



## Network Design Tool Demo

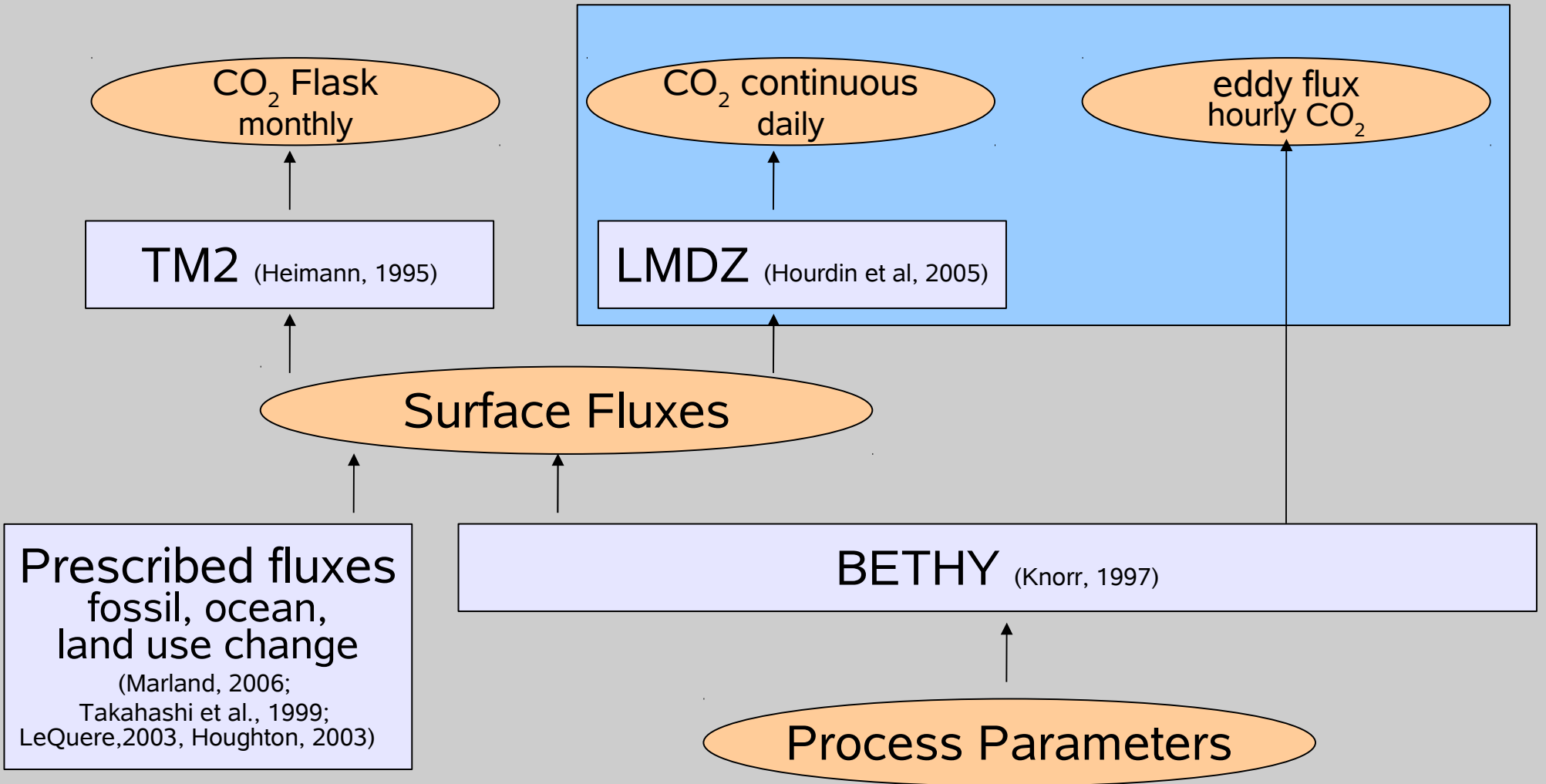
IMECC NA2: FastOpt, LSCE, and University of Bristol

IMECC-ICOS, QND workshop, September 2010, Egham

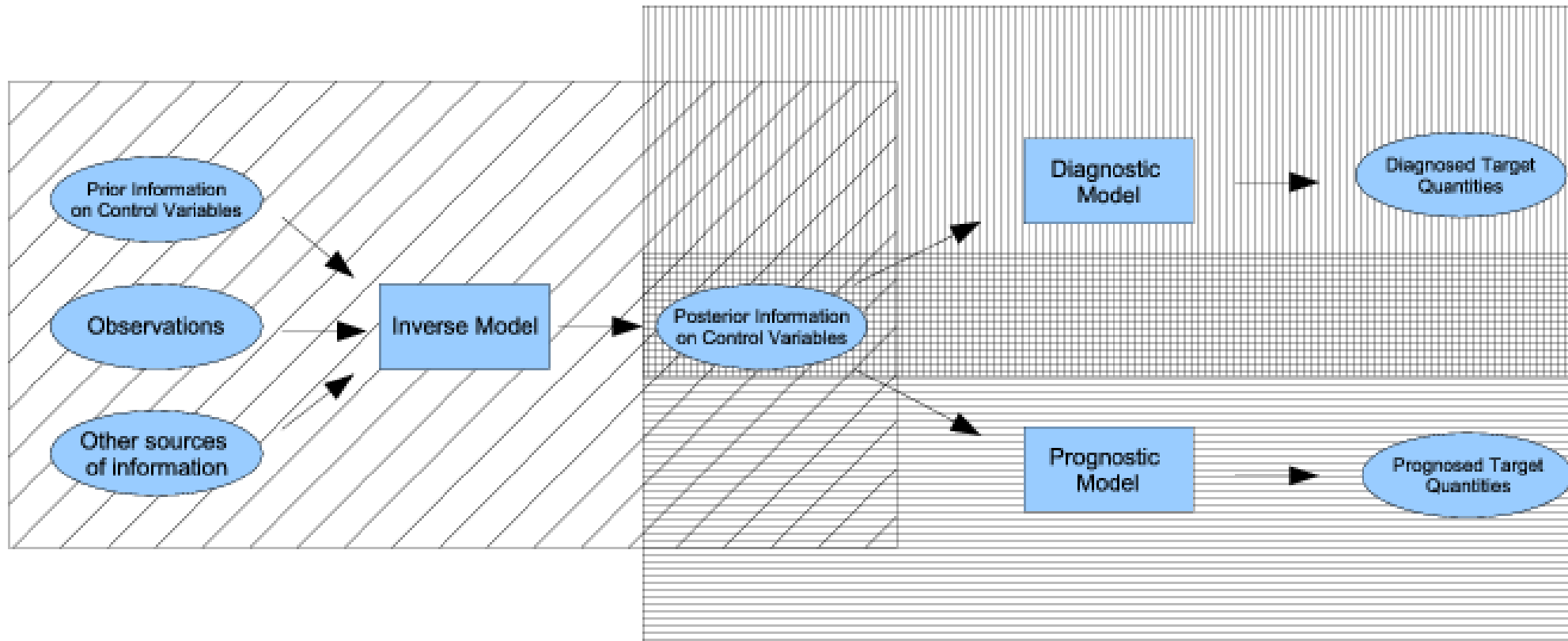
# Outline

- Setup of the model
- Functionality of the tool, simple networks
- Evaluation of larger networks
- Summary
- Next steps

# Carbon Cycle Data Assimilation System (CCDAS) Forward Modelling Chain



# CCDAS scheme



# Uncertainty calculation in 2 steps

$x$ : Parameters

$x_{pr}$ : Priors

$C_{pr}$ : Uncertainties

$M(x)$ : Model

$d$ : Observations

$C_d$ : Their uncertainties

$\sigma_{d_i}$ : Uncorrelated!

$J(x)$ : Cost function

$\frac{d^2 J(x)}{dx^2}$ : Hessian

$x_{po}$ : Posterior parameters

$C_{po}$ : Posterior uncertainties

$y(x)$ : Target quantity

$\sigma_y$ : Its uncertainty

$$J(x) = \frac{1}{2} (x - x_{pr})^T C_{pr}^{-1} (x - x_{pr}) + \frac{1}{2} \sum_{i=1,nd} \left( \frac{M_i(x) - d_i}{\sigma_{d_i}} \right)^2$$

$$\frac{d^2 J(x)}{dx^2} = C_{pr}^{-1} + \sum_{i=1,nd} \frac{1}{\sigma_{d_i}^2} \left( \frac{dM_i(x)}{dx} \frac{dM_i(x)}{dx} + \frac{d^2 M_i(x)}{dx^2} (M_i(x) - d_i) \right)$$

- Hessian independent of  $x$  for linear model
- For synthetic data use  $d = M(x)$ .
- Decomposes nicely, can precompute model contribution

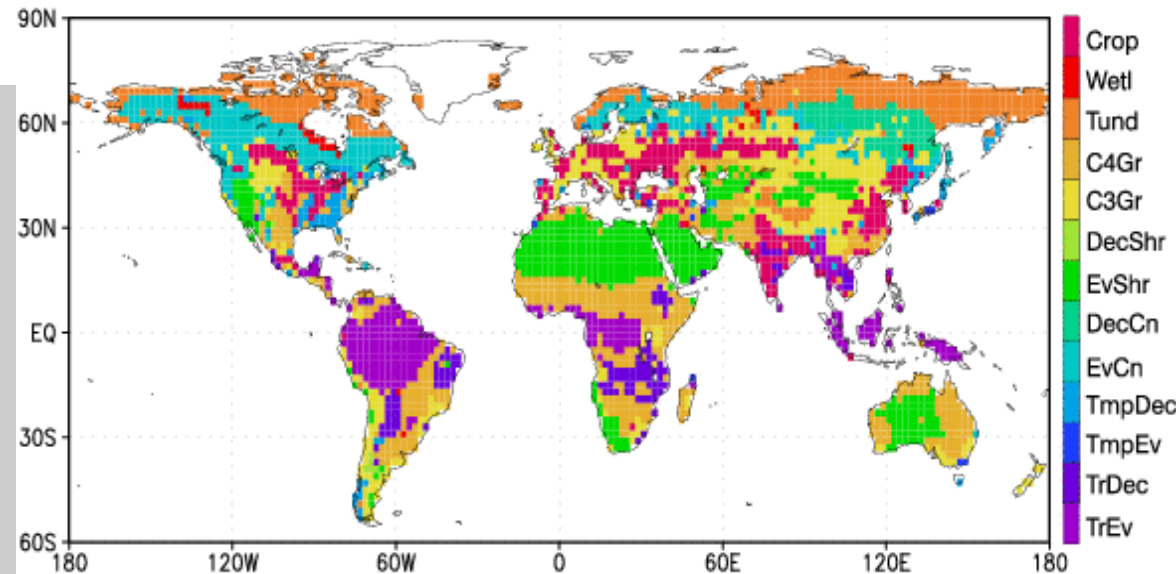
**uncertainty  
in observations  
AND model**

$$C_{po} \approx \frac{d^2 J(x_{po})^{-1}}{dx^2}$$

$$\sigma_y \approx \frac{dy(x_{po})}{dx} C_{po} \frac{dy(x_{po})}{dx}^T \approx \frac{dy(x_{po})}{dx} \frac{d^2 J(x_{po})^{-1}}{dx^2} \frac{dy(x_{po})}{dx}^T$$

# BETHY setup

- 2 by 2 degrees, global
- 13 Plant Functional Types
- 57 Process Parameters
  - 3 PFT specific
  - 17 not PFT specific
  - 1 atmospheric
- Parameter values taken from Scholze et al. (2007)
- Prior parameter uncertainties taken from Scholze et al. (2007), in the order of 25%



# BETHY's PFTs

Table 1. PFTs Defined in BETHY and Their Abbreviations

PFT Number	PFT Name	Abbreviation
1	tropical broadleaved evergreen tree	TrEv
2	tropical broadleaved deciduous tree	TrDec
3	temperate broadleaved evergreen tree	TmpEv
4	temperate broadleaved deciduous tree	TmpDec
5	evergreen coniferous tree	EvCn
6	deciduous coniferous tree	DecCn
7	evergreen shrub	EvShr
8	deciduous shrub	DecShr
→ 9	C3 grass	C3Gr
10	C4 grass	C4Gr
11	tundra vegetation	Tund
12	swamp vegetation	Wetl
13	crops	Crop

# Data Types

20 years of observations

- Flask: monthly mean atmospheric concentration
- Continuous: daily mean atmospheric concentration
- Flux: hourly mean flux value produced by a user-selected mix of up to three PFTs with a climate determined by selecting coordinates

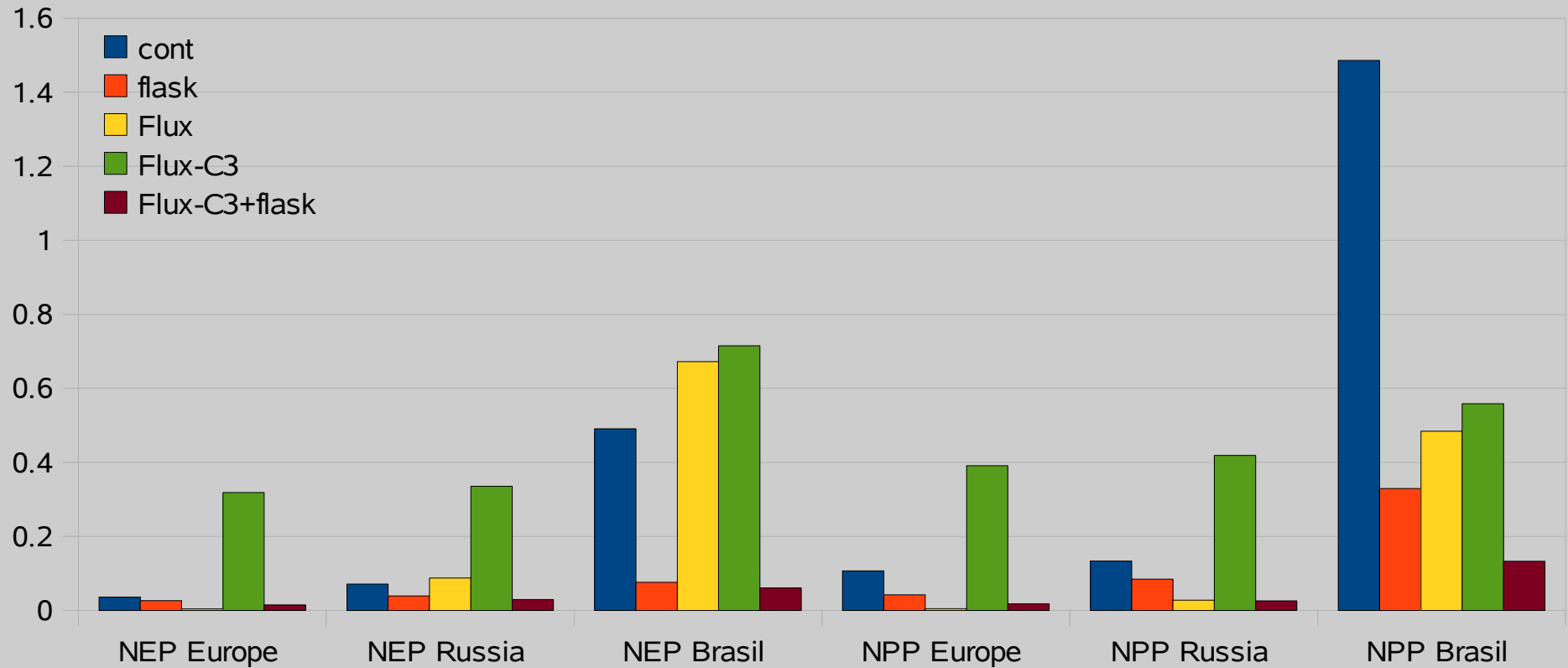
# Target quantities

Uncertainty in annual mean average over twenty years

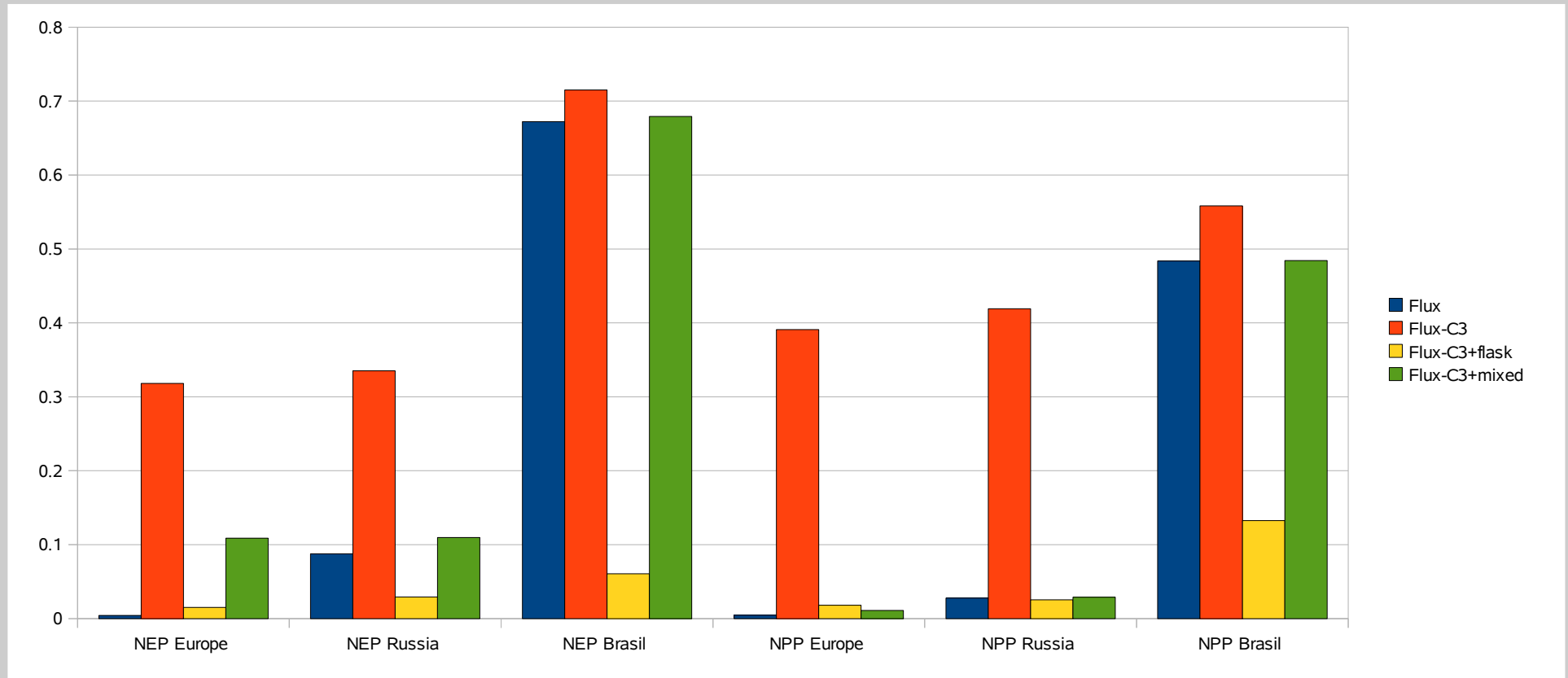
- NEP over three regions
- NPP over three regions
- NEP at 2 by 2 degree resolution (Uncertainty reduction)

Uncertainty contribution from model error in simulation of target quantity as a user-defined percentage of NPP

# Testing candidate networks



# Testing candidate networks

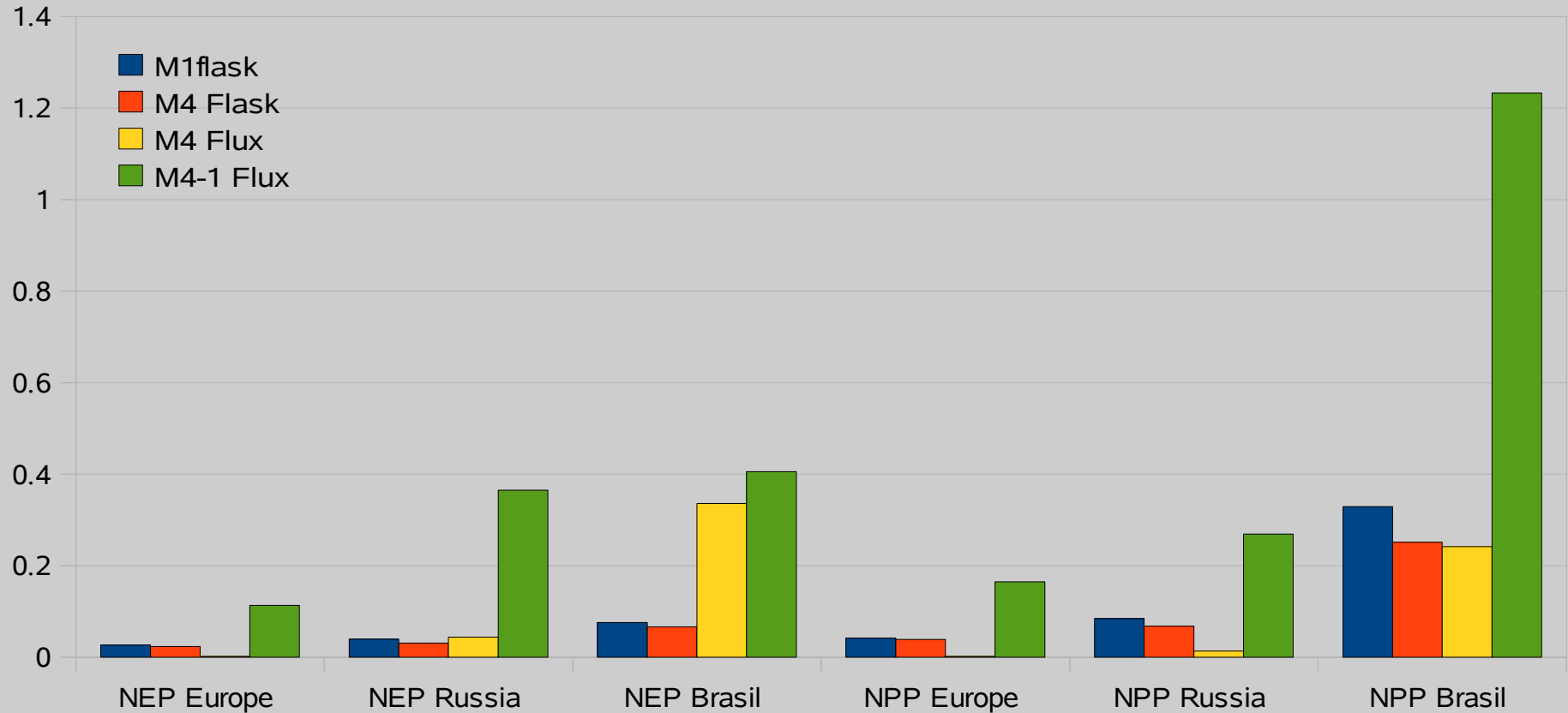


# Higher dimensional parameter space?

A simple test:

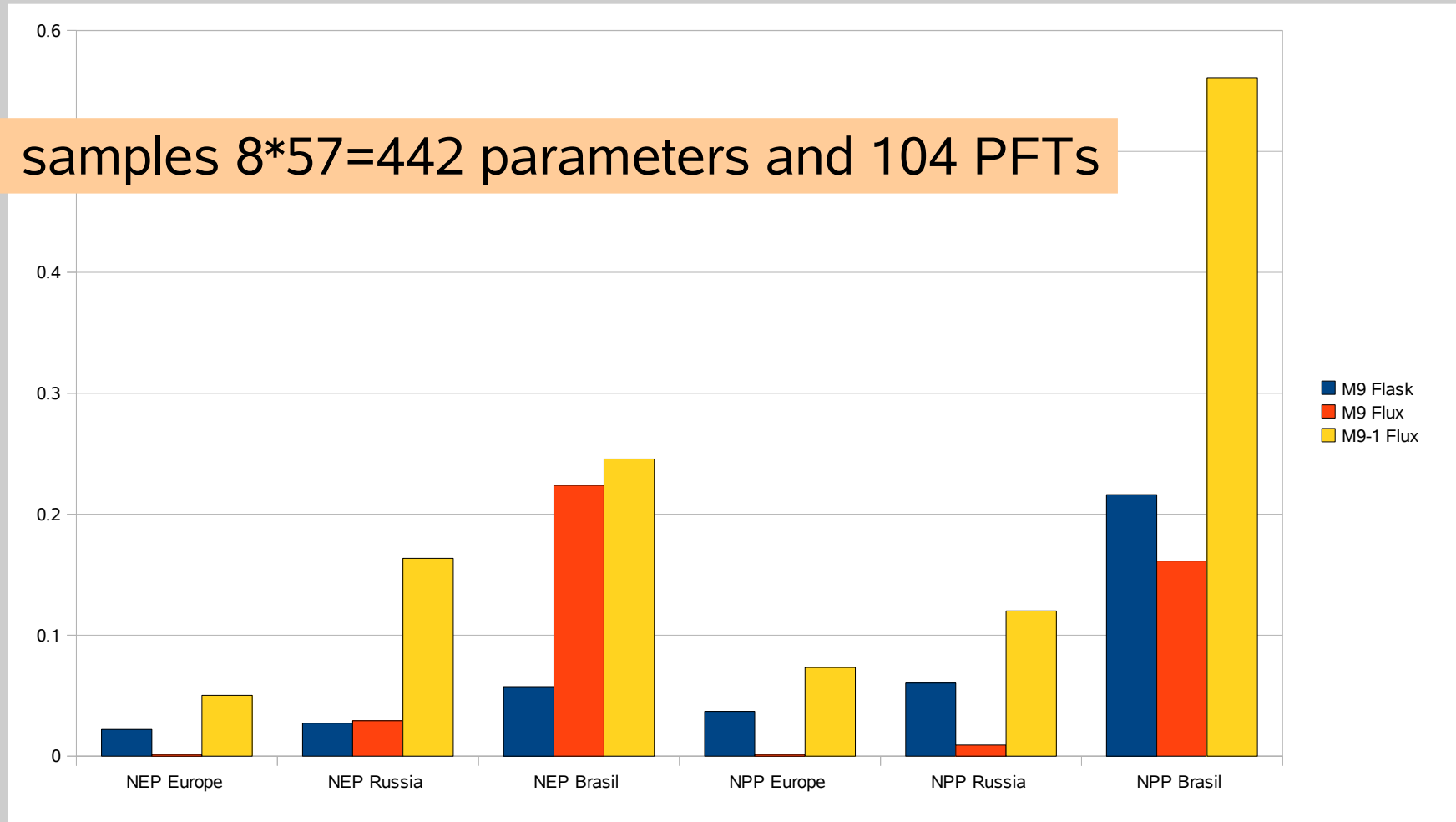
- Can add PFTs without the need to compute new Transport Jacobian, if we create complete copies that share the same locations with the original but each copy has its own parameter set
- Can then check what happens, if we leave one or more copies unsampled
- Notation:
  - M1: only original parameter set (13 PFTs)
  - M4: original + 3 copies
  - M4-1 flux: flux network with 1 parameter copy unsampled (i.e. direct sampling of  $3 \times 13 = 39$  PFTs)

# Higher dimensional parameter space



# Higher dimensional parameter space

M9-1 samples  $8 \times 57 = 442$  parameters and 104 PFTs



# Summary

- Evaluated a set of networks focusing on different data types
- Absolute value depends on details and setup of model
- Can assess relative value of flux and concentration measurements and their combinations
- Atmospheric network essential to avoid risk of incomplete sampling with flux measurements

# Next Steps

- Update Documentation
- Write down tests
- More dissemination (GEO-summit)

# Suggested work plan for RICCO (FP7 IMECC successor)

## Work plan:

- Task X.1: Extend IMECC tool by an oceanic observational data type. (DX.1: Evaluation of oceanic test network in terms of its constraint on the European carbon uptake.)
- Task X.2: Increase spatial resolution of terrestrial model over Europe to about 25 km and increase the resolution in PFT space. (DX.2: Sample calculation of regional high resolution map of flux uncertainties for test network.)
- Task X.3: Extend IMECC tool to allow evaluation of the network performance under climate change via inclusion of simulated future fluxes as additional target quantity (DX.3: Assessment of the performance of a set of test networks in terms of constraining climate change simulations.)
- Task X.4: Assessment of expected uncertainty from model error and errors in background fluxes for individual observational data types. (DX.4: Set of 2/3 dimensional uncertainty maps/fields.)
- Task X.5: Allow arbitrary ATM sampling location and height. (DX.5: Assessment of sensitivity of target uncertainties to small-scale change in ATM sampling position and height.)
- Task X.6: Extend IMECC tool by an inventory observational data type. (DX.6: Evaluation of inventory test network in terms of its constraint on the European carbon uptake.)
- Task X.7: End-to-end performance assessment of a set of potential networks. (DX.7: Integrated assessment of performance of set of Ocean+ATM+ECO networks and their complementarity.)

+ further contributions