Cloud-cover and radiation balance changes over Ireland due to Aircraft-induced Contrails.

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Climate Change in Ireland:

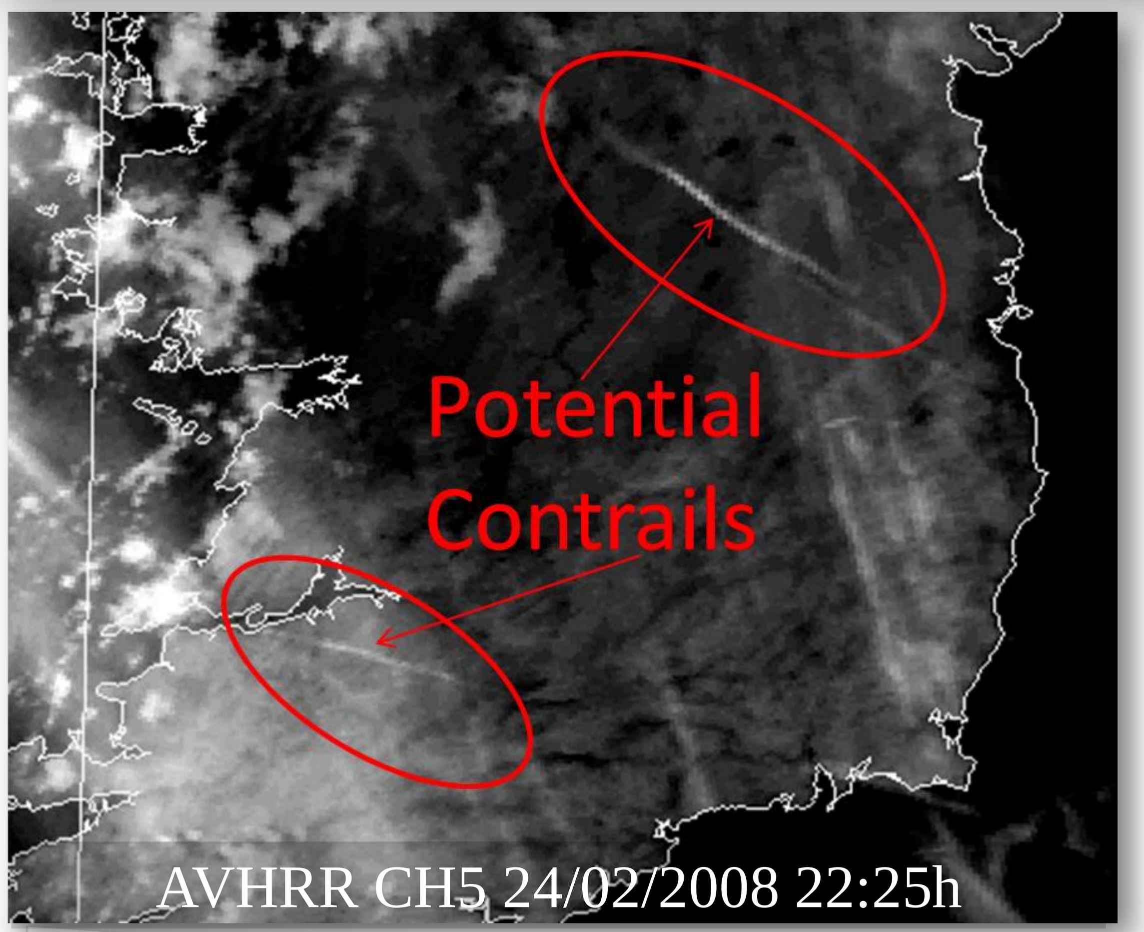
- 4 ground stations (1881-1998): *15% increase in cloud cover* & 20% decrease in annual sunshine hrs *(Palle & Butler, 2001)*
- Cloud cover increase could be partially related to a rise in aircraft traffic: contrails can trigger cirrus formation!
- Clouds are major uncertainty in future climate prediction:
  - clouds reflect sunlight *(cooling effect)*
  - clouds trap heat emitted from surface *(warming effect)*
  - Key Question: *Which effect will dominate in future climate?*

Contrails (i.e. condensation trails) form when exhaust emissions from aircraft engines mix with ambient air, under conditions of low temp and high humidity

Contrails can persist for several hours and be several Km in length

Contrails can also spread, triggering additional cirrus cloud formation which can further impact climate!

Studies show increasing trends in cirrus clouds in flight corridors, in contrast to overall (small) negative trends in cirrus elsewhere!
(Zerefos et. al, 2003, Stordal et. al, 2005)



Contrails and Climate

Evidence shows that persistent contrails contribute a 'small but significant' net warming effect on atmosphere *(Stuber et. al, 2006)*

Climate warming of contrail-cirrus possibly 2-10 times larger than contrails (IPCC, 2007)

Contrail warming effect more pronounced at night, and during the winter:

- Night flights = ~25% air traffic but 60-80% of contrail warming
- Winter flights = ~22% annual air traffic but ~50% of annual mean contrail warming
- Contrails reduce daily temp range: After 9/11, no flights over USA for 3 days: temp range increased in the absence of contrails by ~1.1 K *(Travis et. al, 2002)*

Air traffic predicted to more than double by 2022 *(OECD 2006)*: *magnitude of climate impacts of contrails to rise also?*

Contrail Detection

- From satellites (see picture above):
  - Mainly detected based on linear shape from temp difference in Channels 4 & 5 AVHRR thermal images
  - Also stereo detection from ATSR/AATSR: provides cloud top height & amounts
  - Manual detection of contrails on satellite images found to be too highly subjective
- First automated detection of contrails from satellite images*(AVHRR)*: *Mannstein et. al.(1999)*
  - Avg. contrail coverage in 1996 for central Europe ~0.5%
  - Meyer *et. al.*, (2007): auto. detection contrails over Thailand (0.13%) & Japan (0.25%) for 1998

Overview of Methodology

- Establish algorithms/techniques to extract required information from satellite images
- Calculate % changes in contrails over Ireland from AVHRR imagery (1x1 Km since 1981)
- Use ATSR/AATSR imagery to investigate changes in cirrus occurrence (1x1 Km since 1991/2002)
- Using Meteorology (Radiosonde) data: determine vertical profile of atmosphere
  - Cross-ref & validate meteorological conditions for contrail formation, persistence and spreading
- Use Radiative Transfer Model to est. climate impacts

Project Objectives

- To develop suitable image processing techniques to allow positive identification of contrails on satellite imagery
- To develop the *first satellite-based* detailed cirrus-cloud and contrail climatology for Ireland over the past >20yrs
- To improve knowledge of atmospheric conditions for formation, persistence & spreading of contrails (using radiosonde data)
- To investigate current & former contribution of contrails to Irish cloud cover and regional climate (i.e. Radiative Transfer Model)

References: - Mannstein et al, (1999) Operational Detection of Contrails from NOAA-AVHRR data, Int. J. Remote Sensing, Vol. 20, No. 8, p.1641-1660 - Muller et al., (2007) The EU-CLOUDMAP project, Int. J. Remote Sensing, Vol. 28, No. 9, p.1915-1920 - Palle, E. and Butler, C.J. (2001) Sunshine records from Ireland: cloud factors and possible links to solar activity and cosmic rays; International Journal of Climatology, vol. 21, pp. 709-729 - Stordal, F., Myhre, G., Stordal, E. J. G., Rossow, W. B., Lee, D. S., Arlander, D. W., Svendby, T. (2005) *Is there a trend in cirrus cloud cover due to aircraft traffic?*; Atmos. Chem. Phys., vol. 5, pp. 2155-2162 - Stuber, N., Forster, P., Radel, G. and Shine, K. (2006) The importance of the diurnal and annual cycle of air traffic for contrail radiative forcing; Nature, vol. 441, pp. 864-867 - Travis, D.J. (2002) Contrails Reduce Daily Temperature Range; Nature, Vol. 418, pp. 601-602 - Whitelegg, J., (2006) *Managing the Environmental Impacts of Globalisation on Transport: Aviation Emissions*; Organisation for Economic Co-operation and Development (OECD), ENV/EPOC/WPNEP/T(2006)8 - Zerefos, C. S., Eleftheratos, K., Balis, D. S., Zanis, P., Tselioudis, G., Meleti, C. (2003) *Evidence of impact of aviation on cirrus cloud formation; Atmos*. Chem. Phys., vol. 3, pp. 1633-1644.

Image Credits: Top Left (Ireland) *http://content.answers.com/main/content/wp/en/thumb/6/6f/300px-Iland.A2003004.jpg;* Top Right: *Gillian Whelan;* Bottom Left: Contrails over central Europe 0943UTC 4/5/1995, based on NOAA-12 AVHRR *http://www.grida.no/climate/ipcc/aviation/images/avf3-12.jpg;* Left Middle: ESA MetOpA: Credits: ESA – AOES Medialab, *http://www.esa.int/images/metop_deployment_solar_array_l,0.jpg;* Centre Middle (aircraft with contrail): Gillian Whelan; Centre Left: NOAA/AVHRR CH5 24/02/2008 22:25h c/o Dundee satellite receiving station; Bottom Right (Contrails): *educate-yourself.org/lte/250px-Contrails.jpg*

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