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AVIATION

Contrail Detection and Modelling using Deep Learning

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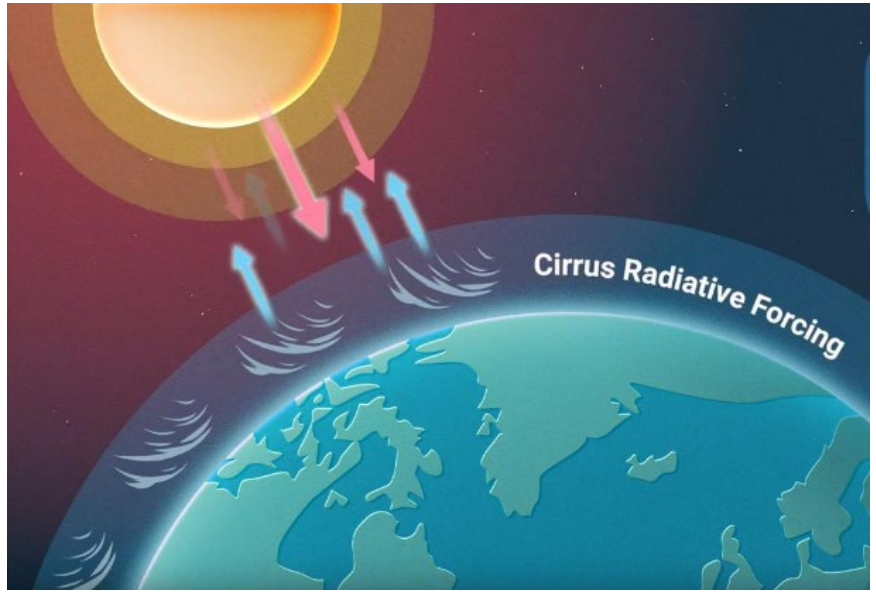
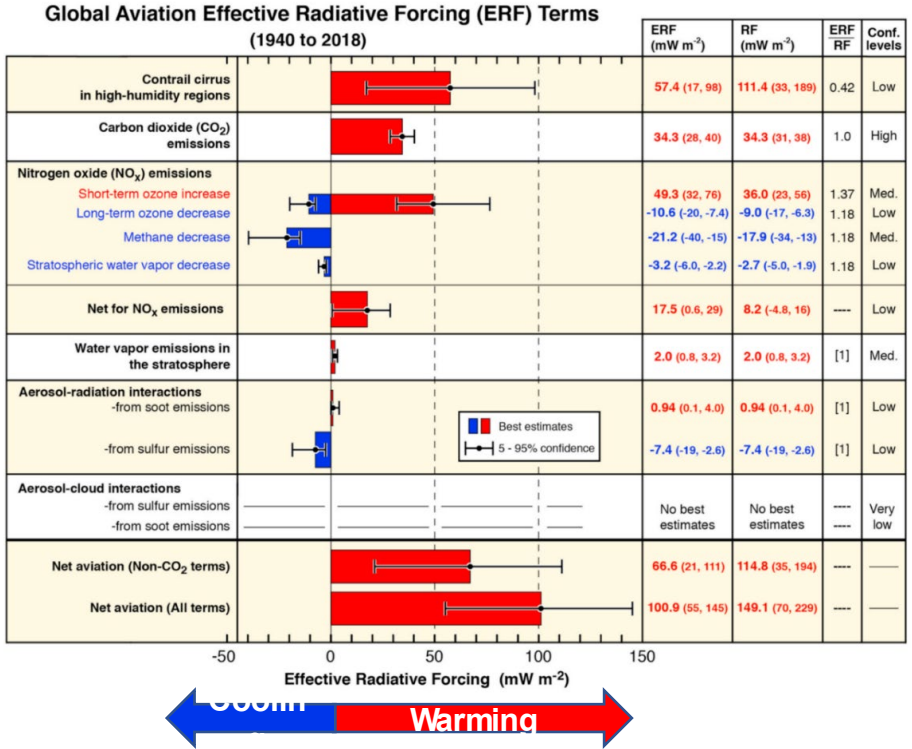
Research Context

- Recent research (*) suggests that persistent condensation trails (“**Contrails**”) may account for a significant part of aviation's overall contribution to the **greenhouse effect.**

- The climate impact of non-CO2 emissions could be of the **same order of magnitude** as CO_2 emissions.



(*) The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018, 2021, Lee et al



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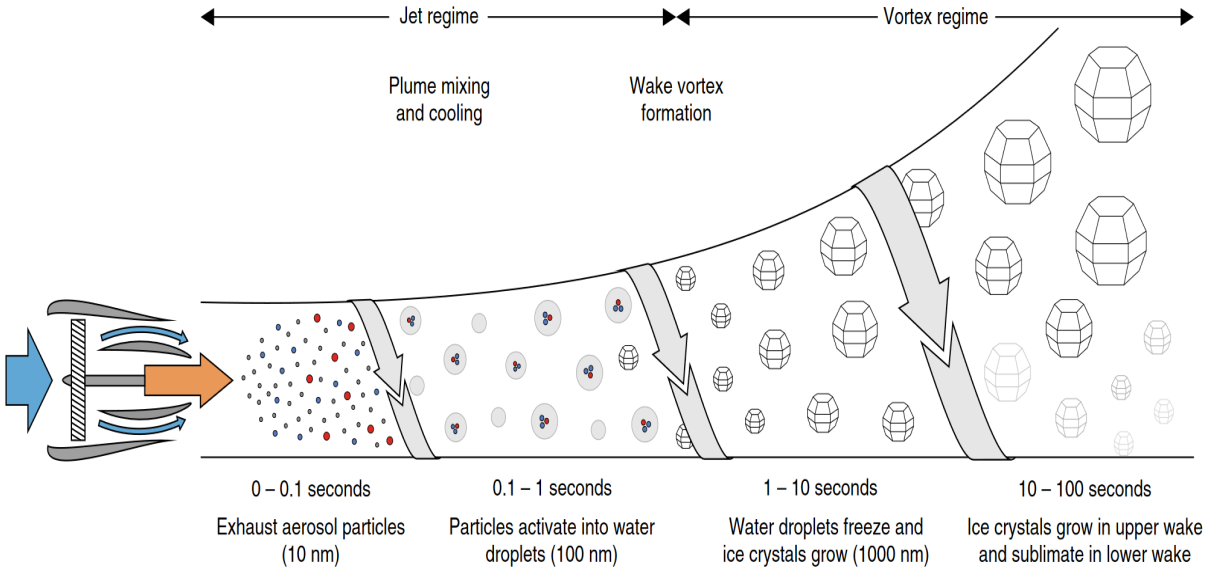
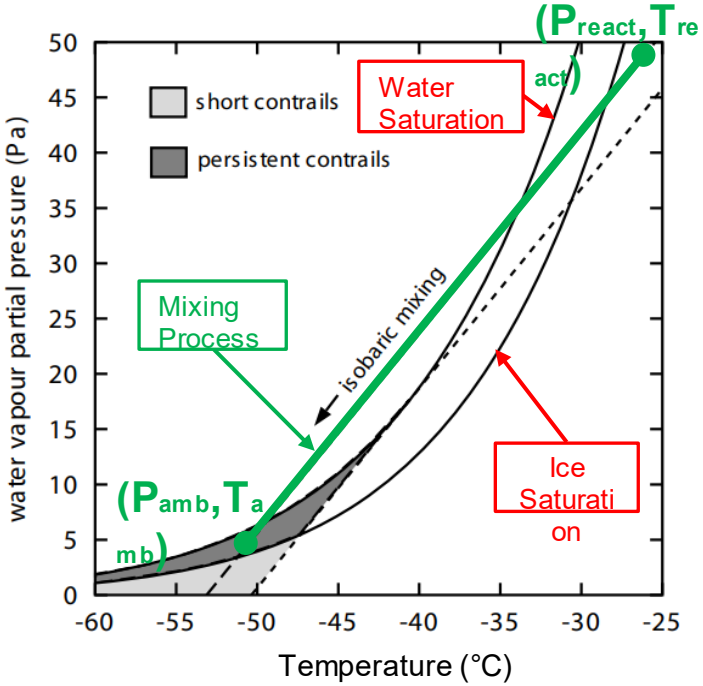
Physical Models

- Contrails forms when the mixture of exhaust gases and ambient air reaches **saturation with respect to liquid water** during the plume expansion (isobaric) process.

- **Contrails persist** if the ambient air is **saturated with respect to ice** at the end of the mixing process.



Source: *Formation and radiative forcing of contrail cirrus, Karcher, 2018*



Source: *A Review of Various Strategies for Contrail Avoidance , Gierens et al., 2008*

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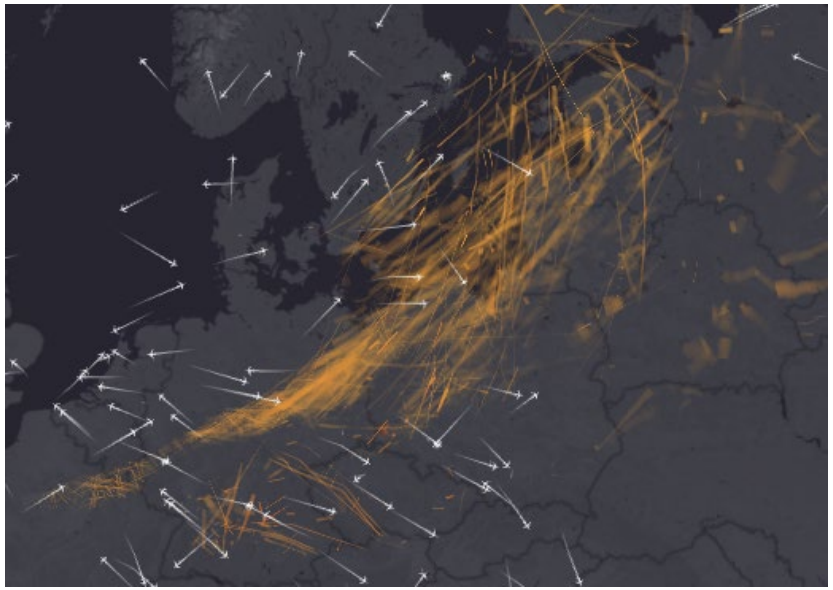
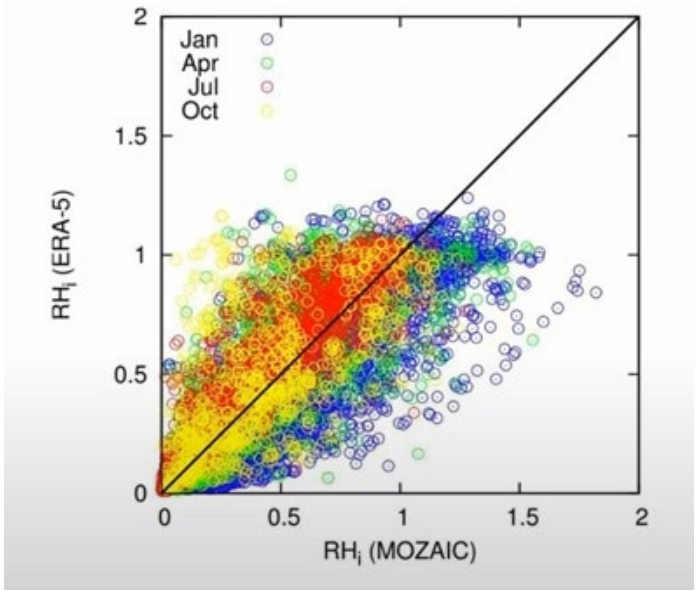
The Difficulty on Contrail Monitoring and Prediction

- Modelling tools based solely on Physics (ISSR, CoCiP, aCCF) depend on the quality of their inputs : **performance model** (BADA, Poll-Schumann), **aircraft trajectories** (ADS-B data, Flight Plans, QAR), **weather data** (Relative Humidity in particular, winds for longer term behavior).

- The Prediction task is limited by the **accuracy of weather predictions, and relative humidity (Gierens, 2020).**



Source: https://map.contrails.org/



Source: How well can contrails be predicted, Gierens at al., 2020.

An Alternative: The Observational Approach

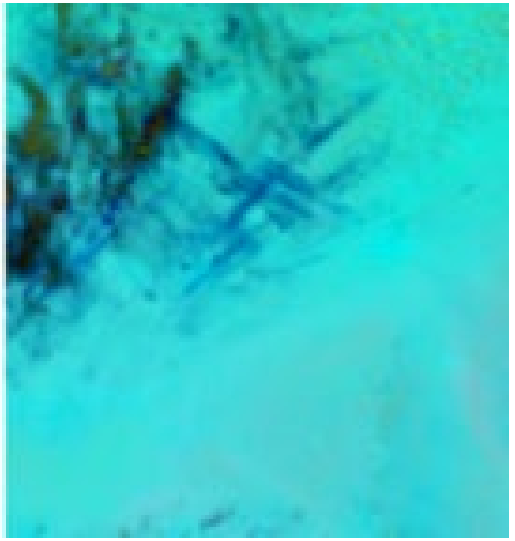
- An increasing number of observational sensors allow to correlate contrail occurrences with other data and to build large databases.

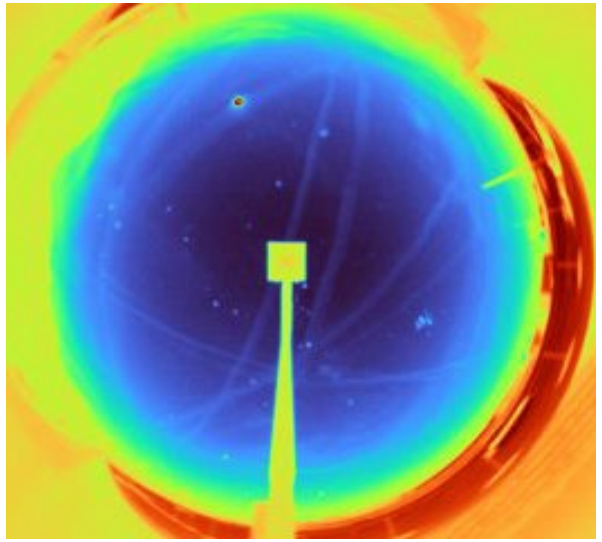
- Observational means include In-Situ measurements (IAGOS, MOZAIC, …), **Geostationary satellites** (GOES, MTG, HIMAWARI), Low orbit satellites (LANDSAT), **Ground Cameras,** LIDARs (satellites and ground-based).

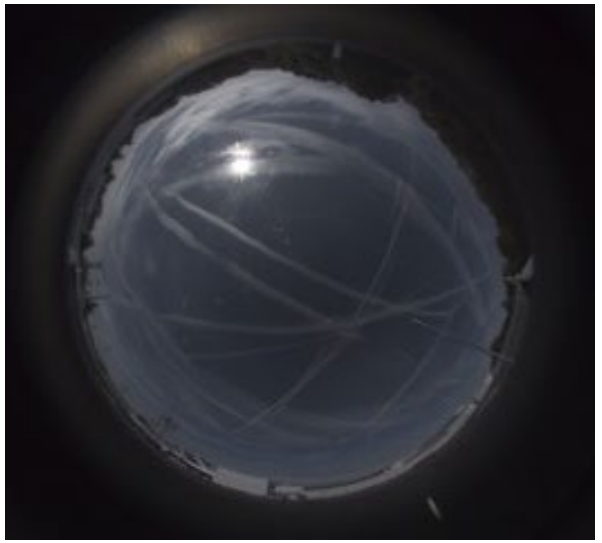
Deep Learning Segmentation

- Deep learning segmentation for contrail detection involves using neural networks to accurately **identify and delineate the precise boundaries of contrail clouds** in satellite and ground-based camera imagery.

- Segmentation models usually require **extensive labelled datasets** to effectively learn and identify the subtle features of these elongated cloud formations in imagery.





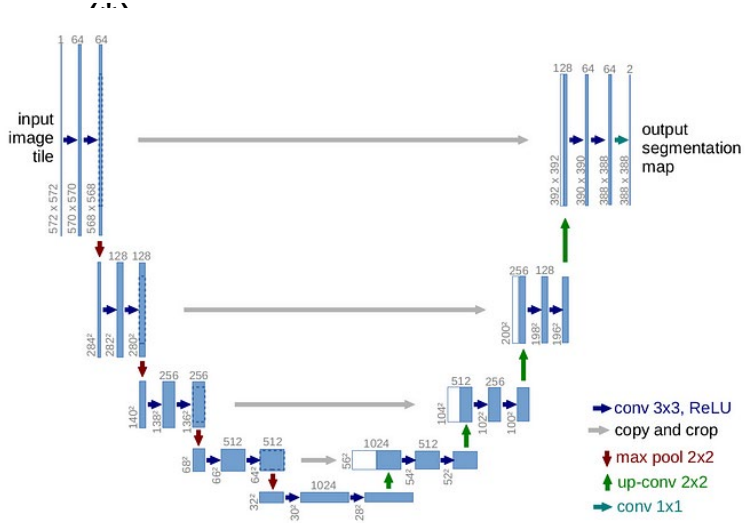


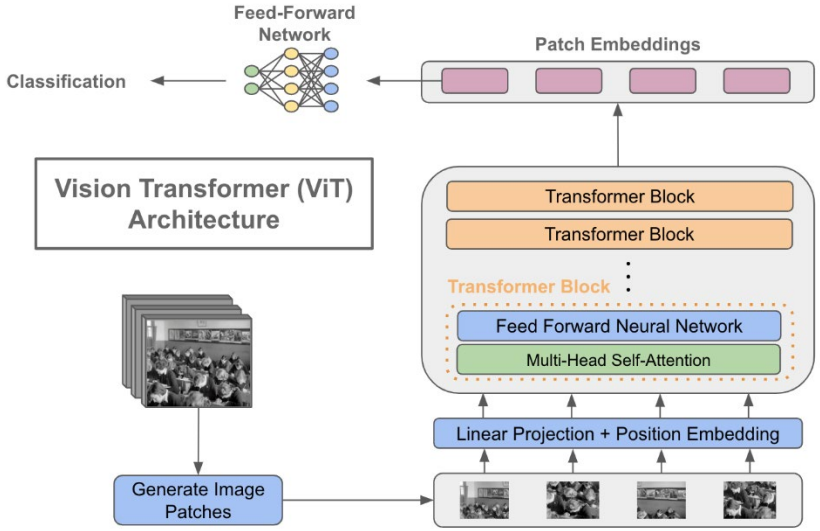
U-net architecture and backbones

- The U-Net model is a convolutional neural network designed for image segmentation, characterized by its "U-shaped" encoder-decoder architecture which combines **downsampling and upsampling operations**.

- The U-Net architecture effectively **utilizes established classification backbones** by adapting them into its contracting (downsampling) path.

- **U-net architecture combined with Vision Transformers backbones** have been shown to perform better on satellite imagery than traditional classification backbones and other architect

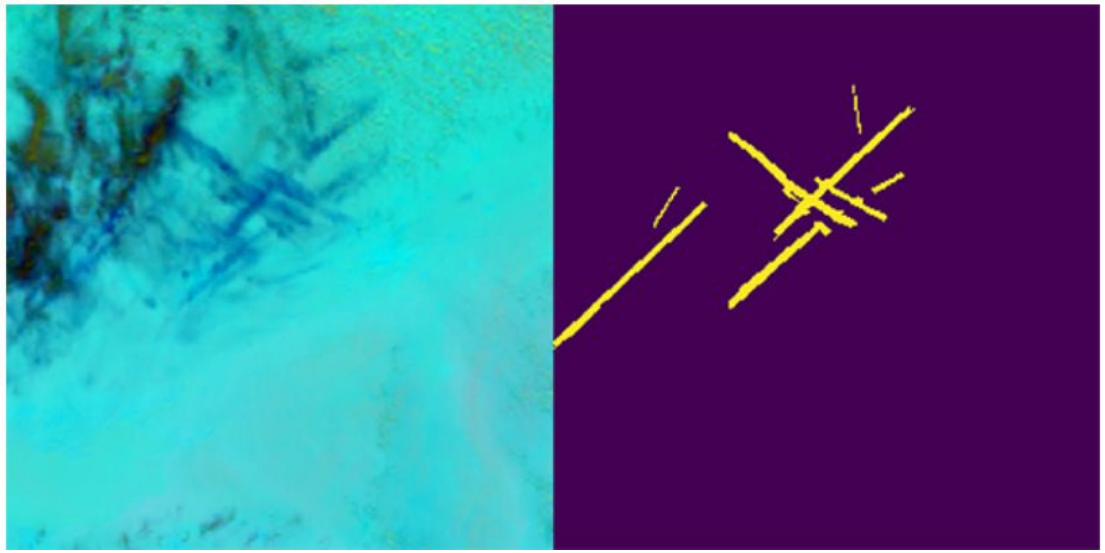




(*) Joe Ng, Carl Elkin, Aaron Sarna, Walter Reade, Maggie Demkin. (2023). Google Research - Identify Contrails to Reduce Global Warming. Kaggle. https://kaggle.com/competitions/google-research-identify-contrails-reduce-global-warming

Example of model predictions

- On bit masks, model performance could be measured using the dice correlation score (pixel correlation). The best models on the GOES-16 dataset are around 72% of dice score.



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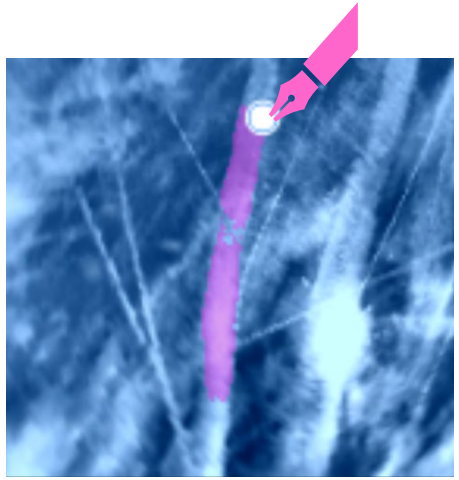
ContrailNet initiative and labelling campaign

- EUROCONTROL, along with Airbus and Thales, launched ContrailNet, a technical network aimed at consolidating European research efforts related to aviation contrails through **a common repository of contrail observation data.**

- EUROCONTROL has launched a **labelling campaign** on ground cameras (visible & infrared) and on the the European Geostationary satellite (MTG).

- EUROCONTROL will **share labelled datasets and trained models** within ContrailNet initiative.



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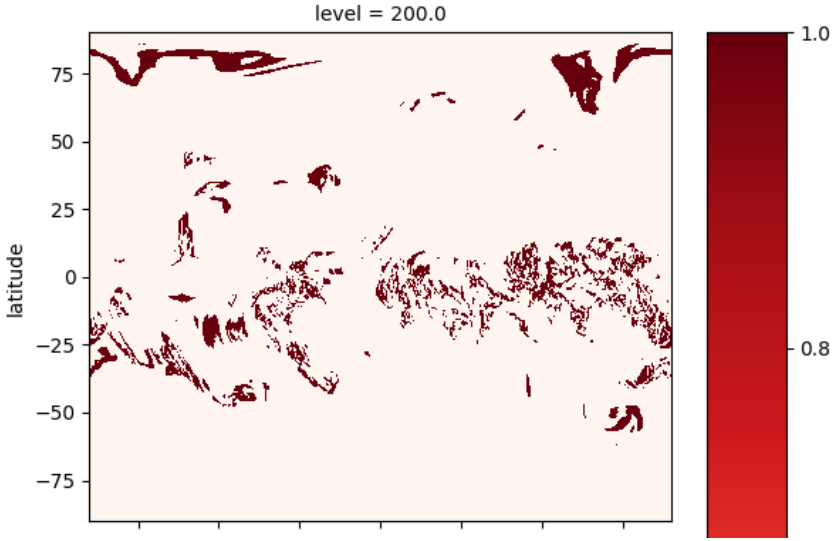
Future works

- Monitoring and tracking of contrails on satellite and ground camera imagery.
- Prediction of Ice Super Saturated Regions (ISSR).
- Modelling of contrail formation using ground cameras (hydrid).



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Thank you!

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