# Potential feedbacks and interactions between biogeochemical cycles and climate change with emphasis on Methane

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# Introduction

**What are global biogeochemical cycles?**

- **circulation of the "life elements" C, N, O, P, and S through the reservoirs – atmosphere, lithosphere, hydrosphere and biosphere to maintain the intrinsic metabolism of the Earth**

**How are global biogeochemical cycles being altered?**

- **Anthropogenic activities are resulting in the accumulation of greenhouse trace gases ($CO_2$, $CH_4$, NMOCs, $NO_x$, $SO_x$) in the atmosphere**
- **Varying atmospheric composition has resulted in perturbed climate**

**How does biosphere feedback on climate?**

- **Perturbed climatic conditions influence the rate of production of climatically important biogenic gases from the biosphere and thus their cycling through the reservoirs**
- **Changing atmospheric composition results in changes in the climate forcing**

# Methane – a case study

## Atmosphere

- Influences composition and oxidizing capacity of the atmosphere

Troposphere

- $CH_4 + OH \rightarrow CO \rightarrow CO_2$
- At high $NO_x$, ↑ $CH_4$ : ↑ $O_3$
- Source of tropospheric HCHO

Stratosphere

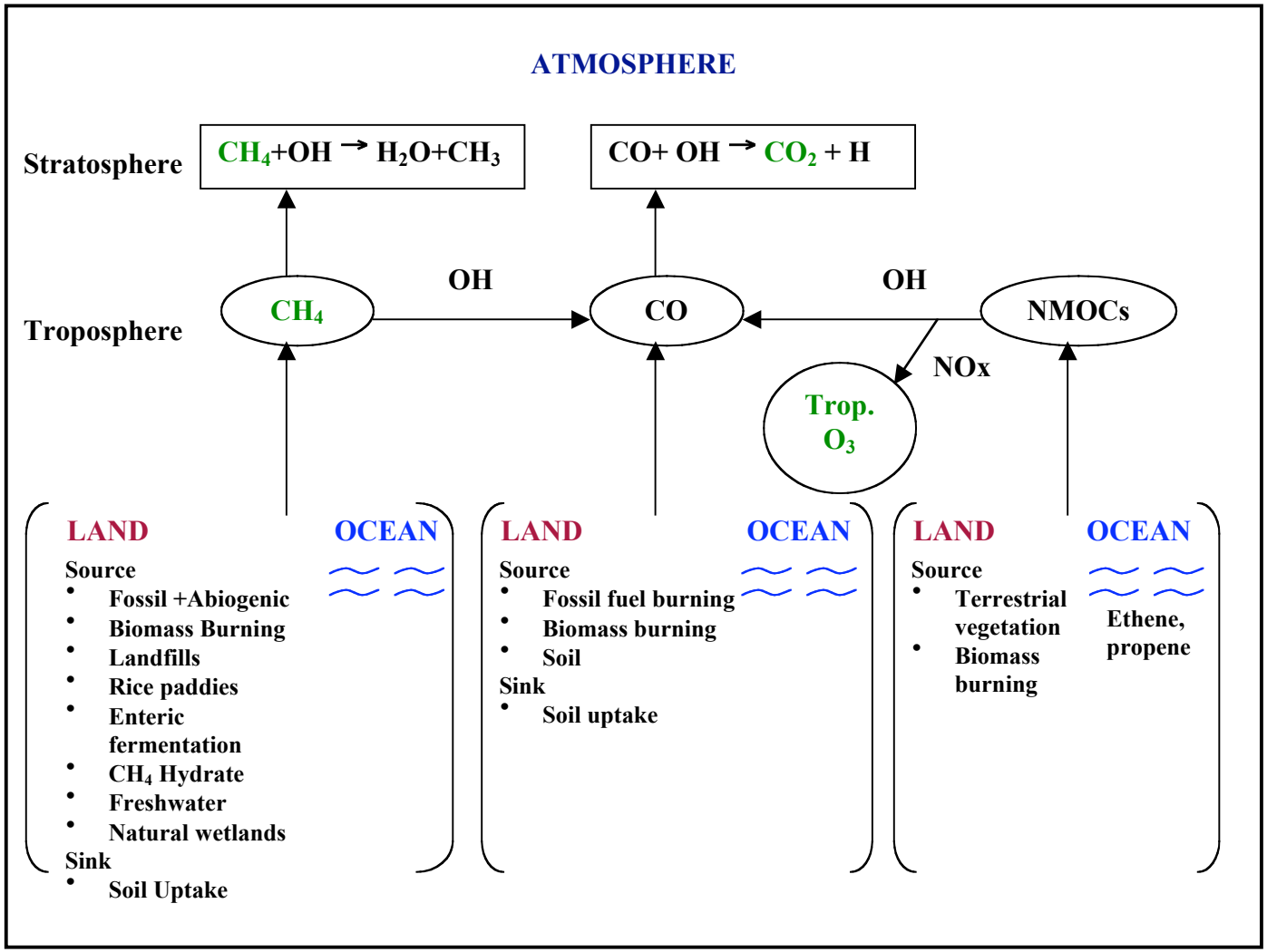
- Source of stratospheric $H_2O$
- Source and sink for reactive chlorine

- Greenhouse gas
  - ↑ $CH_4$ concentration :↑ climate forcing : ↑ Temperature
  - Both directly and indirectly

## Biosphere

- Approximately 70% of natural $CH_4$ is emitted from wetlands
- Wetlands respond to climate change – temperature, precipitation, soil moisture
- Methane output from hydrates is also vulnerable to climate change – temperature and pressure
- Response of soils to climate change is complicated – both a sink and source of $CH_4$
  - + feedback: ↑ $CH_4$
  - – feedback: ↓ $CH_4$

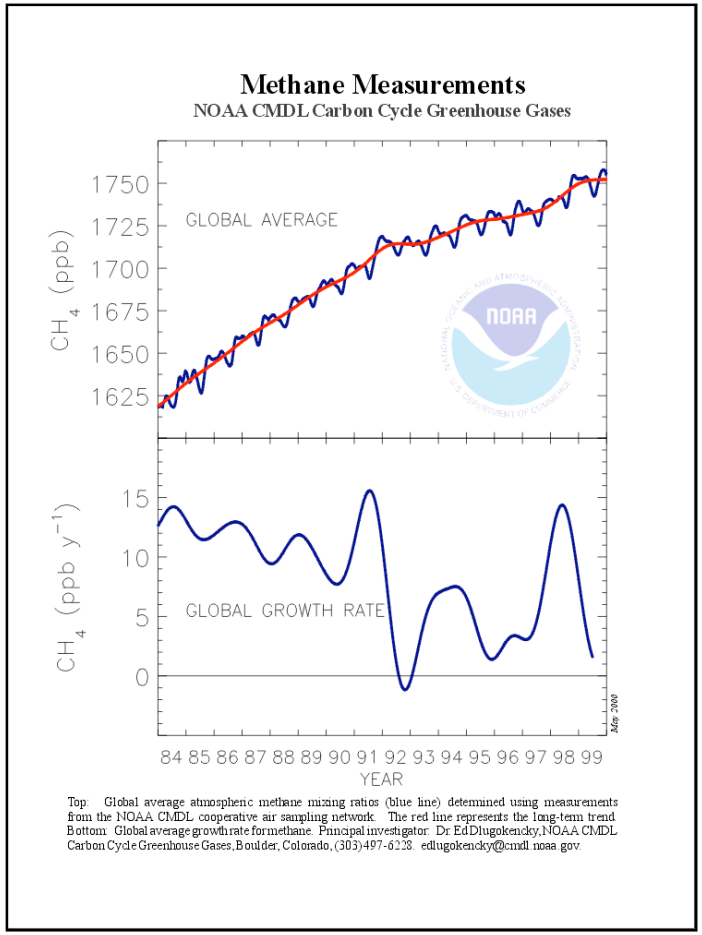
# The Methane Cycle



# Role of NMOCs in the Methane Cycle

- Affect atmospheric composition and tropospheric oxidizing capacity
  - Control tropospheric OH concentrations and hence the atmospheric concentrations of $CH_4$ and CO
  - Enhance ozone formation in environments with elevated $NO_x$ levels
  - Photo-oxidation of NMOCs result in aerosol formation
- Indirect effects on Climate
  - Positive effect as a result of reduction in OH concentrations and hence increase in $CH_4$ abundance
  - Negative effect due to increased albedo as a result of aerosol formation

# Motivation

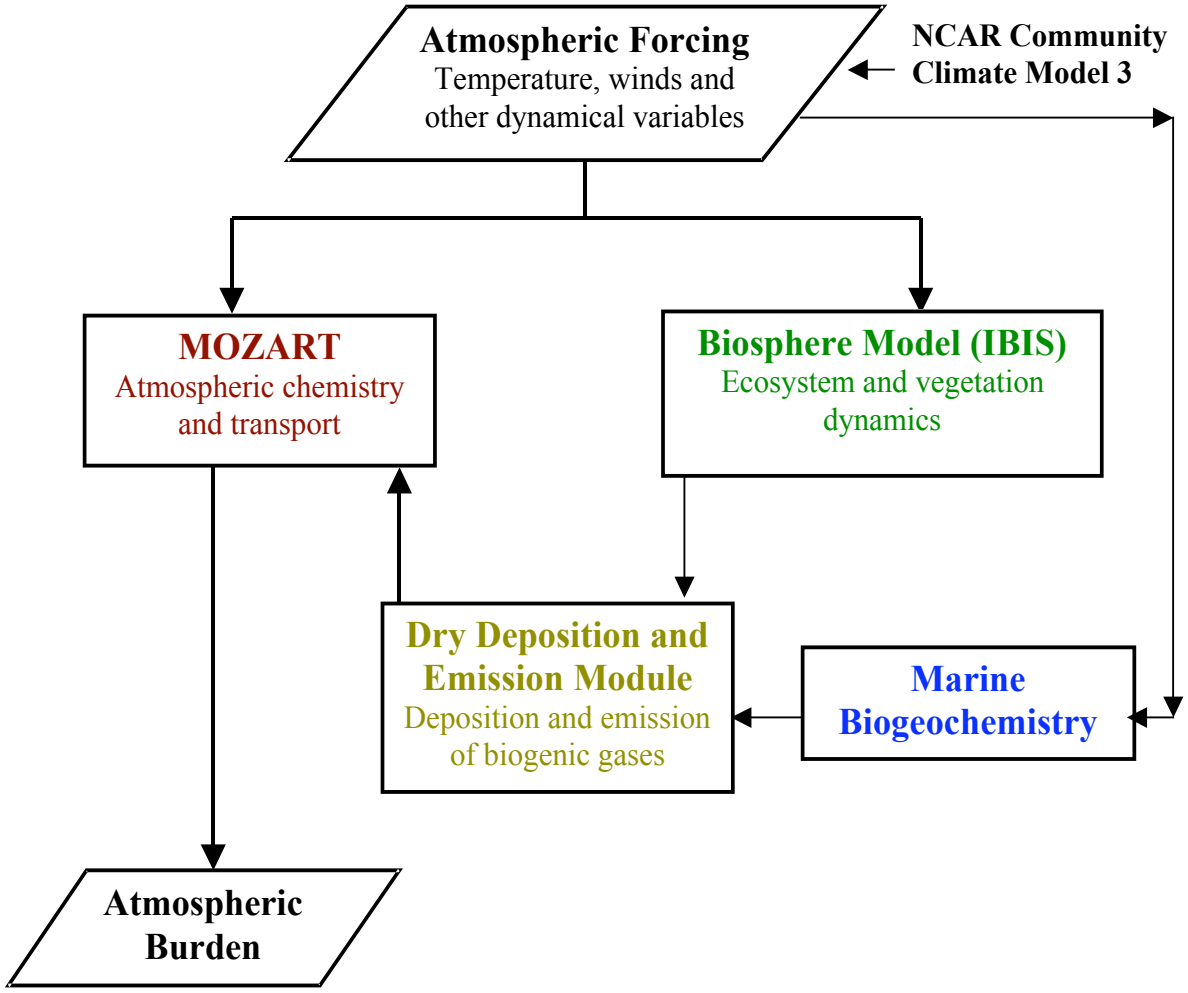



- **What is the cause of the observed increase in $CH_4$ growth rate in 97/98 ? - a signal of biospheric feedback to climate change?**
- **How well can biospheric sources of methane be represented in modeling studies?**
- **How successful are coupled atmosphere-biosphere models in reducing uncertainties in projections of future methane concentrations?**

# Approach

- A coupled biosphere-atmosphere-ocean model will be used for this study. Modules included in the model are:
  - A global three-dimensional chemical-transport model (called MOZART, Brasseur et al., 1998) that would evaluate the atmospheric burden of species by simulating the chemical and physical processes: chemistry, transport, advection, convection, and diffusion. Process-based algorithms for the evaluation of biogenic fluxes of $CH_4$, NMOCs, and CO will be incorporated in the model
  - A dynamic global vegetation model (the Integrated Biosphere Simulator-IBIS, Foley et al., 1996) that would simulate the dynamic behavior of terrestrial ecosystems
  - An ocean model that will generate fluxes of organic compounds from the ocean
  - A climate model that will provide climatological variables to the above modules
- This study will rely extensively on field observations for validation and evaluation of the coupled model

# Implementation of a coupled atmosphere-biosphere-ocean model



# Key Questions Addressed

- How do biospheric emissions of $CH_4$, NMOCs, CO change in response to changing biosphere (due to climate change)?
- How well does the coupled model simulate the observed methane growth rate?
- Do model results associate the observed methane growth rate to change in a particular source of methane?
- How do biospheric feedbacks perturb the methane cycle?