What Science Tells us: why methane is important

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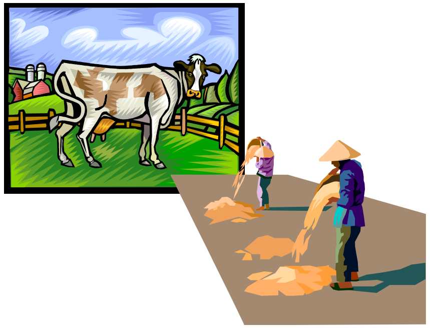
Talk Outline

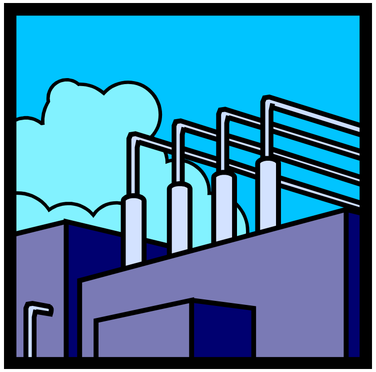
- Overview of methane: emissions, atmospheric concentrations and impacts
- A review of how recent SLCP assessments, including methane, have highlighted relevance to near-term climate change, health and crop yields
- Recent evidence, emphasising important aspects relating to methane and its impacts

Human Activities Leading to Methane Emissions



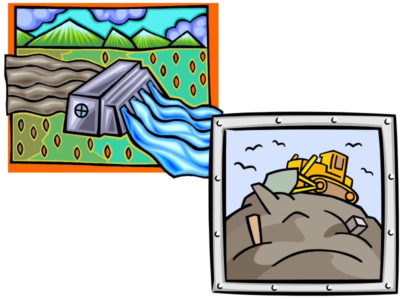
42%

Agriculture (~126 Tg)



32%

Fossil Fuels (~95 Tg)



26%

Waste Treatment (~79 Tg)

Fires
(~35 Tg)

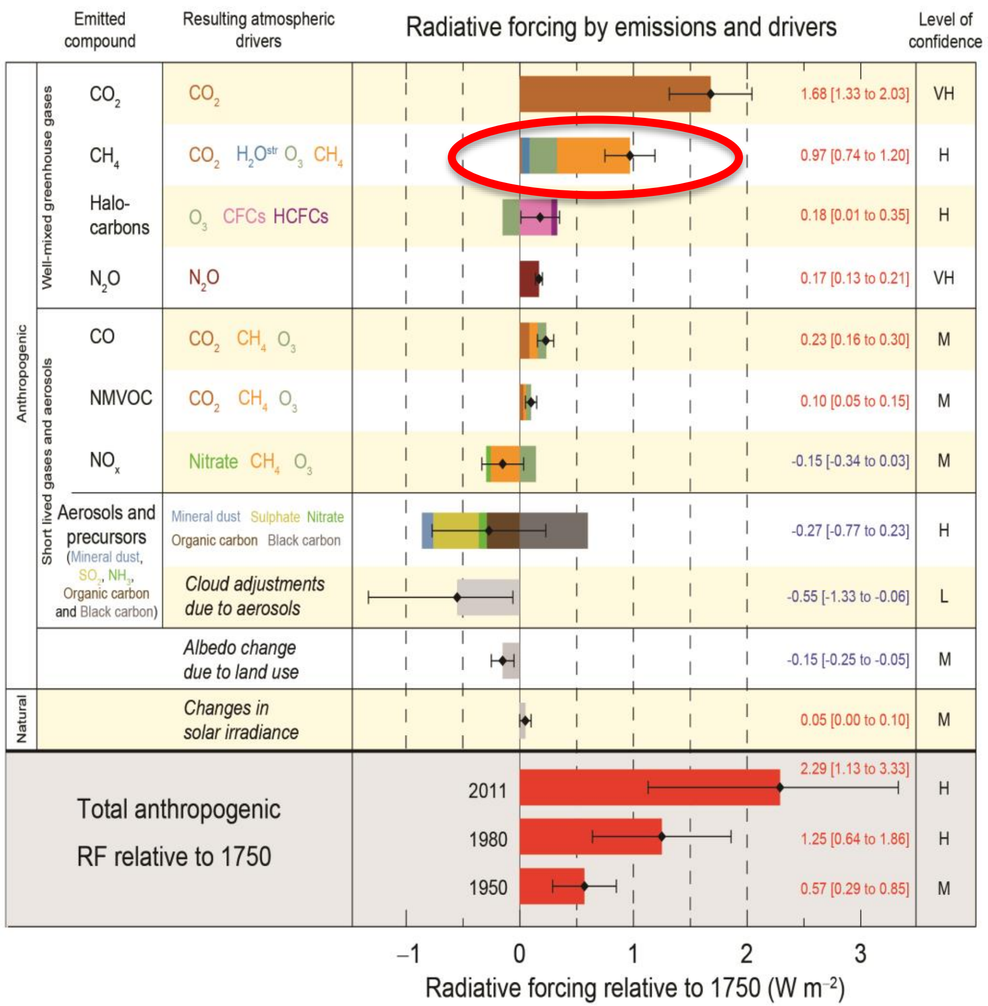
source: IPCC AR5 2013

Methane Emissions lead to Climate Change

- Methane!
- Tropospheric ozone
- Stratospheric water
  ($CH_4 + OH \rightarrow H_2O + CH_3$)
- Carbon dioxide

- Net historical forcing 0.97 W m^{-2}

Methane removal affected by nitrogen oxides, carbon monoxide, and volatile organic compounds



source: IPCC AR5 2013

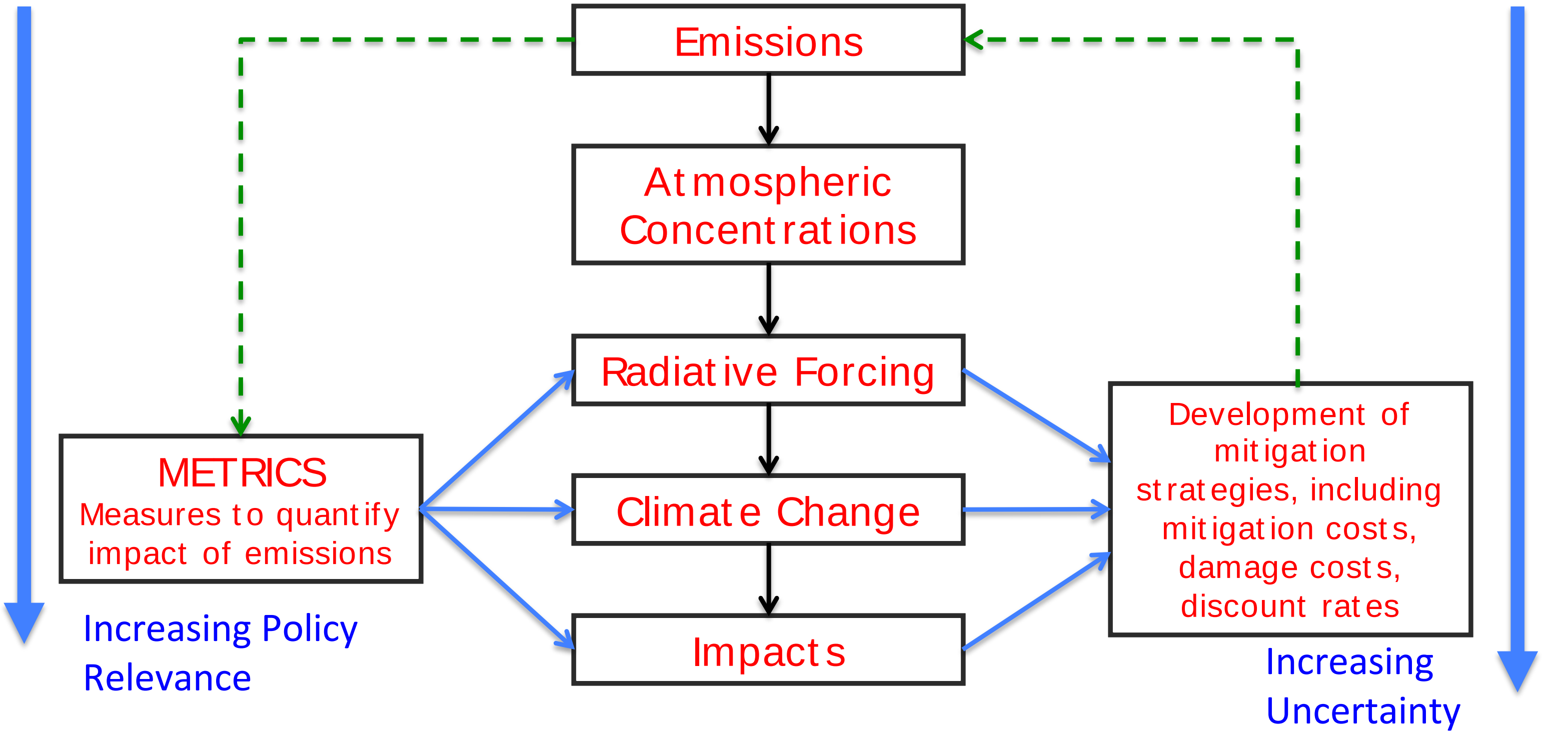
Methane Emissions lead to Air Quality Change

- Tropospheric ozone
  - Affects human health
    - Respiratory & cardiovascular diseases
  - Affects agricultural crops
    - Wheat, maize, rice, soybeans
  - Affects non-agricultural plants
    - Impact on carbon sequestration

Crop Yields

Factor	Response to CO_2	Response to CH_4
Heat	↓	↓
Drought	↓	↓
Fertilization	↑	–
Ozone	–	↓

Quantified Impact of Methane Emissions



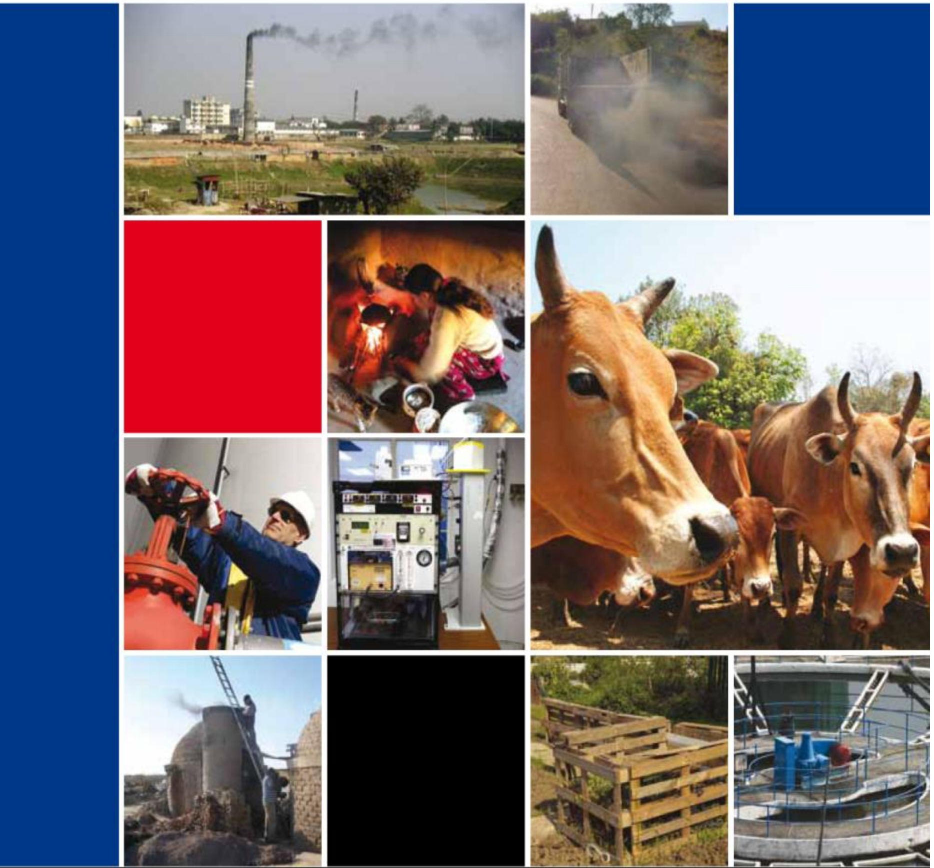
source: IPCC AR5 2013

UNEP

World Meteorological Organization

Integrated Assessment of Black Carbon and Tropospheric Ozone

Summary for Decision Makers



UNEP

Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers

A UNEP Synthesis Report

16 measures identified that substantially reduce emissions and achieve climate, health and crop yield benefits

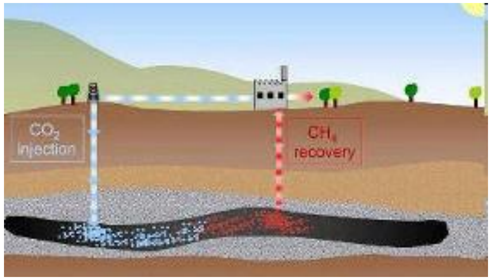
- measures ranked by net climate impact (using GWP) of emission changes
- Considering CO, CH_4, BC, OC, SO_2, NO_X, NMVOCs, and CO_2
- Picked the top measures – about 90% of warming benefit – from IIASA GAINS database of measures

Methane measures

- reducing methane emissions

'Black carbon measures'

- addressing ***emissions from incomplete combustion***
  - BC, OC, methane, CO, NMVOCs



- **No technical breakthroughs**
- **These measures already implemented in many countries**
- **Cost-effective**

The measures aiming at reducing methane emissions

Intermittent aeration -paddy

Recovery from wastewater

Recovery from oil and gas

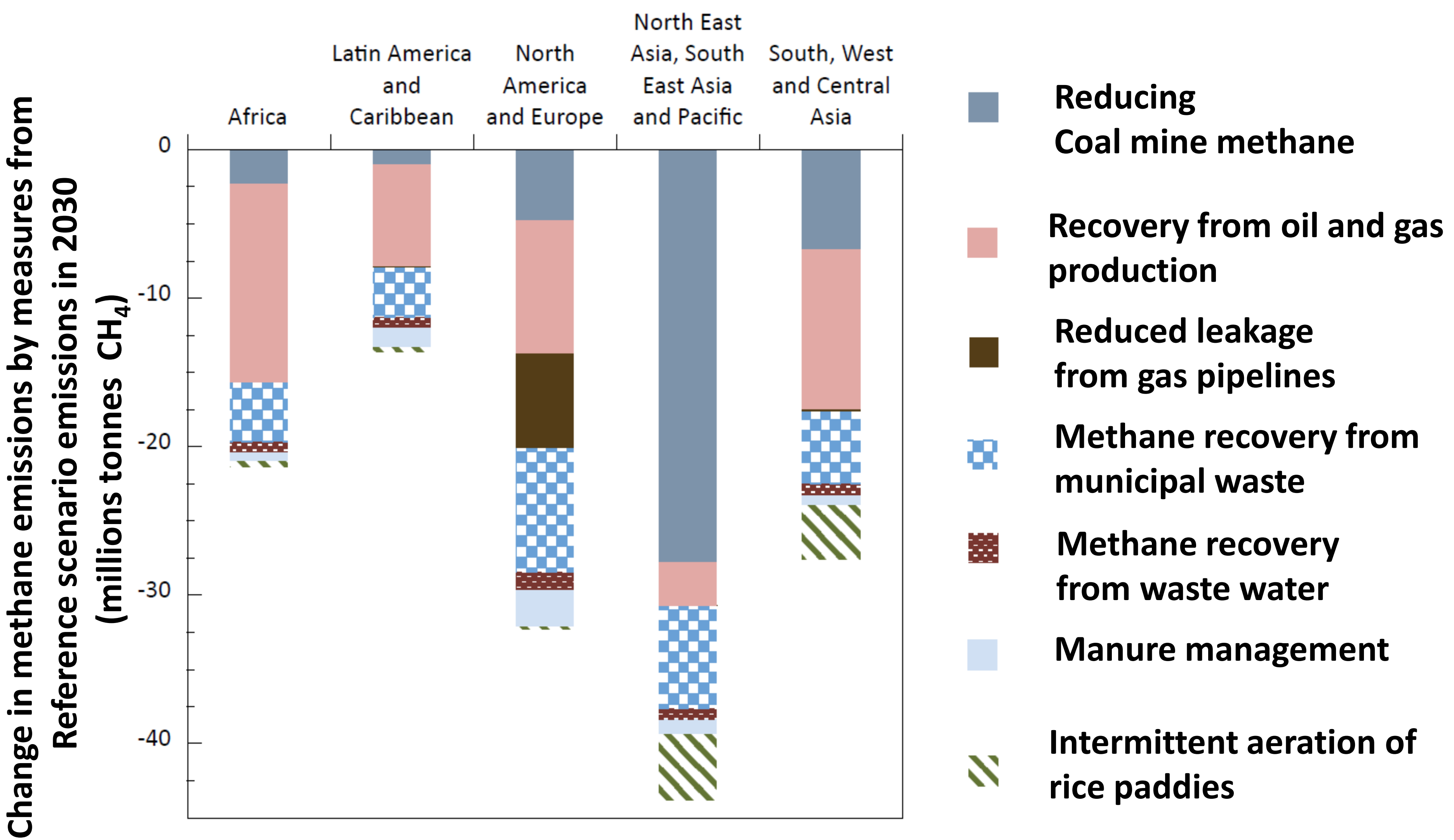
Recovery from landfill

Recovery from livestock manure /change feed

Coal mine methane capture

Reducing pipeline leakage

Effect of methane measures on global emissions relative to reference scenario emissions in 2030 (about 40% reduction)



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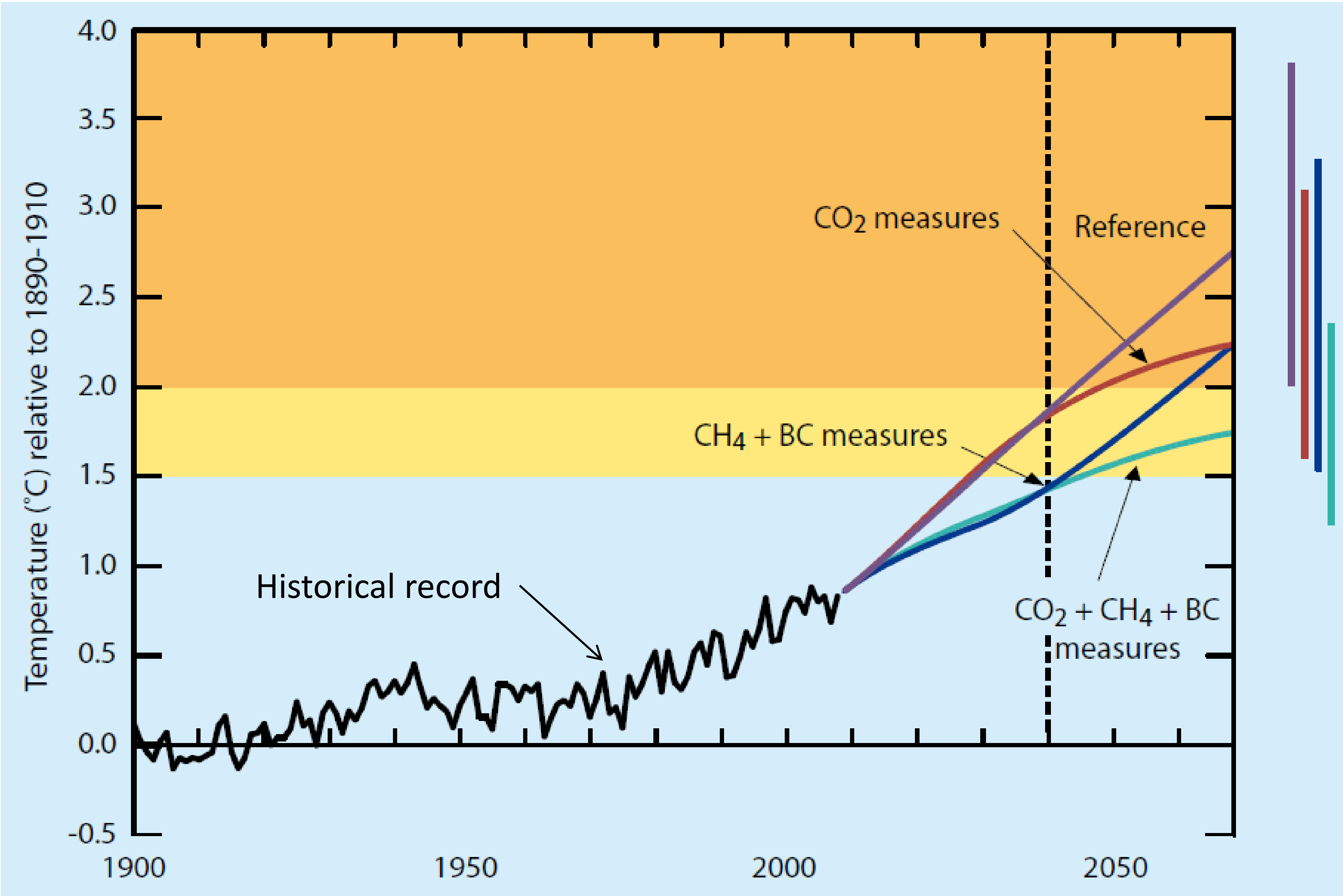
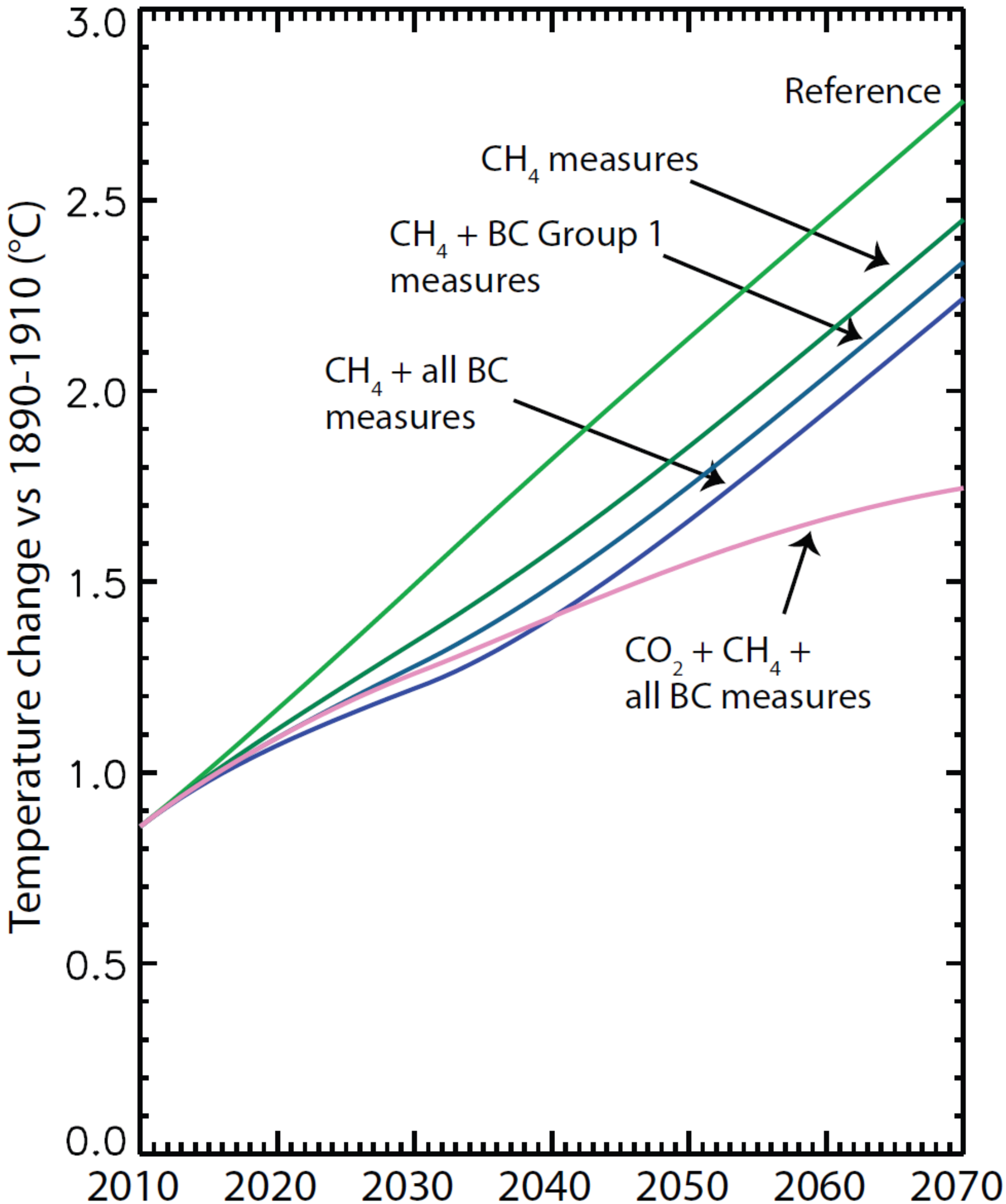
Result for Global Temperature Change: CO_2 and SLCP measures are complementary strategies



Source: UNEP/WMO (2011). Integrated Assessment of Black Carbon and Tropospheric Ozone. UNEP, Nairobi



About half of the reduced warming is from reduced methane emissions and half from preventing incomplete combustion

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Benefits of Reduced Near-term Warming rate

Halving the rate of near term warming will:

- Reduce **the melting rate of glaciers**
- Reduce the change to **agriculture** implied by increased T ^{o}C
- Reduce changes in **distribution of different species**, vegetation types, reducing biodiversity loss
- Allow more time for **vulnerable communities to adapt**

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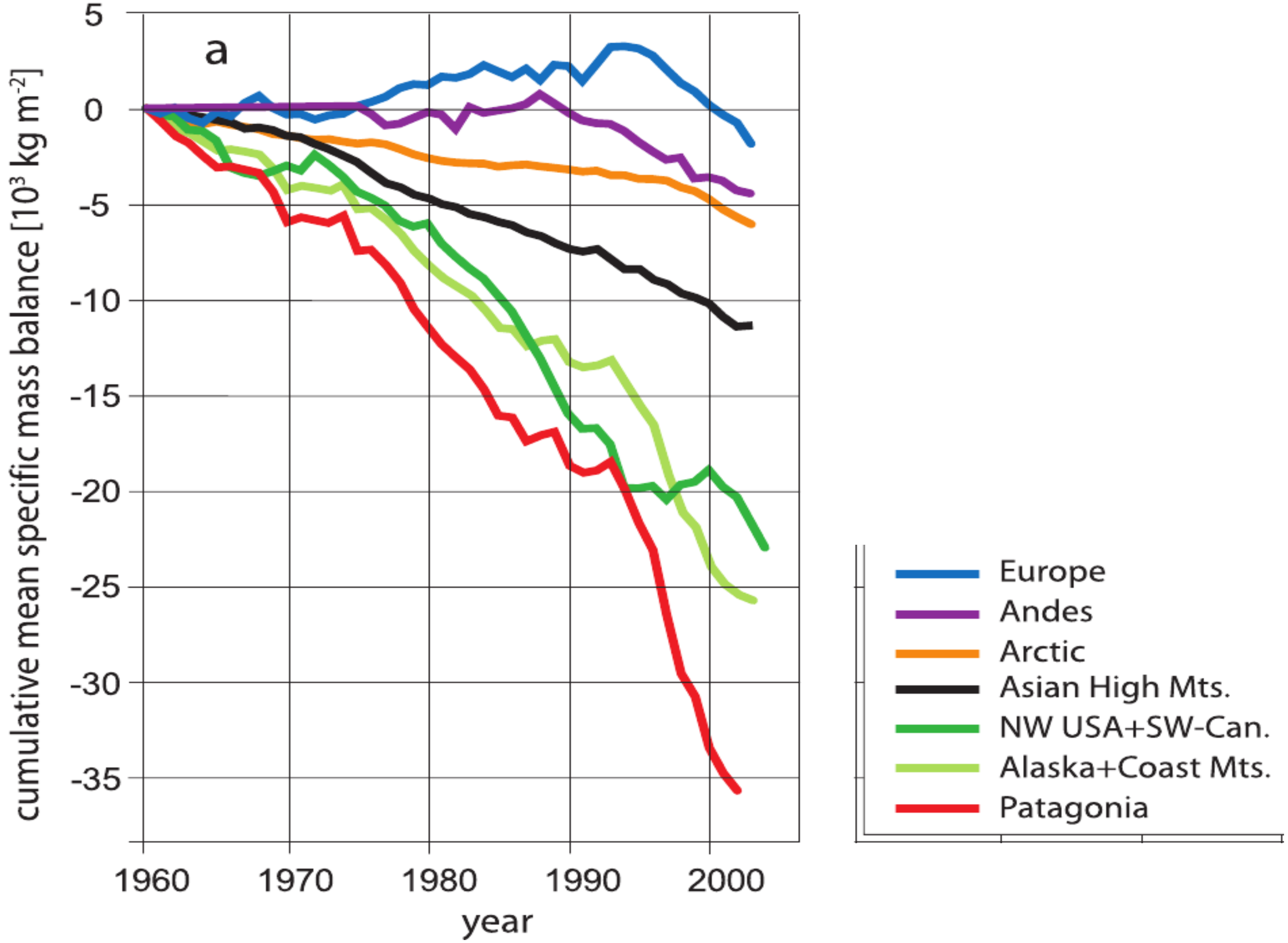
Melting rates in Arctic and mountain glaciers



Time series estimates of glacier mass balance in different regions of the world (from Kaser *et al*., 2006).

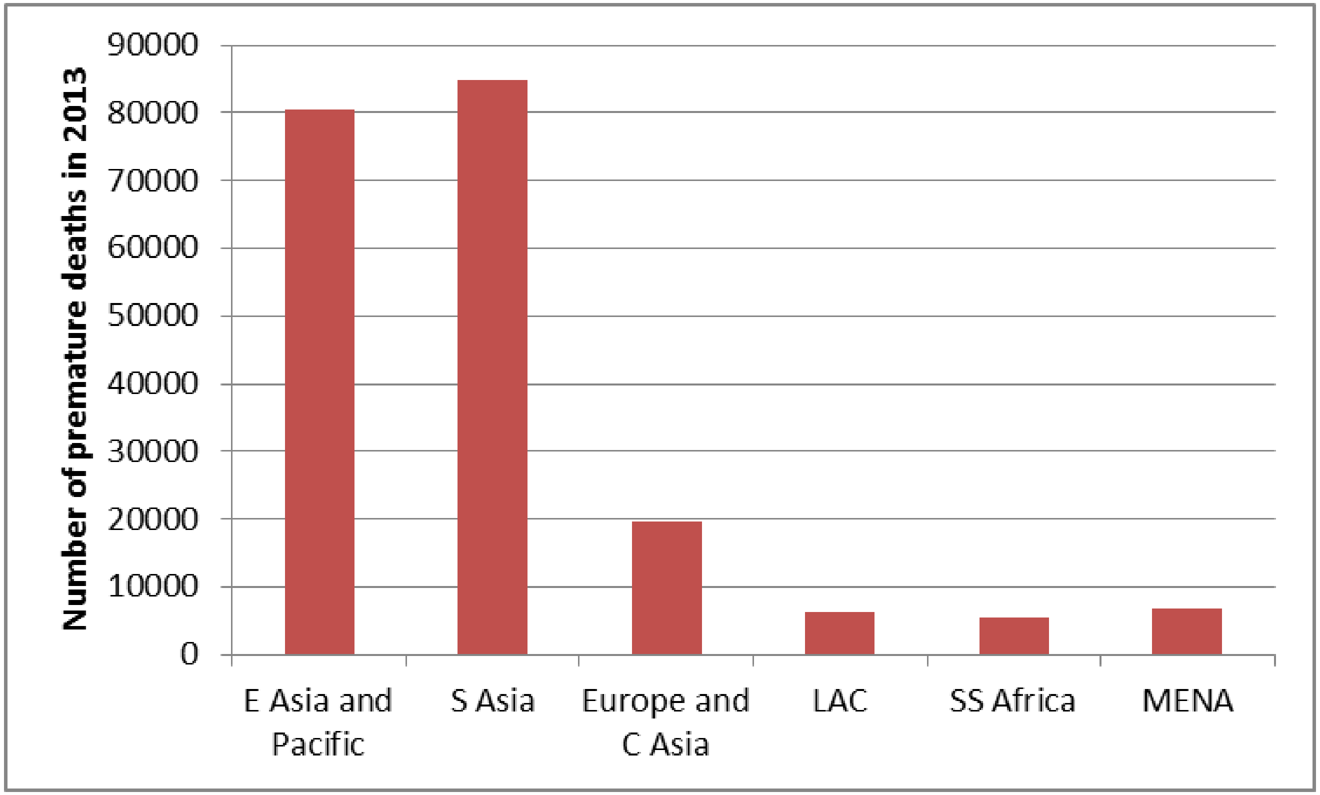
Impacts of ozone on health

- Ozone - powerful oxidant and causes inflammation in the lung
- Effects include:
    - chest tightness, wheezing, or shortness of breath
    - throat irritation; coughing; pain or discomfort in the chest
    - aggravation of lung diseases such as asthma, emphysema, and chronic bronchitis
    - an increase in the frequency of asthma attacks; and increased susceptibility of the lungs to infection.

Exposure to ozone is associated with increases in mortality:

- increased cardiovascular mortality in adults < 75 years;
- increased hospital admissions for COPD and asthma; and heart and respiratory diseases in adults > 65 years;
- increased school absences

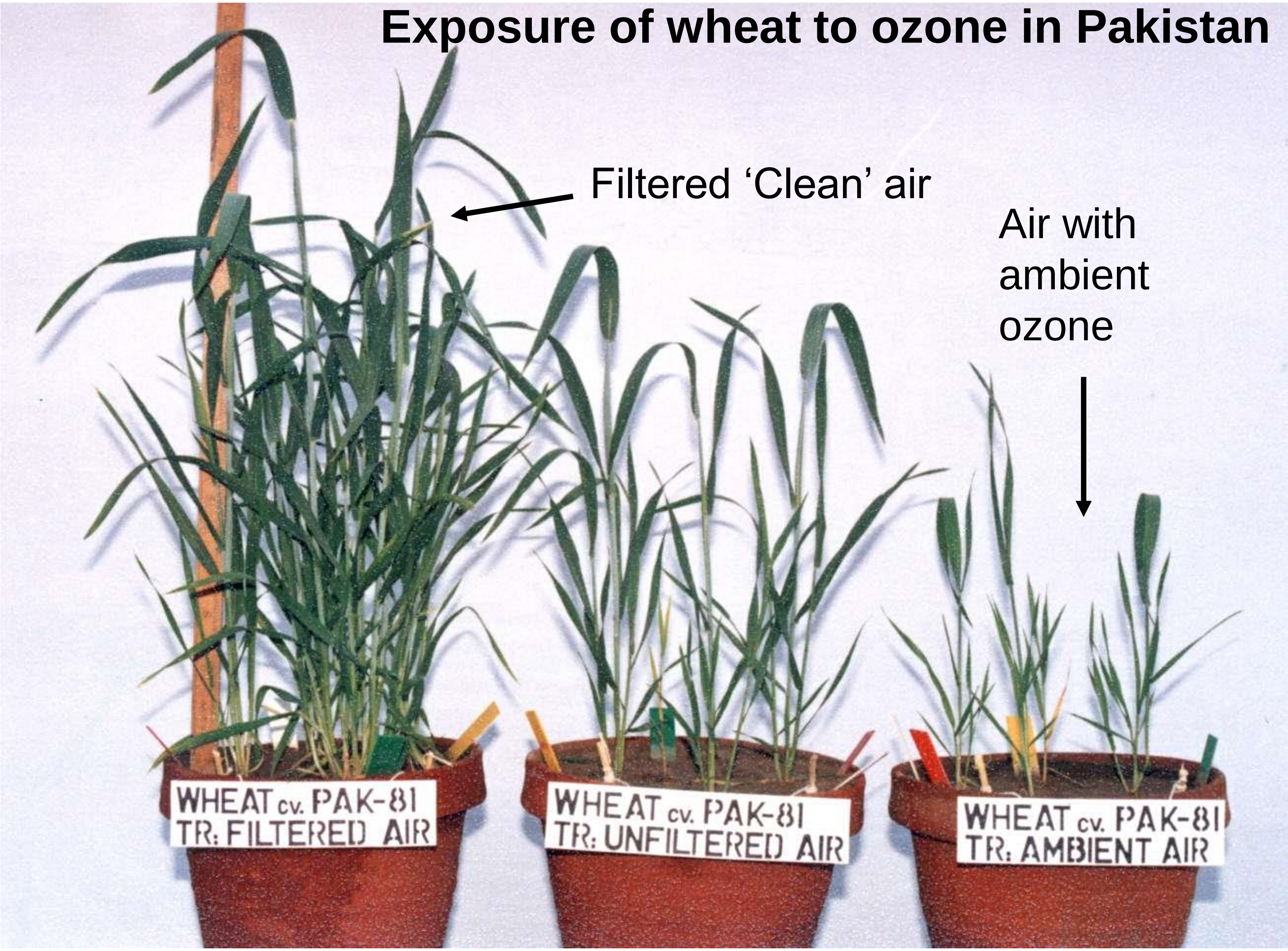
Impacts of ozone on health



Source IHME http://vizhub.healthdata.org/gbd-compare/ accessed Mar 2016

Assessment estimated benefits from reduced ozone at about 100,000 fewer deaths, mainly in Asia

Impact of the Tropospheric Ozone on Crop yields



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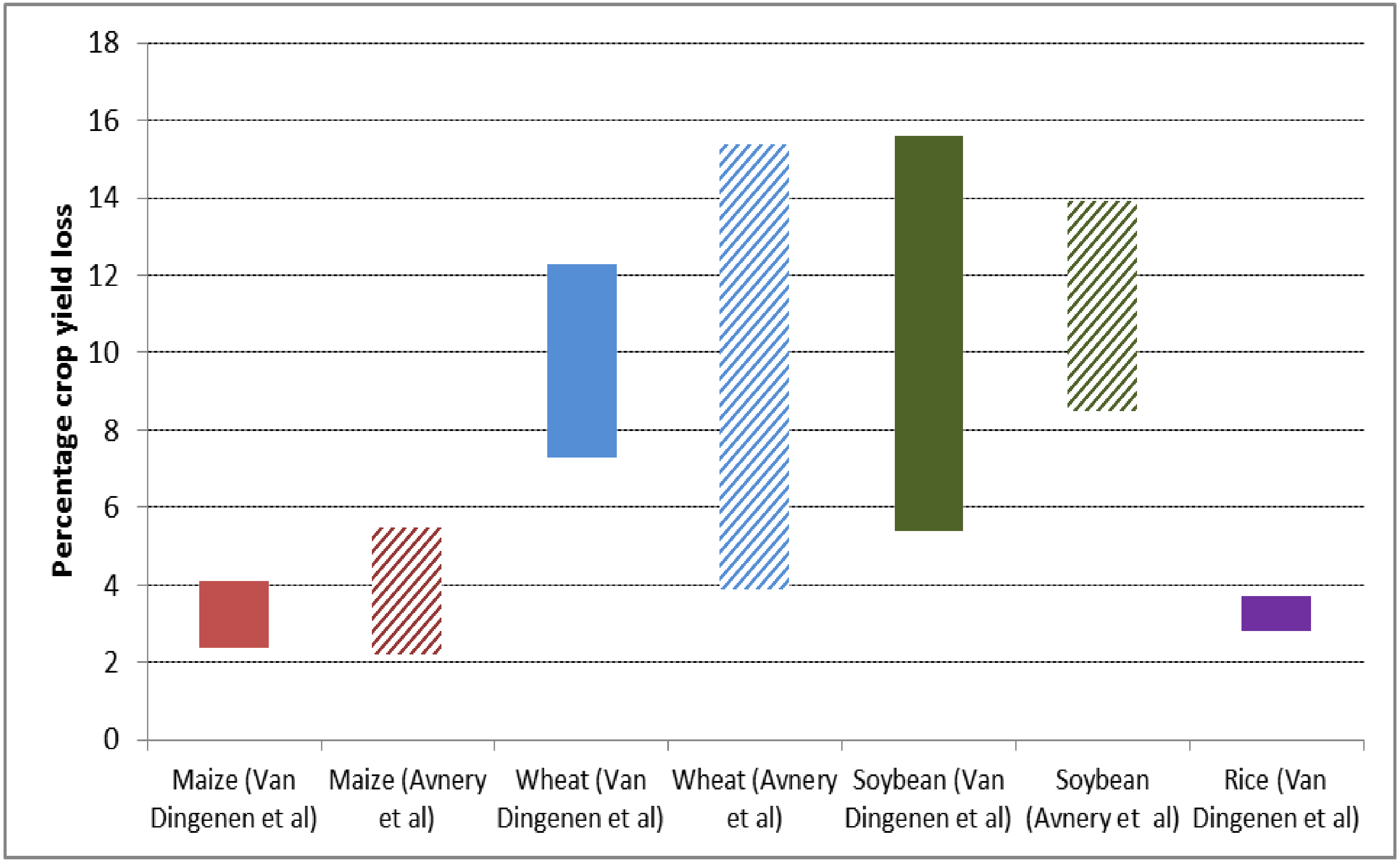
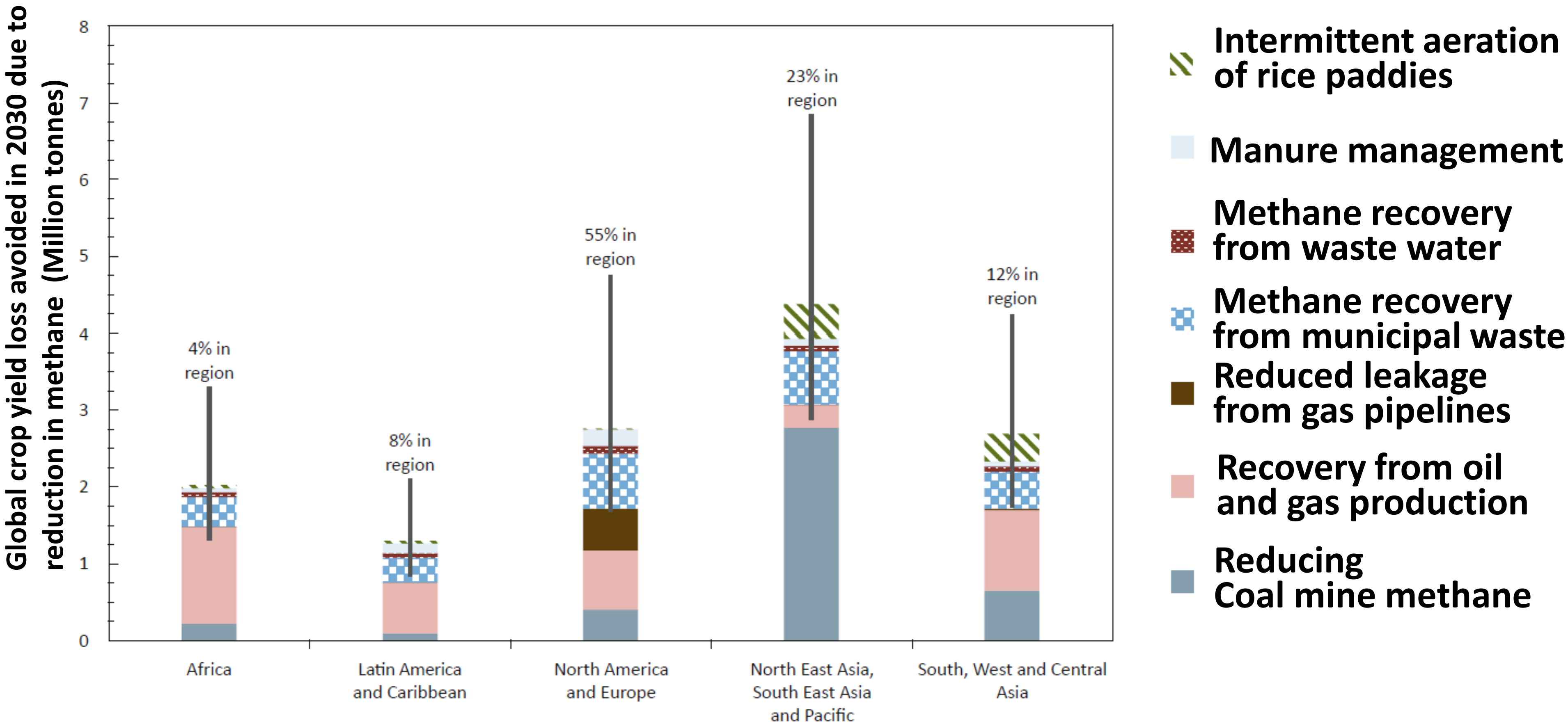
Range of estimated ozone-related yield losses in 2000 in major food crops



Sources: Van Dingenen et al. (2009) and Avnery et al. (2011a). Note: The ranges represent estimates from using two different but commonly used exposure-based metrics.

About 30-50 million tonnes of crop loss avoided by all SLCP measures – about half of benefit from methane measures



This UNEP/WMO Assessment facilitated to the establishment of the Climate and Clean Air Coalition (CCAC) - 6 initial countries

Participants of the CCAC WG meeting in Kathmandu 2015

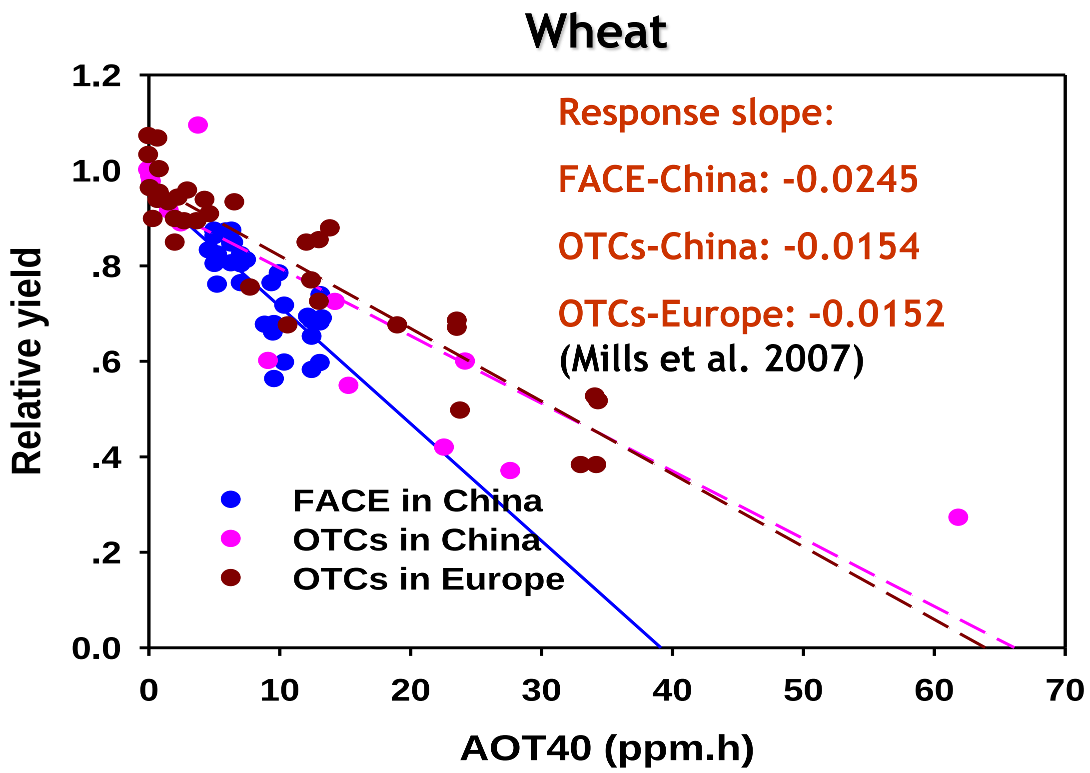
>100 partners; >50 countries

Recent scientific evidence for importance of methane for crop impacts from ozone concentrations:

- Evidence from China
- Influence of different metrics for damage
- Increasing importance of background ozone
- Importance of methane to background O_3

Concentration-based Dose-Response Relationship for Wheat

Different experimental methods suggest different sensitivity



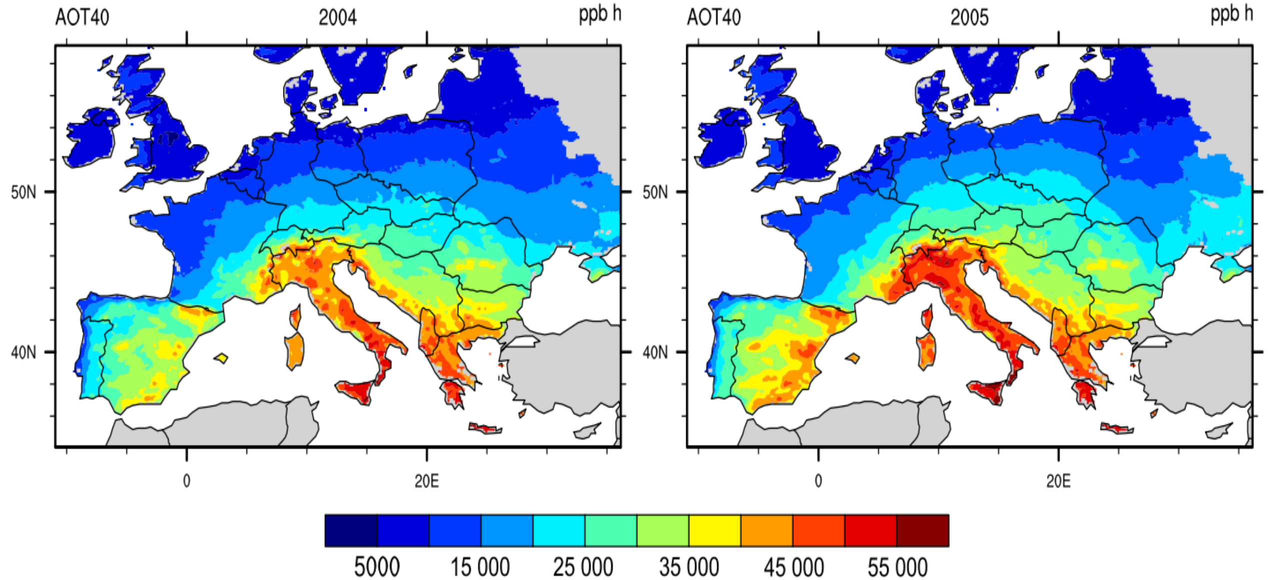


Fig. 4 Spatial distribution of AOT40 (in ppb*h) over different years, computed according to the revised formulation (Eqn 1).

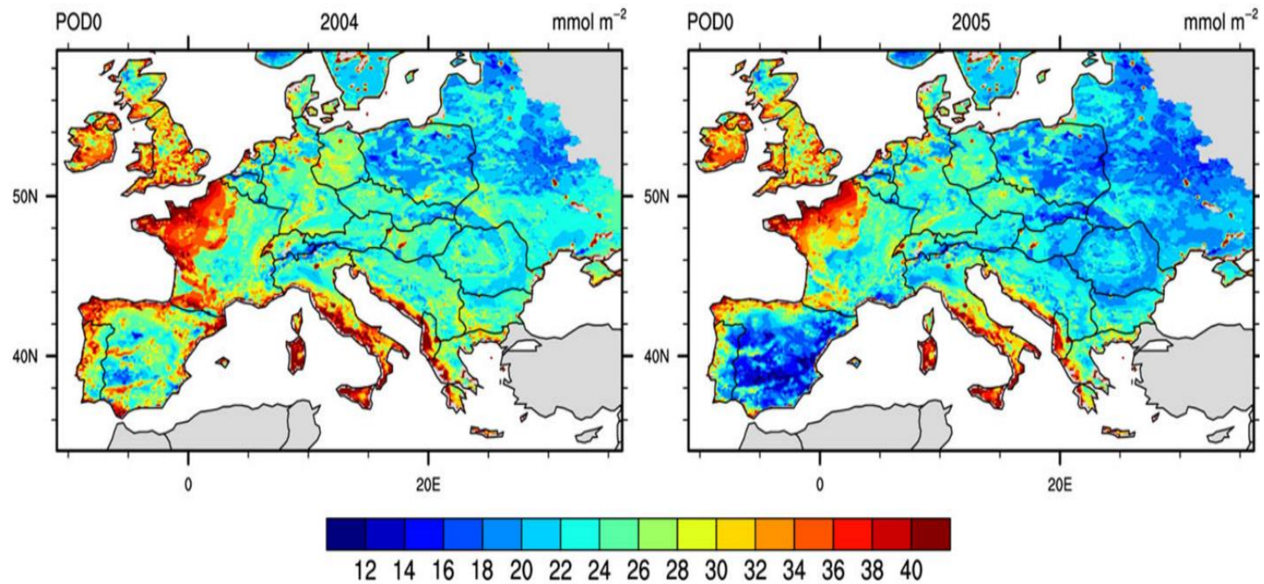
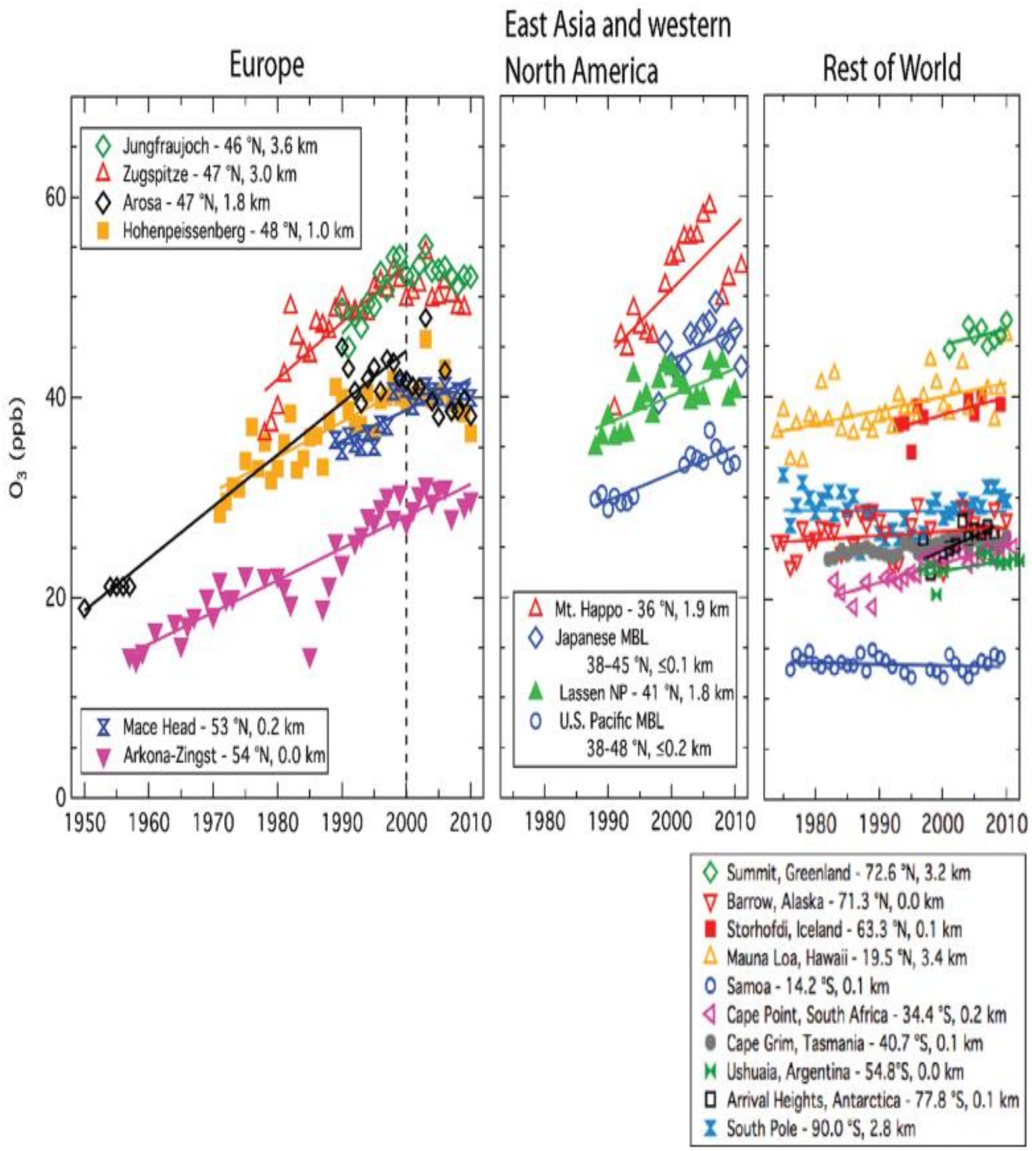


Fig. 5 Spatial distribution of POD0 (in mmol m^{-2}) over different years.

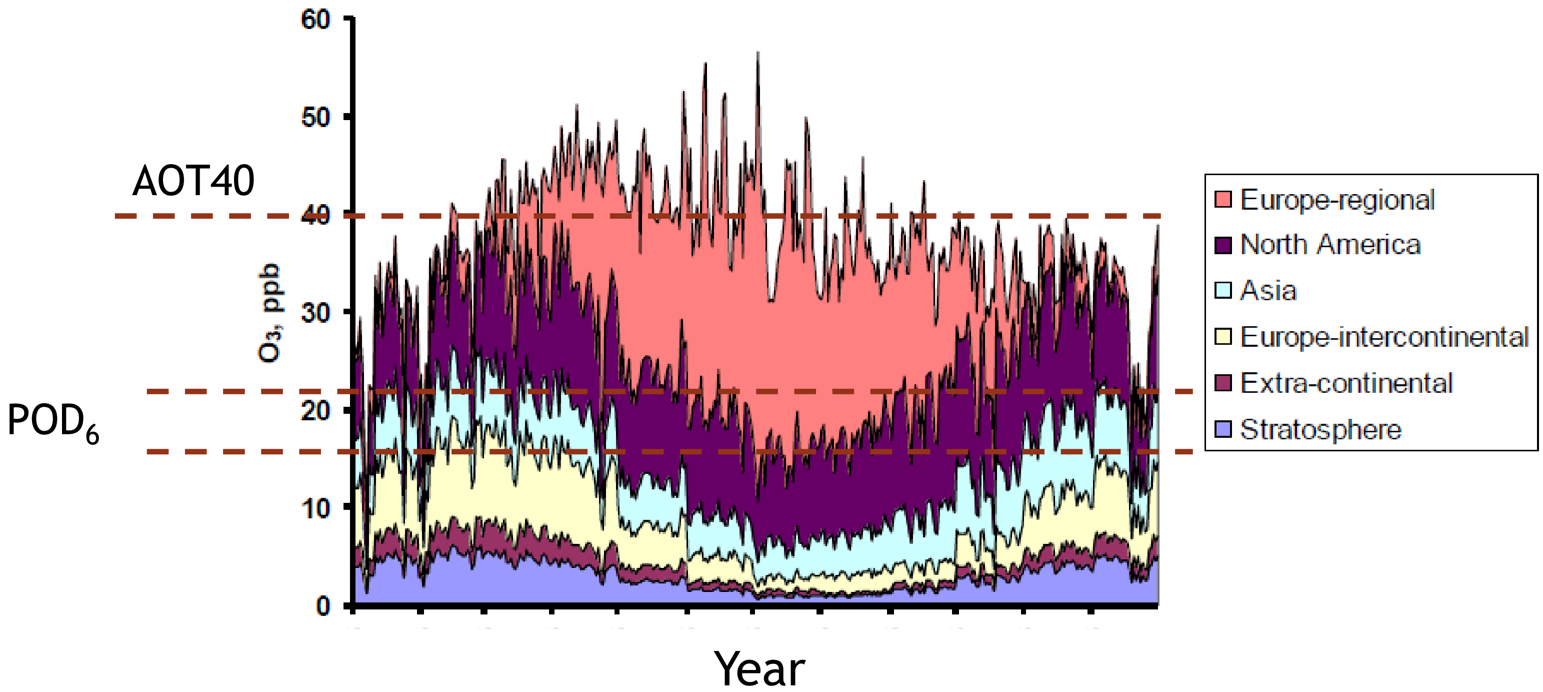
Anav et al 2016 Global Change Biology

Ozone increased in Europe and N America during the late 20th C – levels off after 2000



Cooper et al 2014 Elementa

Source attribution of the ozone found at a rural location in southern England during 2006 (*Derwent*, 2008).



Using AOT40 (or a **higher threshold**) the level of 'domestic' pollution needs to be relatively high for imported pollution to have an effect on vegetation

A **lower threshold** for effects (e.g. POD_6 or POD_2) means that 'imported', and background pollution is likely to have a higher effect on vegetation

Peaks have reduced in this recent decades – due to NO_x and NMVOC reductions

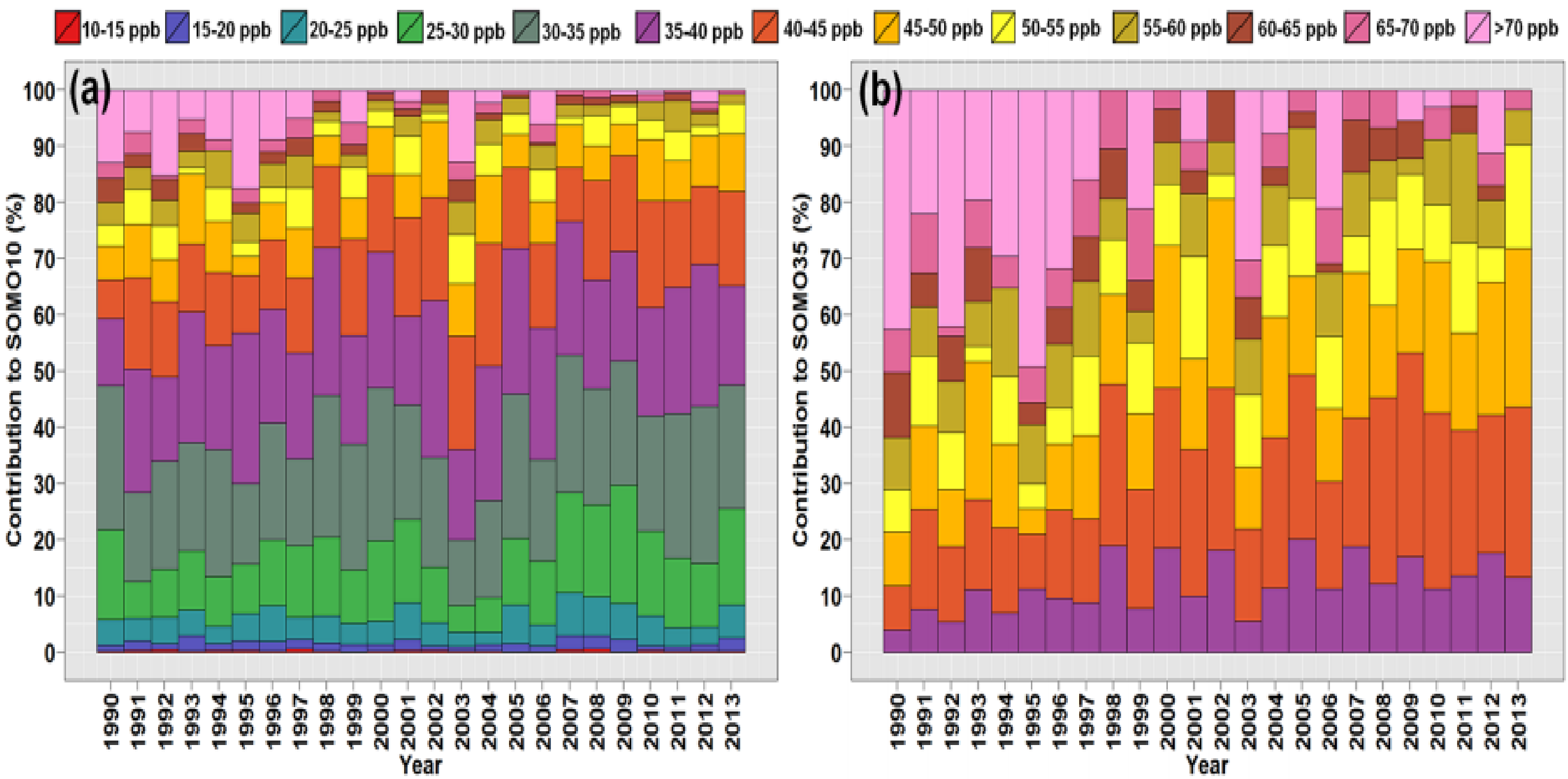


Figure 5. Relative annual contributions to **(a)** SOMO10 and **(b)** SOMO35 at Harwell from different O_3 concentration bins. Concentrations are separated into 13 5 ppb bins spanning daily maximum 8 h mean O_3 concentrations between 10 and > 70 ppb. Note: these concentration bins are contributing to a decreasing long-term trend in SOMO35 and to a constant trend in SOMO10, as illustrated in Fig. 3.

Malley *et al* 2015 Atmos Chem Phys

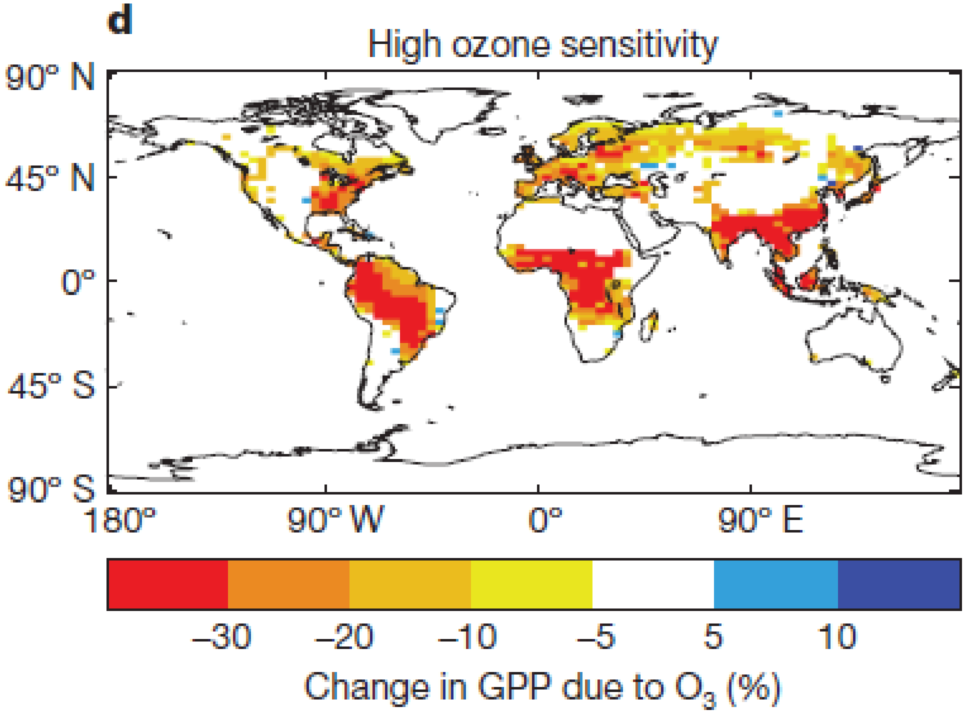
Background levels of ozone are becoming more important for impacts

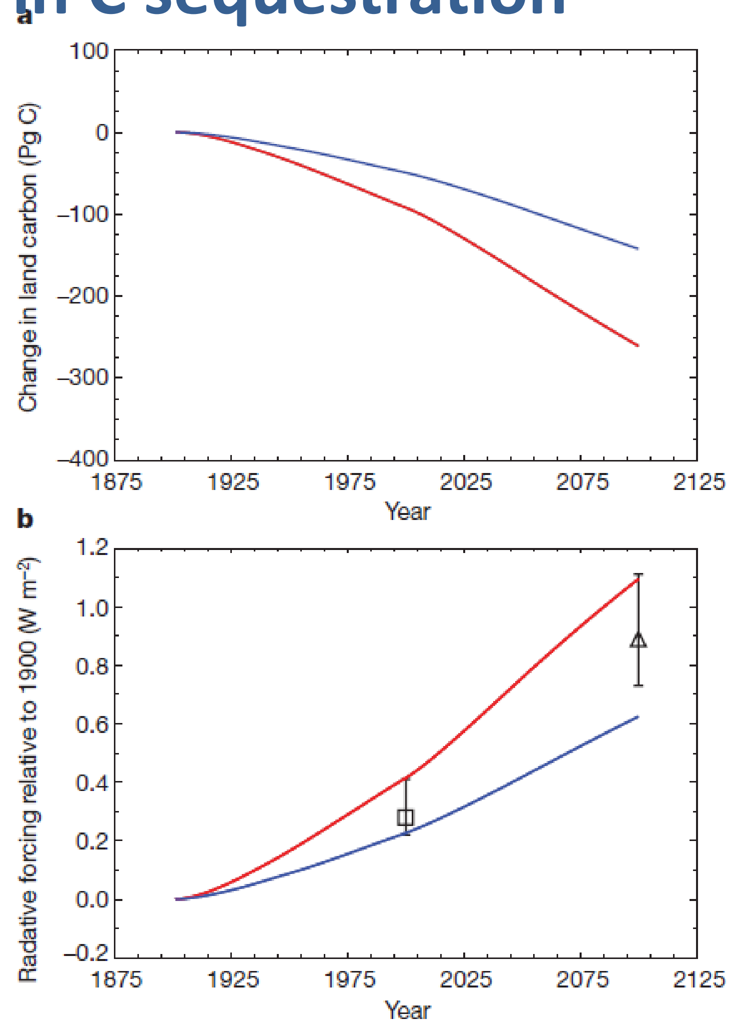
- Flux metric for ozone impacts on veg stayed same between 1990-2013,
- Flux metric highlights greatest veg. damage in areas with lower peaks
- proportion of flux from background increased

And background levels of ozone are heavily affected by methane

- Fiore et al showed that reduced methane by 20% had same reduction of background ozone as 20% reductions in NO_X + NMVOCS + CO combined

O_3 can indirectly affect climate change through reductions in NPP leading to reductions in C sequestration





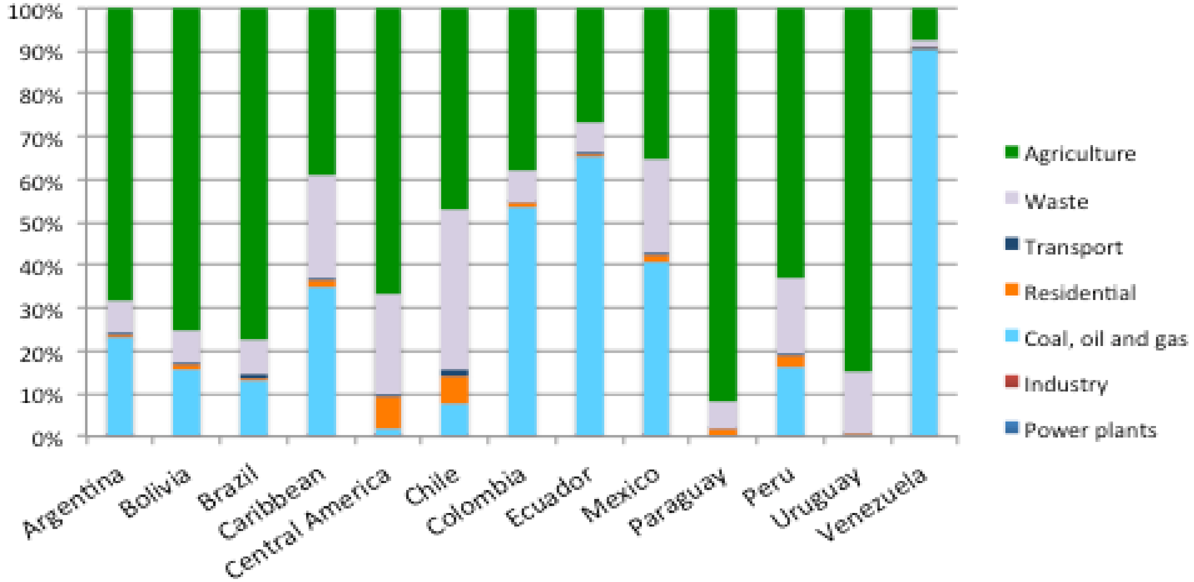
Source: Sitch et al. 2007

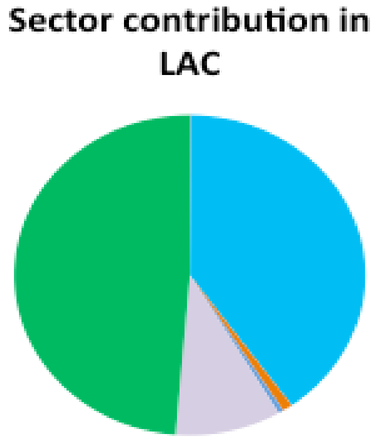
This indirect effect is equivalent to the direct effect of O_3 acting as a radiative forcer

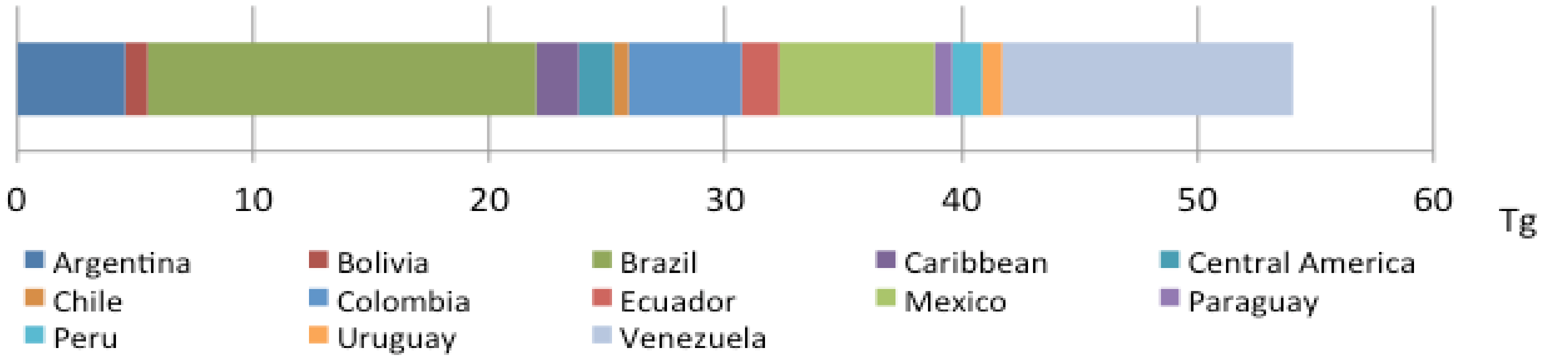
Regional SLCP Assessment in Latin America and the Caribbean

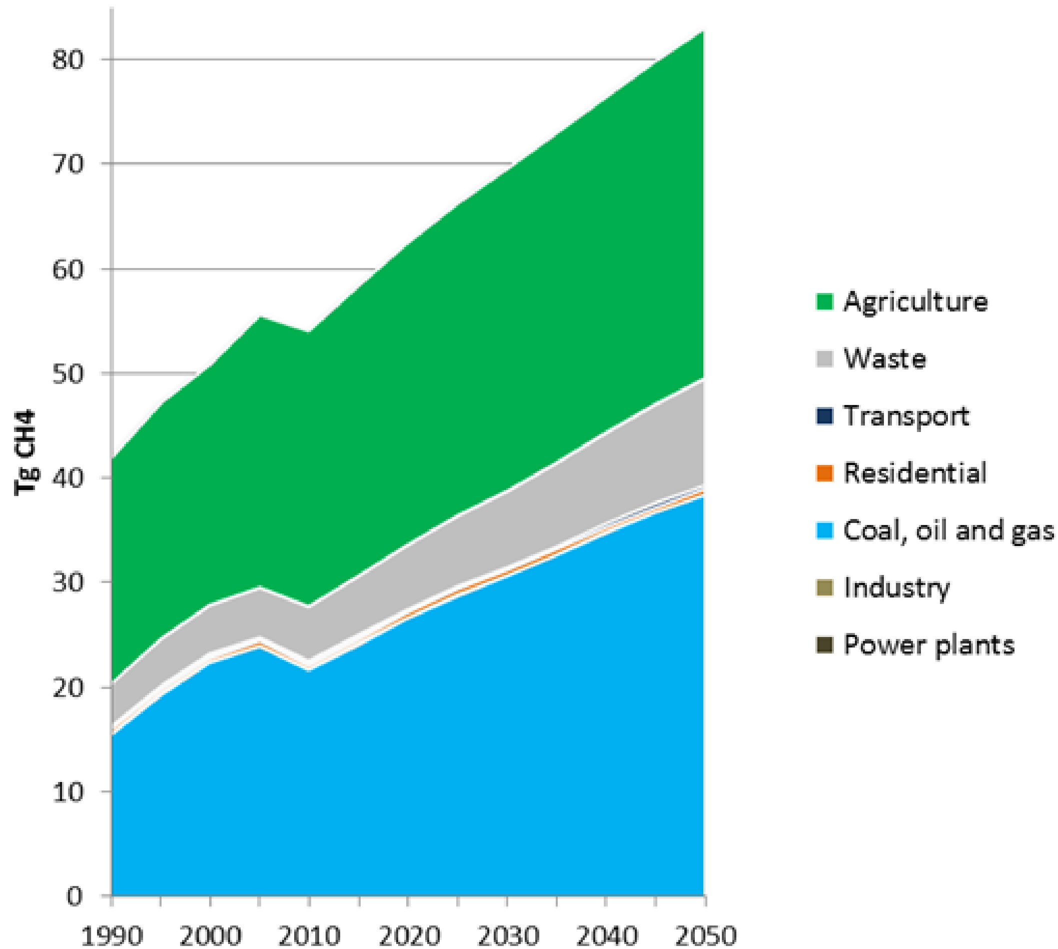
- Results back up UNEP/WMO global assessment
- Assessment tailored to LAC conditions

Methane Emissions in Countries of LAC in 2010 – based on GAINS model



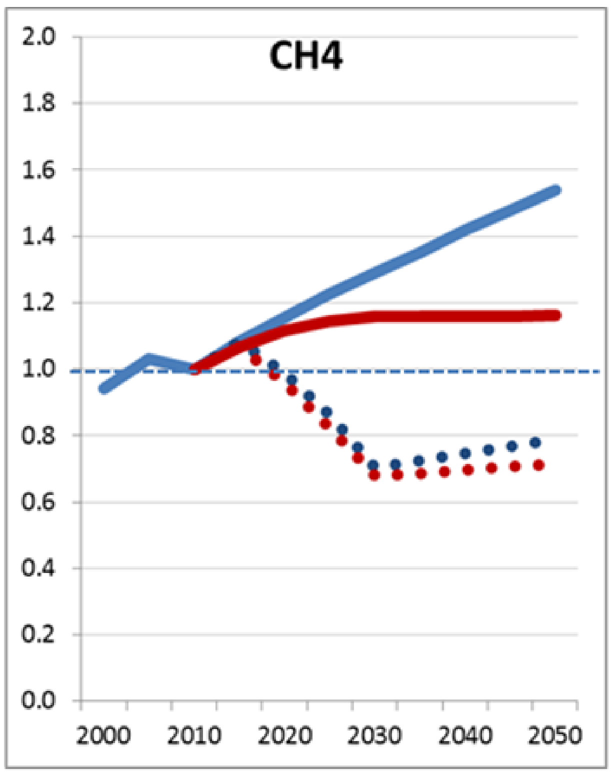






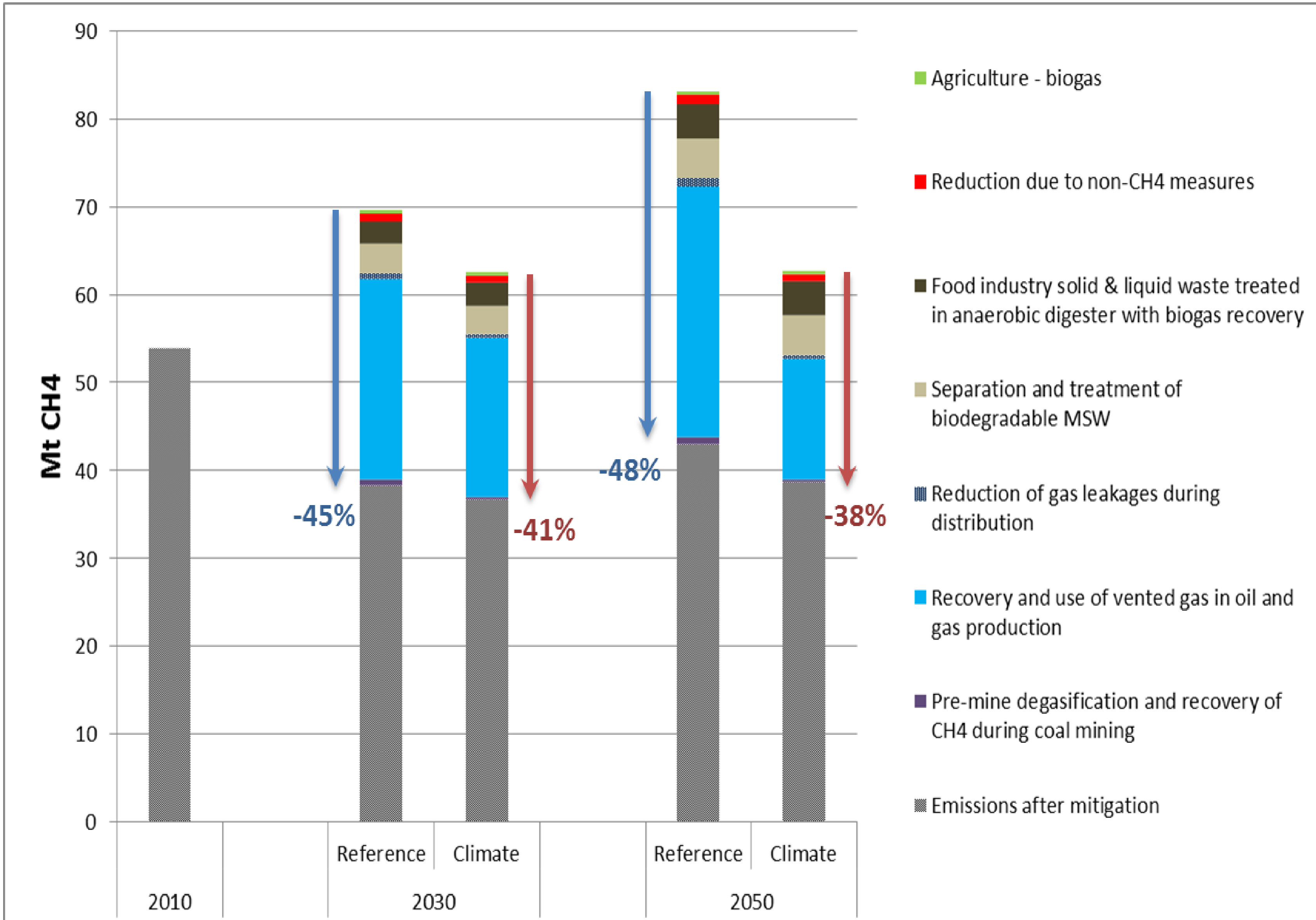
Under the reference scenario LAC methane emissions are expected to increase to 2050 and beyond

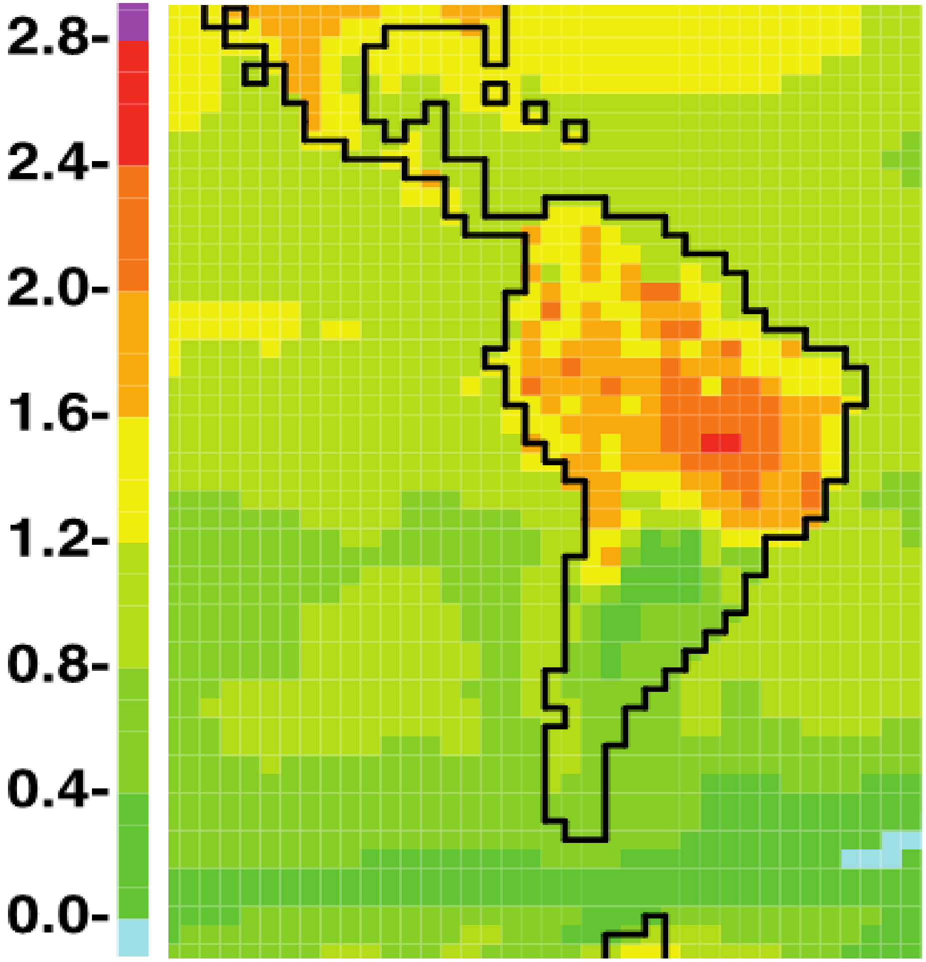
Methane measures	
Oil and gas production and distribution	○ Recovery and use of vented gas in oil and gas production ○ Reduction of gas leakage during distribution
Waste	○ Separation and treatment of biodegradable municipal waste (MSW) ○ Food industry solid & liquid waste treated in anaerobic digester with biogas recovery
Coal mining	○ Pre-mine degasification and recovery of CH_4 during mining
Agriculture	○ Anaerobic digestion - biogas



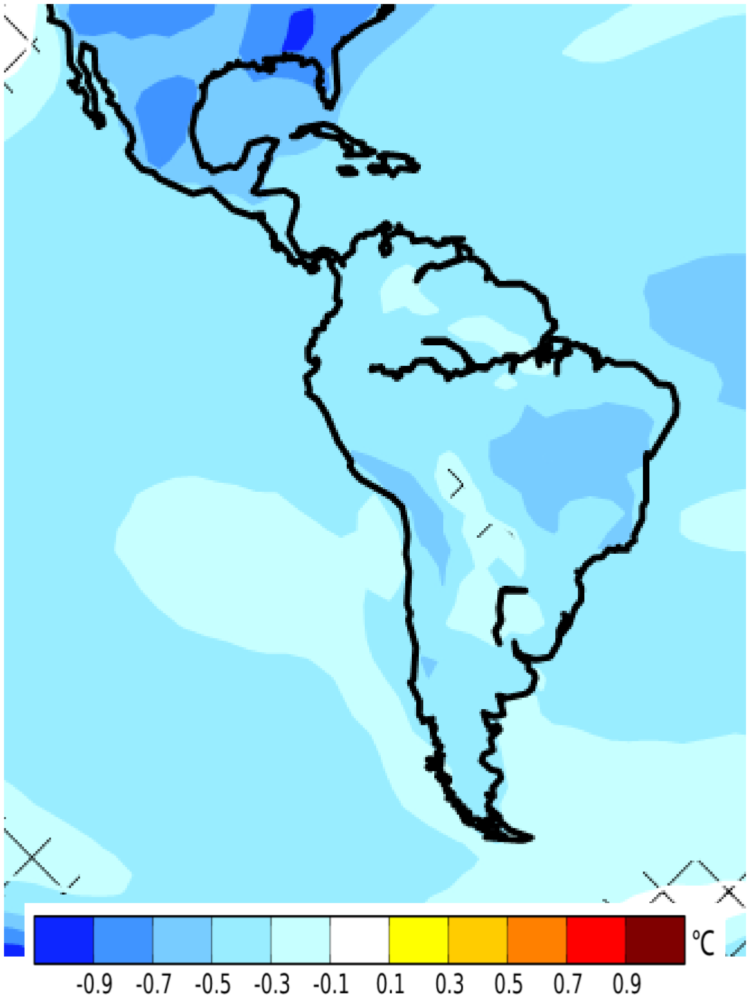
Measures that have the greatest methane reduction potential in LAC, reduce emissions by 21% from 2010 levels, 45% from projected 2030 Reference; 48% from 2050 Reference

Reduction in Methane Emissions by SLCP measures in LAC

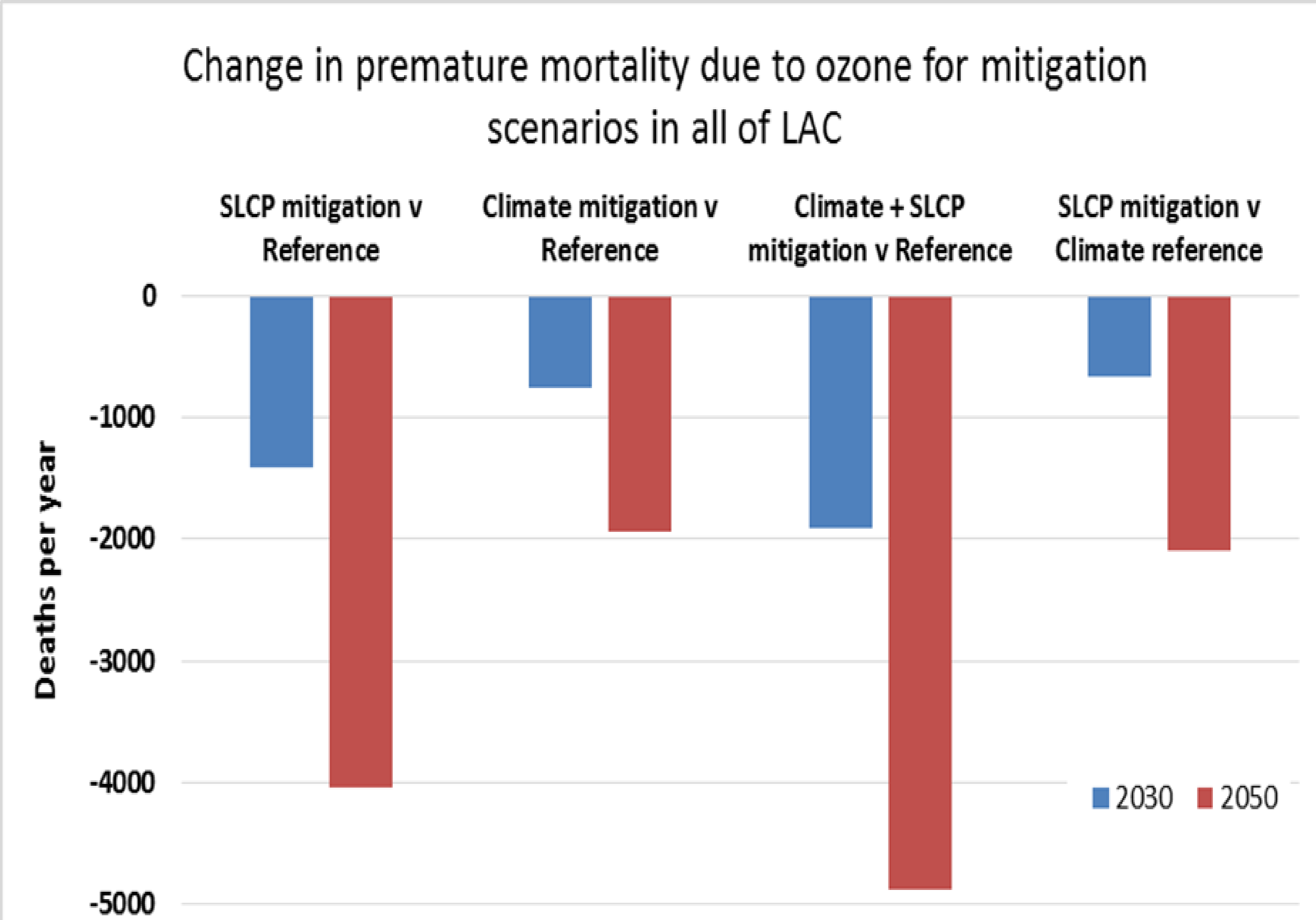




Increase in temperature over LAC region projected by GISS model using the RCP8.5 emissions. The map shows the temperature in the 2070s relative to 2010

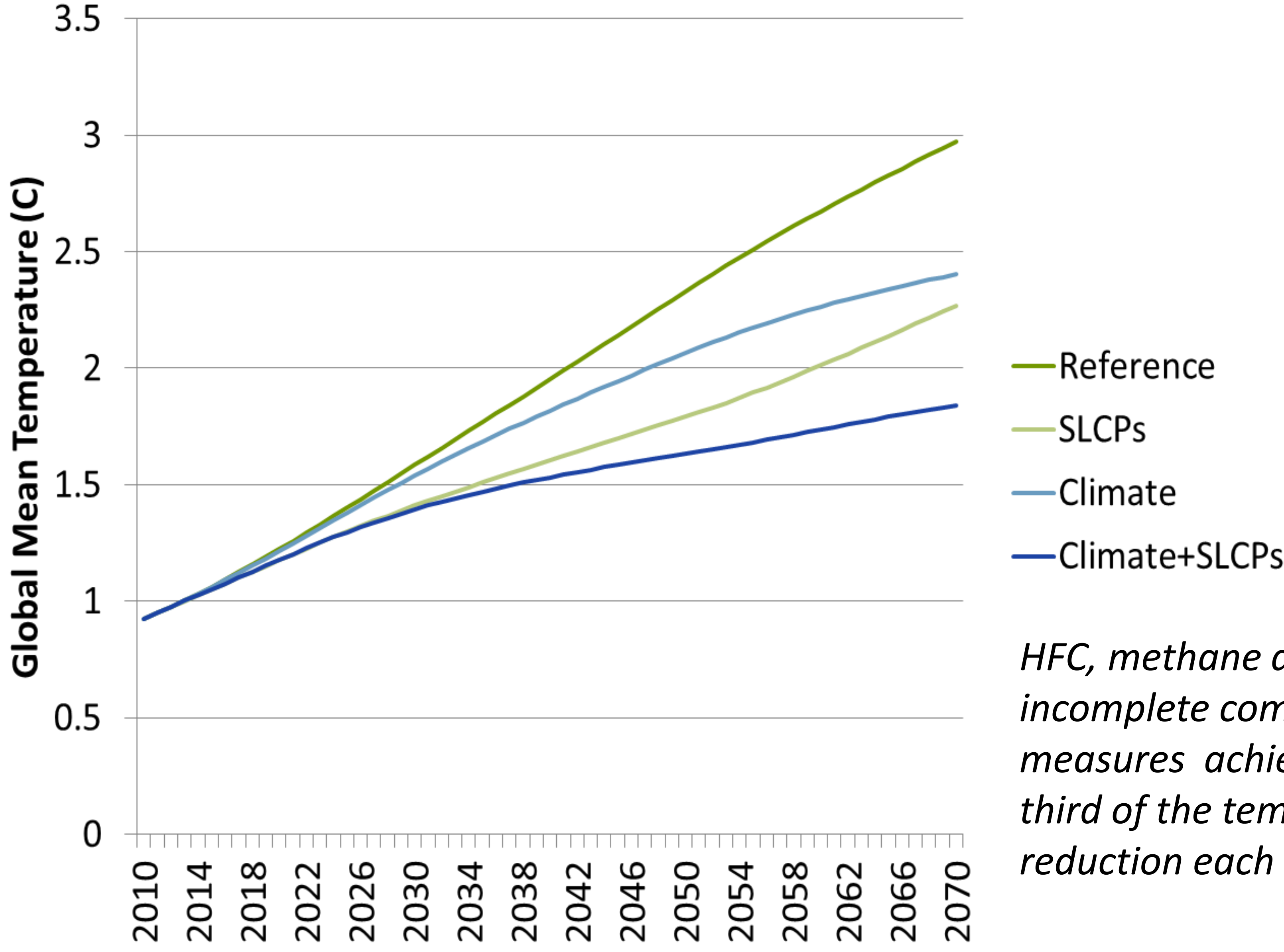


the reduction in temperature from implementation of the SLCP measures relative to the Reference scenario, according to long-term runs using the GISS model.

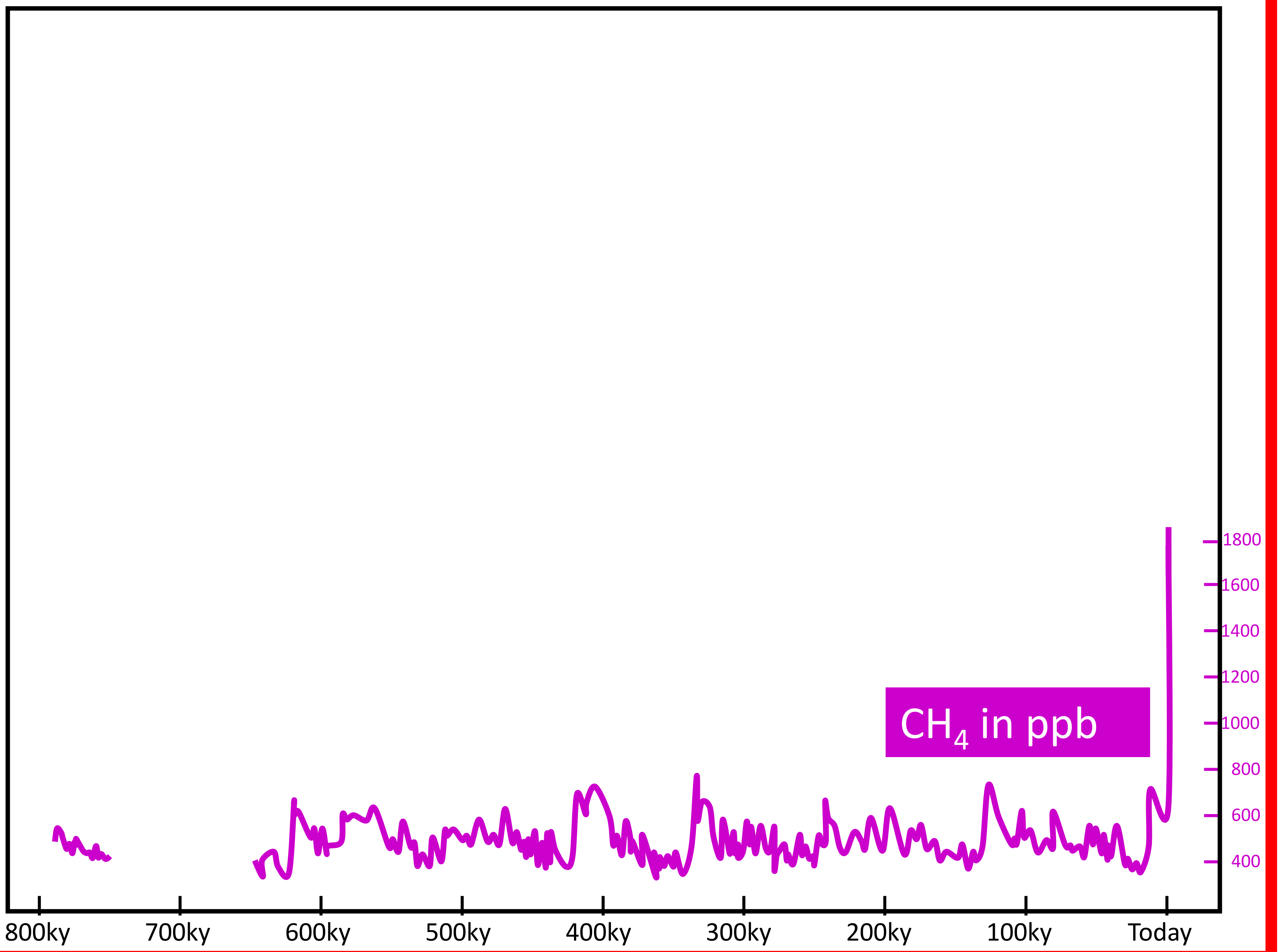


Change in premature mortality due to ozone for mitigation scenarios in all of LAC
SLCP mitigation v Reference
Climate mitigation v Reference
Climate + SLCP mitigation v Reference
SLCP mitigation v Climate reference
0
-1000
-2000
-3000
-4000
-5000
Deaths per year
2030
2050

Progression of temperature under different scenarios – assuming full implementation of SLCP measures globally, compared with Reference and Climate scenarios

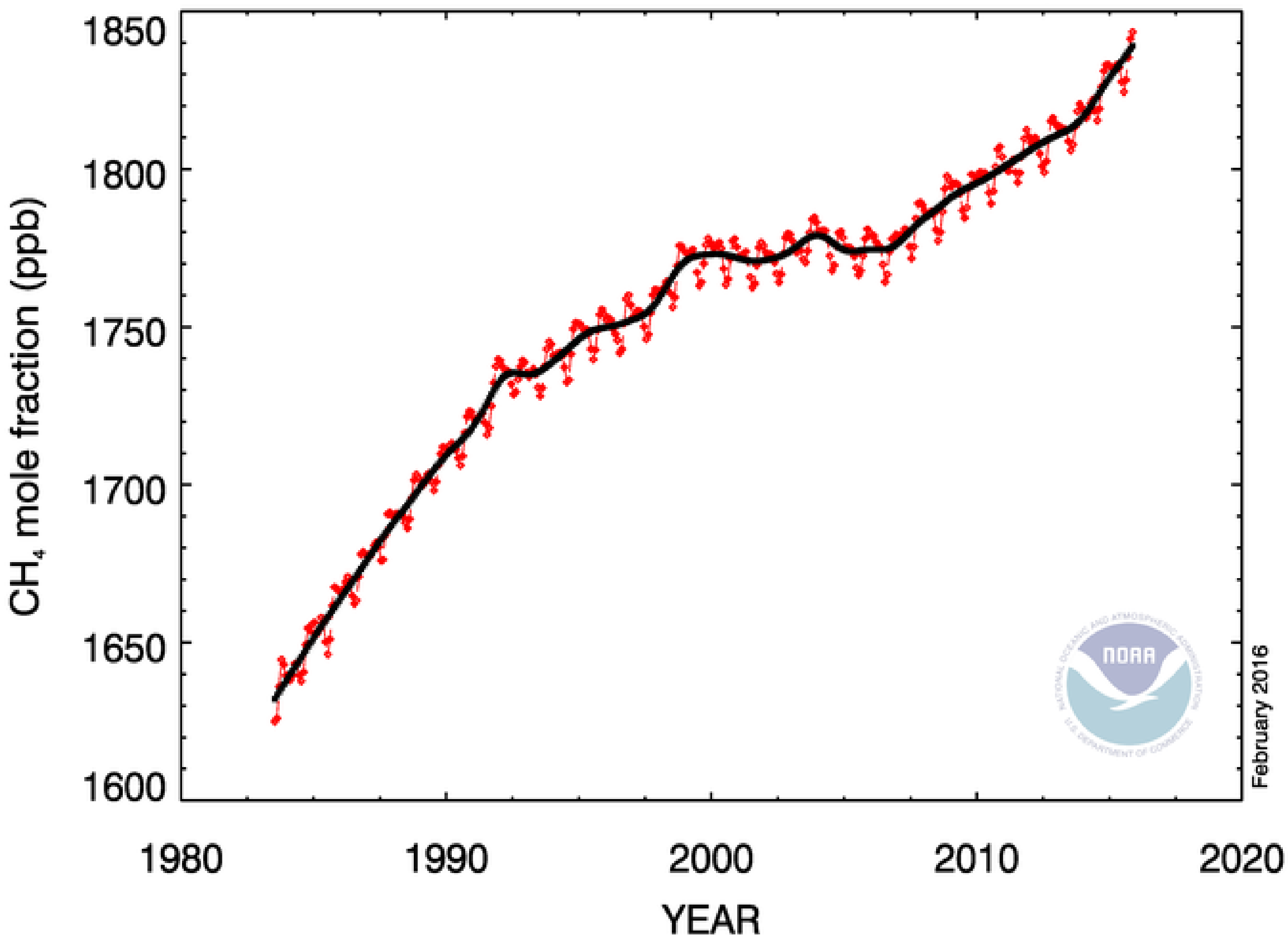


HFC, methane and incomplete combustion measures achieve about a third of the temperature reduction each



CH_4 in ppb
1800
1600
1400
1200
1000
800
600
400
800ky
700ky
600ky
500ky
400ky
300ky
200ky
100ky
Today

Methane More Recently



Why is Methane again increasing rapidly?

Recent studies:

- Carbon isotopes indicate biological sources (agriculture) important
- Simultaneous ethane measurements indicate fossil sources important
- Satellite data suggest in US, gas industry expansion important

How much comes from Oil & Gas?

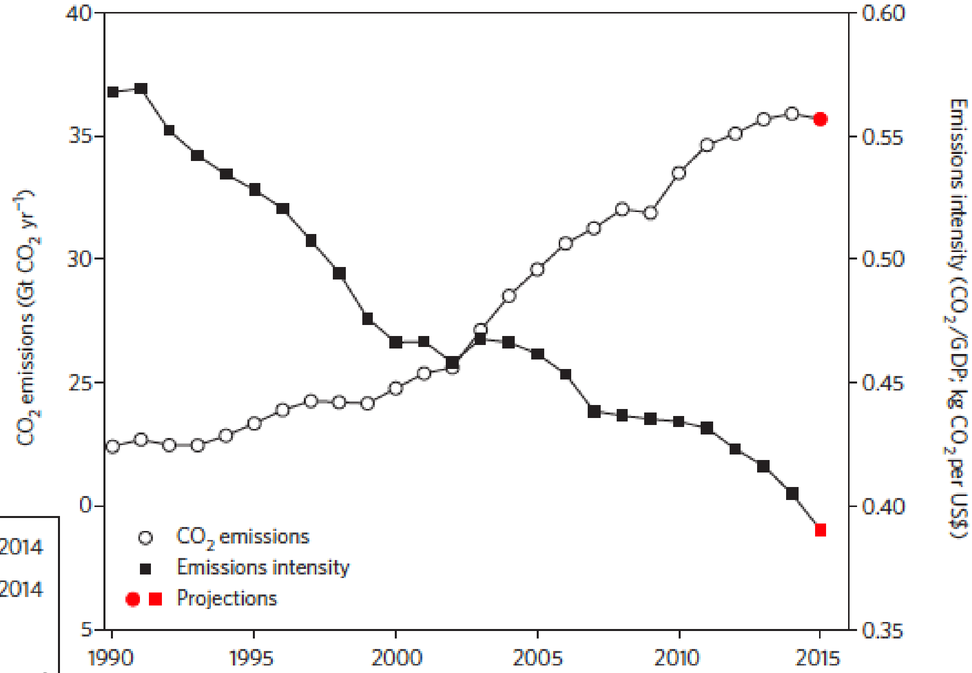
Oil & Gas Industry

- Emissions factors underestimated
- Some compressors missed (mainline included, gathering not always)
- High-flow sampler failure at large methane levels

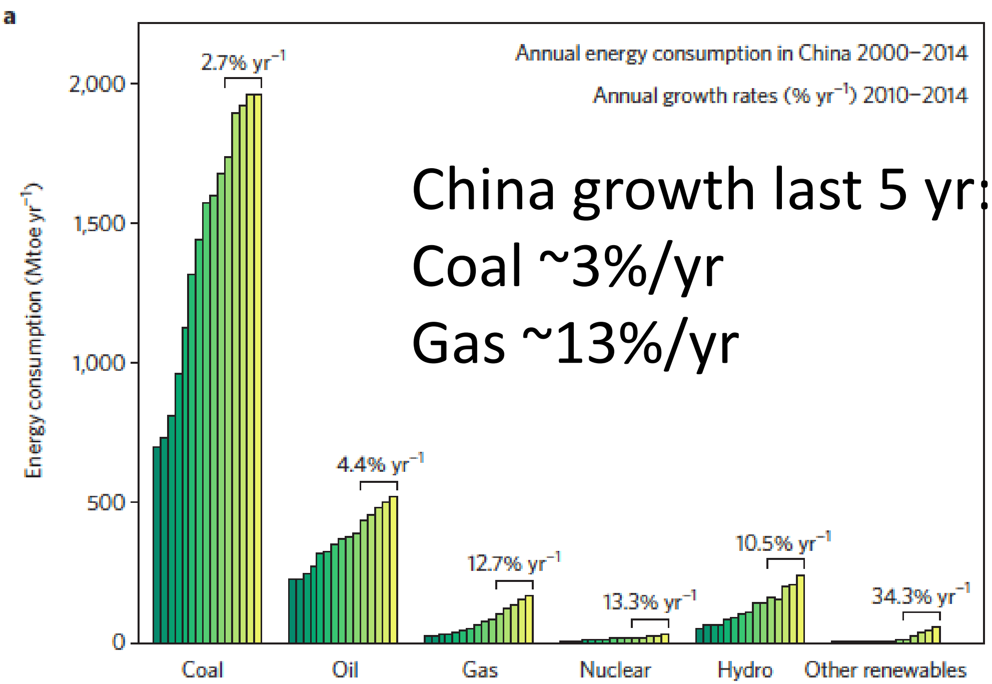
Underestimated bottom-up emissions, explains at least part of discrepancy with top-down

How much comes from Oil & Gas?

CO2 growth rate slowing for first time without global recession ->



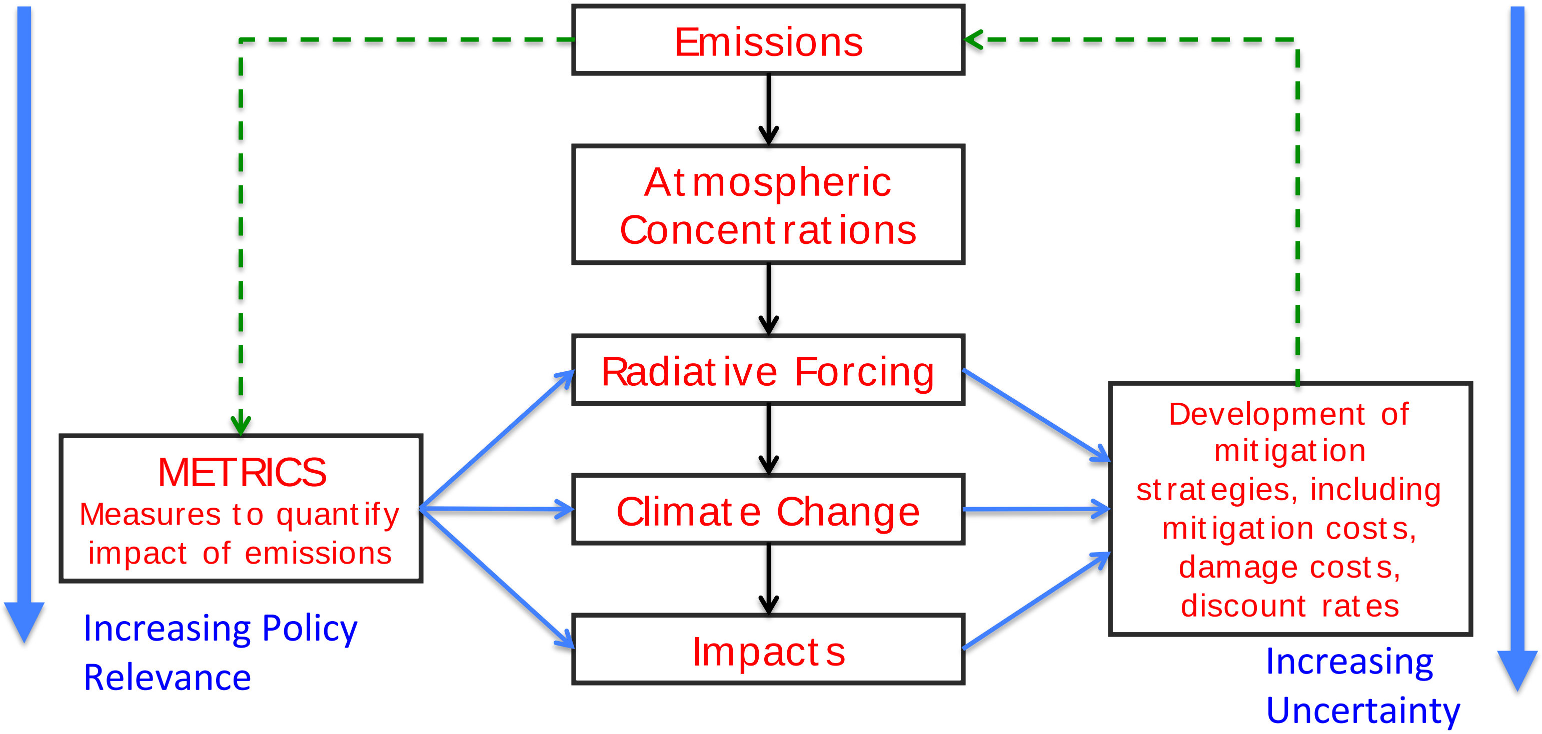
Largest cause is shift from coal to gas in China and US



China growth last 5 yr:
Coal ~3%/yr
Gas ~13%/yr

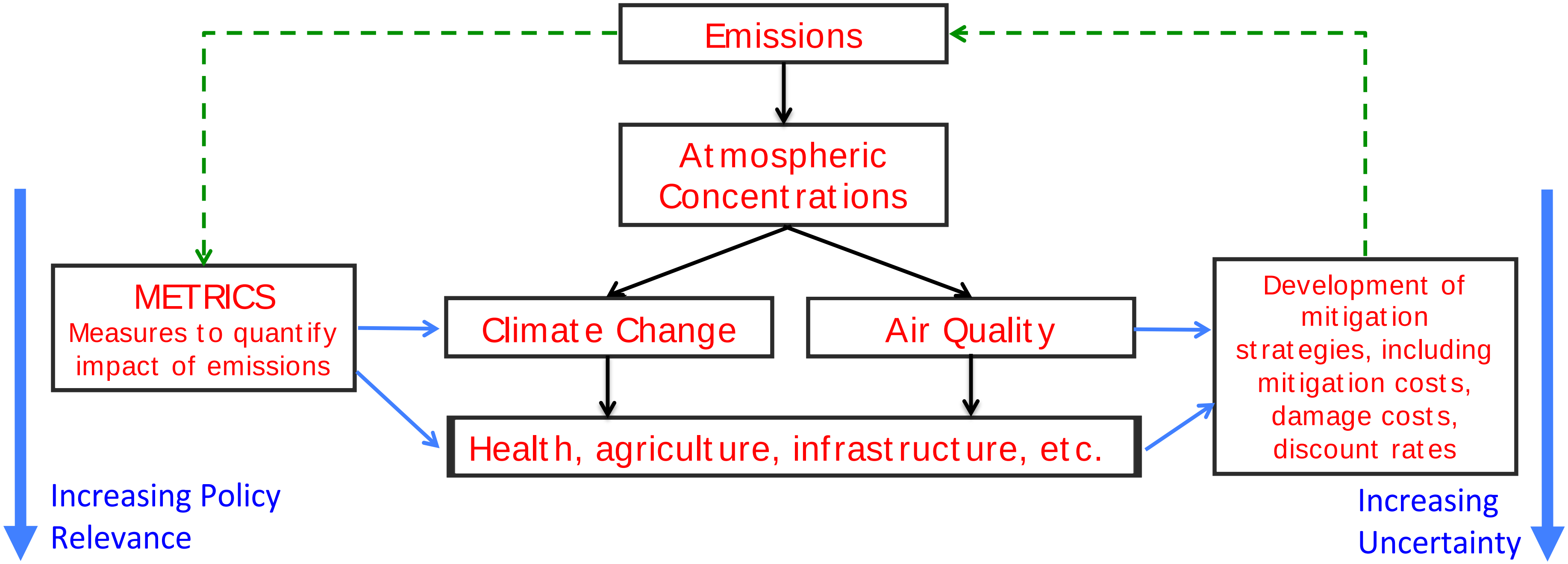
Jackson et al, Nature Climate Change, 2015

Quantified Impact of Methane Emissions



source: IPCC AR5 2013

Quantified Impact of Methane Emissions



How much benefit do we get from reductions?

Each Mt methane emission prevented avoids:

~300-400 premature deaths due to ozone

~186,000 tons of crop yield loss due to ozone

~0.002C warming over 2-4 decades

3000-6000 $US societal benefits

How much benefit do we get from reductions?

Incorporating all quantified impacts, each ton methane emission prevented is comparable to:

~100 tons CO_2 with a near-term focus

~40 tons CO_2 with a long-term focus (or economically optimal declining discount rate)

These exceed either GWP or GTP metrics

Thank you

Motivation for the Assessment

Risks associated with reductions in cooling pollutants e.g. sulphate – and increase in emissions of short-lived warming species

Assessment focus on substances with combined warming and air pollution impact – i.e. on black carbon and ozone

Through the focus on ozone, methane was also included

As the assessment progressed - focus on the near-term climate benefits, as well as air pollution benefits

Methane emission scenarios

Many climate scenarios assume that as countries develop, methane emissions are automatically reduced in the reference scenario

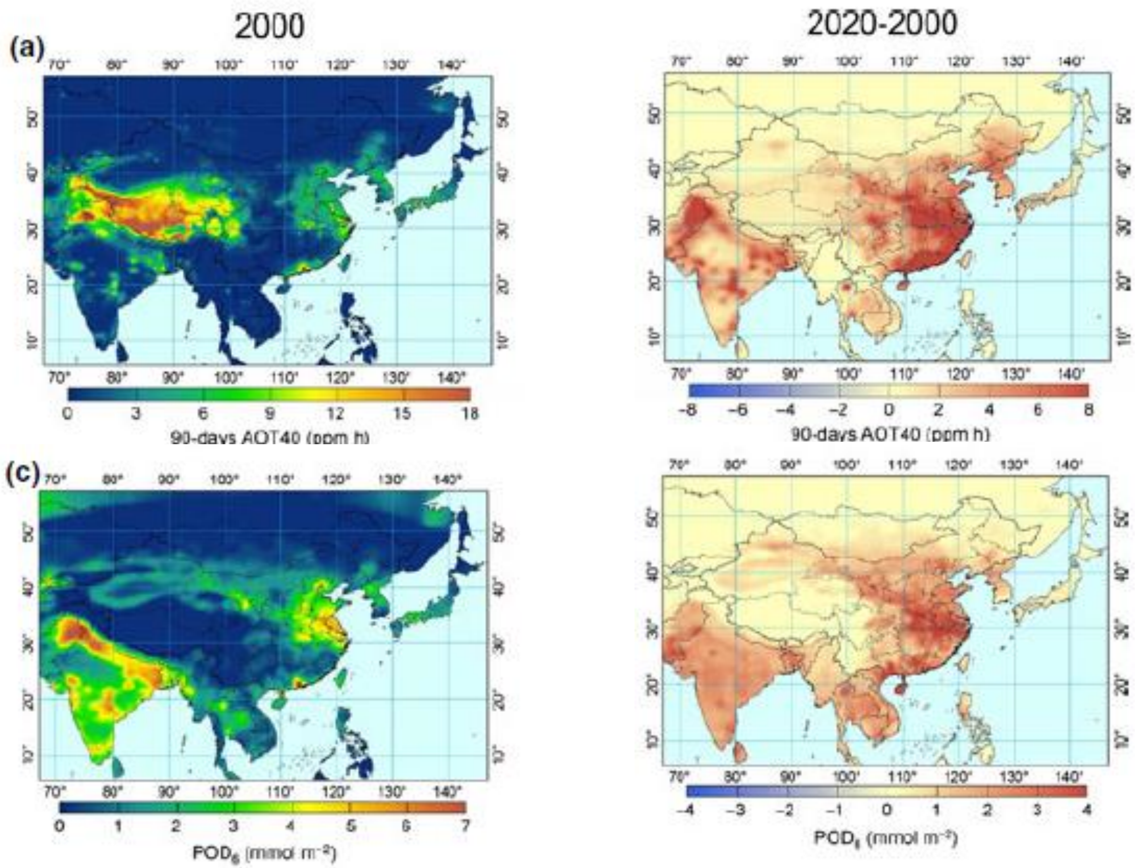
In the Assessment, and the regional SLCP assessment for LAC, the methane measures are not assumed to be implemented in the reference scenario beyond national plans

In the Assessment climate scenarios, methane reduces due to the feedback from reduced use of fossil fuels and hence reduced associated methane emission (coal mine methane etc)

Regional risk assessment modelling across India and China

AOT40 (90d)

POD_6



Tang et al. (2013)

National estimated Relative Yield Loss (%) :

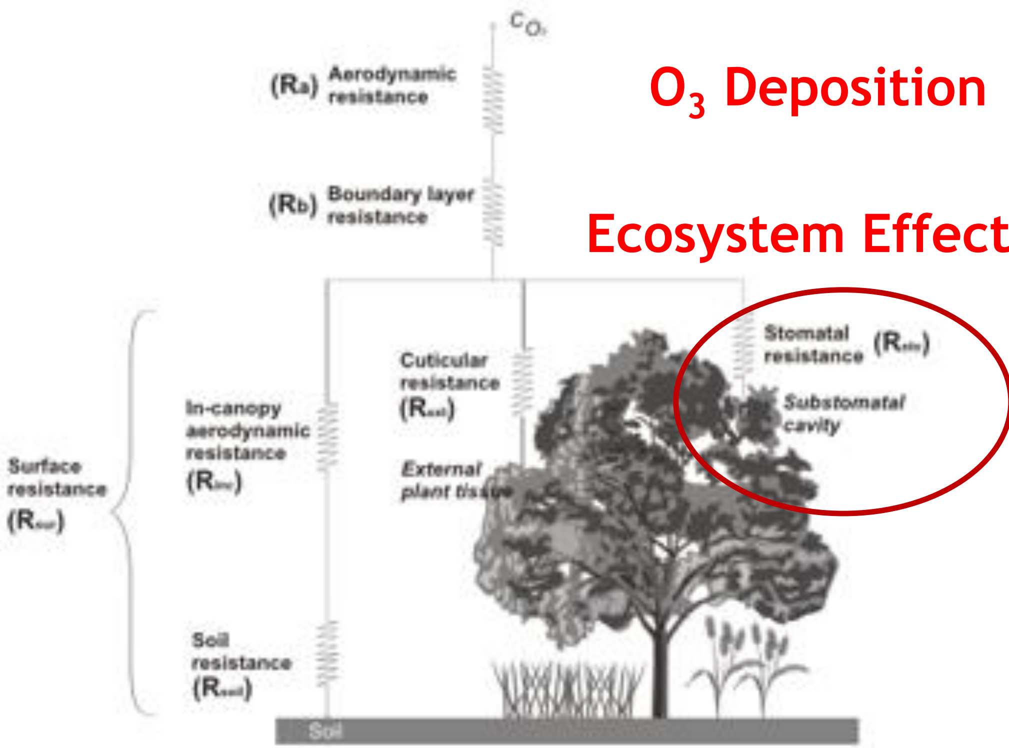
	AOT40 (90d)	AOT40 (75d)	POD_6	POD_{12}
Winter wheat	6.4 (14.8)	7.2 (16.6)	14.9 (23.0)	10.3 (19.2)

Climate Change ← **Atmospheric Composition**

$[CO_2]$

O_3 Deposition

Ecosystem Effects



LAI, gsto

Reduced C sequestration
Altered transpiration
Visible injury
Crop yield losses
Forest biomass losses

methods that can estimate O_3 deposition, effects and associated feedbacks is extremely important….and well suited to Earth System Modelling

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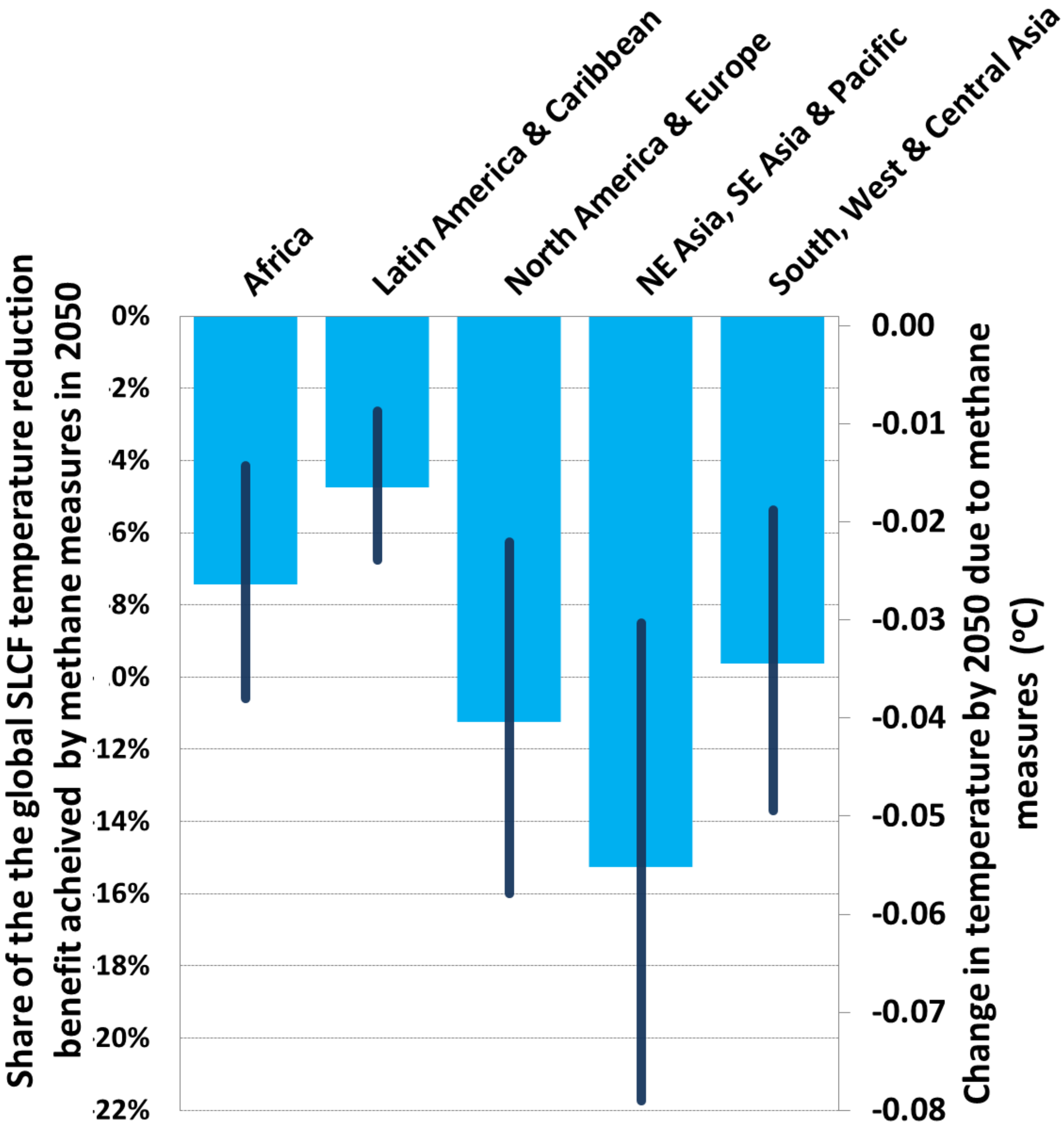
The share of global temperature reduction achieved from implementation of methane measures in different regions



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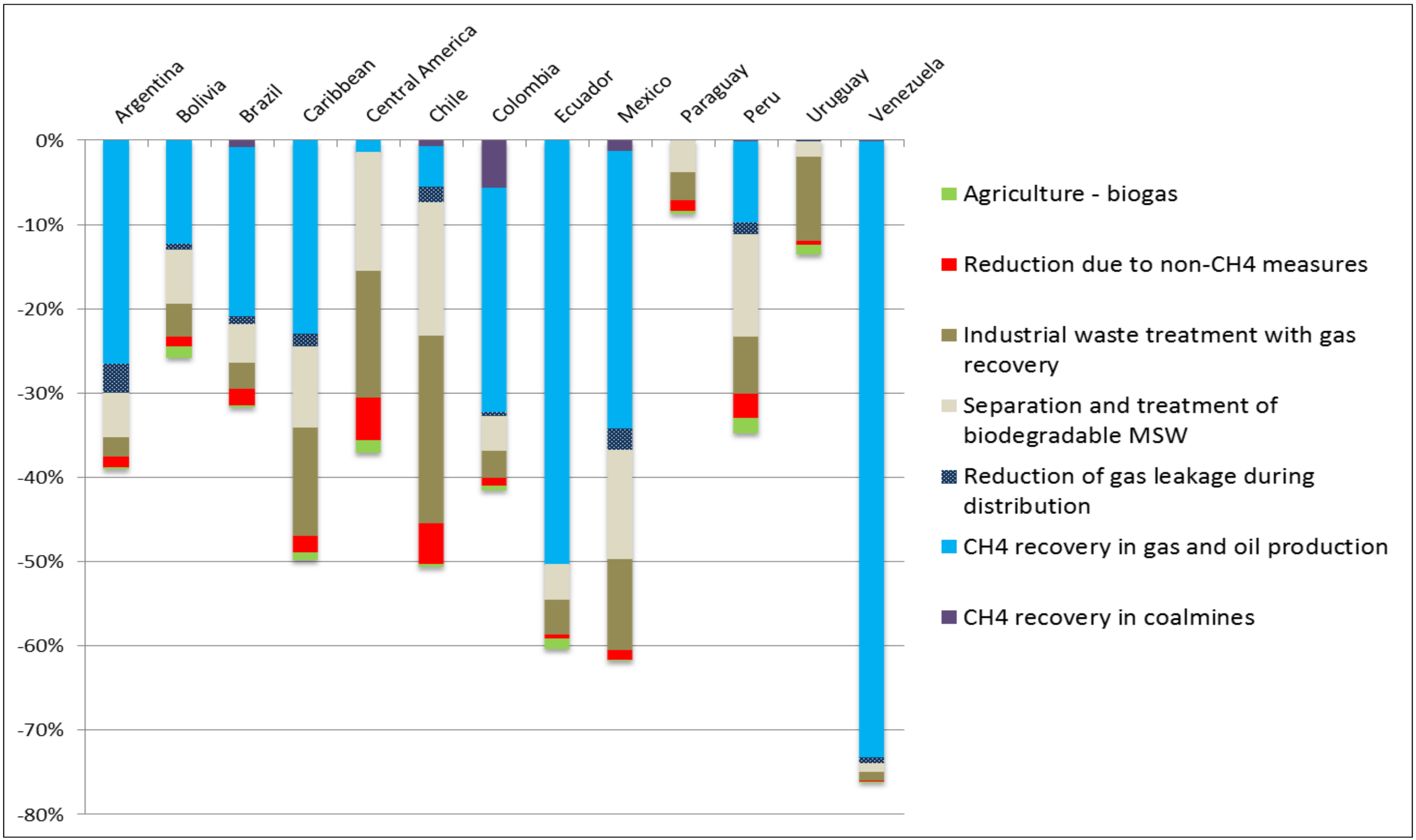
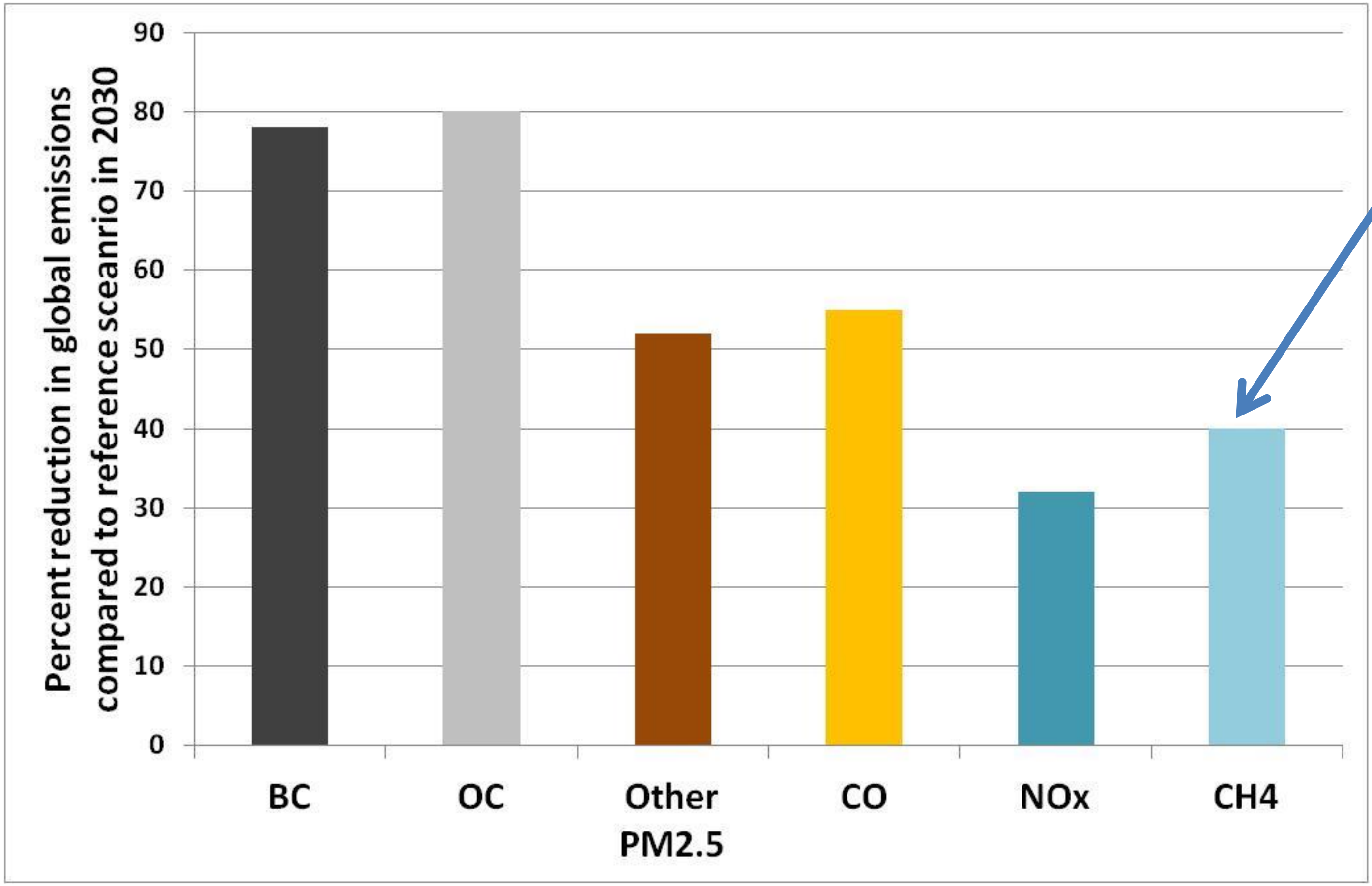

Argentina
Bolivia
Brazil
Caribbean
Central America
Chile
Colombia
Ecuador
Mexico
Paraguay
Peru
Uruguay
Venezuela
0%
-10%
-20%
-30%
-40%
-50%
-60%
-70%
-80%
Agriculture - biogas
Reduction due to non-CH4 measures
Industrial waste treatment with gas recovery
Separation and treatment of biodegradable MSW
Reduction of gas leakage during distribution
CH4 recovery in gas and oil production
CH4 recovery in coalmines

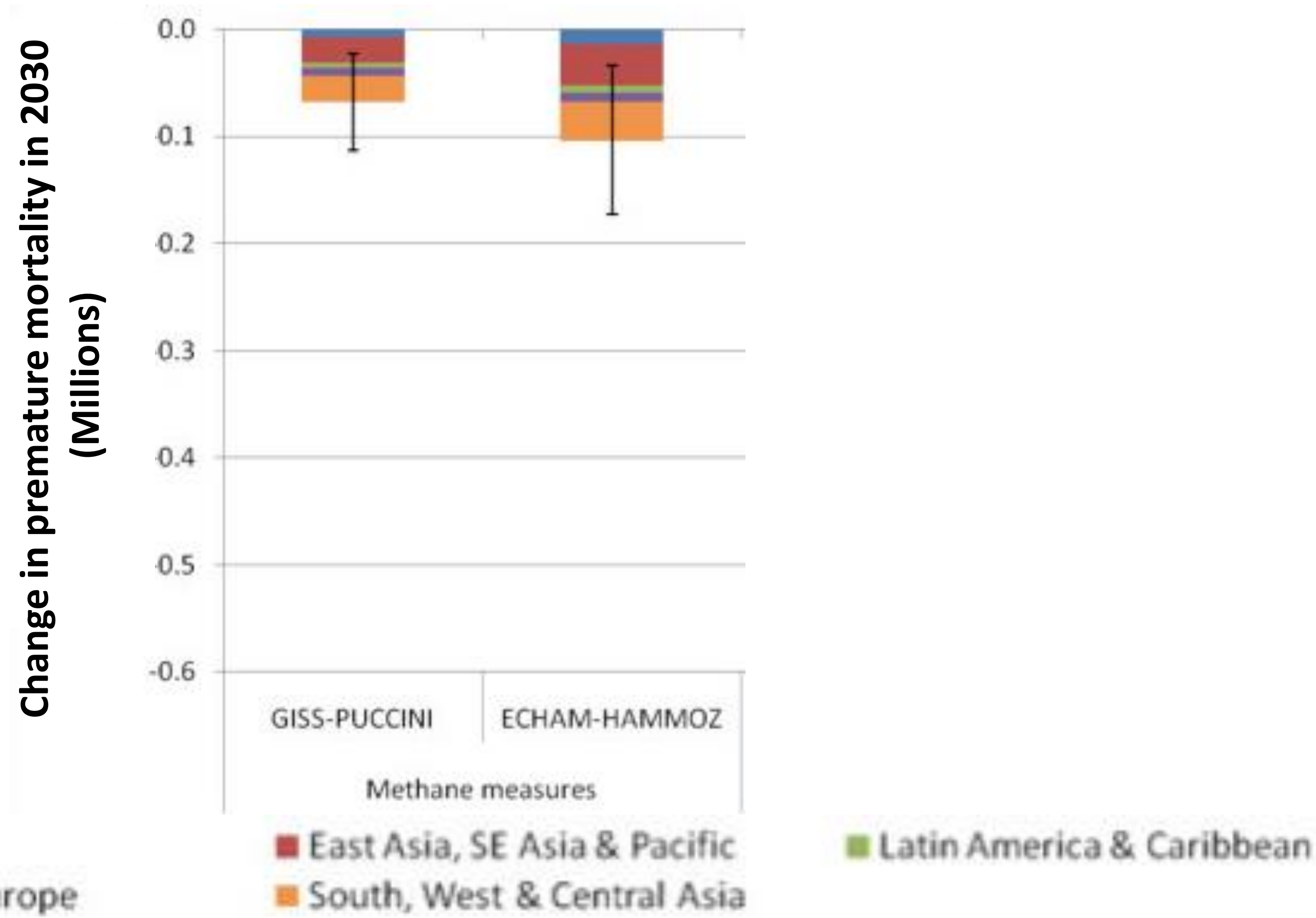
Effect of measures on global emissions projected for 2030 relative to 'Reference Scenario' emissions in 2030

9 BC measures fully implemented in 2030
7 Methane measures fully implemented in 2030



40% reduction In methane emissions

Benefits of methane measures on health



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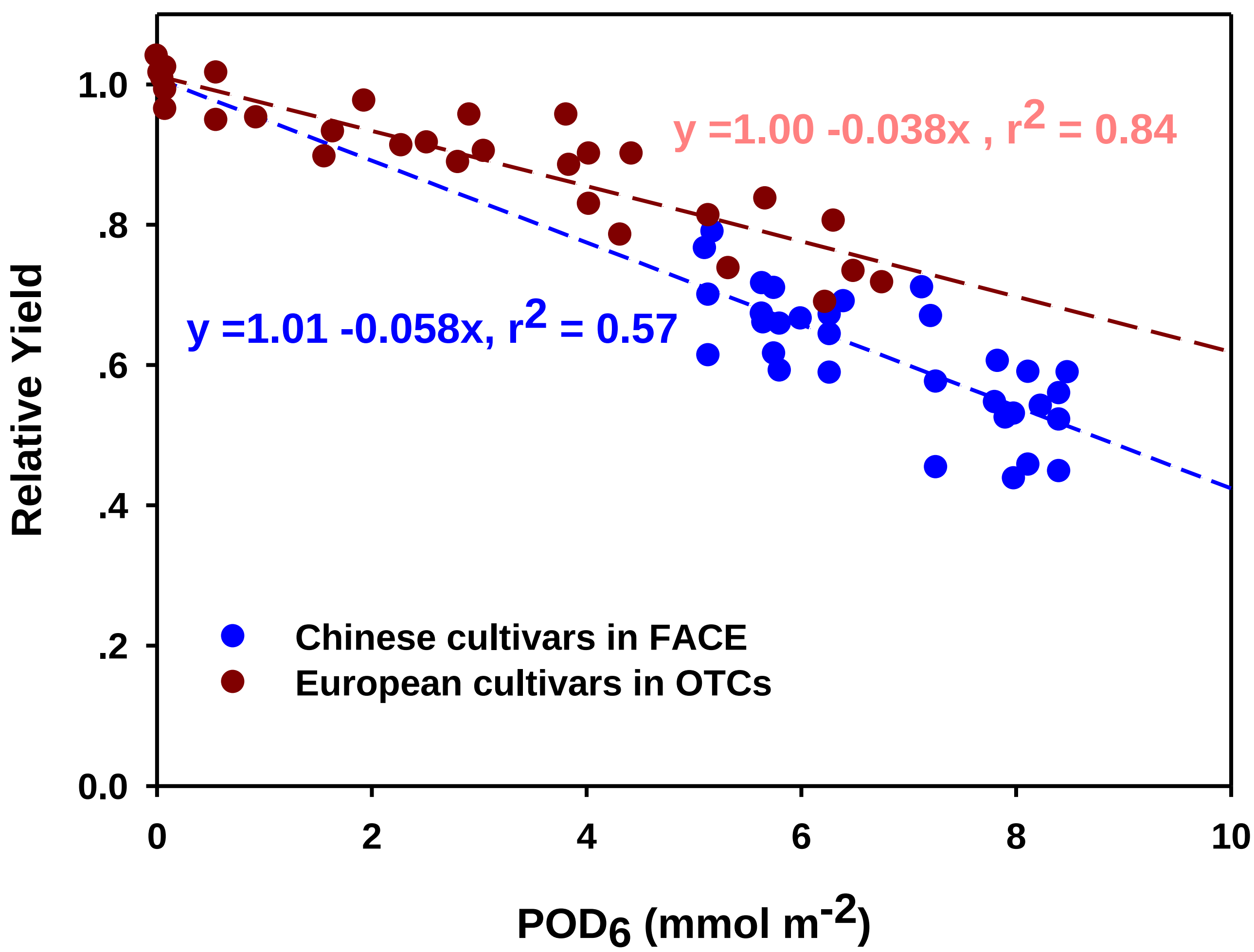
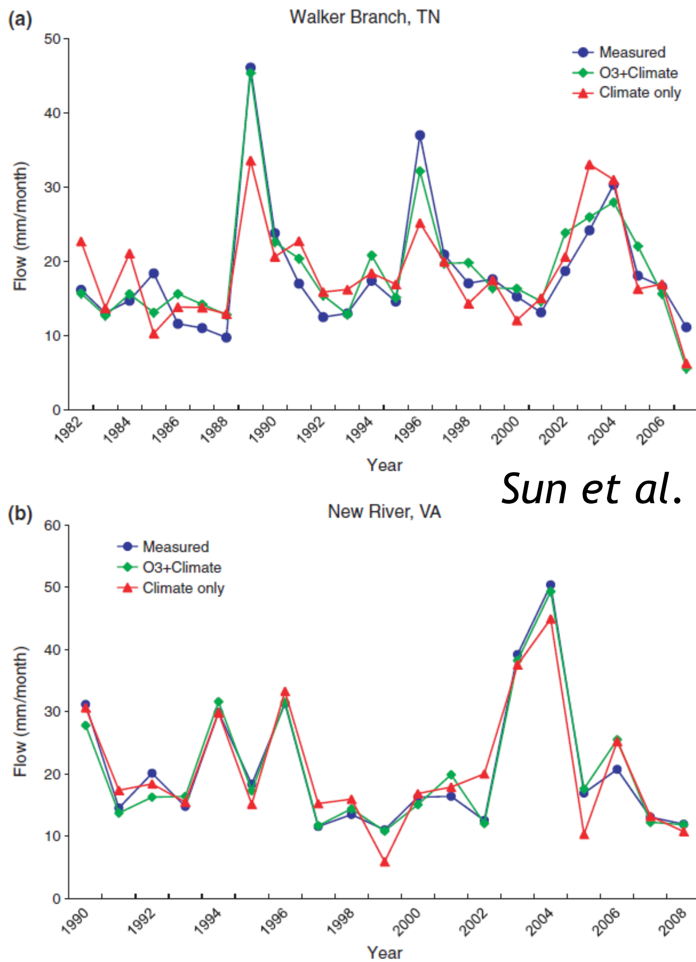
Flux-based Dose-Response Relationship for Wheat



O_3 can affect hydrology (stream flow) through alterations to evapotranspiration

- Stream flow in catchments in the US modelled with and without effects of ozone on NPP
- incorporating ozone gave better fit to observed stream flow data
- The study suggests that stream flow may be decreased by up to 23% in catchments with high ozone concentrations



Sun et al. 2012

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