Changing atmospheric acidity as a modulator of nutrient deposition and ocean biogeochemistry

GESAMP WG38

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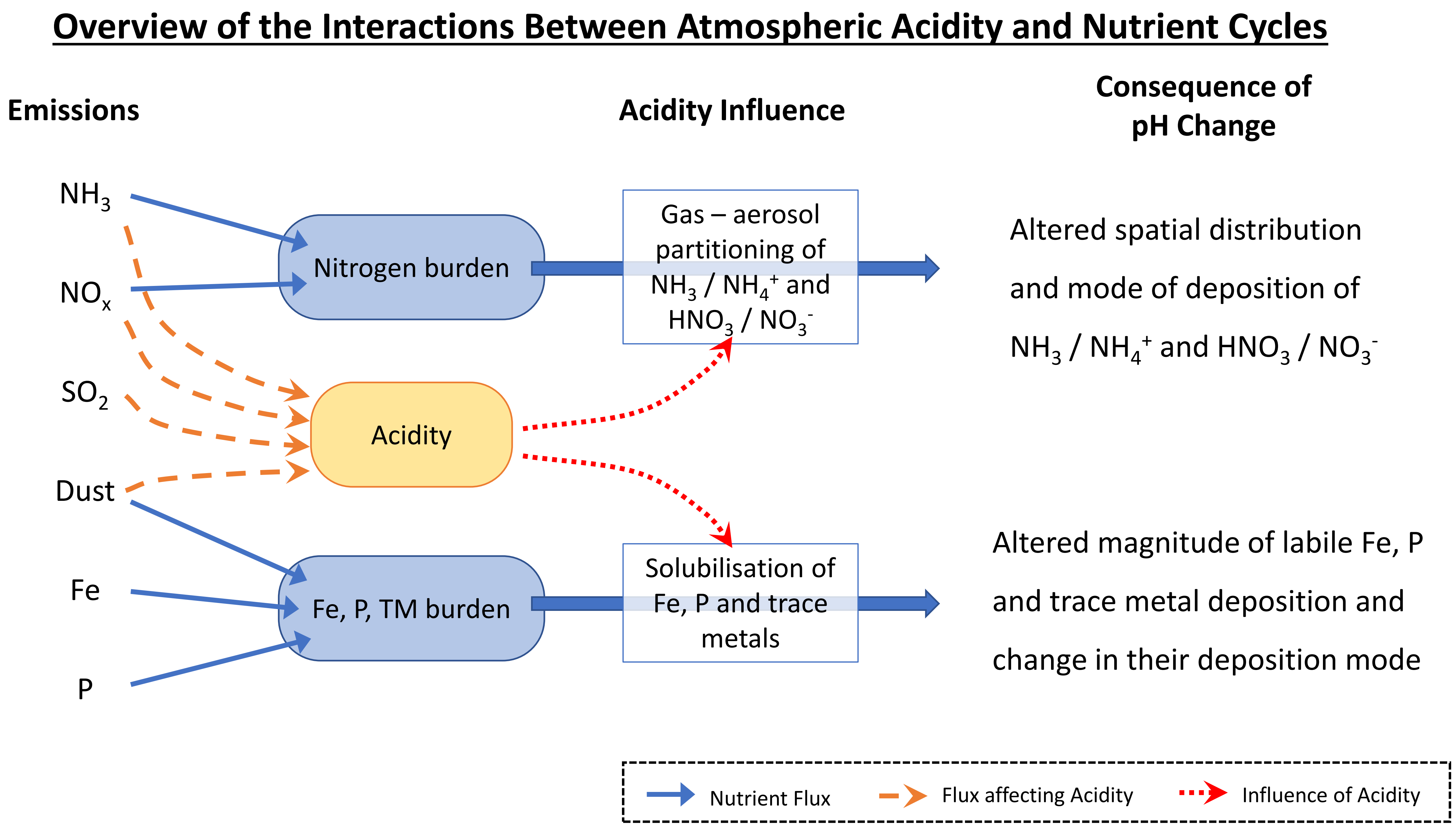
Introduction

Emissions of nitrogen and sulphur oxides, ammonia and mineral dust contribute to the acidity balance of the atmosphere, and together with liquid water content, set the pH of aerosol, cloud water and precipitation.

Anthropogenic emissions of nitrogen and sulphur oxides and ammonia have significantly increased since the Industrial Revolution and lowered the pH of aerosol, cloud water and precipitation, especially in the marine atmosphere in the northern hemisphere.

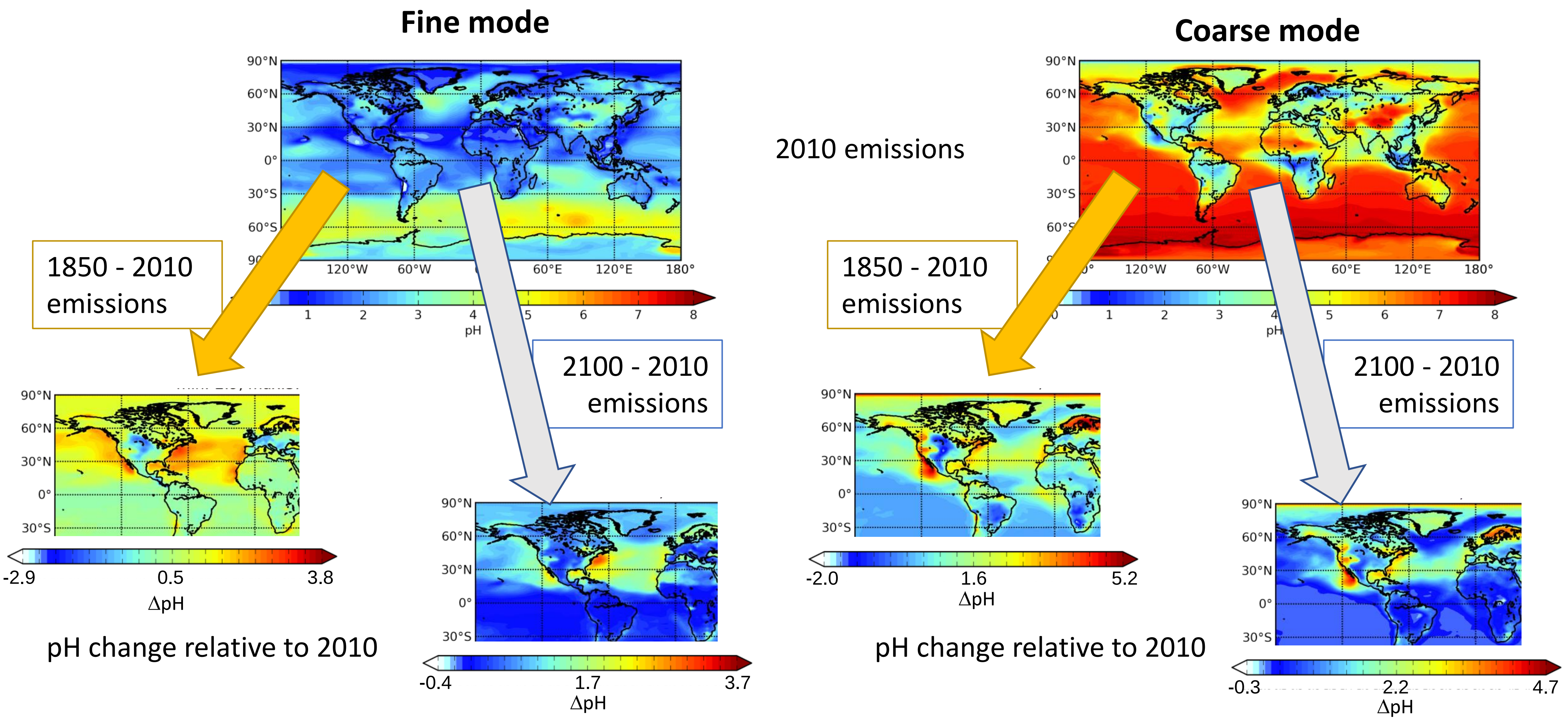
Increases in nitrogen deposition to the ocean due to these emission changes are well documented. This presentation examines the past and future changes induced in atmospheric nutrient supply to the ocean as a result of the influence of atmospheric acidity on oxidized and reduced nitrogen, iron, phosphorus and trace metals (TM).

The consequences of the induced changes in nutrient supply for marine microbial ecology are also discussed.



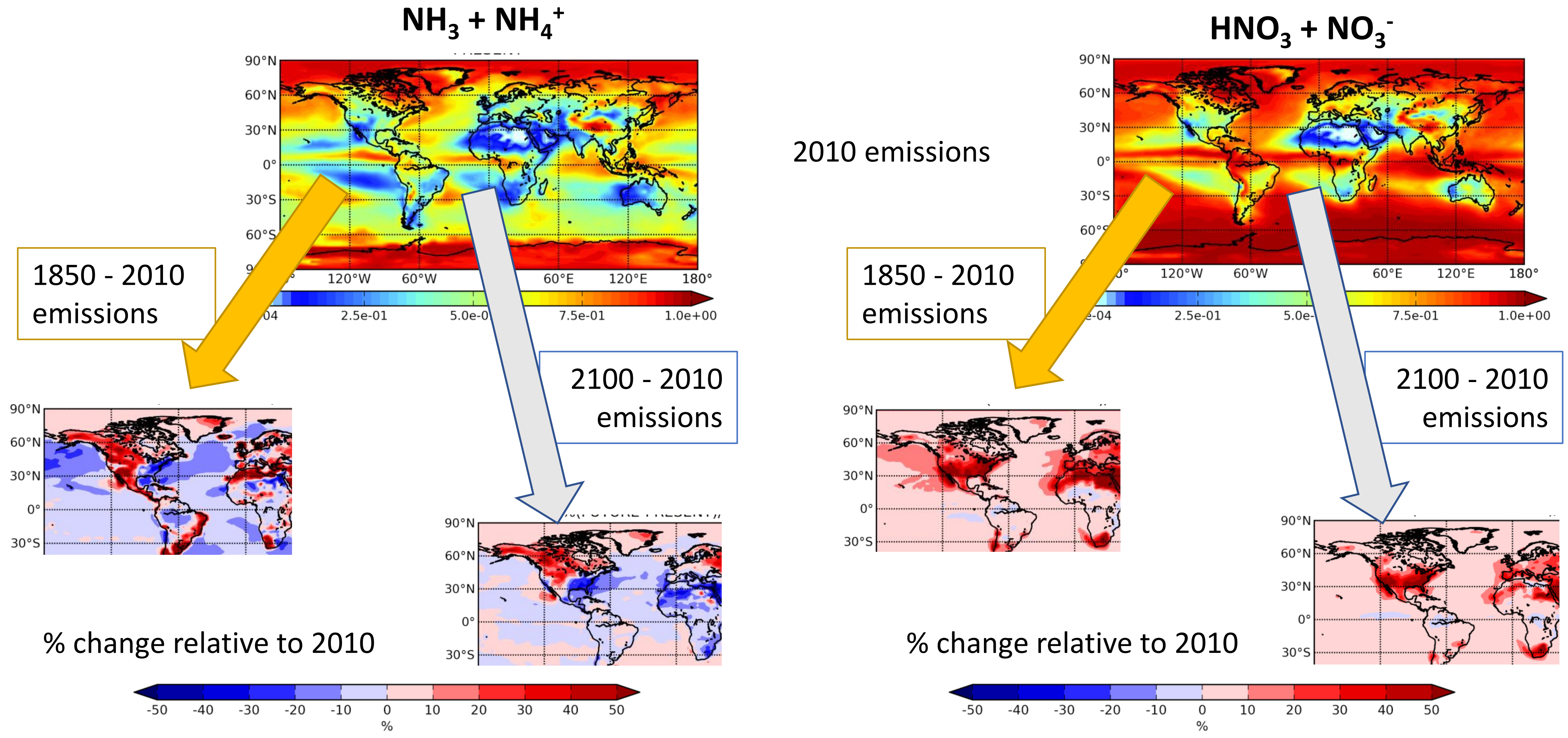
Overview of the Interactions Between Atmospheric Acidity and Nutrient Cycles
Emissions
Acidity Influence
Consequence of pH Change
NH_3
NO_x
SO_2
Dust
Fe
P
Nitrogen burden
Acidity
Fe, P, TM burden
Gas – aerosol partitioning of NH_3 / NH_4^+ and HNO_3 / NO_3^-
Solubilisation of Fe, P and trace metals
Altered spatial distribution and mode of deposition of NH_3 / NH_4^+ and HNO_3 / NO_3^-
Altered magnitude of labile Fe, P and trace metal deposition and change in their deposition mode
Nutrient Flux
Flux affecting Acidity
Influence of Acidity

Aerosol Acidity and its Changes



Simulations are from Kanakidou et al., Deep Sea Res. II, 171, 104606, 10.1016/j.dsr2.2019.06.014, (2020).

Nitrogen Wet to Total Deposition Ratio Changes



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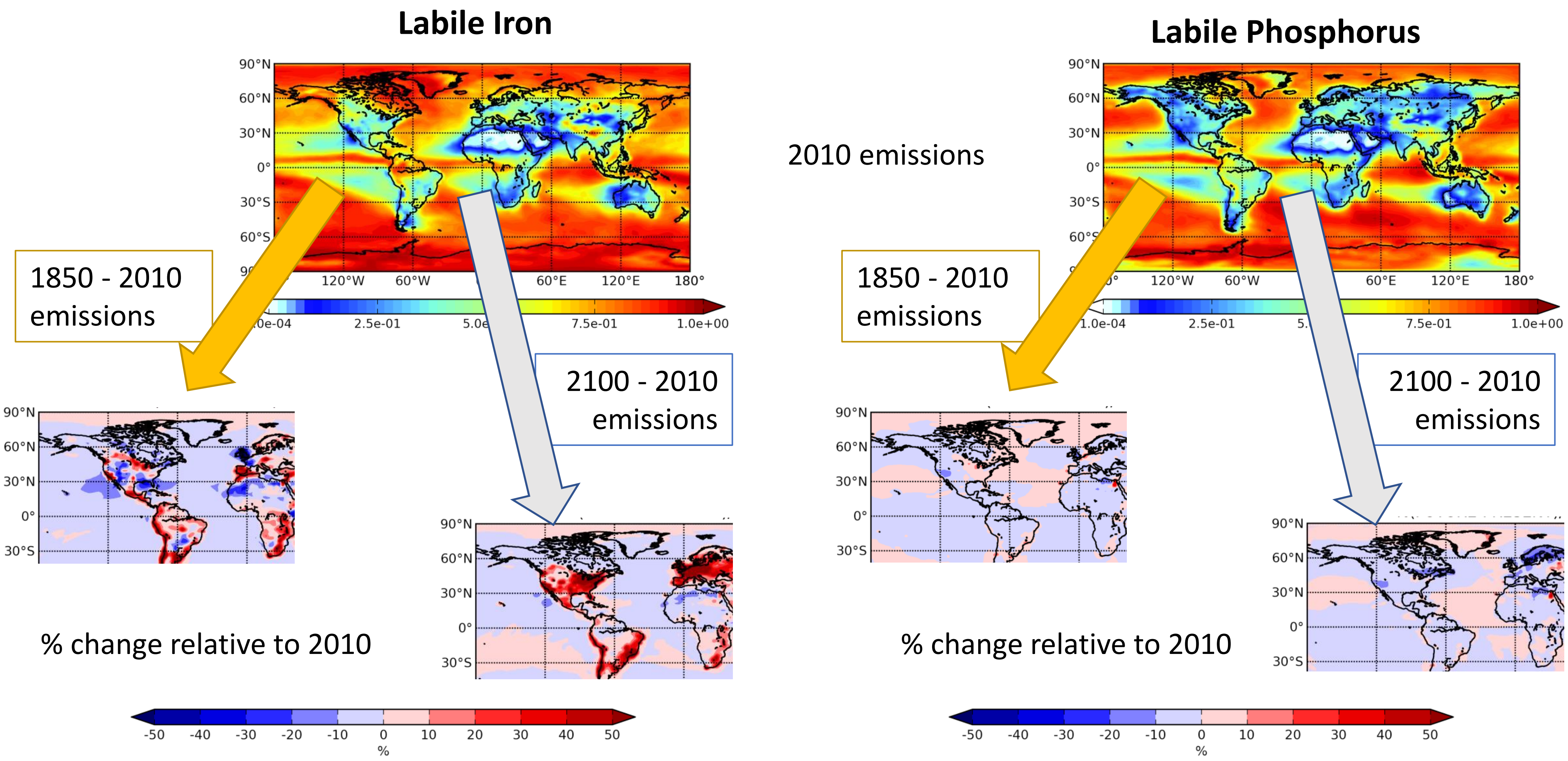
Labile Iron and Phosphorus Wet to Total Deposition Ratio Changes



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Implications of Acidity-Driven Changes in Oceanic Nutrient Supply

Decreases in pH, mainly over the northern hemisphere oceans:

- alter the distribution of nitrogen deposition (e.g. decreasing long-range transport of oxidised N),
- increase the labile fractions of Fe and P in deposition and
- increase the proportion of wet deposition of reduced N (ammonium) and labile Fe.

In combination, these changes in deposition magnitude, distribution and deposition mode:

- alter the relative abundance of nutrients (i.e. N:P, N:Fe, P:Fe) in atmospheric deposition,
- affect the passage of deposited nutrients through the sea surface microlayer (SML) and into bulk seawater.

The impacts of changing nutrient ratios in deposition and modified interactions of nutrients with the unique environment of the SML are uncertain, but could include shifts in marine microbial community structure and nutrient (co-)limitation regimes.

Conclusions

The acidity (and liquid water content) of atmospheric aerosol are key state parameters that profoundly influence the patterns, fluxes and impacts of atmospheric nutrient deposition to the oceans.

These effects are brought about by changes in the gas-aerosol partitioning of nitrogen species and the solubility of iron, phosphorus and trace metals.

Acknowledgments

This paper resulted from the deliberations of United Nations GESAMP Working Group 38, "The Atmospheric Input of Chemicals to the Ocean". We thank the Global Atmosphere Watch and the World Weather Research Programme of the World Meteorological Organization, the International Maritime Organization, the U.S. National Science Foundation, the ICSU Scientific Committee on Oceanic Research, and the University of East Anglia for their support.