MIT
International Center for
Air Transportation

Procedure Design Concepts for Logan Airport Community Noise Reduction

Runway 33L Impacted Communities Focus Briefing

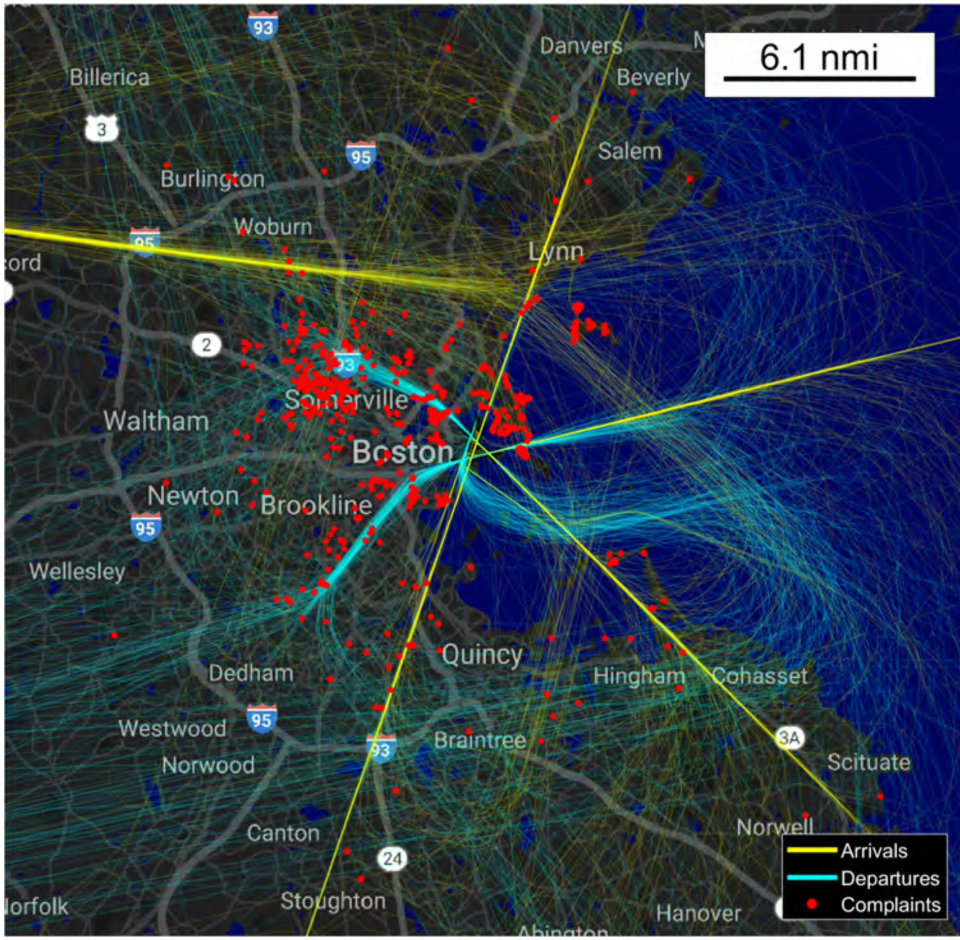
R. John Hansman

rjhans@mit.edu

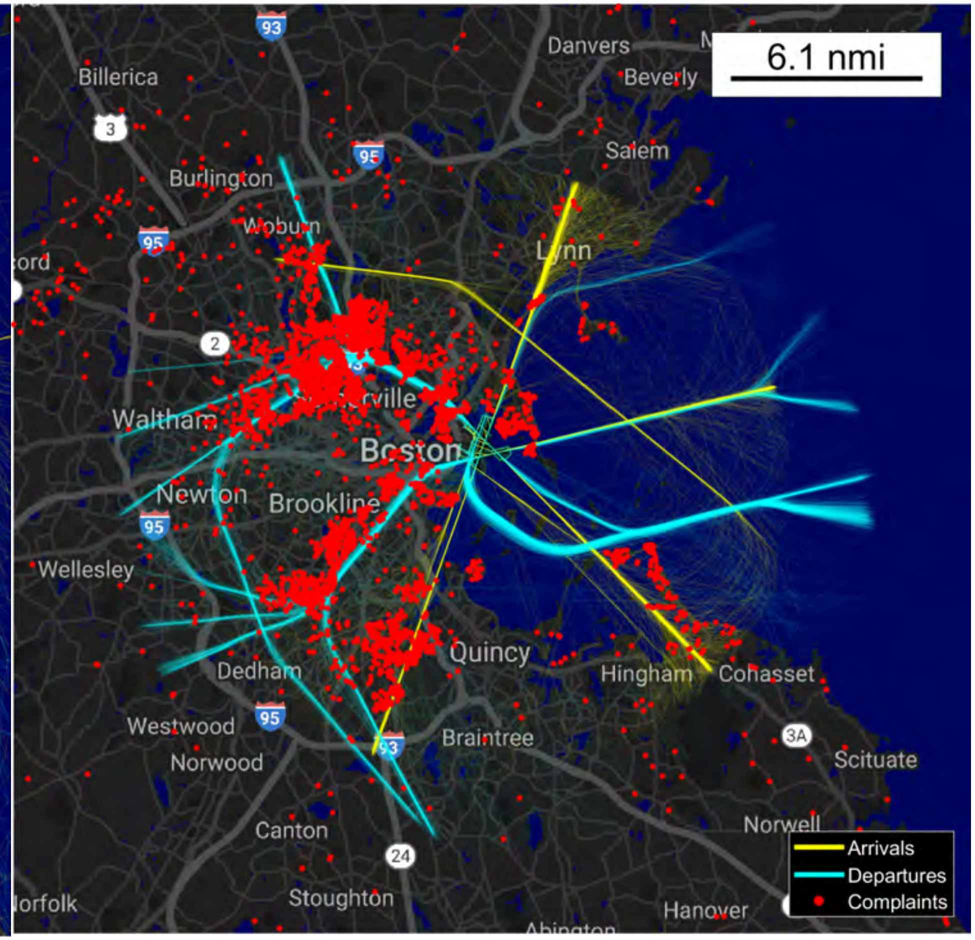
Technical support from MIT ICAT students, HMMH, and Massport

RNAV Track Concentration

2010



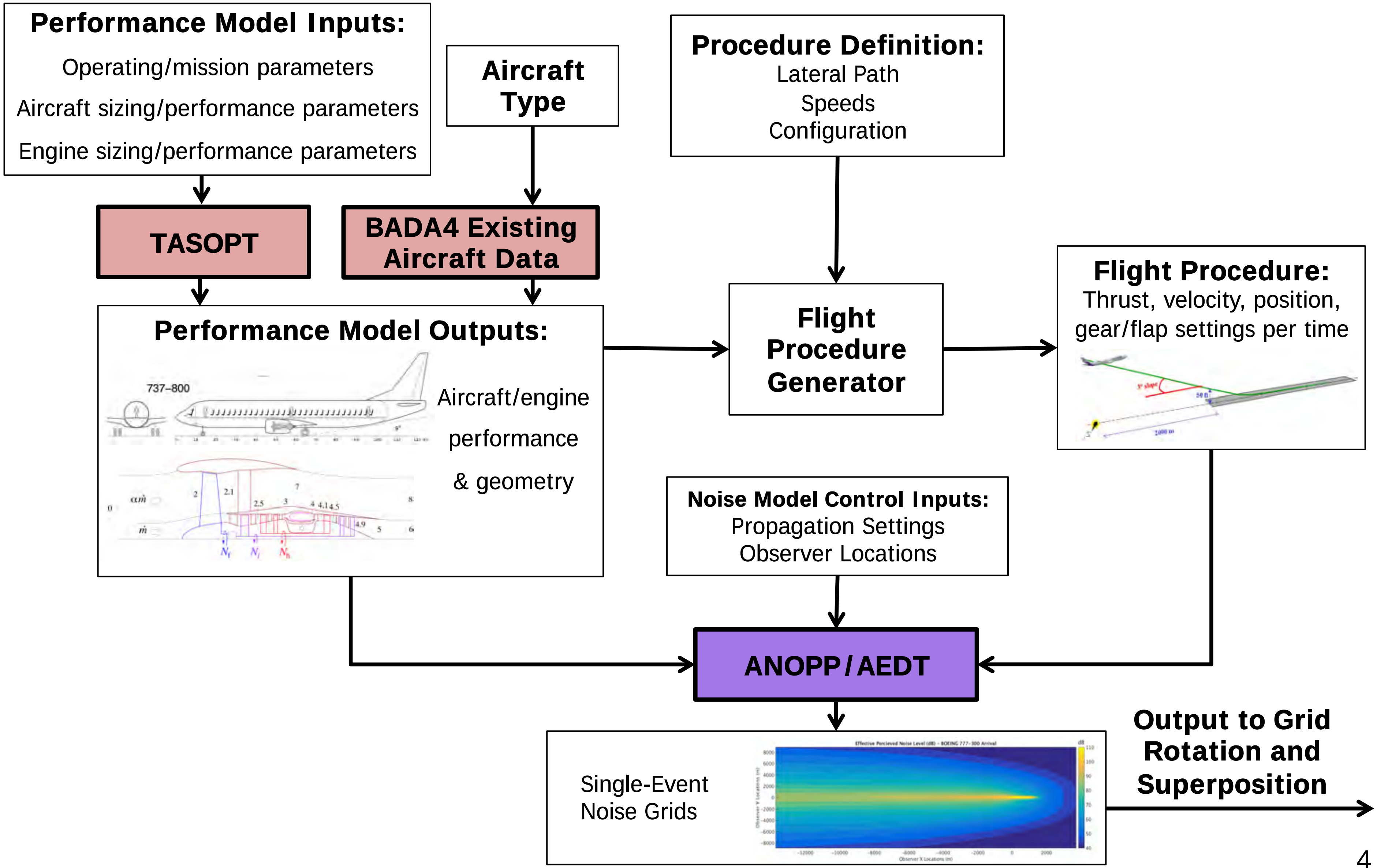
2017



Technical Approach

- Collect Data and Evaluate Baseline Conditions
  - Pre and Post RNAV
  - Community Input (Meetings and MCAC)
- Identify Candidate Procedure Modifications
  - Block 1
    - Clear noise benefit, no equity issues, limited operational/technical barriers
  - Block 2
    - More complex due to potential operational/technical barriers or equity issues
- Model Noise Impact
  - Standard and Supplemental Metrics
- Evaluate Implementation Barriers
  - Aircraft Performance
  - Navigation and Flight Management (FMS)
  - Flight Crew Workload
  - Safety
  - Procedure Design
  - Air Traffic Control Workload
- Recommend Procedural Modifications to Massport and FAA
- Repeat for Block 2

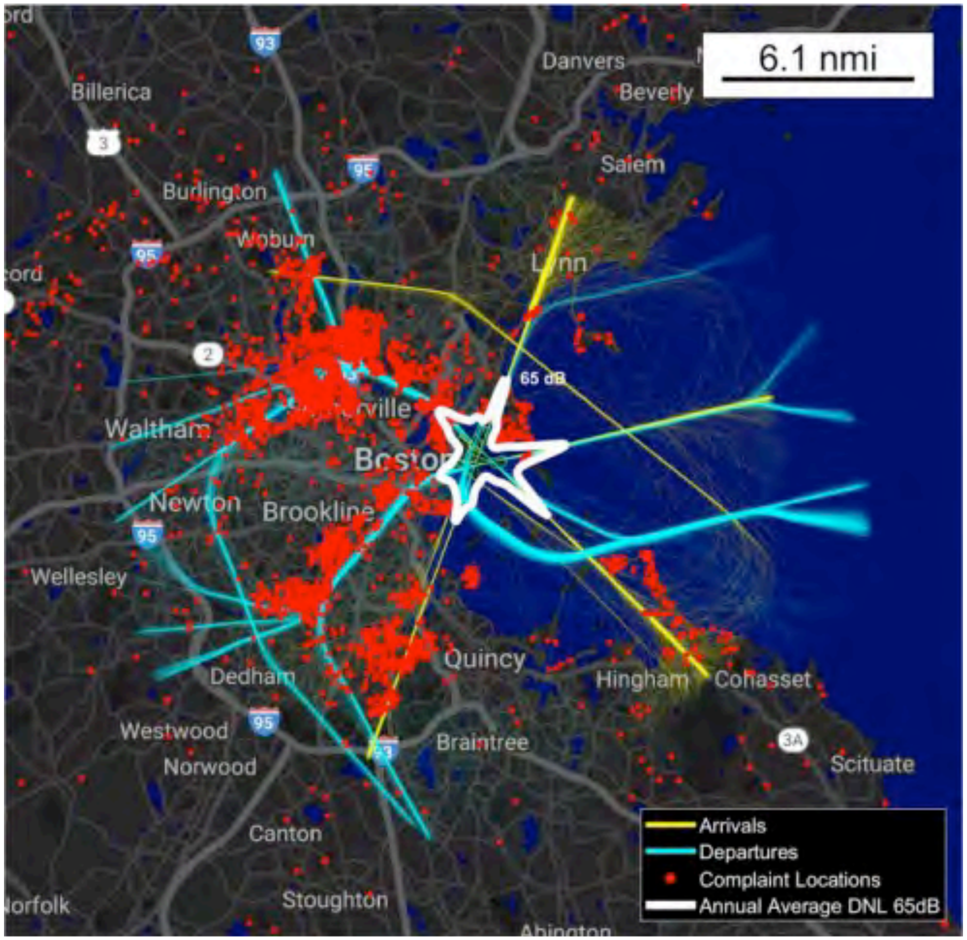
Noise Modeling Framework



Alternative Metrics to Capture RNAV Concentration Impacts

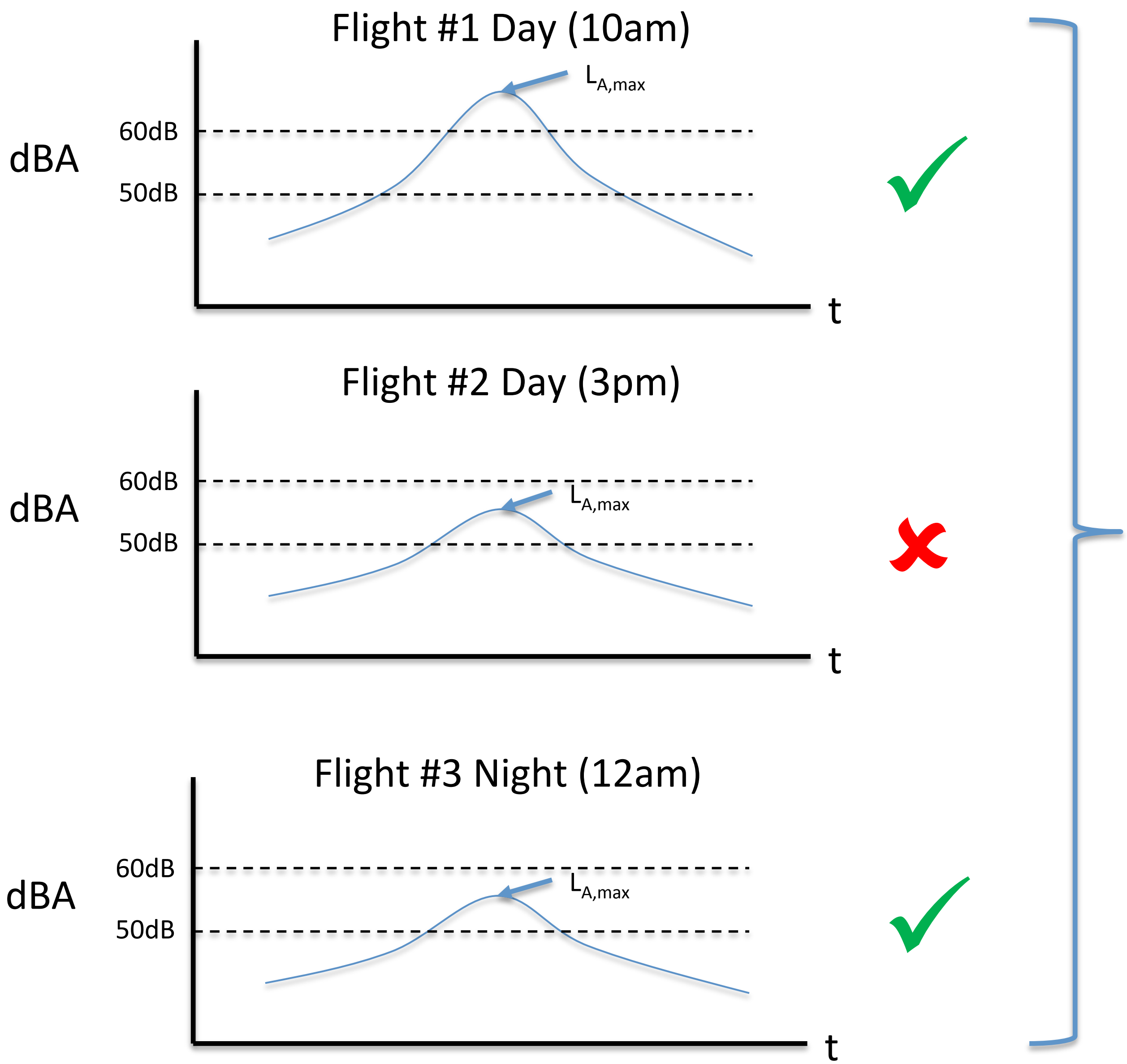
- RNAV concentration issue outside of Annual Average DNL 65dB contour
- Complaints frequently cite repetitive overfights as a concern
- Evaluated number of overflights above a threshold level on a peak day of runway use as an alternative metric at BOS, LHR, CLT, MSP

2017



Alternate Metric

N_{60} Number of Overflight Events (60dB Day, 50 dB Night)



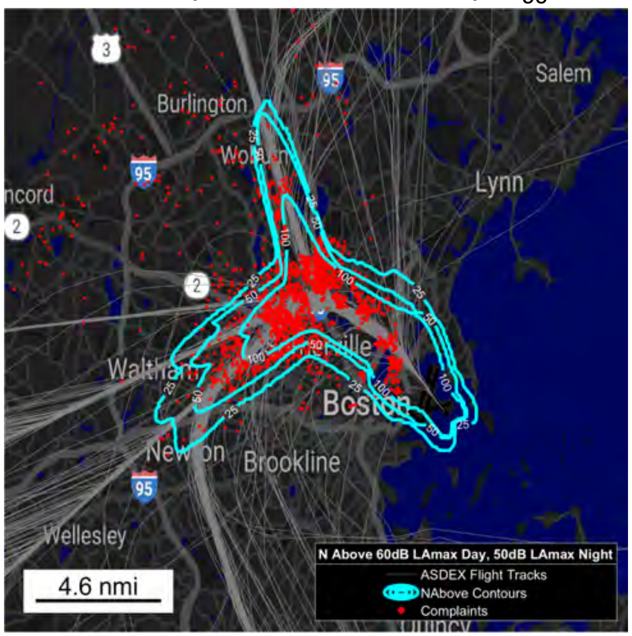
= 2 N_{60}

(60dB $L_{A,max}$ Day
50dB $L_{A,max}$ Night)

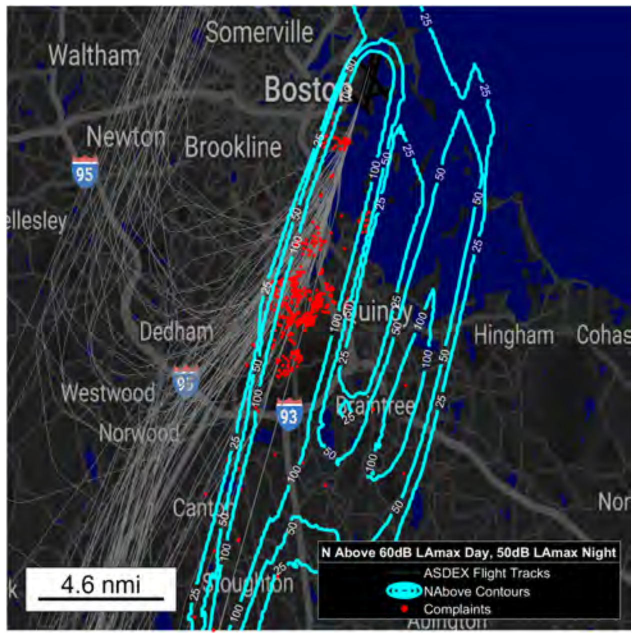
BOS N_{60} Count Thresholds

- N_{60} on a peak day with 50 overflights appears to capture complaint threshold in dispersion analysis

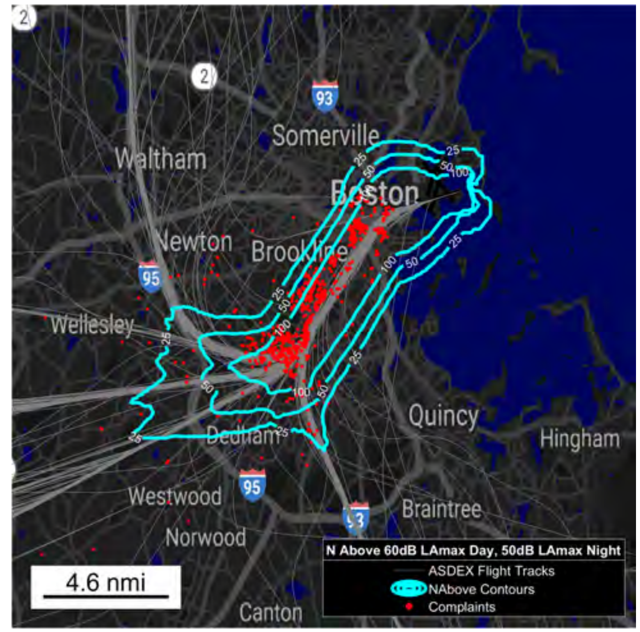
33L Departures Peak Day N_{60}



4L/R Arrivals Peak Day N_{60}



27 Departures Peak Day N_{60}



Peak Day N_{60}	Complaints Captured
25x	87.3%
50x	80.9%
100x	59.4%

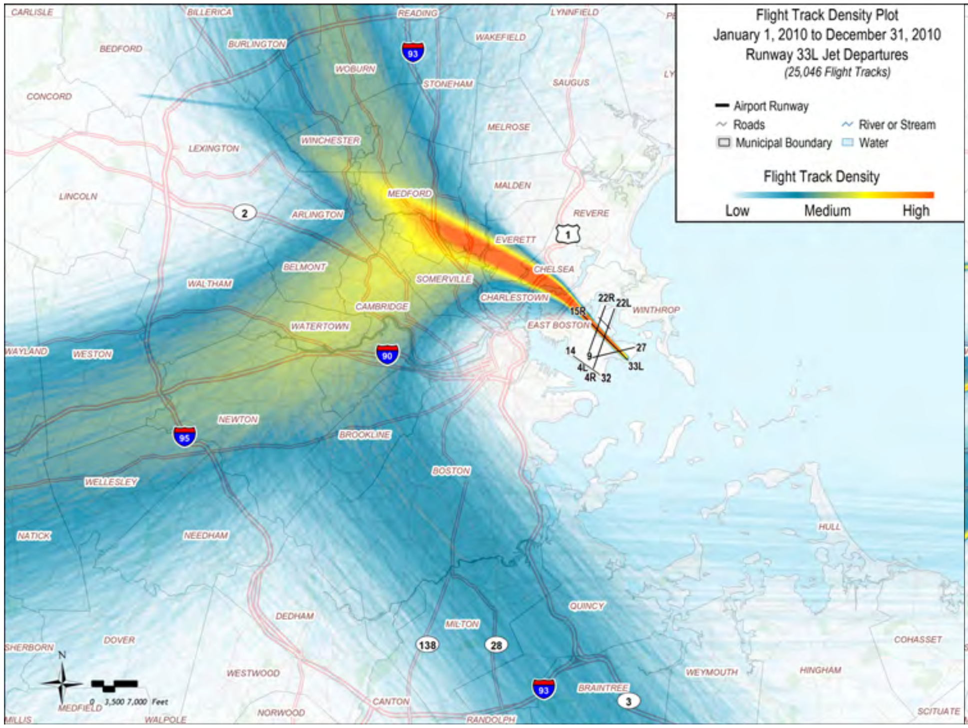
Peak Day N_{60}	Complaints Captured
25x	97.7%
50x	94.7%
100x	81.0%

Peak Day N_{60}	Complaints Captured
25x	95.4%
50x	92.1%
100x	78.8%

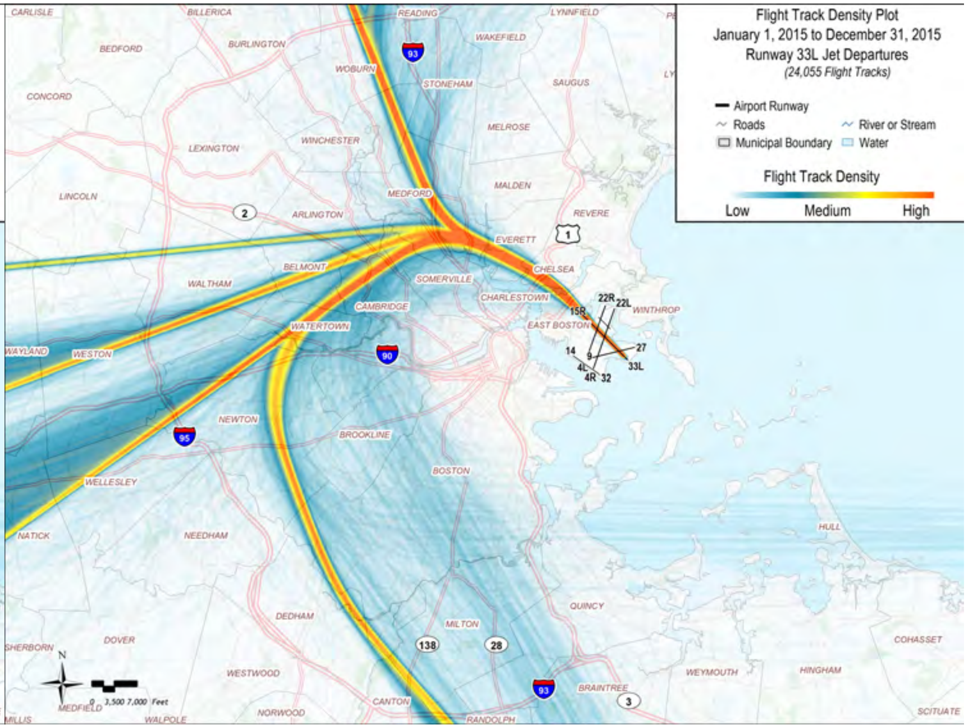
2017 Data

RNAV Track Concentration

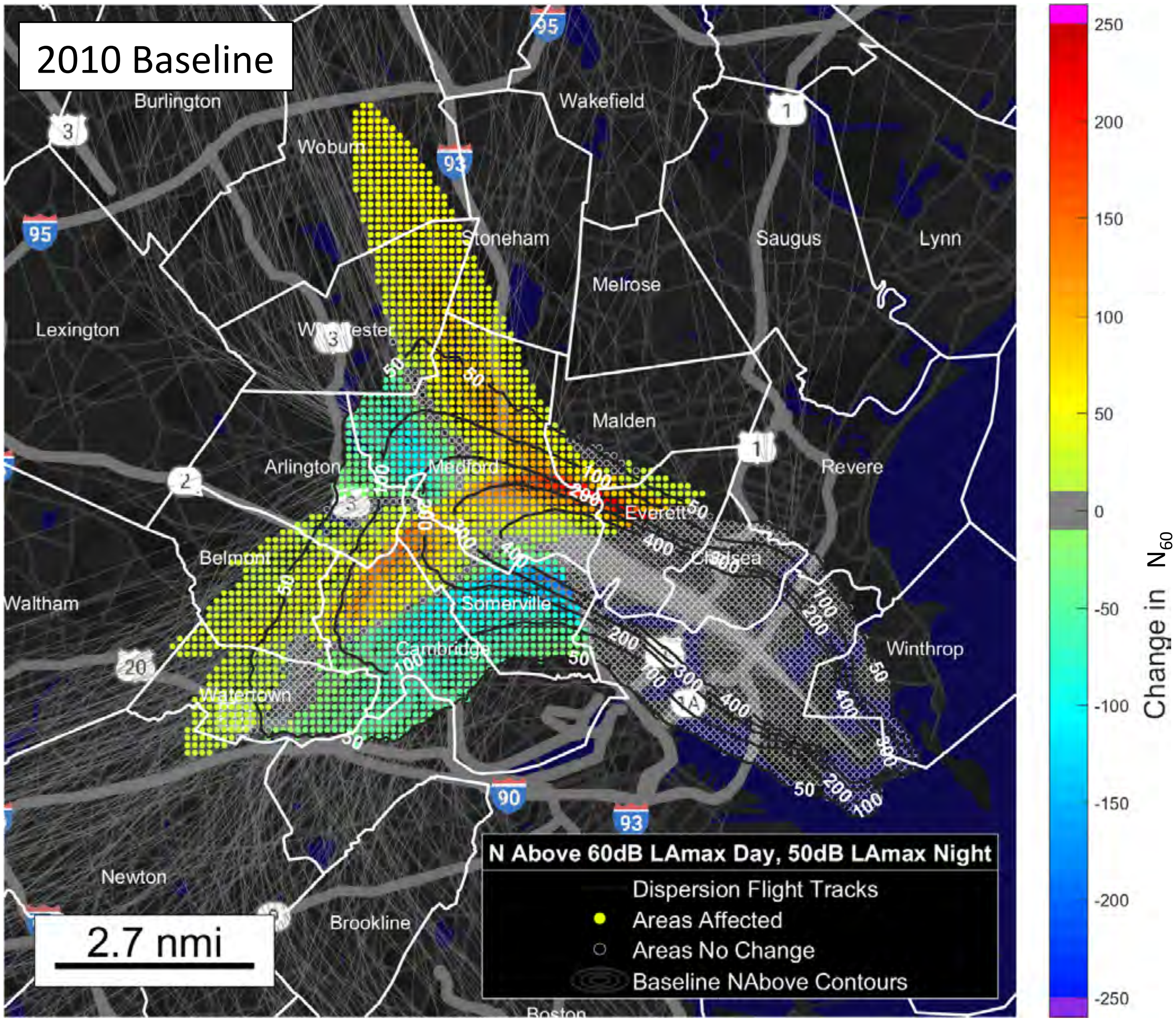
2010



2015



Effect of RNAV Concentration on 33L Departures
2010 to 2017



Population Exposure

N_{60}	50x
Dispersion	356,960
RNAV	344,244
RNAV Benefit	12,716

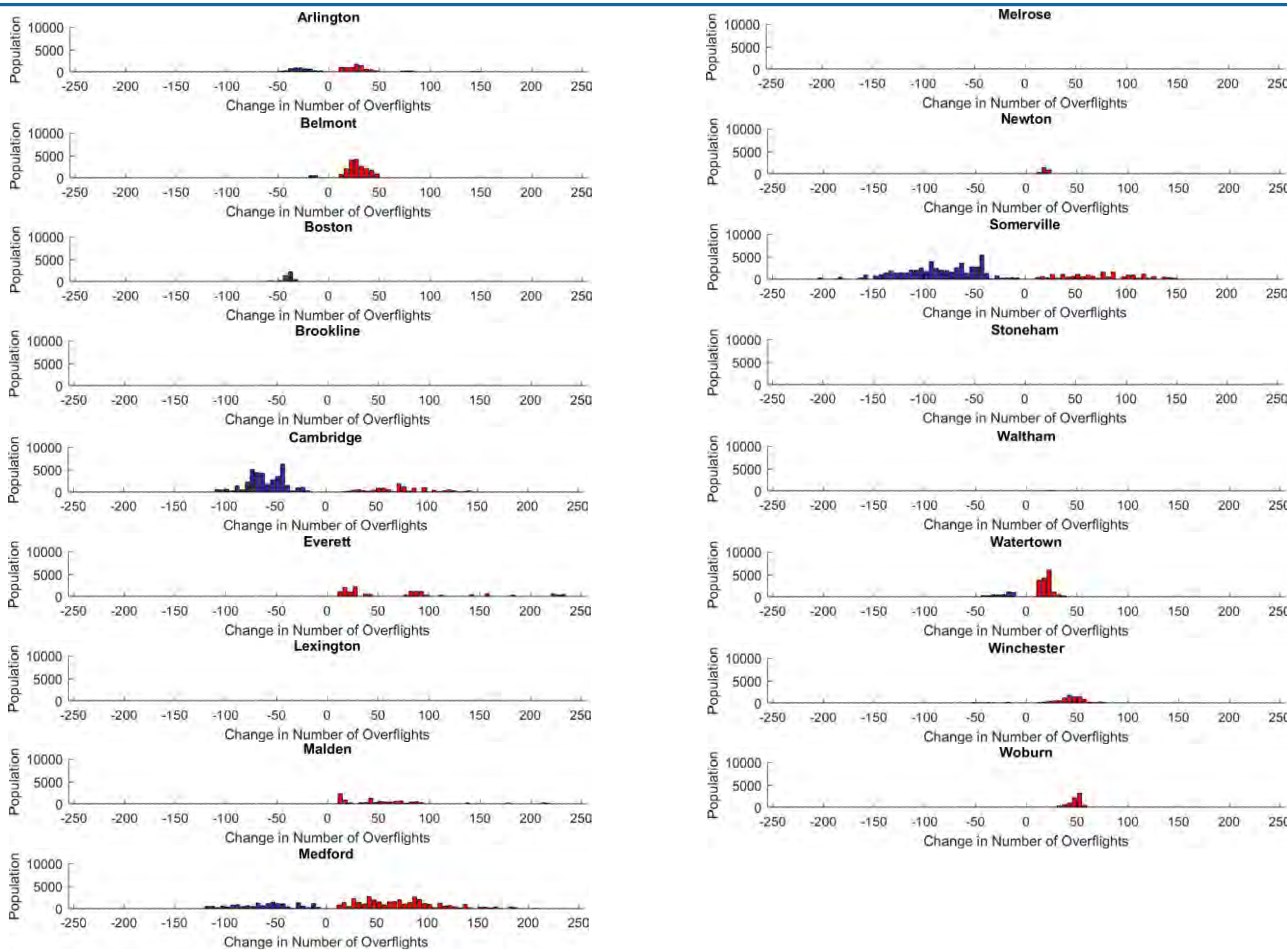
Analysis updated Dec 4 2018 to correct for discretization differences

Analysis based on peak day operations; only includes 33L departures

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

Effect of RNAV Concentration on 33L Departures

2010 to 2017



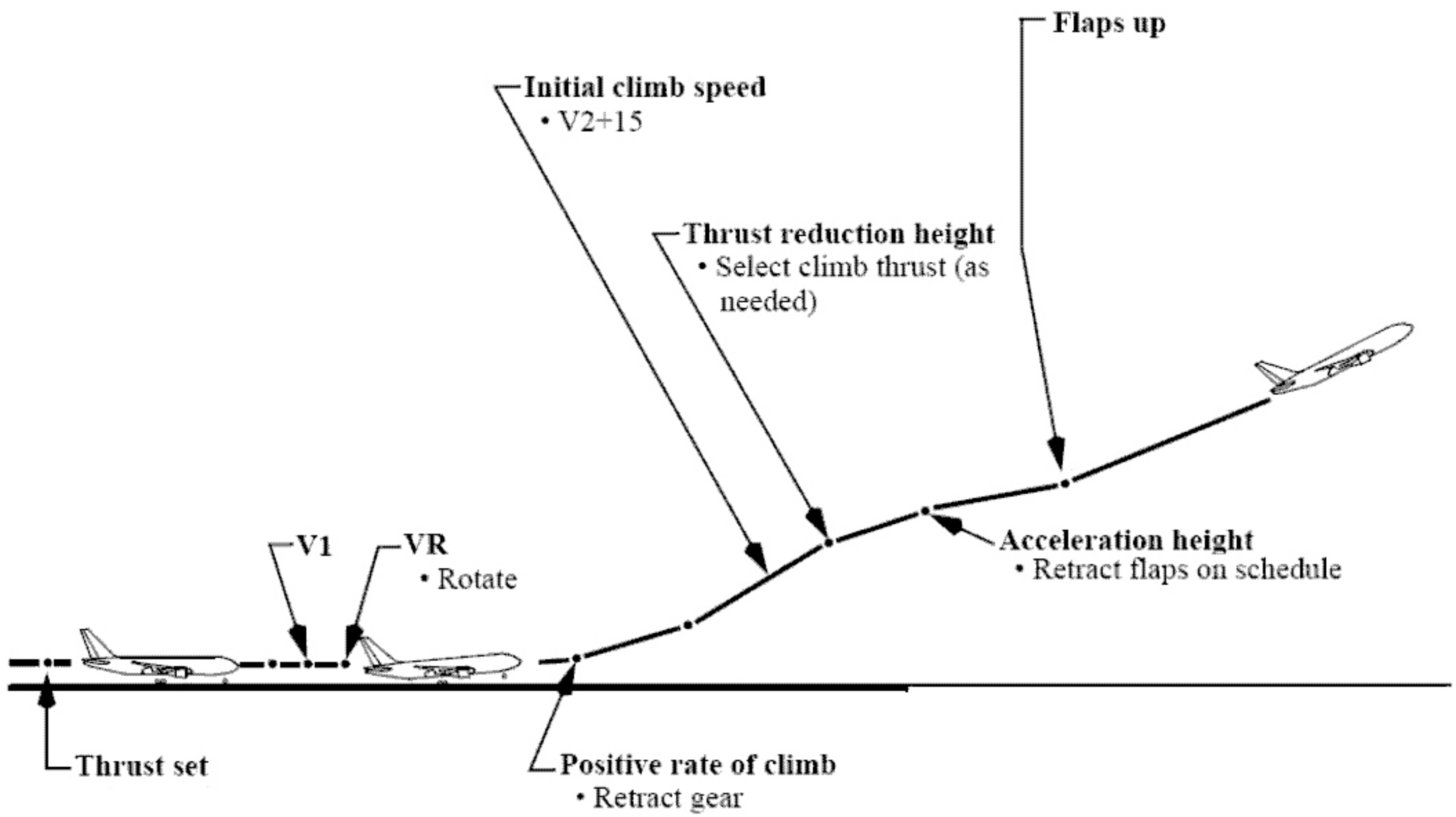
Block 1 Final Recommendations

Proc. ID D = Dep. A = Arr.	Procedure	Primary Benefits
1-D1	Restrict target climb speed for jet departures from Runways 33L and 27 to 220 knots or minimum safe airspeed in clean configuration, whichever is higher.	Reduced airframe and total noise during climb below 10,000 ft (beyond immediate airport vicinity) ***33L Impact***
1-D2	Modify RNAV SID from Runway 15R to move tracks further to the north away from populated areas.	Departure flight paths moved north away from Hull
1-D3	Modify RNAV SID from Runway 22L and 22R to initiate turns sooner after takeoff and move tracks further to the north away from populated areas.	Departure flight paths moved north away from Hull and South Boston
1-D3a	*Option A*: Climb to intercept course (VI-CF) procedure	
1-D3b	*Option B*: Climb to altitude, then direct (VA-DF) procedure	
1-D3c	*Option C*: Heading-based procedure	
1-A1	Implement an overwater RNAV approach procedure with RNP overlay to Runway 33L that follows the ground track of the jetBlue RNAV Visual procedure as closely as possible.	Arrival flight paths moved overwater instead of over the Hull peninsula and points further south
1-A1a	*Option A*: Published instrument approach procedure	
1-A1b	*Option B*: Public distribution of RNAV Visual procedure	

"Block 1 Procedure Recommendations for Logan Airport Community Noise Reduction"

Available at: http://hdl.handle.net/1721.1/114038

1-D1 Reduced Speed Departures

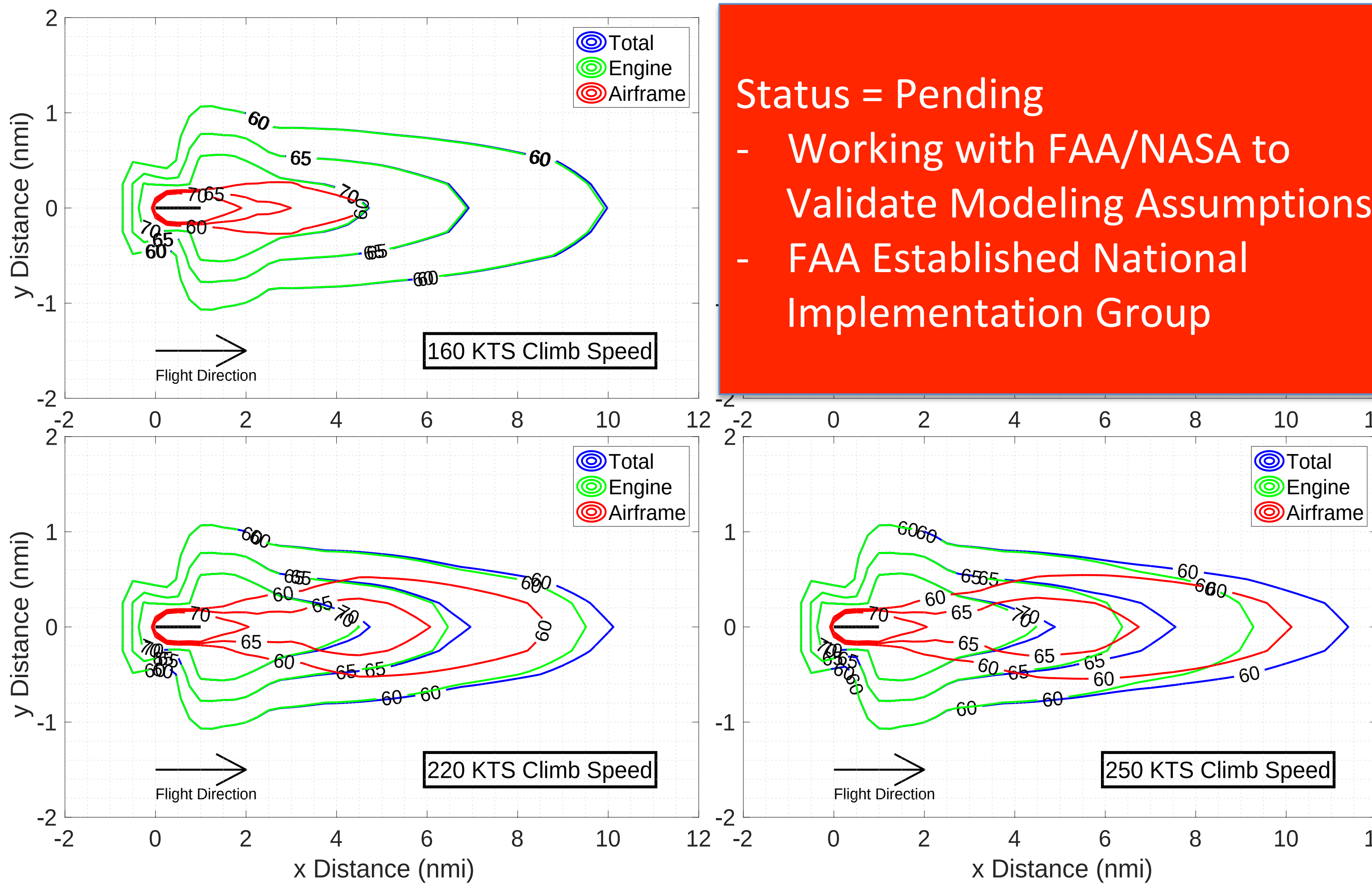


- **Baseline**: Typical profile includes thrust reduction at 1,000' AGL followed by an **acceleration to 250 kt climb speed** & **flap retraction**
- **Reduced Speed Departure**: thrust reduction at 1,000' AGL followed by an **acceleration to 220 kt climb speed or minimum clean airspeed to 10,000 ft**

Impact of Climb Speed

Matching Airframe to Engine Noise Level Minimizes Total

Boeing 737-800 Departure LAMAX Contours with Variations in Climb Speed



Status = Pending

- Working with FAA/NASA to Validate Modeling Assumptions
- FAA Established National Implementation Group

Aerodynamic noise sensitive to "Wing Cleanliness" coefficient in ANOPP

Currently resolving with NASA & exploring clean airframe flight test validation opportunities

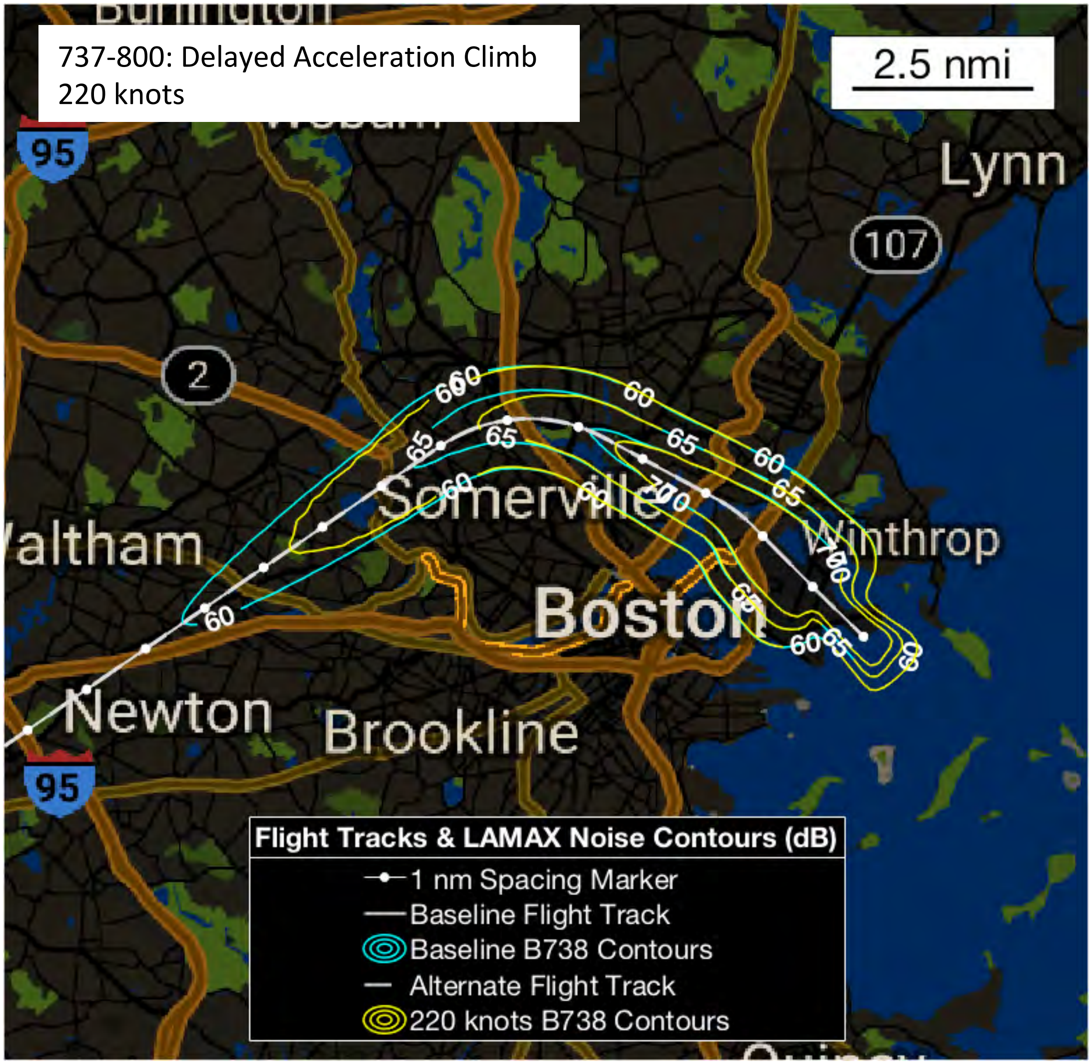
1-D1 Reduced Speed Departures

Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 33L: Maintain Standard Climb Thrust & **220 KIAS to 10,000’**

B737-800
Population Exposure ($L_{A,MAX}$)

	60dB
Baseline	187,106
Reduced Speed Departure	162,558
Baseline – Alternate	24,548

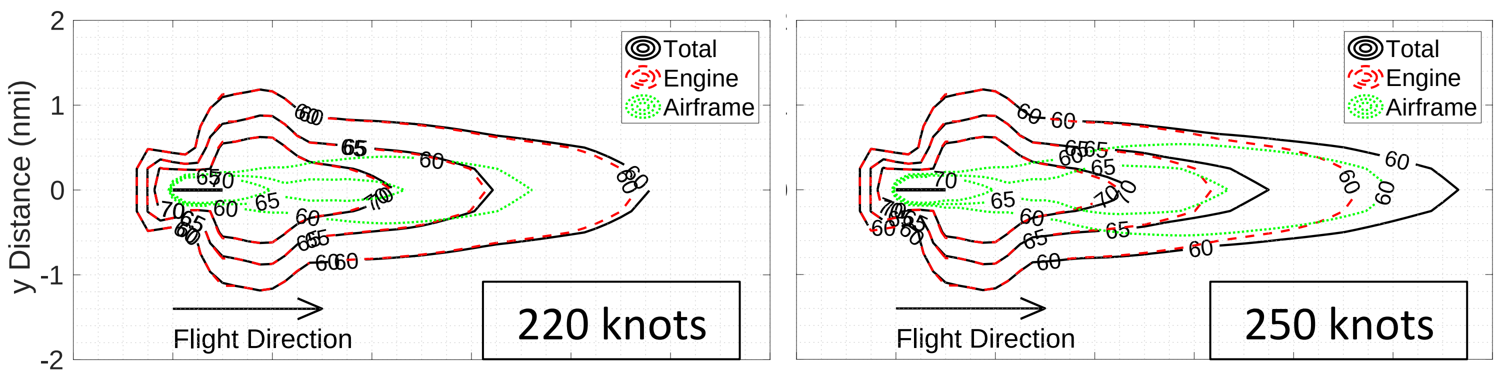
Analysis assumes higher airframe noise assumption
Working with FAA/NASA/Boeing to Validate Modeling Assumptions



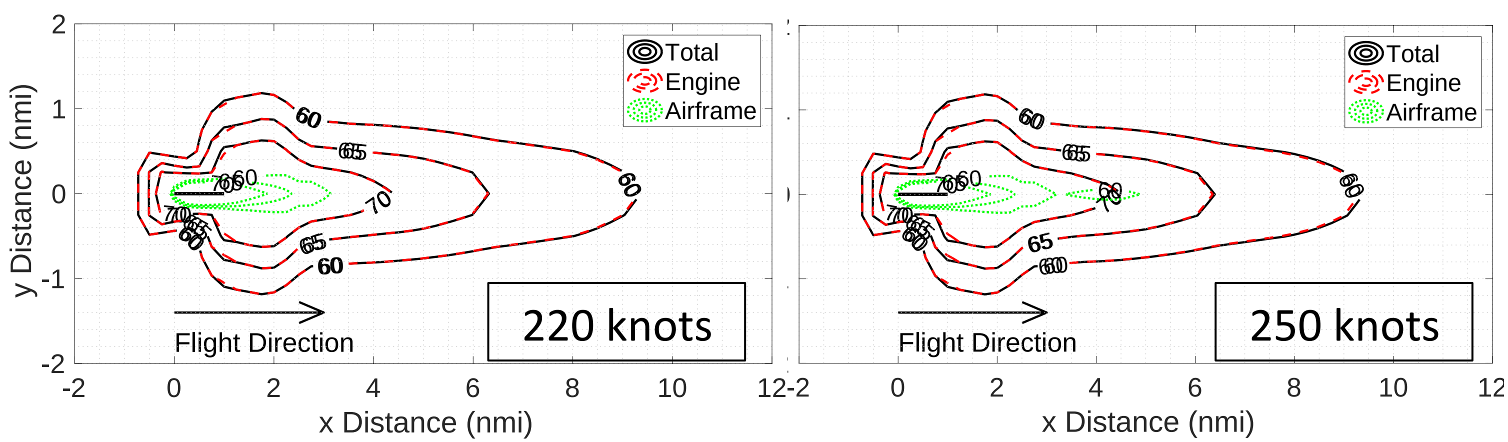
Impact of Climb Speed

Impact Depends on Assumption of Flaps up Airframe Noise

Recent NASA/Boeing data suggests flaps up airframe noise quieter for modern aircraft—thus changing departure climb speed would have minimal impact on departure noise



Flaps up airframe noise data from 1970 flight tests (used in the initial MIT analysis of this procedure)



Model using quiet flaps up airframe noise assumption recommended by NASA

FAA 7100.41 Working Group

- Performance Based Navigation Implementation Process
- Purpose: To vet procedures with industry and facilities including airlines, ATC, and FAA
- Following FAA 7100.41 working group, procedures will be reviewed by flight standards

Lessons learned:

- Stakeholders may have flyability concerns despite a procedure design being within TERPS criteria
  - RNP SIDS are being further analyzed for situations where RNAV SIDS do not meet the desired objectives
- Designing RNAV and RNP procedures that are similar enough to be used simultaneously relieves ATC of workload burdens and allows for slight additional noise benefits in the RNP procedure

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Air Traffic Organization Policy

ORDER 7100.41

Effective Date:
April 3, 2014

SUBJ: Performance Based Navigation Implementation Process

This order provides a standardized five-phase implementation process related to Performance-Based Navigation (PBN) routes and procedures, referred to as the "Performance Based Navigation Implementation Process," which has been deemed compliant by the Office of Safety and meets the requirements set forth by the Federal Aviation Administration (FAA) Air Traffic Organization's (ATO) Safety Management System (SMS).

This order applies to the development and implementation of PBN procedures and routes; specifically, Area Navigation (RNAV)/Required Navigation Performance (RNP) Standard Instrument Departures (SID), RNAV/RNP Standard Terminal Arrivals (STAR), and RNP Authorization Required (AR) Standard Instrument Approach Procedures (SIAP), Q, Tango or "T," and TK (helicopter) Routes, and RNAV/RNP transitions to SIAPs.

Development and implementation of RNAV (GPS, GLS, LPV, etc.) and conventional (ILS, VOR, NDB, etc.) SIAPs, routes, position, and airspace modifications are not covered by this order. This order does not eliminate the SMS process required to decommission existing navigation stations.

This order is to be used in conjunction with and does not supersede other FAA orders and directives related to procedure development and implementation.

Elizabeth L. Ray
Vice President, Mission Support Services

2/7/14
Date Signed

https://www.faa.gov/documentLibrary/media/Order/FAA_JO_7100.41_Performance_Based_Navigation_Implementation_Process.pdf

MIT ICAT

Block 1 Final Recommendations

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1-A1b	*Option B*: Public distribution of RNAV Visual procedure	

Pending resolution of NASA modeling issues and national implementation (1-D1)

Technically infeasible (1-D3a, 1-D3b)

Re-recommended in Block 2 (1-D3c)

"Block 1 Procedure Recommendations for Logan Airport Community Noise Reduction"

Available at: http://hdl.handle.net/1721.1/114038

☐ **Advanced by .41 group** (1-D2, 1-A1)

	Harder			Easier
Ease of Implementation Scale*	(red)	(orange)	(yellow)	(green)

*All Block 2 procedures will be difficult to implement; the color scale only indicates *relative* ease of implementation

Block 2

More complex due to potential operational/technical barriers or equity issues

Block 2 Procedures

Block 2 Arrival Mods

Lateral Path Changes

- RNAV approach with RNP overlay
  - (green) Runway 22L
  - (green) Runway 4R
- RNP approach
  - (yellow) Runway 4R

Vertical Path Changes

- Delayed Deceleration Approach
  - (orange) All approach runways
- Continuous Descent RNAV Profiles
  - (green) Runway 4R Arrivals from South
  - (yellow) Runway 4R Arrivals from North

Block 2 Departure Mods

Lateral Path Changes

- Heading-based departure
  - (yellow) Runway 22: Re-recommend 1-D3c. When runway 27 not in use, heading-based departure then re-join RNAV SID
- Dispersion ***33L Impact***

  Runways 33L and 27
  - (orange) Altitude-based dispersion
    - 3000ft
    - 4000ft
  - (orange) Controller-based dispersion
  - (yellow) Divergent heading dispersion
  - (green) RNAV SID Waypoint Relocation

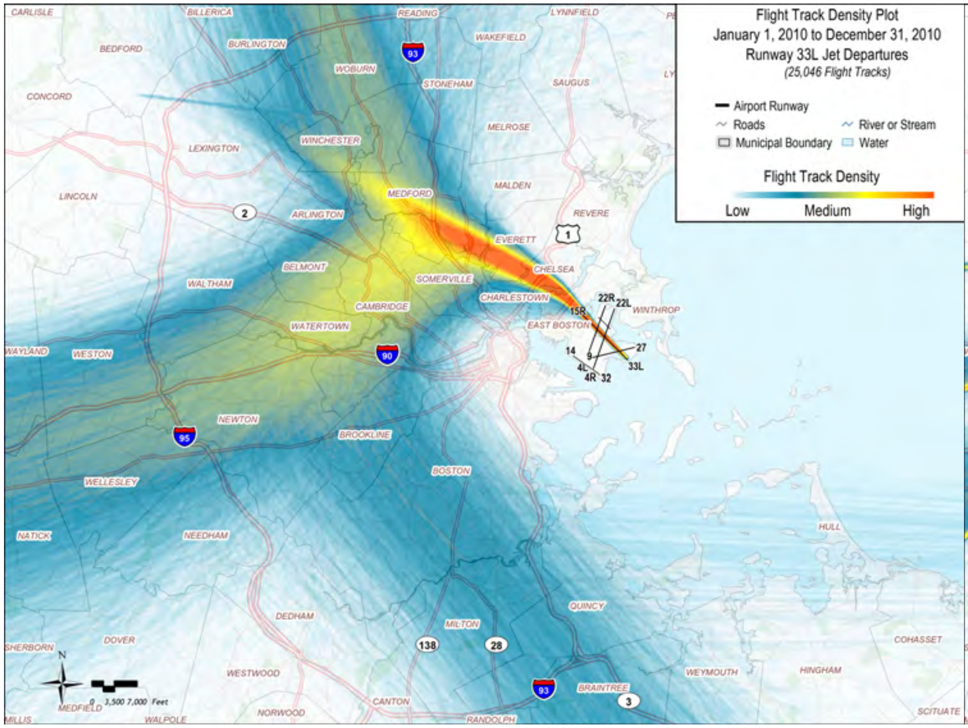
Preliminary/Subject to Change

MIT International Center for Air Transportation

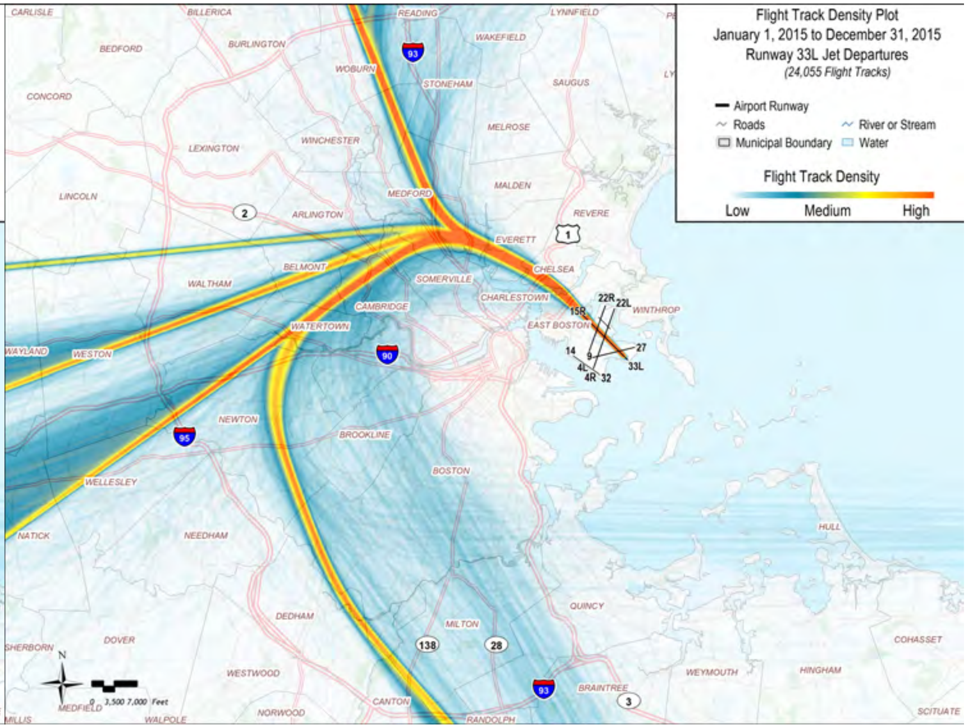
33L Departures Dispersion Analysis

RNAV Track Concentration

2010

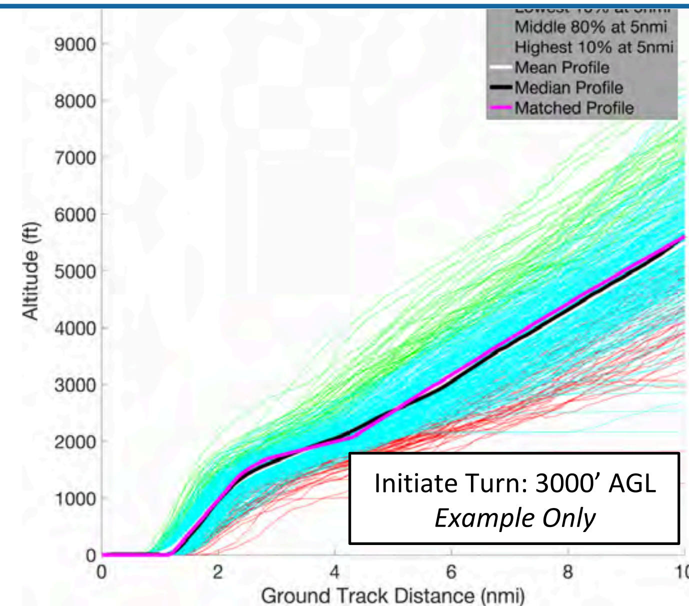


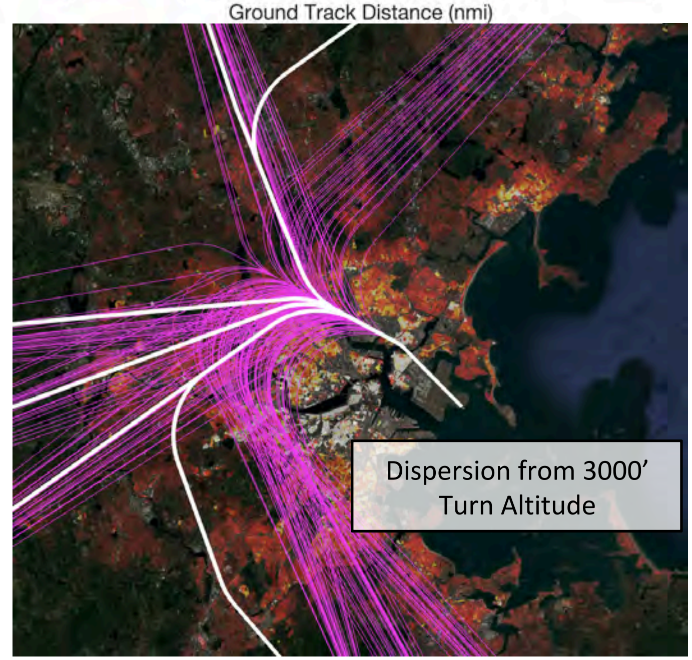
2015



Dispersion Concepts

- Altitude-based dispersion
  - Direct routing to transition waypoint upon reaching specific altitude
- Controller-based dispersion
  - Dispersion arising from radar vectoring
  - 2010 flight track data normalized for comparison with 2017 data
  - Comparison between pre-RNAV and RNAV flight tracks
- Divergent heading dispersion
  - 15^0 divergent headings then direct routing to transition waypoint upon reaching 3000ft
- RNAV Waypoint Relocation
  - Moving the waypoint at which the RNAV tracks branch off could allow for population exposure reduction

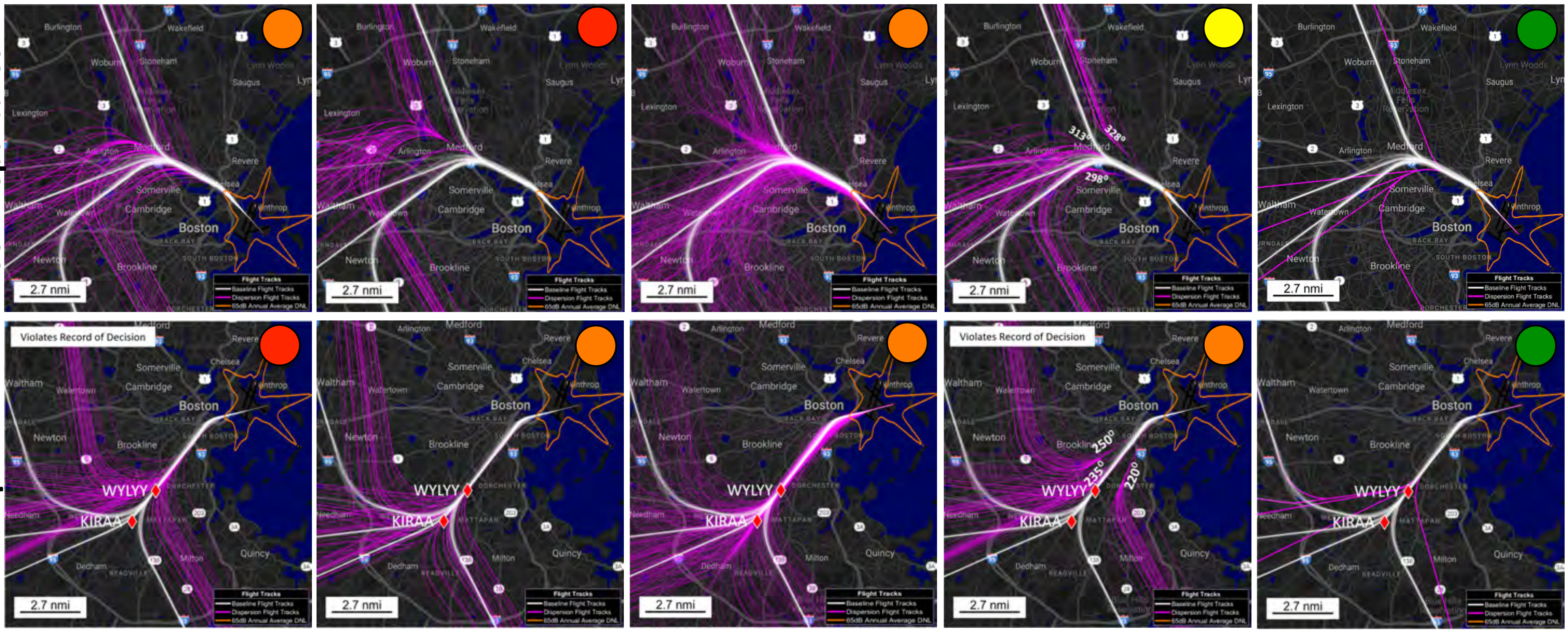




Dispersion Concepts

33L Departures

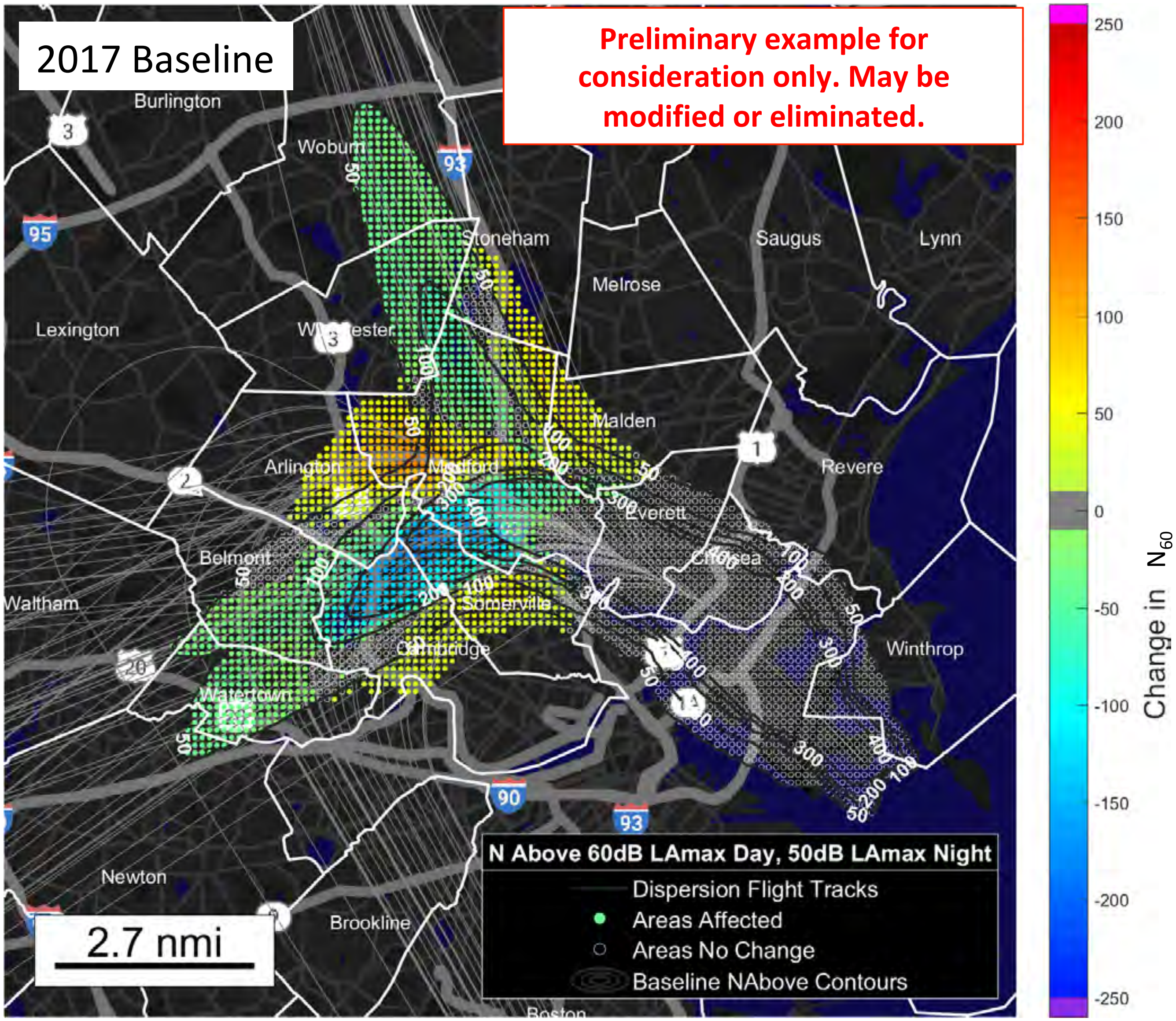
27 Departures



Altitude-Based 3000ft | Altitude-Based 4000ft | Controller-Based | Divergent Headings | RNAV Waypoint Relocation

Preliminary examples for consideration only. May be modified or eliminated.

33L Departures Altitude-Based Dispersion at 3000ft Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	342,387
Baseline - Dispersion	-5,744

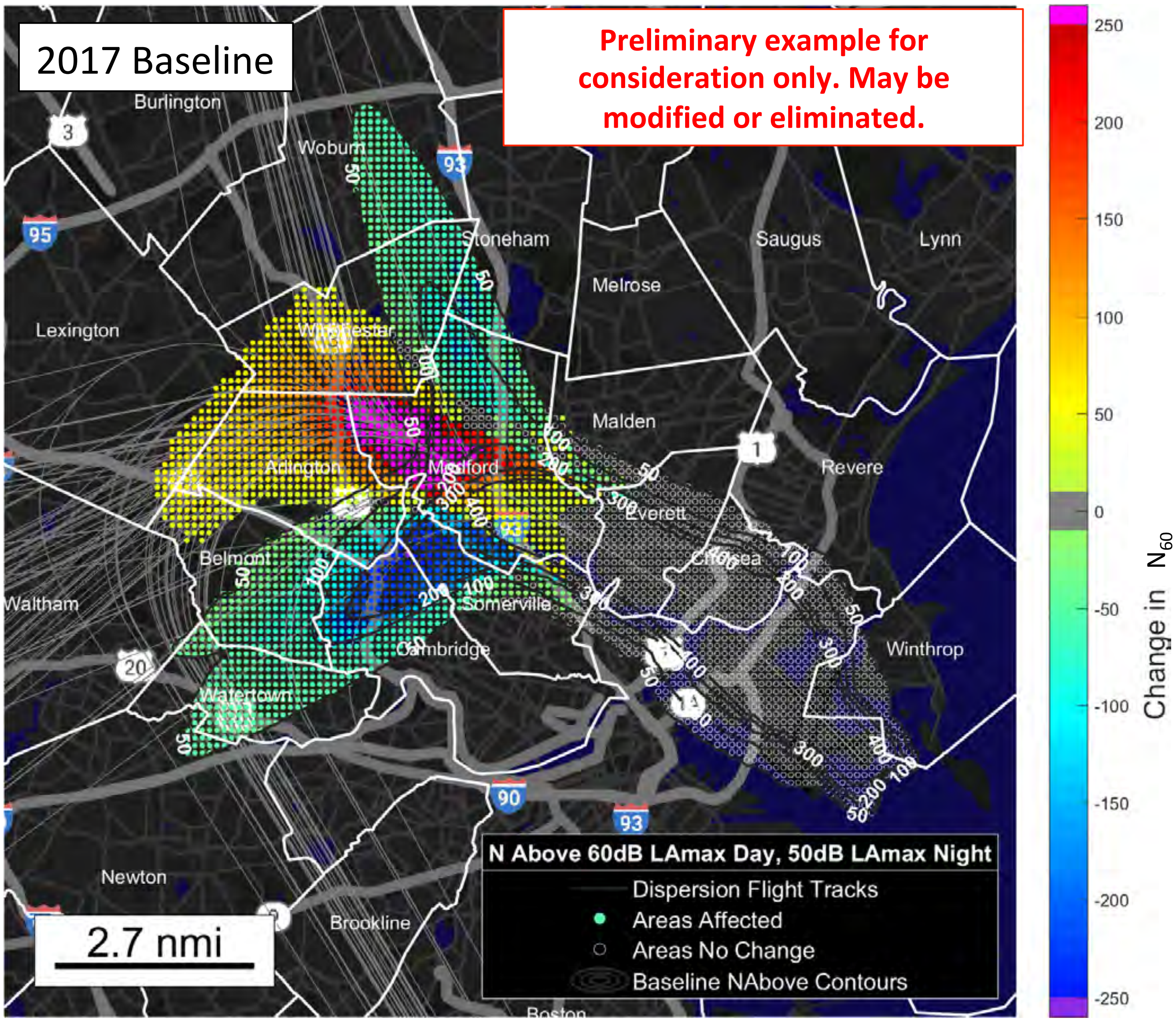
Analysis updated Dec 4 2018 to correct for discretization differences

- Controller concerns about variability in flight path length

Analysis based on peak day operations; only includes 33L departures

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

33L Departures Altitude-Based Dispersion at 4000ft Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	273,878
Baseline - Dispersion	62,765

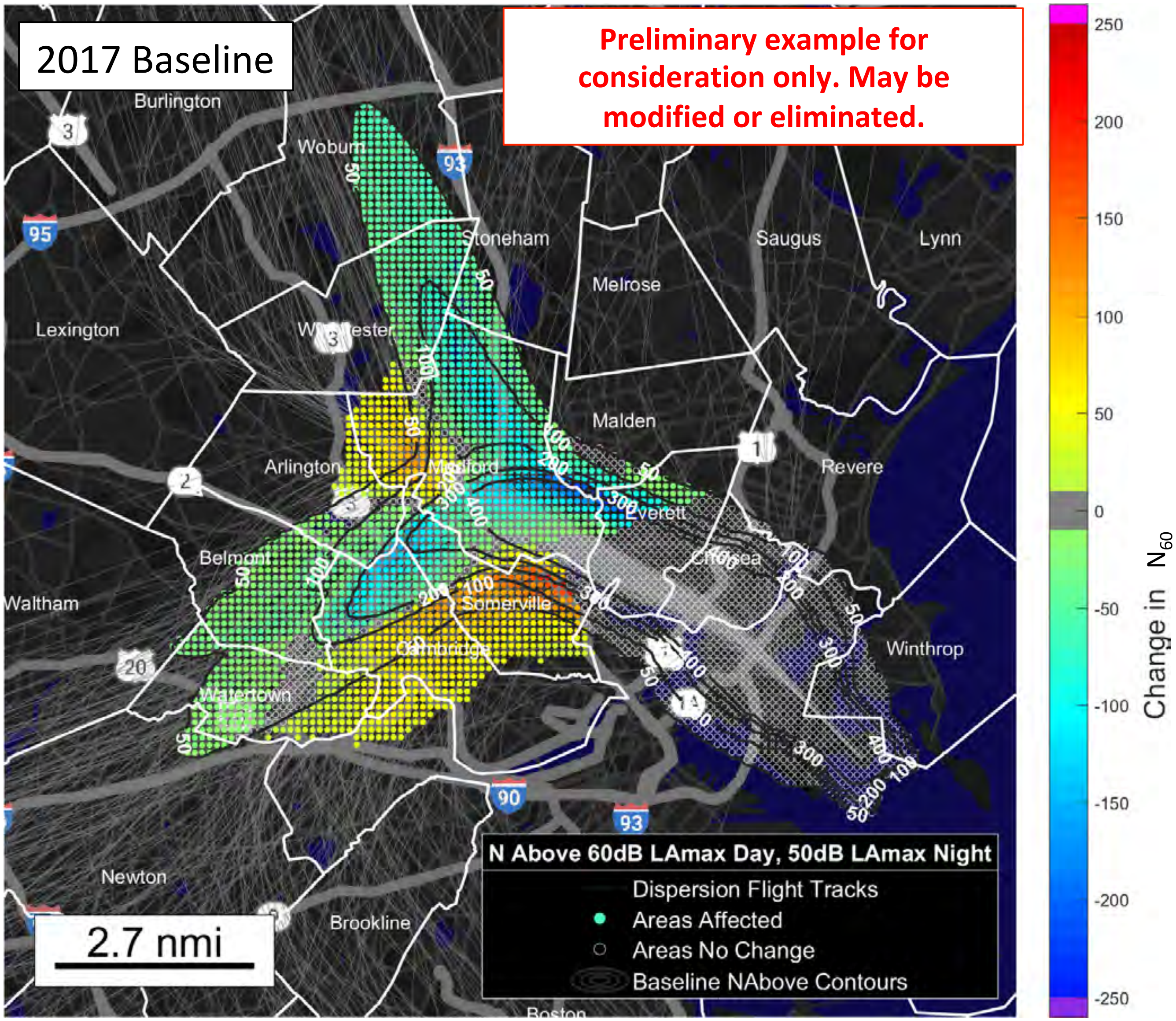
Analysis updated Dec 4 2018 to correct for discretization differences

- Controller concerns about variability in flight path length
- Conflicts with airspace at Hanscom Airport

Analysis based on peak day operations; only includes 33L departures

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

33L Departures Controller-Based Dispersion Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	349,359
Baseline - Dispersion	-12,716

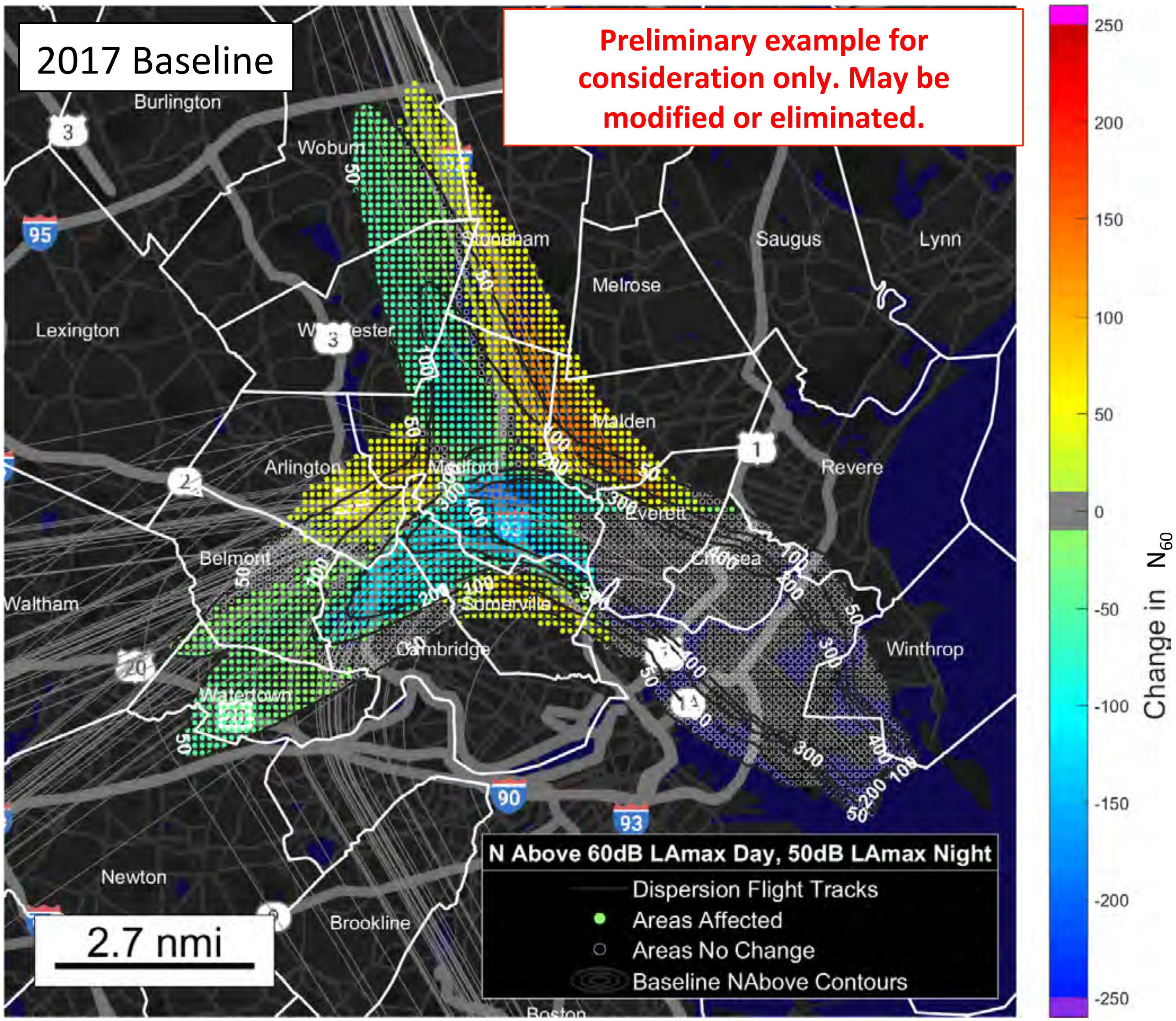
Analysis updated Dec 4 2018 to correct for discretization differences

- Controller concerns about variability in flight path length

Analysis based on peak day operations; only includes 33L departures

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

33L Departures Divergent Headings Dispersion Change in N_{60} Compared to 2017



Analysis based on peak day operations; only includes 33L departures

Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	334,305
Baseline - Dispersion	2,338

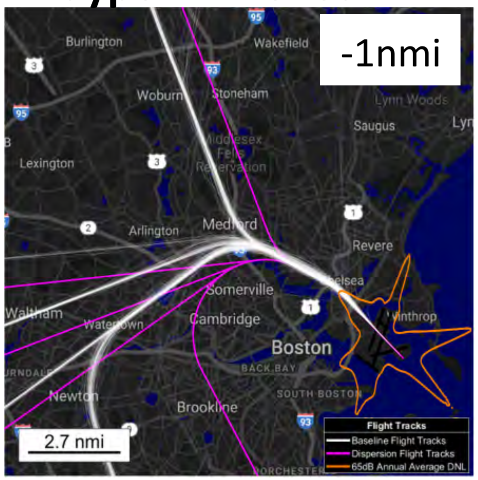
Analysis updated Dec 4 2018 to correct for discretization differences

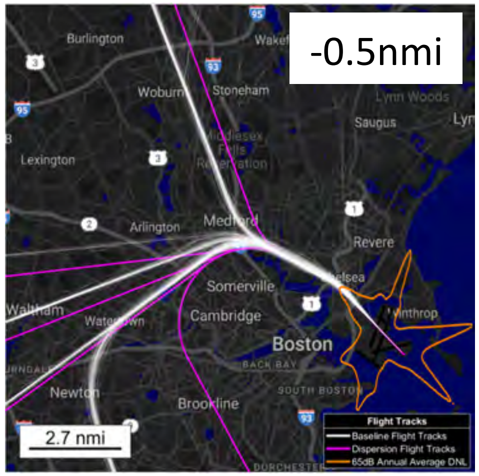
- Divergent headings help to maintain aircraft separation criteria

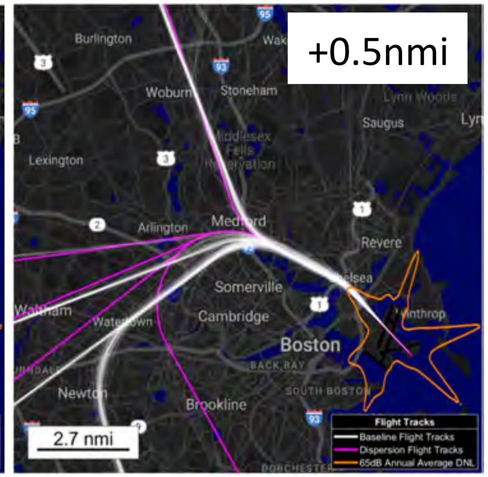
N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

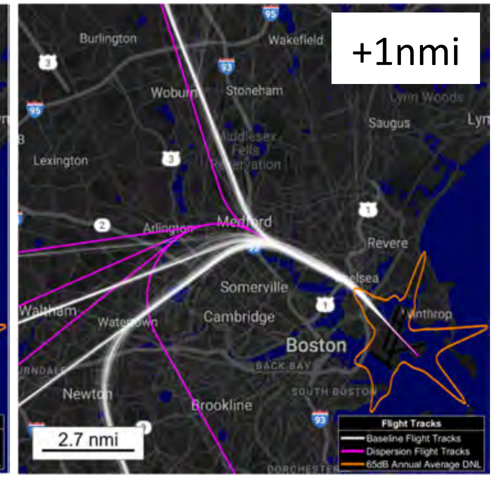
33L Departures RNAV Waypoint Relocation

Waypoint moved:



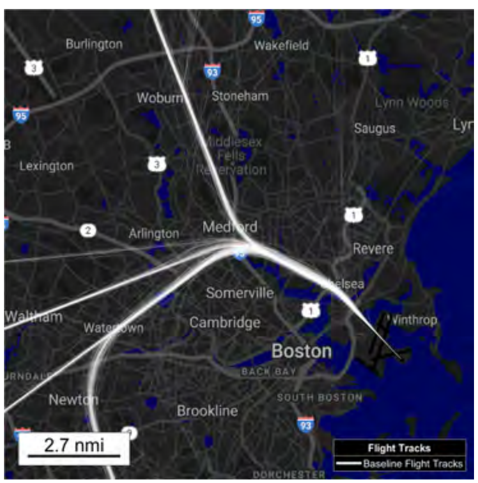






50 N_{60} Population Exposure Change (Baseline – Alternate):

-1nmi	-0.5nmi	+0.5nmi	+1nmi
-43,835	-1,576	36,006	42,659

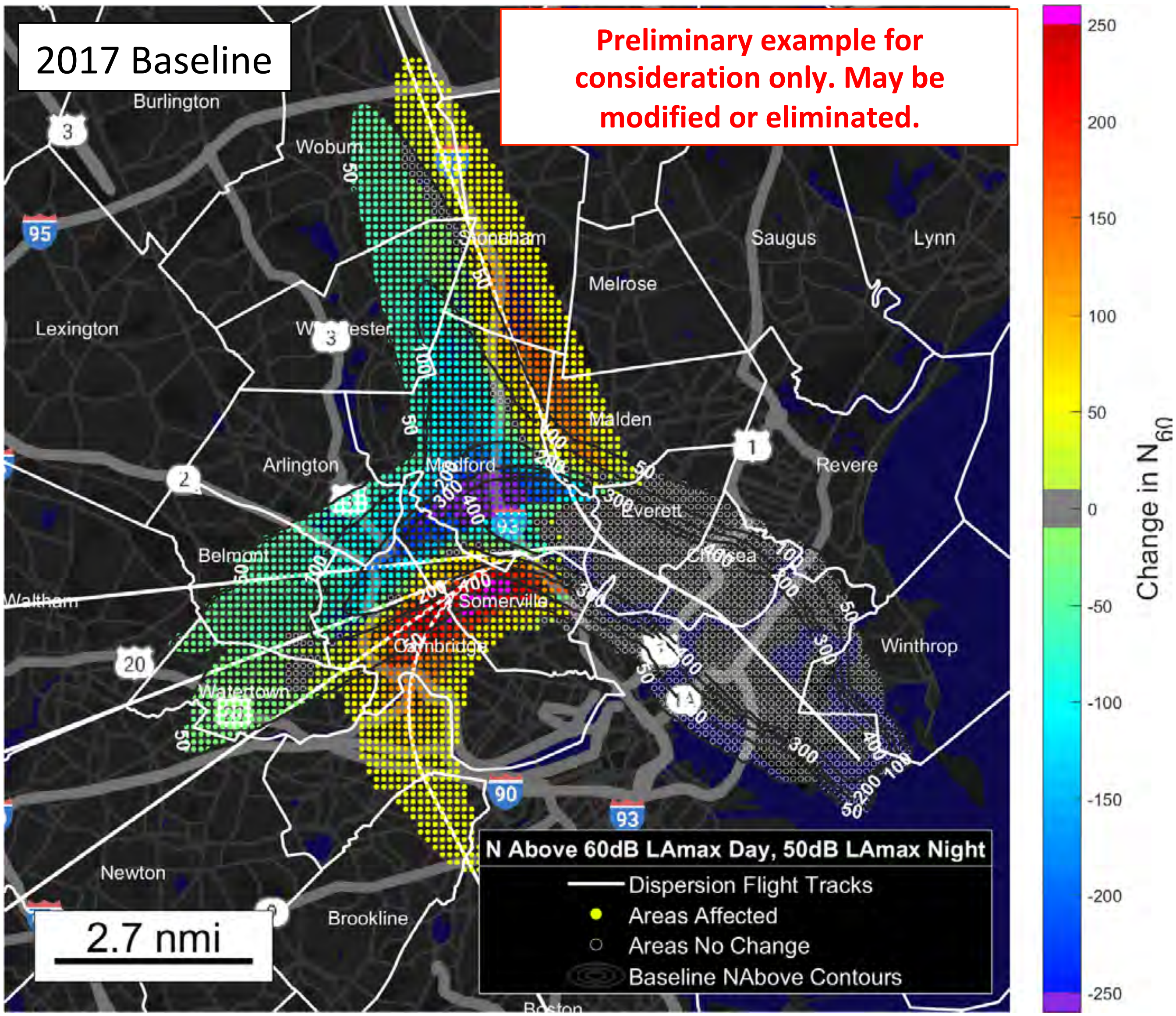


RNAV N_{60} Population Exposure:
336,643

Modification to existing RNAV procedure

Preliminary example for consideration only. May be modified or eliminated.

33L Departures RNAV Waypoint Relocation -1nmi Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	380,478
Baseline - Dispersion	-43,835

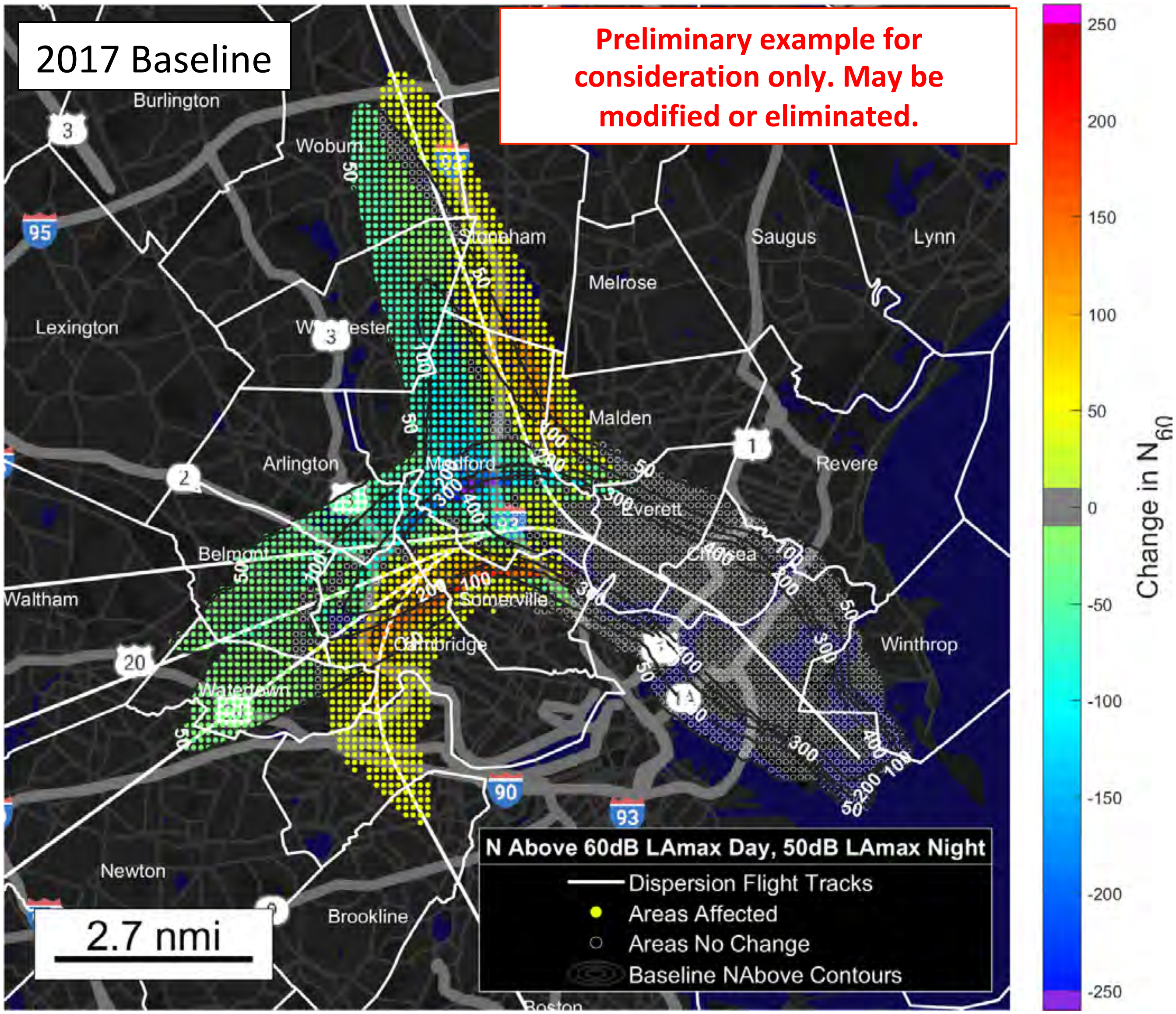
Analysis updated Dec 4 2018 to correct for discretization differences

- Modification to existing RNAV procedure

Analysis based on peak day operations; only includes 33L departures

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

33L Departures RNAV Waypoint Relocation -0.5nmi Change in N_{60} Compared to 2017



Analysis based on peak day operations; only includes 33L departures

Population Exposure

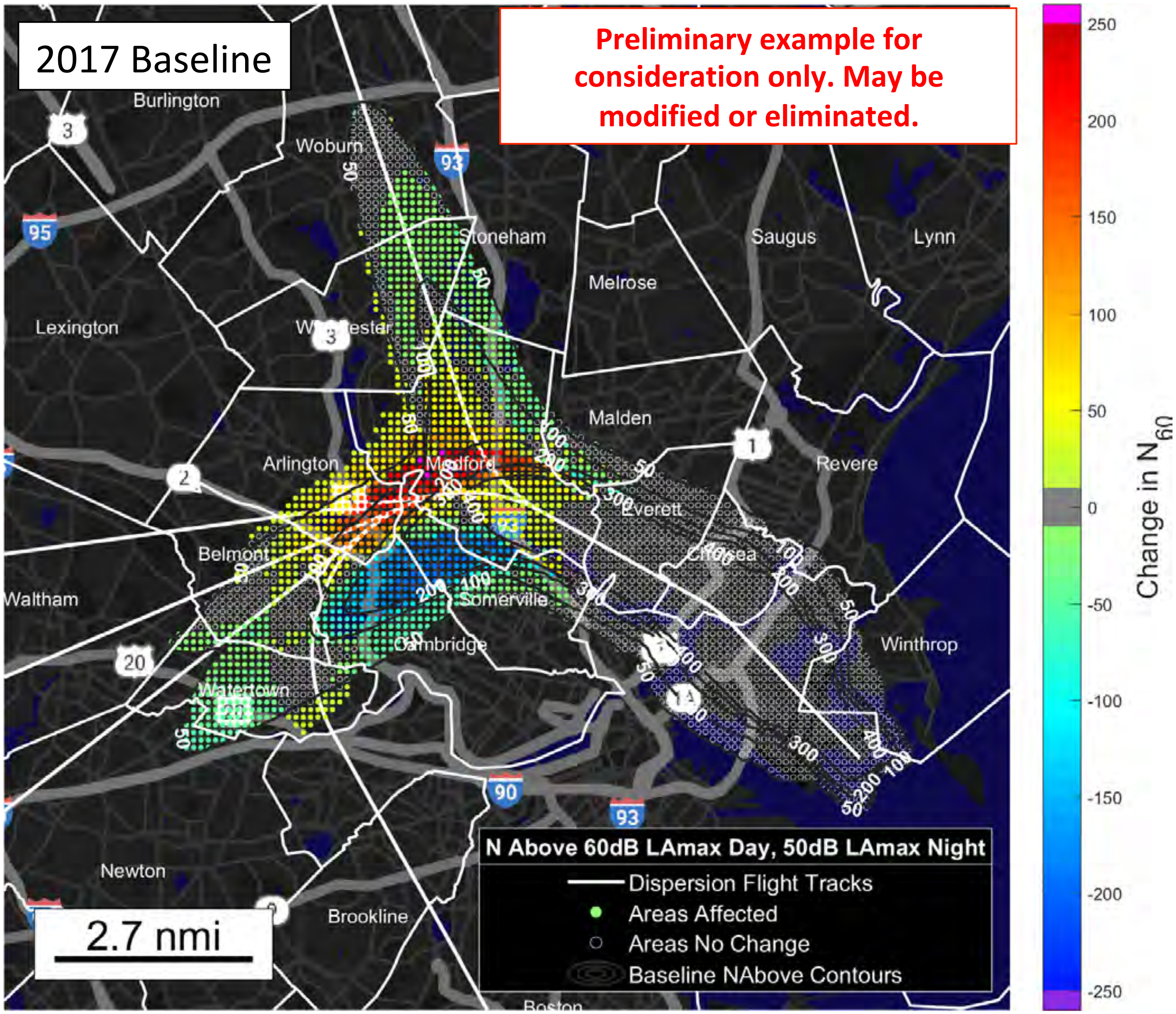
N_{60}	50x
Baseline 2017	336,643
Dispersion	338,219
Baseline - Dispersion	-1,576

Analysis updated Dec 4 2018 to correct for discretization differences

- Modification to existing RNAV procedure

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

33L Departures RNAV Waypoint Relocation +0.5nmi Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	300,637
Baseline - Dispersion	36,006

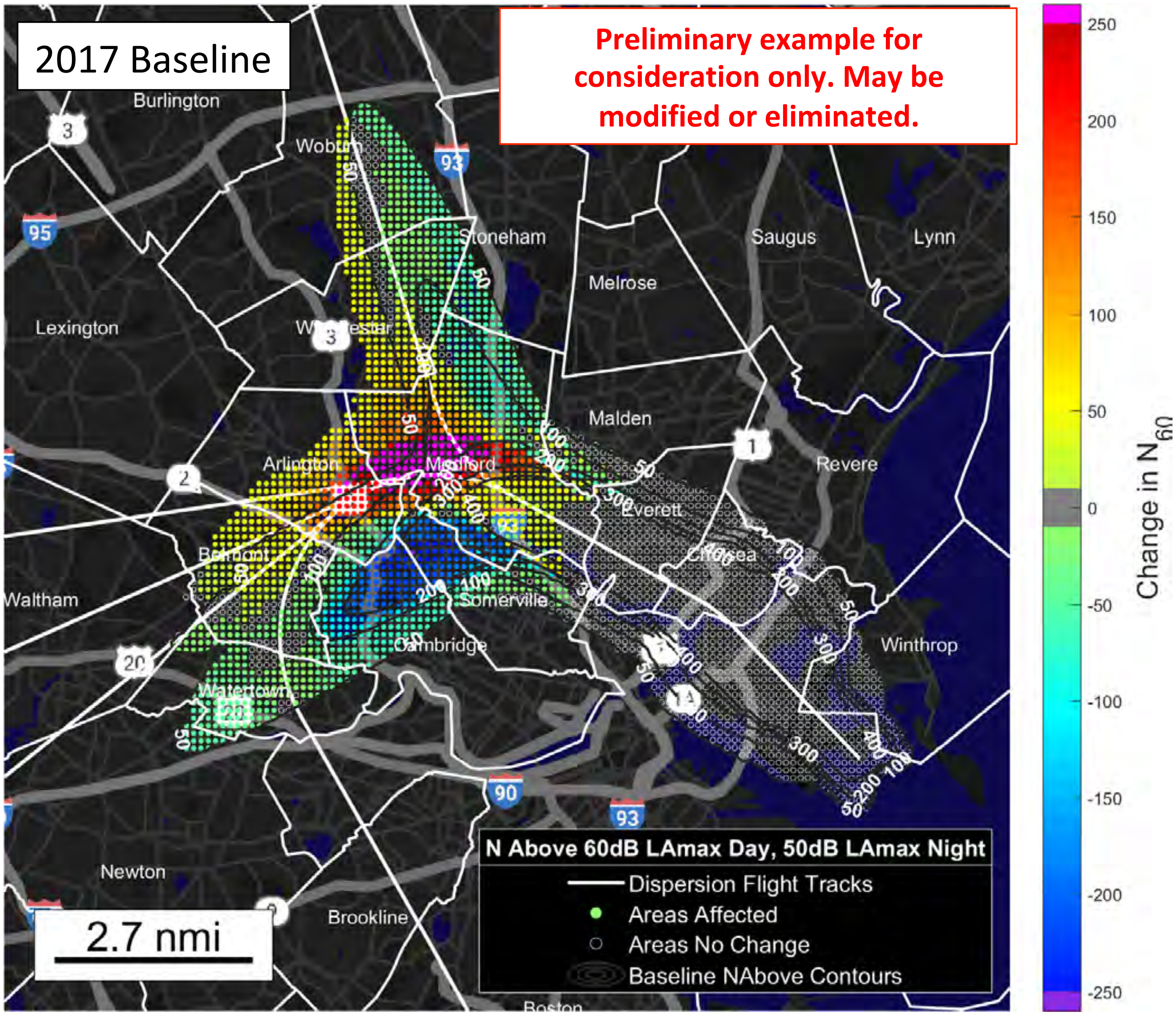
Analysis updated Dec 4 2018 to correct for discretization differences

- Modification to existing RNAV procedure

Analysis based on peak day operations; only includes 33L departures

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

33L Departures RNAV Waypoint Relocation +1nmi
Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	293,984
Baseline - Dispersion	42,659

Analysis updated Dec 4 2018 to correct for discretization differences

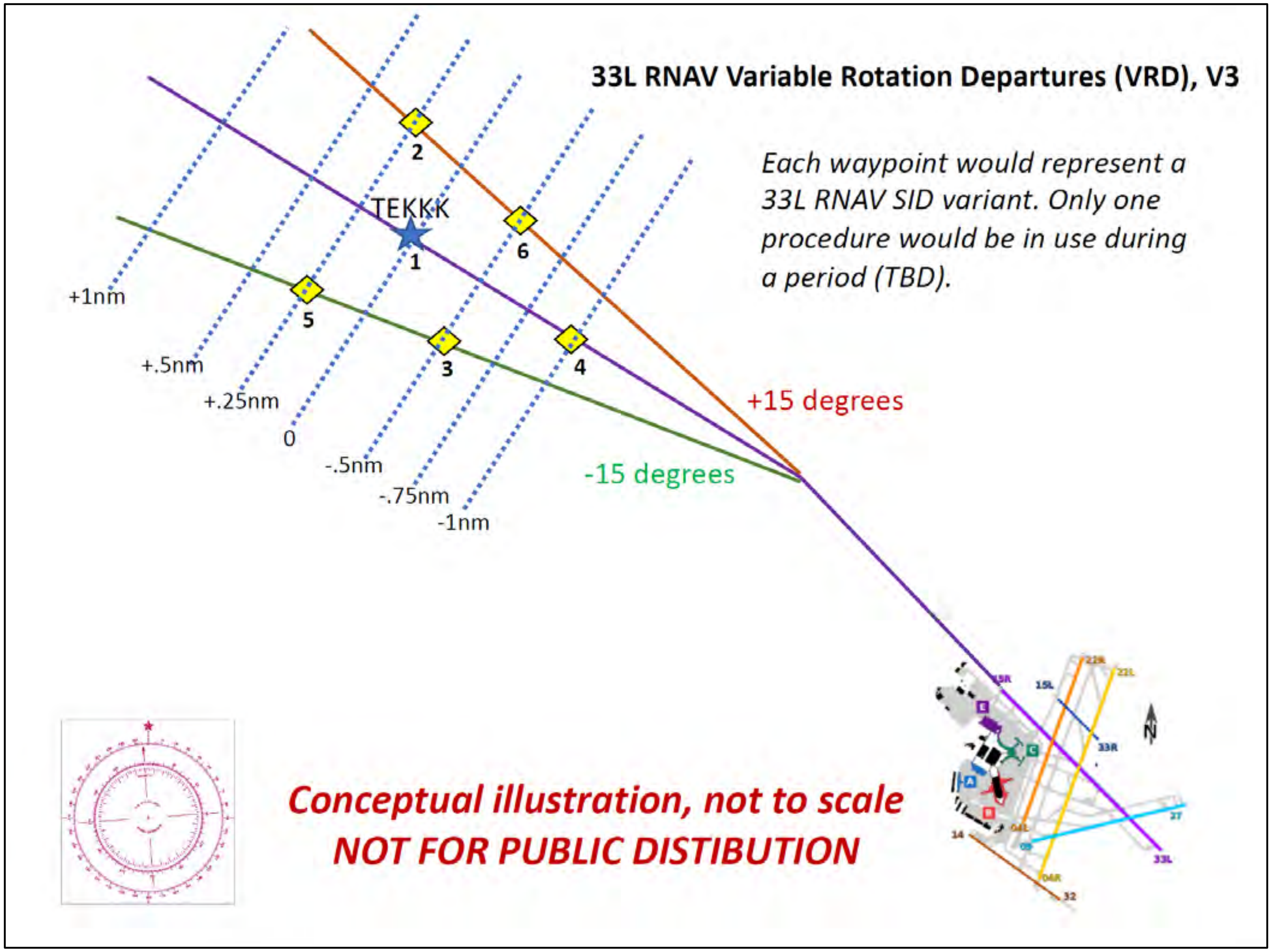
- Modification to existing RNAV procedure

Analysis based on peak day operations; only includes 33L departures

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

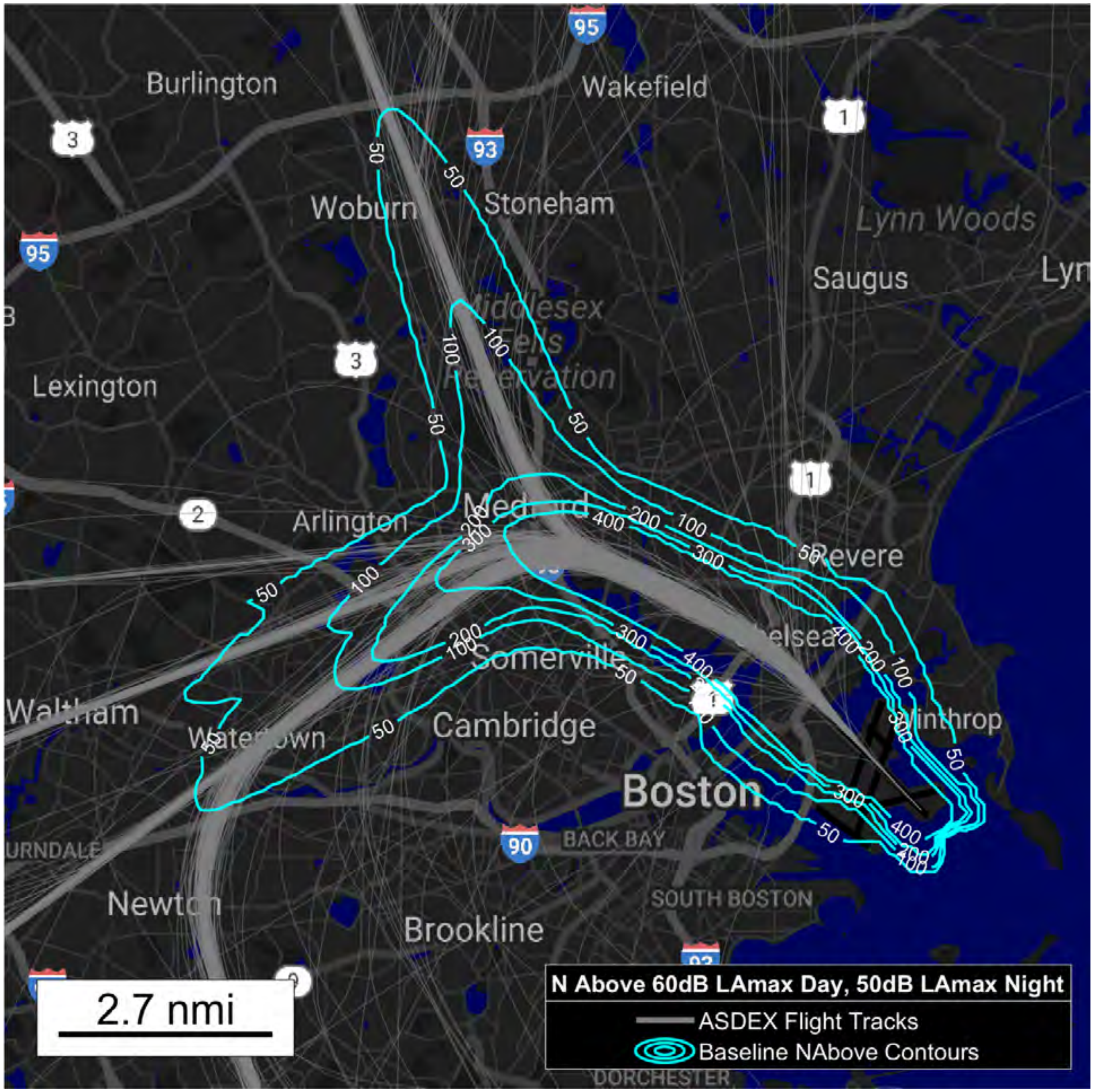
Community Dispersion Suggestion Variable Rotation Departures (VRD)

Analysis done on full peak day of operation using a single waypoint
Other rotations possible.



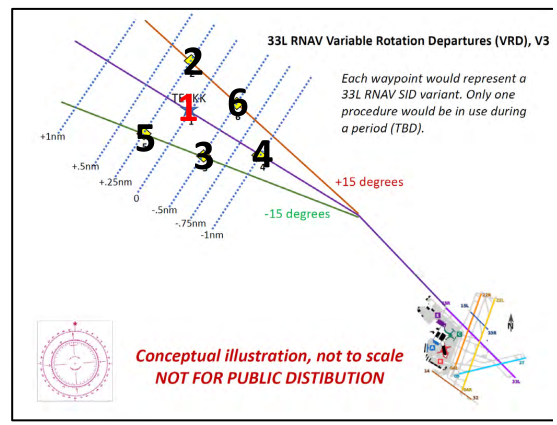
- Complex procedures for ATC and Pilots
- Requires numerous procedures in the Flight Management System
- Rotating between waypoints from day to day does not take advantage of the separation requirements satisfied by divergent headings

VRD Waypoint #1 (Current RNV Procedure)



Population Exposure

N Above	>50x	>100x	>200x
Baseline	336,643	204,039	146,522

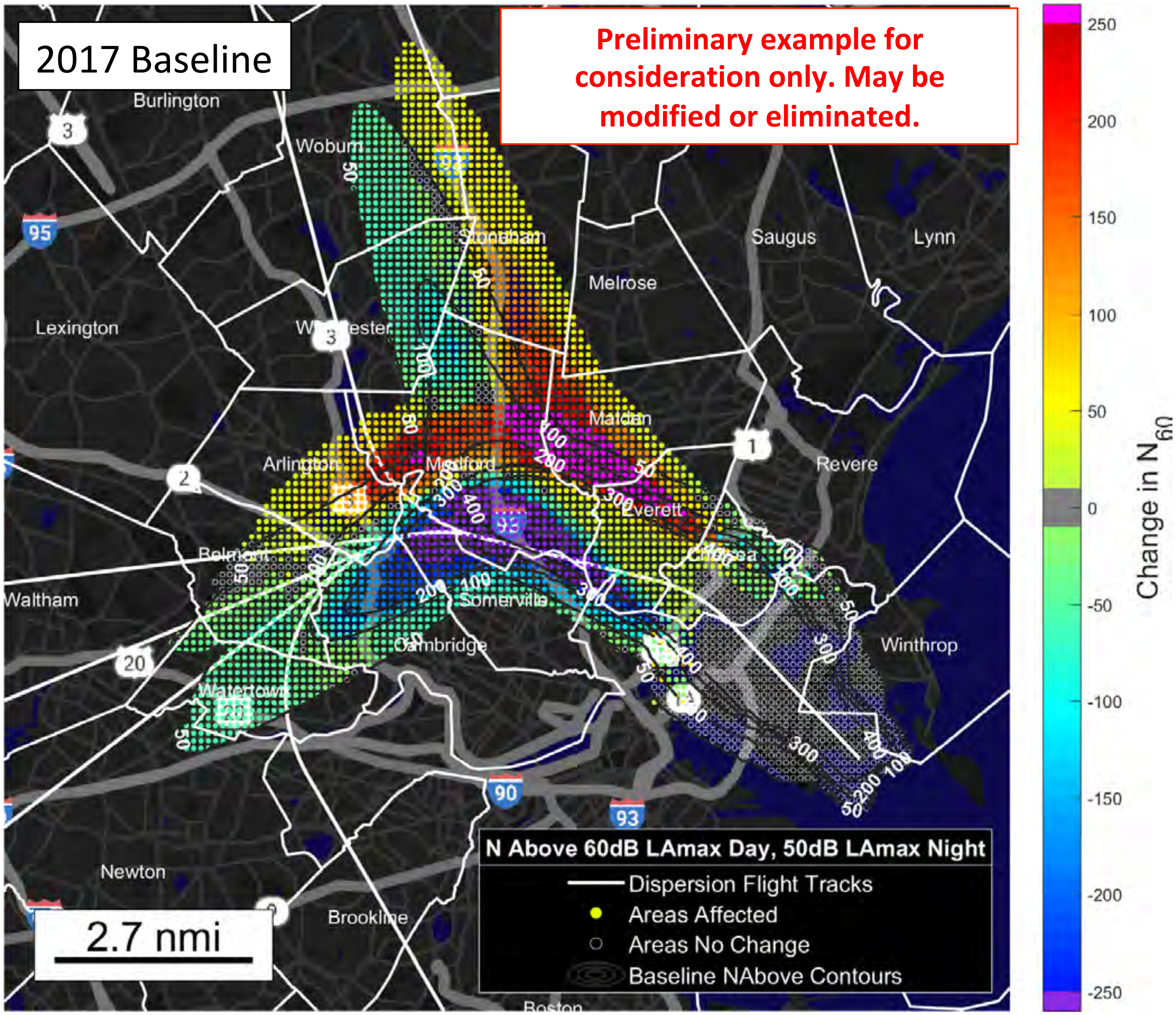


N Above Levels:

60dB $L_{A,max}$ Day

50dB $L_{A,max}$ Night

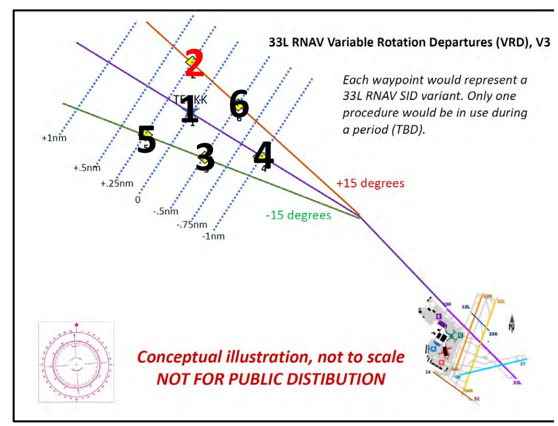
VRD Waypoint #2



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	269,015
Baseline - Dispersion	67,628

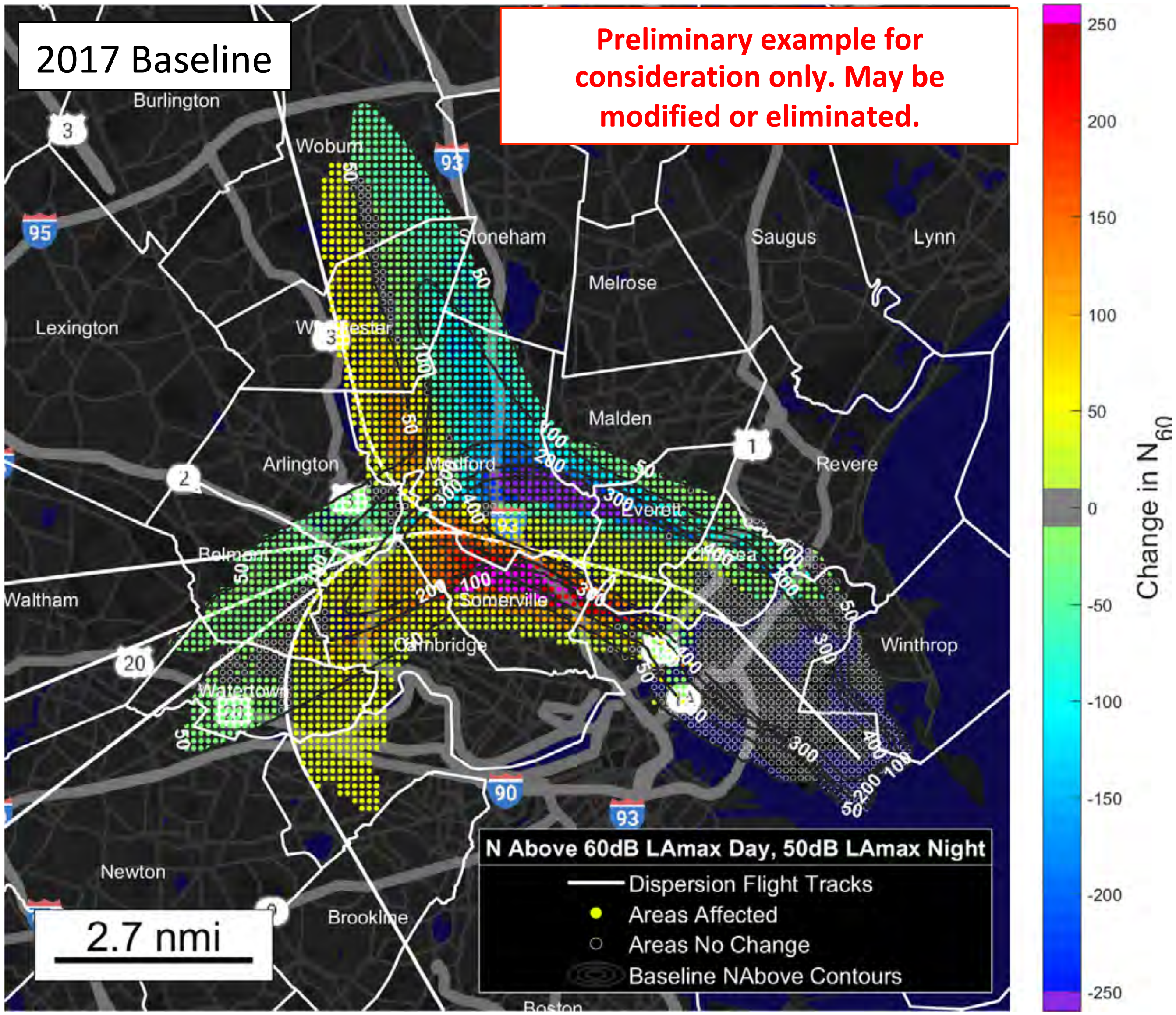
Analysis updated Dec 4 2018 to correct for discretization differences



Analysis based on peak day operations; only includes 33L departures

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

VRD Waypoint #3

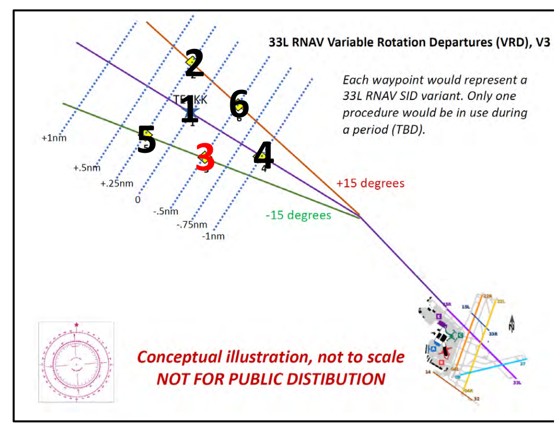


Analysis based on peak day operations; only includes 33L departures

Population Exposure

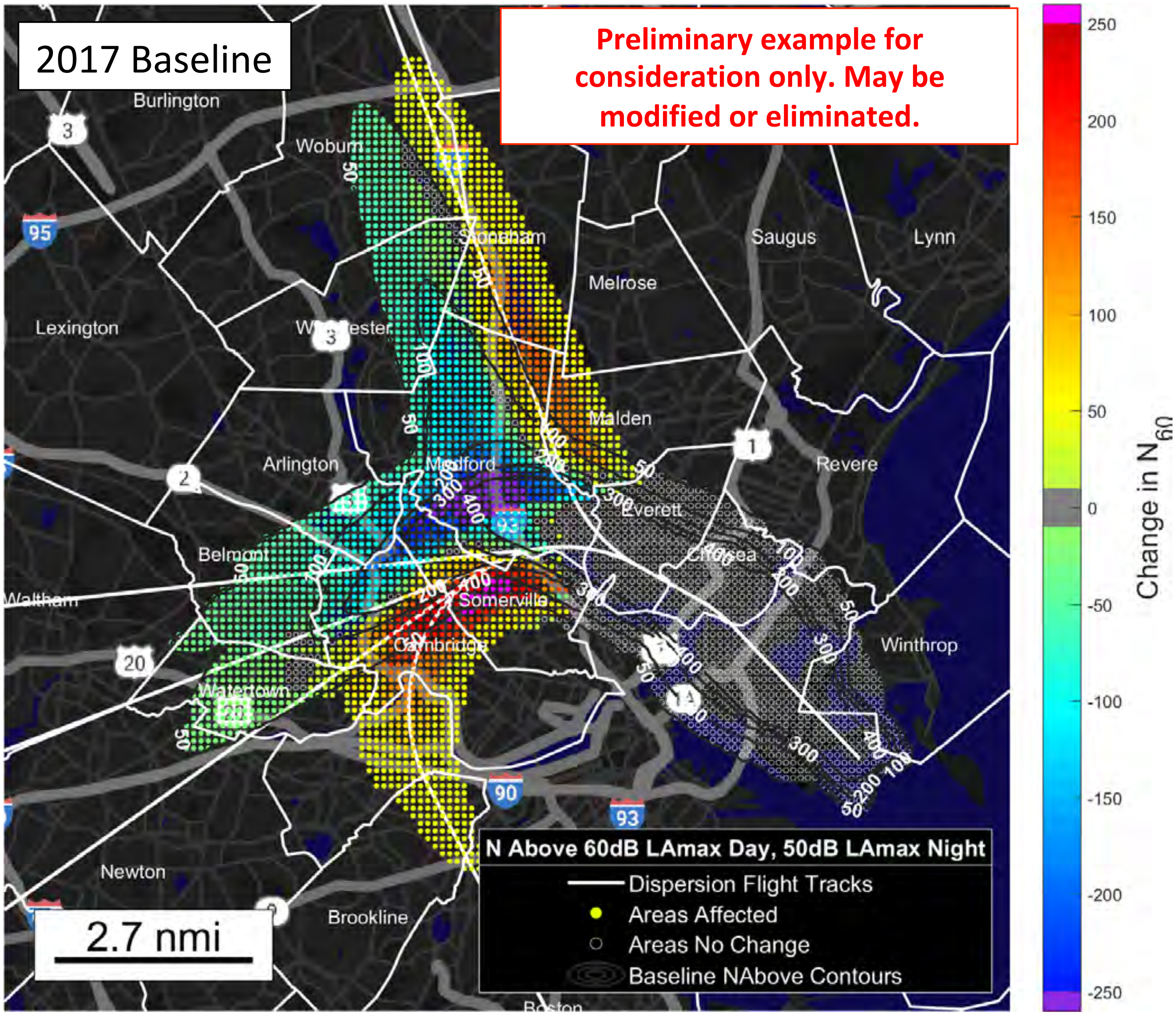
N_{60}	50x
Baseline 2017	336,643
Dispersion	334,445
Baseline - Dispersion	2,198

Analysis updated Dec 4 2018 to correct for discretization differences



N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

VRD Waypoint #4

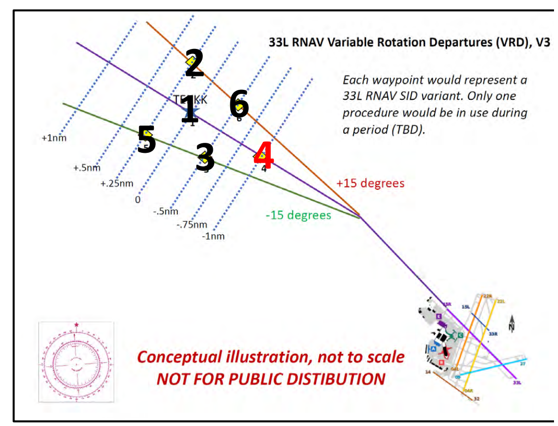


Analysis based on peak day operations; only includes 33L departures

Population Exposure

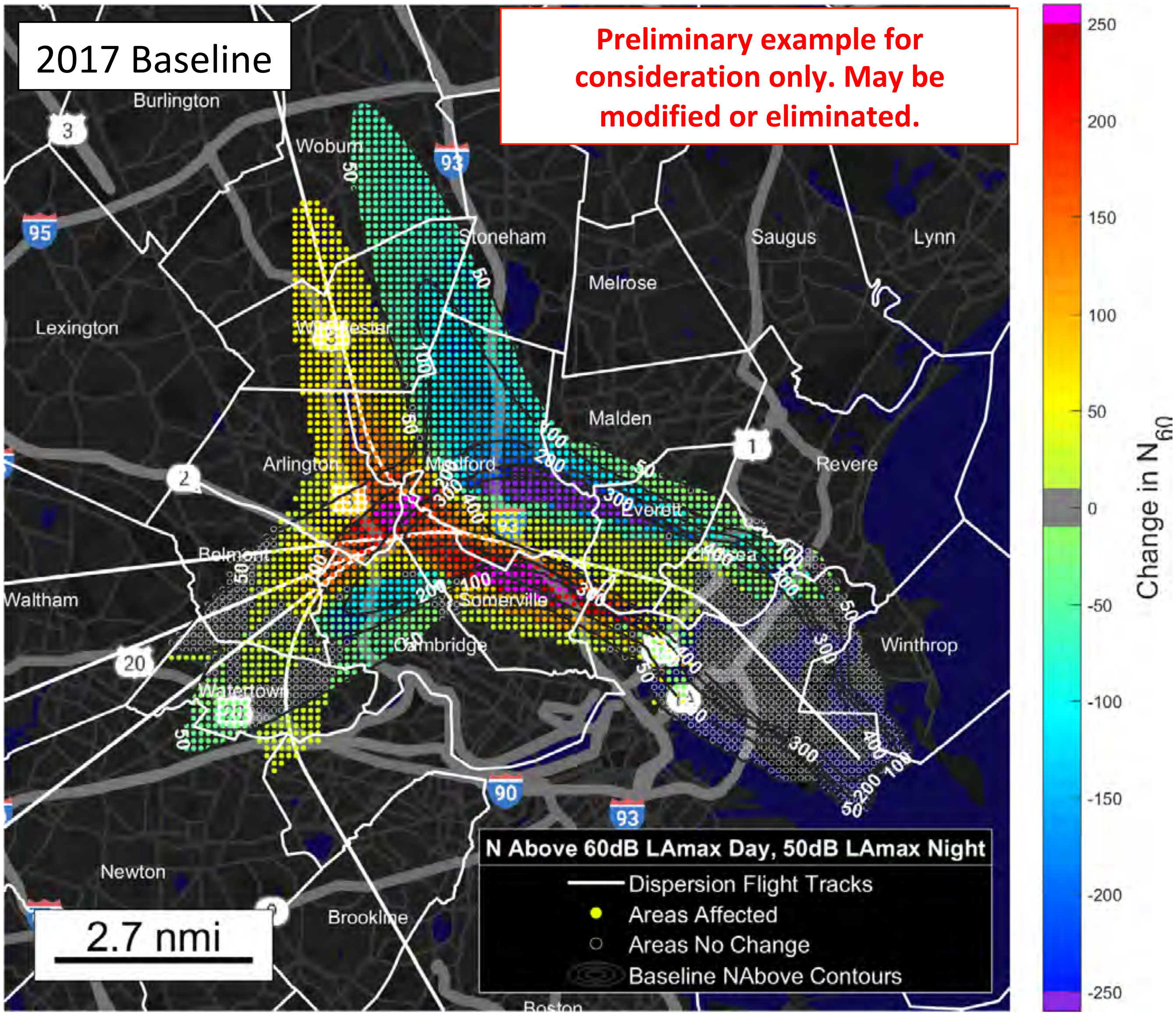
N_{60}	50x
Baseline 2017	336,643
Dispersion	380,478
Baseline - Dispersion	-43,835

Analysis updated Dec 4 2018 to correct for discretization differences



N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

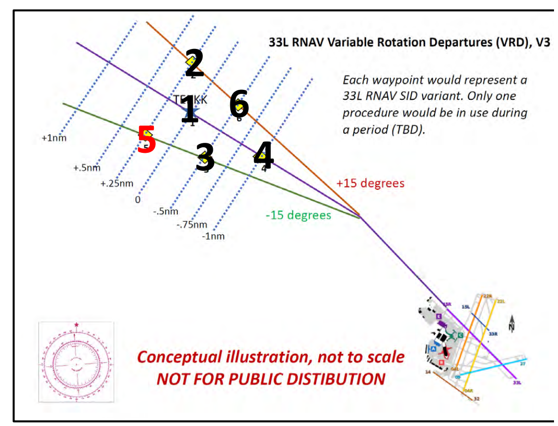
VRD Waypoint #5



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	317,304
Baseline - Dispersion	19,339

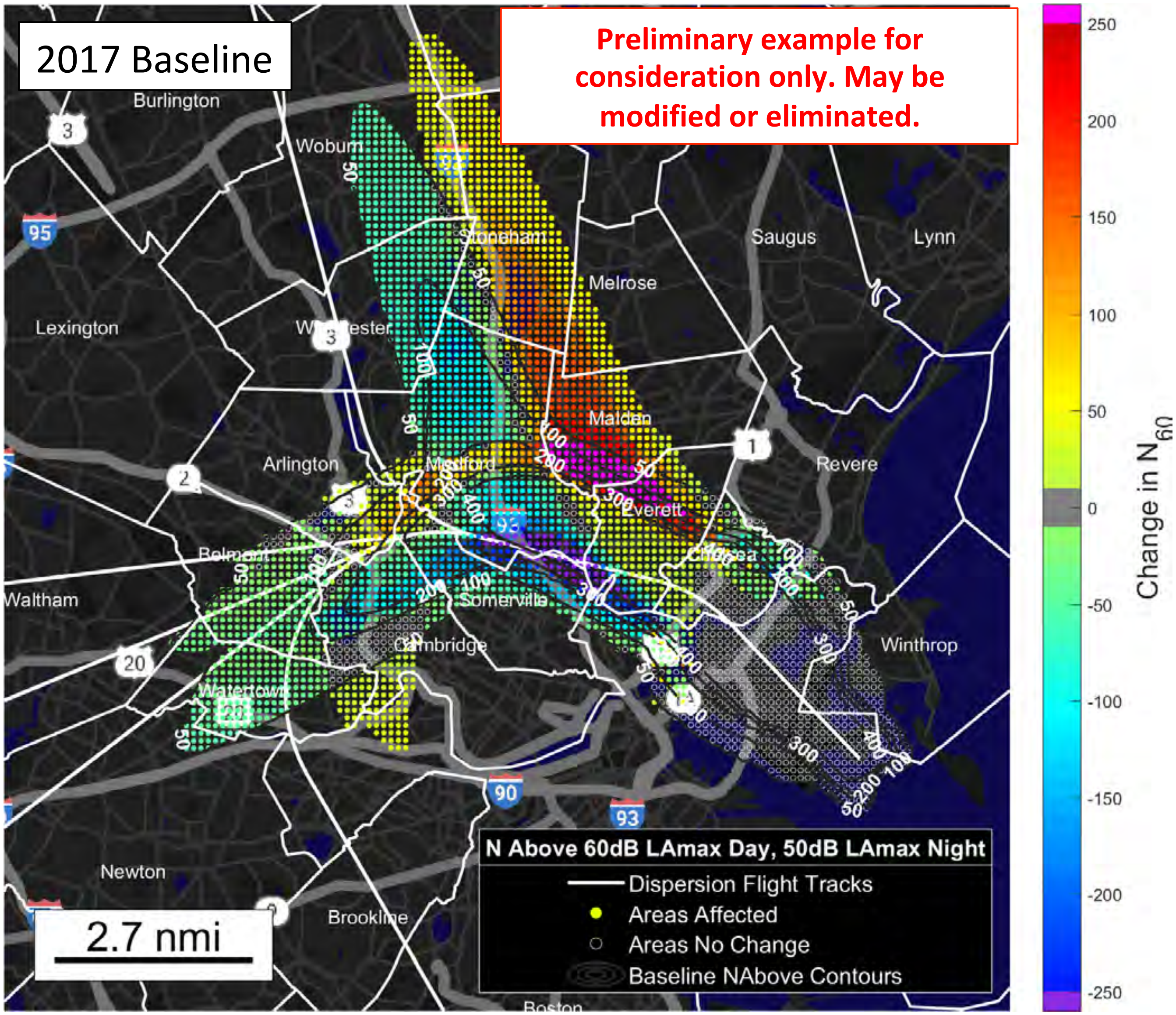
Analysis updated Dec 4 2018 to correct for discretization differences



Analysis based on peak day operations; only includes 33L departures

N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

VRD Waypoint #6

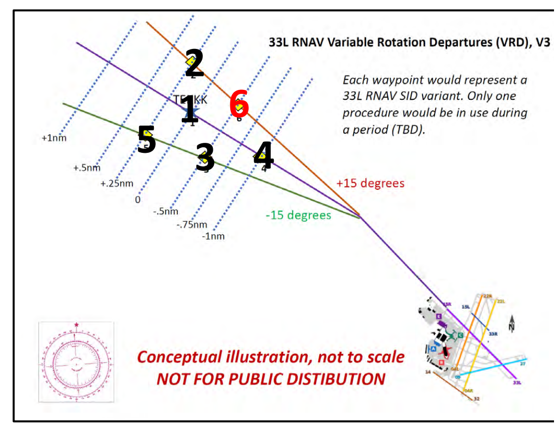


Analysis based on peak day operations; only includes 33L departures

Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	309,639
Baseline - Dispersion	27,004

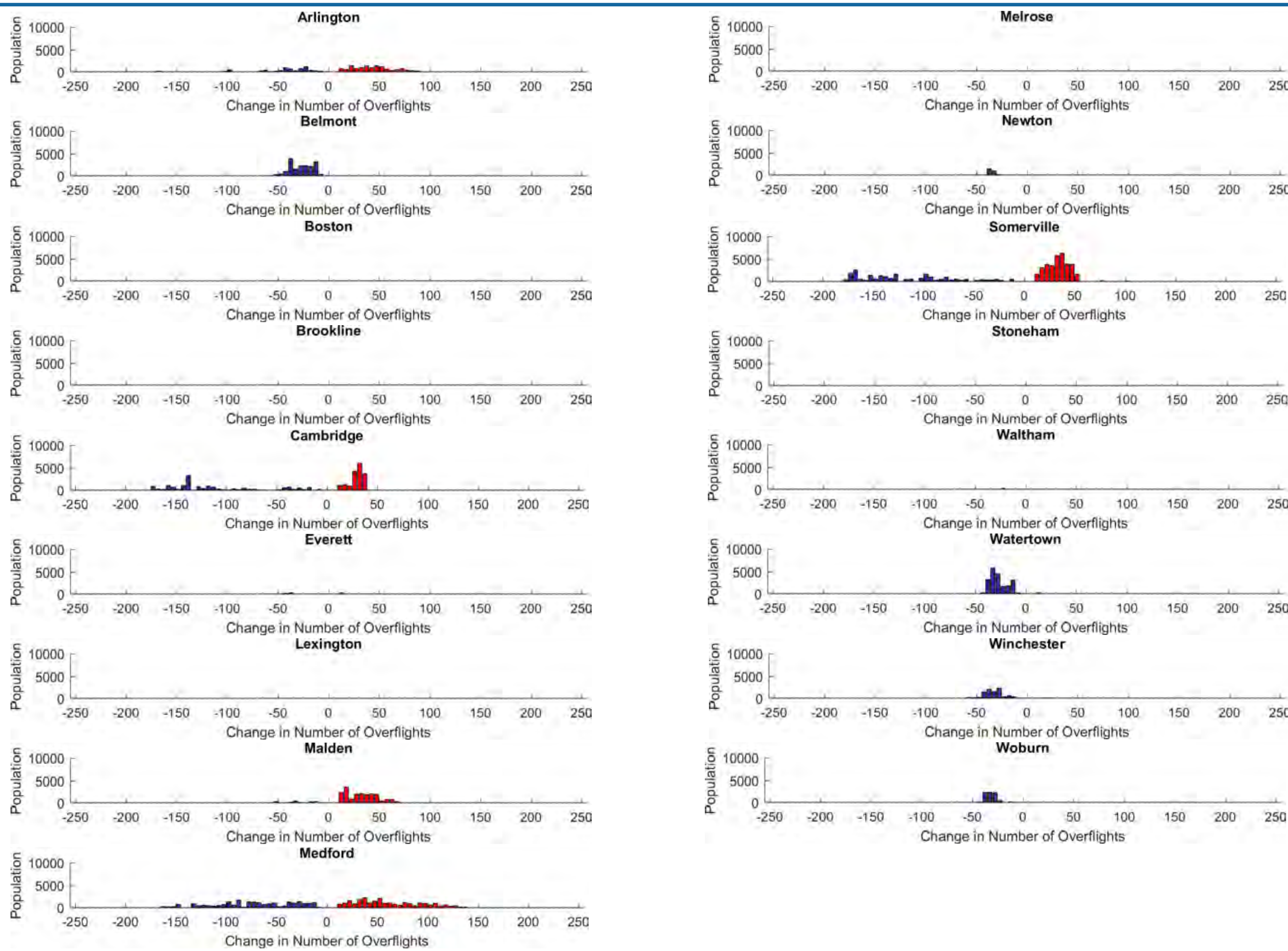
Analysis updated Dec 4 2018 to correct for discretization differences



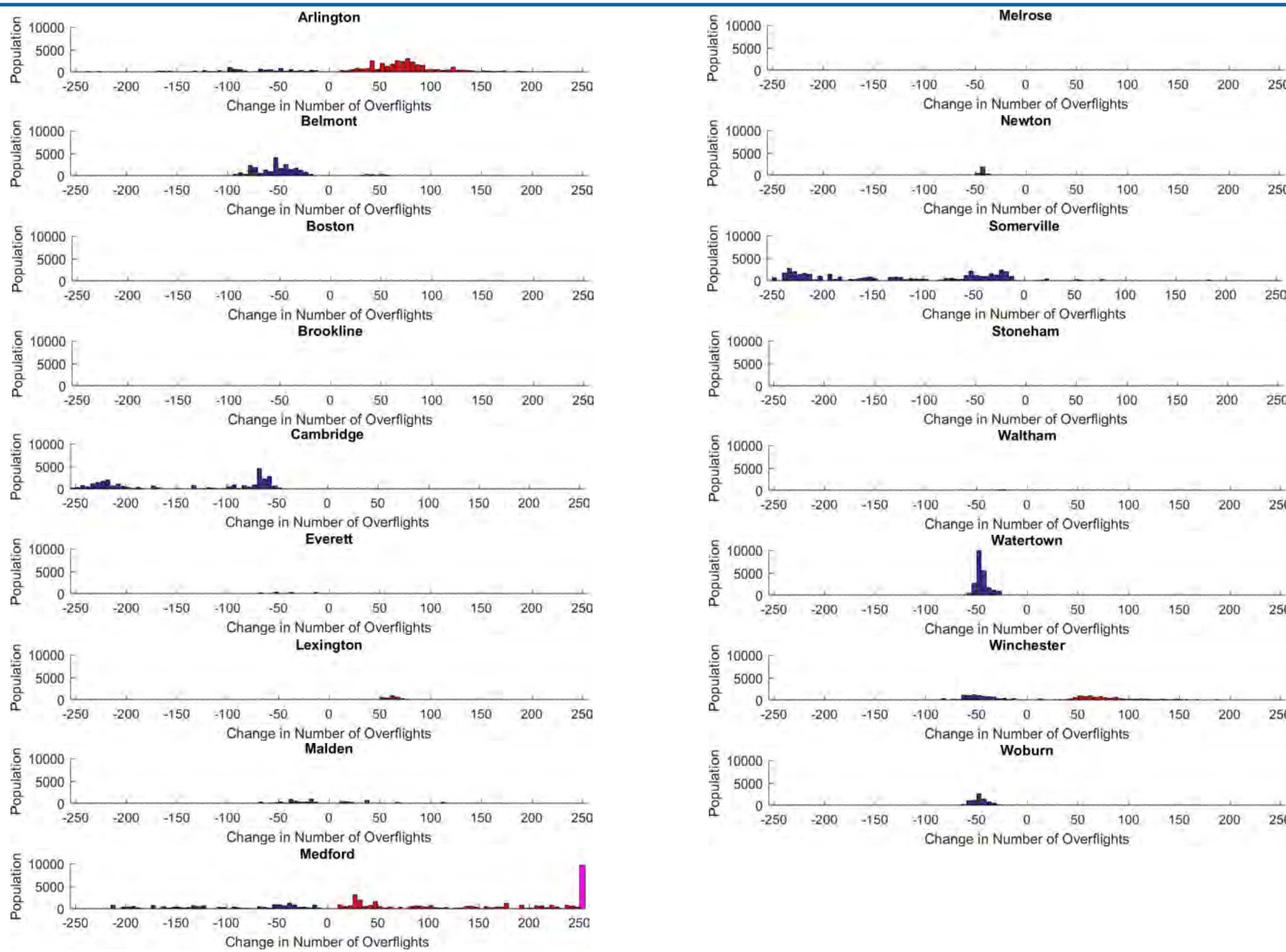
N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

Discussion

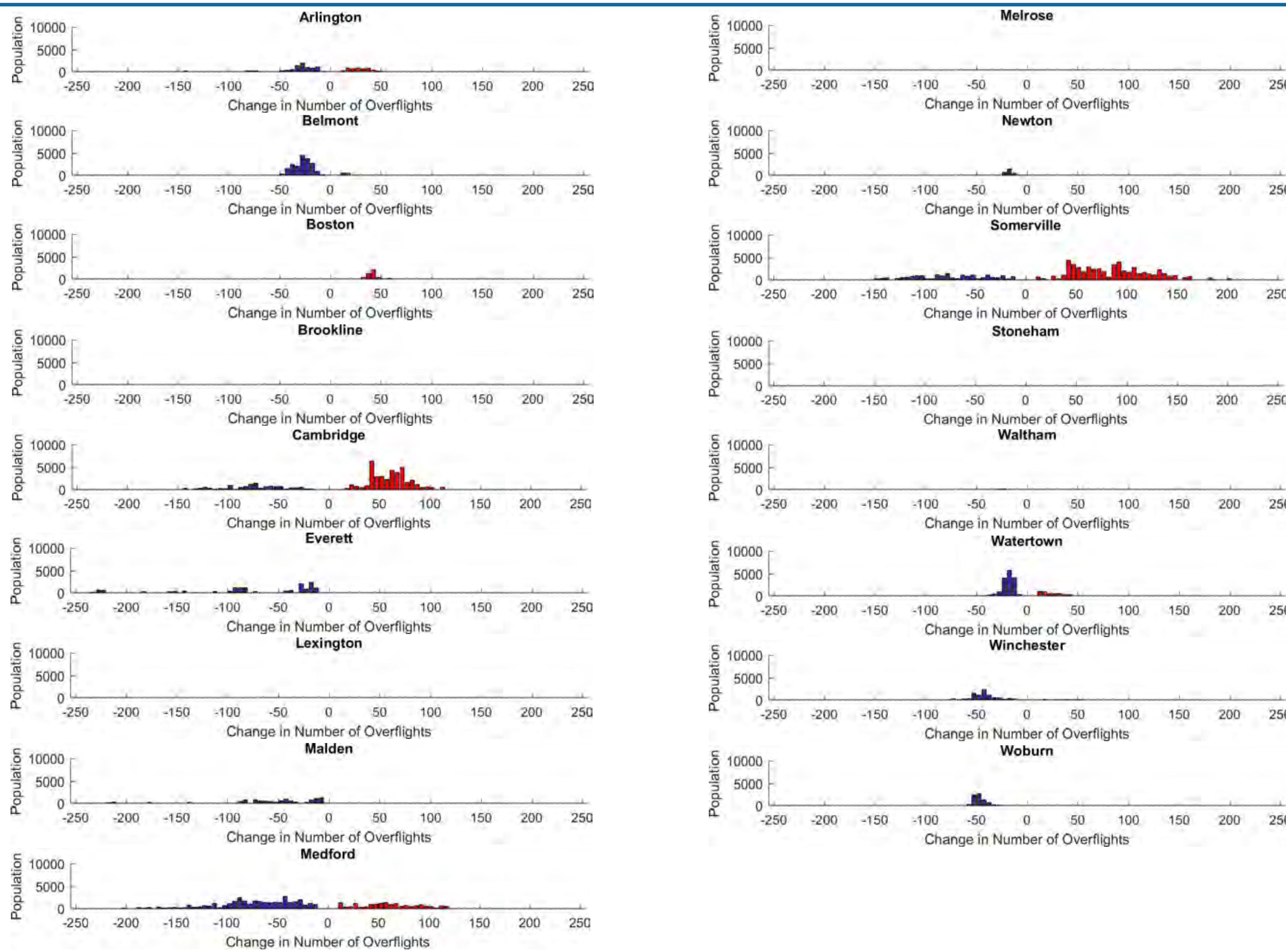
33L Departures Altitude-Based Dispersion at 3000ft Change in N_{60} Compared to 2017



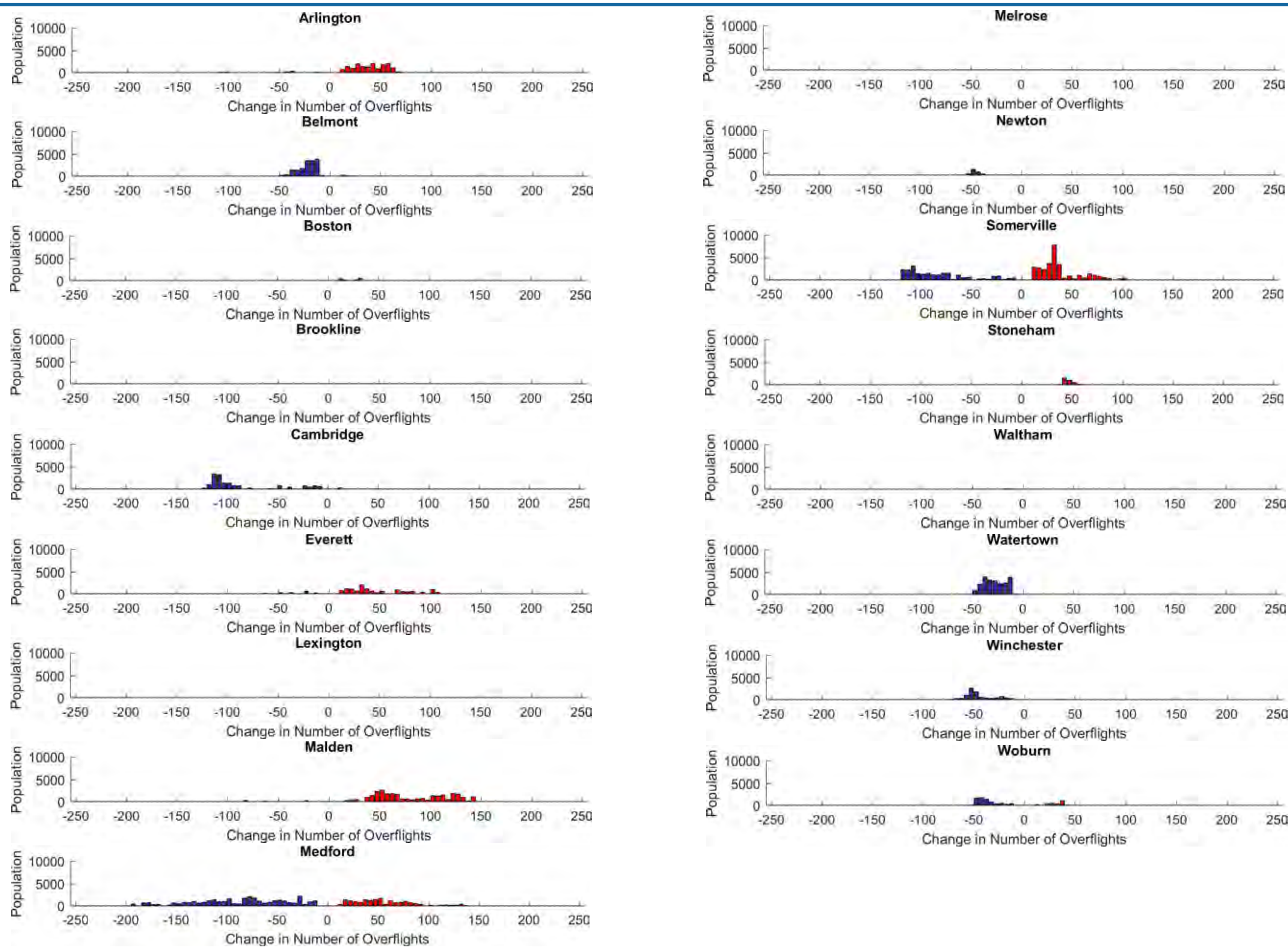
33L Departures Altitude-Based Dispersion at 4000ft Change in N_{60} Compared to 2017



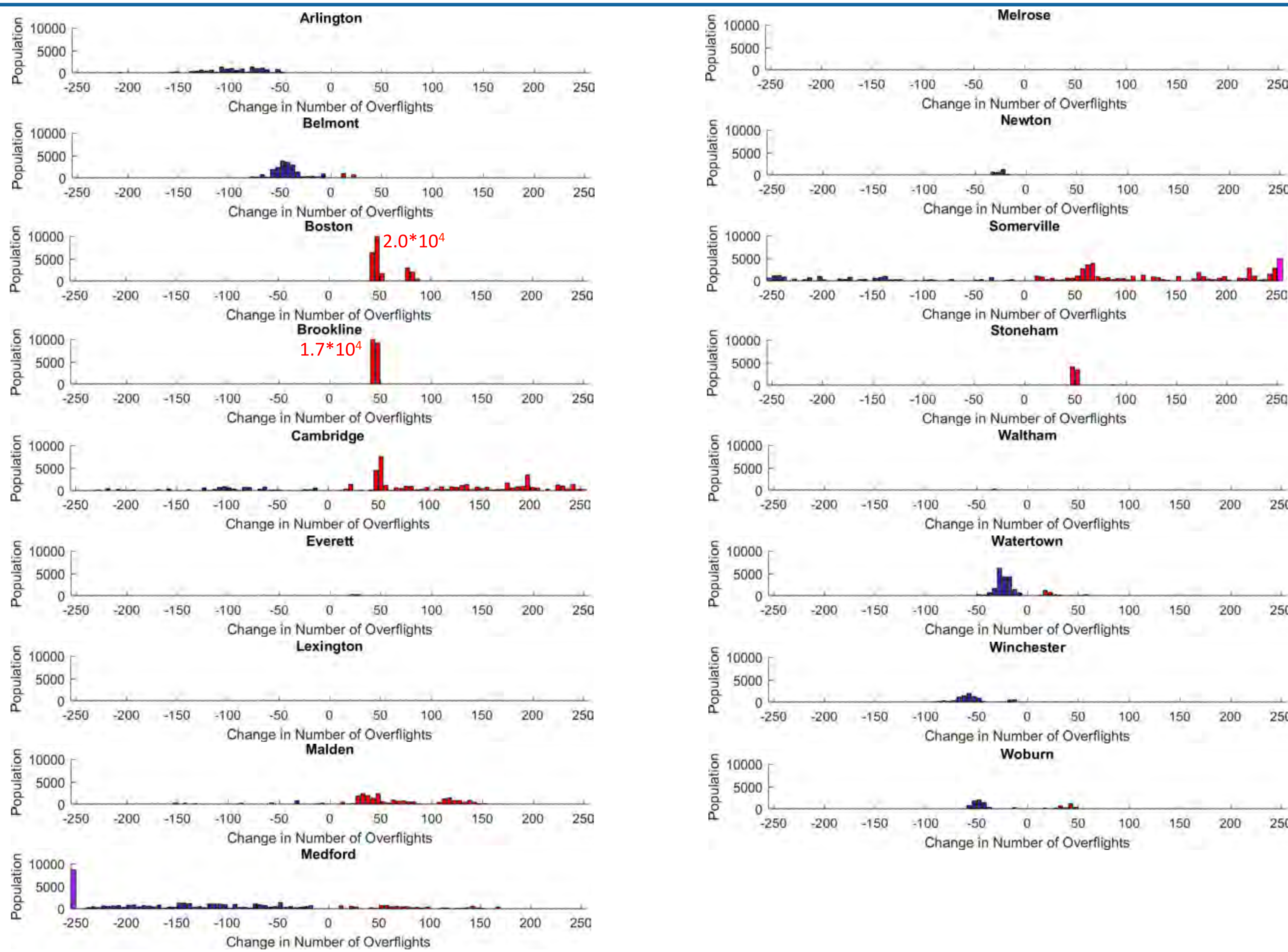
33L Departures Controller-Based Dispersion Change in N_{60} Compared to 2017



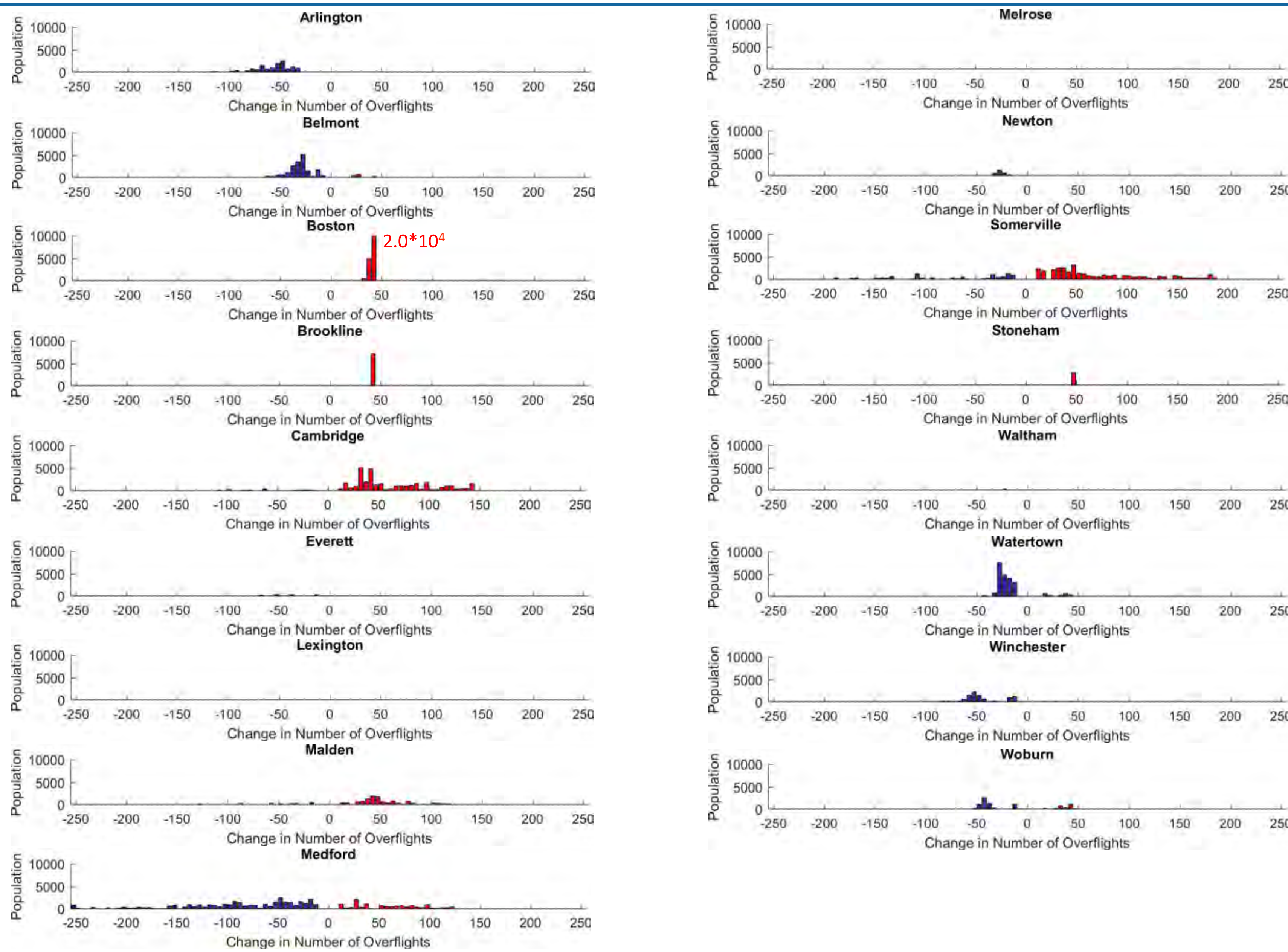
33L Departures Divergent Headings Dispersion Change in N_{60} Compared to 2017



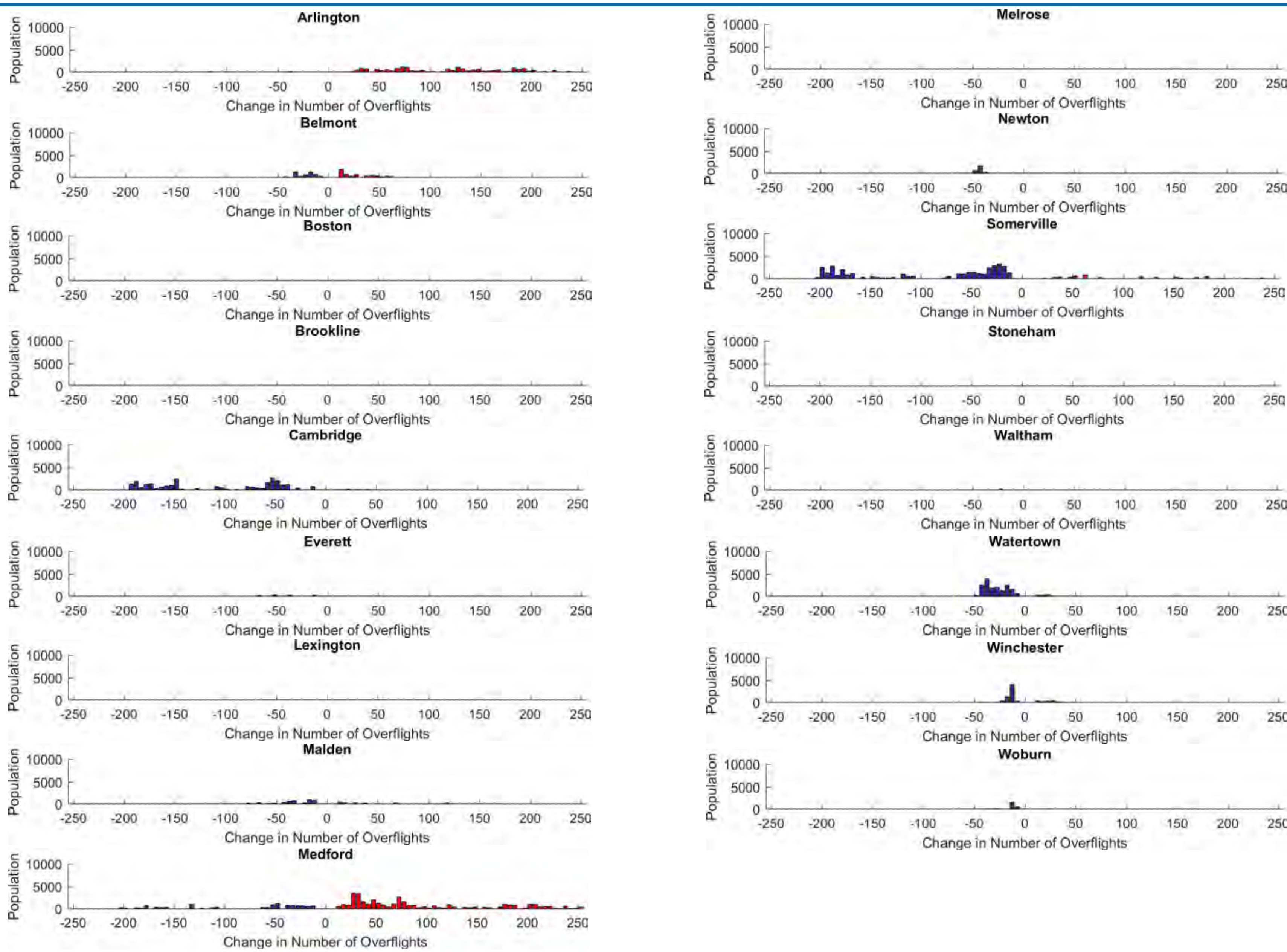
33L Departures RNAV Waypoint Relocation -1nmi
Change in N_{60} Compared to 2017



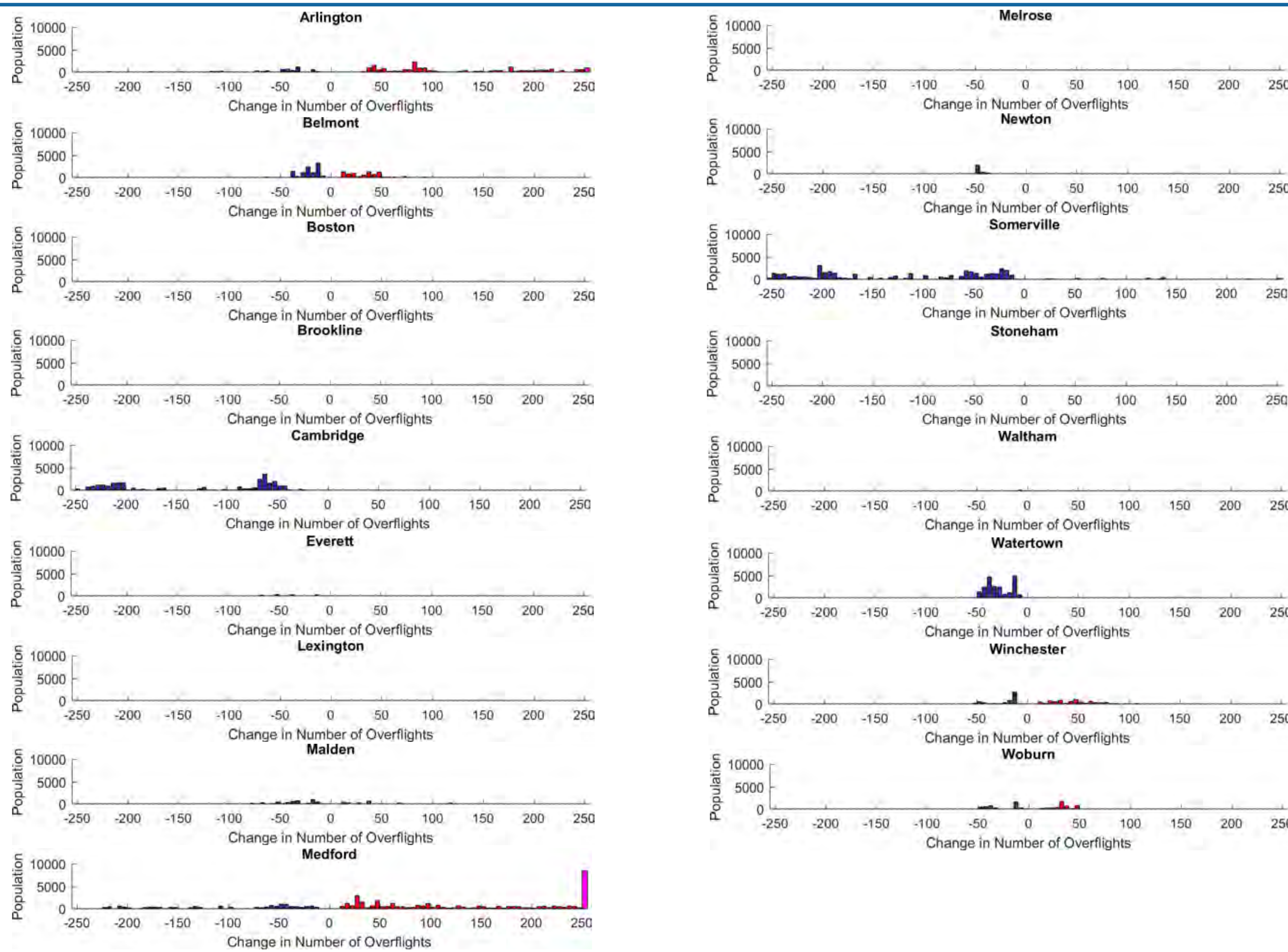
33L Departures RNAV Waypoint Relocation -0.5nmi
Change in N_{60} Compared to 2017



33L Departures RNAV Waypoint Relocation +0.5nmi Change in N_{60} Compared to 2017



33L Departures RNAV Waypoint Relocation +1nmi
Change in N_{60} Compared to 2017



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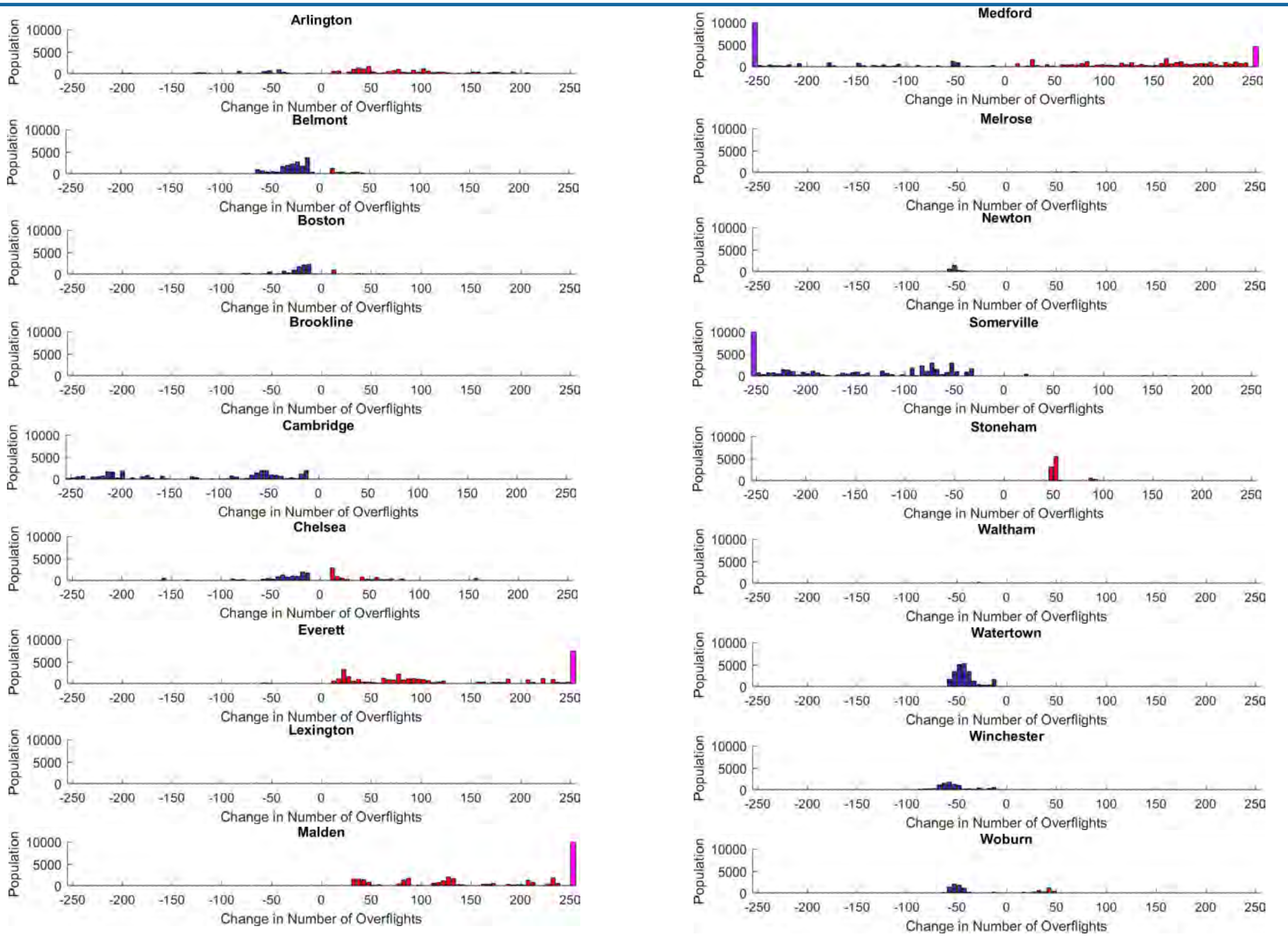
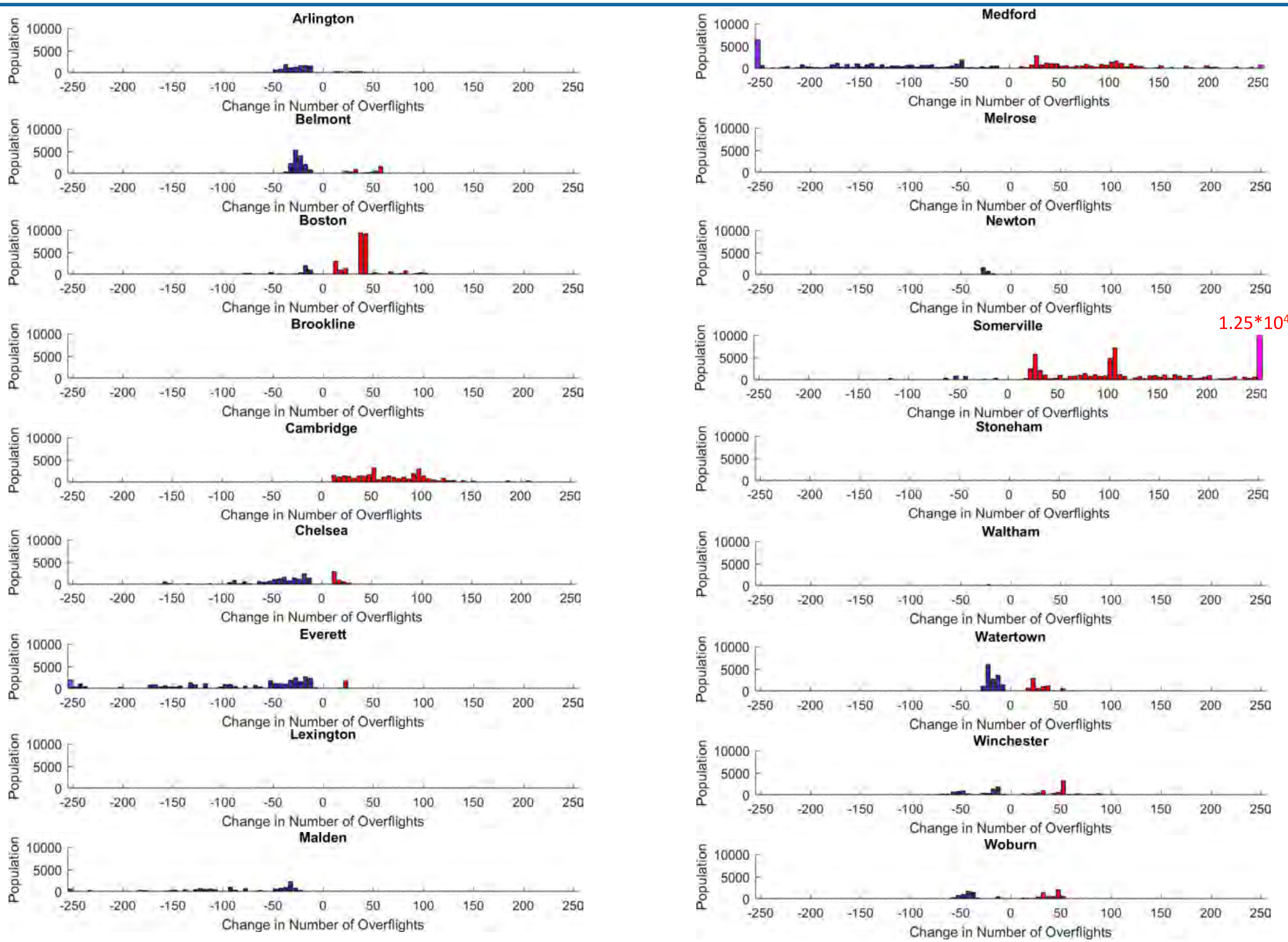
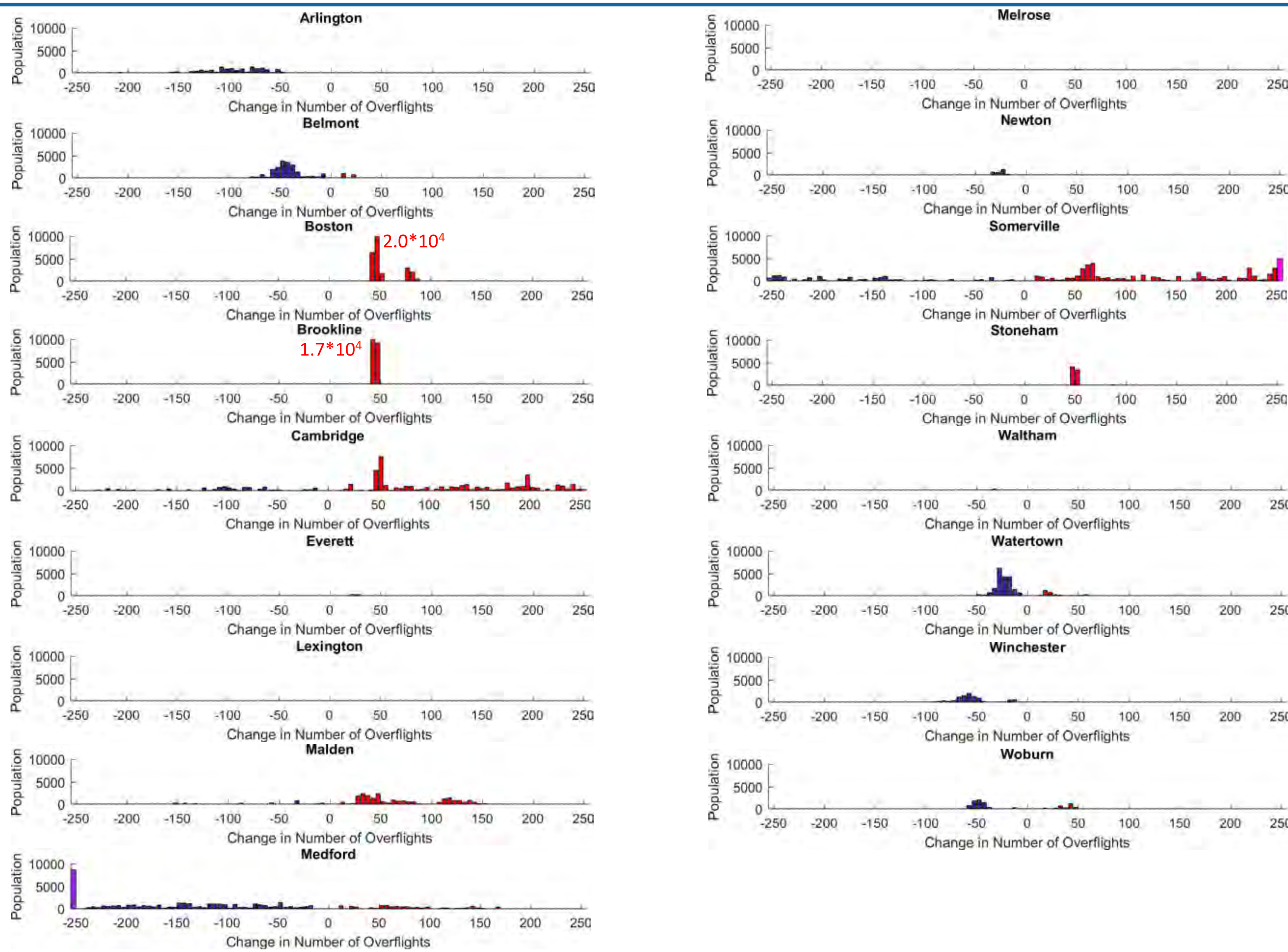
VRD Waypoint #2 Change in N_{60} Compared to 2017



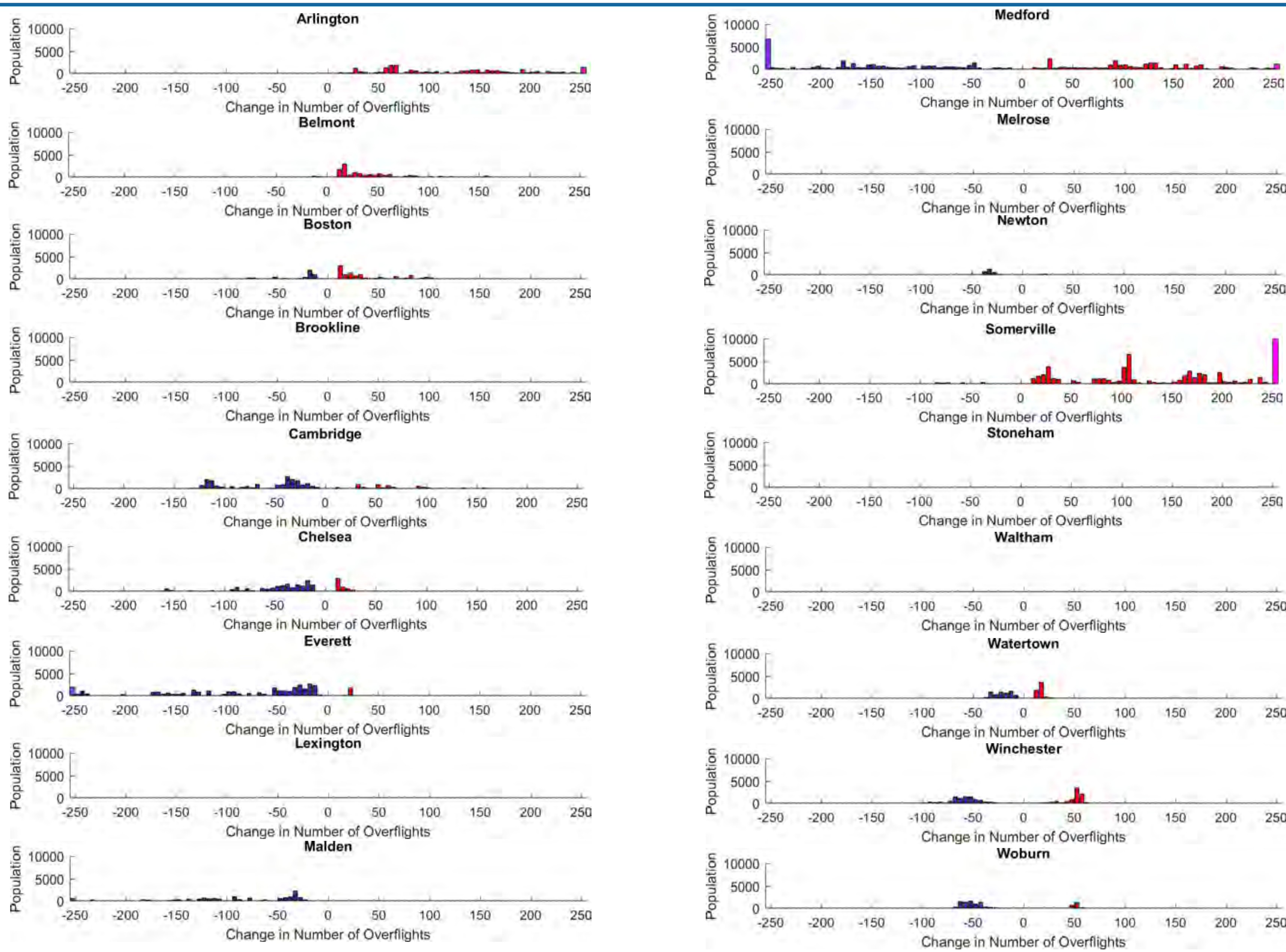
VRD Waypoint #3
Change in N_{60} Compared to 2017



VRD Waypoint #4
Change in N_{60} Compared to 2017



VRD Waypoint #5
Change in N_{60} Compared to 2017



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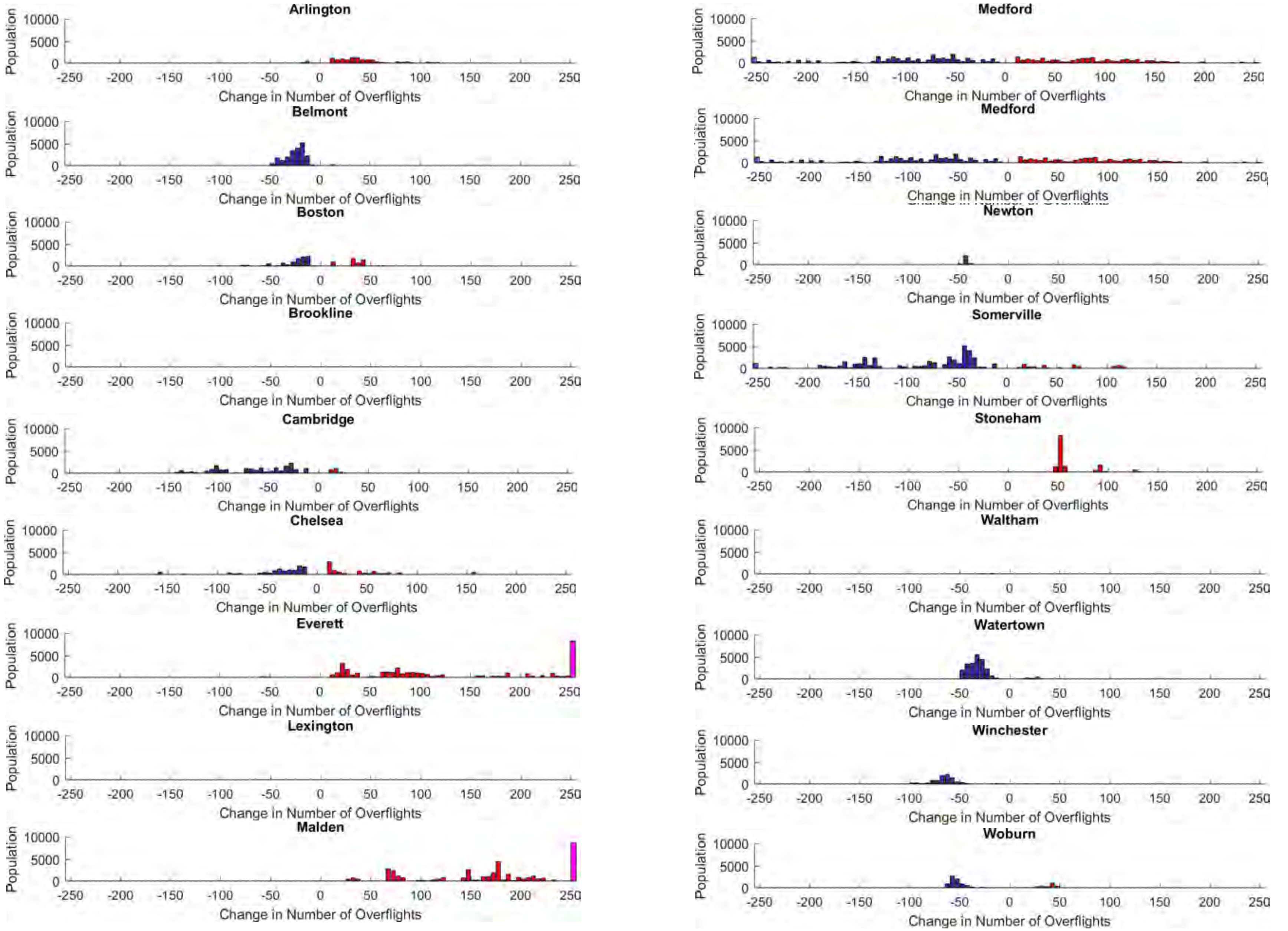
VRD Waypoint #6
Change in N_{60} Compared to 2017



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Backup

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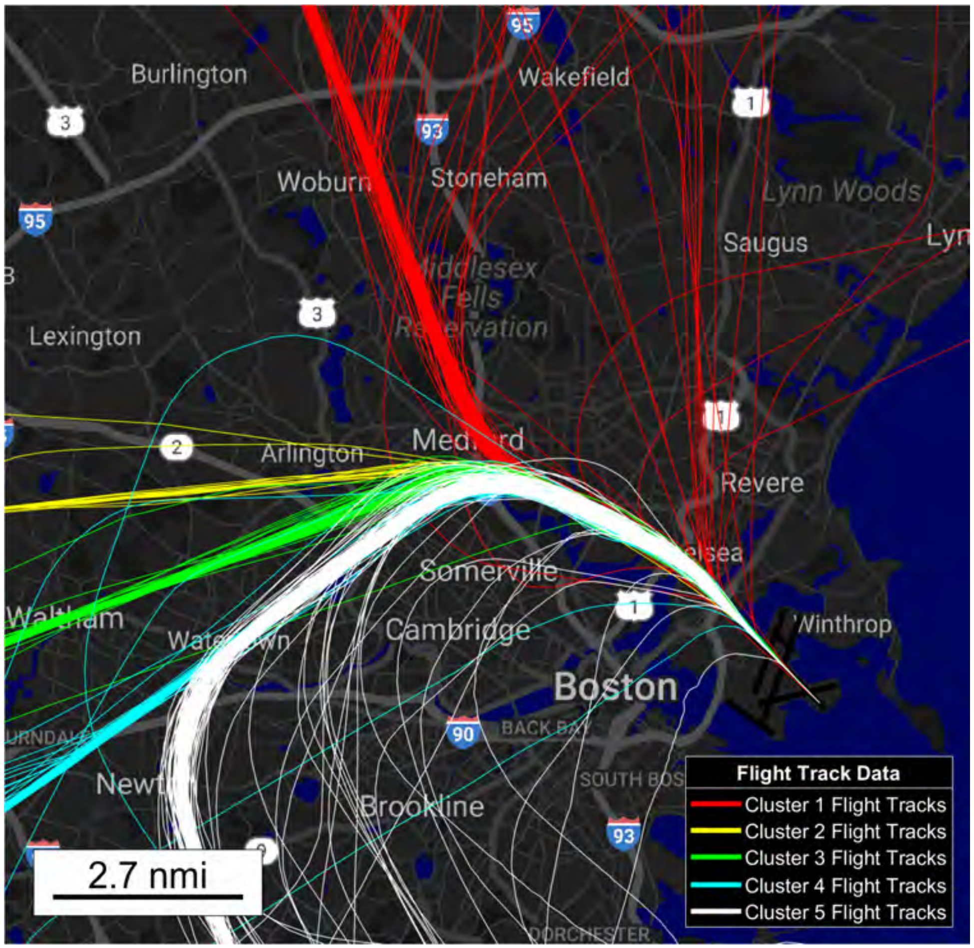
VRD Waypoint #1

- Flight track data analyzed on May 18th, 2017. 487 departures
- Trajectories clustered by applying k-means algorithm to flight track points at distance of 15nmi



	Day	Night
Peak Day	435	52
Average of Top 5 Peak Days	433.8	48.8

1	Day	Night	2	Day	Night	3	Day	Night
TA	6	2	TA	0	0	TA	2	0
B757	2	0	B757	1	0	B757	1	0
A320	40	6	A320	5	0	A320	24	4
B737	32	7	B737	0	0	B737	10	3
OJ	3	0	OJ	0	0	OJ	2	0
LRJ	35	2	LRJ	7	1	LRJ	24	1
SRJ	26	0	SRJ	2	0	SRJ	14	1

4	Day	Night	5	Day	Night
TA	1	1	TA	5	0
B757	1	0	B757	2	0
A320	25	2	A320	33	5
B737	11	2	B737	25	6
OJ	2	0	OJ	2	1
LRJ	21	4	LRJ	35	1
SRJ	14	0	SRJ	22	3

Legend
TA: Twin Aisle (B777)
OJ: Older Jet (MD88)
LRJ: Large Regional Jet (E170)
SRJ: Small Regional Jet (E145)