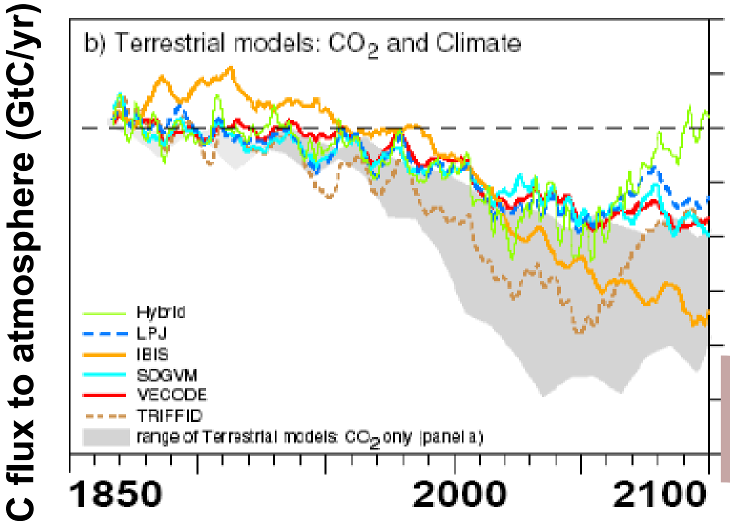
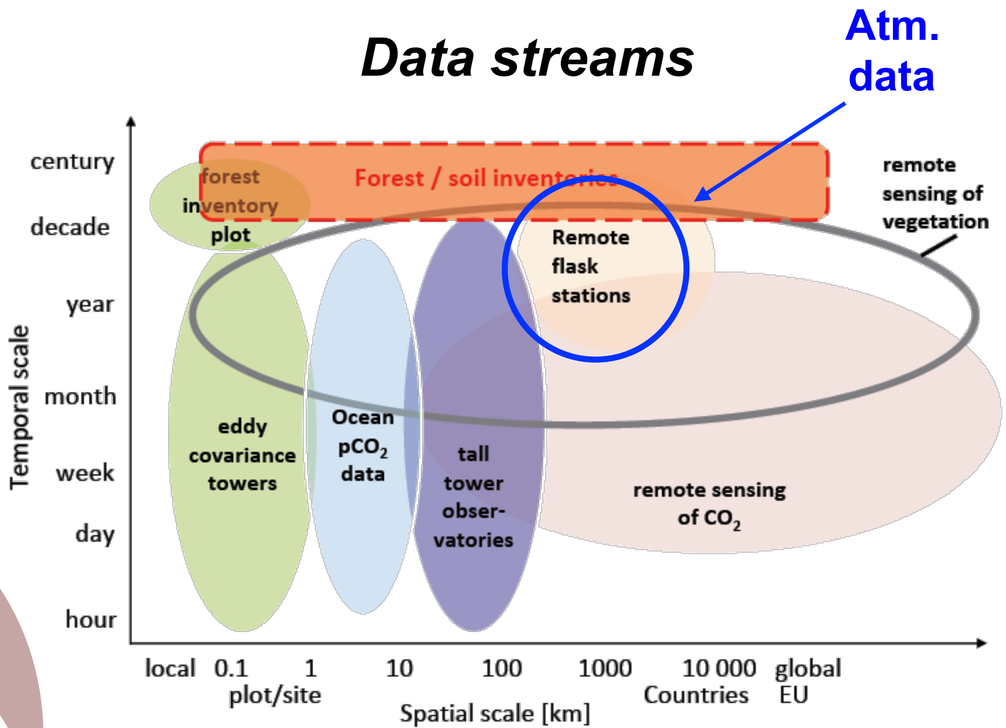
Needs for a Data Assimilation System

Large uncertainty from land to predict global C-balance (C4MIP)



Data streams



OPTIMISATION OF PARAMETERS
→ Data Assimilation

Optimized ecosystem models
➔ reduce the spread ?

Improve:

- **Uncertainty estimates**
- **C land budget estimates**
- **Future climate predictions**
- **Process understaning**

Main actors working on Data Assimilation

Philippe

Natasha

Cedric

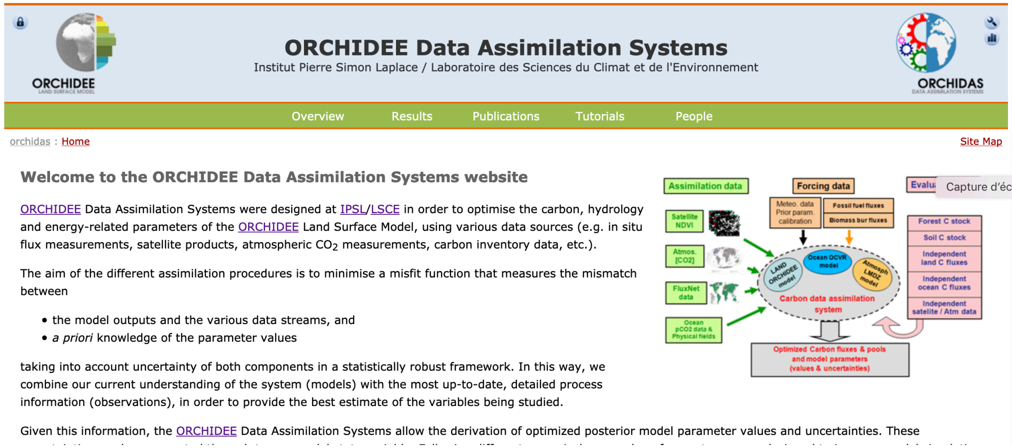
Vladislav

Pascal

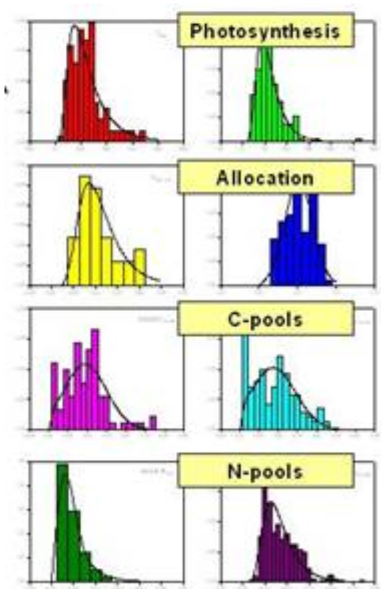
Catherine

Nina

A dedicated web site
https://orchidas.lsce.ipsl.fr/



Bayesian Calibration of process-based models



DATA

Prior pdf for the parameters (ϑ)

Likelihood of the data

Bayes' Theorem $P(\vartheta|D) = P(\vartheta)\, P(D|\vartheta) / P(D)$

Posterior pdf for the parameters

Scaling constant
($= \int P(\vartheta)\, P(D|\vartheta)\, d\vartheta$)

Formalism in the case of Gaussian errors…

Baye's theorem: $$p(\mathbf{x}|\mathbf{y}) = \frac{p(\mathbf{x}).p(\mathbf{y}|\mathbf{x})}{p(\mathbf{y})}$$

Assuming Gaussian Error statistics lead to minimize the cost function J(x) to obtain the mean of p(x|y)

$$J(\mathbf{x}) = (\mathbf{x} - \mathbf{x}_b)^{\mathrm{T}}\mathbf{B}^{-1}(\mathbf{x} - \mathbf{x}_b) + (\mathbf{H}\mathbf{x} - \mathbf{y})^{\mathrm{T}}\mathbf{R}^{-1}(\mathbf{H}\mathbf{x} - \mathbf{y})$$

x: state vector ;

xb: mean prior value of state vector

y: observation vector ;

H: linear observation operator

B / R: Background / Observation error covariance matrix

Past and Ongoing work

- **Technical / Methodological work**
  - Gradient based vs Monte-carlo optimisation method
  - Computation of Tangent Linear and Adjoint models of ORCHIDEE
  - Simultaneous vs sequential data assimilation

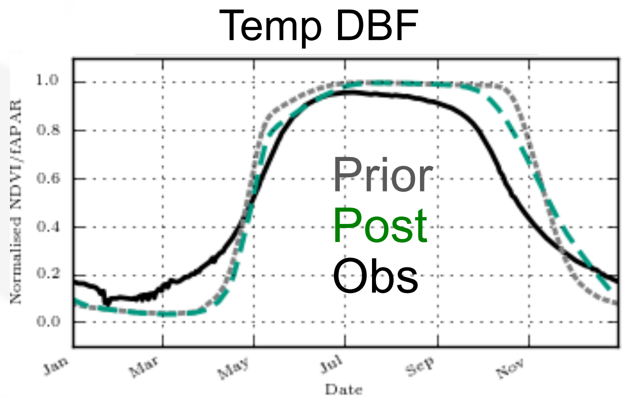
- **Scientific work**
  - **Carbon cycle focussed**
    - FluxNet data assimilation (several papers)
    - NDVI / Fluorescence DA
    - Multi-data streams including [CO2]

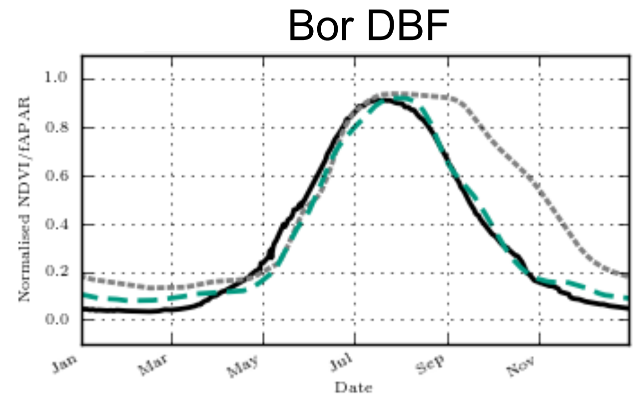
  - **Water / Energy cycle focussed**
    - Assimilation of Surface Soil moisture
    - Surface temperature downscaling

Stepwise approach (20 yr): a compromise!

Step 1:
MODIS-NDVI

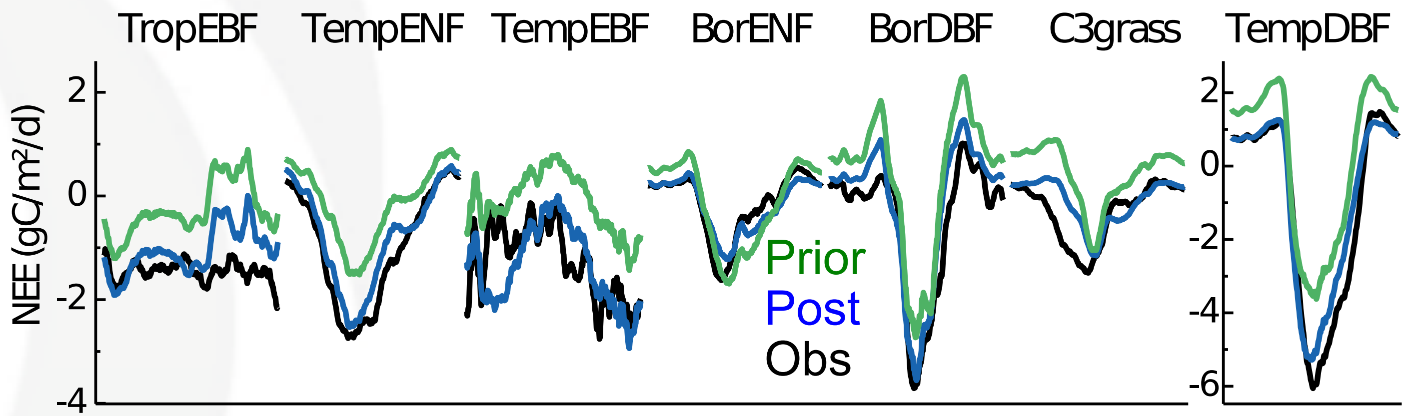
4 params /PFT





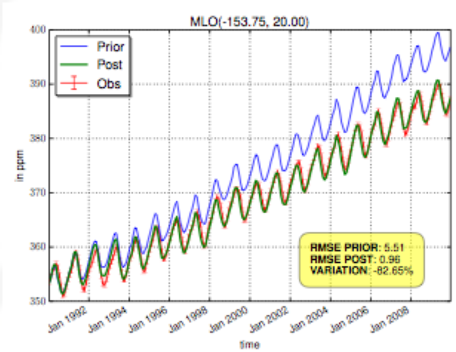
Step 2:
75 fluxnet data

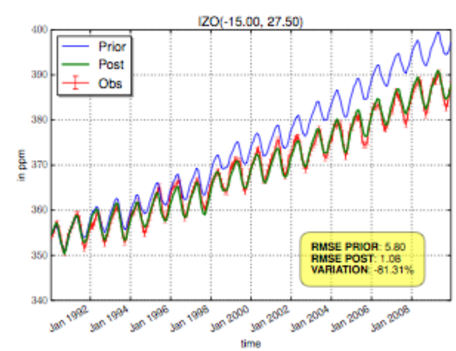
≈ 20 params /PFT



Step 3:
Atmospheric data

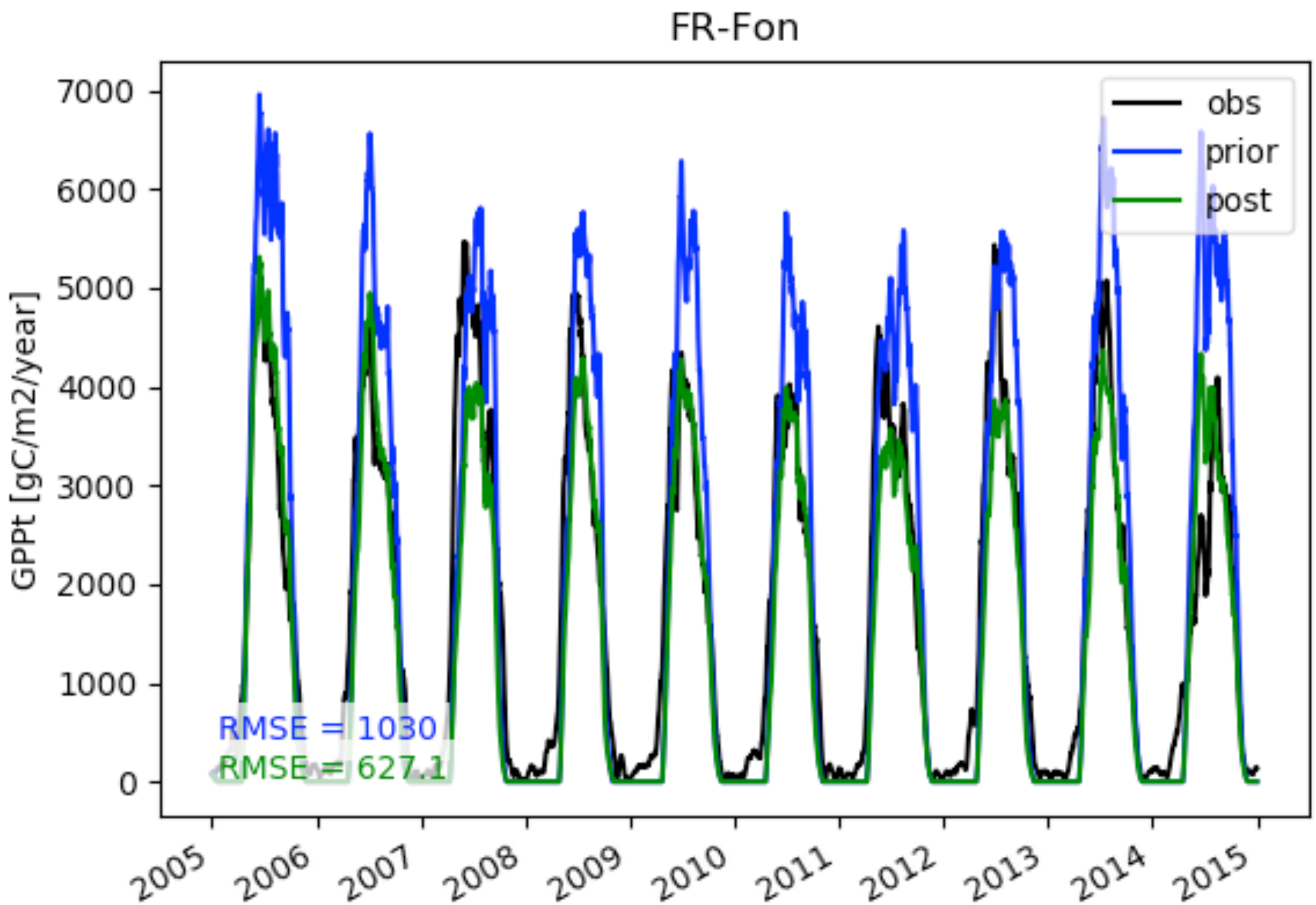
≈ 100 params total



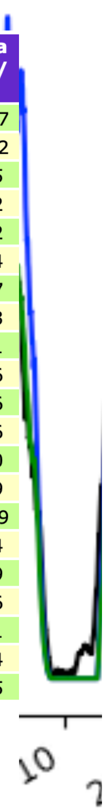


Exemple with current Trunk (CN)

➔ Optimisation against GPP / TER at Deciduous Broadleaf sites
➔ Around 20 parameters are optimised (2 cases: w/wo NUE)



Exemple with current Trunk (CN)



Optimisation including Nitrogen use efficiency param

PARAMETER	PRIOR	MIN	MAX	POST	sigma post	sigma post / post
CN_LEAF_INIT__06	29	22	35	33.33	4.89	0.1467
CN_LEAF_MAX__06	45	36	54	48.04	7.17	0.1492
CN_LEAF_MIN__06	16	11	23	16.18	2.29	0.145
EXT_COEFF__06	0.5	0.3	1	0.8882	0.0814	0.092
EXT_COEFF_N__06	0.15	0.13	0.18	0.1586	0.0194	0.122
FCN_ROOT__06	1	0.6	1.2	0.6464	0.19	0.294
FCN_WOOD__06	0.087	0.06	0.12	0.06719	0.0213	0.317
FRAC_GROWTHRESP__06	0.28	0.2	0.36	0.2085	0.0194	0.093
K_LATOSA_MAX__06	5000	4000	6000	4101	538	0.131
K_ROOT__06	4e-07	3e-07	5e-07	3.886e-07	7.61-08	0.196
K_SAP__06	0.003	0.002	0.004	0.002086	6.59e-04	0.316
LEAFAGECRIT__06	180	90	240	118.8	4.3	0.036
LEAFFALL__06	10	8	12	11.89	1.55	0.130
NUE_OPT__06	33	23	43	24.04	1.66	0,069
RATIO_K_LATOSA__06	0.8	0.7	1	0.8506	0.119	0,1399
RECYCLE_LEAF__06	0.5	0.4	0.6	0.4964	0.0795	0,154
RECYCLE_ROOT__06	0.2	0.1	0.3	0.2386	0.0785	0,329
SLAINIT__06	0.03	0.02	0.04	0.03604	2.04e-04	0,056
SOIL_Q10	0.69	0	1.1	1.093	0.0334	0,031
VMAX_UPTAKE__1	3	2	4	3.541	0.792	0,224
VMAX_UPTAKE__2	3	2	4	2.262	0.757	0,335
COST	**7304**			**2498 (0.3419)**		
COST_GPPt	**3652**			**1355 (0.3709)**		
COST_rap	**3652**			**1126 (0.3084)**		

Optimisation without Nitrogen use efficiency param

PARAMETER	PRIOR	MIN	MAX	POST	sigma post	sigma post / post
CN_LEAF_INIT__06	29	22	35	33.05	4.44	0.134
CN_LEAF_MAX__06	45	36	54	45.17	7.17	0.159
CN_LEAF_MIN__06	16	11	23	22.12	2.02	0.0913
EXT_COEFF__06	0.5	0.3	1	0.3878	0.0253	0.065
EXT_COEFF_N__06	0.15	0.13	0.18	0.1686	0.0194	0.115
FCN_ROOT__06	1	0.6	1.2	0.8022	0.203	0.253
FCN_WOOD__06	0.087	0.06	0.12	0.09283	0.0234	0.252
FRAC_GROWTHRESP__06	0.28	0.2	0.36	0.2074	0.0156	0.075
K_LATOSA_MAX__06	5000	4000	6000	4050	392	0.097
K_ROOT__06	4e-07	3e-07	5e-07	4.476e-07	7.03e-08	0.157
K_SAP__06	0.003	0.002	0.004	0.002651	6.76e-04	0.255
LEAFAGECRIT__06	180	90	240	124.4	5.85	0.045
LEAFFALL__06	10	8	12	10.57	1.49	0.141
RATIO_K_LATOSA__06	0.8	0.7	1	0.8717	0.119	0.137
RECYCLE_LEAF__06	0.5	0.4	0.6	0.597	0.0798	0.134
RECYCLE_ROOT__06	0.2	0.1	0.3	0.2362	0.0794	0.336
SLAINIT__06	0.03	0.02	0.04	0.02617	2.28e-03	0.087
SOIL_Q10	0.69	0	1.1	0.9013	0.0318	0.035
VMAX_UPTAKE__1	3	2	4	3.623	0.8	0.221
VMAX_UPTAKE__2	3	2	4	2.357	0.791	0.336
COST	**7304**			**2239 (0.3066)**		
COST_GPPt	**3652**			**1140 (0.3121)**		
COST_rap	**3652**			**1088 (0.2978)**		

Some take home messages

- Model development should include to a certain extend parameter calibration (DA)

- Definition of prior parameter physical range / uncertainties is crucial

- Be careful about equifinality / overfitting / …
(see next presentation by Natasha on multi-constraints)

- Adjoint model of ORCHIDEE will help doing DA