DR. PETERS: SO WELCOME, EVERYBODY, TO THIS
22 LAST PRESENTATION OF A VERY INTERESTING AND LONG
23 THREE DAYS. I'M GLAD TO SEE A LOT OF PEOPLE ARE
24 STILL HERE, EVEN THOUGH THE PIECES OF LUGGAGE ARE
25 BEING ROLLED INTO THE ROOM ALREADY AND PROBABLY
0823
1 ROLLED OUT PRETTY SOON AFTER I FINISH SPEAKING OR,
2 HOPEFULLY, AFTER THE PANEL, OF COURSE.
3 FOR THOSE OF YOU WHO DON'T KNOW ME, MY NAME
4 IS WOUTER PETERS. I USED TO WORK FOR NOAA'S EARTH
5 SYSTEM RESEARCH LAB. I ACTUALLY STILL WORK FOR THEM,
6 BUT NOW I WORK FROM THE NETHERLANDS. I MOVED THERE
7 ABOUT SIX MONTHS AGO. BEFORE THAT, I WAS FOUR YEARS
8 IN BOULDER, COLORADO, WORKING WITH THEM.
9 I'M VERY HONORED TO BE ABLE TO SPEAK HERE
10 TODAY. FOR A YOUNG SCIENTIST, IT IS QUITE AN
11 OCCASION TO BE HERE IN THE ROOM WITH SO MANY PEOPLE
12 THAT HAVE A LONG HISTORY IN MAKING OBSERVATIONS, A
13 LOT OF EXPERIMENTALISTS. I, MYSELF, AM A MODELER.
14 SO I'M ALWAYS A LITTLE BIT DAUNTED BY THE WORK THIS
15 GROUP OF PEOPLE HAS DONE IN THE PAST, FOR SURE.
16 I'M ALSO A LITTLE BIT INTIMIDATED BECAUSE I
17 WAS KIND OF RESEARCHING MY TALK HERE, AND I LOOKED AT
18 THE MAUNA LOA OBSERVATORY, AND I REALIZED THAT, WELL,
19 OF COURSE, I WASN'T BORN IN 1957, WHEN DAVE KEELING
20 STARTED THE MEASUREMENTS ON TOP OF MAUNA LOA. BUT
21 THEN I LOOKED AGAIN, AND I ACTUALLY REALIZED THAT I
22 WASN'T BORN WHEN THERE WAS AN IN SITU ANALYZER ON
23 MAUNA LOA. SO THIS WAS BACK IN 1974. AND I WAS ABLE
24 TO LOOK AT THE MAUNA LOA RECORD AND FIND OUT WHAT THE
25 CO2 WAS AT EXACTLY THE DATE AND DAY AND HOUR WHEN I
0824
1 WAS BORN, 334.5 PPM.
2 (LAUGHTER)
3 SO THAT'S A TESTIMONY AS TO HOW YOUNG I AM.
4 I GUESS THAT'S WHY I WAS ASKED TO SPEAK HERE TODAY.
5 I'M GOING TO BE TALKING A LITTLE BIT ABOUT
6 THE FUTURE OF CARBON CYCLE MONITORING. AND WHEN YOU
7 TALK ABOUT THE FUTURE, YOU ALWAYS KNOW THAT FIVE OR
8 TEN OR TWENTY OR THIRTY, ONE YEAR FROM NOW, YOU'RE
9 GOING TO BE LAUGHING ABOUT THE THINGS THAT YOU
10 THOUGHT WERE GOING TO BE RELEVANT IN YOUR FIELD TEN
11 YEARS FROM NOW. IT IS A VERY DIFFICULT TASK. AND AT
12 LEAST FROM MY AGE, YOU ALL WILL HAVE MAYBE ANOTHER
13 THIRTY YEARS TO LAUGH ABOUT THE THINGS THAT I'M GOING
14 TO BE SPEAKING ABOUT.
15 OKAY. I'VE SKIPPED A SLIDE, WHICH SAYS WHY
16 WE NEED TO TRACK CARBON. I THINK IT'S VERY CLEAR
17 FROM ALL THE EXCELLENT PRESENTATIONS THAT WE'VE SEEN
18 OVER THE PAST COUPLE OF DAYS THAT THERE'S A REAL
19 INTEREST FROM BUSINESS AND POLICY AND SCIENCE TO BE
20 TRACKING CARBON DIOXIDE CONCENTRATIONS AND TRACKING
21 CARBON IN THIS CASE, I SHOULD ACTUALLY SAY.
22 SO I'LL JUST GO STRAIGHT TO THE DIFFERENT
23 CARBON TRACKING STRATEGIES THAT WE HAVE. I HAVE
24 SPLIT IT UP INTO THREE DIFFERENT CATEGORIES HERE.
25 ONE OF THEM IS TO MEASURE STOCKS. THIS IS

0825
SOMETHING THAT WE'VE HEARD A LOT ABOUT. YOU CAN KEEP TRACK OF HOW MANY BARRELS OF OIL ARE BEING PRODUCED AND SHIPPED AND BOUGHT AND HOW MANY GALLONS OF GASOLINE ARE BEING SOLD AT THE PUMP AND GOING TO PEOPLE'S CARS AND END UP IN THE ATMOSPHERE. YOU CAN KEEP TRACK OF FORESTS. YOU CAN COUNT THE TREES. YOU CAN SEE HOW MUCH THEY'RE GROWING. YOU CAN KEEP TRACK OF HARVEST AND HOW MANY WHEAT PRODUCTS ARE BEING SOLD. THE SAME GOES FOR AGRICULTURAL PRODUCTS, OF COURSE.

SO THERE'S A LOT OF THINGS THAT YOU CAN COUNT; AND I THINK THE COUNTING METHODS HAVE REALLY GIVEN US QUITE A LOT OF INSIGHT INTO THE CARBON CYCLE. IT IS PROBABLY ONE OF THE FIRST METHODS TO GIVE US A COMPLETE PICTURE FOR NORTH AMERICA, OF HOW THE DIFFERENT SOURCES AND SINKS WERE PANNING OUT. IT IS DEFINITELY AN IMPORTANT STRATEGY IN OUR PORTFOLIO.

OF COURSE, ANOTHER WAY TO LOOK AT CARBON IS TO MEASURE THE ACTUAL EXCHANGE. THIS IS THE APPROACH BEING TAKEN, FOR INSTANCE, BY THE AMERIFLUX PEOPLE AND THE PEOPLE DOING ECOSYSTEM MEASUREMENTS THAT ARE ACTUALLY RIGHT THERE NEAR THE FORESTS OR NEAR THE GRASSLANDS OR NEAR THE CROPLANDS, TRYING TO FIND OUT HOW MUCH CO2 IS ACTUALLY COMING OUT OF THE PLANTS OR GOING INTO THE PLANTS.

0826
AND THEN THERE'S THE THIRD ONE. I THINK A LOT OF PEOPLE HAVE AFFINITY WITH THE THIRD COMPONENT THERE, WHICH IS TO MEASURE THE RESULT; THAT IS, TO LOOK AT THE ATMOSPHERE AND SEE WHAT THE RESULT IS OF CARBON EXCHANGE OR CARBON DIOXIDE EXCHANGE, IN THIS CASE, WHICH IS MEASURING CO2, IT'S MEASURING METHANE, IT'S MEASURING CO, IT'S MEASURING LOTS OF OTHER INTERESTING THINGS IN THE ATMOSPHERE, TO MAKE SURE THAT YOU KEEP TRACK OF CARBON DIOXIDE.

SO JUST AS A LITTLE REFERENCE, WHAT NEEDS TRACKING: THERE'S, OF COURSE, A LOT OF THINGS THAT ARE GOING ON IN THE CARBON CYCLE RIGHT NOW, OR THE CLIMATE SYSTEM, I SHOULD SAY, THAT NEED TRACKING. HERE'S JUST A MAP OF THE WORLD WITH A BUNCH OF COLORFUL CIRCLES OR ELLIPSES THAT SHOW YOU WHERE WE NEED TO TRACK A COUPLE OF THINGS.

WE'VE HEARD SOME EXCELLENT PRESENTATIONS ABOUT THE PERMAFROST, FOR INSTANCE. TED SCHUUR WAS TALKING ABOUT THAT AND THE LARGE CHANGES THAT ARE GOING ON AND THE POTENTIAL FOR LARGE CARBON RELEASES FROM THE PERMAFROST. THIS IS CLEARLY SOMETHING THAT WE NEED TO BE ON TOP OF WITH THE FUTURE MONITORING OF THE CARBON CYCLE.

A SIMILAR ARGUMENT CAN BE MADE FOR THE DROUGHTS. WE'VE HEARD OVER THE PAST COUPLE OF DAYS

0827
THAT THE FREQUENCY BUT ALSO THE INTENSITY OF DROUGHTS IS LIKELY TO INCREASE IN A CHANGING WORLD. AND THIS WILL HAVE AN IMPACT ON THE STATE OF FORESTS, IT WILL HAVE AN IMPACT ON AGRICULTURE, AND DAVE LOBELL WAS

TALKING ABOUT THAT PEOPLE IN THE AGRICULTURAL SECTOR ARE ALREADY PREPARING FOR A WORLD WHERE RAIN MIGHT BE MORE FREQUENT BUT THERE MIGHT BE LESS WATER AVAILABLE TO GROW THE CROPS.

OTHER THINGS THAT DEFINITELY NEED OUR ATTENTION IS CHANGING CLIMATE IN THE HIGH-LATITUDE REGIONS. THERE'S DEFINITELY STRONG EVIDENCE THAT THIS IS ALREADY GOING ON AT AN ALARMING RATE; AND THIS IS, FOR INSTANCE, INCREASING GROWING SEASON LENGTHS, WITH MEASURABLE EFFECTS ON THE CARBON CYCLE ALREADY.

FOSSIL FUELS ARE AN IMPORTANT COMPONENT. WE'VE TALKED ABOUT FOSSIL FUELS A LOT ALREADY IN THIS MEETING, I THINK, BUT OBVIOUSLY THERE IS A REAL NEED TO KEEP TRACK FROM AN ATMOSPHERIC POINT OF VIEW WHAT EXACTLY IS GOING ON WITH FOSSIL FUELS. AND I'LL COME BACK TO THAT LATER IN THIS TALK.

A COUPLE OF THINGS THAT WE HAVEN'T TALKED ABOUT MUCH IS DEFORESTATION. MAYBE PEOPLE ARE SAVING THEIR ARGUMENTS FOR BALI NEXT WEEK AND DON'T WANT TO TALK ABOUT IT TOO MUCH RIGHT HERE.

0828

PEAT LAND DRAINAGE IS ANOTHER VERY LARGE LOOMING BEAST IN THE CLOSET, BASICALLY, THAT IS GOING TO BE RELEASING A LOT OF CARBON OVER THE NEXT FIVE TO TEN YEARS, AND WE NEED TO GET A HANDLE ON HOW MUCH EXACTLY THAT'S GOING TO BE.

AND THEN IN THE OCEAN, OF COURSE, THERE IS A LOT GOING ON IN THE CARBON CYCLE, LIKE WE'VE HEARD FROM DICK FEELY, FOR INSTANCE. SATURATION, POSSIBLE SATURATION OF THE NORTH ATLANTIC SINK. IN THE SOUTH, IN THE SOUTHERN OCEAN, THERE SEEMS TO BE A SLOWING DOWN OF THE RATE OF UPTAKE OF CARBON DIOXIDE. I SHOULDN'T SAY THAT'S SATURATION, BUT DEFINITELY SOMETHING TO KEEP TRACK OF.

WHAT'S IN OUR CARBON TRACKING TOOLBOX? WELL, WE HAVE A LOT OF WAYS TO KEEP TRACK OF CARBON. THERE IS ECONOMIC ACTIVITY DATA; THERE'S ECOSYSTEM MEASUREMENTS THAT I'VE TALKED ABOUT BRIEFLY ALREADY. OCEAN SURVEYS HAVE GIVEN US A LOT OF INSIGHTS INTO THE CARBON CYCLE. THERE'S SATELLITE RADIANCES. A LOT OF INTERESTING DATA ARE BEING MEASURED FROM SATELLITES. A LOT OF INTERESTING INFORMATION CAN COME FROM SATELLITES. I WILL TALK ABOUT THAT FOR A SECOND, AS WELL. AND THEN, OF COURSE, THERE'S THE ATMOSPHERIC OBSERVATIONS THAT ARE VERY CLOSE TO A LOT OF US, I THINK, AND DEFINITELY FOR THIS MEETING HAVE

0829

A SPECIAL PLACE.

TO ILLUSTRATE SOME OF THESE WAYS TO -- OR ACTUALLY SOME OF THESE TOOLS THAT ARE IN OUR TOOLBOX, I WILL BE GIVING A FEW EXAMPLES OF THINGS THAT WE ARE OBSERVING AT THE MOMENT AND THAT WE ARE KEEPING TRACK OF AND THAT I THINK WE WILL BE NEEDING TO KEEP TRACK OF FOR THE NEXT X YEARS, X BEING FIVE, TEN, FIFTEEN, TWENTY, AND HOPEFULLY 50.

MY FIRST EXAMPLE DEALS WITH AN EXCELLENT

PAPER. IT CAME OUT ABOUT TWO MONTHS AGO, WRITTEN BY MICHAEL RAUPACH AND HIS CO-AUTHORS: "GLOBAL AND REGIONAL DRIVERS OF ACCELERATING CO2 EMISSIONS." WE'VE SEEN THIS FIGURE ALREADY YESTERDAY. CHRIS FIELD WAS SHOWING IT. AND IT'S BASICALLY SHOWING THAT THE CARBON DIOXIDE OR THE CARBON EMISSIONS, CO2 EMISSIONS, IS ON THE Y AXIS HERE, AND I GUESS IT'S IN PETAGRAMS OF CARBON. THAT'S RIGHT.

SO THE EMISSIONS OF CARBON FROM FOSSIL FUELS, THE WAY WE'RE KEEPING TRACK OF IT RIGHT NOW, IS ALREADY EXCEEDING THE ENVELOPE OF SCENARIOS THAT IPCC CAME UP WITH IN ITS PREVIOUS ESTIMATES. SO WE'RE ALREADY ON THE HIGH SIDE HERE. AND THERE WAS A VERY INTERESTING ANALYSIS TO FIND OUT EXACTLY WHAT WAS DRIVING THIS CHANGE. AND IT IS A GOOD EXAMPLE OF WHAT YOU CAN DO WITH ECONOMIC ACTIVITY DATA.

0830

THERE ARE THREE LINES HERE. WE'LL FIRST LOOK AT THE TOP LINE OR, ACTUALLY, AT THE TOP GRAPH, I SHOULD SAY, THE LIGHT BLUE LINE, THE ONE THAT IS BASICALLY FLAT. AND THIS FLAT LINE IS THE CARBON INTENSITY OF ENERGY. THE CARBON INTENSITY OF ENERGY BASICALLY SAYS IF YOU WANT TO MAKE ONE UNIT OF ENERGY, KILOWATT HOUR HERE, HOW MUCH CARBON DO YOU NEED FOR THAT? AND THIS HAS BASICALLY BEEN FLAT OVER THE PAST 20 YEARS. IT IS TELLING YOU THAT NO COUNTRY, REALLY, AT THE MOMENT IS DECARBONIZING ITS ENERGY INFRASTRUCTURE. WE ARE STILL DOING THE SAME THINGS WE WERE DOING, WHICH WAS USING CARBON TO GENERATE ENERGY.

THERE ARE TWO LINES GOING DOWN VERY RAPIDLY HERE. ONE OF THEM IS THE ENERGY INTENSITY OF GDP. AND THIS, BASICALLY MEASURES IF YOU WANT TO PRODUCE 1 UNIT OF GDP, HOW MUCH ENERGY DO YOU NEED FOR THAT? WE HAVE BECOME VERY EFFICIENT AT THAT. ACTUALLY, TO PRODUCE 1 UNIT OF GDP, WE NEED 2 OR FEWER ENERGY UNITS, BASICALLY.

AND THE OTHER LINE THAT IS GOING DOWN AT ABOUT THE SAME RATE IS THE CARBON INTENSITY OF ENERGY. THIS IS THE AMOUNT OF CARBON THAT YOU NEED TO PRODUCE 1 UNIT OF GDP. VERY RAPIDLY GOING DOWN. IF YOU LOOK AT THAT LINE, IT'S NOT REALLY SURPRISING

0831

THAT THE GREEN LINE, THE CARBON INTENSITY OF GDP, IS WHAT THE BUSH ADMINISTRATION IS ALWAYS VERY PROUD OF, THAT IT IS GOING DOWN, AND THEY SET AS THEIR INITIAL GOALS, AS WELL, WE'RE GOING TO BRING DOWN THE CARBON INTENSITY OF GDP. WELL, THAT WAS NOT REALLY ALL THAT DIFFICULT CONSIDERING THAT WE WERE ALREADY ON A VERY STEEP DECLINE OF THAT.

HERE'S TWO LINES THAT ARE GOING UP PRETTY RAPIDLY. THE RED LINE IS THE TOTAL POPULATION OF THE WORLD. WE KNOW THAT THIS IS GOING UP VERY RAPIDLY. THERE IS ACTUALLY ANOTHER THING THAT'S GOING UP; AND THAT IS THE PER CAPITA GDP. SO THIS IS AMOUNT OF DOLLARS PER PEOPLE.

SO NOW IF YOU WERE TO TAKE THE ORANGE LINE,

THE PER CAPITA GDP, AND MULTIPLY THE POPULATION, YOU GET SOMETHING IN DOLLARS. YOU MULTIPLY THAT BY THE AMOUNT OF CARBON PER DOLLAR, AND YOU ACTUALLY GET CARBON EMISSIONS. AND THIS IS THE BLACK LINE. AND THE THICK BLACK LINE, AS YOU CAN SEE, IS GOING UP PRETTY RAPIDLY.

SO I THOUGHT THIS WAS A VERY INTERESTING ANALYSIS THAT THESE PEOPLE DID IN A REALLY NICE WAY OF USING ECONOMIC ACTIVITY DATA TO LEARN SOMETHING ABOUT WHAT'S GOING ON IN THE CARBON CYCLE.

WHAT IS ALSO IMPORTANT TO KNOW I THINK IS

0832

THAT THESE ARE ALL BASED ON REPORTED EMISSIONS. THESE ARE COUNTRIES THAT ARE TELLING HOW MUCH ECONOMIC ACTIVITY THERE IS AND HOW MUCH THEY'RE EMITTING FROM ALL OF THEIR DIFFERENT SECTORS. WE ALSO KNOW THAT THESE ACCOUNTING MEASURES IN THESE REPORTS, FIRST OF ALL, THEY'RE NOT ALWAYS COMPLETE. SOME COUNTRIES SIMPLY CAN'T COMPLETE THESE COMPLICATED REPORTS SOMETIMES. THEY'RE NOT ALWAYS TIMELY. AT THE MOMENT, YOU CAN GET THE EMISSIONS FOR 2006. IF YOU WANT THOSE FOR 2007, YOU'RE GOING TO HAVE TO WAIT UNTIL 2008 OR 2009 AT LEAST. AND THEY'RE NOT ALWAYS ACCURATE. WE KNOW THAT IN THE CURRENT SYSTEM IN THE WORLD THERE IS A REAL INCENTIVE NOT TO BE COMPLETELY UPFRONT ABOUT YOUR CARBON EMISSIONS BECAUSE CARBON HAS VALUE, AS WE JUST SAW IN THE EXCELLENT TALK BY MIKE WALSH. SO THERE IS A REAL NEED FOR ANOTHER WAY TO KEEP TRACK OF FOSSIL FUEL EMISSIONS OF CARBON DIOXIDE OR CARBON.

NOW, LUCKILY THERE IS. MANY PEOPLE KNOW THIS. RADIOCARBON, THE 14C ISOTOPE IN CO2, IS AN ALMOST UNIQUE TRACER FOR FOSSIL FUEL EMISSIONS. THAT IS BECAUSE FOSSILL CARBON BY DEFINITION IS SO OLD THAT IT'S NOT GOING TO CONTAIN ANY 14 CARBON ANYMORE.

SO WHAT YOU HAVE IN THE ATMOSPHERE IS YOU HAVE A BACKGROUND CONCENTRATION -- NOT REALLY

0833

BACKGROUND BECAUSE THERE WAS NUCLEAR TESTING BACK IN THE 1960S -- AND YOU HAVE A CONCENTRATION OF CO2, 14 CO2, I SHOULD SAY; AND IF YOU EMIT FOSSIL FUELS INTO THERE, THE CONCENTRATION WILL ACTUALLY GO DOWN, OR I SHOULD SAY THE RATIO OF 14 CO2 TO CO2 IS GOING DOWN. AND THIS IS SOMETHING WE CAN DETECT VERY WELL.

LOOKING AT THE GRAPH, STARTING AT THE LOWER PANEL, THERE'S THE CONCENTRATIONS, THE MIX OF RATIOS THAT ARE MEASURED FOR CARBON MONOXIDE. AND THE BLACK LINE THERE IS THE MEASUREMENT RECORD AT . . . RIDGE, THIS IS JUST FOR A THREE-YEAR PERIOD.

THERE IS A -- THE BLACK LINE THERE IS . . . MEASUREMENTS, AND THEN THE COLORED DOTS ARE MEASUREMENTS TAKEN OVER THE EAST COAST FROM AIRCRAFT DATA. AND AS YOU CAN SEE, THERE ARE A LOT OF TIME ZONES ON THIS CO2 MIX OF RATIOS, MEASURED FROM THESE AIRCRAFT ON THE EAST COAST ARE ELEVATED.

IN THE MIDDLE PLOT, YOU CAN SEE THE CO2 MIX OF RATIOS THAT ARE MEASURED ALONGSIDE.

AND THEN AT THE TOP PLOT, YOU CAN SEE THE RATIO OF 14 CO2 TO 12 CO2, WHICH IS THE TRACER THAT I'M TALKING ABOUT HERE. SO JUST KIND OF TO FOCUS YOUR ATTENTION ON A PARTICULAR WINTER PERIOD, YOU CAN SEE HERE IN THIS SHADED LINE, SHADED BOX, I SHOULD SAY, DEFINITELY PERIODS WHERE THE CO2 MIX OF RATIOS

0834

ARE VERY HIGH AND THEN 14 CO2 IS VERY LOW. THIS IS QUITE A GOOD SIGNAL, ESPECIALLY CONSIDERING HOW WELL WE CAN MEASURE 14 CO2, AND THIS PROVIDES A UNIQUE SIGNATURE OF FOSSIL FUEL EMISSIONS THAT WE COULD TRACK.

THERE IS 14 CO2 IN THE BIOSPHERE. THERE'S 14 CO2 IN THE OCEANS. THESE ARE THINGS THAT WE HAVE A PRETTY GOOD HANDLE ON AT THE MOMENT AND THAT WE THINK WE CAN DEAL WITH PRETTY WELL. I WOULD SAY 14 CO2 IS PROBABLY ONE OF THOSE TRACE GASSES THAT WE CAN MEASURE, WHICH REALLY IS READY FOR PRIME TIME. WE CAN DEPLOY A NETWORK OF 14 CO2 MEASUREMENTS, AND WITH ENOUGH UNDERSTANDING, TO KEEP TRACK OF FOSSIL FUEL EMISSIONS. ALL THAT IS NEEDED IS A LITTLE BIT OF BASIC RESEARCH, SOME MONEY TO START THESE MEASUREMENTS ON A VERY LARGE SCALE. I KNOW THERE'S LOT OF LABS IN THE UNITED STATES AND ALSO IN EUROPE THAT HAVE THE CAPACITY TO MEASURE 14 CO2, TO MONITOR THIS ON LARGER SCALES. SO I THINK THIS IS ONE OF THOSE TRACERS THAT IN THE NEXT FIVE YEARS WE SHOULD BE WORKING ON QUITE A LOT AND WILL BE HEARING FROM, AS WELL.

ANOTHER THING THAT IS VERY INTERESTING ABOUT 14 CO2 IS THAT YOU DON'T JUST HAVE THE MIXING RATIO OR THE RATIO OF 14 CARBON TO 12 CARBON IN THE

0835

THE ATMOSPHERE. BUT THE SIGNAL THAT IS IN THE ATMOSPHERE ALSO SEEMS TO BE REFLECTED IN PLANTS THAT ARE GROWING. IF YOU LOOK AT CORN THAT IS GROWING ACROSS THE UNITED STATES, THIS IS ACTUALLY ASSIMILATING CO2 FROM THE ATMOSPHERE AND TAKING THE SIGNAL OF 14 CO2 INTO IT, SO THAT YOU CAN TAKE THAT CORN, SIMPLY PICK IT FROM THE FIELDS, TAKE IT TO THE LAB, MEASURE THE 14 C CONTENT. AND THIS IS A MAP THAT WAS MADE BY DEANA SWADE (PHONETIC). SHE'S FROM . . . LAB, SHE'S A GRAD STUDENT THERE, AND SHE MADE A BEAUTIFUL MAP OF THE 14 CO2 MIXING RATIO DISTRIBUTION OVER THE UNITED STATES JUST BY SAMPLING ABOUT 60 COBS OF CORN, AND THIS IS WHAT YOU GET FROM THAT. SO THIS IS POTENTIALLY A VERY PROMISING METHOD TO FIND OUT WHAT THE FOSSIL FUEL DISTRIBUTION IS OF THE UNITED STATES.

OF COURSE, THERE'S QUESTIONS WITH THIS, AS WELL. BECAUSE SHE WAS COLLECTING THIS IN A PLANT, HOW EXACTLY IS THIS HAPPENING? A PLANT ONLY GROWS ONLY WHEN IT'S LIGHT, AND IT GROWS FASTER WHEN THERE'S MORE LIGHT AND IT GROWS MORE SLOWLY WHEN THERE'S LESS LIGHT. SO THERE'S SOME BASIC RESEARCH TO BE DONE. IF THIS PANS OUT TO BE A VERY GOOD METHOD TO MEASURE FOSSILL FUEL CO2, I THINK FIVE TO

TEN YEARS FROM NOW WE MIGHT BE DOING THIS ON A MUCH
LARGER SCALE.

HERE'S ANOTHER EXAMPLE OF A VERY INTERESTING TRACER THAT HAS RECENTLY MADE ITS WAY INTO THE CARBON CYCLE SCIENCE. THIS IS CARBONYL SULFITE. CARBONYL SULFITE IS VERY MUCH LIKE CO2. ON THE GRAPH, YOU CAN SEE THE MIX OF RATIOS OF CO2 AND CARBONYL SULFITE, MEASURED AT BARROW, ALASKA. THIS DATA WAS PROVIDED BY STEVE MONTZKA FROM NOAA ESRL. AND YOU CAN SEE A VERY STRONG SIMILARITY BETWEEN THE SEASONAL CYCLES OF THESE TWO TRACE GASSES. AND THAT'S BECAUSE THEIR BUDGETS ARE VERY TIGHTLY LINKED. BOTH OF THEM ARE BEING TAKEN UP BY PHOTOSYNTHESIS BY PLANTS GROWING AND ASSIMILATING CO2, BUT ALSO COS. THE INTERESTING THING ABOUT COS IS THAT WE THINK -- AND WE HAVE PRETTY STRONG EVIDENCE FOR THIS -- IS THAT IN CONTRAST TO CO2, COS IS NOT COMING OUT OF THE PLANT ANYMORE. SO IT'S IS A ONE-WAY FLUX INTO THE PLANTS, WHICH WOULD POSSIBLY UNIQUELY IDENTIFY PHOTOSYNTHESIS. SO THIS COULD BE A VERY STRONG TRACER TO KEEP TRACK OF A PARTICULAR PROCESS IN THE CARBON CYCLE. I THINK THIS IS A VERY PROMISING TRACER.

IN TERMS OF ITS SCIENTIFIC UNDERSTANDING AT THE MOMENT, IT IS NOT AS MATURE AS 14 CO2 OR MAYBE EVEN AS MATURE AS SOME OF THE OTHER TRACER GASSES,

BUT I THINK IF WE CAN DO SOME BASIC SCIENTIFIC RESEARCH ON THIS, MAYBE IN TEN TO FIFTEEN YEARS CARBONYL SULFITE WILL BE PART OF A MONITORING EFFORT AND WILL BE USED TO DIAGNOSE THE CARBON CYCLE.

CARBONYL SULFITE IS, ACTUALLY, A NICE BRIDGE TO DROUGHTS. WHAT YOU'RE LOOKING AT HERE IS AN IMAGE OF EUROPE. YOU'RE LOOKING AT THE NET PRIMARY PRODUCTION OVER EUROPE. THIS IS THE AMOUNT OF CARBON BEING TAKEN UP INTO THE PLANTS. AND THIS IS FOR THE SUMMER OF 2003. THIS IS ACTUALLY AN ANOMALY THAT YOU'RE LOOKING AT. THE YELLOW AND RED COLORS ARE SUGGESTING THAT THERE WAS A LOT LESS UPTAKE OF CARBON DIOXIDE FOR THAT PARTICULAR SUMMER. AND THIS WAS RELATED TO A VERY STRONG DROUGHT. THIS IS ONE OF THESE VERY EXTREME DROUGHTS THAT DAVE LOBELL WAS TALKING ABOUT, AS WELL. AND IT DEFINITELY HAD AN IMPACT ON THE CARBON CYCLE. IT'S FROM A PAPER BY . . . AND COLLEAGUES, WHO I THINK DID A VERY NICE JOB ON BRINGING TOGETHER LOTS OF LINES OF EVIDENCE ON THIS. THEY USED ALMOST THE COMPLETE TOOLBOX THAT I WAS DESCRIBING IN ONE OF MY EARLIER SLIDES. THIS IS BASED ON SATELLITE DATA, CROP STATISTICS IN HERE. THEY USED NET ECOSYSTEM EXCHANGE MEASUREMENTS TO DIAGNOSE THIS, CO2 FROM THE ATMOSPHERE WAS USED. REALLY, A LOT OF DATA WAS BROUGHT TOGETHER ON THIS

DRAFT, AND I THINK IT IS ONE OF THE MOST WELL-DOCUMENTED EVENTS IN THE RECENT HISTORY OF THE CARBON CYCLE, IF WE'RE LOOKING AT SORT OF THE

SIX-YEAR TIME SCALE, MAYBE TOGETHER WITH THE EL NINO OF 1997, AND IT IS STILL BEING USED, ACTUALLY, TO LEARN ABOUT THE MODELS AND TO DIAGNOSE WHAT THE CARBON CYCLE MIGHT BE DOING IN A WORLD WHERE DROUGHTS ARE GOING TO BE MORE FREQUENT.

THE RELEVANCE OF THIS DROUGHT, FOR THAT PARTICULAR YEAR, THERE WAS ABOUT A HALF PETAGRAM OF REDUCED UPTAKE OF CARBON DIOXIDE BY PLANTS; AND IT WOULD TAKE ABOUT FOUR AVERAGE YEARS TO RECOVER JUST FROM THIS ONE PARTICULAR EVENT. SO IN A TIME WHEN DROUGHTS MIGHT HAVE A HIGHER FREQUENCY AND EVEN HIGH INTENSITY, YOU'RE NOT LIKELY TO GET FOUR YEARS IN A ROW WITH ABOVE-AVERAGE UPTAKE. SO WHAT WILL HAPPEN AS A RESULT OF THAT IS THAT YOUR TOTAL UPTAKE IS GOING TO GO DOWN.

THIS IS JUST AN ILLUSTRATION OF A DIFFERENT TAKE ON THE DROUGHTS. THIS IS MICROWAVE SATELLITE DATA THAT IS SHOWING YOU THE STATE OF THE VEGETATION IN TERMS OF WATER. THIS IS IN THE MICROWAVE RANGE. AND ALL I WANTED TO SAY ABOUT THIS REALLY IS THAT THERE'S OTHER PEOPLE INTERESTED IN DROUGHTS BESIDES THE CARBON CYCLE SCIENTISTS. THERE'S FIELDS OUT

0839

THERE LIKE THE HYDROLOGISTS THAT HAVE A LOT OF EXPERIENCE MONITORING DROUGHTS, FOR INSTANCE, THROUGH MEANS THAT WE HAVE NOT HAD ACCESS TO SO FAR.

I THINK THERE IS A VERY INTERESTING CONNECTION TO THE DROUGHTS. THIS IS FIRES AND DEFORESTATION. WHAT YOU'RE LOOKING AT HERE IS A FIGURE THAT WAS GIVEN TO ME BY . . . FROM THE NETHERLANDS. YOU'RE AT INDONESIA. THESE ARE THE ISLANDS OF INDONESIA. AND THE BLUE IS AN INDICATION OF THE DRY SEASON LENGTH, WHERE THE LIGHT BLUE COLORS ARE A SHORT, DRY SEASON, AND THE LIGHTER TO WHITE COLORS ARE A LONGER DRY SEASON. AND TOGETHER WITH THAT IS THE NUMBER OF FIRE COUNTS. AND WHAT YOU CAN SEE IS THAT WHEN IT GETS DRY, THERE'S MORE FIRES. NOW, IN PRINCIPLE, THAT'S SOMETHING WE CAN UNDERSTAND QUITE WELL. WHAT'S INTERESTING, OF COURSE, IS THAT WE CAN SEE IT ON THIS SCALE USING SATELLITE RADIANCE AGAIN. WHAT IS EVEN MORE INTERESTING IS THAT THE RELATIONSHIP BETWEEN THE NUMBER OF FIRE COUNTS AND THE DRY SEASON LENGTHS IS NOT LINEAR; IT'S ACTUALLY EXPONENTIAL. AS IT GETS DRIER, THE NUMBER OF FIRES INCREASES EXPONENTIALLY. AND THE REASON FOR THIS IS BECAUSE OF THE MAN-MADE FEEDBACK IN THE CARBON CYCLE. THERE'S PEOPLE THERE WHO ARE ACTUALLY SETTING EVERYTHING ON FIRE AS SOON AS IT IS DRY ENOUGH TO

0840

BURN. AND THEY ARE WAITING FOR EXACTLY THE RIGHT CONDITIONS; AND AS SOON AS THOSE OCCUR, THEY START BURNING LIKE CRAZY. AND THEY'RE CLEARING LAND FOR AGRICULTURE AND FOR PRODUCING CROPS. SO I THINK THIS WILL MAKE A VERY INTERESTING STORY PROBABLY TO COME OUT SOMEWHERE NEXT YEAR. BUT IT SHOWS ANOTHER ASPECT OF DROUGHTS IN CONNECTION WITH DEFORESTATION.

SO IF WE CAN SEE SO MUCH FROM ALL THESE

SATELLITES, THEN WHAT ABOUT SPACE-BASED CO2? CAN WE JUST MONITOR CO2, LAUNCH ONE OF THESE SATELLITES AND SEE IT? YEAH, IN PRINCIPLE, WE CAN. YOU'RE ACTUALLY LOOKING AT A FIGURE, A PICTURE OF CO2 DISTRIBUTION OVER THE EARTH MADE FROM A SATELLITE. THIS IS THE SCIAMACHY SATELLITE. THIS IS FOR A PARTICULAR TWO-MONTH PERIOD, I THINK, IN THE SUMMER OF 2004. AND BECAUSE IT IS SUMMER, YOU CAN SEE THE CARBON DIOXIDE CONCENTRATIONS OVER MUCH OF THE NORTHERN HEMISPHERE ARE DEPLETED. THERE'S OTHER THINGS YOU CAN SEE.

OTHER THINGS THAT YOU CAN SEE IS THAT THERE'S LOTS OF PLACES WHERE WE DON'T REALLY KNOW WHAT'S GOING ON. THAT'S BECAUSE SCIAMACHY IS A SATELLITE THAT CAN'T SEE OVER THE OCEANS. BUT THERE'S ALSO PLACES WHERE IT IS CONSISTENTLY CLOUDY, AND THESE SATELLITES CAN'T SEE THROUGH THE CLOUDS.

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NOW, THIS IS A VERY IMPORTANT POINT, AND THIS WAS WAS EVEN MORE CLEAR, I THINK, BY SCOTT DENNING, IN THE POSTER SESSION, WHERE HE WAS SAYING THAT THESE SATELLITES CAN'T SEE THROUGH CLOUDS. AND IN THE MID LATITUDES, IN THE REGIONS WHERE WE LIVE, CLOUDS ARE ALWAYS FOUND AROUND FRONTS. BUT ALSO WHERE THE FRONTS ARE IS WHERE THE LARGE GRADIENTS IN CO2 ARE. SO, IN OTHER WORDS, THE PLACES WHERE CO2 IS MOST VARIABLE AND WHERE YOU CAN POTENTIALLY LEARN THE MOST ABOUT CARBON IS THE PLACES WHERE THE SATELLITES CAN'T SEE. AND AS A MATTER OF FACT, THIS AVERAGING OVER A TWO-MONTH PERIOD IS LIKELY TO CONTAIN SOME VERY SERIOUS BIASES BECAUSE THEY HAVE AVERAGED OVER PERIODS THAT DON'T INCLUDE MEASUREMENTS UNDER CLOUDS. SO THIS IS ONE OF THE REASONS WHY OBSERVING CO2 FROM SPACE DEFINITELY HAS ITS LIMITATIONS.

IN 2009, THERE'S GOING TO BE TWO OTHER SATELLITES, OCO AND GOSAT, WHICH ARE GOING TO BE LAUNCHED SPECIFICALLY TO MONITOR CO2 FROM SPACE. I THINK IT'S GOING TO BE A REALLY INTERESTING TEST FOR THESE METHODS, AND I'M SURE WE'RE GOING TO GET A LOT OF GOOD SCIENCE OUT OF THEM, AS WELL. WHETHER THEY'RE READY FOR MONITORING, I WOULD DOUBT THAT. AND THAT'S PARTLY RELATED TO A REMARK THAT WAS MADE BY RALPH KEELING ON DAY ONE; AND THAT IS THAT IT'S

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NOT THAT HARD TO GO UP THE MOUNTAIN AND START MEASURING CO2; WHAT'S HARD IS TO DO IT FOR 20, 30 YEARS, CONSISTENTLY, WITH A GOOD INSTRUMENT AND LEARN EVERYTHING THERE IS TO LEARN ABOUT THE SYSTEMATIC ERRORS IN YOUR INSTRUMENT AND BEAT THOSE DOWN TO THE POINT WHERE YOU HAVE A REALLY GOOD SOUND RECORD.

NOW, THESE ARE ALL THINGS THAT SATELLITES ARE NOT MADE FOR. SATELLITES ONLY HAVE A LIFETIME OF ABOUT TWO TO THREE YEARS. THESE ARE REALLY COMPLICATED INSTRUMENTS THAT TAKE TEAMS OF SCIENTISTS TO UNDERSTAND WHAT'S GOING ON WITH THEM. AND JUST WHEN YOU FIGURE YOU HAVE SOME OF THE ERRORS BEATEN DOWN, THE THING GOES OUT OF COMMISSION, AND A NEW ONE

IS LAUNCHED; AND THE NEW ONE IS ALWAYS MORE COMPLICATED THAN THE PREVIOUS ONE BECAUSE YOU NEVER BUILD THE SAME SATELLITE TWICE. IT'S NOT VERY ECONOMIC. SO THERE'S MUCH MORE FUN TO BUILD A NEW ONE, NEW CAPACITIES. SO FOR MONITORING, I THINK THESE SATELLITES ARE PROBABLY NOT GOING TO BE THE FINAL WORD.

I AM CONVINCED THOUGH THAT 15 YEARS FROM NOW WE'RE GOING TO GET A LOT OF THIS SHORT-TERM INFORMATION, AND THE LARGE GRADIENTS IN THE CARBON CYCLE ARE FROM SATELLITES. SO THIS IS DEFINITELY SOMETHING THAT MAYBE 15, 20 YEARS FROM NOW, WHEN

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THESE SATELLITE MEASUREMENTS REALLY MATURE, ARE GOING TO MAKE A BIG IMPACT.

SO THERE'S A CHALLENGE HERE. I'VE JUST KIND OF GIVEN YOU A COUPLE OF EXAMPLES OF THINGS THAT WE CAN MONITOR THAT'S IN OUR TOOLBOX, THINGS THAT WE NEED TO MONITOR, DIFFERENT SATELLITES, DIFFERENT MEASUREMENTS FROM THE ATMOSPHERE, FROM STOCKS. WE NEED TO COMBINE THE INFORMATION FROM ALL OF THESE SOURCES INTO ONE CONSISTENT PICTURE OF THE CARBON CYCLE. THERE IS ONLY ONE CARBON CYCLE. WE CAN'T HAVE FIVE PICTURES FROM FIVE DIFFERENT METHODS. THERE IS ONLY ONE ANALYSIS THAT WE NEED TO PRODUCE WHICH WILL TELL THE WORLD WHAT IS GOING ON WITH THE CARBON CYCLE AT ANY POINT IN TIME. THAT SYSTEM WILL NEED TO BALANCE THEIR STRENGTHS AND WEAKNESSES. WE KNOW THAT SOME METHODS ARE NOT VERY SUITABLE TO DO A PARTICULAR THING; WHEREAS, OTHERS CAN DO THAT BETTER. A SYSTEM THAT IS GOING TO KEEP TRACK OF CARBON IS GOING TO HAVE TO BALANCE THOSE STRENGTHS AND WEAKNESSES.

IF WE'RE TO GAIN AN UNDERSTANDING OF THE PROCESSES, FIRST OF ALL, WE NEED TO PROVIDE OBJECTIVE INFORMATION, SO WE NEED TO KNOW EXACTLY WHAT IS GOING ON IN THE SYSTEM THAT WE HAVE BUILT. IT ALSO NEEDS TO BE ABLE TO PREDICT THE FUTURE. THERE IS A LOT OF

0844

INTEREST, OF COURSE, IN WHAT THE CARBON CYCLE IS GOING TO DO OVER THE NEXT 50 YEARS. IT'S GOING TO . . . UNCERTAINTIES IN . . . CLIMATE PREDICTIONS, ACTUALLY. SO THE SYSTEMS THAT WE ARE GOING TO BUILD ARE GOING TO HAVE TO HAVE SOME PROGNOSTIC SKILLS.

NOW, WHAT TO CALL A SYSTEM LIKE THAT? YOU CAN SAY IT IS A DATA ASSIMILATION SYSTEM. YOU CAN SAY IT'S A DATA FUSION SYSTEM . . . WHATEVER YOU CALL IT. I HAVE GIVEN IT THE LABEL AN INTEGRATED CARBON CYCLE MONITORING SYSTEM. IT INTEGRATES THOSE MODELS FROM DIFFERENT TYPES OF OBSERVATIONS ABOUT EVERYTHING THAT WE CAN LEARN POSSIBLY ABOUT THE CARBON CYCLE.

SO THE REMAINING SLIDES OF MY TALK, I WILL BE TALKING ABOUT THE INTEGRATED CARBON MONITORING EFFORT THAT IS GOING ON IN NOAA ESRL, WHICH WE HAVE CALLED CARBON TRACKER. I THINK IT IS VERY IMPORTANT TO NOTE THAT THIS IS DEFINITELY NOT THE ONLY EFFORT GOING ON. AS A MATTER OF FACT HERE IN . . . THERE

ARE SEVERAL PEOPLE THAT WORKING ON THIS FOR MUCH LONGER THAN NOAA ESRL HAS. A GROUP, MICHAEL HYMAN, FOR INSTANCE, HAS BEEN DOING THIS CARBON MONITORING USING MODELS FOR MORE THAN 50 YEARS AND HAVE MADE SOME REALLY EXCITING PROGRESS, I THINK, THERE.

ANOTHER EXAMPLE IS THE GROUP WITH SCOTT DENNING, WHO IS ALSO TRYING TO BUILD THESE DATA

0845

SIMULATION METHODS FROM A LITTLE DIFFERENT PERSPECTIVE THAN WE ARE. BUT STILL IT IS A VERY PROMISING METHOD. I KNOW THAT INEZ FUNG . . . SHE AND HAROLD REID, TO BUILD A SYSTEM LIKE THIS WITH YET ANOTHER SLIGHTLY DIFFERENT ANGLE. SCOTT DONEY IS IN THIS BUSINESS, AS WELL. THERE'S DEFINITELY MORE GROUPS TRYING THIS. I'M JUST GOING TO GIVE YOU AN EXAMPLE OF CARBON TRACKER BECAUSE IT IS A SYSTEM THAT I'M MOST FAMILIAR WITH.

I THINK IT'S GOOD THAT THERE IS A LOT OF EFFORT IN BUILDING DIFFERENT SYSTEMS, BECAUSE, AGAIN, WE NEED TO WORK OUT THE DETAILS OF THESE SYSTEMS, AND THERE'S SYSTEMATIC ERRORS, AND WE CAN ONLY DO THAT IF WE HAVE SEVERAL VERSIONS OF THIS AND NOT JUST ONE.

SO CARBON TRACKER, I DON'T KNOW IF PEOPLE HAVE BEEN TO OUR WEBSITE, CARBONTRACKER.NOAA.GOV. THE WEBSITE IS OUR PRIME WAY OF SHARING INFORMATION WITH PEOPLE INTERESTED IN OUR PRODUCT. IT IS ALSO WHERE PEOPLE CAN DOWNLOAD, GOOGLE EARTH FILES AND THEY CAN PLAY AROUND. THIS IS MORE OF AN OUTREACH GIMMICK, I WOULD SAY. THERE IS A LARGE . . . SERVER HOOKED UP TO THE CARBON TRACKER WEBSITE, THAT ACTUALLY CONTAINS ALL OF OUR RESULTS. AND ON THESE FTP SITES YOU WILL FIND NET CDF FILES AND LITERATURE, TECHNICAL THINGS FOR SCIENTISTS TO USE, BUT I THINK

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IT IS AN IMPORTANT PART OF CARBON TRACKER.

WE ARE TRYING TO PUT EVERYTHING WE DO WITH THE MODEL OUT THERE. ANYBODY CAN USE OUR RESULTS. ANYBODY CAN USE THE FULL RESULTS. PEOPLE CAN DOWNLOAD OUR CODE. WE HAVE DOCUMENTATION. WE'RE TRYING TO BE AS TRANSPARENT AS POSSIBLE, AND THE REASON FOR BEING SO TRANSPARENT -- AND WE'RE REALLY TRYING TO GIVE EVERYTHING AWAY -- IS, FIRST OF ALL, BECAUSE I FEEL LIKE WE NEED TO GIVE SOMETHING BACK TO THE PEOPLE THAT HAVE MADE ALL OF THESE OBSERVATIONS THAT WE ARE USING IN CARBON TRACKER AND SOMETHING THAT THEY CAN DO SCIENCE WITH.

THE OTHER REASON IS THAT IF WE WANT TO BE THE OBJECTIVE STEWARDS OF THE ATMOSPHERE, IF WE WANT TO GIVE THE INFORMATION ABOUT WHAT IS GOING ON IN THE CARBON CYCLE, WE BETTER MAKE SURE THAT WE'RE COMPLETELY TRANSPARENT AND WE DON'T HOLD ANYTHING BEHIND, WE GIVE EVERYTHING WE HAVE TO THE PEOPLE, AND THEY CAN USE IT IN WHATEVER WAY THEY WANT. WE ARE GIVING THE INFORMATION, AND PEOPLE CAN ACT ON THAT OR NOT.

SO CARBON TRACKER, IT'S REALLY BUILT AROUND THE OBSERVATIONS. YOU'RE LOOKING AT A MAP HERE OF

THE DIFFERENT LOCATIONS WHERE NOAA ESRL AND COLLABORATING INSTITUTES ARE COLLECTING OBSERVATIONS

THAT ARE CURRENTLY GOING INTO CARBON TRACKER; AND THERE'S ABOUT 70 TO 80 LOCATIONS ALL AROUND THE WORLD.

AND JUST TO EXPLAIN TO YOU A LITTLE BIT ABOUT HOW CARBON TRACKER WORKS, THERE'S THIS -- THERE'S THIS CARTOON. I CAN ONLY POINT ONE DIRECTION AT A TIME. SO EVERYBODY FOLLOW ME OVER HERE.

SO AT THE HEART OF CARBON TRACKER IS THE OBSERVATIONS THAT ARE BEING COLLECTED BY SO MANY OF US AND SO MANY OF YOU AROUND THE WORLD. AND THEN WE HAVE DIFFERENT MODULES AROUND THAT. THESE ARE COMPONENTS THAT WE ARE TRYING TO MODEL. ONE OF THEM IS THE FOSSIL FUEL COMPONENT. OVER HERE IS A LOT OF ACCOUNTING INFORMATION THAT GOES INTO OUR FOSSIL FUELS AT THE MOMENT, OUR FOSSIL FUEL MODULES AT THE MOMENT. THERE IS A MODULE DESCRIBING THE BIOSPHERE. THIS IS WHERE WE'RE USING SATELLITE DATA TO BACK OUT . . . AND TO GET A GOOD FIRST GUESS AS TO WHAT'S GOING ON. THIS ALSO USES WEATHER DATA ON A THREE-HOURLY BASIS, SOLAR RADIATION AND TEMPERATURE, FOR INSTANCE.

WE HAVE AN OCEAN MODULE, WHICH IS TRYING TO PREDICT FROM THE PROCESS UNDERSTANDING WHAT IS GOING ON IN THE OCEANS WITH CARBON DIOXIDE. IT MAKES USE OF THE PCO2 MEASUREMENTS FROM THE OCEAN SURVEYS. IT

ALSO HAS THREE-HOUR VARIABILITY BASED ON WIND SPEEDS AND STORMS OVER THE OCEAN.

IN THE FIRE MODULE, WE'RE USING THE TYPE OF INFORMATION THAT I WAS SHOWING BEFORE ABOUT INDONESIA, WHERE WE HAVE FIRE COUNTS BASICALLY BEING COUPLED TO A MODEL OF HOW MUCH FUEL AREAS THEY BURN, AND THIS GIVES CO2 TO GO INTO OUR MODELS.

AND THEN IF WE HAVE ALL THESE DIFFERENT COMPONENTS OF EXCHANGE, IT GOES INTO THE TM5 2-WAY TRANSPORT MODEL. THIS IS AN ATMOSPHERIC TRANSPORT MODEL, TO PREDICT MIXING RATIOS OF CO2 WITH OUR MODEL, TO BE COMPARED WITH THE OBSERVATIONS. NOW, OF COURSE, THOSE ARE NEVER EXACTLY THE SAME, BECAUSE WE HAVE PROBABLY MISDIAGNOSED WHAT IS GOING ON IN THE CARBON CYCLE AT ANY OF THESE DIFFERENT MODULES IN TIME. SO THE DIFFERENCE BETWEEN OBSERVATIONS AND MODEL PREDICTIONS IS MINIMIZED WITH THE FORMAL DATA SIMULATION METHOD. IN OUR CASE, IT'S THE . . . AND IT IS MINIMIZED BY TUNING DIALS, BASICALLY. I THINK THAT'S THE MOST OBJECTIVE WAY TO SAY WHAT'S GOING ON. WE BASICALLY HAVE 135 DIALS ALL AROUND THE WORLD WHICH CAN INCREASE OR DECREASE THE AMOUNT OF CARBON MOLECULE FROM DIFFERENT REGIONS. AND THE REGIONS YOU ARE LOOKING AT ARE DISTRIBUTED ACCORDING TO VEGETATION TYPES. YOU'RE SEEING THE DIFFERENT

VEGETATION TYPES RIGHT HERE. AND THEY'RE ALSO SPLIT BY GEOGRAPHIC LOCATION. SO THERE WOULD BE ABOUT 38

DIALS IN NORTH AMERICA, ABOUT 19 IN EUROPE, ABOUT 57 FOR ASIA, AND 19 FOR AUSTRALIA, AND SO ON; 11 IN THE CASE OF THE LATEST RUN, 30 DIFFERENT REGIONS OVER THE OCEANS. NOW, NORMALLY ALL OF THESE NUMBERS ADDED UP WOULD GIVE YOU ABOUT 221 PARAMETERS OR 221 DIALS, OF WHICH WE'RE TRYING TO FIND OUT WHAT THEIR PERFECT SETTINGS ARE. BUT BECAUSE YOU DON'T FIND A LOT OF ECOSYSTEMS IN DIFFERENT REGIONS OF THE WORLD; FOR INSTANCE, THERE IS NOT A LOT OF SNOWY CONIFERS IN THE SARAHAS, THERE'S NOT A LOT OF TROPICAL FORESTS IN BOREAL CANADA, FOR INSTANCE. THE ACTUAL NUMBER OF DIALS THAT WE CAN TUNE IS ABOUT 135 EACH WEEK. SO FINDING THE SETTING OF 135 DIALS EACH WEEK THAT OPTIMALLY PRODUCE THE OBSERVED CO2 CONCENTRATIONS IN THE WORLD, THAT IS THE PROBLEM THAT WE ARE FACING.

OF COURSE, YOU NEED A LOT OF OBSERVATIONS TO DO THAT. SO CARBON TRACKER AT THE MOMENT, FOR OUR EFFORTS, WE'RE USING ABOUT 28,000 OBSERVATIONS OVER THE PERIOD OF JANUARY 1, 2000 TO JANUARY 1, 2006. SO THIS IS QUITE A LARGE NUMBER.

I HAVE BEEN TALKING TO THE REPORTERS OVER THE PAST WEEK, AND I HAVE MADE IT CLEAR TO THEM THAT IF YOU LOOK AT THE METEOROLOGICAL EFFORT, DATA

0850

SIMULATION, WHICH PRODUCES OUR DAILY WEATHER RECORD, THESE PEOPLE HAVE ABOUT 28,000 OBSERVATIONS EVERY 15 MINUTES. WE HAVE THIS IN SIX YEARS. SO AS A DATA ASSIMILATION SYSTEM, THIS THING IS REALLY HUNGRY FOR MORE INFORMATION, FOR MORE DATA, THE TYPE OF SATELLITE INFORMATION THAT IS OUT THERE, OTHER TRACE GASSES. WHATEVER WE CAN FIND THAT FORMS THE CARBON CYCLE NEEDS TO GO INTO THIS SYSTEM.

IT IS INTERESTING TO NOTE THAT IF YOU LOOK AT THE LATEST EFFORT, WHICH IS GOING TO INCLUDE THE YEAR 2006, WE ALREADY HAVE 36,000 OBSERVATIONS. THAT IS BECAUSE OUR MONITORING CAPACITIES ARE REALLY EXPANDING, ESPECIALLY OVER THE PAST YEAR.

HERE YOU CAN SEE THE CONTINUOUS OBSERVATIONS THAT WE ARE TAKING OVER THE UNITED STATES. SOME OF THEM ARE FROM NOAA ESRL; OTHERS ARE FROM ENVIRON CANADA, AND OTHERS ARE FROM THE RACCOONS SITES.

I ESPECIALLY WOULD LIKE TO SAY THAT THE TALL TOWER NETWORK, THIS EFFORT IS REALLY -- ARYLN ANDREWS' WORK, SHE'S DOING AN EXCELLENT JOB. AS A MATTER OF FACT, EVEN IN THIS YEAR, SHE HAS PUT IN FOUR MORE OF THESE SITES ACROSS NORTH AMERICA, AND SHE HAS BECOME A MOTHER AT THE SAME TIME. I DON'T KNOW WHERE SHE FINDS THE TIME. AND THEN NEXT YEAR

0851

SHE IS GOING TO DO TWO MORE. TALL TOWERS; NOT BABIES.

(LAUGHTER)

SORRY, YOU CAN BREATHE.

SO THERE'S REALLY A LOT OF INFORMATION FOR CARBON TRACKER COMING OUT OF THE TALL TOWER NETWORK FROM ARLYN ANDREWS AND FROM OTHER PEOPLE IN NORTH

AMERICA. A COUPLE OF LOCATIONS ARE NOT PLOTTED ON HERE WHERE PEOPLE ARE ACTUALLY COLLECTING CONTINUOUS DATA . . . TAKING CONTINUOUS CALIBRATED CO2 MEASUREMENTS IN THE PACIFIC NORTHWEST. AND THESE ARE DATA TIME SERIES THAT WE REALLY WOULD LIKE TO START USING IN CARBON TRACKER ANYTIME SOON.

SO THIS IS A LITTLE ANIMATION. YOU'RE LOOKING AT A PARTICULAR MONTH OF 2003. I THINK IT IS JANUARY. YOU'RE SEEING ALL OF THE OBSERVATIONS THAT ARE BEING COLLECTED ON THE CARBON SCALE OF 270 TO 390 PPM.

AND WHAT JUST HAPPENED THERE IS THAT IF YOU FEED THOSE OBSERVATIONS INTO CARBON TRACKER -- AND MAYBE WE CAN -- I CAN -- I SHOULDN'T SAY "WE" -- SKIP BACK AND FORTH ONCE. SO WHAT IS HAPPENING, BASICALLY, IS THAT FROM A VERY LIMITED NUMBER OF OBSERVATIONS AND THE MODELING SYSTEM AND ALL OF THESE DIALS THAT WE'RE FINDING THE OPTIMAL SETTINGS FOR, WE

0852

CAN FILL IN WHAT IS GOING ON IN THE ATMOSPHERE IN A LOT OF DIFFERENT PLACES. AND I THINK THERE'S TWO THINGS ABOUT THIS MOVIE. FIRST OF ALL, IT IS ALWAYS FUN TO SEE A MOVIE. HOPEFULLY, IT KEEPS PEOPLE AWAKE FOR A SECOND. THE SECOND THING IS THAT YOU CAN SEE HOW MUCH OF THE CO2 DISTRIBUTION CARBON TRACKER IS FILLING IN BY ITSELF. IT IS NOT DIRECTLY BASED ON THE OBSERVATIONS. IT'S BASED ON MODELING, OF UNDERSTANDING THE CARBON CYCLE, ON DIFFERENT TYPES OF INFORMATION FEEDING OUR FLUX MODELS, BASICALLY. SO THERE IS A LOT OF INFERENCE ABOUT THE CARBON CYCLE BASED ON THESE OBSERVATIONS.

THE CARBON TRACKER PUBLICATION CAME OUT THIS WEEK ON TUESDAY IN THE PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES. IT'S CALLED, "AN ATMOSPHERIC PERSPECTIVE OF NORTH AMERICAN CARBON DIOXIDE EXCHANGE: CARBON TRACKER." PEOPLE CAN DOWNLOAD IT. IT'S OPEN ACCESS. SO IT IS AVAILABLE DIRECT FROM THE WEBSITE. IT IS ALSO AVAILABLE FROM THE CARBON TRACKER WEBSITE.

I'M NOT GOING TO DISCUSS ALL THE RESULTS THAT ARE IN THAT PAPER AT THE MOMENT. I THINK AN INTERESTING THING IS THAT NORTH AMERICA IS TURNING OUT TO HAVE HAD ITS OWN SPECTACULAR DROUGHT. THIS WAS IN 2002. PEOPLE MIGHT REMEMBER THE DROUGHT

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BECAUSE IT WAS ALMOST ALL THE WAY ACROSS THE BOARD, A VERY LARGE DROUGHT IN THE SUMMER OF 2002. IT WAS CLASSIFIED AS EXTREME OR EXCEPTIONAL IN 45 PERCENT OF THE LAND AREA OF THE UNITED STATES OR NORTH AMERICA, I SHOULD SAY.

THIS HAD A DEFINITE IMPACT ON THE CARBON CYCLE. 2002 IS ONE OF THE HIGHEST EMITTING YEARS OF CARBON DIOXIDE FROM NORTH AMERICA. IT'S ACTUALLY AN ANOMALY OF ABOUT .4 PETAGRAMS OF CARBON, WHICH IS ALMOST UP THERE WITH THE EUROPEAN DROUGHT. IT JUST TOOK A BIT LONGER TO DETECT IT BECAUSE, IN NORTH, AMERICA WE WEREN'T AS READY TO PUT TOGETHER ALL OF

THE INFORMATION ON THE 2002 DROUGHT, LIKE THE EUROPEANS WERE FOR THE 2003 DROUGHT.

ANOTHER IMPORTANT POINT I THINK TO MAKE ABOUT CARBON TRACKER HERE IS THAT WE'RE COMPARING THIS TO OTHER METHODS, TO BOTTOM-UP METHODS. SO THIS IS THE NUMBERS THAT HAVE APPEARED IN THE STATE OF THE CARBON CYCLE REPORT THAT CAME OUT TWO OR THREE WEEKS AGO, I THINK. THIS IS -- THIS IS BASICALLY A COMPLETE ACCOUNTING EFFORT. THIS IS A SIMILAR ESTIMATE OF WHAT IS GOING ON IN THE NORTH AMERICA CARBON CYCLE. BUT THIS IS PURELY BASED ON COUNTING TREES, COUNTING FUELS, COUNTING HARVESTS, COUNTING AGRICULTURAL PRODUCTION, ALL THOSE THINGS. AND

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THERE'S A REAL CONVERGENCE ON THE NUMBERS. AND THIS IS VERY IMPORTANT. THESE ARE NUMBERS EVEN FOR SUBCONTINENTAL AREAS WHERE CARBON TRACKER SEEMS TO BE FINDING ABOUT THE SAME THING THAT THESE OTHER METHODS ARE FINDING. AND THIS IS A VERY IMPORTANT PREREQUISITE IF WE'RE GOING TO PUT THEM TOGETHER. BECAUSE IF YOU HAVE EVIDENCE A AND YOU HAVE EVIDENCE B AND THEY DON'T AGREE AT ALL, YOU DON'T EVEN WANT TO PUT THEM TOGETHER AND AVERAGE THEM AND SAY YOU HAVE THE ANSWER. YOU WANT TO HAVE CONSISTENCY ON THE INFORMATION FROM THE DIFFERENT METHODS FIRST BEFORE YOU CAN PUT THEM INTO AN INTEGRATED CARBON CYCLE MONITORING SYSTEM.

SO THIS IS MERELY MY FINAL SLIDE HERE. ANOTHER IMPORTANT THING ABOUT THE CARBON TRACKER IS I THINK THAT WE'RE PUTTING A LOT OF EFFORT INTO VALIDATING THIS WITH OBSERVATIONS. SO THIS IS KIND OF GOING BACK FULL CIRCLE FROM THE OBSERVATIONS AGAIN.

A SYSTEM LIKE CARBON TRACKER WHICH FILLS IN MORE THAN 95 PERCENT OF THE ATMOSPHERE BY . . . AND USING THE MODEL, DATA ASSIMILATION THAT REALLY NEEDS TO BE CONFRONTED WITH INDEPENDENT OBSERVATIONS TO MAKE SURE THAT WHATEVER IT IS DOING IT'S DOING WELL.

THIS IS ESPECIALLY TRUE FOR AIRCRAFT

0855

PROFILES. DAVE STEVENS HAS SHOWN RECENTLY, THIS SUMMER, IN A "SCIENCE" PUBLICATION THAT PREVIOUS METHODS SEEM TO HAVE ALL HAD SYSTEMATIC ERRORS, WHICH WERE LEADING THEM IN THE SAME WRONG DIRECTION ABOUT WHAT THE . . . CO2 WAS, AND THIS MIGHT HAVE BIASED THEIR CARBON FLUX ESTIMATES, AS WELL. THIS WAS A BIG EFFORT IN 2002, LED BY KEVIN GURNEY, AND THERE WERE A LOT OF MODELS INVOLVED, BUT THEY ALL SEEMED TO BE HAVING THE SAME PROBLEMS. THIS IS WHAT HE WAS SHOWING.

WE'RE COMPARING CARBON TRACKER, AS WELL, TO THESE OBSERVATIONS, TO MAKE SURE THAT WE DON'T HAVE THESE PROBLEMS. WE'RE NOT SURE EXACTLY AT THE MOMENT WHETHER WE HAVE ELIMINATED ALL THE PROBLEMS. THERE DOES SEEM TO BE SOME DIFFERENCE BETWEEN CARBON TRACKER AND THE 15,000 AIRCRAFT OBSERVATIONS THAT WE'VE COMPARED IT TO; BUT OVERALL, WE'RE STARTING TO

FEEL PRETTY CONFIDENT THAT THE AGREEMENT BETWEEN CARBON TRACKER AND THESE OBSERVATIONS IS BETTER THAN WHAT THE OLDER MODELS USED TO PRODUCE.

SO THE NEXT 50 YEARS, THE LIST IS GOING TO BE VERY, VERY LONG IN HAWAII IF I TRY TO INCLUDE EVERYTHING THAT I CAN THINK OF THAT NEEDS TO BE DONE FOR THE NEXT 50 YEARS. I JUST PUT A COUPLE OF KEY POINTS:

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OBSERVATIONS, CLEARLY, ARE KEY. WE NEED TO BE MONITORING THE CARBON CYCLE USING OBSERVATIONS.

BIG INVESTMENTS ARE NEEDED. AT THE MOMENT, OUR OPERATION IS REALLY VERY SMALL SCALE COMPARED TO WHAT IS GOING TO BE NEEDED IN THE FUTURE.

A CONTINUATION OF THE TRADITIONAL RECORDS, SUCH AS AT MAUNA LOA, IS REALLY IMPORTANT BECAUSE YOU CAN'T REPLACE THEM WITH ANYTHING NEW BY JUST SENDING UP A SATELLITE, FOR INSTANCE.

EXPLORATION OF NEW METHODS IS REALLY IMPORTANT. THERE ARE THINGS THAT WE CAN BE MEASURING THAT WE CAN BE EXPLOITING WHICH ARE NOT BEING EXPLOITED AT THE MOMENT.

MAYBE ON A MORE PERSONAL PREFERENCE, I THINK MODELING CAPACITIES NEED TO GROW ALONGSIDE. MONITORING IS BECOMING HARDER AND HARDER. THE TYPE OF SYSTEMS THAT WE'RE TRYING TO BUILD THESE DAYS . . . CARBON MONITORING SYSTEMS WHERE MODELING SYSTEMS REALLY TIE TOGETHER A LOT OF EFFORT FROM DIFFERENT DISCIPLINES, FROM HYDROLOGY, FROM SATELLITE COMMUNITY REMOTE SENSING, FROM BIOSPHERIC MODELING, FROM ATMOSPHERIC MODELING; AND IT REALLY IS A TEAM OF PEOPLE THAT NEEDS TO WORK ON SOMETHING LIKE THIS AND NOT JUST ONE GRAD STUDENT WHO IS EXCITED ABOUT WHAT HE'S DOING. THESE EFFORTS ARE GOING TO GO MUCH

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BEYOND WHAT WE'VE DONE IN THE PAST. THEREFORE, WE NEED TO INVEST IN PEOPLE, I THINK, VERY CLEARLY.

FINAL QUESTION, MAYBE THIS IS SOMETHING THAT WE SHOULD TAKE INTO THE PANEL DISCUSSIONS, THAT I CAN FINISH UP WITH SOME TIME IN QUESTIONS: ARE WE OBSERVING AT THE RIGHT PLACES?

JUST THE FACT THAT I PUT A DOUBLE QUESTION MARK THERE AND A LIGHTLY SHADED "NO" MEANS THAT I REALLY CARE ABOUT THIS POINT. WE ARE NOT OBSERVING AT THE RIGHT PLACES. WE ARE PUTTING A LOT OF DOLLARS INTO MONITORING NORTH AMERICA, A LOT OF DOLLARS INTO EUROPE. BUT IF YOU'RE LOOKING AT PREDICTION OF CLIMATE FOR THE NEXT 30 OR 40 OR 50 YEARS, BIG ISSUES PROBABLY ARE NOT GOING TO COME OUT OF THOSE TWO CONTINENTS. THERE'S A LOT OF THINGS GOING ON IN ASIA WITH HIGH FOSSIL FUEL EMISSIONS. WE'VE LOOKED AT THE HIGH LATITUDES. WE'VE LOOKED AT THE TROPICS. SO WE'RE REALLY NOT OBSERVING AT THE MOMENT; AND IF WE WANT TO MAKE PROGRESS IN HELPING THE CLIMATE PREDICTION EFFORT, WE NEED TO BE MONITORING IN THE RIGHT PLACES.

SO I THINK THIS IS A QUESTION, OR MAY BE A

POINT TO TAKE INTO THE PANEL DISCUSSION THIS AFTERNOON.

SO I WOULD LIKE TO THANK MY MANY CO-WORKERS ON CARBON TRACKER WHO HAVE HELPED ME PUT TOGETHER THIS PRESENTATION, AND I THANK YOU, AND I TAKE QUESTIONS.