Laboratoire des Sciences du Climat et de l'Environnement
LSCE (UMR 8212)

IMPACT OF THE AVIATION SECTOR ON CLIMATE

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2nd ECATS Conference
08 November 2016 - Athens - Greece

1-INTRODUCTION

$C0_2$ climate impact from the aviation sector

- 2% (705 Mt CO2 in 2013) of the world's annual CO_2 emission (Lee et al 2010).
- 3 fold increase in global air traffic rate over next 20 yrs. (4.9% increase per year) (ICAO, 2014), could make the aviation sector the highest CO_2 fossil fuel emitter.
- The IMPACT project aims to contribute reducing uncertainties in calculating the climate impact of aircraft emissions and in particular those associated with:
  - contrails and induced cirrus
  - NOx emissions (impact on methane lifetime and increase ozone)
  - Aerosols (sulfates, nitrates, BC).
- 4 years (2012- 2016) project funded by *Direction Générale de l'Aviation Civile (*DGAC*)* in the framework of the *COnseil pour la Recherche Aéronautique et Civile* (CORAC).
- 5 partners (public and private) in the project: LSCE (CNRS), LMD, Météo-France, CERFACS, SAFRAN-Aircraft engines.

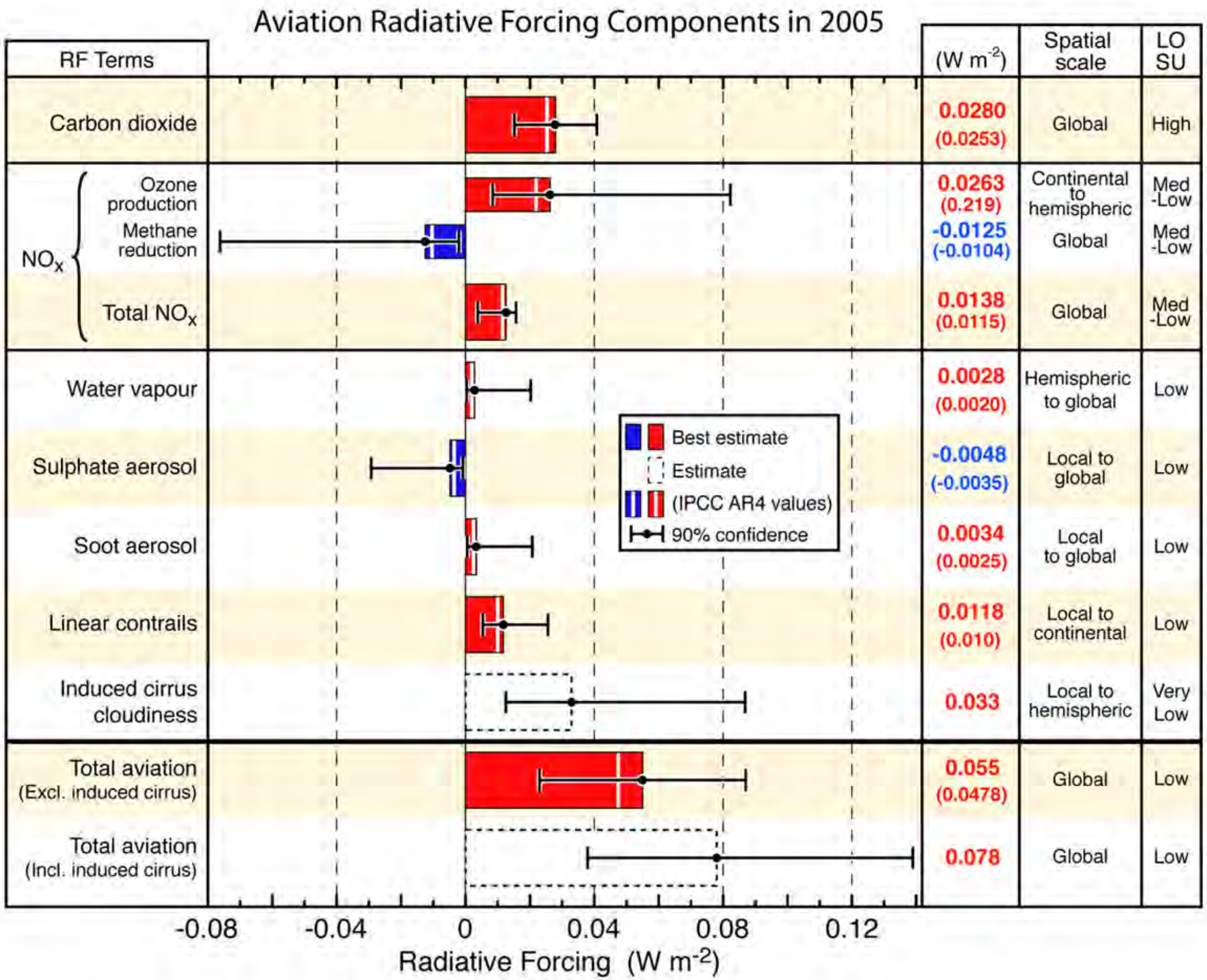


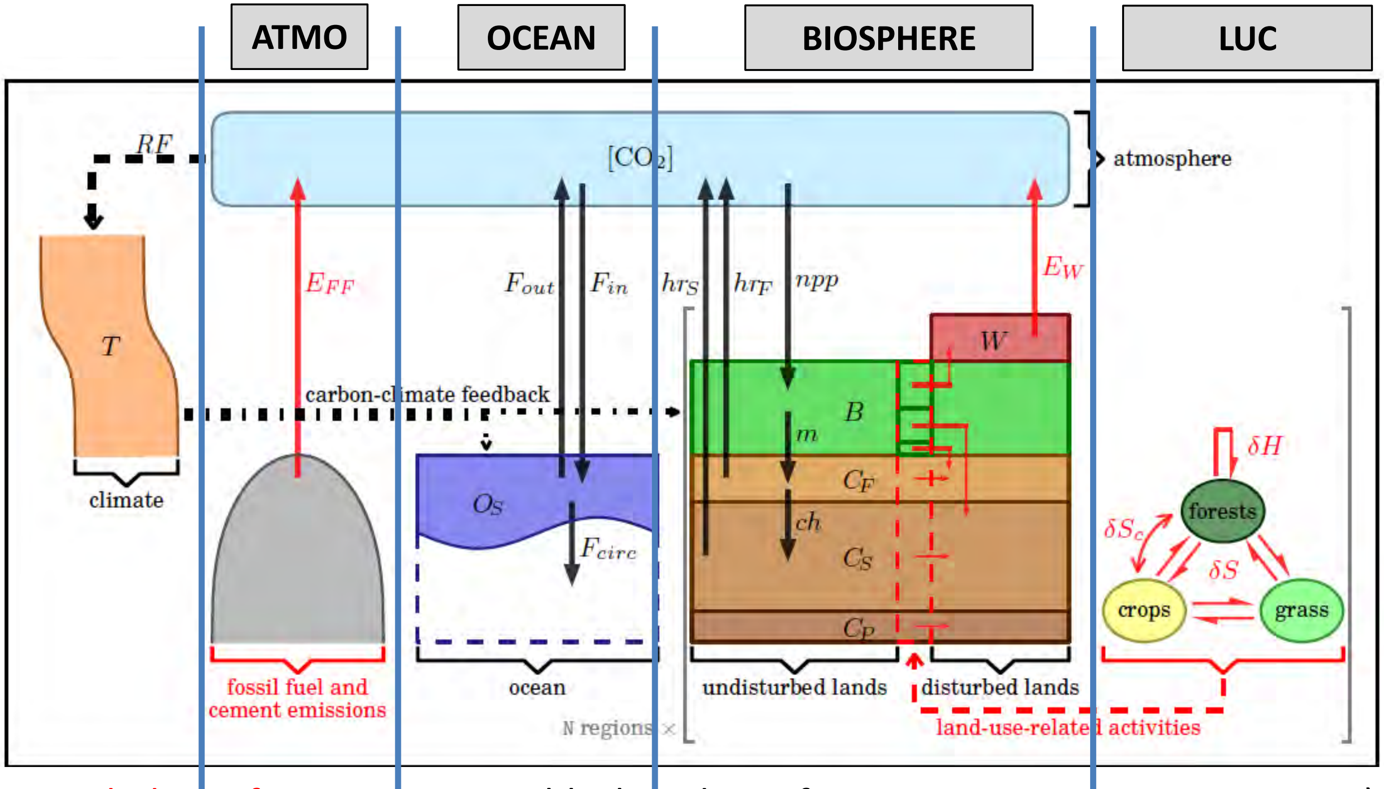
Fig. 28. Radiative forcing components from global aviation as evaluated from preindustrial times until 2005. Bars represent updated best estimates or an estimate in the case of aircraft-induced cirrus cloudiness (AIC). IPCC AR4 values are indicated by the white lines in the bars as reported by Forster et al. (2007a). The induced cloudiness (AIC) estimate includes linear contrails. Numerical values are given on the right for both IPCC AR4 (in parentheses) and updated values. Error bars represent the 90% likelihood range for each estimate. The median value of total radiative forcing from aviation is shown with and without AIC. The median values and uncertainties for the total NO_x RF and the two total aviation RFs are calculated using a Monte Carlo simulation. The Total NO_x RF is the combination of the CH_4 and O_3 RF terms, which are also shown here. The AR4 value noted for the Total NO_x term is the sum of the AR4 CH_4 and O_3 best estimates. Note that the confidence interval for 'Total NO_x' is due to the assumption that the RFs from O_3 and CH_4 are 100% correlated; however, in reality, the correlation is likely to be less than 100% but to an unknown degree (see text). The geographic spatial scale of the radiative forcing from each component and the level of scientific understanding (LOSU) are also shown on the right (Lee et al., 2009).

2-THE OSCAR MODEL
AND
THE SCENARIOS USED

Introduction to the OSCAR model

- OSCAR v1 was a carbon cycle model developed by Gitz and Ciais, 2003.
- Now OSCAR v2.2 (description in Gasser et al., 2016 in GMDD).
- OSCAR is a Simple Climate Change Model (SCCM) also called compact Earth System Model (ESM).
- Compute the interaction (with feedback) of different meta-model (ex: atmosphere, biosphere including LUC, ocean) calibrated against complex climate models outputs (CMIP5 or ACCMIP's models) available in the literature.
- Model the anthropogenic perturbation for different species with respect to ~~theirs~~ pre-industrial concentrations (in 1850):
  - CO_2, CH_4, N_2O, (H)CFC, O_3, sulphates, nitrates, BC, OC.

The carbon cycle in OSCAR v2.1



In red: direct forcing In black: indirect forcing *From Gasser (2014)*

The logic of OSCAR: ΔC -> ΔRF -> ΔT (regional response is possible!)

The radiative forcing (RF) induced by the increase in atmospheric CO2 follows Myhre et al., 1998.

$$\Delta \mathrm{RF}^{\mathrm{CO2}} = \alpha_{\mathrm{rf}}^{\mathrm{CO2}} \ln \left[1 + \frac{\Delta \mathrm{CO2}}{\mathrm{CO2}_0} \right]$$

Reproducing the carbon cycle with OSCAR v2.2

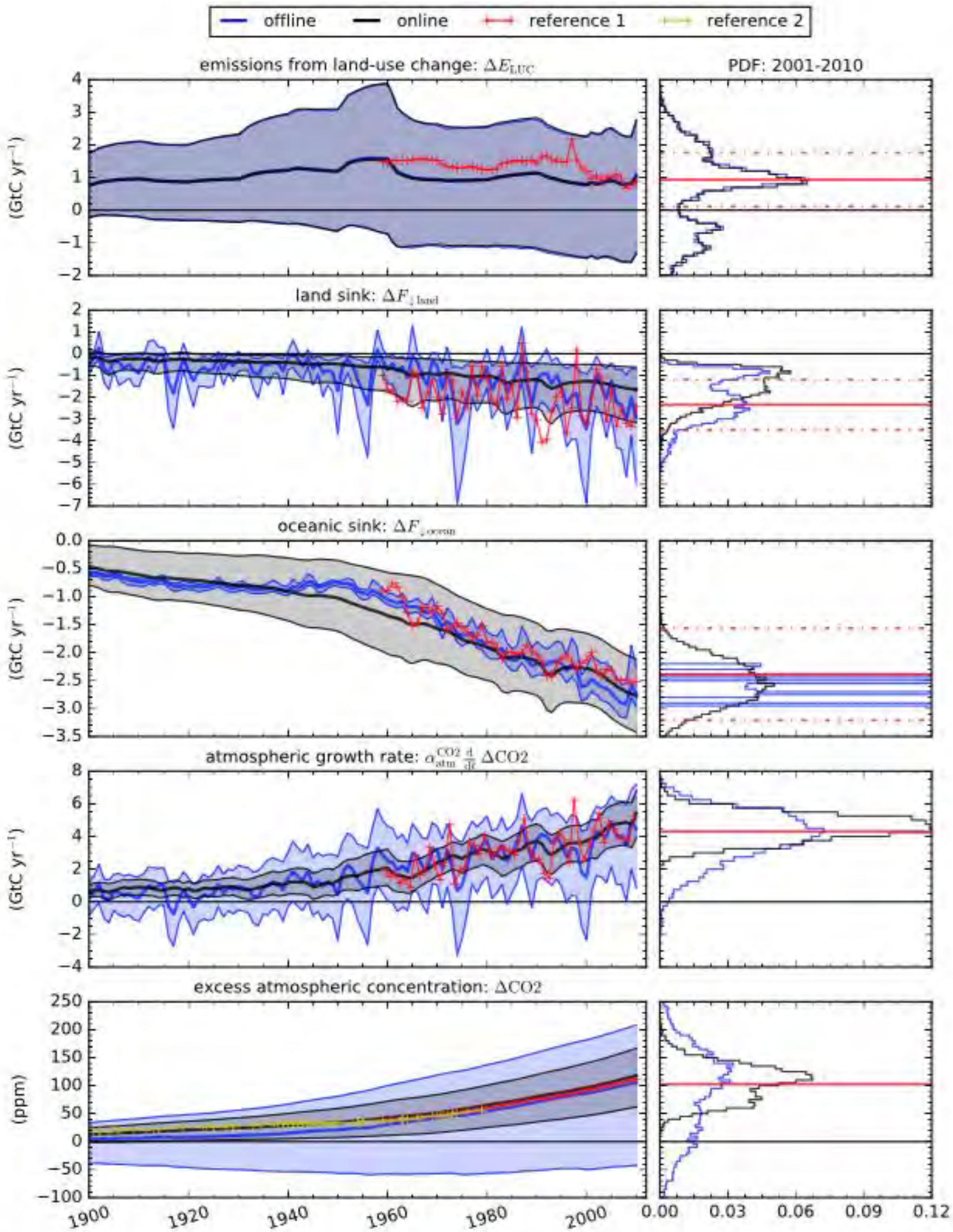
EMISSIONS LUC

LAND SINK

OCEAN SINK

ATMO GROW RATE

DELTA [CO2]



Gasser et al., 2016

Aircraft emissions impact quantification using OSCAR

- For 1940-2006, we use historical data (Sausen and Schumann, 2000 for 1940-1999 period and the REACT4C value for 2006):

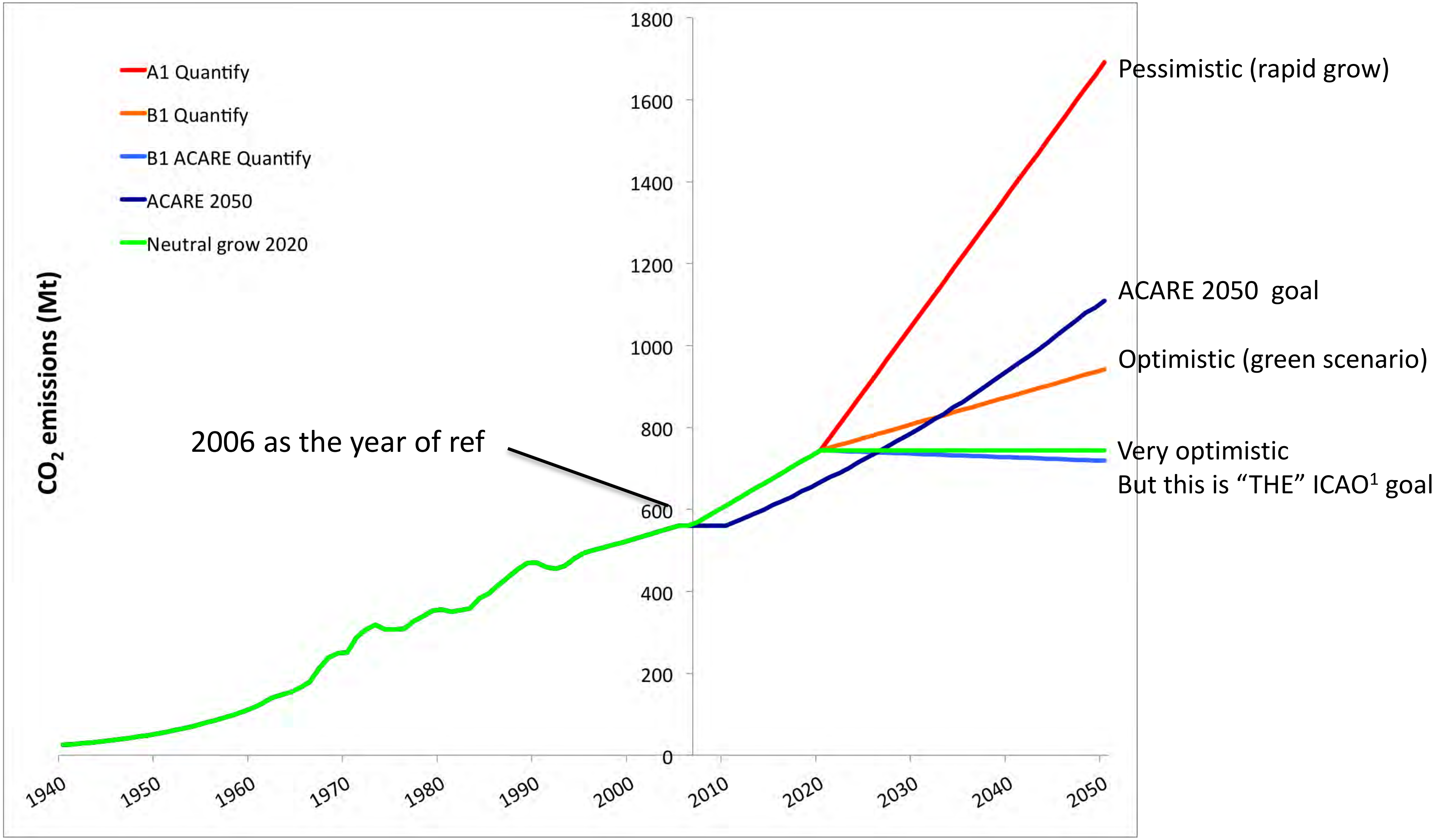
- Then we build two new CO_2 aviation emissions scenarios (2006 -2050):
  - *A1 QUANTIFY (rescaled)* : using the A1 scenario from the QUANTIFY database (Owen et al., 2010).
  - *ACARE[1] 2050 (rescaled)*: Increase of traffic (4.9% $year^{-1}$) + Average fuel eff. of -2.7% kg fuel/km/pass until 2050 (to fulfil the ACARE objective of 75% CO_2 emission/km/pass reduction in 2050 compared to 2000).

[1]Advisory Council for Aeronautics Research in Europe

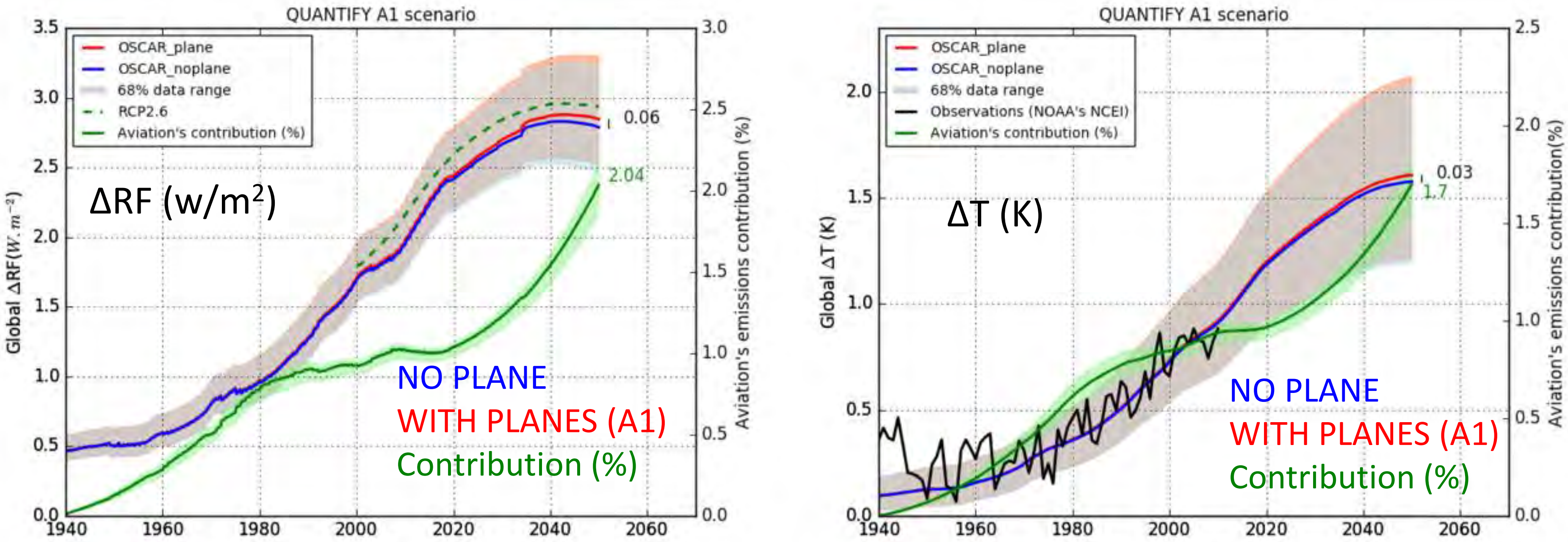
- The two scenarios are performed using the RCP2.6 scenario for the other emissions in order to be in the context of a maximum of 2°C increase (Paris Agreement, 2015):

  - RCP2.6 (max ≈ 3 W/m^2 with a peak of 490 ppm CO_2 eq and a decrease to 2.6 W/m^2 by 2100).
  - Results also available for the 3 other RCPs.

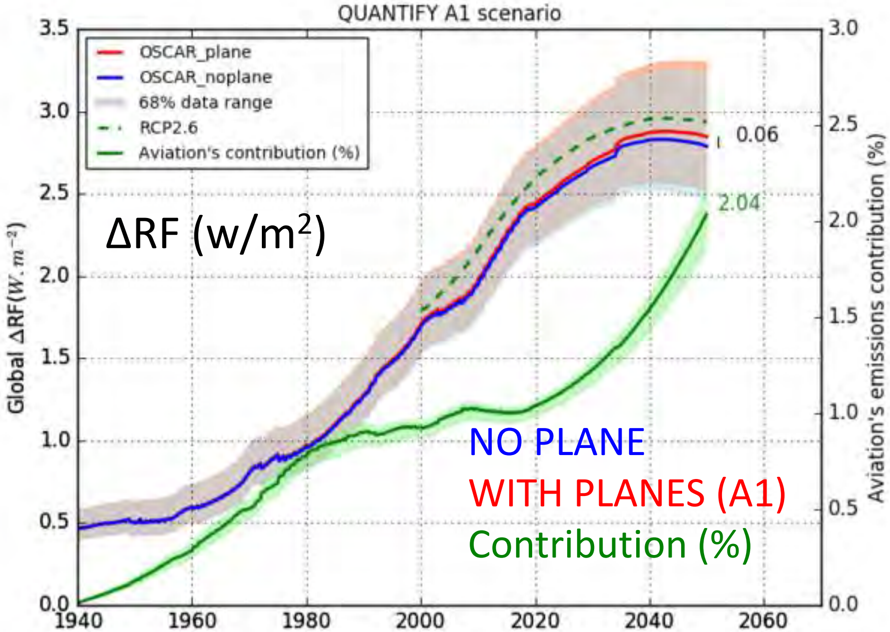
Different CO_2 aviation emissions scenarios used in OSCAR

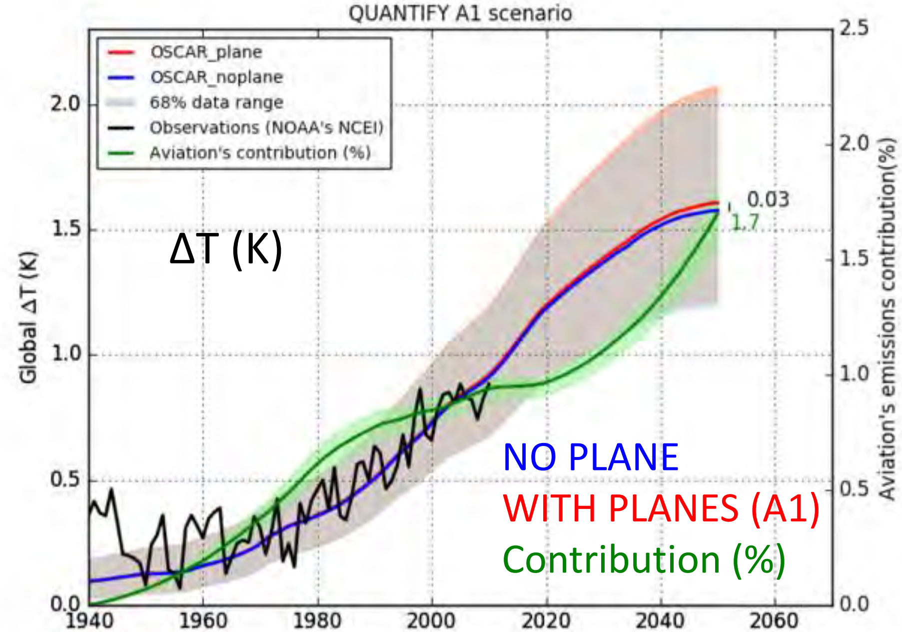


3- RESULTS

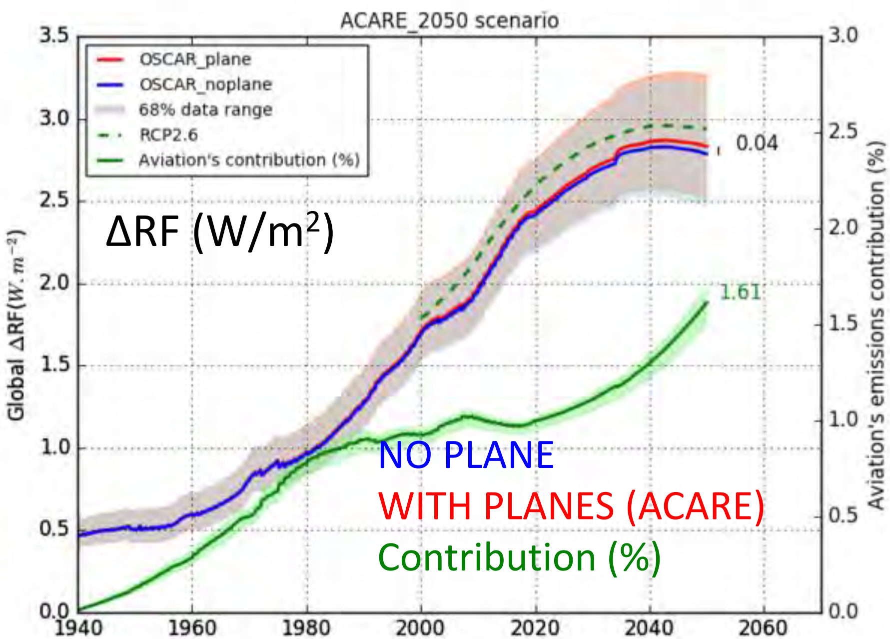

QUANTIFY A1 scenario
OSCAR_plane
OSCAR_noplane
68% data range
RCP2.6
Aviation's contribution (%)
ΔRF (w/m²)
Global ΔRF(W.m⁻²)
Aviation's emissions contribution (%)
0.06
2.04
NO PLANE
WITH PLANES (A1)
Contribution (%)
QUANTIFY A1 scenario
OSCAR_plane
OSCAR_noplane
68% data range
Observations (NOAA's NCEI)
Aviation's contribution (%)
ΔT (K)
Global ΔT (K)
Aviation's emissions contribution(%)
0.03
1.7
NO PLANE
WITH PLANES (A1)
Contribution (%)

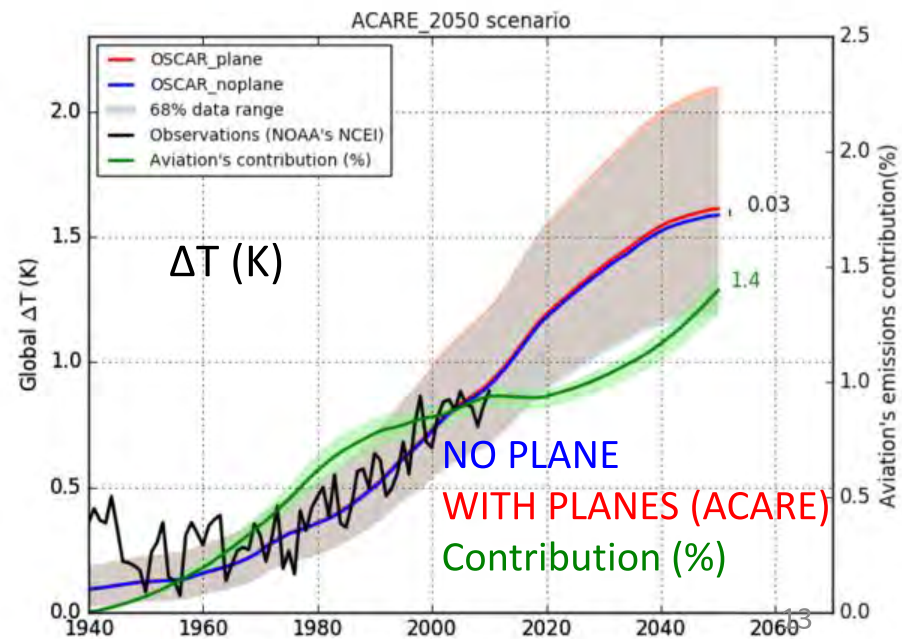
RCP26 (+2°C)


QUANTIFY A1 scenario
OSCAR_plane
OSCAR_noplane
68% data range
RCP2.6
Aviation's contribution (%)
ΔRF (w/m²)
Global ΔRF($W.m^{-2}$)
Aviation's emissions contribution (%)
0.06
2.04
NO PLANE
WITH PLANES (A1)
Contribution (%)

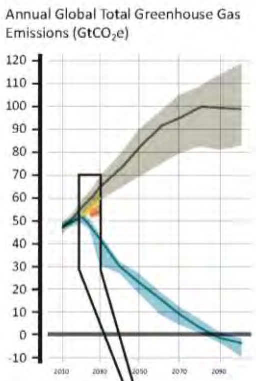

QUANTIFY A1 scenario
OSCAR_plane
OSCAR_noplane
68% data range
Observations (NOAA's NCEI)
Aviation's contribution (%)
ΔT (K)
Global ΔT (K)
Aviation's emissions contribution(%)
0.03
1.7
NO PLANE
WITH PLANES (A1)
Contribution (%)

RCP26 (+2°C)


ACARE_2050 scenario
OSCAR_plane
OSCAR_noplane
68% data range
RCP2.6
Aviation's contribution (%)
ΔRF (W/m²)
Global ΔRF($W.m^{-2}$)
Aviation's emissions contribution (%)
0.04
1.61
NO PLANE
WITH PLANES (ACARE)
Contribution (%)


ACARE_2050 scenario
OSCAR_plane
OSCAR_noplane
68% data range
Observations (NOAA's NCEI)
Aviation's contribution (%)
ΔT (K)
Global ΔT (K)
Aviation's emissions contribution(%)
0.03
1.4
NO PLANE
WITH PLANES (ACARE)
Contribution (%)

Aircraft emissions impact quantification using OSCAR



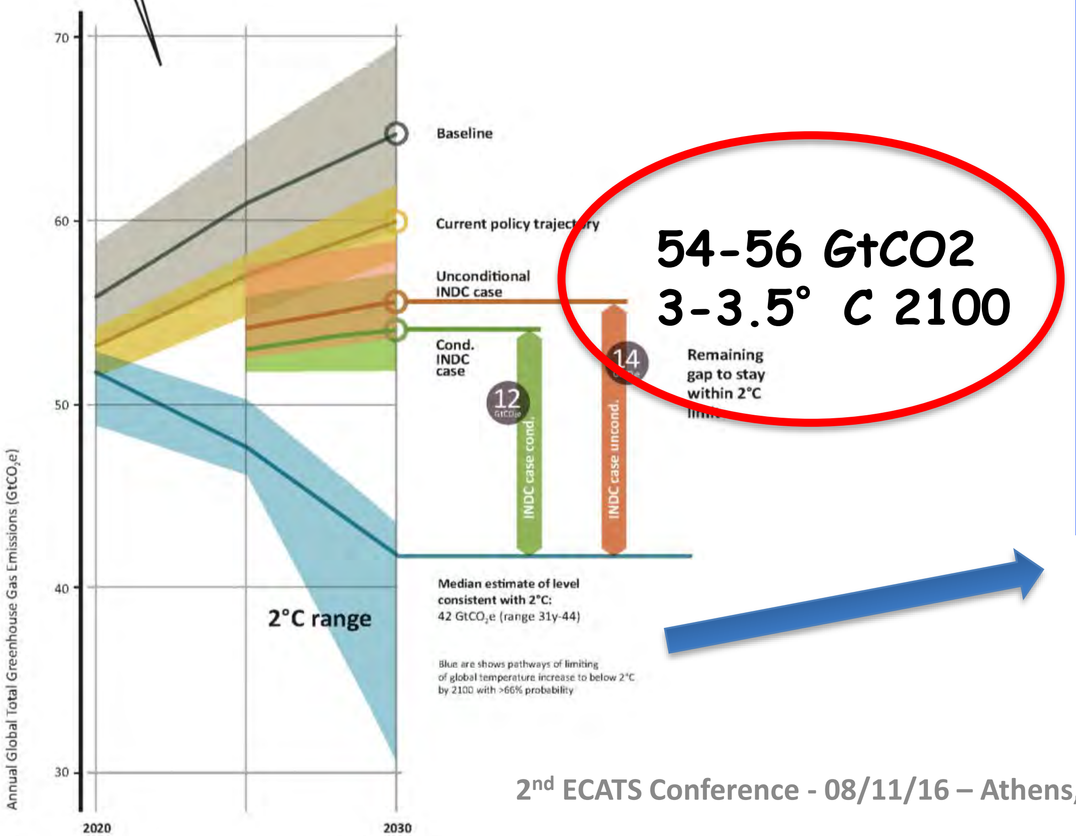
INDCs: Intended Nationally Determined Contributions.
119 INDCs submitted representing 146 states.

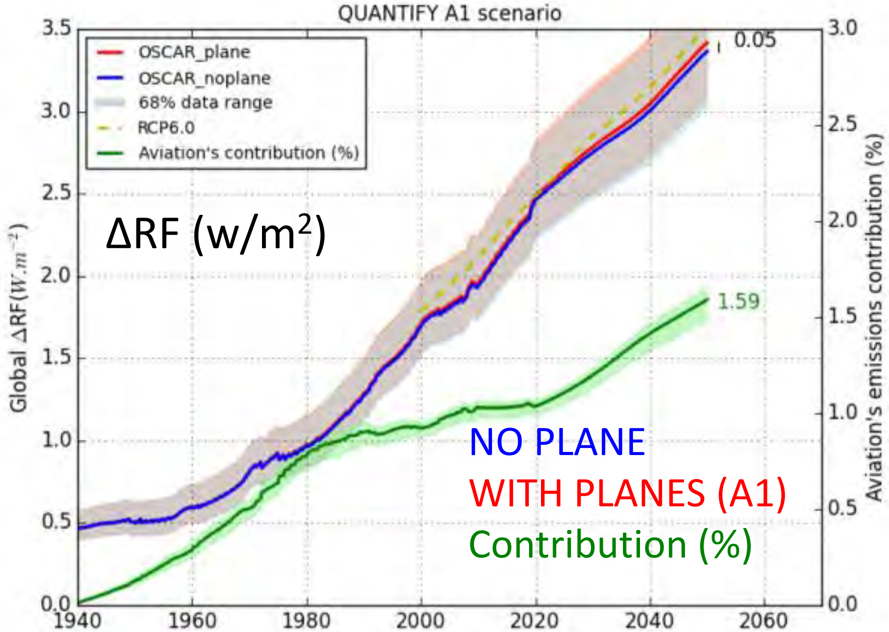
Objective to maintain the temprerature increase to +2° C :

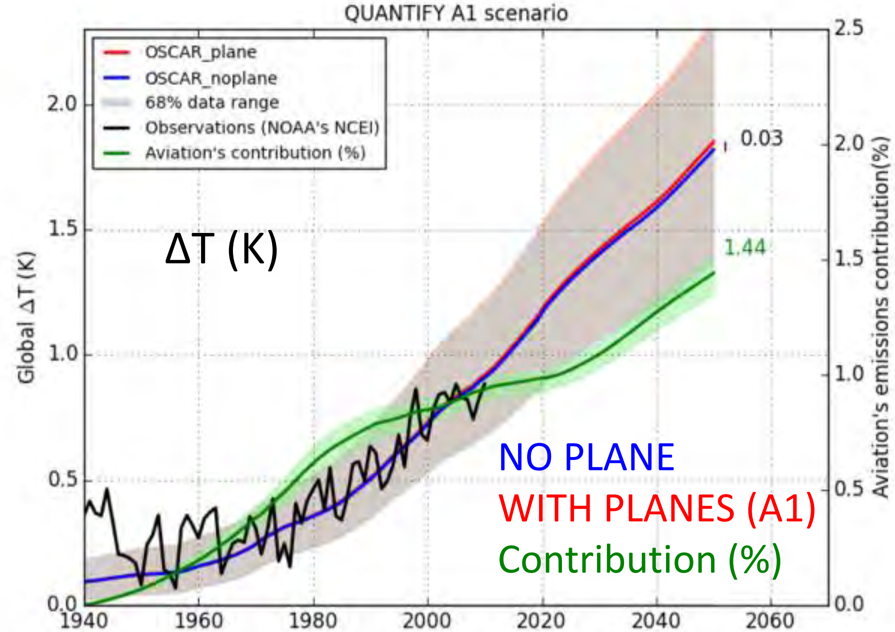
-Emission peak asp + 20% reduction in 2030

-40-50% minimum reduction in 2050

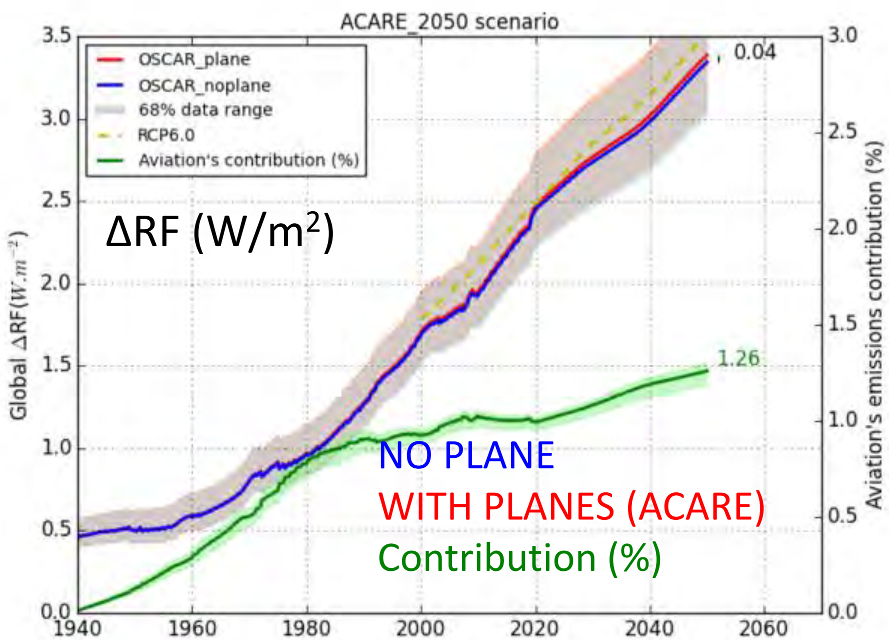
-80-100% minimum reduction in 2100.

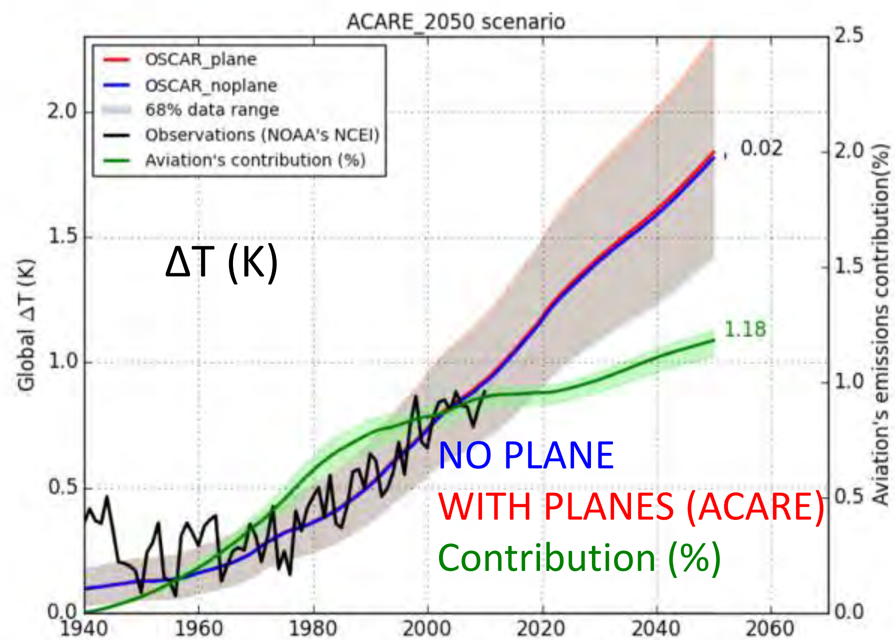




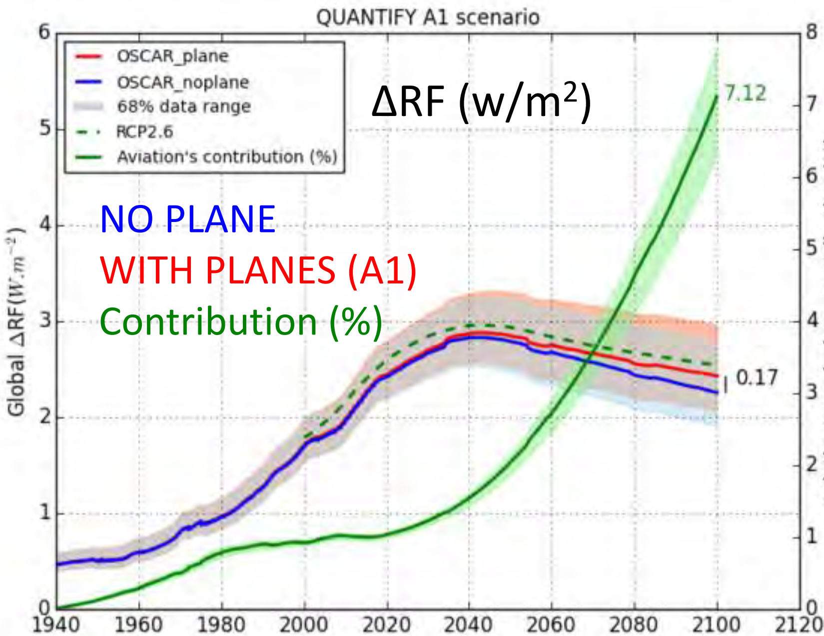


RCP6 (+3°C in 2100)

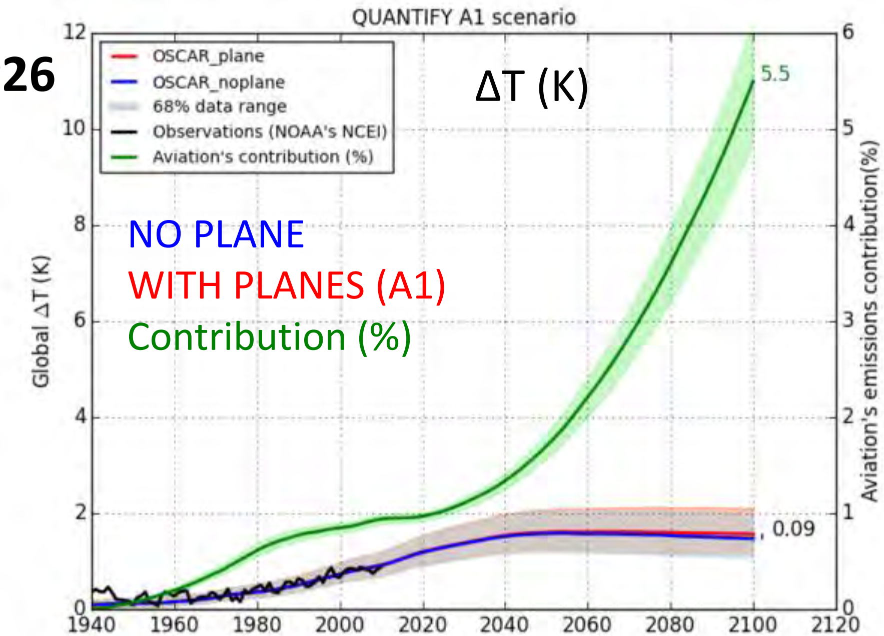




RCP26

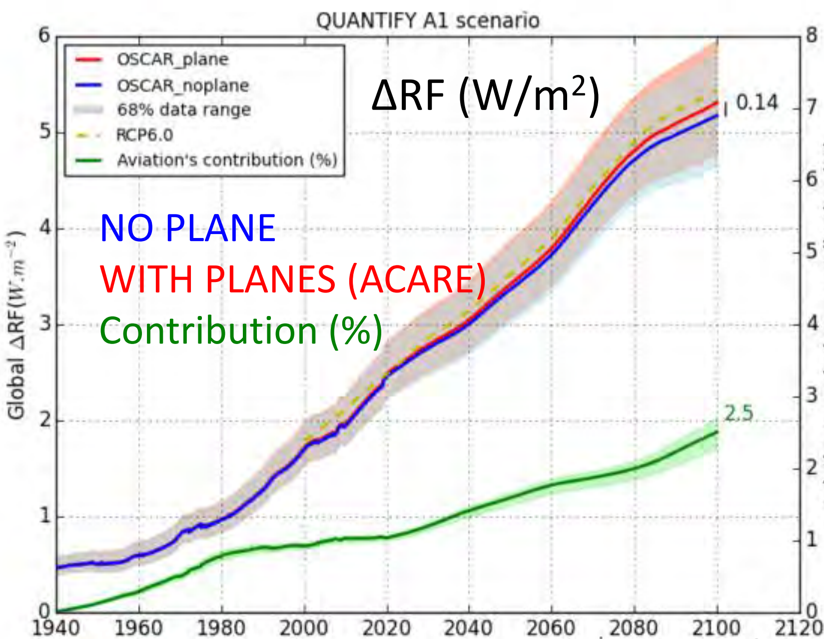


QUANTIFY A1 scenario
OSCAR_plane
OSCAR_noplane
68% data range
RCP2.6
Aviation's contribution (%)
ΔRF (w/m²)
NO PLANE
WITH PLANES (A1)
Contribution (%)
7.12
0.17
Global ΔRF(W.m⁻²)
Aviation's emissions contribution (%)

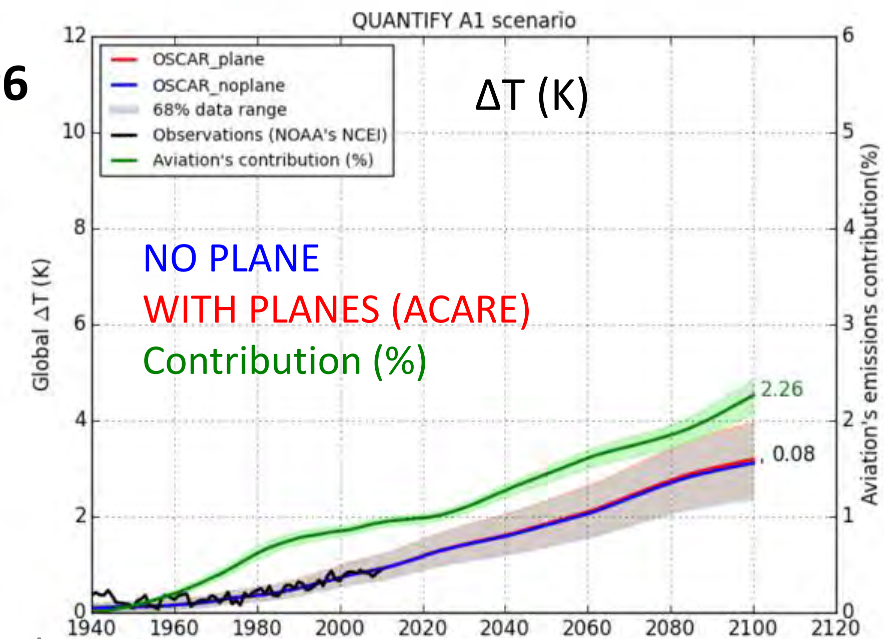


QUANTIFY A1 scenario
OSCAR_plane
OSCAR_noplane
68% data range
Observations (NOAA's NCEI)
Aviation's contribution (%)
ΔT (K)
NO PLANE
WITH PLANES (A1)
Contribution (%)
5.5
0.09
Global ΔT (K)
Aviation's emissions contribution(%)

RCP6

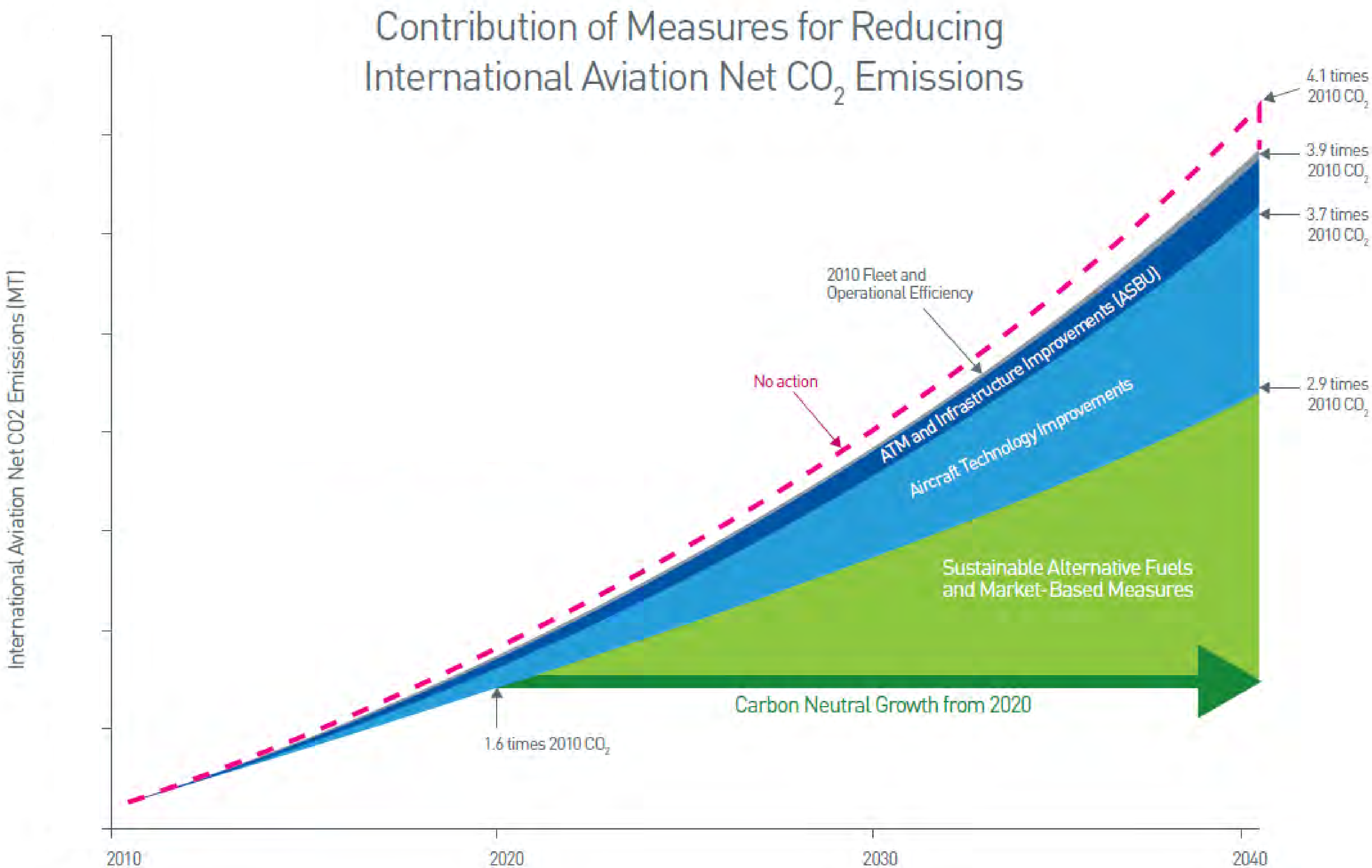


QUANTIFY A1 scenario
OSCAR_plane
OSCAR_noplane
68% data range
RCP6.0
Aviation's contribution (%)
ΔRF (W/m²)
NO PLANE
WITH PLANES (ACARE)
Contribution (%)
0.14
2.5
Global ΔRF(W.m⁻²)
Aviation's emissions contribution (%)



QUANTIFY A1 scenario
OSCAR_plane
OSCAR_noplane
68% data range
Observations (NOAA's NCEI)
Aviation's contribution (%)
ΔT (K)
NO PLANE
WITH PLANES (ACARE)
Contribution (%)
2.26
0.08
Global ΔT (K)
Aviation's emissions contribution(%)

The carbon neutral grow from 2020



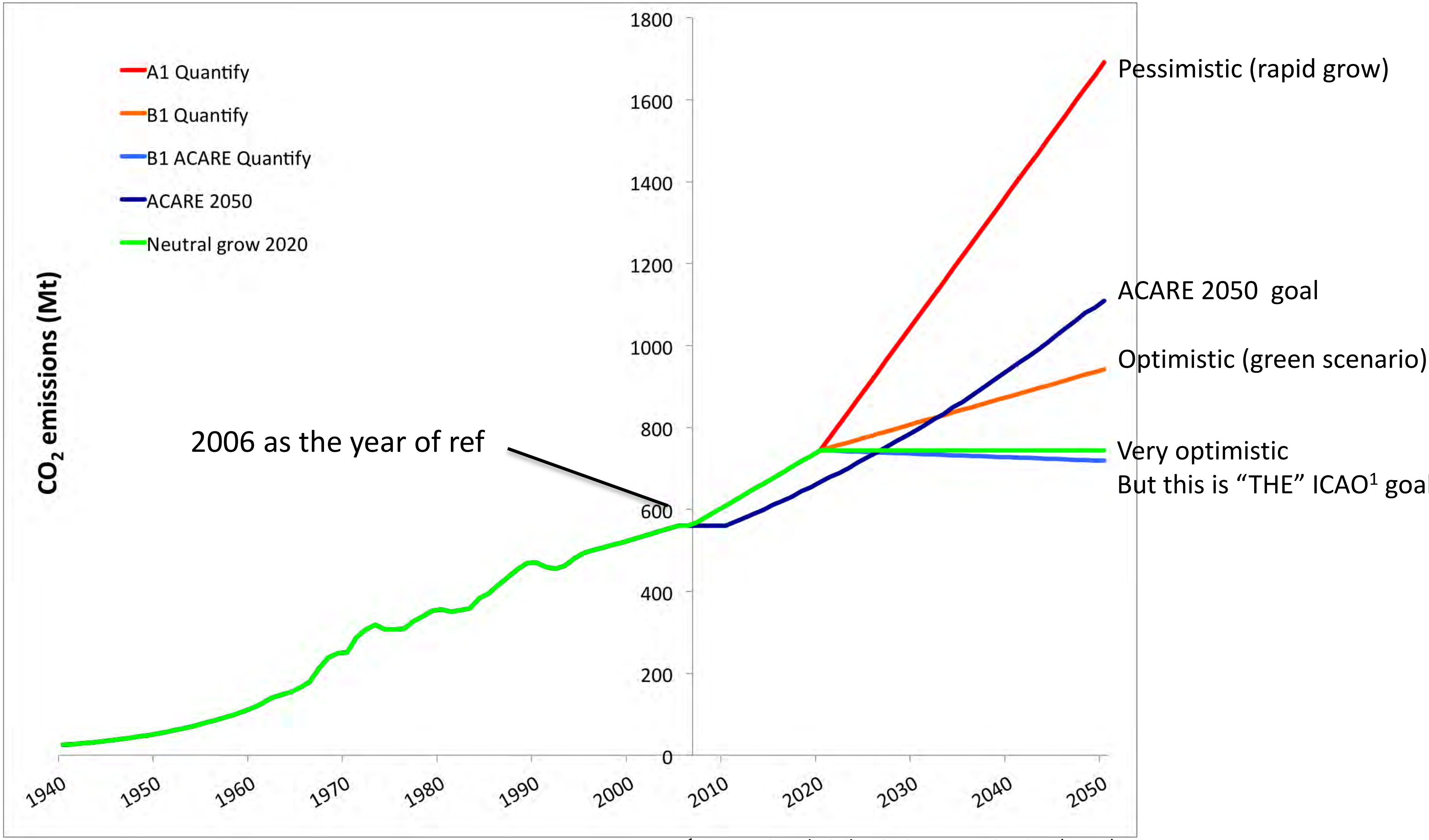
Market based measures (MBMs)

- A market-based measure (MBM) is a policy tool that is designed to achieve environmental goals at a lower cost and in a more flexible manner than traditional regulatory measures.

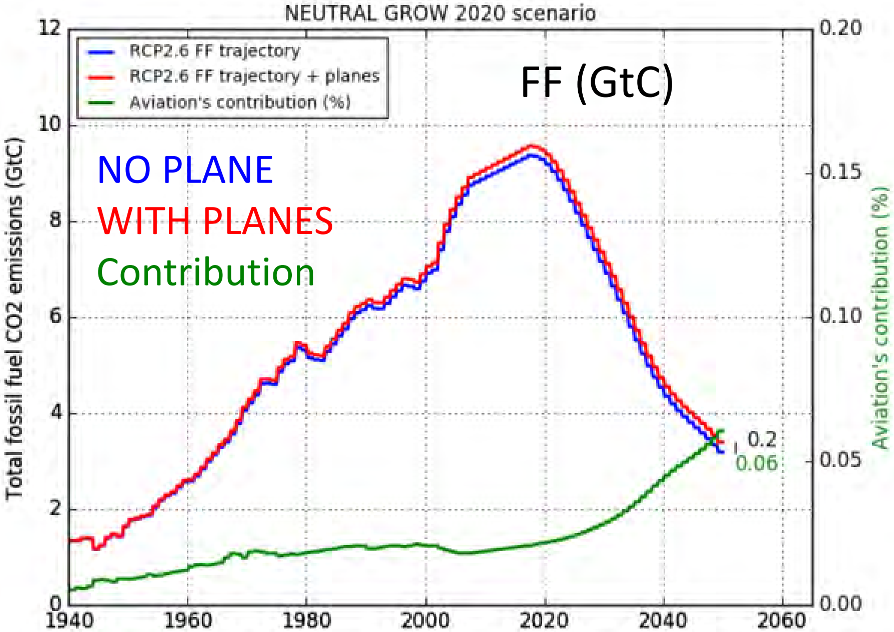
- Examples of MBMs include:
  1. Levies
  2. Emissions Trading Systems (ETS)
  3. Carbon offsetting

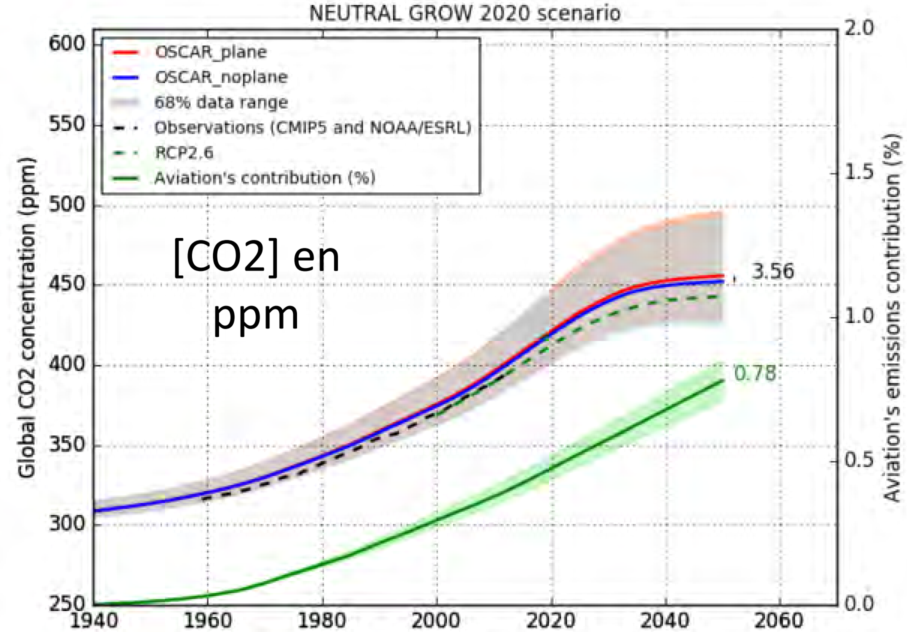
- Using OSCAR to quantify the impact of MBMs that compensate /offset all the CO_2 emissions from planes to follow the carbon neutral grow in 2020.

Different CO_2 aviation emissions scenarios used in OSCAR



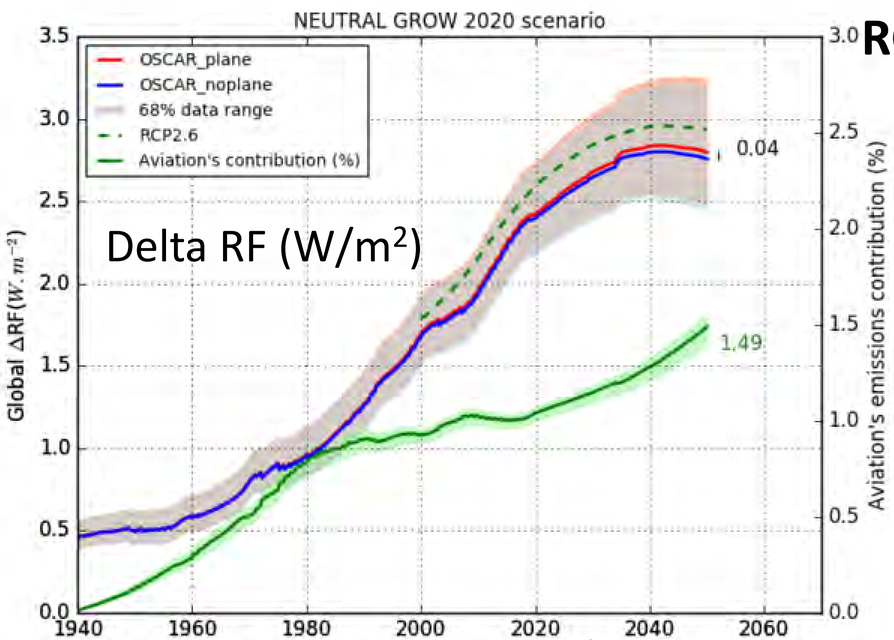
[1]International Civil Aviation Organisation (ICAO)

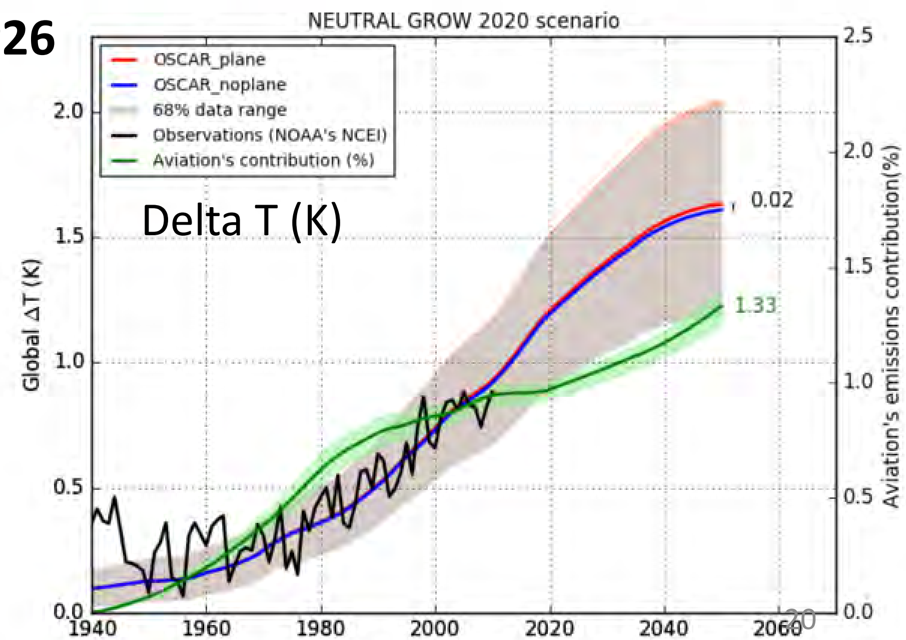


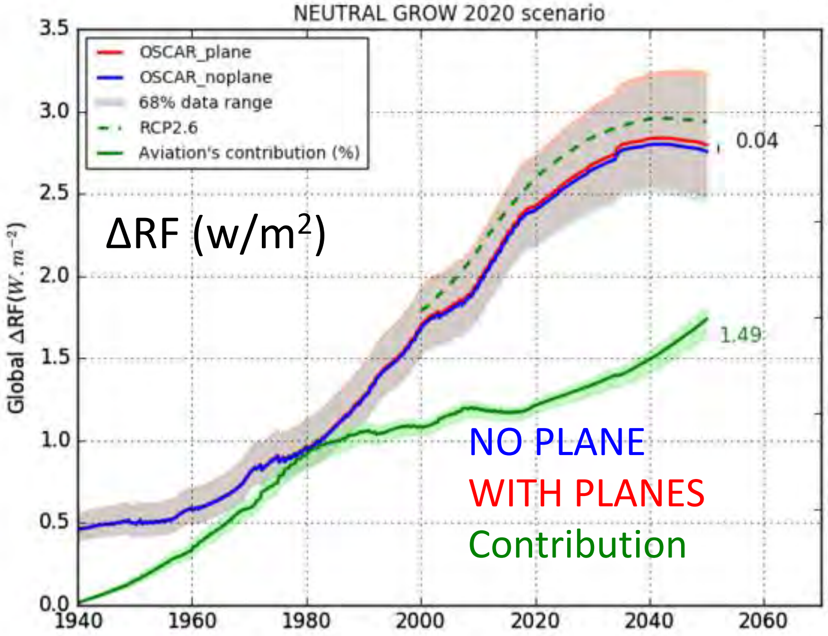


NEUTRAL GROW 2020 (ICAO GOAL)

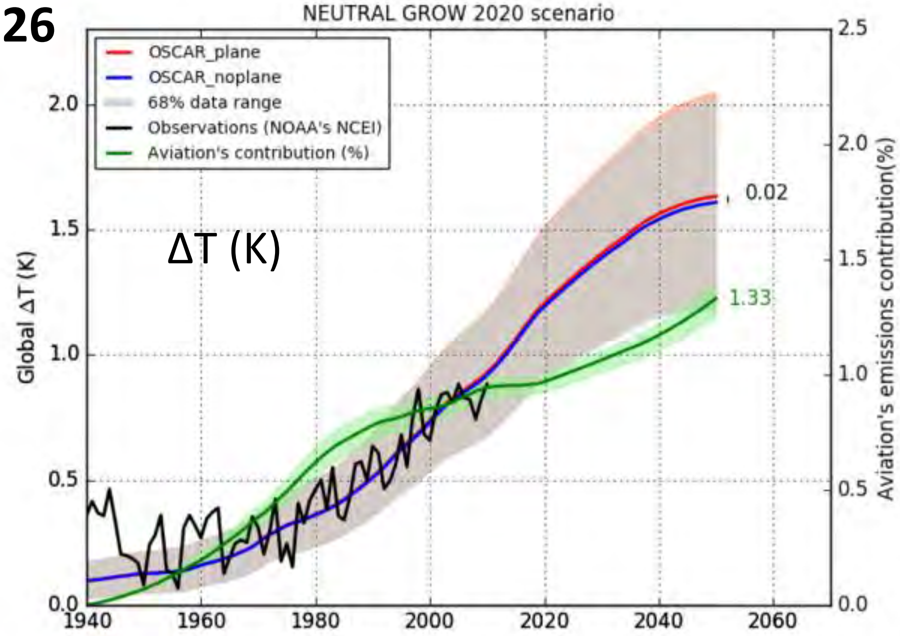
RCP26



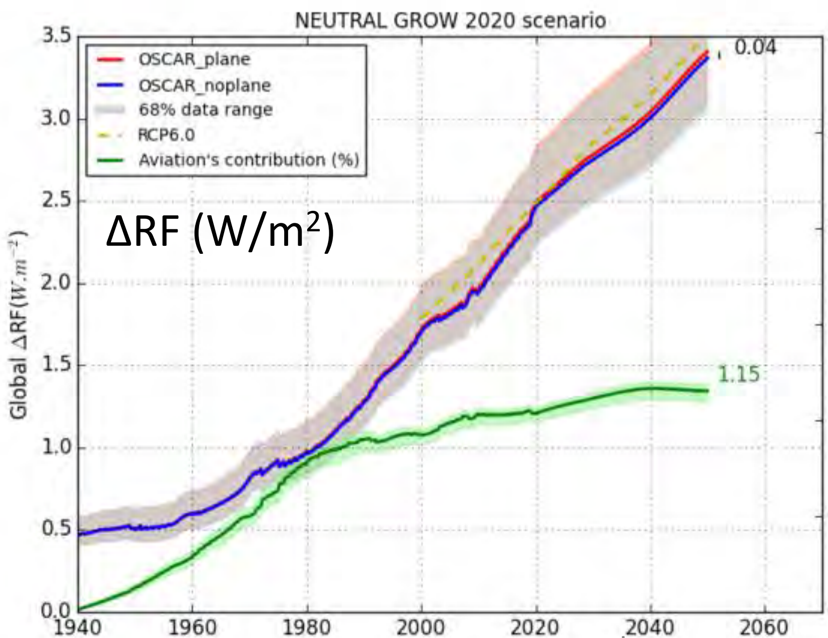




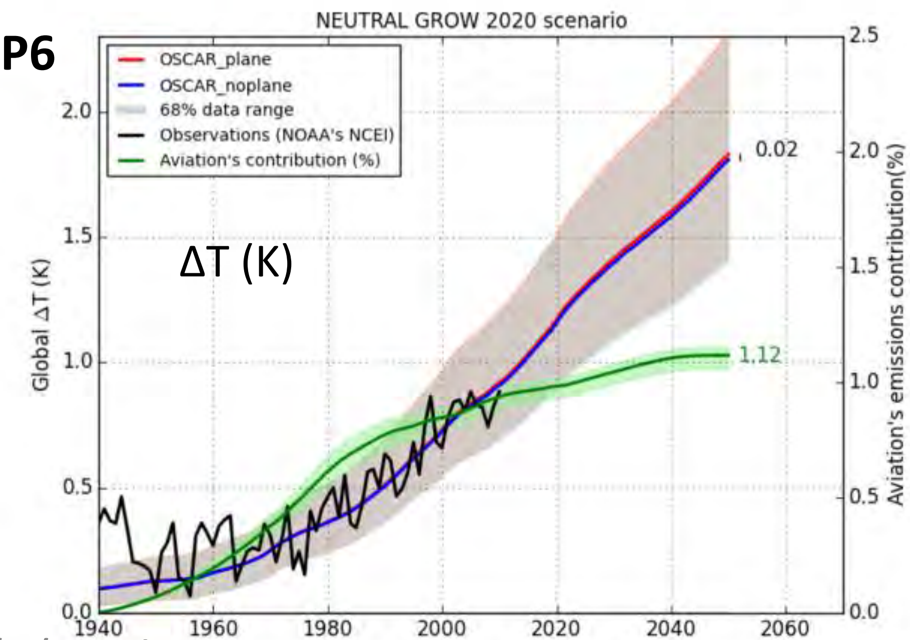
RCP26



NEUTRAL GROW 2020 (ICAO GOAL)



RCP6

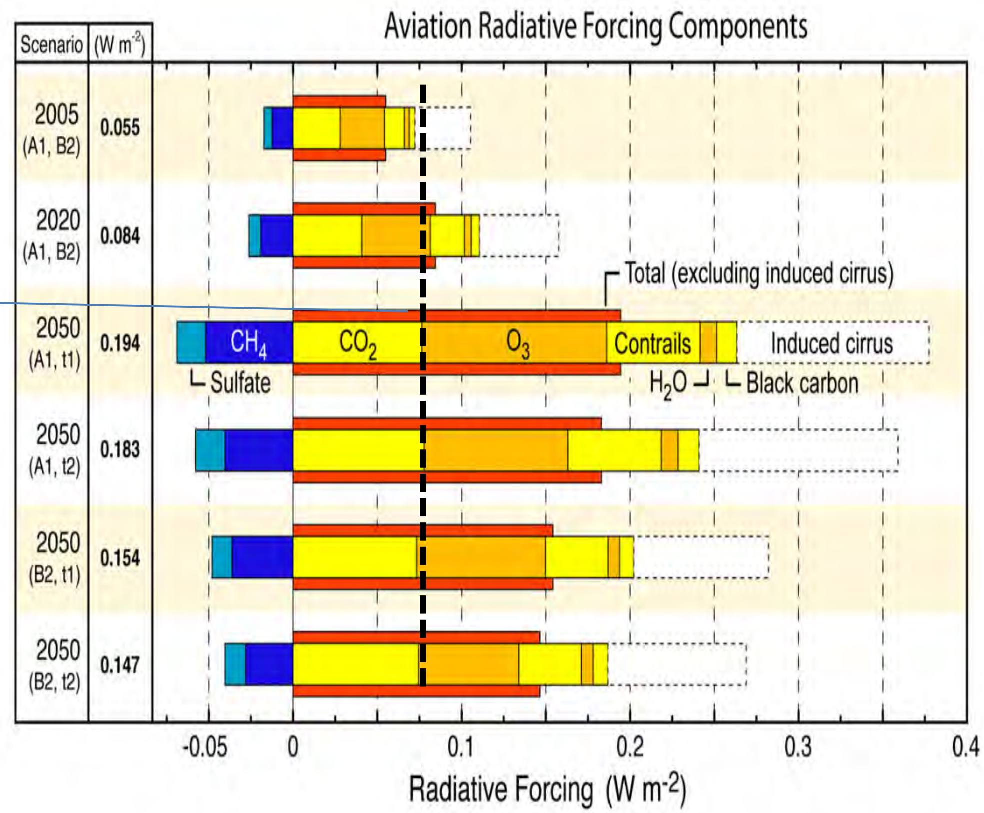


4- SUMMARY AND CONCLUSION

Compare OSCAR with the literature

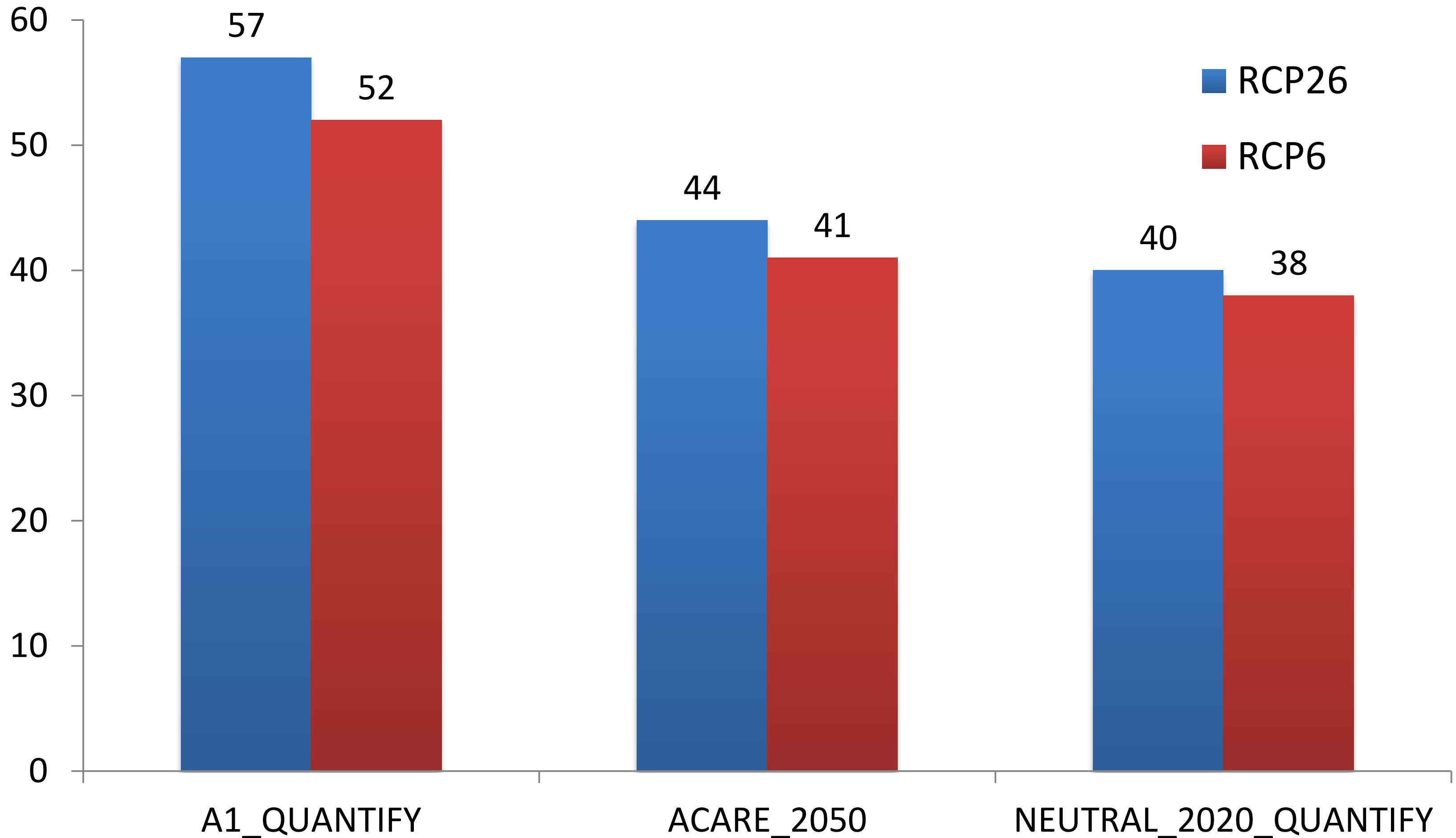
- CO_2 RF = 57 (52 for RCP6) mW/m² for A1 QUANTIFY (scaled over REACT 2006)
- CO_2 RF = 44 (41 for RCP6) mW/m² for ACARE (scaled over REACT 2006)
- CO_2 RF = 40 (38 for RCP6) mW/m² for NEUTRAL GROW (scaled over REACT 2006)

In 2050 with A1 scenario:
CO_2 RF = 75 mW/m²
(Lee et al, 2009)



- Update CO_2 RF for 2050 is lower than previous estimated value

Sum up: 2050 RF (±5mW/m^2) for RCP2.6 and RCP6



- Compared to the 2005 value (18 mW/m^2) the CO_2 RF has increased by a factor 2 (ACARE_2050 and CNG_2020) and a factor 3 is the emissions follow a BAU path.

Next steps

- Calculation of the radiative forcing perturbation for O_3, H_2O, BC/OC, sulphate, nitrate, contrail.
- Develop the aviation option in OSCAR (i.e. OSCAR-aircraft): the goal is to be able to quantify rapidly the radiative impact of any emission scenarios for different forcers (from CO_2 to O_3 and aerosols).
- OSCAR-aircraft will be calibrated against the results from LMDz-INCA ---> more simulations with aircraft emissions are on the way.

Thank you for your attention

Questions?