

Lecture 4: Atmospheric Circulation and Variability

Climate of the Ocean

Lecture 4: Atmospheric Circulation and Variability

Dr. Claudia Frauen Leibniz Institute for Baltic Sea Research Warnemünde (IOW) claudia.frauen@io-warnemuende.de



Lecture 4: Atmospheric Circulation and Variability

The General Atmospheric Circulation



Lecture 4: Atmospheric Circulation and Variability

Annual radiation budget of the earth





Simple sketch of the direct atmospheric circulation (non-rotating earth)





Sketch of the main cells of the general atmospheric circulation





Geostrophic Wind Balance



Essentials of Meteorology, C. Ahrens



Idealized winds generated by pressure gradient and Coriolis Force and actual wind patterns owing to land mass distribution



http://www.ux1.eiu.edu/~cfjps/1400/circulation.html Original in The Atmosphere, 8th edition, Lutgens and Tarbuck



Meridional cross section of the main cells of the general atmospheric circulation



Essentials of Meteorology, C. Ahrens



How jet streams form: Thermal Wind Balance



http://www.ux1.eiu.edu/~cfjps/1400/pressure_wind.html



Climatological mean surface pressure and position of the ITCZ in January



http://www.ux1.eiu.edu/~cfjps/1400/circulation.html Original in The Atmosphere, 8th edition, Lutgens and Tarbuck





Climatological mean surface pressure and position of the ITCZ in July



http://www.ux1.eiu.edu/~cfjps/1400/circulation.html Original in The Atmosphere, 8th edition, Lutgens and Tarbuck



The Equatorial Walker Circulation in the Pacific





Lecture 4: Atmospheric Circulation and Variability

Climate Variability: The El Niño Southern Oscillation (ENSO)



Changes in the Atmosphere and Ocean during El Niño Events





Changes in the Atmosphere and Ocean during La Niña Events





Lecture 4: Atmospheric Circulation and Variability

The Bjerknes Feedbacks



D. Dommenget

EIBNIZ INSTITUTE FOR

TIC SEA RESEARCH

Lecture 4: Atmospheric Circulation and Variability

The 2015 El Niño



NOAA CPC Climate Diagnostics Bulletin 09/2016

EIBNIZ INSTITUTE FOR

IC SEA RESEARCH

Lecture 4: Atmospheric Circulation and Variability

The 2015 El Niño



NOAA CPC Climate Diagnostics Bulletin 09/2016

EIBNIZ INSTITUTE FOR

ALTIC SEA RESEARCH

Lecture 4: Atmospheric Circulation and Variability

The 2015 El Niño



NOAA CPC Climate Diagnostics Bulletin 09/2016



401

30N

20N

ED

105

205

305

405

123JE

140E

160E

10N 👸

Climate of the Ocean

Nino 4

180

1 ecw

Nino 3.4

140%

120**

U %=

Nino 3

Nino 1+2

Lecture 4: Atmospheric Circulation and Variability

How to measure ENSO: The NINO3.4 SST Index

SST Anomaly in Nino 3.4 Region (5N-5S,120-170W)



National Centers for Environmental Information / NESDIS / NOAA

IBNIZ INSTITUTE FOR

C SEA RESEARCH



The Southern Oscillation Index: Pressure difference between Tahiti and Darwin





Lecture 4: Atmospheric Circulation and Variability

EL NIÑO CLIMATE IMPACTS

December-February



June-August



www.climate.gov



Lecture 4: Atmospheric Circulation and Variability

Indonesian fires sending haze across south-east Asia could become worst on record, NASA warns

Updated 3 Oct 2015, 7:08am



PHOTO: Satellite image from September 24, 2015 shows smoke from fires in Indonesia over the coasts of Borneo and Sumatra. (NASA Earth Observatory)

www.abc.net.au



f

El Niño Paints the World's Driest **Place with Color**

Unusually strong rains earlier this year set the stage for a widespread flower bloom across the Chilean desert.



A Rare Sight A mallow field in full bloom in the Atacama region, some 750 kilometers north of Santiago, Chile. The desierto florido (desert in bloom) occurs every five to seven years, though this year's is more vibrant than most.

news.nationalgeographic.com



Corals Are Dying on the Great Barrier Reef

Australian government issues emergency response level and warns that bleaching may be linked to climate change.



This panoramic image reveals coral bleaching at Lizard Island on the Great Barrier Reef in March 2016.

PHOTOGRAPH BY XL CATLIN SEAVIEW SURVEY

news.nationalgeographic.com

Lecture 4: Atmospheric Circulation and Variability

El Niño and La Niña are Predictable



- First successful El Niño prediction in 1986
- Forecast models are reasonably skillful at up to 6-9 month lead times
- Predictability based on slow evolution of upper ocean heat content

C SEA RESEARCH



Upper Ocean Heat Content as ENSO Predictor Recharge Oscillator Theory (Jin, 1997)



LEIBNIZ İNSTITUTE FOR BALTIC SEA RESEARCH WARNEMÜNDE

Lecture 4: Atmospheric Circulation and Variability



SEA RESEARCH

Lecture 4: Atmospheric Circulation and Variability





- ENSO is the most important mode of climate variability on interannual time scales
- It has its origins in the interactions of the tropical Pacific Ocean and the atmosphere, but its impacts reach far beyond the tropical Pacific region
- Over the past 20 years there has been huge progress in the understanding of the processes leading to ENSO events and models are in general able to predict ENSO events up to 6-9 months in advance
- However, the failed El Niño prediction in 2014 shows that it is still not fully understood



Lecture 4: Atmospheric Circulation and Variability

Climate Variability: The North Atlantic Oscillation (NAO)





Icelandic Low, Azores High and mean Storm Tracks in January



http://www.ux1.eiu.edu/~cfjps/1400/circulation.html Original in The Atmosphere, 8th edition, Lutgens and Tarbuck



Lecture 4: Atmospheric Circulation and Variability

Positive and Negative Phases of the NAO





© 2007 Thomson Higher Education



The NAO index: Pressure Difference between Lisbon and Reykjavik





Lecture 4: Atmospheric Circulation and Variability



http://www.cpc.noaa.gov/data/teledoc/ nao_tmap.shtml



Lecture 4: Atmospheric Circulation and Variability



http://www.cpc.noaa.gov/data/teledoc/ nao_pmap.shtml

This figure shows surface

emperature response and ome well-documented

ocio-oconodic impacts

ssociated with a strong

emperature response is a

which winter sea surface/

land station temperatures

vary as a result of changes

regions which are wormer at times when the north-

south pressure gradient

over the Atlantic Basin is

are cooler. Sea surface

from a reconstruction of

historical data while the

colored points are land-

based weather stations

emperatures are taken

reater than usual. Nue marks regions which

in the NAO index.

RED highlights those

secsure of the degree to

NAO index yea



Lecture 4: Atmospheric Circulation and Variability

IMPACTS ASSOCIATED WITH A POSITIVE

NAO YEAR.



NORTHEASTERN US Increased temperature results in decreased number of snow days



Increased wave height affects safety of oil rigs and their operators



Surplus water in hydroelectric reservoirs provides potential for selling surplus electricity



Length of the plant growth season is lengthened by 20 days



CENTRAL US

and river runoff

In the late 16th century, the missionary Hans Egede Saabye, after several years of travelling back and forth between Scandinavia and Greenland, cecorded in his journal:

> "In Greenland, all winters are severe, yet they are not alike. The Danes have noticed that when the winter in Denmark was severe, as we perceive it, the winter in Greenland in its manner was mild, and conversely."

> > As we now know, this east-west temperature see-saw was due to changes in the north-south contrast in sea level pressure over the North Atlantic Ocean, with low pressure in the north near Iceland and high pressure in the south near the Azores. The pressure contrast drives surface winds and wintertime storms from west to east across the North Atlantic. Variations in the pressure gradient affect the winds and storm tracks, thereby altering sea surface temperature, air temperature and precipitation. The impacts of this climate phenomenon reach as far eastward as central Siberia

and the eastern Mediterranean, southward to West Africa, westward to North America and extend throughout the entire Arctic region. These changes in atmospheric pressure and its associated impacts are known as the North Atlantic Oscillation (NAO). IMPACTS ASSOCIATED WITH A NEGATIVE NA0 YEAR.



GULF COAST GULF COAST Warmer sea surface temperatures cause increases in number and strength of hurricanes



Increased growth and recruitment of Northern Cod



EASTERN LONG ISLAND Decreased "brown tide" events increase scallop harvests



PORTUGAL & SPAIN Increased grape and olive harvests



TURKEY Increased precipitation and streamflow in the Tigris-Euphrates River Basin

http://www.ldeo.columbia.edu/res/pi/NAO/pamphlet.html



- The NAO is the most important mode of atmospheric variability in the northern hemisphere
- It impacts not only the North Atlantic but the whole northern hemisphere
- It is one of the main sources of predictability for European winter conditions
- However, models still have problems to predict the NAO