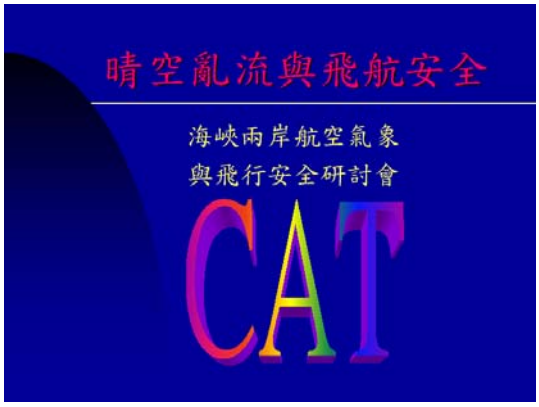
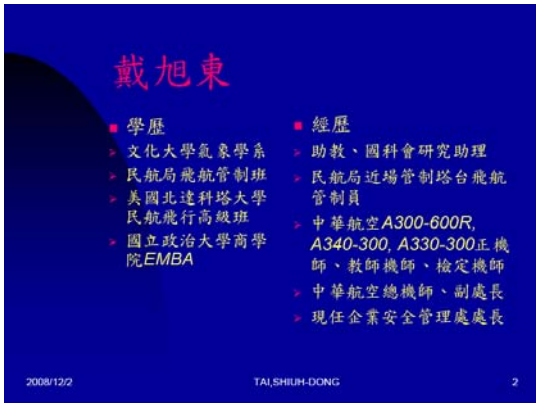
晴空亂流與飛行安全

戴旭東

（中華航空公司）





- *Clear Air Turbulence (CAT)* is the bumpiness experienced by aircraft at high altitudes (above 18,000 feet) in either cloud-free conditions or in stratiform clouds. CAT occurs when undulations (known as *gravity waves*) in the upper atmosphere become steep and unstable, then break down into chaotic motion. The scale of wave motion that normally affects jet aircraft is on the order of ~10 meters to ~1-2 kilometers. These unstable waves occur when vertical wind shear becomes locally excessive, allowing the waves to overcome the stability of environmental temperature conditions. This condition is known as *Kelvin-Helmholtz instability*.

http://www.star.nesdis.noaa.gov/smcd/opdb/aviation/turb/CAT.html

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噴射氣流的類型與特性

- 極鋒噴流(30,000ft)
- 副熱帶噴流(35,000ft~45,000ft)
- 極區夜間噴流
- 高空風速大於50海浬以上
- 伴隨盛行西風帶
- 冬季噴流隨鋒面南移，夏季反之
- 噴流往往發生在對流層頂
- 噴射氣流經常伴隨晴空亂流

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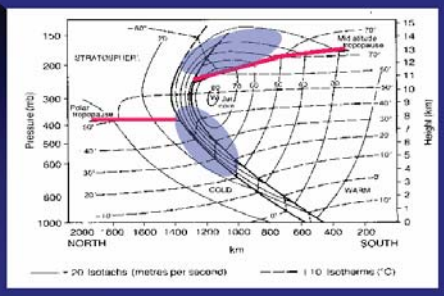
噴射氣流與對流層頂的關係



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晴空亂流的預測

- 組員應詳細檢視顯著天氣圖
- 檢視對流層頂之高度
- 高空風及高空溫度圖
- 300mb、200mb等壓面圖
- Forecast Clear Air Turbulence Index Images
- 衛星雲圖
- 電腦飛行計劃中，各航行點之SR (SHEAR RATE)，當大於等於3時，預期會遭遇中度亂流；當大於等於5時，將遭遇到強烈亂流

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FORECASTING CAT

- VERTICAL WIND GRDIENT (RATE OF CHANGE OR SHEAR RATE) ≥ 5kt / 1000 ft
- HORIZONTAL WIND GRADIENT > 40kt / 150 nm
- HORIZONTAL OAT GRADIENT > 4 °C / 100 nm
- ROUTE IS CLOSE TO THE POLAR SIDE OF A JETSTREAM
- ROUTE IS CLOSE TO AN ALTITUDE TROUGH OF LOW PRESSURE
- A SHARPLY CURVING JET STREAM IS ASSOCIATED WITH GREATER TURBULENCE THAN A STRAIGHT JET STREAM
- EXITING CAT: IF TAT / SAT INCREASE ▲CLIMB
  IF TAT / SAT DECREASE ▼DESCEND
- SEVERE TURBULENCE MAY BE EXPECTED, IF JETSTREAM EXCEEDS 110 kt, ON ITS POLAR SIDE

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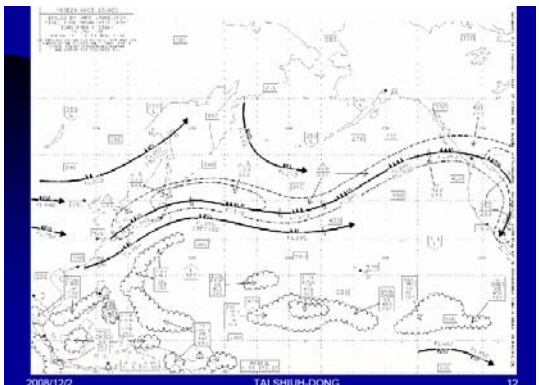

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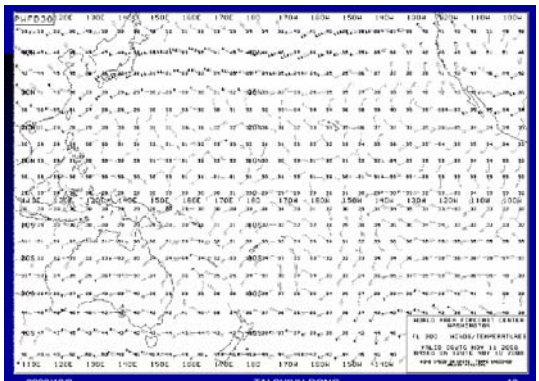

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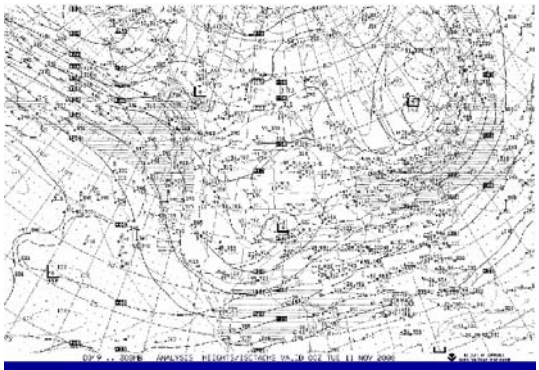

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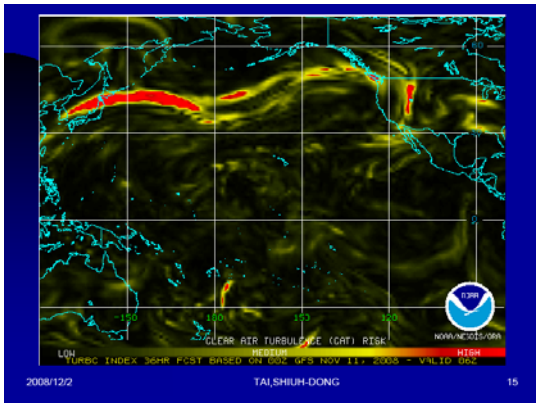

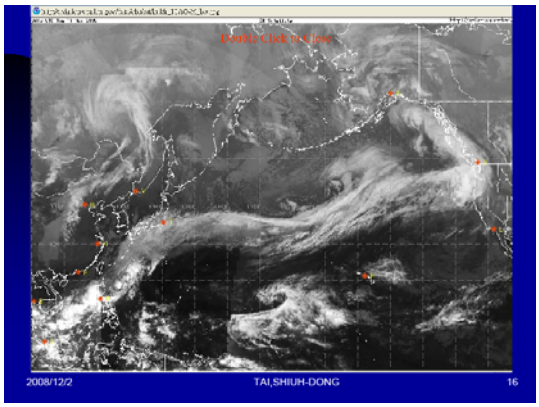

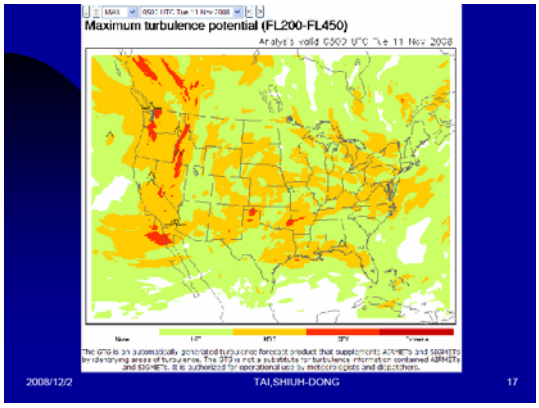

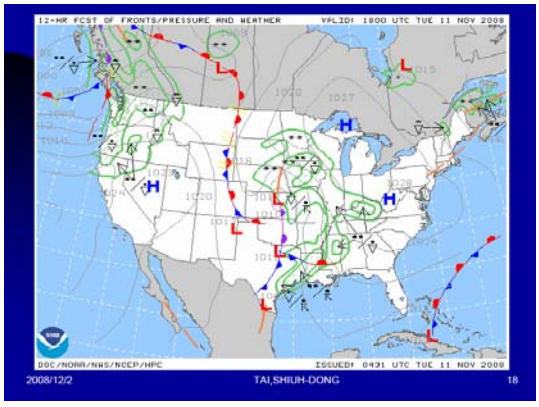

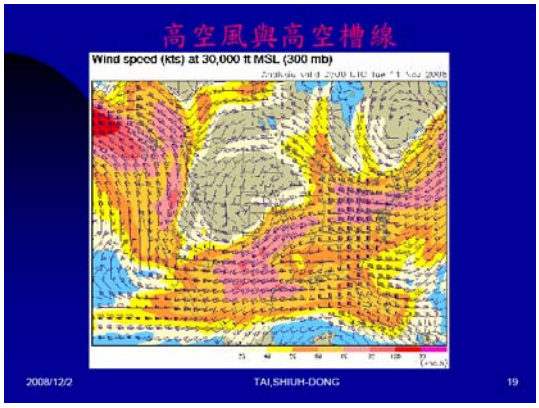

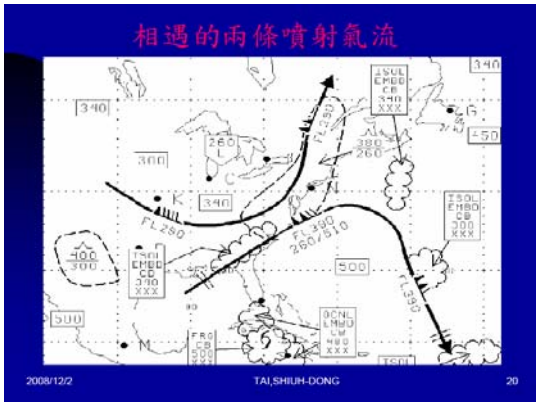

Defining the level of turbulence ICAO

Turbulence severity	*Vertical acceleration (γ)*	*Effect on flight*
Very low	γ ≤±0.05g	Light oscillations in pitch and roll
Low	±0.05g≤ γ ≤±0.2g	Marked frequent oscillations: ride comfort affected
Moderate	±0.2g≤ γ ≤±0.5g	Strong intermittent jolts
Severe	±0.5g≤ γ ≤±1.5g	Aircraft handling affected
Very severe	γ ≥1.5g	Unacceptable for passenger's comfort

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Quantitative measures of turbulence intensity. Values may be positive or negative

	Airspeed Fluctuation(kts)	G-load(g)	Derived Gust(f.p.m.)
Light	5-14.9	0.05 ~ 0.20	300-1199
Moderate	15-24.9	0.2 ~ 0.50	1200-2099
Severe	≥25	0.5 ~ 1.50	2100-2999
Extreme	—	>1.50	≥3000

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晴空亂流易發生之季節與區域

- 北緯15°至北緯30°之間，於冬季期間，因高空槽線向南突出，造成對流層頂較低，也使極鋒噴流南移，於此區與副熱帶噴流相遇，極易產生晴空亂流
- 北緯30°至北緯60°之間，則因低對流層頂及較強之極鋒噴流存在，本區亦較常發生晴空亂流

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建議

- 晴空亂流的認知
- 相關知識與資訊的取得
- 機組人員訓練
- 航情守望
- 任務前的評估
- 任務中的評估
- 與客艙組員的溝通
- 審慎的判斷與決心下達
- 開啟安全帶指示燈
- 減速至亂流穿越速度
- 遭遇亂流後應儘快告知航管
- 填寫維修記錄本

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APPENDIX : RULES OF THUMB

- 風速大於110 Knots
- 高山背風區
- 山岳波
- 300mb、200mb等壓面圖
- 垂直風切
- 彎曲的噴射氣流
- 風變區與槽脊線
- 沿著噴射氣流飛行

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APPENDIX : RULES OF THUMB

- 穿越噴射氣流飛行
- 穿越槽線優於平行槽線
- 溫度變化
- 溫度昇高則爬反之則降
- 衛星雲圖
- PIREP-飛行員報告
- 高高度顯著天氣圖
- SIGMETS/HIWAS

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Mountain wave schematic. The wind flows towards a mountain and produces a first oscillation (A). A second wave occurs farther and higher with *lenticular clouds* stuck on top of the flow (B).
http://en.wikipedia.org/wiki/Lee_waves

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省思與檢討

- 民航飛行員終年必須面對大氣變化無常的挑戰，*晴空亂流*只是其中的一項，唯有充分*掌握資訊*、*充實新知*，方能面對各種挑戰，達到*安全*、*舒適*、*經濟*、*準時*的營運目標。

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結語

- 民航事業日新月異，未來的民航飛行將是以 *FREE FLIGHT* 的觀念為導向，飛行員勢必將擔負起更多的責任與面對更多的挑戰，唯有不斷的自我惕厲，才能立足於未來，享受每一次的飛行。
- 敬祝各位身體健康，萬事如意，*ENJOY THE FLIGHT.*

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參考書目

- AC-0045F
- Turbulence – A new perspective for pilots, Jeppesen, By Peter F. Lester
- Aviation weather - Jeppesen, By Peter F. Lester
- The weather book – USA TODAY
- Atmospheric waves – Tom Beer

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Q&A
AIRBUS A380