# Factors Influencing Estimated Time En Route

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# Outline

1. Why interest in ETE?
2. Trends in ETE
3. ETE distributions
   - Means, std deviations and relative variability
   - Shapes of distributions
   - Modeling ETE distributions w/lognormal mixtures
     - A new way to characterize carrier behavior
4. Standardized ETE
   - ANOVA for Factors affecting ETE
   - Boxplots by equipment and carrier
5. Variation in filed and flown routes
6. Are carriers padding their ETEs?

# 1. Why Interest in ETE?

- ETE is basis for analysis of deviations from flight plans (see Yakovchuk & Willemain, next talk at this conference), so should be understood.
- Average ETE should remain relatively constant but can actually vary a lot: Why?
  - MEM-CVG: 76 ⇨ 58 minutes during winters ‘98-’01
  - BWI-LGA: 36 ⇨ 52 minutes “ “ “
- ETE distributions may tell us about differences in carriers’ behavior.

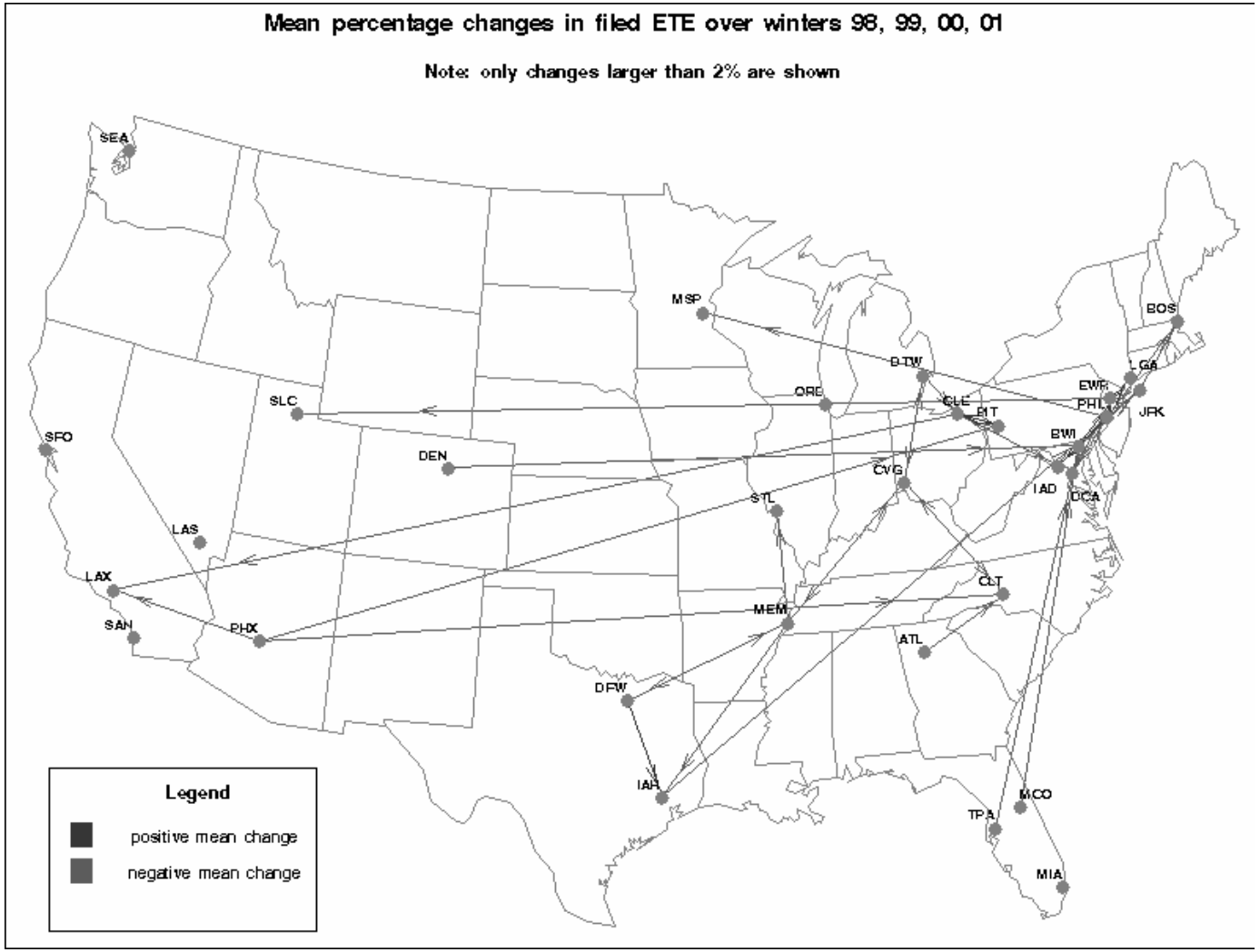
# 2. Trends in ETE

- ASPM data on ETEs
- Studied winters of ’98-’99, ’99-’00, ’00-’01, ’01-’02 to minimize effect of convective weather
- Some OD pairs had large and consistent changes

# OD Pairs with Strong Trends

| Origin | Destination | Average ETE '98-'99 | '99-'00 | '00-'01 | '01-02 | Avg Annual % Change |
|---|---|---|---|---|---|---|
| MEM | CVG | 76 | 73 | 66 | 58 | -8% |
| MEM | IAH | 98 | 85 | 78 | 77 | -8% |
| IAD | CLE | 72 | 68 | 60 | 57 | -7% |
| CVG | CLT | 73 | 65 | 63 | 58 | -7% |
| CLE | IAD | 62 | 58 | 51 | 50 | -7% |
| CLT | CVG | 80 | 76 | 73 | 66 | -6% |
| CVG | MEM | 80 | 79 | 76 | 68 | -5% |
| JFK | BOS | 43 | 41 | 39 | 37 | -5% |
| MEM | STL | 57 | 53 | 51 | 50 | -4% |
| PHL | DCA | 33 | 32 | 30 | 29 | -4% |
| DCA | EWR | 43 | 42 | 40 | 37 | -4% |
| BWI | JFK | 48 | 48 | 44 | 43 | -4% |
| PHL | IAD | 41 | 43 | 43 | 44 | 3% |
| PHL | EWR | 23 | 24 | 25 | 26 | 4% |
| DFW | IAH | 41 | 42 | 42 | 46 | 4% |
| CLE | PIT | 31 | 31 | 34 | 39 | 9% |
| PIT | CLE | 34 | 34 | 40 | 45 | 11% |
| BWI | LGA | 36 | 42 | 51 | 52 | 13% |

# OD Pairs with Strong Trends



# 3. ETE Distributions

- ASPM data
- Approximately 60,000 individual flights
- Variables
  - ETE, in minutes
  - Route: 28 routes (14 OD pairs) with many flights by at least 2 major carriers between major airports
  - Carrier: 6 majors (coded “AAA” to “FFF”)
  - Month: Jan-May 2002
  - Hour of day: departure times from 0600 to 2200 local
  - Equipment: 10 types of aircraft (e.g., 73x)

# Routes Chosen for Study

# Counts of Flights

| | | Carrier | | | | | | |
|---|---|---|---|---|---|---|---|---|
| OD pair | | AAA | BBB | CCC | DDD | EEE | FFF | Range/Average |
| ATL | ORD | 1666 | | 3129 | | 1995 | | 65% |
| EWR | LAX | 897 | 1566 | | | 896 | | 60% |
| EWR | ORD | 2578 | 1876 | | | 3240 | | 53% |
| SFO | LAX | 2253 | | 242 | | 6268 | | 206% |
| ORD | PHL | 2520 | | | | 3096 | 1638 | 60% |
| DTW | CLT | | | | 1121 | | 1191 | 6% |
| MIA | ATL | 1398 | | 2557 | | | | 59% |
| IAH | ATL | | 1964 | 1767 | | | | 11% |
| DTW | EWR | | 1030 | | 2122 | | | 69% |
| DTW | ATL | | | 2060 | 2241 | | | 8% |
| ATL | CLT | | | 2030 | | | 1733 | 16% |
| DTW | DEN | | | | 936 | 606 | | 43% |
| SFO | PHL | | | | | 599 | 949 | 45% |
| IAH | CLT | | 257 | | | | 1032 | 120% |

# Average ETE (minutes)

| OD pair | | Carrier AAA | BBB | CCC | DDD | EEE | FFF | Range/Average |
|---|---|---|---|---|---|---|---|---|
| ATL | ORD | 93 | | 87 | | 88 | | 7% |
| EWR | LAX | 302 | 300 | | | 297 | | 2% |
| EWR | ORD | 106 | 104 | | | 102 | | 4% |
| SFO | LAX | 58 | | 53 | | 55 | | 10% |
| ORD | PHL | 102 | | | | 98 | 99 | 4% |
| DTW | CLT | | | | 77 | | 75 | 3% |
| MIA | ATL | 87 | | 83 | | | | 4% |
| IAH | ATL | | 96 | 94 | | | | 2% |
| DTW | EWR | | 75 | | 75 | | | 1% |
| DTW | ATL | | | 85 | 89 | | | 4% |
| ATL | CLT | | | 37 | | | 39 | 5% |
| DTW | DEN | | | | 146 | 148 | | 1% |
| SFO | PHL | | | | | 310 | 306 | 1% |
| IAH | CLT | | 127 | | | | 123 | 3% |

Largest every time

Smallest every time

# Standard Deviation of ETE

| | | Carrier | | | | | | |
|---|---|---|---|---|---|---|---|---|
| OD pair | | AAA | BBB | CCC | DDD | EEE | FFF | Range/Average |
| ATL | ORD | 8 | | 7 | | 9 | | 27% |
| EWR | LAX | 33 | 37 | | | 33 | | 13% |
| EWR | ORD | 16 | 18 | | | 16 | | 9% |
| SFO | LAX | 4 | | 2 | | 5 | | 70% |
| ORD | PHL | 14 | | | | 14 | 15 | 10% |
| DTW | CLT | | | | 4 | | 5 | 17% |
| MIA | ATL | 6 | | 4 | | | | 39% |
| IAH | ATL | | 10 | 9 | | | | 9% |
| DTW | EWR | | 12 | | 12 | | | 1% |
| DTW | ATL | | | 5 | 7 | | | 22% |
| ATL | CLT | | | 4 | | | 6 | 48% |
| DTW | DEN | | | | 18 | 15 | | 20% |
| SFO | PHL | | | | | 36 | 35 | 2% |
| IAH | CLT | | 16 | | | | 16 | 4% |

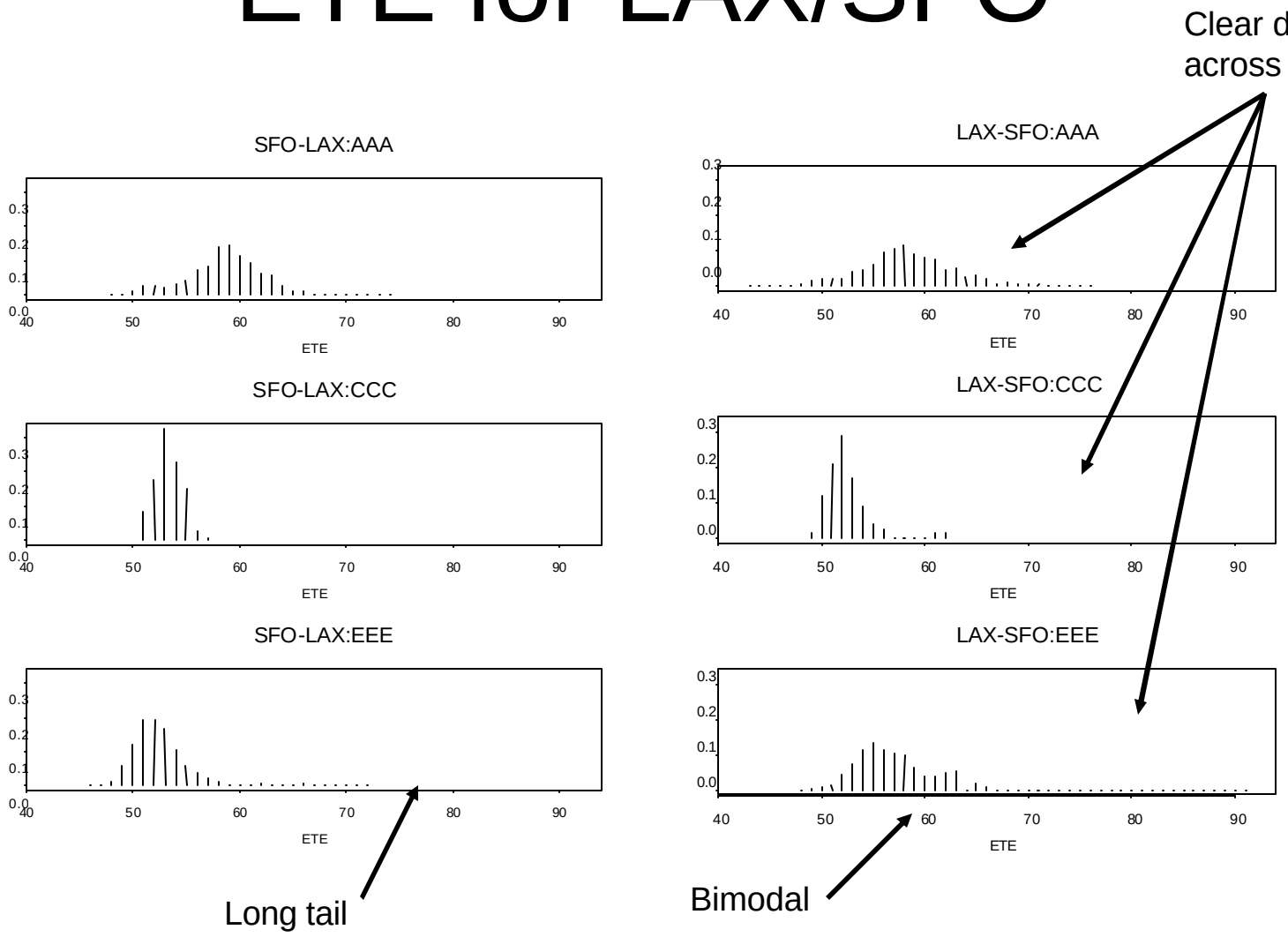
Smallest every time

# Relative Variability (CV) of ETE

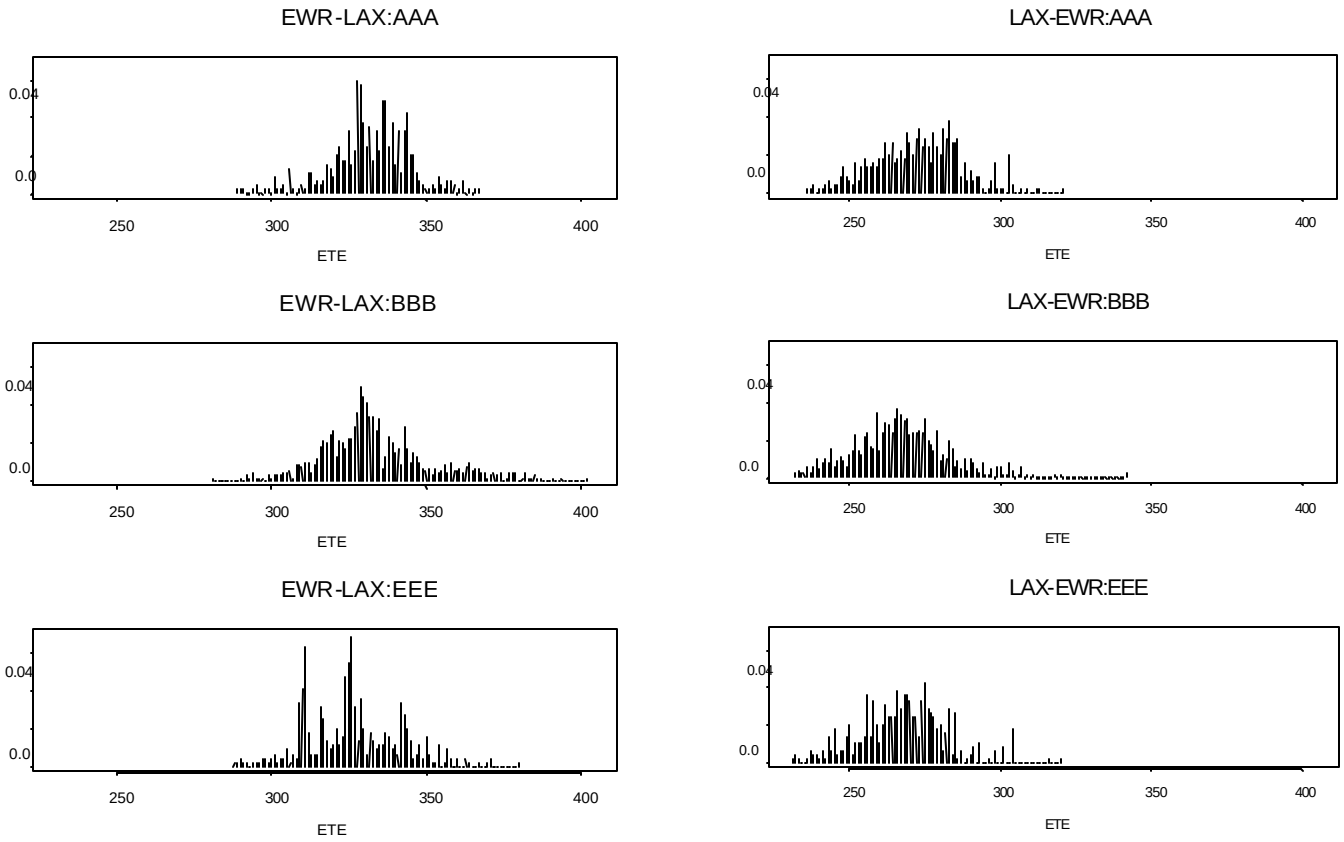
| | | Carrier | | | | | | |
|---|---|---|---|---|---|---|---|---|
| OD pair | | AAA | BBB | CCC | DDD | EEE | FFF | Range |
| ATL | ORD | 9% | | 8% | | 10% | | 2% |
| EWR | LAX | 11% | 12% | | | 11% | | 2% |
| EWR | ORD | 15% | 17% | | | 16% | | 2% |
| SFO | LAX | 7% | | 4% | | 8% | | 4% |
| ORD | PHL | 14% | | | | 14% | 15% | 2% |
| DTW | CLT | | | | 6% | | 7% | 1% |
| MIA | ATL | 7% | | 5% | | | | 2% |
| IAH | ATL | | 10% | 9% | | | | 1% |
| DTW | EWR | | 16% | | 16% | | | 0% |
| DTW | ATL | | | 6% | 8% | | | 1% |
| ATL | CLT | | | 10% | | | 15% | 5% |
| DTW | DEN | | | | 12% | 10% | | 2% |
| SFO | PHL | | | | | 12% | 11% | 0% |
| IAH | CLT | | 12% | | | | 13% | 1% |

Smallest every time

# ETE for LAX/SFO

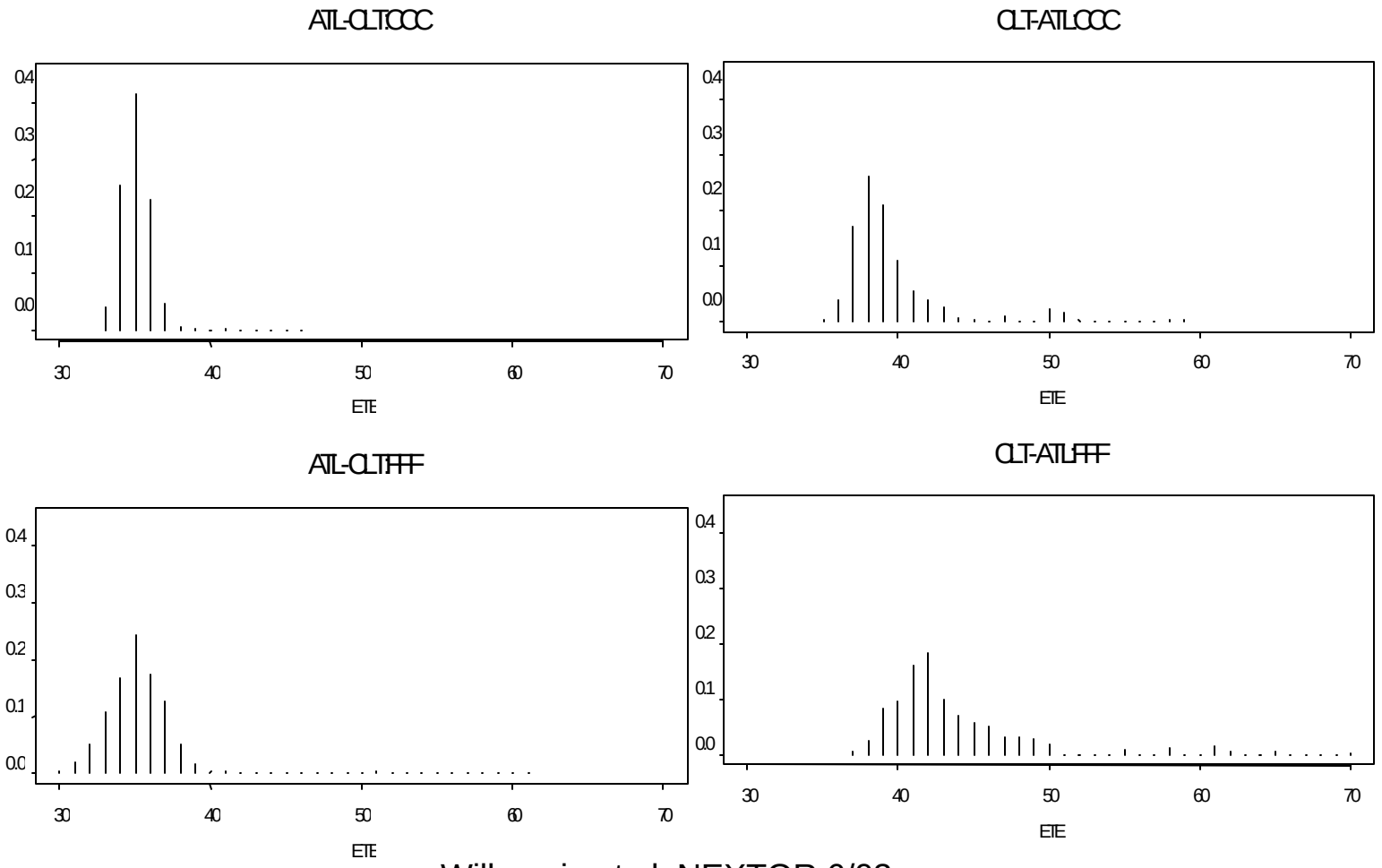


# ETE for EWR/LAX

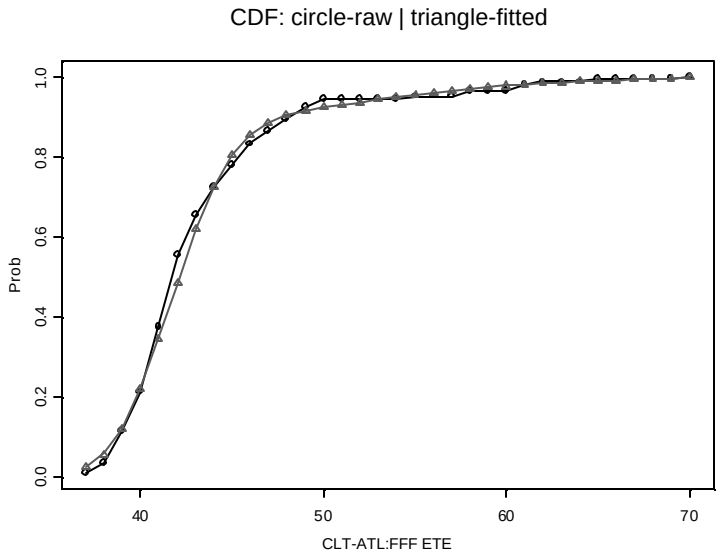


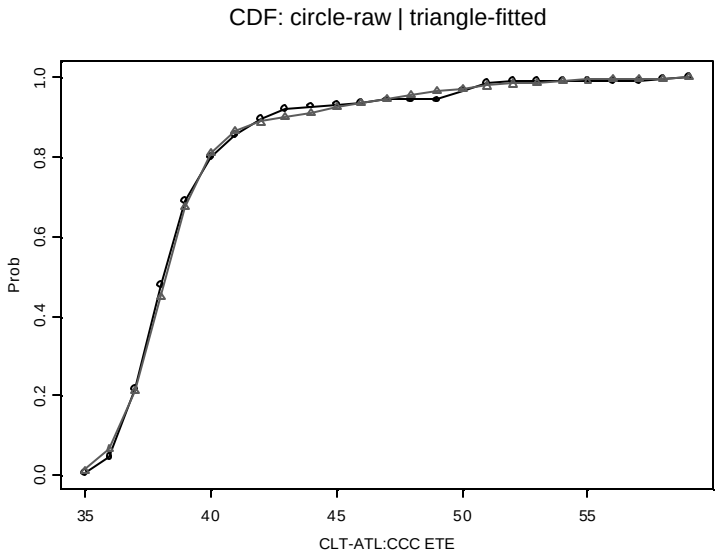

Effect of wind clearly visible when compare eastbound vs westbound ETEs

# ETE for ATL/CLT



# Fit CLT-ATL with Mixture of Lognormals



# Parameter Estimates

| | | Parameters for "Regular" Ops | | | Parameters for "Irregular" Ops | | |
|---|---|---|---|---|---|---|---|
| Route | Carrier | Proportion | Mean | Std Dev | Proportion | Mean | Std Dev |
| ATL to CLT | FFF | 98% | 35 | 2 | 2% | 49 | 5 |
| | CCC | 98% | 35 | 1 | 2% | 46 | 5 |
| CLT to ATL | FFF | 88% | 42 | 3 | 12% | 54 | 8 |
| | CCC | 85% | 38 | 1 | 15% | 46 | 5 |
| SFO to LAX | EEE | 98% | 52 | 2 | 2% | 65 | 3 |
| | AAA | 52% | 59 | 2 | 48% | 58 | 4 |
| LAX to SFO | EEE | 58% | 58 | 4 | 42% | 55 | 2 |
| | AAA | 79% | 58 | 5 | 21% | 58 | 2 |

Use these 5 parameters to characterize carrier flight planning behavior

# 4. Standardized ETE

- Standardized ETE for a route on a given day
  = ETE / {Avg of all ETEs for that route}
- Average Standardized ETE = 1.0
- Allows combining of data from all 28 routes
- Focuses attention on variation around the average
- Distribution is rather symmetric in middle but has a small % (but large #) of extreme outliers

# ANOVA for Standardized ETE

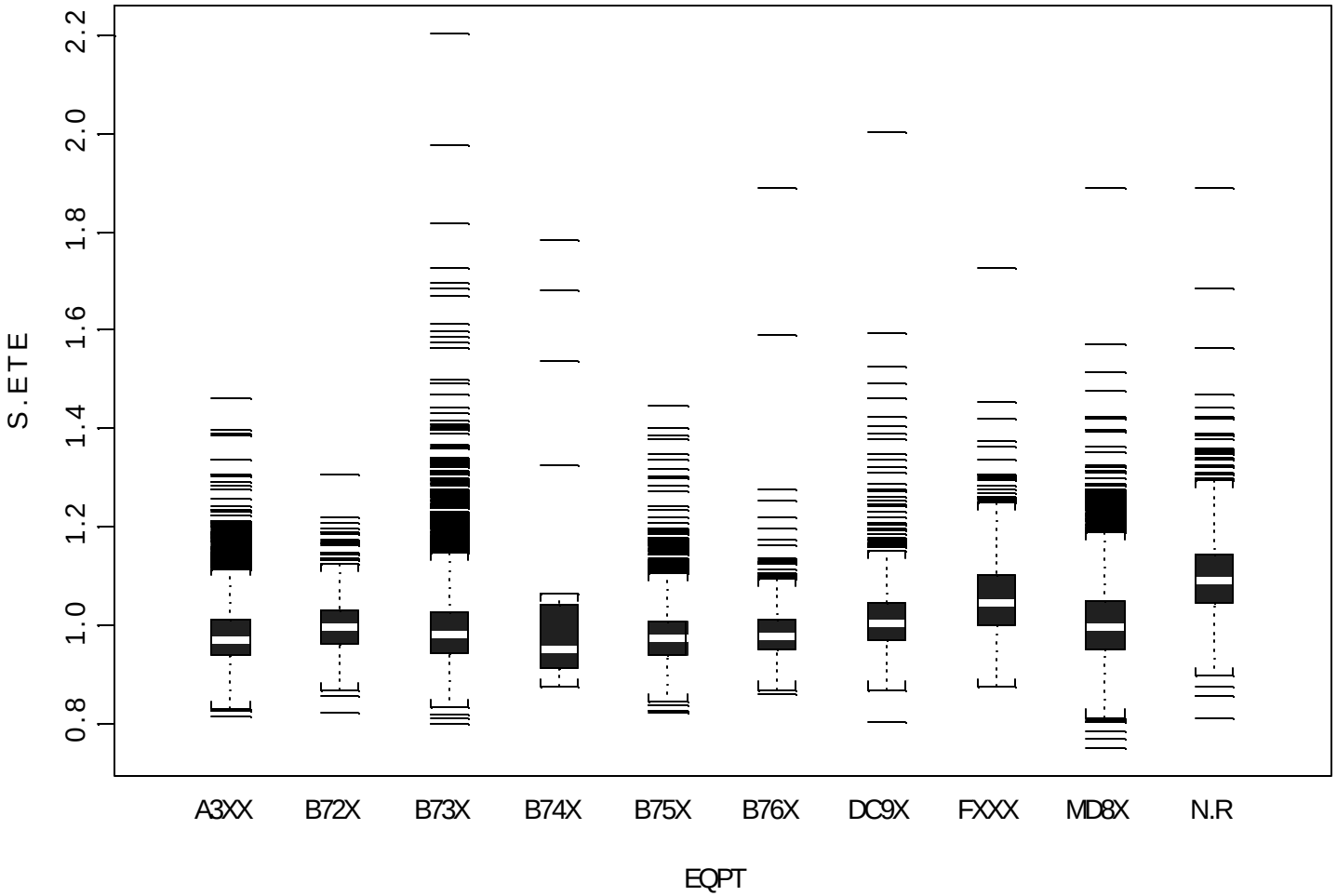
Most of variance unexplained: wind?

| R-Square | Coeff of Var | Root MSE | S_ETE Mean |
|---|---|---|---|
| 0.25 | 6.68 | 0.067 | 1.00 |

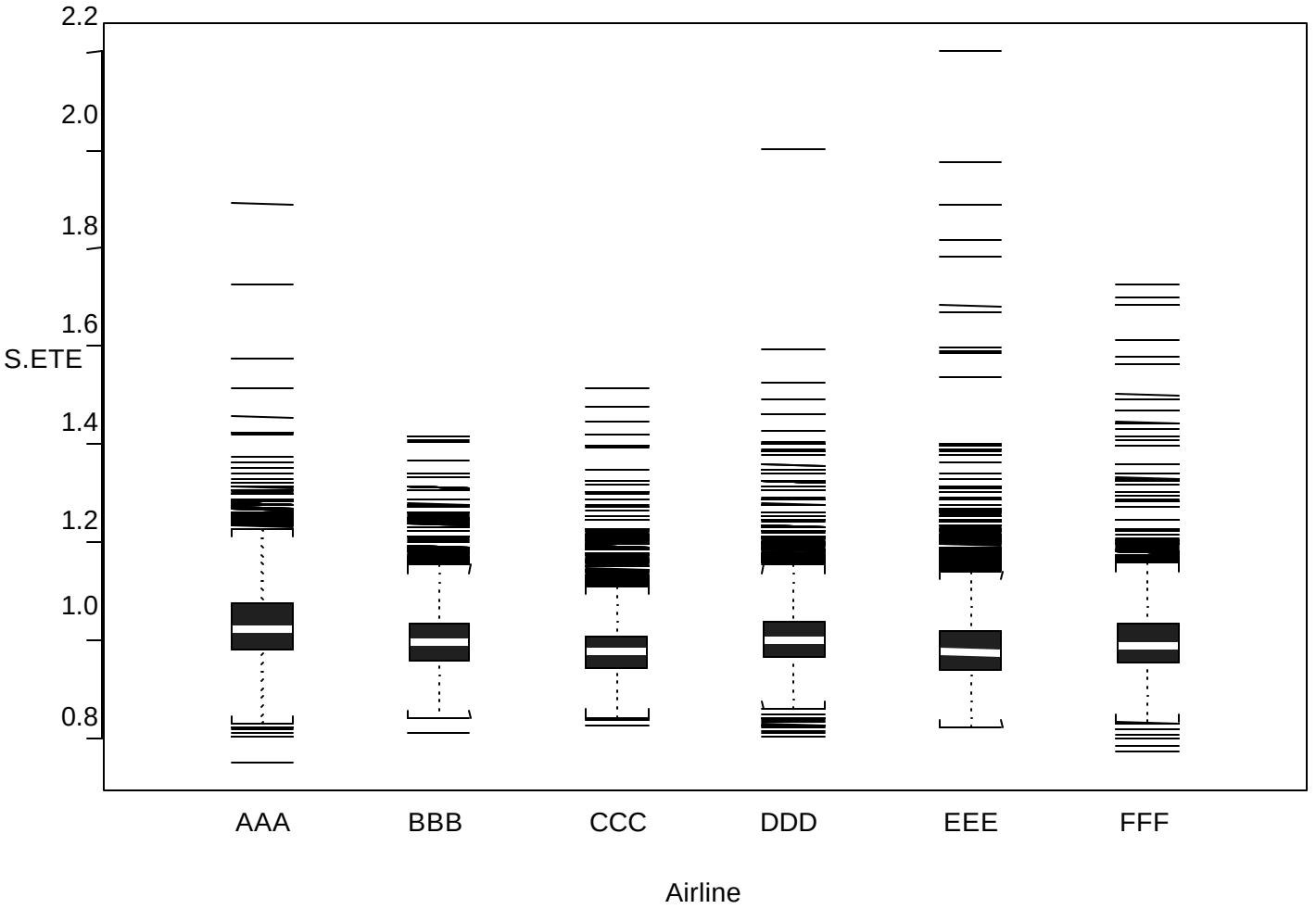
Only 2 factors had much influence

| Source | DF | Type I SS | Mean Square | F Value | Pr > F[(a)] |
|---|---|---|---|---|---|
| Eqpt | 9 | 35.11 | 3.90 | 873.40 | <.0001 |
| Airline | 5 | 10.32 | 2.06 | 462.11 | <.0001 |
| Citypair | 13 | 3.81 | 0.29 | 65.57 | <.0001 |
| Hour | 16 | 3.39 | 0.21 | 47.50 | <.0001 |
| Eqpt*Airline | 21 | 3.71 | 0.18 | 39.54 | <.0001 |
| Month | 4 | 0.64 | 0.16 | 35.79 | <.0001 |
| Eqpt*Citypair | 58 | 5.22 | 0.09 | 20.17 | <.0001 |
| Day | 6 | 0.43 | 0.07 | 15.97 | <.0001 |
| Eqpt*Hour | 129 | 6.02 | 0.05 | 10.45 | <.0001 |
| Eastward(Citypair) | 14 | 0.59 | 0.04 | 9.47 | <.0001 |
| Airline*Hour | 78 | 3.27 | 0.04 | 9.39 | <.0001 |
| Airline*Month | 20 | 0.79 | 0.04 | 8.86 | <.0001 |
| Month*Day | 24 | 0.85 | 0.04 | 7.94 | <.0001 |
| Hour*Citypair | 173 | 5.82 | 0.03 | 7.53 | <.0001 |
| Eqpt*Month | 35 | 1.15 | 0.03 | 7.34 | <.0001 |
| Airline*Citypair | 16 | 0.40 | 0.02 | 5.57 | <.0001 |
| Month*Hour | 64 | 1.47 | 0.02 | 5.13 | <.0001 |
| Month*Citypair | 52 | 0.79 | 0.02 | 3.40 | <.0001 |
| Eqpt*Day | 53 | 0.70 | 0.01 | 2.96 | <.0001 |
| Day*Citypair | 78 | 0.85 | 0.01 | 2.45 | <.0001 |
| Airline*Day | 30 | 0.24 | 0.01 | 1.78 | 0.0053 |
| Day*Hour | 96 | 0.66 | 0.01 | 1.53 | 0.0006 |

# Std ETE by Equipment



# Std ETE by Carrier



# Std ETE by Carrier

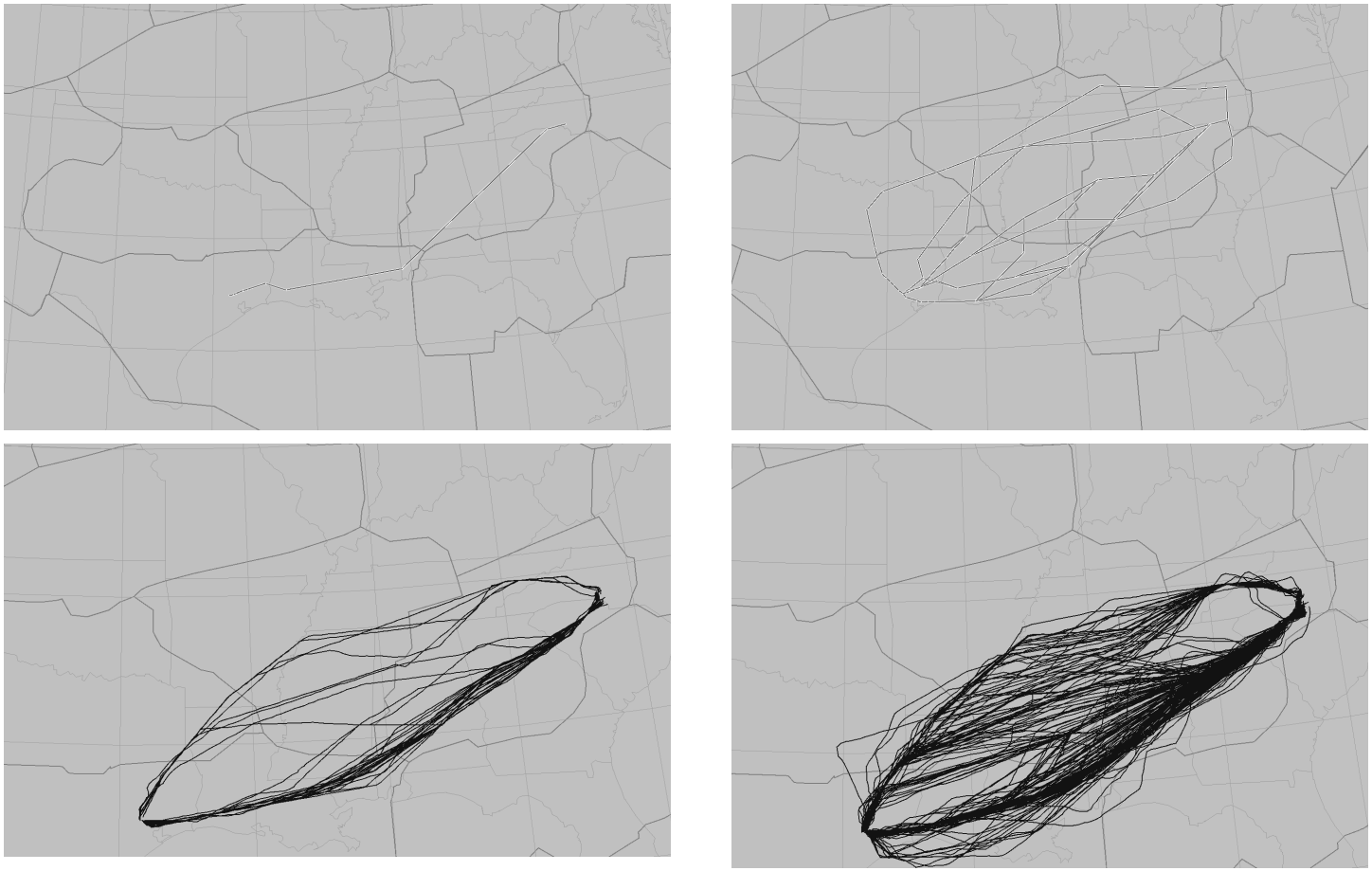
Confirms earlier comparisons using mean and std dev

| | Airline | | | | | |
|---|---|---|---|---|---|---|
| | AAA | BBB | CCC | DDD | EEE | FFF |
| Mean | 1.030 | 1.003 | 0.980 | 1.010 | 0.987 | 1.004 |
| SE of Mean | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| 75%Quantile | 1.078 | 1.035 | 1.009 | 1.041 | 1.020 | 1.035 |
| **50%Quantile** | **1.023** | **0.996** | **0.975** | **1.000** | **0.975** | **0.991** |
| 25%Quantile | 0.978 | 0.956 | 0.942 | 0.964 | 0.939 | 0.954 |
| **IQR** | **0.100** | **0.080** | **0.068** | **0.077** | **0.081** | **0.081** |
| n | 11,313 | 6,693 | 11,785 | 6,432 | 16,700 | 6,543 |

# 5. Spatial Variation

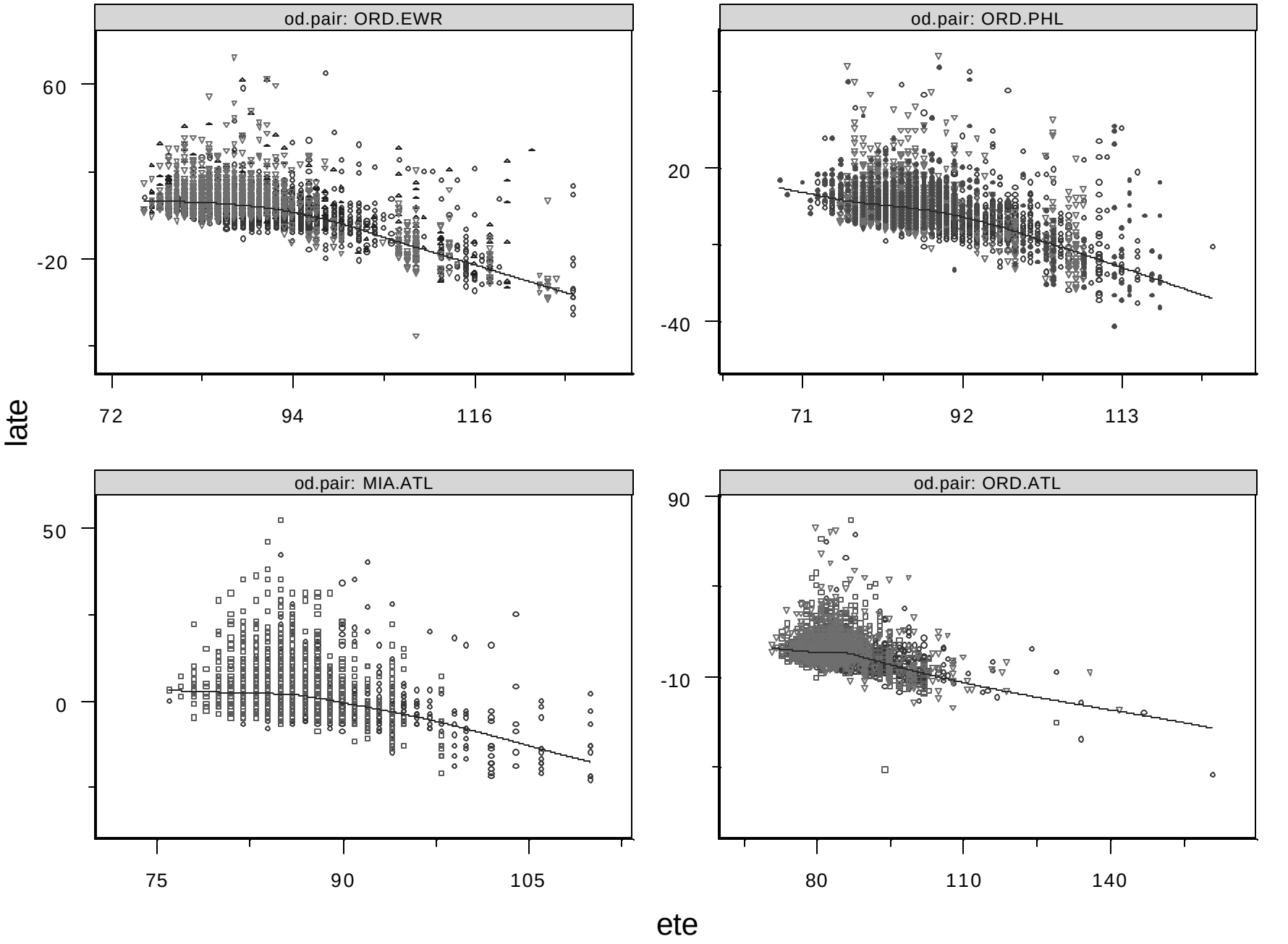
- Data from POET for 10 Sep - 7 Nov 2002; average of 400 flights per route.
- Routes filed can differ greatly by carrier.
- Routes flown can differ greatly from routes filed.
- ETE variability cannot be traced primarily to differences in routes.
  - 3% relative variability in length of filed routes
  - 11% relative variability in ETE

# CLT-IAH Routes: Planned & Flown



# 6. Are Carriers Padding ETE?

- “Padding” = adding extra time so that on-time performance will look better
- If padding, then deviation = actual - ETE will be negative (though “better” to pad G2G than ETE)
- Results
  - Often, longest ETEs do tend to be overestimates, so data give the appearance of padding
  - Interpretation: padding vs heroic recovery?
  - And all carriers seem to have the same patterns


od.pair: ORD.EWR
od.pair: ORD.PHL
od.pair: MIA.ATL
od.pair: ORD.ATL
late
ete
60
-20
20
-40
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0
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-10
72
94
116
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113
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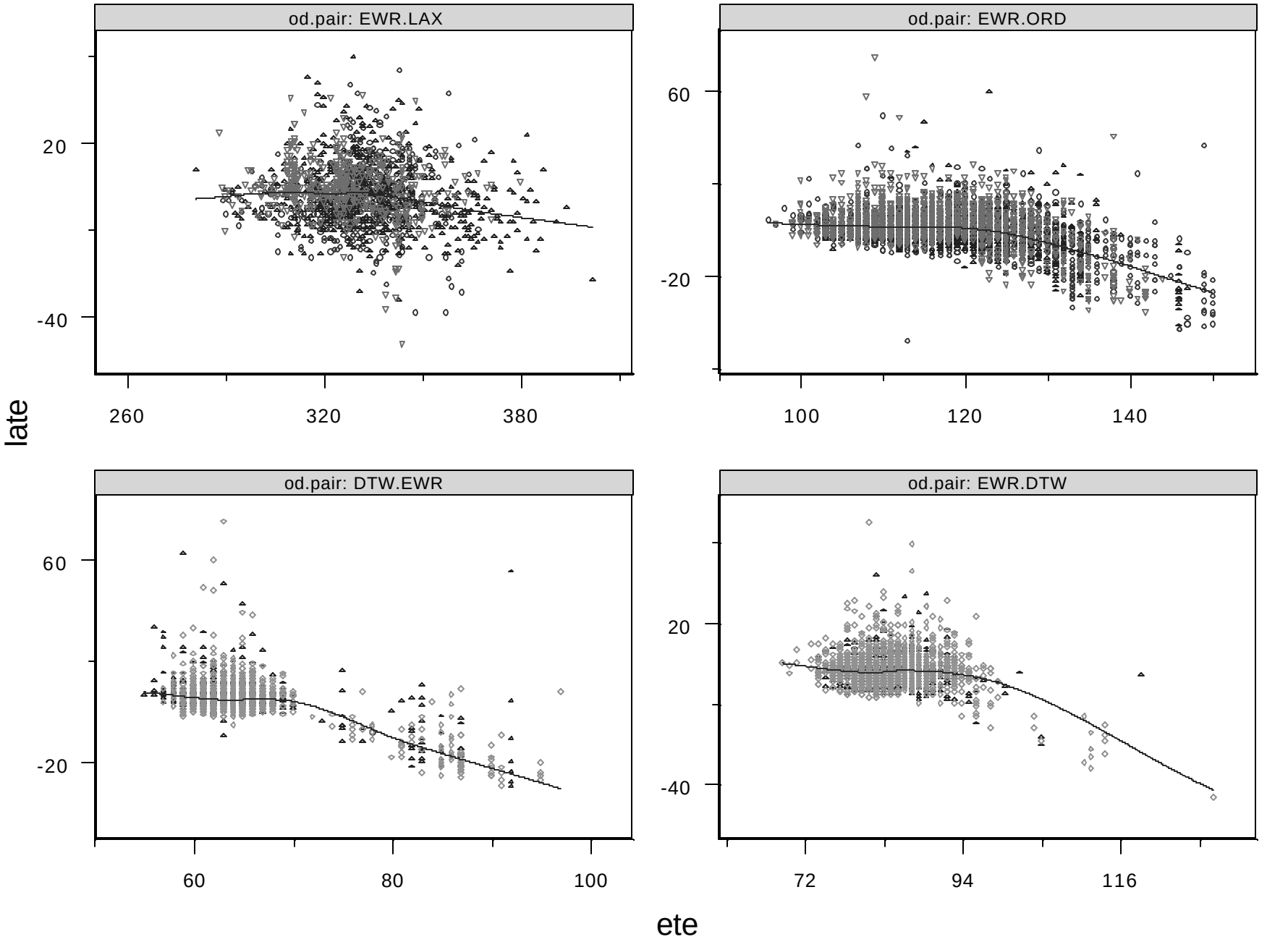
od.pair: EWR.LAX
od.pair: EWR.ORD
od.pair: DTW.EWR
od.pair: EWR.DTW
late
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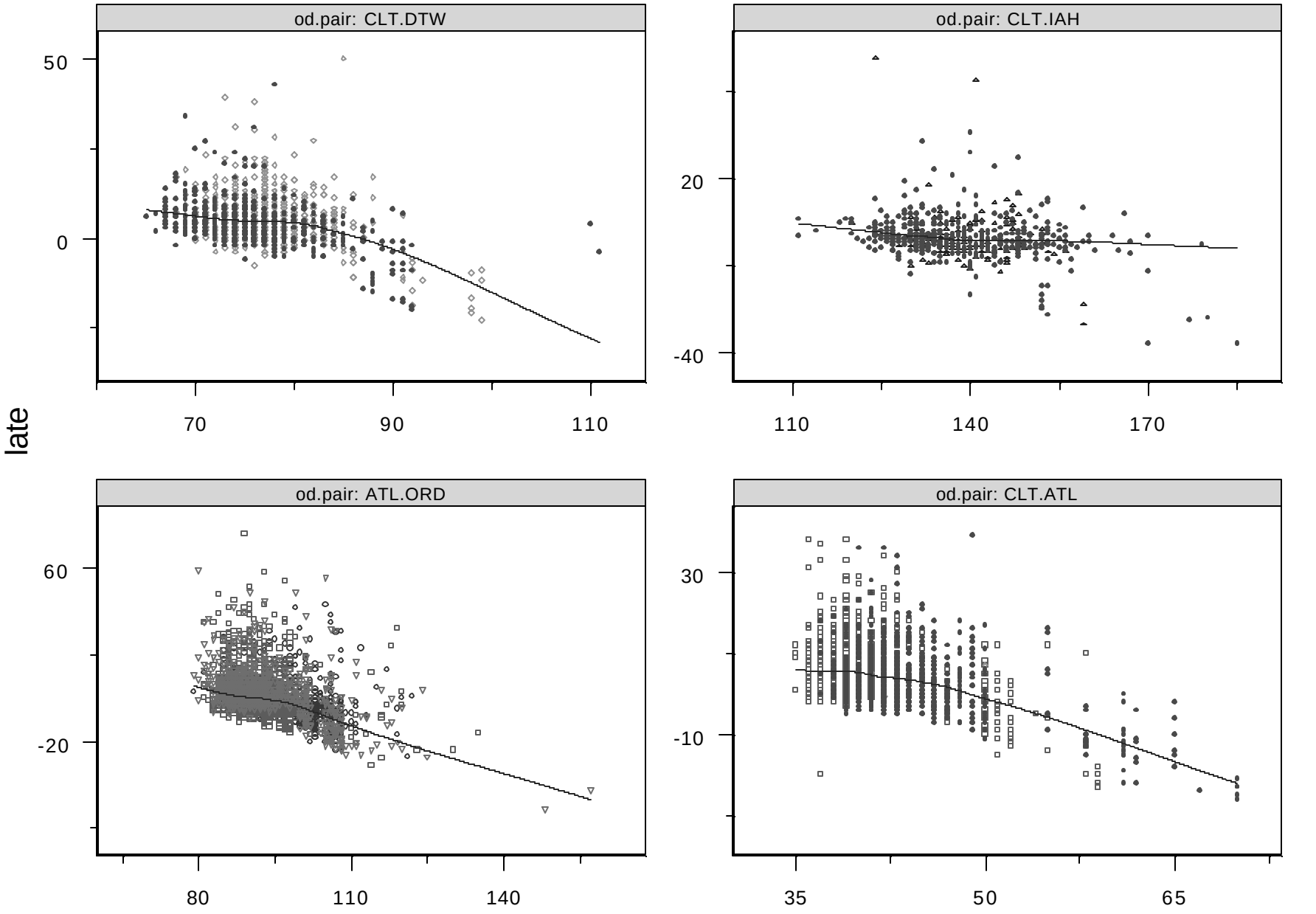
od.pair: CLT.DTW
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od.pair: ATL.ORD
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65

# Summary

- ETE is a dynamic, stochastic quantity.
  - ETE can have sustained trends.
  - ETE is influenced by several factors.
  - Most influence is “random”: errors in wind forecasts?
- Carriers differ in their ETE planning.
  - Some are consistently different.
  - Part of the difference is from route planning.
  - Evidence of “padding-like” behavior for “irregular” ops
- Can model ETE distributions.
  - Fit mixtures of lognormals.
  - Use estimated parameters as new way to characterize carriers’ behavior.

# Acknowledgements


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  - Dave Knorr
  - Ed Meyer
- CNA Corp
  - Joe Post