



Applied Geodata Science I

Session 3

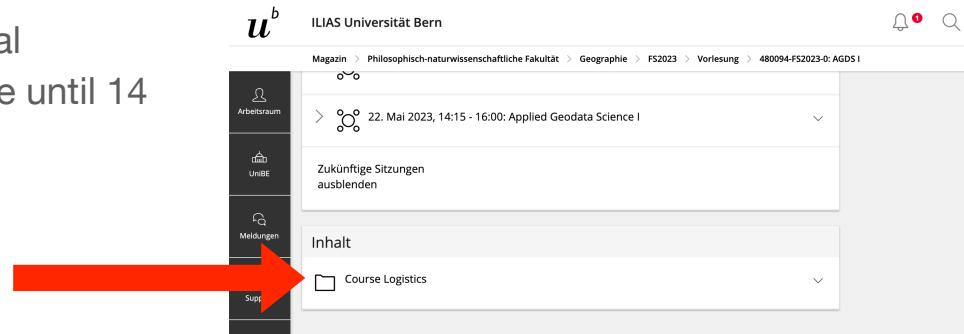
Prof. Dr. Benjamin Stocker
Spring semester 2023

Updated info on course logistics

- On ILIAS
- AGDS I is required for the Proseminar in Applied Geodata Science, held in the autumn semester after AGDS I.
- The course is not formally “creditable” (German: anrechenbar) towards the Master studies in Geography. Requests for crediting can be made and will be handled on an individual basis.
- Master students in Climate Sciences can credit AGDS I as Elective Module.
- Definite course registrations have to be made until 15.03.2023.
- Registrations for the exam (in the form of the Final Report, see separate document) have to be made until 14 days before the last session (22.05.2023).

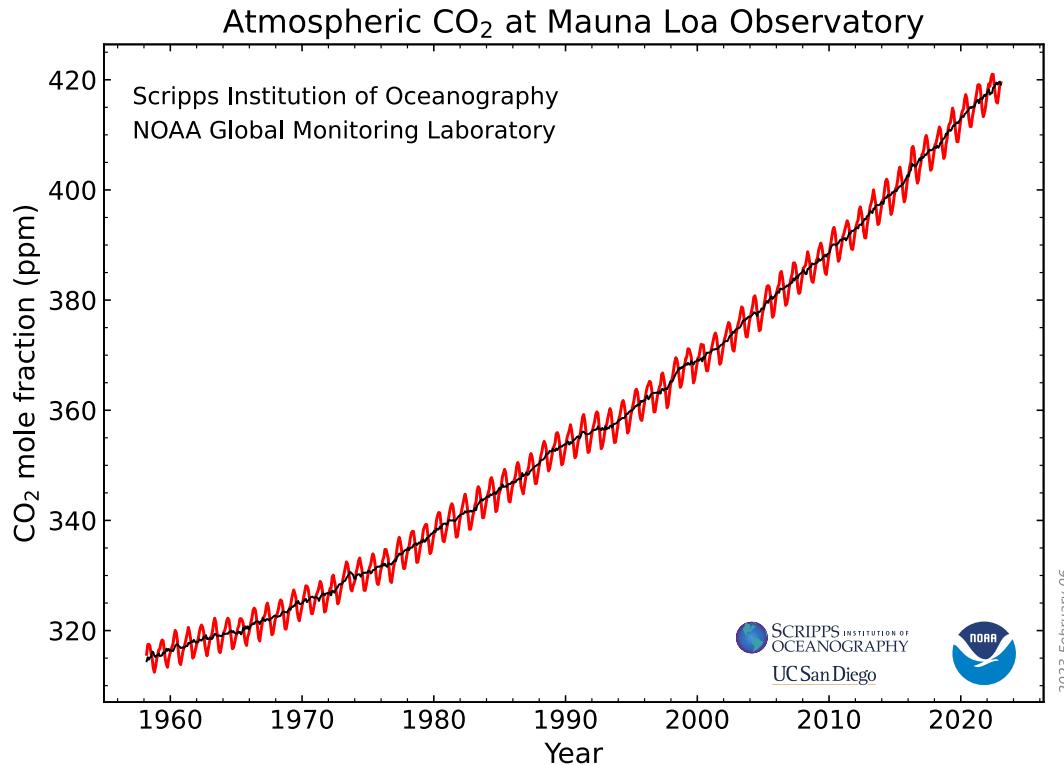
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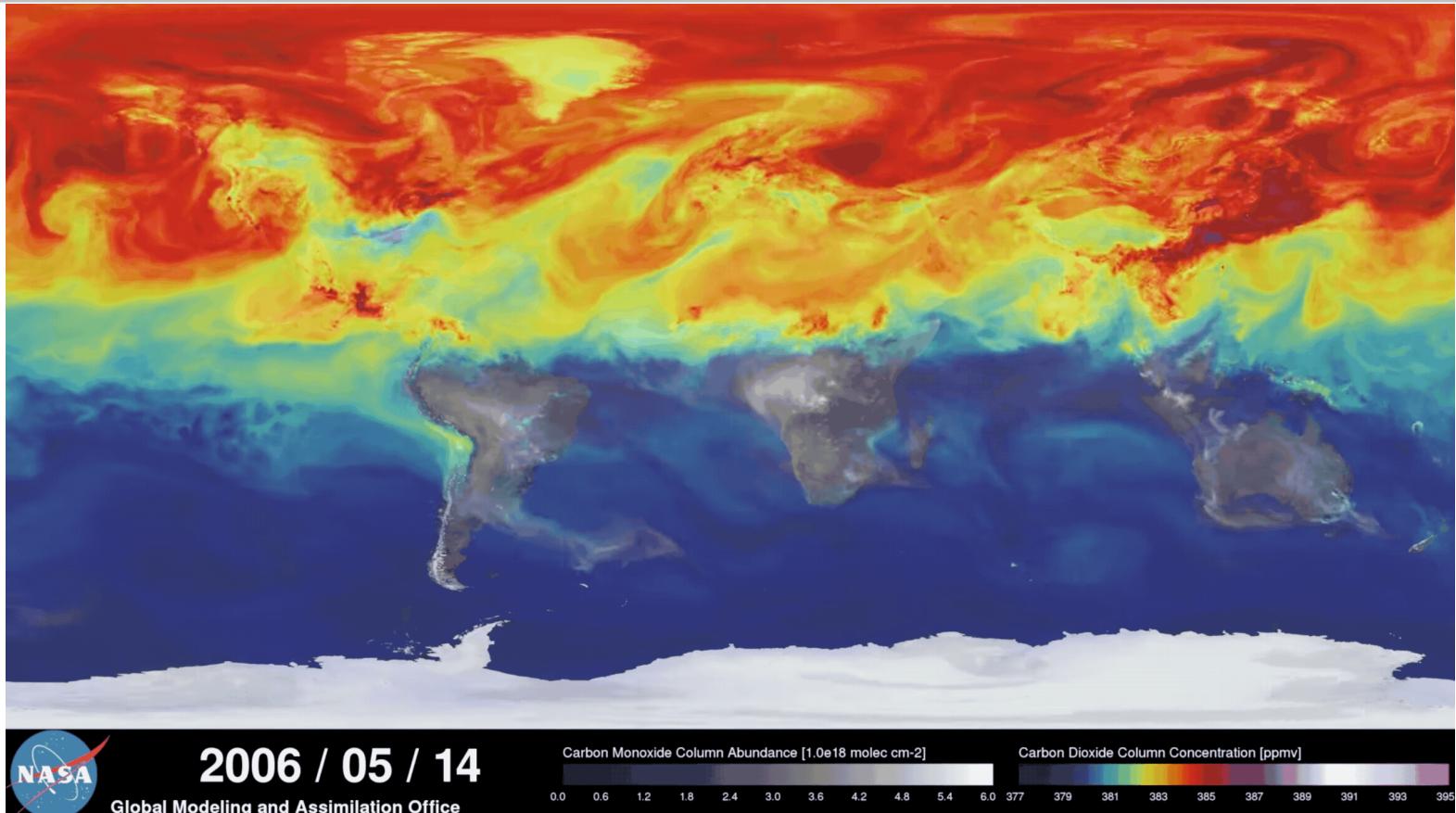


The screenshot shows the ILIAS course logistics page for 'Applied Geodata Science I'. At the top right, there is a navigation bar with links to Magazin, Philosophisch-naturwissenschaftliche Fakultät, Geographie, FS2023, Vorlesung, and 480094-FS2023-0: AGDS I. On the left, a sidebar has icons for Arbeitsraum, UniBE, Meldungen, and Supp. A large red arrow points from the bottom left towards the 'Course Logistics' section in the main content area. The main content area displays a list of future sessions: '22. Mai 2023, 14:15 - 16:00: Applied Geodata Science I'. Below this, there is a link to 'Zukünftige Sitzungen ausblenden'. At the bottom of the content area, there is a section titled 'Inhalt' with a link to 'Course Logistics'.

Atmospheric CO₂ concentration

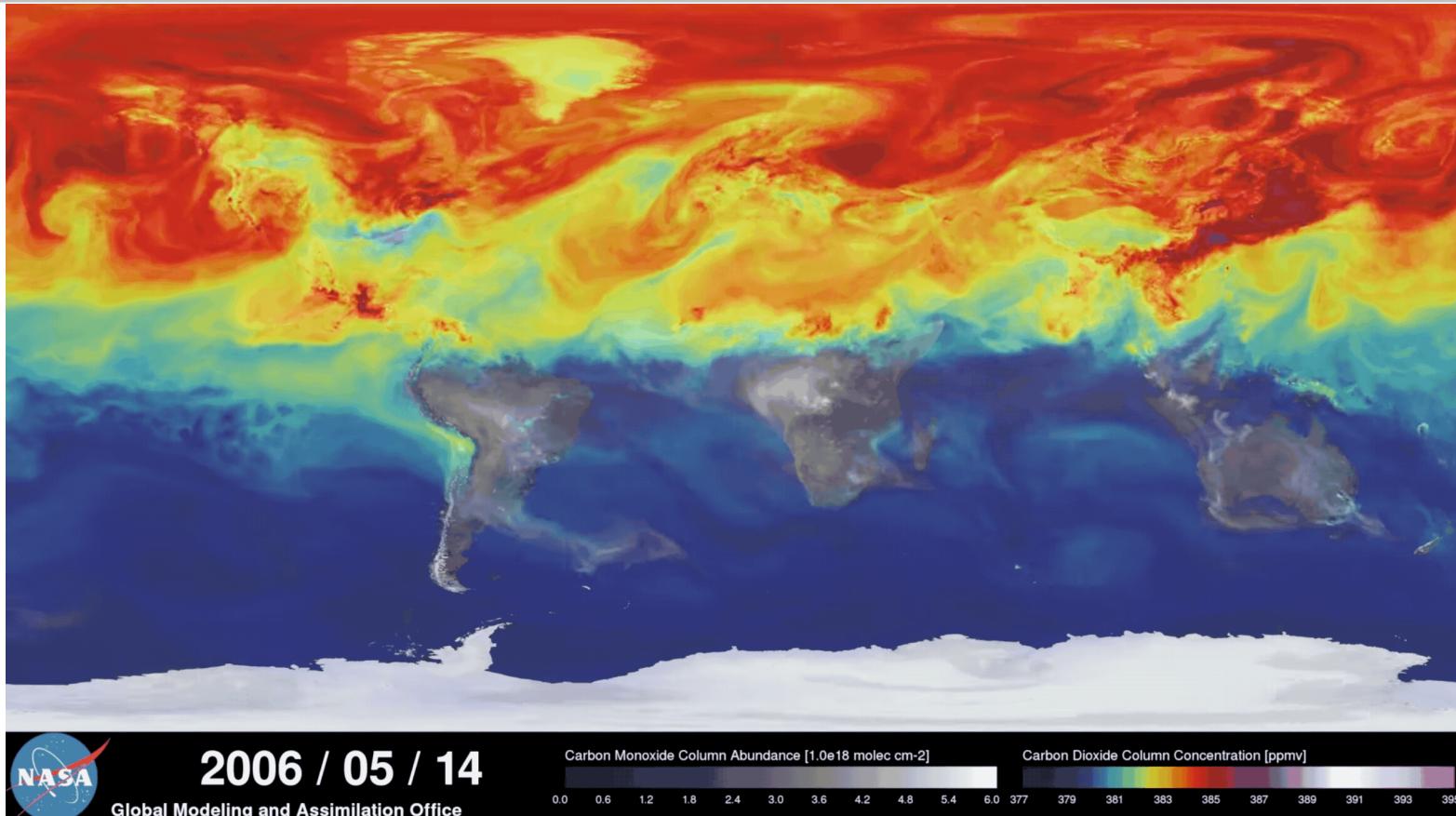


Atmospheric CO₂ concentration



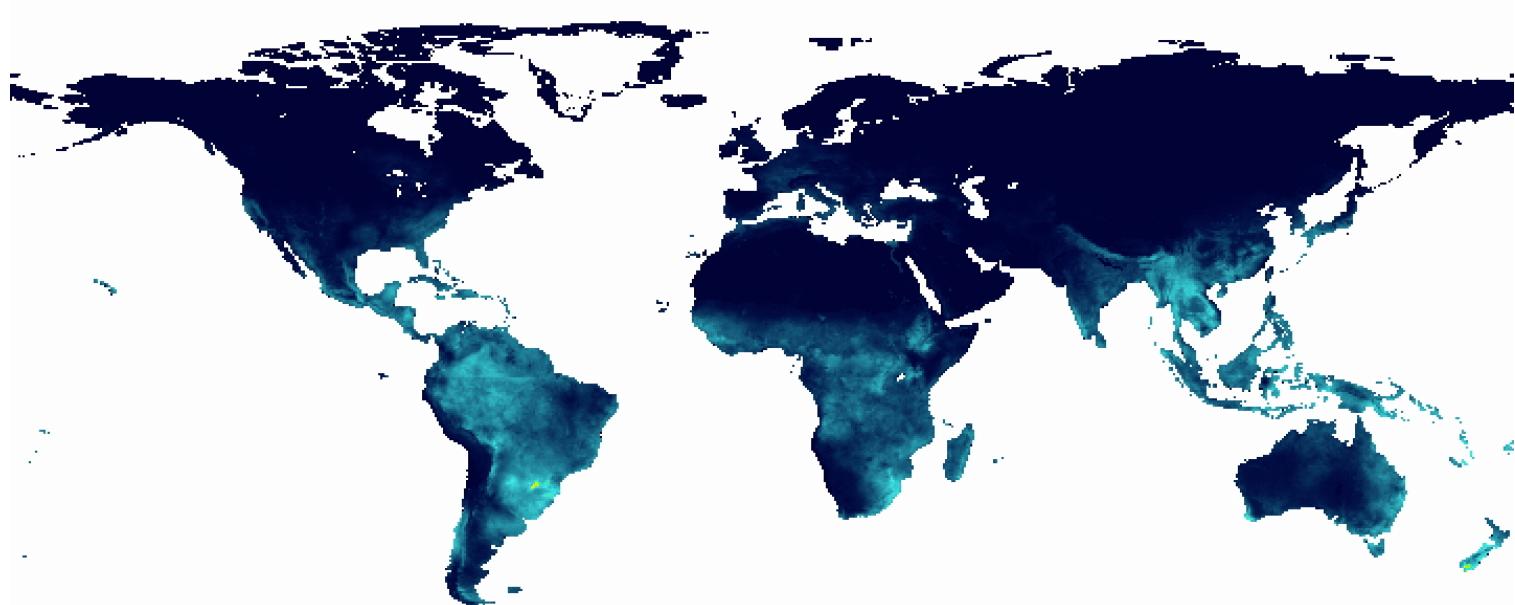
Source: NASA (<https://www.youtube.com/watch?v=x1SgmFa0r04>)

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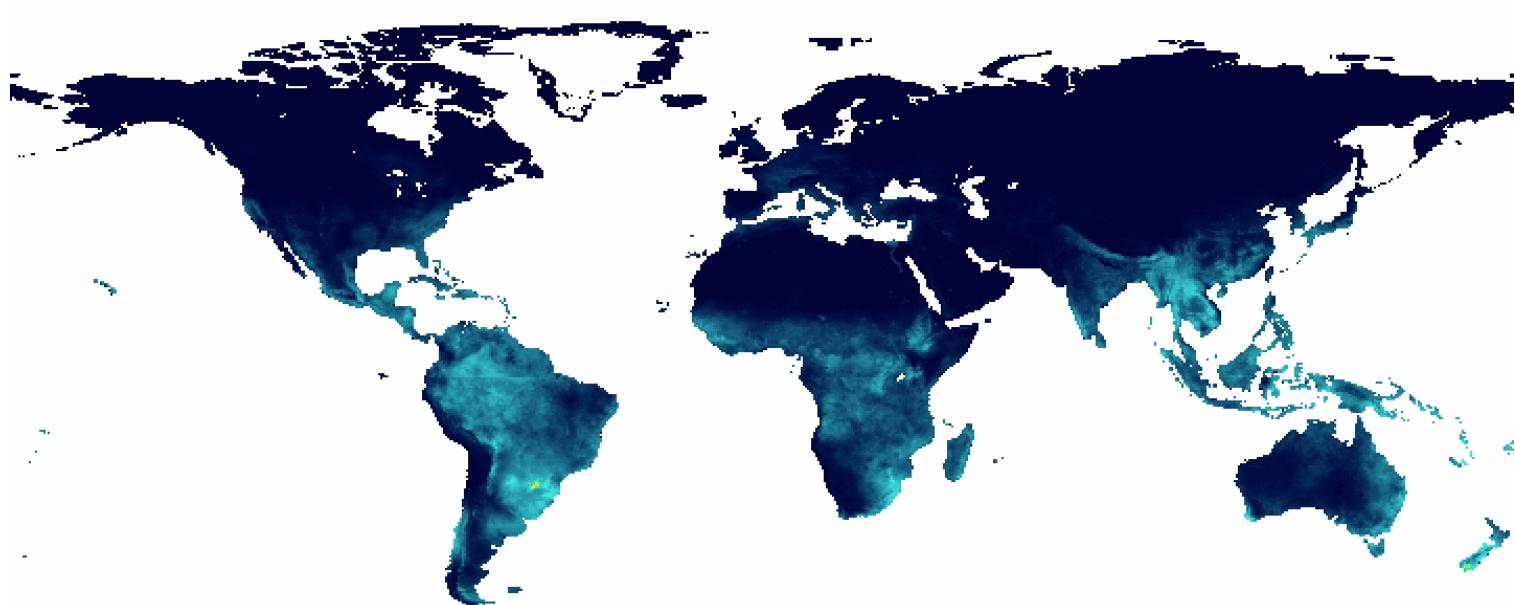
Seasonality in gross primary production



Stocker et al., 2020 GMD



Seasonality in gross primary production

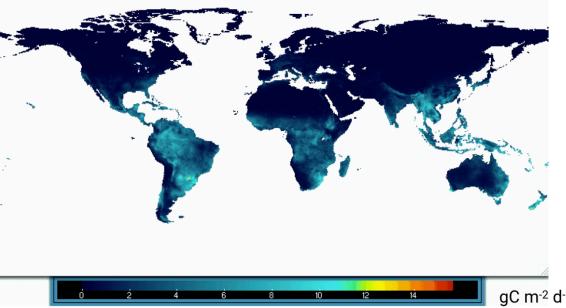


Stocker et al., 2020 GMD



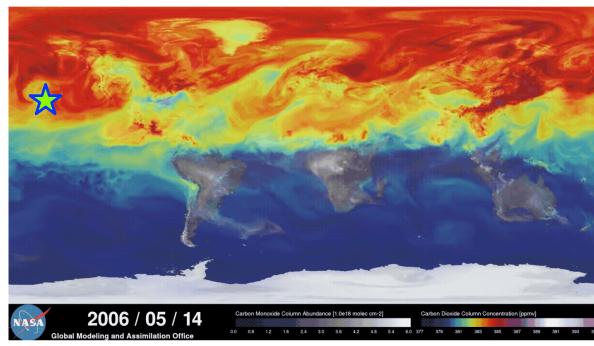
Breathing of the Earth

Photosynthetic CO₂ assimilation

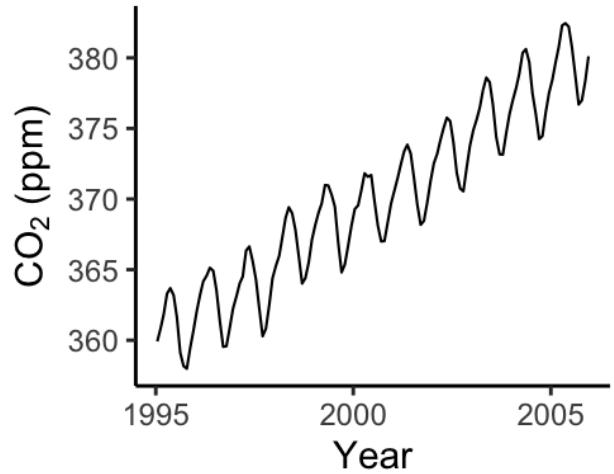


Stocker et al., 2020 GMD

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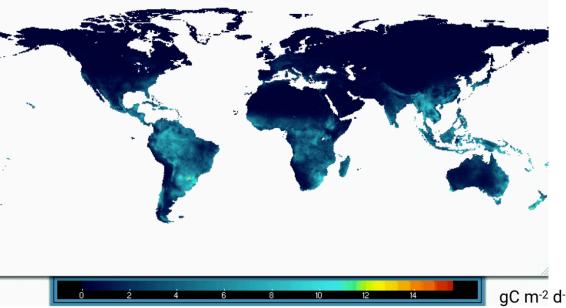
CO₂ concentration at Mauna Loa



Keeling et al., 1976 Tellus
Thoning et al., 1989 JGR

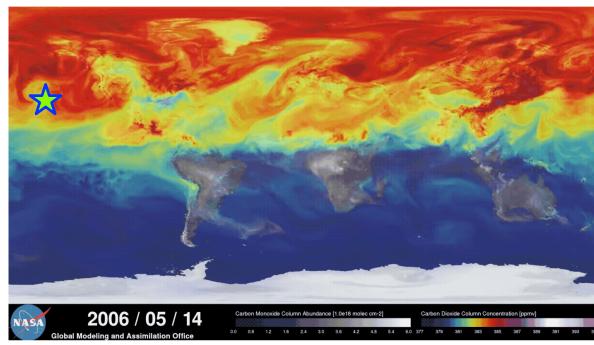
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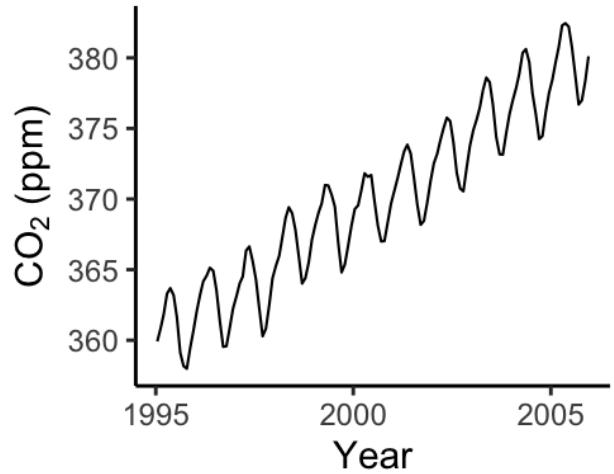


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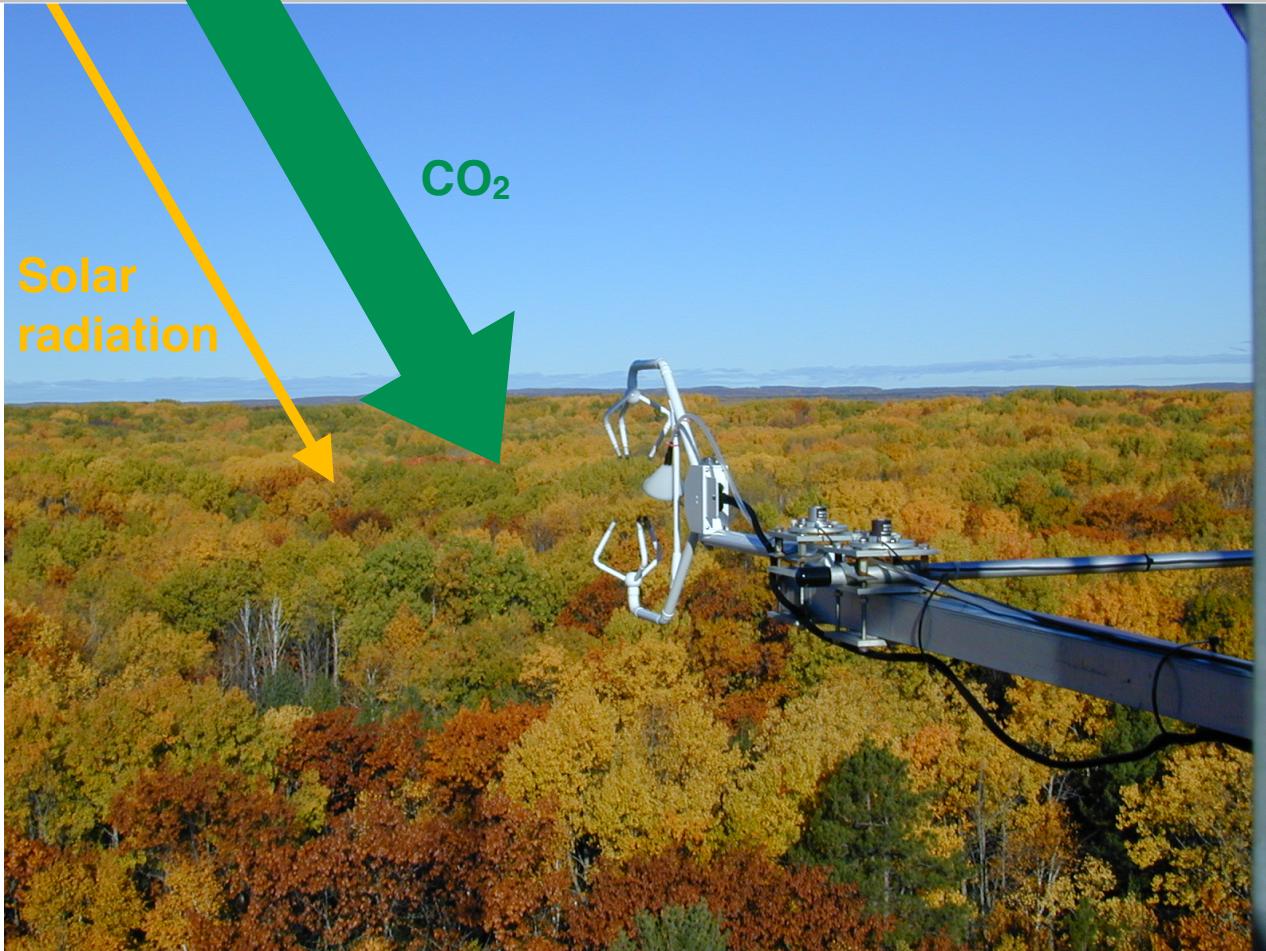


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Thoning et al., 1989 JGR

Breathing of ecosystems: Day



Breathing of ecosystems: Day



Breathing of ecosystems: Night

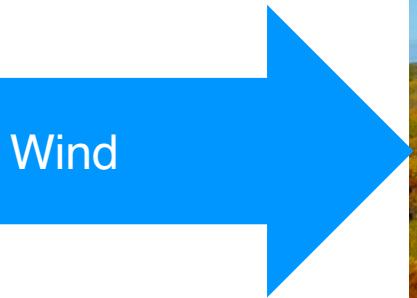


No solar radiation

Land-atmosphere gas exchange through eddies



Land-atmosphere gas exchange through eddies



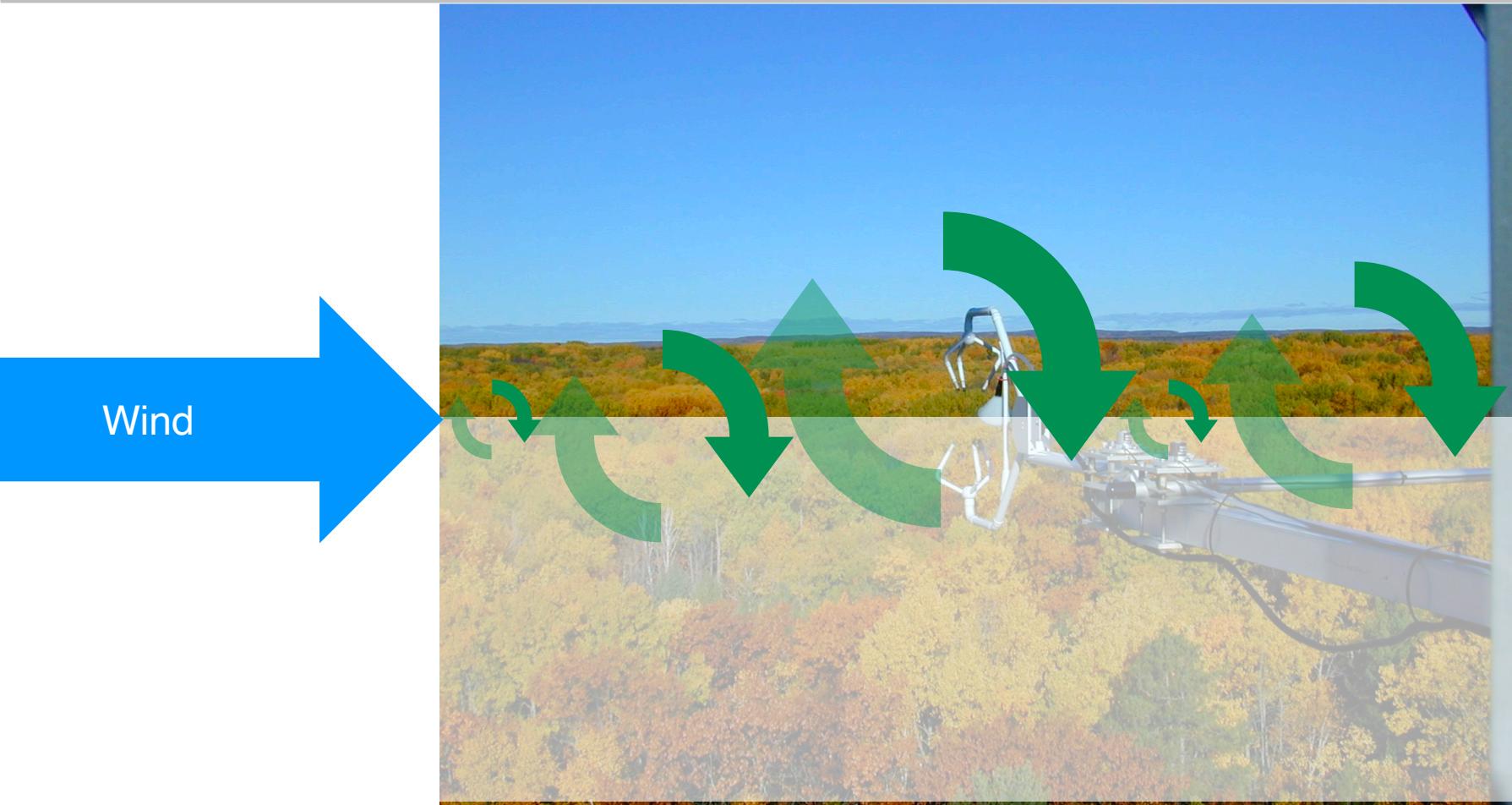
Land-atmosphere gas exchange through eddies



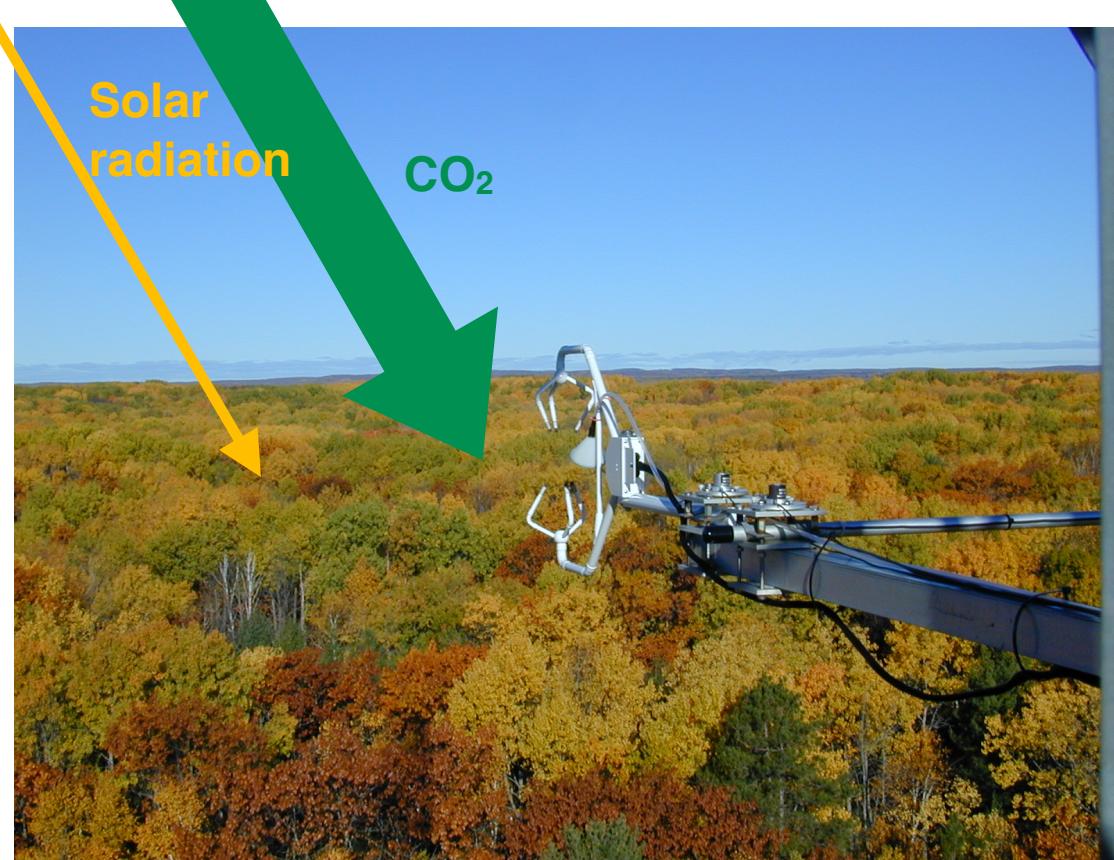
Land-atmosphere gas exchange through eddies



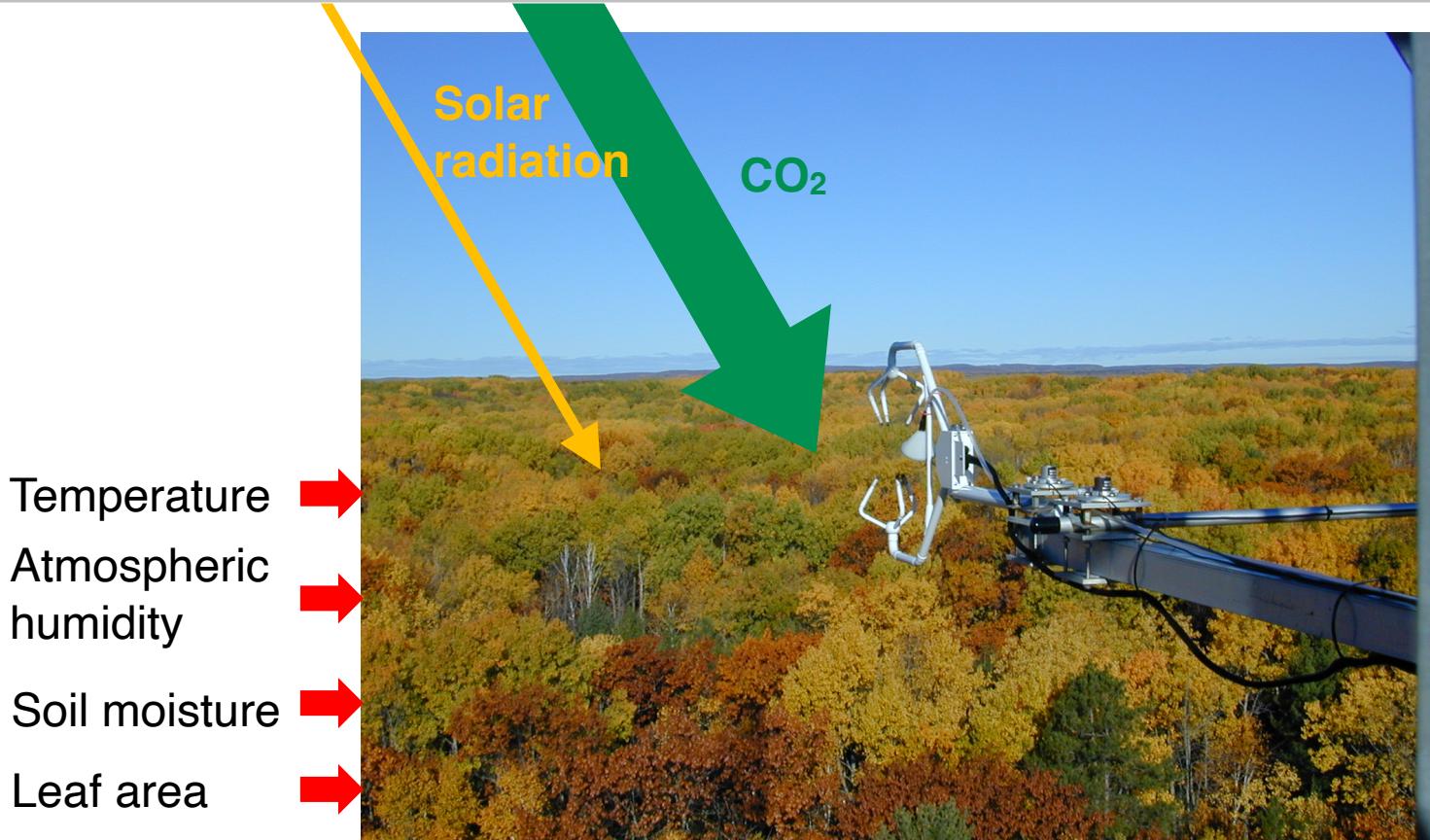
Eddies and CO₂ transport



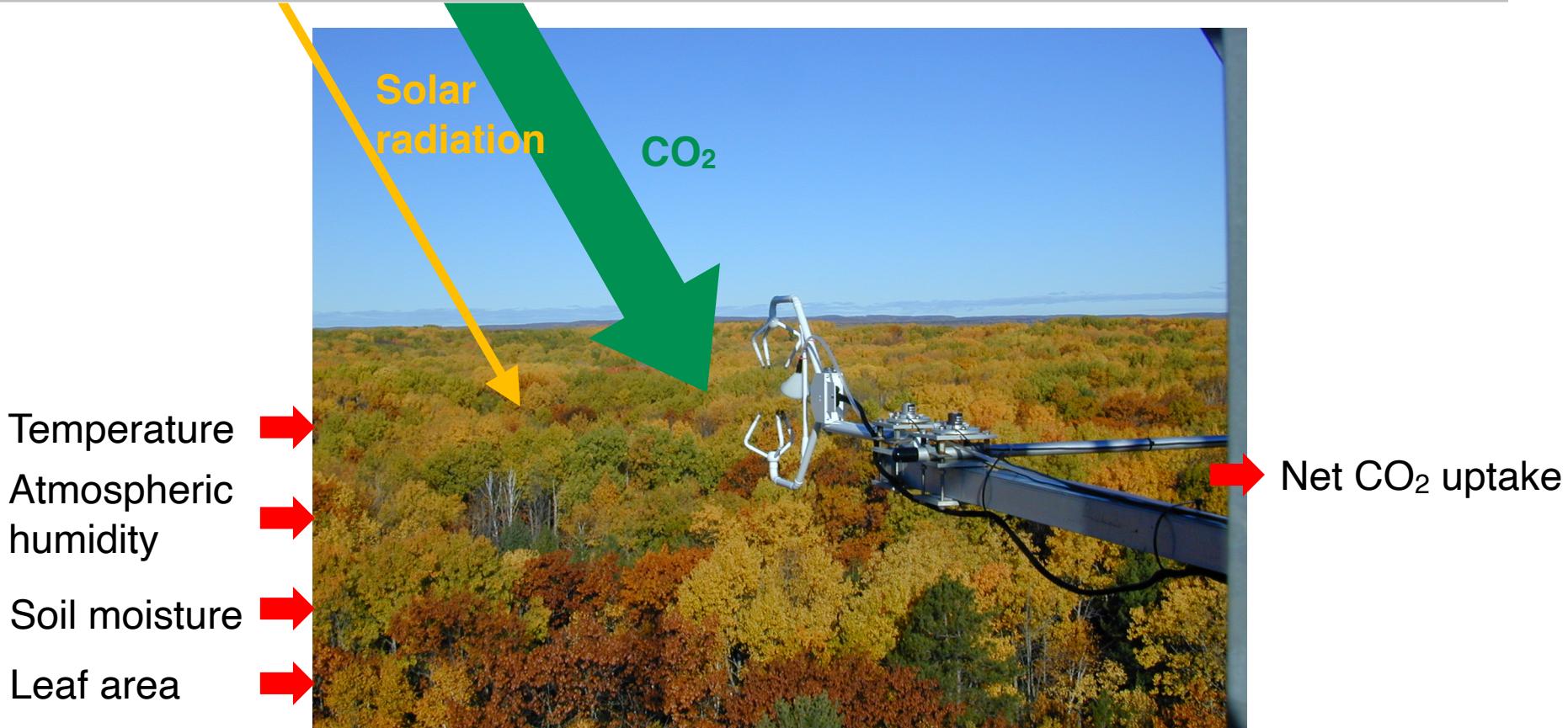
Breathing of ecosystems



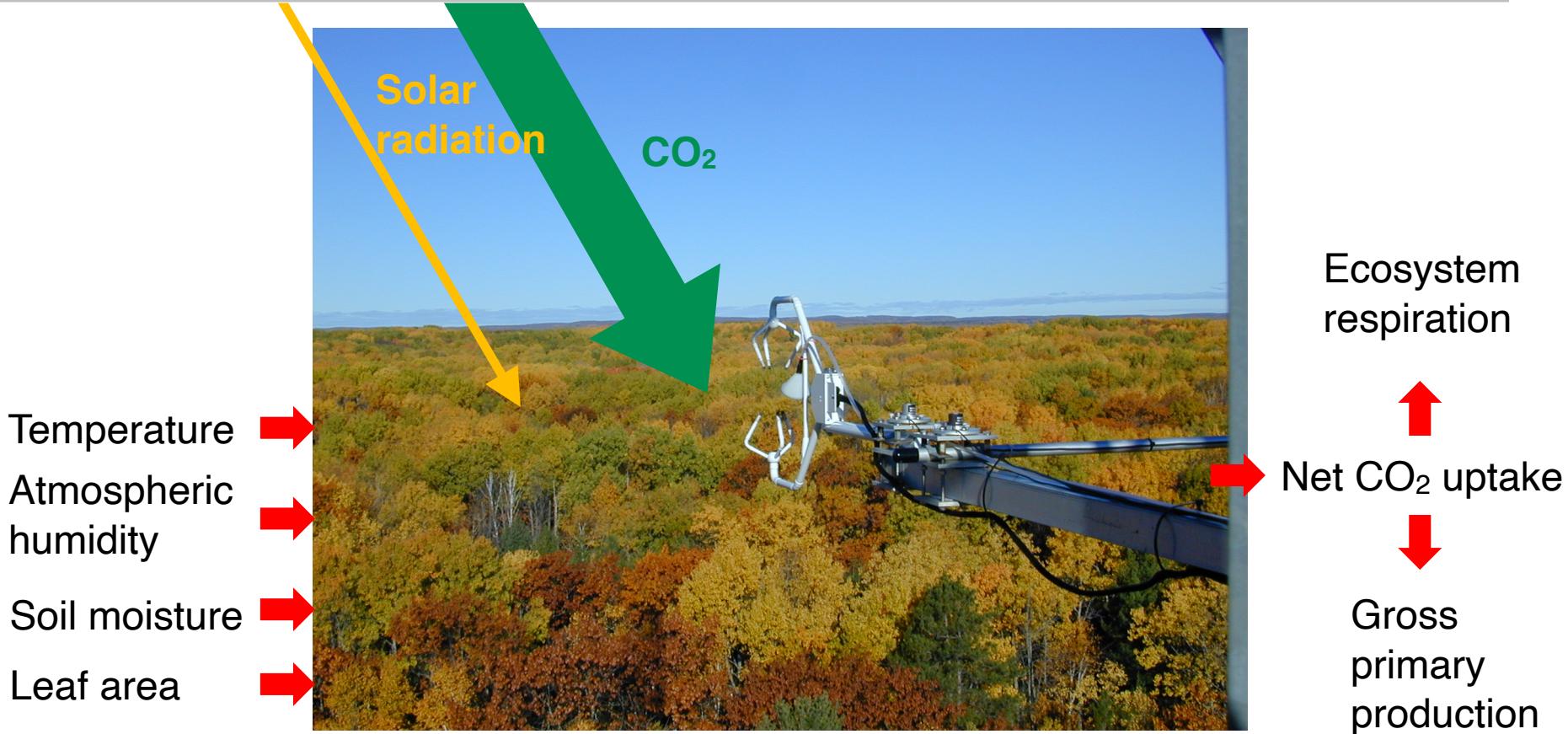
Breathing of ecosystems



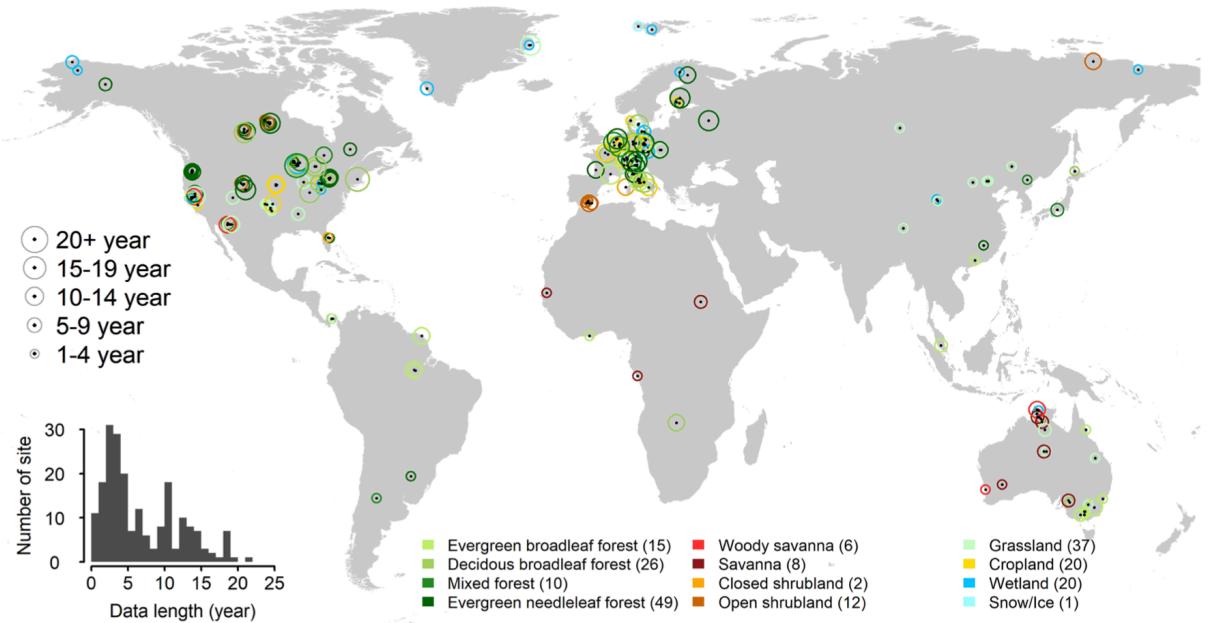
Breathing of ecosystems



Breathing of ecosystems



The FLUXNET network



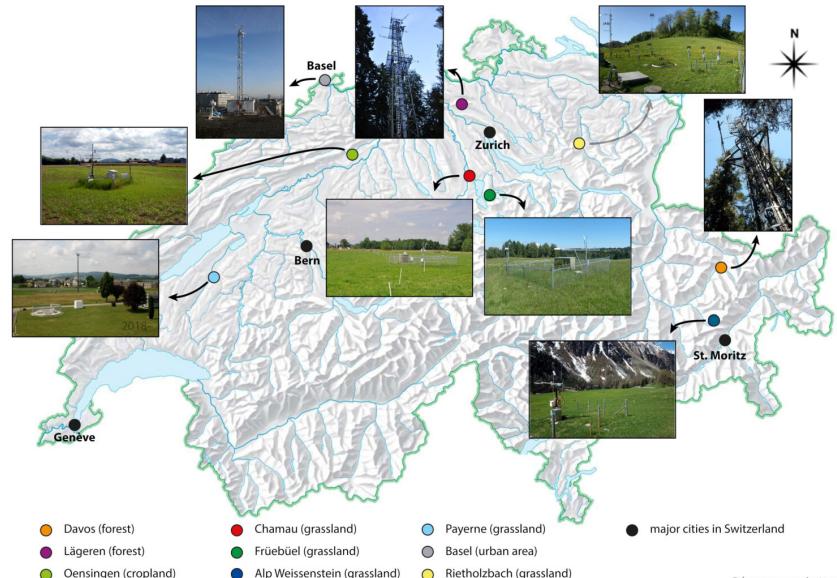




Image Markus Staudinger

Lägern CH-Lae

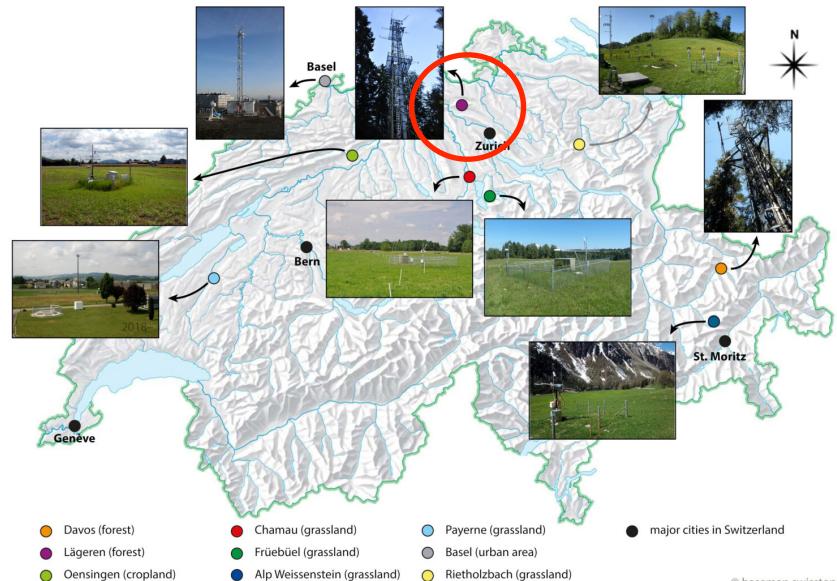




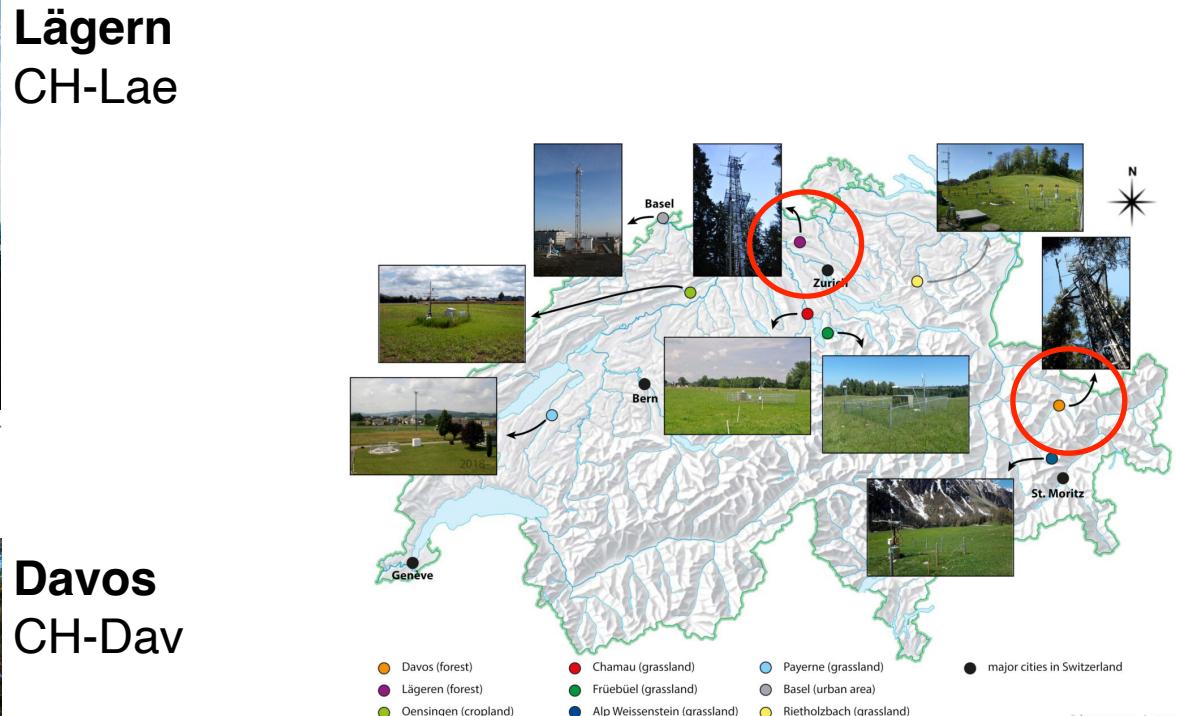
Image Markus Staudinger

Lägern CH-Lae



Image Lukas Hörtnagl

Davos CH-Dav



Variables in a FLUXNET-standard dataset

www.nature.com/scientificdata

SCIENTIFIC DATA



OPEN

The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data

Gilberto Pastorello *et al.**

Variables in a FLUXNET-standard dataset

www.nature.com/scientificdata/

SCIENTIFIC DATA

Check for updates

OPEN

The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data

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DATA DESCRIPTOR

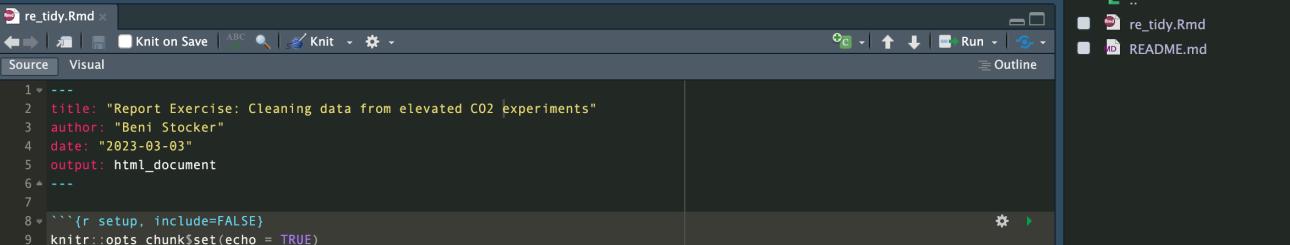
- `TIMESTAMP_START` : Hour and day of the start of the measurement period for which the respective row's data are representative. Provided in a format of “YYYYMMDDhhmm”.
- `TIMESTAMP_END` : Hour and day of the end of the measurement period for which the respective row's data are representative. Provided in a format of “YYYYMMDDhhmm”.
- `TA_*` ($^{\circ}\text{C}$): Air temperature.
- `SW_IN_*` (W m^{-2}): Shortwave incoming radiation
- `LW_IN_*` (W m^{-2}): Longwave incoming radiation
- `VPD_*` (hPa): Vapor pressure deficit (the difference between actual and saturation water vapor pressure)
- `PA_*` (kPa): Atmospheric pressure
- `P_*` (mm): Precipitation
- `WS_*` (m s^{-1}): Wind speed
- `SWC_*` (%): Volumetric soil water content
- `GPP_*` ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$): Gross primary production (the ecosystem-level gross CO_2 uptake flux driven by photosynthesis)
- `*_QC` : Quality control information for the variable `*`. Important for us: `NEE_*_QC` is the quality control information for the net ecosystem CO_2 exchange flux (`NEE_*`) and for GPP derived from the corresponding NEE estimate (`GPP_*`). 0 = measured, 1 = good quality gap-filled, 2 = medium, 3 = poor.

Report Exercise

```
type `contributors()` for more information and  
'citation()' on how to cite R or R packages in publications.
```

```
Type 'demo()' for some demos, 'help()' for on-line help, or  
'help.start()' for an HTML browser interface to help.  
Type 'q()' to quit R.
```

```
> |
```



The screenshot shows the RStudio interface with the following details:

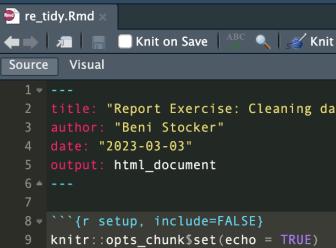
- Title Bar:** Shows the file name "re_tidy.Rmd".
- Toolbar:** Includes "Knit on Save", "ABC", "Knit", and other standard RStudio icons.
- Source Tab:** Active tab, displaying R code in a syntax-highlighted editor.
- Code Content:**

```
1 ---
2   title: "Report Exercise: Cleaning data from elevated CO2 experiments"
3   author: "Beni Stocker"
4   date: "2023-03-03"
5   output: html_document
6 ---
7
8 ````{r setup, include=FALSE}
9 knitr::opts_chunk$set(echo = TRUE)
```
- Right Panel:** Shows the "Files" view with the project structure:
 - Home > agds_report_benist
 - Name
 - ..
 - re_tidy.Rmd
 - README.md

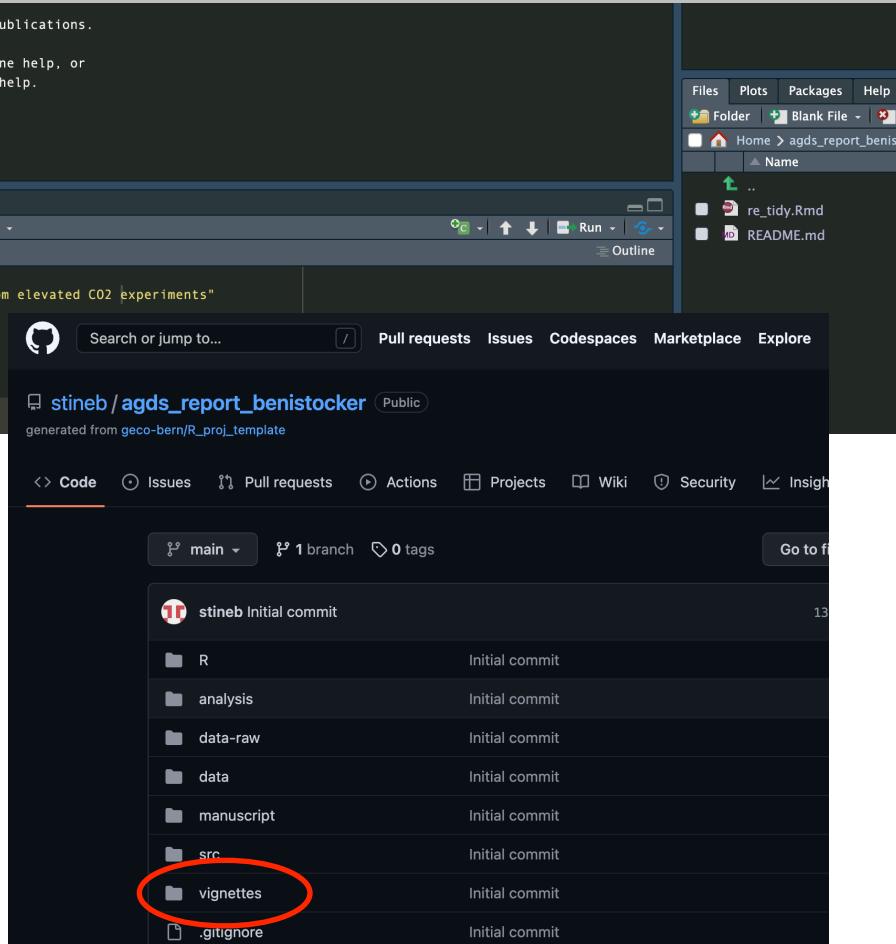
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```
re_tidy.Rmd x  
Knit on Save ABC Knit   
Source Visual  
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```



stineb/agds_report_benistocker Public
generated from geco-bern/R_proj_template

<> Code Issues Pull requests Actions Projects Wiki Security Insights

main 1 branch 0 tags

stineb Initial commit	13
R	Initial commit
analysis	Initial commit
data-raw	Initial commit
data	Initial commit
manuscript	Initial commit
src	Initial commit
vignettes	Initial commit
.gitignore	Initial commit

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Knit on Save ABC Knit ... Source Visual
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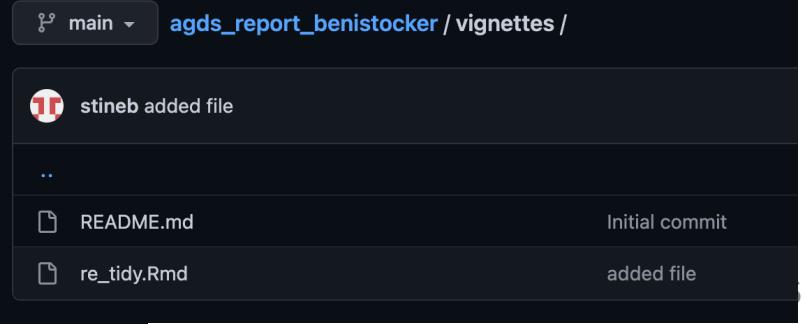
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main 1 branch 0 tags

stineb Initial commit

- R Initial commit
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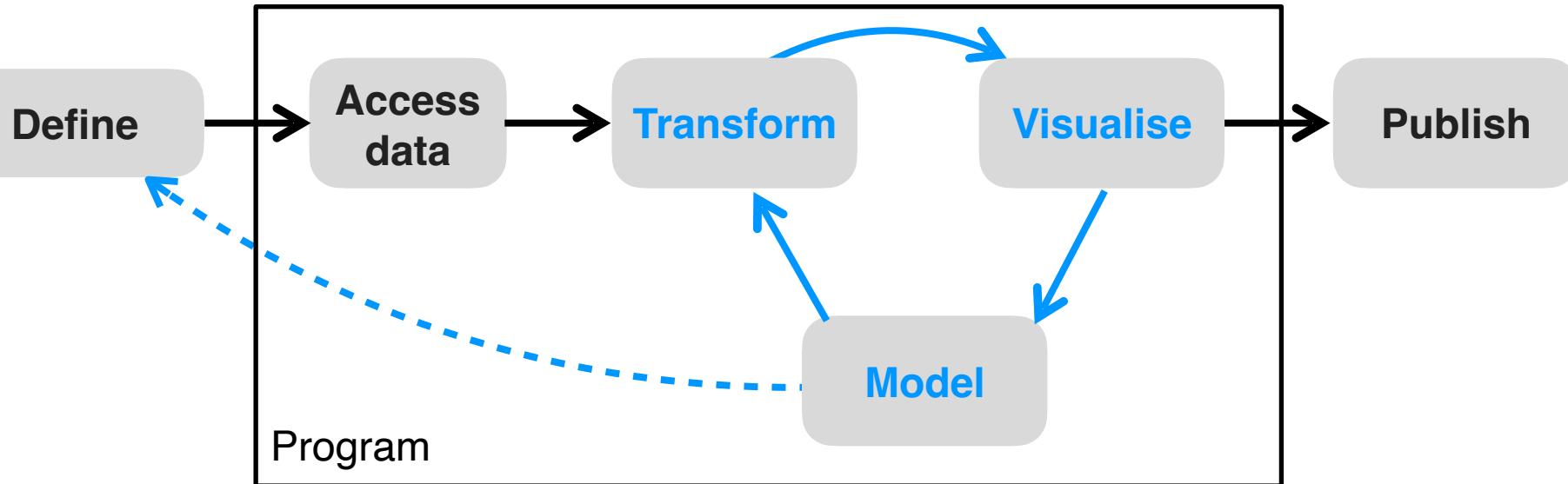


Report Exercise: Criteria

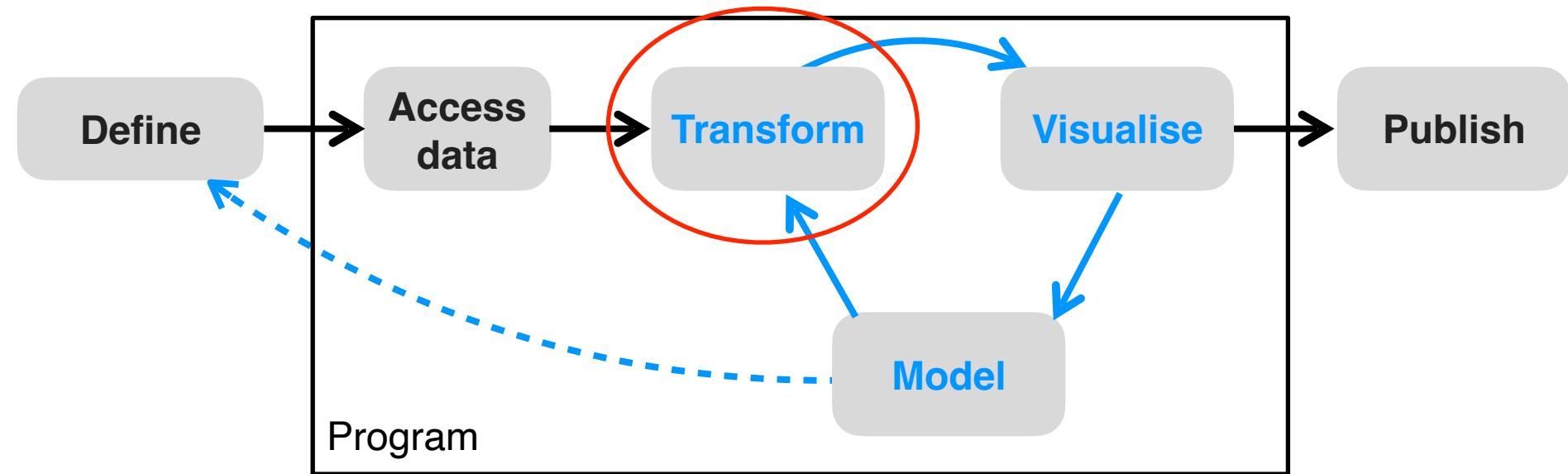


File on ILIAS

The data science workflow



The data science workflow



Chapters 1 and 2

- Getting ready with R
- Data frames

Overview

Chapters 1 and 2

- Getting ready with R
- Data frames

nrow()



ncol() →

```
> hdf
# A tibble: 192,864 x 20
  TIMESTAMP_START   TIMESTAMP_END     TA_F SW_IN_F LW_IN_F VPD_F PA_F P_F WS_F CO2_F_MDS PPFD_IN
  <dttm>           <dttm>      <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
1 2004-01-01 00:00:00 2004-01-01 00:30:00    NA     NA   304.    NA  93.3  0.014    NA     NA   NA
2 2004-01-01 00:30:00 2004-01-01 01:00:00    NA     NA   304.    NA  93.3  0.014    NA     NA   NA
3 2004-01-01 01:00:00 2004-01-01 01:30:00    NA     NA   281.    NA  93.3  0       NA     NA   NA
4 2004-01-01 01:30:00 2004-01-01 02:00:00    NA     NA   281.    NA  93.3  0       NA     NA   NA
5 2004-01-01 02:00:00 2004-01-01 02:30:00    NA     NA   281.    NA  93.3  0       NA     NA   NA
6 2004-01-01 02:30:00 2004-01-01 03:00:00    NA     NA   281.    NA  93.3  0       NA     NA   NA
7 2004-01-01 03:00:00 2004-01-01 03:30:00    NA     NA   281.    NA  93.2  0       NA     NA   NA
8 2004-01-01 03:30:00 2004-01-01 04:00:00    NA     NA   281.    NA  93.2  0       NA     NA   NA
9 2004-01-01 04:00:00 2004-01-01 04:30:00    NA     NA   264.    NA  93.2  0       NA     NA   NA
10 2004-01-01 04:30:00 2004-01-01 05:00:00    NA     NA   264.    NA  93.2  0       NA     NA  NA
# ... with 192,854 more rows, and 9 more variables: GPP_NT_VUT_REF <dbl>, SWC_F_MDS_1 <dbl>, SWC_F_MDS_2 <dbl>,
#   SWC_F_MDS_3 <dbl>, WS <dbl>, WD <dbl>, RH <dbl>, NIGHT <dbl>, NEE_VUT_REF_QC <dbl>
```

Overview



Chapters 1 and 2

- Getting ready with R
- Data frames

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nrow()



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# A tibble: 192,864 x 20
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  <dttm>           <dttm>      <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
1 2004-01-01 00:00:00 2004-01-01 00:30:00    NA     NA   304.    NA  93.3  0.014    NA     NA   NA
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3 2004-01-01 01:00:00 2004-01-01 01:30:00    NA     NA   281.    NA  93.3  0       NA     NA   NA
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7 2004-01-01 03:00:00 2004-01-01 03:30:00    NA     NA   281.    NA  93.2  0       NA     NA   NA
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# , SWC_F_MDS_3 <dbl>, WS <dbl>, WD <dbl>, RH <dbl>, NIGHT <dbl>, NEE_VUT_REF_QC <dbl>
```

Chapter 3

- Understand data and its “dimensions” and “variations”
- Data transformation
- Entering the R *tidyverse*

```
co2_concentration_monthly |>
  pivot_longer(cols = 2:13, names_to = "month", values_to = "co2")
```

```
## # A tibble: 36 x 3
##       year month   co2
##     <int> <chr> <dbl>
## 1  1959 Jan     315.
## 2  1959 Feb     316.
## 3  1959 Mar     316.
```

Variations and dimensions

- **Variation:** How data points vary between observations.
- **Dimension:** Factors that vary along with observations.

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Example:

- **Variation along 1 dimension:**
 - Mean annual temperature along an elevational gradient.

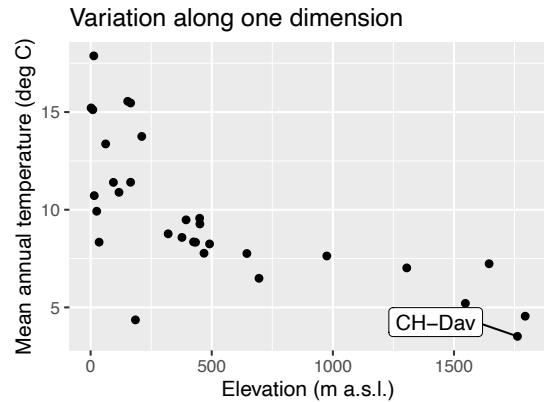
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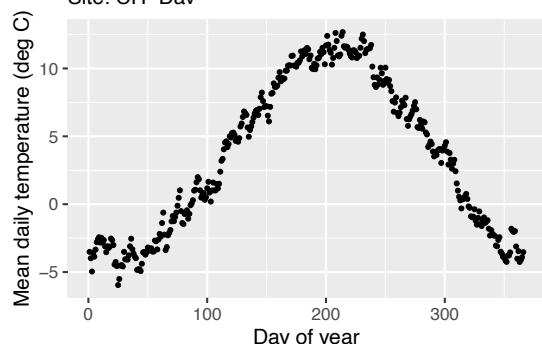
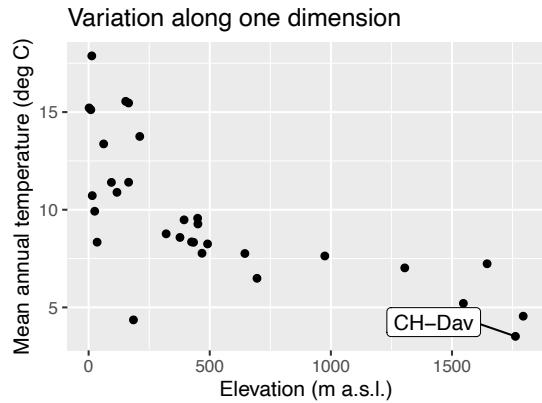
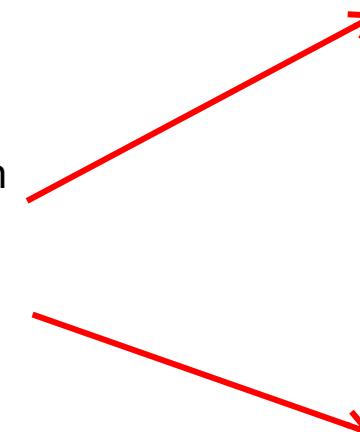
Variations and dimensions

- **Variation:** How data points vary between observations.
- **Dimension:** Factors that vary along with observations.

Example:

- **Variation along 1 dimension:**

- Mean annual temperature along an elevational gradient.
- Temperature mean seasonality (of one site)



Variations and dimensions

- Variation along >1 dimensions:
 - Mean seasonality along an elevation gradient.

Variations and dimensions

- Variation along >1 dimensions:
 - Mean seasonality along an elevation gradient.
 - Data for experiments meta-analysis

Experiment	Citation	Depth	Sample date	Time (years)	g C m ⁻²		n	n
					mean ambient CO ₂	mean increased CO ₂		
ArizonaFACE - wheat - high	Leavitt et al. 2001	0-15 cm	nov. 1995	0.0	1293	1172	4	4
	Leavitt et al. 2001	0-15 cm	may 1996	0.5	1453	1350	4	4
	Leavitt et al. 2001	0-15 cm	dec. 1996	1.0	1313	1177	4	4
	Leavitt et al. 2001	0-15 cm	may 1997	1.5	1246	1472	4	4
Biosphere 2	Trueman and Gonzalez-M	0-25 cm	average 1999	0	5863	6391	1	1
	Trueman and Gonzalez-M	0-25 cm	average 2000	1	5256	4698	1	1
	Trueman and Gonzalez-M	0-25 cm	average 2001	2	6145	4791	1	1
	Trueman and Gonzalez-M	0-25 cm	average 2002	3	5433	4160	1	1
	Trueman and Gonzalez-M	0-25 cm	average 2003	4	5266	4296	1	1
China FACE - low N	Zhong et al. 2009	0-15 cm	mar. 2008	3.66	1911	2170	3	3
	Zhong et al. 2009	0-15 cm	jun. 2008	4.00	1890	2187	3	3
China FACE - high N	Zhong et al. 2009	0-15 cm	mar. 2008	3.66	1889	2196	3	3
	Zhong et al. 2009	0-15 cm	jun. 2008	4.00	1848	2164	3	3
China OTC - low N	Liu et al. 2010	0-20 cm	jul. 2005	0.33	1174	1143	2	3
	Liu et al. 2010	0-20 cm	nov. 2005	0.67	1008	1023	2	3
	Liu et al. 2010	0-20 cm	apr. 2006	1.00	1881	2422	2	3
	Liu et al. 2010	0-20 cm	aug. 2006	1.33	2381	2190	2	3
	Liu et al. 2010	0-20 cm	nov. 2006	1.66	2079	1953	2	3
	Liu et al. 2010	0-20 cm	apr. 2007	2.00	2335	2249	2	3

Variations and dimensions

- Variation along >1 dimensions:
 - Mean seasonality along an elevation gradient.
 - Data for experiments meta-analysis

Experiment

Experiment	Citation	Depth	Sample date	Time (years)	g C m ⁻²		n	n
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	Trueman and Gonzalez-M	0-25 cm	average 2000	1	5256	4698	1	1
	Trueman and Gonzalez-M	0-25 cm	average 2001	2	6145	4791	1	1
	Trueman and Gonzalez-M	0-25 cm	average 2002	3	5433	4160	1	1
	Trueman and Gonzalez-M	0-25 cm	average 2003	4	5266	4296	1	1
China FACE - low N	Zhong et al. 2009	0-15 cm	mar. 2008	3.66	1911	2170	3	3
	Zhong et al. 2009	0-15 cm	jun. 2008	4.00	1890	2187	3	3
China FACE - high N	Zhong et al. 2009	0-15 cm	mar. 2008	3.66	1889	2196	3	3
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China OTC - low N	Liu et al. 2010	0-20 cm	jul. 2005	0.33	1174	1143	2	3
	Liu et al. 2010	0-20 cm	nov. 2005	0.67	1008	1023	2	3
	Liu et al. 2010	0-20 cm	apr. 2006	1.00	1881	2422	2	3
	Liu et al. 2010	0-20 cm	aug. 2006	1.33	2381	2190	2	3
	Liu et al. 2010	0-20 cm	nov. 2006	1.66	2079	1953	2	3
	Liu et al. 2010	0-20 cm	apr. 2007	2.00	2335	2249	2	3

Variations and dimensions

- Variation along >1 dimensions:
 - Mean seasonality along an elevation gradient.
 - Data for experiments meta-analysis

Variable

Experiment

Experiment	Citation	Depth	Sample date	Time (years)	g C m ⁻²		n	n
					mean ambient CO ₂	mean increased CO ₂		
ArizonaFACE - wheat - high	Leavitt et al. 2001	0-15 cm	nov. 1995	0.0	1293	1172	4	4
	Leavitt et al. 2001	0-15 cm	may 1996	0.5	1453	1350	4	4
	Leavitt et al. 2001	0-15 cm	dec. 1996	1.0	1313	1177	4	4
	Leavitt et al. 2001	0-15 cm	may 1997	1.5	1246	1472	4	4
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	Trueman and Gonzalez-M	0-25 cm	average 2002	3	5433	4160	1	1
	Trueman and Gonzalez-M	0-25 cm	average 2003	4	5266	4296	1	1
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	Liu et al. 2010	0-20 cm	apr. 2006	1.00	1881	2422	2	3
	Liu et al. 2010	0-20 cm	aug. 2006	1.33	2381	2190	2	3
	Liu et al. 2010	0-20 cm	nov. 2006	1.66	2079	1953	2	3
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	Trueman and Gonzalez-M	0-25 cm	average 2002	3	5433	4160	1	1
	Trueman and Gonzalez-M	0-25 cm	average 2003	4	5266	4296	1	1
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	Zhong et al. 2009	0-15 cm	jun. 2008	4.00	1890	2187	3	3
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	Liu et al. 2010	0-20 cm	nov. 2006	1.66	2079	1953	2	3
	Liu et al. 2010	0-20 cm	apr. 2007	2.00	2335	2249	2	3

Variations and dimensions

- Variation along >1 dimensions:
 - Mean seasonality along an elevation gradient.
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Variable

Treatment

Experiment	Citation	Dept	Sample date	Time (years)	mean		mean		n	n
					ambient	increased	CO ₂	CO ₂		
ArizonaFACE - wheat - high	Leavitt et al. 2001	0-15 cm	nov. 1995	0.0	1293	1172	4	4		
	Leavitt et al. 2001	0-15 cm	may 1996	0.5	1453	1350	4	4		
	Leavitt et al. 2001	0-15 cm	dec. 1996	1.0	1313	1177	4	4		
	Leavitt et al. 2001	0-15 cm	may 1997	1.5	1246	1472	4	4		
Biosphere 2	Trueman and Gonzalez-M	0-25 cm	average 1999	0	5863	6391	1	1		
	Trueman and Gonzalez-M	0-25 cm	average 2000	1	5256	4698	1	1		
	Trueman and Gonzalez-M	0-25 cm	average 2001	2	6145	4791	1	1		
	Trueman and Gonzalez-M	0-25 cm	average 2002	3	5433	4160	1	1		
	Trueman and Gonzalez-M	0-25 cm	average 2003	4	5266	4296	1	1		
China FACE - low N	Zhong et al. 2009	0-15 cm	mar. 2008	3.66	1911	2170	3	3		
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China FACE - high N	Zhong et al. 2009	0-15 cm	mar. 2008	3.66	1889	2196	3	3		
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Variations and dimensions

- Variation along >1 dimensions:
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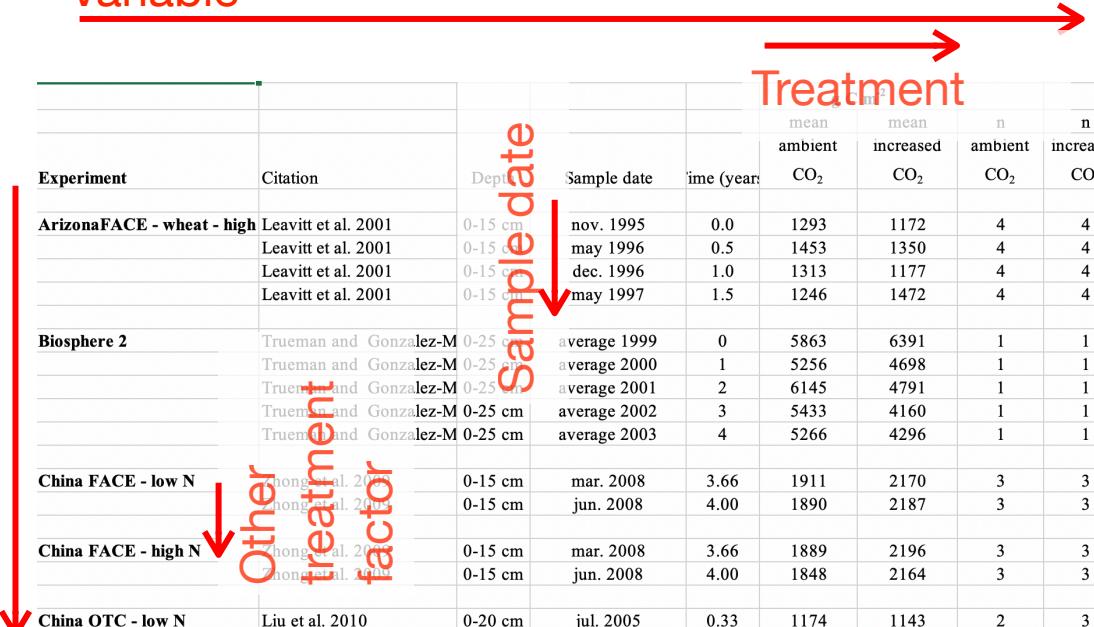
Variable

Experiment	Citation	Depth	Sample date	Time (years)	mean		mean		n	n
					ambient	increased	CO ₂	CO ₂		
ArizonaFACE - wheat - high N	Leavitt et al. 2001	0-15 cm	nov. 1995	0.0	1293	1172	4	4		
	Leavitt et al. 2001	0-15 cm	may 1996	0.5	1453	1350	4	4		
	Leavitt et al. 2001	0-15 cm	dec. 1996	1.0	1313	1177	4	4		
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Biosphere 2	Trueman and Gonzalez-M	0-25 cm	average 1999	0	5863	6391	1	1		
	Trueman and Gonzalez-M	0-25 cm	average 2000	1	5256	4698	1	1		
	Trueman and Gonzalez-M	0-25 cm	average 2001	2	6145	4791	1	1		
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	Liu et al. 2010	0-20 cm	aug. 2006	1.33	2381	2190	2	3		
	Liu et al. 2010	0-20 cm	nov. 2006	1.66	2079	1953	2	3		
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Variations and dimensions

- Variation along >1 dimensions:
 - Mean seasonality along an elevation gradient.
 - Data for experiments meta-analysis

→ Data organisation?
 → Data visualisation? (Chapter 4)



The diagram illustrates the structure of experimental data. A red arrow points horizontally from the 'Variable' column to the 'Treatment' column, indicating the relationship between the measured variable and the experimental treatment. Another red arrow points vertically from the 'Experiment' column to the 'Other treatment factor' column, highlighting the specific experimental design or condition being studied.

Experiment	Citation	Depth	Sample date	Time (years)	mean		n	
					ambient CO ₂	increased CO ₂	ambient CO ₂	increased CO ₂
ArizonaFACE - wheat - high	Leavitt et al. 2001	0-15 cm	nov. 1995	0.0	1293	1172	4	4
	Leavitt et al. 2001	0-15 cm	may 1996	0.5	1453	1350	4	4
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	Liu et al. 2010	0-20 cm	nov. 2006	1.66	2079	1953	2	3
	Liu et al. 2010	0-20 cm	apr. 2007	2.00	2335	2249	2	3

Tidy data

Tidy?

Tidy data

Tidy?

```
## # A tibble: 3 × 13
##   year   Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
##   <int> <dbl> <dbl>
## 1 1959  315.  316.  316.  318.  318.  318.  316.  315.  314.  313.  315.  315.
## 2 1960  316.  317.  317.  319.  320.  319.  318.  316.  314.  314.  315.  316.
## 3 1961  317.  318.  318.  319.  320.  320.  318.  317.  315.  315.  316.  317.
```

Tidy data

Tidy?

```
## # A tibble: 3 × 13
##   year   Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
##   <int> <dbl> <dbl>
## 1 1959  315.  316.  316.  318.  318.  318.  316.  315.  314.  313.  315.  315.
## 2 1960  316.  317.  317.  319.  320.  319.  318.  316.  314.  314.  315.  316.
## 3 1961  317.  318.  318.  319.  320.  320.  318.  317.  315.  315.  316.  317.
```

```
## # A tibble: 36 × 3
##   year month co2
##   <int> <chr> <dbl>
## 1 1959 Jan    315.
## 2 1959 Feb    316.
## 3 1959 Mar    316.
## 4 1959 Apr    318.
## 5 1959 May    318.
## 6 1959 Jun    318
## 7 1959 Jul    316.
## 8 1959 Aug    315.
## 9 1959 Sep    314.
## 10 1959 Oct    313.
## # ... with 26 more rows
```

Tidy data

country	year	cases	population
Afghanistan	1999	745	1937071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898
China	1999	212258	1272915272
China	2000	216766	128042583

variables

country	year	cases	population
Afghanistan	1999	745	1937071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898
China	1999	212258	1272915272
China	2000	216766	128042583

observations

country	year	cases	population
Afghanistan	99	745	1937071
Afghanistan	00	2666	20595360
Brazil	99	37737	172006362
Brazil	00	80488	174504898
China	99	212258	1272915272
China	00	216766	128042583

values