

Properties of Linear Contrails Detected in 2012 Northern Hemisphere MODIS Imagery

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OBJECTIVE & APPROACH

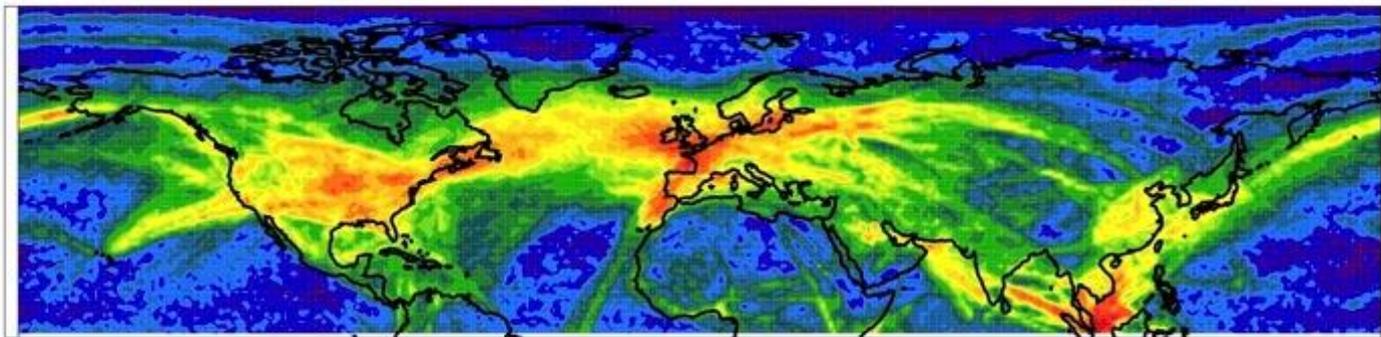
- Develop Northern Hemisphere linear contrail coverage climatology from Terra and Aqua MODIS thermal IR data
 - NH accounts for ~90 percent of contrails
 - Provide the basis for a consistent empirical estimate of contrail radiative forcing & properties for model improvement & validation
- Estimate coverage of cirrus that is closely associated with detected linear contrails (contrail cirrus?)

Cloud Detection Algorithm

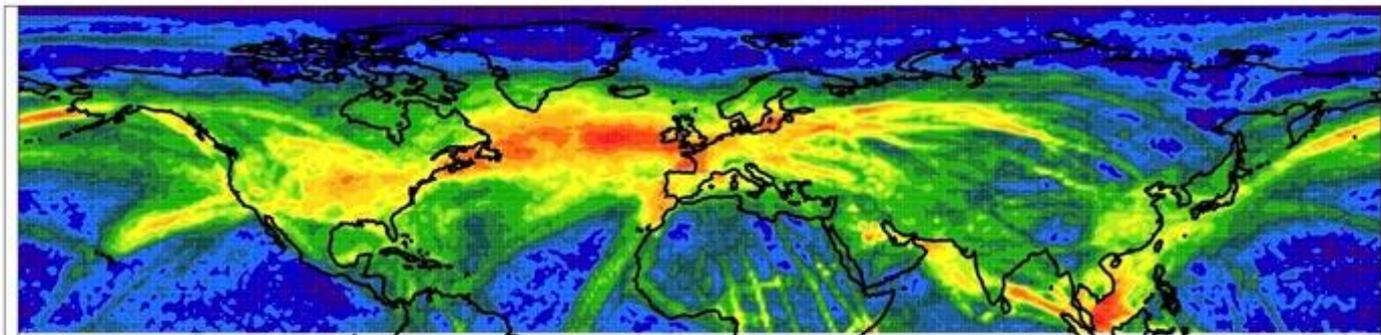
- Modified Mannstein et al. (1999) algorithm with additional thermal IR channels from MODIS
 - Original algorithm developed for AVHRR, extra channels reduce false detection rate of more sensitive MODIS imagery
- Re-projected to standard map to account for distortion at high viewing angles. Fourier frequency processing to remove scan line striping noise while retaining contrail features.
- Global aircraft emissions waypoint data advected forward in time up to 4 h with GEOS-4 (2006 data)/MERRA (2012 data) reanalysis wind profiles to compare detected contrails to flight tracks.

2006 MODIS data

Annual 2006 Terra screened CT fraction B (day+night)



Annual 2006 Aqua screened CT fraction B (day+night)

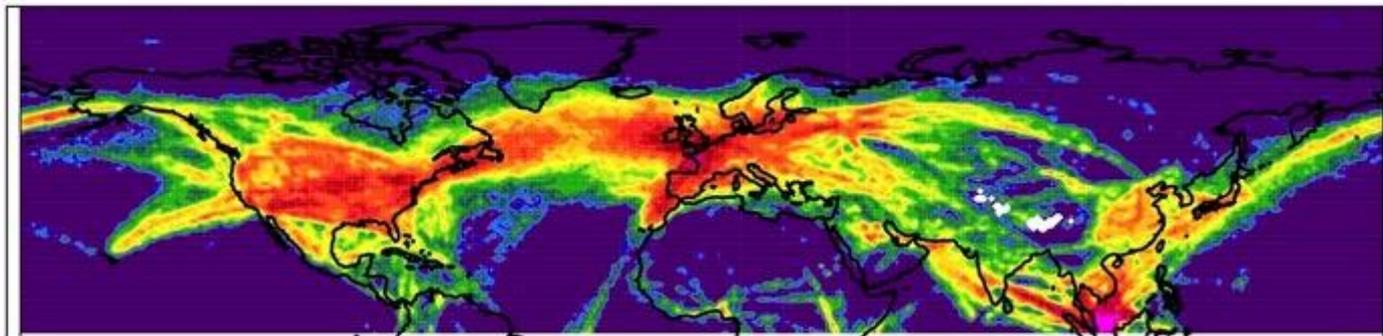


Subjective Visual Analysis

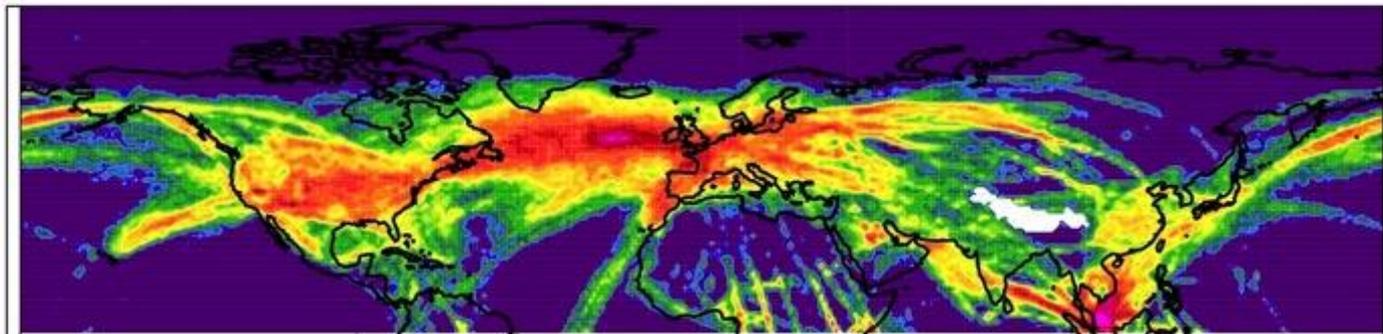
- Evaluate accuracy of CDA by comparing coverage estimates to visual analysis of contrail coverage by human observers of satellite imagery.
- Determine properties of FAR, DEF and STD_{12} to adjust coverage estimates
 - FAR: False Alarm Rate
 - DEF: Detection Efficiency
 - STD_{12} : Standard Deviation of 12-micron BT (proxy for heterogeneity of background thermal IR field)

Corrected 2006 MODIS data

Annual 2006 Terra Corrected CT fraction (three step method) [day + night]

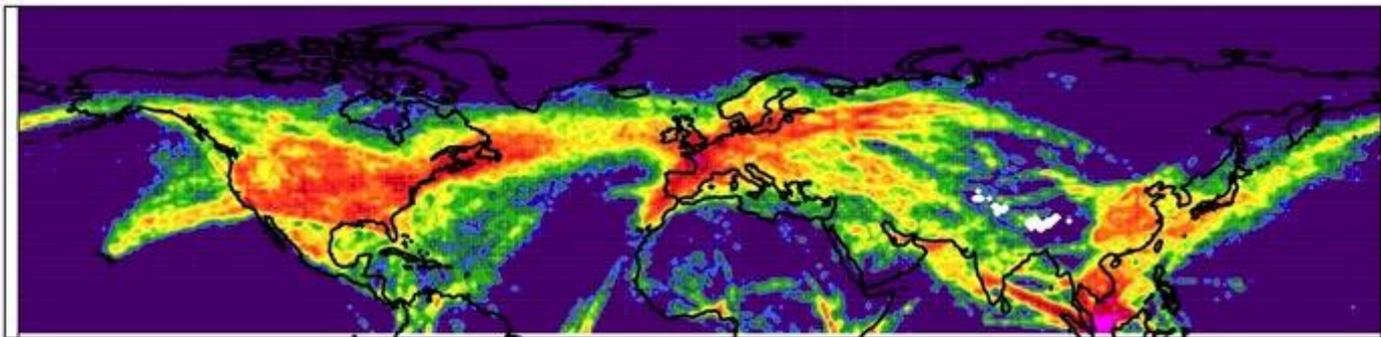


Annual 2006 Aqua Corrected CT fraction (three step method) [day + night]

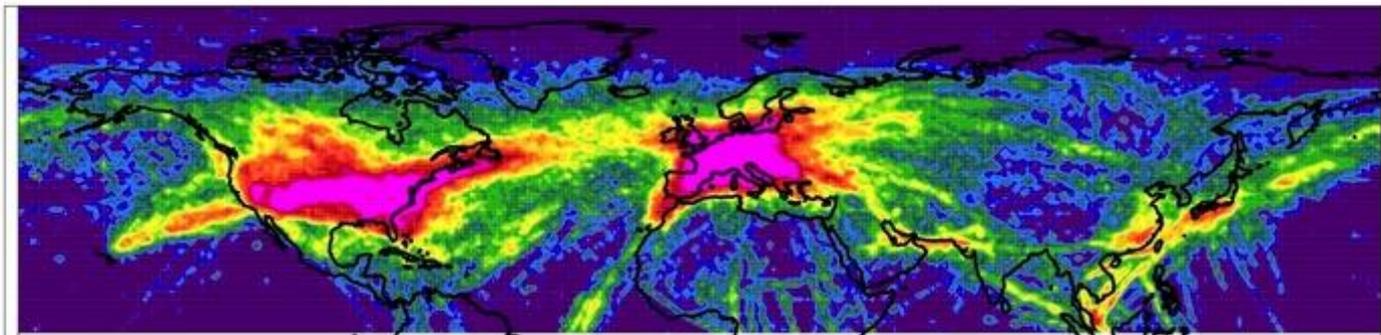


CoCiP coverage filtered by MODIS overpasses

Annual 2006 Terra Corrected CT fraction (three step method) [night]

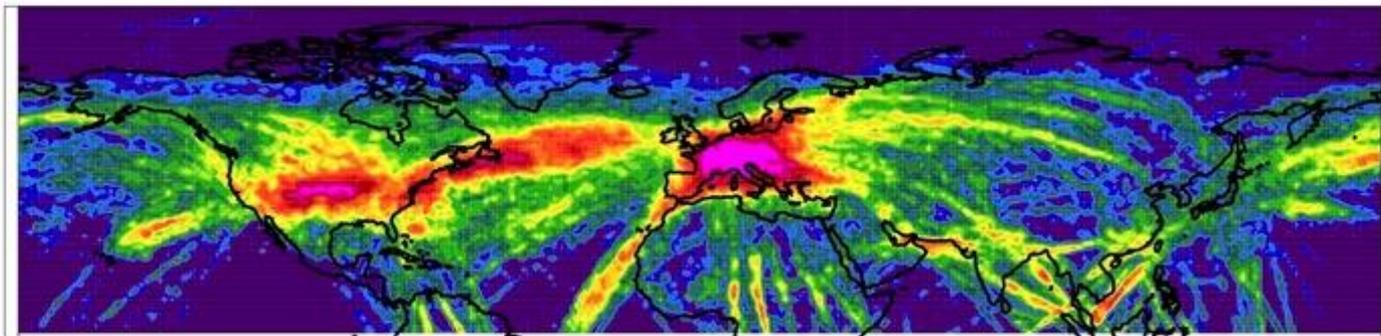


Annual 2006 CoCiP/Terra CT fraction (night, min. tau = 0.20)

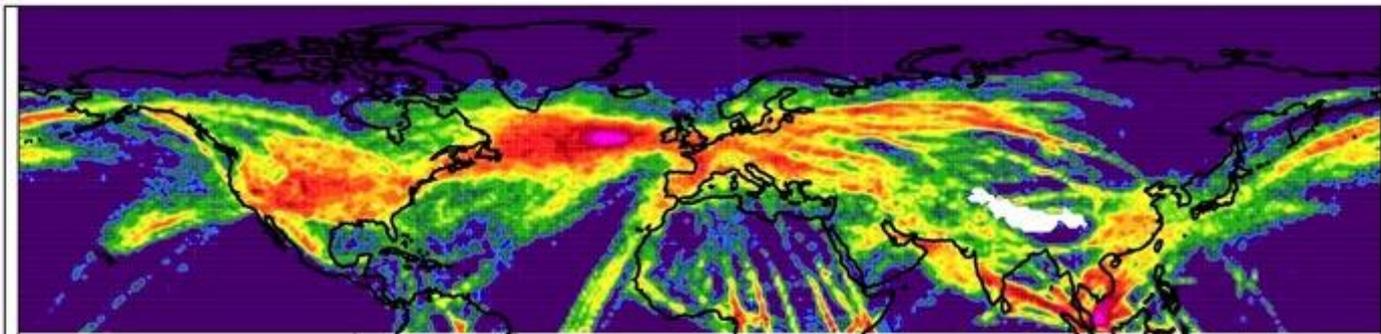


CoCiP coverage filtered by MODIS overpasses

Annual 2006 CoCiP/Aqua CT fraction (night, min. tau = 0.20)



Annual 2006 Aqua Corrected CT fraction (three step method) [night]





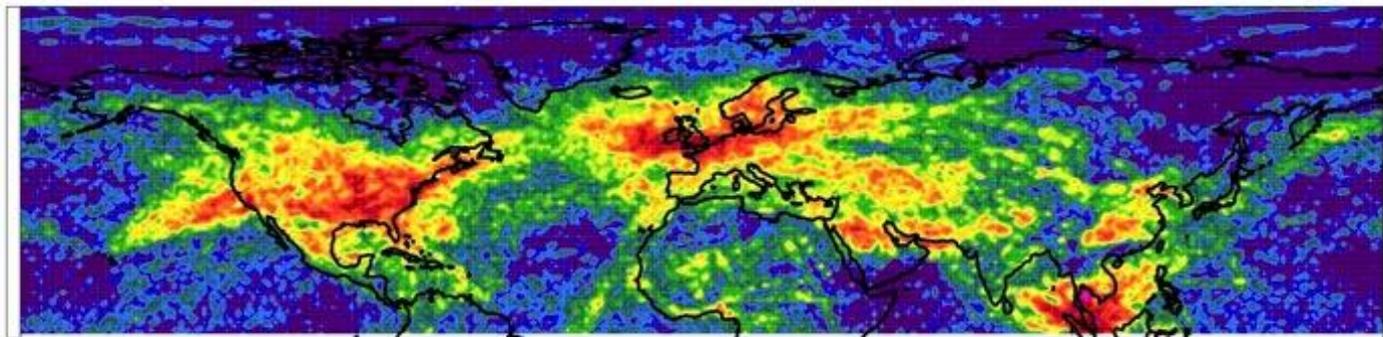
Contrail Detection Algorithm: 2012 data

- **Mask B:** (same as used in 2006 data)
- **Mask D & Mask E:** more conservative than Mask B, used as base for contrail widening procedure

January 2012 Terra (day + night)

January 2006 Terra (day + night)

January 2006 Terra screened CT fraction B (day+night)

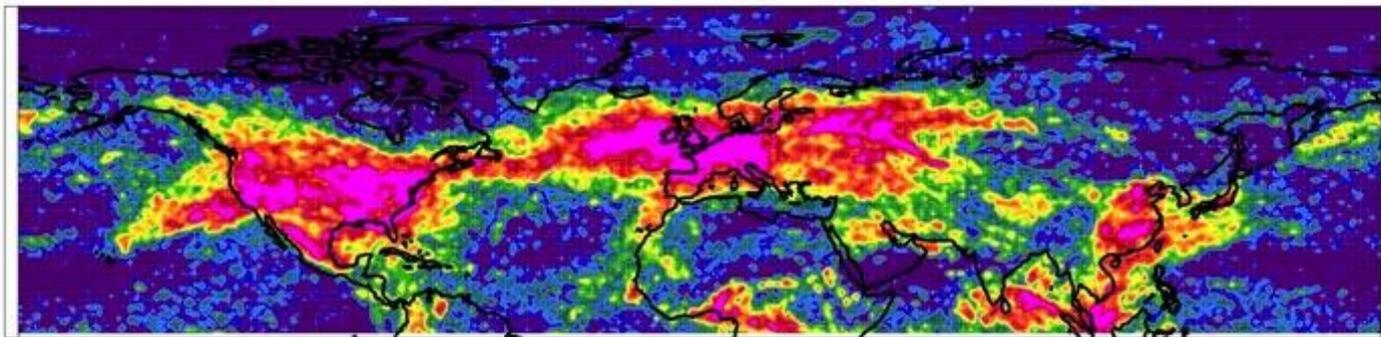


Detection of contrail cirrus

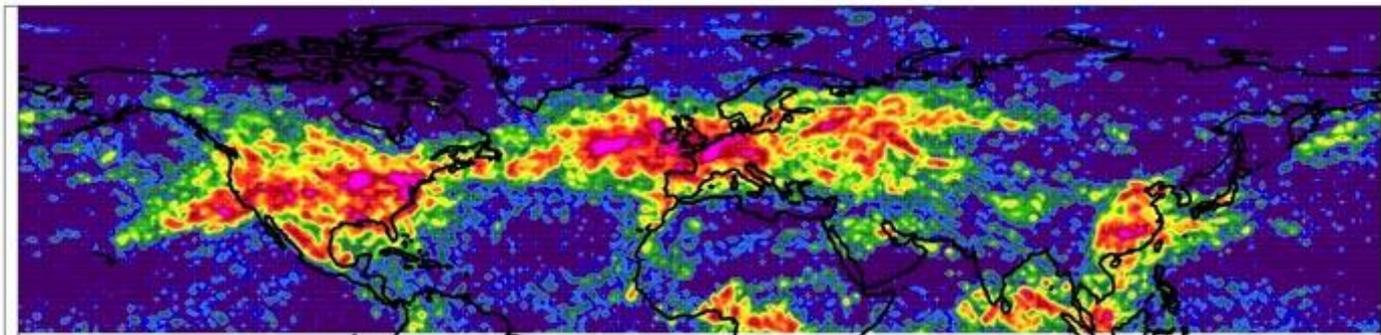
- Compare pixels near detected contrail pixels and add those with similar radiative properties (i.e., similar brightness temperatures)
- Seven threshold tests developed from thermal IR data
 - (11 – 12) micron
 - -13.3 micron
 - -6.8 micron
 - (11 -12) - 13.3 micron
 - (8.6 – 13.3) micron
 - -12 micron
 - 11 – 13.3 micron

Contrail-related cirrus coverage

January 2012 Terra CT-related cirrus fraction D (day+night)



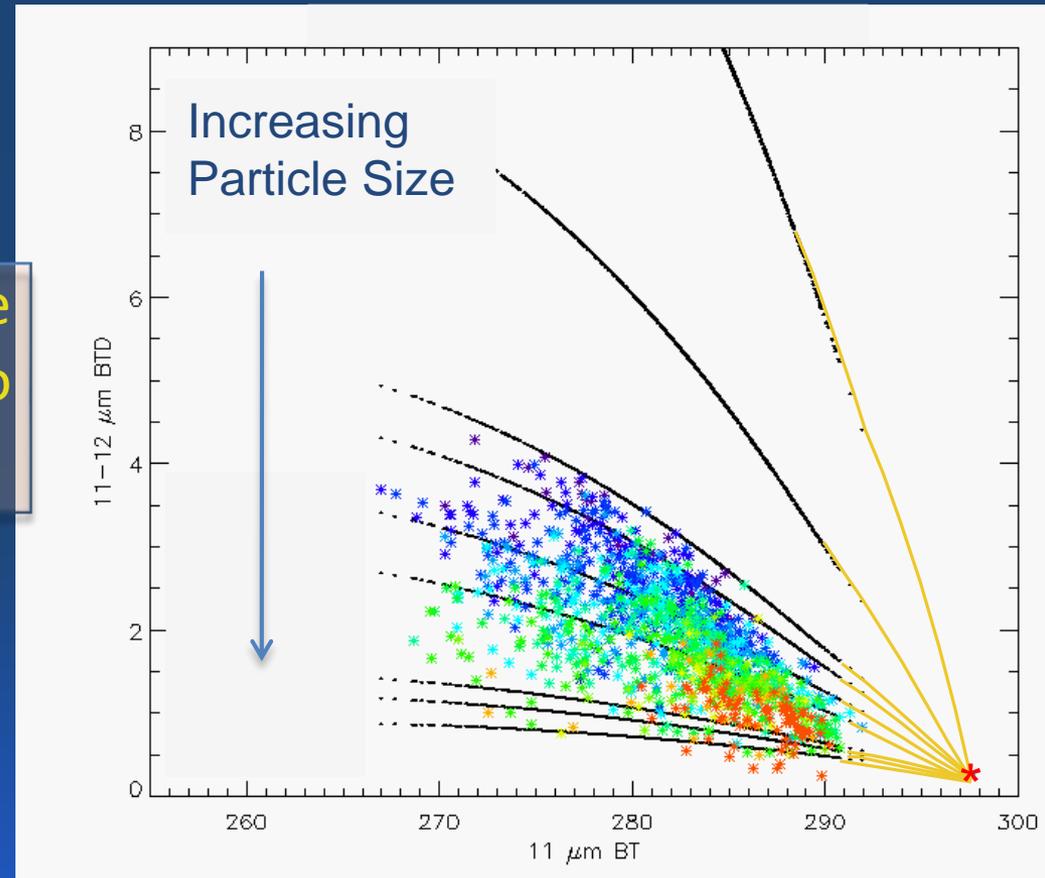
January 2012 Terra CT-related cirrus fraction E (day+night)



- *Technique minimizes difference between the observed and calculated brightness temperature differences (BTD) for 2 IR bands (11 and 12 μm).*

Retrieving Optical Depth & Particle Size

- Based on method of Inoue (1985)
- Uses 9 hexagonal ice column models (Minnis et al. 1998)
- Accurate contrail temperature and background BTDs key to accurate retrievals
- Retrieve τ and D_e simultaneously
 - *Contrail temperature input*
 - Assume or use waypoint data
 - Results used in CRF computations



← Increasing optical depth

Contrail Radiative Forcing

- Fu-Liou (1993) RTM applied to MODIS pixels
- Upwelling SW and LW fluxes and CRF computed at top-of-atmosphere (TOA)
- Clear, ice cloud or water cloud below contrail are considered; Snow/ice and CERES albedo maps
- CRF calculations done at 1-km MODIS pixel level
- Mean CRF calculated for $1 \times 1^\circ$ NH grid
- Data filtered with simple first-order flight track screen (air traffic density only)

Future work

- Finish 2012 processing
 - Contrail masks (subjective analysis of linear contrail coverage)
 - Contrail properties (optical depth, particle size)
 - Contrail radiative forcing
- Continue development of contrail cirrus estimates
 - Compare with contrail cirrus identified with geostationary satellite data