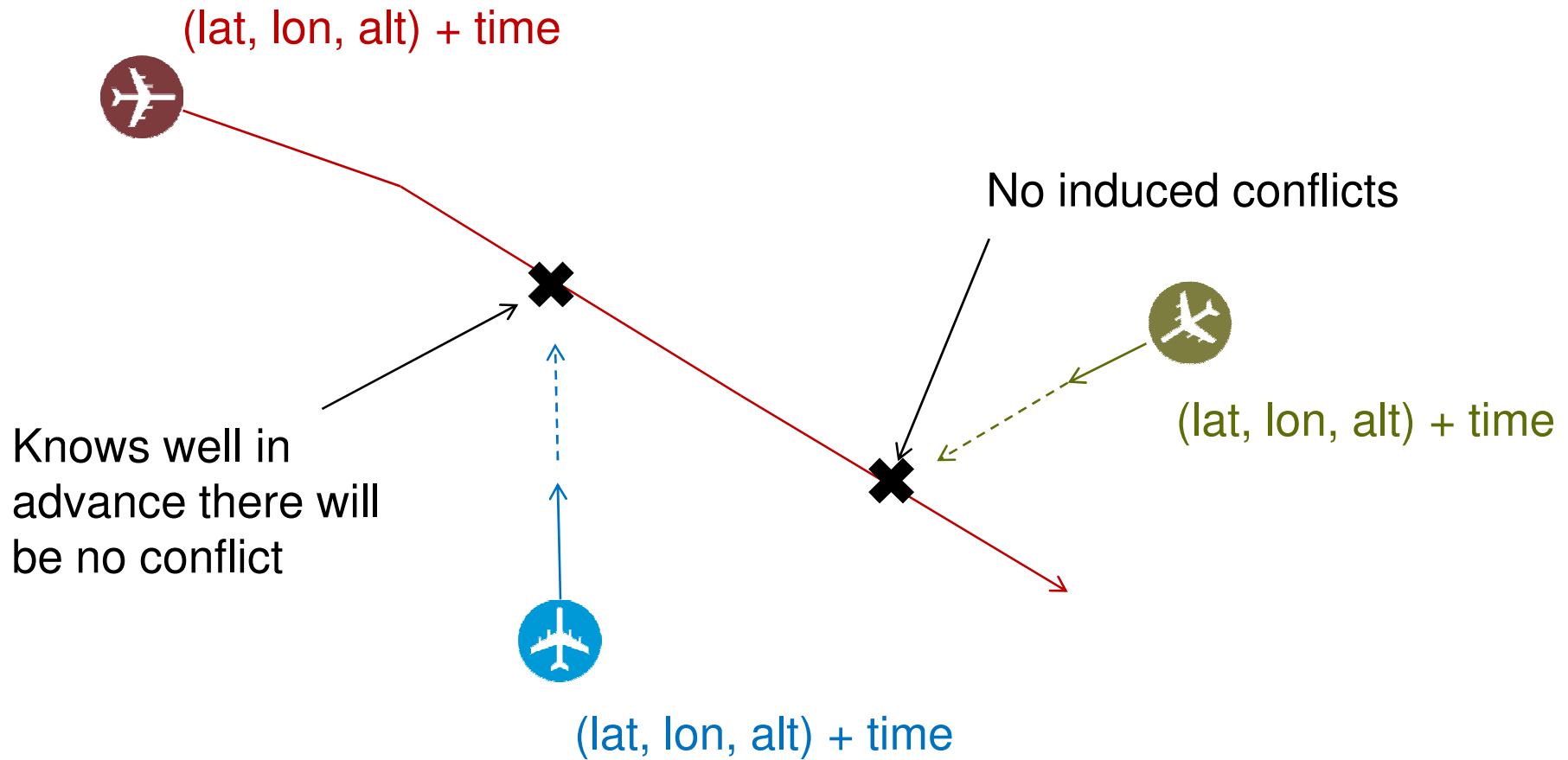
Table of Contents

- Overview of 3D/4D trajectory flight planning
- Current: deterministic trajectory prediction
- What is an ensemble meteorological (MET) forecast?
- Future: ensemble trajectory prediction
- Experimental methods
- Results
- Summary

Flight planning: 3D trajectory



Flight planning: 4D trajectory



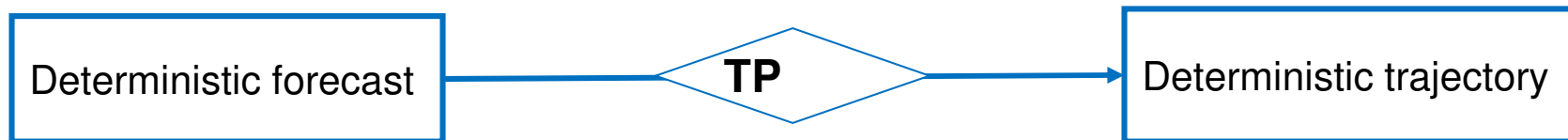


Notes on 4D trajectory requirements

- Predict the location and time in advance (subject to some error)
- Knowing the error of prediction is highly beneficial
- Major source of uncertainty is predictability of weather

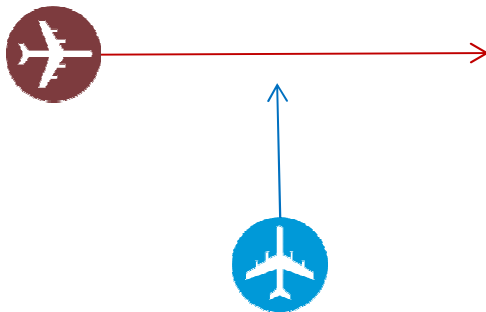
Why is existing TP not good for 4D trajectory planning

Problem with current trajectory prediction

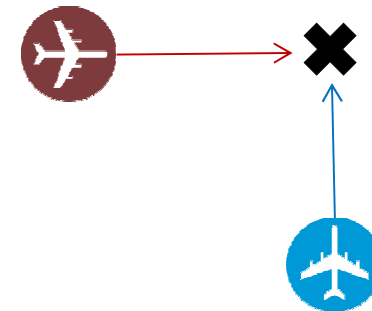


- Flight planning based on single set of wind and temperature forecast
- Bad forecasts could lead to e.g. re-routing, increase fuel costs and pressure on ATC

TP with no estimation of likelihood (deterministic)



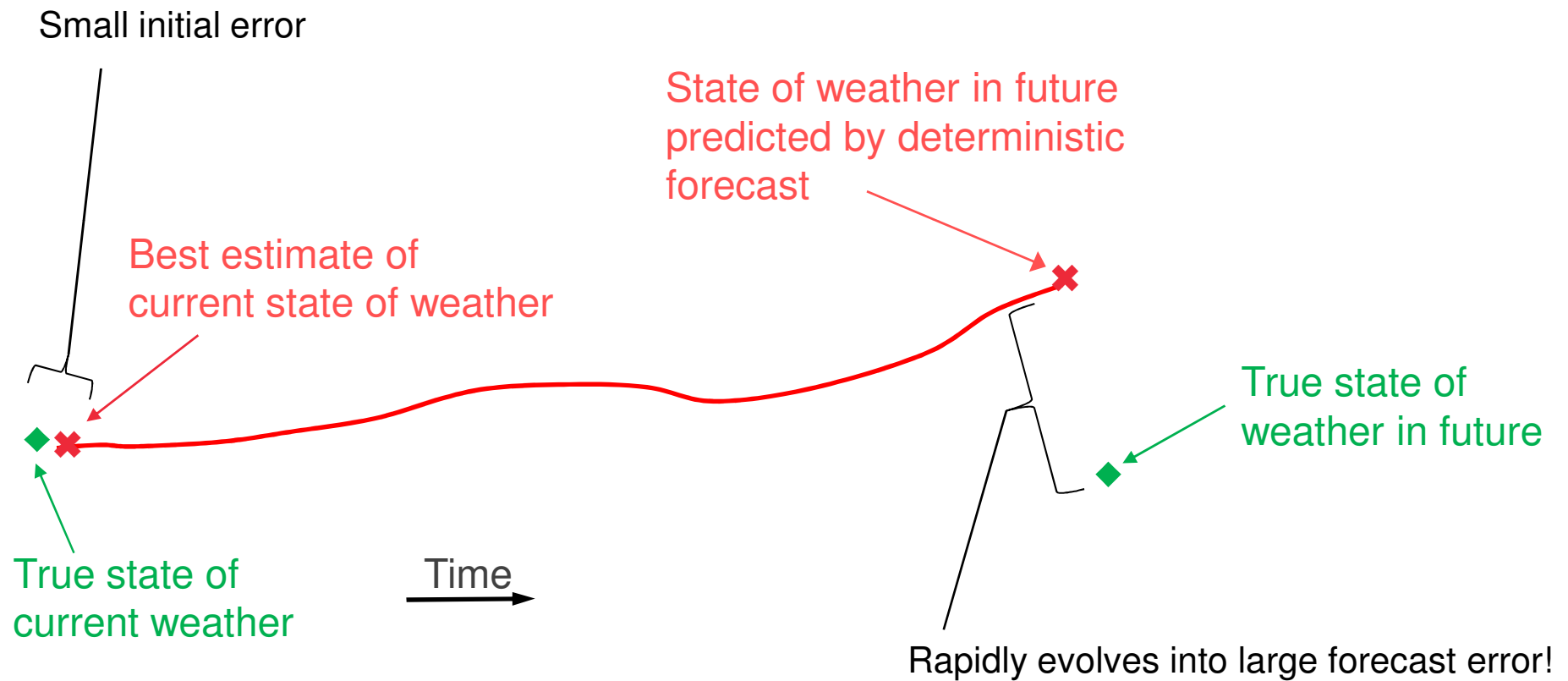
Reality



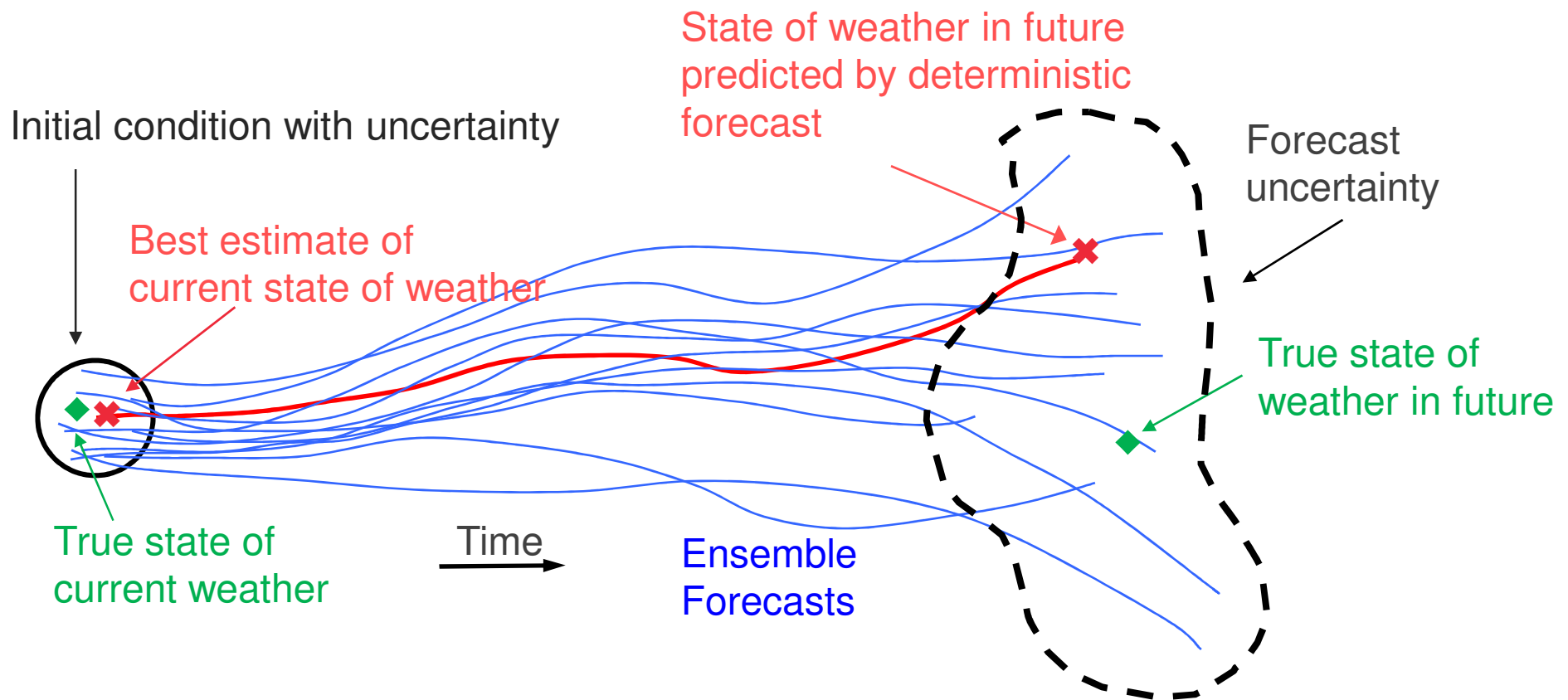
Error in wind/temp forecast

- > Error in flight time prediction
- > ATC still has to step in and resolve

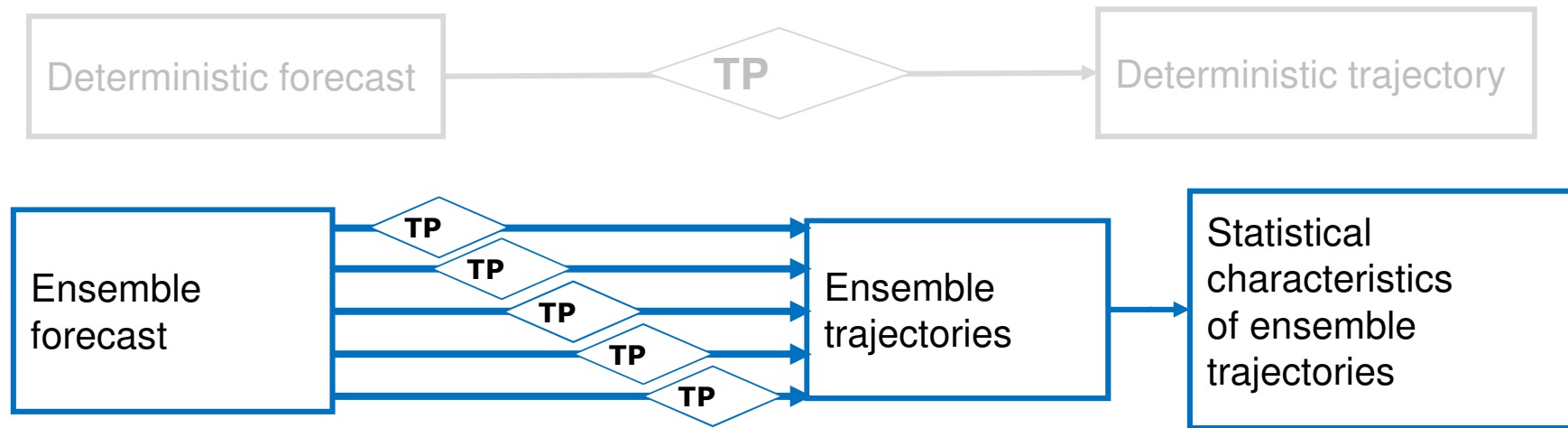
Weather as a chaotic system



Estimating MET uncertainty: Ensemble MET Forecast



Ensemble TP



Advantages

- Provides an estimate of uncertainty in flight time, path taken, etc
- Ensemble forecast models are physical models designed to capture MET uncertainty -> favourable compared to a pure stochastic approach
- Can use existing TP to generate the ensemble trajectories



Experimental methods



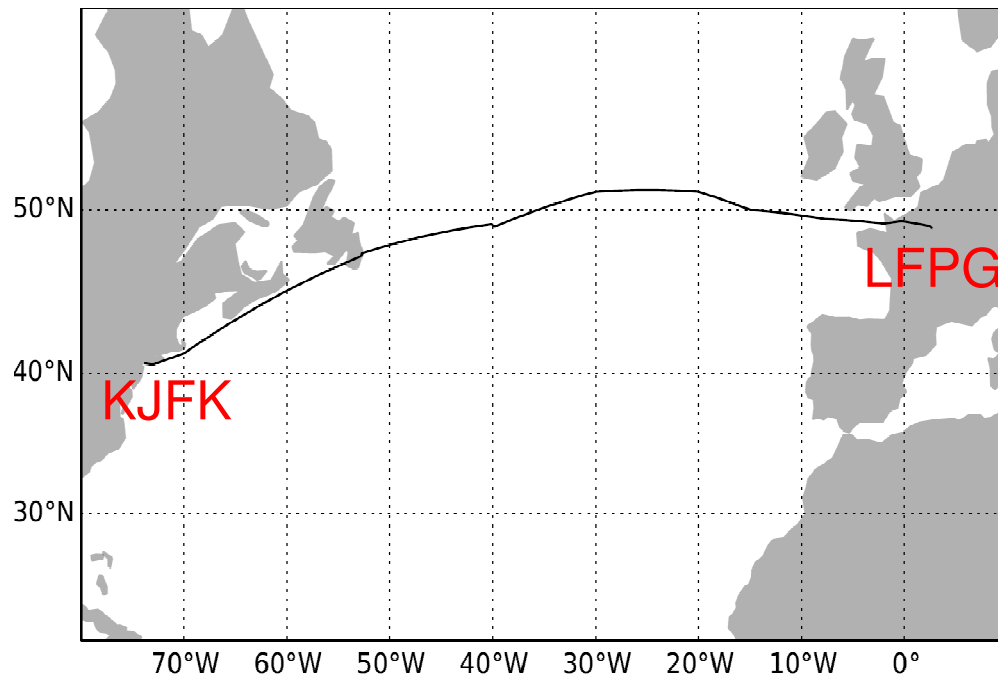
Ensemble Numerical Weather Prediction Model

The Met Office Global and Regional Ensemble Prediction System (MOGREPS)

- Horizontal resolution: ~33km
- Run at 00, 06, 12, 18Z daily
- 12 ensemble members
- Designed to represent MET uncertainty up to 2 days ahead, coinciding with the timescale of flight planning



Experimental Method

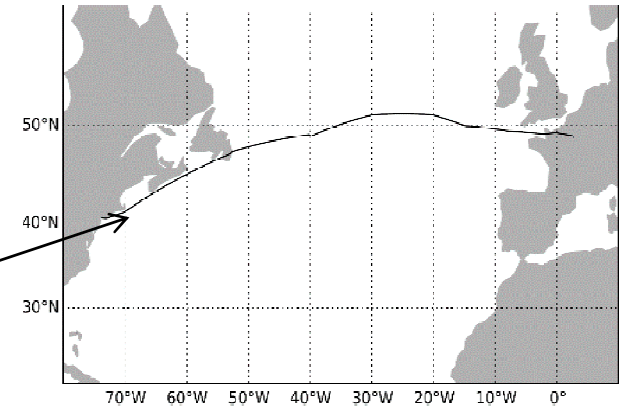


- Fixed eastbound route from KJFK to LFPG
- Fixed Mach: 0.82
- Fixed level: FL340 (~250hPa)
- Test period: 1st May 2013 to 30th April 2014
- Simple speed formulae using wind and temperature
- MET data interpolated on to the route to calculate the flight time for each ensemble member

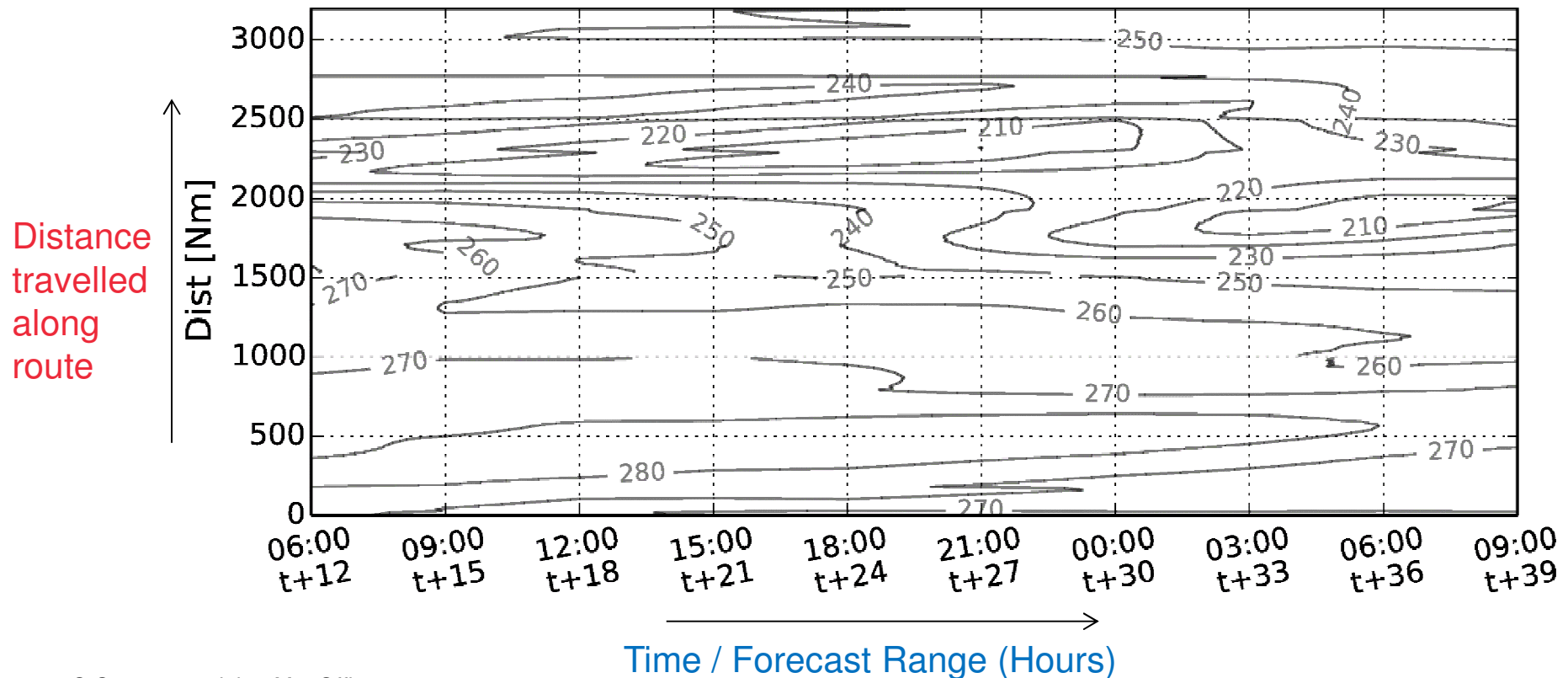


Results

Time series of ensemble mean ground speed along route



N400 Forecast 2013-09-22 18Z



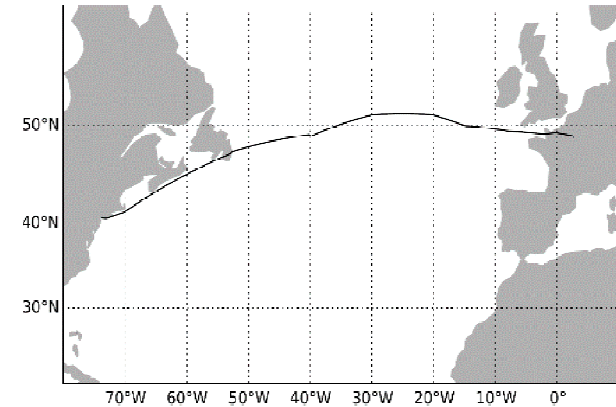


Understanding the x-axis

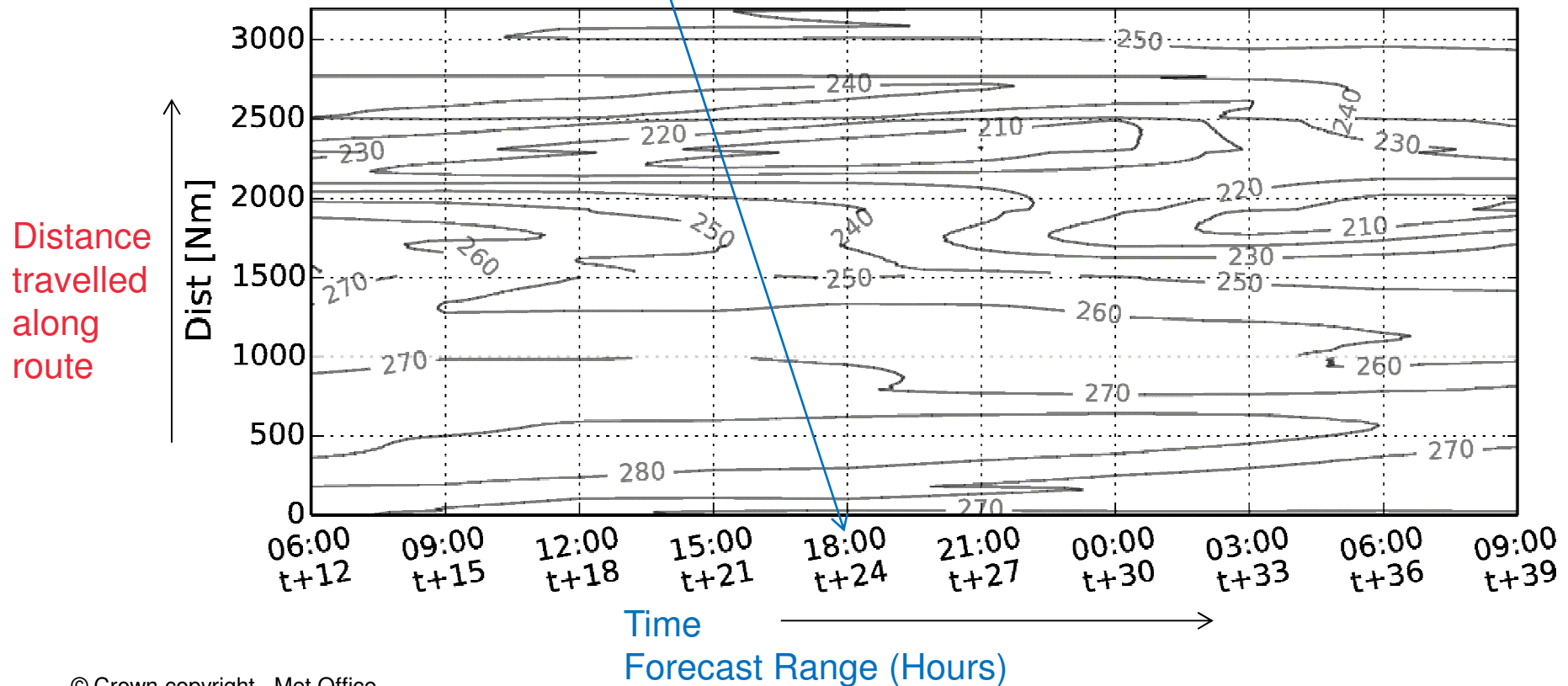
Time : UTC time

Forecast range: how far ahead you are looking into the future

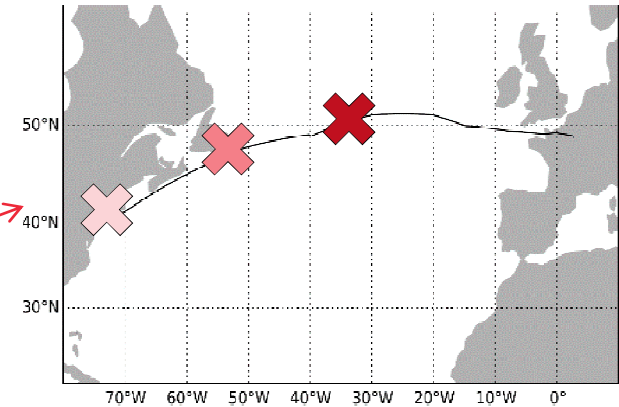
For a forecast issued at 18UTC, a forecast range of t+24 will be referring to 18UTC the next day



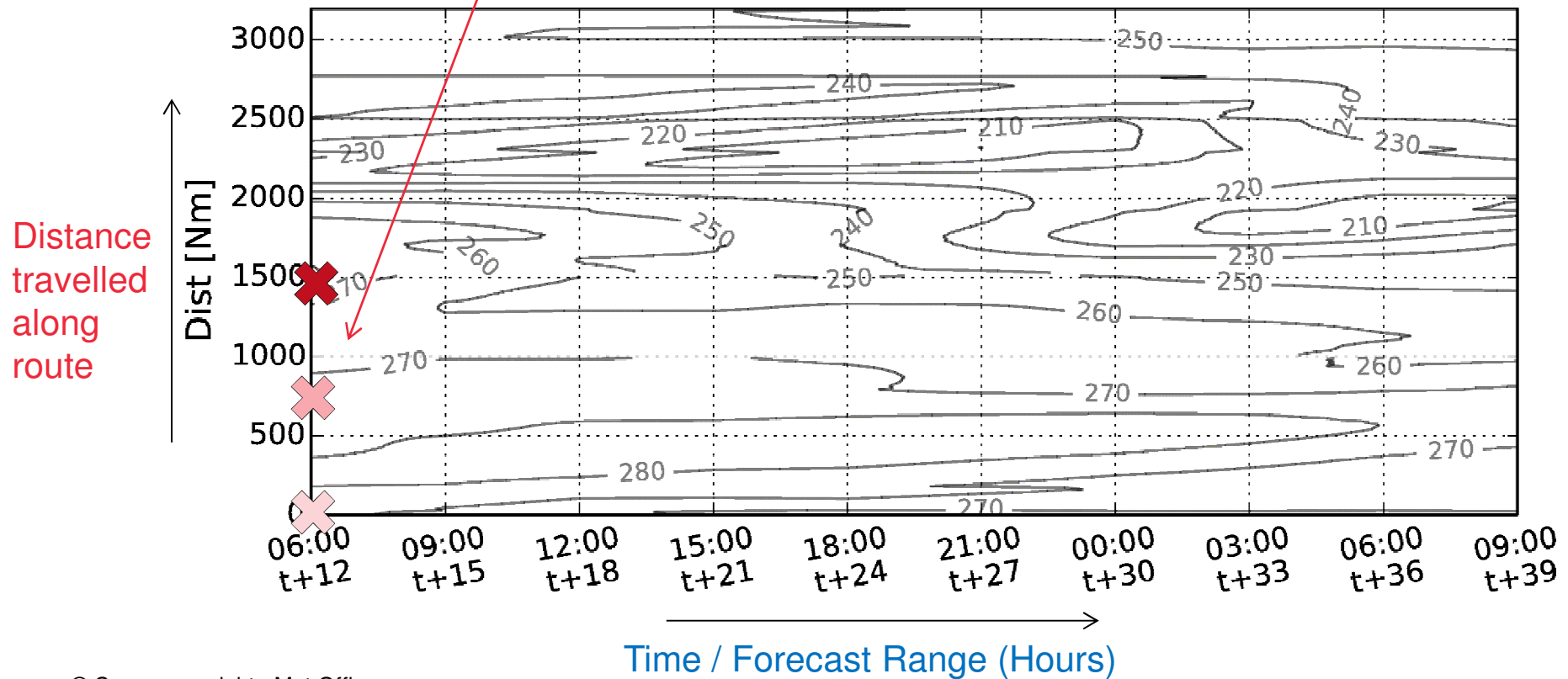
N400 Forecast 2013-09-22 18Z



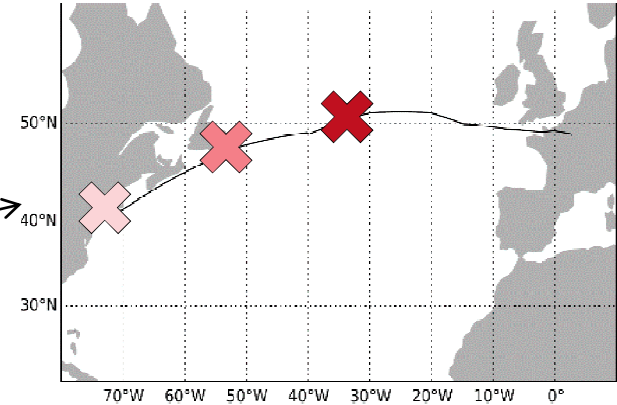
Understanding the y-axis
Freeze time, travel along trajectory



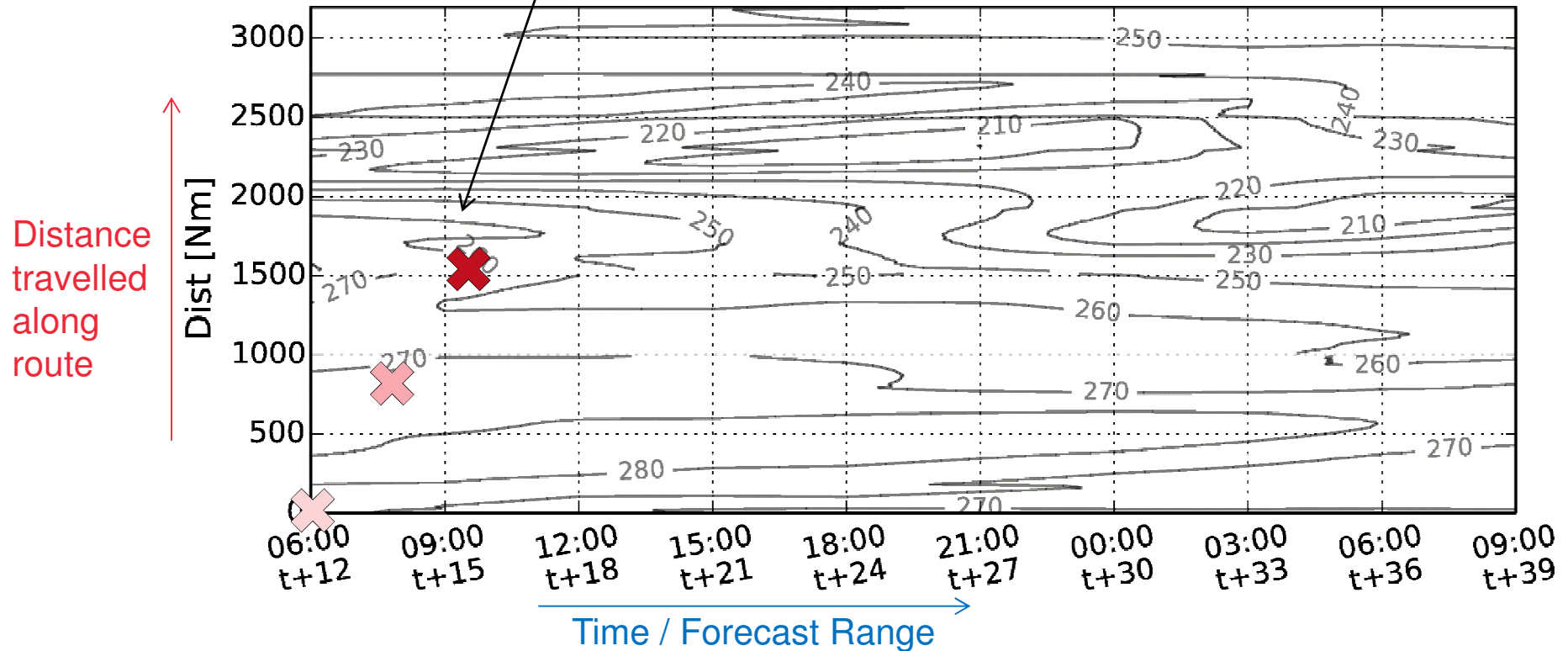
N400 Forecast 2013-09-22 18Z



In reality, time evolves as you travel along trajectory



N400 Forecast 2013-09-22 18Z

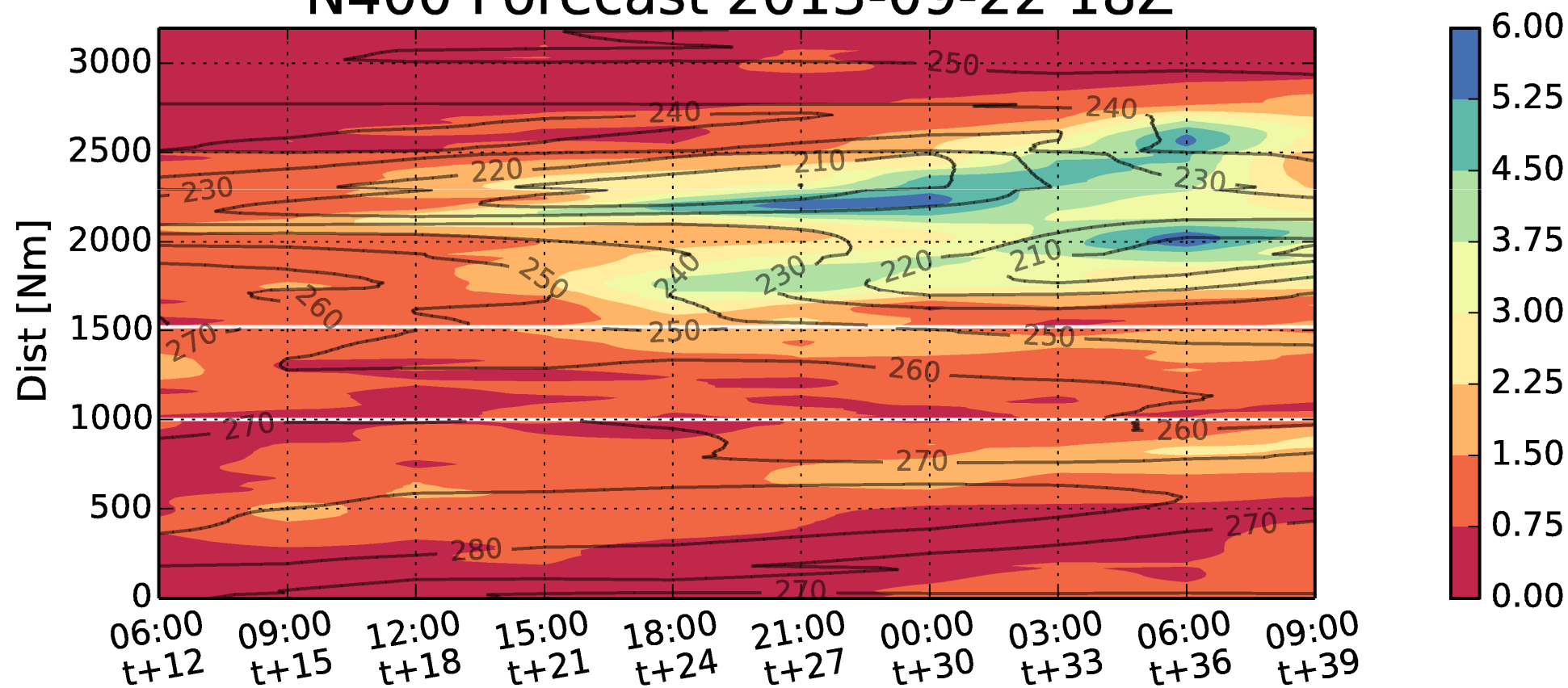


Legend

Contour : Ensemble mean ground speed [m/s]

Colour : Uncertainty of ground speed [m/s]

N400 Forecast 2013-09-22 18Z



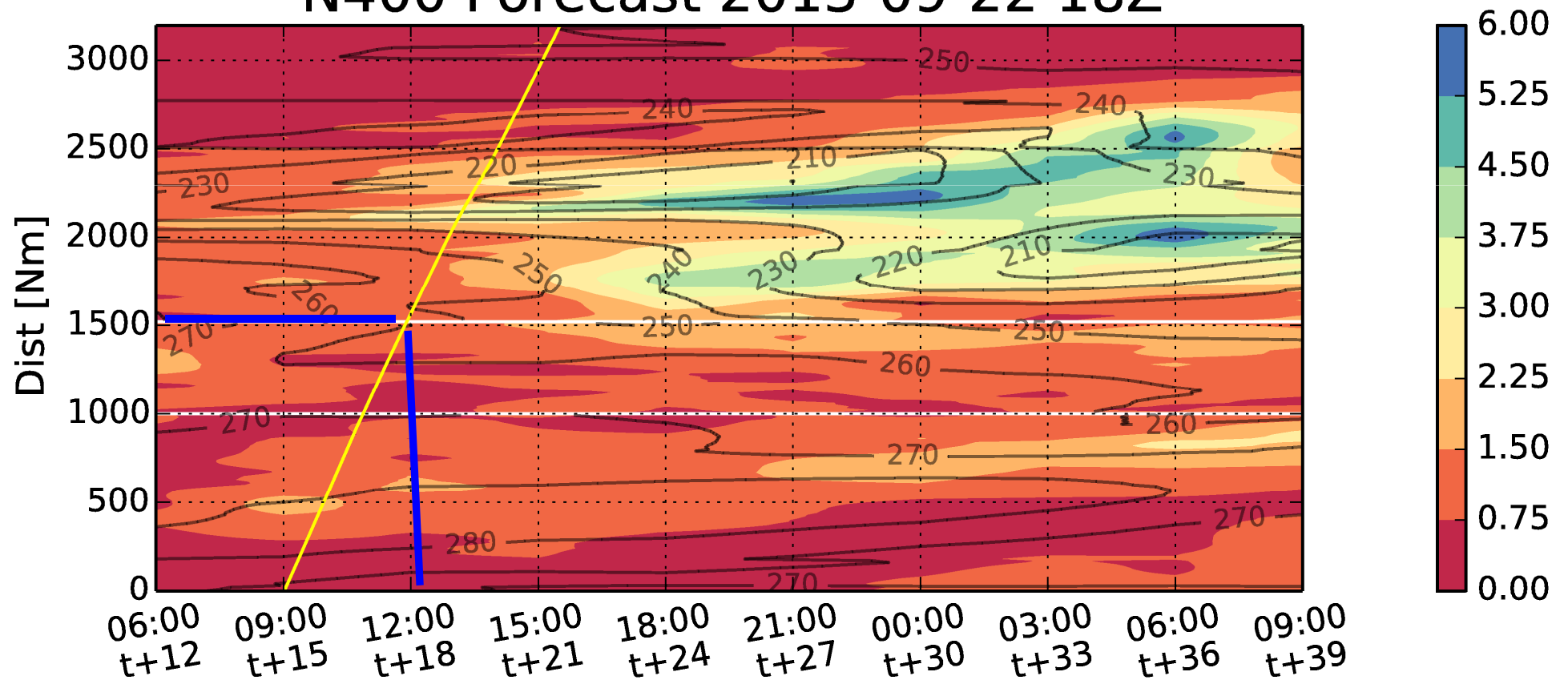
Legend

Contour : Ensemble mean ground speed [m/s]

Colour : Uncertainty of ground speed [m/s]

Yellow line: Position along trajectory for flight taking off at 09:00 (t+15)
as a function of time

N400 Forecast 2013-09-22 18Z



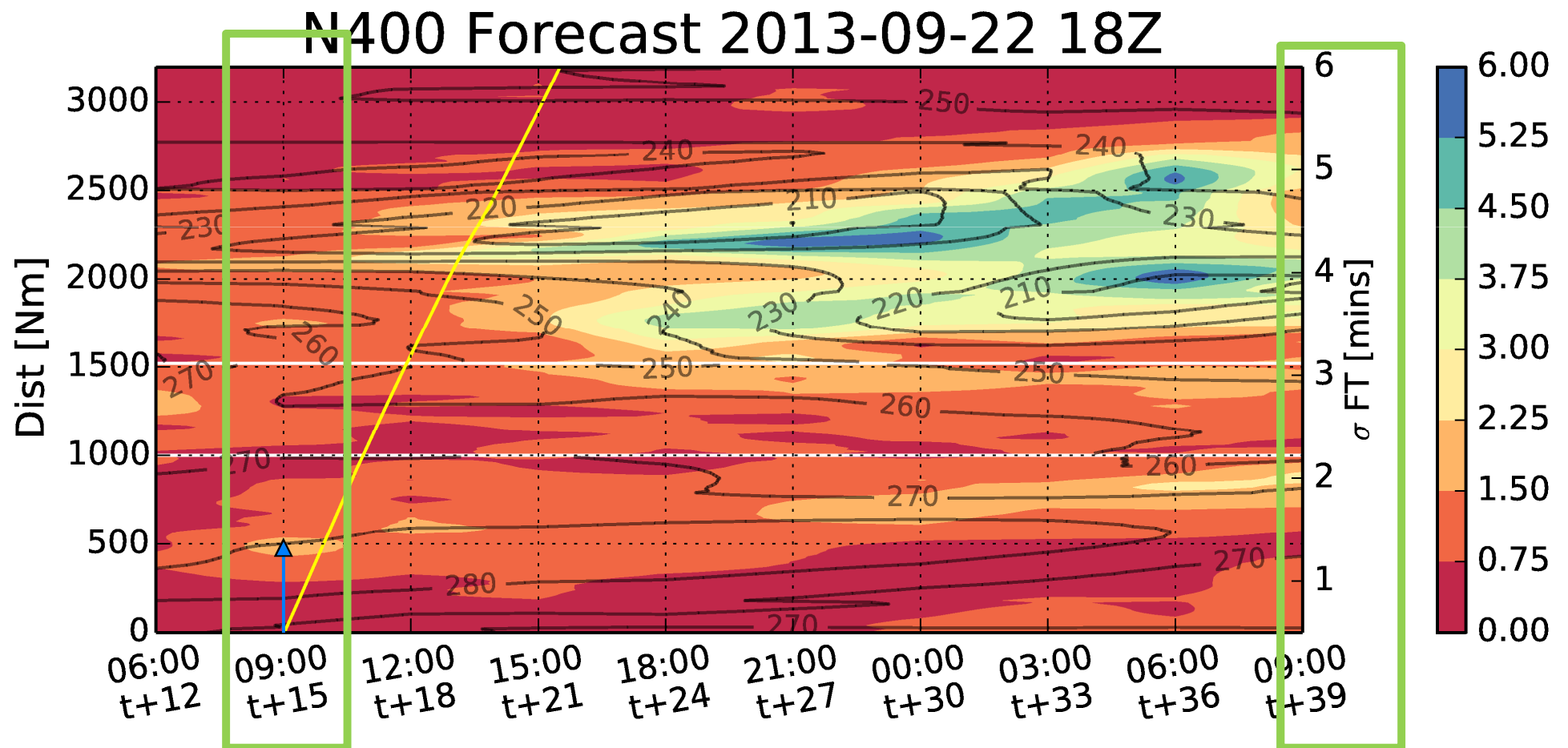
Legend

Contour : Ensemble mean ground speed [m/s]

Colour : Uncertainty of ground speed [m/s]

Yellow line: Position along trajectory for flight taking off at 09:00 (t+15)
as a function of time

Blue arrow: Flight time uncertainty [mins] for aircraft taking off at 09:00 (t+15)



Legend

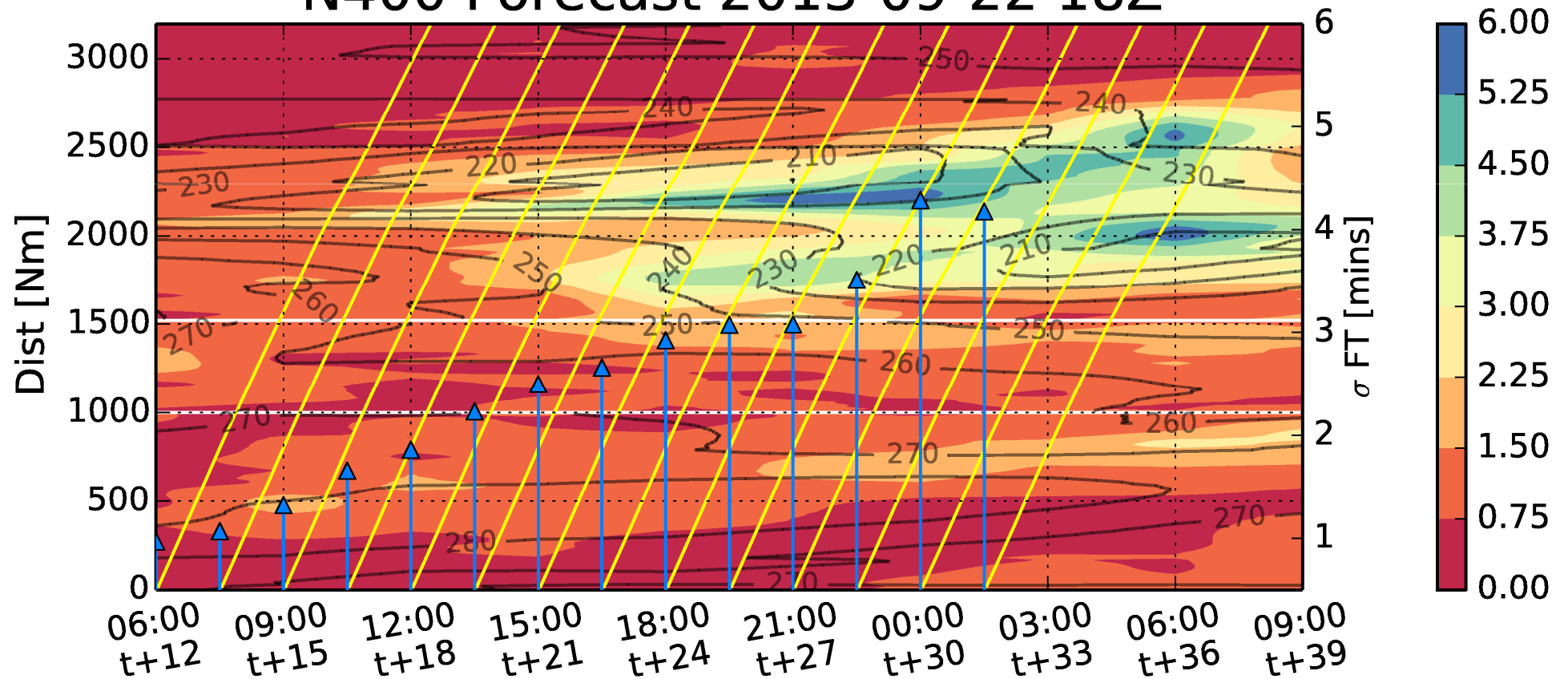
Contour : Ensemble mean ground speed [m/s]

Colour : Uncertainty of ground speed [m/s]

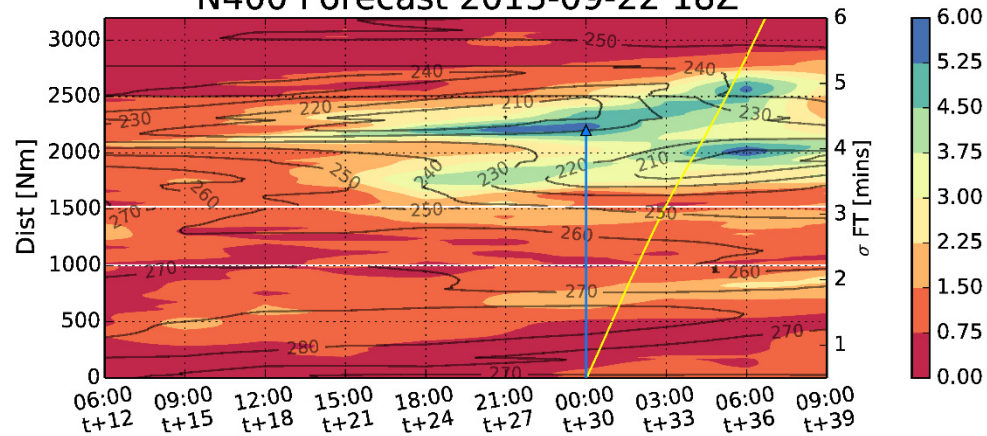
Yellow line: Position along trajectory for flight taking off at HH:MM
as a function of time

Blue arrow: Flight time uncertainty [mins] for aircraft taking off at HH:MM

N400 Forecast 2013-09-22 18Z

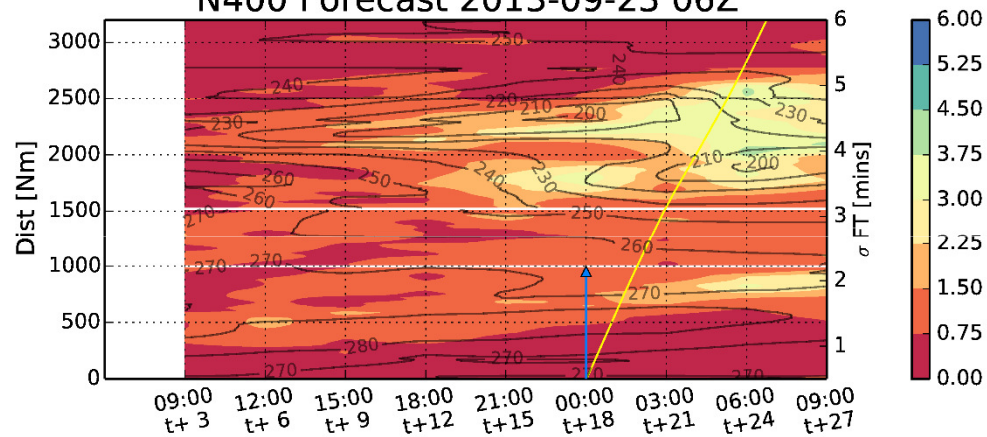


N400 Forecast 2013-09-22 18Z



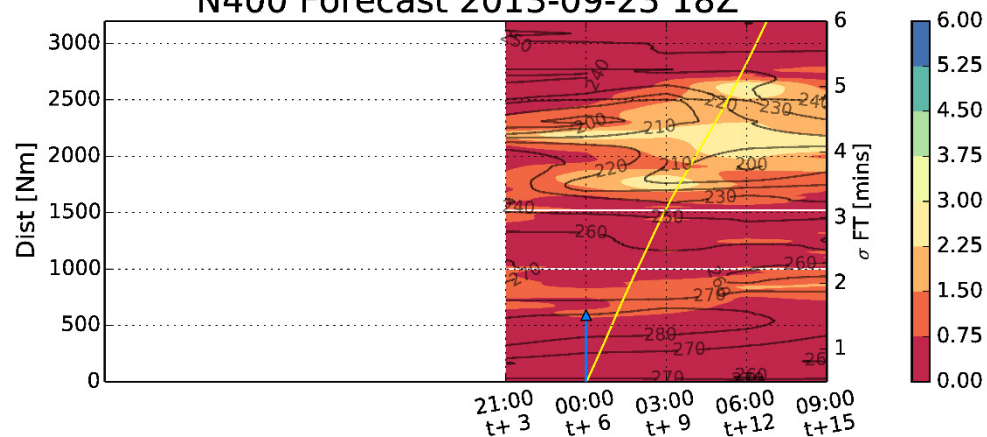
Forecast issued at 18Z,
on day before

N400 Forecast 2013-09-23 06Z



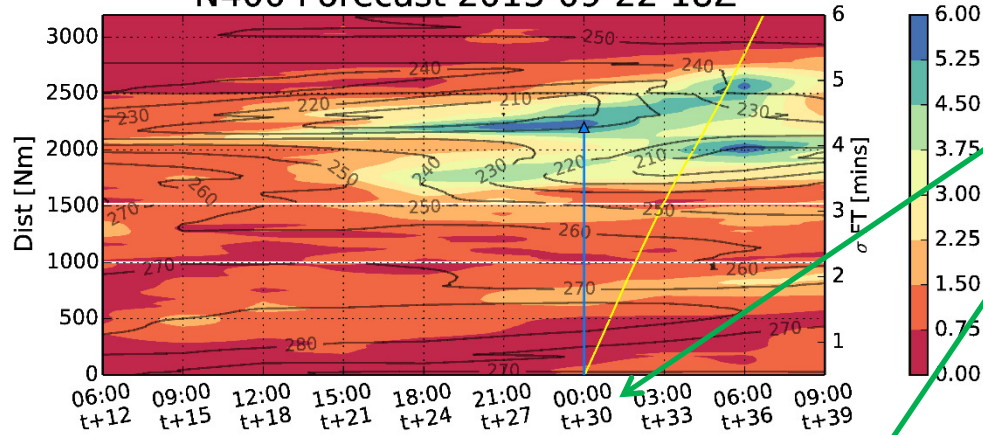
Forecast update issued at 06Z,
on the day

N400 Forecast 2013-09-23 18Z



Forecast update issued at 18Z,
on the day

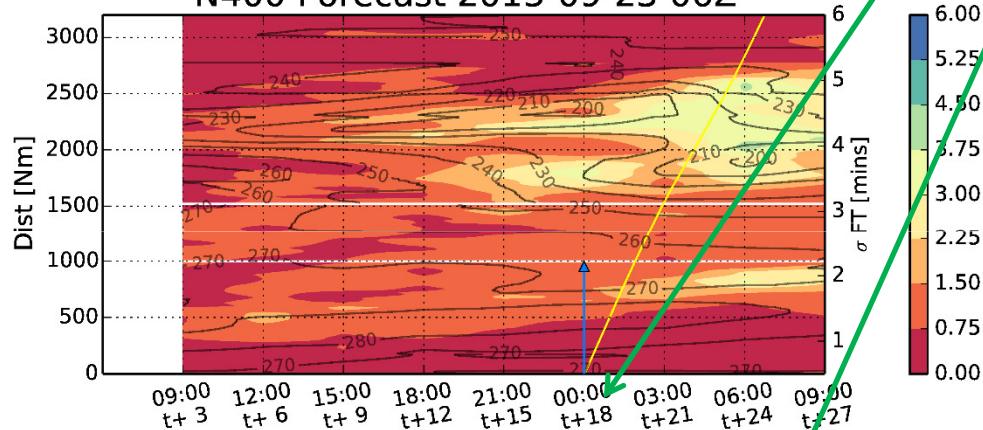
N400 Forecast 2013-09-22 18Z



Same take off time (2013-09-24 00Z)
, different forecast range

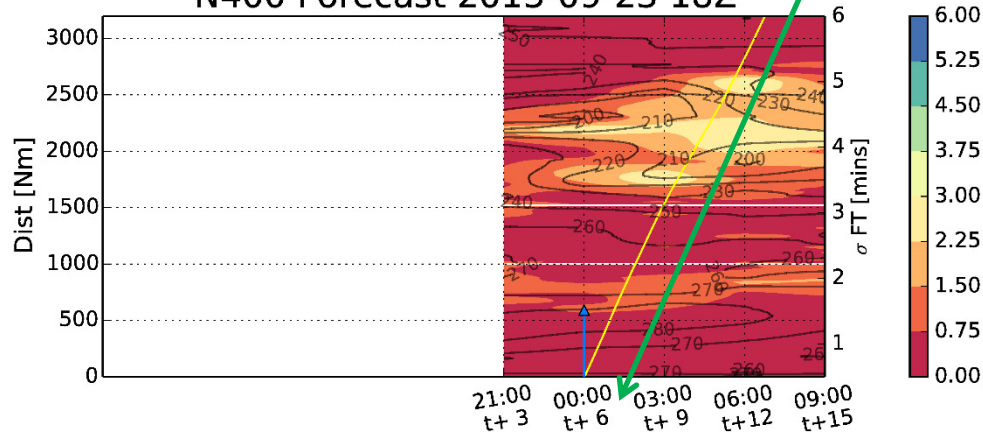
Forecast issued **30 hours**
before take off time

N400 Forecast 2013-09-23 06Z

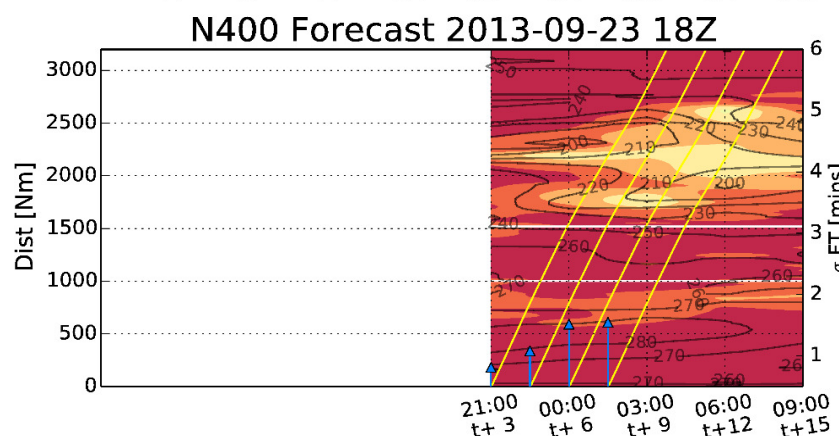
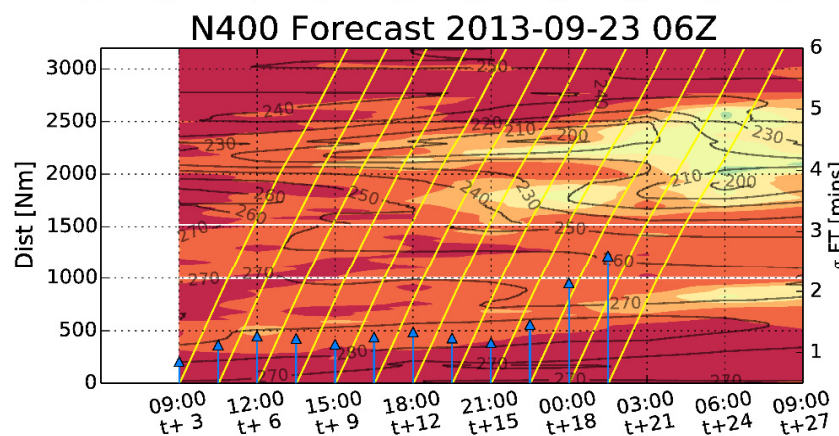
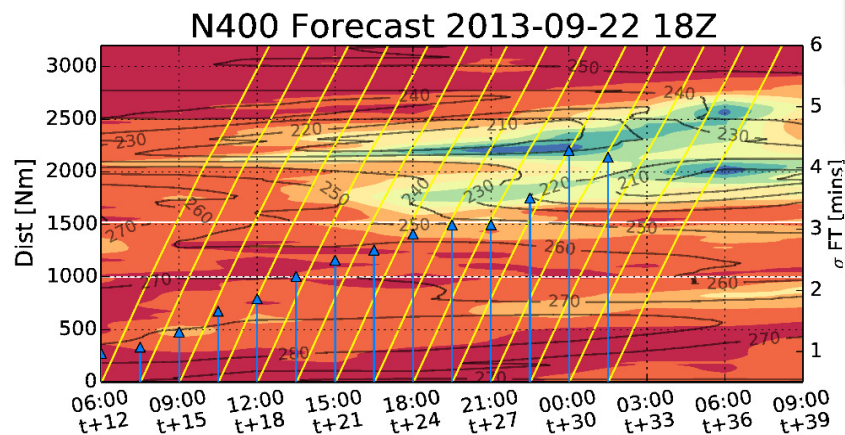


Forecast issued **18 hours**
before take off time

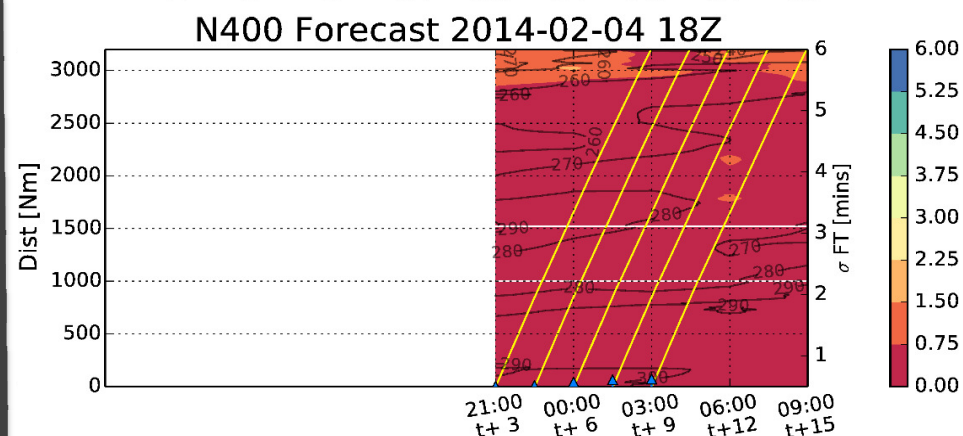
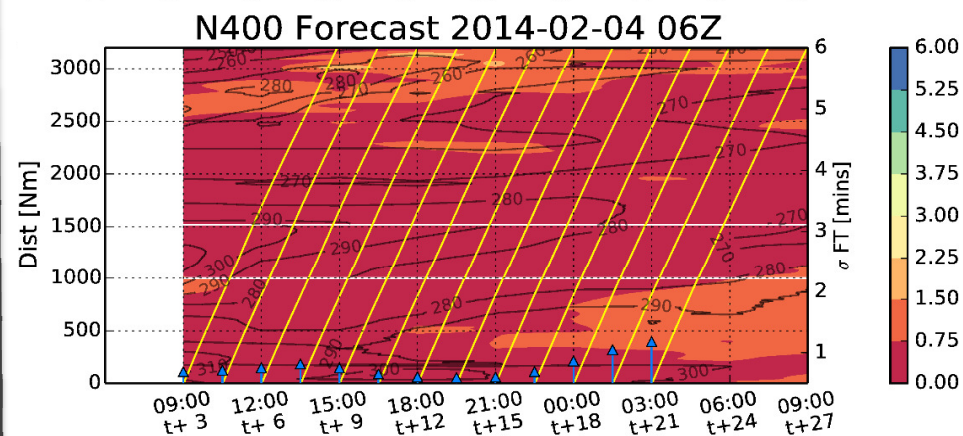
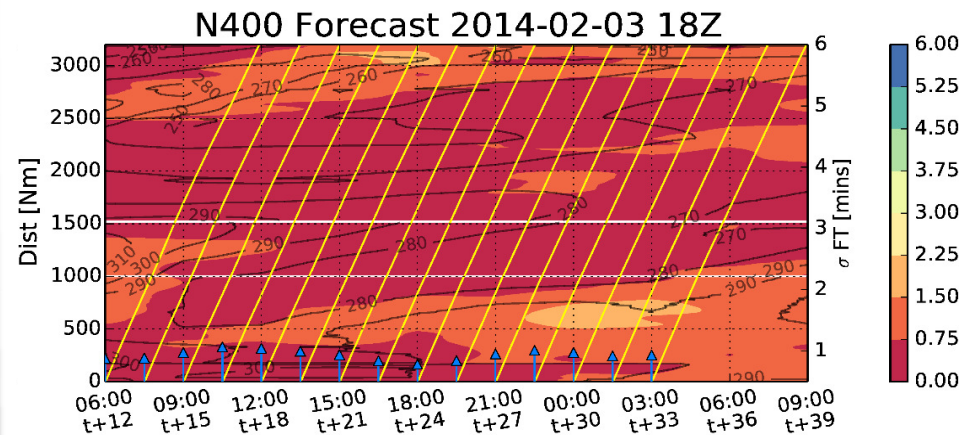
N400 Forecast 2013-09-23 18Z



Forecast issued at **6 hours**
before take off time



High MET Uncertainty

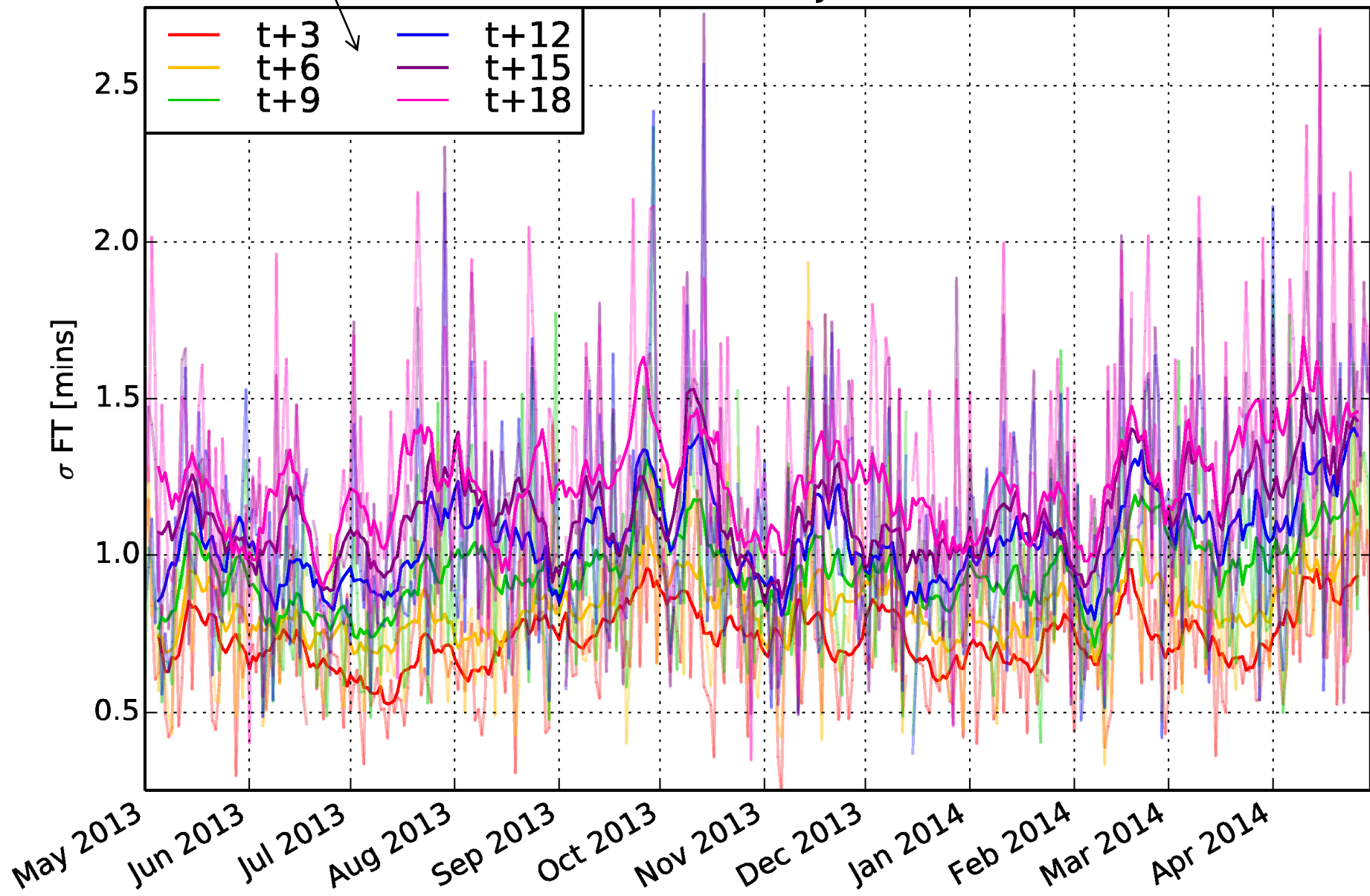


Low MET Uncertainty

Forecast issued X hours
before take off (i.e.
forecast range)

- No seasonal dependence
- Flight time uncertainty increases with forecast range

N400 Linear





Summary

- The impact of MET uncertainty on flight duration have been studied for a fixed route from KJFK to LFPG
- For the forecast range considered (up to 2 days ahead), the impact is significantly different between days of high and low MET uncertainties
- but small compared to the total flight time.
- Uncertainty is smaller if a more recent forecast is used
- Our results show no strong seasonal variation

Next step

- Allow full TP to run to generate an ensemble of trajectories
 - > Spread of flight times
 - > Geospatial spread
- Adverse weather



Questions and answers

