Identification of Convectively-Induced Aircraft Turbulence using Satellite Data

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Motivation: The potential for convective-induced aircraft turbulence can be assessed using new satellite-derived products.

Data

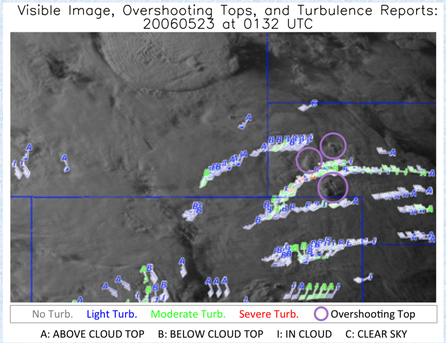
Eddy Dissipation Rate (EDR): objective measure of aircraft vertical acceleration due to turbulence

- No turbulence: EDR ≤ 0.05
- Light Turbulence: 0.05 > EDR ≤ 0.25
- Moderate Turbulence: 0.25 > EDR ≤ 0.45
- Severe Turbulence: 0.45 > EDR

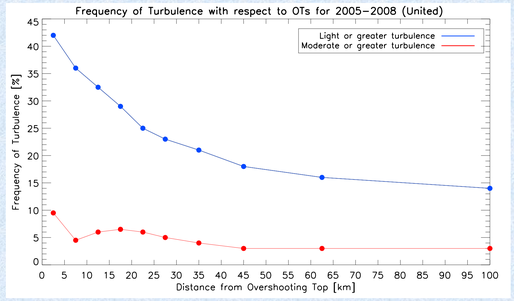
EDR values from 2005-2008 (United Boeing 737 & 757) and 2010-2011 (Delta Boeing 757 & 737)

1. Overshooting Tops

Multiple United aircraft encounter light to severe turbulence when flying through a region with overshooting tops.



Question: What is the probability of an aircraft encountering turbulence within a given distance of an overshooting top (OT)?



Copied from Bedka et al. (2010)

About 25% of aircraft that fly within 25 km of an OT encounter light or greater turbulence.

Future Work:

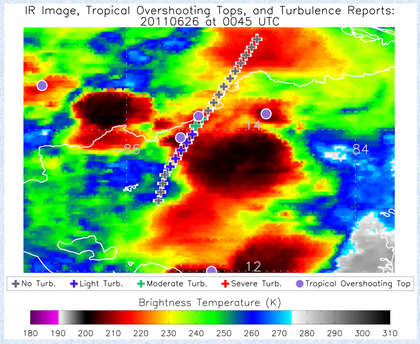
- Assign height to the OTs and compare to aircraft altitude.

For more information on Overshooting Tops:

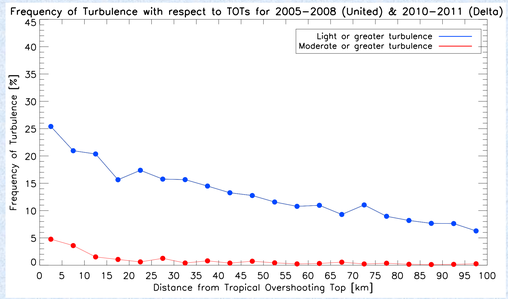
Bedka K., J. Brunner, R. Dworak, W. Feltz, J. Otkin, and T. Greenwald, 2010: Objective Satellite-Based Overshooting Top Detection Using Infrared Window Channel Brightness Temperature Gradients. *J. of Appl. Meteor. Climatol.*, **49**, 181–202.

2. Tropical Overshooting Tops

Delta Flight 355 experiences moderate turbulence when flying near tropical overshooting tops.



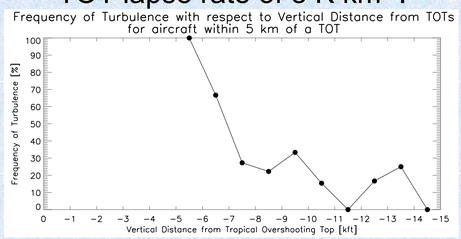
Question: What is the probability this aircraft encounters turbulence given its proximity to a tropical overshooting top (TOT)?



Turbulence probability decreases as distance from TOT increases.

Question: What is the probability of turbulence for aircraft given vertical distance from a TOT?

TOT height is found by calculating the anvil height from the Automated Cloud Height Algorithm plus a TOT lapse rate of 8 K km^{-1}.



Given its location, Delta Flight 355 had a 100% probability of encountering turbulence.

Future Work:

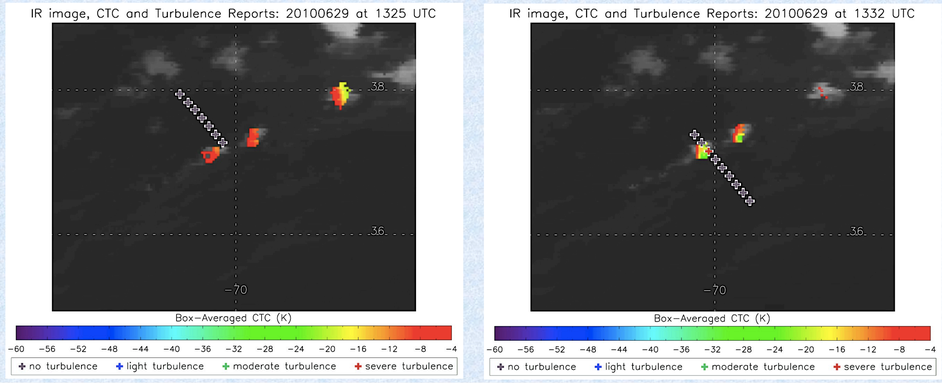
- Expand database for better TOT height analysis

For more information on Tropical Overshooting Tops:

Monette, S. A., C. S. Velden, K. S. Griffin, and C. M. Rozoff, 2012: Examining Trends in Satellite-Detected Tropical Overshooting Tops as a Potential Predictor of Tropical Cyclone Rapid Intensification. *J. Appl. Meteor. Climatol.*, **51**, 1917–1930.

3. Cloud Top Cooling

Delta Flight 577 encounters severe turbulence over an objective GOES cloud top cooling detection.



Question: What is the probability this aircraft, which is within 17 km and ±7 minutes of a cloud top cooling (CTC) detection, would encounter turbulence?

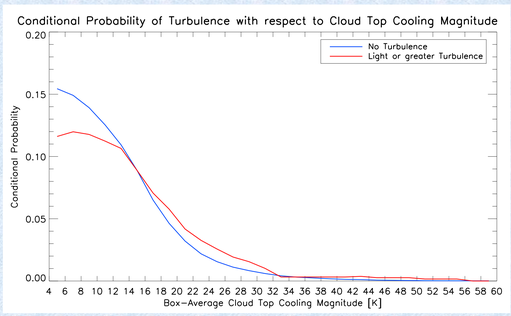
Based on climatology from 2008 and 2010: 2.80%

Better Prediction of Turbulence:

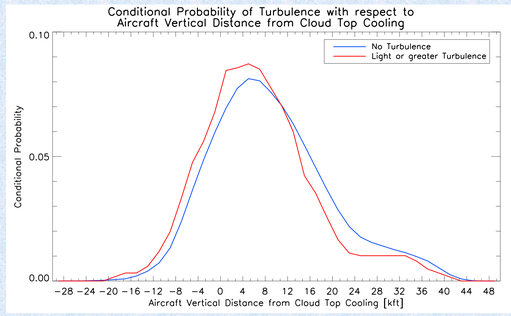
Naïve Bayesian probability of turbulence: $P(C_{\text{turb}}|\mathbf{F}) = \dfrac{P(C_{\text{turb}})\prod_{i=1}^{N} P(F_i|C_{\text{turb}})}{P(\mathbf{F})}$

Turbulence from CTC is a function of:

Magnitude of CTC



Vertical distance between CTC and aircraft flight level



Results:

Independent Analysis of 2011 CTC: Brier Skill Score=0.00386

Low Brier Skill Score due to low climatological probability of turbulence

The Naïve Bayesian Scheme is skillful at predicting when turbulence will occur.

Delta Flight 577 had a 4.38% probability of turbulence, 1.5 times climatology.

Future Work:

- Correlate the cloud top cooling magnitude to cloud height changes.
- Expand CTC analysis to other satellites.

For more information on the Cloud Top Cooling product:

Sieglaff, J. M., L. M. Cronce, W. F. Feltz, K. M. Bedka, M. J. Pavolonis, and A. K. Heidinger, 2011: Nowcasting Convective Storm Initiation Using Satellite-Based Box-Averaged Cloud-Top Cooling and Cloud-Type Trends. *J. Appl. Meteor. Climatol.*, **50**, 110–126.