A Simulation Study of Alternative Route Structures for NOPAC Airspace Reconfiguration

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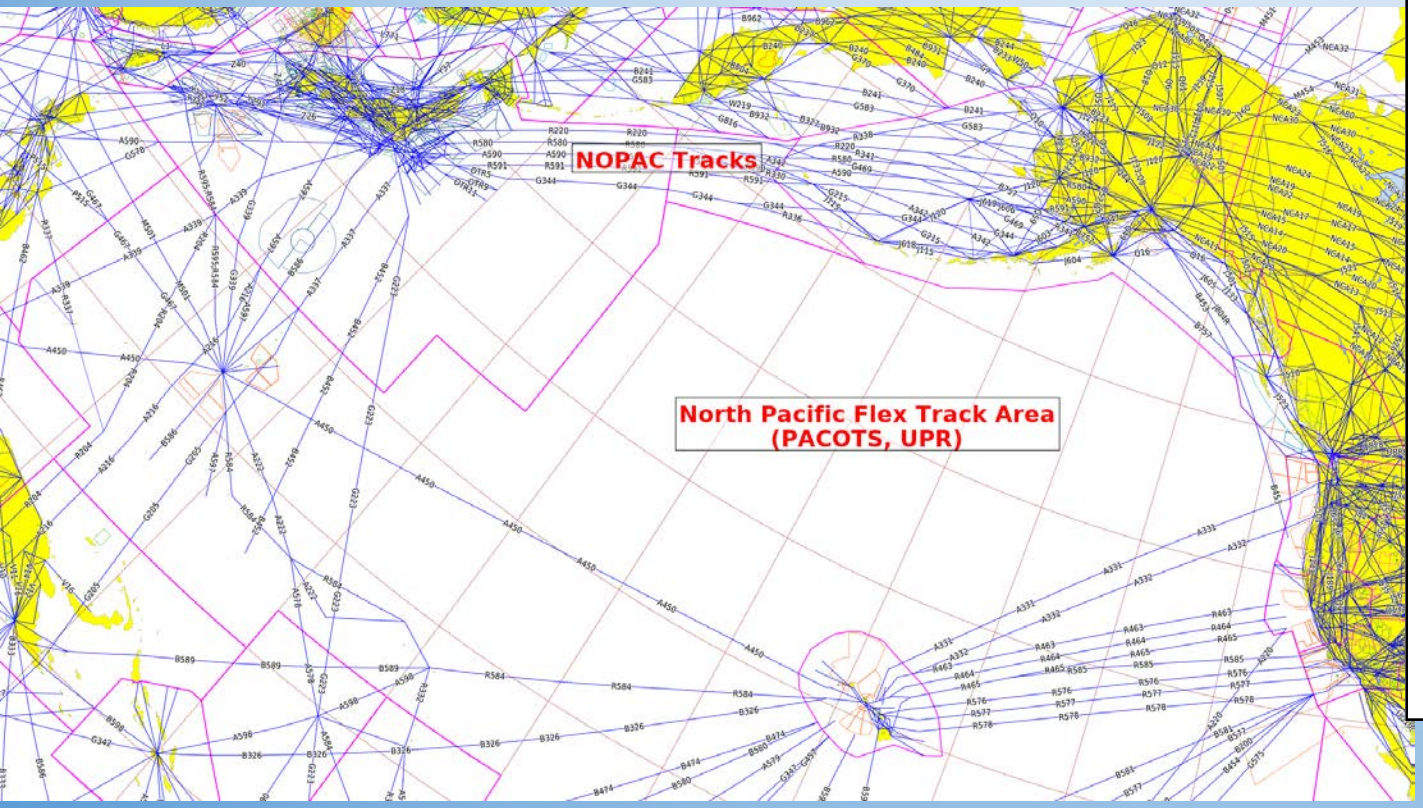
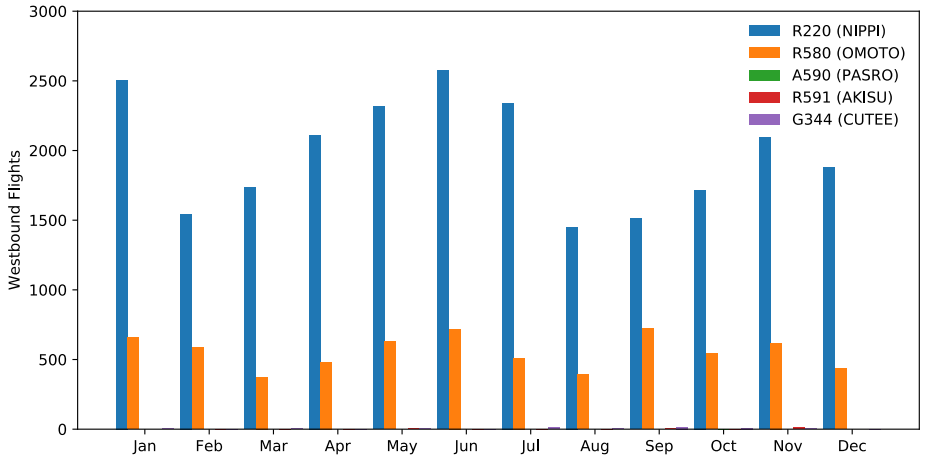
North Pacific operations

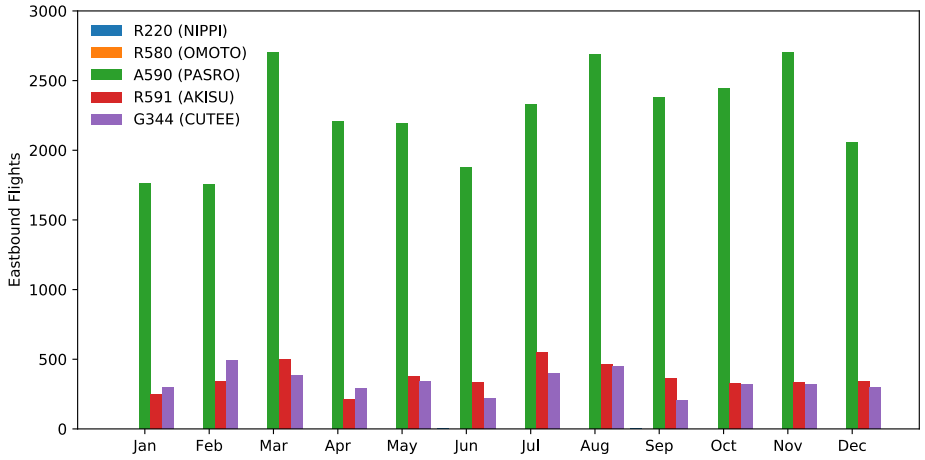
Flights between East Asia and North America in North Pacific airspace affected by seasonal movements of Polar Jet Stream, especially in winter.
-> eastbound flights route to take advantage of tailwinds
-> westbound flights route to avoid strongest headwinds

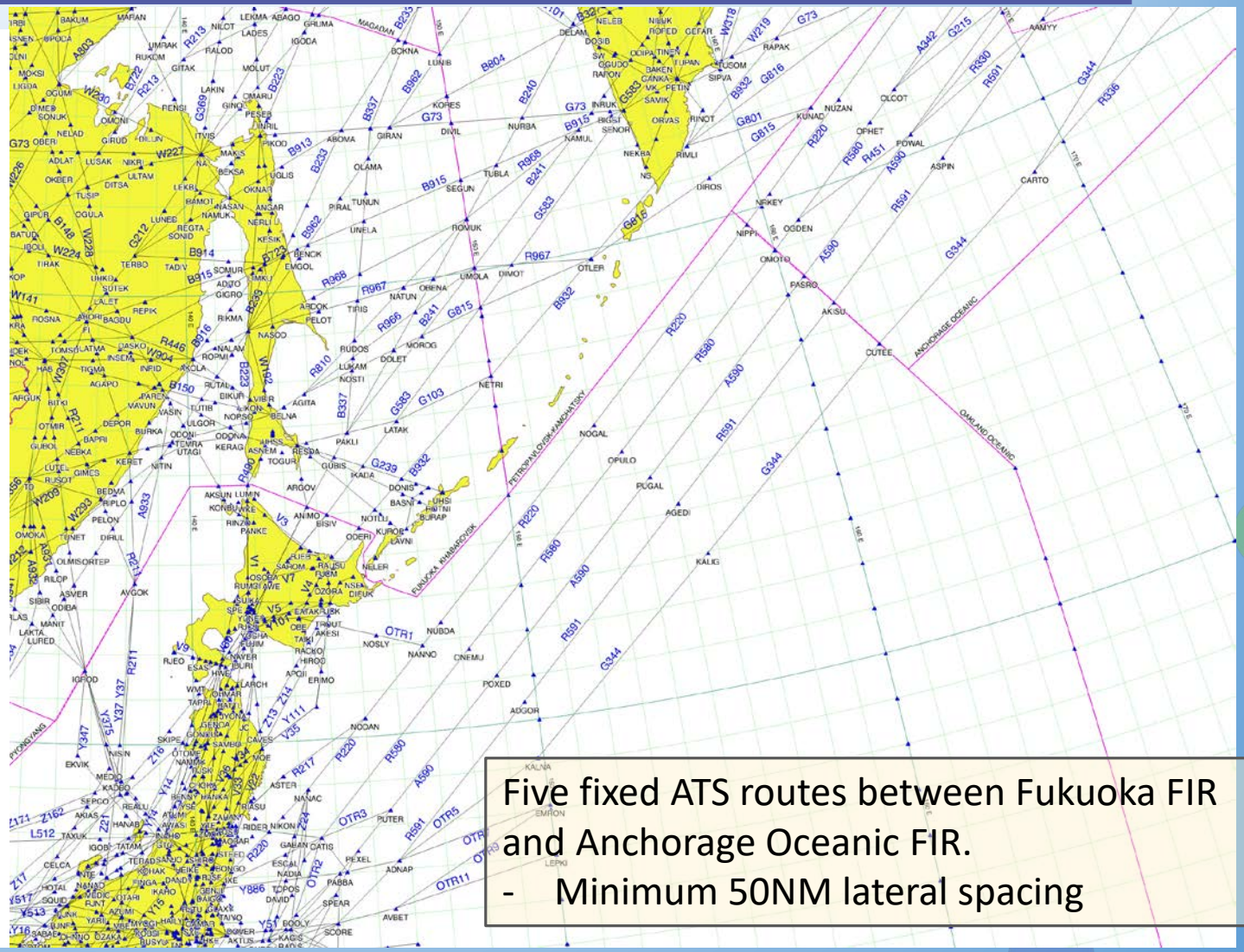


NOPAC routes

Monthly traffic counts 2018







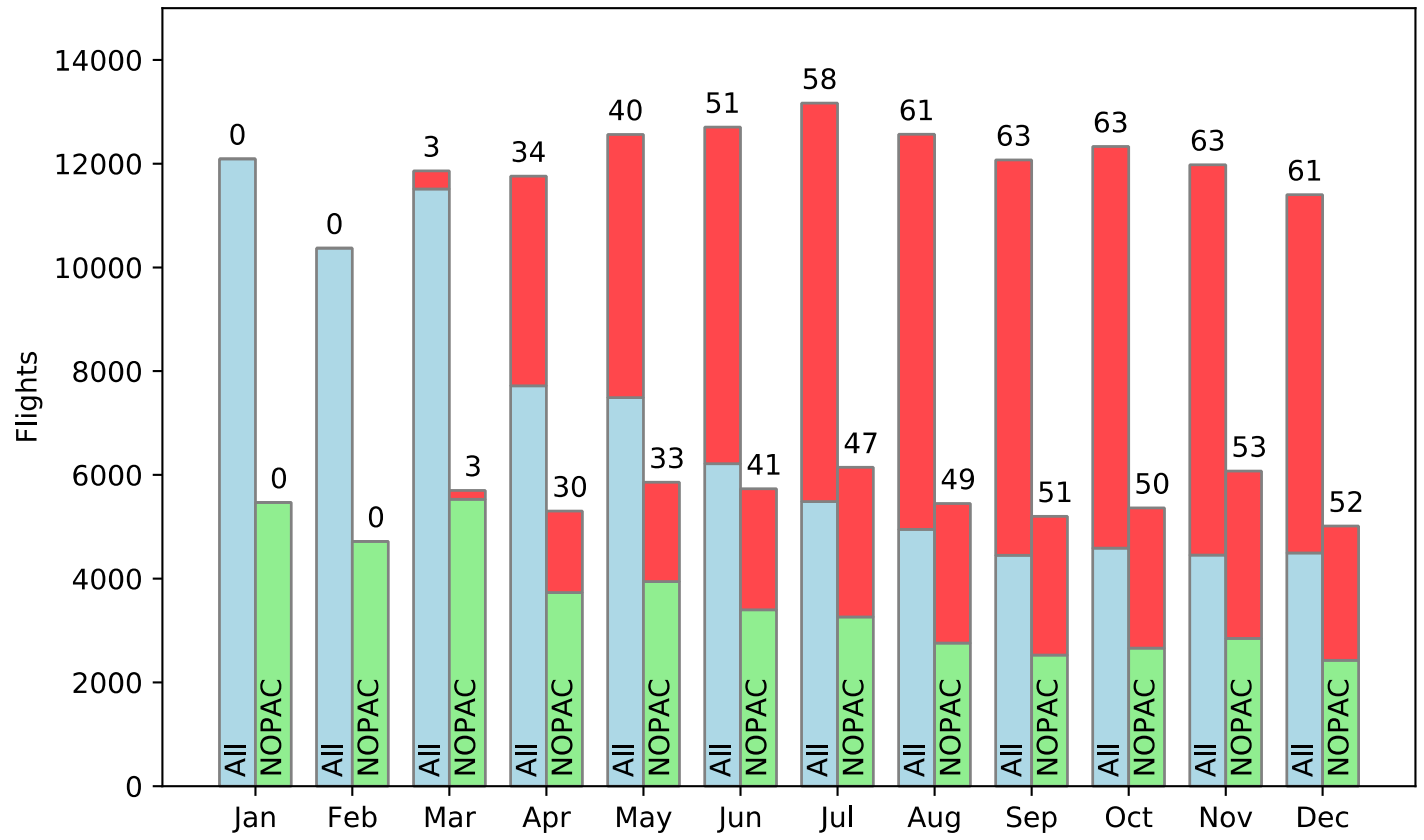
Five fixed ATS routes between Fukuoka FIR and Anchorage Oceanic FIR.

- Minimum 50NM lateral spacing

Need for NOPAC restructuring

- Current NOPAC route structure is as it was designed in 1980s.
  - 50NM lateral separation in oceanic airspace
- Performance-Based Communication & Surveillance (PBCS) leverages long-range data link communications (CPDLC, ADS-C) and improved navigation capability (GNSS) to allow separation to 25/25 (or better). Requires:
  - Airspace and communications performance monitoring
  - Suitably equipped aircraft (avionics capability and performance)
  - Regulator approval on a per airframe basis
- Restructure NOPAC to leverage advances in CNS.
  - Reduce NOPAC lateral route spacing. (Increase airspace available for PACOTS/UPR.)
  - Reduce longitudinal separation to increase capacity.

PBCS equipage



Non-PBCS, all flights

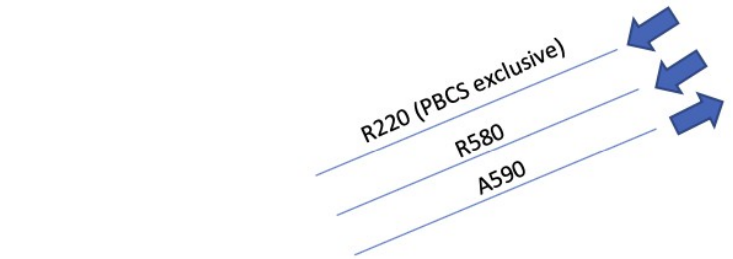
Non-PBCS, NOPAC

PBCS-approved

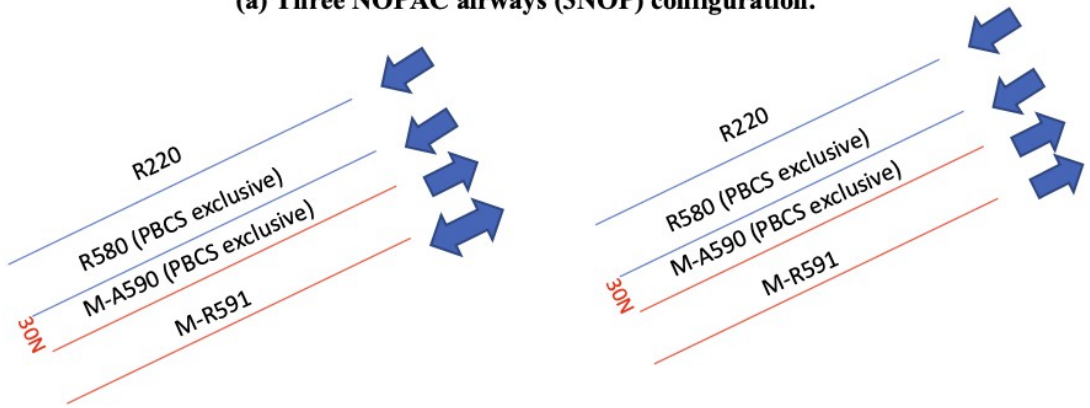
Figures above each column indicate percentage of PBCS-approved flights.

This Study

- "First look" simulation study to evaluate candidate NOPAC configurations proposals. *(Proposals created by Mr. Y. Suzuki of ATSRI, commissioned by JCAB.)*
- Look at fuel benefit, traffic changes, conflicts.



(a) Three NOPAC airways (3NOP) configuration.



(b) Four NOPAC airways with (left) bidirectional modified R591 (4NOP-2way) and (right) eastbound only modified R591 (4NOP-east)

Experiment variables

Variable	Values	Description
NOPAC airway configuration	Baseline	Current NOPAC ATS route configuration (five airways).
	3NOP	Three airways, 50 NM separated, R220 PBCS exclusive.
	4NOP-2way	Four airways, A590 moved to 30 NM parallel to R580, R591 moved to 50 NM parallel to modified A590 and bidirectional. Centre two airways PBCS exclusive.
	4NOP-east	Same as 4NOP-2way but with M-R591 eastbound only.
Season (day)	2018/01/20	Winter seasonal wind pattern (strong jet stream winds).
	2018/07/20	Summer seasonal wind pattern.
PBCS approval	PBCS60	Approximately 60% of flights with PBCS approval.
	PBCS90	Approximately 90% of flights with PBCS approval.

Traffic Scenarios

- All air transportation flights that operated in Fukuoka FIR oceanic airspace between Asia and North America between 00:00-24:00 JST on the scenario days.

PBCS \ Day		2018/01/20		2018/07/20	
	Traffic flow	Flight count	PBCS approved	Flight count	PBCS approved
PBCS60	Eastbound	262	139 (53%)	235	132 (56%)
	Westbound	178	112 (63%)	228	135 (59%)
	Total	440	251 (57%)	463	267 (58%)
PBCS90	Eastbound	262	235 (90%)	235	220 (93%)
	Westbound	178	161 (90%)	228	217 (95%)
	Total	440	396 (90%)	463	437 (94%)

Traffic scenario summary

Scenario		"PBCS approved" flight criterion
Day	PBCS	
2018/07/20	PBCS60	All RCP240 and RSP180 capable flights (from flight plan).
2018/01/20	PBCS60	All callsigns determined as RCP240 and RSP180 capable in the 2018/7/20 scenario, plus flights by major passenger carriers.
2018/07/20	PBCS90	All flights except with aircraft types B737, B763, B772, FA7X, MD11.
2018/01/20	PBCS90	All flights except with aircraft types B737, B763, B772, FA7X, MD11, and 50% of flights with aircraft type B744.

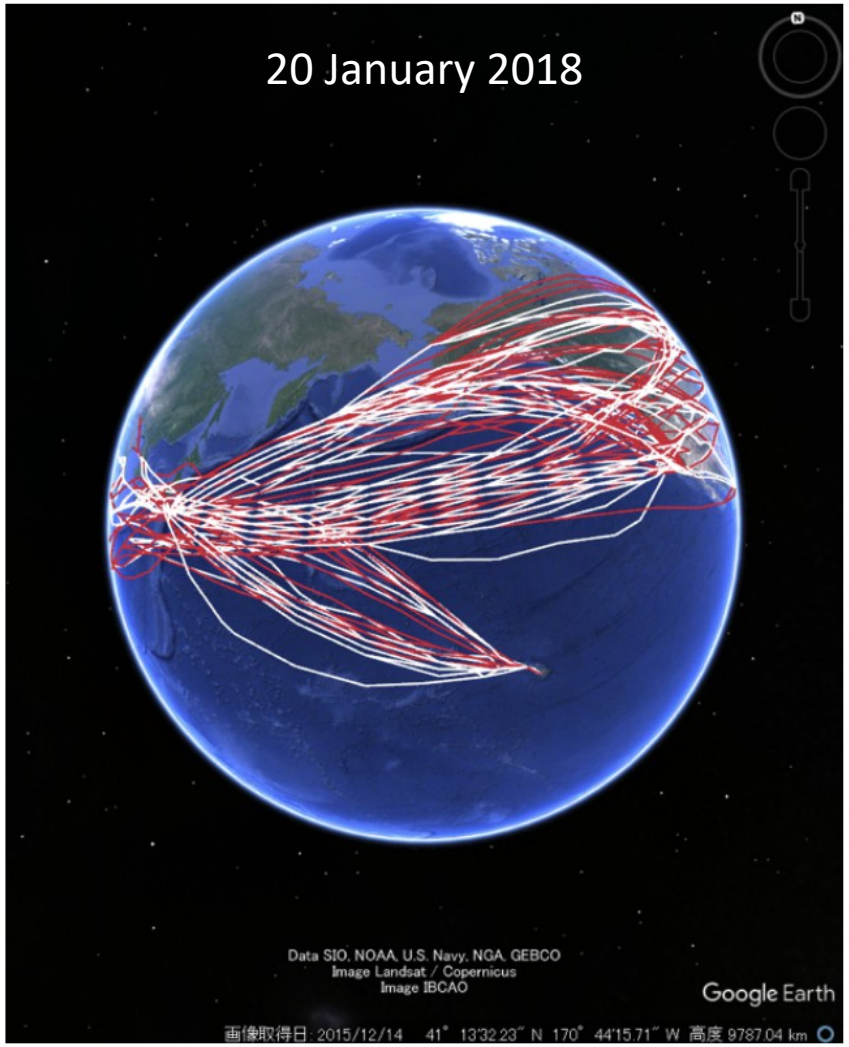
Criteria for determining PBCS flights

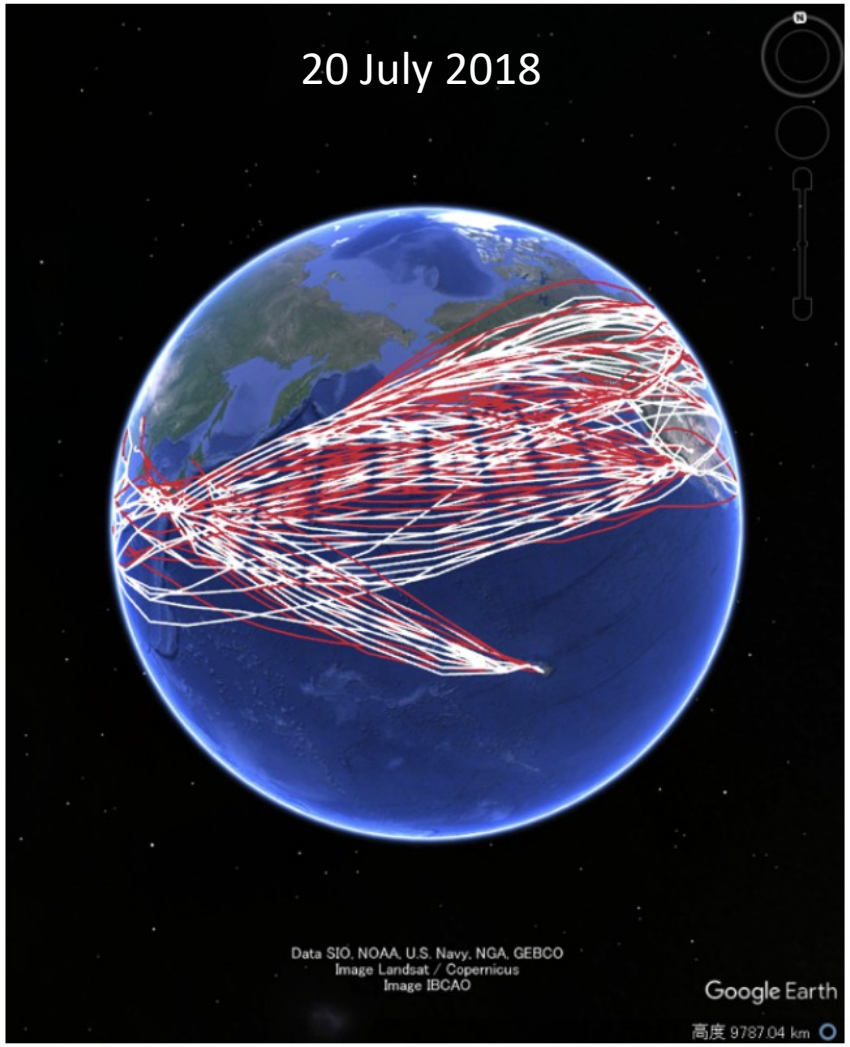
Flight Route and Fuel/Time Calculations

- Routes must be calculated for each flight to reflect wind, NOPAC route structure and PBCS capability/constraints. Create link-node ”graphs” of possible route segments for each NOPAC and PBCS restriction, and calculate minimum time flight routes with Dijkstra’s shortest path search.
  - Cruise phase only.
  - Cruise speed and take-off weight from BADA3.
  - No step climb. Flight plan cruise level used.

- Fast-time simulation with AirTOp using computed routes.
  - Cruise phase only (climb/descent not simulated).
  - ATC/ATM functions (conflict resolution etc.) disabled but trajectories analysed for conflicts.

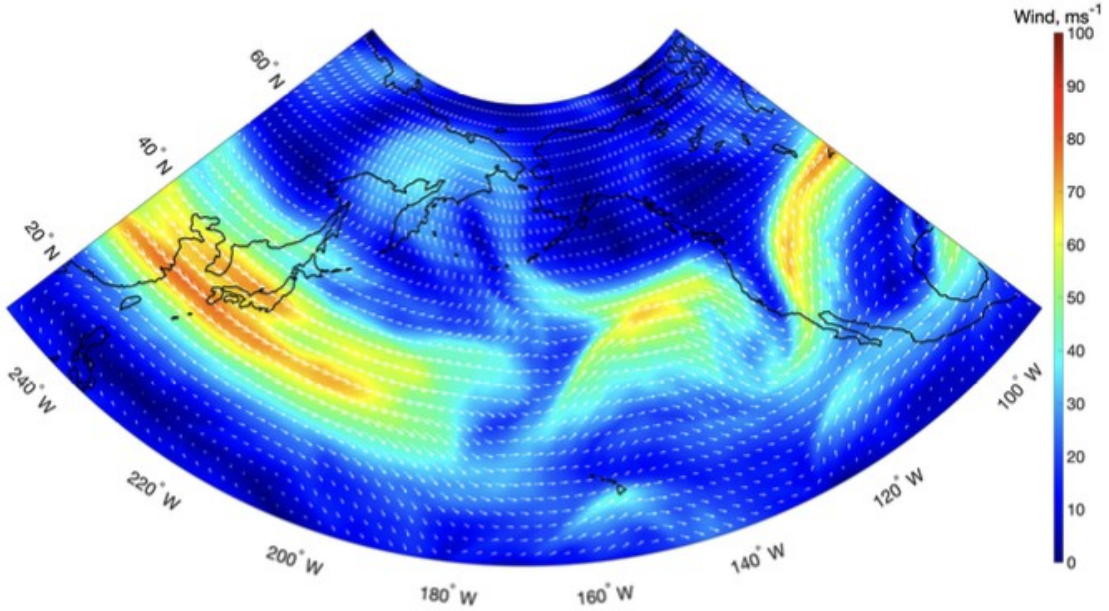
Route Calculation example: flight plan (white) vs min. time (red)



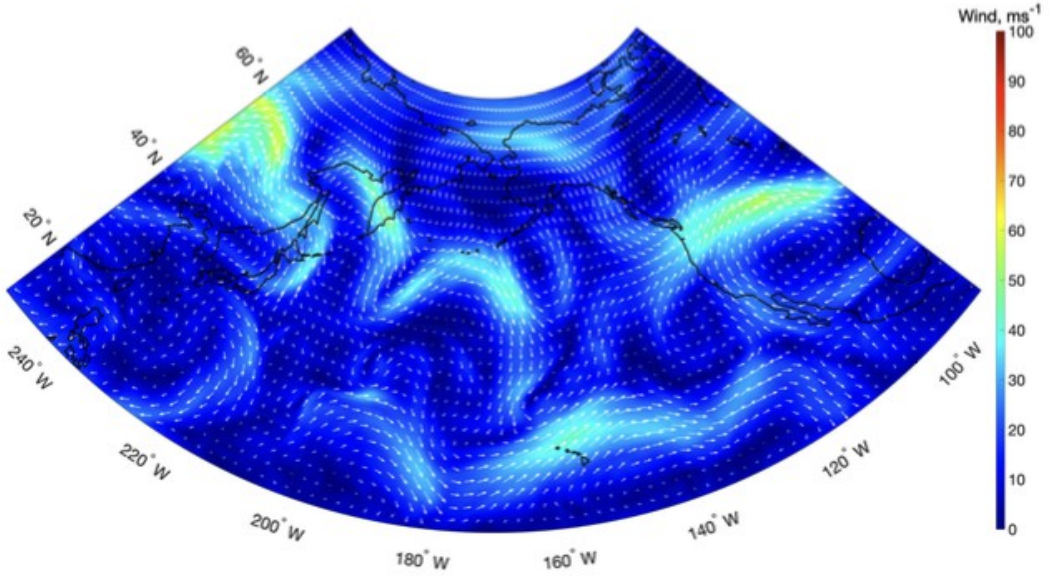


Wind patterns

Winds at 200 hPa from Global Spectral Model numerical forecast (+0h) at 12:00 UTC



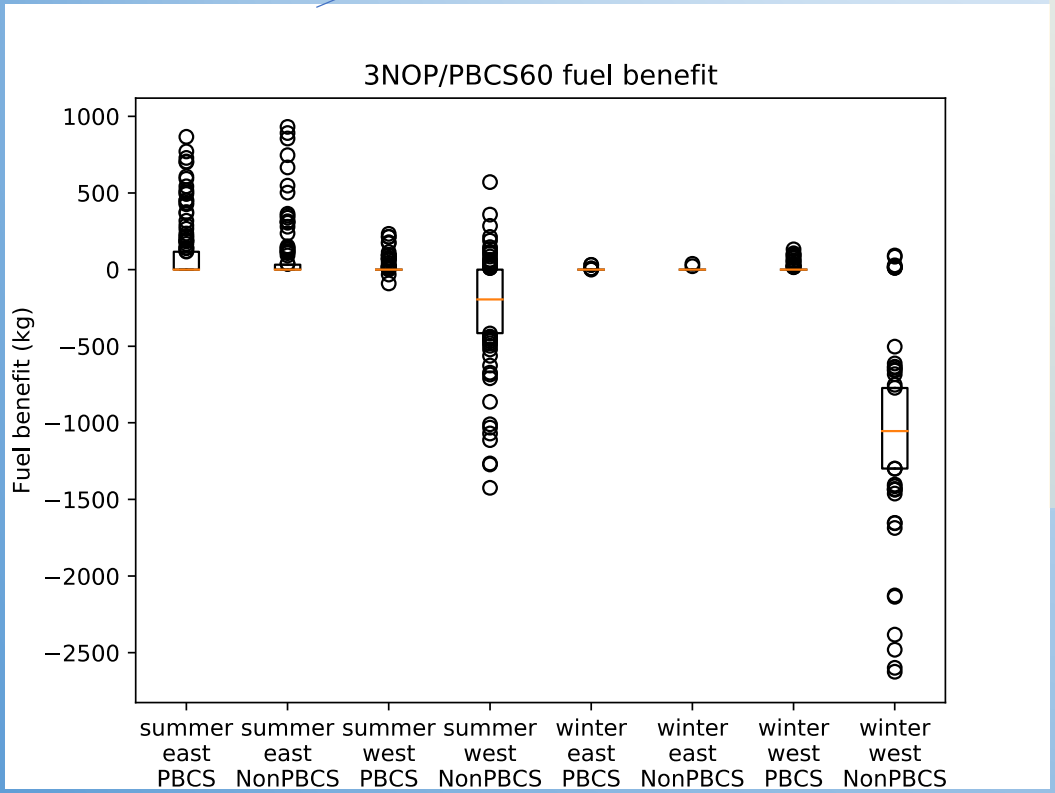
20 January 2018



20 July 2018

Use JMA GSM gridded numerical forecast data (published at 6-hour intervals).
Interpolate spatially and temporally between “nowcast” data sets.

Results: 3NOP



Eastbound (green plots)

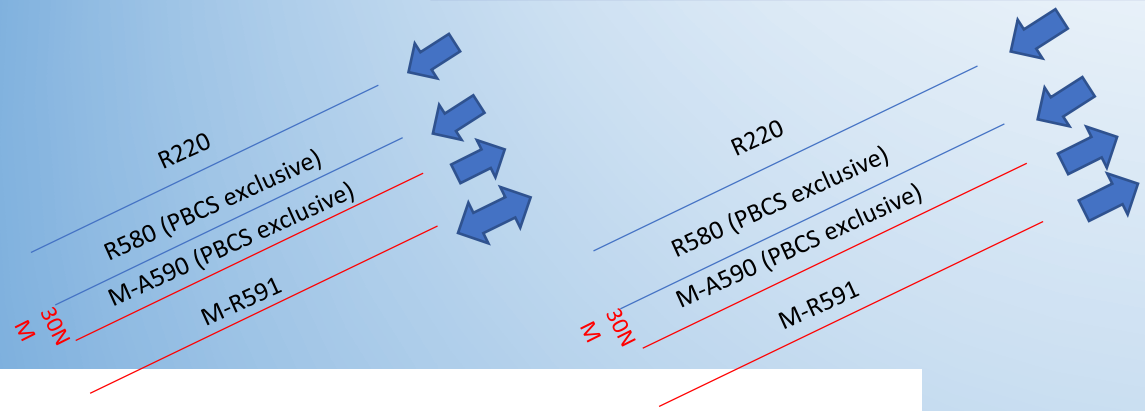
- Smaller NOPAC footprint increases flex track area, giving benefit for eastbound flights especially in summer (jet stream further north).
- Little benefit in winter because jet stream south of current NOPAC area.
- No penalty for non-PBCS aircraft.

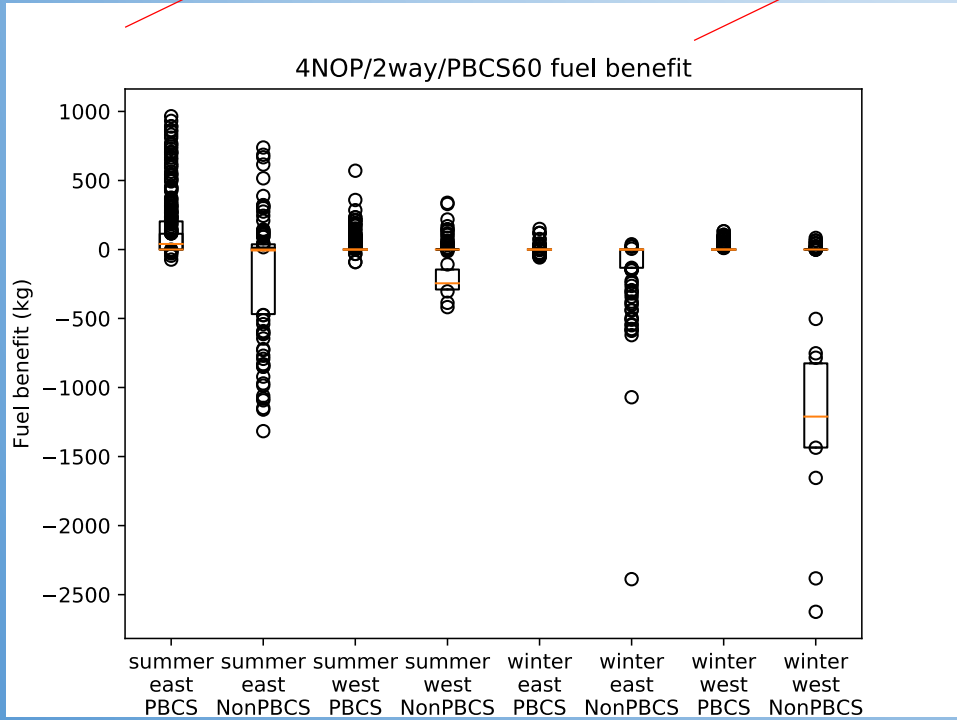
Westbound (red plots)

- Slight benefit for PBCS aircraft in winter/summer – possibly due to R580 being closer to the wind-optimal ideal path (generally as far North as possible in NOPAC).
- Penalty for non-PBCS aircraft since must use R580, not the generally more favourable R220.

Boxes: 25th-75th percentile extent.
Black circles: outliers
Green: eastbound Red: westbound
Dots: PBCS flights Crosses: non-PBCS flights

Results: 4NOP





- Little effect of making R591 bidirectional (on the scenario days)

Eastbound (green plots)

- A590 preferential in baseline scenarios in both summer and winter.
- Net negative benefit for non-PBCS flights – mostly due to cargo flights to PANC unable to use PBCS-exclusive modified A590.

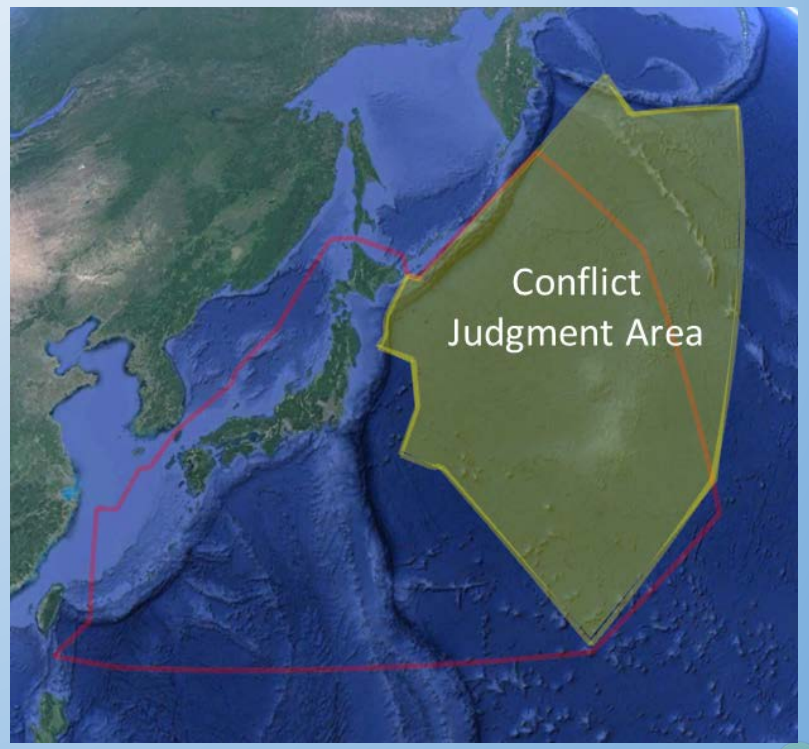
Westbound (red plots)

- Small positive benefit for flights mainly from NAM west coast able to use northward expansion of flex track area.
- Non-PBCS flights penalised by not being able to use PBCS-exclusive R580.

Boxes: 25th-75th percentile extent.
Black circles: outliers
Green: eastbound Red: westbound
Dots: PBCS flights Crosses: non-PBCS flights

Results: Conflicts

- Conflicts increase controller workload.
  Checked for conflicts in the indicated area with minimum separation depending on PBCS status of aircraft pairs.
  More conflicts in winter than summer due to higher demand for R220 and R250 from westbound flights.
- Fewer conflicts in PBCS90 scenarios due to lower permissible separation distances.
- 3NOP:
  - PBCS-exclusive R580 splits westbound traffic between two routes, reducing conflicts in Fukuoka FIR compared to baseline but increases conflicts in Anchorage FIR.
  - Increased conflicts in flex track area in summer as more flights able to take advantage of expanded flex track area.



Capacity

- Not directly addressed in this study.

- PBCS can reduce longitudinal (in trail) spacing, but...
- Increased capacity only really a benefit at peak times and may increase air traffic control workload for “loading” and “unloading” the tracks.

Study Limitations

- Only two wind patterns: the most favourable NOPAC tracks vary depending on the day.
- Created possible route networks between flex track area and airports based on 8 months of flight plans: might not be fully representative for city pairs with few flights.
- Fleet mix for the PBCS90 scenario might not be realistic. However, simulation showed overall effect of increased PBCS equipage.

Conclusion

- Study confirmed expected trends.
  - Reducing the NOPAC area ”footprint” (increasing flex track area) is particularly beneficial in summer but less effect in winter

    (In winter, optimal eastbound tracks are further south and optimal westbound tracks are north of the expanded area.)

  - Making high-demand NOPAC routes PBCS-exclusive penalises non-PBCS operators

    (Non-PBCS mainly cargo operators with older aircraft not economical to retrofit, and flights unable to operate in flex track airspace: e.g. delivery flights, charter, GA.)

- These findings will also apply to other NOPAC configurations.

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