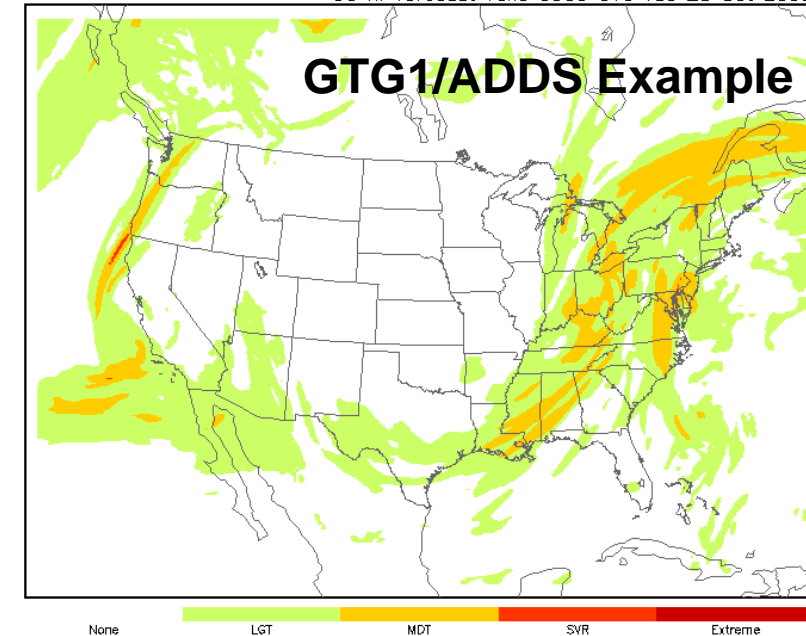


Turbulence forecasting goals

- Completely automated – no human-in-the-loop
- “Operational”, i.e., 24x7
- Rapid updates
- Easy to understand output for airline dispatchers, etc.
- Optimized statistical performance accuracy
- Satisfy a set of NOAA/FAA performance criteria
 - AWTT process
 - Independent expert reviews
 - Independent quality assessment team
- Implemented in the Graphical Turbulence Guidance (GTG) forecast product

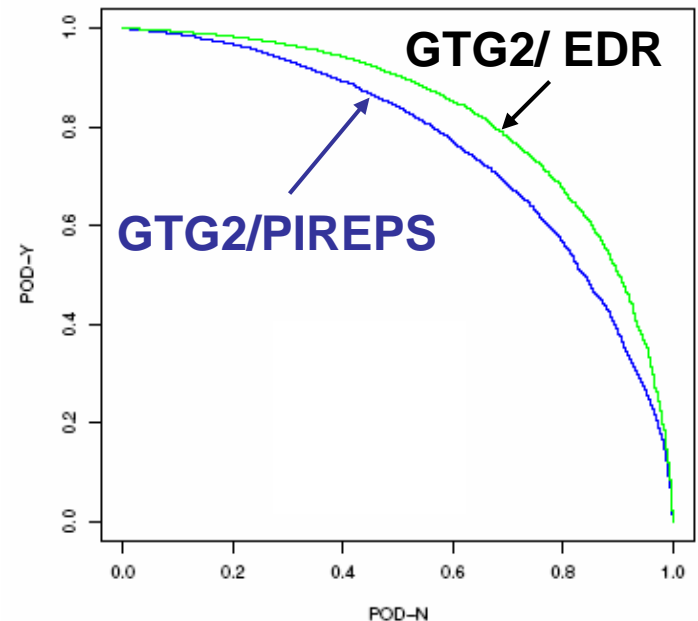
Turbulence forecast at FL300

06 hr forecast valid 0000 UTC Tue 25 Oct 2005



GTG Status

- GTG1
 - On “Operational ADDS” since March 2003
 - CAT above FL200
 - Based on RUC 13/20
 - Forecasts out to 12 hrs
- GTG2
 - On “Experimental ADDS” since Nov 2004
 - Improved turbulence diagnostics
 - “CAT” above FL100
 - Based on RUC 13/20
 - Forecasts out to 12 hrs
 - Textual representation
 - Includes UAL *in situ* EDR measurements above FL200



GTG limitations - insufficient observations for tuning and verification

- Currently PIREPs
 - <10 - ~ 300/ hr over all of CONUS (mid+upper levels)
 - Position uncertainty ~ 50 km
 - Intensity uncertainty ~ 20%
 - Too few in rapidly changing dynamical environments - such as thunderstorms
- Require common, consistent atmospheric turbulence metric for all types of turbulence measurements
- Propose eddy dissipation rate (EDR)
 - all *in situ* measurements (e.g., commercial, TAMDAR)
 - airborne and ground-based radar
 - lidar
 - etc.

GTG limitations – Not all turbulence sources accounted for

FL460

FL100

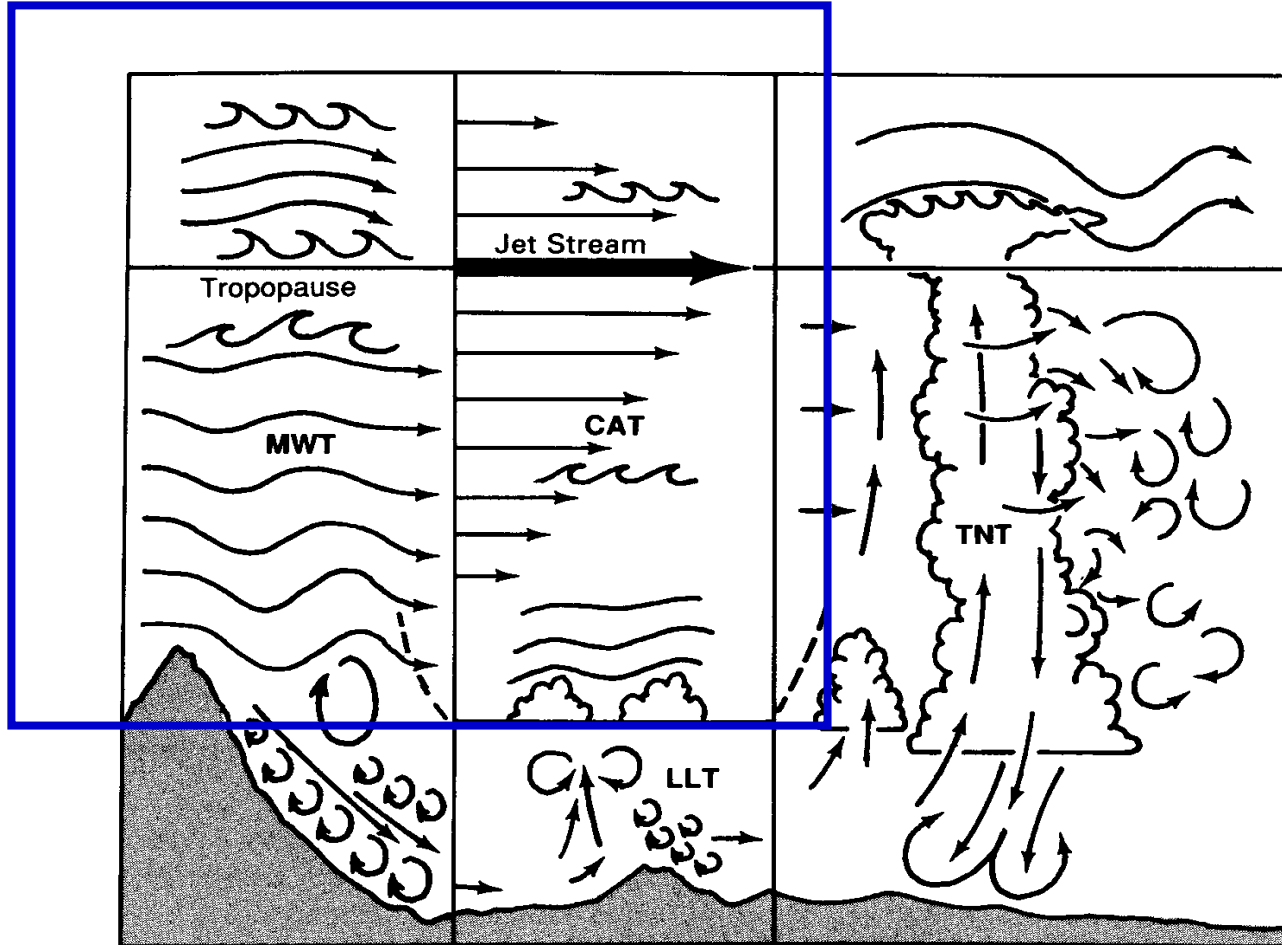
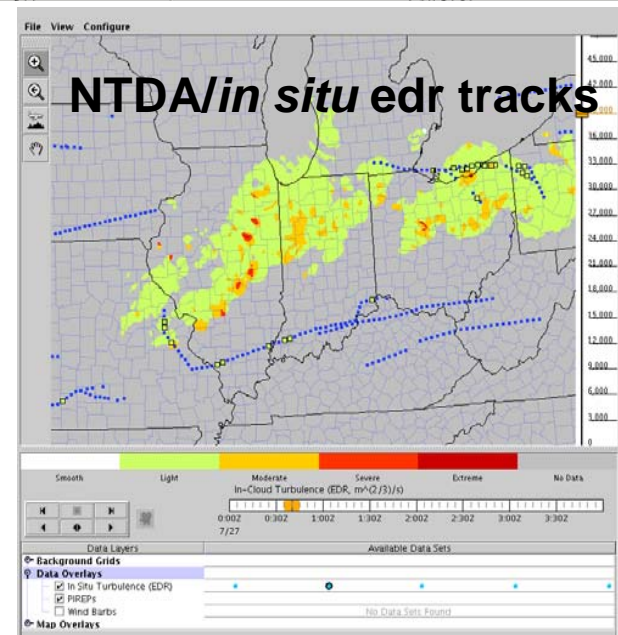
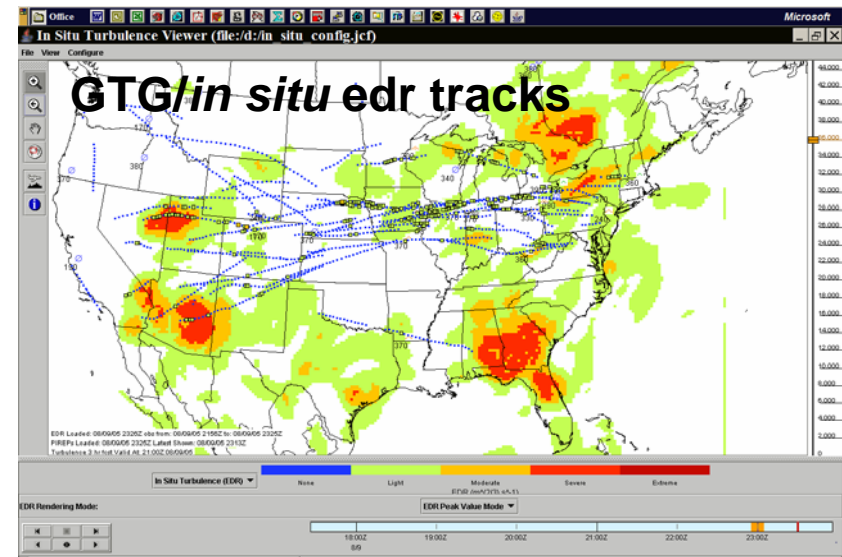


Figure 1-16. Aviation turbulence classifications. This figure is a pictorial summary of the turbulence-producing phenomena that may occur in each turbulence classification.

Current turbulence forecasting research areas

- Development of turbulence diagnostics for other sources of turbulence
 - MWT, CIT
- Development of global forecast product (upper levels)
- Optimal incorporation of *in situ* EDR measurements
- Development of nowcast product (GTGN)
 - Rapid updates (5-10 min)
 - *In situ* EDR measurements
 - PIREPs
 - In-cloud EDR measurements for ground-based radar (NTDA)
- Development of probabilistic forecasts



Tactical avoidance using cockpit displays

- Direct uplinks of products to cockpit are possible:
 - *in situ* data
 - GTG
 - NTDA
- Successful demonstration last summer of NTDA to selected UAL aircraft with character printer
- *in situ* uplink display demonstrations planned for next year
- latest GTG nowcasts/forecasts could also be uplinked during flight
- or forecasts loaded on a PC before takeoff (electronic flight bag)
- Regulatory restrictions?



```
EXP TURB FI UAL [REDACTED]
-- 20 Oct 2005 22:08:57Z
FL 360 orient. 95 deg
'X'=aircraft, '+'=waypoint, '*'=route
' '=no_data, 'o'=smooth, 'l'=light
'M'=mod, 'S'=severe
----- (36nm to COWES) -----
112nm 111 1*MMMMM11
108nm 11M*MMMMMM1
104nm 11M*MM11MM
100nm 1MM*1111
096nm 11 o1 1*11
092nm 1111111111*11 1
088nm 11111M11MM11*1 11111111
084nm 111MMMMM11 * 1111111111
080nm 11111MMMMM *11111111111111
076nm 1111111111 1 *11111111111111
+STL 1111111111M*1111 11111111
068nm 11 111 111*111 111111
064nm 11 11111111*11MM 111111
060nm 111 111111111M*MMM 111MM1
056nm 11 111111MM1M*M MM11MMMM
052nm 1 111111111M*M111MMMMMMMMMM
048nm 111 111 o111111M*M11MMSSMMMMMM
044nm 11MM111o1111111*1111MMSSMMMMMM
040nm M 1111111111*11111MMMM11MM
036nm MM11MM11 11*11111111111111
032nm MMM111111 o1*1 111 1111
028nm MMM111111M1*
024nm M M *
020nm MM11 *
+WELTS 1111 + 11MM
012nm 111 * 11MM
008nm 11 * 11MM
004nm *
valid -----X-----
2205Z -40nm (39.0N, 92.1W) +40nm
```

Projected GTG releases – next 7 years

Version	Capabilities	D3	D4	Op
GTG1	Upper levels RUC20	---	3/03	3/03
GTG2	Improved GTG1 Mid levels RUC13 Text generation Uses in situ	11/04	05/06	8/06
GTG3	Improved GTG2 MWT 10 km RR WRF Probabilistic forecasts	11/07	11/08	2/09
GTG/TFO	Global - GFS	11/07	11/08	2/09
GTG4	Improved GTG3 out-of-cloud turb forecasts	11/08	11/09	2/10
GTGN	Rapid upates in-cloud turb nowcasts in situ GTG4 0-2 hr analyses	11/08	11/09	2/10
GTG5	Improved GTG4 Low levels	11/09	11/10	2/11
GTGAK	Alaska region	11/10	11/11	2/12

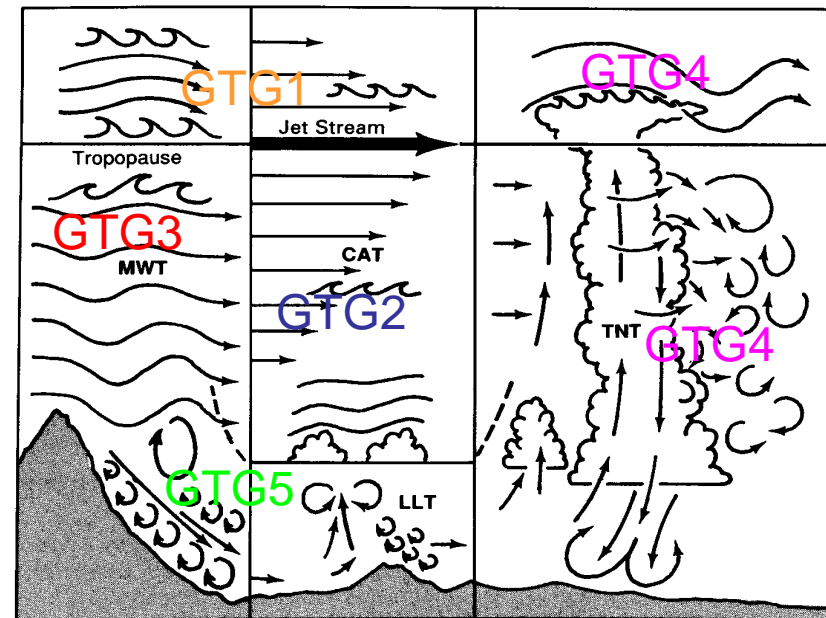


Figure 1-16. Aviation turbulence classifications. This figure is a pictorial summary of the turbulence-producing phenomena that may occur in each turbulence classification.