

Evaluation of PACOTS

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Review PACOTS generation

- PACOTS published once every 24 hours for eastbound (JCAB) and westbound (FAA) directions with different valid times. Use "24H" forecasts.
 - Have a long validity time.
 - Generated for certain city pairs.
 - Generated for certain aircraft types.
 - Modified to ensure separation.
- Aircraft types and traffic patterns change, but cost involved for FAA/JCAB to update systems to reflect different city pairs, recent aircraft fleet types, exploit better CNS performance (e.g. PBCS)
- Is it worth trying to increase frequency of publication?
- Operators may generate UPRs (based on PACOTS) or random tracks using more up-to-date forecasts tailored for the type of operation (aircraft type, city pair), but:
 - Capability may incur a cost.
 - Note all operators have the capability

To help inform decision-making, study three questions

1. What is the effect of forecast error?

1. What is the effect of aircraft type difference?

1. What is the effect of wind changes over the PACOTS validity period?

Methodology

Compare PACOTS Track 3 (RJAA \Rightarrow KLAX) and Track F (KLAX \Rightarrow RJAA) between reference and test conditions. Look at flight time, fuel burn, flight distance, track.

1. Forecast error effect:
 - a. Reference condition (24-hour forecast)
 - b. 0-hour forecast (“Nowcast”)
2. Aircraft Type effect: (basically, cruise altitude)
 - a. Reference condition (B773, M0.84, FL330 eastbound FL340 westbound)
 - b. A359 type (M0.84, FL350 eastbound FL360 westbound)
3. Wind change during PACOTS validity time effect:
 - a. Reference condition
 - b. +/-6 hours using 0-hour forecast (Track 3: 06UTC, Track F: 06UTC)

Reference condition:

Generation time & wind: Minimum time track (MTT) using ENRI tool.

Track 3 previous day 12UTC, forecast +24H, Track F previous day 00UTC, forecast +24H

Aircraft conditions:

B773, M0.84 cruise. Track 3 FL330, Track F FL340

Data and Conditions

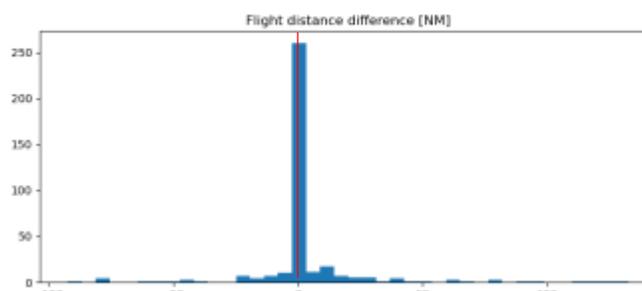
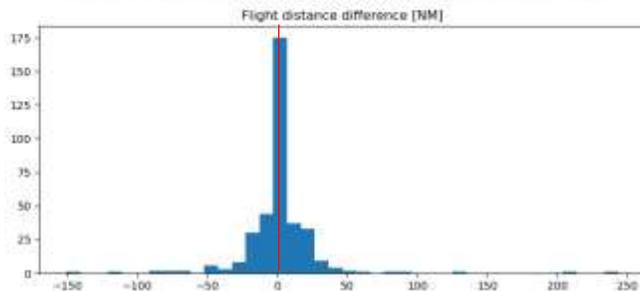
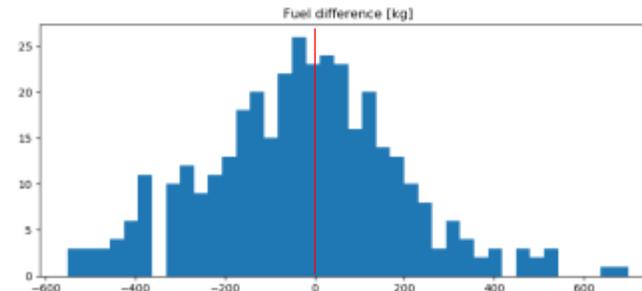
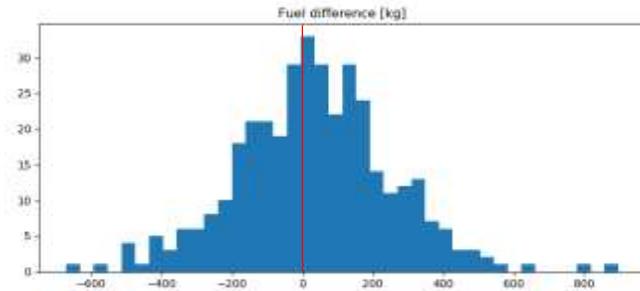
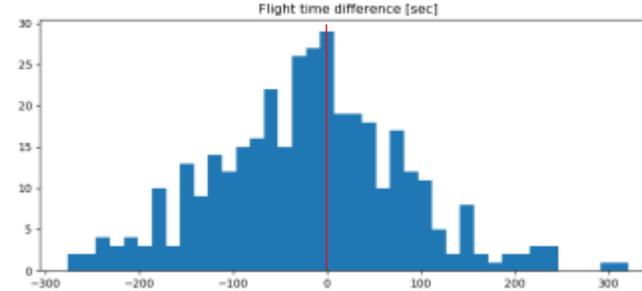
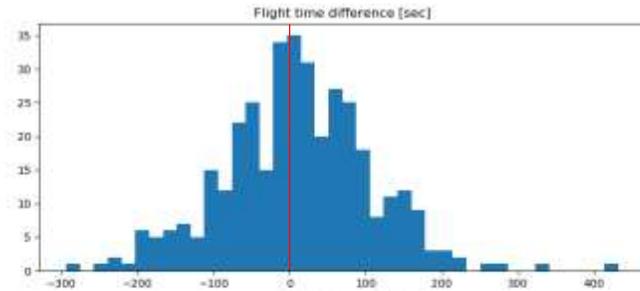
- ENRI calculation tool for minimum time track (MTT) based on winds aloft and a “mesh” of possible waypoints at 1 degree lat/10 degree lon granularity in the PACOTS “free route” area.
- Japan Meteorological Agency GSM (Global Spectral Model) numerical weather forecasts. (Retrieved from Kyoto University RISH server.)
- Reference type B773, M0.84 cruise (no cruise climb).
Use BADA version 3 performance database tables.
Fuel cons. particularly not realistic (use maximum departure mass from BADA) but okay for comparison between data sets.
- One year (1-Jan-2019 to 31-Dec-2019)

Forecast Time (F24 versus F00): Statistics

”nowcast” – “reference”

Track 3

Track F



Track 3

	Time (s)	Fuel (kg)	Dist (NM)
Max	431.80	896.30	243.62
75th pc	73.50	166.20	6.89
Average	10.57	32.79	1.03
Median	9.50	29.10	0.00
Stdev	97.93	218.94	27.86
25th pc	-52.20	-108.80	-4.35
Min	-293.50	-670.40	-150.88

Track F

	Time (s)	Fuel (kg)	Dist (NM)
Max	320.70	698.90	132.38
75th pc	42.00	108.00	0.00
Average	-19.33	-28.67	2.81
Median	-15.80	-24.40	0.00
Stdev	101.93	217.31	22.60
25th pc	-84.90	-165.70	0.00
Min	-275.90	-550.50	-92.22

Not actually a large (variation)

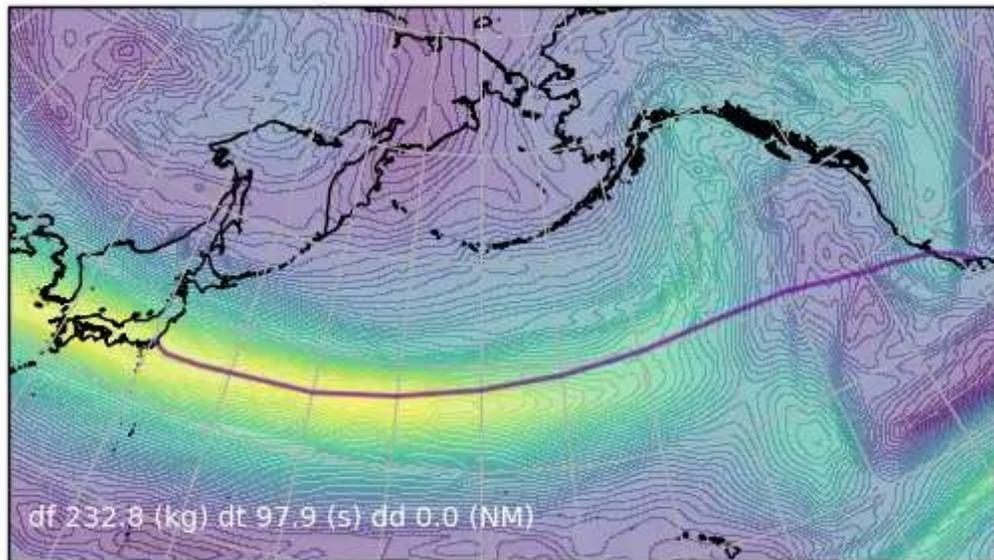
Forecast Time: Track visualisations

Blue line: 24-hour forecast track (PACOTS reference)

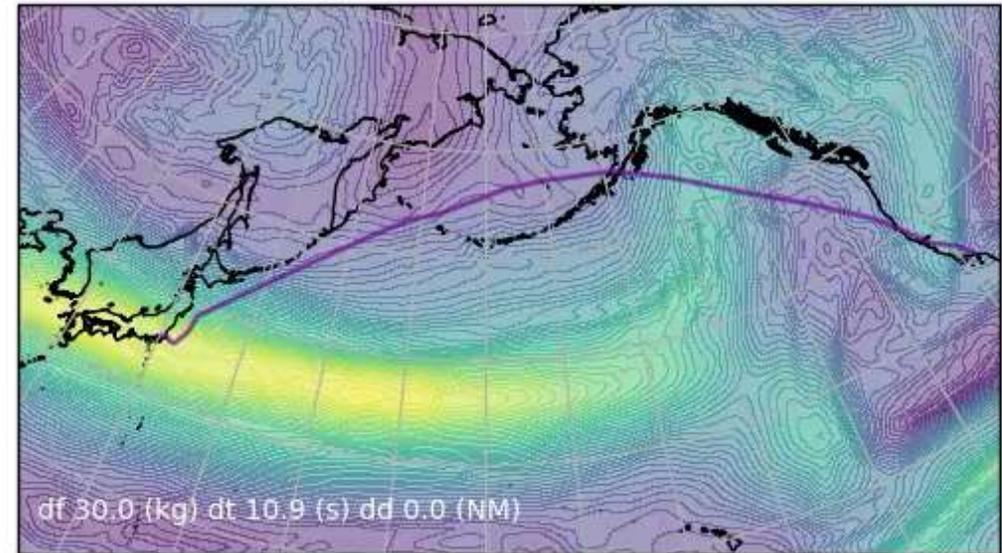
Red line: "nowcast" calculated track

Wind strengths at 200hPa (approximately 39,000ft) level shown for reference

Day 1 (2019-01-01) Track 3



Day 1 (2019-01-01) Track F

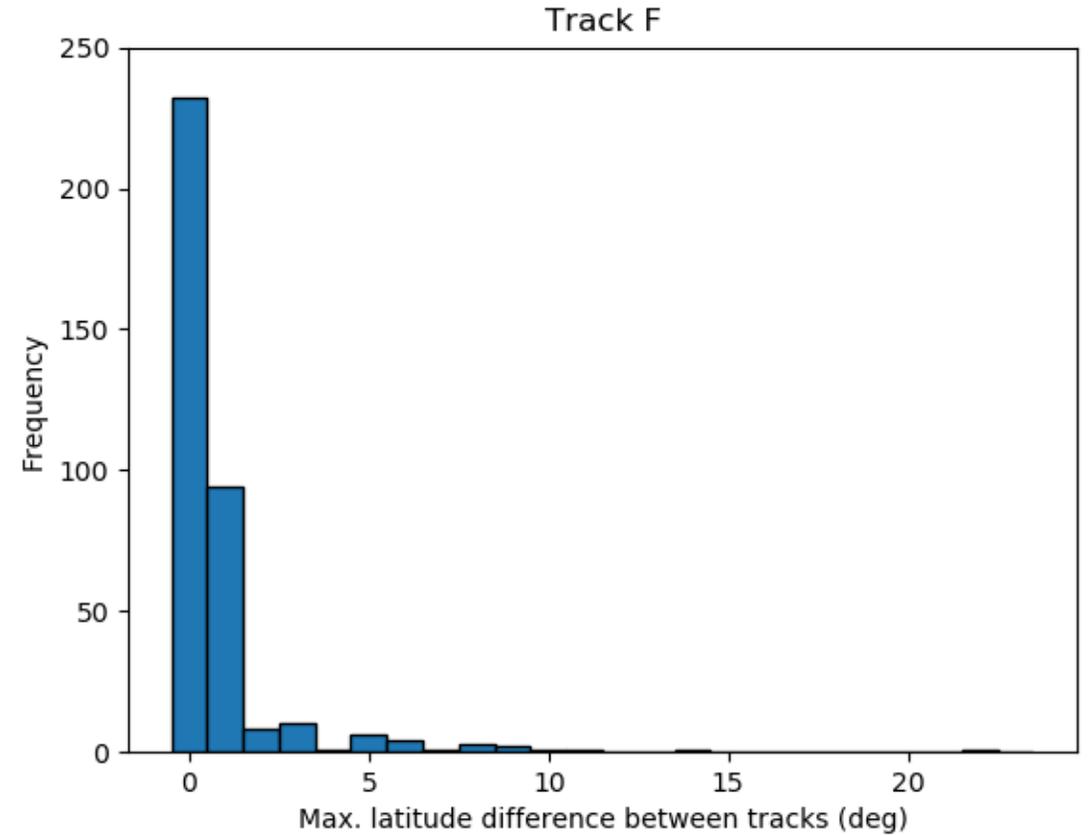
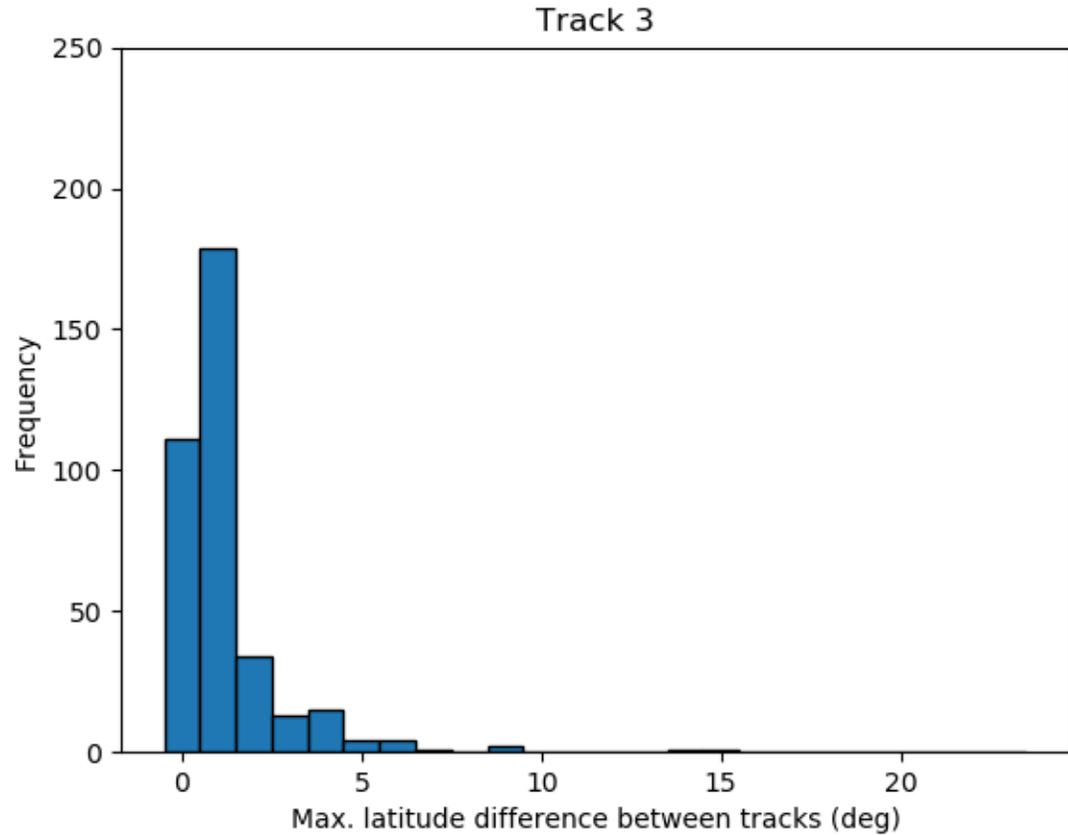


Forecast Time: Track differences

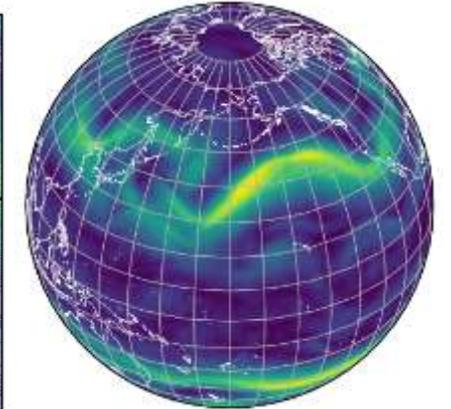
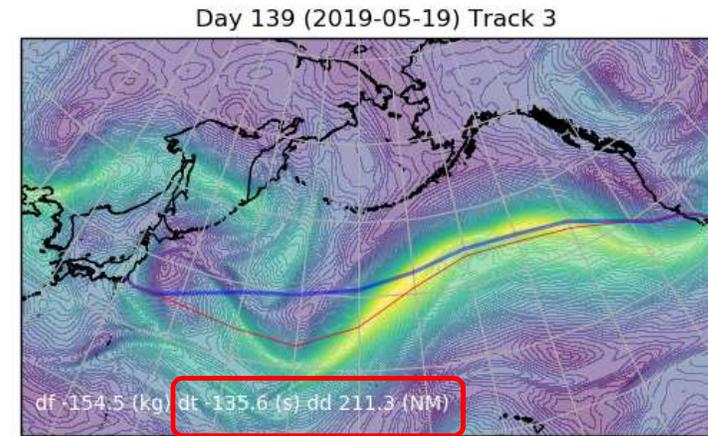
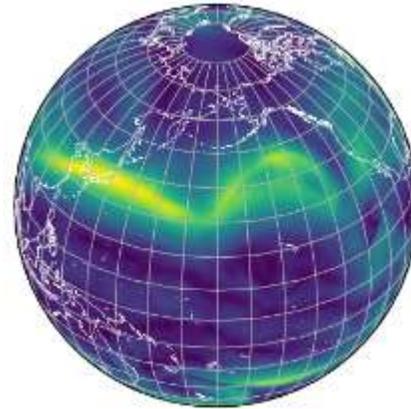
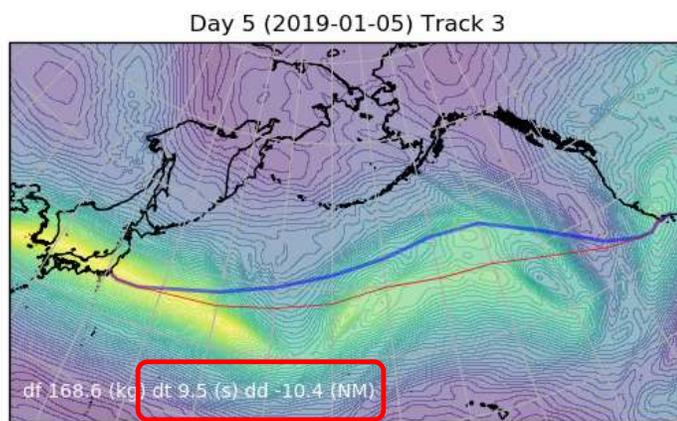
Sample tracks at same meridians and compare latitude differences at each meridian.

Histograms of greatest latitude difference between tracks.

Difference of "0" means tracks are the same.



Forecast Time: Sample “split” cases (Track 3)



Blue line: 24-hour forecast track (PACOTS reference)

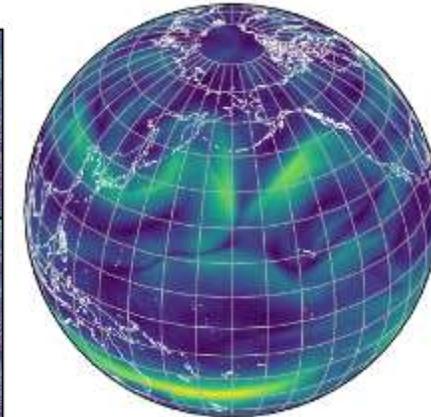
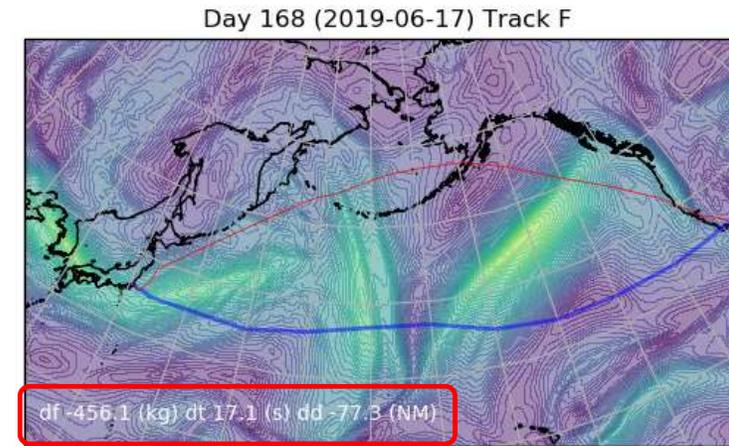
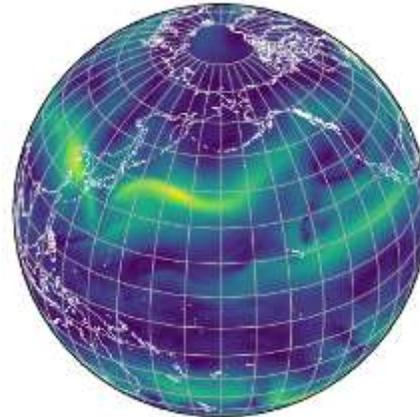
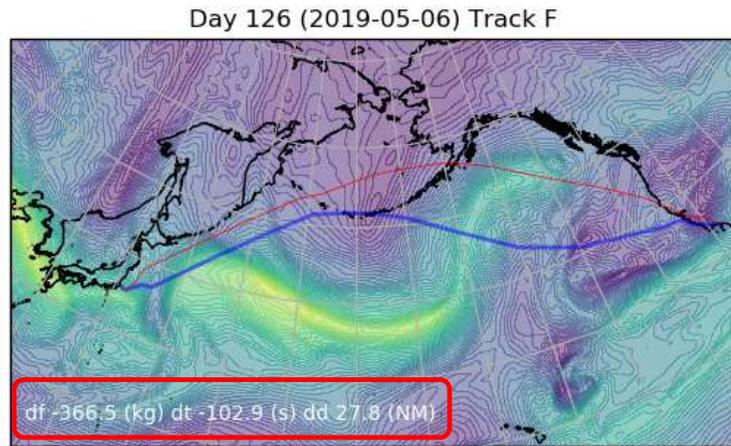
Red line: “nowcast” calculated track

Wind strengths at 200hPa (approximately 39,000ft) level shown for reference

Jet stream core position is slightly different from forecast, leading to difference between F24 and F00 calculated tracks.

Track 3 calculation can be sensitive to changes in westerly jet stream core position and strength between forecast and actual. (Track 3 shows more distance variation in statistics).

Forecast Time: Sample “split” cases (Track F)



Blue line: 24-hour forecast track (PACOTS reference)

Red line: “nowcast” calculated track

Wind strengths at 200hPa (approximately 39,000ft) level shown for reference

Jet stream core position is slightly different from forecast, leading to difference between F24 and F00 calculated tracks.

Track F calculation less sensitive to changes in westerly jet stream core position and strength between forecast and actual since it largely avoids the jet stream area.

(Track F shows less day-to-day variation and distance variation in statistics).

Sometimes best MTT can be south of the jet stream core.

Forecast Time: Conclusions

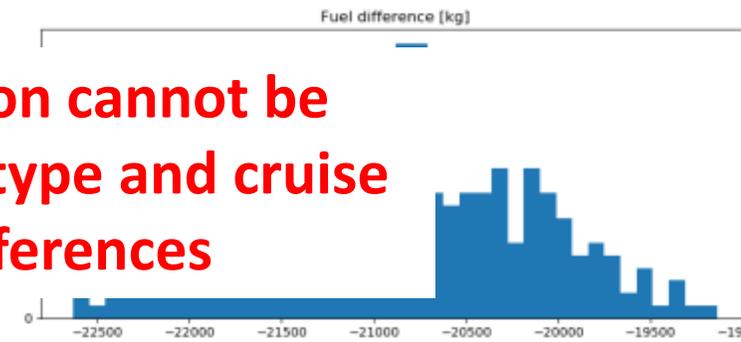
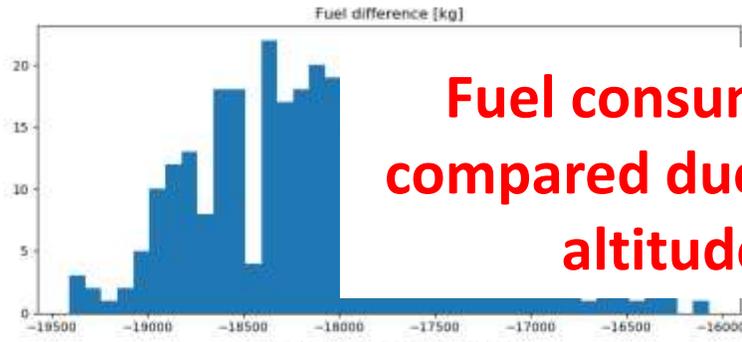
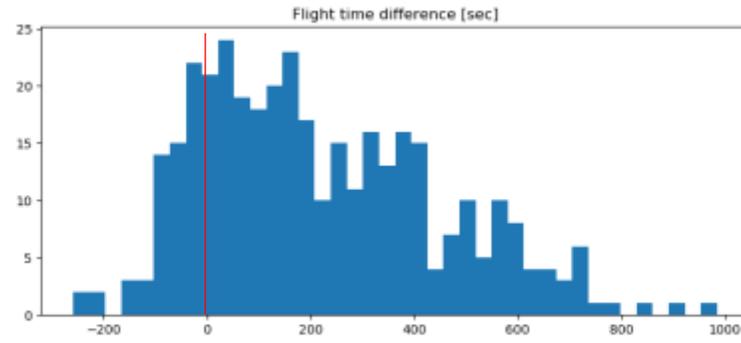
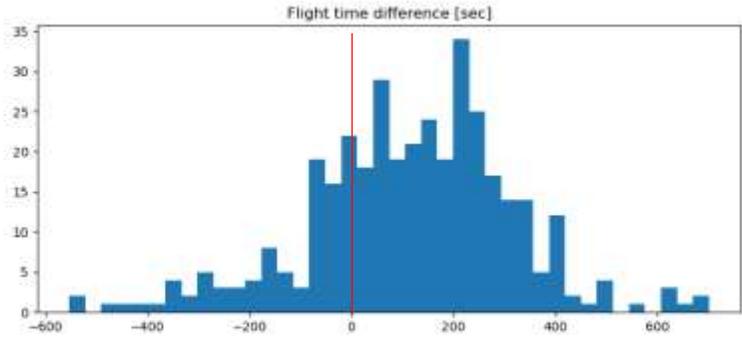
- Cases where difference in jet stream core position differs significantly from forecast lead to track differences, but the effect on the MTT time are not so great.
- Track 3 varies more day-to-day than Track F.
- Variance (mean, standard deviations) actually quite low overall. Central values have opposite signs for track 3 and track F due to prevailing wind direction.
- Distance spread smaller for track F than track 3 since track 3 is more sensitive to jet stream core position and so variation between forecast and actual.

Type difference: Statistics

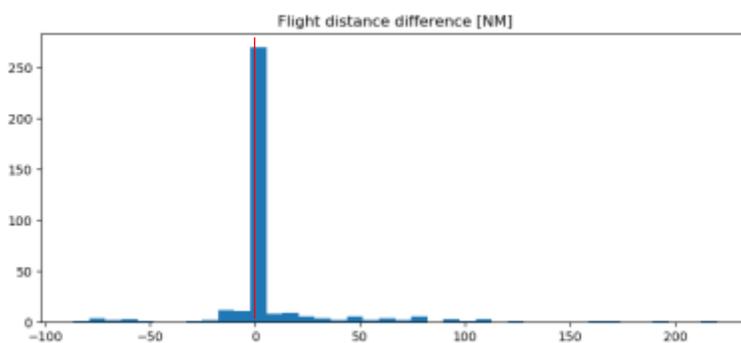
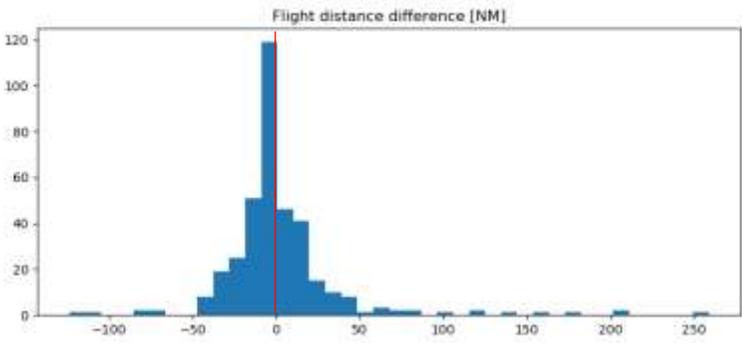
"A359" – "B773"

Track 3

Track F



Fuel consumption cannot be compared due to type and cruise altitude differences



Track 3

	Time (s)	Dist (NM)
Max	700.30	258.98
75th pc	241.50	10.15
Average	117.10	2.71
Median	129.80	0.00
Stdev	199.85	35.39
25th pc	-1.60	-12.19
Min	-552.70	-123.71

Track F

	Time (s)	Dist (NM)
Max	984.50	219.88
75th pc	369.20	0.00
Average	216.97	6.10
Median	170.80	0.00
Stdev	230.94	31.45
25th pc	30.90	0.00
Min	-258.20	-86.64

Little difference in flight distance but slightly longer flight times overall

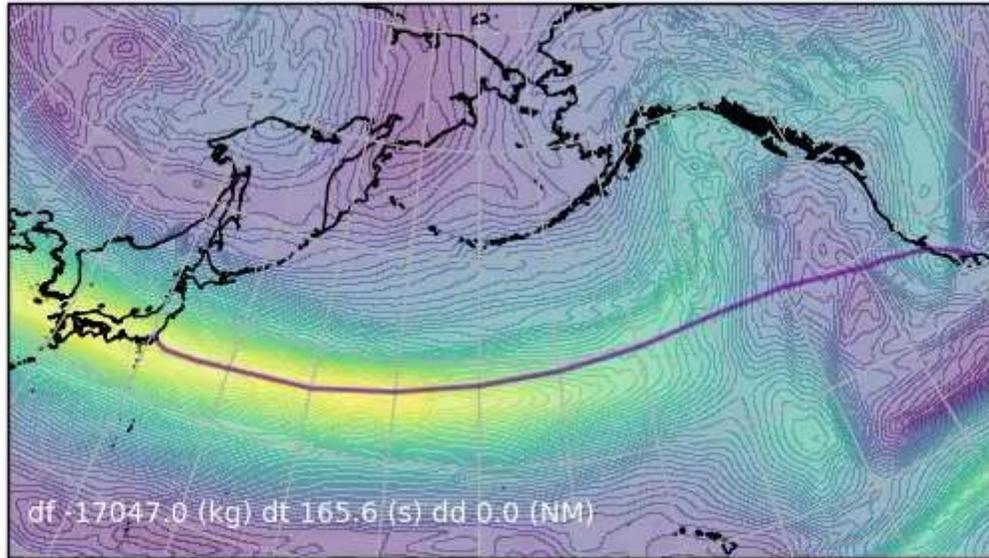
Type difference: Track visualisations

Blue line: B733 track FL330 (PACOTS reference)

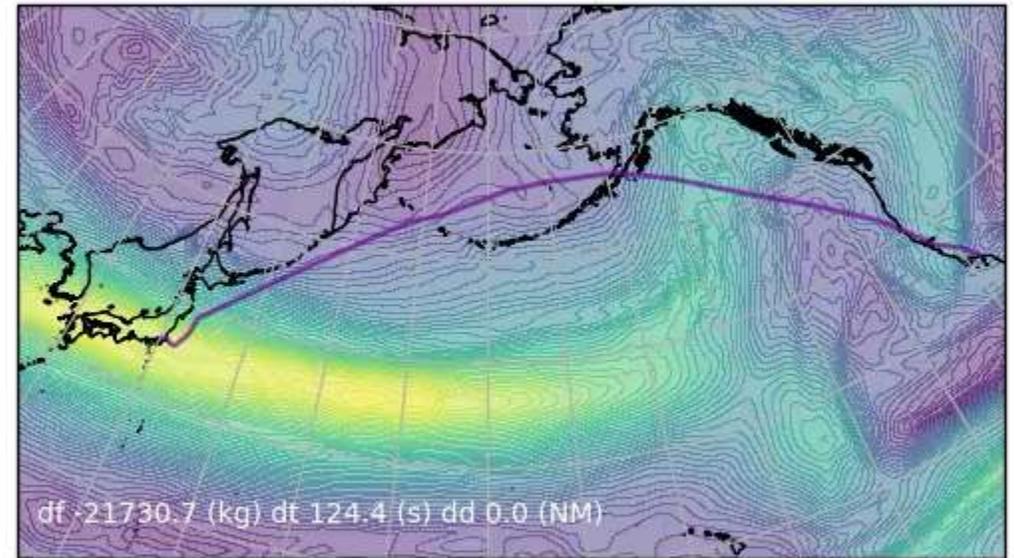
Red line: A359 track FL350 calculated track

Wind strengths at 200hPa (approximately 39,000ft) level shown for reference

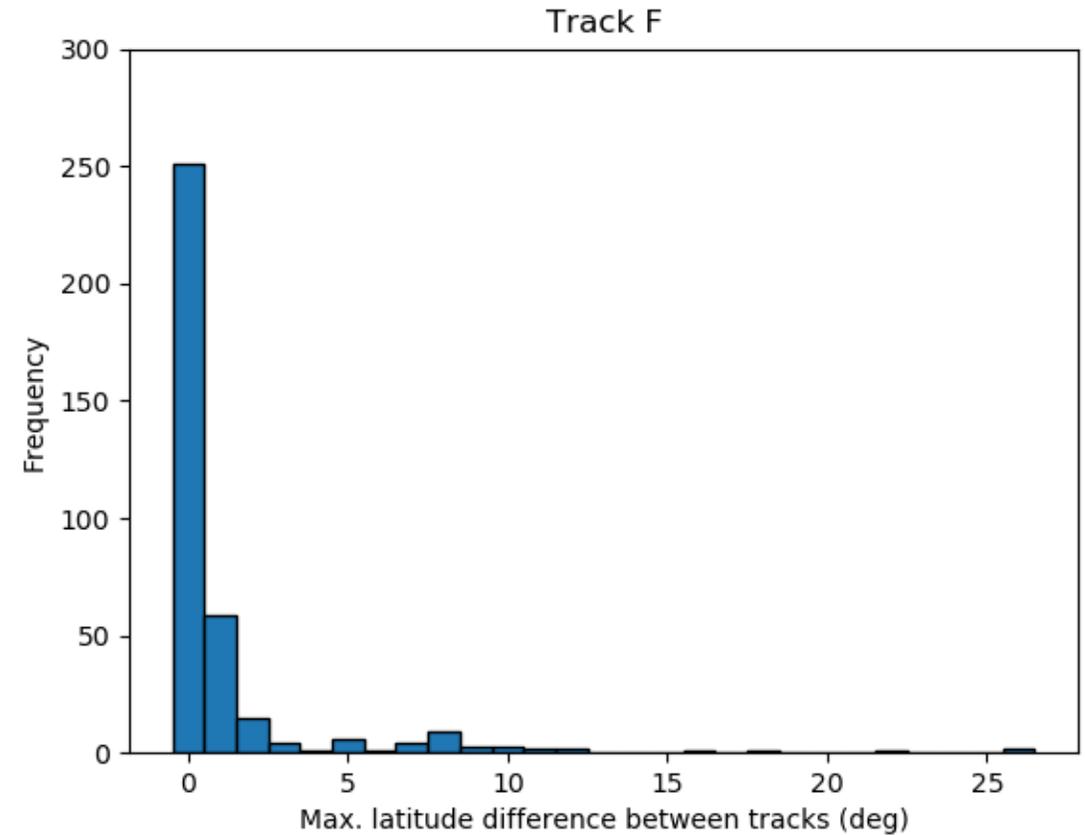
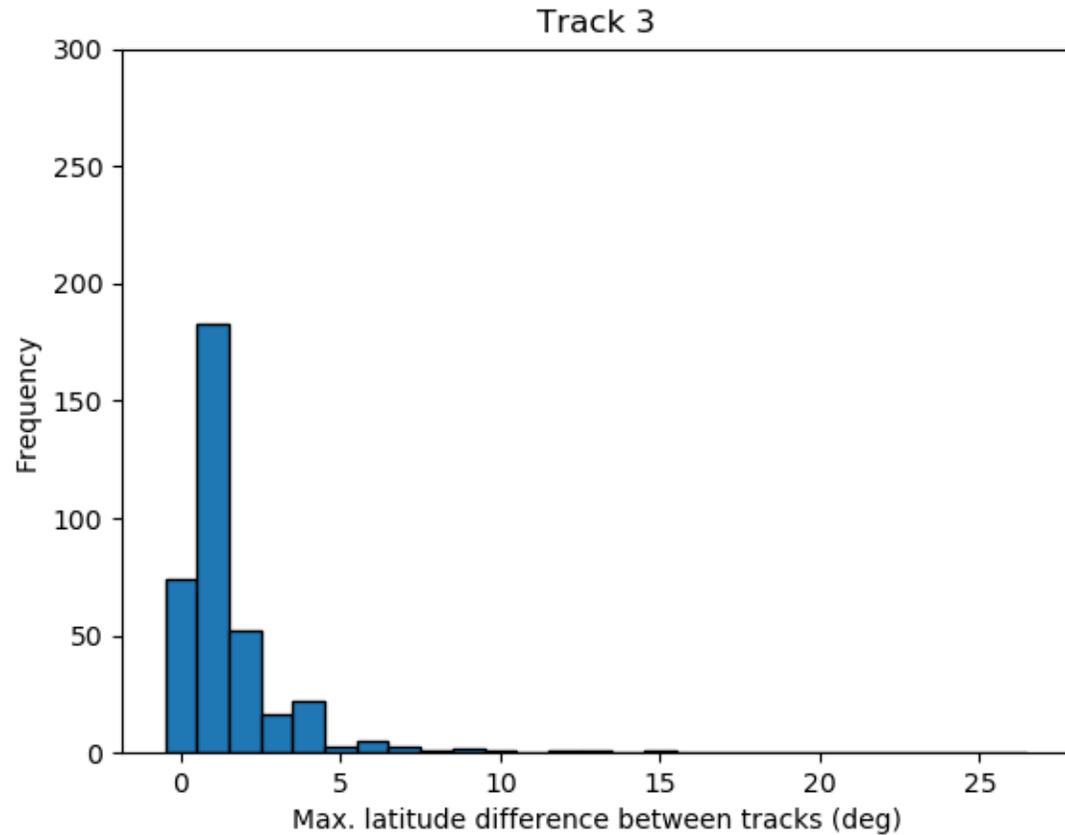
Day 1 (2019-01-01) Track 3



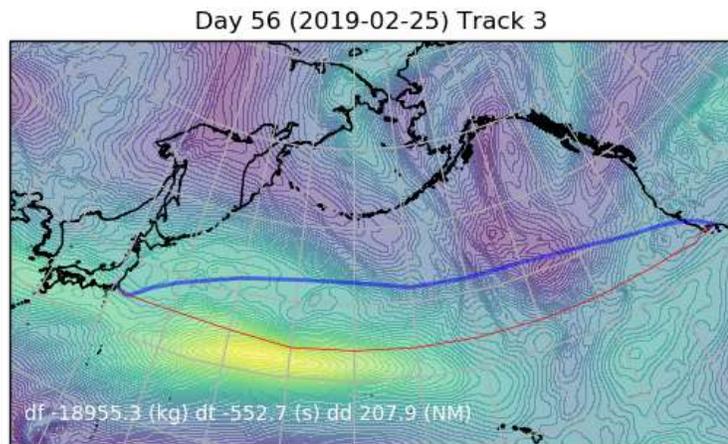
Day 1 (2019-01-01) Track F



Type difference: Track differences



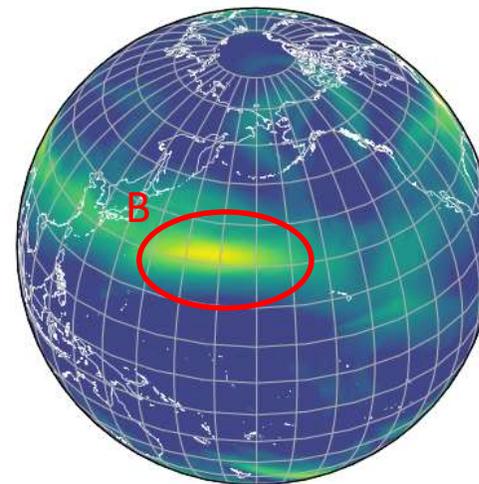
Type difference: Sample “split” case (Track 3)



Blue line: B733 track FL330 (PACOTS reference)
Red line: A359 track FL350 calculated track
Wind strengths at 200hPa (approximately 39,000ft) level
shown for reference



300hPa (~FL300)



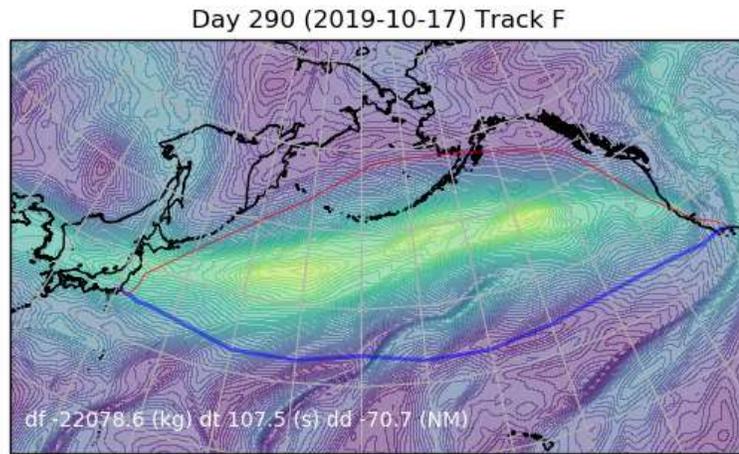
200hPa (~FL390)

Forecast wind 2019-02-25 1200Z +24H

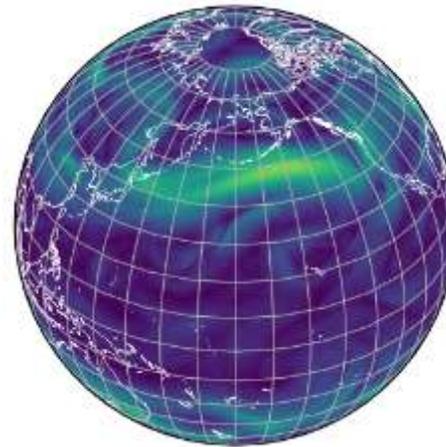
Winds at intermediate levels interpolated between these forecasts.
FL350 calculated track more heavily influenced by jet stream high altitude core B,
FL330 calculated track more influenced by area A.

Calculated tracks for FL330 and FL350 can differ significantly where there is a strong variation of wind with altitude but occurrence not so frequent (see 365-day animation).

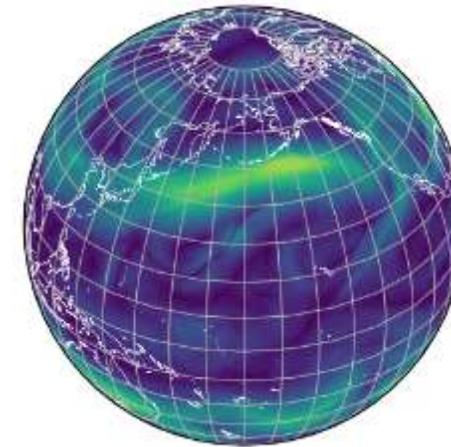
Type difference: Sample “split” case (Track F)



Blue line: B733 track FL340 (PACOTS reference)
Red line: A359 track FL360 calculated track
Wind strengths at 200hPa (approximately 39,000ft) level
shown for reference



300hPa (~FL300)



200hPa (~FL390)

Forecast wind 2019-10-24 00Z +24H

Track F has similar North-South splits to F24 vs. F00 study.

Type difference: Conclusions

- Main difference in cruise altitude rather than type per se.
- Little difference in flight time, track distance between reference PACOTS and tracks calculated for different cruise levels (2,000ft higher).
- Flights at higher altitude slightly longer on average (2min eastbound just under 3min westbound).
 - Possibly due to difference in TAS at higher altitude corresponding to same Mach number (about 4 KTS lower at +2,000ft higher due to lower temp).

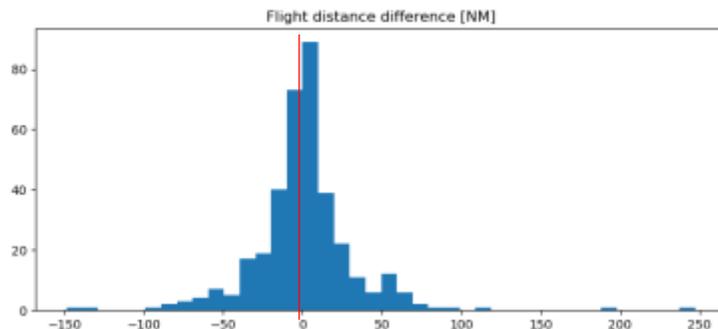
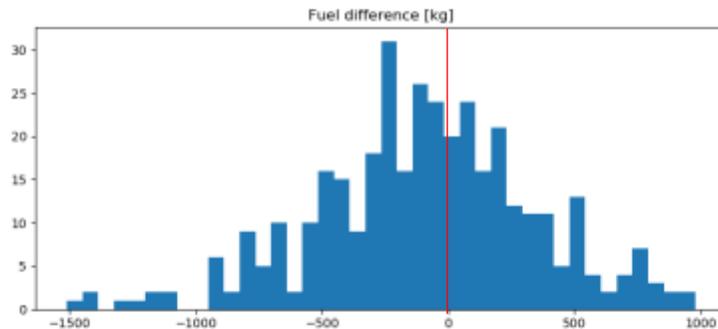
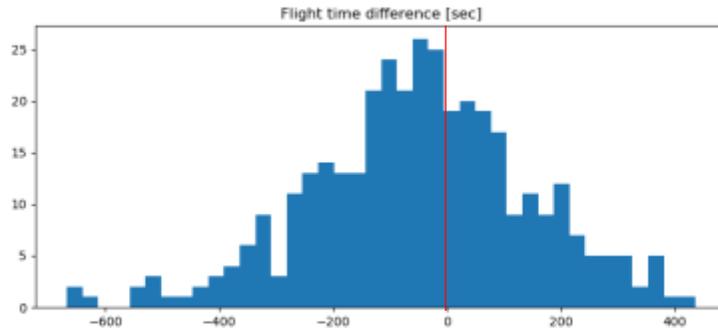
“Quick and dirty” estimate is consistent:

4KTS * 6 HRS (CRZ) = 24NM, or 172 sec at 500KTS ground speed.

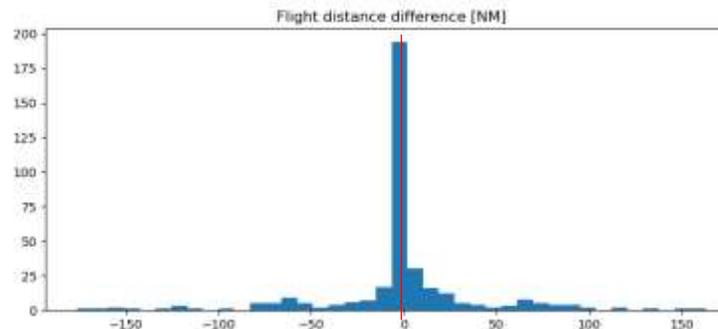
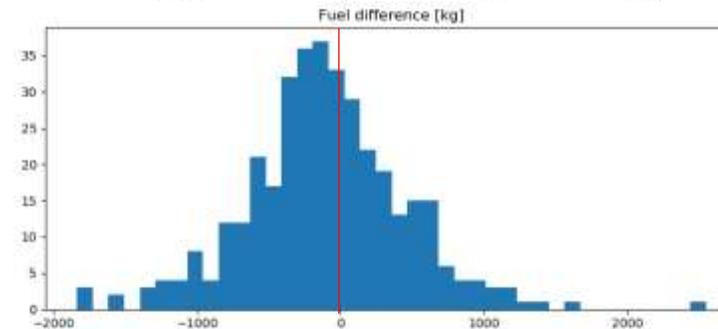
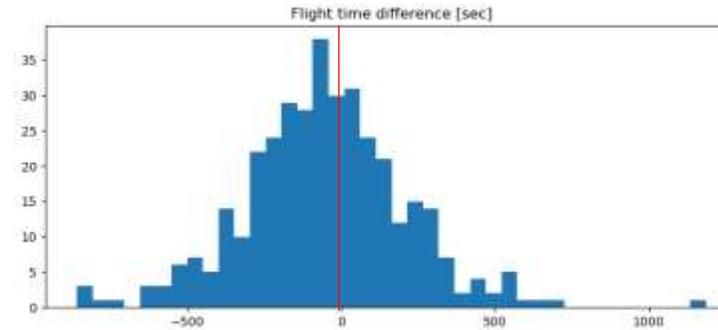
PACOTS validity (PACOTS vs. +6H): Statistics

“+/-6H (nowcast) – PACOTS”

Track 3



Track F



Track 3

Time (s) Fuel (kg) Dist (NM)

Max	435.70	978.00	247.25
75th pc	73.40	198.50	12.72
Average	-47.41	-90.11	0.68
Median	-42.30	-82.90	0.00
Stdev	192.34	435.42	33.87
25th pc	-155.30	-340.00	-12.87
Min	-667.40	-1509.80	-148.35

Track F

Time (s) Fuel (kg) Dist (NM)

Max	1186.20	2544.50	163.24
75th pc	102.20	225.70	2.02
Average	-52.48	-102.74	-0.50
Median	-56.30	-115.40	0.00
Stdev	264.43	560.24	40.86
25th pc	-202.70	-410.50	-2.02
Min	-859.50	-1835.50	-176.44

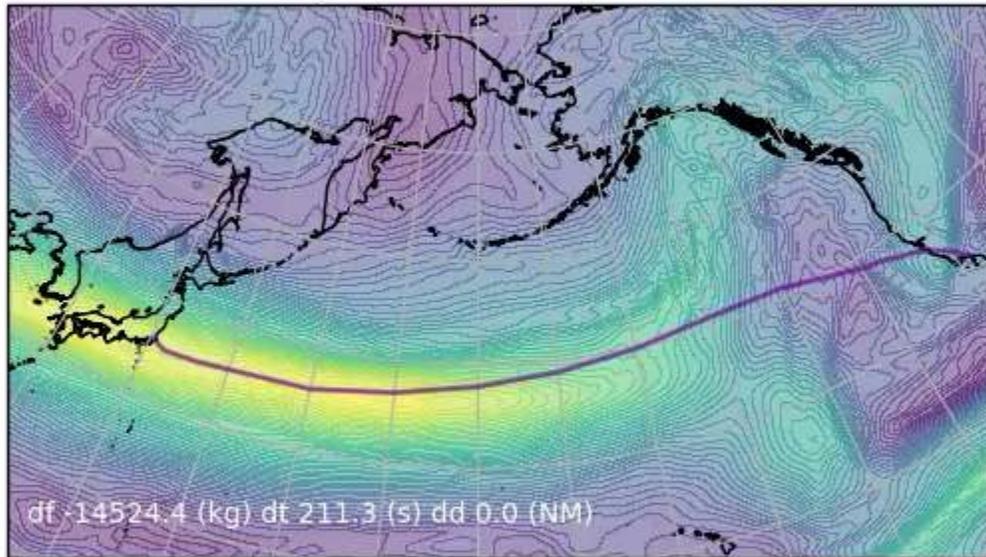
PACOTS validity: Track visualisations

Blue line: PACOTS track

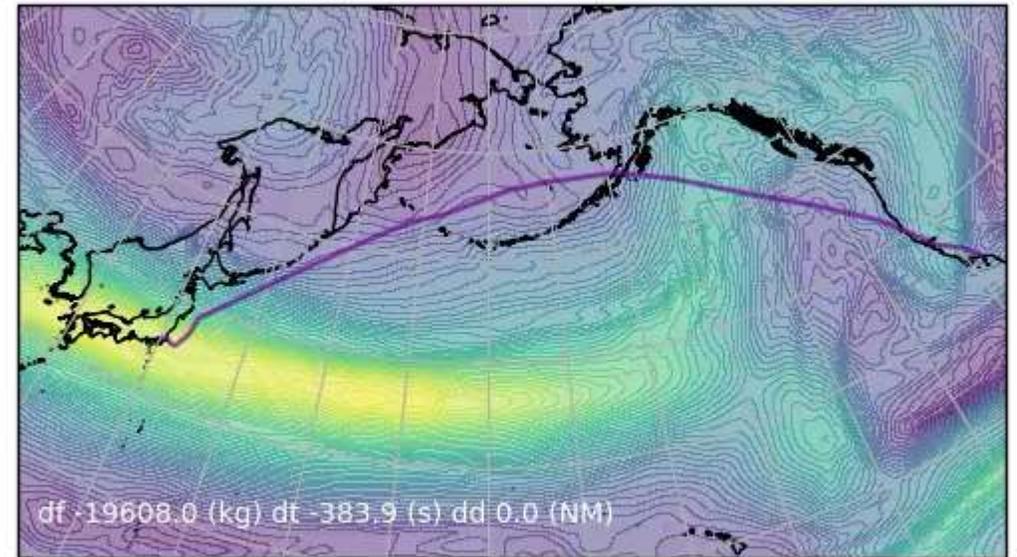
Red line: Compute track at +/-6H (nowcast forecast)

Wind strengths at 200hPa (approximately 39,000ft) level shown for reference

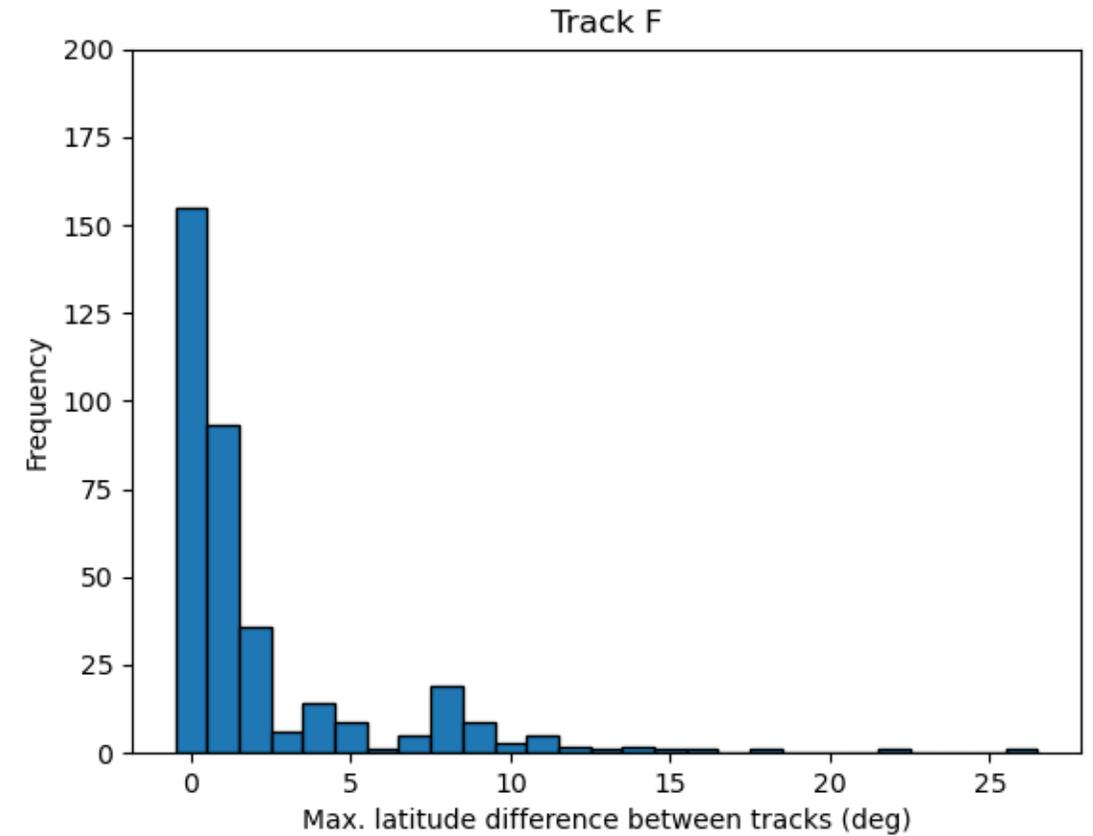
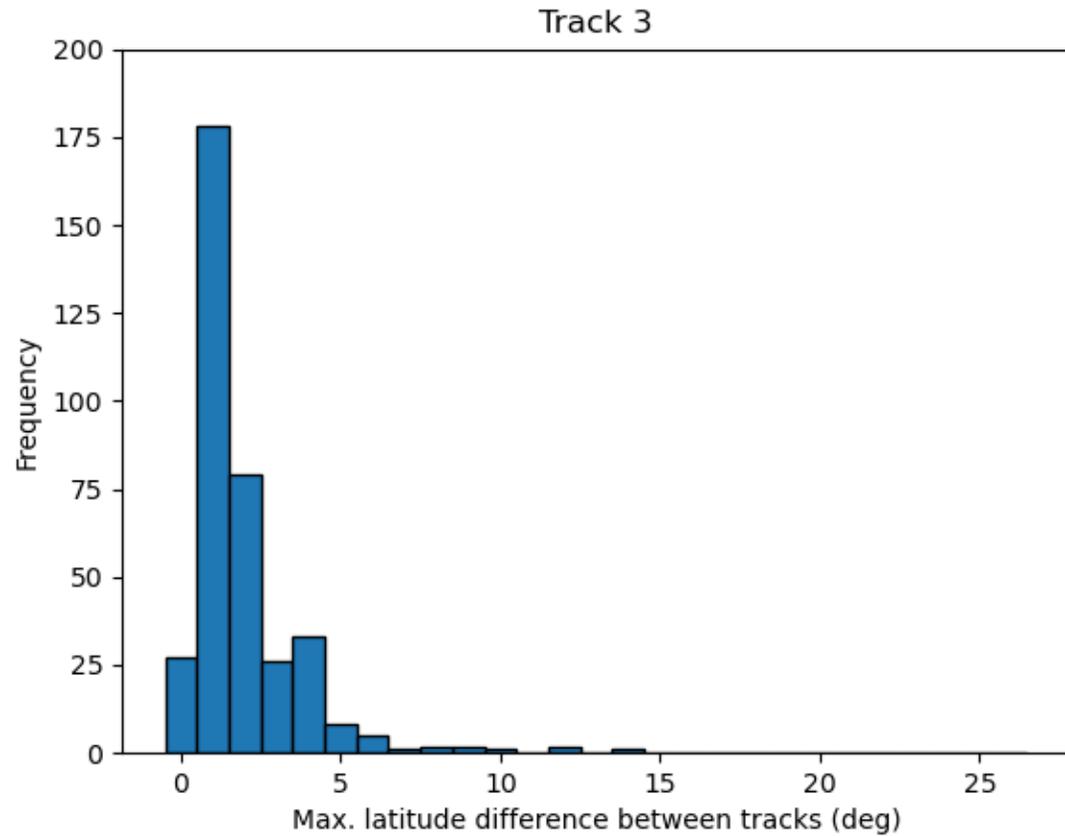
Day 1 (2019-01-01) Track 3



Day 1 (2019-01-01) Track F



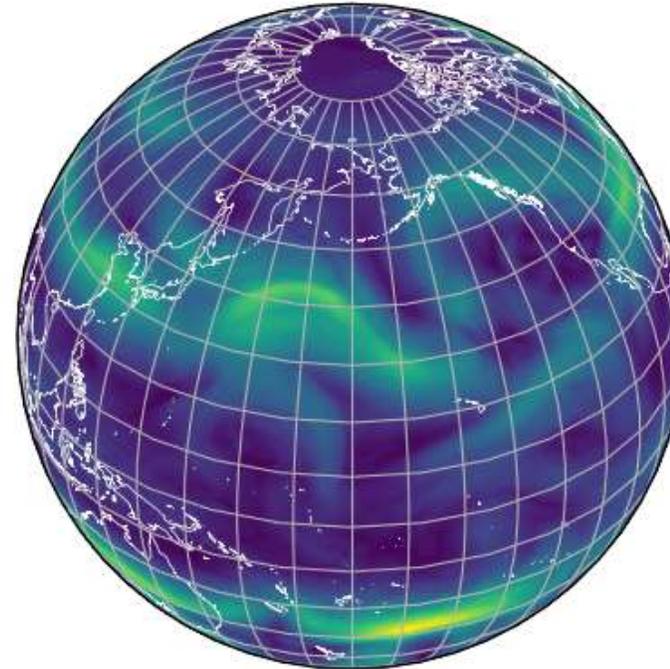
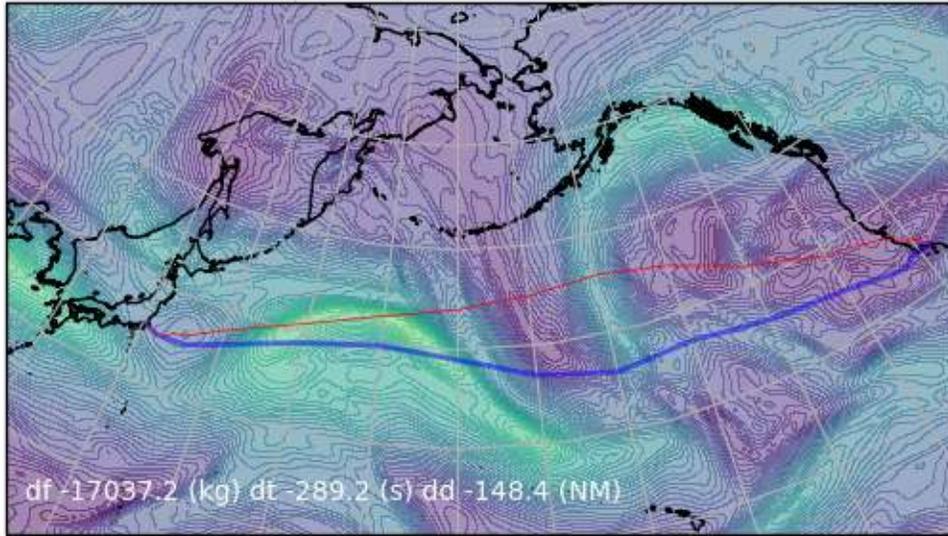
PACOTS validity: Track differences



PACOTS validity: Sample “split” case (Track 3)

2019-11-01 12UTC +24H forecast vs
2019-11-02 18UTC +00H forecast

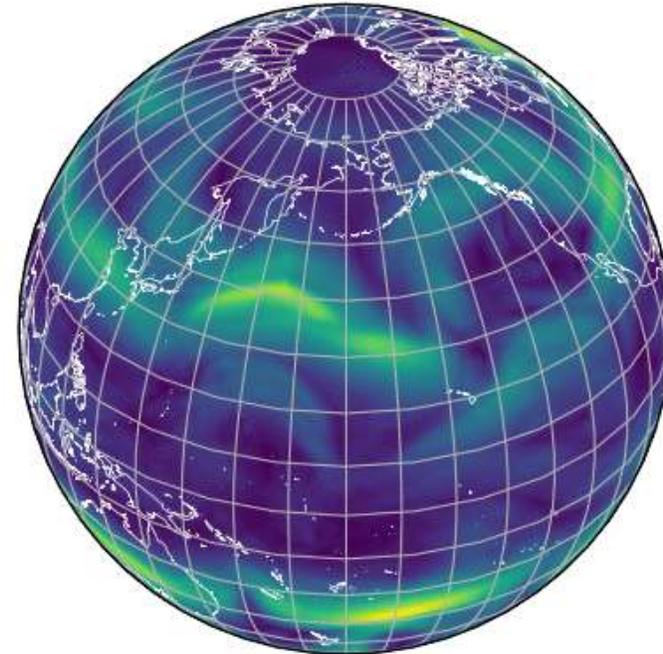
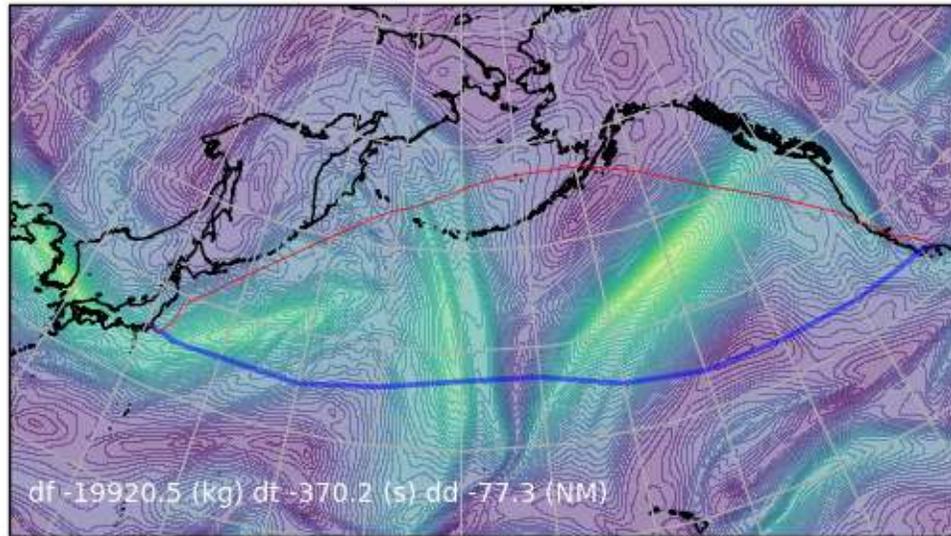
Day 306 (2019-11-02) Track 3



PACOTS validity: Sample “split” case (Track F)

2019-11-01 00UTC +24H forecast vs
2019-11-02 06UTC +00H forecast

Day 168 (2019-06-17) Track F



PACOTS validity: Conclusions

- Changes in computed track occur to Track 3 more than Track F due to greater sensitivity to changes in Jet Stream core position.
- Wind optimal track F may “flip” between north and south of jet stream core but not much difference in flight distance.

Thank you for your attention

Any questions?